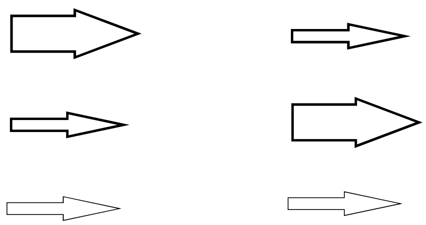
Lectures 16-19

Properties of Ecosystems

- The flow of energy powers ecosystems.
- Matter cycles between the biotic and abiotic world.

Understanding Ecosystem Terms

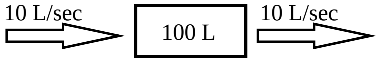
Inflow Stocks Outflow



Mean Residence Time

For a system in dynamic equilibrium:

Mean Residence Time (τ) = stock / inflow or outflow



τ = *Average length of time a given atom or molecule spends in the system between entering and leaving.*

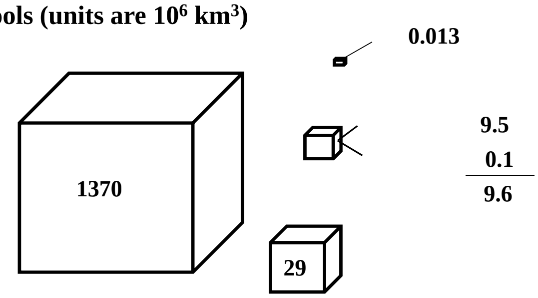
Importance of Nutrient Cycles

Hydrologic Cycle
(water)

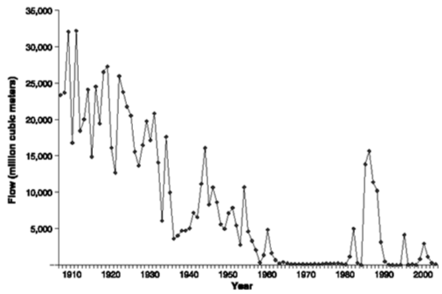
Read pages 36 – 37 in textbook

Hydrologic Cycle
(water)

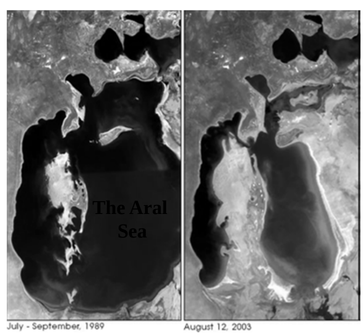
Pools (units are 10^6 km^3)



Change in flow of Colorado River

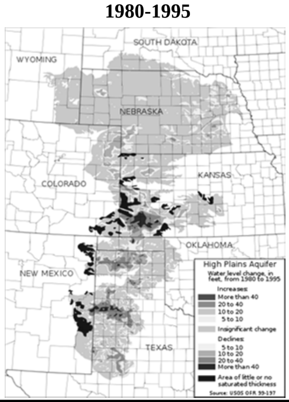


Humans Alter the Hydrologic Cycle



From 1973 to 1987 the Aral dropped from fourth to sixth among the world's largest lakes.

Changes in Ogallala Aquifer 1980-1995



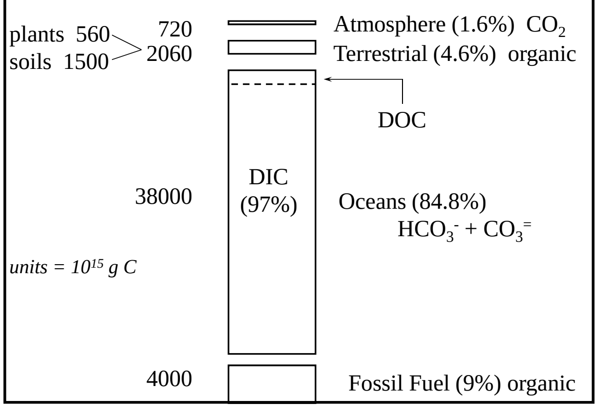
Carbon Cycle

Reciprocal Processes:

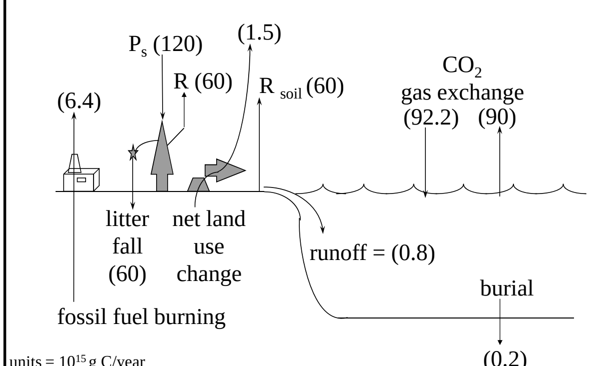
- Photosynthesis (P_s)-

- Cellular Respiration (R) -

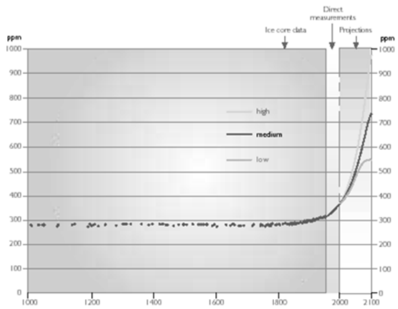
Active Carbon Pools



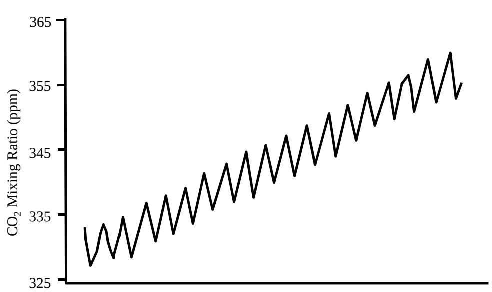
Global Carbon Cycle



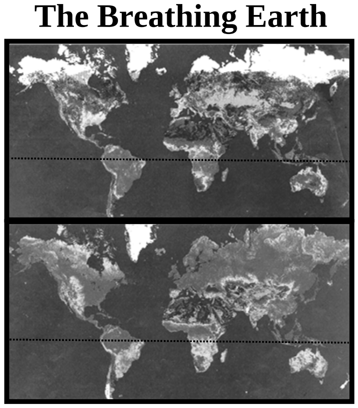
Atmsopheric CO_2 was in dynamic equilibrium for thousands of years.



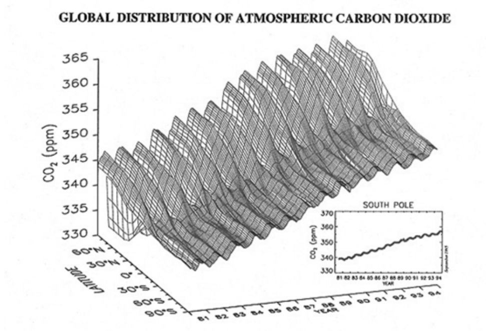
Change in atmospheric CO_2 concentration



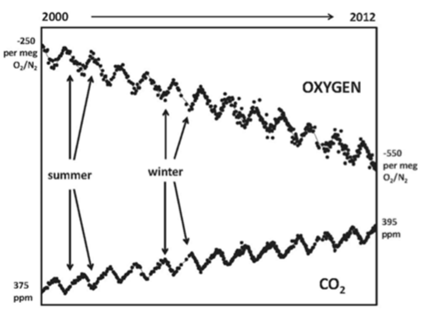
The Breathing Earth



More land & pollution in N. Hemisphere



Seasonal Imbalances between Photosynthesis & Aerobic Respiration



Carbon Cycle

Mean Residence Times

- Oceans ~ 422 years
- Atmosphere ~ 3 years (but atmospheric lifetime > 100 years)
- Land Plants ~ 4.6 years
- At current rates of fossil fuel use, our recoverable supplies will last about 700 years ! (4000 Pg ÷ 6.4 Pg/yr = 625 yrs)

The Carbon Cycle is not Always in Balance

- In the present, inputs of CO_2 > outputs to the atmosphere because …
  - Burning of fossil fuels.
  - Net destruction of terrestrial vegetation.
- Current imbalance results in rising atmospheric CO_2 concentrations.
- In the past, P_s > R because …
  - Fossil fuel deposits formed.
  - Oxygen accumulated in the atmosphere.

The Missing Carbon Sink

Net CO_2 Sources

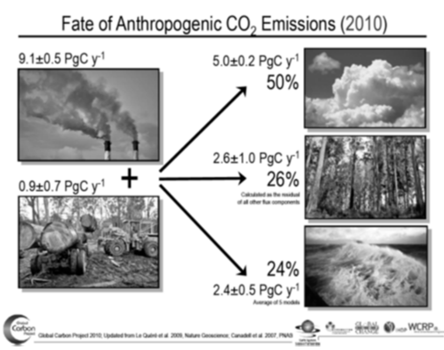
Fossil Fuel Emission	**6.4**
Land Use Change	**1.5**
Total Net Sources	**7.9**

Net CO_2 Sinks

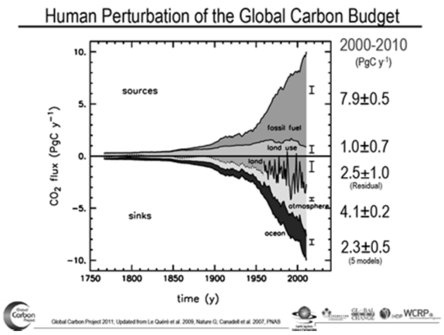
Atmospheric Increase	**3.2**
Ocean uptake	**2.2**
Total Net Sinks	**5.4**

Units are Pg C/yr

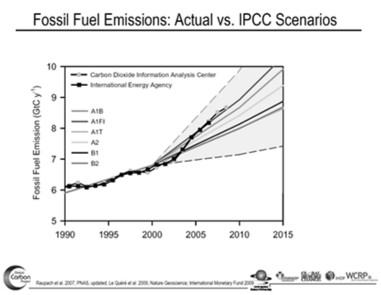
Mother nature mitigates climate change to some extent.



Historical estimates of sources & sinks of CO_2 associated with human activity



Unless we change, we are on the fast track



Summary of Carbon Cycle

- Largest active pool is the ocean.
- Pool on land (plant + soil) ≅ 3x amount in atmosphere
- $P_s \cong R_{total}$
- Soil respiration ≅ 10x fossil fuel emissions
- P_s removes 1/6 of the atmospheric pool of CO_2 each year.
- Concentration of CO_2 in the atmosphere is ca. 0.4% per year (ca. 3×10^{15} g C/yr)

The Nitrogen (N) Cycle

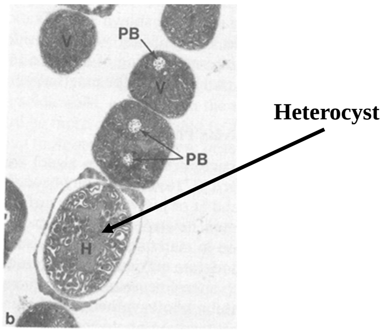
- Atmosphere is ca. 78 % N_2 but most is unavailable to living things because …
- N is important because …
- Microbial processes are important in the steps of the N cycle.

The nitrogen cycle has 5 basic steps

1) Nitrogen Fixation: N_2 => NH_3

Root Nodules on a Legume

Heterocysts in *Anabaena*

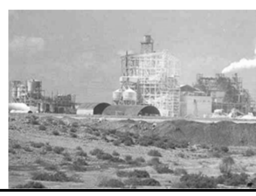


Humans Fix Nitrogen Too !

Fritz Haber

$4N_2 + 12\ H_2$ + catalyst ==> $8\ NH_3$

at 500^oC & several hundred atmospheres of pressure



2) Ammonification: organic N => NH_3

3) Nitrification: NH_3 => NO_2^- => NO_3^-

2-step process - each step by different bacteria.

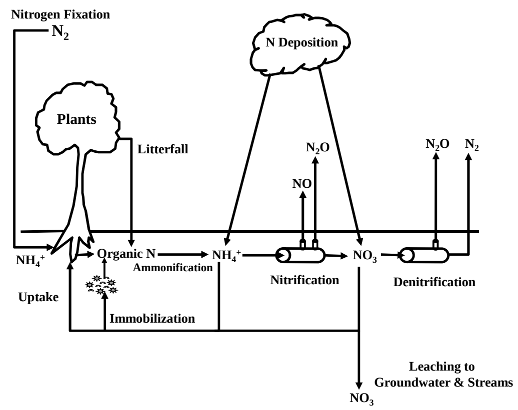
Step 1: oxidation of ammonia (NH_3) to nitrite (NO_2^-) by ____________

Step 2: oxidation of nitrite (NO_2^-) to nitrate (NO_3^-) by ____________

Both steps couple E-releasing oxidations to fixation of carbon - chemoautotrophs.

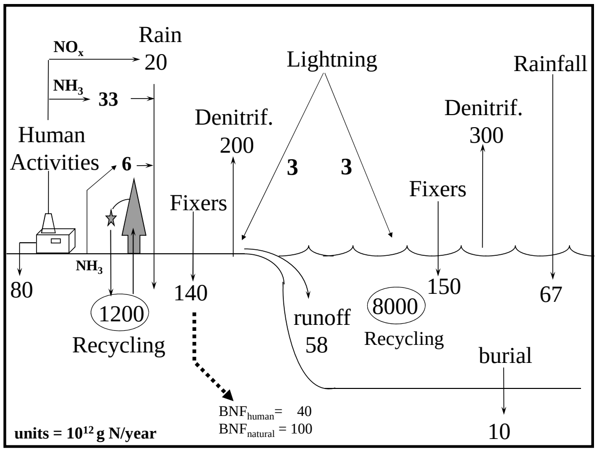
4) <u>Nitrogen Assimilation</u>: NH_3 => organic N
NO_3^- => organic N

5) <u>Denitrification</u>: NO_3^- or NO_2^- => N_2 or N_2O

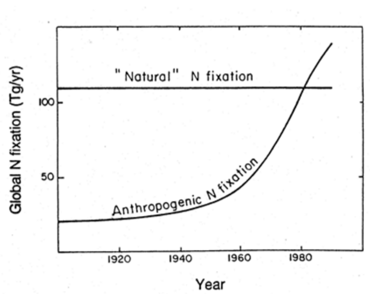


Active N Pools

- Atmosphere 3,800,000 x 10^{15} g N
- Ocean 21,000 x 10^{15} g N
- Soil Organic Matter 95 x 10^{15} g N
- Terrestrial Biota 3.5 x 10^{15} g N



Human Activities Account for More than Half of Total N Inputs on Land



Terrestrial Ecosystems Can be Overfertilized

Potential Consequences of N Saturation

- **Increased surface-water NO_3^- concentrations.**
- **Enhanced losses of nutrient cations.**
- **Soil acidification & greater soluble Al .**

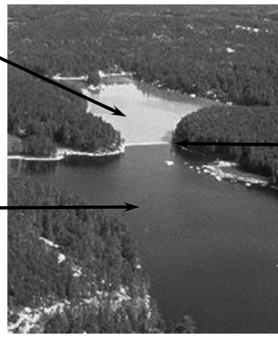
Summary of N Cycle

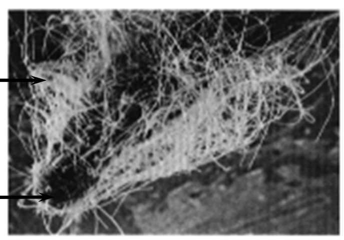
- Largest active pool = N_2 in atmosphere which is 181x > amount in ocean
- N in soil organic matter is 27x > amount in terrestrial biota
- Largest flux = uptake by plants of which almost all is from recycled organic N
- Human activities ≈ 60 % of total inputs to land
- River flow ≈ 20% total inputs to oceans

The Phosphorus (P) Cycle

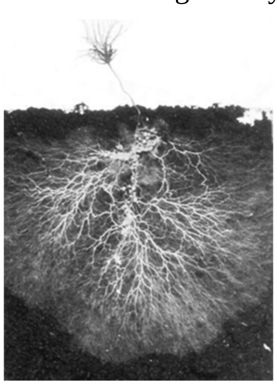
- Example of a sedimentary cycle => no gaseous phase
- P is abundant in soil but in forms that are not readily available to biota
- PO_4^{-3} is an available form of P
- P is important because …

Whole Lake Experiments

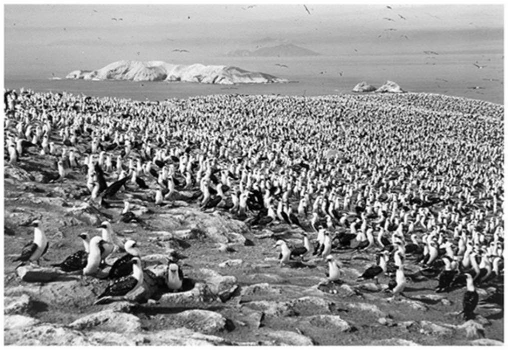




What is the advantage of Mycorrhizae?

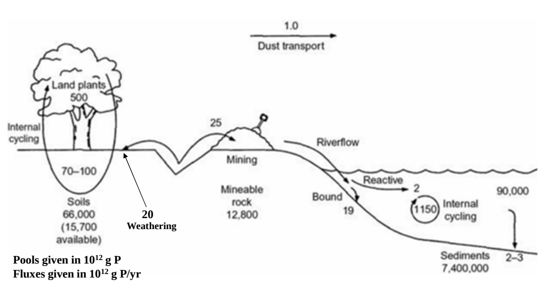


Guano Islands



Mining guano ca. 1860.

The Global P Cycle



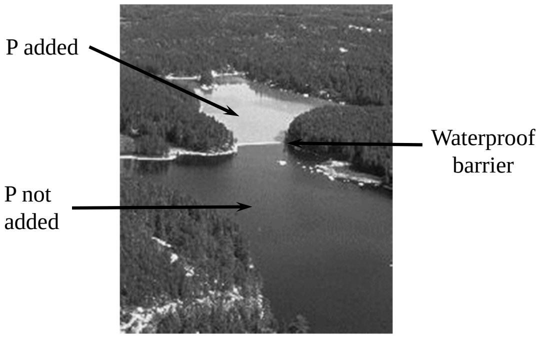
Summary of P Cycle

- 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.

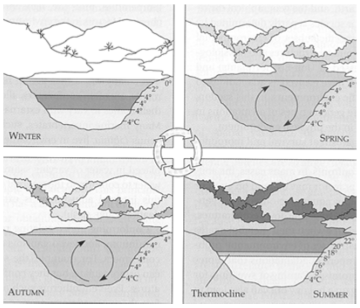
Summary of P Cycle

- Large loss to ocean relative to rate of return to land.
- Losses in runoff are 90% particulate-P
- Mycorrhizae absorption by plant roots
- Mining P-rich rocks is a major source to land.

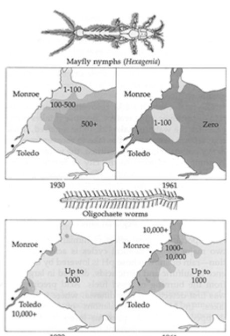
Aquatic Ecosystems Can be Overfertilized



Temperate Lakes Can Thermally Stratify In The Summer



Eutrophication of stratified shallow lakes can change species composition



Cleaner water has allowed mayfly populations to increase again!

Summer 2012
Lakeside, Ohio

Emerging Trends May Cause the return of Eutrophication to Lake Erie

Record-setting algal bloom in Lake Erie** caused **by agricultural and meteorological trends consistent with expected future conditions

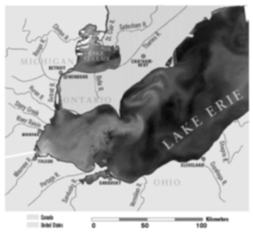
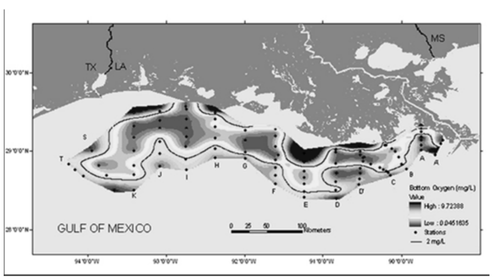


Fig. 1. MODIS satellite image of Lake Erie on September 3, 2011, overlaid over map of Lake Erie tributaries. This image shows the bloom about 6 wk after its initiation in the western basin. On this date, it covers the entire western basin and is beginning to expand into the central basin, where it will continue to grow until October (Fig. S1).

6448–6452 | PNAS | April 16, 2013 | vol. 110 | no. 16

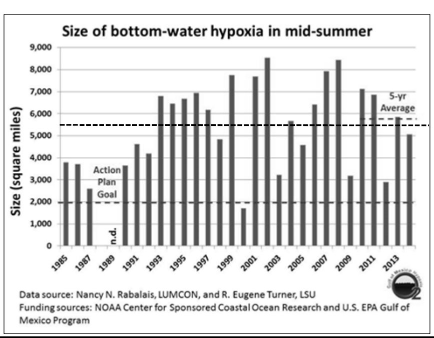
Eutrophication in Coastal Waters Creates "Dead Zones"

Mid-Summer 2007

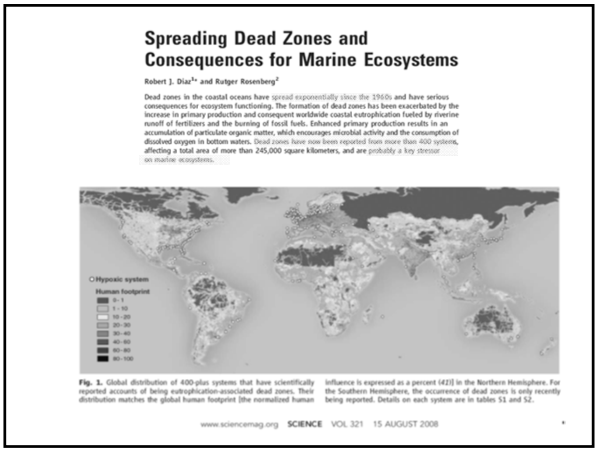


Read pages 556-558 in textbook

Area of mid-summer bottom-water hypoxia (< 2 mg O_2/L) In the Gulf of Mexico



~ Size of Connecticut



Spreading Dead Zones and Consequences for Marine Ecosystems

Robert J. Diaz[1*] and Rutger Rosenberg[2]

Dead zones in the coastal oceans have spread exponentially since the 1960s and have serious consequences for ecosystem functioning. The formation of dead zones has been exacerbated by the increase in primary production and consequent worldwide coastal eutrophication fueled by riverine runoff of fertilizers and the burning of fossil fuels. Enhanced primary production results in an accumulation of particulate organic matter, which encourages microbial activity and the consumption of dissolved oxygen in bottom waters. Dead zones have now been reported from more than 400 systems, affecting a total area of more than 245,000 square kilometers, and are probably a key stressor on marine ecosystems.

Fig. 1. Global distribution of 400-plus systems that have scientifically reported accounts of being eutrophication-associated dead zones. Their distribution matches the global human footprint [the normalized human influence is expressed as a percent (*41*)] in the Northern Hemisphere. For the Southern Hemisphere, the occurrence of dead zones is only recently being reported. Details on each system are in tables S1 and S2.

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