NITROGEN CYCLE

B. Sc. PART – I (Honours)

By : -
Dr. Sananda Sinha
Assistant Professor
Department of Zoology
T. P. S. College
Patliputra University, Patna

Definition

- The nitrogen cycle refers to the cycle of nitrogen atoms through the living and non-living systems of Earth. The nitrogen cycle is vital for life on Earth. Through the cycle, atmospheric nitrogen is converted to a form which plants can incorporate into new proteins.

Brief Introduction of Nitrogen

- **When the Earth was formed, nitrogen gas was the main ingredient in its atmosphere.**
- Nitrogen, is inert and harmless in its gaseous form. **However, nitrogen gas is not accessible to plants and animals for use in their cells.**
- Here we will discuss how nitrogen plays a vital role in the chemistry of life – and how it gets from the atmosphere, into living things, and back again.

Nitrogen Fixation

- In the process of **nitrogen fixation**, bacteria turn nitrogen gas from the atmosphere into ammonia.
- These nitrogen-fixing bacteria, often called "**diazotrophs**," have an enzyme called "**nitrogenase**" which combines nitrogen atoms with hydrogen atoms. Ammonia is a nitrogen compound that can dissolve in water, and is easier for other organisms' enzymes to interact with.
- **Interestingly, the enzyme nitrogenase can only function when oxygen isn't present.** As a result, organisms that use it have had to develop oxygen-free compartments in which to perform their nitrogen fixation.

Nitrogen-fixing legume plants

- Common examples of such nitrogen-free compartments are the ***Rhizobium*** nodules found in the roots of nitrogen-fixing legume plants. The hard casing of these nodules keeps oxygen out of the pockets where *Rhizobium* bacteria do their valuable work of converting nitrogen gas into ammonia.
- oxygen-free ***Rhizobium* nodules**, visible as big round lumps, on the roots of this pea plant.

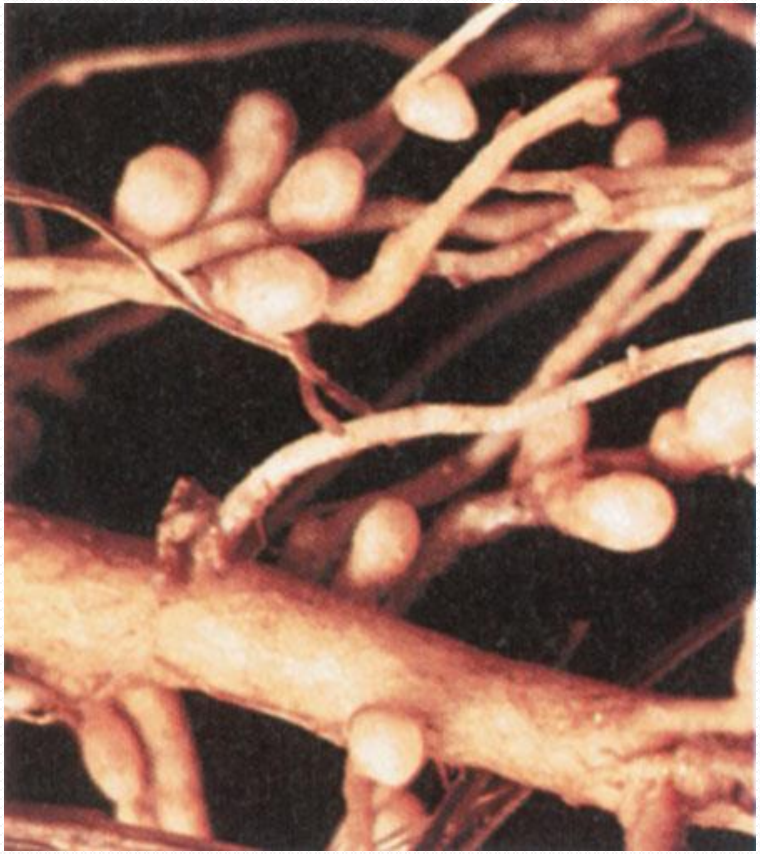
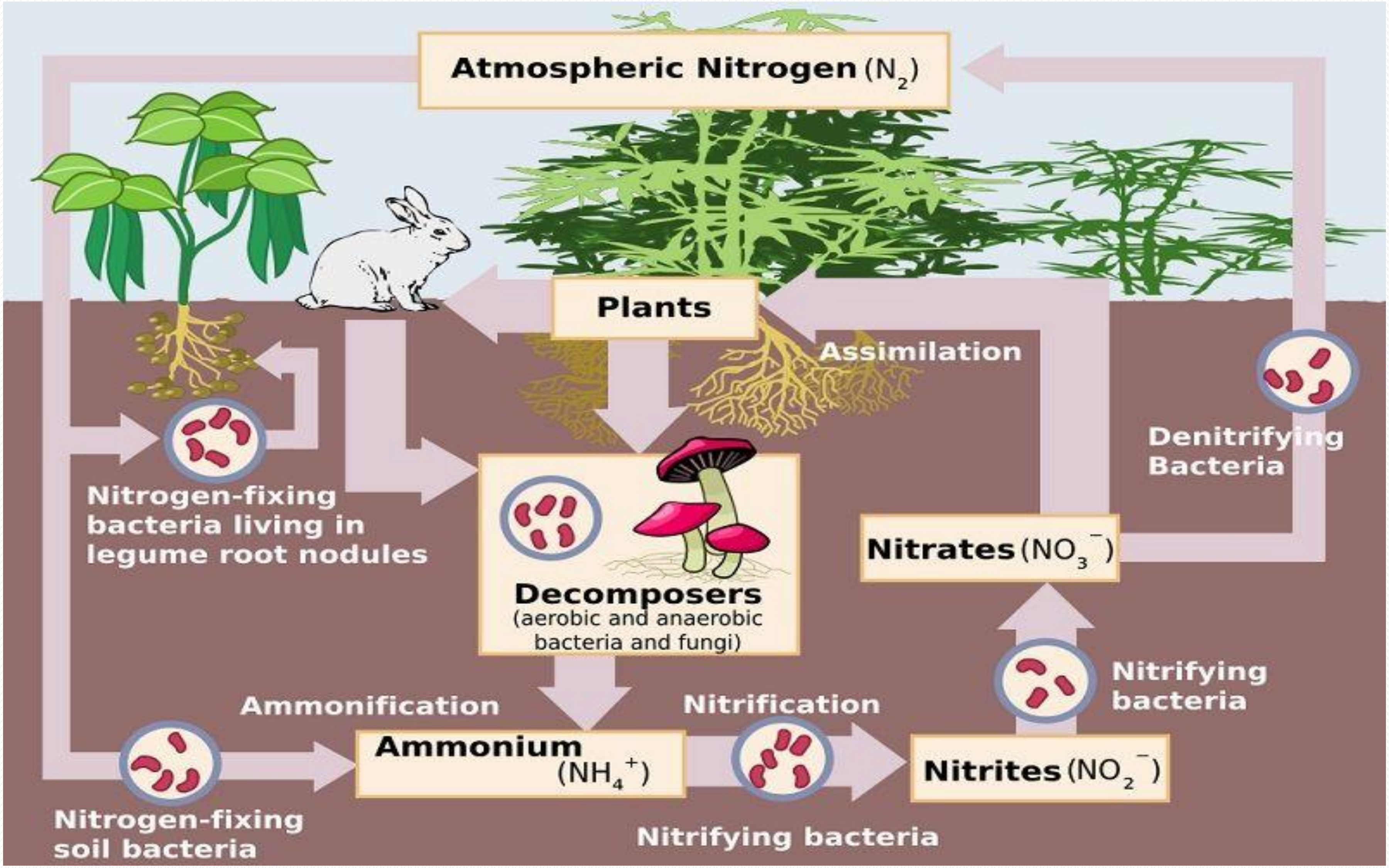
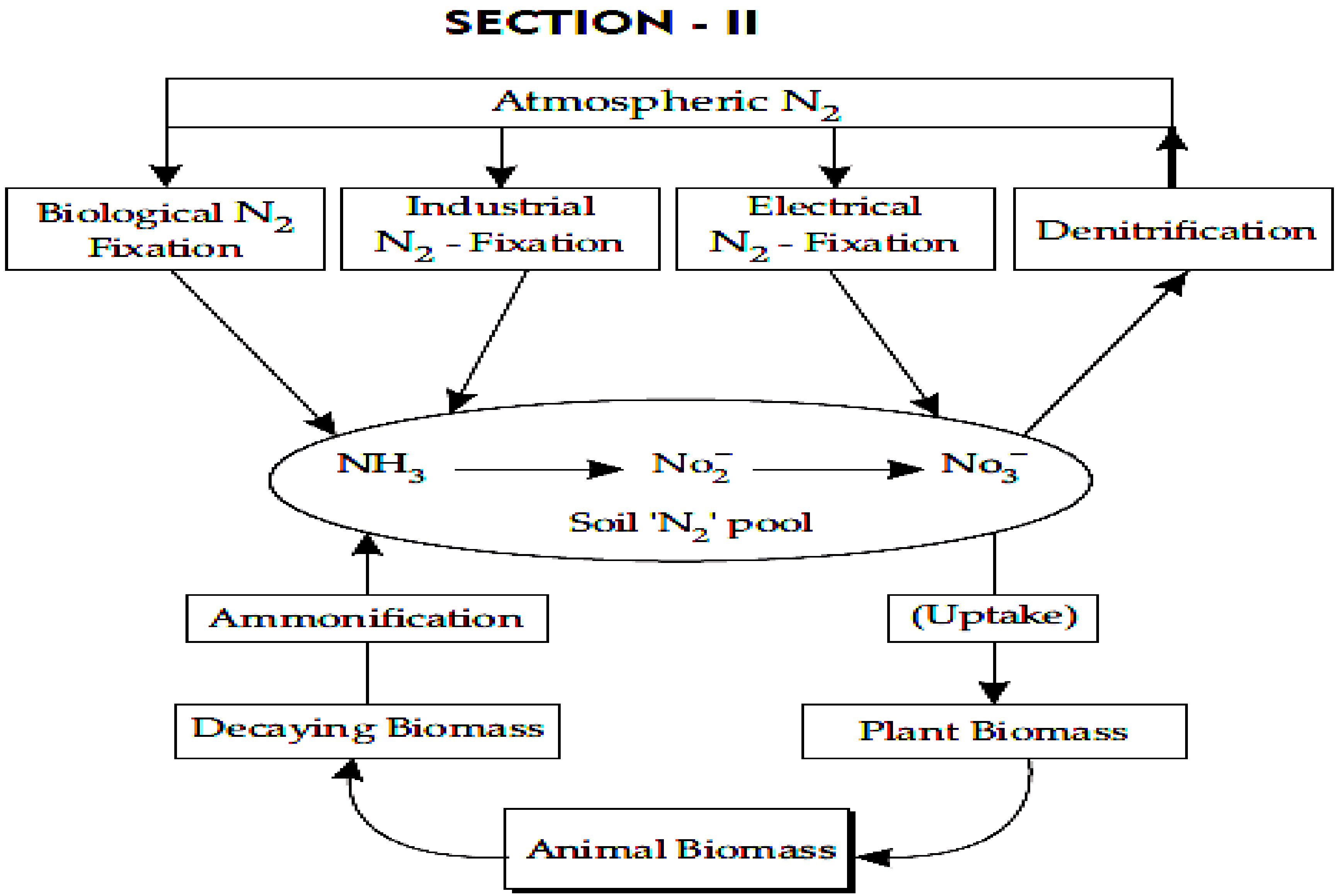


Figure: Root nodules on a pea plant containing nitrogen-fixing bacteria.

Diagrammatic representation steps of N_2-Cycle



Integrated Flow Chart of N_2-Cycle



Steps of Nitrogen Cycle

- The basic steps of the nitrogen cycle are illustrated here:
  - **Nitrification**
  - **Assimilation**
  - **Ammonification**
  - **Denitrification**

Stepwise details are as in the following slides;

Nitrification

- In **nitrification**, a host of soil bacteria participate in turning ammonia into nitrate – the form of nitrogen that can be used by plants and animals. **This requires two steps, performed by two different types of bacteria.**
- First, soil bacteria such as ***Nitrosomonas*** or ***Nitrococcus*** convert ammonia into nitrogen dioxide. Then another type of soil bacterium, called ***Nitrobacter***, adds a third oxygen atom to create nitrate.
- These bacteria don't convert ammonia for plants and animals out of the goodness of their hearts. Rather, they are "**chemotrophs**" who obtain their energy from volatile chemicals. By metabolizing nitrogen along with oxygen, they obtain energy to power their own life processes.
- The process can be thought of as a rough (and much less efficient) analog to the **cellular respiration** performed by animals, which extract energy from carbon-hydrogen bonds and use oxygen as the electron acceptor, yielding carbon dioxide at the end of the process.
- **Nitrates – the end product of this vital string of bacterial reactions – can be made artificially, and are the main ingredient in many soil fertilizers.** This is referred to as "nitrate fertilizer." By pumping the soil full of nitrates, such fertilizers allow plants to grow large quickly, without being dependent on the rate at which nitrogen-fixing bacteria do their jobs.
- Interestingly, high-energy environments such as lightning strikes and volcanic eruptions can convert nitrogen gas directly into nitrates – but this doesn't happen nearly enough to keep modern ecosystems healthy on its own.

Assimilation

- In **nitrogen assimilation**, plants finally consume the nitrates made by soil bacteria and use them to make **nucleotides, amino acids**, and other vital chemicals for life.
- **Plants take up nitrates through their roots and use them to make amino acids and nucleic acids from scratch.** Animals that eat the plants are then able to use these amino acids and nucleic acids in their own cells.

Ammonification

- Now we have moved nitrogen from the atmosphere into the cells of plants and animals.
- Because there is so much nitrogen in the atmosphere, it may seem that the process could stop there – **but the atmosphere's supply is not infinite, and keeping nitrogen inside plant and animal cells would eventually result in big changes to our soil, our atmosphere, and our ecosystems.**
- Fortunately, that's not what happens. In a robust **ecosystem** like ours, anywhere that energy has been put into creating an organic chemical, there is another form of life that is waiting to extract that energy by breaking those chemical bonds.
- **A process called "*ammonification*" is performed by soil bacteria which decompose dead plants and animals.** During the process, these **decomposers break down amino acids and nucleic acids into nitrates and ammonia** and release those compounds back into the soil.
- There, the ammonia may be taken up again by plants and nitrifying bacteria. Alternatively, the ammonia may be converted back into atmospheric nitrogen through the process of **denitrification**.

Denitrification

- In the final step of the nitrogen cycle, **anaerobic bacteria** can turn nitrates back into nitrogen gas.
- This process, like the process of turning nitrogen gas into ammonia, **must happen in the absence of oxygen.** As such it often occurs deep in the soil, or in wet environments where mud and muck keep oxygen at bay.
- In some ecosystems, this **denitrification** is a valuable process to prevent nitrogen compounds in the soil from building up to dangerous levels.
- Excess levels of nitrate, NO_3^-, in water can result in **eutrophication** in the environment. While high levels of nitrate in drinking water are dangerous for infants because the nitrate can be reduced to nitrite in the body which may interfere with oxygen binding by haemoglobin.

Flow Chart of N_2-Cycle in Nature

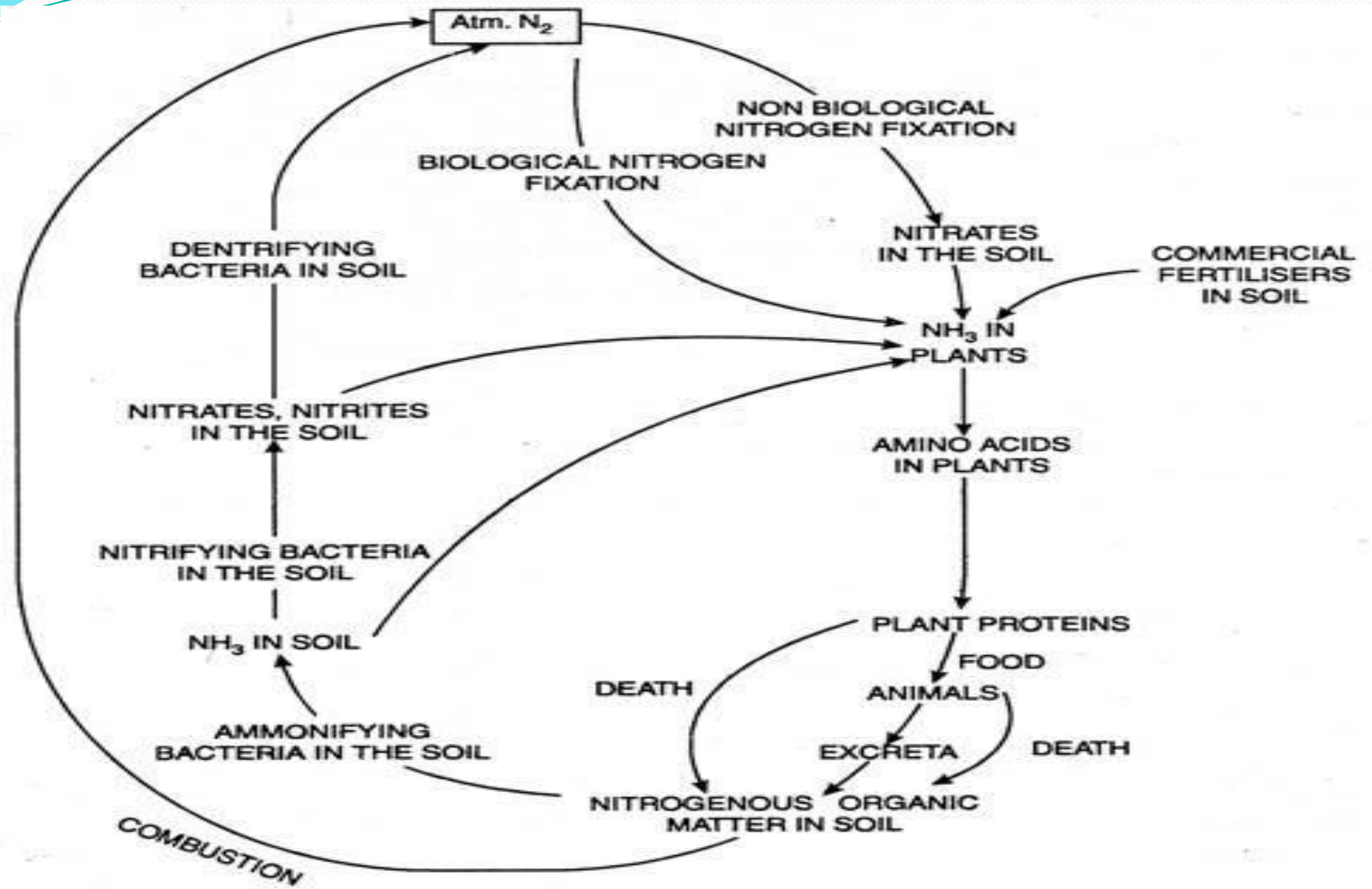


Fig. 9.29. Nitrogen cycle in nature.

Why is the Nitrogen Cycle Important?

- Nitrogen is an essential ingredient for life. Its unique chemical bonding properties allow it to create structures such as DNA and RNA nucleotides, and the amino acids from which proteins are built. **Without nitrogen, these molecules would not be able to exist.**
- It's thought that the first nucleotides and amino acids formed naturally under the volatile conditions of early Earth, where energy sources like lightning strikes could cause nitrogen and other atoms to react and form complex structures
- This process might have naturally produced self-replicating organic chemicals – but in order to reproduce and evolve, life needed to figure out how to make these nitrogen compounds on demand.
- **Today, "nitrogen fixers" are organisms that can turn nitrogen gas from the atmosphere into nitrogen compounds that other organisms can use to produce nucleic acids, amino acids, and more.** These nitrogen fixers are such a vital part of the ecosystem that agriculture cannot occur without them.
- Ancient peoples learned that if they did not alternate growing nitrogen-consuming crops with nitrogen-fixing crops, their farms would become fallow and unable to support growth. Today, most artificial fertilizers contain life-giving nitrogen compounds as their main ingredient to make the soil more fertile.

DEAR STUDENTS
WELCOME FOR DISCUSSION

Thank You