Sustainability: Principles and Practices
Spring 2014

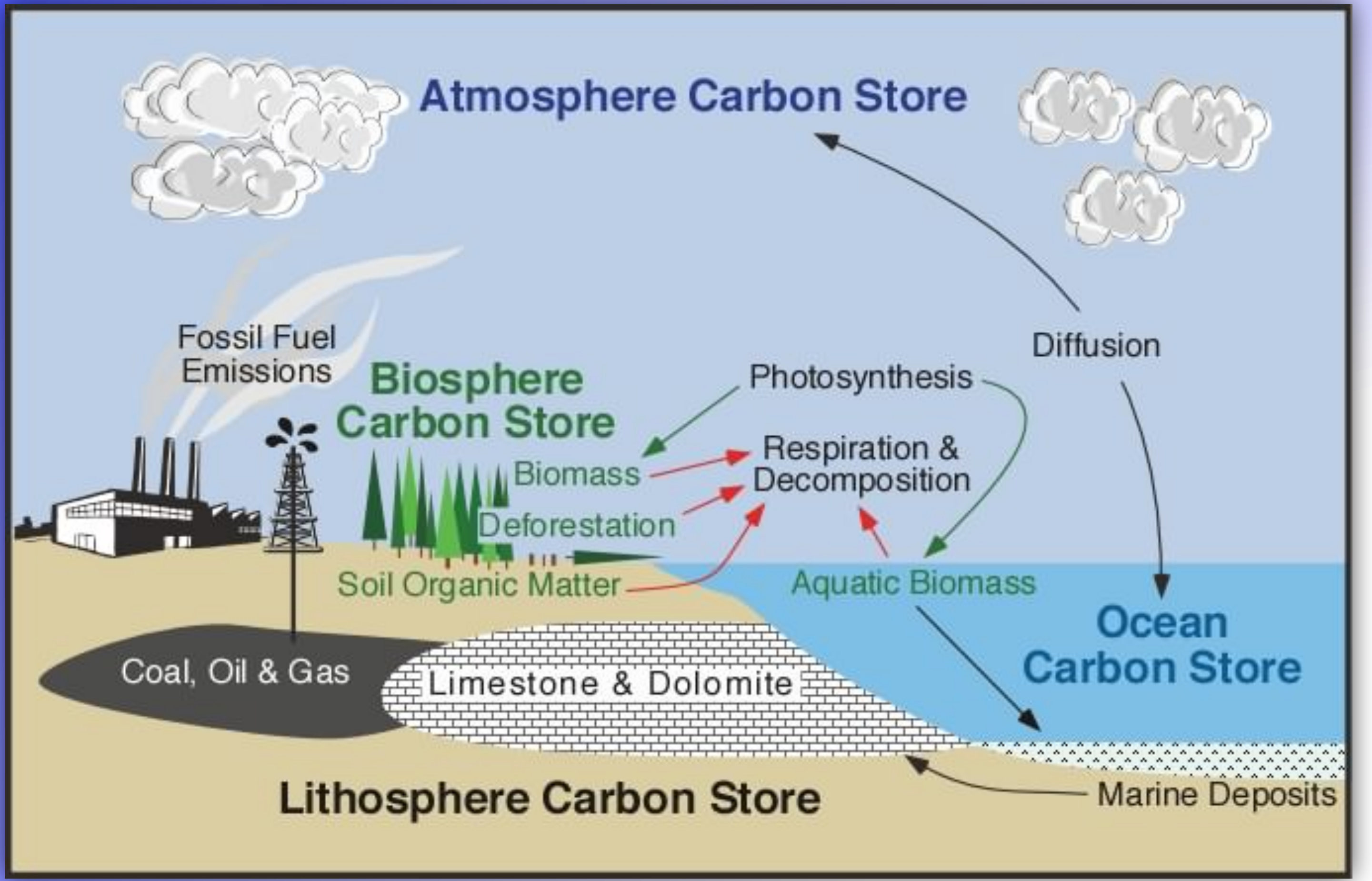
PPT Set 3

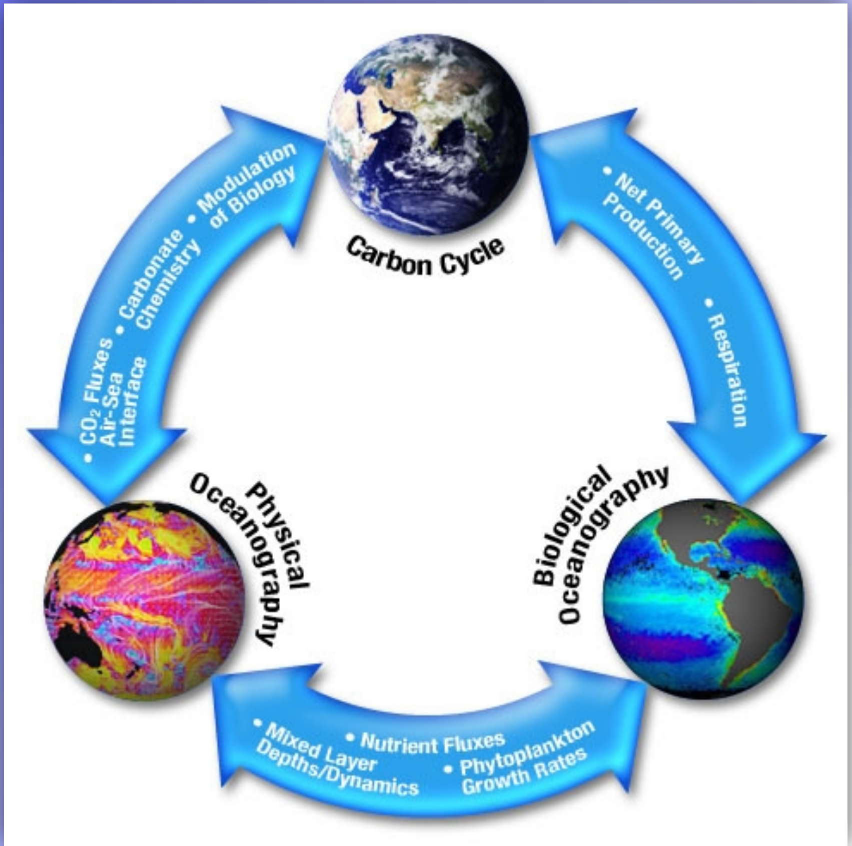
Professor Anthony Serianni

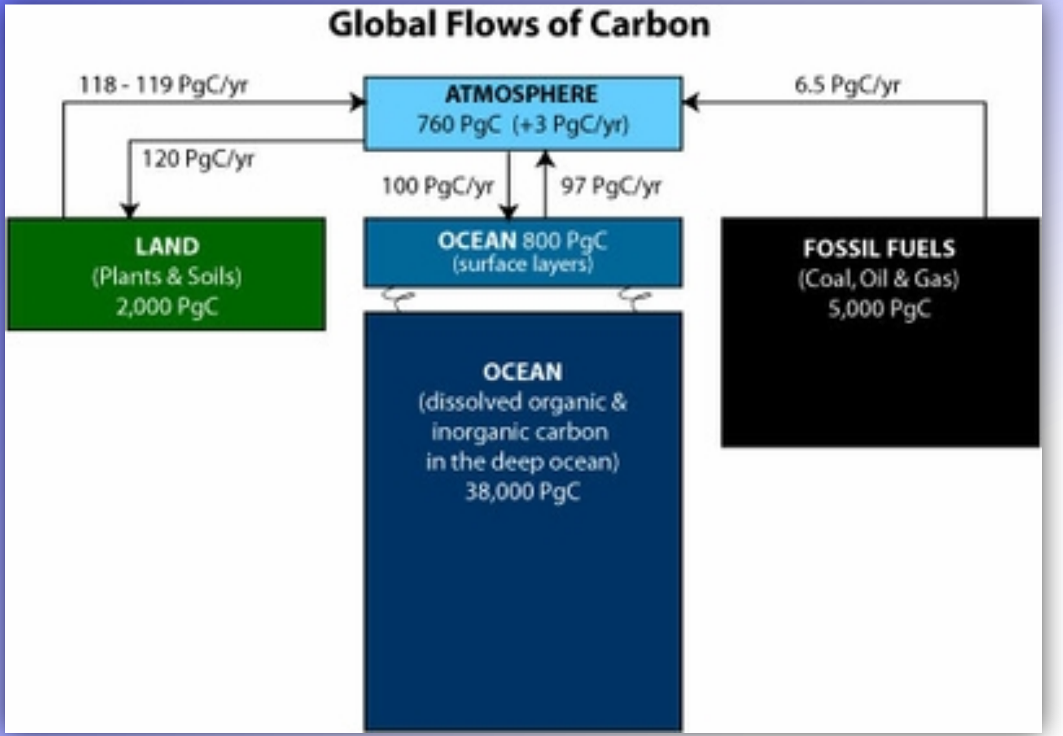
Biogeochemical cycles

- carbon
- oxygen
- nitrogen
- water
- phosphorus
- sulfur

The Carbon Cycle

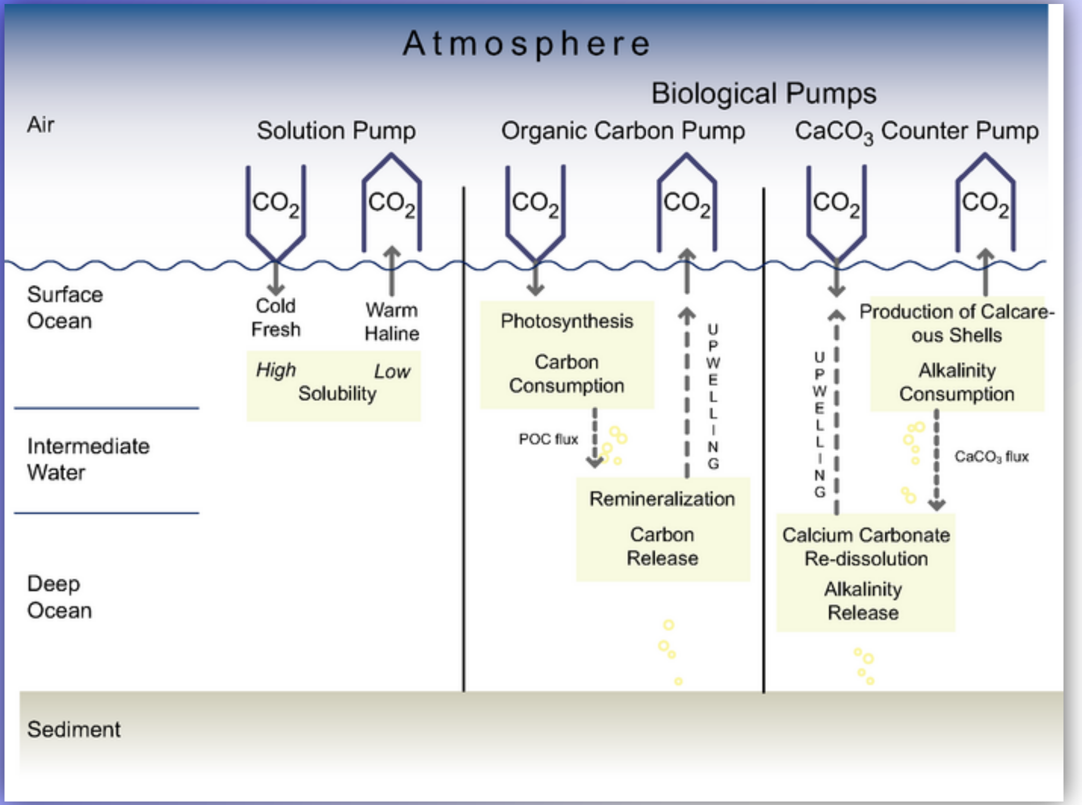


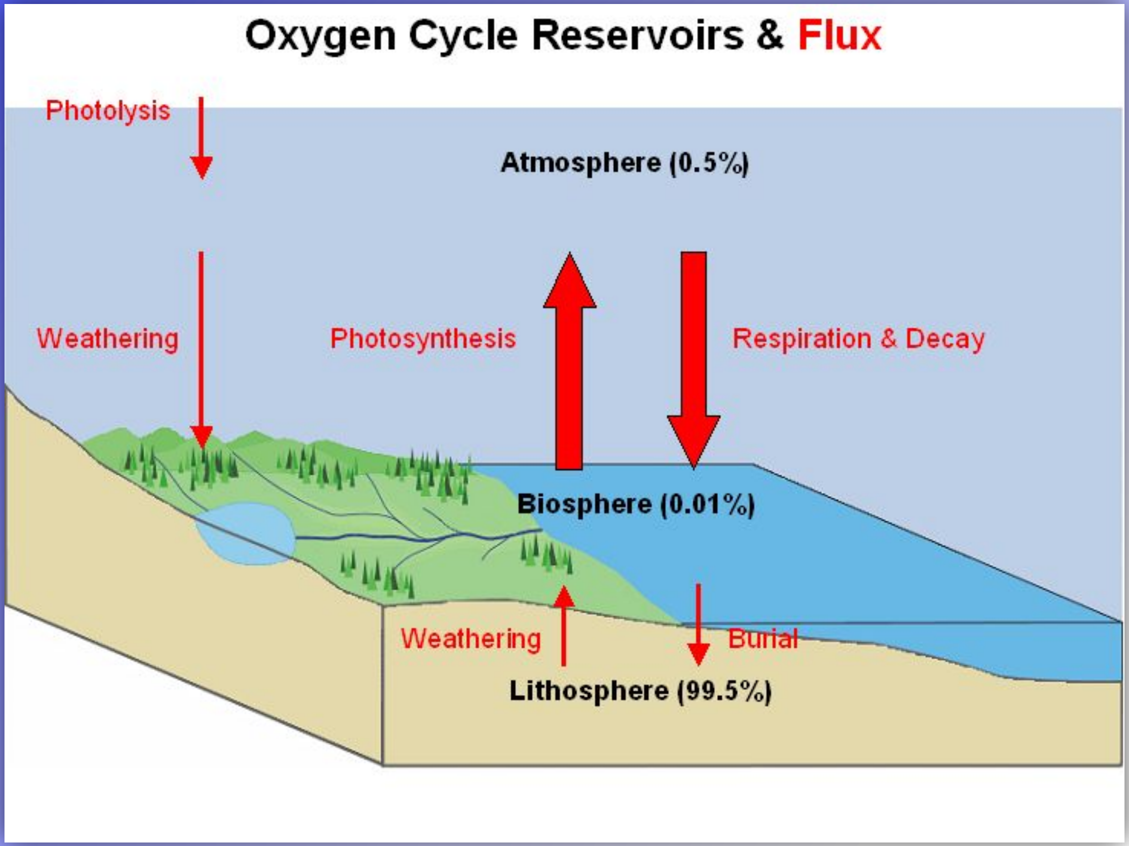

Carbon Cycle
• Modulation of Biology
• Carbonate Chemistry
• CO_2 Fluxes Air-Sea Interface
• Net Primary Production
• Respiration
Physical Oceanography
Biological Oceanography
• Mixed Layer Depths/Dynamics
• Nutrient Fluxes
• Phytoplankton Growth Rates



1 PgC = 10^{15} grams of carbon

Atmosphere-hydrosphere CO_2 pumps



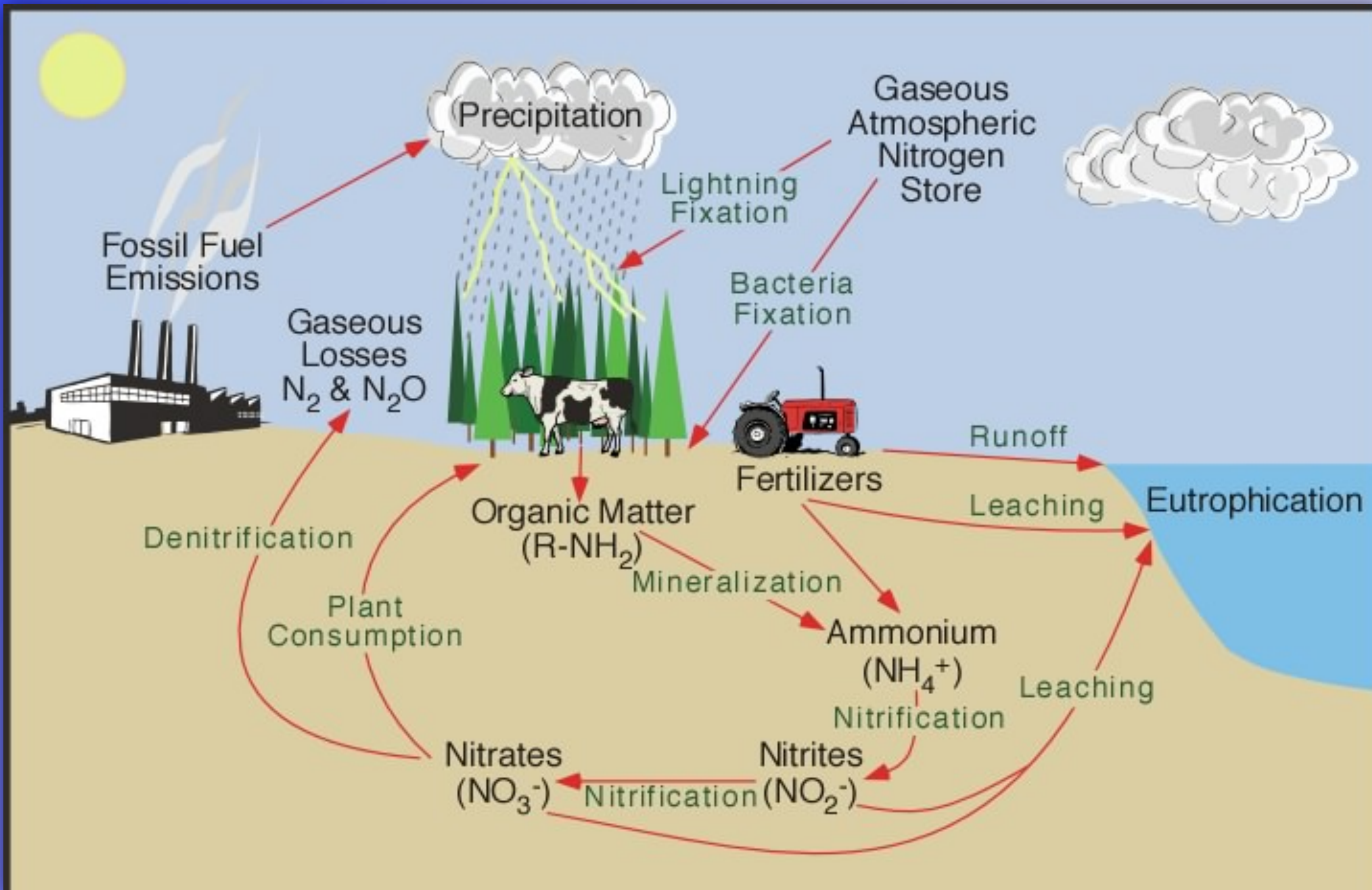


$$6CO_2 + 6H_2O + energy \rightarrow C_6H_{12}O_6 + 6O_2$$ (photosynthesis)

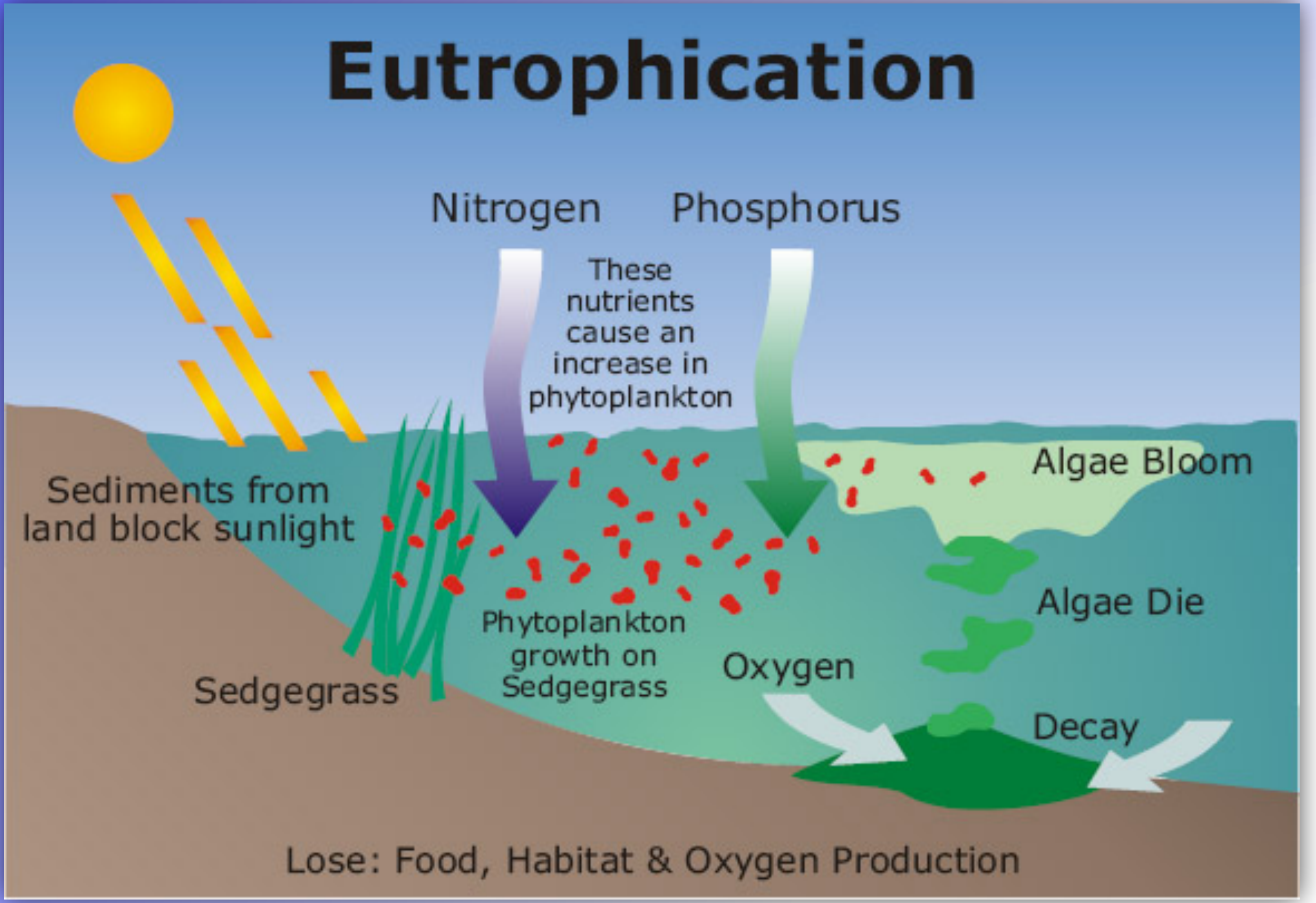
$$2H_2O + energy \rightarrow 4H + O_2$$
$$2N_2O + energy \rightarrow 4N + O_2$$
(photolysis)

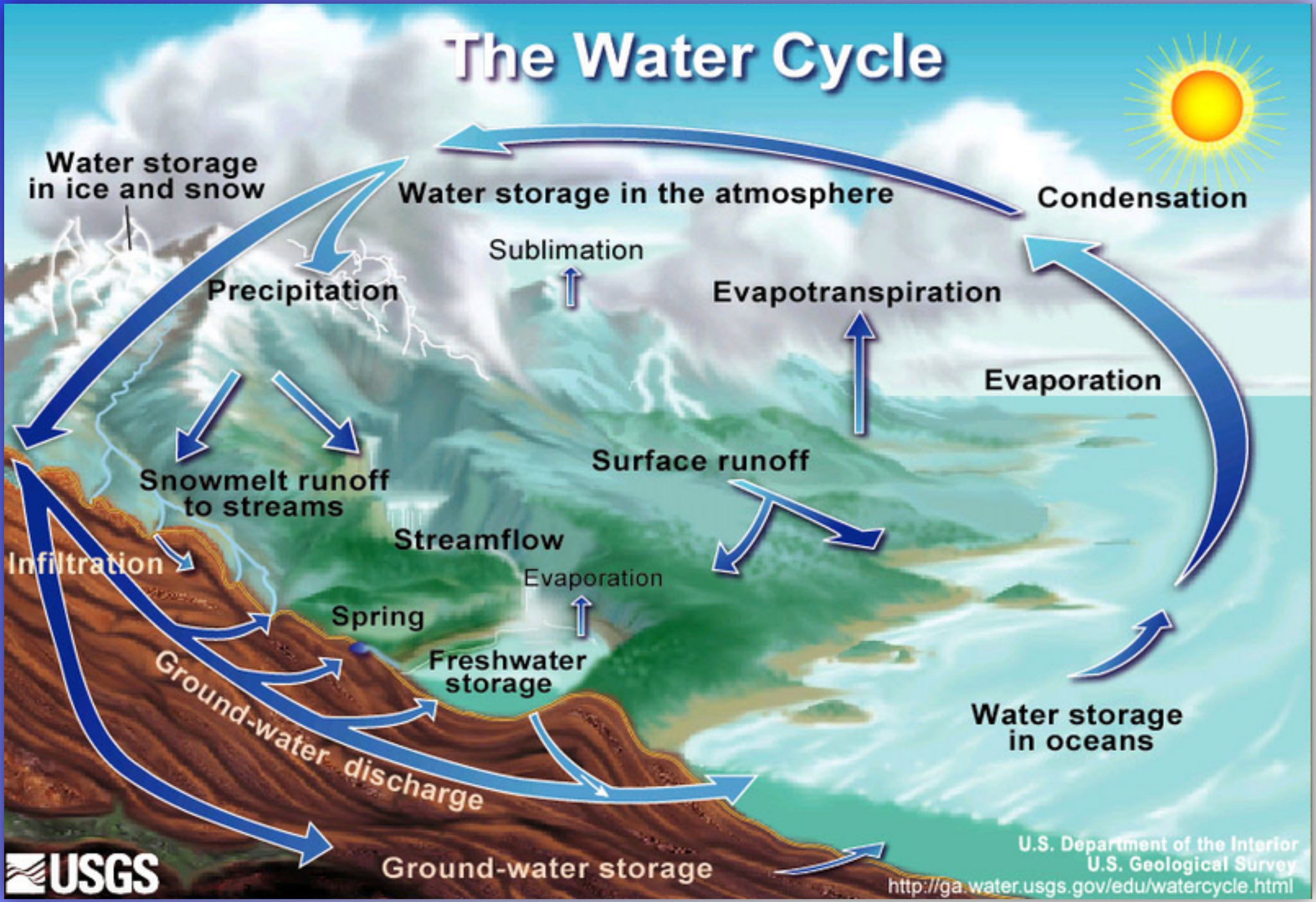
$$4FeO + O_2 \rightarrow 2Fe_2O_3$$
(weathering)

The Nitrogen Cycle



The effect of nitrogen and phosphorus runoff on aquatic systems





The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Sublimation
Precipitation
Evapotranspiration
Evaporation
Snowmelt runoff to streams
Surface runoff
Streamflow
Infiltration
Evaporation
Spring
Freshwater storage
Ground-water discharge
Water storage in oceans
USGS
Ground-water storage
U.S. Department of the Interior
U.S. Geological Survey
http://ga.water.usgs.gov/edu/watercycle.html

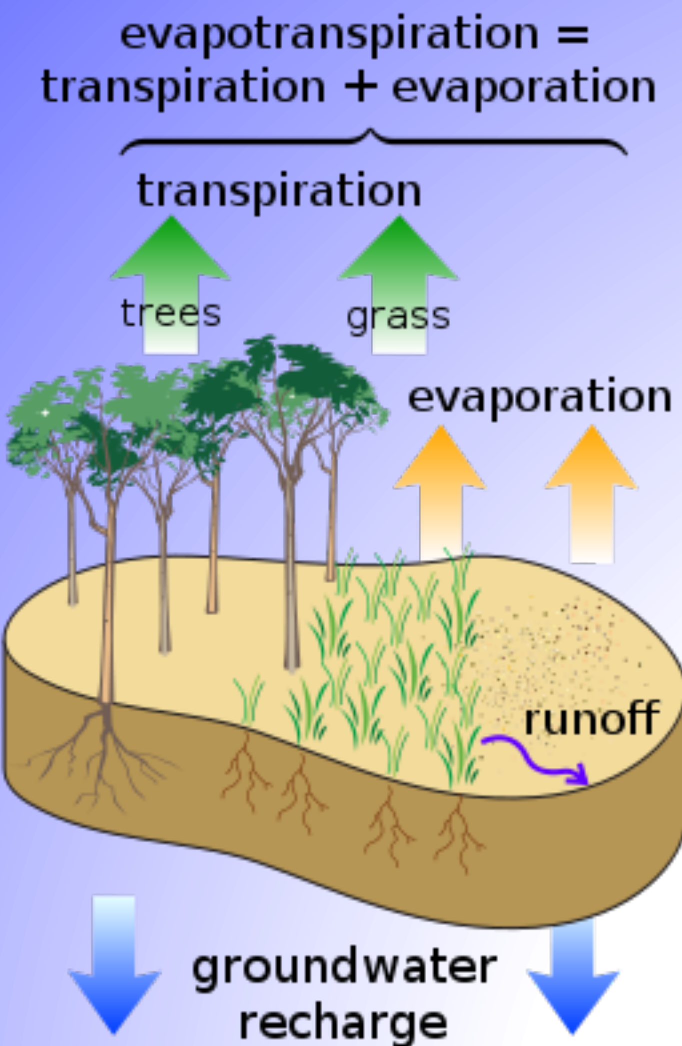
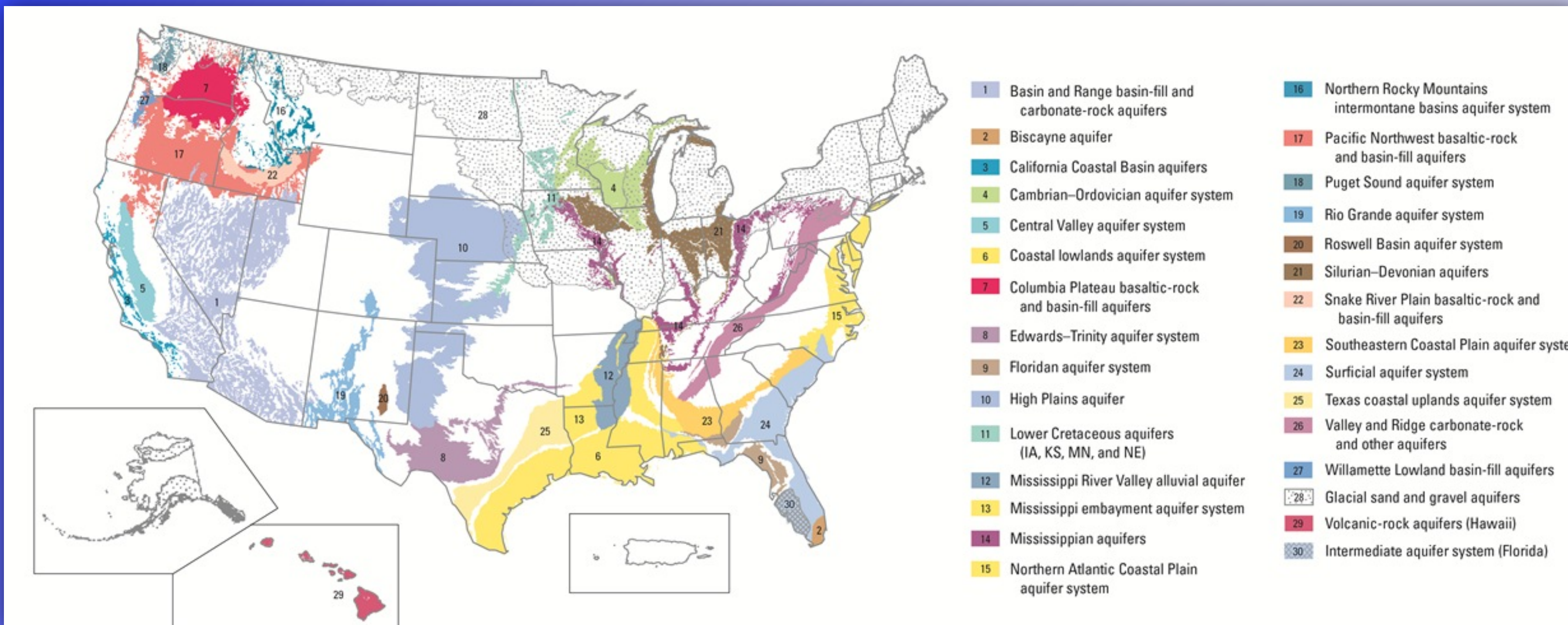

evapotranspiration =
transpiration + evaporation
transpiration
trees
grass
evaporation
runoff
groundwater
recharge

TABLE 21.1 Water in Major Global Reservoirs

Reservoir	Volume of water, km^3	Percentage of total
Oceans	1,370,000,000	97.25
Glaciers and ice sheets	29,000,000	2.05
Underground aquifers	9,565,000	0.69
Lakes	125,000	0.01
Rivers	1,700	0.0001
Atmosphere	13,000	0.001
Biosphere	600	0.00001
Total	1,408,705,300	100

TABLE 21.2 Water Fluxes between Reservoirs

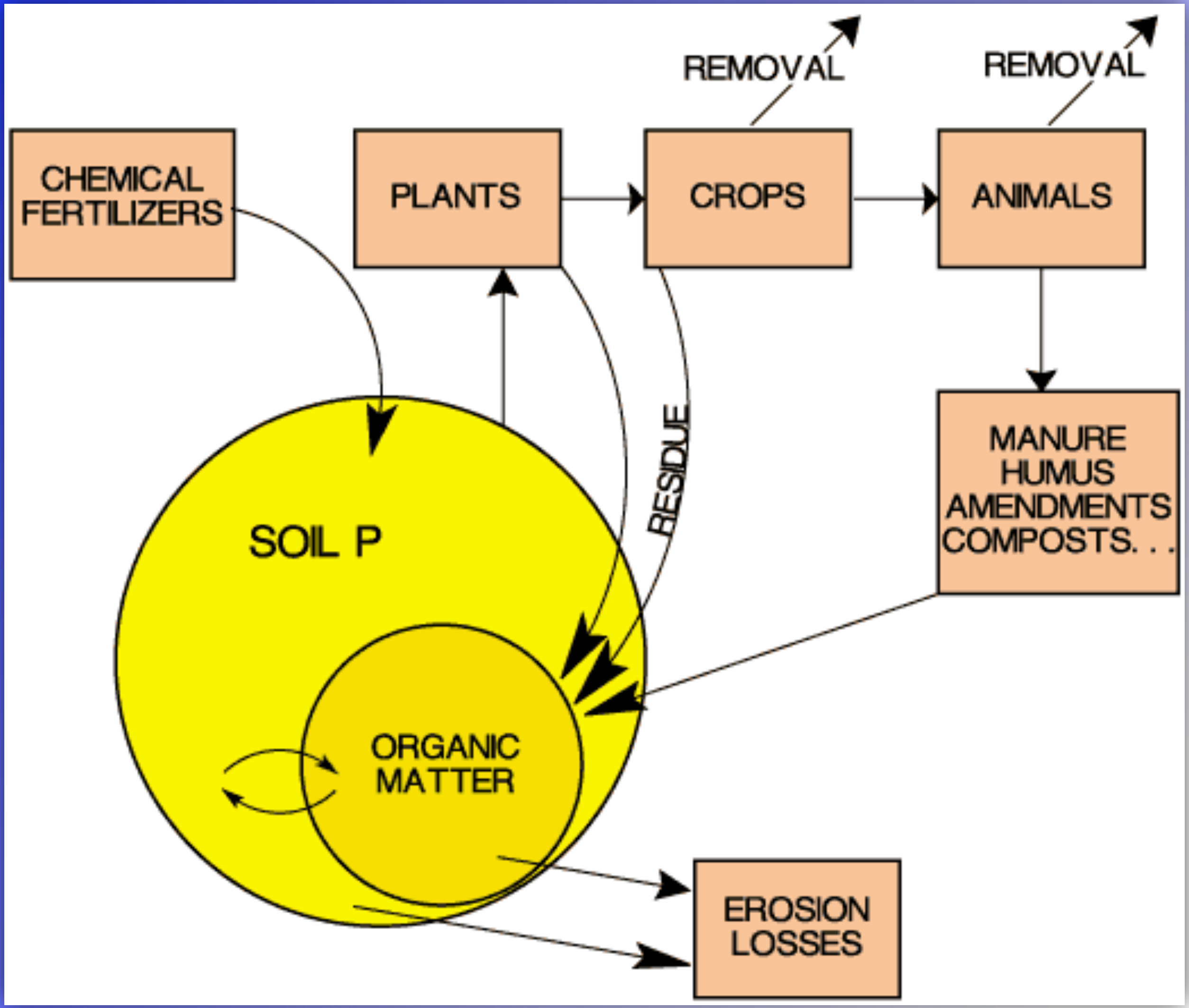
Reservoirs	Process	Flux, $km^3\ yr^{-1}$
Ocean–atmosphere	Evaporation	400,000
	Precipitation	370,000
Land masses–atmosphere	Evaporation	60,000
	Precipitation	90,000
Land masses–ocean	Runoff	30,000



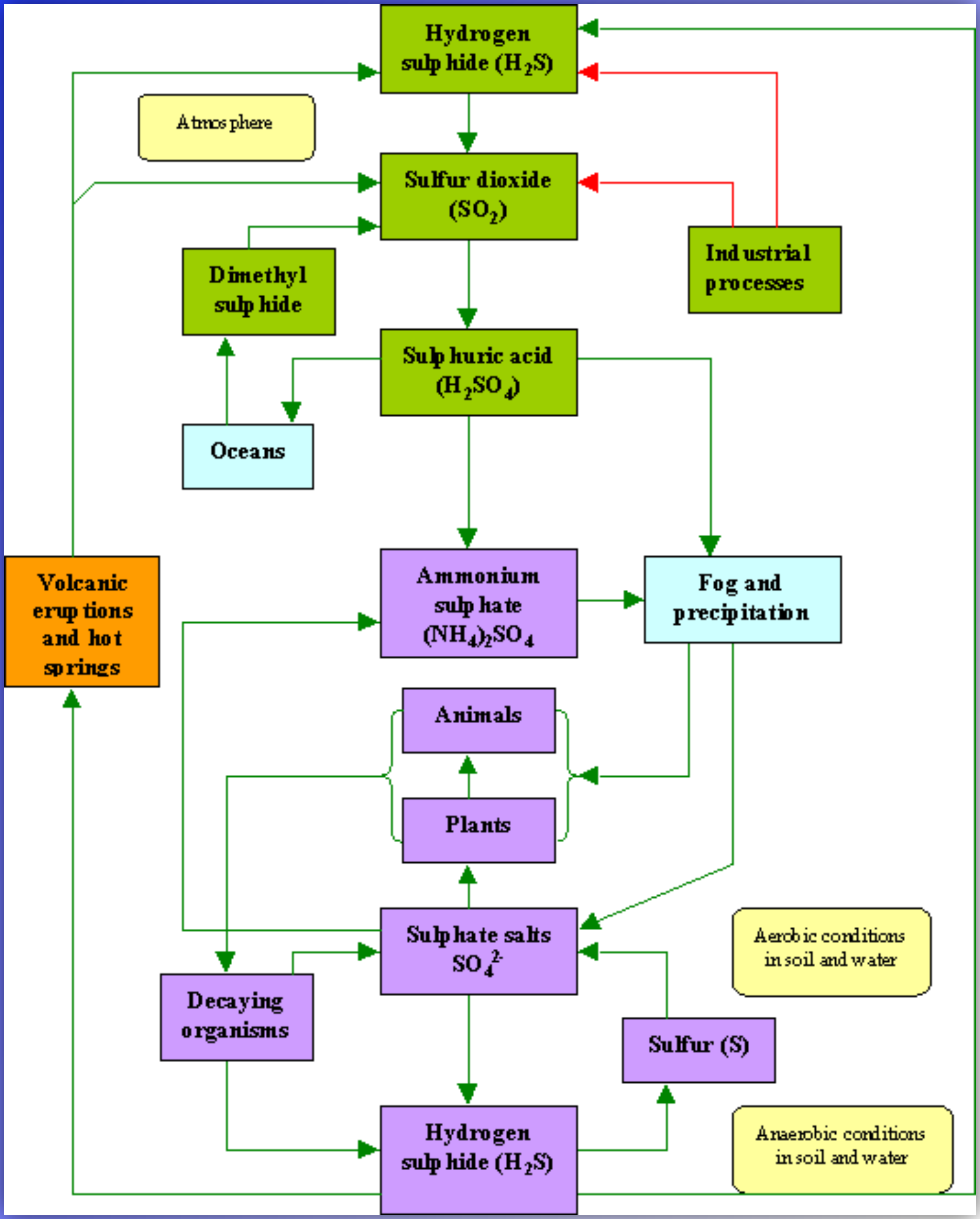
1 Basin and Range basin-fill and carbonate-rock aquifers
2 Biscayne aquifer
3 California Coastal Basin aquifers
4 Cambrian–Ordovician aquifer system
5 Central Valley aquifer system
6 Coastal lowlands aquifer system
7 Columbia Plateau basaltic-rock and basin-fill aquifers
8 Edwards–Trinity aquifer system
9 Floridan aquifer system
10 High Plains aquifer
11 Lower Cretaceous aquifers (IA, KS, MN, and NE)
12 Mississippi River Valley alluvial aquifer
13 Mississippi embayment aquifer system
14 Mississippian aquifers
15 Northern Atlantic Coastal Plain aquifer system
16 Northern Rocky Mountains intermontane basins aquifer system
17 Pacific Northwest basaltic-rock and basin-fill aquifers
18 Puget Sound aquifer system
19 Rio Grande aquifer system
20 Roswell Basin aquifer system
21 Silurian–Devonian aquifers
22 Snake River Plain basaltic-rock and basin-fill aquifers
23 Southeastern Coastal Plain aquifer system
24 Surficial aquifer system
25 Texas coastal uplands aquifer system
26 Valley and Ridge carbonate-rock and other aquifers
27 Willamette Lowland basin-fill aquifers
28 Glacial sand and gravel aquifers
29 Volcanic-rock aquifers (Hawaii)
30 Intermediate aquifer system (Florida)

Other cycles (sedimentary)**:**

The Phosphorus Cycle
The Sulfur Cycle



The Phosphorus Cycle



The Sulfur Cycle

TABLE 2.1 Atmospheric Sulfur Compounds

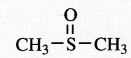
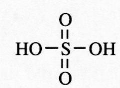
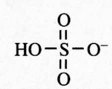
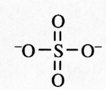
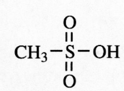
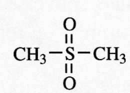
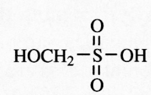
Oxidation State	Compound: Name	Compound: Formula	Chemical Structure	Usual Atmospheric State
−2	Hydrogen sulfide	H_2S	H−S−H	Gas
	Dimethyl sulfide (DMS)	CH_3SCH_3	CH_3−S−CH_3	Gas
	Carbon disulfide	CS_2	S=C=S	Gas
	Carbonyl sulfide	OCS	O=C=S	Gas
	Methyl mercaptan	CH_3SH	CH_3−S−H	Gas
1	Dimethyl disulfide	CH_3SSCH_3	CH_3−S−S−CH_3	Gas
0	Dimethyl sulfoxide	CH_3SOCH_3		Gas
4	Sulfur dioxide	SO_2	O=S=O	Gas
		SO_2 H_2O		Aqueous
	Bisulfite ion	HSO_3^-		Aqueous
	Sulfite ion	SO_3^{2-}		Aqueous
6	Sulfuric acid	H_2SO_4		Gas aqueous/aerosol
	Bisulfate ion	HSO_4^-		Aqueous/aerosol
	Sulfate ion	SO_4^{2-}		
	Methane sulfonic acid (MSA)	CH_3SO_3H		Gas/aqueous
	Dimethyl sulfone	$CH_3SO_2CH_3$		Gas
	Hydroxymethane sulfonic acid (HMSA)	$HOCH_2SO_3H$		Aqueous

TABLE 2.2 Global Sulfur Emissions Estimates, Tg(S) yr^{-1}

Source	H_2S	DMS	CS_2	OCS[d]	SO_2	SO_4	Total[a]
Fossil fuel combustion + industry		Total reduced S: 2.2			70	2.2	71–77 (mid-1980s) (68/6)
Biomass burning	<0.01?		<0.01?	0.075	2.8	0.1	2.2–3.0(1.4/1.1)
Oceans	<0.3	15–25	0.08	0.08		40–320	15–25(8.4/11.6)[b]
Wetlands	0.006–1.1	0.003–0.68	0.0003–0.06				0.01–2 (0.8/0.2)
Plants + soils	0.17–0.53	0.05–0.16	0.02–0.05			2–4	0.25–0.78 (0.3/0.2)[c]
Volcanoes	0.5–1.5			0.01	7–8	2–4	9.3–11.8(7.6/3.0)
Anthropogenic (total)							73–80
Natural (total, without sea salt and soil dust)							25–40
Total							98–120

[a]Numbers in parentheses are fluxes from Northern Hemisphere/Southern Hemisphere.
[b]Excluding seasalt contributions.
[c]Excluding soil dust contributions.
[d]Andreae and Crutzen (1997).

Source: Berresheim et al. (1995).

Ecosystem Energetics

Major Components of an Ecosystem

Nutrients: The nonliving matter, water, oxygen, carbon dioxide, organic compounds, and other chemicals used by plants and animals. The critical nutrients are cycled through the biosphere in the biogeochemical cycles.

Plants, or Primary Producers: Ranging in size from tiny phytoplankton in water to giant trees, they provide food for themselves and other organisms by converting carbon dioxide and water to sugars by photosynthesis.

Animals, or Consumers: Herbivores, such as deer, cows, rabbits, mice, grasshoppers, and sheep, are the primary consumers that feed on plants. In turn, small carnivorous animals, such as frogs, lizards, snakes, cats, and wolves, are secondary consumers that feed on the herbivores. Finally, top carnivores, such as lions, hawks, and fleas can feed on the smaller animals. Omnivorous animals, such as man, are both herbivores and carnivores, feeding on both plants and other animals.

Decomposers: Tiny organisms, such as bacteria and fungi, that complete the cycle of chemicals by breaking down the dead animals and plants and returning their nutrients to the ecosystem for reuse.

Energy: The solar energy that drives the entire system. It flows through the system, and at each level a small part of it is used to support life. Most of it is degraded to less useful forms and returned to the environment as heat, or entropy, in accordance with the Second Law of Thermodynamics.

Chemical cycling and energy flow through an ecosystem

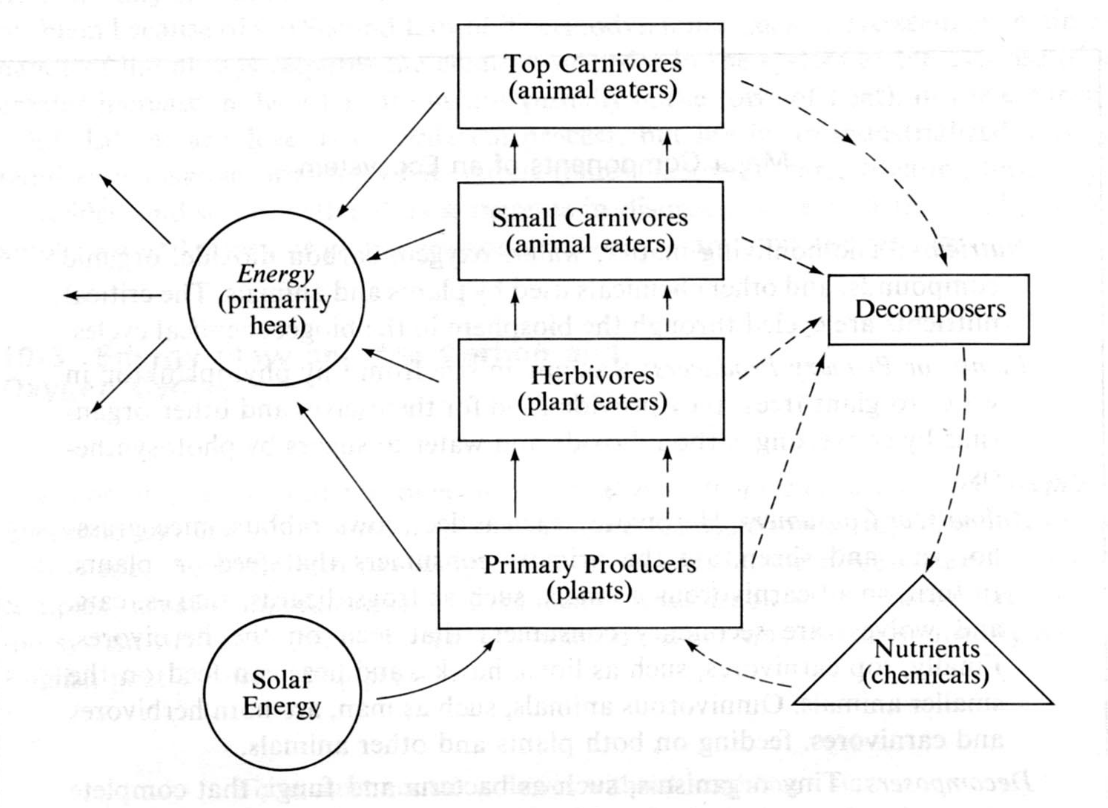


Figure 10-3 Interdependence of Plant and Animal Species in Chemical Cycling (dotted lines) and Energy Flow (solid lines) through an Ecosystem.

The unidirectional flow of energy through the biosphere

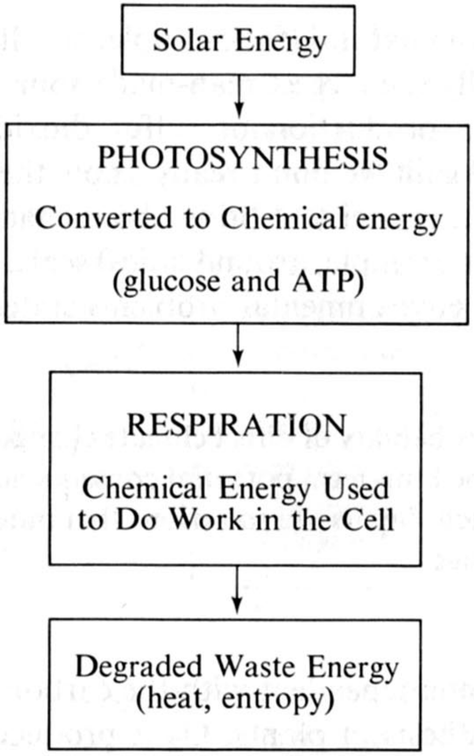
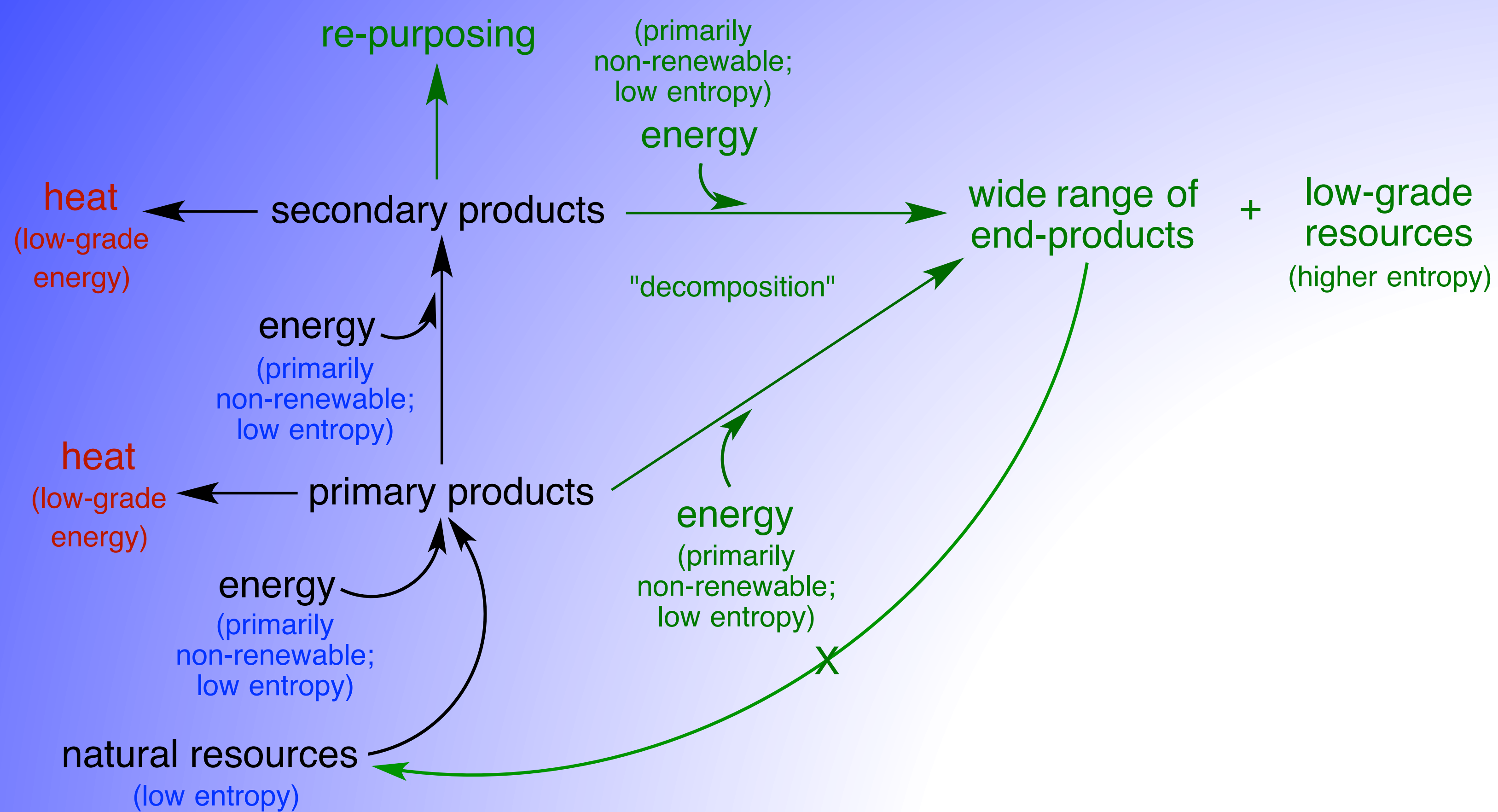


Figure 10-5 The One-Way Flow of Energy through the Biosphere.

Economy as ecosystem



Driving Forces for Biogeochemical Cycles

Energy and Energy Flow:

Thermodynamics