The Nitrogen (N) Cycle

- Atmosphere is ca. 78% N₂ but most is unavailable to living things because …

- N is important because …

- Microbial processes are important in the steps of the N cycle.

The nitrogen cycle has 5 basic steps

1) Nitrogen Fixation: N₂ => NH₃

Root Nodules on a Legume
Lectures 16-18

Heterocysts in *Anabaena*

Fritz Haber

Humans Fix Nitrogen Too!

\[ 4N_2 + 12H_2 + \text{catalyst} \rightarrow 8NH_3 \]

at 500°C & several hundred atmospheres of pressure

2) Ammonification: organic N \( \rightarrow \) NH₃

3) Nitrification: NH₃ \( \rightarrow \) NO₂ \( \rightarrow \) NO₃⁻

2-step process - each step by different bacteria.

Step 1: oxidation of ammonia (NH₃) to nitrite (NO₂⁻) by __________

Step 2: oxidation of nitrite (NO₂⁻) to nitrate (NO₃⁻) by __________

Both steps couple E-releasing oxidations to fixation of carbon - chemoautotrophs.
4) **Nitrogen Assimilation**: \( \text{NH}_3 \Rightarrow \text{organic N} \)
\( \text{NO}_3^- \Rightarrow \text{organic N} \)
Performed by both plants & microbes. Assimilation by microbes is also called **immobilization**.

5) **Denitrification**: \( \text{NO}_3^- \text{ or } \text{NO}_2^- \Rightarrow \text{N}_2 \text{ or } \text{N}_2\text{O} \)
Performed by many bacteria. Returns N to the atmosphere. Anaerobic reaction which allows bacteria to grow and live w/ out oxygen.

---

**Active N Pools**

- **Atmosphere**: \( 3,800,000 \times 10^{15} \text{ g N} \)
- **Ocean**: \( 21,000 \times 10^{15} \text{ g N} \)
- **Soil Organic Matter**: \( 95 \times 10^{15} \text{ g N} \)
- **Terrestrial Biota**: \( 3.5 \times 10^{15} \text{ g N} \)
Fixers Denitrif. 110
Rainfall
Fixers Denitrif. 110
Rain
20 Lightning
Human Activities 6 Fixers
(1200) Recycling
80

Terrestrial Ecosystems Can be Overfertilized

units = 10^{12} g N/year
High Nitrogen Deposition Has Become Widespread

Potential Consequences of N Saturation
- Increased surface-water NO₃⁻ concentrations.
- Enhanced losses of nutrient cations.
- Soil acidification & greater soluble Al.

Nitrogen Cycle
Mean Residence Times
- Atmosphere
  ca. 9 million years
- Land biota
  ca. 3 years
Summary of N Cycle

- Largest active pool = N₂ in atmosphere which is 181x > amount in ocean
- N in soil organic matter is 27x > amount in terrestrial biota
- Largest flux = uptake by plants of which almost all is from recycled organic N
- Human activities ≈ 60% of total inputs to land
- River flow ≈ 40% total inputs to oceans

The Phosphorus (P) Cycle

- Example of a sedimentary cycle => no gaseous phase
- P is abundant in soil but in forms that are not readily available to biota
- PO₄⁻³ is an available form of P
- P is important because …

Whole Lake Experiments

- P added
- P not added
- Waterproof barrier
Lectures 16-18

The Global P Cycle

Pools given in $10^{12}$ g P
Fluxes given in $10^{12}$ g P/yr
Summary of P Cycle

- Abundant but low availability.
- Weathering of P-rich rock is original source.
- Geologic processes are slow (millions of years) so biota rapidly recycle organic-P.
- Residence time in biota is only a few days in the ocean.

Summary of P Cycle

- Large loss to ocean relative to rate of return to land.
- Losses in runoff are 93% particulate-P
- Mycorrhizae ↑ absorption by plant roots
- Mining P-rich rocks is a major source to land.

Aquatic Ecosystems Can be Overfertilized

Waterproof barrier

P added

P not added
Lectures 16-18

Temperate Lakes Can Thermally Stratify In The Summer

Eutrophication of stratified shallow lakes can change species composition

THIRD-LARGEST "DEAD ZONE" SINCE 1985
AREA SIZE OF NEW JERSEY
Mid-Summer 2007