5.7E: Lipid Metabolism

Biological lipids, which are broken down and utilized through β-oxidation, represent a potent energy source.

Learning Objectives

• Outline the process of lipid metabolism, specifically beta-oxidation

Key Points

• In addition to their role as the primary component of cell membranes, lipids can be metabolized for use as a primary energy source.

• Lipid metabolism involves the degradation of fatty acids, which are fundamental biological molecules and the building blocks of more structurally complex lipids.

• In order to be metabolized by the cell, lipids are hydrolyzed to yield free fatty acids that then converted to acetyl-CoA through the β- oxidation pathway.

• One major feature of anaerobic digestion is the production of biogas (with the most useful component being methane), which can be used in generators for electricity production and/or in boilers for heating purposes.

Key Terms

• carboxylic acid: Any of a class of organic compounds containing a carboxyl functional group.

• coenzyme A: A coenzyme, formed from pantothenic acid and adenosine triphosphate, that is necessary for fatty acid synthesis and metabolism.
Lipid Metabolism

Lipids are universal biological molecules. Not only does this broad class of compounds represent the primary structural component of biological membranes in all organisms, they also serve a number of vital roles in microorganisms. Among these, lipids can be metabolized by microbes for use as a primary energy source. Although not stated explicitly, the “Organic Acid Metabolism” atom in this module introduces the concept of lipid metabolism by describing the process of fatty acid metabolism through β-oxidation. This atom will expand on the metabolic pathway that enables degradation and utilization of lipids. Fatty acids are the building blocks of lipids. They are made of a hydrocarbon chain of variable length that terminates with a carboxylic acid group (-COOH). The fatty acid structure (see below) is one of the most fundamental categories of biological lipids. It is commonly used as a building block of more structurally complex lipids (such as phospholipids and triglycerides). When metabolized, fatty acids yield large quantities of ATP, which is why these molecules are important energy sources. Lipids are an energy and carbon source. Before complex lipids can be used to produce energy, they must first be hydrolyzed. This requires the activity of hydrolytic enzymes called lipases, which release fatty acids from derivatives such as phospholipids. These fatty acids can then enter a dedicated pathway that promotes step-wise lipid processing that ultimately yields acetyl-CoA, a critical metabolite that conveys carbon atoms to the TCA cycle (aka Krebs cycle or citric acid cycle) to be oxidized for energy production.

![A free fatty acid](https://bio.libretexts.org/Bookshelves/Microbiology/Book%3A_Microbiology_(Boundless)/5%3A_Microbial_Metabolism/5.07%...

Figure: An example of a fatty acid: A fatty acid is a carboxylic acid with a long aliphatic tail that may be either saturated or unsaturated. The molecule shown here is the eight-carbon saturated fatty acid known as octanoic acid (or caprylic acid).

**β-oxidation**

The metabolic process by which fatty acids and their lipidic derivatives are broken down is called β-oxidation. This process bears significant similarity to the mechanism by which fatty acids are synthesized, except in reverse. In brief, the oxidation of lipids proceeds as follows: two-carbon fragments are removed sequentially from the carboxyl end of the fatty acid after dehydrogenation, hydration, and oxidation to form a keto acid, which is then cleaved by thiolysis. The acetyl-CoA molecule liberated by this process is eventually converted into ATP through the TCA cycle.

β-oxidation can be broken down into a series of discrete steps:

1. **Activation:** Before fatty acids can be metabolized, they must be “activated.” This activation step involves the addition of a coenzyme A (CoA) molecule to the end of a long-chain fatty acid, after which the activated fatty acid (fatty acyl-CoA) enters the β-oxidation pathway.

2. **Oxidation:** The initial step of β-oxidation is catalyzed by acyl-CoA dehydrogenase, which oxidizes the fatty acyl-
CoA molecule to yield enoyl-CoA. As a result of this process, a trans double bond is introduced into the acyl chain.

3. Hydration: In the second step, enoyl-CoA hydratase hydrates the double bond introduced in the previous step, yielding an alcohol (-C=OH).

4. Oxidation: Hydroxyacyl-CoA dehydrogenase oxidizes the alcohol formed in the previous step to a carbonyl (-C=O).

5. Cleavage: A thiolase then cleaves off acetyl-CoA from the oxidized molecule, which also yields an acyl-CoA that is two carbons shorter than the original molecule that entered the β-oxidation pathway.

This cycle repeats until the fatty acid has been completely reduced to acetyl-CoA, which is fed through the TCA cycle to ultimately yield cellular energy in the form of ATP.

Figure: β-oxidation: The sequential steps of the β-oxidation pathway.