Contents

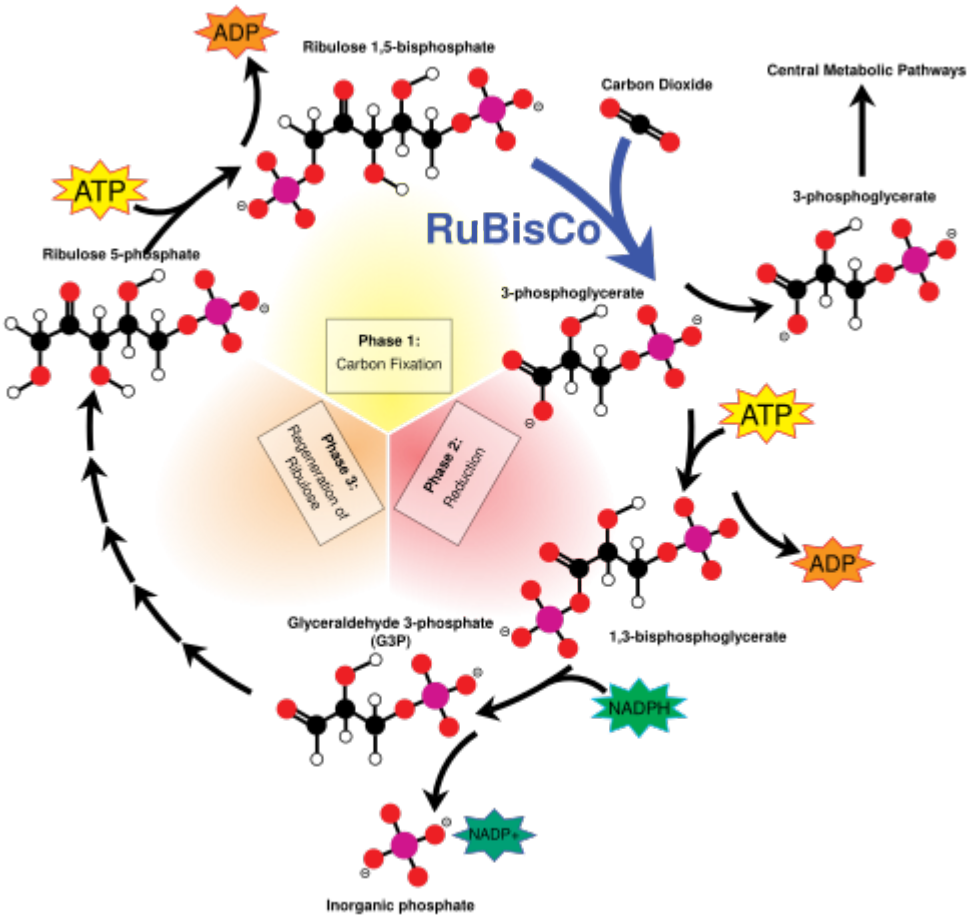
# Reading

- PDF (OpenStax)
- 8.3 Carbon Fixation (OpenStax CNX)

# Learning Outcomes

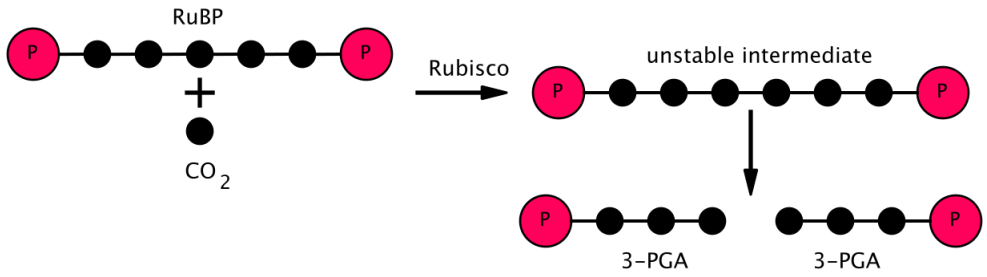
1. Discuss the main events that occur in the Calvin-Bensen cycle, and tell the cycle must turn six times in order to generate a 6-carbon sugar.
2. Explain the process of photo respiration, and describe the environmental conditions that favor this process.
3. Discuss the C4 and CAM pathways; explain why C4 plants photosynthesize more efficiently than C3 plants.
4. Describe the global carbon cycle.

# Light Independent Reactions

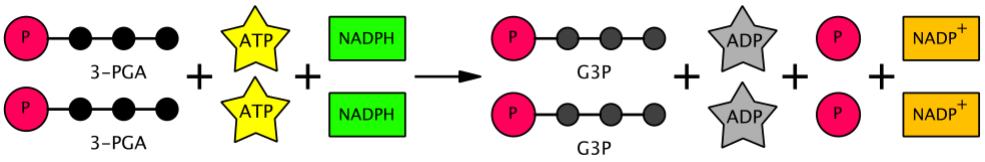



Credit:Mike Jones [CC-BY-SA 3.0]

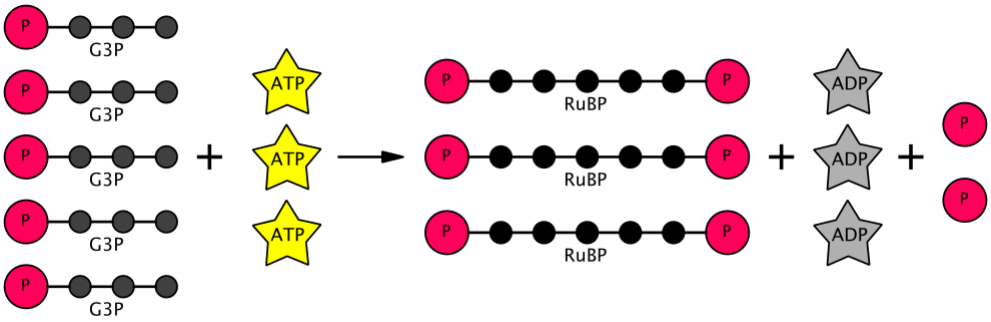
The light independent reactions are also known as the dark reactions or **Calvin Cycle** and utilize the ATP and NADPH from the light-dependent reactions to fix gaseous $CO_2$ into carbohydrate backbones. Photosynthesis is often simplified into $6CO_2 + 6H_2O$ + light –> $C_6H_{12}O_6 + 6O_2$ . However, the true product is 3-phosphoglycerate that can be used to generate longer carbohydrates like glucose. The starting point of **carbon fixation** is the carbohydrate Ribulose 1,5-bisphosphate. The enzyme Ribulose Bisphospate Carboxylase (**RuBisCO**) captures a $CO_2$ molecule onto Ribulose 1,5-bisphosphate to generate 2 molecules of 3-phosphoglycerate which can enter the process of **gluconeogenesis** to generate glucose. ATP from the light reactions can then facilitate the conversion of 3-phosphoglycerate to 1,3 bisphosphoglycerate which can be reduced by NADPH to glyceraldehyde-3-phosphate (G3P). G3P can then be used to regenerate Ribulose 1,5-bisphosphate.




1: Carbon fixation by RuBisCO

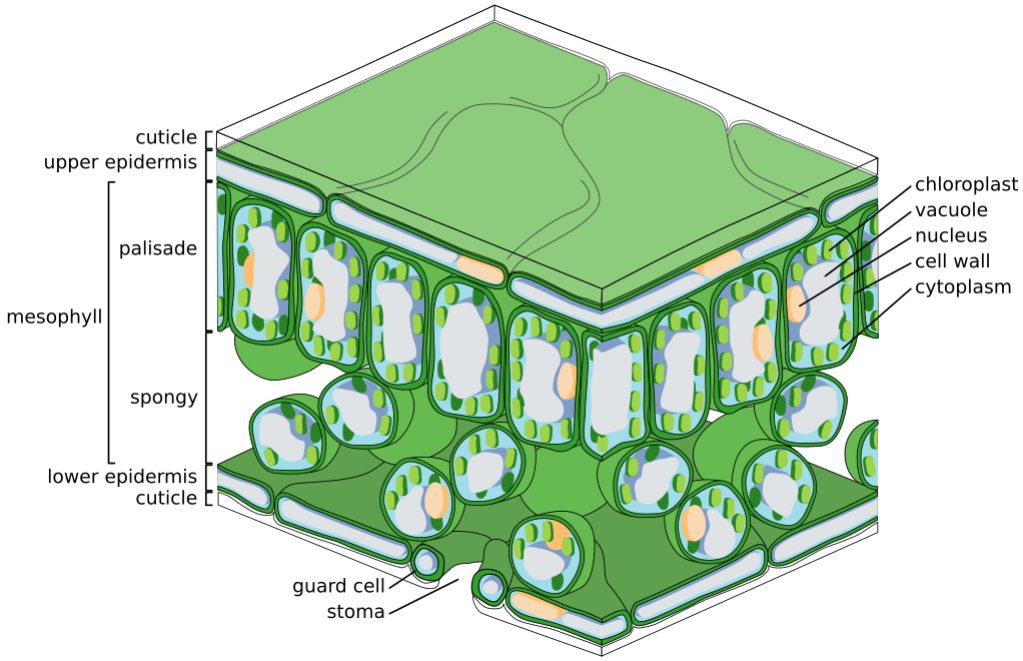



2: Reduction by NADPH

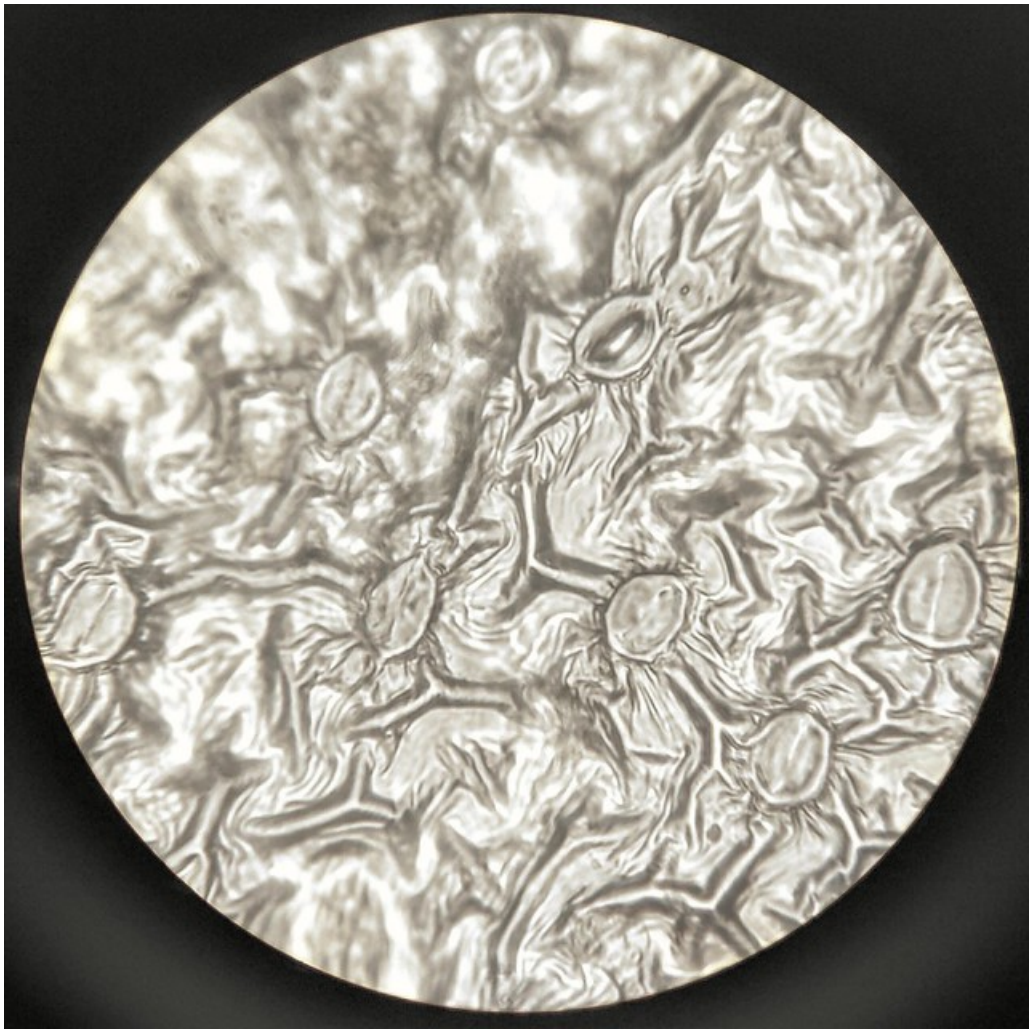



3: Ribulose ,5-bisphosphate regeneration

# Leaf Anatomy

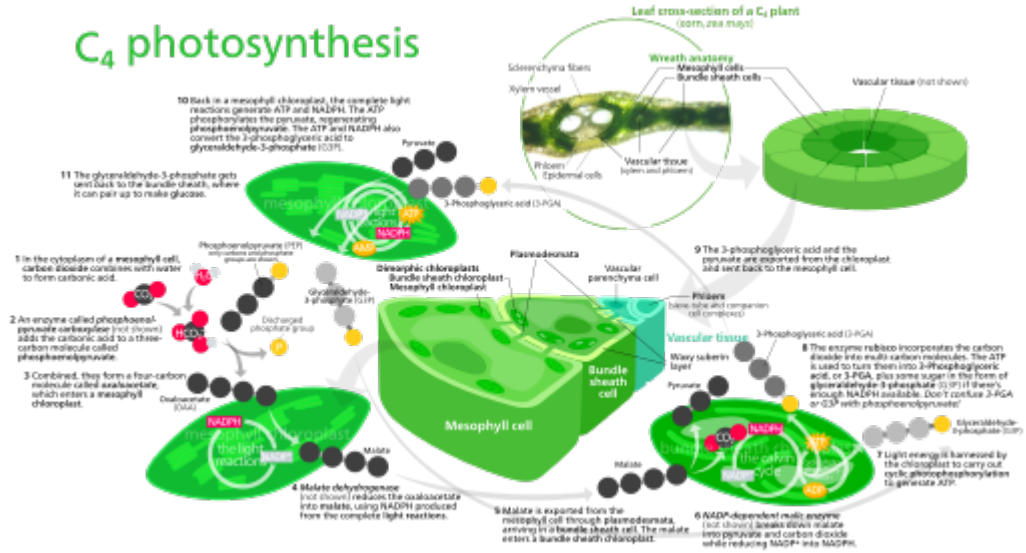



Cross-section of a leaf illustrating the layers of cells. Credit: Zephyris [CC-BY- SA 3.0]



Topographical image of epidermal cells and guard cells of the stomata from the underside of a dandelion leaf. The lip-like stomata open and close to regulate gas and moisture exchange. Credit: jeremy Seto [CC-BY-SA 3.0]

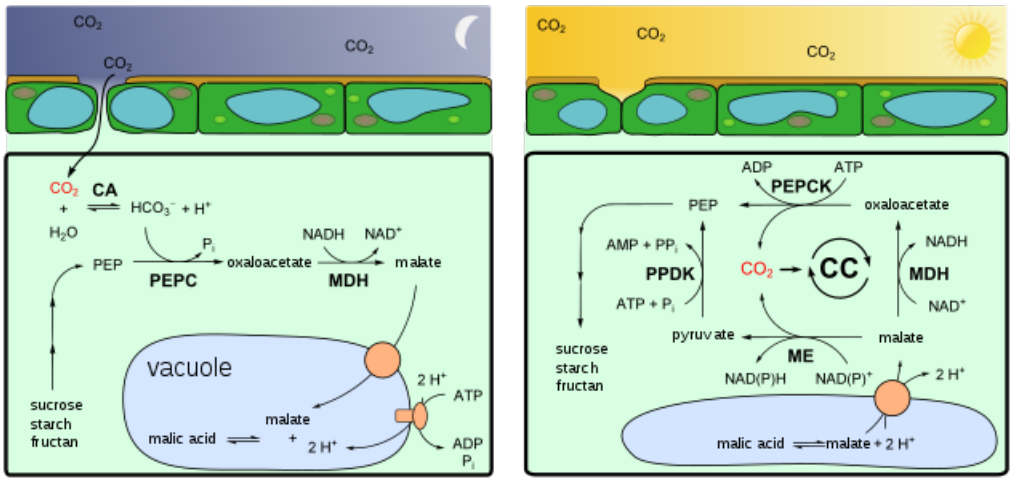
## C4 Photosynthesis




C4 Photosynthesis Credit: Kelvinsong **[CC-BY-SA 3.0]**

# Crassulacean acid metabolism (CAM)

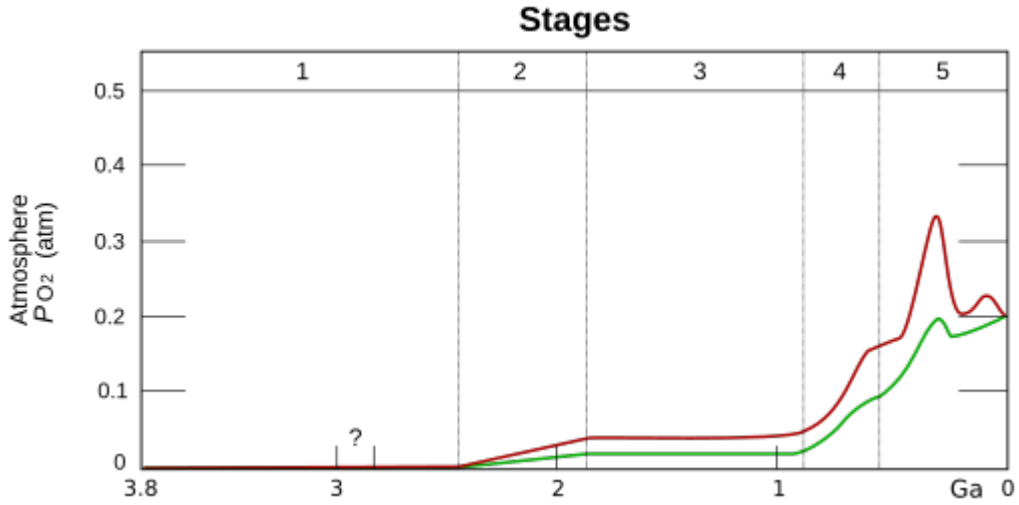
**CAM (Crassulacean acid metabolism) photosynthesis** is a carbon fixation pathway that evolved in some plants as an adaptation to arid conditions. At night, stomata open to permit the entry of $CO_2$ into cells for storage as organic acids in vacuoles. During the day, the stomata close to conserve water and the stored $CO_2$ enters the stroma of chloroplasts to take part int eh Calvin Cycle reactions.




**CAM photosynthesis** CA: carbonic anhydrase CC: Calvin cycle PEP:

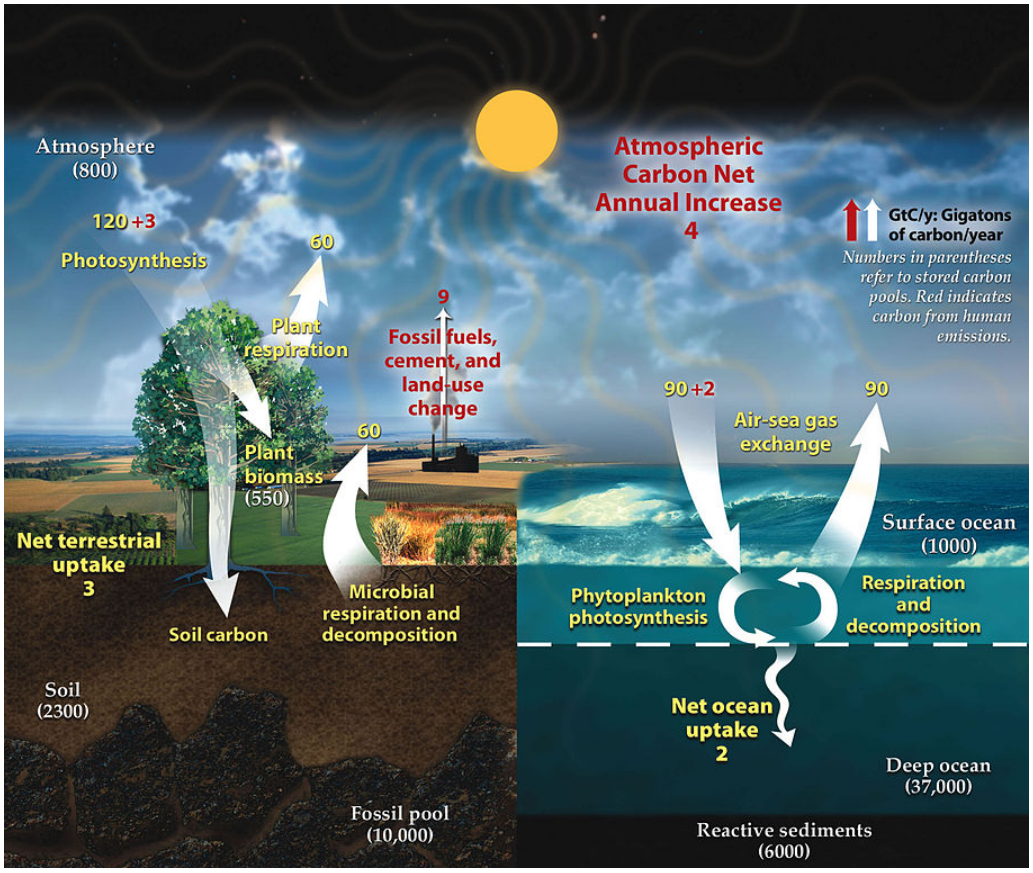
phosphoenolpyruvic acid PEPC: phosphoenolpyruvate carboxylase PEPCK: phosphoenolpyruvate carboxykinase MDH: malate dehydrogenase ME: malic enzyme (malate dehydrogenase) PPDK: pyruvate, phosphate dikinase

# The Great Oxygenation Event

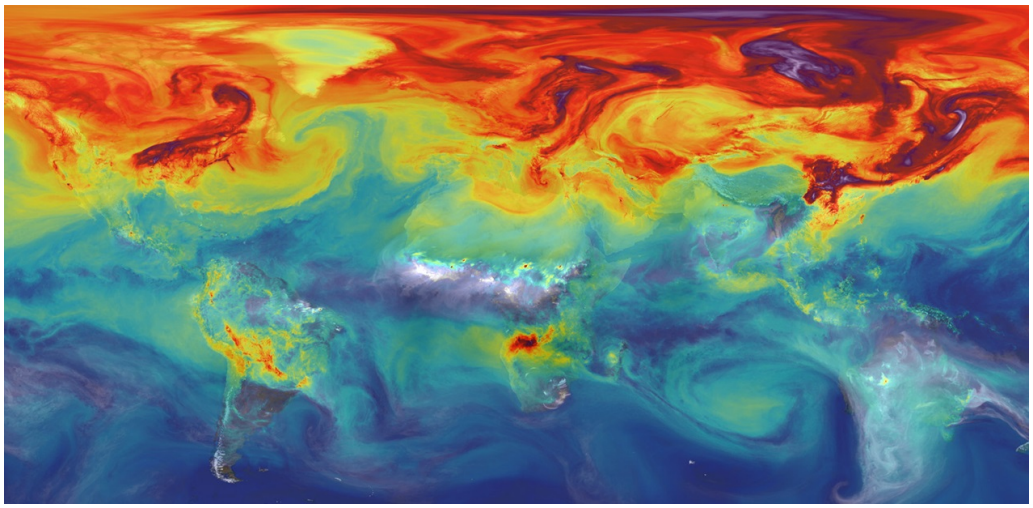



Two estimates of evolution of atmospheric $O_2$. The upper red and lower green lines represent the range of the estimates. Stage 1 (3.85–2.45 Ga) represents the primordial reducing atmosphere. Stage 2 (2.45–1.85 Ga) coincides with the emergence of oceanic cyanobacteria where $O_2$ was being absorbed by the oceans and sediment. $O_2$ escaped the oceans during Stage 3 (1.85–0.85 Ga). $O_2$ sinks filled in Stage 4 (0.85–0.54 Ga ) and Stage 5 (0.54 Ga–present) leading to atmospheric accumulation. Credit: Loudubewe [CC-BY-SA 3.0]

Banded iron formations in 2.1 billion year old rock illustrate the oxidation of dissolved oceanic iron that precipitated in response to accumulating $O_2$ concentrations. Credit: André Karwath aka Aka [CC-BY-SA 2.5]




The Carbon Cycle illustrates carbon sequestration and release between various carbon sinks.



Projection of atmospheric $CO_2$ accumulation without reduction of fossil fuel reduction by NASA

## Test Yourself

- Quiz and Flashcards