# Introduction to Botany: BIOL 154
# Study guide for Exam 1

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Lectures 2–6

## Contents

**Outline**

# 1 Questions and answers

## 1.1 Comments to introductory test

### Question 1

1 Why deciduous plants take off their leaves?

1. To prevent freezing
2. **To prevent drying**
3. To get rid of poisonous chemicals

### Question 2

2 Where does human digestion process start?

1. **In the mouth**
2. In the intestines
3. In the stomach

*Amylase* and *lipase*

### Question 3

3 Which birds do NOT live in Minot on winter?

1. Crows
2. **Hummingbirds**
3. Sparrows

**Question 4**

4 Home country of watermelon:

1. Central America
2. Canada
3. **South Africa**

**Question 5**

5 Why do insectivorous plants eat insects?

1. **To obtain the lacking mineral resources**
2. To get an addition to their common "menu"
3. To get rid of herbivores

**Question 6**

6 Which insects have no queen?

1. Bumblebees
2. Ants
3. **Cockroaches**


*Bumblebees*

**Question 7**

7 Oak tree is pollinated by:

1. **Wind**
2. Bees
3. Flies

*Oak flowers*

**Question 8**

8 Spider has:

1. 6 legs
2. **8 legs**
3. 4 legs

**Question 9**

9 Apple flower has:

1. **5 petals**

2. 4 petals
3. 3 petals

**Question 10**

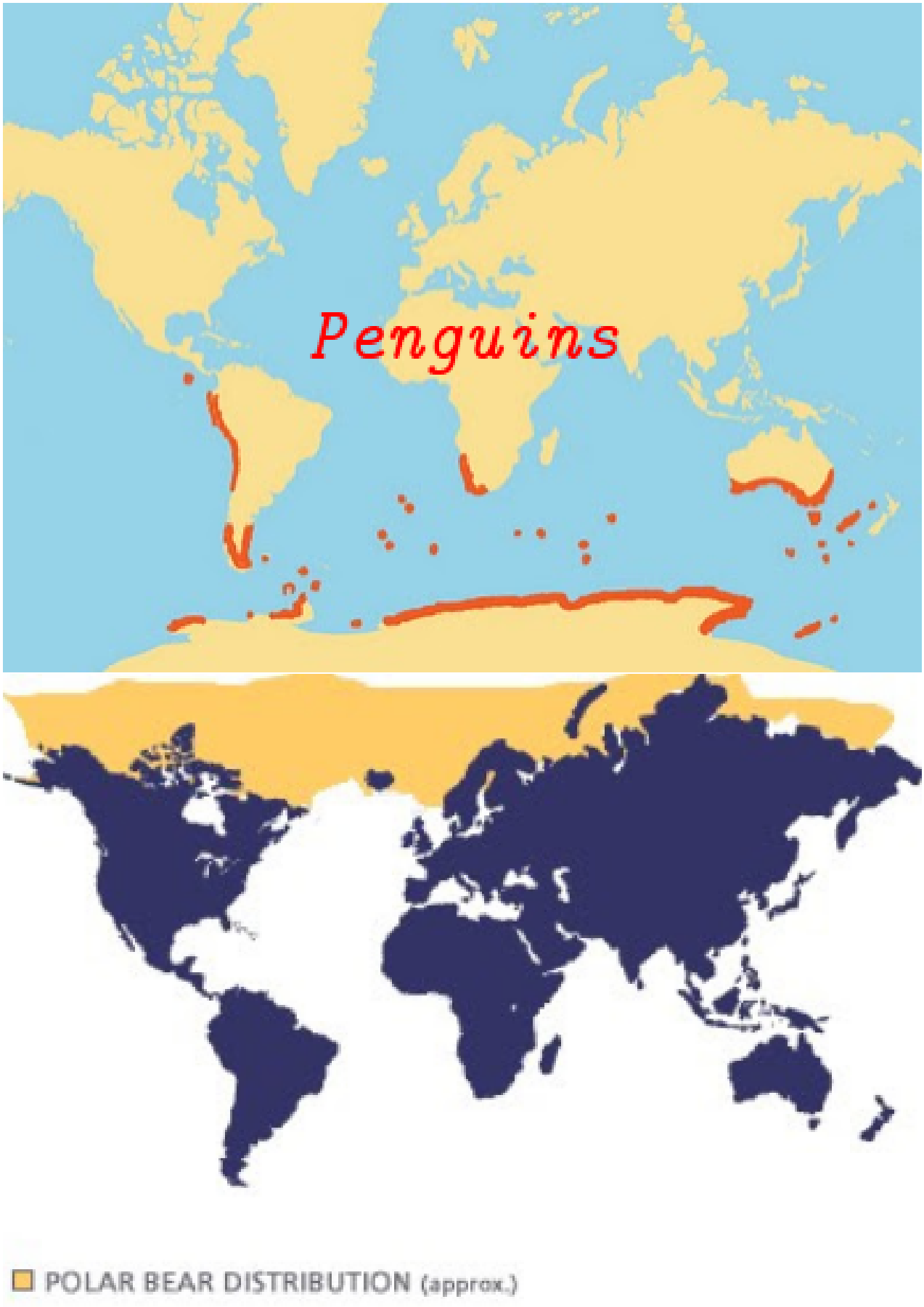
10 Frightened man has:

1. **Bigger pupils**
2. Smaller pupils
3. Normal pupils

**Question 11**

11 Polar bears are not eating penguins because:

1. Penguins run very fast
2. **They cannot meet**
3. Penguins are poisonous for bears




**Question 12**

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

1. 5
2. **4**
3. 3

**Question 13**

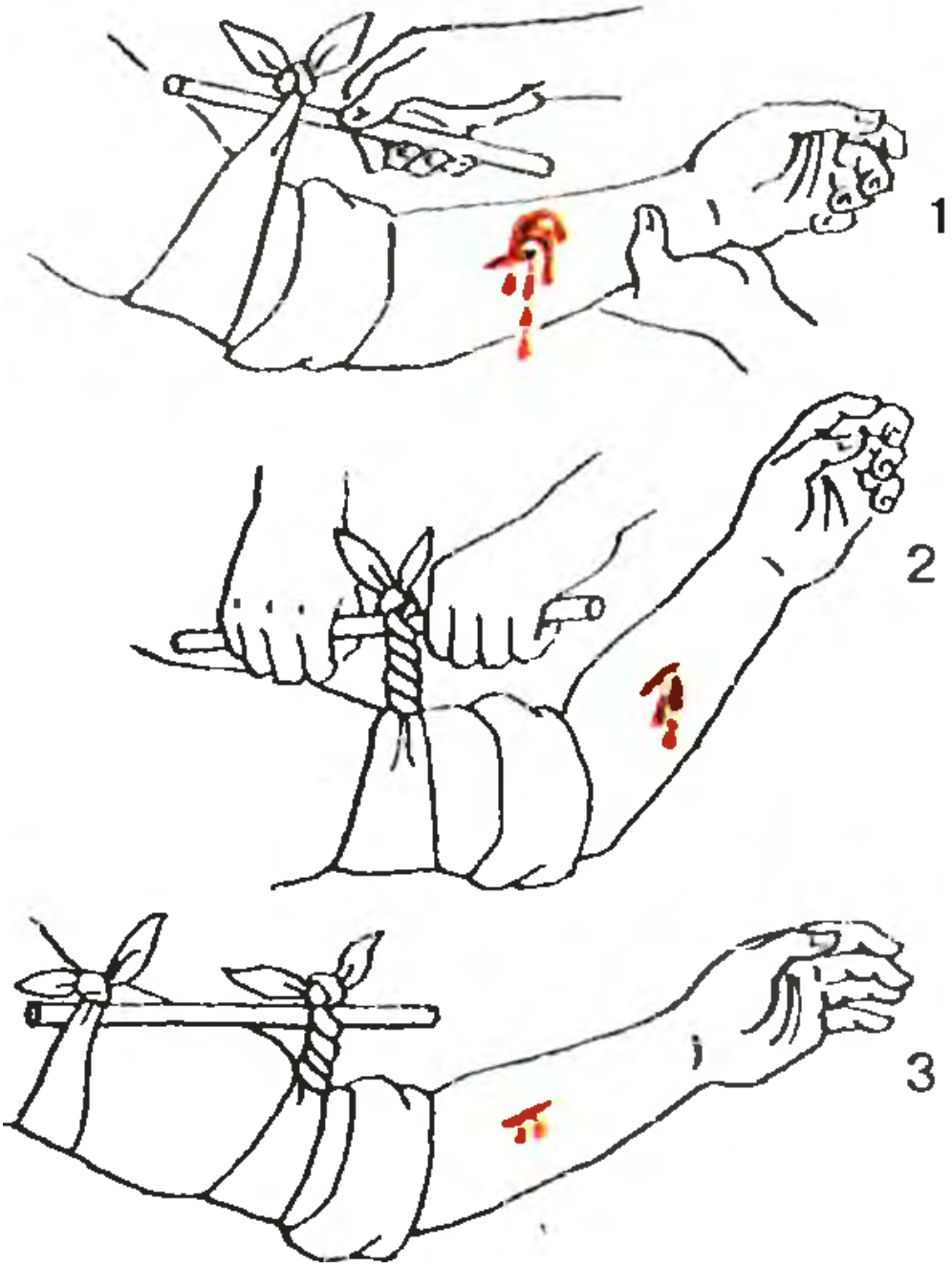
13 Pineapple is a:

1. Tree
2. Shrub
3. **Herb**

**Question 14**

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

1. Put a tight bandage below the cut
2. **Put a tight bandage above the cut**
3. Do nothing




**Question 15**

15 Which of the following is the most precise statement?

1. We are breathing to support our life
2. **We are breathing to obtain the energy from food**
3. We are breathing to have enough strength for food consuming

**Question 16**

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

1. Sycamore

2. **Ash**
3. Yew

**Question 17**

17 Moles eat:

1. **Worms**
2. Roots
3. Frogs

**Question 18**

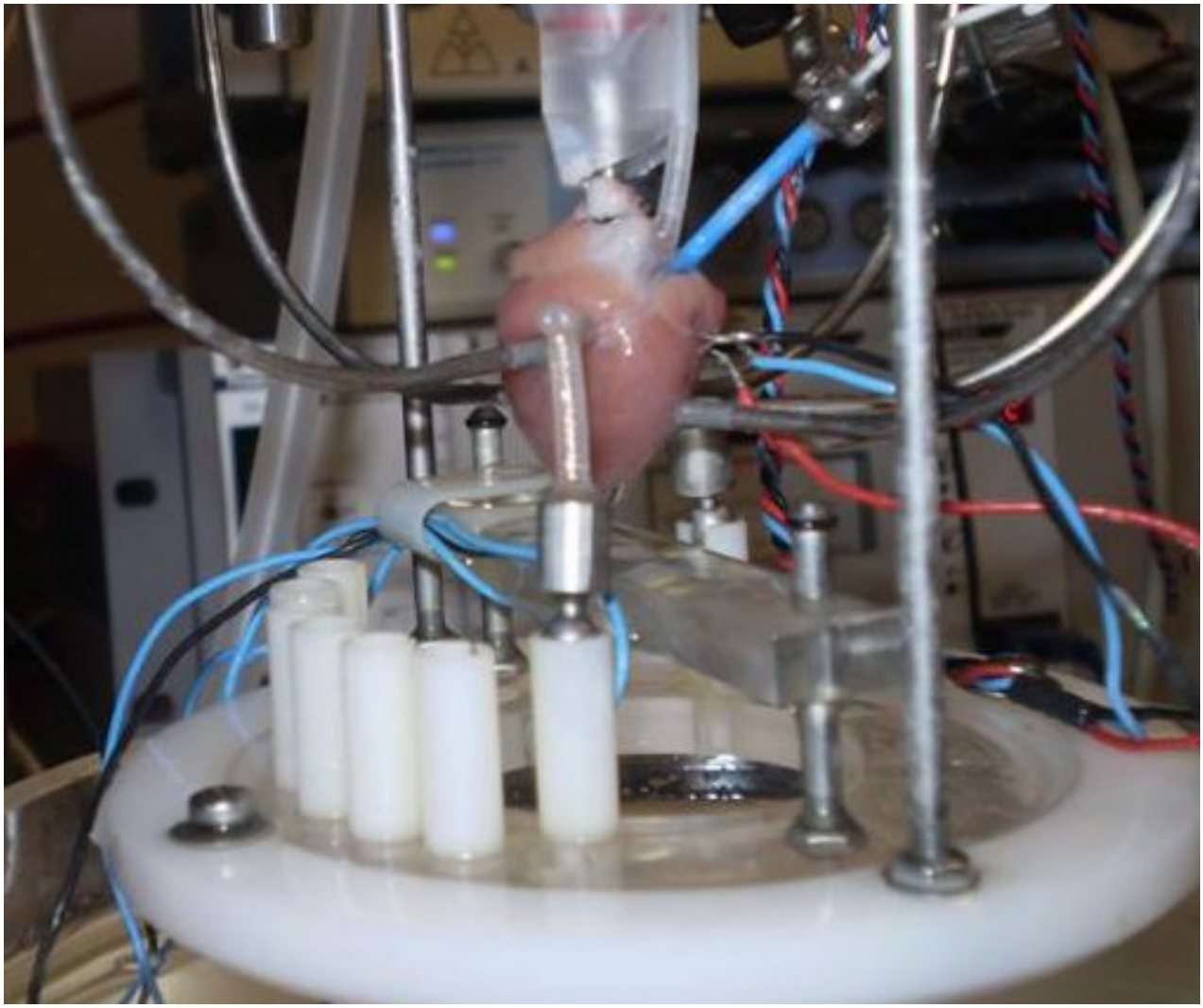
18 Which fish gives birth to the fully developed offspring?

1. Sturgeon
2. **Shark**
3. Flounder

**Question 19**

19 Which human organ lives longer?

1. **Heart**
2. Lungs
3. Brains



**Question 20**

20 Which plant normally has a longer root?

1. Spruce
2. **Chokecherry**
3. Blueberry

*Fallen spruce tree*

# 2 Plants: definition

## 2.1 Plants$_1$ and plants$_2$

**Plants$_1$ and plants$_2$**

- Plants$_1$ are all green photosynthetic organisms
- Plants$_2$ are "typical plants" (better definition follows)

**The nature of two definitions**

- Plants$_1$—ecological definition (based on the role in nature)
- Plants$_2$—taxonomic definition (based on the evolution)

**Plants$_1$ is about ecology**

Plants$_1$ are *photosynthetic organisms*:

$$H_2O + CO_2 + \text{light} \rightarrow \text{organic compounds} + O_2$$

Some plants$_1$ could taxonomically be bacteria or even animals!

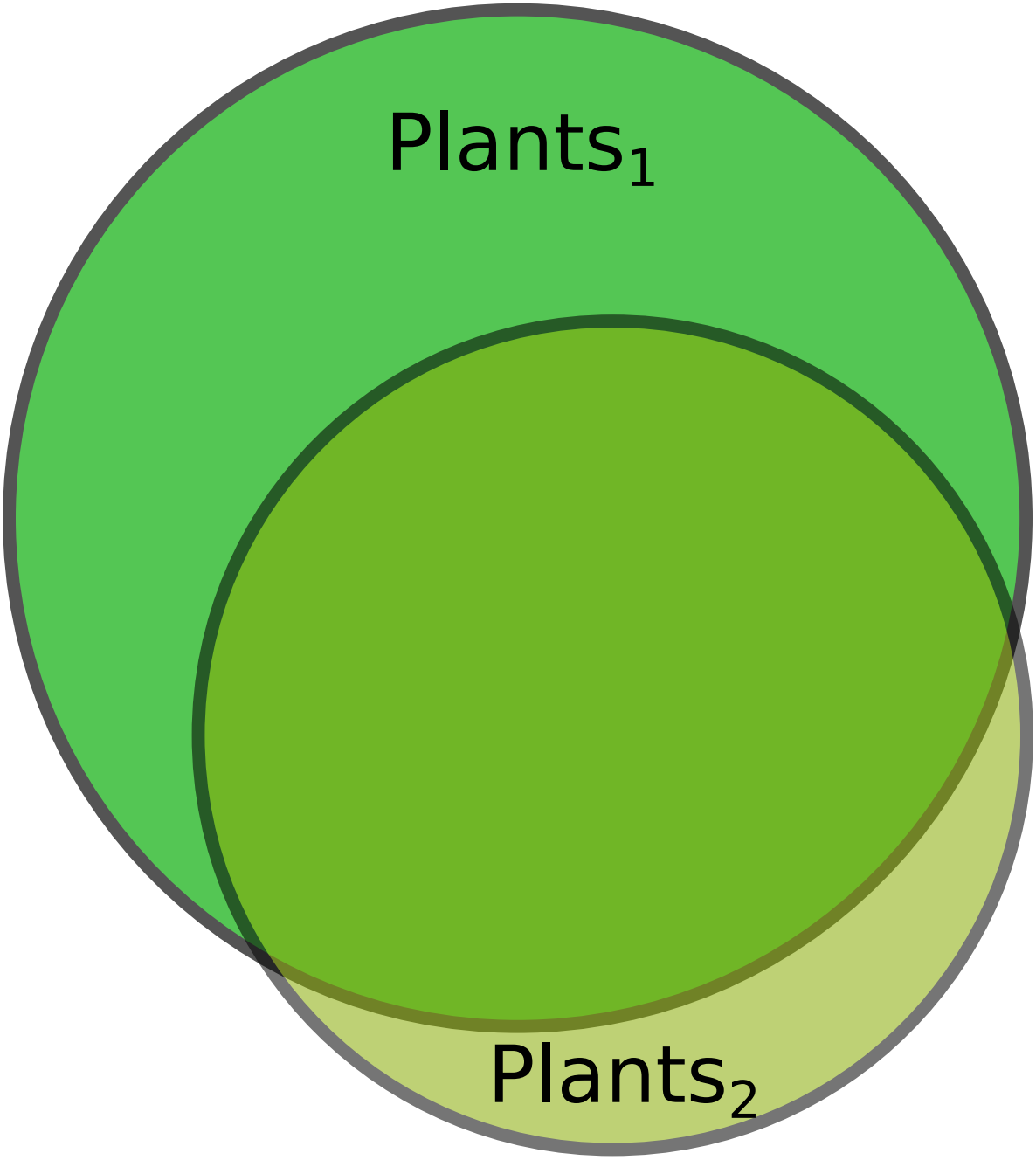
**Green slugs**

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

**Green *Hydra***


No mouth!

**Plants$_1$ and plants$_2$ are similar but not the same**




# 3 Plants in general

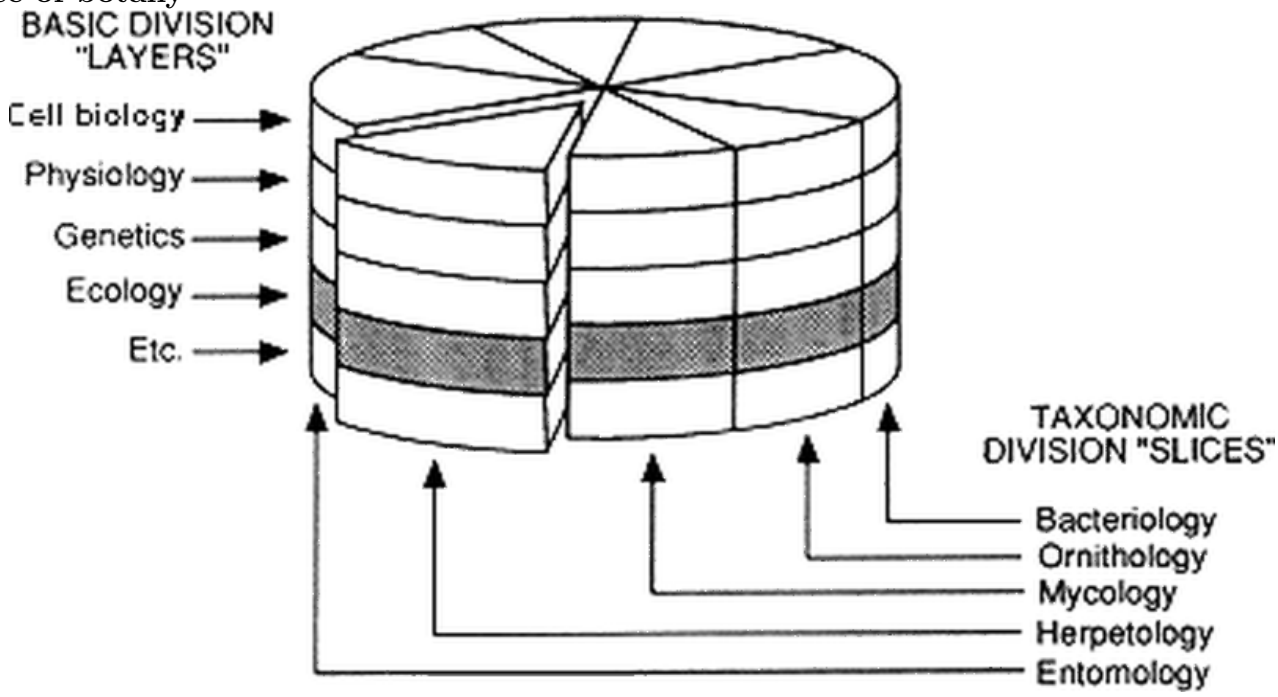
## 3.1 Levels of organization

**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"

## 3.2 Taxonomy

**Ranks**

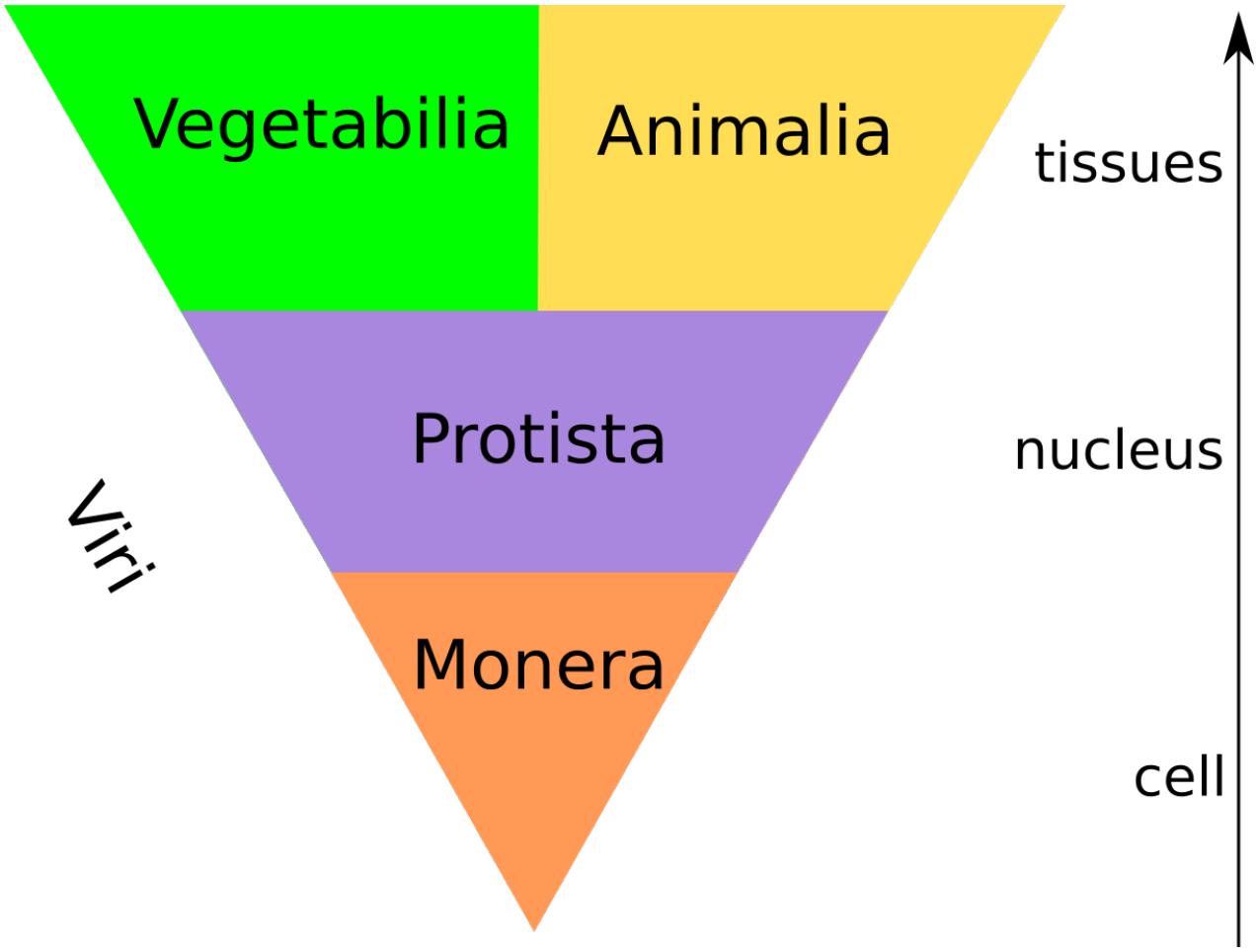
Most scientists accept seven main ranks:

- 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)

**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 plants$_2$?** Vegetabilia

**Where are plants$_1$?** It is not applicable here

**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**.

**Plants$_1$ and plants$_2$ (updated)**

- Plants$_1$ are all photosynthetic organisms
- Plants$_2$ are **Vegetabilia**: multi-tissued, terrestrial, primarily photosynthetic eukaryotes

**Final question (2 points)**

What is the difference between $\text{plants}_1$ and $\text{plants}_2$?

**Summary**

- "Plants" have **two definitions**
- **Botany** is a "slice science" which covers multiple **levels of organization**

**For Further Reading**

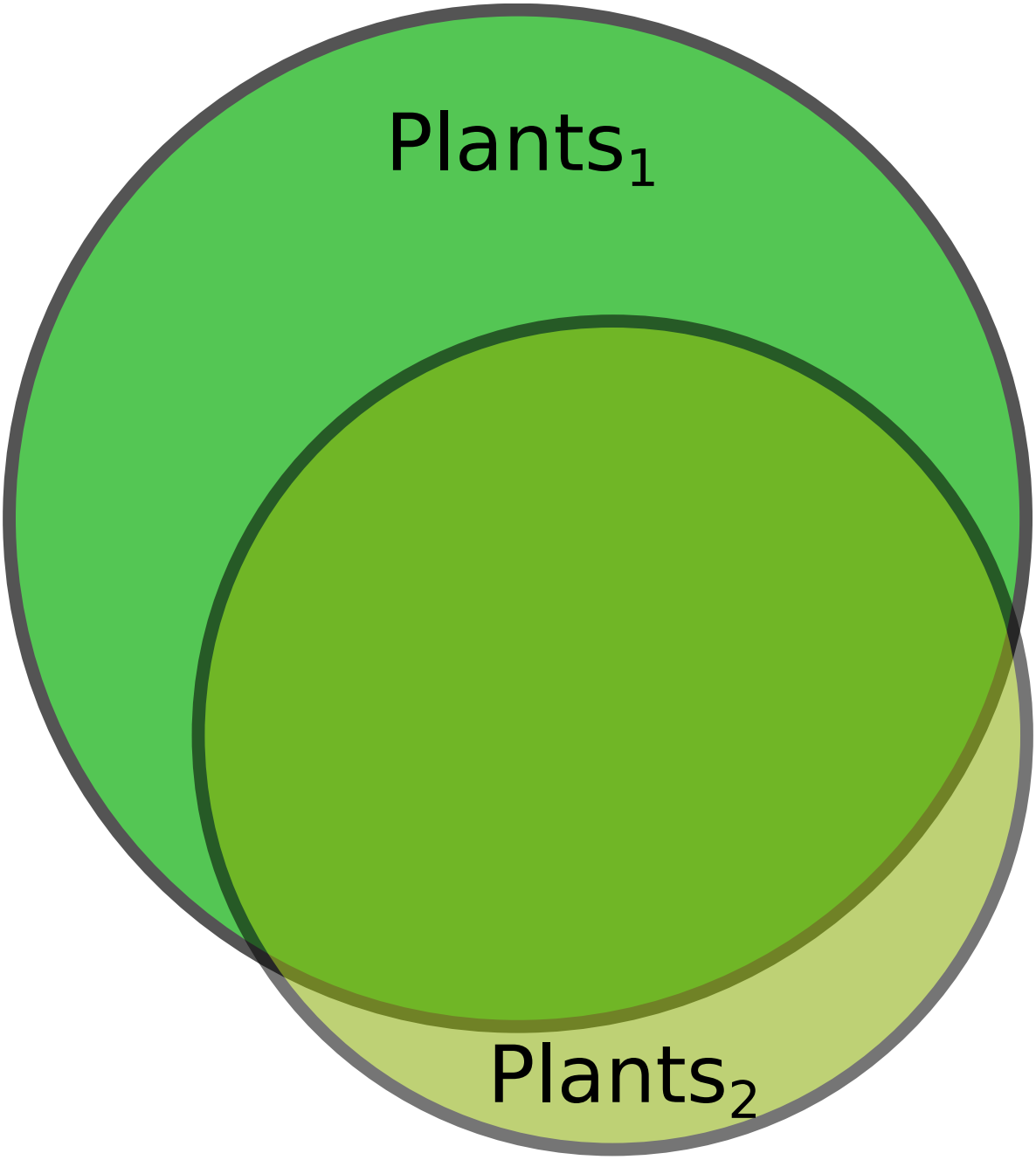
# References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2015. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

**Outline**

# 4 Questions and answers

**Last question**




***Hydnora***

Root parasite

***Pilostyles***

Internal parasite

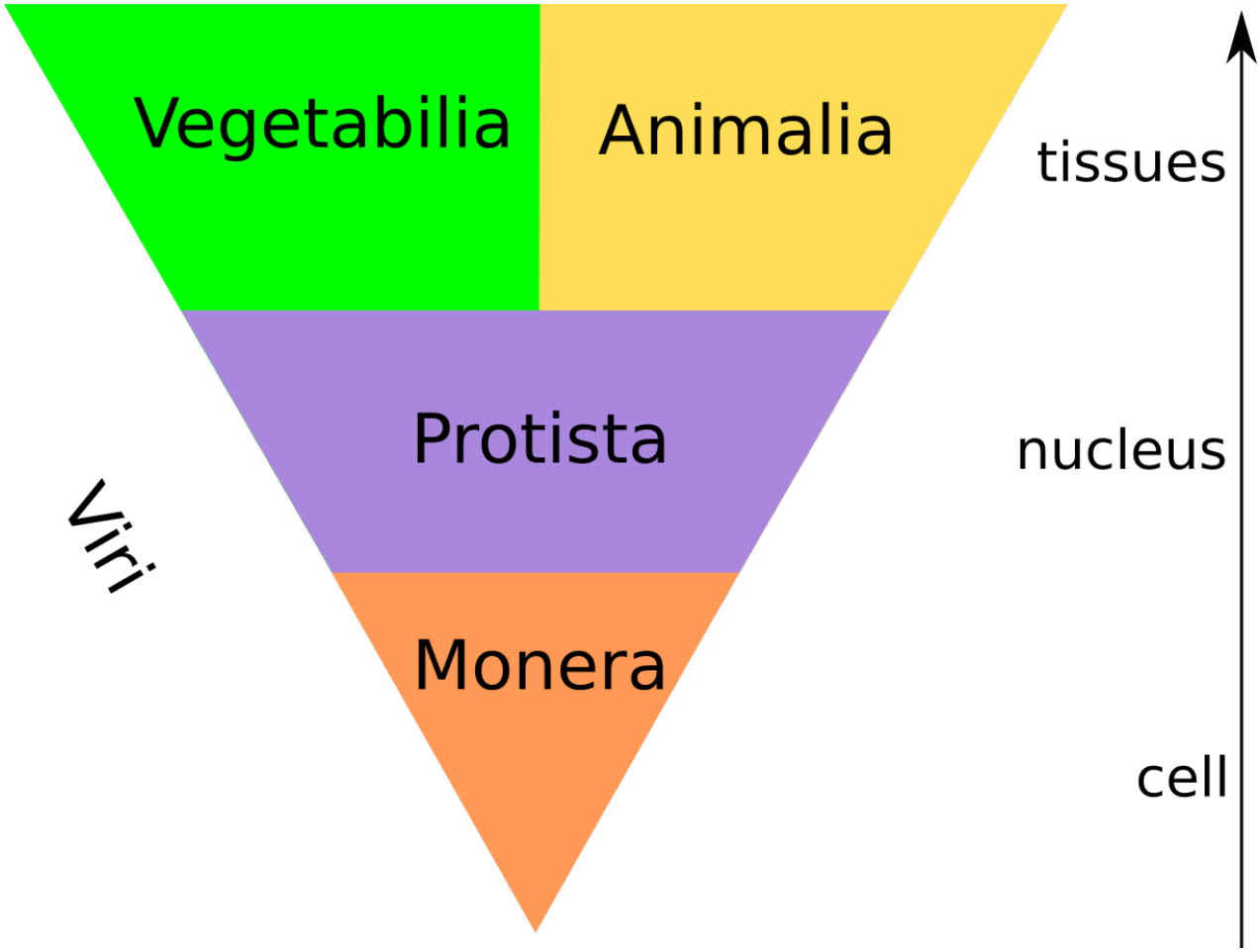
**Dodder**

Stem parasite

# 5 Plants in general

# 6 Plants$_1$ and plants$_2$

**Pyramid of life**

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**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**.

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# 7 Ways of life

## 7.1 Energy and food

### Ways of life

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

### Six life styles and taxonomy

| | **Phototrophs** | **Lithotrophs** | **Organotrophs** |
|---|---|---|---|
| **Autotrophs** | $\text{Plants}_1$: some Monera, some Protista, most of Vegetabilia | Some Monera | Some Monera |
| **Heterotrophs** | Some Monera | Some Monera | Majority of Animalia and many Protista and Monera |

### $\text{Plants}_1$, $\text{plants}_2$ and life styles

- $\text{Plants}_1$ are **photoauthotrophs**
- $\text{Plants}_2$ are photoauthotrophs too but there are exceptions: **fully parasitic plants**. Formally, many parasitic plants are $\text{plants}_2$ but not $\text{plants}_1$
- Carnivorous plants (like sundew or Venus flycatcher) are all photoautotrophs! They "eat" animals to obtain fertilizers: nitrogen and phosphorous.

## 7.2 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

**Summary**

- "Carnivorous" plants are not carnivores
- We will need to know multiple chemical terms (see in the lecture)

**For Further Reading**

# References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2015. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

**Outline**

# 8 Questions and answers

**Last question**

How many protons are in the nucleus of silicon (Si) atom?
Atomic weight 28.086 means that most likely there are 28 and 29 isotops: $^{28}$Si and $^{29}$Si
14 is a number = 14 protons = 14 electrons
Isotope I has: $28 - 14 = 14$ neutrons
Isotope II has: $29 - 14 = 15$ neutrons

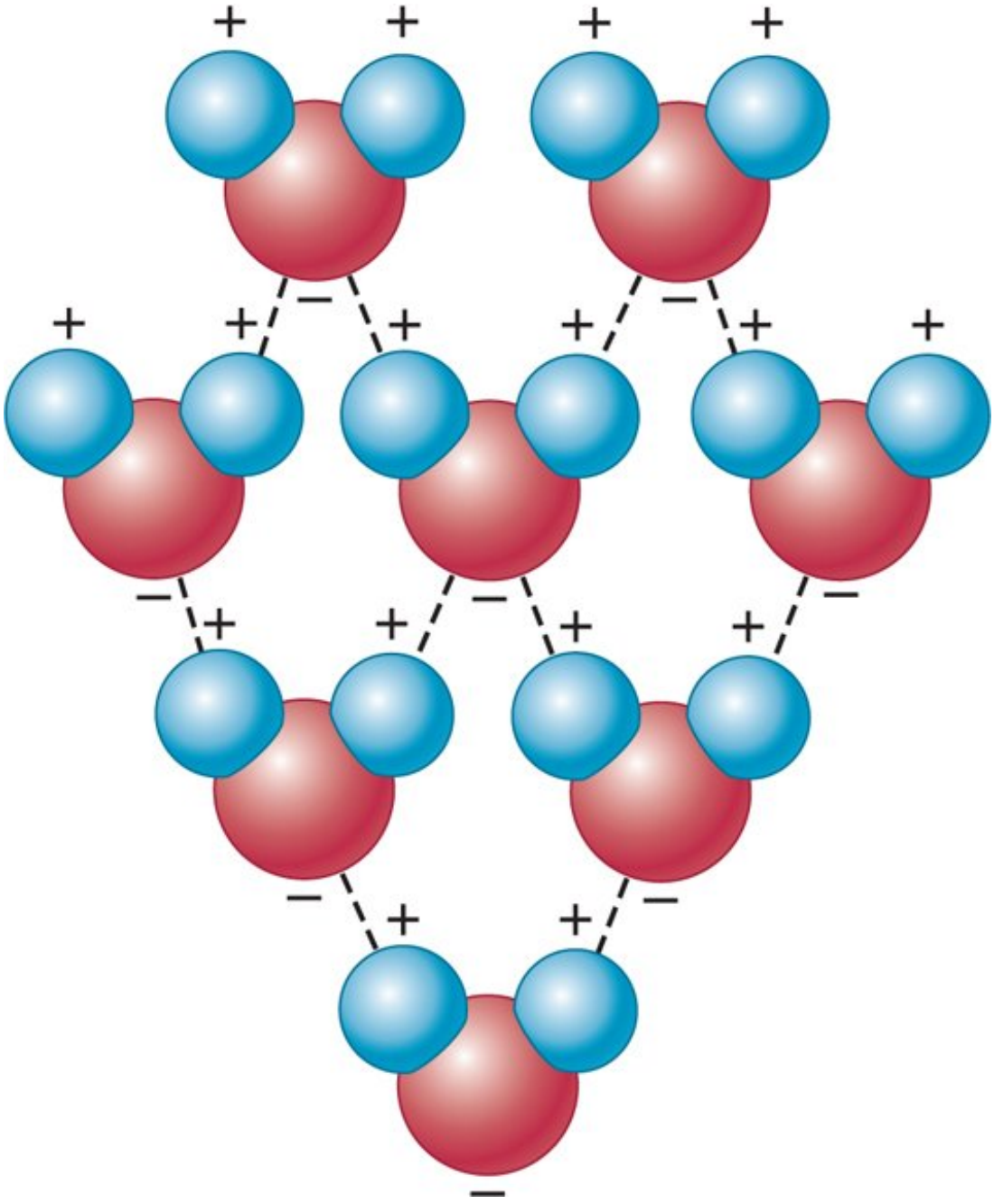
# 9 Chemistry of life

## 9.1 Very basics of chemistry

### 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

### Water with hydrogen bonds



**Acids and bases. Ions**

- Acids: take out $H^+$ (proton), like
  $HCl \rightarrow H^+ + Cl^-$
- Bases: take out $OH^-$ (hydroxyl)
  $NaOH \rightarrow Na^+ + OH^-$

**Molar mass 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, colcentration will still be 1 M whereas amount of diluted salt will decrease twice

**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]. 2015. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

**Outline**

# 10 Questions and answers

**Last question**

What is the molecular weight of $H_2Te$ (Hydrogen telluride)?

130 (the simple way, everything rounded) or 129.616 = 127.6 + 1.008 + 1.008 (practical way, to calculate moles)

It is also possible to use isotope way (there will be several different weights then) but this is non-practical sinse isotopes are not at all easy to separate

# 11 Chemistry of life

## 11.1 Very basics of chemistry

**Acids and bases. Ions**

- Acids: take out $H^+$ cation (proton), like

  $HCl \rightarrow H^+ + Cl^-$

  or

  $H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

[1] If we accept that atomic mass of chlorine in 35.

- Bases: take out $OH^-$ anion (hydroxyl)

  $NaOH \rightarrow Na^+ + OH^-$

**Molar mass and molar concentration**

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- 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, colcentration will still be 1 M whereas amount of diluted salt will decrease twice

**Concentration of protons, and pH and acidity**

- If concentration of protons is 0.1 M ($1 \times 10^{-1}$, 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 $1 \times 10^{-7}$ (0.0000001) M
- This is because water molecules can (rarely) dissociate: $H_20 \rightarrow H^+ + OH^-$
- pH of distilled water is equal to $-\log(10^{-7}) = -(-7) = 7$
- pH of the extremely acidic solution (first example) is 1

## 11.2 Molecules of life

**Organic chemistry: chemistry of carbon**

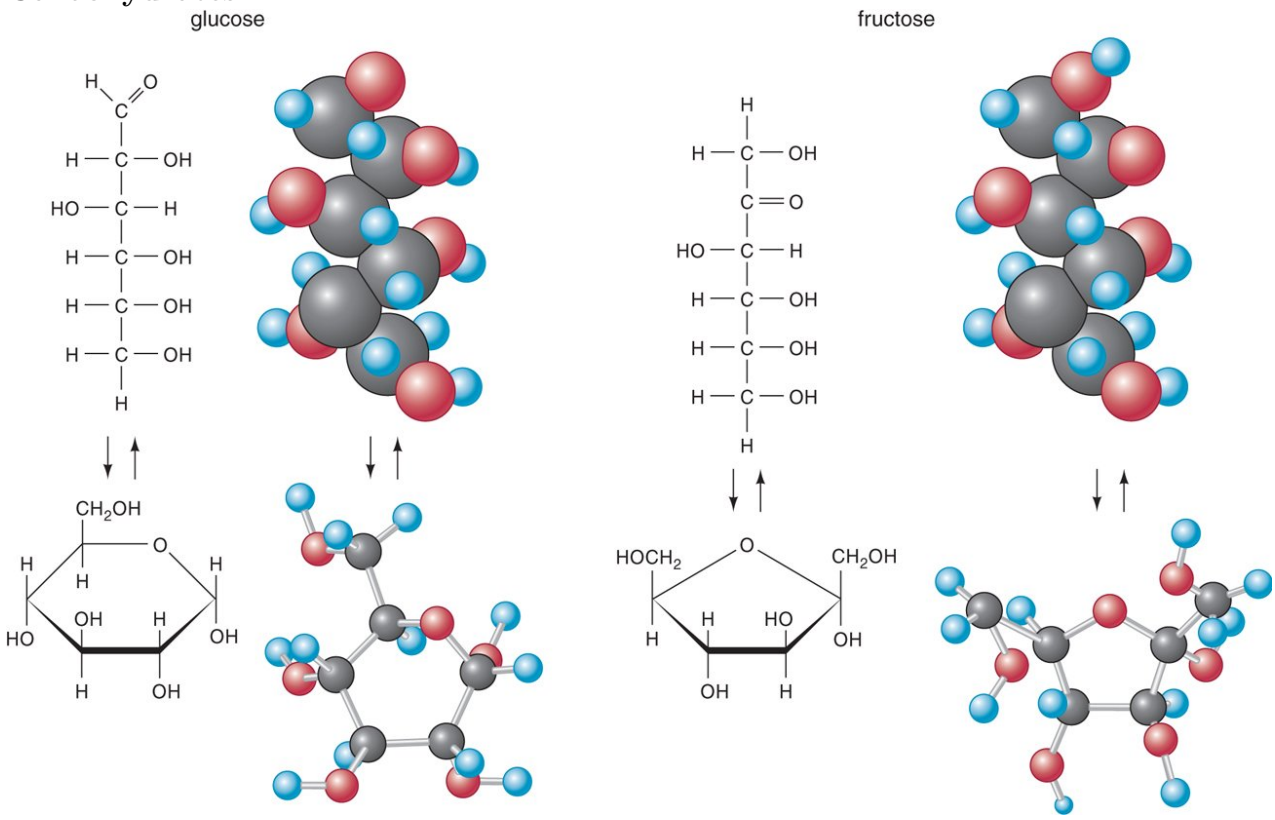
- Carbon skeleton
- And H, O, N, P, S

**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

[2] If we accept that atomic mass of chlorine in 35.

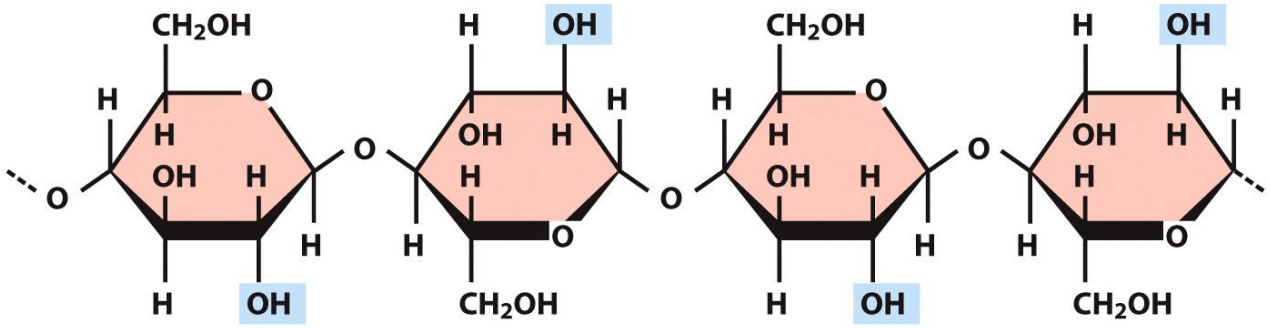
## Carbohydrates




## Organic polymers

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

## Cellulose




**Summary**

- Main biogenic elements: C, H, O, N, P
- Most important monomers: lipids, carbohydrates, amino acids, nucleotides
- Most important polymers: polysaccarides, proteins, nucleic acids

# 12 Photosynthesis

## 12.1 History of photosynthesis studies

**van Helmont**

- Johannes van Helmont (17th century) rejected the idea that plans 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

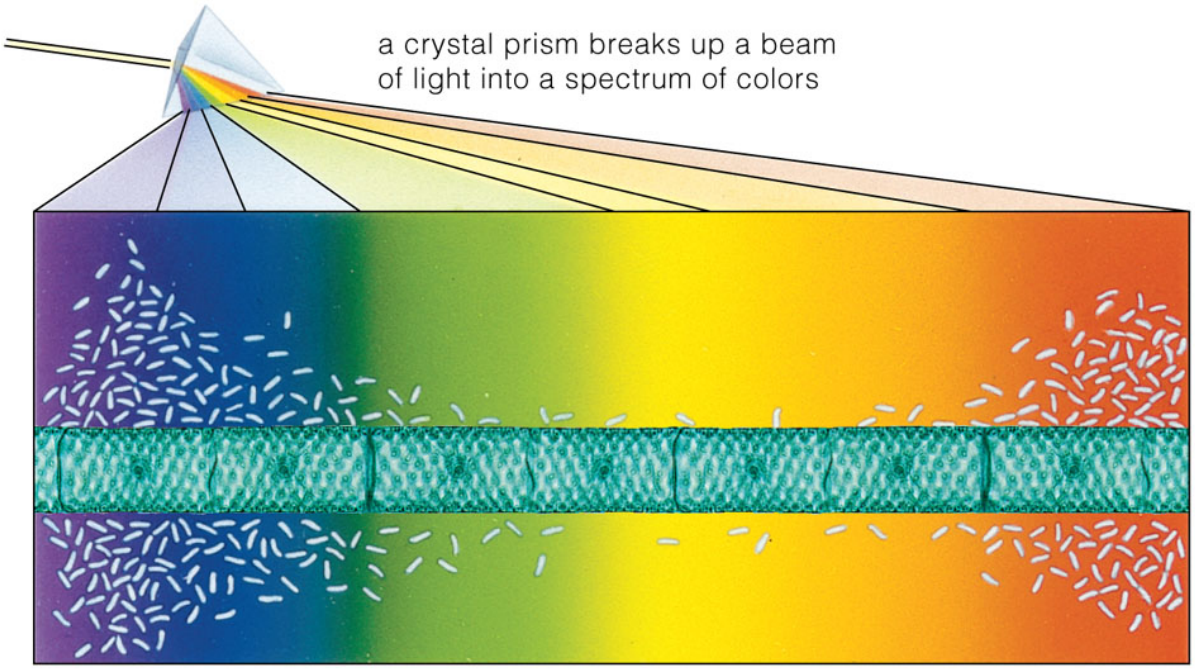
**Further history**

- Jan Ingenhousz (1779–1796) and Jean Senebier (1780) found that:
  - Only in day time the air is reviving
  - $CO_2$ 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**



**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

**Final question (2 points)**

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

**Summary**

- From 17th century, in constantly become clear that plants make their biomass from light, water and carbon dioxide
- **Photosynthesis** is a sum of light-dependent and light-independent reactions

**For Further Reading**

# References

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**Outline**

# 13 Questions and answers

**Last question**

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.

# 14 Photosynthesis

## 14.1 As a whole I

### Blackman

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

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

### Participants of light stage

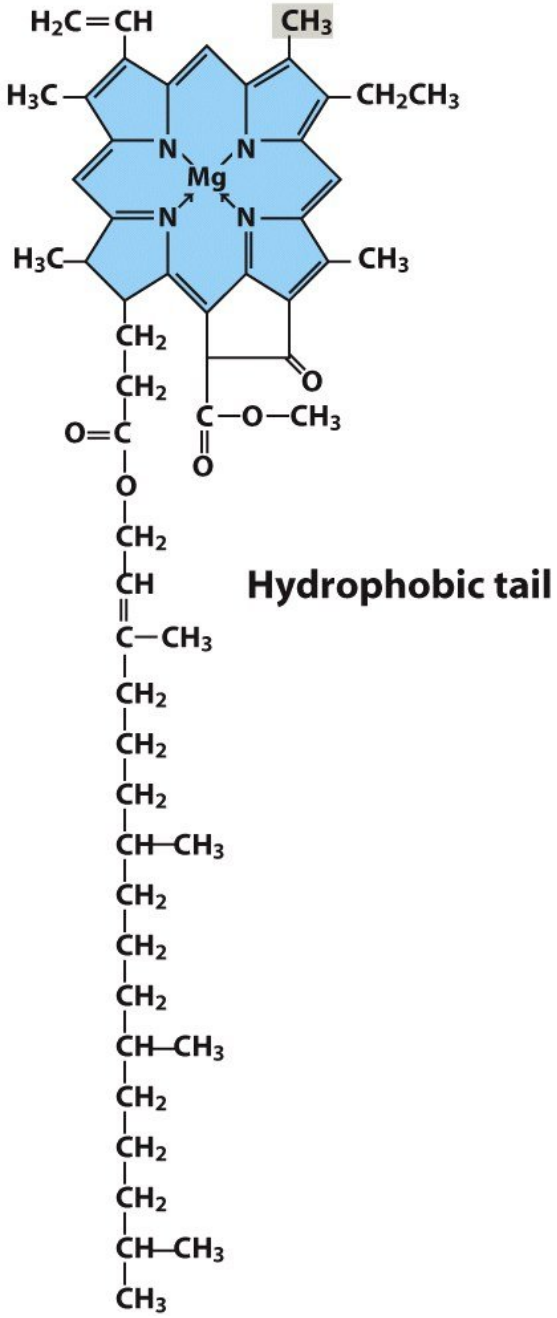
1. Chlorophyll (photosystems II and I)
2. Light
3. Water
4. ATP synthase (ATPase)
5. Protons ($H^+$)
6. Hydrogen carrier ($NADP^+$)

**Where**: around thylakoid membrane

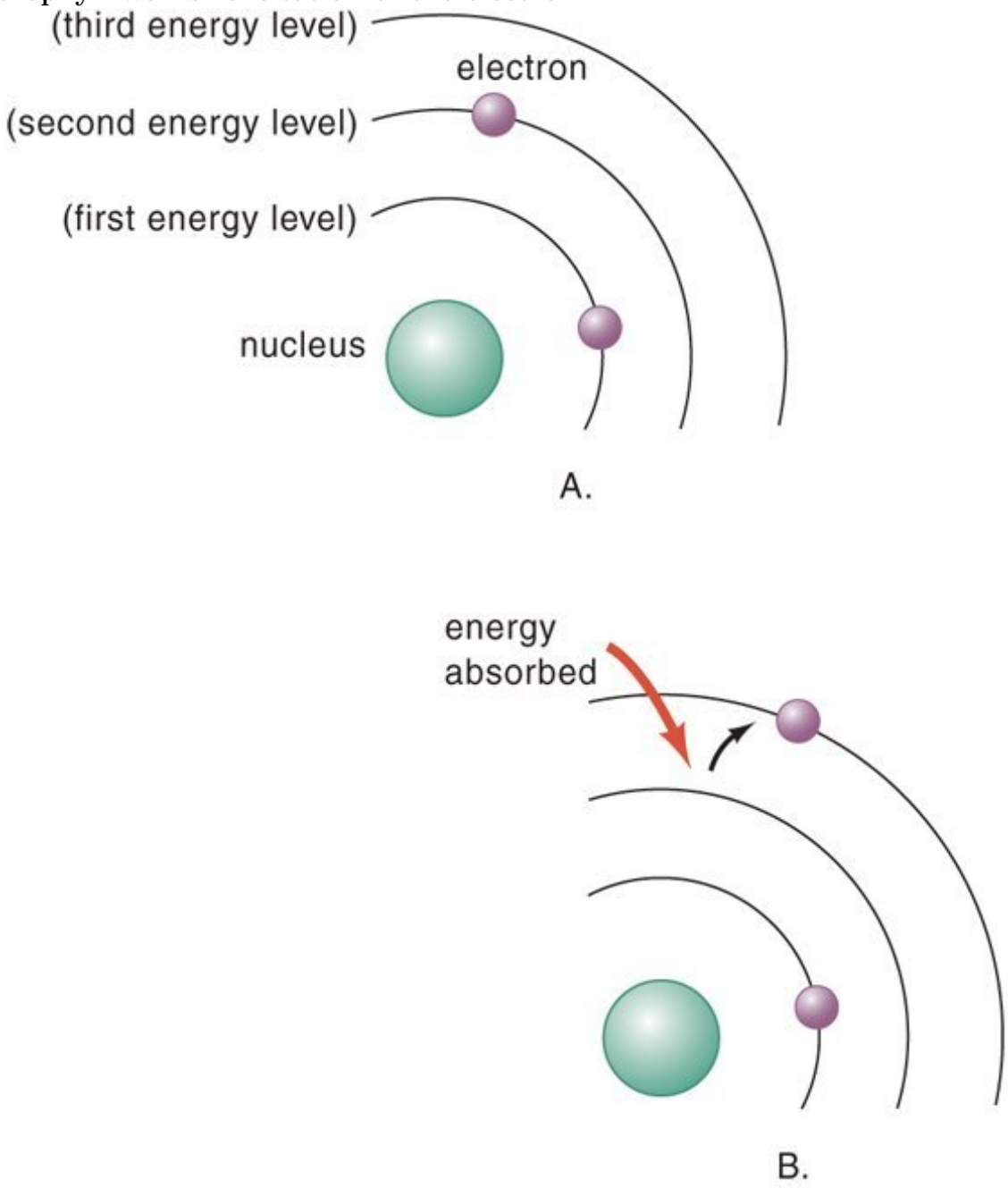
**Logic of the light stage**

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

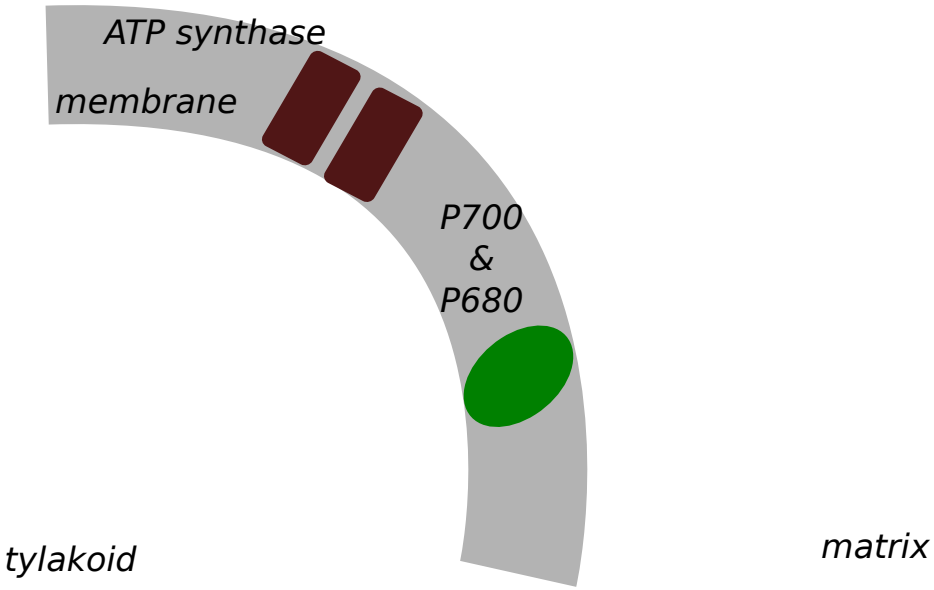
**Why chlorophyll is good for the membrane**

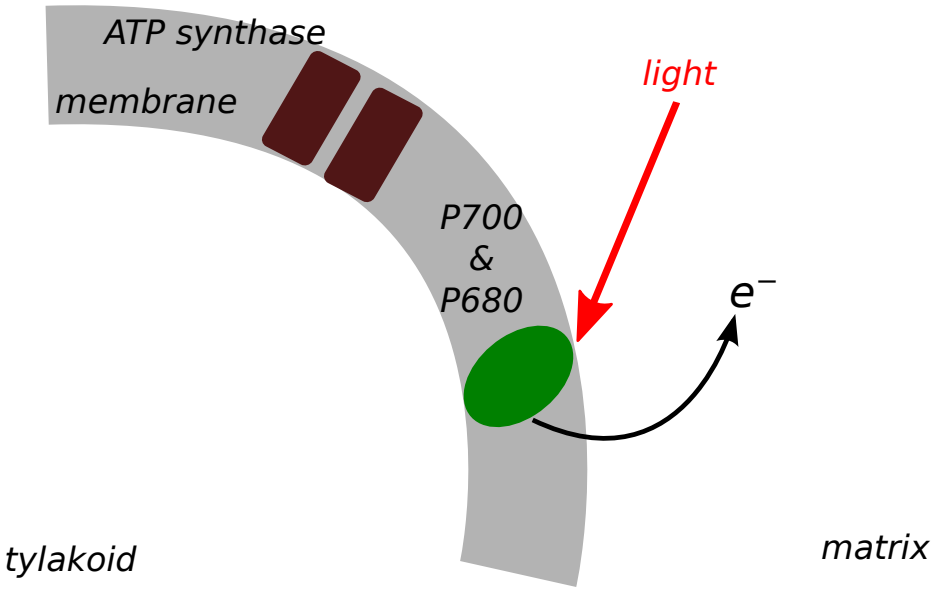


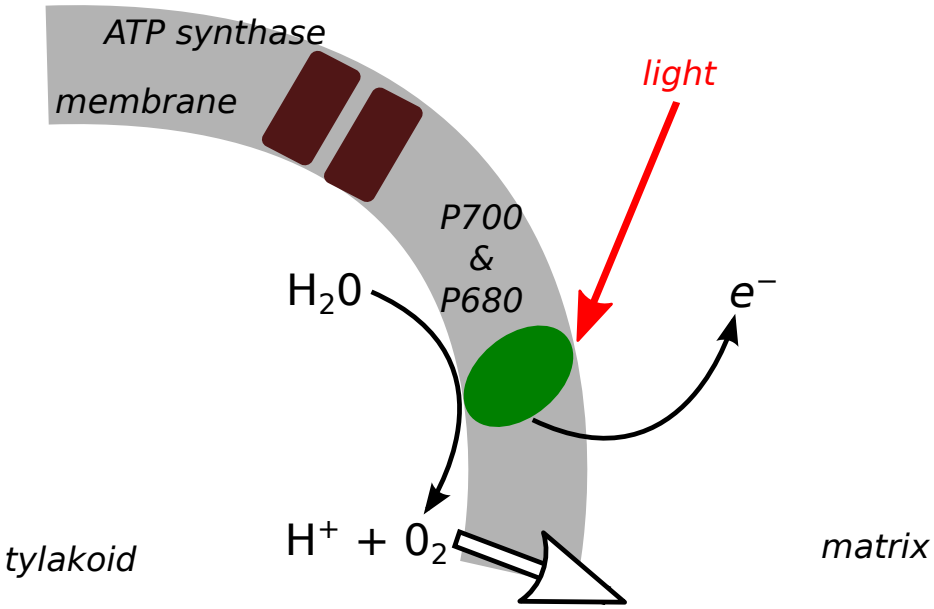
**How chlorophyll works: excitation of the electron**




*Scheme of light stage*


ATP synthase
membrane
P700
&
P680
tylakoid
matrix


ATP synthase
membrane
light
P700
&
P680
e⁻
tylakoid
matrix


ATP synthase
membrane
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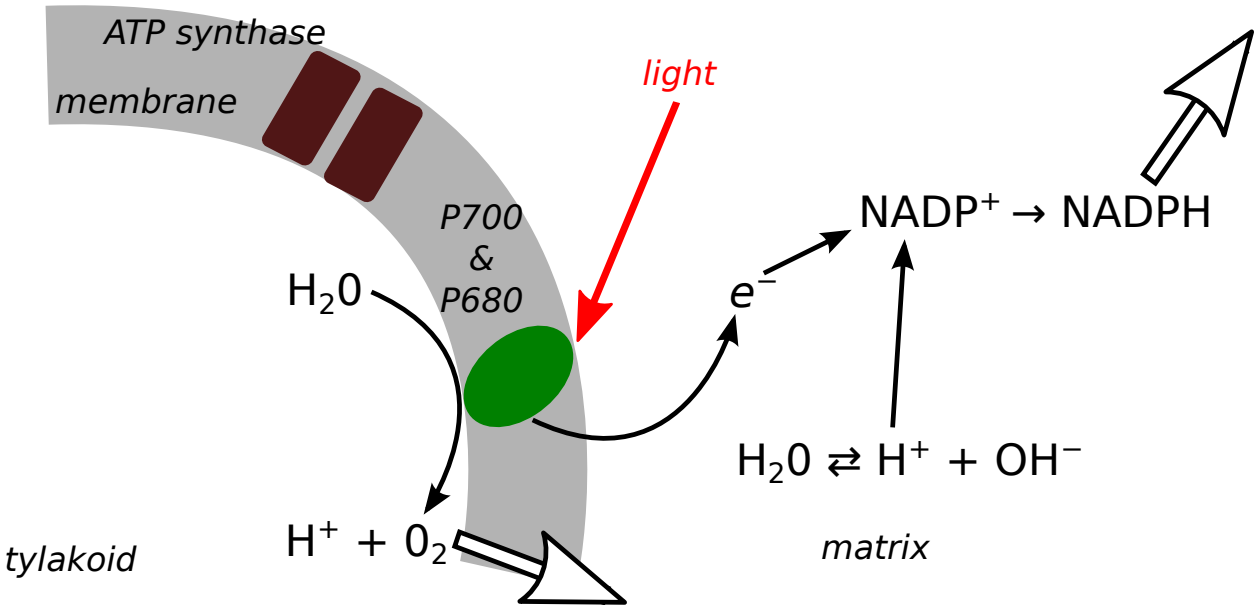
P680
$H_20$
$e^-$
$H^+ + 0_2$
tylakoid
matrix


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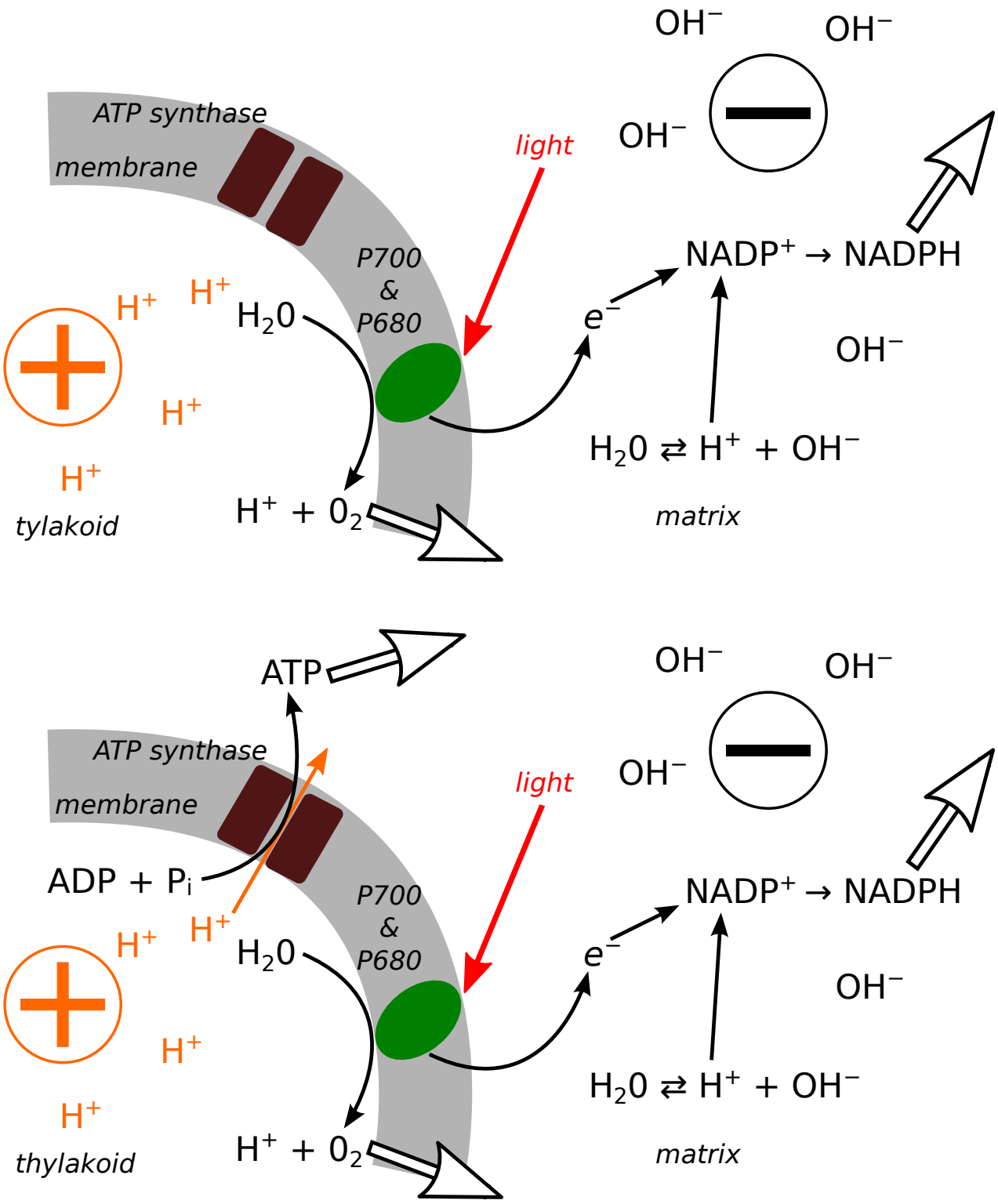
light
P700
&
P680
$H_20$
$e^-$
$NADP^+ \rightarrow NADPH$
$H_20 \rightleftarrows H^+ + OH^-$
$H^+ + 0_2$
tylakoid
matrix




**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 |

## 14.3 Enzymatic stage: fixation of carbon dioxide

**Participants of enzymatic stage**

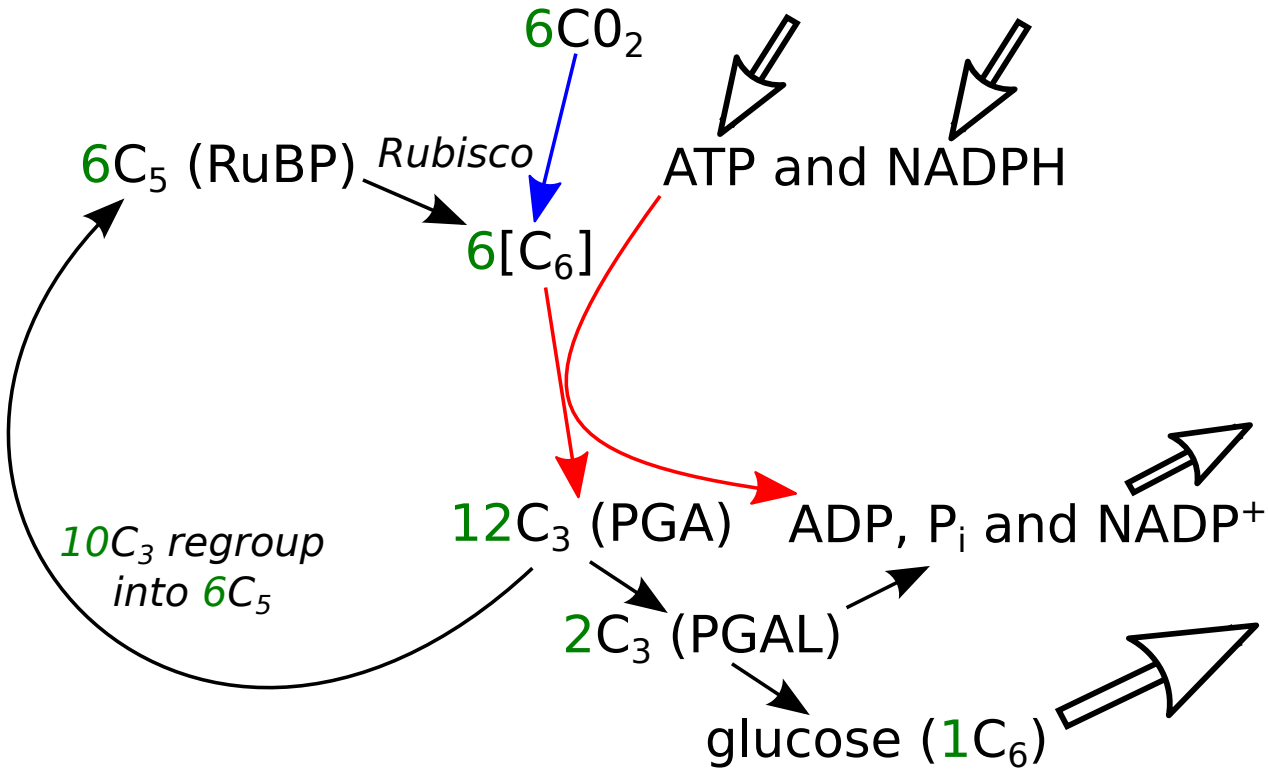
1. Carbon dioxide ($CO_2$)
2. Hydrogen carrier with hydrogen (NADPH)
3. Source of energy (ATP)
4. Ribulose biphosphate (RuBP, five-C-hydrocarbonate, "$C_5$")
5. *Rubisco* and other enzymes

**Place**: in the matrix (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)
   - Organic molecules are synthesized from $C_3$ (PGA) through energy-rich **PGAL** (phosphoglyceric aldehyde)

**Enzymatic stage: scheme**



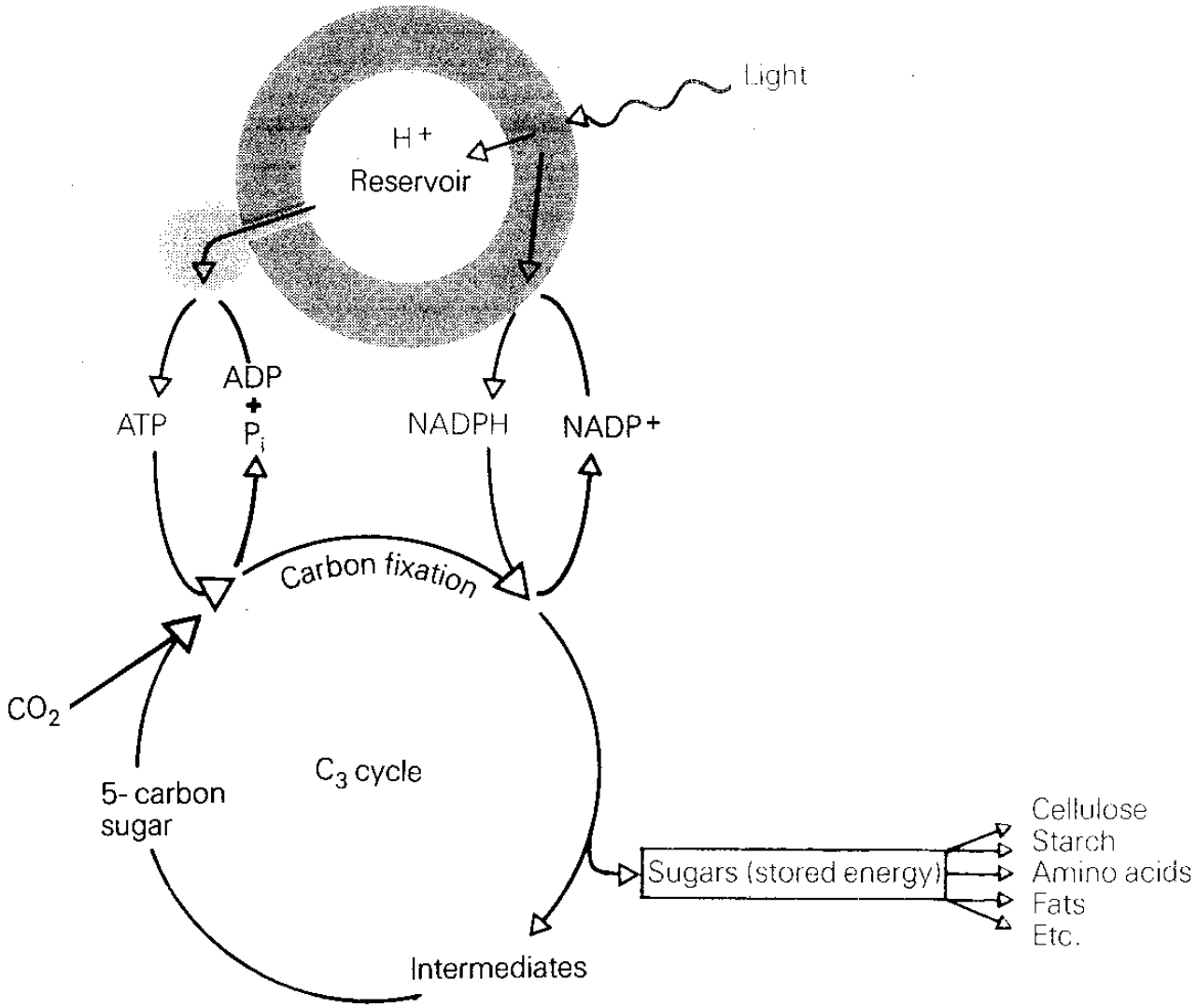

**Results of enzymatic stage**

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

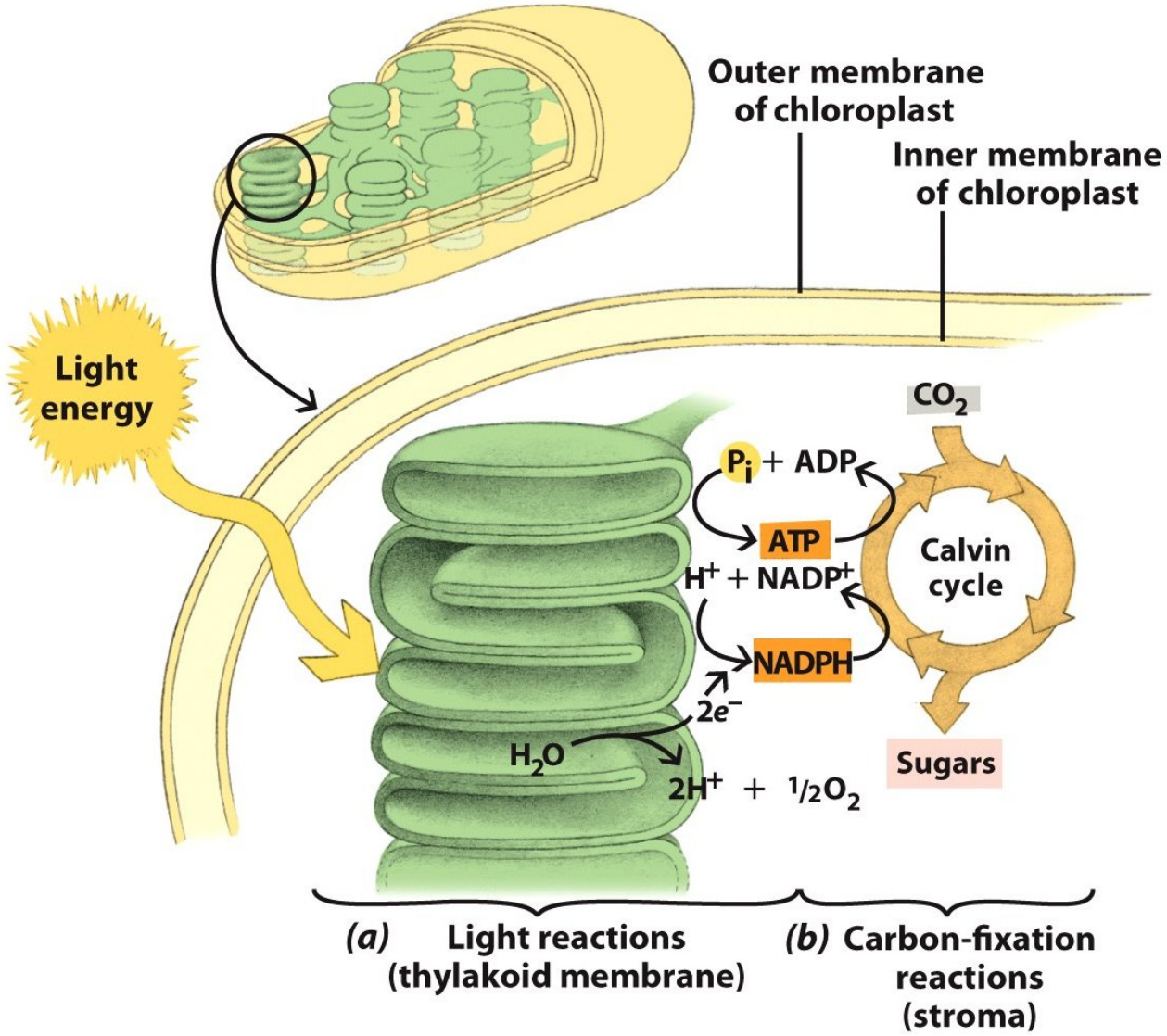
The other names for enzymatic stage are "Calvin cycle" and "$C_3$ cycle"

## 14.4 As a whole II

**Overview of photosynthesis**




**Photosynthesis in the cell**




Photosynthesis movie

**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
- **Enzymatic stage** of photosynthesis results in synthesis of organic molecules

**For Further Reading**

# References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2015. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

# Example questions for the exam

*Start time* _____ *End time* _____

## Short answers

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

_____
_____
_____
_____
_____
_____
_____

## Multiple choice

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

1. 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) Lipidr and nitrogen
2. In photosynthesis, water used to make:
   (a) carbon dioxide
   (b) oxygen
   (c) more water
3. Dodder is:
   (a) $\text{Plant}_1$ (ecological definition) and $\text{plant}_2$ (taxonomic definition)
   (b) $\text{Plant}_1$ only
   (c) $\text{Plant}_2$ only

*(answers on next page)*

Answers: 1A, 2B, 3C