MATTER, ENERGY, & LIFE

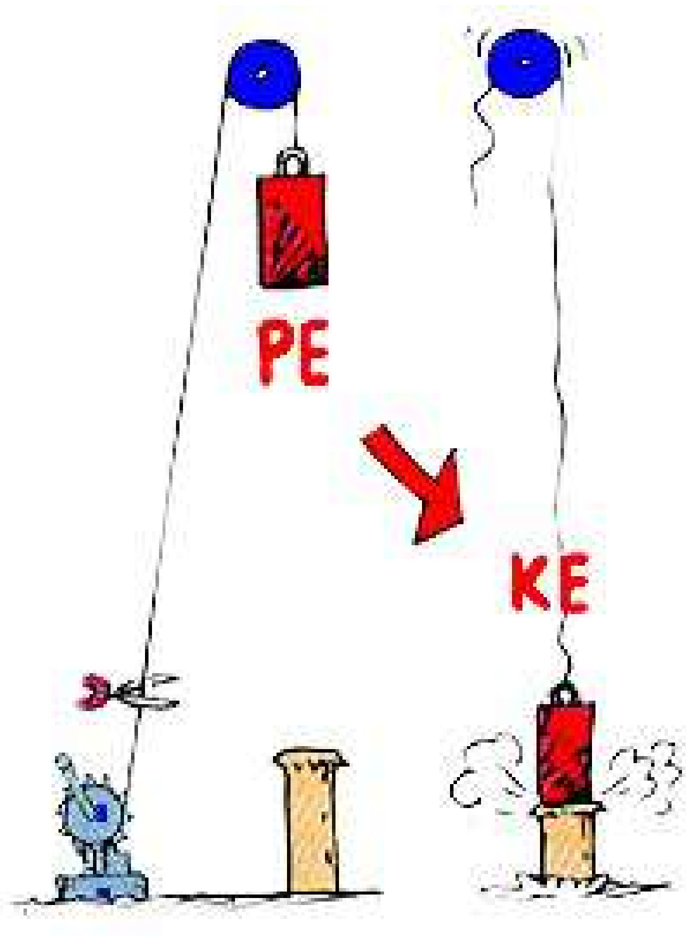
Energy flow & Nutrient cycles

What is matter?

- Matter- materials of which things are made
- Can be solid, liquid, or gas
- Law of Conservation of Matter- matter cannot be created nor destroyed- recycled or transformed
- All life is made of matter

What is energy?

- Provides the force to hold matter together, tear it apart, & move from one place to another.
- Kinetic energy- energy in moving objects
- Potential energy- stored energy; latent & ready for use.
- Chemical energy- energy stored in food or carbon compounds

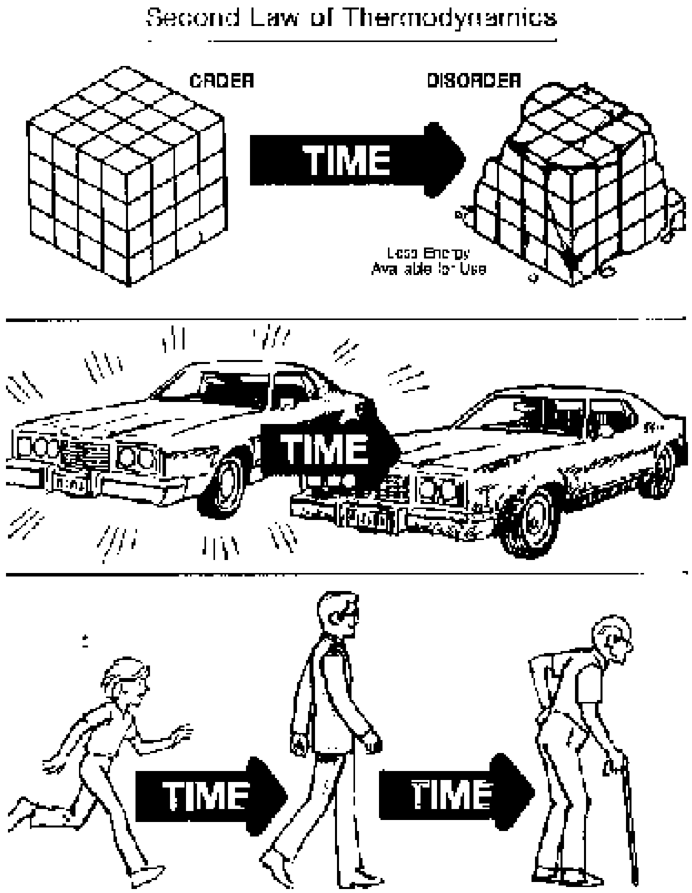


What is the difference between high quality energy and low quality energy?

- High quality- intense, concentrated, & high in temperature
  - Ex: energy in fossil fuels
- Low quality- diffused, dispersed, low in temperature
  - Ex: low heat energy of ocean is huge but hard to capture & use

How is energy transfer related to Thermodynamics?

- <u>1st law of thermodynamics</u>: energy is conserved, neither created nor destroyed
- <u>2nd law of thermodynamics</u>: entropy (disorder) increases in all natural systems; less energy is available to do work; it has not been destroyed, only dissipated.



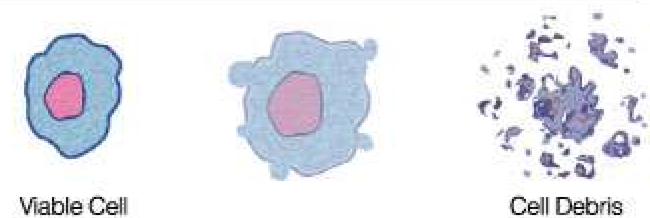
Why do organisms need a constant supply of energy?

- Needed to replace energy that is dissipated as used.
- If no constant supply of energy, cells can’t perform work, causes death.
- 90% of energy is used to do work or lost as heat

Apoptosis

	Time Zero	30 minutes–4 hours	24 hours
LDH Release	0	+	+++
Caspase	0	+++	++
ATP	+++	++	0
MTS	+++	++	0
Resazurin	+++	++	0

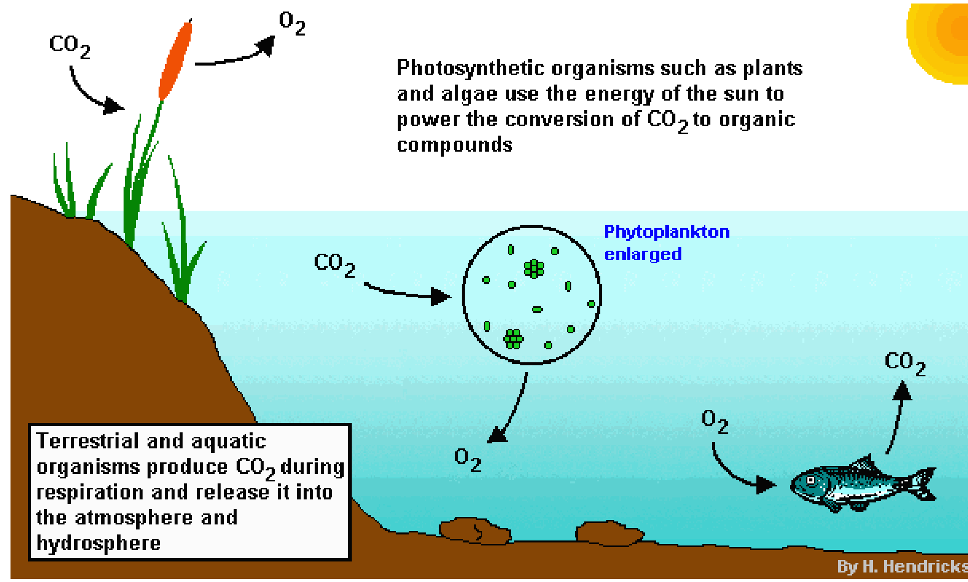
Necrosis

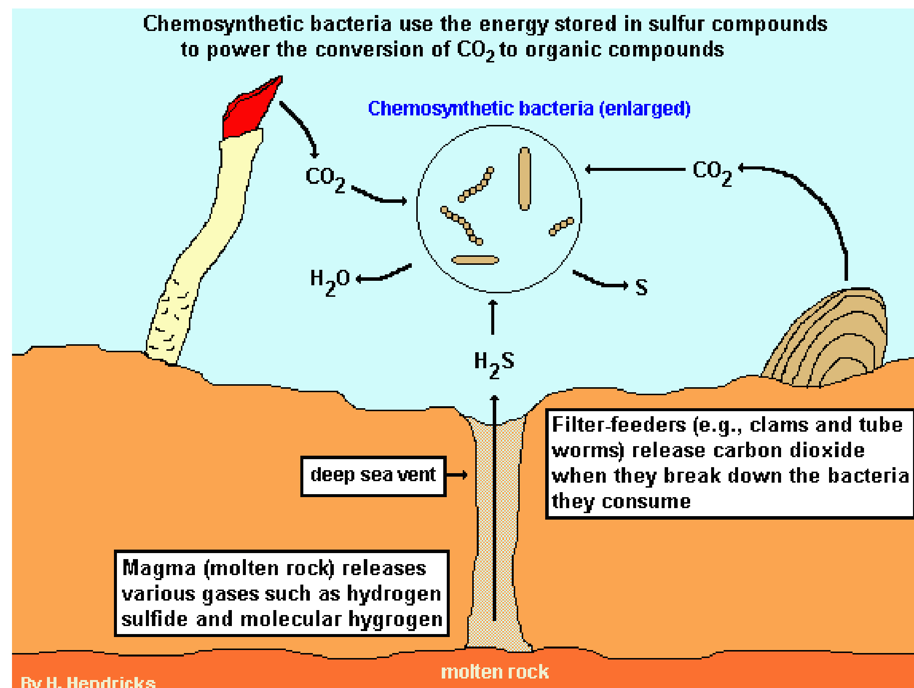


	Time Zero	30 minutes–4 hours	24 hours
LDH Release	0	+++	++
Caspase	0	0	0
ATP	+++	0	0
MTS	+++	0	0
Resazurin	+++	0	0

How do organisms get energy?

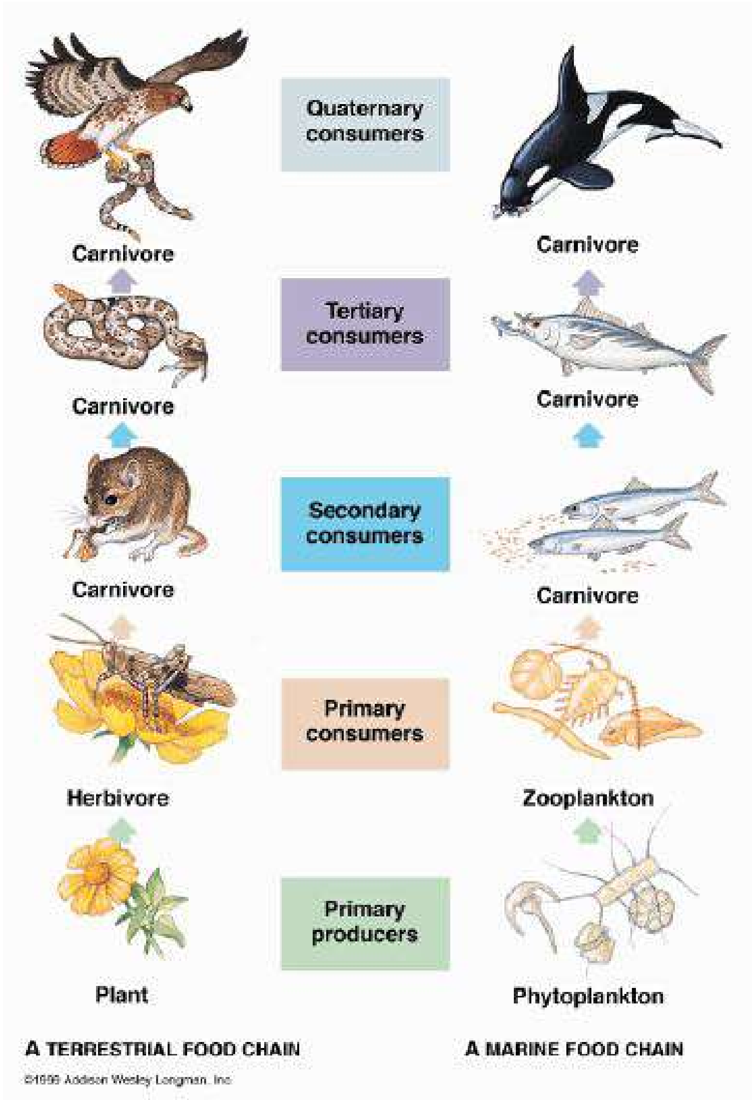
- Chemosynthesis- use chemicals like sulfur to create organic food compounds.
  - EX: chemosynthetic bacteria near hydrothermal vents in ocean; no sunlight in this ecosystem= no producers
- Photosynthesis- use radiation energy from sun to create organic food compounds.
  - EX: plants make glucose from sunlight
- Cellular respiration- use ATP to breakdown glucose to store energy in chemical bonds of more ATP
  - EX: all living organisms





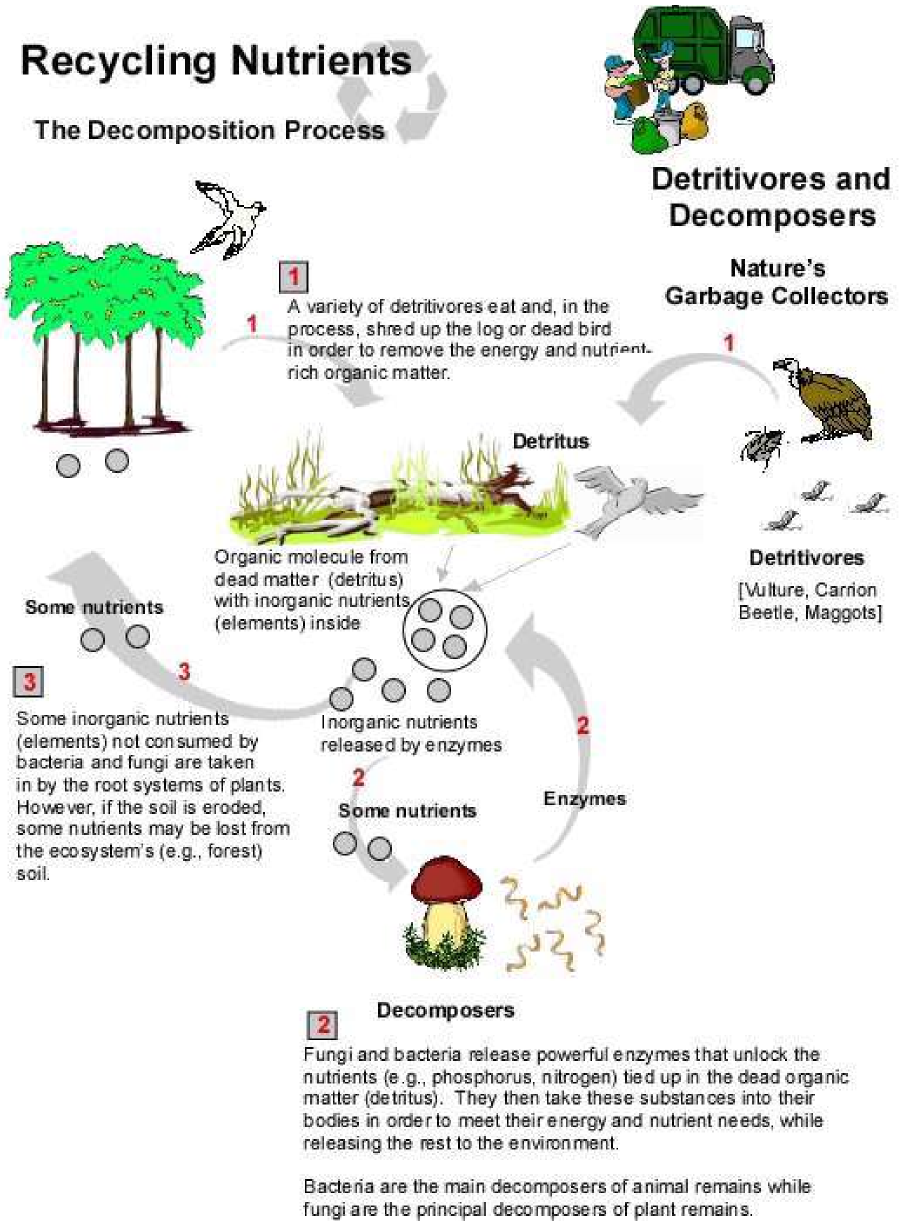
How is energy transferred in an ecosystem?

- Tertiary consumers- top carnivores or omnivores
- Secondary Consumers- carnivores
- Primary Consumers- herbivores
- Primary Producers- plants



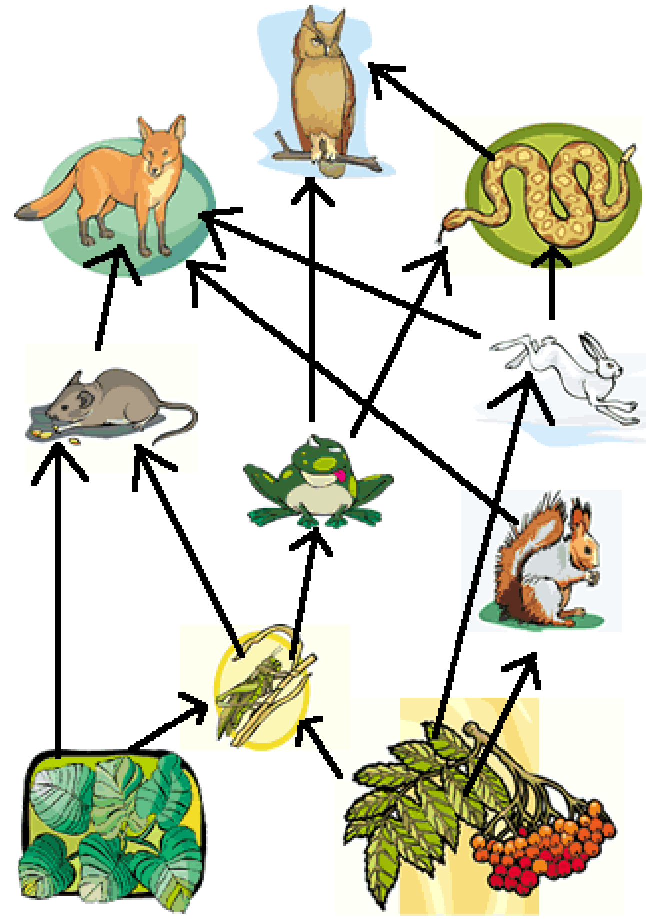
How is energy transferred in an ecosystem?

- <u>Scavengers-</u> eat dead carcasses with mouth
  - Ex: vulture, crow
- <u>Detritivores-</u> eat leaf litter, dung, debris
  - Ex: ants, beetles, worms
- <u>Decomposers-</u> absorb nutrients from dead or dung thru cell wall
  - Ex: fungus, bacteria
- Occupy any level
- Clean up and recycle nutrients to soil



How can we show this transfer of energy?

- Food chains show one possible relationship
- Food Webs more complex- show all feeding relationships in ecosystem
- Length can indicate health, harshness of ecosystem
  - Ex: arctic food webs smaller than tropical food webs
  - Diversity=stability



How can we show this transfer of energy?

- <u>Pyramid of Numbers-</u> shows actual numbers of organisms at each level

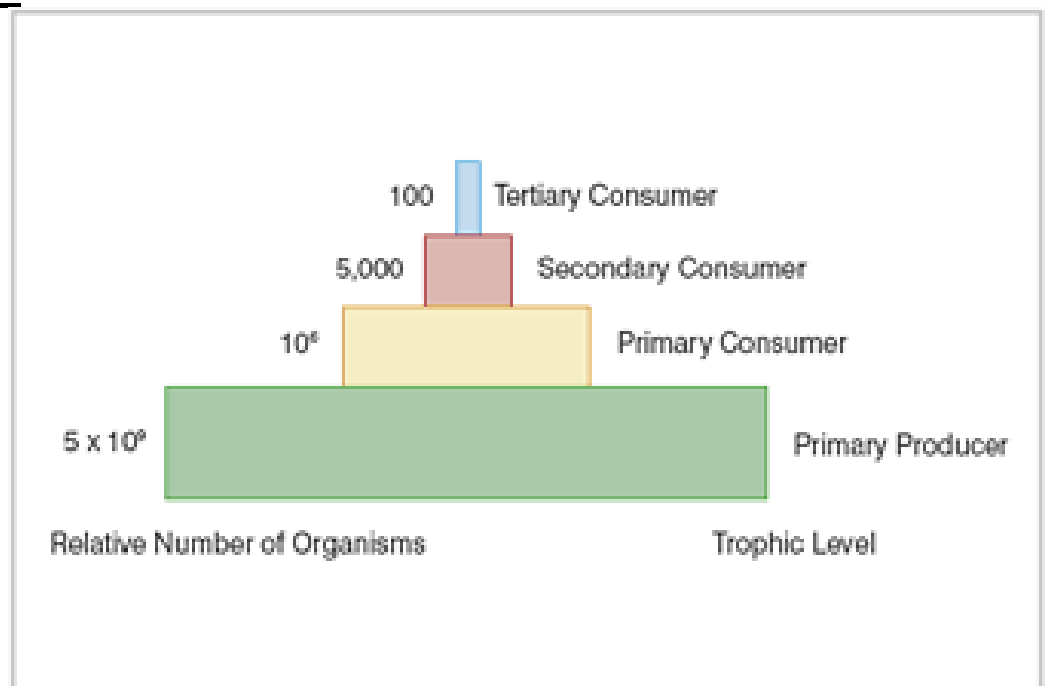
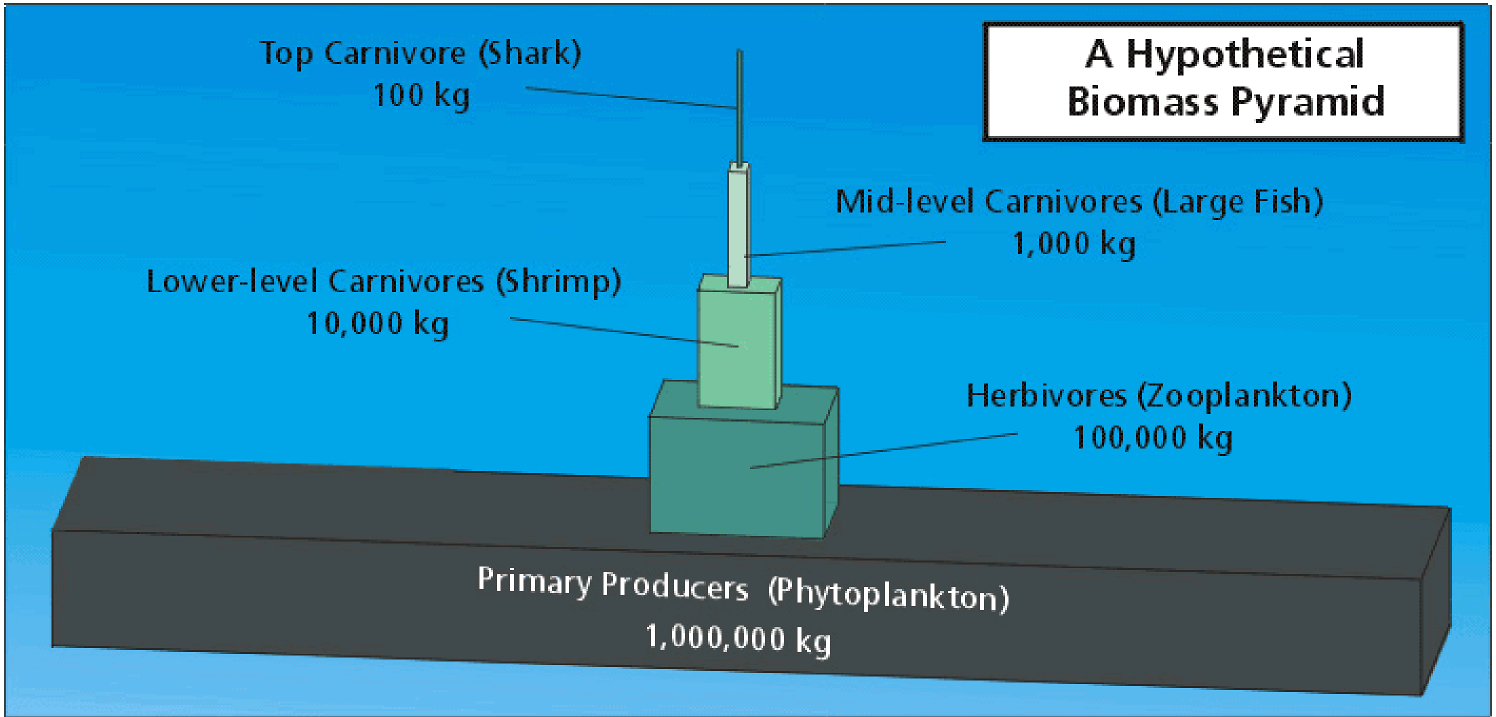


Fig.4 Pyramid of numbers

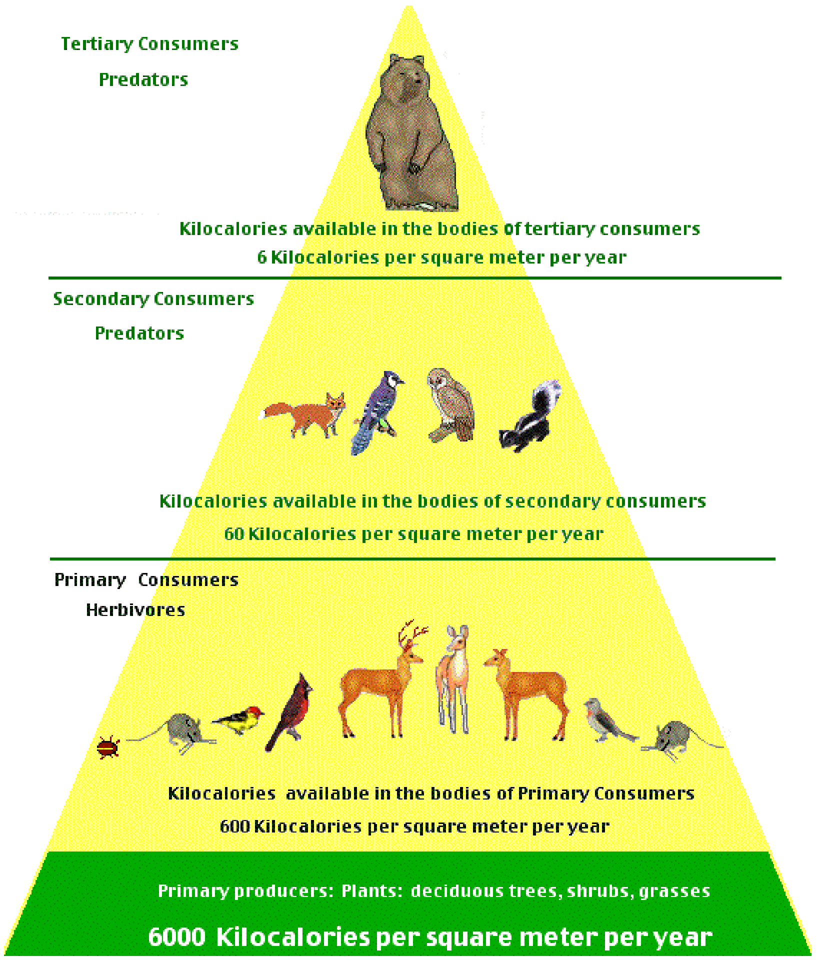
How can we show this energy transfer?

- <u>Pyramid of Biomass-</u> shows mass of available nutrients at each level



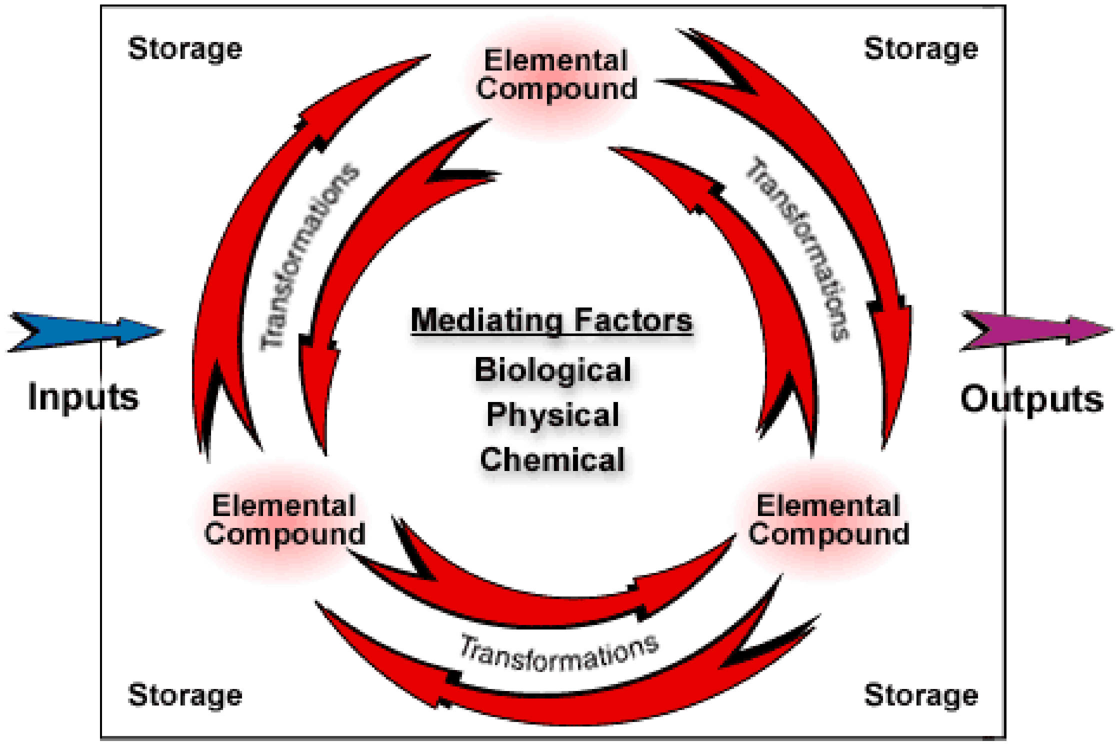
What happens to the energy at each level?

- Energy decreases at each level (2^{nd} law of thermodynamics)
- Where does it go?
  - Used in organisms own daily life functions
  - Lost as heat
  - Lost as feces
- 90% used- 10% stored in organism and passed to next level when organism gets eaten- “ECOLOGICAL RULE OF THUMB”
- As a result, less energy = fewer organisms at top of food chain.
- This is why there are not 6, 7, 8^{th} level consumers.



So….

- Energy is NOT recycled in an ecosystem
- BUT…
- Matter is… which leads us to the biogeochemical cycles!



The Hydrologic Cycle

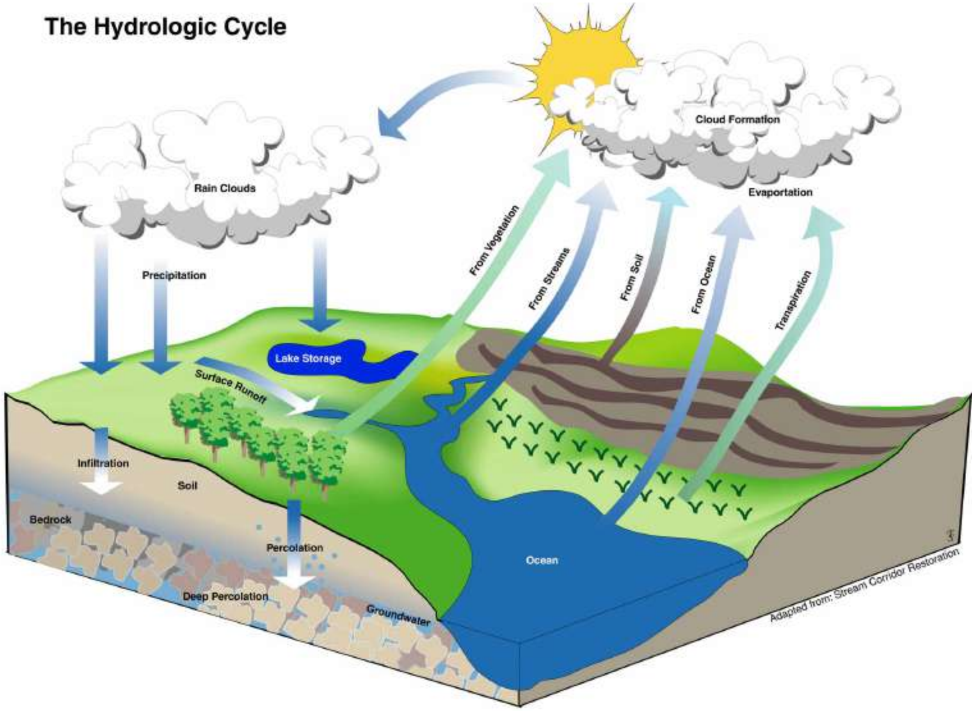
- Importance- need water for chemical reactions in body
- Water gets into air thru…
  - Evaporation
  - Transpiration from plants
  - Cellular respiration
- Condensation- clouds
- Precipitation- rain
- Back through organisms where used in chemical reactions inside body

OR

- Runoff- into surface water

OR

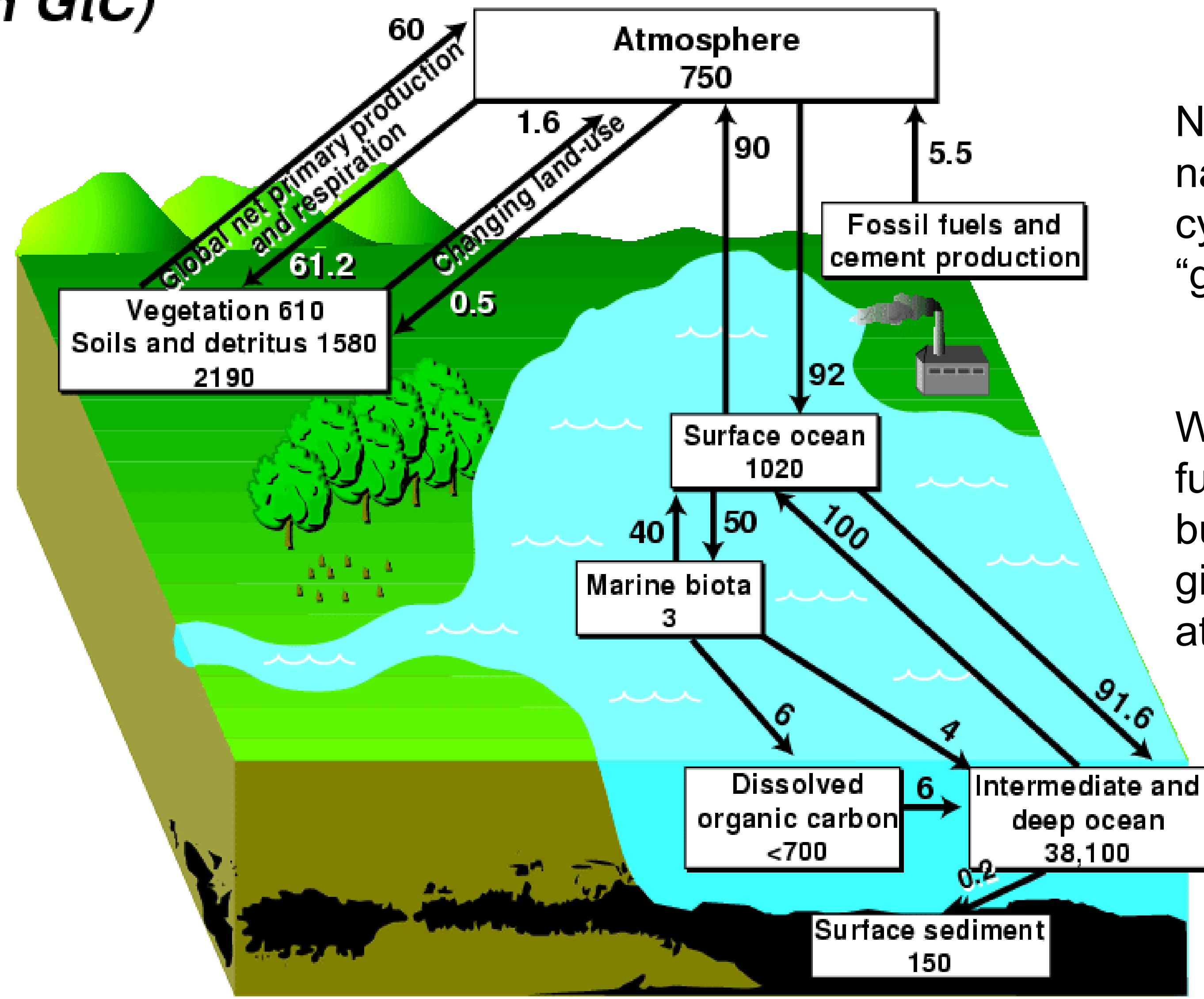
- Infiltration- thru soil into groundwater



The Carbon Cycle

- Importance- makes up all organic molecules & stores energy in its bonds
- Plants take CO_2 out of air thru photosynthesis
- Animals eat plants get Carbon in sugars.
- Animals die/defecate and decomposers return carbon to soil or air.
- Large masses of trees and the oceans are **carbon sinks-** they take CO_2 out of air.
- Humans alter carbon cycle by
  - Combustion of fossil fuels
  - Massive deforestation
  - Pollution in ocean decreases algae
- These lead to extra carbon in air which leads to global warming.

Global Carbon Cycle
(in GtC)



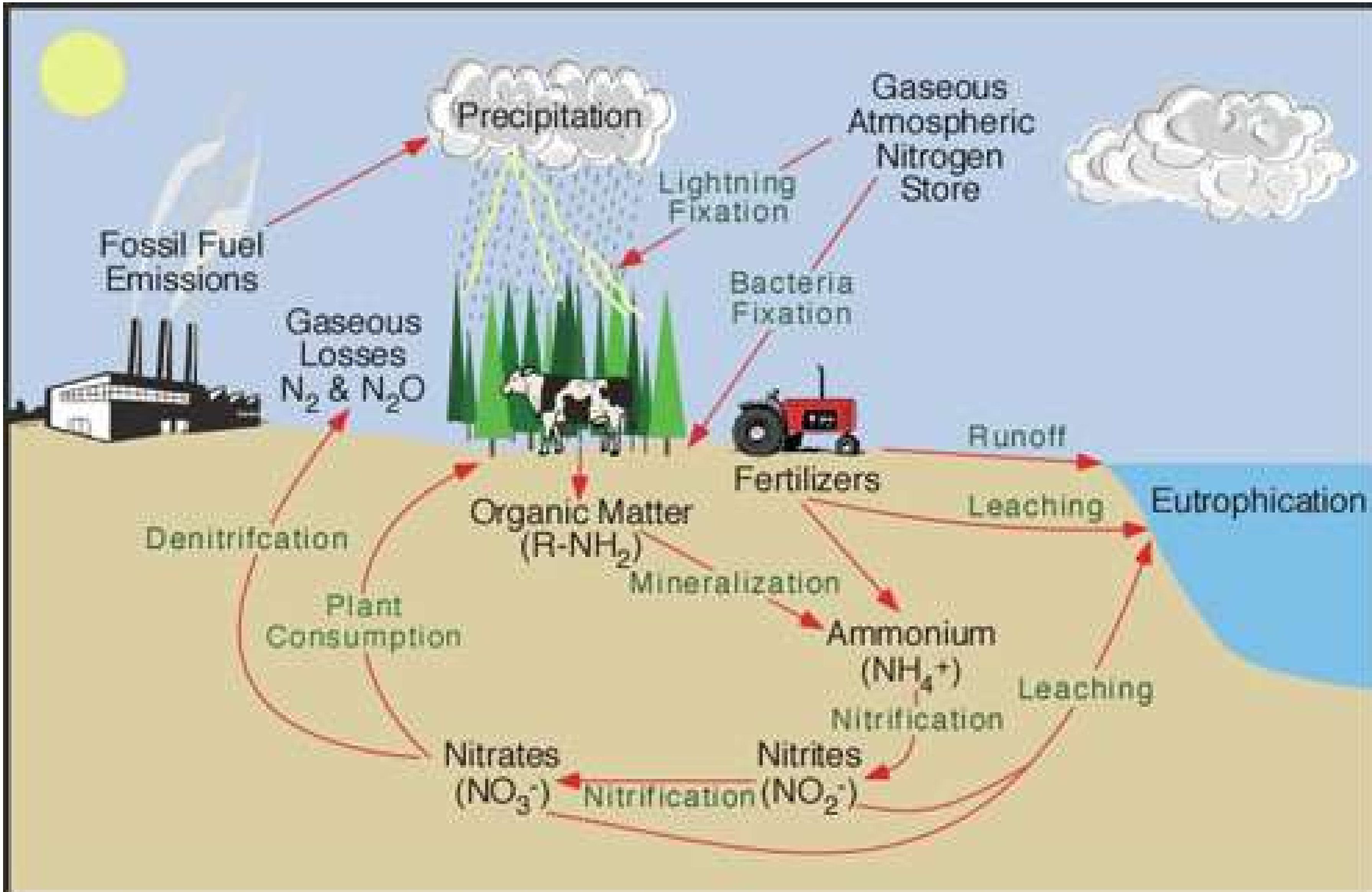
GtC- gigatons of carbon

Notice how all natural parts of cycle are equal “give” & “take”

When fossil fuels are burned- only given to atmosphere

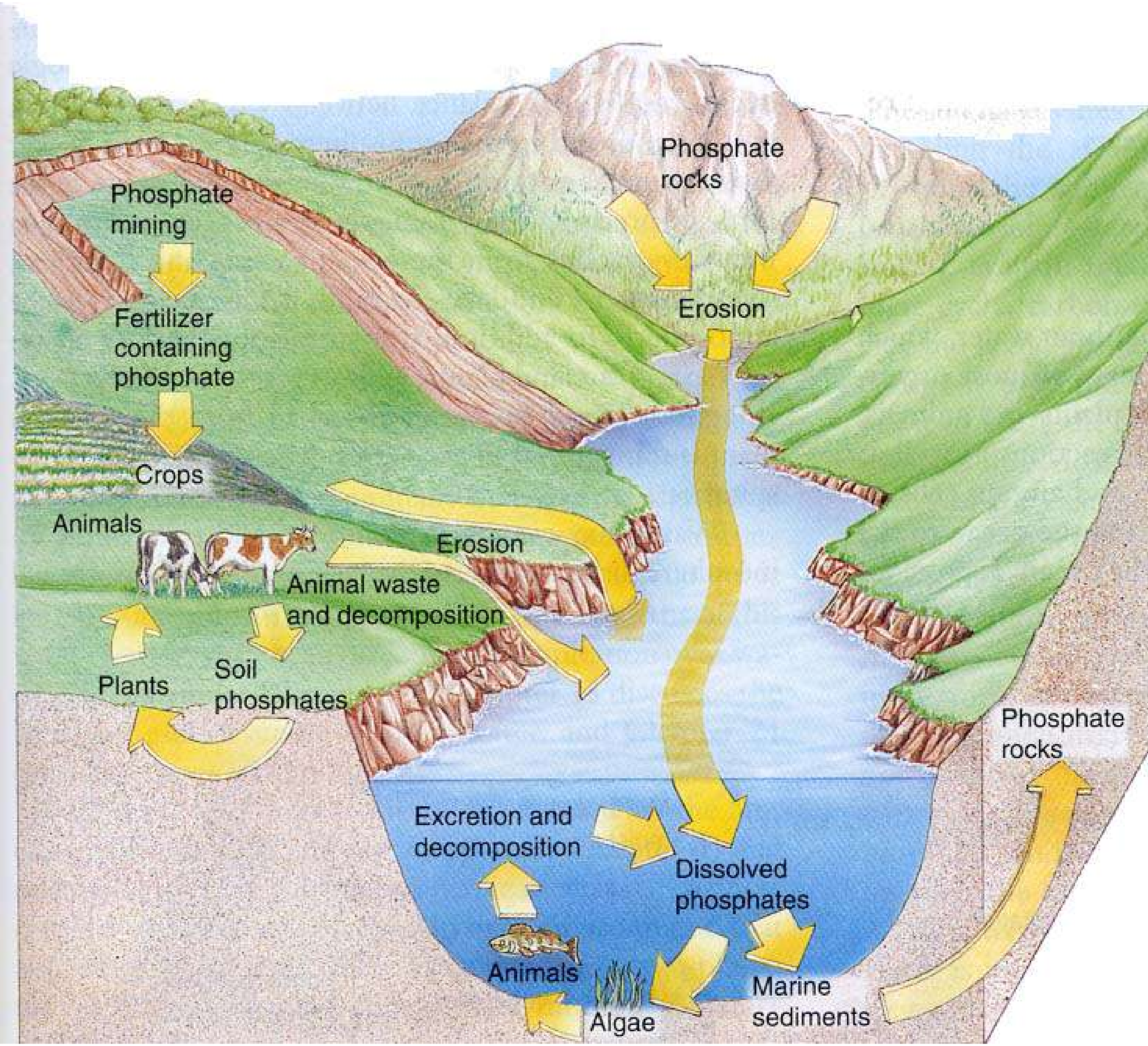
The Nitrogen Cycle

- Importance- Nitrogen needed to build proteins & DNA
- N_2 is most abundant atmospheric gas (78%)- but can't be taken in by organisms.
- Some nitrogen is added to soil during lightning storms.
- Nitrogen fixing bacteria (on roots of legumes) remove N_2 from air and "fix" it into usable form for plants
  - Ammonification- nitrogen fixing bacterial pull N_2 out of air and bond H to make ammonia (NH_3)
  - Nitrification- bacteria turn ammonia into nitrites (NO_2)
  - Nitrification- other bacteria turn NO_2 to nitrate (NO_3)
  - Assimilation- plants absorb NO_3 and incorporate into tissues
- Animals eat plants and get N in their bodies
- Animal dies/defecates, decomposers return N to soil
- Other decomposers return N to air- Denitrification
- Humans have altered by using synthetic fertilizers, cultivating nitrogen-fixing crops (legumes), and burning fossil fuels, overloading nitrogen in soil.
- Causes eutrophication, loss of other soil nutrients, increase in greenhouse gas, NO_x, and some acid rain.


Precipitation
Gaseous
Atmospheric
Nitrogen
Store
Lightning
Fixation
Fossil Fuel
Emissions
Bacteria
Fixation
Gaseous
Losses
N_2 & N_2O
Runoff
Fertilizers
Eutrophication
Leaching
Organic Matter
($R-NH_2$)
Denitrifcation
Mineralization
Plant
Consumption
Ammonium
(NH_4^+)
Leaching
Nitrification
Nitrates
(NO_3^-)
Nitrites
(NO_2^-)
Nitrification

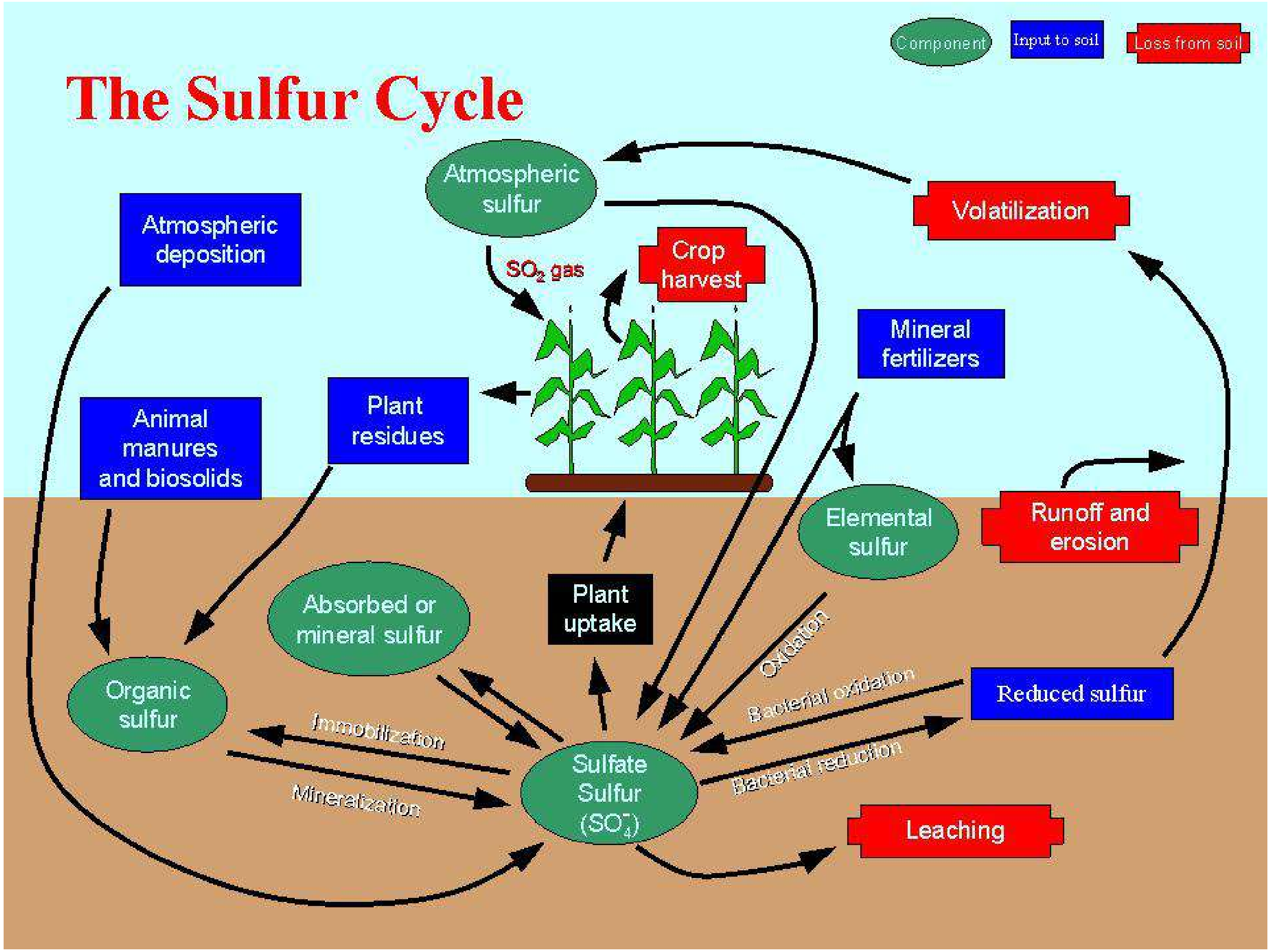
The Phosphorus Cycle

- Important- main component in ATP
- P is stored in rocks & minerals
- Weathering releases P to soil or water
- Plants absorb, animals eat plants, die/defecate & decomposers return P to soil/water
- Humans alter by mining phosphorus for fertilizer. Runoff can cause eutrophication.


Phosphate rocks
Phosphate mining
Fertilizer containing phosphate
Crops
Erosion
Animals
Erosion
Animal waste and decomposition
Plants
Soil phosphates
Phosphate rocks
Excretion and decomposition
Dissolved phosphates
Animals
Algae
Marine sediments

The Sulfur Cycle

- Importance- component of protein
- Studied to determine acidity of water/soil, can also cause climate change
- Stored in rocks & minerals
- Weathering, underwater sea vents, & volcanic eruptions, & bacteria releases compounds
- Plants take in S, animals eat plants, die/defecate, decomposers return to soil.
- Humans alter when burning fossil fuels that contain sulfur- creates acid rain, absorbs UV radiation, creates clouds, cools cities. Maybe offsets some of rising CO_2 levels?


Component
Input to soil
Loss from soil
The Sulfur Cycle
Atmospheric sulfur
Volatilization
Atmospheric deposition
SO_2 gas
Crop harvest
Mineral fertilizers
Animal manures and biosolids
Plant residues
Elemental sulfur
Runoff and erosion
Absorbed or mineral sulfur
Plant uptake
Oxidation
Organic sulfur
Bacterial oxidation
Reduced sulfur
Immobilization
Sulfate Sulfur (SO_4^-)
Bacterial reduction
Mineralization
Leaching