5.15A: Nitrogenase and Nitrogen Fixation

LEARNING OBJECTIVES

• Describe the importance of nitrogen fixation

Nitrogen fixation also refers to other biological conversions of nitrogen, such as its conversion to nitrogen dioxide. Nitrogen fixation is a process by which nitrogen (N\textsubscript{2}) in the atmosphere is converted into ammonia (NH\textsubscript{3}). Atmospheric nitrogen or elemental nitrogen (N\textsubscript{2}) is relatively inert: it does not easily react with other chemicals to form new compounds. Dinitrogen is quite inert because of the strength of its N≡N triple bond. To break one nitrogen atom away from another requires breaking all three of these chemical bonds. Fixation processes free up the nitrogen atoms from their diatomic form (N\textsubscript{2}) to be used in other ways. Nitrogen fixation, natural and synthetic, is essential for all forms of life because nitrogen is required to biosynthesize basic building blocks of plants, animals, and other life forms, e.g., nucleotides for DNA and RNA and amino acids for proteins. Therefore, nitrogen fixation is essential for agriculture and the manufacture of fertilizer. Microorganisms that fix nitrogen are bacteria called diazotrophs.
Some higher plants, and some animals (termites), have formed associations (symbioses) with diazotrophs. Diazotrophs are microbes. They are intensively studied by microbiologists. Biological nitrogen fixation was discovered by the German agronomist Hermann Hellriegel and Dutch microbiologist Martinus Beijerinck. Biological nitrogen fixation (BNF) occurs when atmospheric nitrogen is converted to ammonia by an enzyme called nitrogenase. Nitrogenases are enzymes used by some organisms to fix atmospheric nitrogen gas (N₂). There is only one known family of enzymes that accomplishes this process. All nitrogenases have an iron – and sulfur-containing cofactor that includes a heterometal complex in the active site (e.g., FeMoCo). In most species, this heterometal complex has a central molybdenum atom. However, in some species it is replaced by a vanadium or iron atom. Enzymes responsible for nitrogenase action are very susceptible to destruction by oxygen. Many bacteria cease production of the enzyme in the presence of oxygen. Many nitrogen-fixing organisms exist only in anaerobic conditions, respiring to draw down oxygen levels, or binding the oxygen with proteins.

**Key Points**

- Nitrogen fixation takes elemental nitrogen (N₂) and converts it into ammonia, a format usable by biological organism.
- The fixed form of nitrogen (NH₃) is needed as an essential component of DNA and proteins. Therefore, it is needed for all life on earth.
- Nitrogen fixation is carried out by the enzyme nitrogenase, which are found in microbes.

**Key Terms**

- **fixation**: The act of uniting chemically with a solid substance or in a solid form; reduction to a non-volatile condition; — said of gaseous elements.
- **cofactor**: A substance, especially a coenzyme or a metal, that must be present for an enzyme to function.
- **heterometal**: Describing a complex containing two (or more) different metals
- **nitrogen fixation**: the conversion of atmospheric nitrogen into ammonia and organic derivatives, by natural means,
especially such conversion, by microorganisms in the soil, into a form that can be assimilated by plants