Introduction to Botany. Lecture 5

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Outline

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1. Questions and answers

2. Photosynthesis
   - Light stage: electron transport, synthesis of ATP and NADPH

Previous final question: the answer

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

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- Mouse and candle both "spend good air"
- Plant revives the air

Blackman

- In 1905, Frederick Blackman discovered that if light intensity is low, increase of temperature has a little effect on the rate if 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
   $CO_2 + H_2O \xrightarrow{\text{light}}$ carbohydrates $+ H_2O + O_2$

Photosynthesis

Light stage: electron transport, synthesis of ATP and NADPH

Participants of light stage

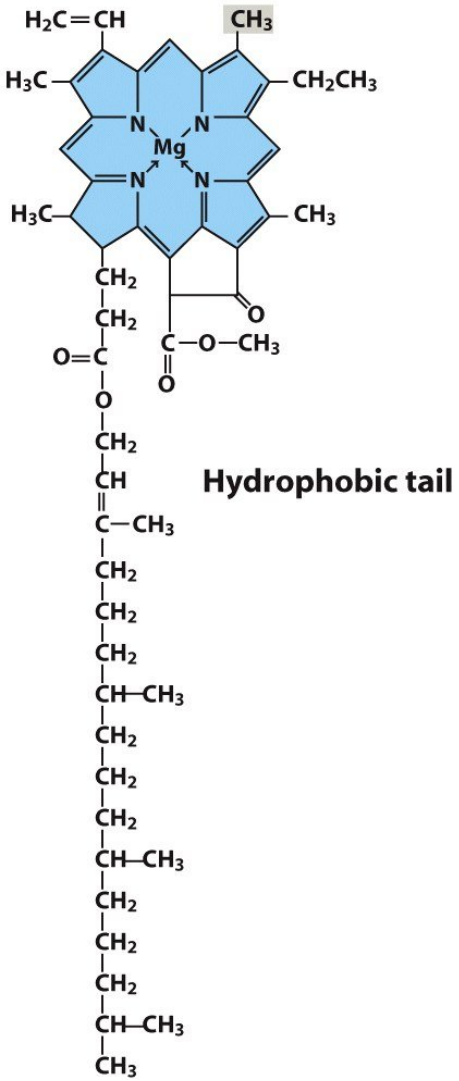
1. Chlorophyll (photosystems II and I)
2. Light
3. Water
4. ATP synthase (ATPase)
5. Protons (H^+)
6. Hydrogen carrier ($NADP^+$)

Where: around thylakoid membrane

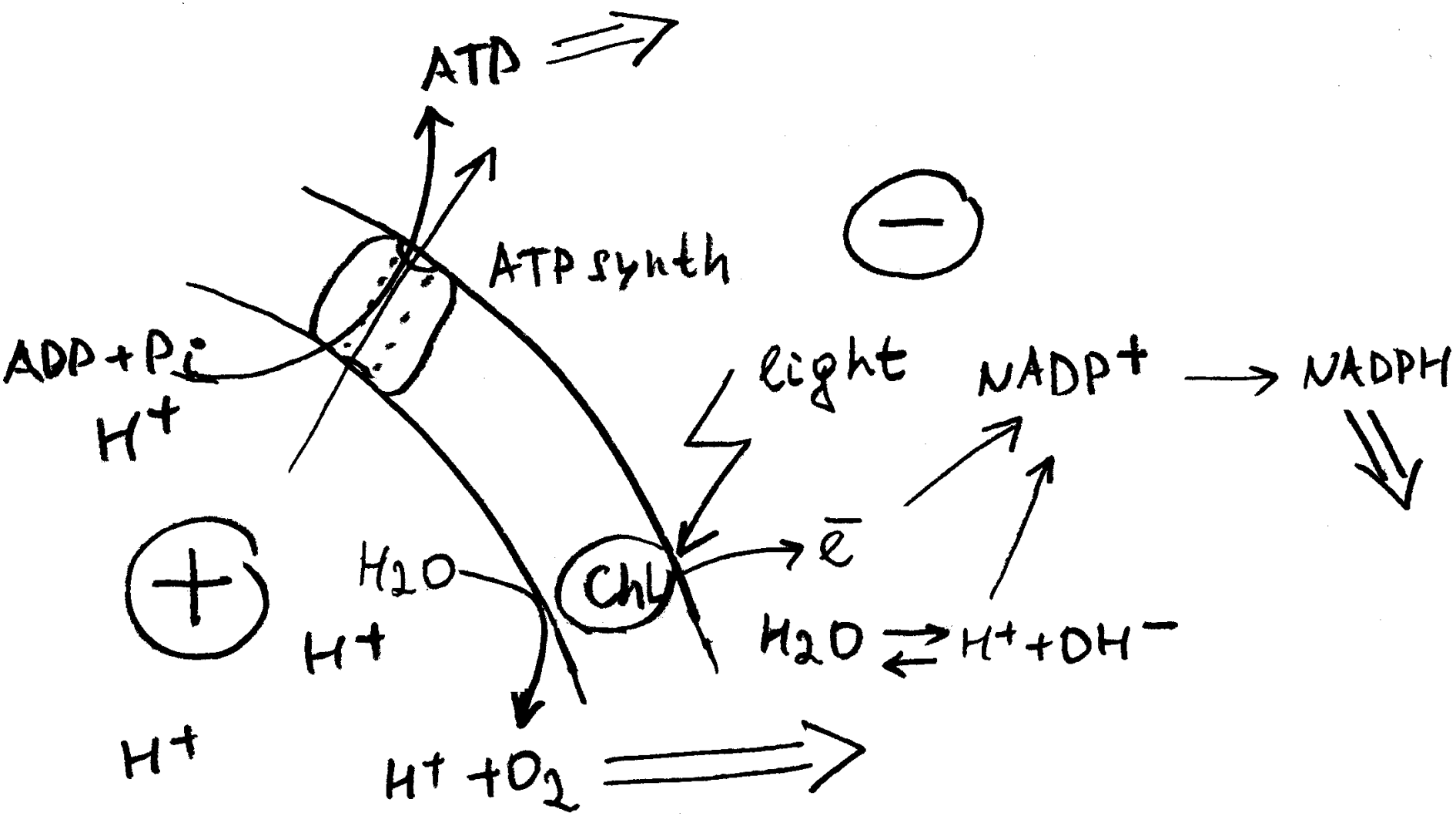
Logic of the light stage

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 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



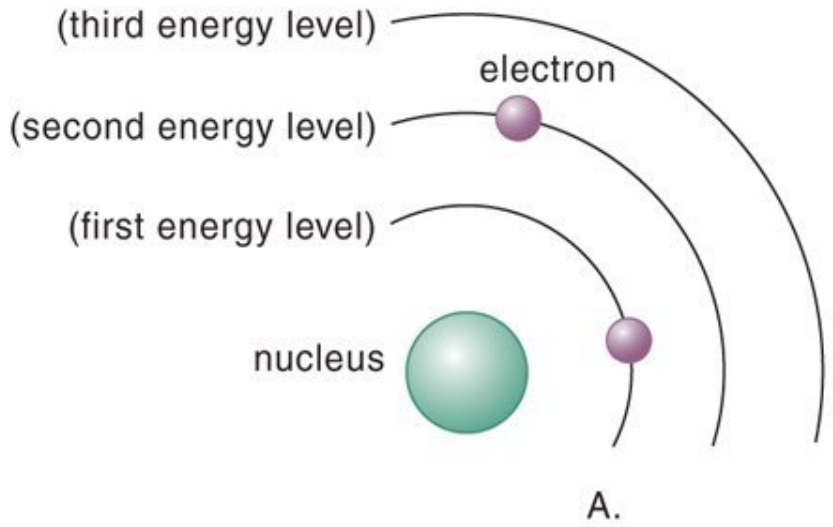
Scheme of light stage


ATP
ATP synth
ADP + Pi
H+
light
NADP+
NADPH
H2O
Chl
e−
H2O ⇄ H+ + OH−
H+
H+
H+ + O2

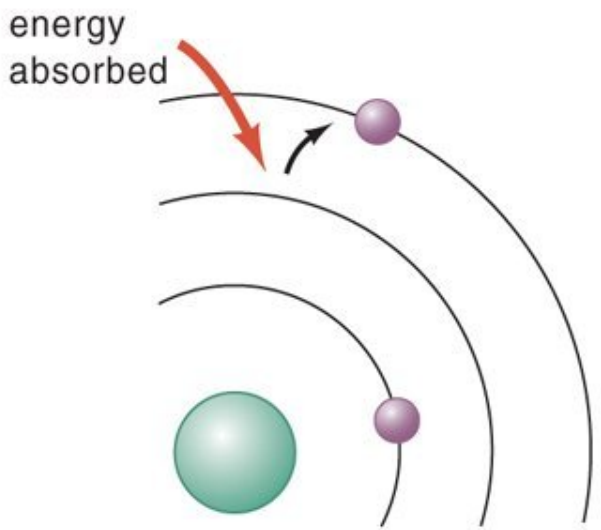
Main events of light stage

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**

How chlorophyll works: excitation of the electron



A.

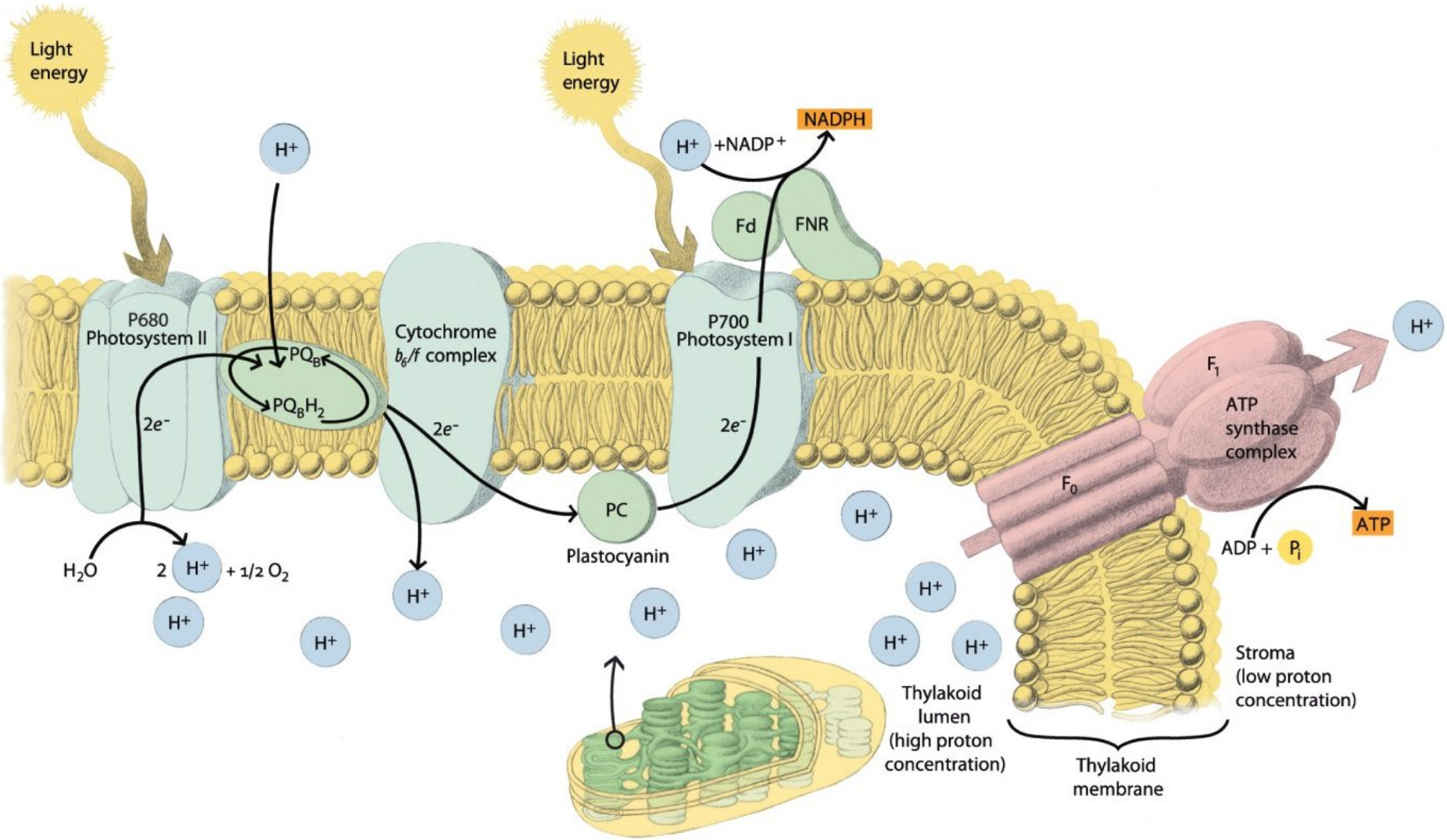


B.

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)
- Photosystem II (P_{680}) splits water, makes proton gradient and then ATP
- Photosystem I (P_{700}) makes NADPH

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

Final question (4 points)

Which photosystem is responsible for every product of the light stage?

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At the end	Photosystem ...
H_2O (result of pump) and $\mathbf{O_2}$	...
Chlorophylls	...
ATP	...
NADPH	...

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].
2010—onwards.
Mode of access:
`http://ashipunov.info/shipunov/school/biol_154`

Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy.
Plant Biology. 2nd edition.
Thomson Brooks/Cole, 2006.
Chapters 2 and 10.