Faculty Science
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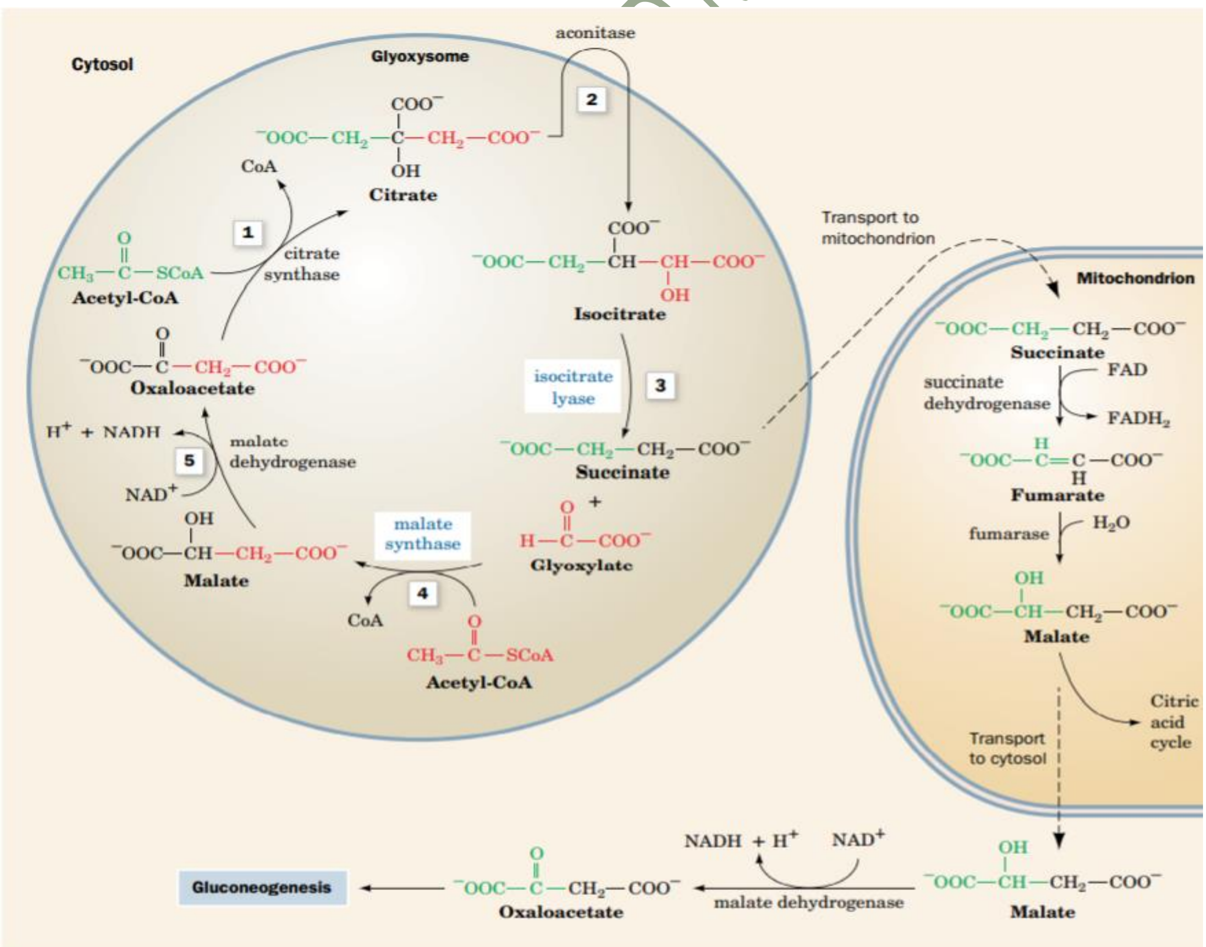
Topic- The Glyoxylate Cycle

In plants, certain invertebrates, and some microorganisms (including E. coli and yeast) acetate can serve both as an energy-rich fuel and as a source of phosphoenolpyruvate for carbohydrate synthesis. These organisms possess enzymes that mediate the net conversion of acetyl-CoA to oxaloacetate, which can be used for gluconeogenesis. In plants, these enzymes constitute the glyoxylate cycle which operates in two cellular compartments: the mitochondrion and the glyoxysome, a membrane-bounded plant organelle that is a specialized peroxisome. Most of the enzymes of the glyoxylate cycle are the same as those of the citric acid cycle.



The Glyoxylate Cycle

The glyoxylate cycle consists of five reactions:

Reactions 1 and 2. - Glyoxysomal oxaloacetate is condensed with acetyl CoA to form citrate, which is isomerized to isocitrate as in the citric acid cycle. Since the glyoxysome contains no aconitase, Reaction 2 presumably takes place in the cytosol.

Reaction 3. - Glyoxysomal isocitrate lyase cleaves the isocitrate to succinate and glyoxylate (hence the cycle's name).

Reaction 4. - Malate synthase, a glyoxysomal enzyme, condenses glyoxylate with a second molecule of acetyl-CoA to form malate.

Reaction 5. - Glyoxysomal malate dehydrogenase catalyzes the oxidation of malate to oxaloacetate by NAD^+.

The glyoxylate cycle therefore results in the net conversion of two acetyl-CoA to succinate instead of to four molecules of CO2 as would occur in the citric acid cycle. The succinate produced in Reaction 3 is transported to the mitochondrion where it enters the citric acid cycle and is converted to malate, which has two alternative fates: (1) It can be converted to oxaloacetate in the mitochondrion, continuing the citric acid cycle and thereby making the glyoxylate cycle an anaplerotic process (filling up process or process that forms intermediates of a metabolic pathway) or (2) it can be transported to the cytosol, where it is converted to oxaloacetate for entry into gluconeogenesis. The overall reaction of the glyoxylate cycle can be considered to be the formation of oxaloacetate from two molecules of acetyl-CoA:

$$2\ \text{Acetyl-CoA} + 2\ NAD^+ + FAD \rightarrow \text{oxaloacetate} + 2\ \text{CoA} + 2\ NADH + FADH_2 + 2\ H^+$$

Isocitrate lyase and malate synthase do not occur in animals. In plants, these enzymes enable germinating seeds to convert their stored triacylglycerols, through acetyl-CoA, to glucose. A mutant of Arabidopsis thaliana (an oilseed plant) lacking isocitrate lyase, and hence unable to convert lipids to carbohydrates, nevertheless germinated. This process was inhibited only when the mutant plants were subjected to low light conditions. Therefore, it now appears that the glyoxylate cycle's importance in seedling growth is its anaplerotic function in providing four-carbon units to the citric acid cycle, which can then oxidize the triacylglycerol-derived acetyl-CoA. Organisms that lack the glyoxylate pathway cannot undertake the net synthesis of glucose from acetyl-CoA. This is the reason humans cannot convert fats (that is, fatty acids, which are catabolized to acetyl-CoA) to carbohydrates (that is, glucose)

Role of the glyoxylate cycle in various organisms:

Plants: It occurs in glyoxysome and plays an important role during seedlings. During the seed germination plants converts store lipid molecule into carbohydrate using glyoxylate cycle. During seed germination photosynthesis is not operating so role of glyoxylate cycle is crucial. It enables plant to use acetate as a carbon and energy source.

Fungi: It plays an important role in pathogenesis of fungi. It was observed that concentration of isocitrate lyase and malate synthase is significantly increased during pathogenesis. Exact correlation is not understood.

Bacteria: Many bacteria have enzymes of glyoxylate and citric acid cycle in the cytoplasm. It enables them to grow on acetate as their sole source of carbon and energy. Glyoxylate bypass explains the ability of bacteria, yeast, and other microorganisms to utilize acetate as a sole source of carbon for growth. It plays an important role in pathogenesis of bacteria. It was observed that concentration of isocitrate lyase and malate synthase is significantly increased during pathogenesis.

References-

1. https://en.wikipedia.org/wiki/Glyoxylate_cycle.
2. Voet D, Voet J (2018) in "Biochemistry". 5th edition. J. Wiley & Sons, USA.