Introduction to Botany: BIOL 154
Study guide for Exam 2

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Lectures 7–16

Outline

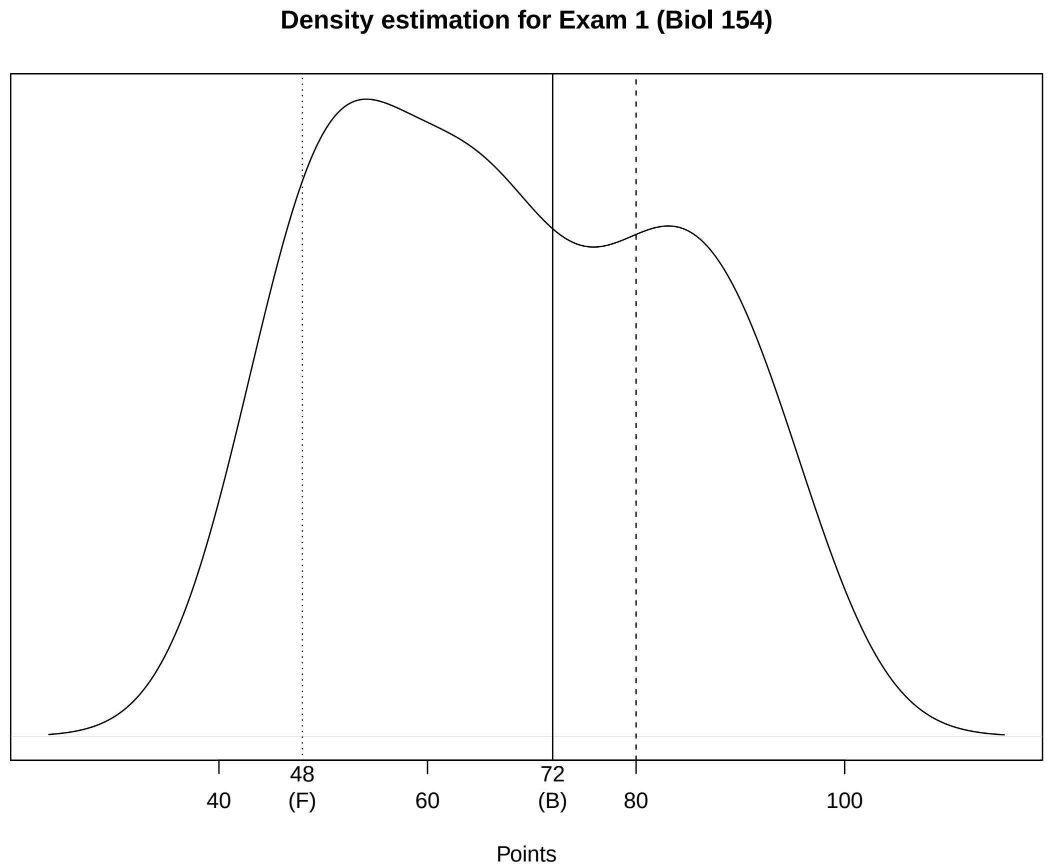
Contents

1 Questions and answers

Results of Exam 1: statistic summary

```
Summary:
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
  45.00   52.00   65.00   67.59   81.00   94.00       7
Grades:
  F   D   C   B max
 48  56  64  72  80
```

Results of Exam 1: the curve



22. Two isotopes of same element:

    (a) **Have the same number of protons and electrons but different number of neutrons**
    (b) Have the same number of protons and neutrons but different number of electrons
    (c) Have the same number of neutrons and electrons but different number of protons

36. Botany is a "slice" science, whereas _ is a "layer" science:

    (a) Zoology
    (b) Entomology
    (c) **Cytology**

46. Which of the following statements is NOT true?

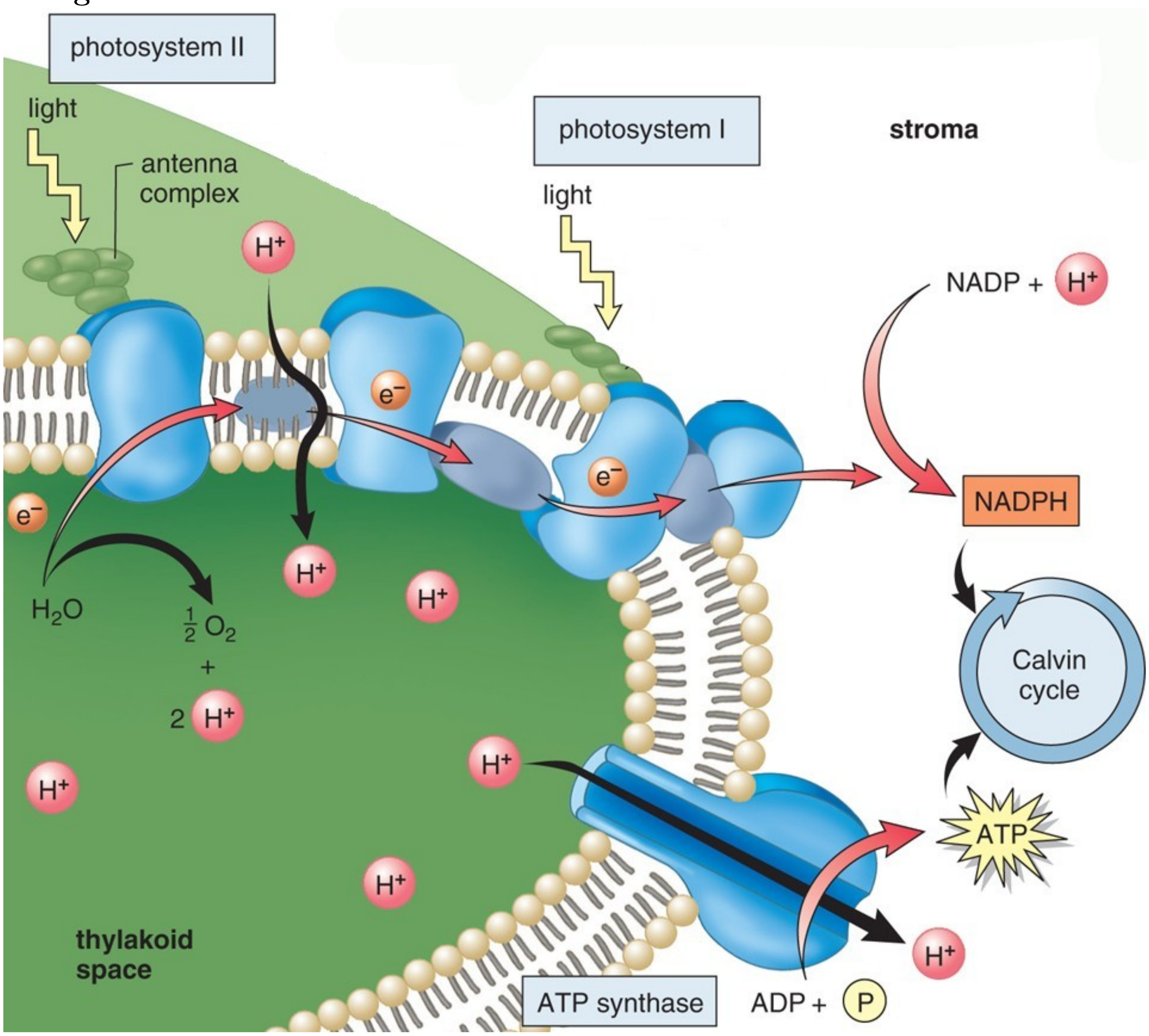
    (a) Carnivorous plants are authotrophs
    (b) **Carnivorous plants are organotrophs**
    (c) Carnivorous plants are phototrophs

Previous final question: the answer

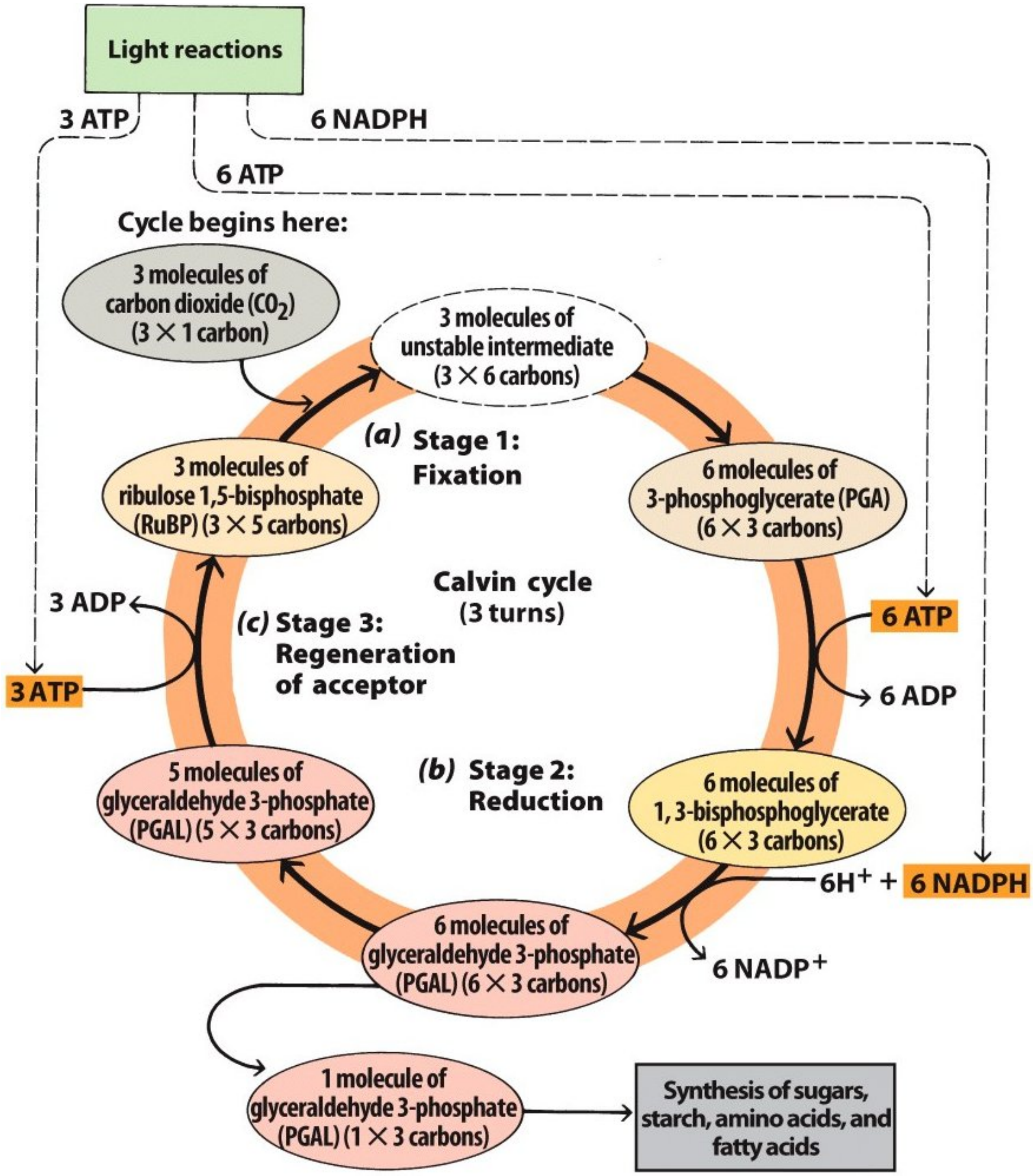
What is wrong in this picture?

Before photosynthesis	After photosynthesis
H_2O	O_2, H_2O
$NADP^+$	NADPH ~~NADPH~~ $NADP^+$
CO_2	$C_6H_{12}O_6$ (or other organic molecules)

Light stage



Enzymatic stage



2 Photosynthesis

2.1 Special case of photosynthesis: C_4 pathway

Photorespiration

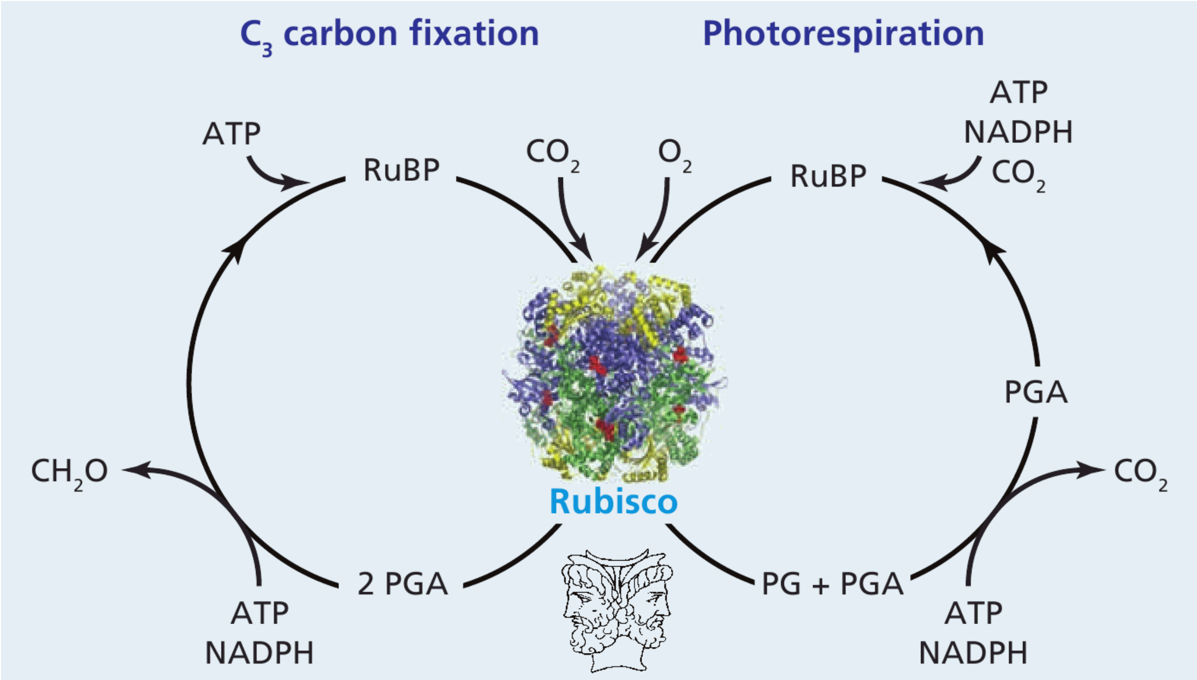
Rubisco is two-faced enzyme, it catalyzes **photorespiration** if the concentration of O_2 and/or temperature is high:

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



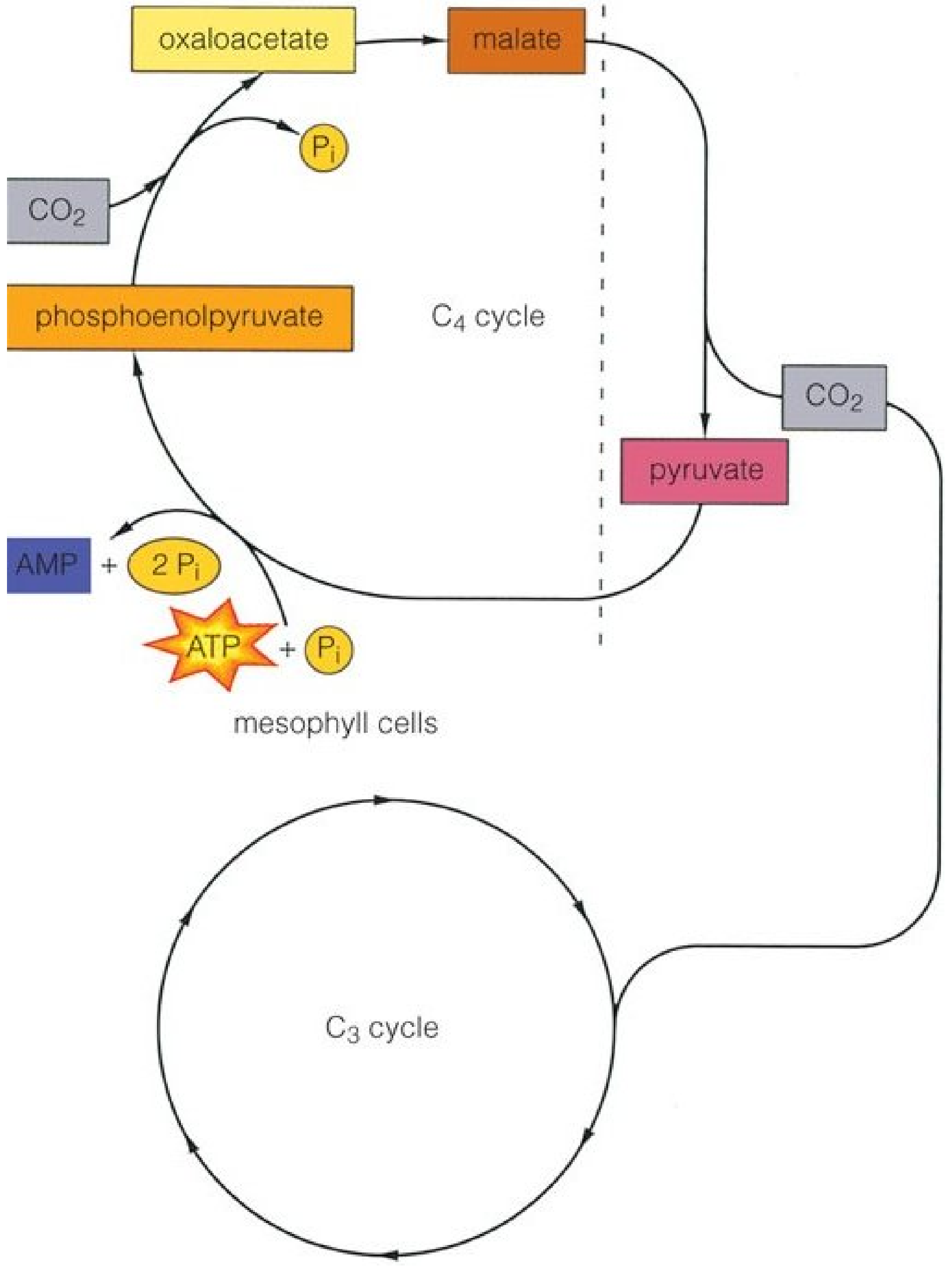
Minimization of photorespiration

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

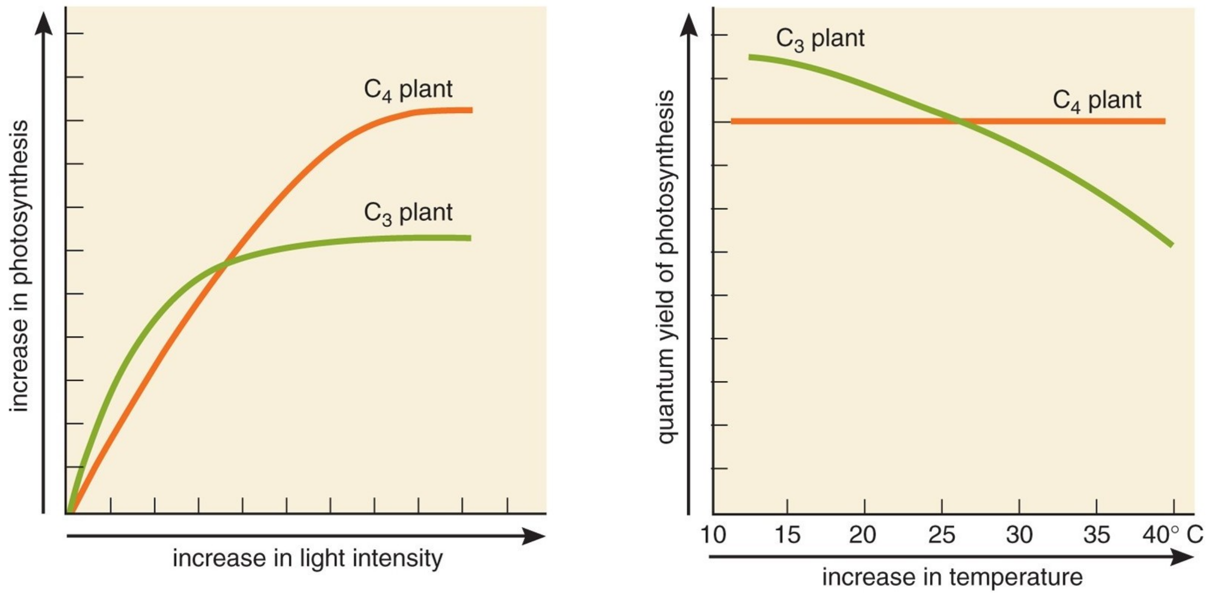
1. $CO_2 + C_5$ (PEP, phosphoenolpyruvate) $\xrightarrow{\text{PEP carboxylase}}$ C_4 (different organic acids): this is the temporarily accumulation of carbon dioxide
2. $C_4 \longrightarrow$ pyruvate + CO_2: release of carbon dioxide will increase its concentration
3. Pyruvate + ATP $\longrightarrow$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

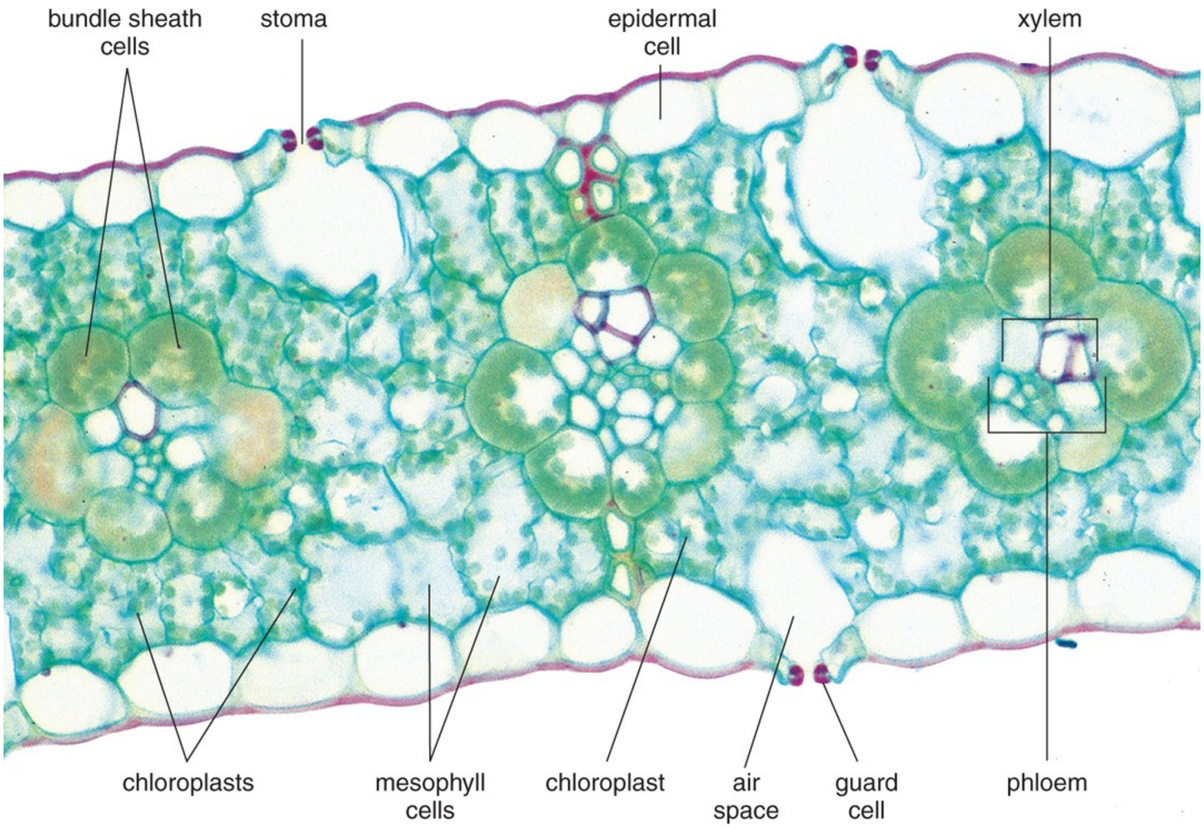


C_4-pathway plants waste ATP to recover PEP but outperform strict C_3 plants when concentration of oxygen is high

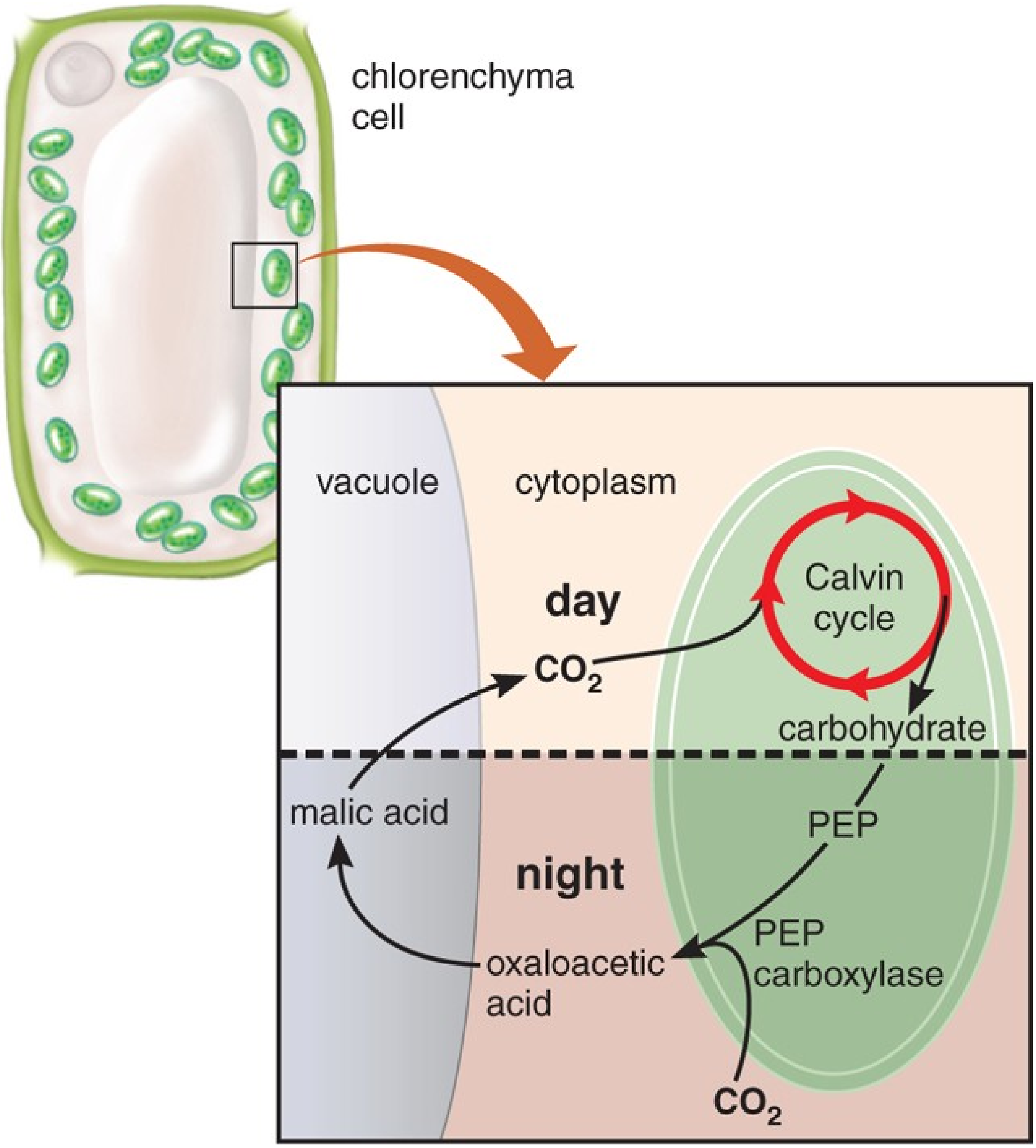
C_4 and CAM plants both use C_4 pathway

- **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)

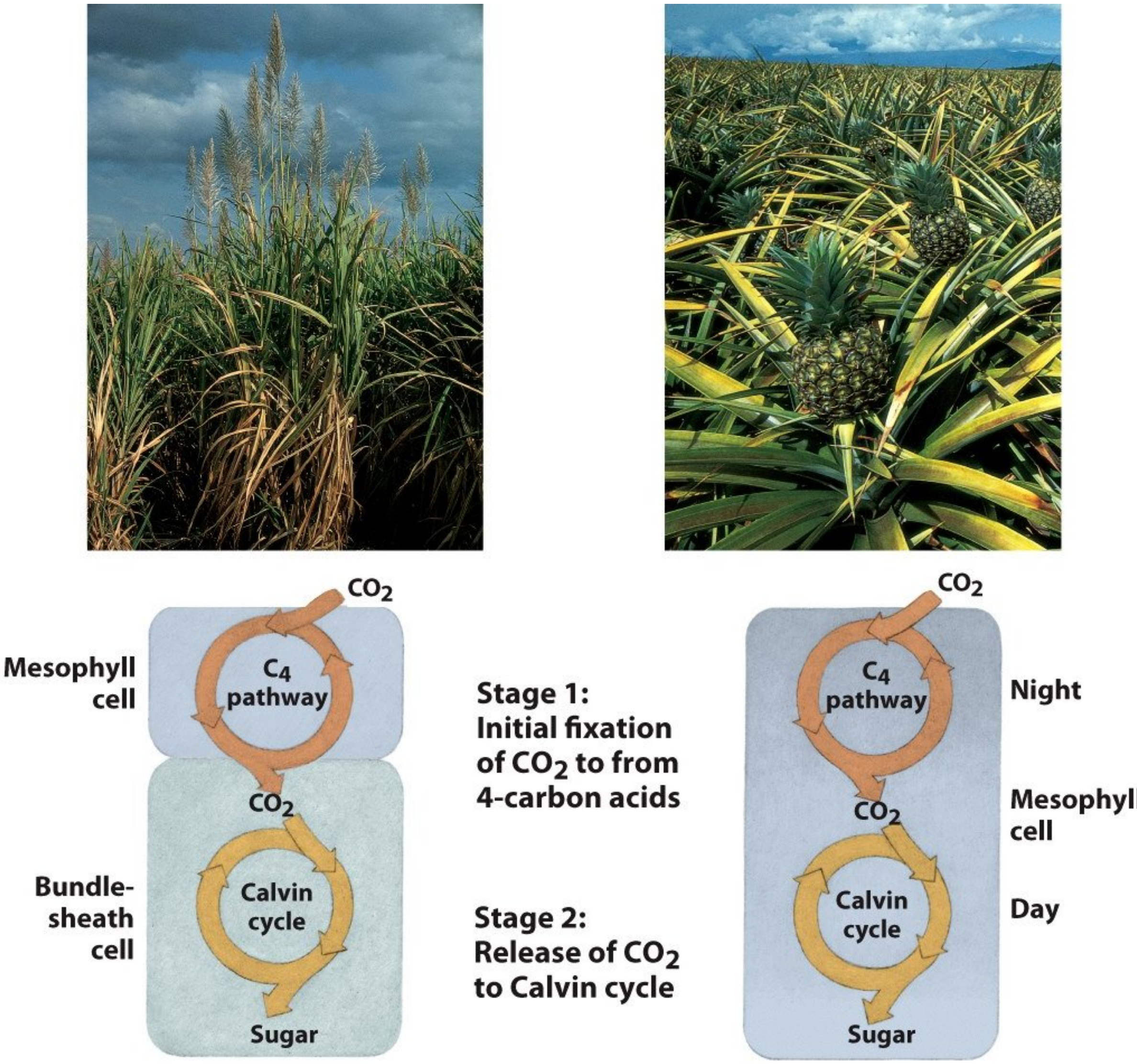
Leaf of C_4 plant: spatial separation of C_3 and C_4 pathways



CAM plants separate C_3 and C_4 pathways in time



CAM plants and C_4 plants



(a) C_4 photosynthesis *(b)* CAM photosynthesis

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

Final question (2 points)

Photorespiration increases when concentration of oxygen grows. Why is photorespitation so intensive at high temperatures?

Summary

- To prevent wasteful **photorespiration**, plants "invented" the addition to photosynthesis, C_4-pathway
- 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]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

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

Outline

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3 Questions and answers

Previous final question: the answer

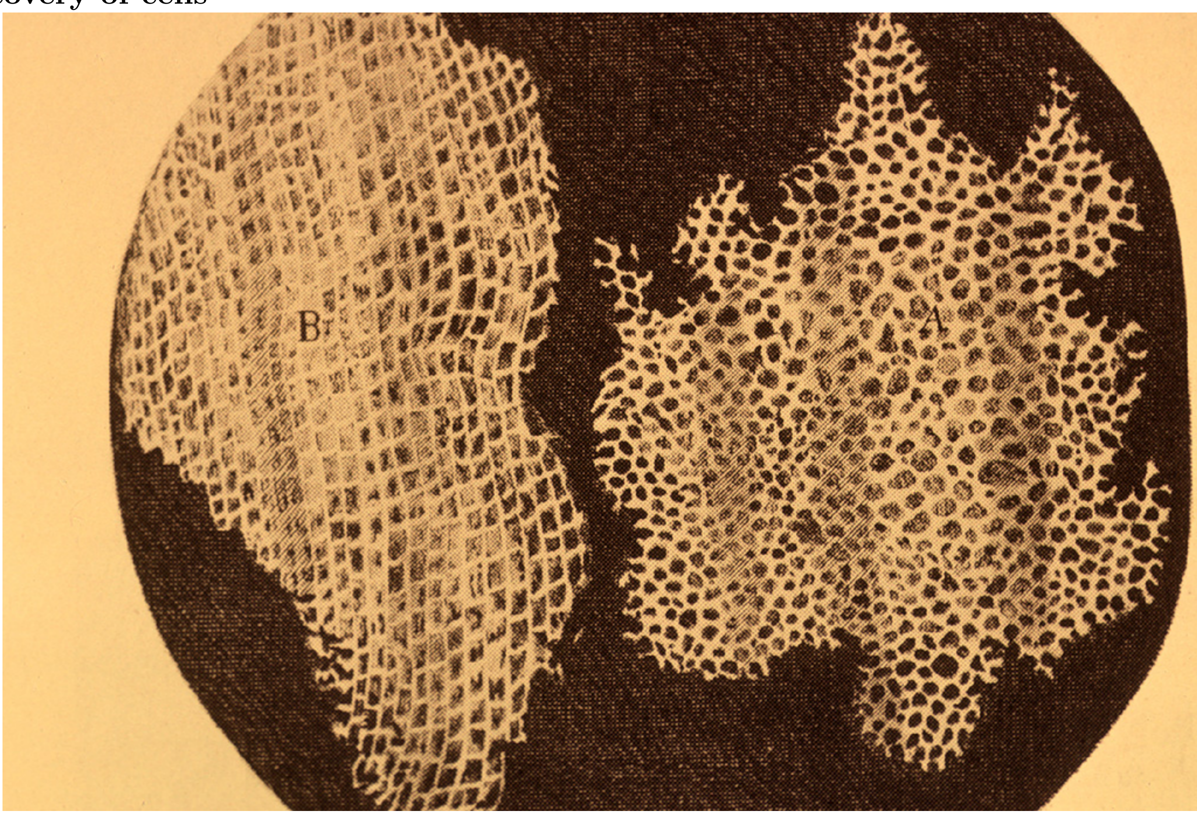
Photorespiration increases when concentration of oxygen grows. Why is photorespitation so intensive at high temperatures?

- When temperature is high, light stage makes more oxygen
- When temperature is high, plants closes stomata to avoid water loss. As a sideway result, concentration of oxygen in leaf tissues grows

4 Plant cell

4.1 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 (1838, Matthias Schleiden and Theodor Schwann)
2. Cells reproduce themselves (1858, Rudolf Virchow)
3. All cells arise by reproduction from previous cells (1858, Rudolf Virchow)

Miscroscopes

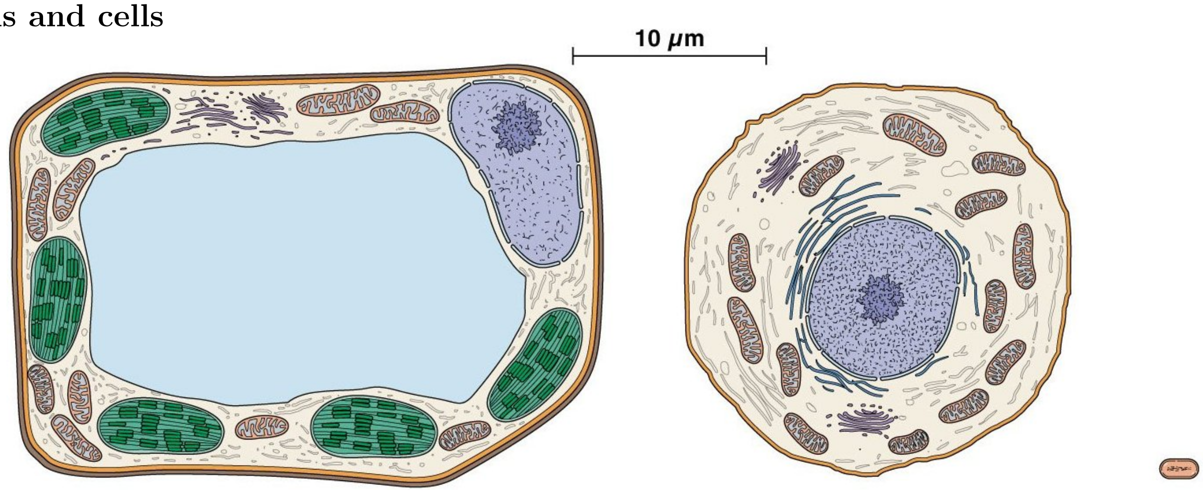
Light microscopy was an early technological breakthrough that contributed to our understanding of cell structure. Dissectiscopes use reflected light, microscopes use translucent light. Magnification is of 10^3 order.

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.

4.2 Structure of cell

Cells and cells



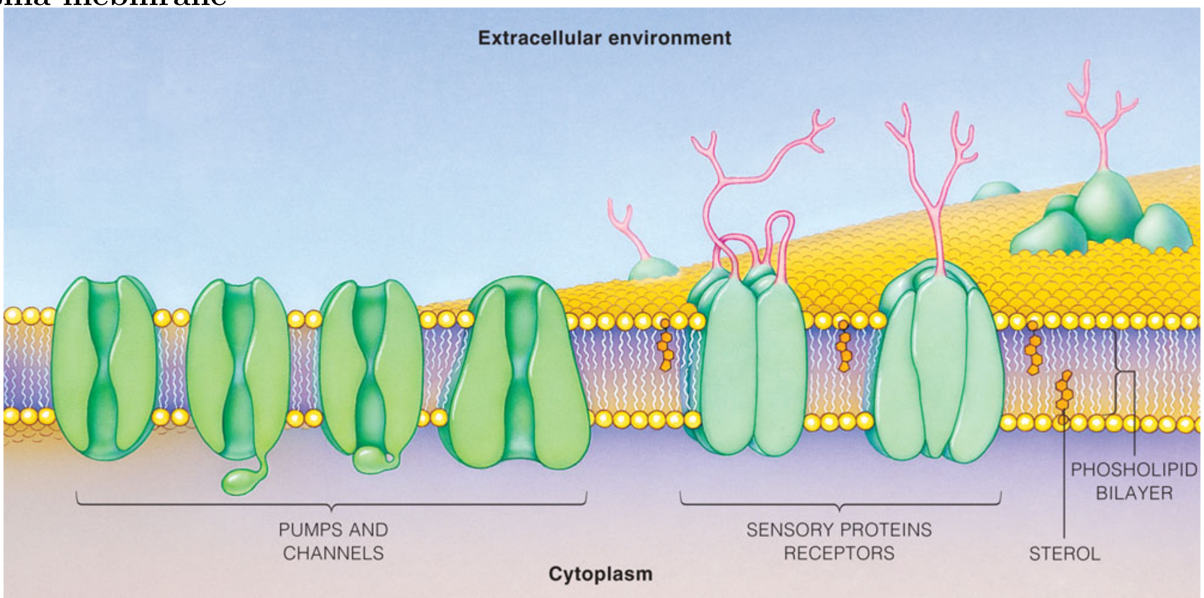
Eukaryotic and prokaryotic cells are fundamentally different

Cells

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

Plasma mebmrane



Phospholipids, sterols, proteins: pumps, receptors, channels

Final question (2 points)

What is the symbiogenesis?

Summary

- Eukaryotic and prokaryotic cells are cells of different levels of organization; eukaryotic cells are ecosystems
- Chloroplasts and mitochondria are both results of symbiogenesis

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology.* 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 3.*

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5 Questions and answers

Previous final question: the answer

What is the symbiogenesis?

- Making one organism from two in the process of evolution

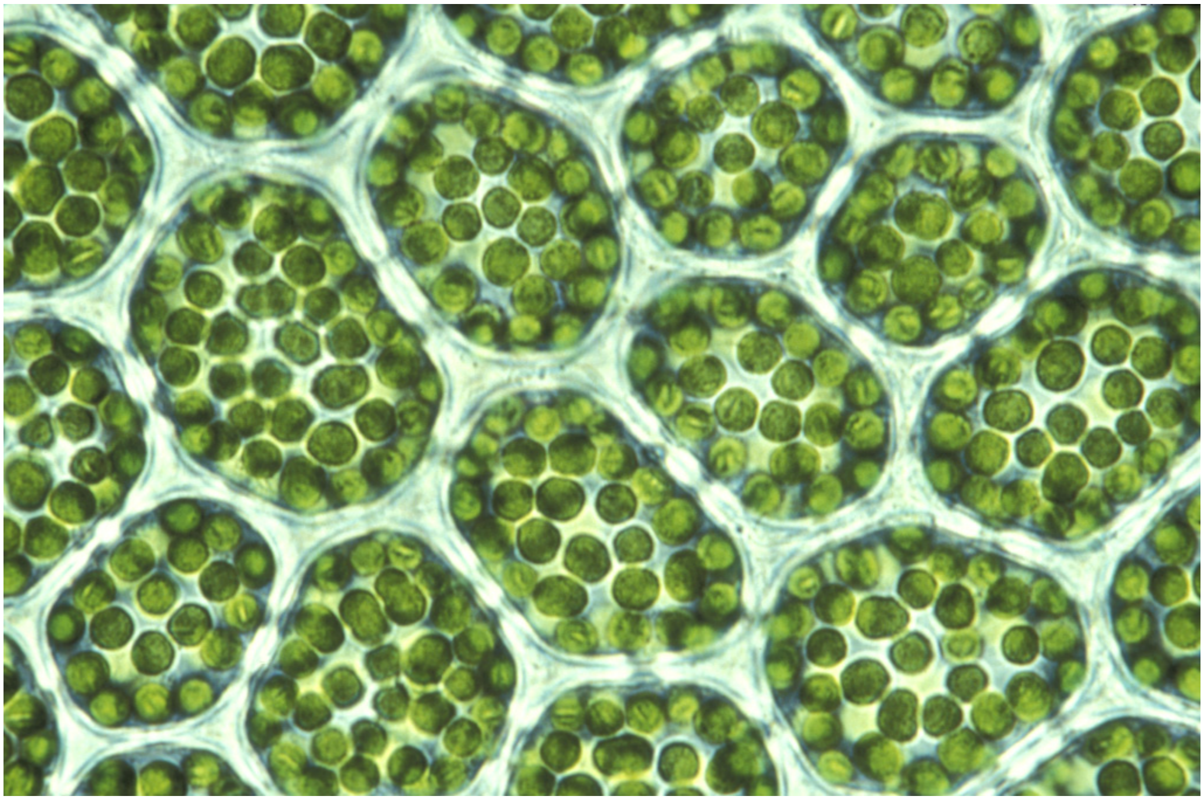
6 Plant cell

6.1 Cells from cells: mitochondria and chloroplasts

Symbiogenesis

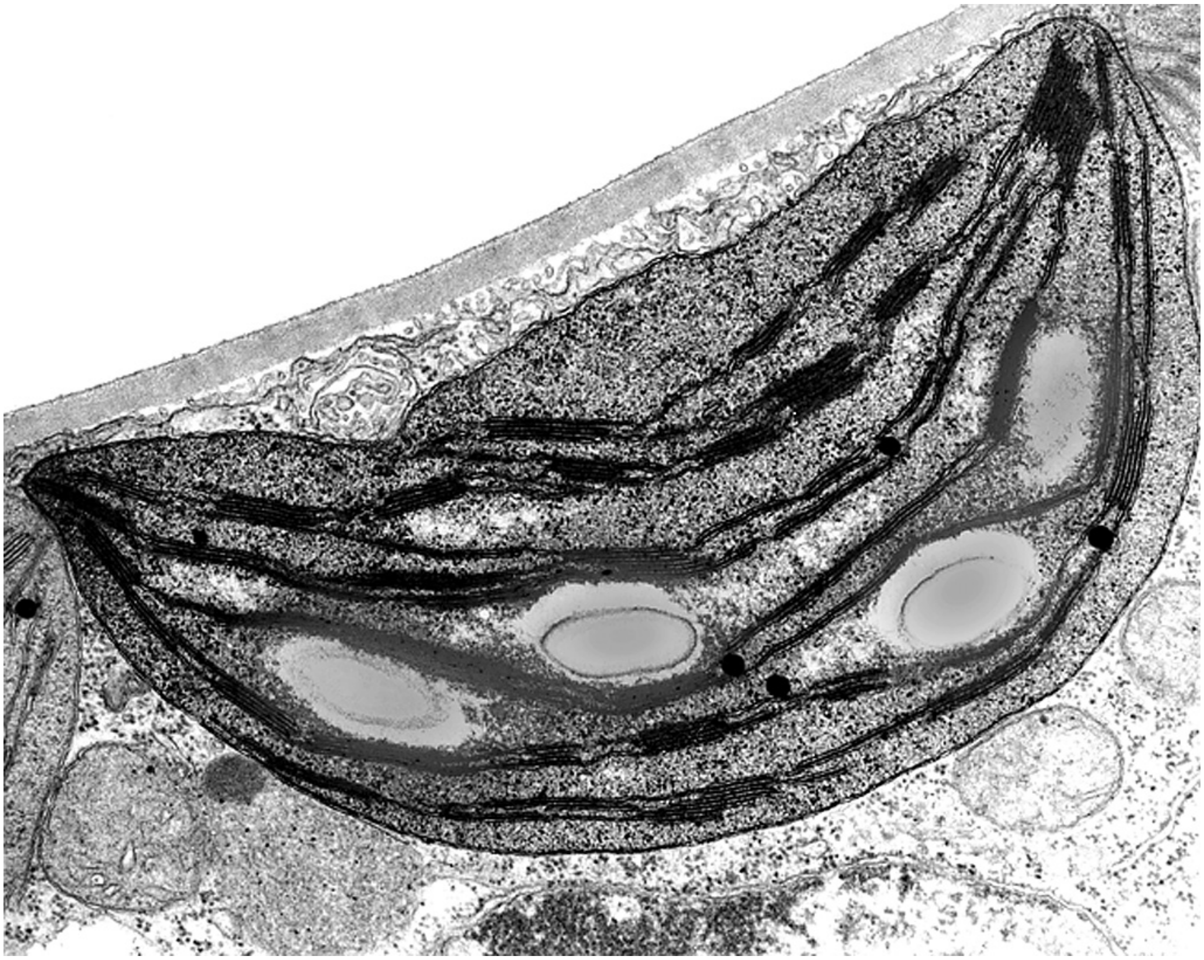
- Small, rigid procaryotic cells became larger to escape from predators
- To keep all parts of larger cell communicable, they developed cytoplasm motility based on actin protein
- Cytoplasm motility allowed for phagocytosis so they became predators
- These predator cells captured many bacteria and digested 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 (plants$_1$) and became algae with chloroplasts

Plastids



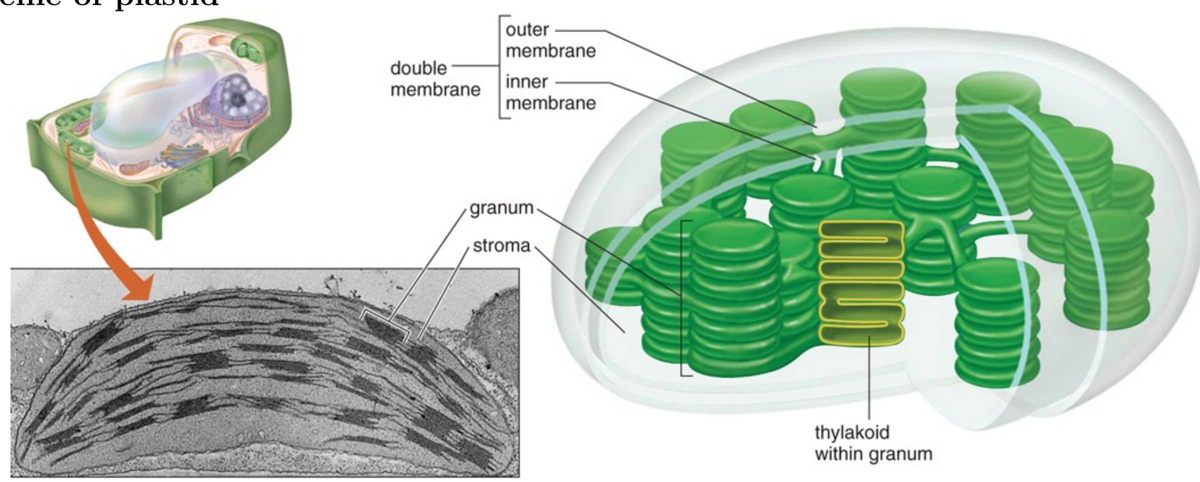
Chloroplasts in leaf cells of *Rhizomnium pseudopunctatum* (LM ×500)

Plastid structure

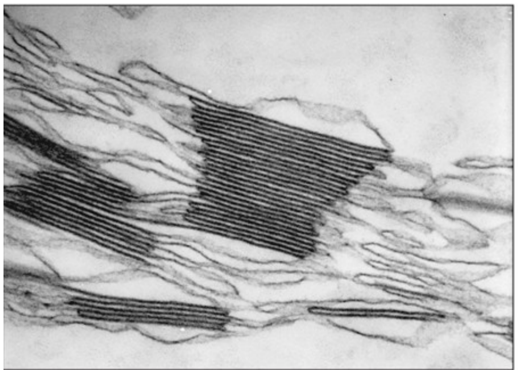


Tylacoids, stroma and starch granules (TEM $\times 37,500$)

Scheme of plastid



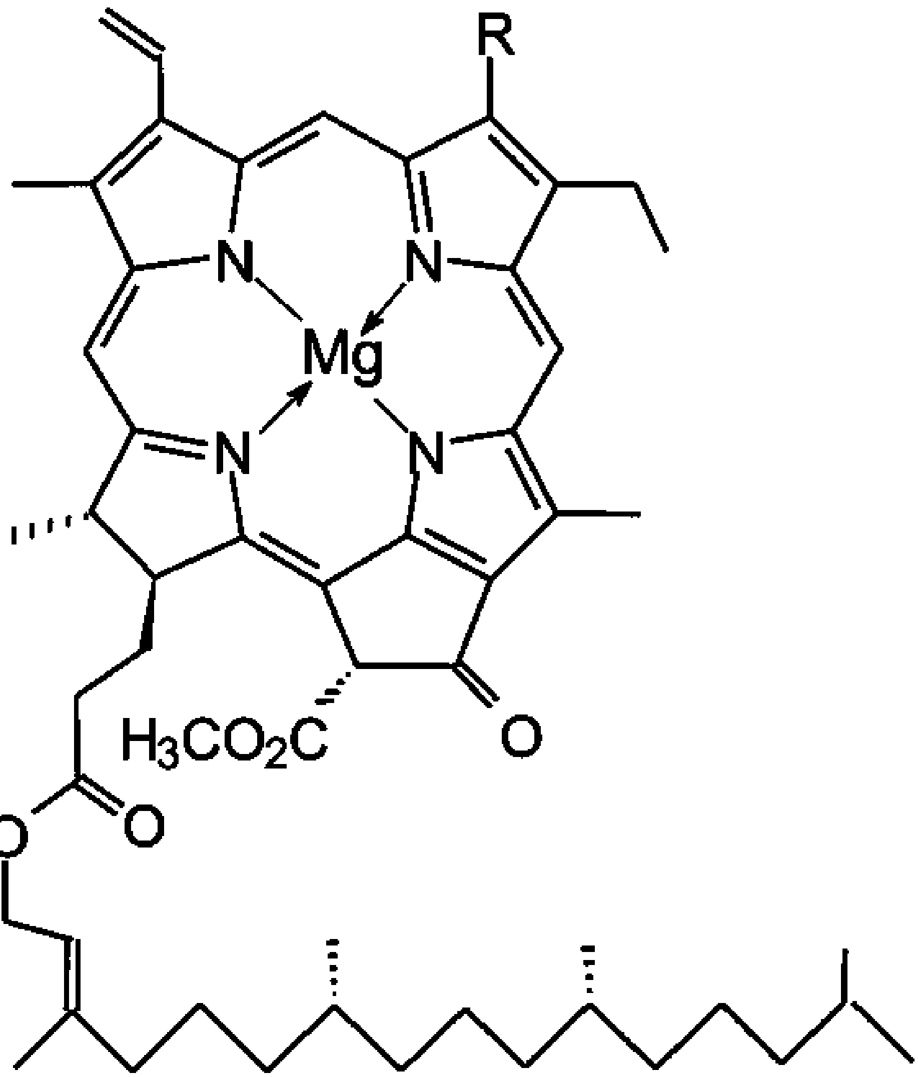
Grana



Pigments

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

Chlorophylls *a* and *b*

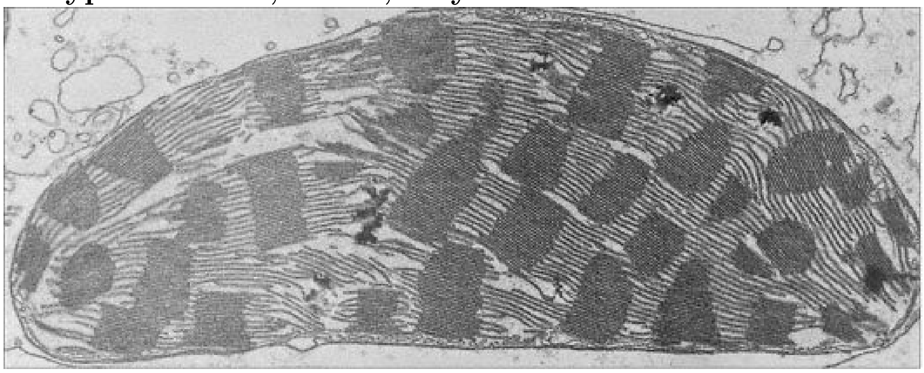


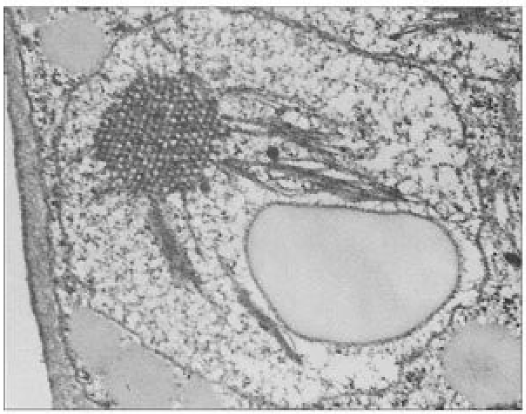
chlorophyll *a* (R = CH_3)
chlorophyll *b* (R = CH=O)

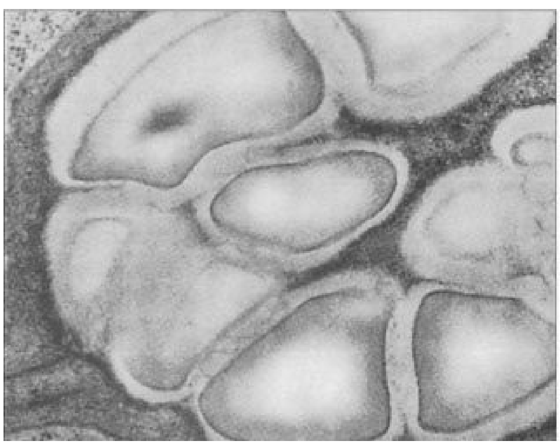
Plastid types

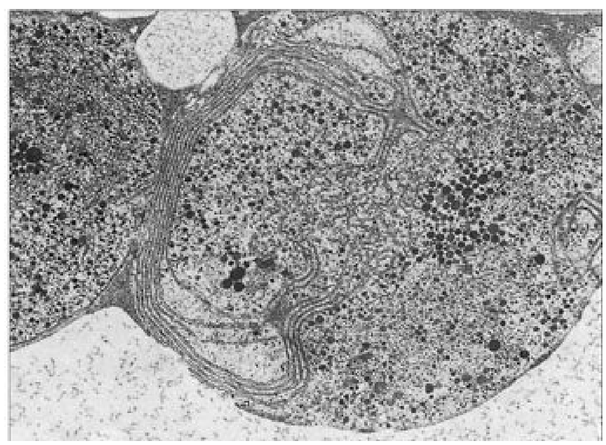
- **Chloroplast** (from "chloro-" = "yellow-green"). Photosynthesis, convert light energy into chemical energy, store carbohydrates as starch grains
- **Leukoplast** (from "leuko-" = "white"). Store carbohydrates in form of starch
- **Amyloplast** (from "amylo-" = "starch"). Leukoplasts that contain large granules of starch
- **Chromoplast** (from "chromo-" = "color"). Stores carotenes and xanthophylls, give orange-to-red color to certain plant tissues.

Plastid types: chloro-, leuco-, amylo- and chromo-









Mitochondria

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

Final question (2 points)

What are differences between chloroplasts and mitochondria?

Summary

- Eukaryotic cell is a "second-level" cell, cell from cells
- Chloroplasts and mitochondria are both results of symbiogenesis

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 3*.

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7 Questions and answers

Previous final question: the answer

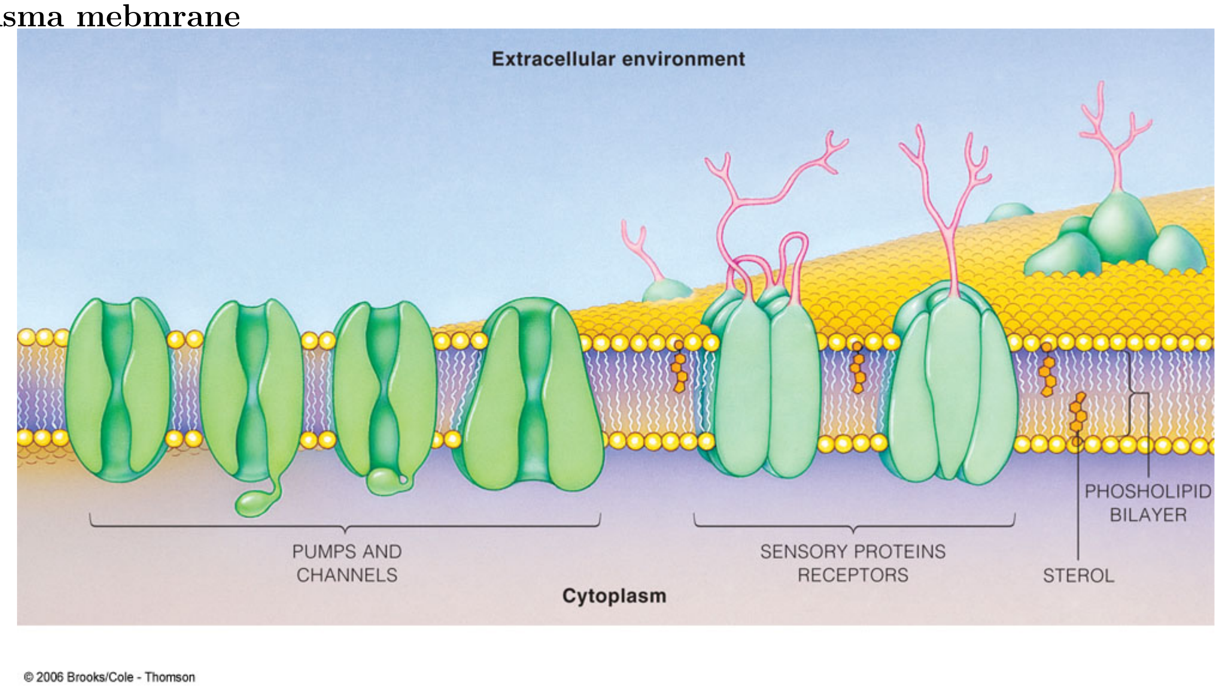
What is the difference between chloroplasts and mitochondria?

- While chloroplasts are synthesizing organic compounds, mitochondria produce most of cytoplasmic ATP (energy source) in the plant cell.
- The inner membrane of mitochondria form cristae
- Chloroplasts contain thylakoids bearing chlorophyll in their membrane

8 Plant cell

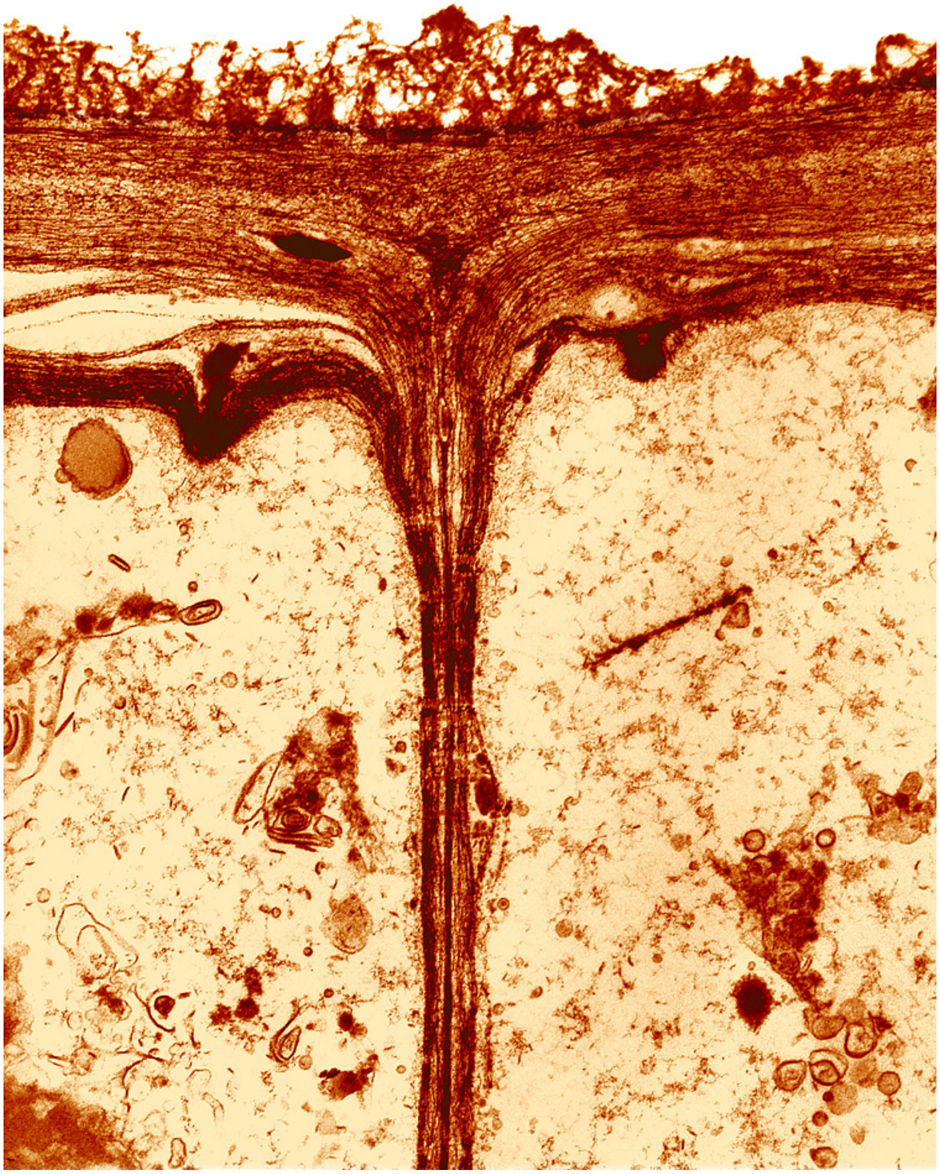
8.1 Cell boundaries

Plasma mebmrane



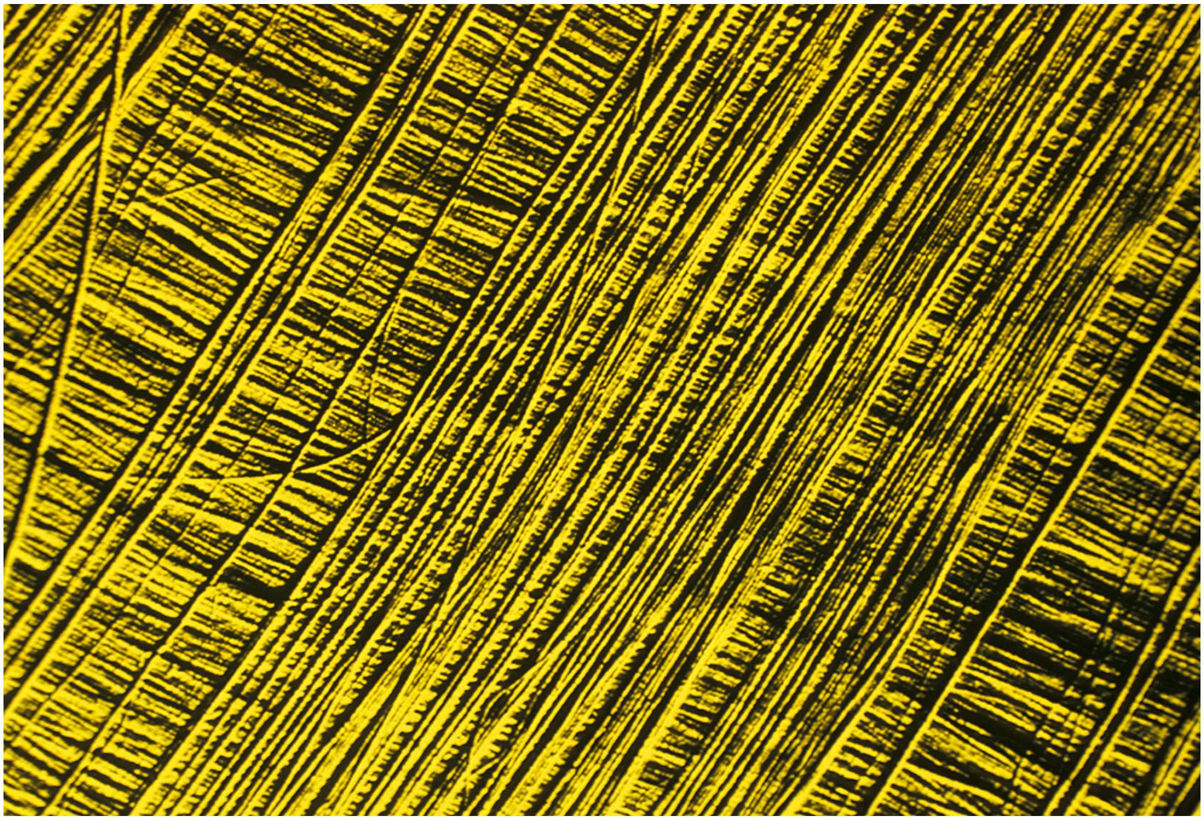
Phospholipids, sterols, proteins: pumps, receptors, channels

Cell wall 1



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

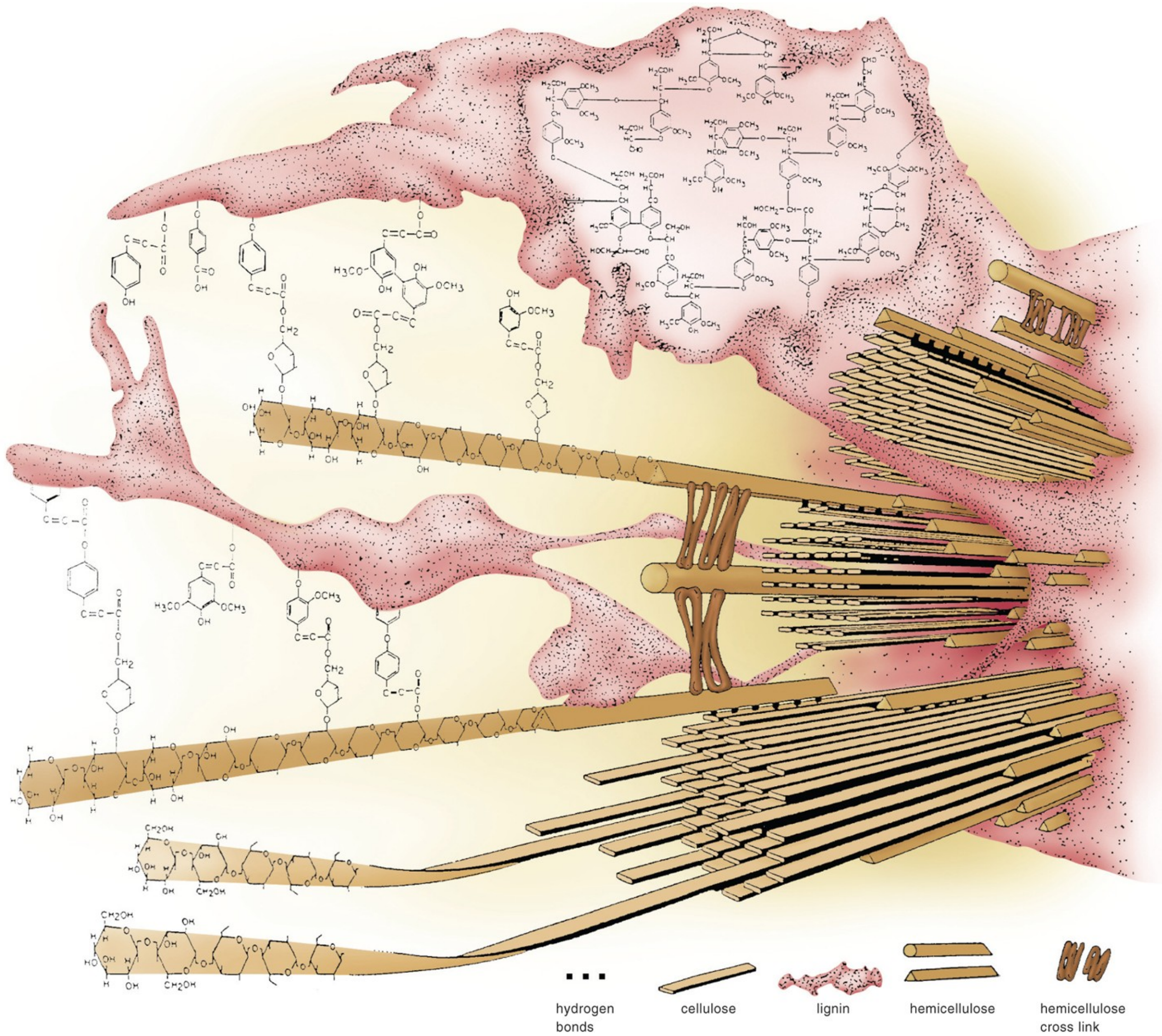
Cell wall 2


Cellulose fibers in the plant cell wall (SEM)

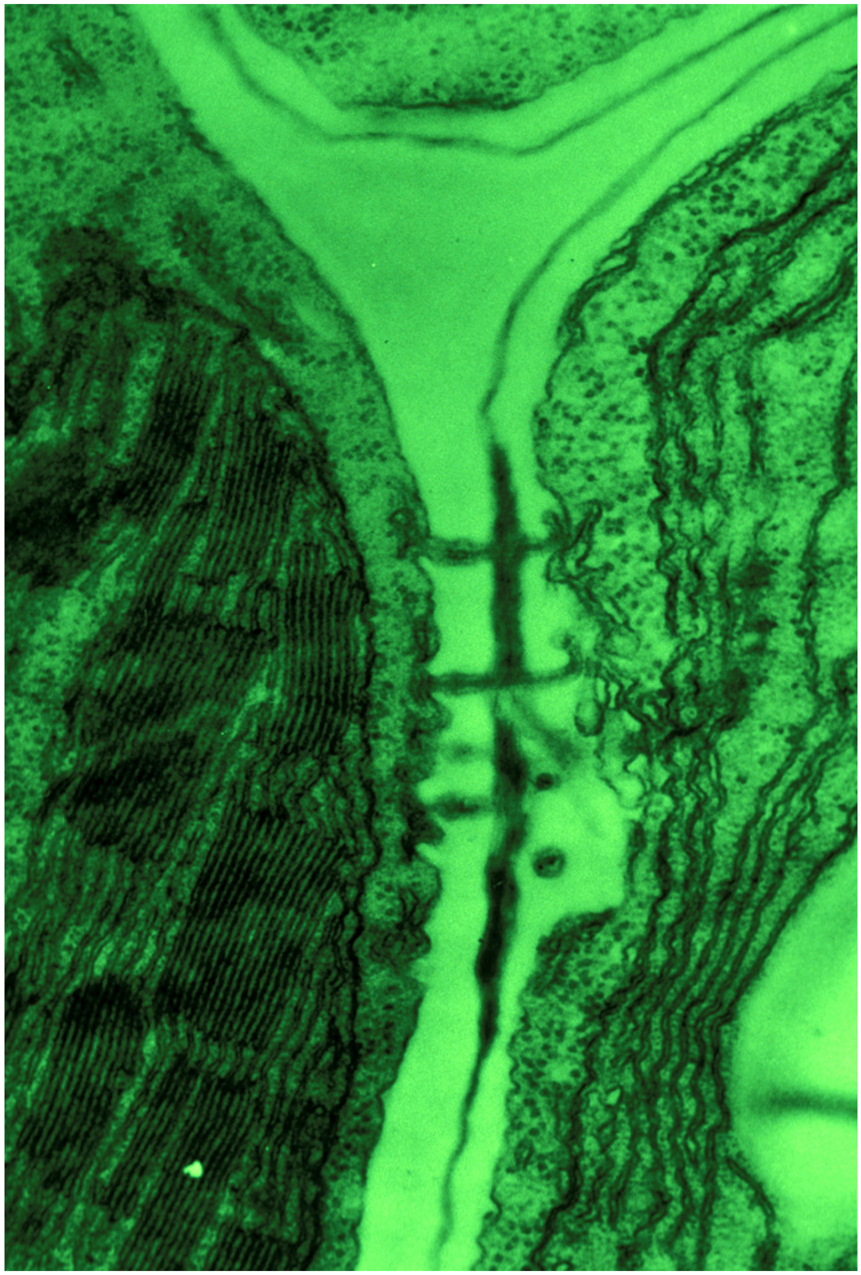
Primary and secondary cell walls

- **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

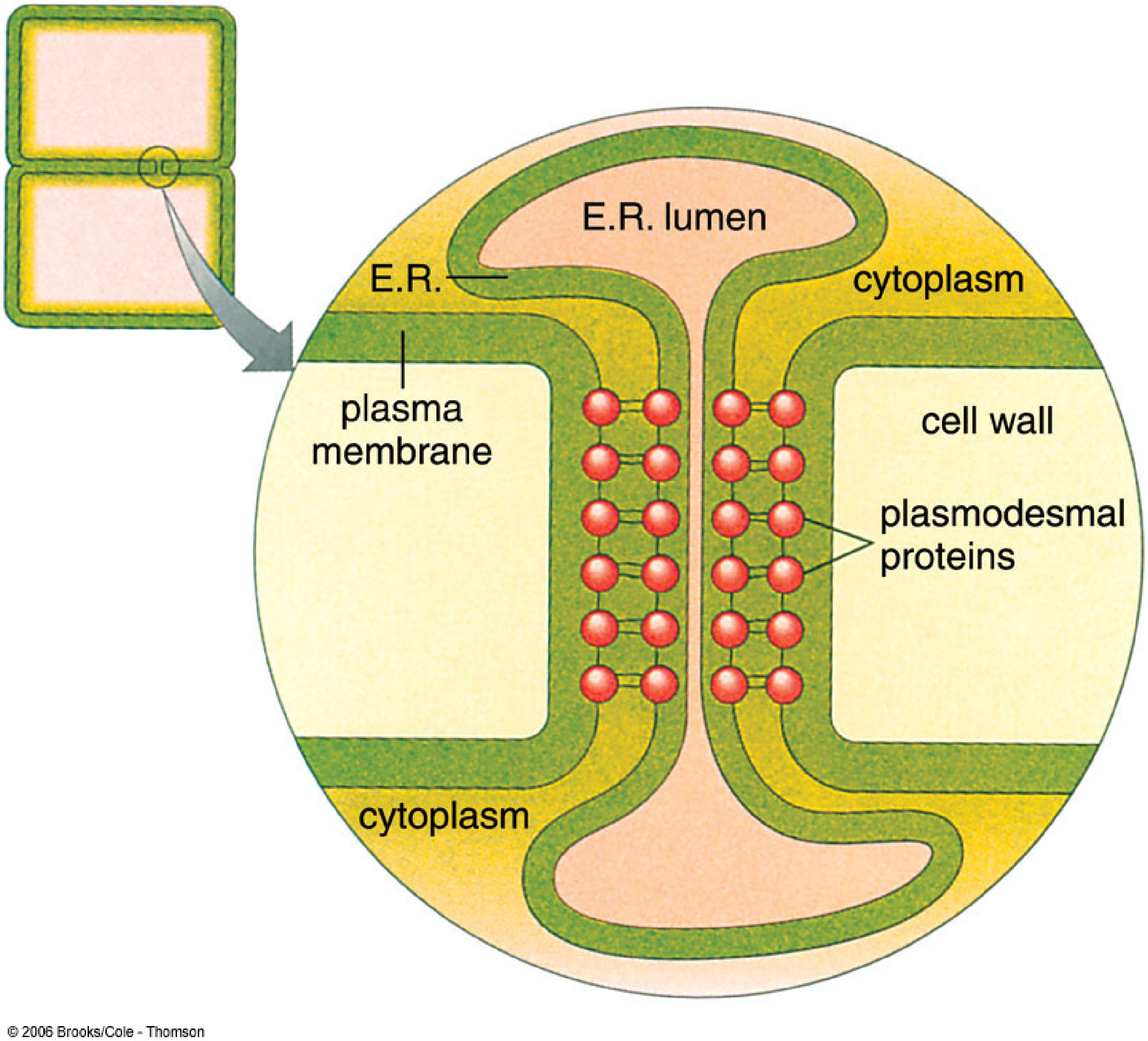


Plasmodesmata 1



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

Plasmodesmata 2



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

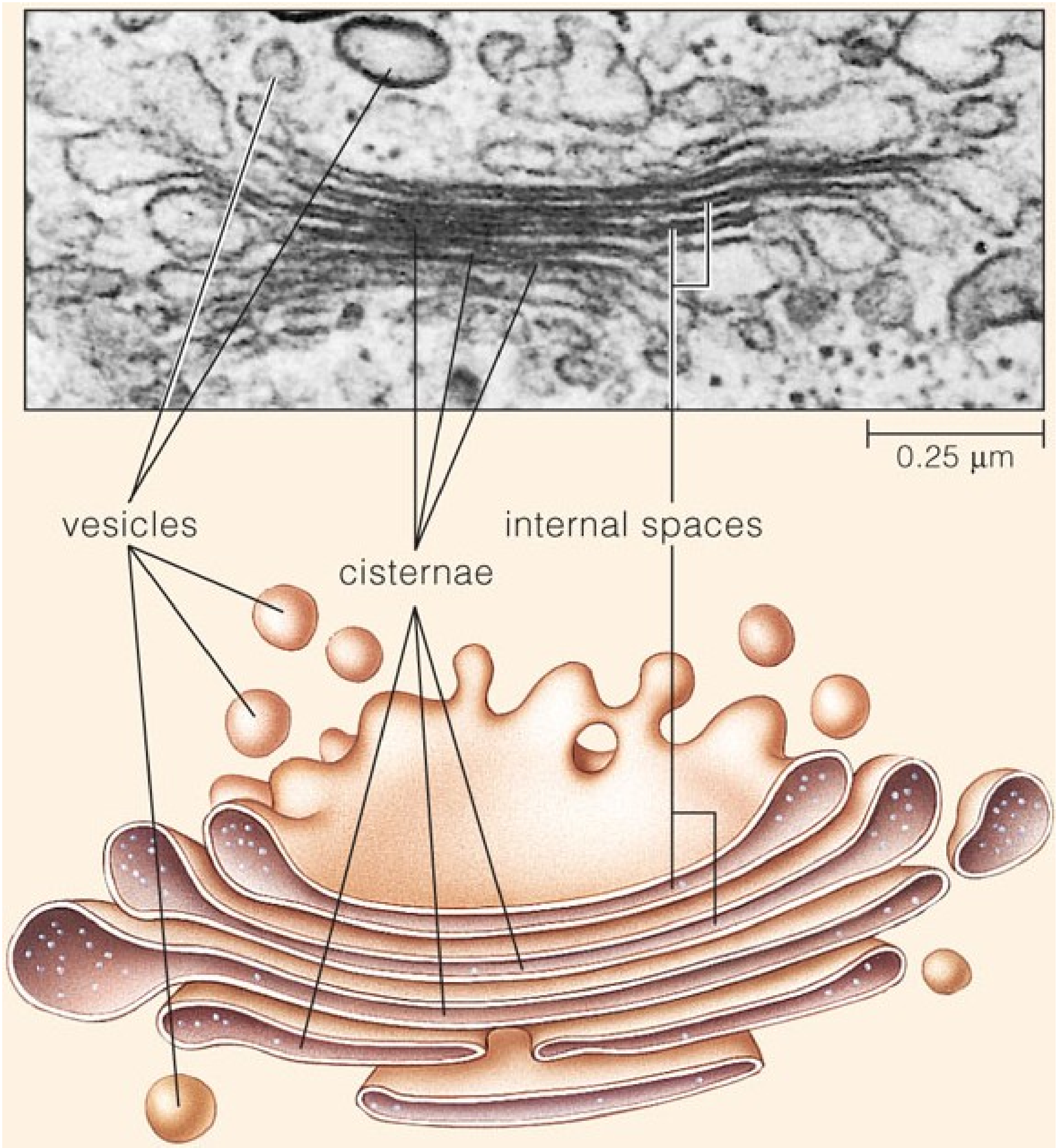
- **Symplast** — name for continuous cytoplasm in set of cells
- **Apoplast** — space outside cell; area of considerable metabolic activity

8.2 Cellular transport

Endoplasmatic reticulum (network), ER

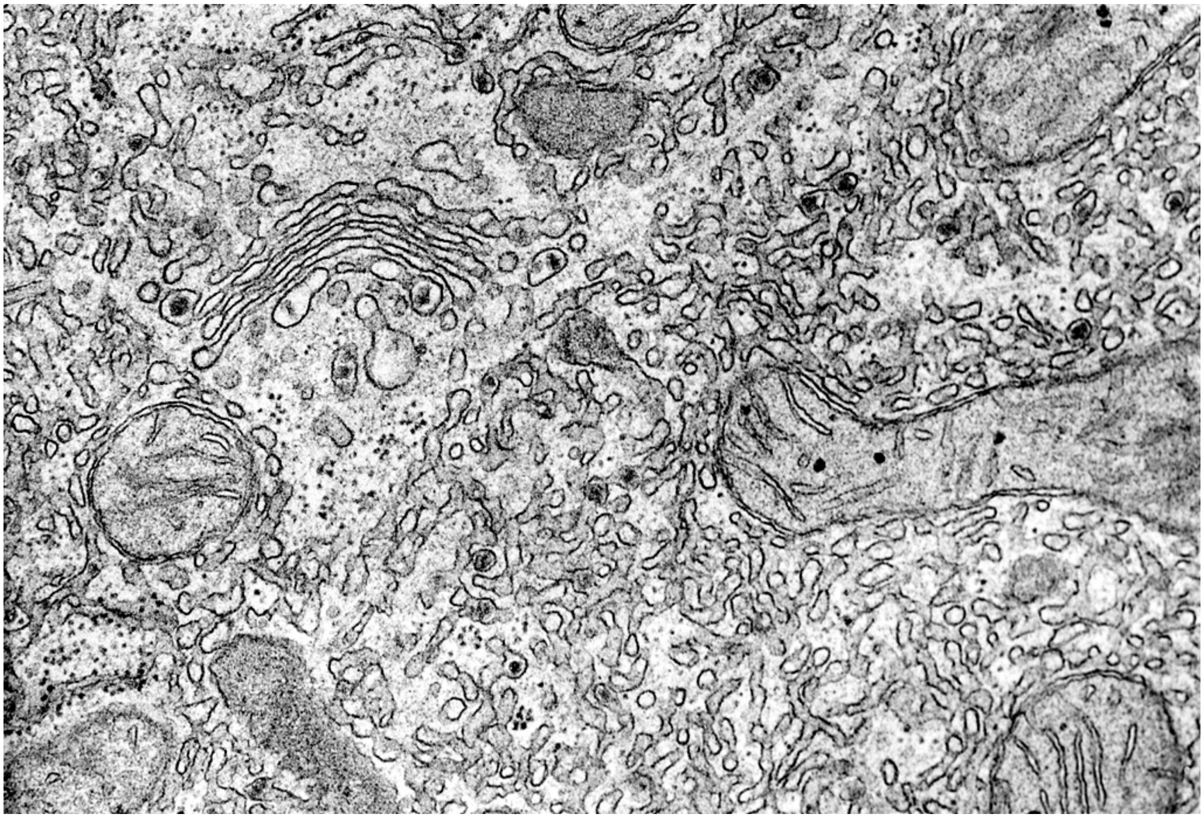
Rough endoplasmic reticulum with ribosomes along outer surface. Manufactures many proteins destined for secretion or for incorporation into membranes (TEM)

Goldgi apparatus (dictyosomes) 1



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 (dictyosomes) 2



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

Final question (2 points)

List at least two differences between plant and animal cells.

Summary

- Vacuole, chloroplasts and cell wall are three most important cell parts specific to plants.
- There are **two ways** of moving things between plant cells: through symplast or through apoplast
- **ER** handles ribosomes and packages proteins
- **Golgi apparatus** guides the movement of proteins

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 3.*

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9 Questions and answers

Previous final question: the answer

List at least two differences between plant and animal cells.

- Chloroplasts
- Vacuole
- Cell wall
- Plasmodesmata
- Almost no phagocytosis, only few sterols etc.

10 Plant cell

10.1 Protein synthesis

Nucleus structure

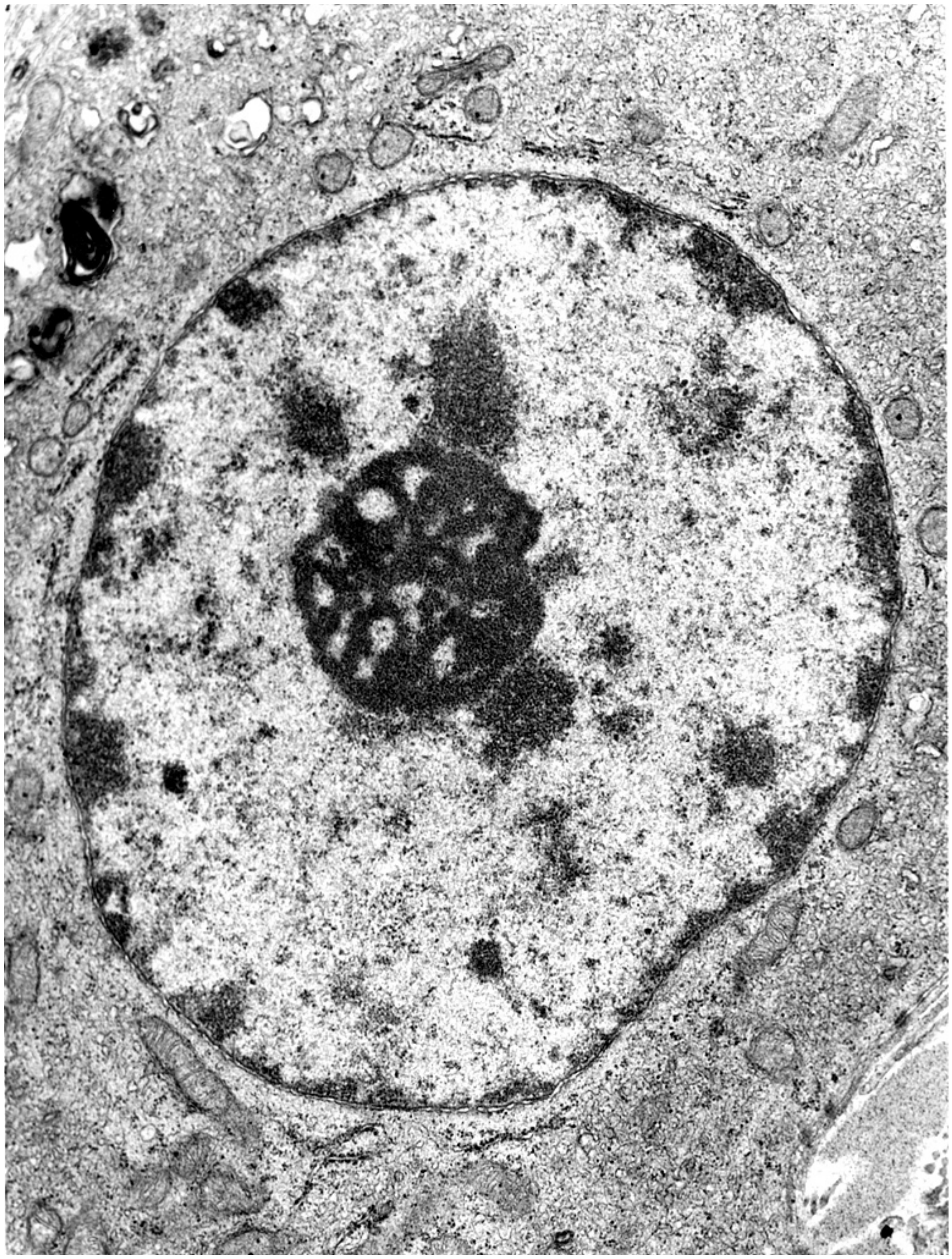
Nuclear envelope Double layered membrane, filaments of protein lamin line inner surface and stabilize structure, inner and outer membranes connect to form pores

Nucleoplasm Portion inside the nuclear envelope

Nucleoli Dark staining bodies within nucleus, site for ribosome synthesis

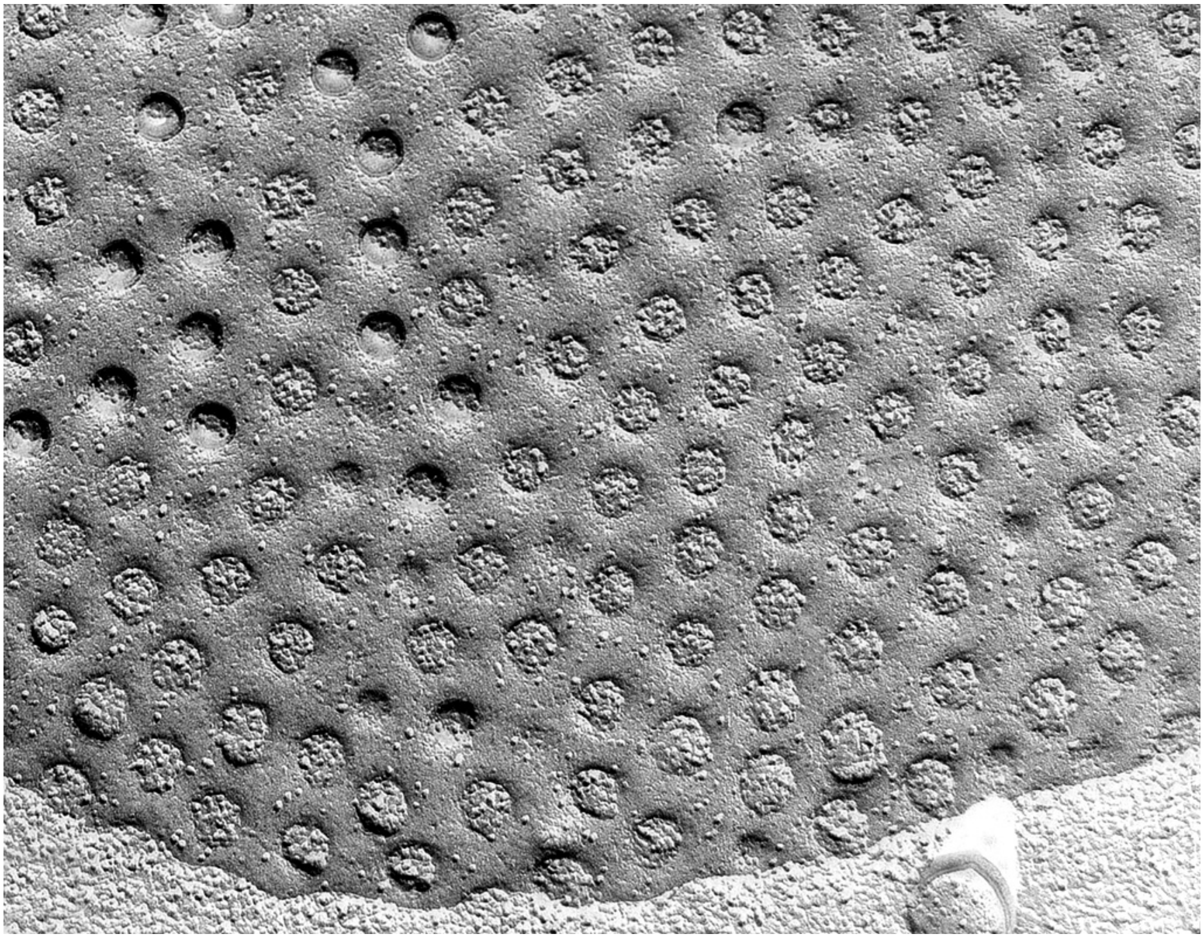
Chromosomes Store genetic information in nucleotide sequences, each chromosome consists of chain of nucleosomes (long DNA molecule and associated histone proteins)

Nucleus



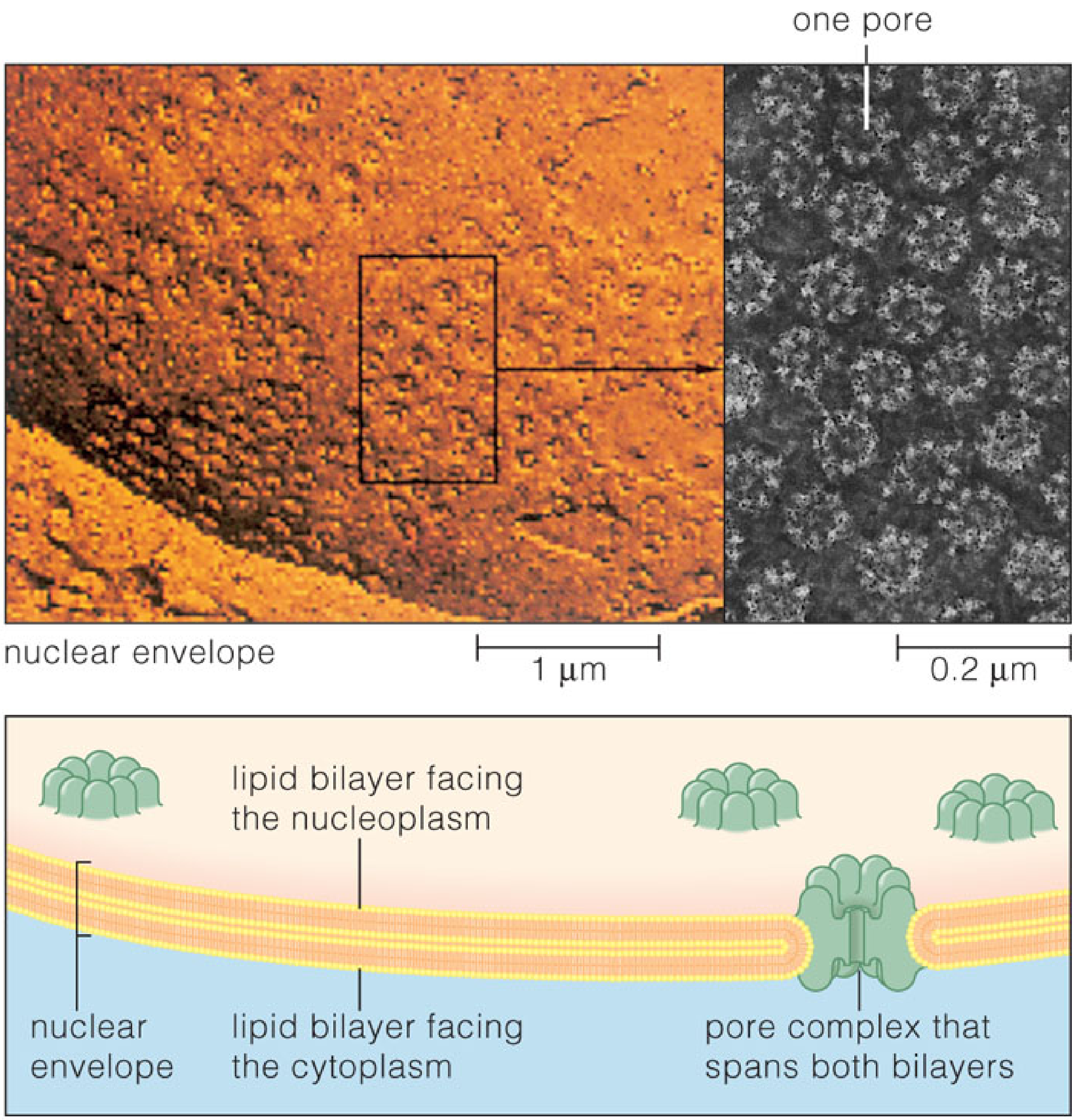
A typical nucleus with a prominent nucleolus (TEM).

Nuclear pores

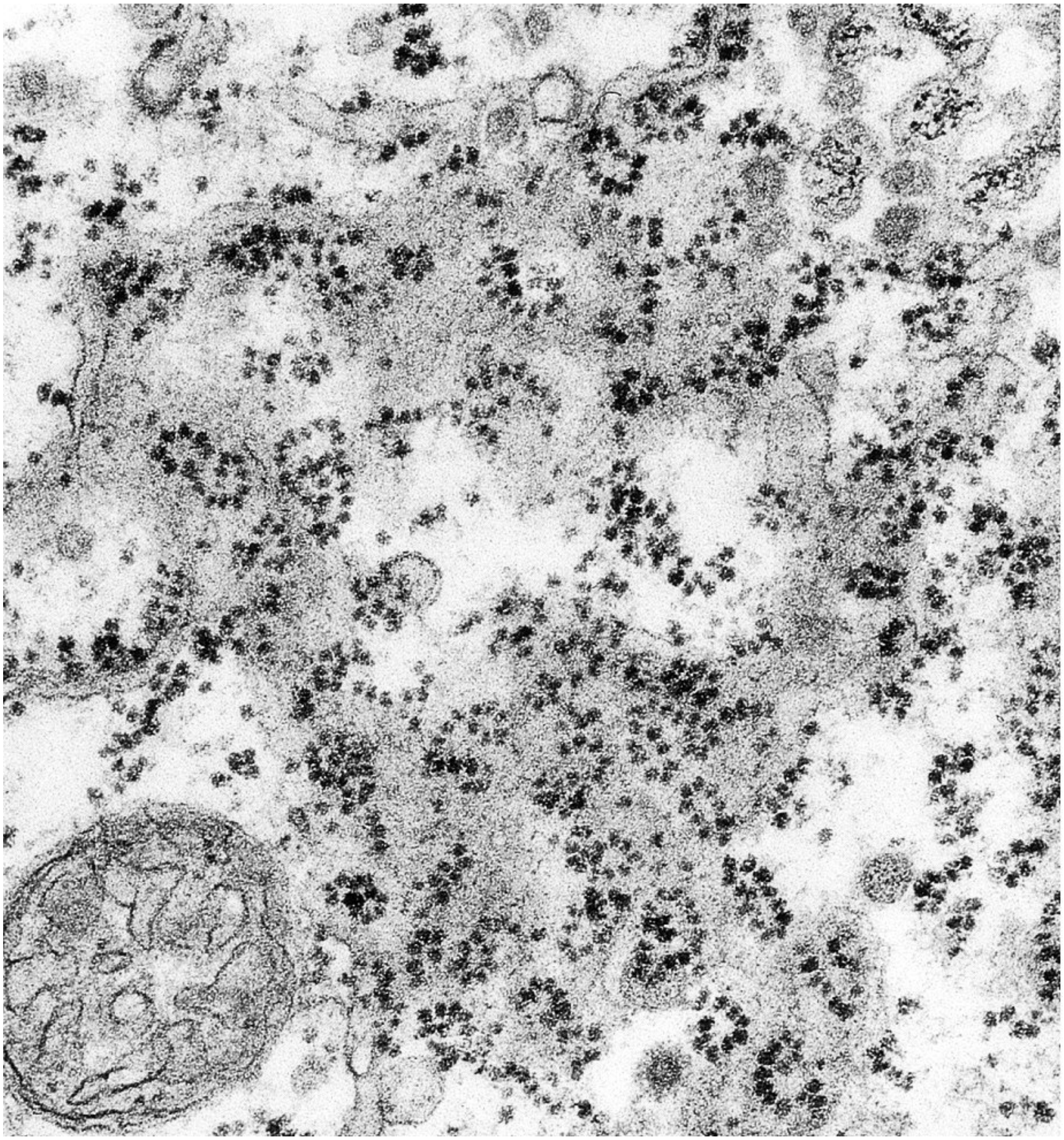


Freeze-fracture technique used to show nuclear pores. Nuclear pores are structures in the nuclear envelope that allow passage of certain materials between the cell nucleus and the cytoplasm (TEM $\times 100,000$)

Nuclear pores and envelope


one pore
nuclear envelope
1 μm
0.2 μm
lipid bilayer facing the nucleoplasm
nuclear envelope
lipid bilayer facing the cytoplasm
pore complex that spans both bilayers

Ribosomes



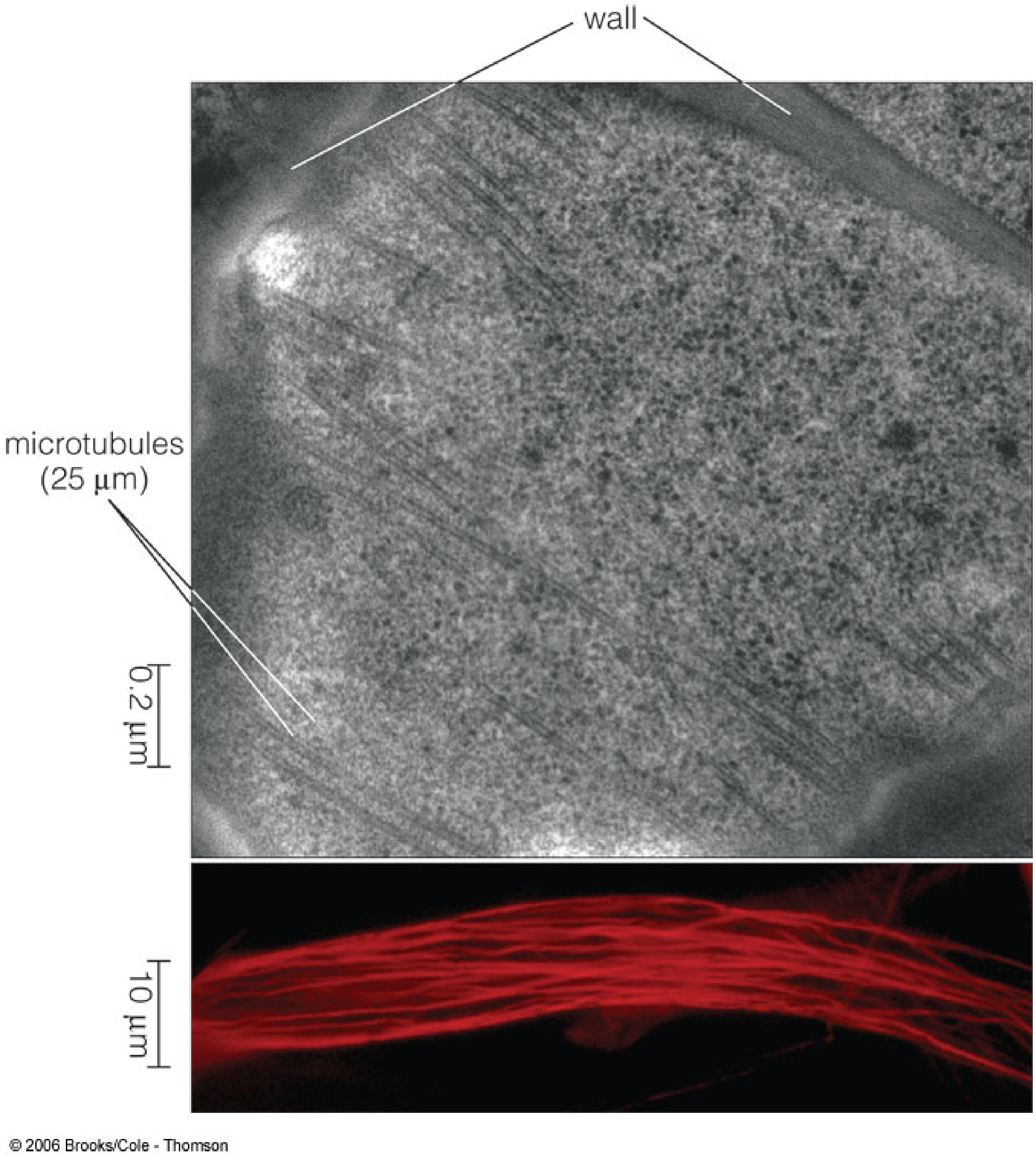
10.2 Other cell structures

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



Plant cell

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 karyokinesis
- Cytokinesis is a different process, the part of **cell cycle**

Final question (2 points)

What is the difference between symplast and apoplast?

Summary

- **Nucleus** stores and expresses genetic information
- Three main stages of cell cycle are: interphase, mitosis and cytokinesis genetic information

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology.* 2nd edition. Thomson Brooks/Cole, 2006. *Chapters 3 and 12.*

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12 Questions and answers

Previous final question: the answer

What is the difference between symplast and apoplast?

- Symplast: cytoplasm of different cells connected with plasmodesmata
- Apoplast: cell walls connected side-by-side

13 Mitosis and meiosis

13.1 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

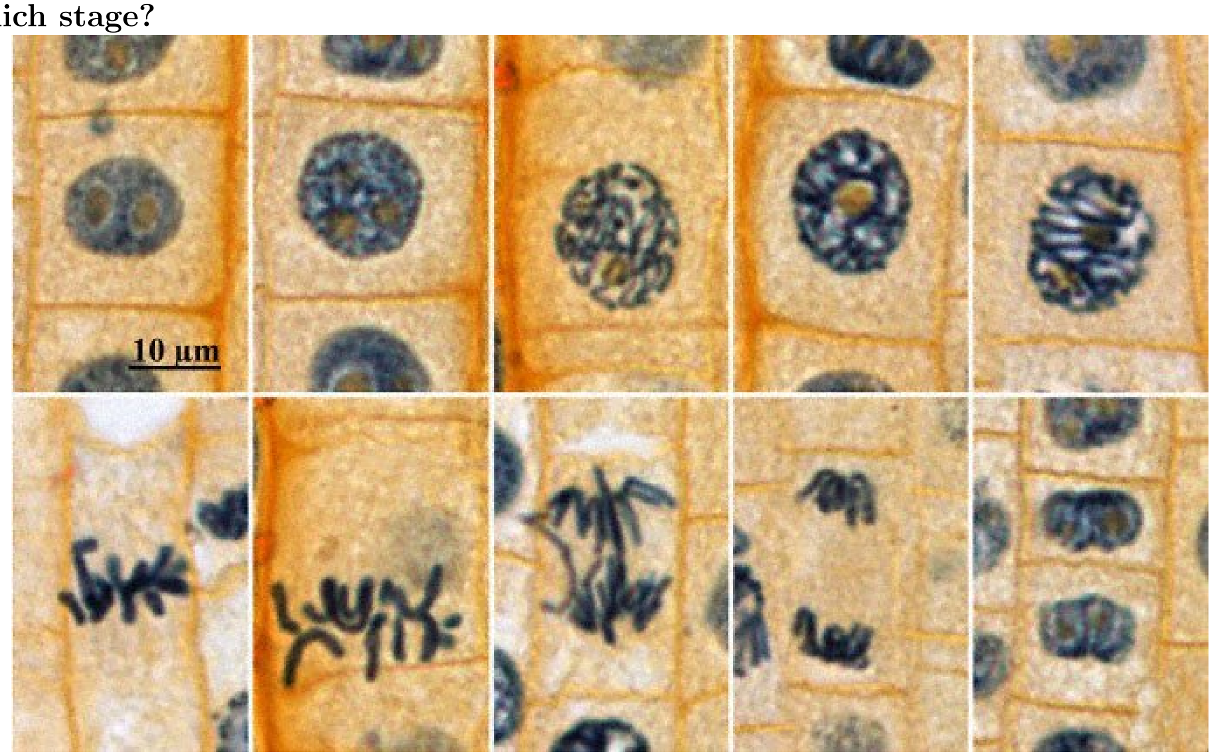
Mitosis, karyokinesis and cytokinesis

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

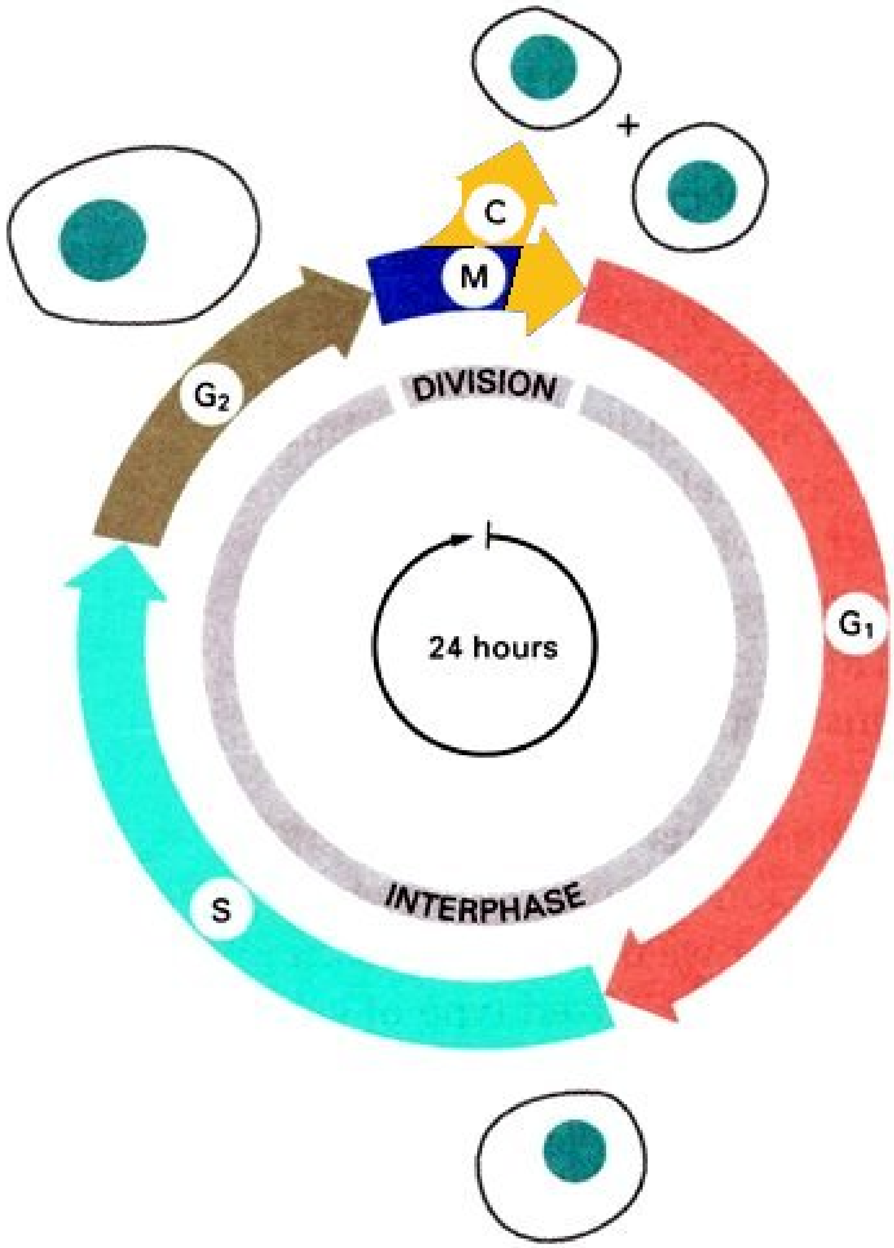
Stages of mitosis

- Prophase
- Metaphase
- Anaphase
- Telophase

Which stage?



Cell cycle



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

13.2 Meiosis

Exchange and renovation of DNA

- To sustain with the ever-changed environment, organisms must evolve
- 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 meiosis

- *Reductive cell division, where each of daughter cells receives the half of mother cell chromosomes*
- Chromosome formula: XX $\longrightarrow$ X + X $\longrightarrow$ I + I + I + I
- **The goal of meiosis** is to counterbalance the syngamy
- Meiosis changes genotype of cells because: (1) chromosomes are **recombined** and (2) chromosomes exchange their genetic material

Final question (2 points)

Why do organisms have sexual process?

Summary

- **Mitosis** is a process of cell multiplication, ploidy stays constant, genotype does not change
- **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]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 12 (skip the angiosperm life cycle!*.

Outline

Contents

14 Questions and answers

Previous final question: the answer

Why do organisms have sexual process?

- To diversify the population because diversity is a basement of natural selection and subsequent adaptation
- To reduce genetic load because carriers of lethal mutations will die; consequently, these mutations will not be transfered to the offspring

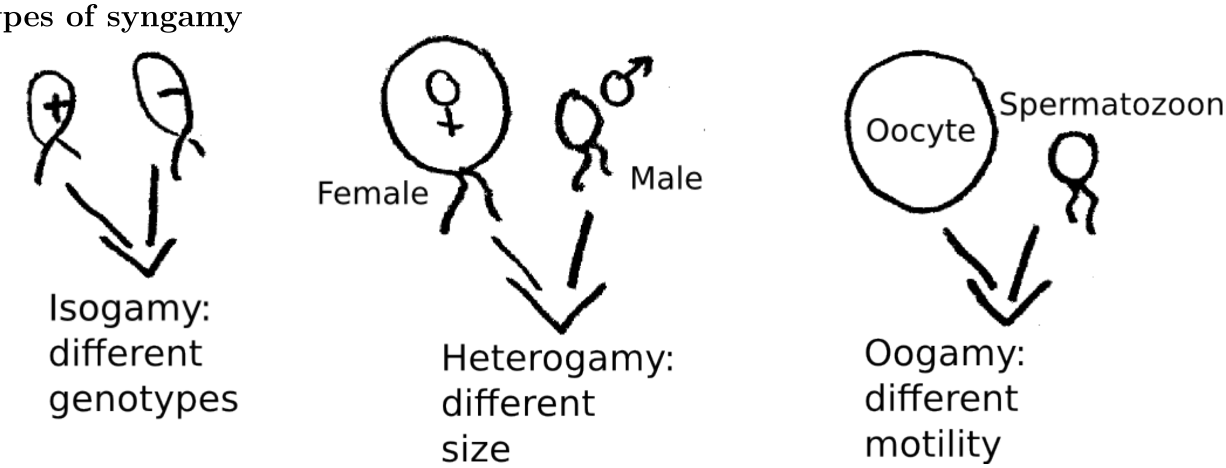
15 Mitosis and meiosis

15.1 Syngamy (Y!)

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



15.2 Meiosis (R!)

Some useful terms

- Gene
- Protein

- Enzyme
- Genotype
- Genome
- Population
- Mutation
- Syngamy

Exchange and renovation of DNA

- To sustain with the ever-changed environment, organisms must evolve
- 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 meiosis

- *Reductive cell division, where each of daughter cells receives the half of mother cell chromosomes*
- Chromosome formula: XX $\longrightarrow$ X + X $\longrightarrow$ I + I + I + I
- **The goal of meiosis** is to counterbalance the syngamy
- Meiosis changes genotype of cells because: (1) number of chromosomes reduced, (2) chromosomes are **recombined** and (3) chromosomes exchange their genetic material

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

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**

Final question (2 points)

What is the difference between anaphase I of meiosis and anaphase of mitosis?

Summary

- **Mitosis** is a process of cell multiplication, ploidy stays constant, genotype does not change
- **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]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

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Outline

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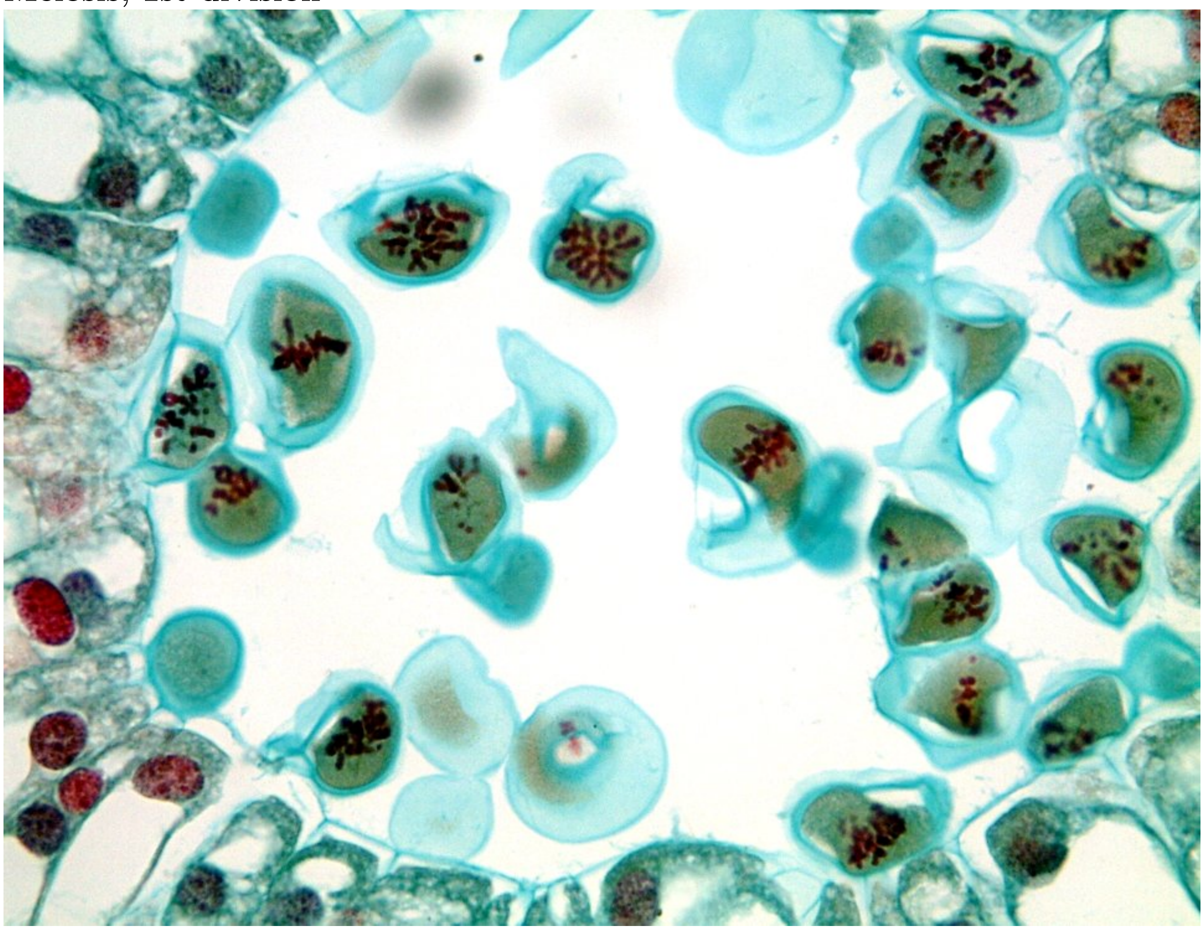
16 Questions and answers

Previous final question: the answer

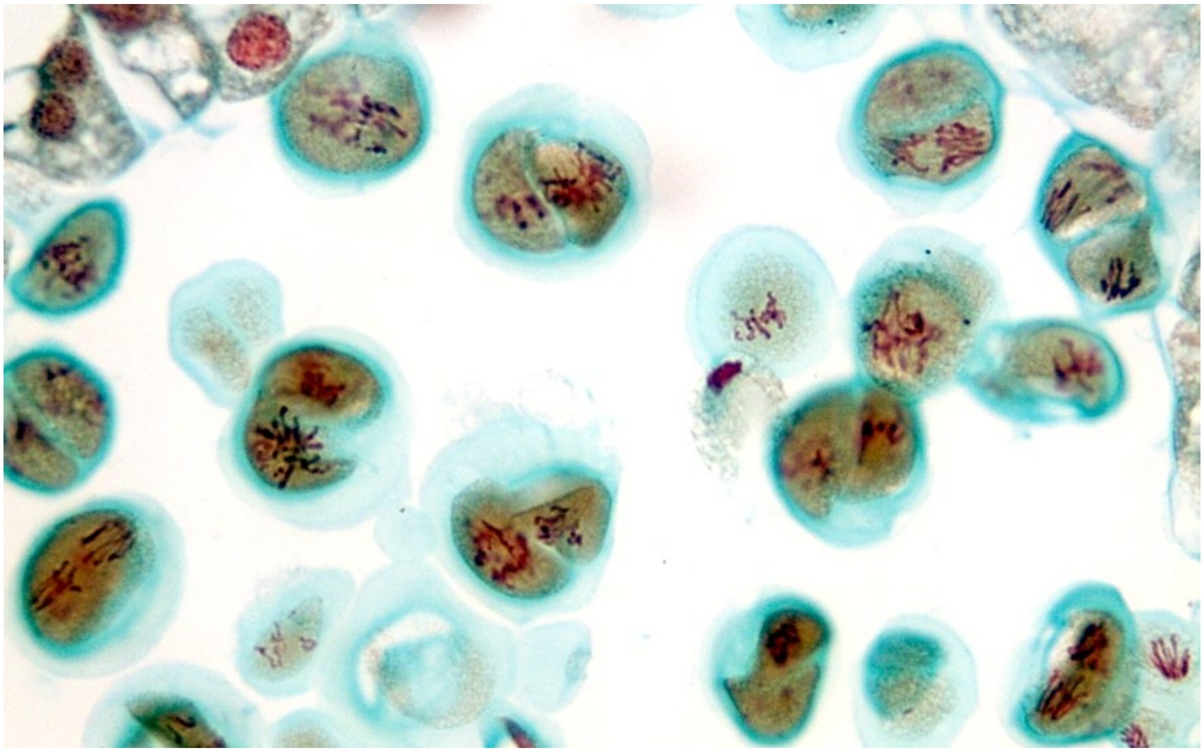
What is the difference between anaphase I of meiosis and anaphase of mitosis?

- Meiosis: homologous chromosomes will go *independently* to different poles
- Mitosis: halves of *every* chromosome go to different poles

Meiosis, 1st division



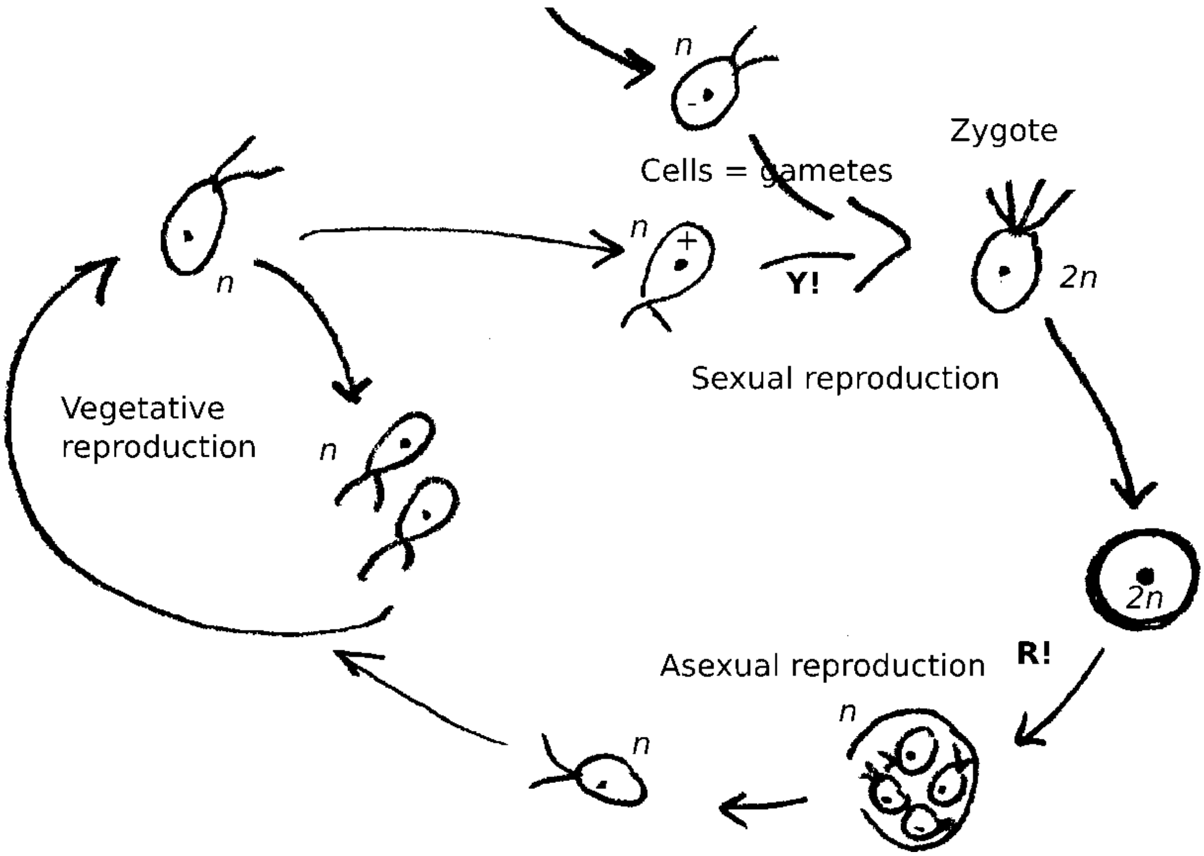
Meiosis, 2nd division



17 Life cycle

17.1 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

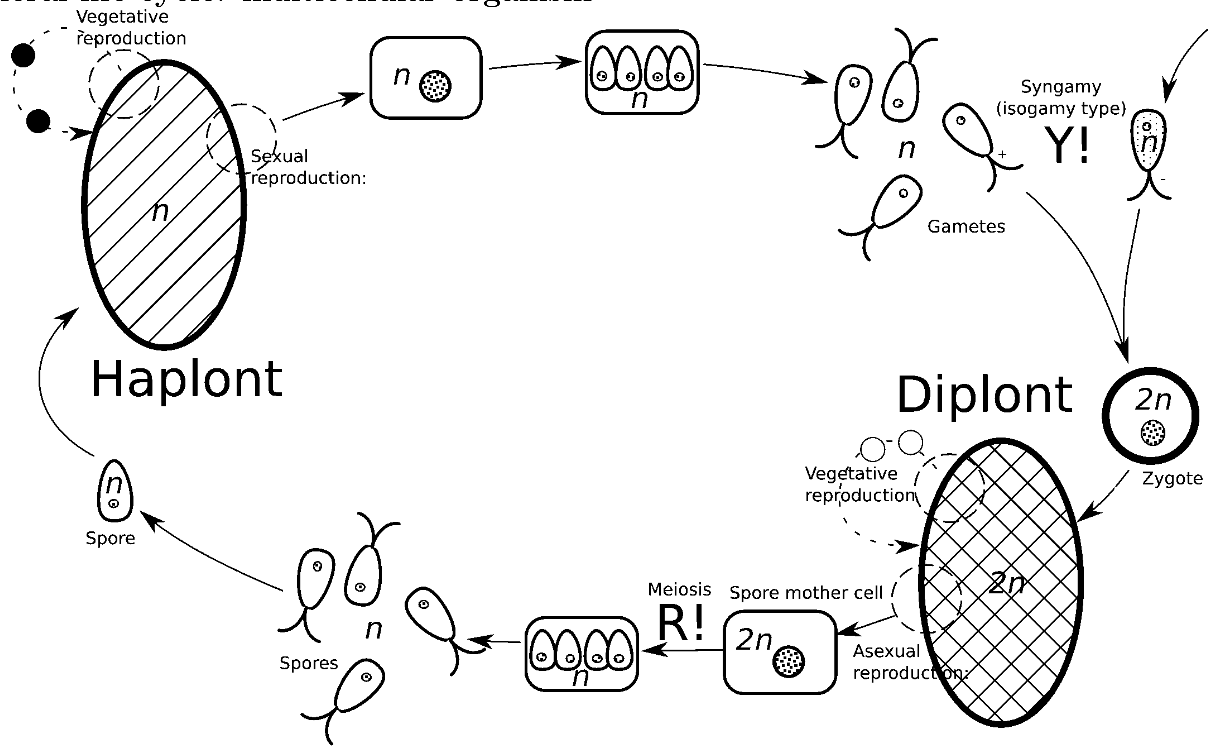
Multicellularity, or Origin of Death

- 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**.

General life cycle: multicellular organism



Associated terms: haplont, diplont, spores, mitospores

Final question (2 points)

In most organisms, cells participating in syngamy are unequal (male and female).Why?

Summary

- **Mitosis** is a process of cell multiplication, ploidy stays constant, genotype does not change
- **Meiosis** is a process of reduction of DNA amount, ploidy halves, genotype changes
- **Syngamy** is a process of DNA renovation, ploidy doubles, genotype changes

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 12 (skip the angiosperm life cycle!)*.

Outline

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18 Questions and answers

Previous final question: the answer

In most organisms, cells participating in syngamy are unequal (male and female).Why?

- This is a division of labor which saves resources. They are concentrated in one place ("female") whereas the other gender ("male") may increase in number to make fertilization more likely.
- It is easier to recognize different genotypes if they have phenotypic differences.

Two fundamental evolutionary ideas

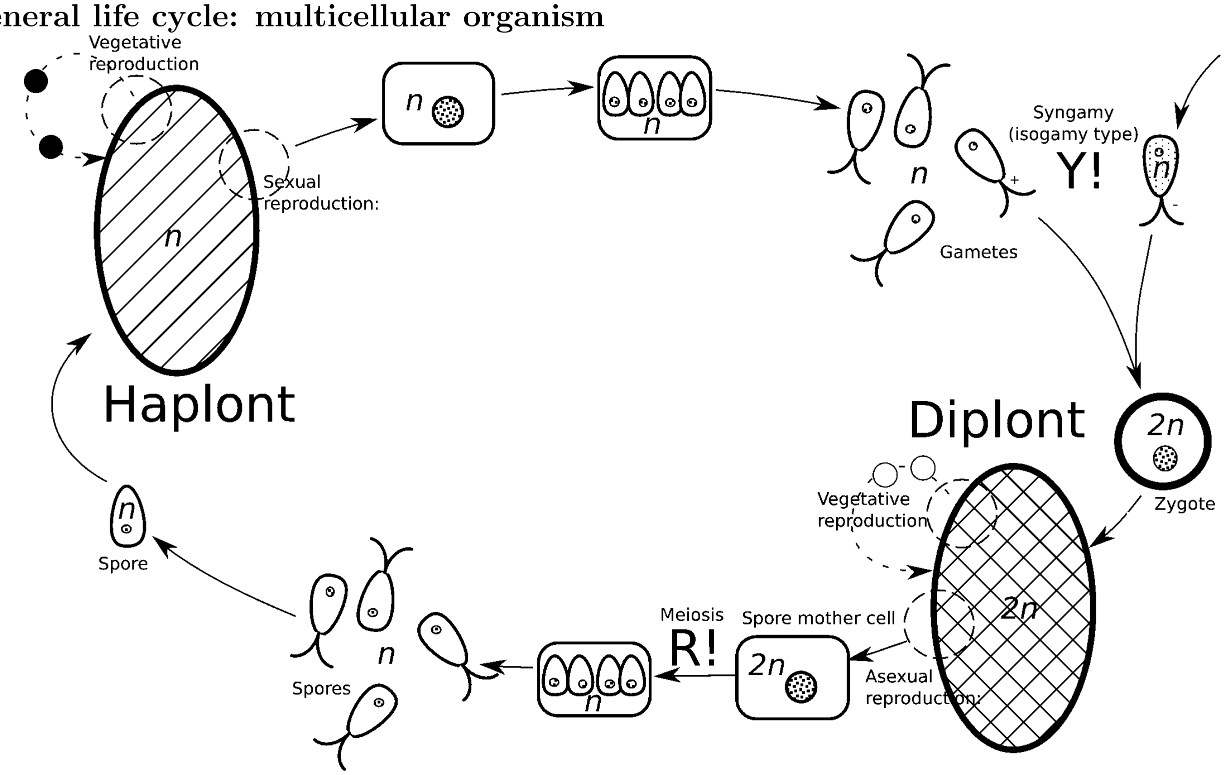
DIVISION OF LABOR Split the work to make life easier. Examples: male and female, germ and somatic cells

ARMS RACE For every action, there is an opposite reaction. Examples: effective predation causes the growing of prey, that happens in the origin of eukaryotes and origin of multicellularity

19 Life cycle

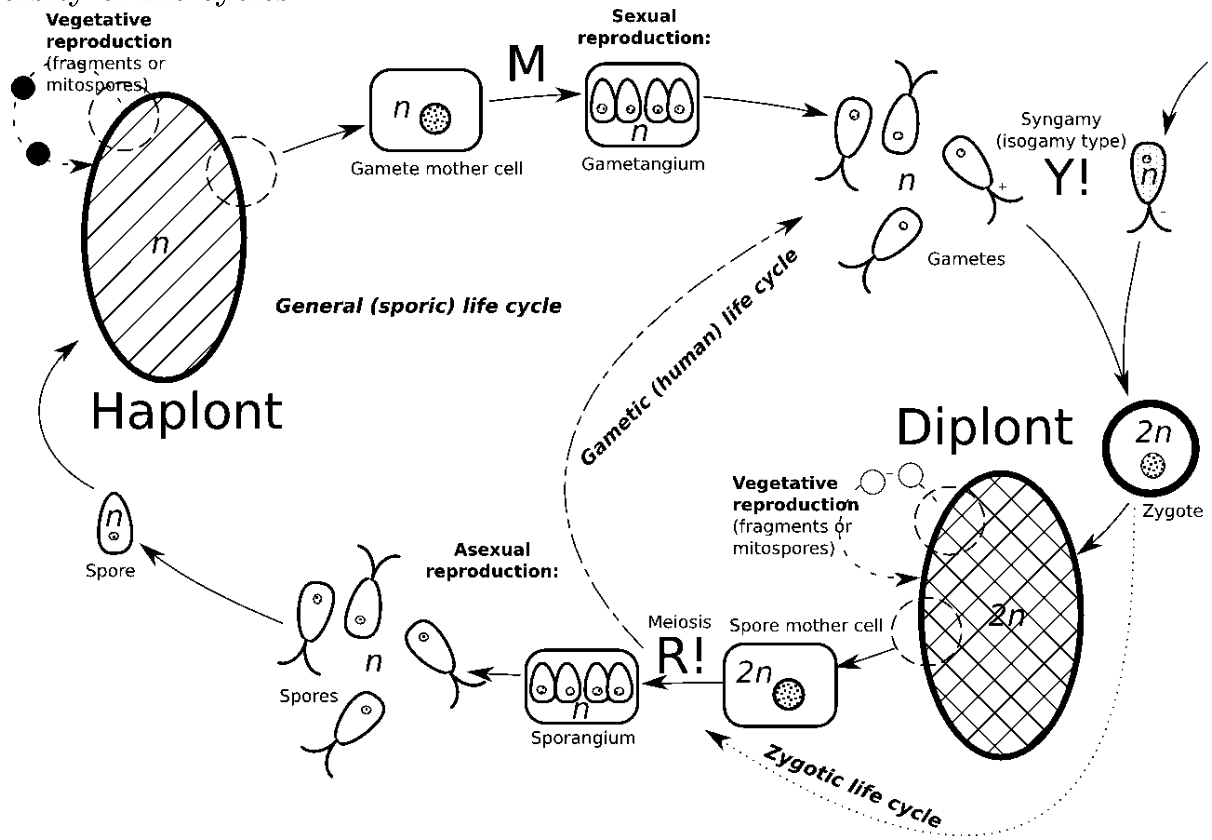
19.1 Diversity of life cycles

General life cycle: multicellular organism

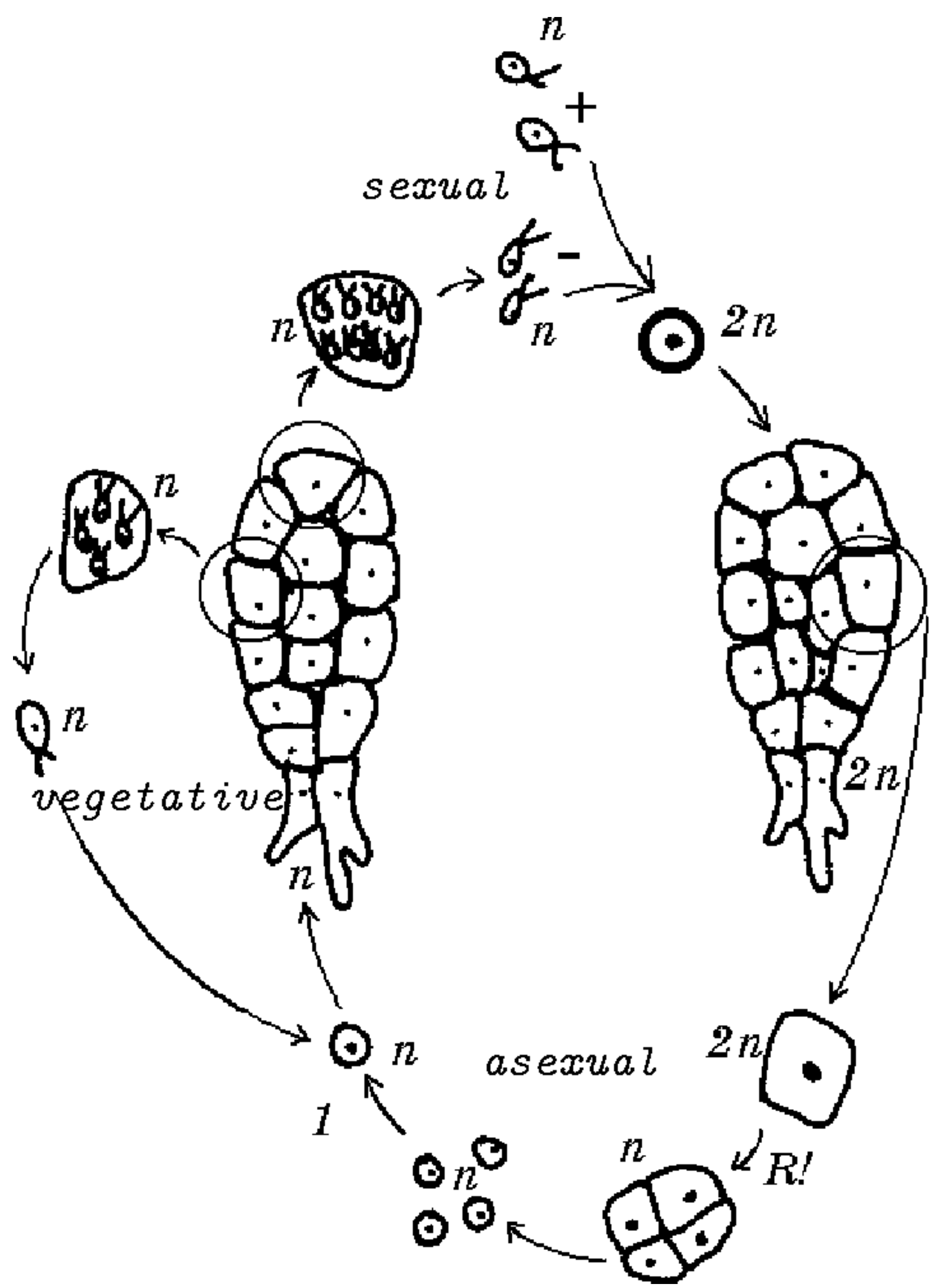


Associated terms: mitosis, meiosis (R!), syngamy (Y!), reproduction, sexual reproduction, asexual reproduction, vegetative reproduction, isogamy, heterogamy, oogamy, zygote, gamete, male, female, spermatozoon, oocyte, haplont, diplont, spores, mitospores

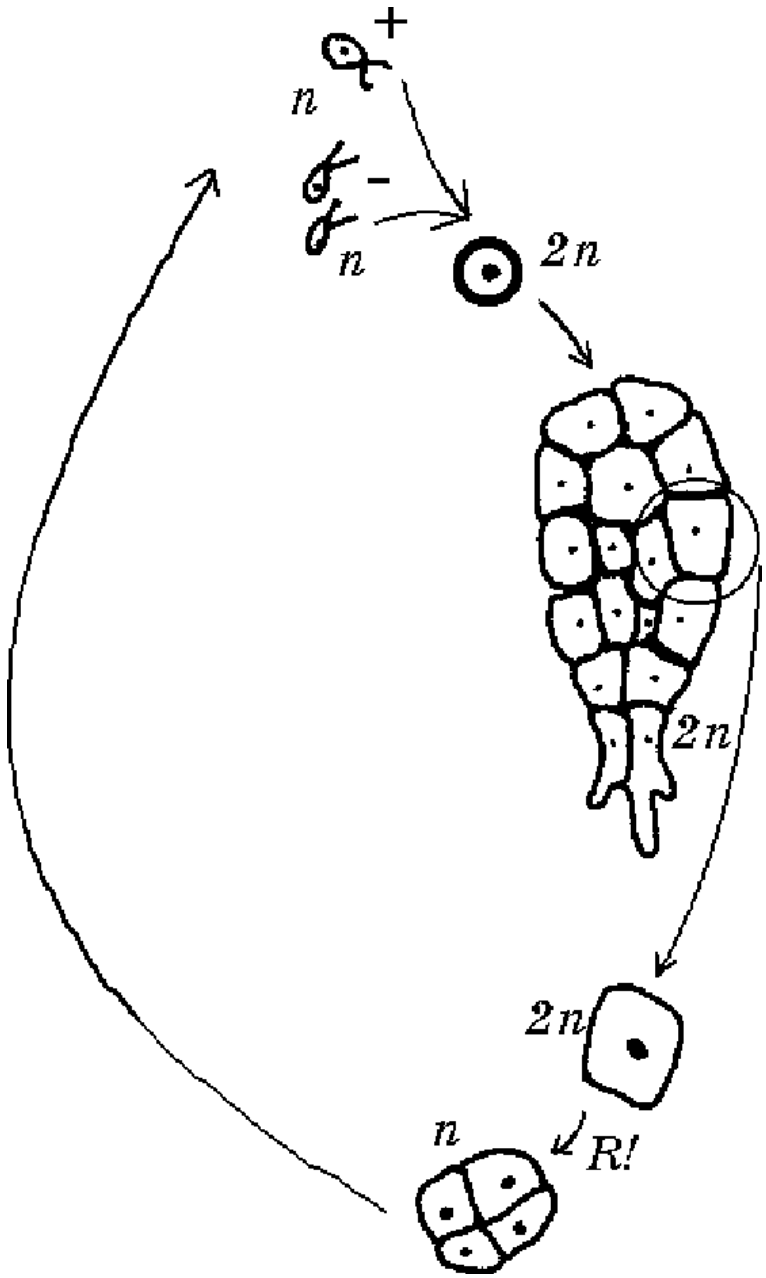
Diversity of life cycles



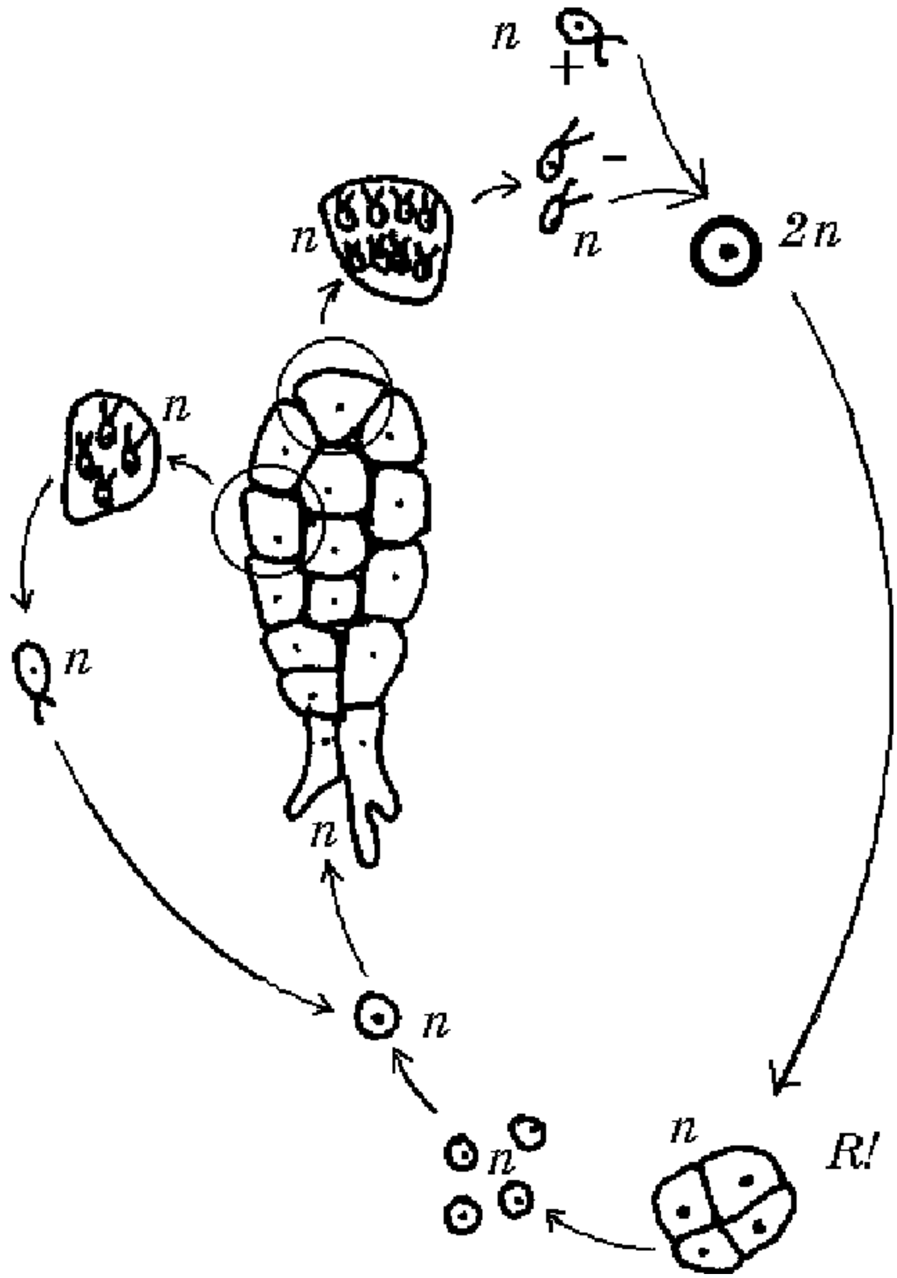
Sporic life cycle: plants



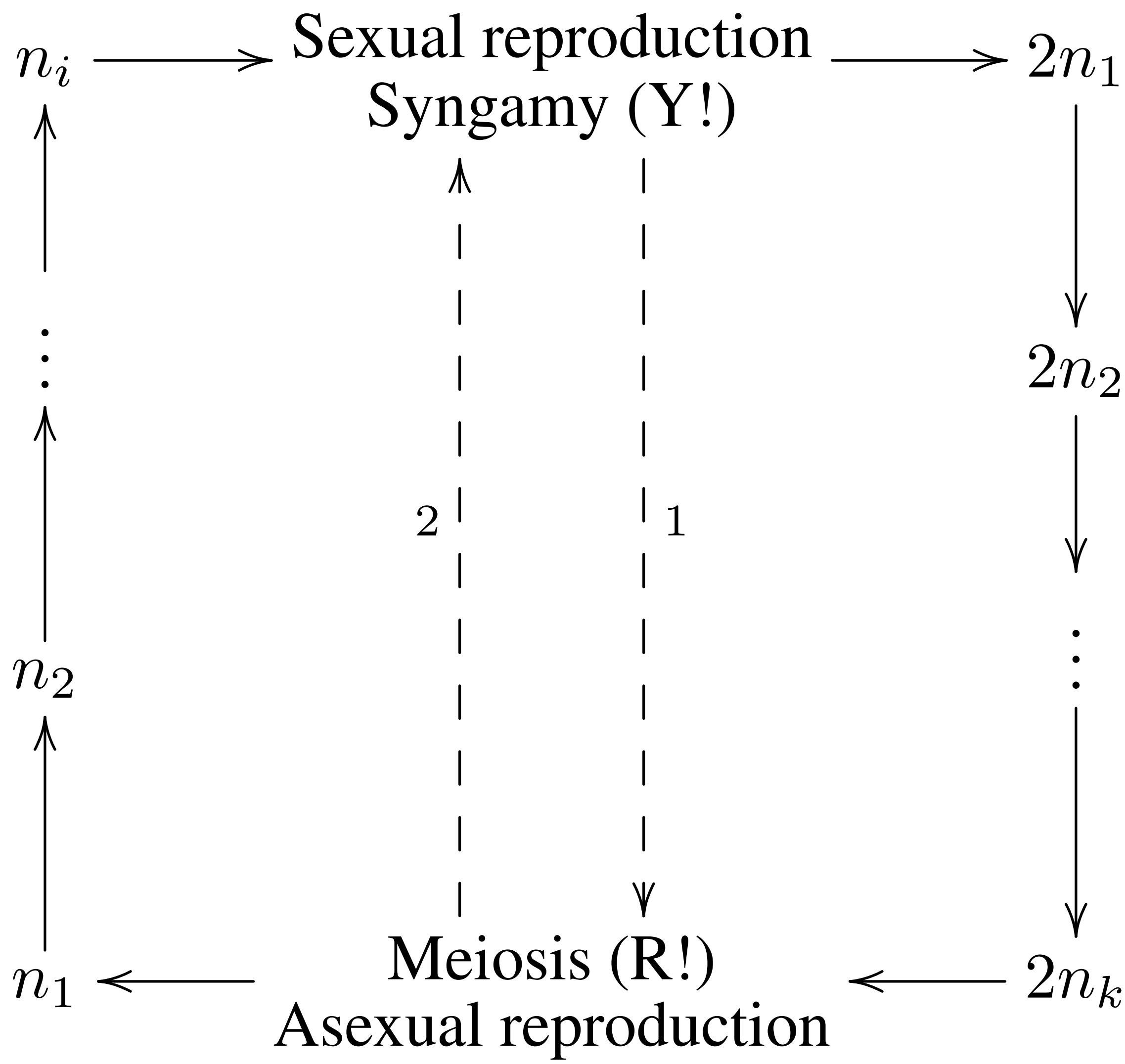
Gametic life cycle: animals



Zygotic life cycle: protists



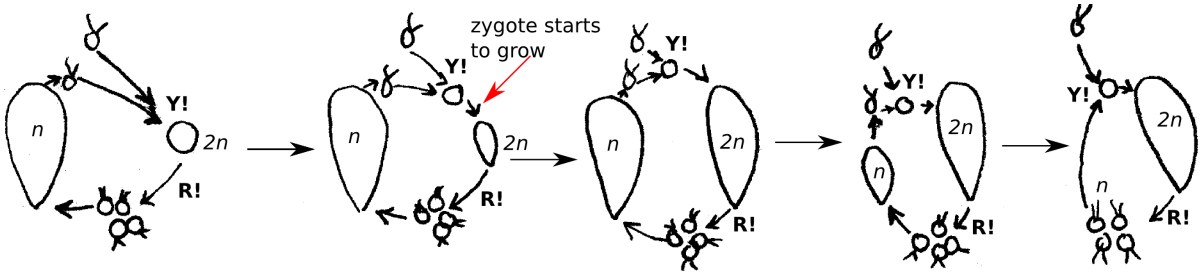
Life cycle math



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

19.2 Evolution of life cycles

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

Final question (2 points)

What is the difference between zygotic and gametic life cycles?

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 preferred in the evolution

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 12 (skip the angiosperm life cycle!).*

Outline

Contents

20 Questions and answers

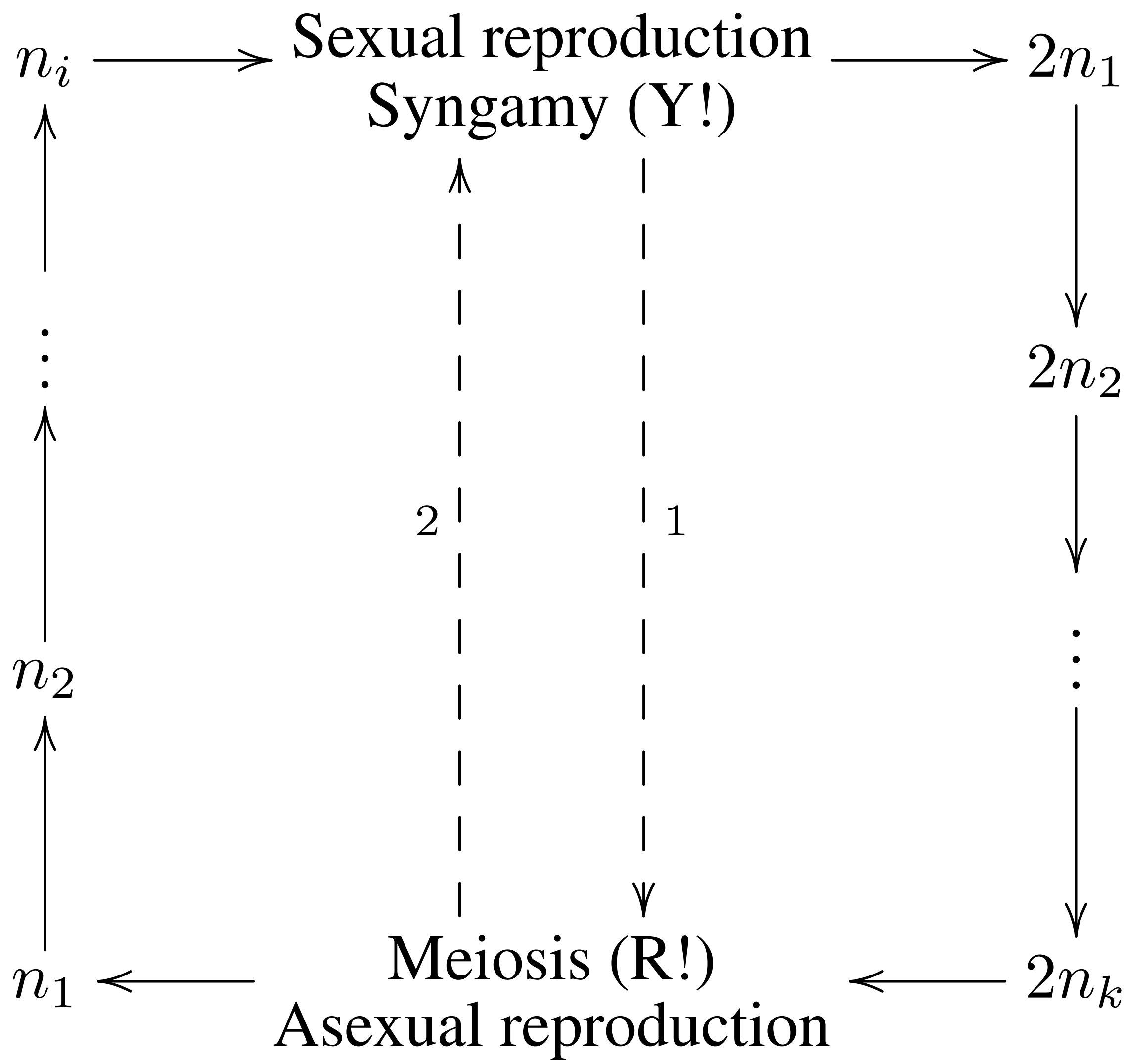
Previous final question: the answer

What is the difference between zygotic and gametic life cycles?

- **Zygotic**: Y! → R!, no diplont, many protists
- **Gametic**: R! → Y!, ho haplont, animals and few protists

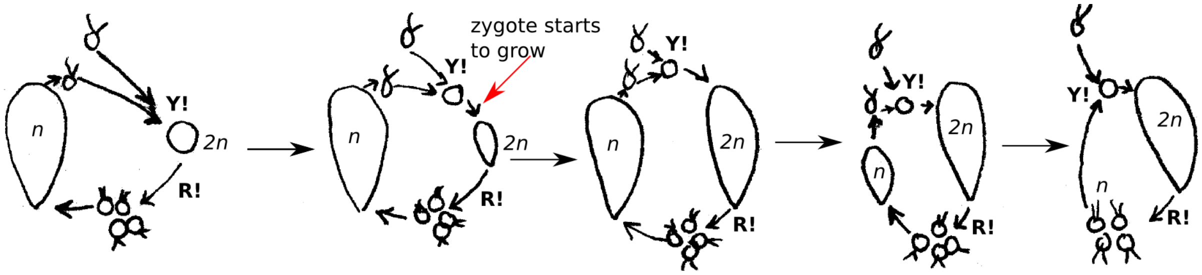
21 Life cycles

Life cycles



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

Evolution of life cycles: diplonts grow, haplonts reduce

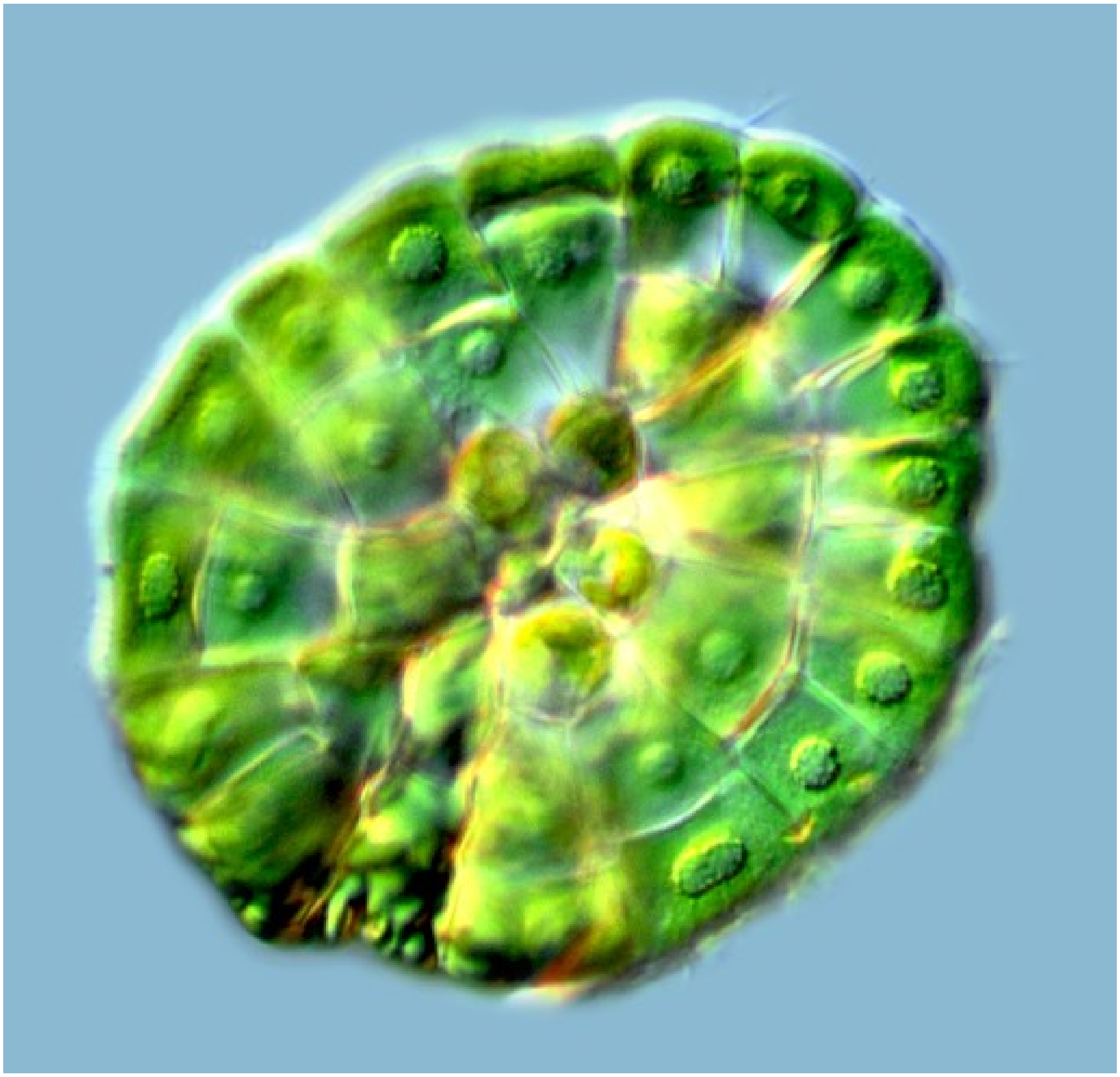


Directions of life cycle evolution

- The simplest life cycle of unicellular organism is the alternation of syngamy (cell fusion) and meiosis
- Next stage is a zygotic cycle of many algae and fungi
- When zygote starts to divide without changing genotype, sporic life cycle arises
- Initial sporic cycle was probably with haplont dominance (mosses), then with equal generations
- Advanced sporic cycle is with diplont predominance (ferns and seed plants)
- Finally, gametic cycle of animals and some algae in the final step of life cycle evolution

21.1 Origin of plants$_2$: life cycle

Stonewort, *Coleochaete scutata*

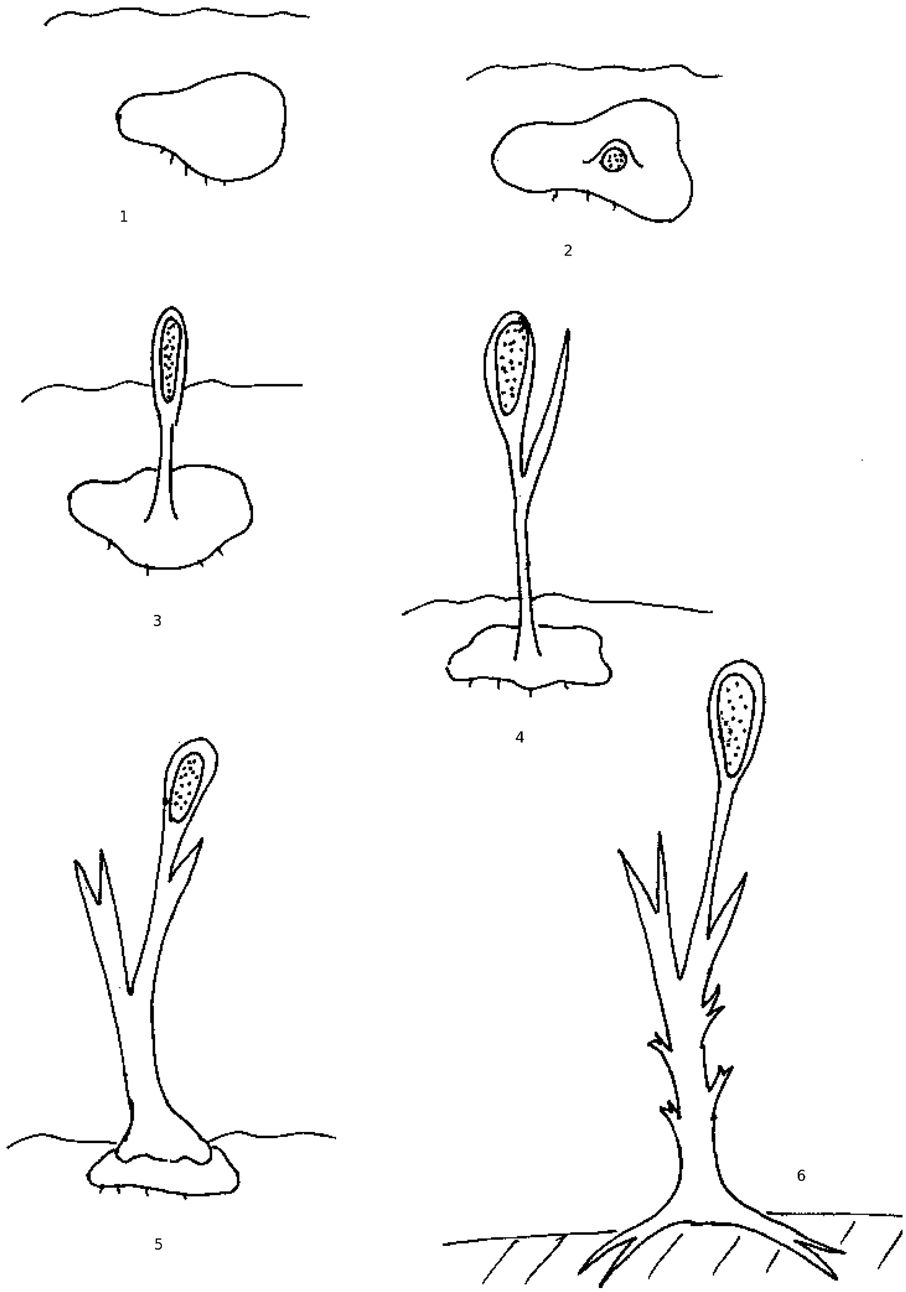


Stonewort is an alga with zygotic life cycle but it belongs to the **sister group** of all $plants_2$

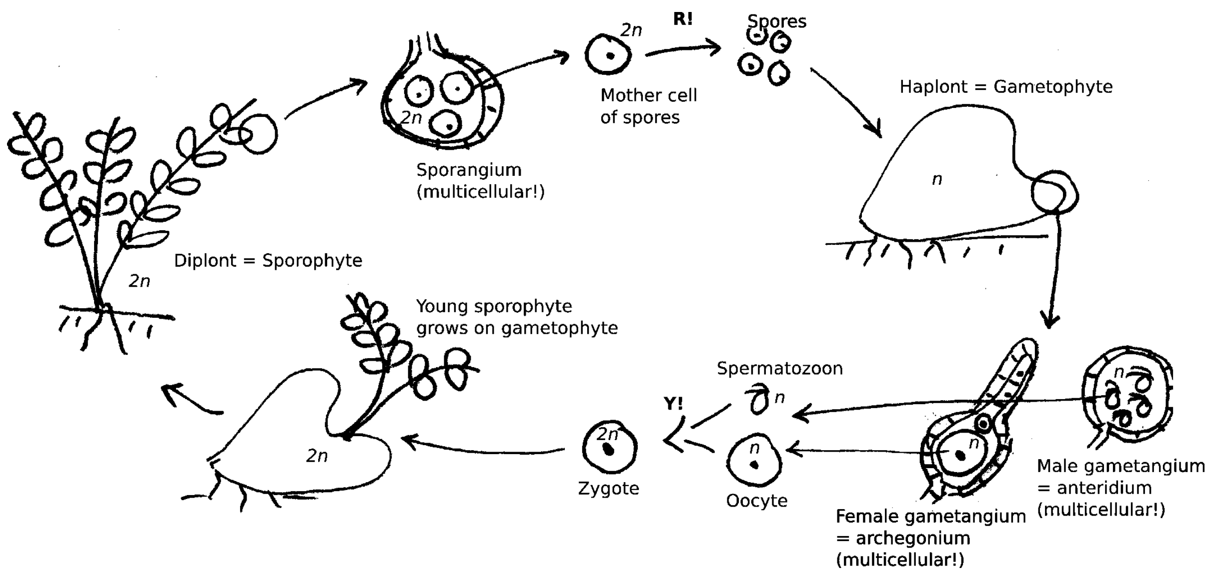
Origin of sporophyte in $plants_2$

- Land colonization requires the intensive reproduction
- Distribution of spores is more effective with wind
- Diploid sporangium on the stalk is one of most effective ways

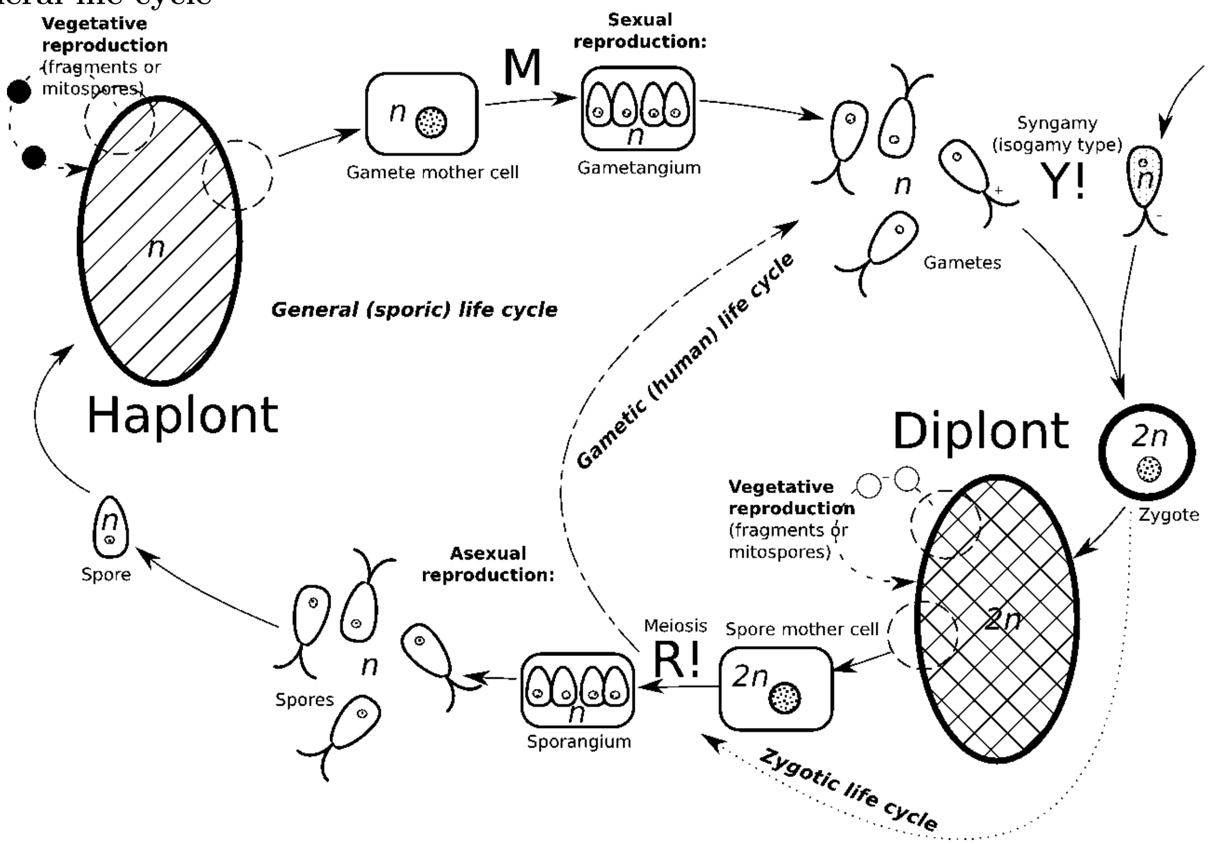
Origin of sporophyte in $plants_2$



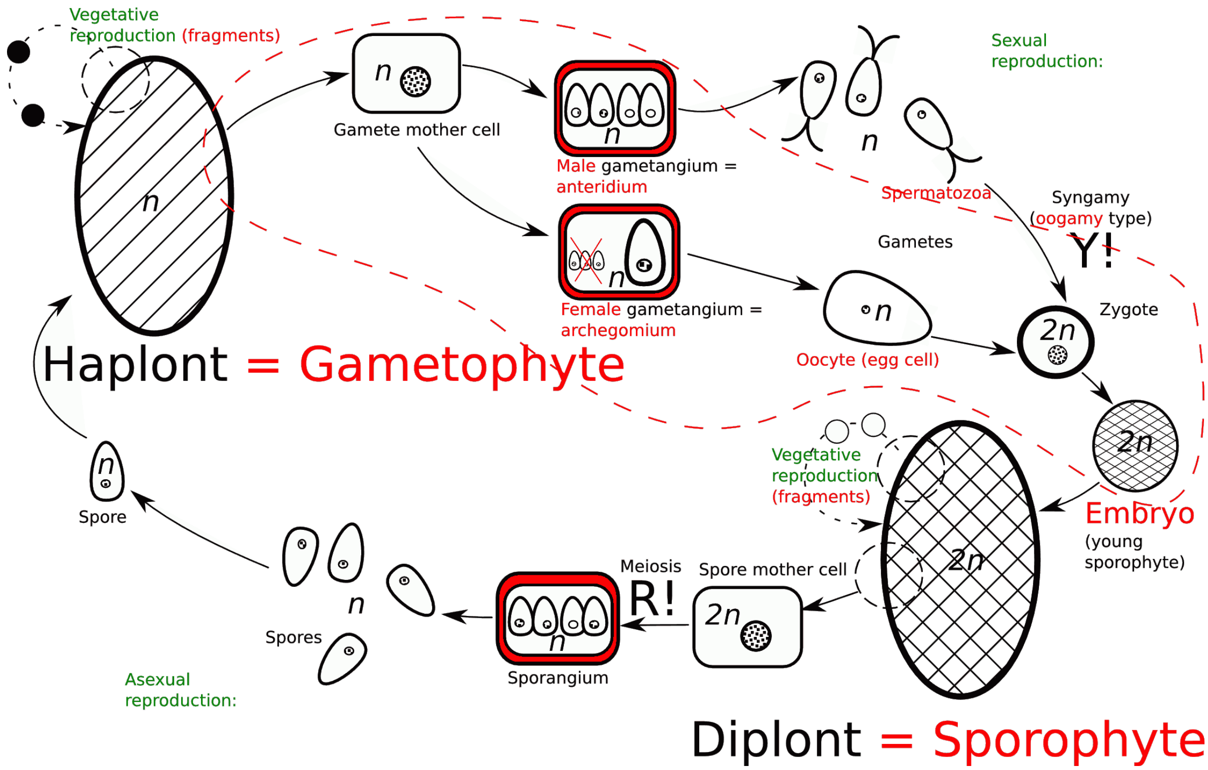
Life cycle of land plants



General life cycle



Life cycle of land plants: differences



Final question (2 points)

Why is diplont better?

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 preferred in the evolution

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