

Introduction to Botany: BIOL 154

Study guide for Exam 1

Alexey Shipunov

Lectures 2–9

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Outline

Help in greenhouse?

Volunteers to help on Friday, August 31st, 3pm?

1 Intro test

1.1 Multiple choice questions

Question 1

- 1 Why do our deciduous plants drop their leaves?
 - A. To prevent freezing
 - B. To prevent desiccation
 - C. To prevent sunburns

Question 2

- 2 Where does human digestion process start?
 - A. In the mouth
 - B. In the intestines
 - C. In the stomach

Question 3

- 3 Which birds do NOT live in Minot on winter?
 - A. Crows
 - B. Hummingbirds
 - C. Sparrows

Question 4

4 Home country of watermelon:

- A. Central America
- B. Canada
- C. South Africa

Question 5

5 Why do insectivorous plants eat insects?

- A. To obtain the lacking mineral resources
- B. To get an addition to their common “menu”
- C. To get rid of herbivores

Question 6

6 Which insects have no queen?

- A. Bumblebees
- B. Ants
- C. Cockroaches

Question 7

7 Oak tree is pollinated by:

- A. Wind
- B. Bees
- C. Flies

Question 8

8 Spider has:

- A. 6 legs
- B. 8 legs
- C. 4 legs

Question 9

9 Apple flower has:

- A. 5 petals
- B. 4 petals
- C. 3 petals

Question 10

10 Frightened man has:

- A. Bigger pupils
- B. Smaller pupils
- C. Normal pupils

Question 11

11 Polar bears are not eating penguins because:

- A. Penguins run very fast
- B. They cannot meet
- C. Penguins are poisonous for bears

Question 12

12 How many toes are on each of cat's hind legs?

- A. 5
- B. 4
- C. 3

Question 13

13 Pineapple is a:

- A. Tree
- B. Shrub
- C. Herb

Question 14

14 If somebody has an artery cut on the arm or leg, it is recommended:

- A. Put a tight bandage below the cut
- B. Put a tight bandage above the cut
- C. Do nothing

Question 15

15 Which of the following is the most precise statement?

- A. We are breathing to support our life
- B. We are breathing to obtain the energy from food
- C. We are breathing to have enough strength for food consuming

Question 16

16 Which tree is better to plant in Minot house backyard:

- A. Sycamore
- B. Ash
- C. Yew

Question 17



17 Moles eat:

- A. Worms
- B. Roots
- C. Frogs

Question 18

18 Which fish gives birth to the fully developed offspring?

- A. Sturgeon
- B. Shark
- C. Flounder

Question 19

19 Which human organ lives longer?

- A. Heart
- B. Lungs
- C. Brains

Question 20

20 Which plant normally has a longer root?

- A. Spruce
- B. Chokecherry
- C. Blueberry

The key

1B; 2A; 3B; 4C; 5A; 6C; 7A; 8B; 9A; 10A; 11B; 12B;
13C; 14B; 15B; 16B; 17A; 18B; 19A; 20B

Please calculate a sum (every right answer = 1 virtual point)

1.2 Comments to introductory test

Question 1

1 Why do our deciduous plants drop their leaves?

- A. To prevent freezing
- B. **To prevent desiccation**
- C. To prevent sunburns

Question 2

2 Where does human digestion process start?

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- B. In the intestines
- C. In the stomach

Amylase and lipase

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Bumblebees

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- C. Flies



Oak flowers

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- B. **8 legs**
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C. Penguins are poisonous for bears



 POLAR BEAR DISTRIBUTION (approx.)

12 How many toes are on each of cat's hind legs?

- A. 5
- B. 4
- C. 3



Question 13

13 Pineapple is a:

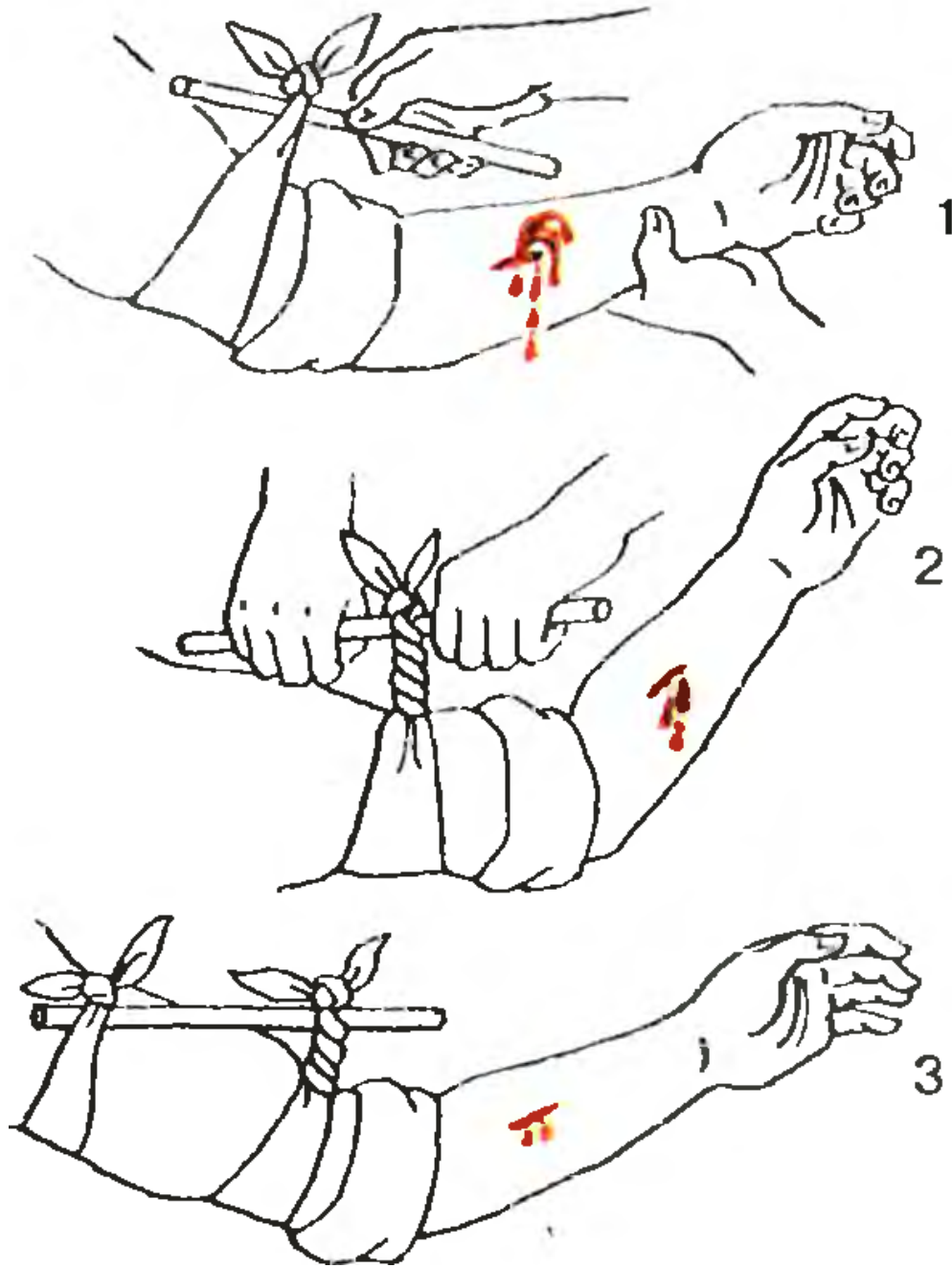
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- B. Shrub
- C. **Herb**



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- B. **Put a tight bandage above the cut**
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B. **Ash**

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B. Roots

C. Frogs



Question 18

18 Which fish gives birth to the fully developed offspring?

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B. **Shark**

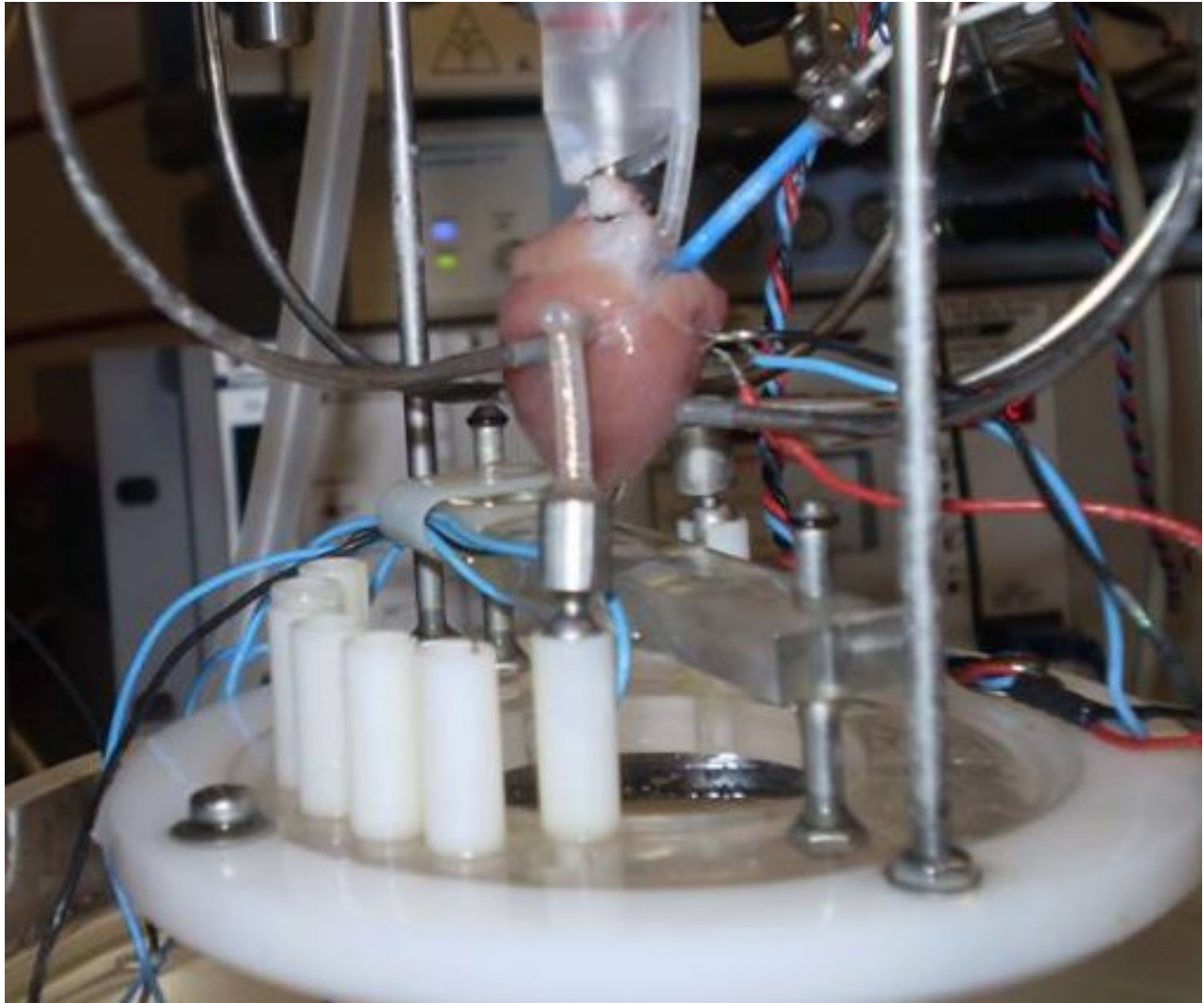
C. Flounder



Question 19

19 Which human organ lives longer?

- A. **Heart**
- B. Lungs
- C. Brains



Question 20

20 Which plant normally has a longer root?

- A. Spruce
- B. **Chokecherry**
- C. Blueberry



Fallen

spruce tree

2 Importance of Plants

2.1 Class discussion

Importance of plants

Why are plants important?

Final question (1 point)

Why are plants important?

Summary

- BIOL 154: download (and read!) the syllabus from the Web site (http://ashipunov.info/shipunov/school/biol_154/)
- Plant is not an animal!
- Plants are extremely important, highly diverse and deserve a scientific study

For Further Reading

References

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

Outline

3 Questions and answers

Importance of plants

Why are plants important?

- Food
- Oxygen
- ...?

[aesthetics, landscape, materials, drugs,...]

4 Plants: definition

4.1 Plants₁ and plants₂

Plants₁ and plants₂

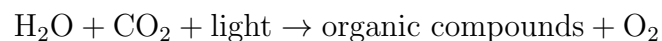
- Plants₁ are all green photosynthetic organisms
- Plants₂ are “typical plants” (better definition follows)

The nature of two definitions

- Plants₁—ecological definition (based on the role in nature)
- Plants₂—taxonomic definition (based on the evolution)

Plants₁ is about ecology

Plants₁ are *photosynthetic organisms*:



Some plants₁ could taxonomically be bacteria or even animals!

Green slugs





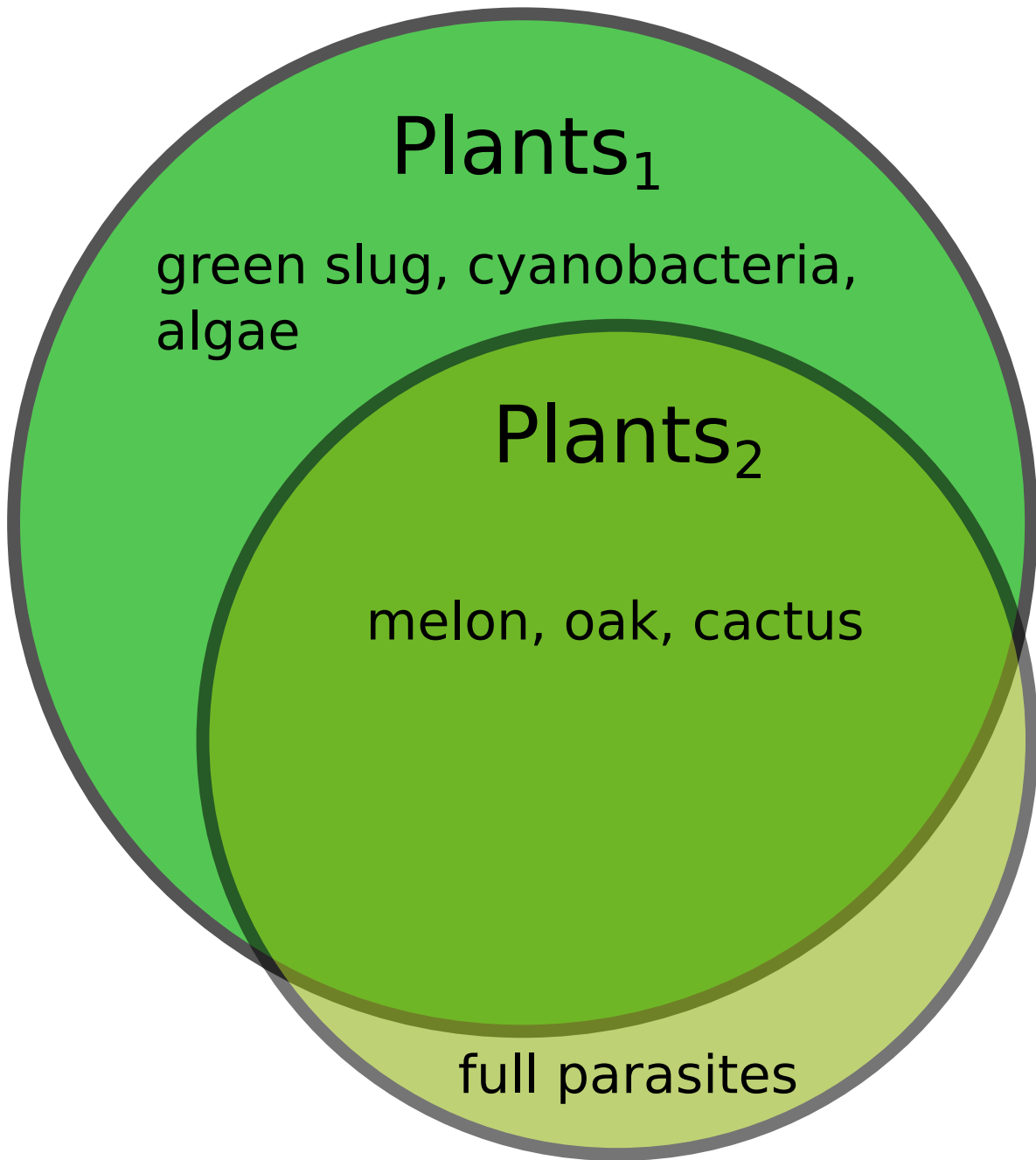
Green slugs obtain chloroplasts from algae, but keep them all their life, feed from them and even use chloroplast genes.

Green *Hydra*



No mouth!

Plants₁ and plants₂ are similar but not the same



Hydnora



Root parasite

Pilostyles



Tissue parasite

Dodder



Stem parasite

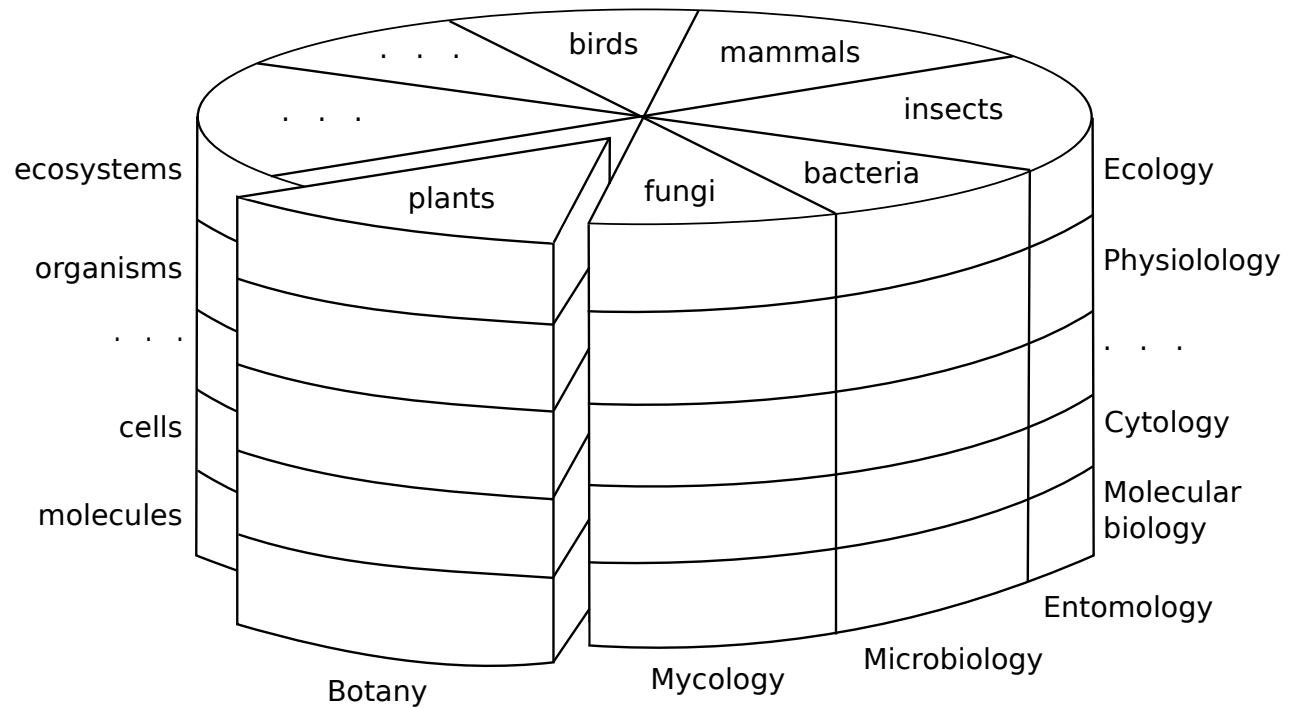
5 Plants in general

5.1 Levels of organization

Levels of organization

- Ecosystems OR Taxa
- Populations
- Organisms
- Organs
- Tissues
- Cells
- Organelles
- Molecules

Place of botany



Layered cake of biology (Odum, 1971): botany is a “slice science”

5.2 Taxonomy

Ranks

Most scientists accept seven main ranks:

- Kingdom
- Phylum
- Class
- Order
- Family
- Genus
- Species

Names

- Names of species are binomials like *Solanum tuberosum* (potato)
- Names of other ranks are uninomials like **Vegetabilia** (plant kingdom)

Plants₁ and plants₂ (updated)

- Plants₁ are all photosynthetic organisms
- Plants₂ are **Vegetabilia**: multi-tissued, terrestrial, primarily photosynthetic eukaryotes

Summary

- “Plants” have **two definitions**
- Botany is a “slice” science

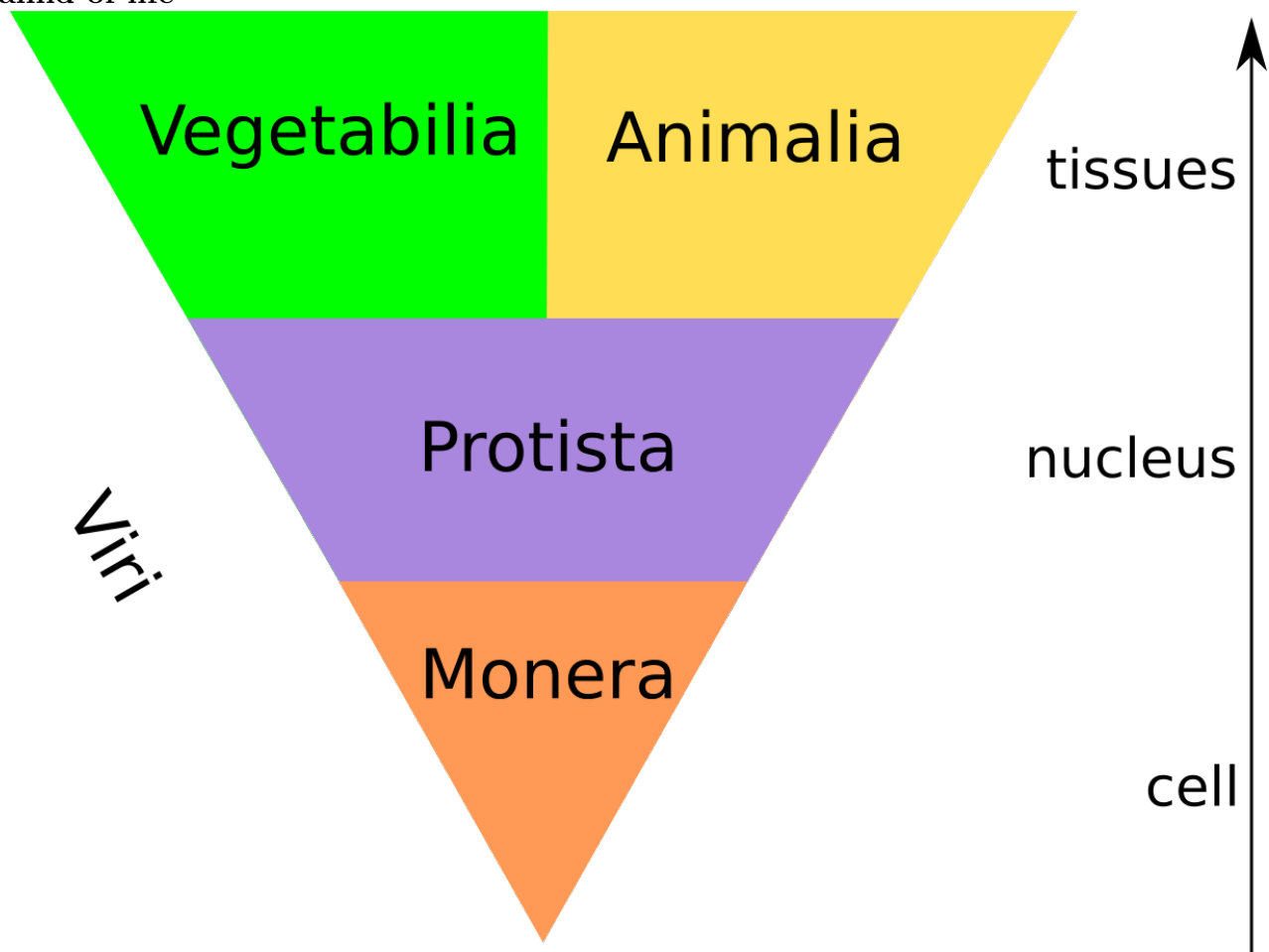
For Further Reading

References

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

Outline

Pyramid of life



Questions about pyramid

What is Monera? Prokaryotes: (1) Bacteria and (2) Archaea

What is Protista? Eukaryotes without tissues

Where are eukaryotes? Protista, Vegetabilia and Animalia

Where are fungi? They belong to different protists

Where are plants₂? Vegetabilia

Where are plants₁? Here it is not applicable

Why are two groups on one level? Vegetabilia and Animalia both have tissues but obtained them for the radically different purposes. Animals acquired *kinoblast* and *phagocytoblast* **to hunt and digest**, and plants have *epidermis* and *photosynthetic tissue* **to survive on land**.

6 Ways of life

6.1 Energy and food

Ways of life

- How to obtain energy?
 - A. From sun light: **phototrophy**
 - B. From chemical reactions with inorganic matter (“rocks”): **lithotrophy**
 - C. From breaking organic molecules into inorganic (typically, carbon dioxide and water): **organotrophy**
- How to obtain building blocks?
 - A. From assimilation of carbon dioxide: **autotrophy**
 - B. From other living beings: **heterotrophy**

Six life styles and taxonomy

	Phototrophs	Lithotrophs	Organotrophs
Autotrophs	Plants ₁ : some Monera, some Protista, most of Vegetabilia	Some Monera	Some Monera
Heterotrophs	Some Monera	Some Monera	Majority of Animalia and many Protista and Monera*

* Note that green plant cells do both photoautotrophy and organoheterotrophy.

Plants₁, plants₂ and life styles

- Plants₁ are **photoautotrophs**
- Plants₂ are photoautotrophs too but there are exceptions: **fully parasitic plants**. Formally, many parasitic plants are plants₂ but not plants₁
- Carnivorous plants (like sundew or Venus flycatcher) are all photoautotrophs! They “eat” animals to obtain fertilizers: nitrogen and phosphorous.

7 Basics of life

7.1 Chemistry of life

Very basics of chemistry

- Atoms
 - Protons
 - Neutrons
 - Electrons
- Atomic weight
- Isotopes
- Elements
- Periodic table: rows and columns
- Chemical bonds: ionic, covalent, hydrogen
- Valence and group
- Molecules
- Molecular weight

Final question (3 points)

How many protons, electrons and neutrons are in niobium atom?

Summary

- “Carnivorous” plants are not carnivores

For Further Reading

References

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

Outline

8 Questions and answers

8.1 Quiz

Quiz question (3 points)

What is the number of protons, electrons and neutrons in niobium atom?

41 protons, 41 electrons, and 52 or 51 (likely, rare) neutrons.

9 Basics of life

9.1 Chemistry of life

Very basics of chemistry

- Atoms
 - Protons
 - Neutrons
 - Electrons
- Atomic weight
- Isotopes
- Elements
- Periodic table: rows and columns
- Chemical bonds: ionic, covalent, hydrogen
- Valence and group
- Molecules
- Molecular weight

Mole: the example

To cook one molecule of water (H_2O), we need one molecule of hydrogen (H_2) and half molecule of oxygen (O_2)

To cook one **mole** of water, we need one **mole** of hydrogen and half a **mole** of oxygen

To cook 18 grams ($2 \times 1 + 16$) of water, we need 2 grams (2×1) of hydrogen and 16 grams ($\frac{16 \times 2}{2}$) of oxygen

To cook 180 grams of water, we need 20 grams of hydrogen and 160 grams of oxygen

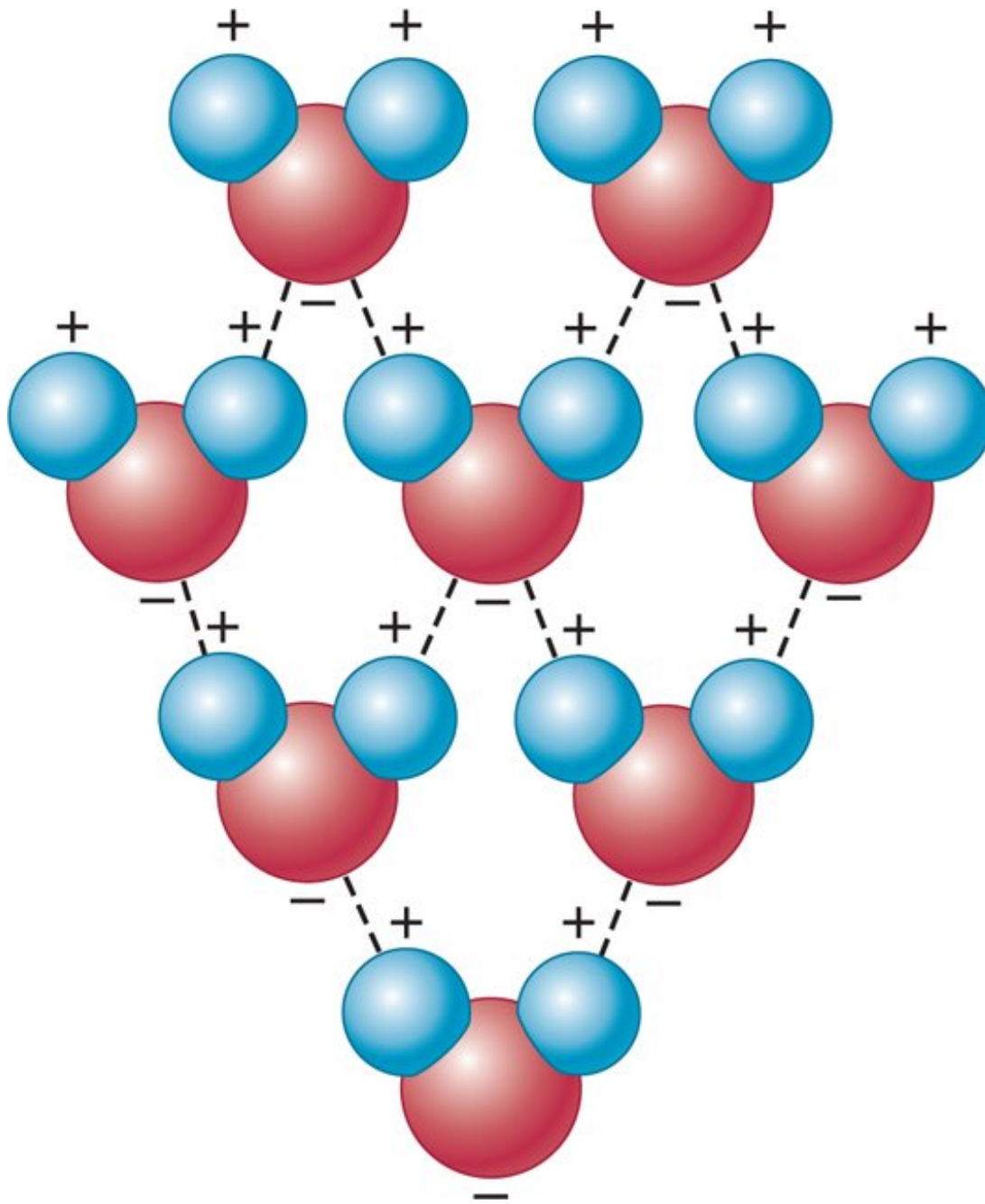
... and so on

Molar mass, mole and molar concentration

- Molar mass is a gram equivalent of molecular mass
- For example, molecular mass of salt (NaCl) is $23 + 35^1 = 58$ Da. We take “Da” out and replace it with “g” (grams). Therefore, 1 mole of salt is 58 g.
- Every mole contains $6.02214078 \times 10^{23}$ molecules (Avogadro’s number)
- Concentration is the density of dissolved substance
- In water solution, 1 M (1 molar) concentration of salt means that in 1 liter of distilled water 58 g of salt was diluted
- If we take half of this water, concentration will still be 1 M whereas amount of diluted salt will decrease twice

Water with hydrogen bonds

¹If we accept that atomic mass of chlorine is 35.



Acids and bases. Ions

- Acids: take out H^+ cation (proton), like
 $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$
 or
 $\text{H}_2\text{SO}_4 \rightarrow 2\text{H}^+ + \text{SO}_4^{2-}$
- Bases: take out OH^- anion (hydroxyl)
 $\text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^-$

Concentration of protons, and pH and acidity

- If concentration of protons is 0.1 M (1×10^{-1} , 0.1 g of protons in 1 l of water), this is an extremely acidic solution
- In distilled water, concentration of protons is equal to 1×10^{-7} (0.0000001) M
- This is because water molecules can (rarely) dissociate: $\text{H}_2\text{O} \rightarrow \text{H}^+ + \text{OH}^-$
- pH of distilled water is equal to $-\log(10^{-7}) = -(-7) = 7$
- pH of the extremely acidic solution (first example) is 1

Final question (2 points)

What is a molecular weight of hydrochloric acid, HCl?

Summary

- Most important bonds: polar and non-polar covalent (intramolecular) and hydrogen (intermolecular)

For Further Reading

References

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

Outline

10 Questions and answers

10.1 Quiz

Quiz question (2 points)

What is a molecular weight of hydrochloric acid, HCl?

$$1 + 35 = 36 \text{ atomic units (not grams!)}$$

11 Basics of life

11.1 Molecules of life

Concentration of protons, and pH and acidity

- If concentration of protons is 0.1 M (1×10^{-1} , 0.1 g of protons in 1 l of water), this is an extremely acidic solution
- In distilled water, concentration of protons is equal to 1×10^{-7} (0.0000001) M
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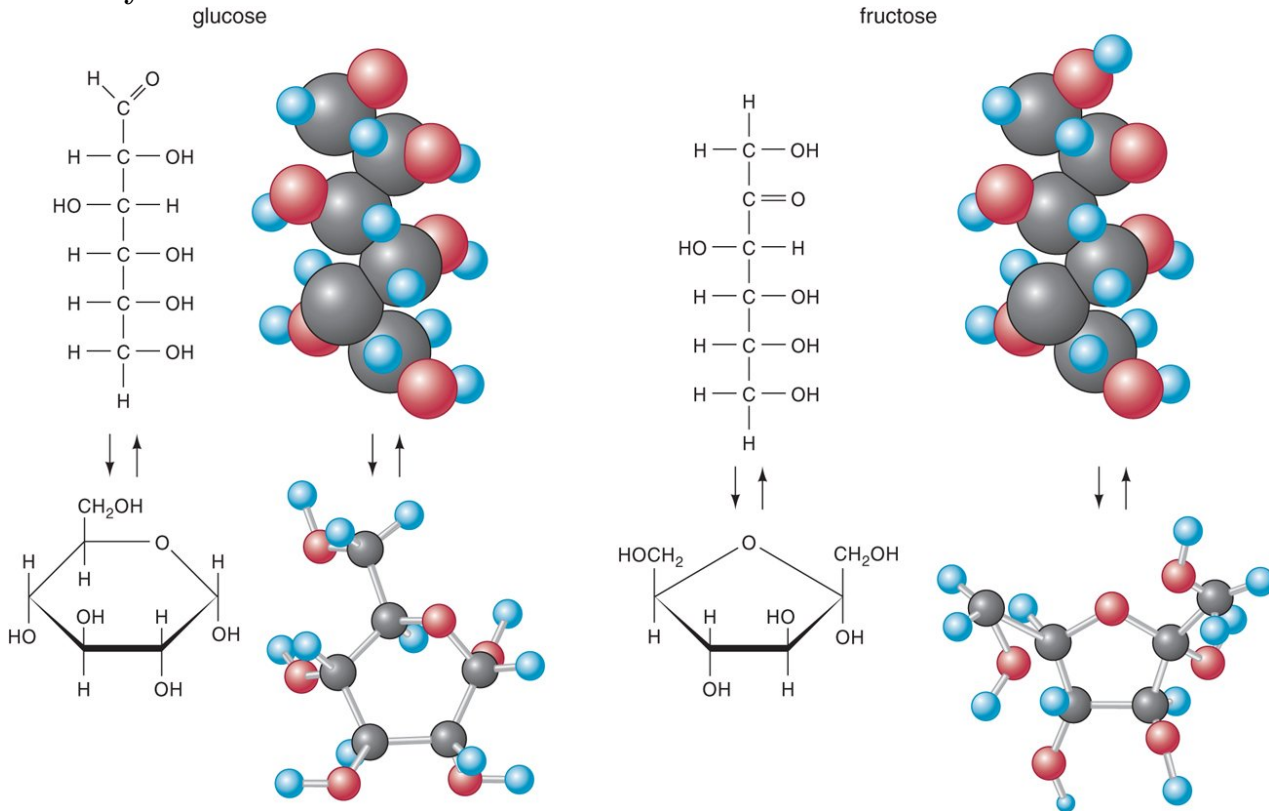
Organic chemistry: chemistry of carbon

- Carbon skeleton
- And H, O, N, P, S

Four types of biomolecules

- Lipids: hydrophobic
- Carbohydrates (sugars): multiple -OH groups
- Amino acids: N + C + O and hydrogen
- Nucleotides: cycle with nitrogen (heterocycle), sugar and phosphoric acid

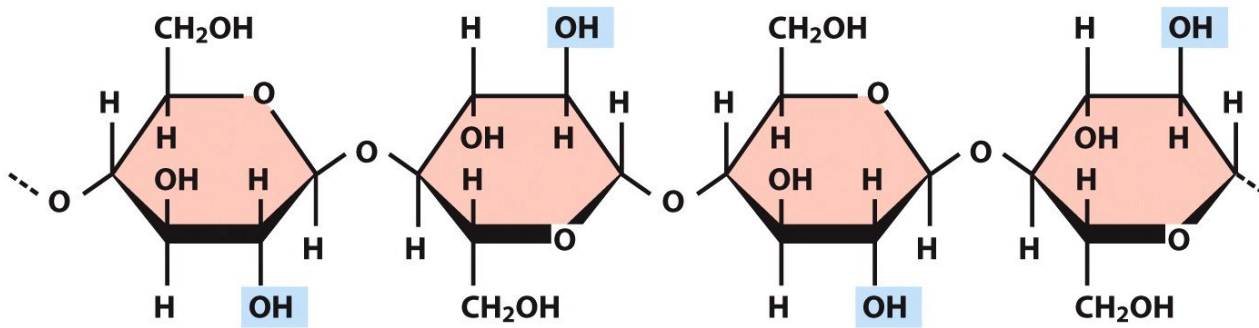
Carbohydrates



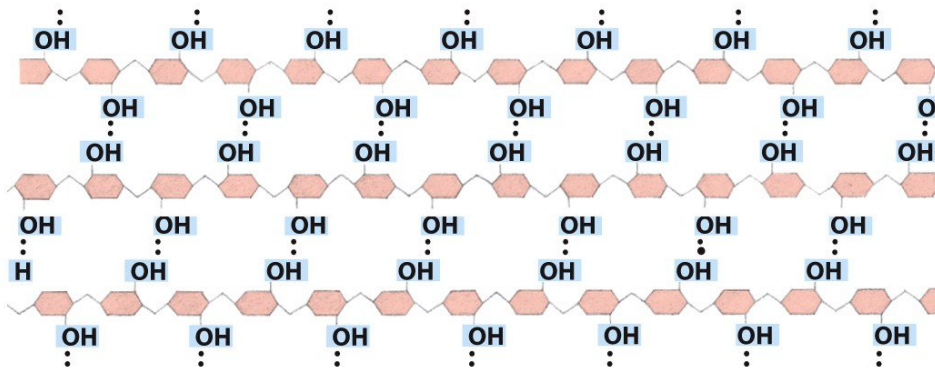
Organic polymers

- Polymeric carbohydrates: polysaccharides (like cellulose and starch)
- Polymeric amino acids: proteins
- Polymeric nucleotides: nucleic acids (DNA and RNA)

Cellulose



(a)



(b)

Summary

- Most important bonds: polar and non-polar covalent (intramolecular) and hydrogen (intermolecular)
- Obligatory biogenic elements: C, H, O, N, P
- Most important monomers: lipids, carbohydrates, amino acids, nucleotides
- Most important polymers: polysaccharides, proteins, nucleic acids

12 Photosynthesis

12.1 History of photosynthesis studies

van Helmont

- Johannes van Helmont (17th century) rejected the idea that plants take most of their biomass from soil
- Willow (*Salix* sp.) tree of 2.27 kg grew to 67.7 kg in five years, but weight of soil decreased only by 57 g
- van Helmont concluded that plants take most of their weight from water

Pristley

- Famous Joseph Pristley in 1772, made series of experiments with mouse, candle and sprig of mint (*Mentha* sp.)
- Mouse behave similar to candle, they both “spent” air
- Plant revives the air for both candle and mouse

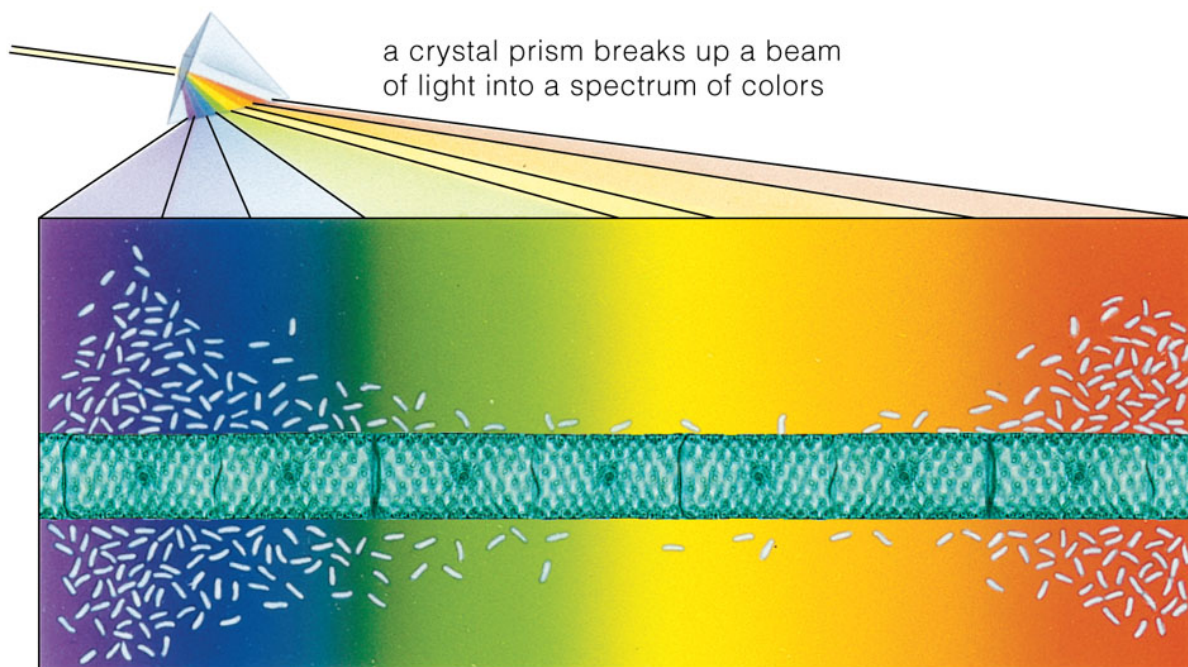
Further history

- Jan Ingenhousz (1779–1796) and Jean Senebier (1780) found that:
 - Only in day time the air is reviving
 - CO₂ is assembled
- Antoin-Laurent Lavoiser (1783) found that the “revived air” is a separate gas, **oxygen**

Engelmann

- Thomas Engelmann in 1884 found that *Spirogyra* alga produce oxygen mostly in blue and red parts of spectrum
- Therefore, the key photosynthetic pigment should accept blue and red rays and reflect green rays
- Chlorophyll fits best to this description

Experiment of Engelmann



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

Final question (2 points)

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

Summary

- Main biogenic elements: C, H, O, N, P
- Most important monomers: lipids, carbohydrates, amino acids, nucleotides
- Most important polymers: polysaccharides, proteins, nucleic acids
- From 17th century, it constantly became clear that plants make their biomass from light, water and carbon dioxide

For Further Reading

References

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

Outline

13 Questions and answers

13.1 Quiz

Quiz question (2 points)

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:

There are many pigments in plants. Which of them is responsible for photosynthesis?

Photosynthesis makes oxygen AND bacteria like oxygen AND bacteria concentrate around blue and red spots → photosynthesis is going on these blue and red spots → photosynthetic pigment accepts blue and red (but not green) → photosynthetic pigment IS green.

14 Photosynthesis

14.1 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. But if temperature is low, light works!
 - A. If light and temperature were completely *independent*, this could not happen
 - B. If temperature and light were *components of the chain*, then light was first and temperature second
- Consequently, photosynthesis has two stages:
 - A. Light stage which relates more with light intensity
 - B. “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

Light and enzymatic (“dark”) reactions

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Four equations of photosynthesis

- A. $6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow{\text{light}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$ is *not a formula*, but merely a general description of a process
- B. Water molecules arise from both sides, and the better formula is $6\text{CO}_2 + 12\text{H}_2\text{O} \xrightarrow{\text{light}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O} + 6\text{O}_2$
or even
- C. carbon dioxide + hydrogen donor $\xrightarrow{\text{light}}$ carbohydrate + water + oxidized hydrogen donor
- D. And the best one is probably $\text{CO}_2 + \text{H}_2\text{O} \xrightarrow{\text{light}} \text{carbohydrates} + \text{H}_2\text{O} + \text{O}_2$

14.2 Light stage: electron transport, synthesis of ATP and NADPH

Participants of light stage

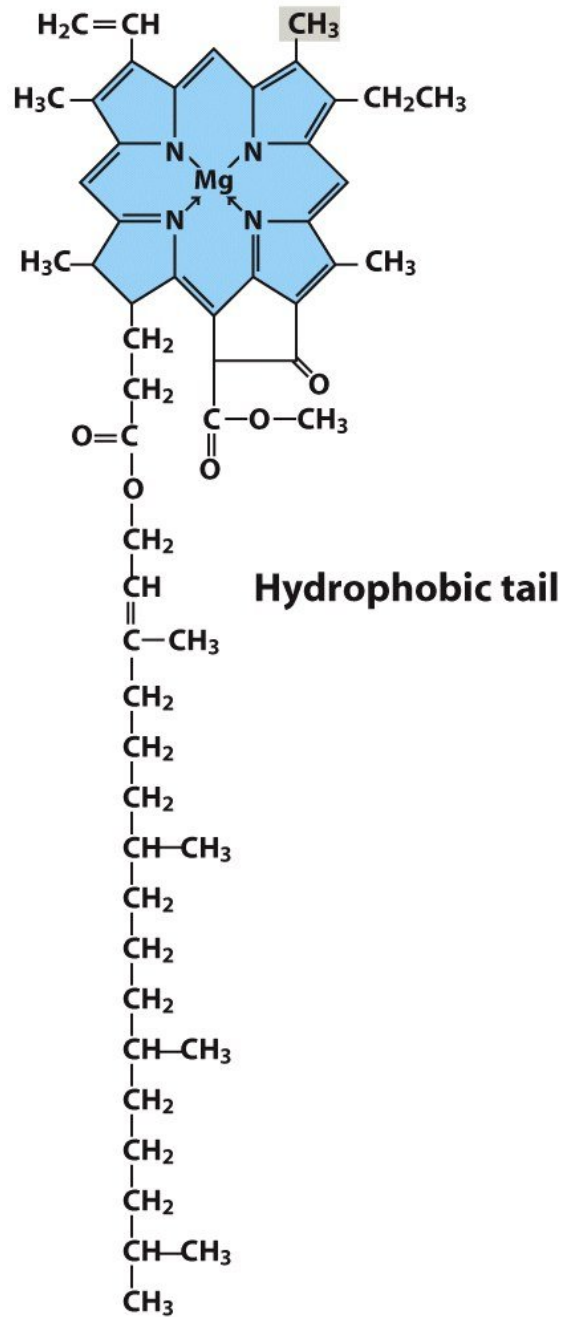
- A. Chlorophyll (photosystems II and I)
- B. Light
- C. Water
- D. ATP synthase (ATPase)
- E. Protons (H^+)
- F. Hydrogen carrier (NADP^+)

Where: around thylakoid membrane

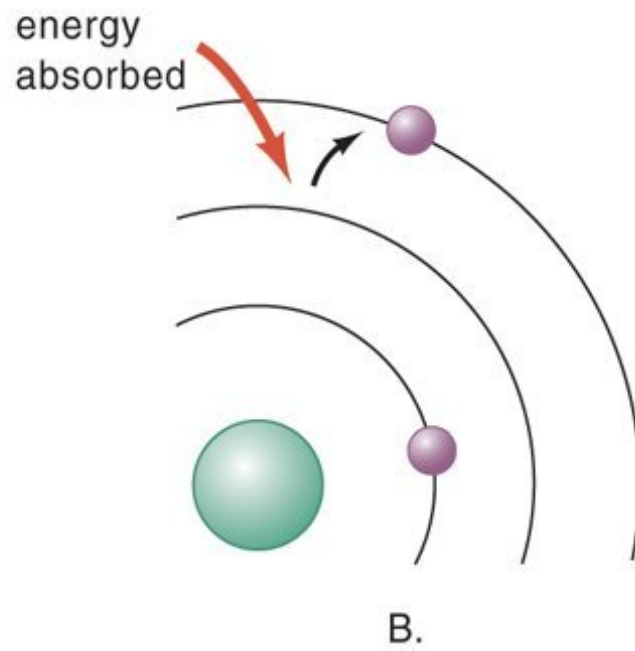
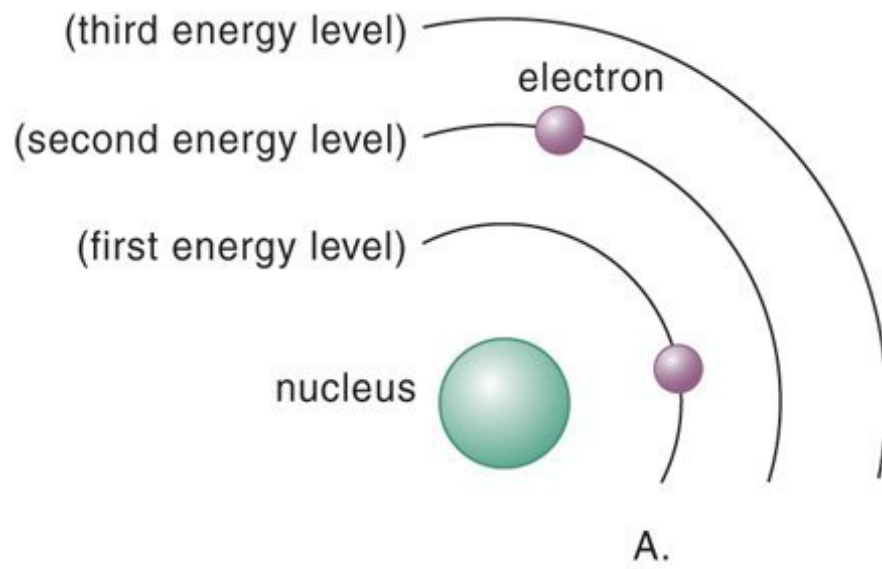
Logic of the light stage

- A. To assemble carbon dioxide into sugar, we need ATP
- B. To make ATP, we need *electrical current* through the proton pump
- C. To make this current, we need the *difference in charge* (voltage difference) between thylakoid and matrix (stroma) compartments
- D. 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
- E. To segregate ions, we need the energy and the energy booster. These are sun rays and chlorophyll

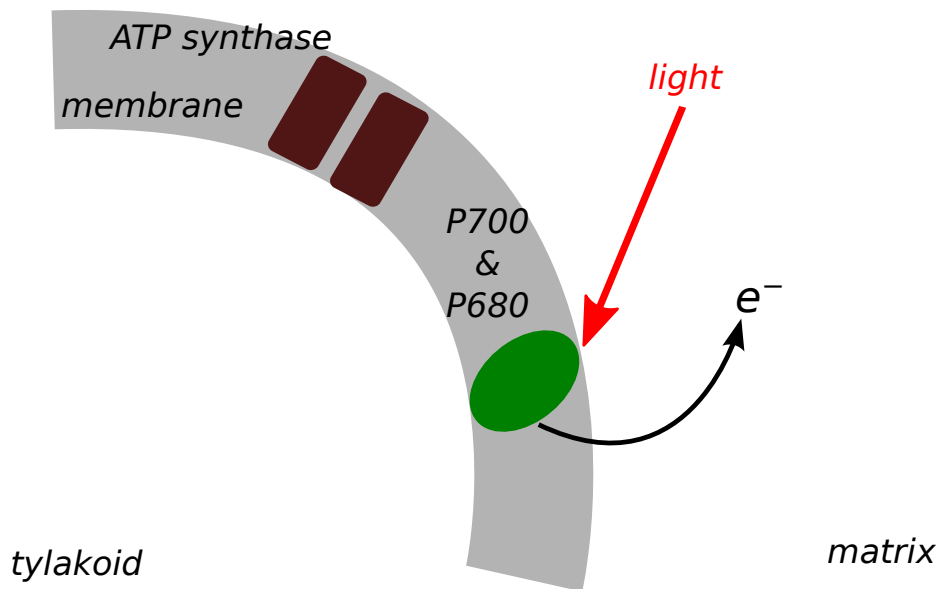
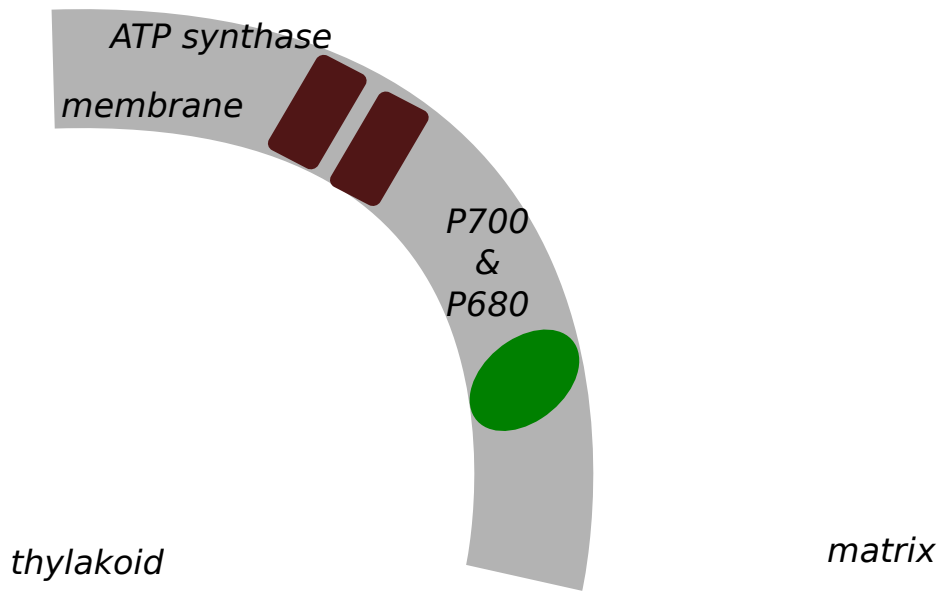
Why chlorophyll is good for the membrane



How chlorophyll works: excitation of the electron



Scheme of light stage



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

References

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Outline

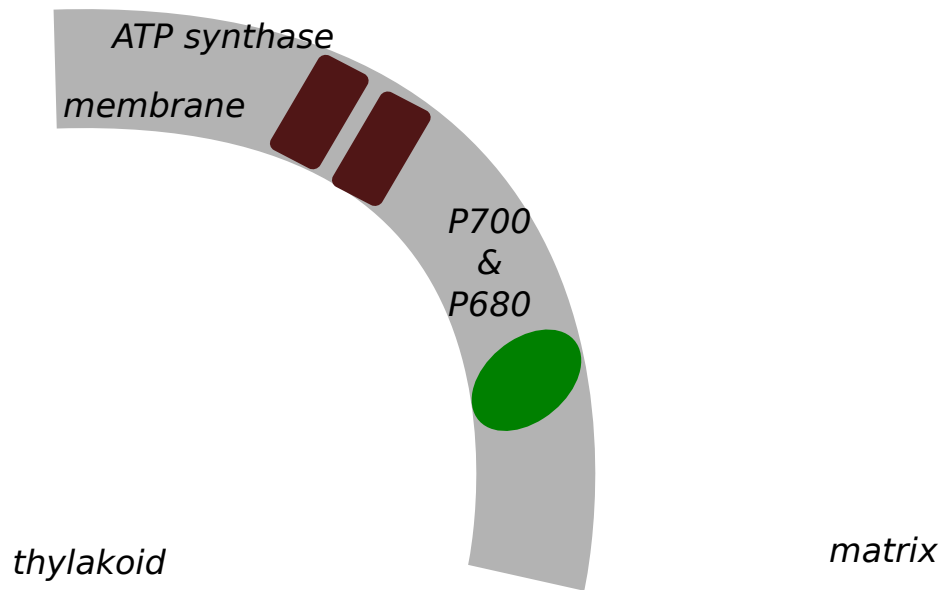
15 Photosynthesis

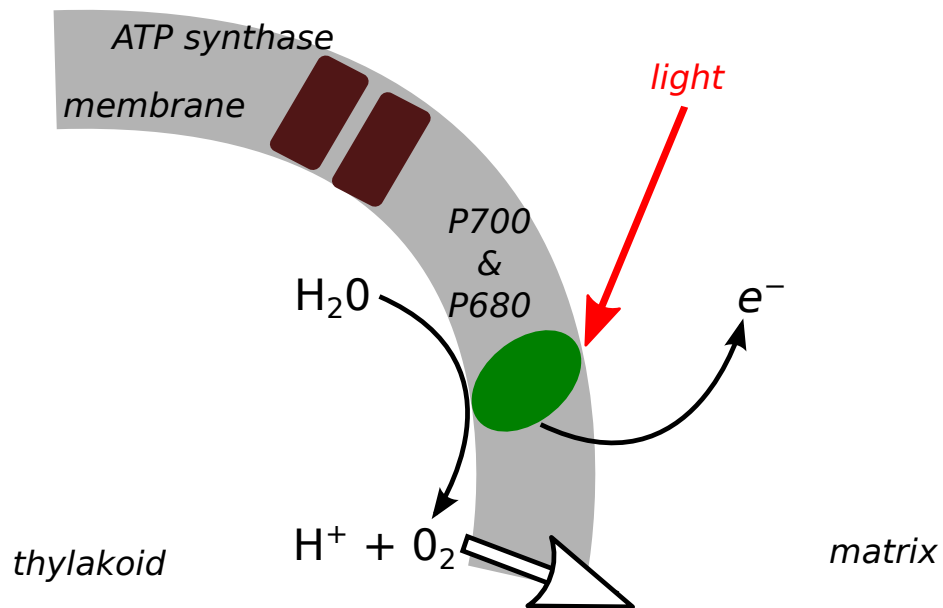
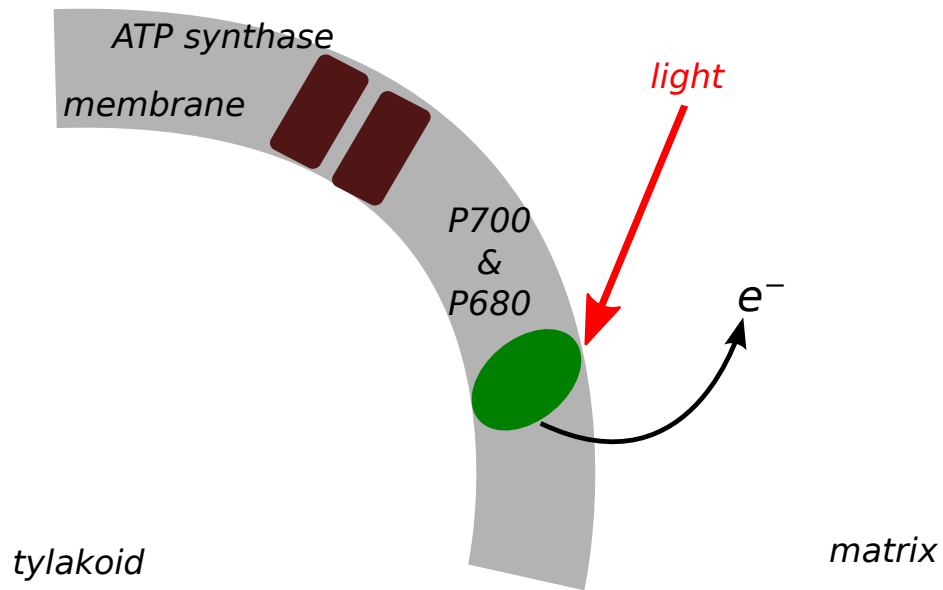
15.1 Light stage: electron transport, synthesis of ATP and NADPH

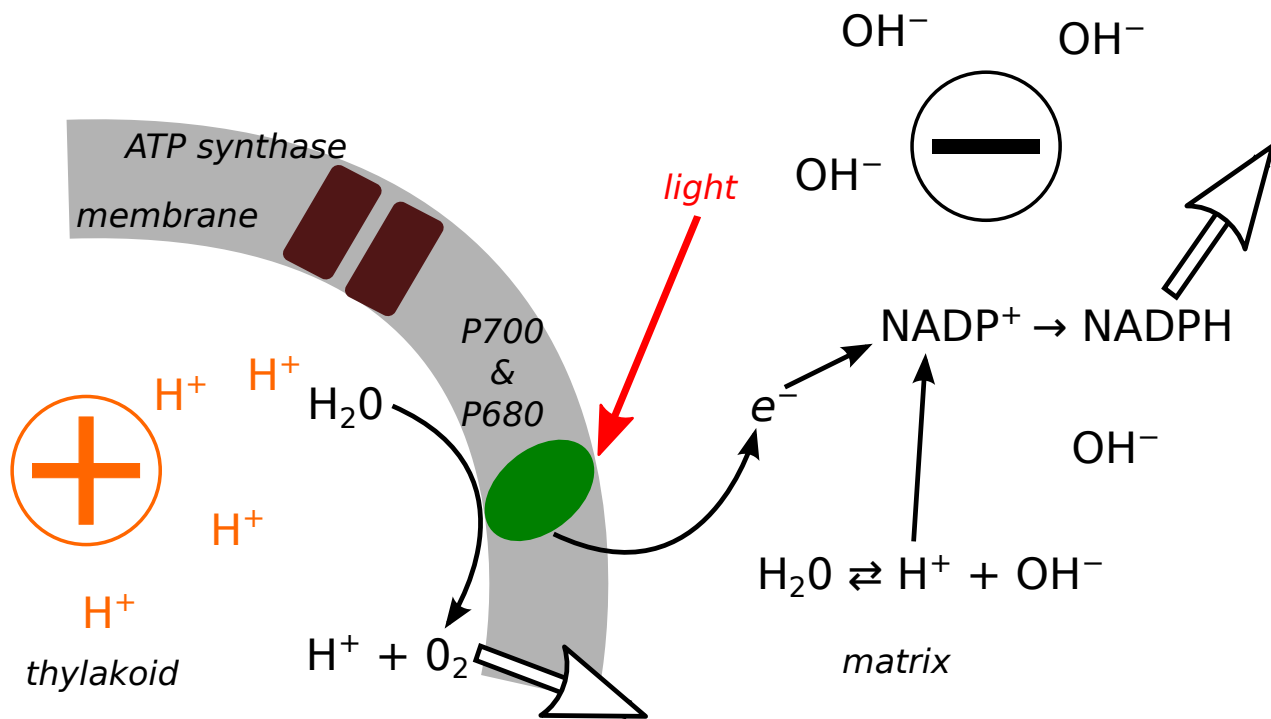
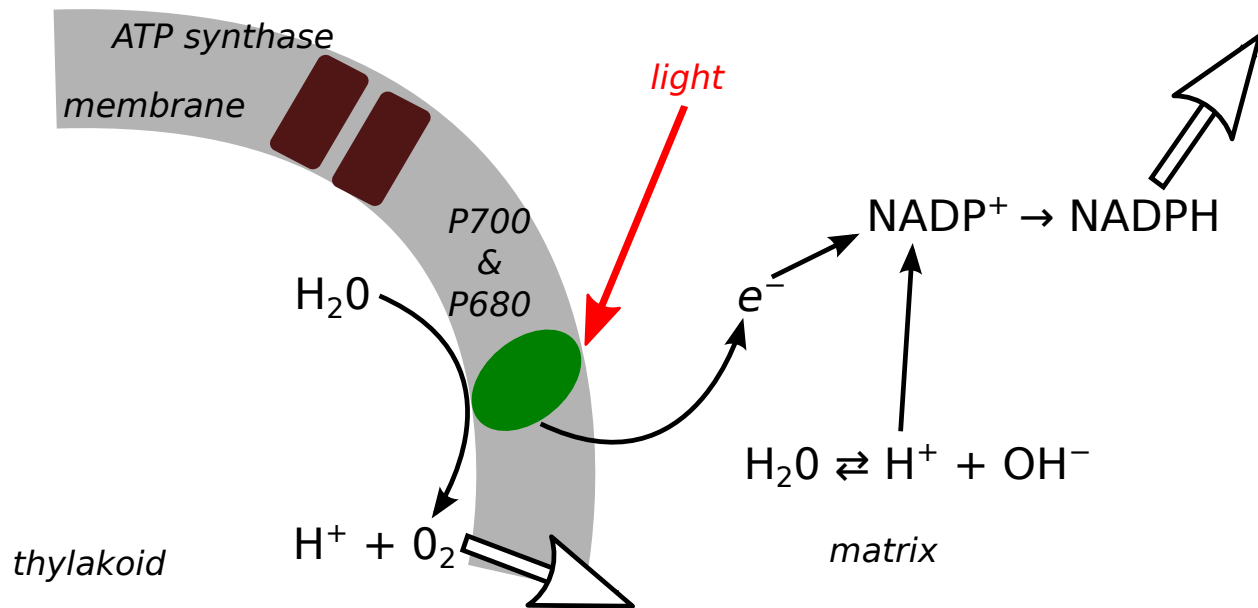
Participants of light stage

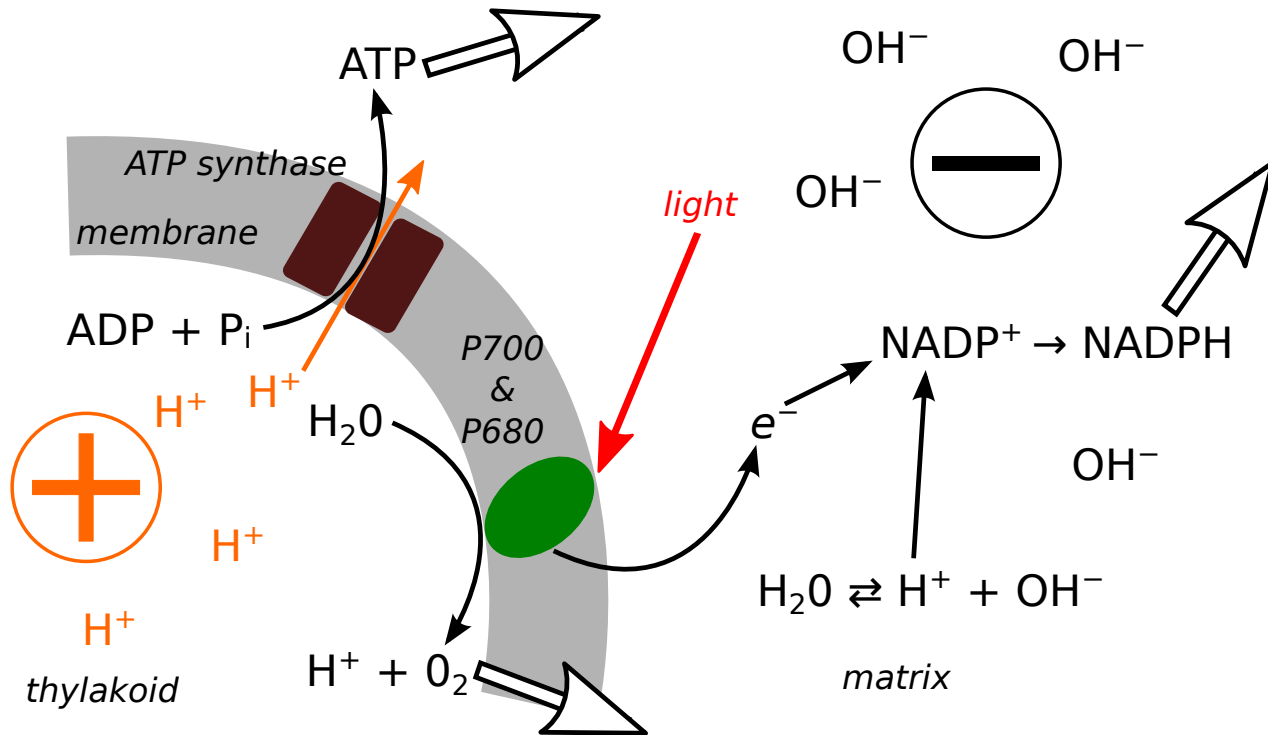
- A. Chlorophyll (photosystems II and I)
- B. Light
- C. Water
- D. ATP synthase (ATPase)
- E. Protons (H^+)
- F. Hydrogen carrier ($NADP^+$)

Where: around thylakoid membrane









Main events of light stage

- Chlorophyll + Light \rightarrow Electron (e^-) + Chlorophyll $^+$
- $\text{e}^- + \text{H}^+$ (from water) + Hydrogen carrier (NADP $^+$) \rightarrow NADPH (moves away)
- $\text{H}_2\text{O} \rightarrow \text{H}^+$ (accumulates inside) + $\text{e}^- + \text{O}_2$
- H^+ (inside) + OH^- (from water, located outside) \Rightarrow gradient \Rightarrow proton pump \Rightarrow H_2O TOGETHER WITH ADP + P_i (inorganic phosphate) \rightarrow **ATP**

Photosystems

- Photosystem II (P_{680} , contains chlorophylls and carotene):
 - decomposes water;
 - forwards electron to Photosystem I;
 - 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 O_2
Chlorophylls	Chlorophylls
ADP and P_i (inorganic phosphate)	ATP
NADP $^+$	NADPH

Quiz question (2 points)

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

References

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

Outline

16 Questions and answers

16.1 Quiz

Final question (2 point)

Explain the role of hydrogen carrier (NADP^+)

- In the light stage of photosynthesis, with the help of Photosystem I (P_{700}) it takes hydrogen (protons from water and electrons from chlorophyll) and removes them from the space outside of membrane
- Hydrogen used in enzymatic reactions
- Accumulated OH^- helps with the gradient and therefore with the electrical current through ATPase

17 Photosynthesis

17.1 Enzymatic stage: fixation of carbon dioxide

Participants of enzymatic stage

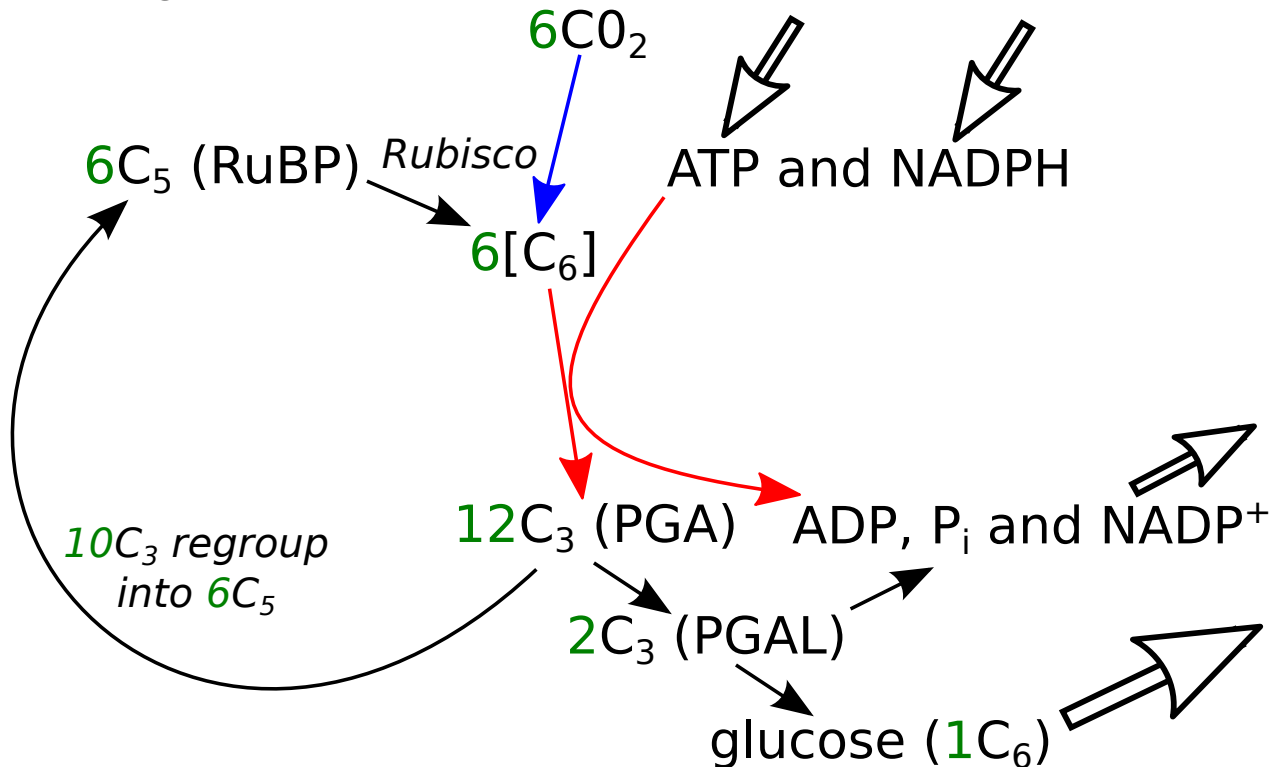
- A. Carbon dioxide (CO_2)
- B. Hydrogen carrier with hydrogen (NADPH)
- C. Source of energy (ATP)
- D. Ribulose biphosphate (RuBP, five-C-hydrocarbonate, “ C_5 ”)
- E. *Rubisco* and other enzymes

Place: in the matrix (stroma) of chloroplast

Main events of enzymatic stage

- A. $\text{CO}_2 + \text{C}_5 \text{ (RuBP, ribulose biphosphate)} \xrightarrow{\text{Rubisco}} \text{C}_6$
- B. $\text{C}_6 \longrightarrow 2\text{C}_3 \text{ (PGA, phosphoglyceric acid)}$
- C. $\text{C}_3 + \text{NADPH} + \text{ATP} \longrightarrow \text{C}_6\text{H}_{12}\text{O}_6 \text{ (or other organic molecules)} + \text{C}_5 + \text{NADP}^+ + \text{ADP} + \text{P}_i \text{ (inorganic phosphate)}$
 - Organic molecules are synthesized from C_3 (PGA) through energy-rich **PGAL** (phosphoglyceric aldehyde)

Enzymatic stage: scheme



Results of enzymatic stage

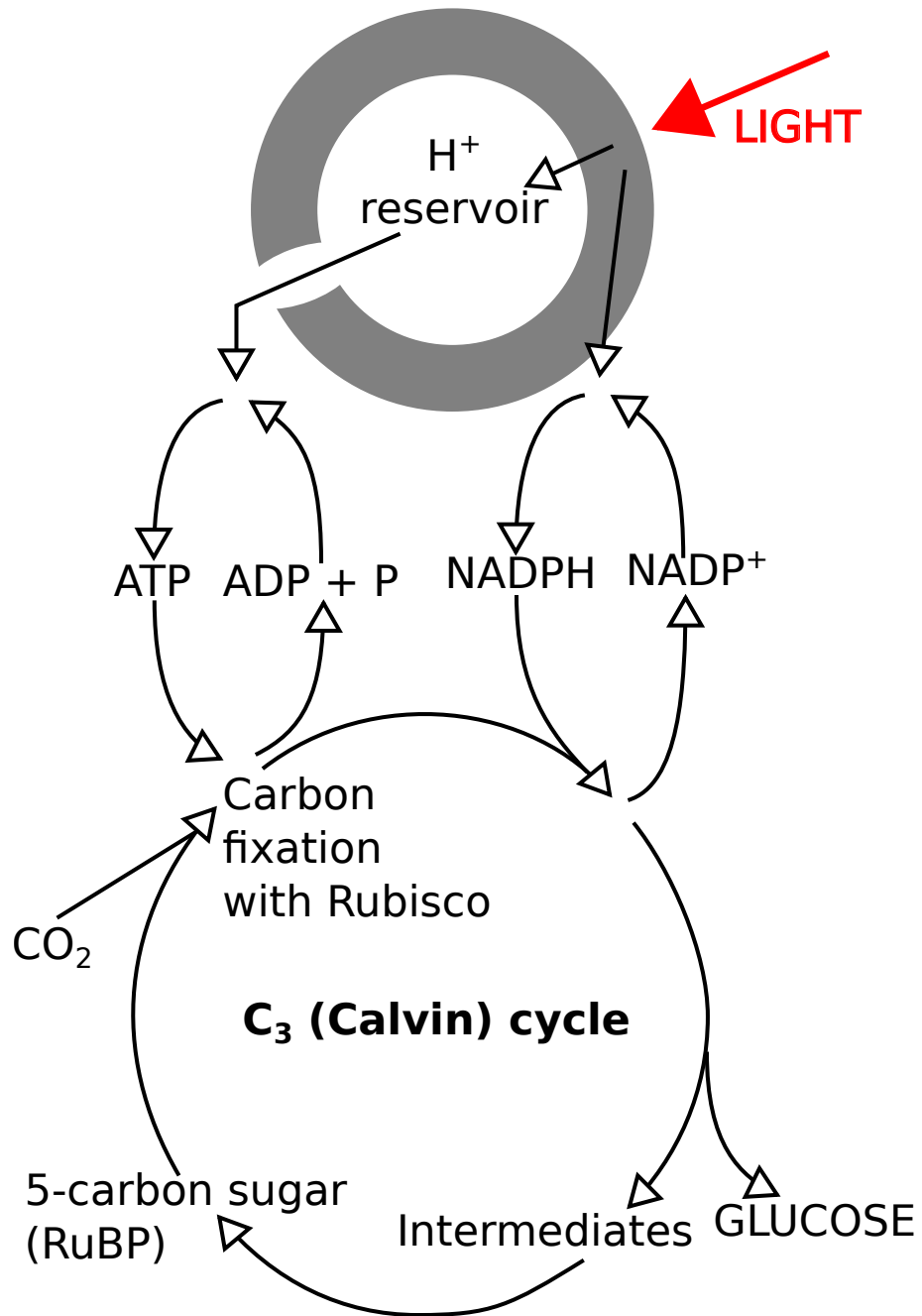
At the start	At the end
CO_2	$\text{C}_6\text{H}_{12}\text{O}_6$ (or other organic molecules)
NADPH	NADP^+ (H goes to $\text{C}_6\text{H}_{12}\text{O}_6$)
ATP	ADP and P_i (inorganic phosphate)
C_5	C_5
<i>Rubisco</i>	<i>Rubisco</i>

The other names for enzymatic stage are “Calvin cycle” and “ C_3 cycle”

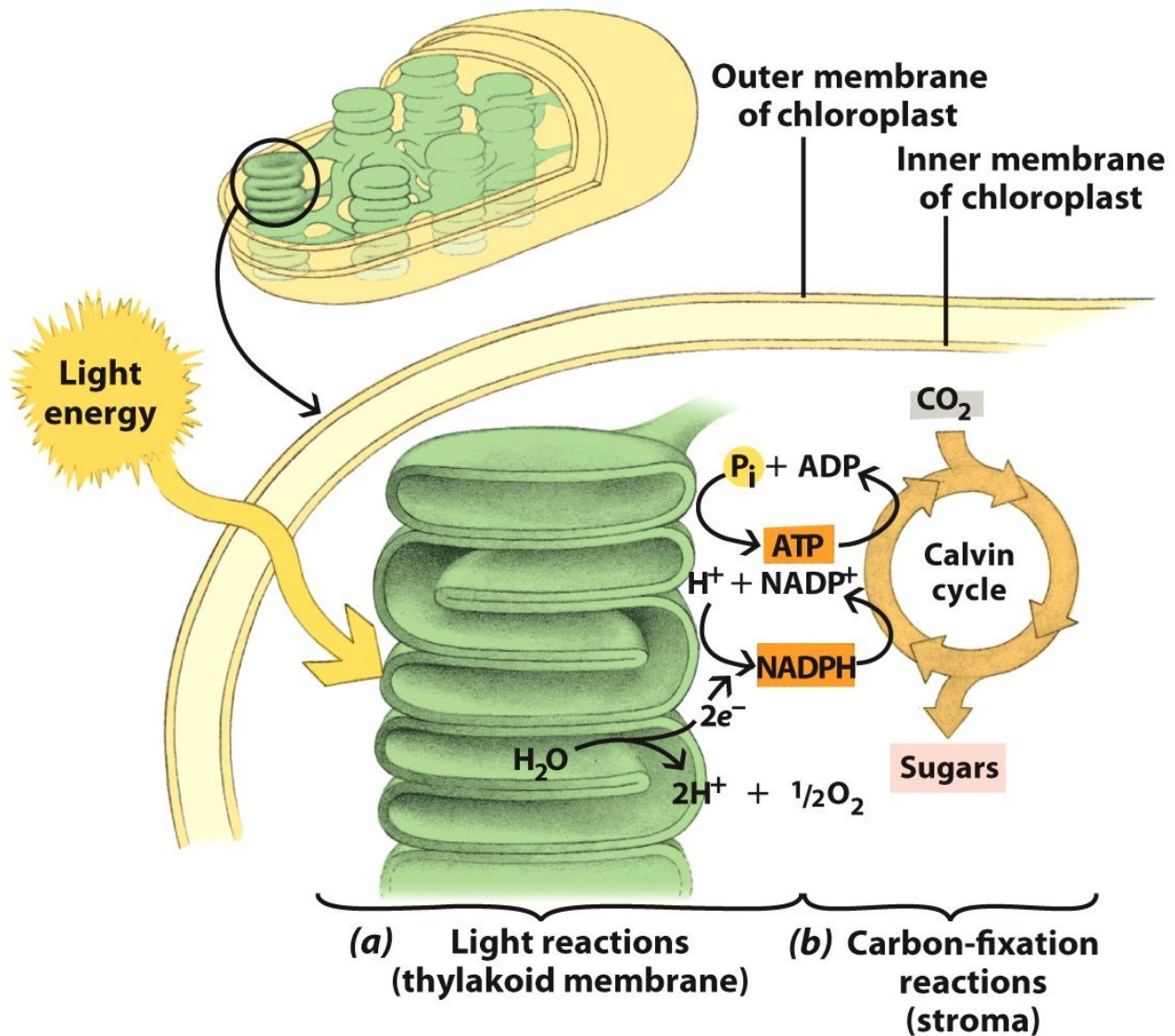
17.2 As a whole



Overview of photosynthesis



Photosynthesis in the cell



Photosynthesis movie

Final question (2 points)

Explain the role of NADPH in the enzymatic stage.

Summary

- **Photosynthesis** is a sum of light-dependent (photo-) and light-independent (auto-) reactions
- **Light stage** of photosynthesis results in accumulation of energy and hydrogen, and release of oxygen
- **Enzymatic stage** of photosynthesis results in assimilation of the CO₂ and synthesis of organic molecules

For Further Reading

References

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

Example questions for the exam

Start time _____

End time _____

Short answers

A. Why do carnivorous plants catch insects? Explain. (*4 points*)

Multiple choice

Every question in this section costs either 2 or 0. Please **mark** the appropriate answer on the **scantron**.

A. Which set of three components can make a amino acid?

- (a) Oxygen, hydrogen, nitrogen and carbon skeleton
- (b) Phosphoric acid, sugar and carbon cycle with nitrogen
- (c) Lipids and nitrogen

B. In photosynthesis, water used to make:

- (a) Carbon dioxide
- (b) Oxygen
- (c) More water

C. Dodder is:

- (a) Plant₁ (ecological definition) and plant₂ (taxonomic definition)
- (b) Plant₁ only
- (c) Plant₂ only

(answers on next page)

Answers: 1A, 2B, 3C