5.7D: Organic Acid Metabolism

Microbes can harness energy and carbon derived from organic acids by using a variety of dedicated metabolic enzymes.

LEARNING OBJECTIVES

Give examples of types of organic acid metabolism that are used by microorganisms for a sole source of energy

KEY TAKEAWAYS

Key Points

- Some microbes are capable of utilizing organic acids such as fatty acids, amino acids, or straight-chain unsaturated acids (e.g., lactate) as a sole source of energy.
- Metabolism of the organic acid formate is important in methylotrophic organisms. It is vital in the catabolism of C1 compounds (such as methanol).
- Many bacteria are capable of utilizing fatty acids as sole energy and carbon sources through the cyclic β-oxidation pathway, which ultimately yields acetyl-CoA.

Key Terms

- **fatty acid**: Any of a class of aliphatic carboxylic acids, of general formula CnH2n+1COOH, that occur combined with glycerol as animal or vegetable oils and fats. Only those with an even number of carbon atoms are normally found in natural fats.
• **acyl**: Any of class of organic radicals, RCO-, formed by the removal of a hydroxyl group from a carboxylic acid.

• **acetyl CoA**: Acetyl coenzyme A or acetyl-CoA is an important molecule in metabolism, used in many biochemical reactions. Its main function is to convey the carbon atoms within the acetyl group to the citric acid cycle (Krebs cycle) to be oxidized for energy production.

### Organic Acid Metabolism

A great many organisms generate organic acids (such as lactate) as a byproduct of fermentation. Some microbes are capable of utilizing such compounds as a sole source of energy.

The most commonly metabolized organic acids are the carboxylic acids, which are organic acids containing at least one carboxyl (-COOH) group. The general formula of a carboxylic acid is R-COOH, where R is a monovalent functional group. Many types of carboxylic acids can be metabolized by microbes, including:

- Fatty acids (carboxylic acids with long acyl tails)
- Amino acids (the building blocks of proteins)
- Straight-chained, saturated acids (e.g., formate, acetate, and palmitate)

### FORMATE METABOLISM

Formate metabolism is important in methylotrophic organisms. It is vital in the catabolism of C₁ compounds such as methanol (see the “Methylotrophy and Methanotrophy” atom for more information on C₁ compound utilization). Methylotrophic microbes convert single-carbon compounds to formaldehyde, which is oxidized to formate by formaldehyde dehydrogenase. Degradation of formate is then catalyzed by formate dehydrogenase (FDH), which oxidizes formate to ultimately yield CO₂. It permits the donation of electrons to a second substrate (such as NAD⁺) in the process. This is a critical late step in the hydrocarbon utilization pathway. The ability to metabolize formate is also critical in bacterial anaerobic metabolism, in which case formate is also oxidized by an FDH enzyme but the electrons are donated to cytochromes (proteins involved in electron transport).

### FATTY ACID METABOLISM

Many bacteria are capable of utilizing fatty acids of various tail lengths as sole energy and carbon sources. This process requires the β-oxidation pathway, a cyclic process that catalyzes the sequential shortening of fatty acid acyl chains to the final product, acetyl-CoA. The step-by-step process occurs as follows:

1. Fatty acid chains are converted to enoyl-CoA (catalyzed by acyl-CoA dehydrogenase).
2. Enoyl-CoA is converted to 3-hydroxyacyl-CoA (catalyzed by enoyl-CoA hydratase).
3. 3-hydroxyacyl-CoA is converted to 3-ketoacyl-CoA (catalyzed by 3-hydroxyacyl-CoA dehydrogenase).
4. 3-ketoacyl-CoA is thiolated (by 3-ketoacyl-CoA thiolase) to yield one molecule of acetyl-CoA and a derivative of the original input fatty acid that is now shorter by two carbons.

The fatty acid chain that is left over after the thiolation step can then reenter the β-oxidation pathway, which can cycle until the fatty acid has been completely reduced to acetyl-CoA. Acetyl-CoA is the entry molecule for the TCA cycle.
TCA cycle is the process used by all aerobic organisms to generate energy.

Figure: **β-oxidation of fatty acids**: Free fatty acids are broken down to acetyl-CoA by dedicated enzymes in the β-oxidation pathway.