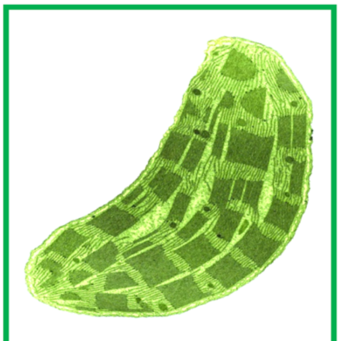
PHOTOSYNTHESIS

Content Statements:

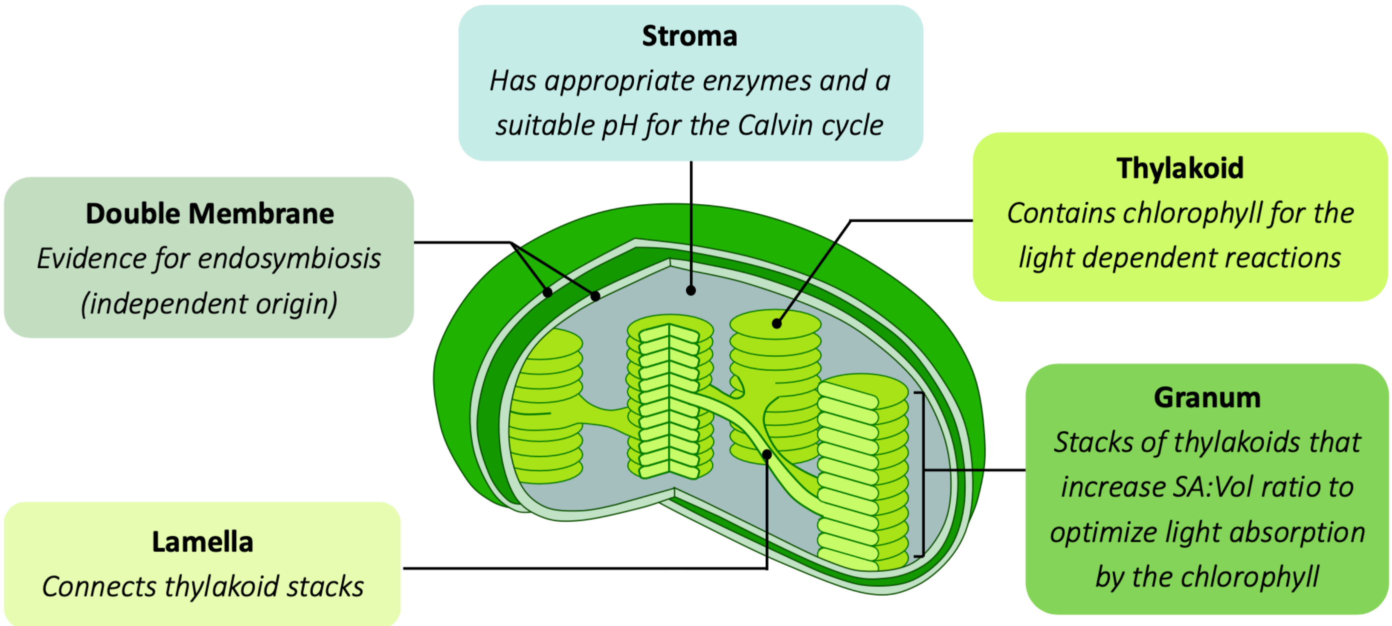
C1.3.9	Photosystems as arrays of pigment molecules that can generate and emit excited electrons
C1.3.10	Advantages of the structured array of different types of pigment molecules in a photosystem
C1.3.11	Generation of oxygen by the photolysis of water in photosystem II
C1.3.12	ATP production by chemiosmosis in thylakoids
C1.3.13	Reduction of NADP by photosystem I
C1.3.14	Thylakoids as systems for performing the light-dependent reactions of photosynthesis
C1.3.15	Carbon fixation by Rubisco
C1.3.16	Synthesis of triose phosphate using reduced NADP and ATP
C1.3.17	Regeneration of RuBP in the Calvin cycle using ATP
C1.3.18	Synthesis of carbon compounds using the products of the Calvin cycle and mineral nutrients
C1.3.19	Interdependence of the light-dependent and light-independent reactions
B2.2.5	Adaptations of the chloroplast for photosynthesis

CHLOROPLAST

The chloroplast is an organelle in the **leaf tissue** of plants that is responsible for photosynthesis. It is believed to have evolved via endosymbiosis, when a photosynthetic prokaryote (a cyanobacterium) was engulfed by another cell. This is evidenced by the presence of circular DNA (naked) and 70S ribosomes. In terms of structure, chloroplasts contain membrane discs called **thylakoids** that are arranged into stacks called **grana**. These thylakoids have chlorophyll and are the site of the light dependent reactions. The fluid of the chloroplast is called the **stroma** and is the location of the light independent reactions.

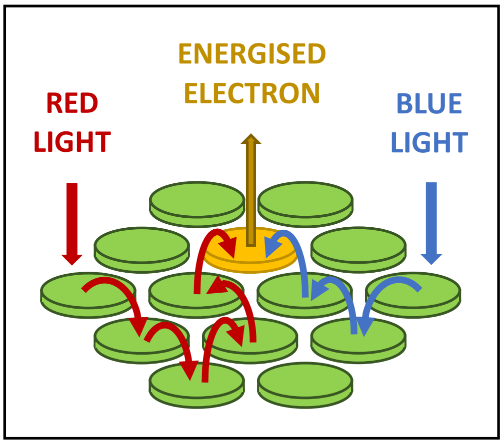


Chloroplast Structure



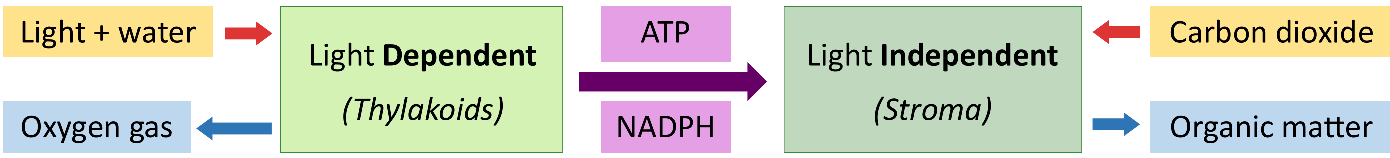
PHOTOSYSTEMS

Photosynthetic organisms do not rely on one pigment to absorb light, but instead benefit from the combined action of many. The pigments are grouped into molecular arrays called photosystems that are located within a **thylakoid membrane**. When a pigment is energised by light, it releases high energy electrons. Accessory pigments transfer their energised electrons to a central **reaction centre** containing a special chlorophyll. The release of energised electrons from the reaction centre allows chloroplast to produce ATP and reduce hydrogen carriers (NADP → NADPH). By grouping pigments into photosystems, the cell maximises light absorption.



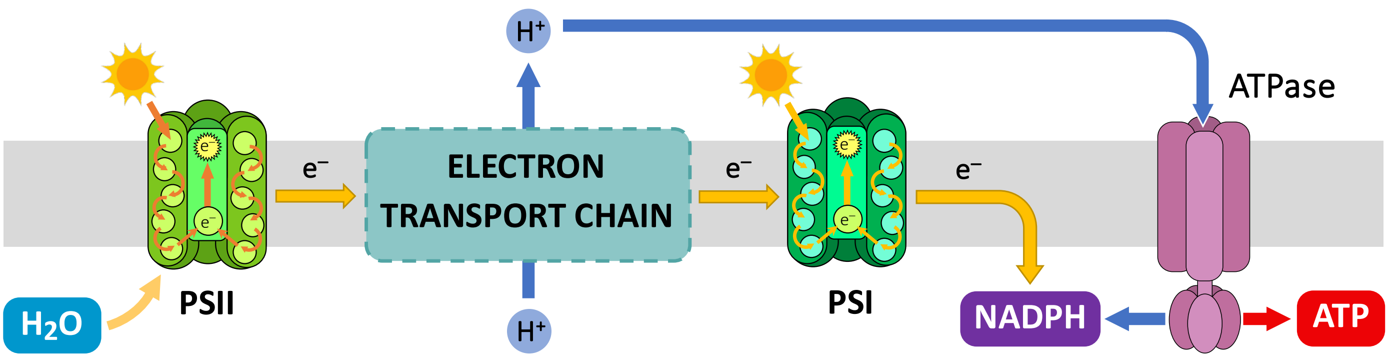
PHOTOSYNTHESIS

Photosynthesis is a two-step process whereby cells harness light energy to synthesise organic molecules. The light dependent reactions convert light energy into chemical energy (ATP) and splits water to release hydrogen atoms. The light independent reactions use the chemical energy to fuse the hydrogen atoms to a carbon source (CO_2), producing organic compounds. The two photosynthetic reactions are **interdependent** (the light dependent stage *loads* the coenzymes while the light independent stage *unloads* the coenzymes).



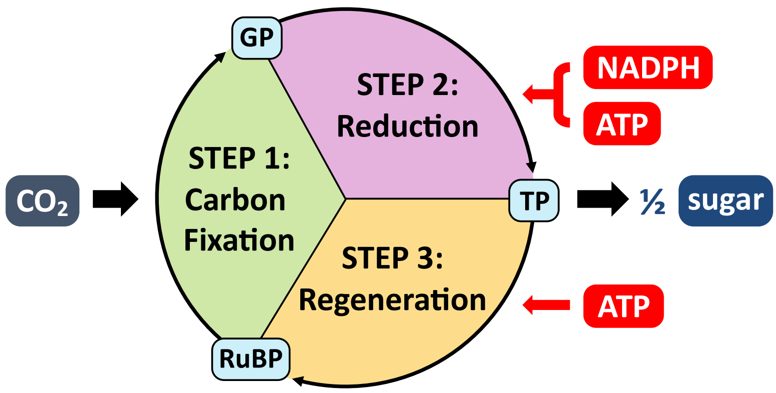
LIGHT DEPENDENT REACTIONS

The light dependent reactions consist of two photosystems within the thylakoid membrane. **Photosystem II** releases electrons into an electron transport chain. As energised electrons pass through the chain they lose energy, which is used to translocate protons from the stroma into the thylakoid lumen. The accumulation of protons in the lumen creates an electrochemical gradient. The protons return to the stroma via an enzyme within the membrane called ATP synthase (this proton movement is called chemiosmosis). ATP synthase uses the passage of protons to catalyse ATP synthesis (photophosphorylation). The de-energised electrons are taken up by a second photosystem. **Photosystem I** accepts the electrons from the transport chain as a replacement for the energised electrons it transferred to a hydrogen carrier (NADP → NADPH). The initial electrons from Photosystem II are replaced by the photolysis of water. Photosystem II contains an enzyme that is able to split water molecules into hydrogen (i.e. protons and electrons) and oxygen (a by-product). The products of the light dependent stage (ATP and NADPH) are transferred to the light independent stage.



LIGHT INDEPENDENT REACTIONS

The light independent reactions use the chemical energy derived from light dependent reactions to form organic molecules. This is accomplished by a series of chemical reactions collectively called the **Calvin cycle**. In the Calvin cycle, an enzyme called **Rubisco** catalyses the attachment of carbon dioxide to a 5C compound called RuBP. The resulting 6C compound is unstable and is broken down into two 3C compounds called **GP** (glycerate-3-phosphate). The GP is next converted into a triose phosphate (**TP**), using protons and electrons from NADPH and energy from ATP. Some of the TP produced is then used to form organic compounds, the remainder is used to regenerate stocks of RuBP (completing the cycle). The regeneration of RuBP requires ATP hydrolysis. A single cycle produces one molecule of TP – two cycles are required to synthesise **glucose**.



Calvin Cycle Summary:

1. Carbon Fixation
   $3 \times RuBP + 6 \times CO_2 \rightarrow 6 \times GP$
2. Oxidation of NADPH
   $6 \times GP \rightarrow 6 \times TP$
3. Regeneration of RuBP
   $5 \times TP \rightarrow 3 \times RuBP$

ORGANIC COMPOUNDS

The triose phosphate produced by the Calvin cycle is used to synthesise a variety of **organic compounds**. The four main types of organic compounds are carbohydrates, lipids, nucleic acids and proteins. Synthesis of these molecules involves a variety of metabolic reactions that take place within the cytoplasm. Some of these organic molecules may require the additional incorporation of **mineral ions**. Proteins and nucleotides both require nitrogen, while nucleic acids and phospholipids require phosphorus. Certain amino acids also need sulphur. Organic matter made by photosynthetic organisms is ingested and assimilated by consumers.

OVERVIEW OF PHOTOSYNTHESIS