4.9 Lysosomes

Lysosomes are membrane-enclosed compartments filled with hydrolytic enzymes that are used for the controlled *intracellular* digestion of macromolecules. They contain about 40 types of hydrolytic enzymes, including proteases, nucleases, glycosidases, lipases, phospholipases, phosphatases, and sulfatases. All are *acid hydrolases* because for optimal activity they require an acid environment and the lysosome provides this by maintaining a pH of about 5.0 in its interior. A H^+ pump in the lysosomal membrane uses the energy of ATP hydrolysis to pump H^+ into the lysosome, thereby maintaining the acidic pH of lumen. Lysosomes greatly vary in size and shape. There are two types of lysosomes : *Primary lysosomes* (do not contain particle or membrane for digestion) and *Secondary lysosomes* (contain particles or membranes in the process of being digested).

Lysosomes are responsible for the degradation of large particles taken up by phagocytosis and for the gradual digestion of the cell's own components by autophagy. On this basis lysosome can be divided into

Heterophagic vacuole (or heterolysosome or phagolysosome)

They are formed by the fusion of primary lysosome with cytoplasmic vacuoles containing *extracellular* substances brought into the cell by an endocytic process.

Autophagic vacuoles (or autolysosomes)

Autophagic vacuoles contain particles isolated from the cells own cytoplasm including mitochondria, microbodies etc.

Autophagy: A process of self-digestion

During autophagy, sequestration begins with the formation of a *phagophore*. Phagophores form *de novo* in the cytoplasm from a cup-shaped membrane that expands into a double-membrane bound *autophagosome* surrounding a portion of the cytoplasm. The autophagosome may fuse with an endosome. The product of the endosome-autophagosome fusion is called an *amphisome*. The completed autophagosome or amphisome fuses with a lysosome, which supplies acid hydrolases. The enzymes in the resulting compartment, an autolysosome, break down the inner membrane from the autophagosome and degrade the cargo. The resulting macromolecules are released and recycled in the cytosol.

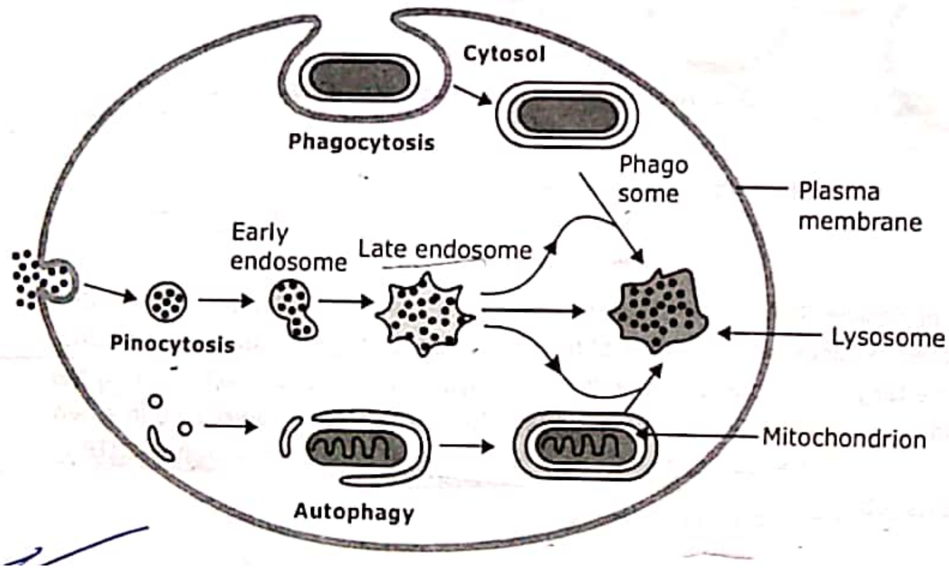

Figure : 4.38
Schematic overview of three pathways by which materials are moved to lysosomes :endocytic pathway, phagocytic pathway and autophagic pathway.

Most plants and fungal cells (including yeasts) contain one or several very large, fluid-filled vesicles called **vacuoles**. Vacuoles are related to the lysosomes of animal cells, containing a variety of hydrolytic enzymes, but their functions are remarkably diverse. Like a lysosome, the lumen of a vacuole has an acidic pH, which is maintained by similar transport proteins in the vacuolar membrane. The plant vacuole can act as a storage organelle for both nutrients and waste products, as a degradative compartment, and as a controller of turgor pressure. Different vacuoles with distinct functions (e.g., digestion and storage) are often present in the same cell.

4.10 Mitochondria

Mitochondria are *energy-converting organelles*, which are present in virtually all eukaryotic cells. Mitochondria are double membrane-bound mobile as well as plastic organelle. The outer membrane is fairly smooth. But the inner membrane is highly convoluted; forming folds called *cristae* and is highly impermeable to small ions due to having a very high content of a phospholipid called *cardiolipin*. The cristae greatly increase the inner membrane's surface area. The outer membrane protects the organelle, and contains specialized transport proteins such as *porin* which allows free passage for various molecules into the intermitochondrial space (the space between the inner and outer membranes) of the mitochondria.

The matrix (large internal space) contains several identical copies of the mitochondrial DNA genome, special mitochondrial ribosomes, tRNAs, and various enzymes required for expression of the mitochondrial genes. Mitochondrial ribosomes of different species vary considerably in their sedimentation coefficients, ranging from 55S-80S, while cytoplasmic ribosomes are uniformly 80S.

Mitochondrial genome

Mitochondrial genome is circular (the linear DNA molecule in Paramecium, Tetrahymena and others) dsDNA. The size of mitochondrial DNA varies greatly among different species.

Origin of mitochondria as cellular organelles

Mitochondria are semi-autonomous organelle and are supposed to have evolved in eukaryotes from *endosymbiotic* association of purple photosynthetic bacteria about 1.5×10^9 years ago. The captured cell (the endosymbiont) was then reduced to a functional organelle bound by two membranes, and was transmitted vertically to subsequent generations. The *endosymbiotic theory* was proposed by Lynn Margulis in 1967. The term *endosymbiosis* has a Greek origin (*endo*, meaning 'within'; *syn*, meaning 'with'; and *biosis*, meaning 'living'), and it refers to the phenomenon of an organism living within another organism.

Evidences to support endosymbiotic theory

- Mitochondria are self-replicating bodies like bacteria and divide in a manner resembling binary fission in bacteria. Mitochondria are surrounded by two membranes, and the innermost of these membranes is very similar in composition to bacteria.
- Mitochondria have their own DNA and has a simple circular structure which is structurally similar to bacterial DNA.
- Mitochondrial ribosomes, enzymes, and transport systems are all similar to those of bacteria.
- Mitochondria are of approximately the same size as bacteria.
- Mitochondrial DNA share similar structural motifs with bacterial DNA.
- Protein synthesis in mitochondria is inhibited by a variety of antibiotics (e.g., chloramphenicol, tetracycline, erythromycin) that inactivate many bacterial ribosomes, but have little effect on ribosome in the cytosol of eukaryotic cells.

4.11 Chloroplast

The chloroplast is an organelle where photosynthesis occurs in photosynthetic eukaryotes. It is surrounded by a double membrane. The inner membrane encloses a fluid-filled region called the **stroma** that contains enzymes for the Calvin cycle, light-independent reactions of photosynthesis. Embedded in the stroma is a complex network of stacked sacs. Each stack is called a **granum** and each of the flattened sacs which makes up the granum is called a **thylakoid**. The thylakoid membrane, that encloses a fluid-filled thylakoid interior space, contains chlorophyll and other photosynthetic pigments as well as electron transport chains. The light-dependent reactions of photosynthesis occur in the thylakoids.

A chloroplast is a semi-autonomous organelle. The stroma contains chloroplast DNA, 70S ribosomes, tRNAs, and various enzymes required for expression of the chloroplast genes. Chloroplast DNAs vary in length from 120-190 kb. There are multiple copies of the genome per organelle, typically 20-40 in a higher plant. The chloroplast genome codes for all the rRNA and tRNA species needed for protein synthesis. The chloroplast genome codes for ~50 proteins.

Chloroplast differentiates from *proplastids*. Proplastids also differentiate into *leucoplasts* and *chromoplasts*. Chromoplasts are mainly the site for pigment synthesis and storage. Whereas, leucoplasts may differentiate into more specialized forms:

- Amyloplasts: for starch storage
- Elaioplasts: for storing fat
- Proteinoplasts: for storing and modifying protein

A collective term for these different kinds of organelles, all derived from proplastids, is *plastid*. Like mitochondria, all plastids come from the division of pre-existing plastids.