PLANT PHYSIOLOGY

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PHYSIO/LOGY

Comes from the word *physis* (Greek) means "nature" or "origin"

Comes from the word *logos* (Greek) means "study"

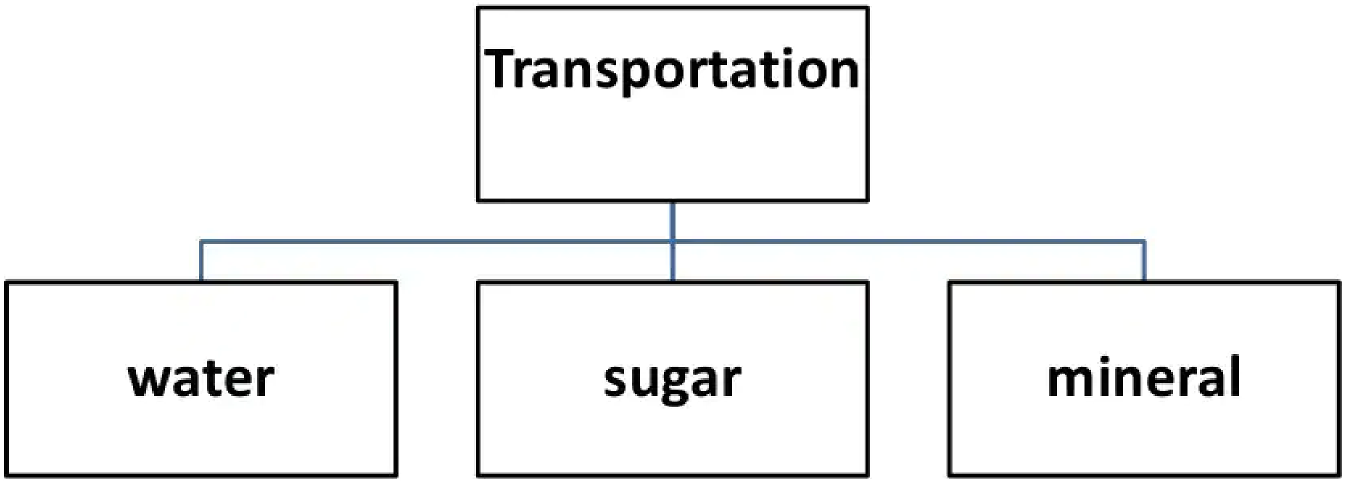
The scientific study of function in living systems. A sub-discipline of biology, its focus is in how organisms, organ systems, organs, cells, and bio-molecules carry out the chemical or physical functions that exist in a living system.

Plant Physiology

- Study of :

a) Processes occurring in plant
b) Function of processes occurring in plant
c) How plant works?

4.1 Plant Transportation System



3 level of transportation in plant

At cellular level

↓

Short distance (tissue)

↓

Long distance (xylem & Phloem)

4.1.1 Water movement

1) Diffusion

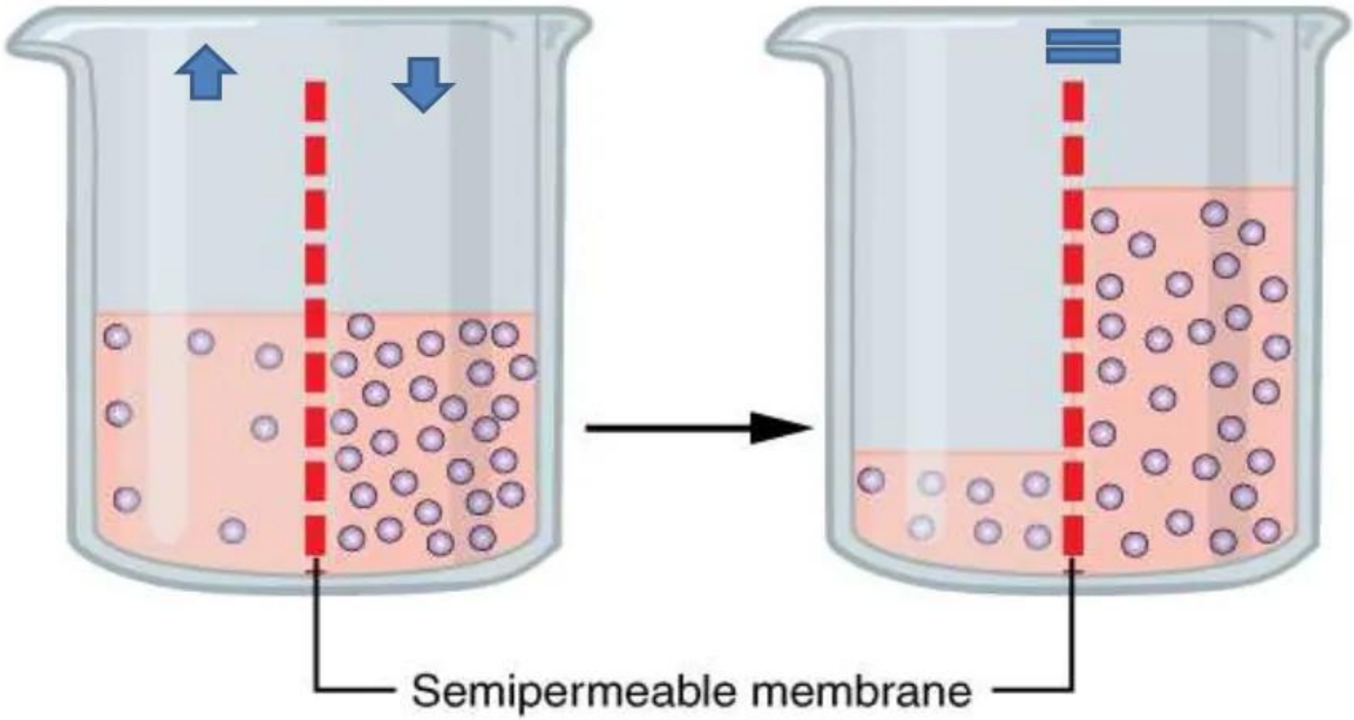
- The net, random movement of individual molecules from one area to another. The molecules move from [hi] → [low], following a concentration gradient.

Diffusion

- Another way of stating this is that the molecules move from an area of high free energy (higher concentration) to one of low free energy (lower concentration). The net movement stops when a **dynamic equilibrium** is achieved.

2) Osmosis

- the spontaneous net movement of solvent molecules through a partially permeable membrane into a region of higher solute concentration, in the direction that tends to equalize the solute concentrations on the two sides –dynamic equilibrium
- Water potential is a measure of the energy state of water.
- determines the direction and movement of water.
- Unit for water potential MegaPascal Mpa


Semipermeable membrane

- Ψ pure water at 1 atm = 0 Mpa

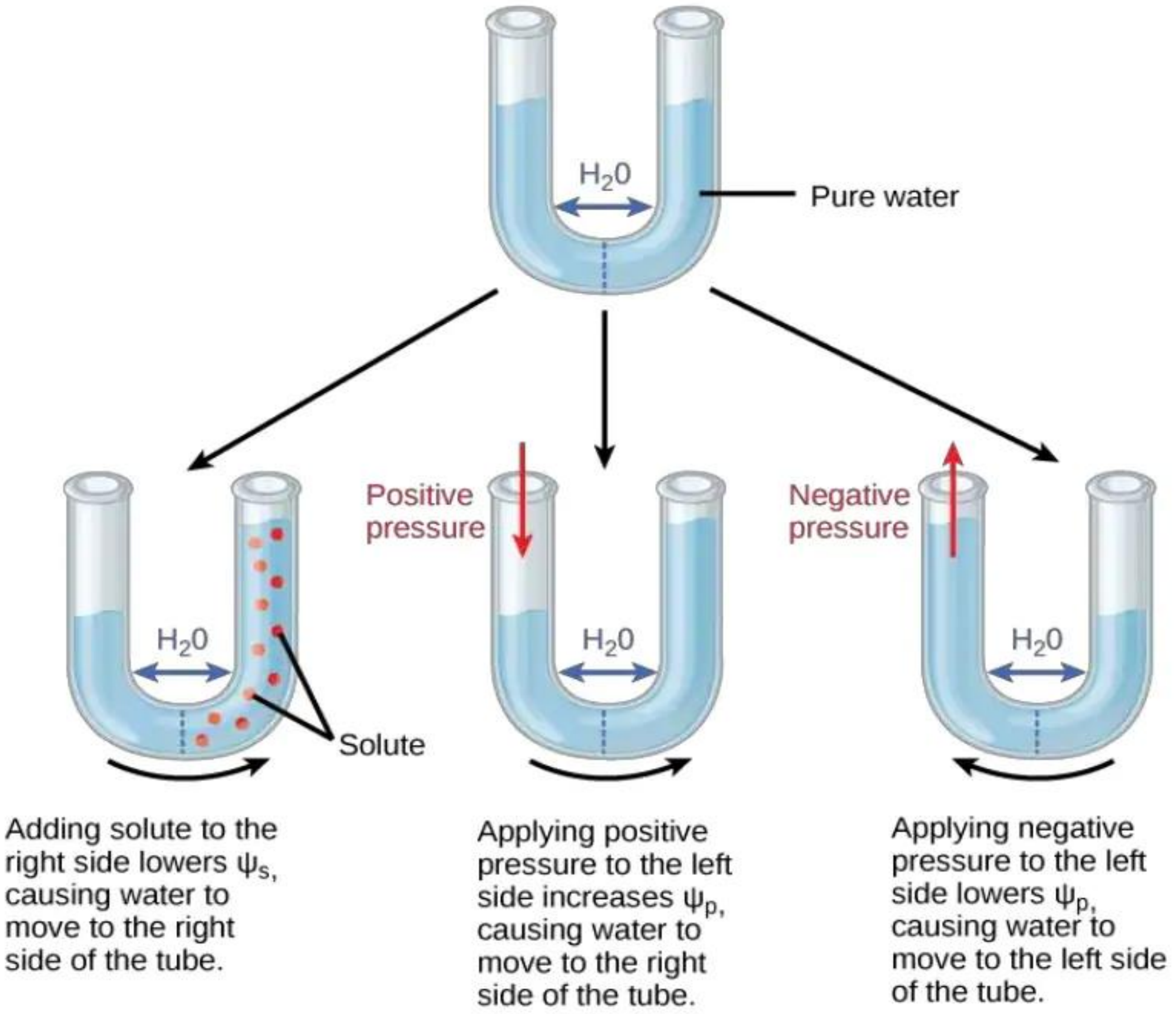
$$\Psi = \Psi_s + \Psi_p$$

Ψ= water potential

Ψ_s=solute potential (osmotic potential) –Always negative

Ψ_p=(pressure potential)

- Water molecules move from higher water potential to lower water potential

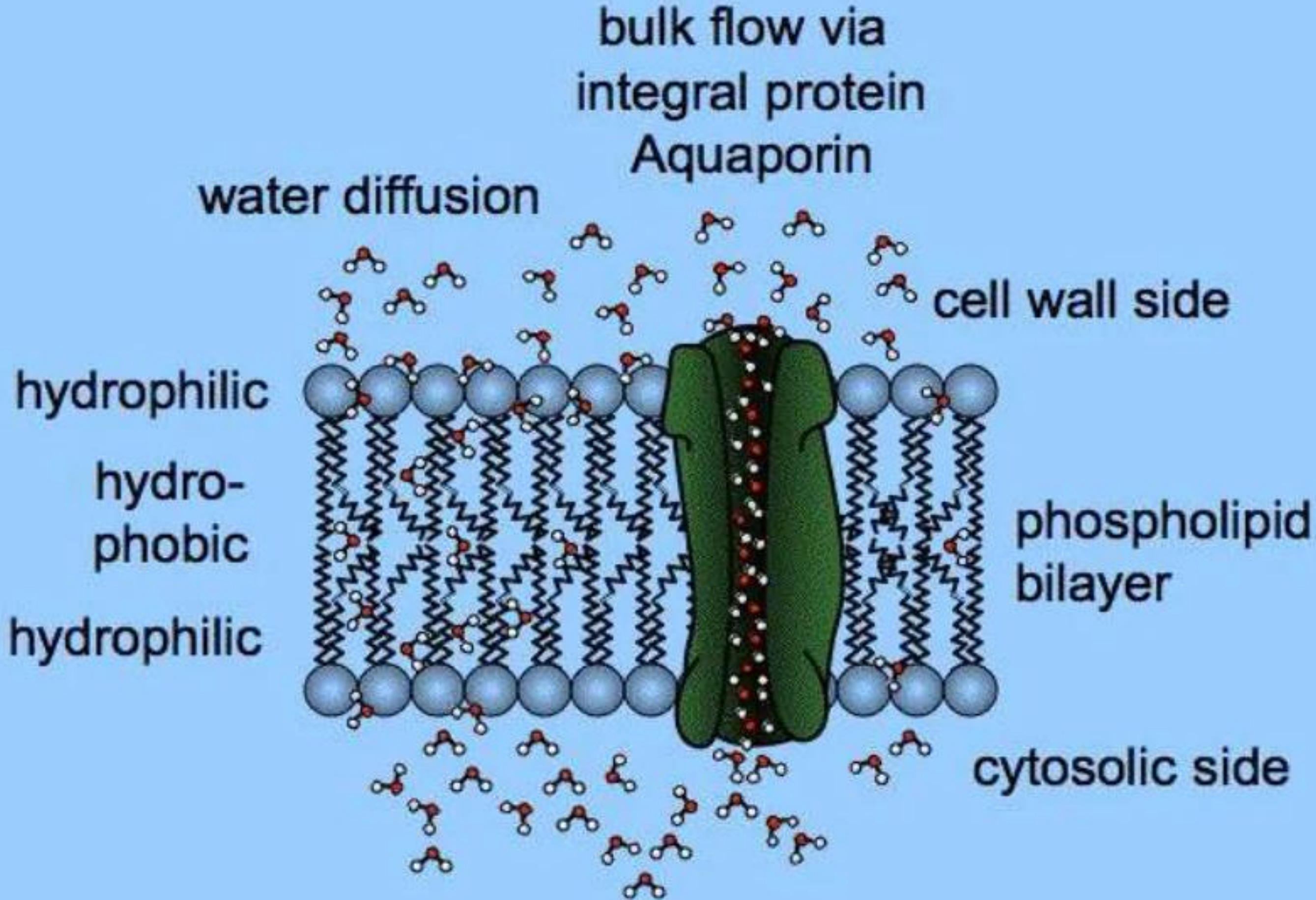


H_2O
Pure water
Positive pressure
Negative pressure
H_2O
H_2O
H_2O
Solute
Adding solute to the right side lowers ψ_s, causing water to move to the right side of the tube.
Applying positive pressure to the left side increases ψ_p, causing water to move to the right side of the tube.
Applying negative pressure to the left side lowers ψ_p, causing water to move to the left side of the tube.

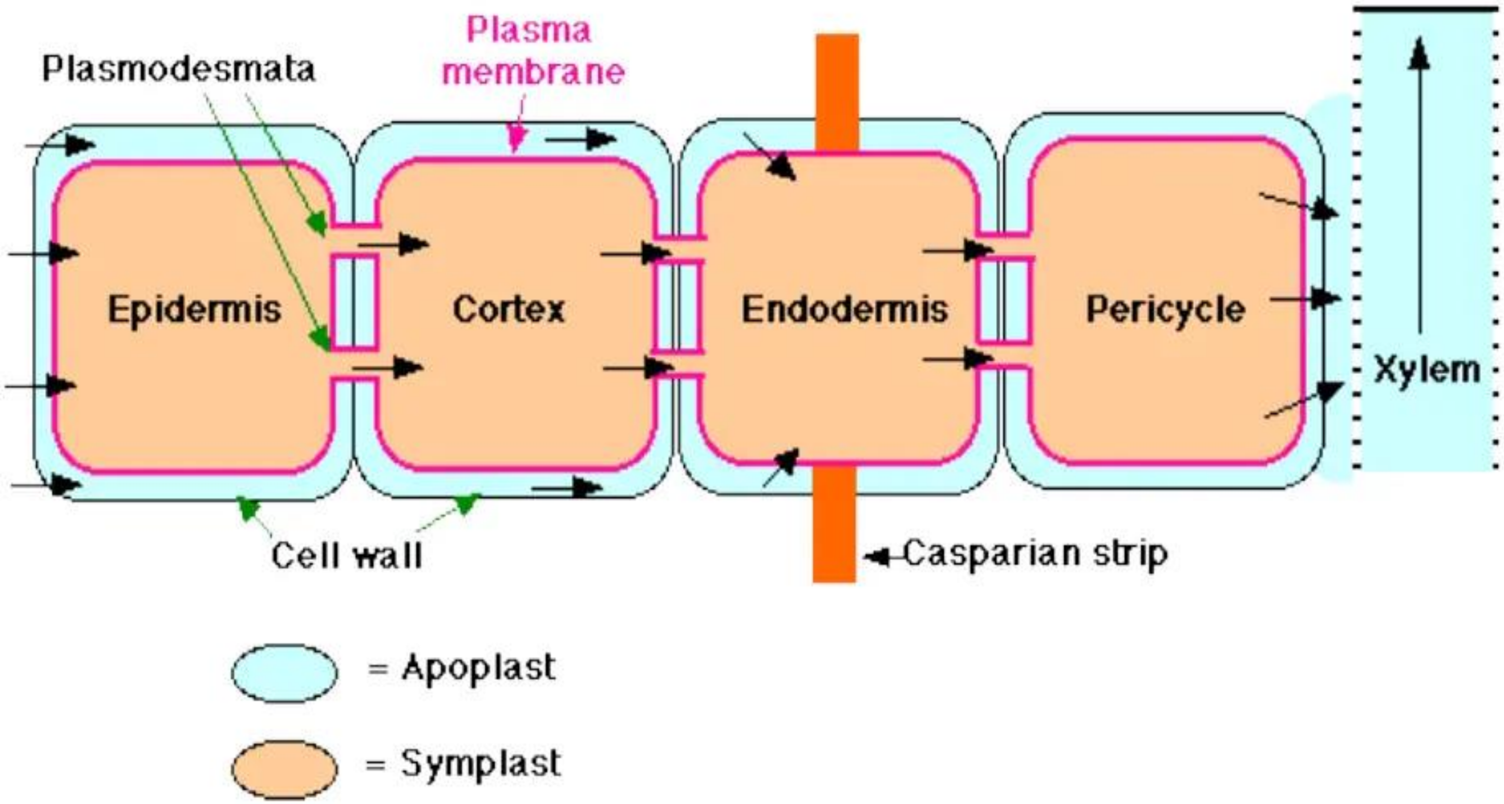
Water movement in plant at cellular level

- moves in and out of cell depend on osmotic force.
- Freely across phospholipid bilayer
- Through transport protein -- Aquaporins

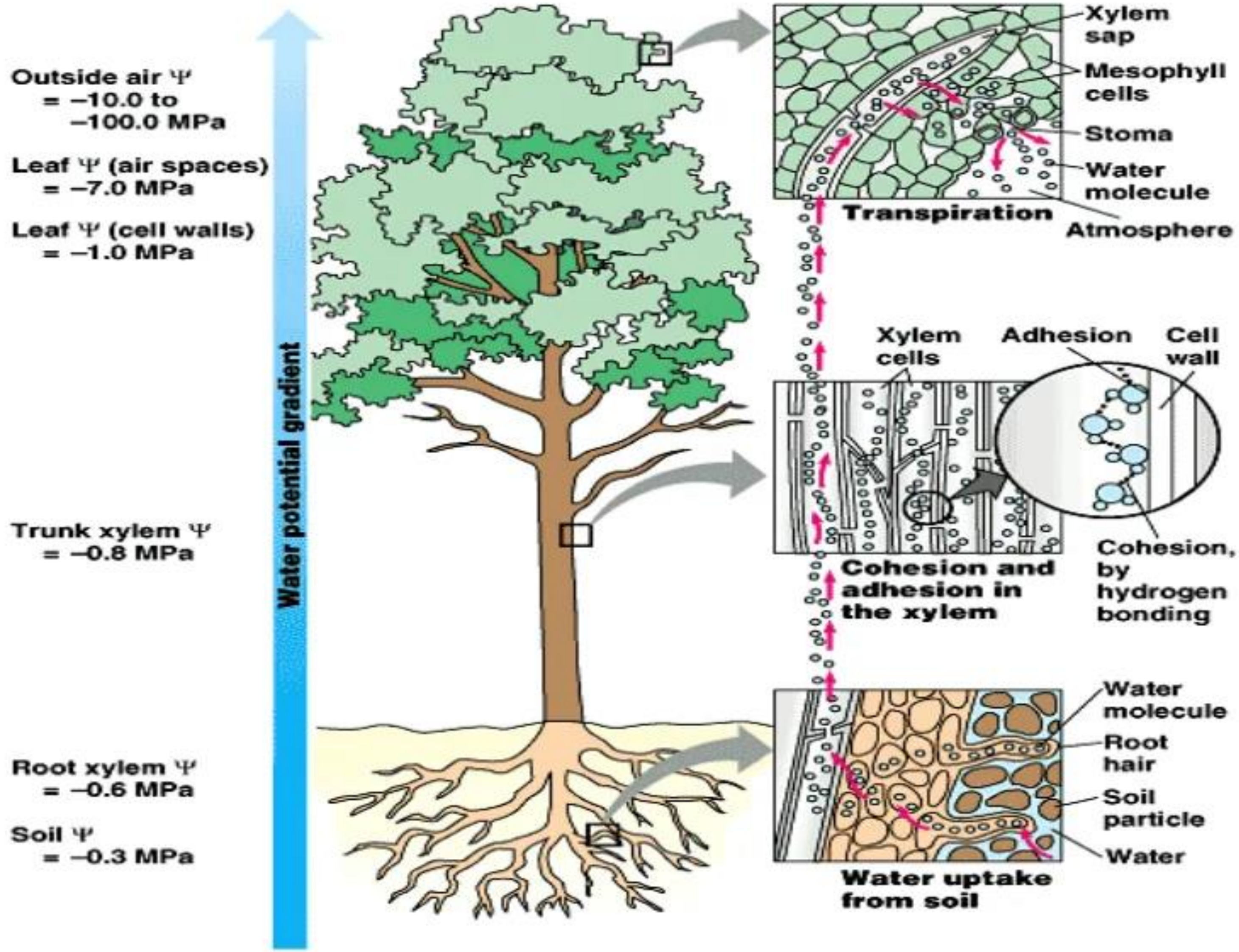
Osmosis: water movement across membrane



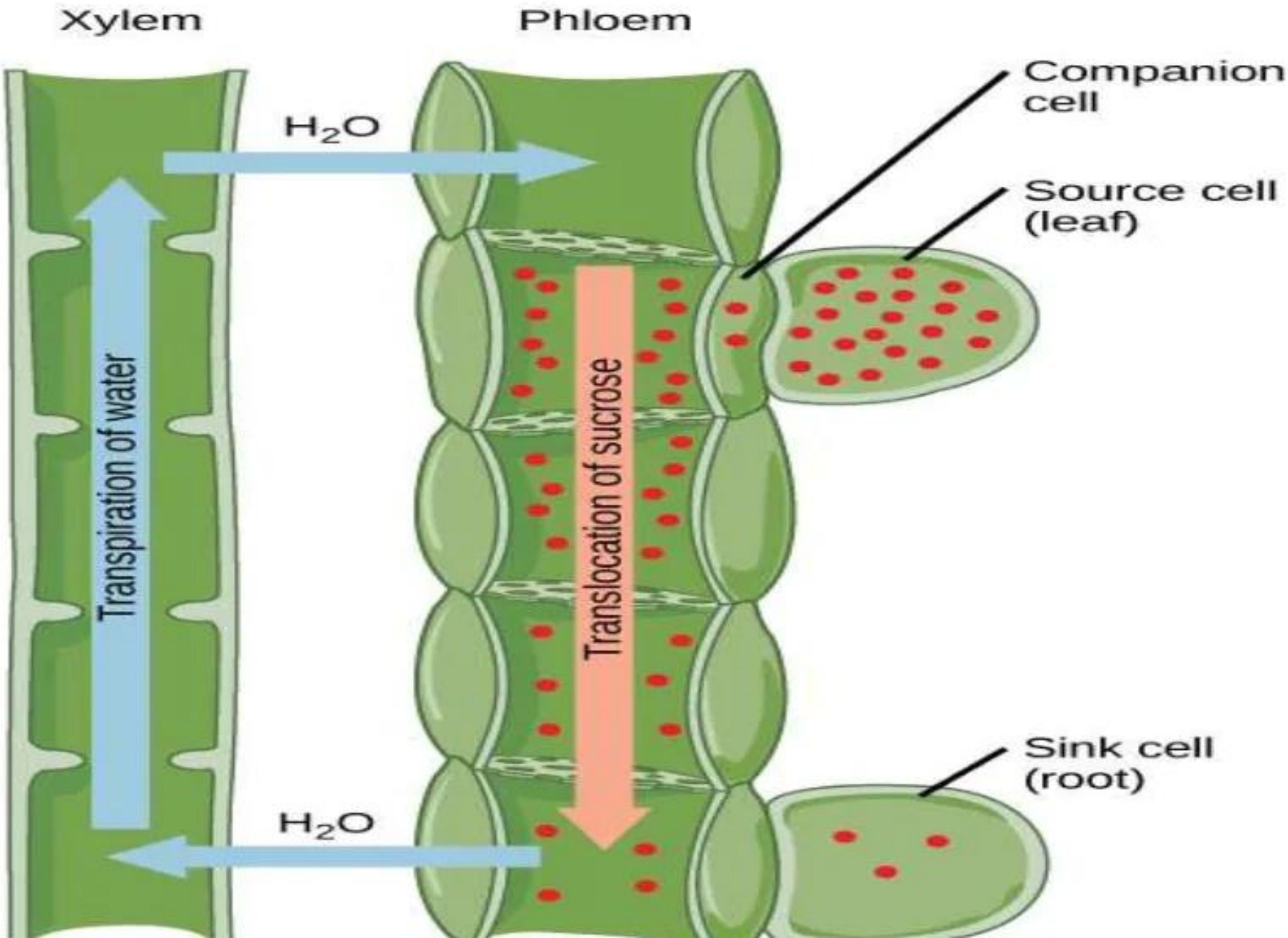
Water movement in plant at tissue level



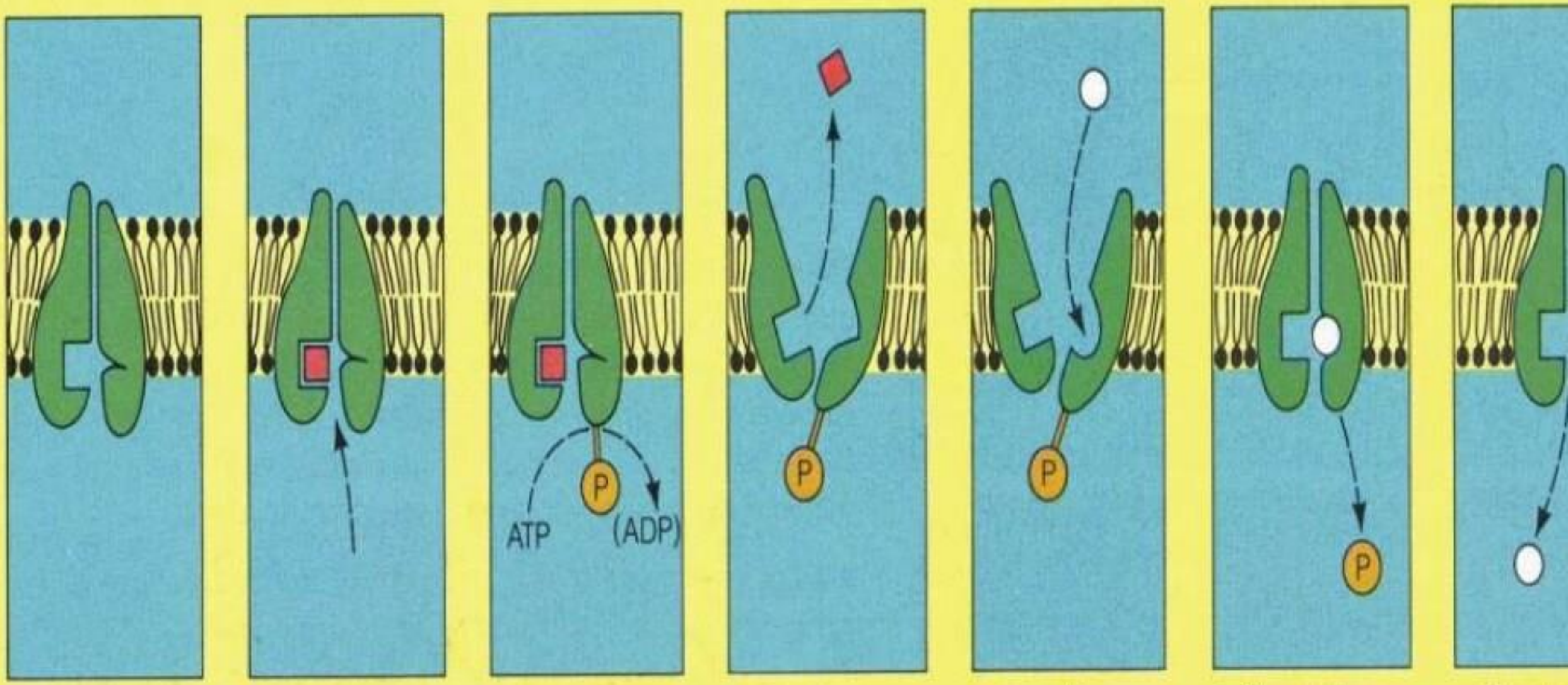
Bulk Water movement in plant



Sugar transportation



Mineral transportation (active transportation)



a Transport protein with two binding sites.

b Specific solute binds at one site.

c Phosphate group is transferred from ATP to protein.

d Protein changes shape, pumps the solute across membrane.

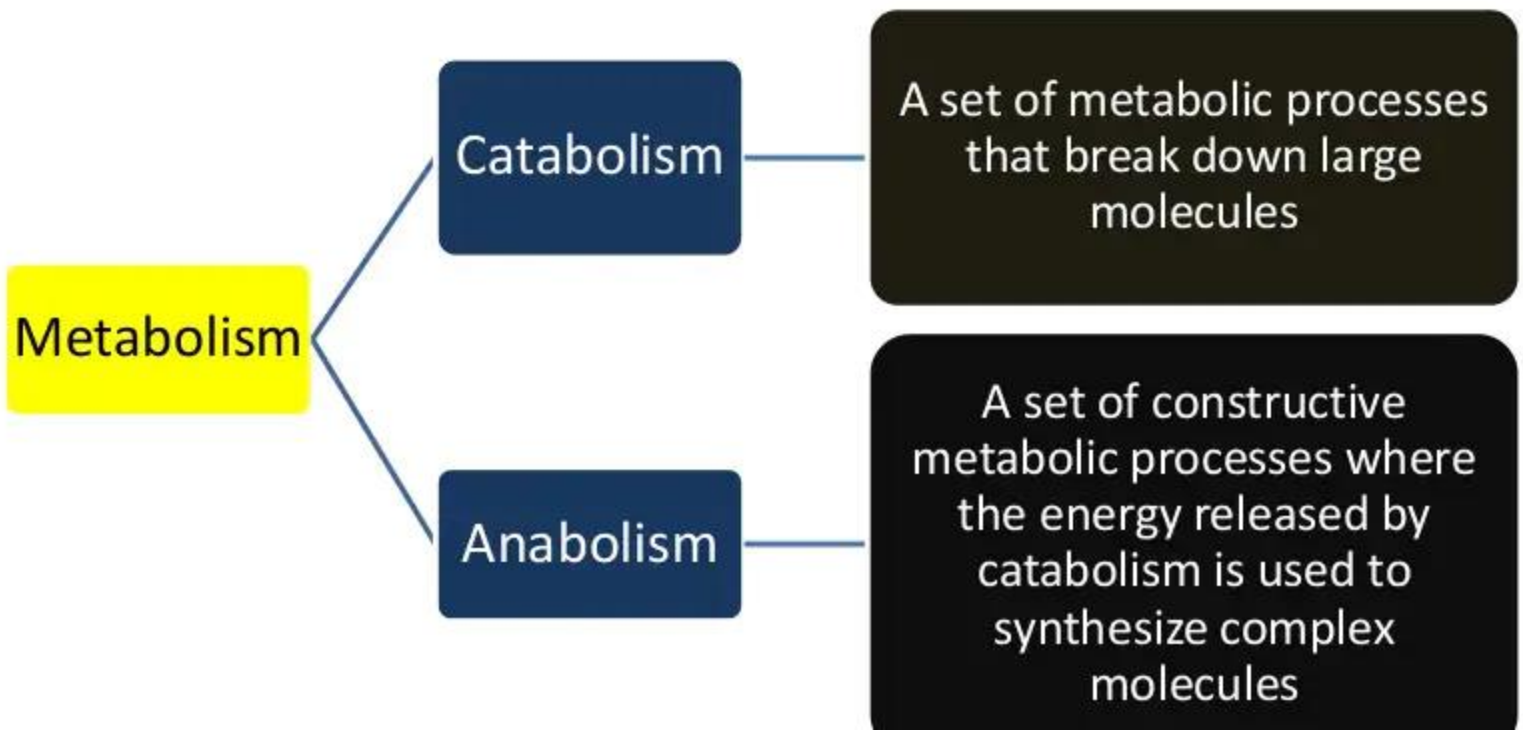
e The other binding site is now exposed, different solute binds to it.

f Phosphate group is released, protein returns to original shape.

g The sha change ca the solute released.

4.2 Energy Metabolism

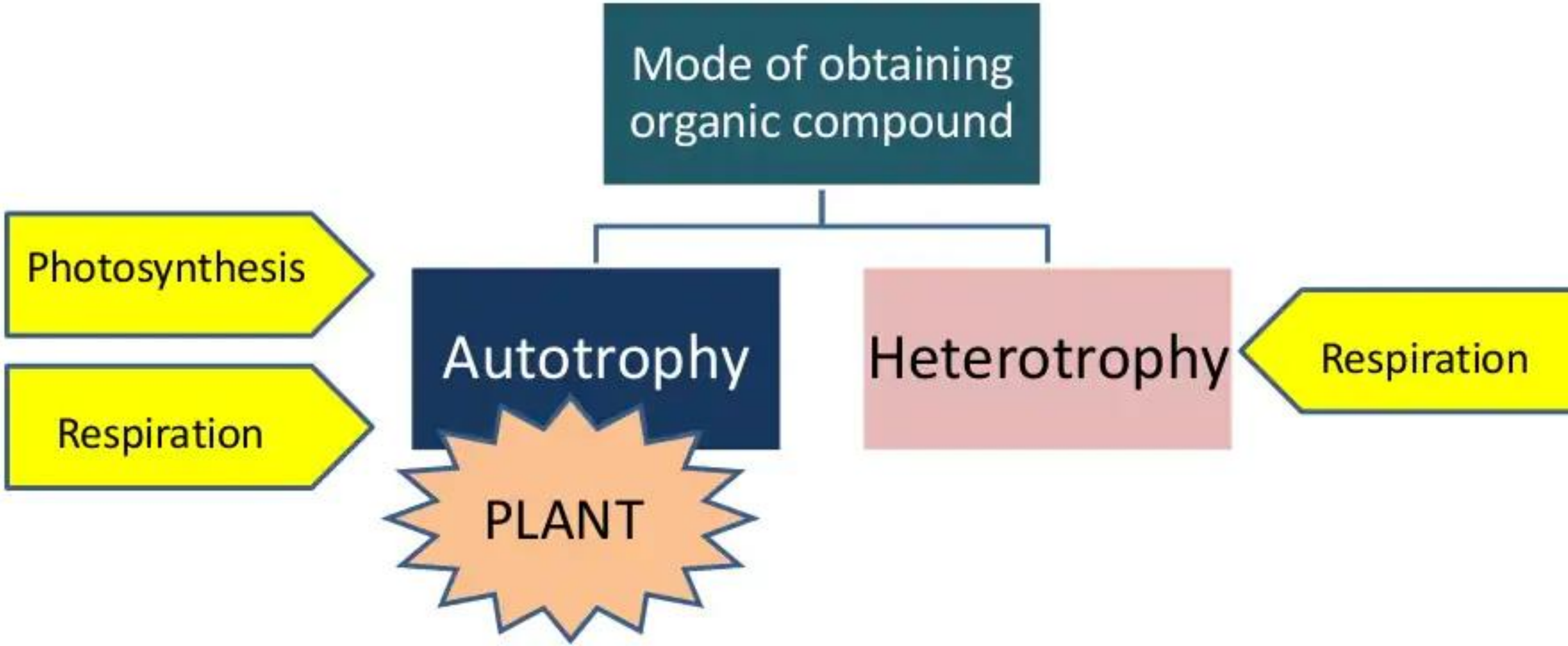
- Metabolism = a set of life-sustaining chemical transformations within the cells of living organisms

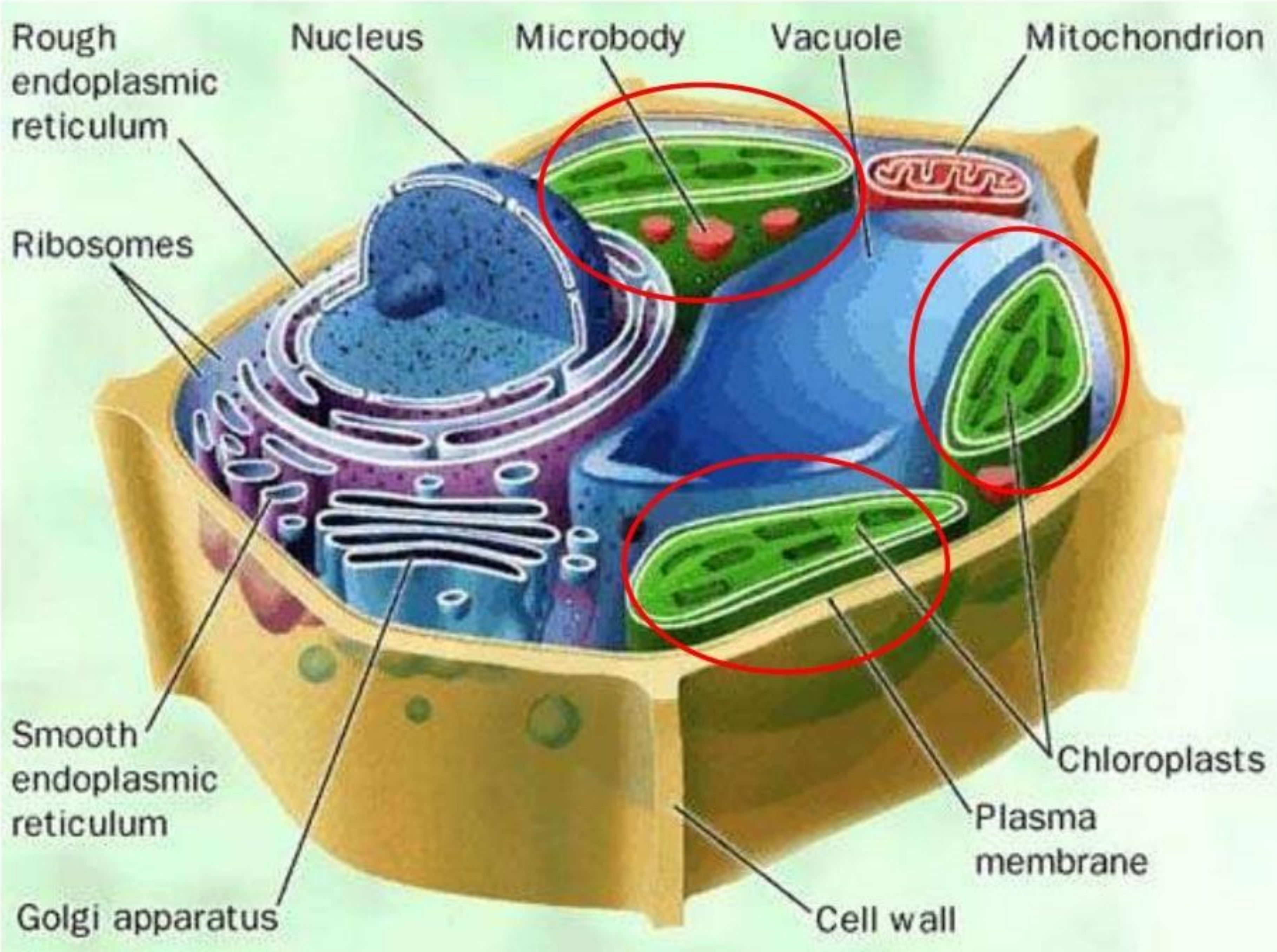


4.2.1 Photosynthesis

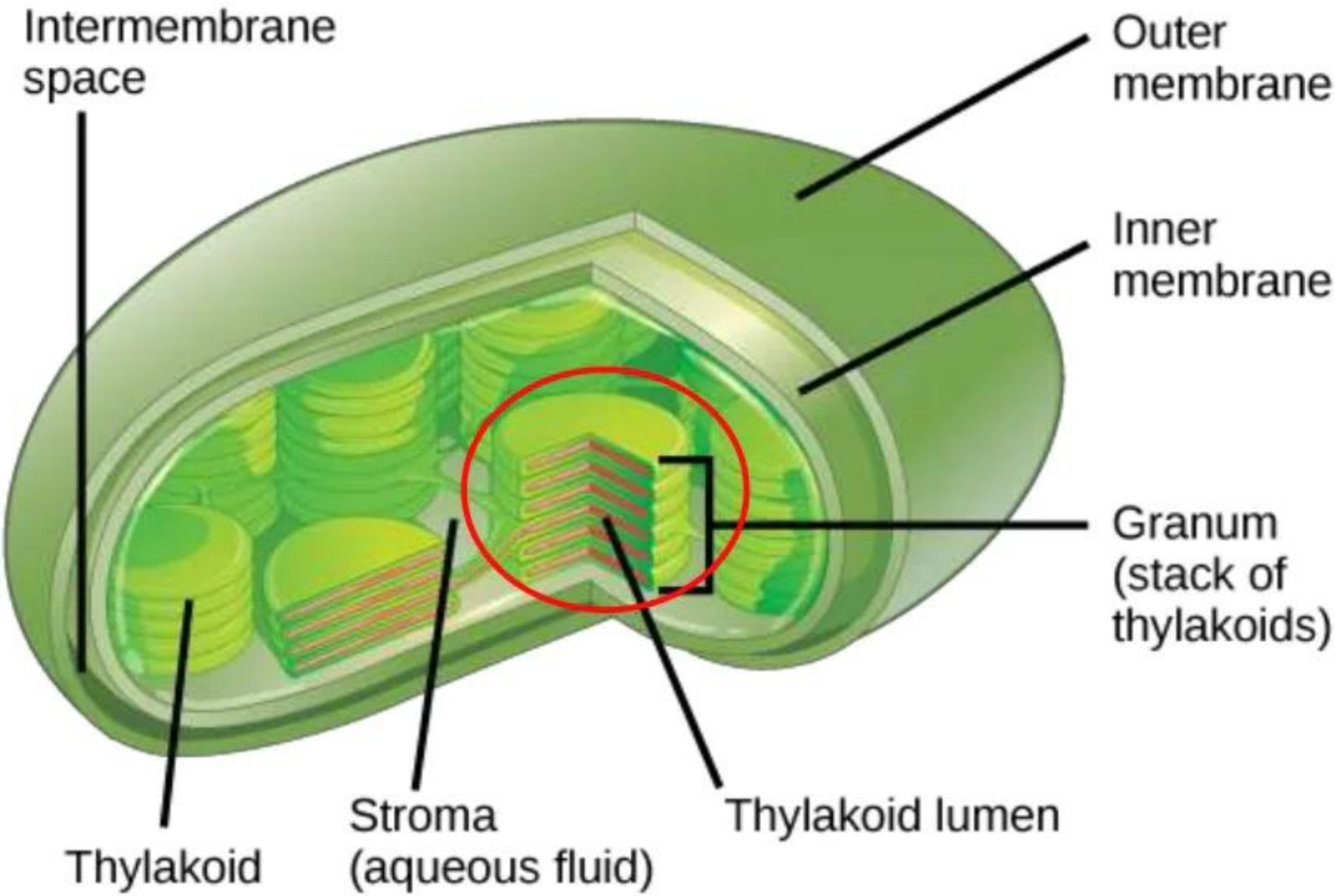
- harvesting sunlight and convert it to chemical energy stored in sugar

- Occurs at all green parts of plant, leaves are the major site. At the cellular level photosynthesis in the **chloroplast**.




Rough endoplasmic reticulum
Nucleus
Microbody
Vacuole
Mitochondrion
Ribosomes
Smooth endoplasmic reticulum
Golgi apparatus
Chloroplasts
Plasma membrane
Cell wall

CHLOROPLAST



- Chlorophylls are pigments in chloroplast absorb red and blue light and reflect green and yellow light to excite electron (e-) – plant appears green.

- Plant absorbs **CO_2**, **H_2O** and **O_2** as raw material of photosynthesis.

- **Carbon dioxide + water → Sugar + Oxygen + Water + Sunlight**
- **$6\ CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$**

There are 2 stages of photosynthesis

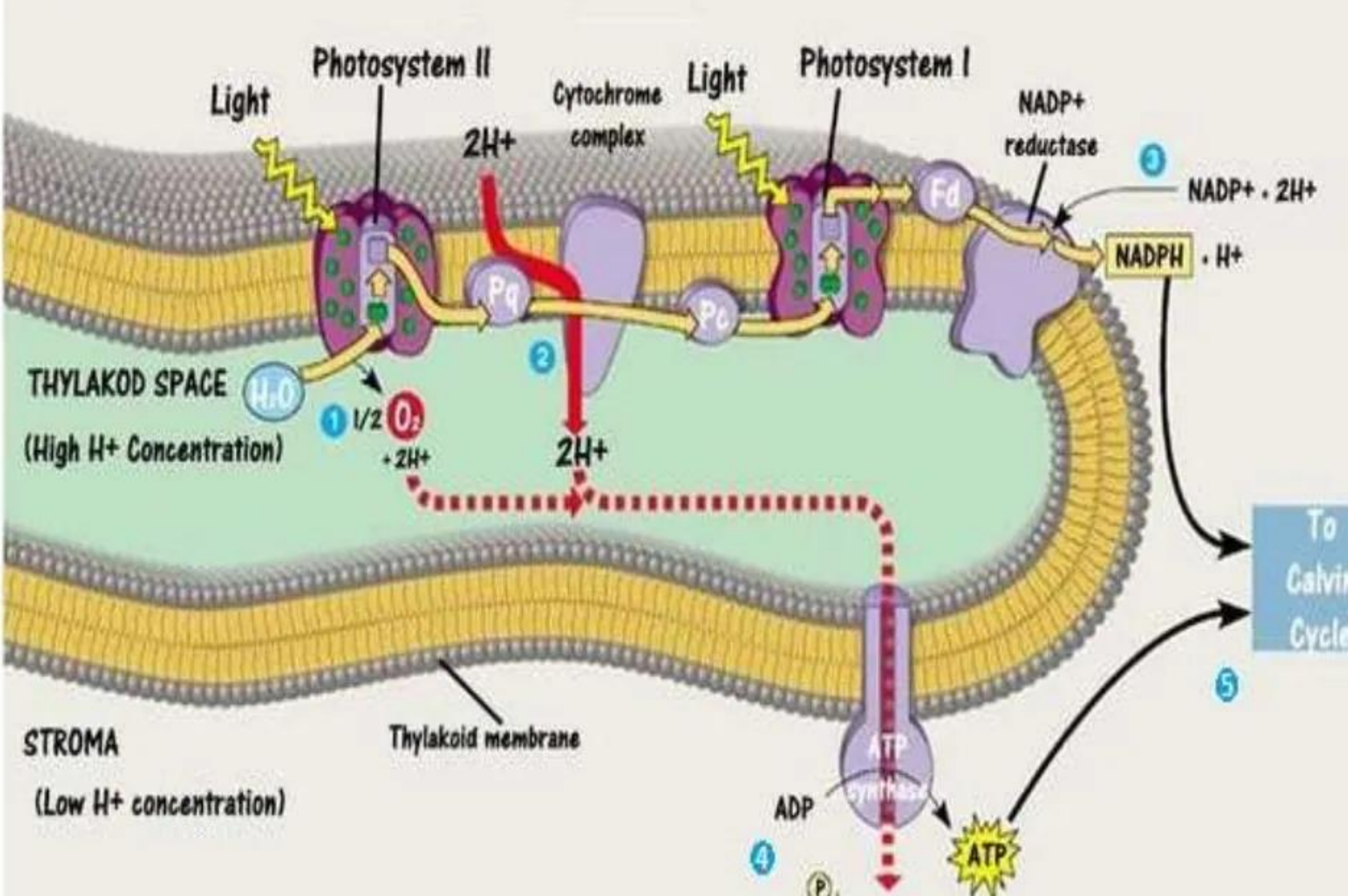
Light Reduction

- convert solar energy into chemical energy (e-, ATP, NADPH)
- occurs at the thylakoid membrane
- Excitation of chlorophyll
- Chemiosmosis

Calvin Cycle

- convert CO2 into sugar by using ATP and NADPH
- also known as Dark Reaction
- Occurs in the stroma
- Carbon Fixation

LIGHT REACTION/ CHEMIOSMOSIS



1) **Water** split into O_2 and H^+ produce e^-, **2e-** will be tranffered into photosystem II and will be excited by received photon of sunlight. The energized **2e-** will be tranfered to Cytochrome complex by **Plastoquinone (Pq)**.

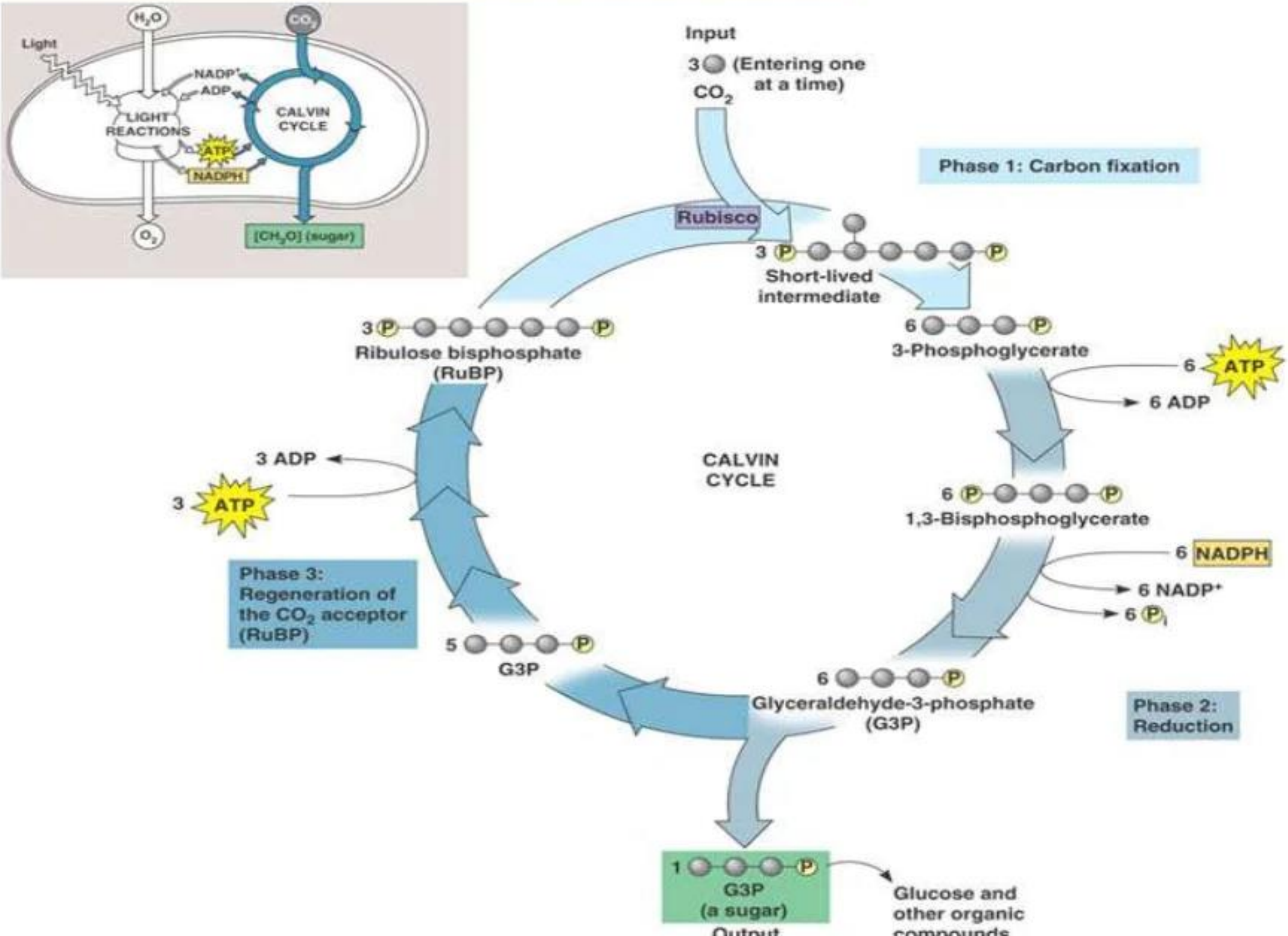
2) As the electron carrier, **Pq** transfer **2e-** to the **Cytochrome complex**, **2 Protons (H^+)**, are translocated across the membrane from **stroma** to thylakoid space.

3) **Hydrogen ion (H^+)** is removed from **stroma** when it is taken up by $NADP^+$ to produce **NADPH**.

4) H^+ from **thylakoid** space will be diffused back to **stroma** (along the H+ concentration gradient) powers the **ATP Synthase** to phosphorylate **ADP** to **ATP**.

5) The produced **NADPH** and **ATP** will shuttle energy to **Calvin Cycle**.

DARK REACTION/ CALVIN CYCLE



- **Calvin Cycle**
- Produces carbohydrate directly from carbon CO_2.
- Consumes **ATP** as energy source and **NADPH** as reduction.
- Produce **glyceraldehydes-3-phosphate (G3P)**, net synthesis of one molecule of this sugar, the cycle must takes place 3 times.
- There are 3 phases in Calvin Cycle **1) Carbon Fixation**, **2) Reduction**, **3) Regeneration of CO_2 acceptor (RuBP)**.

a) Carbon fixation

1. 1 **CO_2** molecule will attach to 5 Carbon sugar named **Ribulose Biphosphate (RuBP)** catalyzed by **RuBP Carboxylase** also known as **Rubisco**.
2. This reaction produce unstable 6 carbon immediate compound that will immediately split in half known as **3-Phosphoglycerate (PGA)**.

b) Reduction

1. The **PGA** molecule will be phosphorilate by **ATP** produces **1,3-bisphosphoglycerate.**
2. Next, **1,3-biphosphoglycerate** will be reduce by **NADPH** to produce **G3P**.
3. 6 G3P are 3 carbon sugar molecules, 1 in every 6 cycle produced G3P will be used in glucose production. The other 5 will continue in generation of CO_2 receptors

c) Regeneration of CO_2 acceptor (RuBP)

1. In a complex series of reaction, all 5 molecule of 3 carbon **G3P** will be **rearranged** into 3 molecules of **RuBP.**

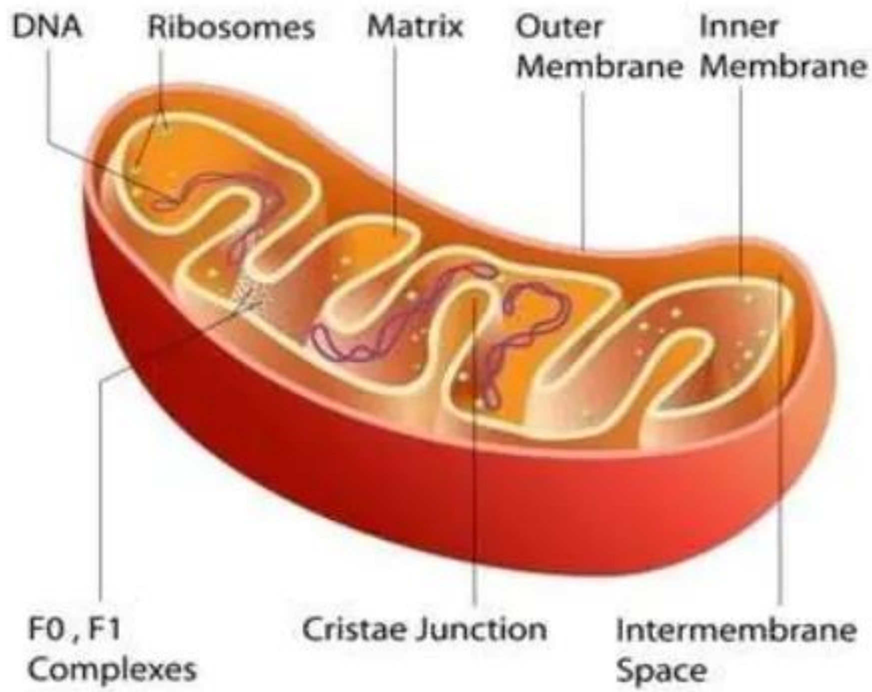
2. **3 ATP** will be used to to phosphorylate all 3 molecules of **RuBP**. Now, all 3 **RuBP** are ready to receive **CO_2** again.

4.2.2 Cellular Respiration

- set of metabolic reactions and processes that take place in the cells of organisms to convert biochemical energy from nutrients into ATP, and then release waste products.

- occurs in all living thing. In cellular level, respiration occurs in Mitochondria.

- process of breaking larger molecules to smaller molecules releasing energy to fuel cellular activities.

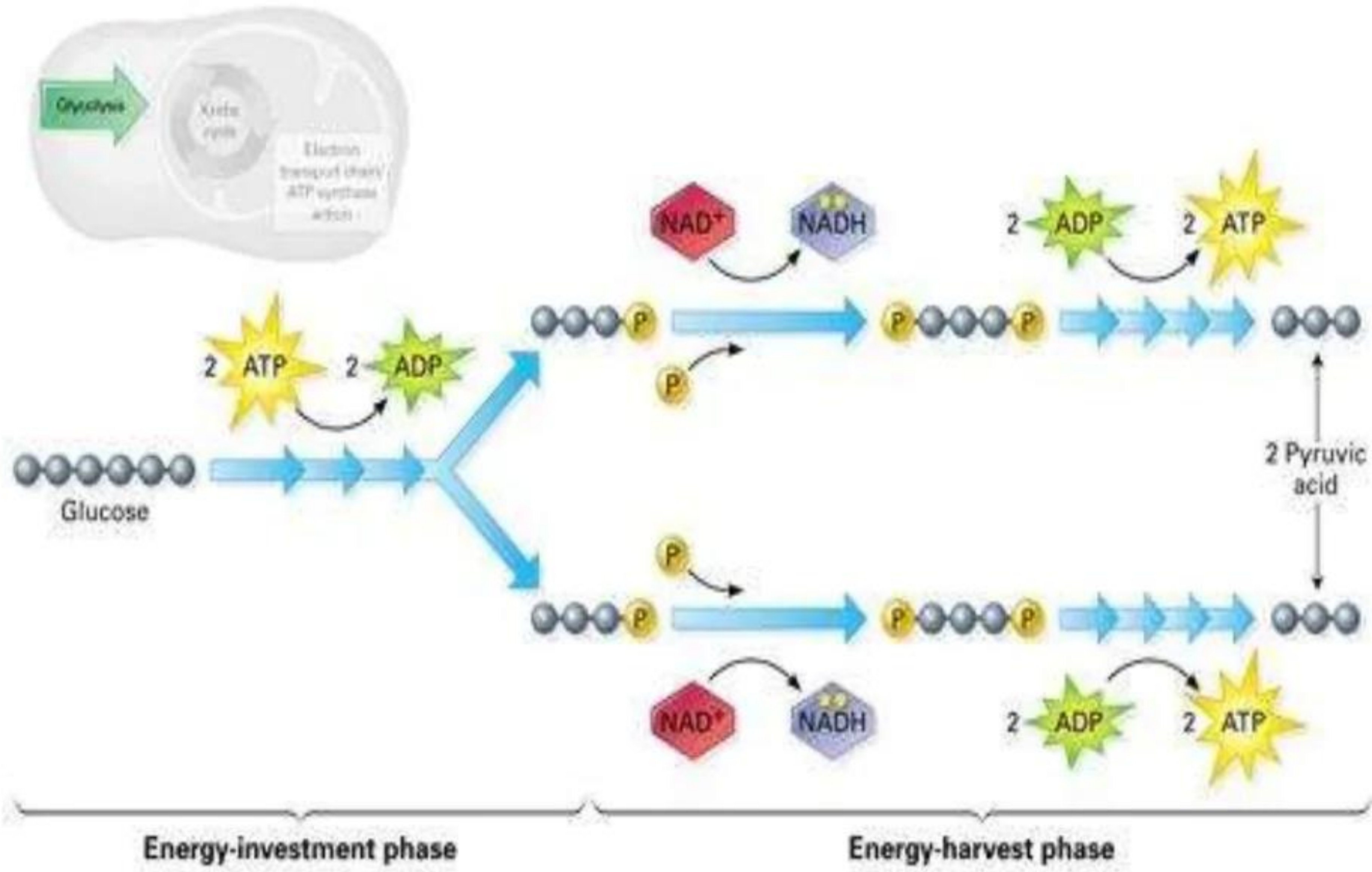


-**Glucose + oxygen → Carbon Oxide + Water + Energy (ATP and Heat)**

-**$C_6H_{12}O_6$ + O2 → CO_2 + H_2O + Energy (ATP and Heat)**

- Cellular respiration is an cumulative function of three metabolic stages: **a) Glycolysis**, **b) Citric Acid Cycle (Kreb Cycle)**, **c) Oxidative Phosphorylation; Electron transport and Chemiosmosis**.

GLYCOLYSIS



NAD+
NADH
2 ADP
2 ATP
P
2 ATP
2 ADP
Glucose
2 Pyruvic acid
NAD+
NADH
2 ADP
2 ATP
Energy-investment phase
Energy-harvest phase

A) Glycolysis

- "Glucose" means sugar and "lysis" means degradation. Splitting of sugar, degradation of sugar.
- Consists of 2 phases: **i) Energy investment ii) Energy harvesting**

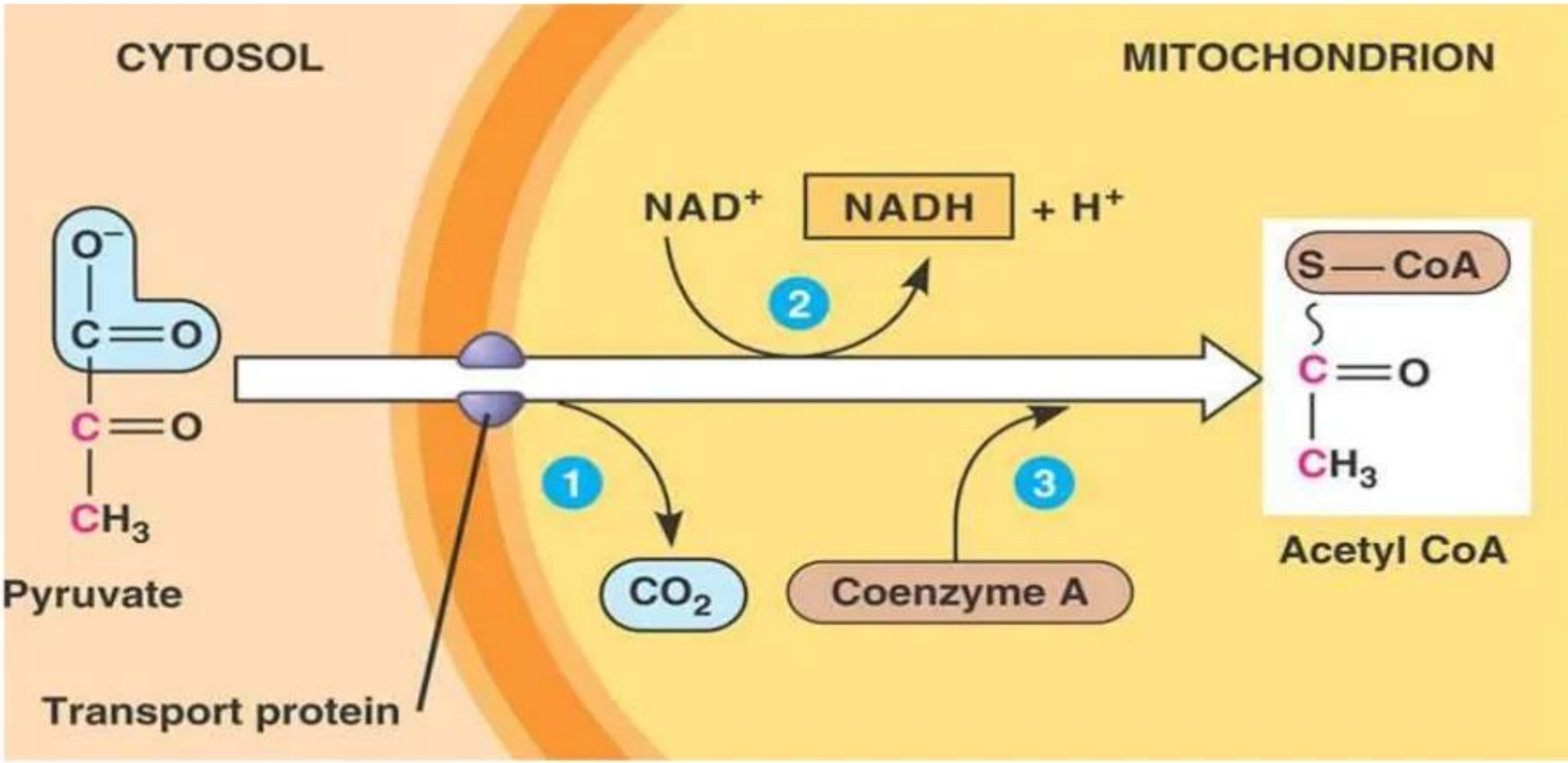
i) Energy Investment

1. Glucose will be phosphorilate by ATP to produce Fructose 1,6-Biphosphate
2. Enzymatic reaction will change 6 carbon Fructose 1,6-Biphosphate molecule into 3 carbon Dihydroxyaceton phospahate (DHAP) dan Glyceraldehyde -3-Phosphate (G3P)
3. DHAP ditukarkan kepada bentuk G3P.
4. 2 Phosphate group will be added to the molecules by enzymatic reactions.

ii) Energy Harvesting

1. G3P will be oxidized by NAD^+ to produce NADPH
2. 4 ATP will be produced when 4 phosphate groups are transferred to 4 ADP.
3. The final result of Glycolysis is 3 carbon molecule of pyruvate.

CONVERSION OF PYRUVATE TO ACETYL COA



b) Conversion of Pyruvate to Acetyl CoA

1. Pyruvate enters mitochondria via active transport

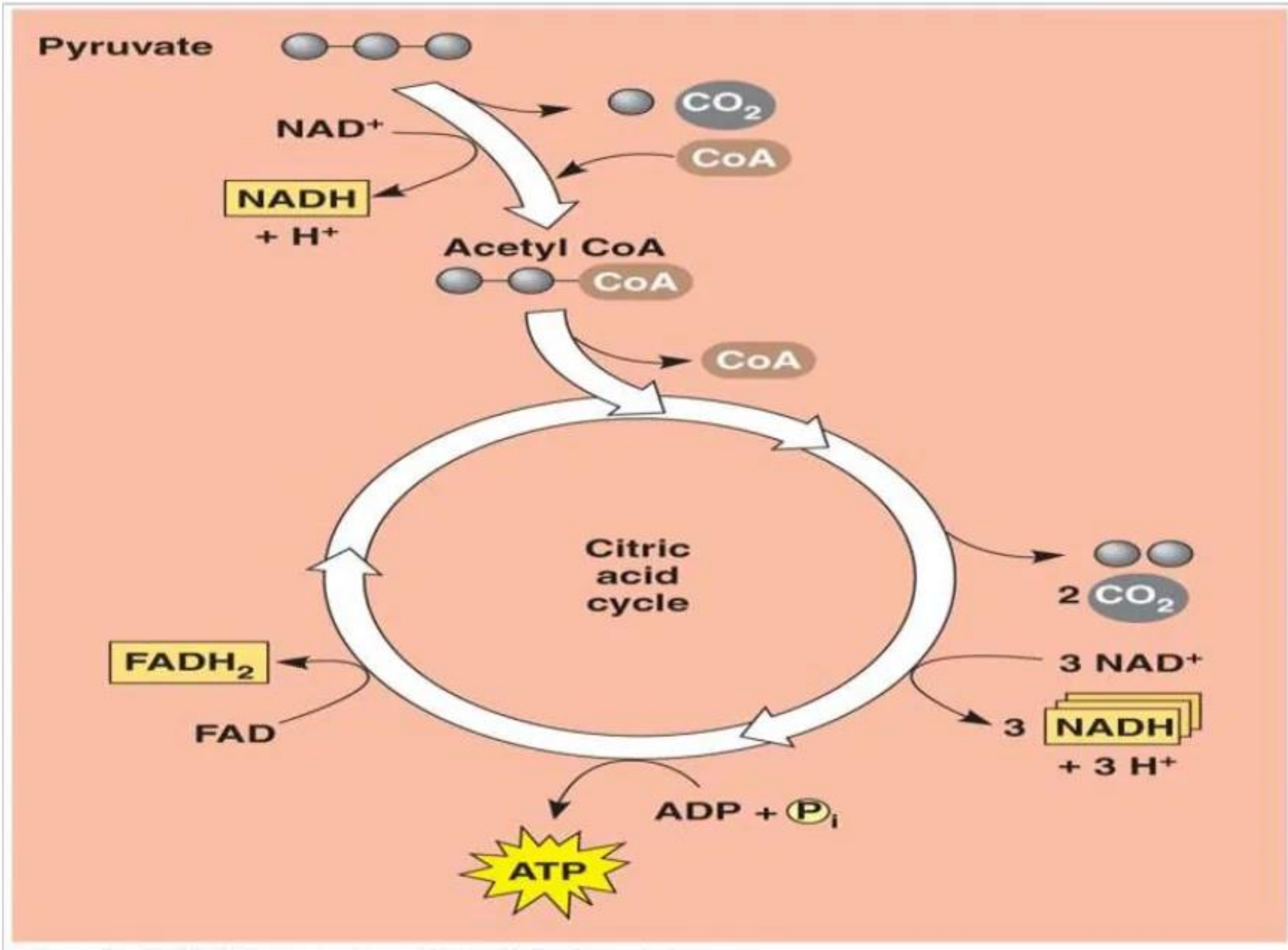
2. Pyruvate will be converted to acetyl CoaA before enters the Citric Acid Cycle (Krebs Cycle)

3. CO2 will be remove from pyruvate, produce 2 Carbon molecule

4. NAD+ with the molecule produce NADH

5. Coenzyme A (derivative of Vitamin B) attached to the molecule to produce Acetyl CoA.

CITRIC ACID CYCLE / KREB CYCLE



c) Citric Acid Cycle (Krebs Cycle)

1. Acetyl CoA will be added to the Oxaloacetate from the previous cycle

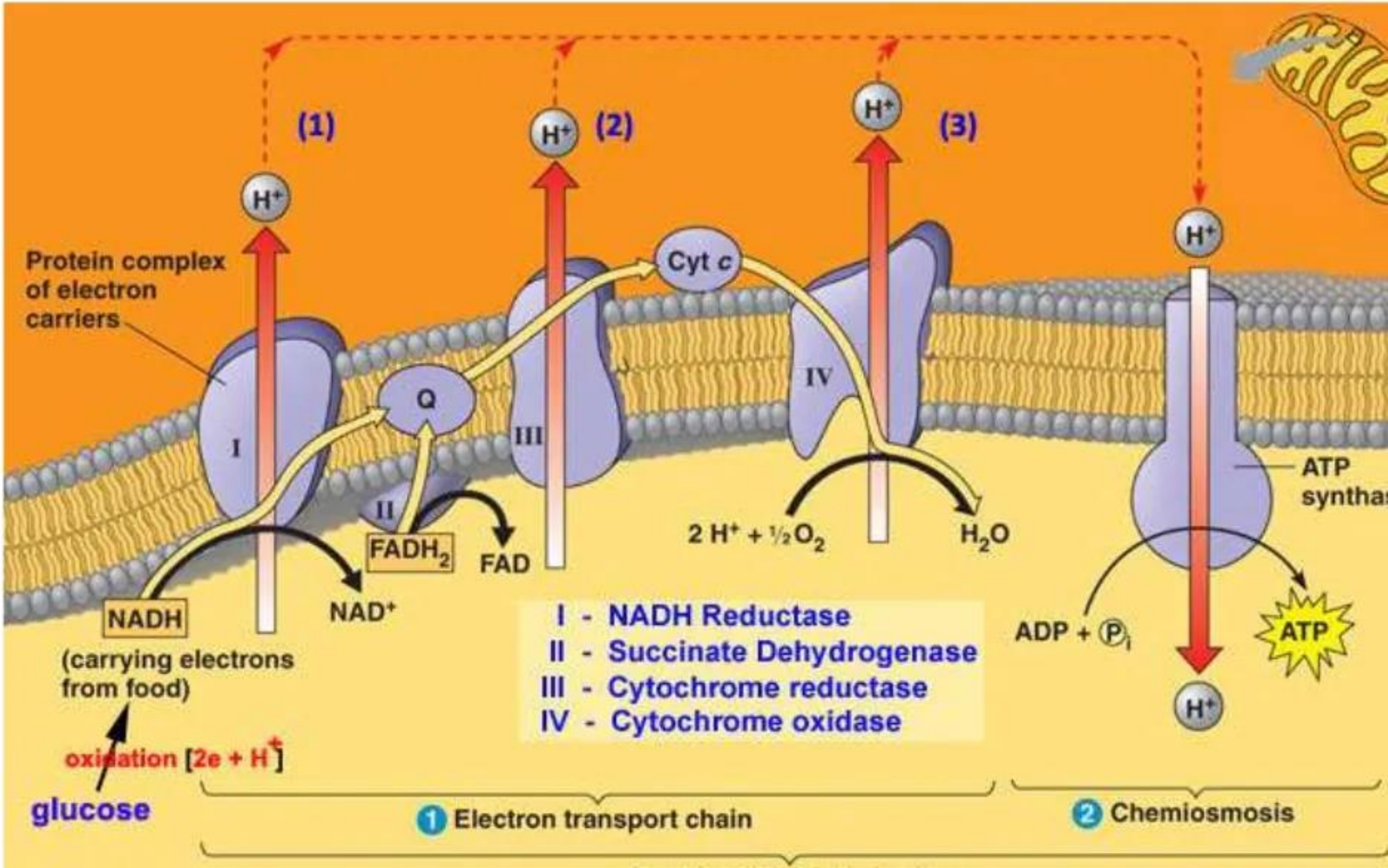
2. CoA will be removed from the acetyl CoA molecule.

3. Co2 will be removed from the molecule
4. 3 NAD+ will gain e- from the molecule produce 3 NADH

5. Phosphate group will be transferred to ADP to produce ATP

6. FAD will be reduced to FADH2 and produces Oxaloacetate.

OXIDATIVE PHOSPHORYLATION; ELECTRON TRANSPORT AND CHEMIOSMOSIS.



d) Oxidative Phosphorylation (OXPHOS); Electron transport and Chemiosmosis.

1. NADH and FADH2 shuttle high energy e- (from glycolysis) to an electron transport chain

2. As e- is transported by complexes, they pump H+ from mitochondrial matrix into intermembrane space

3. E- will accepted by O2 (from breathing) combining with H= to produce H2O

4. H+ flow back down their gradient into mitochondrial matrix via ATP Synthase.

5. H+ motive force phosphorilate ADP to ATP

COMPARISON TABLE

② OVERALL CONCEPT

Cellular Energy

① CONCEPT	① CONCEPT
Photosynthesis	**Cellular Respiration**

③ CHARACTERISTICS	③ CHARACTERISTICS
High-energy electrons are transported through proteins Flow of hydrogen ions through ATP synthase produces ATP Processing organelle is chloroplast Calvin Cycle in stroma of chloroplasts builds sugar molecules Produces sugar (C H O) and O	High-energy electrons are transported through proteins Flow of hydrogen ions through ATP synthase produces ATP Processing organelle is mitochondrion Krebs Cycle of mitrochondria breaks down C-based molecules Produces carbon dioxide (CO) and H O

⑨ EXTENSIONS

How does cellular respiration help to keep our bodies warm?

④ LIKE CHARACTERISTIS

High-energy electrons are transported through proteins
Flow of hydrogen ions through ATP synthase produces ATP

⑤ LIKE CATEGORIES

Transport of energy
Production of ATP

⑥ UNLIKE CHARACTERISTICS

Organelle is chloroplast	Organelle is mitochondrion
Calvin Cycle	Krebs Cycle
Produces sugar	Produces carbon dioxide

⑦ UNLIKE CATEGORIES

Organelles' location
Cycles
Products

⑧ SUMMARY

Both photosynthesis and celluar respiration occur in the interior space of their respective organelles; both are cycles of chemical change. Photosynthesis builds larger carbon-based molecules in chloroplasts to store energy. Cellular respiration breaks down carbon-based molecules in the mitochondria to release energy.

4.3 Plant Nutrition

- the study of the chemical elements and compounds that are necessary for plant growth, and also of their external supply and internal metabolism

Macro Nutrients

Carbon (C)
Hydrogen (H)
Oxygen (O)

— Used in exceptionally large quantities

Nitrogen (N)
Phosphorus (P)
Potassium (K)

— Used in large quantities

Secondary Nutrients

Calcium (Ca)
Magnesium (Mg)
Sulfur (S)

— Used in moderate quantities

Micronutrients

Boron (B)
Chlorine (Cl)
Cobalt (Co)
Copper (Cu)
Iron (Fe)
Manganese (Mn)
Molybdenum (Mo)
Nickel (Ni)
Silicon (Si)
Sodium (Na)
Zinc (Zn)
Vanadium (Va)

Used in small quantities

Carbon, Hydrogen and Oxygen represent 90-96% of the dry matter of all plants. The
elements are supplied by atmospheric carbon dioxide and water. The plant obtains t
remaining 4-10% from the soil and/or fertiliser inputs.

In commercial agriculture the following elements are applied, when necessary, to improve crops.

Macronutrients	Secondary Nutrients	Micronutrients
Nitrogen (N)	Calcium (Ca)	Zinc (Zn)
		Iron (Fe)
Phosphorus (P)	Magnesium (Mg)	Manganese (Mn)
		Copper (Cu)
Potassium (K)	Sulfur (S)	Boron (B)
		Molybdenum (Mo)

NUTRIENT	FUNCTIONS IN THE PLANT	DEFICIENCY SYMPTOMS	CONDITIONS THAT REDUCE AVAILABILTY	SENSITIV CROPS
Nitrogen (N)	• an essential element in all living systems • needed by all cells • occurs in the living substance (protoplasm) of cells • a major component of protein • a major component of chlorophyll which converts sunlight into plant energy • affects both yields and quality.	• lighter green or yellow coloured leaves (first evident in older leaves) – some plants eg. berries can develop red or orange colours • stunted growth • lower protein levels in pasture and grain • delayed maturity • decreased resistance to disease and/or insect attack • smaller fruit • lower yields • shorter storage life	▪ light or sandy soils where nitrate nitrogen is leached ▪ water logged soils ▪ soils with structural problems as a result of poor aeration ▪ mineral soils low in organic matter ▪ soils where nitrogen has been depleted by previous crops ▪ soils where the ammonium form has been applied to high pH soils (free ammonia)	All crops are sensit nitrogen deficiency
Phosphorus (P)	• necessary for proper cell division and the formation of new cells • photosynthesis • sugar and starch formation • energy transfer • carbohydrate transport.	• reduced growth – sometimes stunted and other times only evident from shortened internodes, smaller leaves and reduced shoot growth. • dark green colour in some crops • purple leaves in others eg. brassicas • reduced tillering in cereals • small misshapen fruit – can be pulpy with poor storage life • poor seed development	▪ soil with a pH less than 5.5 or more than 7.0 ▪ soil with a high clay content ▪ mineral soils low in organic matter ▪ soil with high levels of hydrous oxides of aluminum or iron ▪ soils where phosphorus has been depleted by previous crops	Cereals, maize, bro cabbage, cucumbe lettuce, potatoes, s fruits, tree fruits (particularly citrus) tomatoes.

NUTRIENT	FUNCTIONS IN THE PLANT	DEFICIENCY SYMPTOMS	CONDITIONS THAT REDUCE AVAILABILTY	SENSITIV CROPS
Potassium (K)	• aids photosynthesis and the functioning of chlorophyll • important for the formation and translocation of starches, sugars and fats • involved in protein formation • aids many enzyme actions • helps cells maintain their internal pressure • reduces wilting and respiration by maintaining the balance of salts and water in cells • improves crop quality • increases root growth and resistance to disease and drought • decreases lodging.	• light green to yellow older leaves which later develop marginal leaf scorch- different plants have their own visual deficiency symptoms • plant growth is retarded • lodging • disease resistance is reduced • stalks are weakened • seed and fruit is misshapen	▪ continuously cropped soils with low levels of organic matter ▪ soils without balanced fertiliser programs ▪ light sandy soils where potassium has been leached ▪ periods of drought ▪ prolonged periods of heavy rain ▪ some clay soils (eg. Krasnozems) ▪ soils in which deficiencies of phosphorus and molybdenum have been corrected ▪ heavily limed soil ▪ soils formed from parent material low in potassium	Apples, beans, be broccoli, citrus, cu grapes, legumes, l maize, nuts, passi peas, potatoes, rh stone fruit, sunflov tomatoes.
Calcium (Ca)	▪ necessary for the proper functioning of growing points particularly root tips ▪ forms compounds which strenghten cell walls ▪ aids in cell division and elongation ▪ neutralises organic acids ▪ aids in the proper working and permeability of cell membranes ▪ regulates protein synthesis and slows the aging	▪ terminal buds and root tips fail to develop normally. • lodging • stunted root systems • leaves of grasses do not open properly the tips of which stick to the next lowest leaf • soft fruit • senescent breakdown and poor storage life of fruit • internal and external disorders of many fruit and vegetables	• low pH soils. • where there is an unfavourable balance of calcium, magnesium and potassium in the soil (particularly heavy potassium inputs in sandy soils) • where high rates of nitrogen have been used	Tree crops, fruit ar vegetables. Calcium is not eas translocated in pla a constant supply required. This sho foliar applied and i fruiting crops be a from after flowerin onwards.

NUTRIENT	FUNCTIONS IN THE PLANT	DEFICIENCY SYMPTOMS	CONDITIONS THAT REDUCE AVAILABILTY	SENSITI CROPS
Magnesium (M)	▪ the only mineral constituent of the chlorophyll molecule ▪ aids plants to form sugars and starches ▪ plays an important part in the translocation of phosphorus ▪ aids several plant enzymes to function.	• interveinal chlorosis beginning in the tips of older leaves. Veins remain green, the chlorotic areas change from yellow to brown (other colours in some plants). • leaves become brittle and necrotic and may drop prematurely • yield can be seriously reduced • cotton leaves develop a purplish – red colour between green veins • some varieties of black grapes and stone and pit fruit can develop interveinal red chlorotic areas • grass tetany in sheep and cattle • excessive premature fruit drop	• sandy acid soils – particularly in high rainfall areas • course textured soils in humid regions • cold wet conditions • soils where there have been heavy inputs of potassium • soils which have received repeated green manuring	Vines, pome frui fruit, citrus, maize tomatoes, capsic broccoli, cauliflow lettuce, potatoes, pumpkin and ma others.
Sulfur (S)	▪ similar requirements to phosphorus in plants ▪ a constituant of several amino acids which are essential for protein production ▪ aids the activities of some enzymes and vitamins ▪ needed for chlorophyll formation ▪ deficiency adversely affects the oil content in some oil crops and the baking quality in wheat crops ▪ aids efficient nitrogen stabilisation	• generally very similar to nitrogen deficiency - a uniform pale green to yellow leaf but the difference is sulfur deficiency starts in the new leaves whereas nitrogen deficiency starts in the old leaves. • In legumes the nodules produced are smaller, pale rather than pink and reduced in number • deficiencies in field crops include poor low yielding plants, low protein and pale green and yellow leaves in wheat.	▪ soils low in organic matter that have been cropped for many years. ▪ acid sandy soils where sulphate has been leached - especially such areas with high winter rainfall.	Cotton, clovers, barrel medic, luc canola, wheat, b maize, sunflowe soybean, navy b sorghum, oats a triticale.

NUTRIENT	FUNCTIONS IN THE PLANT	DEFICIENCY SYMPTOMS	CONDITIONS THAT REDUCE AVAILABILTY	SENSITIV CROPS
Boron (B)	▪ plays a role in cell division, ▪ aids efficient translocation of calcium, ▪ protein synthesis, ▪ carbohydrate metabolism, ▪ pollen viability ▪ flower and fruit set and formation. ▪ Hormone formation	• thick, curled and brittle tissues – cracking and splitting, sometimes with gumosis • surfaces of leaf, petioles, stems and midribs develop cracks or a corky appearance • reduced flowering, seed set and fruit set. • Growth points can die forming multiple side shoots • Small misshapen fruit • Internal flesh disorders and cracking in fruit and vegetables	▪ high pH soils ▪ overlimed soils ▪ soils with high levels of nitrogen and/or calcium ▪ sandy soils that are easily leached ▪ soils with low organic content ▪ cold wet weather (especially following a long dry spell)	Cotton, barley, oats, s sunflower, lucerne, navy be beans, citrus, nut fruit, stone fru crops and vegeta
Copper (Cu)	▪ required for chlorophyll production ▪ helps with photosynthesis ▪ aids in the production of enzyme protein ▪ involved in several enzyme systems ▪ involved in several oxidation reduction reactions and the formation of lignins ▪ helps regulate water movement in plants. ▪ Required for seed production	• marginal chlorosis of young leaves sometimes necrotic tips (if severe) • twig dieback • sometimes necrotic and brown spots over leaf surface • reduced growth and yields	▪ soils with excess nitrogen and/or phosphorus ▪ high pH soils ▪ heavily limed soils ▪ soils that have had molybdenum applied ▪ peat and muck soils – high in organic matter ▪ leached acid soils ▪ alkaline and calcarious soils ▪ cold wet conditions (availability can often be delayed at spring time) ▪ soils with high concentrations of iron and manganese ▪ soils formed from parent	Cereals, maize, l citrus trees, carro lettuce and onion

NUTRIENT	FUNCTIONS IN THE PLANT	DEFICIENCY SYMPTOMS	CONDITIONS THAT REDUCE AVAILABILTY	SENSITIV CROPS
Iron (Fe)	▪ necessary for the formation of chlorophyll ▪ aids in photosynthesis ▪ involved in the oxidation process that releases energy from starches and enzymes ▪ aids in the formation of proteins ▪ involved in the conversion of nitrate to ammonia in the plant. ▪ aids respiration.	• young leaves – interveinal chlorosis with green veins • later in season – yellowing of leaves (margins and tips can scorch) • stunted growth • reduced yield and quality	▪ high pH soils ▪ after heavy liming ▪ soils with high levels of metallic ions ▪ poorly drained and/or aerated soils ▪ soils with high levels of copper ▪ soils with low potassium levels especially when associated with high potassium levels	Vines, fruit crops fruits, citrus, veg field peas, bea cereals
Manganese (Mn)	▪ essential for chlorophyll production and photosynthesis. ▪ aids nitrogen and carbohydrate metabolism ▪ oxidation reduction ▪ involved in the activity of several enzymes ▪ combines with copper, iron and zinc to aid plant growth processes.	• chlorosis of recently matured leaves with no reduction in leaf size • less pronounced mottling in some broad leaf plants • small grains can show a longitudinal striping • "grey fleck" in oats • chlorosis in citrus (more evident on the shady side of the tree	▪ high pH soils ▪ limed soils ▪ light sandy soils ▪ soils low in potassium ▪ soils low in organic matter ▪ soil high in copper, iron and zinc ▪ cold wet periods ▪ soils that have evolved from parent materials low in manganese	Citrus, pome frui fruit, vines, strawt tomatoes, potatoe legumes, vegetab cereals (especiall sorgham

NUTRIENT	FUNCTIONS IN THE PLANT	DEFICIENCY SYMPTOMS	CONDITIONS THAT REDUCE AVAILABILTY	SENSITIV CROPS
Molybdenum (Mo)	▪ is a co-factor in the enzyme nitrate-reductose ▪ aids in the conversion of nitrates of ammonium (the initial stage of synthesis of proteins) ▪ essential for Rhyzobia to enable legume crops to fix aerobic (atmospheric) nitrogen ▪ helps plants to utilise nitrate nitrogen ▪ involved in phosphate and iron metabolism	• in general similar to nitrogen deficiency - yellowing or pale leaves, stunting, necrotic leaf margins and tips (this is because without molybdenum plants cannot metabolise nitrogen) – symptoms start in older leaves first • flowers can wither or be suppressed	▪ low pH soils – particularly if they contain aluminium and/or iron oxides ▪ soils with high copper levels ▪ soils with low phosphate levels ▪ soils derived from parent materials low in molybdenum	Cucurbits (cucum melons etc.) Crucifers (cabbag canola, cauliflowe Legumes (beans, lucerne, peas, so beans etc.)
Zinc (Zn)	▪ necessary for the formation of chlorophyll ▪ involved in several enzyme systems, the growth hormone auxins and the synthesis of nucleic acids ▪ plays a part in the intake and use of water in by plants.	• stunted growth • leaves reduced in size and misshapen • chlorosis (leaf mottling) leading to necrosis and premature leaf fall • chlorotic leaves and dieback in citrus • rosetting and/or "little leaf" in fruit trees • "tram lining" – light striping both sides of the midrib- in maize • bronze spotting on older leaves later giving a mottled appearance in legumes • reduced development and size of	▪ soils evolved from parent material low in zinc ▪ high pH soils and soils heavily limed ▪ clay soils with high magnesium levels ▪ soils high in organic matter ▪ soils high in potassium ▪ soils that have been leveled, exposing the sub-soils ▪ soils that have had high nitrogen inputs ▪ cold wet conditions (availability can often be delayed at spring time)	Cereals, cotton, fr and citrus trees, r oilseed crops, po rice, stone fruit, vegetables.

4.4 Plant Responses

- Plants are affected by their environment. They respond to it in various ways. For example, a plant may display a bending movement called tropism. Tropism is a plant's response to such stimuli as light, gravity, water and touch.

Plant Responses to Environmental Cues

Phototropism - plant growth response to light
- shoots bend toward light - positive phototropism
- roots sometimes bend away from light - negative phototropism
- allows shoots to capture more light
- mediated by the plant hormone auxin

Gravitropism - plant growth response to gravity
- shoots bend away from gravity - negative gravitropism
  - mediated by auxin - causes lower side of stem to elongate
- roots grow toward gravity - positive gravitropism
  - mediated by gravity sensing cells in root cap

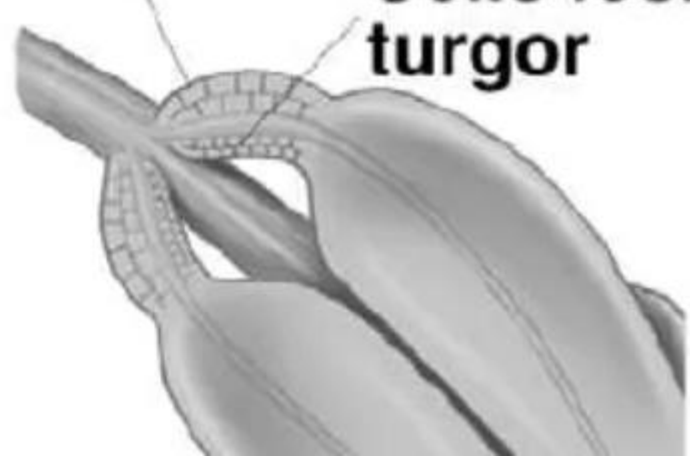
Thigmotropism - plant growth response to touch
- causes coiling of tendrils
- mediated by auxin and ethylene

Turgor Movement

Turgor is pressure within a living cell resulting from water diffusion.

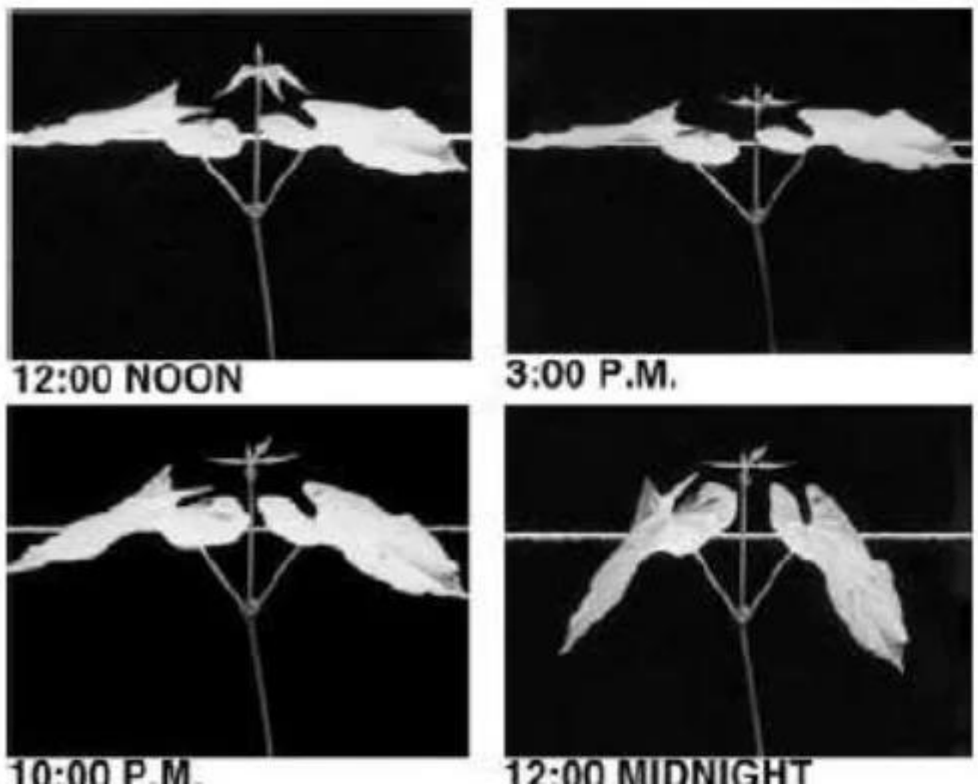
After exposure to a stimulus, changes in leaf orientation are mostly associated with rapid turgor pressure changes in pulvini - multicellular swellings located at base of each leaf or leaflet

turgor movements are reversible



Circadian clocks are endogenous timekeepers that keep plant responses synchronized with the environment.
circadian rhythm characteristics

- must continue to run in absence of external inputs
- must be about 24 hours in duration
- can be reset or entrained
- can compensate for temperature differences



Plant Hormones

Auxin - indole acetic acid (IAA) - causes stem elongation and growth - formation of adventitious and lateral roots, inhibits leaf loss, promotes cell division (with cytokinins), increases ethylene production, enforces dormancy of lateral buds

produced by shoot apical meristems and other immature parts

Cytokinins - stimulate cell division (with auxin), promote chloroplast development, delay leaf aging, promote formation of buds, inhibit formation of lateral roots

produced by root apical meristems and immature fruits

Gibberellins - promote stem elongation, stimulate enzyme production in germinating seeds

produced by roots and shoot tips, young leaves, seeds

Plant Hormones

Ethylene - controls abscission (shedding) of leaves, flowers, fruit
promotes fruit ripening

produced by apical meristems, leaf nodes, aging flowers, ripening fruit

Abscissic acid - inhibits bud growth, controls stomate closing, enforces seed dormancy, inhibits other hormones

produced by leaves, fruits, root caps, and seeds

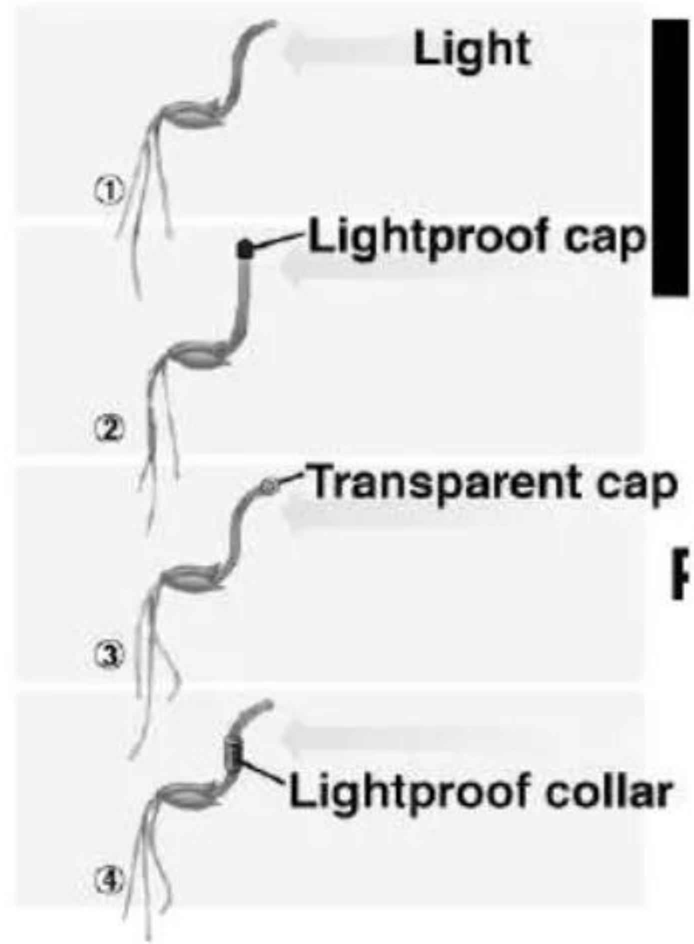
Auxin

Responsible for phototropism

Charles and Francis Darwin wondered what caused plants to bend toward light

They demonstrated that growing tips of plants sense light

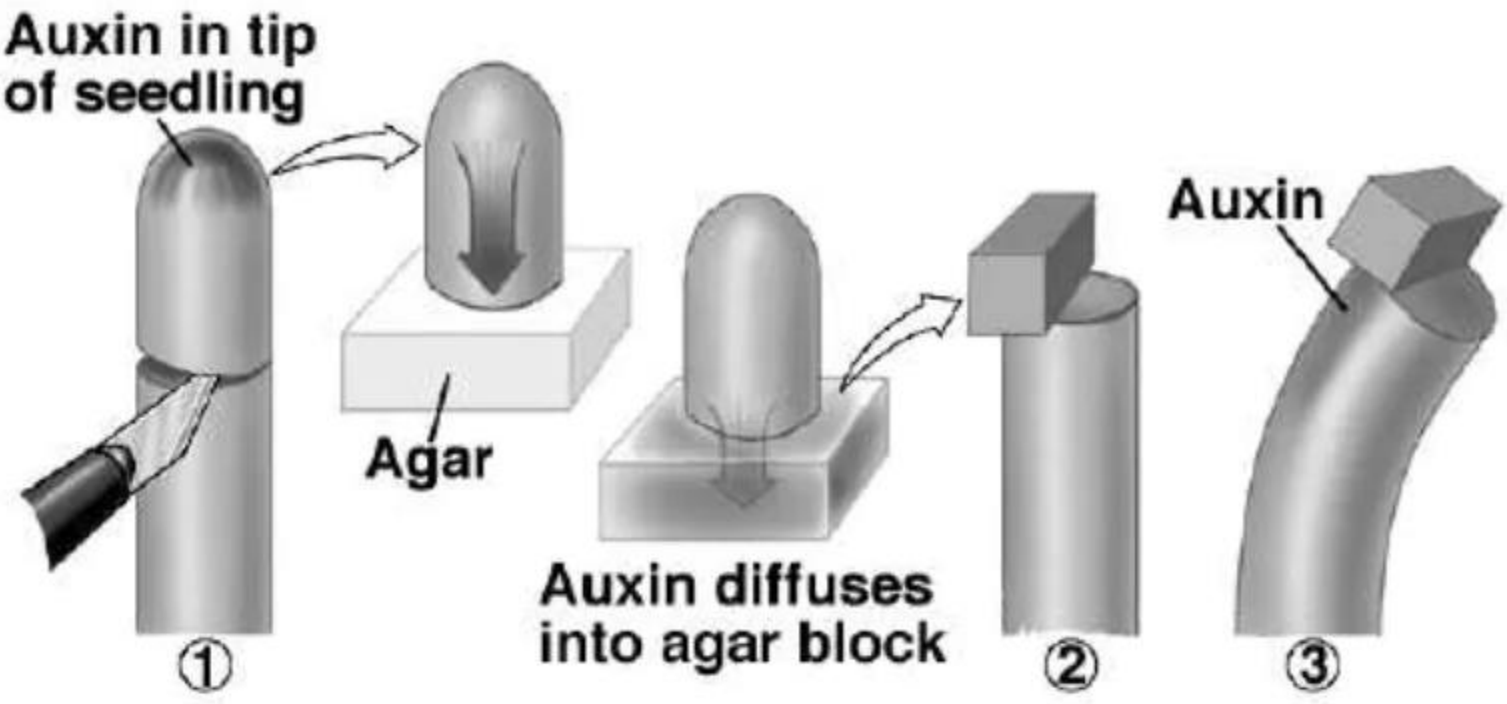
The ability to sense light is not present in areas behind the shoot apex



Went demonstrated that a chemical produced in the shoot tip is responsible for the shoot bending - he called it "auxin"

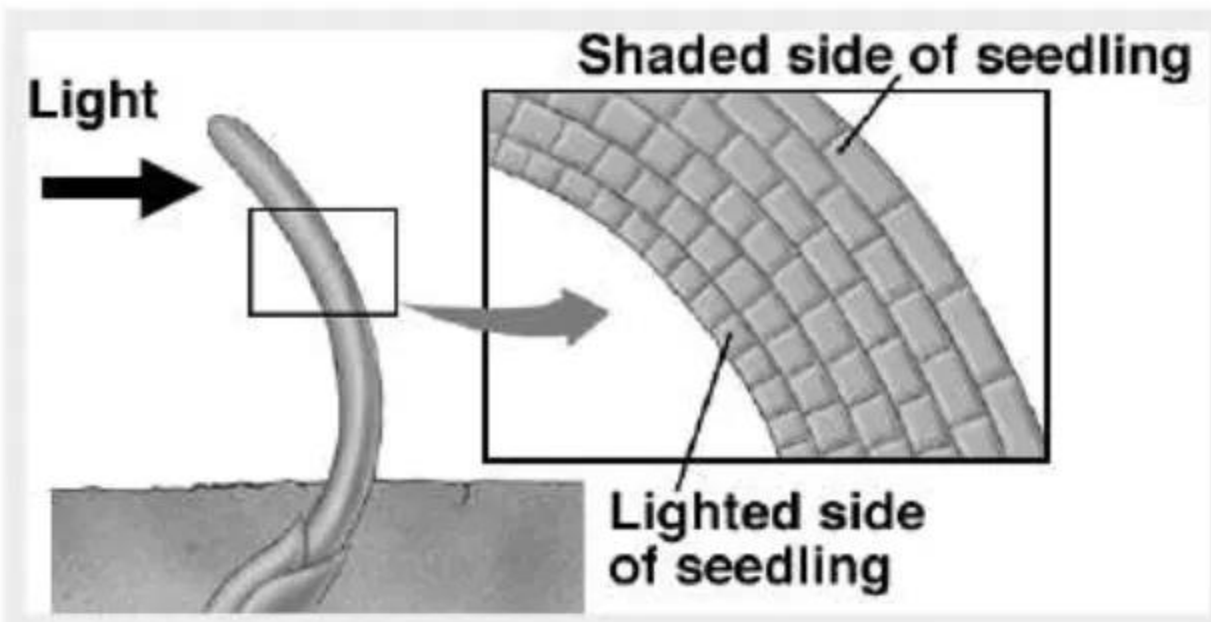
An agar block can absorb chemicals below a growing shoot tip

When the block is applied to an immature shoot, the shoot elongates more on the side where the agar block is applied



Auxin is produced uniformly by growing shoot tips but is transported to the unlighted side of the shoot

It causes cells on the unlighted side to elongate more than cells o the lighted side - it does this by making cell walls softer and mor easily stretched by expansion of the cell's cytoplasm



Other effects of auxins

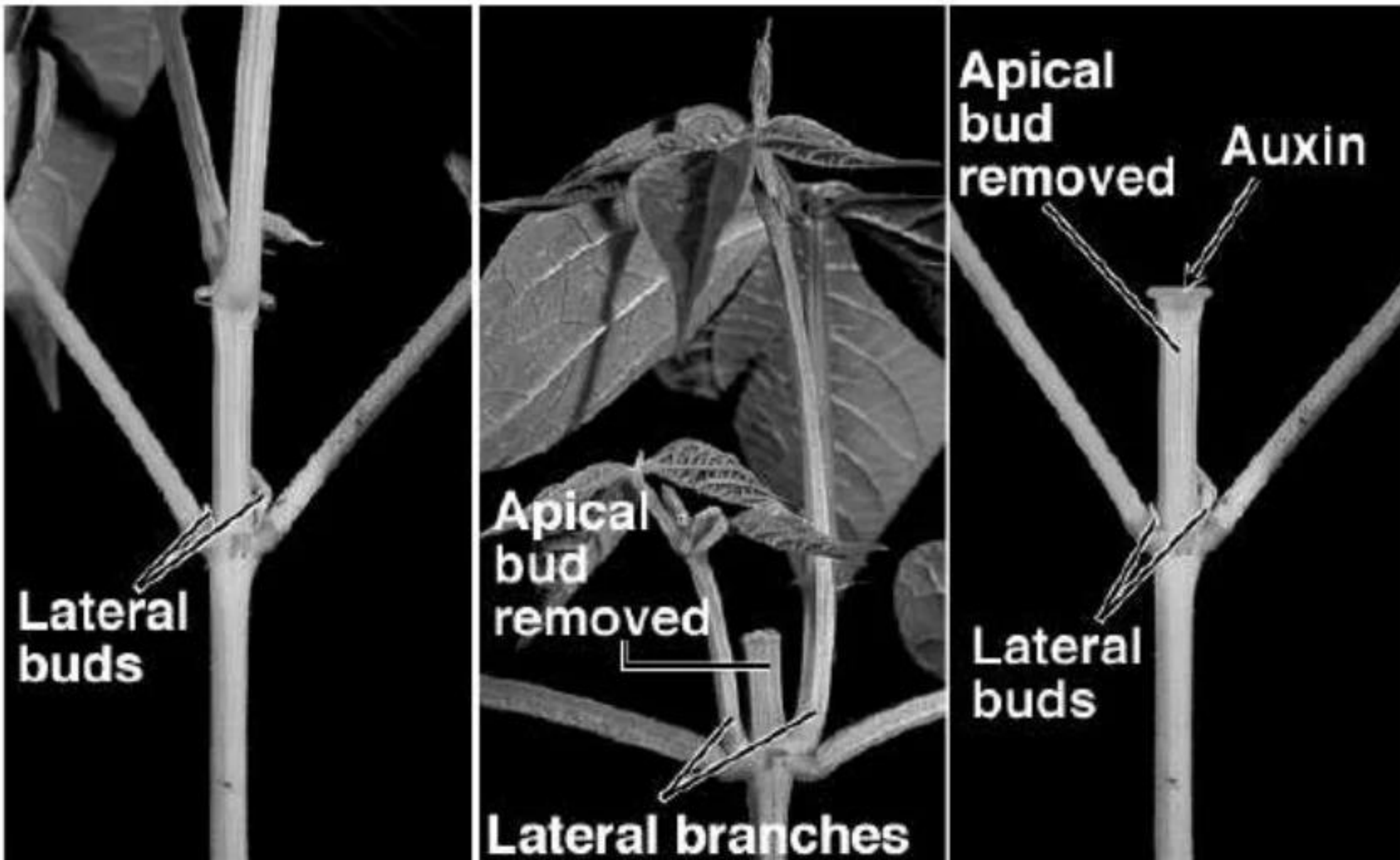
Stimulates formation of fruits
- pollen contains large amounts of auxin - pollen's auxin is a chemical signal that pollination has happened and fruit formation can begin - synthetic auxins can cause fruit formation without pollination

Addition of synthetic auxins to cuttings stimulates formation of roots in plant cuttings - "rooting hormone"

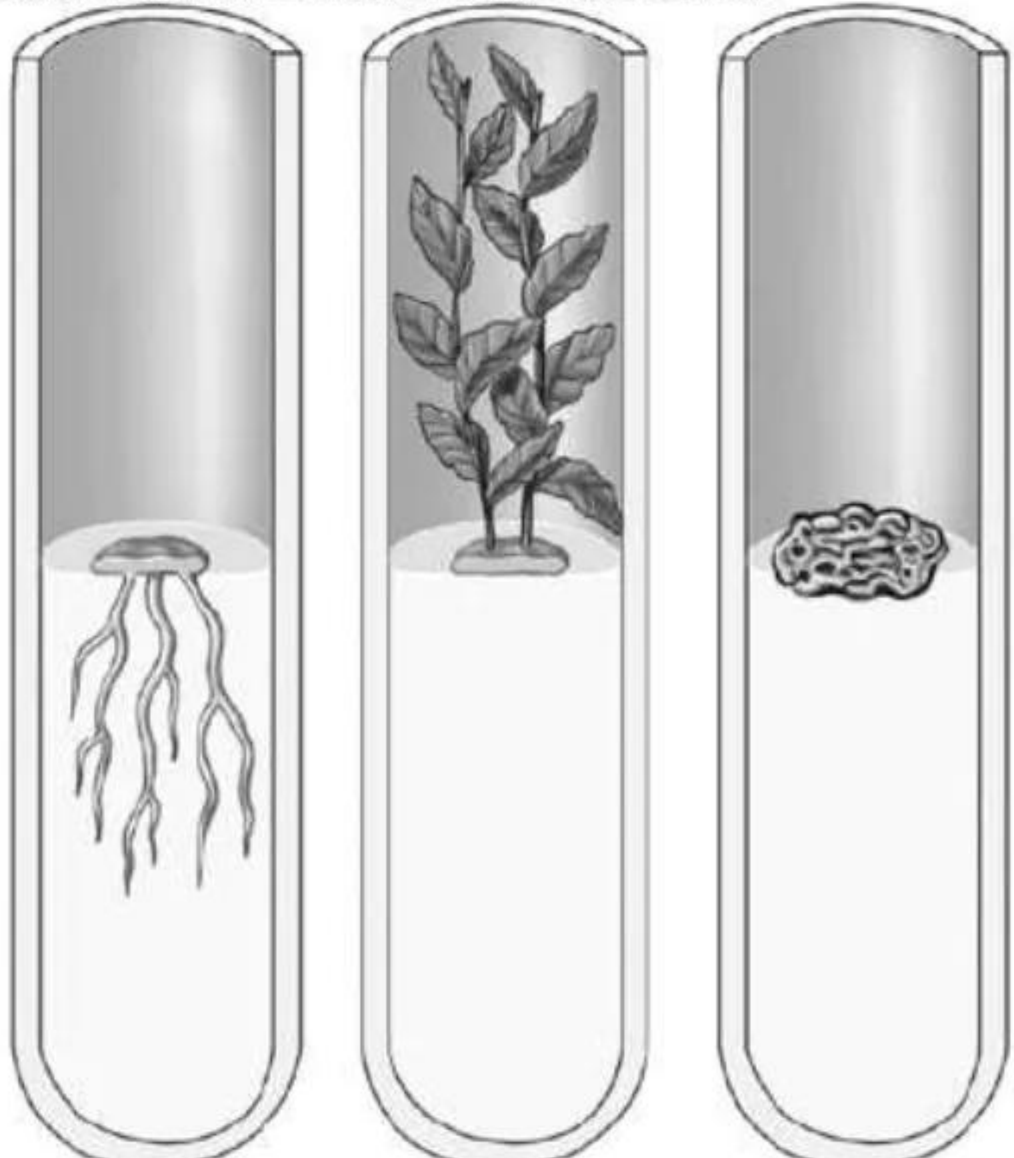
Auxin inhibits the growth of lateral buds in shoots - production of auxin by the shoot apex stops growth of neighboring lateral buds - "apical dominance"

Synthetic auxins can be used to control weedy dicots through the inhibition of growth of shoots - it doesn't harm monocots - most commonly used synthetic auxin is 2,4D - often used in lawn "weed and feeds"

Apical Dominance - the tip of a growing shoot (apical bud) produces auxin that inhibits the growth of lateral buds below the apical bud



Plant Responses to Cytokinin/ Auxin Ratios



Auxin:	High	Low	Intermediate
Cytokinin:	Low	High	Intermediate

Gibberellins

Produced in apical portions of roots and shoots

Cause elongation of internodes in stems (with auxin)

Ethylene

Produced in mature fruit and in some apical meristems

Initial observation of ethylene gas inducing defoliation

Suppresses lateral bud formation when combined with auxin

Suppresses stem and root elongation

Plays major role in ripening of fruit

- Fruit forms separation layer at base of leaf petioles
- Hastens ripening, increases respiration
- Complex carbohydrates broken down into simple sugars
- Chlorophylls broken down
- Cell walls become soft
- Volatile chemicals produced, associated with flavor and scen of ripe fruit

Ethylene used commercially to ripen green fruits -

- Carbon dioxide has opposite effect, fruit is often shipped in CO_2 atmosphere, ethylene applied at destination

Abscissic Acid

Produced by aging leaves and fruits

Application on leaves causes yellow spots and premature aging

May induce formation of winter buds

Suppresses growth of buds and formation of bud "scales" for protection

Suppresses growth of dormant lateral buds (with ethylene)

Counters effects of gibberellins

Promotes senescence (decline with age) by countering auxin

Causes dormancy of seeds

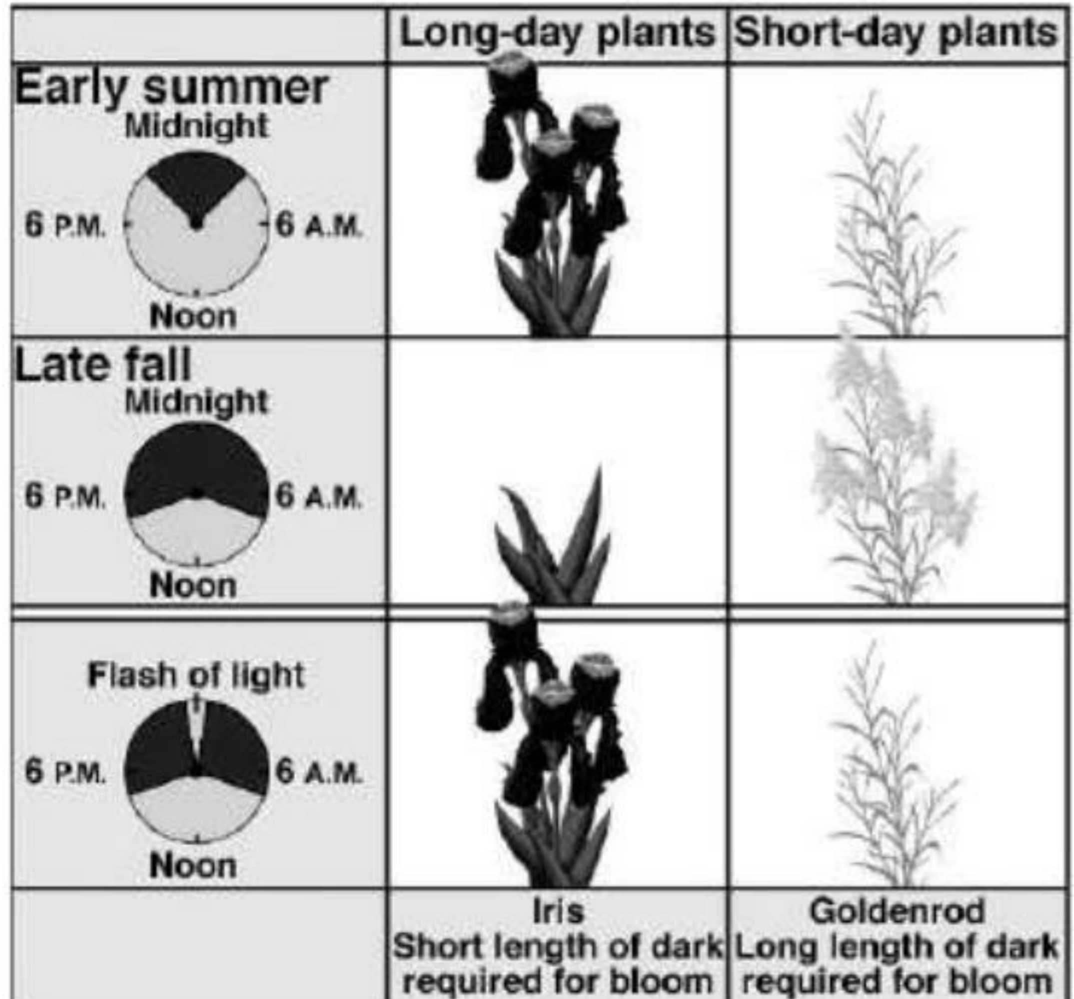
Controls opening and closing of stomata - produced when plants are stressed - causes loss of K^+ from guard cells

Photoperiodism - plant responses to day and/or night length

Long-day plants flower in the late Spring and early Summer, when days are long and nights are short

Short-day plants flower in the late Summer and early Fall, when days are short and nights are long

A single flash of light during a long night will undo the normal effect of a long night



Long days: 12 - 16 hours, short nights 8-12 hours

Short days: < 14 hours, long nights > 8 hours

Day and night length are often manipulated in greenhouses to produce flowering out of season

Poinsettias normally flower in the Spring when day length is increasing - they can be grown indoors under artificial lighting that mimics the light conditions of Spring, just in time for Christmas

Chemical Basis of the Photoperiodic Response

Two light wavelengths important in the response

- Red 660 nm
- Far-red 703 nm

Chemistry: two forms of phytochrome: P_r and P_{fr}

- P_{fr} is biologically active, P_r is biologically inactive
- P_r absorbs red light, converted quickly to P_{fr}, during day
- P_{fr} absorbs far-red light and is converted slowly to P_r, at nigh

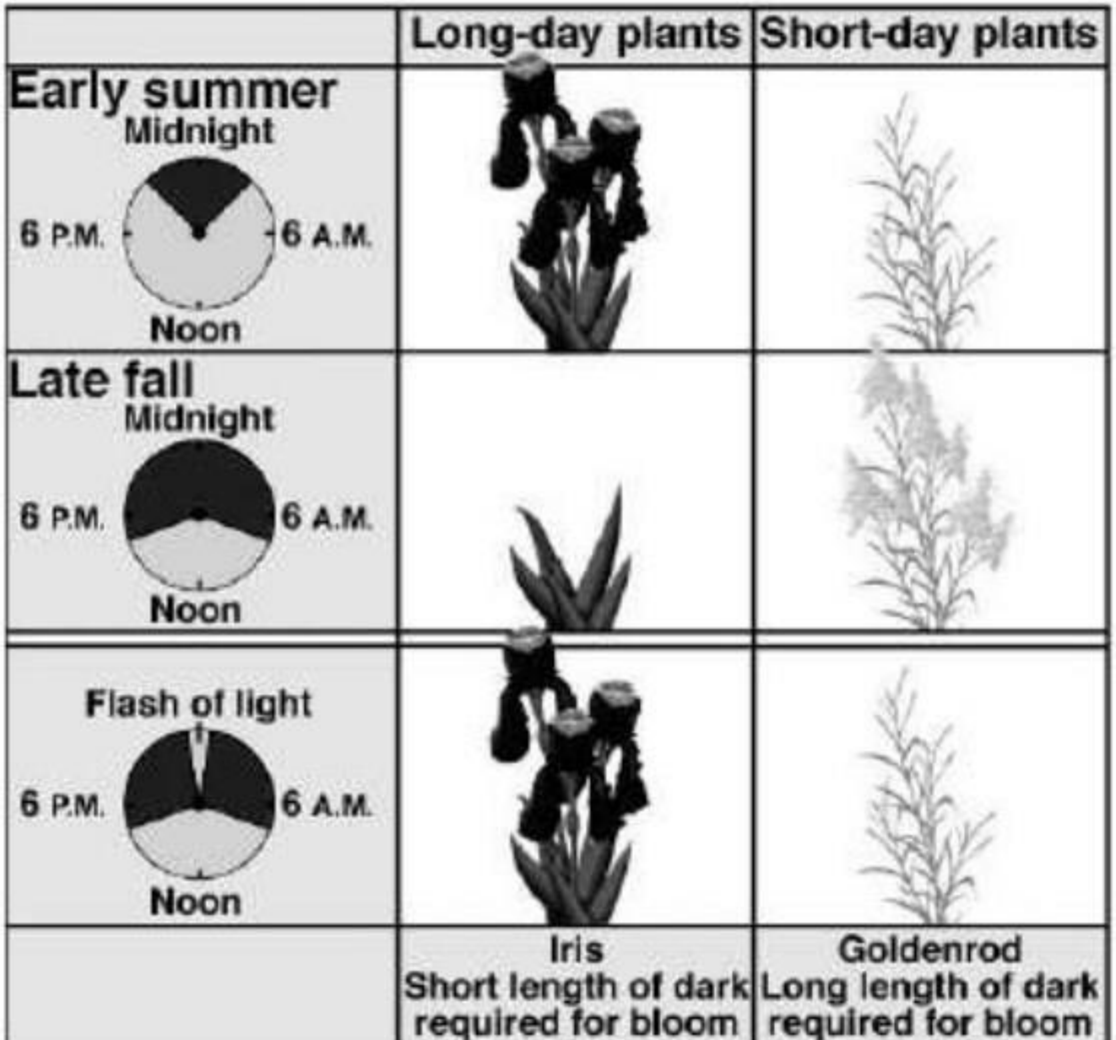
Low concentrations of P_{fr} indicate a long night (short day)

- induces flowering in short-day plants,
- suppresses flowering in long-day plants

High concentrations of P_{fr} indicate a short night (long day)

- induces flowering in long-day plants,
- suppresses flowering in short-day plants

In a short day plant, a single flash of red light converts P_r to P_{fr} and flowering is suppressed



day

$[P_{fr}] \rightleftharpoons [P_r]$

night

$[P_{fr}]$	$[P_r]$
High	Low
Low	High
High	Low

There must be a lengthy and continuous period of darkness for P_{fr} concentrations to become low