5.9D: Methanogenesis

Methanogenesis is a form of anaerobic respiration that uses carbon as an electron acceptor and results in the production of methane.

Learning Objectives

- Recognize the characteristics associated with methanogenesis

Key Points

- Carbon dioxide or acetic acid are the most commonly used electron acceptor in methanogenesis.
- Microbes capable of producing methane are called methanogens. They have been identified only from the domain Archaea – a group that is phylogenetically distinct from eukaryotes and bacteria.
- The production of methane is an important and widespread form of microbial metabolism. In most environments, it is the final step in the decomposition of biomass.
- Methane is a major greenhouse gas. The average cow emits around 250 liters of methane a day as a result of the breakdown of cellulose by methanogens. Therefore, the large scale raising of cattle for meat is a considerable contributor to global warming.

Key Terms

- methanethiol: A colourless gas, a thiol with a smell like rotten cabbage, found naturally in plants and animals.
- cofactor: A substance, especially a coenzyme or a metal, that must be present for an enzyme to function.
- 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.

Methanogenesis, or biomethanation, is a form of anaerobic respiration that uses carbon as the terminal electron acceptor, resulting in the production of methane. The carbon is sourced from a small number of low molecular weight organic compounds, such as carbon dioxide, acetic acid, formic acid (formate), methanol, methylamines, dimethyl sulfide, and methanethiol. The two best described pathways of methanogenesis use carbon dioxide or acetic acid as the terminal electron acceptor:

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\text{CO}_2 + 4 \text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}
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\[
\text{CH}_3\text{COOH} \rightarrow \text{CH}_4 + \text{CO}_2
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The biochemistry of methanogenesis is relatively complex. It involves the coenzymes and cofactors F420, coenzyme B, coenzyme M, methanofuran, and methanopterin.

Microbes capable of producing methane are called methanogens. They have been identified only from the domain Archaea – a group that is phylogenetically distinct from eukaryotes and bacteria – though many live in close association with anaerobic bacteria. The production of methane is an important and widespread form of microbial metabolism, and in most environments, it is the final step in the decomposition of biomass.

During the decay process, electron acceptors (such as oxygen, ferric iron, sulfate, and nitrate) become depleted, while hydrogen (H2), carbon dioxide, and light organics produced by fermentation accumulate. During advanced stages of
organic decay, all electron acceptors become depleted except carbon dioxide, which is a product of most catabolic processes. It is not depleted like other potential electron acceptors.

Only methanogenesis and fermentation can occur in the absence of electron acceptors other than carbon. Fermentation only allows the breakdown of larger organic compounds, and produces small organic compounds. Methanogenesis effectively removes the semi-final products of decay: hydrogen, small organics, and carbon dioxide. Without methanogenesis, a great deal of carbon (in the form of fermentation products) would accumulate in anaerobic environments.

Methanogenesis also occurs in the guts of humans and other animals, especially ruminants. In the rumen, anaerobic organisms, including methanogens, digest cellulose into forms usable by the animal. Without these microorganisms, animals such as cattle would not be able to consume grass. The useful products of methanogenesis are absorbed by the gut. Methane is released from the animal mainly by belching (eructation). The average cow emits around 250 liters of methane per day. Some, but not all, humans emit methane in their flatus!

Some experiments even suggest that leaf tissues of living plants emit methane, although other research indicates that the plants themselves do not actually generate methane; they are just absorbing methane from the soil and then emitting it through their leaf tissues. There may still be some unknown mechanism by which plants produce methane, but that is by no means certain.

Methane is one of the earth’s most important greenhouse gases, with a global warming potential 25 times greater than carbon dioxide (averaged over 100 years). Therefore, the methane produced by methanogenesis in livestock is a considerable contributor to global warming.

Methanogenesis can also be beneficially exploited. It is the primary pathway that breaks down organic matter in landfills (which can release large volumes of methane into the atmosphere if left uncontrolled), and can be used to treat organic waste and to produce useful compounds. Biogenic methane can be collected and used as a sustainable alternative to fossil fuels.