VIBE PROJECT

Virtual Biomedical and STEM/STEAM Education

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PÉCSI TUDOMÁNYEGYETEM
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VIBE PROJECT

The structure of eukaryotic cells

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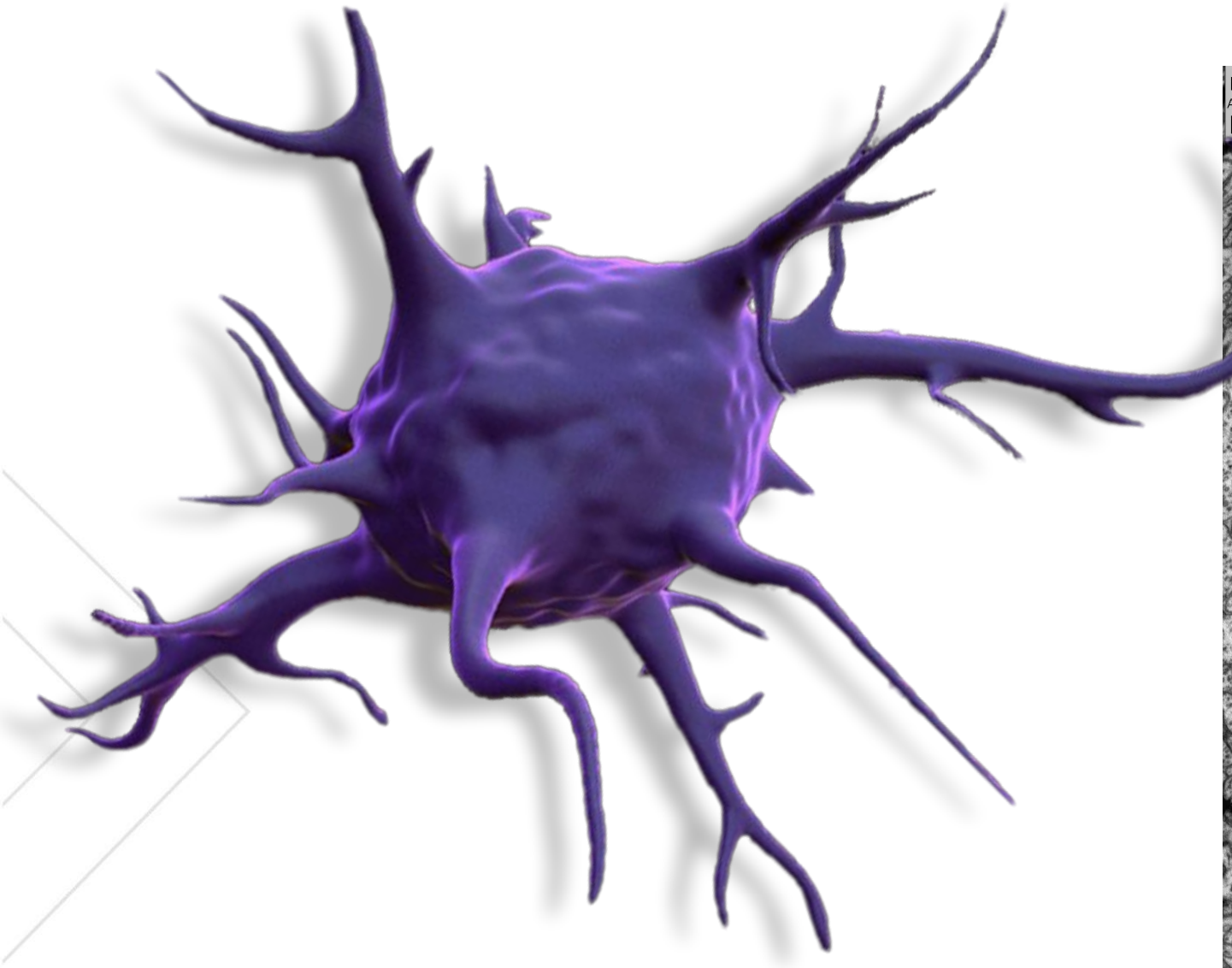
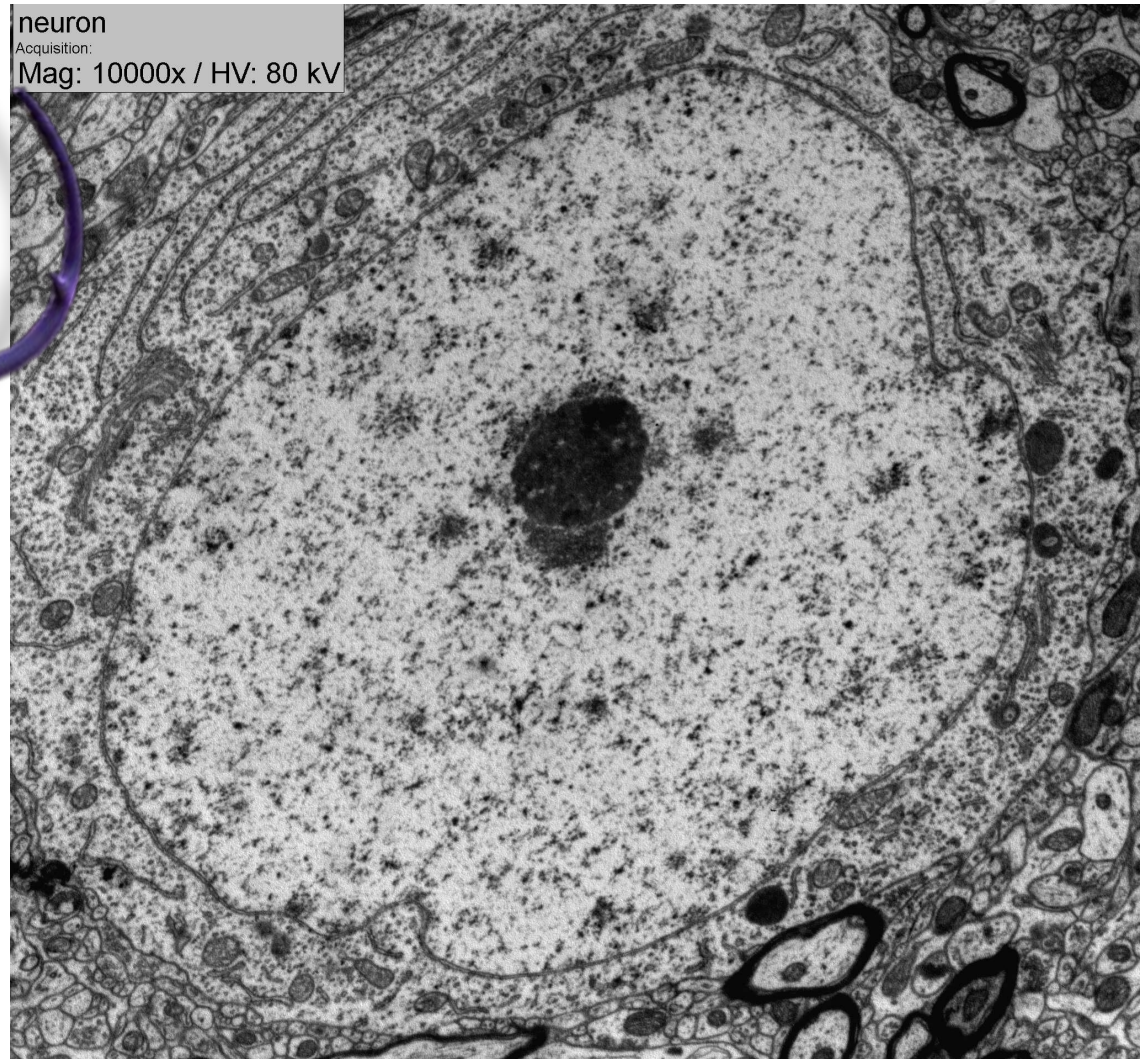
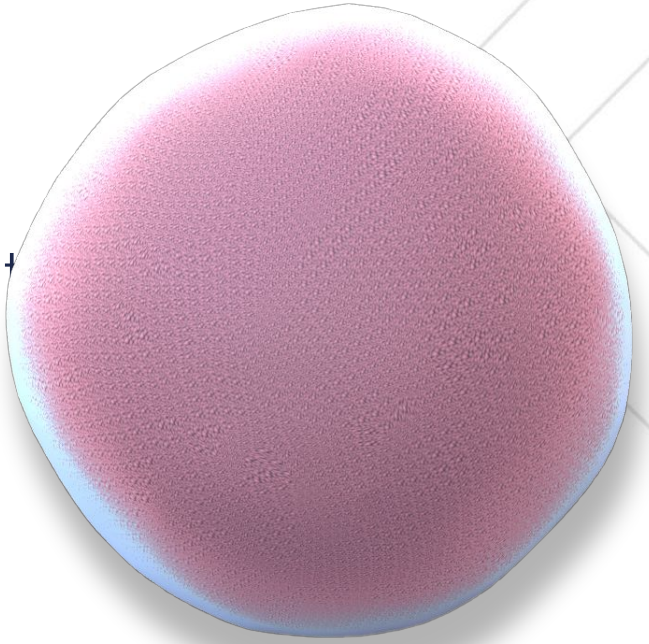
The structure of a neuron

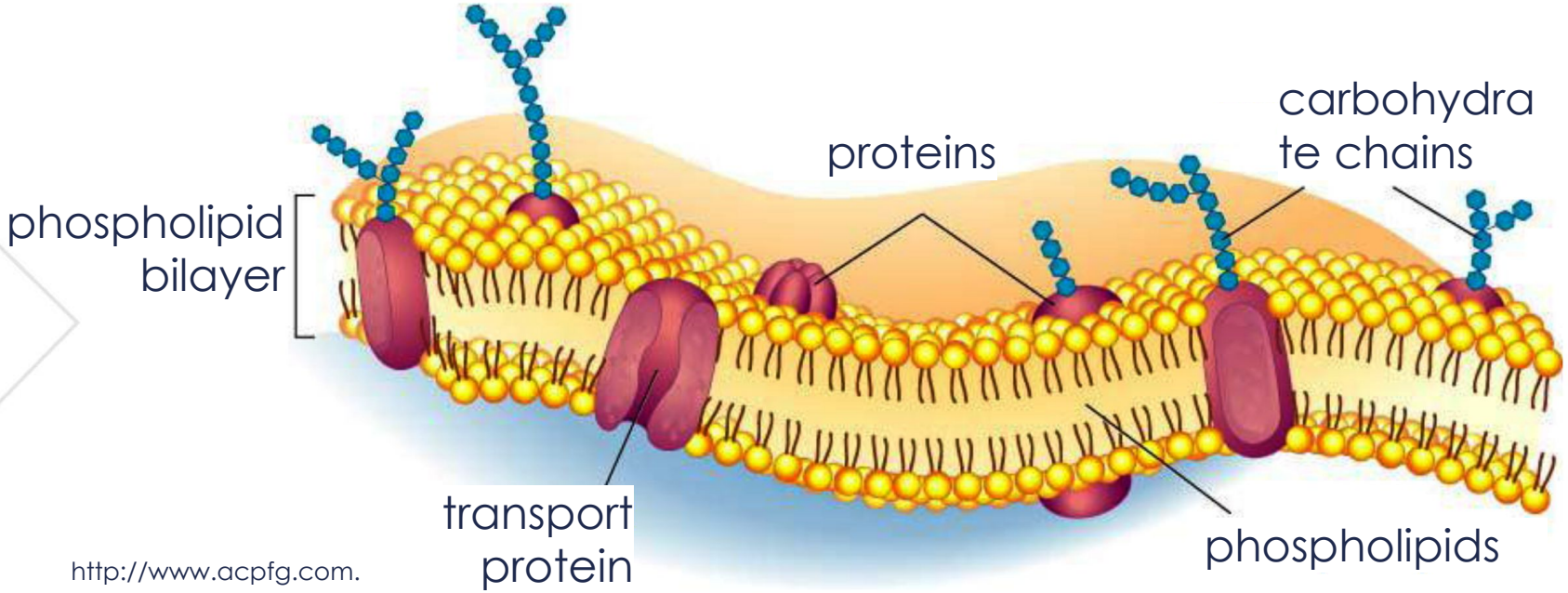




The cell membrane and biological membranes of intracellular organelles

- Phospholipid bilayer with embedded proteins (ratios approx.50-50%)
- fluid mosaic model
- glycoproteins and glycolipids contain carbohydrate chains
- membranes allow selective transport, separate but also connect to t
  environment (via receptors involved in signaling)





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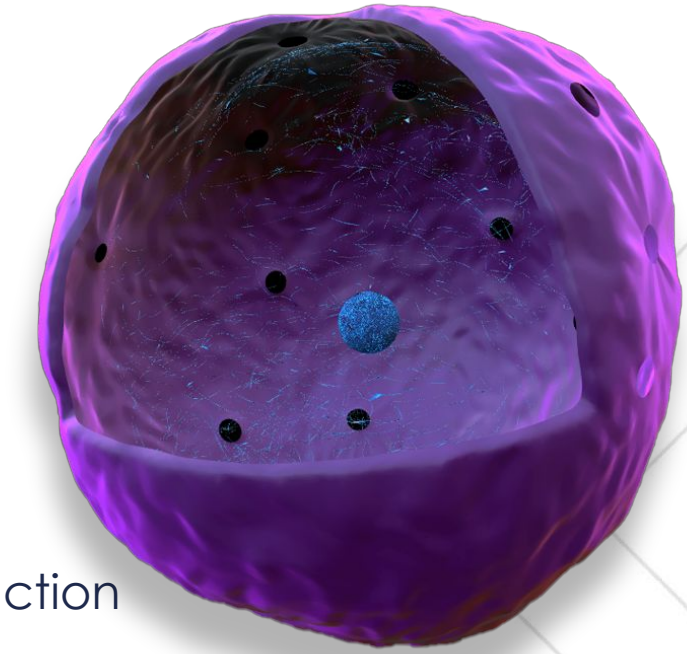
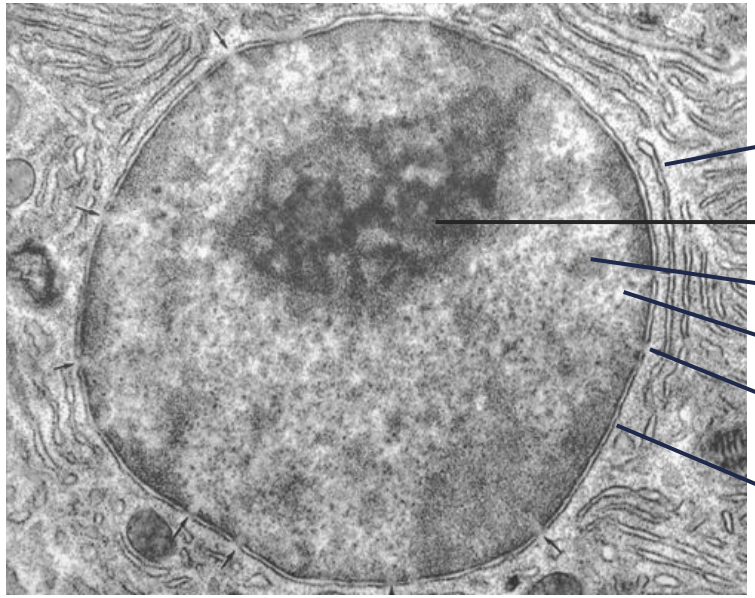
The nucleus



- The largest organelle
- Its shape can be round, flat, rod or a string
- Size: 5-10 µm
- It stores most of the cell's DNA, i.e. the genetic material
- It is the cell's control center: gene expression→ cellular structure and function
- It is the site of DNA replication, transcription (= RNA synthesis) and RNA processing



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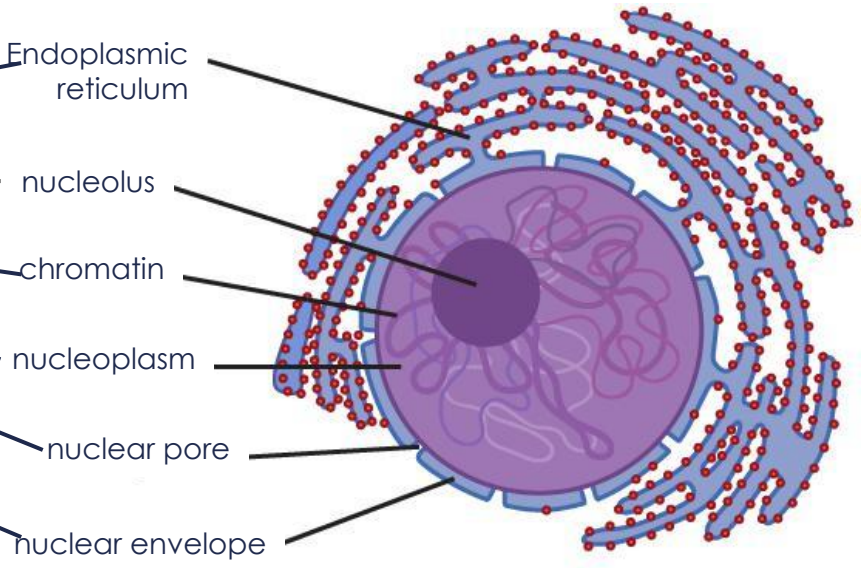
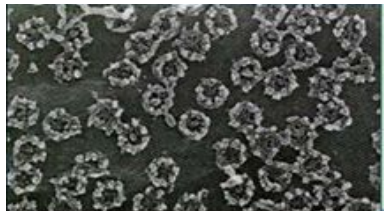
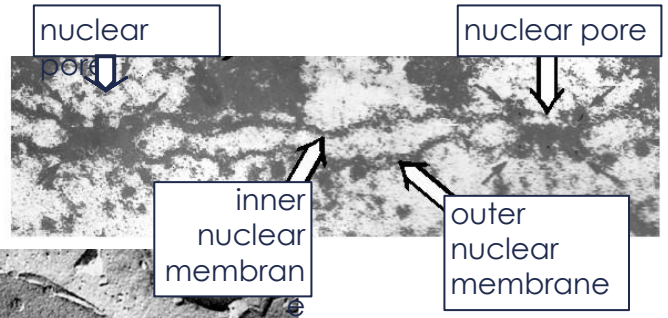


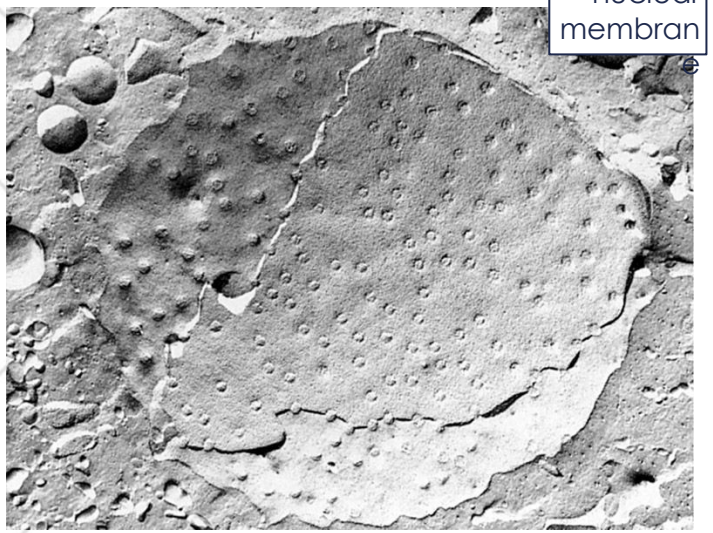
Wiki

The nuclear envelope

- Consists of an outer and inner membrane + perinuclear space
- Abounds in nuclear pore complexes: intensive transport (e.g. protein import, RNA export)
- Nuclear lamina: a protein layer lining the inner surface of the inner nuclear membrane







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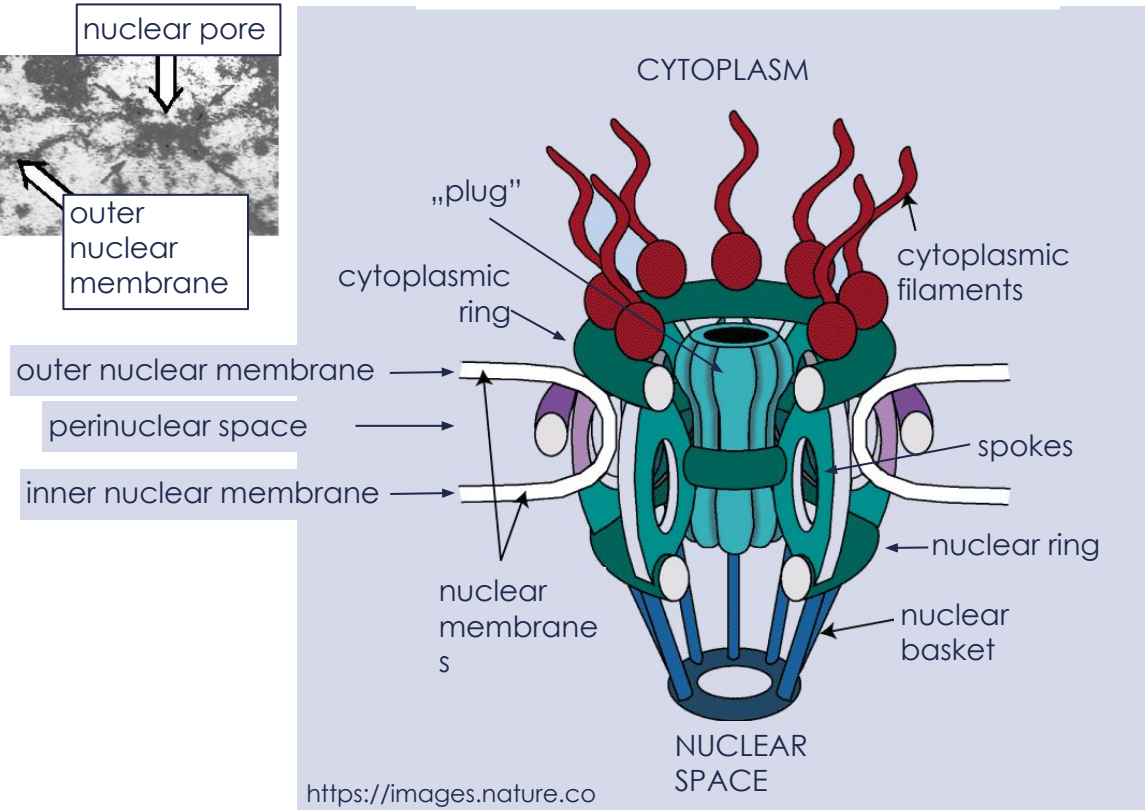

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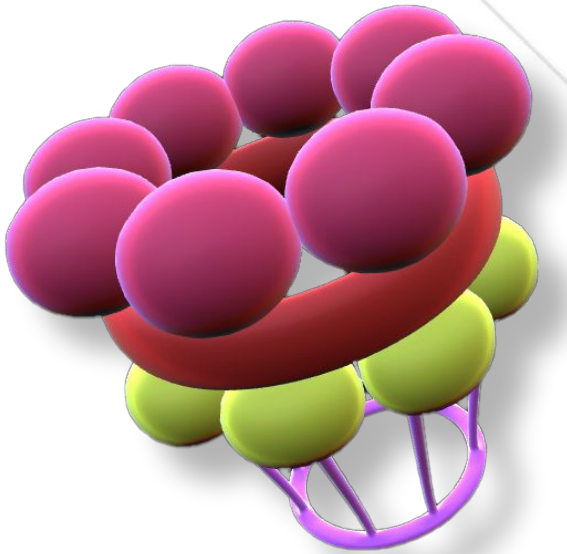
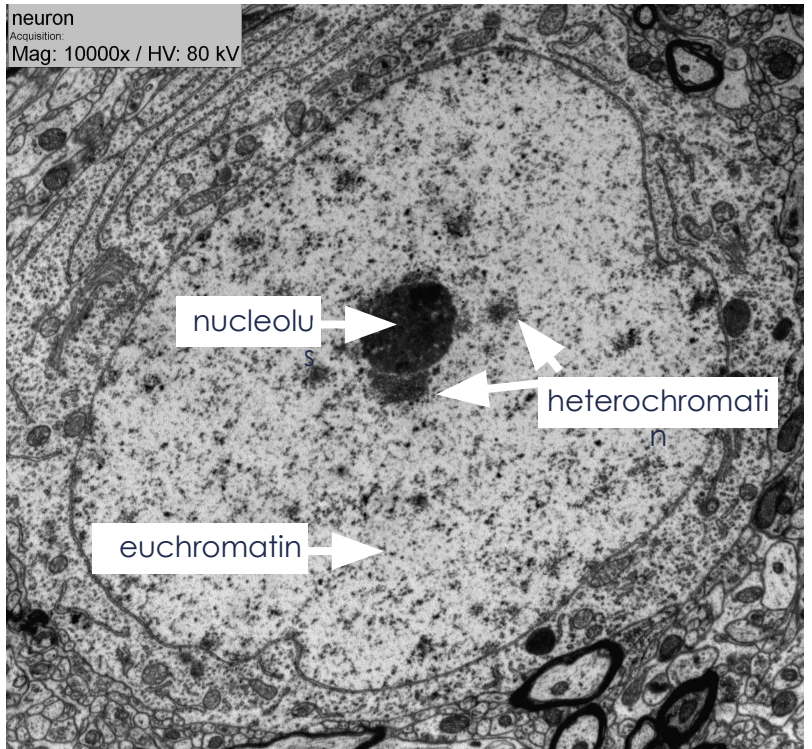


The structure of the nucleus

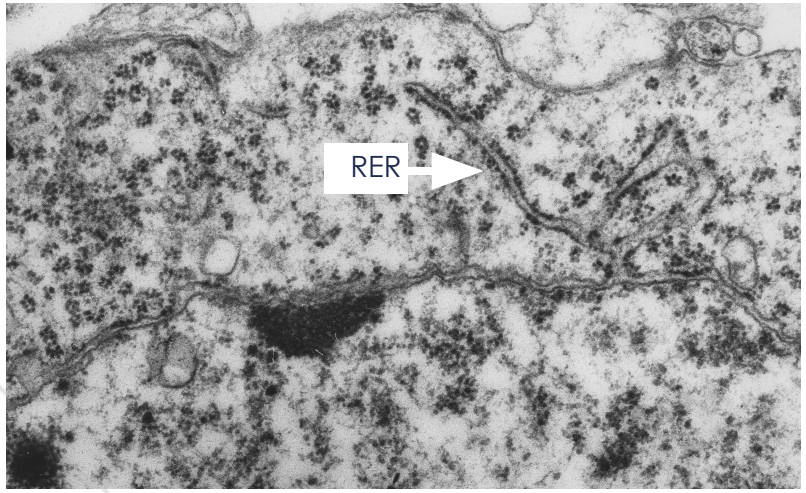
- Chromatin: DNA + proteins + RNA + ions
- Histone and nonhistone proteins bind to DNA
  - Euchromatin: looser structure, transcription takes place in it
  - Heterochromatin: more condensed structure, inactive regarding transcription

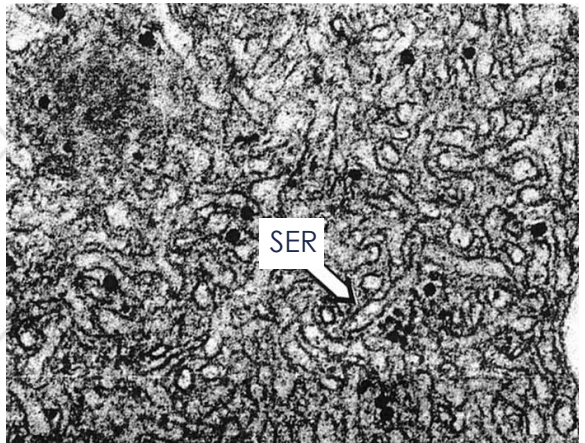


- Nucleolus: manufactures ribosomal subunits
- Nucleoplasm: the inner substance of the nucleus

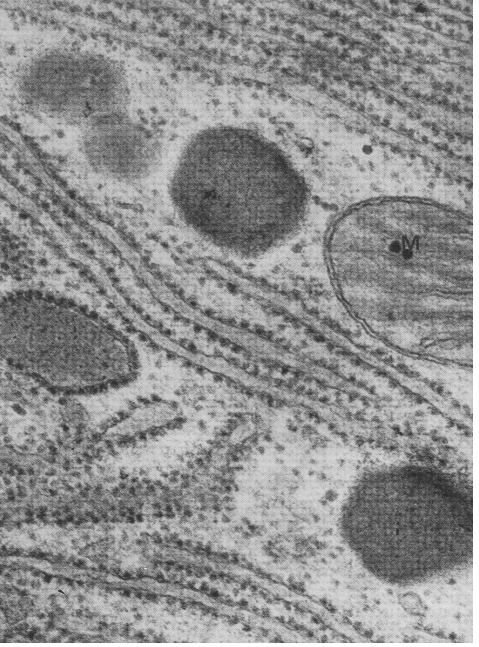
The endoplasmic reticulum

- An extensive membrane system connected to the outer nuclear membrane

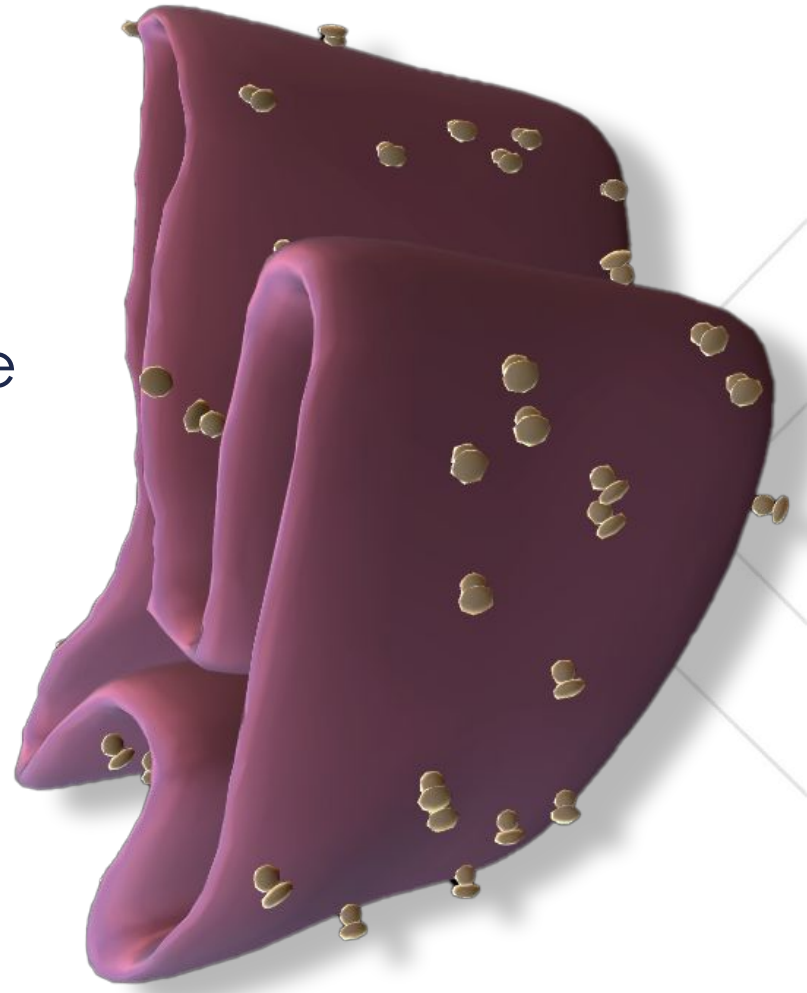




- Rough endoplasmic reticulum (RER)
- Smooth endoplasmic reticulum (SER)



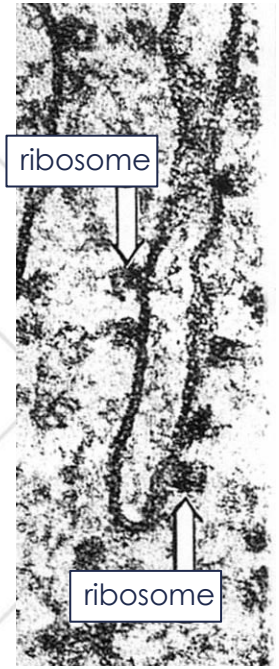
Rough ER



There are bound ribosomes on its surface

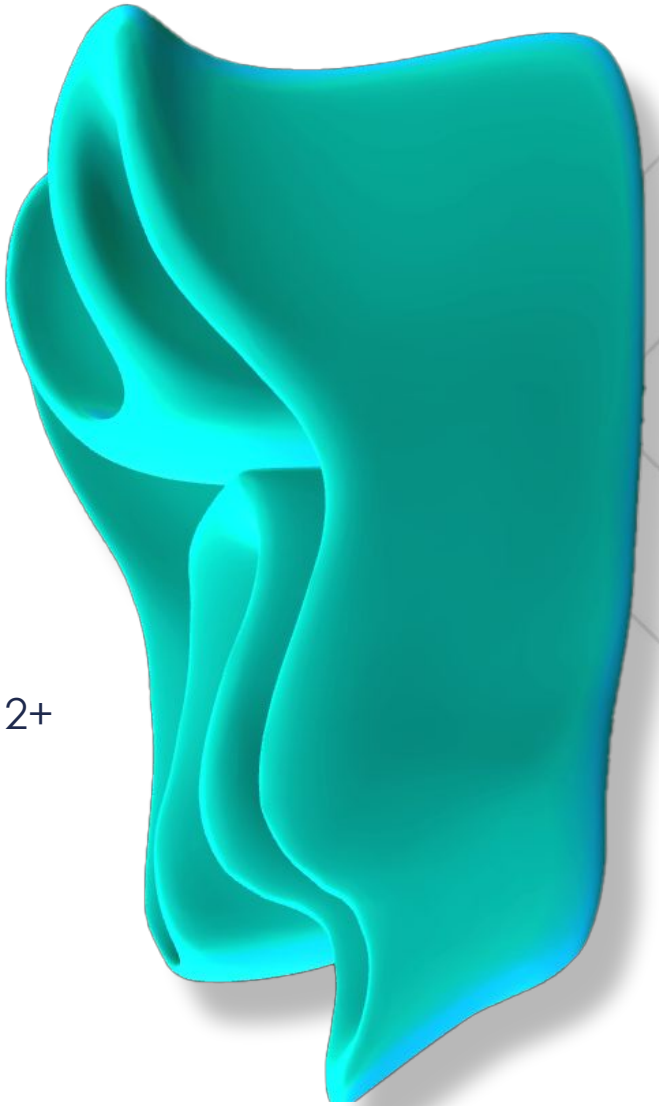
Functions:

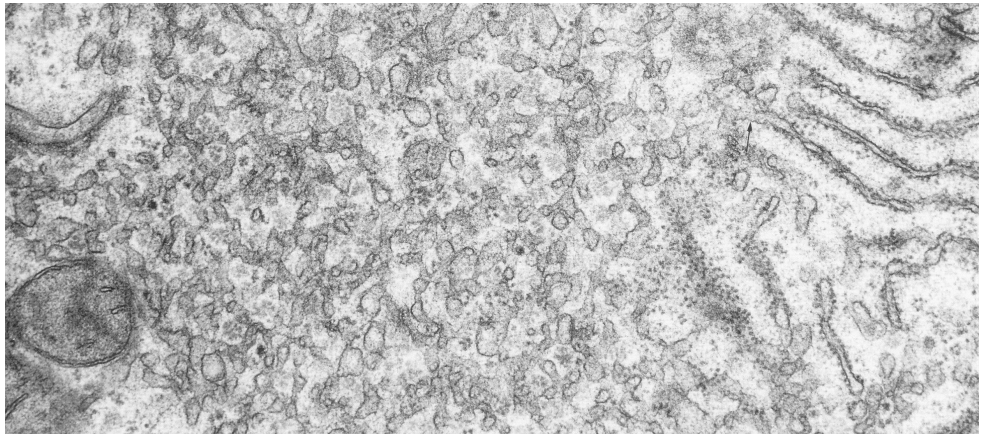
- Protein synthesis, for various organelles:
  - RER
  - Golgi apparatus
  - cell membrane
  - lysosomes
  - secretory proteins
- Protein processing (maturation):
  - Folding: formation and stabilization of conformation – with the help of chaperone proteins
  - Disulfide bond formation
  - Chemical modifications e.g. glycosylation (addition of carbohydrates)
- Quality control of proteins

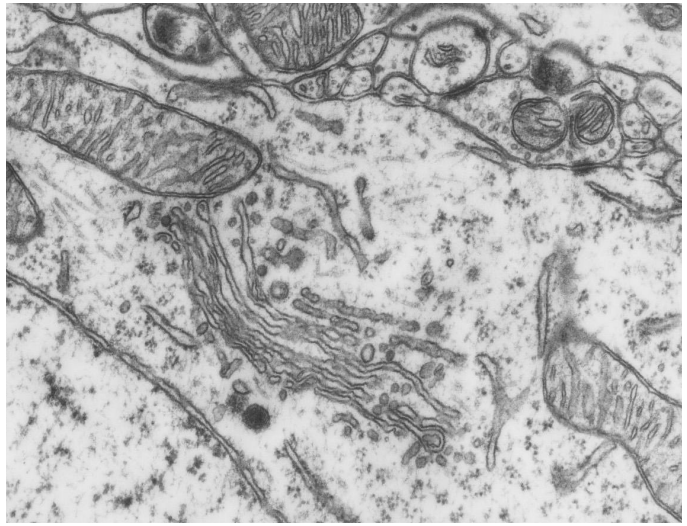


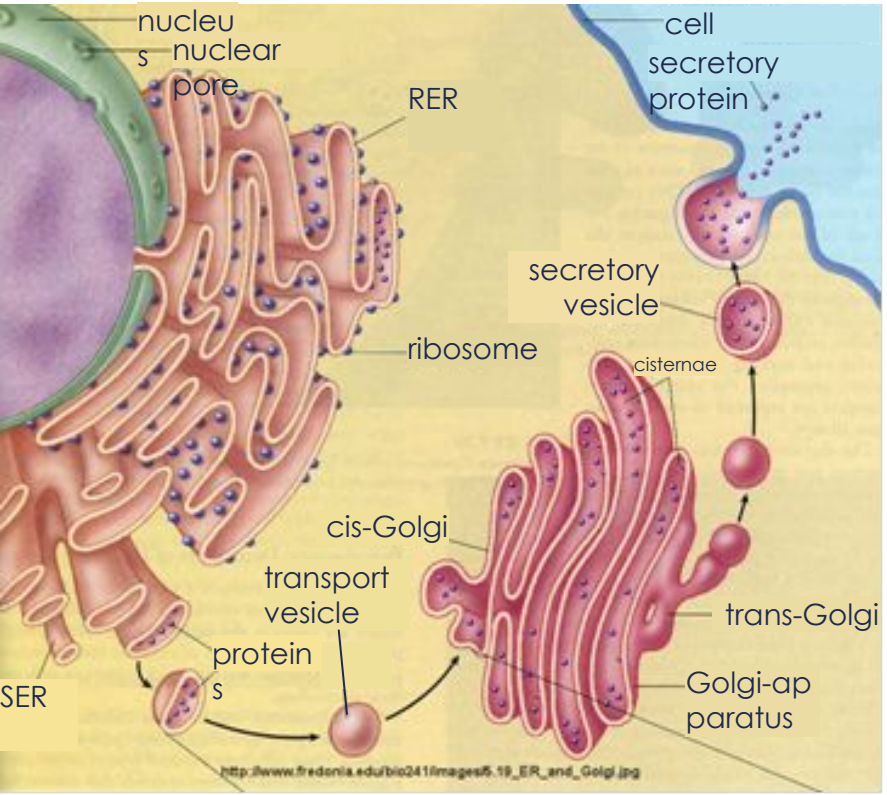
Smooth ER

- There are no ribosomes on its surface
- Its structure is not as well-ordered as that of the RER
- Functions:
  - Synthesis of lipids (e.g. phospholipids, steroids)
  - Ca^{2+} storage
  - Detoxification: biotransformation of foreign molecules
- In muscle: sarcoplasmic reticulum (a special SER): Ca^{2+} release from it → muscle contraction









Golgi apparatus

- is the next station of intracellular protein transport (along the „secretory pathway")
- It is composed of flat compartments (cisternae)
  - cis-Golgi
  - median-Golgi
  - trans-Golgi

Functions:

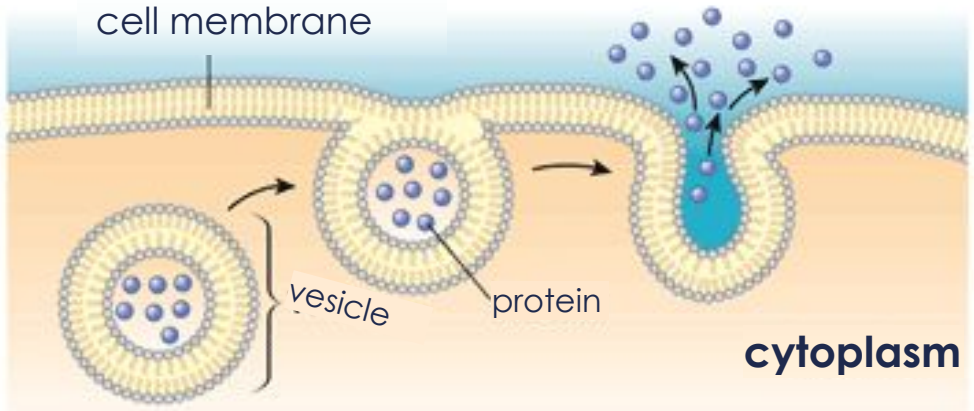
- protein maturation (e.g. glycosylation)
- sorting, and packaging of proteins into transport vesicles (by the trans-Golgi)

Vesicular transport

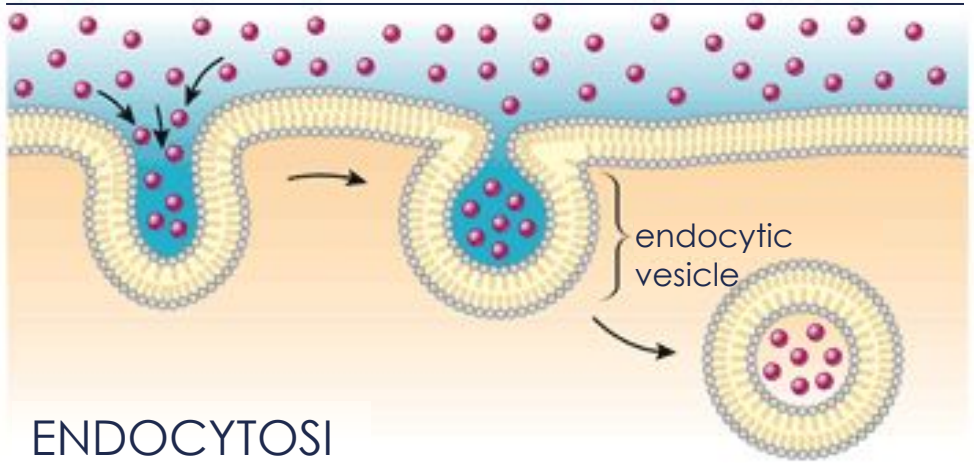
- The transport of materials (proteins, lipids, liquids, etc.) between the RER, Golgi apparatus, and SER is performed via transport vesicles (membrane-enclosed sacs)
- Along 2 major pathways:
  - endocytic pathway

    endocytosis: materials are taken up from the outside of the cell by a membrane invagination process
    - phagocytosis (e.g. leukocytes engulf bacteria)
    - pinocytosis (liquid uptake, „cell drinking")
    - receptor-mediated endocytosis (e.g. uptake of LDL particles)

    Endocytosis → endosome → merging with primary lysosomes → secondary lysosome (or alternatively storage, exocytosis)
  - Secretory pathway → exocytosis (secretion): transport of materials into the extracellular space: RER → transport vesicle → Golgi-apparatus → transport (secretory-) vesicle → exocytosis

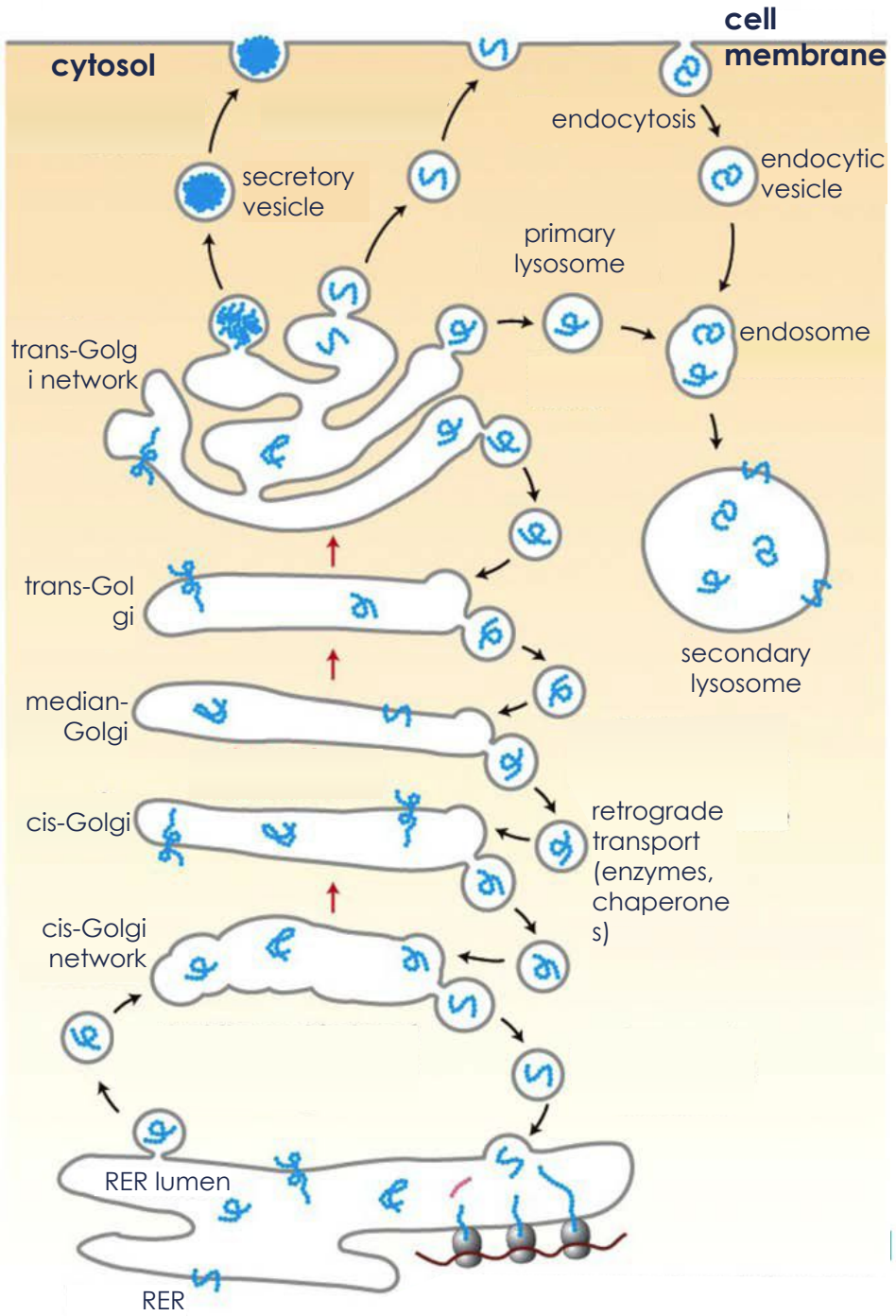


EXOCYTOSIS



ENDOCYTOSIS

http://mrtbiologysmhs.weebly.com



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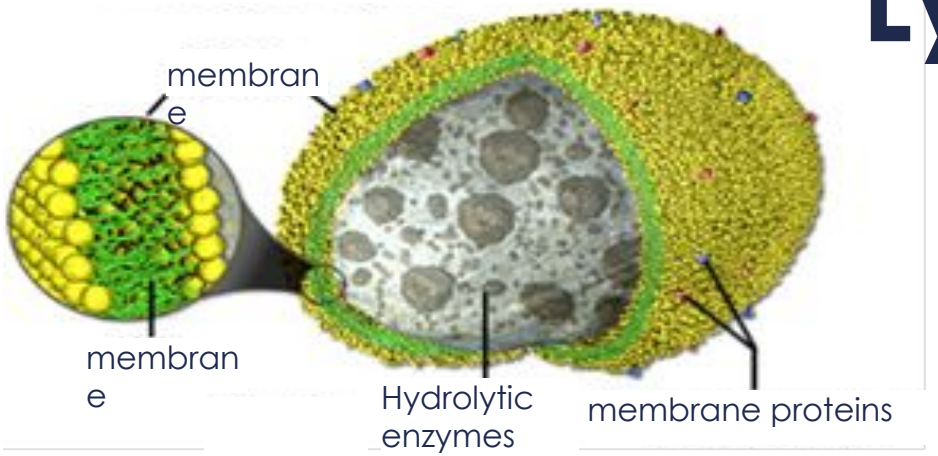
Lysosome

- Organelles of degradation and digestion. A single biomembrane surrounds a special content:
  - primary lysosomes: low pH (approx. 5), degradative enzymes (acid hydrolases). They originate form the trans-Golgi by budding.
  - secondary lysosomes: formed when primary lysosomes are fused to other vesicles. They contain materials which are being degraded (and are usually bigger in size).
- Degradation of molecules from different sources:
  - taken up from the cell's surroundings (by endocytosis, phagocytosis): heterophagy
  - intracellular molecules: e.g. worn out/damaged organelles (autophagy)

Lysosome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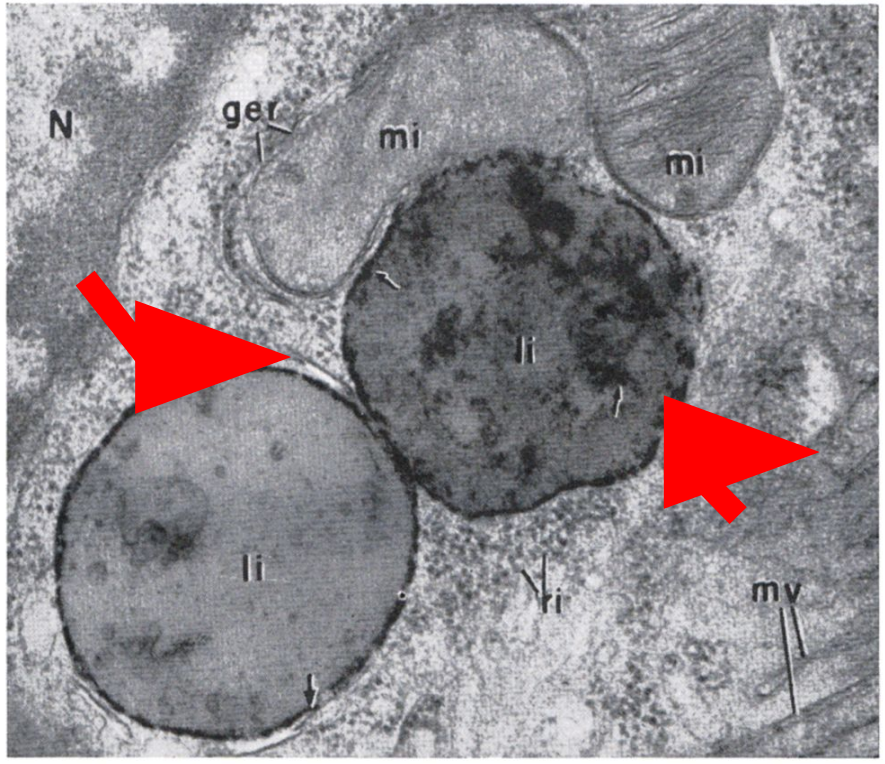
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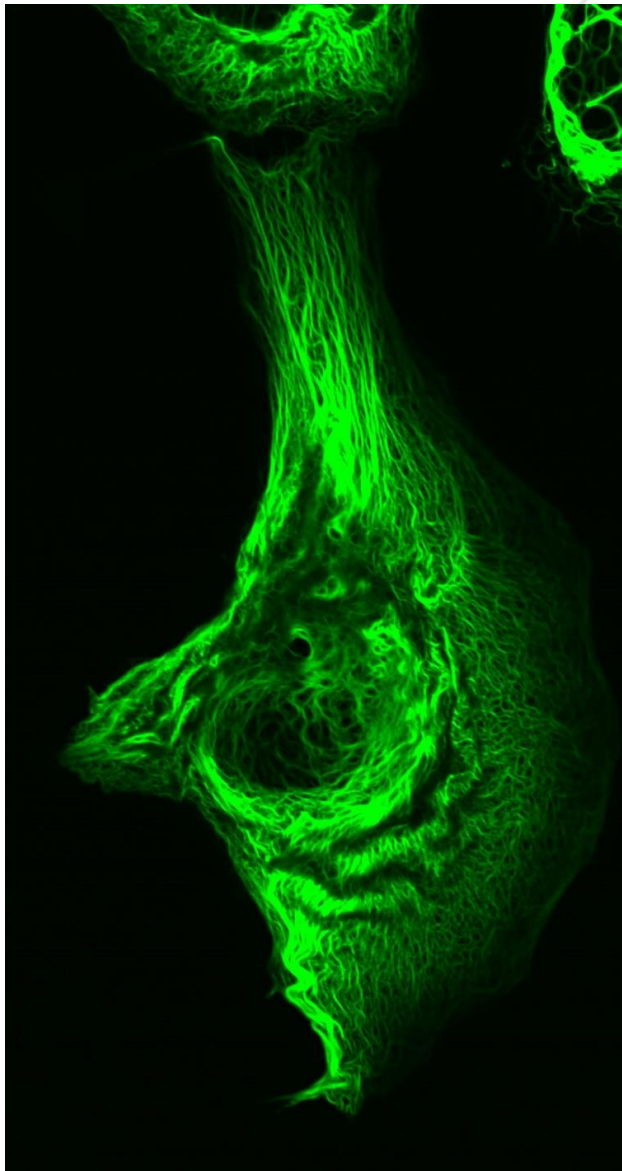
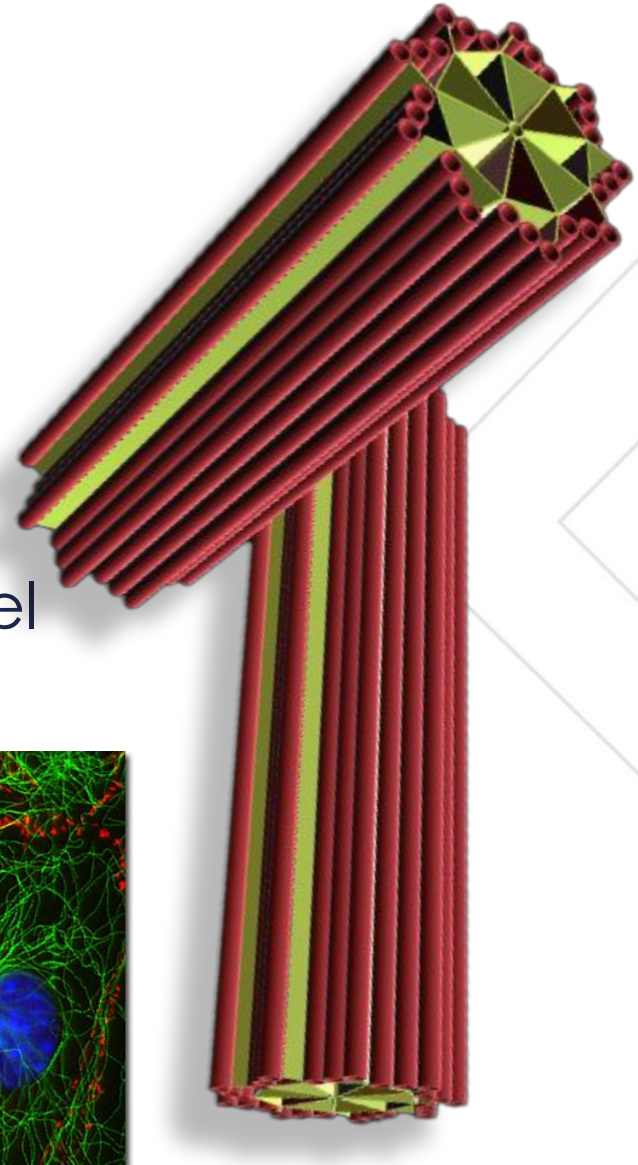
Cytoskeleton

- Secondary bonds are formed between protein monomers during a polymerization process → filaments
- Roles:
  - determines cell shape
  - provides mechanical support
  - cell movement, shape alterations
  - chromosome movement during cell division
  - intracellular transport (movement of vesicles)
  - roles in intracellular signaling
  - 3 types: **- microfilaments,**
    - intermediate filaments and
    - microtubules

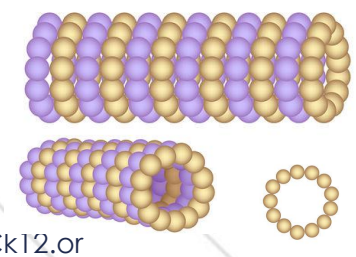


Centrosome

- The organizing center of microtubules
- composed of 2 centrioles
- in a centriole, 9 microtubule triplets form a cylinder
- microtubules are small tubes, composed of 13 paralel protofilaments of tubulin proteins



microtubule

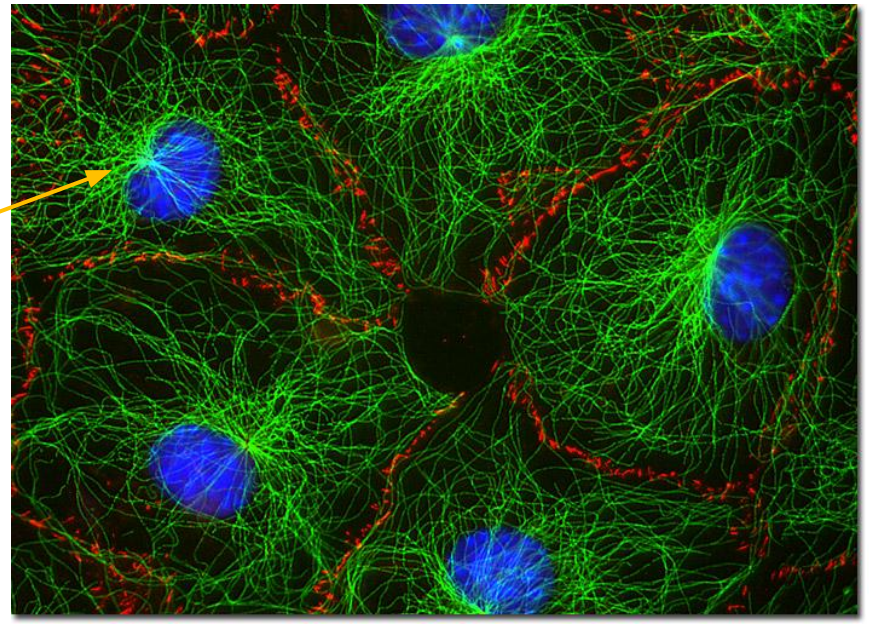


Ck12.org

centrosome

centriole

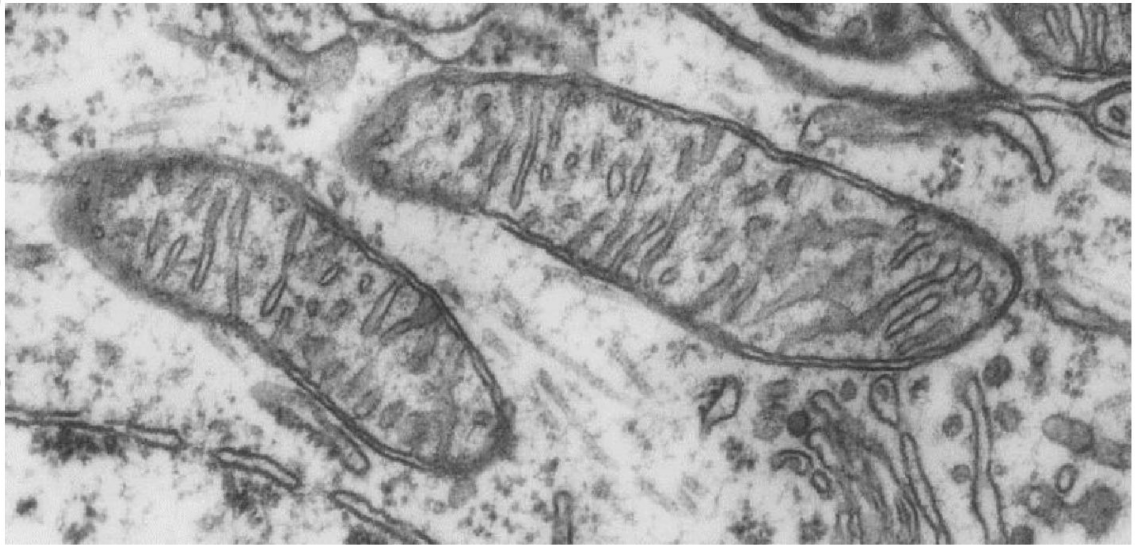
Study.co

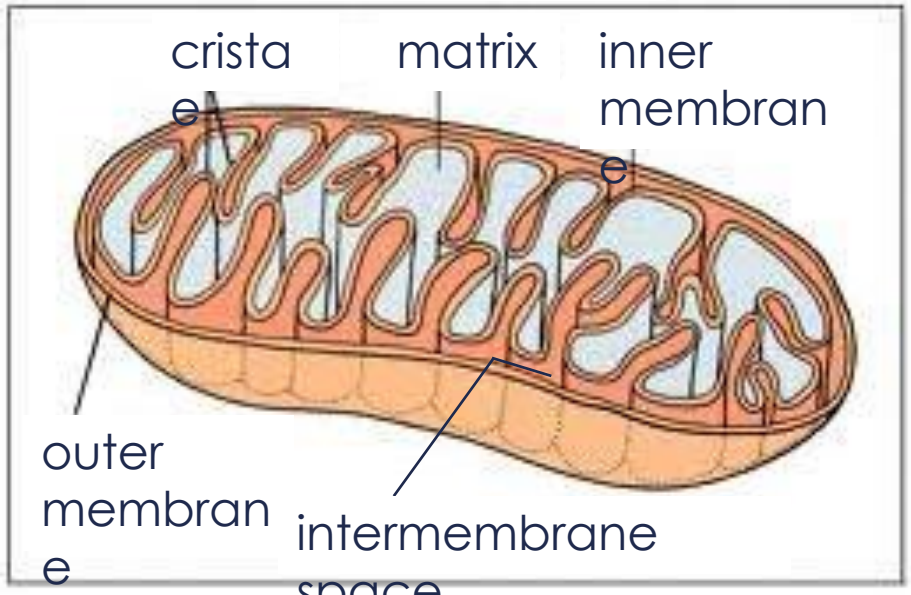


https://people.maths.bris.ac.uk/~matbl/images/mousefibroblasts.j

Mitochondrion

- Size ~ 0,5-1 µm
- Wide range in numbers: 1 – thousands of mitochondria /cell
- Role: „power plant of the cell", has a major role in ATP synthesis
- Cristae can show a laminar or tubular structure

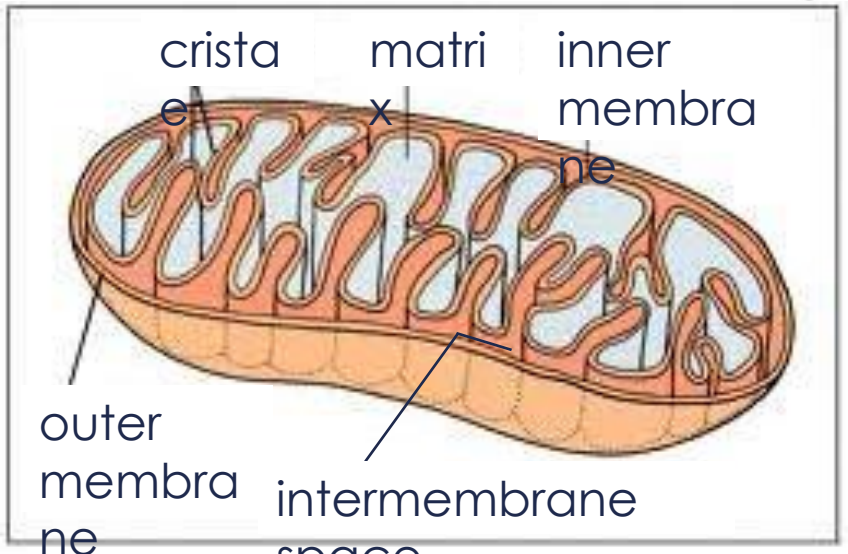




The structure of mitochondria

- **Outer membrane**: highly permeable
- Therefore, the **Intermembrane space** has a composition similar to that of the cytosol
- **Inner membrane**: highly impermeable, it contains important proteins:
  - transport proteins (e.g. H^+/pyruvate symporter, ADP/ATP antiporter) necessary due to the high degree of impermeability
  - Respiratory chain (electron transport chain) proteins
  - ATP synthase

  cristae are to increase the surface area
- **Matrix**: contains a lot of enzymes and also the mitochondrial DNA



The function of mitochondria

- ATP synthesis through aerobic cellular respiration, in the breakdown process of glucose:

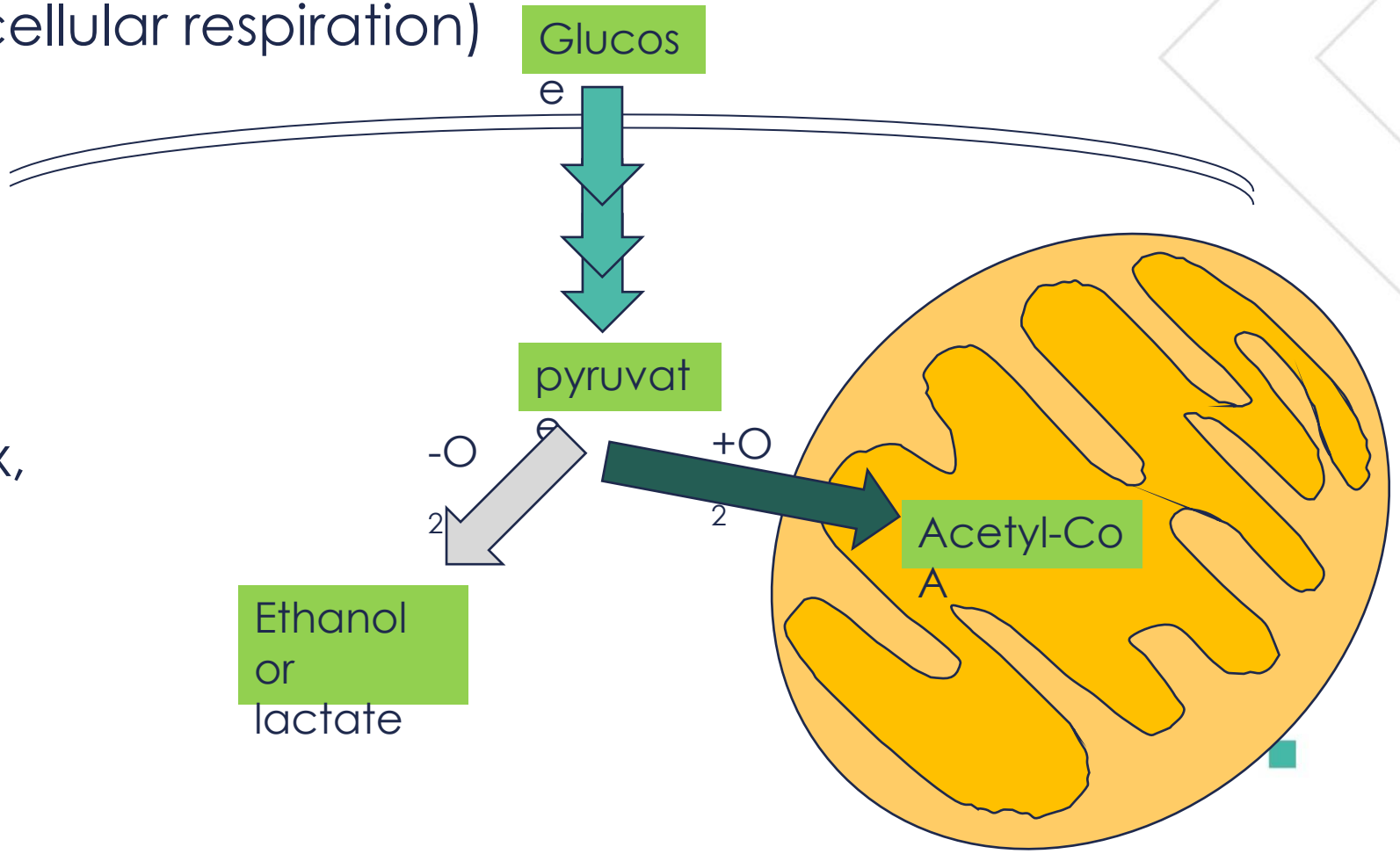
$$1\ C_6H_{12}O_6 = 6\ CO_2 + 6\ H_2O \text{ and } 36\ ATP$$

- 3 phases:
  - Glycolysis in the cytoplasm
  - Citric acid cycle in the mitochondrial matrix
  - Terminal oxidation along the inner mitochondrial membrane

Glycolysis

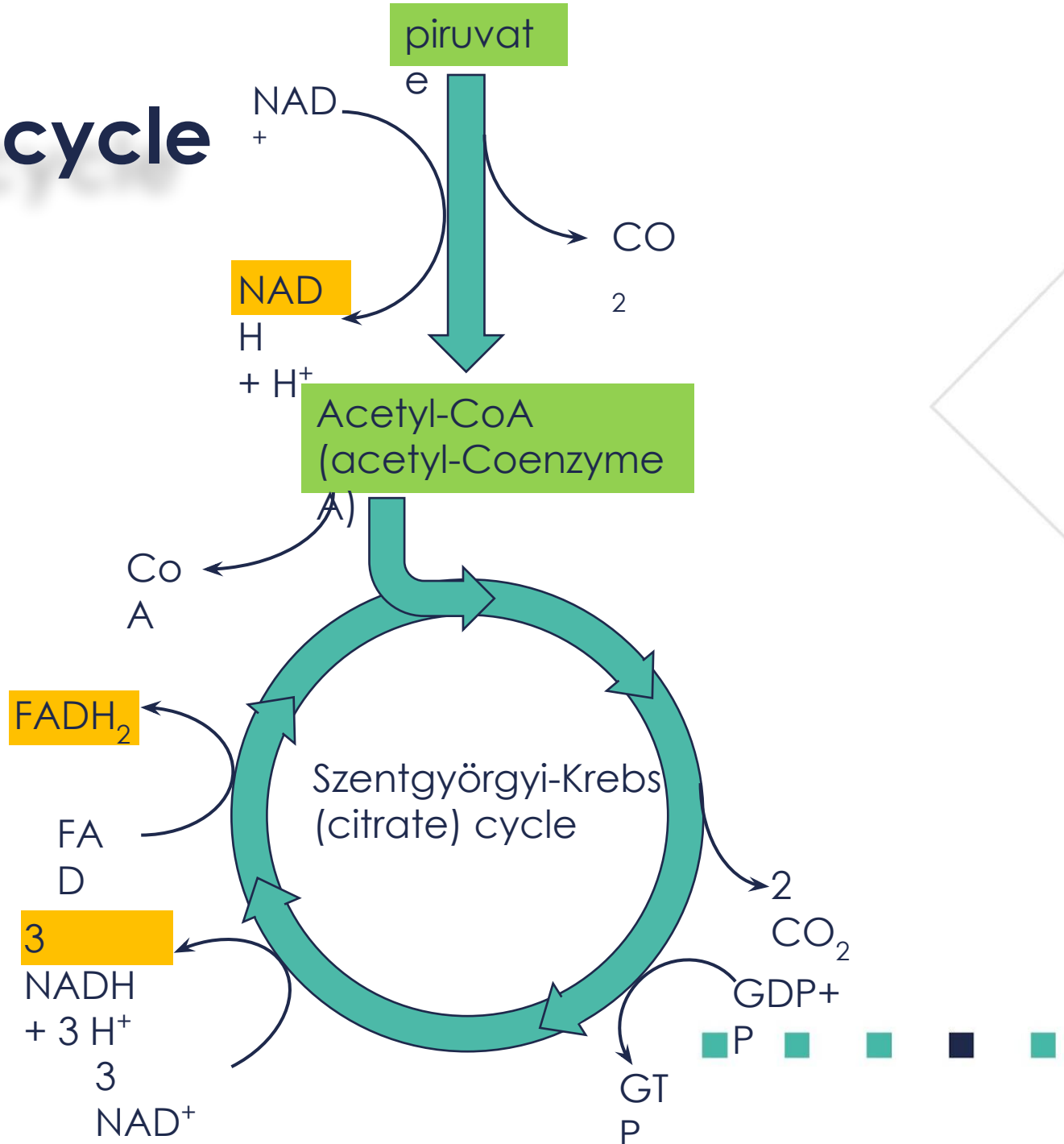
- Glucose (with 6 carbons)→ 2 pyruvates (with 3 carbons each)
- In the absence of oxygen: e.g. lactic acid (lactate) is produced (fermentation, anaerobic cellular respiration)

- A small amount of ATP molecules, and reduced coenzymes (NADH) are also produced
- In the mitochondrial matrix, pyruvate is turned into acetyl groups (2 carbons), which are bound to Coenzyme A (CoA)



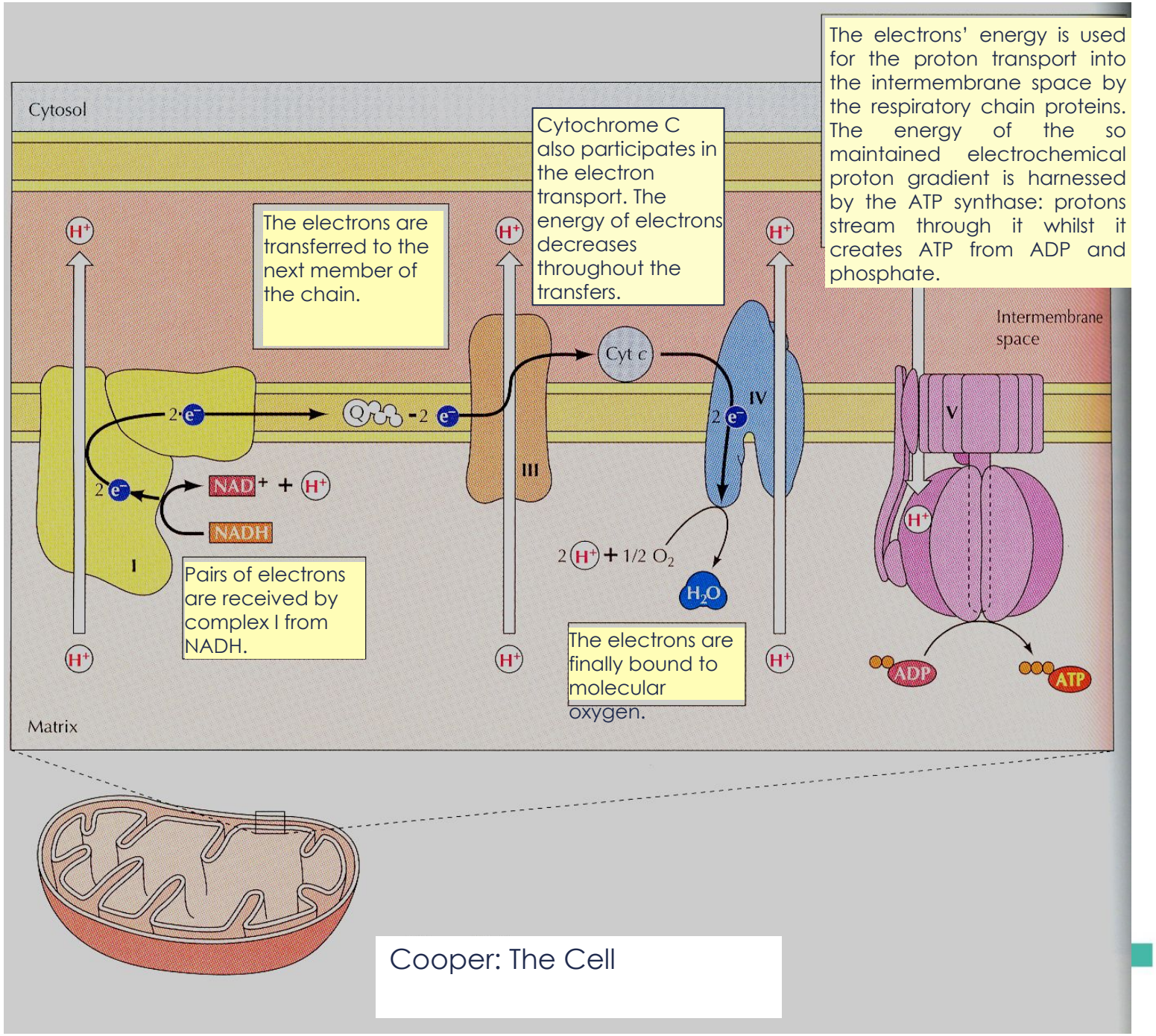
The citric acid cycle

- Also called Szentgyörgyi-Krebs or citrate cycle
- Oxaloacetate (4 C-atoms) + acetyl group (2 C-atoms) → citric acid (6 C-atoms)
- products:
  - 2 CO_2
  - GTP
  - Reduced coenzymes: NADH, $FADH_2$ (they contain high energy electrons)

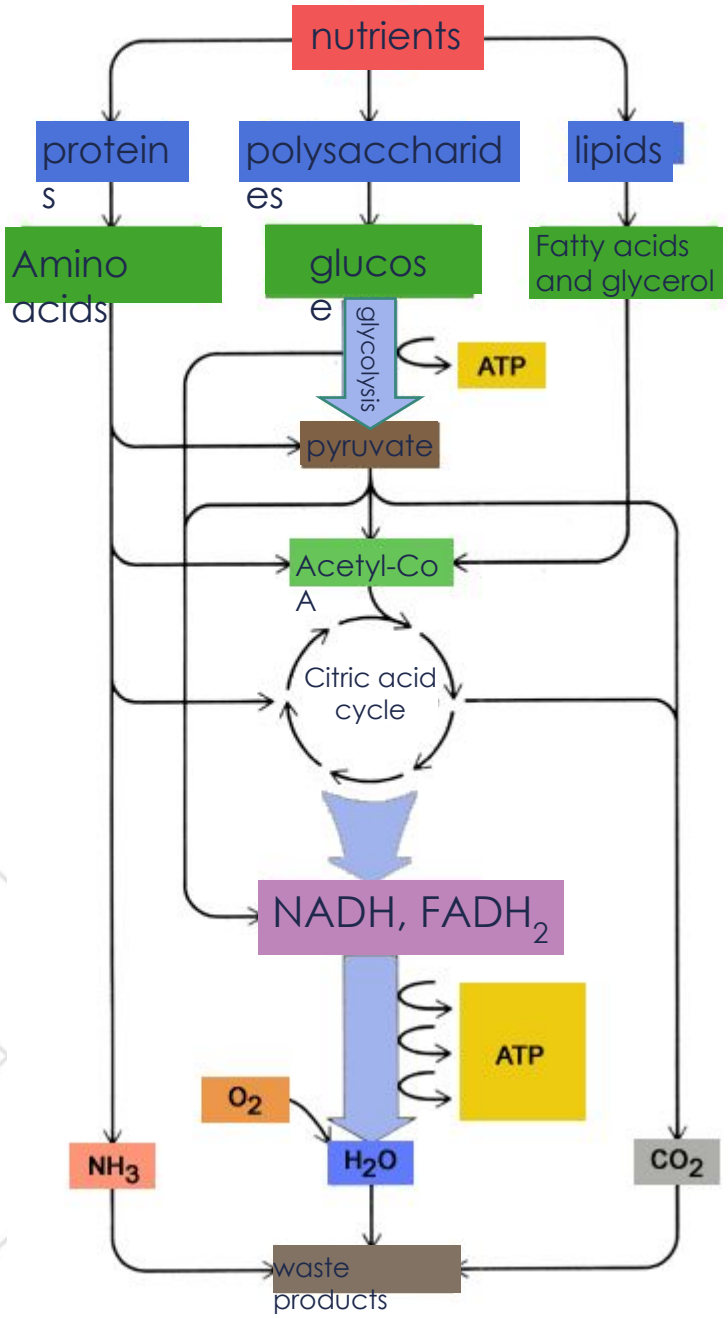


Terminal oxidation

- NADH, $FADH_2$ →electrons → respiratory chain (electron transport chain) proteins
- Respiratory chain members I. →II. →III. →IV.
- Cytochromes participate: they contain iron (Fe^{2+} or Fe^{3+})
- Respiratory chain proteins transport protons from the matrix into the intermembrane space
- This maintains a H^+ concentration difference: electrochemical proton gradient
- The energy of this gradient is harnessed by the ATP synthase protein in the inner membrane: protons are streaming back into the matrix, whilst ADP + P → ATP
- Peter D. Mitchell: chemiosmosis theory



Cooper: The Cell

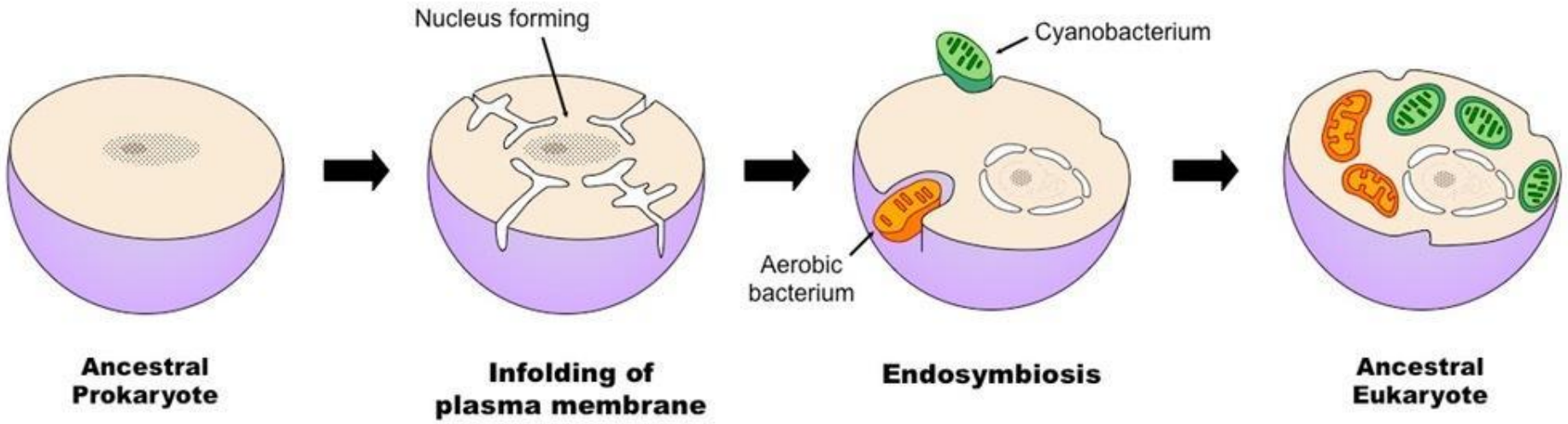


Summary: breakdown of glucose and other nutrients with the help of mitochondria

Mitochondrial DNA

- Small, circular
- Codes for: mRNA, tRNA, rRNA molecules of mitochondria
- But most mitochondrial proteins are imported from the cytosol (synthesized on free ribosomes)
- The presence of DNA is supportive of endosymbiosis:
- Mitochondria derived from ancient prokaryotes

Endosymbiosis theory



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