

Introduction to Botany. Lecture 9

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1 Questions and answers

- Quiz

2 Photosynthesis

- Enzymatic stage: fixation of carbon dioxide
- As a whole
- Special case of photosynthesis: C₄ pathway



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2 Photosynthesis

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Questions and answers

Quiz



Final question (2 points)

Explain the role of NADPH in the enzymatic stage.



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Explain the role of NADPH in the enzymatic stage.

- It provides hydrogen to use in glucose
- In addition, it provides energy in the way similar to ATP



Photosynthesis

Enzymatic stage: fixation of carbon dioxide





Participants of enzymatic stage

- 1 Carbon dioxide (CO_2)
- 2 Hydrogen carrier with hydrogen (NADPH)
- 3 Source of energy (ATP)
- 4 Ribulose biphosphate (RuBP, five-C-hydrocarbonate, "C₅")
- 5 *Rubisco* and other enzymes

Place: in the matrix (stroma) of chloroplast

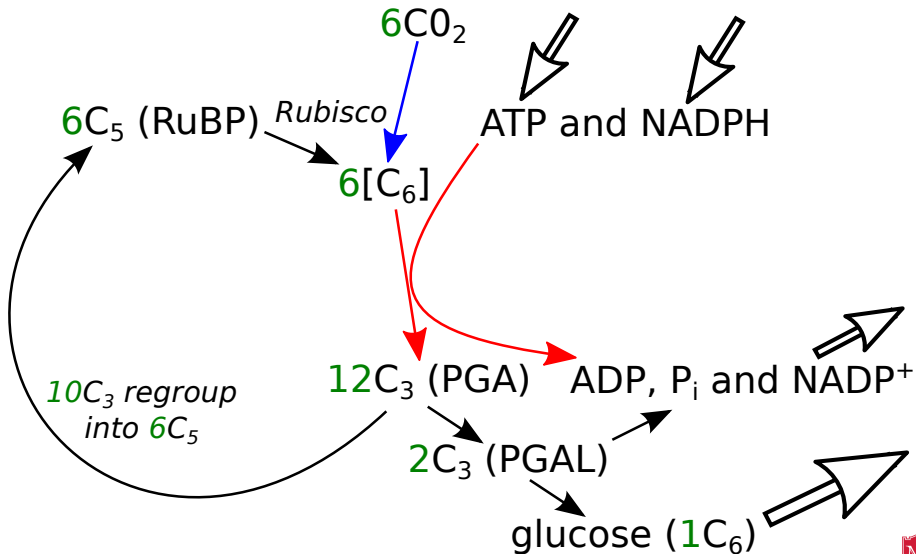


Main events of enzymatic stage

- 1 $\text{CO}_2 + \text{C}_5$ (RuBP, ribulose biphosphate) $\xrightarrow{\text{rubisco}}$ C_6
- 2 $\text{C}_6 \longrightarrow 2\text{C}_3$ (PGA, phosphoglyceric acid)
- 3 $\text{C}_3 + \text{NADPH} + \text{ATP} \longrightarrow \text{C}_6\text{H}_{12}\text{O}_6$ (or other organic molecules) + $\text{C}_5 + \text{NADP}^+ + \text{ADP} + \text{P}_i$ (inorganic phosphate)
 - Organic molecules are synthesized from C_3 (PGA) through energy-rich **PGAL** (phosphoglyceric aldehyde)



Enzymatic stage: scheme



Results of enzymatic stage

At the start	At the end
CO ₂	C ₆ H ₁₂ O ₆ (or other organic molecules)
NADPH	NADP ⁺ (and H to organic molecules)
ATP	ADP and P _i (inorganic phosphate)
C ₅	C ₅
Rubisco	Rubisco

The other names for enzymatic stage are “Calvin cycle” and “C₃ cycle”

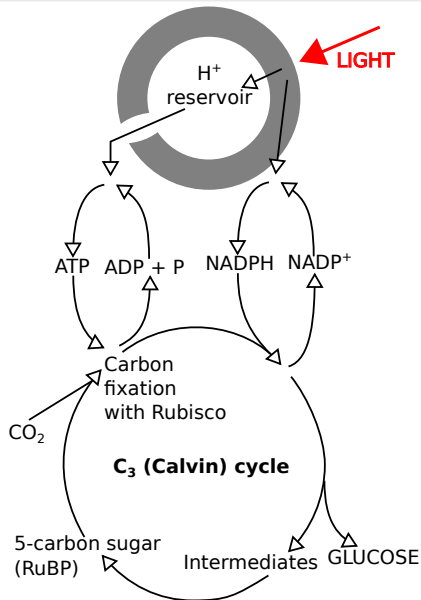


Photosynthesis

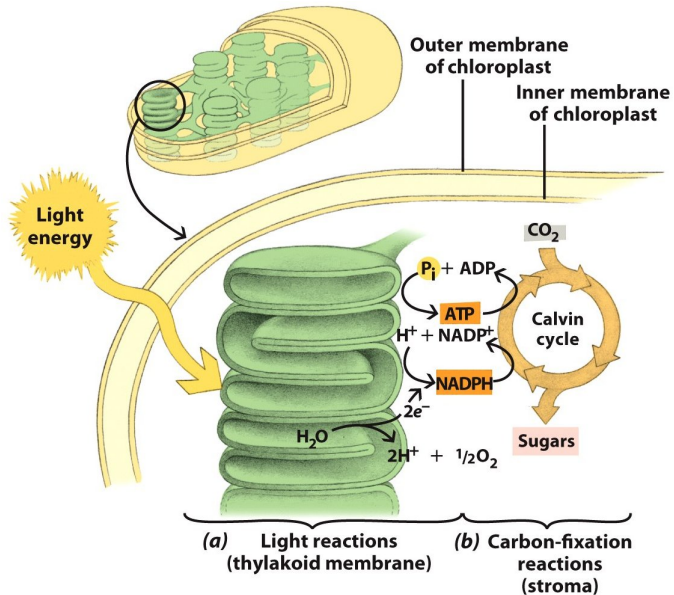
As a whole



Overview of photosynthesis



Photosynthesis in the cell



Photosynthesis movie



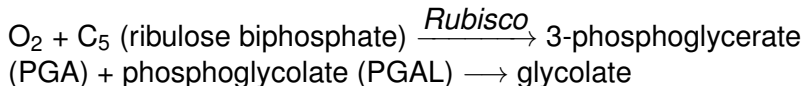
Photosynthesis

Special case of photosynthesis: C₄ pathway



Photorespiration

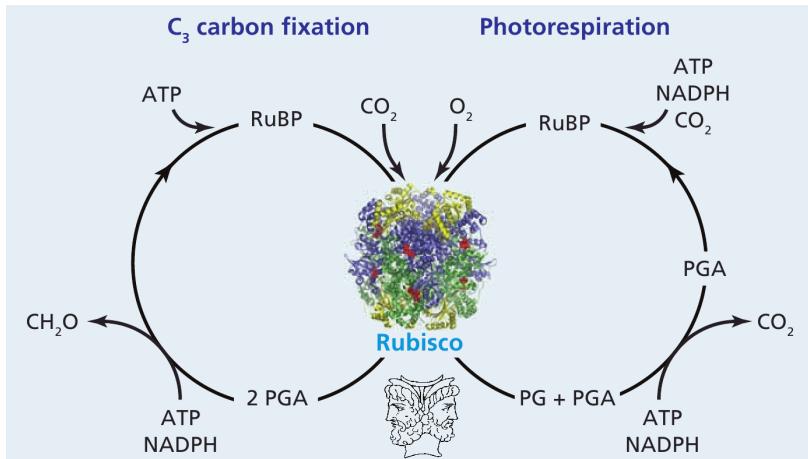
Rubisco is two-faced enzyme, it catalyzes **photorespiration** if the concentration of O₂ and/or temperature is high:



- To return glycolate into the Calvin cycle, cell must use peroxisomes, mitochondria and spend ATP
- Photorespiration wastes C₅ and ATP
- Photorespiration is said to be an evolutionary relic from times when atmosphere contained little oxygen



Two-faced Rubisco



Minimization of photorespiration

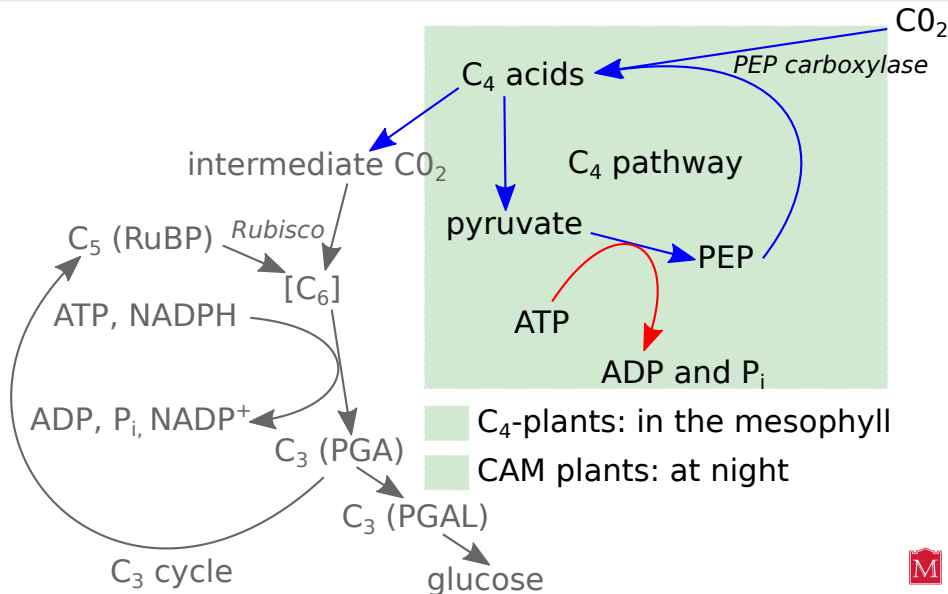
To minimize photorespiration, plants need to increase concentration of CO₂. This is how they do it:

- 1 CO₂ + C₅ (PEP, phosphoenolpyruvate) $\xrightarrow{\text{PEP carboxylase}}$ C₄
(different organic acids): this is the temporarily accumulation of carbon dioxide
- 2 C₄ → pyruvate + CO₂: release of carbon dioxide will increase its concentration
- 3 Pyruvate + ATP → PEP + AMP + 2P_i: PEP recovery costs ATP

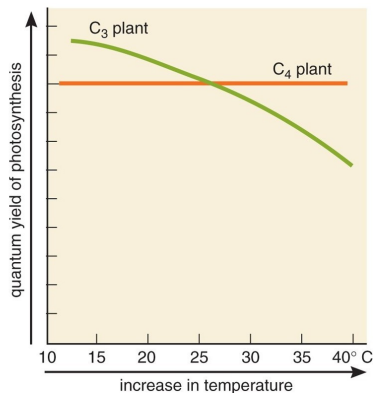
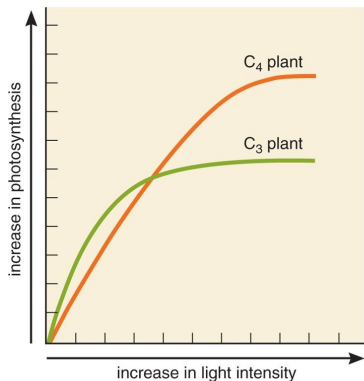
Processes above called C₄ pathway, it is an addition to Calvin (C₃) cycle in order to increase concentration of CO₂



C₄ pathway at-a-glance



C₄-pathway plants feel better at high temperature and light intensity



C₄-pathway plants waste ATP to recover PEP but outperform strict C₃ plants when concentration of oxygen is high



Final question (2 points)



Final question (2 points)

What is photorespiration?



Summary

- **Photosynthesis** is a sum of light-dependent and light-independent reactions
- **Light stage** of photosynthesis results in accumulation of energy and hydrogen, and release of oxygen
- **Enzymatic stage** of photosynthesis results in synthesis of organic molecules



For Further Reading



A. Shipunov.

Introduction to Botany [Electronic resource].

2016.

Mode of access:

http://ashipunov.info/shipunov/school/biol_154

