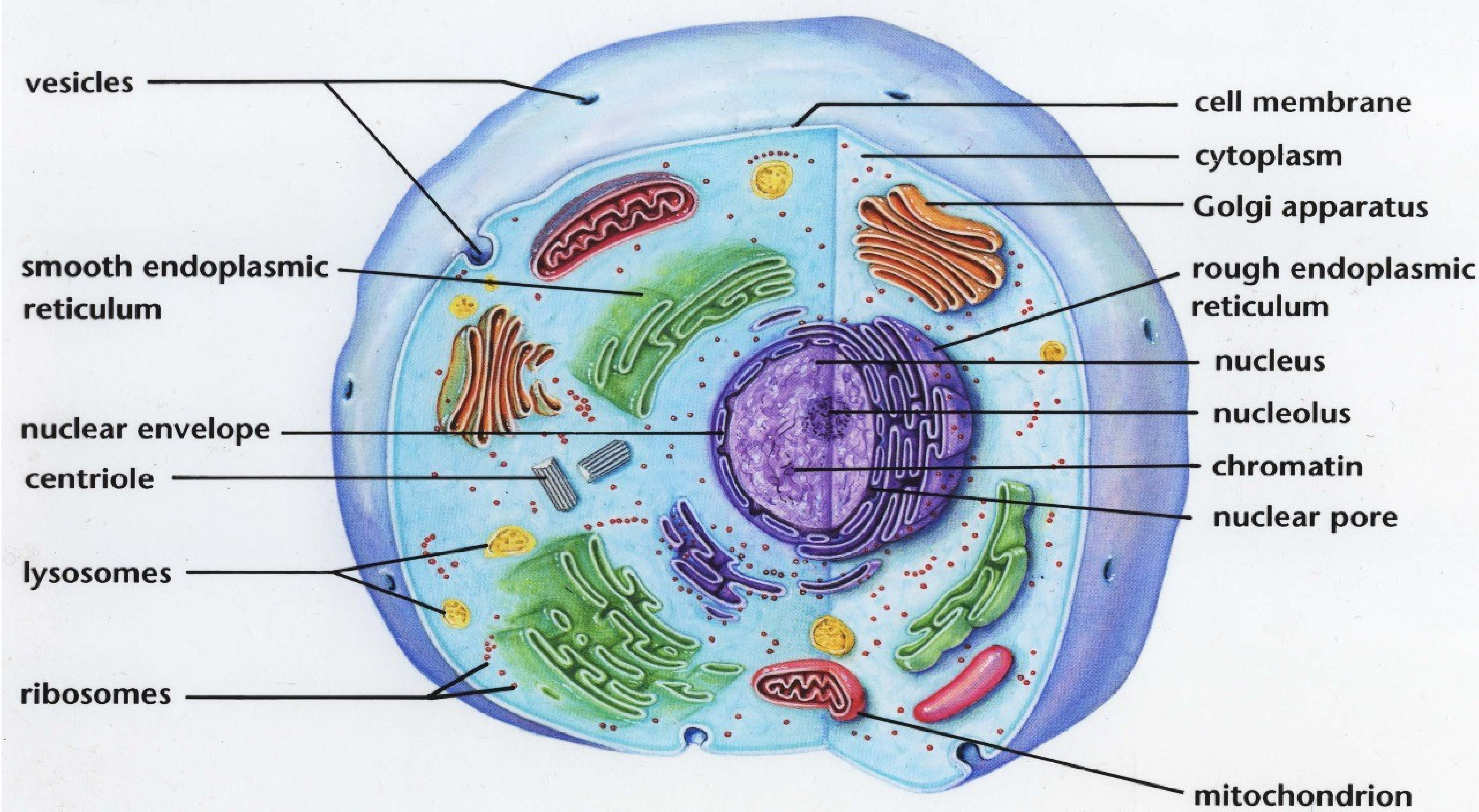
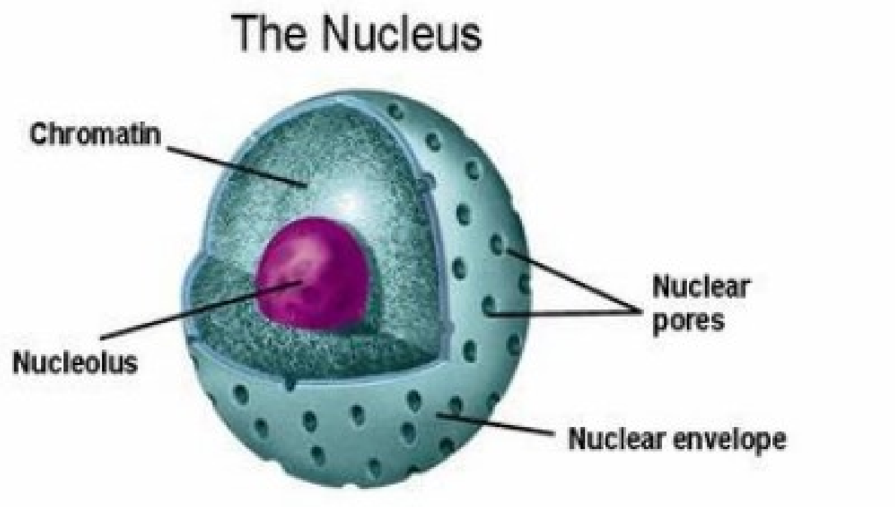
The cell


vesicles
cell membrane
cytoplasm
Golgi apparatus
smooth endoplasmic reticulum
rough endoplasmic reticulum
nucleus
nucleolus
nuclear envelope
centriole
chromatin
nuclear pore
lysosomes
ribosomes
mitochondrion

Nucleus

- 1 or 2 (rarely more)
- diameter: 4 – 10 µm
- shape – spherical, oval, lobated, segmented
- contains **chromosomes** with DNA and proteins (genetic informations), chromosomes are visible only during cell division (mitosis, meiosis); during interphase (= period between cell divisions) chromosomes are decondensed and form fine, granular **chromatin**

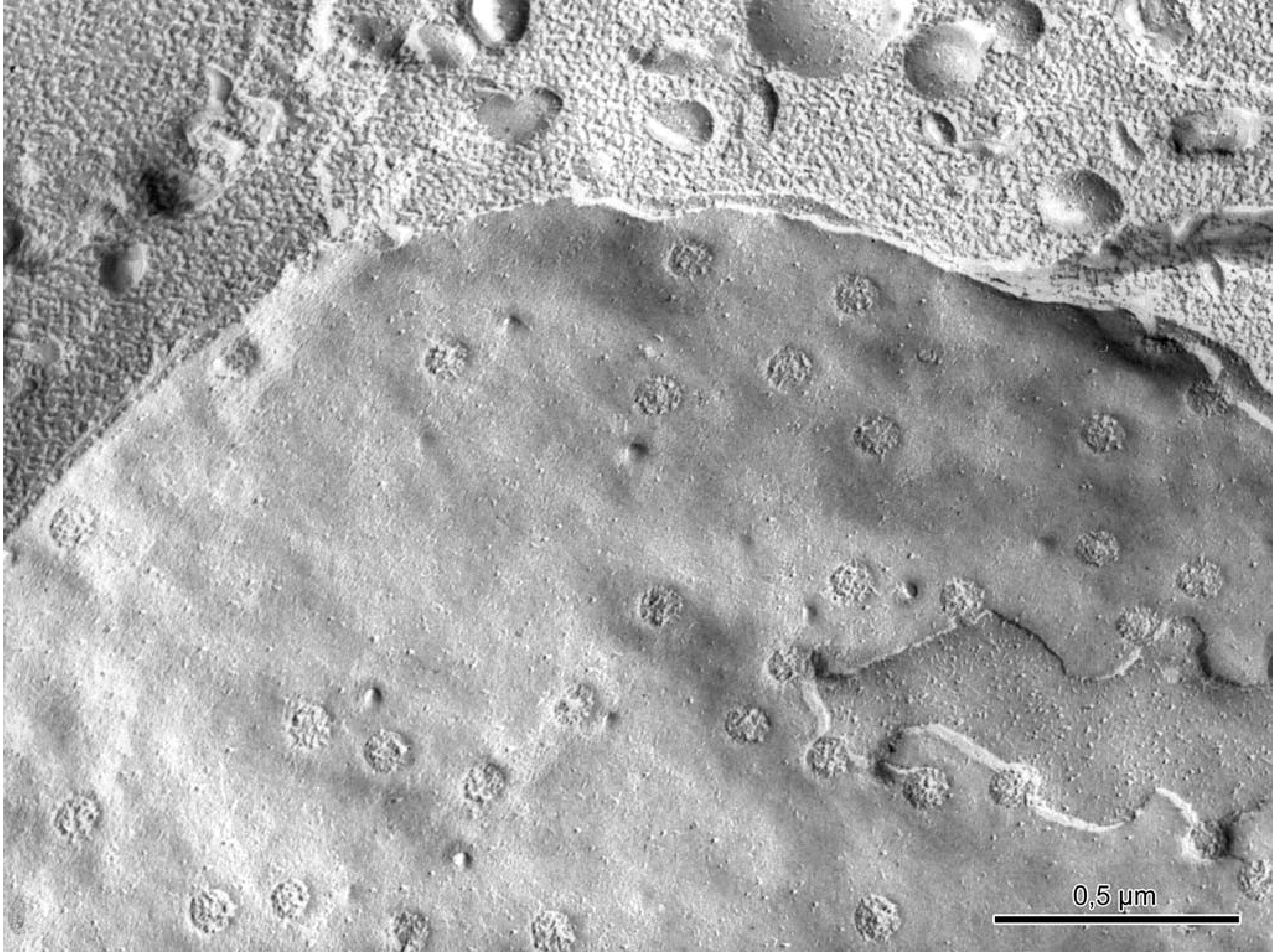
- **NUCLEAR COMPONENTS:**
- chromatin (decondensed chromosomes)
- nucleolus
- nuclear envelope – inner + outer membrane
- nuclear skeleton



Nuclear envelope

The nucleus is enveloped by a pair of membranes (inner + outer) enclosing a **perinuclear space** that is continuous with rough endoplasmic reticulum and ribosomes can be attached to the external surface of outer membrane. The inner membrane is stabilized by a meshwork of intermediate filament proteins called **lamins**.

- is perforated by **nuclear pores** that control the passage of molecules in and out
- nuclear pores are constructed from a number different proteins called **nucleoporins**.


0,5 µm

Chromatin

- Decondensed chromosomes during interphase of cell division

2 types of chromatin :

- euchromatin – light in EM, completely decondensed chromosomes, intensly active RNA synthesis

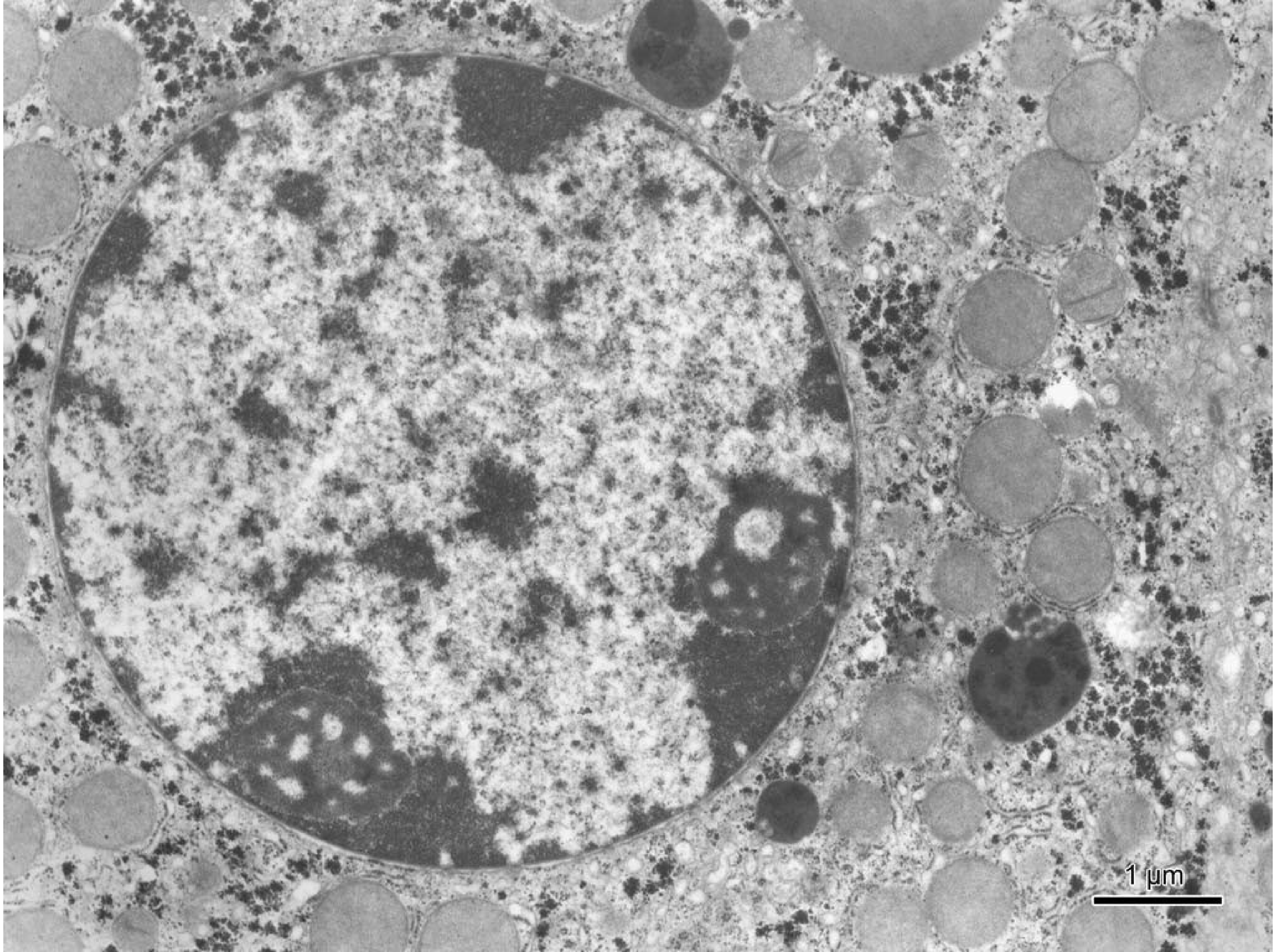
- **heterochromatin** – **dark** in EM, partly decondensed chromosomes, inactive,

  according to localization in nucleus 3 types of heterochromatin are recognised:

  marginal heterochromatin (attached to inner membrane)

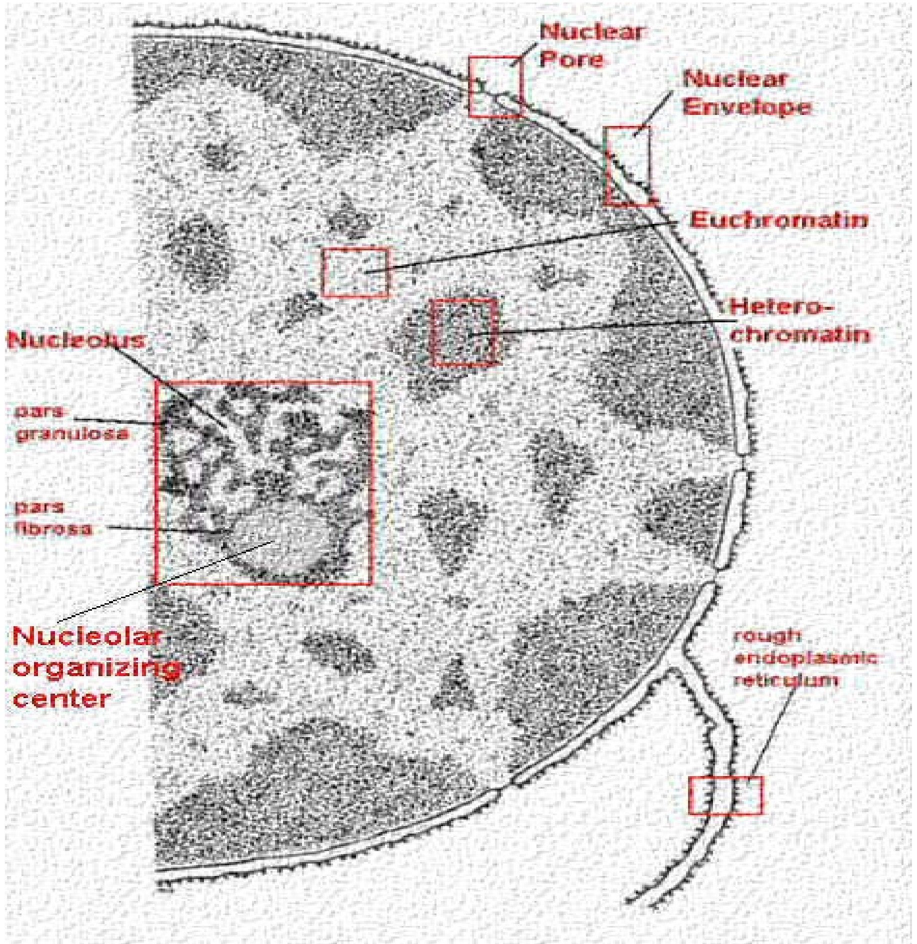
  perinucleolar heterochromatin (around nucleolus)

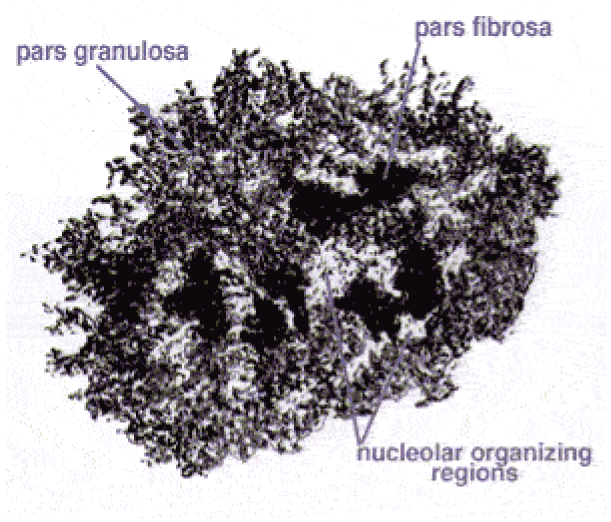
  karyosomes (within euchromatin)

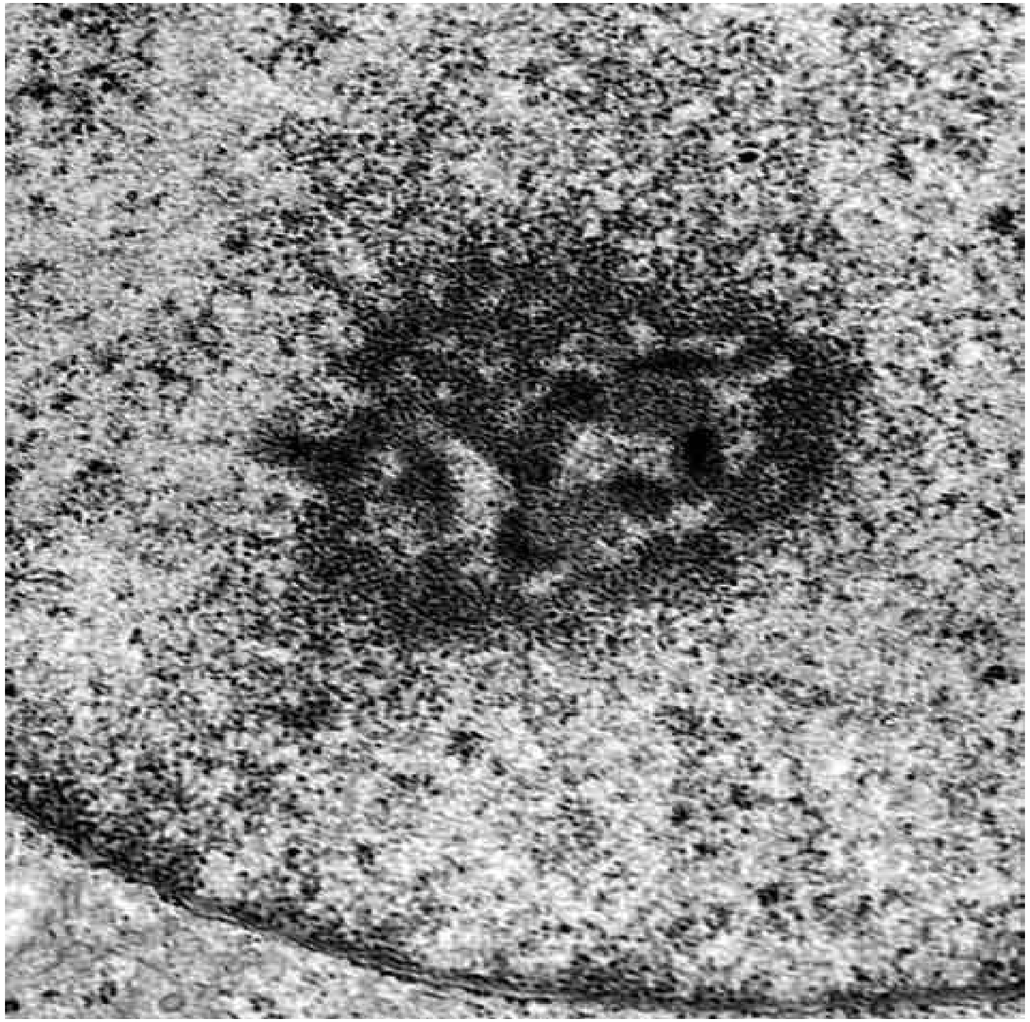

1 µm

Nucleolus

- **Nucleolus**
- 1 – 2 – more nucleoli in nucleus during the period between cell divisions (interphase)
- 1 – 3 µm ∅
- is not separated by any membrane
- contain: RNA, DNA, proteins
- structure in EM: pars fibrosa (with fibrilar form of RNA), pars granulosa (with granular form of RNA), fibrilar center(s) with DNA







Types of nucleoli: reticular, ring-shaped, compact

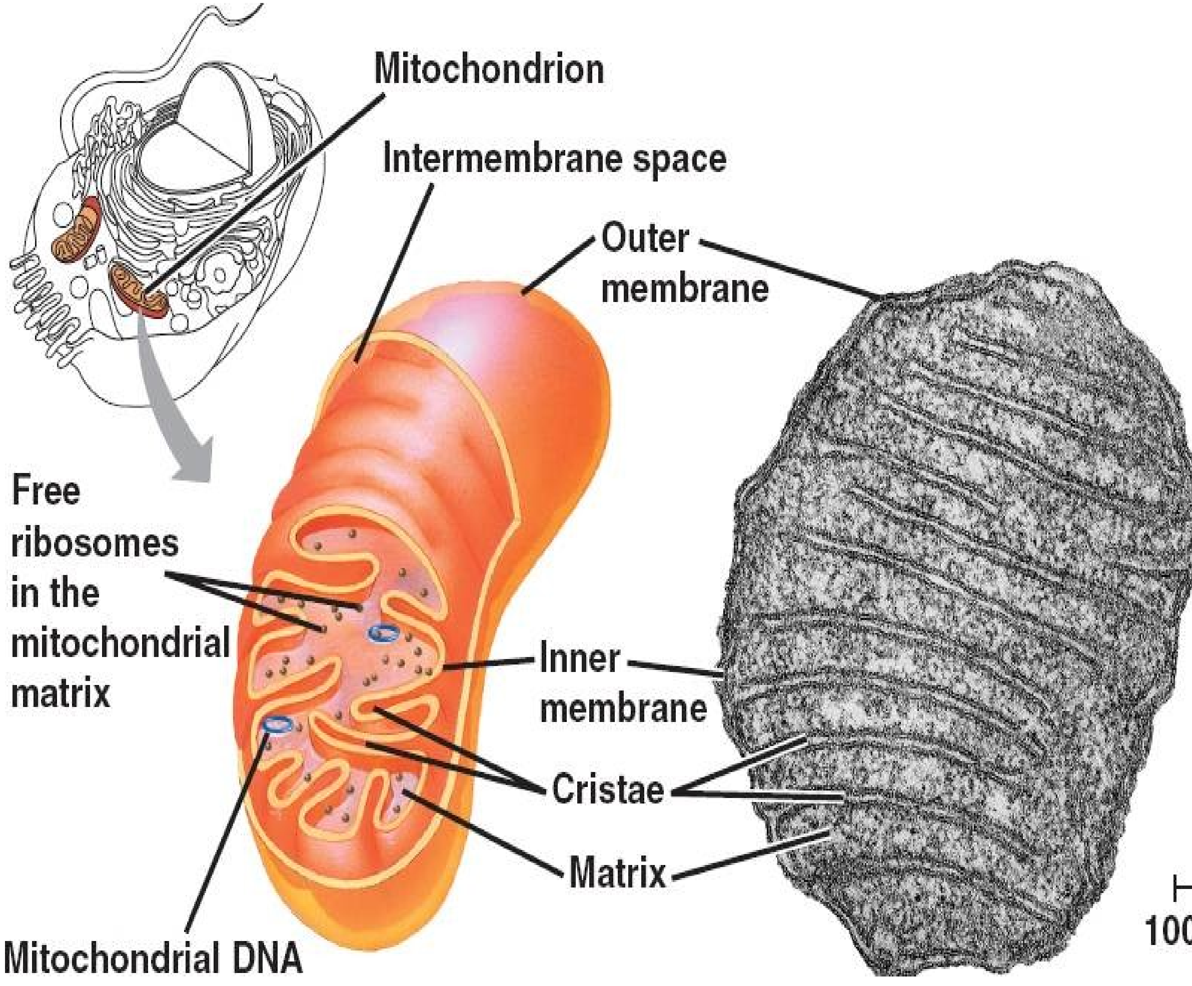
function: synthesis of preribosomal RNA which is connected with proteins forming together ribosomal subunits, these are transported into the cytoplasm through pores in nuclear envelope.

Mitochondrion

- spherical or oval or elongated bodies
- 0.5 µm ∅, length of elongated mitochondria 1-10 µm
- volume density of mitochondria in the cytoplasm depends on the metabolic activity of the cell

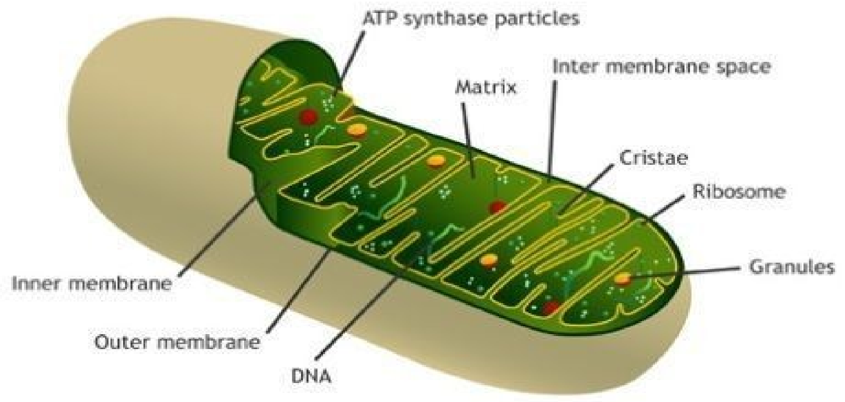
function: oxydative phosphorylation (transformation of energy of chemical compound into energy of macroergic bounds

ATP - the universal energy currency of the cell).

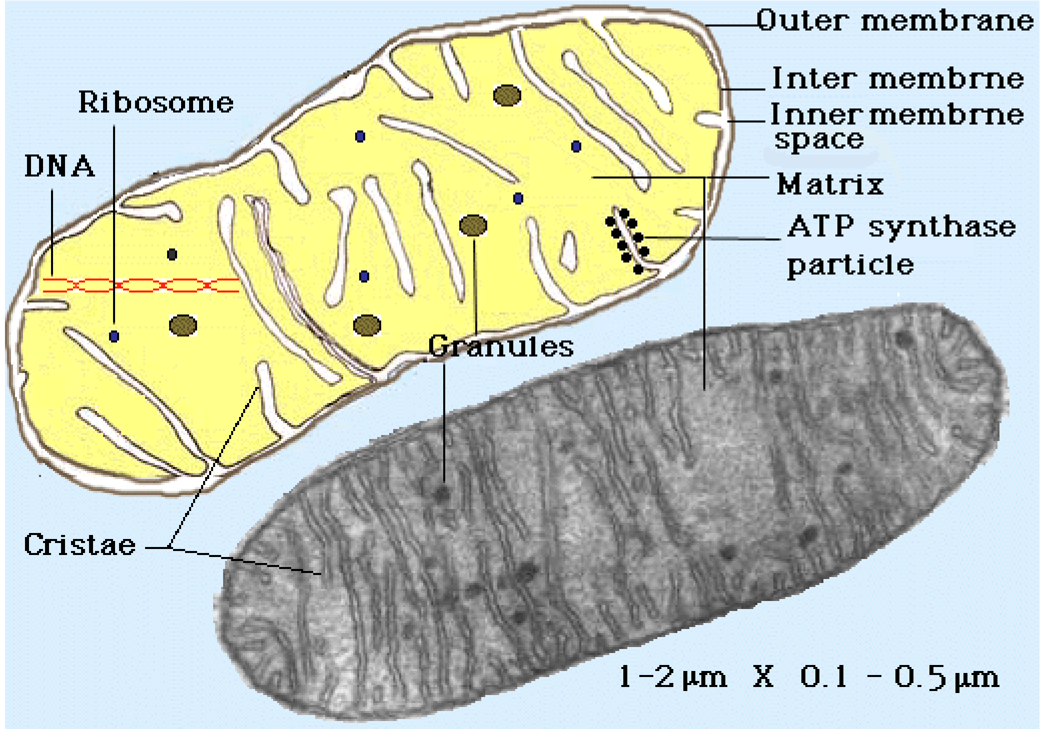


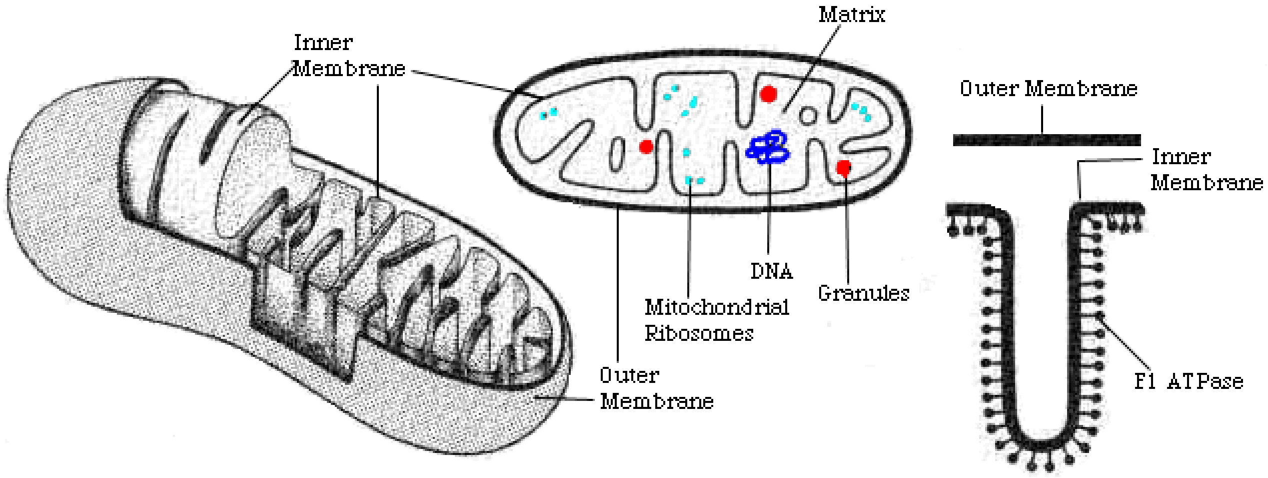
Mitochondrion

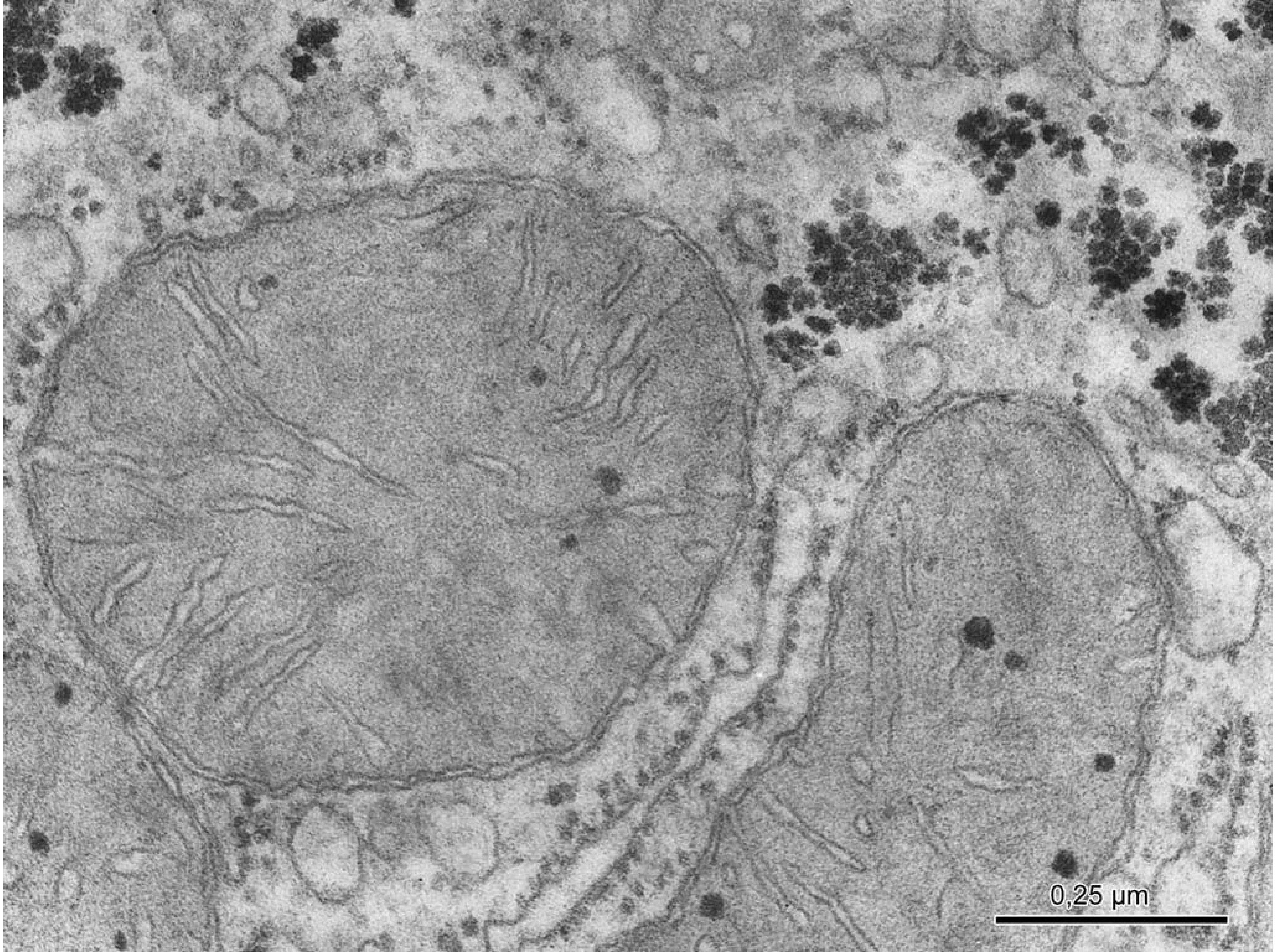
- **Structure**:
- outer mitochondrial membrane – smooth; with transporting channels
- inner mitochondrial membrane – forms flattened (rarely tubular) invaginations into the inner matrix called **cristae** (there are ATP synthase enzyme molecules, which produce ATP)
- intermembrane space between the membranes contains enzyme cytochrome C
- mitochondrial matrix – finely granulated, contains enzymes of Krebs' cycle (citric acid cycle), ADP, ATP, DNA, RNA, ribosomes, proteins, ribosomes and **granules** (with ions Ca, Mg mainly)
- mitochondria are partly autonomous (semiautonomous) structures: they contain <u>DNA</u> and their own <u>ribosomes</u> and produce own <u>proteins</u>
- they are able divide themselves (replication)



Mitochondrion





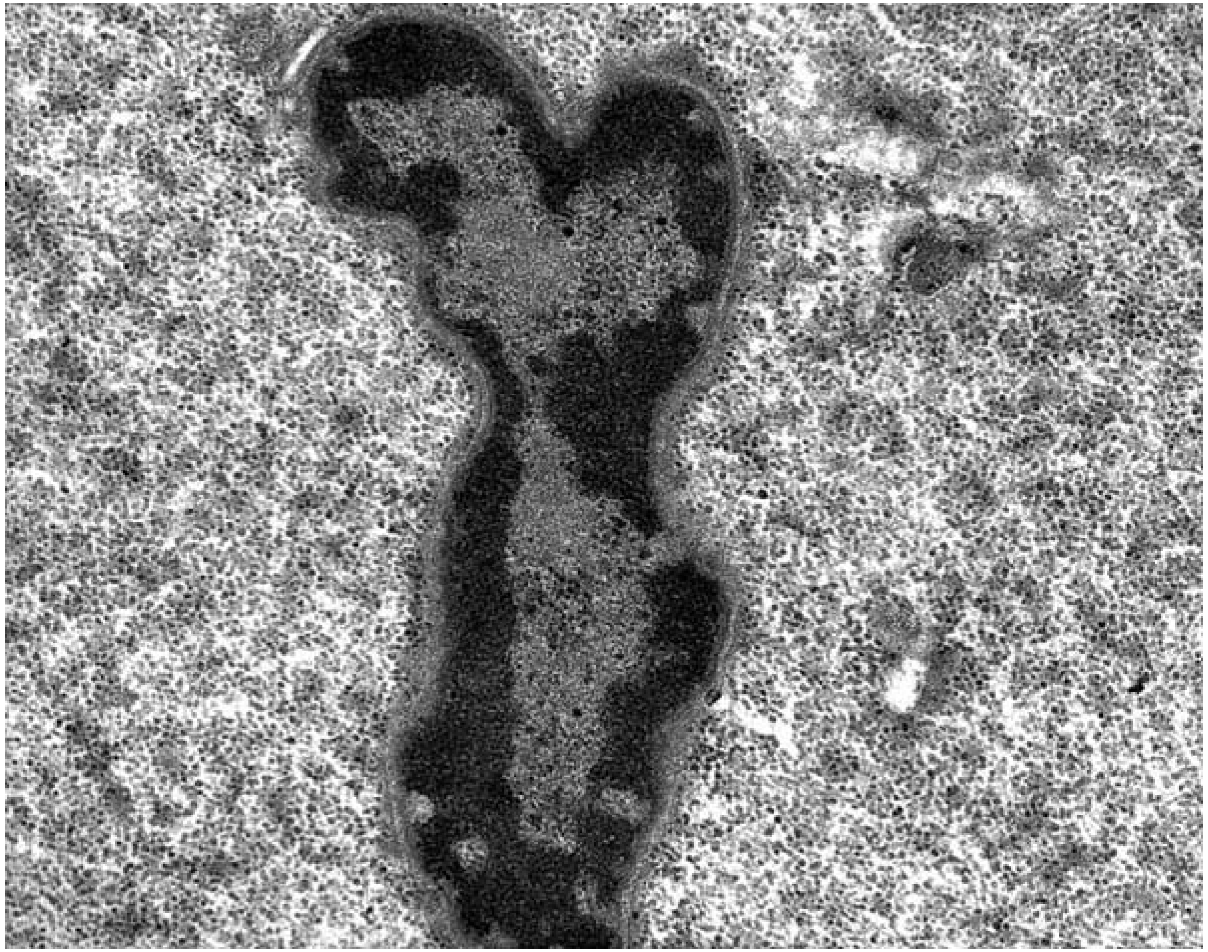

0,25 µm

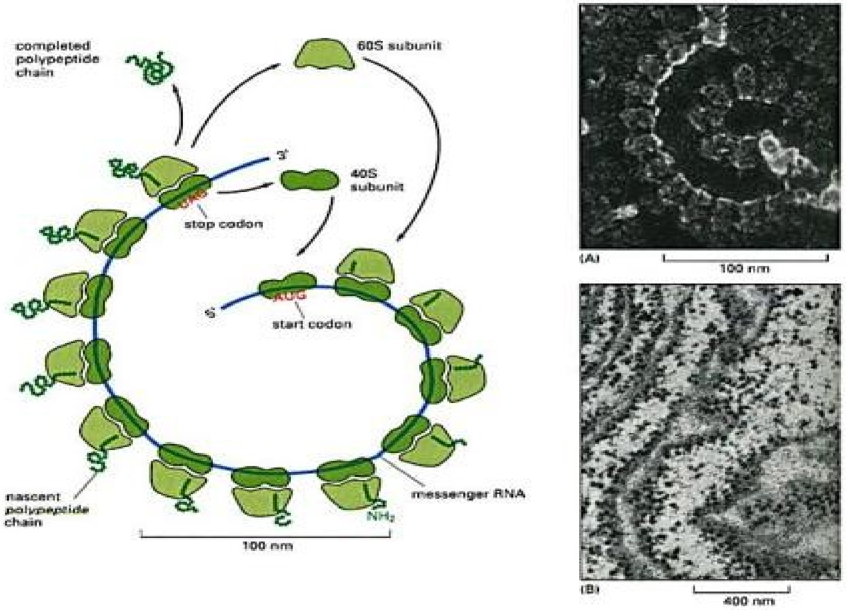
Ribosomes

- small particles (below recognizing ability of LM)
- in EM they appear as granules sized 20 – 25 nm
- chemical composition: several types of RNA with associated proteins (cells containing large amount of ribosomes show basophilia of cytoplasm because ribosomes are acid structures in the cell)

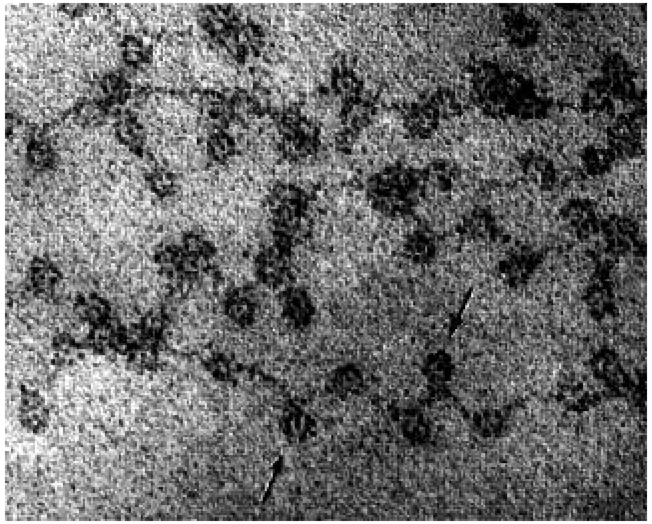
- Forms of ribosomes:
- free ribosomes
- polysomes
- connected with membrane of rough endoplasmic reticulum

Ribosomes





completed polypeptide chain
60S subunit
3'
40S subunit
stop codon
5'
AUG
start codon
nascent polypeptide chain
messenger RNA
NH2
100 nm
(A)
100 nm
(B)
400 nm

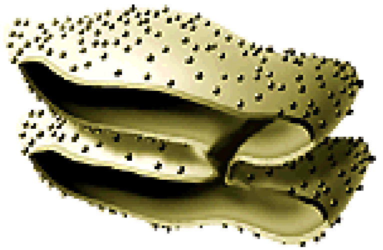


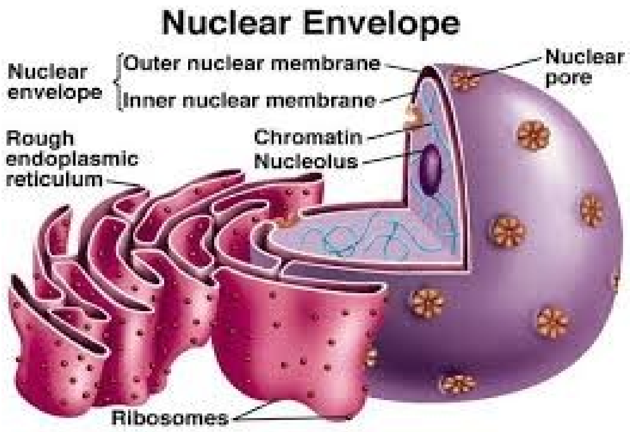
Ribosomes

- Function of ribosomes:
- synthesis of proteins (polypeptides) for “export” (are released externally from cell cytoplasm) by rough endoplasmic reticulum
- synthesis of proteins used by cell by free ribosomes and polysomes (stem cells need proteins to grow intensly – examples: “young” cells involved in embryogenesis, “young” blood cells – precursors of mature blood cells)

GER

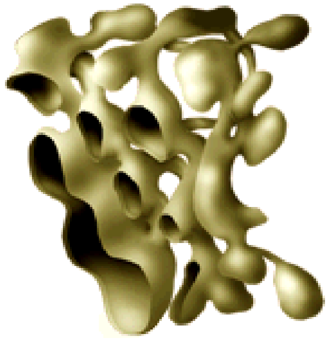
- 3D system of communicating flattened cisternae with membrane covered with ribosomes
- binding of ribosomes to GER is reversible, they can be released from membrane.
- function of GER – protein synthesis for export. GER is the site of translation and folding of and transport of proteins that are to become part of the cell membrane (e.g., transmembrane receptors and other integral membrane proteins) as well as proteins that are to be secreted or "exocytosed" from the secretory cell (e.g., digestive enzymes).

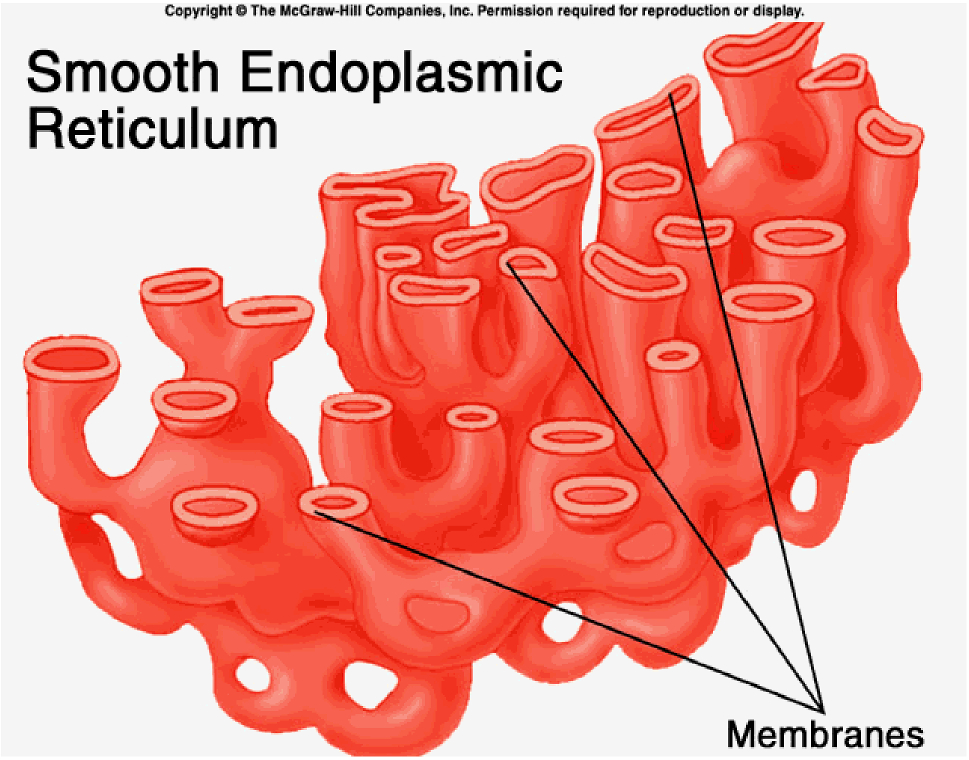




AER

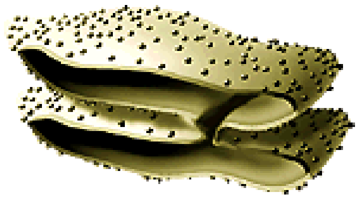
- 3D system of communicating short tubules and small vesicles with smooth membrane without ribosomes
- Function of AER – numerous:
  - participatin in detoxicating processes in the cells (liver and some kidney cells)
  - participation in steroid hormones production
  - participation in glycogen metabolism (liver cells)
  - reservoir of Ca ions (sarcoplasmic reticulum in muscle cells)
  - etc.

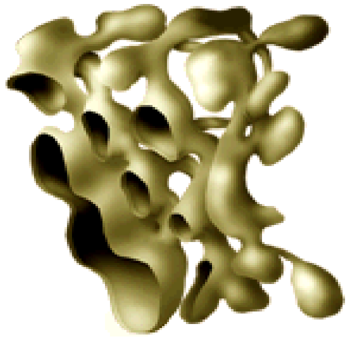


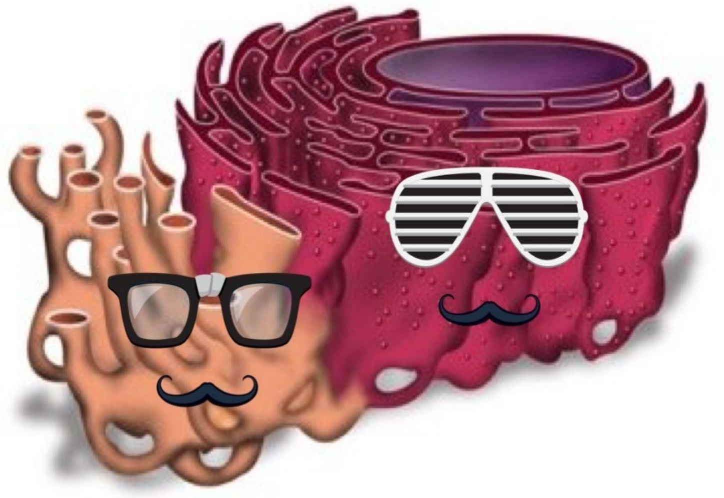


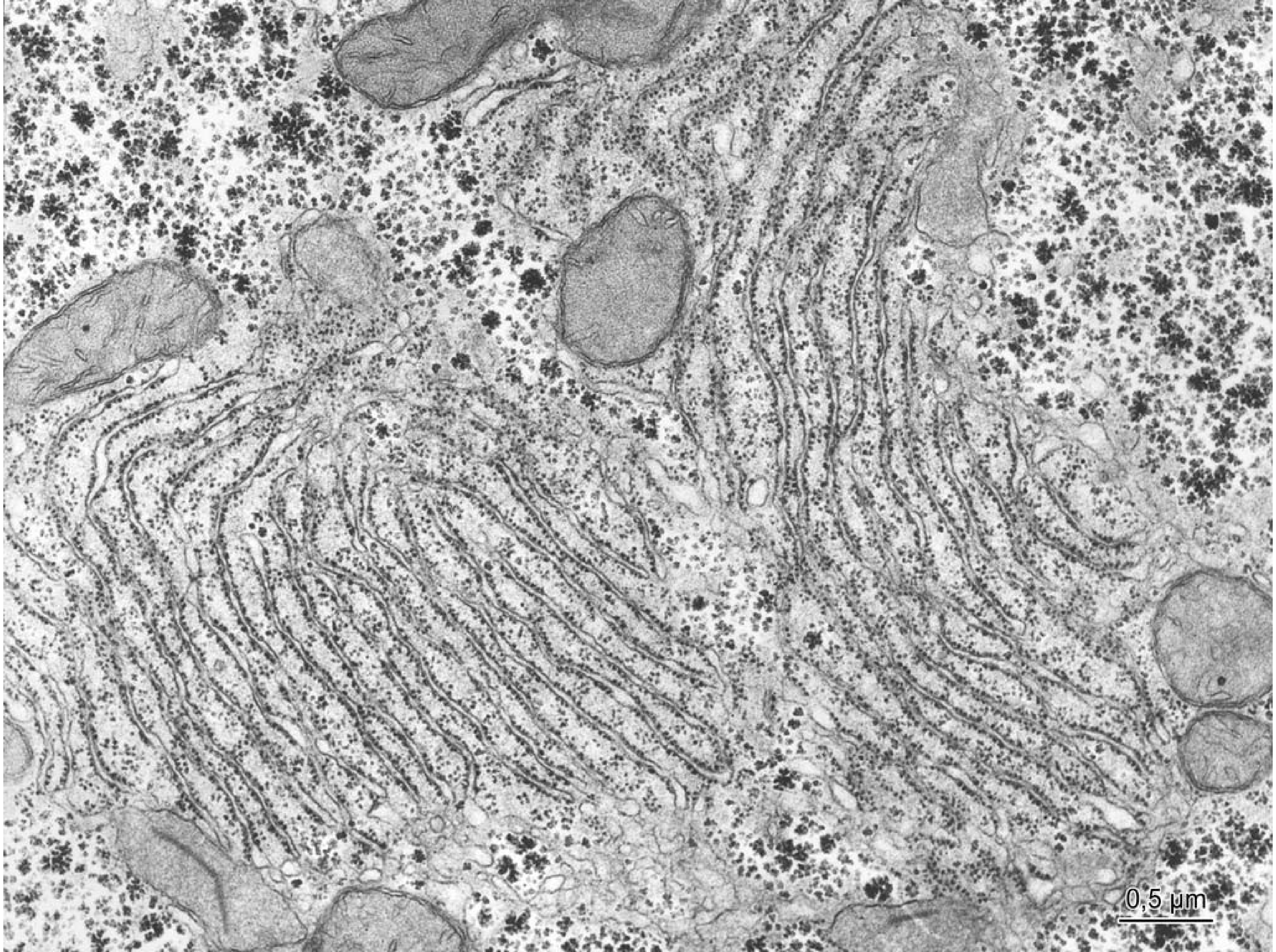
Endoplasmic reticulum

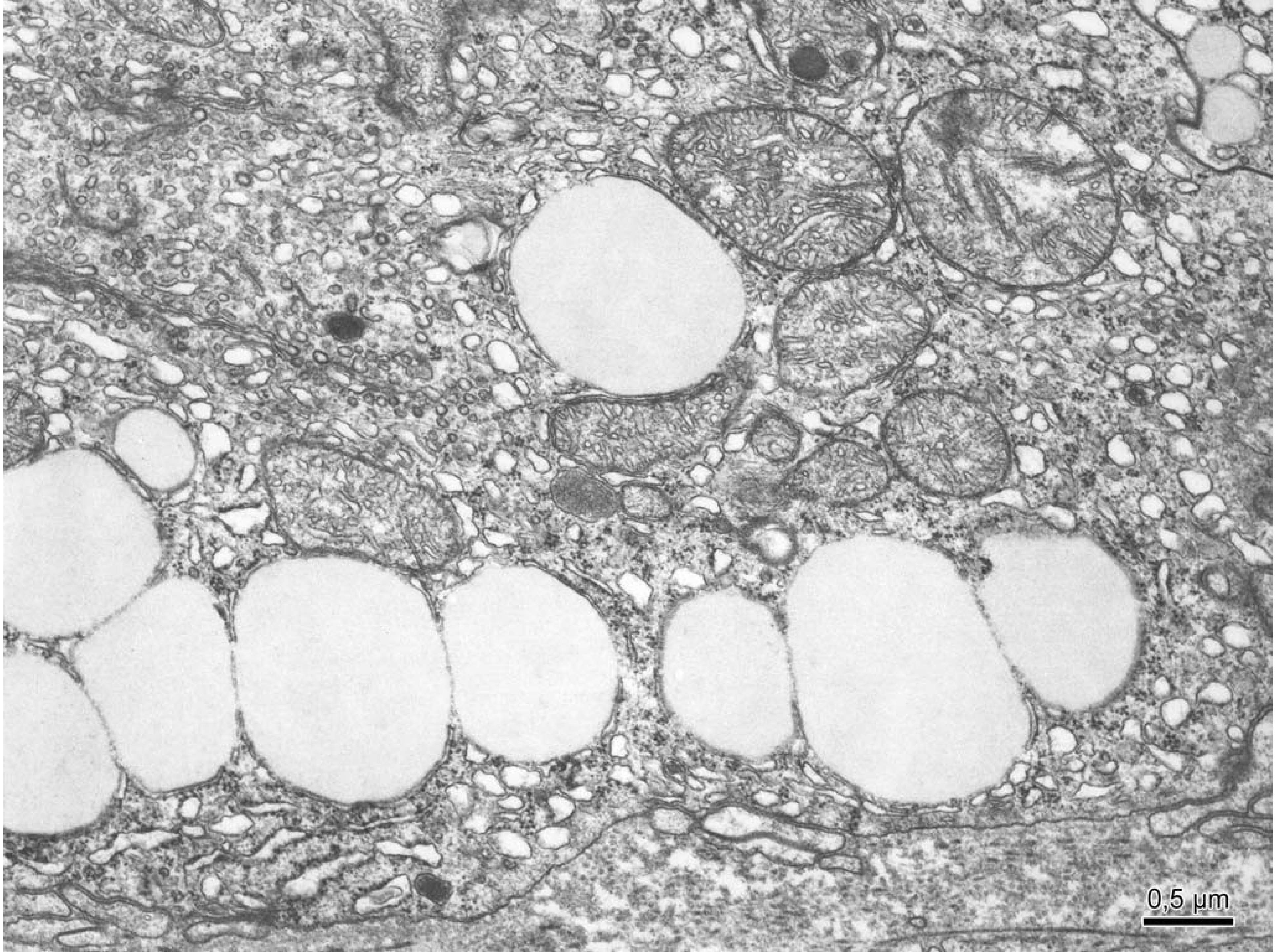
•2 forms: rough (granular) – **GER**, and smooth (agranular) – **AER**








0,5 µm


0,5 µm

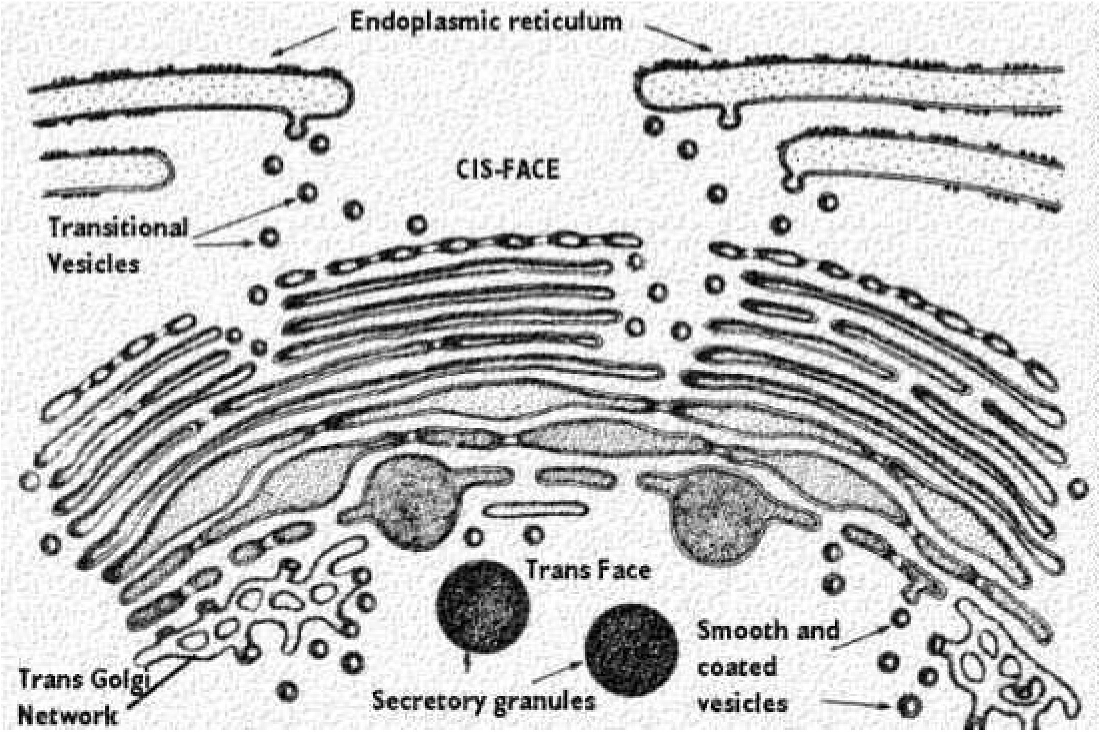
Golgi apparatus

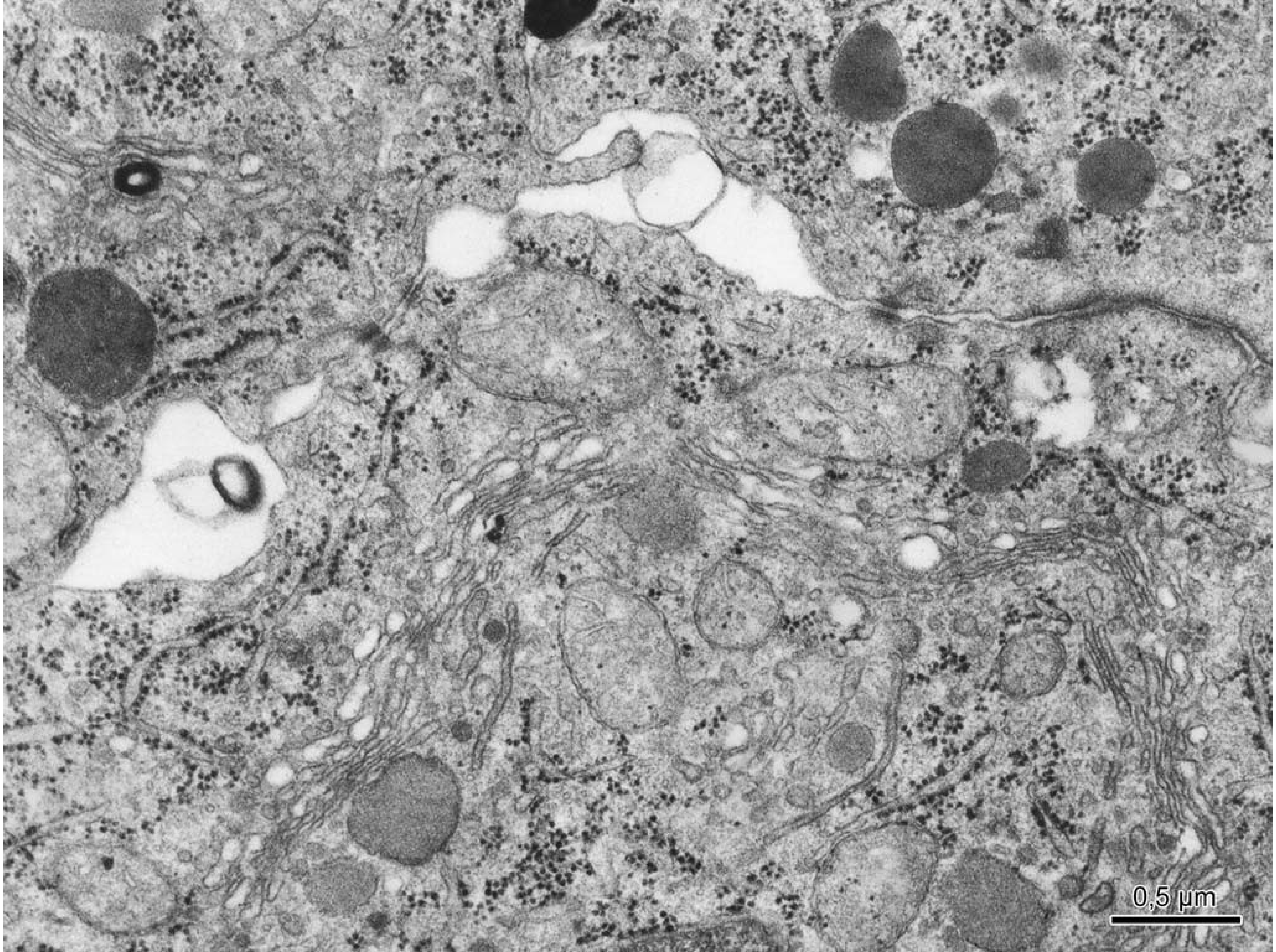
- usually near the nucleus; several GA in some region of cytoplasm = Golgi field
- 3 components:

  - paralell flat **cisternae** (3 – 10) – they are curved like horse-shoe and polarized: **cis–face** (forming face) and **trans–face** (maturing face) are distinguished

  - small **vesicles** (numerous)

  - large **vacuoles** (several)



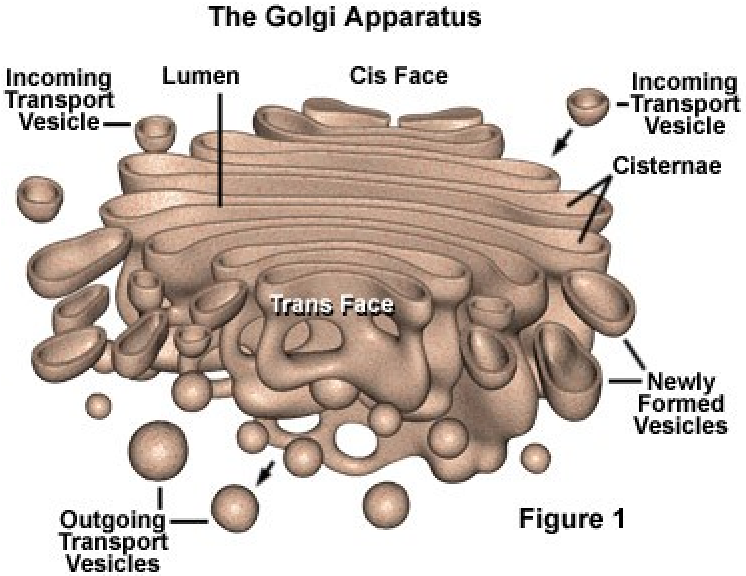

0,5 µm

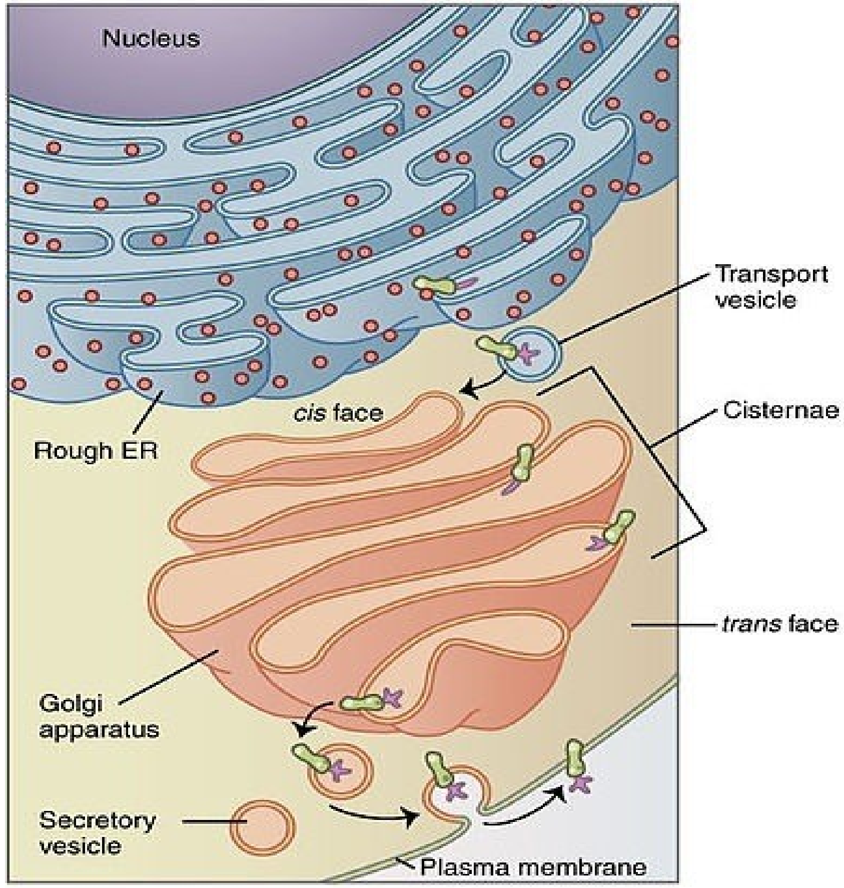
Golgi apparatus

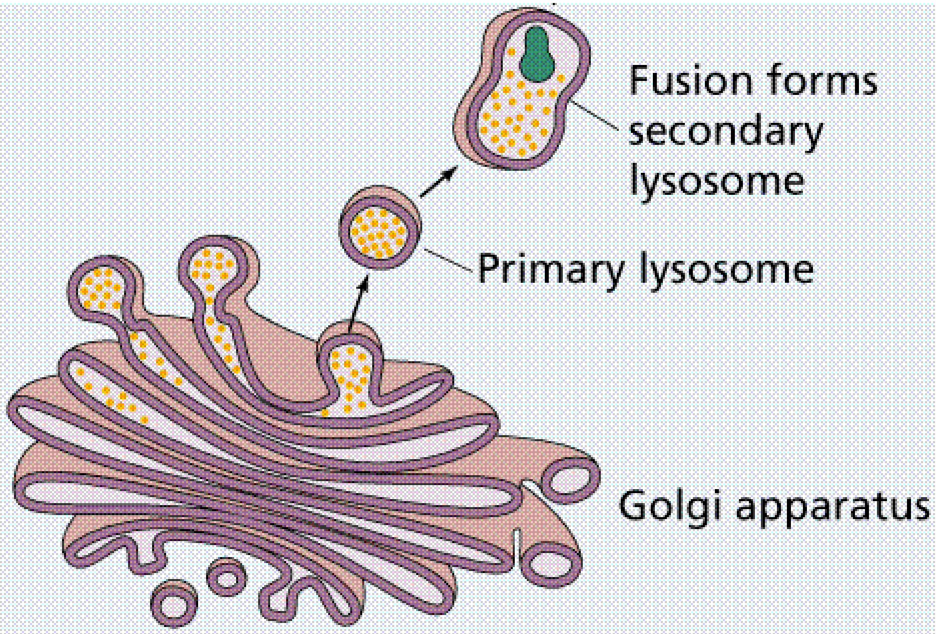
Function : GER + GA cooperate together, functionally connected system of 3D network of cisternae, vesicles and vacuoles with metabolic, proteosynthetic and secretory functions:

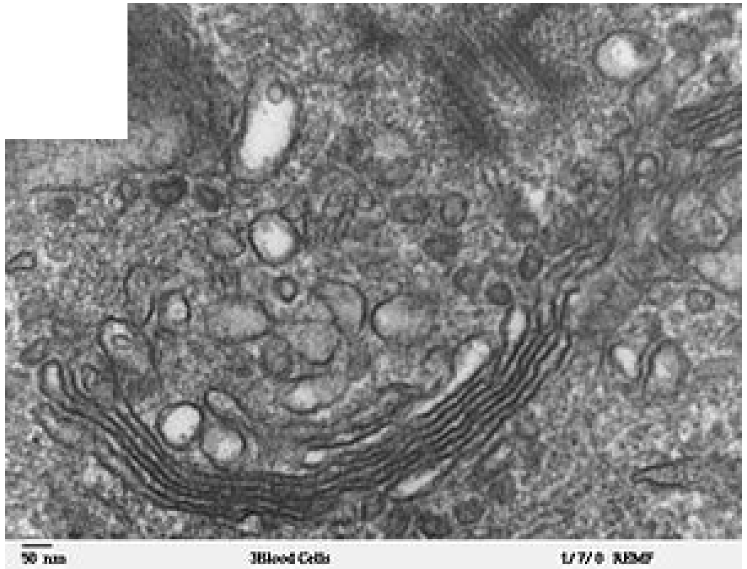
- **ribosomes** on GER – produce polypeptides and release them into cisternae of GER
- contant of **GER** cisternae is transported through them and small transporting vesicles with proteins are detached
- transporting vesicles migrate to cis–cisterna of **GA** and fuse together, protein is released into GA, pass through all cisternae into GA trans–cisterna; proteins are processed in GA (finalization of product into hormones, enzymes and other substances)

- vesicles and **vacuoles** with final product are detached from trans–cisterna; their contant is condensed and vacuoles are transformed into secretory granules, lysosomes, smooth and coated vesicles for exocytosis


The Golgi Apparatus
Incoming Transport Vesicle
Lumen
Cis Face
Incoming Transport Vesicle
Cisternae
Trans Face
Newly Formed Vesicles
Outgoing Transport Vesicles
Figure 1


Nucleus
Transport vesicle
Cisternae
cis face
Rough ER
trans face
Golgi apparatus
Secretory vesicle
Plasma membrane


Fusion forms secondary lysosome
Primary lysosome
Golgi apparatus



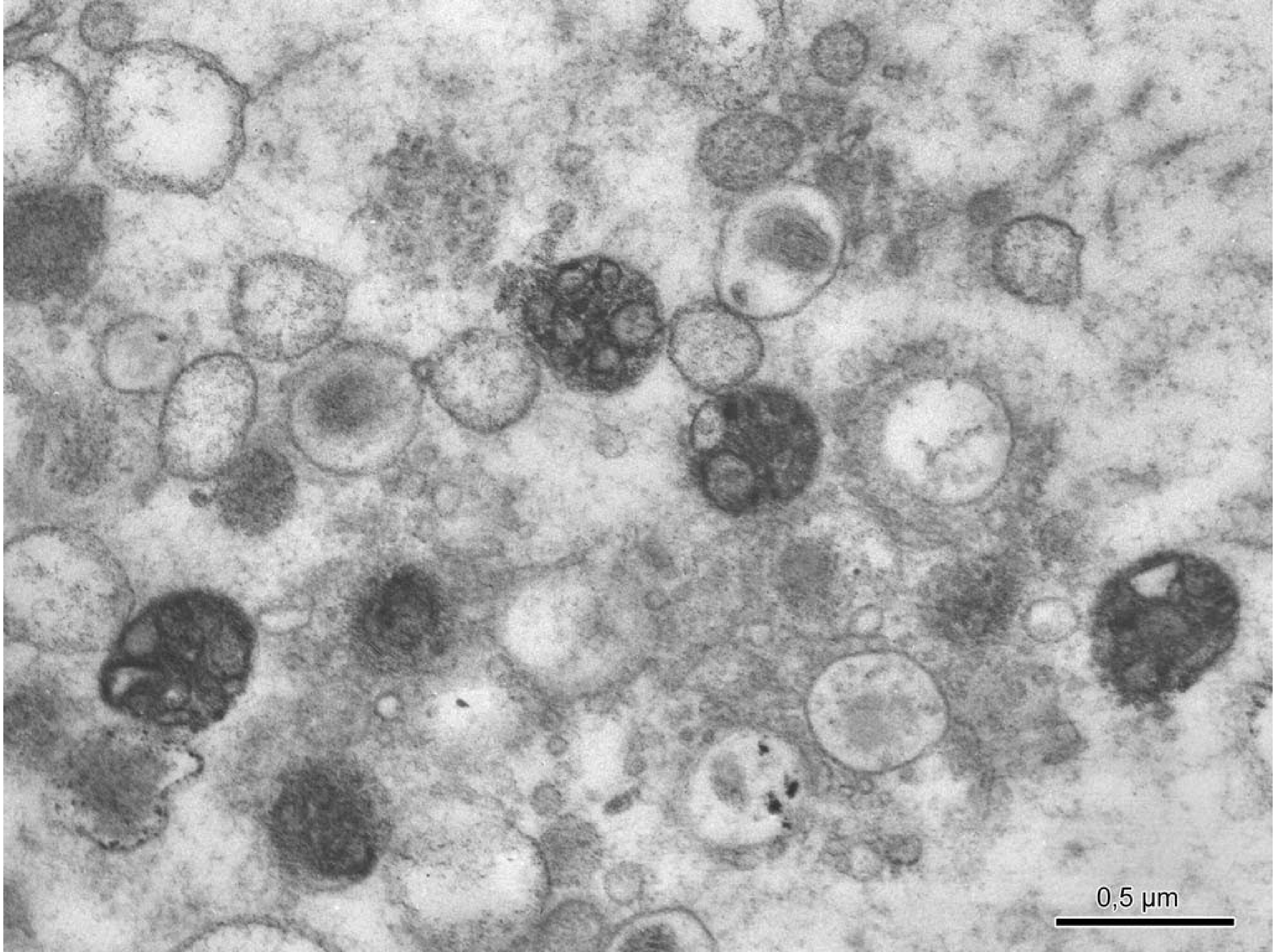
Lysomes

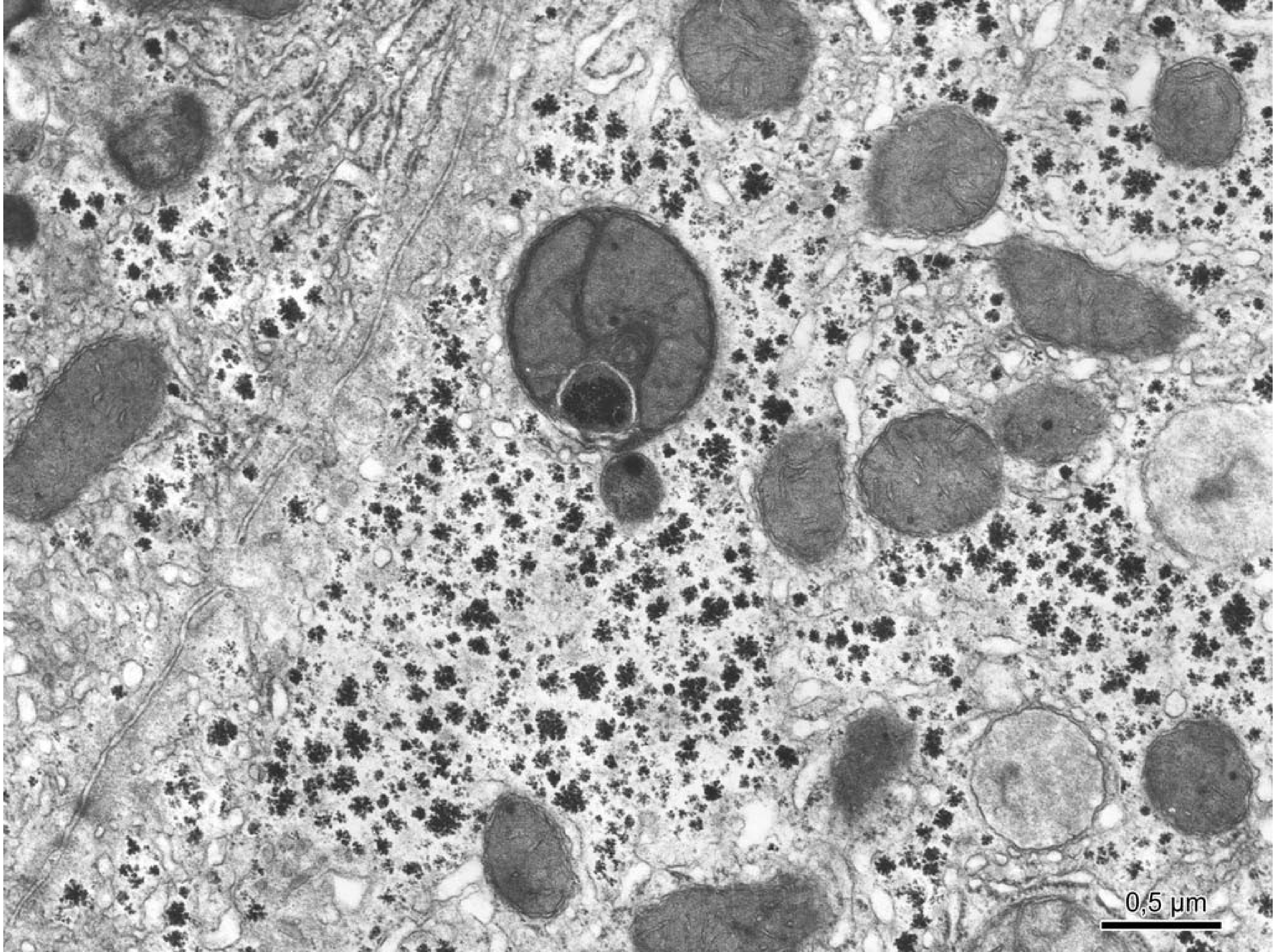
- **lysosomes** – heterogenous group of spherical bodies (0.05 -0.5 µm ∅) containing hydrolytic enzymes

  - **primary lysosomes** – small vesicles with intact enzyme contant

  - **secondary lysosomes** – after fusion with material for digestion; according to origin of this material they are divided into **fagosomes** (extracellular origin) and **autophagic vacuoles** (intracellular origin)

  - **residual bodies** – inactive lysosomes with indigestible material (rest)


0,5 µm


0,5 µm

Peroxisomes

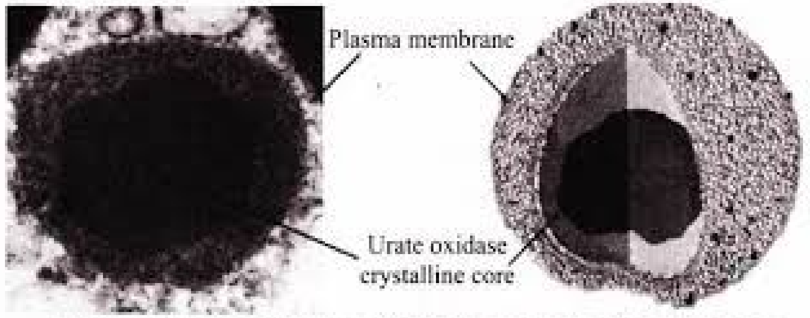
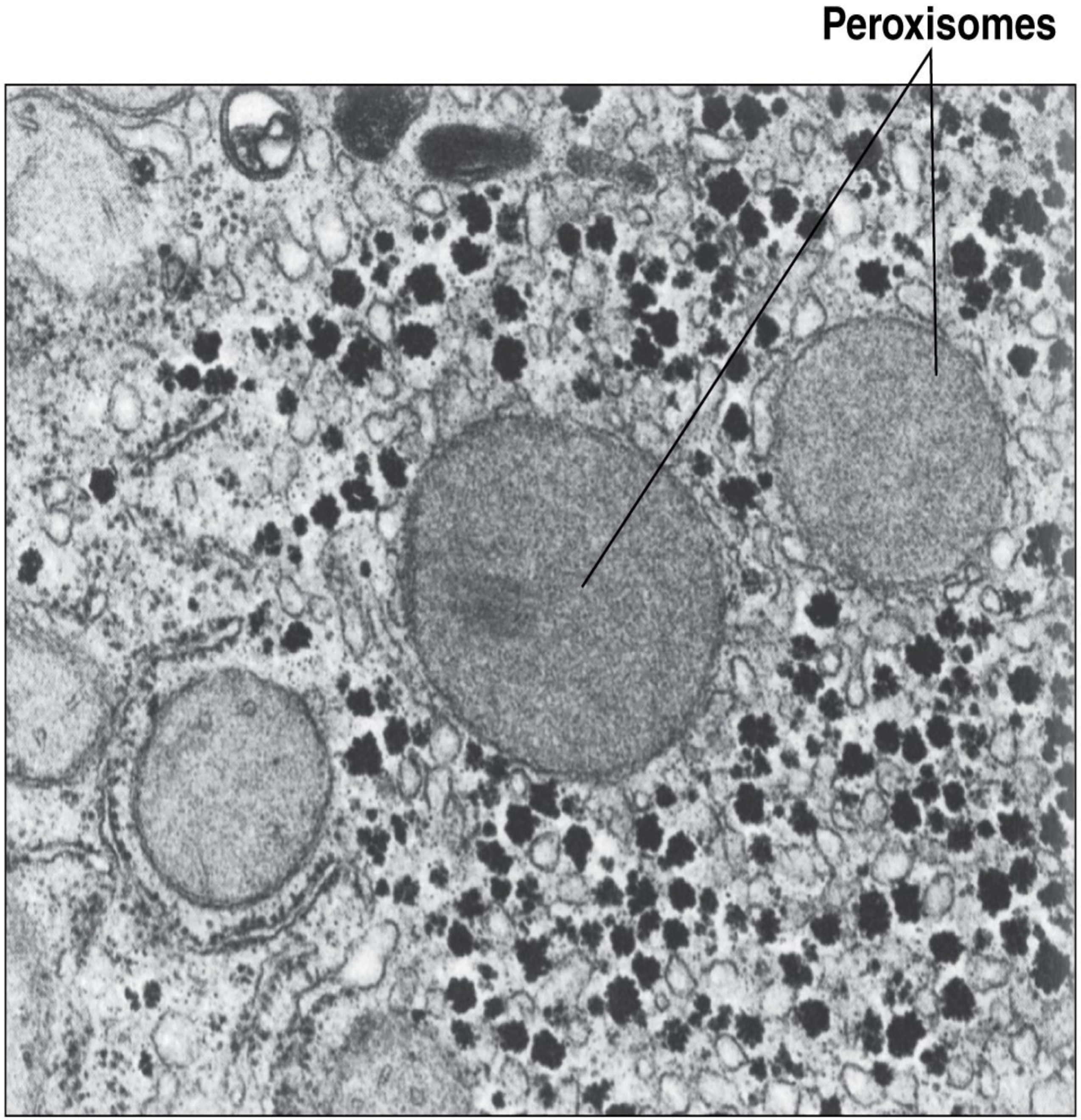
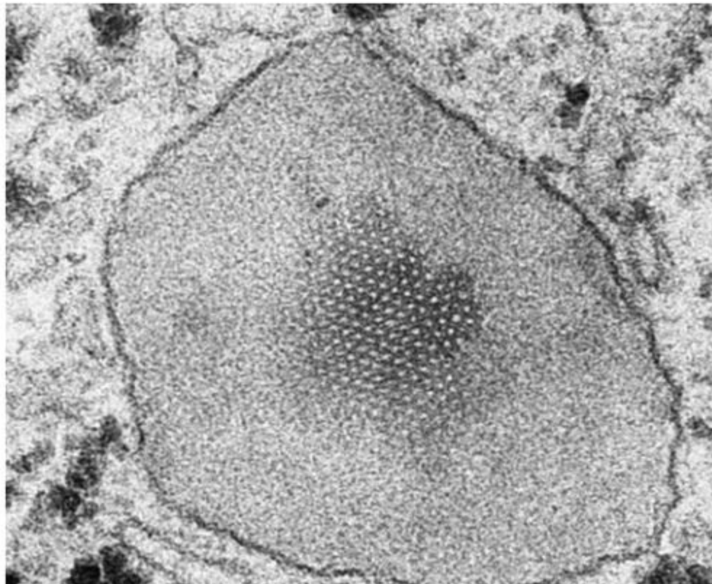


Figure 4.59: Transmission electron micrograph of a peroxisome

- spherical vesicles
- ∅ 0.5 µm
- surrounded by single membrane
- nucleoid
- enzymes: uricase, oxidase (oxidation of long and very long chain fatty acids) , catalase (splits H_2O_2 - detoxication)
- in nearly all eukaryotic cells, mainly in liver cells (hepatocytes) and in epithelial cells of proximal tubule of kidney
- function: participation in anabolic (bile acid, cholesterol or phospholipids synthesis) and catabolic processes

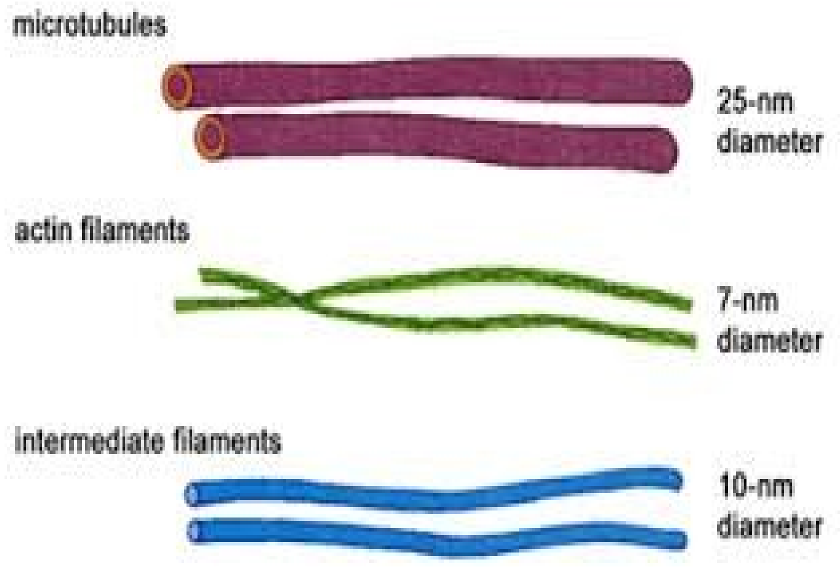

Peroxisomes


200 nm



Cytoskeleton

- Cells contain protein fibers that serve such functions as:
- establishing cell shape
- providing mechanical strength
- locomotion
- chromosome separation during cell division
- intracellular transport of organelles
- The cytoskeleton is made up of three kinds of protein filaments:
- **microtubules**
- **microfilaments**
- **intermediate filaments**



Microtubules

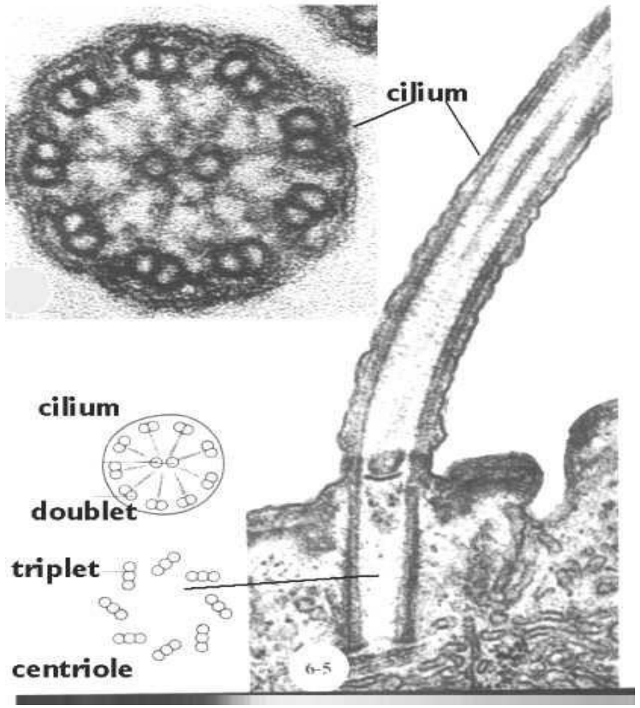
- are straight, hollow cylinders
- have a diameter of about 25 nm
- are variable in length but can grow 1000 times as long as they are thick (grow at each end by the polymerization of tubulin dimers and shrink at at each end by the release of tubulin dimers (depolymerization)
- are built by the assembly of dimers of **alpha and beta tubulin**.
- Microtubules participate in a wide variety of cell activities. Most involve motion. The motion is provided by protein "motors" that use the energy of ATP to move along the microtubule.
- **Microtubule motors -** there are two major groups of microtubule motors
- **kinesins** (most of these move toward the plus end of the microtubules) and
- **dyneins** (which move toward the minus end).

Microtubules

- Kinocilia

Cilium – 9 doublets + 1

Basal body = centriol – 9 triplets (kinetic center of cilium)



Microfilaments

- Monomers of the protein **actin** polymerize to form long, thin fibers. These are about 8 nm in diameter and, being the thinnest of the cytoskeletal filaments, are also called **microfilaments**. (In skeletal muscle fibers they are called „thin“ filaments, while „thick“ filaments are composed of protein **myosin**). Some functions of actin filaments:
- form a band just beneath the plasma membrane that
  - provides mechanical strength to the cell
  - links transmembrane proteins (e.g., cell surface receptors) to cytoplasmic proteins
  - anchors the centrosomes at opposite poles of the cell during mitosis
  - pinches dividing animal cells apart during cytokinesis
- generate cytoplasmic streaming in some cells
- generate locomotion in cells such as white blood cells and the amoeba
- interact with myosin filaments in skeletal muscle fibers to provide the force of muscular contraction

Intermediate filaments

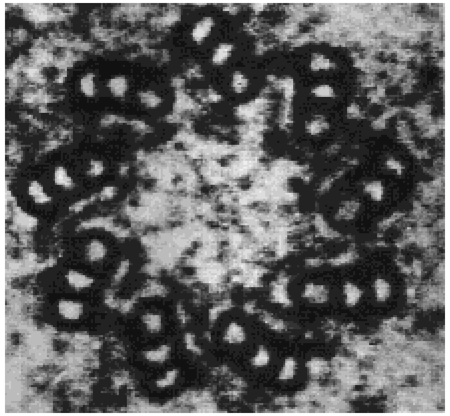
- These cytoplasmic fibers average 10 nm in diameter (and thus are "intermediate" in size between actin filaments (8 nm) and microtubules (25 nm)
- There are several types of intermediate filament, each constructed from one or more proteins characteristic of it.

Type of filament	Cells where they are found
cytokeratins	epithelial cells, and also form hair and nails
vimentin	cells of mesenchymal origin – smooth muslce cells, some endothelial and connective tissue cells
desmin	muscle cells
neurofilaments	strenthen the long axons of neurons
glial fibrilary acid protein	supporting neuroglial cells in nerve system

Despite their chemical diversity, intermediate filaments play similar roles in the cell: providing a supporting framework within the cell.
Detection of type of intermediate filaments in tumor cells is used for estimation of tumor origin.

Centriole

- oval body
- ∅ 0.2 µm and 0.2 – 0.5 µm in the length
- 9 triplets of microtubules
- paired organelle: one centriol is organized at right angle to the other
- in centrosome = centrosphere (region of cytoplasm near the nucleus)



Centriole

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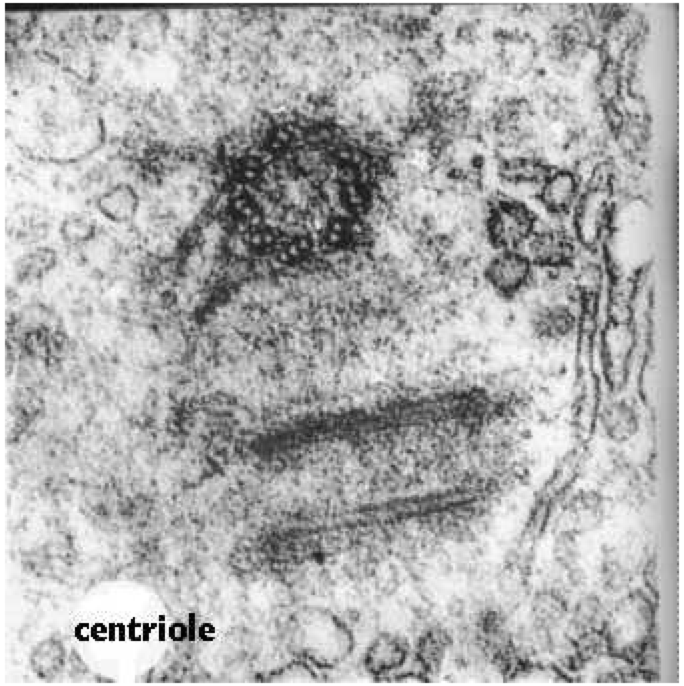
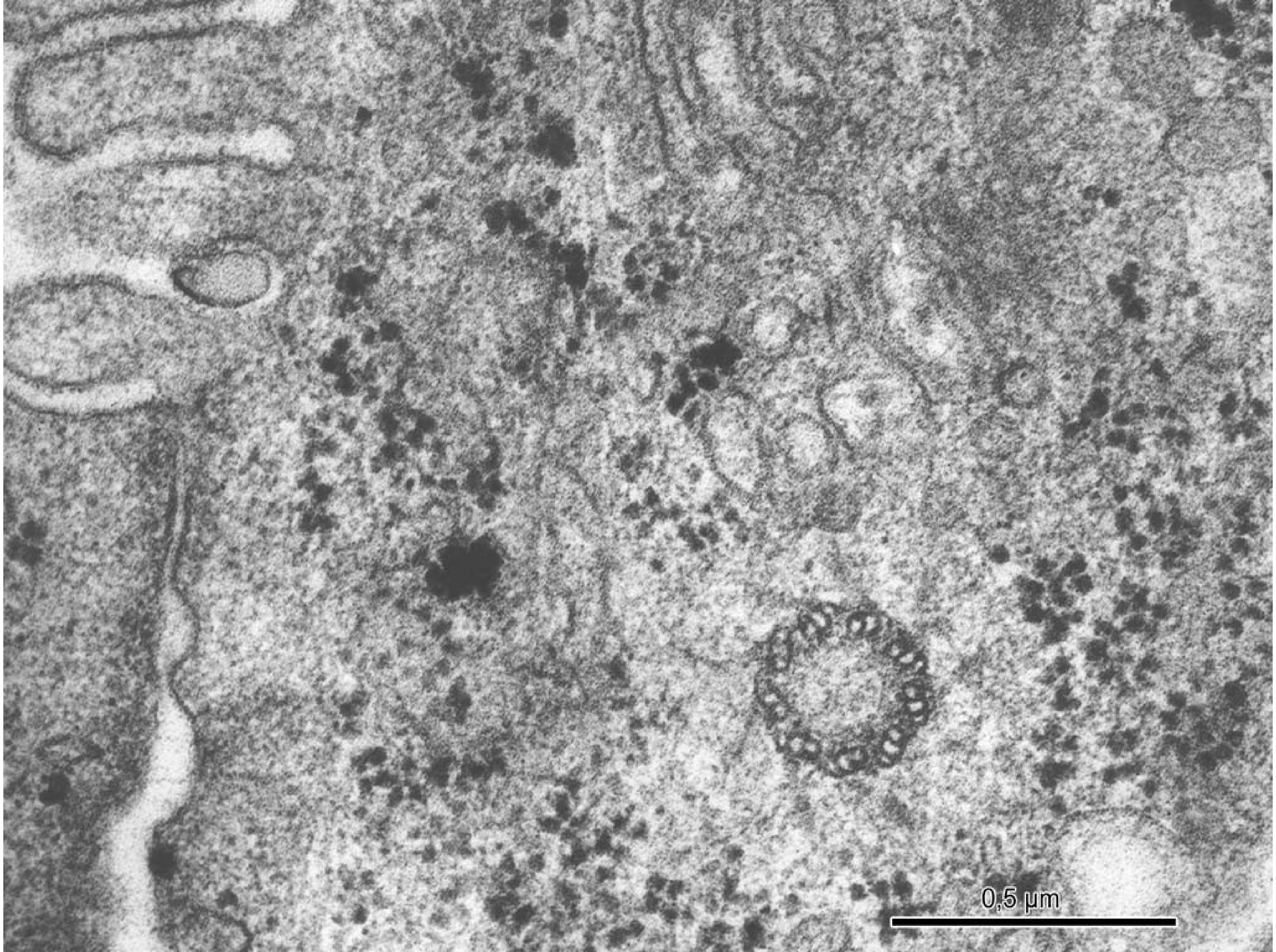
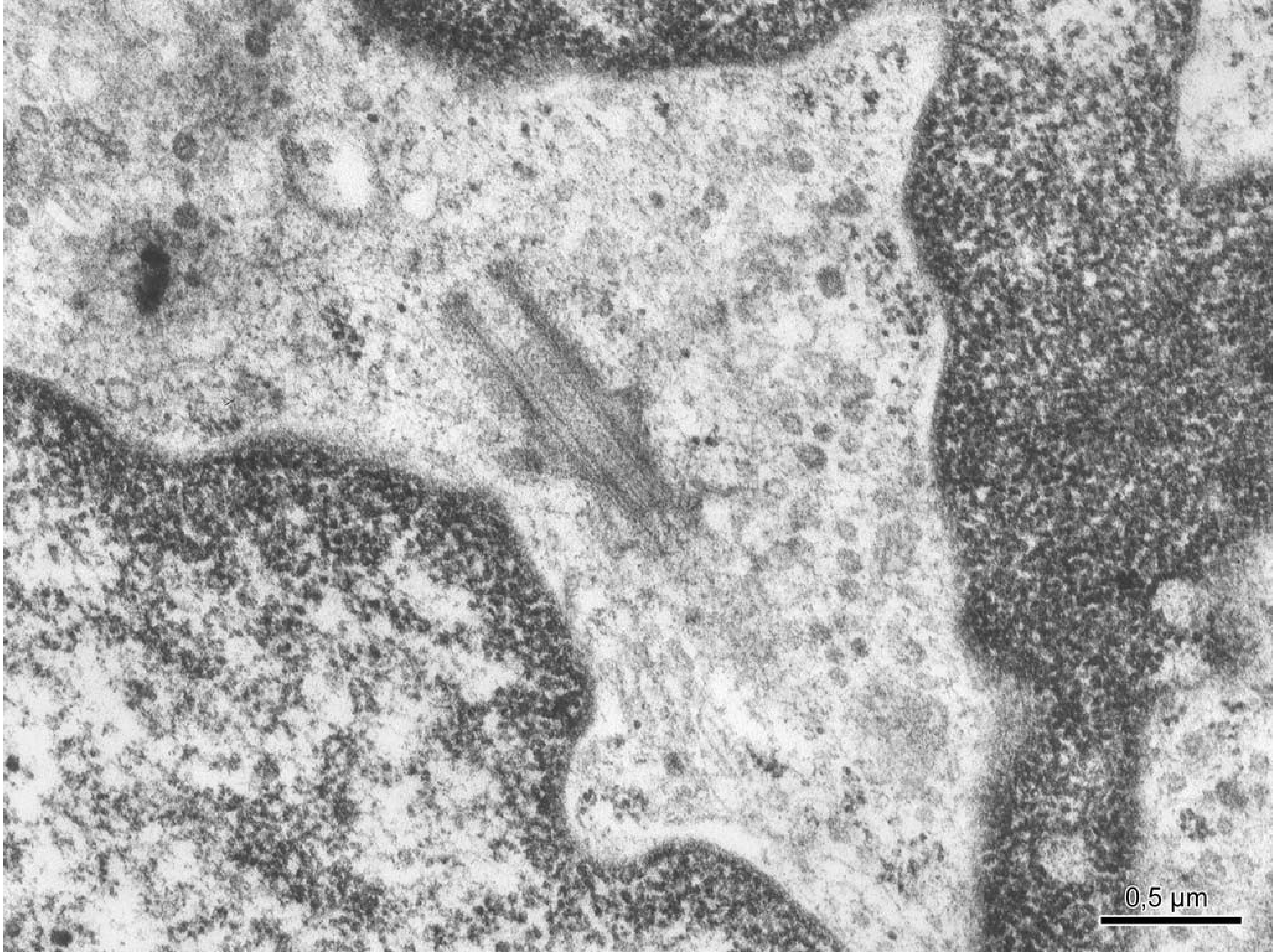


Centriole

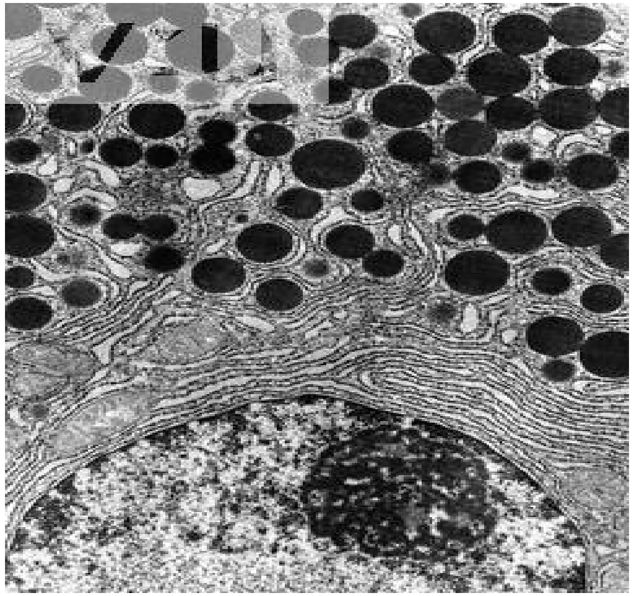
- Function:
- after duplication or multiplication
- centrioles organize the microtubules of **mitotic spindle** apparatus at the beginning of mitosis
- are also needed to make cilia (ciliogenesis) and flagella – these project from cell surface and centriols as **basal bodies** of cilia or flagella are present in the cytoplasm bellow them.


0,5 µm


0,5 µm

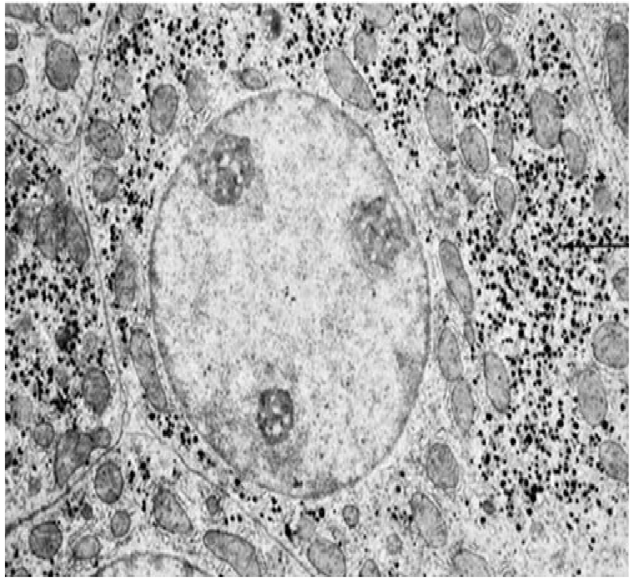
Inclusions

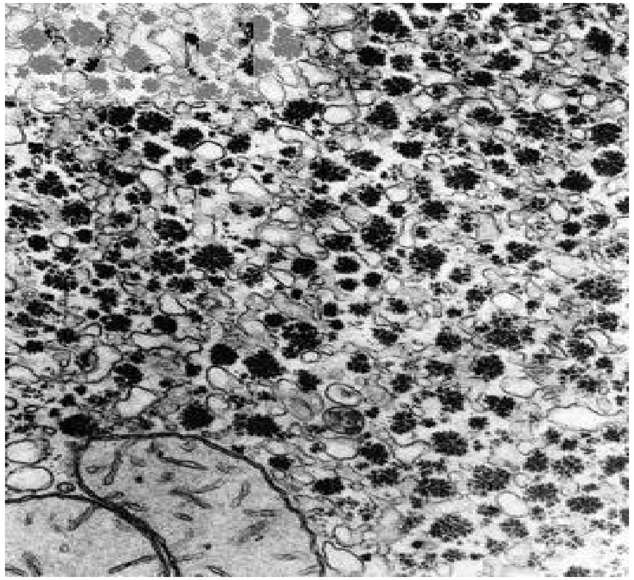
- are cytoplasmic structures of transitional character arrising by accumulution of unsoluble metabolits of storing materials or they are of exogenous origin and enter the cell via phagocytosis.
- **Secretory granules**
- membranous vesicles with protein or glycoprotein contant in glandular cells
- they are released from the cell

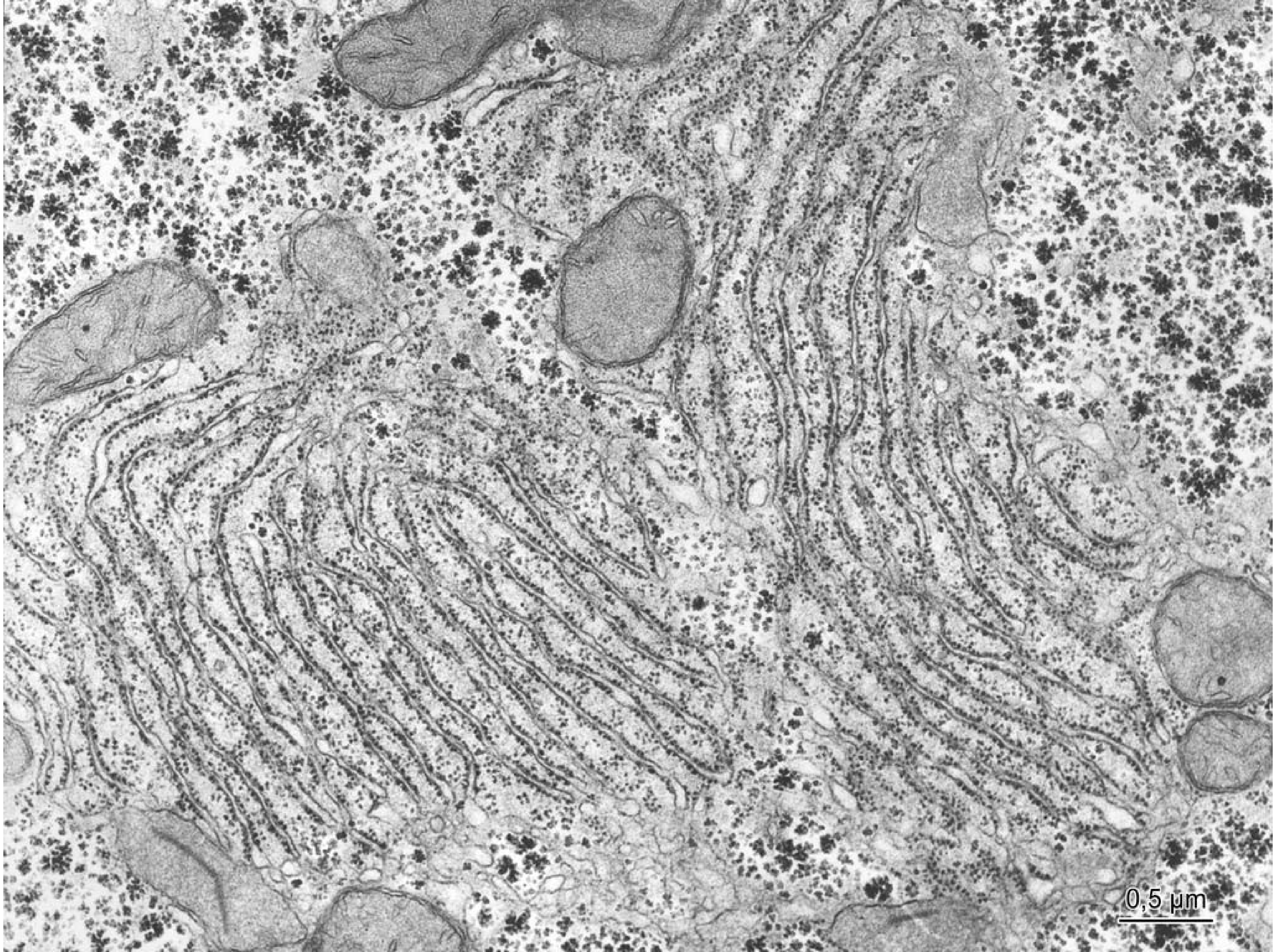


Inclusions

- **<u>Reserve materials</u>**:
  Glycogen
- **β** – granules (sized 20 nm) or **α** – granules (clusters of **β** – granules, sized 500 nm)






0,5 µm

Inclusions

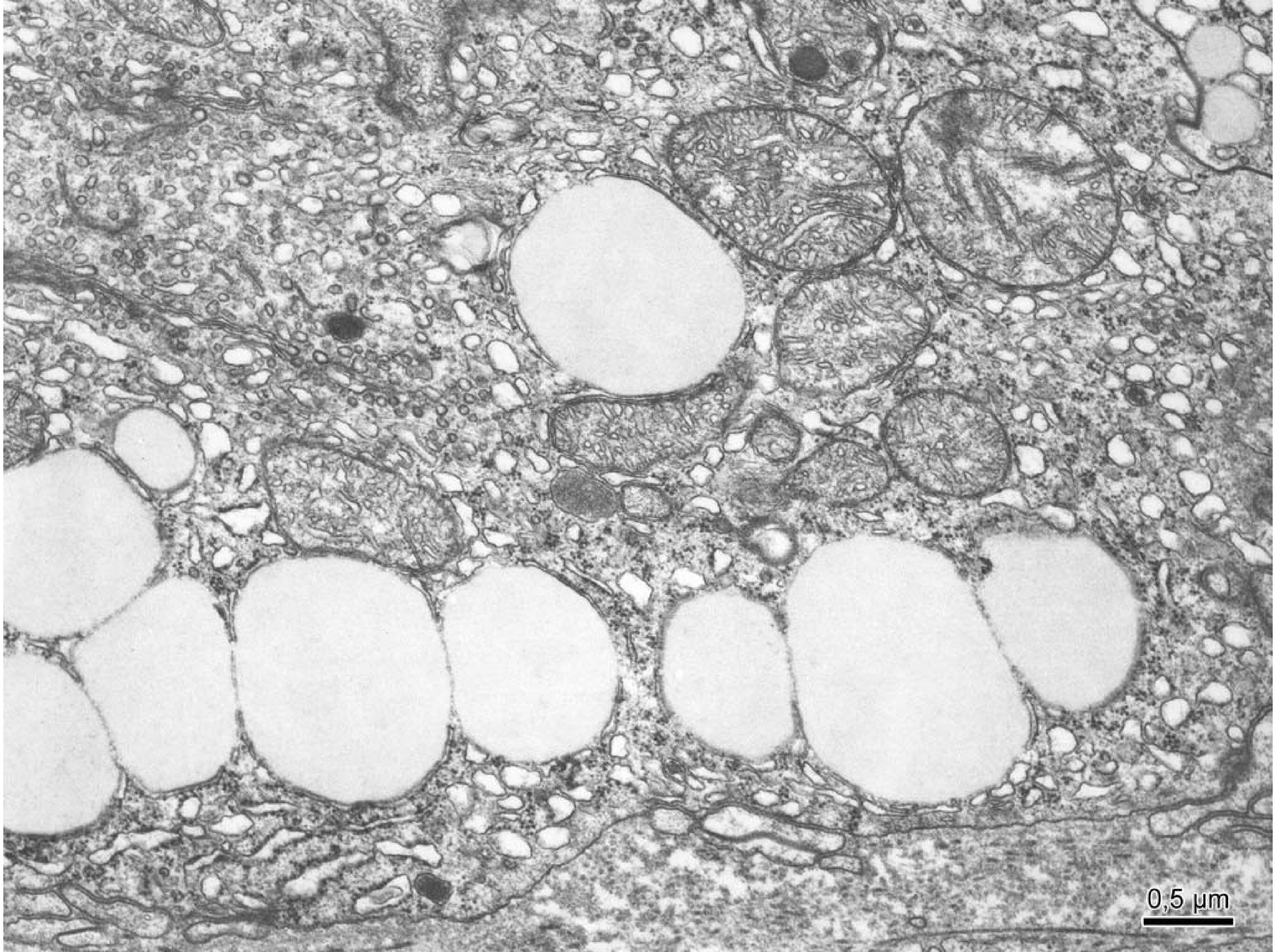
- **Lipid droplets**

- non-membranous, round particles (∅ 100 nm – 10 µm)

- **Kristals**

- **Pigments:**

- colored inclusions are divieded into
- autogenous – synthetized from precursors inside of cell and having specific function (**melanin**)
- hematogenous – arrise by break-down of hemoglobin (**hemosiderin**, **biliverdin** → **bilirubin**)
- exogenous – from extracellular medium (carotens, dust particles, arteficial dyes – tattoo)


0,5 µm