Photosynthesis

Advantages of having light harvesting complexes embedded in membrane

- The photo systems and cytochromes held close to each other In thylakoid membrane, facilitating sequential flow of electrons from photosystem II to cytochrome to photosystem I during light independent reaction
- The ATP synthases are held in the thylakoid membrane such that ATP synthesis would occur on the Stroma side of the thylakoid where ATP is needed for light independent reactions of photosynthesis

---

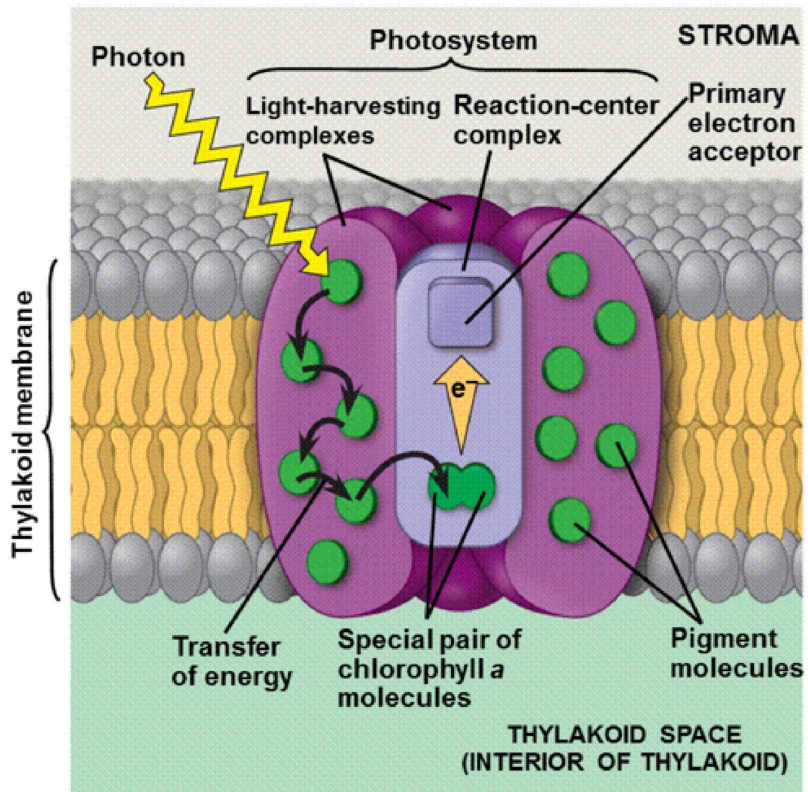
Describe photosynthesis

- Photosynthesis is the process wheee a plant makes sugar from sunlight, water and carbon dioxide, made up of 2 stages which is light dependent and light independent reaction
- Light energy from sun is converted into chemical energy in plant
- Light dependent reaction takes place in the thylakoid membrane of the chloroplast
- During non-cyclic phosphorylation, a photon of light stricken the accessory pigment molecule in a light harvesting complexes in PSII, exciting an electron
- As the excited electron drop to ground state The energy released is then passed on to neighbouring pigment molecules down an energy gradient until it reaches to P680 chlorophyll a molecules in the reaction centre of PSII
- One electron of the P680 molecules is excited to a higher energy level and captured by primary electron acceptor in PSII causing an electron hole in the reaction centre and the electron displaced from the reaction centre is replaced by photolysis of water which takes place in the thylakoid space forming oxygen as a by product

- Each photo excited electron is passed down a series of increasingly electronegative electrons carriers from primary electrons in PSII to PSI via an electron transport chain and the high energy electron loses energy as it travels down the electron transport chain
- The energy released is used to actively pump H+ from the storms into the thylakoid space against the concentration gradient, creating a proton gradient so that the H+ ions can diffuse down the proton gradient from the thylakoid space and into the stroma via ATP synthase and then phosphorylating ADP to ATP
- Accessory pigments in the light harvesting complex of PSI also receives photons and excites an electron of one of the two P700 chlorophyll a molecules and the electron is captured by the primary electron acceptor in PSII
- The electron loser is replaced by by electrons from the electron transport chain form PSII
- The displaced electron in OAI is passed down a second electron transport chain and accept by NADP reductase to reduce NADP to NADPH
- In cyclic phosphorylation, electrons do not pass through PSII but instead electrons displaced from PSI are transferred to the primary electron acceptor in PSI and then to the electron transport chain between PSII and PS I and back to PS I, NADPH not produced but ATP synthesis will still occur via chemiosmosis in the same manner as non-cyclic photophosphorylation
- The light Independent reaction occurs in the stroma of chloroplast and using NADPH and ATP generated from light independent reaction
- During carbon fixation, CO2 combines with RUBp to form an unstable 6 carbon intermediate in the presence of RUBisco which then breaks down into 2 molecules of Glycerate-3-phosphate (GP)
- NADPH from light dependent reaction is used to reduced GP to glyceraldehyde-3-phosphate (G3P) with ATP as the source of energy. Triose phosphate/G3P is the first sugar formed in photosynthesis and the end product of Calvin cycle

- 5 molecules of G3P is the used to generate 3 RuBP so that cycle of carbon fixation can continue. 3 ATP molecules is needed. G3P can also be converted to sugars and polymerised to form starch which are stored in leaves.

Use this image to help you visualise the photosystem



Role of NADP

- It is the final electron acceptor in non-cyclic photophosphorylation process during the light dependent phase of photosynthesis, accepting protons from photolysis of water which produces O2 required for aerobic respiration
- NADP is reduced to NADP(by NADP reductase and carries the protons into the stroma for light independent phase
- Reduced NADPH donates the protons into to Calvin cycle for reducing 3-phosphoglycerate to glyceraldehyde-3-phosphate with the use of ATP in Calvin cycle (linking the light dependent reactions to the Calvin cycle)

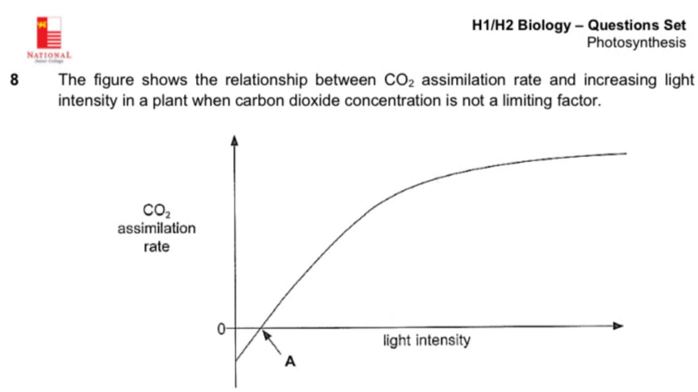
- NADP is then regenerated for the continuation of the non-cyclic photo phosphorylation process which produces ATP required for the light independent phase

Role of NADPH

- sysntheised in light dependent reaction which is needed for Calvin cycle to occur
- It reduces glycerate phosphate to glyceraldehyde-3-phosphate (opposite of respiration) By providing reducing power for the reaction as high energy electrons are stored in it

---

Graph for CO2 assimilation rates



- Light saturation point: CO2 assimilation rates levels off at high light intensity as the photosystems on the thylakoid membrane were saturated with light therefore photosynthesis was at a maximum rate and light is no longer a limiting factor as such, other factors such as temperature weee liming, assimilation rate did not increase further. Hence, this point as a highest increase in growth as there is highest rate of the production of glucose
- At lowest light intensity, CO2 assimilation rate was negative as there would be a low rate or no photosynthesis but respiration would still occur. CO2 given off during respiration was greater than CO2 incorporated during Calvin cycle and hence the rate fell below compensation point

- At compensation point, rate of respiration equals to rate of photosynthesis and there was no net gain in dry mass and no growth as any products of photosynthesis are used up in respiration. This means that rate of glucose used as a respiratory substrate equals to rate of production of photosynthesis

---

Explain how environmental factors can limit the rate of Calvin cycle

- Low Temperature
  - The lower the temperature, the lower is kinetic energy of CO_2, RuBP and rubisco. Thus there is a decrease in frequency of effective collisions of enzyme and substrate molecules per unit time, lowering rate of carbon fixation per unit time, limiting the Calvin cycle
- Low CO_2 concentration
  - CO_2 is one of the substrates in the carbon fixation phase of Calvin cycle. Lower CO_2 concentration, fewer effective collisions with RUBP, CO_2 and rubisco per unit time, decrease in enzyme-substrate complex formed per unit time, lower rate of carbon fixation, limiting rate of Calvin cycle

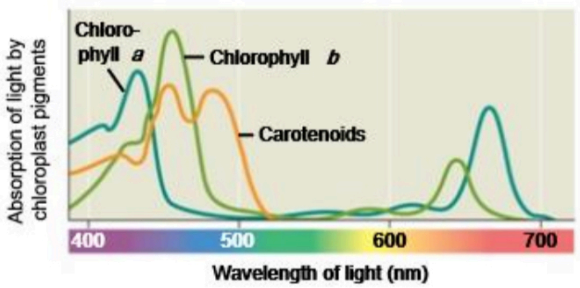
---

Why is light needed for Calvin cycle to continue

- The products from light dependent reaction, ATP and NADPH are required in the reduction of GP to G3P/TP
- ATP is also needed in the regeneration of RUBP

Role of chlorophyll and carotenoids

- Acts as accessory pigments that absorb light/photons in light harvesting complexes
- Pass energy on to specialised chlorophyll a in the reaction Center of LHC
- Absorb different wavelengths of light not absorbed by chlorophyll a



Role of different structures during light independent reaction

- Photosystem II
    - harvest light energy from photons and emit electrons which is passed to the electron transport chain
    - photolysis of water also occurs so that electron emitted can fill the electron hole in PSII
- Electron carrier and protein pump
    - Uses energy loss from electron flow to pump protons from stroma into the thylakoid space
    - Protons generate proton gradient for chemiosmosis to occur
- Photosystem I
    - Harvest light energy from photons and emit electrons
    - Electrons passed to NADP reductase and it catalyses formation of NADPH from NADP
- ATP synthase
    - Allows protons to pass through it from thylakoid space into the stroma down a concentration gradient via chemiosmosis
    - Electron motive force generated by flow of protons used to catalyse formation of ATP from ADP and pi

Why is oxygen not produced during cyclic phosphorylation

- energy from light will be absorbed by PSI and be channeled to P700 of PSI which will be excited and displace electron that will be accepted by primary electron acceptor subsequently transport to the middle of first ETC
- electron is then transported down the ETC and is finally recycling back to PSI filling electron hole
- Hence no photolysis of water is needed to emit electron hole and hence no oxygen is produced

---

How light energy is converted to chemical energy during light dependent reactions of photosynthesis

- When a photon of light strikes a chlorophyll molecule, one if it's electrons excited to a higher energy state and this energy is relayed from pigment to pigment via resonance transfer of energy until it reaches chlorophyll a , P680 or 700 in the two photosystem II/I reaction centre
- Excited electron in the chlorophyll a is then captured by primary electron acceptor
- Excited electrons flow down a chain of ETC with progressively lower energy levels
- Energy released is coupled to pumping H+ ions from stroma and into the thylakoid space through the thylakoid membrane establishing a proton gradient
- H+ then diffuse down the concentration gradient back into the stroma via ATP synthase
- ADP is phosphorylated to form ATP via chemiosmosis
- Electrons from PSI passed down ETC transferred To final electron acceptor NADP which combines together with H+ to form reduced NADP in stroma

---

Outline the 3 phases of Calvin cycle

- Carbon fixation
  - Carbon dioxide combines with RuBP catalysed by Rubisco

- Carbon reduction
    - NADPH provide reducing power for reduction of glycerate 3 phosphate to glyceraldehyde 3 phosphate amd ATP is source of energy required for reaction
- Regeneration of RuBP
    - Some G3P used to regenerate RuBP so that cycle of carbon fixation can continue while some leaves cycle to make sugars like glucose for aerobic respiration or starch molecules for storage

---

Why is rate of photosynthesis for plant low at green wavelength of light

- frequency of light absorption by pigment is low
- Less photo activation of electrons at reaction centres less NADPH and ATP generated during LDR
- Less G3P produced during LIR leads to lower rate of photosynthesis