Biology

Ecosystems

PCHS Standard 1
Objectives 1 and 2

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

- **2 Fundamental Processes of Ecosystems**:
  - Energy Flow and Chemical Cycling.

Conservation of Energy

- **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.
- **First Law of Thermodynamics**: energy can not be created nor destroyed...only transferred and transformed.

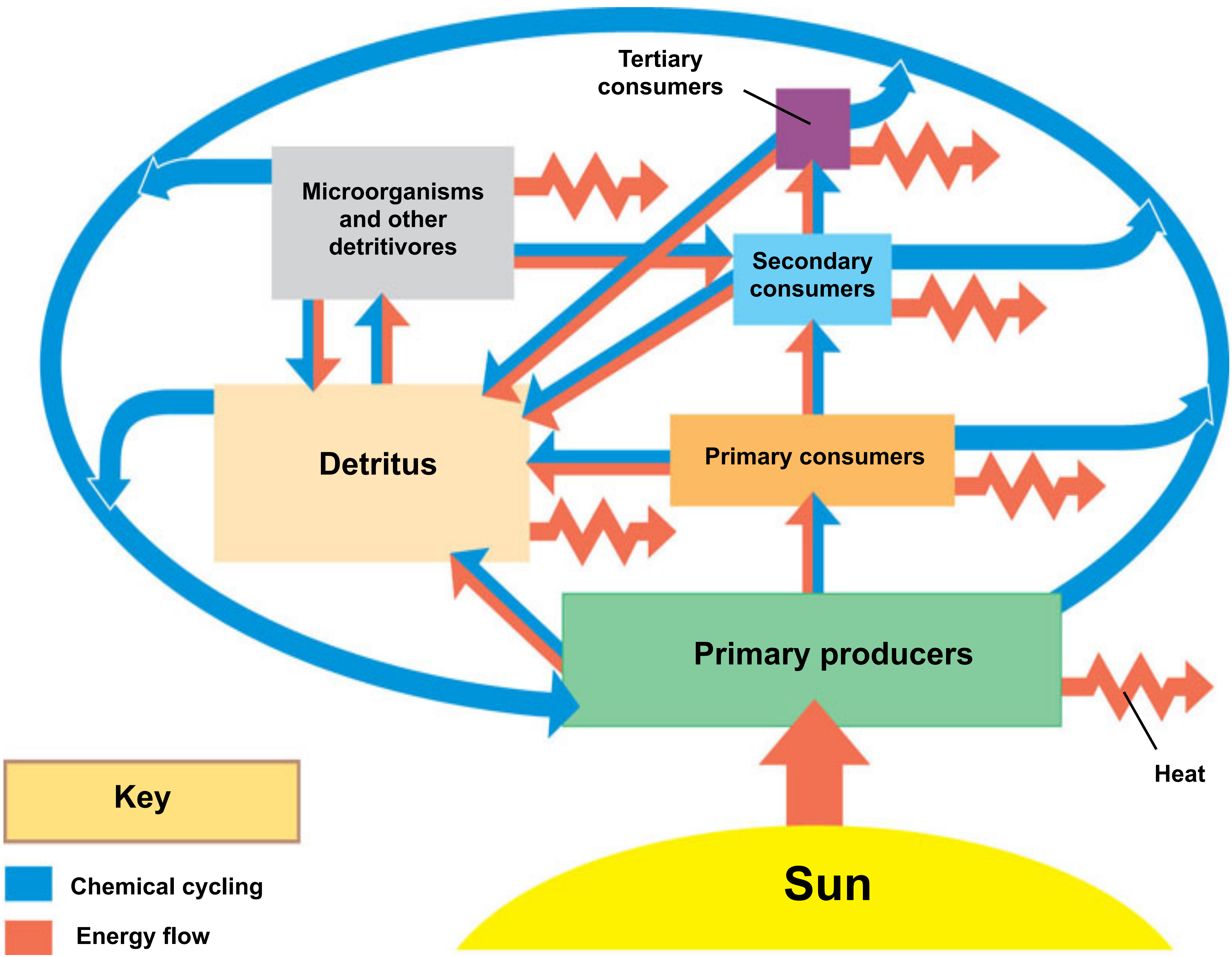
- **Second Law of Thermodynamics**: energy exchanges (transfers and transformations) increase the entropy of the universe. In other words energy exchanges are inefficient some energy is always lost as heat
    - Remember energy is passing through food chains.
    - As chemical energy is passing through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

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.

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.


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 Fungi and Bacteria

- They play a critical role in recycling matter...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

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

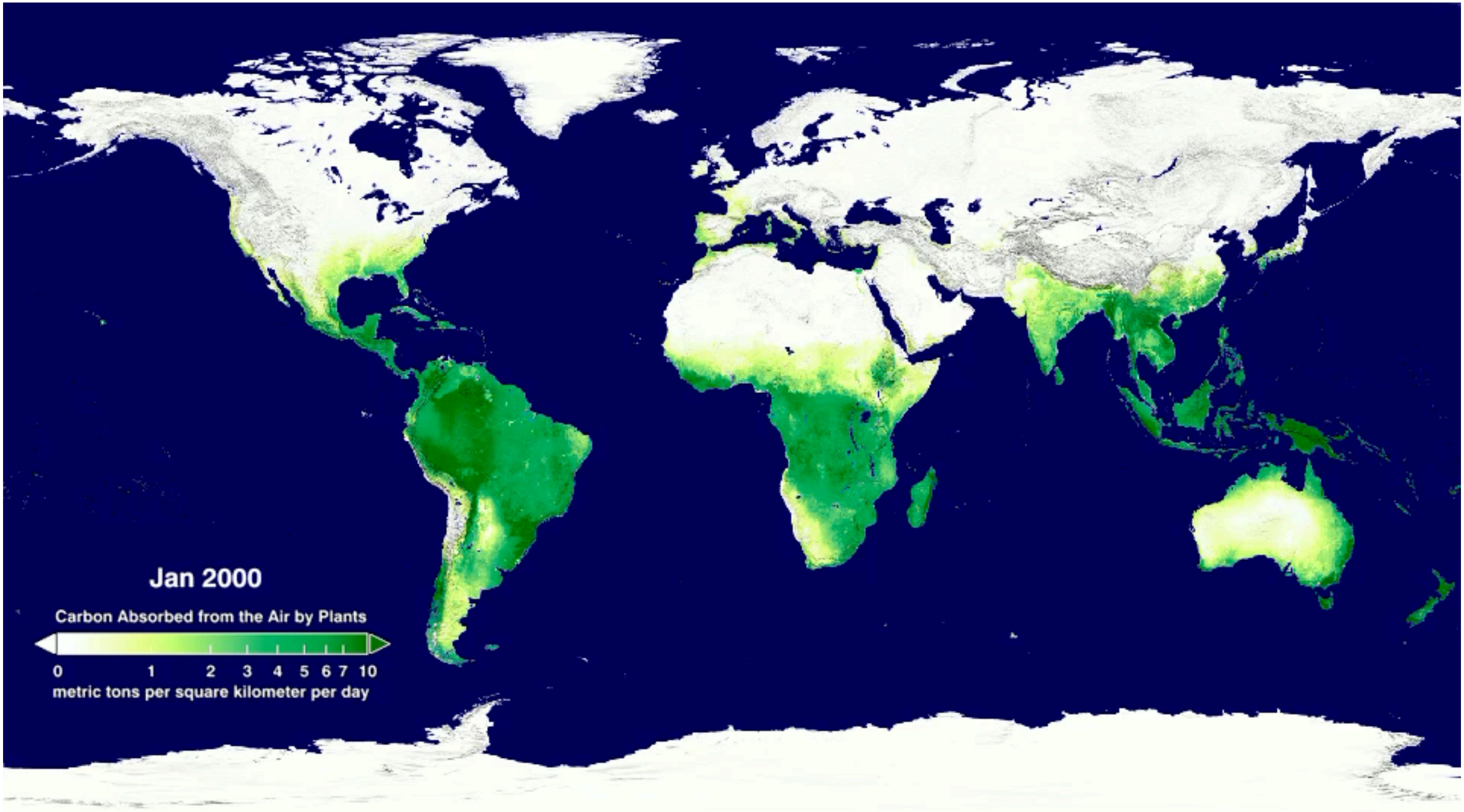
- **Primary production** is the amount of light energy converted to chemical energy in a given period of time
- The amount of light energy converted to chemical energy by autotrophs effects the amount of heterotrophs it can support in higher trophic levels.
- **Energy transfer is a major theme in biology,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

Ecosystem Energy Budgets

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.

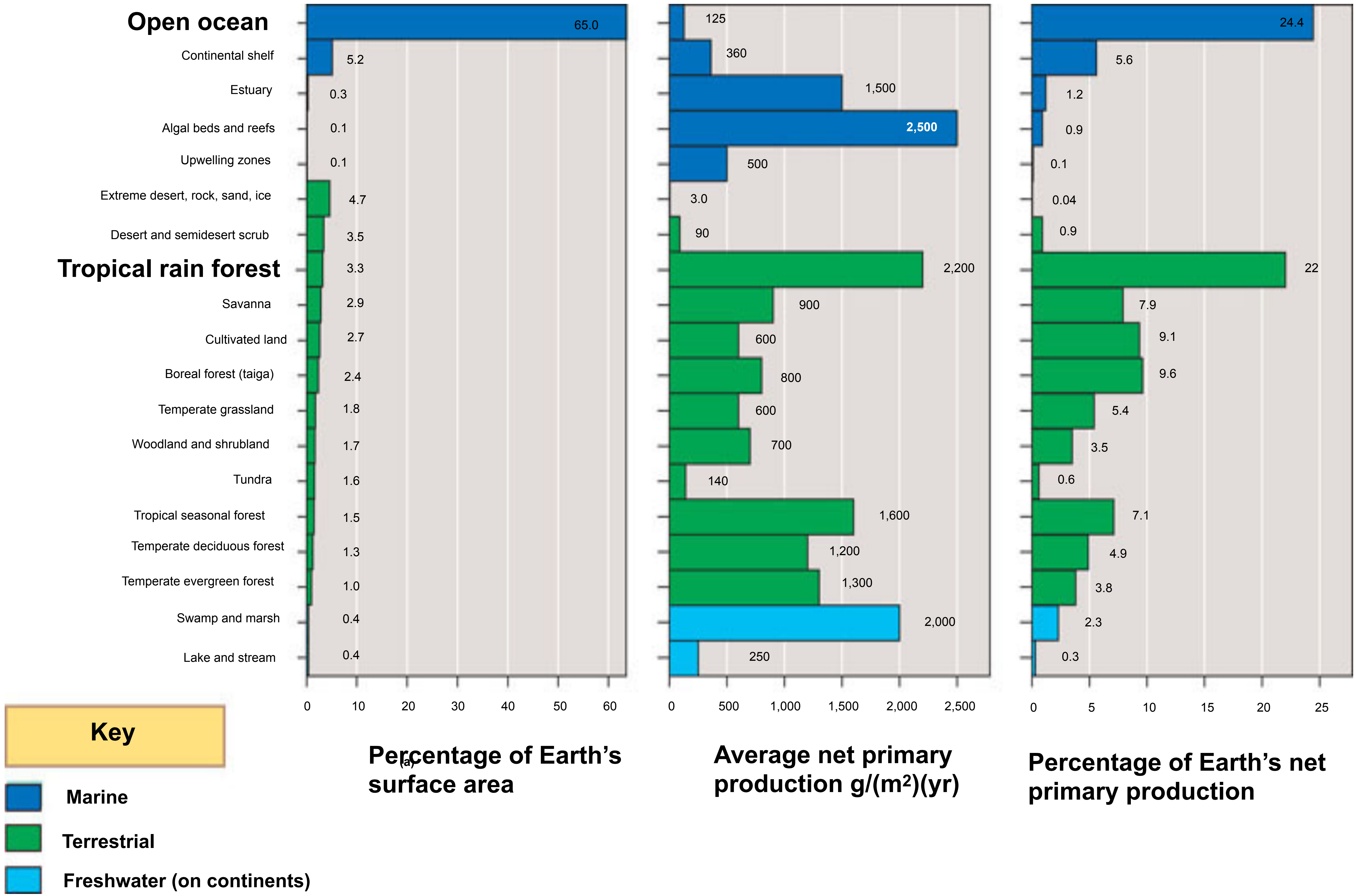
- **Gross Primary Production (GPP)** is the total amount of solar energy converted to chemical energy



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.

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.
    - $NPP = GPP - R_a$
        - Think of R_a as the energy that plants use to "run themselves" whatever energy is leftover can be used by the plant to add new biomass (grow)
            - This new biomass contains the chemical energy for heterotrophs


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
0 10 20 30 40 50 60
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
0 500 1,000 1,500 2,000 2,500
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
0 5 10 15 20 25
Percentage of Earth's net primary production
Key
Marine
Terrestrial
Freshwater (on continents)

Primary Production in Aquatic Ecosystems

1. Light Limitations

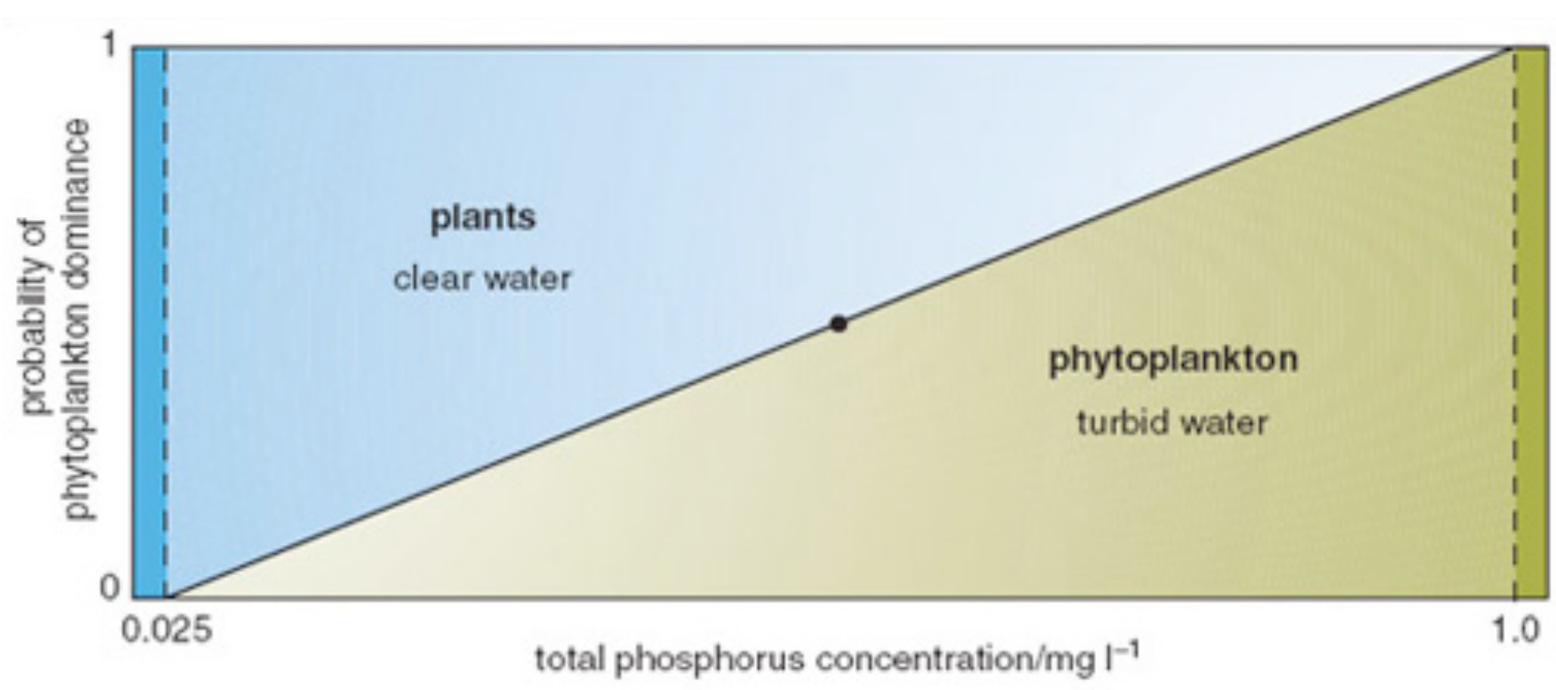
- Light is the obvious choice as limiting factor.
- After all more than half of the solar radiation is absorbed in the first 15 meters of water.
- *Light is very important however it does not appear to be the key limiting factor in aquatic ecosystems!*

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?

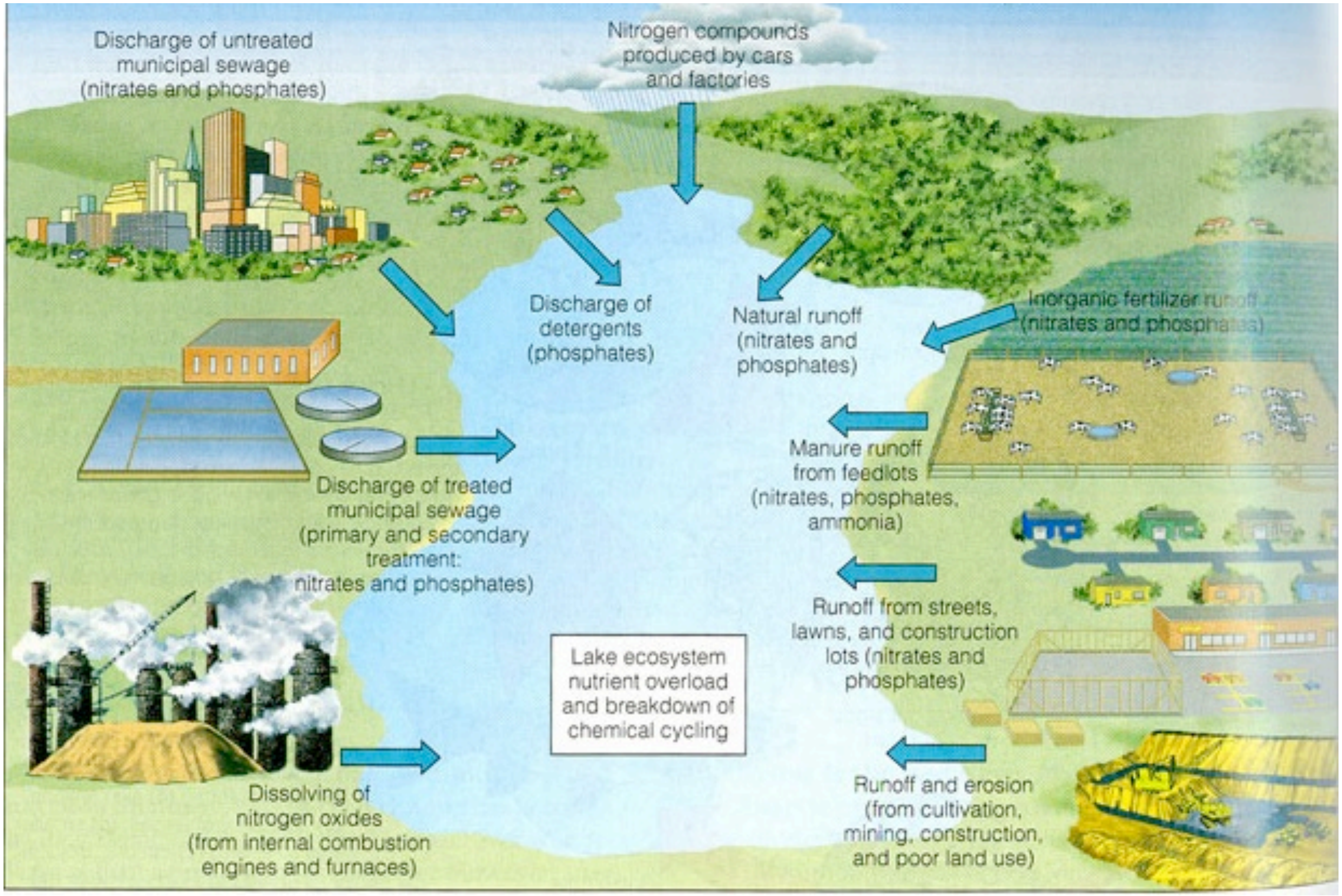
2. Nutrient Limitations

- *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.
  - *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.*

Increase in Phosphorous can cause Eutrophication



Cultural Eutrophication



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.

Ecosystems

III.

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

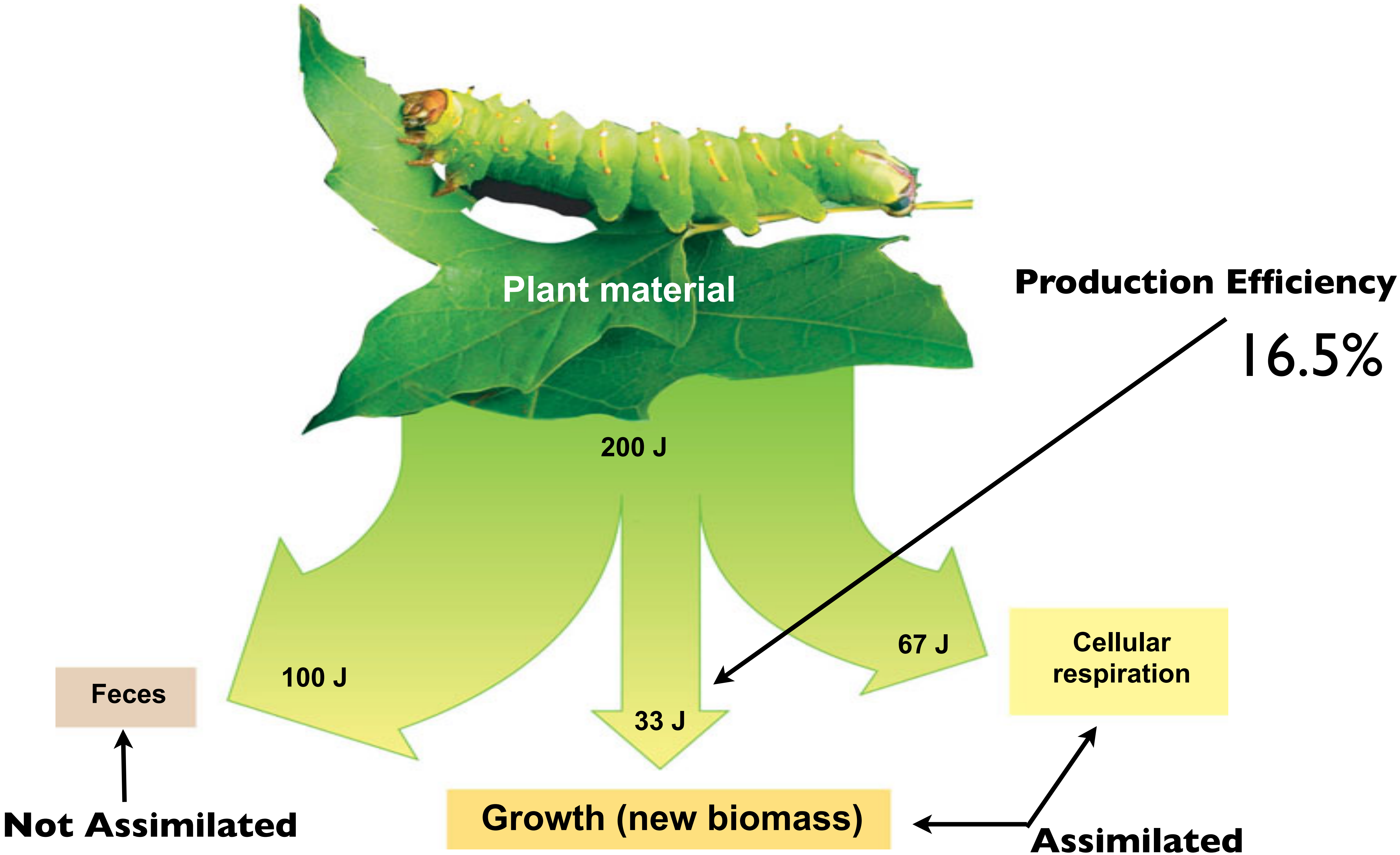
ENERGY TRANSFER BETWEEN TROPHIC LEVELS IS TYPICALLY AROUND 10% (WITH 90% LOST)

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

Production Efficiency

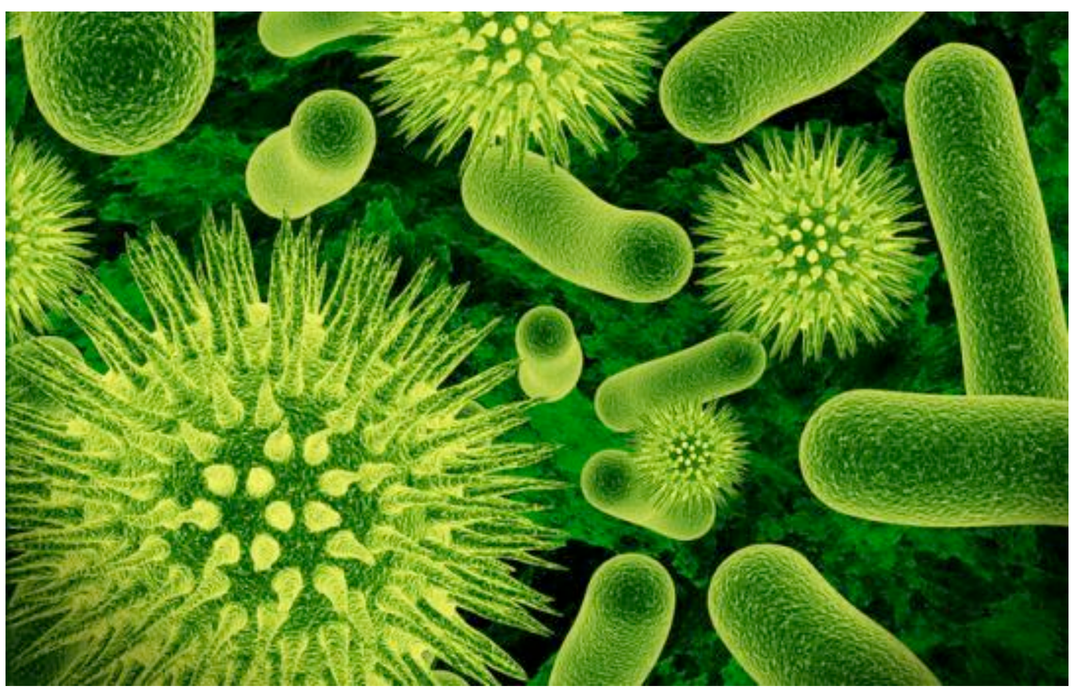
- **Think about it...** only the chemical energy stored by herbivores is in their biomass (either in their own biomass or the biomass of their offspring)
  This is only energy available to secondary consumers!

- We can measure production efficiency.


Plant material
200 J
Production Efficiency
16.5%
Feces
100 J
33 J
67 J
Cellular respiration
Growth (new biomass)
Not Assimilated
Assimilated

Match the pictures with their production efficiencies.





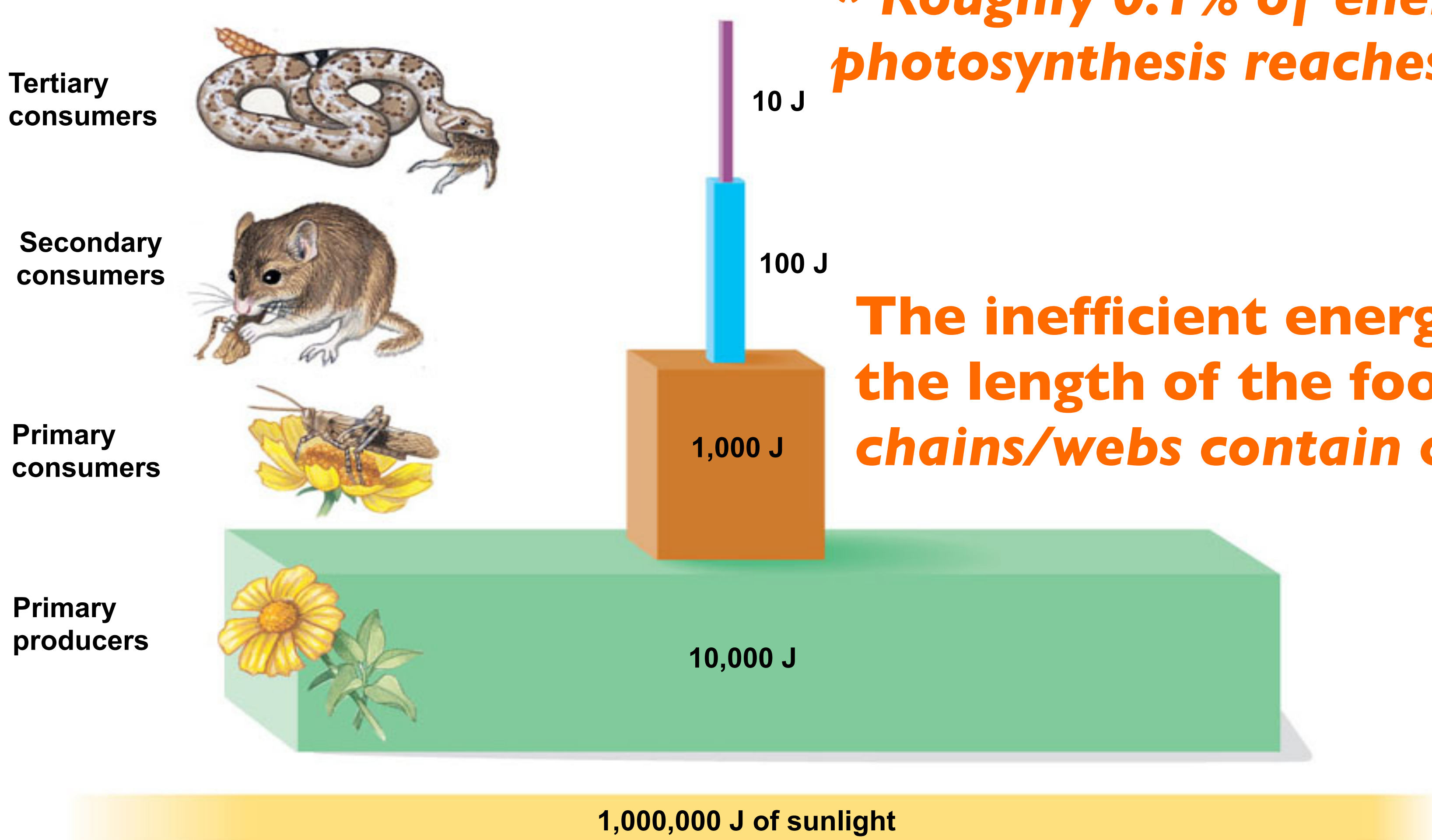

1-3%
1-3%
10%
40%
90%

Explain your choices.

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

Trophic Efficiency & Ecological Pyramids

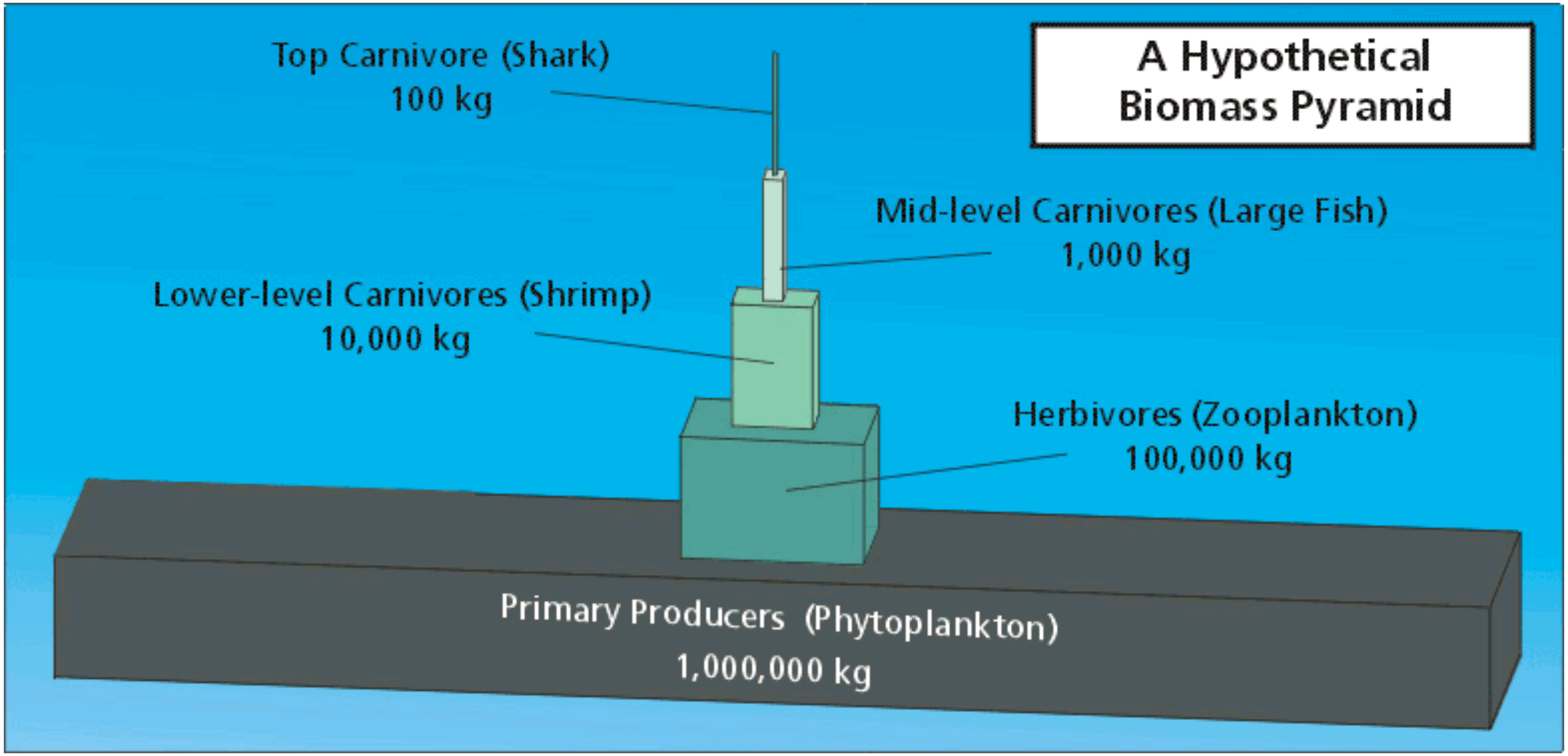
- **Trophic Efficiency**, the percent of production transferred one trophic level to the next. (Ranges between 5-20%)
  - Trophic efficiency must be less than production efficiency.



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

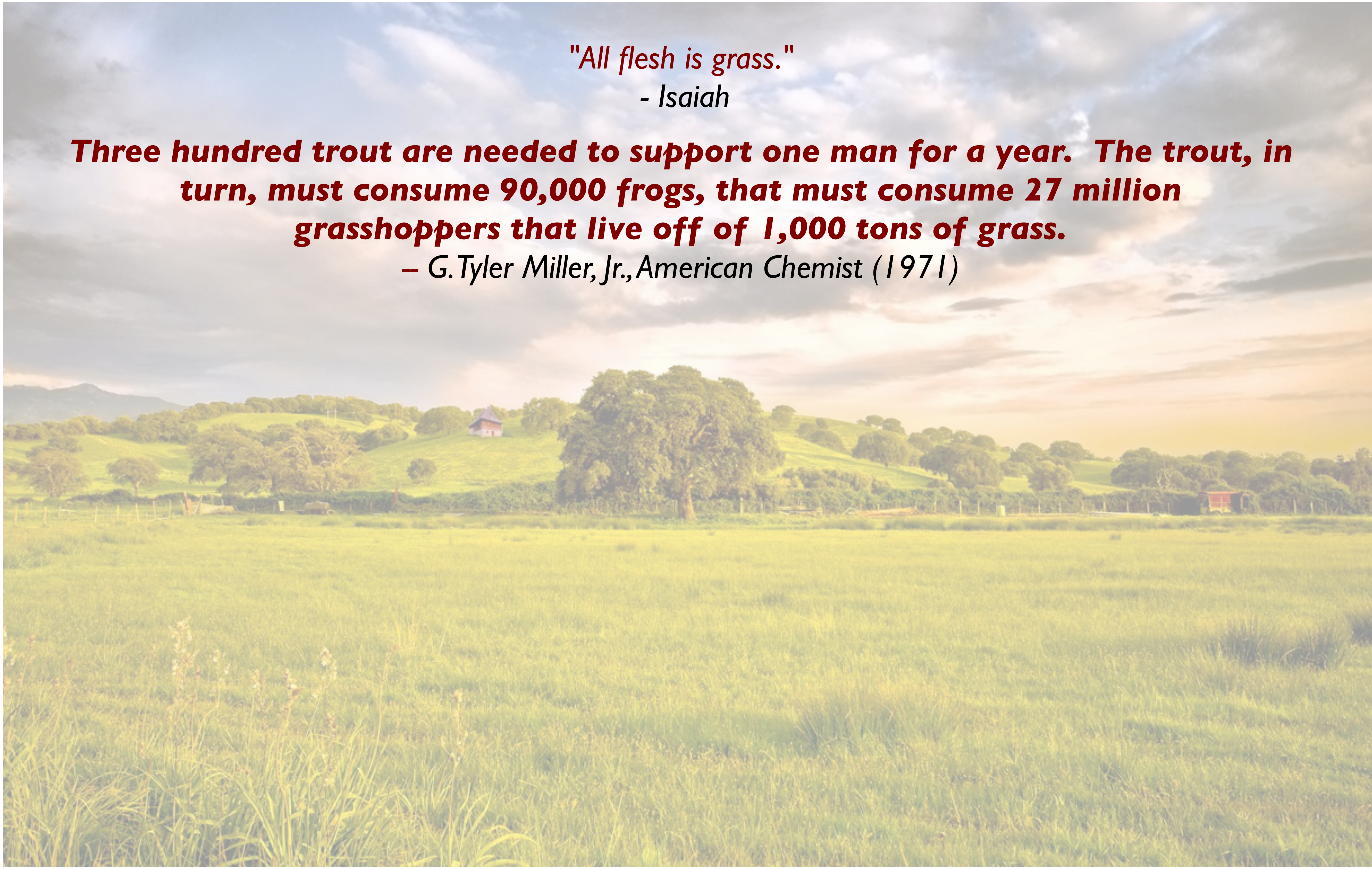
The inefficient energy transfer is multiplied over the length of the food chain. *Thus most food chains/webs contain only 4 or 5 trophic levels.*

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?



"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)

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*.

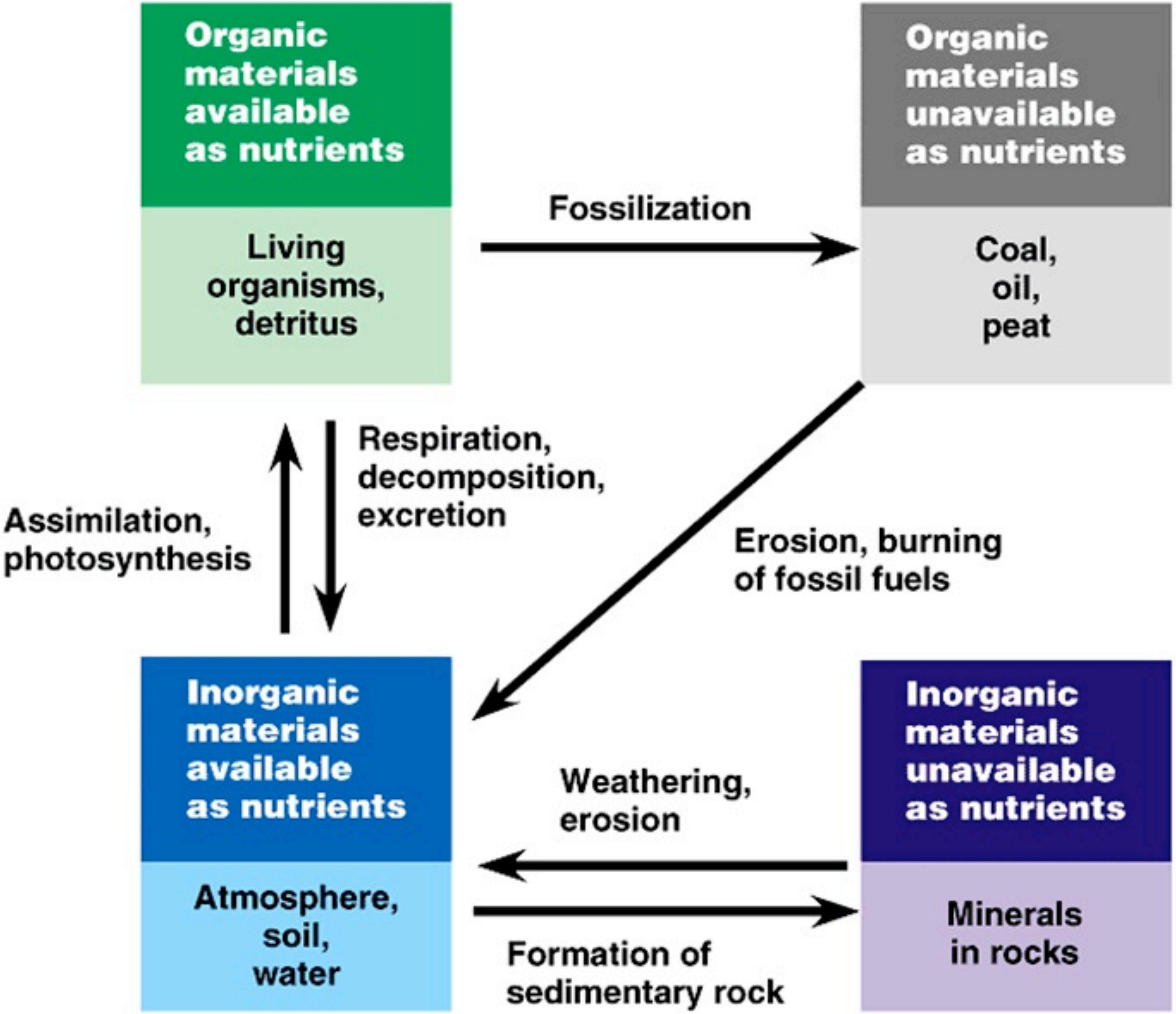
Biogeochemical Cycles

- These cycles occur on both on a local and 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

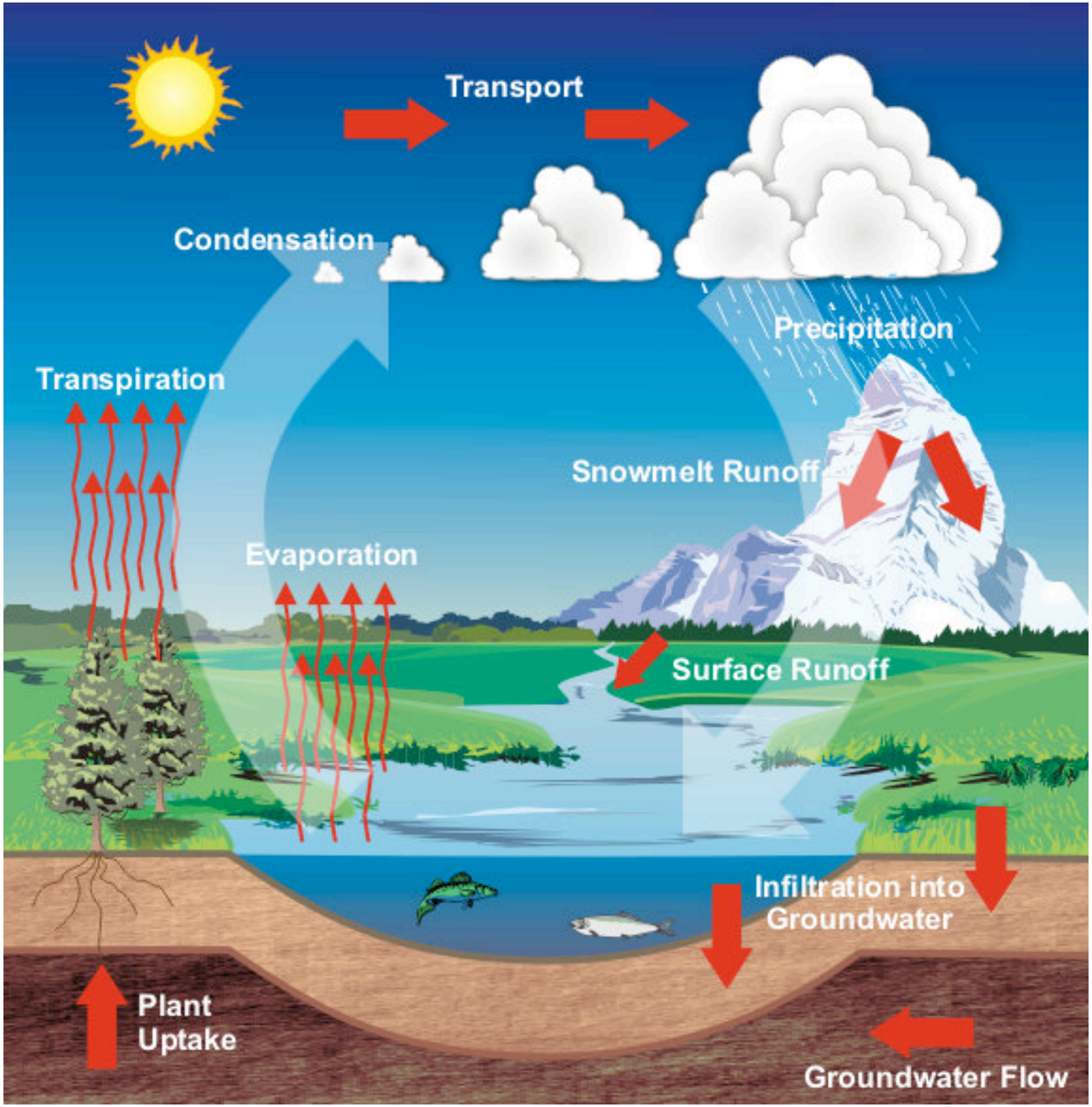
- Reservoirs.
  - Atmosphere
  - Hydrosphere
  - Lithosphere
  - Biosphere

- Chemicals in these reservoirs have different average storage times
  - Long in lithosphere (rocks)
  - Short in the atmosphere
  - Intermediate in the hydrosphere and biosphere



Can you match these reservoirs using the terms on the previous slide?

WATER CYCLE


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

BIOLOGICAL IMPORTANCE

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

FORMS AVAILABLE TO LIFE

- Mainly liquid water

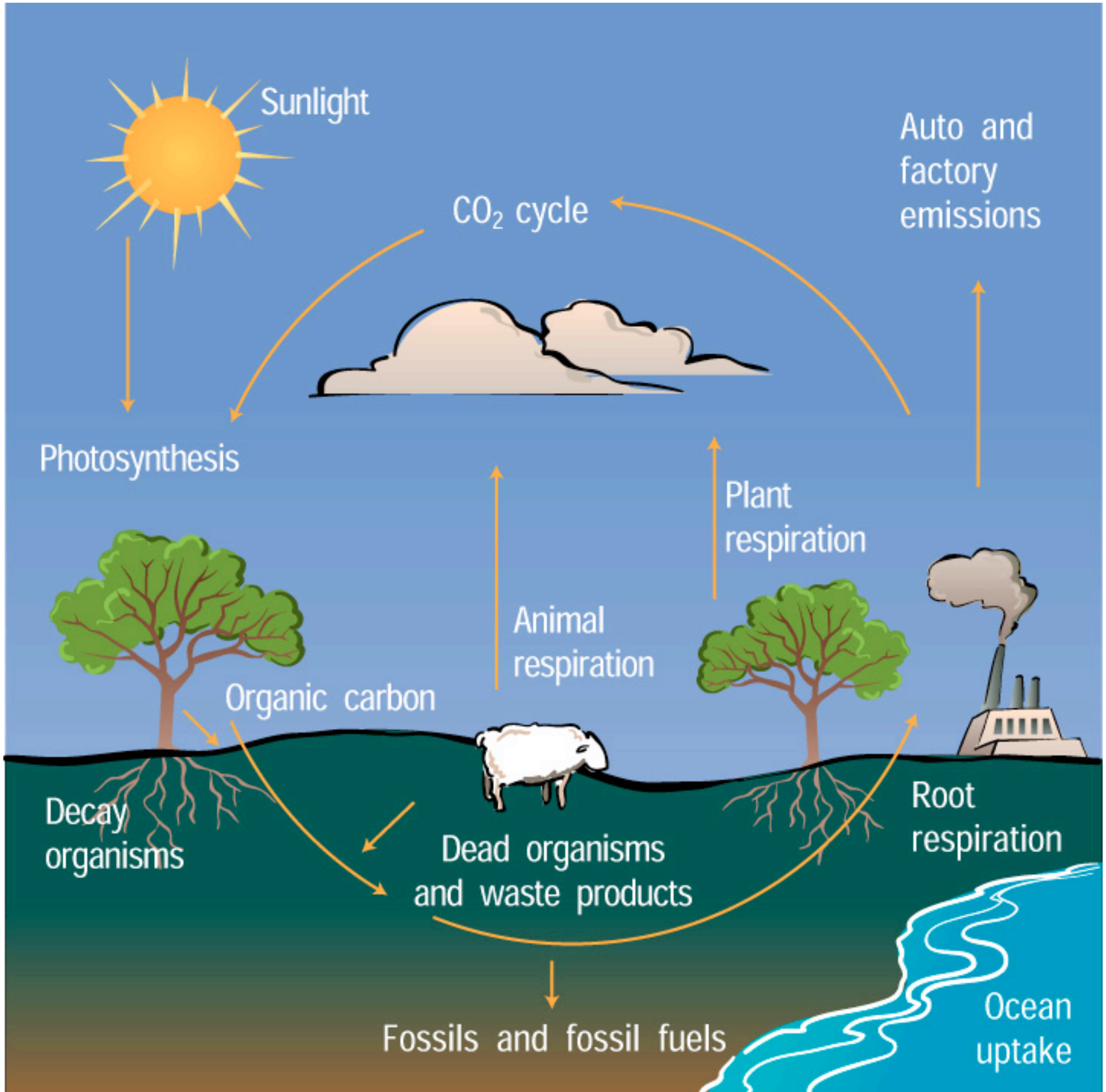
RESERVOIRS

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

KEY PROCESSES

- Evaporation, Condensation and Precipitation

CARBON CYCLE



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.

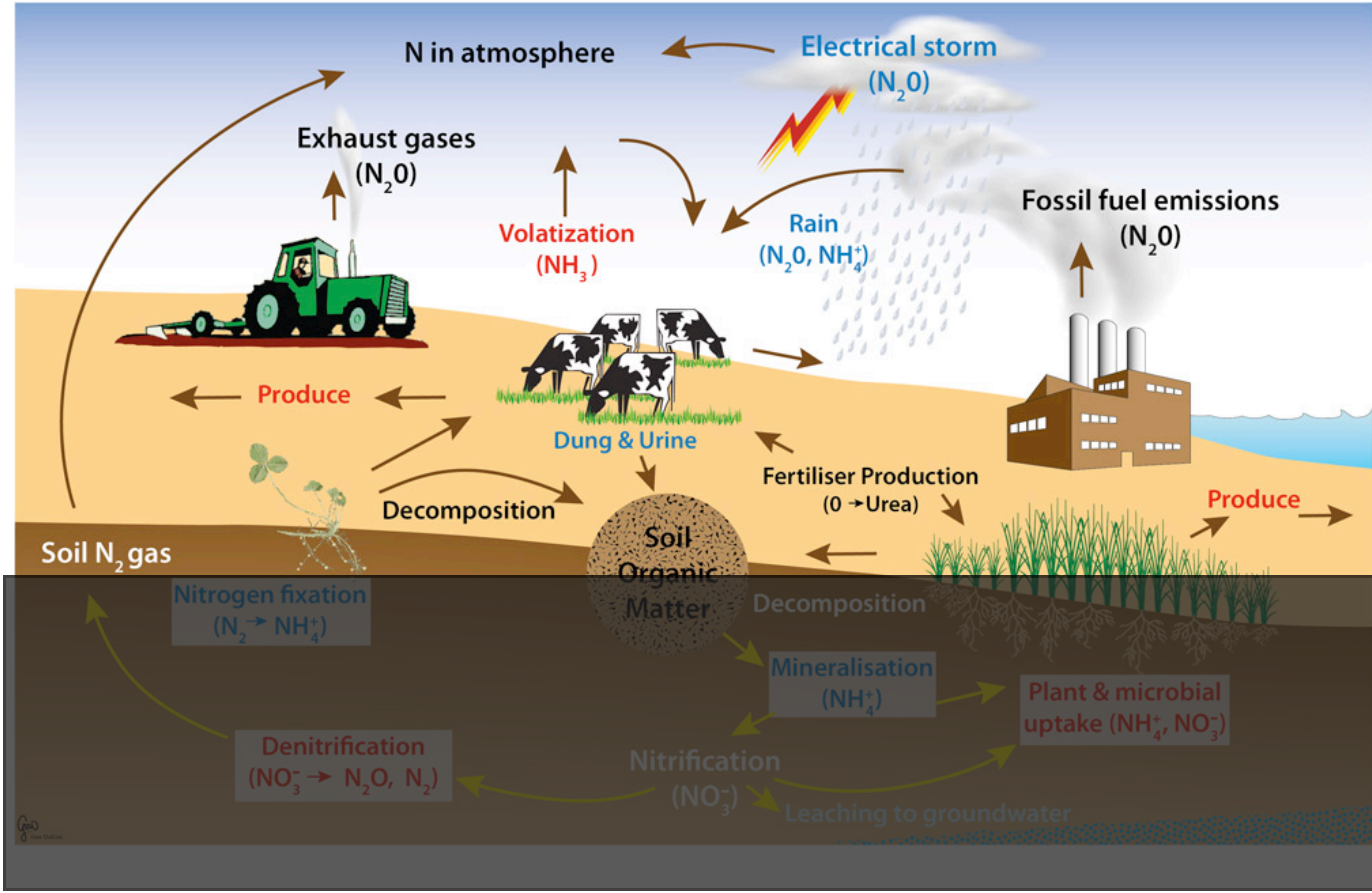
RESERVOIRS

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

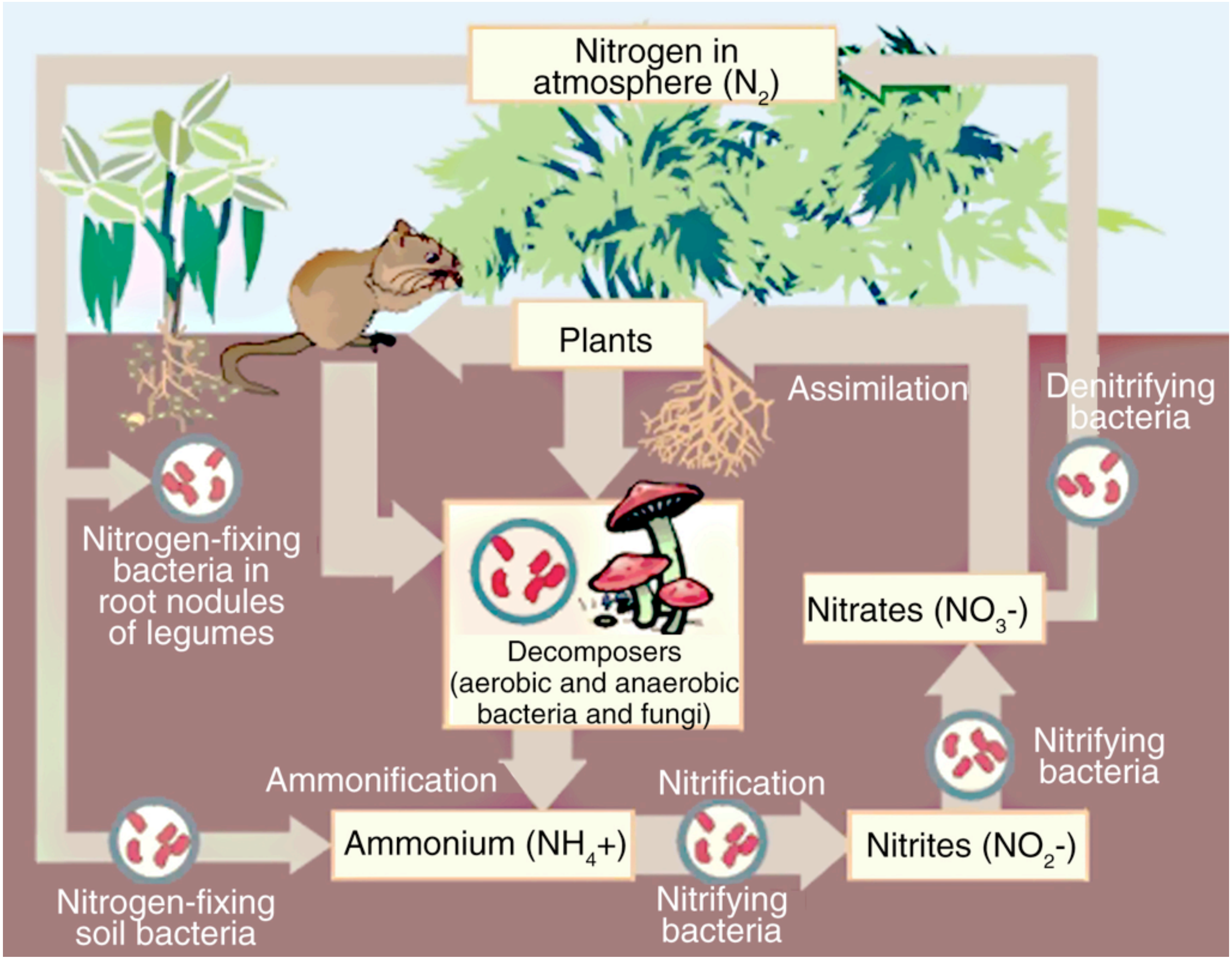
KEY PROCESSES

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

NITROGEN CYCLE (abiotic +)



NITROGEN CYCLE (biotic focus)



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.

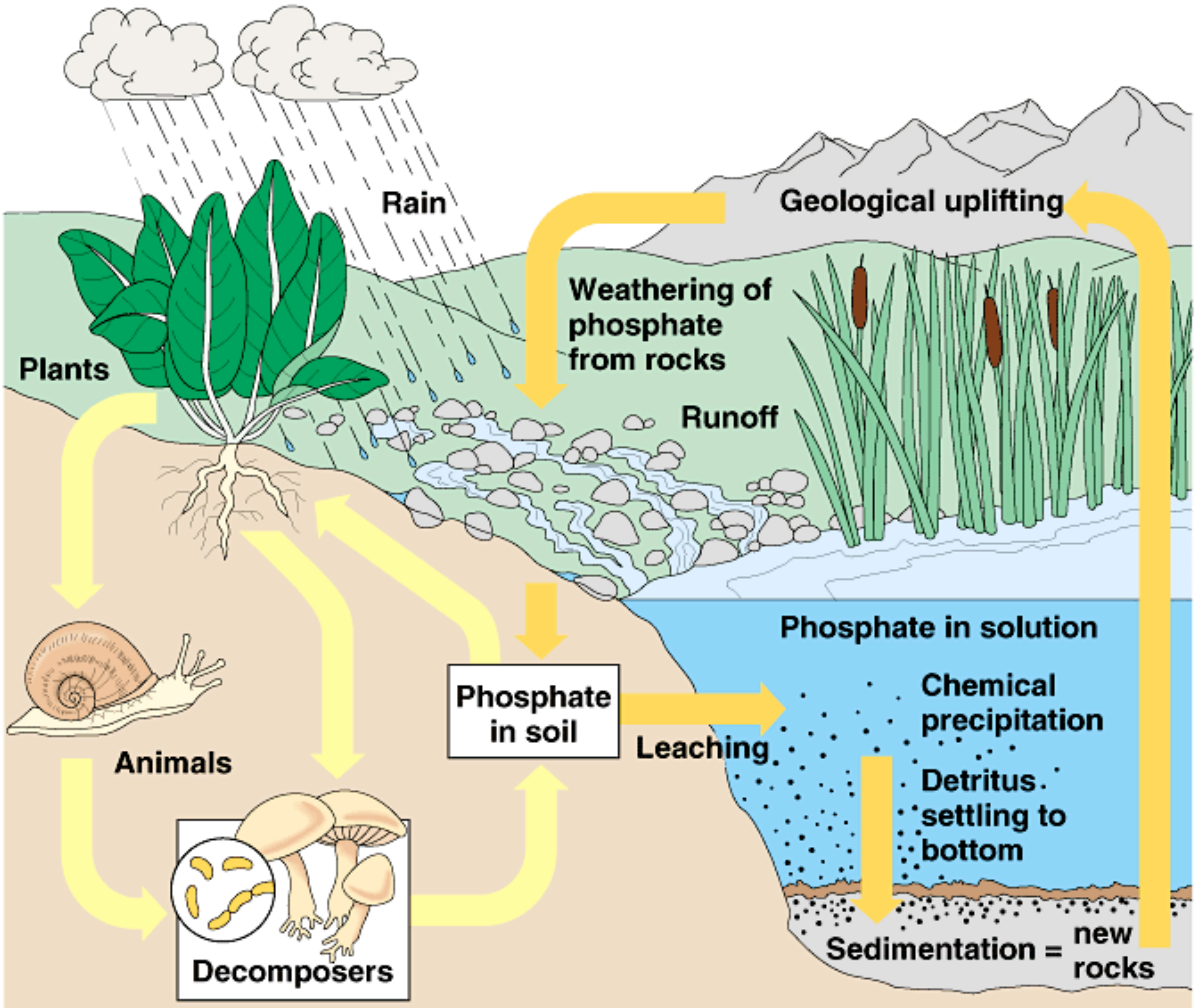
RESERVOIRS

- 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



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

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

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

Which variable belongs on the X axis? Y axis?

Identify the biomes below.

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