Chapter 55 (Campbell)
Ecosystems

(55) Ecosystems

I.

Main Idea: Physical laws control energy flow and chemical cycling.

Main Idea: Energy *flows through* ecosystems.

Main Idea: Chemicals (matter) *cycles within* ecosystems.

PHYSICAL LAWS GOVERN ENERGY FLOW & CHEMICAL CYCLING IN ECOSYSTEMS

A. Conservation of Energy

- **First Law of Thermodynamics**: energy can not be created nor destroyed...only transferred and transformed.
  - **The sun is the ultimate source of energy for most ecosystems and life itself on our planet.**
  - Energy enters ecosystems as solar radiation.
  - Autotrophs *transform* solar radiation into chemical energy.
  - Heterotrophs consume autotrophs and *transfer* this chemical energy through food chains.

- **Second Law of Thermodynamics**: energy exchanges (transfers and transformations) increase the entropy of the universe. In other words energy exchanges are inefficient some energy is always lost as heat
    - Remember energy is passing through food chains.
    - As chemical energy is passing through food chains it is ultimately *transformed* to heat and *transferred* back to space

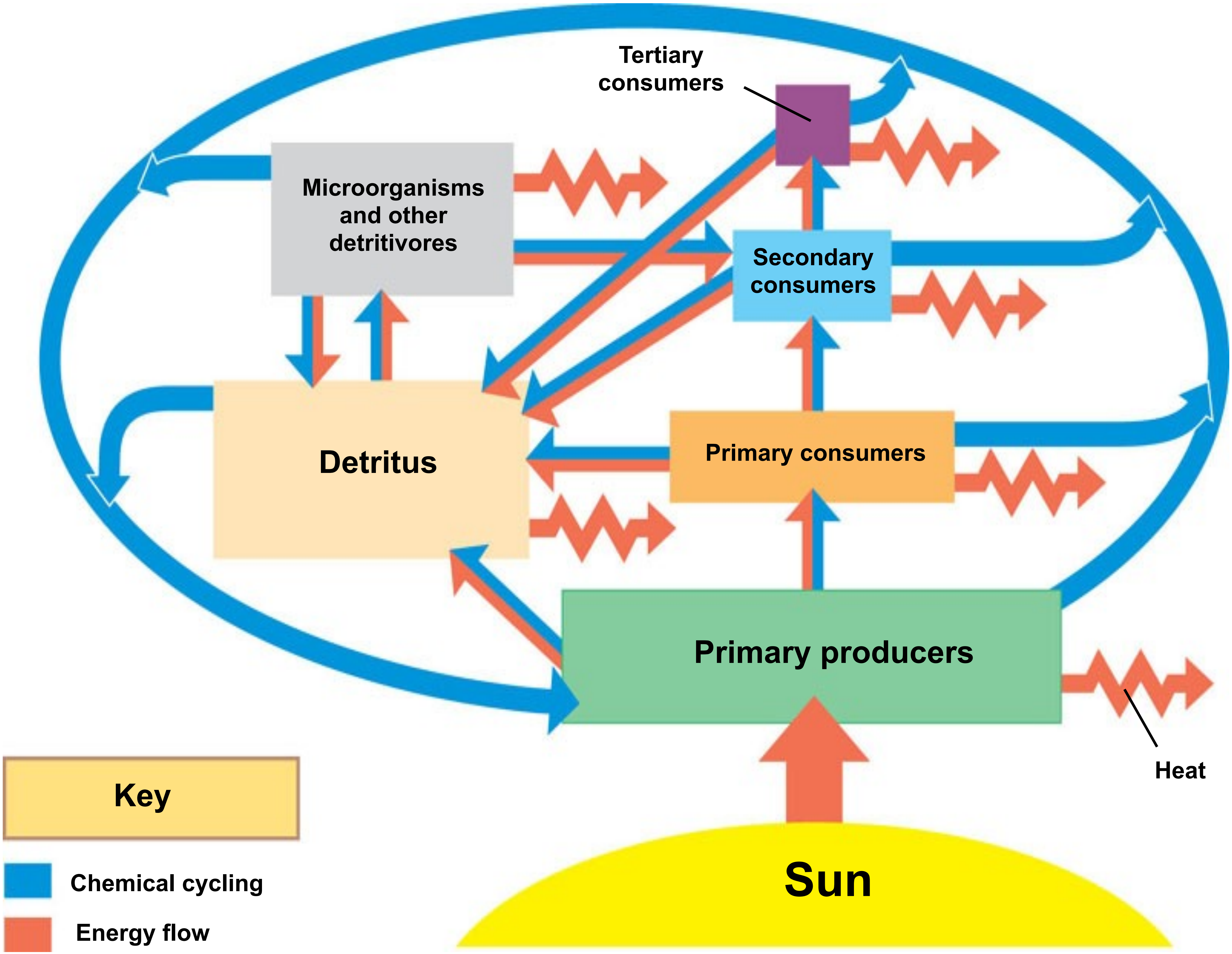
B. Conservation of Mass

- **Law of Conservation of Mass**: like energy, matter can not be created or destroyed.
    - Very little matter enters earth from space.
    - Thus the matter on *earth* is constant. Matter has been, is and will continue to be recycled over time.
    - Be Careful! Matter can be gained and lost from *ecosystems* themselves.

C. Energy, Mass & Trophic Levels

- **Primary Producers** *consists of autotrophs and their trophic level supports all others*. Think of it this way...autotrophs link heterotrophs to the ultimate source of energy for most life...the sun!
  - Producers (autotrophs) are *photosynthetic organisms* that use solar energy to synthesize organic compounds (sugars) which they use to fuel cellular respiration and as building blocks for growth.
    - As producers begin to synthesize compounds chemical bonds must be formed. It is the energy in these bonds that provide the energy for life processes and growth.
      - An exception to this scenario is found in chemosynthetic bacteria that serve as producers in a few less common ecosystems.

Does the 2nd Law of Thermodynamics contradict the theory of evolution? Explain



Tertiary consumers
Microorganisms and other detritivores
Secondary consumers
Detritus
Primary consumers
Primary producers
Heat
Key
Chemical cycling
Energy flow
Sun

- **Decomposers/Detrivores** consume **Detritus**, nonliving organic material (dead organisms and feces)

- Two most significant and important decomposers are <u>Fungi</u> and <u>Bacteria</u>

- They play a critical role in <u>recycling matter</u>...decomposers convert organic material into inorganic material that producers can then uptake and reuse. (recycled back into the ecosystem)

    - Consider This! If decomposition stopped detritus would build up and life would not exist

(55) Ecosystems

II.

Main Idea: Energy and other limiting factors control primary production.

Main Idea: Primary production dictates the energy budget for the entire ecosystem.

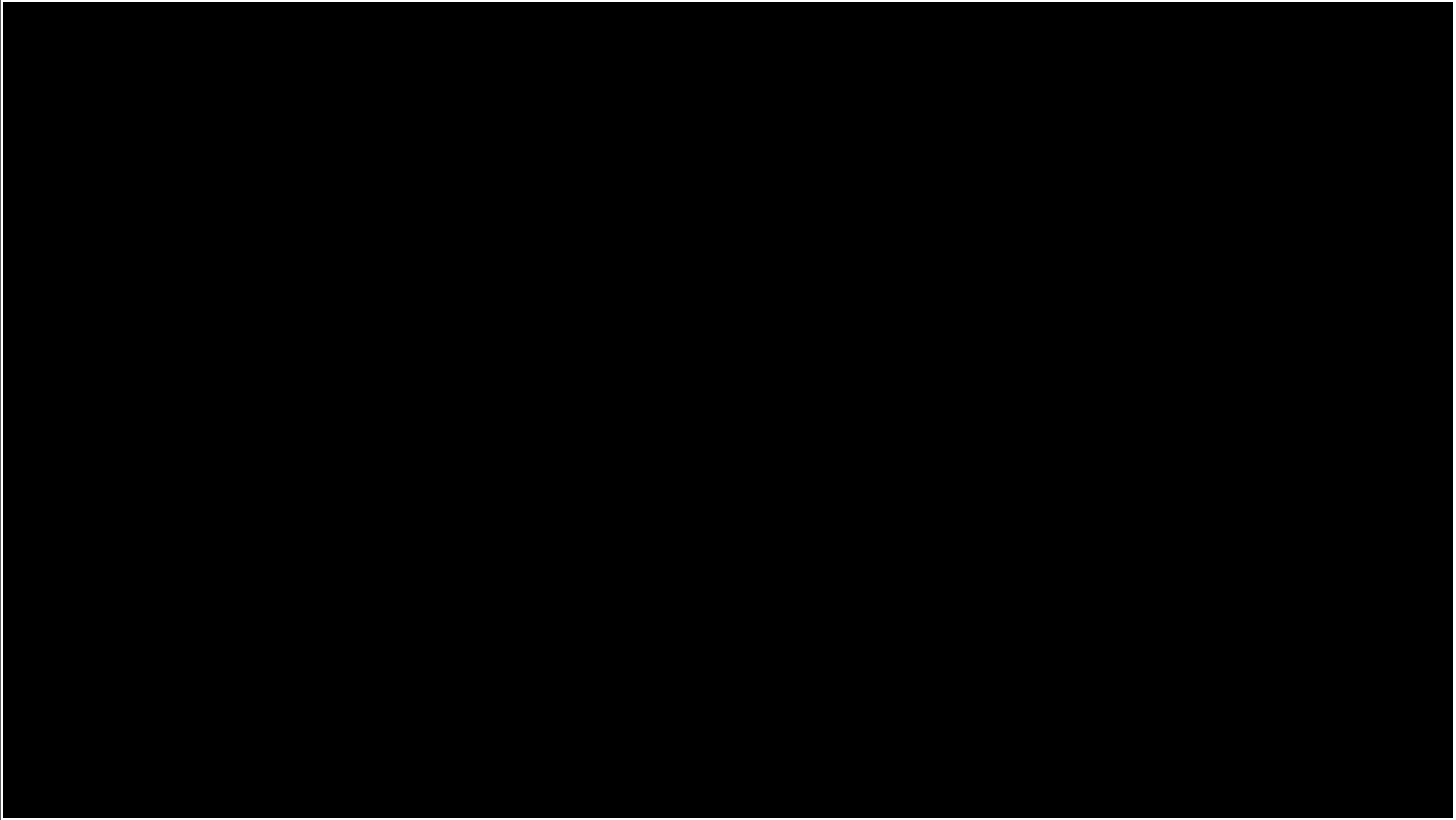
ENERGY AND OTHER LIMITING FACTORS CONTROL PRIMARY PRODUCTION IN ECOSYSTEMS

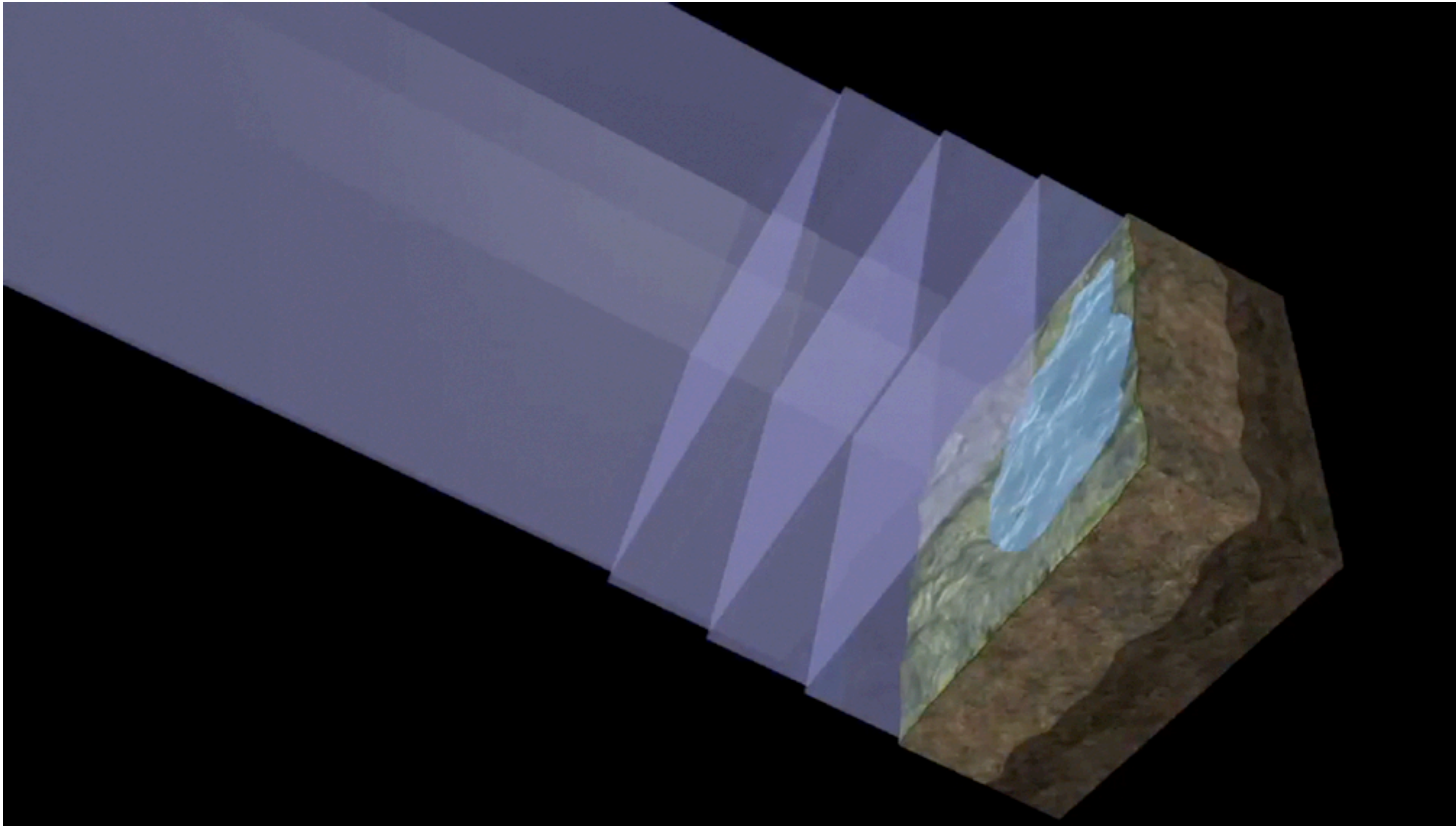
- **Primary production** is the amount of light energy converted to chemical energy in a given period of time
- The amount of light energy converted to chemical energy by autotrophs effects the amount of heterotrophs it can support in higher trophic levels.
- **Energy transfer is a major theme in biology, energy transfer underlies all biological interactions.**

A. Ecosystem Energy Budgets

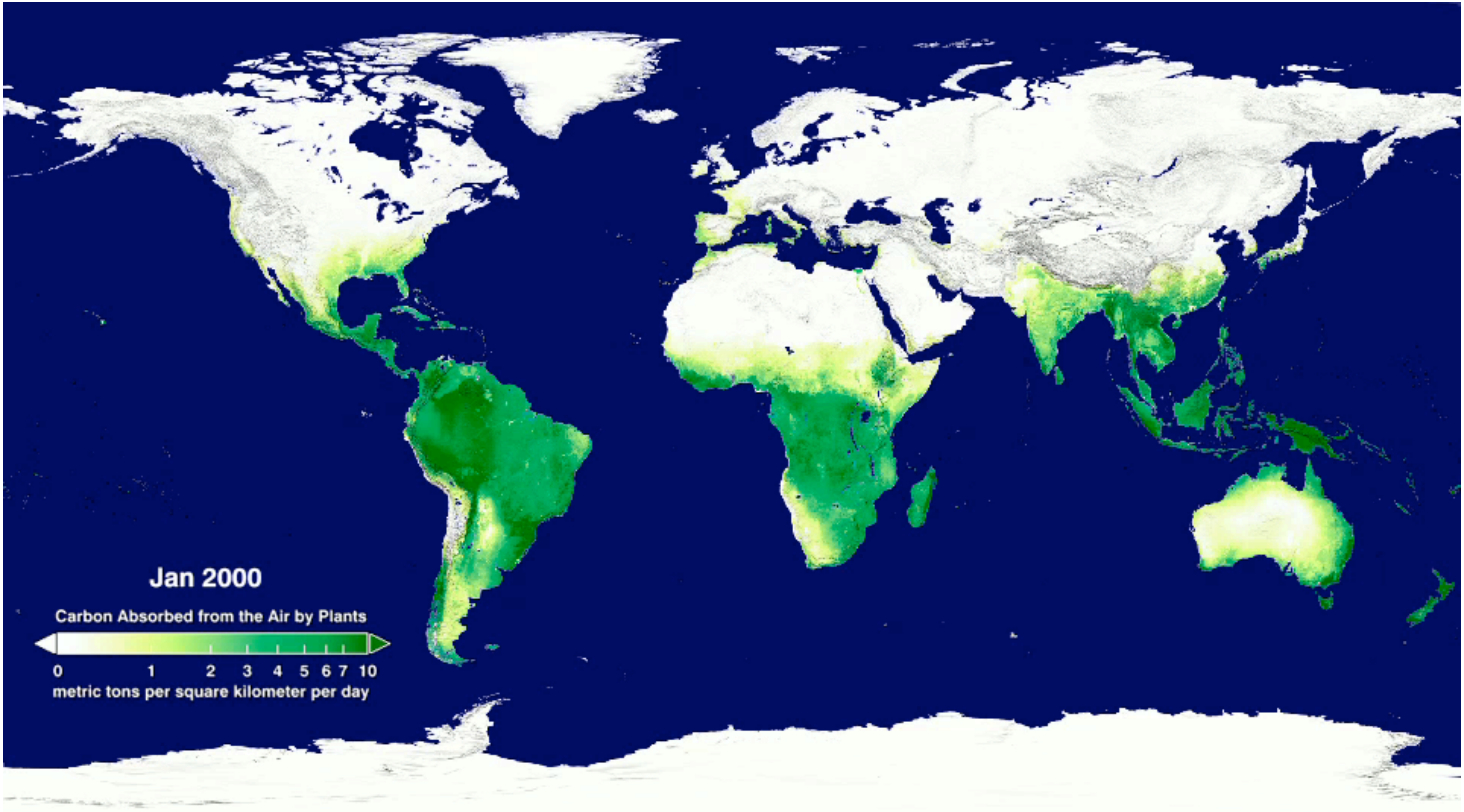
1.Global Energy Budgets

- WOW...In one day the earth receives enough solar energy to power every human beings' energy need for the next 20+ years at our current consumption rate. BUT...
- A lot of solar radiation is absorbed, scattered or reflected by our atmosphere.
- Most of the solar radiation that does reach the earth contacts things that can not photosynthesize and of the light that reaches autotrophs only certain wavelengths power photosynthesis
- All in all about 1% of visible light is converted to chemical energy.
  - *This 1% is enough to create roughly 150 billion metric tons of organic material annually!*





- **Gross Primary Production (GPP)** is the total amount of solar energy converted to

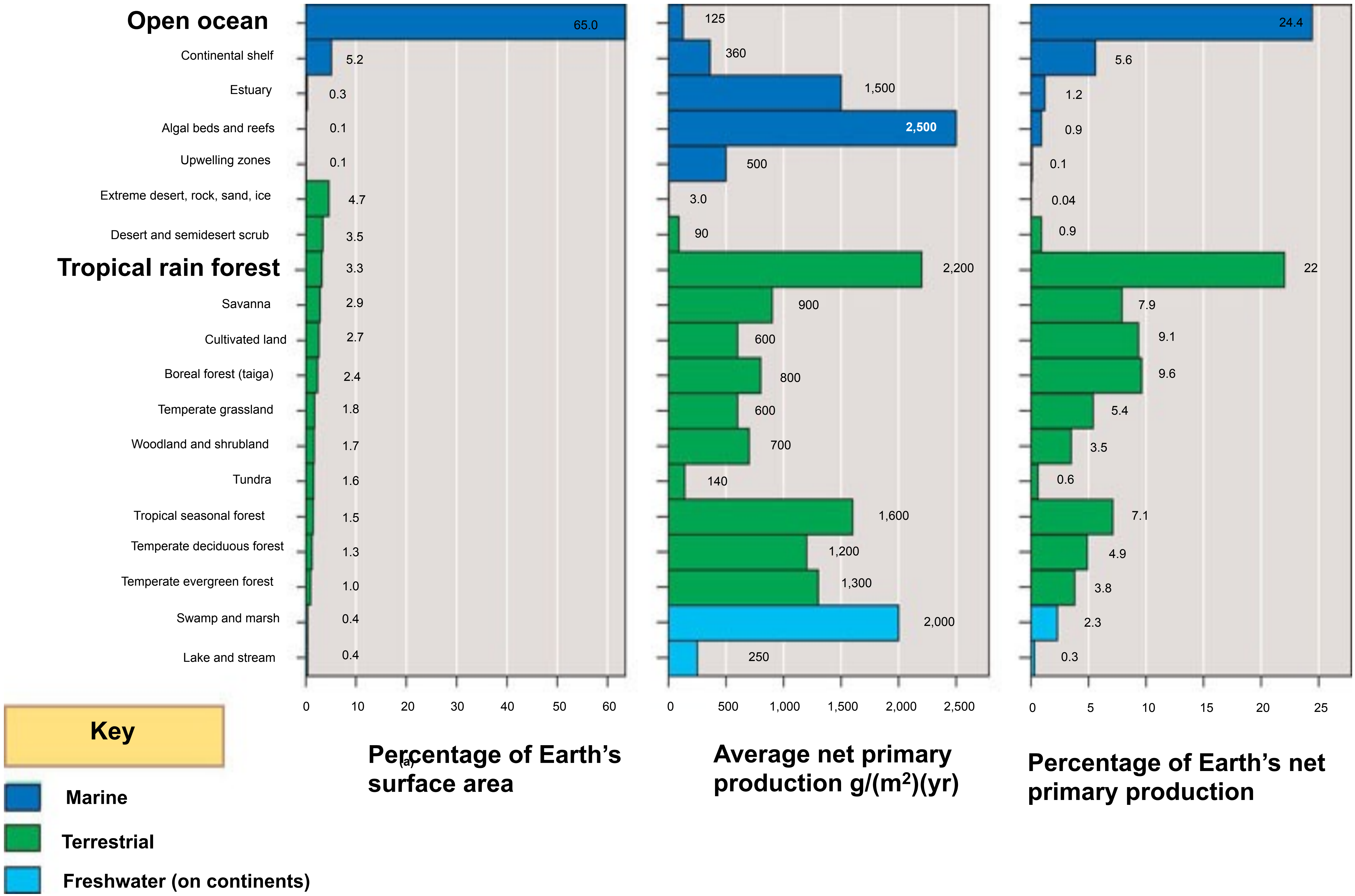


The gross primary productivity of the world's land areas for the period 2000-2009 as calculated from Terra's MODIS instrument. The original 8-day average GPP data has been smoothed to a 24-day average to make the animation less noisy.

2. Gross and Net Production

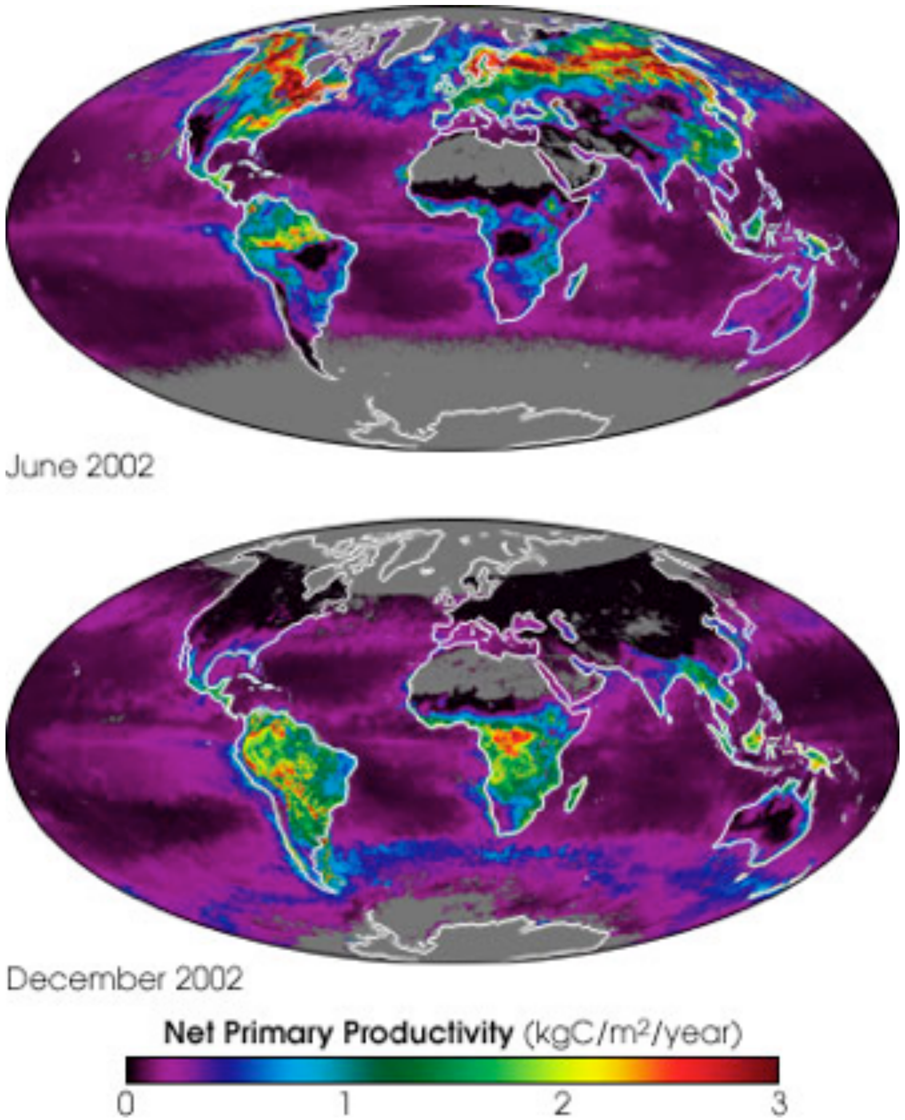
- **Gross Primary Production (GPP)** is the total amount of solar energy converted to chemical energy per unit time.
- **Net Primary Production (NPP)** is the difference between GPP and autotrophic respiration R_a.
  - $NPP = GPP - R_a$ (on average NPP is about half of GPP)
  - NPP can be expressed in two ways:
    - { $J/(m^2)(year)$ } or { $g/(m^2)(year)$ }

Be careful! Do not confuse *standing crop* (**total biomass**) with *primary production* (**new biomass** per unit time)

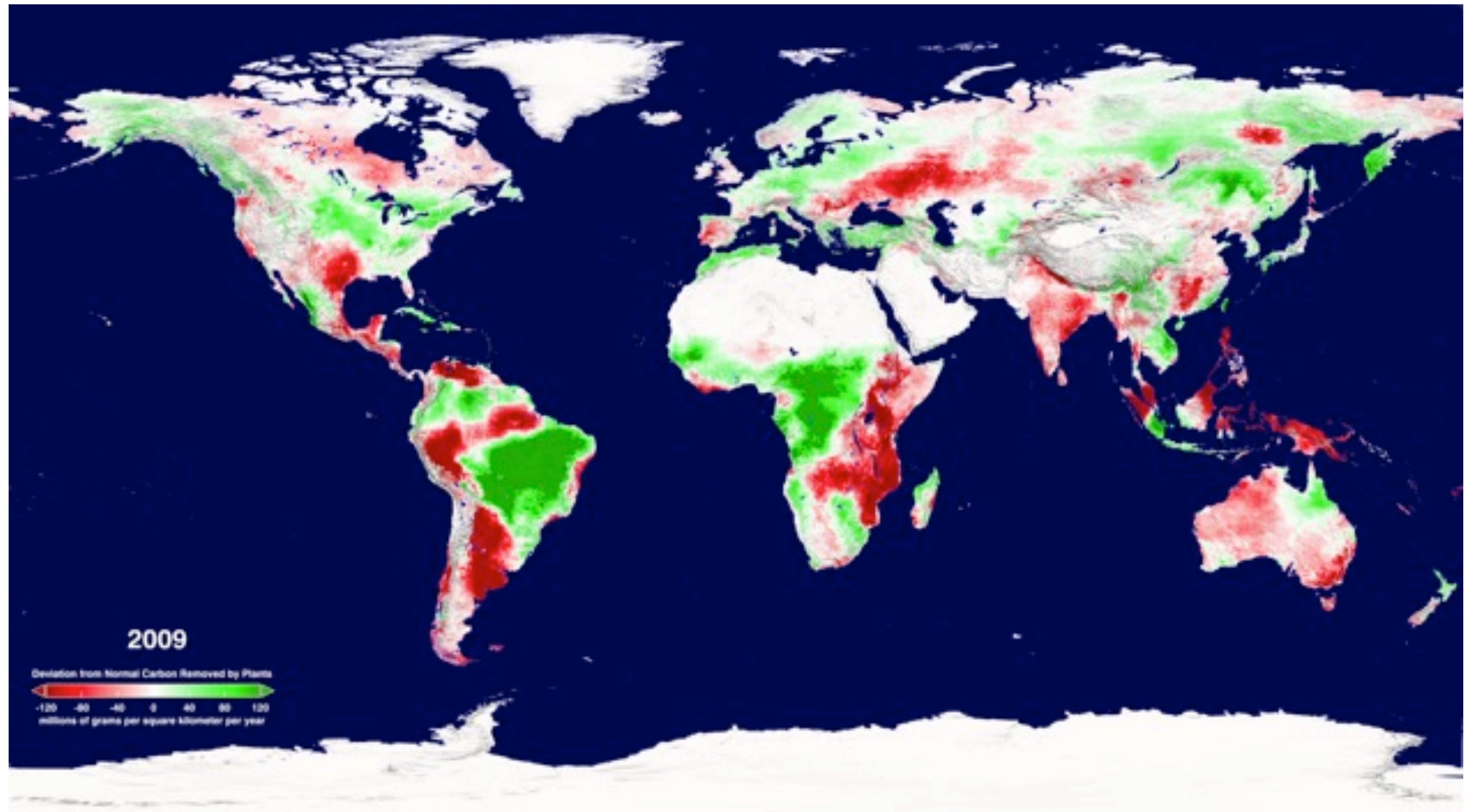

Open ocean
Continental shelf
Estuary
Algal beds and reefs
Upwelling zones
Extreme desert, rock, sand, ice
Desert and semidesert scrub
Tropical rain forest
Savanna
Cultivated land
Boreal forest (taiga)
Temperate grassland
Woodland and shrubland
Tundra
Tropical seasonal forest
Temperate deciduous forest
Temperate evergreen forest
Swamp and marsh
Lake and stream
65.0
5.2
0.3
0.1
0.1
4.7
3.5
3.3
2.9
2.7
2.4
1.8
1.7
1.6
1.5
1.3
1.0
0.4
0.4
Percentage of Earth's surface area
(a)
125
360
1,500
2,500
500
3.0
90
2,200
900
600
800
600
700
140
1,600
1,200
1,300
2,000
250
Average net primary production g/(m²)(yr)
24.4
5.6
1.2
0.9
0.1
0.04
0.9
22
7.9
9.1
9.6
5.4
3.5
0.6
7.1
4.9
3.8
2.3
0.3
Percentage of Earth's net primary production
Key
Marine
Terrestrial
Freshwater (on continents)

Net Primary Productivity

Summer

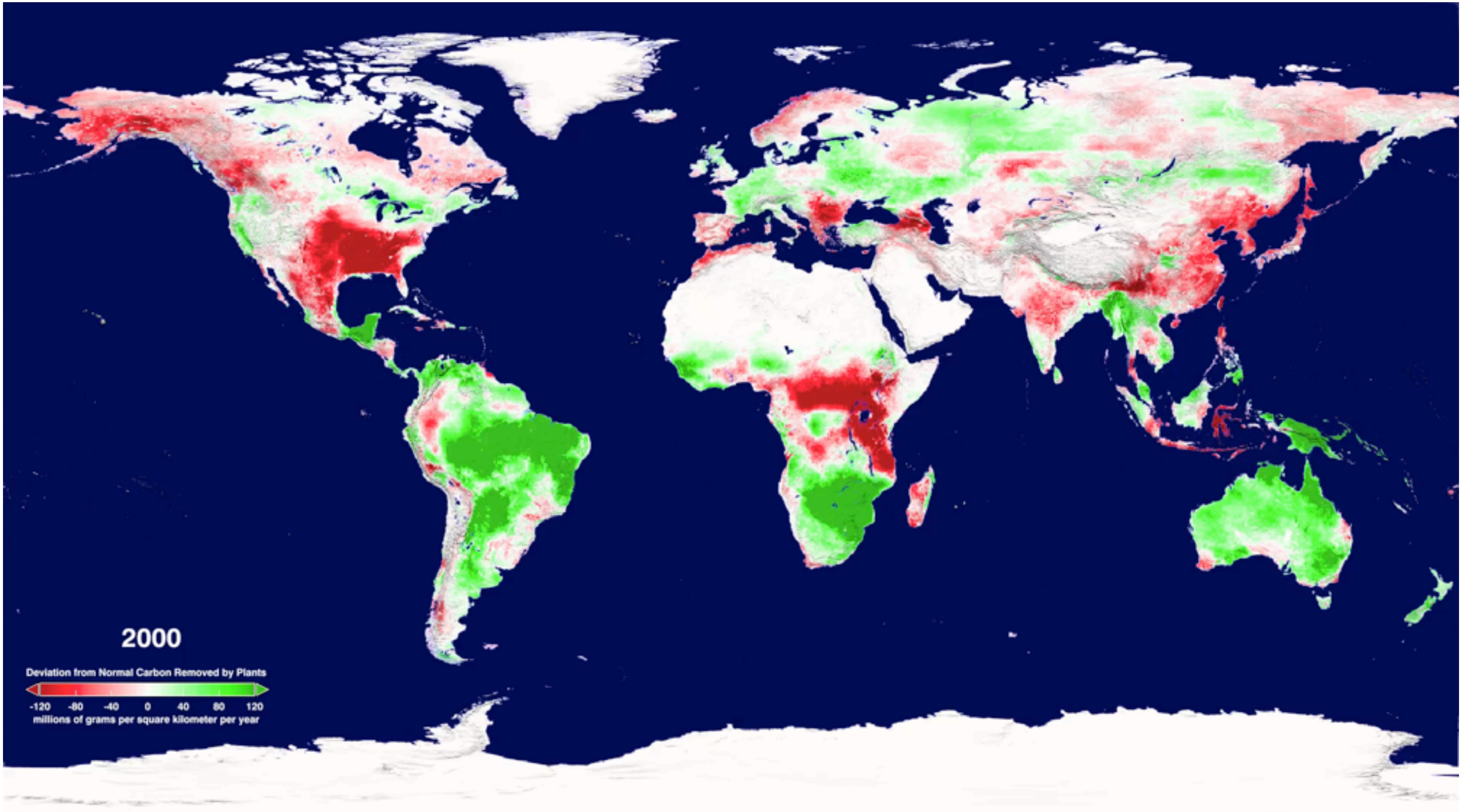


Winter



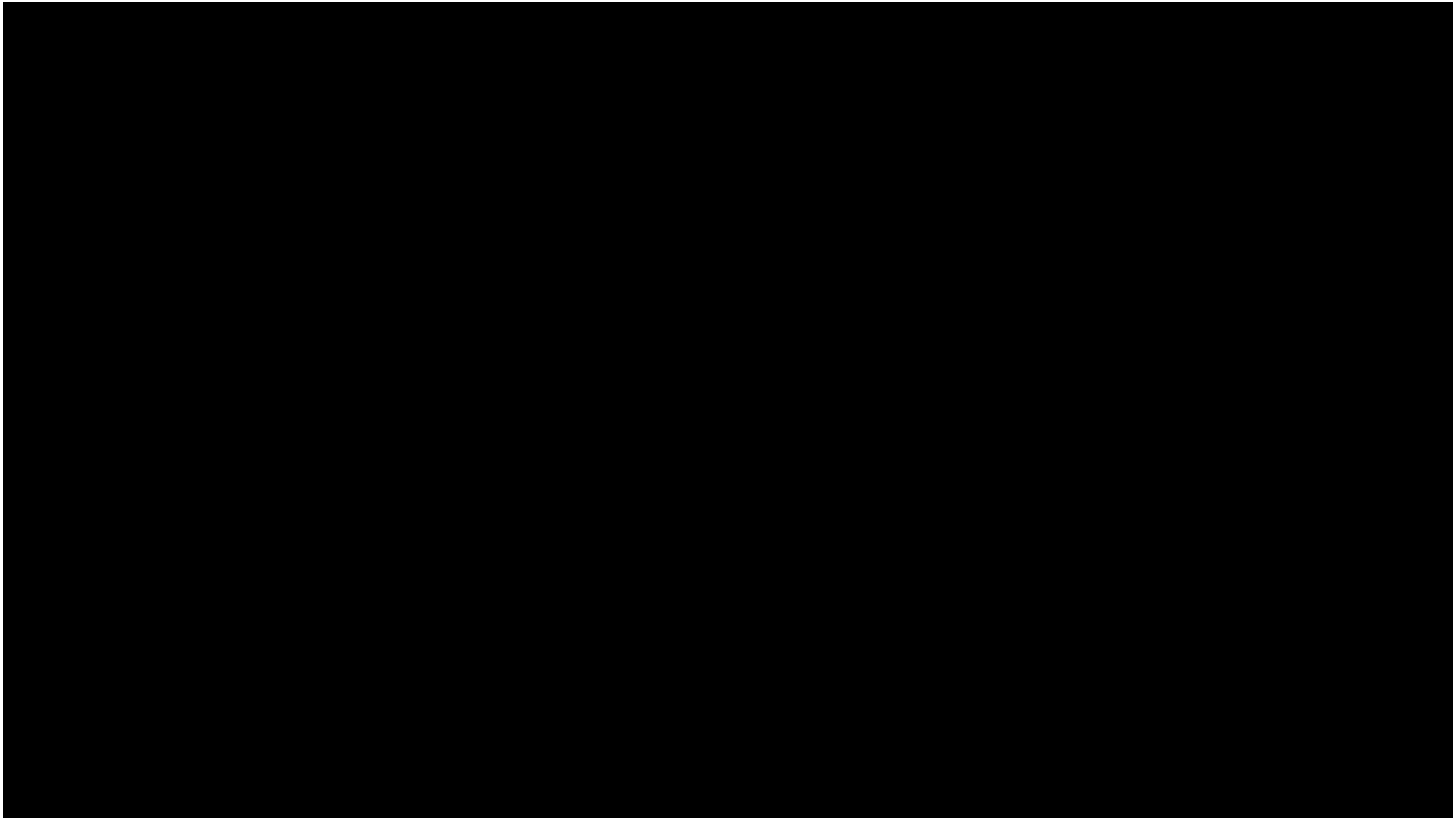
The change from normal of the annual net primary productivity of the world's land areas for the period 2000-2009 as calculated from Terra's MODIS instrument. This version adds a date and colorbar to the animation.

How are satellites able to measure productivity?


2000
Deviation from Normal Carbon Removed by Plants
-120
-80
-40
0
40
80
120
millions of grams per square kilometer per year

- **Net Ecosystem Production (NEP)** is the total biomass accumulation per unit time.
- **Net Ecosystem Production (NEP)** is the difference between GPP and total respiration of all organisms R_t.
    - NEP = GPP - R_t (on average NPP is about half of GPP)
    - NEP has value because it determines if an ecosystem is gaining or losing carbon

Consider an ecosystem where heterotrophs release carbon dioxide at a rate faster than the autotrophs can incorporate them into organic compounds. What is the relative value of NEP in this scenario?



The past decade is the warmest on record since instrumental measurements began in the 1880s. Previous research suggested that in the '80s and '90s, warmer global temperatures and higher levels of precipitation -- factors associated with climate change -- were generally good for plant productivity. An updated analysis published this week in Science indicates that as temperatures have continued to rise, the benefits to plants are now overwhelmed by longer and more frequent droughts. High-resolution data from the Moderate Resolution Imaging Spectroradiometer, or MODIS, indicate a net decrease in NPP from 2000-2009, as compared to the previous two decades.

B. Primary Production in Aquatic Ecosystems

1. Light Limitations

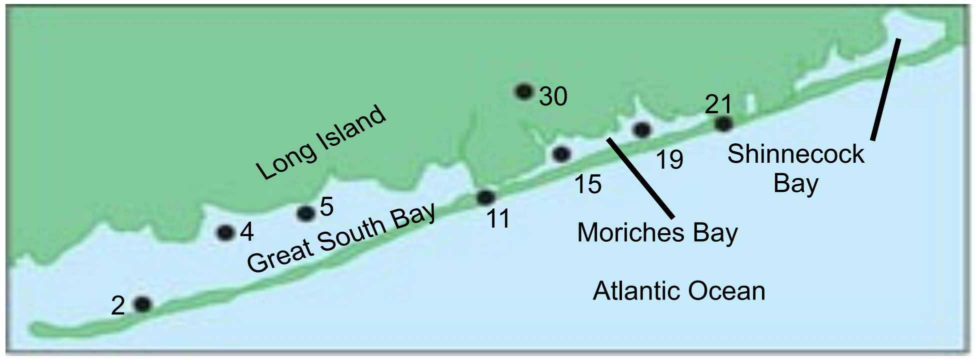
- Light is the obvious choice as limiting factor.
- After all more than half of the solar radiation is absorbed in the first 15 meters of water.
- *Light is very important however it does not appear to be the key limiting factor in aquatic ecosystems!*

Assuming that light was the key limiting factor scientists predicted that a gradient in production from the poles to the equator. Would the production gradient increase or decrease as moved away from the poles? Why? Does this gradient exist?

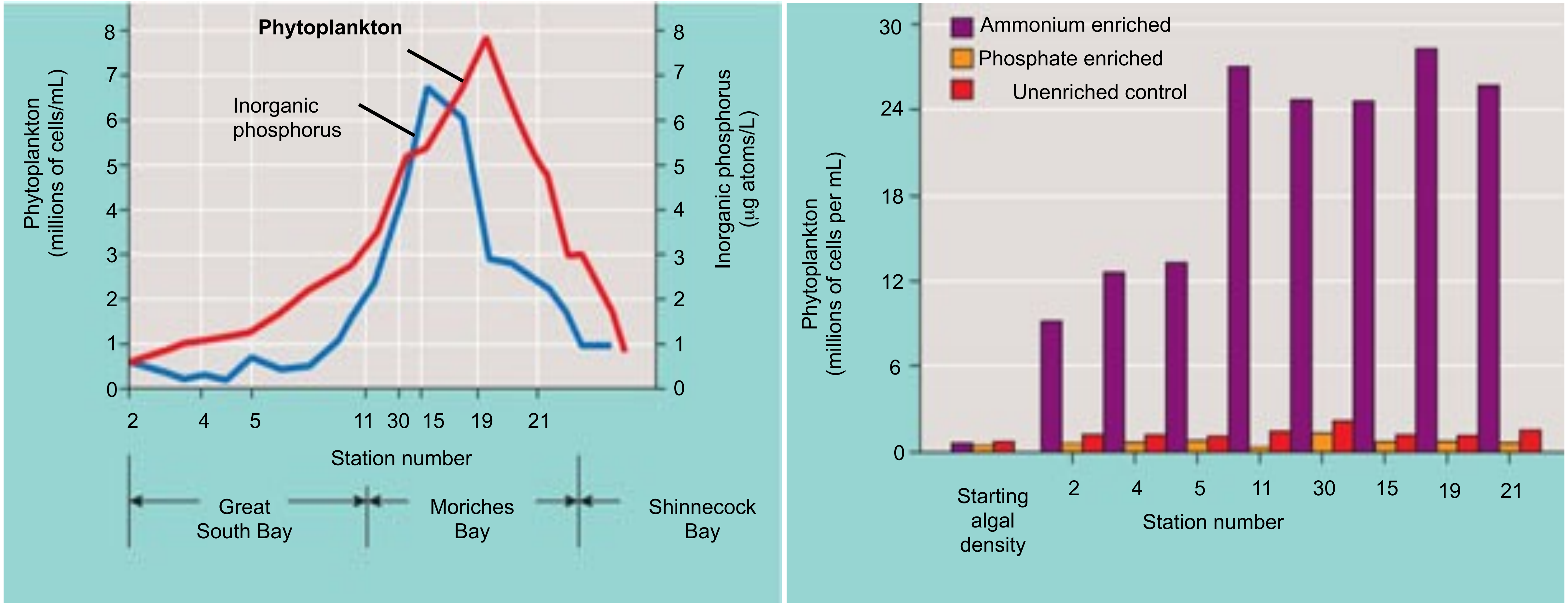
2. Nutrient Limitations

- *Nutrients appear to be the key limiting factor in aquatic ecosystem production!*
- The most common limited nutrients in aquatic ecosystems are the (macronutrients) nitrogen and phosphorous.
  - Nitrogen happens to be the most limited nutrient in soils as well.
- Micronutrients can be limited in aquatic ecosystems as well.
  - Iron (Fe) happens to be very important and is often limited.
  - *Further support is found in upwellings (deep nutrient rich waters that circulate to the ocean surface).*
    - *Areas of upwellings are diverse and abundant with life...they are often prime fishing locations.*
    - *The abundant nutrients provide a large base for the food webs*

EXPERIMENT Pollution from duck farms concentrated near Moriches Bay adds both nitrogen and phosphorus to the coastal water off Long Island. Researchers cultured the phytoplankton Nannochloris atomus with water collected from several bays.



RESULTS Phytoplankton abundance parallels the abundance of phosphorus in the water (a). Nitrogen, however, is immediately taken up by algae, and no free nitrogen is measured in the coastal waters. The addition of ammonium (NH_4^+) caused heavy phytoplankton growth in bay water, but the addition of phosphate (PO_4^{3+}) did not induce



(a) Phytoplankton biomass and phosphorus concentration

(b) Phytoplankton response to nutrient enrichment

CONCLUSION Since adding phosphorus, which was already in rich supply, had no effect on *Nannochloris* growth, whereas adding nitrogen increased algal density dramatically, researchers concluded that nitrogen was the nutrient limiting phytoplankton growth in this ecosystem.

Table 54.1 Nutrient Enrichment Experiment for Sargasso Sea Samples

Nutrients Added to Experimental Culture	Relative Uptake of ^{14}C by Cultures*
None (controls)	1.00
Nitrogen (N) + phosphorus (P) only	1.10
N + P + metals (excluding iron)	1.08
N + P + metals (including iron)	12.90
N + P + iron	12.00

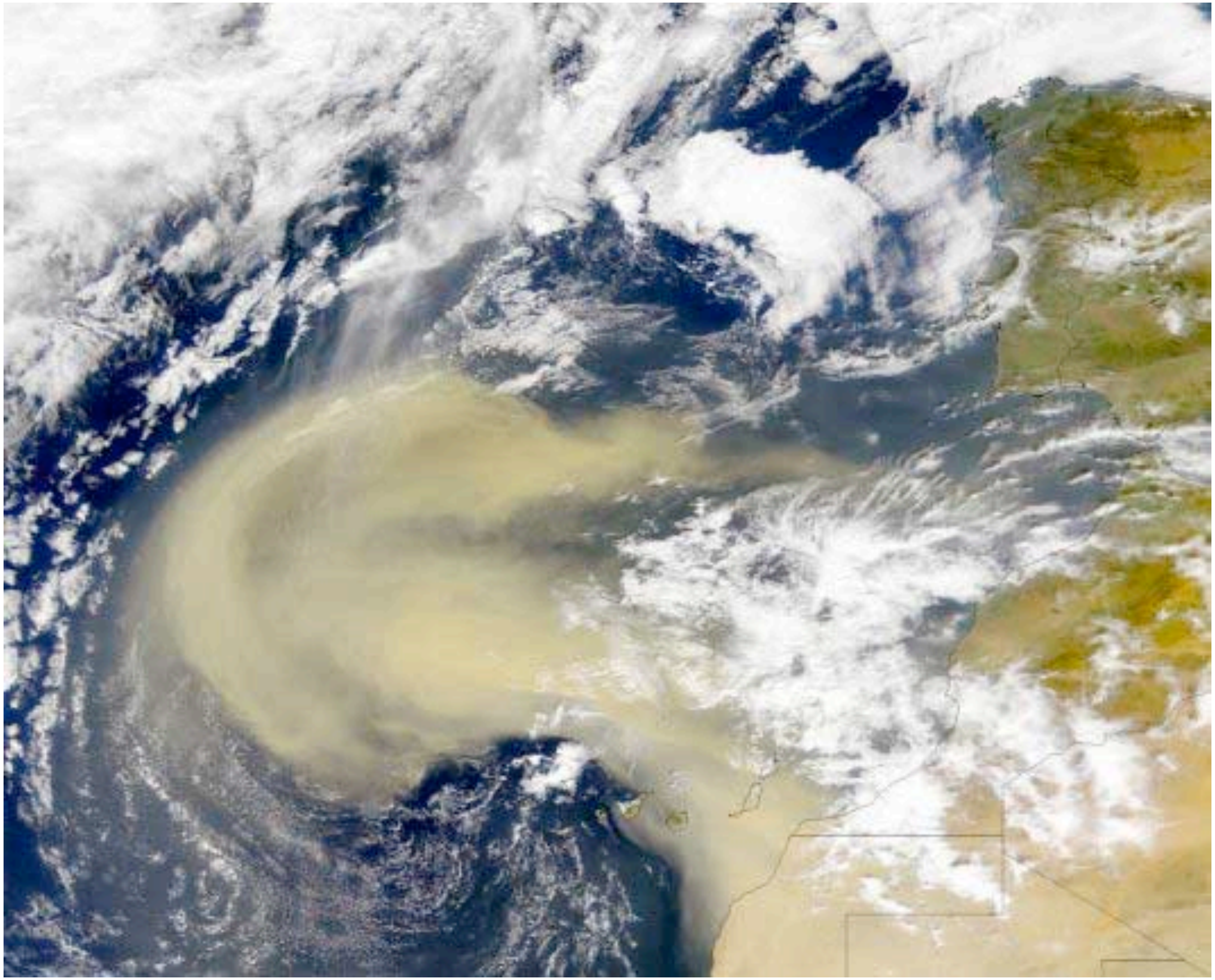
*^{14}C uptake by cultures measures primary production.

Data from Menzel and Ryther, *Deep Sea Research* 7(1961): 276–281.

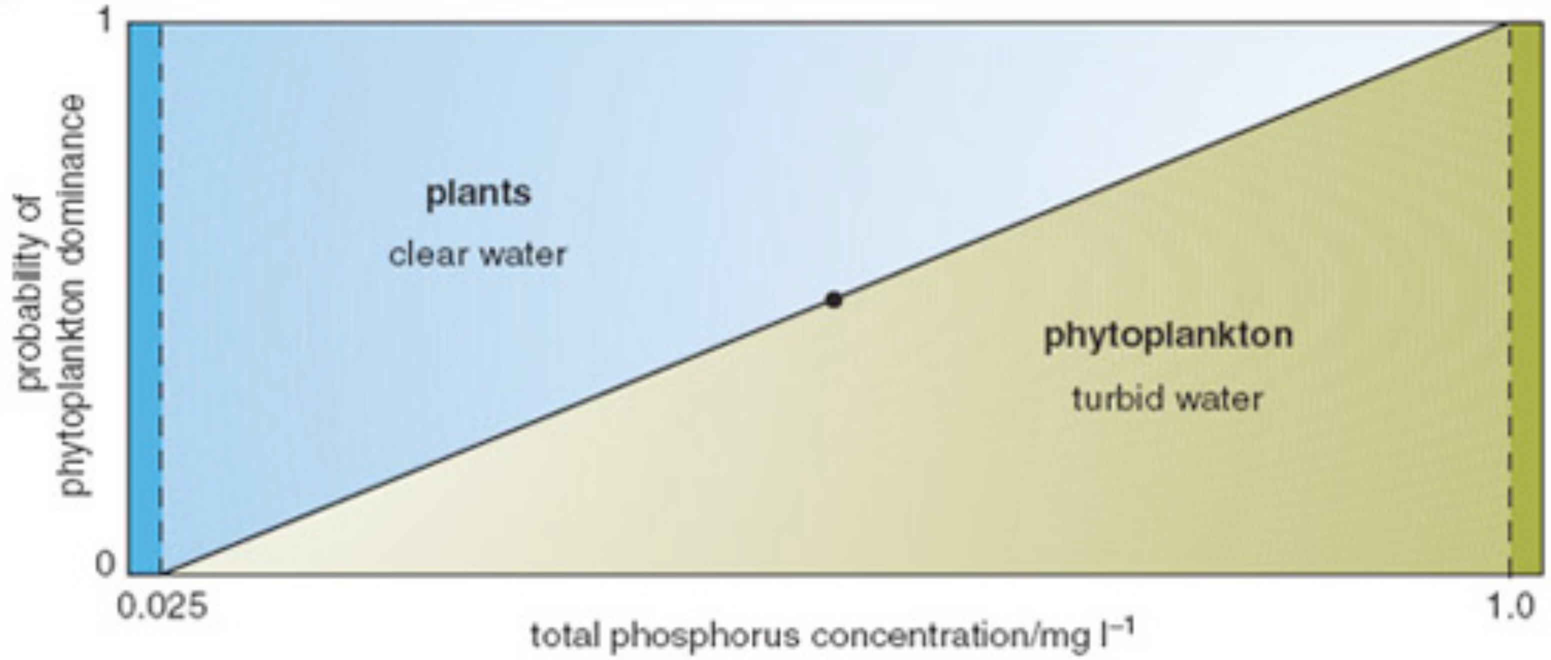
What conclusion can you draw from this data? How is this data from the Sargasso Sea different and similar from the Long Island experiment on the last slide

Where does the Iron come from? Hint below

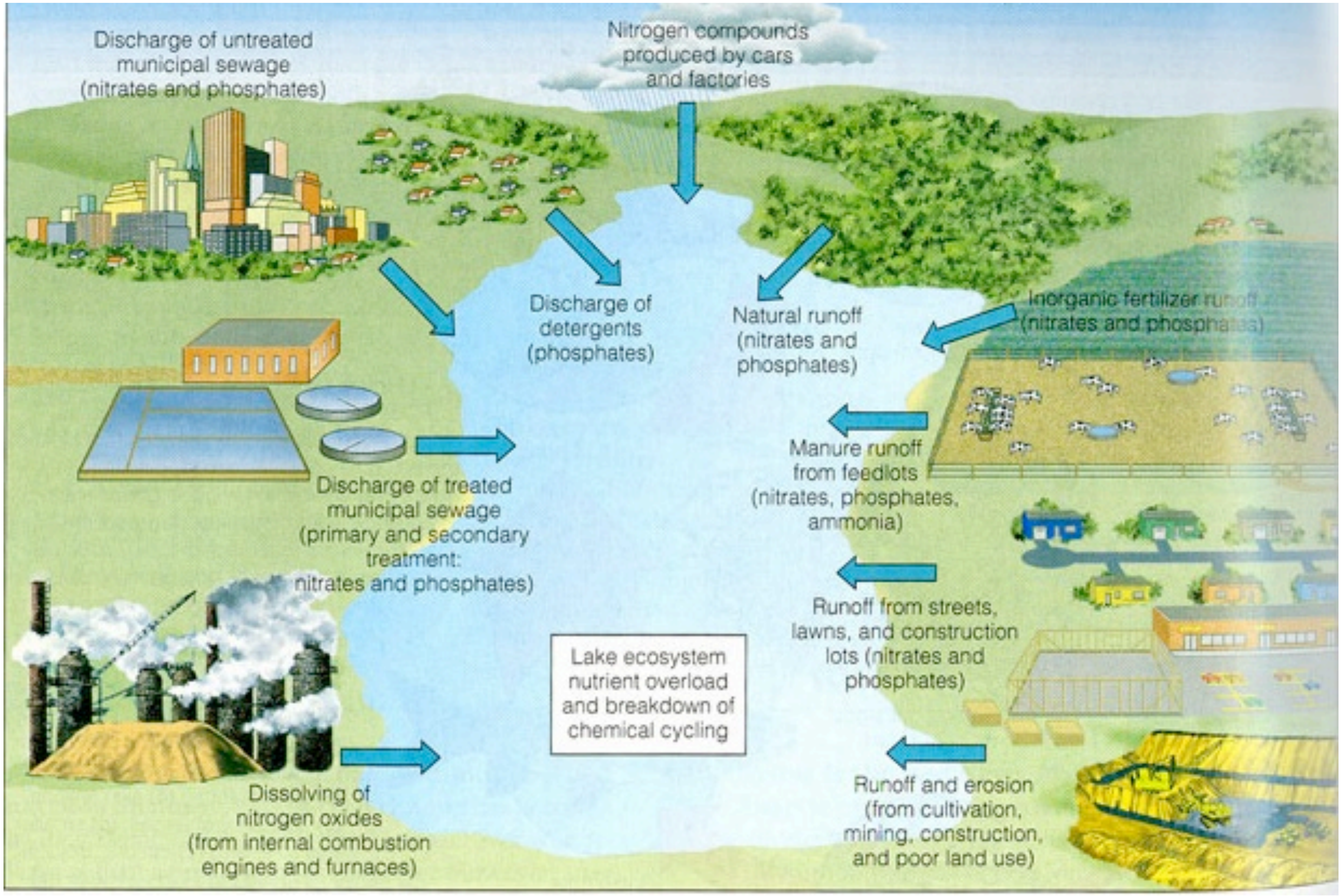
Adding Iron can stimulate growth of cyanobacteria which in turn fixes more nitrogen which then stimulates the growth of phytoplankton thereby increasing primary productivity.



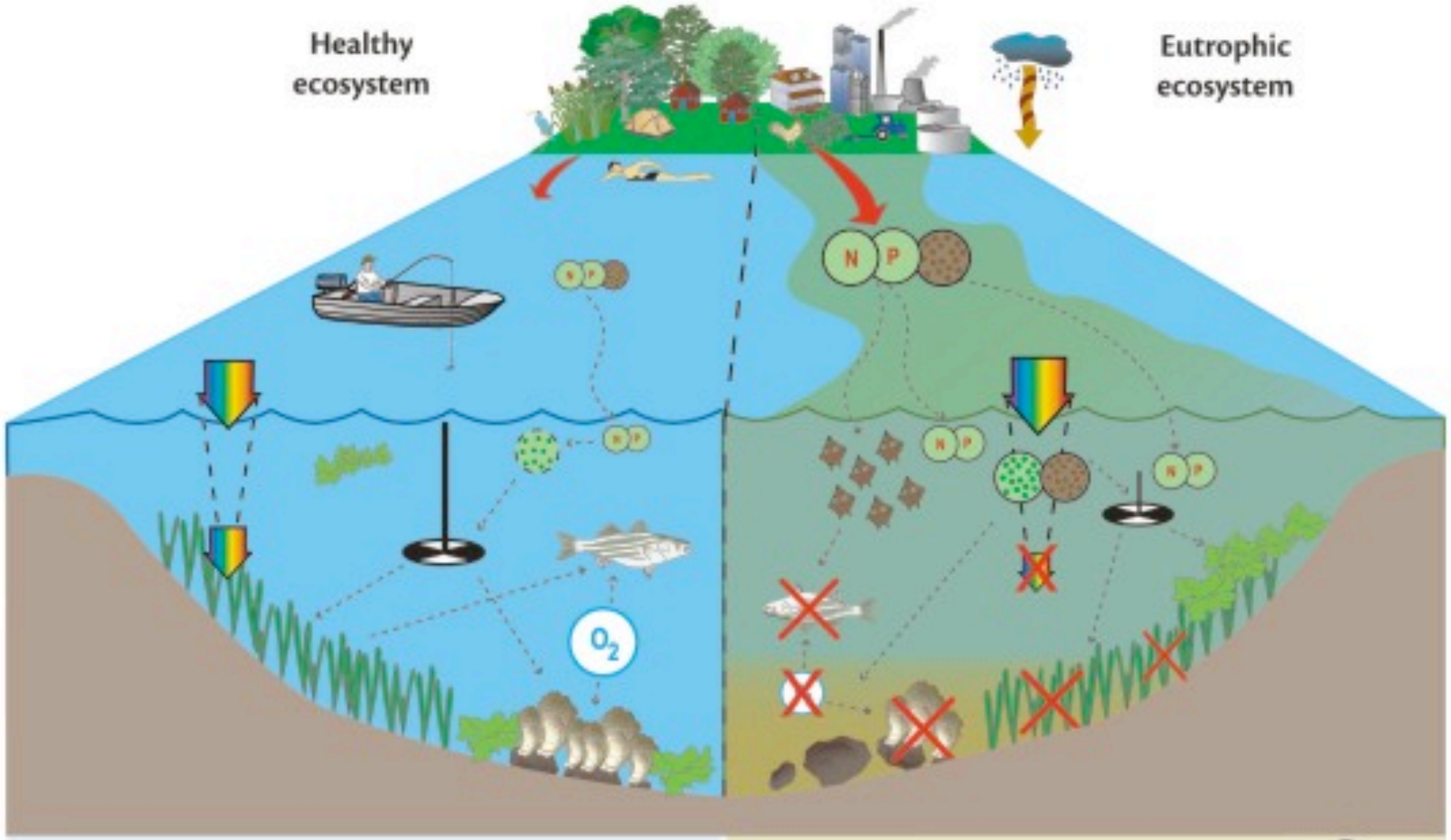
Increase in Phosphorous can cause Eutrophication



Cultural Eutrophication



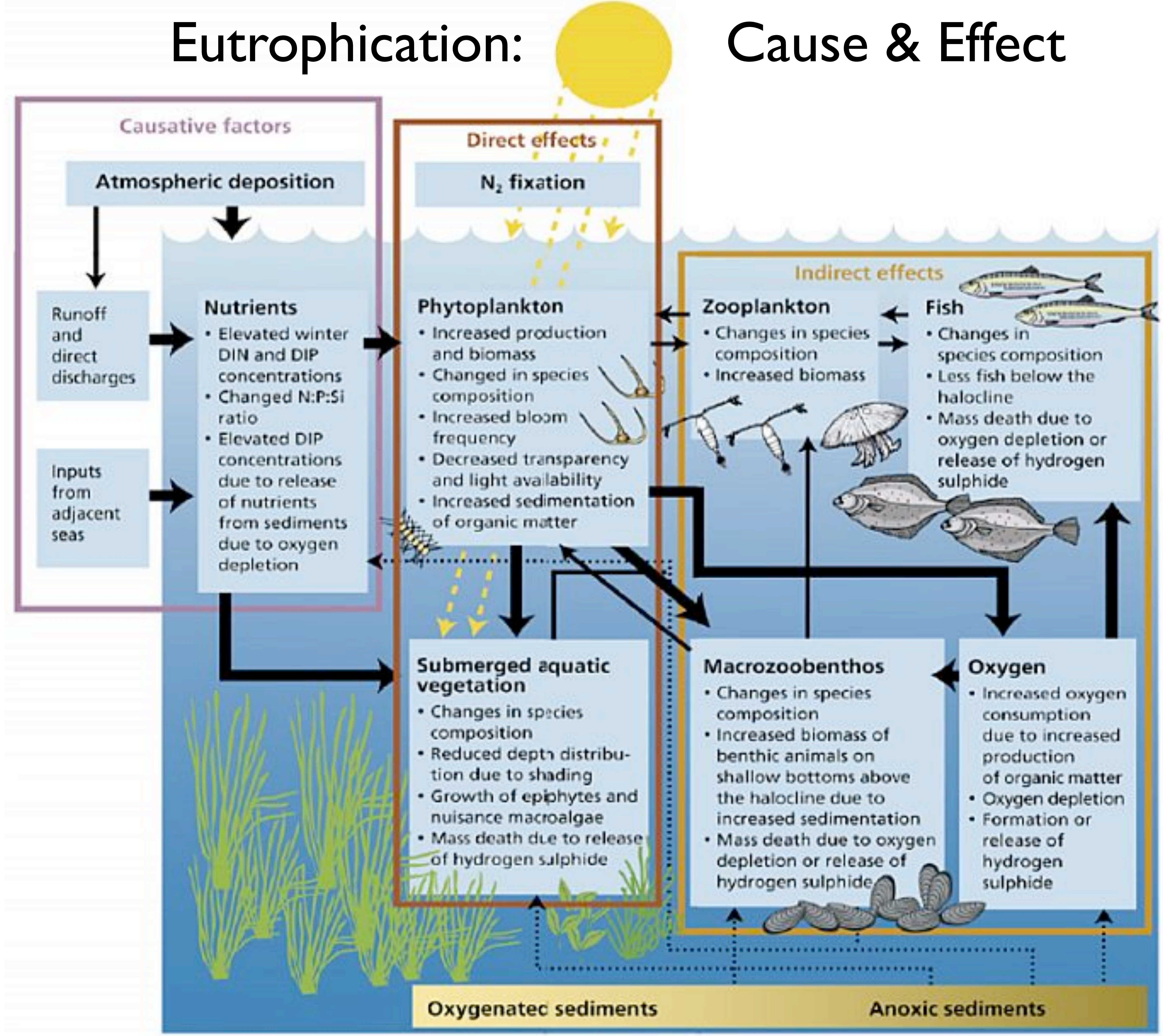
Eutrophication: Before & After



In healthy ecosystems, nutrient inputs, specifically nitrogen and phosphorus, occur at a rate that stimulates a level of macroalgal and phytoplankton (chlorophyll *a*) growth in balance with grazer biota. A low level of chlorophyll *a* in the water column helps keep water clarity high, allowing light to penetrate deep enough to reach submerged aquatic vegetation. Low levels of phytoplankton and macroalgae result in dissolved oxygen levels most suitable for healthy fish and shellfish so that humans can enjoy the benefits that a coastal environment provides.

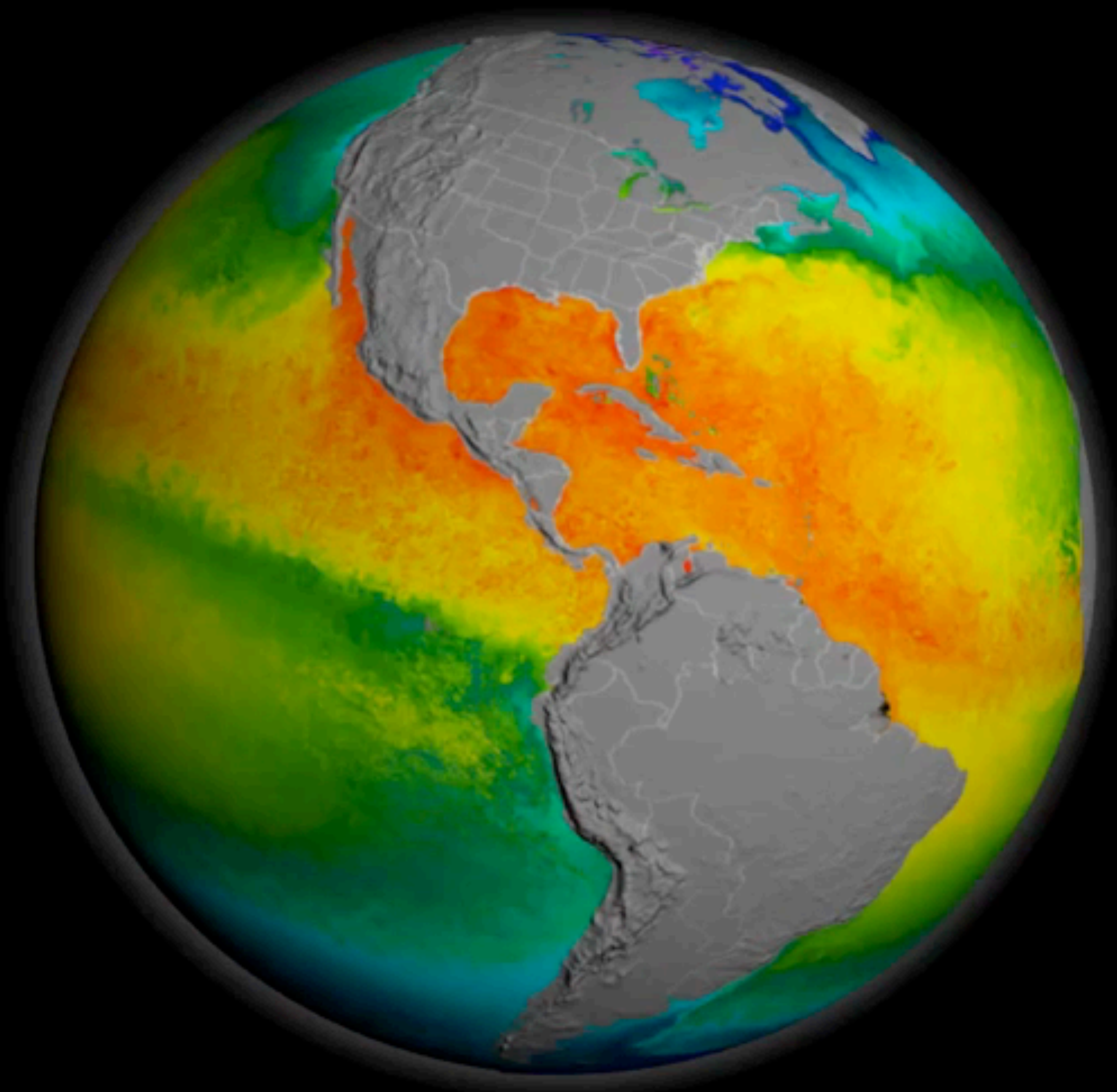
In a eutrophic ecosystem, increased sediment and nutrient loads from farming, urban development, water treatment plants, and industry, in combination with atmospheric nitrogen, help trigger both macroalgae and phytoplankton (chlorophyll *a*) blooms, exceeding the capacity of grazer control. These blooms can result in decreased water clarity, decreased light penetration, decreased dissolved oxygen, loss of submerged aquatic vegetation, nuisance/toxic algal blooms and the contamination or die off of fish and shellfish.

Eutrophication: Cause & Effect



Is it likely that temperature would $\uparrow$ primary production?

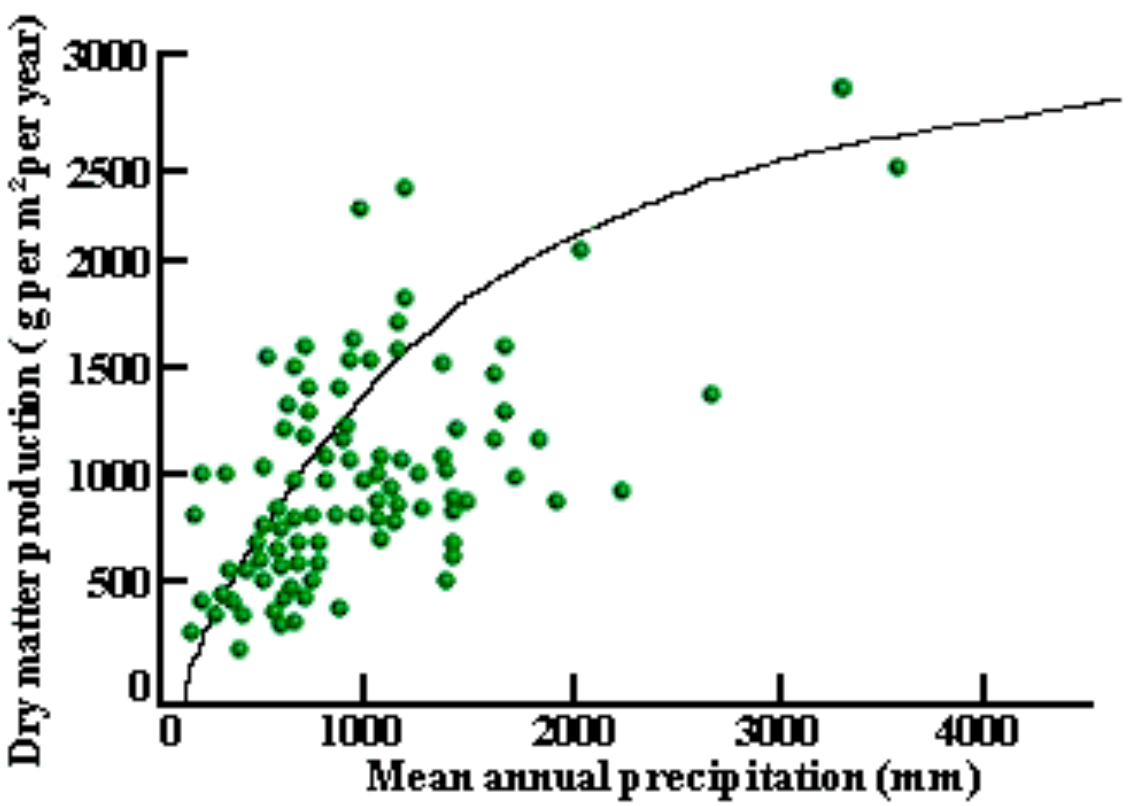
Not generally however consider this...



A recent study indicates there is a correlation between ocean nutrients and changes in sea surface temperature (SST). The results show that when ocean water warms, marine plant life in the form of microscopic phytoplankton tend to decline. When water cools, plant life flourishes. Changes in phytoplankton growth influence fishery yields and the amount of carbon dioxide the oceans remove from the atmosphere. This could have major implications on the future of our ocean's food web and how it relates to climate change.

C. Primary Production in Terrestrial Ecosystems

- **Water** and **Temperature** are the key limiting factors.
- In fact precipitation is a useful tool for predicting productivity because there is such a strong correlation between the two.
  - Actual evapotranspiration is a second useful tool used to predict terrestrial productivity



Where did we see this graph before?

1. Adaptations to Nutrient Limitations

- Globally nitrogen is the most common limiting factor.
- Phosphorous is more likely limiting in older soils.
  - *Various adaptations have evolved to address these challenges*
  - *1. Root Nodules (symbiosis between prokaryotes and plants)*
  - *2. Mycorrizhae (symbiosis between fungi and plants)*
  - *3. Root Hairs (increase surface area)*
  - *4. Enzymes and *Chelating substances (that increase the availability of nutrients in the soil)*

***The word "chelation" comes from the root word, "chele" which is Greek for the claw of a lobster or crab. So, "chelation" refers to a"grabbing" action as when a lobster grabs something with its claw.**
Chelation is a process where some substance grabs another -- the more technical term would be that some substance "binds" to another substance. This "binding" involves the actions of atoms and gets rather complex, at least in terms of chemistry. But, in concept is is easy to understand.

(55) Ecosystems

III.

Main Idea: Energy transfer is not efficient, most energy is lost.

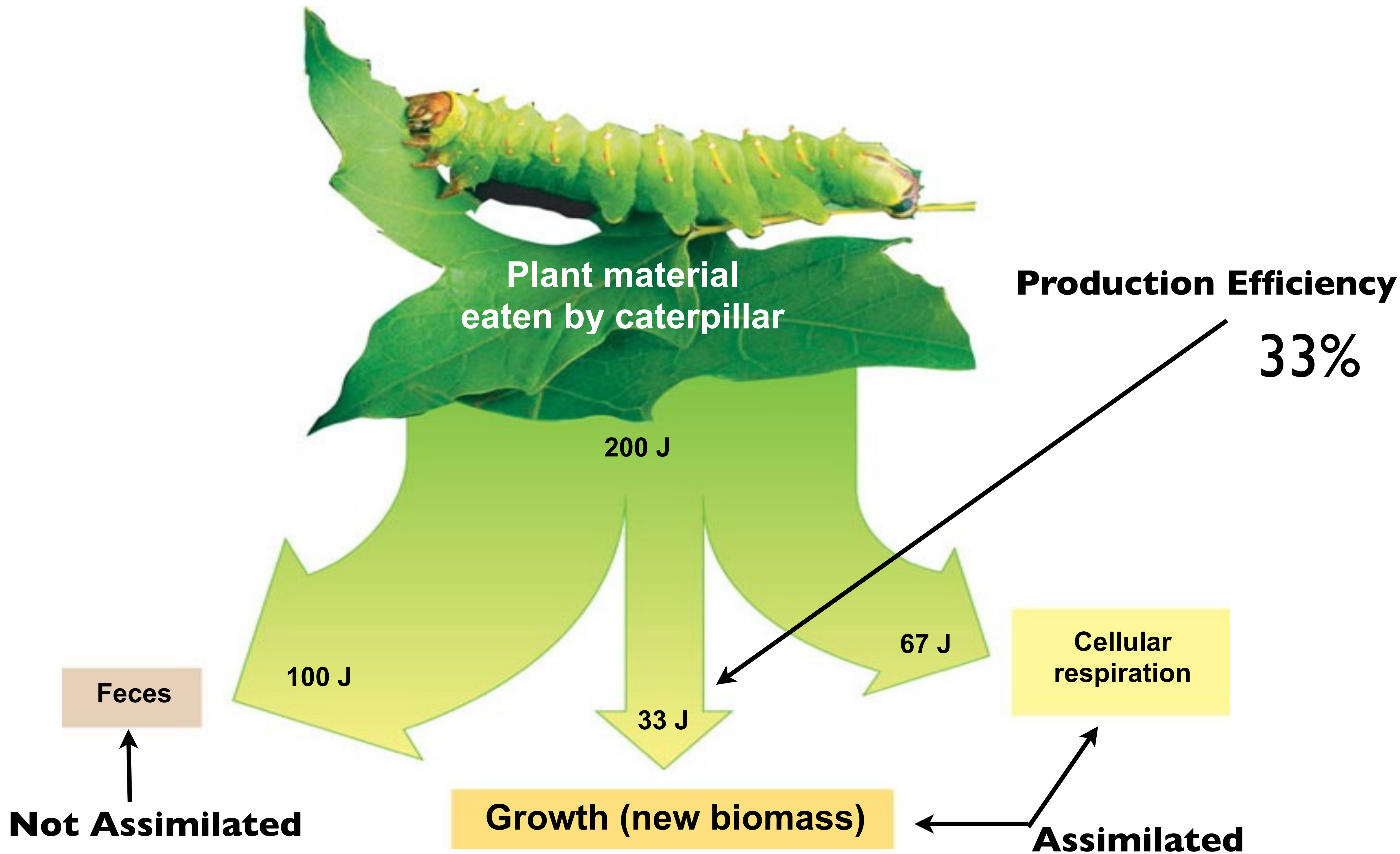
ENERGY TRANSFER BETWEEN TROPHIC LEVELS IS TYPICALLY AROUND 10% (WITH 90% LOST)

- **Secondary production**: the amount of chemical energy in consumers food that is actually converted to their own *new biomass* during some time period.

A. Production Efficiency

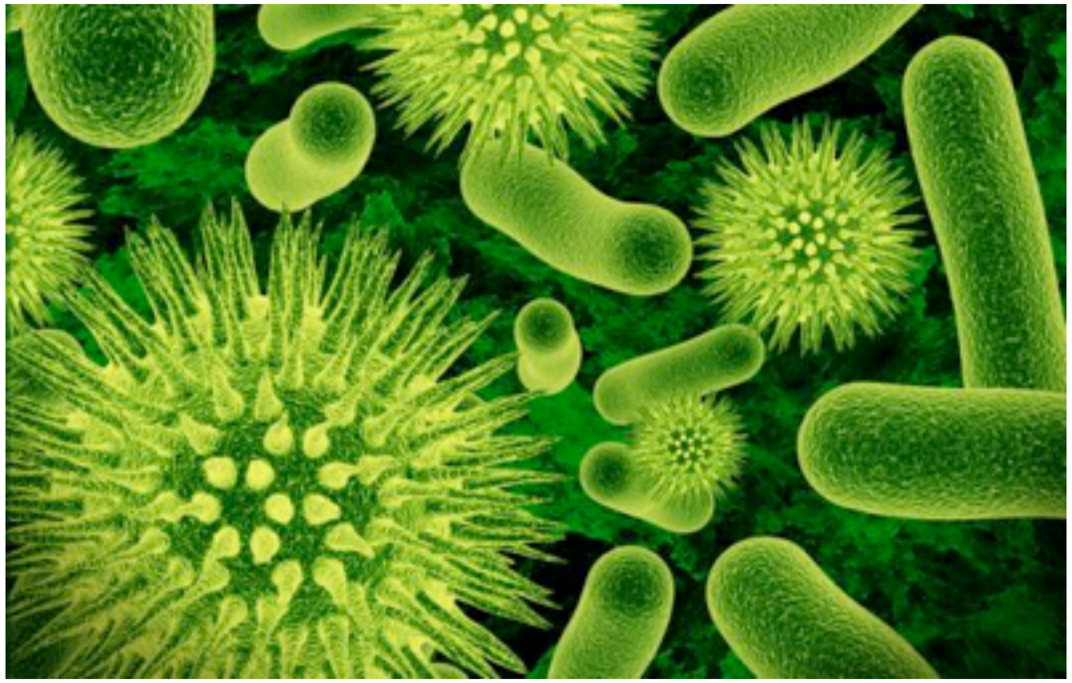
- **Think about it...** only the chemical energy stored by herbivores is biomass (either in their own growth or reproduction of offspring) This is only energy available to secondary consumers
- We can measure production efficiency.

$$\text{Production Efficiency} = \frac{\text{Net Secondary Production} \times 100\%}{\text{Assimilation of Primary Production}}$$


Plant material
eaten by caterpillar
200 J
Production Efficiency
33%
100 J
67 J
33 J
Feces
Cellular
respiration
Not Assimilated
Growth (new biomass)
Assimilated

Match the pictures with their production efficiencies.





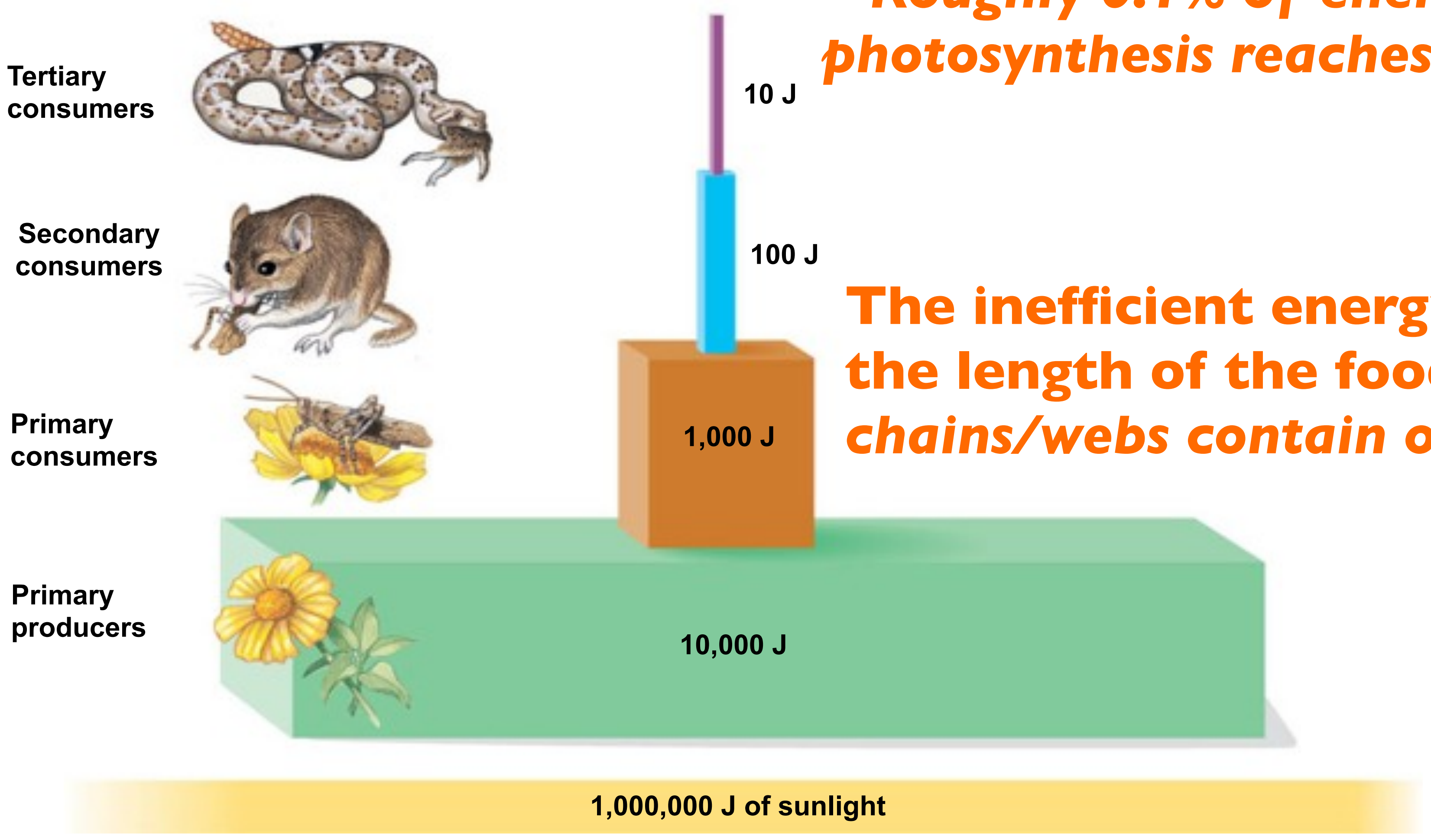

1-3%
1-3%
10%
40%
90%

Explain your choices.

Birds & Mammals(1-3%), alot of energy maintaining body heat
Fish (10%)
Microorganisms (40%) due efficient surface area to volume ratio

B. Trophic Efficiency & Ecological Pyramids

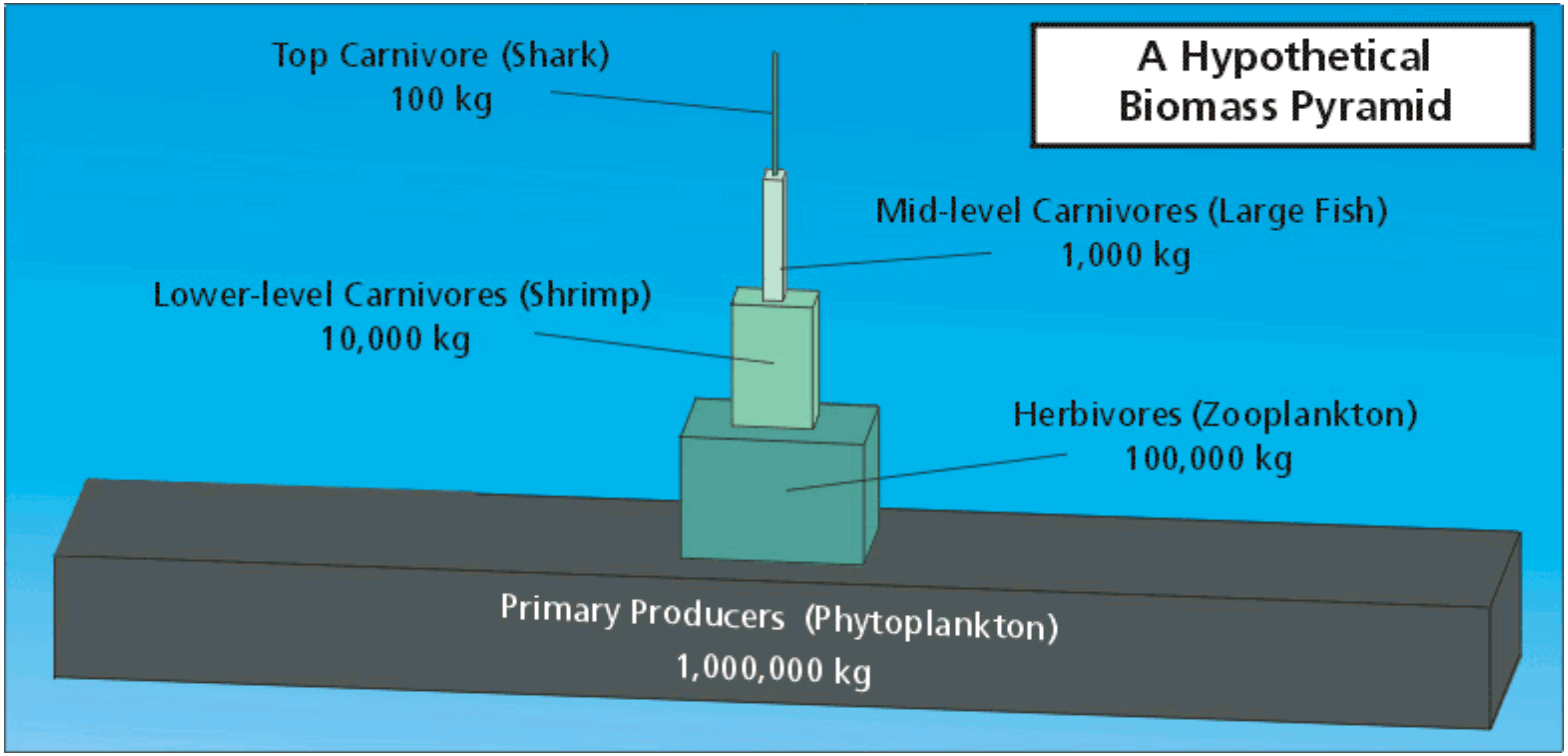
- **Trophic Efficiency**, the percent of production transferred one trophic level to the next. (Ranges between 5-20%)
  - Trophic efficiency must be less than production efficiency.



** Roughly 0.1% of energy fixed by photosynthesis reaches top consumers*

The inefficient energy transfer is multiplied over the length of the food chain. *Thus most food chains/webs contain only 4 or 5 trophic levels.*

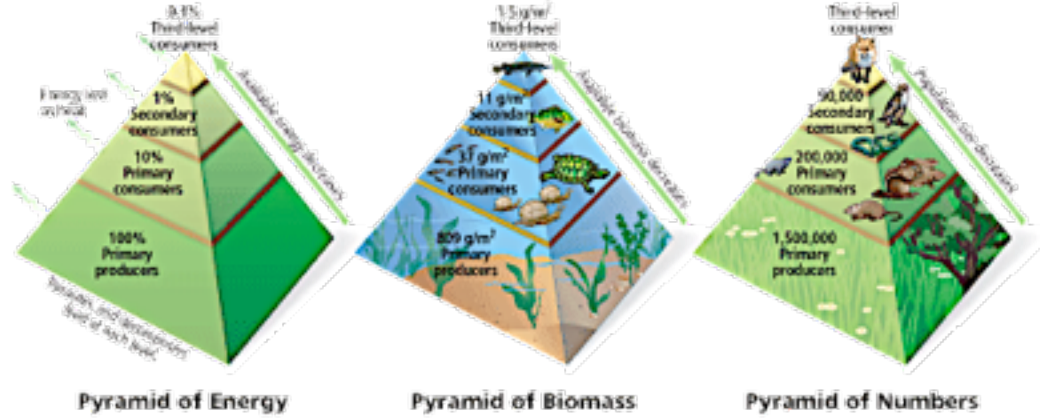
Which trophic level is most vulnerable to extinction? Why?

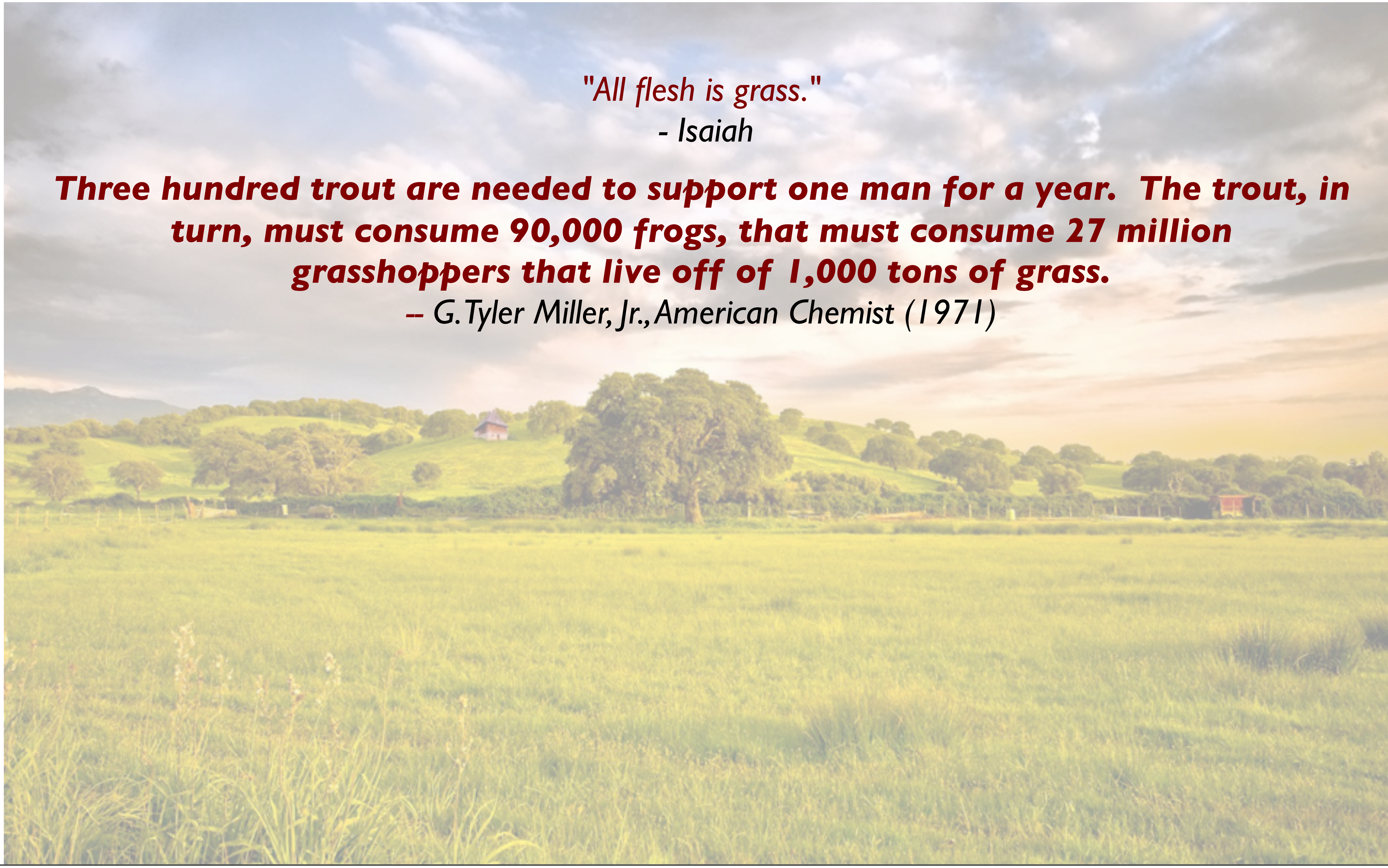


Each tier represents the standing crop (the total dry mass of all organisms) in a trophic level.

Can you make an argument that humans might be better off if they were vegetarians?

Most common or Standard Pyramids



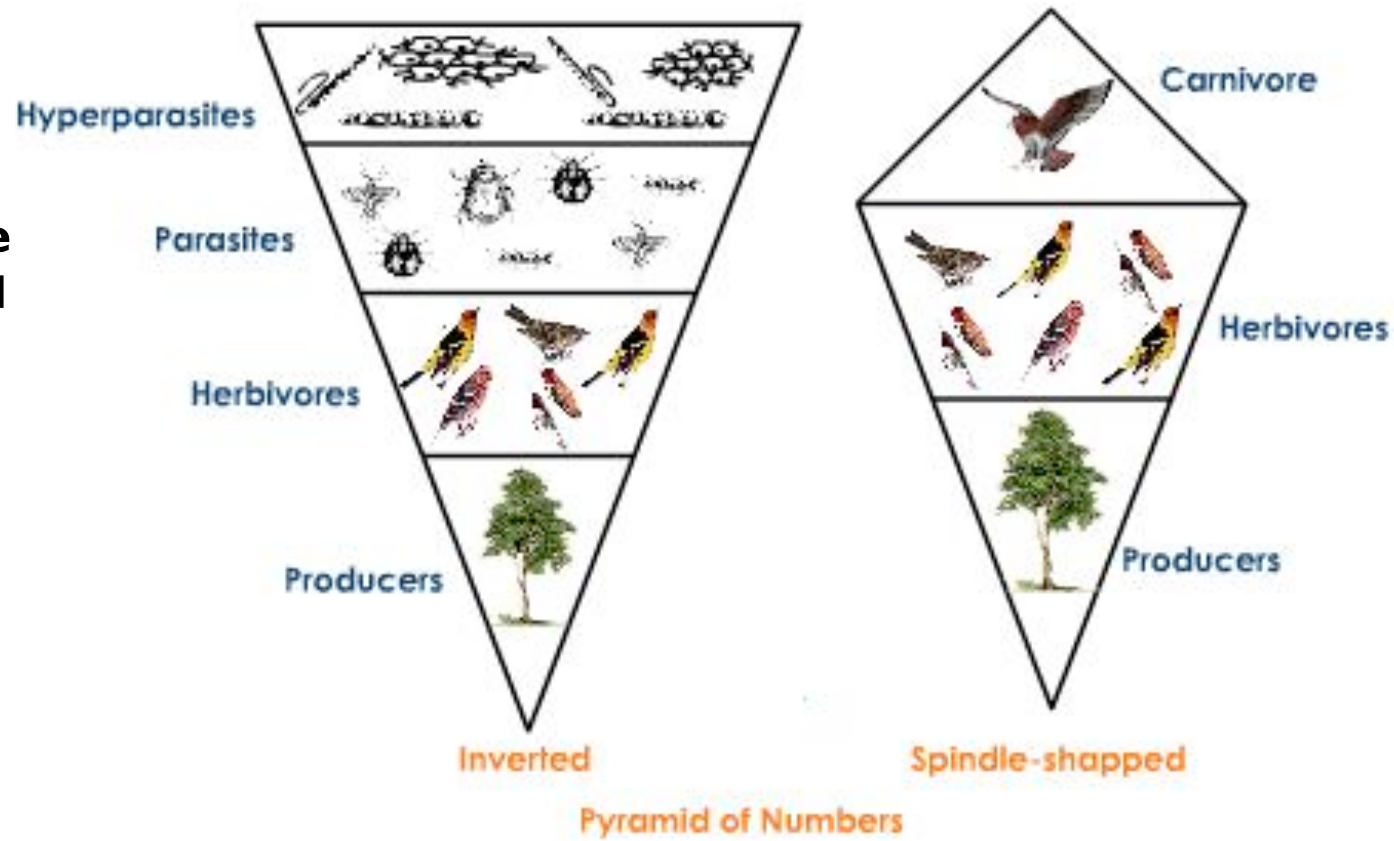


"All flesh is grass."
- Isaiah

Three hundred trout are needed to support one man for a year. The trout, in turn, must consume 90,000 frogs, that must consume 27 million grasshoppers that live off of 1,000 tons of grass.

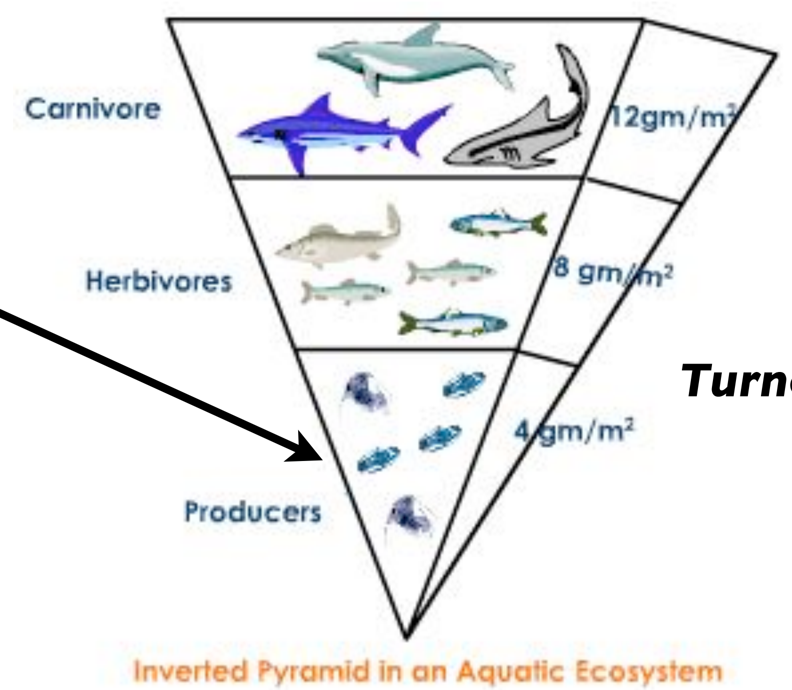
-- G.Tyler Miller, Jr., American Chemist (1971)

(LEFT) In a parasitic food chain, for e.g., an oak tree, the large tree provides food to several herbivorous birds. The birds support larger population of ectoparasites leading to the formation of an inverted pyramid.



(RIGHT) When a large tree support larger number of herbivorous birds which in turn are eaten by carnivorous birds like falcon and eagle, which are smaller in number, it forms a spindle shaped pyramid.

The phytoplankton have a short *turnover time*, they have a small standing crop compared to their production.



$$\textit{Turnover Time} = \frac{\text{Standing Crop } (g/m^2)}{\text{Production } (g/m^2 \cdot day)}$$

(ABOVE) In an aquatic habitat the pyramid of biomass is inverted or spindle shaped where the biomass of trophic level depends upon the reproductive potential and longevity of the member.

(55) Ecosystems

IV.

Main Idea: Most ecosystems receive an abundant supply of solar energy but chemical elements are they usually limited.

Main Idea: Solar energy is continually bombarding the earth but chemical elements on earth are finite and must be recycled.

BIOGEOCHEMICAL PROCESSES CYCLE NUTRIENTS AND WATER IN ECOSYSTEMS

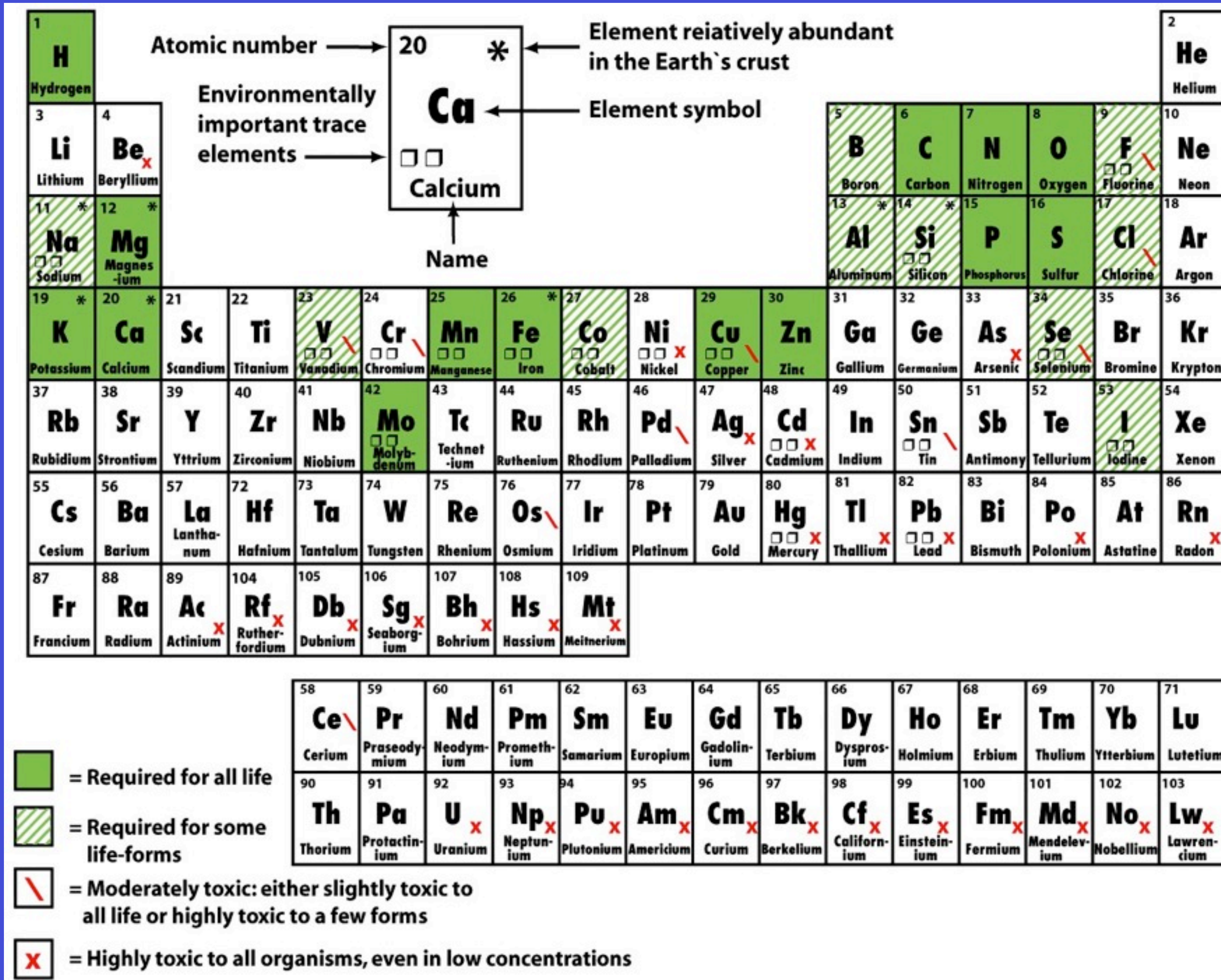
- Nutrients are recycled using both *biotic and abiotic* processes together, hence the name *biogeochemical cycles*.

A. Biogeochemical Cycles

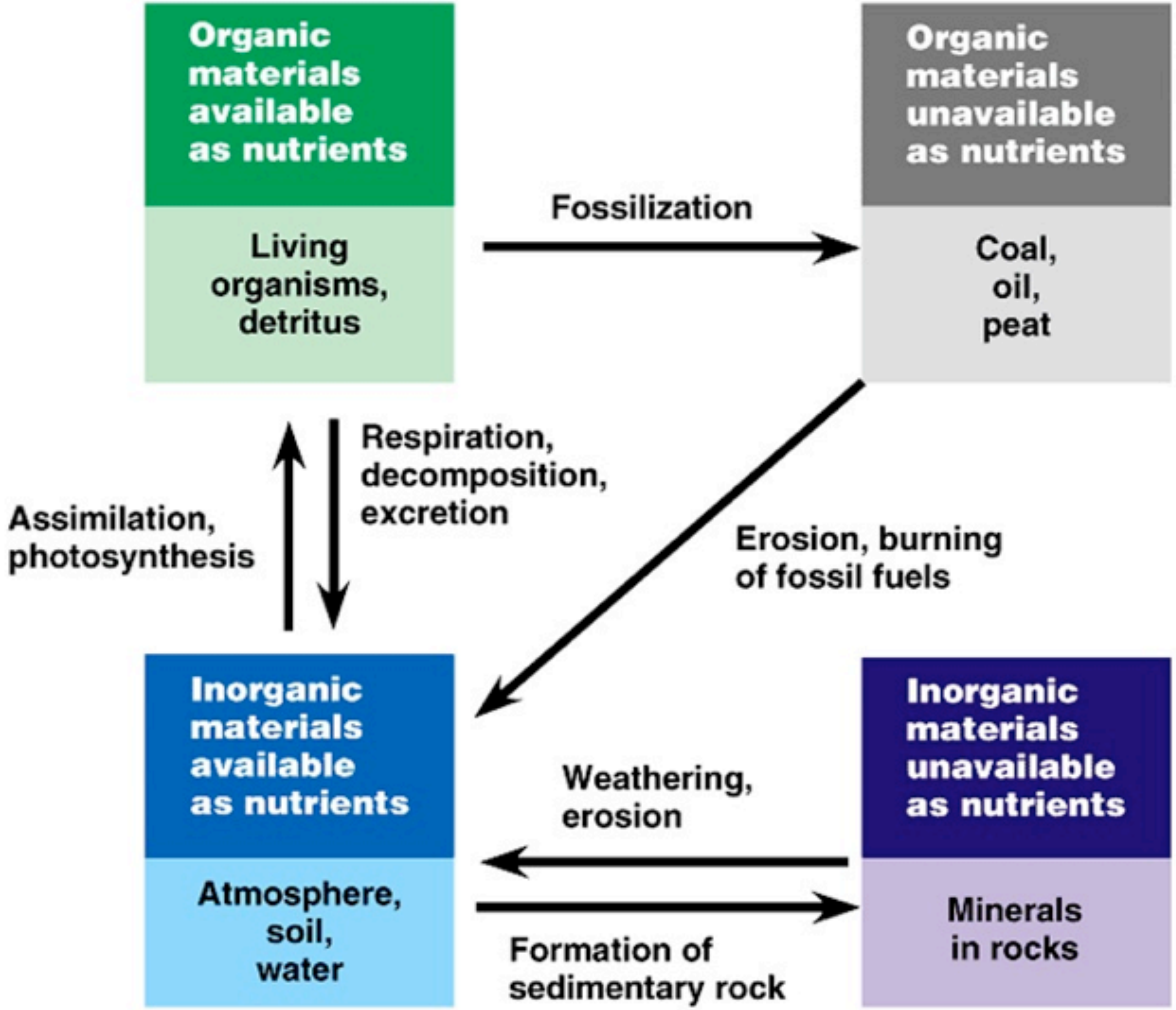
- These cycles occur on both on a local and global level.
- The gaseous forms of nitrogen, oxygen, sulfur and carbon cycle on a more global level.
- A general look at cycles finds two key components:
  - A *Reservoir* (the location of the element)
  - A *Process* (the means of moving the element)

Biogeochemical Cycles

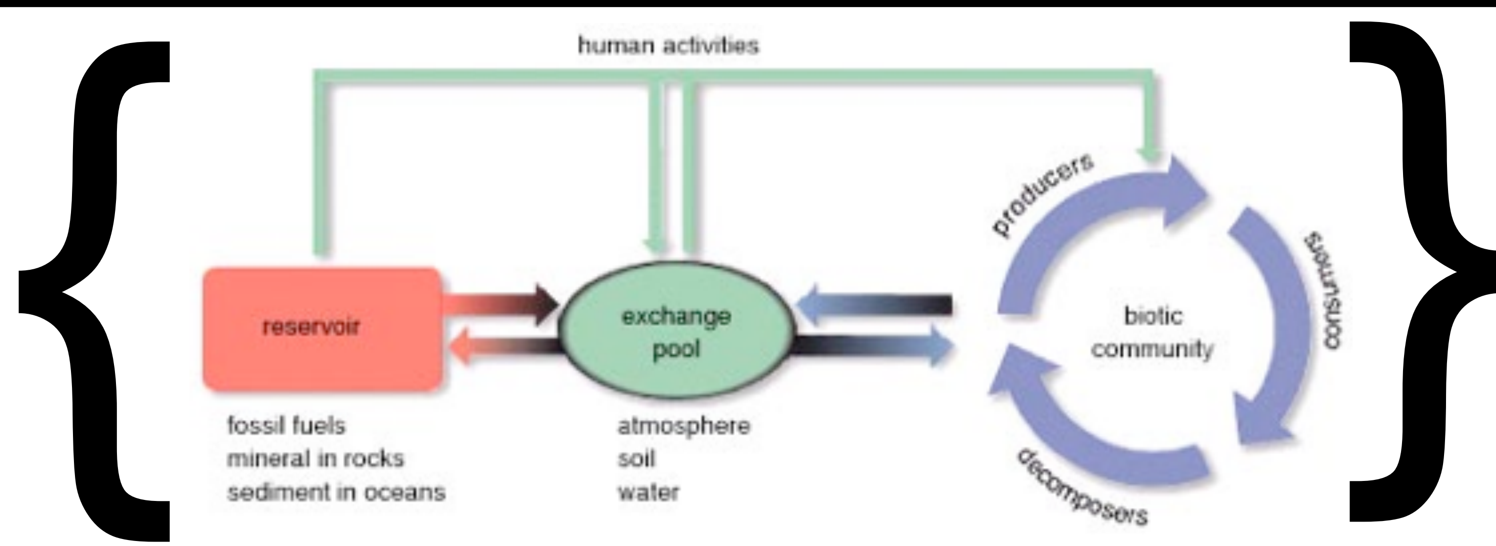
- A biogeochemical cycle is the complete path a chemical takes through the four major components of Earth's system.
  - Atmosphere
  - Hydrosphere
  - Lithosphere
  - Biosphere
- Chemicals in the four major components have different average storage time
  - Long in lithosphere (rocks)
  - Short in the atmosphere
  - Intermediate in the hydrosphere and biosphere



Atomic number
Element reiatively abundant in the Earth`s crust
Element symbol
Environmentally important trace elements
Name
20 * Ca Calcium
1 H Hydrogen
2 He Helium
3 Li Lithium
4 Be Beryllium
5 B Boron
6 C Carbon
7 N Nitrogen
8 O Oxygen
9 F Fluorine
10 Ne Neon
11 * Na Sodium
12 * Mg Magnes-ium
13 * Al Aluminum
14 * Si Silicon
15 P Phosphorus
16 S Sulfur
17 Cl Chlorine
18 Ar Argon
19 * K Potassium
20 * Ca Calcium
21 Sc Scandium
22 Ti Titanium
23 V Vanadium
24 Cr Chromium
25 Mn Manganese
26 * Fe Iron
27 Co Cobalt
28 Ni Nickel
29 Cu Copper
30 Zn Zinc
31 Ga Gallium
32 Ge Germanium
33 As Arsenic
34 Se Selenium
35 Br Bromine
36 Kr Krypton
37 Rb Rubidium
38 Sr Strontium
39 Y Yttrium
40 Zr Zirconium
41 Nb Niobium
42 Mo Molyb-denum
43 Tc Technet-ium
44 Ru Ruthenium
45 Rh Rhodium
46 Pd Palladium
47 Ag Silver
48 Cd Cadmium
49 In Indium
50 Sn Tin
51 Sb Antimony
52 Te Tellurium
53 I Iodine
54 Xe Xenon
55 Cs Cesium
56 Ba Barium
57 La Lantha-num
72 Hf Hafnium
73 Ta Tantalum
74 W Tungsten
75 Re Rhenium
76 Os Osmium
77 Ir Iridium
78 Pt Platinum
79 Au Gold
80 Hg Mercury
81 Tl Thallium
82 Pb Lead
83 Bi Bismuth
84 Po Polonium
85 At Astatine
86 Rn Radon
87 Fr Francium
88 Ra Radium
89 Ac Actinium
104 Rf Ruther-fordium
105 Db Dubnium
106 Sg Seaborg-ium
107 Bh Bohrium
108 Hs Hassium
109 Mt Meitnerium
58 Ce Cerium
59 Pr Praseody-mium
60 Nd Neodym-ium
61 Pm Prometh-ium
62 Sm Samarium
63 Eu Europium
64 Gd Gadolin-ium
65 Tb Terbium
66 Dy Dyspros-ium
67 Ho Holmium
68 Er Erbium
69 Tm Thulium
70 Yb Ytterbium
71 Lu Lutetium
90 Th Thorium
91 Pa Protactin-ium
92 U Uranium
93 Np Neptun-ium
94 Pu Plutonium
95 Am Americium
96 Cm Curium
97 Bk Berkelium
98 Cf Californ-ium
99 Es Einstein-ium
100 Fm Fermium
101 Md Mendelev-ium
102 No Nobellium
103 Lw Lawren-cium
= Required for all life
= Required for some life-forms
= Moderately toxic: either slightly toxic to all life or highly toxic to a few forms
= Highly toxic to all organisms, even in low concentrations

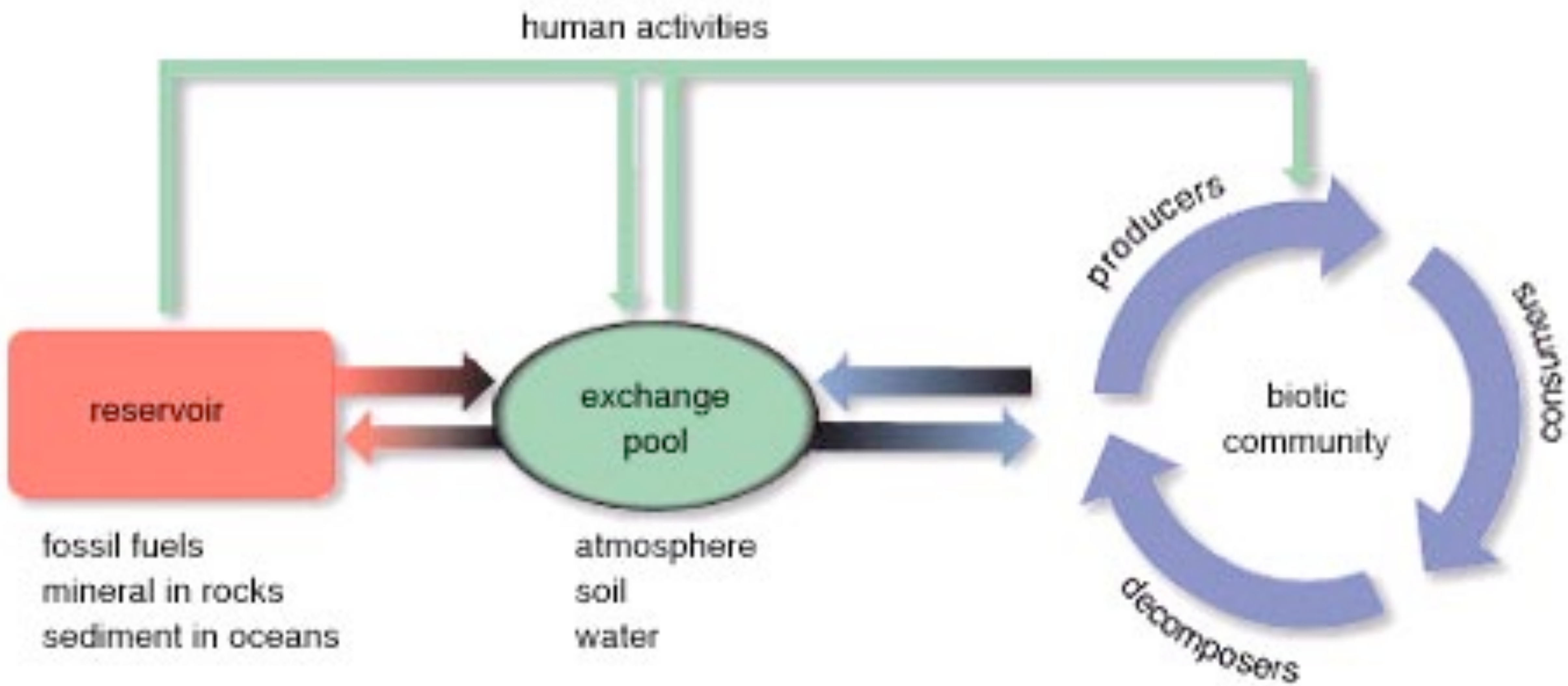


Simplified Version

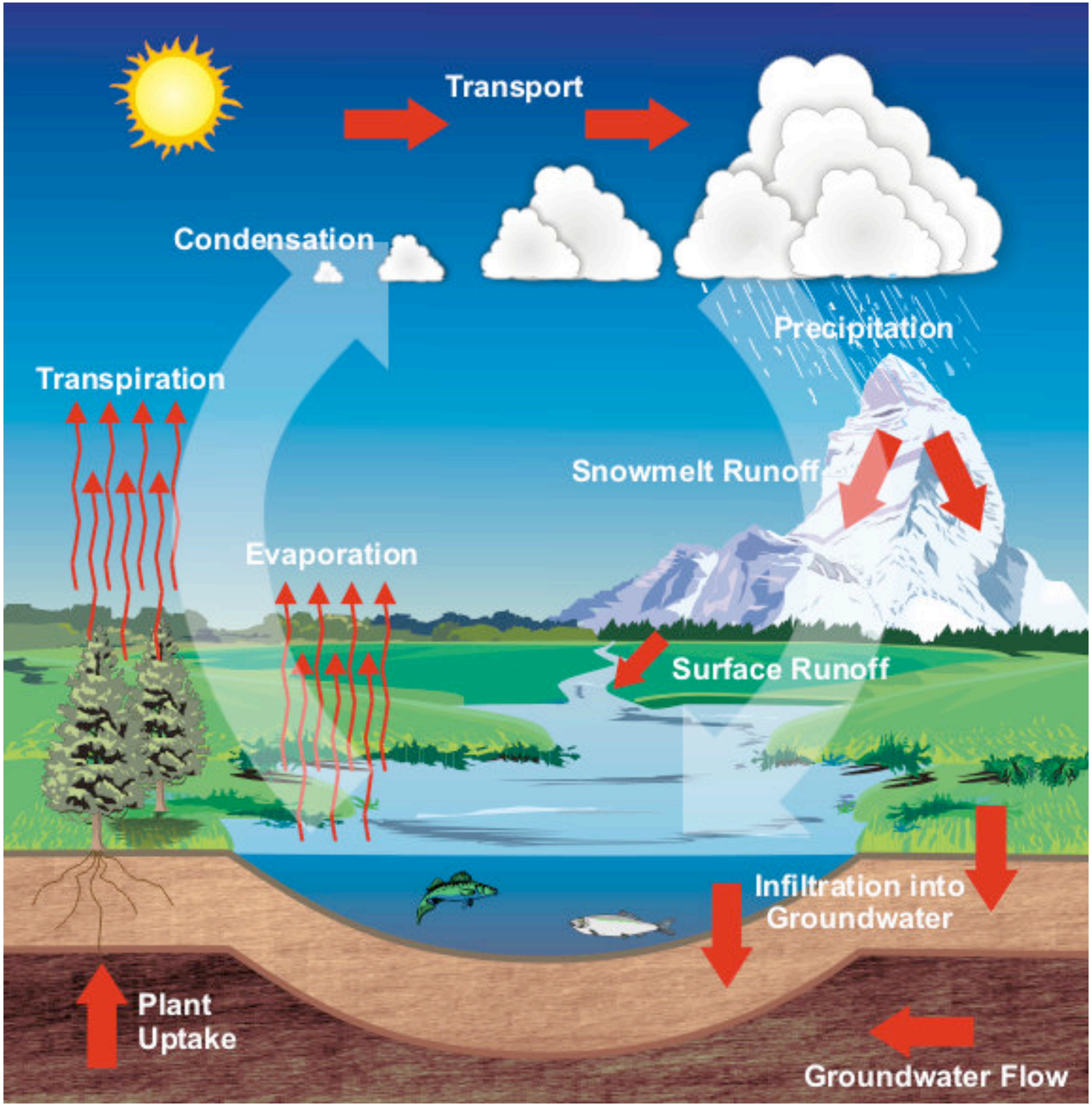


Simplified Version

A closer look!

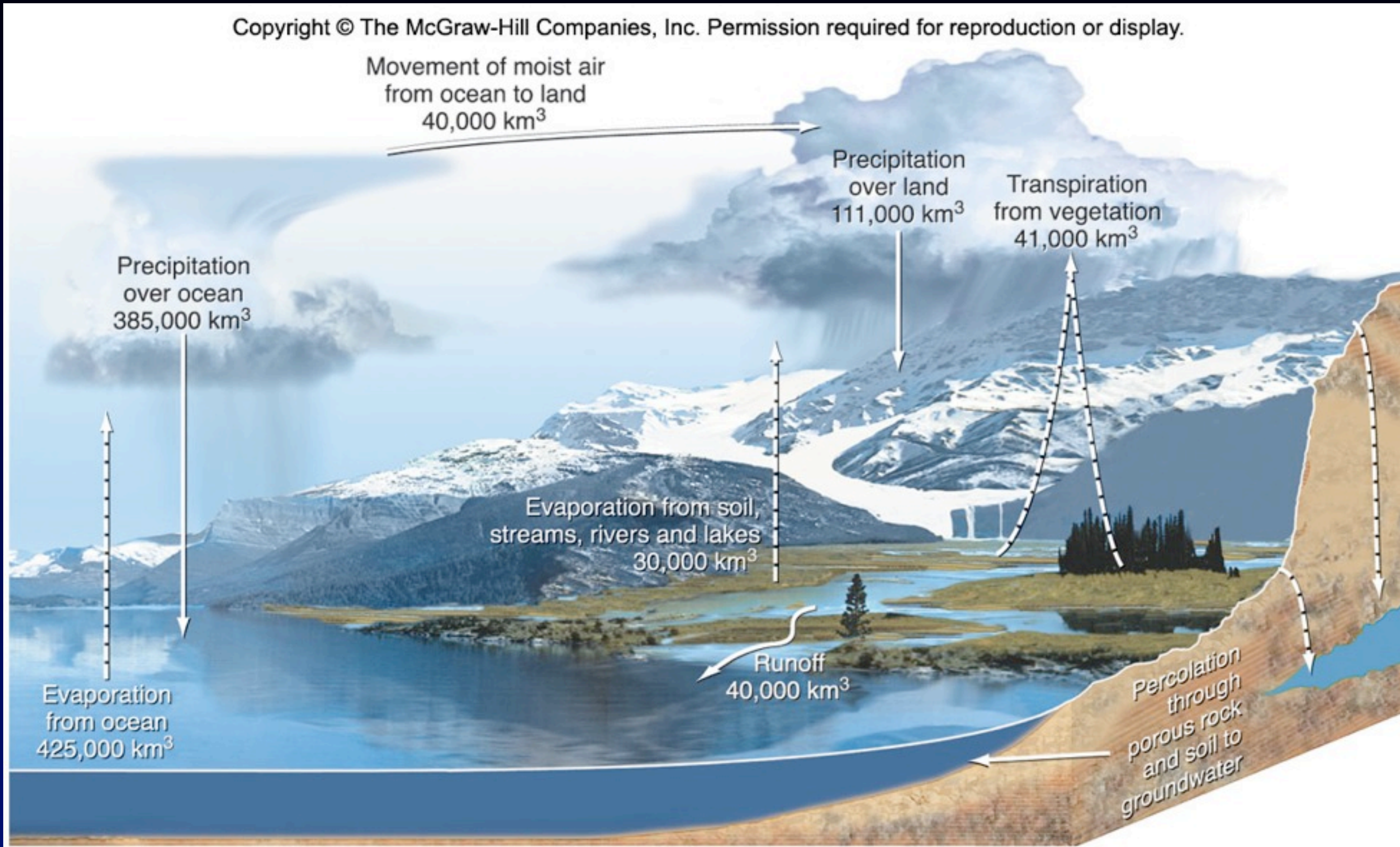


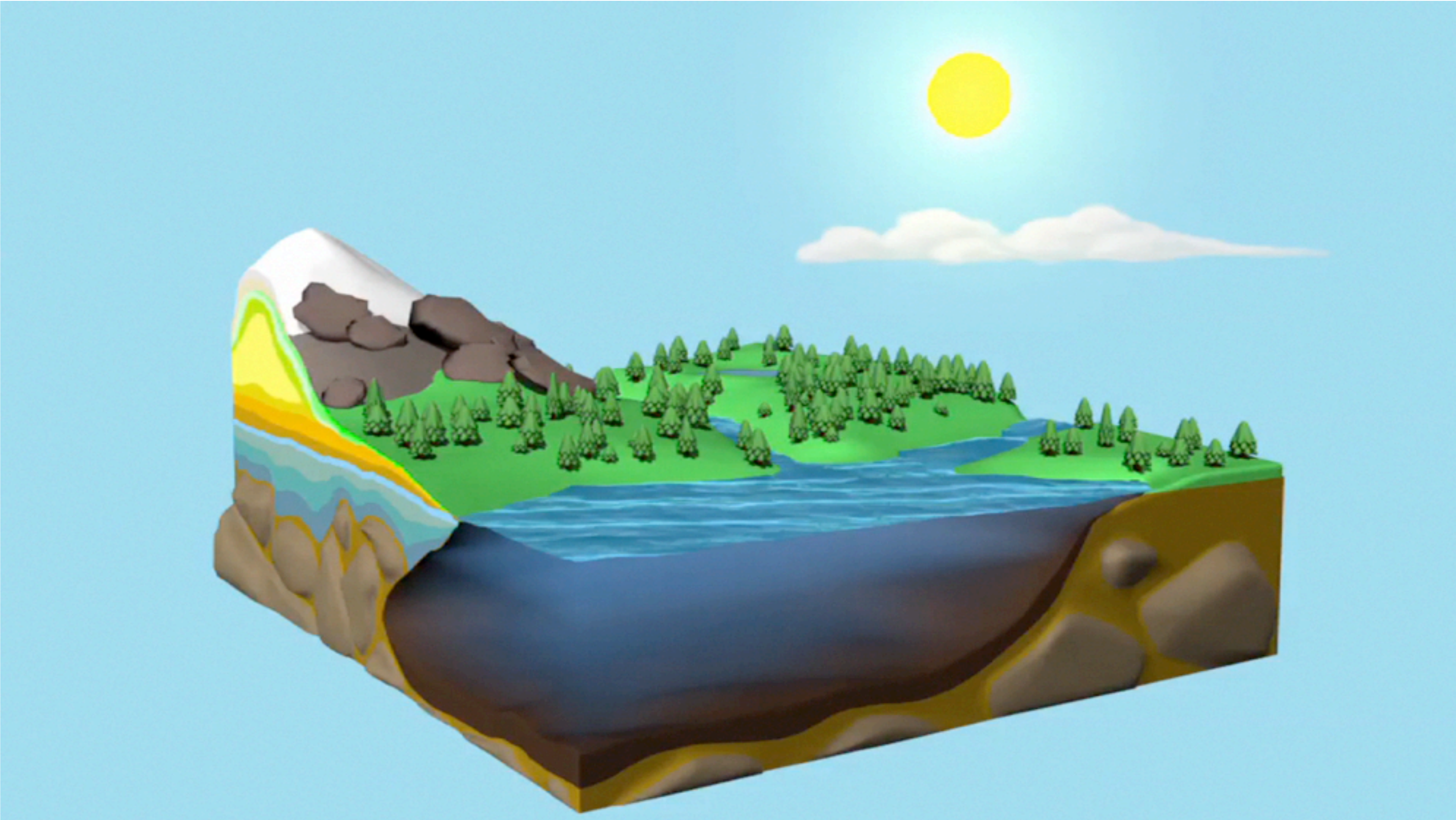
WATER CYCLE



Transport
Condensation
Precipitation
Transpiration
Snowmelt Runoff
Evaporation
Surface Runoff
Infiltration into Groundwater
Plant Uptake
Groundwater Flow

Hydrologic Cycle





BIOLOGICAL IMPORTANCE

- Water is essential for all life, water also influences production & decomposition

FORMS AVAILABLE TO LIFE

- Mainly liquid water

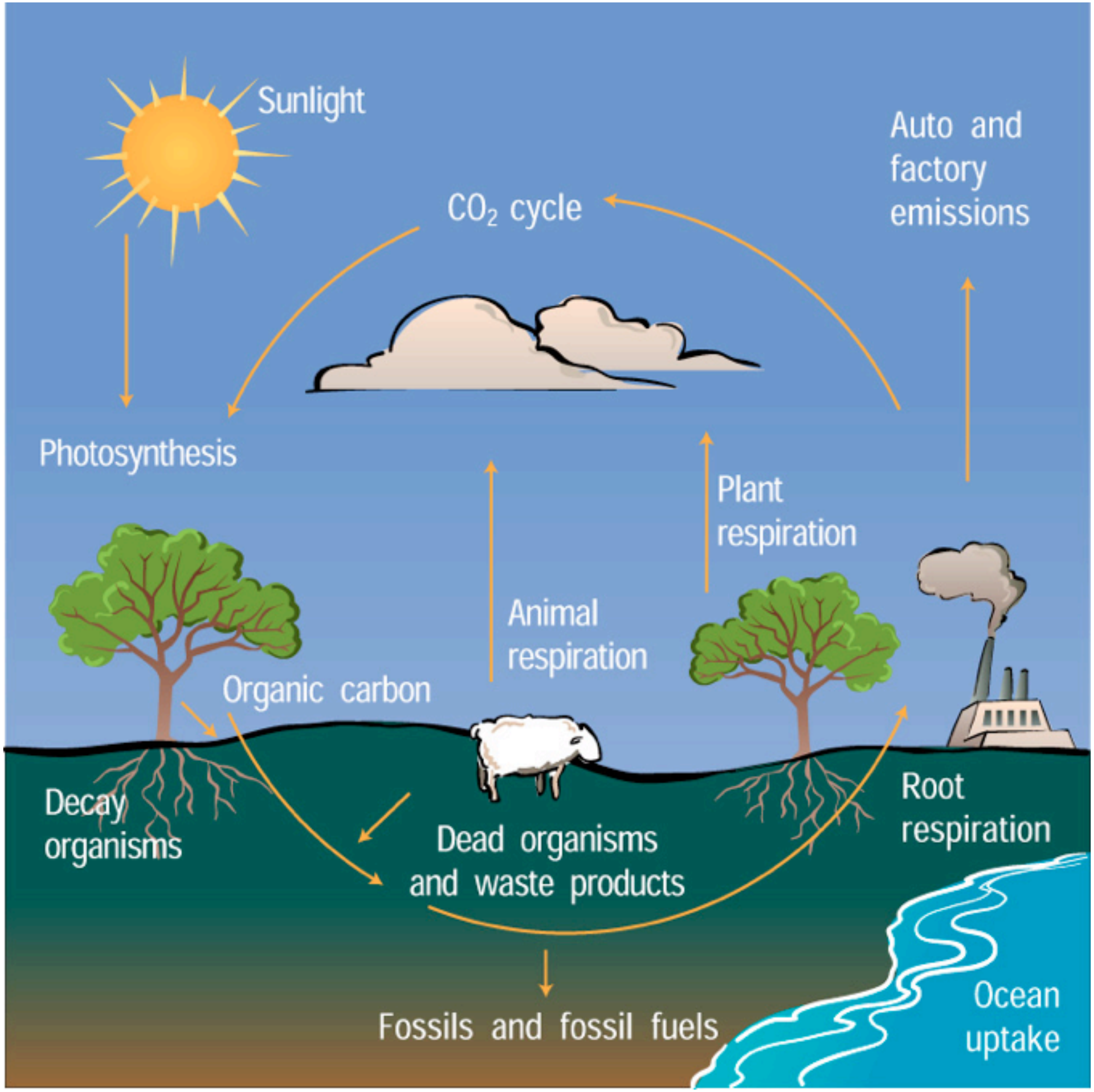
RESERVOIRS

- Rough estimations: 97% in oceans, 2% in glaciers and ice caps, 1% in rivers and lakes

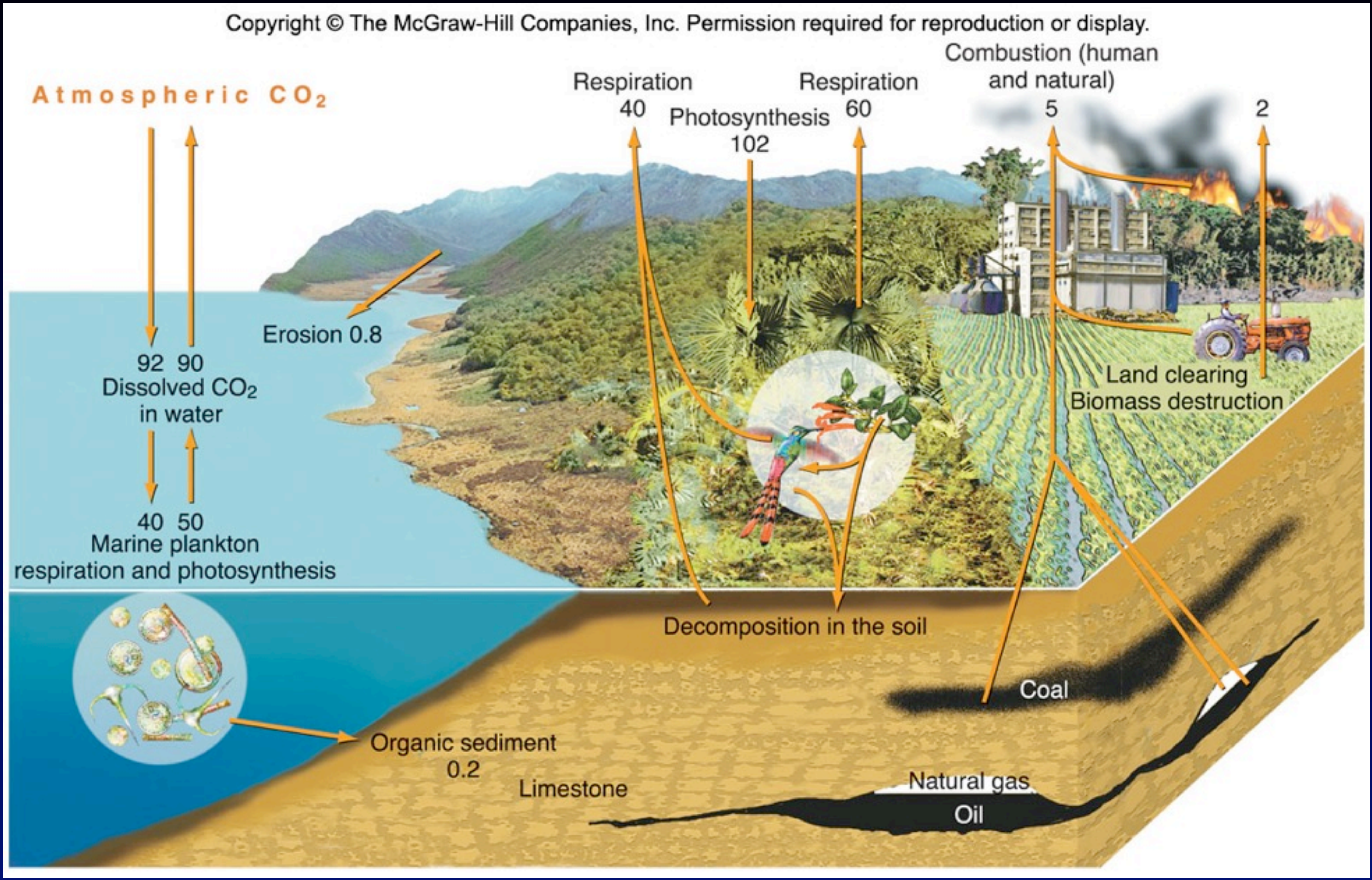
KEY PROCESSES

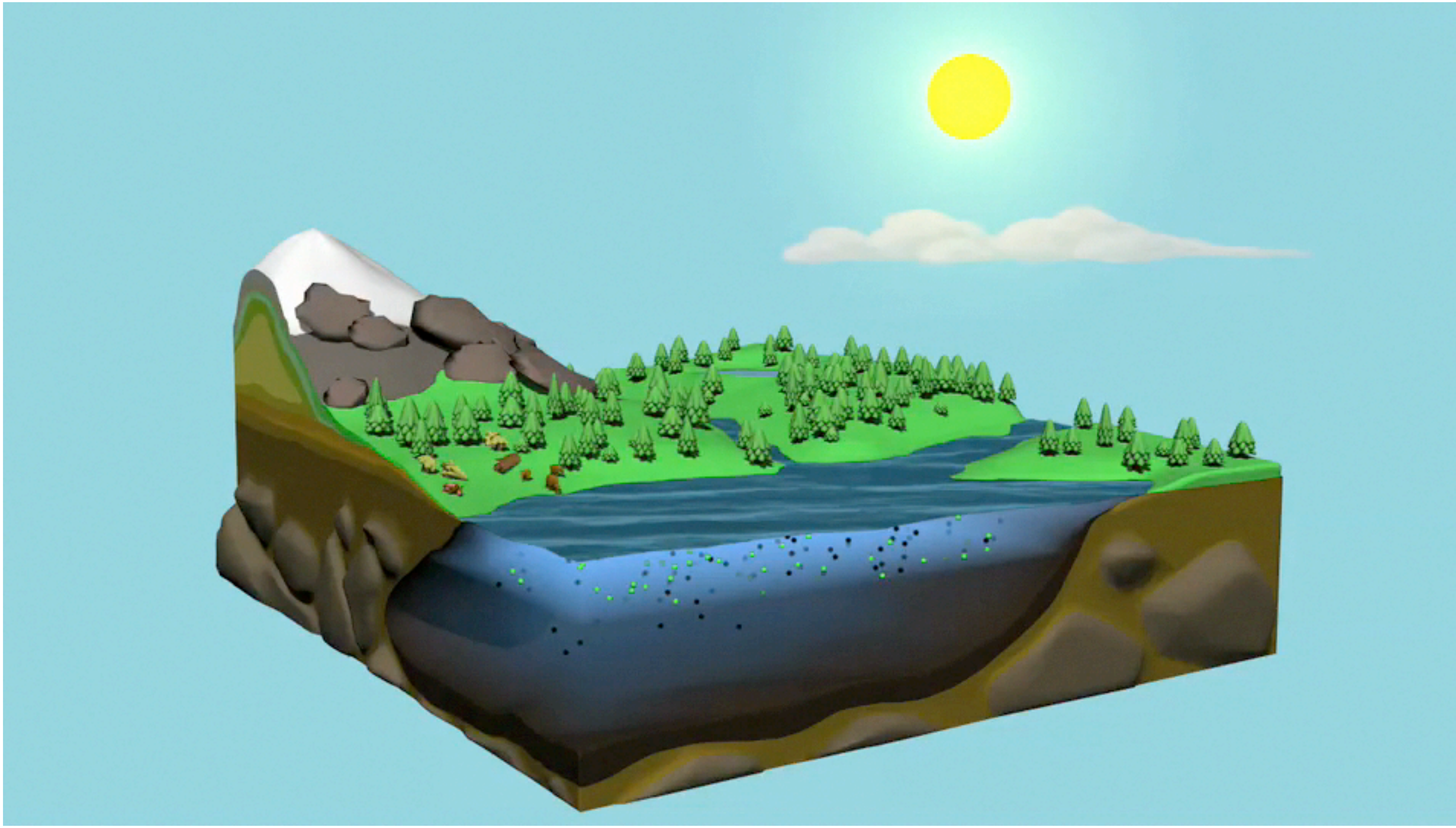
- Evaporation, Condensation and Precipitation

CARBON CYCLE



Carbon Cycle





BIOLOGICAL IMPORTANCE

- Carbon is the backbone of all organic compounds essential for life.

FORMS AVAILABLE TO LIFE

- CO_2 used by autotrophs, many other organic forms used by the rest of life.

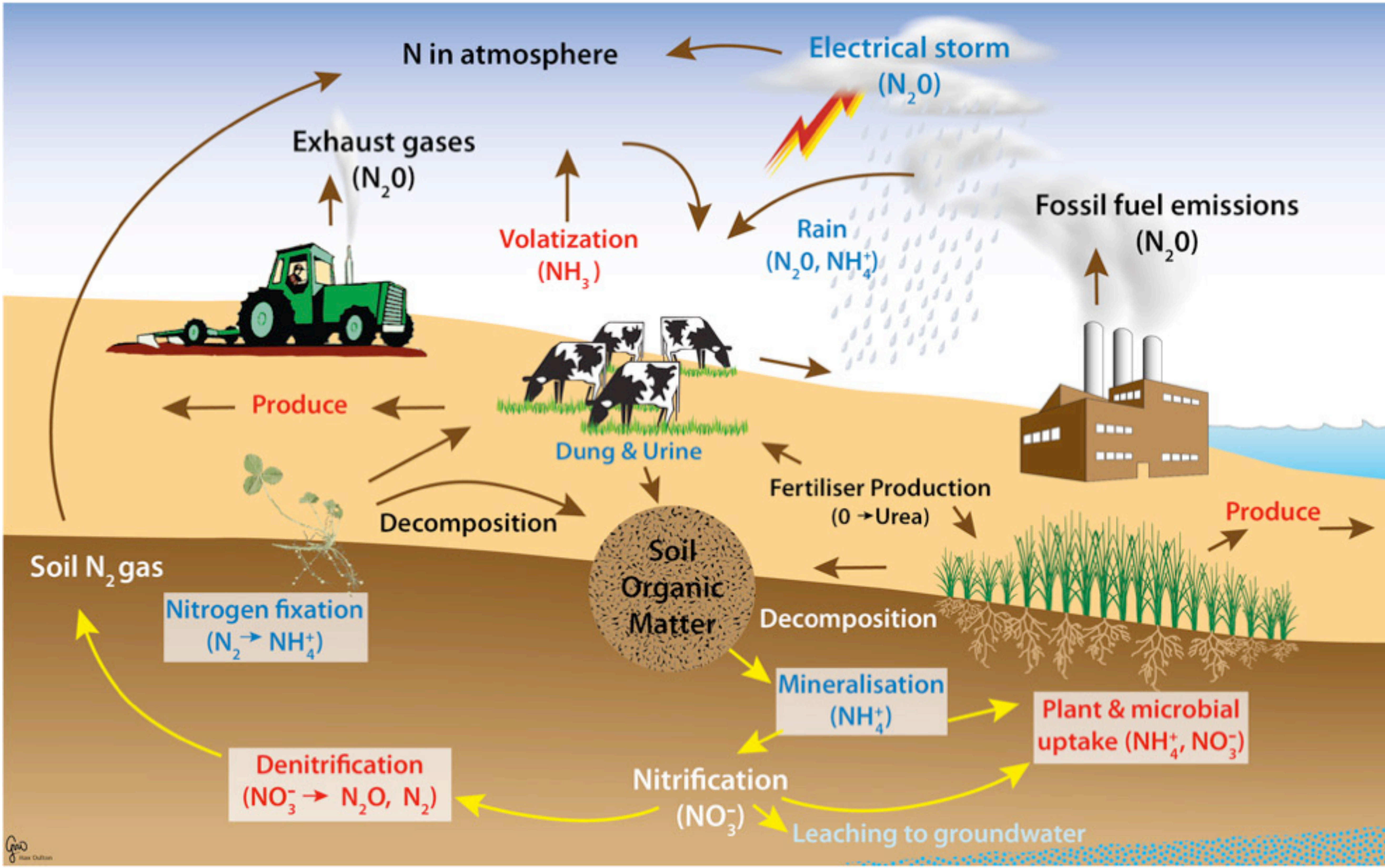
RESERVOIRS

- Fossil fuels, sediments of aquatic ecosystems, dissolved carbon in oceans, plant/animal biomass, atmosphere, sedimentary rocks (the largest)

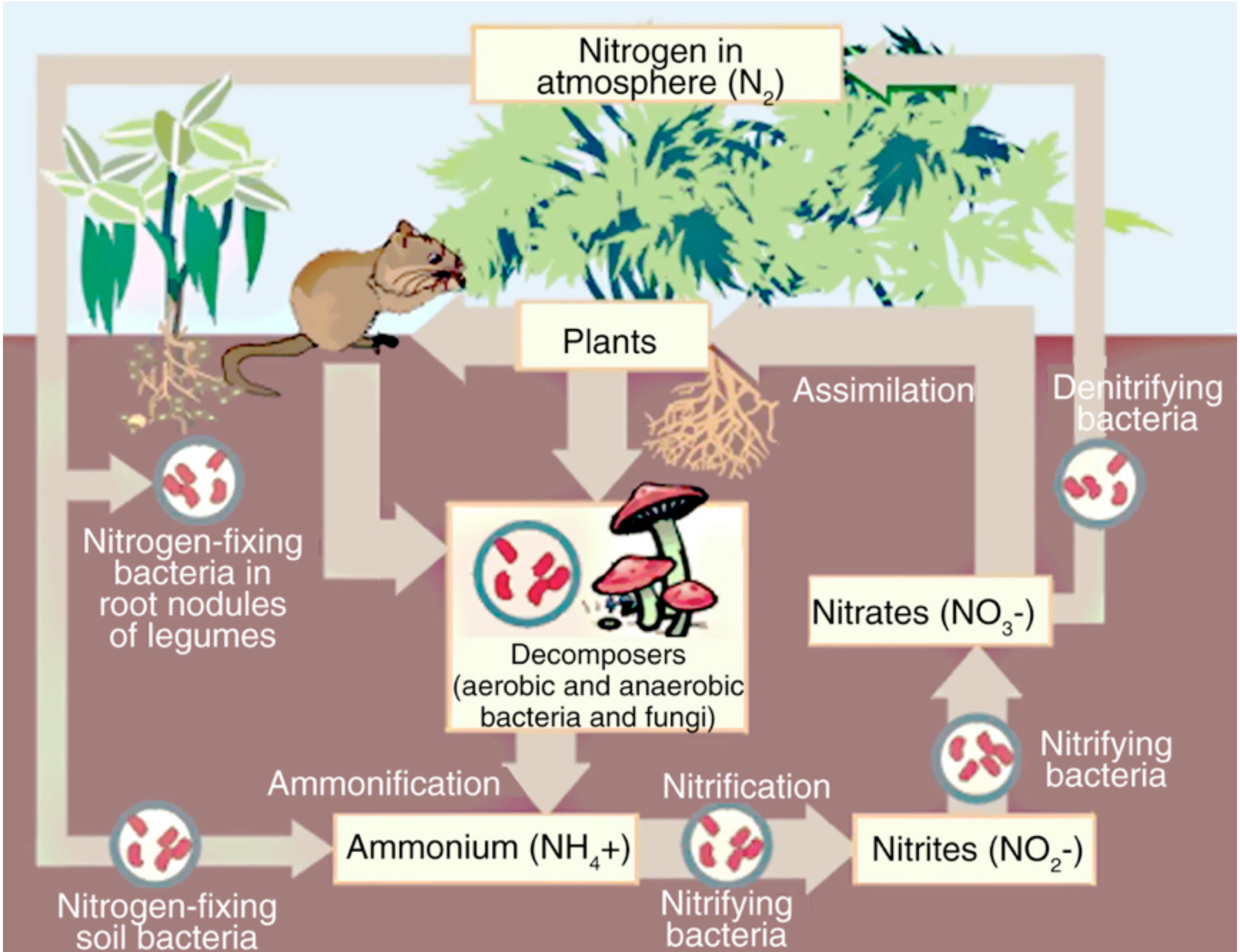
KEY PROCESSES

- Mainly photosynthesis and cellular respiration, burning of fossil fuels, volcanoes

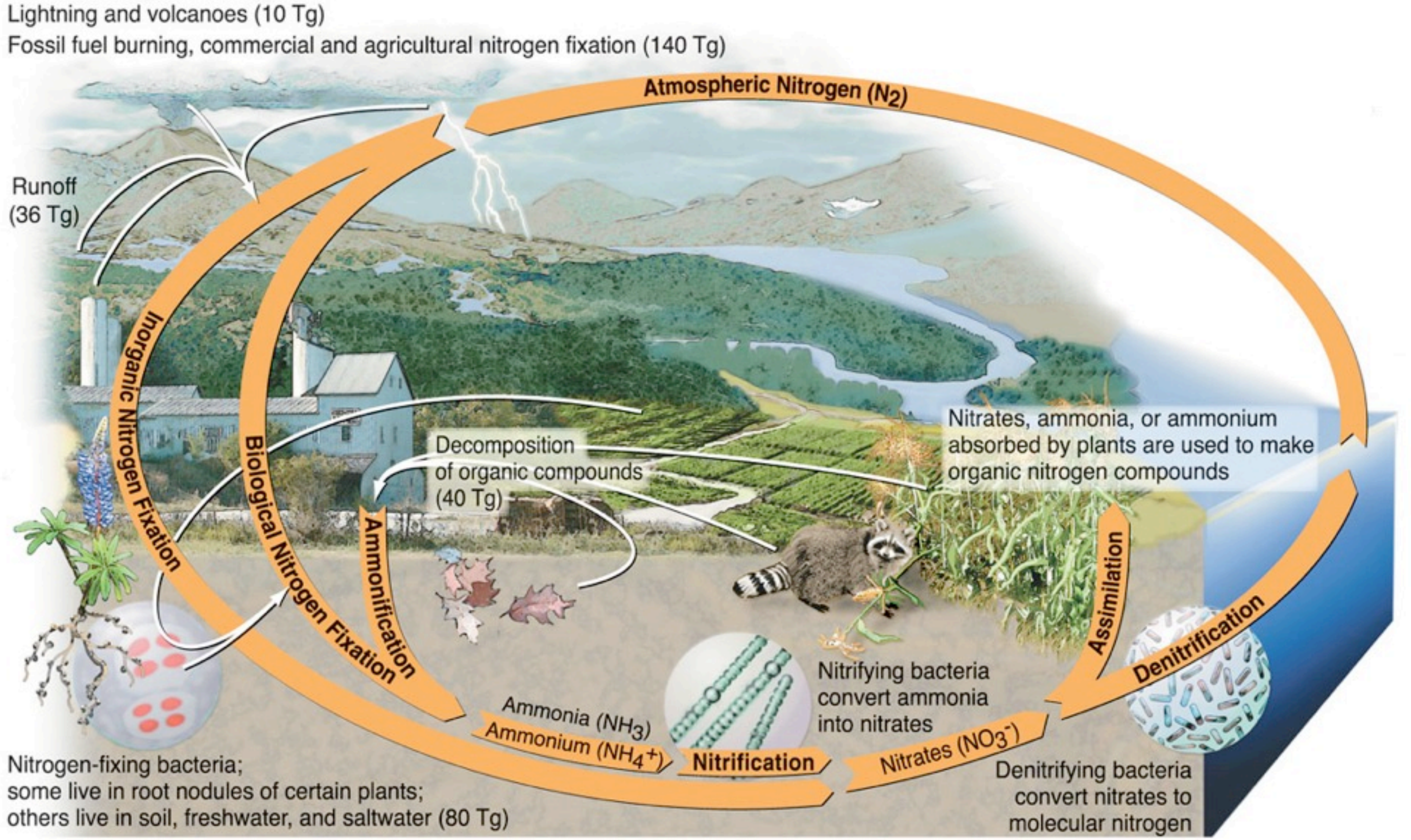
NITROGEN CYCLE (abiotic +)



NITROGEN CYCLE (biotic focus)



Nitrogen Cycle



BIOLOGICAL IMPORTANCE

- Nitrogen is an important part of proteins and nucleic acids.

FORMS AVAILABLE TO LIFE

- Bacteria can use ammonium (NH_4^+), nitrates (NO_3^-), nitrites (NO_2^-) and some organic forms. Plants use all of the above except nitrites (NO_2^-). Animals can only use organic forms.

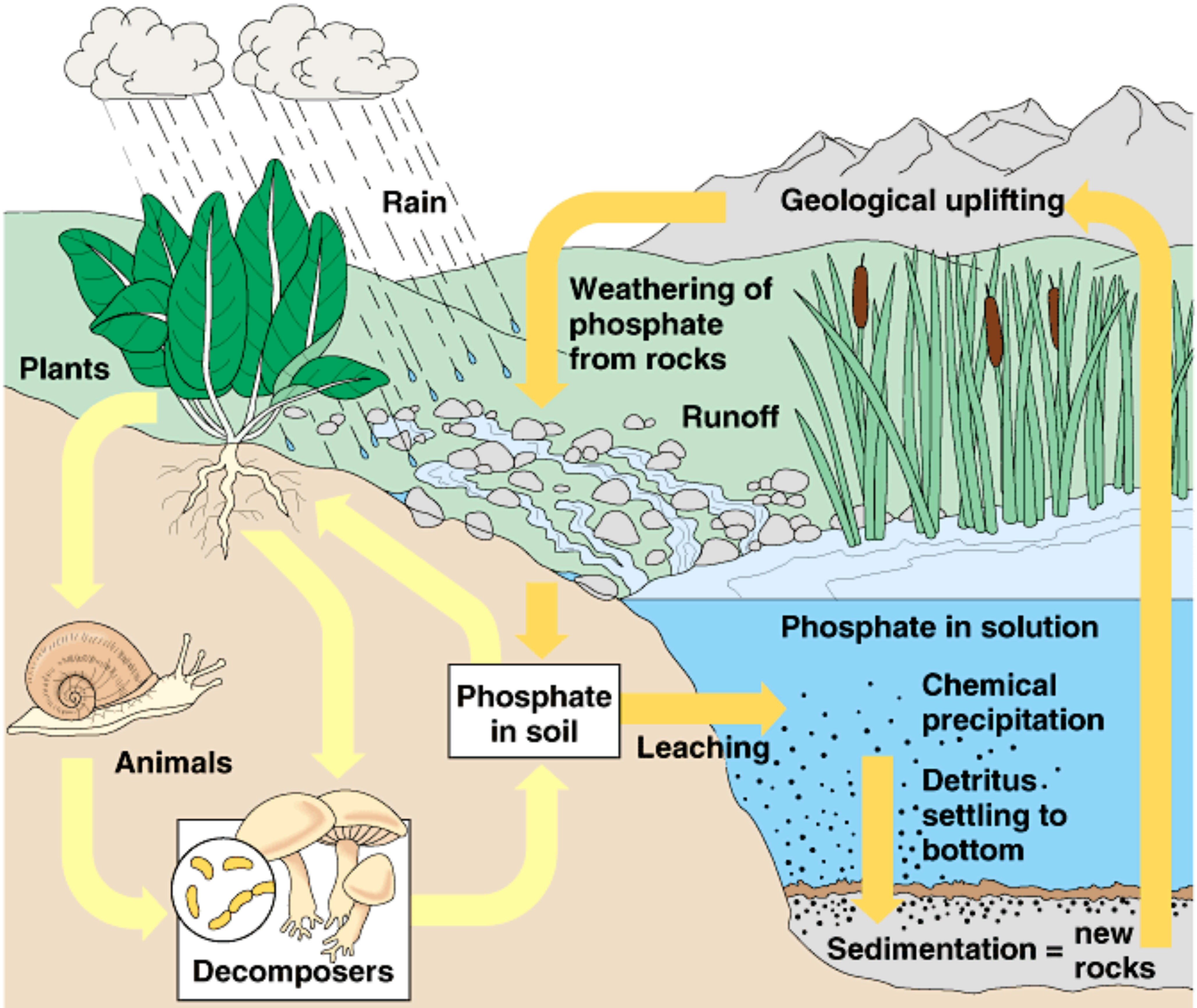
RESERVOIRS

- Atmosphere(the largest), soils, sediments of aquatic ecosystems, dissolved in water and biomass of living organisms

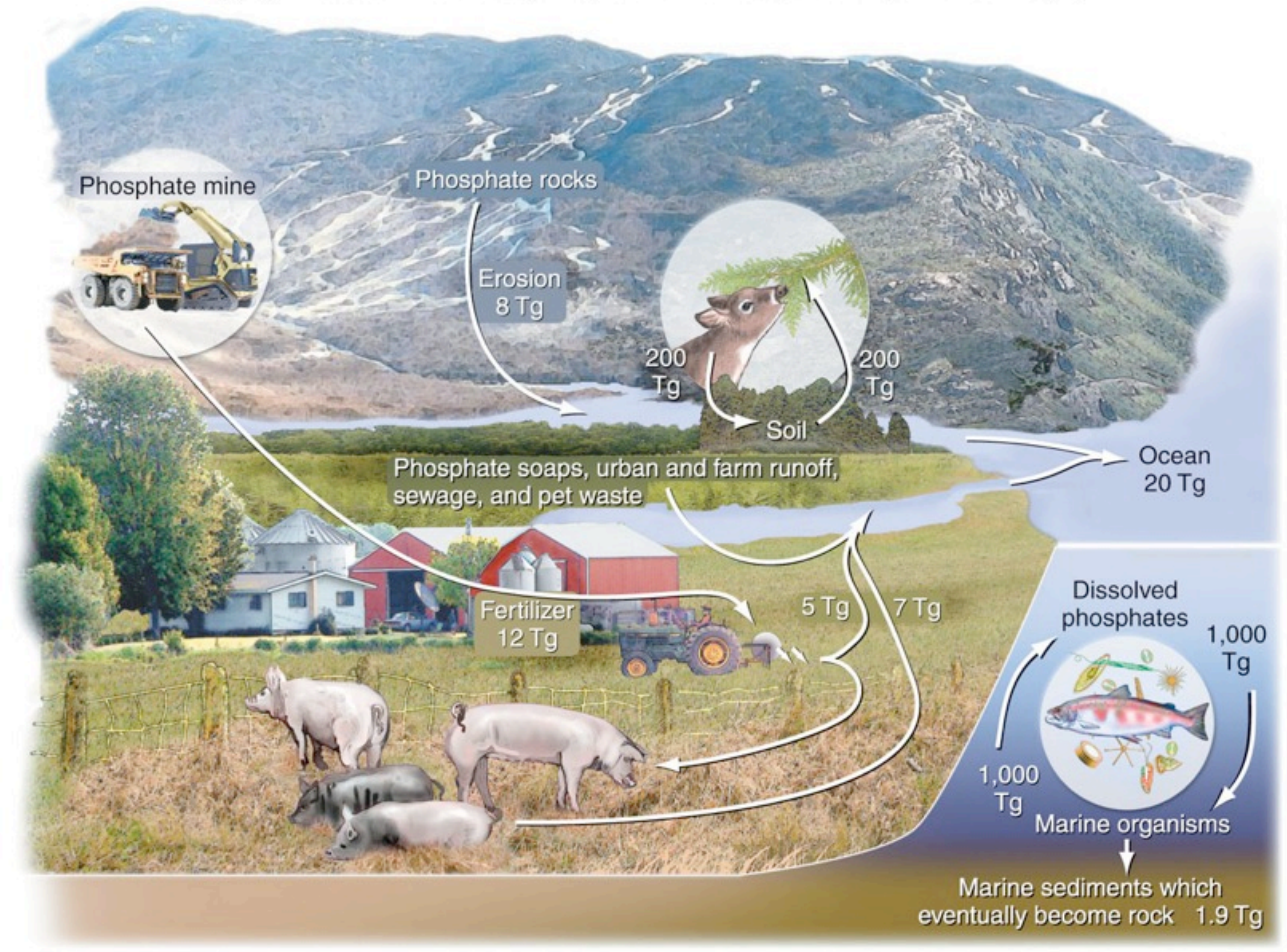
KEY PROCESSES

- Mainly nitrogen fixation, lightning, industrial fertilizers

PHOSPHORUS CYCLE



Phosphorus Cycle



BIOLOGICAL IMPORTANCE

- Phosphorus is an important part of phospholipids (needed to make cell membranes), nucleic acids and ATP. In addition phosphorus is a mineral constituent of bones and teeth.

FORMS AVAILABLE TO LIFE

- Phosphates (PO_4^{3-}) absorbed by plants

RESERVOIRS

- Sedimentary rocks, soil, dissolved in the ocean and in biomass of organisms.

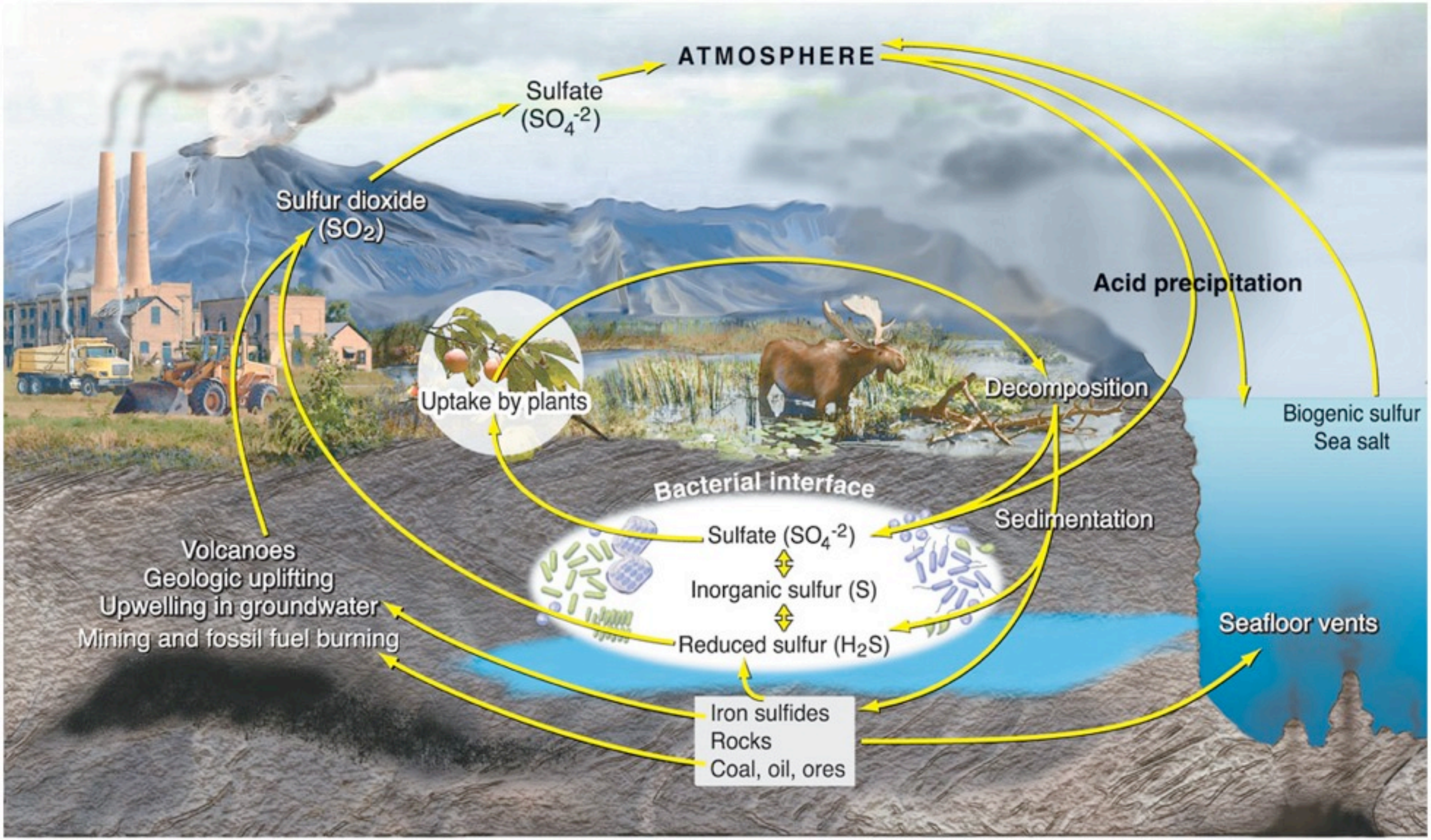
KEY PROCESSES

- Weathering of rocks, leaching form soil, eaten by consumers, excretion by organisms

Sulfur Cycle

- Most sulfur is tied up in underground rocks and minerals. Inorganic sulfur is released into air by weathering and volcanic eruptions.
  - Cycle is complicated by large number of oxidation states the element can assume.
  - Human activities release large amounts of sulfur, primarily by burning fossil fuels.
    - Important determinant in rainfall acidity

Sulfur Cycle



BIOLOGICAL IMPORTANCE

- P

FORMS AVAILABLE TO LIFE

- P

RESERVOIRS

- S

KEY PROCESSES

- W

B. Decomposition & Nutrient Cycle Rates

- Decomposition is ***essential*** for nutrient cycling.
- Decomposition is ***highly variable***, mainly due to differences in rates of decomposition.
- Decomposition is once again ***under the influence of***:
  - *Temperature, Moisture and Nutrient Availability*
    - There is an optimum temperature for decomposition
- Decomposition in aquatic sediments is very slow, these are often sinks of nutrients and only surface in upwellings

What type of curve would you predict if graphed temperature and rates of decomposition?

Which variable belongs on the X axis? Y axis?

Which ecosystem has better (more fertile) soil?

- Decomposition in Tropical Rain Forests occurs rapidly
  - As a result nutrients spend little time in the soil
    - Ironically there soil is low nutrients, about 10% of ecosystems total

- Decomposition in Temperate Forests occurs less rapidly
  - As a result nutrients spend more time in the soil
    - The soil has a moderate amount of nutrients, about 50% of ecosystems total

C. Hubbard Brook Experimental Forest

- Began in 1963, Located in New Hampshire.
- Six small valleys each drained by a creek.
- Normally 60% of water added by rain/snow leaves via the creeks, 40% by evapotranspiration:
- Normally minerals are conserved through recycling

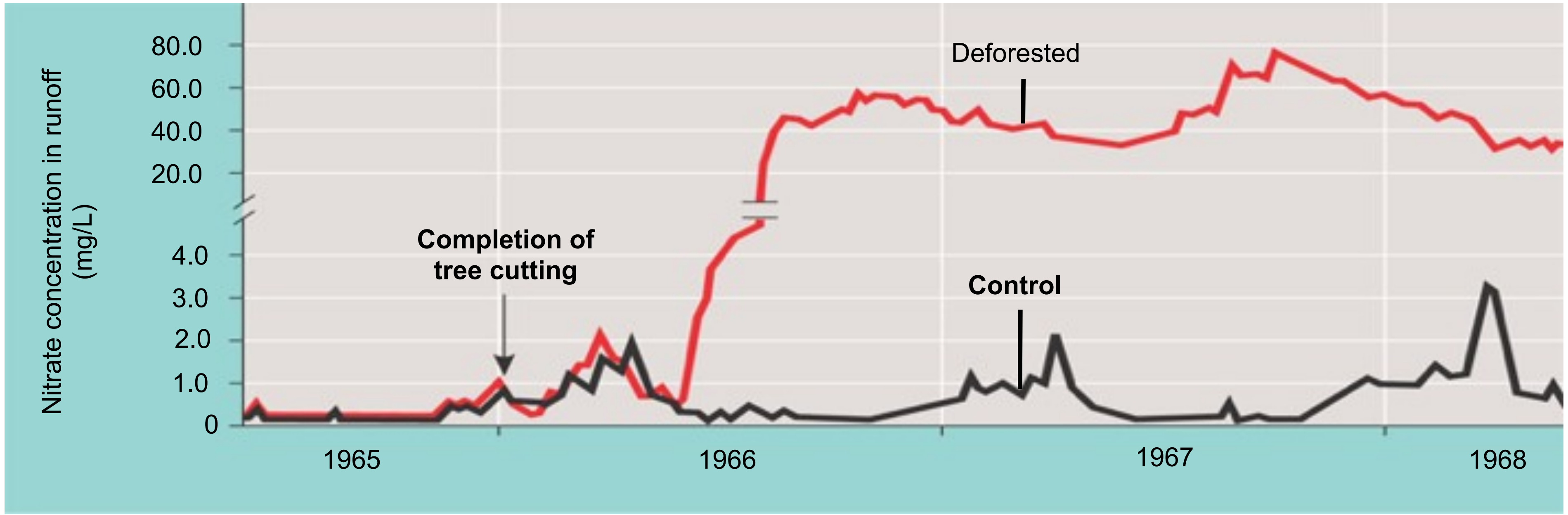
Experimental Deforestation (3 year period)

- Deforested watershed showed a 30-40% greater water loss.
- Concentration of minerals in the creek also increased.
  - Calcium(4X increase), Potassium(15X), Nitrates(60X)
- Plants apparently control the loss of nutrients in forests

Can you explain these results?

Concrete dams and weirs built across streams at the bottom of watersheds enabled researchers to monitor the outflow of water and nutrients from the ecosystem.

One watershed was clear cut to study the effects of the loss of vegetation on drainage and nutrient cycling.



The concentration of nitrate in runoff from the deforested watershed was 60 times greater than in a control (unlogged) watershed.

(55) Ecosystems

V.

Main Idea: Environmental damage is somewhat reversible, ecosystems appear to be resilient.

Main Idea: It usually takes a long time for ecosystems to recover from degradation and they are not infinitely resilient.

RESTORATION ECOLOGISTS HELP RETURN DEGRADED ECOSYSTEMS TO A MORE NATURAL STATE

A. Bioremediation

- Bioremediation- using organisms (bacteria, fungi or plants) to detoxify polluted ecosystems
- Some plants and lichens can extract and accumulate potentially toxic heavy metals (uranium, cadmium, lead, zinc, nickel) from the soil
  - This can be helpful in cleaning up old mining sites
  - *Shewanella oneidenis* bacteria can convert soluble uranium into insoluble forms

B. Biological Augmentation

- <u>Biological Augmentation</u>- uses organisms to add essential materials to a degraded ecosystem.
- Ecologists can use either plants and/or animals to speed up succession and recovery
  - Lupines have been used in the western United States to increase nitrogen concentration in the soil.
  - Mycorrhizal symbionts were added to the soil of the tall grass prairies of Minnesota to restore the soil.


Lupines

C. Global Restoration Projects

- A very new discipline that is steadily evolving.
- Even still many success stories exist today


Kissimmee River Restoration
Channel built to combat flooding instead it increased pollution, decreased biodiversity and caused lakes to nearly dry up.

Maungatautari, New Zealand

Ducktown, Tennesee 1965

Ducktown, Tennesee 2009

Stop and Think

Some plants produce energetically expensive secondary compounds. These molecules help them in some particular way (perhaps it is poison to ward off herbivores) but these compounds are not necessary for essential life functions. Will the plants production efficiency be effected? Explain.

Why is logging in Tropical Rainforests potentially more harmful than logging in Boreal or Temperate Forests?