Peroxisomes

Peroxisomes are small, membrane-enclosed cellular organelles containing oxidative enzymes that are involved in a variety of metabolic reactions, including several aspects of energy metabolism.

They are considered as an important type of microbody found in both plants and animal cells.

They were identified as organelles by Belgian cytologist Christian de Duve in 1967 after already been described.

They are most abundantly found in detoxifying organs such as the liver and kidney cells. However, they can be induced to proliferate in response to metabolic needs.

Structure of Peroxisomes

They are membrane-bound spherical bodies of 0.2 to 1.5 µm in diameter found in all eukaryotic organisms including both plants and animal cells.

They are found floating freely in the cytoplasm in close association of ER, mitochondria or chloroplast within the cell.

They are among the simplest of eukaryotic organelles.

They exist either in the form of a network of interconnected tubules called peroxisome reticulum or as individual microperoxisomes.

They are variable in size and shape according to the cell and usually circular in cross-section.

They range from 0.2 -1.5 µm in diameter.

It consists of a single limiting membrane of lipid and protein molecules enclosing the granular matrix.

The matrix consists of fibrils or a crystalloid structure containing enzymes.

Peroxisomal Enzymes

Approximately 60 known enzymes are present in the matrix of peroxisomes.

They are responsible to carry out oxidation reactions leading to the production of hydrogen peroxide.

The main groups of enzymes include: Urate oxidase, D-amino acid oxidase, Catalase

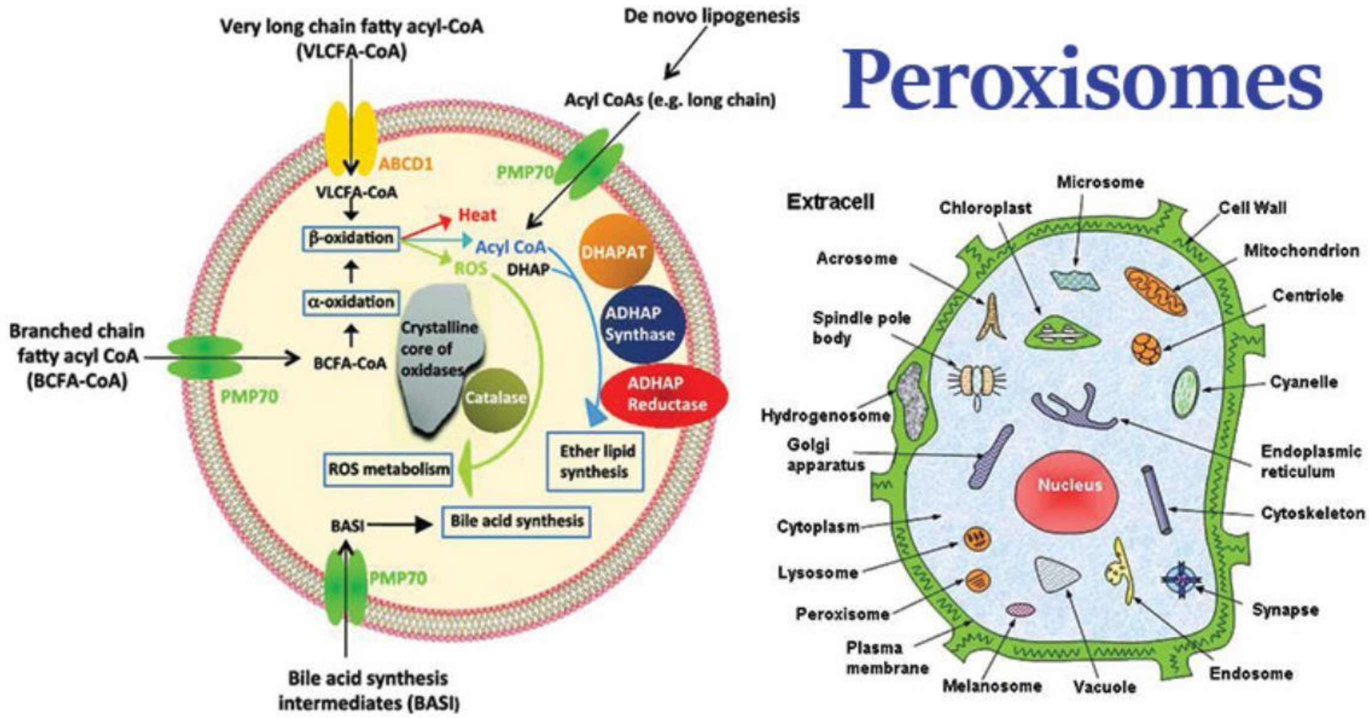

Fig: Structure of Peroxisomes

Functions of Peroxisomes

1. Hydrogen Peroxide Metabolism: Enzymes present in the peroxisomes both lead to the production and elimination of H_2O_2 which is a reactive oxygen species.

2. Fatty acid oxidation: Oxidation of fatty acids, in animal cells, occurs in both peroxisomes and mitochondria, but in yeasts and plants, only limited to peroxisomes. Oxidation is accompanied by the production of H_2O_2 which is decomposed by catalase enzyme. This provides a major source of metabolic energy.

3. Lipid biosynthesis: Synthesis of cholesterol and dolichol occurs in both ER and peroxisomes. Bile acid synthesis takes place from cholesterol in the liver. Peroxisomes contain enzymes to synthesize plasmalogens, a family of phospholipids which are important membrane components of tissues of the heart and brain.

4. Germination of seeds: Peroxisomes in seeds responsible for the conversion of stored fatty acids to carbohydrates, critical to providing energy and raw materials for the growth of germinating plants.

5. Photorespiration: Peroxisomes in leaves particularly in the green ones carry out the photorespiration process along with chloroplasts.

6. Degradation of purines: Carry out the catabolism of purines, polyamines and amino acids especially by uric acid oxidase.

7. Peroxisomes derive their name from their use of molecular oxygen for metabolic processes. These organelles are largely associated with lipid metabolism and the processing of reactive oxygen species. Within lipid metabolism, peroxisomes mostly deal with β–oxidation of fatty acids, the mobilization of lipid stores in seeds, cholesterol biosynthesis and steroid hormone synthesis.

   * β–oxidation: The main reason for the high energy density of fats is the low proportion of oxygen atoms in every fatty acid molecule. For instance, palmitic acid, a fatty acid containing 16 carbon atoms and having a molecular mass of over 250 gms/mole, has only two oxygen atoms. While this makes lipids good storage molecules, they cannot be directly burnet as fuel or quickly catabolized in the cytoplasm through glycolysis. They need to be processed before they can be shunted into the mitochondria for complete oxidation through the citric acid cycle and oxidative phosphorylation.

   When these molecules need to be oxidized to release ATP, they need to be first broken down into smaller molecules before they can be processed in the mitochondria. Within peroxisomes, long chain fatty acids are progressively broken down to generate acetyl coenzyme A (acetyl coA) in a process called β–oxidation. Acetyl coA then combines with oxaloacetate to form citrate. While most carbohydrates enter the citric acid cycle as a three-carbon molecule called pyruvate which is then decarboxylated to form acetyl coA, peroxisomal β–oxidation allows fatty acids to access the citric acid cycle directly.

   One of the main byproducts of β–oxidation is hydrogen peroxide which can be harmful for the cell. This molecule is also carefully detoxified by the enzyme catalase within peroxisomes.

Peroxisomes in Plants

1. In plants, peroxisomes play important roles in seed germination and photosynthesis. During seed germination, fat stores are mobilized for anabolic reactions that lead to the formation of carbohydrates. This is called the glyoxalate cycle and begins with β–oxidation and the generation of acetyl CoA as well.
2. In leaves, peroxisomes prevent the loss of energy during photosynthetic carbon fixation through recycling the products of photorespiration. (A crucial enzyme called Ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO) is necessary for photosynthesis,

catalyzing the carboxylation of ribulose-1,5-bisphosphate (RuBP). This is the central reaction for fixation of carbon dioxide to form organic molecules. However, RuBisCO, as the name suggests, can also oxygenate RuBP, using molecular oxygen, releasing carbon dioxide – in effect, reversing the net result of photosynthesis. This is particularly true when the plant is exposed to hot, dry environments and the stomata close in order to prevent transpiration.)

3. When RuBisCO oxidizes RuBP, it generates a 2-carbon molecule called phosphoglycolate. This is captured by peroxisomes where it is oxidized to glycine. Thereafter, it is shuttled between the mitochondria and peroxisomes, undergoing a series of transformations before it is converted into a molecule of glycerate that can be imported into chloroplasts to participate in the Calvin cycle for photosynthesis.