5.8C: Syntrophy

Learning Objectives

- Give examples of syntrophy in microbial metabolism

Syntrophy, or symbiosis, is the phenomenon involving one species living off the products of another species. For example, house dust mites live off human skin flakes. A healthy human being produces about 1 gram of skin flakes per day. These mites can also produce chemicals that stimulate the production of skin flakes. People can become allergic to these compounds. Another example are the many organisms that feast on feces or dung. A cow eats a lot of grass, the cellulose of which is transformed into lipids by micro-organisms in the cow’s large intestine.

Figure: *House dust mite:* The house dust mite (sometimes referred to by allergists as HDM) is a cosmopolitan guest in human habitation. Dust mites feed on organic detritus such as flakes of shed human skin and flourish in the stable environment of dwellings.
These microorganisms cannot use the lipids because of a lack of dioxygen in the intestine, so the cow does not take up all the lipids produced. When the processed grass leaves the intestine as dung and comes into open air, many organisms, such as the dung beetle, feast on it. Yet another example is the community of micro-organisms in soil that live off leaf litter. Leaves typically last one year and are then replaced by new ones. These microorganisms mineralize the discarded leaves and release nutrients that are taken up by the plant. Such relationships are called reciprocal syntrophy because the plant lives off the products of micro-organisms. Many symbiotic relationships are based on syntrophy. Finally, anaerobic fermentation/methanogenesis is an example of a syntrophic relationship between different groups of microorganisms. Although fermentative bacteria are not strictly dependent on syntrophic relationships, they still gain profit from the activities of the hydrogen-scavenging organisms. The fermentative bacteria gain maximum energy yield when protons are used as electron acceptor with concurrent H₂ production.

Fermentation is a specific type of heterotrophic metabolism that uses organic carbon instead of oxygen as a terminal electron acceptor. This means that these organisms do not use an electron transport chain to oxidize NADH to NAD⁺ and therefore must have an alternative method of using this reducing power and maintaining a supply of NAD⁺ for the proper functioning of normal metabolic pathways (e.g. glycolysis). As oxygen is not required, fermentative organisms are anaerobic. Many organisms can use fermentation under anaerobic conditions and aerobic respiration when oxygen is present. These organisms are facultative anaerobes. To avoid the overproduction of NADH, obligately fermentative organisms usually do not have a complete citric acid cycle. Instead of using an ATP synthase as in respiration, ATP in fermentative organisms is produced by substrate-level phosphorylation where a phosphate group is transferred from a high-energy organic compound to ADP to form ATP. As a result of the need to produce high energy phosphate-containing organic compounds (generally in the form of CoA-esters) fermentative organisms use NADH and other cofactors to produce many different reduced metabolic by-products, often including hydrogen gas (H₂). These reduced organic compounds are generally small organic acids and alcohols derived from pyruvate, the end product of glycolysis. Examples include ethanol, acetate, lactate, and butyrate. Fermentative organisms are very important industrially and are used to make many different types of food products. The different metabolic end products produced by each specific bacterial species are responsible for the different tastes and properties of each food.

The best studied example of syntrophy in microbial metabolism is the oxidation of fermentative end products (such as acetate, ethanol and butyrate) by organisms such as Syntrophomonas. Alone, the oxidation of butyrate to acetate and hydrogen gas is energetically unfavorable. However, when a hydrogenotrophic (hydrogen-using) methanogen is present the use of the hydrogen gas will significantly lower the concentration of hydrogen (down to 10⁻⁵ atm) and thereby shift the equilibrium of the butyrate oxidation reaction under standard conditions (ΔGₒ) to non-standard conditions (ΔG'). Because the concentration of one product is lowered, the reaction is “pulled” towards the products and shifted towards net energetically favorable conditions (for butyrate oxidation: ΔGₒ= +48.2 kJ/mol, but ΔG' = -8.9 kJ/mol at 10⁻⁵ atm hydrogen and even lower if also the initially produced acetate is further metabolized by methanogens). Conversely, the available free energy from methanogenesis is lowered from ΔGₒ= -131 kJ/mol under standard conditions to ΔG' = -17 kJ/mol at 10⁻⁵ atm hydrogen. This is an example of intraspecies hydrogen transfer. In this way, low energy-yielding carbon sources can be used by a consortium of organisms to achieve further degradation and eventual mineralization of these compounds. These reactions help prevent the excess sequestration of carbon over geologic time scales, releasing it back to the biosphere in usable forms such as methane and CO₂.
Key Points

• Anaerobic fermentation / methanogenesis is an example of a syntrophic relationship between different groups of microorganisms.

• Fermentation is a specific type of heterotrophic metabolism that uses organic carbon instead of oxygen as a terminal electron acceptor.

• The best studied example of syntrophy in microbial metabolism is the oxidation of fermentative end products (such as acetate, ethanol and butyrate) by organisms such as Syntrophomonas.

Key Terms

• **syntrophy**: The relationship between the individuals of different species (especially of bacteria) in which one or both benefit nutritionally from the presence of the other.

• **symbiosis**: A close, prolonged association between two or more organisms of different species, regardless of benefit to the members.

• **fermentation**: Any of many anaerobic biochemical reactions in which an enzyme (or several enzymes produced by a microorganism) catalyses the conversion of one substance into another; especially the conversion (using yeast) of sugars to alcohol or acetic acid with the evolution of carbon dioxide.

LICENSES AND ATTRIBUTIONS

CC LICENSED CONTENT, SPECIFIC ATTRIBUTION

• OpenStax College, Biology. October 16, 2013. **Provided by**: OpenStax CNX. **Located at**: http://cnx.org/content/m44444/latest/?collection=col11448/latest. **License**: CC BY: Attribution

• OpenStax College, Biology. October 28, 2013. **Provided by**: OpenStax CNX. **Located at**: http://cnx.org/content/m44444/latest/?collection=col11448/latest. **License**: CC BY: Attribution

• archaea. **Provided by**: Wikipedia. **Located at**: en.Wikipedia.org/wiki/archaea. **License**: CC BY-SA: Attribution-ShareAlike

• anaerobic respiration. **Provided by**: Wikipedia. **Located at**: en.Wikipedia.org/wiki/anaerobic%20respiration. **License**: CC BY-SA: Attribution-ShareAlike

• fermentation. **Provided by**: Wiktionary. **Located at**: en.wiktioinary.org/wiki/fermentation. **License**: CC BY-SA: Attribution-ShareAlike

• OpenStax College, Metabolism Without Oxygen. October 16, 2013. **Provided by**: OpenStax CNX. **Located at**: http://cnx.org/content/m44444/latest/Figure_07_05_01.jpg. **License**: CC BY: Attribution

• OpenStax College, Metabolism Without Oxygen. October 16, 2013. **Provided by**: OpenStax CNX. **Located at**: http://cnx.org/content/m44444/latest/Figure_07_05_02.png. **License**: CC BY: Attribution

• OpenStax College, Metabolism Without Oxygen. October 16, 2013. **Provided by**: OpenStax CNX. **Located at**: http://cnx.org/content/m44444/latest/Figure_07_05_03.jpg. **License**: CC BY: Attribution

• Acidogenesis. **Provided by**: Wikipedia. **Located at**: en.Wikipedia.org/wiki/Acidogenesis. **License**: CC BY-SA: Attribution-ShareAlike

• acetogenesis. **Provided by**: Wiktionary. **Located at**: en.wiktioinary.org/wiki/acetogenesis. **License**: CC BY-SA: Attribution-ShareAlike

• metabolite. **Provided by**: Wiktionary. **Located at**: en.wiktioinary.org/wiki/metabolite. **License**: CC BY-SA: Attribution-ShareAlike
OpenStax College, Metabolism Without Oxygen. October 16, 2013. Provided by: OpenStax CNX. Located at: http://cnx.org/content/m44444/latest/Figure_07_05_02.png. License: CC BY: Attribution

