

# Introduction to Botany. Lecture 18

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# Outline

- 1 Questions and answers
- 2 Light stage: electron transport, synthesis of ATP and NADPH
- 3 Enzymatic stage: fixation of carbon dioxide

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## Previous final question: the answer

Which conclusions can be drawn from Priestley's experiments?  
Please list more than one.

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Which conclusions can be drawn from Priestley's experiments?  
Please list more than one.

- Mouse and candle “spend” air
- Plant “revives” air

# Participants of light stage

- 1 Chlorophyll
- 2 Light
- 3 Water
- 4 ATP synthase
- 5 Protons ( $H^+$ )
- 6 Hydrogen carrier ( $NADP^+$ )

**Where:** around thylacoid membrane

# Main events of light stage

- 1 Chlorophyll + Light  $\longrightarrow$  Electron ( $e^-$ ) + Chlorophyll $^+$
- 2  $H_2O \longrightarrow H^+ + OH^-$  (accumulates outside)
- 3  $e^- + H^+ + \text{Hydrogen carrier (NADP}^+) \longrightarrow \text{NADPH}$  (moves away)
- 4  $H_2O \longrightarrow H^+$  (accumulates inside) +  $e^- + O_2$
- 5  $H^+$  (inside) +  $OH^-$  (outside)  $\implies$  gradient  $\implies$  PROTON PUMP  $\implies H_2O$ ,  
and  $ADP + P_i$  (inorganic phosphate)  $\longrightarrow$  **ATP**

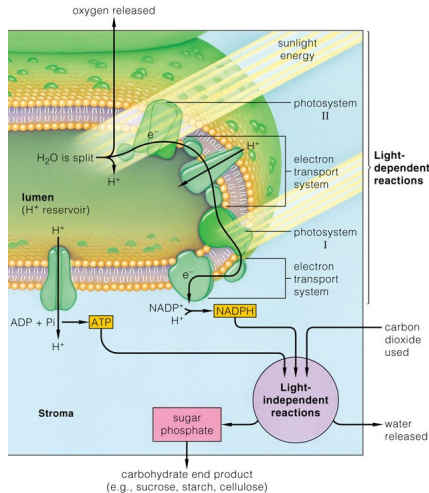


## *Scheme of light stage*

Light stage: electron transport, synthesis of ATP and NADPH

Enzymatic stage: fixation of carbon dioxide

# Bird view of light stage



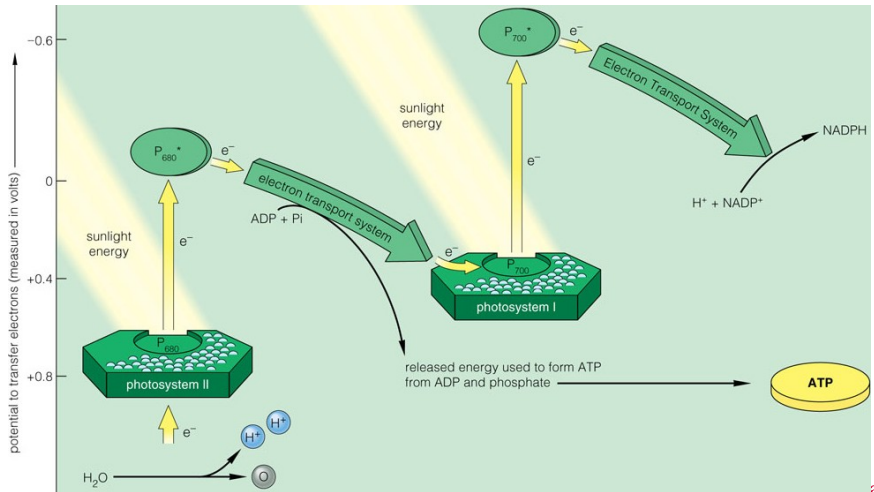
# Photosystems I and II

- Photosystem II ( $P_{680}$ , contains chlorophylls and carotene) decomposes water and forwards electron to Photosystem I ( $P_{700}$ , contains only chlorophylls)
- $P_{680}$  makes proton gradient and then ATP: this is a **photophosphorylation**
- $P_{700}$  makes NADPH
- Processes above are an **noncyclic electron transport** and **noncyclic** photophosphorylation because electrons move from one photosystem to another and finally accepted by  $NADP^+$
- **Cyclic** electron transport requires only  $P_{700}$  but do not produce any NADPH, only ATP

Light stage: electron transport, synthesis of ATP and NADPH

Enzymatic stage: fixation of carbon dioxide

# Two photosystems



# Results of the light stage

At the start	At the end
$\text{H}_2\text{O}$	$\text{H}_2\text{O}$ (result of pump) and $\text{O}_2$
Chlorophylls	Chlorophylls
ADP and $\text{P}_i$ (inorganic phosphate)	ATP
$\text{NADP}^+$	NADPH

# Participants of enzymatic stage

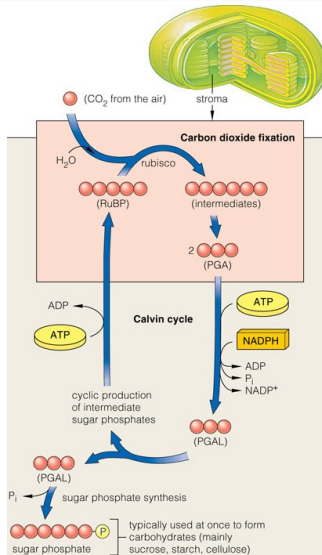
- 1 Carbon dioxide ( $\text{CO}_2$ )
- 2 Hydrogen carrier with hydrogen (NADPH)
- 3 Source of energy (ATP)
- 4 Ribulose biphosphate (RuBP, five-C-hydrocarbonate, " $\text{C}_5$ ")
- 5 Rubisco and other enzymes

**Place:** in the stroma of chloroplast

# Main events of enzymatic stage

- 1  $\text{CO}_2 + \text{C}_5 \text{ (RuBP, ribulose biphosphate)} \xrightarrow{\text{rubisco}} \text{C}_6$
- 2  $\text{C}_6 \longrightarrow 2\text{C}_3 \text{ (PGA, phosphoglyceric acid)}$
- 3  $\text{C}_3 + \text{NADPH} + \text{ATP} \longrightarrow \text{C}_6\text{H}_{12}\text{O}_6 \text{ (or other organic molecules)} + \text{C}_5 + \text{NADP}^+ + \text{ADP} + \text{P}_i \text{ (inorganic phosphate)}$
- 4 Processes above are **Calvin (C<sub>3</sub>) cycle**, because it starts and ends with C<sub>5</sub>
- 5 Organic molecules are synthesized from C<sub>3</sub> (PGA) through energy-rich **PGAL** (phosphoglyceric aldehyde)

# Calvin ( $C_3$ ) cycle





# Results of enzymatic stage

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

# Summary

- **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

## Final question (2 points)

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List more than one difference between light and enzymatic stages of photosynthesis

# 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.  
*Chapter 10.*