The Interworking's of the Calvin Cycle

In plants, carbon dioxide (CO_2) enters the plant through the stomata. The carbon dioxide then diffuses into the stroma of the chloroplast where the Calvin cycle reactions take place (Figure 7.20). The reactions are named after Nobel Prize-winning American scientist Melvin Calvin, who discovered them.

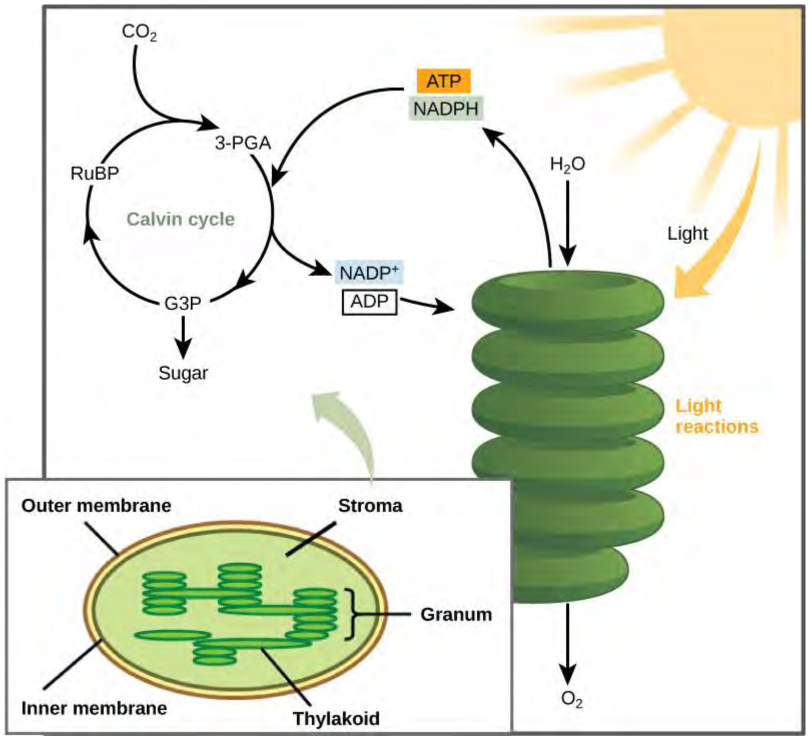

Figure 7.20 Light-dependent reactions harness energy from the sun to produce ATP and NADPH. These energy-carrying molecules travel into the stroma where the Calvin cycle reactions take place. (credit: Fowler et al. / Concepts of Biology OpenStax)

The Calvin cycle reactions (Figure 7.21) can be organized into three basic stages: carbon fixation, reduction, and regeneration. In addition to CO_2, two other molecules are needed to start the Calvin cycle: Rubisco (an enzyme), and the molecule ribulose bisphosphate (RuBP). RuBP is a five-carbon molecule with a phosphate group at the end of the molecule.

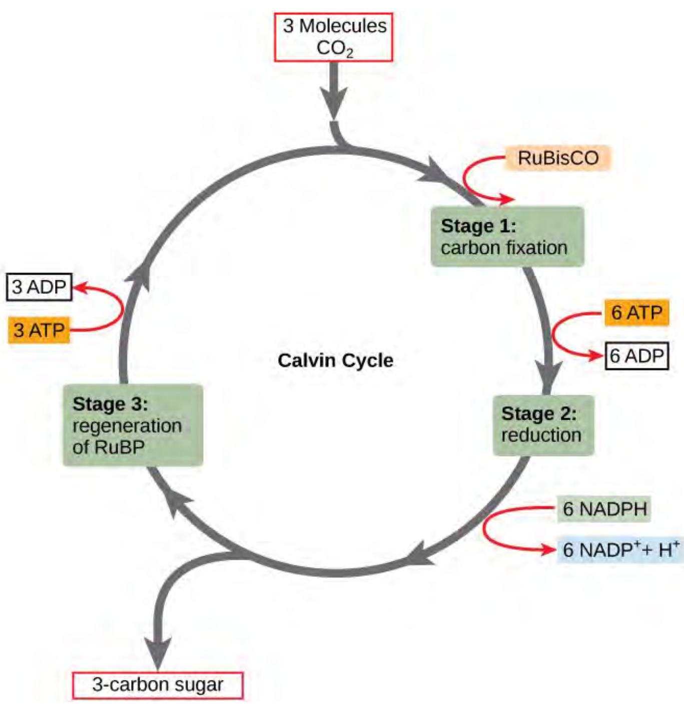

Figure 7.21 The Calvin cycle has three stages. (credit: Fowler et al. / Concepts of Biology OpenStax)

Rubisco catalyzes a reaction between 3 molecules of CO_2 and three molecules of RuBP. This reaction results in the formation of three six-carbon compounds. These three six-carbon molecules immediately split into six three-carbon compounds called 3-PGA (Figure 7.22). This process is called carbon fixation because CO_2 is "fixed" from its inorganic form into the organic form of 3-PGA.

ATP and NADPH use their stored energy to convert the six 3-PGA, into another three-carbon compound called G3P (Glyceraldehyde 3-phosphate) (Figure 7.22). This type of reaction is called a reduction reaction because it involves the gain of electrons. The molecules of ADP and $NADP^+$ resulting from the reduction reaction return to the light-dependent reactions to be re-energized.

One of the G3P molecules leaves the Calvin cycle and can be used to form carbohydrates. To form a glucose molecule, a six-carbon sugar, it takes two molecules of G3P. The Calvin cycle needs to make two turns before it can yield one glucose molecule. The remaining G3P molecules regenerate RuBP, which enables the system to prepare for another round of carbon-fixation (Figure 7.22). ATP is also used in the regeneration of RuBP.

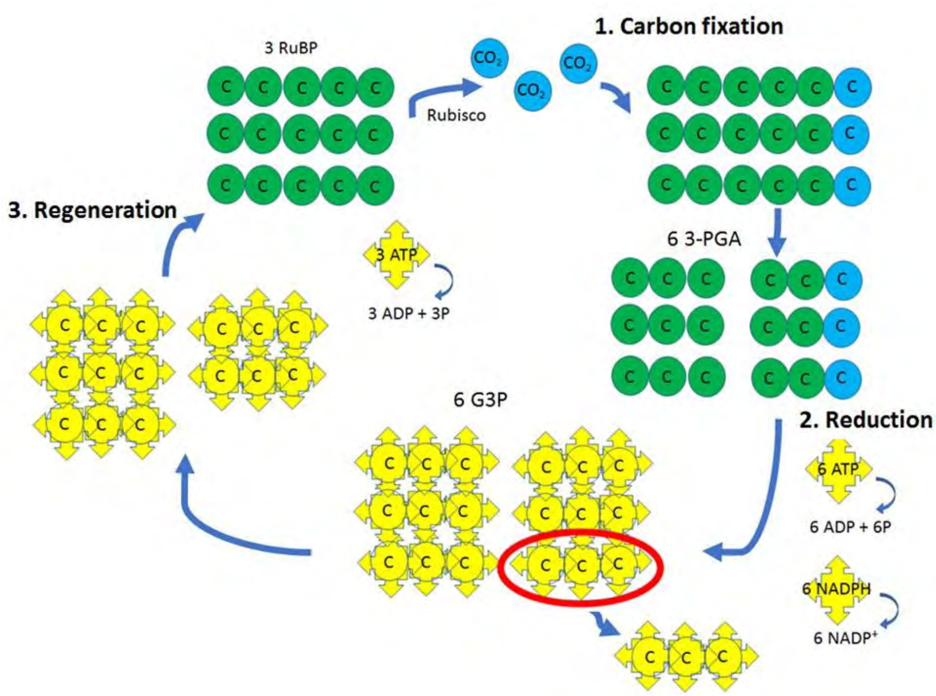

Figure 7.22 The Calvin cycle has three stages. (credit: Elizabeth O'Grady)

In summary, nine ATP, six NADPH, and three molecules of carbon dioxide are needed to start each round of the Calvin cycle. Both the ATP and NADPH are generated in the thylakoid membrane through the light-dependent reactions (Figure 7.23). The Calvin cycle occurs in the stroma and begins when carbon dioxide is fixed to RuBP with the help of the enzyme rubisco. For one turn of the Calvin cycle, the plant cell gets to use one G3P to synthesize carbohydrates (Figure 7.23). Simple carbohydrates, such as glucose, can then be used by the plant to perform aerobic cellular respiration.

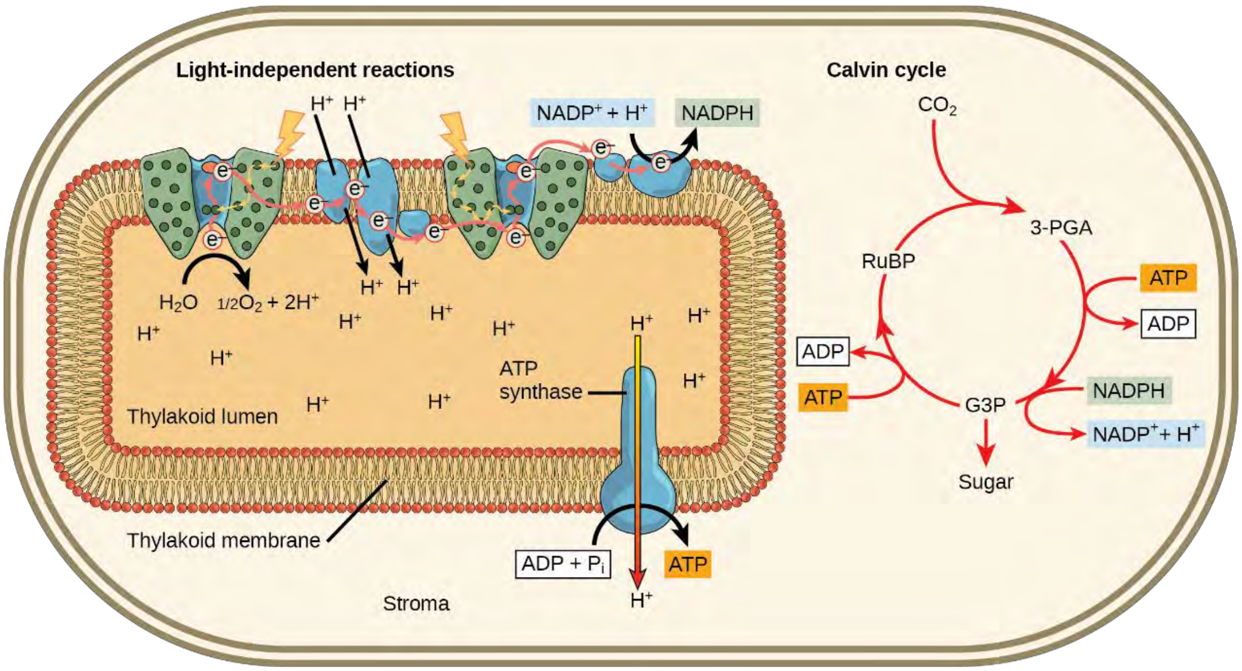

Figure 7.23 Light reactions harness energy from the sun to produce chemical bonds, ATP, and NADPH. These energy-carrying molecules are made in the stroma where carbon fixation takes place. (credit: Clark et al. / Biology 2E OpenStax)

CONCEPTS IN ACTION- The following is a link to an animation of the Calvin cycle. Click Stage 1, Stage 2, and then Stage 3 to see G3P and ATP regenerate to form RuBP.

Photorespiration

The basic process of photosynthesis has changed very little over time. The light-dependent reactions work to absorb light and produce short-term energy carriers. The energy is then used in the Calvin cycle reactions to make sugar. As with all biochemical pathways, a variety of conditions has led to different adaptations.

When plants are forced to close their stomata for prolonged periods of time, gas exchange cannot occur or is extremely limited. Because plants can continue to do the light-dependent reactions, oxygen builds up in the cells. Recall, in the light-dependent reactions, water is split to replace the electron on the special chlorophyll *a* molecule. This reaction generates oxygen as a by-product. Rubisco, the enzyme used for carbon fixation in the Calvin cycle, can bind to carbon dioxide *or oxygen* and fix it to RuBP. In times when oxygen is in a higher concentration than carbon