

STREAM ECOLOGY

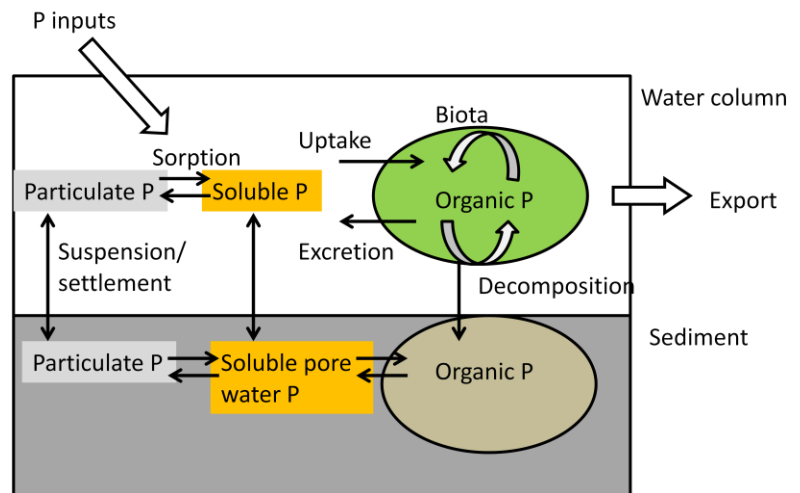
STREAM CHEMISTRY

In addition to energy, life needs nutrients. Nutrients are chemicals that help plants and animals survive, grow, and reproduce. The biological demand for Nitrogen (N) and Phosphorus (P) is often greater than their availability. Thus, N and P often limit productivity of streams.

General concept of nutrient cycling.—Nutrients are input into stream reaches and then are exported over time. They change from one chemical form to another. The nutrients are cycled between living and non-living portions of the ecosystem and between water column and the sediments. These cycles can be incredibly quick (e.g., microbe taking up dissolved P) or very slow (e.g., weathering of rock releases P on geologic time). In streams, these cycles occur over space as water flows transports nutrients downstream. We focus on: different forms of nutrients, their sources, and how they are transformed.

PHOSPHORUS

Phosphorus is derived from the lithosphere (rocks), and cycles between sediment pore water and water column locations, living and dead components of the organic pool, and between particulate and soluble forms.



Forms of Phosphorus

- Soluble Reactive Phosphorus (SRP)—Dissolved forms of phosphorus that are available for uptake by primary producers. Includes organic (DOP) and inorganic forms (e.g., Orthophosphate). Generally around 10% of total phosphorus. SRP in general is fairly rare but very important, often taken up rapidly when available.
- Orthophosphate—Inorganic form of phosphate (PO_4^{3-}). Orthophosphate is a key form of SRP.
- Dissolved organic phosphorus (DOP)—Released by organisms (living/dead), includes ATP.
- Particulate organic phosphorus (POP)—Phosphorus locked up in living or dead plant and animal matter.
- Particulate inorganic phosphorus (PIP)—Orthophosphate that has been locked up by other molecules such as calcium, iron (Fe), or magnesium. Relatively inert (inactive) form of P.

Major sources of Phosphorus

- Rocks and soil (lithosphere)—P is common in many rocks and soils. Often found as apatite (calcium phosphate), which is often formed from left-over shells. Thus, sediments that are derived from old oceans are often high in P. Rocks are most important reservoir P. P can enter streams as a part of sediment (particulate P) or dissolved by erosion and weathering.

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- Biotic—Especially in freshwaters, a lot of P is found in plants and animals. Excretion is a major pathway by which accessible P becomes available.
- Atmosphere—Occurs generally as particulate matter in dust.

Processes that transform P

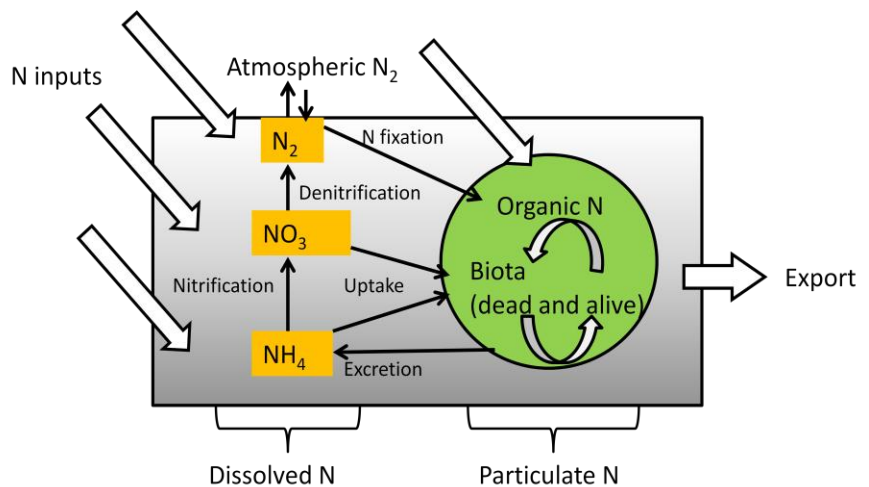
- Uptake--Soluble P (PO_4 , SRP, or DOP) is rapidly taken up by plants and microbes.
- Excretion--Animals excrete soluble P (DOP and PO_4). Without excretion, most of the P would be locked up as particulate organic P. Thus, most of the P in many systems is found in the tissues of plants and animals.
- Sorption—Soluble P can be bound up into particles, or released (desorption).

Animals play a huge role in cycling P. Fish and invertebrates eat particulate organic phosphorus (POP) and then excrete soluble P (DOP and PO_4).

Nitrogen Cycle

NITROGEN

Nitrogen also commonly limits productivity in streams. Nitrogen limitation occurs when there is excess P input (such as due to sewage inputs or due to rock weathering). The N cycle is very different from the P cycle: the N cycle has more transformations, different sources. Similar to the P cycle it cycles between biotic and abiotic components and cycles between the sediment and water column.



Forms:

- Nitrogen gas (N_2): This gas makes up ~80% of the atmosphere. Thus, the atmosphere is a huge reservoir of Nitrogen. However, it is relatively inert, and only some bacteria (and lightning) can convert N_2 to more usable forms such as nitrogen oxides (NO_x) or ammonia (NH_4).
 - Alder is a very common N-fixing riparian plant. Many watersheds get most of their nitrogen from
- Nitrate (NO_3^-) and nitrite (NO_2^-): Nitrate can be used by plants. Too much nitrite can be toxic to life (and humans).

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- Ammonia (NH_4): This form is created by nitrogen fixation (by bacteria or human industry). In addition, ammonium is often released as a waste product. When O_2 is present, Ammonia oxidizes to Nitrate.
- Organic nitrogen: Nitrogen is often found as part of organic nitrogen compounds such as amino acids (R-NH_2).

Reservoirs:

- Atmosphere: This is the dominant reservoir of nitrogen, where N_2 gas composes ~80% of the atmosphere.
- Rocks: N can be found in rocks, but this is not as important as the atmosphere. Organic soils (e.g., dead leaves) have lots of N.
- Oceans: N is also found dissolved in ocean water.
- Freshwaters: N_2 gas dissolves into water, but is inert unless transformed during N fixation.
- Food webs: Like P, N is often found within the materials of plants and animals of aquatic food webs.

Processes that transform N:

- N fixation: $\text{N}_2 \rightarrow \text{NH}_4$ (Nitrogen gas to Ammonia). N fixation is performed by bacteria (alone or in symbiosis). Blue-green algae (aka., cyanobacteria) fix nitrogen with special enzymes that only work in the absence of oxygen. *Heterocysts* are morphological adaptations of many blue-green algae that allow this to happen—thick-walled cells without oxygen. N fixation is energetically costly, so generally only happens when nitrogen becomes limiting (often due to excess P inputs).
- Nitrification: $\text{NH}_4 \rightarrow \text{NO}_2$ or NO_3 (Ammonia to Nitrate/Nitrite). Happens due to bacteria *only in the presence of Oxygen*.
- Denitrification: $\text{NO}_3 \rightarrow \text{N}_2$ (Nitrate to Nitrogen gas). Happens in the absence of Oxygen.
- Assimilation: $\text{NO}_3 \rightarrow \text{R-N}$. (Nitrate to organic matter). Algae and bacteria take up NH_4 (ammonia) and NO_3 (nitrate—shown above) to build matter (such as amino acids).
- Excretion: $\rightarrow \text{NH}_4$ (ammonia) or $\text{HN}(\text{CH}_3)_2$ (urea). Organisms excrete nitrogen as a waste product of metabolism.

General concepts

Stoichiometry.—Organisms take up and excrete nutrients at a set ratio. Thus, the ratio of available forms of nutrients will determine which nutrient is limiting. For example,

- *Redfield ratio*.—Generally accepted that N:P ratio of algae is 16:1. In other words, algae need 16 molecules of N for every 1 molecule of P. Thus, if the N:P ratio is less than 16:1, then we would predict N would be limiting. If the N:P ratio is greater than 16:1, then we would predict P would be limiting.

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Nutrient limitation.—Scientists can learn about which nutrient is limiting by adding different nutrients and recording which nutrients stimulate algal growth the most.

Spiraling distance.—the distance an average nutrient travels between forms (organic to inorganic to organic). Usually, uptake length is the critical component (how long until dissolved inorganic chemicals travel before taken up).

Shorter spiral distances if:

- Nutrient is limiting (heavily used)
- Lower stream water flows
- Nutrient is retained longer in particulate form

Humans have fundamentally changed nutrient cycling on land, the atmosphere, and waters. N and P are produced or mined in enormous quantities for fertilizers.

Eutrophic—One of the major human perturbations of freshwaters is eutrophication. Eutrophication refers to an aquatic habitat becoming more productive and exhibiting rapid light attenuation, high rates of primary productivity. Excess nutrient inputs (generally P) drive eutrophication. Human activities can increase N and P via direct and indirect sources:

- Sewage
- Septic systems
- Run-off from agriculture
- Increased erosion