Introduction to Botany. Lecture 21

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Outline

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Previous final question: the answer

List at least one difference between light and enzymatic stages of photosynthesis.

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List at least one difference between light and enzymatic stages of photosynthesis.

- Light stage locates in thylakoid membrane, enzymatic—in stroma
- Light stage need sun, enzymatic stage—ATP

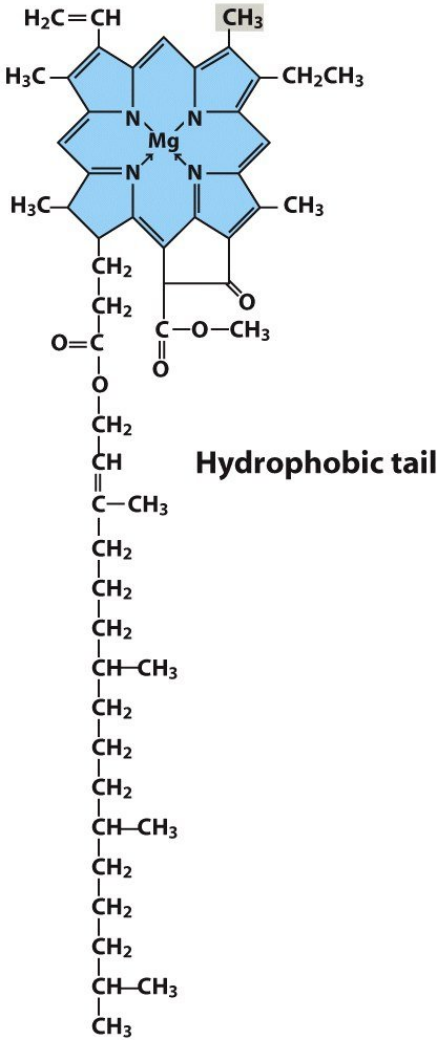
Photosynthesis

Light stage: electron transport, synthesis of ATP and NADPH

Basic ideas of light stage

1. We need ATP
2. It means that we need electrical current through the proton pump
3. To make this current, we need the difference in charge (voltage difference) between thylakoid and stroma
4. To make the difference, we need to segregate ions: positively charged (like H^+) will go from outside and stay inside, negatively charged (like e^- and OH^-) will go from inside and stay outside
5. To segregate, we need the energy and the energy booster. These are sun rays and chlorophyll

Why chlorophyll may be inserted in the membrane



Scheme of light stage

Participants of light stage

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

Where: around thylakoid membrane

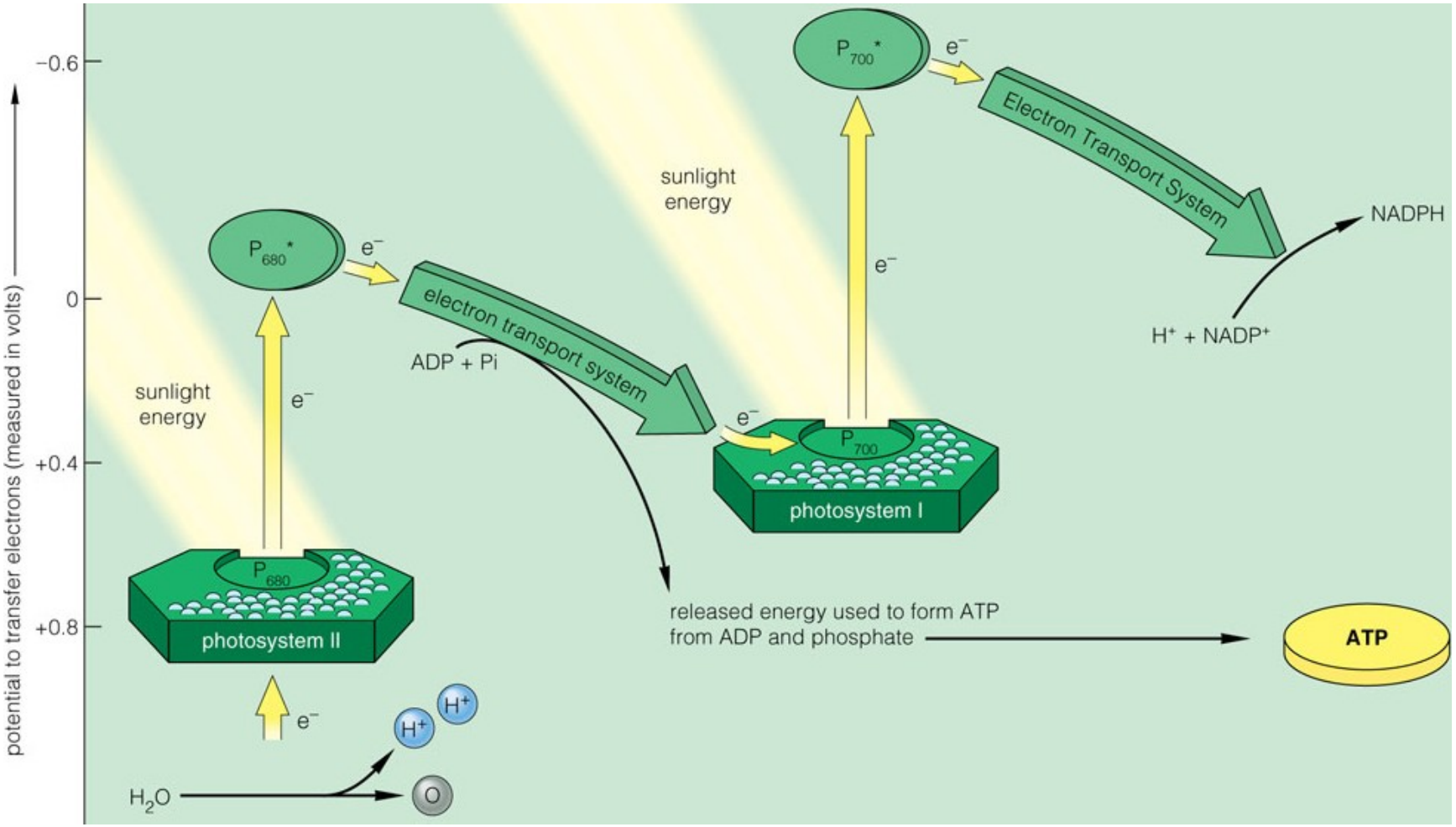
Main events of light stage

1. Chlorophyll + Light $\longrightarrow$ Electron (e^-) + Chlorophyll$^+$
2. $H_20 \longrightarrow H^+ + OH^-$ (accumulates outside)
3. $e^- + H^+$ + Hydrogen carrier ($NADP^+$) $\longrightarrow$ NADPH (moves away)
4. $H_2O \longrightarrow H^+$ (accumulates inside) + e^- + O_2
5. H^+ (inside) + OH^- (outside) $\Longrightarrow$ gradient $\Longrightarrow$ PROTON PUMP $\Longrightarrow$ H_2O, and ADP + P_i (inorganic phosphate) $\longrightarrow$ **ATP**

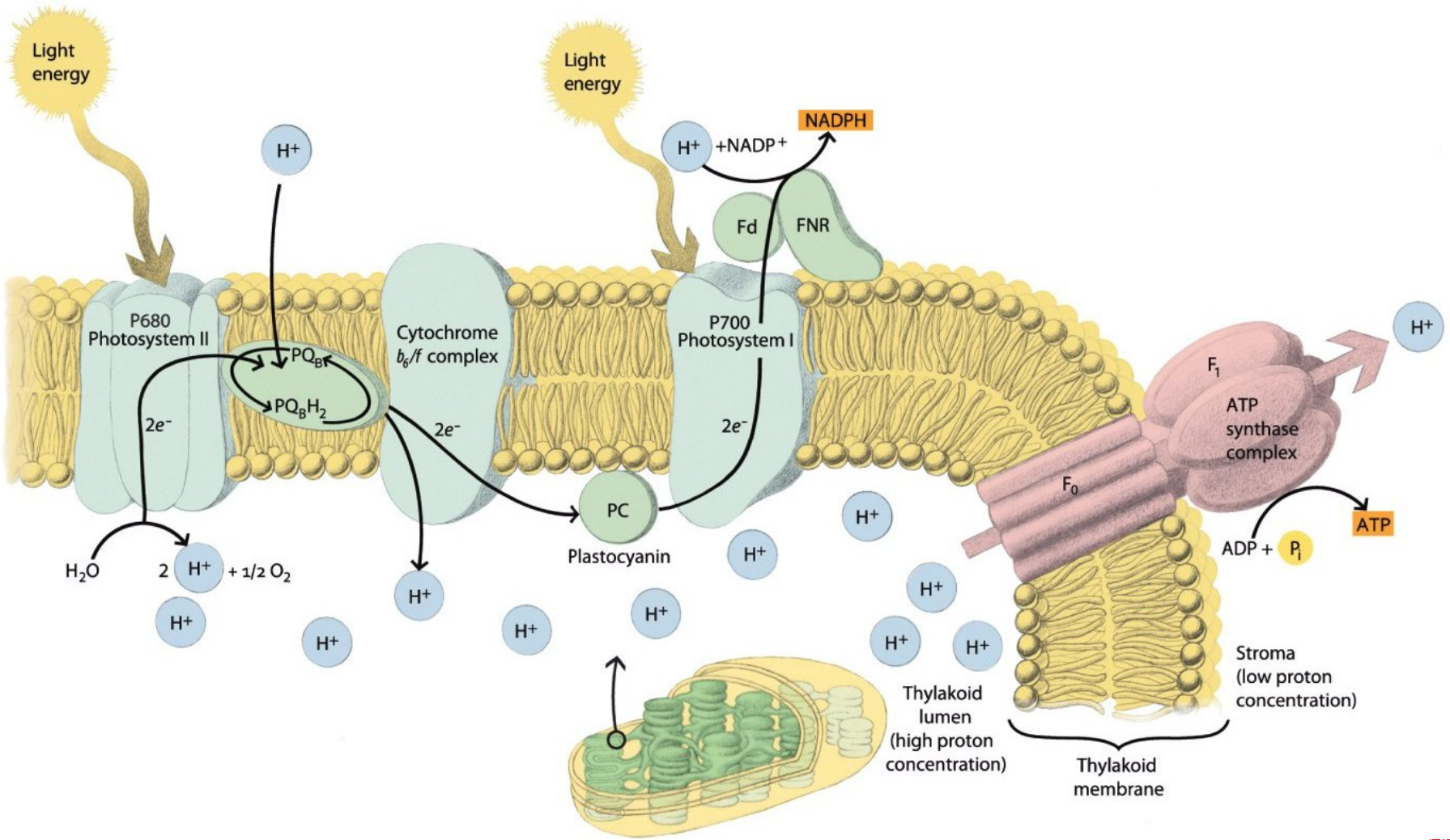
Photosystems I and II

- Photosystem II (P_{680}, contains chlorophylls and carotene) decomposes water and forwards electron to Photosystem I (P_{700}, contains only chlorophylls)
- Ph II/P_{680} makes proton gradient and then ATP: this is a **photophosphorylation**
- Ph I/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 Ph I/P_{700} but do not produce any NADPH, only ATP

Two photosystems: division of labor between chlorophylls



Two photosystems and main events of light stage



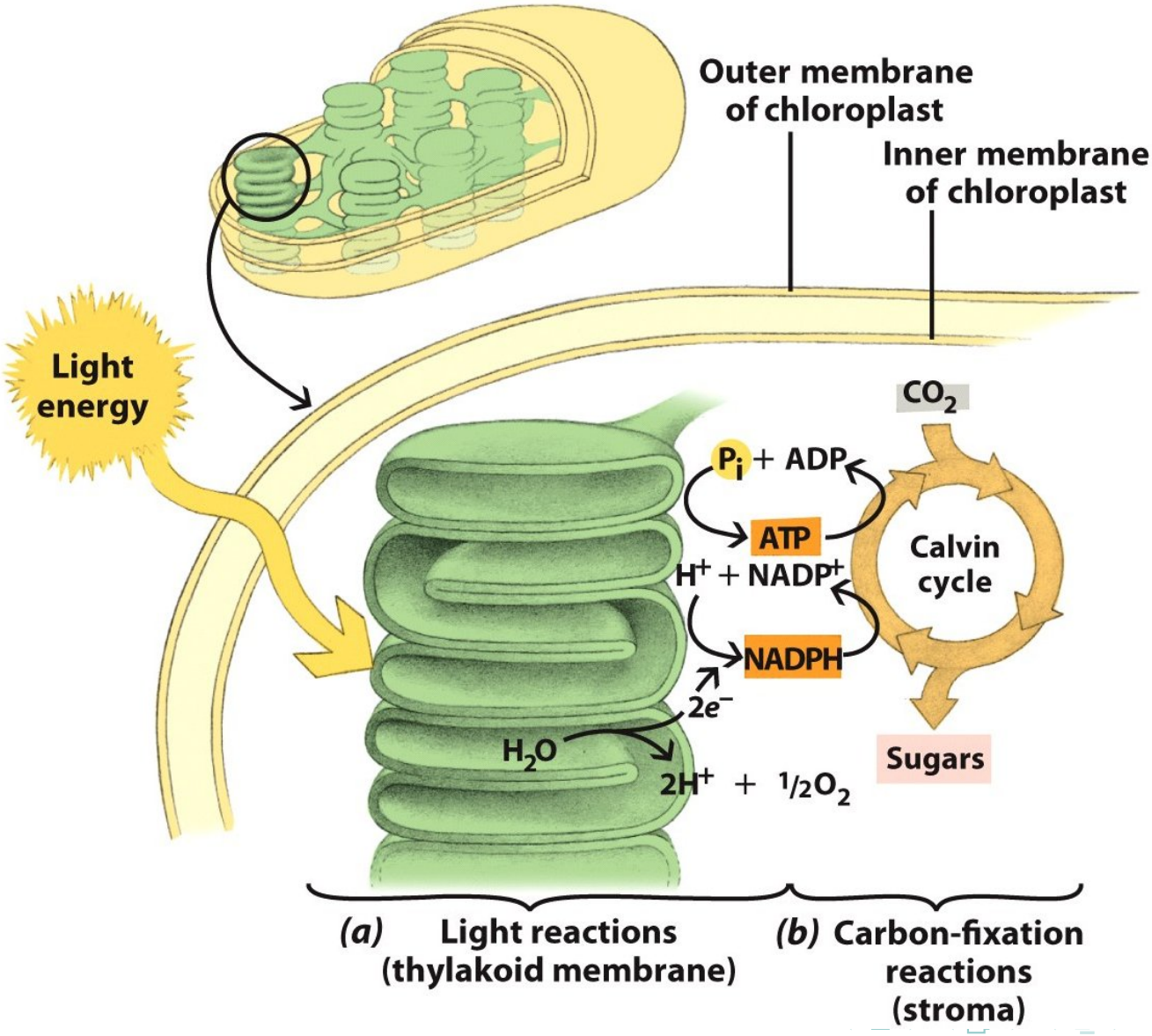
Results of the light stage

At the start	At the end
H_2O	H_2O (result of pump) and $\mathbf{O_2}$
Chlorophylls	Chlorophylls
ADP and P_i (inorganic phosphate)	ATP
$NADP^+$	NADPH

Photosynthesis

Enzymatic stage: fixation of carbon dioxide

Light and enzymatic stages



Participants of enzymatic stage

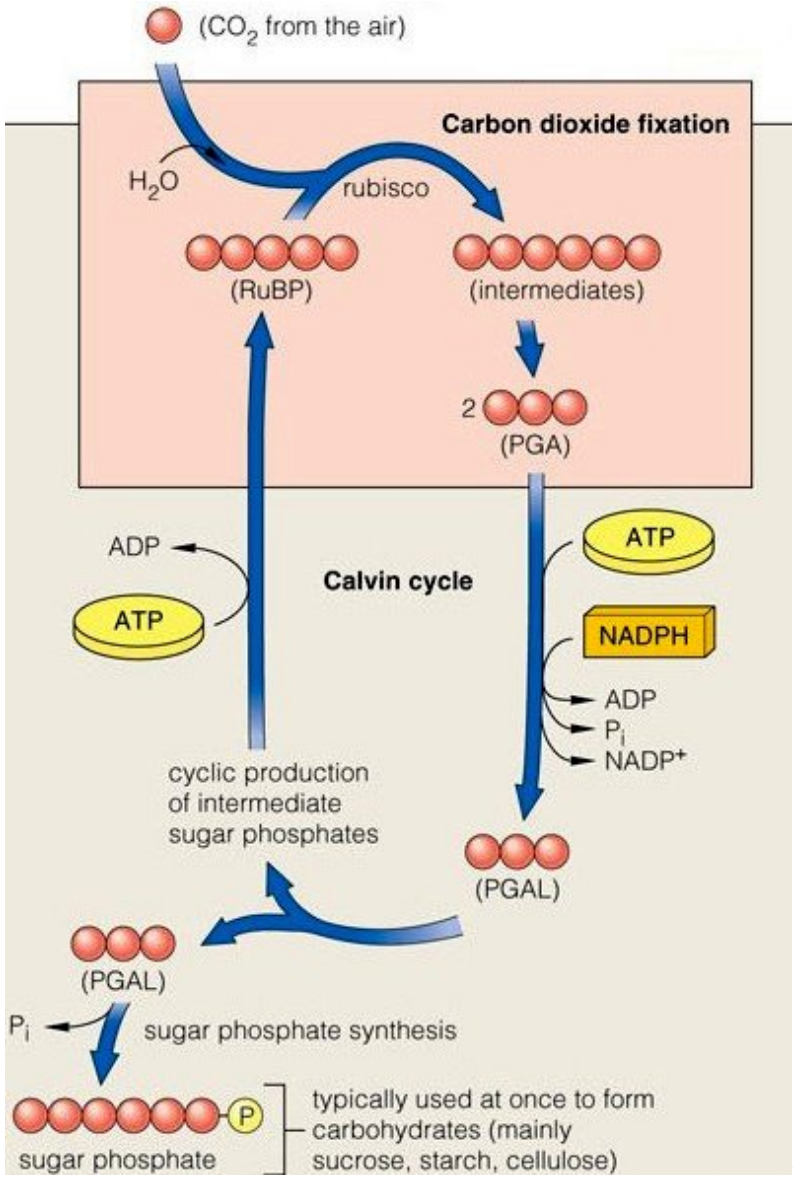
1. Carbon dioxide (CO_2)
2. Hydrogen carrier with hydrogen (NADPH)
3. Source of energy (ATP)
4. Ribulose biphosphate (RuBP, five-C-hydrocarbonate, "C_5")
5. Rubisco and other enzymes

Place: in the stroma of chloroplast

Main events of enzymatic stage

1. CO_2 + C_5 (RuBP, ribulose biphosphate) $\xrightarrow{\text{rubisco}}$ C_6
2. $C_6 \longrightarrow 2C_3$ (PGA, phosphoglyceric acid)
3. C_3 + NADPH + ATP $\longrightarrow$ $C_6H_{12}O_6$ (or other organic molecules) + C_5 + $NADP^+$ + ADP + P_i (inorganic phosphate)
4. Processes above are **Calvin (C_3) *cycle***, because it starts and ends with C_5
5. Organic molecules are synthesized from C_3 (PGA) through energy-rich **PGAL** (phosphoglyceric aldehyde)

Calvin (C_3) cycle



Results of enzymatic stage

At the start	At the end
CO_2	$C_6H_{12}O_6$ (or other organic molecules)
NADPH	$NADP^+$ (and H to organic molecules)
ATP	ADP and P_i (inorganic phosphate)
C_5	C_5
Rubisco	Rubisco

Final question (2 points)

What is wrong in this picture?

Final question (2 points)

What is wrong in this picture?

Before photosynthesis	After photosynthesis
H_2O	O_2
$NADP^+$	NADPH
CO_2	$C_6H_{12}O_6$ (or other organic molecules)

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

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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