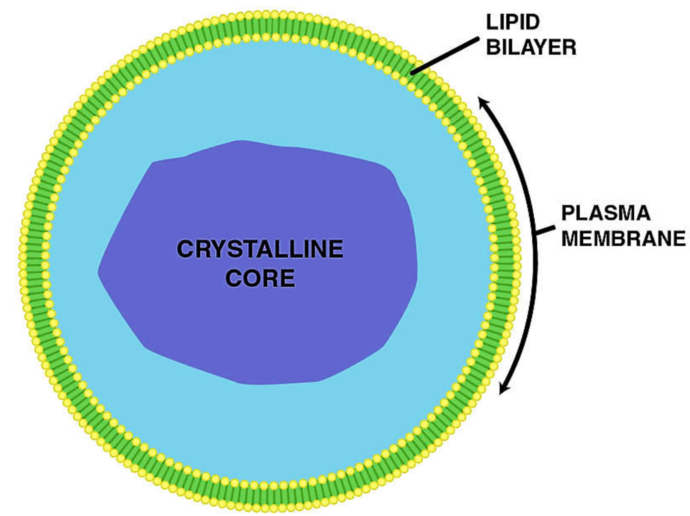

Subhadipa 2020
Peroxisome

What is peroxisome?

- Peroxisomes are small, **membrane-enclosed organelles that contain enzymes** involved in a variety of metabolic reactions, including several aspects of energy metabolism.
- Peroxisomes were discovered by **Christian de Duve in 1967.**
- Although peroxisomes are **morphologically similar to lysosomes, they are assembled, like mitochondria and chloroplasts.**
- Although peroxisomes do **not contain their own genomes**, they are similar to mitochondria and chloroplasts in that **they replicate by division.**
- It is found **in the cytoplasm** of virtually **all eukaryotic cells.**
- Peroxisomes contain a battery of **oxidative enzymes** that are involved in breakdown of small molecules. Important **peroxisomal enzymes include D-amino acid oxidase and catalase,** the enzyme responsible for the **degradation of dangerous peroxides**. Peroxisomes are also involved in **drug detoxification** and the **biosynthesis of essential ether-phospholipids known as plasmalogens.**

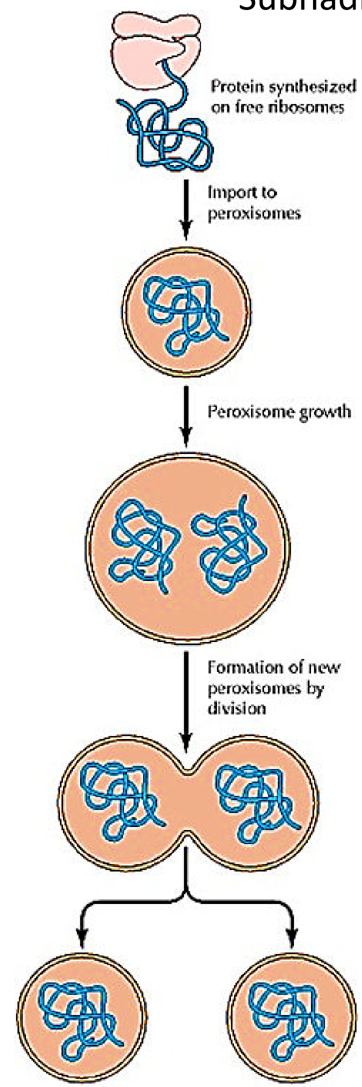
Structure

- Peroxisomes are enclosed in a **single membrane** and are **0.5 micrometer in diameter**.
- It contains fine **granular substances** that may condense to form an **opaque urate oxidase crystalline core** or **nucleoid.**
- The peroxisome **without nucleoid** is called **microperoxisome**.
- Peroxisomes contain **more than 50 enzymes and self-replicate by enlarging and then dividing**.
- They **contain H_2O_2 producing enzymes like oxidases and catalases** as well as **oxidative enzymes like peroxidase, Catalase, glycolic acid oxidase** and some other enzymes.
- Often compared to lysosomes, peroxisomes differ in that they **hold anti-oxidative enzymes**. Main enzymes are **uric acid oxidase, D amino acid oxidase, NADH glyoxylate reductase, catalases etc.**
- Peroxisomes contain **no DNA or ribosomes** and have **no means of producing proteins.** Instead, all of these proteins are imported across the membranes.



Peroxisome Assembly

- The assembly of peroxisomes is fundamentally **similar to that of mitochondria and chloroplasts**, rather than to that of the endoplasmic reticulum, Golgi apparatus, and lysosomes.
- Proteins destined for peroxisomes are **translated on free cytosolic ribosomes and then transported into peroxisomes** as completed polypeptide chains.
- **Phospholipids are also imported** to peroxisomes, **via phospholipid transfer proteins,** from their major site of synthesis in the ER.
- The import of proteins and phospholipids **results in peroxisome growth, and new peroxisomes are then formed by division of old ones.**
- Proteins are targeted to the interior of peroxisomes by at least two pathways, which are conserved from yeasts to humans



Protein export in Peroxisome

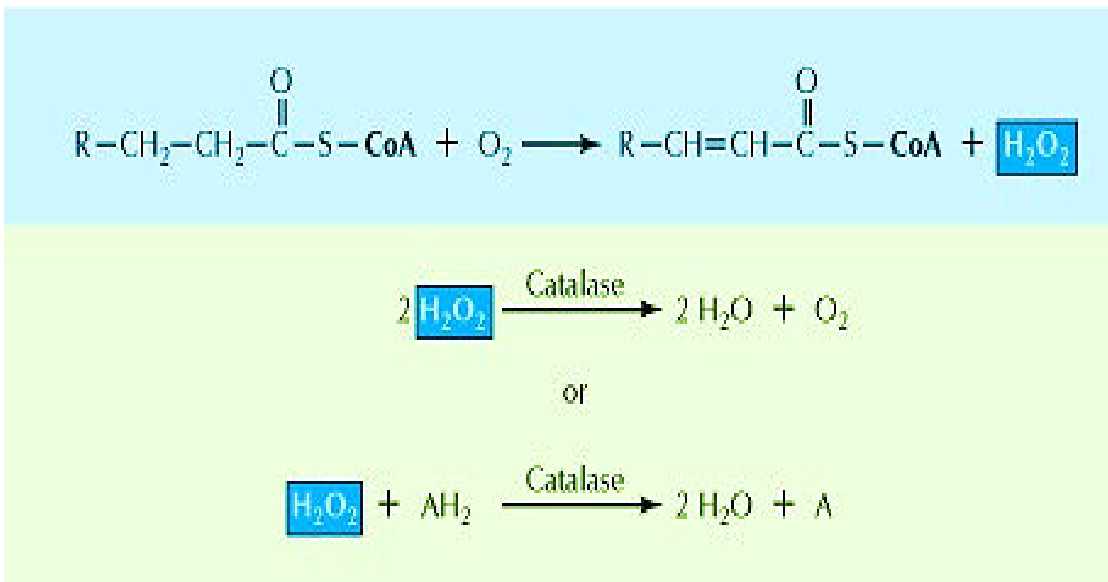
- Most proteins are targeted to peroxisomes by the simple amino acid sequence **Ser-Lys-Leu at their carboxy terminus** (peroxisome targeting signal 1, or **PTS1**). Other proteins are targeted by a **sequence of nine amino acids (PTS2) at their amino terminus**, and some proteins may be targeted by alternative signals that have not yet been well defined.
- PTS1 and PTS2 are **recognized by distinct receptors** and then transferred to a translocation complex that mediates their transport across the peroxisome membrane.
- In contrast to the translocation of polypeptide chains across the membranes of the endoplasmic reticulum, mitochondria, and chloroplasts, **targeting signals are usually not cleaved during the import of proteins into peroxisomes.**
- **Cytosolic Hsp70** has been implicated in protein import to peroxisomes, but the possible role of molecular chaperones within peroxisomes is unclear. Moreover, it appears that proteins can be transported into peroxisomes in at least partially folded conformations, rather than as extended polypeptide chains.
- Some **peroxisome membrane proteins are similarly synthesized on cytosolic ribosomes and targeted to the peroxisome membrane by distinct internal signals**. However, other experiments suggest that some peroxisomal membrane proteins may be synthesized on membrane-bound polysomes of the endoplasmic reticulum and then transported to peroxisomes, suggesting a role for the endoplasmic reticulum in peroxisome maintenance.

Functions of peroxisomes

- Peroxisomes are membrane-bound organelles in most eukaryotic cells, primarily involved in **lipid metabolism** and the conversion of reactive oxygen species such as **hydrogen peroxide into safer molecules like water and oxygen.** Peroxisomes are **vital to the healthy function of the liver**. These vesicles are found surrounding liver cells and contain enzymes responsible for many metabolic reactions including energy **metabolization and holding the digestive enzymes necessary for breaking down toxic matter in the cell**.
- Peroxisomes originally were defined as organelles that carry out **oxidation reactions leading to the production of hydrogen peroxide.** Because hydrogen peroxide is harmful to the cell, peroxisomes also contain the enzyme **catalase,** which **decomposes hydrogen peroxide either by converting it to water or by using it to oxidize another organic compound.** A variety of substrates are broken down by such oxidative reactions in peroxisomes, including uric acid, amino acids, and fatty acids.

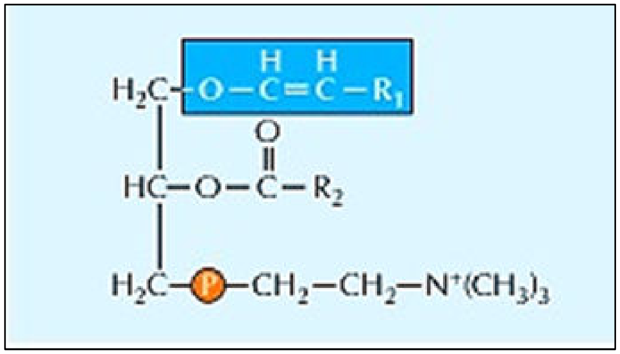
1. Oxidation of fatty acids

It is a particularly important example, since it provides a major source of metabolic energy. In animal cells, fatty acids are oxidized in both peroxisomes and mitochondria, but in yeasts and plants fatty acid oxidation is restricted to peroxisomes.



2. Lipid biosynthesis

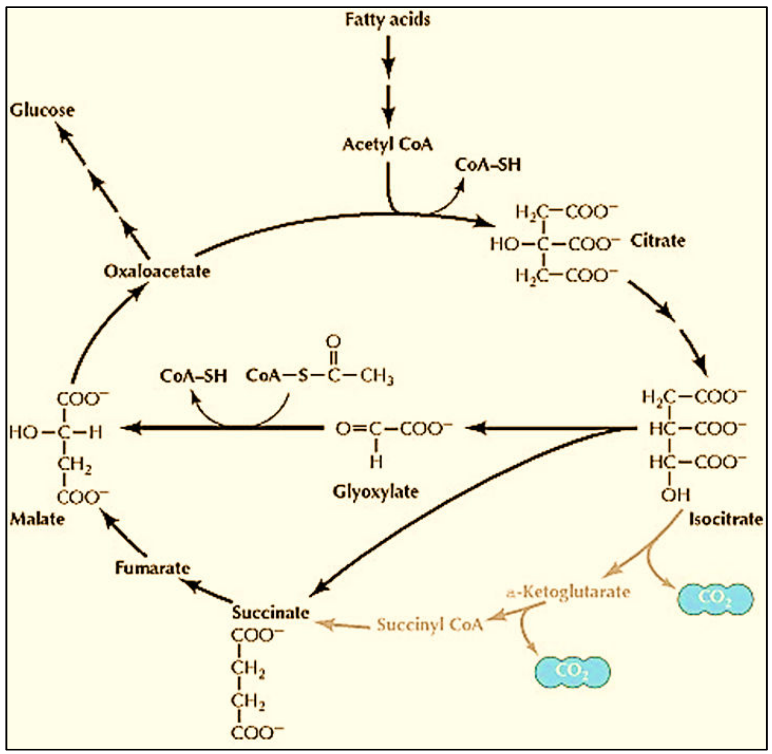
- In addition to providing a compartment for oxidation reactions, peroxisomes are involved in **lipid biosynthesis.**
- In animal cells, cholesterol and dolichol are synthesized in peroxisomes as well as in the ER.
- In the liver, peroxisomes are also involved in the synthesis of bile acids, which are derived from cholesterol.
- In addition, peroxisomes contain enzymes required for the **synthesis of plasmalogens**—a family of phospholipids in which one of the hydrocarbon chains is joined to glycerol by an ether bond rather than an ester bond. Plasmalogens are important membrane components in some tissues, particularly heart and brain, although they are absent in others.



3. Peroxisomes play two particularly important roles in plants

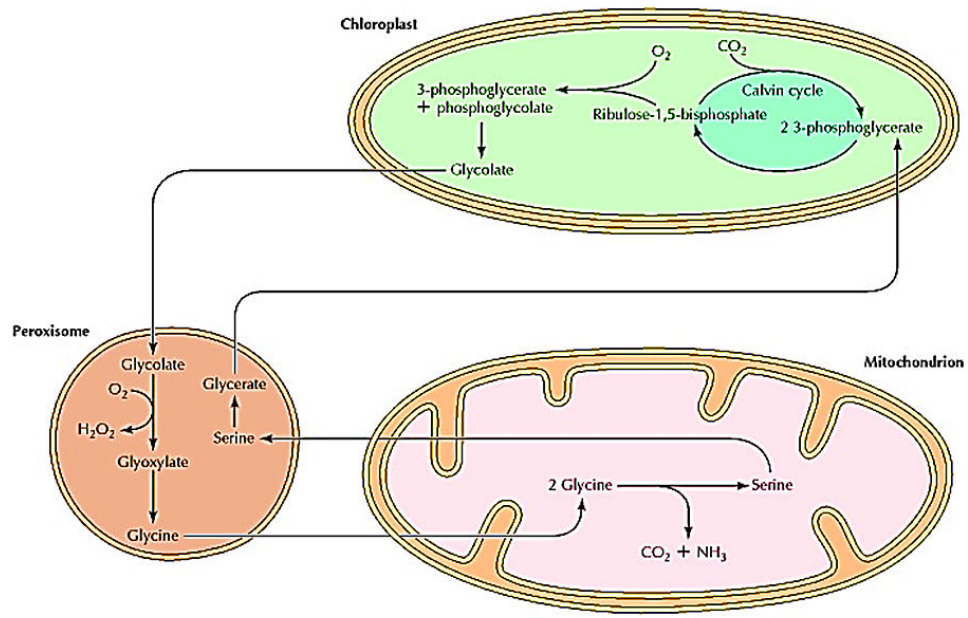
i. Glyoxylate cycle

Peroxisomes in seeds are responsible for the conversion of stored fatty acids to carbohydrates, which is critical to providing energy and raw materials for growth of the germinating plant. This occurs via a series of reactions termed the **glyoxylate cycle,** which is a variant of the citric acid cycle. The peroxisomes in which this takes place are sometimes called **glyoxysomes.**



ii. Photorespiration

- Peroxisomes in leaves are involved in **photorespiration,** which serves to metabolize a side product formed during photosynthesis. CO_2 is converted to carbohydrates during photosynthesis via a series of reactions called the Calvin cycle. The first step is the addition of CO_2 to the five-carbon sugar ribulose-1,5-bisphosphate, yielding two molecules of 3-phosphoglycerate (three carbons each).
- However, the enzyme involved (ribulose bisphosphate carboxylase or rubisco) sometimes catalyzes the addition of O_2 instead of CO_2, producing one molecule of 3-phosphoglycerate and one molecule of phosphoglycolate (two carbons). This is a side reaction, and phosphoglycolate is not a useful metabolite.
- It is first converted to glycolate and then transferred to peroxisomes, where it is oxidized and converted to glycine.
- Glycine is then transferred to mitochondria, where two molecules of glycine are converted to one molecule of serine, with the loss of CO_2 and NH_3.
- The serine is then returned to peroxisomes, where it is converted to glycerate.
- Finally, the glycerate is transferred back to chloroplasts, where it reenters the Calvin cycle.



Note: Photorespiration does not appear to be beneficial for the plant, since it is essentially the reverse of photosynthesis—O2 is consumed and CO2 is released without any gain of ATP. However, the occasional utilization of O2 in place of CO2 appears to be an inherent property of rubisco, so photorespiration is a general accompaniment of photosynthesis. Peroxisomes thus play an important role by allowing most of the carbon in glycolate to be recovered and utilized.