# Introduction to Botany: BIOL 154
# Study guide for Exam 2

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Lectures 8–17

## Contents

**Outline**

# 1 Questions and answers

## 1.1 Quiz

**Final question (1 point)**

Explain the role of $NADP^+$

- 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 lately
- Accumulated $OH^-$ (hydroxide ion) makes the gradient and then the electrical flow through ATPase

# 2 Photosynthesis

## 2.1 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)

**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 $CO_2$ and synthesis of organic molecules

**For Further Reading**

# References

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

**Outline**

# 3 Questions and answers

## 3.1 Quiz

**Final question (2 points)**

Explain the role of NADPH in the enzymatic stage.

- It provides hydrogen to use in glucose
- In addition, it provides energy in the way similar to ATP

# 4 Photosynthesis

## 4.1 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) $\xrightarrow{\text{rubisco}}$ $C_6$
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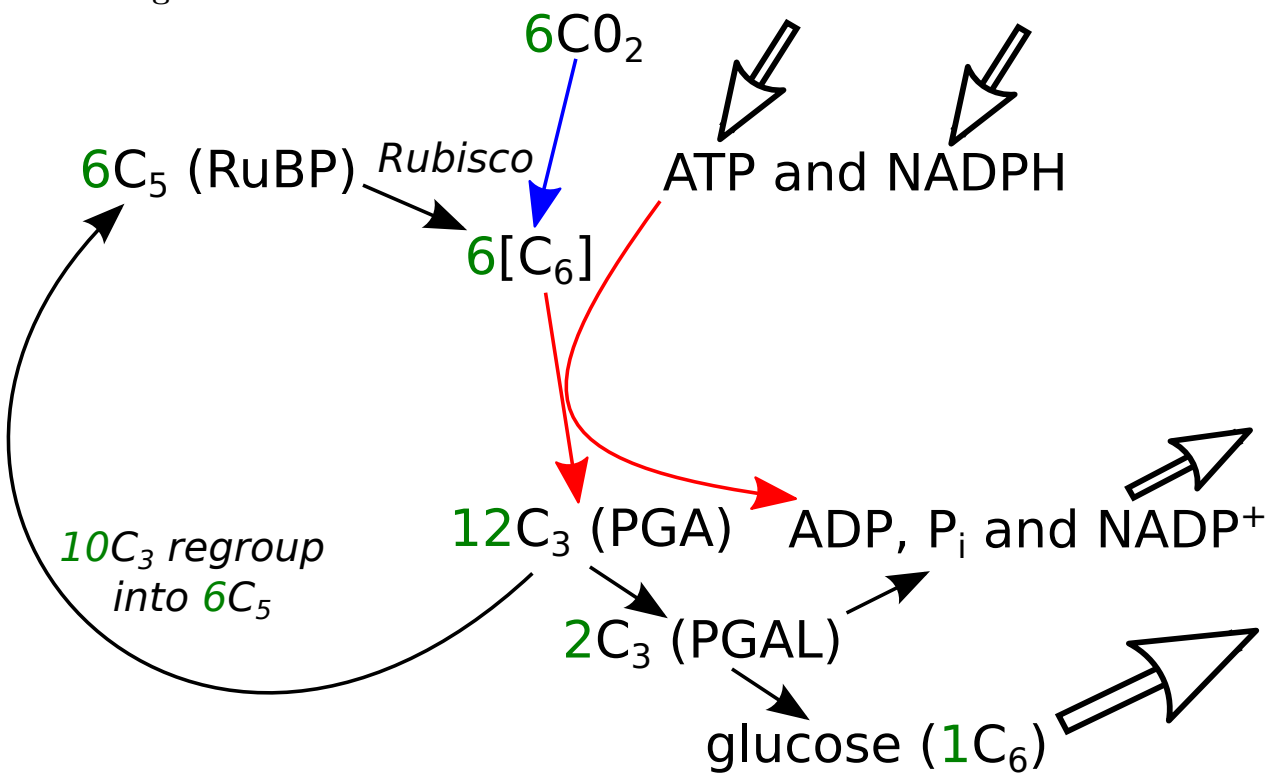
3. $C_3$ + NADPH + ATP $\longrightarrow$ $C_6H_{12}O_6$ (or other organic molecules) + $C_5$ + $NADP^+$ + ADP + $P_i$ (inorganic phosphate)

    - Organic molecules are synthesized from $C_3$ (PGA) through energy-rich **PGAL** (phosphoglyceric aldehyde)

**Enzymatic stage: scheme**



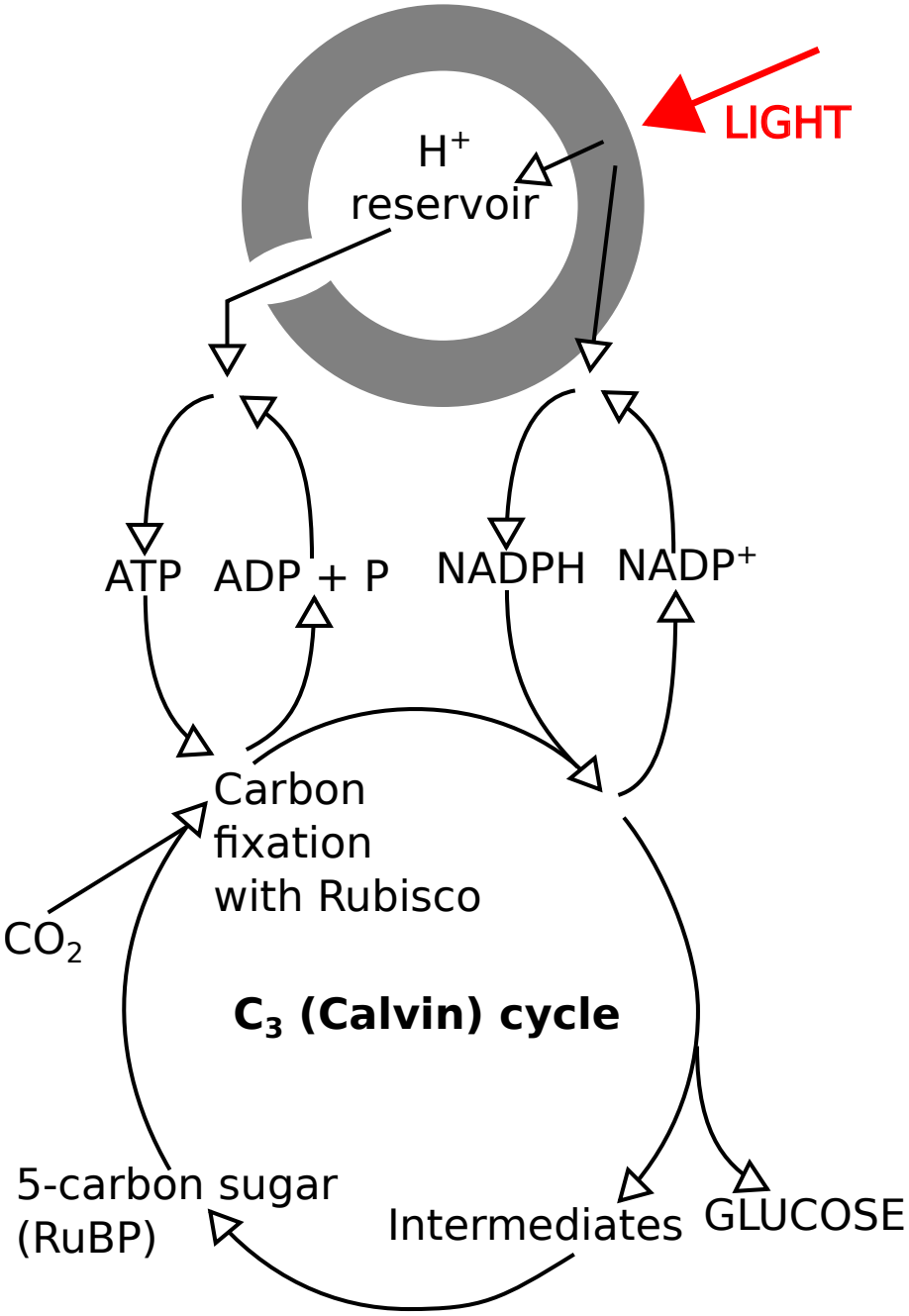

**Results of enzymatic stage**

| 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 |

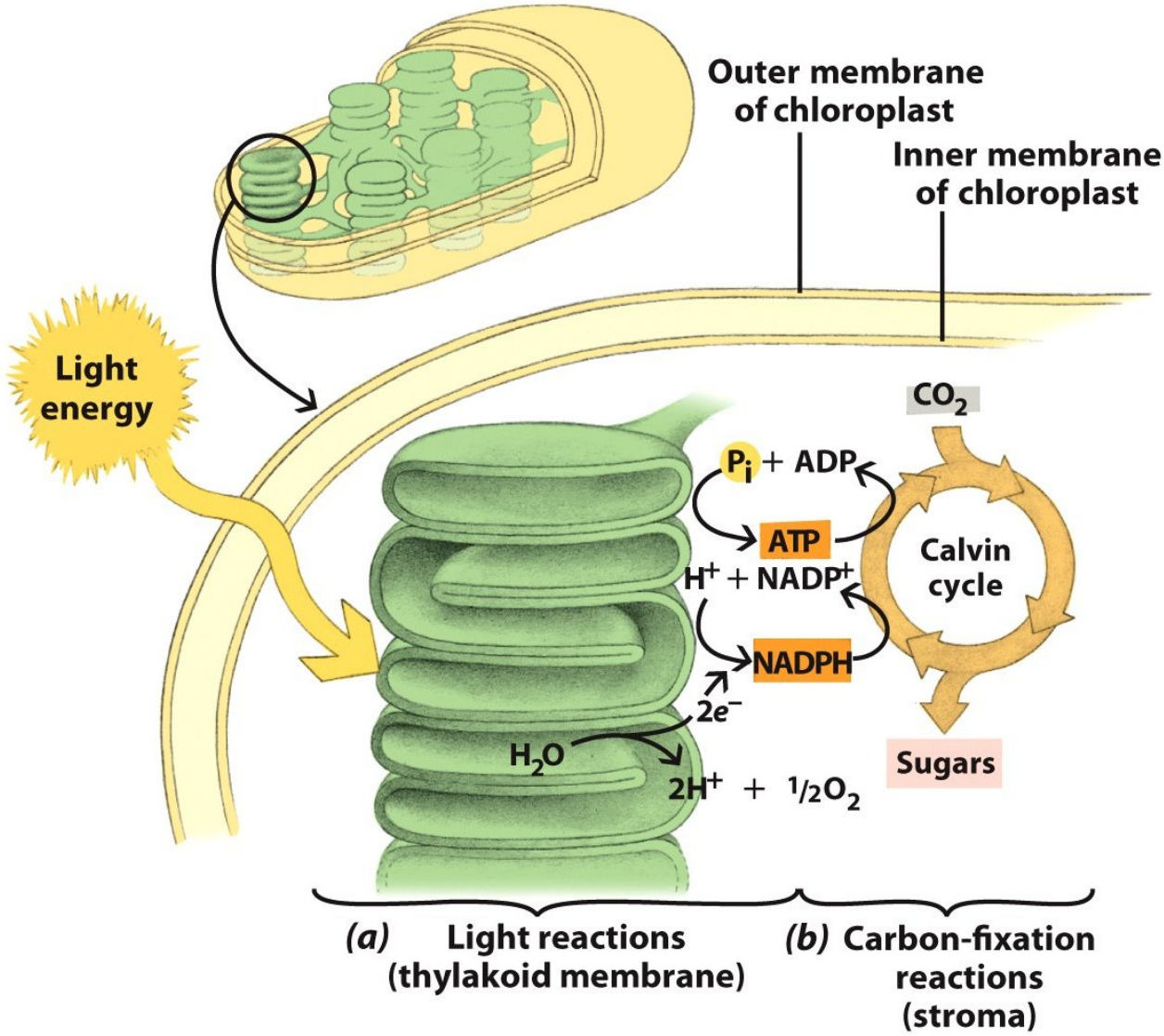
The other names for enzymatic stage are "Calvin cycle" and "$C_3$ cycle"

## 4.2 As a whole

**Overview of photosynthesis**




**Photosynthesis in the cell**




Photosynthesis movie

## 4.3 Special case of photosynthesis: $C_4$ pathway

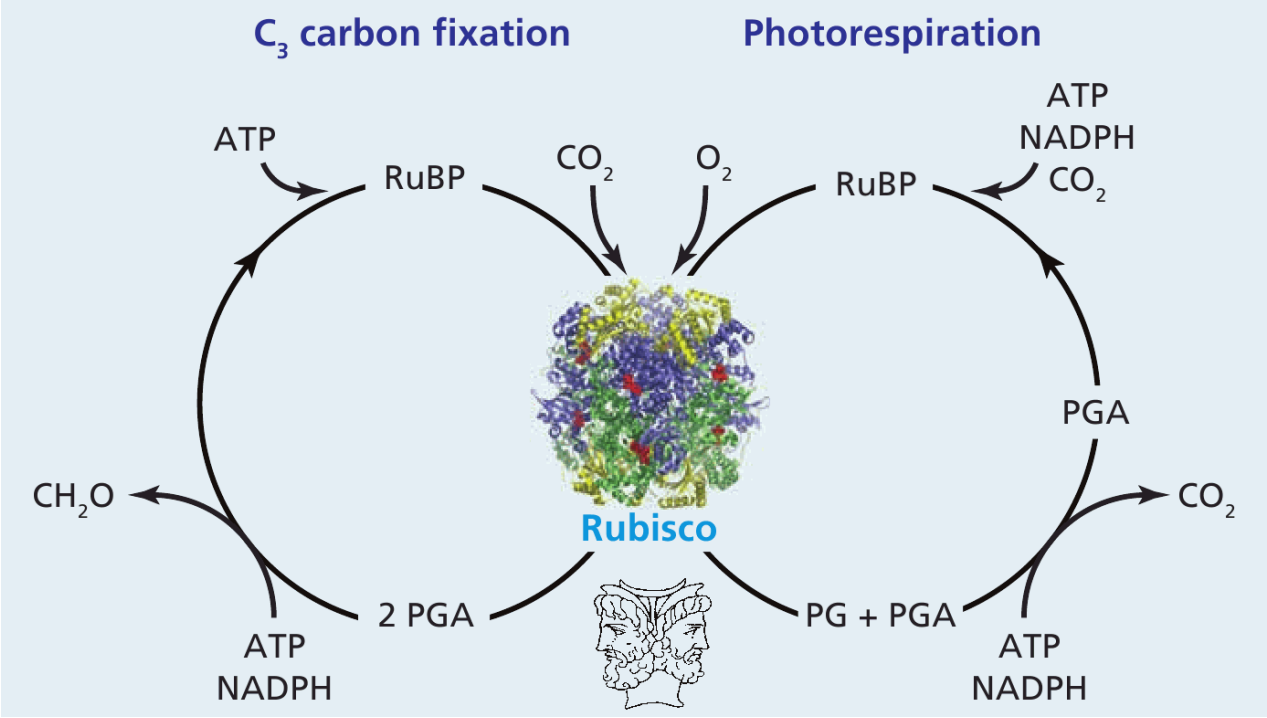
**Photorespiration**

*Rubisco* is two-faced enzyme, it catalyzes **photorespiration** if the concentration of $O_2$ and/or temperature is high:

$$O_2 + C_5 \text{ (ribulose biphosphate)} \xrightarrow{Rubisco} \text{3-phosphoglycerate (PGA)} + \text{phosphoglycolate (PGAL)} \longrightarrow \text{glycolate}$$

- To return glycolate into the Calvin cycle, cell must use peroxisomes, mitochondria and spend ATP
- Photorespiration wastes $C_5$ and ATP
- Photorespiration is said to be an evolutionary relic from times when atmosphere contained little oxygen

**Two-faced Rubisco**



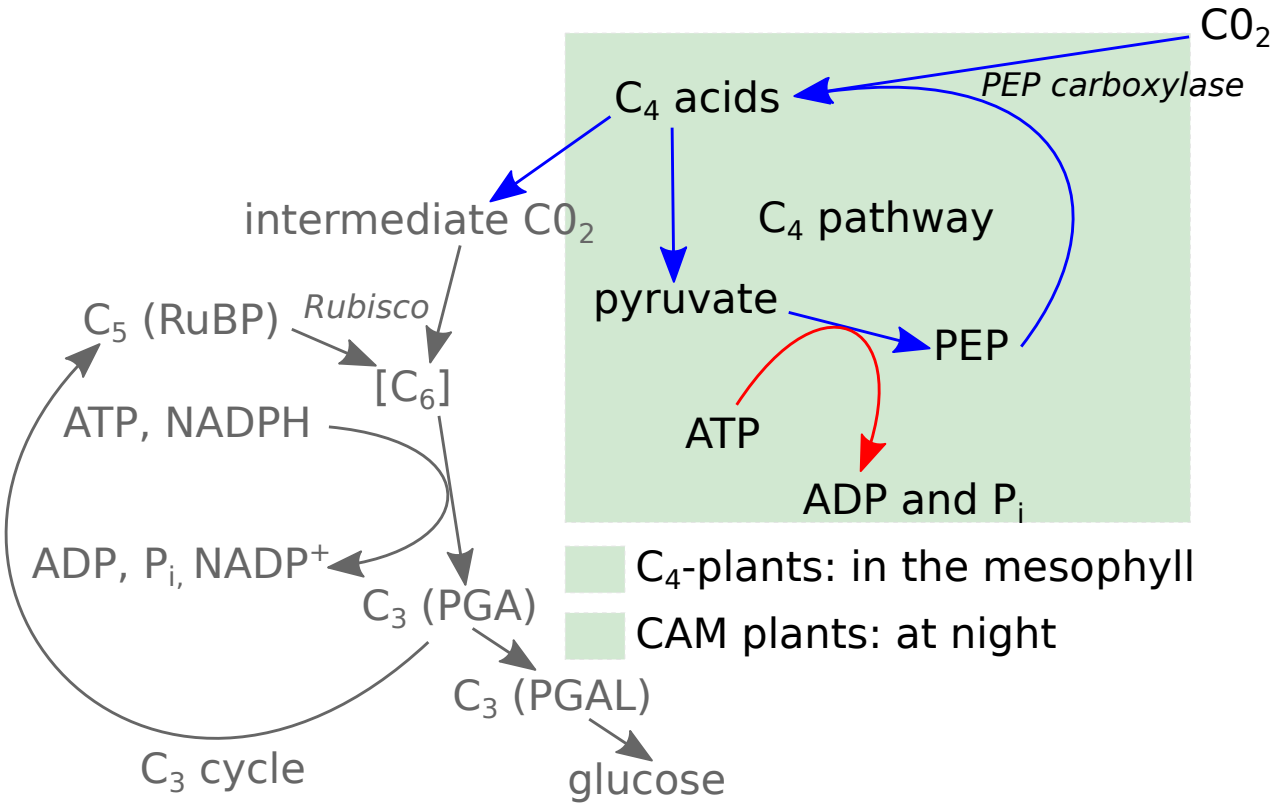

**Minimization of photorespiration**

To minimize photorespiration, plants need to increase concentration of $CO_2$. This is how they do it:

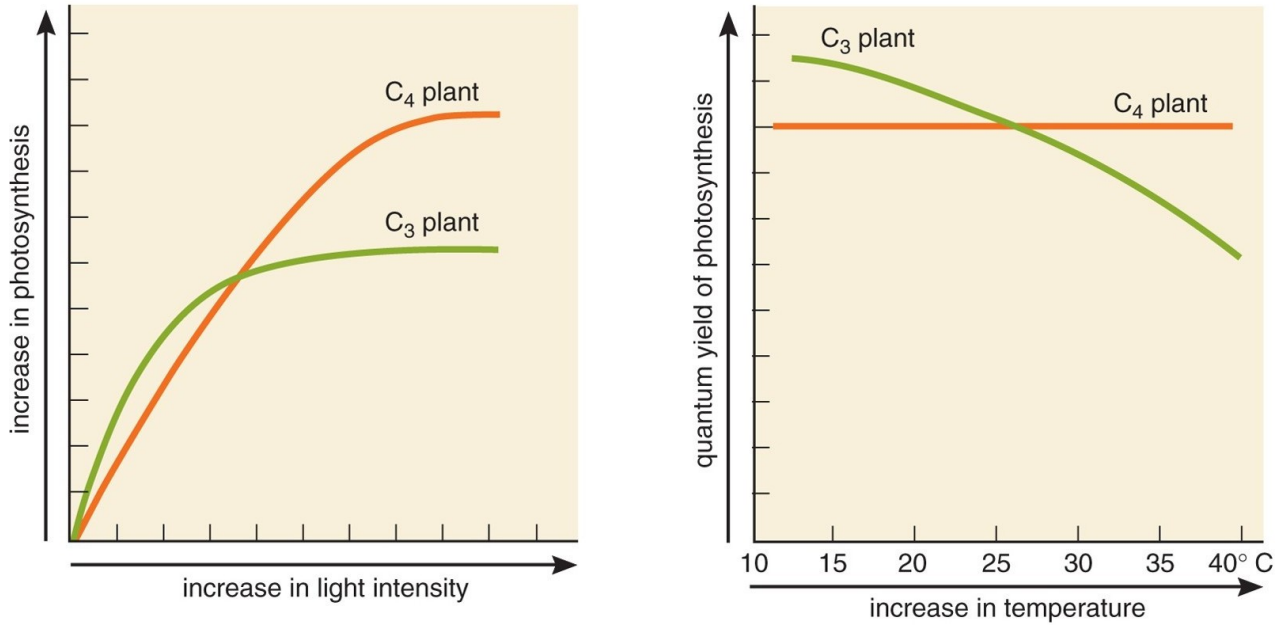
1. $CO_2 + C_5$ (PEP, phosphoenolpyruvate) $\xrightarrow{\text{PEP carboxylase}}$ $C_4$ (different organic acids): this is the temporarily accumulation of carbon dioxide
2. $C_4 \longrightarrow$ pyruvate + $CO_2$: release of carbon dioxide will increase its concentration
3. Pyruvate + ATP $\longrightarrow$ PEP + AMP + $2P_i$: PEP recovery costs ATP

Processes above called $C_4$ pathway, it is an addition to Calvin ($C_3$) cycle in order to increase concentration of $CO_2$

**$C_4$ pathway at-a-glance**




**C$_4$-pathway plants feel better at high temperature and light intensity**




C$_4$-pathway plants waste ATP to recover PEP but outperform strict C$_3$ plants when concentration of oxygen is high

**Final question (2 points)**

What is photorespiration?

**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

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**Outline**

# 5 Questions and answers

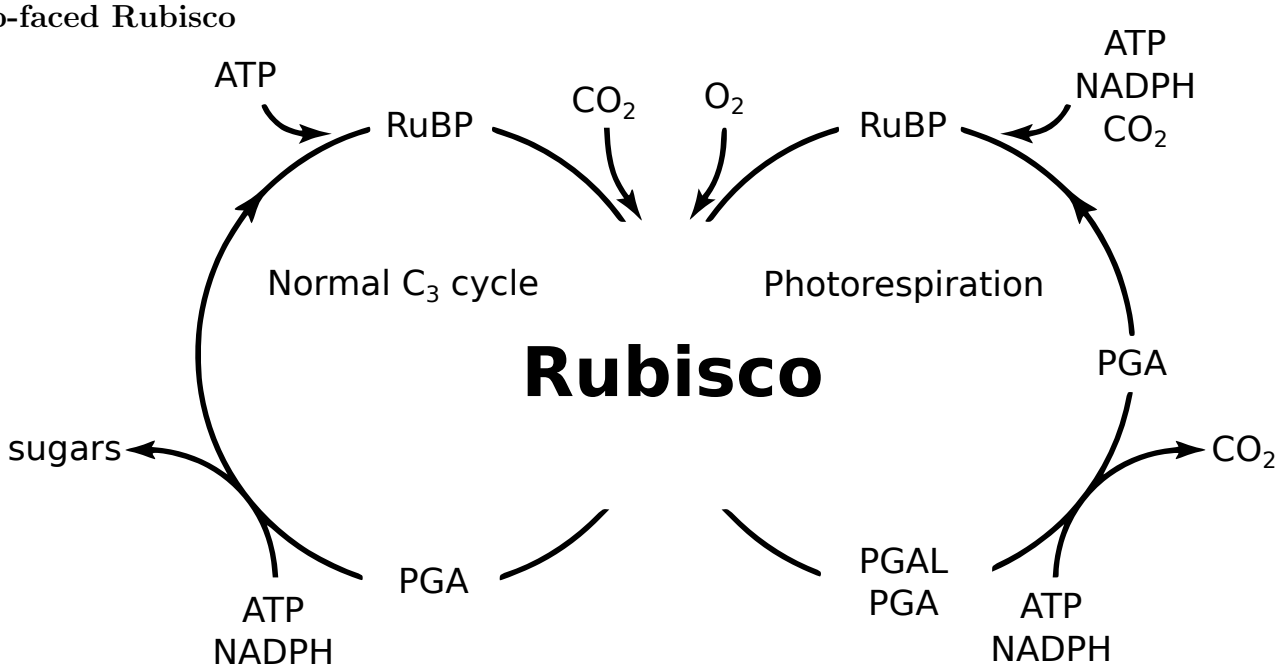
## 5.1 Quiz

**Final question (2 points)**

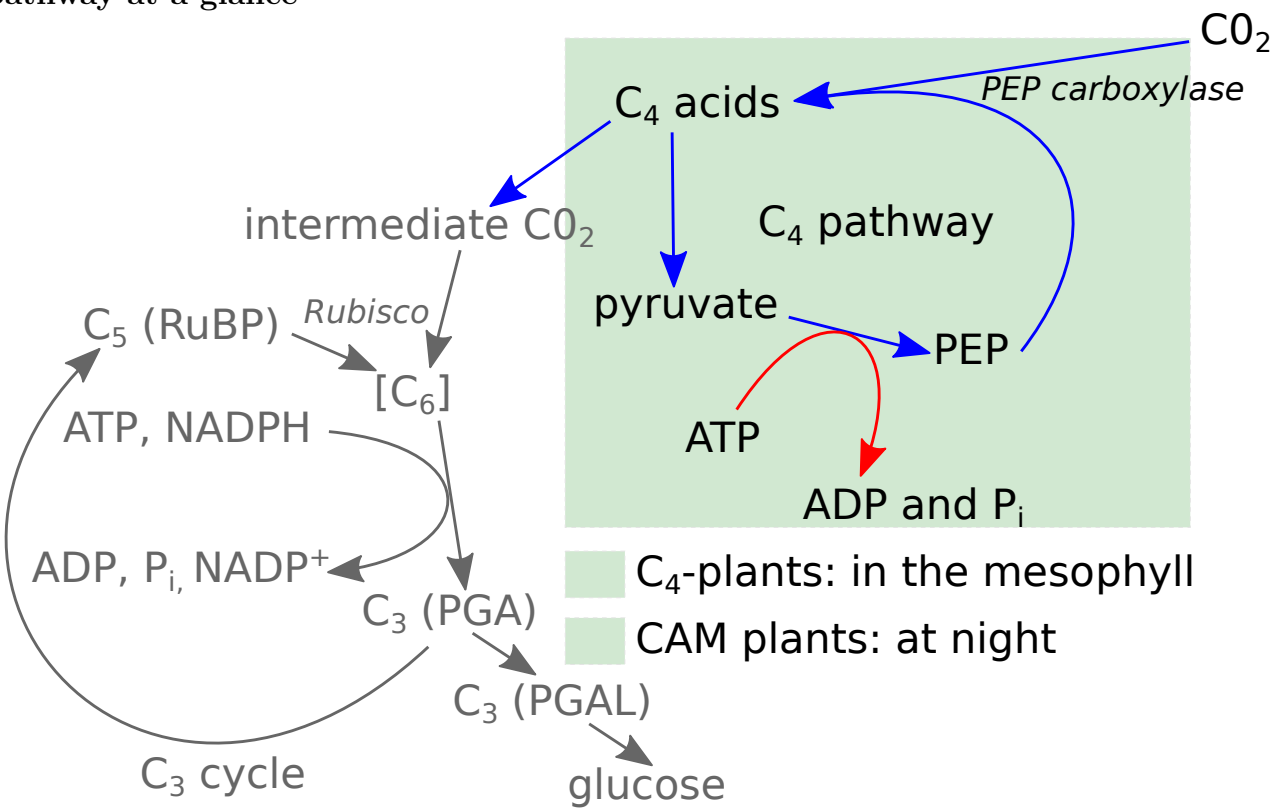
What is photorespiration?

- This is a "wrong turn" of Calvin cycle when there are too many oxygen molecules
- Instead of carbon dioxide, Rubisco takes oxygen and then many efforts (and ATP) required to restore everything back to normal

**Two-faced Rubisco**



**$C_4$ pathway at-a-glance**



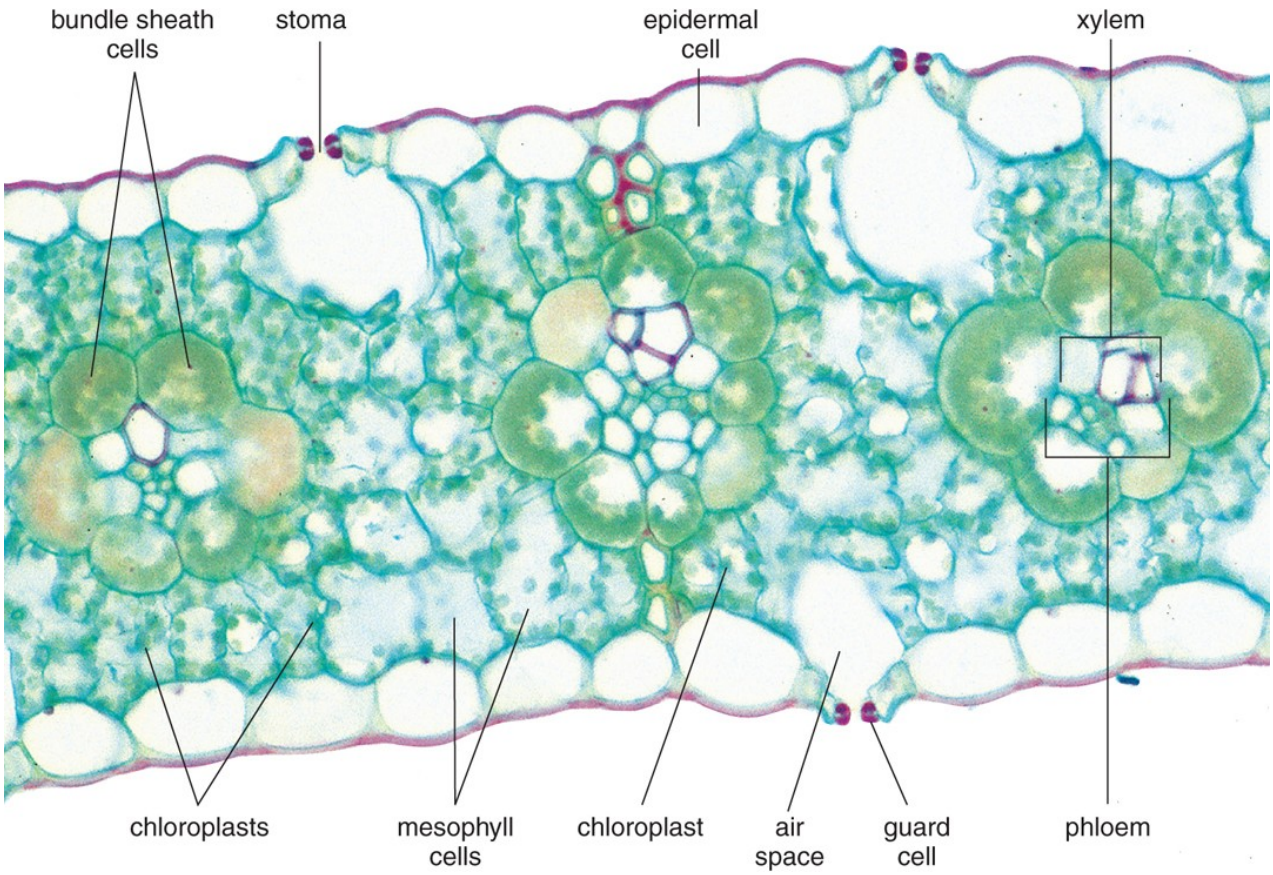

# 6 Photosynthesis

## 6.1 $C_4$ and CAM plants

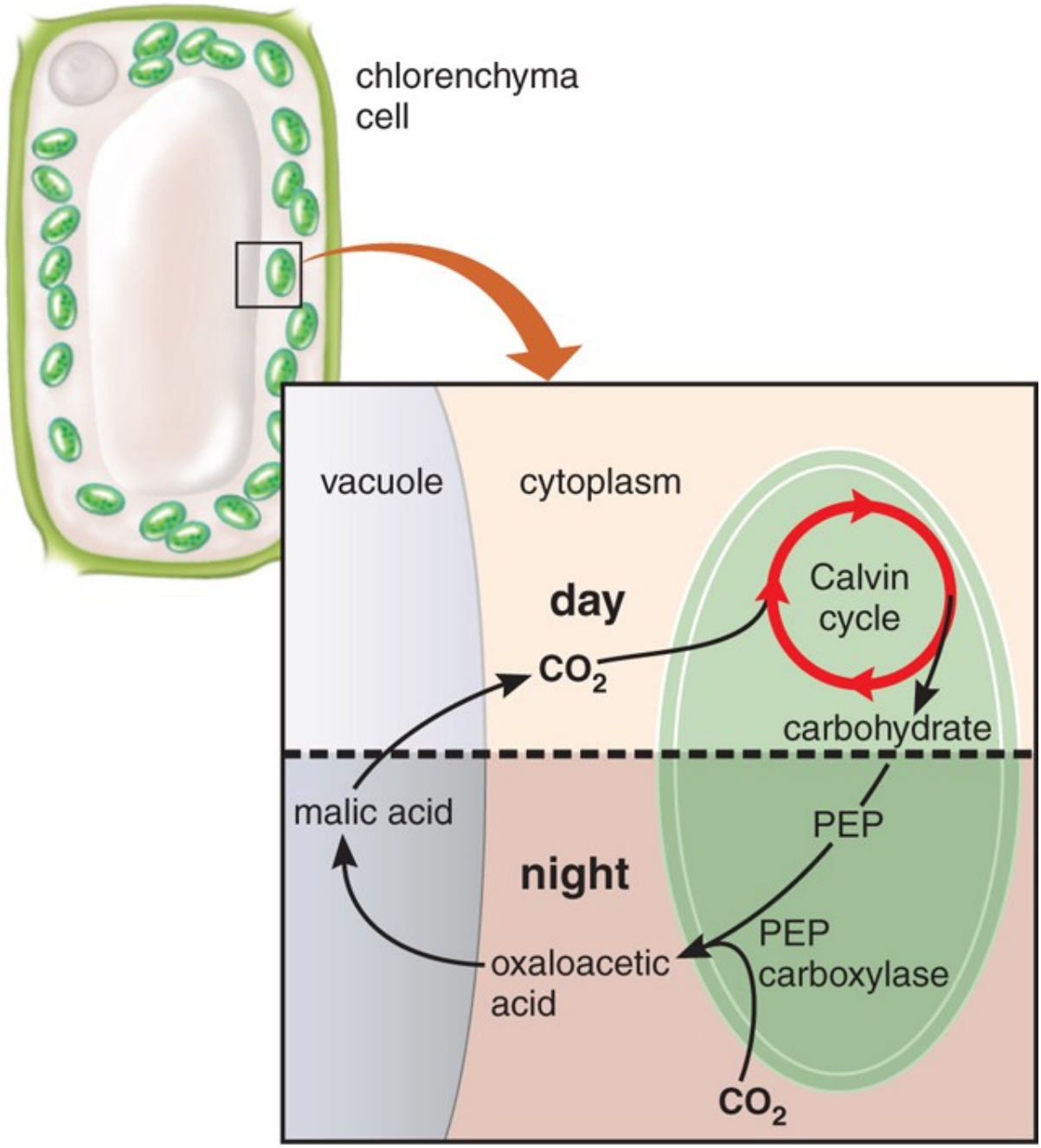
**$C_4$ and CAM plants both use $C_4$ pathway**

- **CAM-plants** which drive $C_4$ cycle at nights:
  - This is a **temporal** separation between accumulation of $CO_2$ and photosynthesis)
  - CAM-plants (17,000 species, 7% of plant biodiversity) are mostly succulents from different orders and families (e.g., cacti—Cactaceae from Caryophyllales)
- **$C_4$-plants** which drive $C_4$ in mesophyll cells and $C_3$ in bundle sheath cells:
  - This is a **spatial** separation between accumulation of $CO_2$ and photosynthesis: $C_4$ pathway is located in "normal" mesophyll cells whereas the Calvin cycle is separated to **bundle sheath cells**.
  - $C_4$-plants (7,300 species, 3%) are especially common among Poales (grasses order, e.g., corn) and Caryophyllales (pink order)

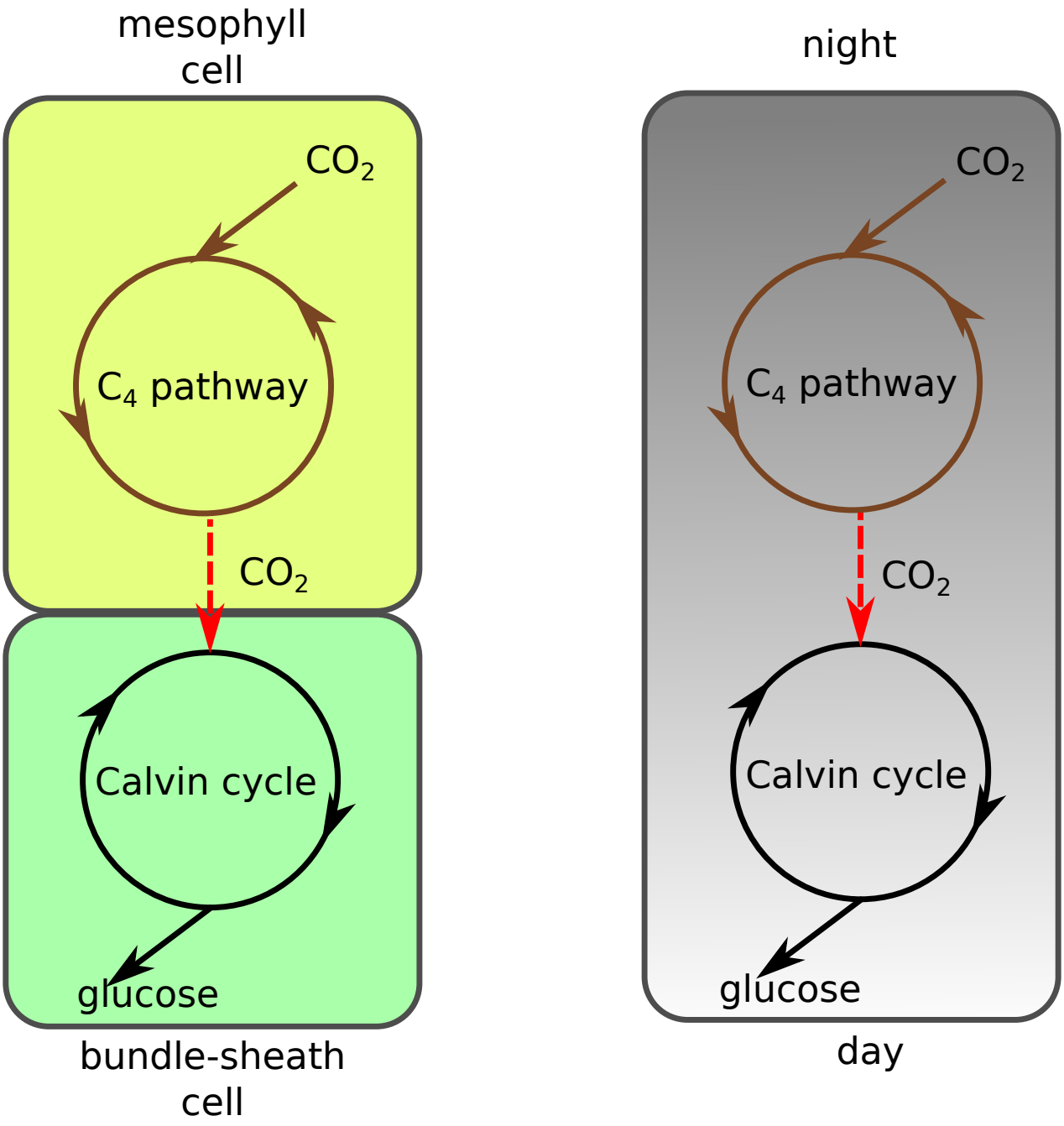
**Leaf of $C_4$ plant: spatial separation of $C_3$ and $C_4$ pathways**




**CAM plants separate $C_3$ and $C_4$ pathways in time**




**CAM plants and $C_4$ plants**


mesophyll cell
CO2
C4 pathway
CO2
Calvin cycle
glucose
bundle-sheath cell
night
CO2
C4 pathway
CO2
Calvin cycle
glucose
day

**Jade plant**

CAM is named after the family Crassulaceae, Jade plant (*Crassula ovata*) family

**Corn**

Corn (*Zea mays*) is the $C_4$ plant which minimizes photorespiration at higher temperatures

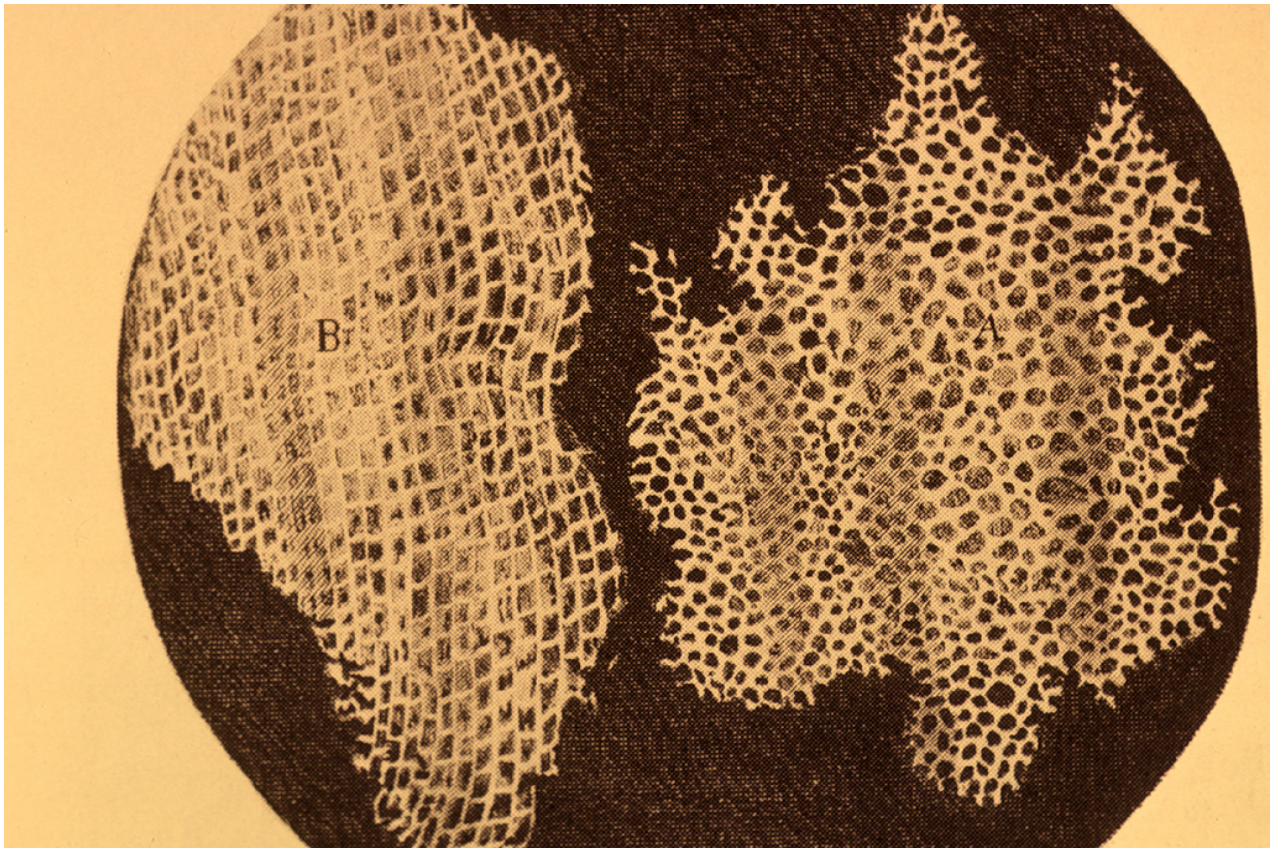
**Why to know photosynthesis?**

`http://www.nature.com/nature/journal/vaop/ncurrent/full/nature13776.html`

# 7 Plant cell

## 7.1 Discovery of cell

**Discovery of cells**




In 1665, Robert Hooke looked at cork tissue under microscope and found "little boxes or cells distinct from one another ... that perfectly enclosed air"

**Hooke's microscope**

National Library of Medicine

### Cell theory

1. All plants and animals are composed of cells (1839, Matthias Schleiden and Theodor Schwann)
2. Cell is most basic unit (atom) of life (1839, Matthias Schleiden and Theodor Schwann)
3. All cells arise by reproduction from previous cells (1858, Rudolf Virchow)

### Miscroscopes

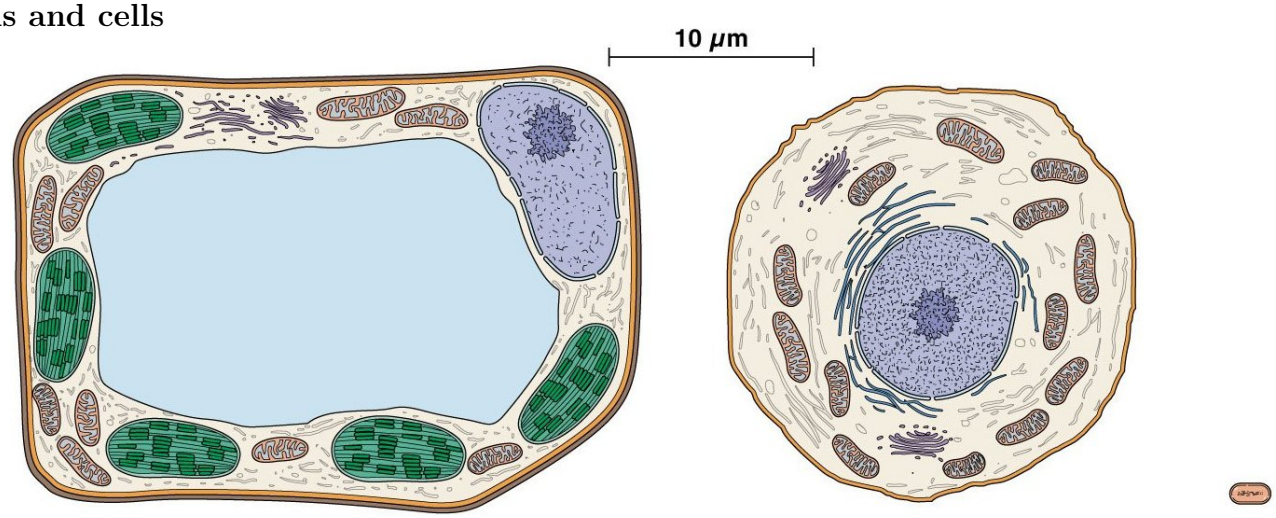
**Light microscopy** was an early technological breakthrough that contributed to our understanding of cell structure. Dissectiscopes use reflected light, microscopes use translucent light. Magnification is of $10^3$ order.

**Transmission electron microscopy** (TEM) allows us to see the internal organization of cells and organelles. Use translucent electronic "light" (electronic beam) which kills objects. Objects are often stained with osmium (Os). Magnification if of $10^7$ order.

**Scanning electron microscopy** (SEM) provides an image of the surface of cells and organisms. Use reflected electronic "light" (electronic beam). Objects are covered with thin layer of gold (Au). Magnification if of $10^6$ order.

## 7.2 Structure of cell

**Cells and cells**




Eukaryotic and prokaryotic cells are fundamentally different

*Plant cell*

**Final question (2 points)**

How to avoid photorespiration?

**Summary**

- $C_4$ and CAM plants accumulate and then release carbon dioxide and therefore increase its concentration

**For Further Reading**

# References

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

**Outline**

# 8 Questions and answers

## 8.1 Quiz

**Final question (2 points)**

How to avoid photorespiration?

- Decrease photosynthesis (foolish solution)
- Pump oxygen out (does not really work – why?)
- Pump carbon dioxide in ($C_4$ pathway)

# 9 Plant cell

## 9.1 Cell structure

*Plant cell*

**List of cell structures**

- Cell membrane
- Cytoplasm
- Nucleus, nuclear pore, nucleolus, chromatine
- **Chloroplast, thylakoids**
- Mitochondrion, cristae
- ER (endoplasmatic reticulum/network)
- Goldgi apparatus (AG)
- **Vacuoles**, lysosomes, peroxisomes
- Ribosomes
- **Cell wall**

Chloroplasts and mitochondria are both results of symbiogenesis

**Final question (1 point)**

How to avoid photorespiration? (Yes, again.)

**Summary**

- Eukaryotic and prokaryotic cells are cells of different levels of organization
- Eukaryotic cell is a "second-level" cell, cell from cells, ecosystems
- Chloroplasts and mitochondria are both results of symbiogenesis

**For Further Reading**

# References

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**Outline**

# 10 Questions and answers

## 10.1 Quiz

**Final question (2 points)**

How to avoid photorespiration?

- Decrease photosynthesis (foolish solution)
- Pump oxygen out (does not really work – why?)
- Pump carbon dioxide in ($C_4$ pathway)

# 11 Plant cell

## 11.1 Cell structure

*Plant cell*

**List of cell structures**

- Cell membrane
- Cytoplasm
- Nucleus, nuclear pore, nucleolus, chromatine
- **Chloroplast, thylakoids**
- Mitochondrion, cristae
- ER (endoplasmatic reticulum/network)
- Goldgi apparatus (AG)
- **Vacuoles**, lysosomes, peroxisomes
- Ribosomes
- **Cell wall**

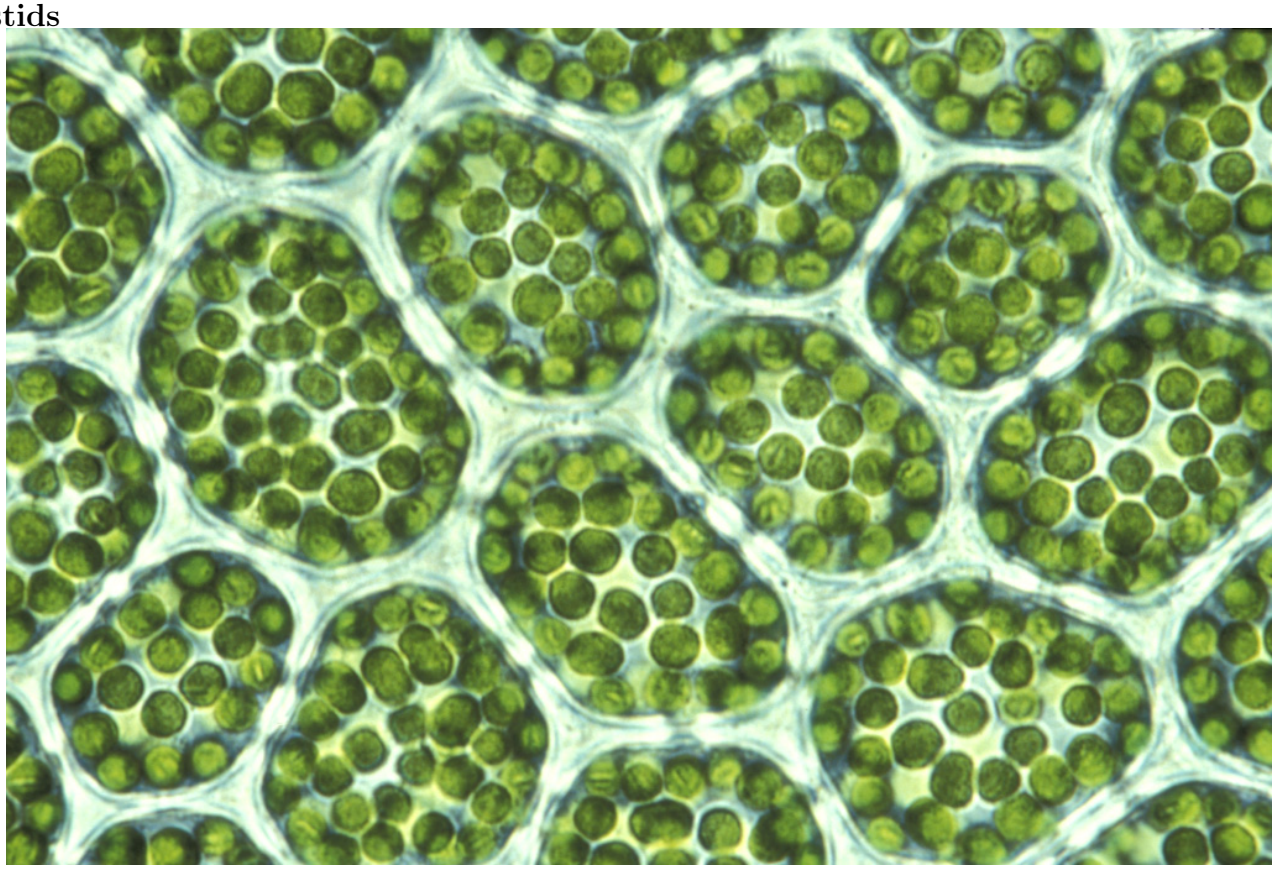
Chloroplasts and mitochondria are both results of symbiogenesis

## 11.2 Cells in cells: mitochondria and chloroplasts

### Symbiogenesis

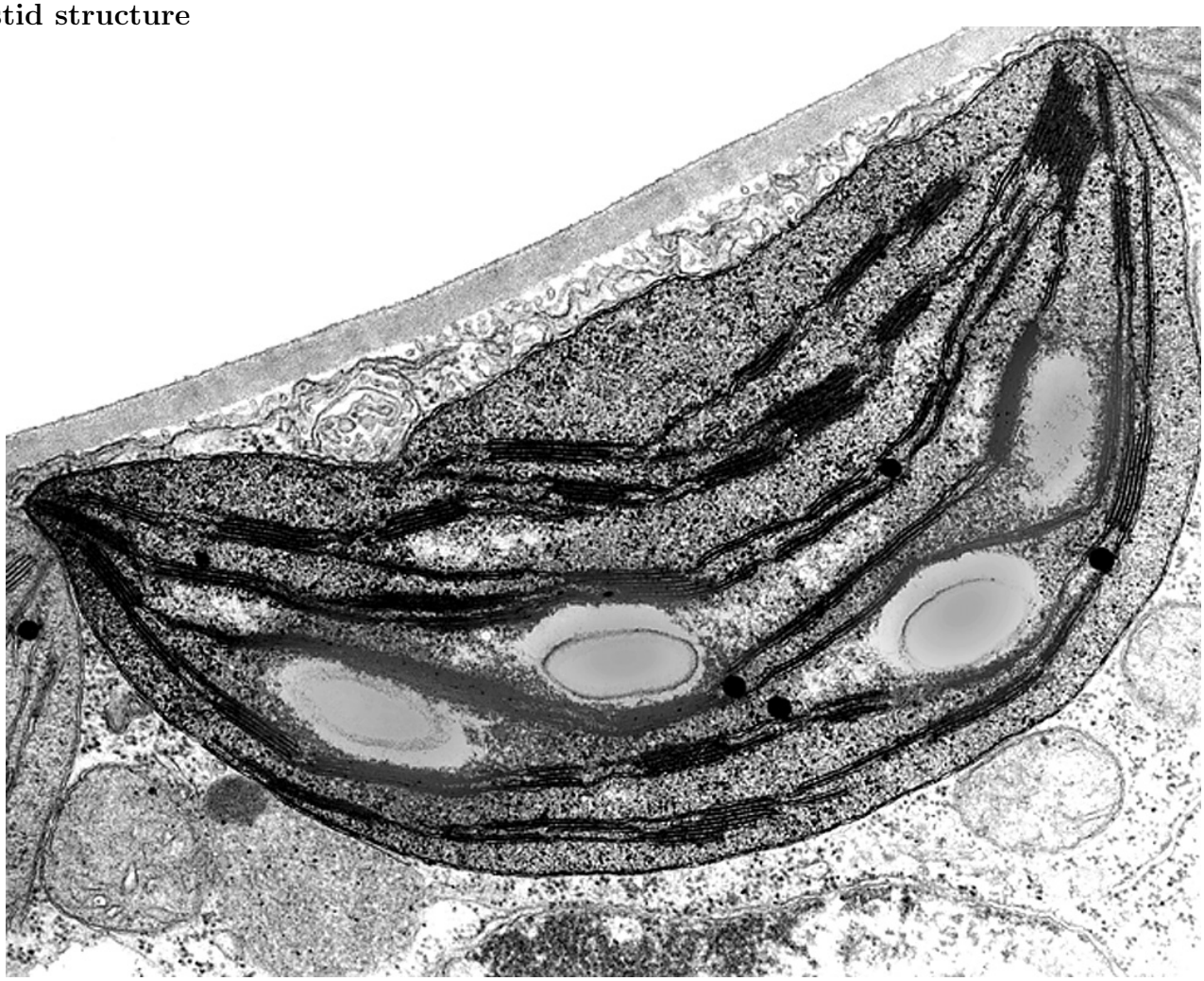
- Small, rigid procaryotic cells became larger to escape from predators
- To keep all parts of larger cell communicable, they developed cytoplasm motility based on **actin** protein
- Cytoplasm motility allowed for **phagocytosis** so they became predators
- These predator cells captured many bacteria and digested them in lysosomes; they also developed nucleus to (a) guard DNA and (b) prevent the horizontal transfer of genes from alien organisms
- Some of prey were not digested (probably, by mistake) but were still useful because they provide ATP
- This condition were naturally selected, and these prey became mitochondria; mitochondria originated from purple bacteria
- Some mitochondial eukaryotes also captured cyanobacteria ($\text{plants}_1$) and became **algae** with chloroplasts

### Plastids



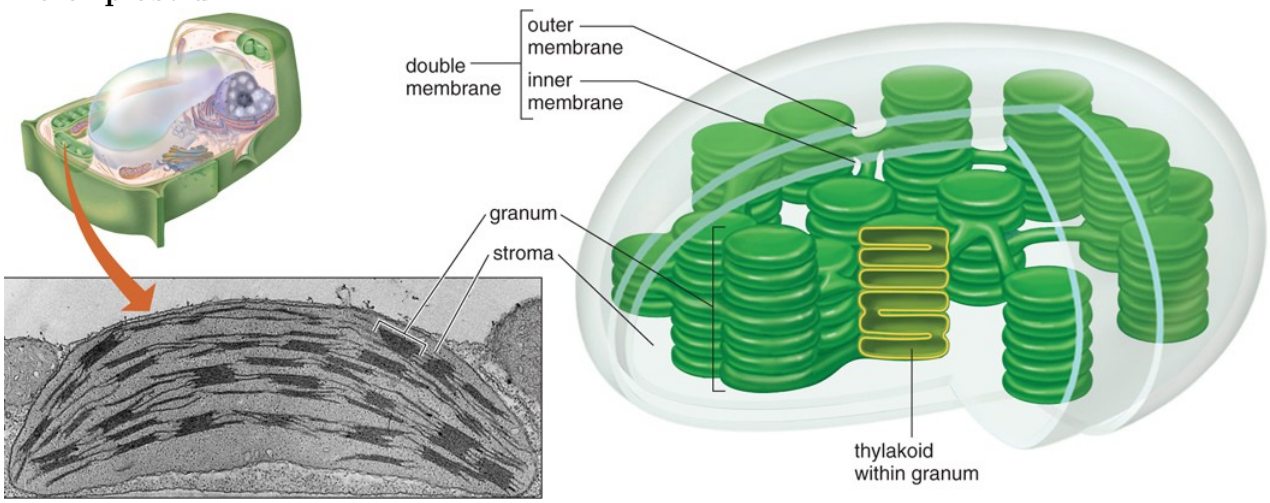
Green plastids (chloroplasts) in leaf cells of *Rhizomnium pseudopunctatum* (LM $\times 500$)

### Plastid structure

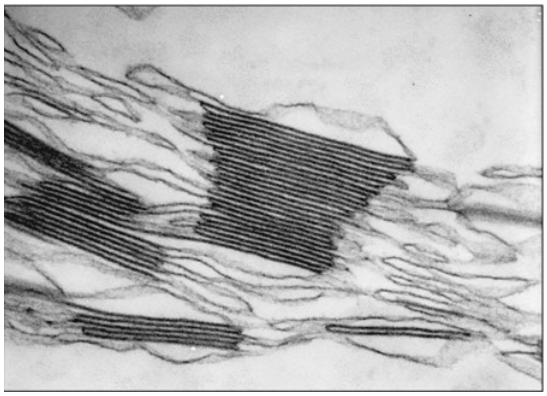


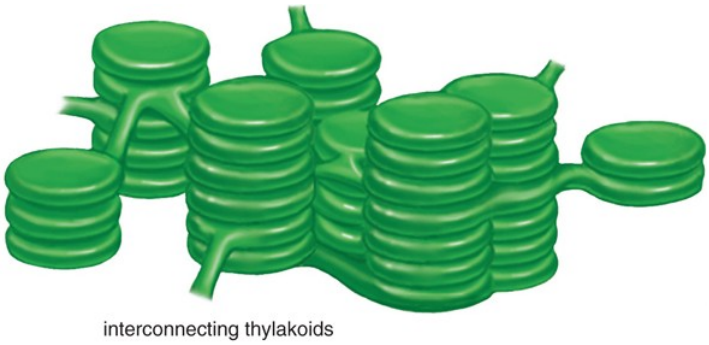
Thylakoids, stroma and starch granules (TEM $\times 37,500$)

### Scheme of plastid




### Grana



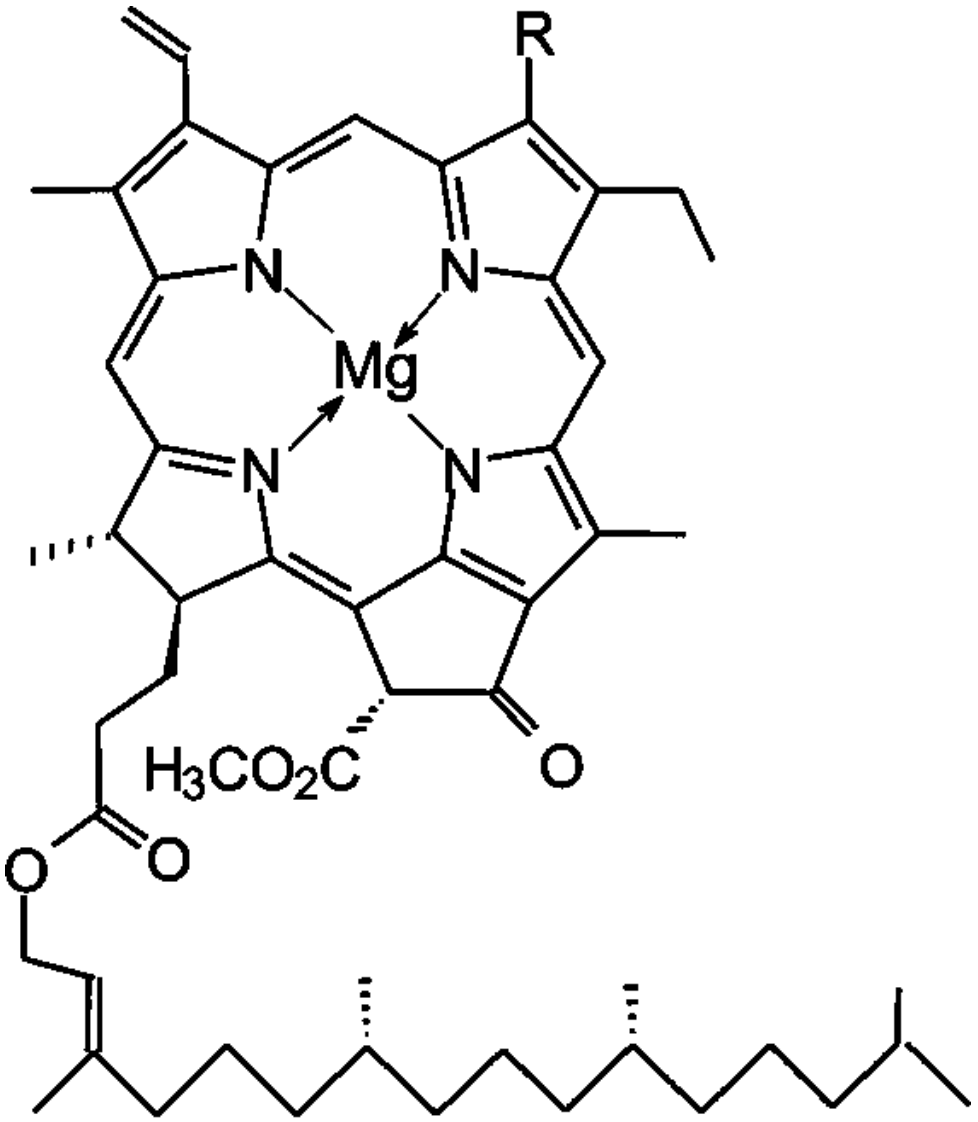



**Grana** is plural, **granum** singular.

### Pigments

- Chlorophylls ($a$ and $b$) are photosynthetic lipids, including magnesium (Mg)
- Carotenoids facilitate photosynthesis, responsible for autumn colors

### Chlorophylls *a* and *b*



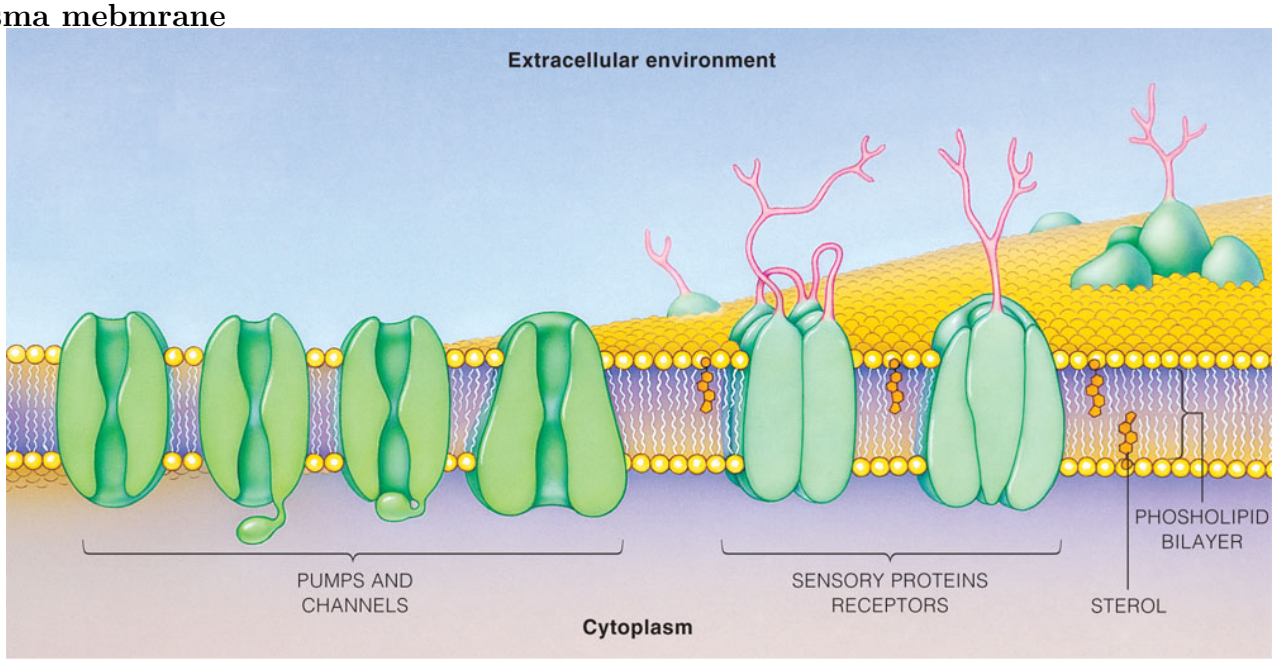

chlorophyll *a* ($R = CH_3$)
chlorophyll *b* (R = CH=O)

**Mitochondria**

Mitochondrion showing foliate *cristae* and matrix granules. Mitochondria are the main energy source (in form of ATP) of the cell (TEM)

## 11.3 Cell boundaries

### Plasma mebmrane



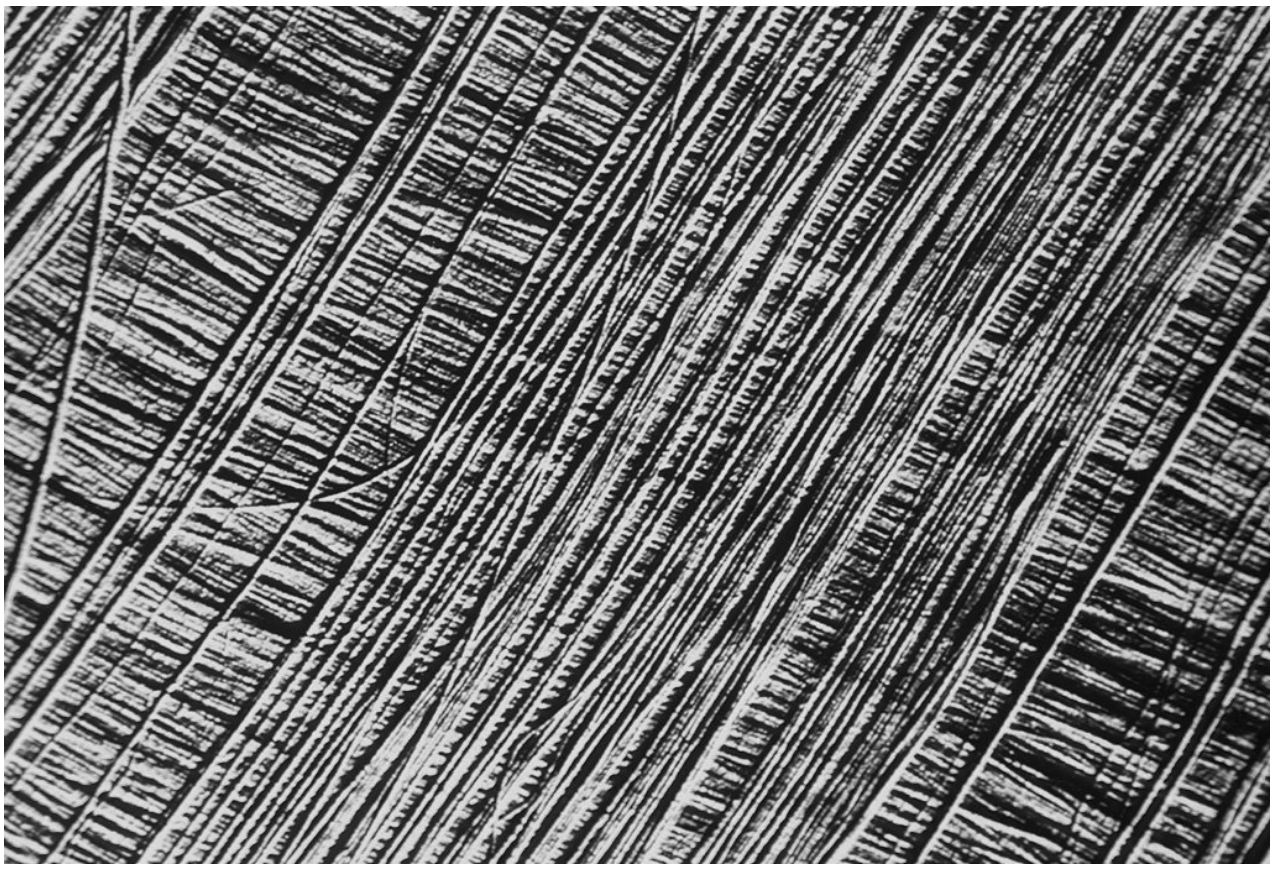



Phospholipids, sterols, proteins: pumps, receptors, channels

**Cell wall**

Root cells of an onion showing the cell wall (TEM $\times 47,000$)

**Fibers**

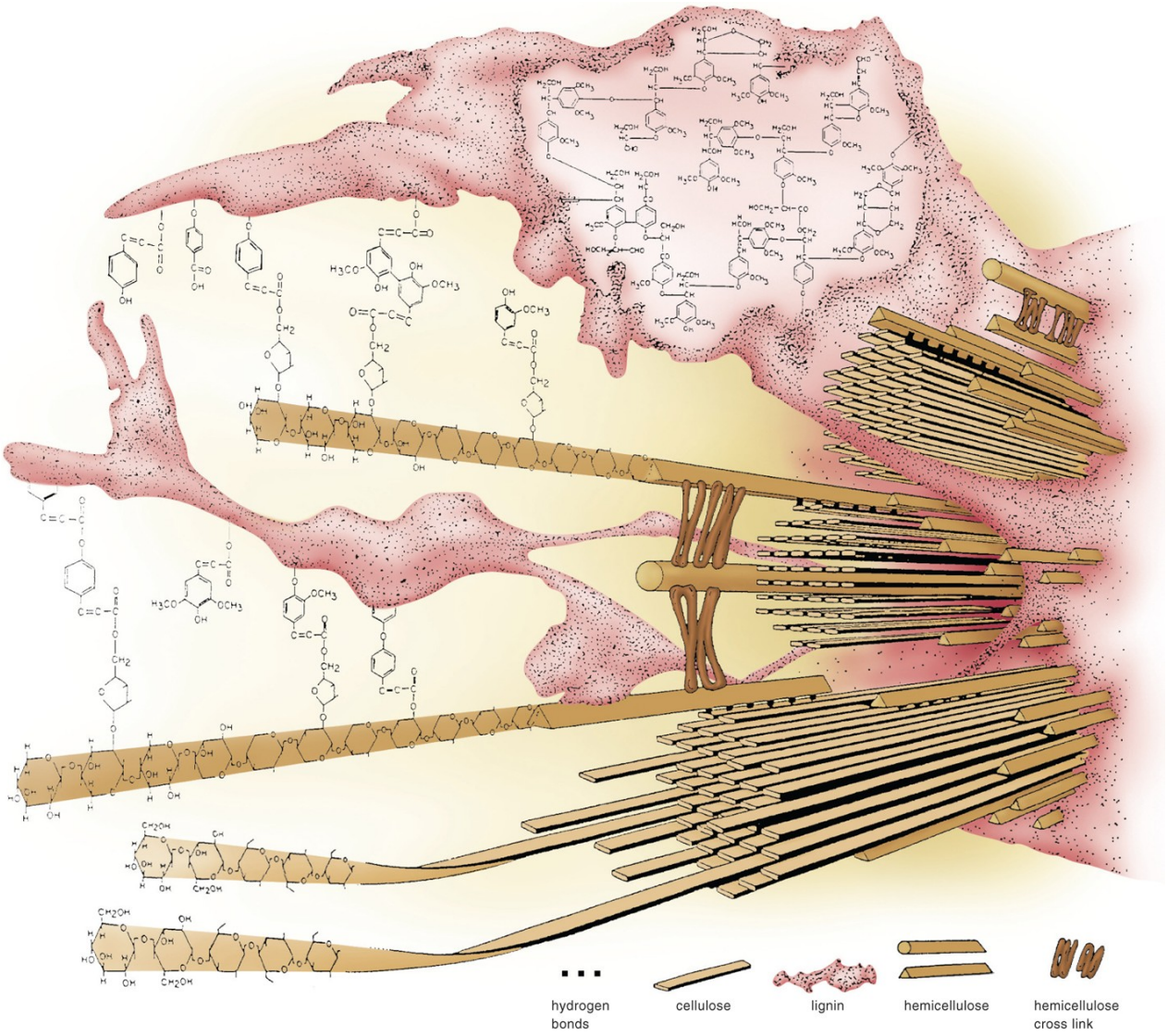


Cellulose fibers in the plant cell wall (SEM)

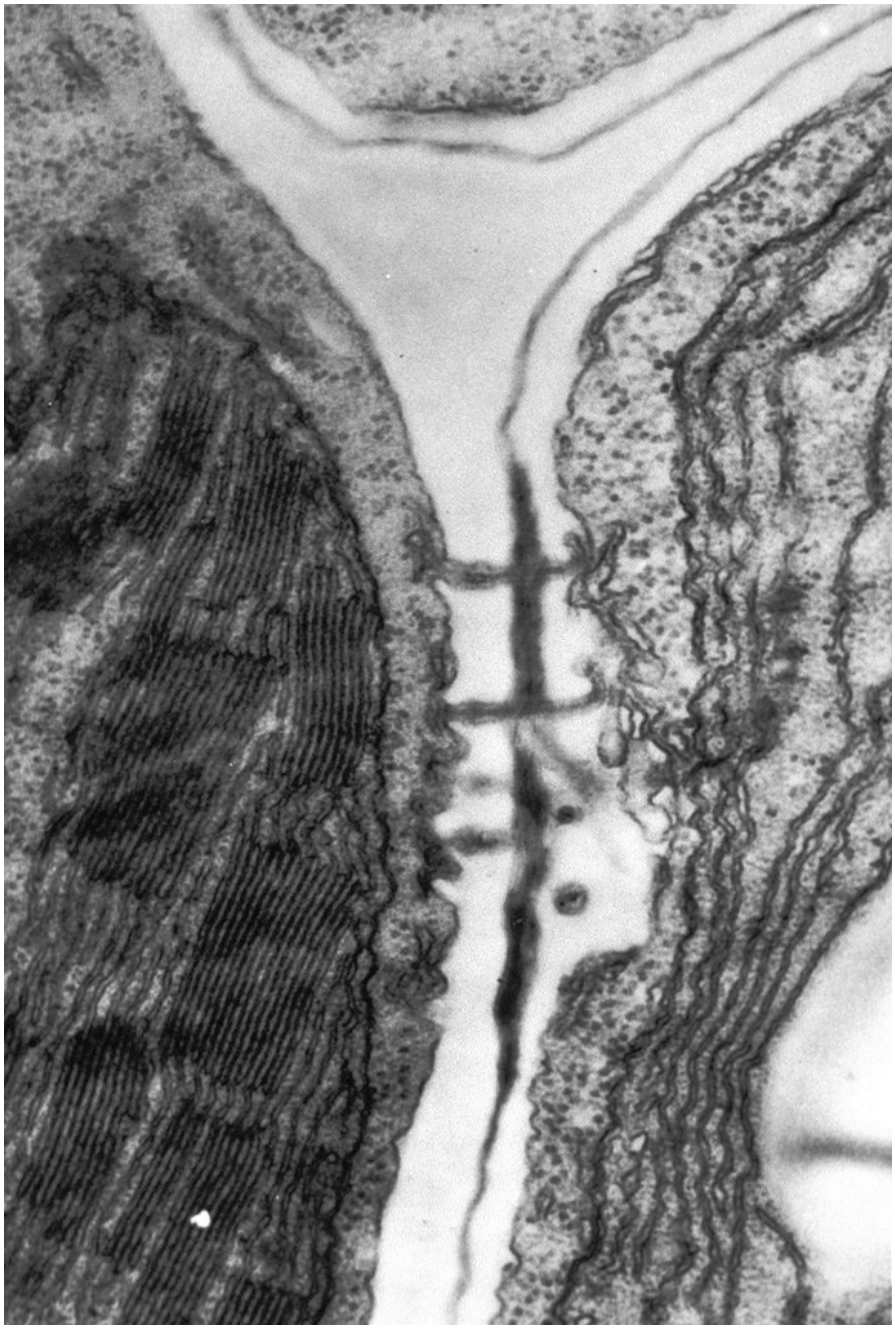
**Primary and secondary cell walls**

- **Primary cell wall** consists mostly of cellulose and proteins, they are thin and flexible
- **Secondary cell wall** includes hydrophobic lignine and suberine; this inclusion leads to the death of cell. However, dead cells are very useful for plants

**Secondary cell wall: molecules**

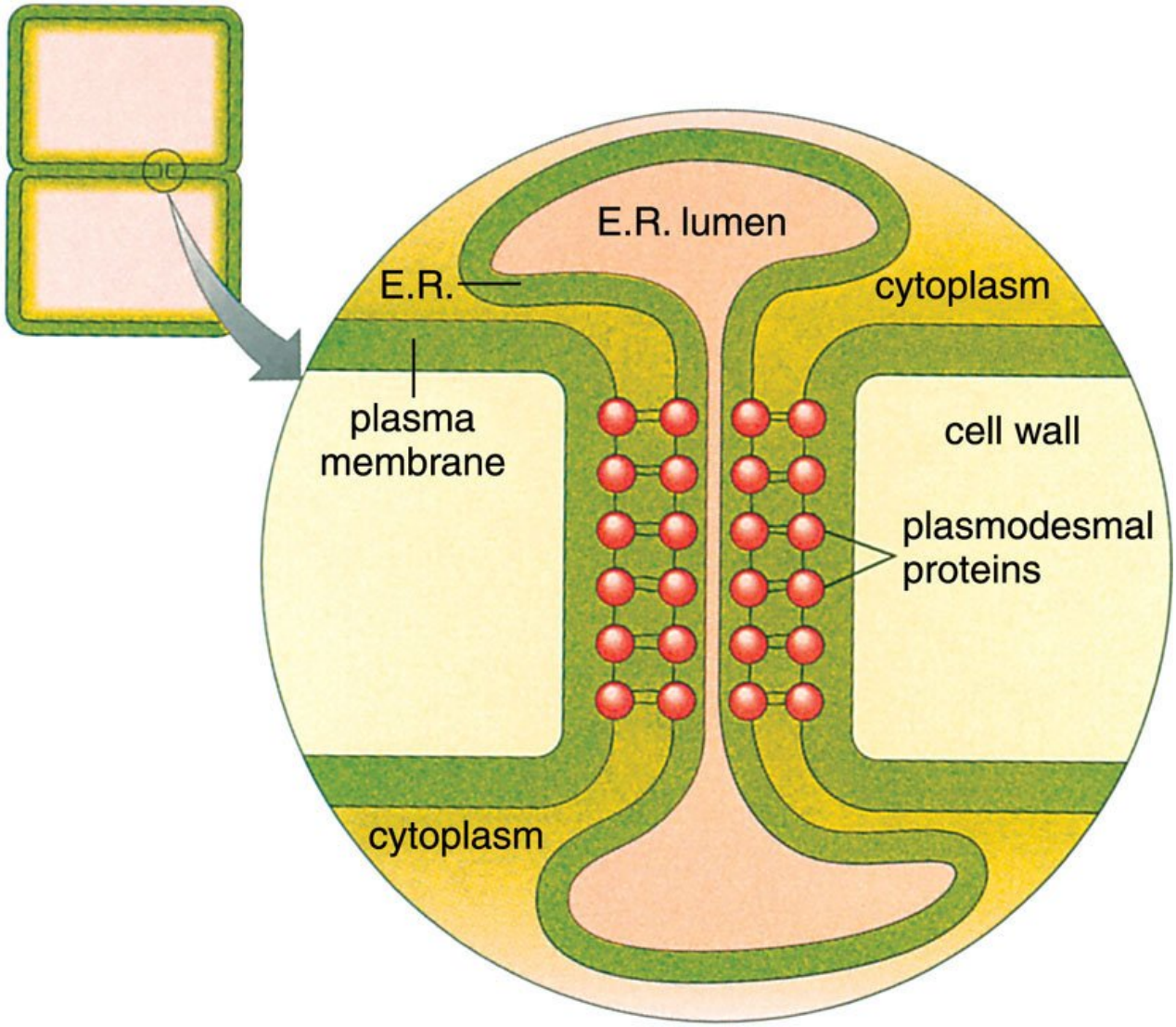



## Plasmodesmata



Plasmodesmata in a corn leaf between a mesophyll cell and a bundle sheath cell (TEM)

**Plasmodesmata: shematic view**




E.R. = endoplasmic reticulum (endoplasmic network)

**Final question (1 point)**

What is the difference between primary and secondary cell walls?

**Summary**

- Eukaryotic and prokaryotic cells are cells of different levels of organization
- Eukaryotic cell is a "second-level" cell, cell from cells, ecosystems
- Chloroplasts and mitochondria are both results of symbiogenesis

**For Further Reading**

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**Outline**

# 12 Questions and answers

## 12.1 Quiz

**Final question (1 point)**

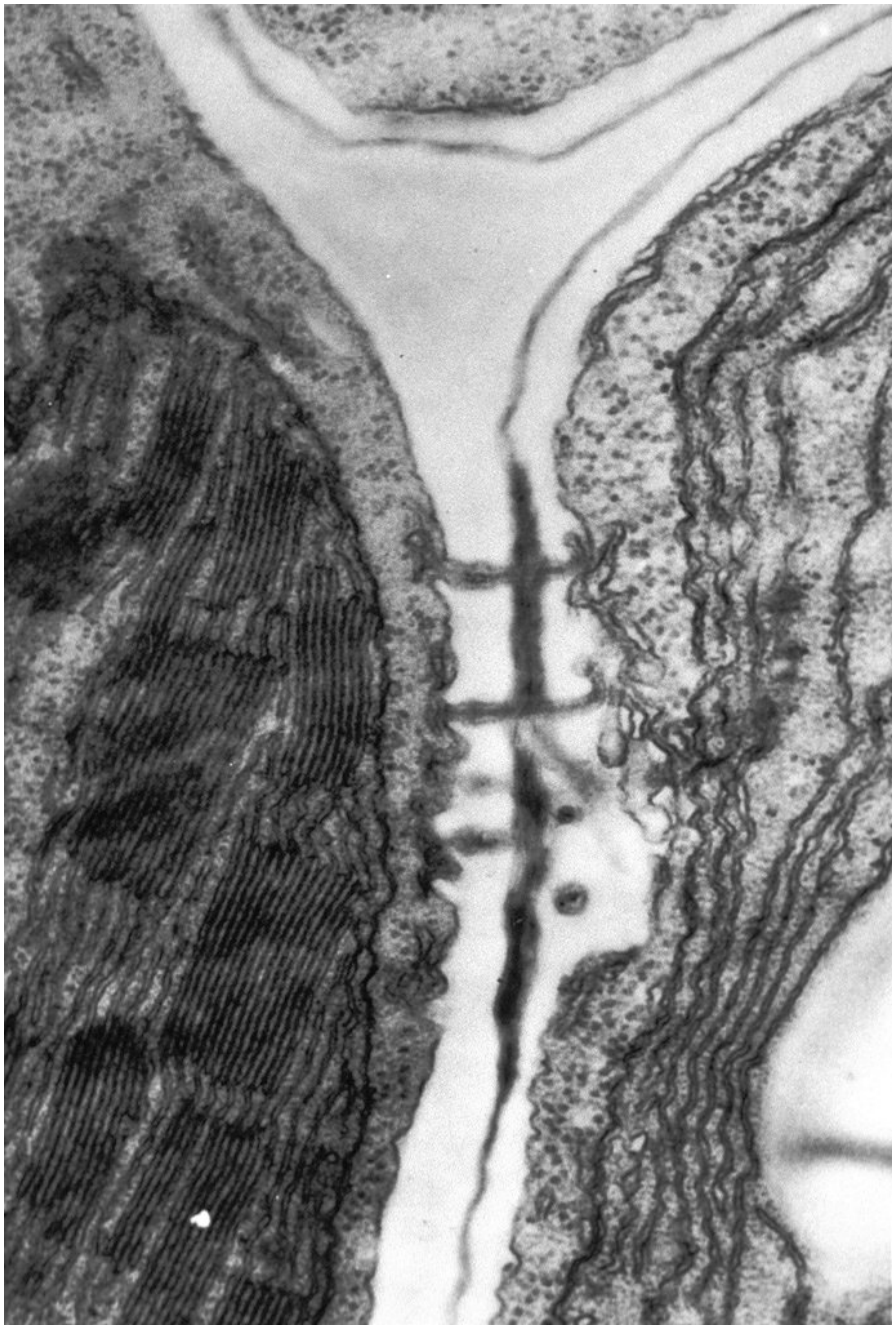
What is the difference between primary and secondary cell walls?

- Primary is soft, secondery is hard
- Primary allows for chemical exchange, secondary does not
- Secondary cell walls contain lignin and/or suberin
- Secondary cell walls essentially cover dead cells

# 13 Plant cell

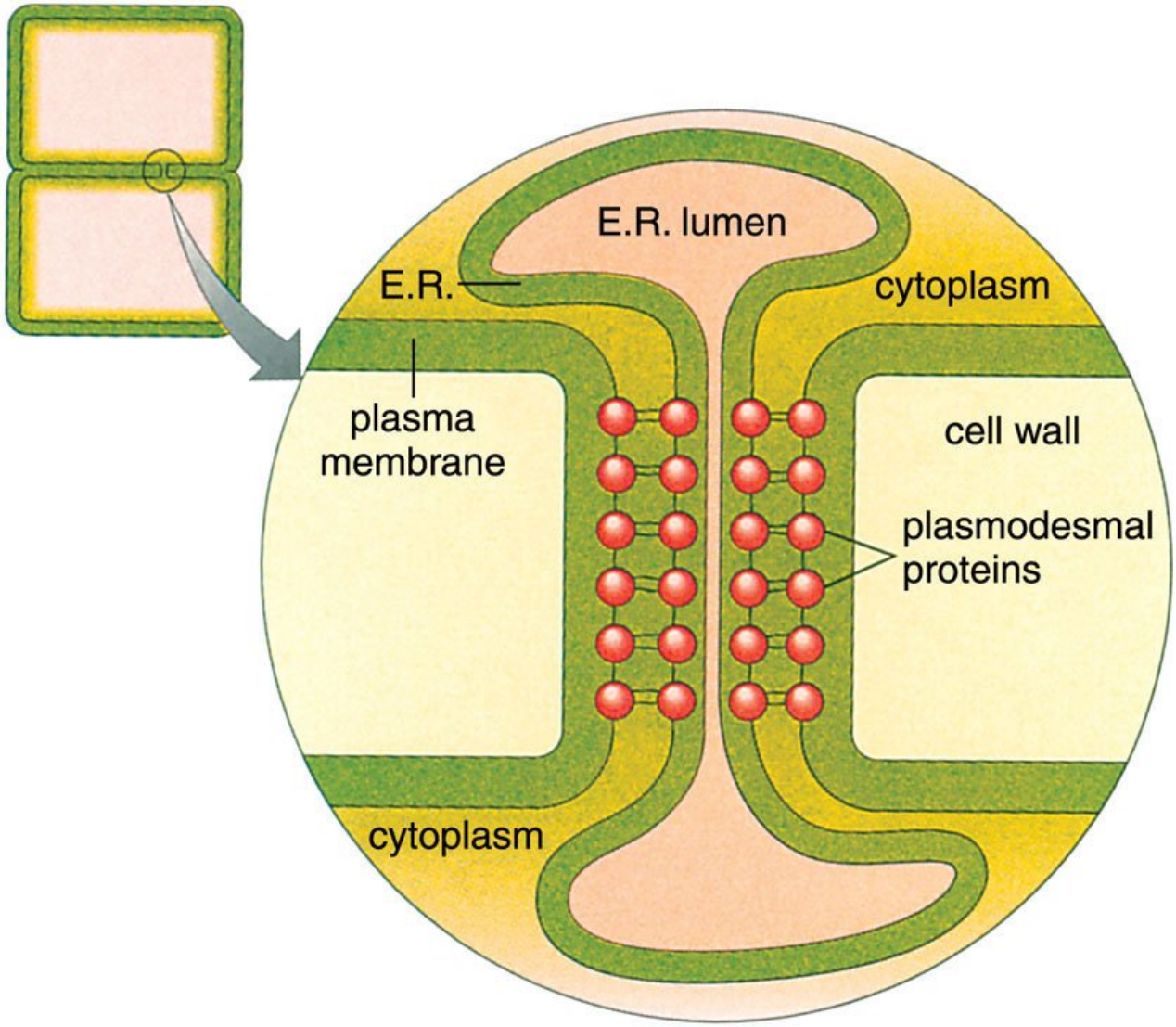
## 13.1 Cell boundaries

**Plasmodesmata**



Plasmodesmata in a corn leaf between a mesophyll cell and a bundle sheath cell (TEM)

**Plasmodesmata: shematic view**




E.R. = endoplasmic reticulum (endoplasmic network)

**Vacuoles, osmosis and turgor pressure**

- If cell vacuoles contain more concentrated solution of salts then water surrounding cell (i.e., water outside is *hypotonic*), water will flow inside a cell. It is called **osmosis**
- Cell wall prevents cell from explosion due to high **turgor pressure**
- When water flows outside a cell, cell content will shrink: this is **plasmolysis**

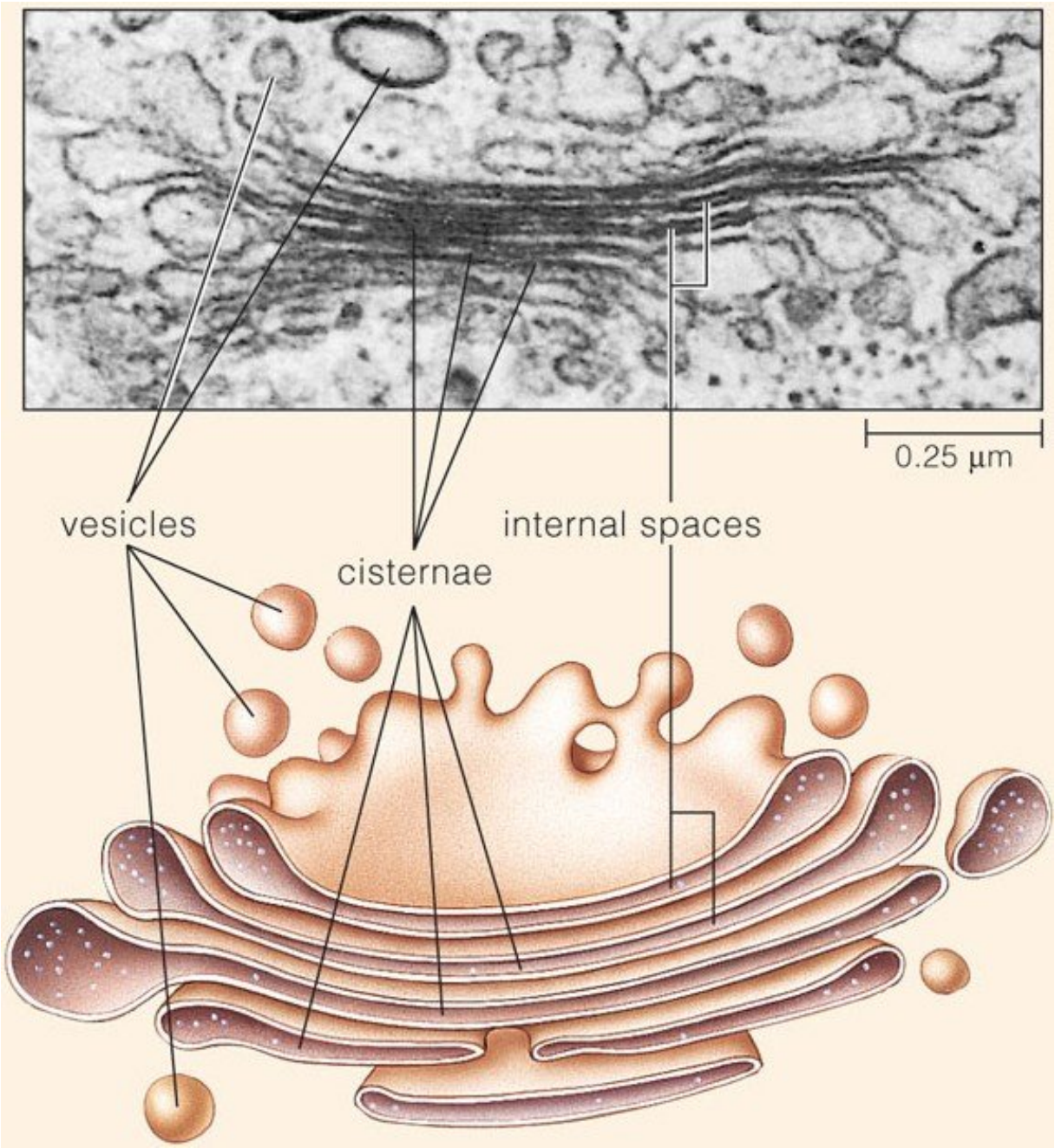
**Symplast and apoplast**

- **Symplast**—name for continuous cytoplasm in set of cells
- **Apoplast**—space outside cell; area of considerable metabolic activity

**Endoplasmatic reticulum (network), ER**

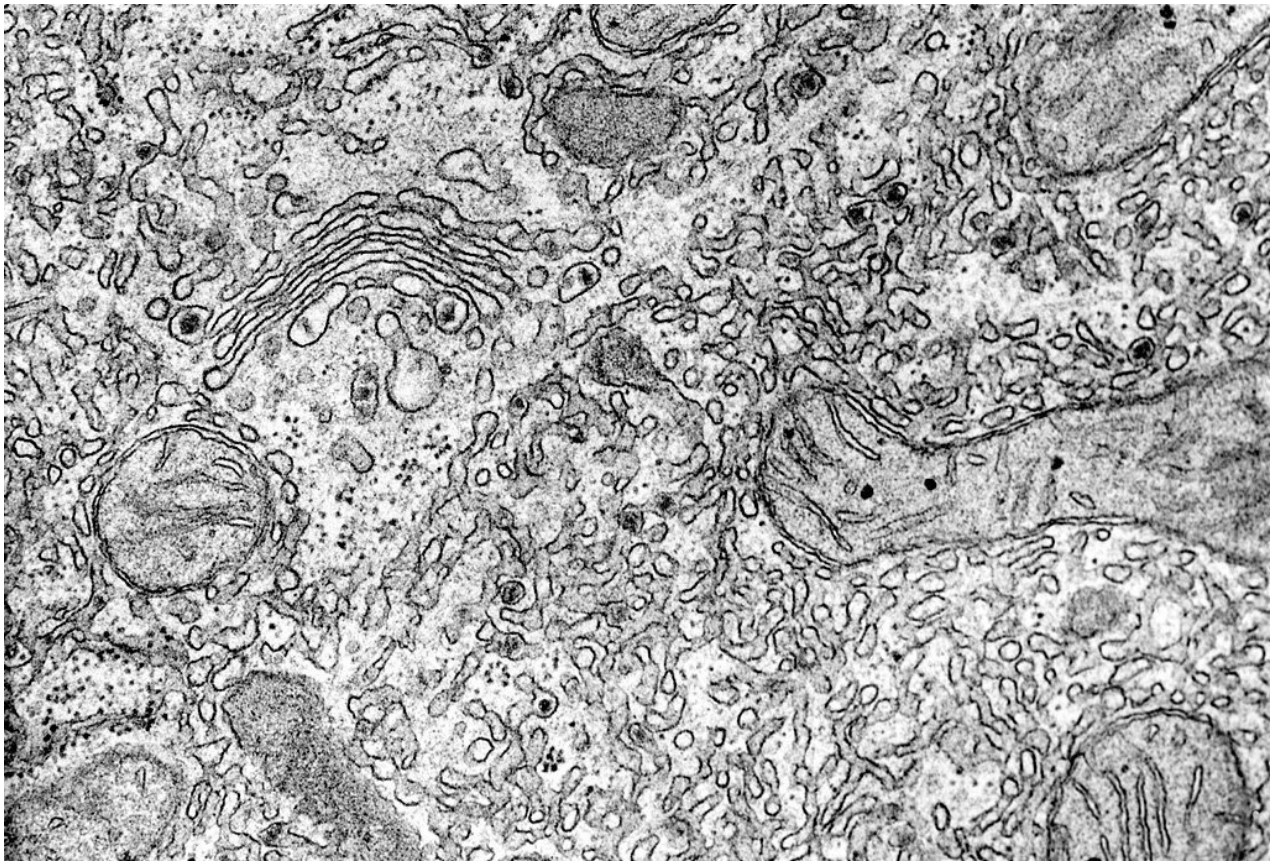
Rough endoplasmic reticulum with ribosomes along outer surface. Manufactures many proteins destined for secretion or for incorporation into membranes (TEM)

**Goldgi apparatus (dictyosomes)**




The Golgi is an organelle composed of stacks of flattened, membranous sacs mainly responsible for modifying, packaging, and sorting proteins that will be secreted or targeted to other organelles of the internal membrane system or to the plasma membrane

## Goldgi apparatus on TEM



Golgi complex and smooth endoplasmic reticulum in a liver cell (TEM)

## 13.2 Protein synthesis

**Nucleus structure**

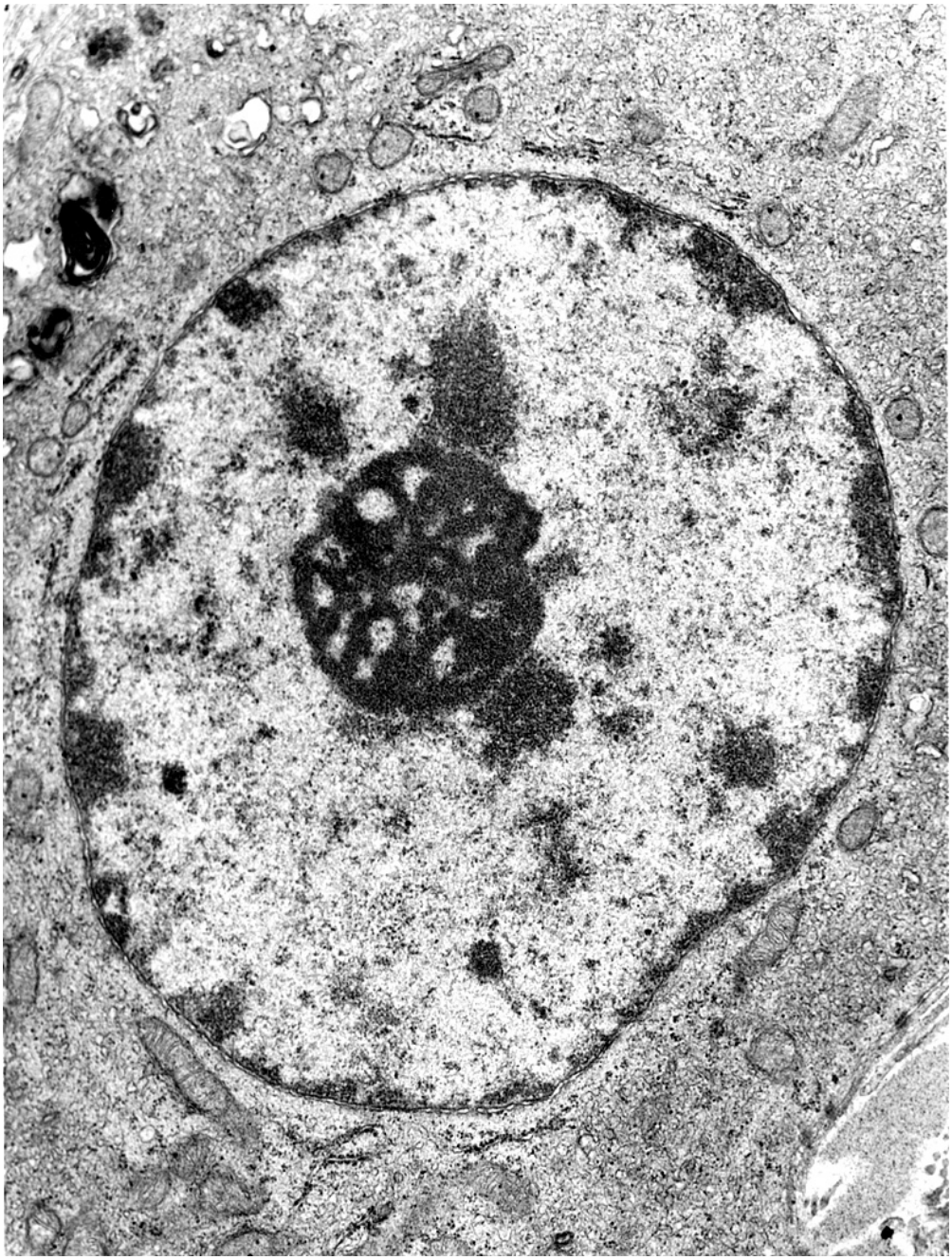
**Nuclear envelope** Double layered membrane, filaments of protein lamin line inner surface and stabilize structure, inner and outer membranes connect to form pores

**Nucleoplasm** Portion inside the nuclear envelope

**Nucleoli** Dark staining bodies within nucleus, site for ribosome synthesis

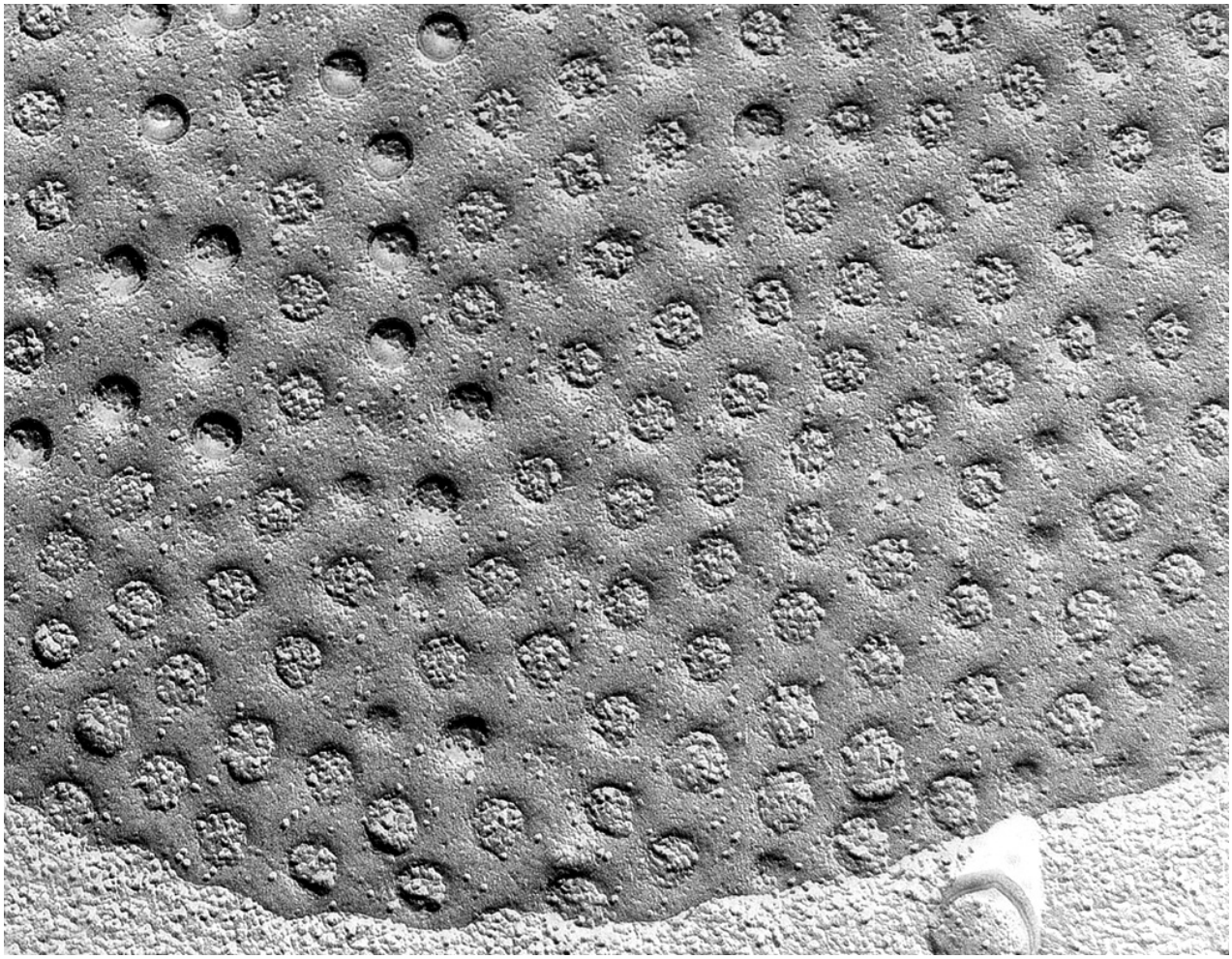
**Chromosomes** Store genetic information in nucleotide sequences, each chromosome consists of chain of nucleosomes (long DNA molecule and associated histone proteins). When cell is not dividing, chromosomes are frequently seen as **chromatin**.

**Nucleus**



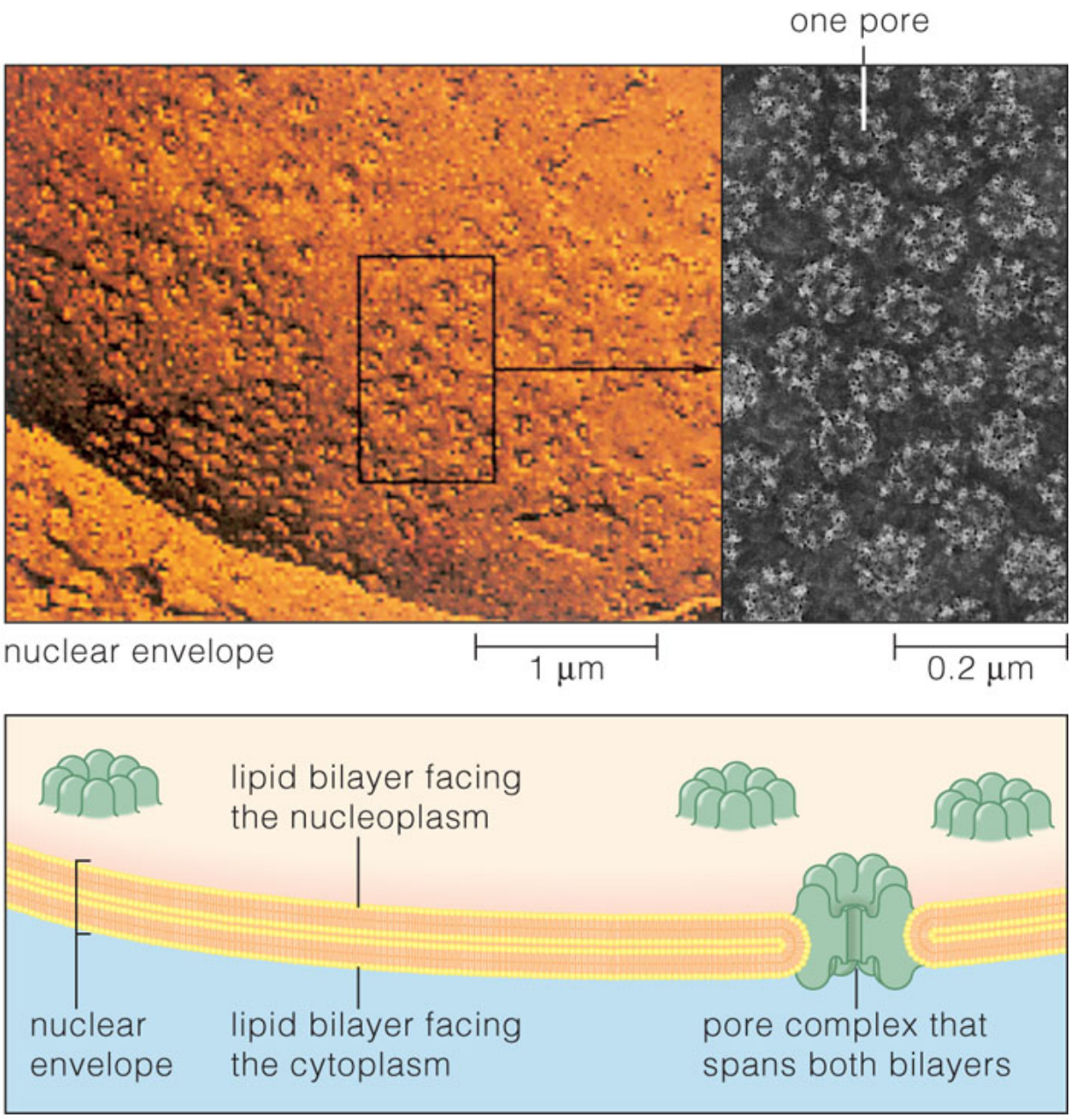
A typical nucleus with a prominent nucleolus (TEM).

**Nuclear pores**



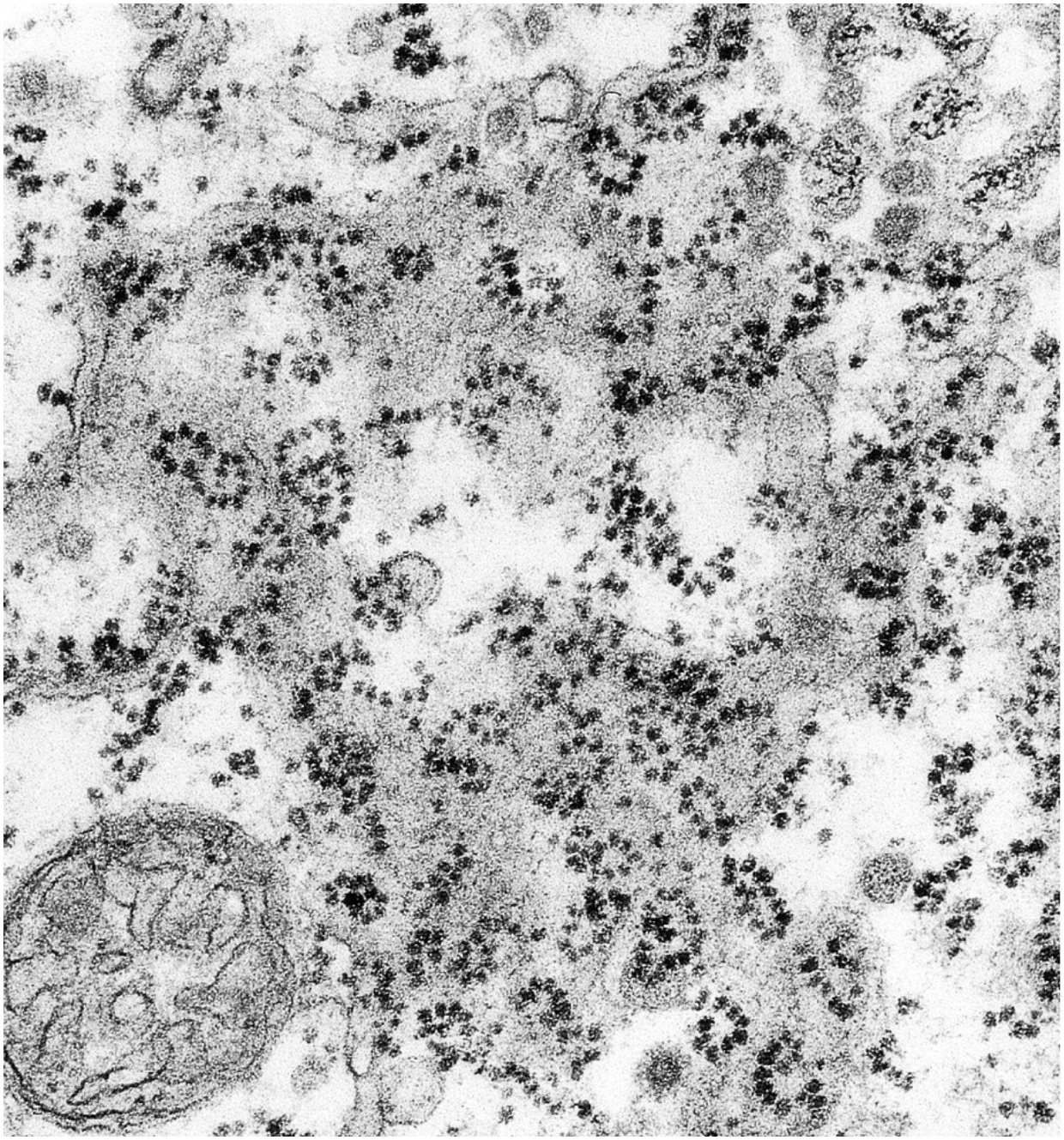
Freeze-fracture technique used to show nuclear pores. Nuclear pores are structures in the nuclear envelope that allow passage of certain materials between the cell nucleus and the cytoplasm (TEM $\times 100,000$)

**Nuclear pores and envelope**






**Ribosomes**



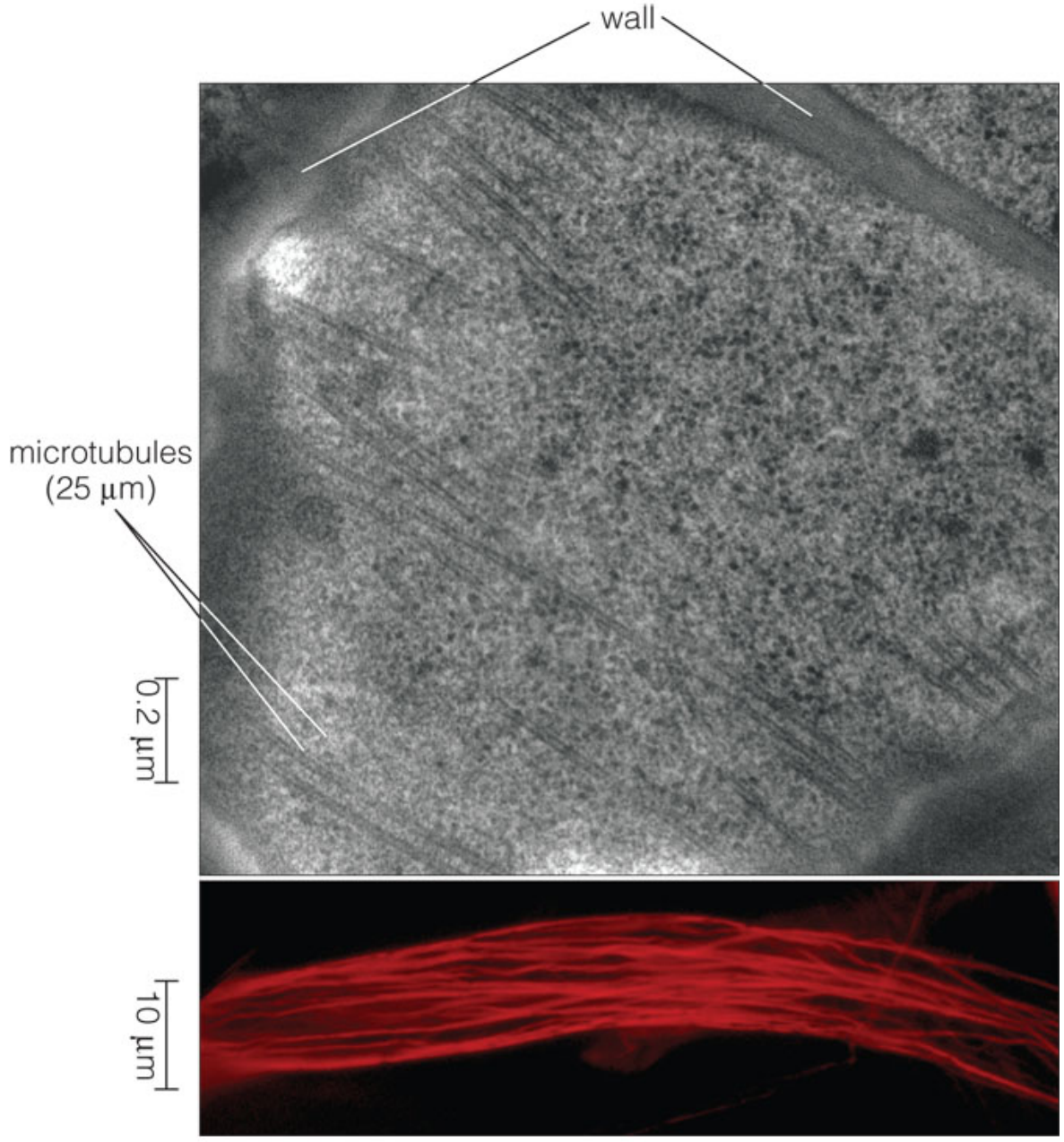
## 13.3 Other cell structures

**Cellular skeleton**

*Collection of long, filamentous structures within cytoplasm:*

- **Microtubules**. Movement based on tubulin-kinesins interactions. They are key organelles in cell division, form basis of cilia and flagella, serve as guides for the construction of cell wall
- **Microfilaments**. Movement based on actin-myosin interactions. Serve as guides for movement of organelles within cell

**Cytoskeleton**





# 14 Mitosis and meiosis

## 14.1 Mitosis

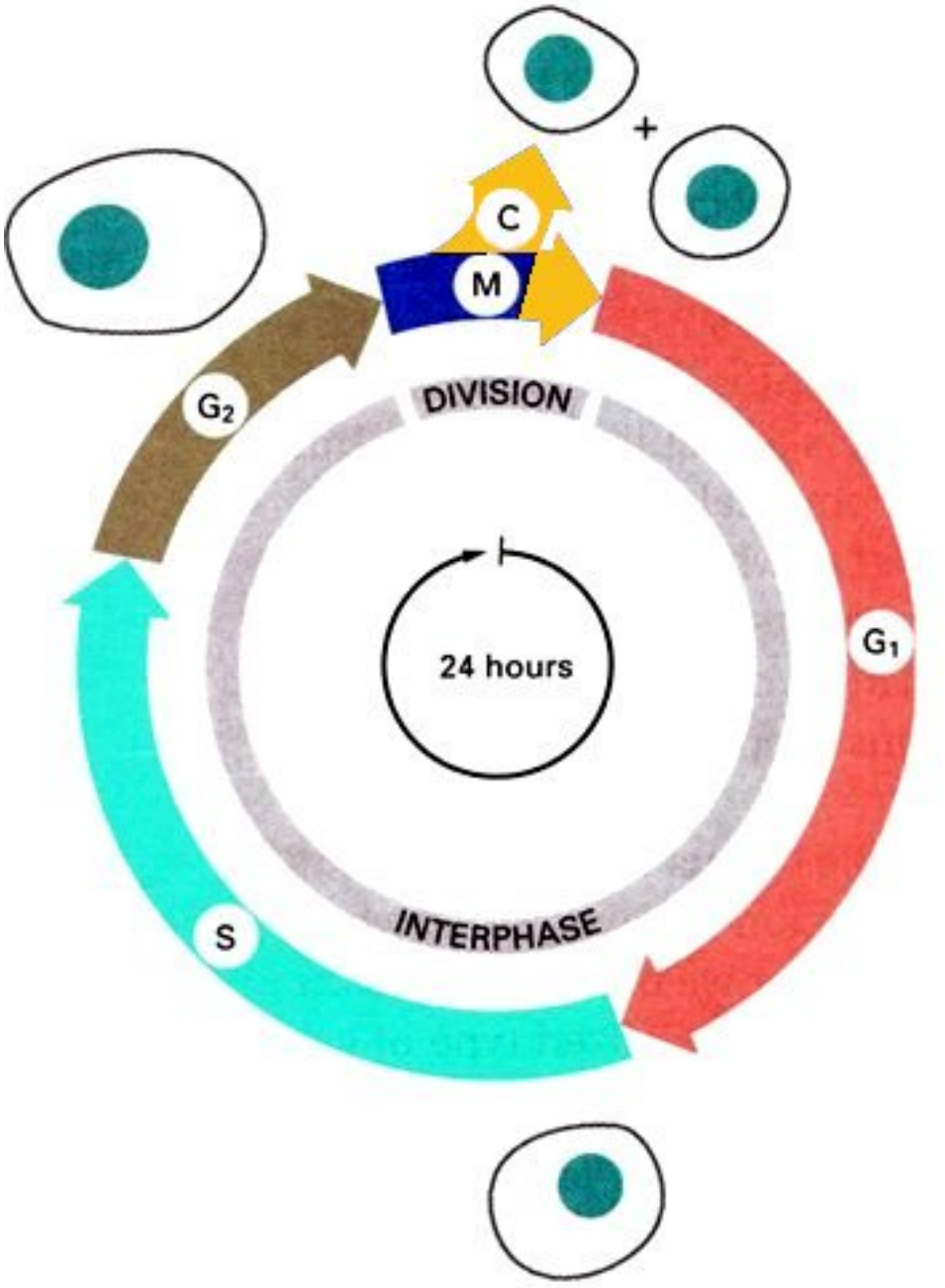
### Definition of mitosis

- *Equal cell division, where each of daughter cells receives the same number of chromosomes as a mother cell*
- Chromosome formula: X $\longrightarrow$ I + I
- **The goal of mitosis** is the equal distribution of pre-synthesized DNA
- Mitosis does not change genotype of cells

**Mitosis, karyokinesis and cytokinesis**

- Mitosis is the kind of nucleus division, **karyokinesis**
- Cytokinesis is a different process, the part of **cell cycle**

**Cell cycle**



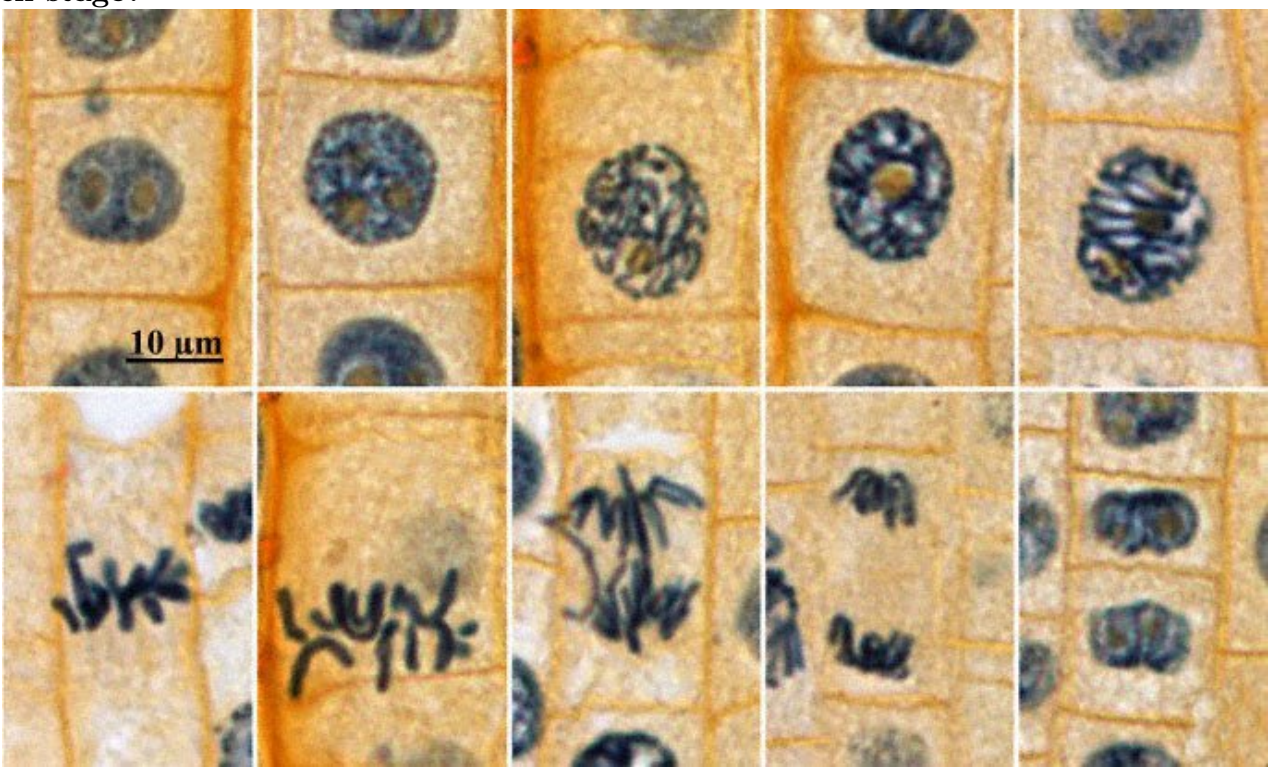

- Interphase
  - Pre-synthetic stage ($G_1$)
  - Sythetic stage (S): DNA duplicated
  - Post-synthetic stage ($G_2$)
- Mitosis

  - Prophase
  - Metaphase
  - Anaphase
  - Telophase
- Cytokinesis

**Stages of mitosis**

- Prophase
- Metaphase
- Anaphase
- Telophase

**Which stage?**




**Final question (3 points)**

Why do living things support diversity?

**Summary**

- Eukaryotic and prokaryotic cells are cells of different levels of organization
- Eukaryotic cell is a "second-level" cell, cell from cells, ecosystems

**For Further Reading**

# References

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

**Outline**

# 15 Questions and answers

## 15.1 Quiz

**Final question (3 points)**

Why do living things support diversity?

- Individual: diverse genes increase adaptation
- Population: diverse individuals make population survive

## 15.2 Syngamy (Y!)

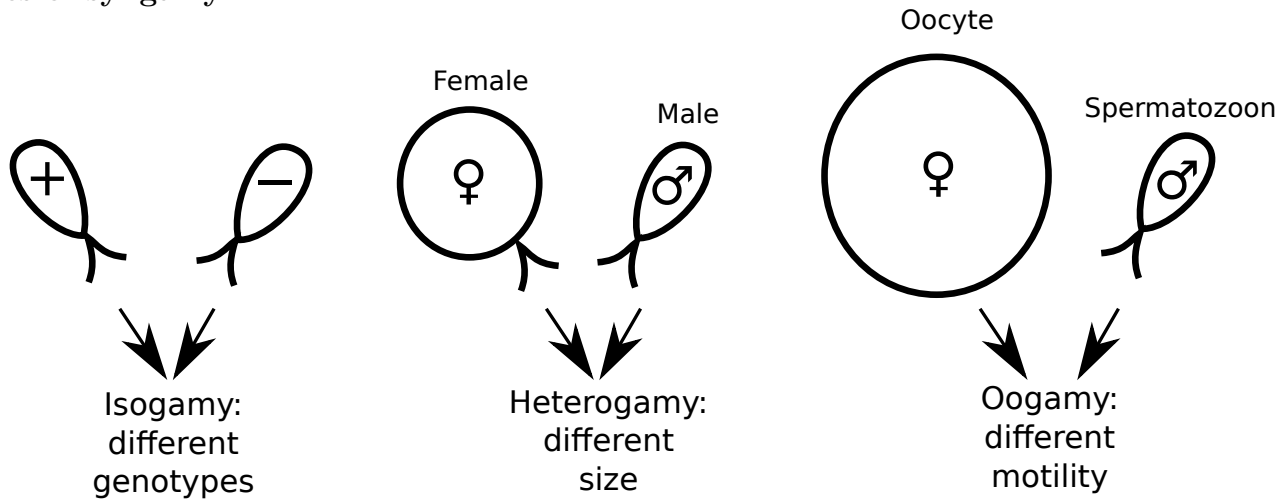
**Exchange and renovation of DNA**

- To sustain with the ever-changed environment, organisms must evolve ("Red Queen Law")
- To evolve, they need a genetic diversity: different genotypes in different organisms
- To be genetically diverse, they need a process of genetic exchange
- One of ways of exchange is a sexual process in a form of **syngamy**
- However, constant syngamy will result in constant increase of DNA amount
- Meiosis is a counterbalance to syngamy

**Definition of syngamy**

- *Fusion of two cells, where resulted cell will have two times more chromosomes*
- Initial cells are **gametes**, resulted cell is a **zygote**
- Chromosome formula: X + X $\longrightarrow$ XX
- **The goal of syngamy** is the renovation of genetic material
- Syngamy changes genotype of cells

**Types of syngamy**




## 15.3 Meiosis (R!)

**Some useful terms**

- Gene
- Protein
- Enzyme
- Genotype
- Phenotype
- Genome
- Population
- Mutation
- Syngamy

**Ploidy, or chromosome set**

- In diploid ($2n$) organisms, chromosomes form pairs
- Paired chromosomes (XX) are **homologous**
- In haploid ($n$) organisms, all chromosomes are single
- In mitosis, ploidy will be the same: $2n \longrightarrow 2n + 2n$
- In syngamy, ploidy will increase: $n + n \longrightarrow 2n$
- In meiosis, ploidy will reduce: $2n \longrightarrow n + n$

**Stages of meiosis**

- First division: reductive part
  - Prophase I: homologous chromosomes form pairs (**synapses**) and start to exchange DNA (**crossing-over**)
  - Metaphase I
  - Anaphase I: homologous chromosomes will go *independently* to different poles
  - Telophase I becomes Prophase II, without interphase (and typically without cytokinesis)
- Second division: equal part (similar to mitosis)
  - Prophase II
  - Metaphase II
  - Anaphase II
  - Telophase II

**Final question (2 points)**
Before syngamy, every cell has 3 picograms of DNA. How many DNA are in zygote immediately after syngamy?

**Summary**

- **Syngamy** is a sexual process of cell fusion, ploidy doubles, genotype changes
- **Meiosis** is a process of reduction of DNA amount, ploidy halves, genotype changes

**For Further Reading**

# References

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

**Outline**

# 16 Questions and answers

## 16.1 Quiz

**Final question (3 points)**
Before syngamy, every cell has 3 picograms of DNA. How many DNA are in zygote immediately after syngamy?

- $3 + 3 = 6$ picograms

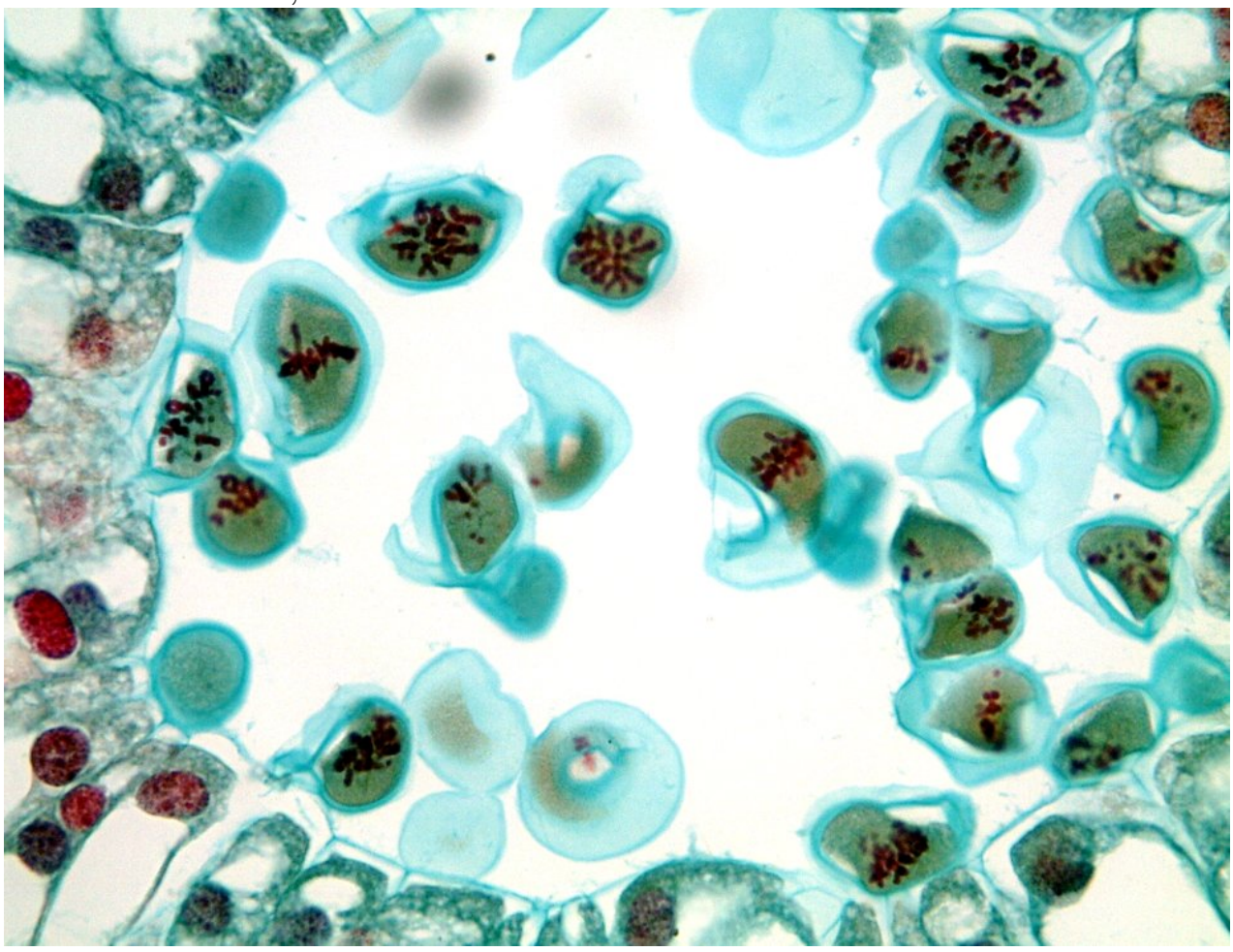
# 17 Life cycle

## 17.1 Meiosis (R!)

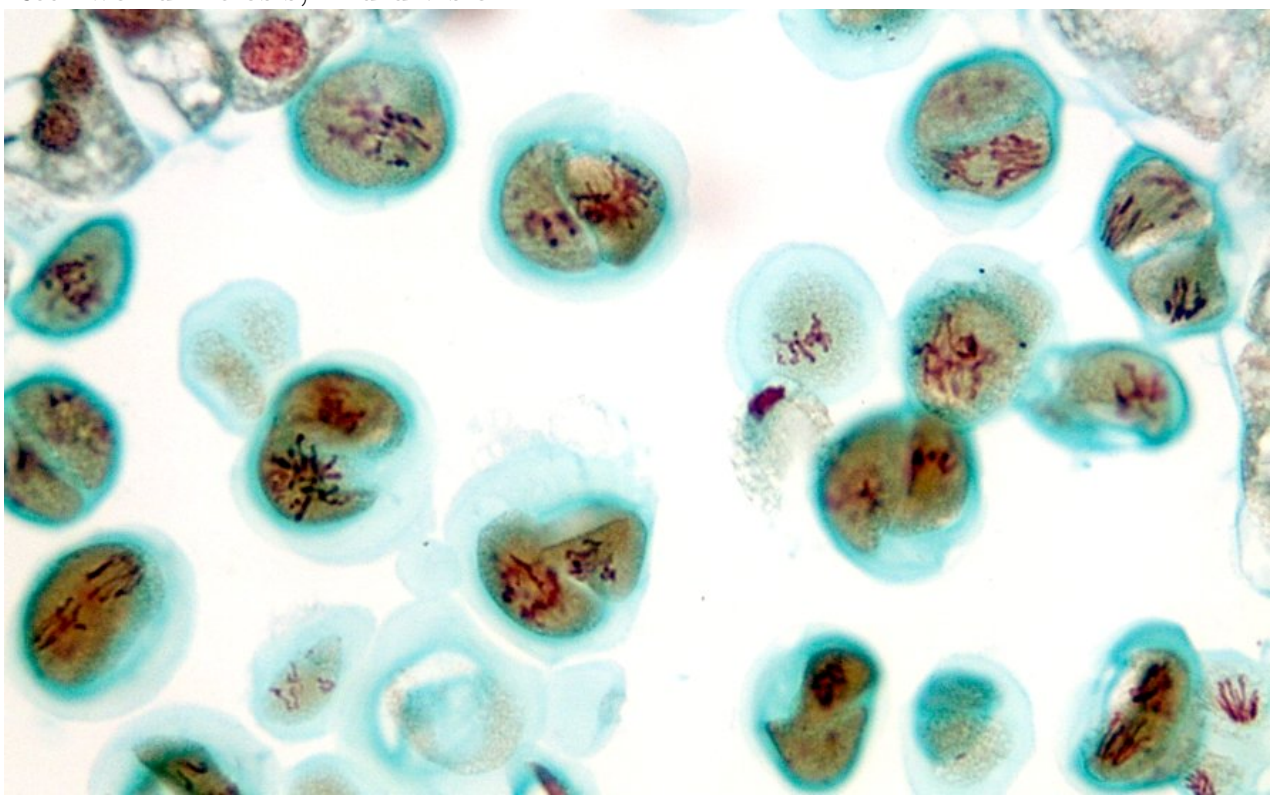
### Stages of meiosis

- First division: reductive part
  - Prophase I: homologous chromosomes form pairs (**synapses**) and start to exchange DNA (**crossing-over**)
  - Metaphase I
  - Anaphase I: homologous chromosomes will go *independently* to different poles
  - Telophase I becomes Prophase II, without interphase (and typically without cytokinesis)
- Second division: equal part (similar to mitosis)
  - Prophase II
  - Metaphase II
  - Anaphase II
  - Telophase II

### Real-world meiosis, 1st division



**Real-world meiosis, 2nd division**



**Polyploids**

- If for some reason, meiosis will not run correctly, one of resulted cells could receive double set of chromosomes ($2n$ instead of $n$)
- If this cell goes to syngamy, resulted zygote will have $3n$ chromosomes
- Cells with $> 2n$ chromosomes are **polyploids**

**Summary**

- Meiosis has two stages: first to reduce ploidy, second to split exact copies of DNA

**Final question (2 points)**

Why does meiosis happen in two stages?

**For Further Reading**

# References

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

**Outline**

# 18 Questions and answers

## 18.1 Quiz

**Final question (3 points)**

Why does meiosis happen in two stages?

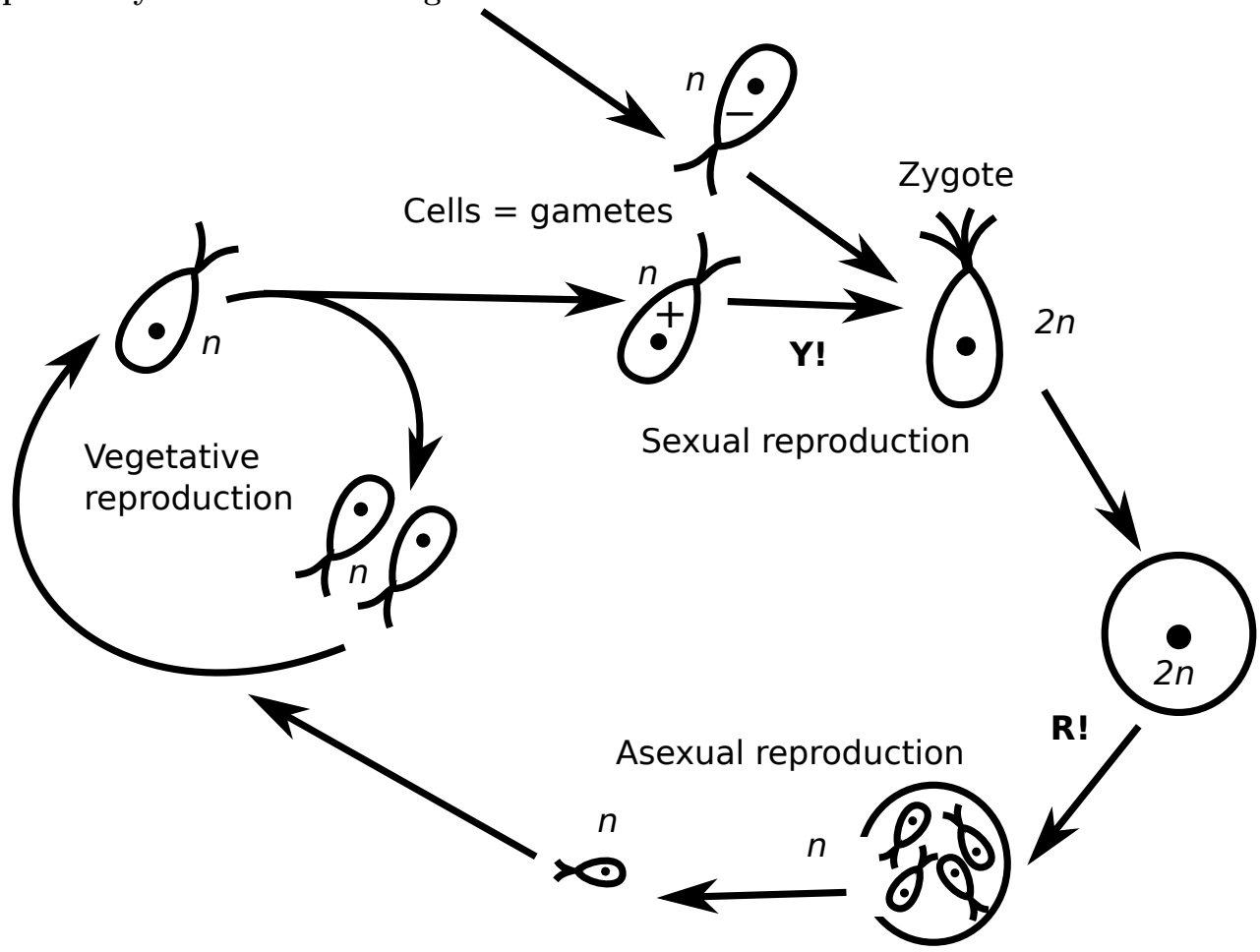
Because it has two goals:

- Reduce ploidy—split homologous pairs
- Split X-shaped chromosomes in half

# 19 Life cycle

## 19.1 Basics

**Simple life cycle: unicellular organism**

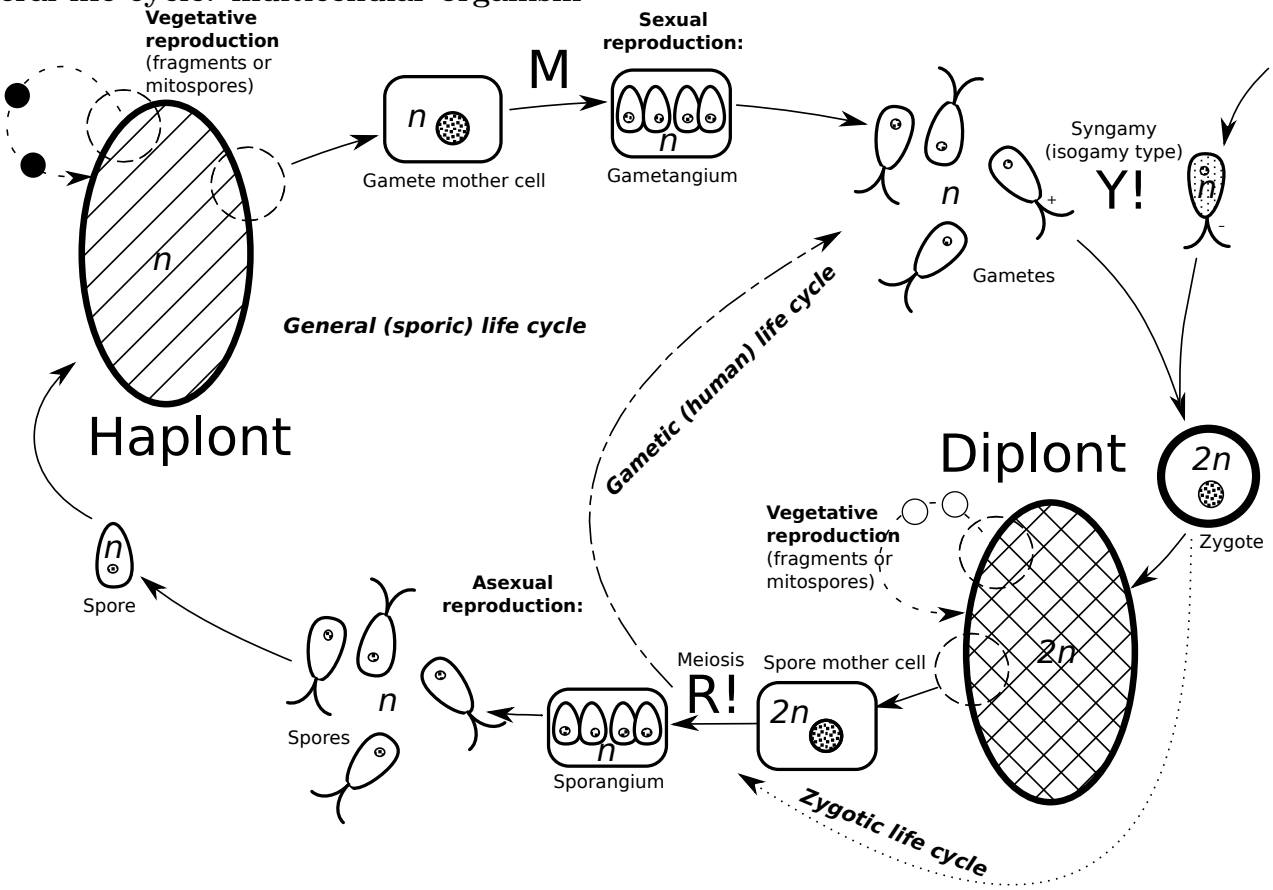



Associated terms: mitosis, meiosis (R!), syngamy (Y!), reproduction, sexual reproduction, asexual reproduction, vegetative reproduction, isogamy, heterogamy, oogamy, zygote, gamete, male, female, spermatozoon, oocyte

**Multicellularity, or Origin of Death**

- Sometimes, cells do not part after mitosis. These simple cell aggregates may benefit from their size (e.g., harder to swallow) and putative division of labor (e.g., capture light from different sides and share products of photosynthesis)
- Next step is to separate *germ cells* and *somatic cells*. Somatic cells with eventually die whereas germ cells may give an offspring.
- This is the beginning of **multicellularity**.
- Life cycles of multicellular organisms are based on interleaving **gaplont** and **diplont**, the second is making **spores**

**General life cycle: multicellular organism**




**Final question (2 points)**

Why are there two places of vegetative reproduction in a scheme of the life cycle?

**For Further Reading**

# References


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

# 20 Questions and answers

## 20.1 Quiz

**Final question (3 points)**

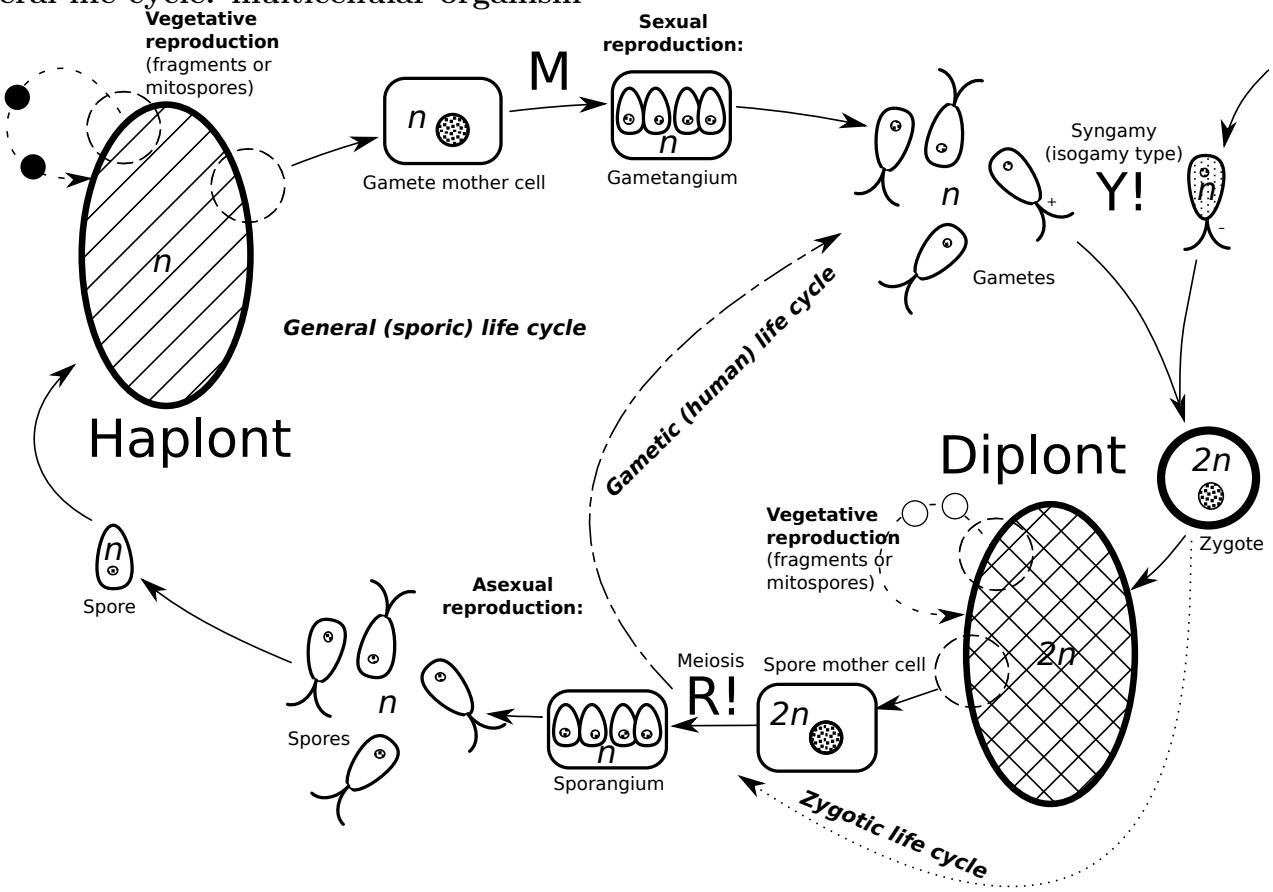
Why are there two places of vegetative reproduction in a scheme of the life cycle?

- Because both haplont and diplont could clone themselves.

# 21 Life cycle

## 21.1 Basics

**General life cycle: multicellular organism**

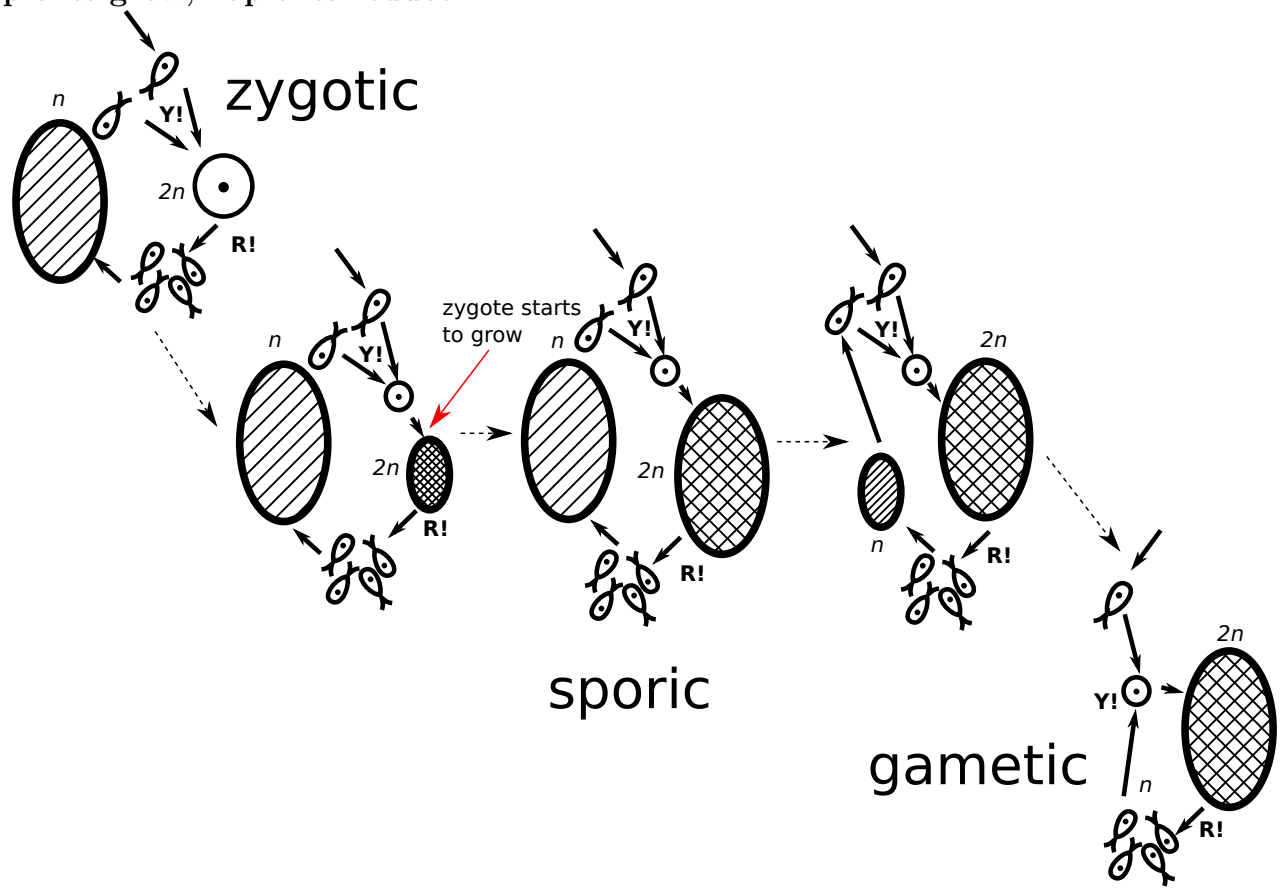



## 21.2 Evolution of life cycles

**3 cycles**

- **Zygotic**: Y! → R!, no diplont, many protists
- **Gametic**: R! → Y!, ho haplont, animals and few protists
- **Sporic**: both haplont and diplont, many protists and all plants$_2$

**Diplonts grow, haplonts reduce**



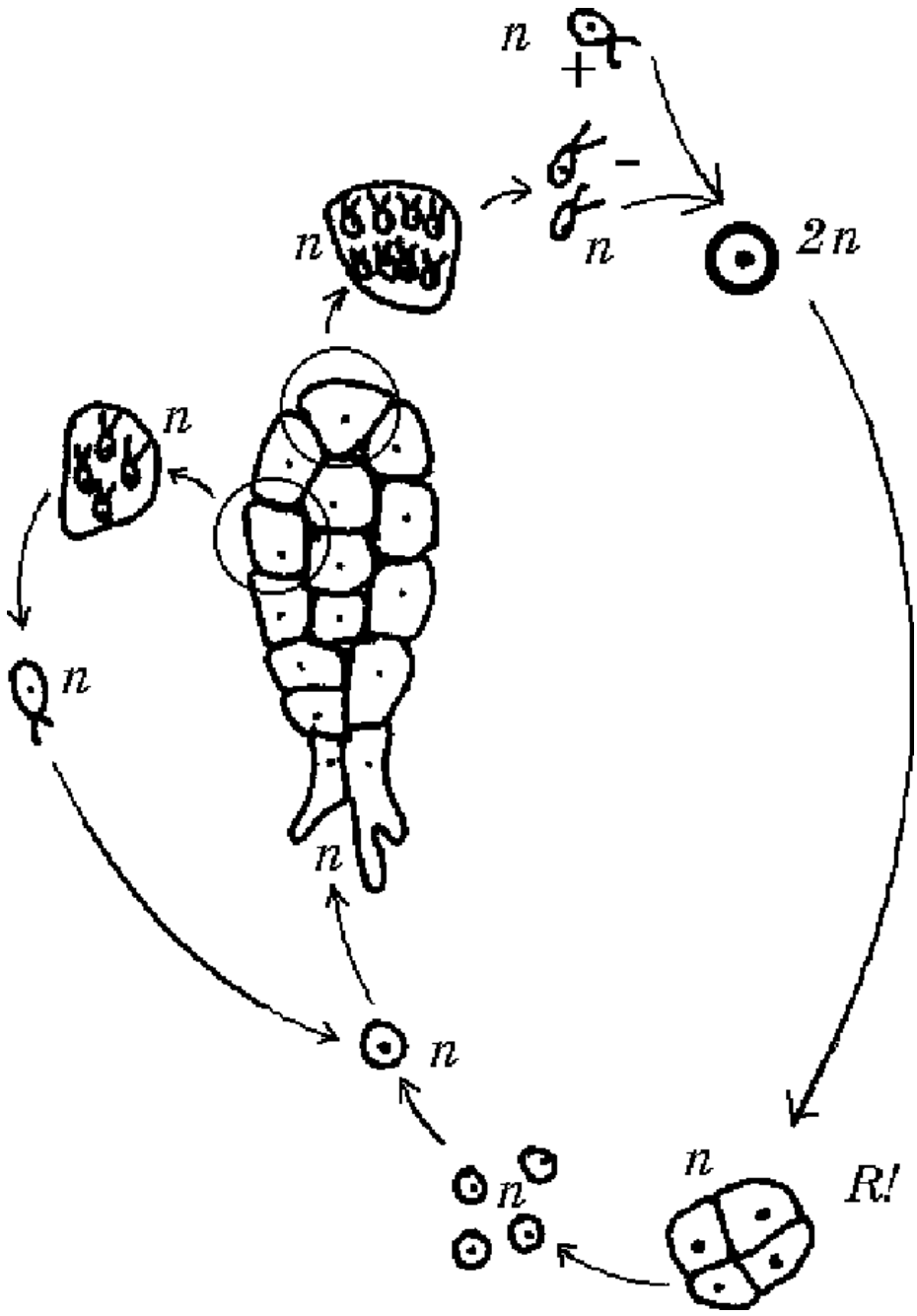

**Why diplonts are better?**

They have two variants of each gene!

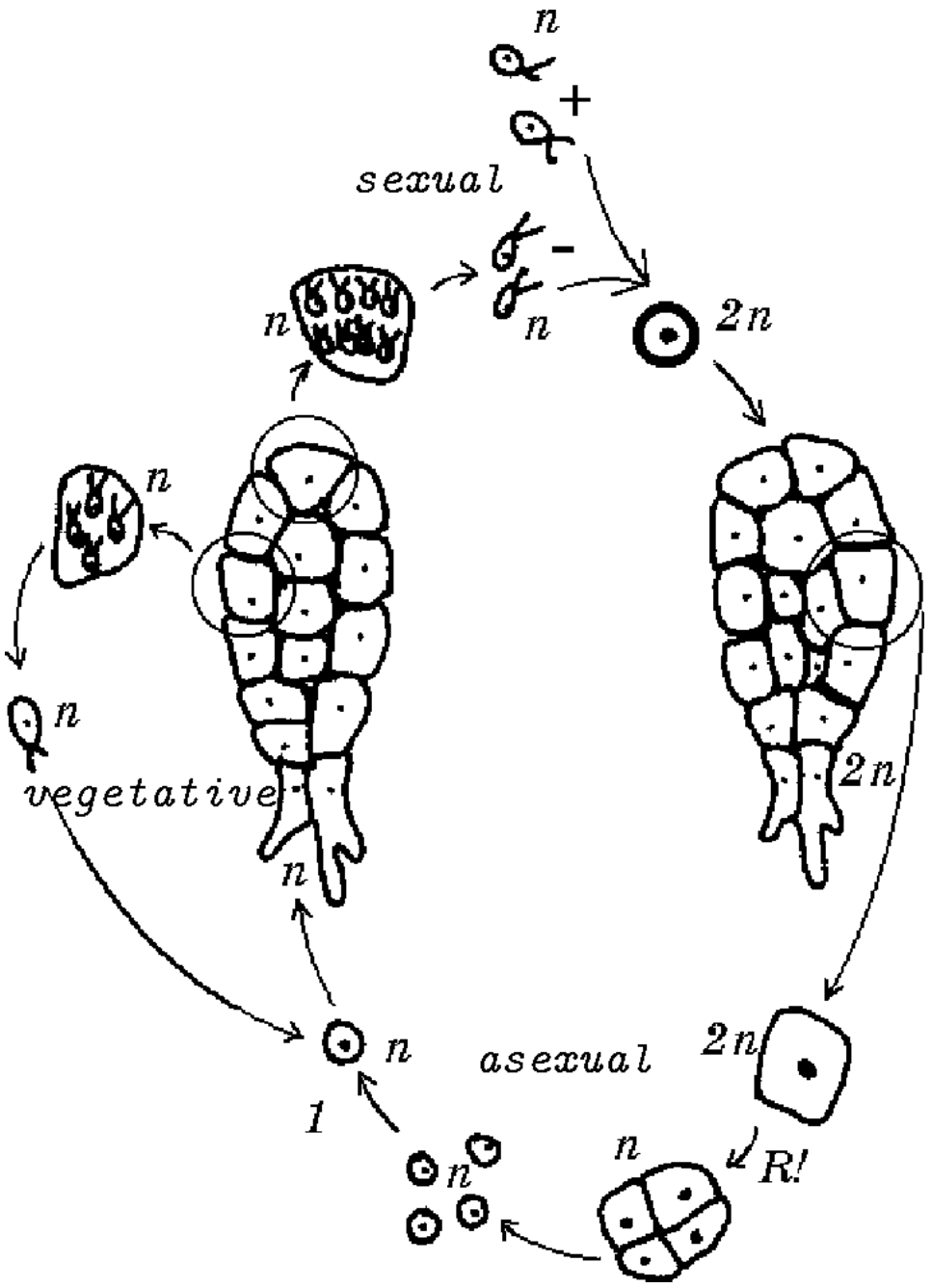
1. **Dominance**: if one gene is deadly mutated, there is the second working variant
2. **Protein production**: two genes will give more protein
3. **Diversity**: if one gene is producing protein adapted to +5...+30°C and other—to +10...+35°C, the organism may live under +5...+35°C

## 21.3 Diversity of life cycles

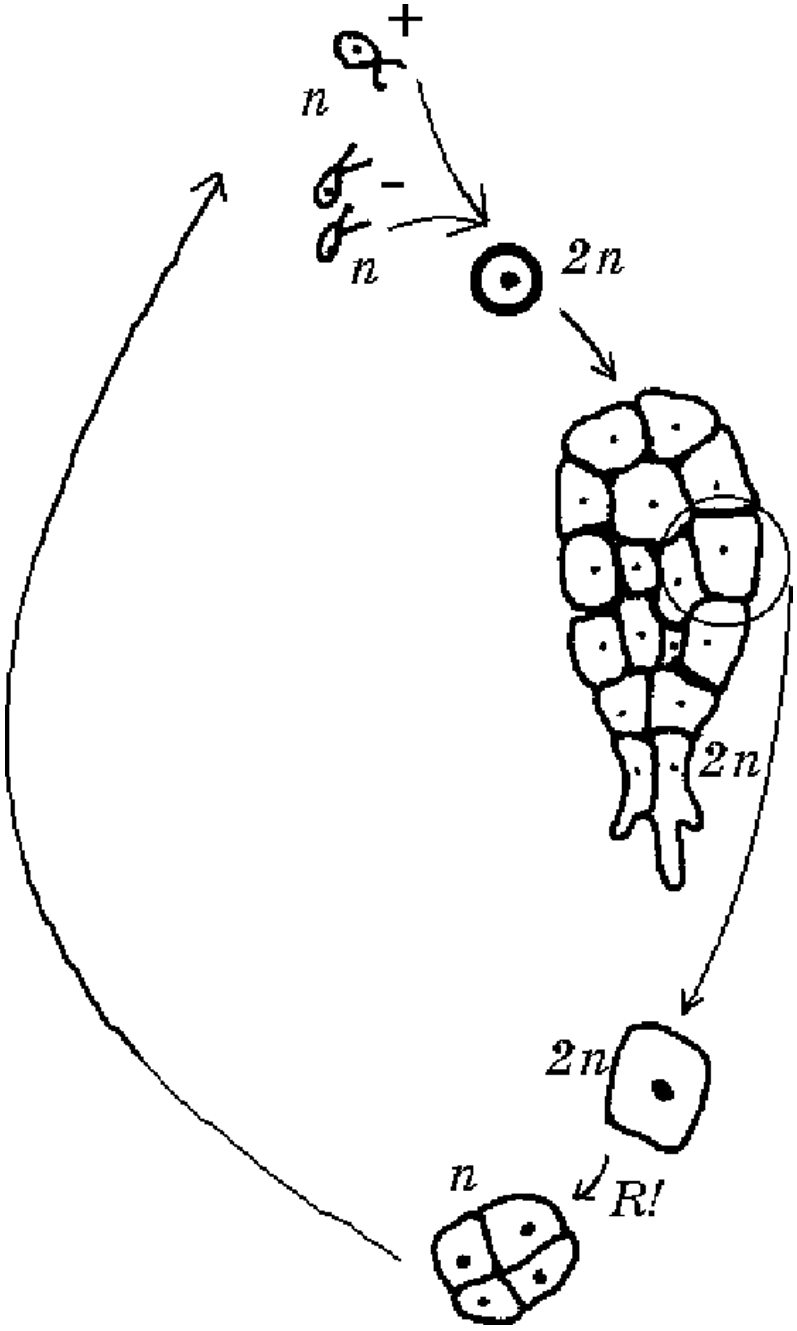
**Zygotic life cycle: protists**



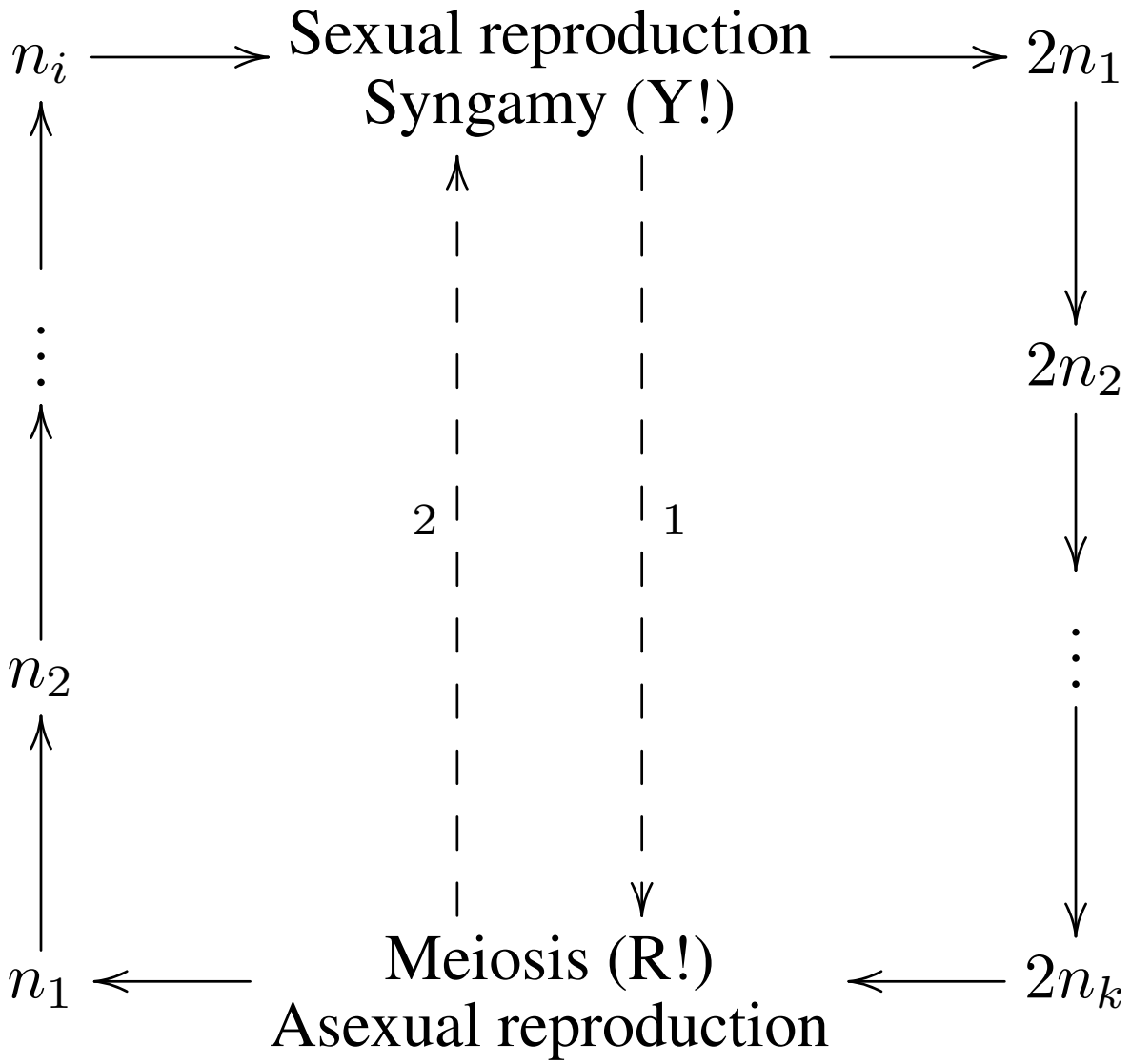

**Sporic life cycle: plants**




**Gametic life cycle: animals**

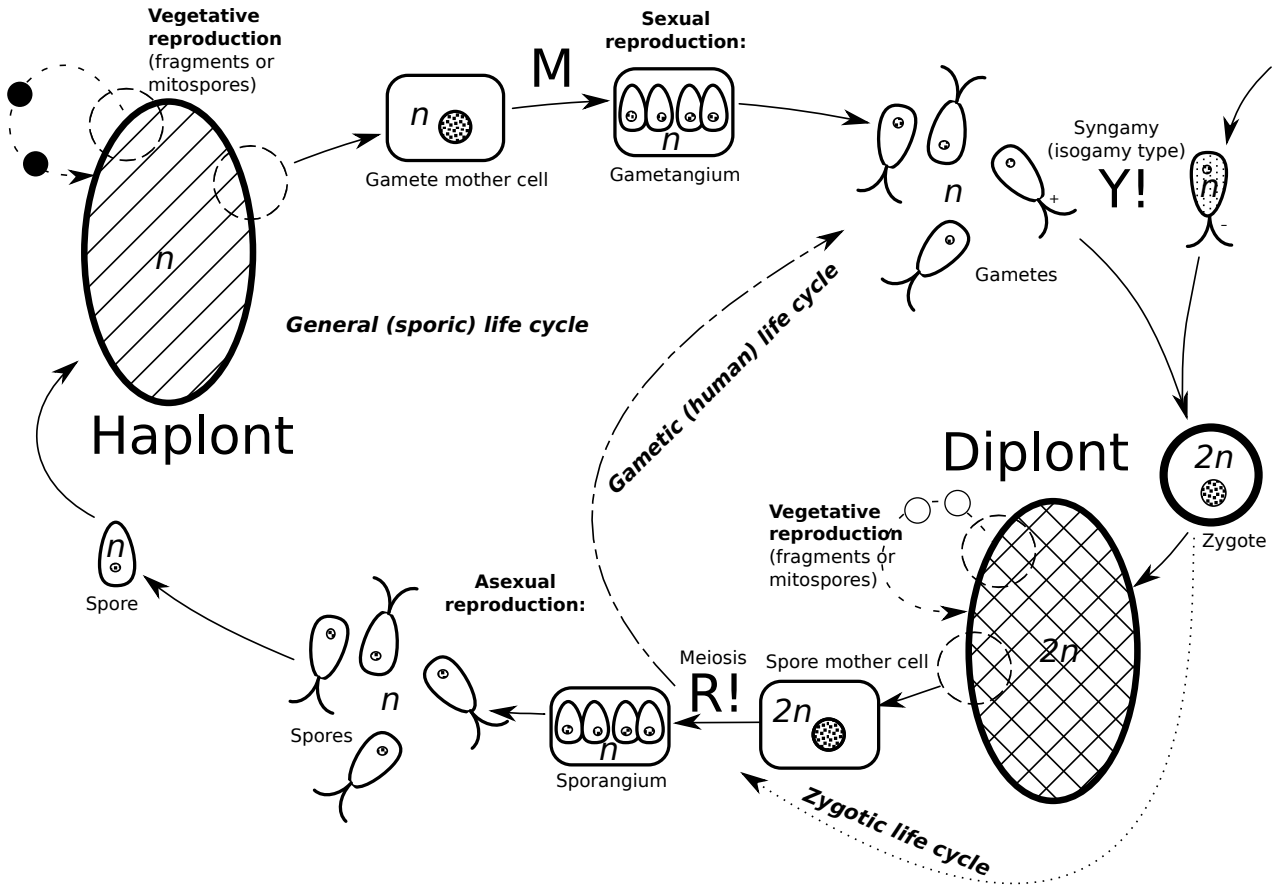



**Life cycle math**

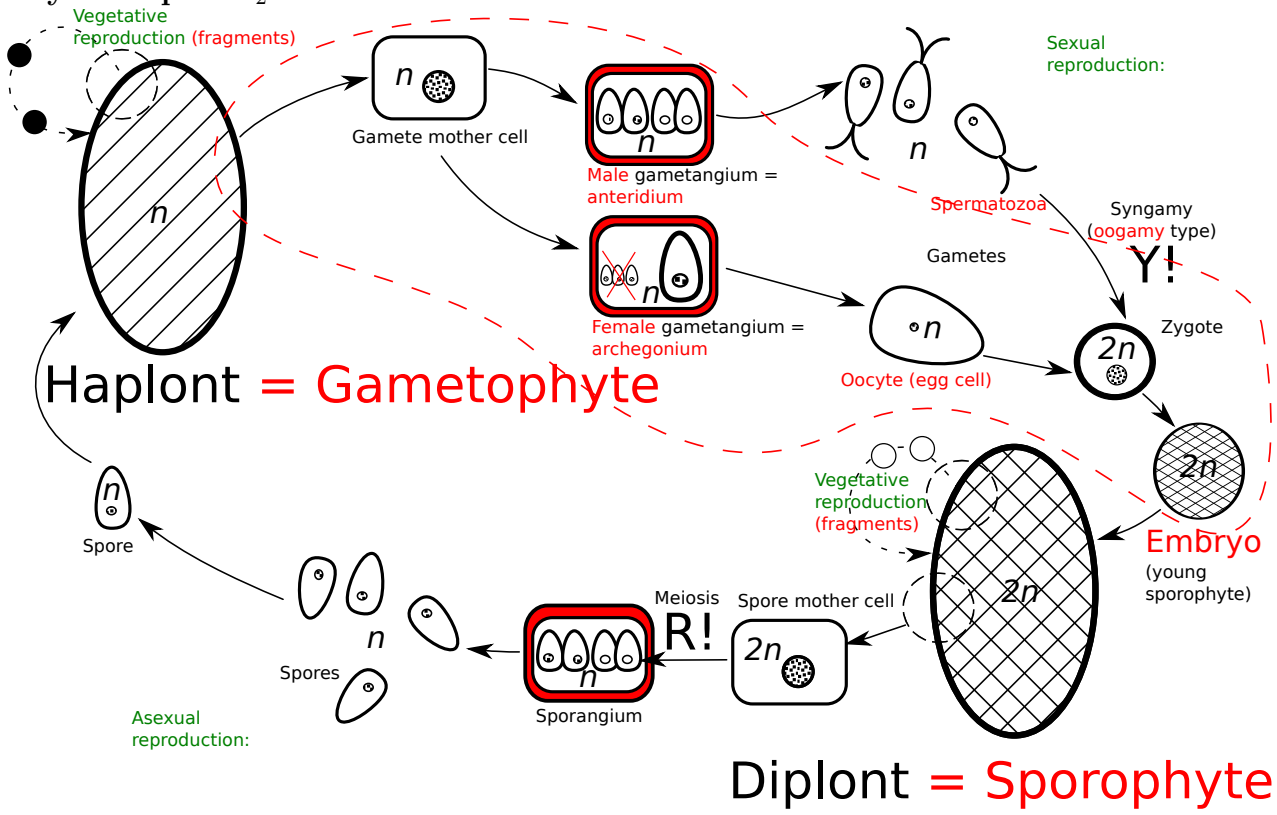



1 — zygotic cycle (Y!→R!);
2 — gametic cycle (R!→Y!).

**Life cycle (again)**




Life cycle of plants[2]



# 22 Tissues

## 22.1 Origin of tissues

**Summary**

- **Zygotic** life cycle has no *diplont*, **gametic** life cycle has no *haplont*, **sporic** life cycle has both *haplont* and *diplont*
- The evolution of life cycles goes from zygotic to sporic and then to gametic because "diplonts are better"

**Final question (2 points)**

Ask me a question about the current part of Botany course.
Answers will be provided on your paper fragments, please check it ASAP!

**For Further Reading**

# References

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