

APES CHAPTER 3 NOTES (MRS. BAUCK): ECOSYSTEM ECOLOGY

MODULE 6: The Movement of Energy

- I. Unclear ecosystem boundaries
- A. general terms
- 1) **biota = biotic community**—*plants, animals, and microbes of an area*
 - 2) **biosphere**—*all species on Earth and their ecosystems*
 - 3) **ecosystem**—*biotic factors (plants, animals, microbes) interacting in a specific area with each other and with the environment*
 - 4) **landscapes**—*a group of ecosystems which affect one another (interdependence and interactions)*
 - 5) **ecotone**—*a transition area between ecosystems, with blended characteristics*
 - 6) **biomes**—*major ecosystems of the world (grasslands, deserts, forests...)*
- B. some ecosystems have clear boundaries, some do not (cave vs. savannah)
- C. some ecosystems are large, some are small (Greater Yellowstone Ecosystem vs. a pond)
-

II. Photosynthesis and cellular respiration

- A. **photosynthesis**—*the process of converting carbon dioxide and water into glucose and oxygen*

PHOTOSYNTHESIS (requires E; low E to high E)



- 1) **autotroph**—*organism which produces its own food (usually through photosynthesis, sometimes chemosynthesis)*
 - 2) **primary producer** = *green plants* = synthesize new organic materials (glucose)
 - 3) *primary production* = sustained photosynthesis
 - 4) **gross primary production (GPP)**—total amount of photosynthetic activity
 - 5) **net primary production (NPP)**—rate of production
(total amount of photosynthetic activity) – (energy consumed by plants)
- B. **cell respiration**—*process of breaking down organic molecules (glucose) to release energy*
- 1) **aerobic respiration**—*process of breaking down glucose in the presence of oxygen to release energy*
 - a) **oxidation**—*release of energy through a reaction with oxygen*
 - b) body heat is released (proof of efficiency less than 100%)

CELL RESPIRATION, AEROBIC (emits E; high E to low E)



- 2) **anaerobic respiration**—*process of breaking down glucose in the absence of oxygen to release energy*

CELL RESPIRATION, ANAEROBIC (emits E; high E to low E)

glucose \rightarrow lactic acid $C_6H_{12}O_6 \rightarrow 2C_3H_6O_3$

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + 2ATP$
(ethanol)

- 3) the fate of food – organic material eaten by consumers:
 - a) *oxidized for energy (over 60%)*
 - b) *used for growth, maintenance, repair, fat storage*
 - c) *passed as waste products*
 - cellulose = plant fiber; roughage
 - CO_2 , H_2O , other compounds
 - 4) *detritus feeders and decomposers—the detritivores*
 - a) adaptations – digestion of cellulose
 - b) breakdown of food into CO_2 , H_2O , and other compounds
 - c) release of heat energy
 - d) *fermentation—cell respiration by partial breakdown of glucose into alcohol, acetic acid*
 - i. $C_6H_{12}O_6 \rightarrow CH_3CH_2OH + CO_2$ (unbal.)
 - ii. *products can also include CH_4 , CH_3COOH*
 - e) *anaerobic environments do not contain oxygen*
-

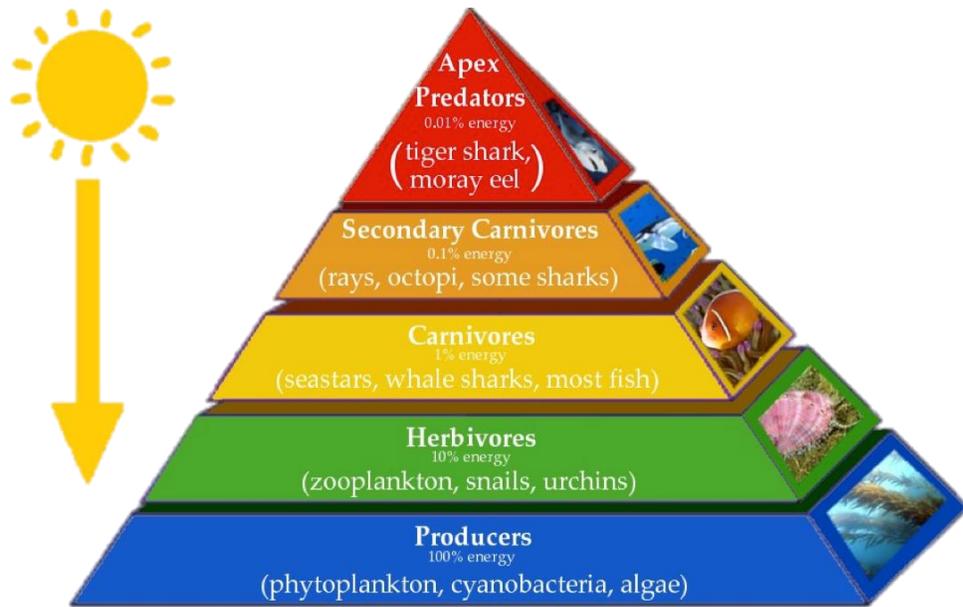
III. Trophic levels

A. Trophic levels on a typical pyramid

- 1) bottom layer – *autotrophs/producers*
 - a) **producers (autotrophs)**—*organisms which make their own food (through photosynthesis or chemosynthesis)*
 - b) *trophic levels must begin with producers*
 - c) green plants, phytoplankton, some bacteria
 - d) *chlorophyll—green pigment*
 - e) *organic—carbon-based; from living organisms or organisms that were once alive (example: wood)*
 - f) *Inorganic—non-organic components; not carbon-based (example: quartz)*
- 2) second layer from bottom – *herbivores (primary consumers)*
 - a) **consumers (heterotrophs)**—*organisms which feed on organic material/living prey*
 - b) **primary (1°) consumers**— *herbivores—organisms which feed on plants/autotrophs/producers*
- 3) third layer from bottom – **secondary (2°) consumers (carnivores)**—*organisms which feed on the primary consumers*
- 4) Fourth layer from bottom – **tertiary (3°) consumers (carnivores)**
- 5) Top – *apex predators*

B. “diet” terms

- 1) **carnivores**—animal-eaters
- 2) **herbivores**—plant-eaters
- 3) **omnivores**—plant-and-animal eaters



Source: Gravitate

- C. predator-prey relationships (more later)
 - 1) **predator**—*organism doing the hunting and feeding*
 - 2) **prey**—*organism which is fed upon*
- D. parasite-host relationships (more later)
 - 1) **parasite**—*organism feeding off another organism, weakening it but not usually killing it*
 - 2) **host**—*organism which is fed upon*
 - 3) viruses and bacteria are pathogens but are considered to be types of parasites
- E. **decomposers & detritus feeders**—*organisms which feed on dead organic material: dead organisms and/or their products*
 - 1) **detritus**—*dead plant and animal material*
 - 2) **primary detritus feeders (detritivores)**—*organisms feeding directly on detritus*
 - 3) **secondary detritus feeders (detritivores)**—*organisms feeding on 1° detritus feeders*
- F. trophic relationships
 - 1) **food chain**—*a simple, linear arrangement of feeding relationships: GRASS eaten by ANT eaten by LIZARD eaten by SNAKE*
 - 2) **food web**—*complex arrangement of food chains; all possible feeding relationships in an area*

IV. Ecosystem productivity and energy transfer

- A. Energy flow in ecosystems
 - 1) **primary production** (g C/m²/yr)
 - a) **GPP = gross primary productivity** – *the total amount of solar energy captured by the producers in an ecosystem*
 - b) **NPP = net primary productivity = (GPP – energy for respiration)**

- c) *sunlight supplies the initial energy in almost all ecosystems, those with photosynthetic and not chemosynthetic producers*
 - d) *only 1% of sunlight is harnessed for photosynthesis*
 - e) *standing crop biomass—primary producer biomass total*
 - *tropical rain forest = high gross & net productivity*
 - *open ocean = high gross productivity, but low net productivity*
 - 2) **energy flow and efficiency**
 - a) *review of three options for energy use:*
 - *growth (or maintenance, repair, storage)*
 - *respiration (oxidized for energy)*
 - *waste*
 - 3) **biomass**—*total mass of living organisms in an area; can be estimated at each trophic level*
 - 4) **standing crop**—*the amount of biomass in an ecosystem*
 - 5) **biomass pyramid (trophic pyramid)**
 - a) *graphic representation of biomass at different levels*
 - b) *energy flows in one direction: up through the biomass pyramid*
 - c) **ecological efficiency**—*proportion of energy passed from one trophic level to another*
- B. 10% rule**—*approximately 10% of the biomass of a trophic levels goes to the next level*
- 1) **** most of the food eaten by consumers (>60%) is metabolized for energy, not incorporated into the body mass*
 - 2) **** much of the producers' biomass goes directly to the detritivores / decomposers*
 - 3) *some is undigested and passed as waste*
 - 4) *trophic level biomass and energy drastically decrease up the pyramid*

MODULE 7: The Movement of Matter – biogeochemical cycles (*natural cycling of substances which “flow” between “pools”*)

- I. Hydrologic cycle (DO NOT call it the “WATER CYCLE!”) (\uparrow = given off \downarrow = taken in)
 - A. **hydrologic cycle**—*the movement of water through the biosphere*
 - B. main processes
 - 1) **transpiration**— $H_2O \uparrow$, *plants releasing water into the atmosphere through leaves*
 - 2) **evaporation**— $H_2O \uparrow$, *phase change from a liquid to a gas or vapor above Earth*
 - a) (review kinetic energy and phase changes)
 - b) “vapor” is used to describe a substance when it found as a gas, even though the normal state is not
 - 3) **evapotranspiration**— $H_2O \uparrow$ *dual processes: evaporation and transpiration*
 - 4) **sublimation**— $H_2O \uparrow$, *phase change from a solid to a vapor*
 - 5) **precipitation**— $H_2O \downarrow$, *water returning to the surface of Earth (rain, snow, etc.)*
 - 6) **condensation**— $H_2O \downarrow$, *phase change from a vapor or gas to a liquid (dew)*
 - 7) **runoff**— $H_2O \downarrow$, *water (storm water, snow melt, etc.) moving on the surface, usually moving into rivers or streams*
 - C. other processes
 - 1) $H_2O \downarrow$, *water in glaciers*
 - 2) $H_2O \downarrow$, *water stored in lakes, ponds, streams, etc. (surface water)*

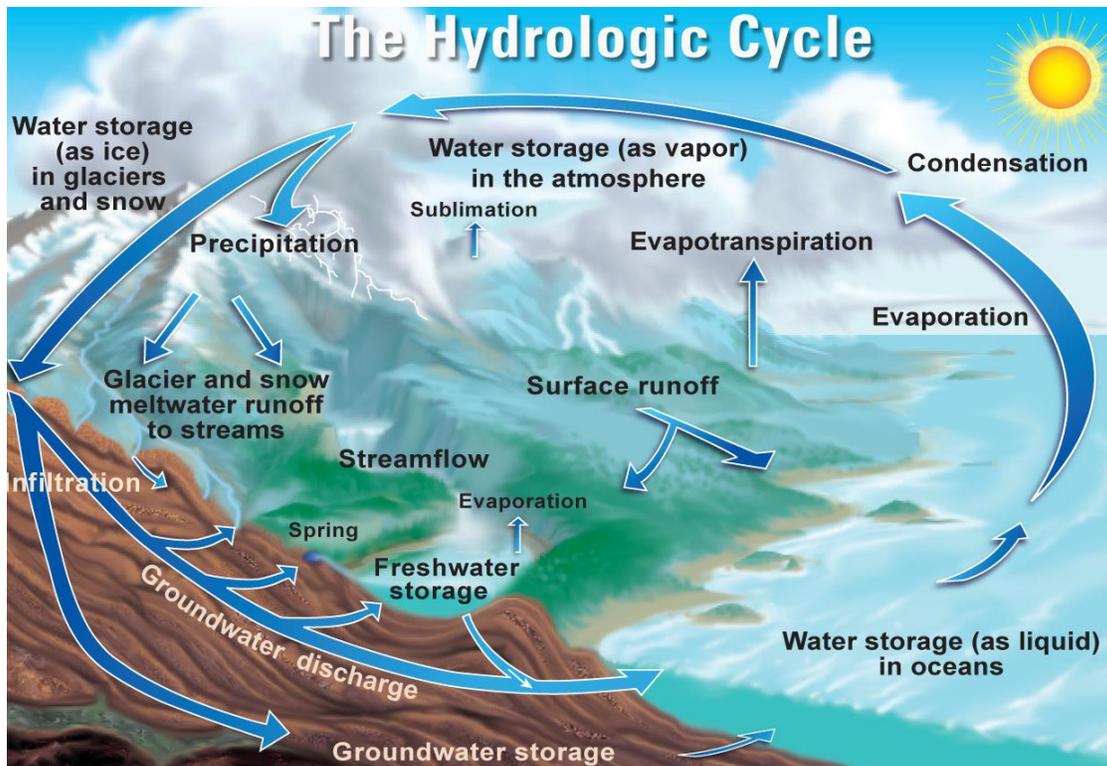
- 3) H_2O ↓, water stored in oceans
- 4) H_2O ↓, water underground (groundwater)
- 5) H_2O ↓, infiltration and percolation
- 6) H_2O ↑, as water vapor (humidity) in the air

D. natural water purification from the hydrologic cycle

- 1) water will evaporate, leaving behind the formerly dissolved materials
- 2) water will condense (with some dissolved pollutants and aerosols)
- 3) evaporation and condensation act as a natural purification process

E. some human activities impacting the hydrologic cycle (more later)

- 1) deforestation
- 2) unsustainable farming practices
- 3) water diversion (dams)
- 4) paving over land



Source: usgs.gov

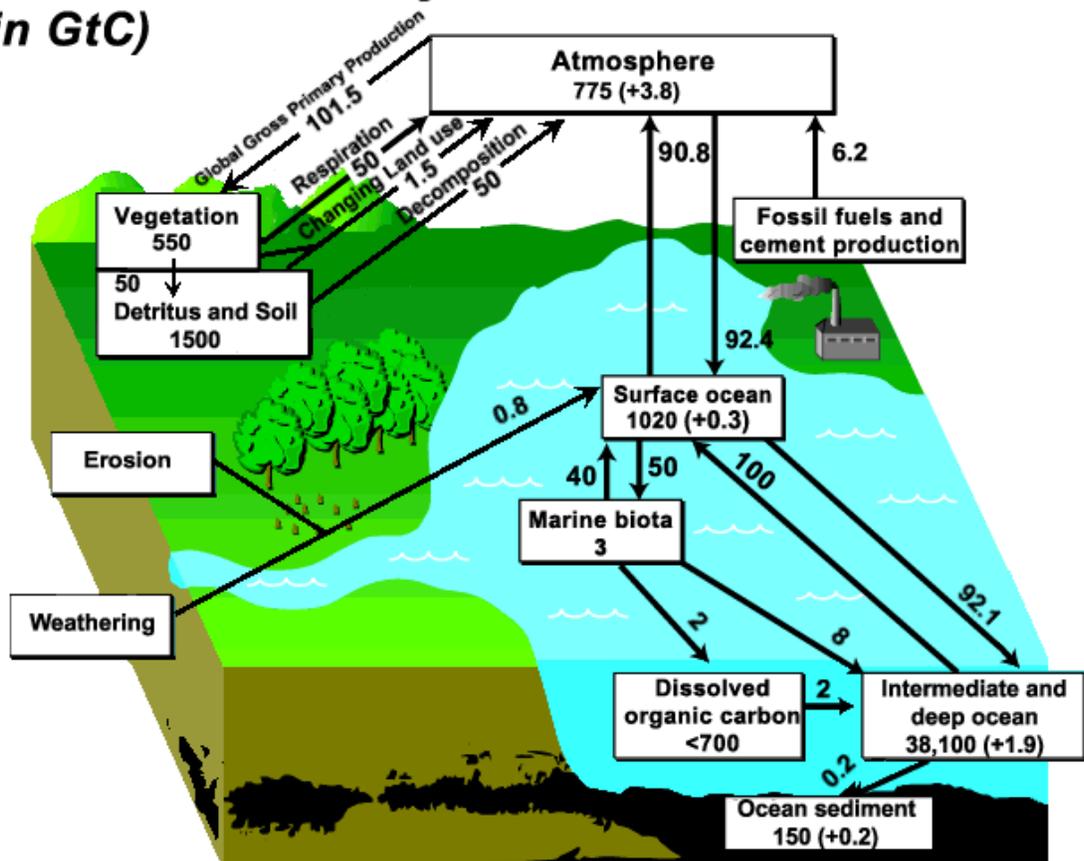
II. **Carbon cycle** (↑ = given off ↓ = taken in)

A. main processes

- 1) photosynthesis: CO_2 ↓, carbon in $C_6H_{12}O_6$ from photosynthesis
- 2) respiration: CO_2 released by respiration ↑
- 3) exchange: CO_2 passes back and forth from ocean to atmosphere;
 - a) CO_2 in ocean water ↓; $(HCO_3)^-$ in ocean water ↓, $(CO_3)^{2-}$ in ocean water ↓
 - b) $CO_2 + H_2O \rightarrow H_2CO_3$ ocean acidification ***
 - c) CO_2 diffusing out of ocean water ↑
- 4) sedimentation: CO_2 ↓, carbon stored in limestone rock ($CaCO_3$)
 - a) $Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$ in shells/skeletons of aquatic organisms

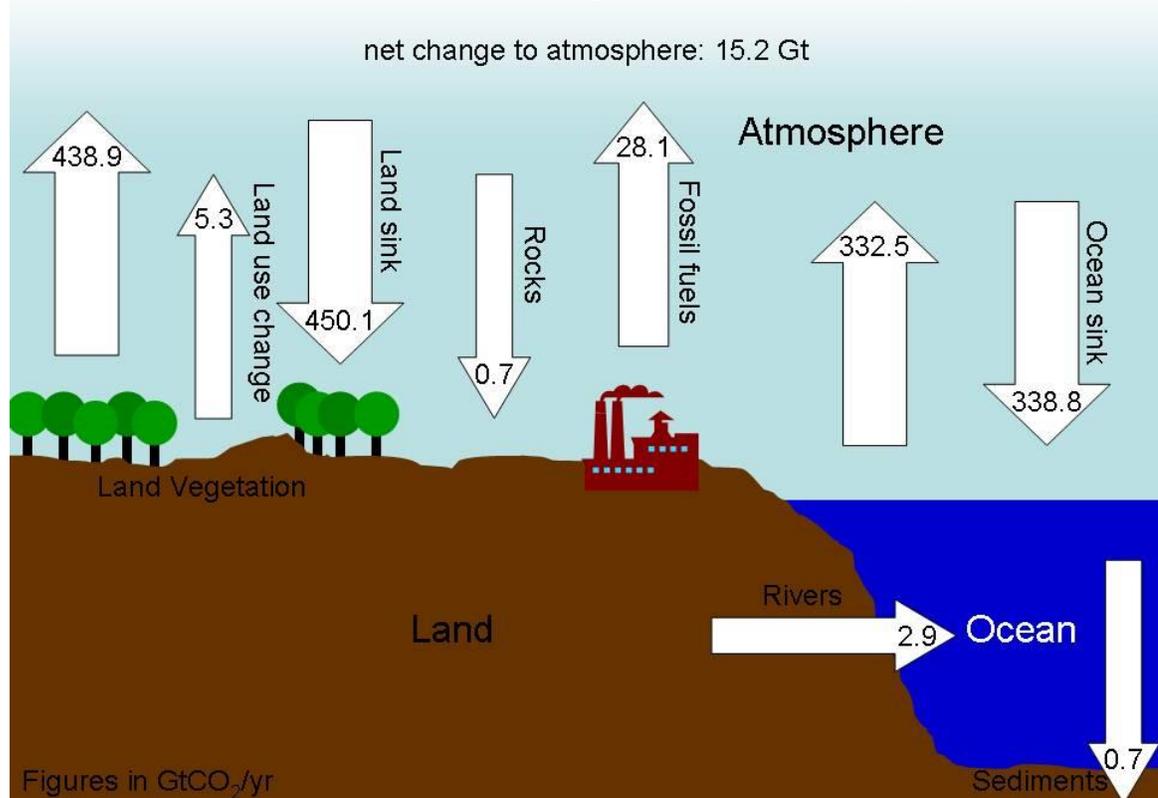
- b) $\text{CaCO}_3 \rightarrow$ buried, long period of time, pressure \rightarrow limestone
 - c) $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{HCO}_3^-$ (bicarbonate ions) + CO_3^{2-} (carbonate ions)
 - 5) burial: $\text{CO}_2 \downarrow$, small amount of carbon material is buried on the ocean floor and fossilized over millions of years
 - 6) extraction—humans bringing carbon to the surface (fossil fuels)
 - 7) combustion: CO_2 released by combustion of organics & fossil fuels
- B. other processes
- 1) CO_2 released by decomposition \uparrow
 - 2) CO_2 released by volcanic eruptions \uparrow
 - 3) “carbon sinks”
 - a) largest reservoir of carbon = sedimentary rocks
 - b) second largest reservoir of carbon = ocean (dissolved CO_2 , aquatic organisms)
- C. some human activities impacting the carbon cycle (more later)
- 1) combustion of fossil fuels
 - 2) deforestation

Global Carbon Cycle (1992-1997) (in GtC)



Source: Carbon Dioxide Information Analysis Center

Global Carbon Cycle (2000-2008)



Source: jameswight

III. Nitrogen cycle (↑ = given off ↓ = taken in)

A. main processes

- 1) **nitrogen fixation**—changing gaseous nitrogen (N_2) into a usable form for plants
 - a) nitrogen-fixing bacteria & cyanobacteria ↓
 - b) nitrogen fixation-- lightning ↓
 - c) nitrogen fixation-- industrial ↓ (fertilizer)
 - d) **legumes**—plants with root nodules containing nitrogen-fixing bacteria
 - e) reactions ↓
 - i. $N_2 + 3H_2 \rightarrow 2NH_3$ first...
 - ii. ...then $NH_3 + H_2O \rightarrow NH_4OH$ ($NH_4^+ + OH^-$)
soil bacteria; cyanobacteria can do this in water
- 2) **denitrification**—changing nitrates and nitrites in the soil to gaseous nitrogen
 - a) denitrifying bacteria ↑ NO_3^- and/or $NO_2^- \rightarrow N_2$
 - b) anaerobic bacteria convert ammonia back into N_2 or N_2O
- 3) **assimilation**—incorporating the nitrogen-based ions into the tissues of the producer
- 4) **nitrification**—ammonia (NH_3) is converted to nitrite ions (NO_2^-) and then into nitrate ions (NO_3^-)
 - a) ↓ through nitrogen compound oxidation
 - b) nitrite ions are not used by most producers; nitrate ions are
- 4) **mineralization / ammonification**—conversion of (often organic) N_2 into NH_3 by ammonifying bacteria

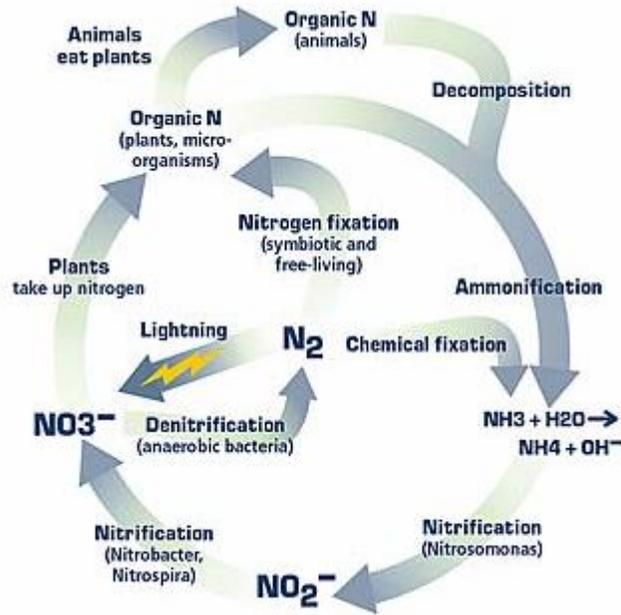
B. other processes

- 1) *death; decomposers put into soil* ↓ (production of NH_3 , NO_3^- , & NO_2^-)
- 2) *fertilizer runoff into soil* ↓
- 3) *waste products, into soil* ↓

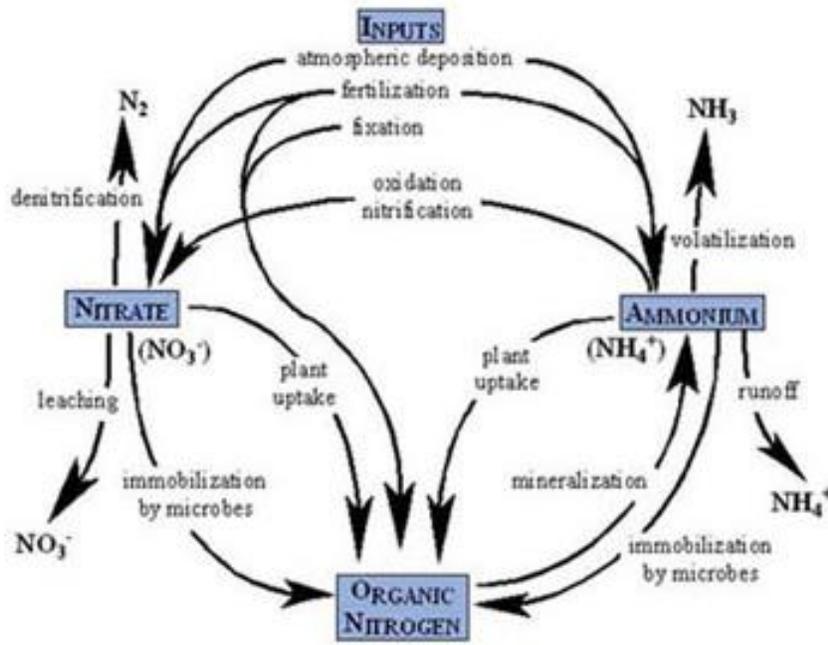
C. some human activities impacting the nitrogen cycle (more later)

- 1) application of fertilizers
- 2) leaching of chemicals
- 3) eutrophication

NITROGEN CYCLE



Source: learner.org



Source: learner.org

IV. Phosphorus cycle

A. NOTE: *no gaseous phase involved – a sedimentary cycle only* (all ↓)

(rain or sea spray can dissolve some P compounds, making them airborne, but it is miniscule)

B. focuses on phosphate: *water-soluble phosphate ion; insoluble phosphate precipitates; organic phosphate (organophosphate)* ↓

C. main processes

1) **assimilation**— *incorporating the phosphate-based ions into the tissues of the producer as organic phosphate (organophosphate)* ↓

2) **mineralization**

a) *actions by detritivores and decomposers: $(PO_4)^{3-}$ ↓ to soil organic phosphate (organophosphate) → inorganic phosphate*

b) *waste products from animals etc. containing phosphate, $(PO_4)^{3-}$ ↓ to soil*

3) **sedimentation**—*ocean sediment containing phosphate rocks*

4) **geologic uplift**—*mountain formation from deposits of rock*

5) **weathering**— *$(PO_4)^{3-}$ dissolved from weathering, ↓ into water*

*** *P is a limiting nutrient in aquatic ecosystems* ***

D. other processes

1) *fertilizer on crops, $(PO_4)^{3-}$ ↓ to soil*

2) *discharge of sewage, ↓ into water*

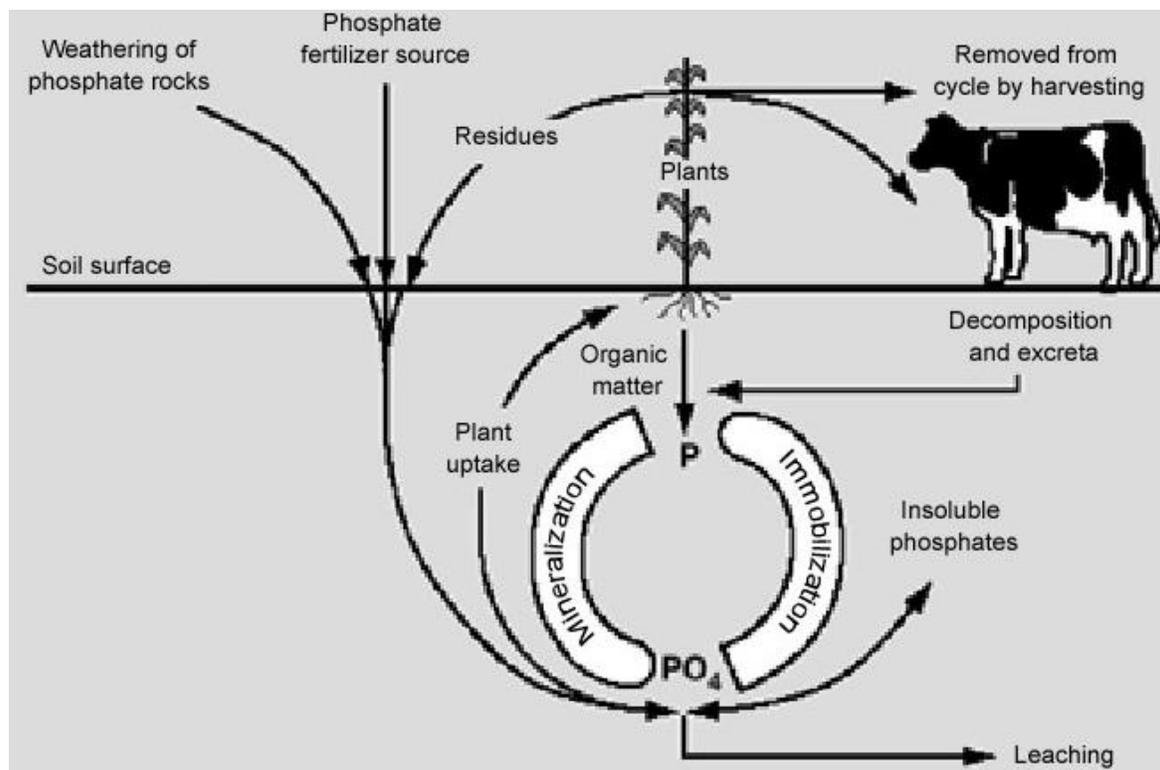
E. some human activities impacting the phosphorus cycle (more later)

1) application of fertilizers

2) leaching of chemicals

3) **eutrophication, algal blooms, hypoxia / hypoxic zones**

PHOSPHORUS CYCLE



Source: learner.org

V. Sulfur cycle

A. focuses on *sulfate ion* (SO_4^{2-})

B. *mainly an atmospheric cycle*

C. main processes

1) **volcanism**— H_2S (*hydrogen sulfide*) and SO_2 (*sulfur dioxide*) released into atmosphere from natural (volcanoes) and non-natural sources ↑

2) **assimilation**—sulfates taken up by plants and animals ↓

3) atmospheric reactions (unbalanced is OK) ↑

a) $H_2S + O_2 \rightarrow SO_2 + H_2O$

b) $SO_2 + O_2 \rightarrow SO_3$ (*sulfur trioxide*)...

c) ... then $SO_3 + H_2O \rightarrow H_2SO_4$ (*sulfuric acid*)

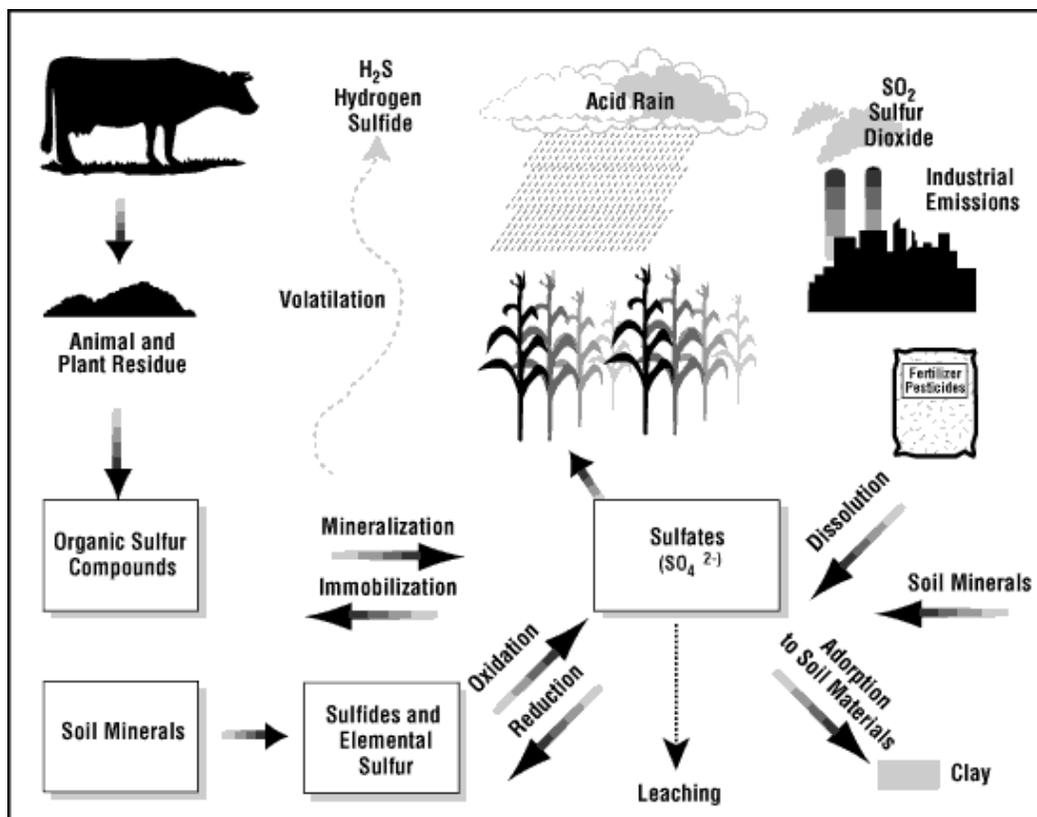
d) (see c) *acid deposition, sulfur returned to water and soil* ↑

D. other processes

1) combustion of S-containing coal ↑

2) *mining fossil fuels* ↑

3) *copper refining involving SO_2 gas* ↑



Source: NYU

- VI. Other cycles: calcium, magnesium, potassium
- A. all can form ions in water
 - B. all can be airborne as dust
 - D. Ca^{2+} and Mg^{2+} high affinity to soil
 - E. K^+ easily leached from soil
 - D. CaCO_3 – limestone (*sedimentary*); marble is metamorphosed limestone
-

MODULE 8: Responses to Disturbances (more later – see MODULE 21 and more)

- I. Ecosystems show resilience when subject to disturbance.
- A. **disturbance**—*an event caused by chemical, physical, or biological agents which results in an environmental change*
 - 1) population and/or community changes
 - 2) can be major, intermediate, or minor
 - B. **resilience**—*the rate at which an ecosystem returns to normal functioning and integrity after a disturbance*
 - C. resilience mechanisms—how an ecosystem “recovers” and deals with a disturbance
 - D. **resistance**—*how much a disturbance can affect the matter and energy flow in an ecosystem; how an ecosystem compensates*
 - E. **restoration ecology**—active in the Florida Everglades and Chesapeake Bay (an estuary in Maryland and Virginia)

“Ecological restoration has a growing role in policy aimed at reversing the widespread effects of environmental degradation. It includes activities to assist the recovery of ecosystem structure and function, and the associated provision of goods and services.” (sciencedirect.com)

watershed—*any area of land which drains into a body of water*

- II. Equilibrium ideas
- A. *equilibrium theory*—ecosystems are stable environments with competition and predation occurring (biotic interactions)
 - B. *nonequilibrium theory*—ecosystems are in a constant state of change
 - 1) early-stage species enter an area from surrounding areas in stages of succession
 - 2) later-stage species come from species in later stages of succession
 - 3) If any biotic or abiotic factors change, this causes a shifting in equilibrium, as species must adjust due to favorable or unfavorable impact on them.