

Introduction to Botany. Lecture 22

Alexey Shipunov

Minot State University

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Outline

1 Where we are?

- Light and enzymatic stages again

2 Photosynthesis

- Special cases of photosynthesis: C_4 pathway



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- 1 Where we are?
 - Light and enzymatic stages again
- 2 Photosynthesis
 - Special cases of photosynthesis: C_4 pathway



Previous final question: the answer

What is wrong in this picture?

Before photosynthesis	After photosynthesis
H_2O NADP^+ CO_2	O_2 NADPH $\text{C}_6\text{H}_{12}\text{O}_6$ (or other organic molecules)



Previous final question: the answer

What is wrong in this picture?

Before photosynthesis	After photosynthesis
H_2O	O_2
NADP^+	NADPH NADP^+
CO_2	$\text{C}_6\text{H}_{12}\text{O}_6$ (or other organic molecules)



Where we are?

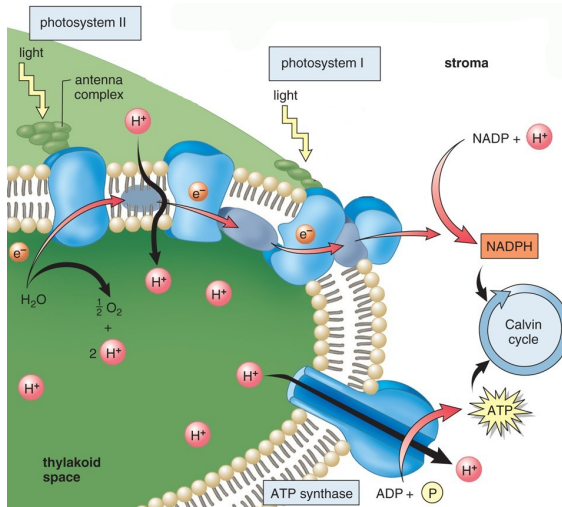
Light and enzymatic stages again



Overview of photosynthesis



Light stage



How two photosystems are working



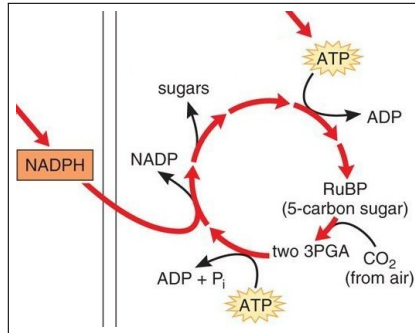
Results of the light stage

At the start of light stage	At the end light stage
H_2O Chlorophylls ATP synthase ADP and P_i NADP^+	O_2 Chlorophylls ATP synthase ATP NADPH

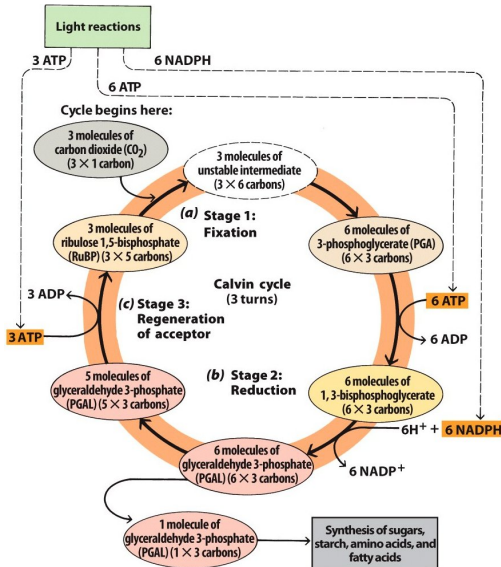
*Photosystem II and Photosystem I



Enzymatic stage (simplistic scheme)



Enzymatic stage (with numbers for math lovers)



Results of enzymatic stage

At the start of enzymatic stage	At the end of enzymatic stage
CO_2	$\text{C}_6\text{H}_{12}\text{O}_6$
NADPH	NADP^+
ATP	ADP and P_i
C_5	C_5
Rubisco	Rubisco



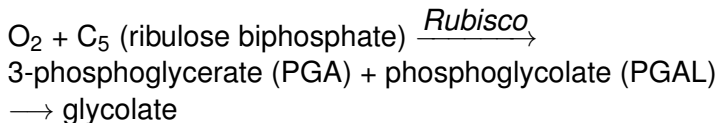
Photosynthesis

Special cases of photosynthesis: C₄ pathway



Photorespiration

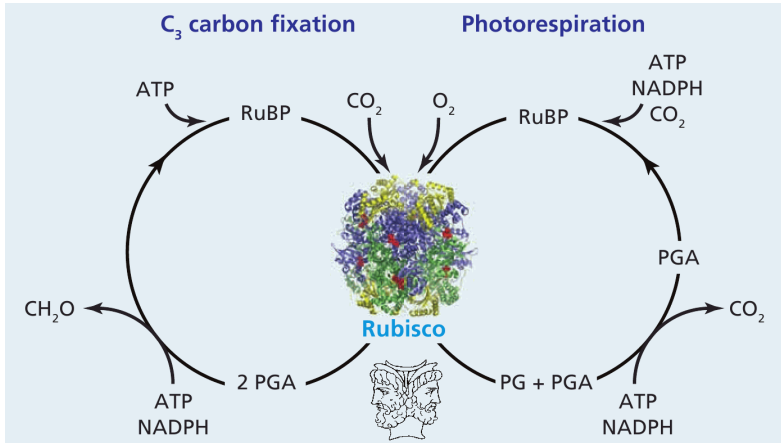
Rubisco is two-faced enzyme, it catalyzes **photorespiration** if the concentration of O₂ and/or temperature is high:



- 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

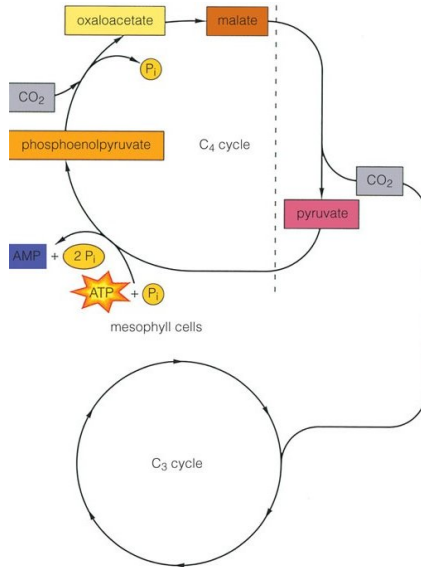
To minimize photorespiration, plants need to increase concentration of CO₂. This is how they do it:

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

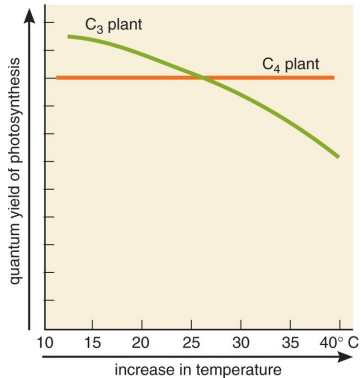
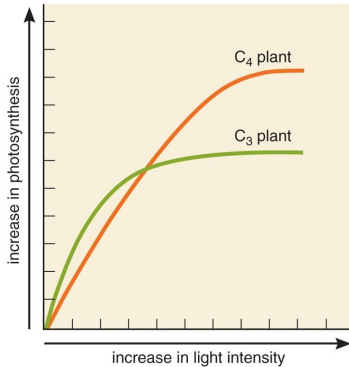
Processes above called C₄ pathway, it is an addition to Calvin (C₃) cycle in order to increase concentration of CO₂



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

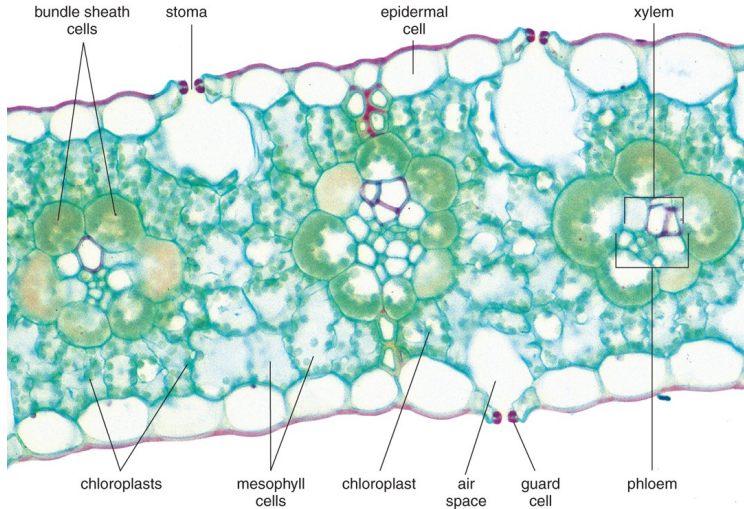


C₄ and CAM plants both use C₄ pathway

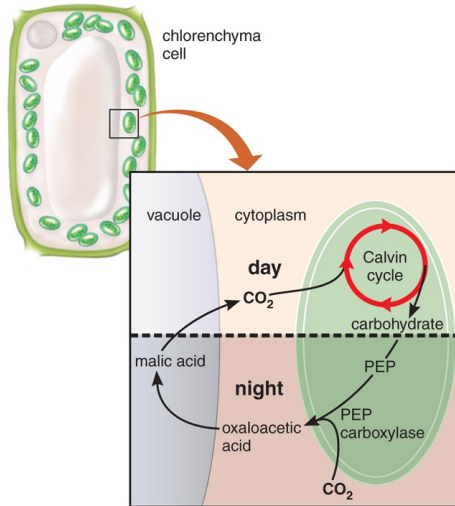
- **CAM-plants** which drive C₄ cycle at nights:
 - This is a **temporal** separation between accumulation of CO₂ and photosynthesis)
 - CAM-plants (17,000 species, 7% of plant biodiversity) are mostly succulents from different orders and families (e.g., cacti—Cactaceae from Caryophyllales)
- **C₄-plants** which drive C₄ in mesophyll cells and C₃ in bundle sheath cells:
 - This is a **spatial** separation between accumulation of CO₂ and photosynthesis: C₄ pathway is located in “normal” mesophyll cells whereas the Calvin cycle is separated to **bundle sheath cells**.
 - C₄-plants (7,300 species, 3%) are especially common among Poales (grasses order, e.g., corn) and Caryophyllales (pink order)



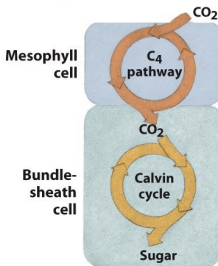
Leaf of C_4 plant: spatial separation of C_3 and C_4 pathways



CAM plants separate C_3 and C_4 pathways in time

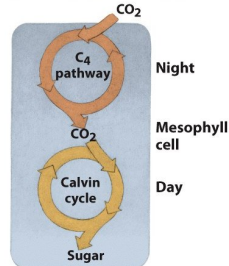


CAM plants and C_4 plants



Stage 1:
Initial fixation
of CO_2 to form
4-carbon acids

Stage 2:
Release of CO_2
to Calvin cycle



Jade plant



CAM is named after the family Crassulaceae,
Jade plant (*Crassula ovata*) family



Corn



Corn (*Zea mays*) is the C_4 plant which minimizes photorespiration at higher temperatures



Final question (2 points)



Final question (2 points)

Photorespiration increases when concentration of oxygen grows. Why is photorespiration so intensive at high temperatures?



Summary

- To prevent wasteful **photorespiration**, plants “invented” the addition to photosynthesis, C₄-pathway
- C₄ and CAM plants accumulate and then release carbon dioxide and therefore increase its concentration



For Further Reading



J. E. Bidlack, Sh. H. Jansky.
Stern's introductory plant biology. 12th edition.
McGraw-Hill, 2011.
Chapter 10.



Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy.
Plant Biology. 2nd edition.
Thomson Brooks/Cole, 2006.
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