

Biogeochemical Cycles

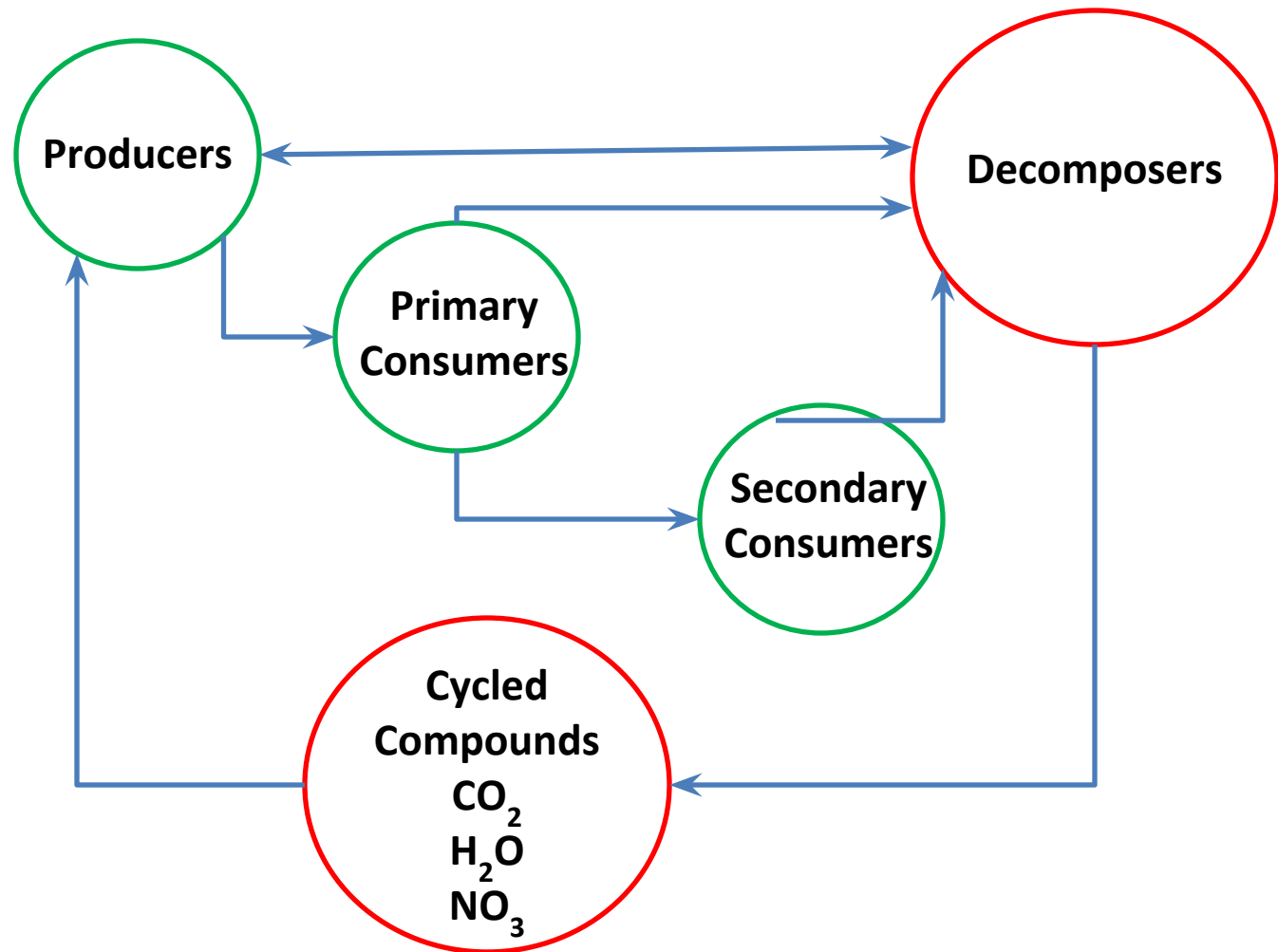


Background

- All substances within organisms cycle through ecosystems over time.
- The bulk of the material is NOT bound in organisms at any given time.
- Atmospheric cycling: C (primarily), N, O
- Geologic cycling: P, K, others

Cycles in Nature

- **Reservoir:** place where large quantity of nutrients are stored for a long period of time
- **Exchange pool:** where nutrient sits for a short period of time
- **Residency time:** amount of time nutrient sits in reservoir or exchange pool
 - Energy that drives biogeochemical cycles is from the Sun and heat from the earth's mantle and core
 - Movement of nutrients is via abiotic mechanisms (wind); or biotic mechanisms (living organisms)
- **Law of Conservation of Matter:** matter can neither be created nor destroyed
 - Nutrients can be rendered unavailable



Energy Flow Through Biogeochemical Cycles

Hydrologic Cycle

- All life depends directly on the presence of H_2O .
 - Plants absorb it from the geosphere.
 - Animals drink it directly & absorb it by consuming plants.
- Solar radiation drives evaporation of H_2O into the atmosphere.
 - Most of the $H_2O(g)$ precipitates into the ocean or infiltrates the ground.
 - 98% of Earth's H_2O is cycling.

Water Cycle

- **Precipitation:** when water condenses from a gaseous state to form a liquid or solid
- **Groundwater:** when precipitation travels below ground
 - Lakes and oceans are reservoirs for water: maybe trapped as snow or ice
- **Photosynthesis:** cycling through living systems; plants consume water and produce carbohydrates
- **Evaporation:** water is returned to the atmosphere from both the earth's surface and living things
- **Transpiration:** water released from plants into the atmosphere

Reservoirs:

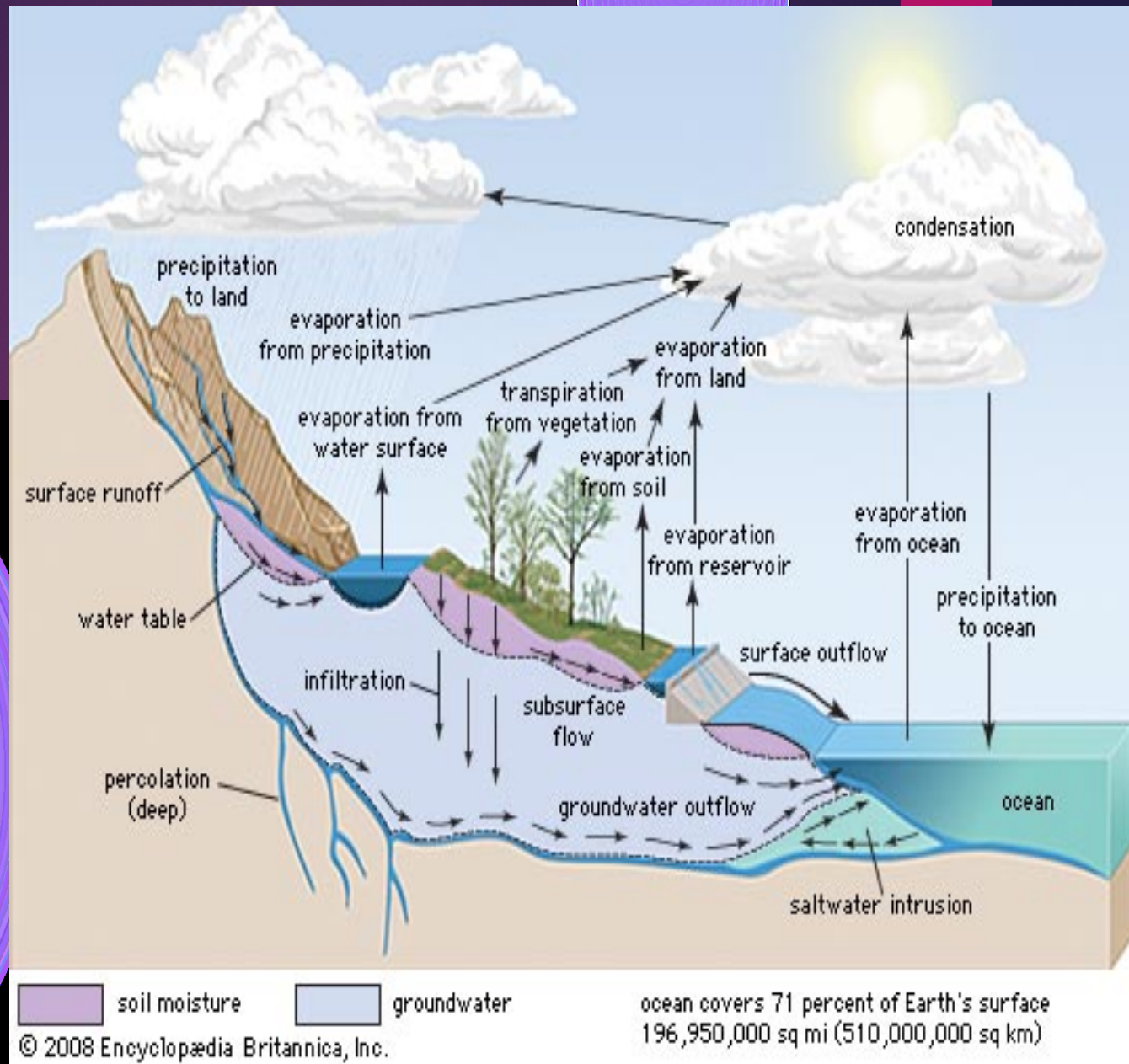
- Atmosphere: 0.001%
- Oceans: 97%
- Geosphere: 1%
- Ice: 2%

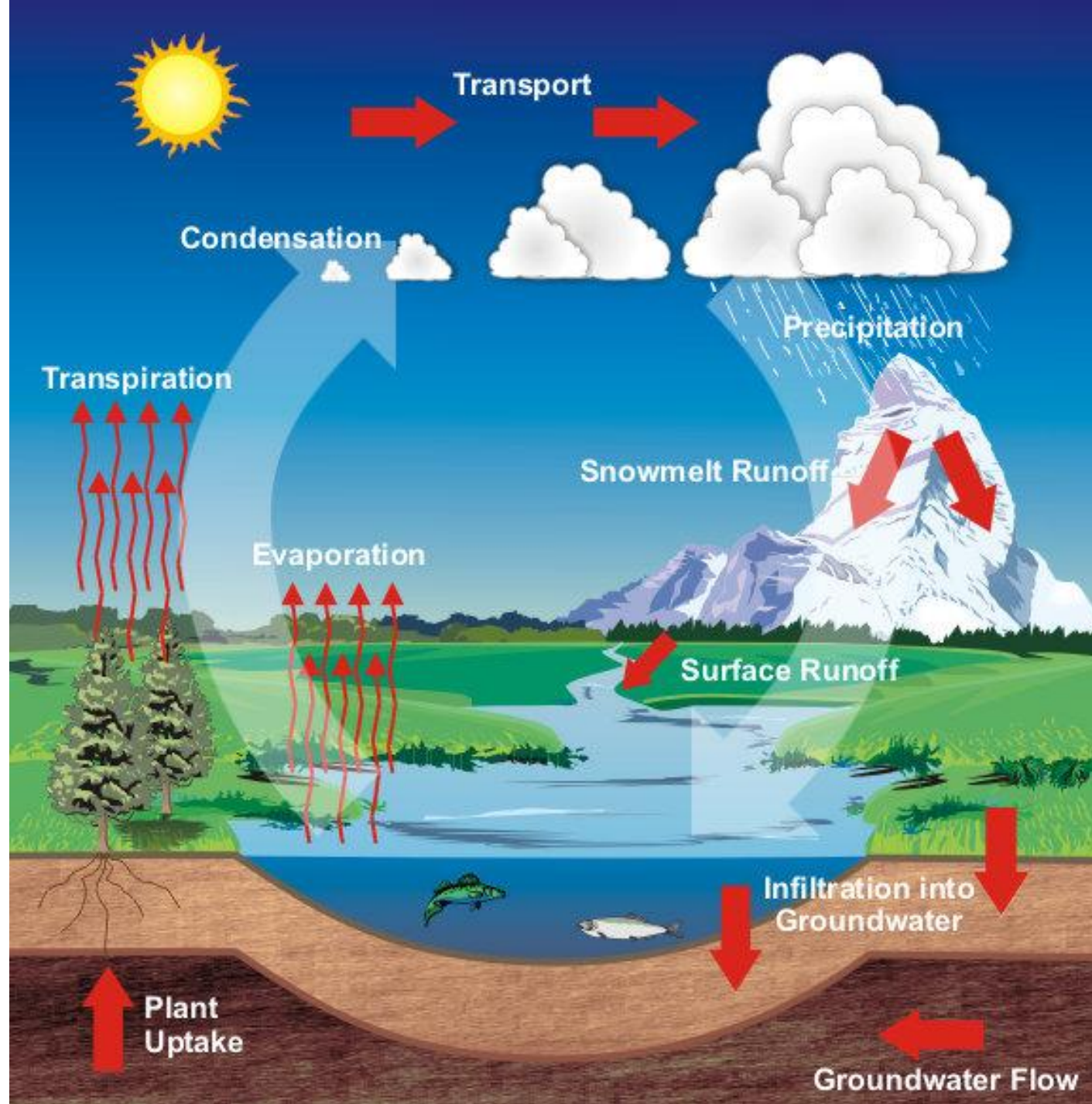
Precipitation:

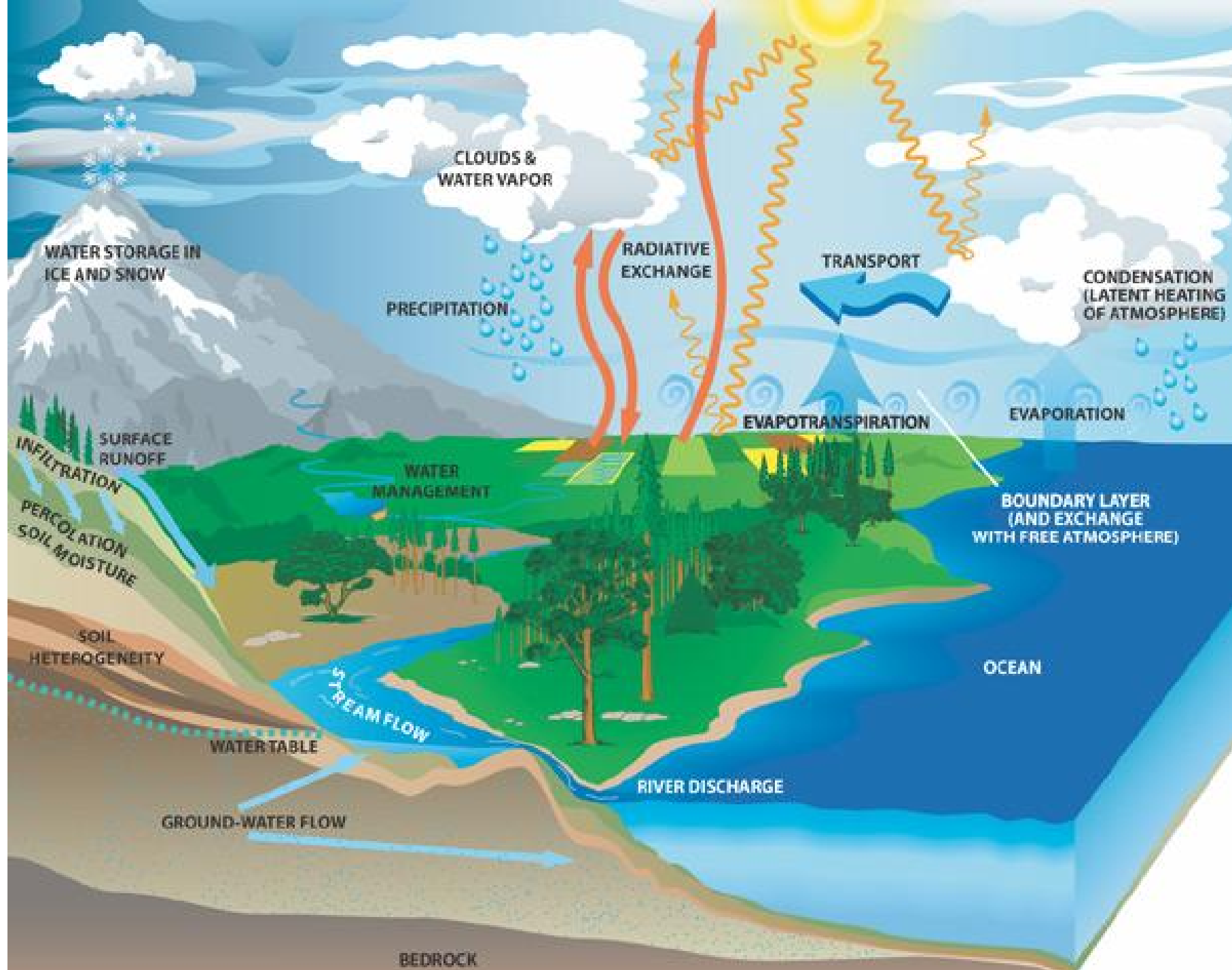
- Land: 23%
- Oceans: 77%

Evaporation:

- Land: 15%
- Oceans: 85%

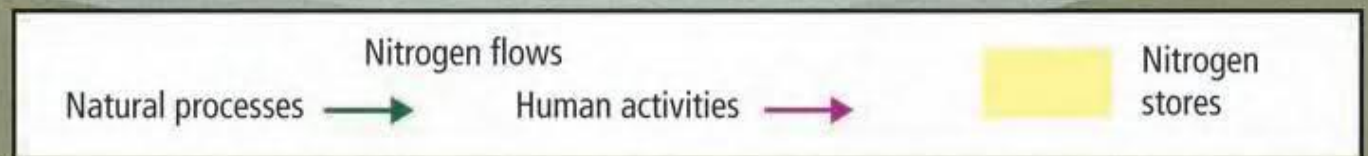






Nitrogen Cycle

- 78% of atmosphere
- Very small amount fixed in soil, oceans, & organisms
- Only certain bacteria can fix atmospheric N_2 into biologically useful form
- $N_2 \rightarrow$ triple bond (very stable)
- Bacteria—free-living or symbiotic (ex: root nodules of legumes)



Forms of N



- Plant & animal waste
- Ammonification converts biologic nitrogen into ammonia
- Ammonia oxidized by nitrifying bacteria to produce NO_2^-



- Formed via nitrification which releases energy



- Nitrate formed via **nitrification** by nitrifying bacteria
- Plants reduce nitrate to make ammonia (amino acid production)
- **Denitrification** releases fixed nitrogen back to atmosphere

The Nitrogen Cycle

1. All life requires nitrogen-compounds, e.g., proteins and nucleic acids.
2. Air, which is 79% nitrogen gas (N_2), is the **major reservoir** of nitrogen.
 - a. Most organisms cannot use nitrogen from the air.
 - b. Plants must secure their nitrogen in "fixed" form, i. e., incorporated in compounds such as ammonia.
 - c. Animals secure their nitrogen (and all other) compounds from plants (or animals that have fed on plants).

3. There are four processes in the cycling of nitrogen through the biosphere. Micro-organisms play primary roles at all stages.

a. Nitrogen Fixation

(1) atmospheric fixation by lightning

(2) biological fixation by certain microbes (cyanobacteria) in aquatic environments or in symbiotic relationships with plants.

(3) industrial fixation Under great pressure, at a temperature of 600° atmospheric nitrogen and hydrogen can be combined to form ammonia (NH_3).

b. Nitrification: transfer of nitrogen through the food web from bacteria.

c. Decay

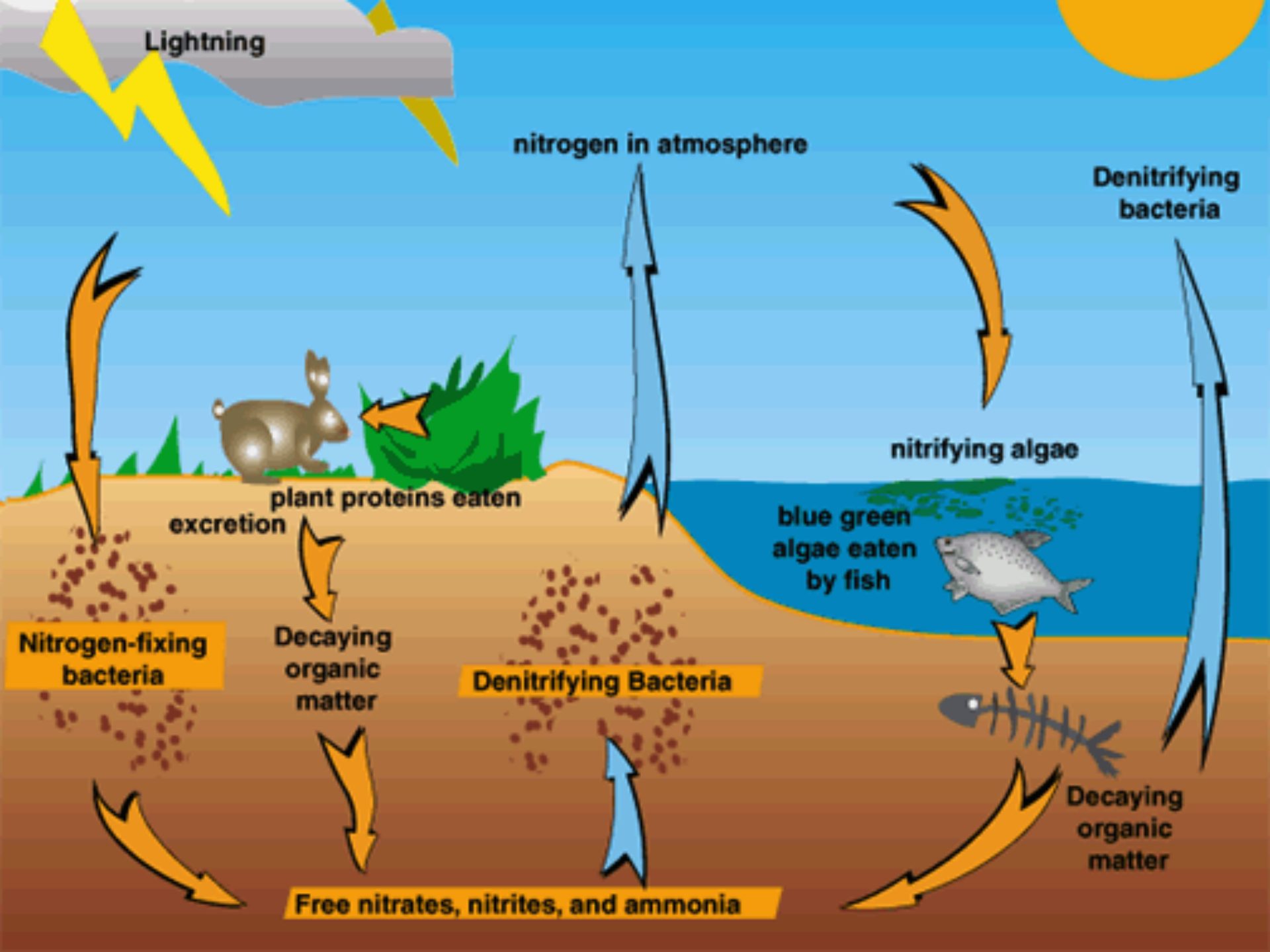
Microorganisms break down the protein molecules in excretions and dead organisms into ammonia.

d. Denitrification

Denitrification reduces nitrates to nitrogen gas, thus replenishing the atmosphere.

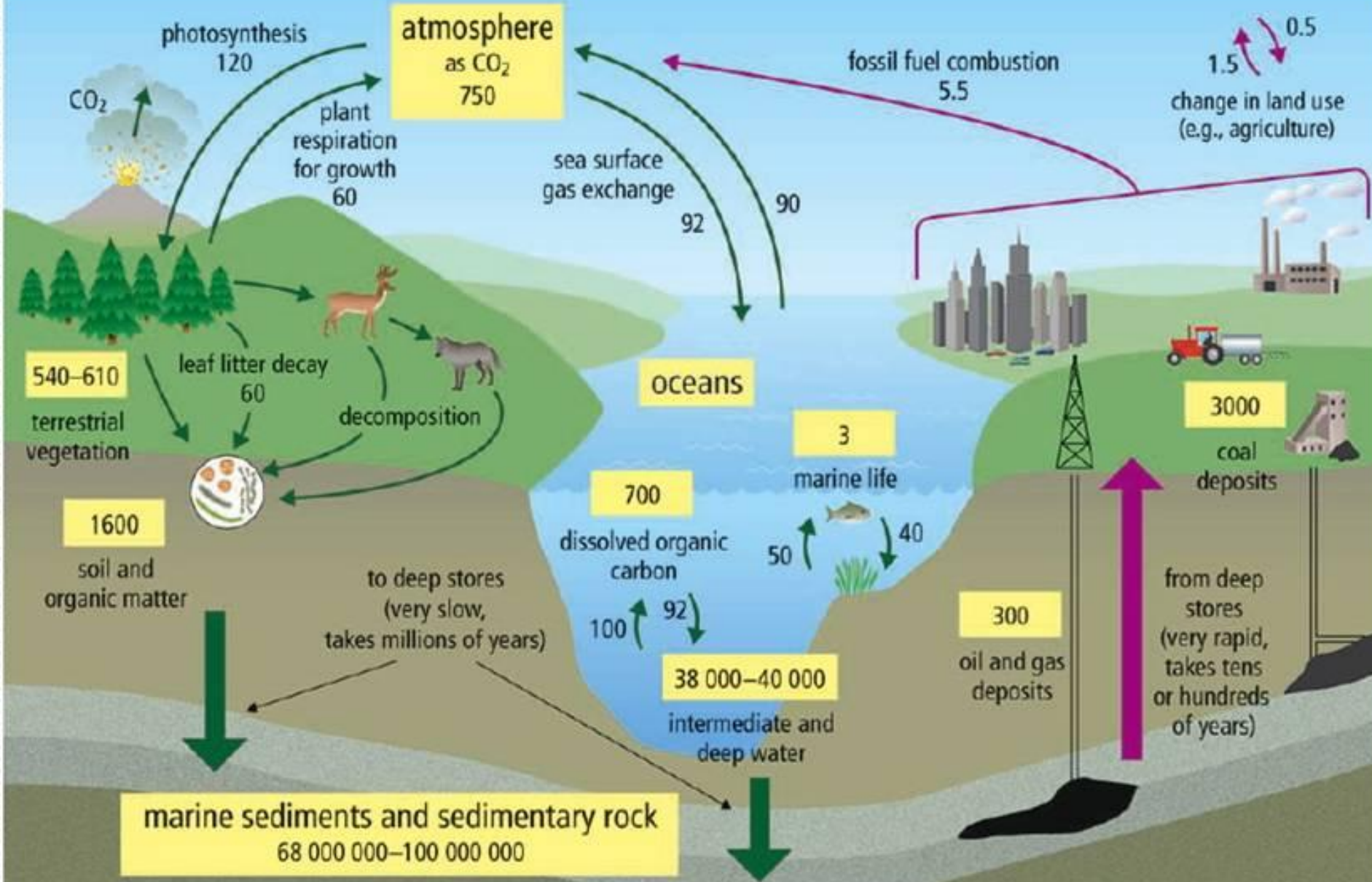
Humans Interfere by:

- Emit Nitrous oxide into atmosphere when burning any fuel. It reacts with water and makes acid rain.
- Emit heat-trapping nitrous oxide gas into atmosphere through fertilizers, etc.
- Mine nitrogen containing mineral deposits
- Leach nitrate ions from soil with irrigation
- Burn grassland and forests
- Add nitrogen compounds to aquatic ecosystems in agricultural runoff and discharge of sewage



Carbon Cycle

- Based on atmospheric CO₂
- Rough balance of photosynthesis & respiration
- Synthesis of organic compounds via photosynthesizers
- Heterotrophs need carbon too; consume it



Carbon flows (exchanges) in gigatonnes per year

Natural processes → Human activities →

1600 Carbon stores in gigatonnes

Carbon Cycle

Sinks

- Atmosphere
- Biosphere—vegetation
- Hydrosphere—oceans
- Geosphere—rocks, fossil fuels, & minerals
- Cellulose resistant to breakdown → fossil fuels

Producers

- Biological respiration
- Decomposition
- Forest Fires
- Volcanoes

Human Inputs

- Cement production
- Burning of fossil fuels
- Deforestation

The Carbon Cycle

1. Carbon's Location

- a. The concentration of carbon in living matter (18%) is almost 100 times greater than its concentration in the earth (0.19%).
- b. Living things extract carbon from their nonliving environment. For life to continue, this carbon must be recycled.

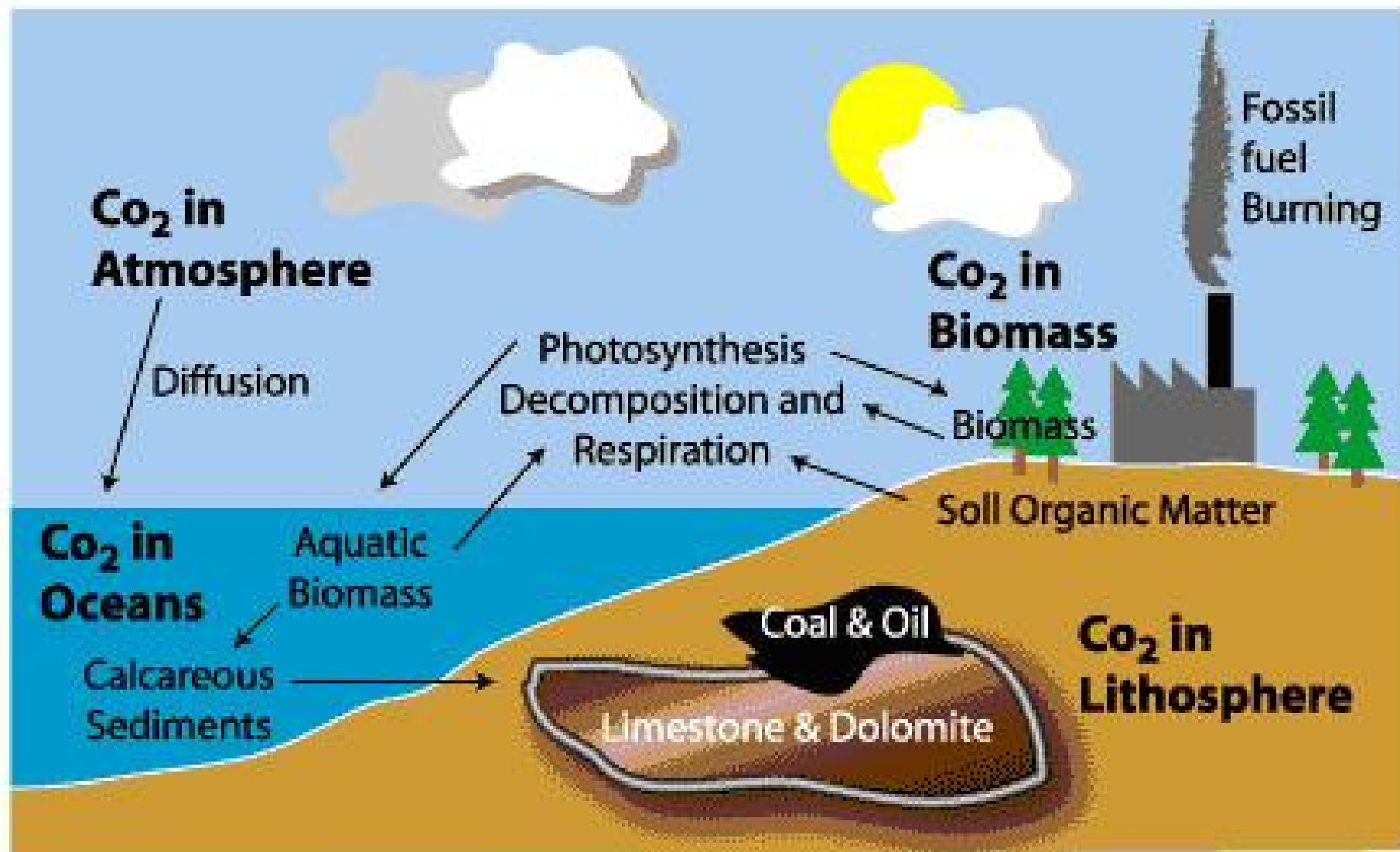
2. Carbon exists in the nonliving environment as:

- a. carbon dioxide (CO_2) in the atmosphere and dissolved in water (forming HCO_3)
- b. carbonate rocks (limestone and coral = CaCO_3)
- c. deposits of coal, petroleum, and natural gas derived from once-living things
- d. dead organic matter, e.g., humus in the soil

3. Carbon enters the biotic world through the action of autotrophs:
 - a. **photoautotrophs**, like plants and algae, that use the energy of light to convert carbon dioxide to organic matter.
 - b. **chemoautotrophs** - bacteria do the same but use the energy derived from a breakdown of molecules in their environment.
4. Carbon returns to the atmosphere and water by
 - a. respiration (as CO_2)
 - b. burning
 - c. decay (producing CO_2 if oxygen is present, methane (CH_4) if it is not.

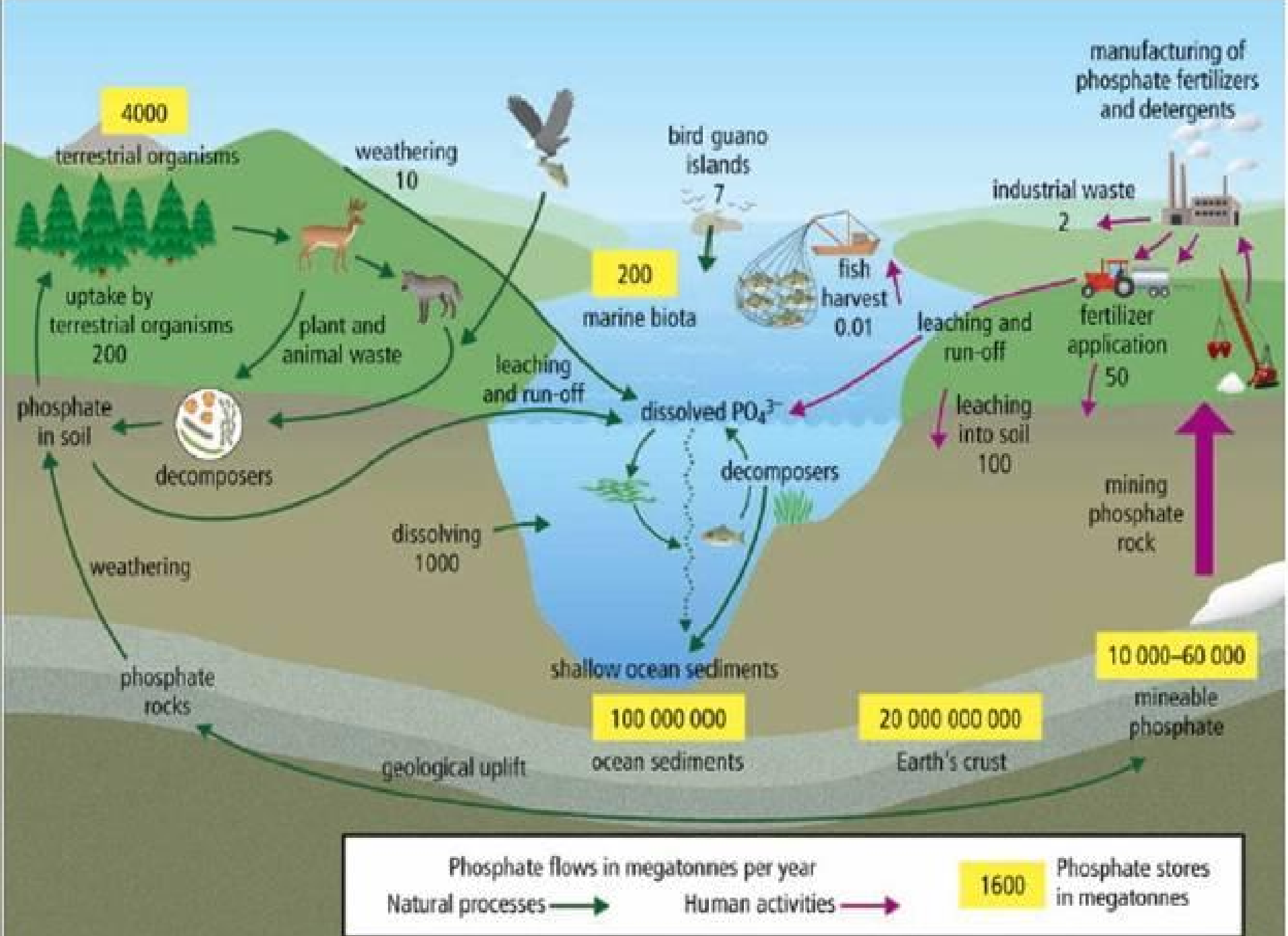
Human Interference: Carbon Cycle

- Removing plant life that absorbs CO₂ in photosynthesis
- Burning fossil fuels and wood that releases CO₂ into atmosphere
- Greenhouse effect caused mostly by water vapor and carbon dioxide
- Concrete production acts as carbon sink (storing CO₂)



Phosphorous Cycle

- Most biogeochemical cycle reservoirs are mineral in nature.
- Phosphate exists in the soil only in small amounts.
- Is relatively soluble & contained in only certain types of rocks
- Released via weathering & is then transported to the oceans
- Brought to surface via natural uplifting of land masses or by marine organisms
- Sea bird guano rich in P



Phosphorous Cycle

- ❑ Millions of tons of phosphate added to farmland yearly (fertilizer)
- ❑ Absorption in plants often aided by fungal mycorrhizae
- ❑ Large quantities carried to sea yearly

Phosphorus Cycle

- Phosphorus exists in the **atmosphere** as dust particles
- Major component of nucleic acids and other biological molecules
- Phosphorus **cycles more locally** than water, carbon or nitrogen
- Found in soil, rock and sediments and **released from rocks through weathering**
- Released in the form of **phosphate** (PO_4) which is soluble and absorbed from soil by plants
- Phosphorus is a **limiting factor for plant growth**
- Phosphates enter the water table, travel to oceans and become incorporated into rock on ocean floor
- Terrestrial cycle: through geologic cycle, ocean mixing and upwelling, rocks from seafloor may rise up so that their components are cycled again

Human Influence Phosphorous Cycle

- Mine large quantities of phosphate rock
- Cutting of forests
- Add excess phosphate to aquatic ecosystems by runoff from animal wastes, fertilizers, and sewage

D. Sulfur Cycle

- Sulfur makes up proteins and vitamins
- Plants absorb sulfur when it is dissolved in water and is taken up through their roots when it is
- Dissolved in groundwater. Animals obtain sulfur by consuming plants
- Most sulfur is in rocks and salts buried in sediment on ocean floor
- Some sulfur can be found in the **atmosphere** entered from both human and natural sources
- Natural way sulfur enters atmosphere is through **volcanic activity, bacterial functions and decay of living organisms**
- Human activity is mainly through industrial processes as **sulfur dioxide (SO₂) and hydrogen sulfide (H₂S) gases.**

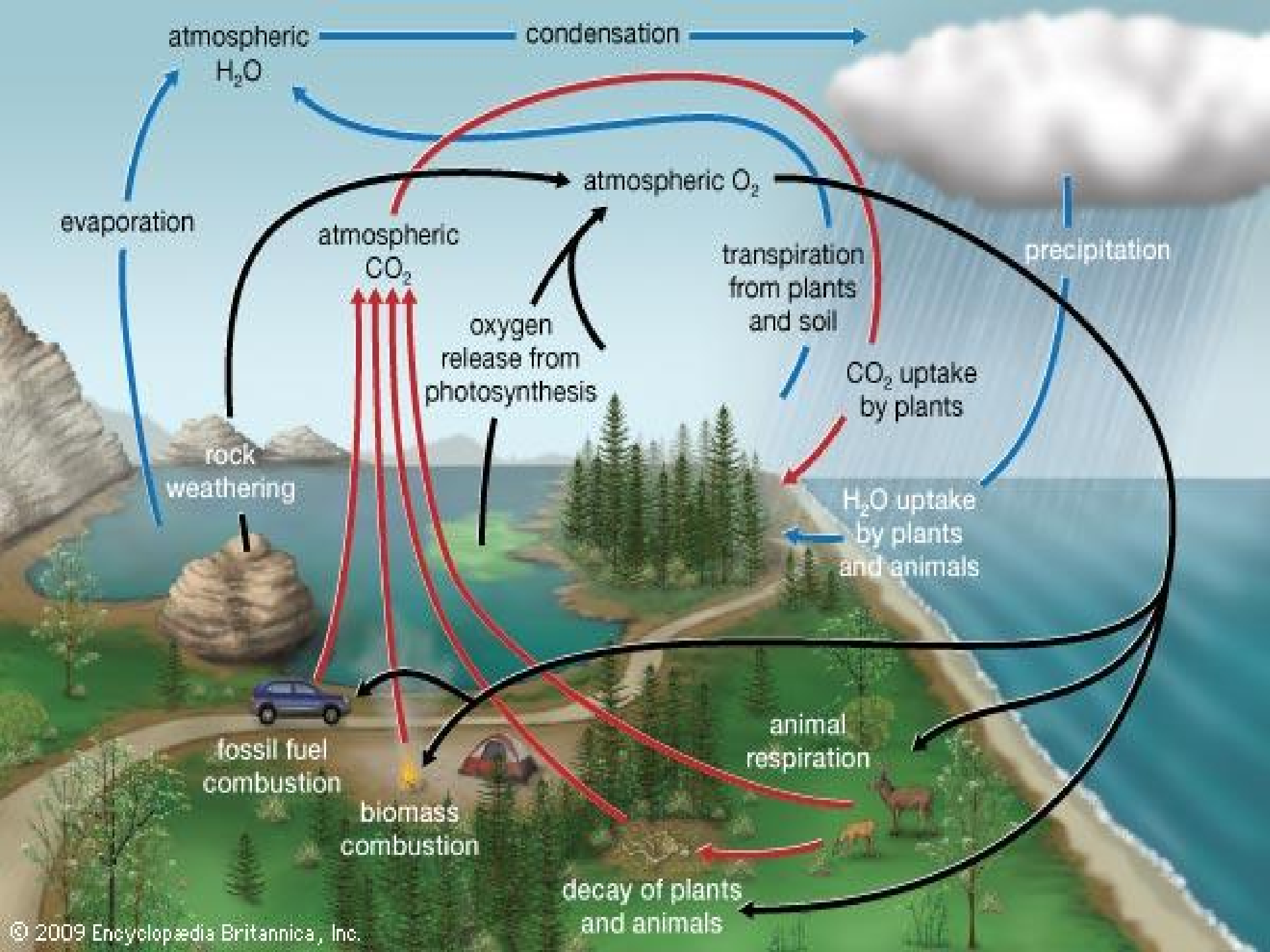
Human Interference: Sulfur

- 1/3 of all sulfur going into atmosphere comes from human activities:
 - Burning sulfur-containing coal and oil for electricity
 - Refining petroleum
 - Smelting sulfur compounds of metallic

Oxygen Cycle

- Only Earth possesses significant quantities of free oxygen
- Product of 3 billion years of photosynthesis

Without photosynthesis, respiration would deplete all non-atmospheric oxygen within 50 years



Gaia Hypothesis

- States that organisms have evolved with the physical environment to provide an intricate control system that keeps earth's conditions favorable for life
- Utterly unique to Earth:
 - - Chemistry of the atmosphere
 - - Strongly buffered physical environment

Gaia Hypothesis

- From the very beginning organisms played the major role in the development & control of a geochemical environment favorable to themselves
- pH: NH_3 produced in soils causes a soil pH favorable to life

Condition	Earth Without Life	Earth With Life
Atmospheric CO_2	98%	0.03%
Atmospheric N_2	1.79%	79%
Atmospheric O_2	Trace	21%
Surface Temperature	290 +/- 50 °C	13 °C