Introduction to Botany. Lecture 7

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Outline

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1. Questions and answers
   - Quiz
2. Photosynthesis
   - History
   - Light stage: electron transport, synthesis of ATP and NADPH

Questions and answers

Quiz

Final question (1 point)

Why did Engelmann decide that photosynthetic pigment has a green color?

Final question (1 point)

Why did Engelmann decide that photosynthetic pigment has a green color?

- Because he saw that oxygen-loving bacteria are concentrating only in places where red and blue light present. It means that pigment of question accepts blue and red so it is green.
- In other words: photosynthesis makes oxygen AND bacteria like oxygen AND bacteria concentrate around blue and red spots $\rightarrow$ photosynthesis is going on these blue and red spots $\rightarrow$ photosynthetic pigment accepts blue and red (but not green) $\rightarrow$ photosynthetic pigment IS green.

Next lab

Please bring the printed tree manual.

Photosynthesis

History

Blackman

- In 1905, Frederick Blackman discovered that if light intensity is low, increase of temperature has a little effect on the rate of photosynthesis
  1. If light and temperature were *independent*, this could not happen
  2. If temperature and light were *components of the chain*, than light was first and temperature second
- Consequently, photosynthesis has two stages:
  1. Light stage which relates more with light intensity
  2. “Dark” (now called *enzymatic*) stage which relates more with temperature

Light and enzymatic (“dark”) reactions

- Light reactions depend on the light and water, they produce oxygen and energy (in form of ATP)
- Enzymatic reactions depend on carbon dioxide and water, they take energy from light reactions and result in production of carbohydrates

Four equations of photosynthesis

1. $6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$ is *not a formula*, but merely a general description of a process
2. Water molecules arise from both sides, and the better formula is
   $6CO_2 + 12H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6H_2O + 6O_2$
   or even
3. carbon dioxide + hydrogen donor $\xrightarrow{\text{light}}$ carbohydrate + water + oxidized hydrogen donor
4. And the best one is probably
   $CO_2 + H_2O \xrightarrow{\text{light}} \text{carbohydrates} + H_2O + O_2$

Photosynthesis

Light stage: electron transport, synthesis of ATP and NADPH

Participants of light stage

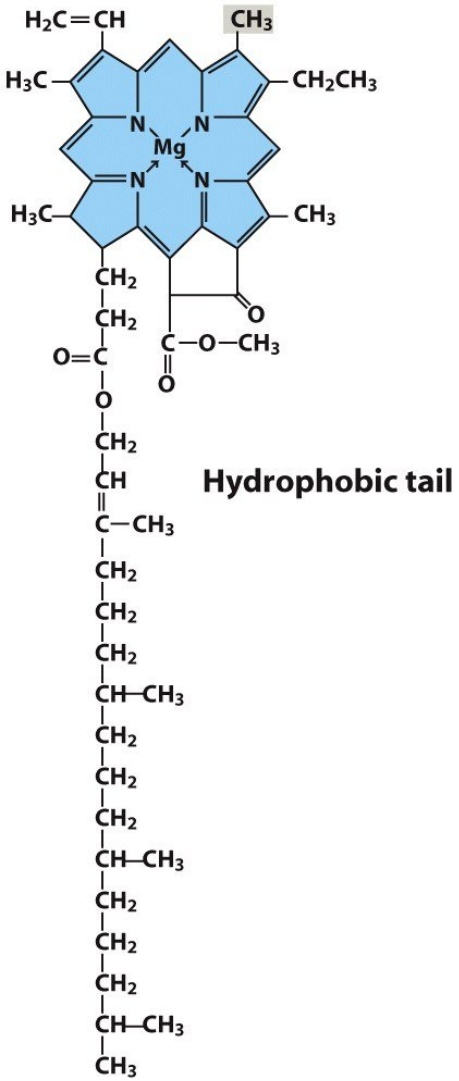
1. Chlorophyll (photosystems II and I)
2. Light
3. Water
4. ATP synthase (ATPase)
5. Protons (H^+)
6. Hydrogen carrier ($NADP^+$)

Where: around thylakoid membrane

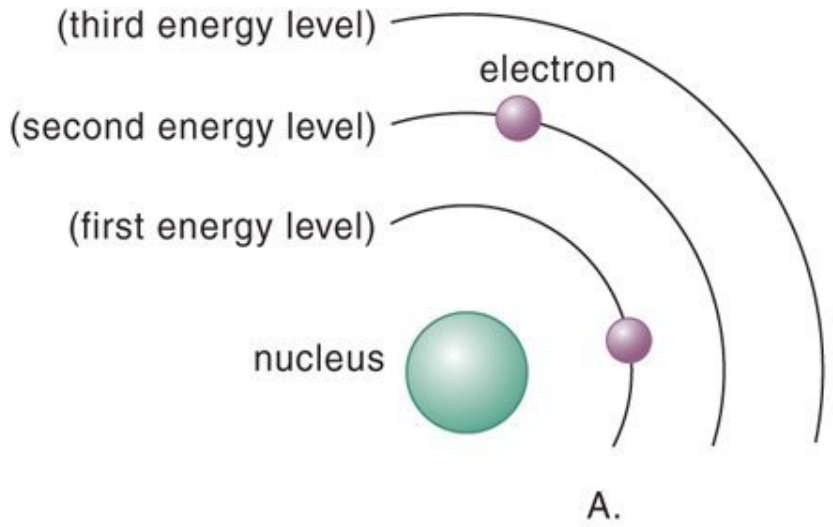
Logic of the light stage

1. To assemble carbon dioxide into sugar, we need ATP
2. To make ATP, we need *electrical current* through the proton pump
3. To make this current, we need the *difference in charge* (voltage difference) between thylakoid and matrix (stroma) compartments
4. To make this 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 ions, we need the energy and the energy booster. These are sun rays and chlorophyll

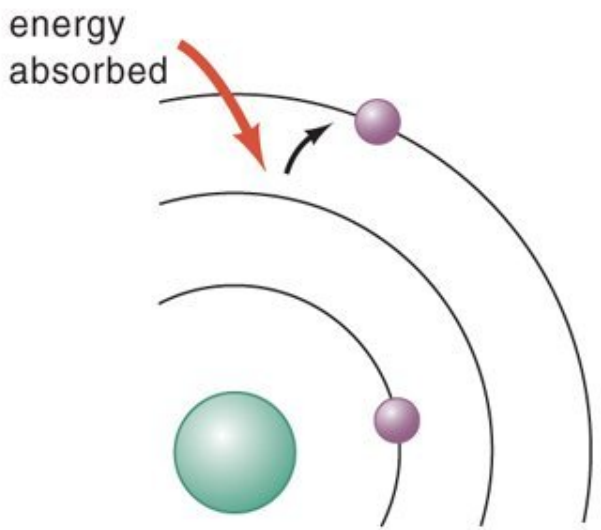
Why chlorophyll is good for the membrane



How chlorophyll works: excitation of the electron

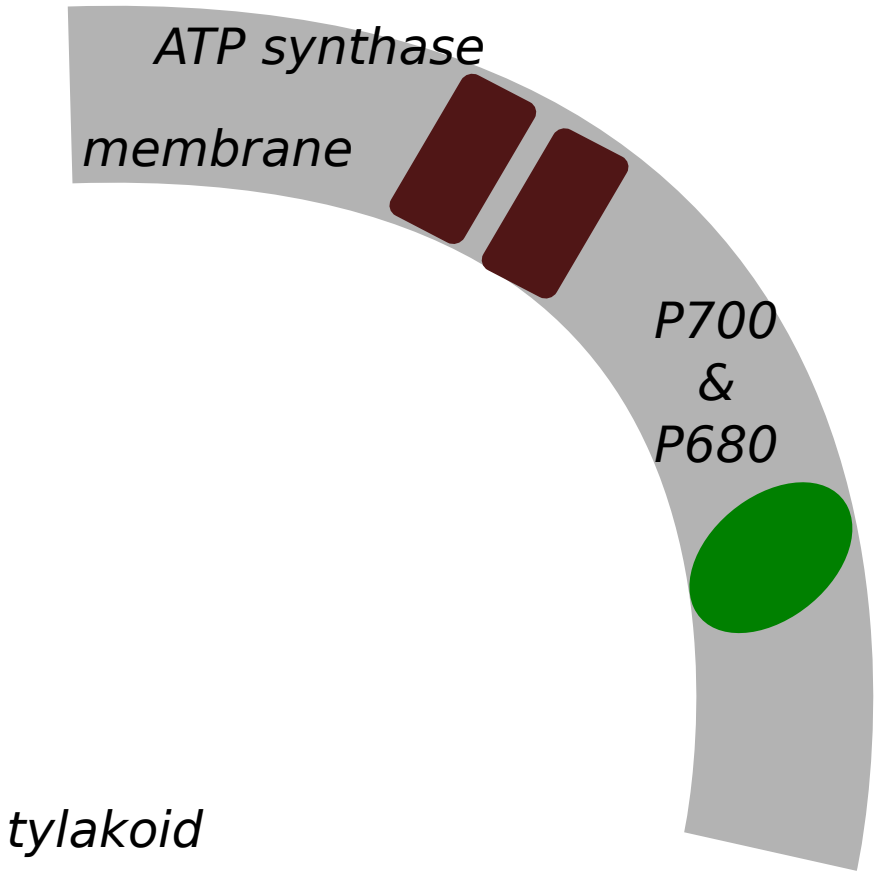


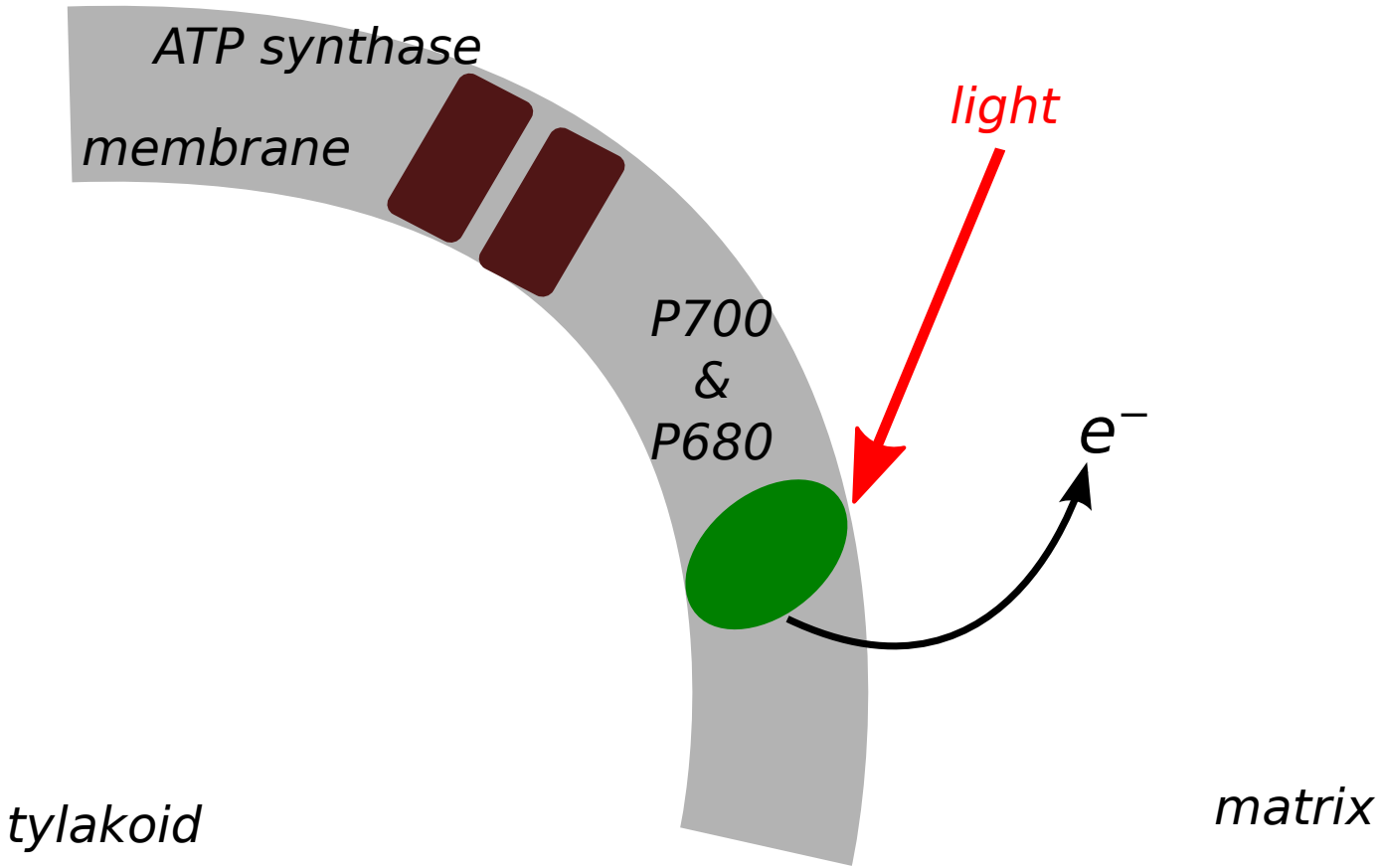
A.

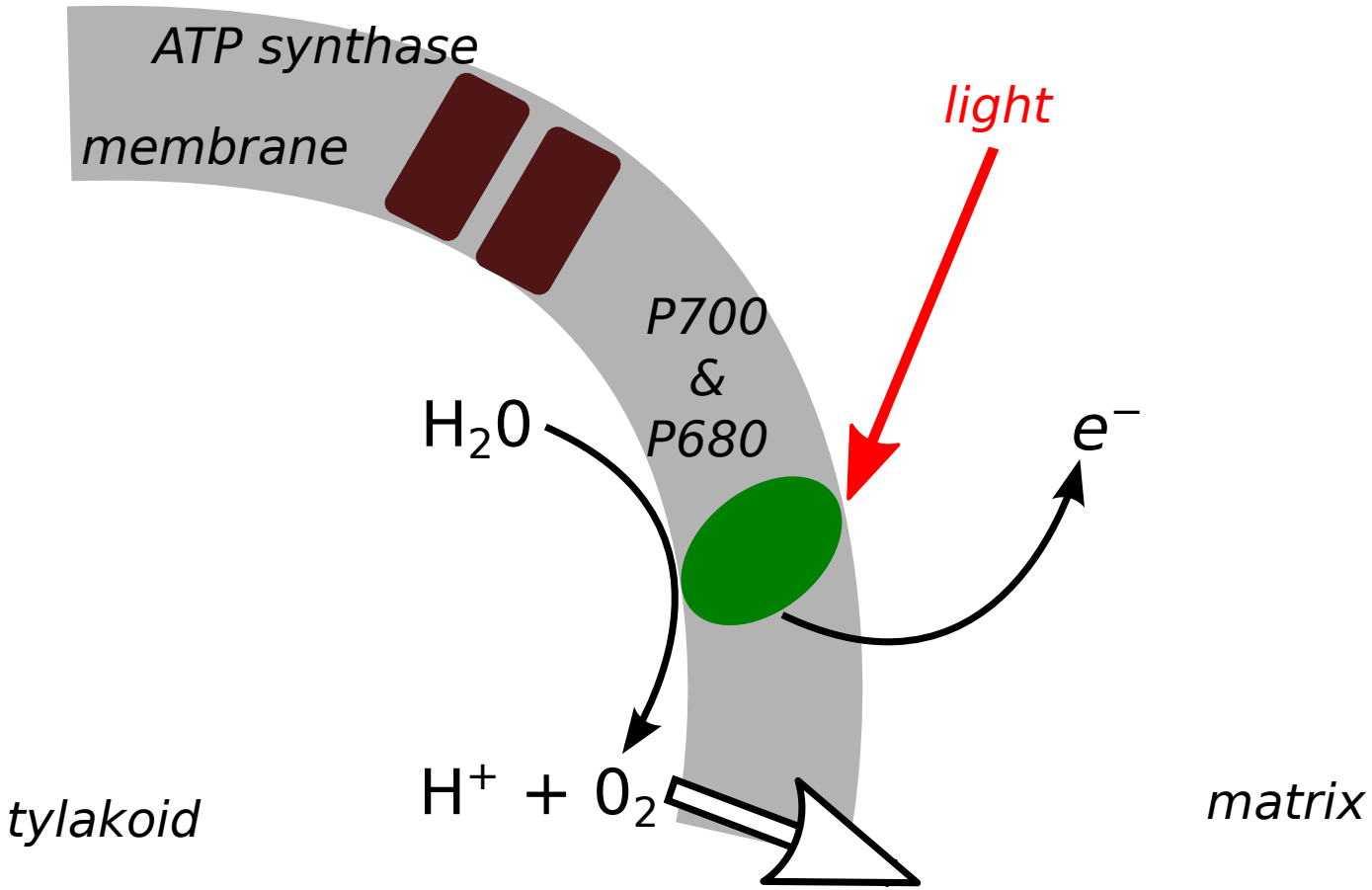


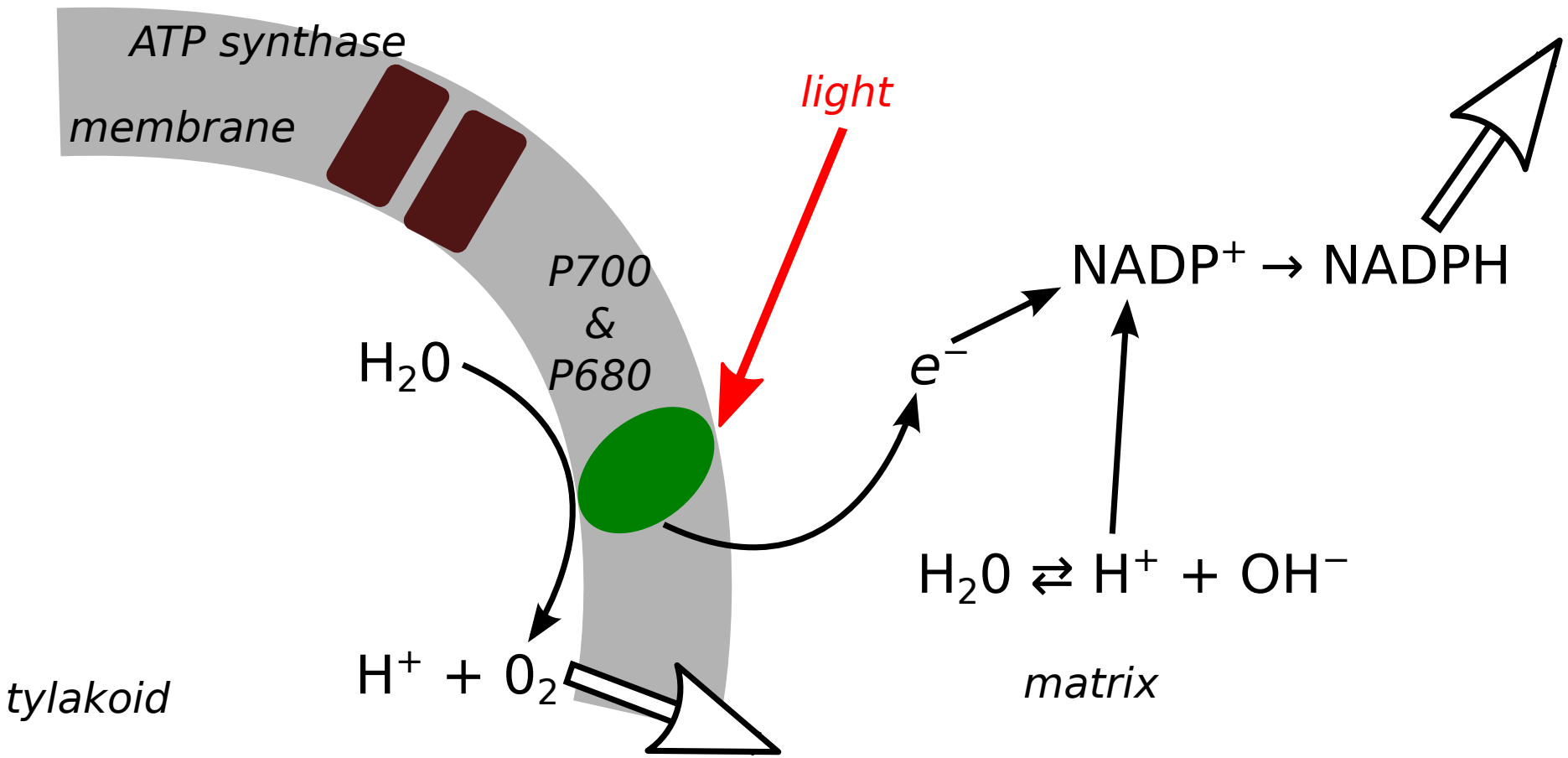
B.

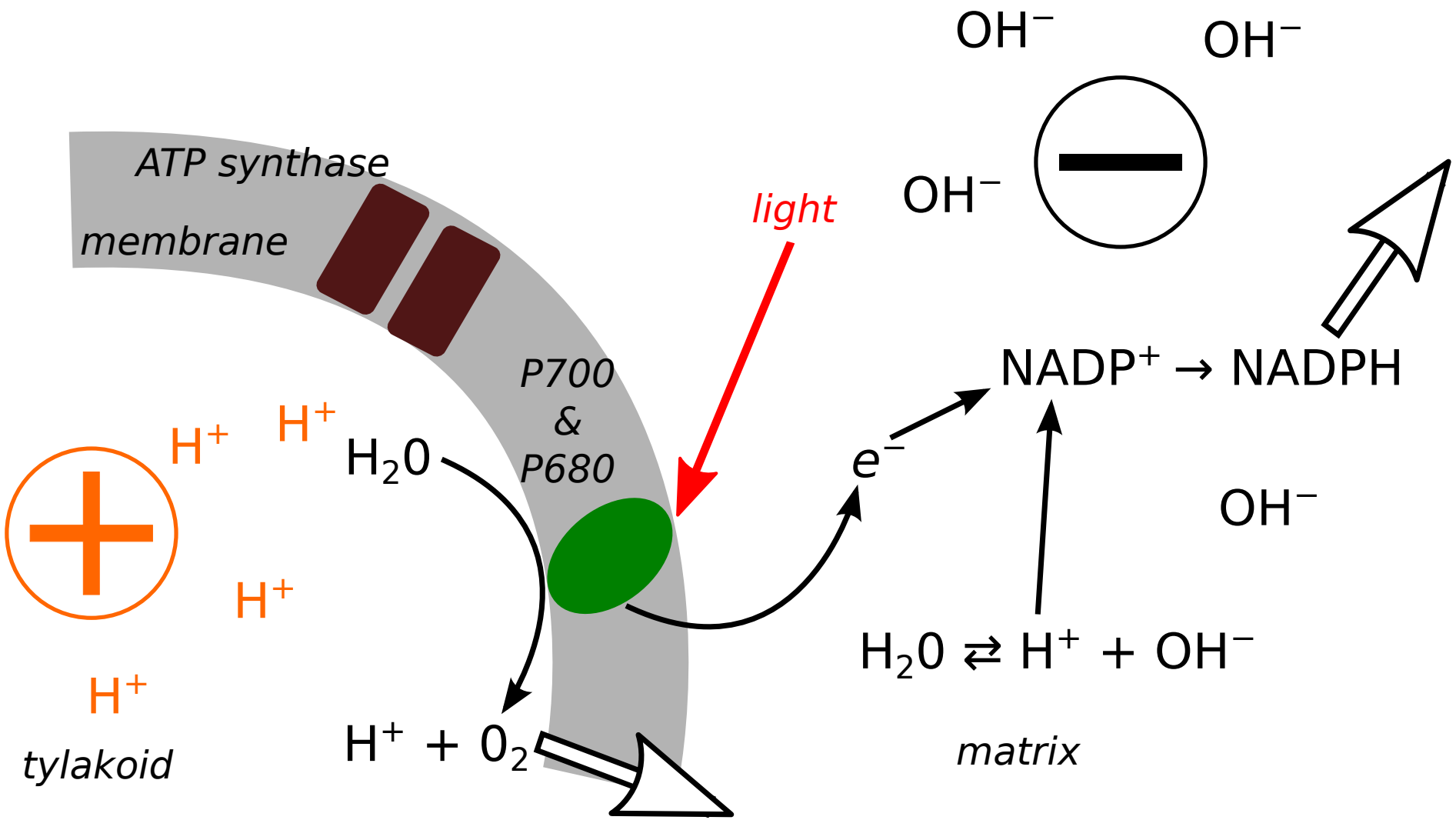
Scheme of light stage

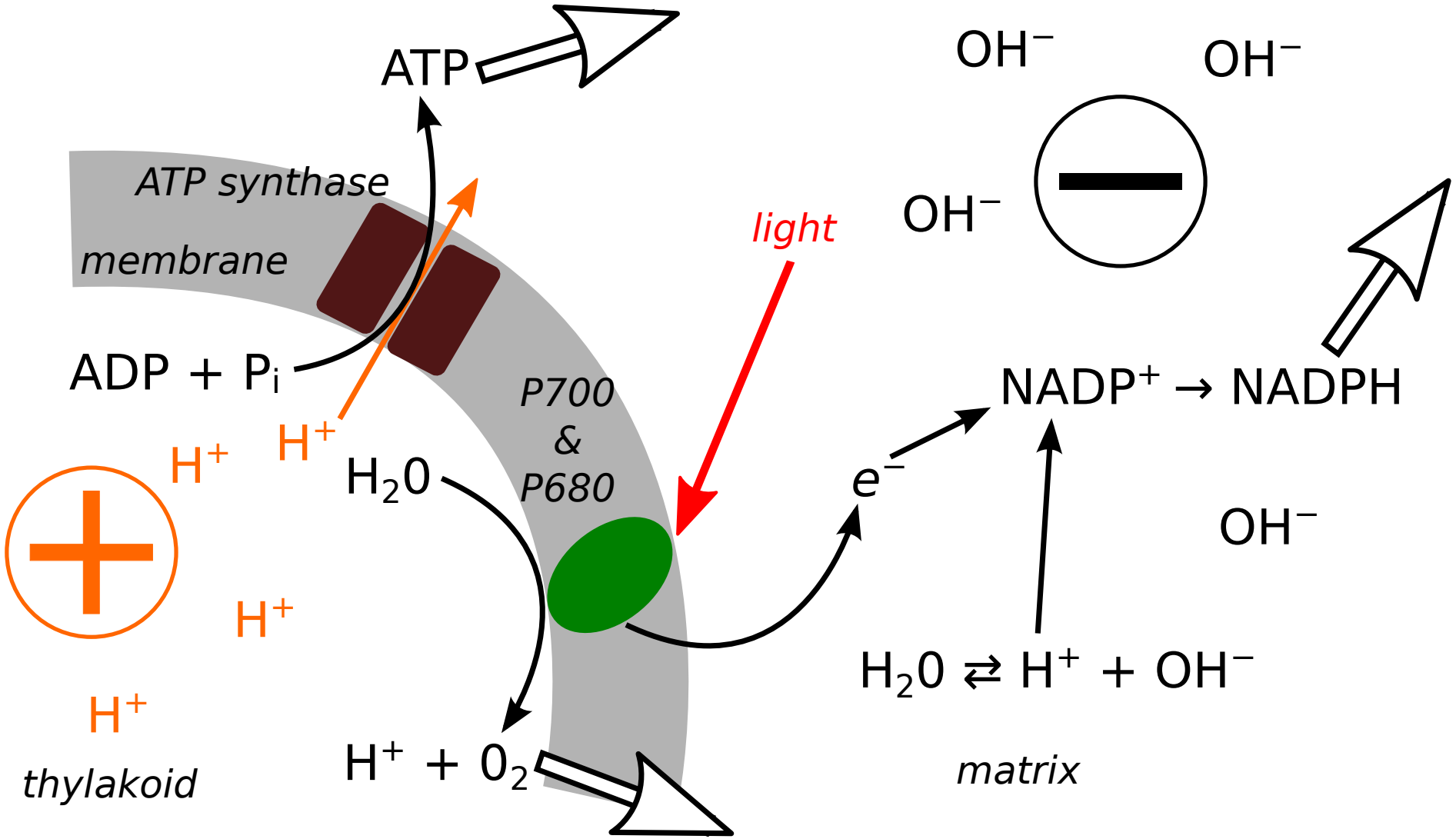

ATP synthase
membrane
P700
&
P680
tylakoid
matrix


ATP synthase
membrane
light
P700
&
P680
e^-
tylakoid
matrix


ATP synthase
membrane
light
P700
&
P680
H_2O
e^-
$H^+ + O_2$
tylakoid
matrix


ATP synthase
membrane
light
P700
&
P680
H_20
e^-
$NADP^+ \rightarrow NADPH$
$H_20 \rightleftarrows H^+ + OH^-$
$H^+ + 0_2$
tylakoid
matrix


ATP synthase
membrane
light
P700
&
P680
OH^-
OH^-
OH^-
$NADP^+ \rightarrow NADPH$
OH^-
H^+
H^+
H^+
H^+
H_20
e^-
$H_20 \rightleftarrows H^+ + OH^-$
$H^+ + 0_2$
tylakoid
matrix


ATP
ATP synthase
membrane
ADP + Pi
H+
H+
H+
H+
H+
thylakoid
H20
P700
&
P680
light
e−
H+ + 02
OH−
OH−
OH−
NADP+ → NADPH
OH−
H20 ⇄ H+ + OH−
matrix

Main events of light stage

1. Chlorophyll + Light $\longrightarrow$ Electron (e^-) + Chlorophyll$^+$
2. e^- + H^+ (from water) + Hydrogen carrier ($NADP^+$) $\longrightarrow$ NADPH (moves away)
3. $H_2O \longrightarrow H^+$ (accumulates inside) + e^- + O_2
4. H^+ (inside) + OH^- (from water, located outside) $\Longrightarrow$ gradient $\Longrightarrow$ proton pump $\Longrightarrow$ H_2O
   TOGETHER WITH
   ADP + P_i (inorganic phosphate) $\longrightarrow$ **ATP**

Photosystems

- Photosystem II (P_{680}, contains chlorophylls and carotene):
  1. decomposes water;
  2. forwards electron to Photosystem I;
  3. makes proton gradient
- Photosystem I (P_{700}, contains only chlorophylls) makes NADPH

Photosystems movie

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

Final question (2 points)

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Explain the role of $NADP^+$

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

For Further Reading

A. Shipunov.
Introduction to Botany [Electronic resource].
2016.
Mode of access:
http://ashipunov.info/shipunov/school/biol_154