Lysosomes, Peroxisomes and Centrioles

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Outline

- Lysosomes
  - Endosomes
  - Molecule transport to the lysosomes
    - Endocytosis
    - Exocytosis
    - Autophagy
- Vacuoles
- Peroxisomes
- Centrioles

Lysosomes

- Lysosomes are spherical organelles
- They are produced in the Golgi apparatus
- They are only found in eukaryotic cells:
  - animal cells but rarely in plant cells
- They account for 1-15% of cell volume (most abundant in liver and kidney)
- Their shape vary depending on the material digested
- The size of lysosomes varies from 0.1–1.2 µm

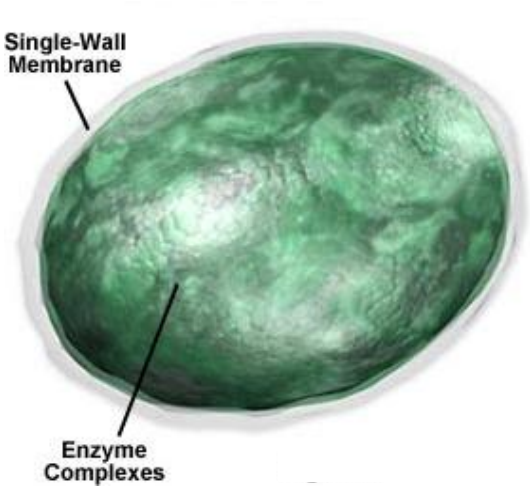
Lysosomes

- Lysosomes contain about 40-50 types of hydrolytic enzymes
- These enzymes are produced by rough endoplasmic reticulum
- Some examples of these enzymes:
  - Lipase digests lipids
  - Amylase digests carbohydrates
  - Proteases digest proteins
  - Nucleases digest nucleic acids

Lysosomes

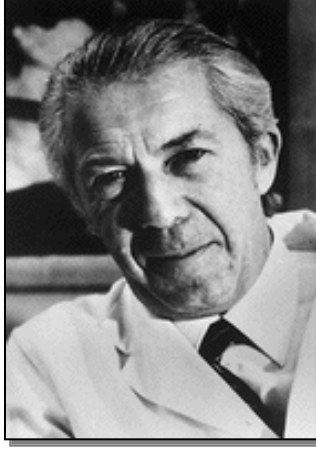
- For optimal activity of lysosomes and the enzymes they contain, they require an acidic environment (pH 4.5-5.0) in its interior.
  - The contents of the cytosol are protected against attack by the cell's own digestive system: the membrane of the lysosome keeps the digestive enzymes out of the cytosol.

Structure of Lysosome



- Spherical bag-like shape
- Single layer membrane
- Membrane functions as a protective barrier that protects the rest of the cells from enzymes found within the lysosomes
- The membrane contains
  - transport systems to carry particles between lumen and organelle
  - an electrogenic proton pump
  - several membrane proteins: highly glycosylated, which helps to protect them from the lysosomal proteases in the lumen

1974 Nobel Prize: Christian de Duve Lysosome Discovery



- In 1955, Belgian scientist Christian de Duve observed that the cells released an enzyme much larger amounts when they were repeatedly frozen and thawed before centrifugation
- de Duve suggested that the digestive enzyme must be placed in a membrane-bound organelle
- He defined this organelle as: lysosomes; spherical organelles contained by a single layer membrane, though their size and shape vary to some extent.
- The name ‘lysosome’ was given because of these enzymes' ability to "lyse" the cell

Why do cells need lysosomes?

- Intracellular and extracellular digestion of macromolecules.
  - Lysosomes contain hydrolytic enzymes that break up food for digestion
  - They use endocytosis or phagocytosis
- They form a chain that is responsible for
  - the trafficking and digestion of endocytosed molecules
  - the digested food can then diffuse through the vacuole membrane and enter the cell to be used for energy or growth
  - participate actively in sorting and recycling

Why do cells need lysosomes?

Digestion of macromolecules:

Transport of macromolecules to the lysosome

A "road-map" of the biosynthetic-secretory and endocytic pathways

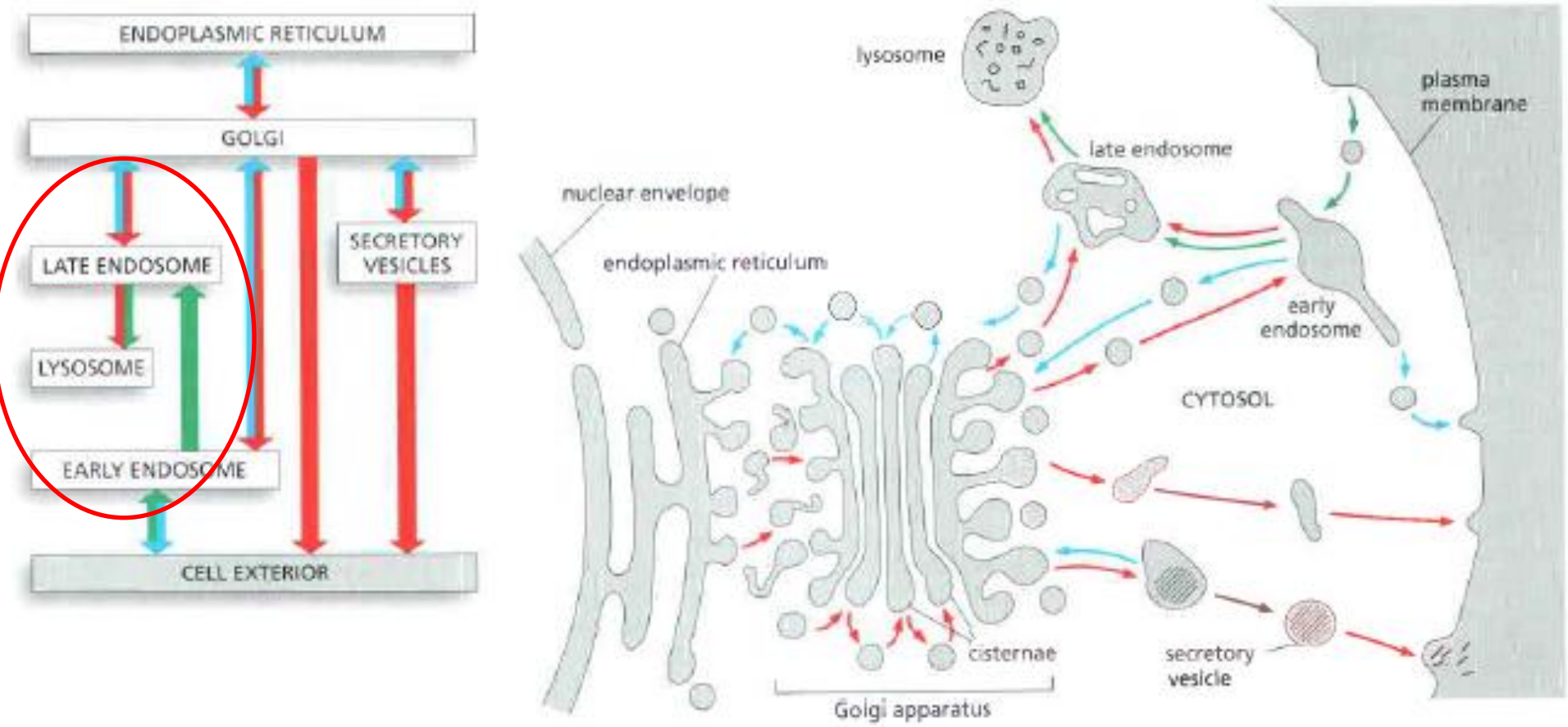


Figure 13-3 A "road-map" of the biosynthetic-secretory and endocytic pathways

Transport of macromolecules to the lysosome

- The materials being digested may be extracellular or intracellular
- Extracellular materials enter the cell either by endocytosis or phagocytosis

Transport of macromolecules to lysosome: Endocytosis

- **Endocytosis**: cells remove plasma membrane components and deliver them to internal compartments
  - Cells take up proteins by invaginating the plasma membrane
- Two main types
  - Differ according to size of the endocytic vesicle formed
- Phagocytosis
- Pinocytosis

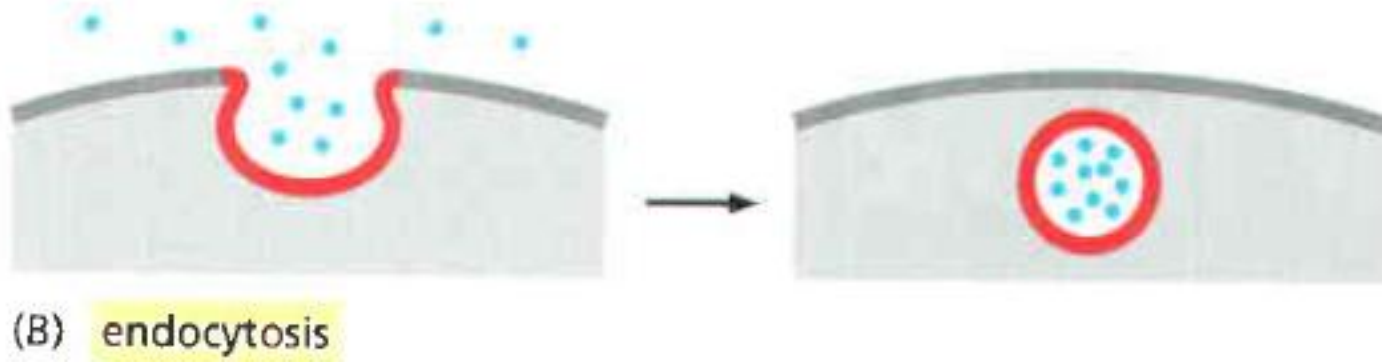
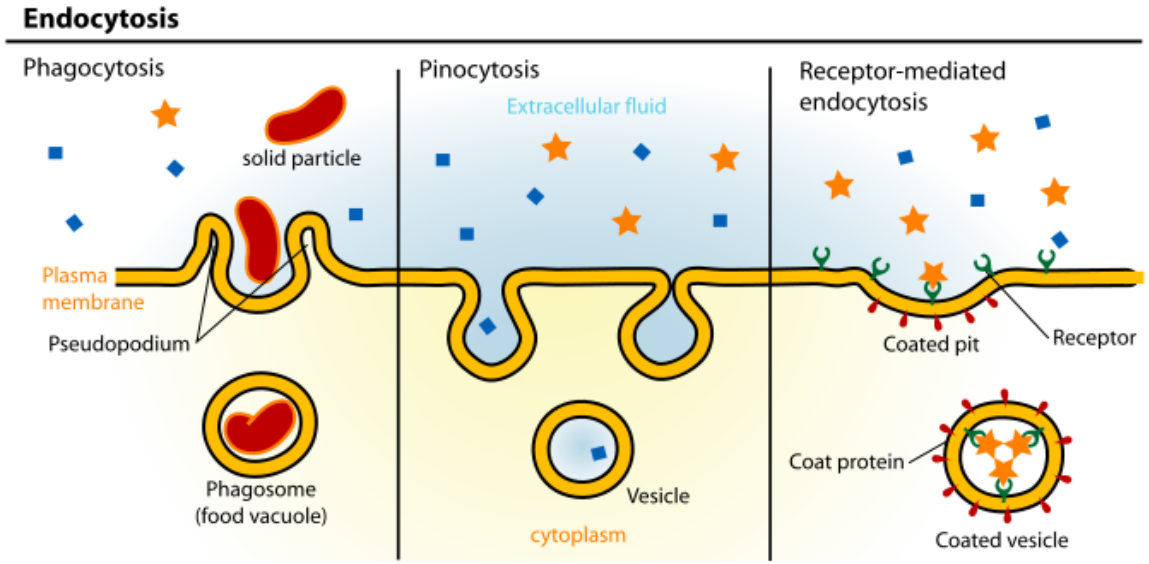


Figure 13-1 Exocytosis and endocytosis. Molecular Biology of the Cell, 5th ed.

Transport of macromolecules to lysosome: Phagocytosis

- Phagocytosis: cell eating
  - cell uses large endocytic vesicles (phagosomes) to ingest large particles
  - eg. Microorganisms and dead cells
- Pinocytes: cell drinking
  - uptake of extracellular fluid through endocytosis



Transport of macromolecules to the lysosome: Endosomal–Lysosomal System

- Materials are delivered
  - to the early endosome,

    situated at the cell peripher
  - then to the late endosome,

    which is perinuclear
  - then to the lysosome

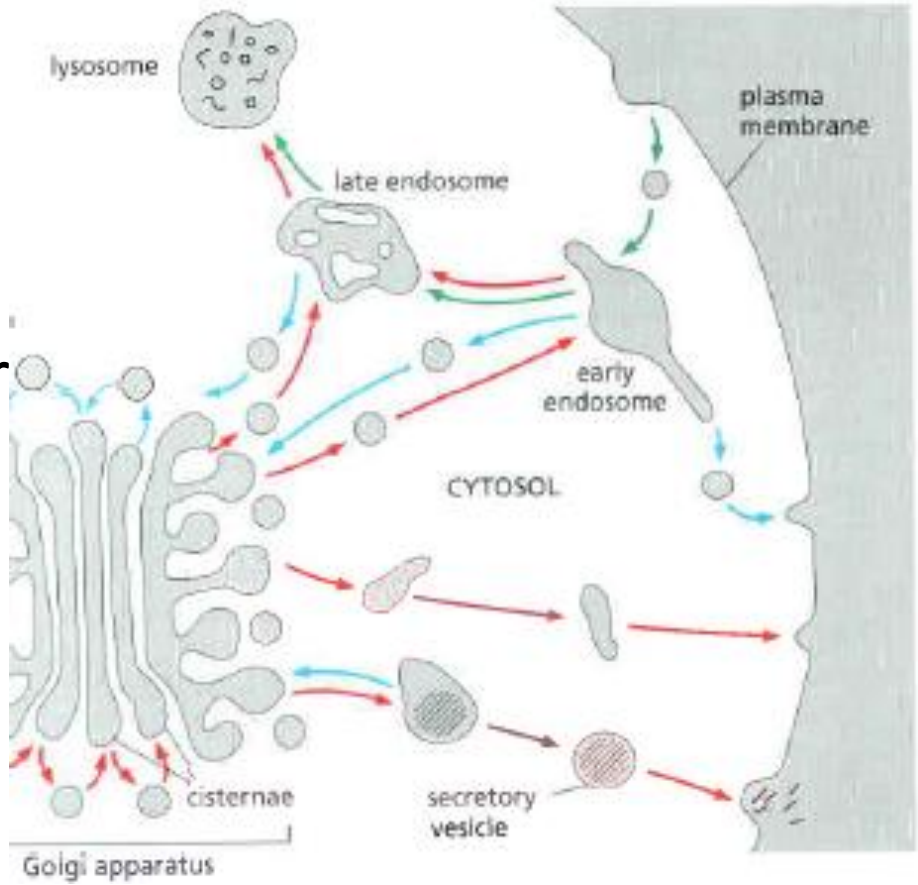
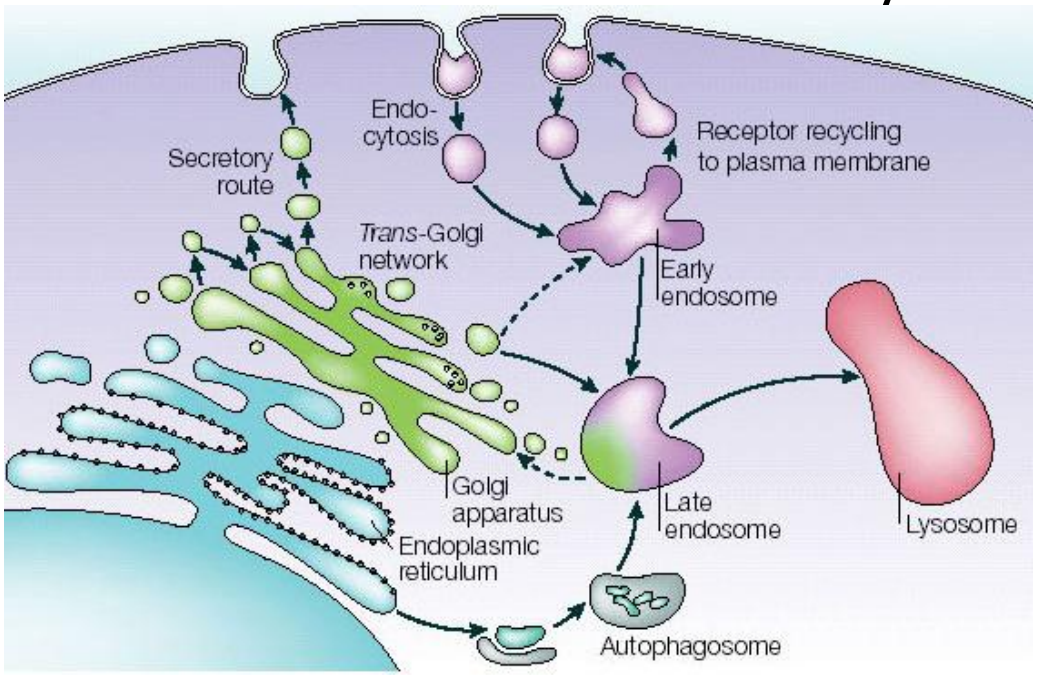


Figure 13-3 A "road-map" of the biosynthetic-secretory and endocytic pathways

Transport of macromolecules to the lysosome: Endosomal–Lysosomal System

- Late endosomes contain materials from both the plasma membrane by endocytosis and newly synthesized lysosomal hydrolases and therefore they resemble lysosomes.
- Late endosomes fuse with pre-existing lysosomes to form structures that are sometimes called endolysosomes



Transport of macromolecules to the lysosome: Endosomal–Lysosomal System

- When the majority of the endocytosed material within an endolysosome is digested and only resistant or slowly digestable residues remain, they become "classical" lysosomes.
- They can enter the cycle again by fusing with late endosomes or endolysosomes.
- Thus no distinction between late endosomes and lysosomes: they are the same except that they are in different stages of a maturation cycle.
- For this reason lysosomes are viewed as a heterogeneous collection of distinct organelles

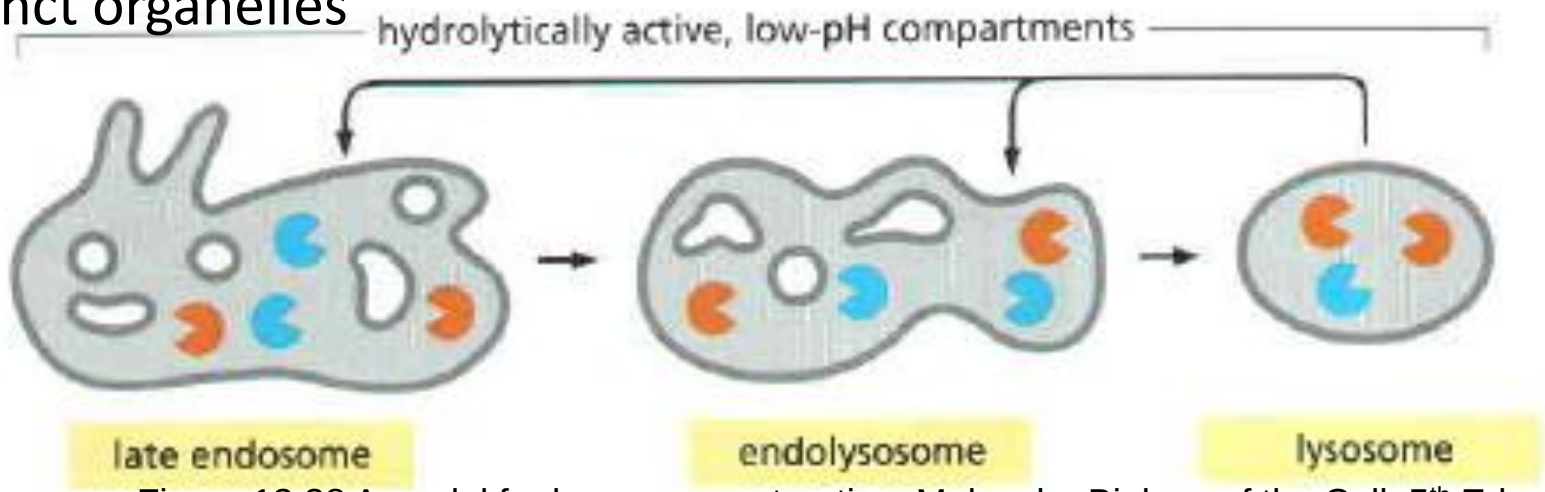


Figure 13.38 A model for lysosome maturation. Molecular Biology of the Cell. 5th Ed.

Endocytosis: from plasma membrane to lysosome

- Maturation of early endosome to late endosome occurs through the formation of multivesicular bodies
- Multivesicular bodies move inward along microtubules that recycle components to the plasma membrane.
- They gradually convert into late endosomese by fusing with each other or by fusing with preexisting late endosomes

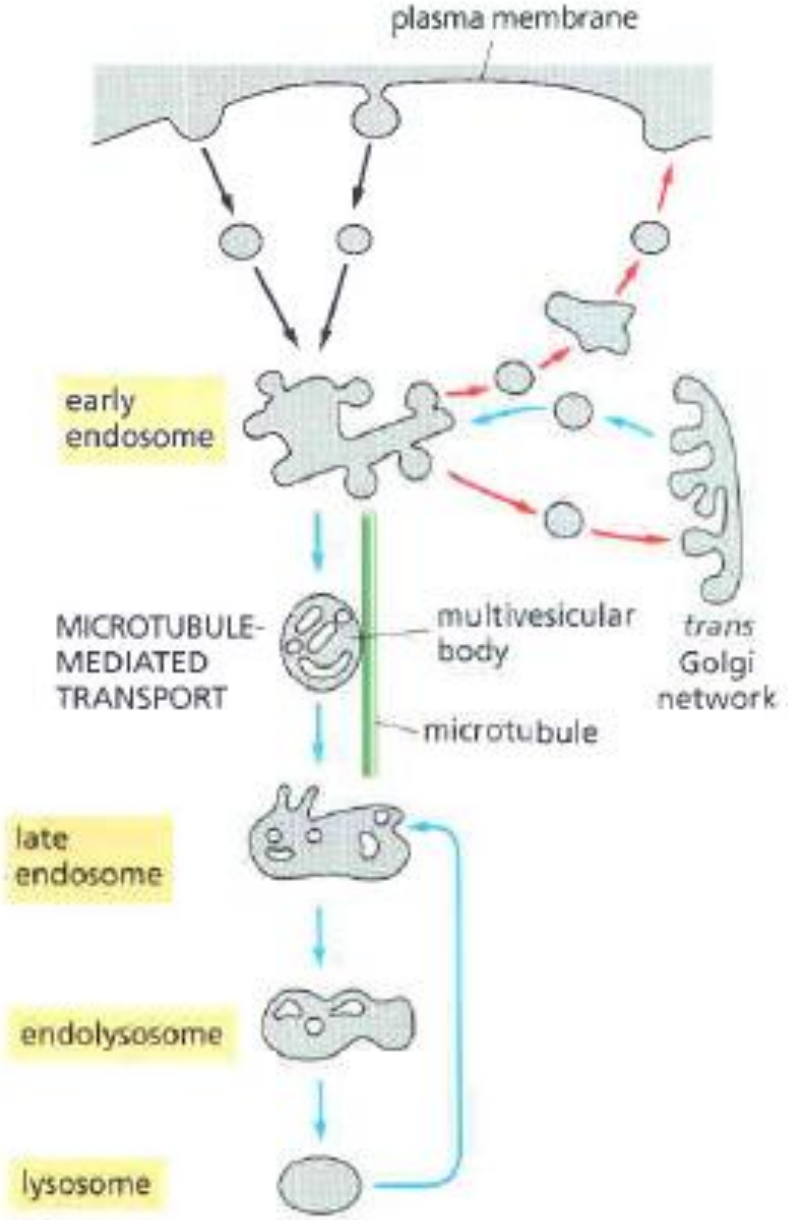


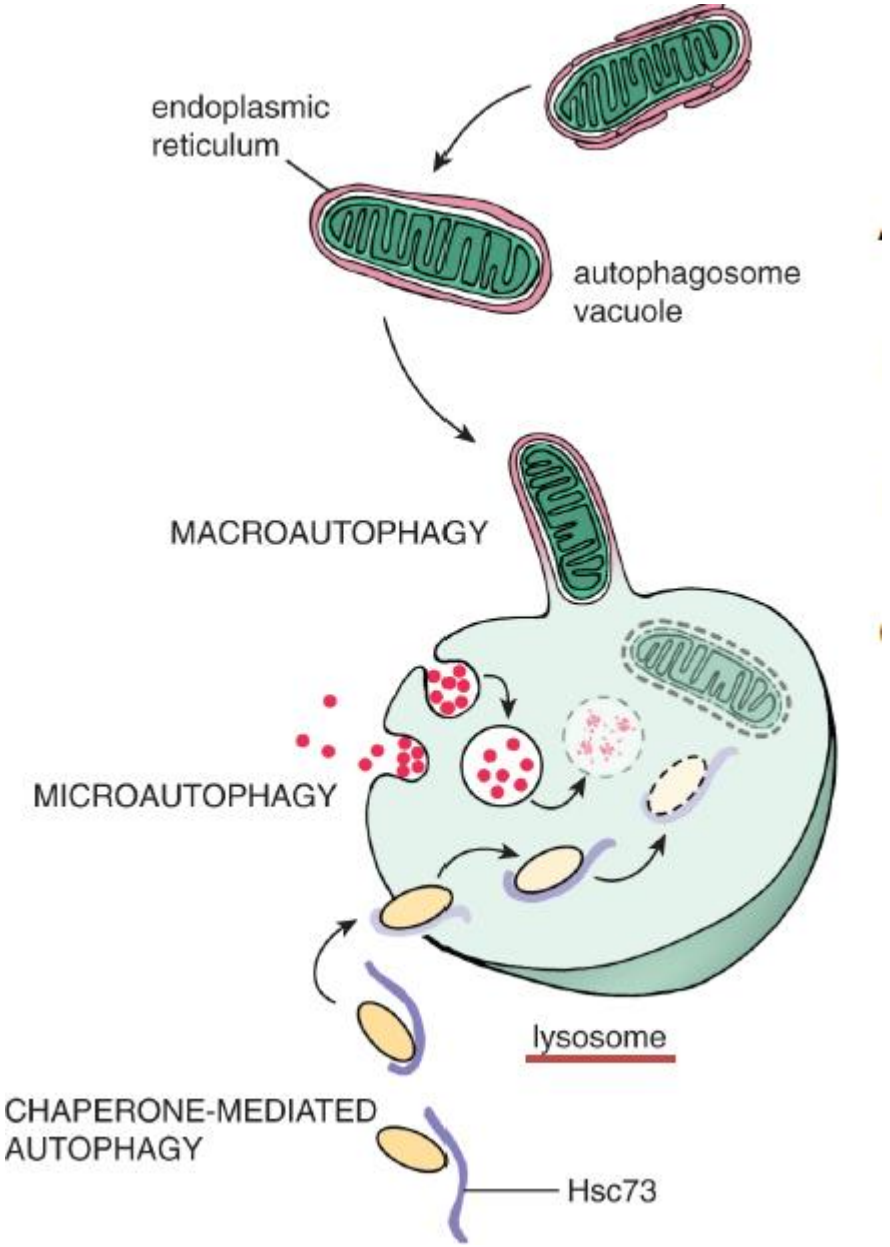
Figure13-56 Details of the endocytic pathway from the plasma membrane to lysosome

Why do cells need lysosomes?

Autophagy & Cell Death

Why do cells need lysosomes?

- Autophagy & Cell Death:
  - digesting internal parts of the cell, such as organelles
- Microautophagy
  - cytoplasm is segregated into membrane -bound compartments and are then fused to lysosome
- Macroautophagy
  - entire organelles such as mitochondria, ER and other large cytoplamic entities are engulfed and then fused with the lysosome



Lysosomes: Autophagy

1) Nucleation and extension of a delimiting membrane into a crescent-shaped structure that engulfs a portion of the cytoplasm
2) Closure of the autophagosome into a sealed double-membrane-bounded compartment
3) Fusion of the new compartment with lysosomes
4) Digestion of the inner membrane of the autophagosome and its contents

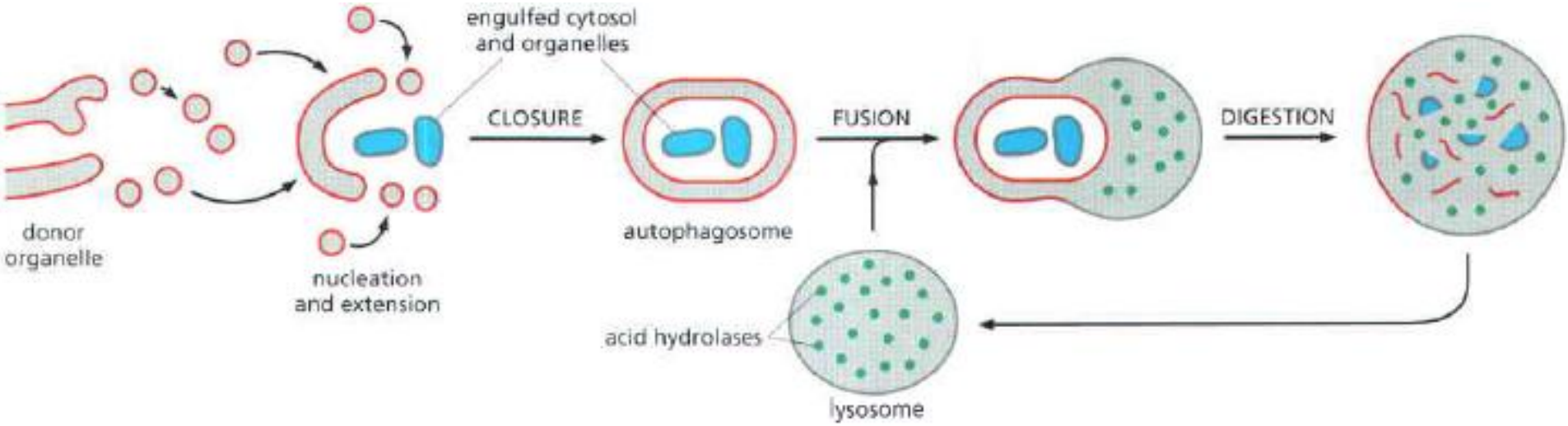


Figure 13-41 A model of autophagy. Molecular Biology of the Cell. 5th Ed.

Lysosomal Degradation: Overview

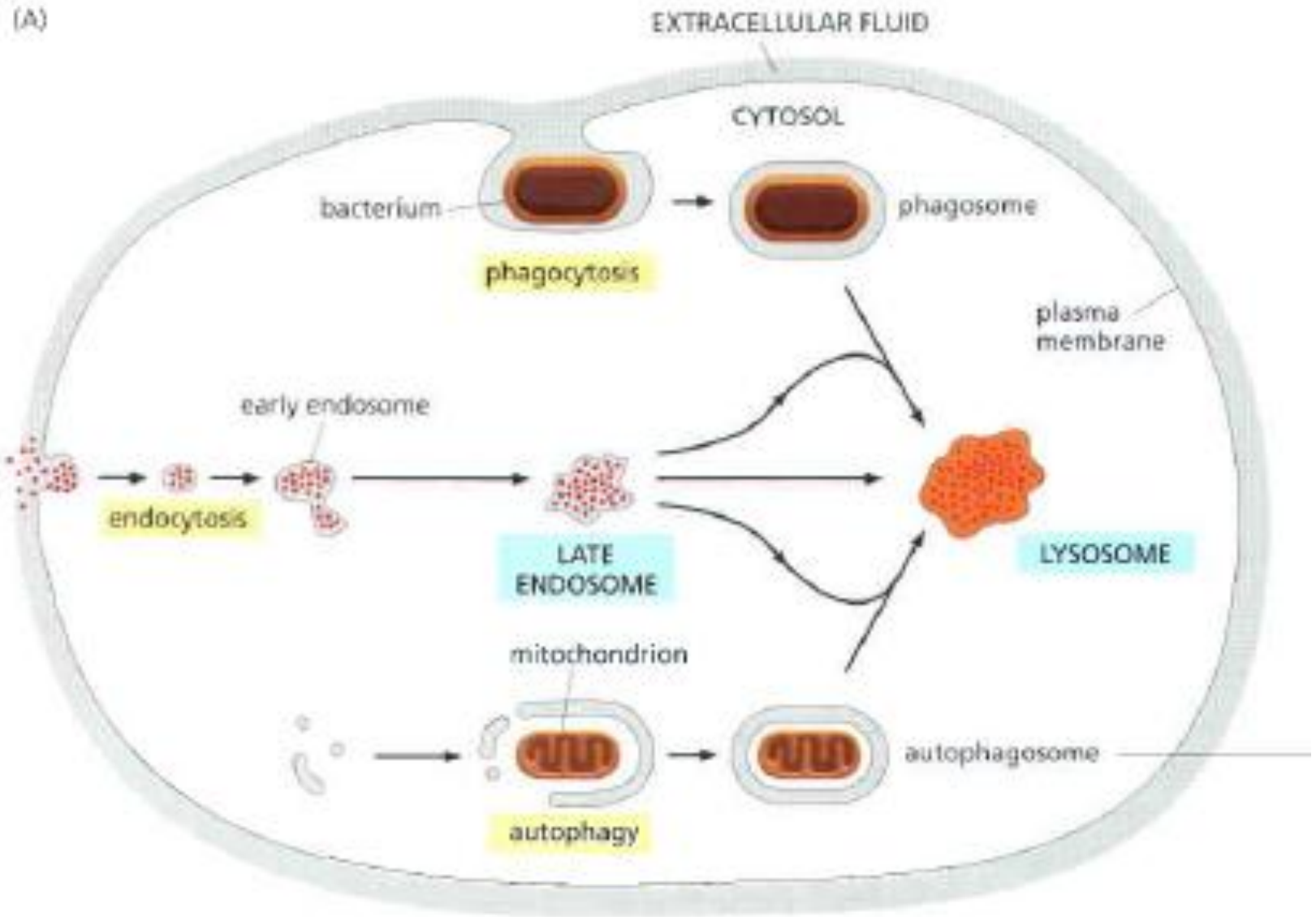


Figure 13-42 Three pathways to degradationin lysosomes. Molecular Biology of the Cell. 5th Ed.

Lysosomal Degradation

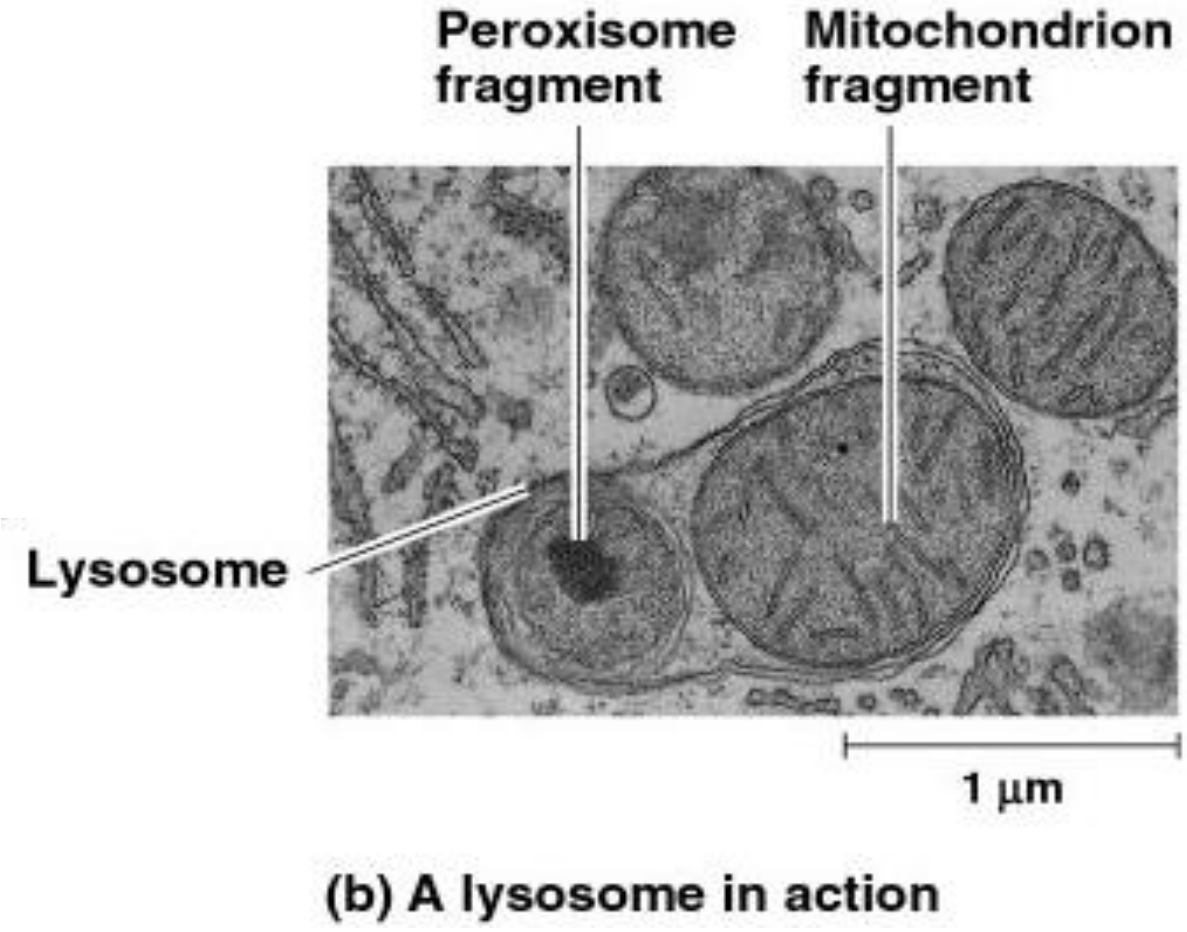


Figure 13-42 Three pathways to degradationin lysosomes. Molecular Biology of the Cell. 5th Ed.

What happens when lysosomes are not functioning correctly?

- Accumulation of unwanted materials
- Death of the cell
- Diseases

What happens when lysosomes are not functioning correctly?

- Often fatal
  - digestive enzyme not working in lysosome
  - materials can not be digested
  - lysosomes fill up with undigested material
  - they grow larger and therefore disrupt cell & organ function
- lysosomal storage diseases
    - eg. Tay-Sachs disease: build up undigested fat in brain cells

Vacuoles

- Large compartment filled with fluid that is in the cytoplasm of plant and animal cells.
- They are larger forms of vesicles
  - formed by fusion of multiple vesicles
- They have no basic shape or size
- Structure varies according to the needs of the cell
- Occupy 30-90% of cell volume

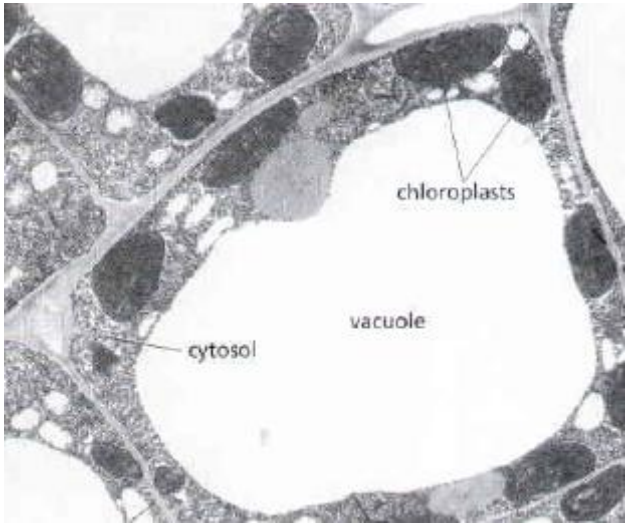


Figure 13.39 The plant cell vacuole. Molecular Biology of the Cell. 5th Ed.

Vacuoles

- Vacuoles are not part of the endomembrane system.
- They enable the cell to change shape.
- They help to isolate materials that might be harmful or threat to the cell.
- The vacuoles increase the size of the surface area of the cell allowing absorption of plant and animal nutrition.

Vacuole

- Vacuoles in animals cells are smaller then those in plant cells.
- In an animal cell, the vacuole is filled with solid food particles being digested and waste material.
- Most plant and fungal cells (including yeasts) have one or several vacuoles

Why do cells need vacuoles?

- More important for plant cells
- The same cell may have different vacuoles with distinct functions
  - eg. Digestion and storage
- Storage organelle for both nutrients and waste products
  - Sugars, minerals, proteins, water and toxic substances
- Degradative compartment of the cell
- Carry out waste from the cell

Why do cells need vacuoles?

- Food vacuoles: phagocytosis, fuse with lysosomes
- Contractile vacuoles: in freshwater protists, pump excess water out of cell
- Central vacuoles: in many mature plant cells

Why do cells need vacuoles?

- Vacuoles in animal cells take part in the process of endocytosis and exocytosis

- Vacuoles are also a part of the process phagocytosis and pinocytsosis

Peroxisomes

- Found in eukaryotic cells – plant and animal
- Peroxisomes bud off from the endoplasmic reticulum
- They resemble lysosome but are not the same
- The size is variable
- Self-replicating by dividing
- Self assembling, 1 day lifespan
- Each cell contains several hundreds of peroxisomes

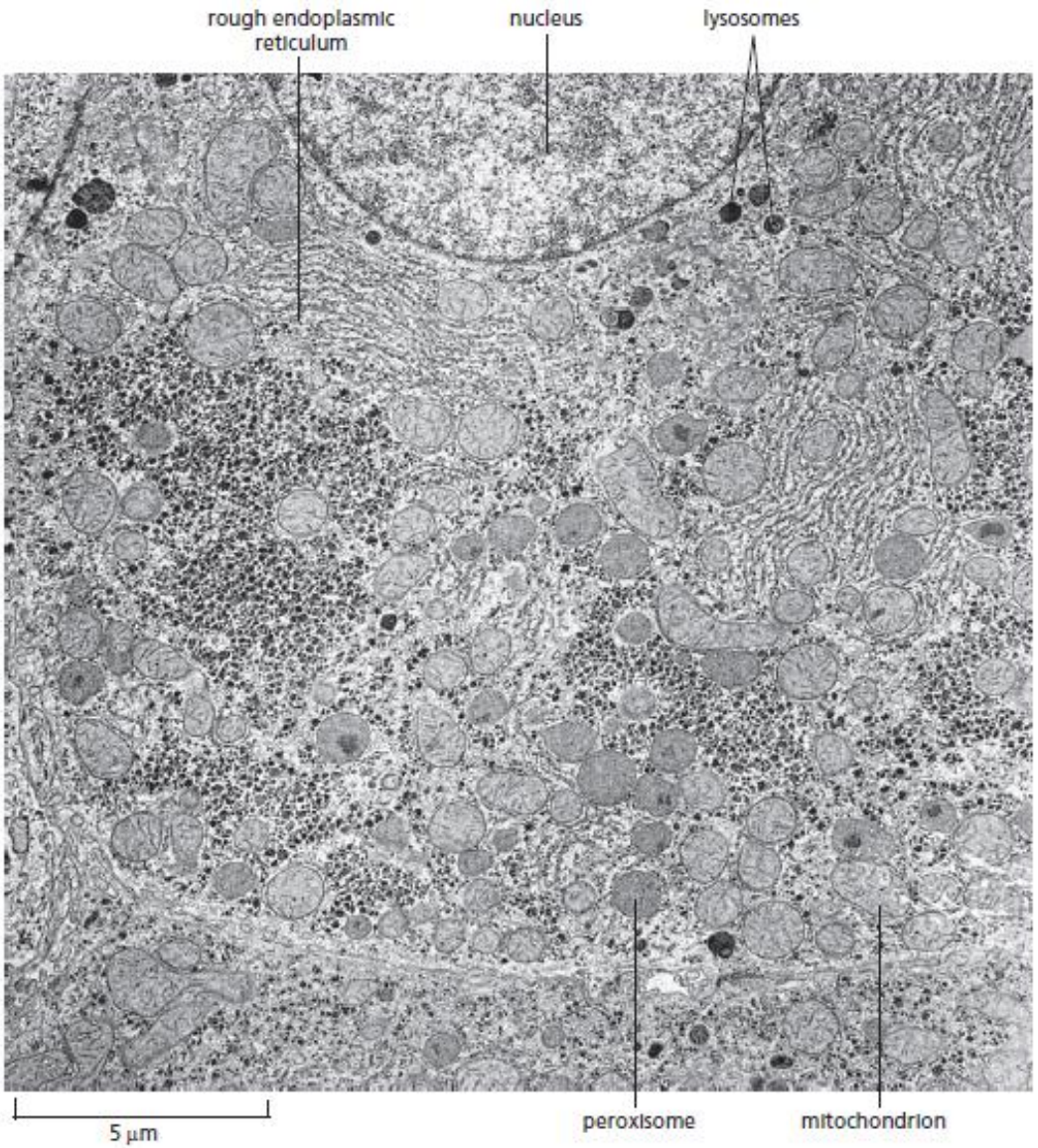


Figure 12–2 An electron micrograph of part of a liver cell seen in cross section. Molecular Biology of the Cell. 5th Ed.

Peroxisomes

- Peroxisomes are diverse organelles
- In the various cell types of a single organism, they may contain different sets of enzymes.
- They adapt remarkably to changing conditions.
  - eg. Yeasts grown on sugar have small peroxisomes. But when some yeasts are grown on methanol, they develop large peroxisomes that oxidize methanol and when grown on fatty acids they develop large peroxisomes to break down fatty acids

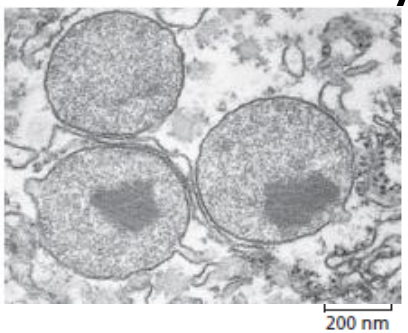


Figure 12–30 An electron micrograph of three peroxisomes in a rat liver cell. Molecular Biology of the Cell. 5th Ed.

Structure of Peroxisomes

- Single membrane that separates their contents from the cytosol
- They are round or oval vesicles surrounded by a phosolipid bilayer
- They contain
  - membrane proteins critical for various functions
  - many enzymes

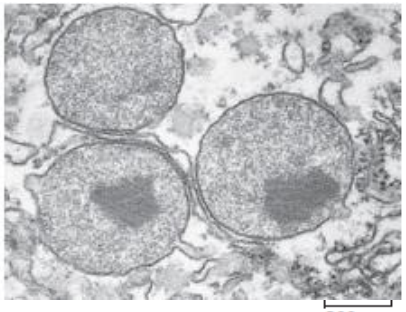


Figure 12–30 An electron micrograph of three peroxisomes in a rat liver cell. Molecular Biology of the Cell. 5th Ed.

Peroxisomes

- Contain digestive enzymes
  - enzymes to oxidize organic substances, such as fats
  - breakdown fatty acids to sugars
    - easier to transport & use as energy source
  - They use oxygen to break down molecules
- Toxic effects of hydrogen peroxide produced by metabolism are prevented by peroxisomes

Peroxisomes: Protein Sorting

- All of the peroxisome proteins are encoded in the nucleus.
- Peroxisome proteins enter the peroxisome by selective import from the cytosol
  - Each contains a **p**eroxisomal **t**argeting **s**ignal (**PTS**) that directs the proteins into the peroxisome.
  - Some enter the peroxisome membrane via the ER.

Why do cells need Peroxisomes?

- Detoxification
  - detoxifies alcohol & other poisons
- Oxygen utilization
- Breakdown of excess fatty acids
- Degradation of purine to uric acid
- Peroxisomes harbor enzymes that rid the cell of toxic peroxides

Why do cells need Peroxisomes?

- Participate in the formation of amine and bile salts
- Lipid metabolism
- Purine catabolism

Defects of Peroxisome Functioning

- Peroxisome biogenesis disorders
- Peroxisomal multi-enzyme disorders
- Peroxisomal single-enzyme disorders

Defects of Peroxisome Functioning

- Peroxisomes biogenesis disorders:
  - Peroxisomes do not function
- Peroxisomal multi-enzyme disorders
  - certain proteins inside the peroxisome do not develop
- Peroxisomal single-enzyme disorders:
  - occur when the peroxisome is working properly with the exception of a defect in a single enzymatic process

What happens when peroxisomes do not function?

- Severe abnormalities in
  - brain
  - liver
  - Kidneys
- Zellweger syndrome: failure of transporting peroxisomal proteins into peroxisomes
  - Child born is deformed and most likely suffers from seizures and early death (within 1 year of birth)

Centrioles

- Found only in animal cells, not found in plant cells
- The wall of each centriole cylinder is made of 9 microtubule triplets
- Usually found in pairs orientated at right angles to one another
- Located in centrosome
- 0.2 x 0.5 μm

Centrioles

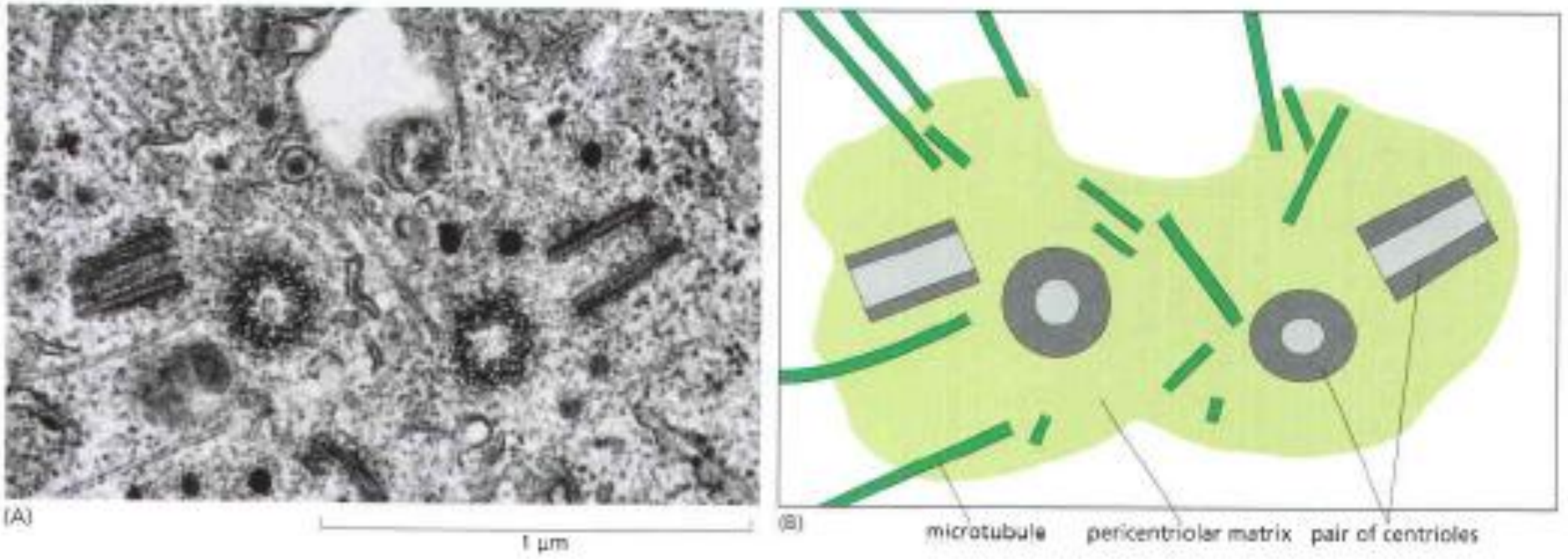
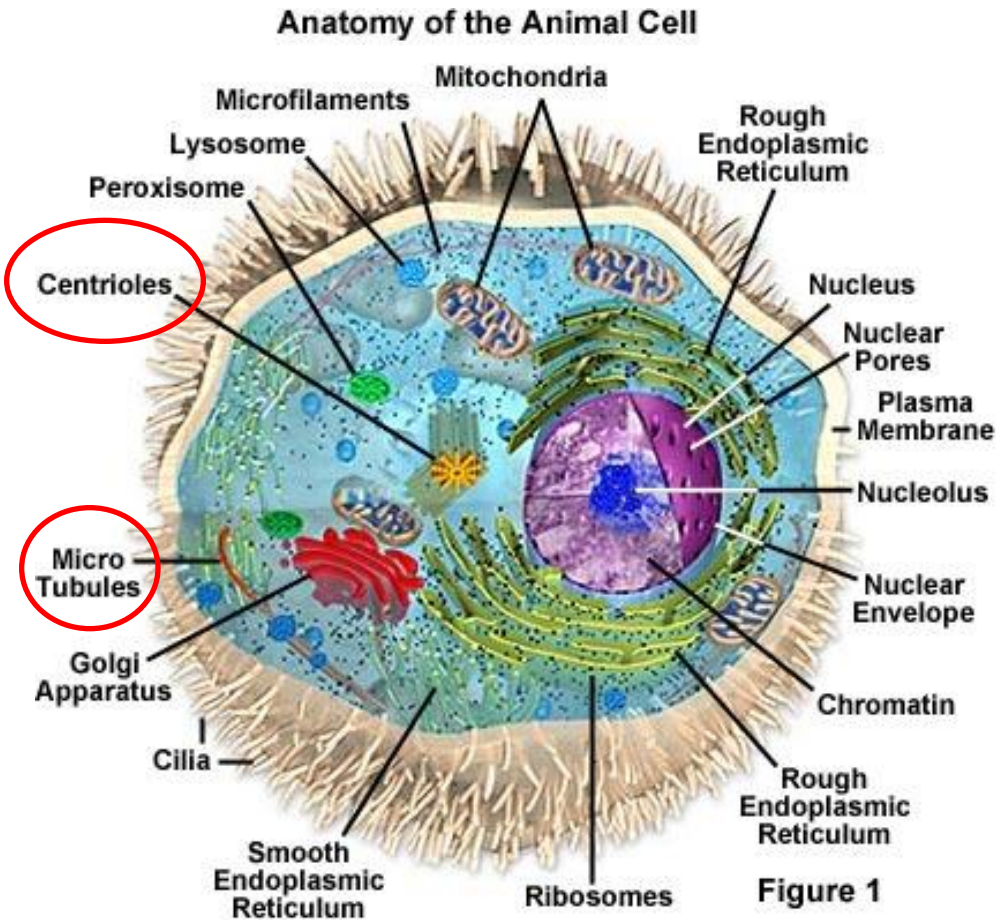


Figure 17-29 The centrosome

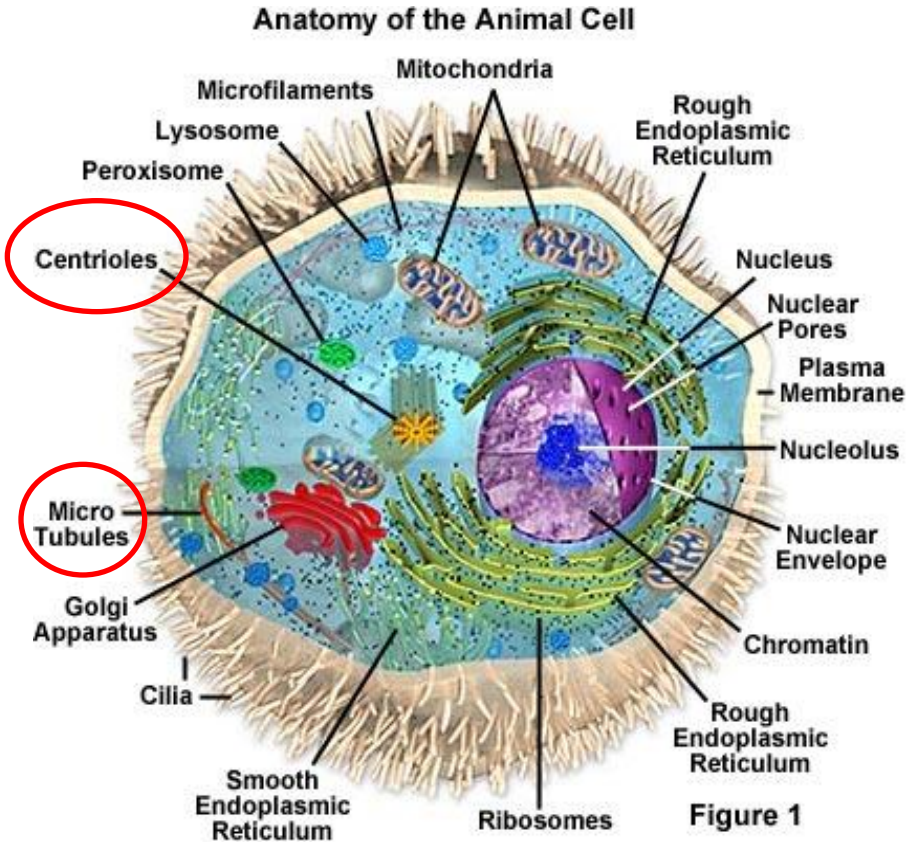
Structure of Centrioles

- Centrioles are cylindrical structures
- No membrane bound
- They are composed of groupings of microtubules arranged in a 9 + 3 pattern.
  - Microtubules are part of a structural network (cytoskeleton) within the cell's cytoplasm



Structure of Centrioles

- A ring of nine microtubule "triplets" are arranged at right angles to one another
  - Two centrioles are arranged such that one is perpendicular to the other.



Why do cells need centrioles?

- Centrioles organize cell division
- They are involved in cellular organization
  - Organize microtubules

Summary: Lysosomes

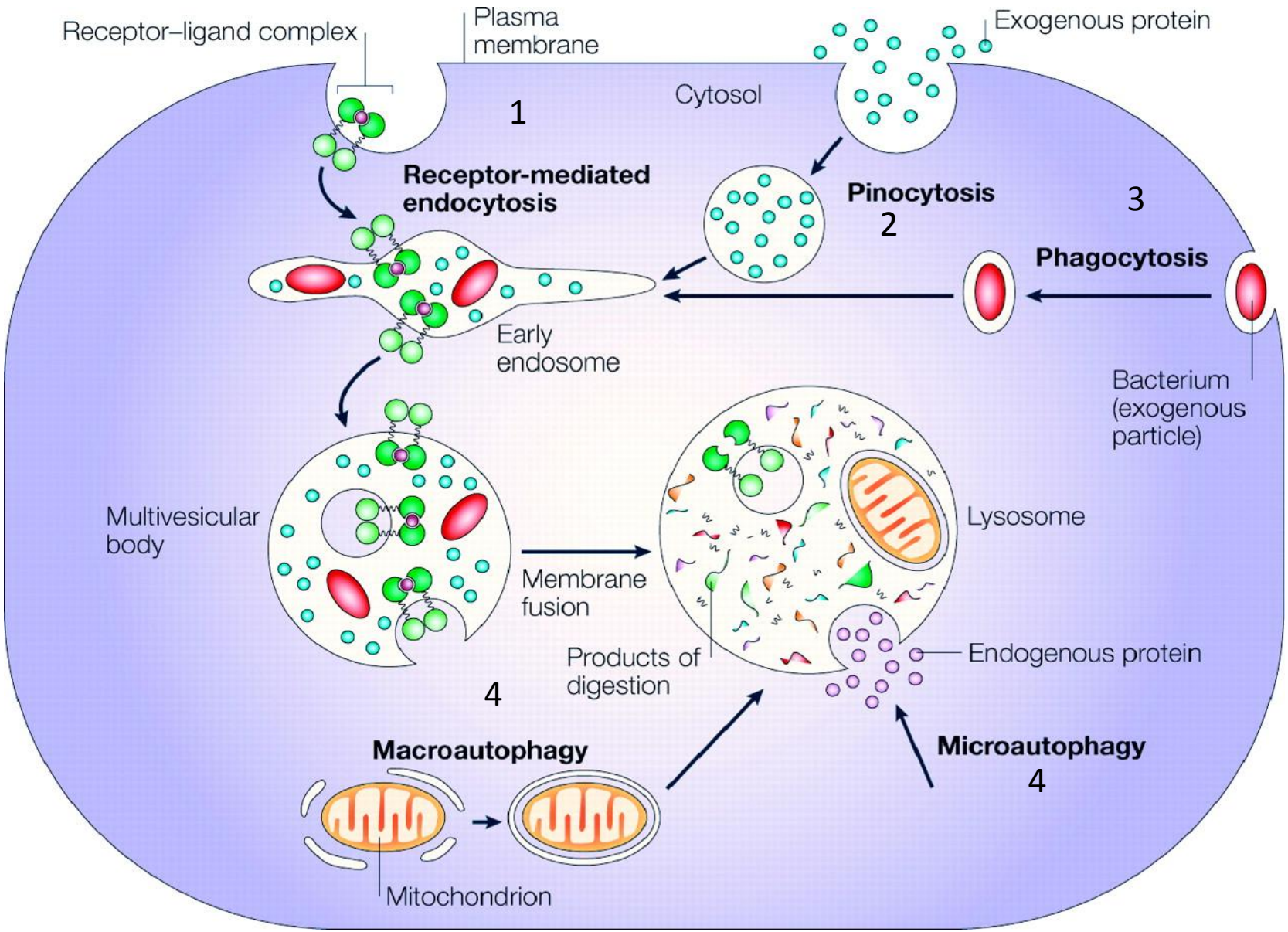
- Lysosomes are spherical organelles containing about 40-50 types of hydrolytic enzymes
- Their function is intracellular and extracellular digestion of macromolecules.
- They use
  - Endocytosis: cells remove plasma membrane components and deliver them to internal compartments

Summary: Lysosomes

- Phagocytosis: cell uses large endocytic vesicles (phagosomes) to ingest large particles
- Autophagy & Cell Death: digesting internal parts of the cell, such as organelles

- Lysosomal storage diseases: Accumulation of unwanted materials leading to death of the cell or diseases

Summary: Lysosomal Degradation



Summary: Vacuole

- Large compartment filled with fluid that is in the cytoplasm of plant and animal cells.
- Storage organelle for both nutrients and waste products
  - Sugars, minerals, proteins, water and toxic substances
- Degradative compartment of the cell, carry out waste from the cell

Summary: Peroxisomes

- Peroxisomes bud off from the endoplasmic reticulum
- Peroxisomes are specialized for carrying out oxidation reactions
- Peroxisomes are self-replicating organelles
- Their proteins are encoded in the cell nucleus.

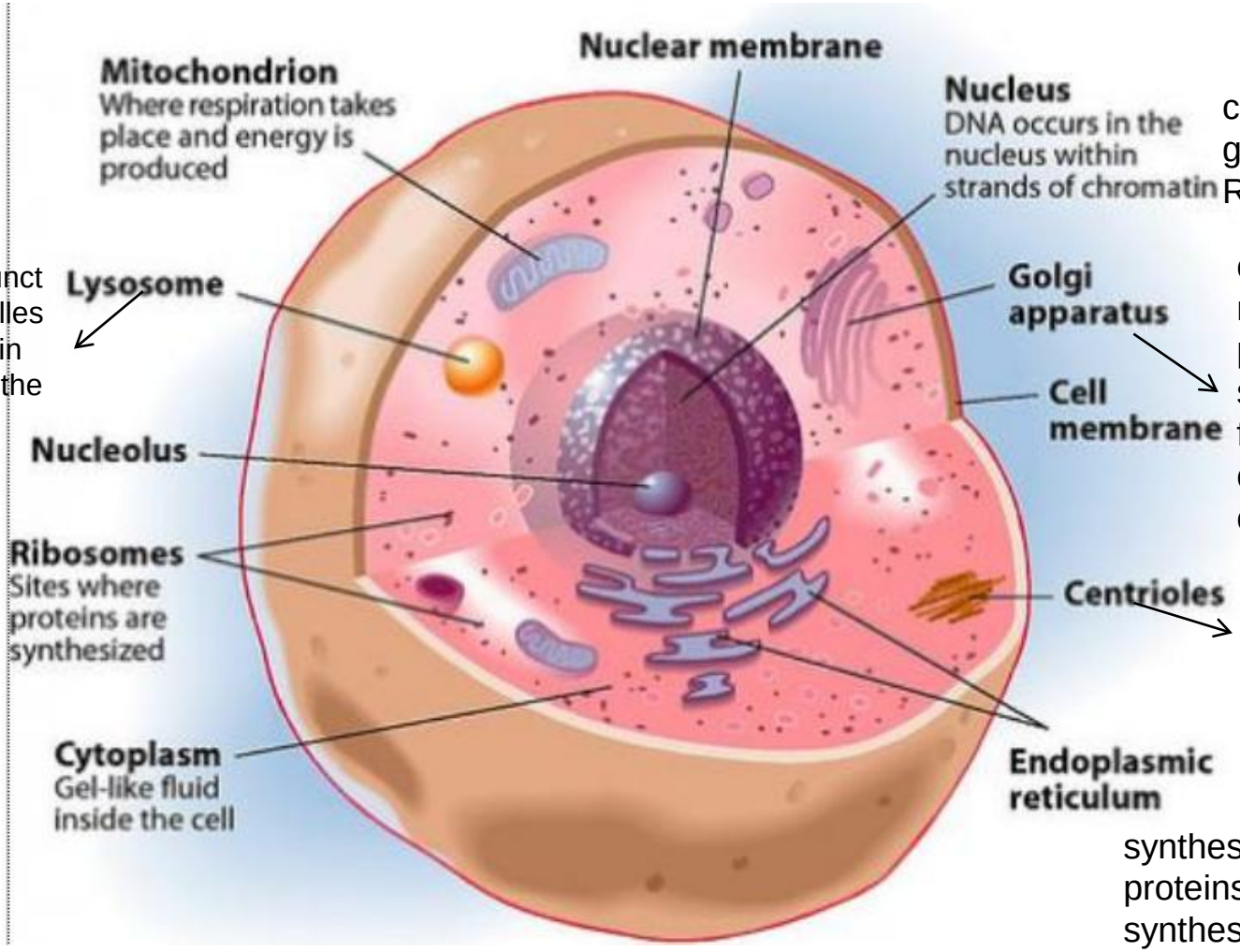
Summary: Peroxisomes

- Contain digestive enzymes
  - enzymes to oxidize organic substances, such as fats
  - breakdown fatty acids to sugars
    - easier to transport & use as energy source
  - They use oxygen to break down molecules
- Toxic effects of hydrogen peroxide produced by metabolism are prevented by peroxisomes

Summary: Centrioles

- Found only in animal cells, not found in plant cells
- Centrioles are cylindrical structures
- No membrane bound
- They are composed of groupings of microtubules arranged in a 9 + 3 pattern
- Centrioles organize microtubules and cell division

Overall Summary



contains main genome, DNA and RNA synthesis

degradation of defunct intracellular organelles and material taken in from the outside of the cell by endocytosis

covalent modification of proteins from ER, sorting of proteins for transport to other parts of the cell

organize microtubules and cell division

synthesis of proteins, lipid synthesis

Reading

Chapter 12: 721-723

Chapter 13: 779-799

The figures are mainly obtained from Molecular Biology of the Cell, 5th Edition.