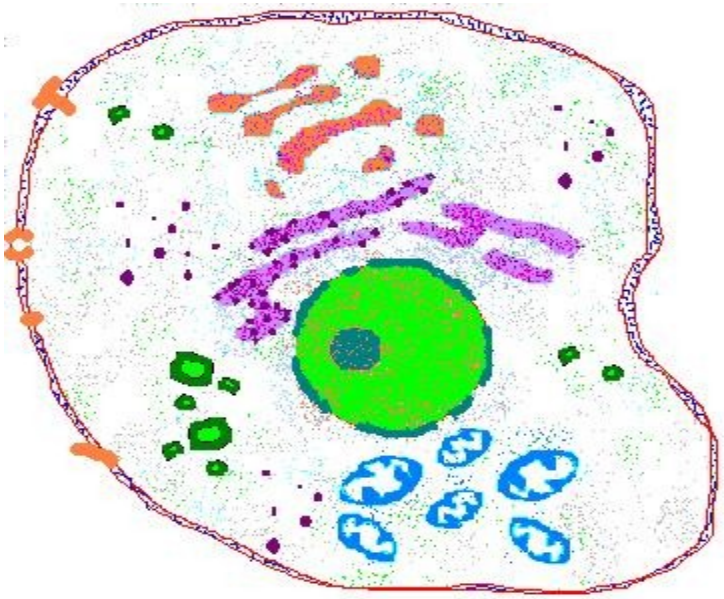
The cell



The basic structural and functional unit of multicellular organism, which is able to exist independently on the organism, *in vitro*, if the suitable conditions are given (*in cell culture medium*)

Important events in the discovery of cells

- 1665 - Robert Hooke looks at cork under a microscope. Calls the chambers he see "cells"
- 1665 - 75 Anton van Leeuwenhoek, the inventor of the microscope, studies organisms living in pond water. He calls them "Animalcules."
- 1830 - German scientists Schleiden and Schwann summarize the findings of many scientists and conclude that all living organisms are made of cells. This forms the basis of the Cell Theory.

Types of Cells

- **Prokaryotes**
  - Pro = before; karyon = nucleus
  - relatively small - 5 to 10 um
  - lack membrane-bound organelles
  - earliest cell type

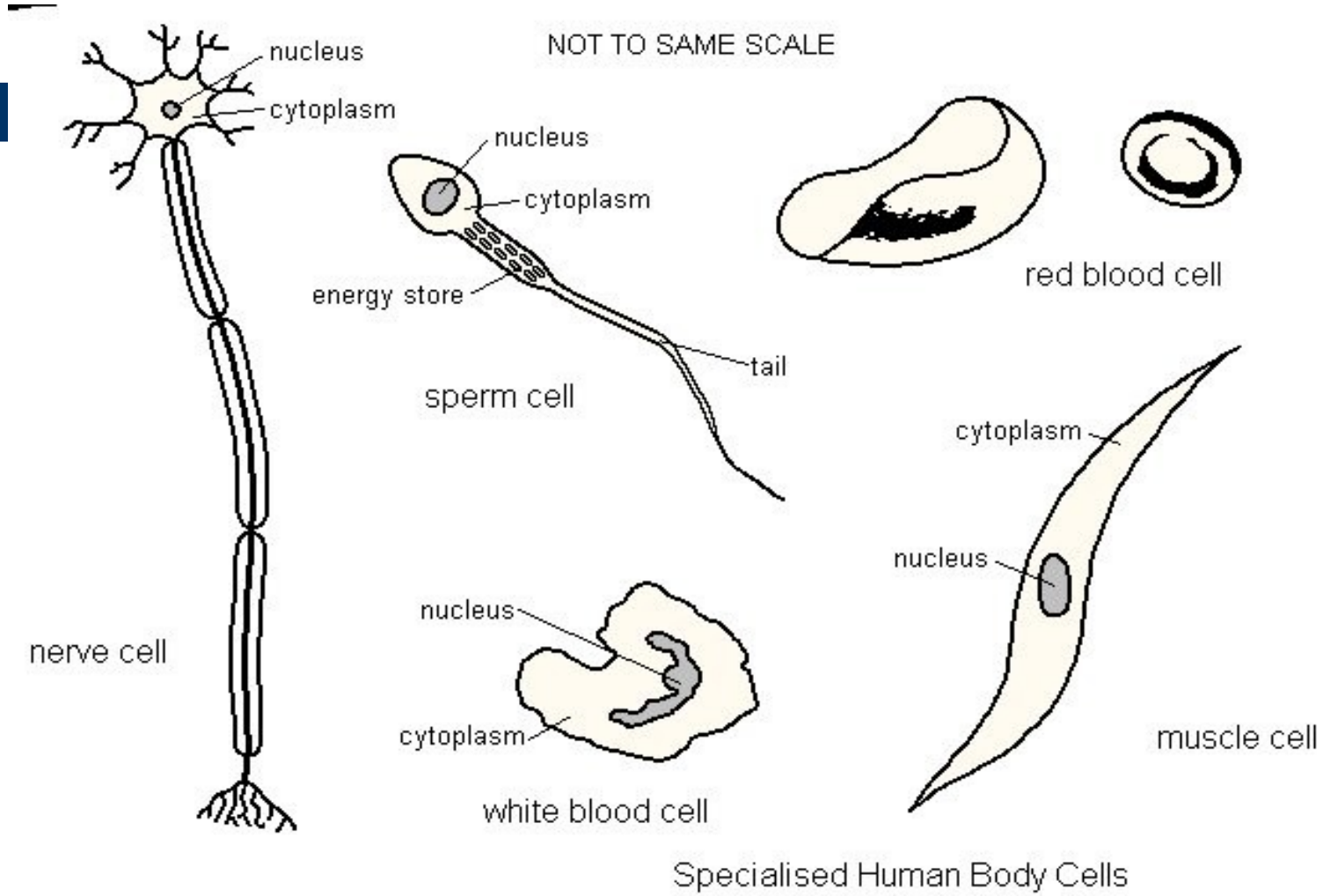
- **Eukaryotes**
  - Eu = true; karyon = **nucleus**
  - contain membrane-bound organelles
  - Evolved from prokaryotes by endosymbiotic association of two or more prokaryotes
  - Include Protists, Fungi, Animals, and Plants

The size of the cells

- **5 – 120 μm**
  - granular neurons of cerebellar cortex 4 – 5 μm
  - erythrocytes 7,4 μm
  - Purkynje cells of cerebellar cortex or pyramidal cells of brain cortex 80 – 100 μm
  - oocyte 120 μm
  - megakaryocyte in bone marrow up to 150 μm

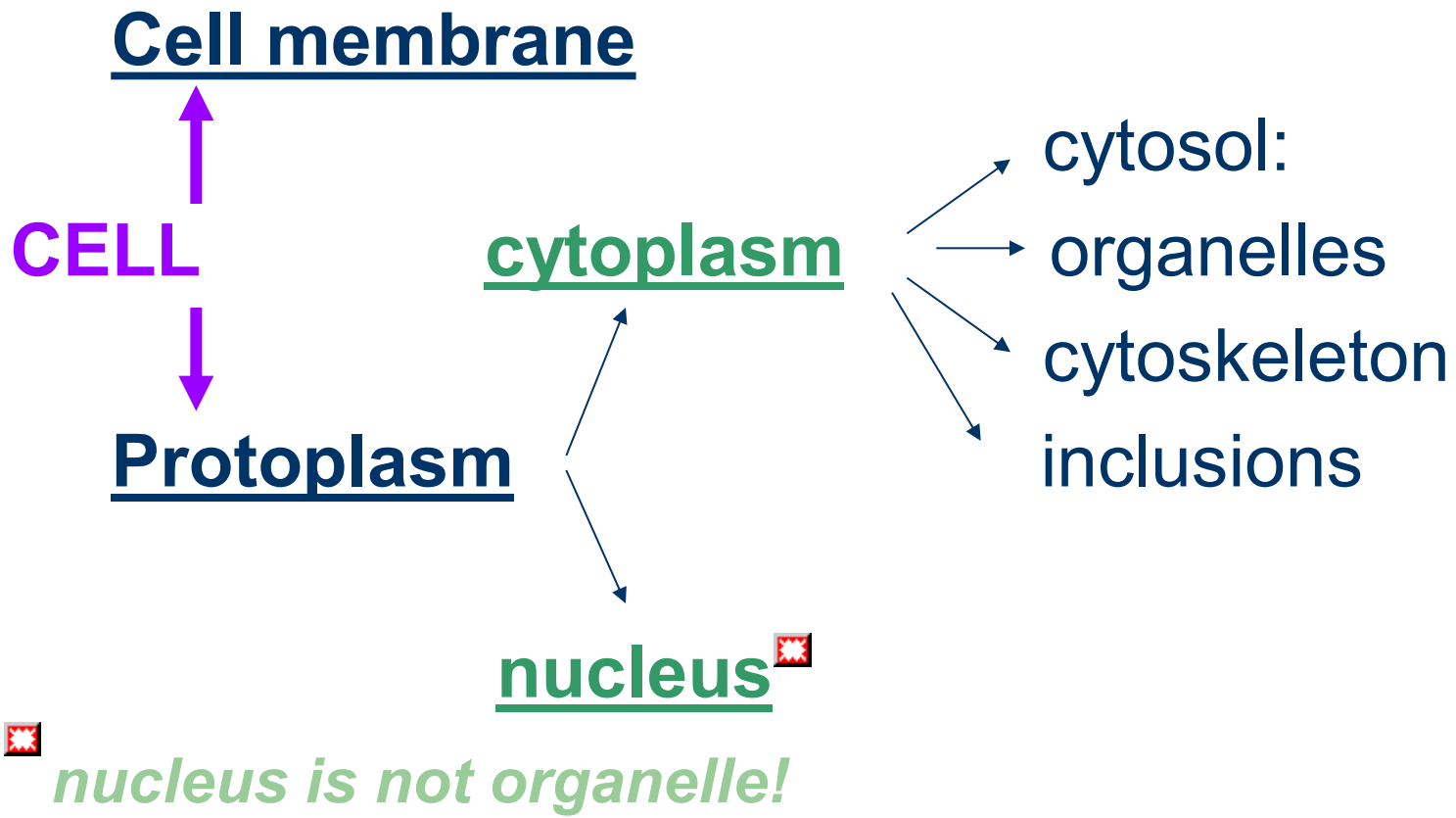
The majority of the somatic cells has about 10 – 20 μm

The shape of the cells



Specialised Human Body Cells

The structure of the cell



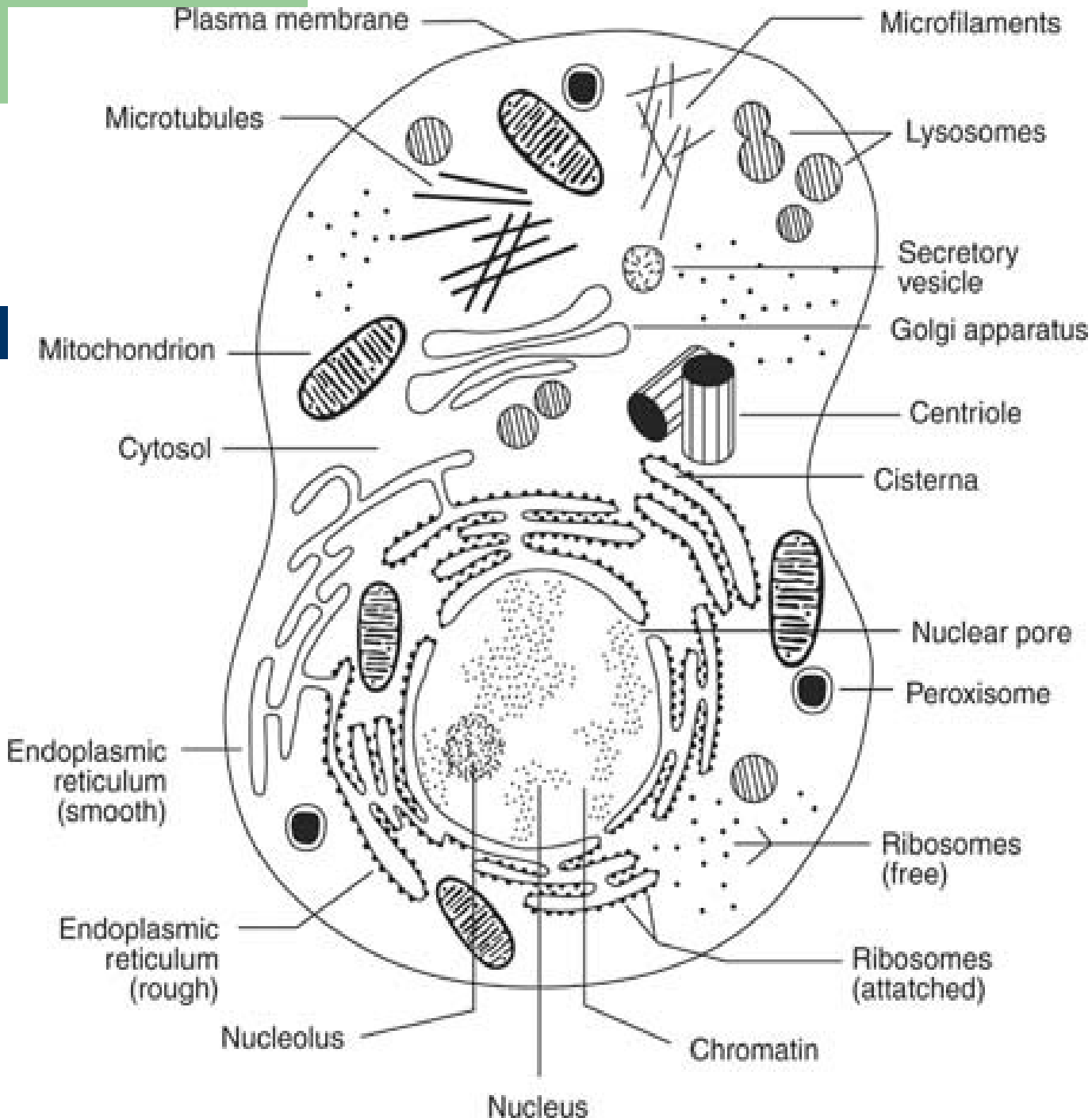
nucleus is not organelle!

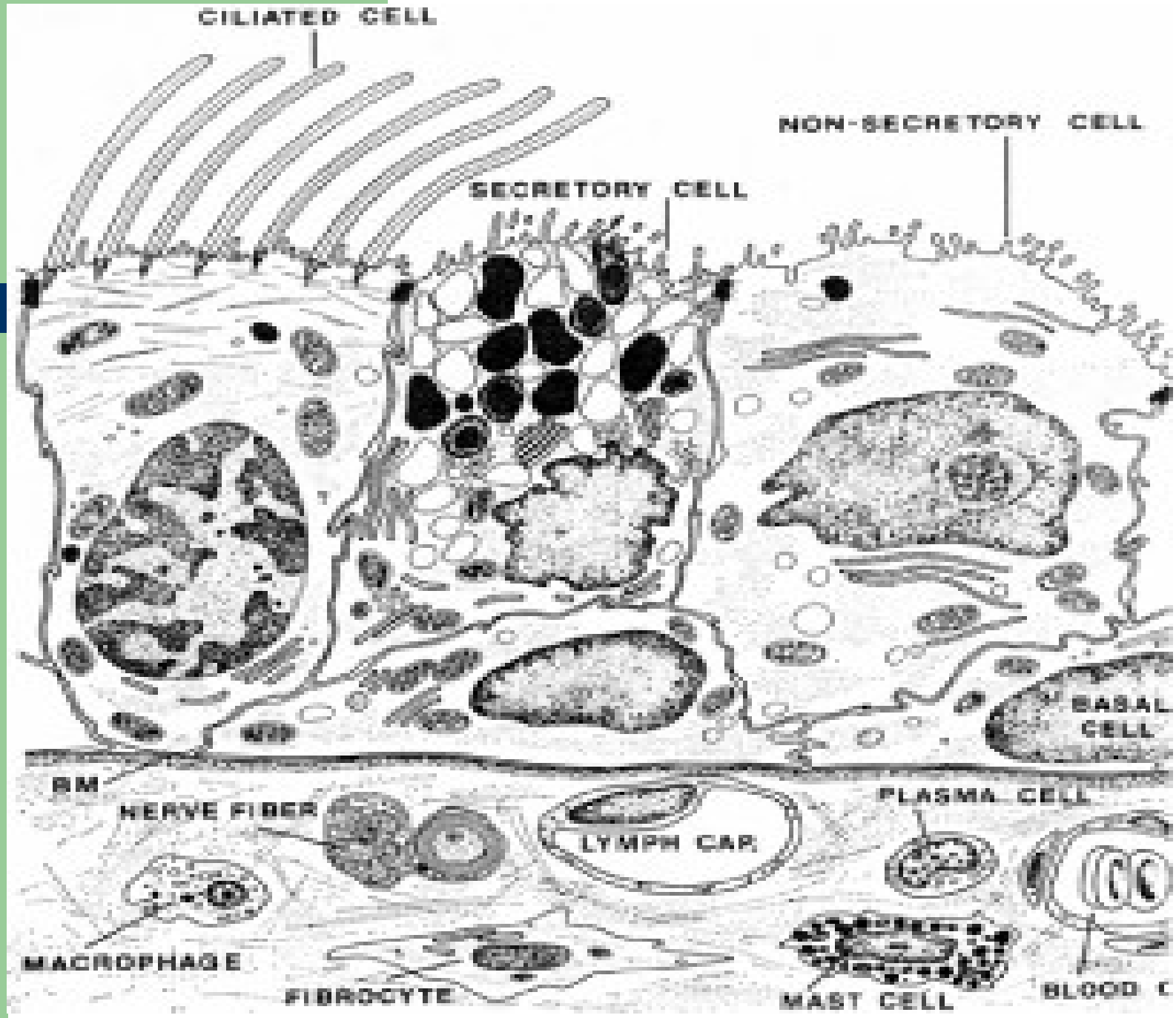
Cytosol = basic cytoplasm

Dual colloid system: gel and **sol** **(varies depending on the density of cytoskeleton and organelles)**

composition:

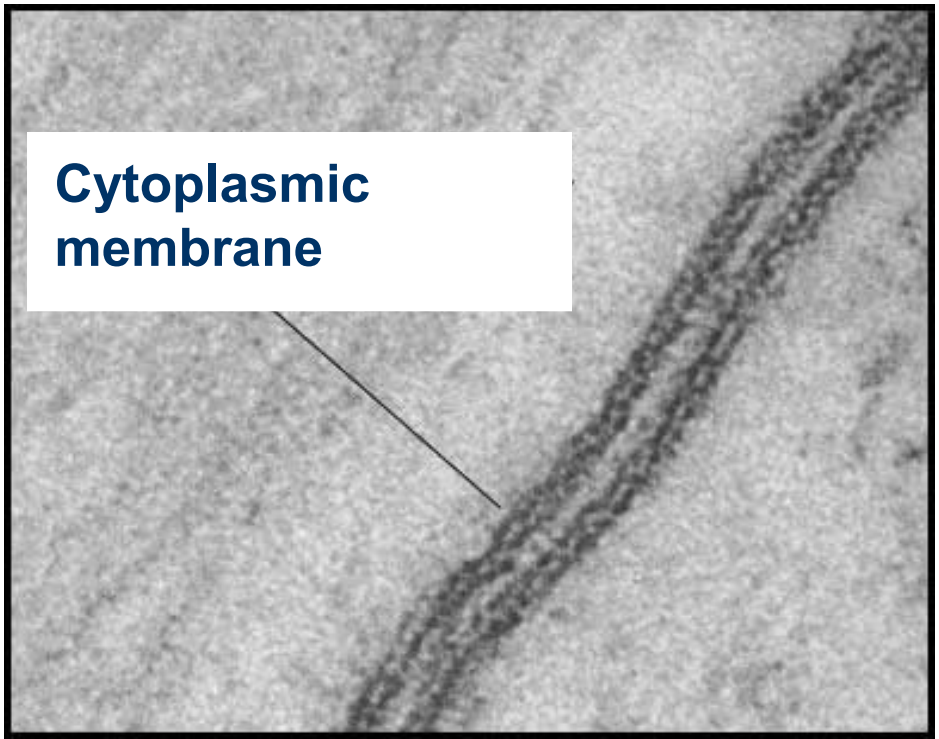
60 % water, 5 % minerals, 35 % organic substances (saccharids, lipids, proteins – albumins, globulins, aminoacids, phospho-lipoproteins).


Plasma membrane
Microfilaments
Microtubules
Lysosomes
Secretory vesicle
Golgi apparatus
Mitochondrion
Centriole
Cytosol
Cisterna
Nuclear pore
Peroxisome
Endoplasmic reticulum (smooth)
Ribosomes (free)
Endoplasmic reticulum (rough)
Ribosomes (attatched)
Nucleolus
Chromatin
Nucleus


CILIATED CELL
NON-SECRETORY CELL
SECRETORY CELL
BASAL CELL
BM
NERVE FIBER
LYMPH CAP
PLASMA CELL
MACROPHAGE
FIBROCYTE
MAST CELL
BLOOD C

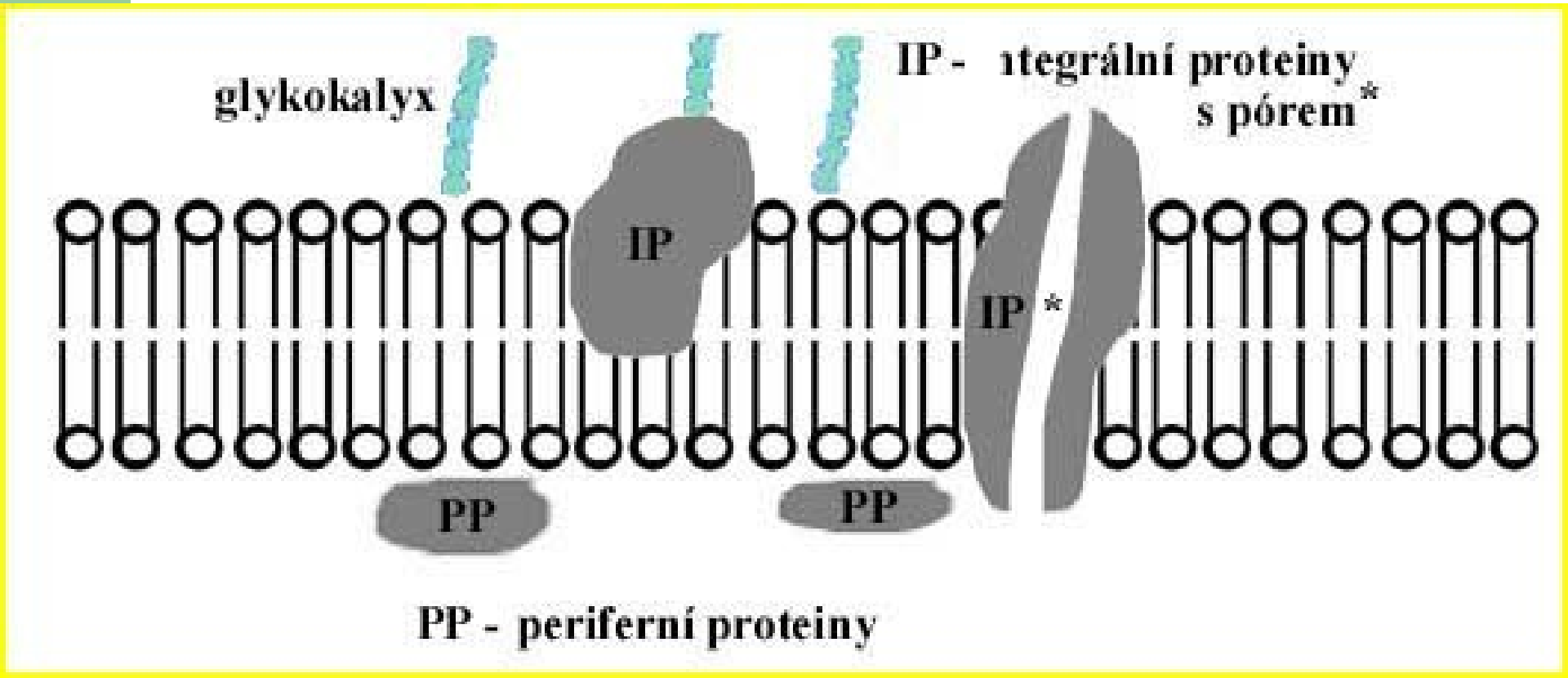
The cell membrane (plasmalemma)

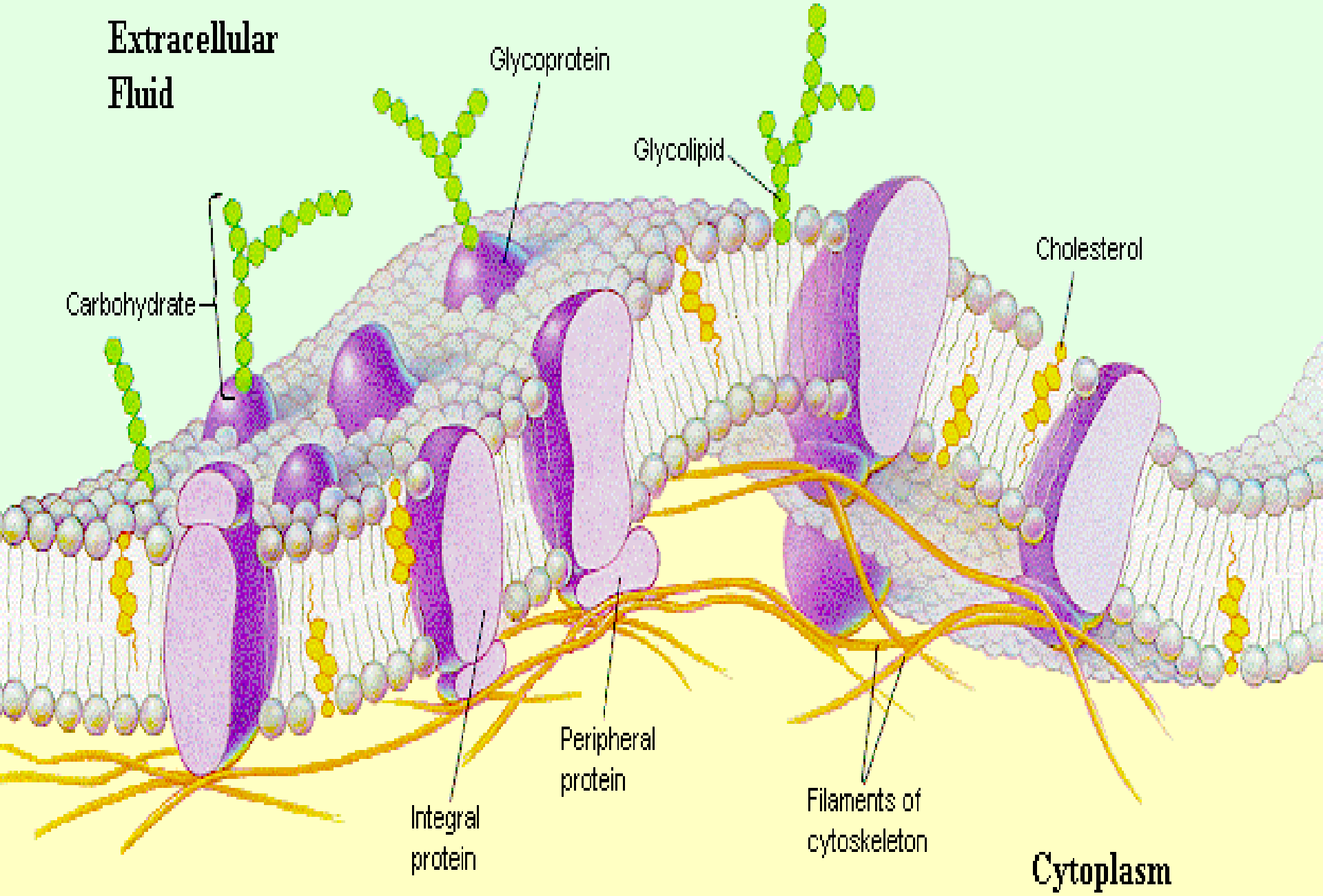
- biomembrane – **membrane units:** phospholipids, proteins, cholesterol
- glycocalyx
- thickness 7.5 – 10 **nm**



„fluid mosaic model“

- in EM – 2 layers of phospholipids with 3-layered appearance




Extracellular Fluid
Glycoprotein
Glycolipid
Carbohydrate
Cholesterol
Peripheral protein
Integral protein
Filaments of cytoskeleton
Cytoplasm

Functions of integral proteins in membrane

- Pumps (*aktive transport, needs energy*)
- Canals (*selectivení regulation of substances transport*)
- Receptors (**specific bonds of molecules**)
- Transducers (*transfer of informations into the cell*)
- Enzymes (*on the mitochondrial membrane*)
- Structural proteins

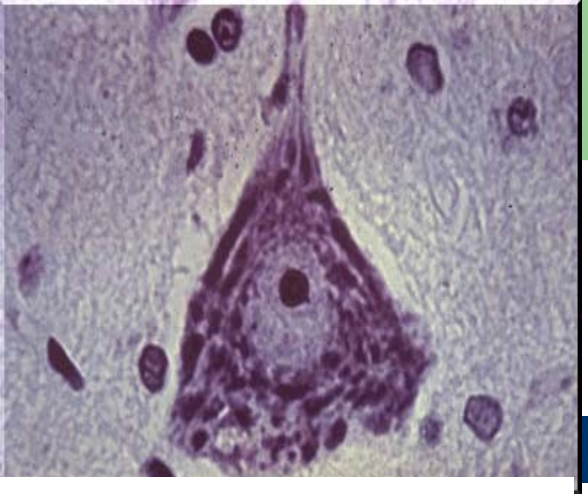
Function of the cell membrane

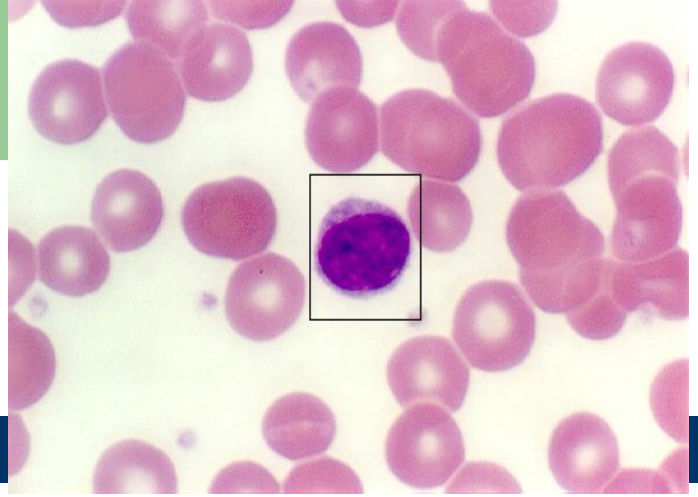
- selective barrier – regulation of substances transport from/into the cell
- regulatory and recognazing functions
  (receptors, glycocalyx – antigenic functions)

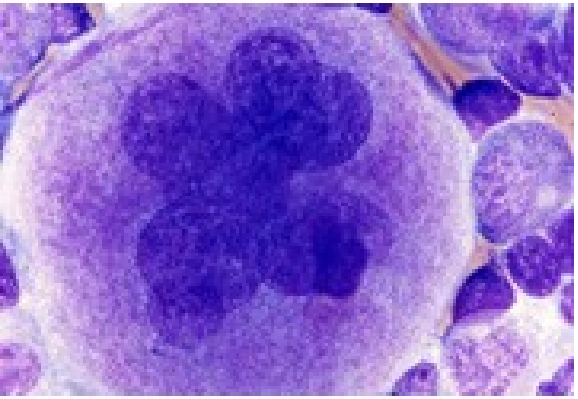
Nucleus

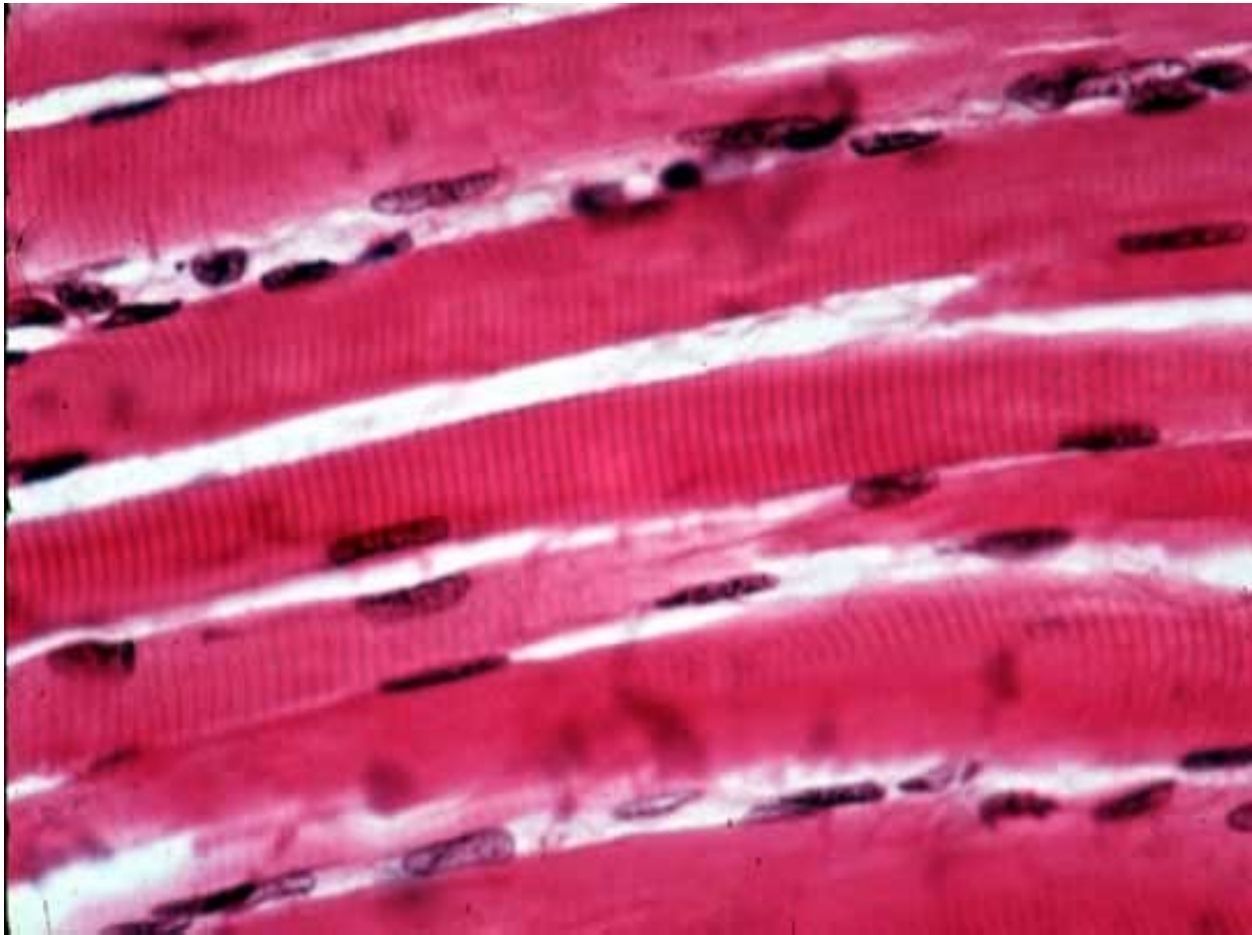
- controles cell activity, which is encoded in chromosomes

- Numbers of nuclei in the cell
  (usually: 1, *hepatocytes: 2, osteoklasts: 50, skeletal muscle cell: 20 - 40/1 mm of the length,* ***human erythrocytes*** *– without nucleus)*
- Size of nucleus
  (in many cells 5 – 15 μm)
- Shape of nucleus
  (corresponds to the cell shape – usually spherical or oval; can be lobated, segmented)
- Appearance of nucleus



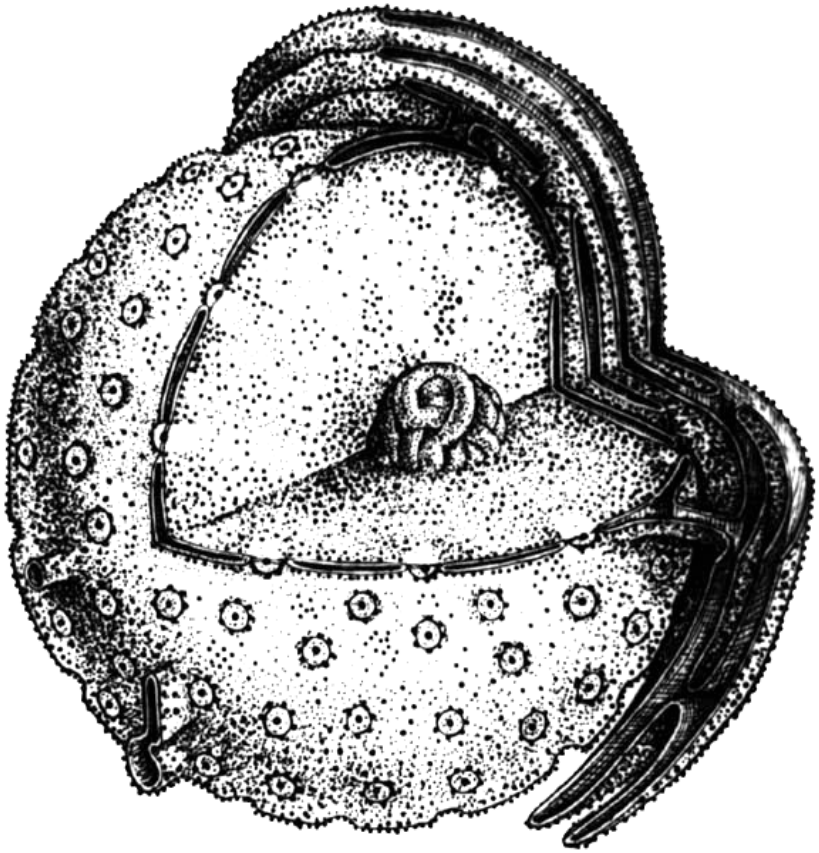






Nucleus structure

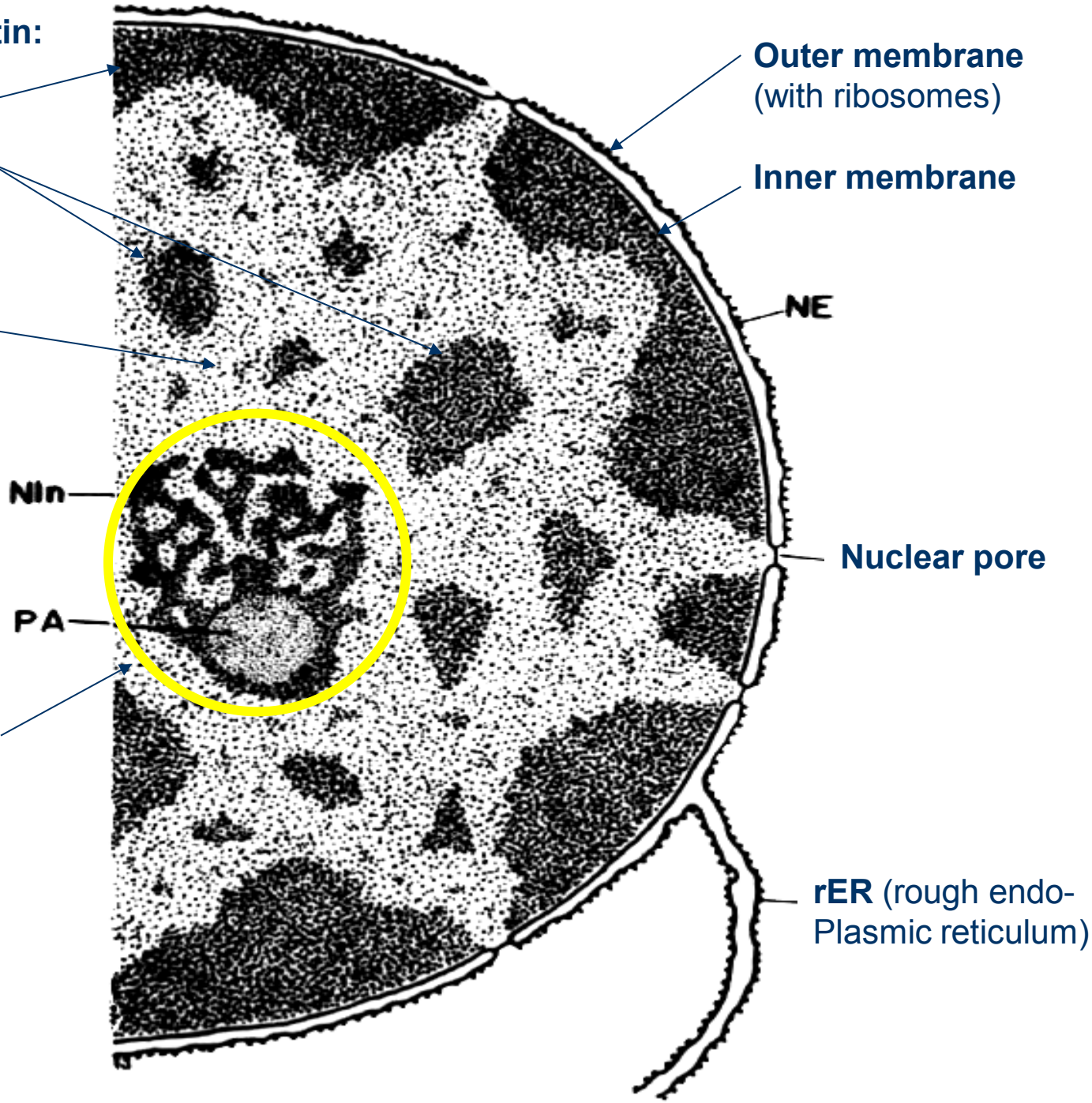
- Nuclear envelope – consists of 2 membranes
- Nuclear matrix – nucleoplasm
- Chromatin (during interphase) / chromosomes (during cell division)
- Nuclear skeleton
- Nucleolus (1 or more)



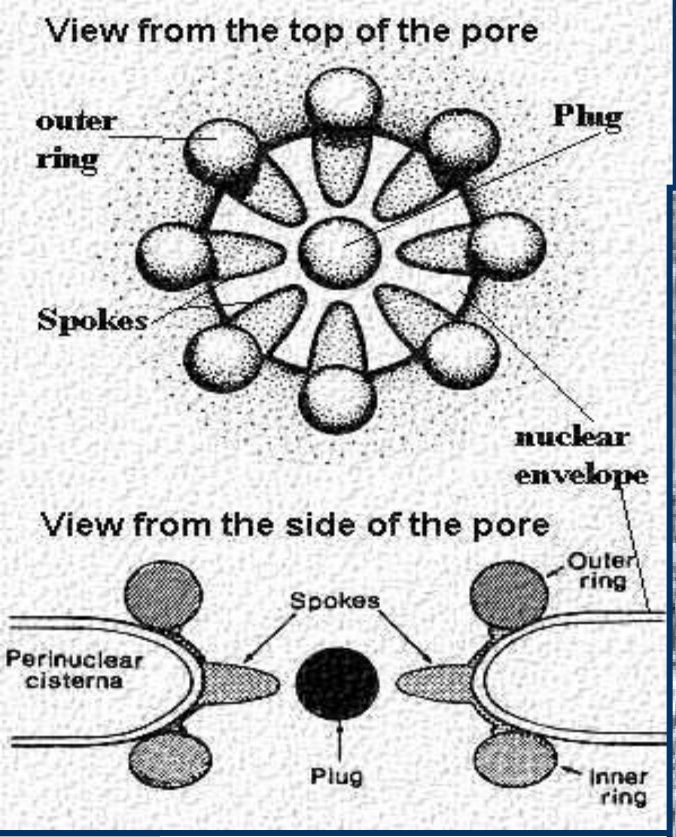
Nuclear envelope

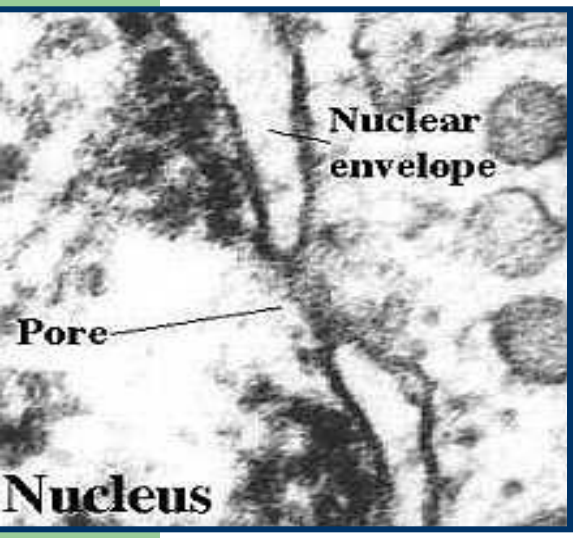
- outer nuclear membrane (+ ribosomes)
- perinuclear space (40 – 70 nm width)
- inner nuclear membrane
- pores (60 – 70 nm ∅, with diaphragm and central granule)

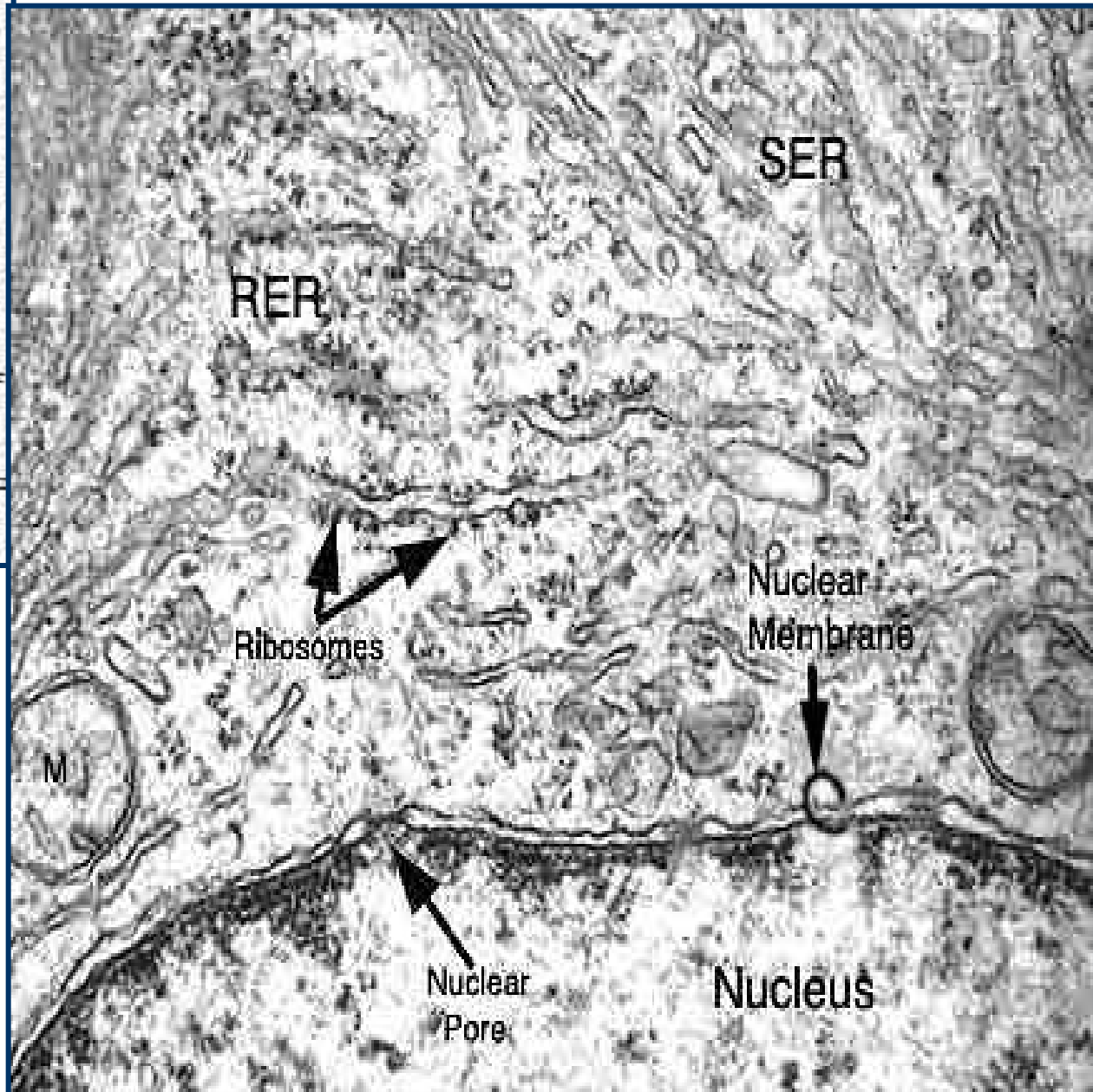
NUCLEUS


Heterochromatin:
- marginal
- karyosomes
Euchromatin
Nucleolus
Nln
PA
Outer membrane
(with ribosomes)
Inner membrane
NE
Nuclear pore
rER (rough endo-
Plasmic reticulum)

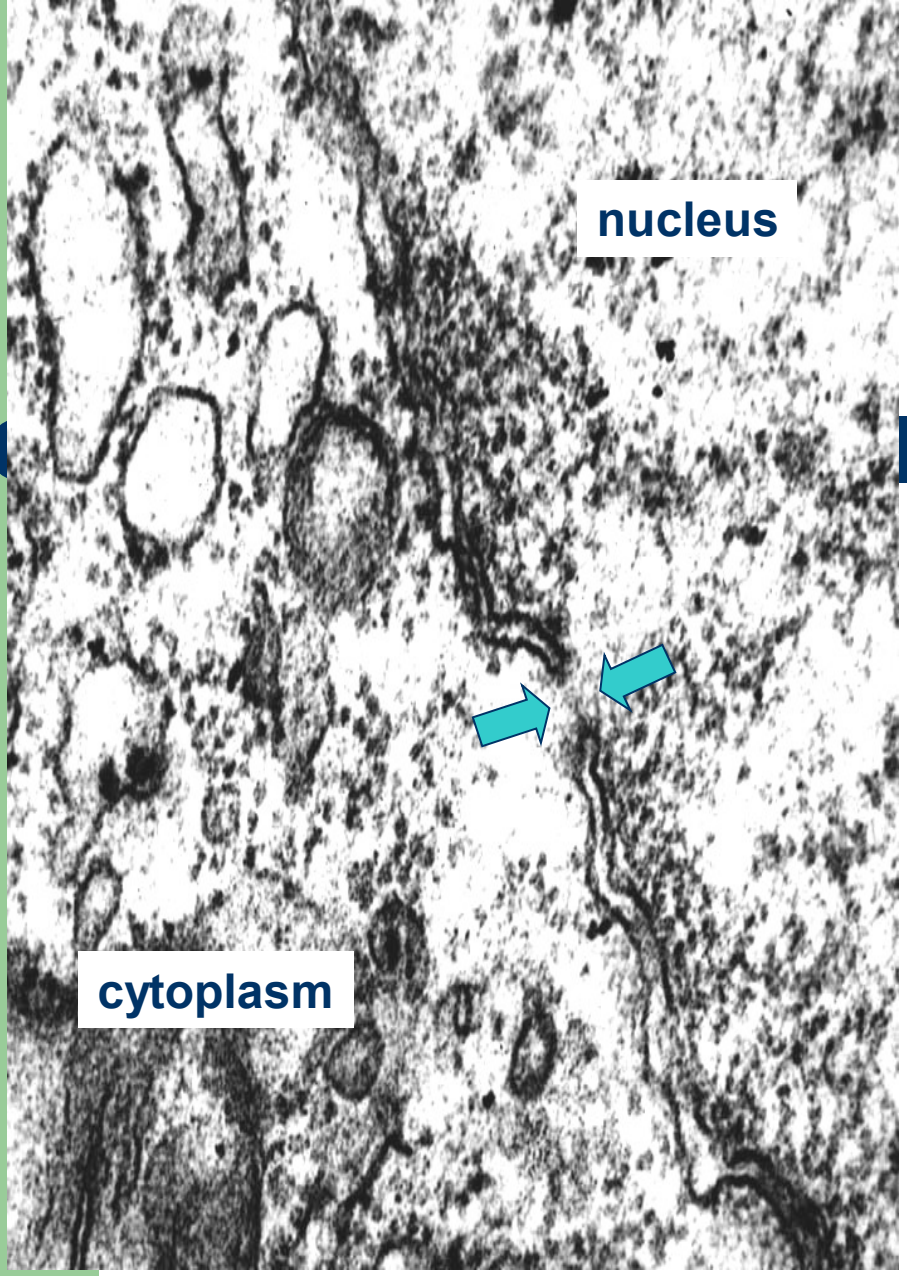
Nuclear pores







Nucleus - pores



Nuclear matrix and skeleton

- Matrix – amorphous substance surrounding chromatin and nucleolus
- Composition: proteins, metabolits, ions

- Skeleton – anastomosing trabecules

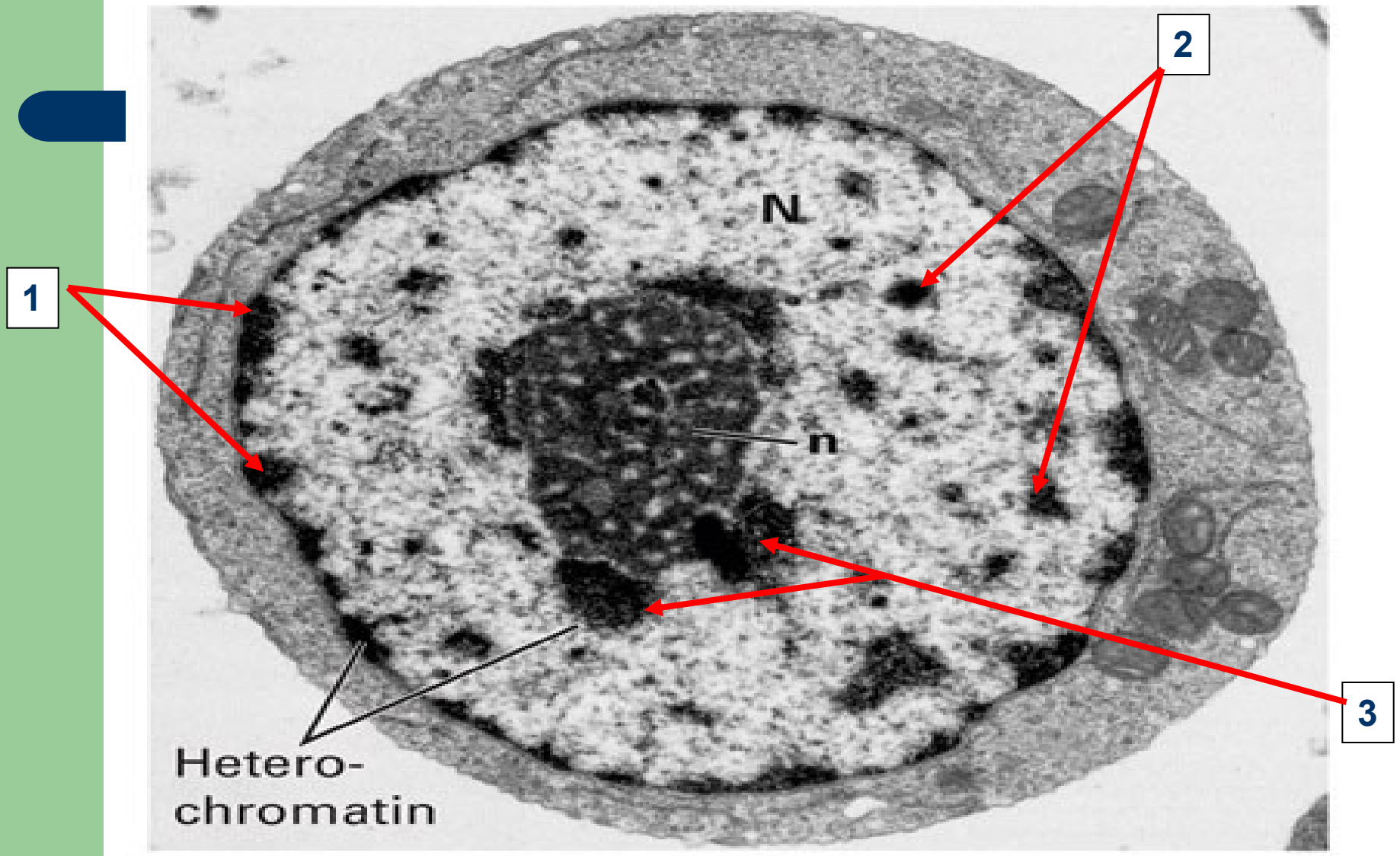
Chromatin

Decondensed chromosomes during interphase

- Heterochromatin – **dark**
  (spiralised and dehydrated parts of chromosomes)
  - marginal heterochromatin
  - karyosomes
  - perinucleolar heterochromatin (assotiated with nucleolus)
- Euchromatin – **pale, unstained**
  (active parts of chromosomes with intensive synthesis of RNA)

Heterochromatin:

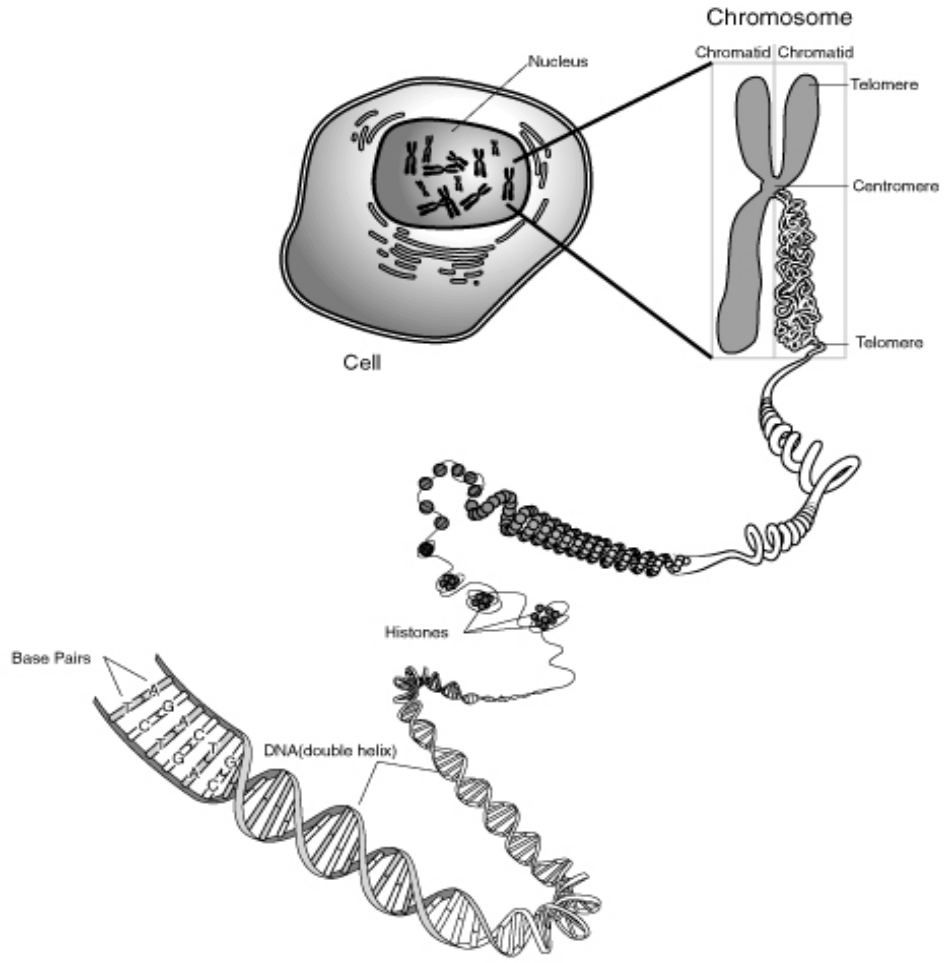
1. marginal, 2. karyosomes, 3. perinucleolar

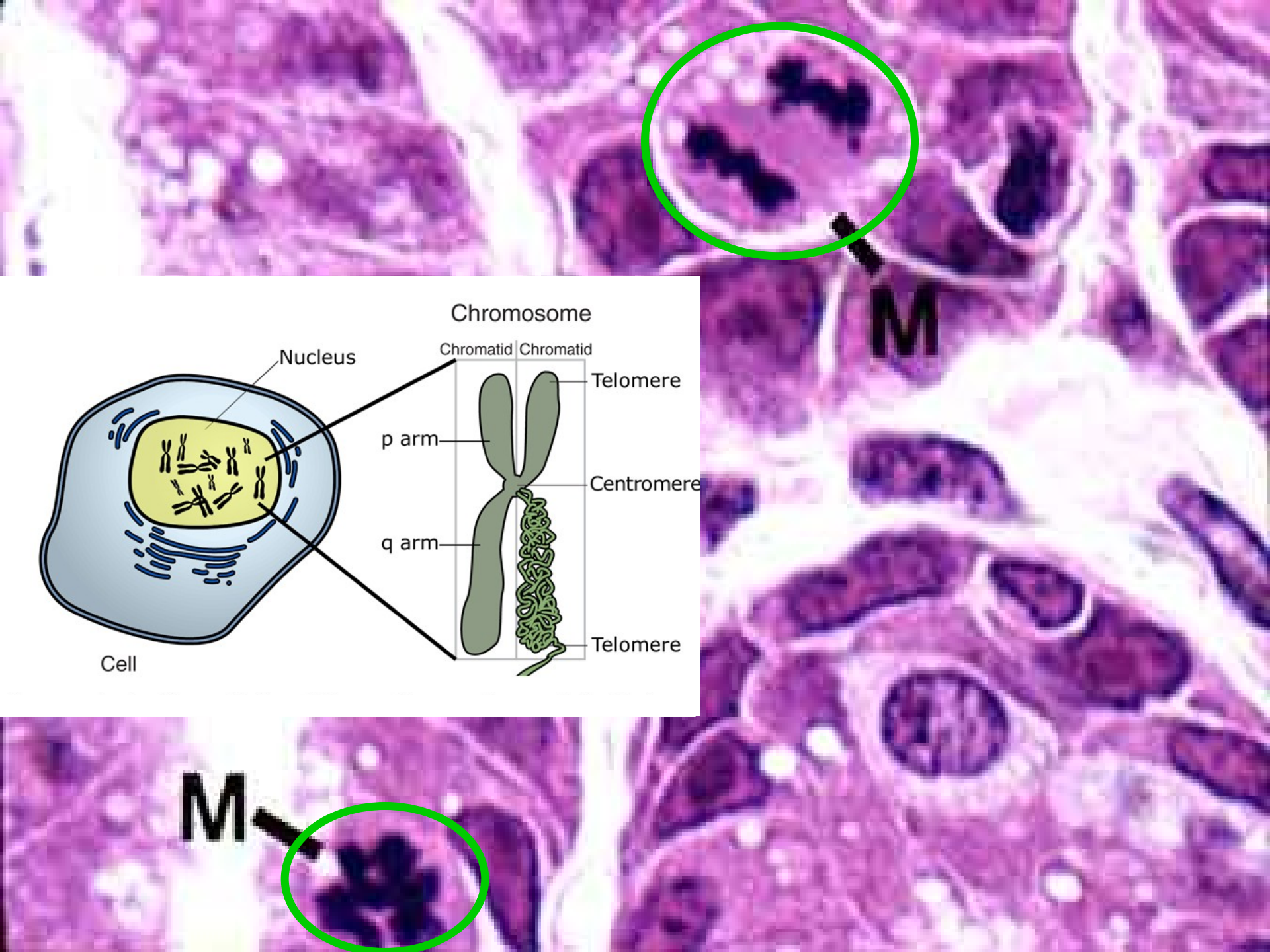


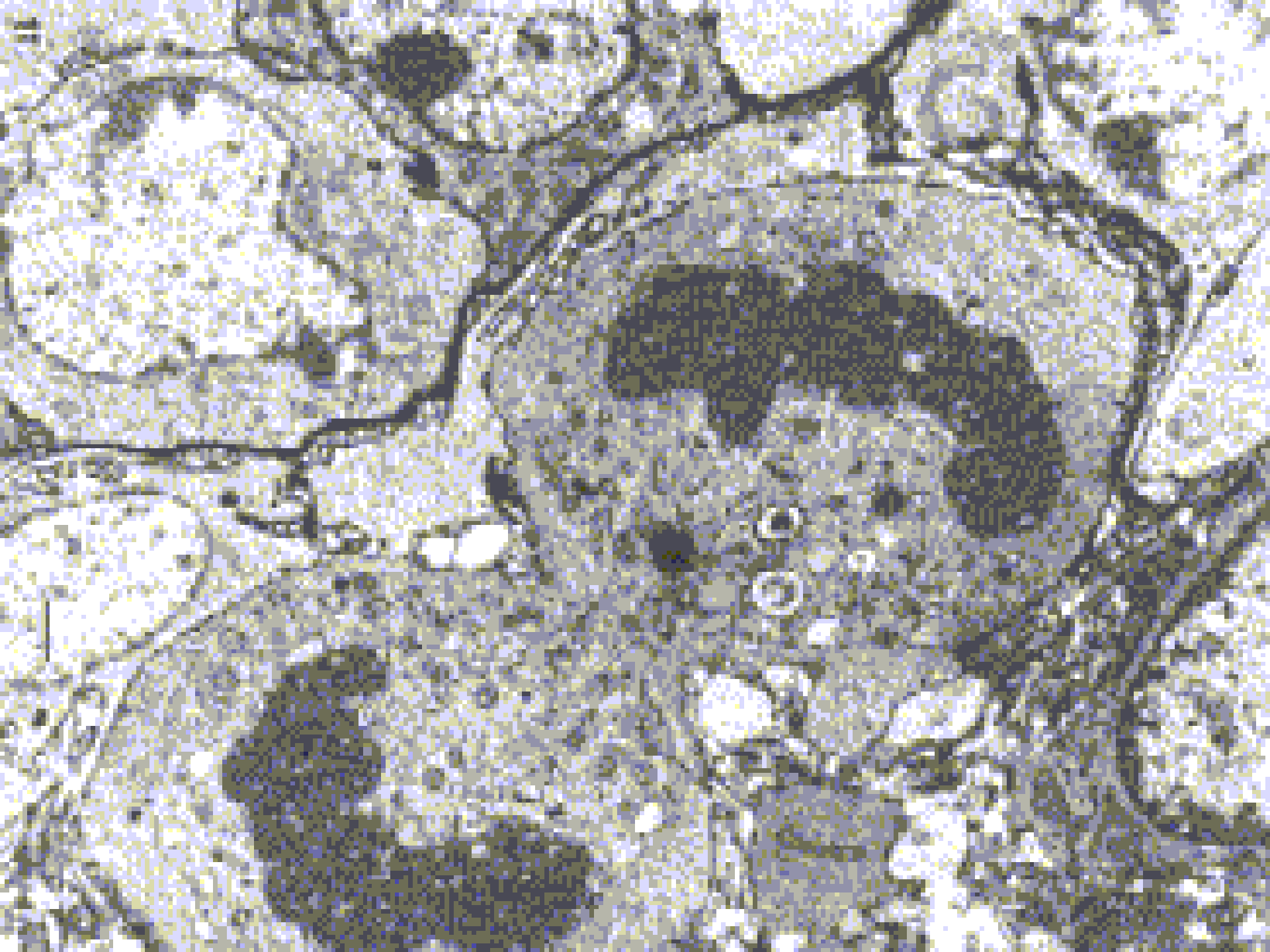
Chromosomes

- visible fibers of DNA during mitosis

- Chromatids (2)
- Centromere
  primary constriction
- Organizer of nucleolus
  secondary constriction
- **Diploid set of chromosomes (2x23)**
  in every somatic cell
- **Gamets – haploid set**
  + X or Y in spermatozoon
  22 + X in ovum




M
Chromosome
Nucleus
Chromatid
Chromatid
Telomere
p arm
Centromere
q arm
Telomere
Cell
M

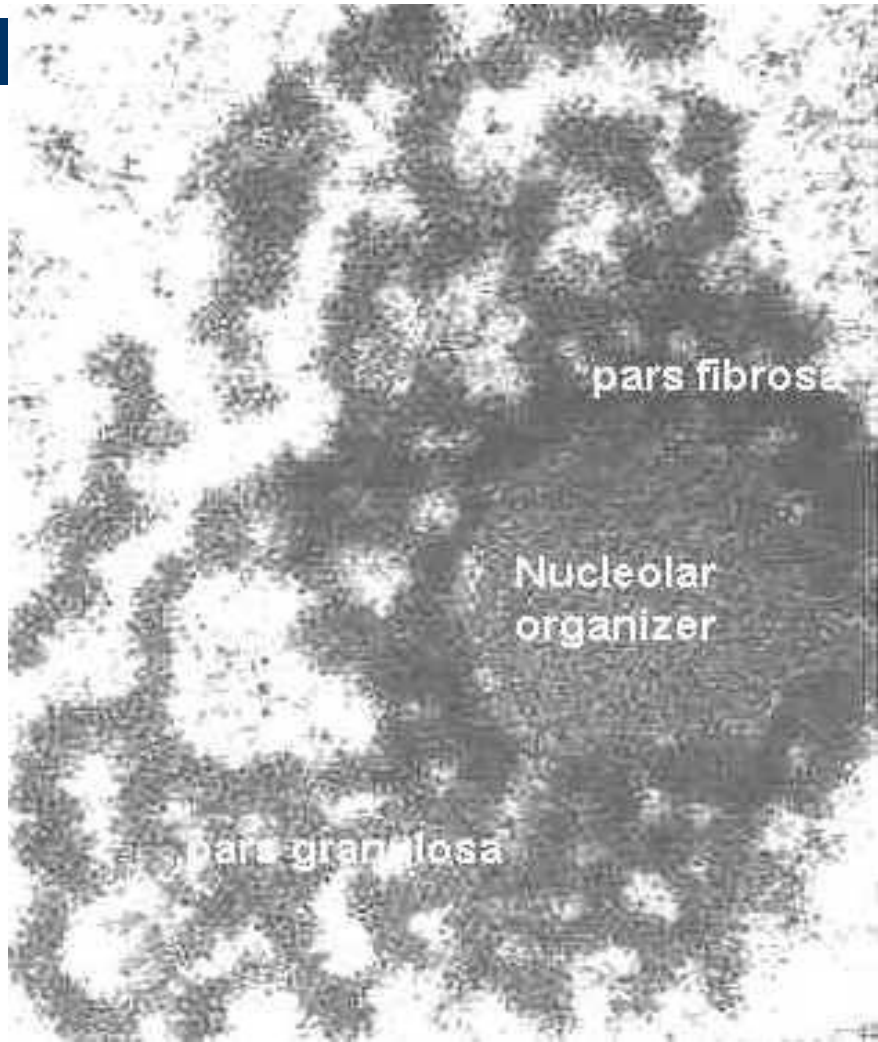


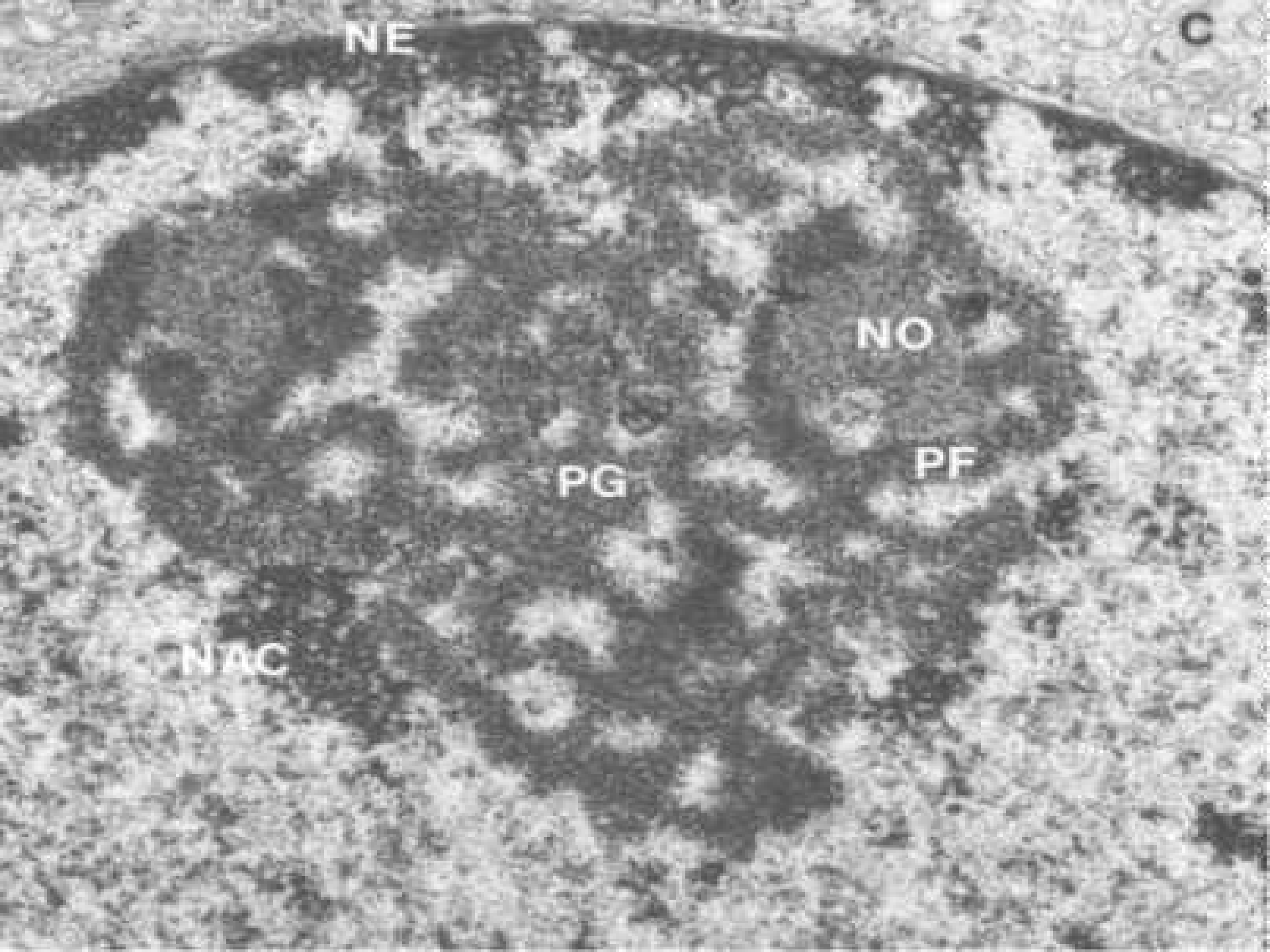
Nucleolus

- Number: not constans (1 or more), disapeare(s) during prophase of mitosis, apear(s) during telophase
- Size: 1 – 2 μm
- Shape: round
- Composition: RNA, proteins, DNA
- **without membrane**

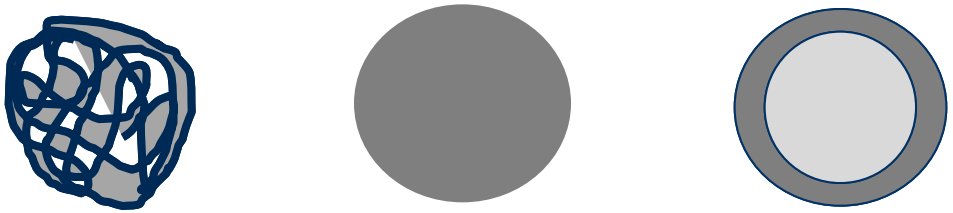
Structure of the nucleolus

- **pars granulosa –** RNA granules (preribosomes) ∅ 15 – 20 nm,
- **pars fibrosa –** RNA fibrils ∅ 3 – 5 nm,
- **Nucleolar organizer (fibrilar center) –** DNA

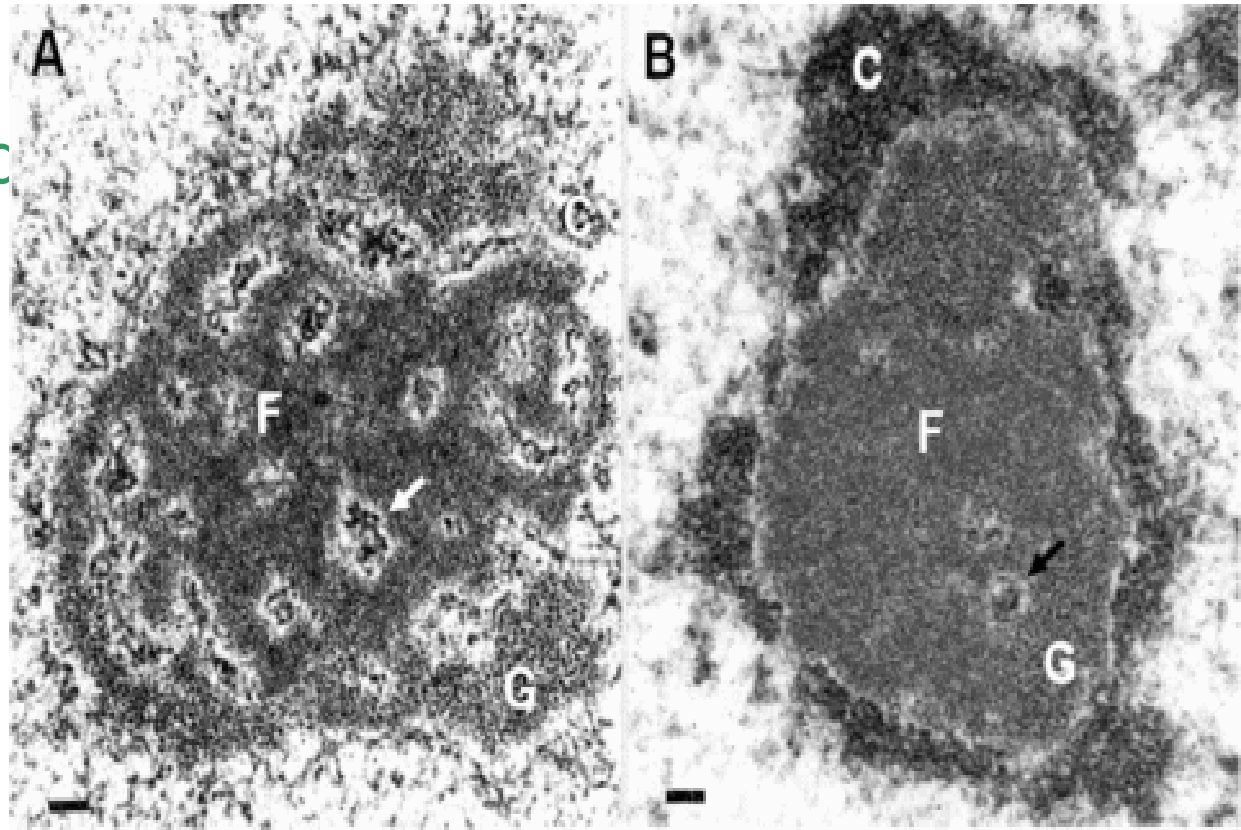



NE
C
NO
PG
PF
NAC

Types of nucleoli

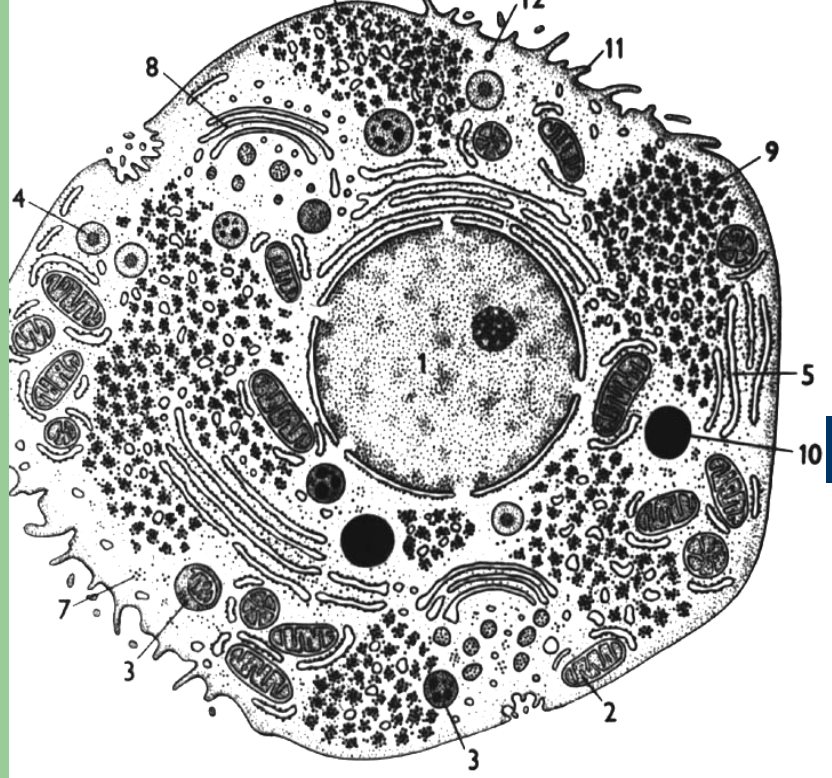


A. reticular
B. compact
C. ring-shaped



Function of nucleus and nucleolus

- Regulation of cell activity by RNA production (⇨ proteosynthesis)
- Communication with cell through nuclear pores
- Place of genetic information (DNA), control of cell division and transfer of genetic information to daughter cells
- Nucleolus – production of ribosomes (cells with intense proteosynthesis)



Cell organelles

Memebranous

- Mitochondria
- Endoplasmic reticulum
- Golgi apparatus
- Lysosomes
- Peroxysomes

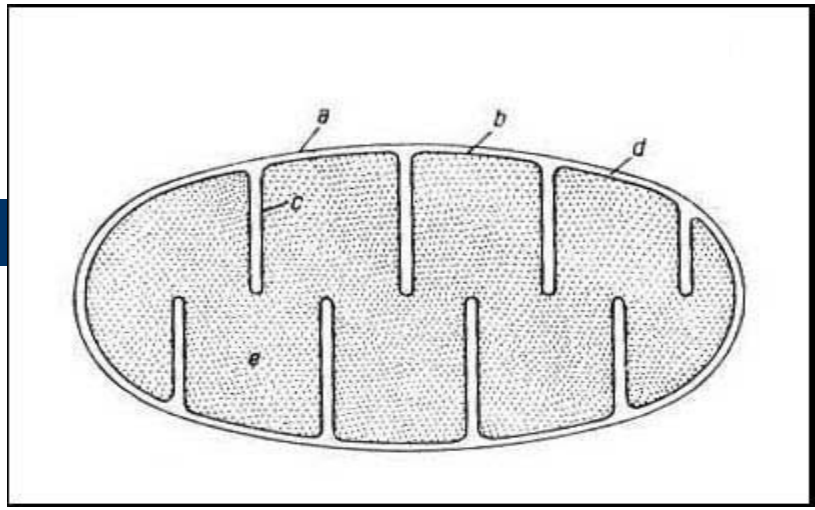
Without membrane

- Ribosomes
- Centrioles

Mitochondrion

- Shape: round, oval (elongated - fibrilar)
- Size: ∅ 0,5 μm, length of fibrilar Mi – up to 10 μm
- Number: different, according to metabolic activity of the cell and its energetic requirements (*e.g. liver cell contains about 1000 – 2000 Mi)*

Structure of mitochondrion

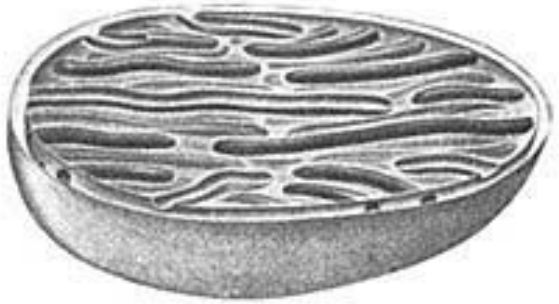


- Outer membrane (smooth)
- Inner membrane (with cristae)
- Cristae mitochondriales (+ elementary particles)
- Matrix (proteins, DNA, RNA) – semiautonomic
- Mitochondrial bodies (ions)
- Mitochondrial ribosomes

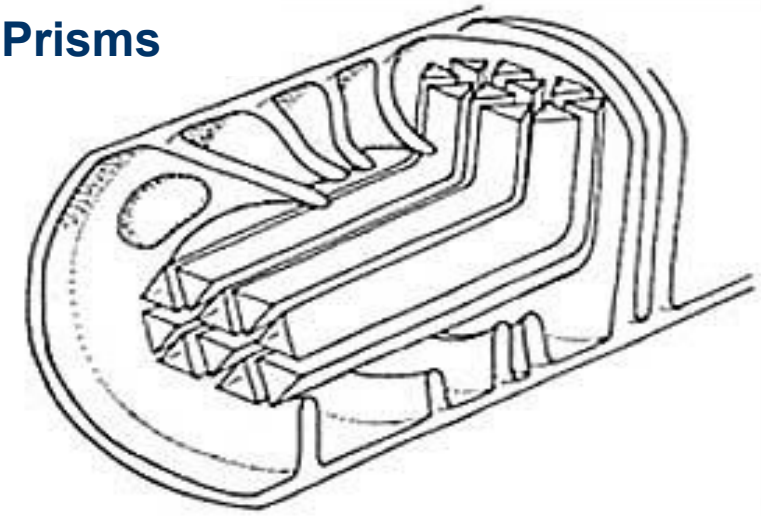
Mitochondrial cristae

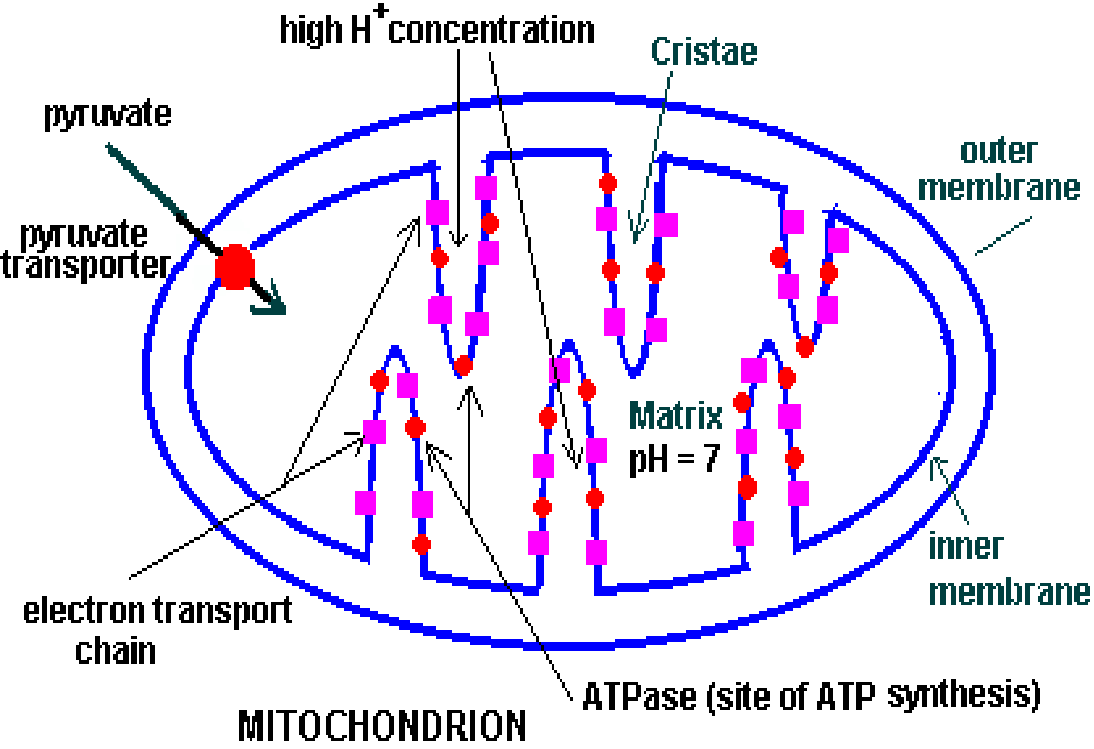
Cristae

Tubules



Prisms



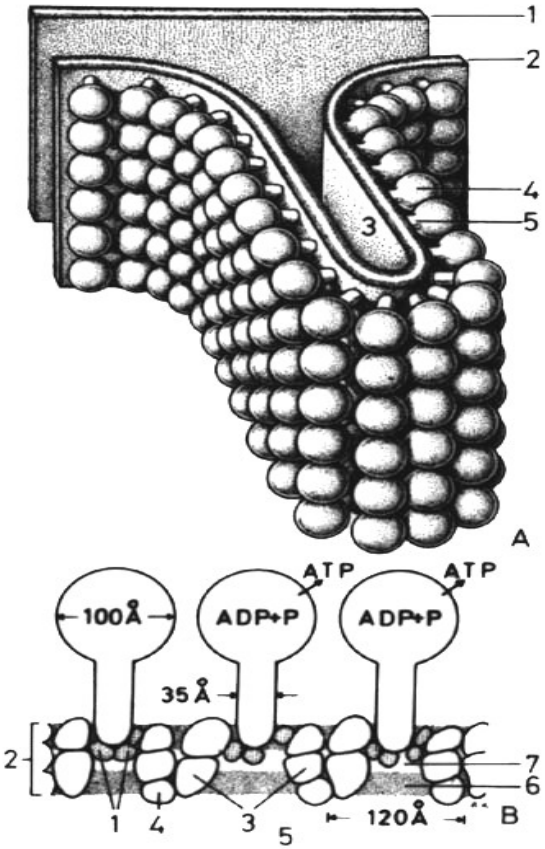


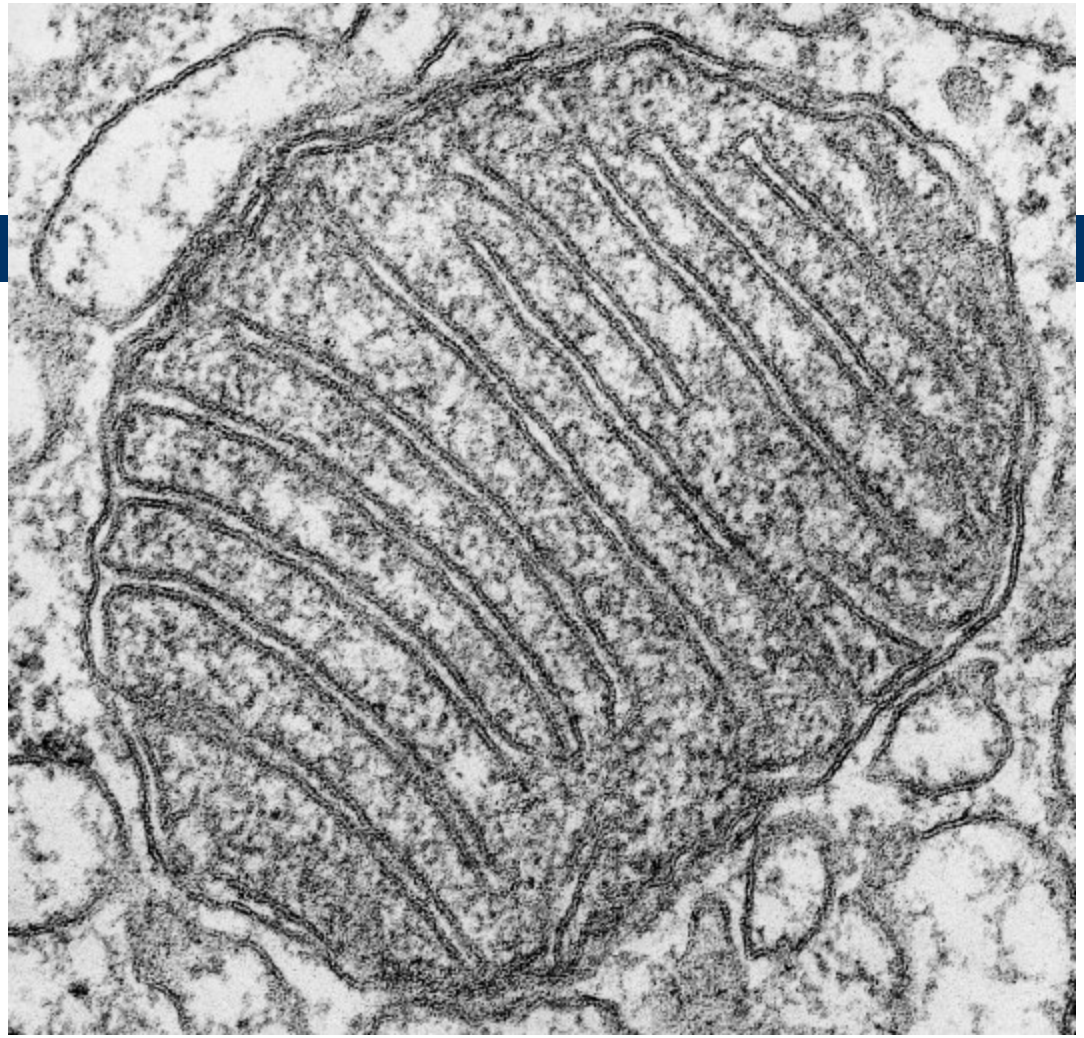
Function Mi

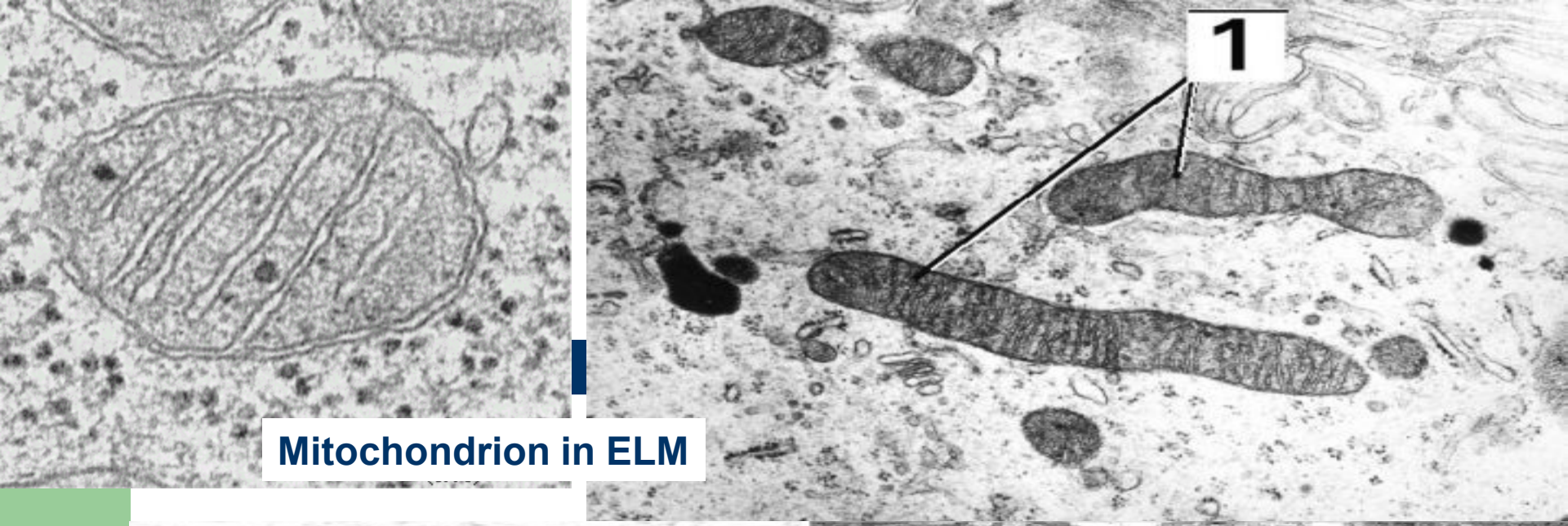
In matrix and particles:

- enzymes of Krebs' cycle, oxidative phosphorylation

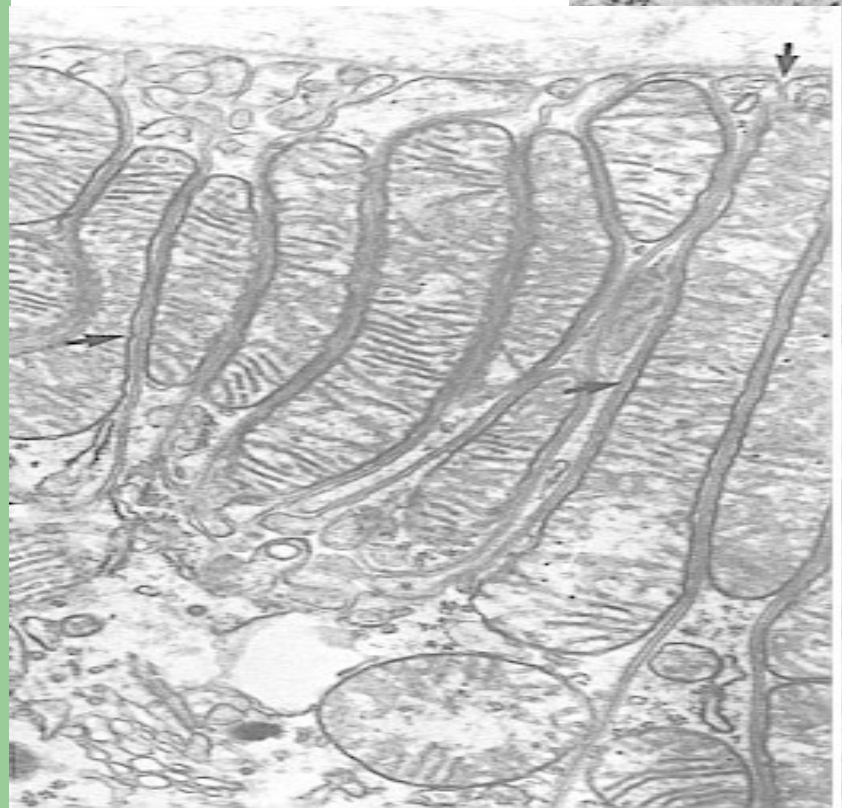
Main function of Mi: energy releasing during ATP splitting

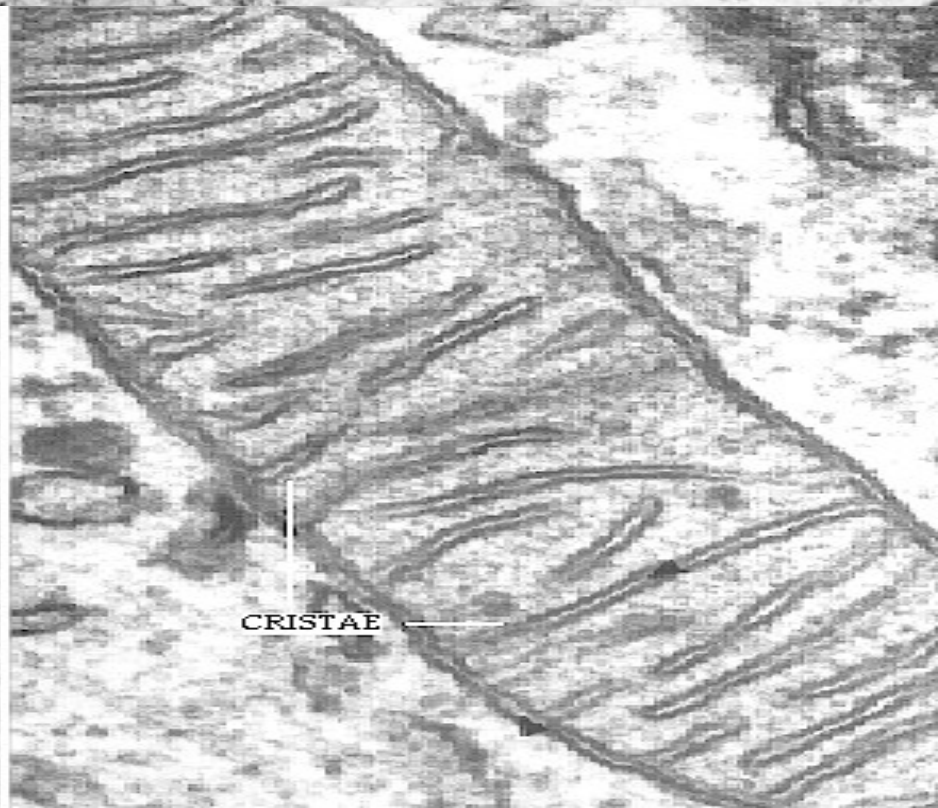






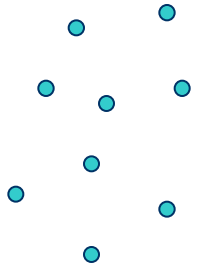
Mitochondrion in ELM

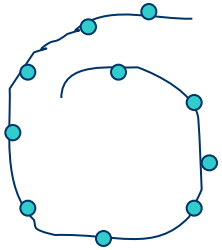


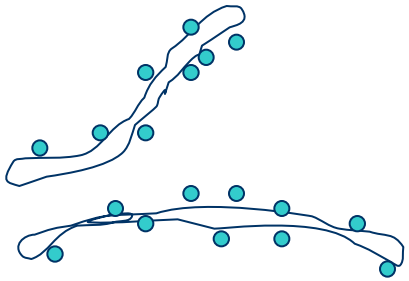


Ribosomes

- Bodies composed of 2 subunits
- Size of ribosome: 20 nm Ø





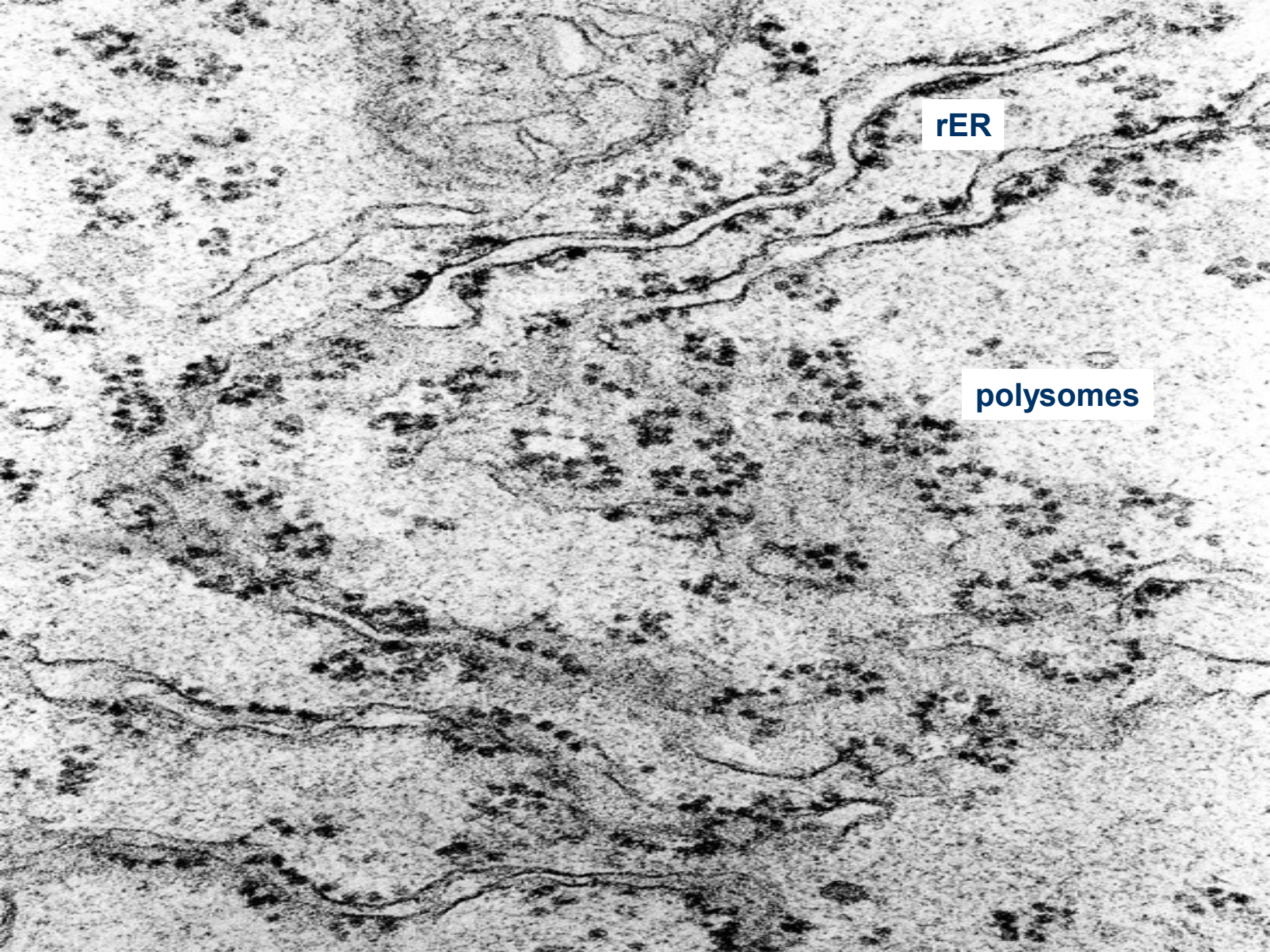


free ribosomes

poly(ribo)somes

ribosomes attached to endoplasmic reticulum

Proteosynthesis „for cell“ and „for export“ (*e.g. glandular cells)*

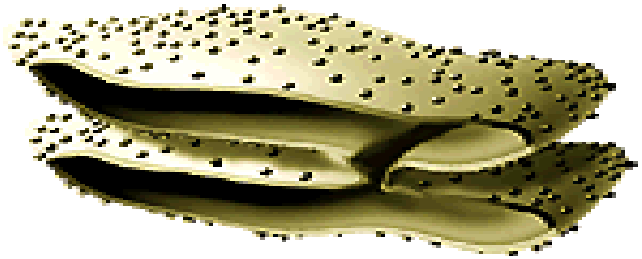

rER
polysomes

Endoplasmic reticulum

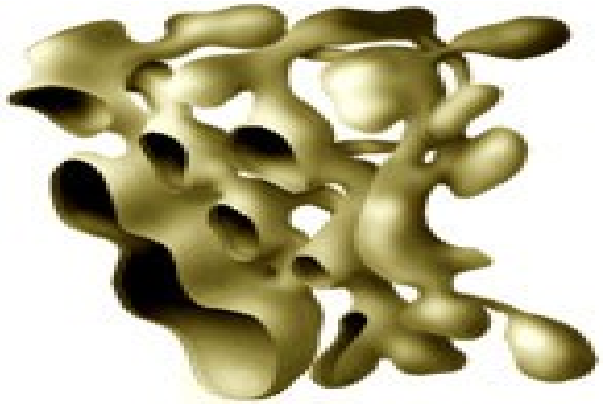
3D system of membranes

in cell cytoplasm – 2 forms:

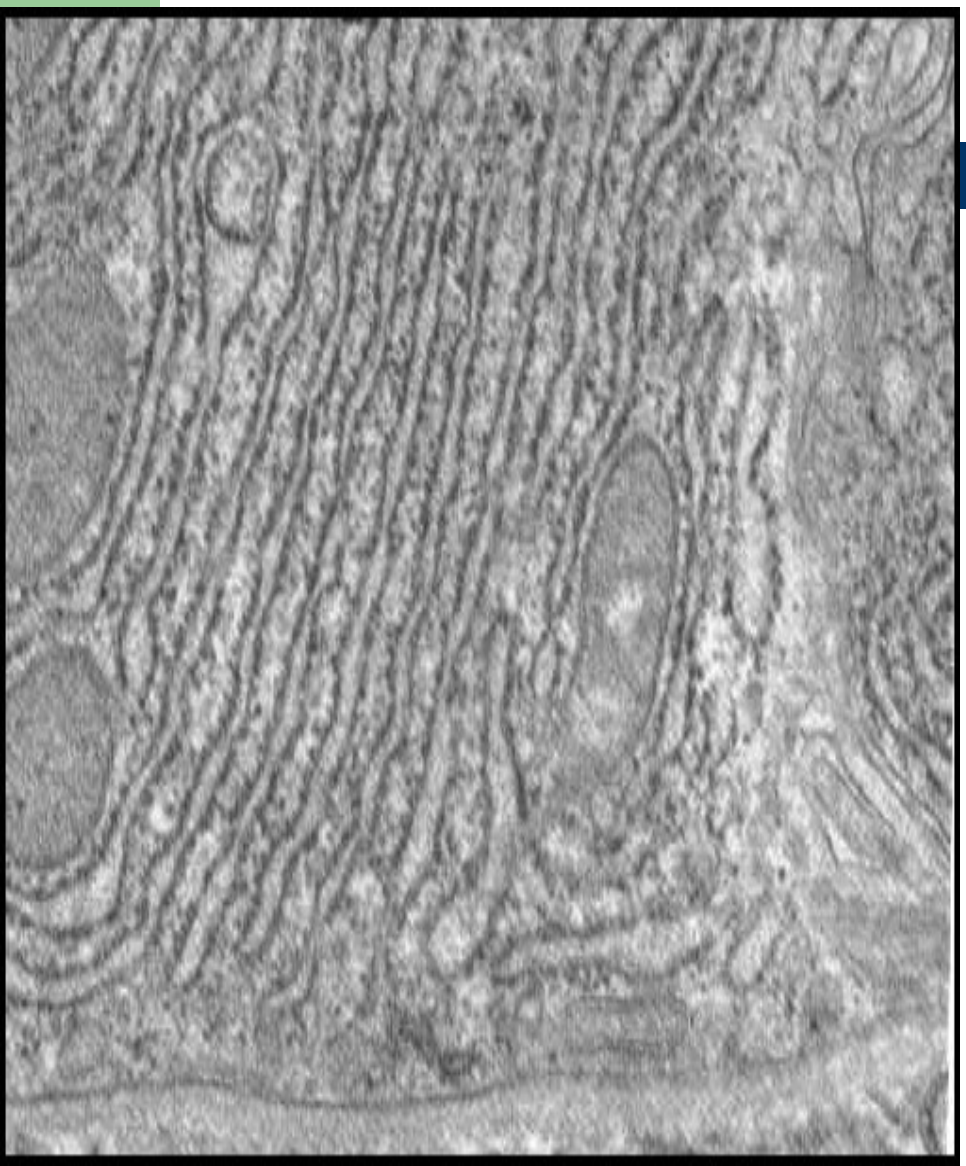
- Granular (rough) ER – GER, RER:
  system of flattened, anastomosing cisterenae with (poly)ribosomes reversibly bound to membrane

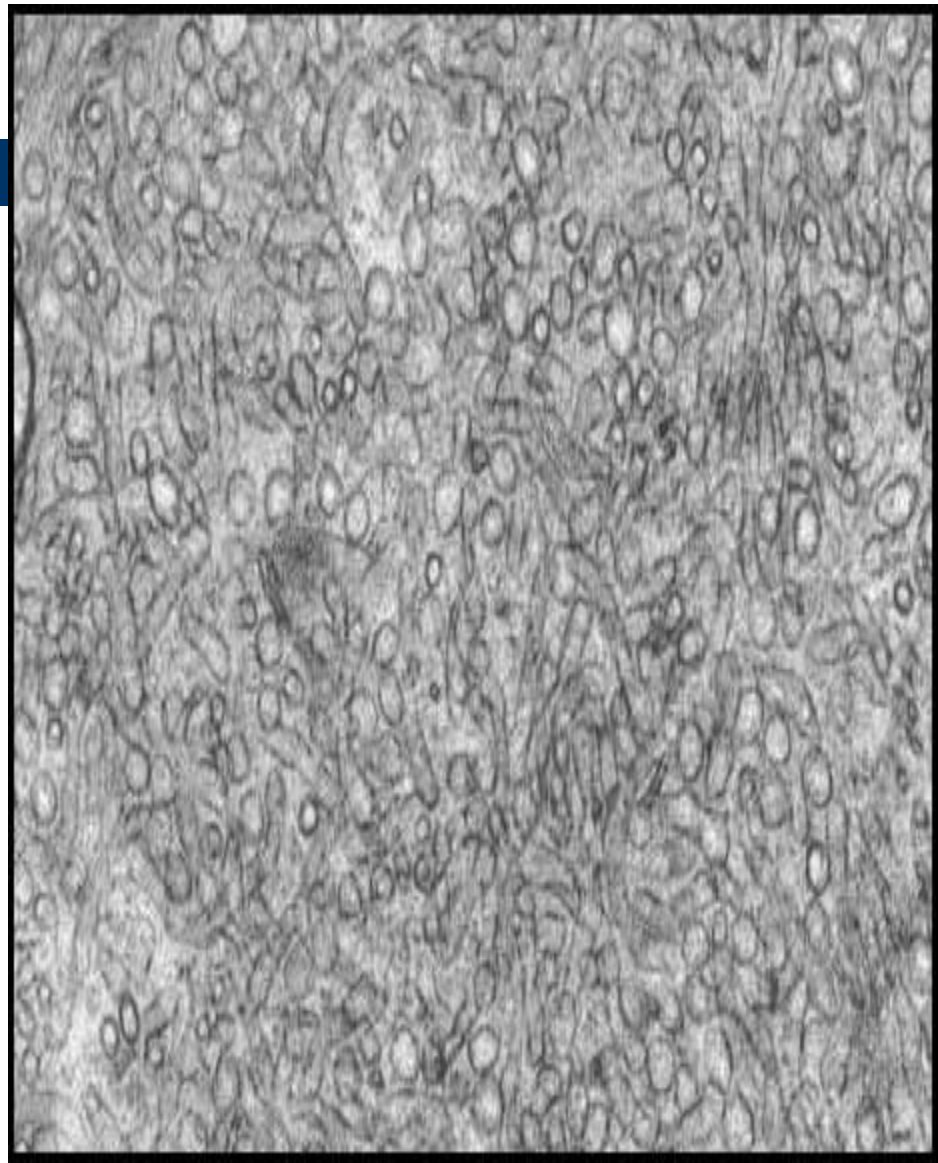


- Agranular (smooth) ER – AER, SER:
  system of tubules and vesicles with smooth membrane without ribosomes



GER AER



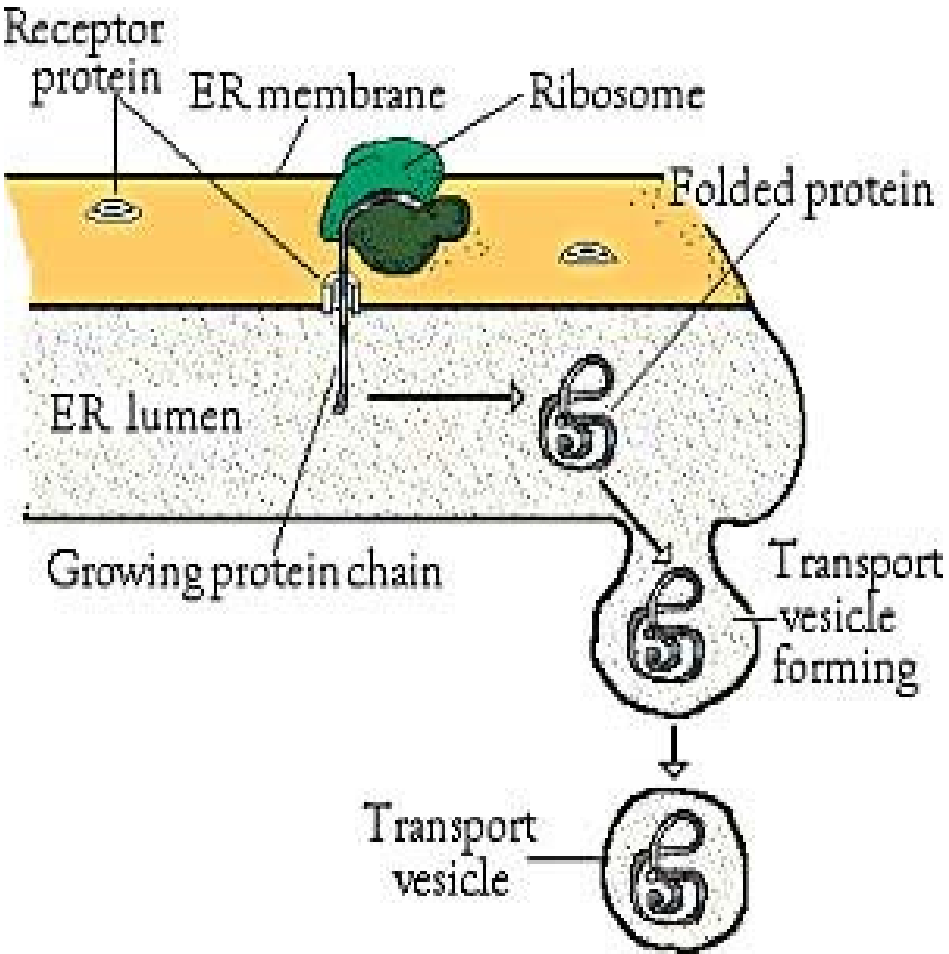


Function of GER

- GER – proteosynthesis (Ri) and transport of proteins into GA (by transporting vesicles)
- Cooperation with GA:

– intracelular storing (e.g. in lysosomes and speciphic granules of leukocytes)

– temporary intracelular storing before following transport from the cell (secretory granules)



Function of AER

- AER – occures in the cells which:

– synthesize **steroids** (cells of adrenal cortex, Leydig cells of testis, cells of corpus luteum in the ovary)

– break down **glycogen** (liver cell)

– synthesize **HCl** (parietal cells in gastric glands)

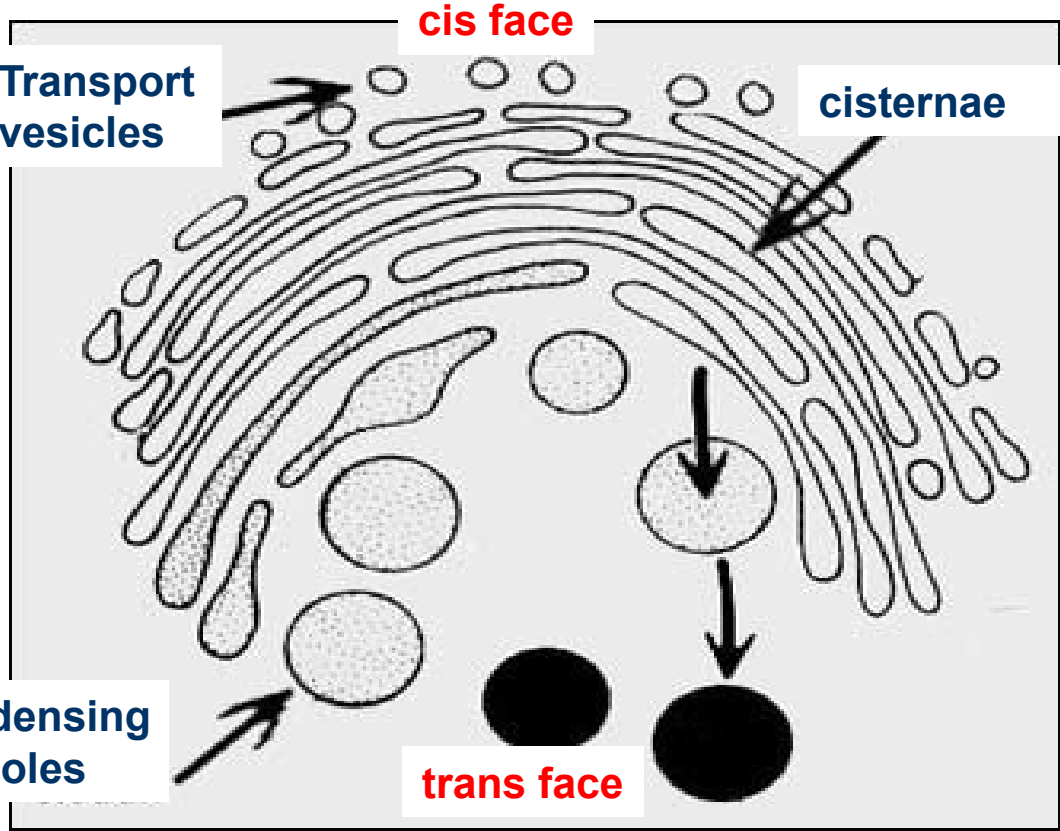
– store **Ca ions** (muscle cells; *sarcoplasmic reticulum*)

Golgi apparatus

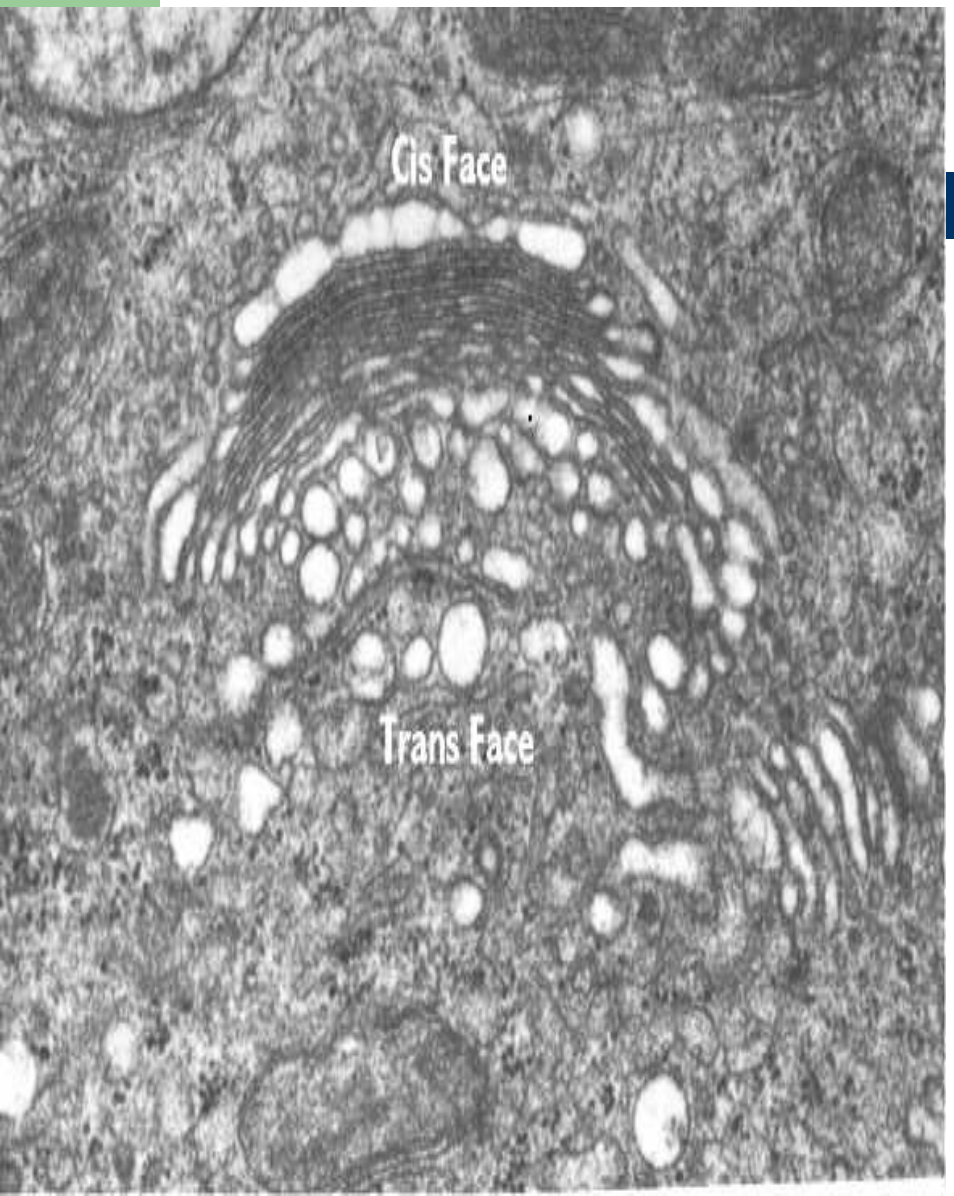
- System of smooth membranes forming

1. cisternae (5-20)
2. vesicles
3. vacuoles

Polarity of GA:
cis, trans



Functional polarity of GA



Transport of proteins from GER:

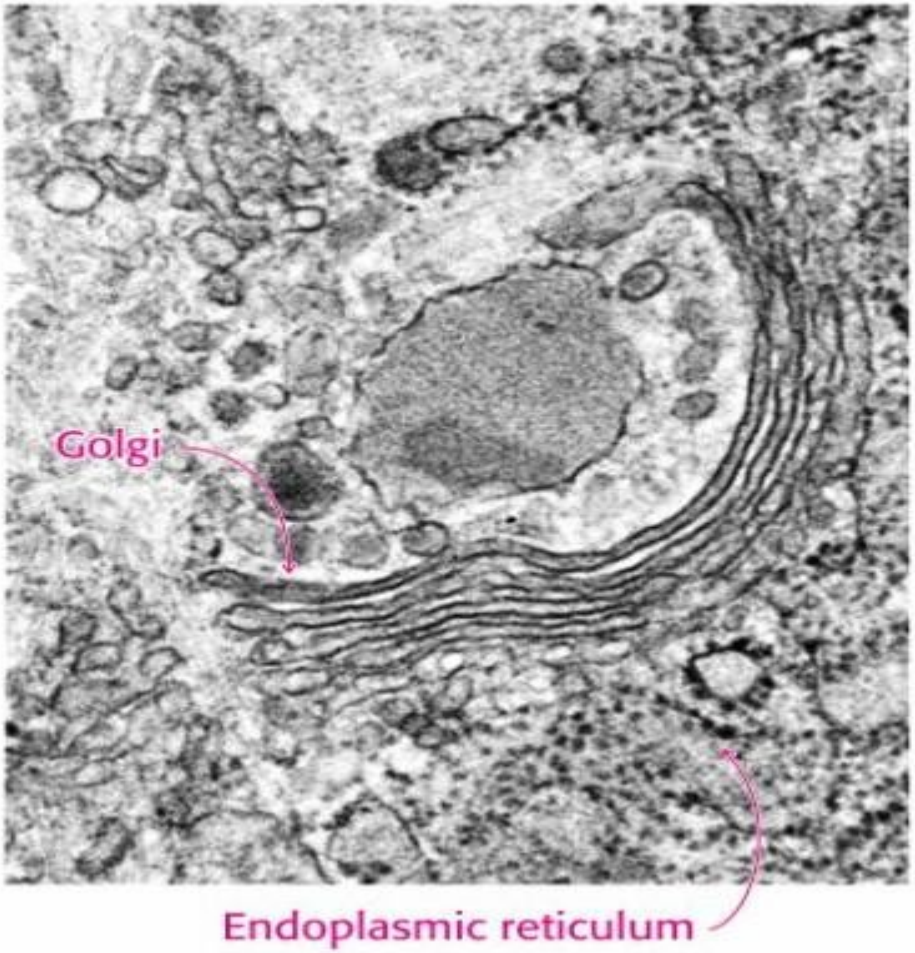
transport vesicles

Convex side – **cis** face
(forming face)

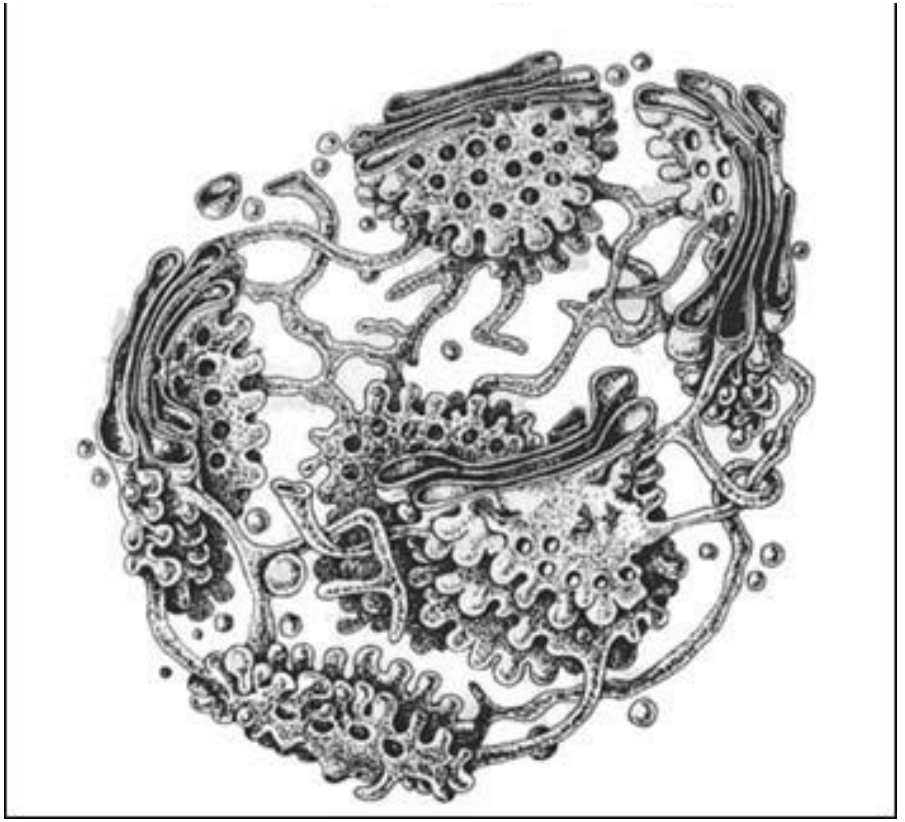
Concave – **trans** face
(maturing face)

condensing vacuoles

secretory granules lysosoes



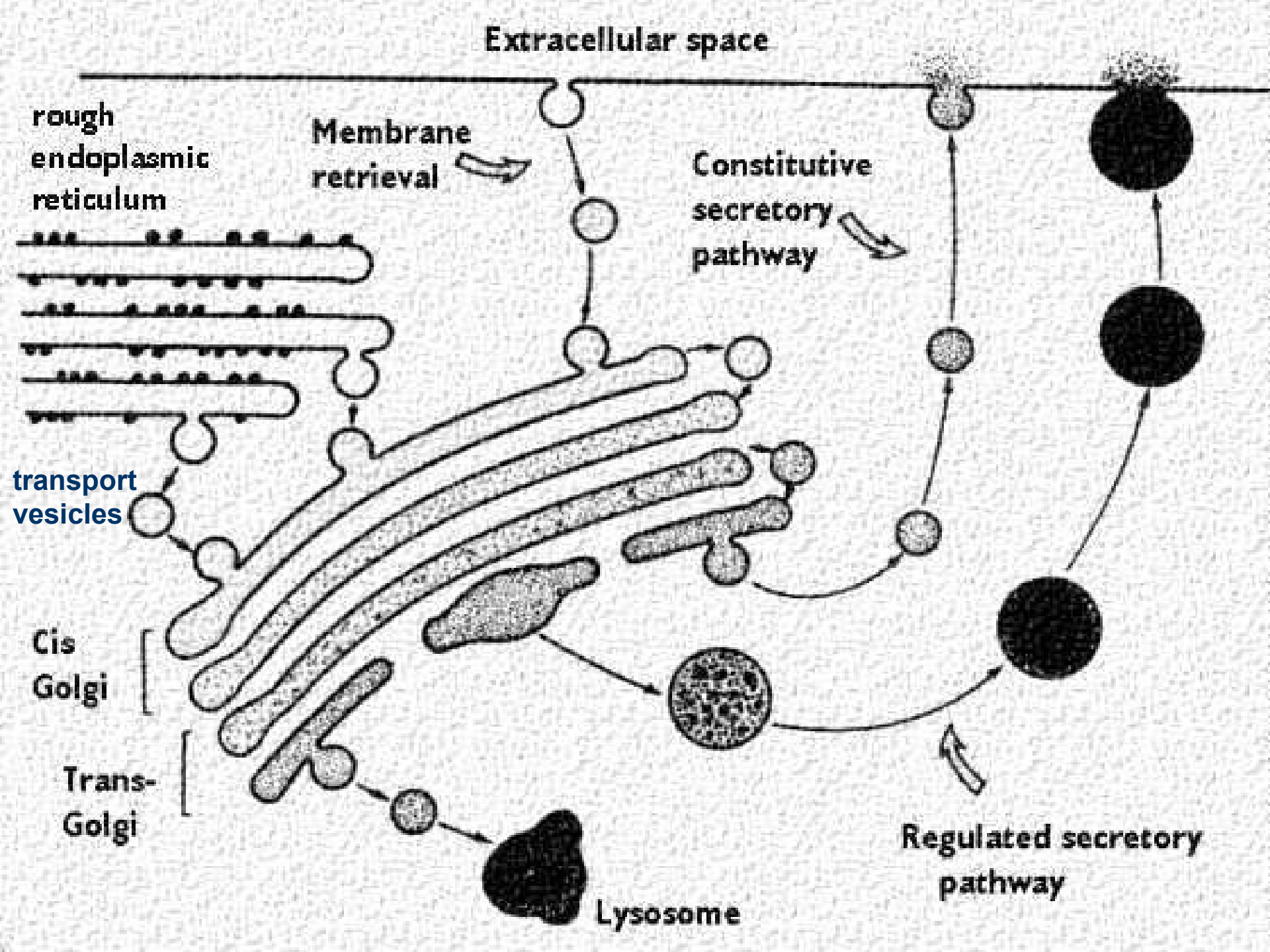
Schema of Golgi apparatus structure



„Golgi fields“

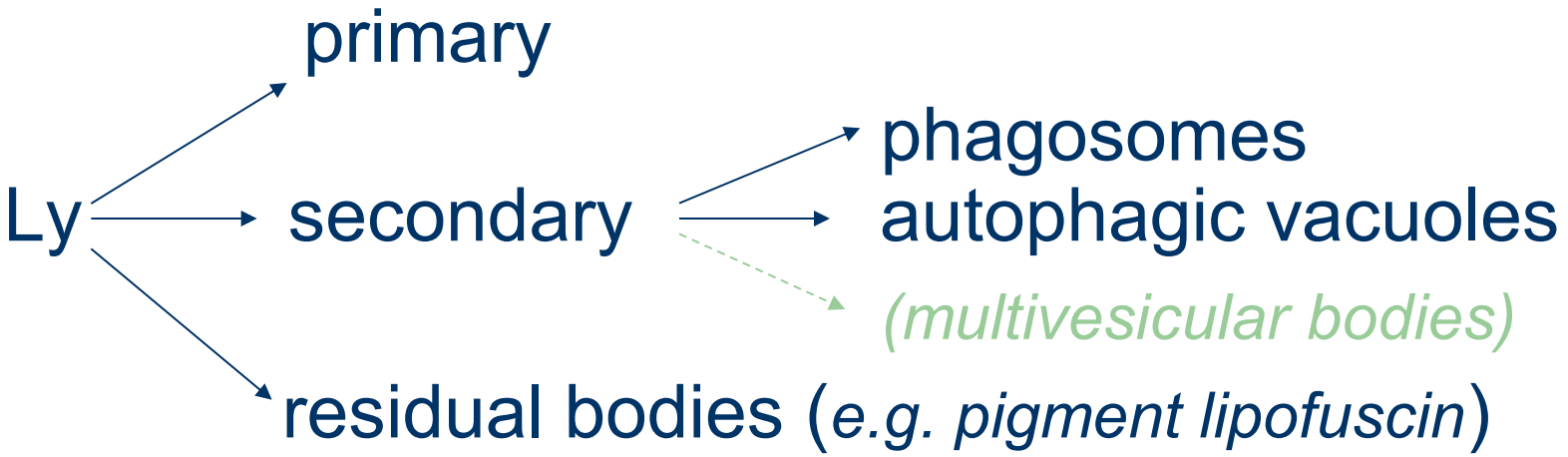
Function of GA

- Postsynthetic modification of proteins (glycosylation, sulfatation, phosphorylation)
- Condensation and storing of secretory products ⇨ condensing vacuoles, secretory granules, lysosomes, peroxysomes
- Formation of acrosomal vesicle during transformation of spermatid into spermatozoa
- Donor of membranes (for some organelles)


Extracellular space
rough endoplasmic reticulum
Membrane retrieval
Constitutive secretory pathway
transport vesicles
Cis Golgi
Trans-Golgi
Lysosome
Regulated secretory pathway

Lysosomes

- Vesicles – from 0,5 μm Ø, single membrane, matrix with hydrolytic enzymes of acid pH *(acid phosphatase, carboxylesterhydrolases, catepsins, hyaluronidase, non-specific esterase, lipase, ribonukleases, …)*

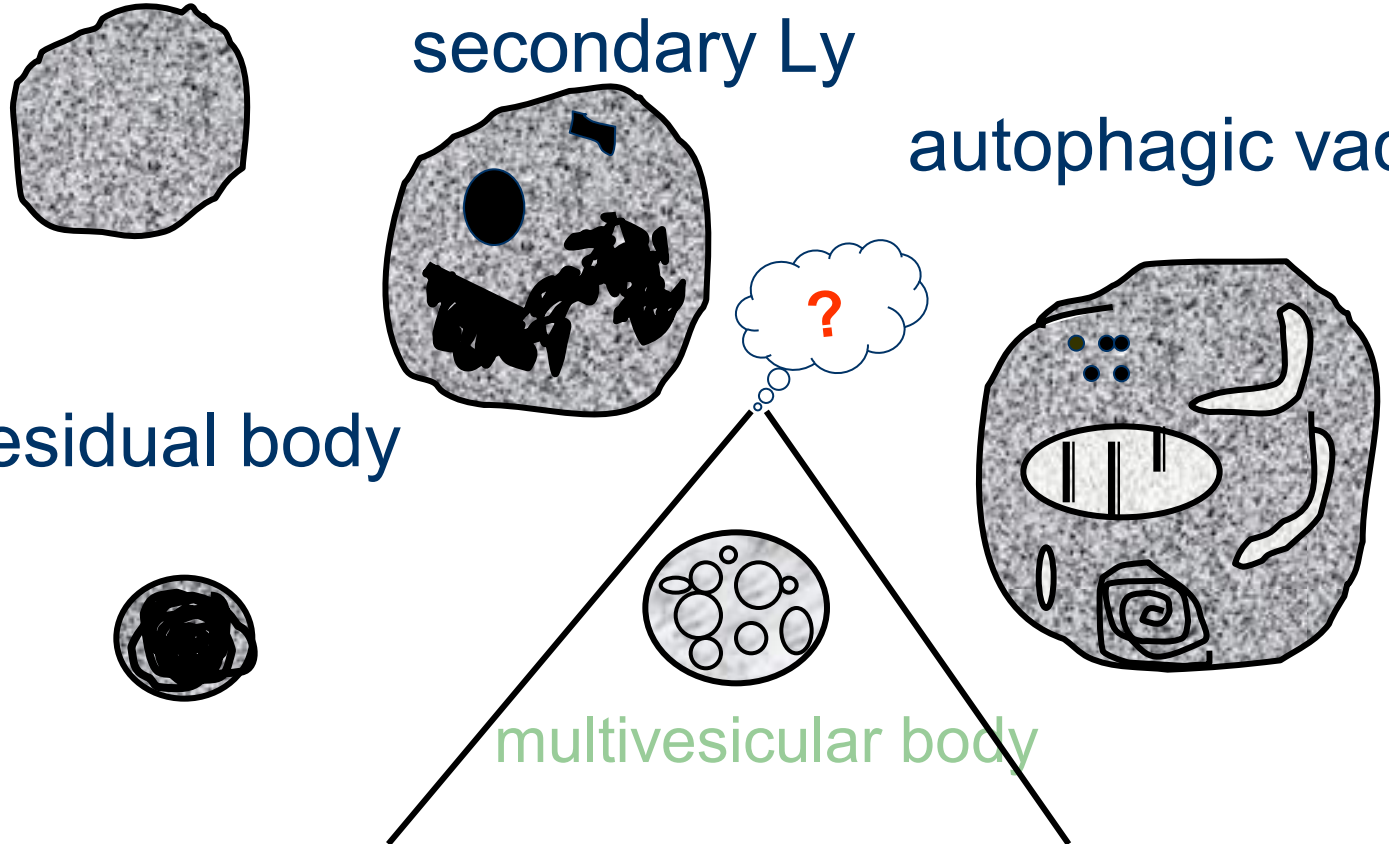


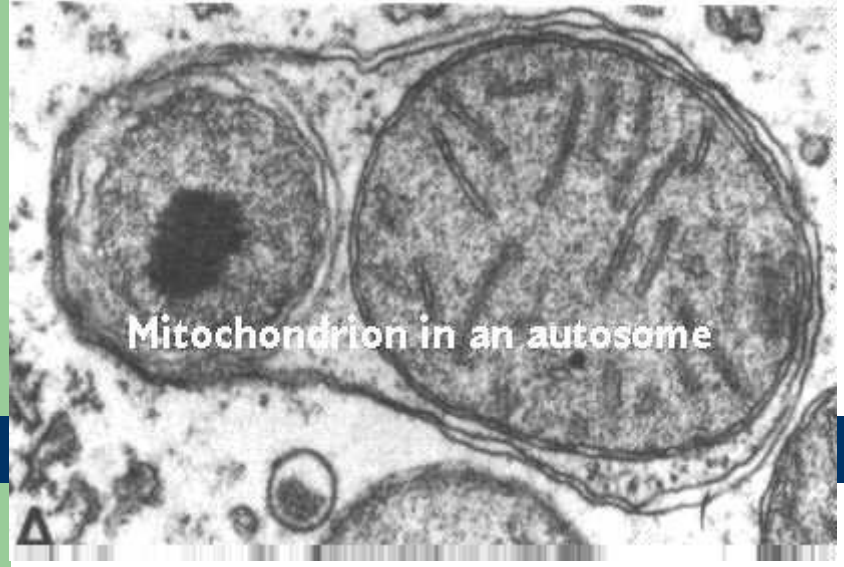
Lysosomes

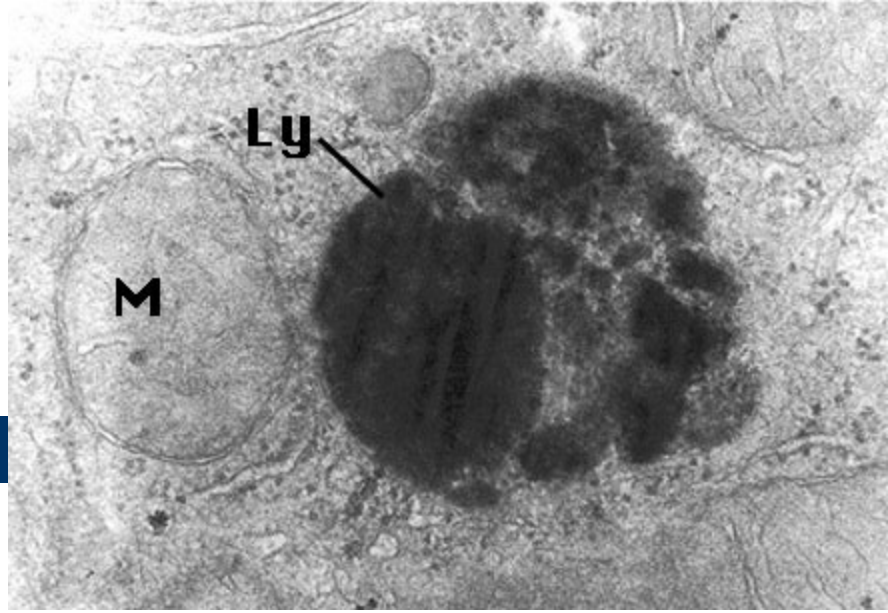
primary Ly *(0.5 μm)*

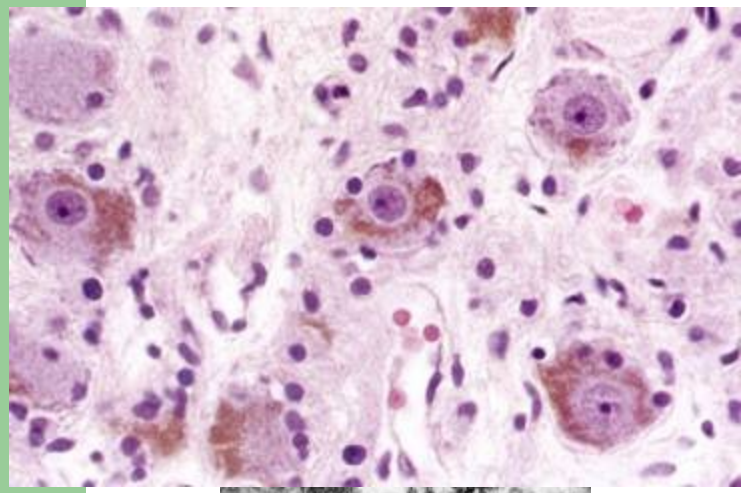
secondary Ly

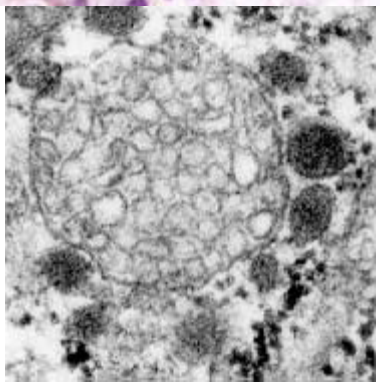
autophagic vacuole

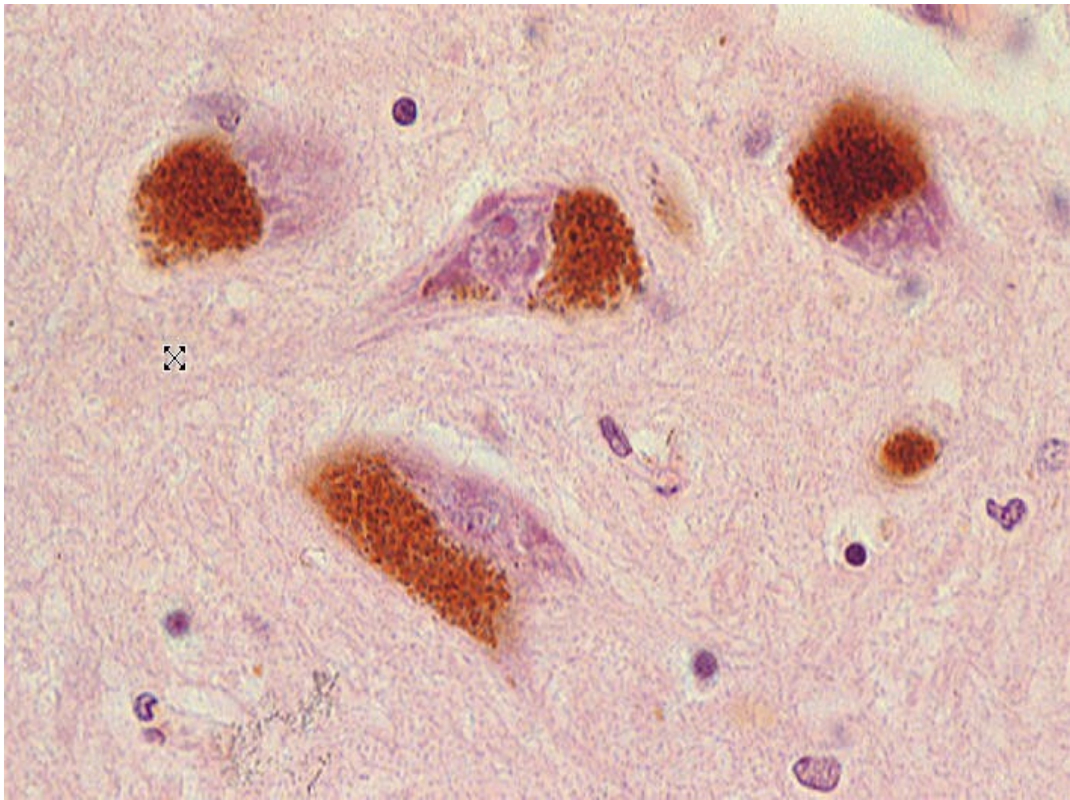



Mitochondrion in an autosome

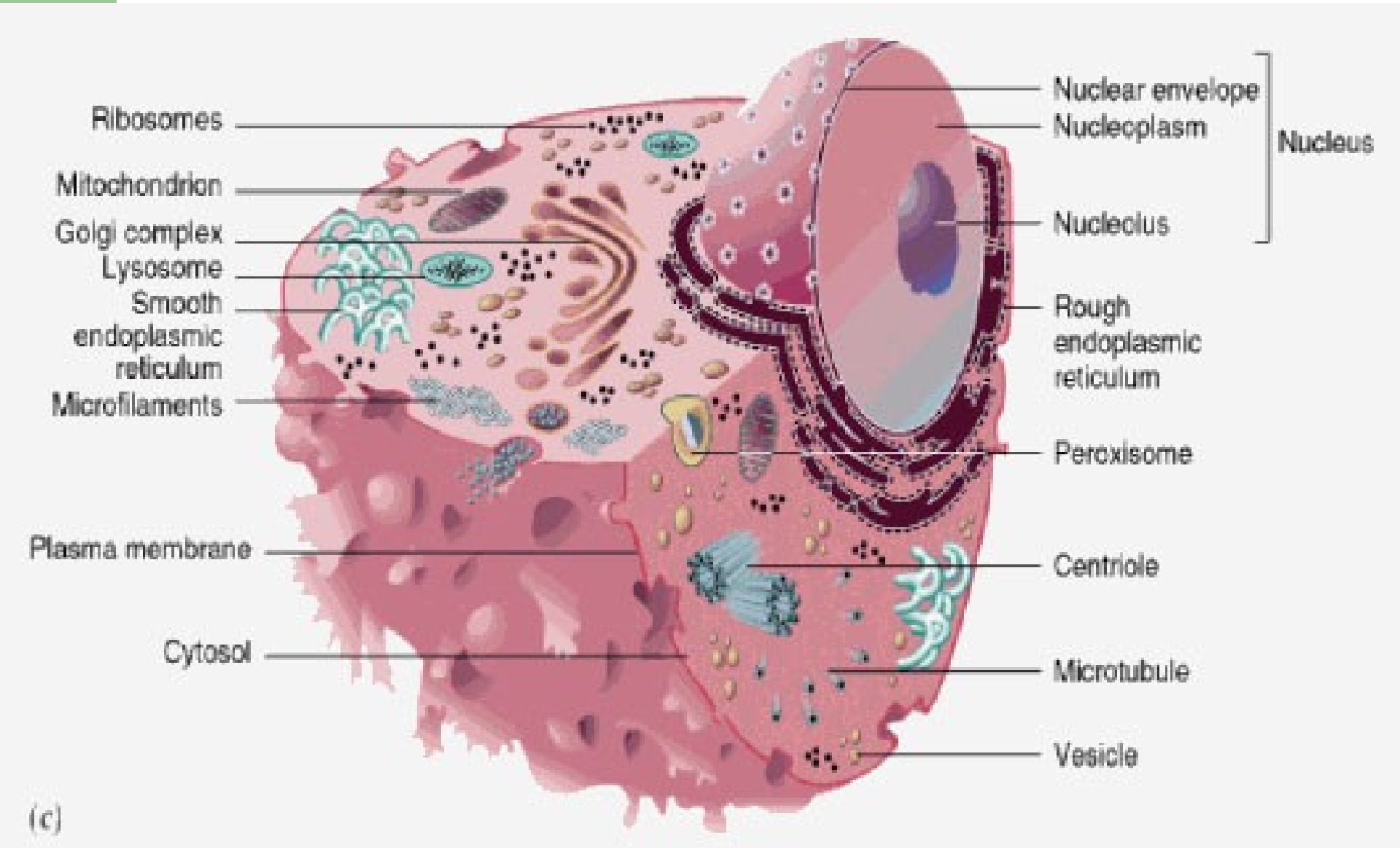

Ly
M



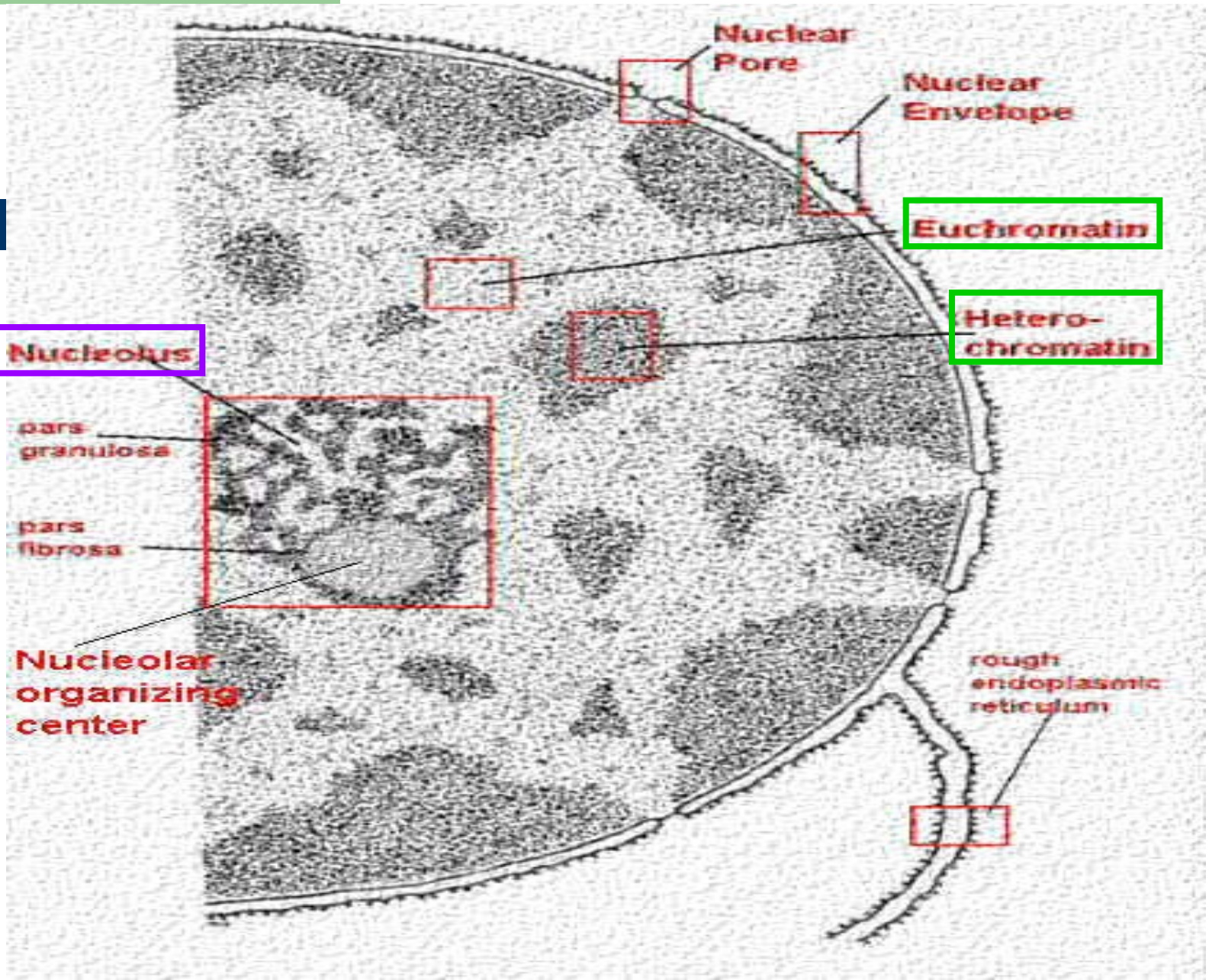


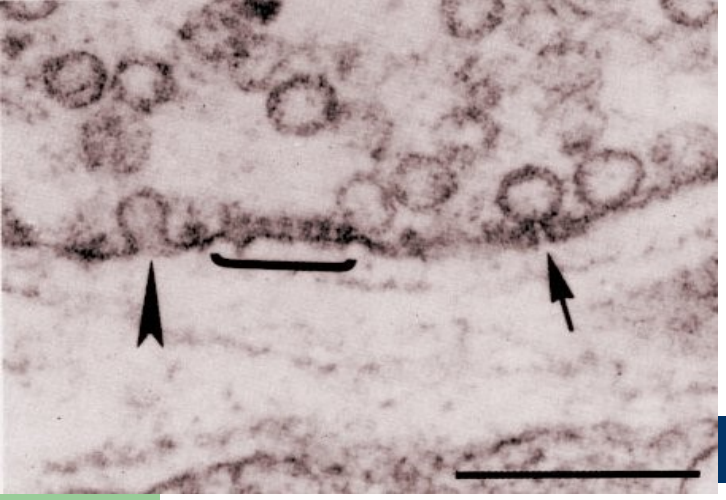


Structure of the cell



Nucleus and nucleolus





Lysosomes, endosomes

- Endosomes: membranous vesicles (Ø 20-150 nm) enter the cell by pinocytosis,

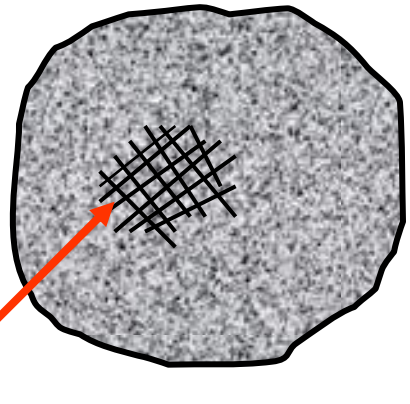
in the cell → transcytosis

in the cell → fusion with Ly ⇨ secondary Ly

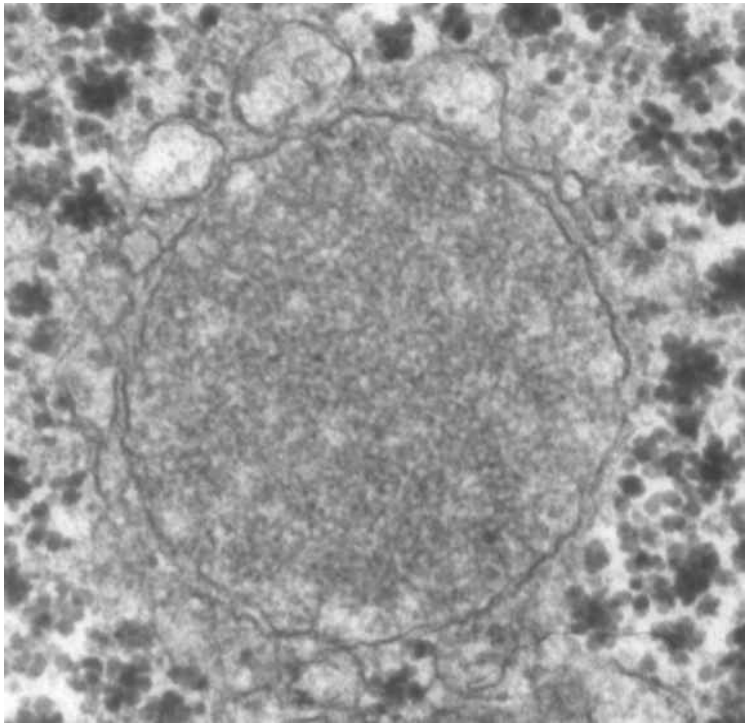
Cell 2

Peroxisomes (microbodies)

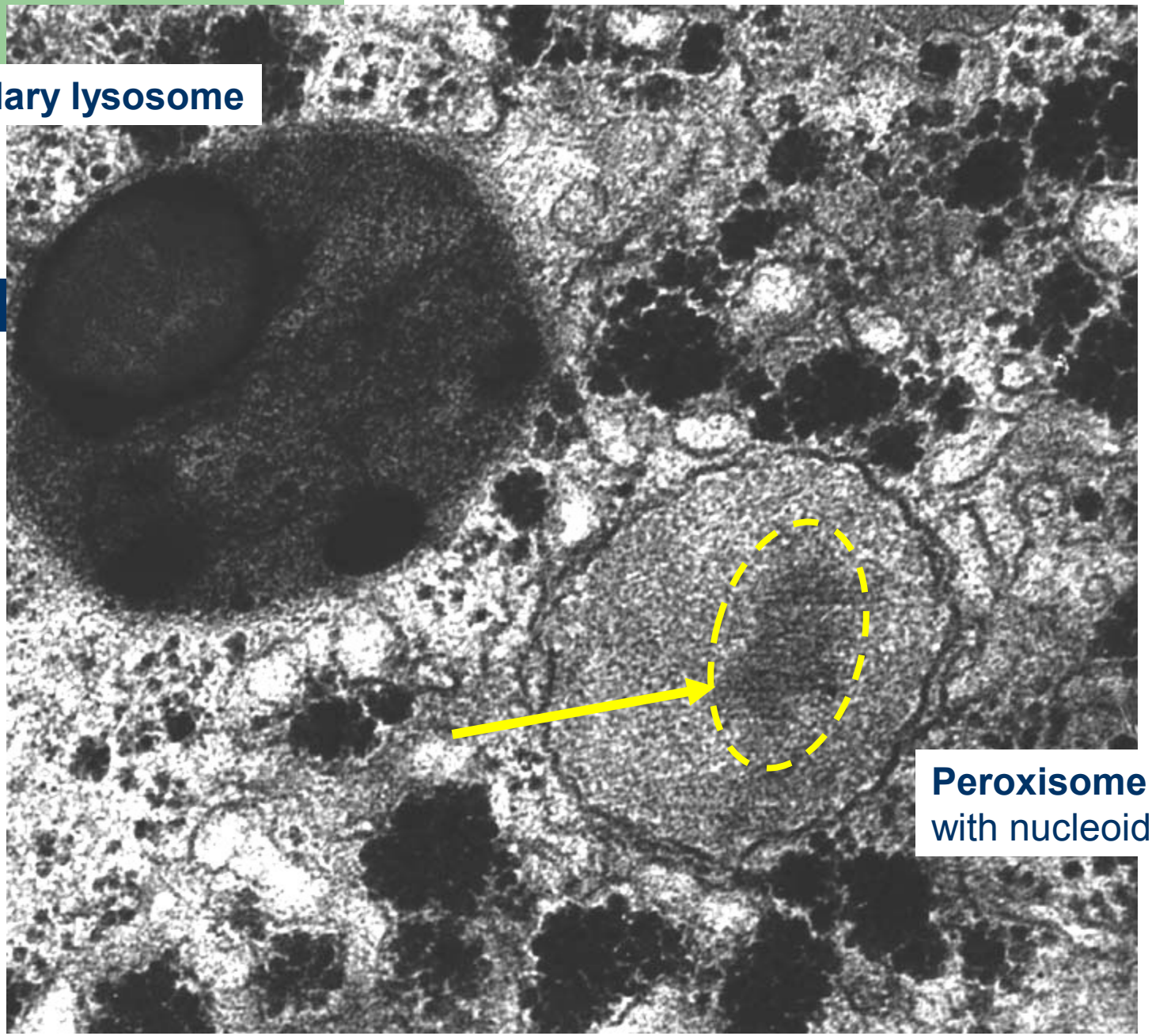
- Vesicles – 0,1 - 0,5 μm Ø, single membrane, matrix with oxidative enzymes (peroxidase, katalase, urikase aj.)



- [nucleoid = crystaloid]

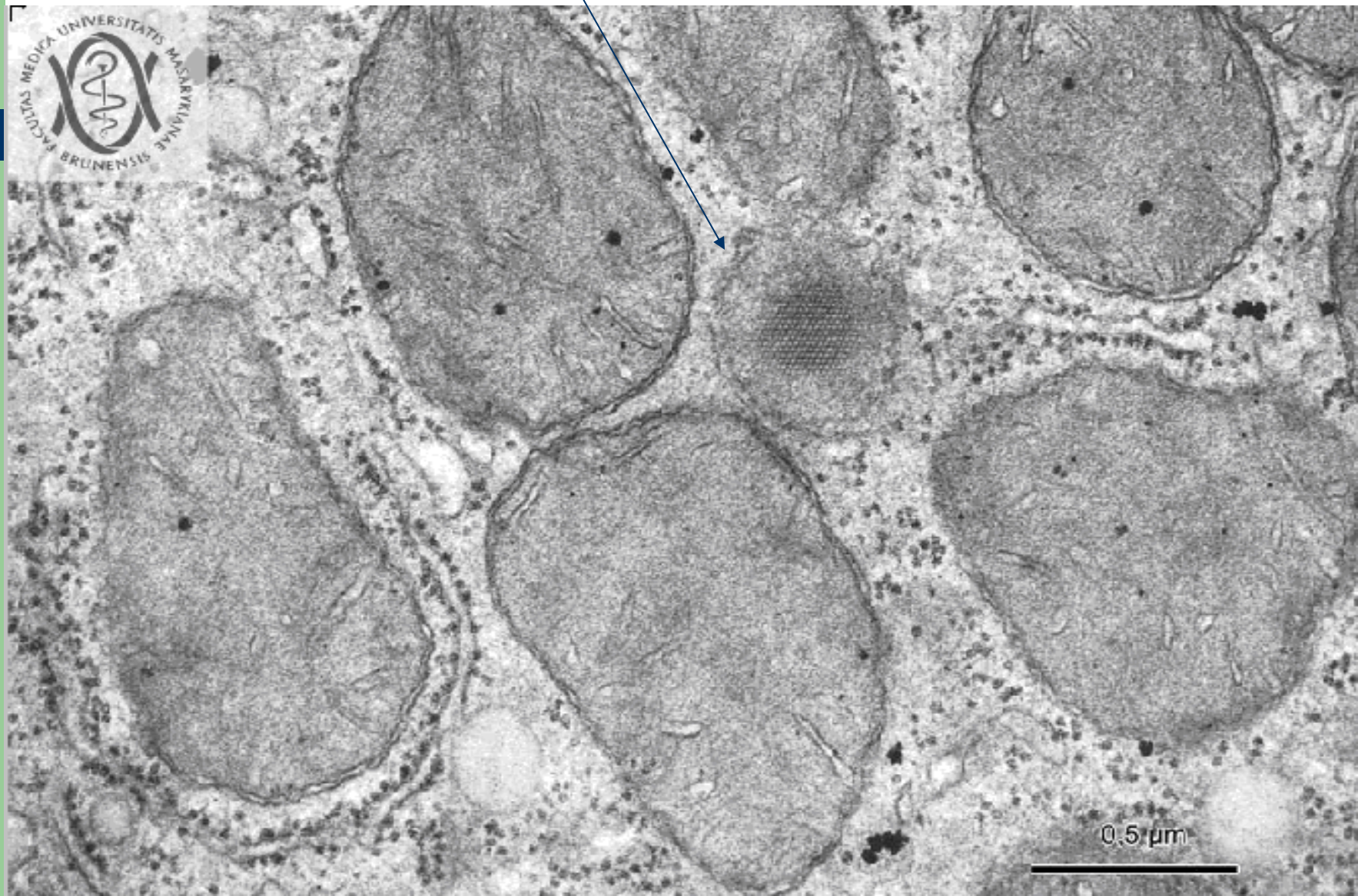


Secondary lysosome

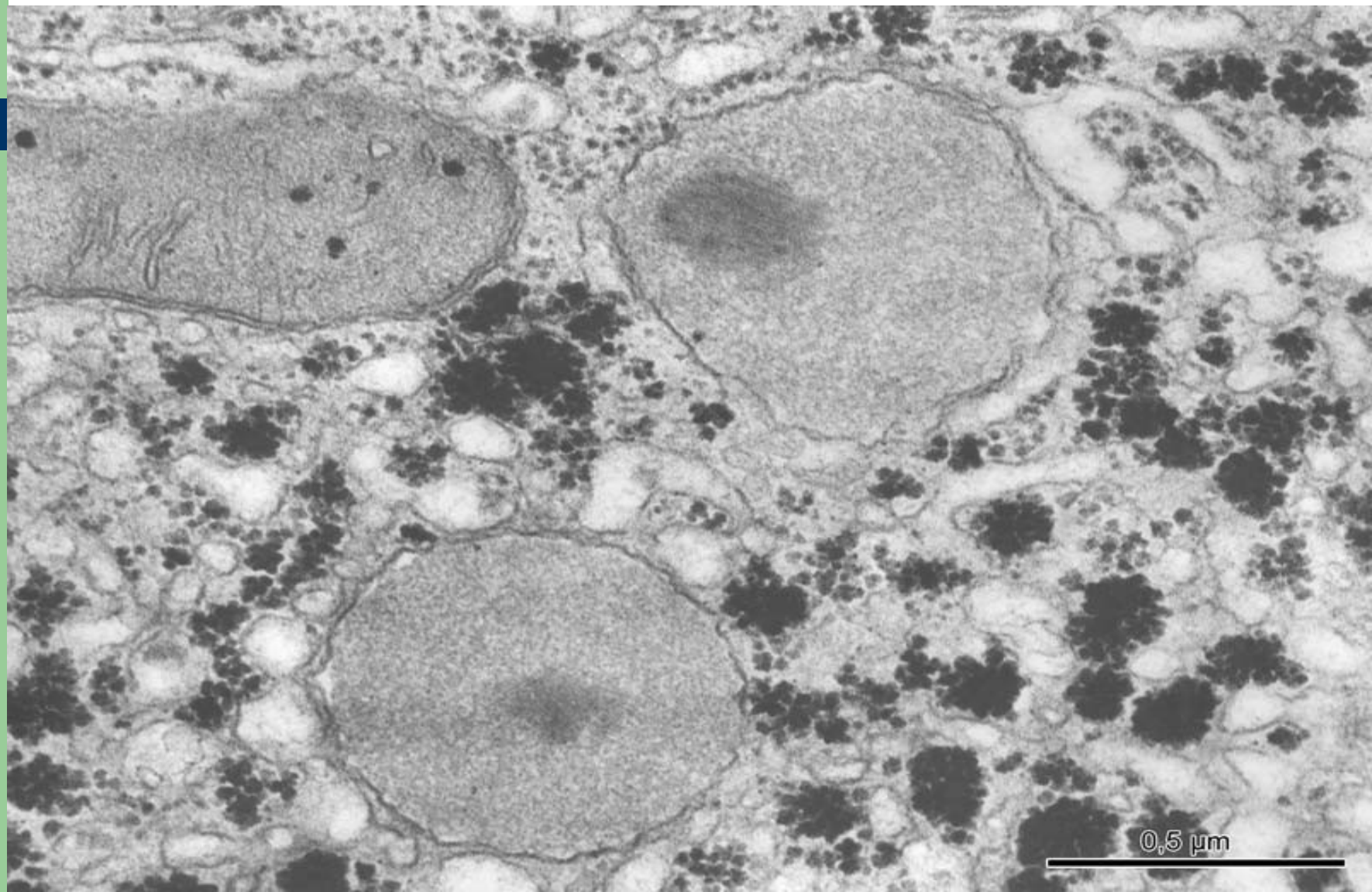


Peroxisome
with nucleoid

Peroxisome



Peroxisomes - TEM

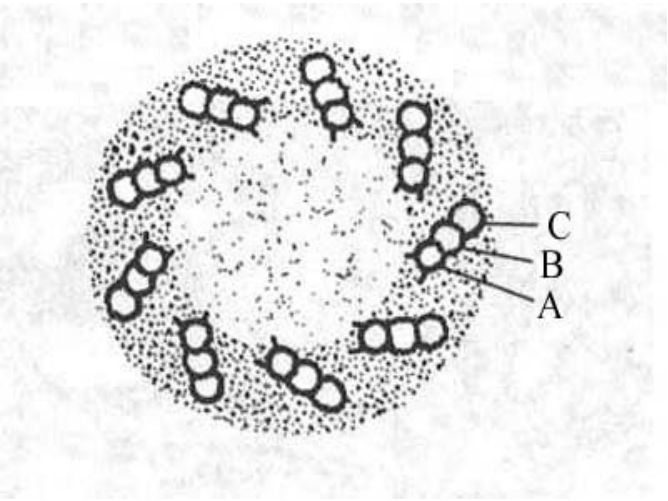


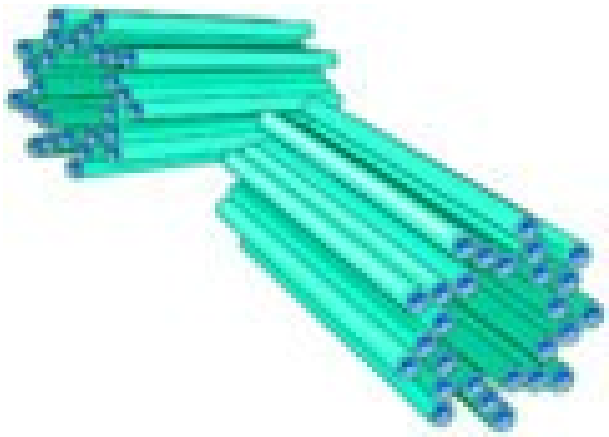
Function of lysosmes and peroxisomes

- Ly – intracellular digestion of endo- and exo-genous material
- Pe – detoxication (break down of H_2O_2, splitting of purins and fat acids)

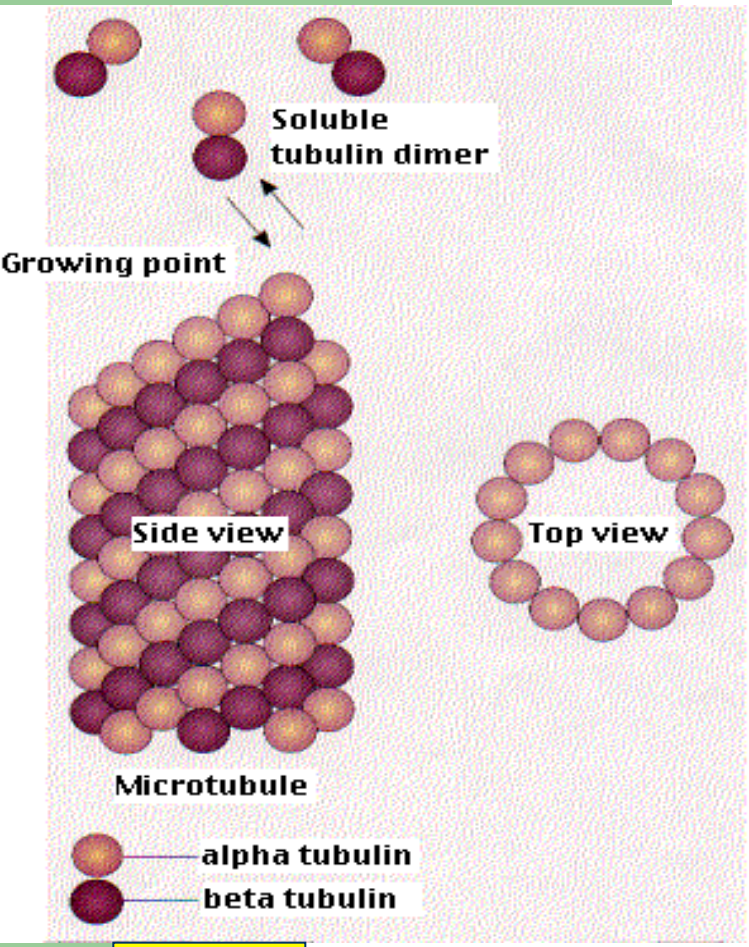
Centriole

- Shape: cylinder
- Size: Ø 0,2 μm, length 0,3 - 0,5 μm
- Structure: 9 triplets of microtubules
- Occurence in the cells (during interphase):
  1 pair of centrioles [„T“] in centrosoma (region of cytoplasm near the nucleus)





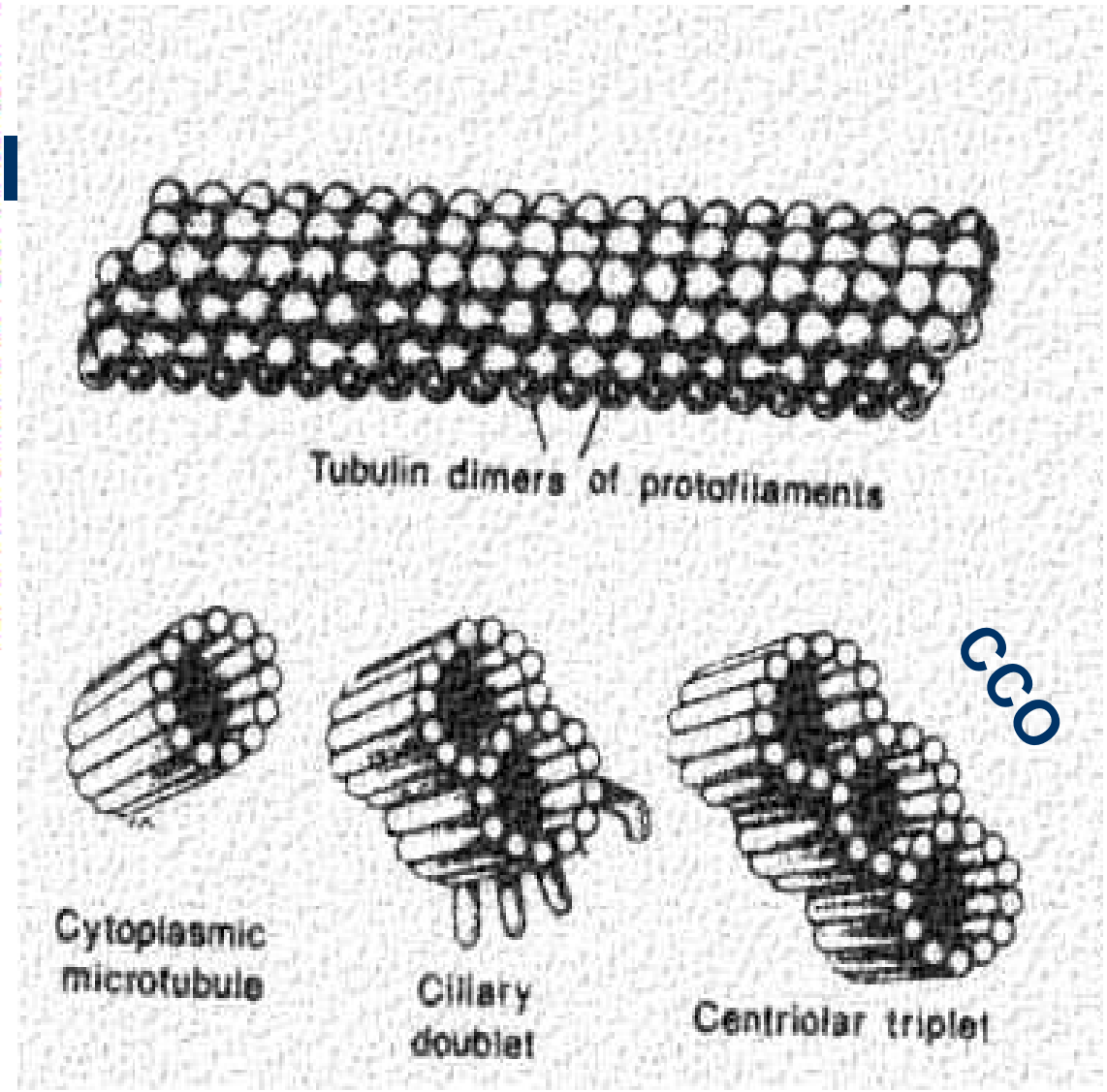
triplet of microtubules



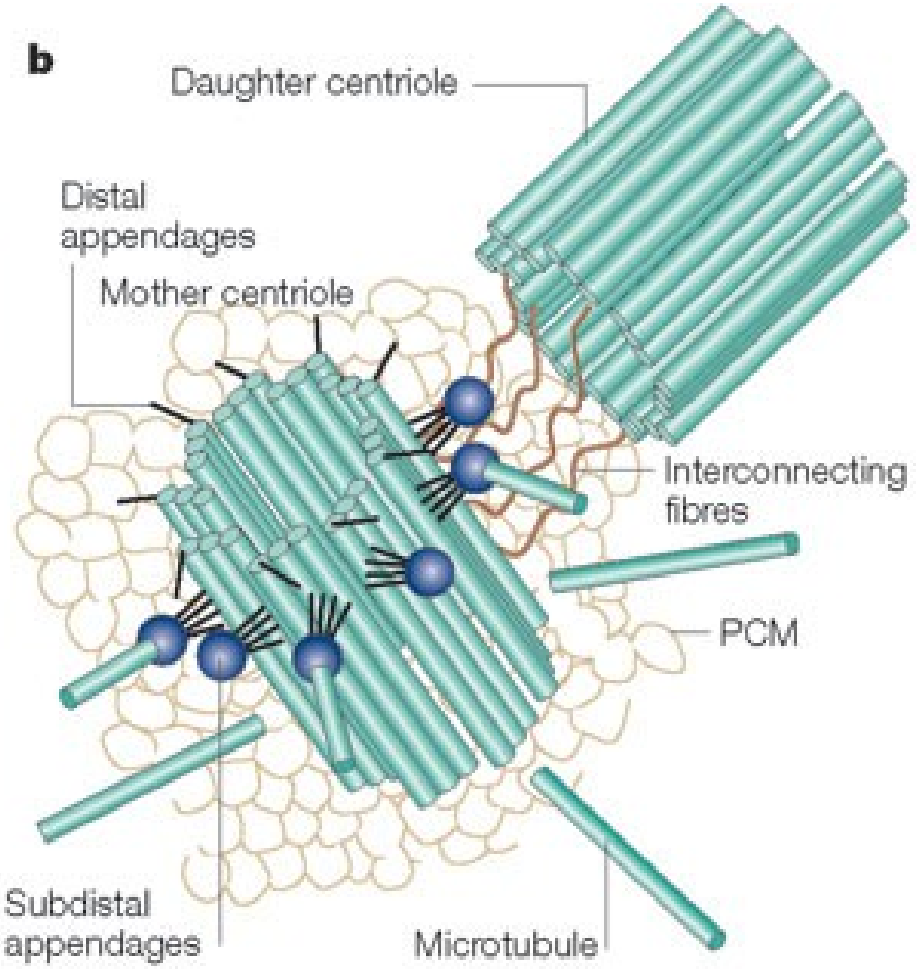
CCO

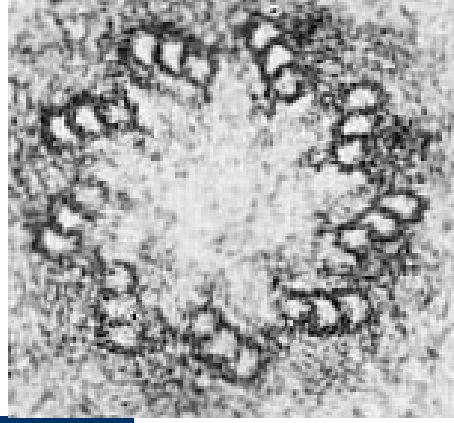
C B A microtubule

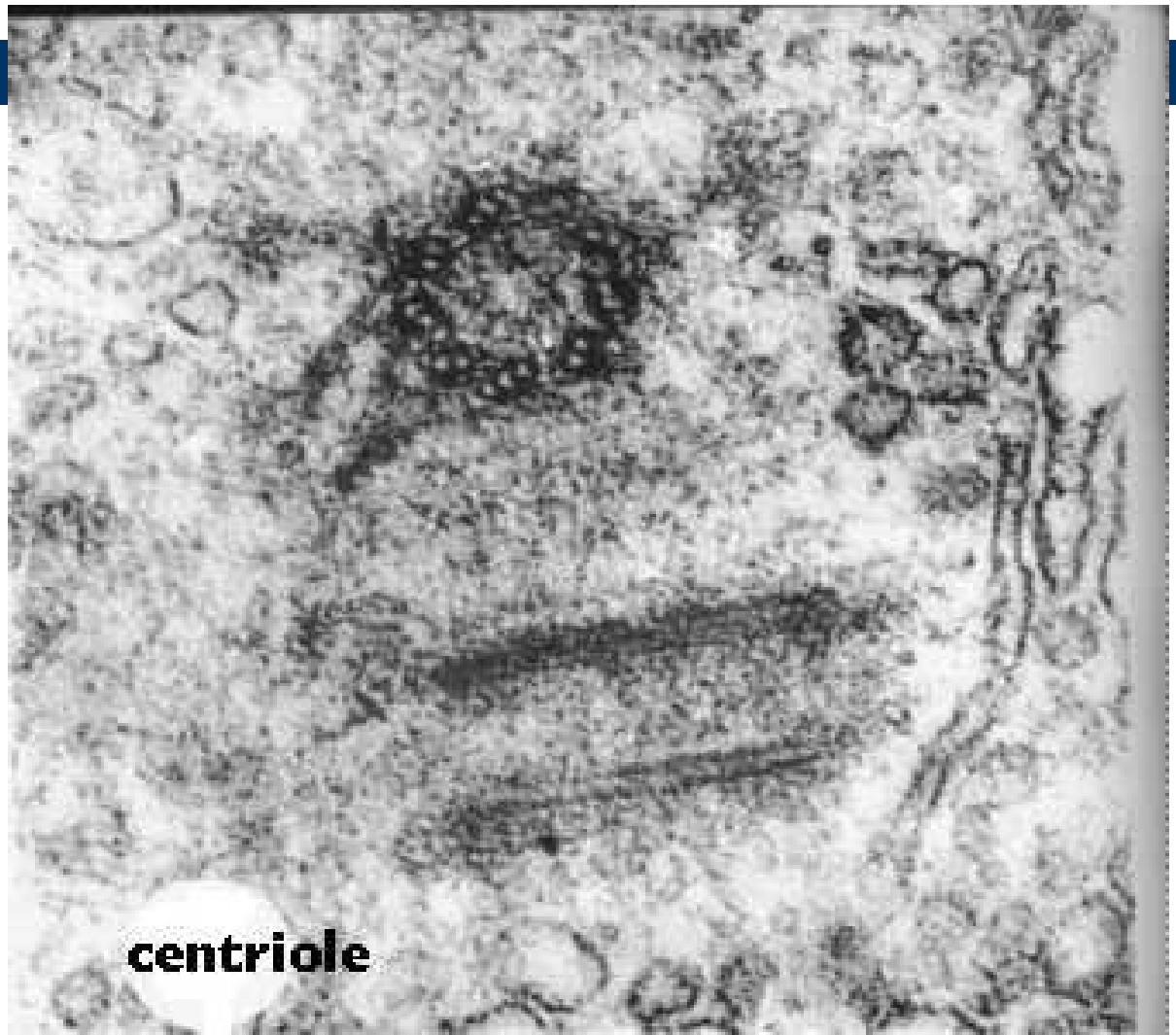
10/10/13 protfilament



Structure of centriole



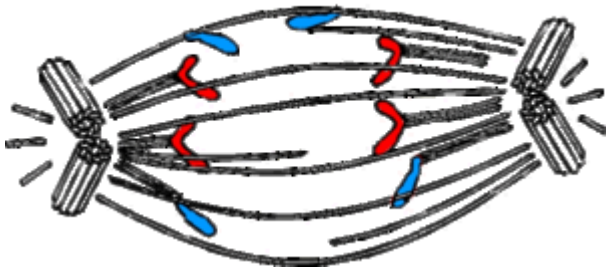



centriole

Function of centrioles

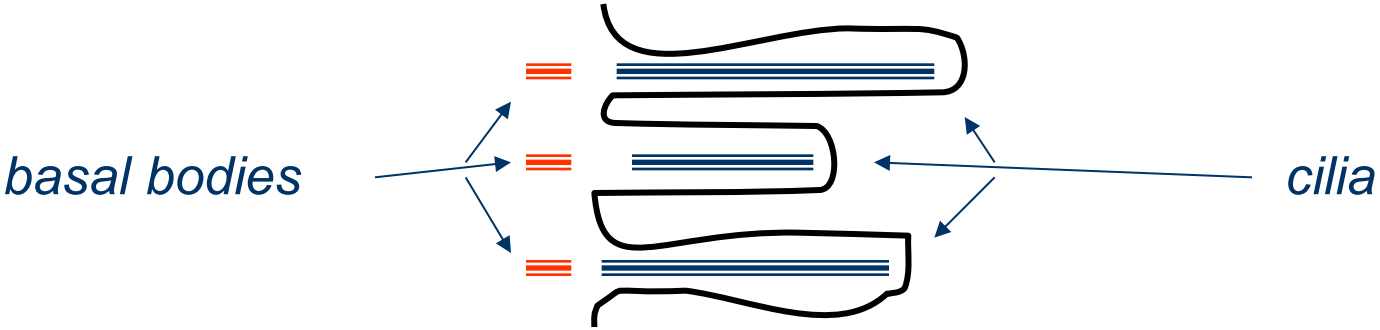
Reduplication of centrioles during cell division

⇨ formation of mitotic spindle

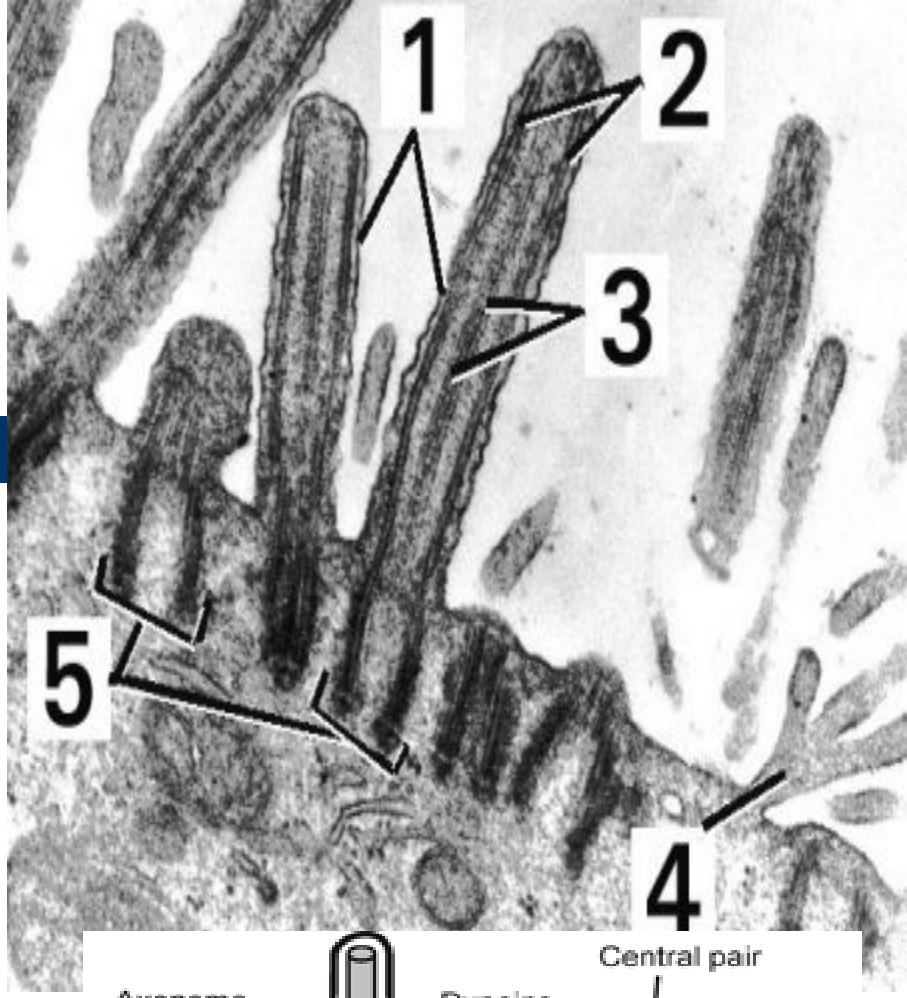


Multiplication of centrioles during ciliogenesis

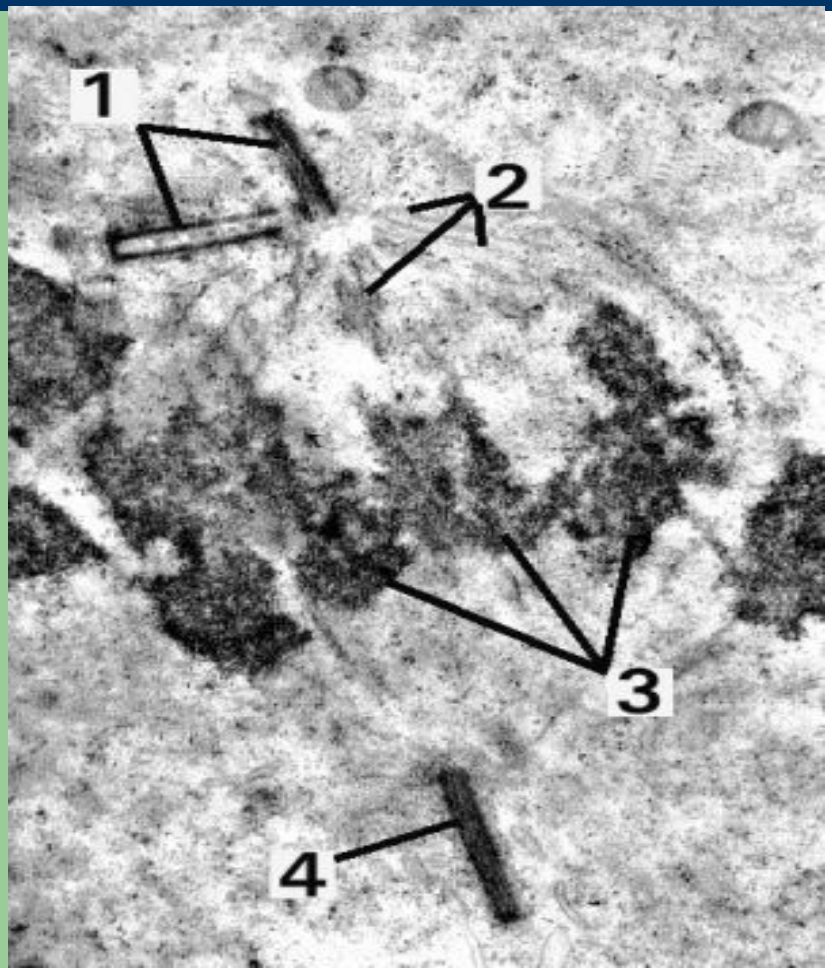
⇨ formatiom of basal bodies of kinocilia

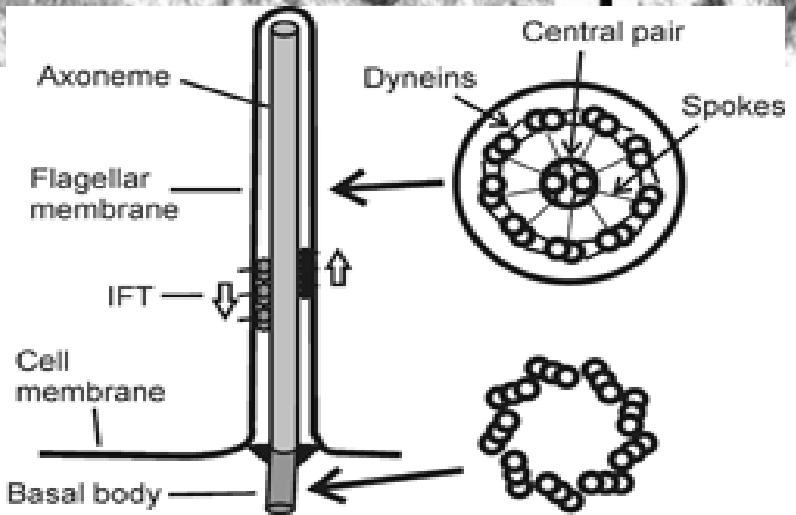


Cilia with basal bodies



Mitotic spindle





Inclusions

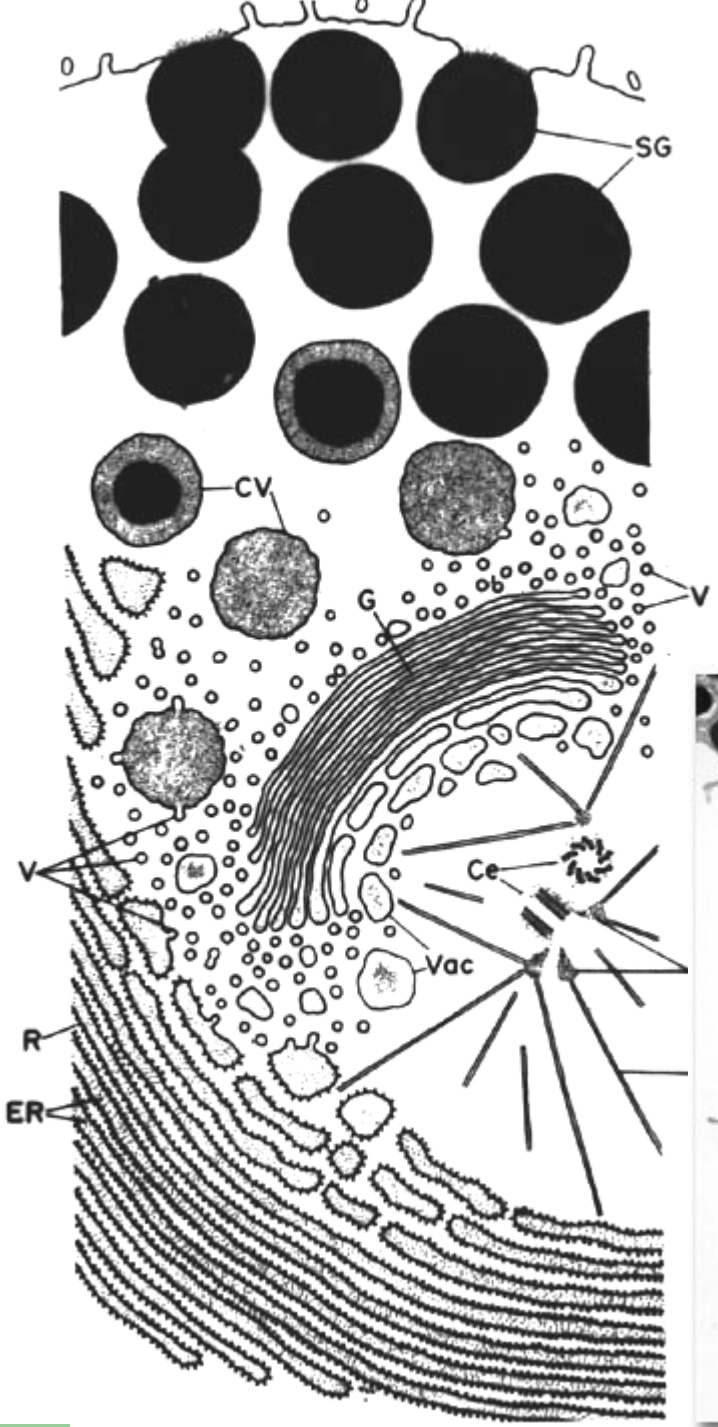
are cytoplasmic structures of transitional character arrising by accumulution of unsoluble metabolits of storing materials or they are of exogenous origin and enter the cell via phagocytosis.

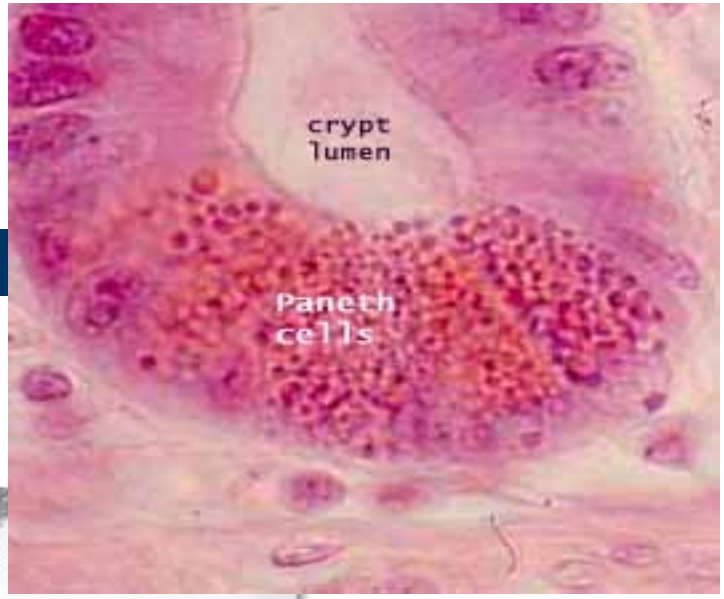
- Secretory granules
- Reserve material → glycogen
  → lipid droplets
- Crystals (proteins)
- Pigments

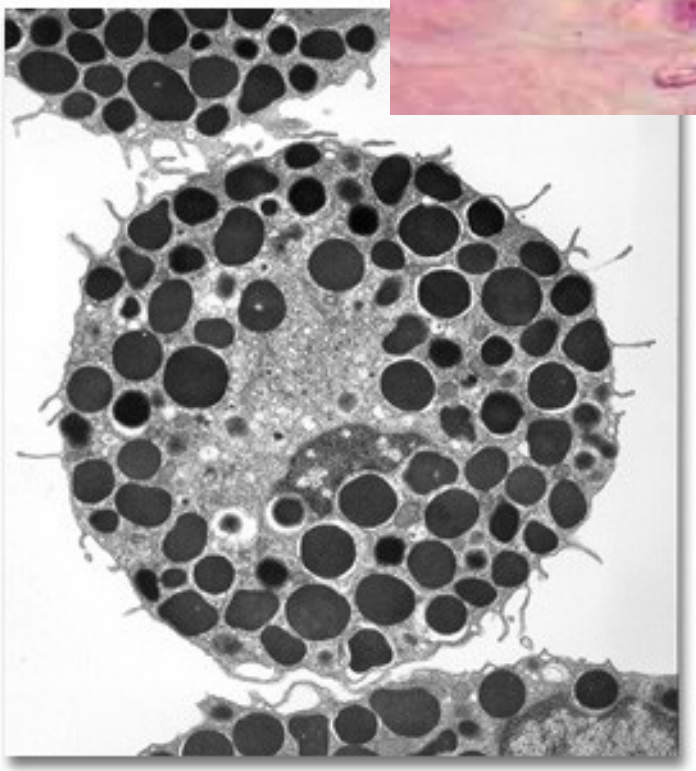
endogenous → autogenous
→ hematogenous
→ lipofuscin

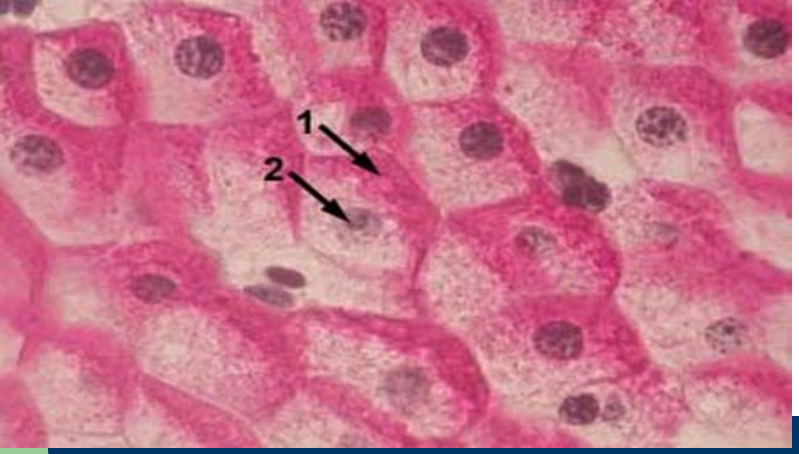
exogenous – dust, dyes (carotene), tattoo

Secretory granules



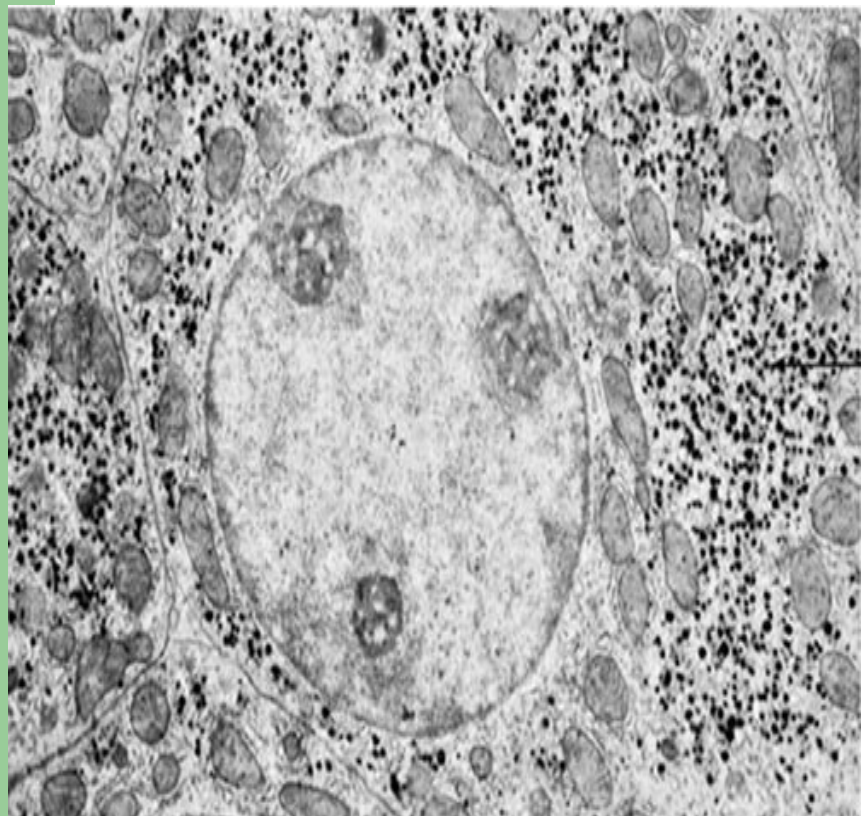


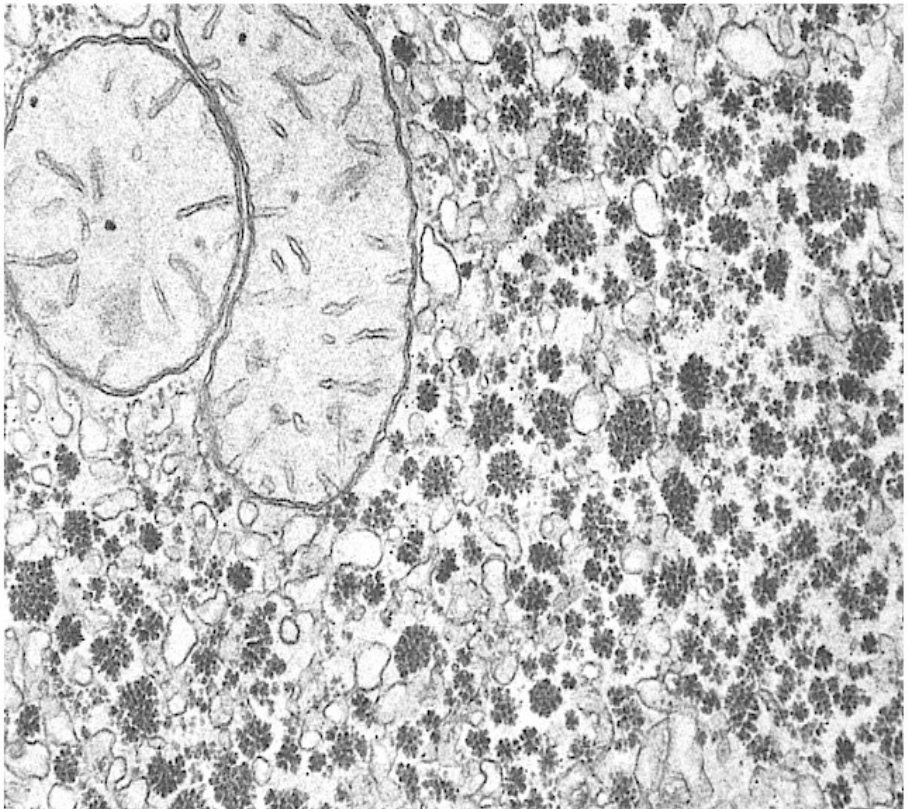




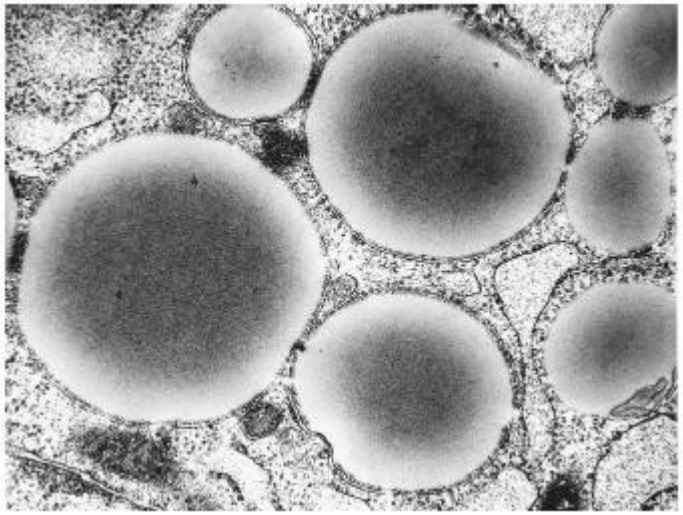
Glycogen

- β – granules (40 nm)
- α – granules (up 400 nm)

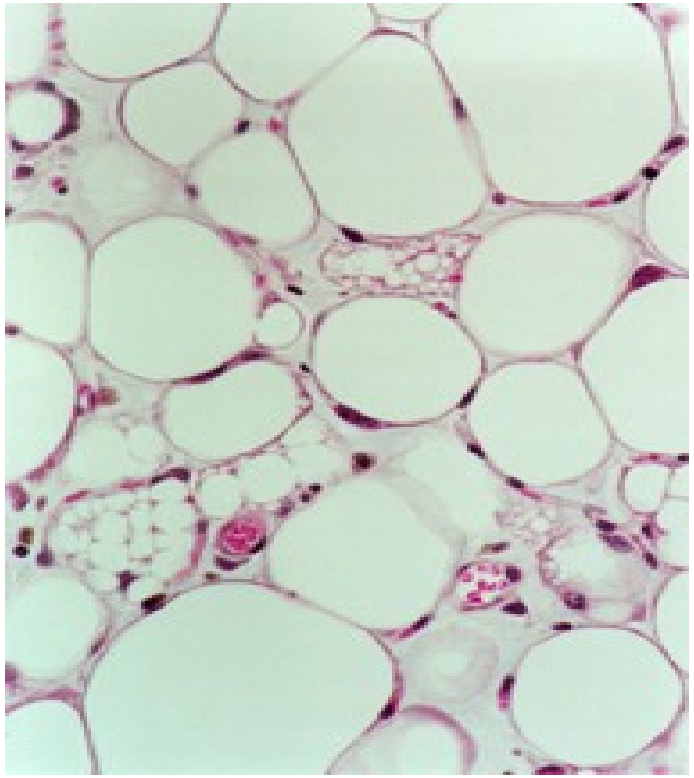




Lipid droplets

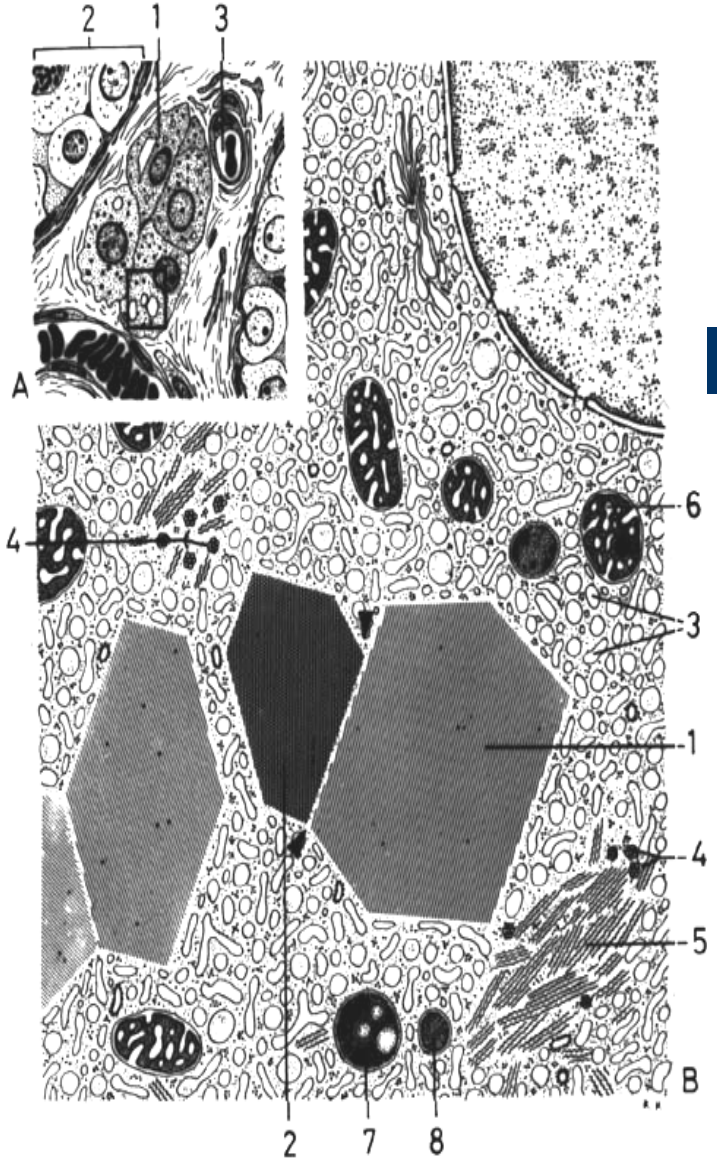


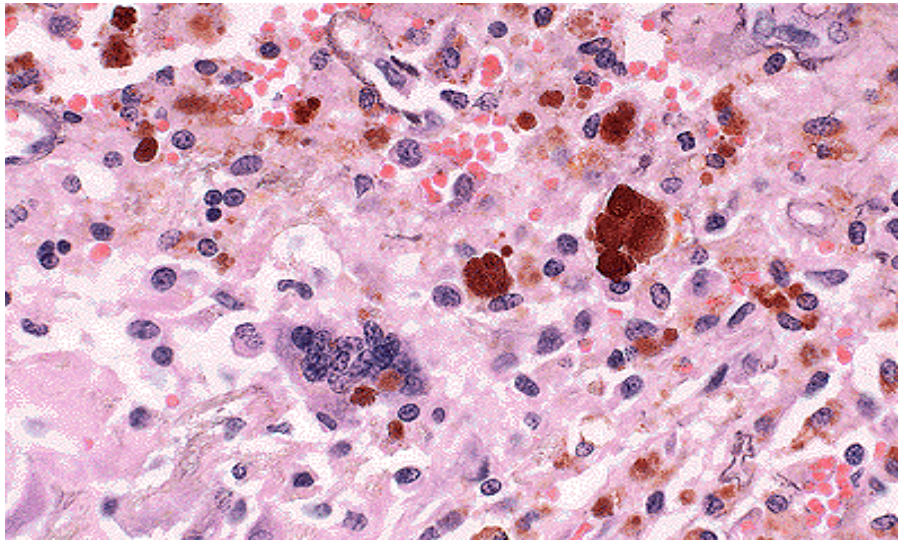
Lipid droplets in cell



Lipid droplet in adipocytes

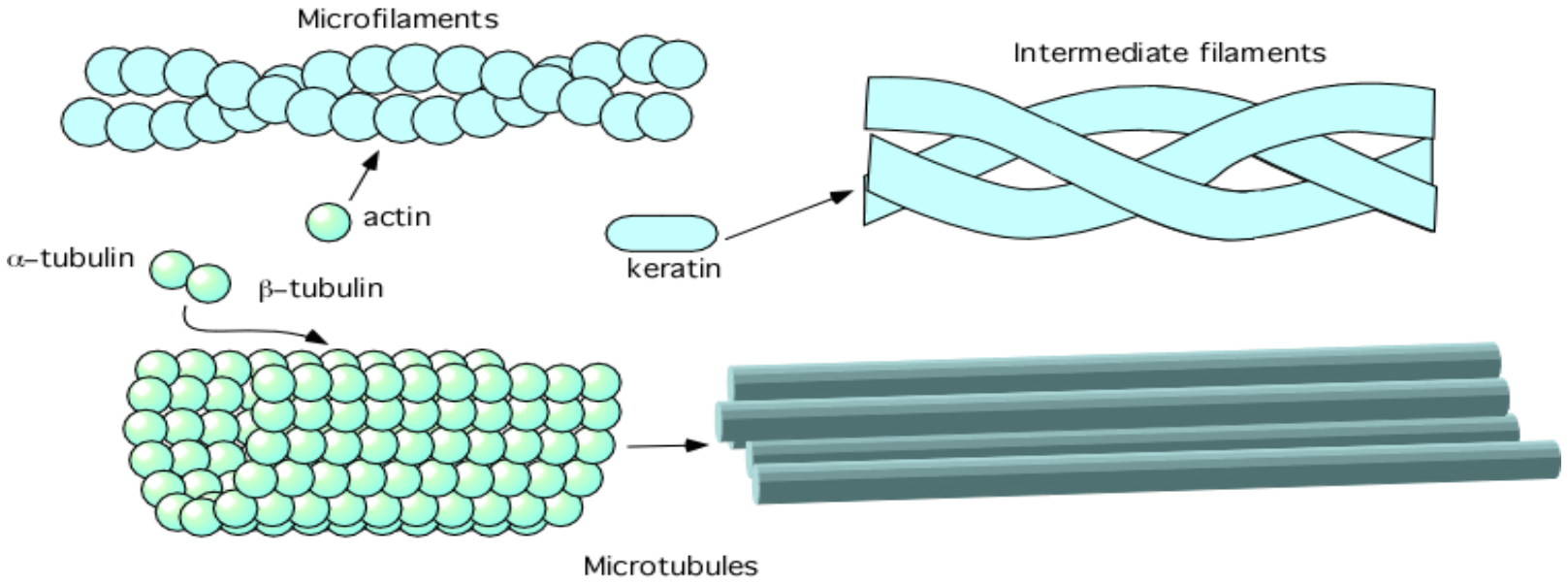
Crystals and pigments

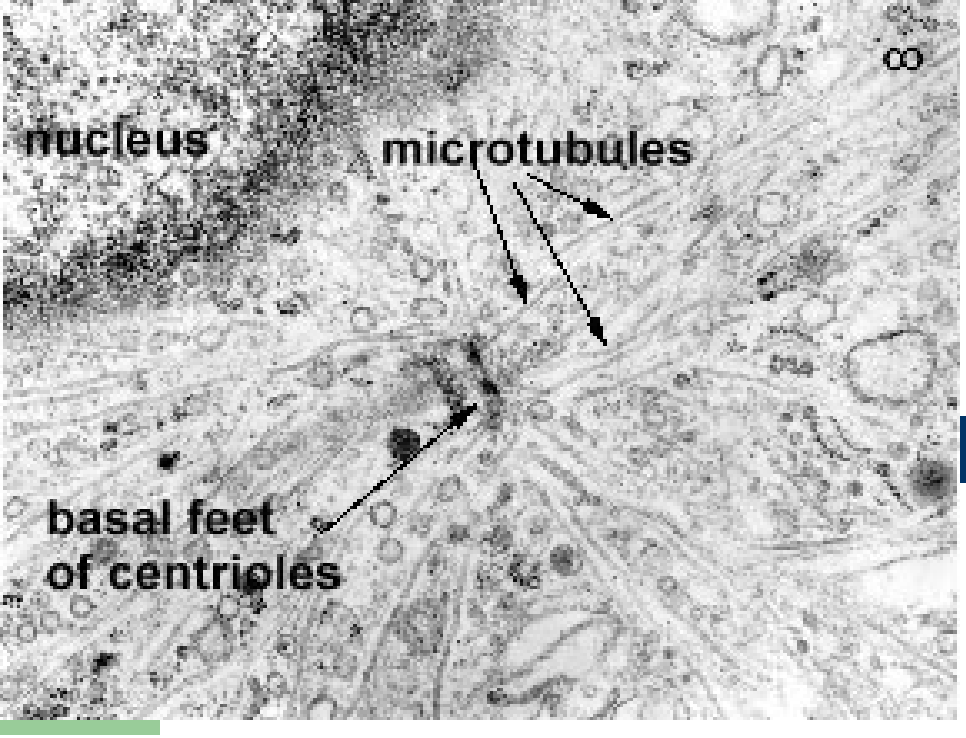




Cytoskeleton

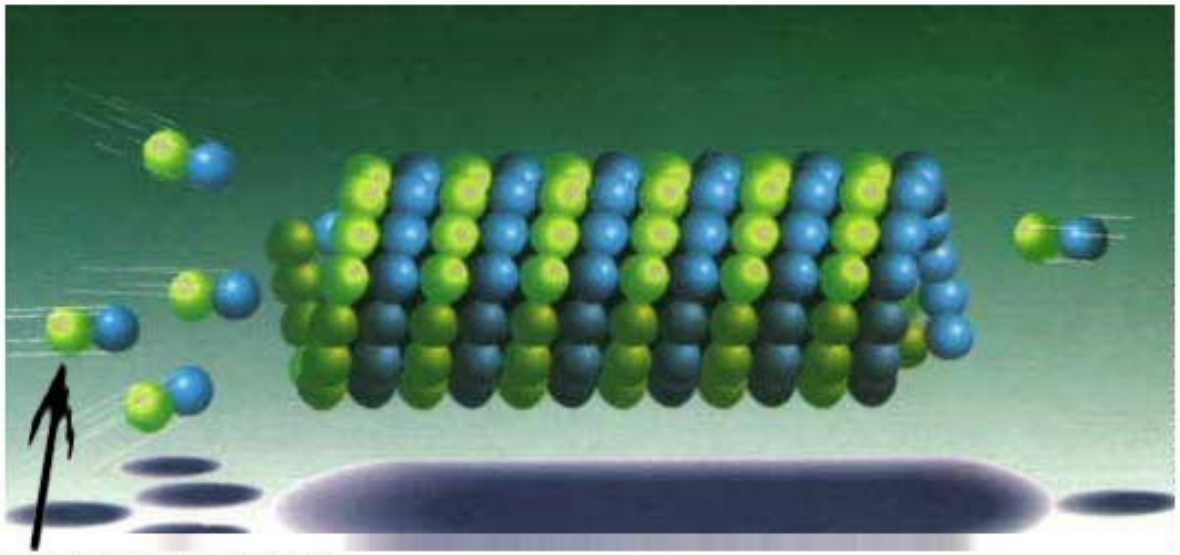
- Microtubules [cylinders - Ø 22 nm, α + β TUBULIN]
- Microfilaments [fibers - Ø 5-7 nm, AKTIN]
- Intermediate filaments [fibers - Ø 8-11 nm, CYTOKERATIN, VIMENTIN, DESMIN, NEUROFILAMENTA, GFAP]

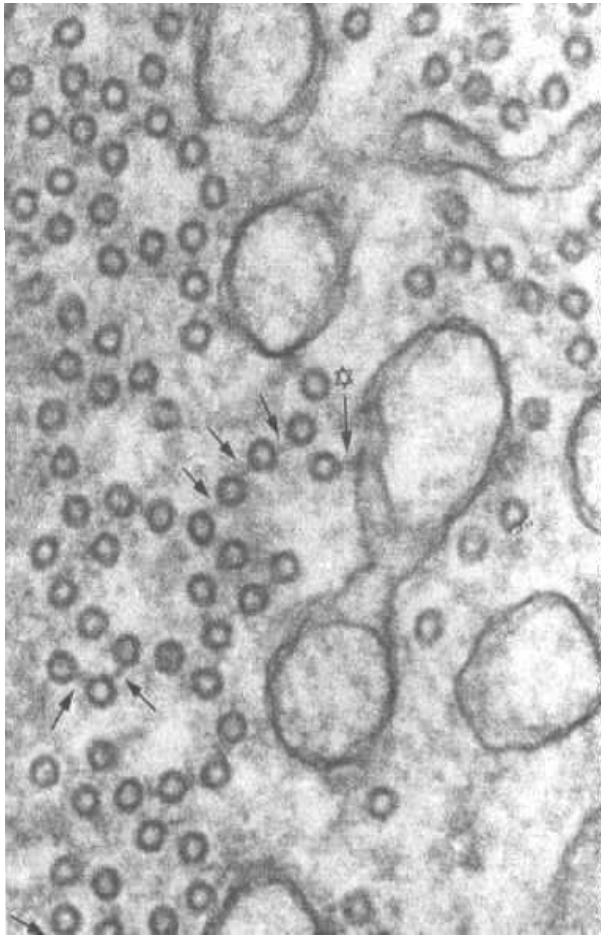




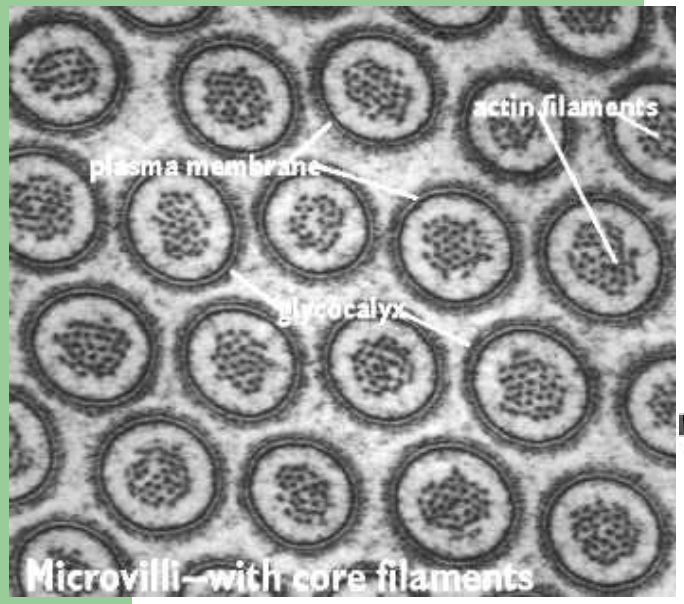
Microtubules

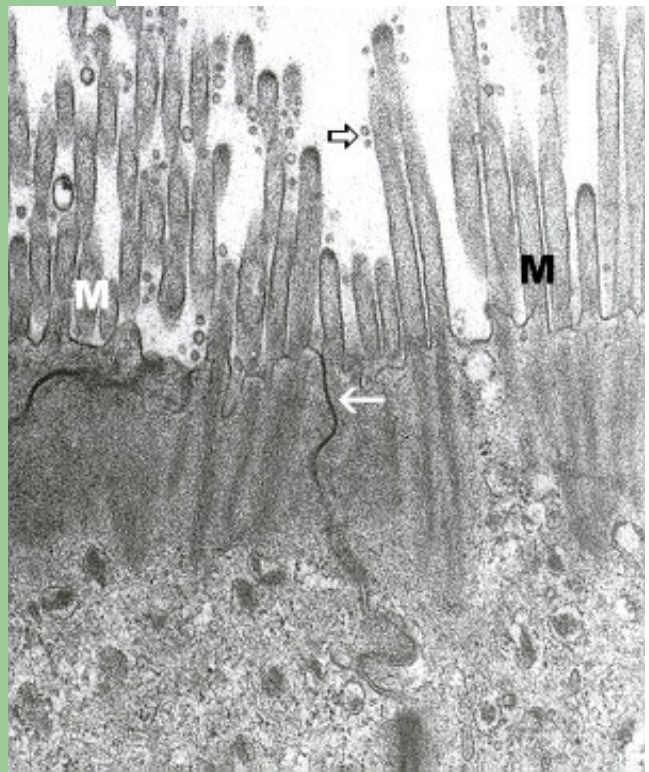
Model ultrastruktury mikrotubulů

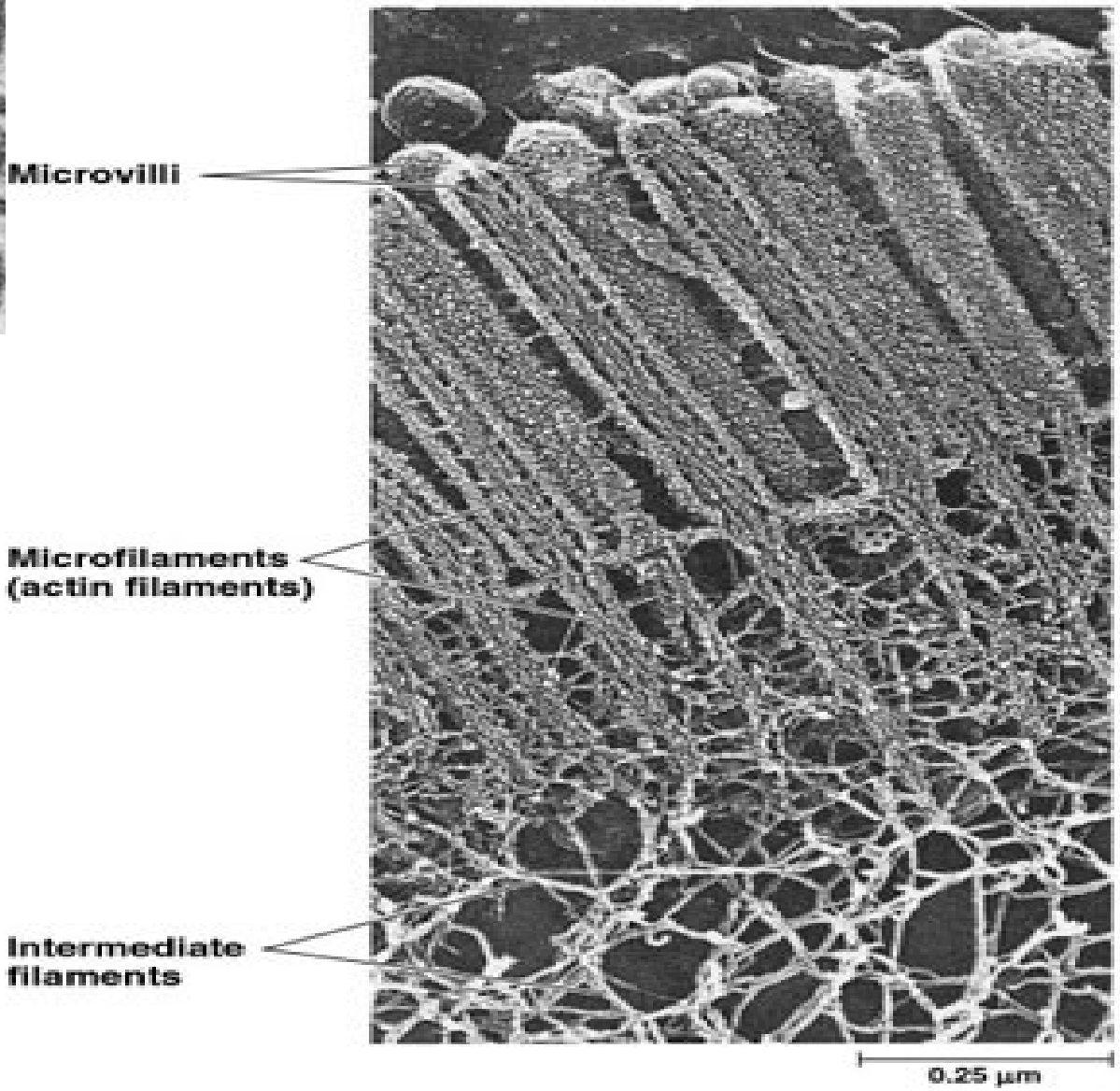




Microfilaments, intermed.filaments

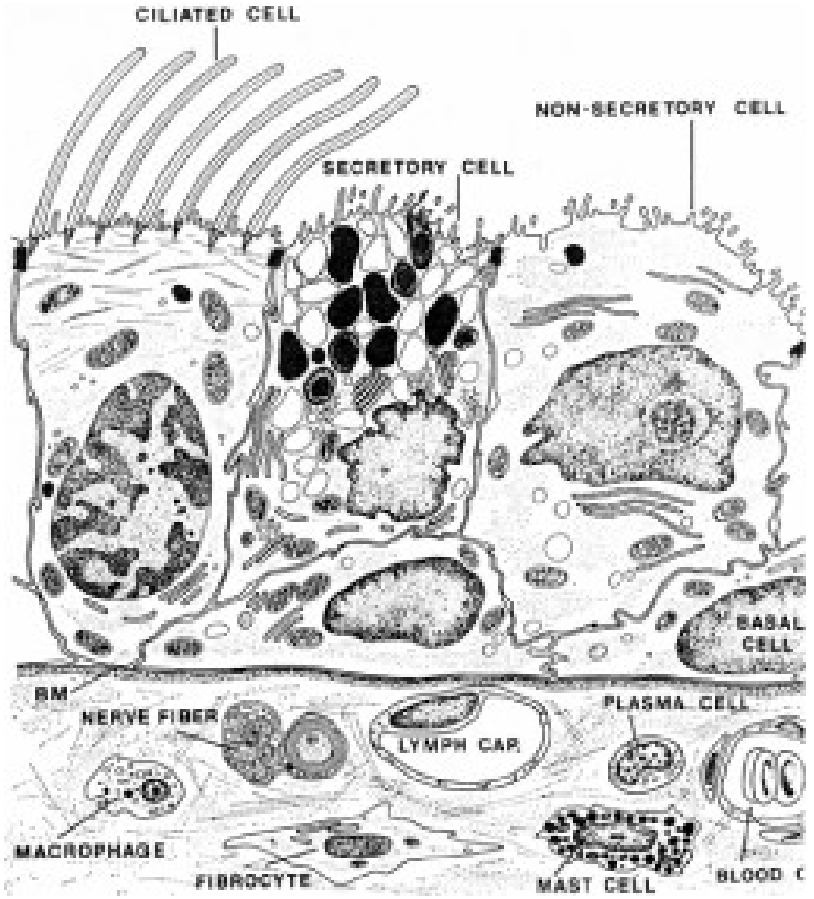






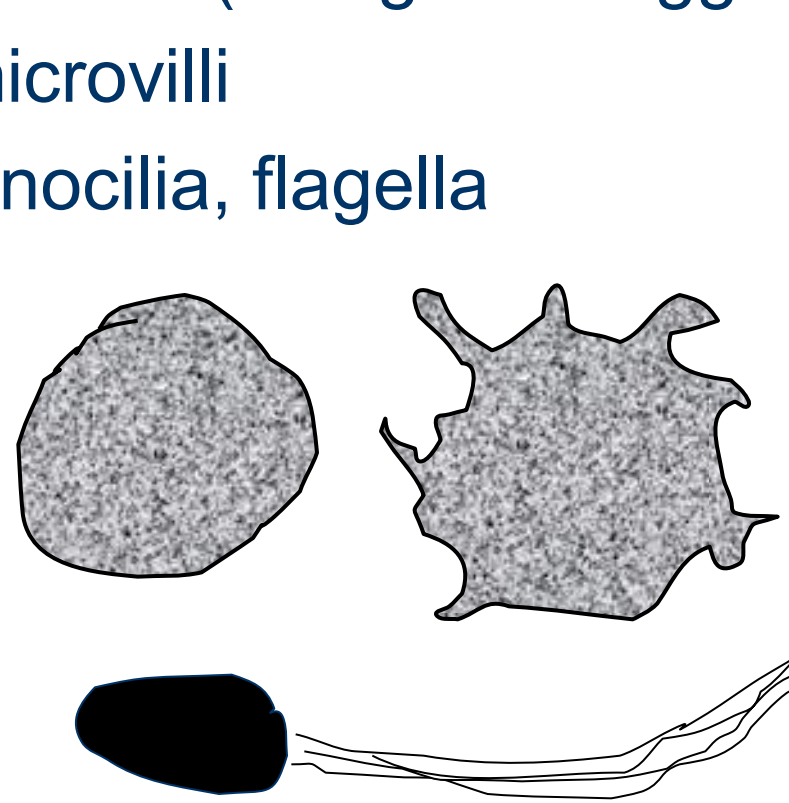
Cell surface - modifications

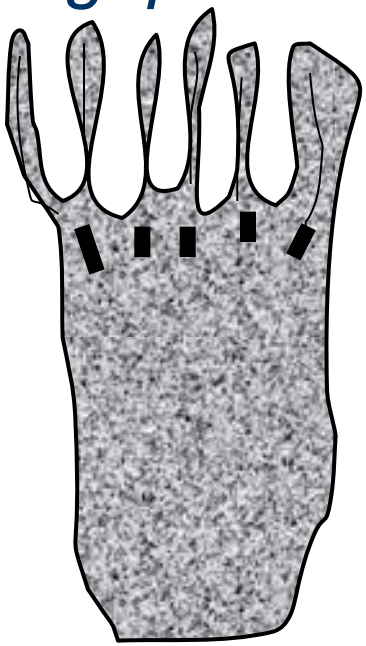
- free surface (apical)
  – smooth or with processes (microvilli, cilia, flagella)
- surface turned to neighbour cell (lateral) – intercellular junctions
- surface turned to non-cellular structure – lamina basalis or basement membrane – ½ desmosomes (hemidesmosomes)

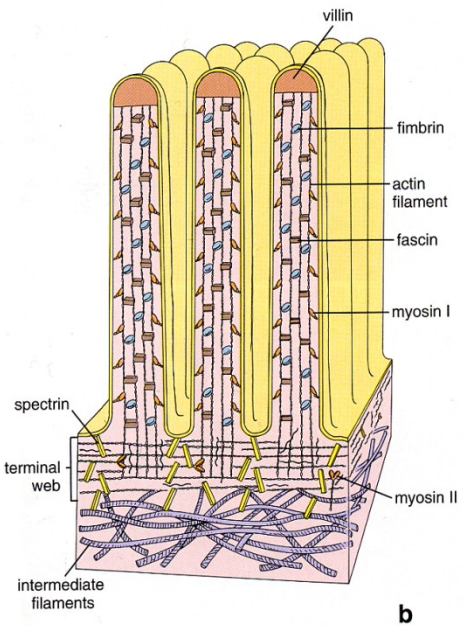


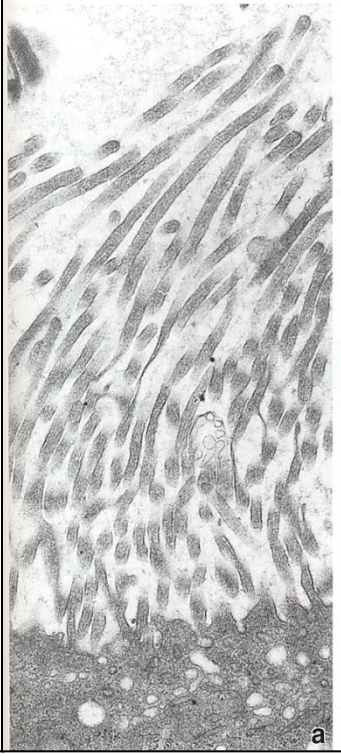
Free surface

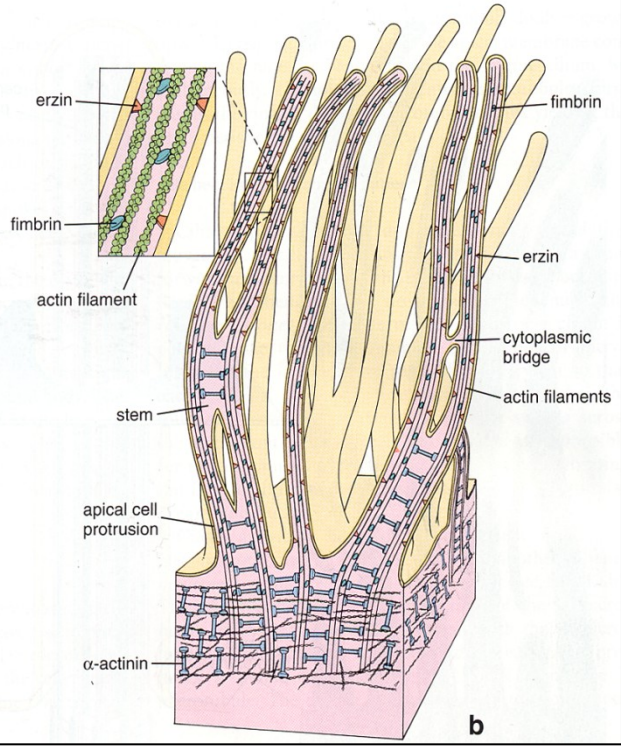
- smooth (straight or rugged – *e.g. pseudopodia*)
- microvilli
- kinocilia, flagella





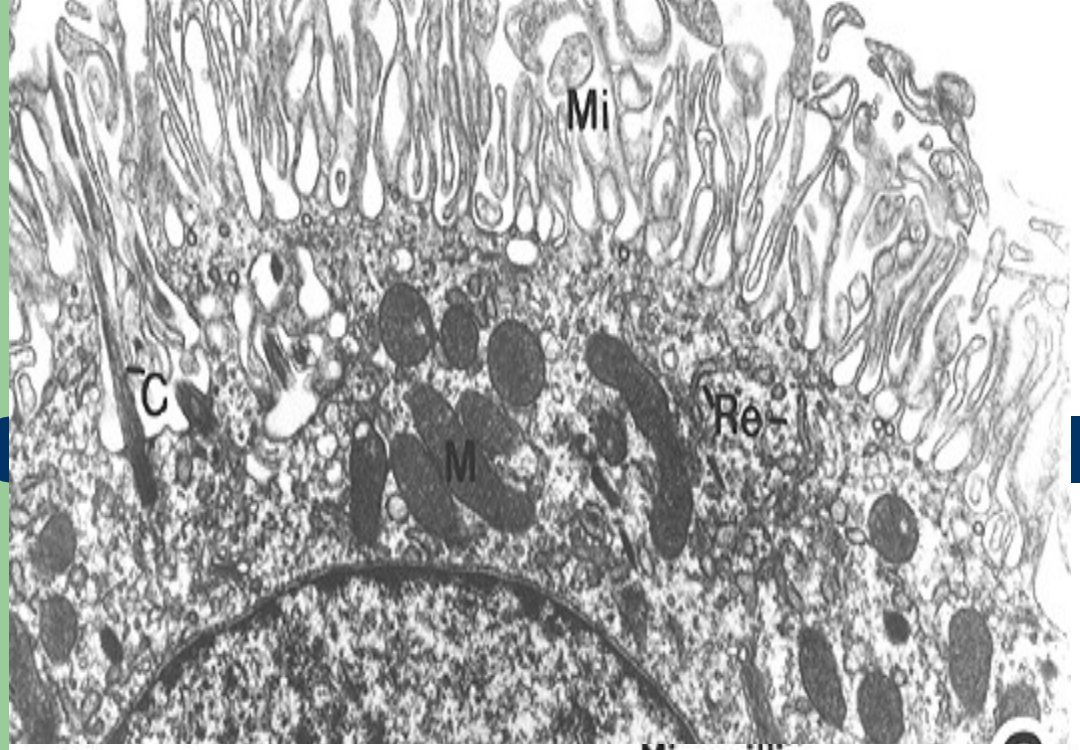




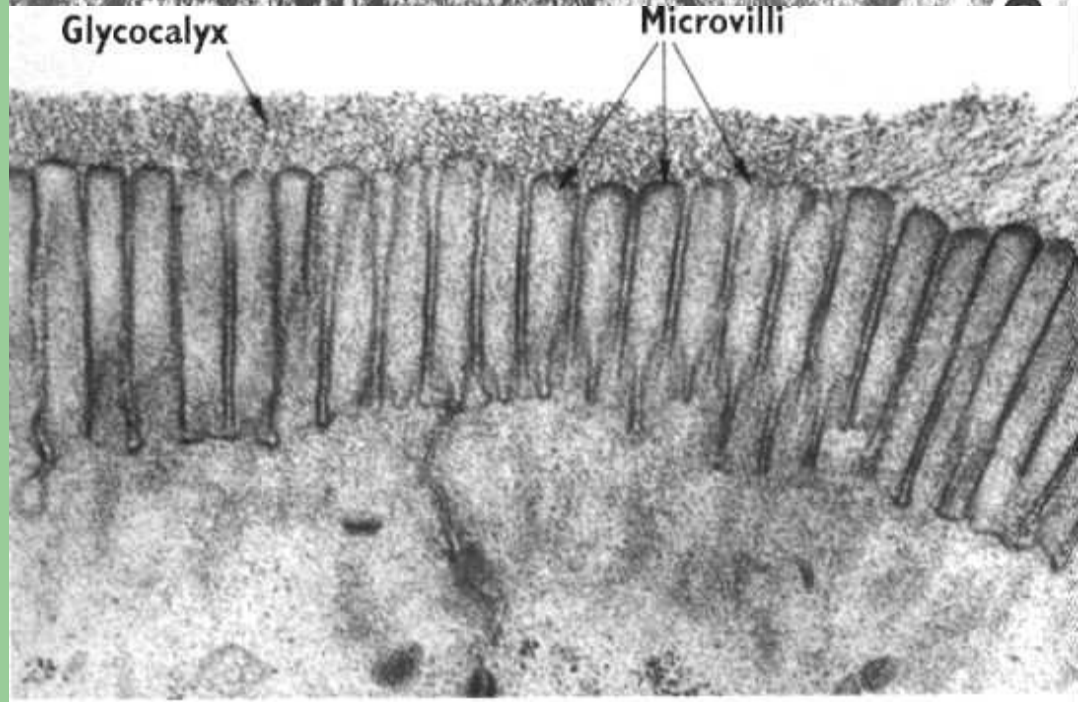


Mikrovilli = cytoplasmic processes scaffolded by actin microfilaments – *according to arrangement*:

- short, irregular
- striated border – *e.g. intestines*
- brush border– *e.g. kidney tubules*
- stereocilia – *e.g. ductus deferens*

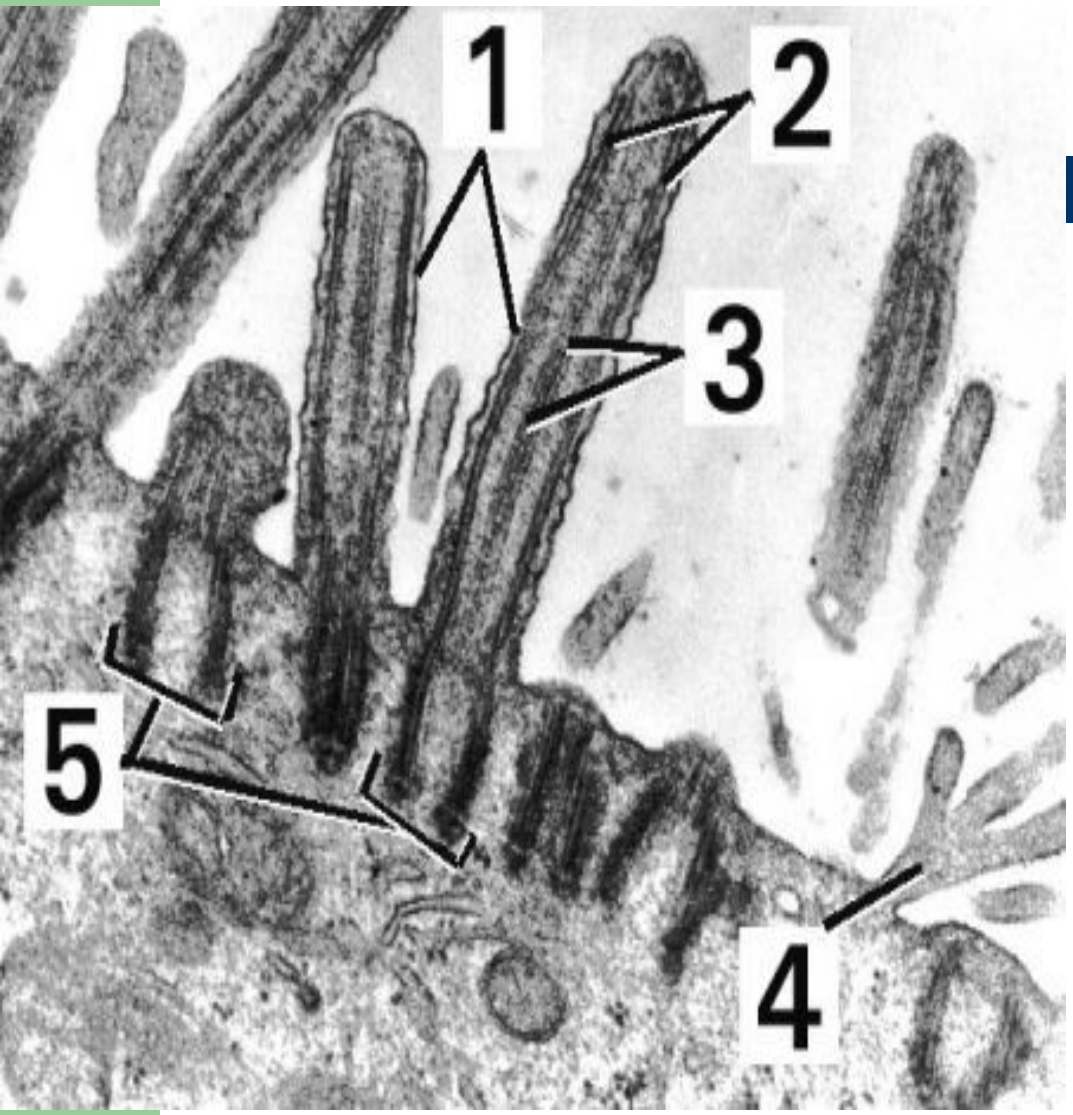


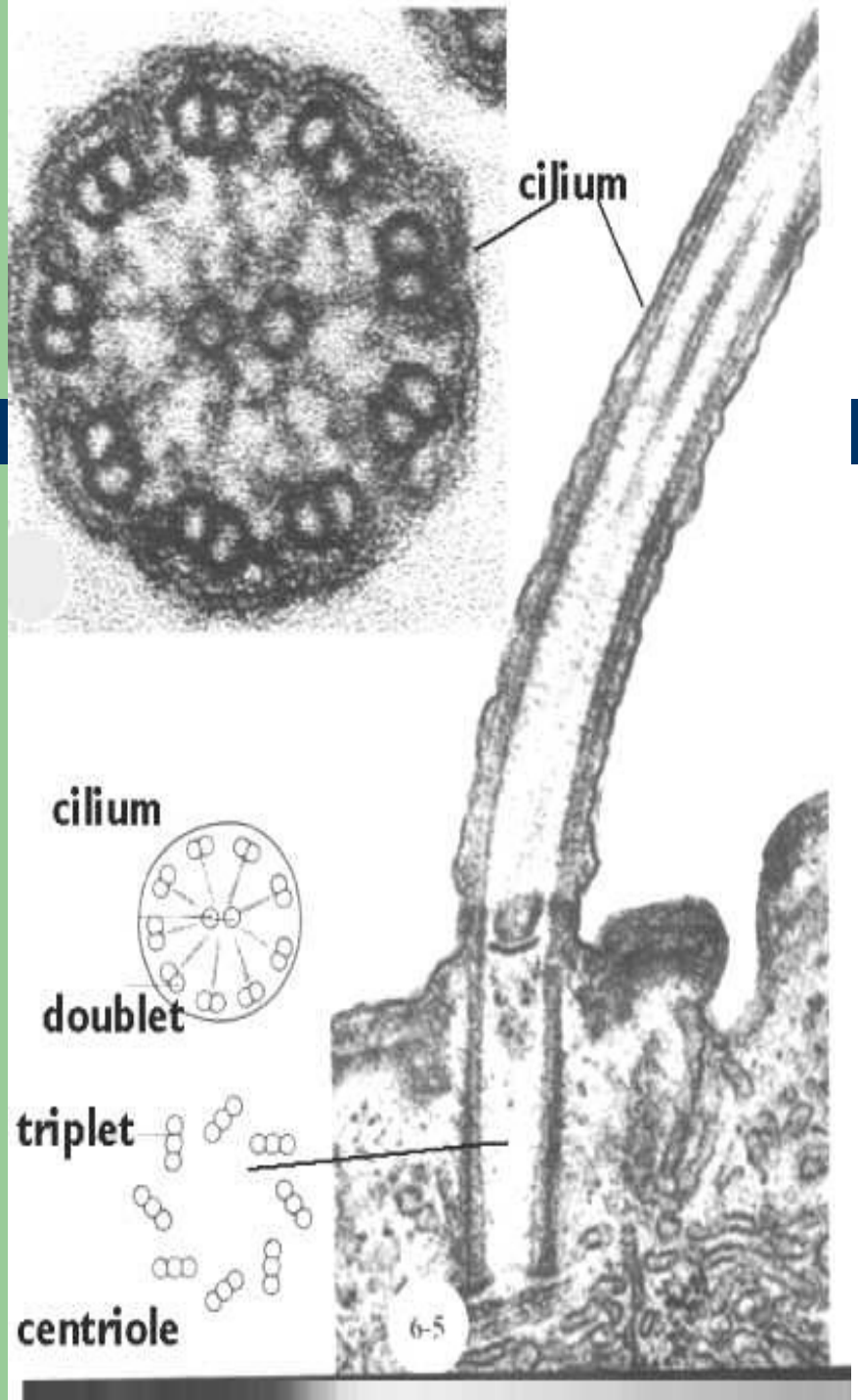
Brush border
(on epithelial cells lining renal tubules)



Striated border
(on epithelial cells lining intestines)

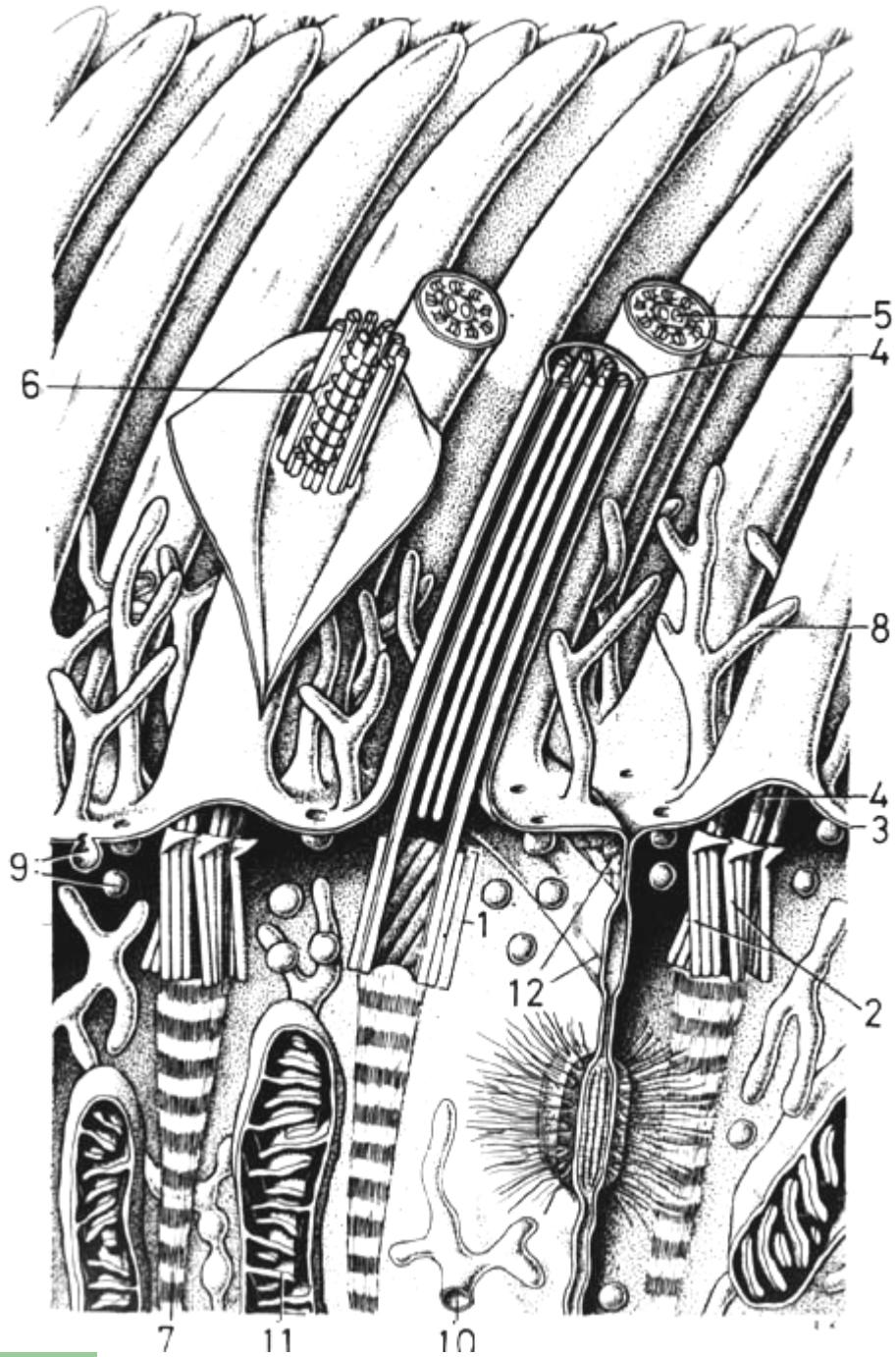
Kinocilium and flagellum





Cilia, flagella

- Moveable processes of cytoplasm scaffolded by **microtubules**:
  9 dublets + 1 central pair = **AXONEMA**
- **Basal body** = centriole
- Striated rootlet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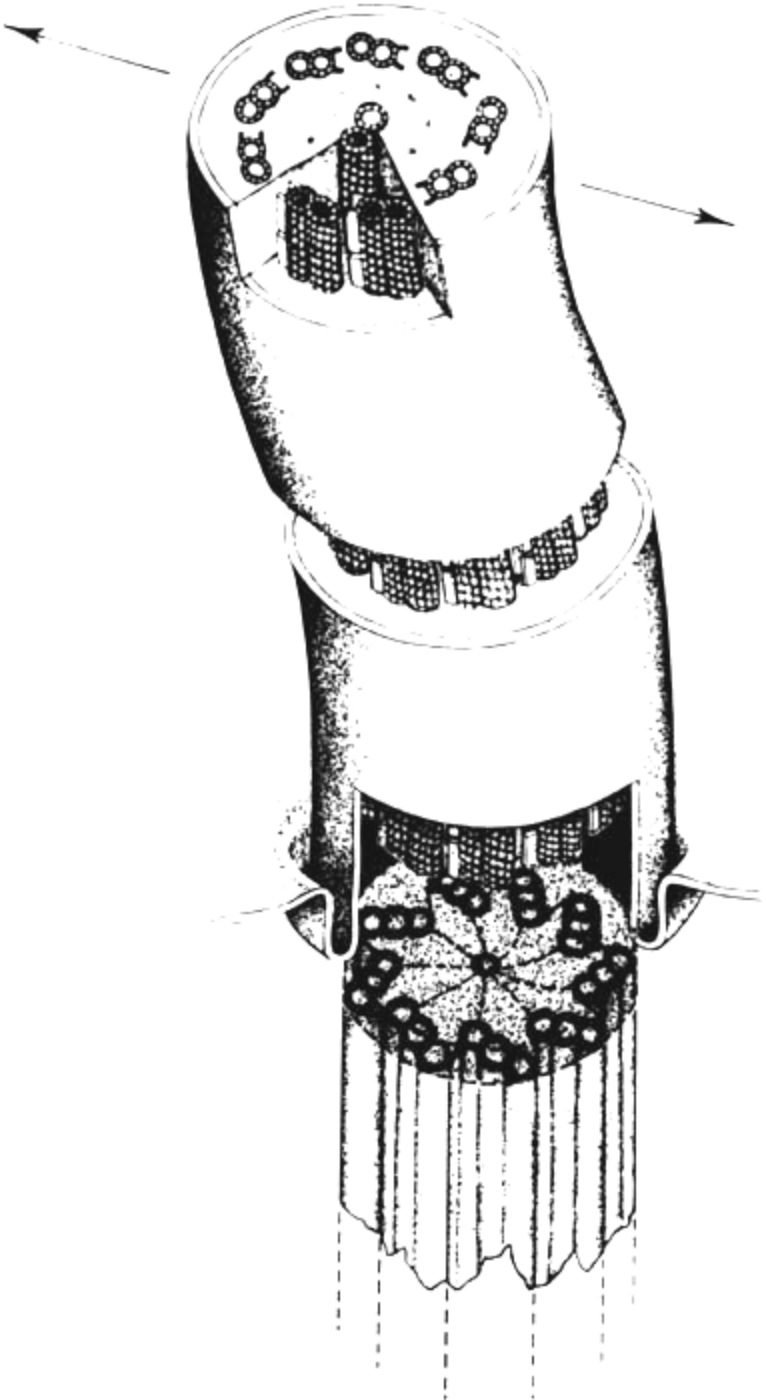
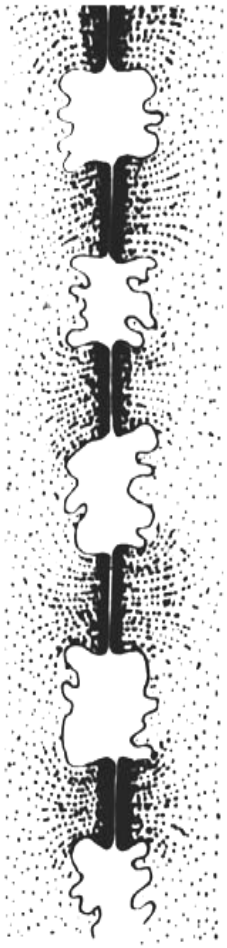


Lateral surface, intercellular cleft (20 nm); zonulae and maculae



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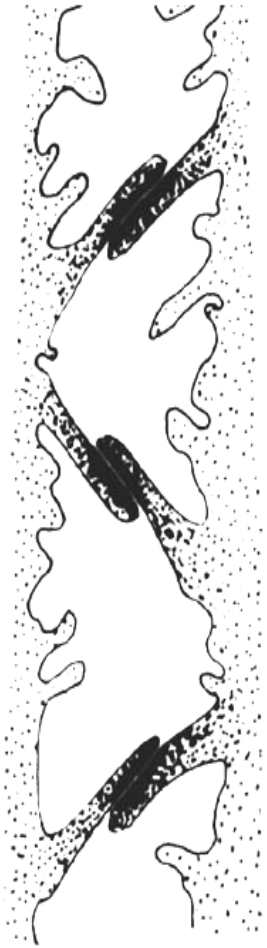

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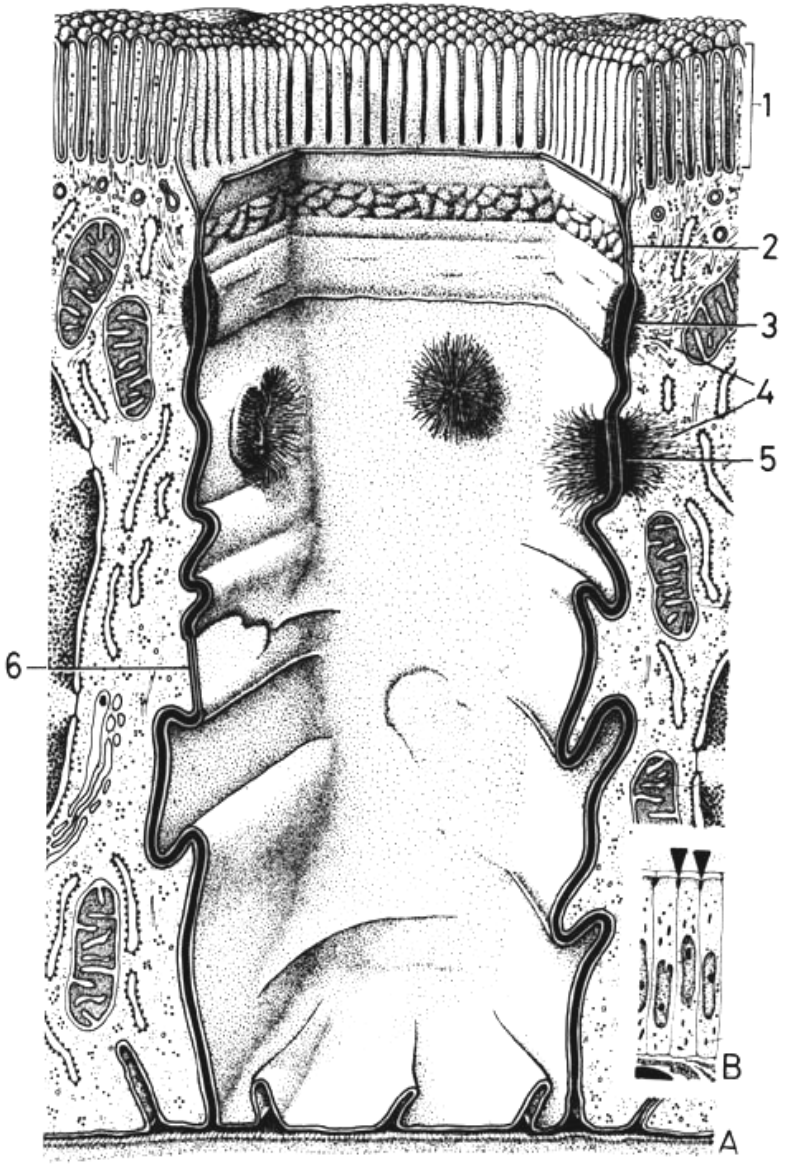
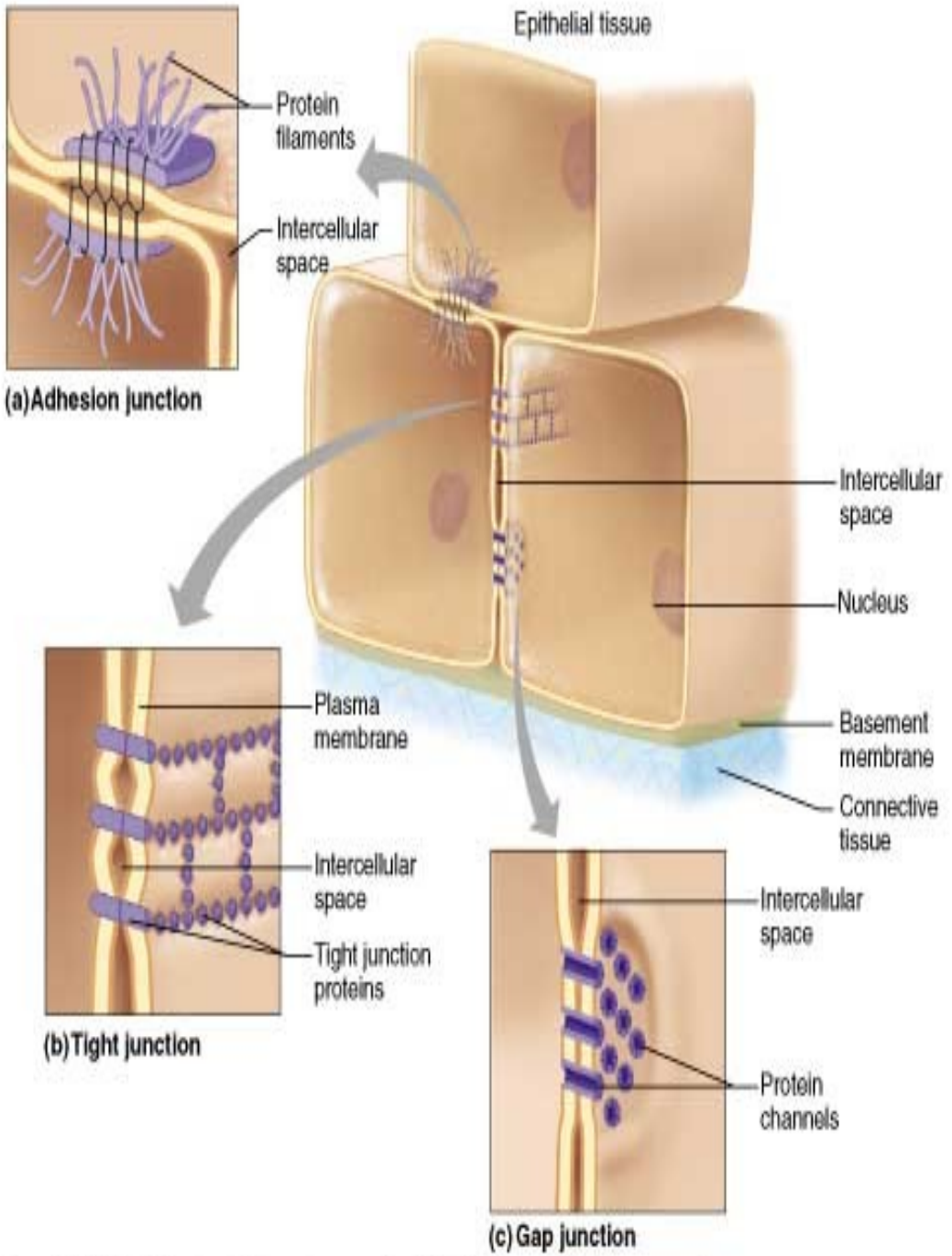
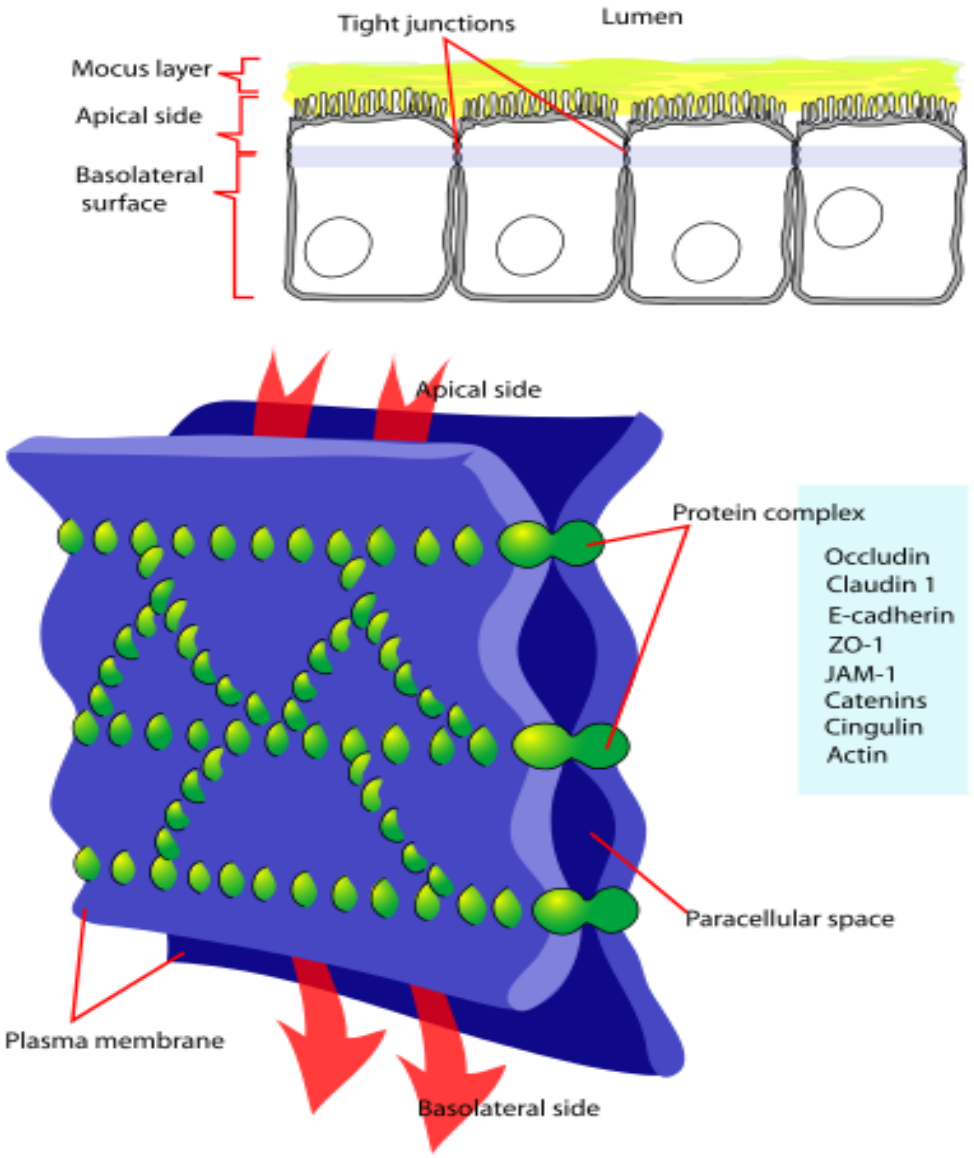


Intercellular junctions

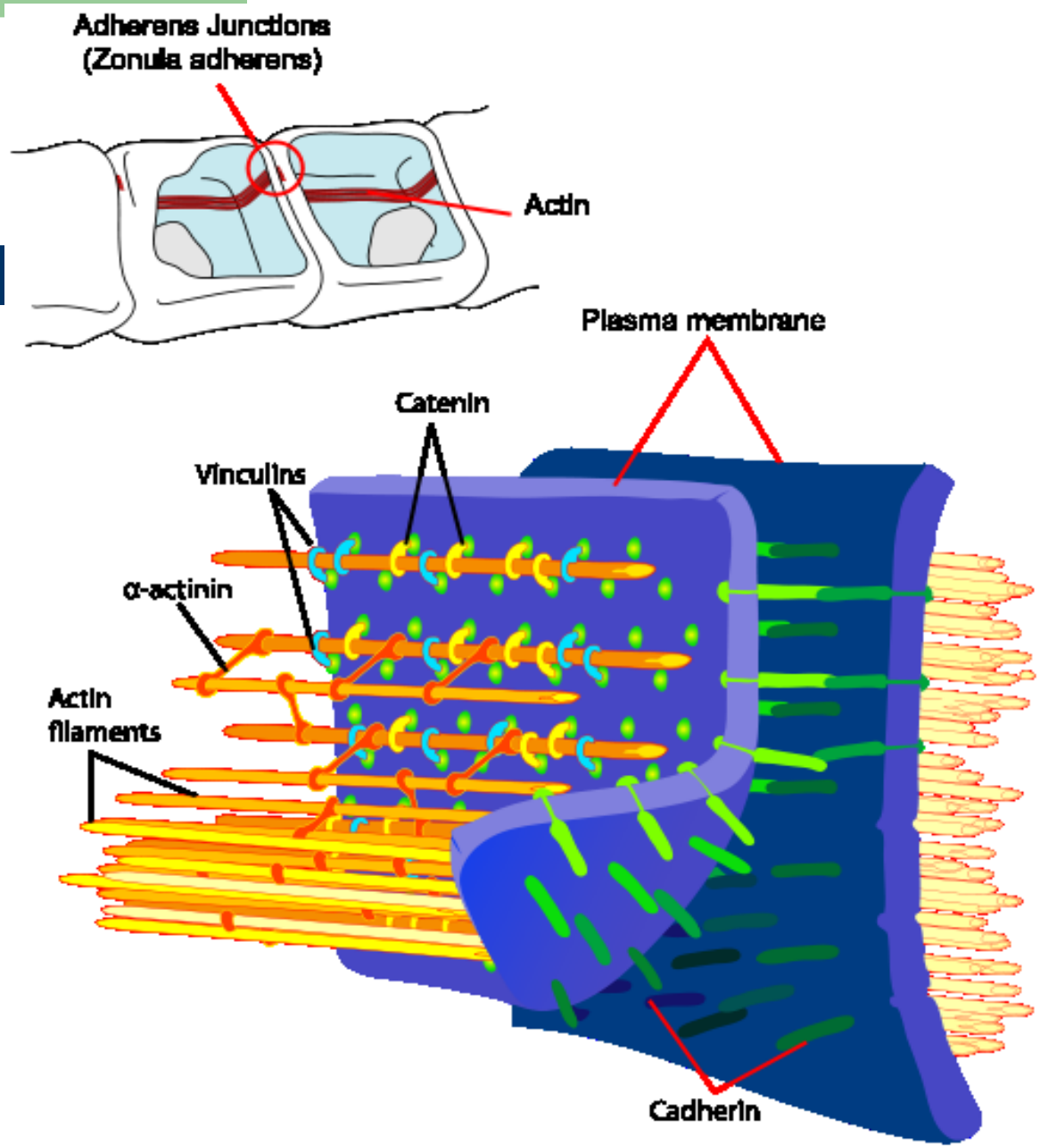
- tight=occlusive: zonula occludens
- adhesive: zonula adherens, desmosom (macula adherens)
- komunicative: nexus (gap junction)



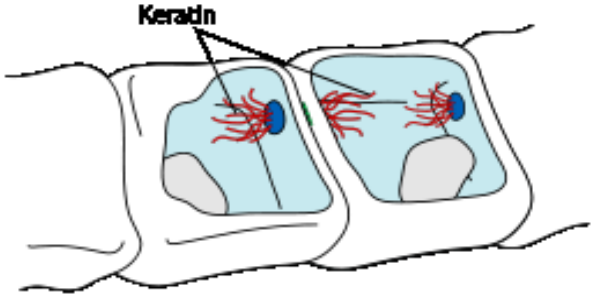
Zonula occludens

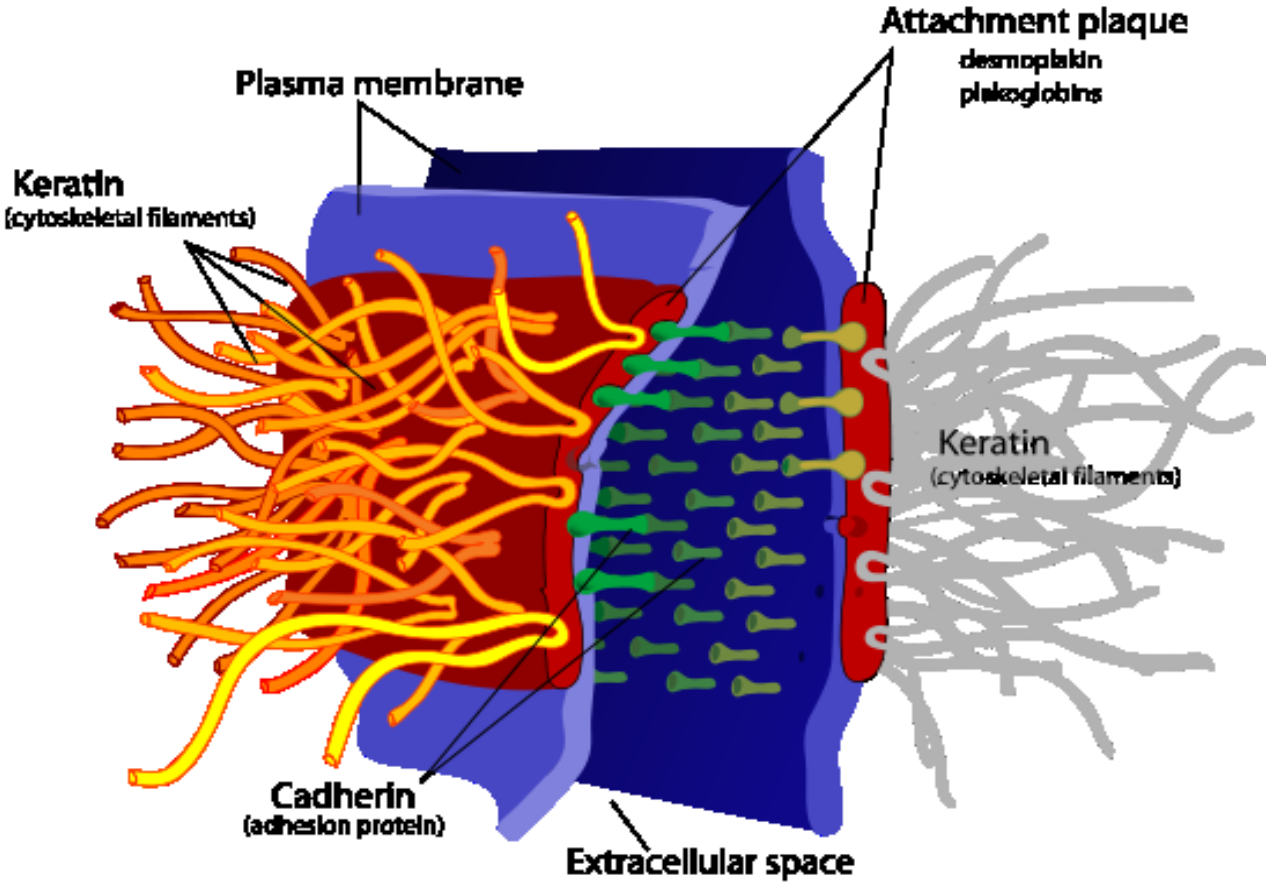


Zonula adherens

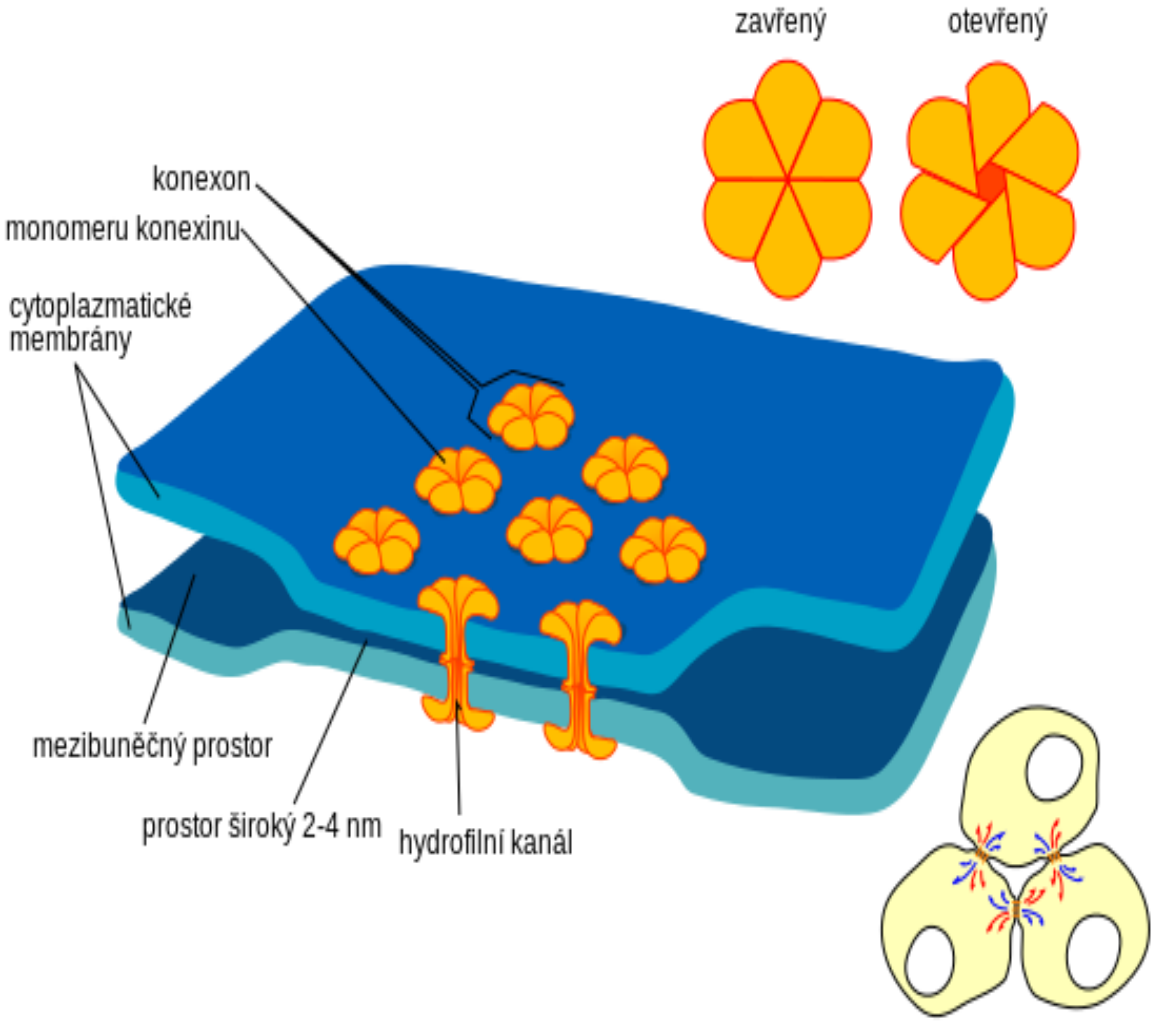


Desmosom (macula adherens)

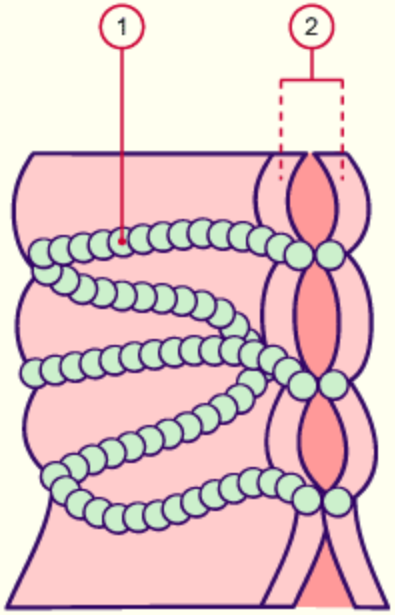


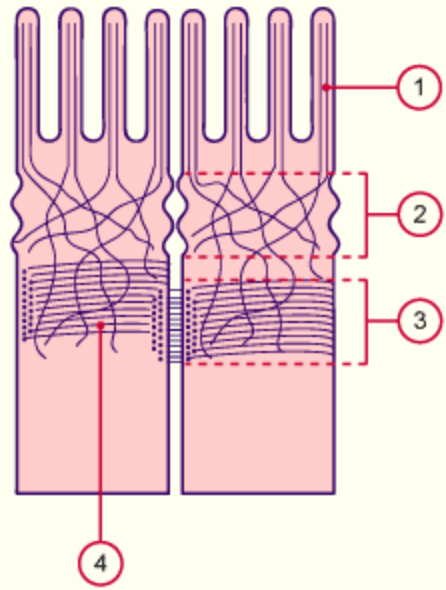


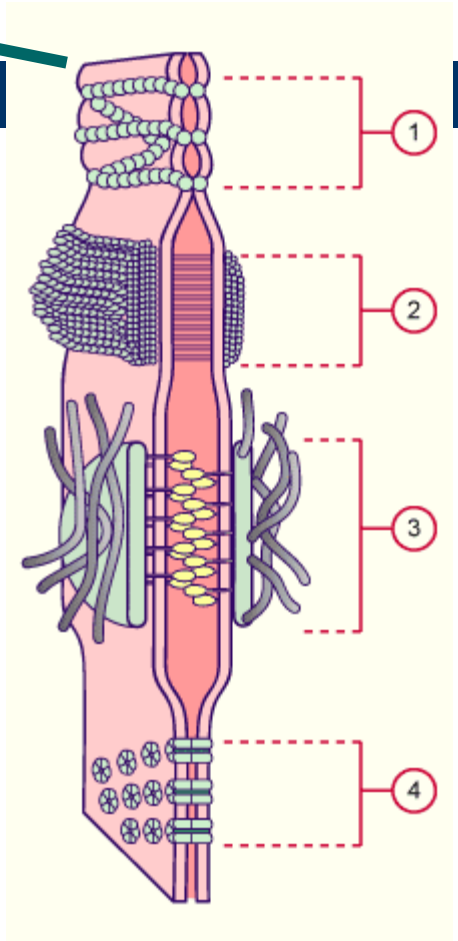
Nexus
gap junction

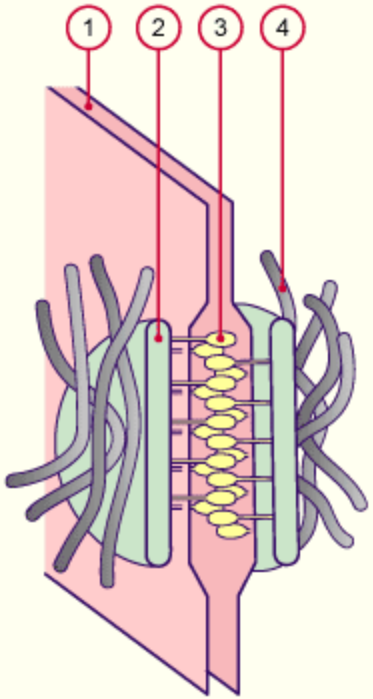


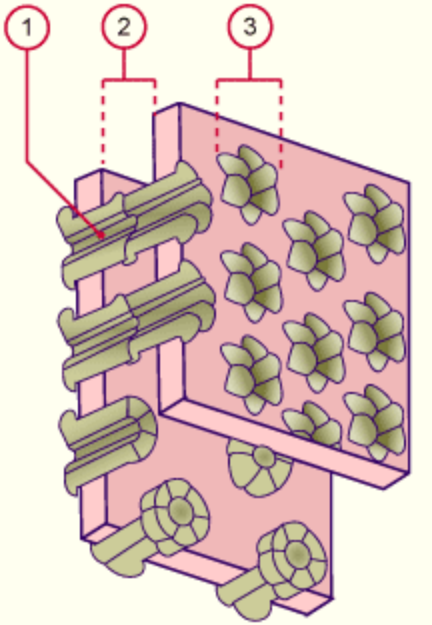
1. ZO, 2. ZA, 3.MA, 4.N

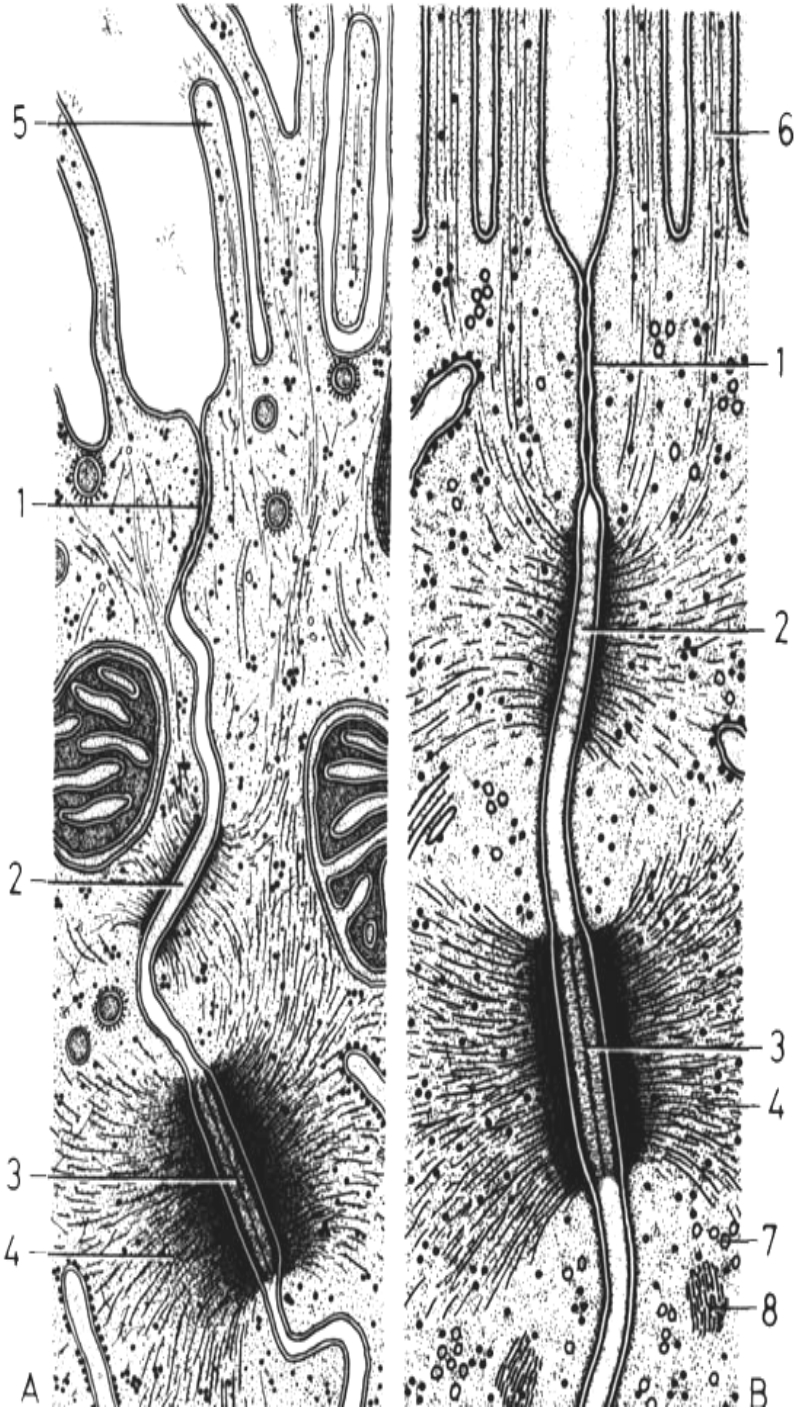








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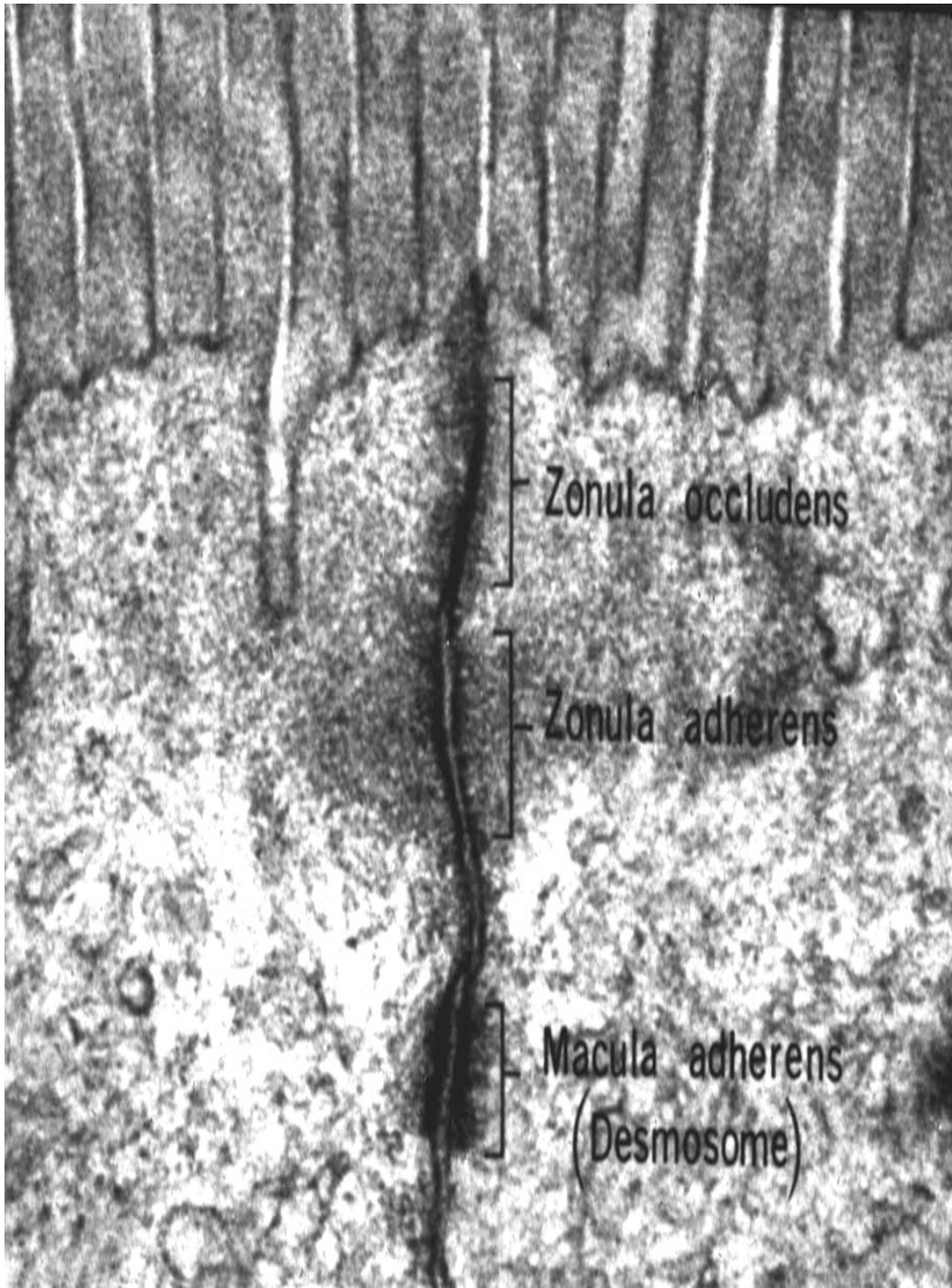
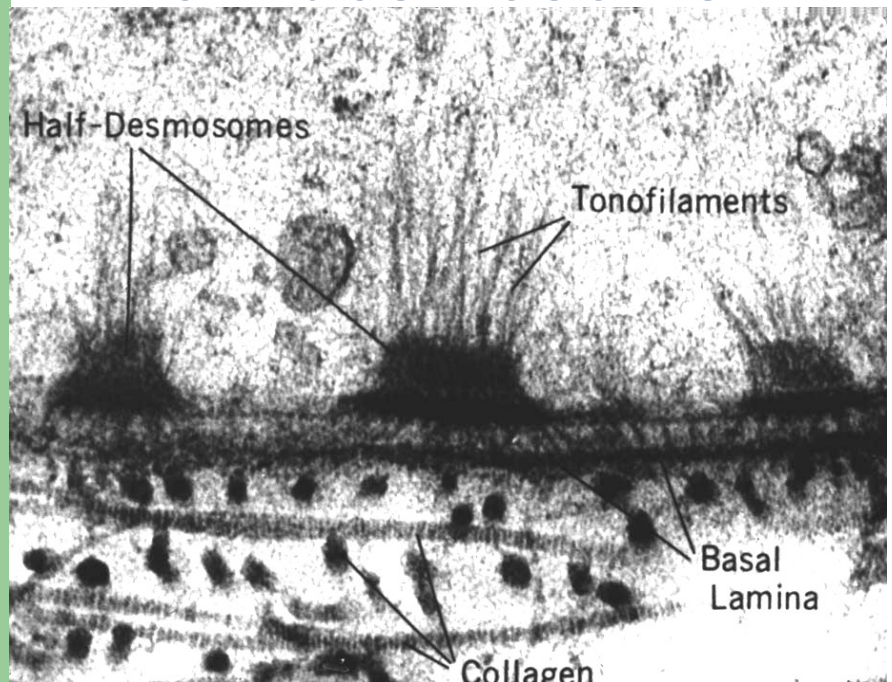
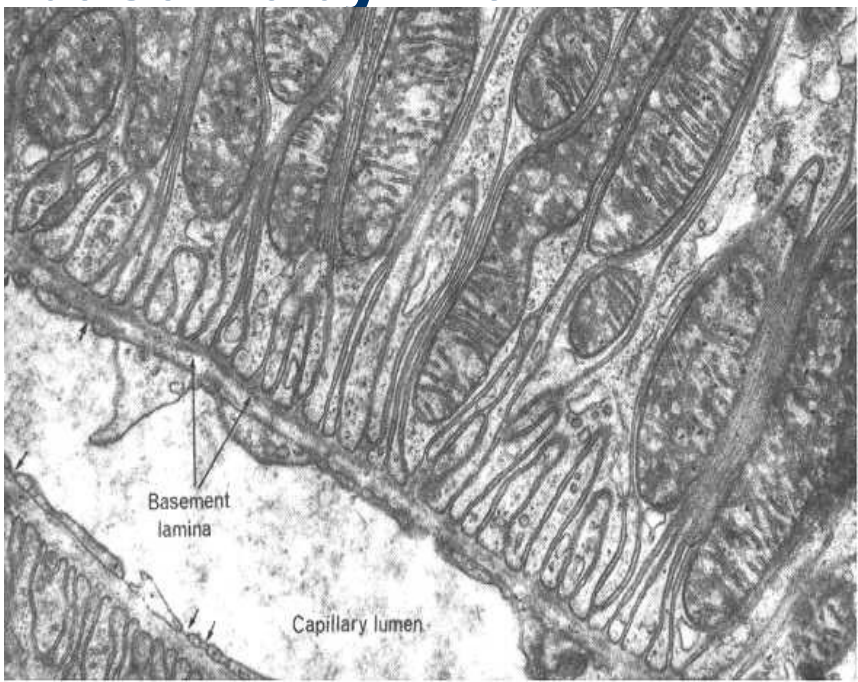

Zonula occludens
Zonula adherens
Macula adherens
(Desmosome)

Basal surface

- Turned tu non-cellular structure: lamina basalis or basement membrane

hemidesmosoms **basal labyrinth**

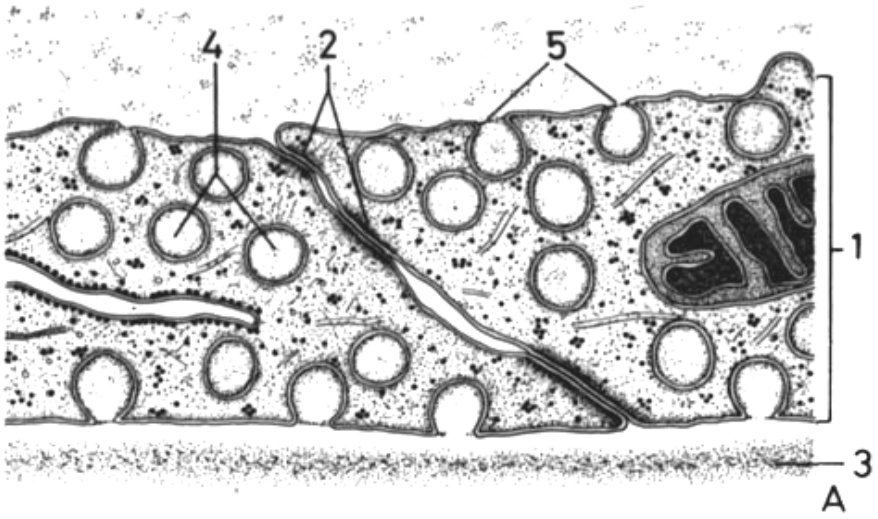


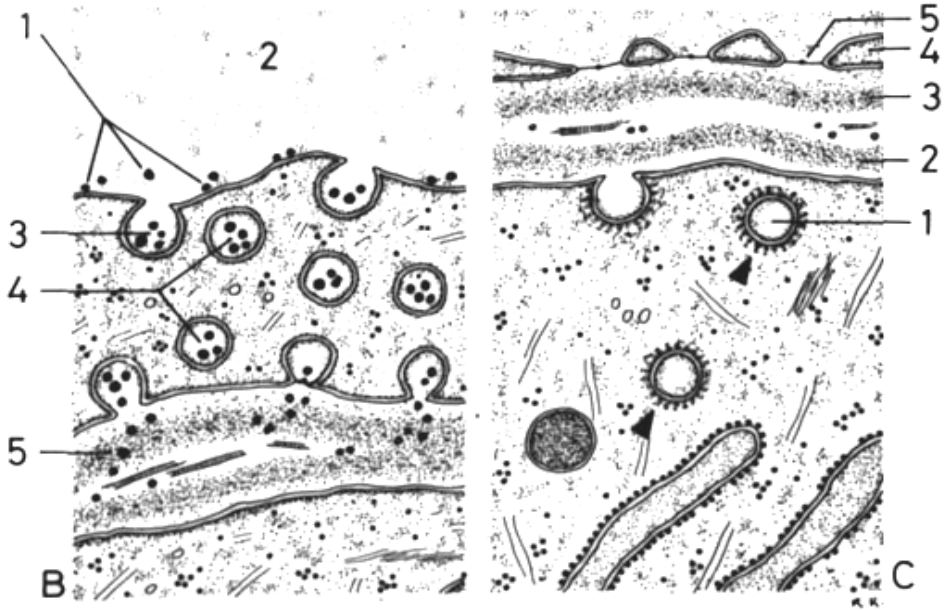


Vital manifestations of the cell

- **movement** (intracellulsrní, ameboid, with using of flagella or kinocilia)
- **metabolism** (reception, metabolism, output)
- **irritability**
- **growing**
- **reproduction – mitosis, meiosis**
- **death – apoptosis, nekrosis**

transport mechanisms





Endocytosis → phagocytosis

pinocytosis

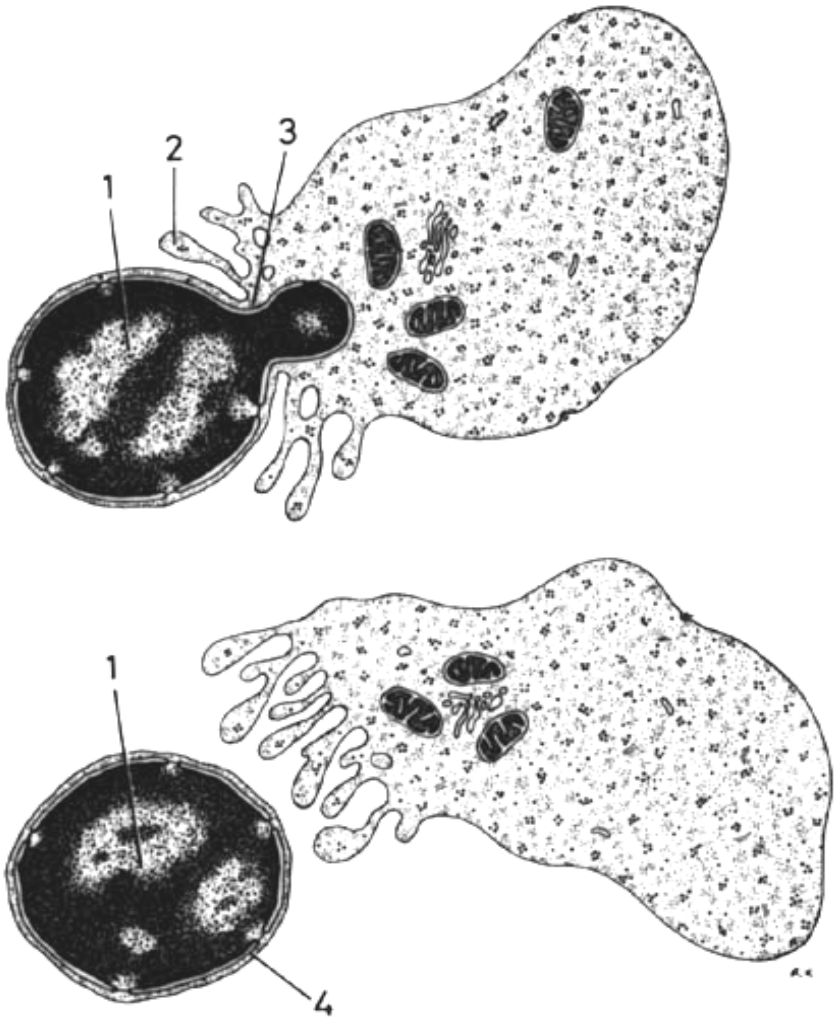
<u>nonspecif.</u> pinocytic vesicles

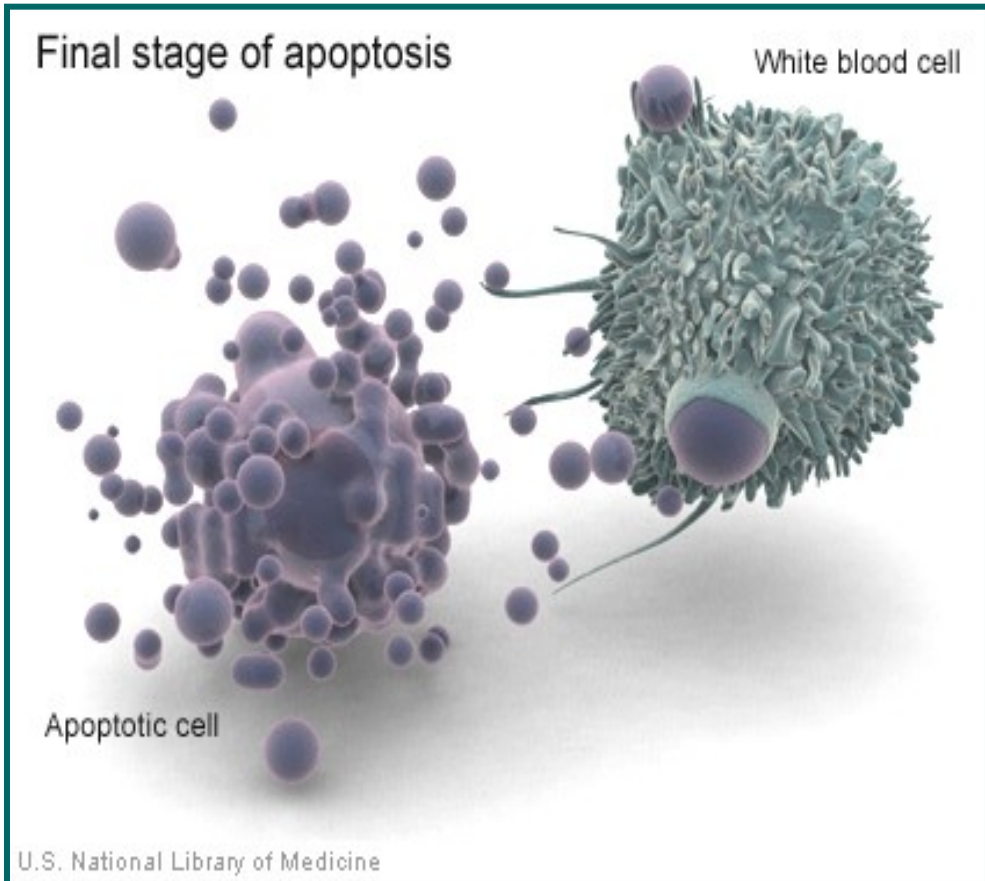
<u>specif.</u> „coated vesicles“

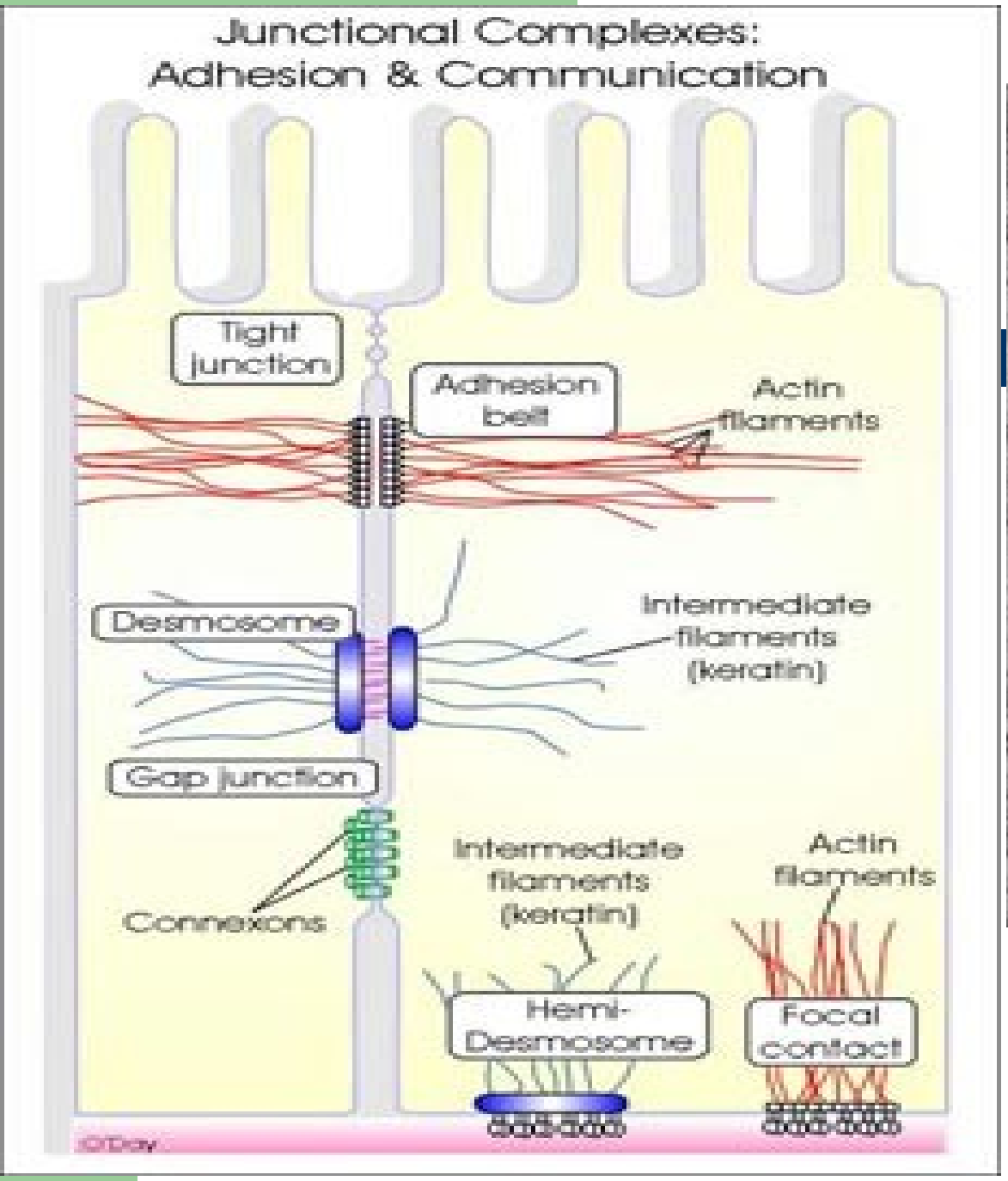
Exocytosis – secretion

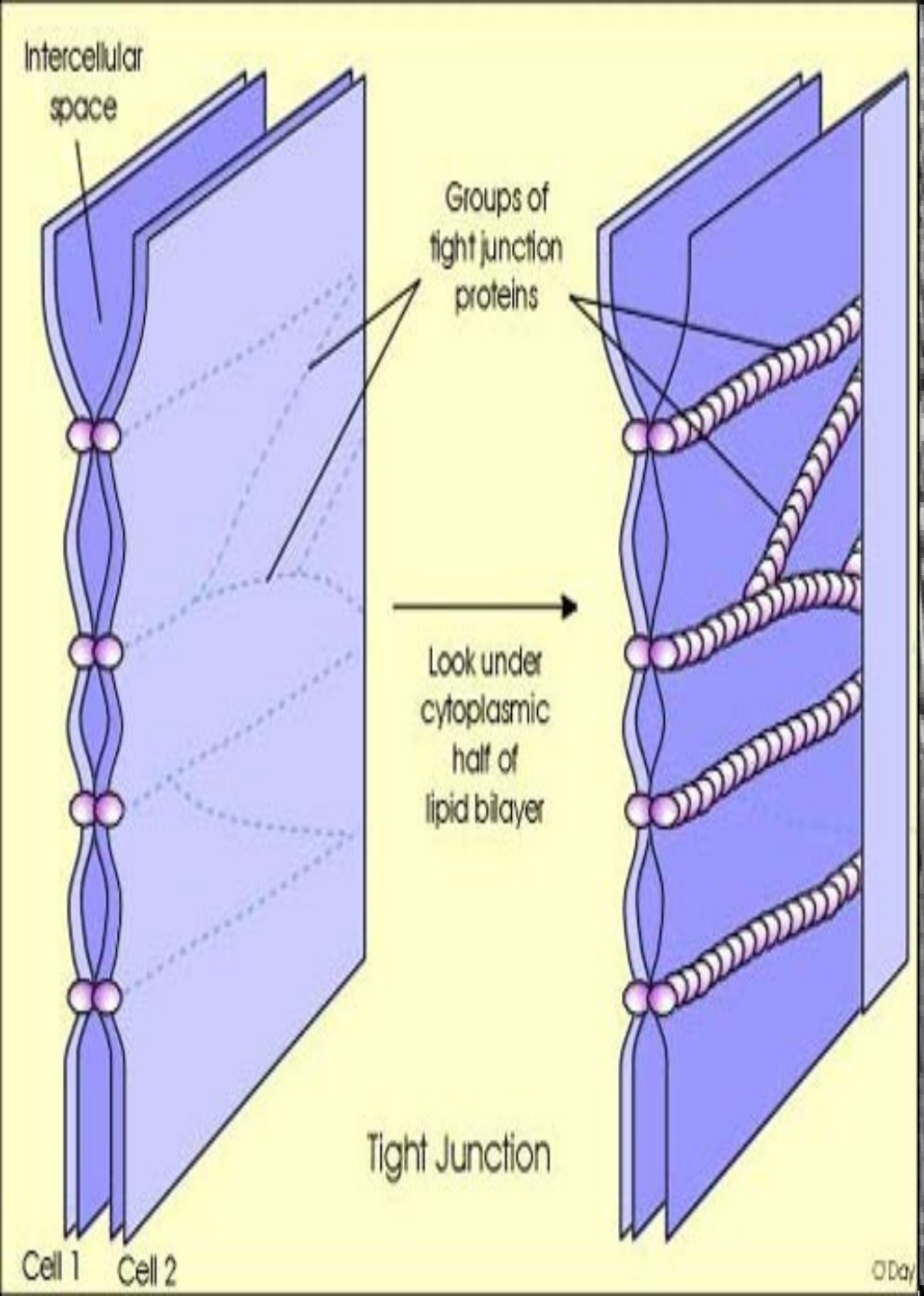
kontinuous and regulated

phagocytosis

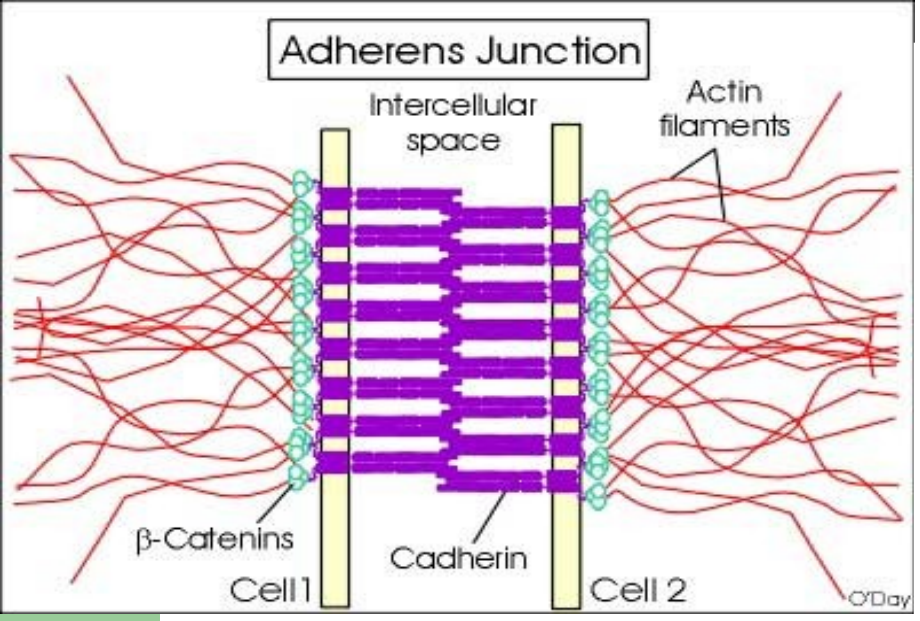





Junctional Complexes:
Adhesion & Communication
Tight junction
Adhesion belt
Actin filaments
Desmosome
Intermediate filaments (keratin)
Gap junction
Connexons
Intermediate filaments (keratin)
Actin filaments
Hemi-Desmosome
Focal contact

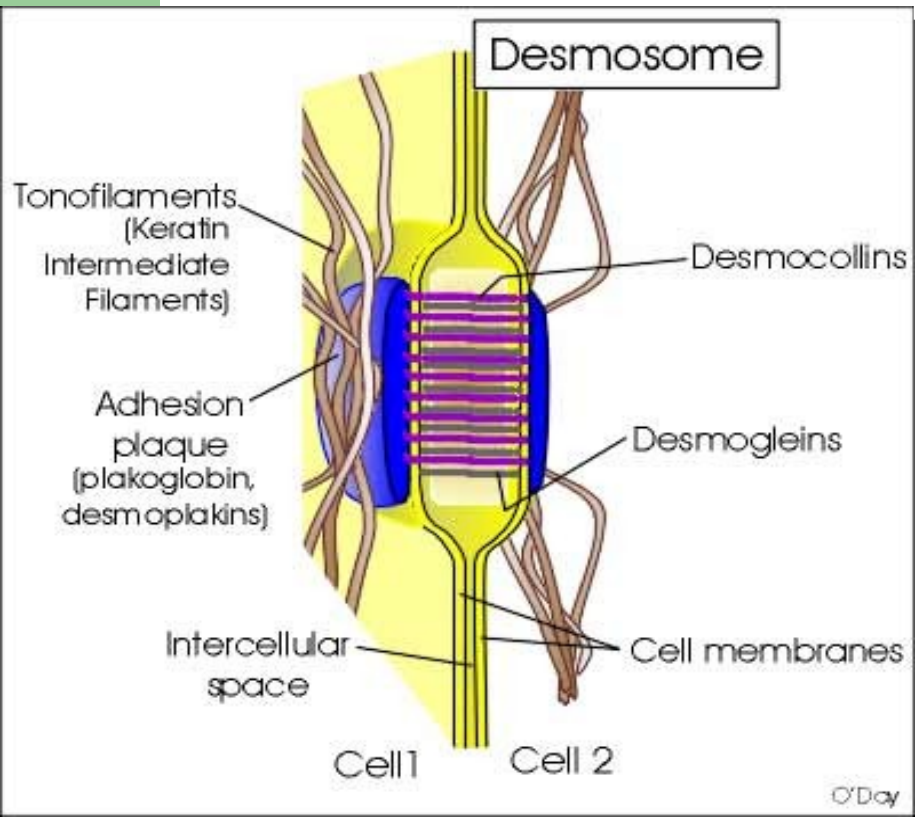

Intercellular space
Groups of tight junction proteins
Look under cytoplasmic half of lipid bilayer
Tight Junction
Cell 1
Cell 2


Tight Junction



Adherens Junctions

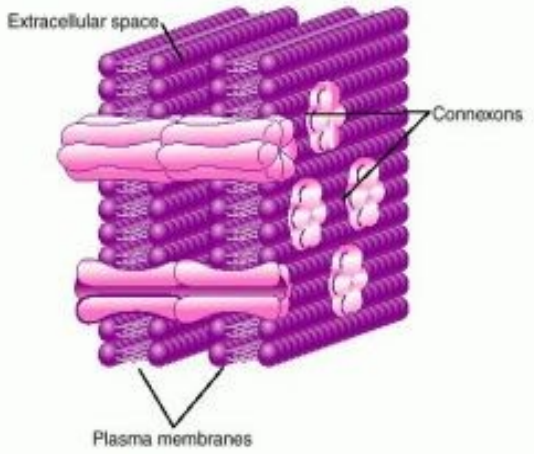
Mainly in epithelial cells
Lie just below tight junctions
Form a continuous "belt" of cadherin around cells
Cadherin binds to ß-catenins in cytoplasm
Associate with actin filaments (microfilaments) rather than intermediate filaments



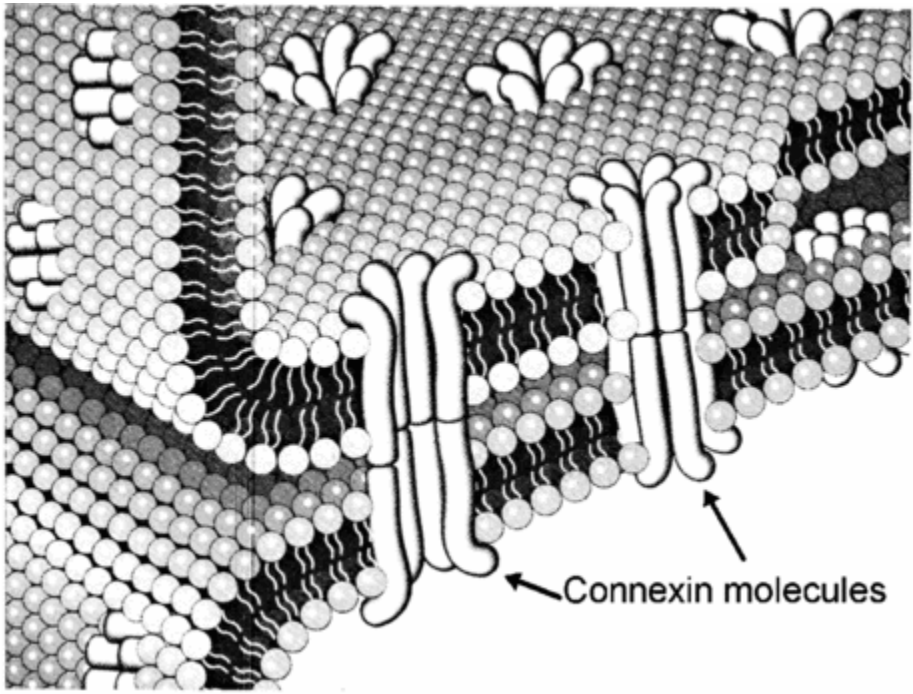
Desmosome

Desmogleins and desmocollins are desmosomal forms of cadherins. They differ in their intracellular domains. The dense plaques on the inner side of the membrane are sites where the desmoplakin and plakoglobin linker molecules link the cytoplasmic tails of the desmogleins and desmocollins to the intermediate filaments. Plakoglobin for example is very similar to ß-catenin.

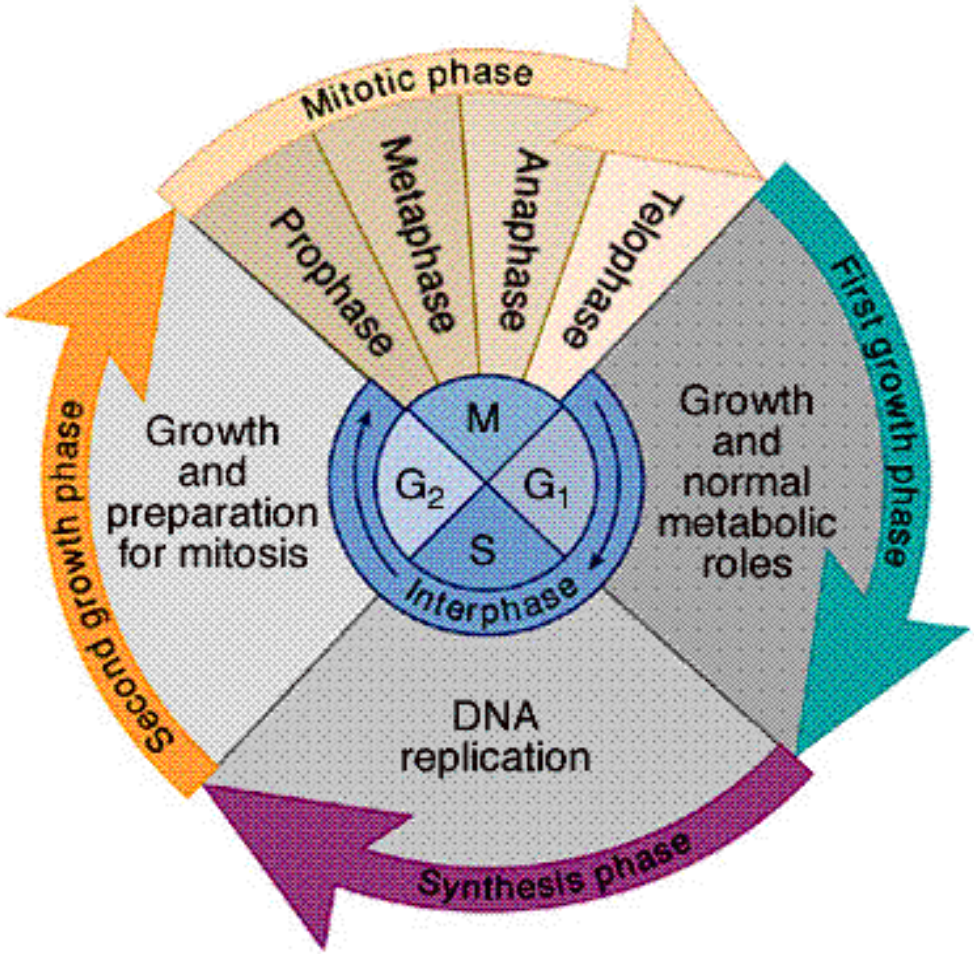
Nexus



- Intercellular cleft
  2 – 4 nm
- konexons – canals
- konexins – 6 protein.mol.



Cell cycle

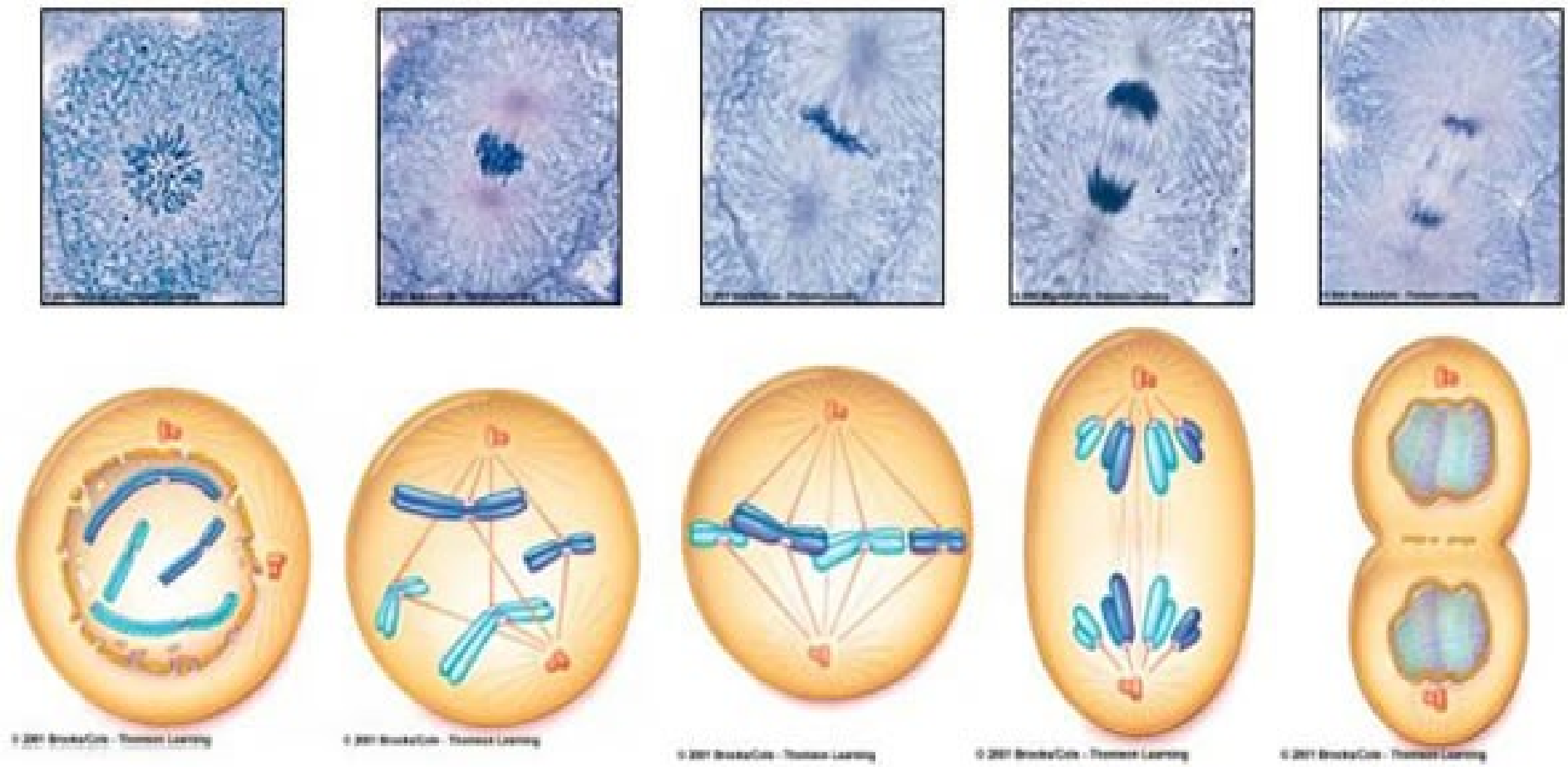


- **G_1** – phase *(time depends on the type od cell)*
- **S** – phase *(about 8 hours)*
- **G_2** – phase
- **M** – phase (mitosis) *(G_2 + M – phases = 2.5 – 3 hours)*

- ***G_0*** *– phase = stoped cycle (neurons, muscle cells)*

Mitosis

1) **Prophase**
   - disintegration of nuclear envelope and nucleoli
   - duplikation of centrioles (2 pairs + mitotic spindle)
   - condensation and spiralisation of chromosomes
2) **Metaphase**
   chromosomes – in equatorial plane
   mitotic spindle – connected with chromosome centromeres
3) **Anaphase**
   separation of chromosomes in centromeres
   spindle microtubules shortening – chromosomes migrate to poles of the cell.
4) **Telophase**
   despiralisation of chromosomes, reconstruction of nuclear envelope and nucleoli, beginning of cytokinesis.



Prophase:
Chromosomes Condense

Prometaphase:
Chromosomes Attach

Metaphase:
Chromosomes align

Anaphase:
Chromosomes separate

Telophase:
Chromosomes relax

Meiosis

reduction division of gametes

Principle of meiosis: two immediately following reducing divisions; synthesis (repliction) of DNA does not occured between them

The 1st meiotic division – reduction of chromosomes:
result – haploid cell 23 + 2n

The 2nd meotic division – reduction of DNA:
result – haploid cell 23 + 1n

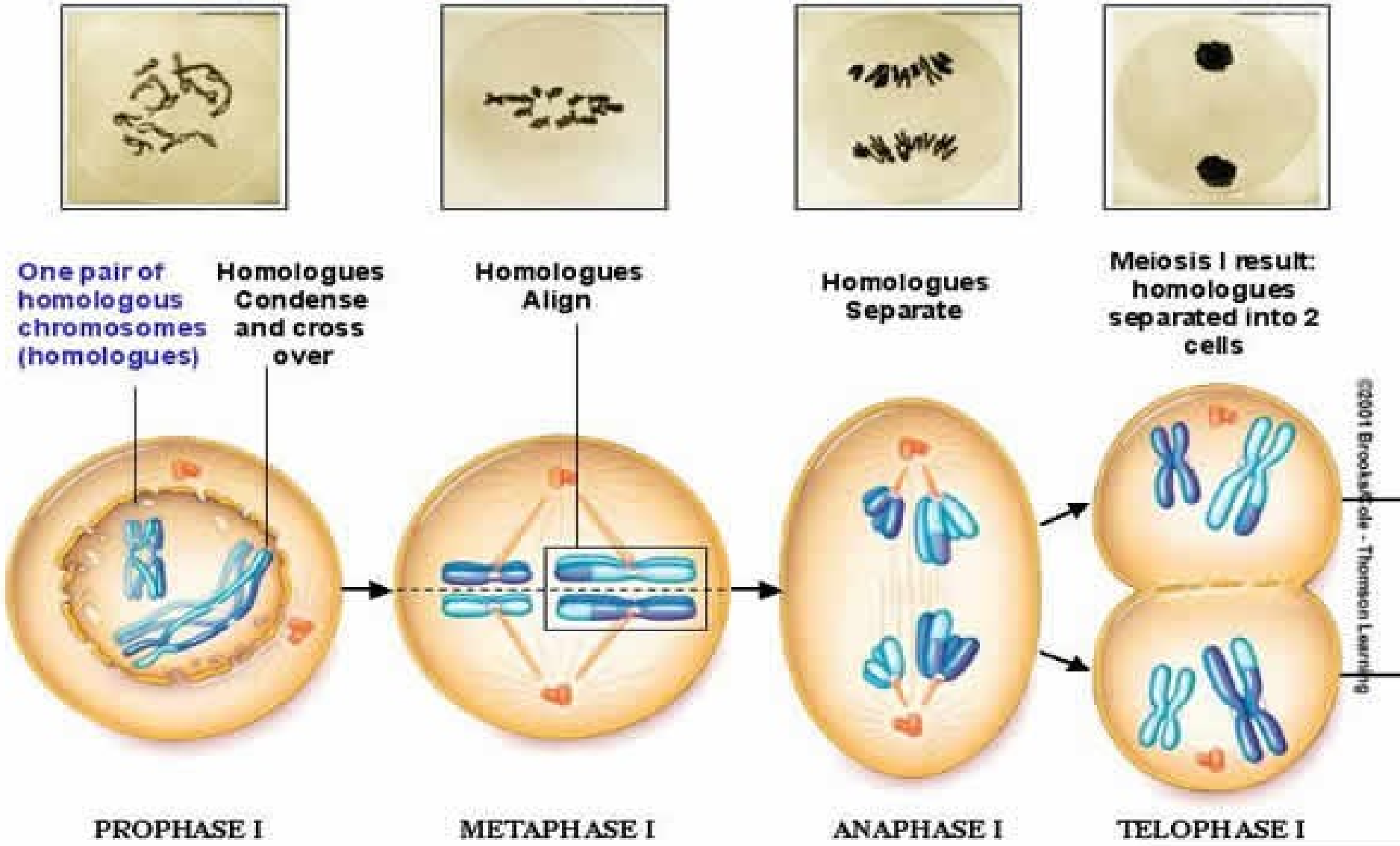
Somatic cell is **diploid**: 46 + 4n

Gametes are **haploid**: 23 + 1n

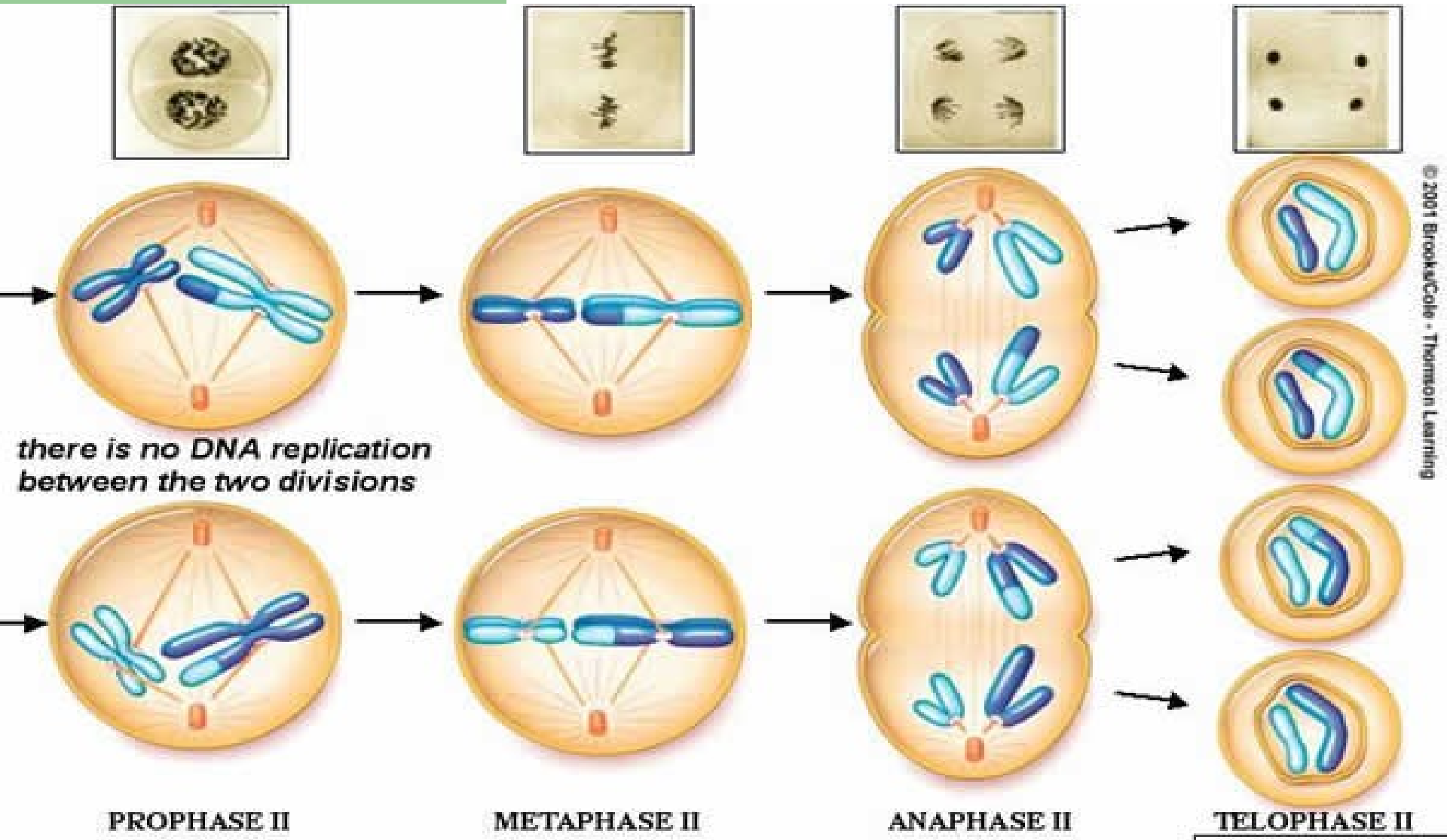
Meiosis

1. Meiotic division – long prophase I:
Leptotene – condensation of chromosomes
Zygotene – pairing of homologous chromosomes - bivalents
Pachytene – chromatids = tetrads, crossing-over
Diplotene – dehiscence of tetrads, chiasmats – regions with crossing-over
Diakinesis – disappearance (terminalisation) of chiasmats, disintegration of nuclear envelope, end of prophase

Meta-, ana-, telo-phase



MEIOSIS I: Separate the Homologues



MEIOSIS II: Separate the Sister Chromatids (by mitosis)

Comparison of mitosis and meiosis

- **Mitosis**
- rise of diploid cell
- daughter cells are identic with mother
- mother cell

↓

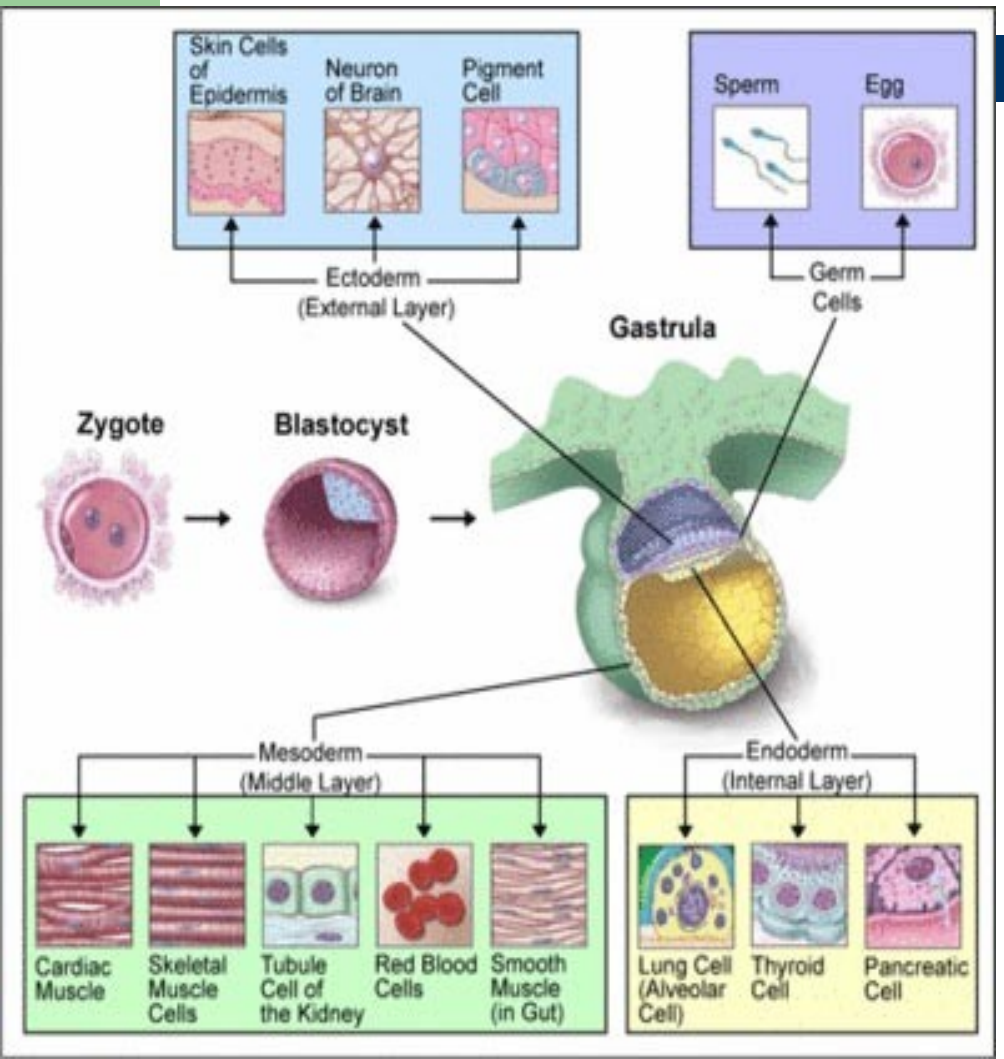
2 daughter cells

- **Meiosis**
- rise of haploid cell
- crossin-over
- gametogonia (1 cell):

spermatogonia → 4 sperms (2X, 2Y)

oogonia → 1 oocyte + 2-3 polar bodies

Differentiation of the cells



- Specialization of the cells (biochemical, morfological and functional) realized by sequntional gene expression *(transformation of nedifferentiated cells – totipotent cells – into specialized types of cells)*
- Role of signals from cell neighbourhood = reciprocal cell interactions in multicellular organism or tissue

Thanks for your attention ☺