Photosynthesis

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a. With reference to the chloroplast structure, explain the light dependent reactions of photosynthesis (no biochemical details are needed but will include the outline of cyclic and non-cyclic light dependent reactions, and the transfer of energy for the subsequent manufacturing of carbohydrates from carbon dioxide)

1. Light energy, in the form of protons, hit and activates the photosynthetic pigments in the photosystems of the thylakoid membrane, it results in the photoactivation of the pigments, releasing a pair of excited electrons.
    a. Chlorophyll a and b
        i. Absorb mainly red and blue-violet light
        ii. Chlorophyll a is most abundant → Primary pigment → Directly converts solar energy to chemical energy (excited electrons)
        iii. Chlorophyll b functions as an accessory pigment → Absorbs light energy as passes it to chlorophyll a
    b. Carotenoid
        i. Absorb blue-violet
        ii. Functions mainly as an accessory pigment → Absorbs wavelengths of light that chlorophylls cannot
2. The excited electrons are passed to the reaction centre of the *photosystem*, which passes them to the *electron transport chain*. The lost electron pair is replaced via the photolysis of water, which also produces hydrogen ions and oxygen.
    a. Photosystem I: Reaction centre contains a pair of P700 chlorophyll a molecules → Absorb λ700nm light
    b. Photosystem II: Reaction centre contains pair of P680 chlorophyll a molecules → Absorb λ680nm light
3. The electrons are then passed from one electron carrier to the next of a lower energy level via chemiosmosis, till the final electron acceptor, NADP, which is reduced to NADPH/H+. The energy produced is used to pump hydrogen ions across the thylakoid membrane from the stroma to the thylakoid space, producing a proton motive force.
    a. Cyclic Photophosphorylation
        i. Photosystem II → Primary electron acceptor on ETC → Photosystem I → ETC → NADP
    b. Non-cyclic Photophosphorylation
        i. Photosystem I → ETC → Photosystem I
4. ATP synthase utilises this proton motive force to phosphorylate ADP to ATP via chemiosmosis of hydrogen ions from the thylakoid space to the stroma

Structure	Description	Functions
Chloroplast Envelope	• Double membrane surrounding the organelle	• Compartmentalisation -- Separates chloroplast from cytoplasm • Increases surface area of lamellae system

Lamellae System	• Membrane system within the chloroplast
	• Comprises of:
	  • *Thylakoids*
	    ○ Flattened sacs containing the fluid-filled *thylakoid space*
	    ○ Stacked into *grana*
	  • *Intergranal Lamellae*
	    ○ Sheet-like membrane enclosing a narrow space
		• Site of *light reactions*
		• Large surface area for attachment of photosynthetic pigments, electron carriers and ATP synthase → Maximum absorption of light
		• Allows electron carriers to be located in close proximity and be arranged in order
		• Compartmentalisation of thylakoid space → Formation of *proton gradient*

Stroma	• Gel-like matrix
	• Contains:
	  • Enzymes
	  • Nutrients such as organic acids and sugars
	  • Starch grains
	  • Lipid droplets
	  • Circular DNA and ribosomes
		• Site of *Calvin cycle*
		  • Catalysed by enzymes in stroma
		• Surrounds the lamella system → Allows for products of light reaction (ATP) to quickly enter Calvin cycle
		• Large area for temporary storage of sugars and starches
		• DNA codes for chloroplast proteins, synthesised by ribosomes

b. Outline the three phases of the Calvin cycle:
   i. CO2 uptake
   ii. carbon reduction
   iii. ribulose bisphosphate (RuBP) regeneration and indicate the roles of ATP and NADP in the process.

1. CO_2 Uptake:
   Carbon dioxide combines with ribulose bisphosphate (RuBP) in a carboxylation reaction catalysed by RuBP carboxylase, producing an unstable 6-carbon molecule, which then breaks down to form 2 molecules of glycerate-3-phosphate.
2. Carbon Reduction:
   Glycerate-3-phosphate is converted to triose phosphate via a reduction reaction, catalysed by the addition of ATP and NADPH/H+. The triose phosphate molecules are then linked together to form glucose phosphate, which is used to form starch