# Introduction to Botany. Lecture 10

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# Outline



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1. Questions and answers
   - Quiz
2. Photosynthesis
   - Special case of photosynthesis: $C_4$ pathway
   - $C_4$ and CAM plants

# 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

## Special case of photosynthesis: $C_4$ pathway

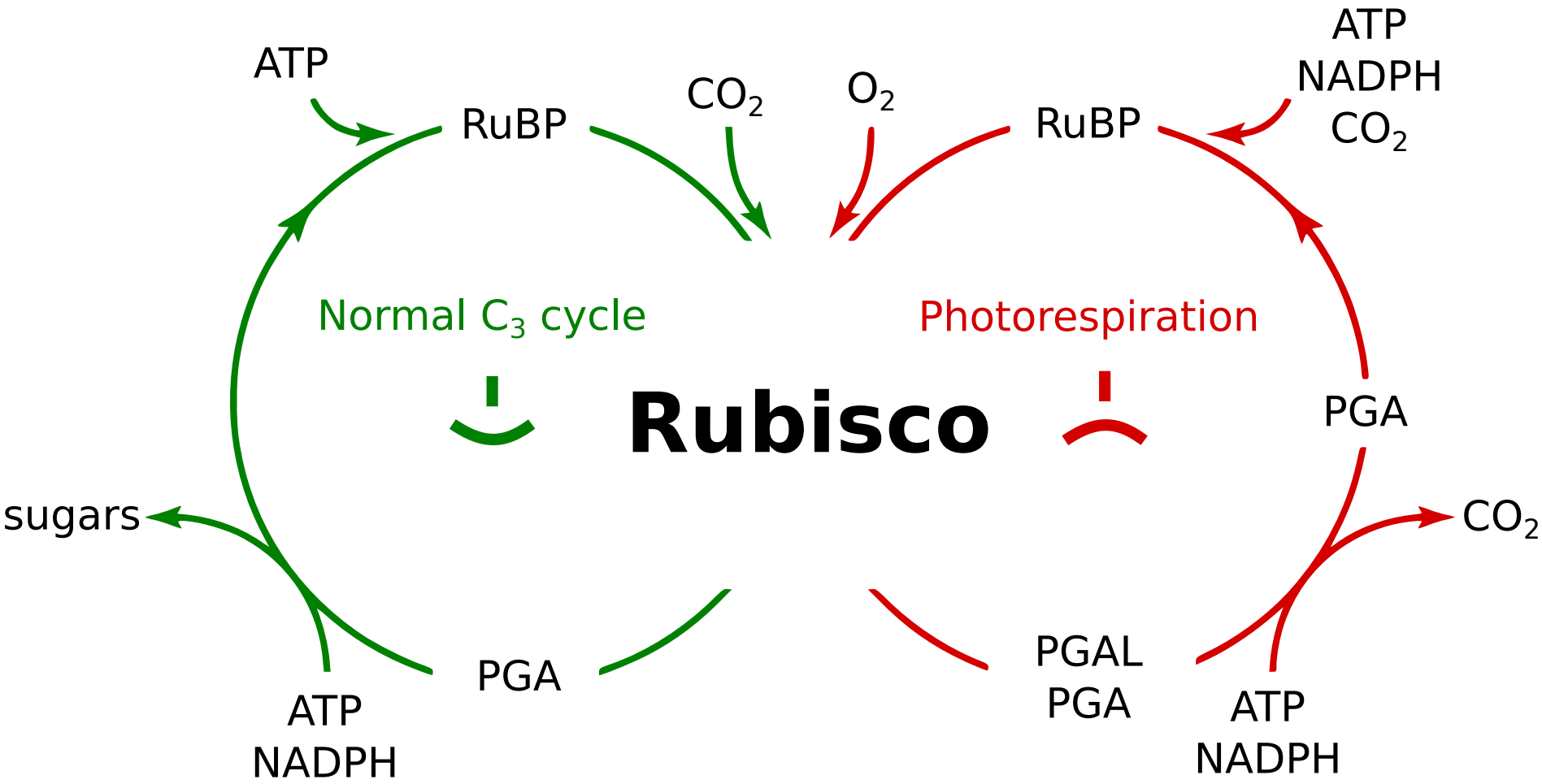
# Photorespiration

*Rubisco* is two-faced enzyme, it catalyzes **photorespiration** if the concentration of $O_2$ and/or temperature is high:

$O_2$ + $C_5$ (ribulose biphosphate) $\xrightarrow{Rubisco}$ 3-phosphoglycerate (PGA) + phosphoglycolate (PGAL) $\longrightarrow$ glycolate

- To return glycolate into the Calvin cycle, cell must use peroxisomes, mitochondria and spend ATP
- Photorespiration wastes $C_5$ 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 $CO_2$. This is how they do it:

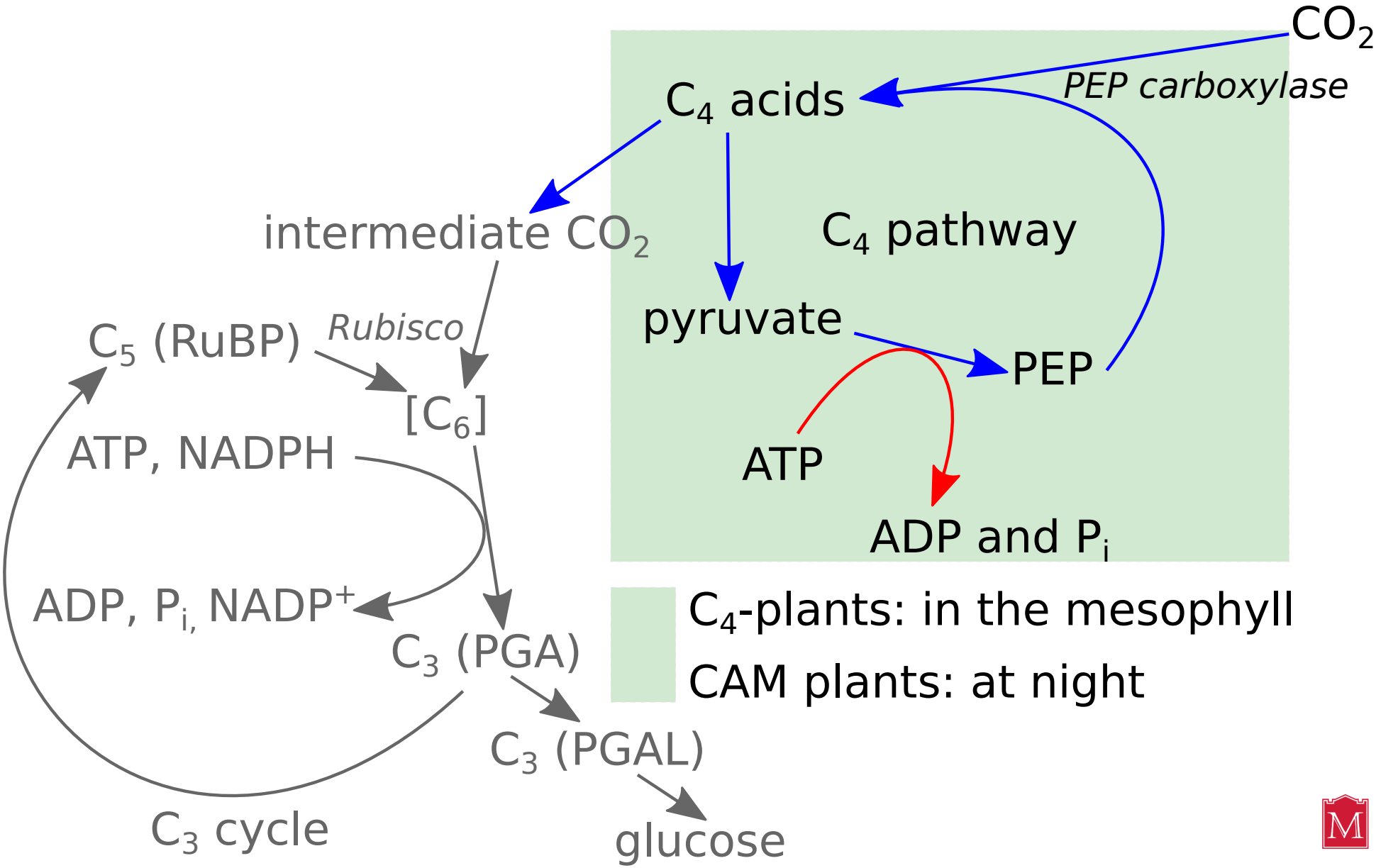
A. $CO_2$ + $C_5$ (PEP, phosphoenolpyruvate) $\xrightarrow{\text{PEP carboxylase}}$ $C_4$ (different organic acids): this is the temporarily accumulation of carbon dioxide

B. $C_4 \longrightarrow$ pyruvate + $CO_2$: release of carbon dioxide will increase its concentration

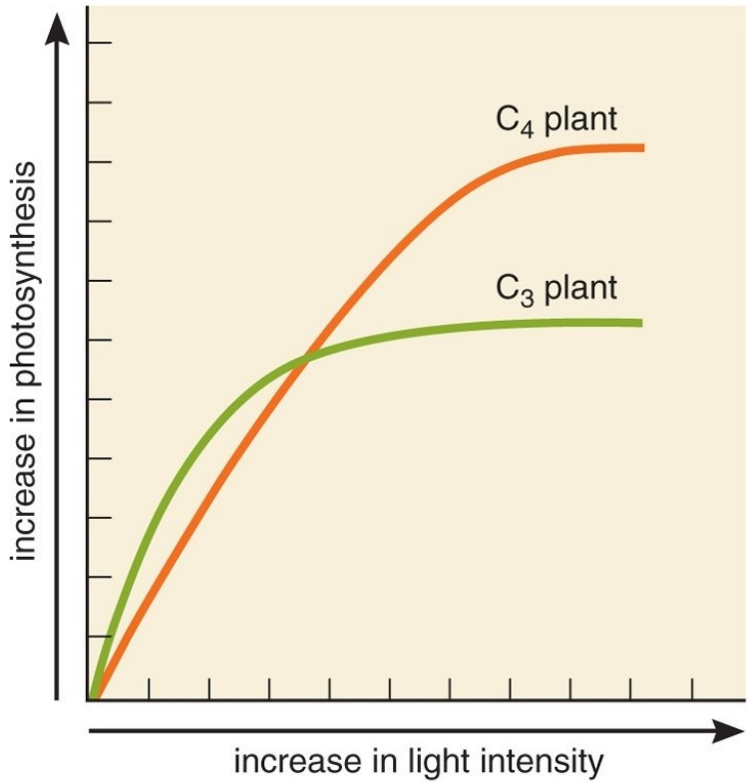
C. Pyruvate + ATP $\longrightarrow$ PEP + ADP + $P_i$: PEP recovery costs ATP! (but **less** then photorespiration)

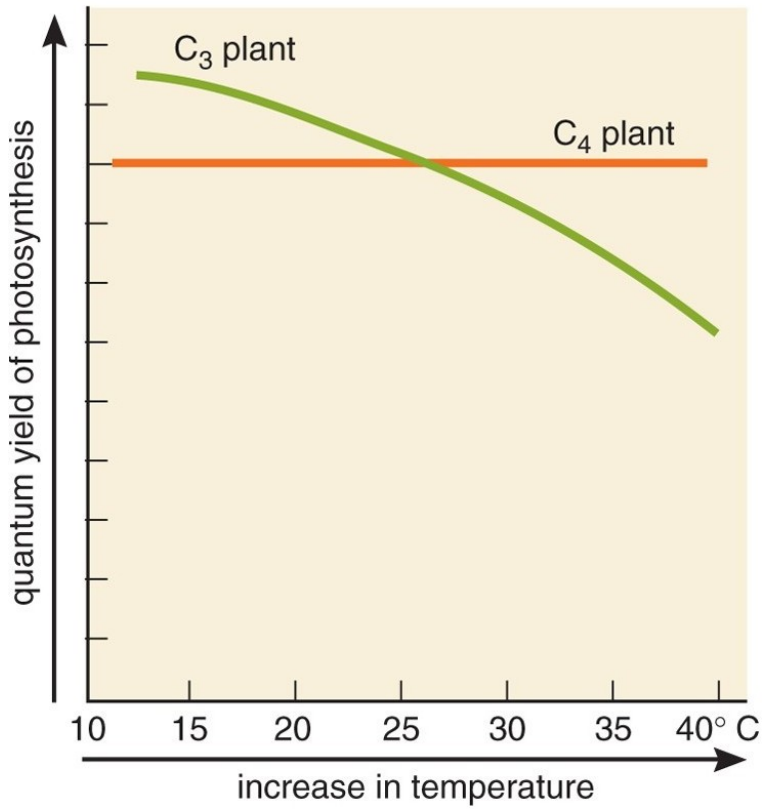
Processes above called $C_4$ pathway, it is an addition to Calvin ($C_3$) cycle in order to increase concentration of $CO_2$

# $C_4$ pathway at-a-glance



# $C_4$-pathway plants feel better at high temperature and light intensity




$C_4$-pathway plants waste ATP to recover PEP but outperform strict $C_3$ plants when concentration of oxygen is high

# Photosynthesis

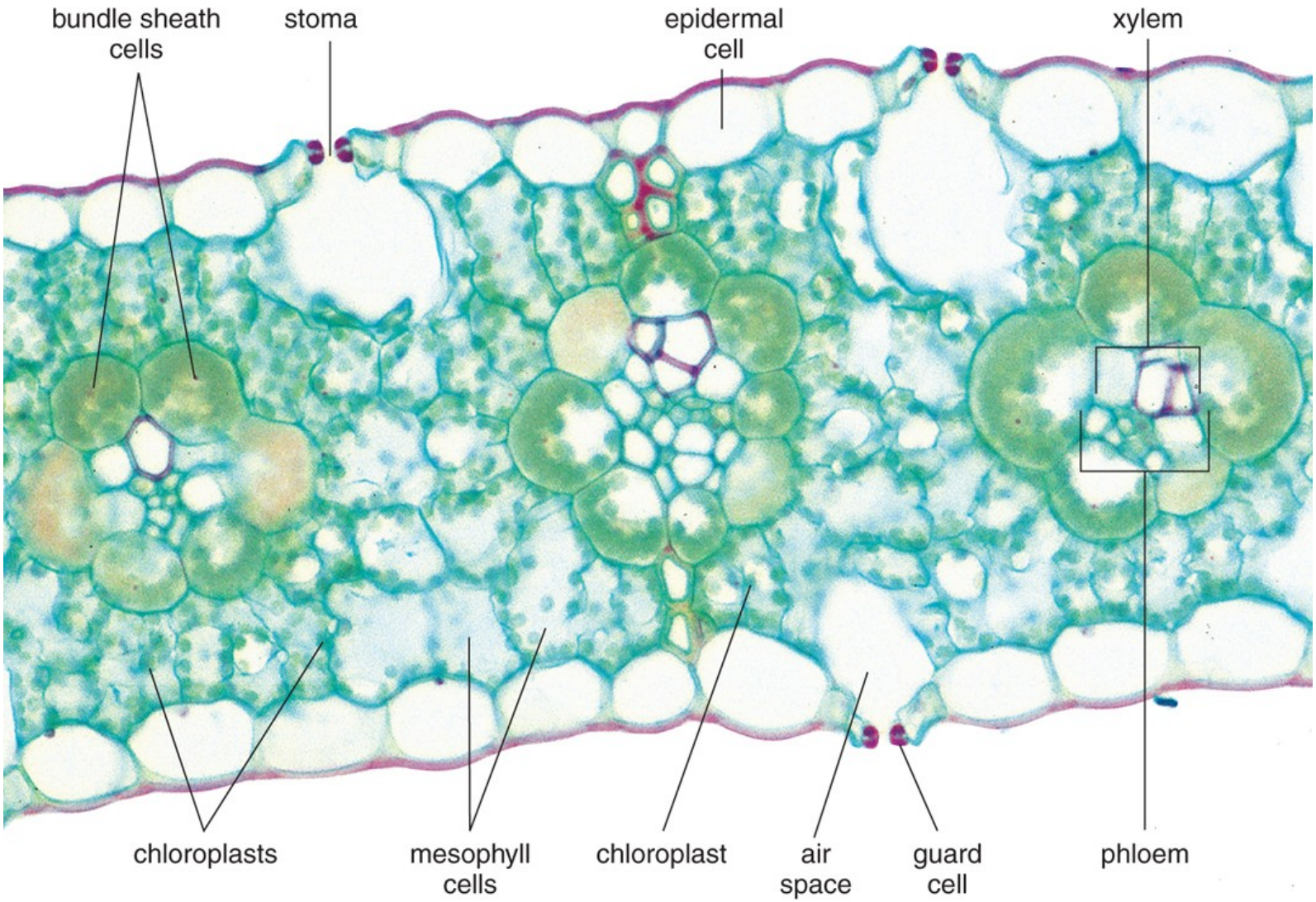
## $C_4$ and CAM plants

# $C_4$ and CAM plants both use $C_4$ pathway

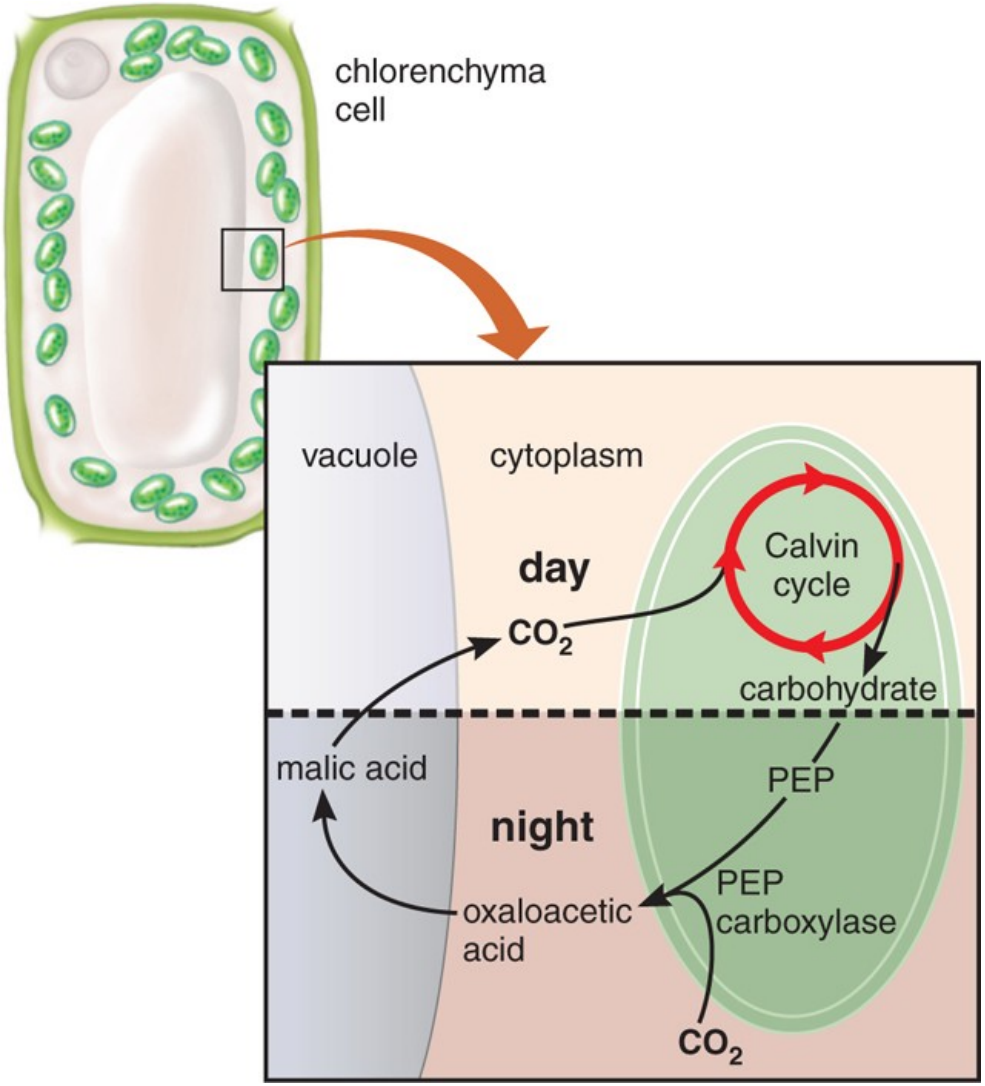
- **CAM-plants** which drive $C_4$ cycle at nights:
  - This is a **temporal** separation between accumulation of $CO_2$ and photosynthesis)
  - CAM-plants (17,000 species, 7% of plant biodiversity) are mostly succulents from different orders and families (e.g., cacti—Cactaceae from Caryophyllales), other examples are bromeliads like pineapple.
- **$C_4$-plants** which drive $C_4$ in mesophyll cells and $C_3$ in bundle sheath cells:
  - This is a **spatial** separation between accumulation of $CO_2$ and photosynthesis: $C_4$ pathway is located in "normal" mesophyll cells whereas the Calvin cycle is separated to **bundle sheath cells**.
  - $C_4$-plants (7,300 species, 3%) are especially common among Poales (grasses order, e.g., corn, millet, sorghum) and Caryophyllales (pink order)

There are plants which combine $C_4$ and CAM (*Portulacaria*) and even $C_3$ and CAM (*Clusia*).

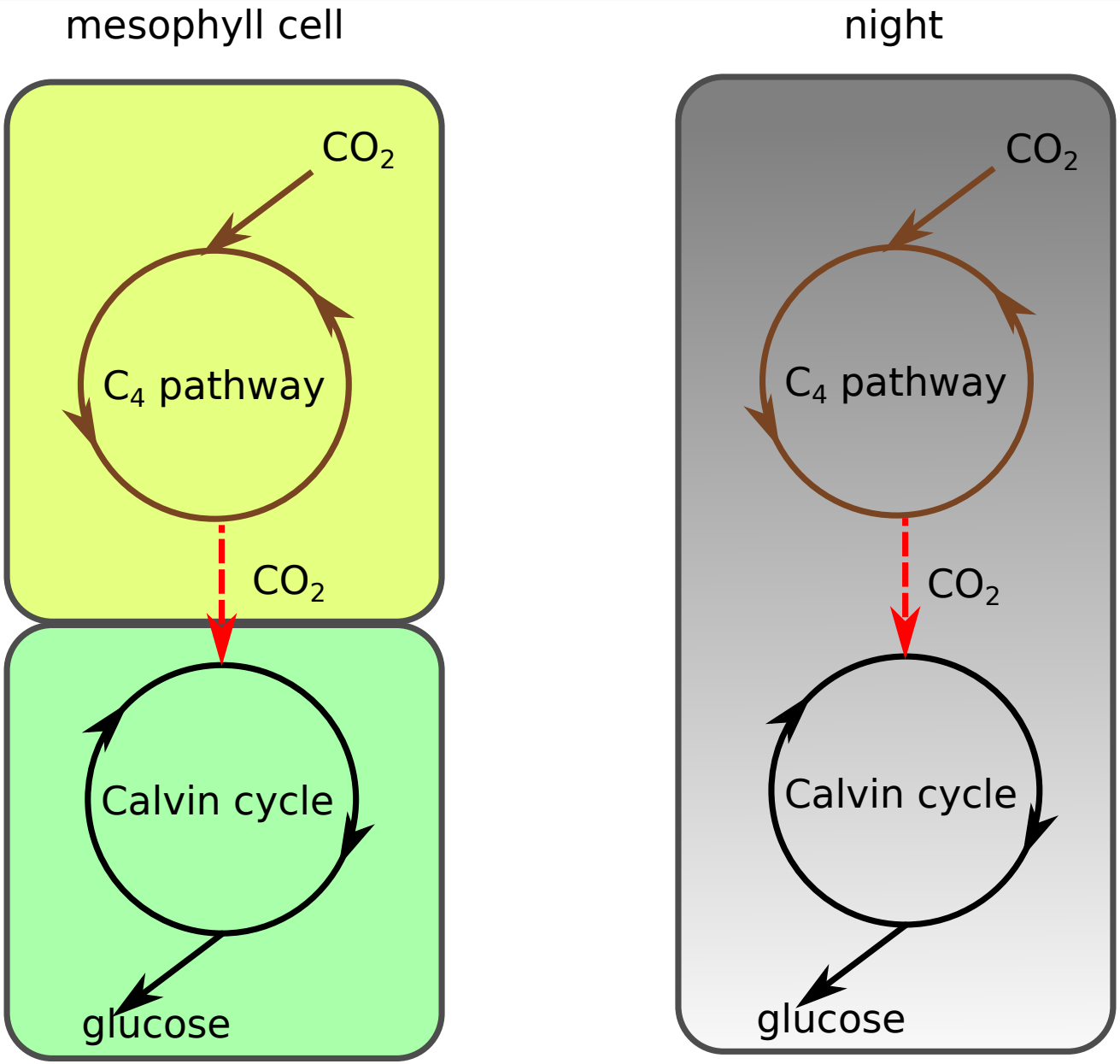
# Leaf of $C_4$ plant: spatial separation of $C_3$ and $C_4$ pathways



# CAM plants separate $C_3$ and $C_4$ pathways in time



# CAM plants and $C_4$ plants



# 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

# True respiration

- The common misconception about plants is that their only energy-related metabolic process is photosynthesis:

$$CO_2 + H_2O + \text{energy} \longrightarrow \text{carbohydrates} + O_2$$

- However, as most eukaryotes, plants have mitochondria in cells and use *aerobic* (oxygen-related) respiration to obtain energy:

$$\text{carbohydrates} + O_2 \longrightarrow CO_2 + H_2O + \text{energy}$$

- Typically, plants spend much less oxygen in respiration then they make in photosynthesis. However, at nights plants do exactly the same as animals, and make only carbon dioxide!

# Final question (2 points)

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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
- $C_4$ and CAM plants accumulate and then release carbon dioxide and therefore increase its concentration

# For Further Reading

A. Shipunov.
*Introduction to Botany* [Electronic resource].
Mode of access:
http://ashipunov.info/shipunov/school/biol_154