Fix, reduce and regenerate

The Calvin cycle takes place in the chloroplast stroma. It incorporates inorganic carbon from carbon dioxide into organic compounds using ATP and reduced NADP.

1. FIX CARBON DIOXIDE

$$RuBP\ (5C) + CO_2\ (1C) \rightarrow 2\ GP\ (3C\ each)$$

Rubisco catalyses the combination of carbon dioxide with ribulose bisphosphate (RuBP). The unstable six-carbon intermediate immediately splits into two molecules of glycerate 3-phosphate (GP).

Carbon is conserved: 5 + 1 = 2 × 3. Rubisco is the enzyme; RuBP is its five-carbon substrate. GP is also called 3-phosphoglycerate or 3-PGA.

2. REDUCE GP TO TRIOSE PHOSPHATE

GP is converted to triose phosphate (TP) through reactions requiring ATP and reduced NADP. ATP supplies energy; reduced NADP supplies hydrogen and electrons for reduction and becomes oxidised NADP. TP is a three-carbon sugar phosphate.

3. REGENERATE THE CARBON ACCEPTOR

Most TP is rearranged into RuBP in reactions that use ATP. Regeneration replenishes the acceptor needed to fix more carbon dioxide. Some TP is available for synthesis of carbohydrates and other organic molecules; the whole TP supply cannot leave the cycle.

Light-independent does not mean independent of the light-dependent stage. Without a continuing supply of ATP and reduced NADP, the cycle cannot be sustained. It is not a process that runs only at night.

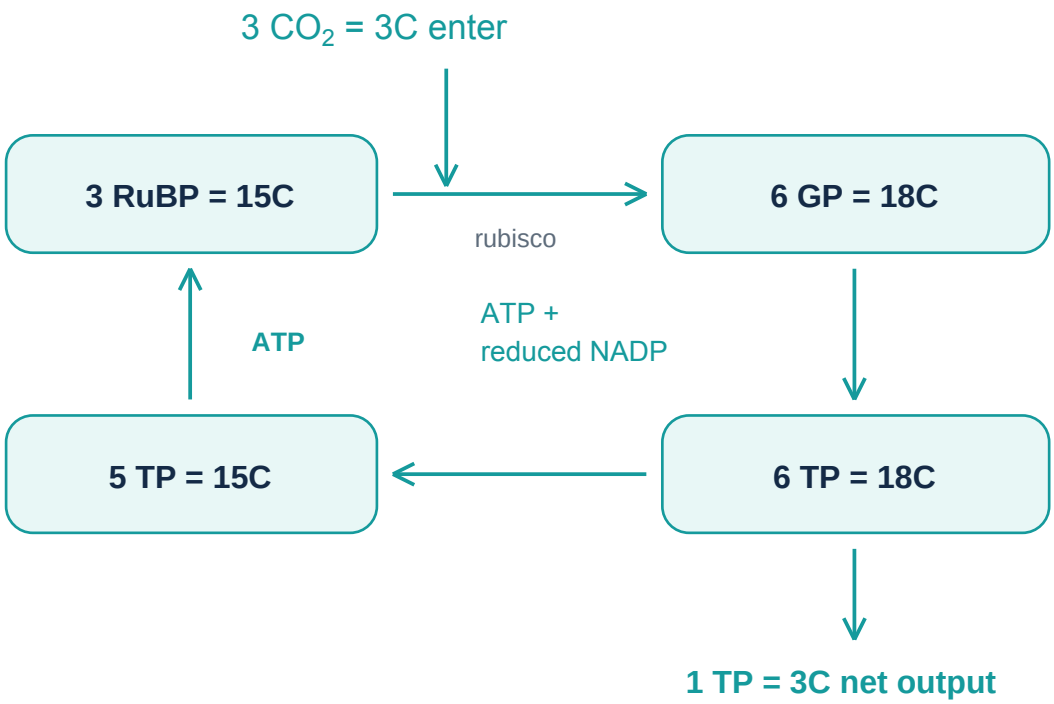
Three stages and carbon fixation: OpenStax, Biology 2e 8.3.
ATP, reducing power and regeneration: Cooper, The Cell, Photosynthesis.

Scope: Cambridge Biology 9700, section 13.1, outcomes 2-3 and 11-12, pp. 35-36.

Track the carbon, not just the arrows

Count a batch of three carbon dioxide molecules. This makes the net output and the need for RuBP regeneration easier to see.

1. THREE FIXATIONS GIVE ONE NET TP



Carbon totals: 15C recycled; 3C gained. Individual atom positions are not shown.

2. WHY SIX TP IS NOT THE NET YIELD

Six GP become six TP, but five TP must supply the carbon skeletons for three RuBP. Only one TP is gained overall per three carbon dioxide molecules fixed. Two net TP provide the carbon equivalent of one hexose; glucose is not the direct cycle product.

Accounting aid: for three CO_2, GP reduction uses 6 ATP and 6 reduced NADP; regeneration uses another 3 ATP. Total: 9 ATP and 6 reduced NADP per net TP. These totals extend the core stage outline.

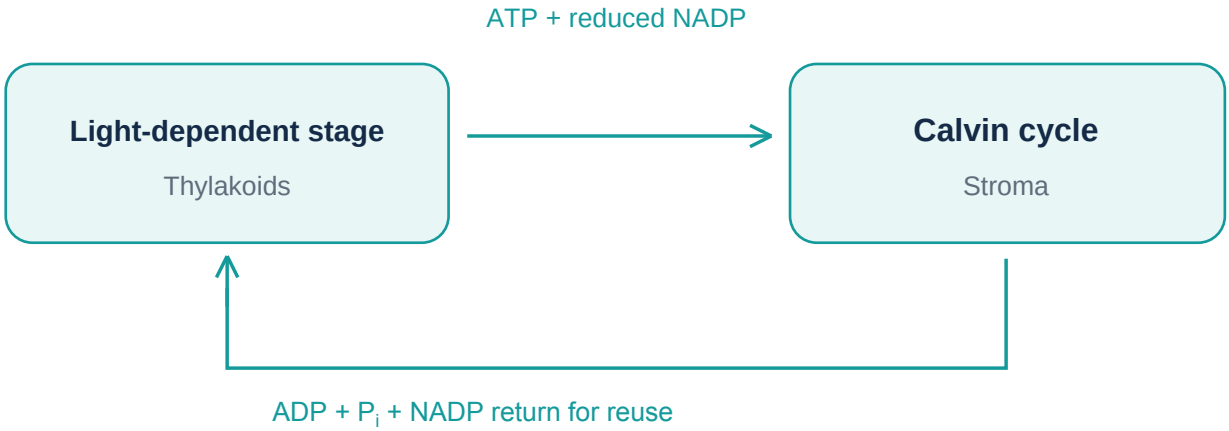
Carbon and ATP accounting: OpenStax, Biology 2e 8.3.
Cycle stoichiometry and sugar synthesis: Alberts et al., Chloroplasts.

Scope: Cambridge Biology 9700, section 13.1, outcomes 2-3 and 11-12, pp. 35-36.

Connect the cycle to the whole plant

The Calvin cycle is both a carbon-fixing pathway and a source of intermediates for biosynthesis. Its energy and reducing power come from the light-dependent stage.

1. TWO STAGES EXCHANGE CARRIERS



2. GP CAN SUPPLY AMINO ACID SKELETONS

GP is used to produce some amino acids. Nitrogen must also be supplied, for example from assimilated nitrate or ammonium; fixing carbon dioxide alone does not supply every element needed for proteins.

3. TP SUPPORTS SEVERAL SYNTHETIC PATHWAYS

TP can contribute to carbohydrates, lipids and amino acids through further reactions. Carbohydrate products include sucrose for transport, starch for storage and cellulose for cell walls. These products are not all formed directly within the Calvin cycle.

Keep the roles distinct: carbon dioxide supplies carbon; ATP supplies energy; reduced NADP supplies reducing power. RuBP is regenerated, while rubisco catalyses fixation and is not consumed.

Next: how light intensity, carbon dioxide concentration and temperature limit photosynthesis.

Sugar production and carrier recycling: Cooper, The Cell, Photosynthesis.
Carbon assimilation and organic products: Alberts et al., Chloroplasts.

Scope: Cambridge Biology 9700, section 13.1, outcomes 2-3 and 11-12, pp. 35-36.