Nutrient Use and Remineralization

- Use of Nutrients
- Nutrient Availability and Limitation
- Resource Ratios and Stoichiometry of Primary Producers
- Stoichiometry of Heterotrophs, their Food, and Nutrient Remineralization

Limiting Resources

- The potential of a resource to limit a population depends on availability relative to demand:
  - this concept is embodied in **Liebig's law of the minimum**:
    - each population increases until the supply of some **limiting resource** becomes depleted

Liebig's Law of the minimum: the rate of a process will be limited by the slowest subprocess

Limitation by More Than One Resource

- Experiments with multiple resources on plant growth exhibit the difficulties with Liebig's law:
  - fertilized plants are better capable to respond to light than unfertilized plants
  - various nutrients (e.g., nitrogen and phosphorus) interact in a synergistic fashion to promote plant growth

The Competitive Exclusion Principle

- Results from many studies were summarized by Gause and others in the **competitive exclusion principle**:
  - two species cannot coexist indefinitely on the same limiting resource
  - although similar species exist, careful study usually reveals that they differ in their habitat or diet requirements

Hutchinson's Paradox of the Plankton

- Competitive exclusion principle- only one organism is a best competitor for a limiting resource and will dominate
- Leibig's Law- only one nutrient limits
- Observation- most phytoplankton cells have similar composition
- The Paradox- why are there commonly 100's of species of phytoplankton in a lake?

Why the Paradox?

- Predation prevents Competitive Exclusion
- Environment is not as homogeneous as it seems
- Mutualisms benefit inferior competitors
- Temporal variability
- Different species have different limiting nutrients
- Chaos when species compete for more than 3 nutrients

Resource Ratios and Stoichiometry of Primary Producers

- Redfield Ratio
- 106:16:1 C:N:P by moles
- Algal cells have approximately this composition under balanced growth
- When N is limiting, may have 106:5:1
- When P is limiting, may have 206:32:1
- When N and P are limiting, may have 500:16:1
- Can serve as an index of nutrient limitation

Nutrient Remineralization

- Usually uptake is high enough that nutrients would be completely exhausted without remineralization (regeneration)
- The concentration of dissolved nutrients is an amount, the flux through that pool is a rate. These two should not be confused
- Phosphate and ammonium concentrations can be very low in a eutrophic lake

Processes that lead to Nutrient Remineralization

- Leakage from healthy cells, excretion from animals
- Heterotrophic activities of bacteria
- Viral infections cause lysis of cells
- Nutrient remineralization often dominated by microbial processes
- In some cases, moving animals assist nutrient import (salmon, hippos, migrating zooplankton)

Nutrient Pulses

- Large algal cells (i.e., gulpers) are poor competitors for nutrients at low concentrations (low surface area to volume ratio) (Example 16.1)
- Pulses of nutrients may last long enough to give large cells an advantage if they run into the patches, but are they stable?

Stoichiometry of Heterotrophs, their Food, and Nutrient Remineralization

- Heterotrophs remineralize nutrients in excess of need
- Assume 9 C of energy needed for each C used for growth, and growth is at Redfield ratio
- A heterotroph needs food at 1000:16:1. If it eats food at 106:16:1, it will excrete N and P

Most Chemical Defense Models Assume a 2-way Tradeoff Between GROWTH and DEFENSE

- "Because both growth and differentiation are dependent on photosynthate, they are negatively correlated…, and we can speak of a balance of growth and differentiation in which growth is dominant under favorable conditions and differentiation is at a maximum only when conditions other than supply of photosynthate are suboptimum for growth" Loomis, 1953.
- "The decline in growth with nutrient stress is generally greater than the decline in photosynthesis so that carbohydrates and carbon-based secondary metabolites such as phenols accumulate". Bryant et al. 1983
- "When resources are limited, plants with inherently slow growth are favored over those with fast growth rates: slow rates in turn favor large investments in antiherbivore defenses.", Coley et al. 1985.
- The Dilemma of Plants: To Grow or Defend, Herms and Mattson, 1992