Introduction to Botany: BIOL 154
Study guide for Exam 2

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Lectures 7–17

Contents

Outline

1 Questions and answers

Previous final question: the answer

Explain the difference between light and enzymatic stages of the photosynthesis.

- Energy
- Carbon dioxide
- ~~Darkness~~

Enzymatic stage is not "dark", is light-independent!!! If you switch the light off, in seconds photosynthesis will altogether stop.

Exam 1

1) Nucleotides
2) pH

2 Photosynthesis

2.1 Special case of photosynthesis: C_4 pathway

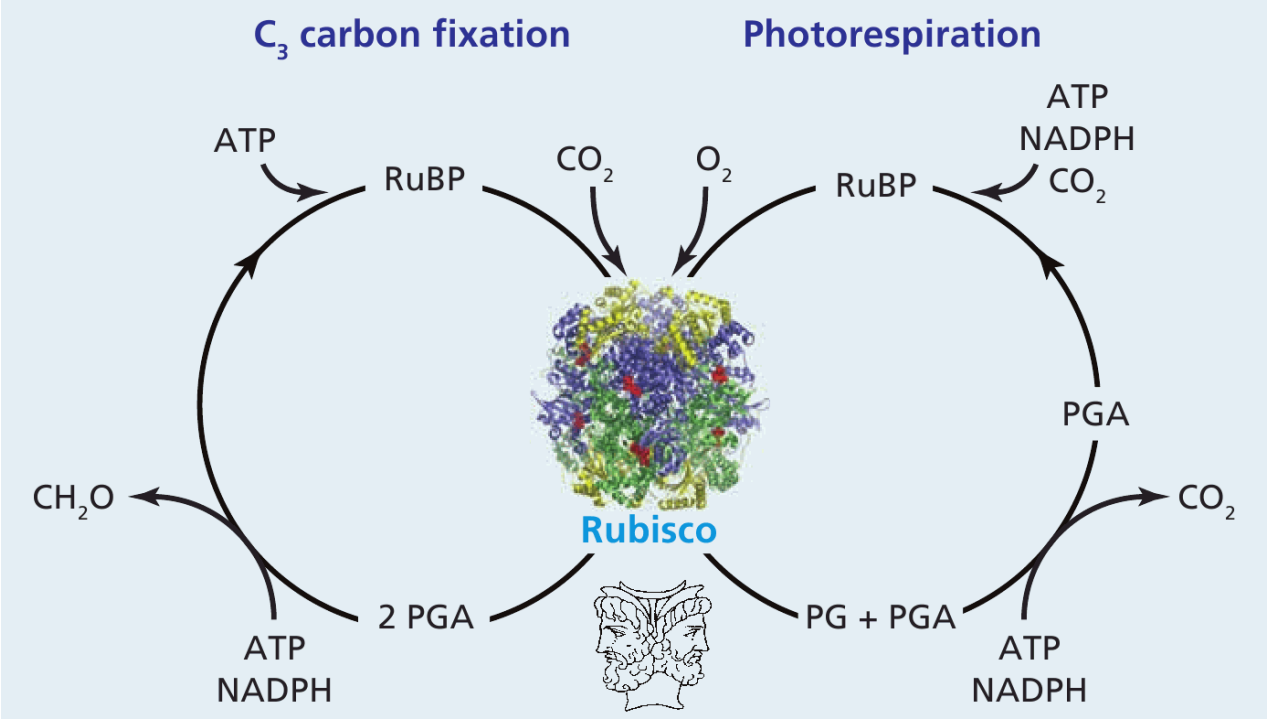
Photorespiration

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



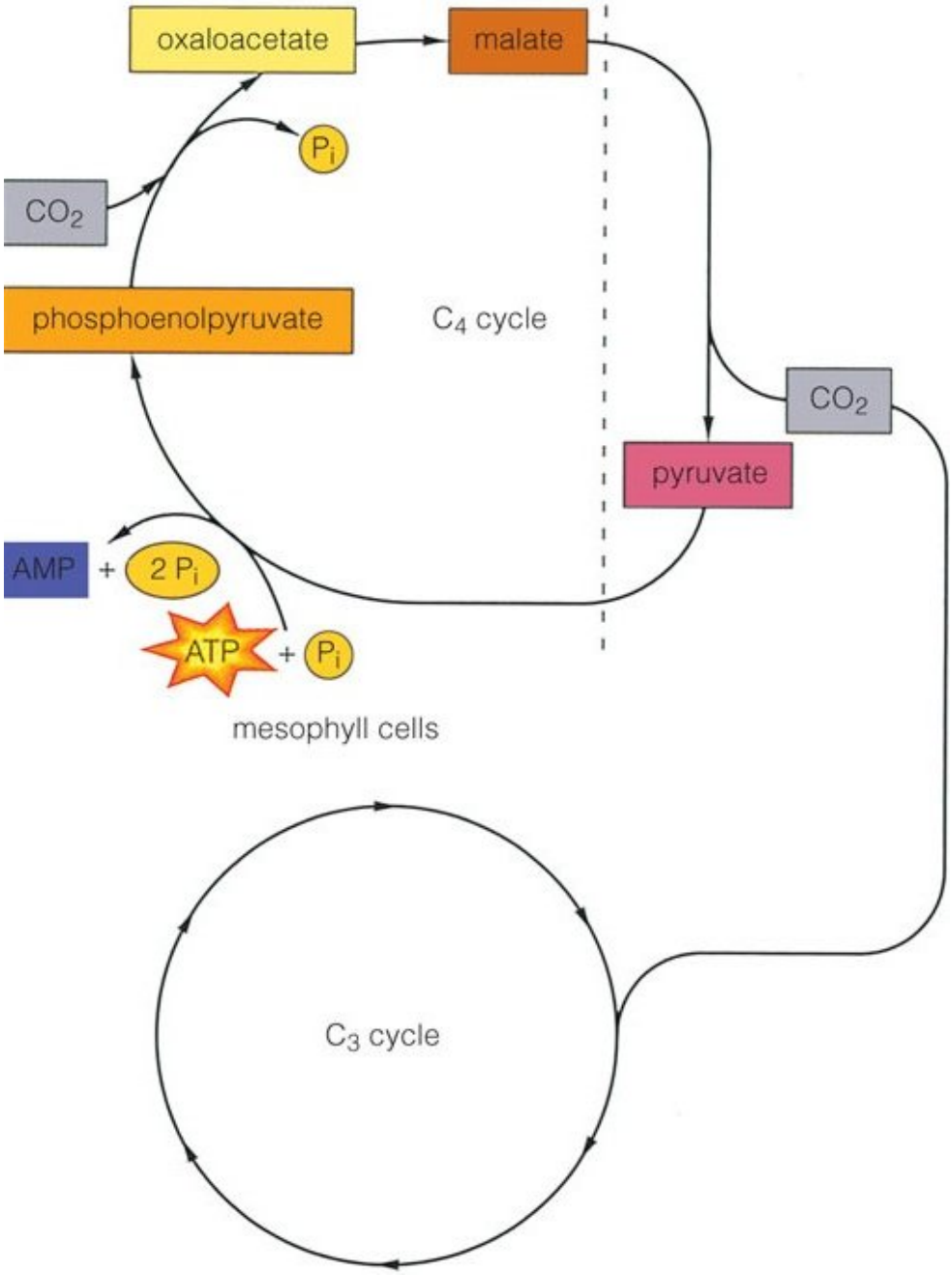
Minimization of photorespiration

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

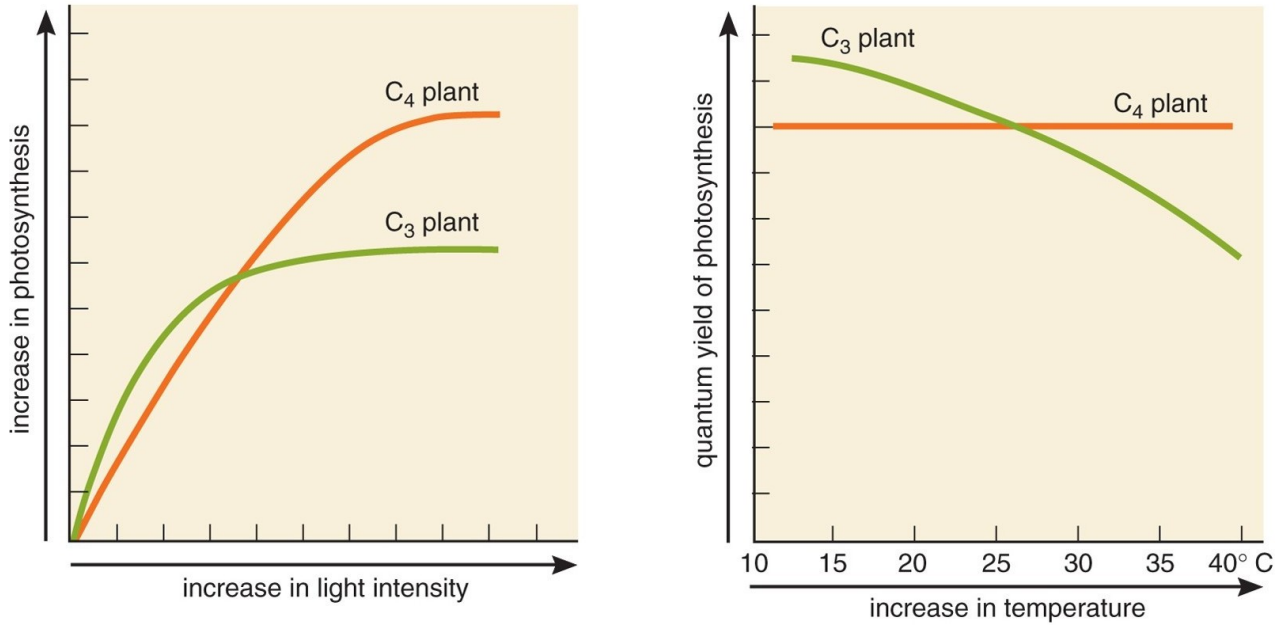
1. $CO_2 + C_5$ (PEP, phosphoenolpyruvate) $\xrightarrow{\text{PEP carboxylase}} C_4$ (different organic acids): this is the temporarily accumulation of carbon dioxide
2. $C_4 \longrightarrow$ pyruvate + CO_2: release of carbon dioxide will increase its concentration
3. Pyruvate + ATP $\longrightarrow$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

Summary

- To prevent wasteful **photorespiration**, plants "invented" the addition to photosynthesis, C_4-pathway
- Plants with C_4 pathway accumulate and then release carbon dioxide and therefore increase its concentration

For Further Reading

References

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

Outline

3 Questions and answers

Previous final question: the answer

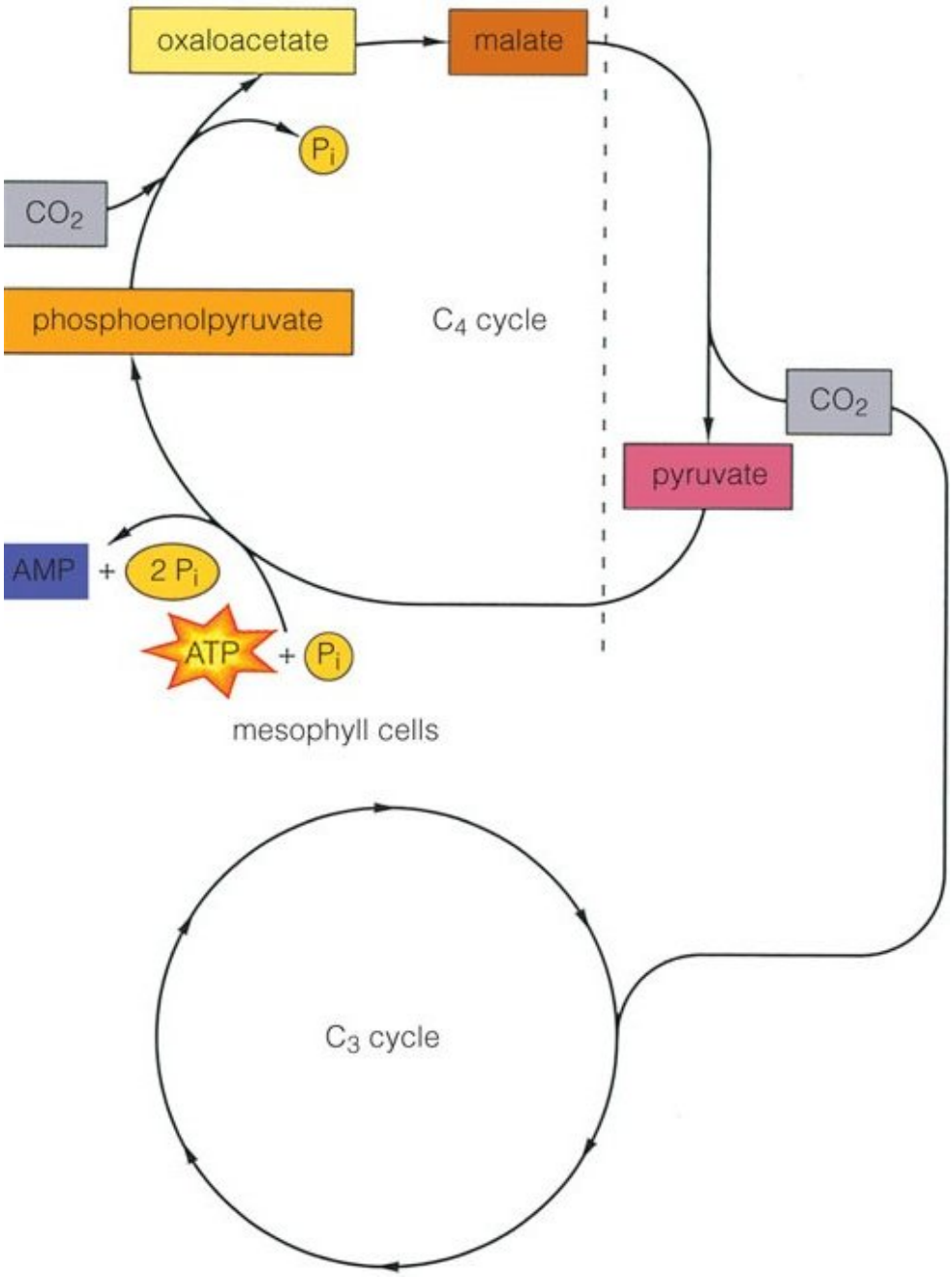
Why C_4 is better than C_3?

In essence, it decreases photorespiration which is especially helpful at higher temperatures—when all chemical reactions speed up, light stage makes more oxygen and in addition, plant close its stomata to prevent water loss.

4 Photosynthesis

4.1 Special case of photosynthesis: C_4 pathway

C_4 pathway at-a-glance

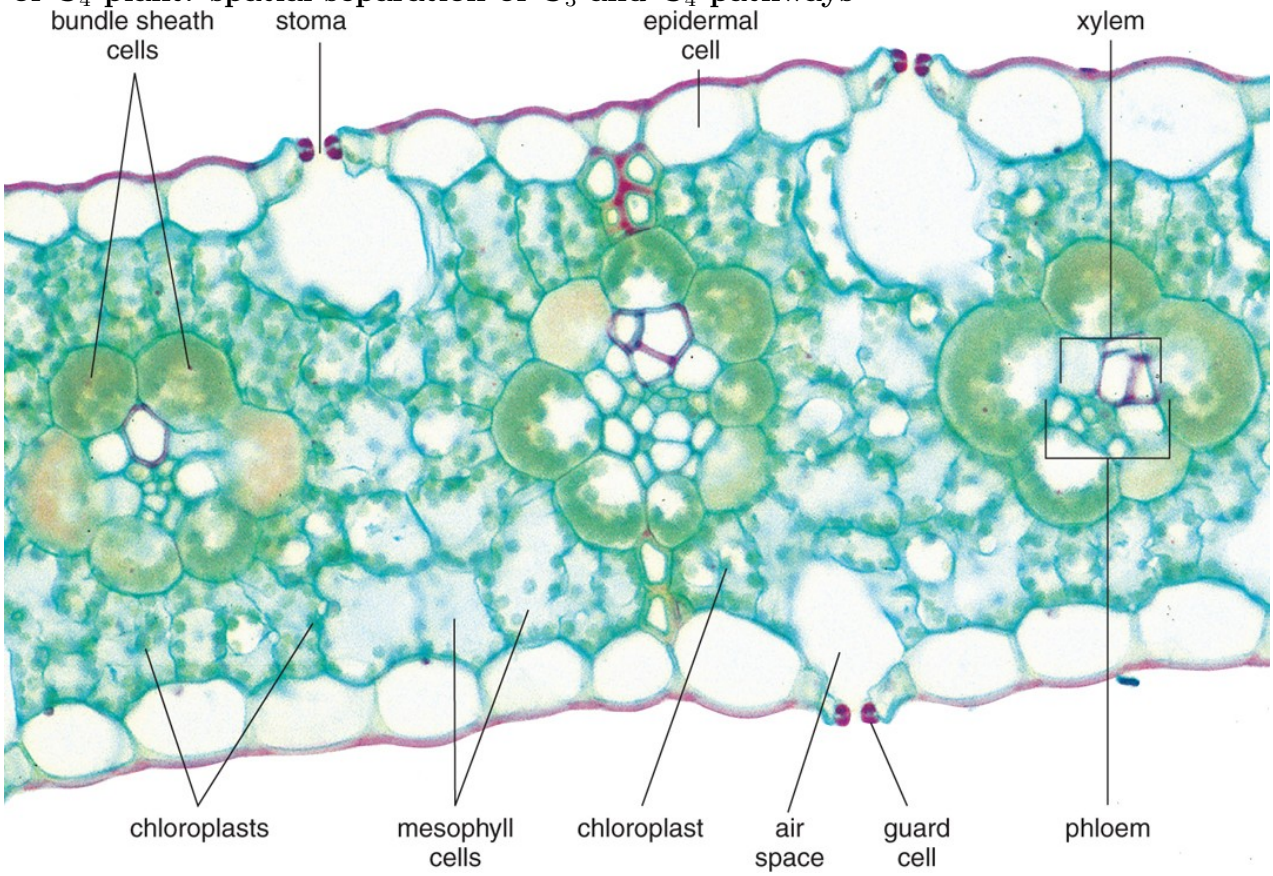


C_4 and CAM plants both use C_4 pathway

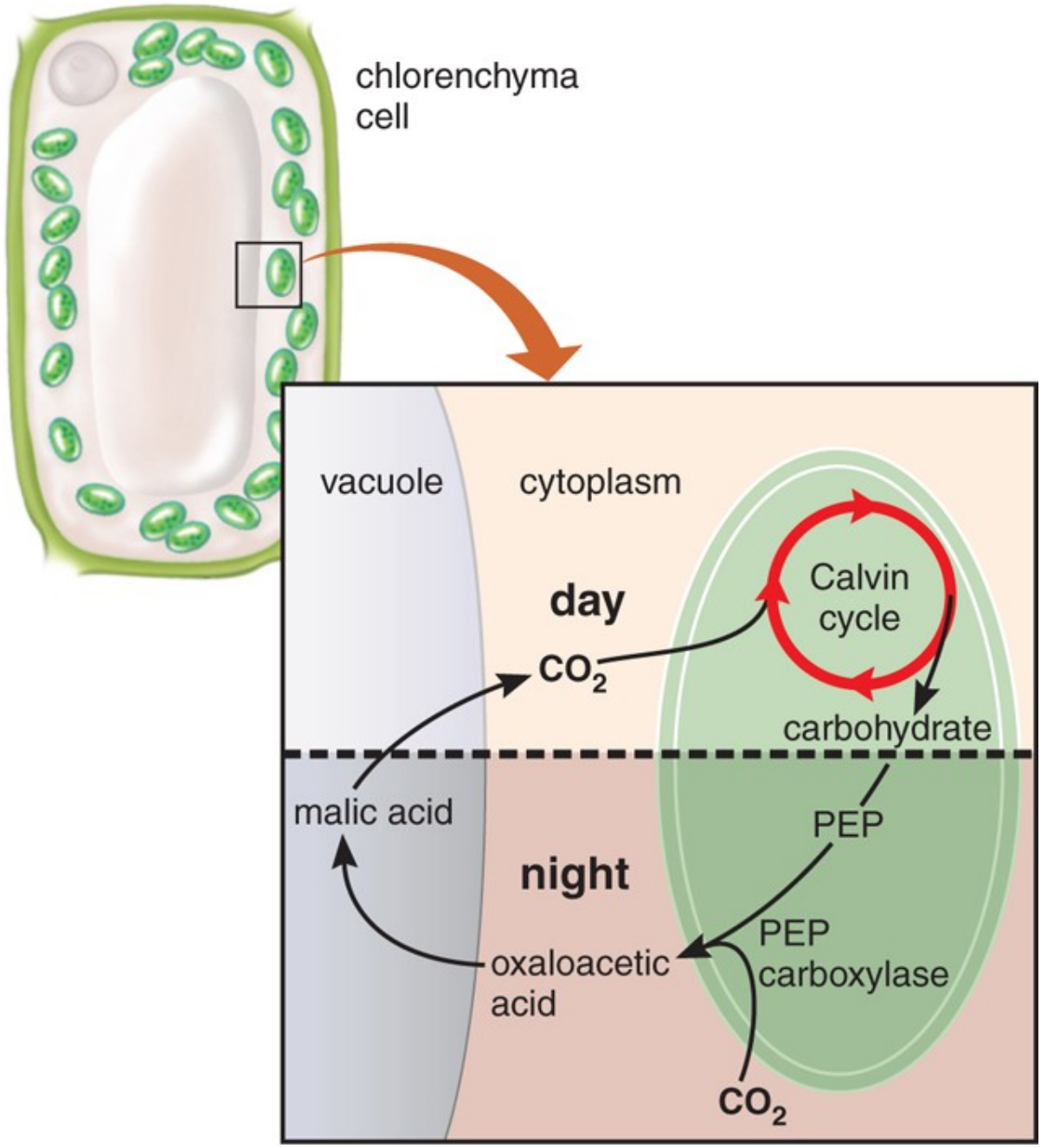
- **CAM-plants** which drive C_4 cycle at nights:
  - This is a **temporal** separation between accumulation of CO_2 and photosynthesis)
  - CAM-plants (17,000 species, 7% of plant biodiversity) are mostly succulents from different orders and families (e.g., cacti—Cactaceae from Caryophyllales)
- **C_4-plants** 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)

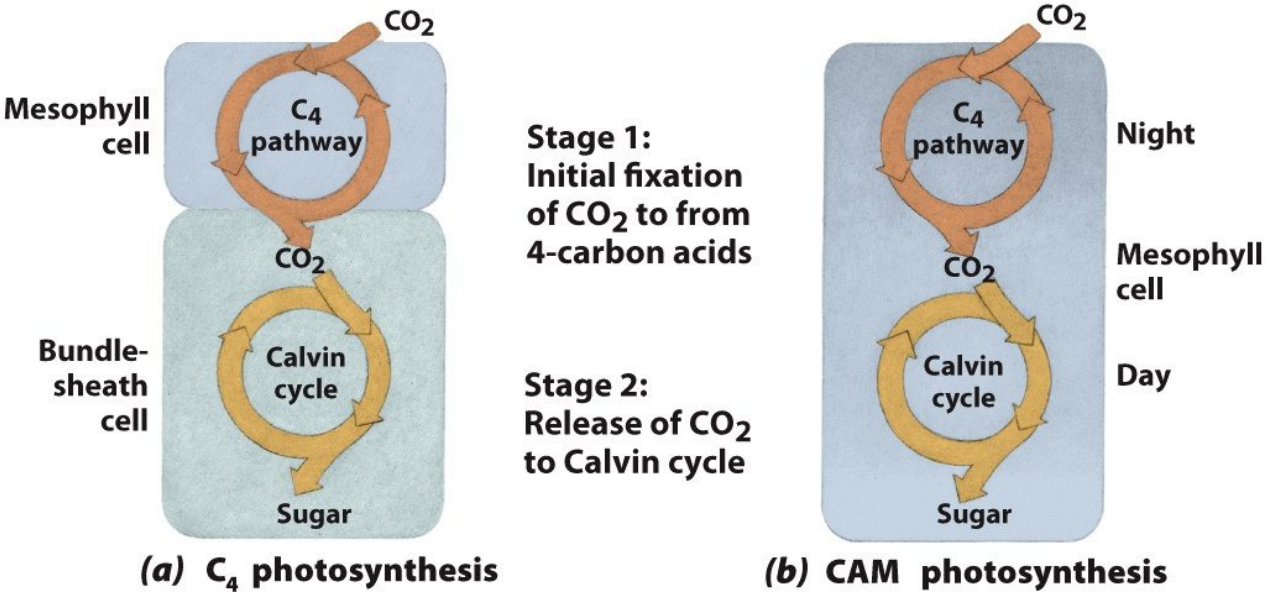
Leaf of C_4 plant: spatial separation of C_3 and C_4 pathways



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

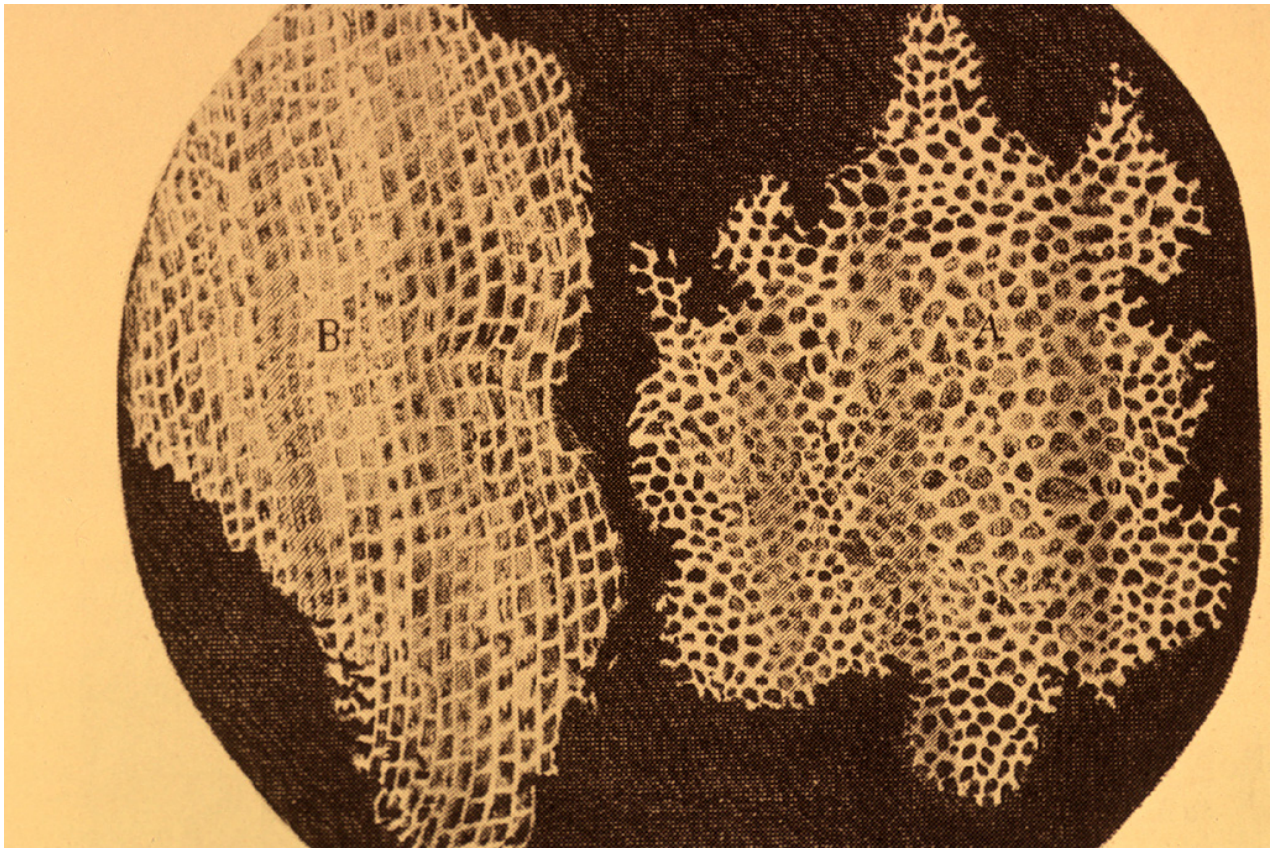
Why to know photosynthesis?

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

5 Plant cell

5.1 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

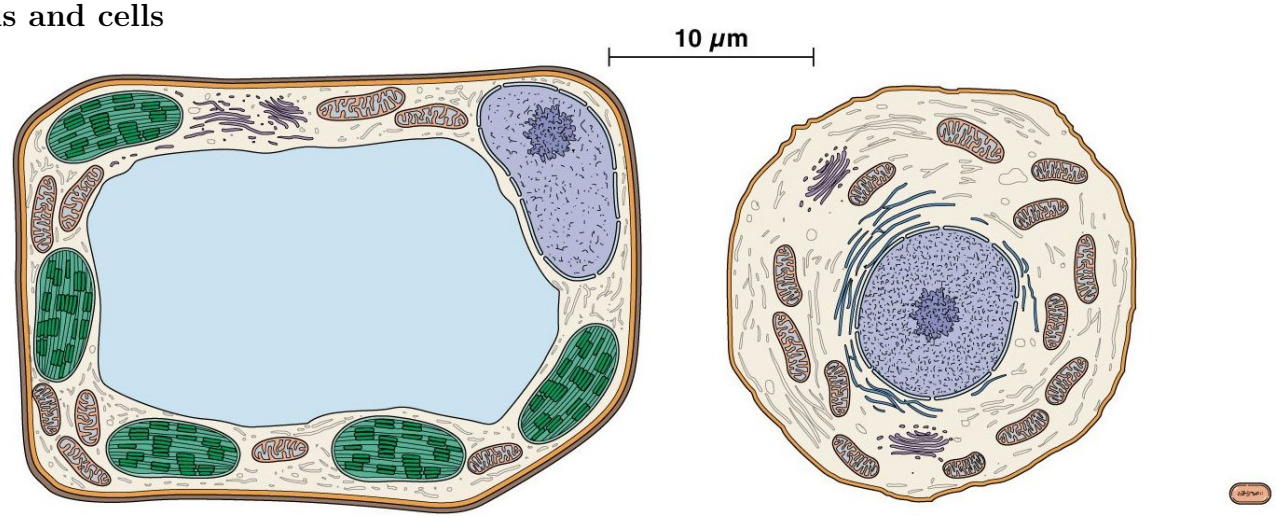
Light microscopy was an early technological breakthrough that contributed to our understanding of cell structure. Dissectiscopes use reflected light, microscopes use translucent light. Magnification is of 10^3 order.

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.

5.2 Structure of cell

Cells and cells



Eukaryotic and prokaryotic cells are fundamentally different

Cells

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

Outline

6 Questions and answers

Previous final question: the answer

How do photorespiration and high temperatures relate?

- The higher is a temperature, the more oxygen from light stage.
- Also, all chemical reactions (including photorespiration) will speed up.
- Also, some plants close stomata at hot hours and (not willingly) increase oxygen concentration in tissues.

7 Cell

7.1 Plant cells

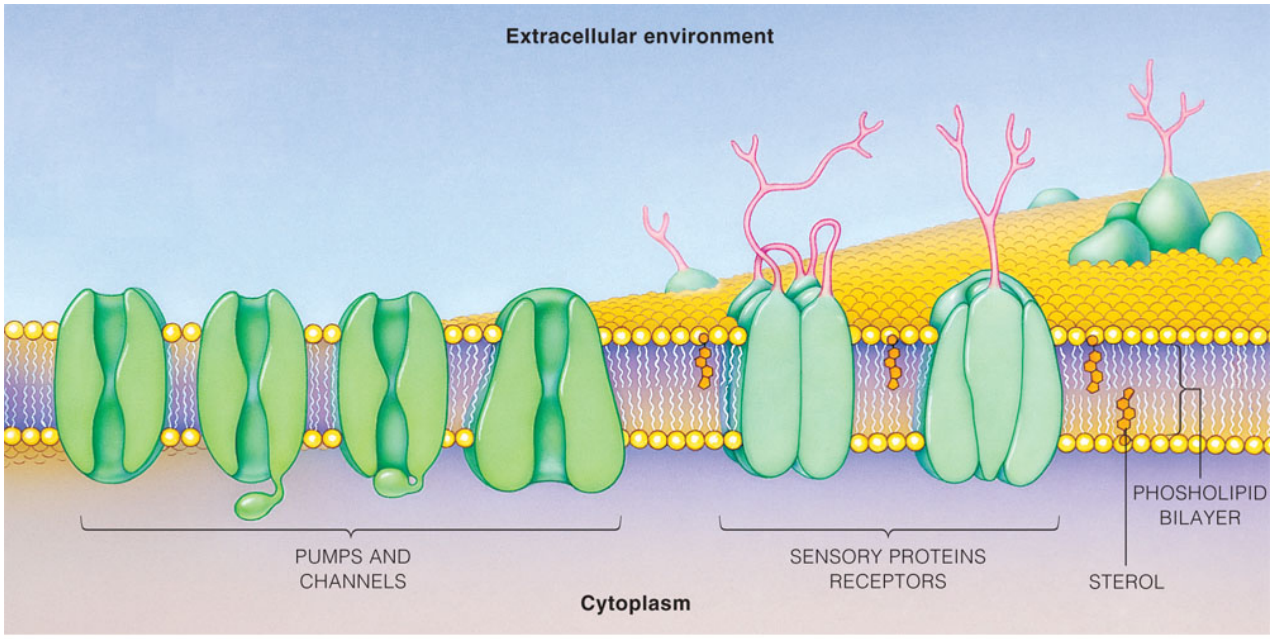
Plant cells

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**

Chloroplasts and mitochondria are both results of symbiogenesis

Plasma mebmrane



Phospholipids, sterols, proteins: pumps, receptors, channels

Final question (1 point)

Name main differences between animal and plant cell.

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

Outline

8 Questions and answers

Previous final question: the answer

Name main differences between animal and plant cell.

- Chloroplasts
- Vacuole(s)
- Cell wall

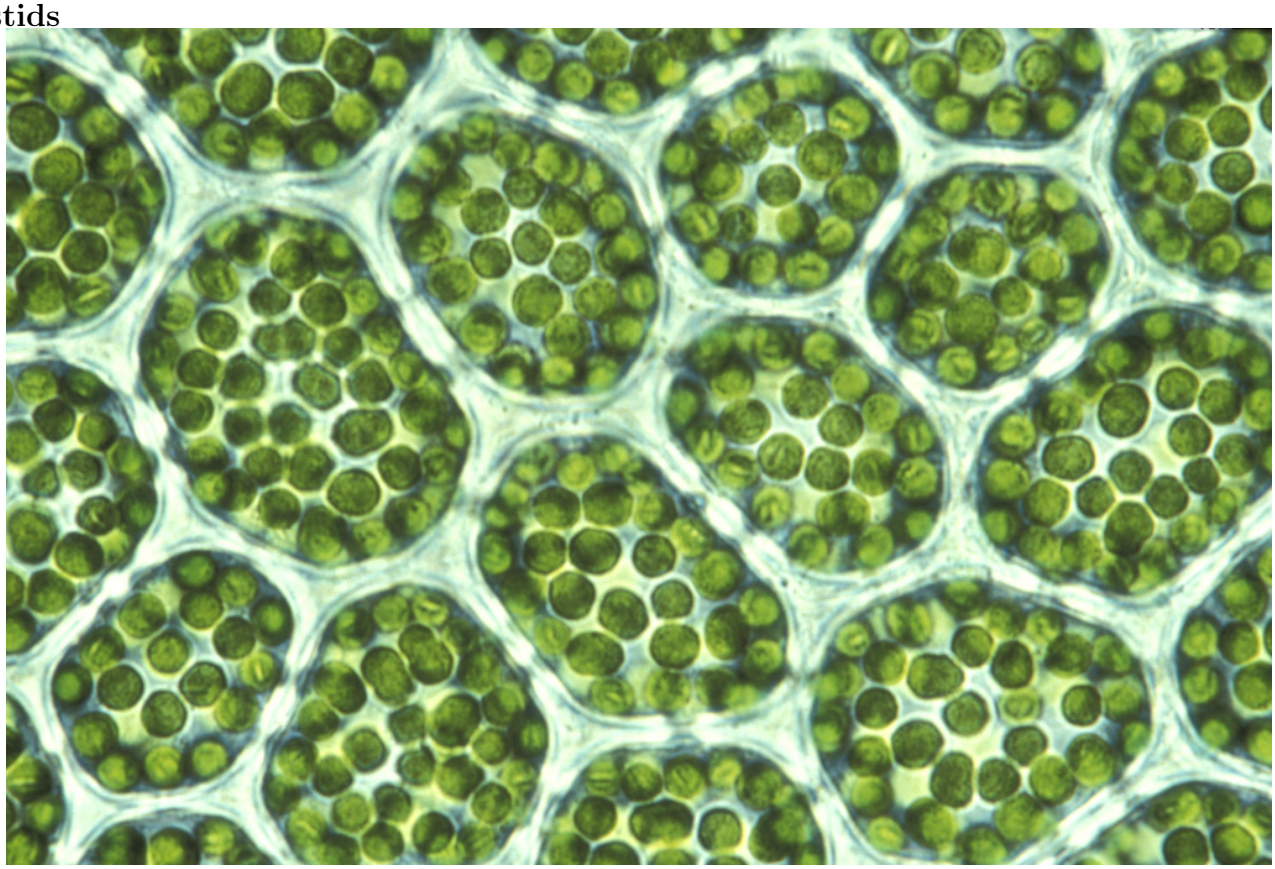
9 Cell

9.1 Cells from cells: mitochondria and chloroplasts

Symbiogenesis

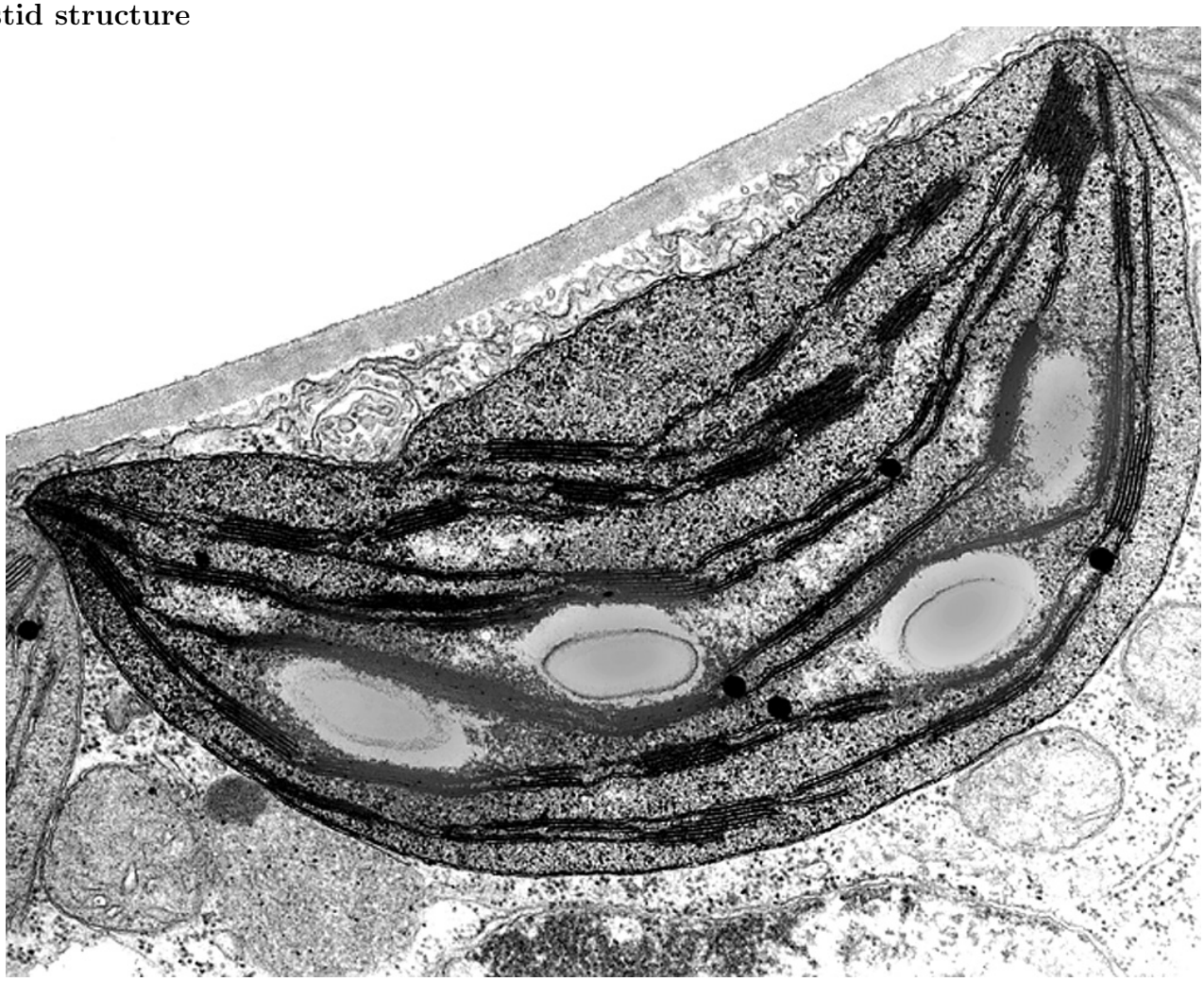
- Small, rigid procaryotic cells became larger to escape from predators
- To keep all parts of larger cell communicable, they developed cytoplasm motility based on actin protein
- Cytoplasm motility allowed for phagocytosis so they became predators
- These predator cells captured many bacteria and digested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



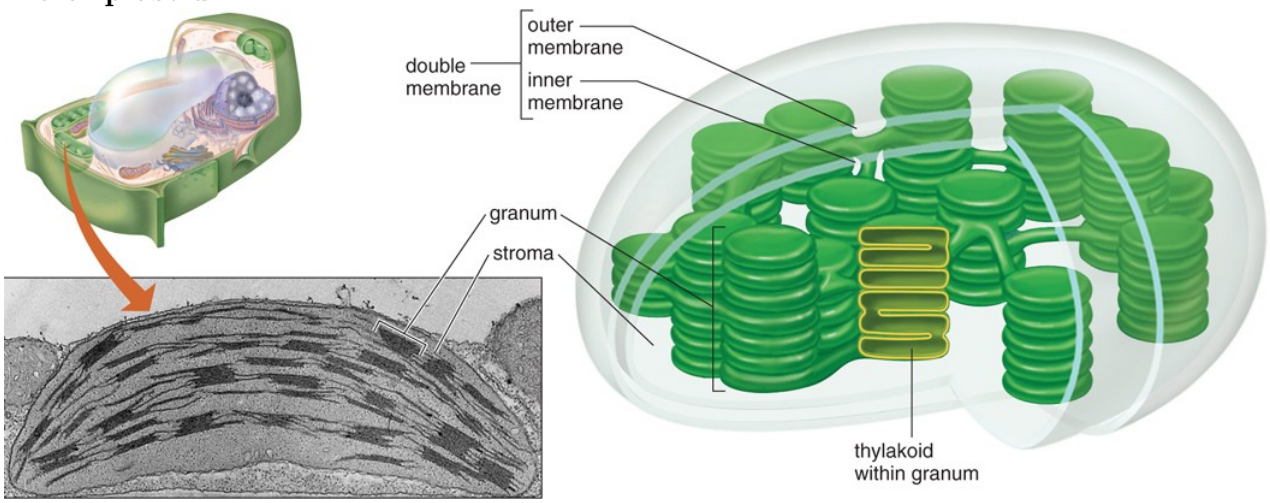
Chloroplasts in leaf cells of *Rhizomnium pseudopunctatum* (LM ×500)

Plastid structure

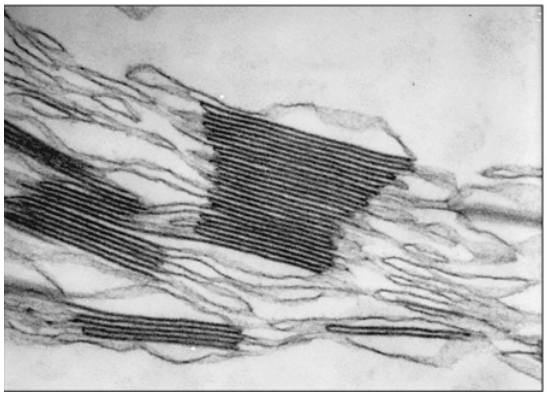


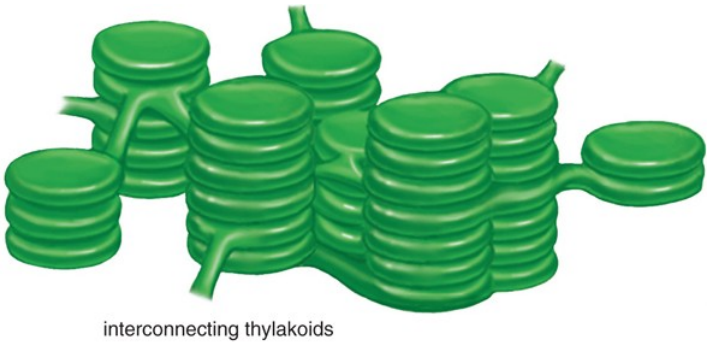
Tylacoids, stroma and starch granules (TEM $\times 37,500$)

Scheme of plastid



Grana

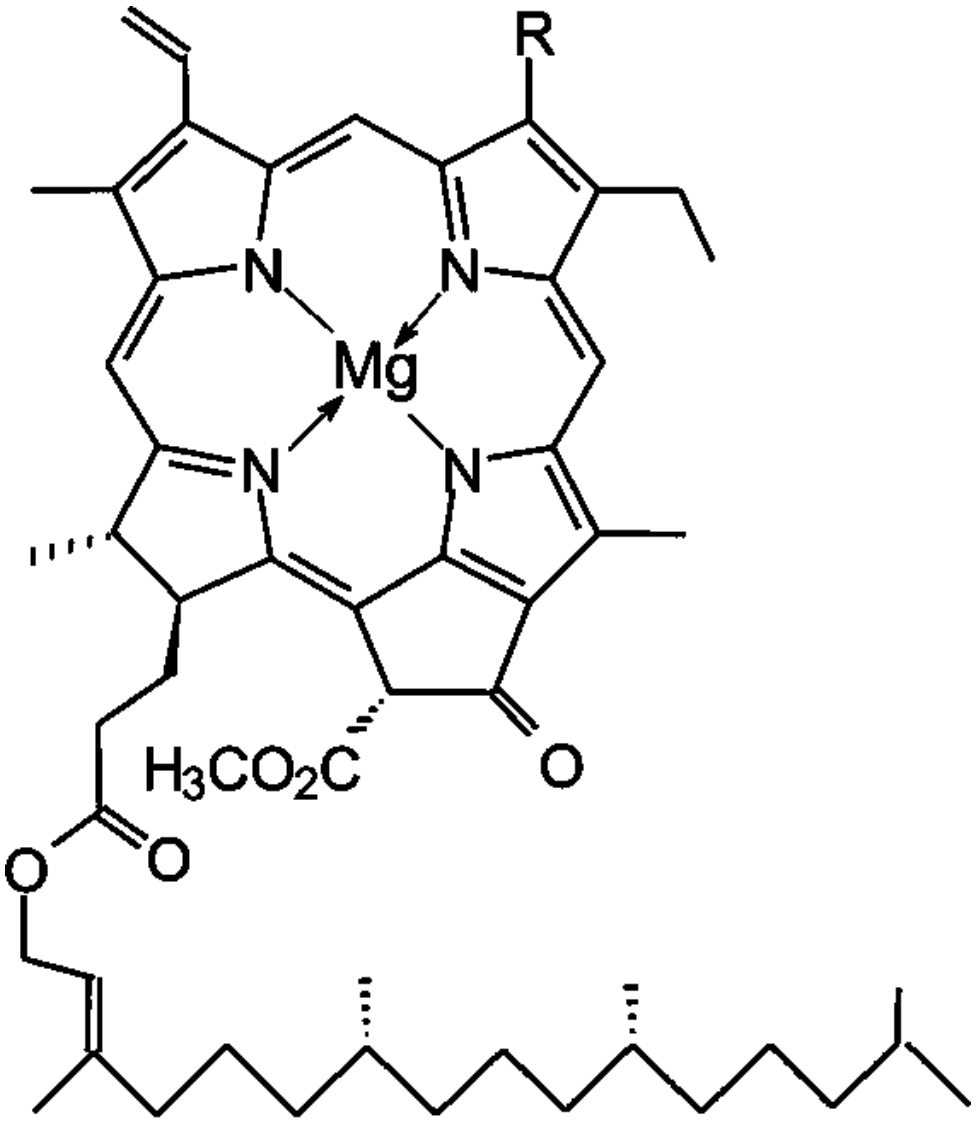




Pigments

- 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)

Mitochondria

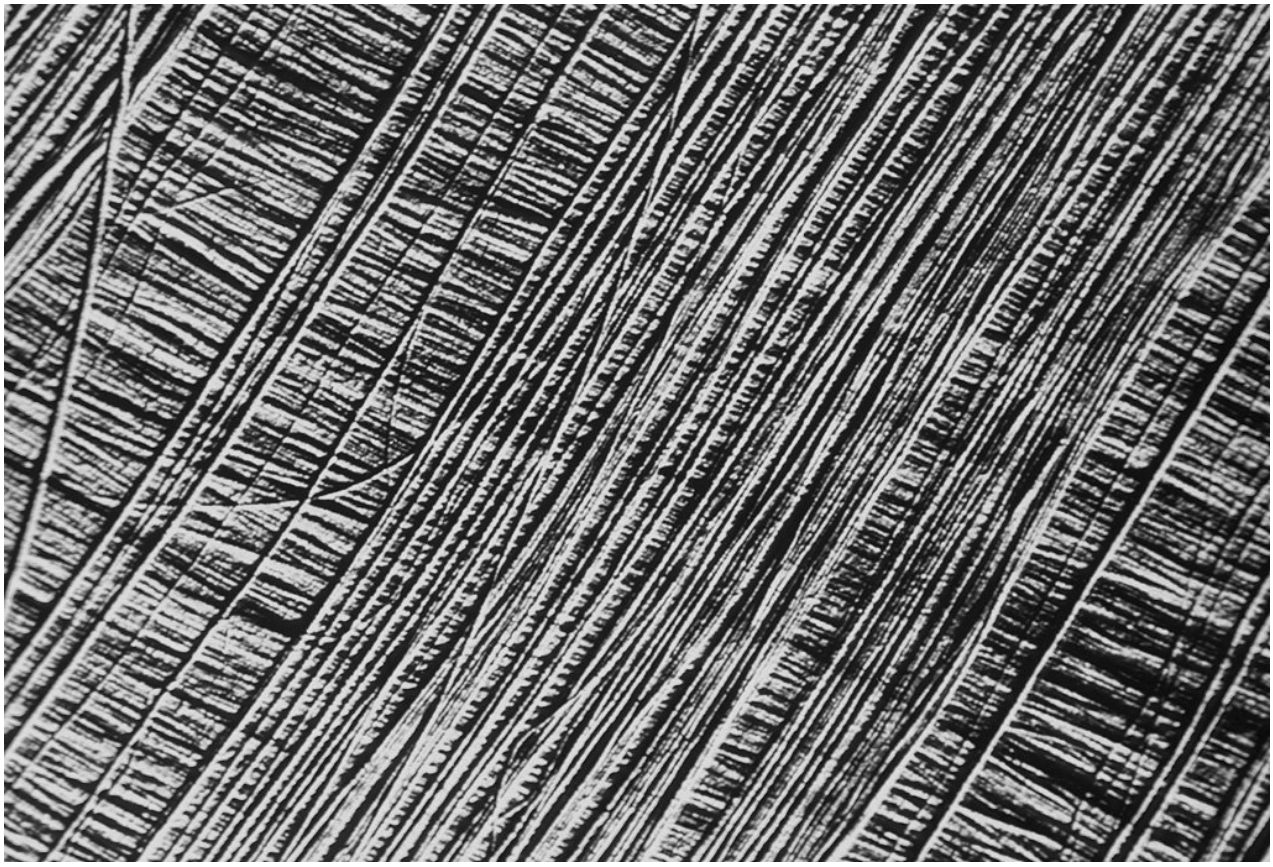
Mitochondrion showing foliate *cristae* and matrix granules. Mitochondria are the main energy source (in form of ATP) of the cell (TEM)

9.2 Cell boundaries

Cell wall 1

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

Cell wall 2

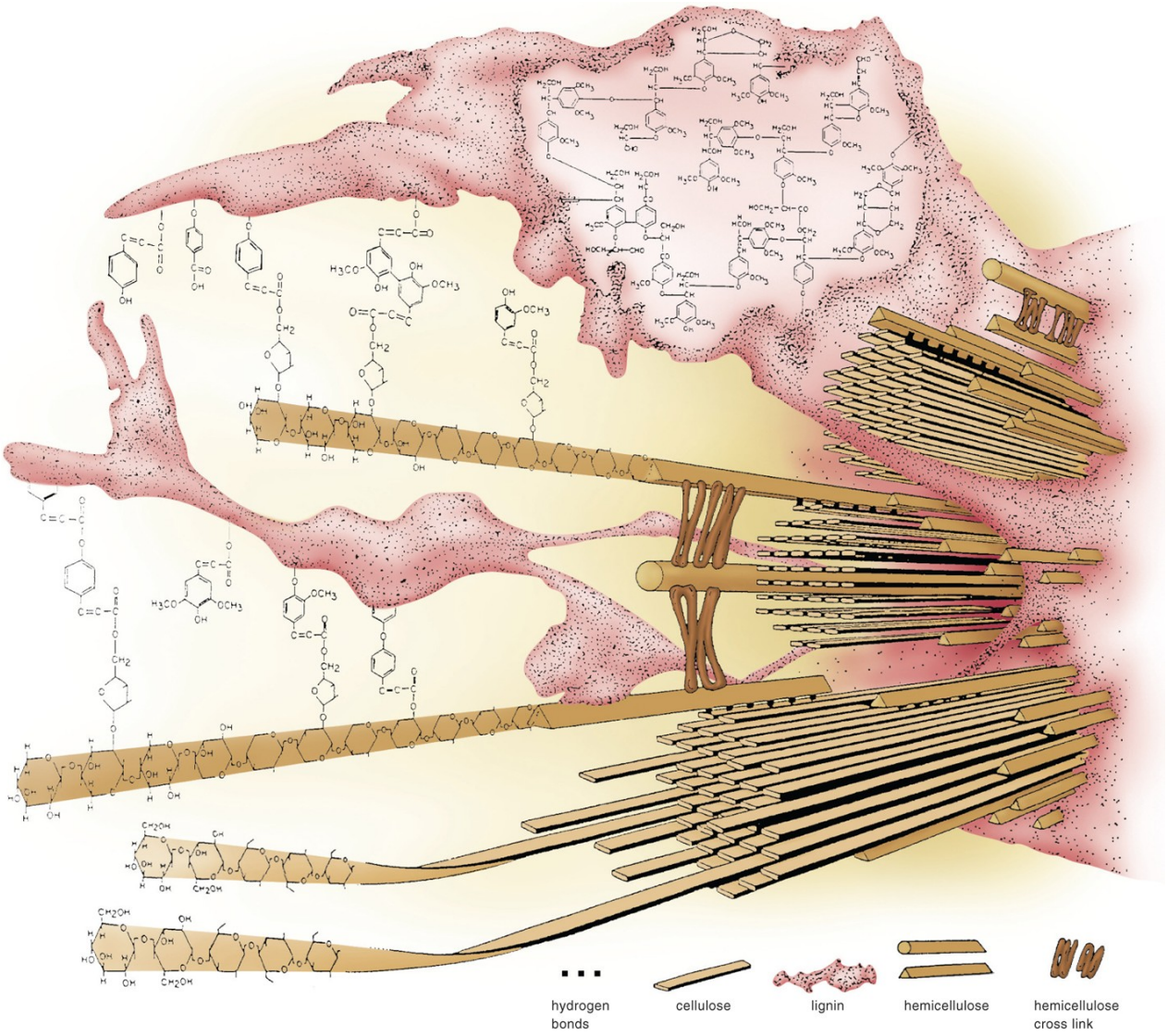


Cellulose fibers in the plant cell wall (SEM)

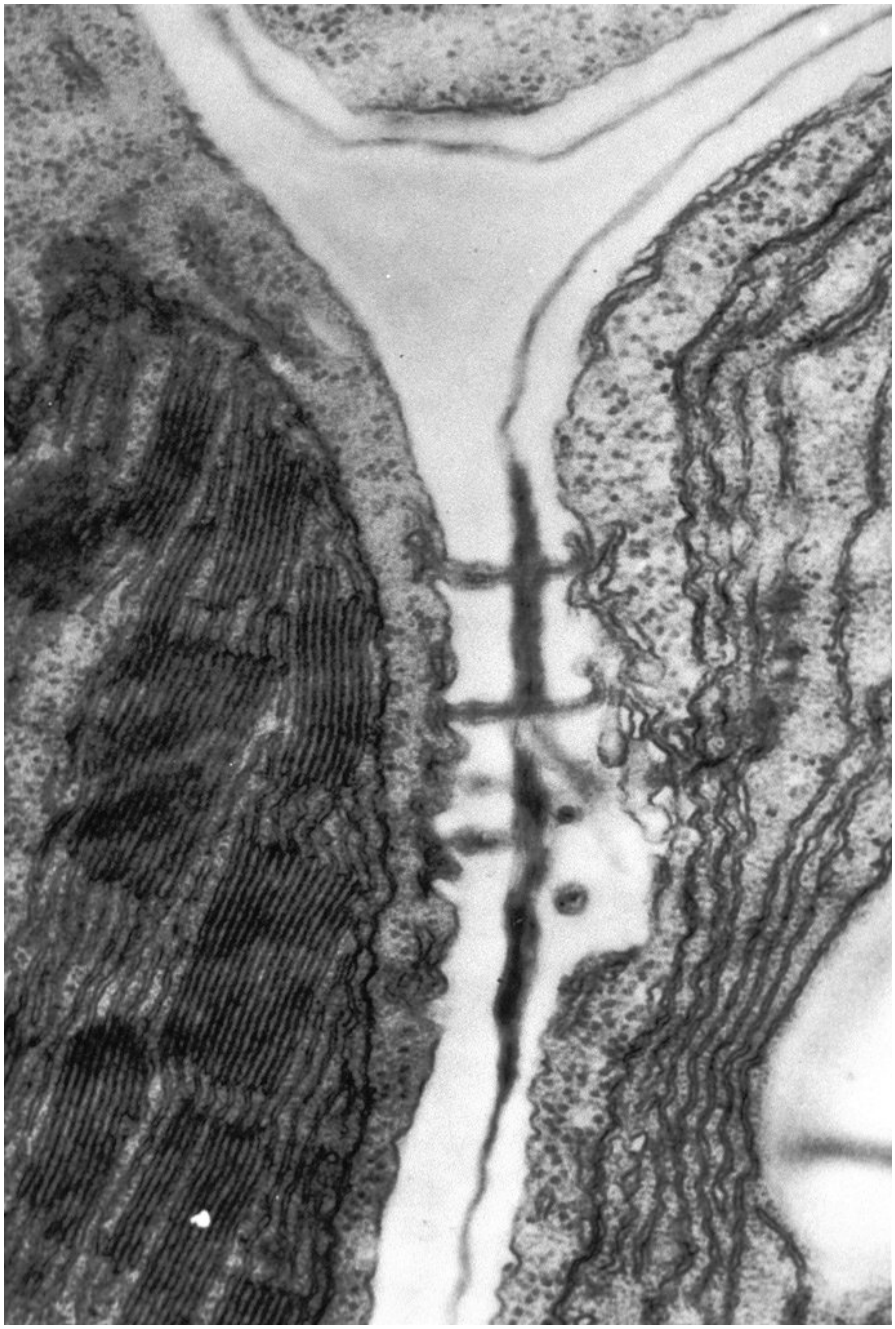
Primary and secondary cell walls

- **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

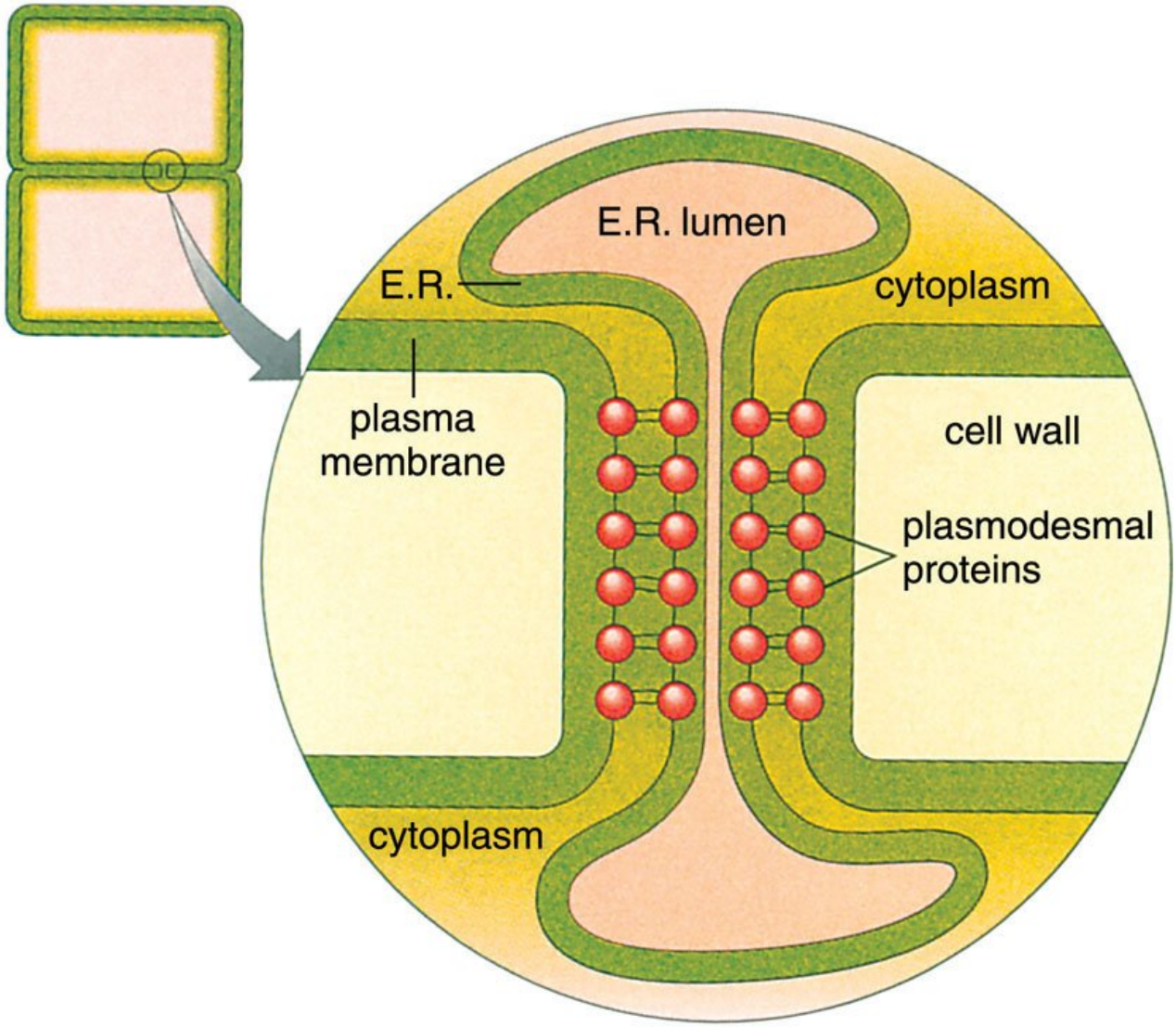


Plasmodesmata 1



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**

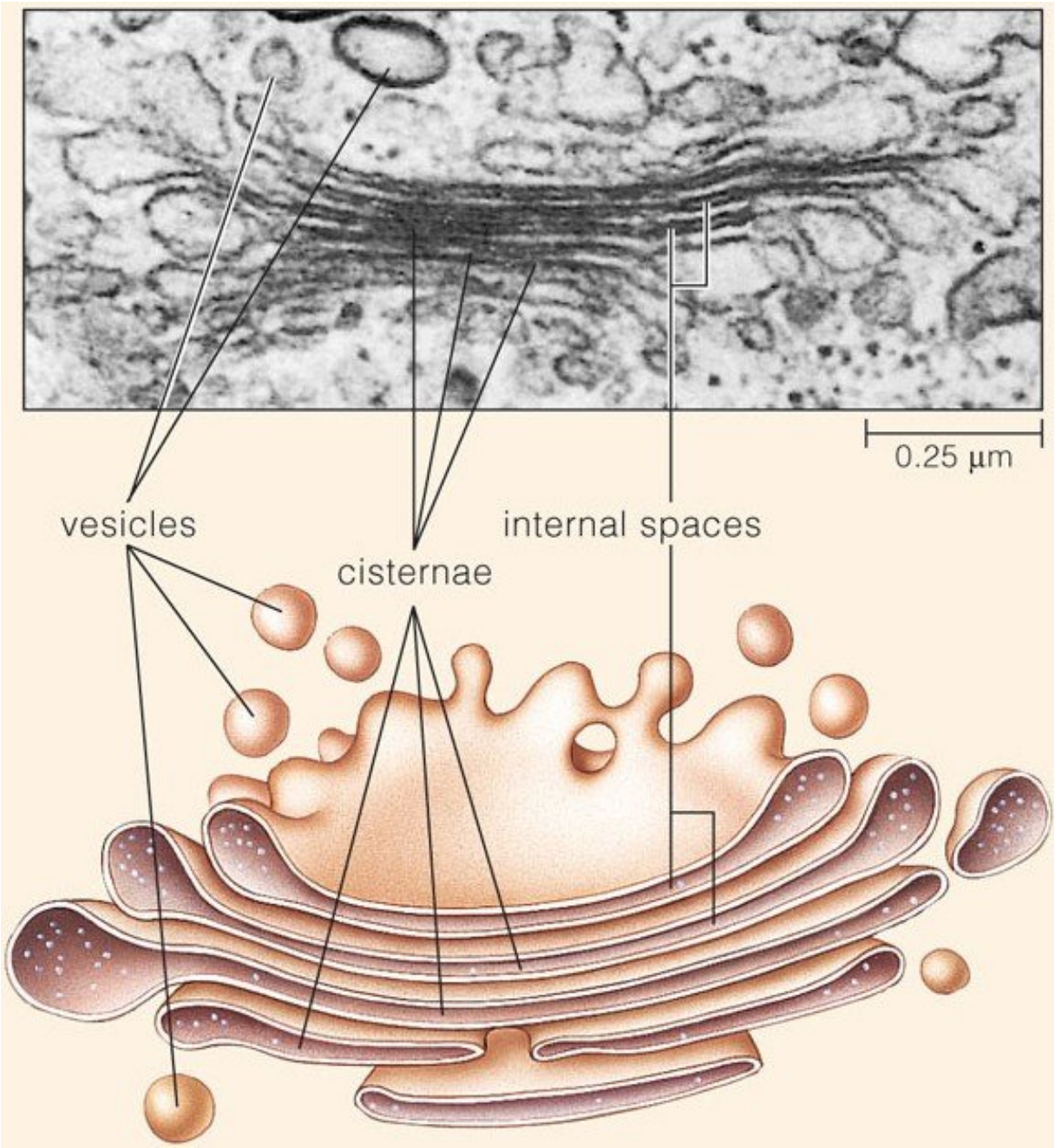
Symplast and apoplast

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

Endoplasmatic reticulum (network), ER

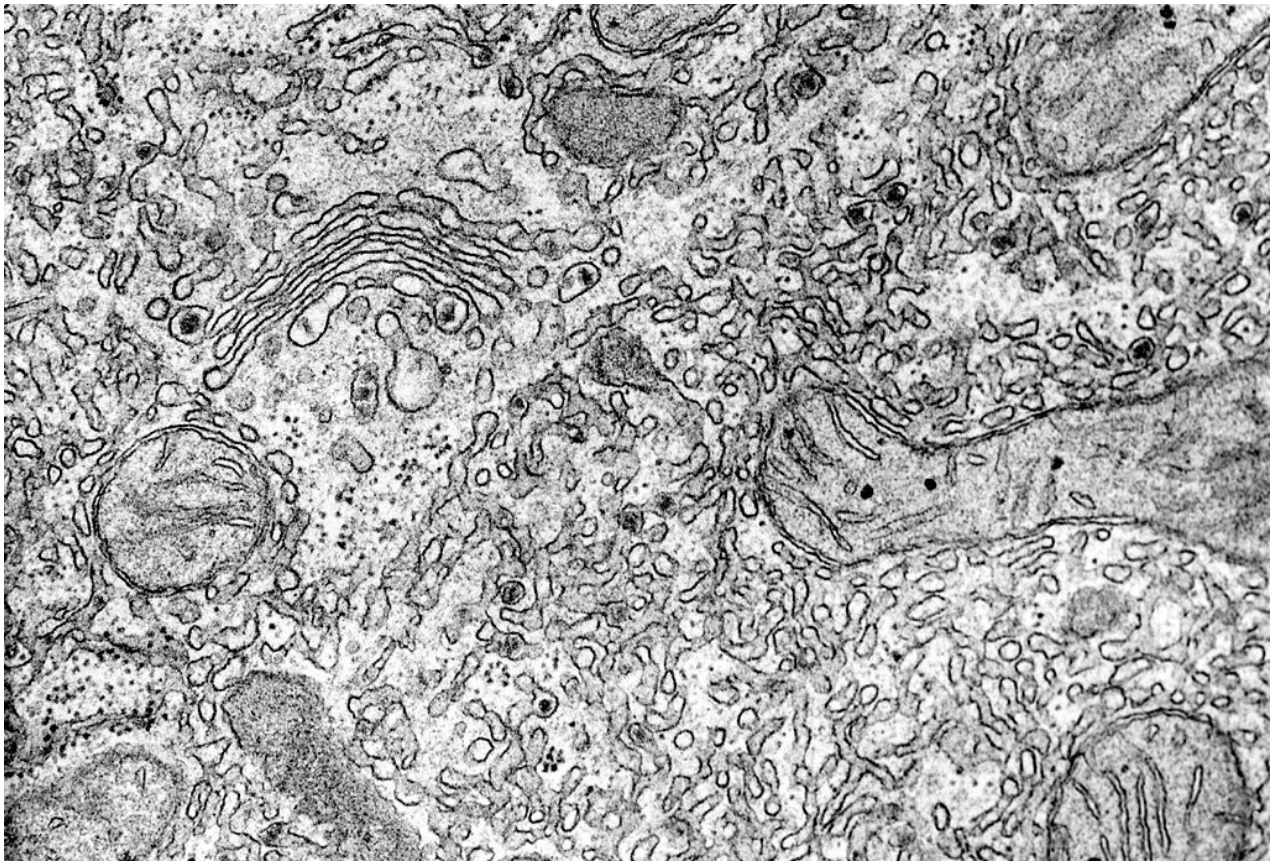
Rough endoplasmic reticulum with ribosomes along outer surface. Manufactures many proteins destined for secretion or for incorporation into membranes (TEM)

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)

9.3 Protein synthesis

Nucleus structure

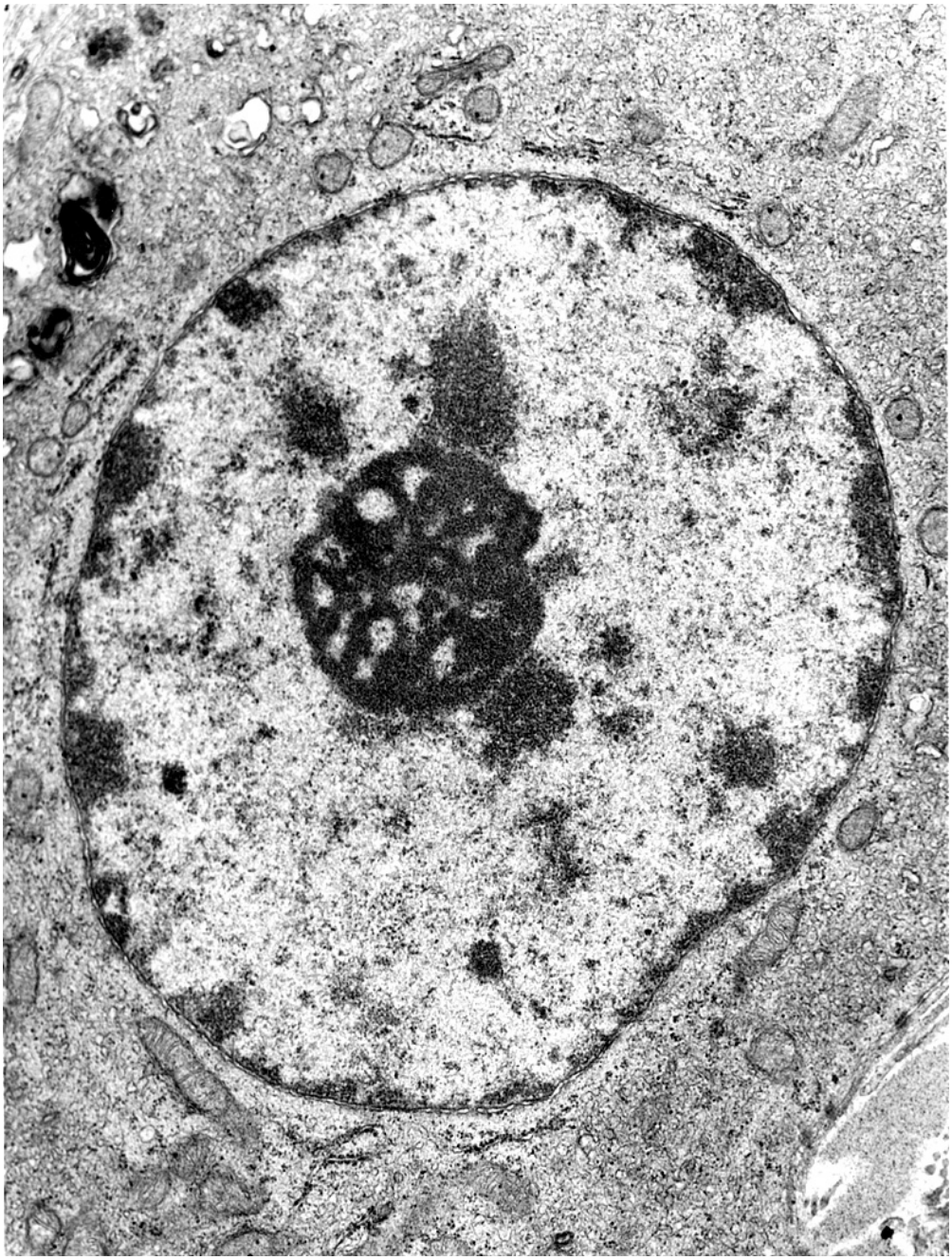
Nuclear envelope Double layered membrane, filaments of protein lamin line inner surface and stabilize structure, inner and outer membranes connect to form pores

Nucleoplasm Portion inside the nuclear envelope

Nucleoli Dark staining bodies within nucleus, site for ribosome synthesis

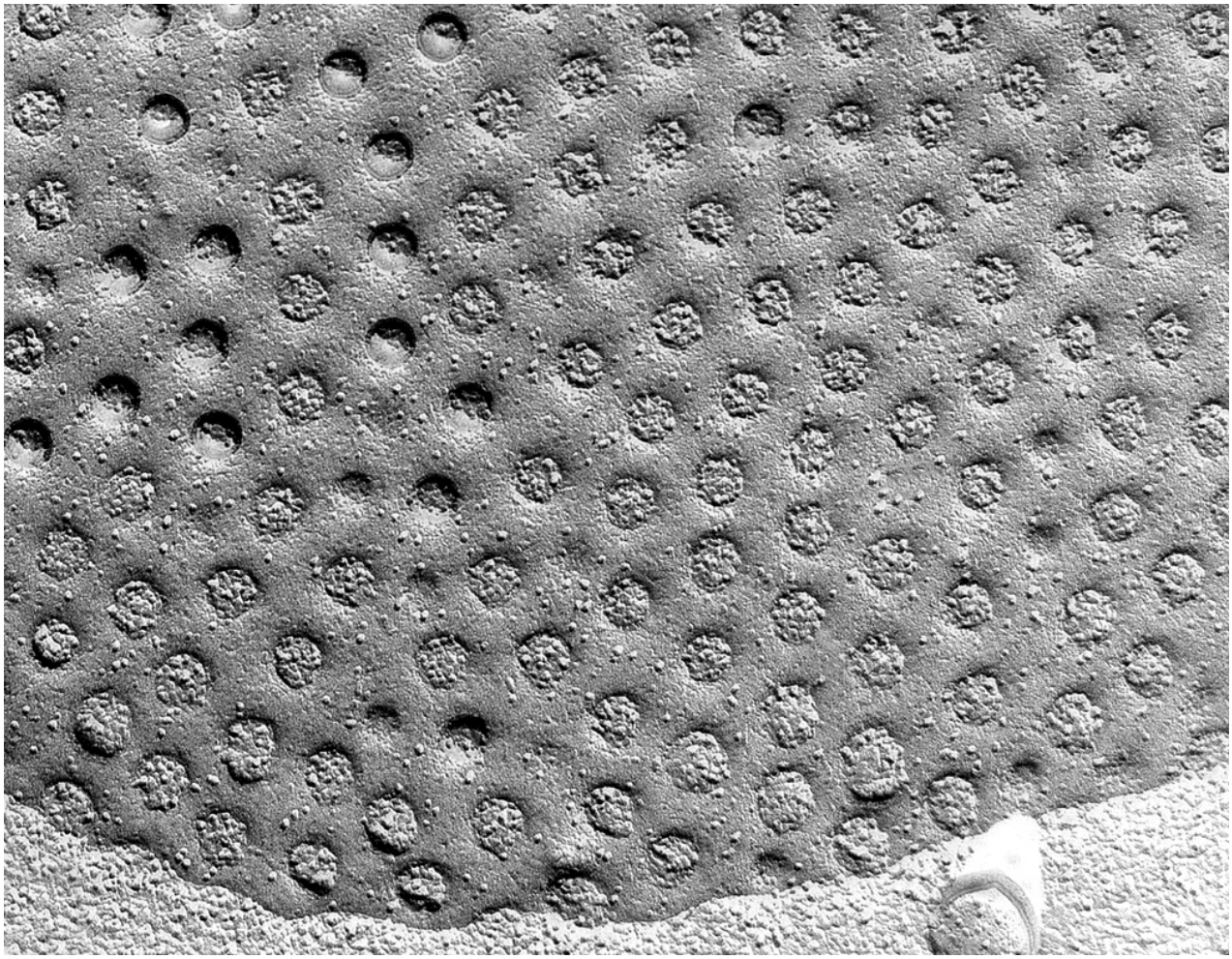
Chromosomes Store genetic information in nucleotide sequences, each chromosome consists of chain of nucleosomes (long DNA molecule and associated histone proteins)

Nucleus



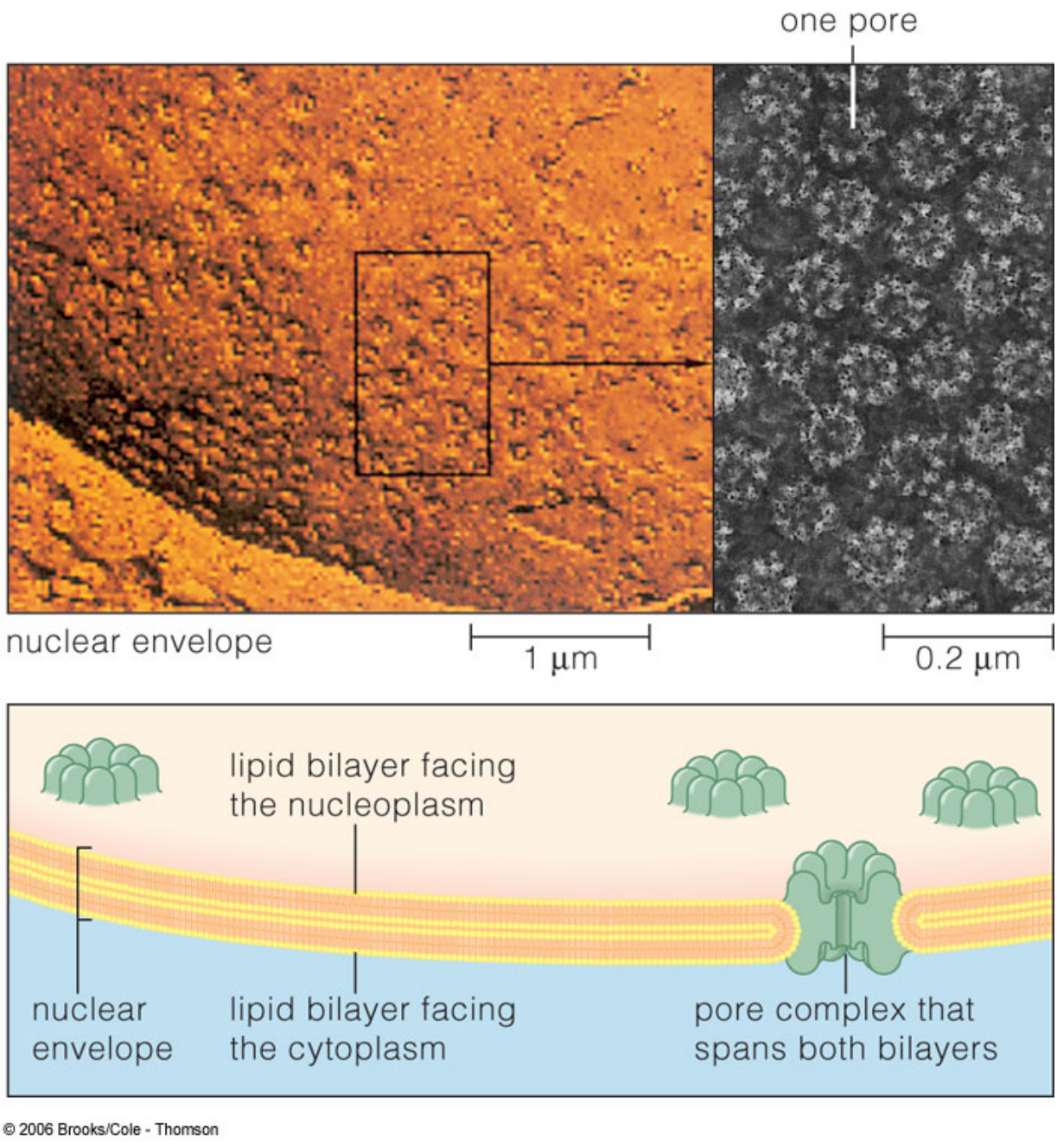
A typical nucleus with a prominent nucleolus (TEM).

Nuclear pores

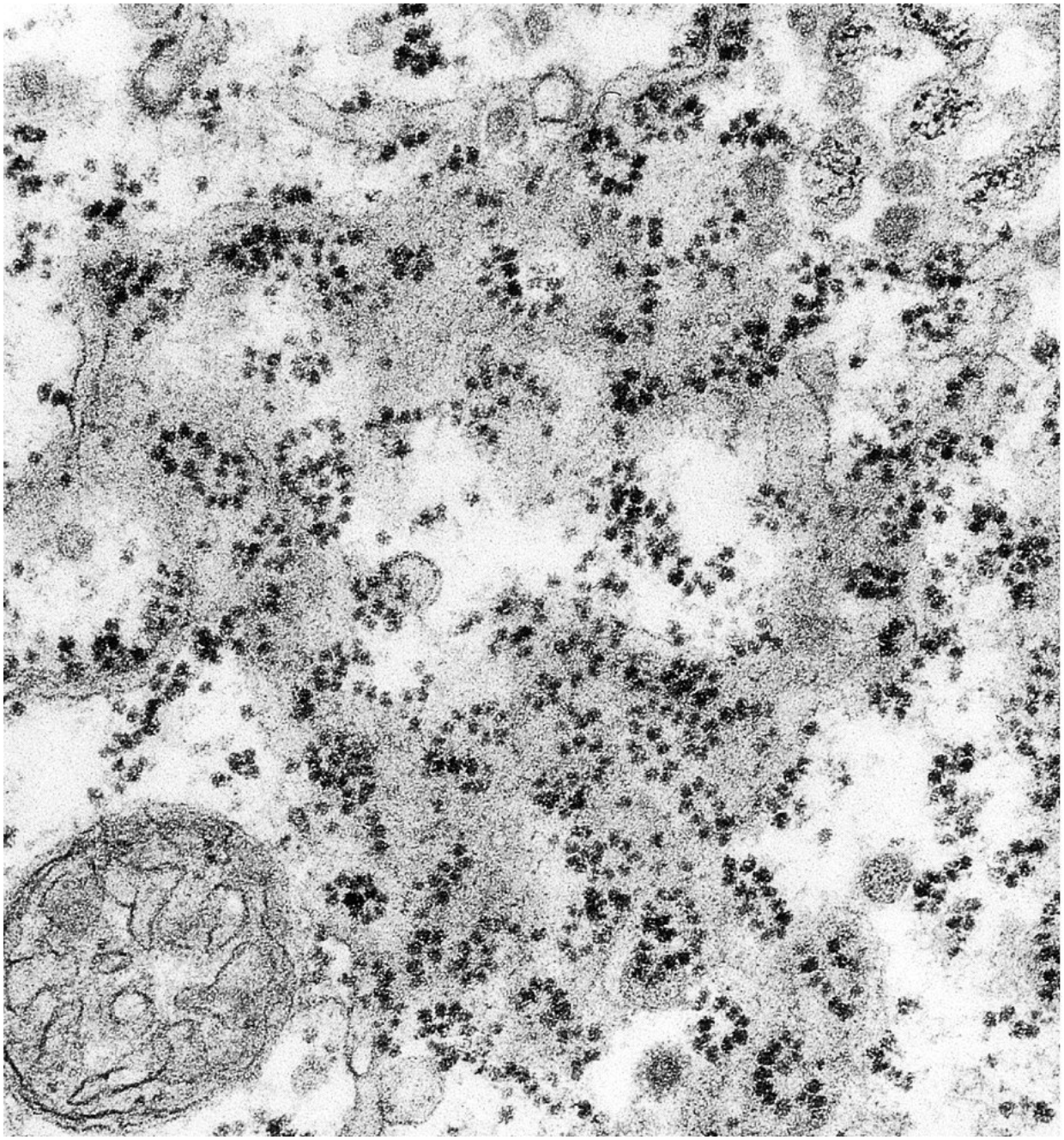


Freeze-fracture technique used to show nuclear pores. Nuclear pores are structures in the nuclear envelope that allow passage of certain materials between the cell nucleus and the cytoplasm (TEM $\times 100,000$)

Nuclear pores and envelope



Ribosomes



Final question (2 points)

What is the difference between primary and secondary cell walls?

Summary

- Chloroplasts and mitochondria are both results of symbiogenesis
- 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
- **Nucleus** stores and expresses genetic information

For Further Reading

References

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

Outline

10 Questions and answers

Previous final question: the answer

What is the difference between primary and secondary cell walls?

- Secondary cell walls contain lignin and/or suberin
- Secondary cell walls cover dead cells

11 Cell

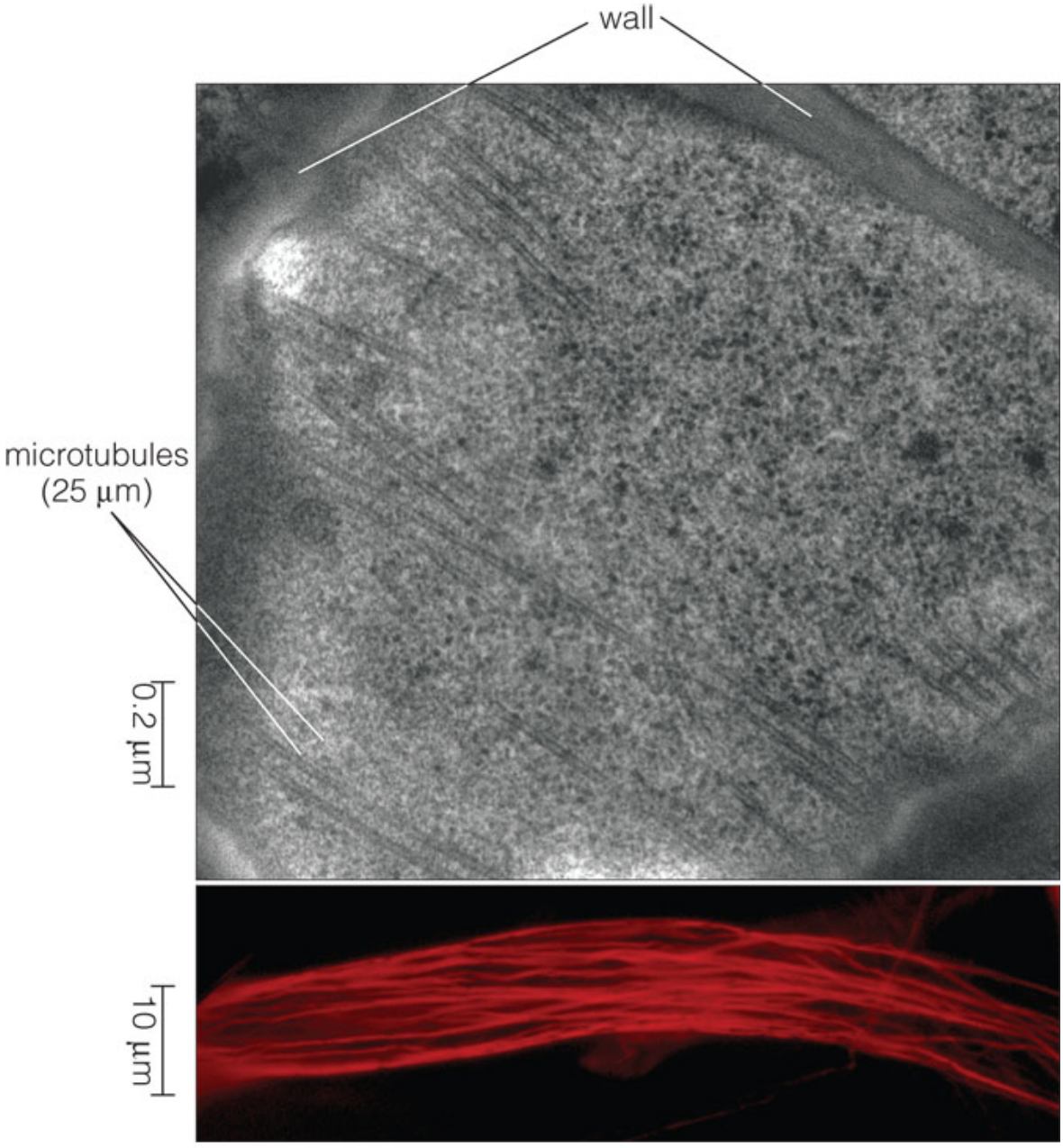
11.1 Other cell structures

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



12 Mitosis and meiosis

12.1 Mitosis

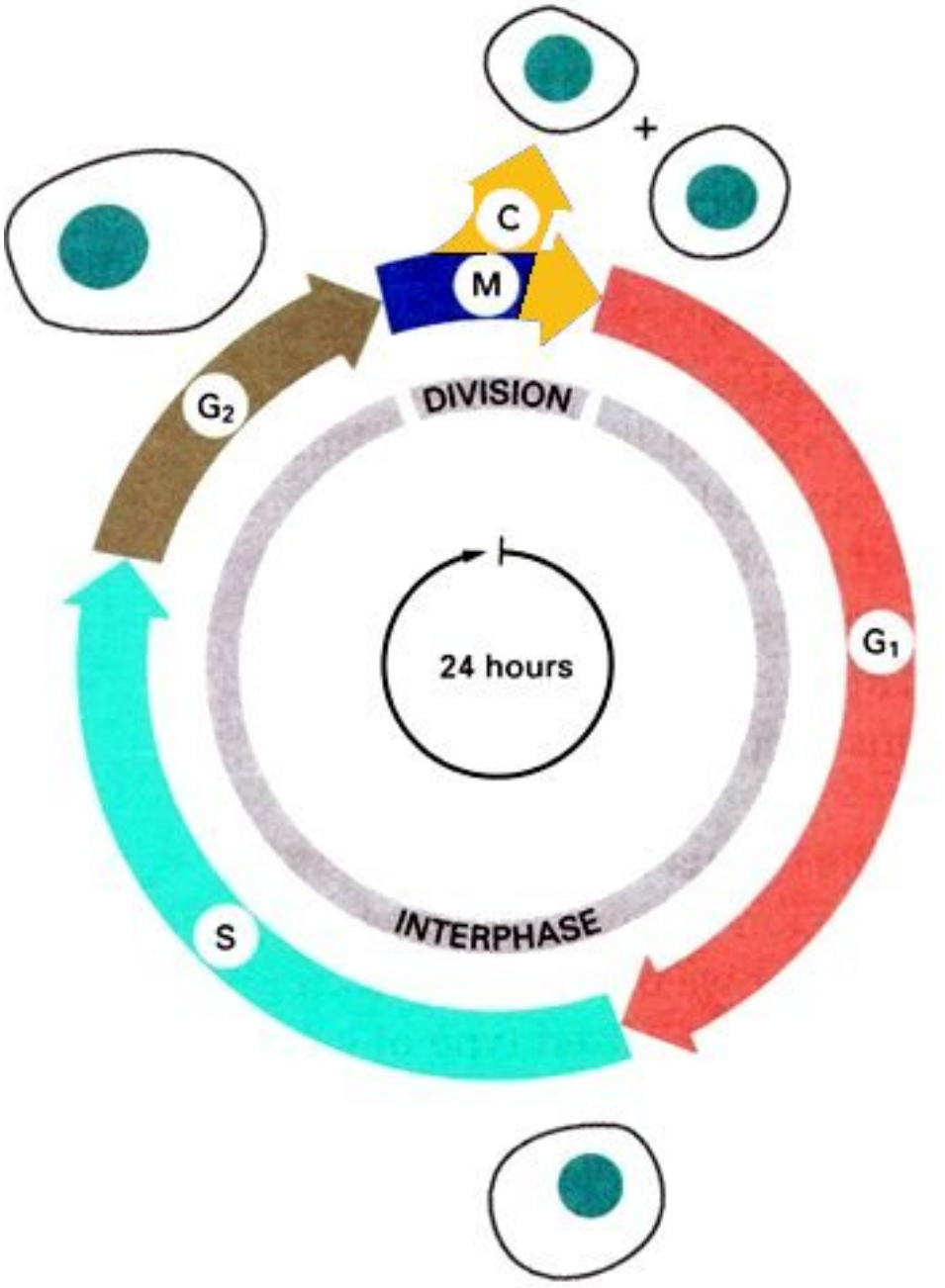
Definition of mitosis

- *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**

Cell cycle



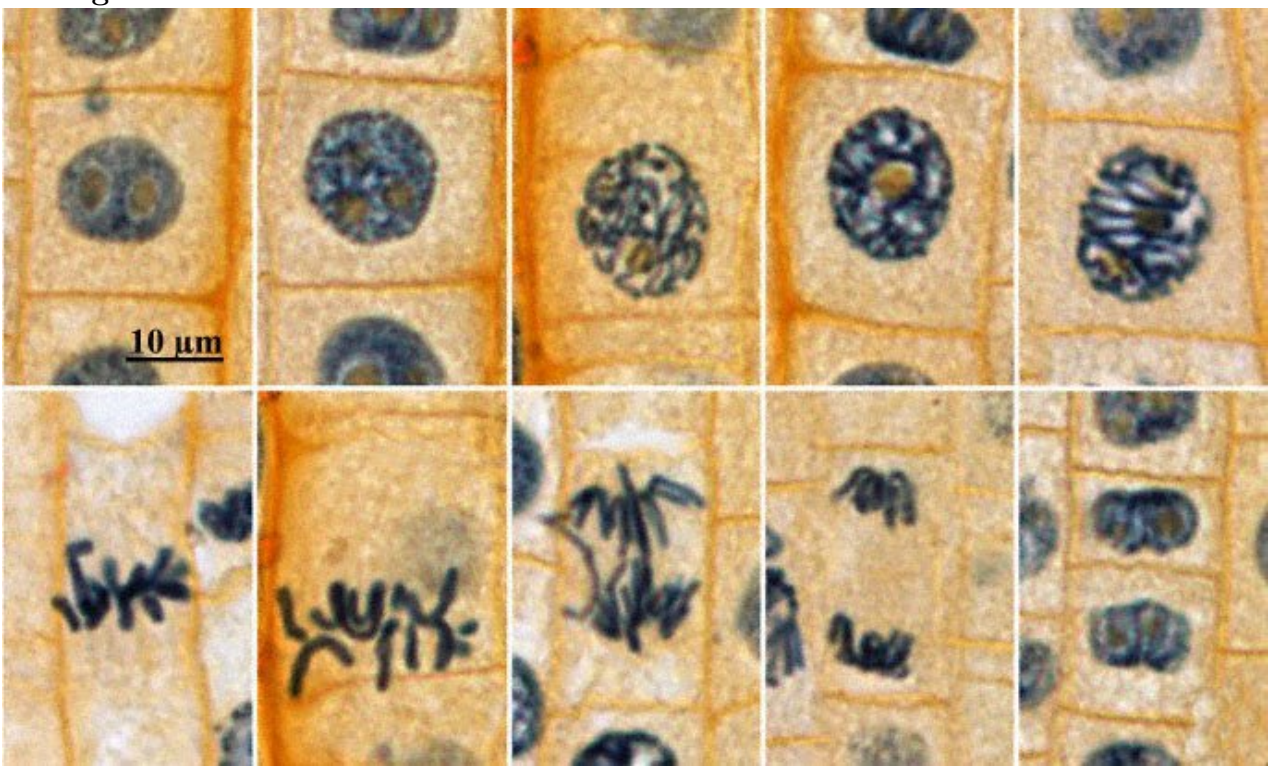
- Interphase
  - Pre-synthetic stage (G_1)
  - Sythetic stage (S): DNA duplicated
  - Post-synthetic stage (G_2)
- Mitosis

  - Prophase
  - Metaphase
  - Anaphase
  - Telophase
- Cytokinesis

Stages of mitosis

- Prophase
- Metaphase
- Anaphase
- Telophase

Which stage?



12.2 Syngamy (Y!)

Exchange and renovation of DNA

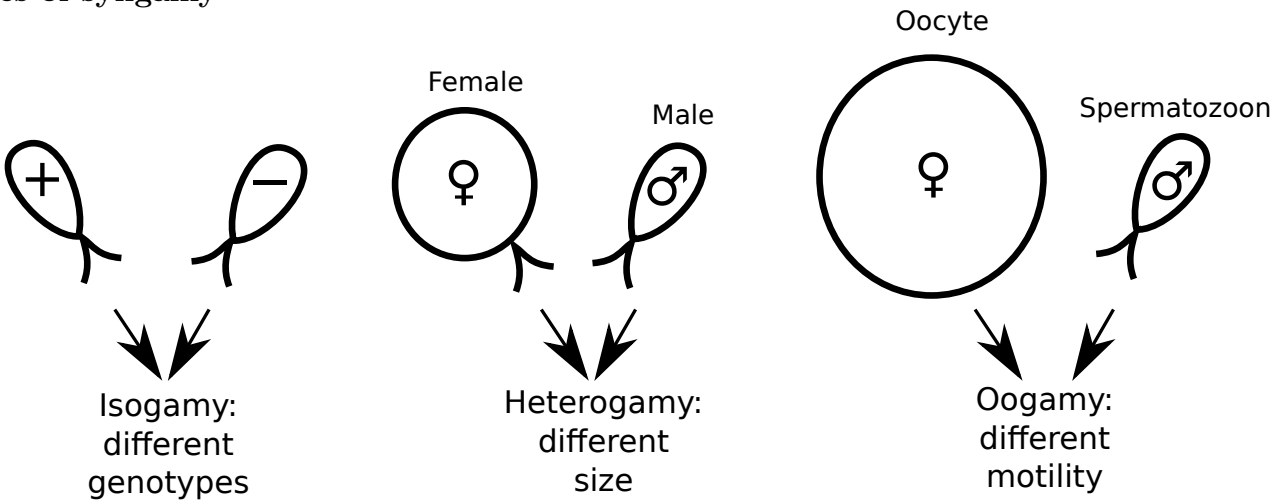
- To sustain with the ever-changed environment, organisms must evolve
- To evolve, they need a genetic diversity: different genotypes in different organisms
- To be genetically diverse, they need a process of genetic exchange
- One of ways of exchange is a sexual process in a form of **syngamy**

- However, constant syngamy will result in constant increase of DNA amount
- Meiosis is a counterbalance to syngamy

Definition of 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



Summary

- **Mitosis** is a process of cell multiplication, ploidy stays constant, 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]. 2015. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

Outline

13 Questions and answers

Previous final question: the answer

Why do chromosomes (DNA) consense before mitosis?

- To make equal splitting faster and more error-proof

14 Mitosis and meiosis

14.1 Meiosis

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

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

Outline

15 Questions and answers

Previous final question: the answer

How do metaphase and anaphase of mitosis differ from metaphase I and anaphase I of meiosis?

- In mitosis, cell splits every chromosome
- In meiosis, cell splits homologous pairs

16 Mitosis and meiosis

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: $2n \longrightarrow n + n$

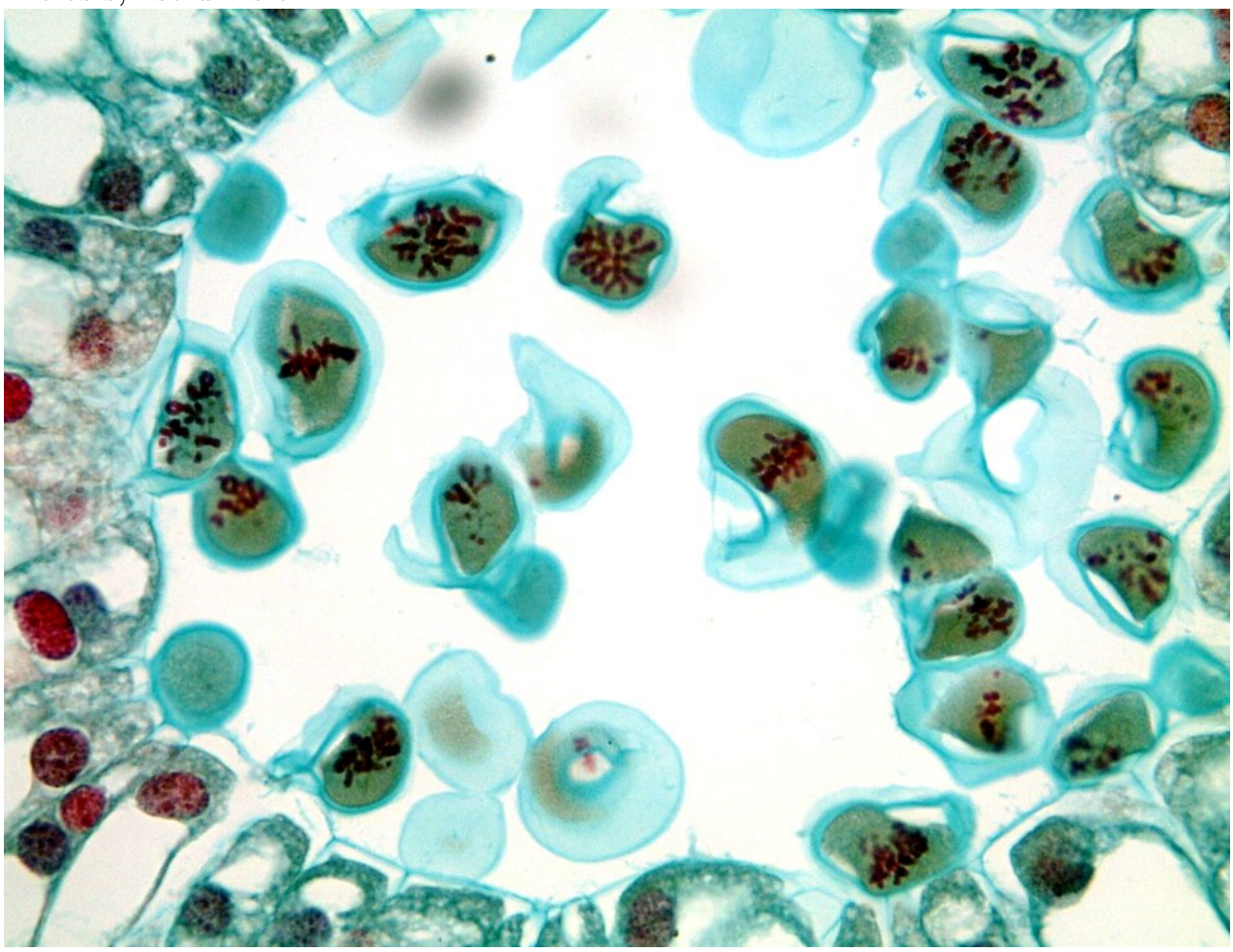
Stages of meiosis

- 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

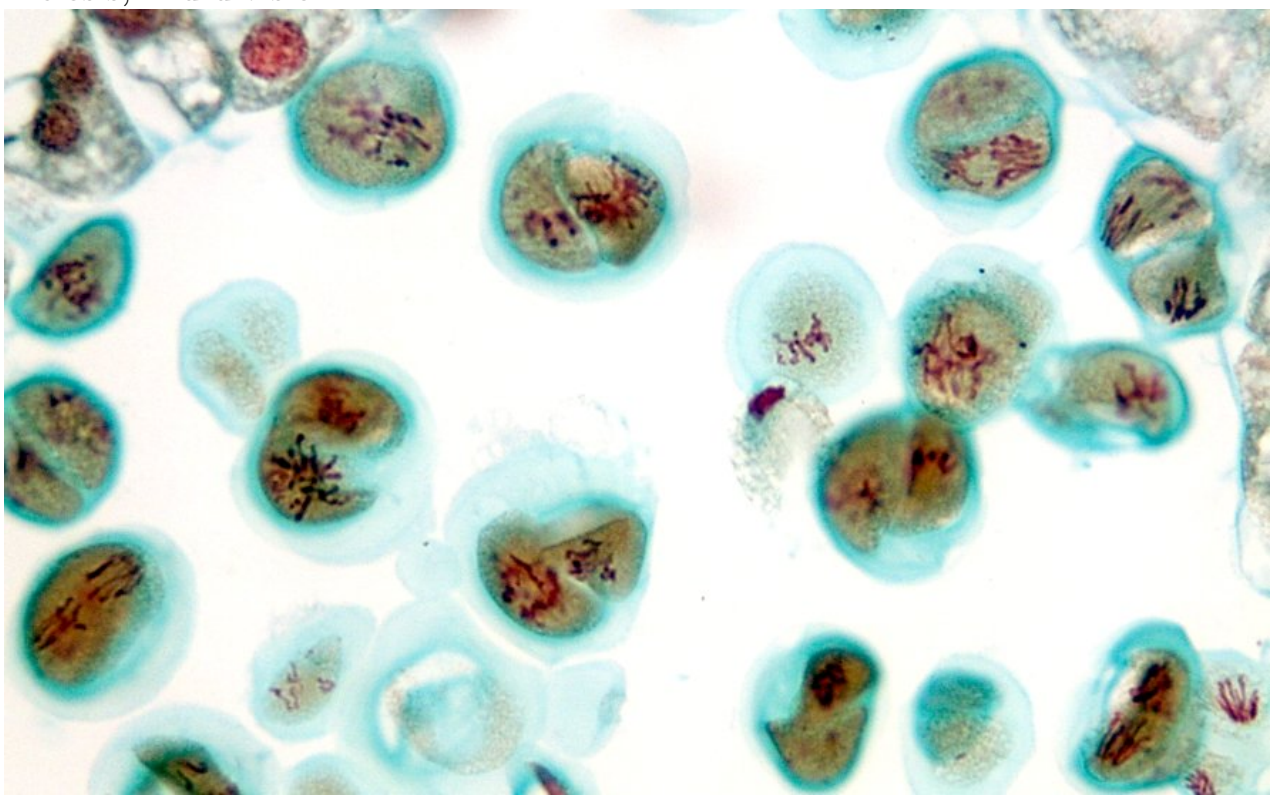
Polyploids

- 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**

Meiosis, 1st division



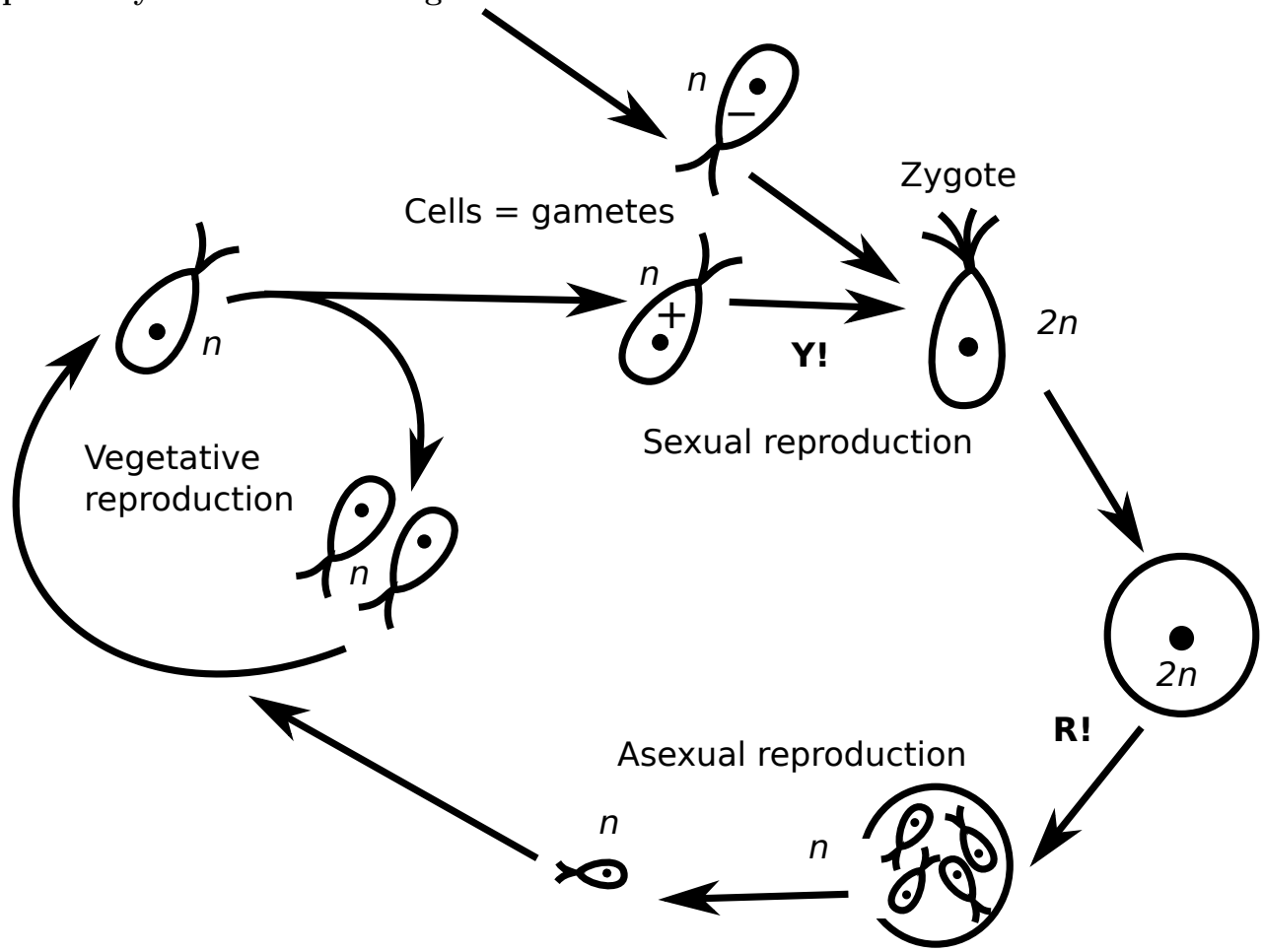
Meiosis, 2nd division



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**.
- Life cycles of multicellular organisms are based on interleaving **gaplont** and **diplont**, the second is making **spores**

Summary

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

Outline

18 Questions and answers

Previous final question: the answer

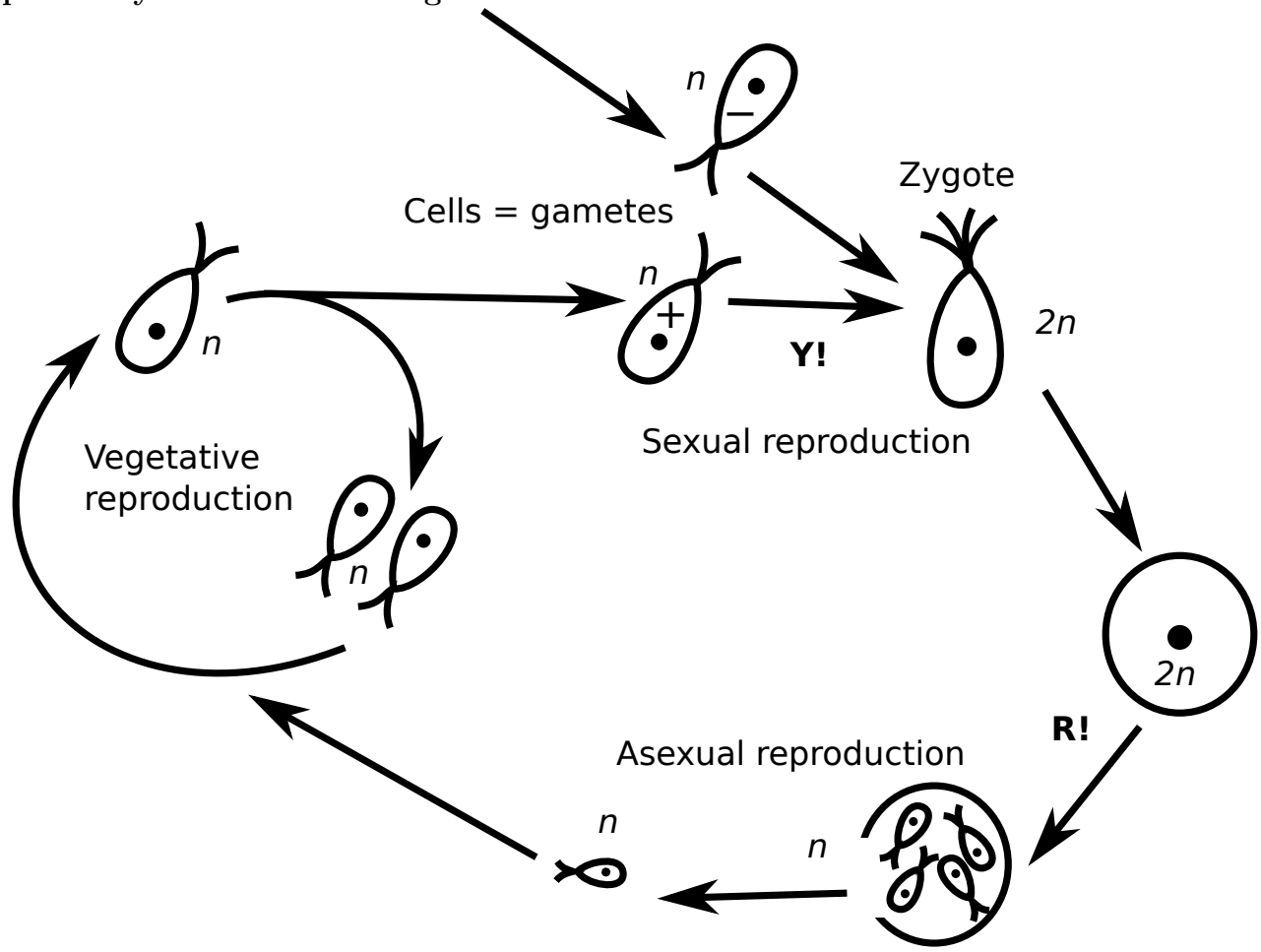
In the beginning of mitosis, cell has 10 ng of DNA. How much DNA has each of daughter cells in the end of mitosis?

- 5 ng

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

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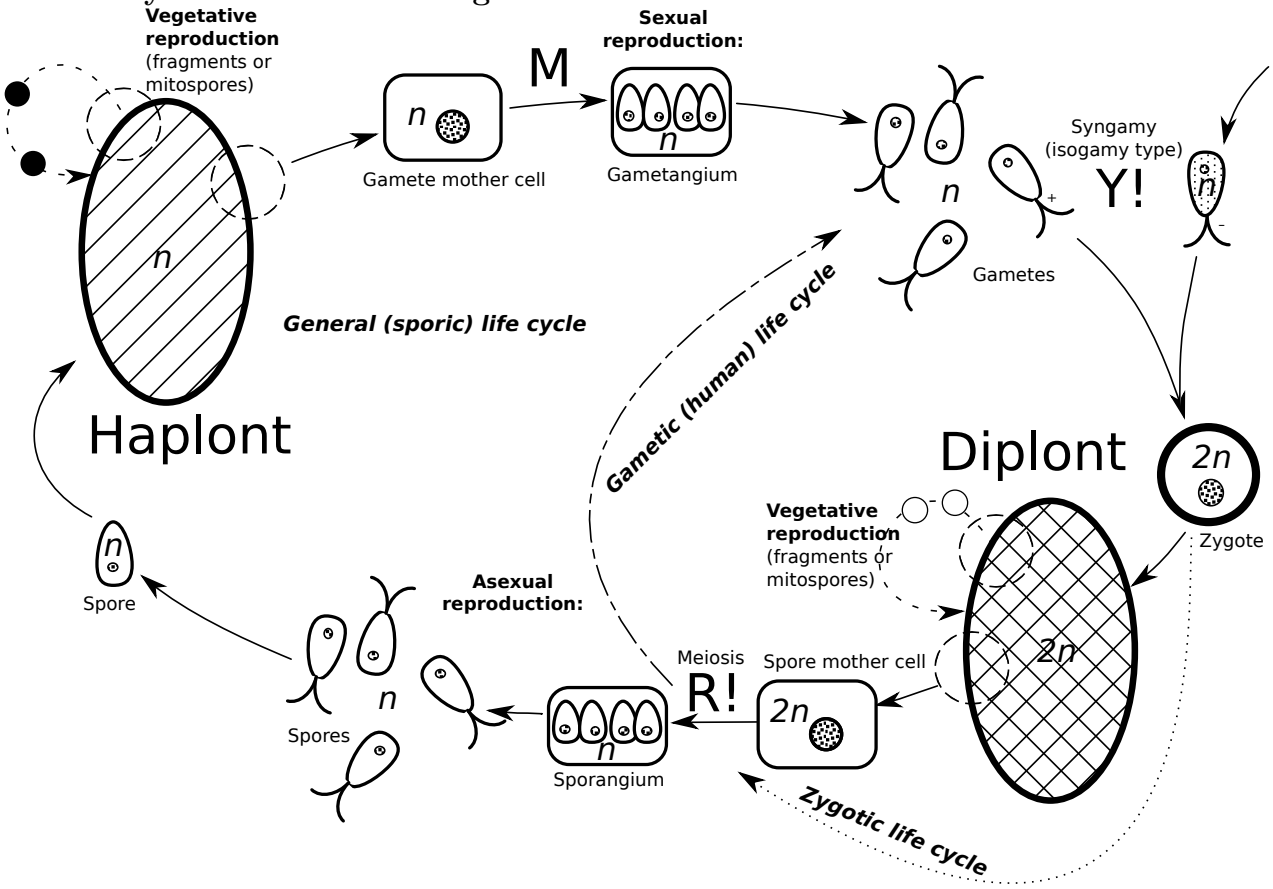
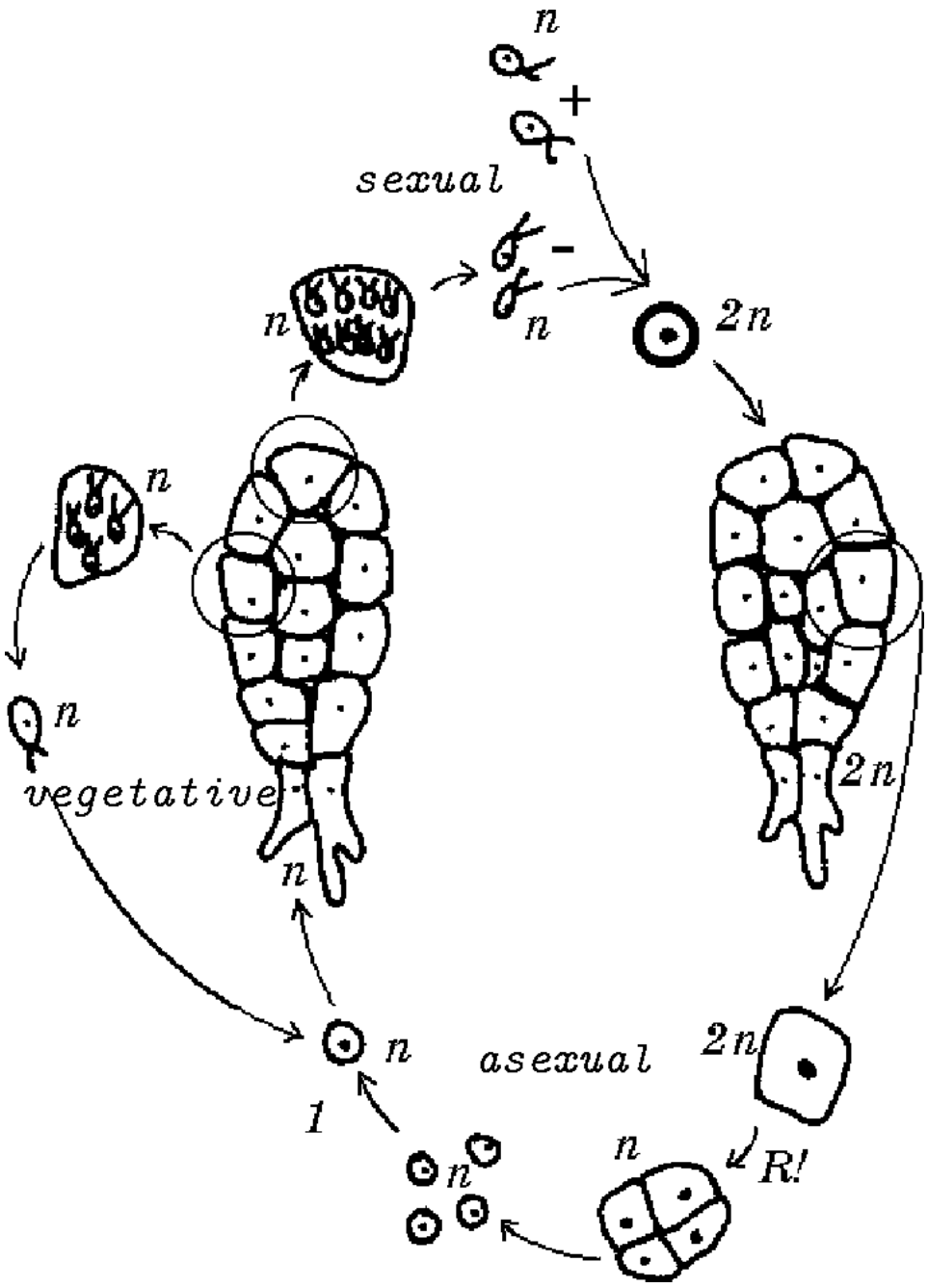
- This is the beginning of **multicellularity**.
- Life cycles of multicellular organisms are based on interleaving **gaplont** and **diplont**, the second is making **spores**

General life cycle: multicellular organism

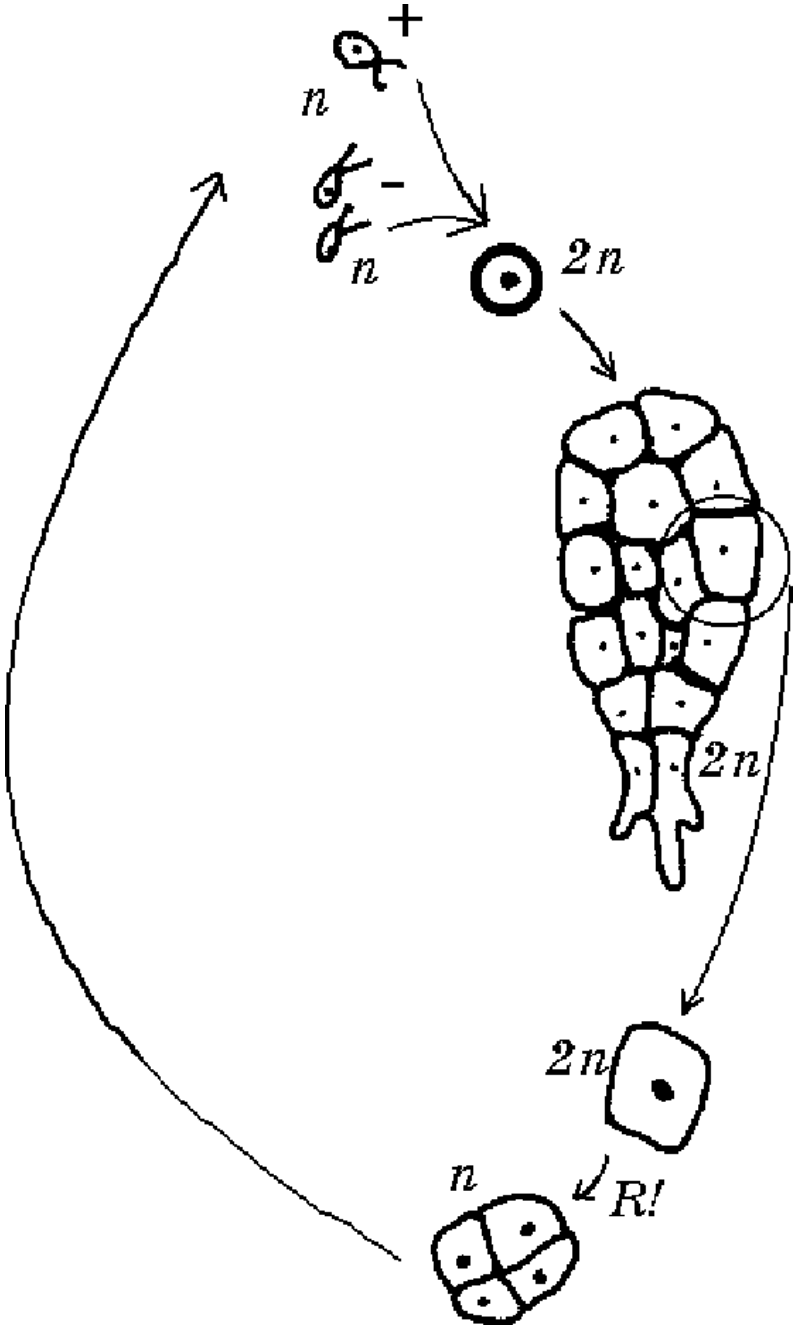


19.2 Diversity of life cycles

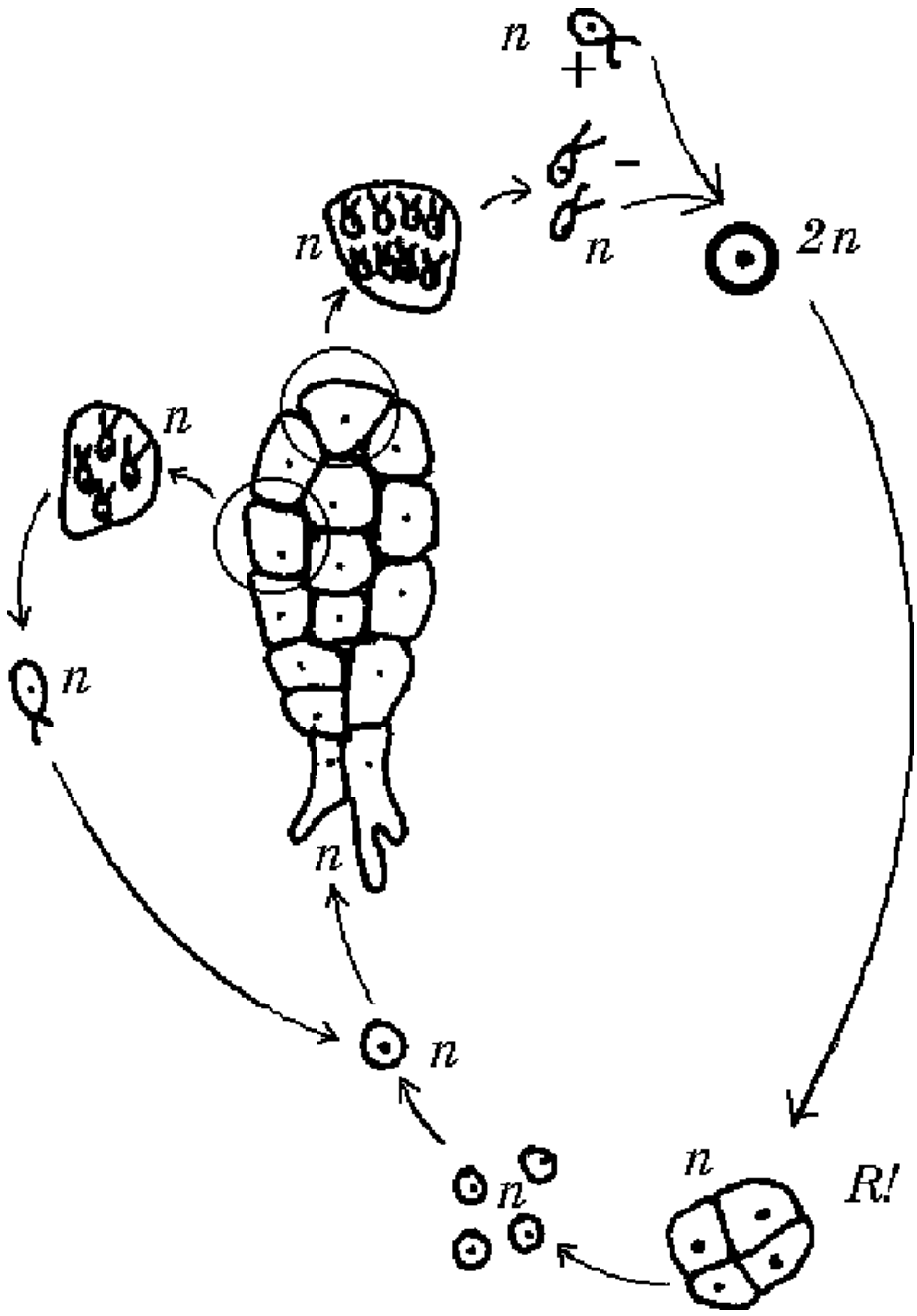
Sporic life cycle: plants



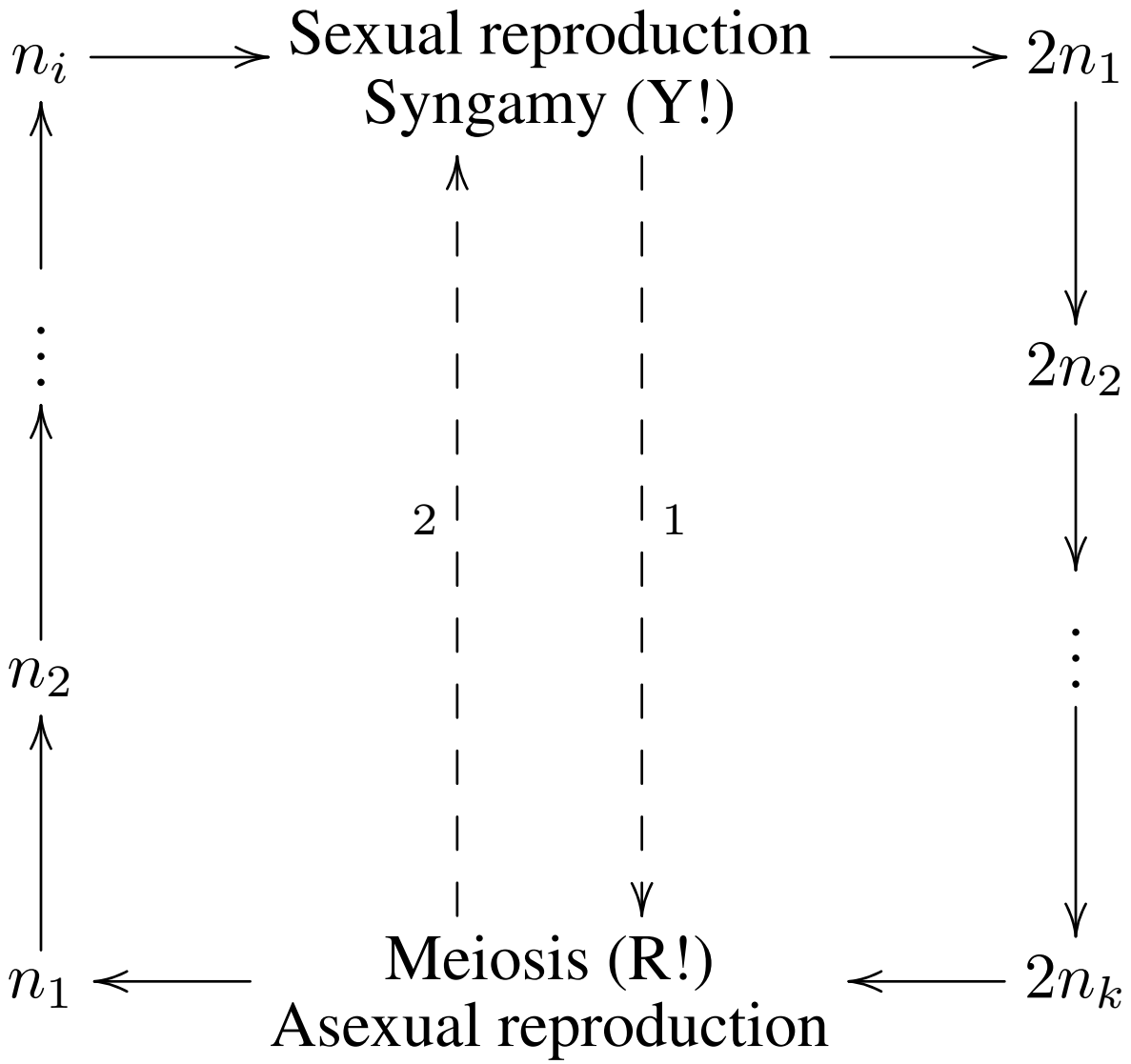
Gametic life cycle: animals



Zygotic life cycle: protists



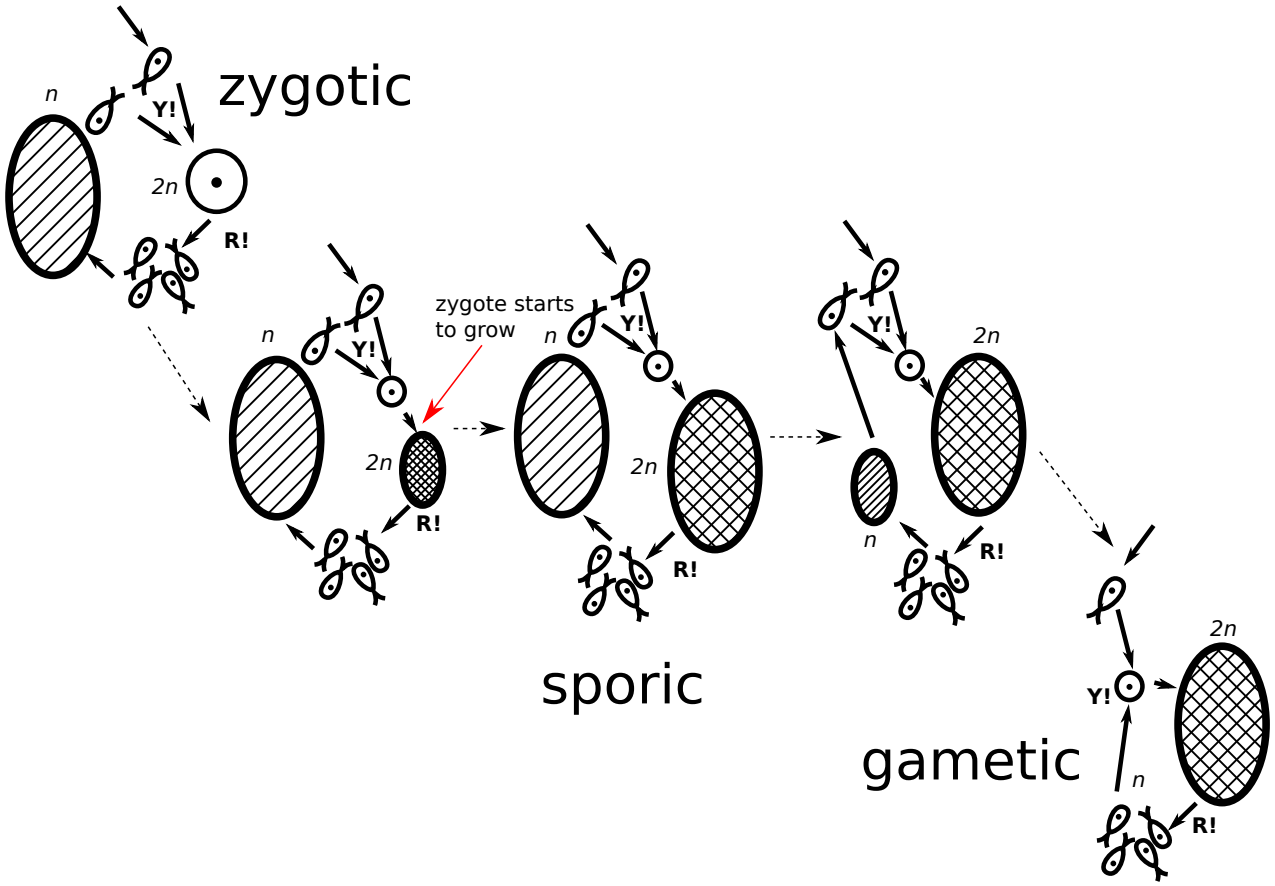
Life cycle math



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

19.3 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

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"

For Further Reading

References

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

Outline

20 Questions and answers

Previous final question: the answer

Decribe the difference between haplont and diplont

- Haplont n, capable to sexual reproduction
- Diplont $2n$, capable to asexual reproduction

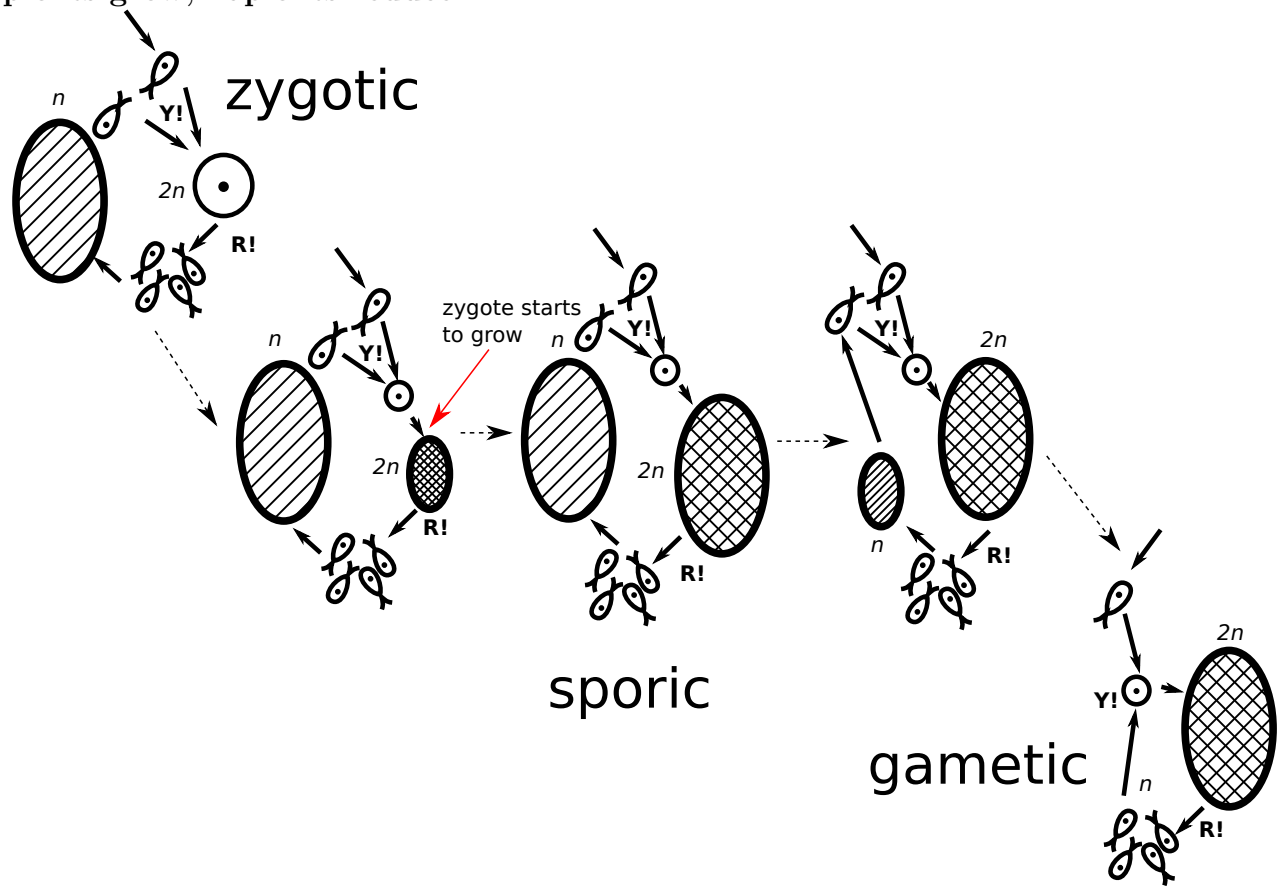
21 Life cycle

21.1 Evolution of life cycles

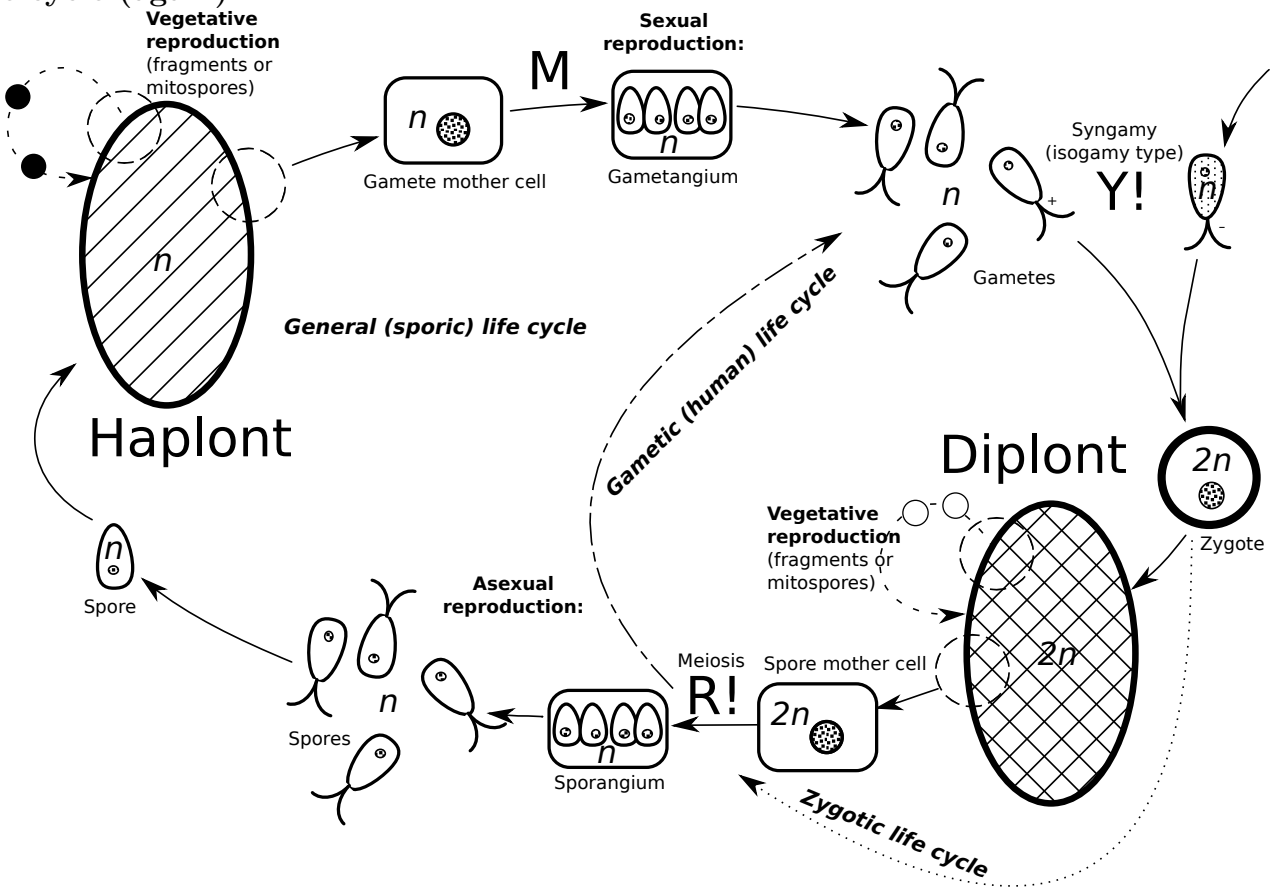
3 cycles

- **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$_2$

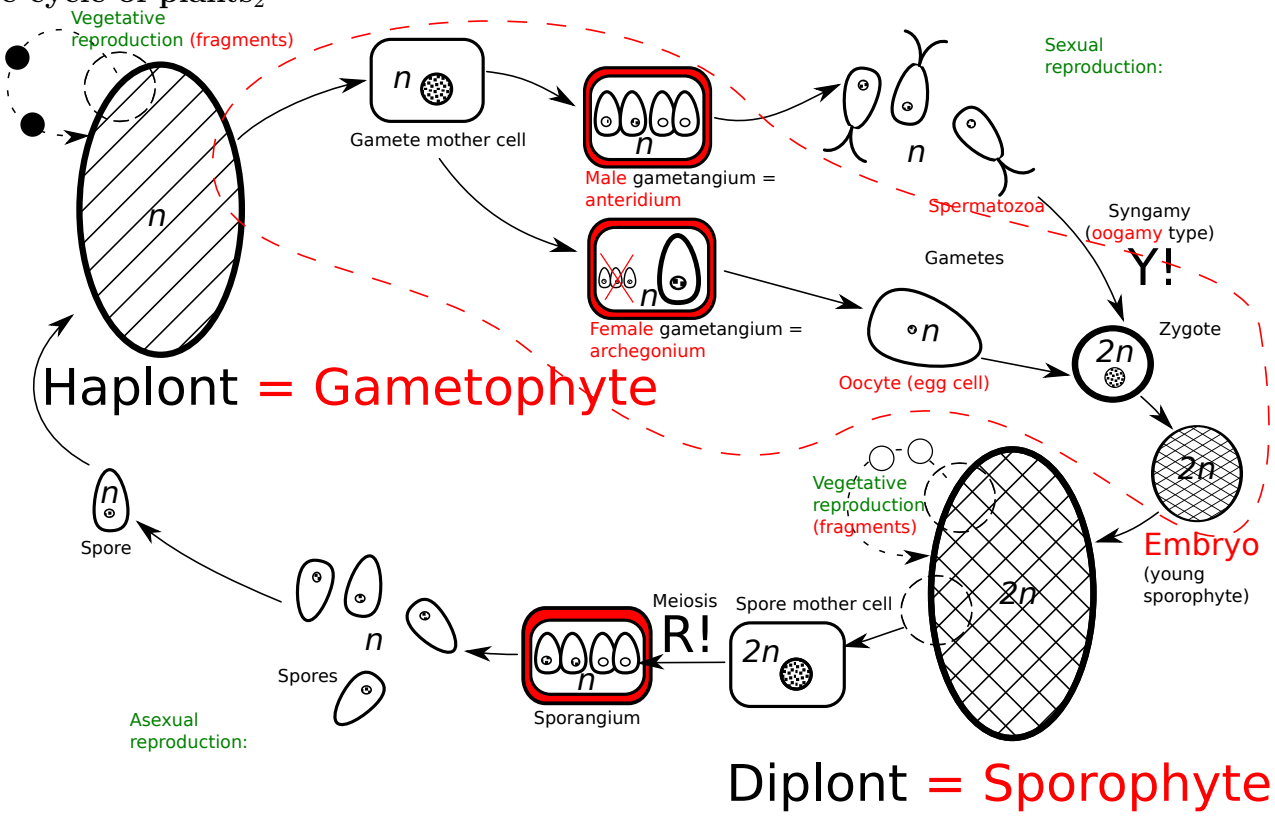
Diplonts grow, haplonts reduce



Life cycle (again)



Life cycle of plants$_2$



22 Tissues

22.1 Origin of tissues

Origin of tissues and organs of plants: first steps

Why did plants go to the land? Which problems did they meet and how did they resolve them? What was the plant way of acquiring tissues comparing with animals?

Summary

- **Zygotic** life cycle has no *diplont*, **gametic** life cycle has no *haplont*, **sporic** life cycle has both *haplont* and *diplont*
- The structure of plant body, its organs and tissues is a result of land colonization

For Further Reading

References

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

Outline

23 Questions and answers

Previous final question: the answer

Describe the difference between diplont and sporophyte

- All sporophytes are diplonts but not all diplonts are sporophytes
- Sporophyte is a diplont of plants_2 (Vegetabilia)

24 Tissues

24.1 Origin of tissues

Origin of tissues and organs of plants: first steps

Why did plants go to the land? Which problems did they meet and how did they resolve them? What was the plant way of acquiring tissues comparing with animals?

24.2 Tissues basics

Definition of tissues and organs

- **Tissue** is a union of cells which have common origin, function, and similar morphology
- **Organ** is a union of different tissues which have common function(s) and origin

Simple and complex tissues

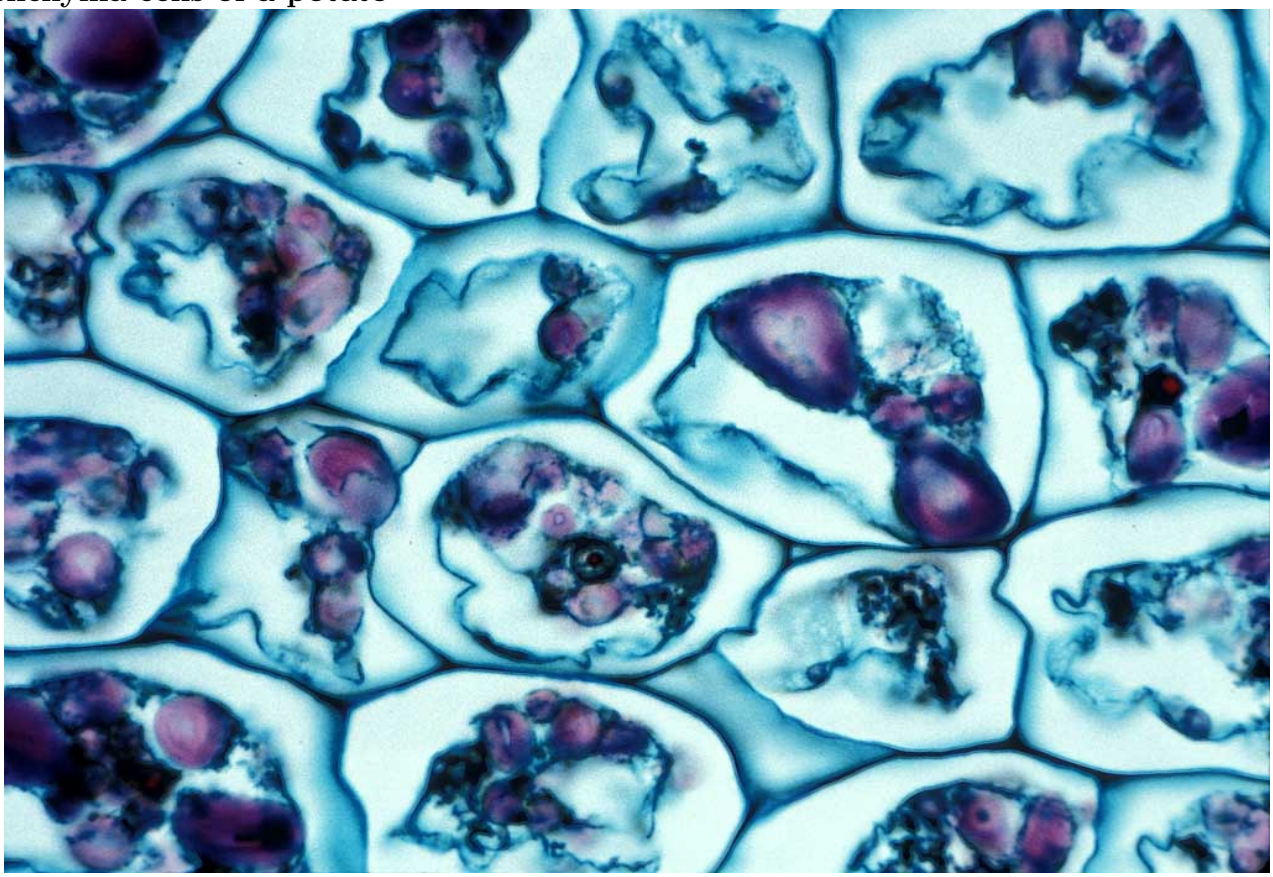
- **Simple tissues** have only one kind of cells
- **Complex tissues** have more than one cell type. This tissue type is unique for plants

24.3 First tissues: parenchyma and epidermis

Parenchyma (ground, main tissue)

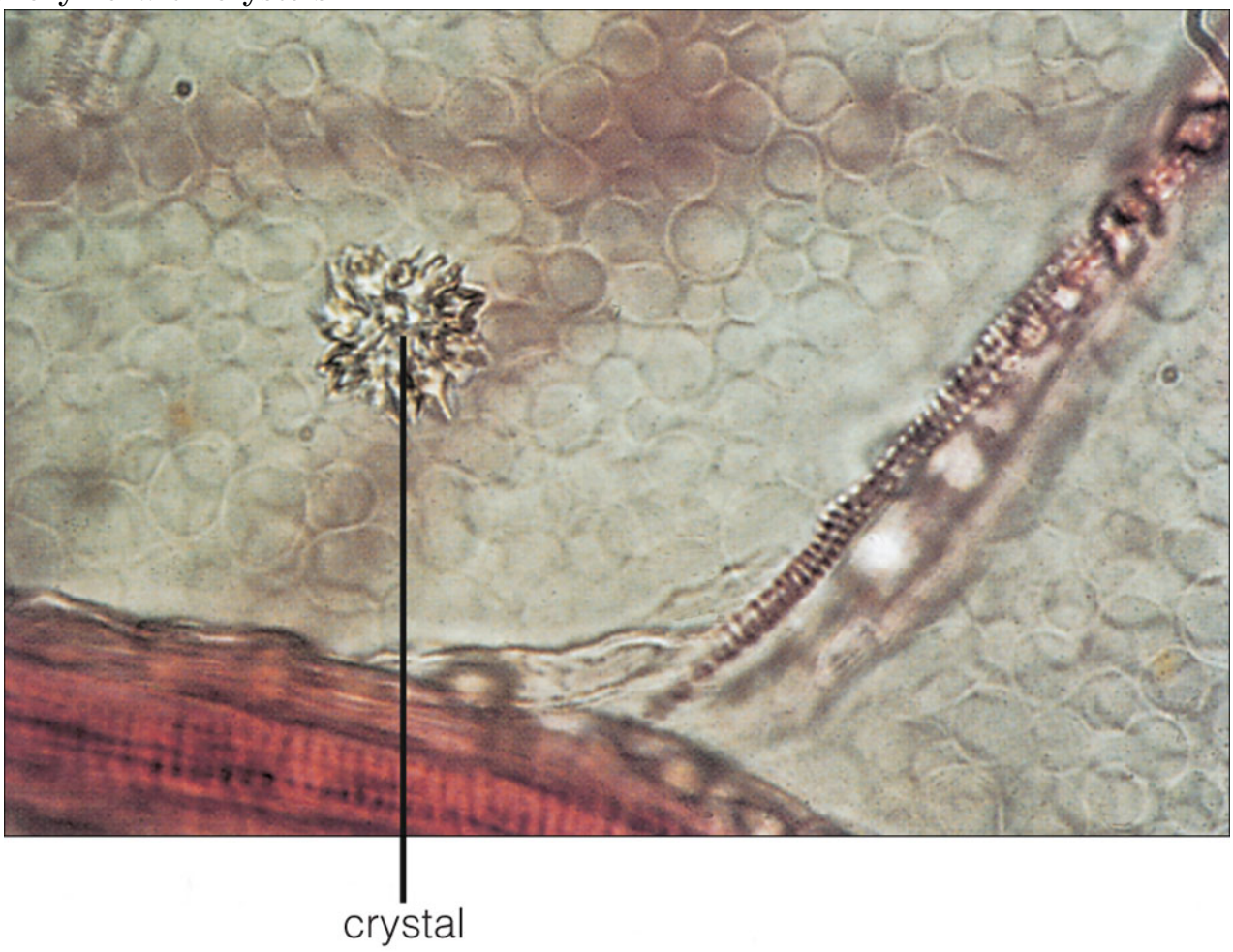
- Spherical or elongated cells
- Thin primary cell wall
- Sometimes, crystal inclusion bodies
- Main functions: photosynthesis and storage

Parenchyma cells of a potato



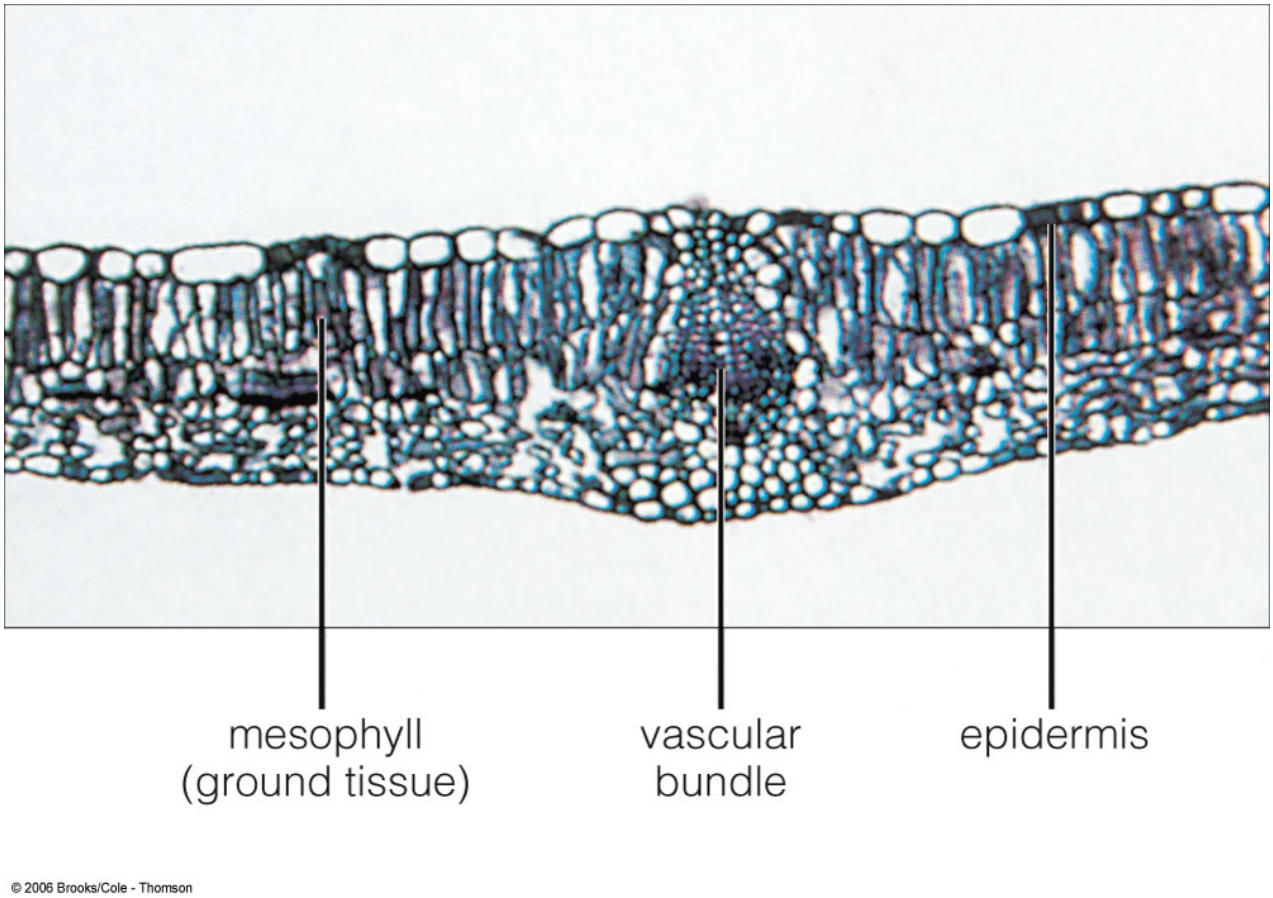
Parenchyma cells of a potato; the central cell shows obvious nucleus with starch stained purple (LM ×83)

Parenchyma with crystals



Parenchyma cells often include crystals (e.g., of calcium oxalate)

Photosynthetic parenchyma

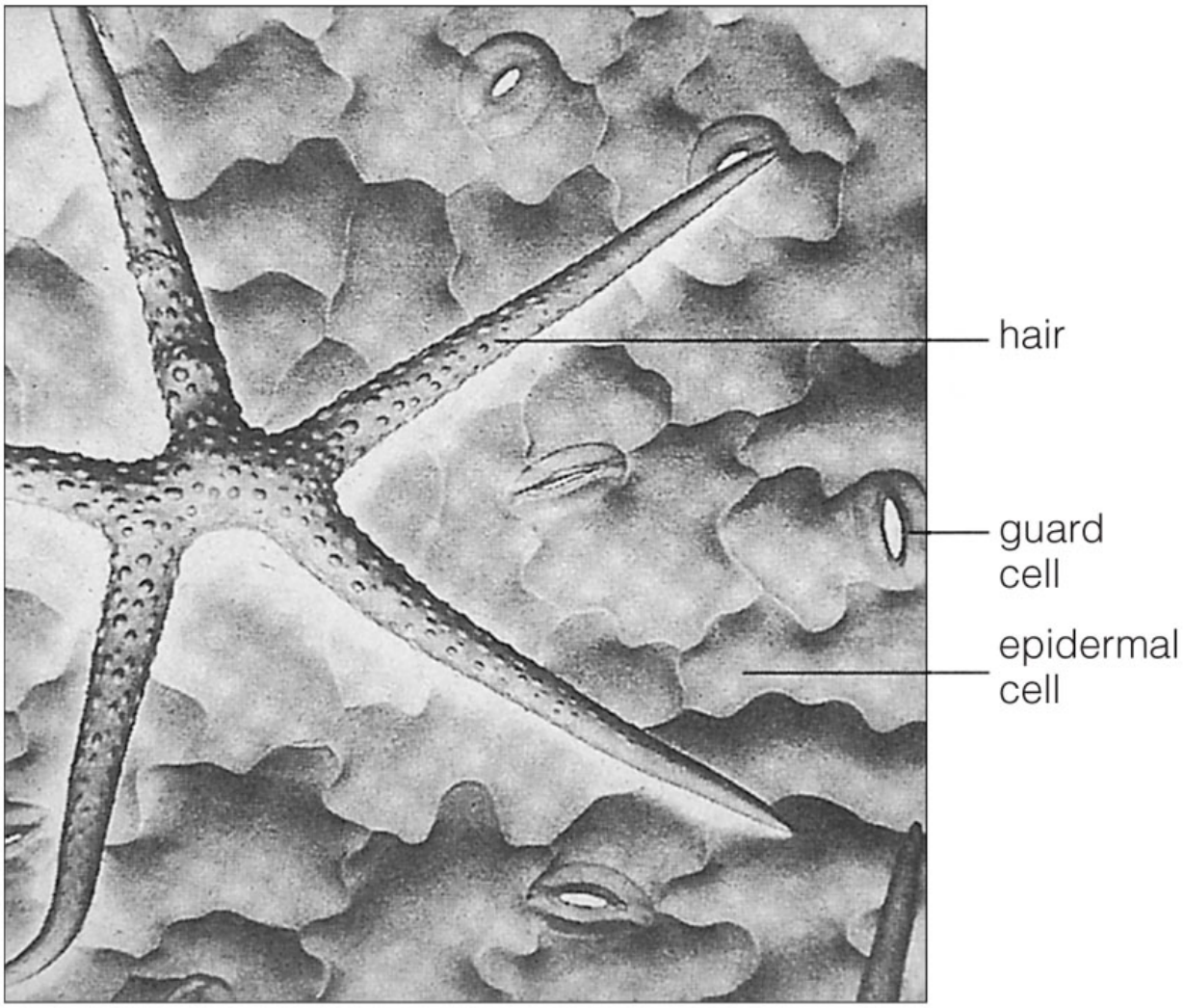


Photosynthetic parenchyma in lilac (*Syringa vulgaris*) leaf

Epidermis: the complex tissue

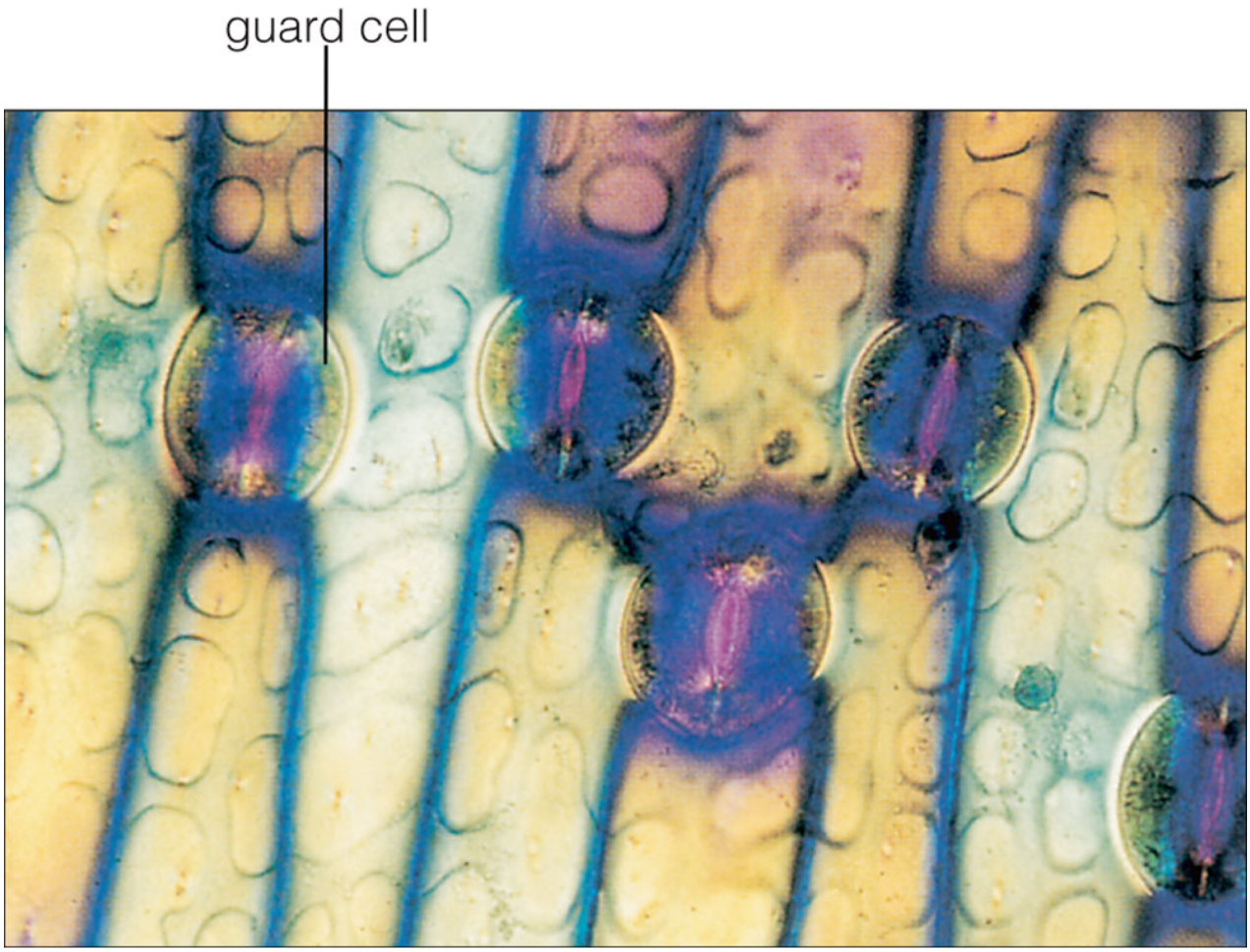
- Complex tissue of different cell types:
  1. Epidermal cells
  2. Stomata cells:
     - Guard cells
     - Subsidiary cells
  3. Trichomes
- Shapes and chemical compounds vary
- Main functions: gas exchange, transripration, defense

Epidermal cells



Three kinds of Shepard's purse (*Capsella bursa-pastoris*) epidermal cells

Stomata



Stomata with guard cells and pores (*Iris* sp.)

Summary

- **Zygotic** life cycle has no *diplont*, **gametic** life cycle has no *haplont*, **sporic** life cycle has both *haplont* and *diplont*
- The structure of plant body, its organs and tissues is a result of land colonization
- **Complex tissues** have different cell types, **secondary tissues** originate from lateral meristems (i.e., cambium)
- **Parenchyma**, or ground tissue, is a main component of young plant organs
- **Epidermis** is a complex tissue which includes stomata

For Further Reading

References

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

Outline

25 Questions and answers

Previous final question: the answer

How does epidermis prevent the loss of water?

- Cutilcle
- Stomata

26 Tissues

More about plants$_2$ classification

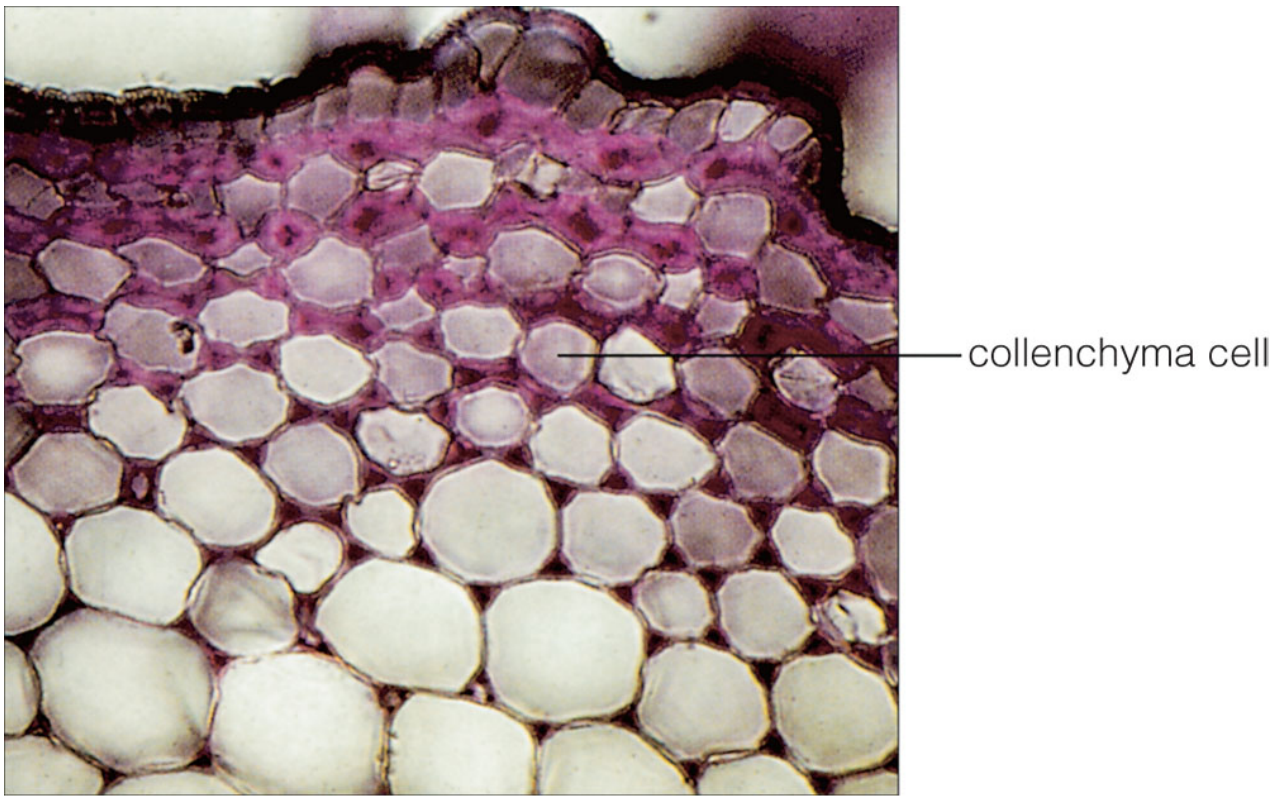
- Mosses (Bryophyta)
- Ferns and allies (Pteridophyta)
- Seed plants (Spermatophyta)
  - Conifers (Pinopsida)
  - Some other classes of seed plants
  - Angiosperms (Magnoliopsida)
    - Monocots (Liliidae)
    - Other subclasses of angiosperms (together: "dicots")

26.1 Step two: skeleton. Supportive tissues

Collenchyma: living supportive tissue

- Elongated cells
- Thick primary cell wall (pectins + cellulose)
- Main functions: mechanical support of young stems and leaves

Angled collenchyma

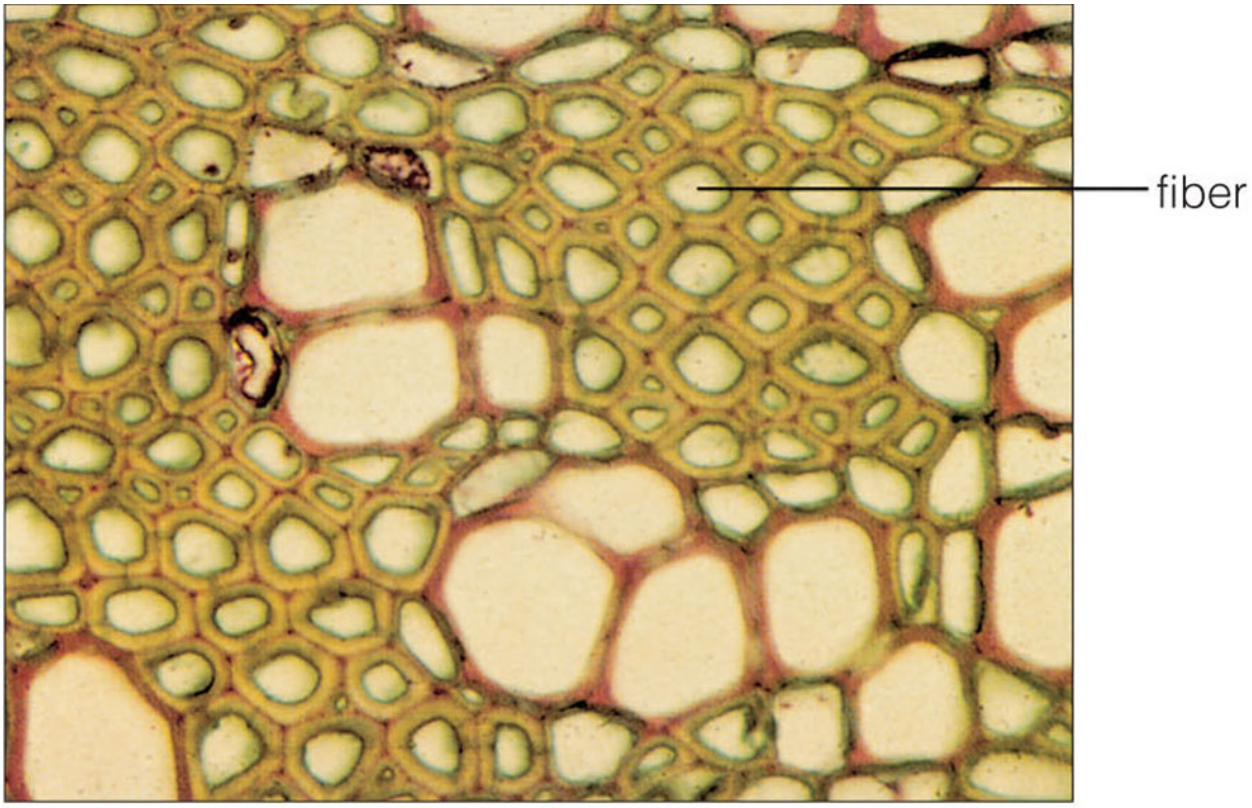


Collenchyma cells of marigold (*Calendula officinalis*)

Sclerenchyma: dead supportive tissue

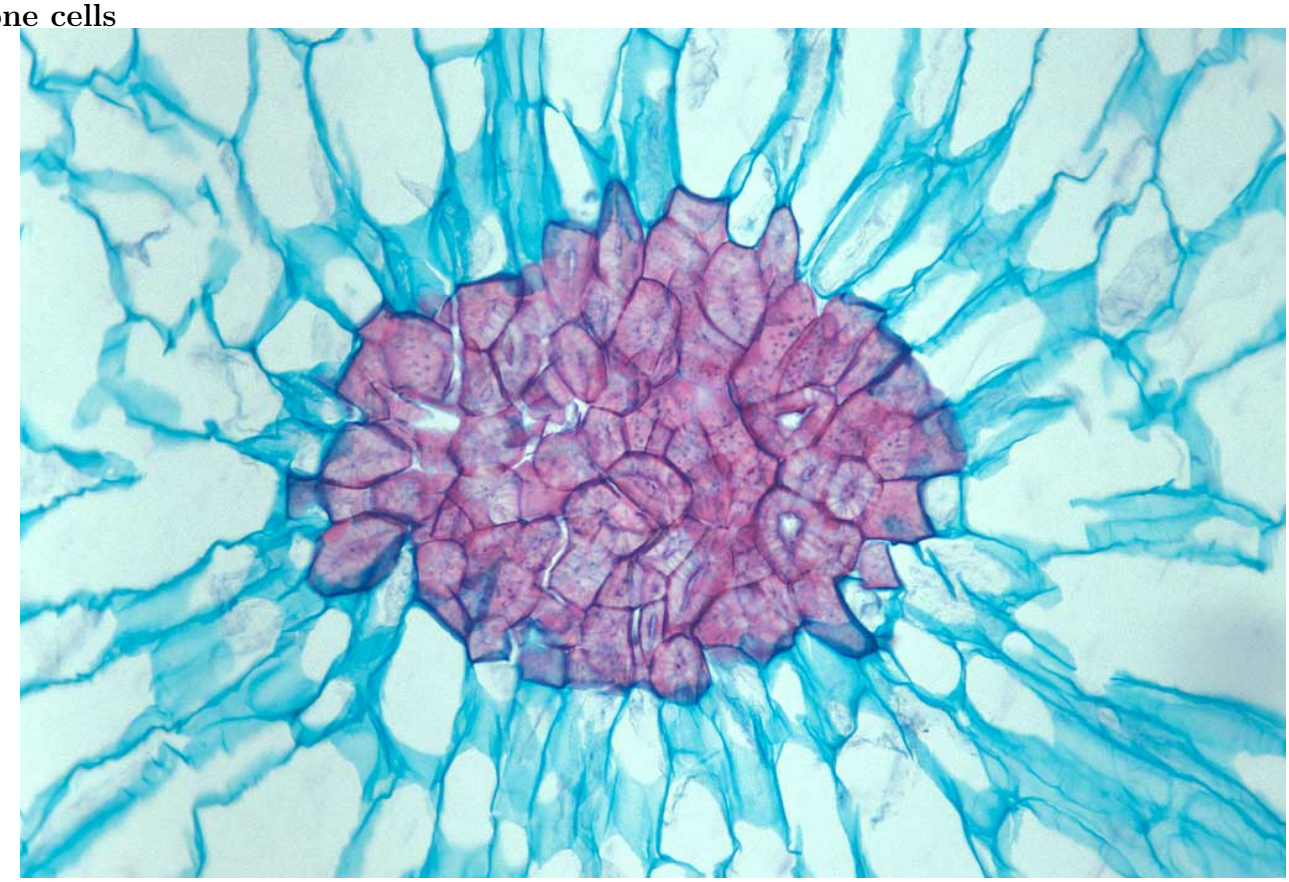
- Long cells (sclerenchyma fibers) or short crystal-like cells (sclereids)
- Dead cells with thick secondary cell wall, rich of lignin
- Supports weight of older plant organs, makes fruits non-edible before they become rip, makes stems firm

Sclerenchyma fibers



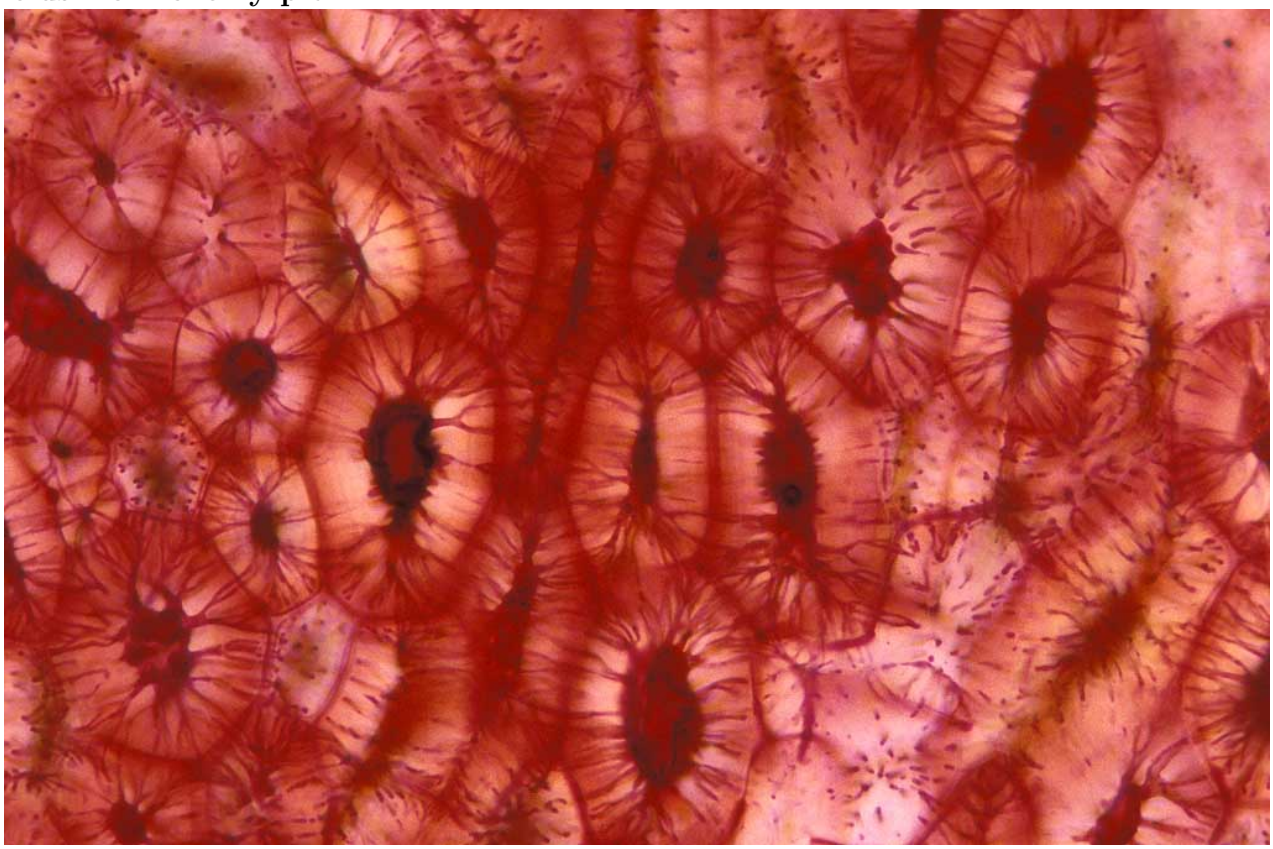
Cross-section of sclerenchyma fibers in geranium (*Pelargonium* sp.)

Stone cells



Stone cells (kind of sclereids) in pear fruit (*Pyrus communis*)

Sclereids from cherry pit



Sclereids from cherry (*Prunus* sp.) pit (LM ×400)

26.2 Step three: construction sites. Meristems

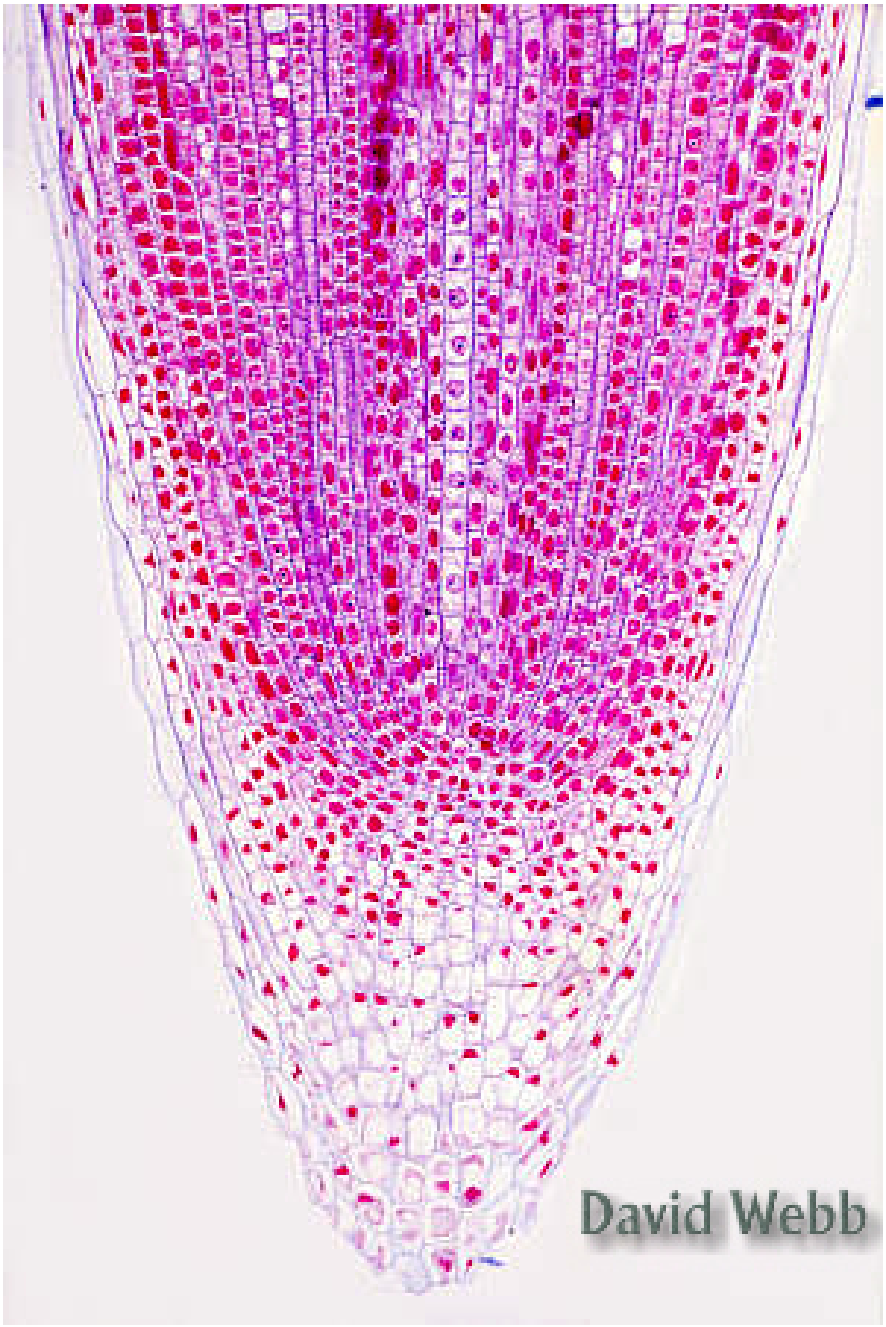
Meristems: apical

- Centers of plant development
- Locate on the very ends of roots (RAM) and shoots (SAM)
- Produce intermediate primary meristems which form all primary tissues

SAM

Coleus sp. stem apical meristem (LM ×100); primordia (embryonic leaves) are visible.

RAM



Corn (*Zea mays*) root apical meristem (© D. Webb)

Lateral meristem: cambium

- Originates from procambium which in turn originates from apical meristems
- Usually arises between two vascular tissues
- Main function: thickening. Produces secondary vascular tissues

Primary and secondary tissues

- Primary tissues originate from stem or root apex through primary meristems
- Secondary tissues originate from lateral meristems

Additional meristems

- **Intercalary** meristems: locate in stems, regulates stem elongation
- **Marginal** meristems are leaf-specific, they regulate leaf shape
- **Repair** meristems help to cure wounds, they form buds and roots in unusual places

Summary

- **Collenchyma** and **sclerenchyma** are simple supportive tissues
- **Secondary tissues** originate from lateral meristems (i.e., cambium)

For Further Reading

References

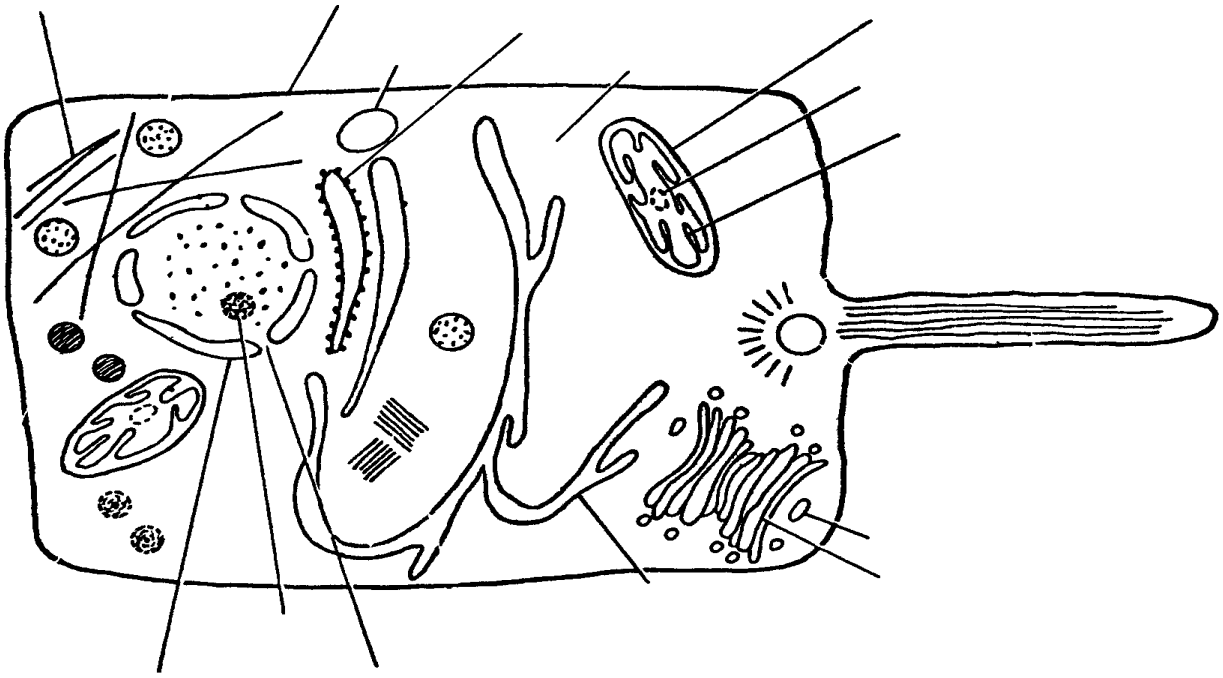
[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2015. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

Example questions for the exam

Start time _____ *End time* _____

Short answers (10 points)

1. Label the picture below (cell under electronic microscope). *One point per correct label; 10 labels maximum.*



Multiple choice

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

1. If nucleus would be enclosed in one membrane:
   (a) Ribosomes will not accept DNA
   (b) Pores will be impossible to place
   (c) Both of above
2. DNA of prokaryotes is:
   (a) The circular molecule
   (b) Situated inside a nucleus
   (c) Both of above
3. Diploid plants$_2$ can also be called:
   (a) Diplonts
   (b) Diploid generation
   (c) Sporophytes
   (d) All of the above

(answers on next page)

Answers: 1B, 2A, 3D