# Photosynthesis

## OUTLINE OF PHOTOSYNTHESIS

- Definition => The fixation of $CO_2$ and its subsequent reduction to carbohydrate using H from $H_2O$.
- $nCO_2 + nH_2O \xrightarrow[\text{in the presence of chlorophyll}]{\text{light energy}} (CH_2O)_n + nO_2$
- Hexose sugars usually formed ∴ n = 6
- Light energy needed for
  - → photolysis of $H_2O$ ($H_2O \rightarrow H_2 + O_2$) ← waste product
  - → provide chemical energy in the form of ATP
- Photosynthetic pigments → primary pigments / → accessory pigments
- Pigments arranged in photosystems → in funnel like structures.
  - → photosystem I
  - → " II
- Light energy absorbed by different pigments then passed to primary pigment → reaction centre.

## PHOTOLYSIS OF WATER

- Photosystem II includes water-splitting enzyme
- $H_2O \rightarrow 2H^+ + 2e^- + \frac{1}{2}O_2$
- $O_2$ = waste product
- $H^+$ + $e^-$ of photosystem I + NADP = rNADP
- $2H^+ + 2e^- + NADP \rightarrow$ reduced NADP
- rNADP to light independent & used in synthesis of carbohydrate.

## HILL REACTION

- Chloroplasts have 'reducing power', demonstrated using redox agent that changed colour on reduction.
- $O_2$ liberated in presence of an oxidising agent
- used to investigate effect of light intensity / wavelength
- eg. DCPIP can substitute NADP

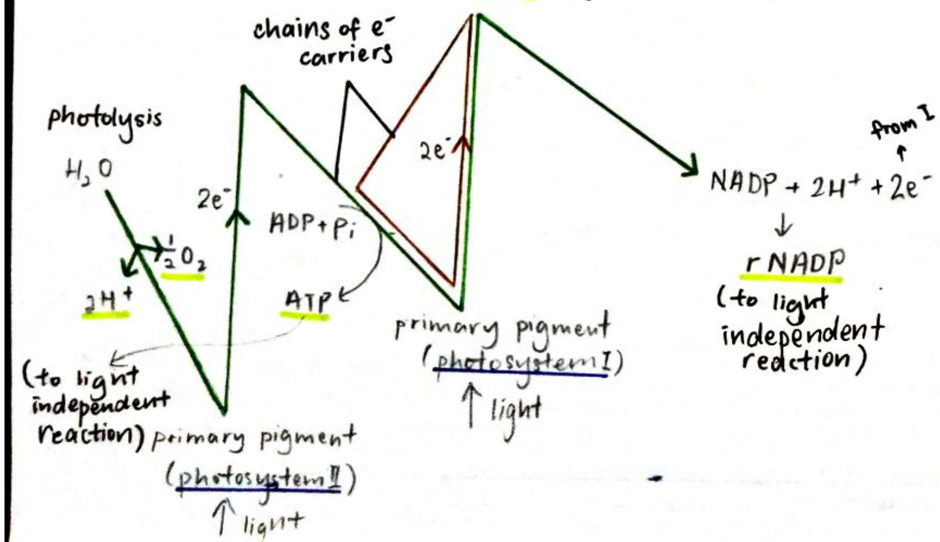
Oxidised DCPIP (blue) $\xrightarrow{\text{chloroplasts in light}}$ reduced DCPIP (colourless)

$H_2O$ → $\frac{1}{2}O_2$

takes place in thylakoid membranes

- consists of :
  - photolysis
  - photophosphorylation (ATP synthesis)

## LIGHT DEPENDENT REACTION




### CYCLIC PHOSPHORYLATION

- → involves photosystem I only
- → light absorbed by photosystem I and passed to primary pigment
- → $e^-$ in chlorophyll molecule of it is excited and emitted → photo activation
- → $e^-$ captured by electron acceptor and passed back to chloropyll of 1° pigment via chain of electron carriers.
- → energy released to synthesise ATP from ADP & phosphate group by chemiosmosis.
- * all $e^-$ to 1° pigment of photosystem I (chlorophyll)

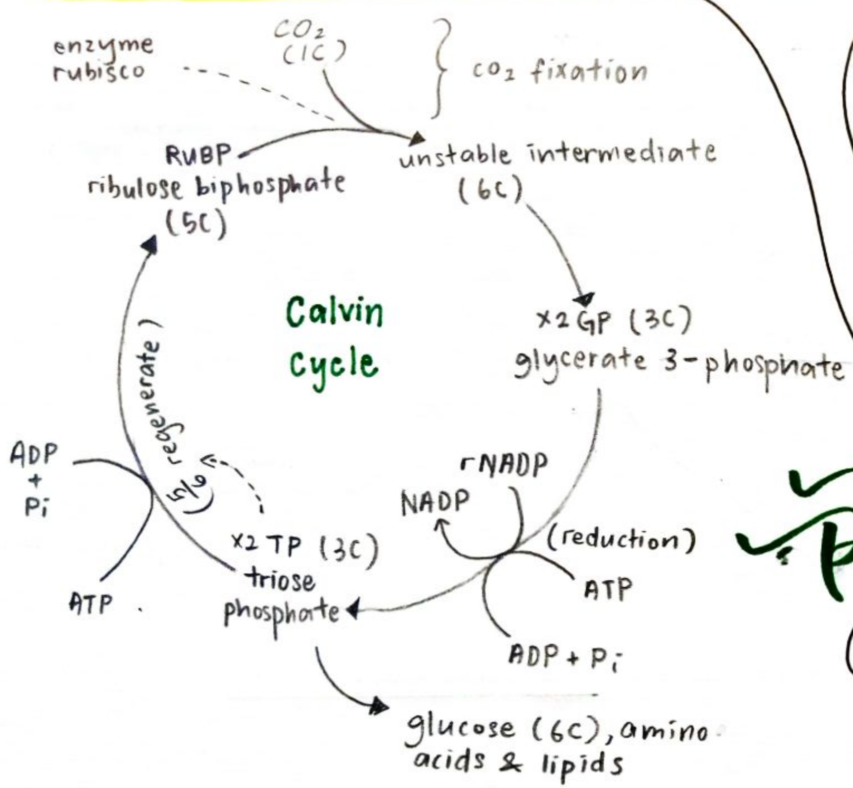
ADP +Pi, $H^+$, $O_2$ $H_2O$, ATP

### NON-CYCLIC PHOSPHORYLATION

- → involves both photosystems.
- → light absorbed by both, $e^-$ emitted from 1° pigment of both
- → $e^-$ absorbed by electron acceptors and passed along chains of e carriers. (ATP synthesised)
  - → phostosystems +vely charged
  - → 1° pigment of photosystem I absorbs $e^-$ from II
  - → II receives replacement $e^-$ from photolysis of $H_2O$

# photosynthesis

## LIGHT INDEPENDENT REACTION




- takes place in stroma
- $CO_2$ binds to ribulose biphosphate, RuBP (5C) to form unstable intermediate, catalysed by enzyme rubisco (ribulose biphosphate carboxylase)
- intermediate broken down to 2 GP (3C)
- GP reduced & activated → 2x TP (3C)
- Energy provided by ATP & NADPH (ADP & NADP return to thylakoid membrane for recycling.)
- Most TP used to regenerate RuBP using ATP
- Some TP combine to form:
  - glucose
  - starch
  - cellulose
  - sucrose
- Some TP converted to:
  - glycerol
  - fatty acids
  - acetyl coenzyme A

## CHLOROPLASTS


**GRANUM (GRANA plu.)**
- stacks of thylakoids
- membranes provide large surface area which holds:
  - pigments,
  - enzymes,
  - $e^-$ carriers
- Enclose $H^+$ reservoir for chemiosmosis

**STROMA**
- bathes membranes of grana to receive product of LDR.
- site of LIR
- contains rubisco, sugars, organic acids, circular DNA, lipid droplets, starch grains

**70S RIBOSOMES (+ circular DNA)**
- make chloroplast proteins

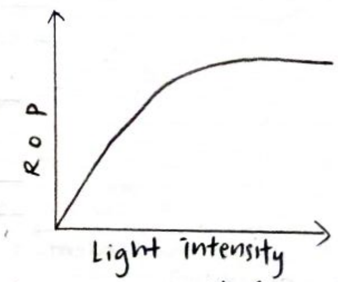
**THYLAKOID**
- flattened, fluid-filled sacs
- site of light dependent reactions
- has chlorophyll, accessory pigments, $e^-$ transport chain

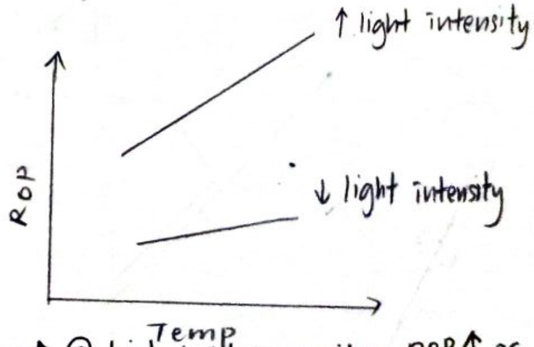
## FACTORS NECESSARY FOR PHOTOSYNTHESIS

- Light intensity
- water supply
- $CO_2$
- Photosynthetic pigments

## FACTORS AFFECTING RATE OF PHOTOSYNTHESIS

- light intensity & wavelength
- temperature
- $CO_2$ conc.




- As light intensity ↑, ROP ↑
- @ high light intensity, ROP plateau ∴ limited by $CO_2$ / temp
- @ high light intensity, ROP ↑ as temp ↑ over limited range
- @ low temp → little effect

∴ ⇒ ~~Photochemical reactions not affected by temp~~ ∴ must be 2 sets of reactions in photosynthesis, LDR & LIR

# Photosynthesis

## LIMITING FACTORS

- The rate of any process which depends on a series of reactions is limited by the slowest reaction.
- Effects of limiting factors are investigated using aquatic plant.
  - → light intensity - alter, d, of small light source from plant.
    - light intensity ∝ $\frac{1}{d^2}$
  - → λ of light - use diff colour filters w/ same light intensity.
  - → $CO_2$ conc. - add diff quantities of sodium hydrogen carbonate
  - → temp - place in beaker/$H_2O$ bath
- Rate of production of $O_2$ = rate of photosynthesis.

## GROWING PLANTS IN PROTECTED ENVIRONMENTS

- manage environmental factors for crops ∴ yield ↑
- in glasshouse, sensors monitor light intensity, humidity, $CO_2$ conc, etc
- easy to control pests, ∴ yield ↑

## C4 PLANTS

- First compound produced in LIR = 4C
- most tropical grasses.
- have higher optimum temp
- Rubisco catalyses reaction of $CO_2$ + RuBP AND $O_2$ + RuBP
- ∴ Photosynthesis ↓ ∵ RuBP wasted → photorespiration
- occurs most readily @ high temp & high light intensity.

## TRAPPING LIGHT ENERGY

- Photosynthetic pigments
  - → chlorophylls (primary)
    - a (yellow - green)
    - b (blue - green)
  - → carotenoids (accessory)
    - β carotene (orange)
    - xantophyll (yellow)

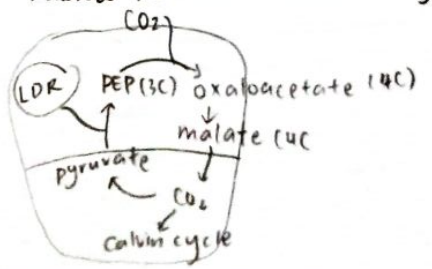
colour :

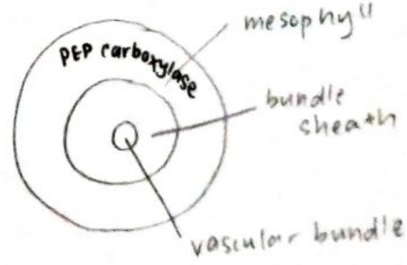
- absorption spectrum
  - ↳ graph of absorbance of diff λ of light by pigment.
- action spectrum
  - ↳ ROP at diff λ
- → λ ↓ energy ↑
- ↓ absorption = λ not absorbed but reflected
  ∴ plants = green ∵ least absorbed

## CHROMATOGRAPHY

## AVOIDING PHOTORESPIRATION

- cells w/ RuBP + rubisco arranged around vascular bundles
  - ↳ bundle sheath cells (no direct contact w/ air inside leaf)
- $CO_2$ absorbed by mesophyll cells (in contact w/ air)
- mesophyll cells contain PEP carboxylase → catalyses combination of $CO_2$ + PEP (3C) (phosphoenolpyruvate)
  - oxaloacetate $\xrightarrow{\text{convert}}$ malate } in mesophyll cell
- malate passed to bundle sheath cells.
- $CO_2$ removed from malate molecules & delivered to RuBP by rubisco in the normal way



1. Grind leaf with propanone (solvent)
2. leaf extract contains mixture of pigments.
3. Draw pencil line on filter paper & place extract on it.
4. Placed & dried several times to concentrate extract.
5. Place paper vertically in jar of diff solvent.
6. Each pigment travels @ diff speed ∴ separated can calc $R_f$ value

$$R_f = \frac{\text{dist. pigment}}{\text{dist. solvent}}$$

→ caretenoids ≈ 1
chlorophyl b - low
chlorophyl a - between carotenoids & chlorophyll b