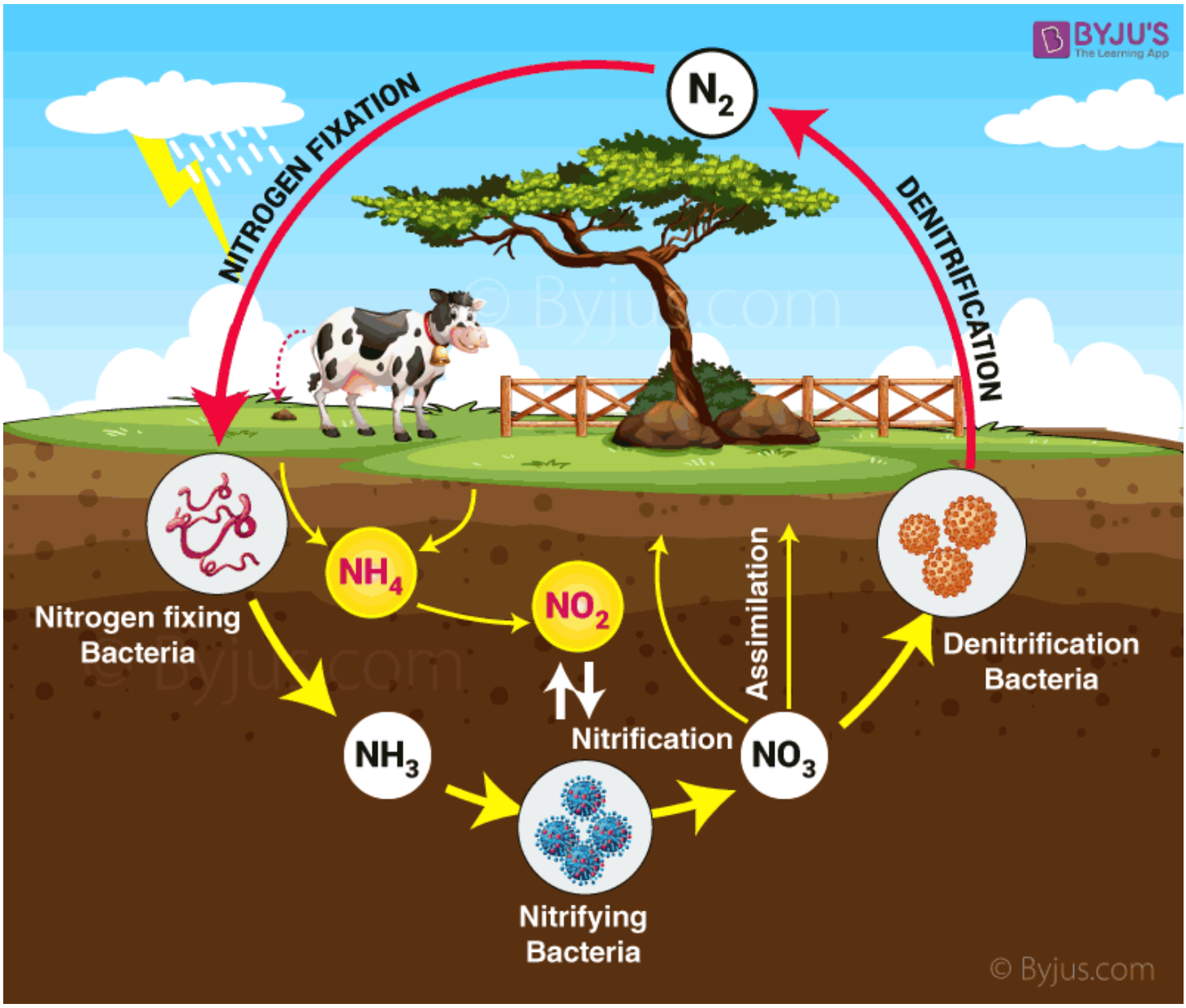
Nitrogen Cycle

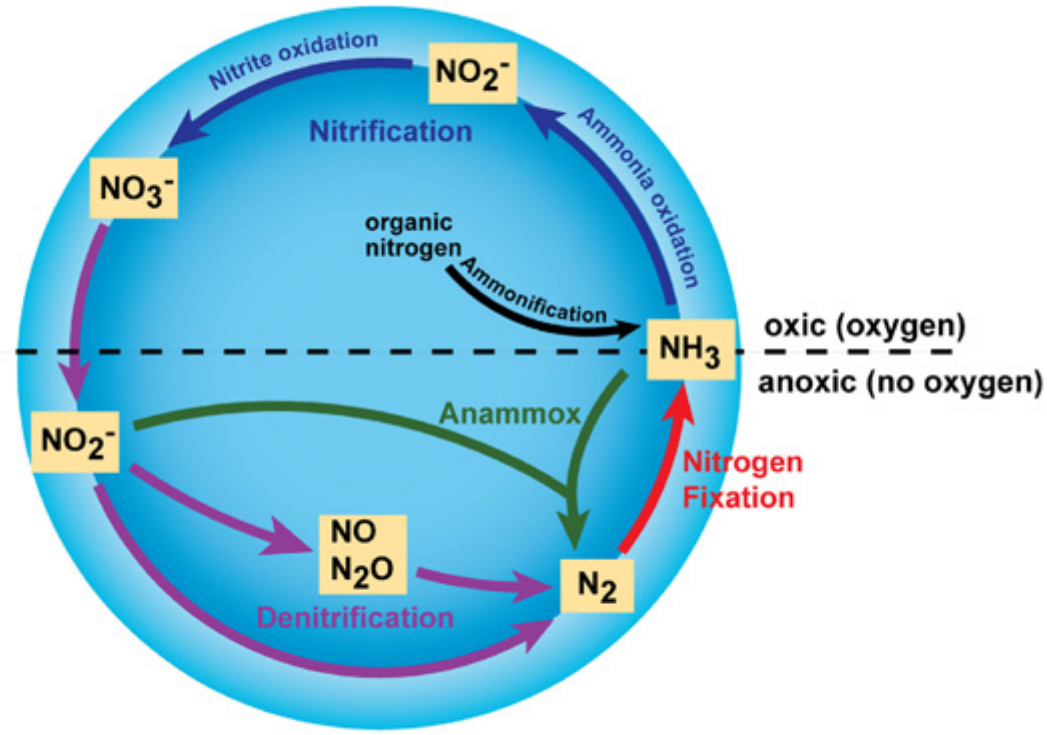
> Nitrogen Cycle is a biogeochemical process which transforms the inert nitrogen present in the atmosphere to a more usable form for living organisms.

Nitrogen is converted into many forms, consecutively passing from the atmosphere to the soil to organism and back into the atmosphere. Nitrogen undergoes various types of transformation to maintain a balance in the ecosystem. It involves several processes such as **nitrogen fixation**, **nitrification**, **denitrification**, **anammox**, **assimilation** and **ammonification**.



Although nitrogen is very abundant in the atmosphere as N_2, it is largely inaccessible in this form to most organisms, making nitrogen a scarce resource and often limiting primary productivity in many

ecosystems. Only when nitrogen is converted from N_2 into NH_3 does it become available to primary producers. Besides, human activities like **making fertilizers** and **burning fossil fuels**, have significantly altered the amount of fixed nitrogen in the Earth's ecosystems.



Nitrogen Fixation

The process of converting N_2 into biologically available nitrogen is called nitrogen fixation.

$$N_2 + 8H^+ + 8e^- \overset{\geq 16ATP}{\longrightarrow} 2NH_3 + H_2$$

1. **Atmospheric fixation**: 5 ± 3 Tg N yr^{-1} (N_2O) (Zhang et al., 2020)

$$N_2 \overset{lightening}{\longrightarrow} NO_X \overset{used}{\longrightarrow} plants$$

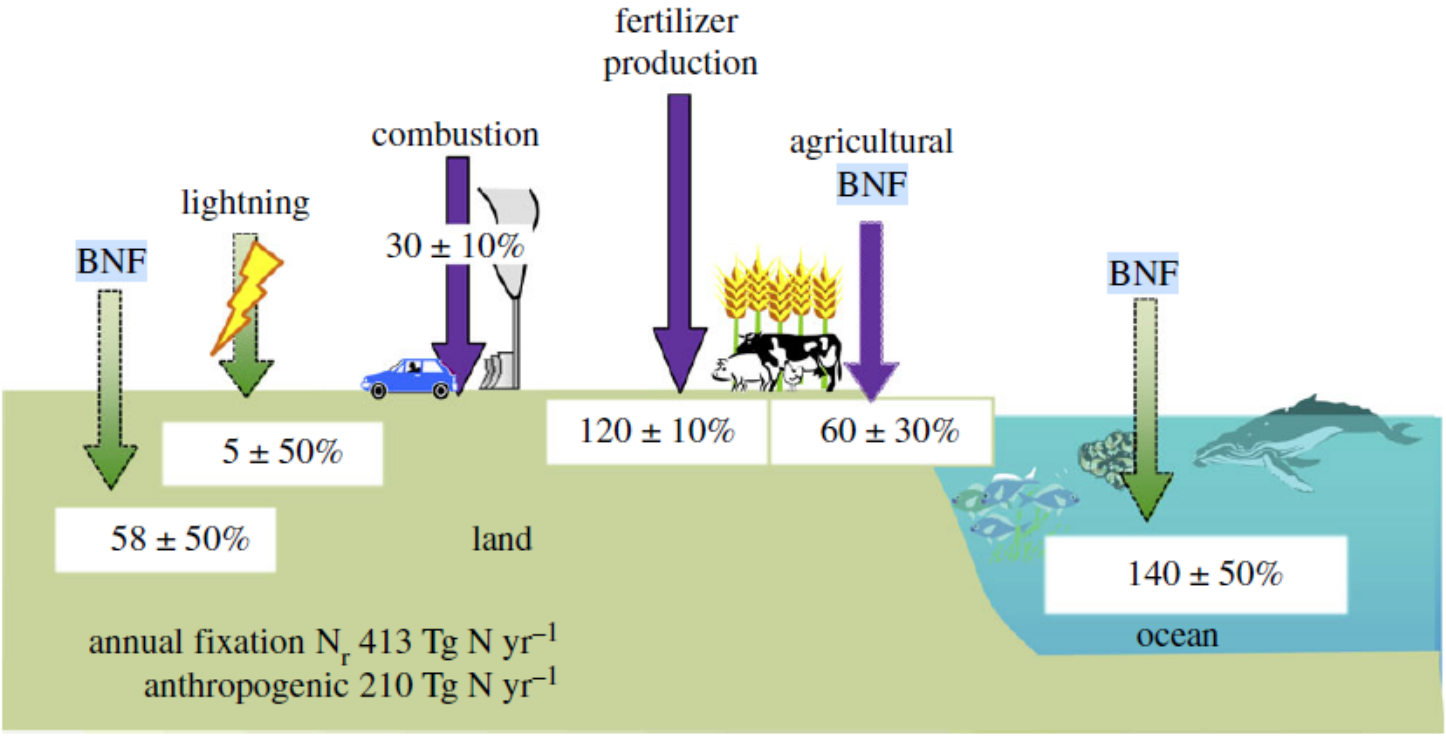
2. **Anthropogenic nitrogen fixation**: through combustion, fertilizer and industrial production through the Haber–Bosch process.
    - **Industrial nitrogen fixation/Reduced nitrogen**: ~120 Tg yr^{-1}

$$N_2 + H_2 \overset{high\ T/P}{\longrightarrow} NH_3 \longrightarrow fertilizer\ (e.g., uera)$$

- **Biological nitrogen fixation in cropland**: ~60 Tg N yr^{-1} (Fowler et al., 2013), contribution from nitrogen-fixing agricultural crops.
- **Oxidized nitrogen**: combustion within internal combustion engines and industrial power plants, especially for electricity supply.

3. **Biological nitrogen fixation**:

$$N_2 \overset{bacteria}{\longrightarrow} N-compounds \overset{in\ soil}{\longrightarrow} fixed$$



Nitrification

Nitrification is the process that converts NH_3 to NO^-_2 and then to NO^-_3.

- Step 1: The oxidation of NH_3 to NO^-_2.

$$NH_3 + O_2 \overset{enzyme\ (酶)}{\longrightarrow} NO_2^- + 3H^+ + 2e^-$$

$$NH_4^+ + O_2 \overset{enzyme\ (酶)}{\longrightarrow} NO_2^- + 4H^+ + 2e^-$$

- Step 2: The oxidation of NO^-_2 to NO^-_3.

$$NO_2^- + O_2 \overset{bacteria}{\longrightarrow} 2NO_3^-$$

Anammox

A type of ammonia oxidation occurring under anoxic (缺氧) conditions discovered by Strous et al. (1999).

$$NH_4^+ + NO_2^- \overset{bacteria}{\longrightarrow} N_2 + 2H_2O$$

Assimilation

Plants take in the nitrogen compounds from the soil with the help of their roots, which are available in the form of NH_3, NO^-_2, NO^-_3 or $NH4^+$ and are used in the formation of the plant and animal proteins.

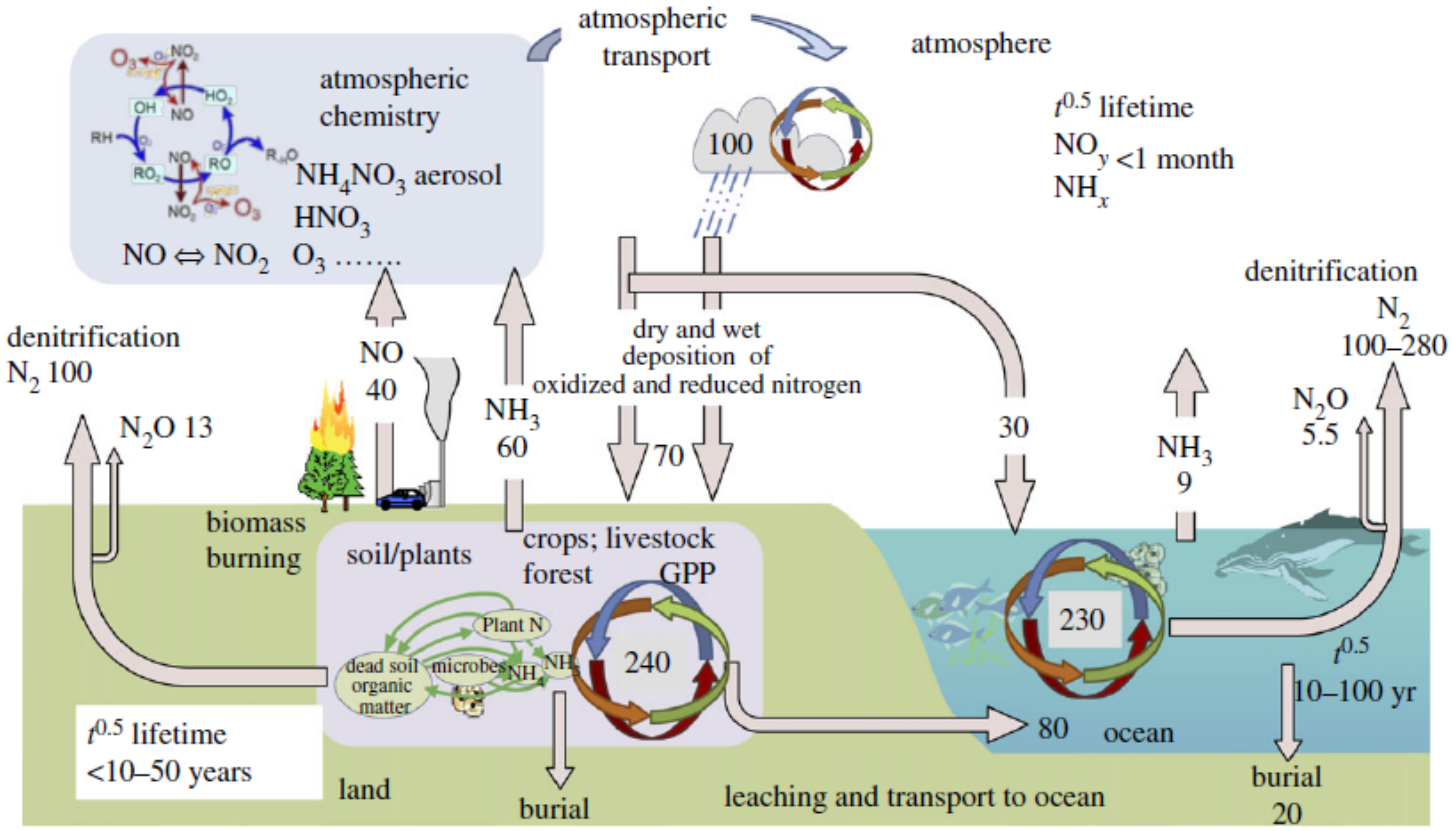
Ammonification

The decomposers convert the nitrogen present in the organic matter back into $NH4^+$.

Denitrification

The process in which the nitrogen compounds makes its way back into the atmosphere by converting NO^-_3 into N_2.

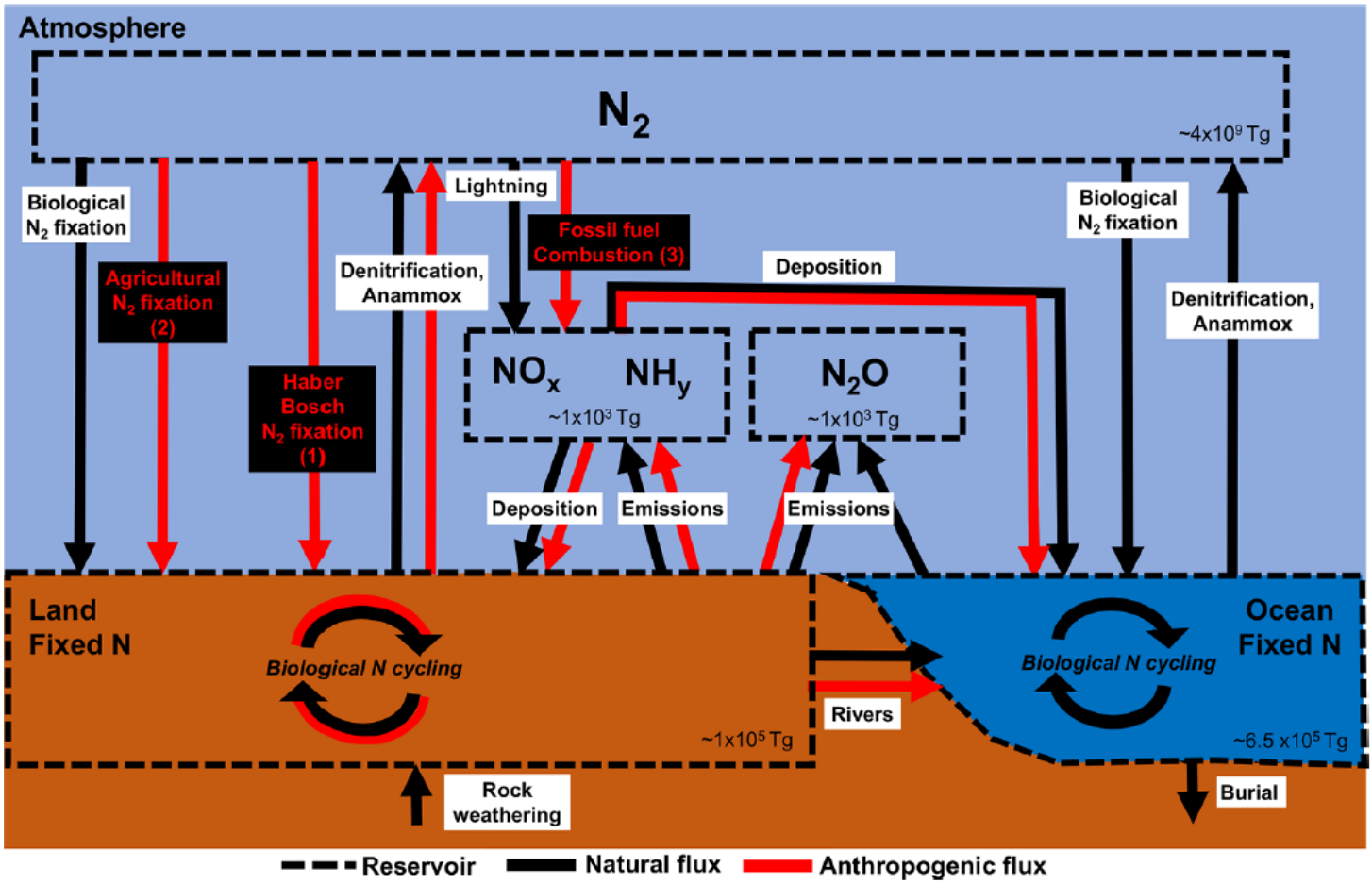
$$2NO_3^- \longrightarrow NO_2^- \longrightarrow NO + N_2O \longrightarrow N_2$$



Human Alterations to the Nitrogen Cycle

Many human activities have a significant impact on the nitrogen cycle. Burning fossil fuels, application of nitrogen-based fertilizers, and other activities can dramatically increase the amount of biologically available nitrogen in an ecosystem. These processes, increase the levels of nitrogen-containing compounds in the atmosphere. The fertilizers containing nitrogen are washed away in lakes and rivers and results in eutrophication (富营养化).

Human activities related to food production and fossil fuel combustion have perturbed the global N cycle since the Industrial Revolution by introducing new N into terrestrial and marine fixed N inventories.



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