SLE 132 – Form and Function
Plant Nutrition

Learning Outcomes

- Know that most plants obtain inorganic nutrients from the soil.
- Recognise nutrient deficiencies—tell-tale signs.
- Know how nutrients are obtained from other biological sources including bacteria to supply nitrogen and the importance of mycorrhizae in enhancing plant nutrition.
- Know the plant world includes parasites and carnivores.

Soil

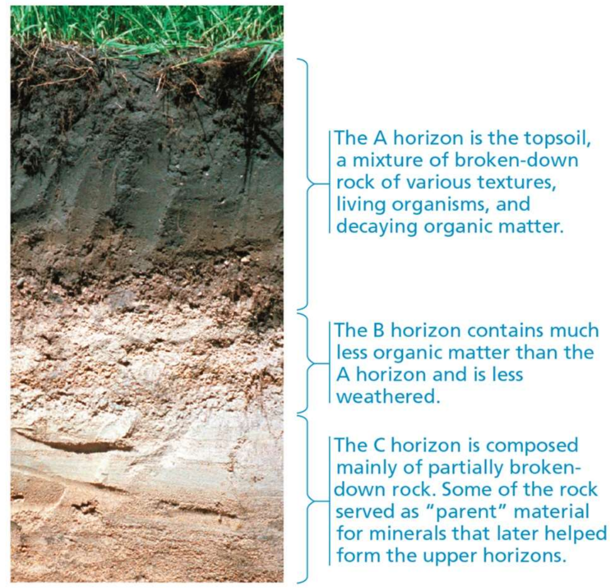
- Healthy soils improve plant growth by enhancing plant nutrition
- Farmland productivity suffers
  - Chemical contamination
  - Mineral deficiencies
  - Acidity
  - Salinity
  - Poor drainage

Soil

- Plants obtain most of their water and mineral from upper layers of soil
- Living organisms play an important role in these soil layers
- Complex and fragile ecosystem

Soil Texture

- Soil particles are classified by size; from largest to smallest
  - Sand
  - Silt
  - Clay
- Soil is stratified into layers – **soil horizons**
- Topsoil consists of mineral particles, living organisms and humus (decaying organic material)



▲ **Figure 37.2** Soil horizons.

Soil Texture

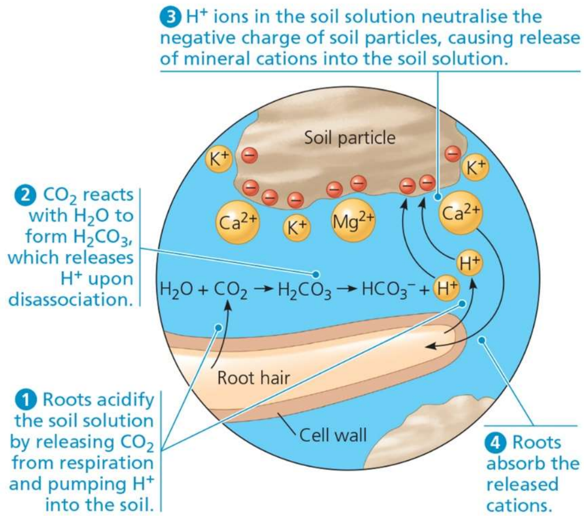
- After heavy rainfall, water drains from larger spaces in the soil. Smaller spaces retain water because of the attraction to clay and other particles

- This film of loosely bound water is usually available for plants

- **Loams** are the most fertilise of topsoils, contain equal amounts of clay, silt and sand.

Inorganic Components

- **Cation exchange**
- Topsoil: inorganic and organic chemical components
  - Cations (K^+, Ca^{2+}, Mg^{2+}) adhere to negatively charged soil particles



▲ **Figure 37.3** **Cation exchange in soil.**

? *Which are more likely to be leached from the soil by heavy rains—cations or anions? Explain.*

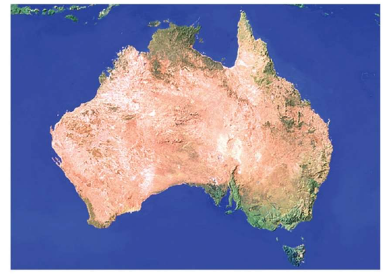
Organic Components

- **Humus** (organic matter) builds a crumbly soil
  - Retains water but is porous
  - Increases soils capacity to exchange cations
  - Serves as a **reservoir of mineral nutrients**

- Topsoil contains bacteria, fungi, algae, other protists, insects, earthworms and plant roots
  - **Help to decompose** organic material and mix the soil

Australian Soils

- Australia is notable for its nutrient poor soils
  - support low density woodlands/grasslands
- Much of Australia's foundations consist of rocks with **high quartz content**
  - Break down slowly
  - produce nutrient-poor soil with considerable quantities of salt



▲ **Figure 37.6 Australia as seen from space.** The ancient and nutrient-poor soils of the western two-thirds of Australia support low-density woodlands and grasslands.

▲ **Figure 37.7 Western Australia's China Wall.** The high quartz content of much of Australia's foundations breaks down slowly, gives up few nutrients, and releases significant quantities of mineral salt. Each of these traits reinforces the slow rate of soil development, the nutrient paucity of the landscape, and soils already rich in salt.

- Farming practises that were not suited to Australian conditions have had significant environmental impact
- Grazing and tilling broke up the delicate mat of **algae and lichen** that held the topsoil together

▲ **Figure 37.9 Impacts of cattle grazing and agriculture on Australia's ancient soils.** Cattle grazing destroyed the mat of lichen and algae holding together the uppermost layer of soil. Exposure of the underlying soil layers began a process of wind and water mediated erosion that led to catastrophic dust storms that carried enormous volumes of soil across the landscape (Figure 37.1) and into the sea.

▲ **Figure 37.1 Dust storms like this one that cloaked much of Australia's east coast in 2009 continue to increase in frequency and severity, in response to over 200 years of land clearing and soil degradation.**

Australian Soils

The replacement of deep rooted native plants with shallow rooted crops has led to the loss of productive land to **salinity**

▲ **Figure 37.8 Grazing land in Western Australia affected by salinity.** Land clearing causes water tables to rise, carrying to the surface salt long held in the soil and producing salt scalds like the one here. Few plants can tolerate such highly saline soils.

DEAKIN COLLEGE

Plant Nutrition

- Essential Plant nutrients are necessary for the plant to complete their life cycle
- Most common sign of nutrient deficiency is **stunted growth** and **discoloured leaves**
- There are 17 essential elements
  - 9 macronutrients
  - 8 micronutrients

DEAKIN COLLEGE

Macronutrients

- Macronutrients are substances that the plant requires a lot of
  - **Carbon**
  - **Oxygen**
  - **Hydrogen**
  - **Nitrogen**
  - **Potassium**
  - **Calcium**
  - **Magnesium**
  - **Phosphorus**
  - **sulphur**

Table 37.1 Essential Elements in Plants

Element (Form Primarily Absorbed by Plants)	% Mass in Dry Tissue	Major Functions	Early Visual Symptoms of Nutrient Deficiencies
Macronutrients			
Carbon (CO_2)	45%	Major component of plant's organic compounds	Poor growth
Oxygen (CO_2)	45%	Major component of plant's organic compounds	Poor growth
Hydrogen (H_2O)	6%	Major component of plant's organic compounds	Wilting, poor growth
Nitrogen (NO_3^-, NH_4^+)	1.5%	Component of nucleic acids, proteins, and chlorophyll	Chlorosis at tips of older leaves (common in heavily cultivated soils or soils low in organic material)
Potassium (K^+)	1.0%	Cofactor of many enzymes; major solute functioning in water balance; operation of stomata	Mottling of older leaves, with drying of leaf edges; weak stems; roots poorly developed (common in acidic or sandy soils)
Calcium (Ca^{2+})	0.5%	Important component of middle lamella and cell walls; maintains membrane function; signal transduction	Crinkling of young leaves; death of terminal buds (common in acidic or sandy soils)
Magnesium (Mg^{2+})	0.2%	Component of chlorophyll; cofactor of many enzymes	Chlorosis between veins, found in older leaves (common in acidic or sandy soils)
Phosphorus ($H_2PO_4^-$, HPO_4^{2-})	0.2%	Component of nucleic acids, phospholipids, ATP	Healthy appearance but very slow development; thin stems; purpling of veins; poor flowering and fruiting (common in acidic, wet, or cold soils)
Sulphur (SO_4^{2-})	0.1%	Component of proteins	General chlorosis in young leaves (common in sandy or very wet soils)

Micronutrients

- Many micronutrients play a catalytic role, i.e. They are cofactors
  - Thus they get used repeatedly, and therefore plants do no need much of these micronutrients
  - E.g. – Mo – 1 atom to 16 million H atoms

- **Iron**
- **Chlorine**
- **Copper**
- **Manganese**
- **Zinc**
- **Molybdenum**
- **Boron**
- **Nickel**

FYI – not assessed

Element (Form Primarily Absorbed by Plants)	% Mass in Dry Tissue	Major Functions	Early Visual Symptoms of Nutrient Deficiencies
Micronutrients			
Chlorine (Cl^-)	0.01%	Photosynthesis (water-splitting); functions in water balance	Wilting; stubby roots; leaf mottling (uncommon)
Iron (Fe^{3+}, Fe^{2+})	0.01%	Respiration; photosynthesis: chlorophyll synthesis; N_2 fixation	Chlorosis between veins, found in young leaves (common in basic soils)
Manganese (Mn^{2+})	0.005%	Active in formation of amino acids; activates some enzymes; required for water-splitting step of photosynthesis	Chlorosis between veins, found in young leaves (common in basic soils rich in humus)
Boron ($H_2BO_3^-$)	0.002%	Cofactor in chlorophyll synthesis; role in cell wall function; pollen tube growth; stability of plasma membrane formation; formation of pectin network	Death of meristems; thick, leathery, and discoloured leaves (occurs in any soil; most common micronutrient deficiency)
Zinc (Zn^{2+})	0.002%	Active in formation of chlorophyll; cofactor of some enzymes; needed for DNA transcription	Reduced internode length; crinkled leaves (common in some geographic regions)
Copper (Cu^+, Cu^{2+})	0.001%	Component of many redox and lignin-biosynthetic enzymes	Light green colour throughout young leaves, with drying of leaf tips; roots stunted and excessively branched (common in some geographic regions)
Nickel (Ni^{2+})	0.001%	Nitrogen metabolism	General chlorosis in all leaves; death of leaf tips (common in acidic or sandy soils)
Molybdenum (MoO_4^{2-})	0.0001%	Nitrogen metabolism	Death of root and shoot tips; chlorosis in older leaves (common in acidic soils in some geographic areas)

MAKE CONNECTIONS *Explain why CO_2, rather than O_2, is the source of much of the dry mass oxygen in plants. See Concept 10.1.*

Symptoms of mineral deficiency

- Symptoms of mineral deficiency depend on the nutrient's function and mobility within the plant
- Deficiency of a **mobile nutrient** usually affects older organs more than young ones
- Deficiency of a **less mobile nutrient** usually affects younger organs more than older ones
- The most common deficiencies are those of **nitrogen, potassium, and phosphorus**

DEAKIN COLLEGE DEAKIN UNIVERSITY

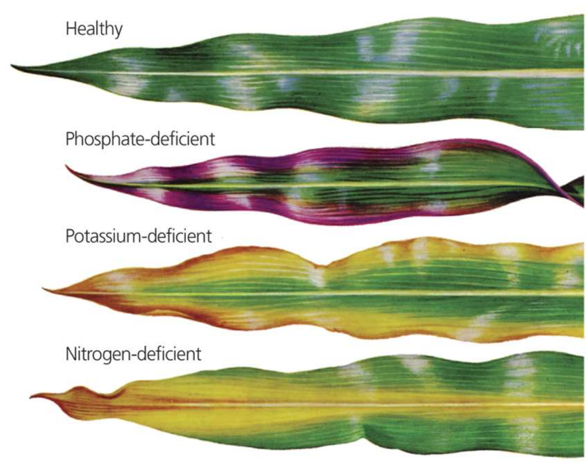
Common mineral deficiencies

Nitrogen deficiency – stunted growth, yellow – green leaves in older leaves

Phosphorus – reduced growth, new growth is spindly and brittle, red/purple on underside of leaf

Potassium – older leaves turn yellow with brown spots, fall off, stunting

Magnesium – yellowing of leaves, first seen in older leaves

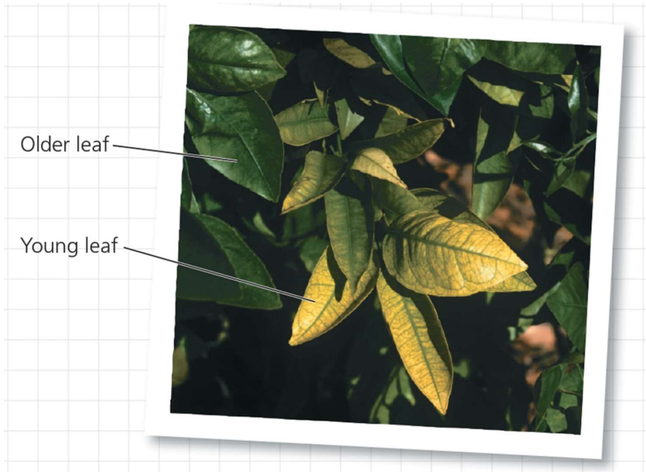


► **Figure 37.11 The most common mineral deficiencies, as seen in maize leaves.** Mineral deficiency symptoms may vary in different species. In corn, phosphate-deficient plants have reddish purple margins, particularly in young leaves. Potassium-deficient corn plants exhibit "firing," or drying, along tips and margins of older leaves. Nitrogen deficiency is evident in a yellowing that starts at the tip and moves along the center (midrib) of older leaves.

DEAKIN COLLEGE DEAKIN UNIVERSITY

Which macronutient is this plant most likely deficient in?

Refer to Table 37.1 page 830



Nutrients can be obtained from other biological sources

1. **Root hairs** – increase surface area

2. **Mycorrhiza** – increase surface
    - Increases phosphorus uptake
    - Secretes acids which increases solubility of soil minerals which increases uptake of other nutrients

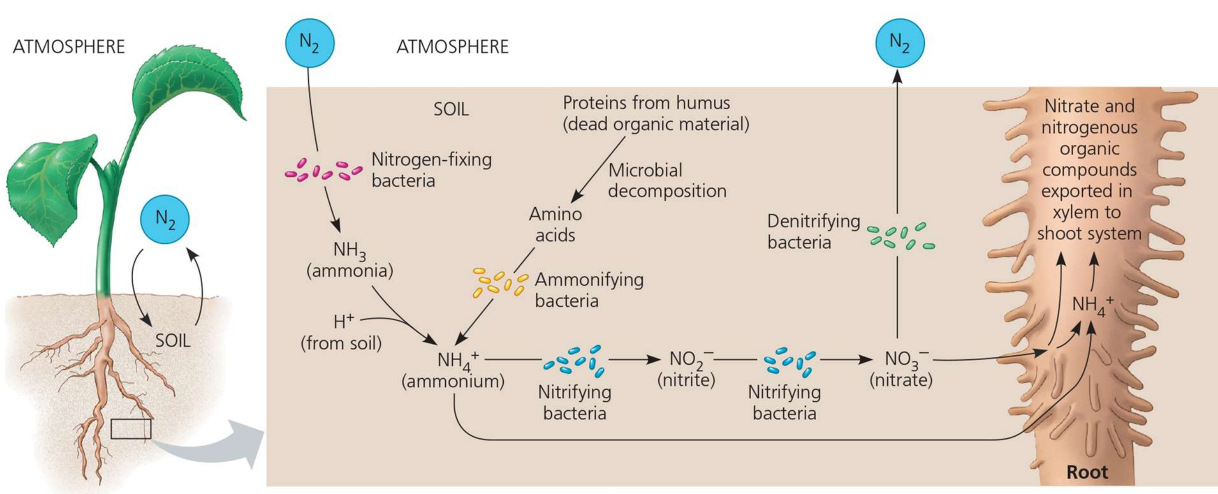
Nutrients can be obtained from other biological sources

3. Bacteria

Nitrogen fixing bacteria - Atmosphere – 80% Nitrogen – but plants can't use it. Soil bacteria converts N_2 into ammonium which plants can use. This process is called **nitrogen fixation**.

Ammonifying bacteria – Bacteria that convert organic material to NH4+

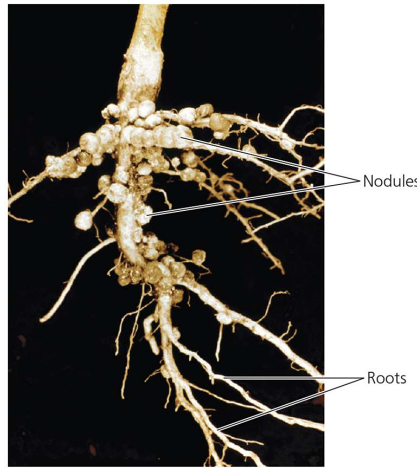
Nitrifying bacteria – convert NH4+ to NO3- (nitrate)



▲ **Figure 37.13 The roles of soil bacteria in the nitrogen nutrition of plants.** Ammonium is made available to plants by two types of soil bacteria: those that fix atmospheric N_2 (nitrogen-fixing bacteria) and those that decompose organic material (ammonifying bacteria). Although plants absorb some ammonium from the soil, they absorb mainly nitrate, which is produced from ammonium by nitrifying bacteria. Plants reduce nitrate back to ammonium before incorporating the nitrogen into organic compounds.

Root nodules

- Swellings due to bacterial or mycorrhizal association
- Can also increase nitrogen uptake



▲ **Figure 37.14 Root nodules on a legume.** The spherical structures along this soybean root system are nodules containing *Rhizobium* bacteria. The bacteria fix nitrogen and obtain photosynthetic products supplied by the plant.

? *How is the relationship between legume plants and* Rhizobium *bacteria mutualistic?*

Parasitic plants

- **Dodder**
  - Doesn’t photosynthesize
  - Modified roots tap into host vascular tissue
- **Mistletoe**
  - Photosynthesizes
  - Supplements nutrients by tapping into host vascular tissue
- Both can destroy host by blocking light or taking too much nutrients

▼ Figure 37.17

Exploring Unusual Nutritional Adaptations in Plants

Epiphytes

An **epiphyte** (from the Greek *epi*, upon, and *phyton*, plant) is a plant that grows on another plant. Epiphytes produce and gather their own nutrients; they do not tap into their hosts for sustenance. Usually anchored to the branches or trunks of living trees, epiphytes absorb water and minerals from rain, mostly through leaves rather than roots. Some examples are staghorn ferns, bromeliads, and many orchids, including the vanilla plant.

▶ **Staghorn fern**, an epiphyte

Parasitic Plants

Unlike epiphytes, parasitic plants absorb water, minerals, and sometimes products of photosynthesis from their living hosts. Many species have roots that function as haustoria, nutrient-absorbing projections that tap into the host plant. Some parasitic species, such as *Rafflesia arnoldii*, lack chlorophyll entirely, whereas others, such as mistletoe (genus *Phoradendron*), are photosynthetic. Still others, such as Indian pipe (*Monotropa uniflora*), absorb nutrients from the hyphae of mycorrhizae associated with other plants.

◀ **Mistletoe**, a photosynthetic parasite

▲ ***Rafflesia***, a nonphotosynthetic parasite

▲ **Indian pipe**, a nonphotosynthetic parasite of mycorrhizae

Carnivorous Plants

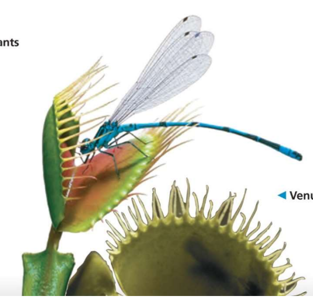
- Mainly obtains nitrogen from animal tissue
- Many grow in bogs
  - Organic decay is very slow
  - Little nitrogen
- Examples include, Venus fly trap, Sundew and pitcher plants

Carnivorous Plants

Carnivorous plants are photosynthetic but supplement their mineral diet by capturing insects and other small animals. They live in acid bogs and other habitats where soils are poor in nitrogen and other minerals. Pitcher plants such as *Nepenthes* and *Sarracenia* have water-filled funnels into which prey slip and drown, eventually to be digested by enzymes. Sundews (genus *Drosera*) exude a sticky fluid from tentacle-like glands on highly modified leaves. Stalked glands secrete sweet mucilage that attracts and ensnares insects, and they also release digestive enzymes. Other glands then absorb the nutrient "soup". The highly modified leaves of Venus flytrap (*Dionaea muscipula*) close quickly but partially when a prey hits two trigger hairs in rapid enough succession. Smaller insects can escape, but larger ones are trapped by the teeth lining the margins of the lobes. Excitation by the prey causes the trap to narrow more and digestive enzymes to be released.

▲ Sundew

◀ Pitcher plants



◀ Venus flytraps

https://www.youtube.com/watch?v=aladpRIVdRI (6 min)

SLE 132 – Form and Function
Plant Hormones

Learning Outcomes

- Understand Auxin was the first plant hormone discovered, but most have been only recently described.
- Understand that hormones coordinate growth and development, and responses to environmental stimuli by regulating gene expression and act through signal transduction pathways
- Learn the major plant hormones are auxins, cytokinins, gibberellins, abscisic acid, and ethylene.

Actions of Plant Hormones

- The interaction of environment with genotype results in the overall phenotype

- **Growth** – irreversible increase in size or volume i.e. Permanent increase in dry matter
- **Development** – an orderly sequence of events dictated by precise set of genes turning "on" and "off" at every stage
  - E.g. Reproductive cycle

Actions of Plant Hormones

The timing of gene actions in plants is under control of/ in response to external environmental factors:

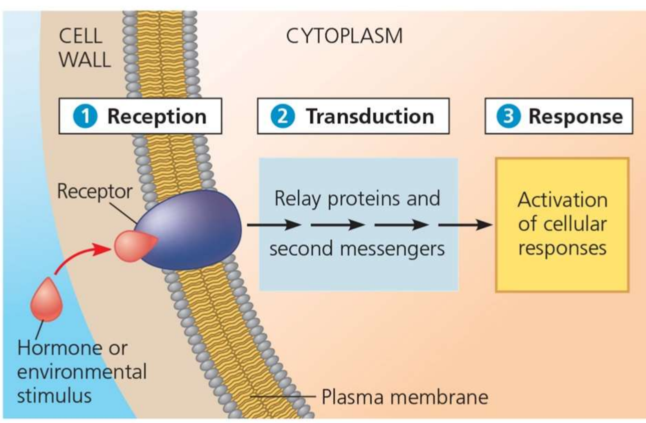
- Light
- Rain
- Onset of autumn
- Day/night length

Plant Hormones

Plant hormones

- Activate cellular responses via signal transduction pathways
- Are chemical messengers
- Manufactured in one place and **transported** to site of action
  - which therefore makes them different from enzymes which are manufactured in the cell in which they act

Signal Transduction pathways



▲ **Figure 39.3 Review of a general model for signal transduction pathways.** As discussed in Chapter 11, a hormone or other kind of stimulus interacting with a specific receptor protein can trigger the sequential activation of relay proteins and also the production of second messengers that participate in the pathway. The signal is passed along, ultimately bringing about cellular responses. In this diagram, the receptor is on the surface of the target cell; in other cases, the stimulus interacts with receptors inside the cell.

1. Reception – a signal is received by a **target cell** with **an appropriate receptor**
2. Transduction – the signal is **relayed and often amplified** via a series of proteins/second messengers
3. Response – The output response is activated – often switching on or off a gene

Plant hormones

- In general, hormones control plant growth and development by affecting the **division, elongation, and differentiation of cells**
- Plant hormones are produced in very low concentration, but a **minute amount** can greatly affect growth and development of a plant organ
- They work synergistically with one another, ie. they rarely work along and relative amounts are often important.

Plant hormones

5 main types of plant hormones:

Auxins - development of the embryo, leaf formation, phototropism, gravitropism.

Gibberellins - growth, influence various developmental processes, stem elongation, germination, dormancy, flowering, sex expression, and leaf and fruit aging

Cytokinins - Growth and differentiation, affects apical dominance, axillary bud growth, promote cytokinesis in plant roots and shoots.

Abscisic acid - Induces stomatal closure, Inhibits fruit ripening, seed dormancy

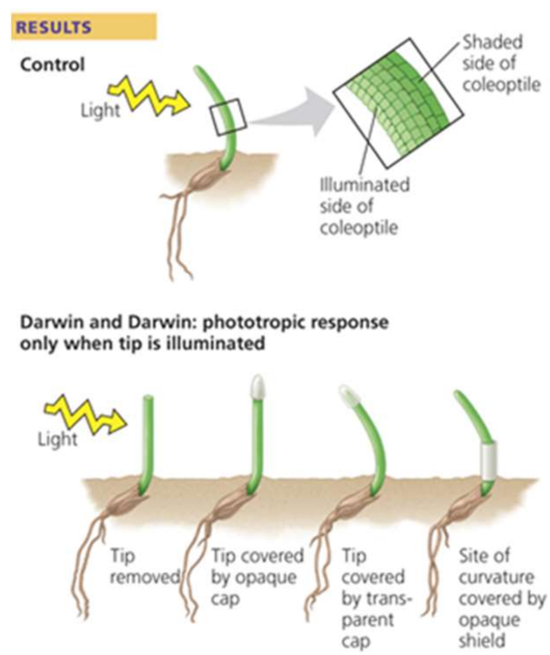
Ethylene – Ripening of fruit, opening of flowers.

The discovery of Plant Hormones

- In the late 1800s, Charles Darwin and his son Francis conducted experiments on phototropism, a plant's response to light
- They observed that a grass seedling could bend toward light only if the **tip** of the coleoptile (sheath protecting emerging shoot) was present
- They postulated that a signal was transmitted from the tip to the elongating region

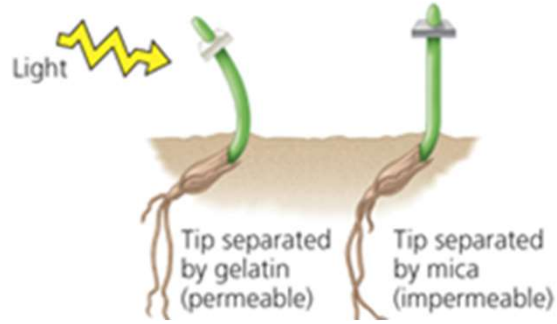
The discovery of Plant Hormones

- Grass seedling can bend towards light (Phototropism)
- Only if the tip of the coleoptile was present
- signal must be transmitted from the tip to the elongating region

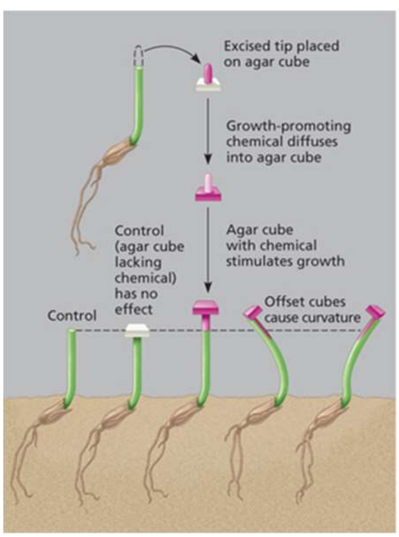


The discovery of Plant Hormones

- In 1913, Peter Boysen-Jensen demonstrated that the signal was a mobile chemical substance
- Shoot bends if it is separated by a permeable barrier
- Not if separated by an impermeable barrier
- Substance controlling bending <u>must be a mobile chemical substance</u>



The discovery of Plant Hormones



- In 1926, Frits Went extracted the chemical messenger for phototropism, **Auxin**, by modifying earlier experiments
- Stimulus was chemical
- It accumulated on **side away from light**
- Bending is caused by uneven distribution of Auxin
- **Cells on shaded side elongate**, causing bending towards light.

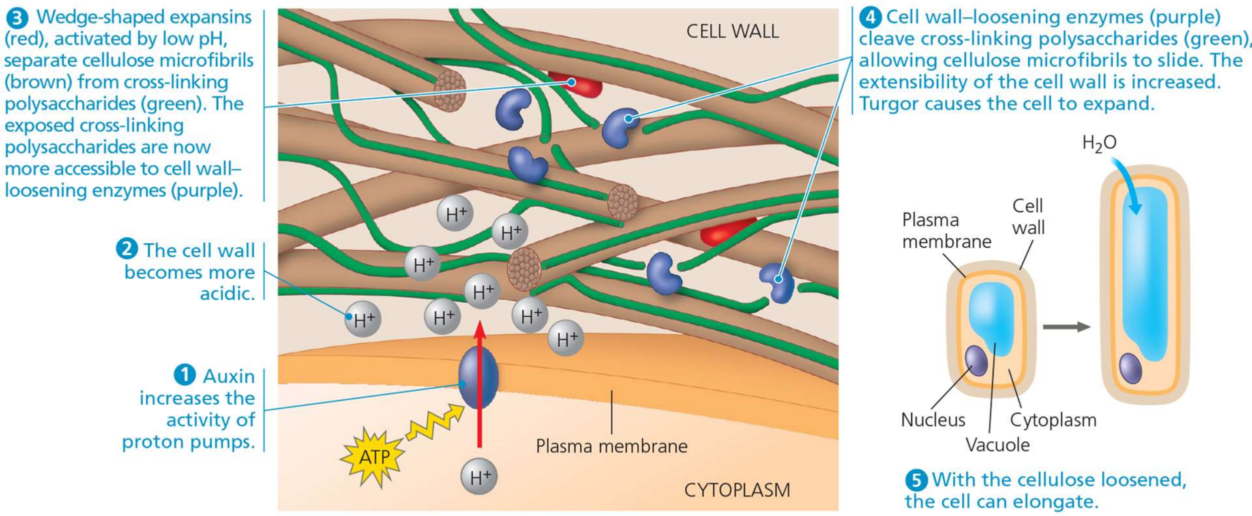
Auxins

1. **Elongation**
   - Cell Elongation – seedlings normally bend towards the light.
   - Phototropism, caused by the uneven distribution of auxin.
2. **Inhibition of abscission** (dropping of leaf, fruit, flower or seed)
3. Adventitious and lateral **root formation**
4. **Apical dominance**
5. **Cell differentiation**

Cell elongation

- According to the **acid growth hypothesis**, auxin stimulates proton pumps in the plasma membrane
- The proton pumps lower the pH in the cell wall, activating **expansins**, enzymes that loosen the wall's fabric
- With the cellulose loosened, the cell can elongate

Acid growth hypothesis



▲ **Figure 39.7** **Cell elongation in response to auxin: the acid growth hypothesis.**

Polar auxin transport

Auxin transport – unidirectional

1. It enters the cell at the apical end
2. Exits at the basal end
3. Diffuses across cell wall
4. Enters apical end of next cell

Continued or prolonged effect is due to regulation of gene expression

- Auxins have different effects depending on concentration & tissue type
- For example – Auxin **induces root growth** in cut stems at low concentrations but **inhibits root growth** at high concentrations
- Auxin from the apical bud inhibits lateral growth
  - thus **promoting apical dominance**
  - If an apical bud is removed, lateral branches develop

Plant Hormone activity:

As a group use pages 874 – 880 of the text book and the plant hormone activity slides on moodle to complete a summary of the main functions of the plant hormone your group has been assigned.

Auxin	Gibberellin	Cytokinin	Abscisic acid	Ethylene