

10.3

Light independent reaction or the Calvin Cycle

Once light energy has been converted to the chemical energy and stored in ATP or NADPH molecules, cells will need to move the stored energy into more stable forms of storage like carbohydrates. Interestingly, energy stored as ATP or NADPH will last only millionth of seconds, whereas energy in carbohydrate form will last millions of years! The transfer of chemical energy from temporary storage to long term storage occurs in the light independent reactions and is called the Calvin cycle. In brief, CO_2 will enter the Calvin cycle and leave as sugar (carbohydrate). The Calvin cycle becomes a story about carbons and recycling and can be thought of occurring in three stages.

Stage 1: Carbon Fixation

Stage 1 employs an enzyme called Ribulose-1,5-bisphosphate carboxylase-oxygenase (**RuBisCO**) which can take CO_2 and incorporate it into a five-carbon molecule called ribulose 1,5-bisphosphate (**RuBP**) to form a highly unstable six carbon molecule. The six-carbon intermediate is cleaved immediately to form two 3-carbon molecules of 3-phosphoglyceric acid (3-PGA).

Stage 2: Reduction

In stage 2, each 3-PGA molecule receives a phosphate group from ATP and is reduced using electrons from NADPH to form one molecule of glyceraldehyde 3-phosphate (**G3P**) and the other 3-PGA molecule will be used to regenerate RuBP (stage 3). G3P will eventually react to form monosaccharides and then polysaccharides. Since only one molecule of carbon can be incorporated at a time (stage 1), and because glucose contains six carbons, the cycle will need to be run six times to get enough G3P to make one glucose molecule.

Stage 3: Regeneration

In stage 3, we need to regenerate RuBP, the five-carbon molecule that starts the whole process. Again, because we can only incorporate one carbon at a time from CO_2 , it takes multiple turns of the Calvin cycle to get enough intermediates. The same is true for replacing RuBP. Let's try to track the carbons and see if we can follow the regeneration step. If we run through the Calvin cycle six times, we will have accumulated 36 carbons. More specifically, RuBP is a five-carbon molecule that becomes six when CO_2 is incorporated on it. Thus, with each turn, we use six carbons, but only one of the carbons is a "new" carbon that we can use for glucose. Running the Calvin cycle six times will generate six "new" carbons but 30 "old" carbons. Those 30 old carbons will be used to replace RuBP ($30 \text{ carbons} / 5 = 6$).

The generation of glucose from G3P is essentially glycolysis but in reverse. In glycolysis we split a 6-carbon molecule to make two three carbon molecules along with NADH and ATP. In photosynthesis we take two 3 carbon molecules along with NADPH and ATP and make a 6-carbon molecule. This back and forth of making and breaking glucose is the basis of life!



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