

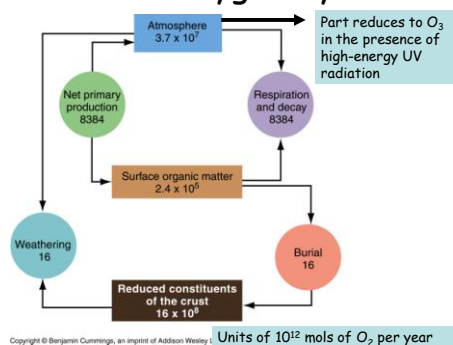
Cycling of Nutrients and Materials: Biogeochemistry II

- Differences between local vs. global scale cycles
- Human interference in biogeochemical cycles
- Environmental problems affect ecosystem integrity
 - Human-generated contaminants
 - Effects on ecosystems and food chains
 - Acid deposition, Heavy-metals, chlorinated hydrocarbons, radionuclides, etc.

The Global Oxygen Cycle

- Oxygen → byproduct of photosynthesis
 - highly reactive nature
 - Linked with C and N cycles (fluxes)
 - Primary role as electron acceptor
 - Oxidation and reduction reactions (energy!)
 - Maintained in dynamic equilibrium
 - Production vs. Consumption
- Atmosphere as major supply
 - Photodissociation of water vapor
 - Photosynthesis
 - Burial and storage of partially decomposed OM

The Global Oxygen Cycle



The Global Oxygen Cycle

- The Ozone Layer
 - Most resides in the stratosphere (10-50 km above Earth)
 - Shields Earth from biologically harmful solar ultraviolet radiation
- $$O_2 \rightarrow O + O \dots \rightarrow O + O_2 \rightarrow O_3$$
- $$\rightarrow \dots O_3 \rightarrow O + O_2 \dots O + O_3 \rightarrow 2O_2$$
- Under natural conditions (in the atmosphere), a balance exists between the rate of ozone formation and destruction

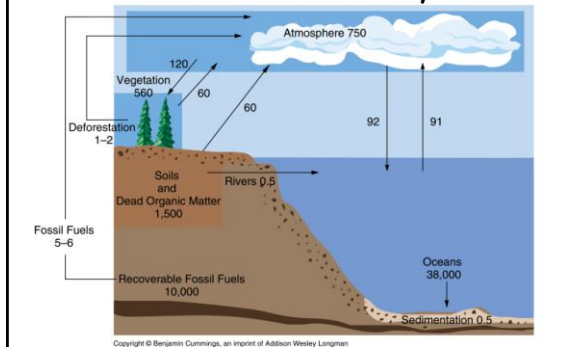
The Global Oxygen Cycle

- The Ozone Layer
 - Thinning in the O_3 layer discovered in 1975
 - South Pole ('75); Arctic ('90)
 - CFCs, natural aerosols or sulfuric acid (im. NO's)
 - Nitrogen oxides protect the ozone by tying up chlorine into harmless forms
 - Why should we care?
 - Depleted 50 - 95%
 - Adverse ecological effects
 - Altering DNA, severe sunburn, skin cancer, photosynthetic inhibition

The Global Carbon Cycle

- Earth contains about 10^{23} g of C
 - Most buried in sedimentary rocks
 - So where is it? Where does it go?
 - C cycling is about 55,000 gigatons (GT)
 - 10,000 GT in fossil fuels
 - 38,000 GT in oceanic pool
 - 2,000 GT in terrestrial pool
 - 750 GT in atmospheric pool

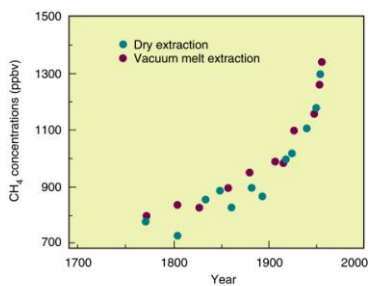
The Global Carbon Cycle



The Global Carbon Cycle

- Human Impact on the Carbon Cycle
 - Flux disrupted by rapid injection of CO_2 in atmosphere from:
 - Burning of fossil fuels
 - Forest clearing
 - Increase in green house gases (methane; CH_4)
 - (Examples: ruminants, decomposition in marshes, swamps and tundra, release of industrial gases)

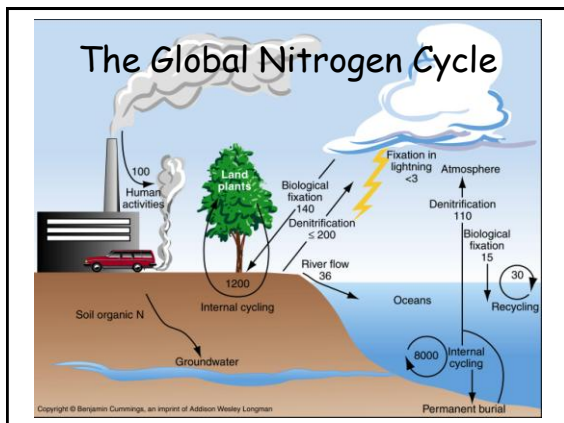
Concentration of atmospheric methane over the past 200 years as indicated by air samples taken from ice cores at Siple Station, Antarctica (Stauffer et al. 1991)



The Global Nitrogen Cycle

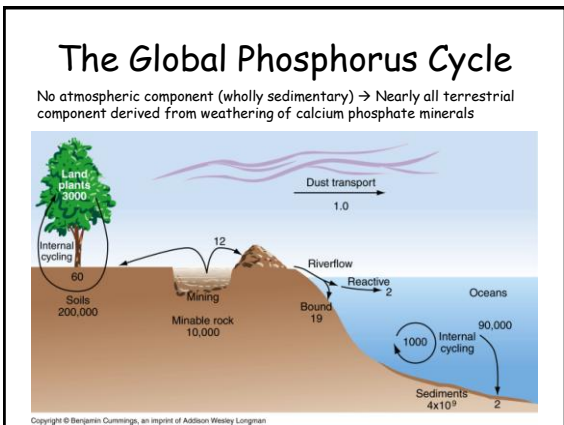
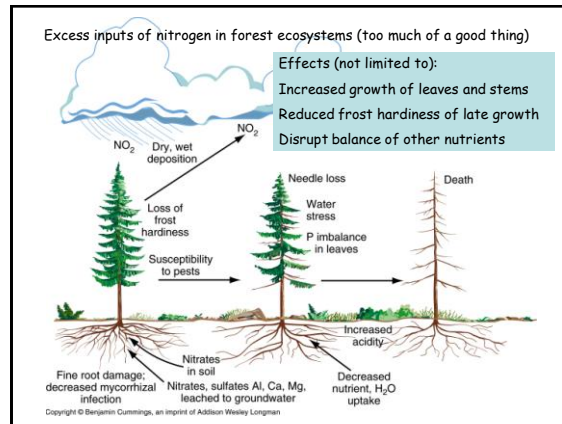
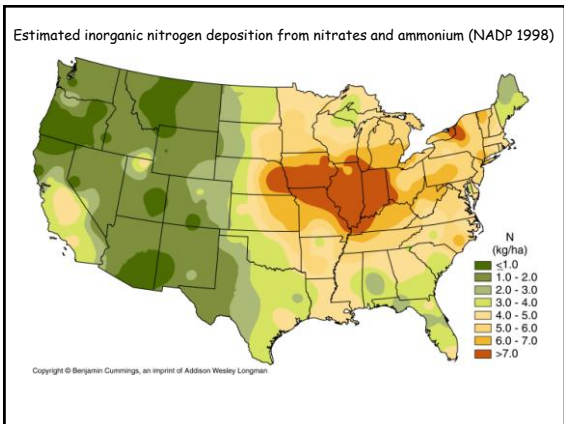
- Global cycle similar to local cycle
 - Atmosphere = major pool ($\sim 3.9 \times 10^{21}$ g)
 - Biomass (3.5×10^{15} g)
 - Soils ($95-140 \times 10^{15}$ g)
- Major sources:
 - Biological (140×10^{12} g per yr)
 - High energy fixation (3×10^{12} g per yr)
 - Most tied up in OM (living and dead)

The Global Nitrogen Cycle

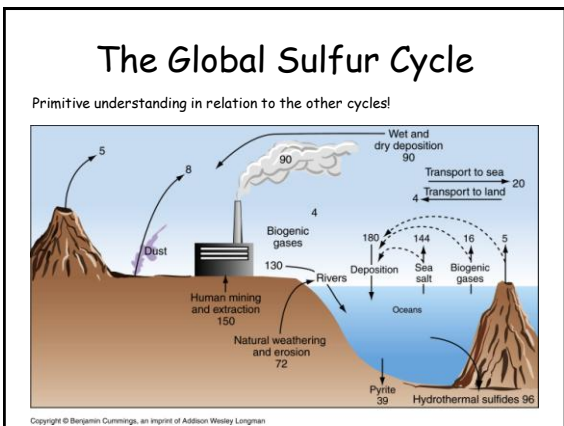


The Global Nitrogen Cycle

- Human Impact on the Nitrogen Cycle
 - Losses:
 - Conversion of forests and grasslands to cropland = decline of N concentration in soil
 - Mixing and breaking up soil = increased decomposition and leaching
 - N removal through harvested crops and grazing
 - Increases:
 - Commercial fertilizers = disrupt natural balance btw fixation and denitrification
 - Human waste (sewage) released into water bodies
 - Automobiles and power plants (atmospheric pollutants)



- ### The Global Phosphorus Cycle
- Human Impact on the Phosphorus Cycle
 - Alterations:
 - Agricultural application of fertilizers
 - Combines with other elements in soil (insoluble)
 - Phosphorus enrichment from sewage disposal plants (aquatic systems)
 - Problems:
 - Over-enrichment (**Eutrophication**)
 - Aquatic systems are generally P limited, thus when P is available in excess = algal blooms

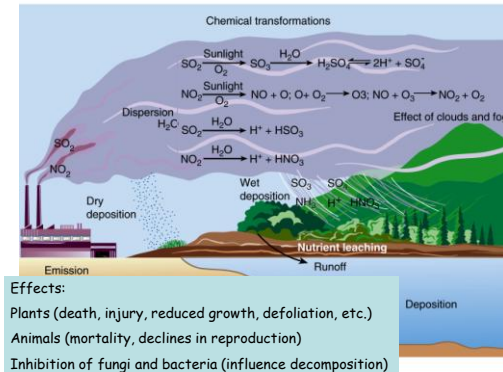


- ### The Global Sulfur Cycle
- Biogenic (natural) sources to cycle
 - Gaseous phase permits circulation @ global scale
 - Annual flux 300×10^{12} g (atmosphere)
 - Sulfur dioxide, hydrogen sulfide, sulfate particles (dryfall)
 - Ocean → large natural source of aerosols (sulfate)
 - Terrestrial and FW habitats → minor sources (not well understood); Volcanic activity also contributes

The Global Sulfur Cycle

- Human Impact on the Sulfur Cycle
 - Largest source → emissions from industrial activities ($\sim 50\text{-}100 \times 10^{12}$ g sulfur dioxide)
 - 70% → coal burning
 - Deposited as precipitation or dryfall (locally)
 - River transport significant portion to oceans
 - 25% derived from air pollution, mining, erosion, and other human activities
 - Once in atmosphere sulfur dioxide (SO_2) reacts with moisture (H_2O) to form sulfuric acid (H_2SO_4) → acid rain!

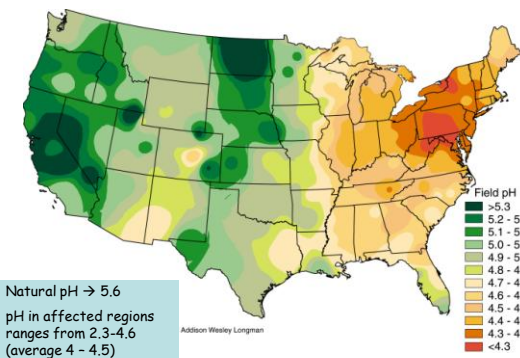
Formation of acid depositions: Excessive S and N being poured in to atmosphere



Acid Deposition

- Sulfur dioxide and nitrogen oxides
 - Since Industrial Revolution $\sim 75\text{-}100$ million tons annually (eastern NA & central Europe)
 - Mix in atmosphere
 - Dry deposition (air dust)
 - Wet deposition (rain, snow, fog)
- Major Sources
 - Power plants, industrial complexes, motor vehicles, internal combustion engines

Hydrogen ion concentration as pH from field measurements (1998 NADP)



Acid Deposition

- Aquatic Ecosystems
 - Heavy acid water input (pH reductions!)
 - Decline in reproduction (retard growth & development, increased mortality)
 - Reduces bacterial activity (decomposition)
- Terrestrial Ecosystems
 - Induced leaching of nutrients (reduced nutrient pools)
 - Affects root structure and uptake capabilities
 - Inhibit microbial activity (decomposition)
 - Forest declines associated to air pollution

Other Human Impacts

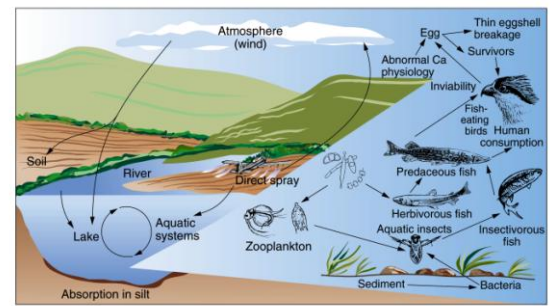
- Heavy Metals: Lead
 - Automobiles (then) → now banned!
 - Mining, smelting, lead refining, coal combustion, lead-consuming industries, burning of refuse and sewage sludge, burning and decay of lead-painted surfaces
 - Accumulated in soil → bound to OM → enters food chain → humans
 - Problems → retardation, paralysis, loss of hearing, death!

Other Human Impacts

• Chlorinated Hydrocarbons

- DDT and PCBs
 - Effects on ecosystems and non-target species
 - Rachel Carson's *Silent Spring* (1962)
- Persistent and stable (> 20 years)
- Atmosphere receives most (> 50% applied)
 - Atmosphere becomes circulating reservoir
- Concentrates on fatty tissues of organisms
 - Undergo little degradation
 - Interfere with metabolism, inhibit enzymes, etc.

The movement of chlorinated hydrocarbons in terrestrial and aquatic systems. Initial input comes from spraying of vegetation. Large portion recirculates in the atmosphere, other portions retained in soils, transported to water bodies.



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Other Human Impacts

• Radionuclides (fission & nonfission products)

- Impact of nuclear radiation (atomic age)
- Ionizing radiations
 - High-energy, short-wavelength radiation
 - Remove electrons from some atoms into others
 - Gamma radiation (penetrates matter easily)
- Sources:
 - Nuclear weapons & reactors, radioactive wastes (fallout)
 - Enter the food chain (incorporated into tissue)
 - Can cause cancer, genetic defects, etc.