

Introduction to Botany: BIOL 154

Study guide for Exam 2

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Lectures 8–17

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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

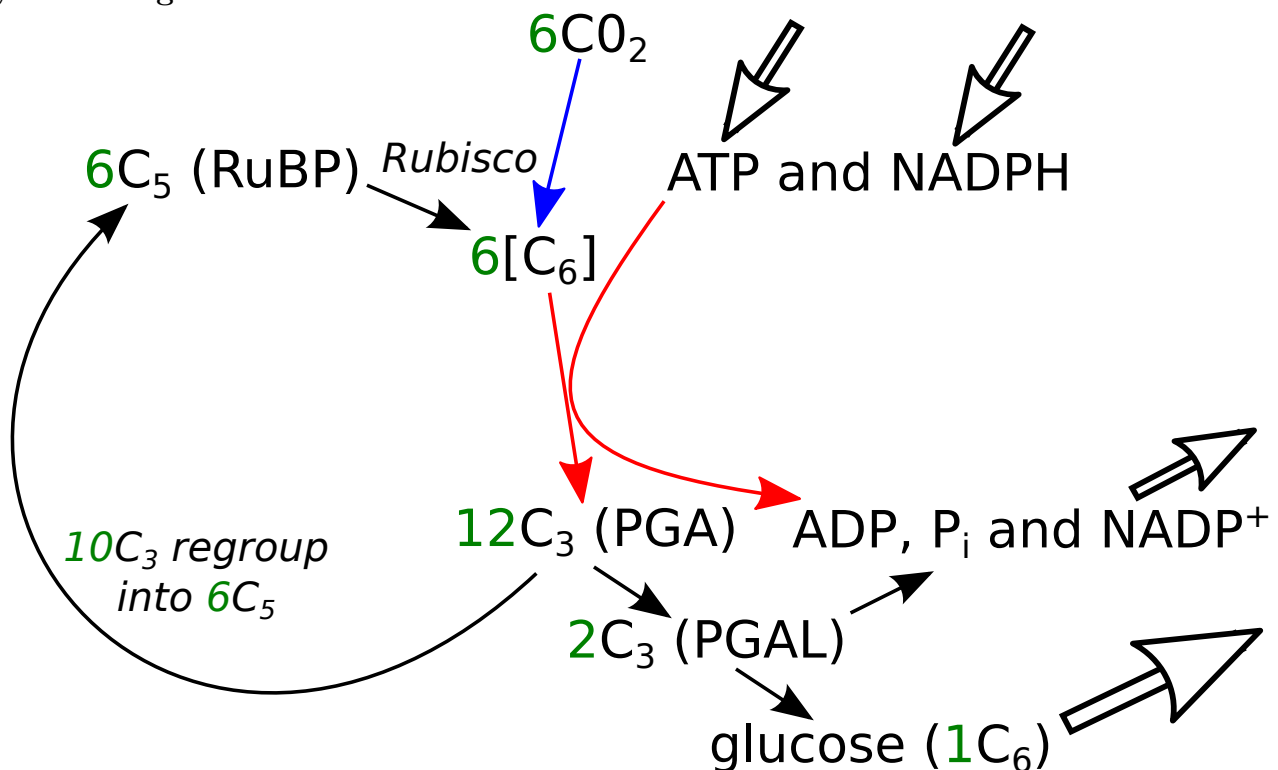
- A. Carbon dioxide (CO_2)
- B. Hydrogen carrier with hydrogen (NADPH)
- C. Source of energy (ATP)
- D. Ribulose biphosphate (RuBP, five-C-hydrocarbonate, “ C_5 ”)
- E. *Rubisco* and other enzymes

Place: in the matrix (stroma) of chloroplast

Main events of enzymatic stage

- A. $\text{CO}_2 + \text{C}_5$ (RuBP, ribulose biphosphate) $\xrightarrow{\text{rubisco}}$ C_6
- B. $\text{C}_6 \longrightarrow 2\text{C}_3$ (PGA, phosphoglyceric acid)
- C. $\text{C}_3 + \text{NADPH} + \text{ATP} \longrightarrow \text{C}_6\text{H}_{12}\text{O}_6$ (or other organic molecules) + $\text{C}_5 + \text{NADP}^+ + \text{ADP} + \text{P}_i$ (inorganic phosphate)
 - Organic molecules are synthesized from C_3 (PGA) through energy-rich **PGAL** (phosphoglyceric aldehyde)

Enzymatic stage: scheme



Results of enzymatic stage

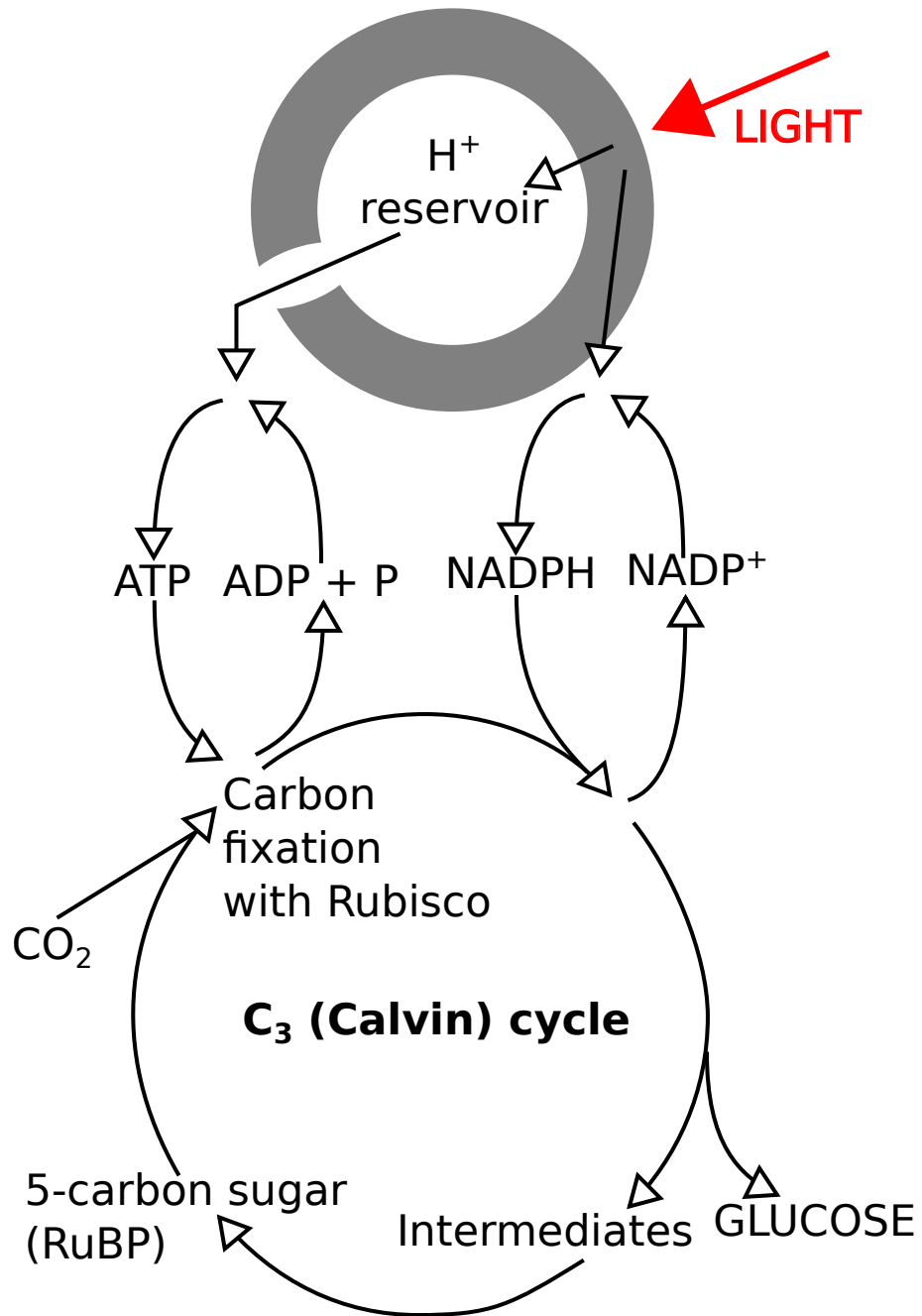
At the start	At the end
CO ₂	C ₆ H ₁₂ O ₆ (or other organic molecules)
NADPH	NADP ⁺ (and H to organic molecules)
ATP	ADP and P _i (inorganic phosphate)
C ₅	C ₅
Rubisco	Rubisco

The other names for enzymatic stage are “Calvin cycle” and “C₃ cycle”

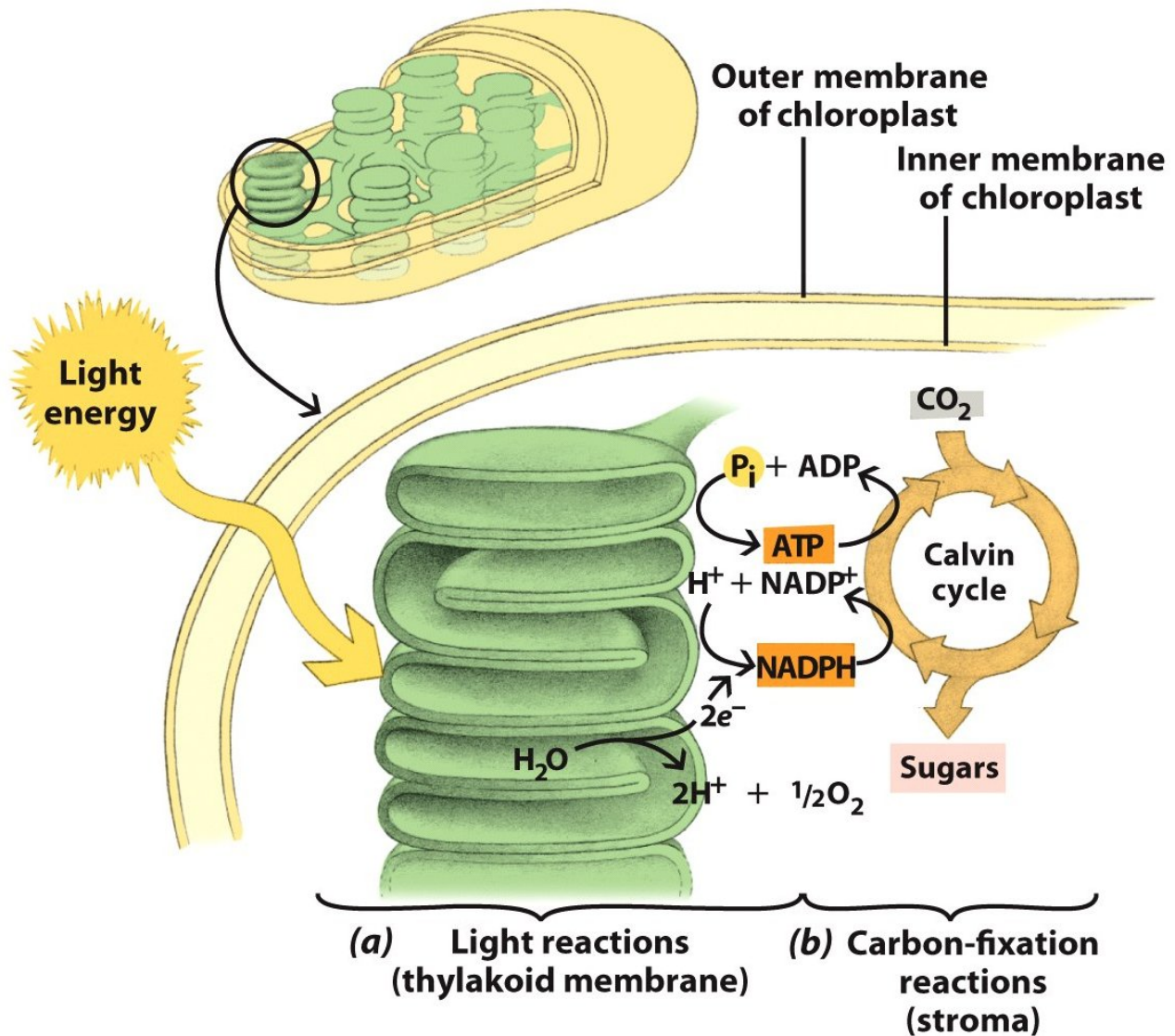
2.2 As a whole



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

Outline

3 Questions and answers

3.1 Quiz

Final question (2 points)

Explain the role of NADPH in the enzymatic stage.

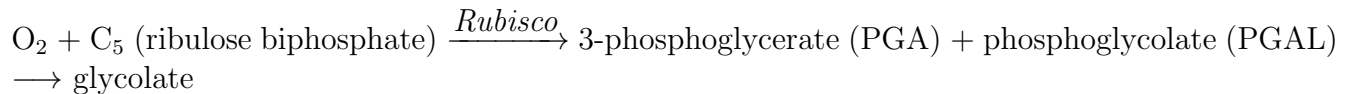
- It provides hydrogen to use in glucose
- In addition, it provides energy in the way similar to ATP

4 Photosynthesis

4.1 Special case of photosynthesis: C₄ pathway

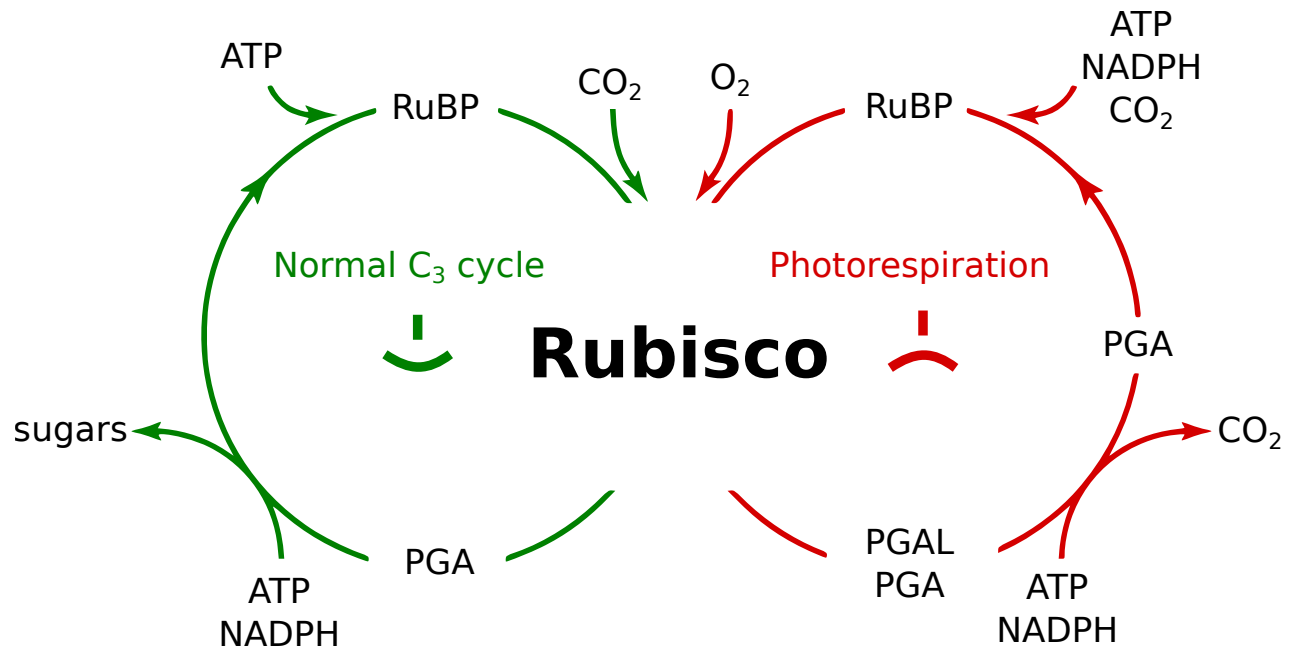
Photorespiration

Rubisco is two-faced enzyme, it catalyzes **photorespiration** if the concentration of O₂ and/or temperature is high:



- To return glycolate into the Calvin cycle, cell must use peroxisomes, mitochondria and spend ATP
- Photorespiration wastes C₅ and ATP
- Photorespiration is said to be an evolutionary relic from times when atmosphere contained little oxygen

Two-faced Rubisco



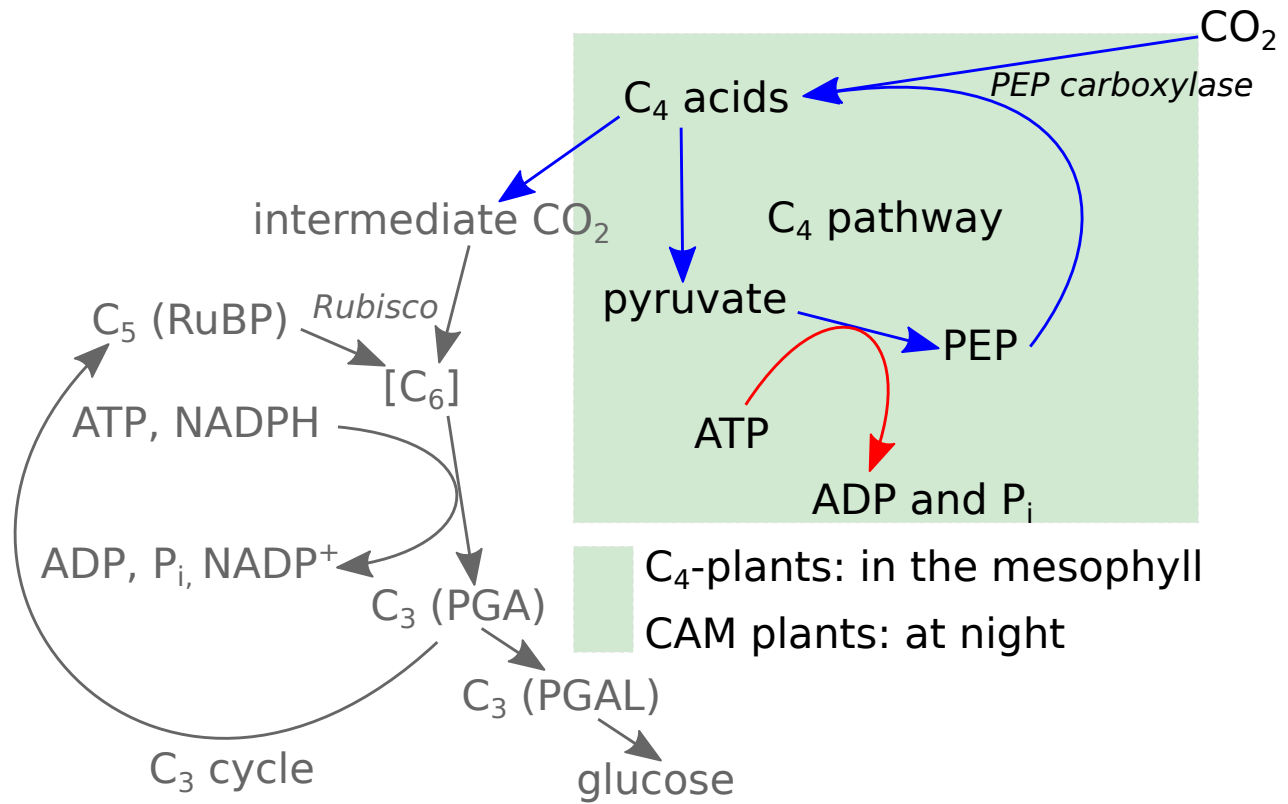
Minimization of photorespiration

To minimize photorespiration, plants need to increase concentration of CO₂. This is how they do it:

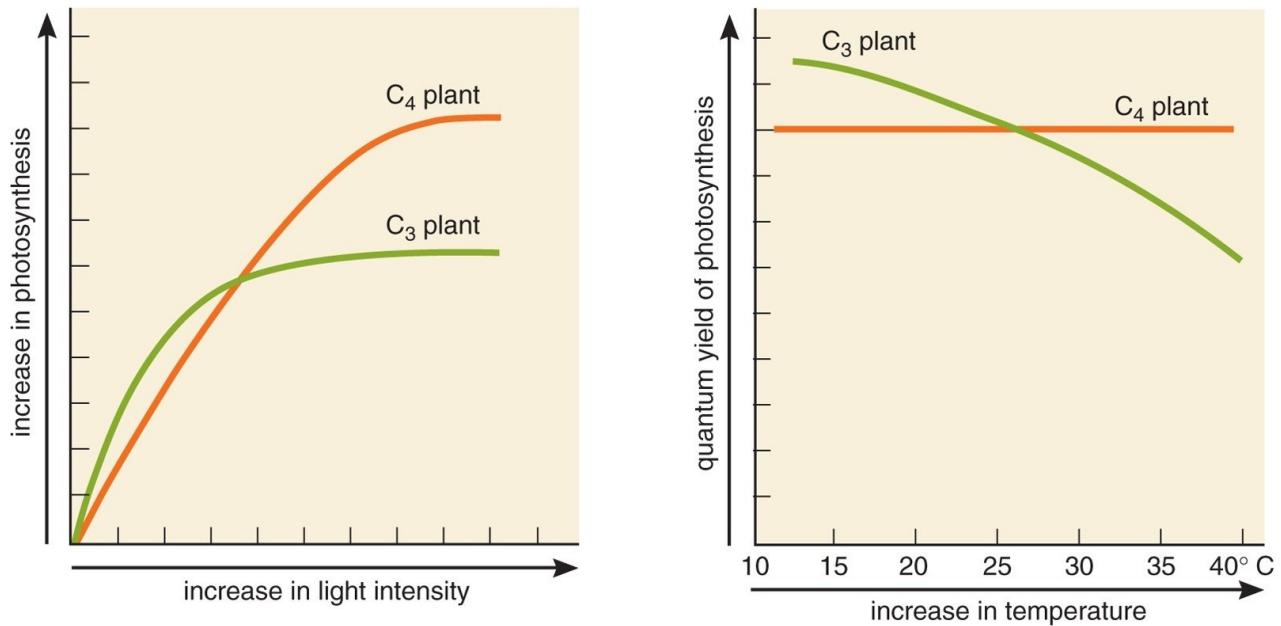
- CO₂ + C₅ (PEP, phosphoenolpyruvate) $\xrightarrow{\text{PEP carboxylase}}$ C₄ (different organic acids): this is the temporarily accumulation of carbon dioxide
- C₄ \longrightarrow pyruvate + CO₂: release of carbon dioxide will increase its concentration
- Pyruvate + ATP \longrightarrow PEP + ADP + P_i: PEP recovery costs ATP! (but **less** than photorespiration)

Processes above called C₄ pathway, it is an addition to Calvin (C₃) cycle in order to increase concentration of CO₂

C₄ 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

4.2 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)

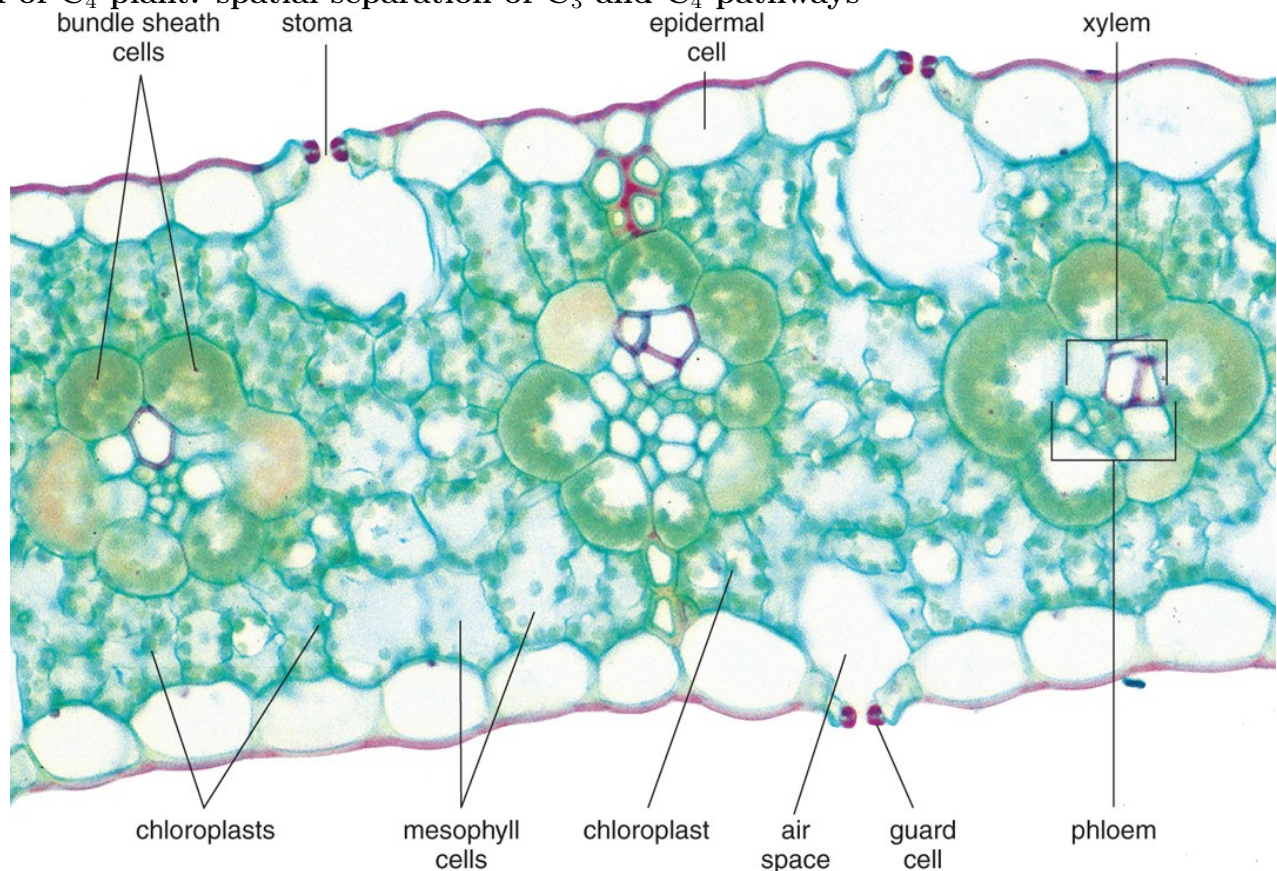
- CAM-plants (17,000 species, 7% of plant biodiversity) are mostly succulents from different orders and families (e.g., cacti—Cactaceae from Caryophyllales), other examples are bromeliads like pineapple.

- **C₄-plants** which drive C₄ in mesophyll cells and C₃ in bundle sheath cells:

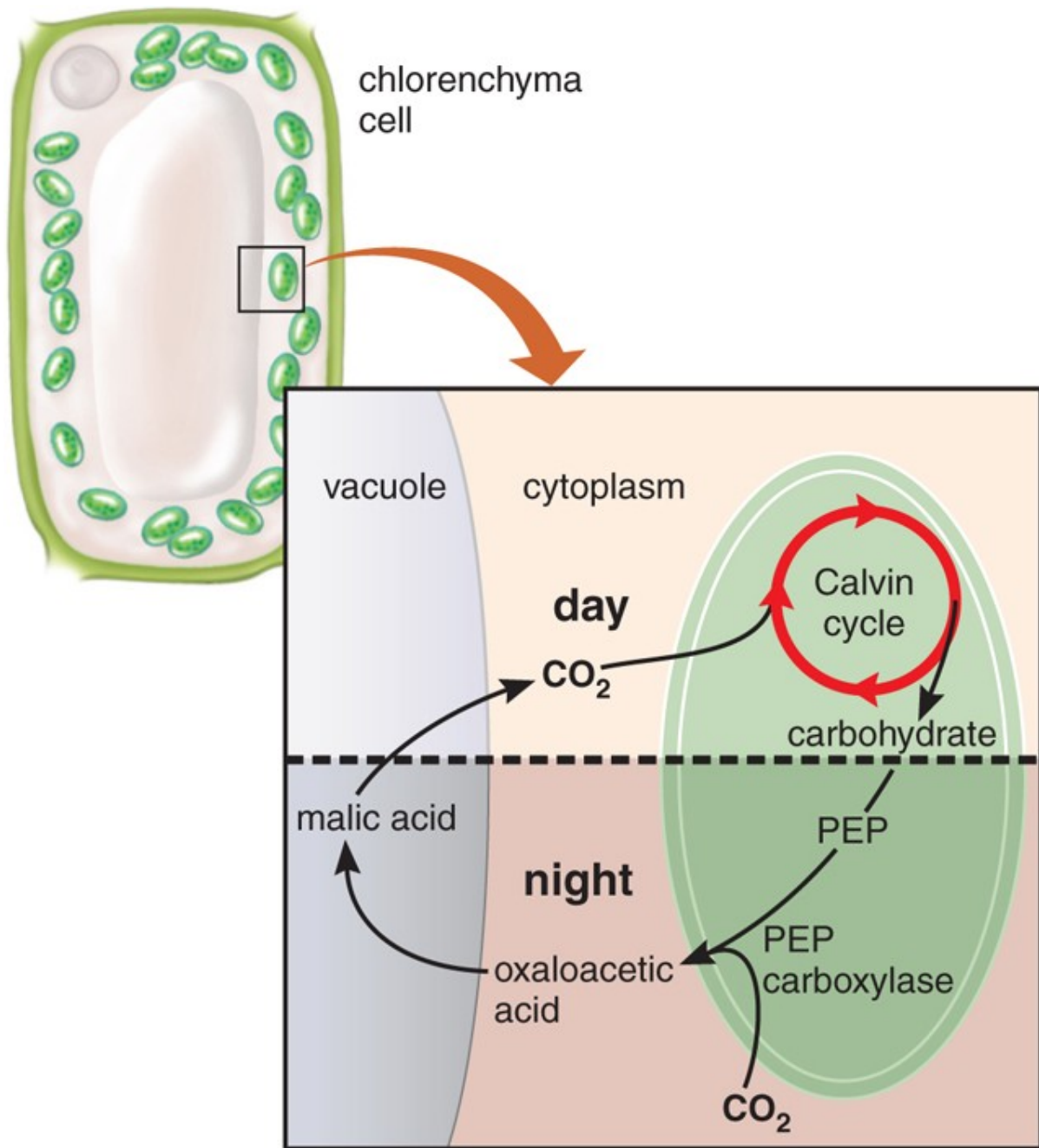
- This is a **spatial** separation between accumulation of CO₂ and photosynthesis: C₄ pathway is located in “normal” mesophyll cells whereas the Calvin cycle is separated to **bundle sheath cells**.
- C₄-plants (7,300 species, 3%) are especially common among Poales (grasses order, e.g., corn, millet, sorghum) and Caryophyllales (pink order)

There are plants which combine C₄ and CAM (*Portulacaria*) and even C₃ and CAM (*Clusia*).

Leaf of C₄ plant: spatial separation of C₃ and C₄ pathways

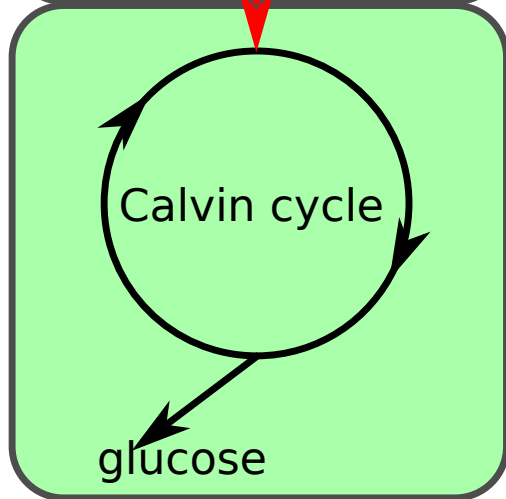
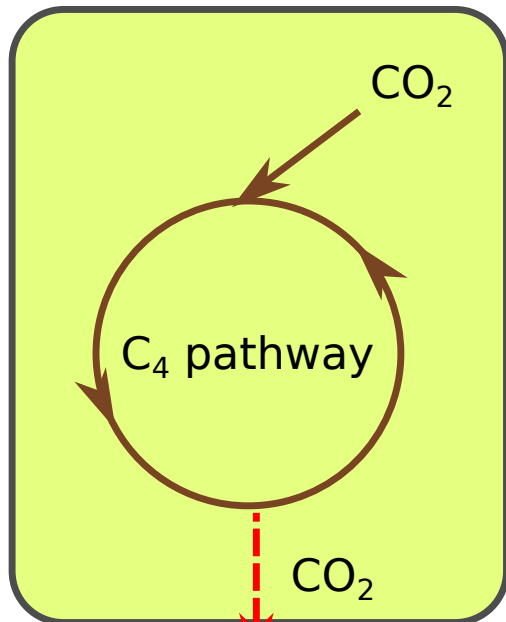


CAM plants separate C₃ and C₄ pathways in time



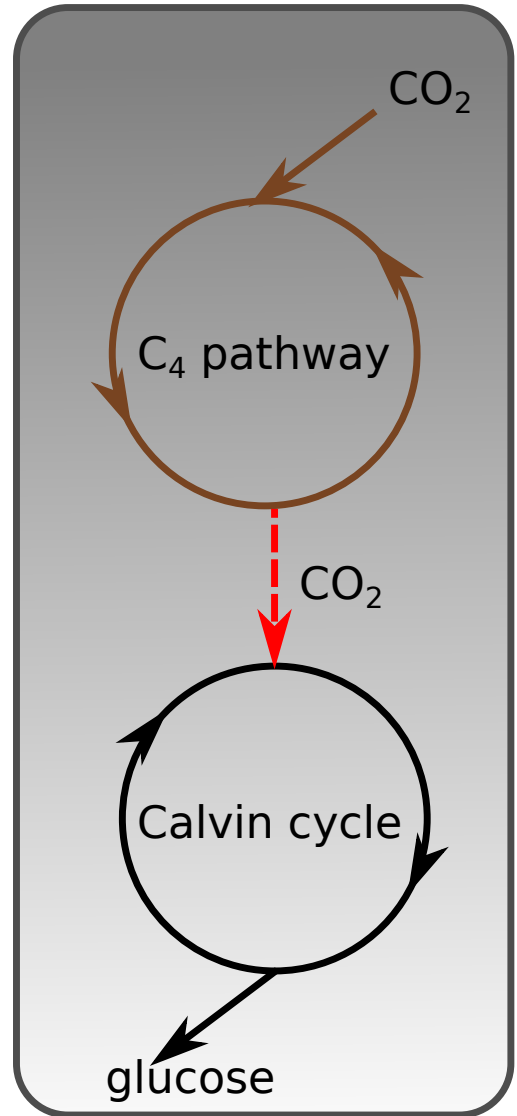
CAM plants and C_4 plants

mesophyll cell



bundle sheath cell

night



day

Jade plant



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

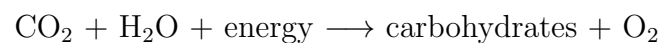
Corn



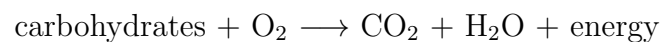
Corn (*Zea mays*) is the C_4 plant which minimizes photorespiration at higher temperatures

True respiration

- The common misconception about plants is that their only energy-related metabolic process is photosynthesis:



- However, as most eukaryotes, plants have mitochondria in cells and use *aerobic* (oxygen-related) respiration to obtain energy:



- Typically, plants spend much less oxygen in respiration than they make in photosynthesis. However, at nights plants do exactly the same as animals, and make only carbon dioxide!

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
- C₄ 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]. Mode of access: http://ashipunov.info/shipunov/school/biol_154

Outline

5 Questions and answers

5.1 Quiz

Final question (2 points)

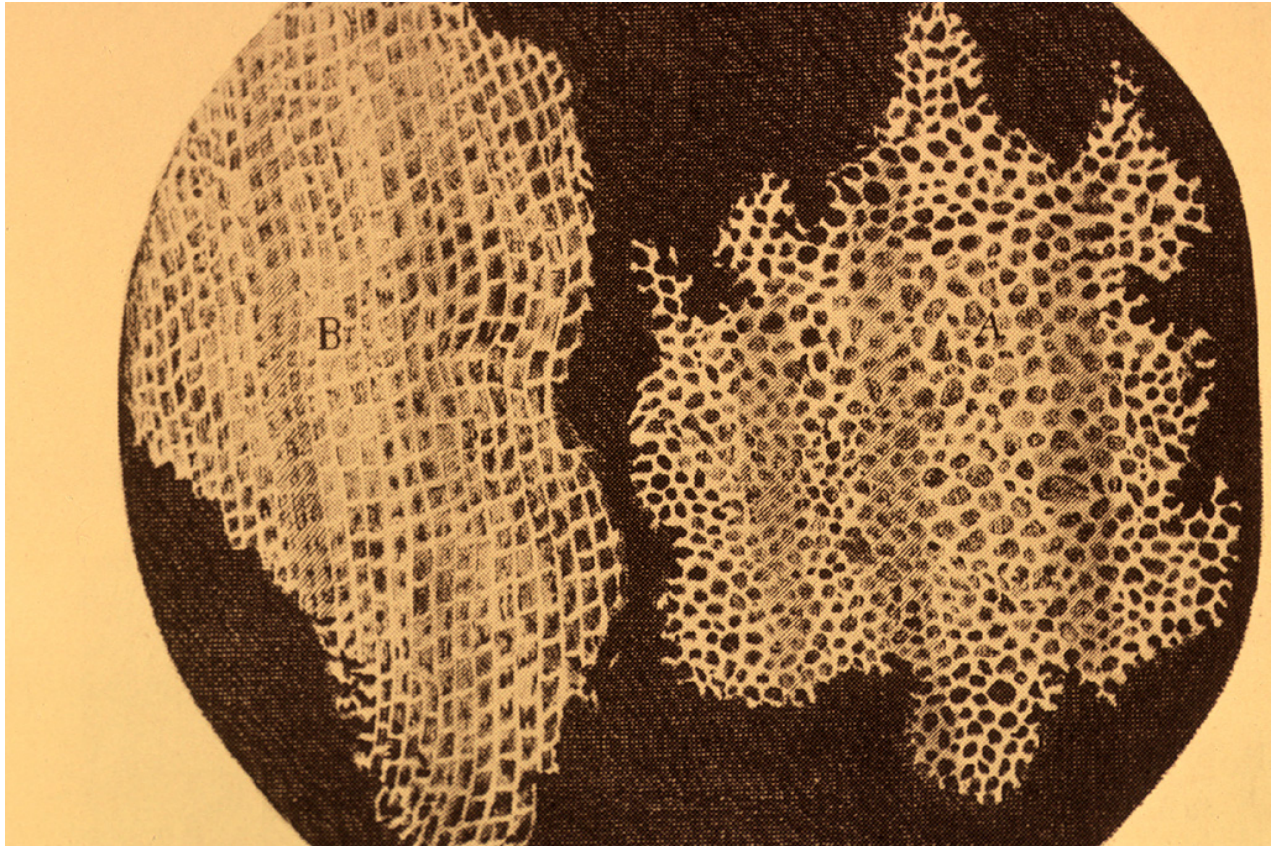
What is photorespiration?

- 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

6 Plant cell

6.1 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

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

Microscopes

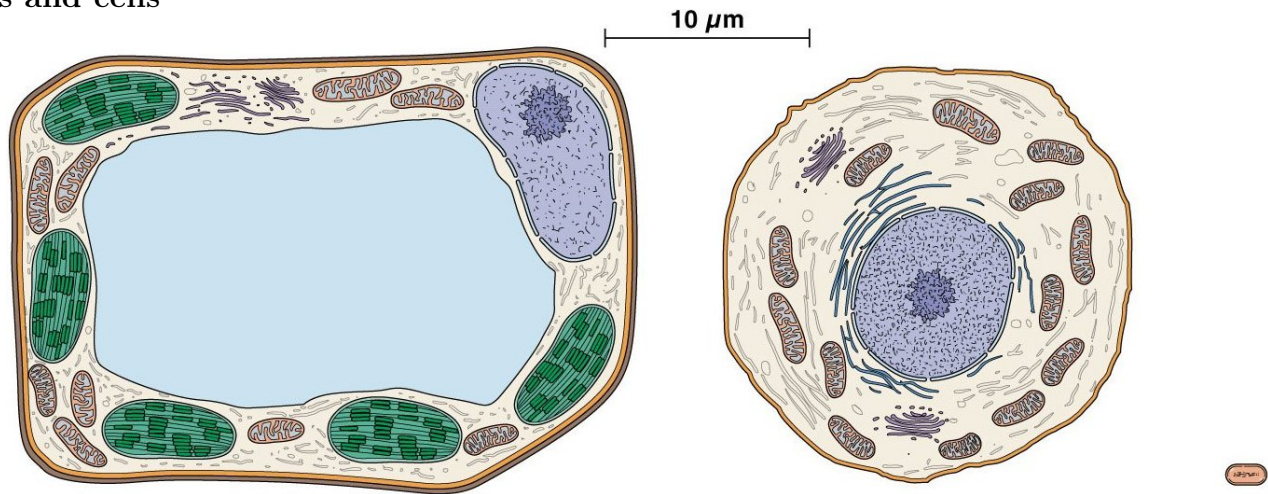
Light microscopy was an early technological breakthrough that contributed to our understanding of cell structure. Dissectiscopes use reflected light, microscopes use translucent light. Magnification is of 10^3 order.

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.

6.2 Structure of cell

Cells and cells



Eukaryotic and prokaryotic cells are fundamentally different

Plant cell

Final question (2 points)

TBA

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

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

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

Outline

7 Questions and answers

7.1 Quiz

Final question (2 points)

How to avoid photorespiration?

- Decrease photosynthesis (non-practical solution)
- Pump oxygen out (does not really work – why?)
- Pump carbon dioxide in (C₄ pathway)

8 Plant cell

Plant cell

List of cell structures

- *Cell membrane*
- *Cytoplasm*
- *Nucleus, nuclear pore, chromosomes*
- *Chloroplast, thylakoids*
- *Mitochondrion, cristae*
- ER (endoplasmatic reticulum/network)
- Goldgi apparatus (AG)

- **Vacuoles**, lysosomes, peroxisomes
- Ribosomes
- **Cell wall**

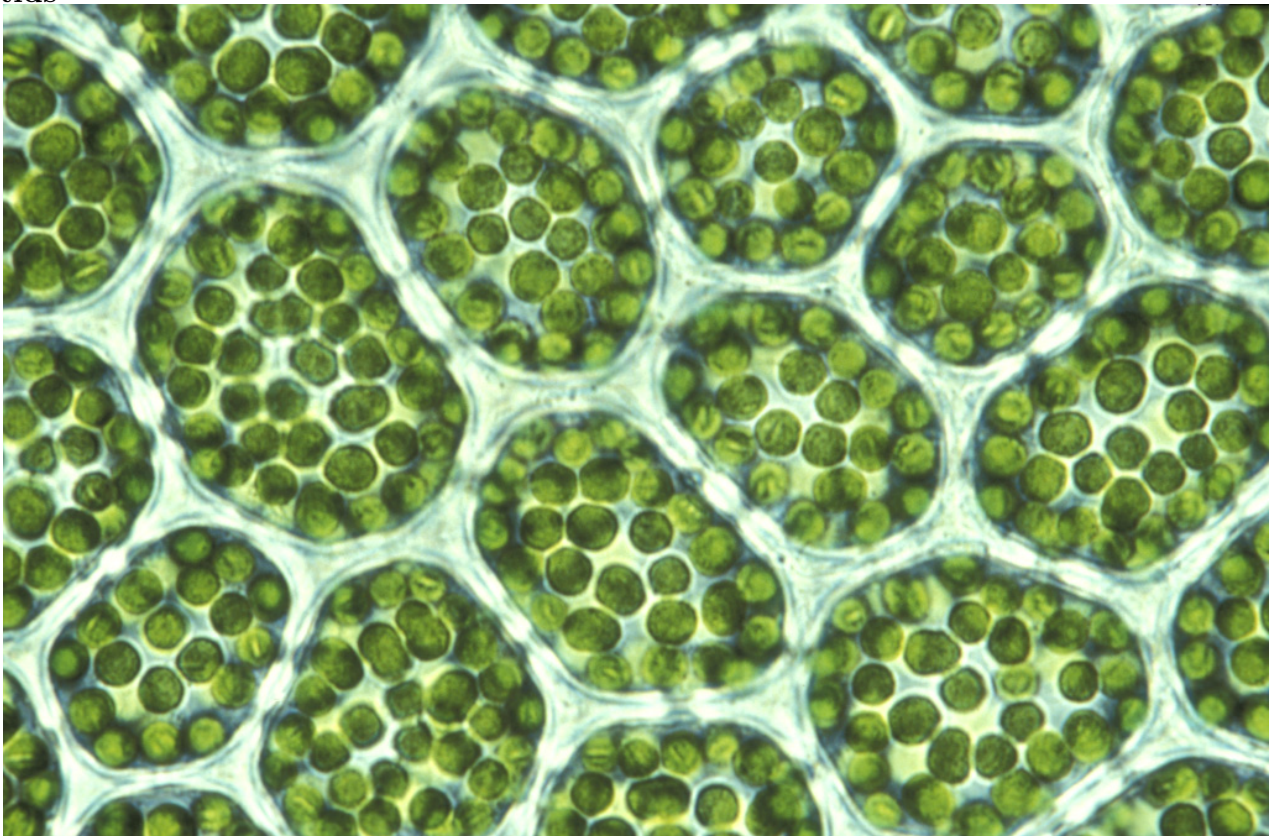
Chloroplasts and mitochondria are both results of symbiogenesis

8.1 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 mitochondrial eukaryotes also captured cyanobacteria (plants₁) and became **algae** with chloroplasts

Plastids



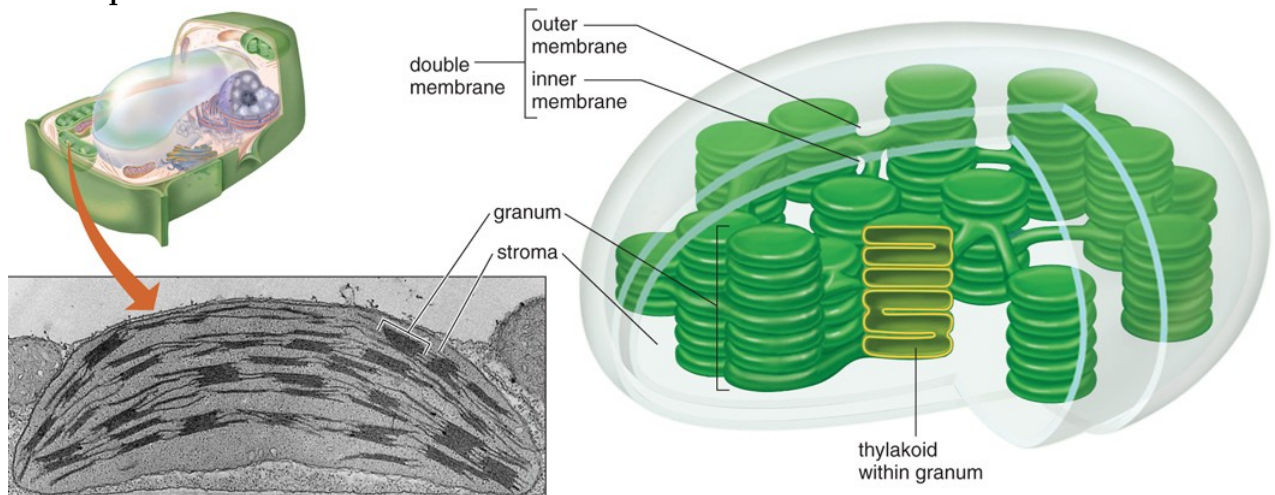
Green plastids (chloroplasts) in leaf cells of *Rhizomnium pseudopunctatum* (LM $\times 500$)

Plastid structure

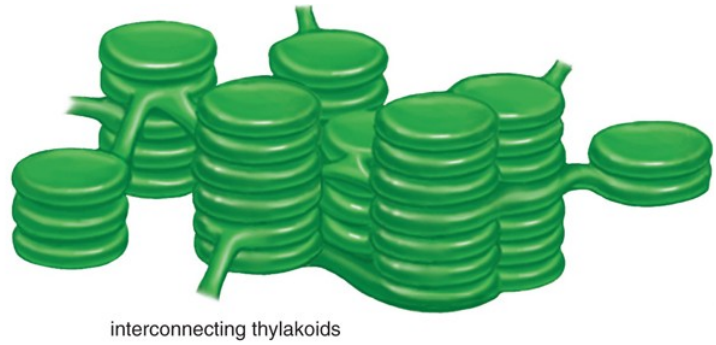
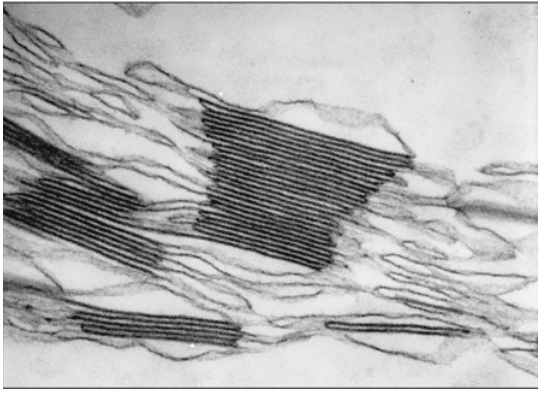


Thylakoids, stroma and starch granules (TEM $\times 37,500$)

Scheme of plastid



Grana

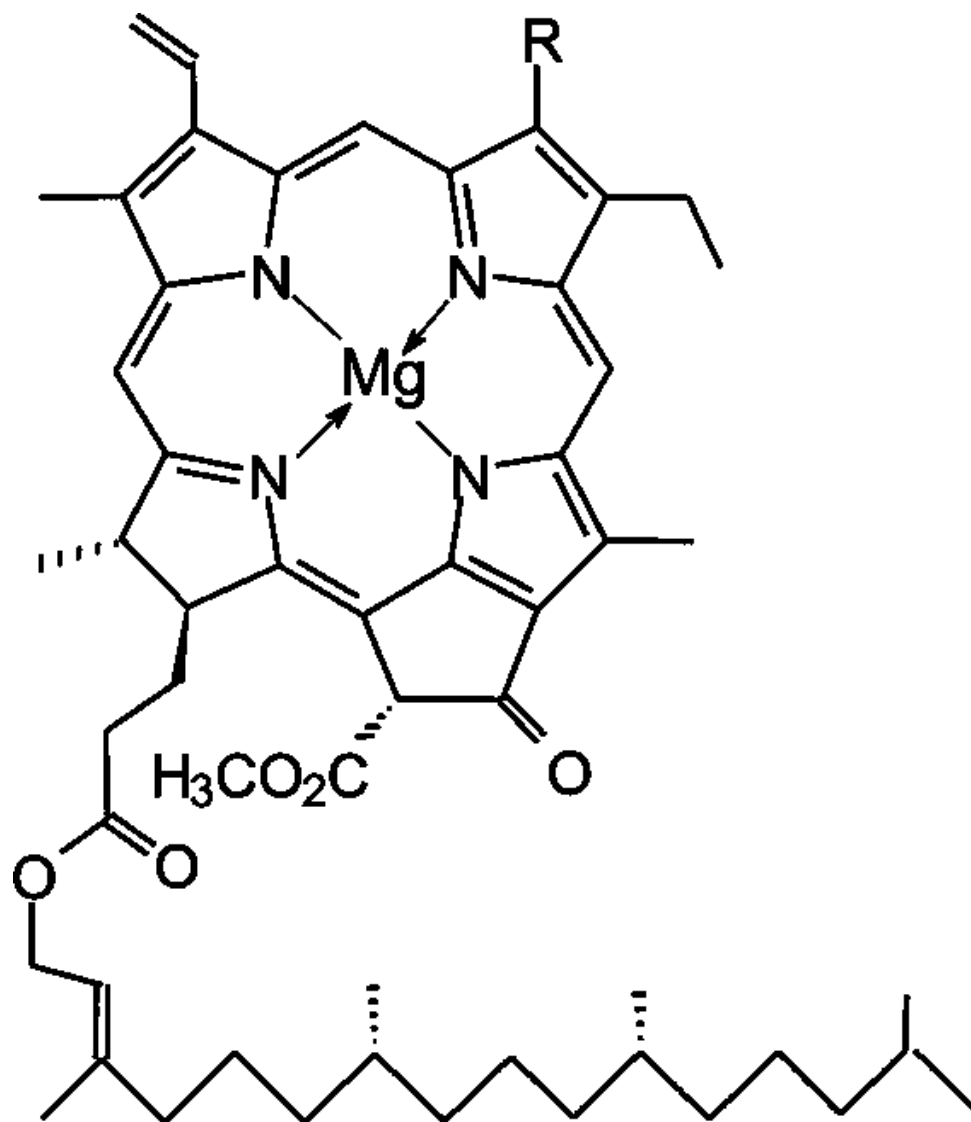


Grana is plural, **granum** singular.

Pigments

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

Chlorophylls *a* and *b*



chlorophyll *a* ($R = \text{CH}_3$)
 chlorophyll *b* ($R = \text{CH}=\text{O}$)

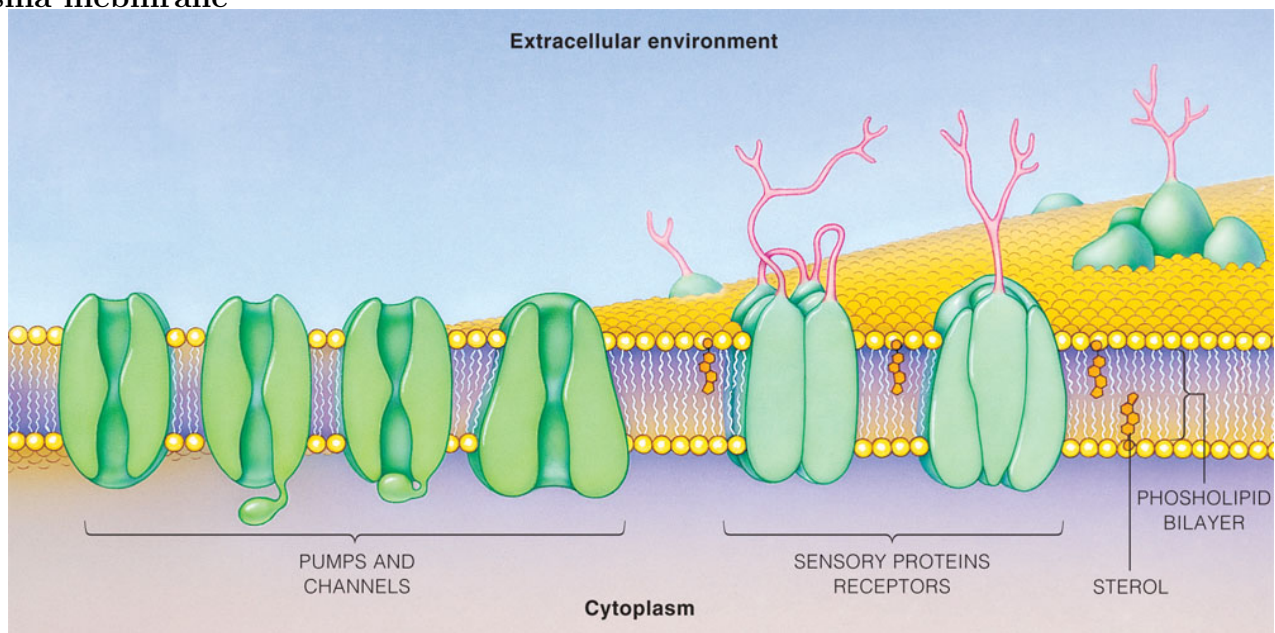
Mitochondria



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

8.2 Cell boundaries

Plasma mebmrane



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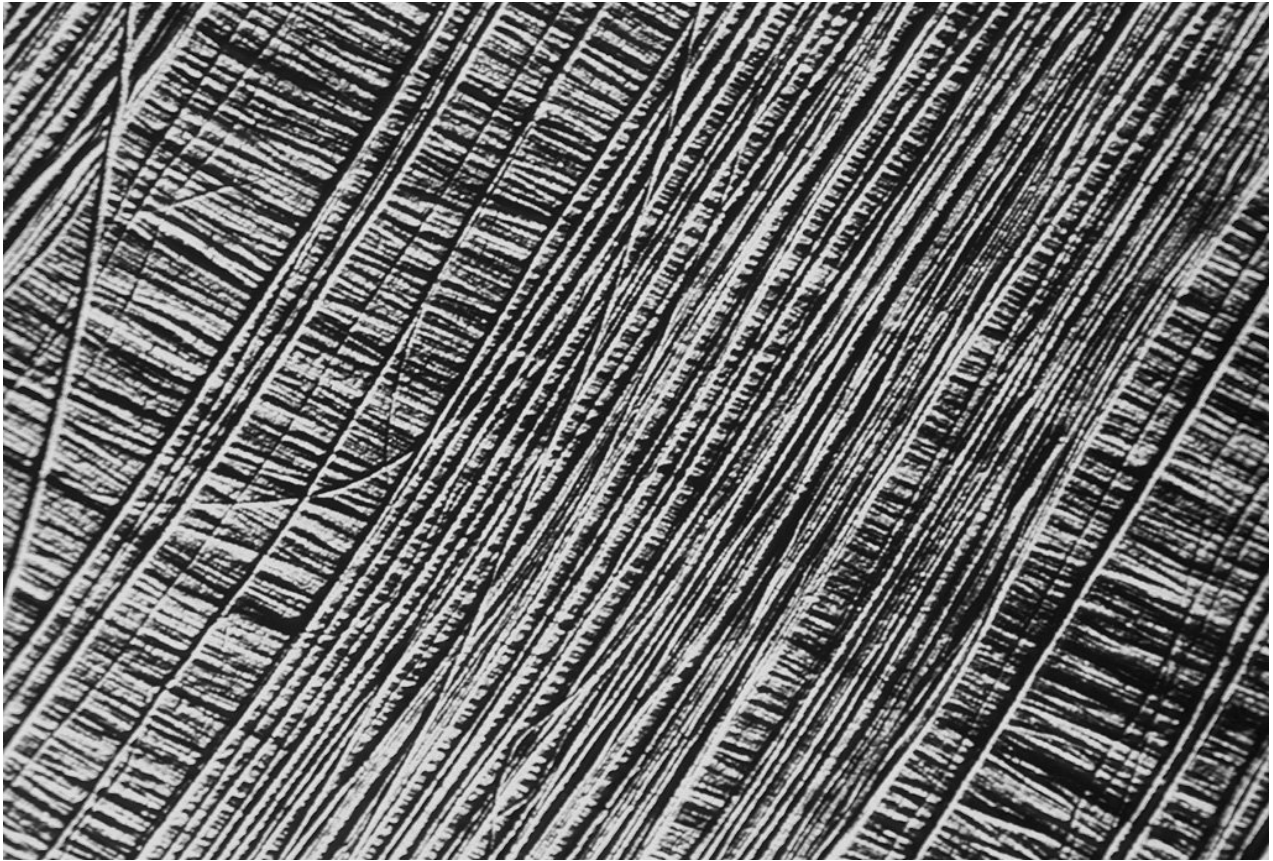
Phospholipids, sterols, proteins: pumps, receptors, channels

Cell wall



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

Fibers

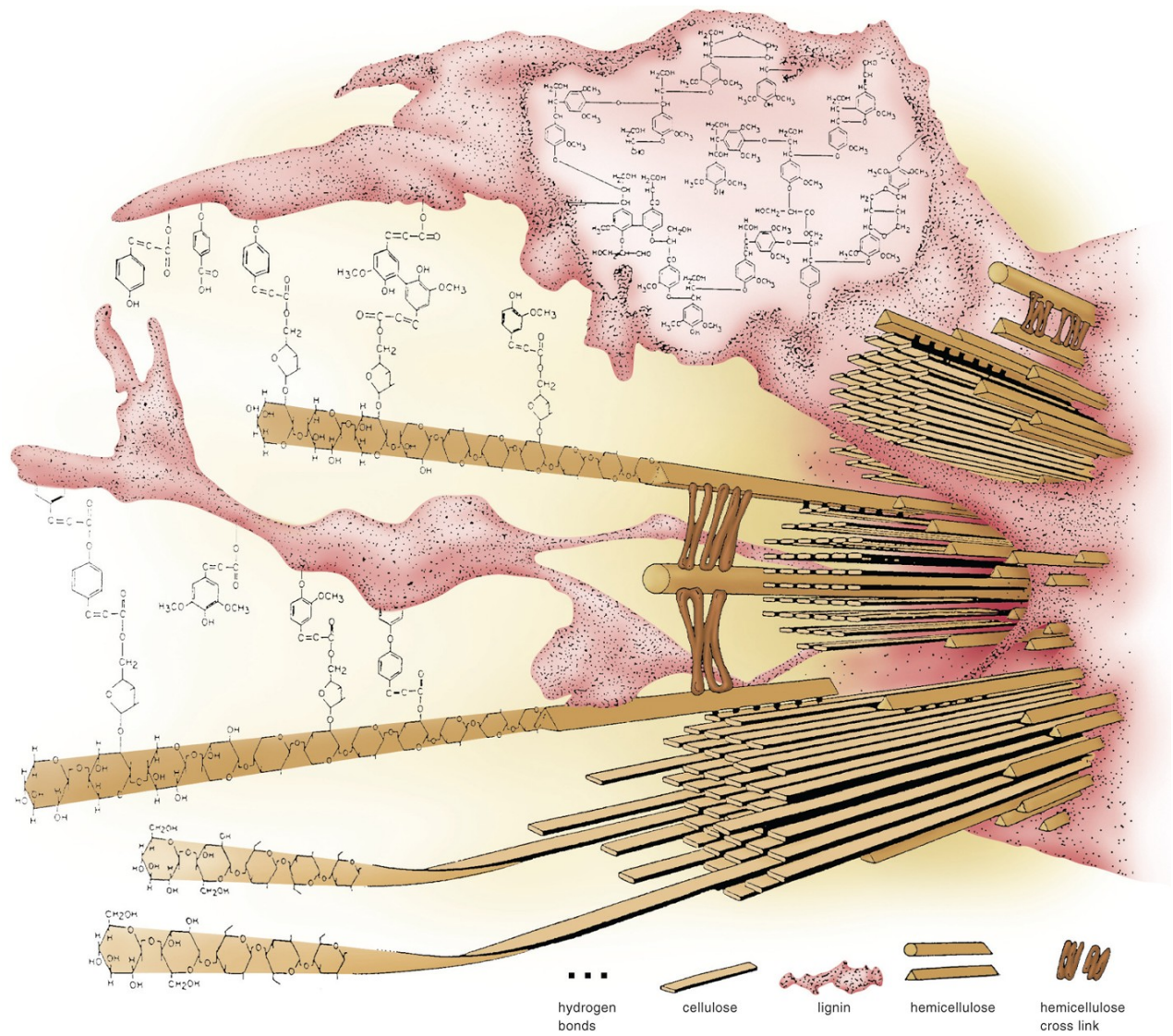


Cellulose fibers in the plant cell wall (SEM)

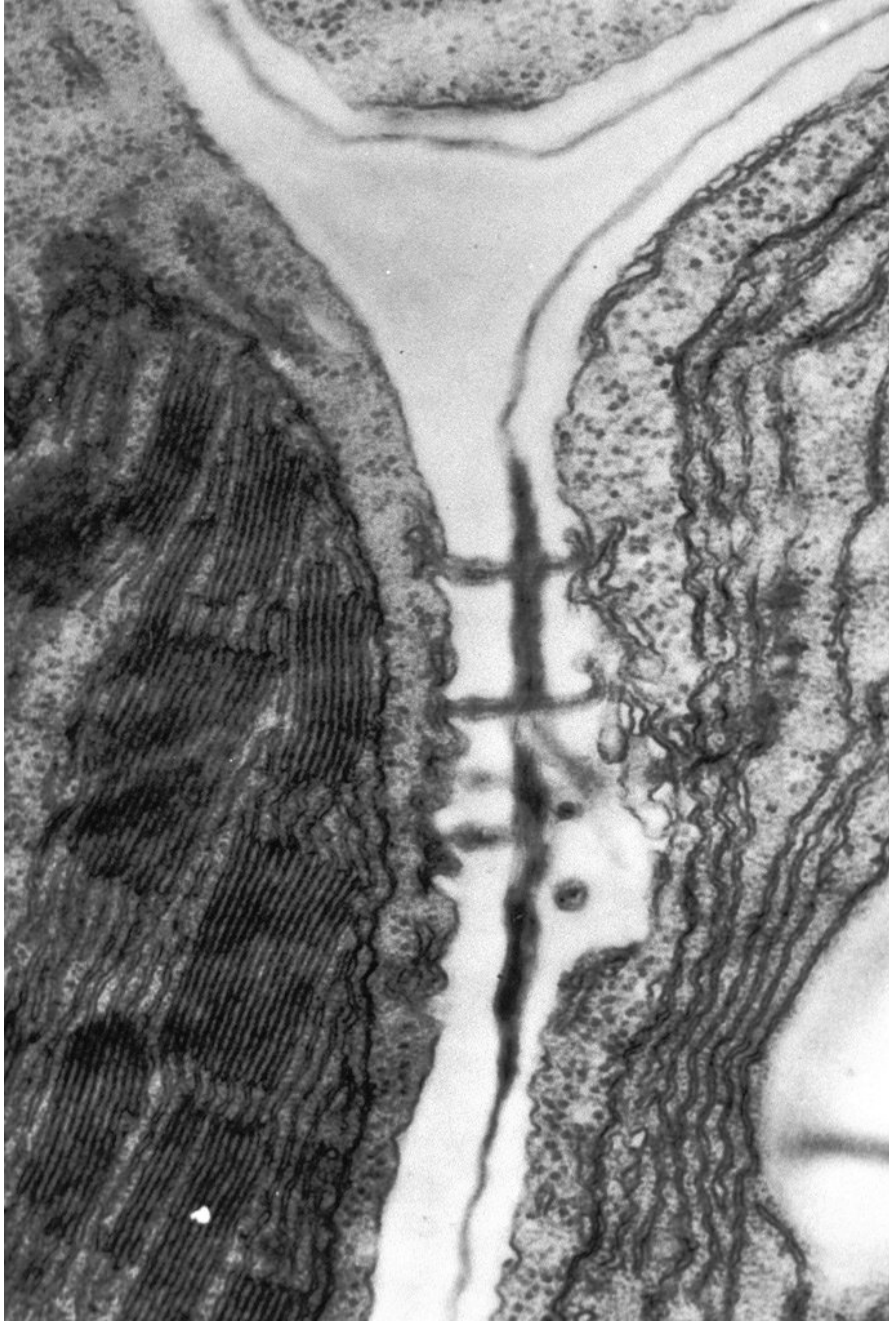
Primary and secondary cell walls

- **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

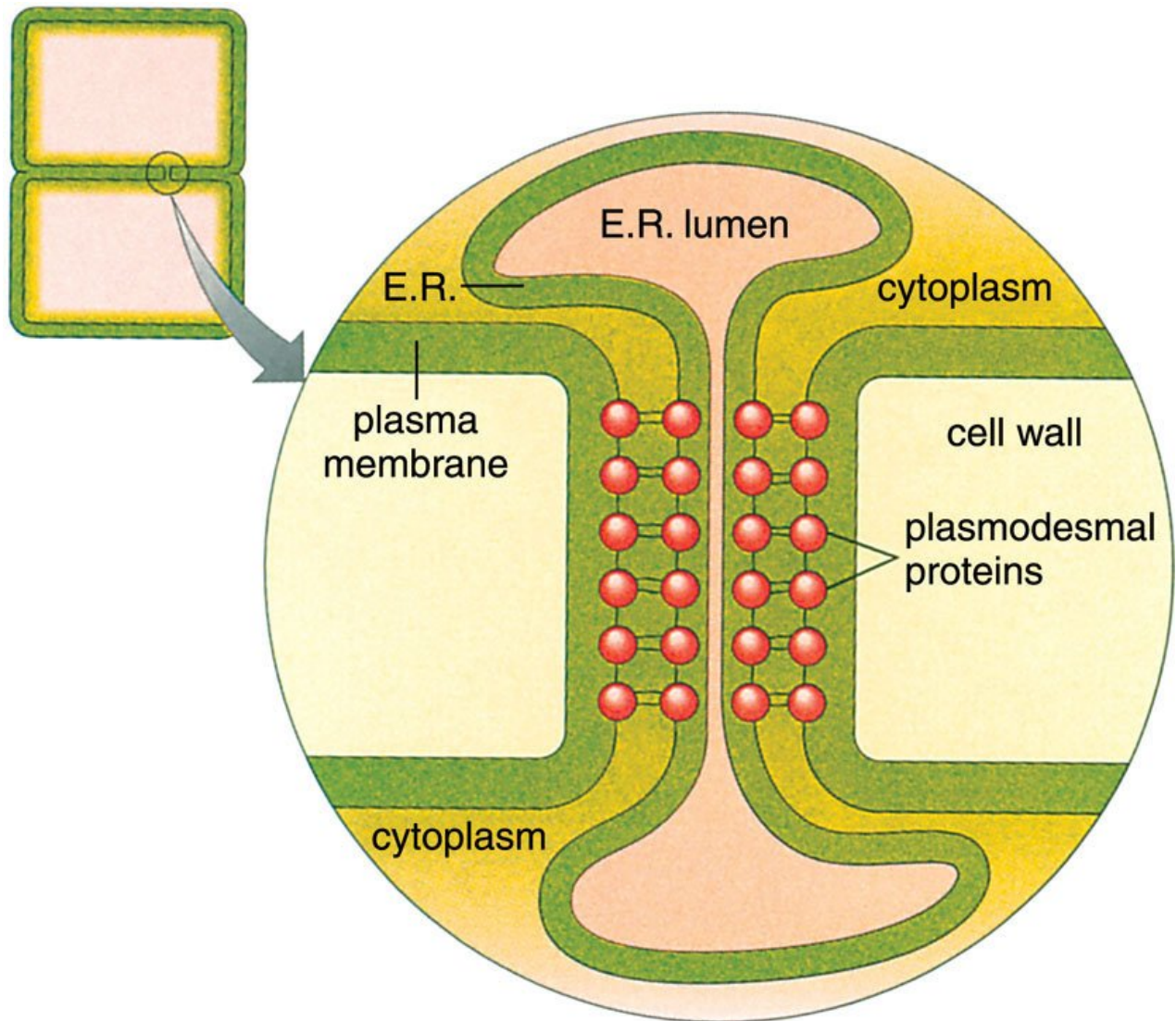


Plasmodesmata



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 (2 points)

Name two differences between plant and animal cells.

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
- Secondary cell walls cover dead cells

For Further Reading

References

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

Outline

9 Questions and answers

9.1 Quiz

Final question (2 points)

Name 2 differences between animal and plant cells.

- Cell wall
- Vacuole
- Size
- Cell wall
- Plasmodesmata

10 Plant cell

10.1 Cell boundaries

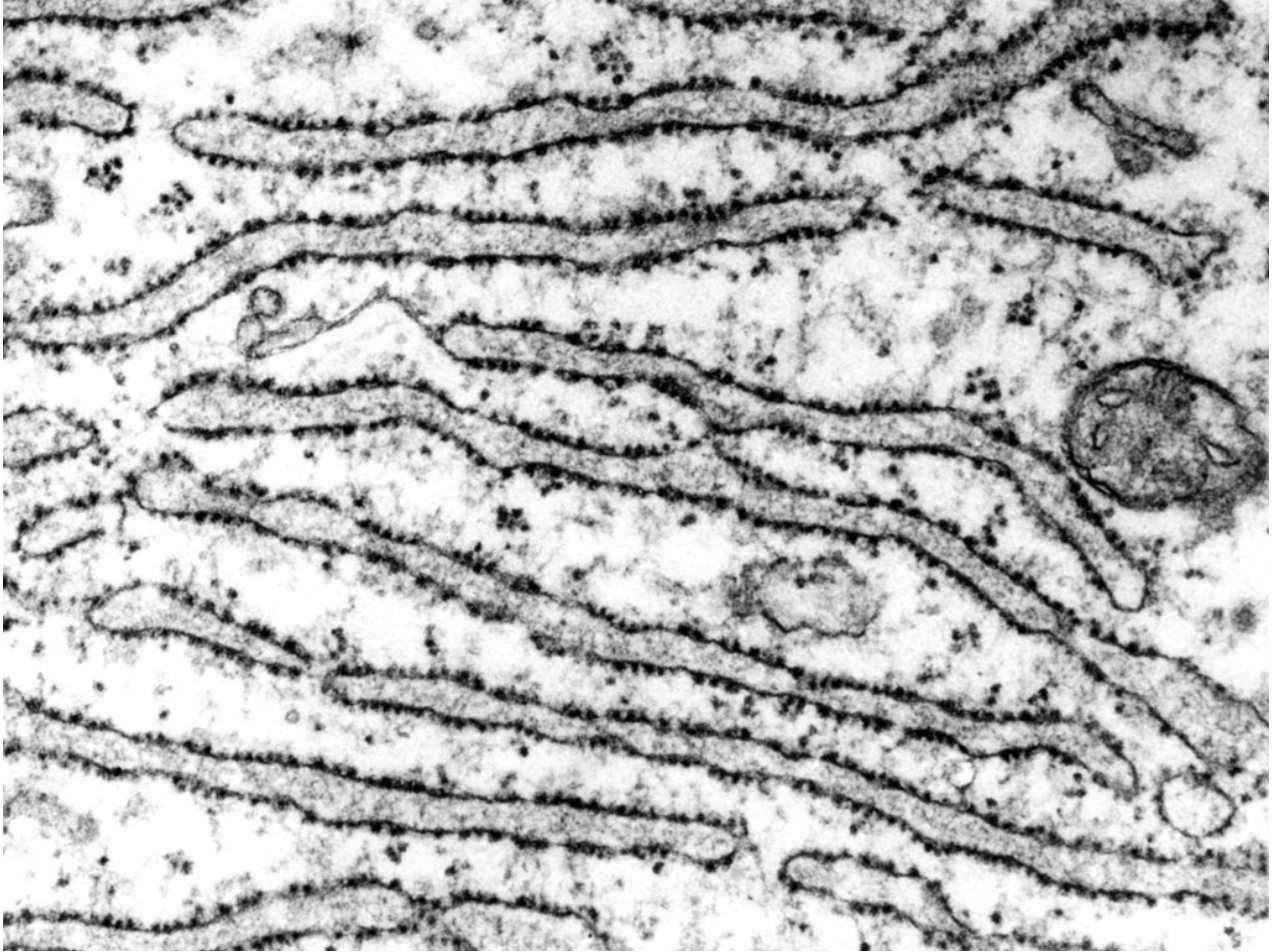
Vacuoles, osmosis and turgor pressure

- If cell vacuoles contain more concentrated solution of salts than 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

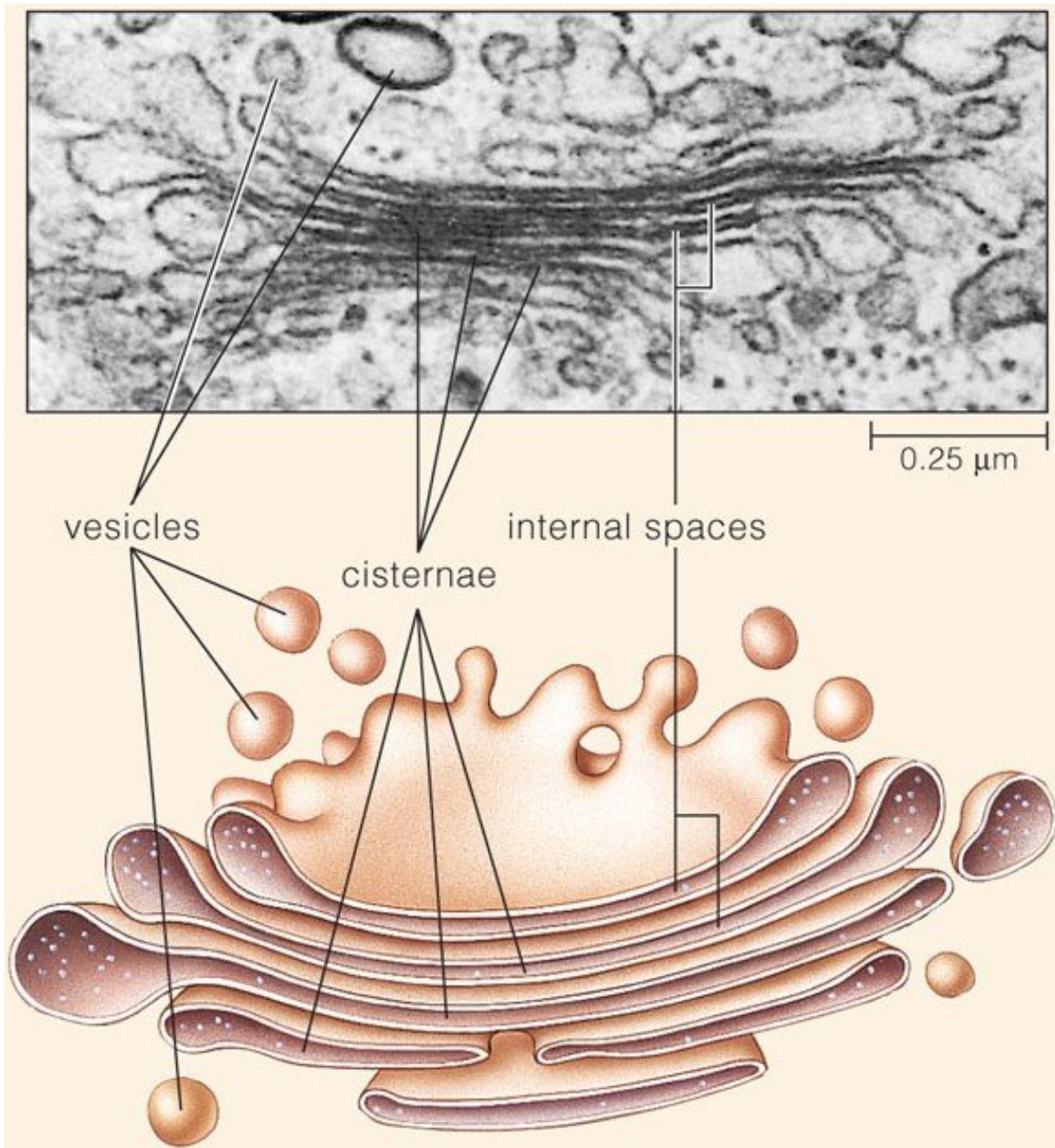
- **Symplast**—name for continuous cytoplasm in set of cells
- **Apoplast**—space outside cell; area of considerable metabolic activity

Endoplasmatic reticulum (network), ER



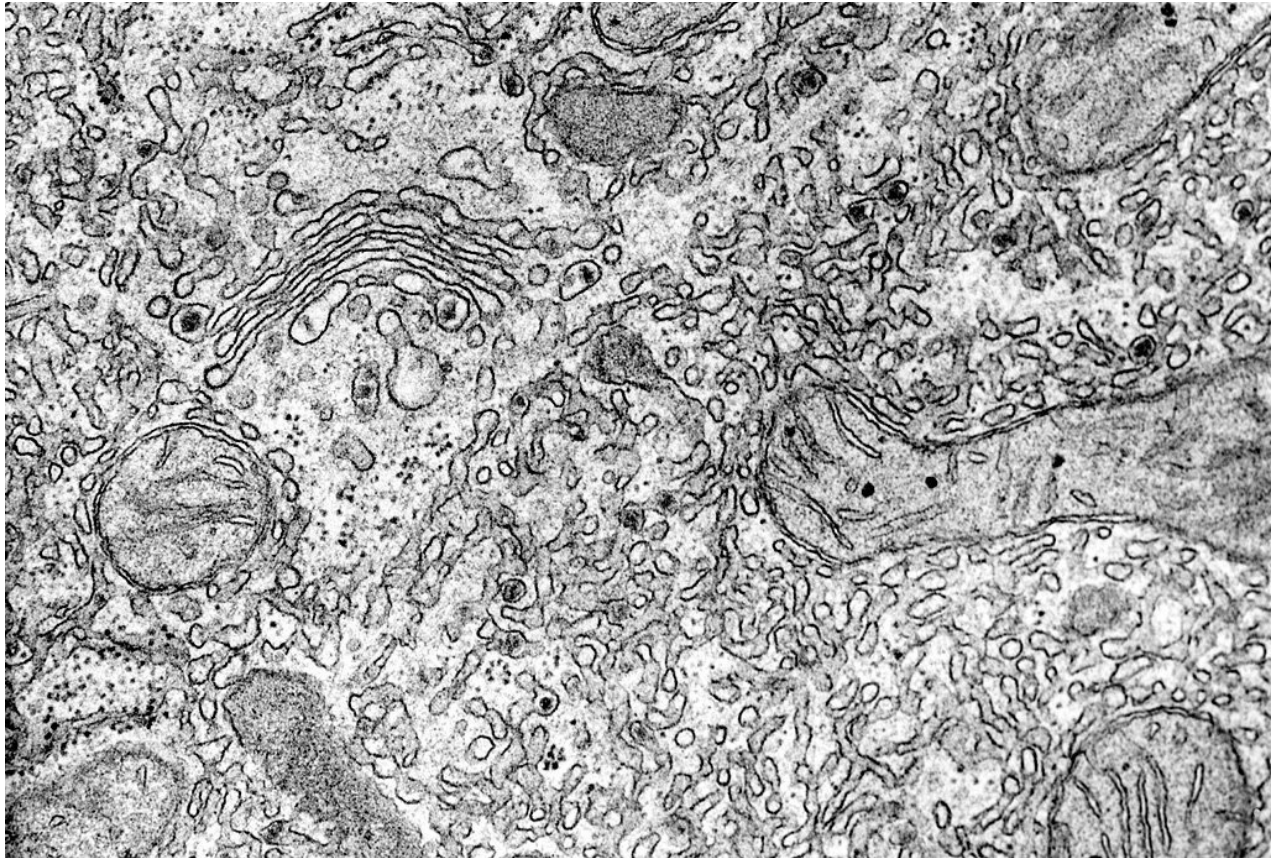
Rough endoplasmic reticulum with ribosomes along outer surface. Manufactures many proteins destined for secretion or for incorporation into membranes (TEM)

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

Golgi apparatus on TEM



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

10.2 Protein synthesis

Nucleus structure

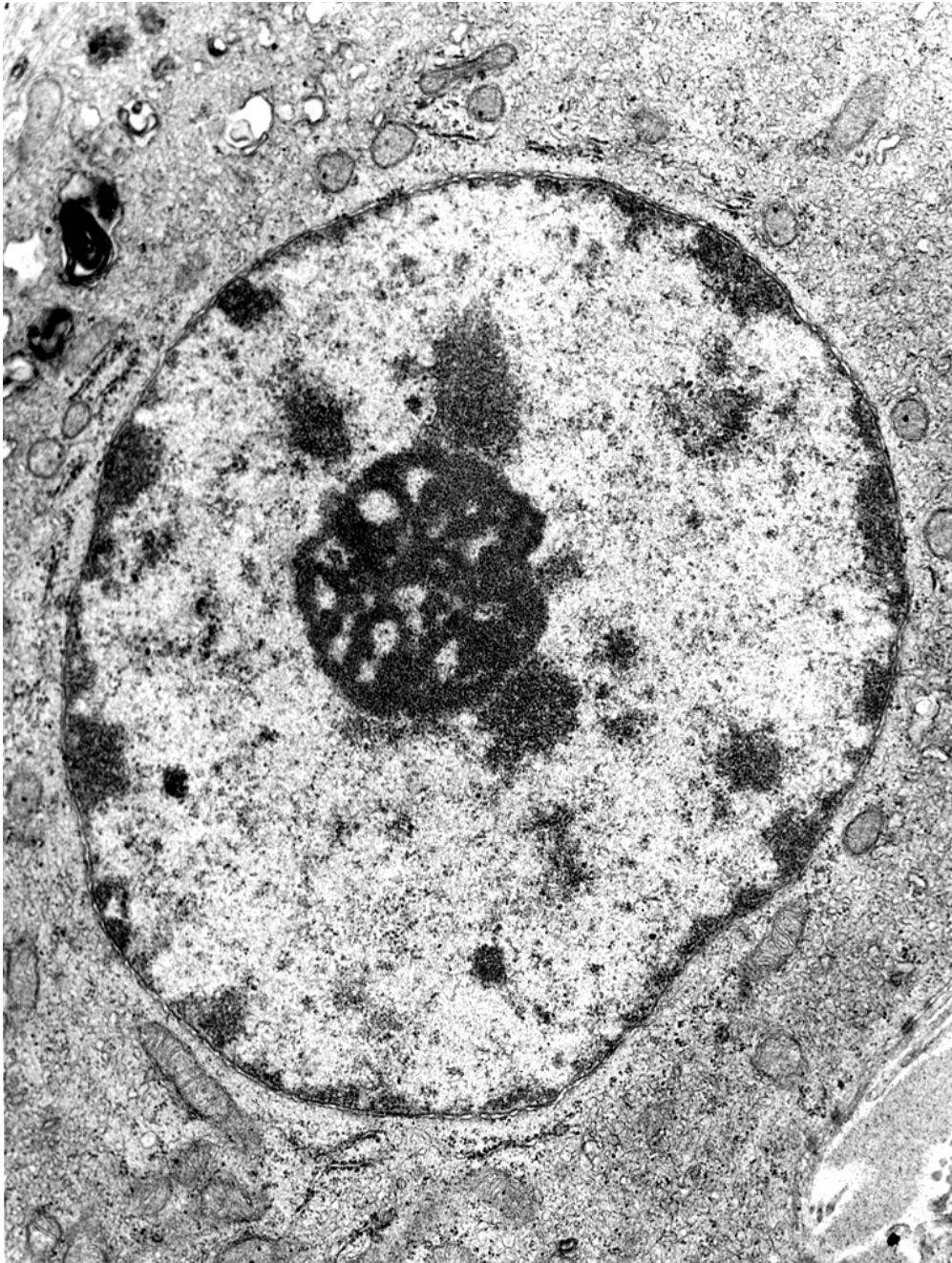
Nuclear envelope Double layered membrane, filaments of protein lamin line inner surface and stabilize structure, inner and outer membranes connect to form pores

Nucleoplasm Portion inside the nuclear envelope

Nucleoli Dark staining bodies within nucleus, site for ribosome synthesis

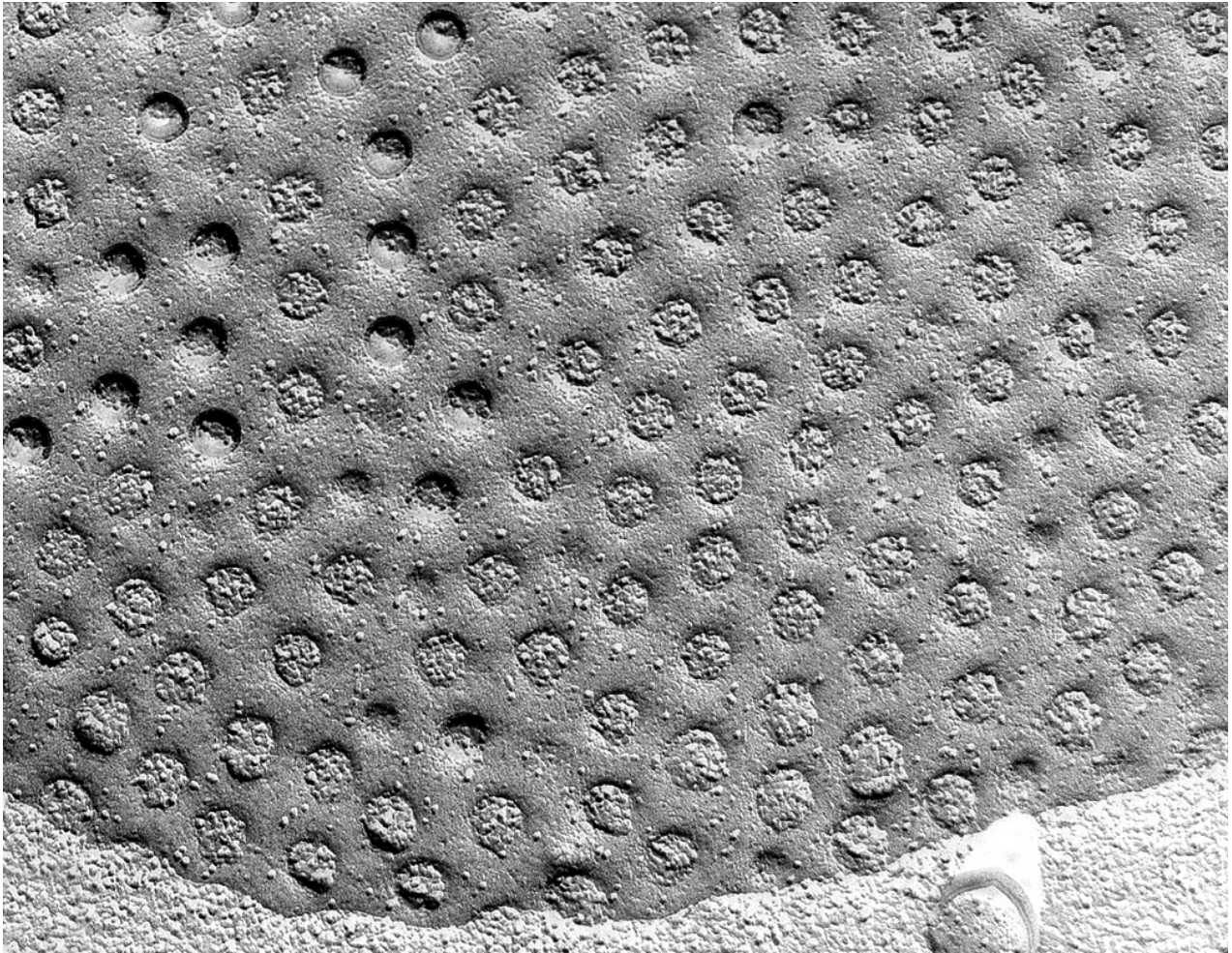
Chromosomes Store genetic information in nucleotide sequences, each chromosome consists of chain of nucleosomes (long DNA molecule and associated histone proteins). When cell is not dividing, chromosomes are frequently seen as **chromatin**.

Nucleus



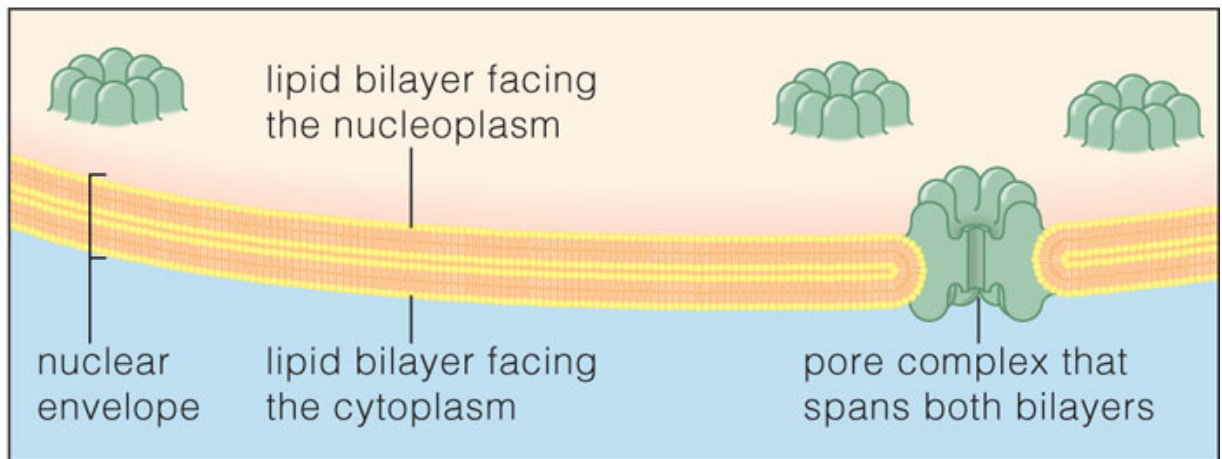
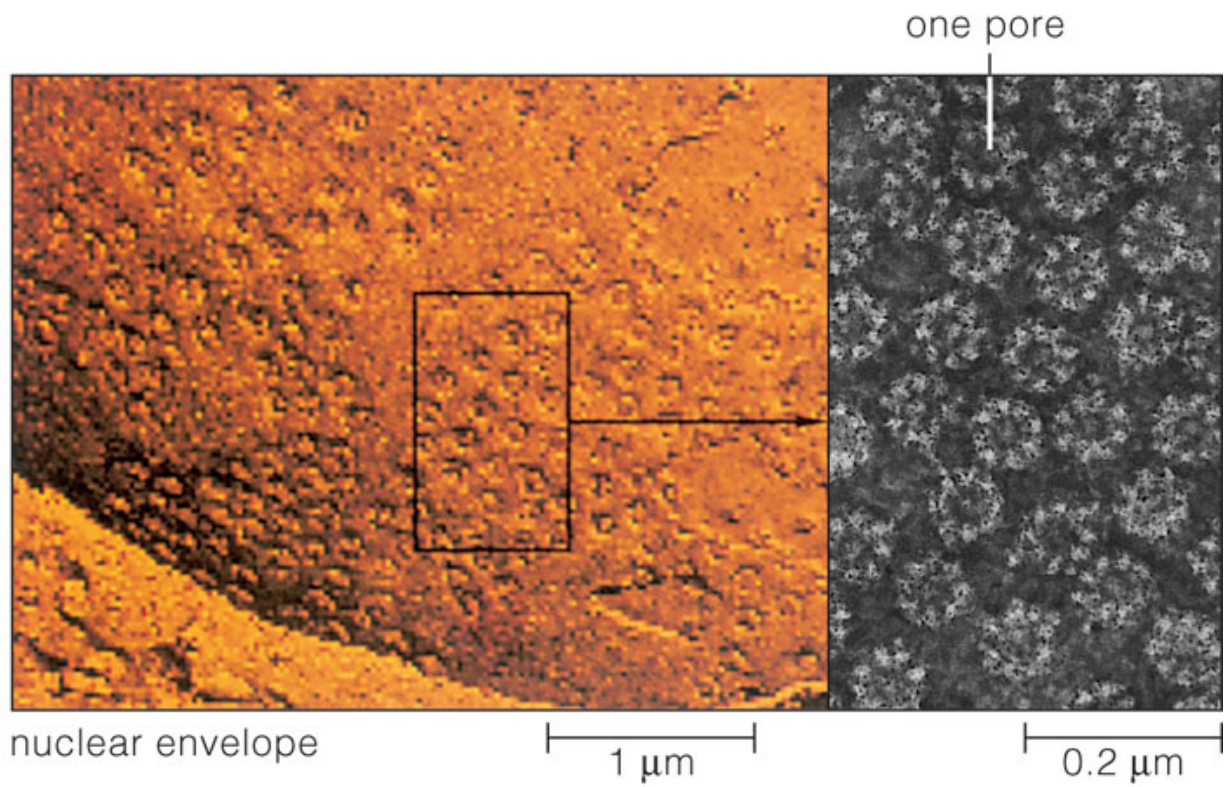
A typical nucleus with a prominent nucleolus (TEM).

Nuclear pores



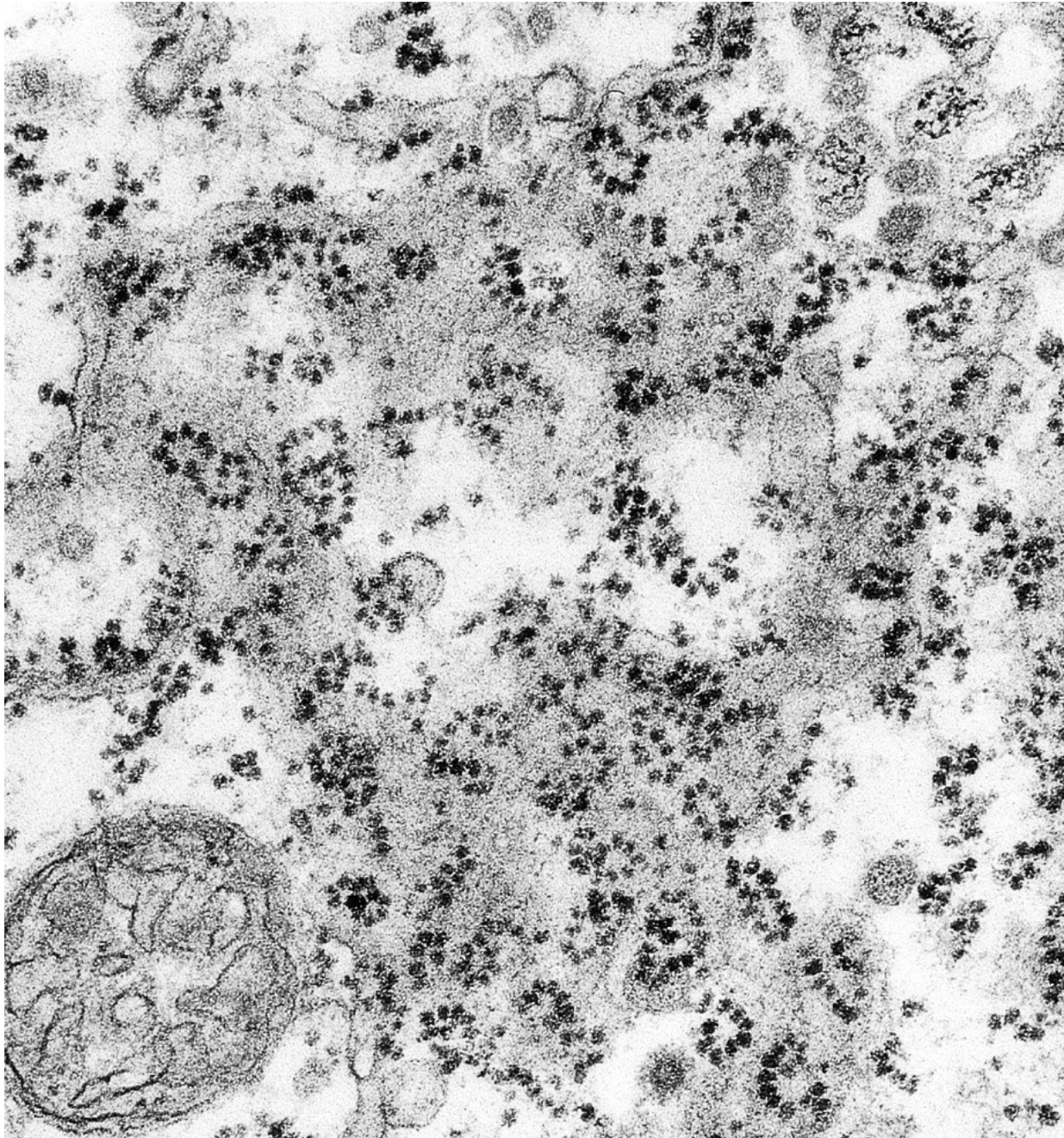
Freeze-fracture technique used to show nuclear pores. Nuclear pores are structures in the nuclear envelope that allow passage of certain materials between the cell nucleus and the cytoplasm (TEM $\times 100,000$)

Nuclear pores and envelope



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Ribosomes



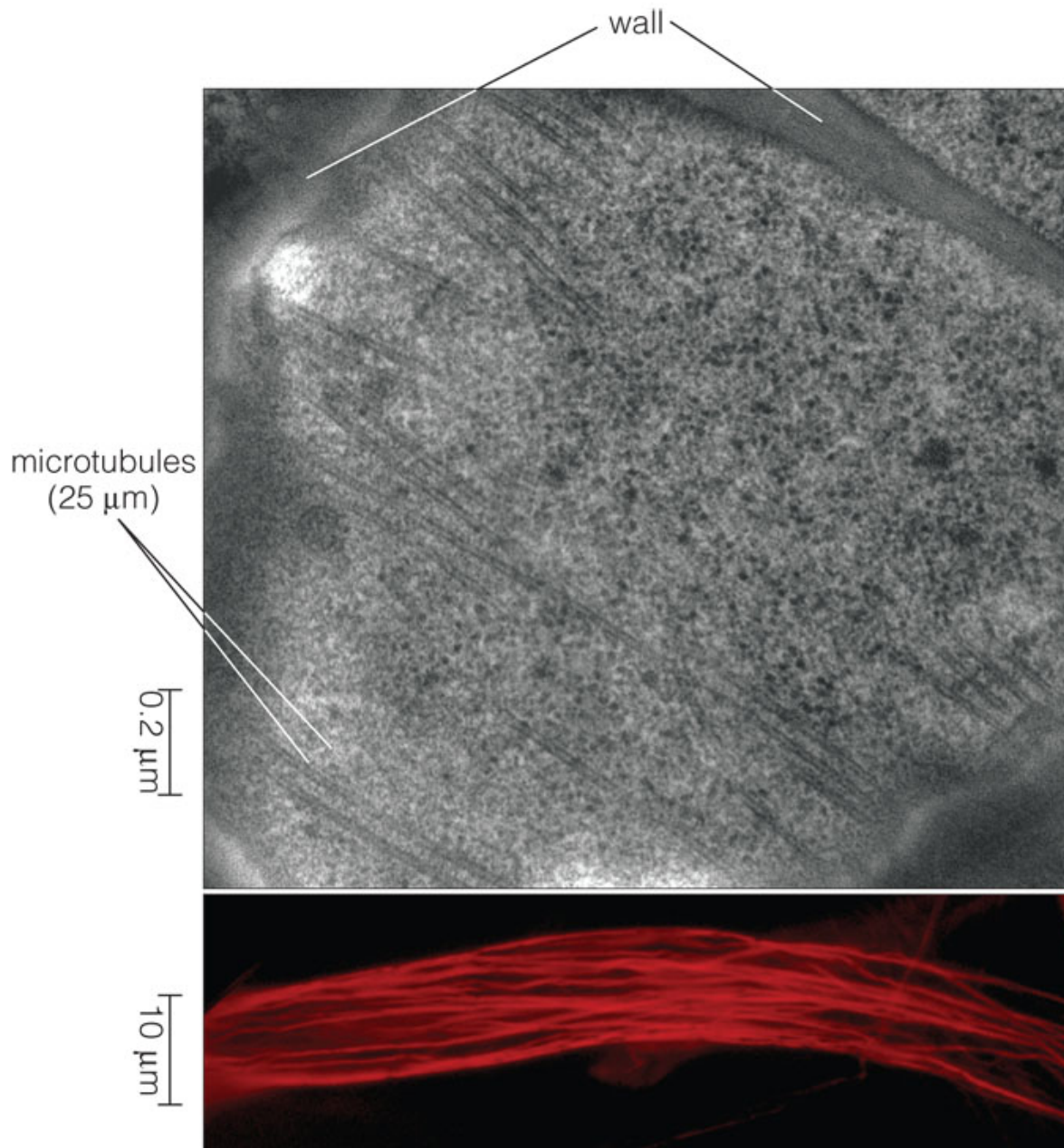
10.3 Other cell structures

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



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11 Mitosis and meiosis

11.1 Mitosis

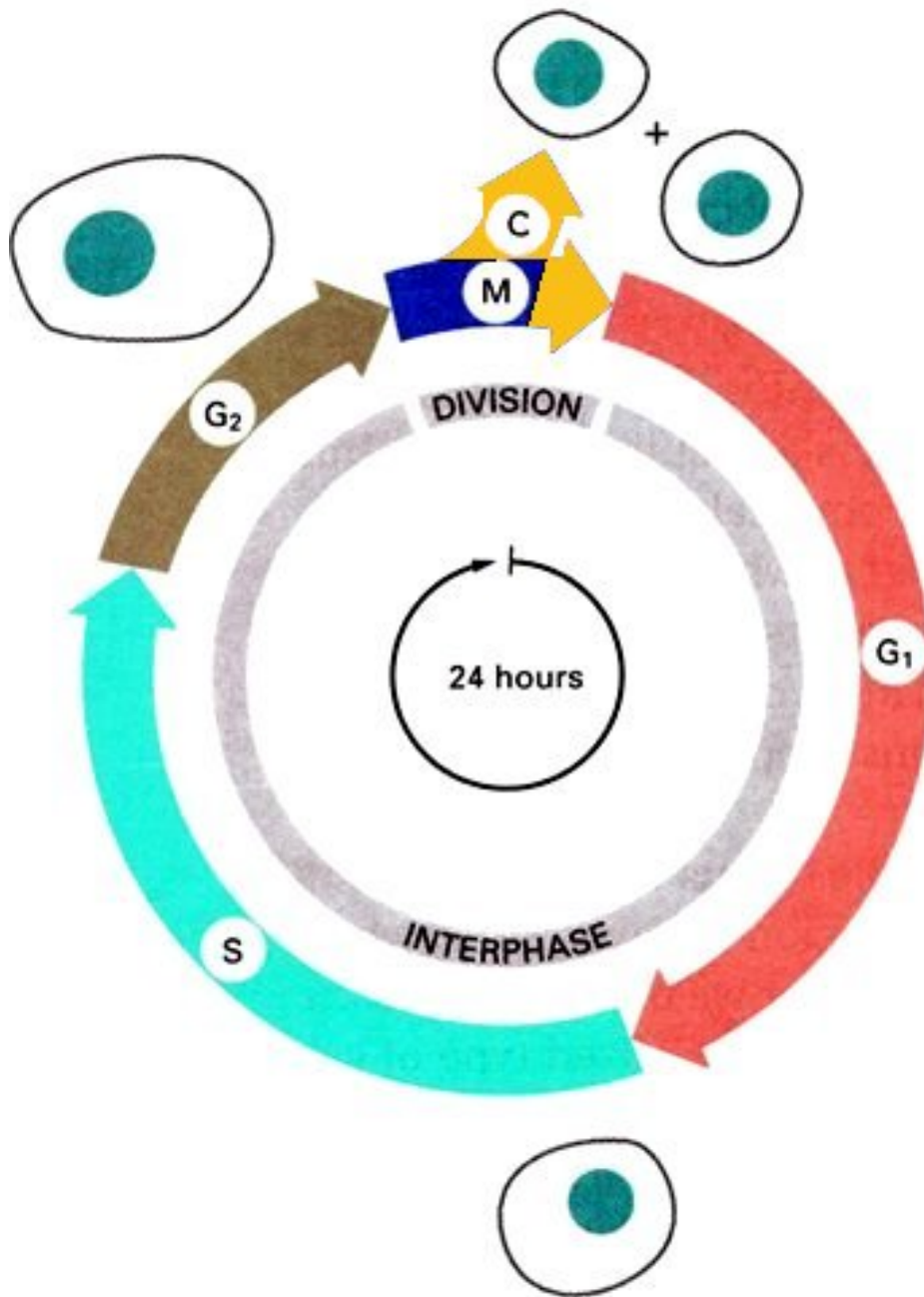
Definition of mitosis

- *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 (G₁)
 - Synthetic stage (S): DNA duplicated
 - Post-synthetic stage (G₂)
- Mitosis

- Prophase
- Metaphase
- Anaphase
- Telophase

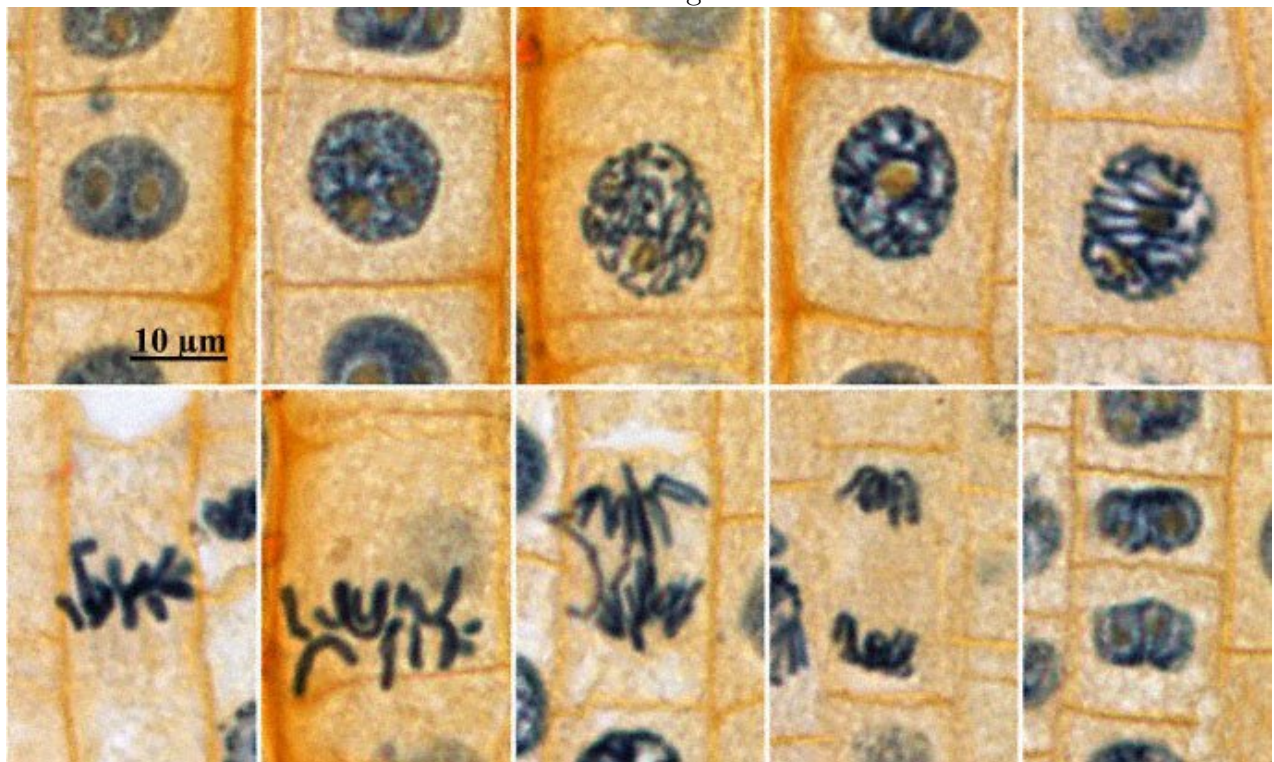
- Cytokinesis

Stages of mitosis

- Prophase
- Metaphase
- Anaphase
- Telophase

Final question (2 points)

Which stage?



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
- Secondary cell walls cover dead cells

For Further Reading

References

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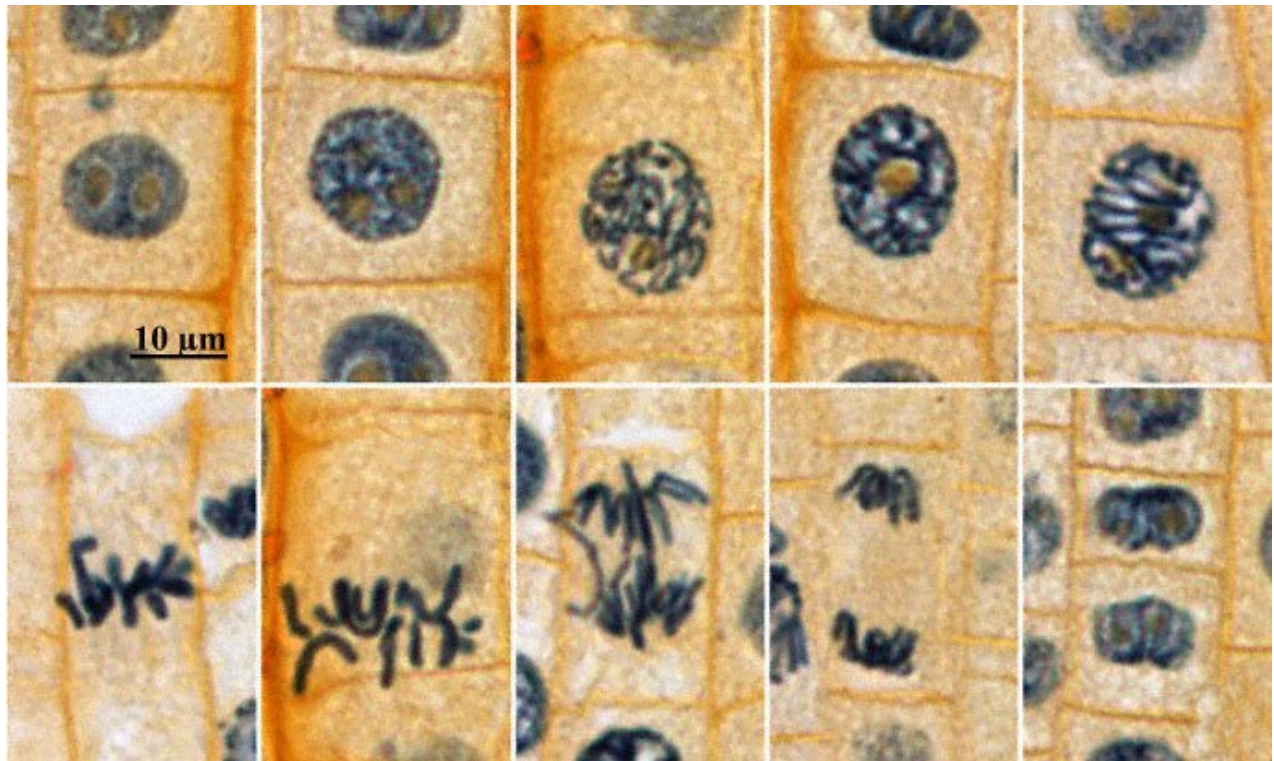
Outline

12 Questions and answers

12.1 Quiz

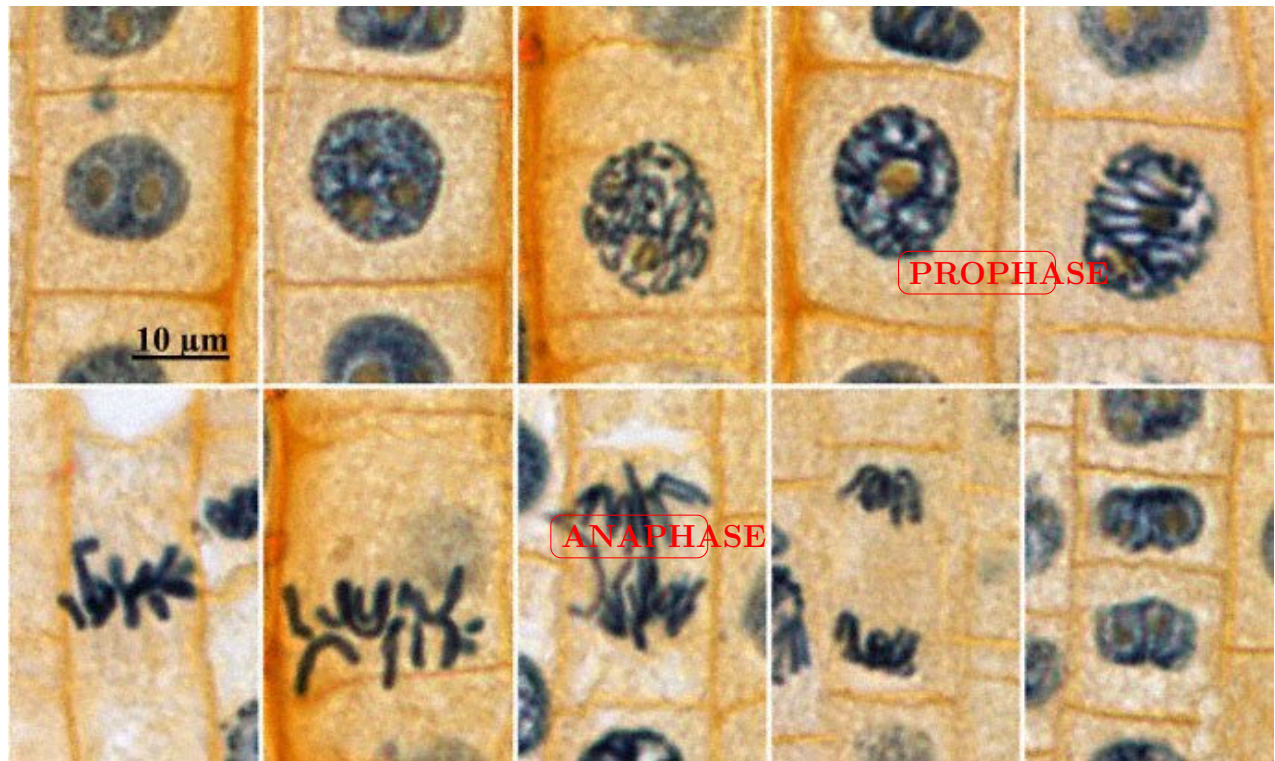
Final question (2 points)

Which stage?



Final question (2 points)

Which stage?



13 Mitosis and meiosis

13.1 Syngamy (Y!)

Why do living things support diversity

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

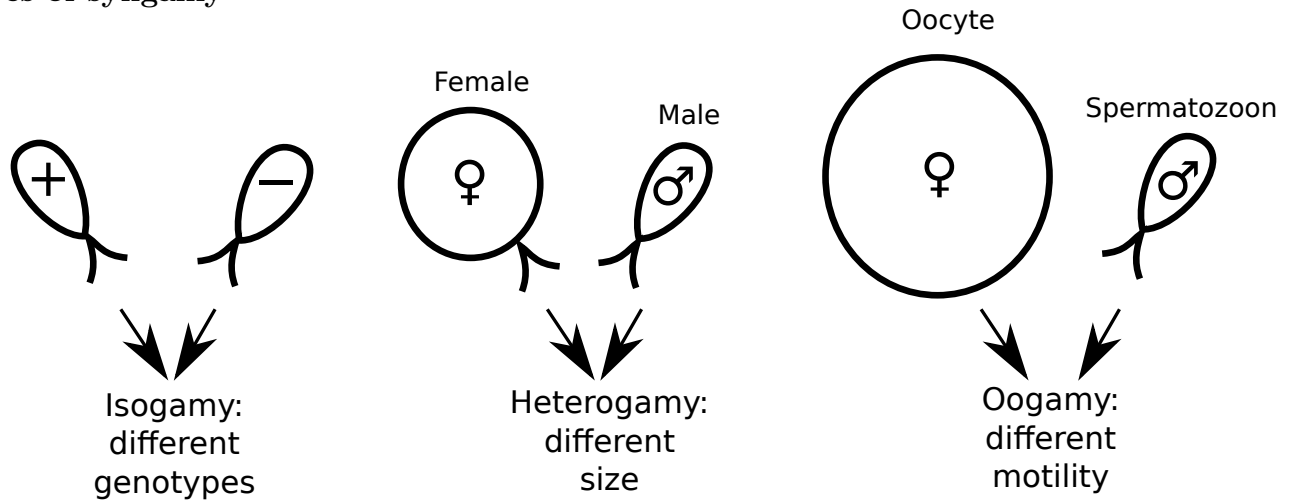
Exchange and renovation of DNA

- 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: $X + X \rightarrow XX$
- **The goal of syngamy** is the renovation of genetic material
- Syngamy changes genotype of cells

Types of syngamy



13.2 Meiosis (R!)

Some useful terms: checklist

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

Final question (2 points)

How do male and female gametes split their job?

Summary

- **Mitosis** is a equal division of DNA, **ploidy does not change**, **genotype does not change**
- **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]. Mode of access: http://ashipunov.info/shipunov/school/biol_154

Outline

14 Questions and answers

14.1 Quiz

Final question (2 points)

How do male and female gametes split their job?

- Male gender invests in numbers to increase probability of syngamy
- Female gender invests in resources to increase probability of zygote survival

15 Life cycle

15.1 Syngamy and meiosis

Some useful terms: checklist

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

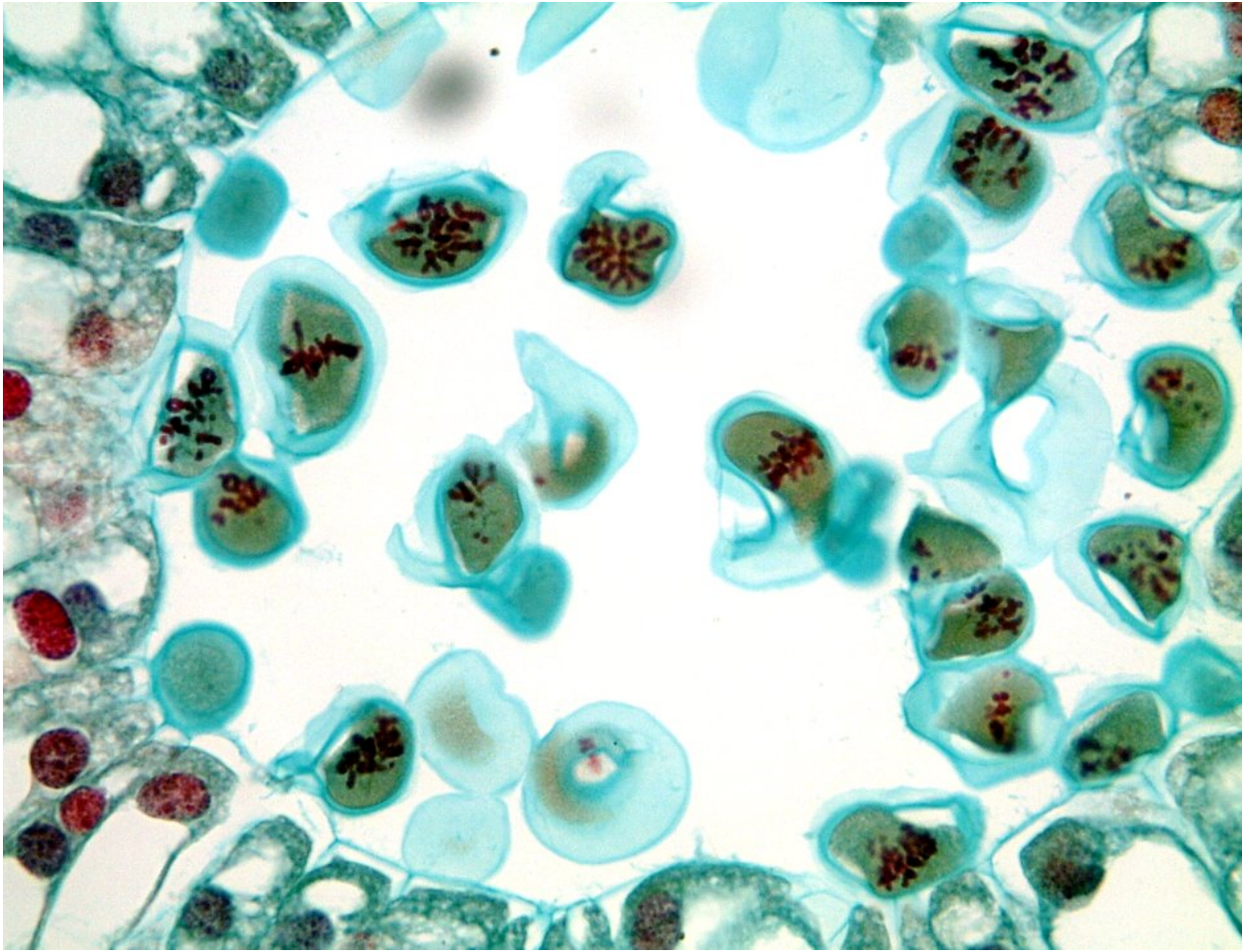
Ploidy, or chromosome set

- 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: $2n \longrightarrow n + n$

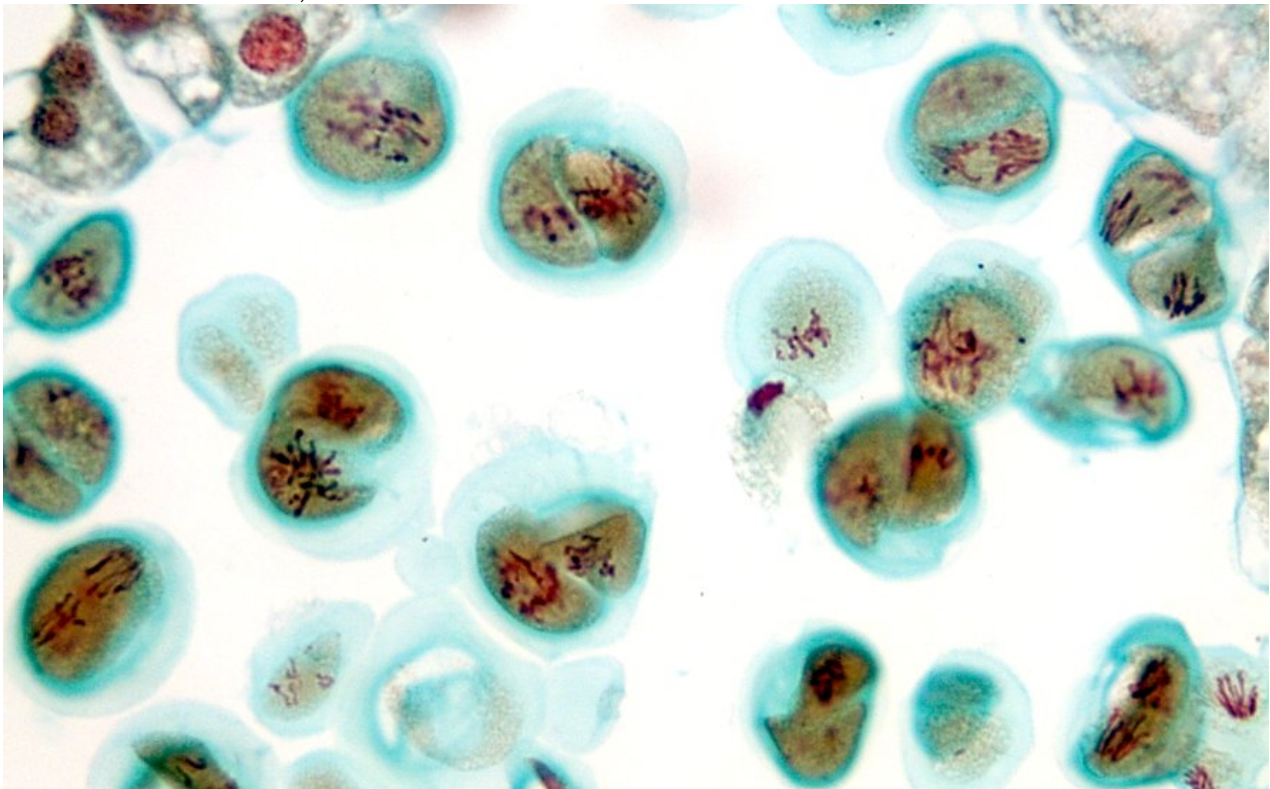
Stages of meiosis

- 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

Real-world meiosis, 1st division



Real-world meiosis, 2nd division

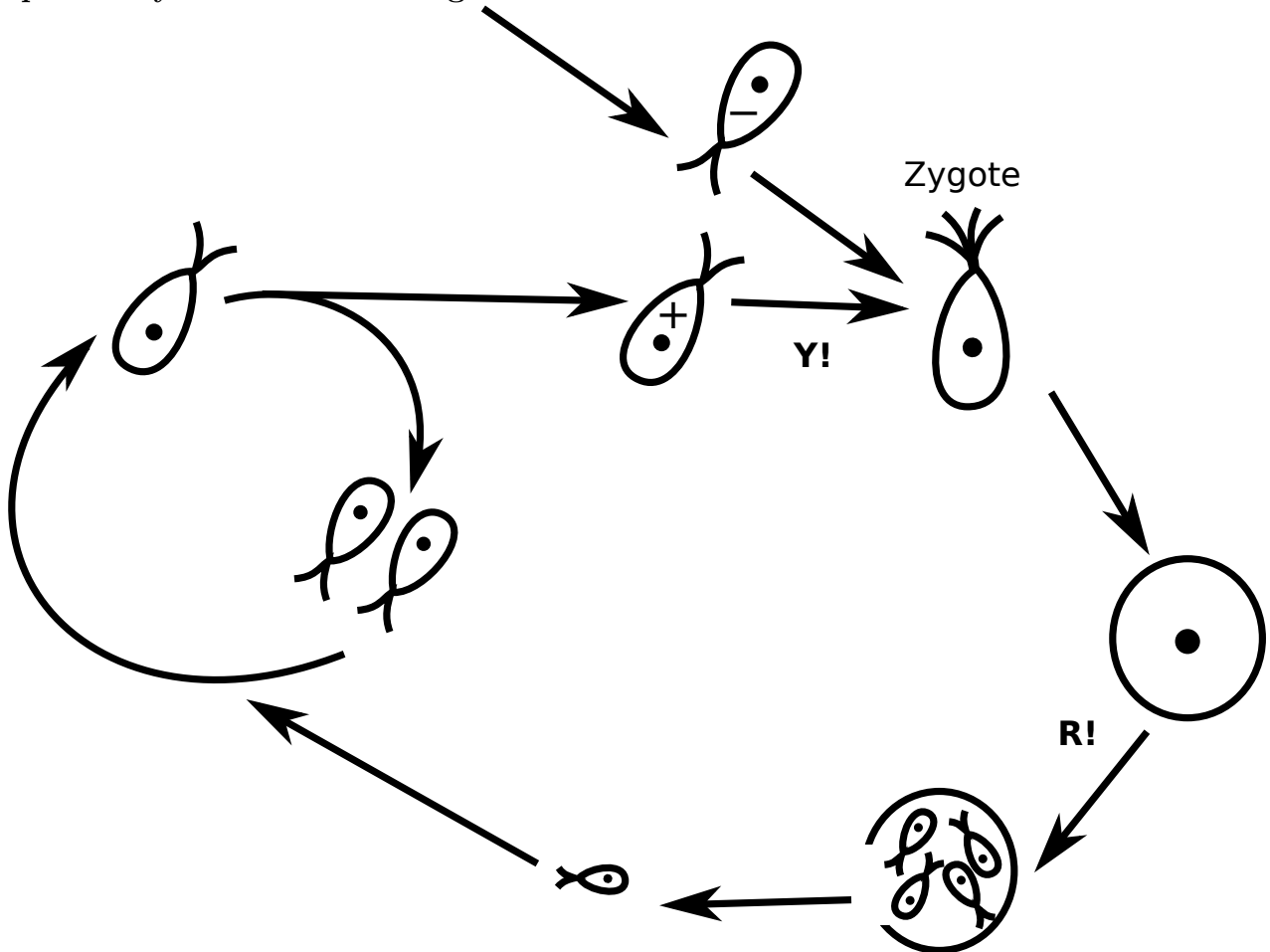


Polyploids

- 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**

15.2 Basics of life cycles

Simple life cycle: unicellular organism



Final question (2 points)

Before the meiosis, the cell had 6 picograms of DNA. How much DNA will be in the each daughter cells after meiosis?

Summary

- **Mitosis** is a equal division of DNA, **ploidy does not change**, **genotype does not change**
- **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**
- Meiosis has two stages: first to reduce ploidy, second to split exact copies of DNA

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 points)

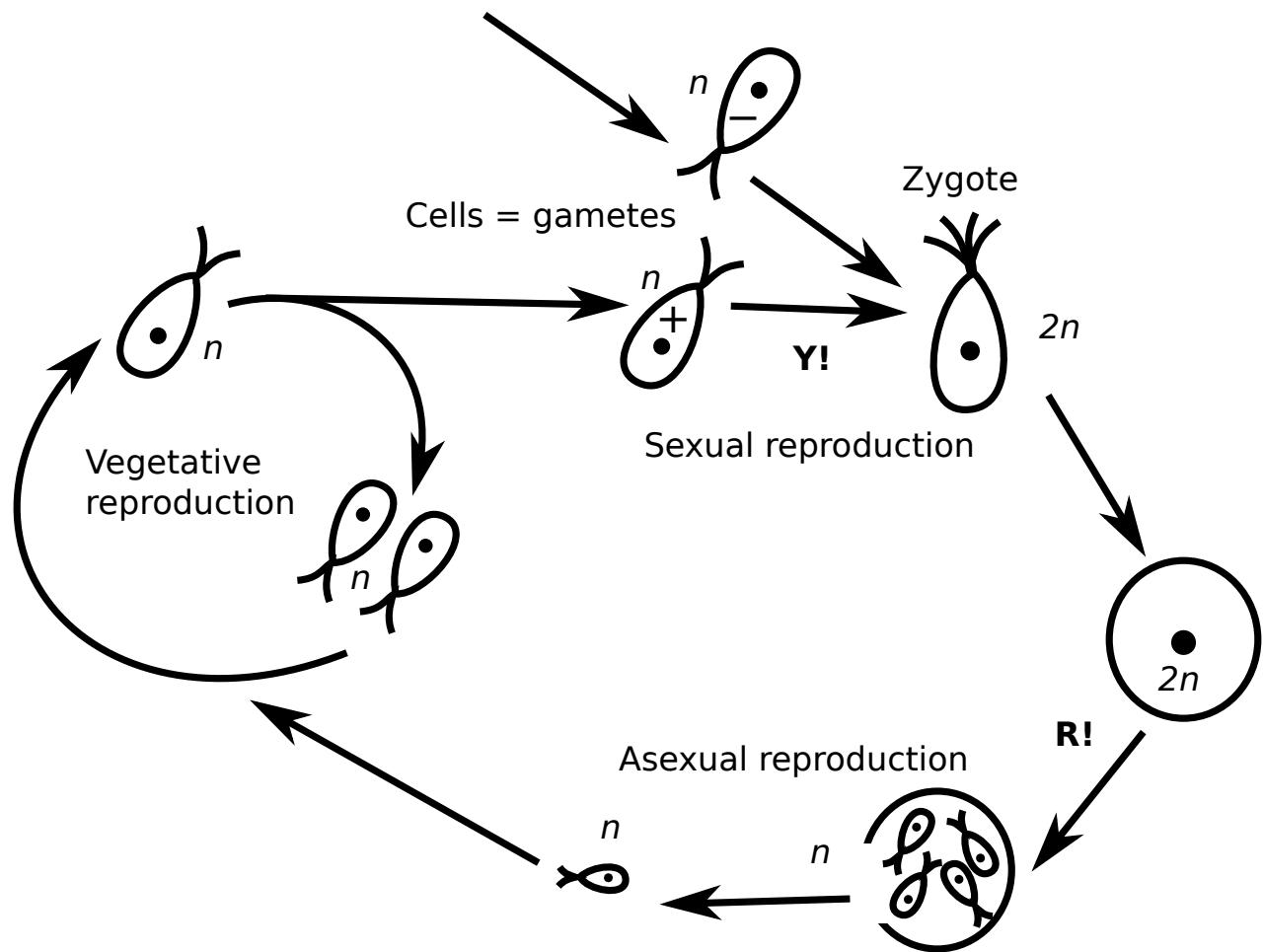
Before the meiosis, the cell had 6 picograms of DNA. How much DNA will be in the each daughter cells after meiosis?

- 6 picograms divided between 4 cells = 1.5 picograms

17 Life cycle

17.1 Basics of life cycles

Simple life cycle: unicellular organism

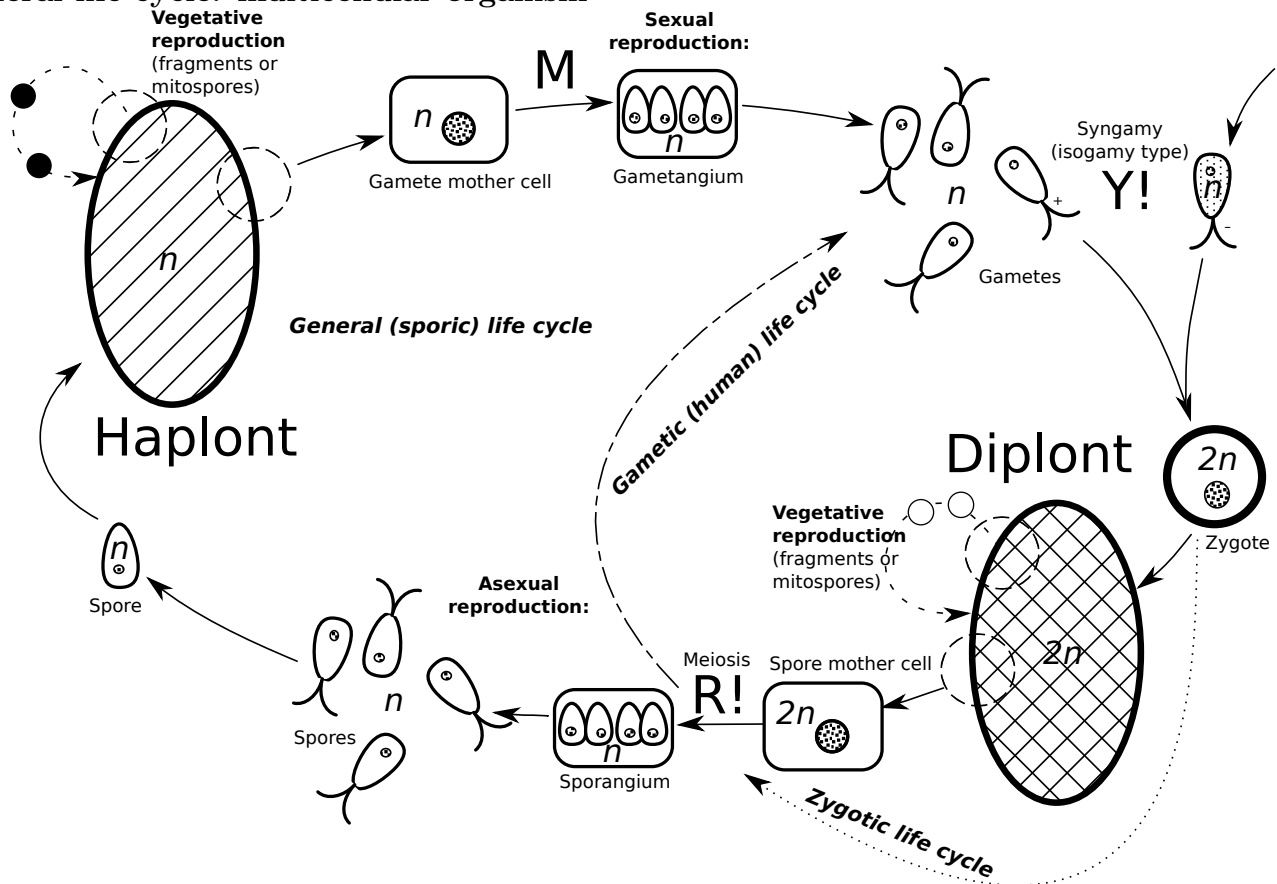


Associated terms: mitosis, meiosis (R!), syngamy (Y!), reproduction, sexual reproduction, asexual reproduction, vegetative reproduction, isogamy, heterogamy, oogamy, zygote, gamete, male, female, spermatozoon, oocyte

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 will eventually die whereas germ cells may give an offspring.
- This is the beginning of **multicellularity**.
- Life cycles of multicellular organisms are based on interleaving **haplont** and **diplont**, the second is making **spores**

General life cycle: multicellular organism



Final question (2 points)

Why is zygotic life cycle more ancient?

Summary

- **Mitosis** is a equal division of DNA, **ploidy does not change**, **genotype does not change**
- **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**
- Meiosis has two stages: first to reduce ploidy, second to split exact copies of DNA

For Further Reading

References

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Outline

18 Questions and answers

18.1 Quiz

Final question (2 points)

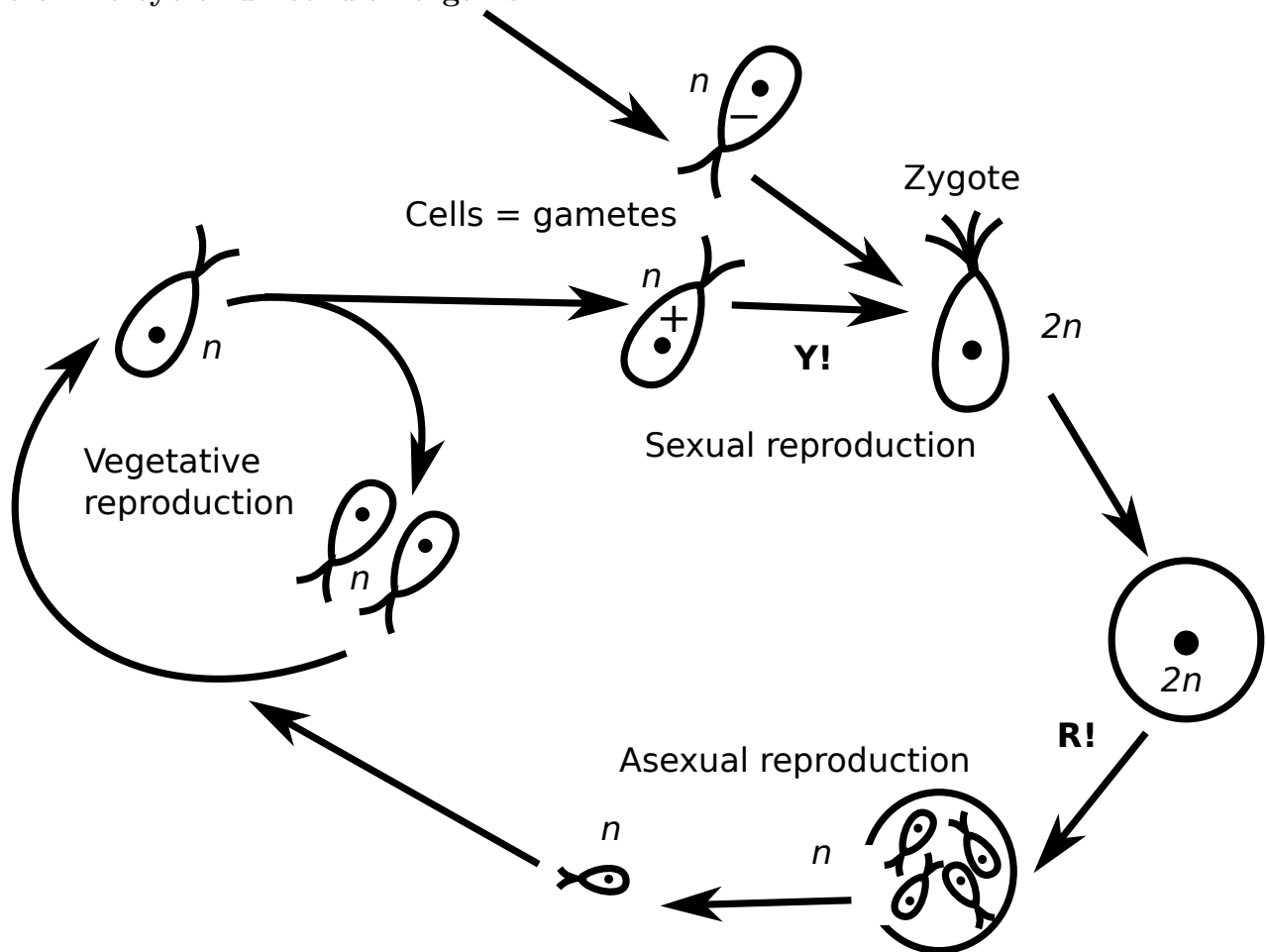
Why is zygotic life cycle most primitive?

- Because it directly relates with typical life cycle of unicellular organism.

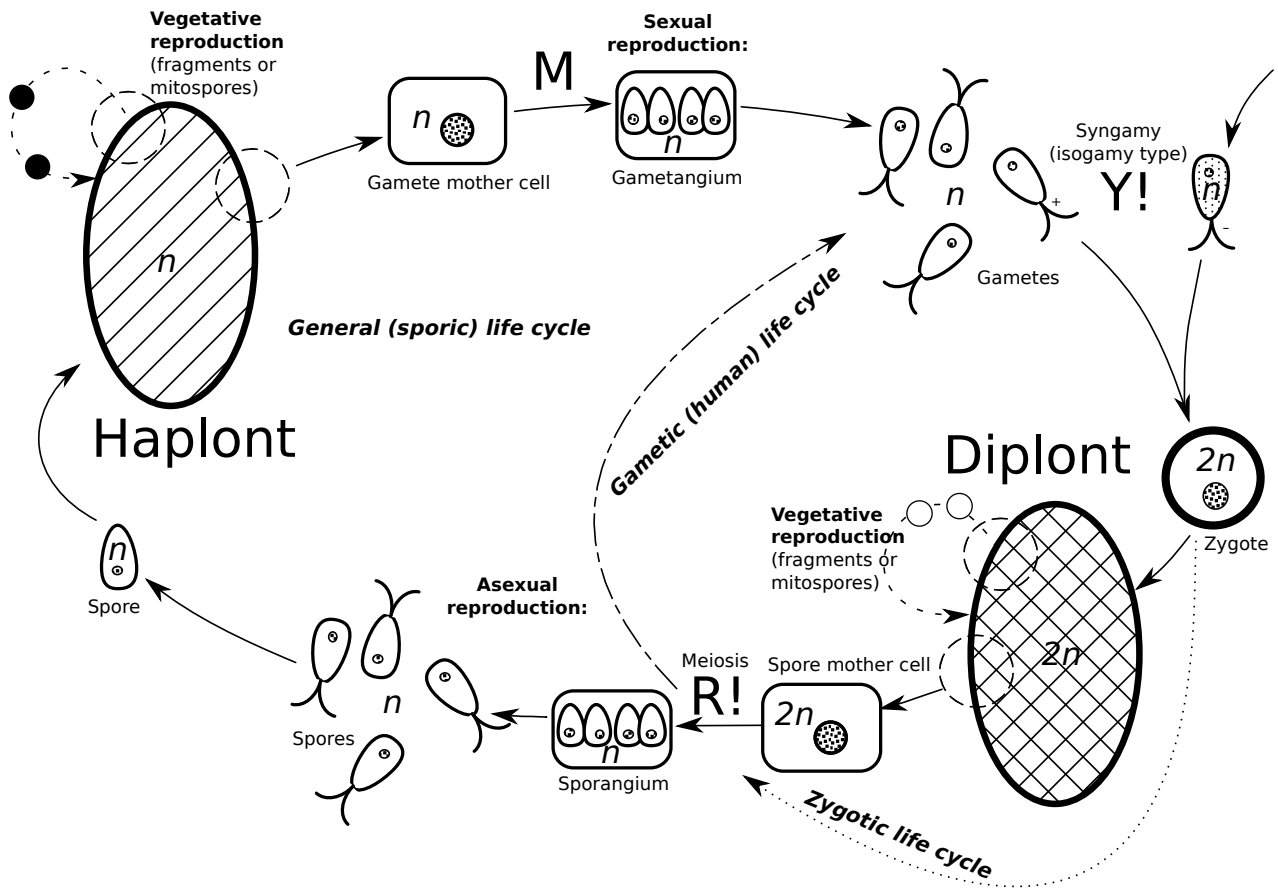
19 Life cycle

19.1 Basics

General life cycle: unicellular organism



General life cycle: multicellular organism

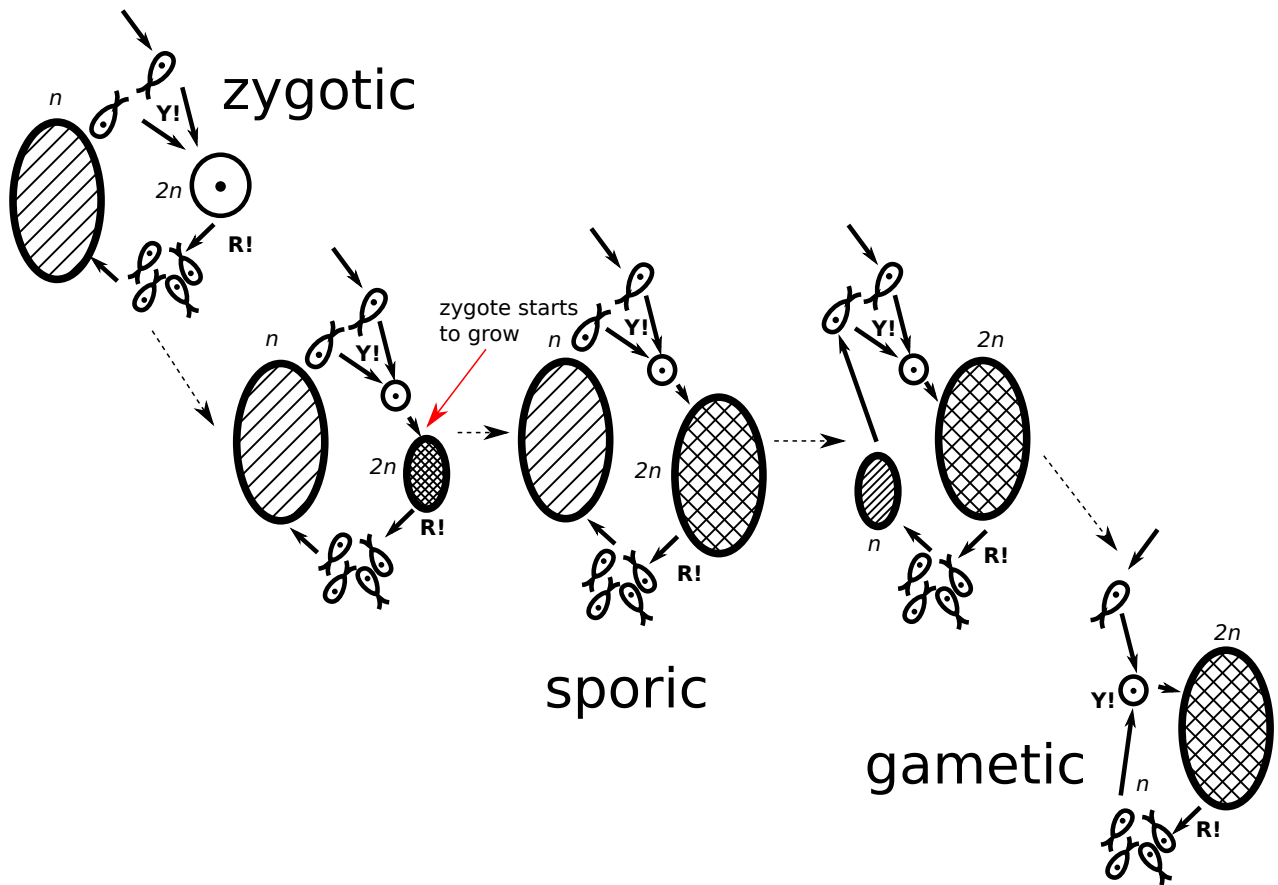


19.2 Evolution of life cycles

3 cycles

- **Zygotic:** Y! \rightarrow R!, no diplont, many protists
- **Gametic:** R! \rightarrow Y!, no haplont, animals and few protists
- **Sporic:** both haplont and diplont, many protists and all plants₂

Diplonts grow, haplonts reduce



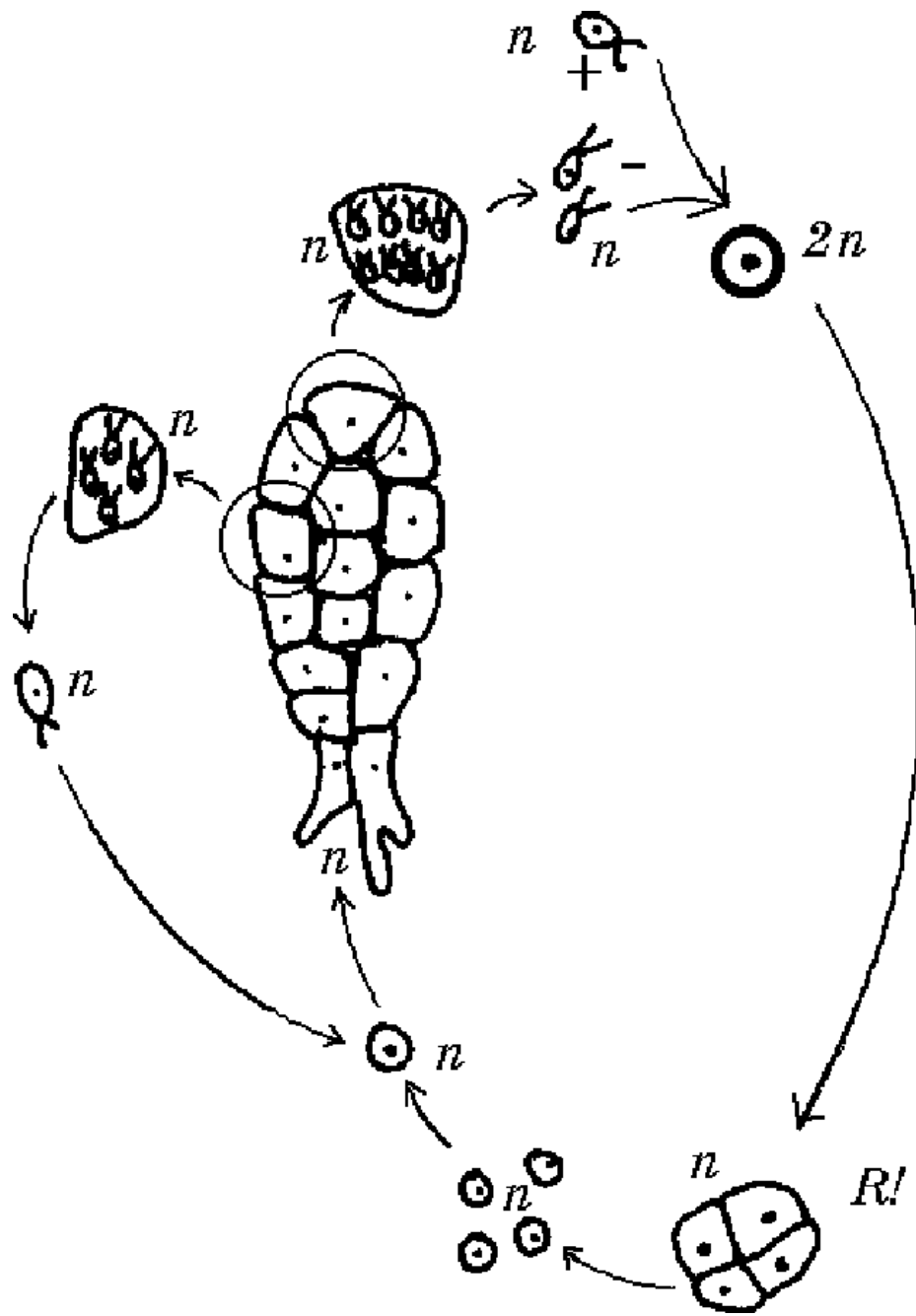
Why diplonts are better?

They have two variants of each gene!

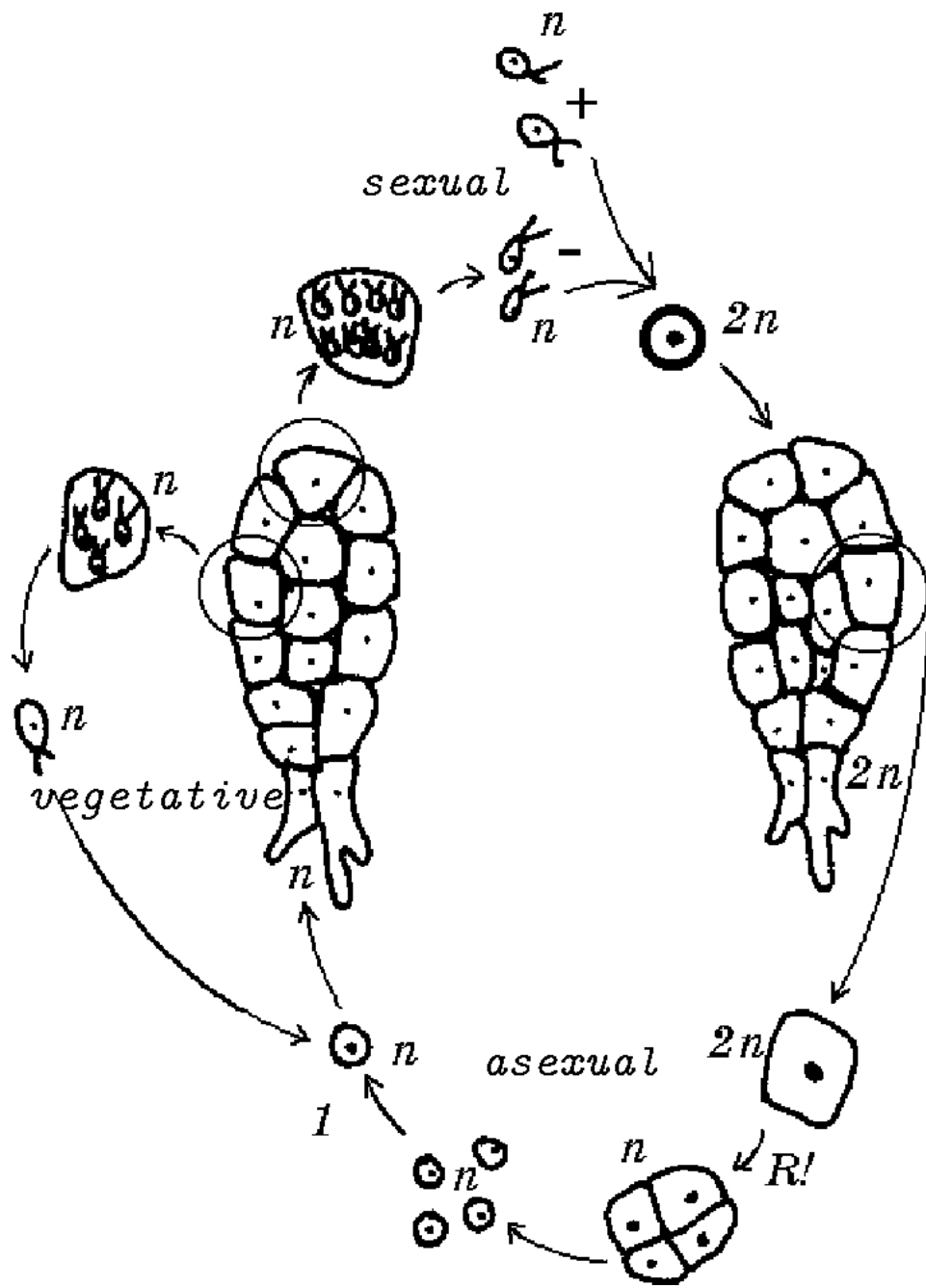
- A. **Dominance:** if one gene is deadly mutated, there is the second working variant
- B. **Protein production:** two genes will give more protein
- C. **Diversity:** if one gene is producing protein adapted to $+5...+30^{\circ}\text{C}$ and other—to $+10...+35^{\circ}\text{C}$, the organism may live under $+5...+35^{\circ}\text{C}$

19.3 Diversity of life cycles

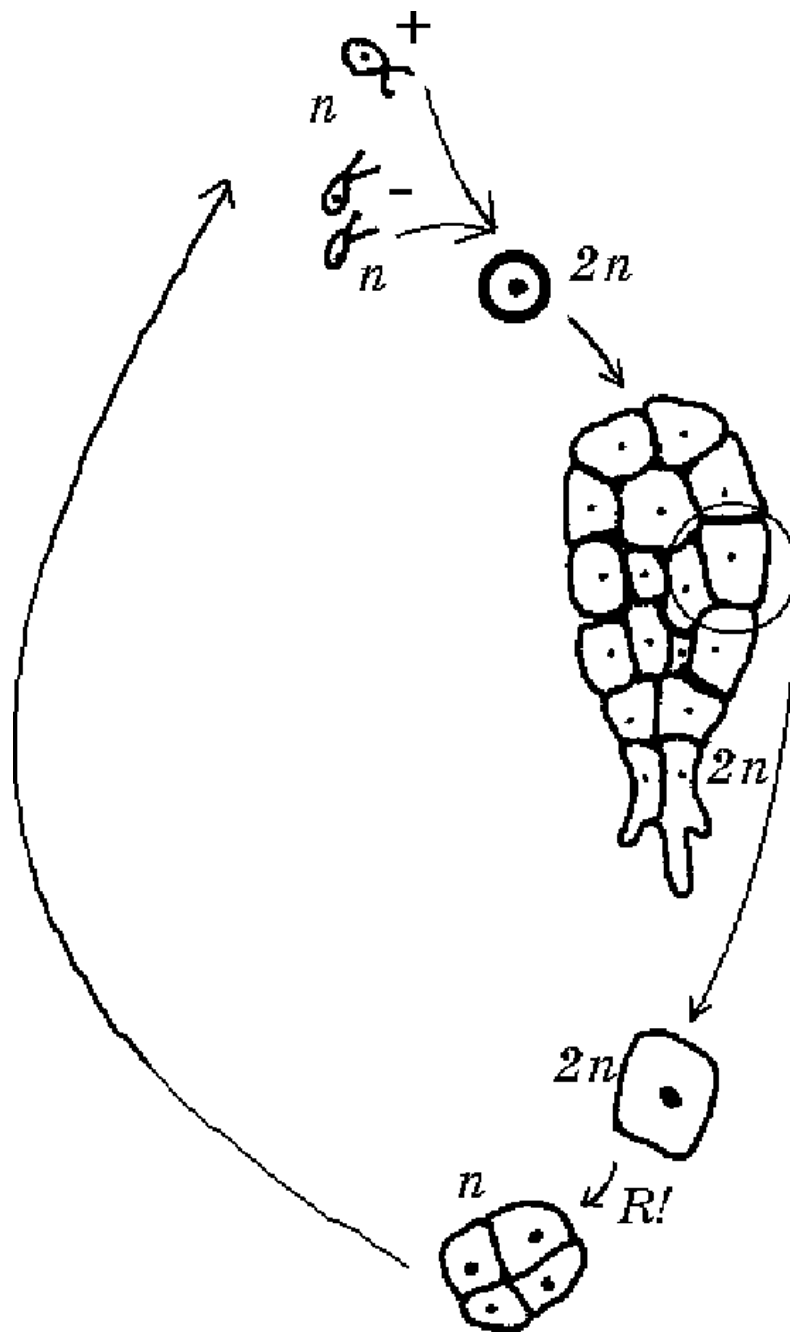
Zygotic life cycle: protists



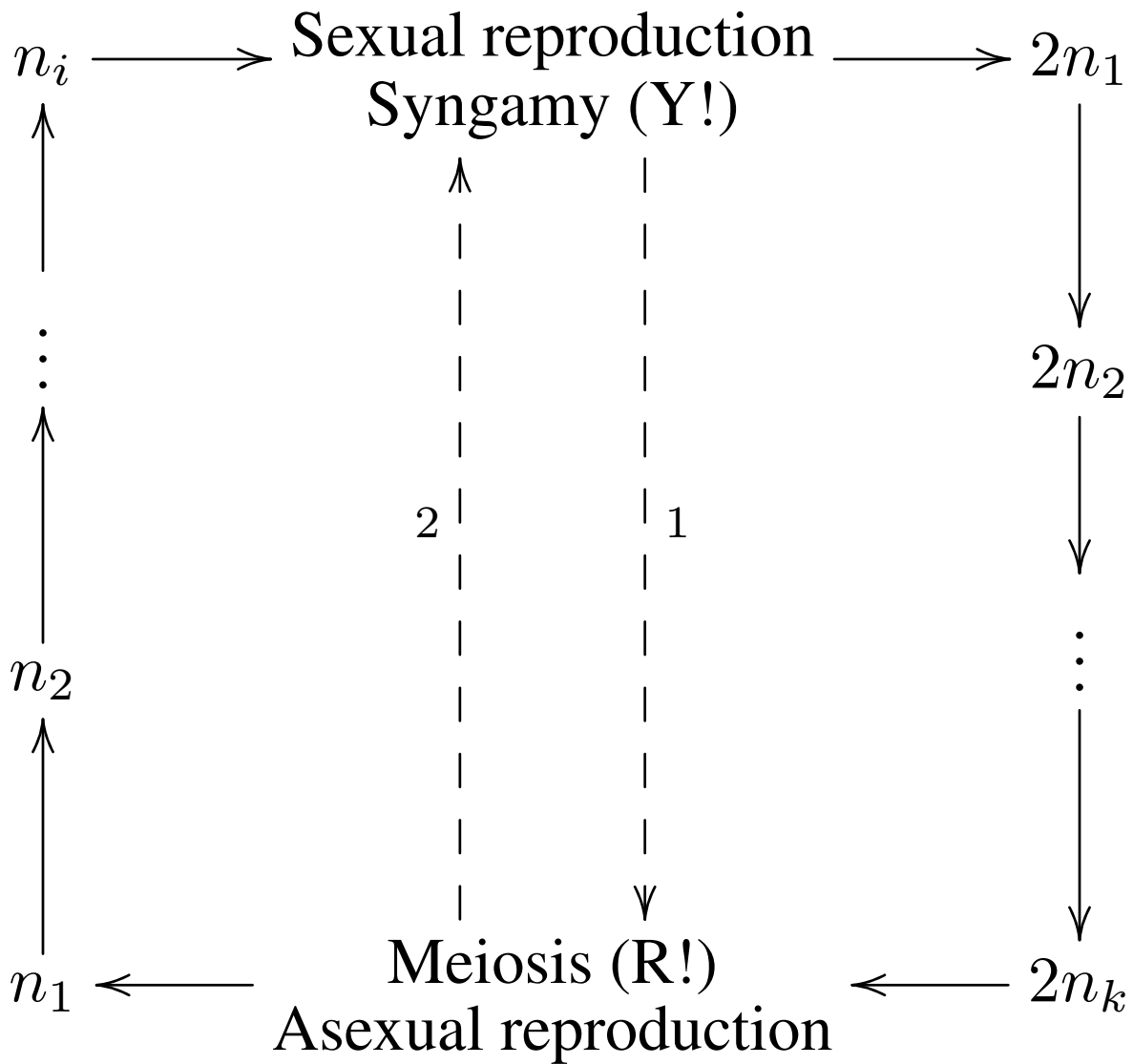
Sporic life cycle: plants



Gametic life cycle: animals

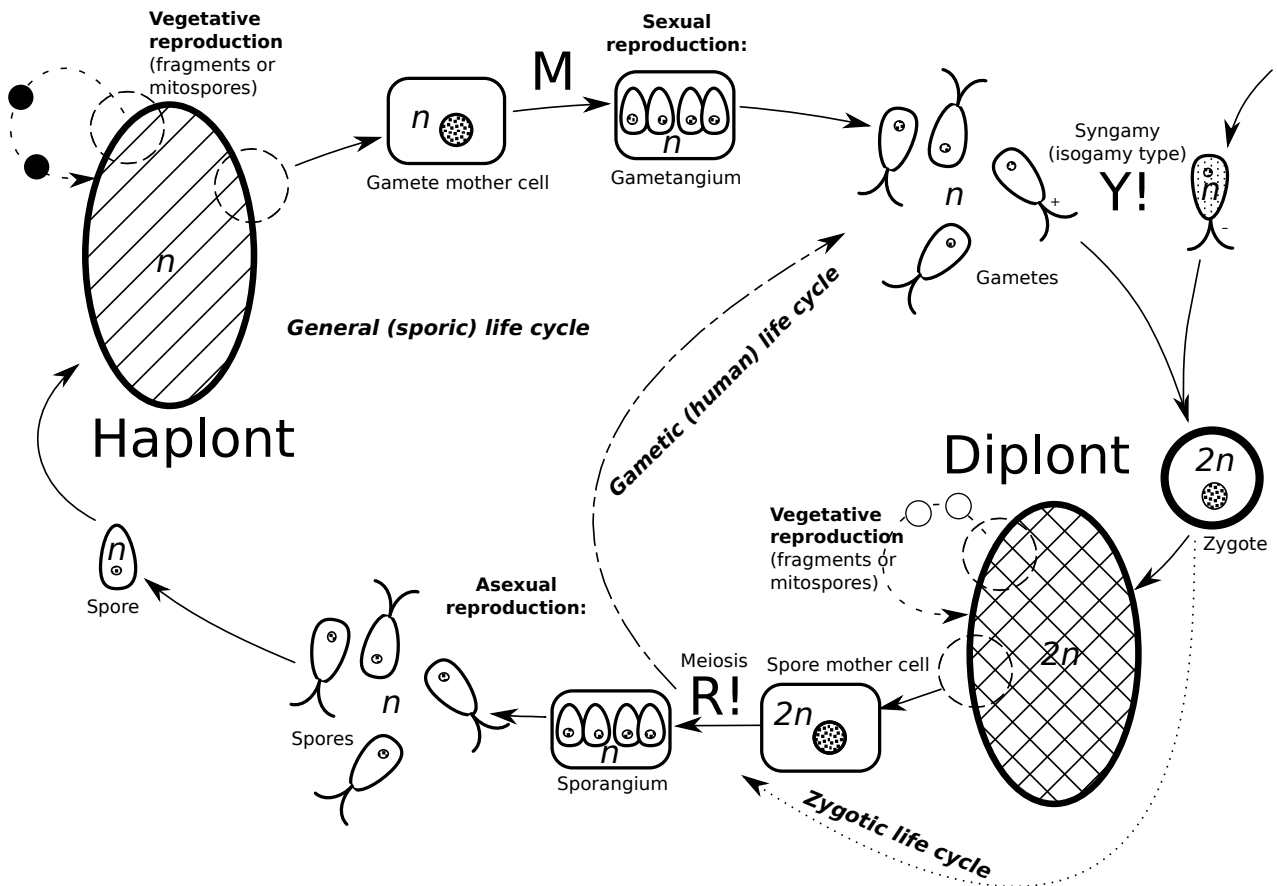


Life cycle math

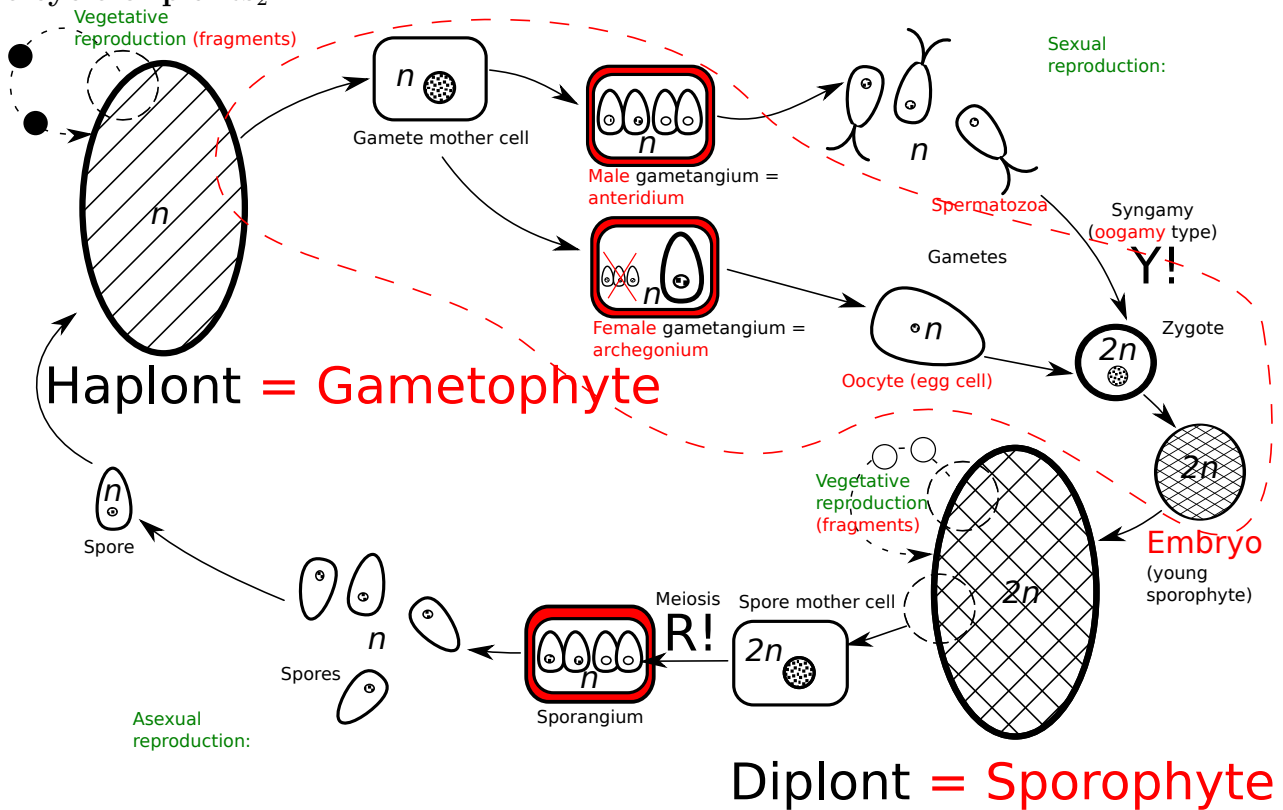


1 — zygotic cycle ($Y! \rightarrow R!$);
 2 — gametic cycle ($R! \rightarrow Y!$).

Life cycle (again)



Life cycle of plants₂



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