4.12 Peroxisomes

Peroxisomes are ubiquitous organelles in eukaryotes. Peroxisomes were discovered by *Christian de Duve* in 1965. They are small organelles, approximately 0.2–1 μm in diameter. Peroxisomes lack DNA and ribosomes and are lined by a single membrane. Thus all peroxisomal proteins are encoded by nuclear genes, synthesized on ribosomes free in the cytosol, and then incorporated into pre-existing peroxisomes. Peroxisomes divide, forming new ones, similar to mitochondria and chloroplasts.

Peroxisomes contain oxidative enzymes, such as *catalase* and *urate oxidase*. Like the mitochondrion, peroxisomes contain enzymes that use molecular oxygen to oxidize various substrates. Some peroxisomal enzymes use molecular oxygen to remove hydrogen atoms from specific organic substrates in an oxidative reaction that produces H_2O_2. Enzyme catalase efficiently decomposes H_2O_2 into H_2O.

$$H_2O_2 + H_2O_2 \xrightarrow{\text{Catalase}} 2H_2O + O_2$$

Another enzyme that destroys hydrogen peroxide is *peroxidase*, which differs from catalase. Catalase catalyzes the decomposition of hydrogen peroxide to water and oxygen. Peroxidases are a large family of enzymes that typically catalyze a reaction of the form:

$$ROOR' + 2e^- + 2H^+ \longrightarrow ROH + R'OH$$

Substrates for peroxidase can be hydrogen peroxide, lipid peroxides and others and it requires a reductant for activity, usually NADH.

A major oxidative reactions carried out in peroxisomes is the *β-oxidation*. β-oxidation in mammalian cells occur both in mitochondria and peroxisomes; in plant cells, however, this essential reaction is exclusively found in peroxisomes. Peroxisomes also have two important roles in plants - *photorespiration* and *glyoxylate cycle*. In *photorespiration*, glycolate-2-phosphate produced by oxygenase activity of rubisco is metabolized into serine, CO_2 and NH_3. This pathway involves three subcellular compartments, the chloroplasts, peroxisomes and mitochondria. *Glyoxylate cycle* occurs in specialized peroxisomes called *glyoxysomes*. In the glyoxylate cycle two molecules of acetyl CoA produced by *β-oxidation* are used in the synthesis of succinic acid.

Targeting of peroxisomal proteins

Proteins that are required for peroxisome formation are called **peroxins**. Transport of proteins to peroxisomes occur *post-translationally*. Peroxisomal proteins synthesized on cytosolic ribosomes are generally fold into their mature conformation in the cytosol before import into the organelle. Proteins that are imported into the peroxisome have *peroxisomal targeting sequences*–PTS1 and PTS2. The PTS1 is a tri- or tetrapeptide at the C-terminus. It was first characterized in catalase as a *Ser-Lys-Leu* sequence (SKL in one-letter code) at the very C-terminus. The PTS2 signal is a sequence of nine amino acids and can be located near the N-terminus or internally.

The importance of the import process in peroxisomes is dramatically demonstrated by the inherited human disease, *Zellweger syndrome*. It is a rare, congenital disorder, characterized by the reduction or absence of peroxisomes due to defect in importing proteins into peroxisomes.

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.

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.