BIOLOGICAL NITROGEN FIXATION

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Introduction

Nitrogen, after carbon, hydrogen and oxygen is the most abundant component of living organisms. It is found in a range of organic compounds such as nucleic acids, amino acids - and therefore proteins - and in chlorophyll, coenzymes and vitamins. Most of this organic nitrogen is derived from inorganic compounds of nitrogen in the Earth's soils and waters. Dinitrogen makes up 80% of the atmosphere, but it is not directly available to higher plants or animals. To grow, multiply or just survive, these organisms need a source of fixed nitrogen. This is especially important with regard to agriculture. Higher plants which are used as food crops require nitrogen for better growth and increased yields. But since they are incapable of fixing atmospheric nitrogen directly it must be converted to a suitable form which can be used by the plants.

NITROGEN FIXATION

Non-biological — *Biological*

Lightening

$N_2 + O_2$ -----> $2NO$

$2NO + O_2$ -----> $2NO_2$

$2NO_2 + H_2O$ -----> $HNO_3 + HNO_2$

Haber Bosch Process

$N_2 + 3H_2$ ------> $2NH_3$

high pressure

high temperature

Biological

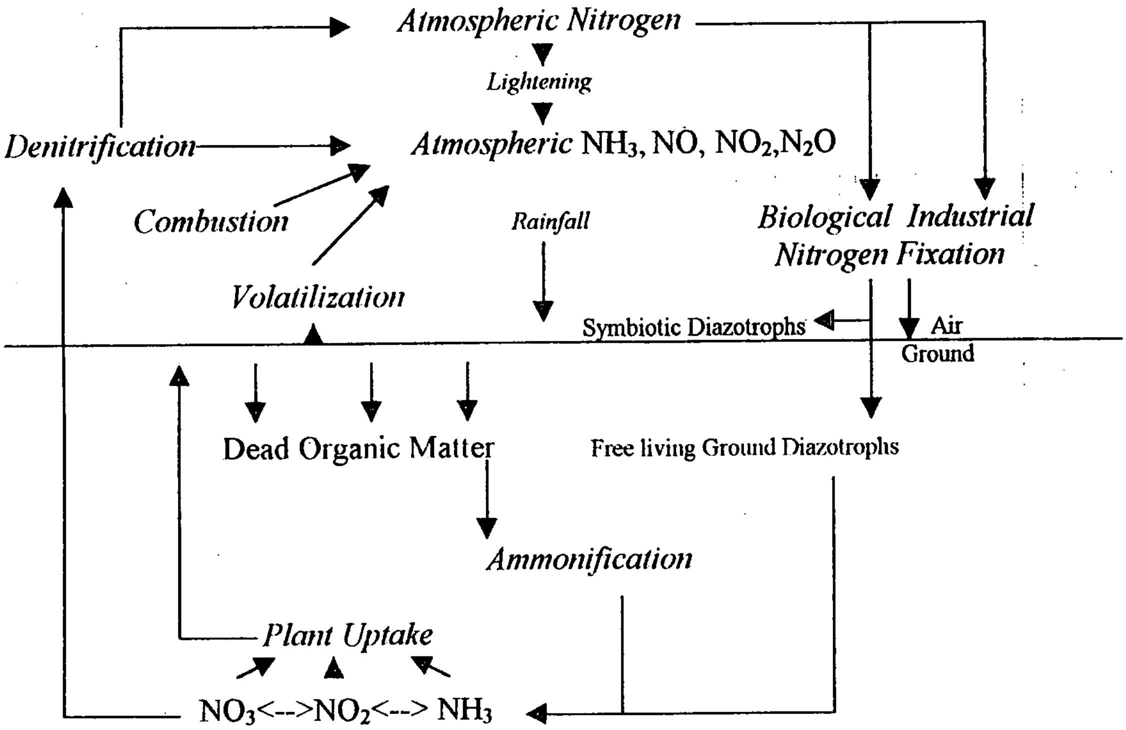
$N_2 + 3H_2$ -----> $2NH_3$

> Atmospheric nitrogen or nitrogen in the air is fixed both biologically and non-biologically.

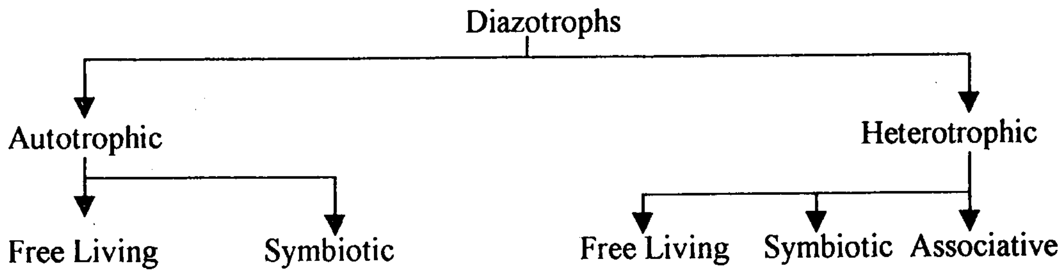
Biological nitrogen fixation

Biological nitrogen fixation is the conversion of inert dinitrogen, found in the atmosphere, to organic nitrogen by living organisms. The overall result is the production of ammonia. This ability to reduce atmospheric dinitrogen is confined to prokaryotic microorganisms. These organisms are collectively known as 'diazotrophs'. The diazoatrophs have the ability to carry out this reductive reaction because of an enzyme complex known as the **Nitrogenase** complex which catalyses the above reaction. BNF is a major process in the global nitrogen cycle.

The Global Nitrogen Cycle



Diazotrophs



The symbiotic relationship between the diazotophs called Rhizobia and legumes can provide large amounts of nitrogen to the plant and can have a significant impact on agriculture. The symbiosis occurs within structures known as 'nodules' in the root/stem of the legume. The plant supplies energy materials to the diazotrophs, which in turn reduce atmospheric nitrogen to ammonia. This ammonia is transferred from the bacteria to the plant to meet the plant's nutritional nitrogen needs for the synthesis of proteins, enzymes, nucleic acids, chlorophyll and so forth.

Biological Nitrogen Fertilizer vs Synthetic Nitrogen Fertilizer

There has been a steadily growing interest in BNF due to both ecological and economical reasons.

(1) *Global Nitrogen Cycle*
Until recently there has been a balance between nitrogen fixation and denitrification. But there has been a steady increase in industrial nitrogen fixation which could affect the natural cycle, *e.g.*, 2 tons of industrially fixed nitrogen is needed as fertilizer to equal the effect of 1 ton of biologically fixed nitrogen.

(2) ***Water Pollution***
Not all fertilizer nitrogen applied to crops is used. Some of it is converted to nitrates which go through the soil to pollute groundwater and other water bodies. In contrast, all of the biologically fixed nitrogen is assimilated by legume crops.

(3) Greenhouse Gases
Nitrous oxide, along with carbon dioxide, methane and chlorofluorocarbons is a "greenhouse" gas that traps reflected sunlight and may cause global warming. Denitrification of nitrate produces about 90% nitrogen gas and 10% nitrous oxide. The global budget for nitrous oxide appears to be out of balance and the increase is seen to correlate with the increase in the use of fertilizer nitrogen. Thus, increased use of fertilizer nitrogen may contribute substantially to the potential for global warming.

(4) ***Energy***
Industrial manufacture of nitrogen fertilizers require a large amount of energy. This energy is produced by using fossil fuels which are by-products of petroleum and are therefore non-renewable. The rapid depletion of non-renewable resources is a major concern of the fertilizer industry. The energy requirements of BNF in contrast is met by renewable sources such as plant synthesized carbohydrates rather than from non-renewable fossil fuels such as natural gas.

(5) ***Cost of Fertilizers***
The large energy requirement for the production of synthetic nitrogen fertilizers is of special significance to countries that do not have the necessary fuel resources. These countries depend entirely on imports, which ultimately results in the increase in price of the final fertilizer product. In much of the developing world, nitrogen is the nutrient most commonly limiting agricultural productivity. But in many situations, nitrogen fertilizer is too expensive or not available. Under these circumstances, the exploitation of nitrogen fixing legumes is particularly important.