CHAPTER 3
Biogeochemical Cycles

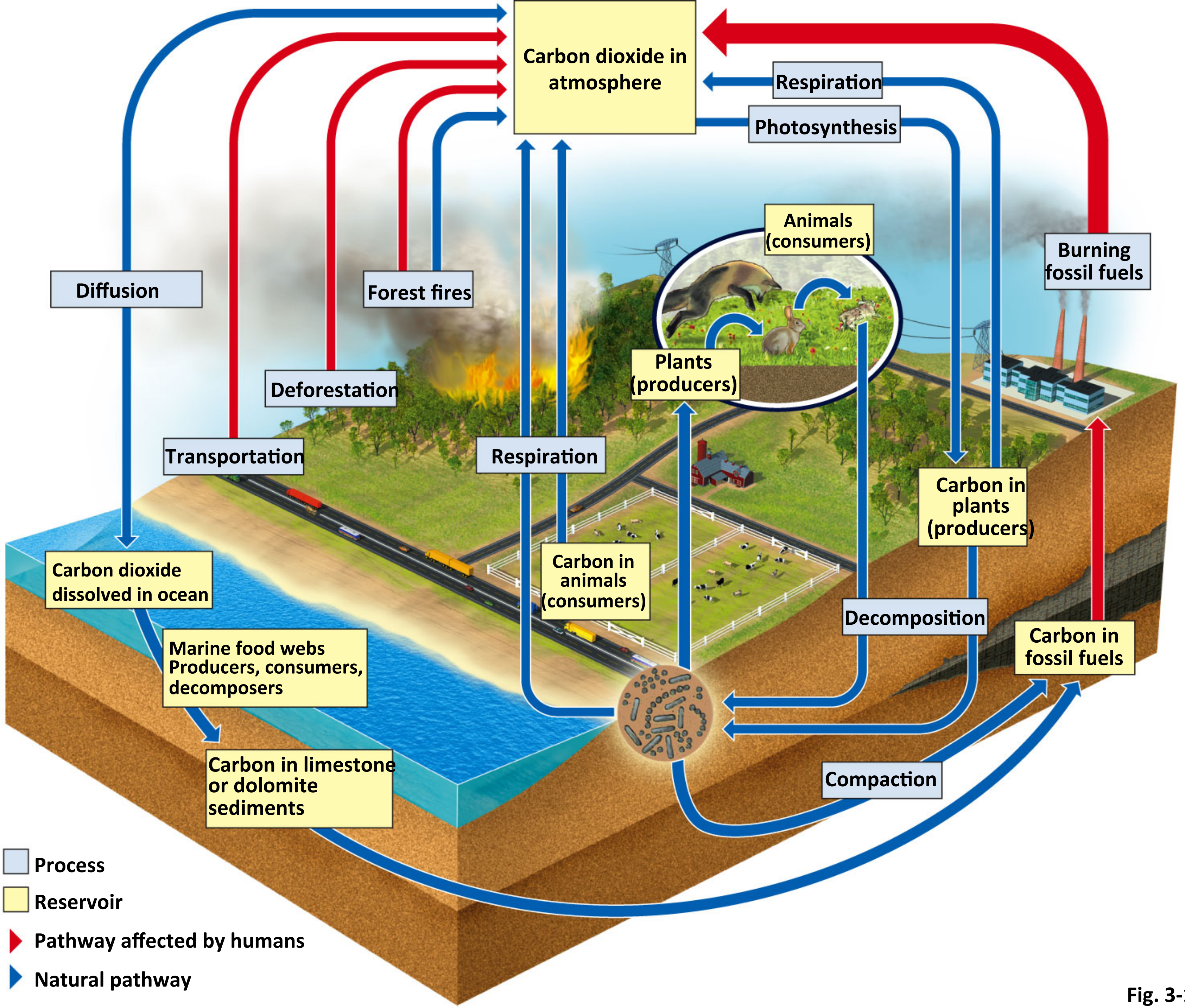

Carbon dioxide in atmosphere
Respiration
Photosynthesis
Diffusion
Forest fires
Deforestation
Transportation
Respiration
Animals (consumers)
Plants (producers)
Burning fossil fuels
Carbon in plants (producers)
Carbon in animals (consumers)
Carbon dioxide dissolved in ocean
Marine food webs Producers, consumers, decomposers
Decomposition
Carbon in fossil fuels
Compaction
Carbon in limestone or dolomite sediments
Process
Reservoir
Pathway affected by humans
Natural pathway

Fig. 3-19, p. 70

Biogeochemical Cycles: The Carbon Cycle

The movement of carbon throughout the carbon cycle depends largely on photosynthesis, respiration, & decomposition.

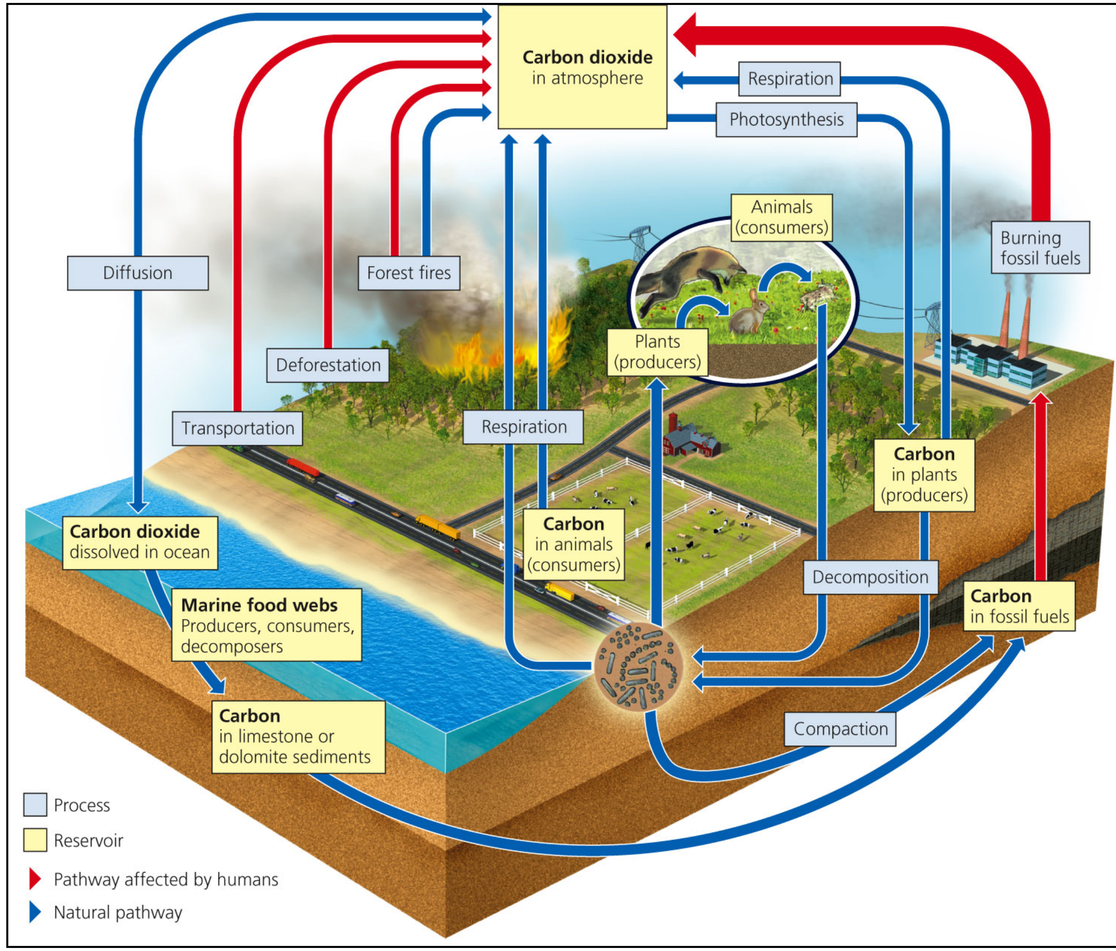
Photosynthesis: Removes carbon dioxide from the atmosphere.

$6\ CO_2 + 6\ H_2O + \text{Energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$

Cellular respiration: Emits carbon dioxide to the atmosphere.

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + \text{Energy}$

Decomposition: Breaking down of organic material (dead plants and animals). *Aerobic respiration* releases carbon dioxide and *anaerobic respiration* releases methane to the atmosphere.



Photosynthesis

$$6\ CO_2 + 6\ H_2O + \text{Energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

Cellular Respiration

$$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O + \text{Energy}$$

Biogeochemical Cycles: The Carbon Cycle

CO_2 dissolves (diffuses) into ocean water and becomes part of marine sediments, as well as the skeletons of marine organisms.

The Process

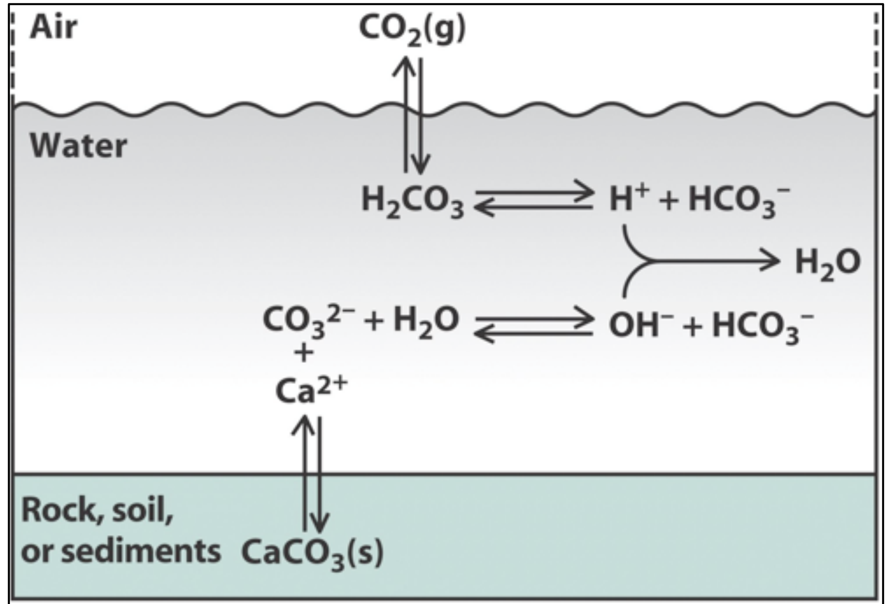
CO_2 (dissolved) reacts with ocean water to produce carbonic acid.

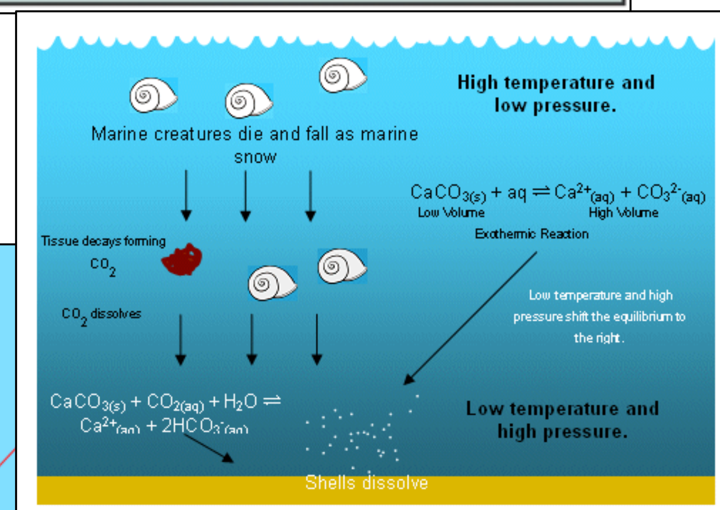
Ionization: Carbonic acid reacts with hydrogen ions producing a bicarbonate ion (HCO_3^-) and a carbonate ion (CO_3^{2-})

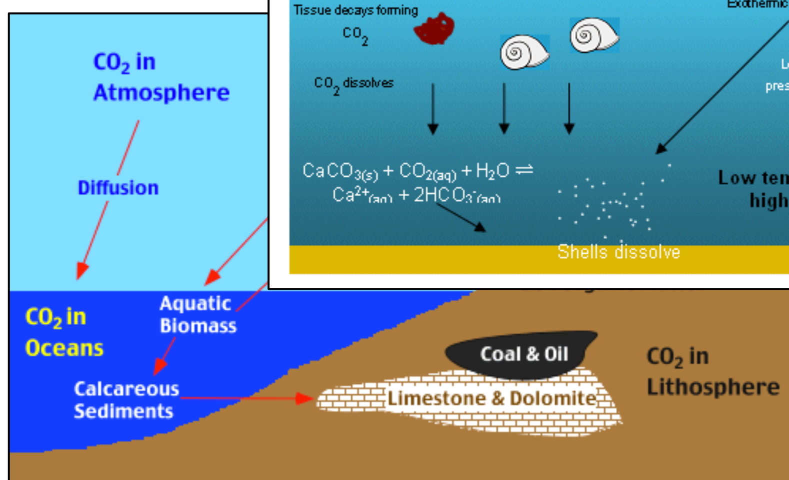
$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$ (calcium carbonate) in shells/skeletons of aquatic organisms

$CaCO_3$ or Calcium Carbonate forms <u>**limestone**</u> when shells and skeletons of marine organisms sink and are buried and compacted over long periods of time.

The largest reservoir of carbon is sedimentary rock such as limestone.

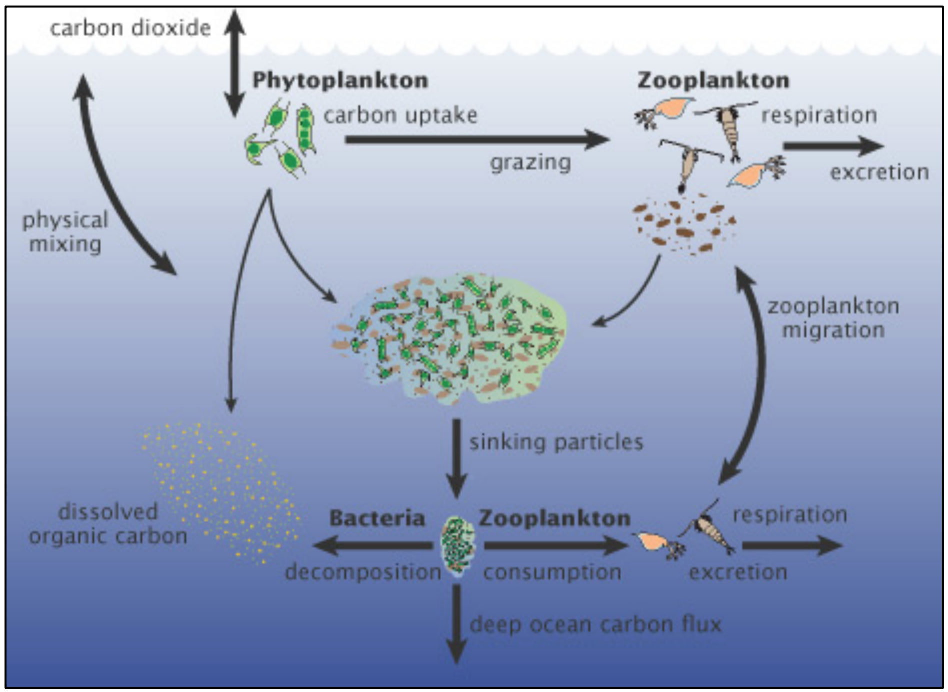


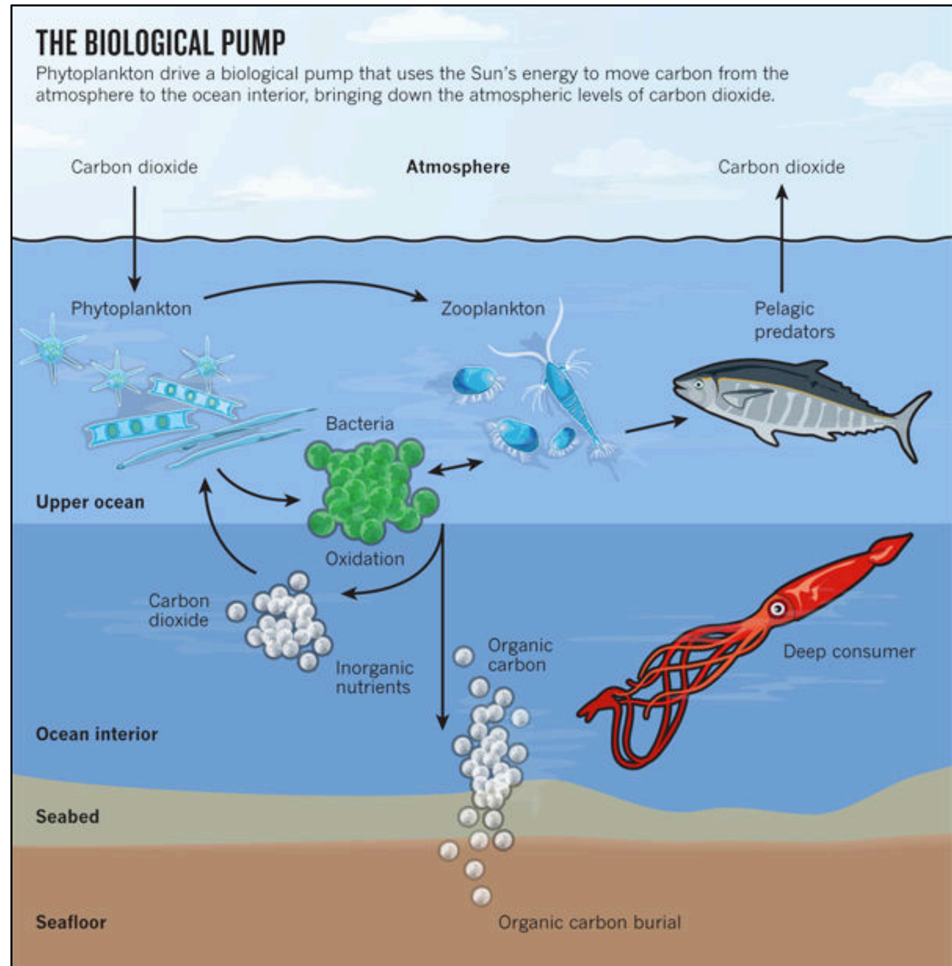




Biogeochemical Cycles: The Carbon Cycle

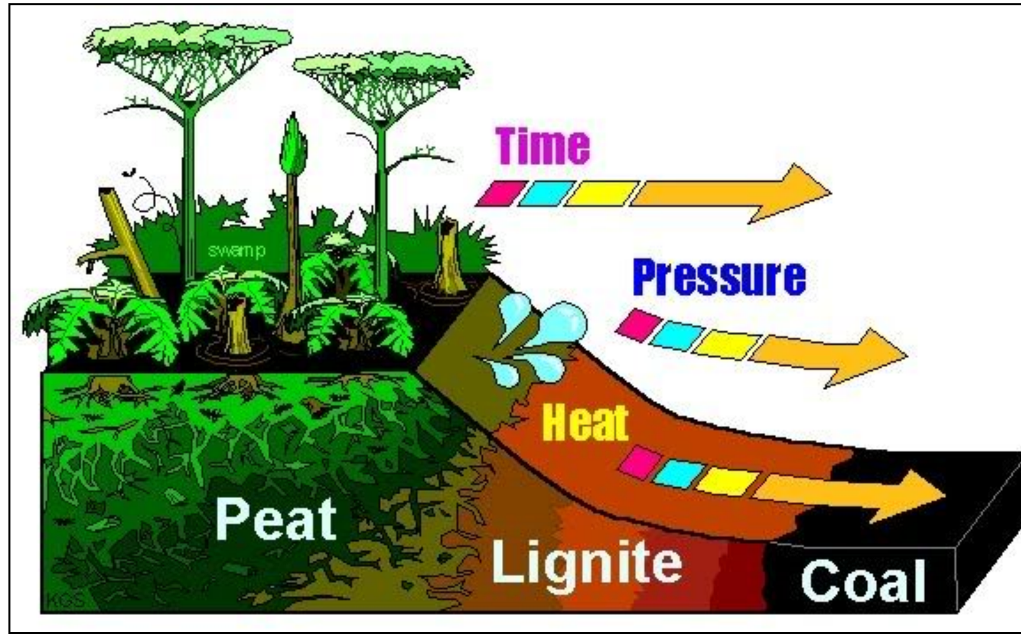
Photosynthetic phytoplankton large amounts of store carbon. When they die and sink to the bottom, carbon accumulates in the deep ocean. This phytoplankton when buried and subjected to time, heat, and pressure will form petroleum (oil and natural gas).

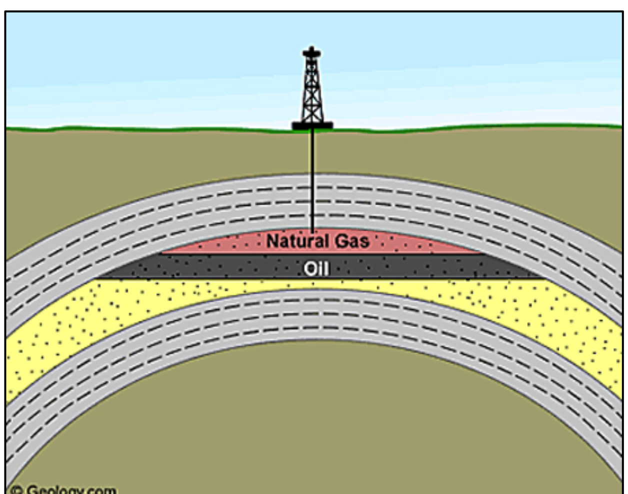


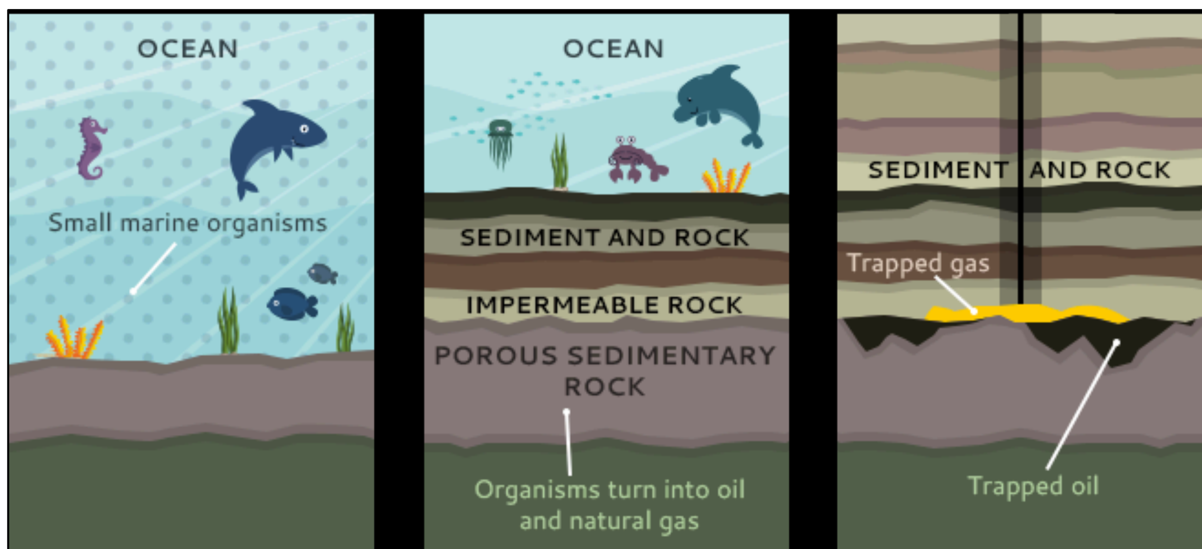


Biogeochemical Cycles: The Carbon Cycle

Organic carbon in dead biomass that was rapidly buried beneath layers of sediments as a result of a combination of time, heat, and pressure become coal, oil, and natural gas; i.e. fossil fuels.

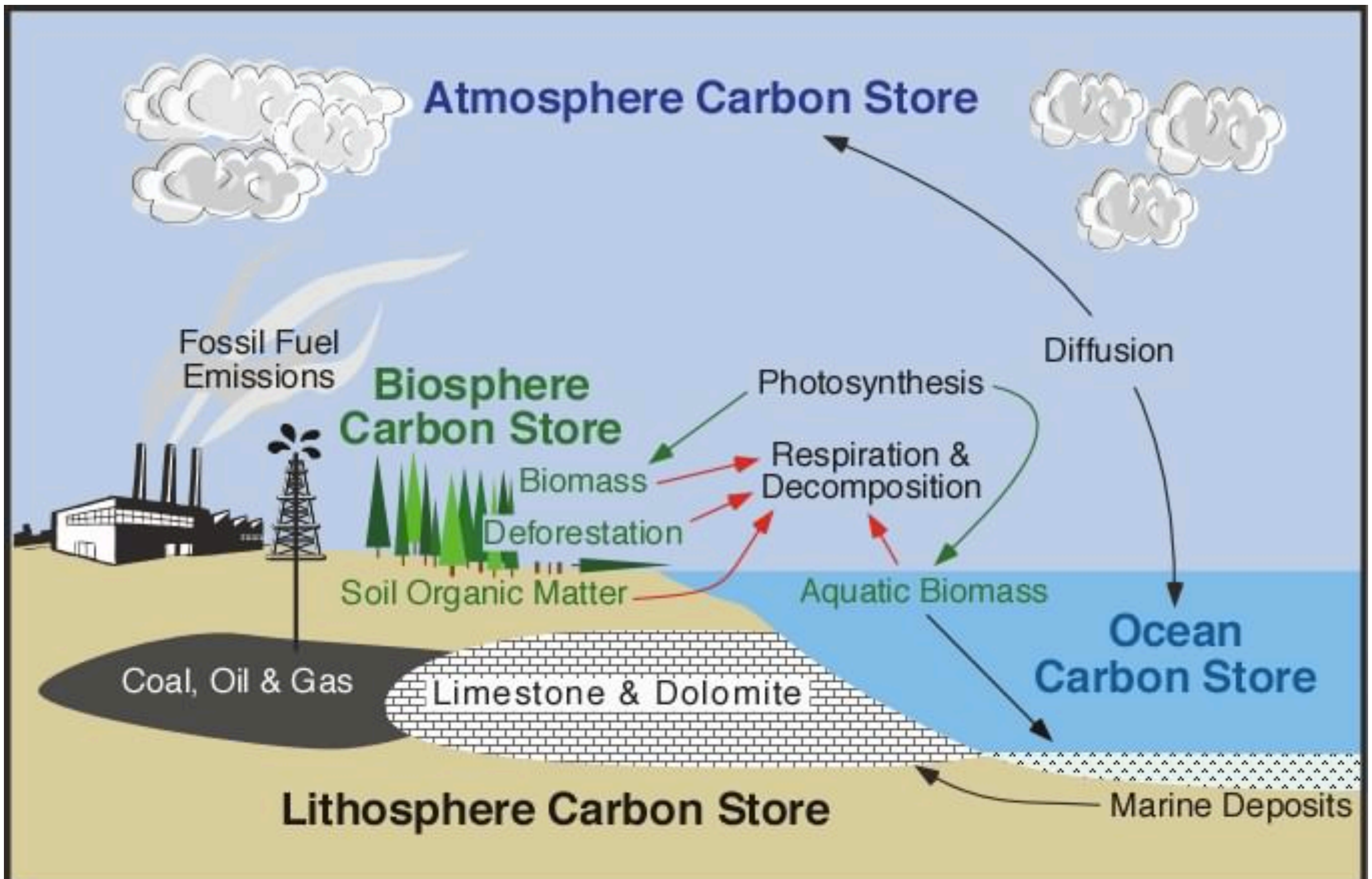






Biogeochemical Cycles: The Carbon Cycle

Carbon locked in organic molecules (hydrocarbons) in fossil fuels is converted to atmospheric carbon in carbon dioxide by combustion (burning to produce energy to power cars and produce electricity).
Removal of fossil fuels from the Earth and burning them (combustion) releases carbon, in the form of carbon dioxide, to the atmosphere.



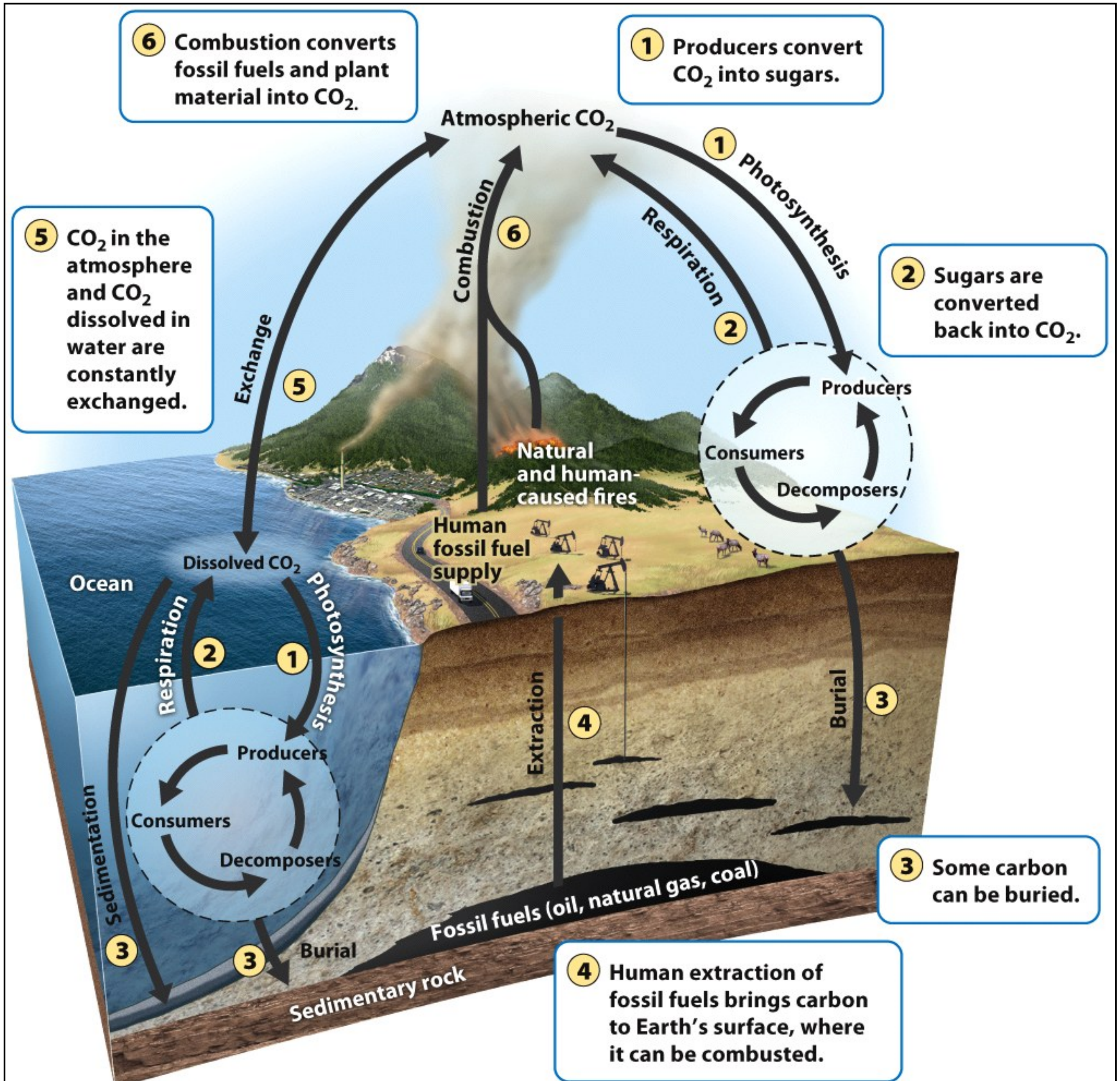
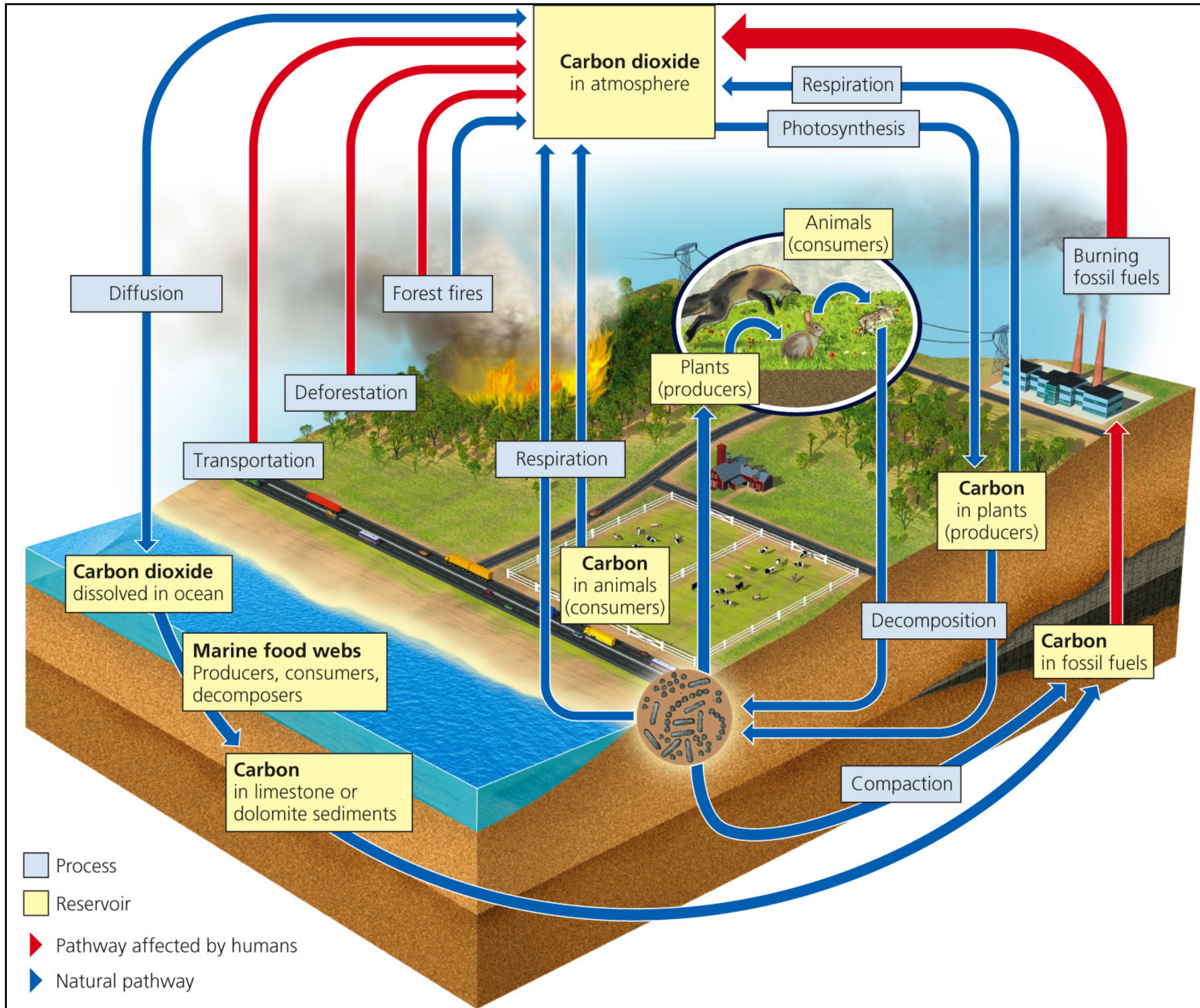


Figure 3.11
Environmental Science

How are we disrupting the carbon cycle?

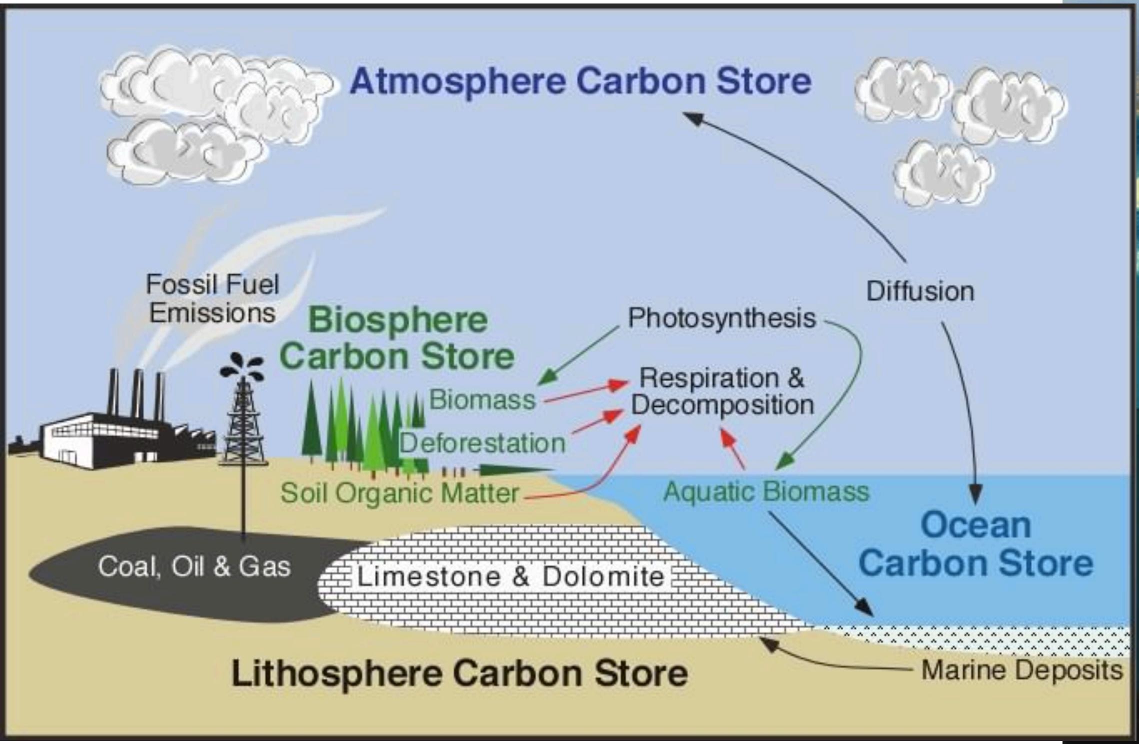
<u>Human Interventions in the Carbon Cycle</u>:

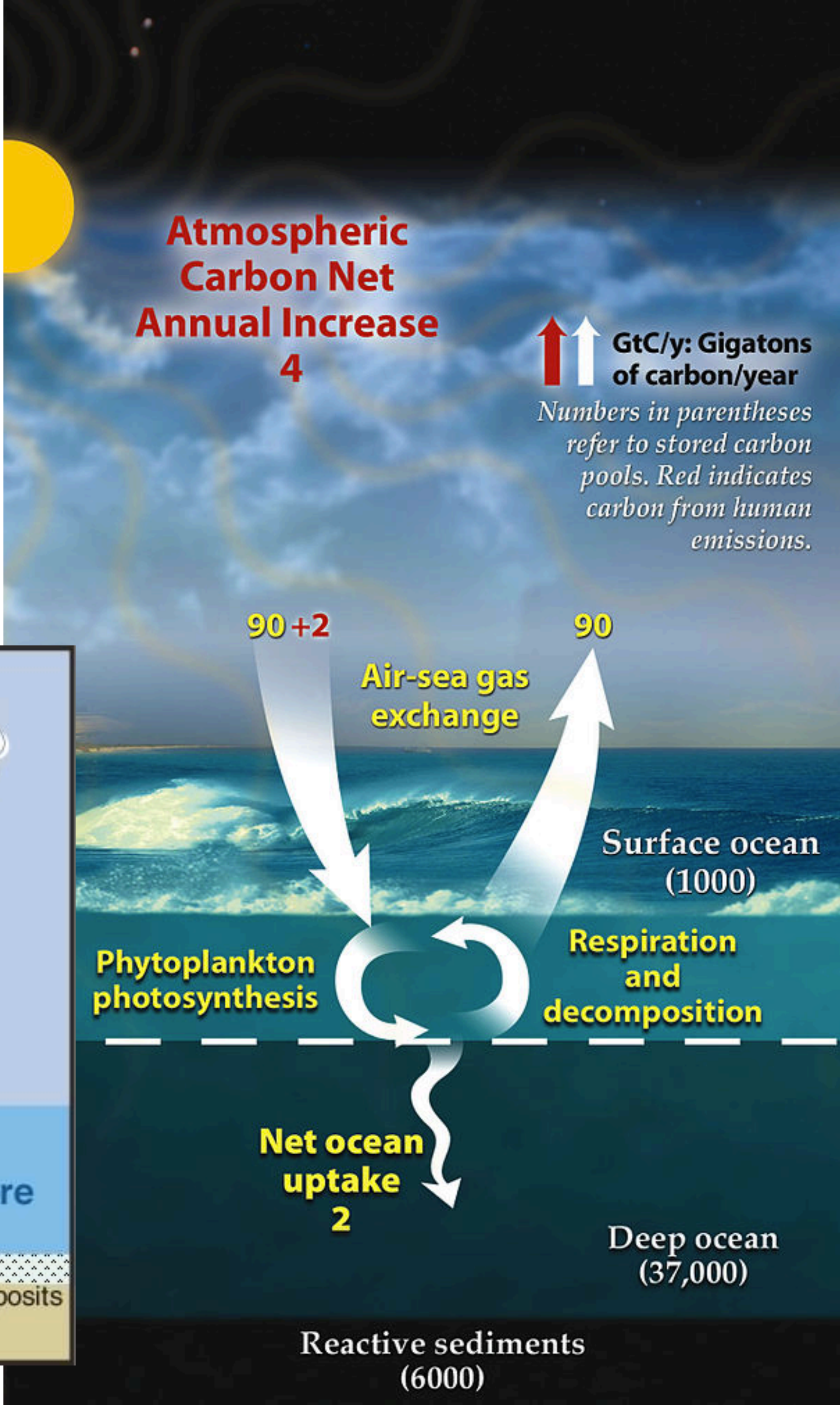
- **Large Scale Deforestation**
- **Burning Fossil Fuels**
- **Burning Biomass**
- **Raising Cattle**
- **Making Cement**
- **Waste Incineration**
- **Destruction/**
- **Draining of Wetlands**



Carbon Sinks and Reservoirs

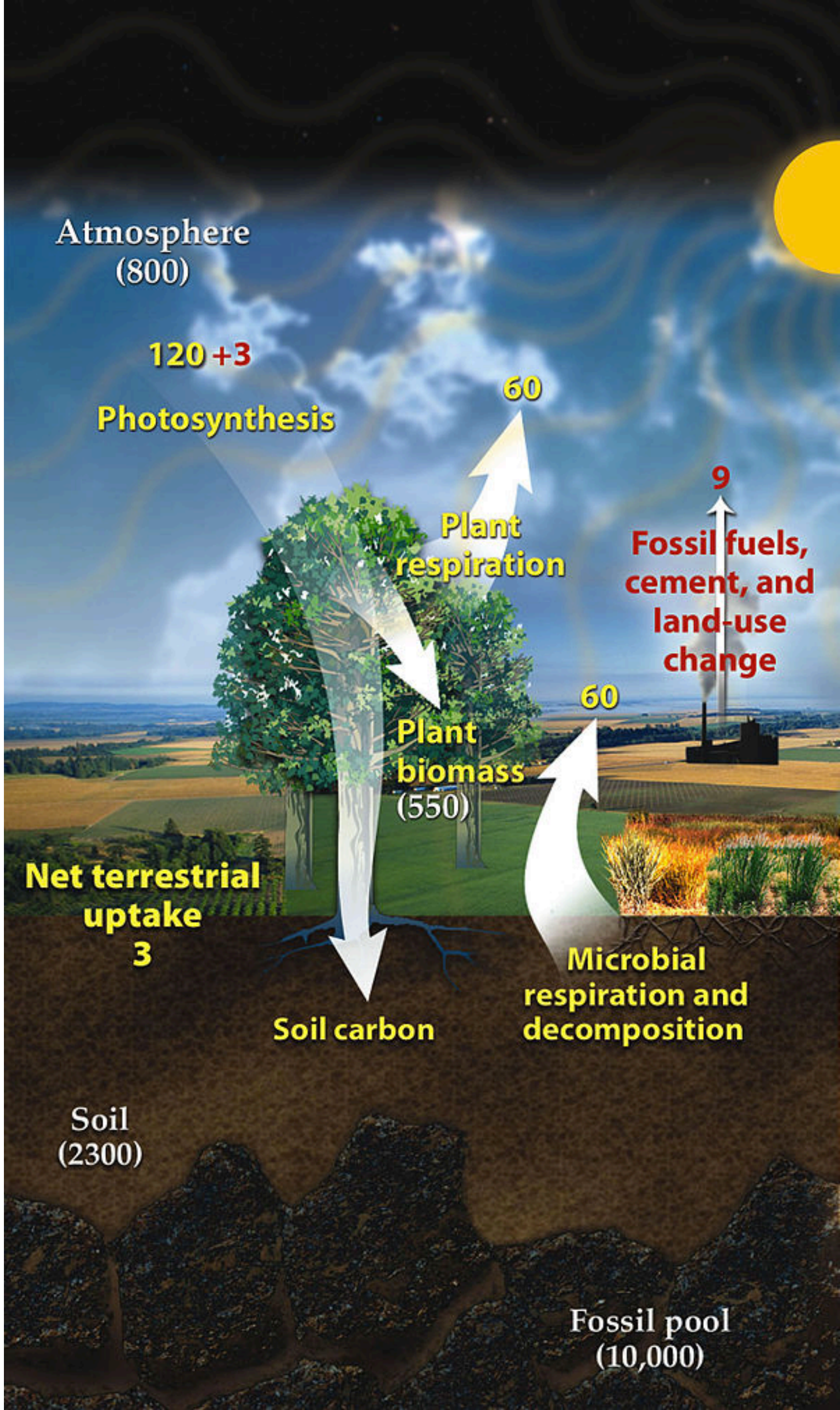
- The largest reservoir of carbon is sedimentary rock such as limestone.
- Oceans are the second largest reservoir of carbon on Earth. Carbon is stored in the oceans in three ways: **1)** dissolved carbon dioxide in ocean water; **2)** in living things in ocean such as shells, skeletons, and coral reef; and **3)** in photosynthetic phytoplankton.

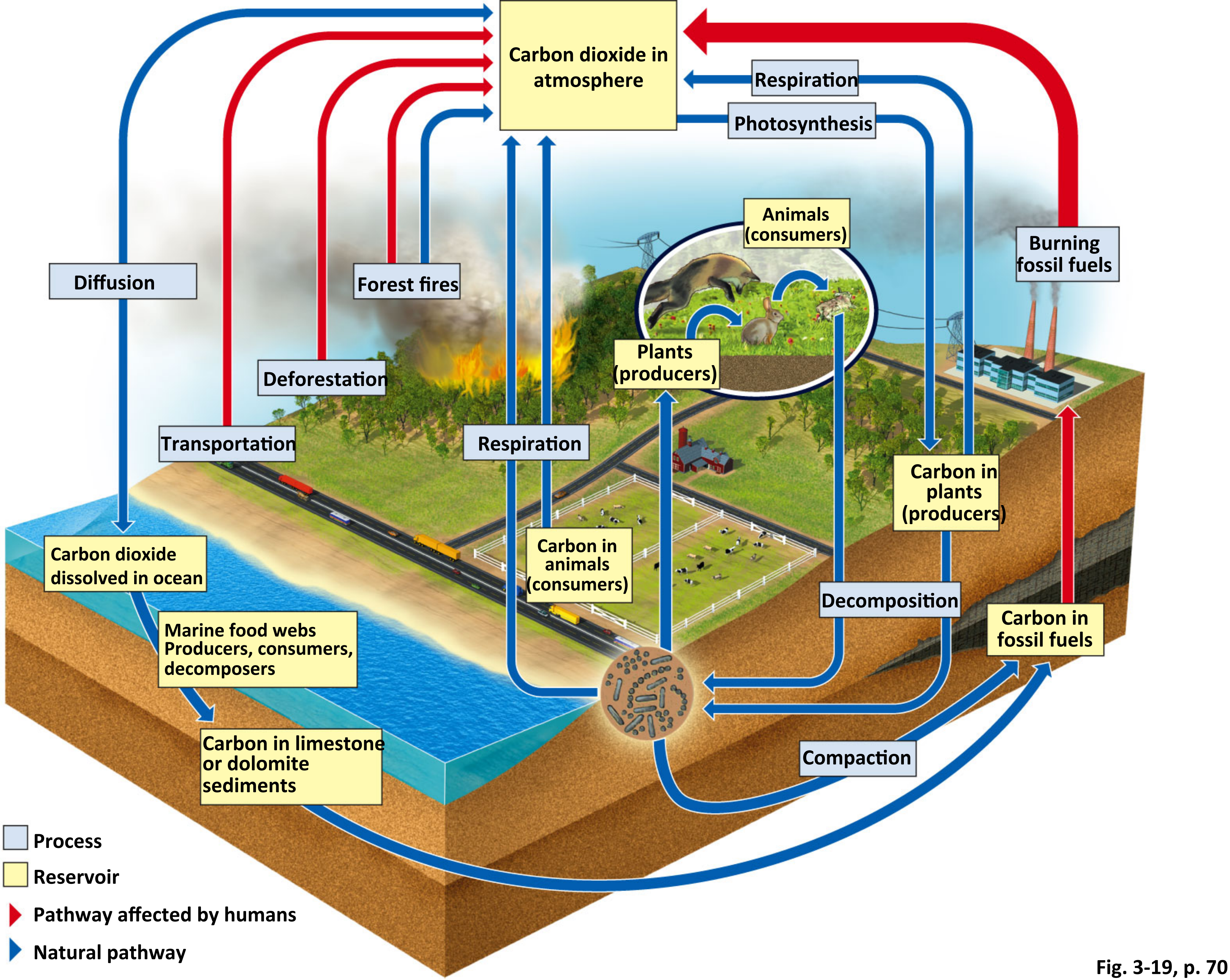




Carbon Sinks and Reservoirs

- Trees of *old growth forest* that live for thousands of years are a major terrestrial carbon sink.
- Soil: Carbon is incorporated into soil by many natural processes including volcanism and decomposition of organic material. Therefore, soil is major terrestrial carbon sink that can store carbon for thousands of years.
- Wetlands and bogs are major terrestrial carbon sinks that can store carbon in plants, soil, and water for thousands of years.

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Natural pathway

Fig. 3-19, p. 70

Biogeochemical Cycles: The Nitrogen Cycle

Nitrogen Cycle Processes (*That you must know!*)

Plants and animals cannot use free nitrogen gas in the atmosphere. They must have nitrogen in "fixed" form.

- Nitrogen is fixed by lightning, ***bacteria*** in soil in terrestrial ecosystems and cyanobacteria in aquatic systems.
  - **Nitrogen Fixation:** $N_2 \rightarrow NH_3/NH_4^+$
    - Free N_2 in atmosphere is "fixed" by nitrogen-fixing bacteria to NH_3 (ammonia):

      $$N_2 + 3H_2 \rightarrow 2NH_3$$
    - Nitrogen fixing bacteria (rhizobium) live in nodules on the roots of leguminous plants (soybeans, peas, clover, and alfalfa.)
    - Gaseous nitrogen reacts with hydrogen to produce ammonia (NH_3) and ammonium ions (NH_4^+)

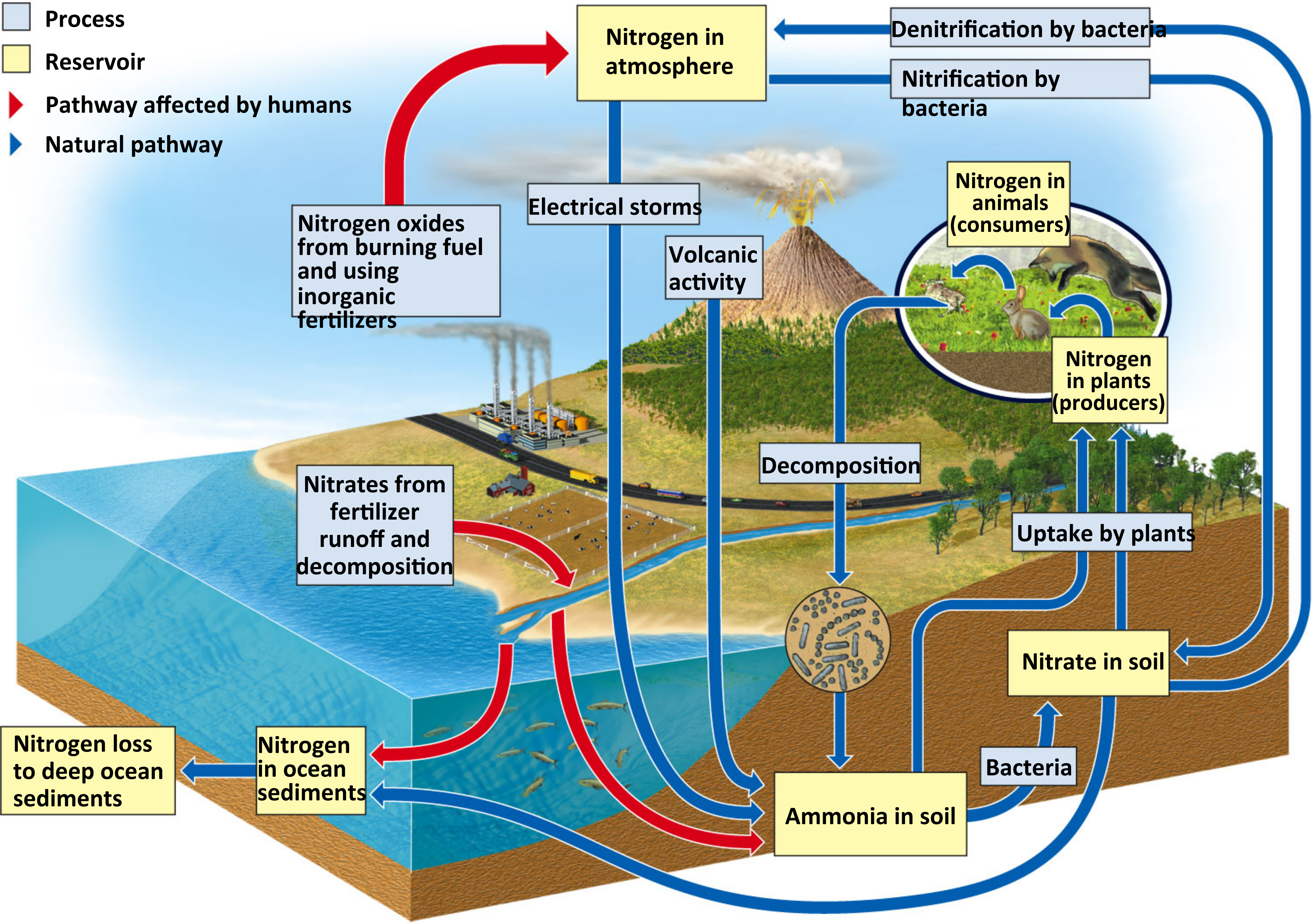
  - **Nitrification:** $NH_3 \rightarrow NH_4^+ \rightarrow NO_2^-/NO_3^-$
    - Water in the soil reacts with ammonia (NH_3) to form NH_4^+ (ammonium ion)
    - Another specialized species of bacteria performs nitrification once ammonium has formed:

      $NH_4^+ \rightarrow NO_2^-$ (nitrite; toxic) NO_3^- (nitrate; plant nutrient)

  - **Assimilation:** NH_3 or NH_4^+ or NO_2^- or NO_3^- $\rightarrow$ organic compounds (proteins)
    - Producers (plants) take up nitrogen in the form of ammonia, ammonium, nitrite, or most readily nitrate for use to make nucleic acids and proteins; the building blocks of plant tissue.
    - Consumers then get fixed nitrogen by eating plants, insects, or other animals.

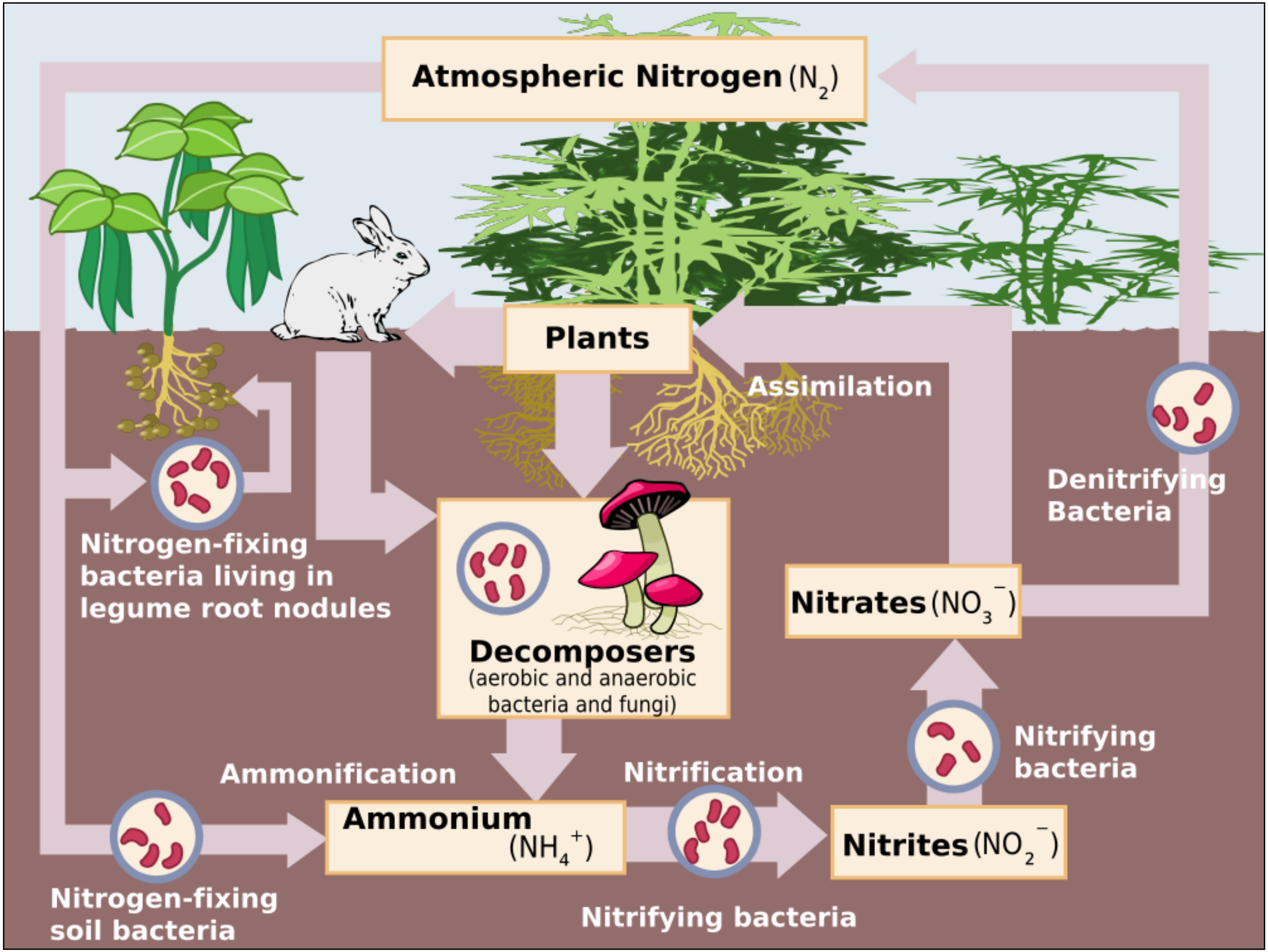
  - **Ammonification (a.k.a. Mineralization):** organic compounds $\rightarrow NH_3$
    - Eventually all organisms die and their tissue decompose.
    - Fungal and bacterial decomposers break down organic material found in dead bodies and waste products and convert organic compounds back into inorganic compounds; Such as inorganic forms of nitrogen like ammonia or ammonium ions (NH_3/NH_4^+).

  - **Denitrification:** NH_3 or NH_4^+ $\rightarrow$ NO_2^- and/or NO_3^- $\rightarrow$ N_2 (nitrogen gas) and N_2O (nitrous oxide)
    - The final step that completes nitrogen cycle.
    - In a series of steps, another group of bacteria convert ammonia or ammonium ions into nitrate then to atmospheric nitrogen compounds: the gases nitrous oxide (N_2O) and nitrogen gas (N_2).



Process
Reservoir
Pathway affected by humans
Natural pathway
Nitrogen in atmosphere
Denitrification by bacteria
Nitrification by bacteria
Nitrogen oxides from burning fuel and using inorganic fertilizers
Electrical storms
Volcanic activity
Nitrogen in animals (consumers)
Nitrogen in plants (producers)
Decomposition
Nitrates from fertilizer runoff and decomposition
Uptake by plants
Nitrate in soil
Bacteria
Ammonia in soil
Nitrogen loss to deep ocean sediments
Nitrogen in ocean sediments

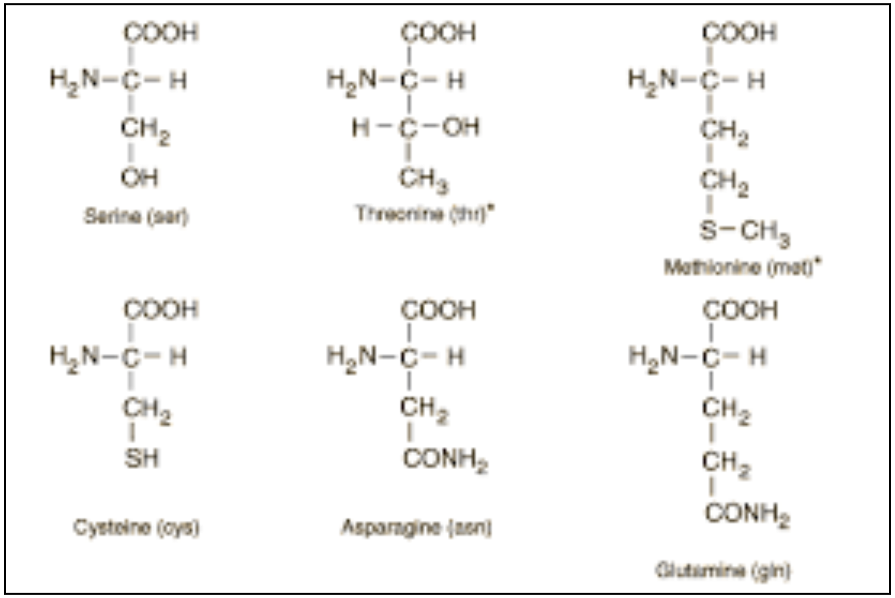
Fig. 3-20, p. 71

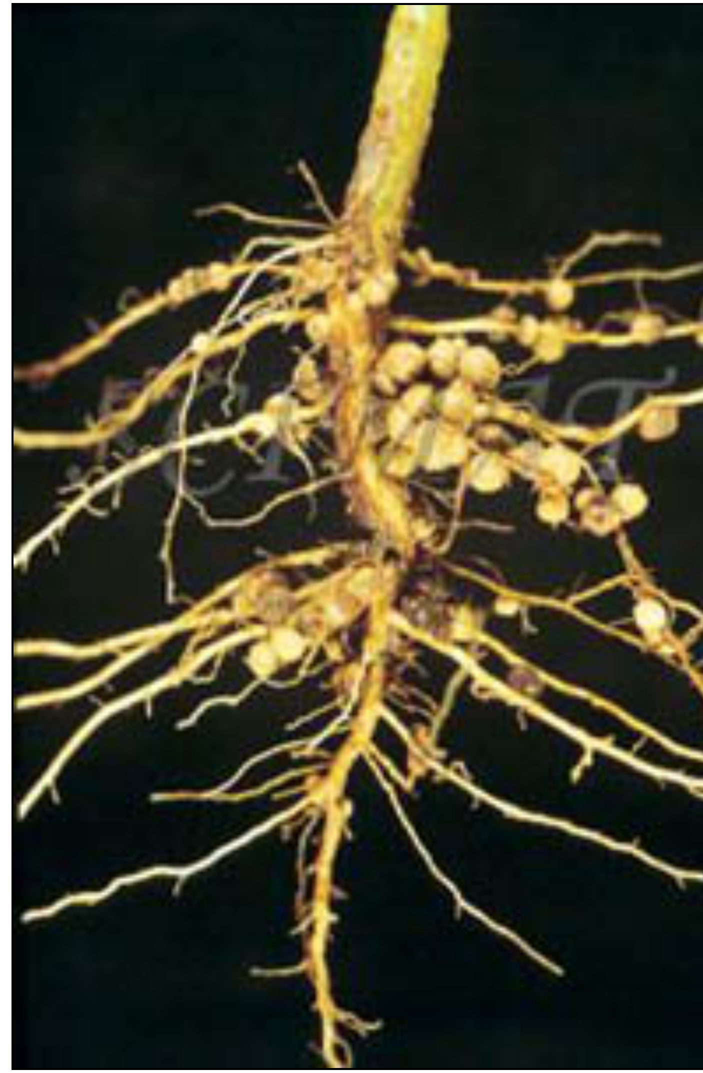


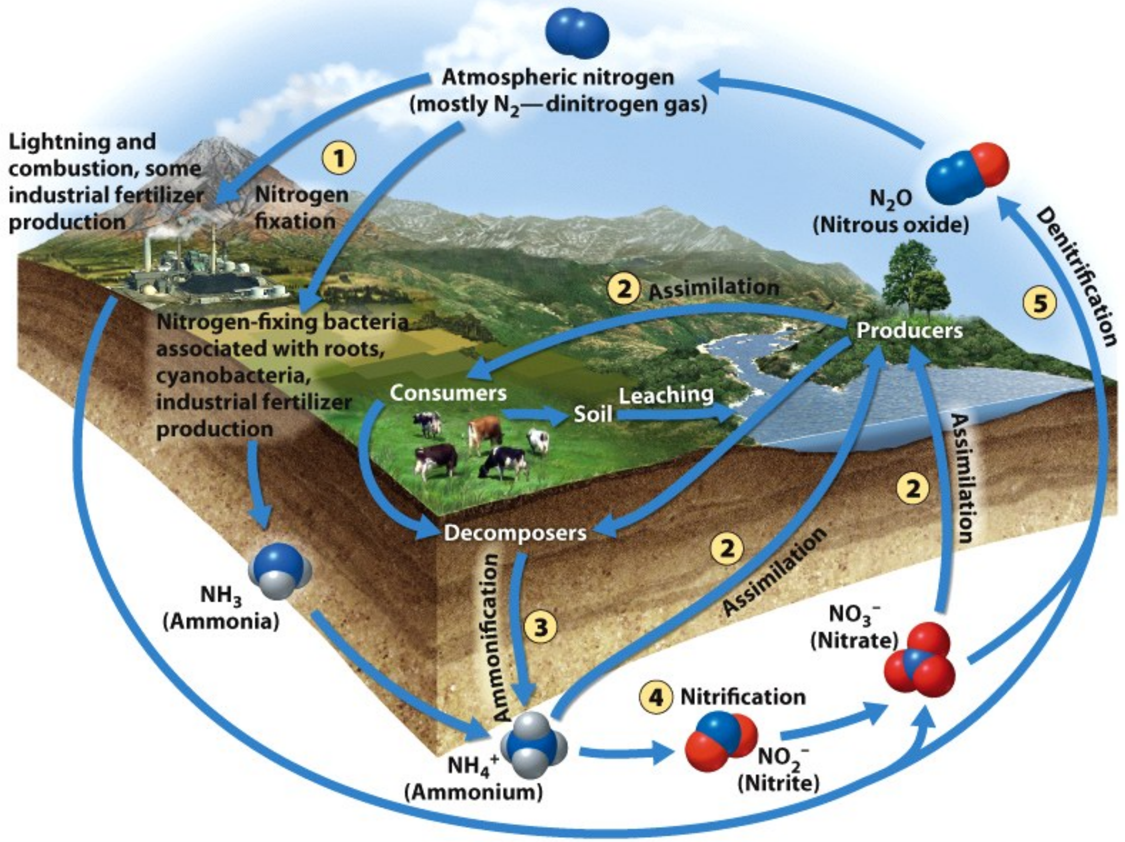
Atmospheric Nitrogen (N_2)
Plants
Assimilation
Denitrifying Bacteria
Nitrogen-fixing bacteria living in legume root nodules
Decomposers
(aerobic and anaerobic bacteria and fungi)
Nitrates (NO_3^-)
Nitrifying bacteria
Ammonification
Nitrification
Ammonium (NH_4^+)
Nitrites (NO_2^-)
Nitrogen-fixing soil bacteria
Nitrifying bacteria

Biogeochemical Cycles: The Nitrogen Cycle

Important Organic Nitrogen Containing Molecules







1 Nitrogen Fixation

Nitrogen fixation converts N_2 from the atmosphere. Biotic processes convert N_2 to ammonia (NH_3), whereas abiotic processes convert N_2 to nitrate (NO_3^-).

2 Assimilation

Producers take up either ammonium (NH_4^+) or nitrate (NO_3^-). Consumers assimilate nitrogen by eating producers.

3 Ammonification

Decomposers in soil and water break down biological nitrogen compounds into ammonium (NH_4^+).

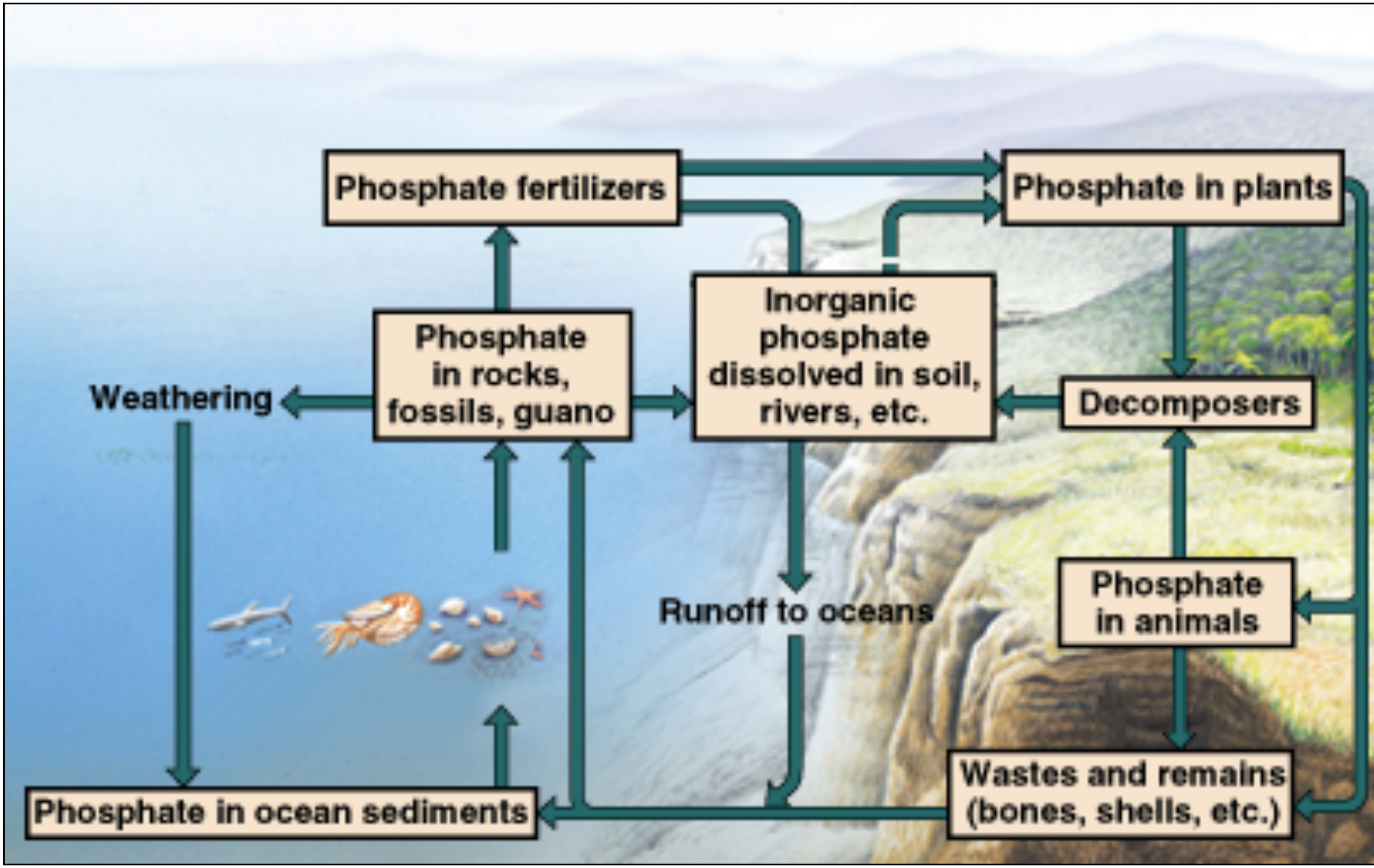
4 Nitrification

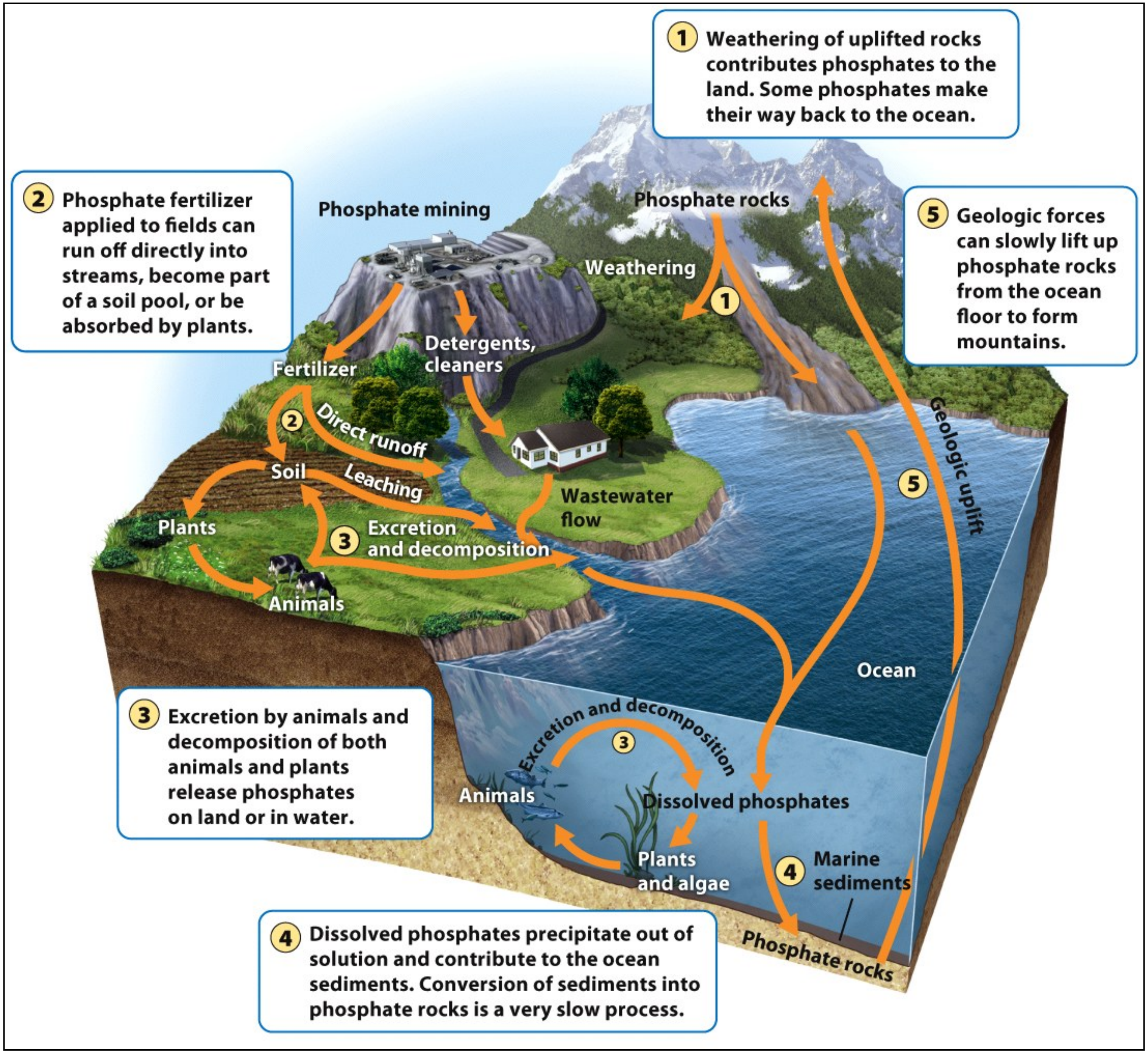
Nitrifying bacteria convert ammonium (NH_4^+) into nitrite (NO_2^-) and then into nitrate (NO_3^-).

5 Denitrification

In a series of steps, denitrifying bacteria in oxygen-poor soil and stagnant water convert nitrate (NO_3^-) into nitrous oxide (N_2O) and eventually nitrogen gas (N_2).

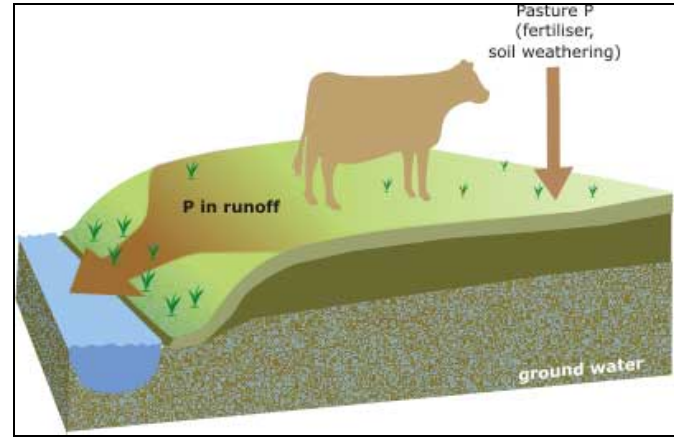
Biogeochemical Cycles: The Phosphorus Cycle

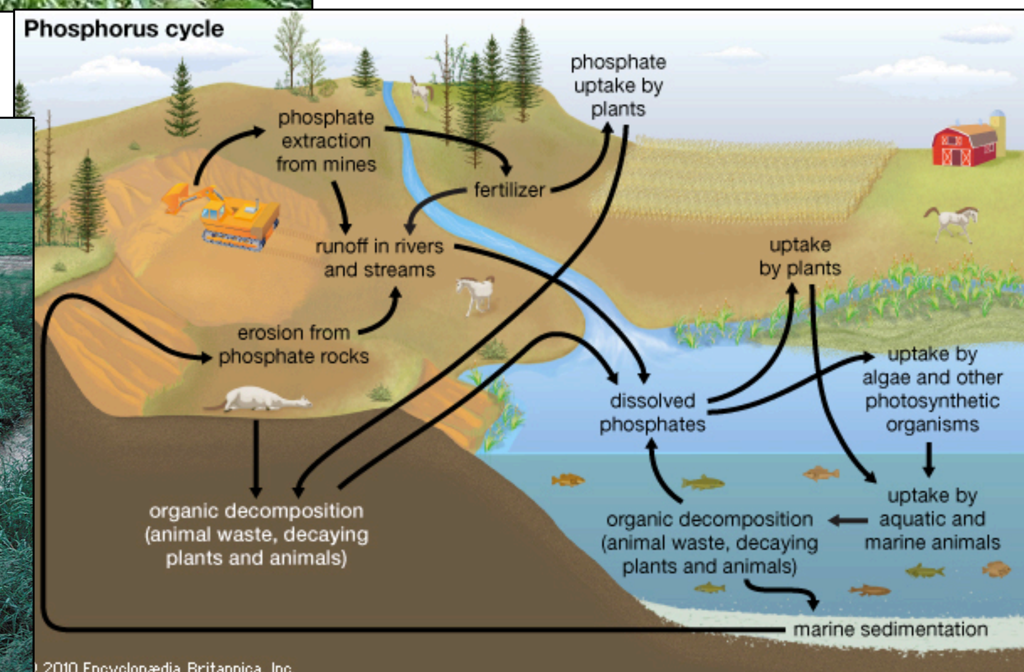



1 Weathering of uplifted rocks contributes phosphates to the land. Some phosphates make their way back to the ocean.
2 Phosphate fertilizer applied to fields can run off directly into streams, become part of a soil pool, or be absorbed by plants.
Phosphate mining
Phosphate rocks
Weathering
1
5 Geologic forces can slowly lift up phosphate rocks from the ocean floor to form mountains.
Detergents, cleaners
Fertilizer
2
Direct runoff
Soil
Leaching
Wastewater flow
Geologic uplift
5
Plants
3
Excretion and decomposition
Animals
Ocean
3 Excretion by animals and decomposition of both animals and plants release phosphates on land or in water.
Excretion and decomposition
3
Animals
Dissolved phosphates
Plants and algae
4
Marine sediments
Phosphate rocks
4 Dissolved phosphates precipitate out of solution and contribute to the ocean sediments. Conversion of sediments into phosphate rocks is a very slow process.

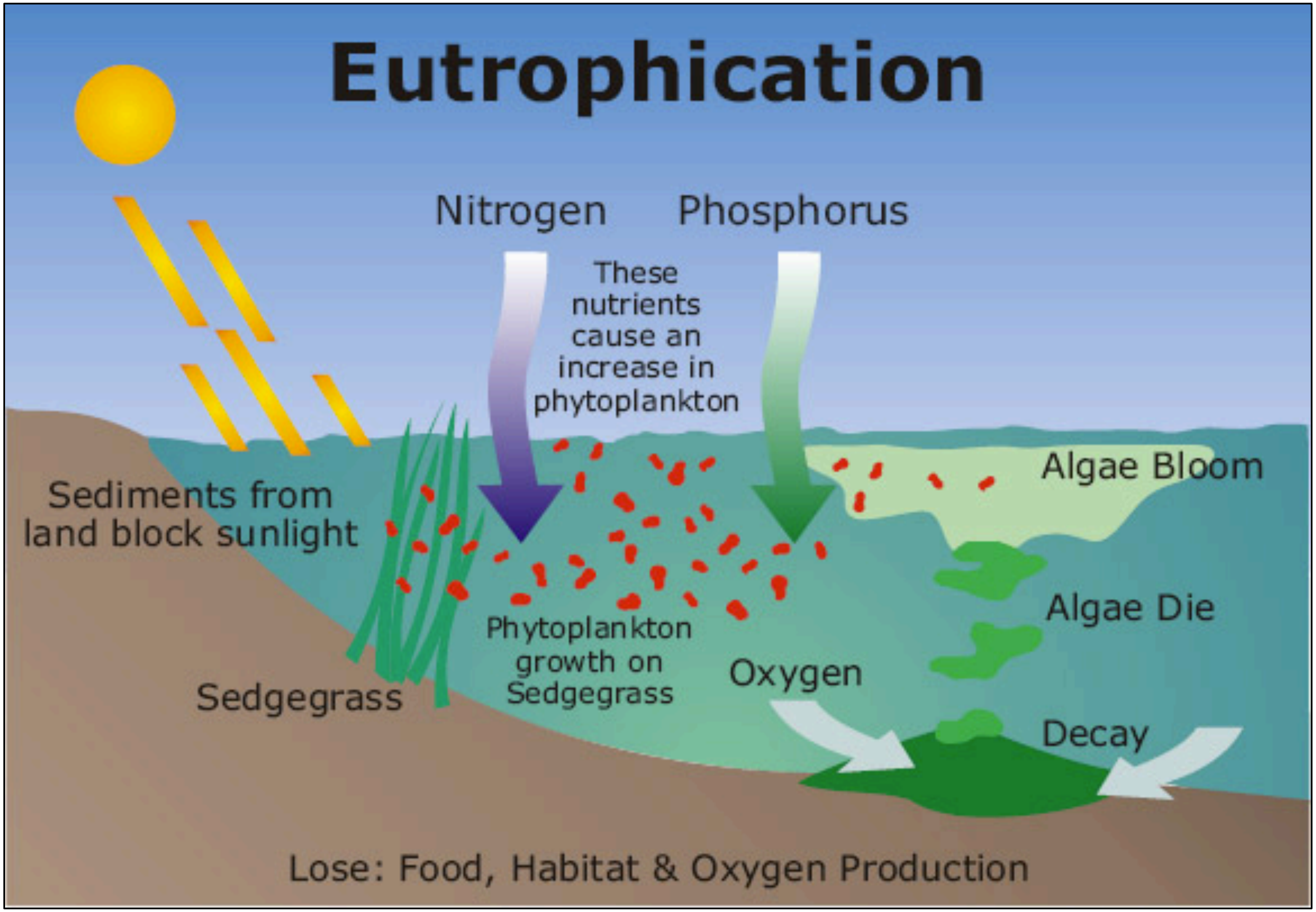
Biogeochemical Cycles: The Phosphorus Cycle

Biogeochemical Cycles: The Phosphorus Cycle

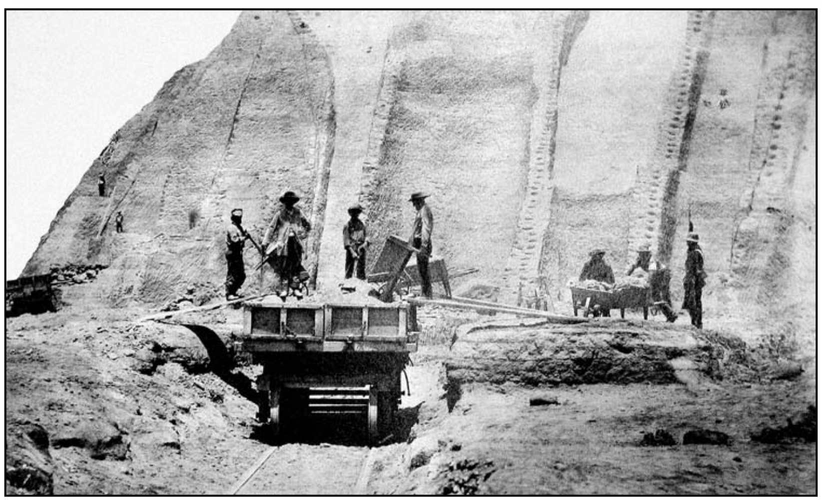


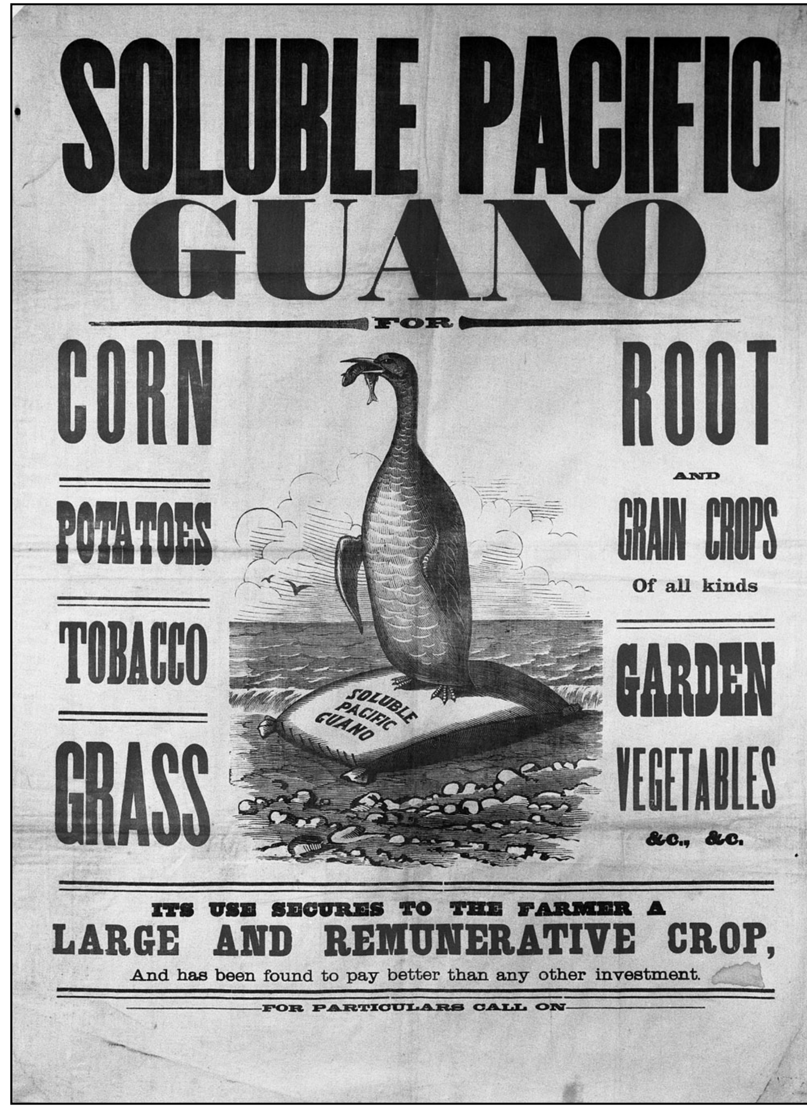


Biogeochemical Cycles: The Phosphorus Cycle



Biogeochemical Cycles: The Phosphorus Cycle





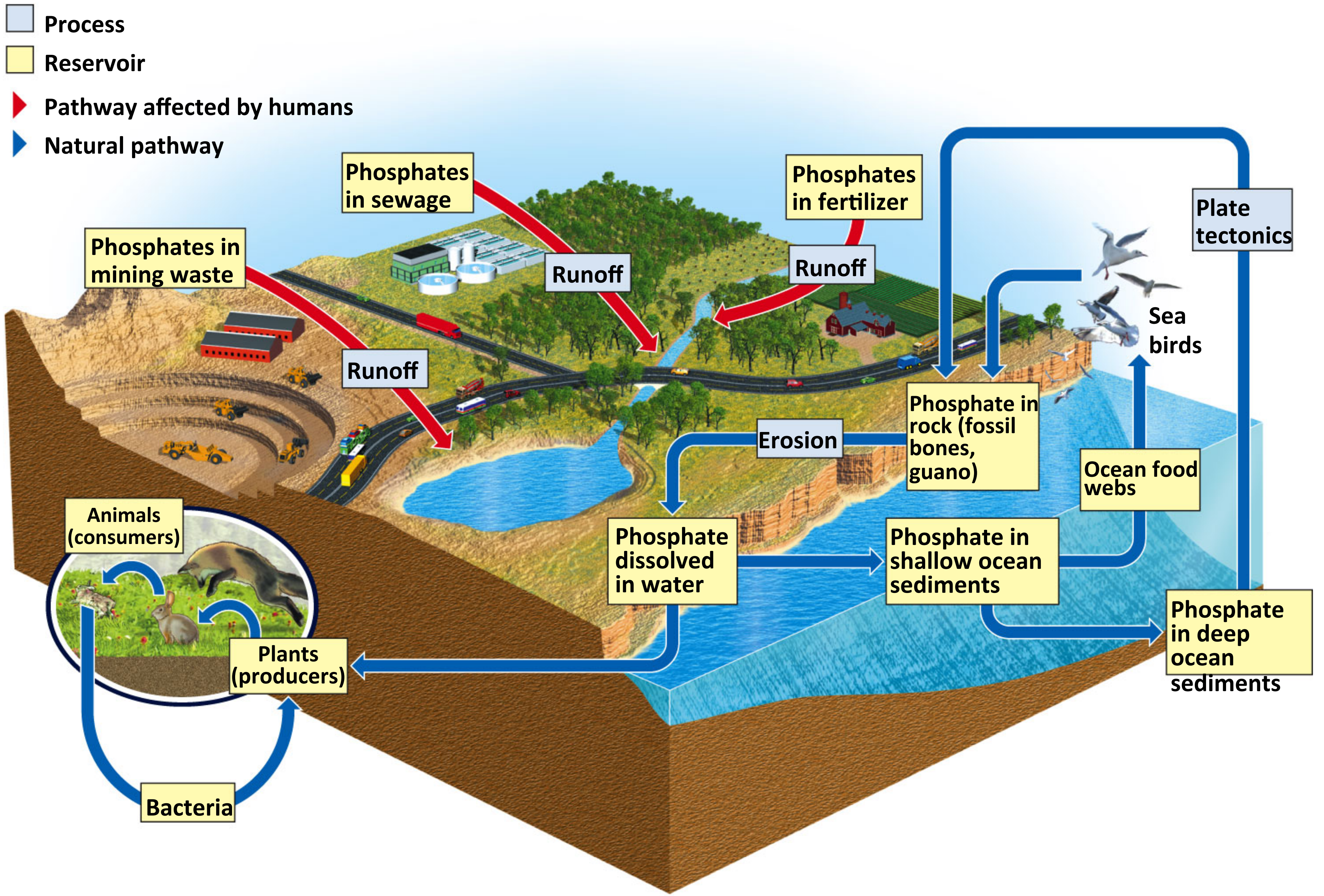
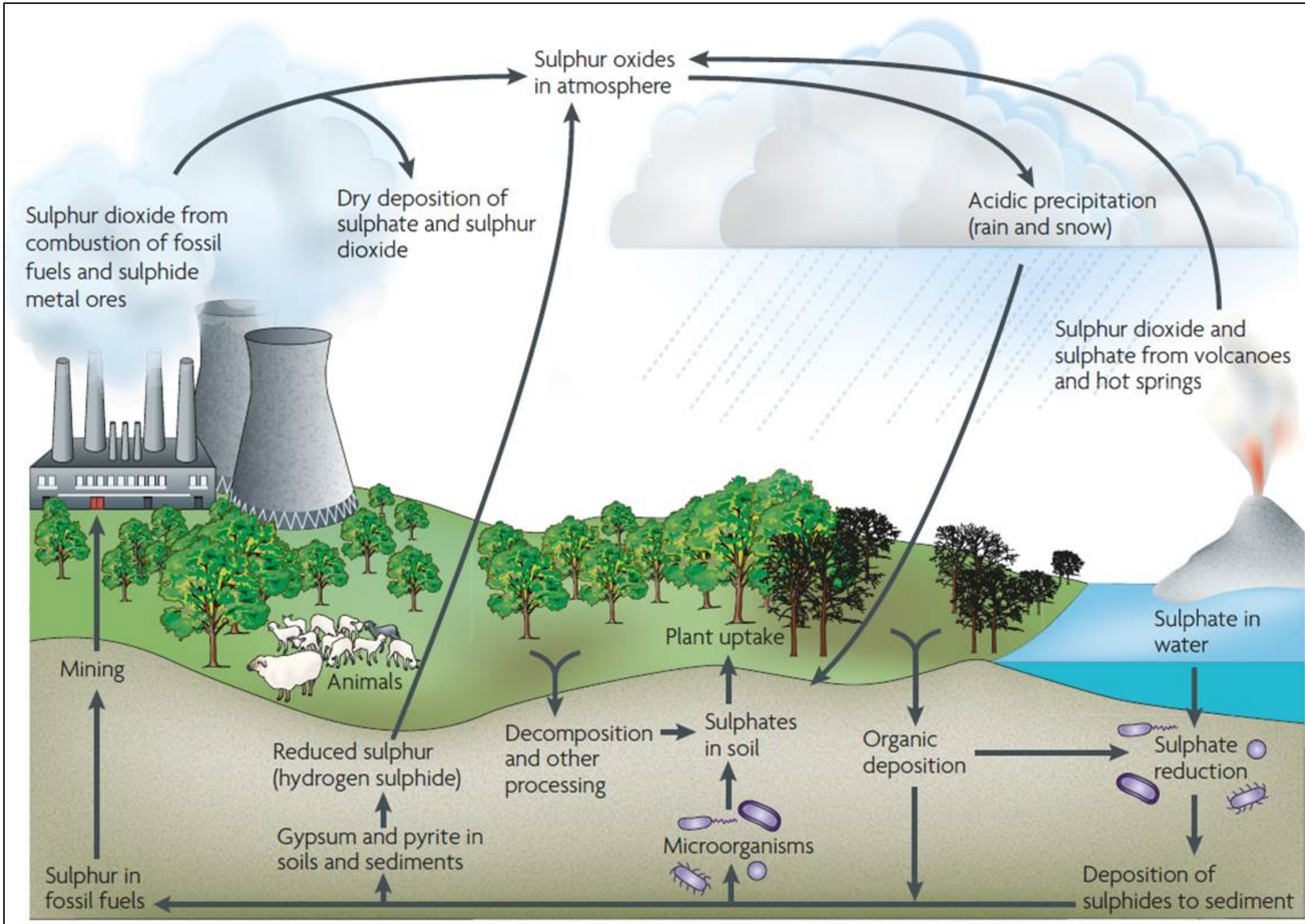
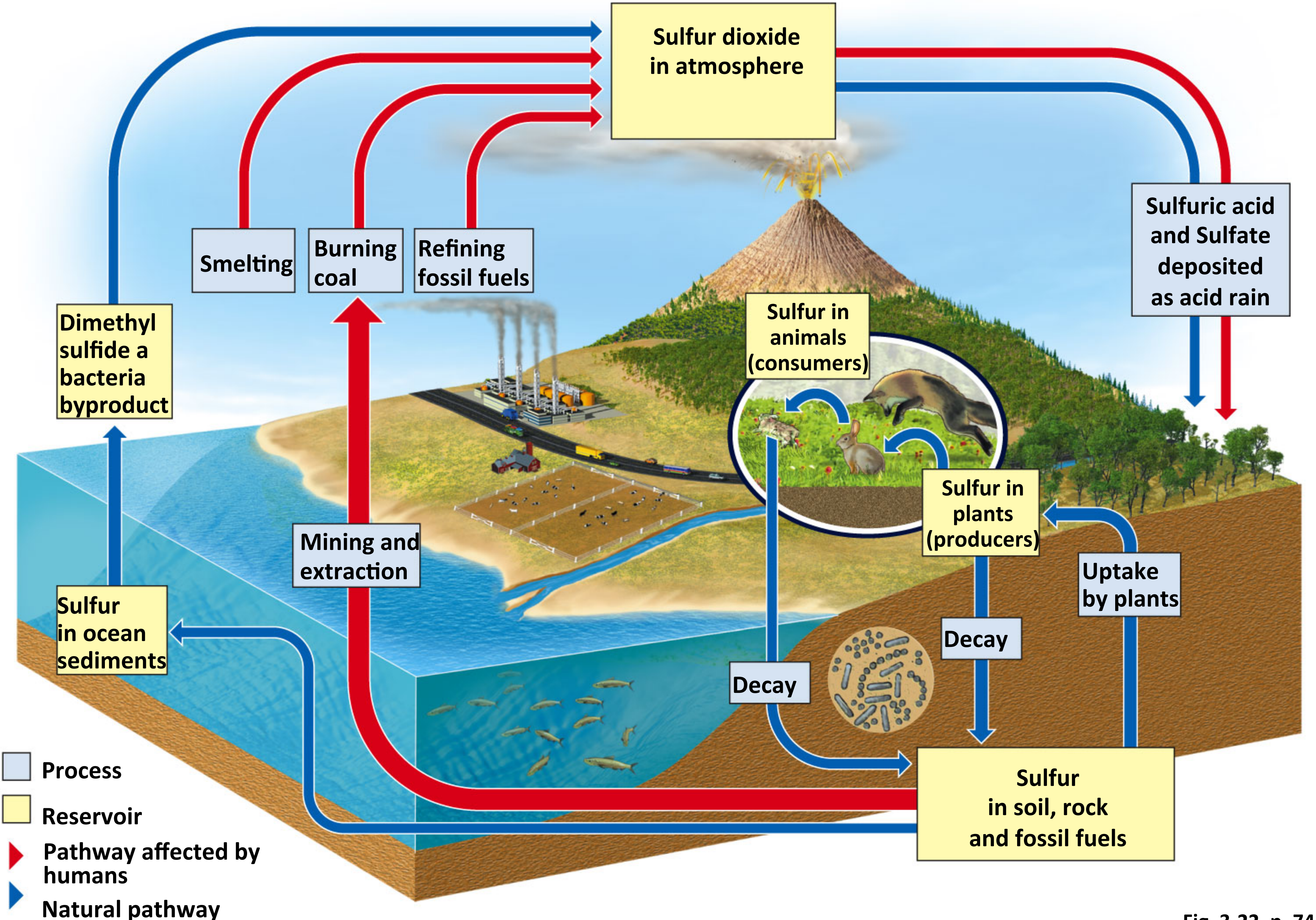

Process
Reservoir
Pathway affected by humans
Natural pathway
Phosphates in sewage
Phosphates in fertilizer
Plate tectonics
Phosphates in mining waste
Runoff
Runoff
Sea birds
Runoff
Phosphate in rock (fossil bones, guano)
Erosion
Ocean food webs
Animals (consumers)
Phosphate dissolved in water
Phosphate in shallow ocean sediments
Phosphate in deep ocean sediments
Plants (producers)
Bacteria

Fig. 3-21, p. 73

Biogeochemical Cycles: The Sulfur Cycle

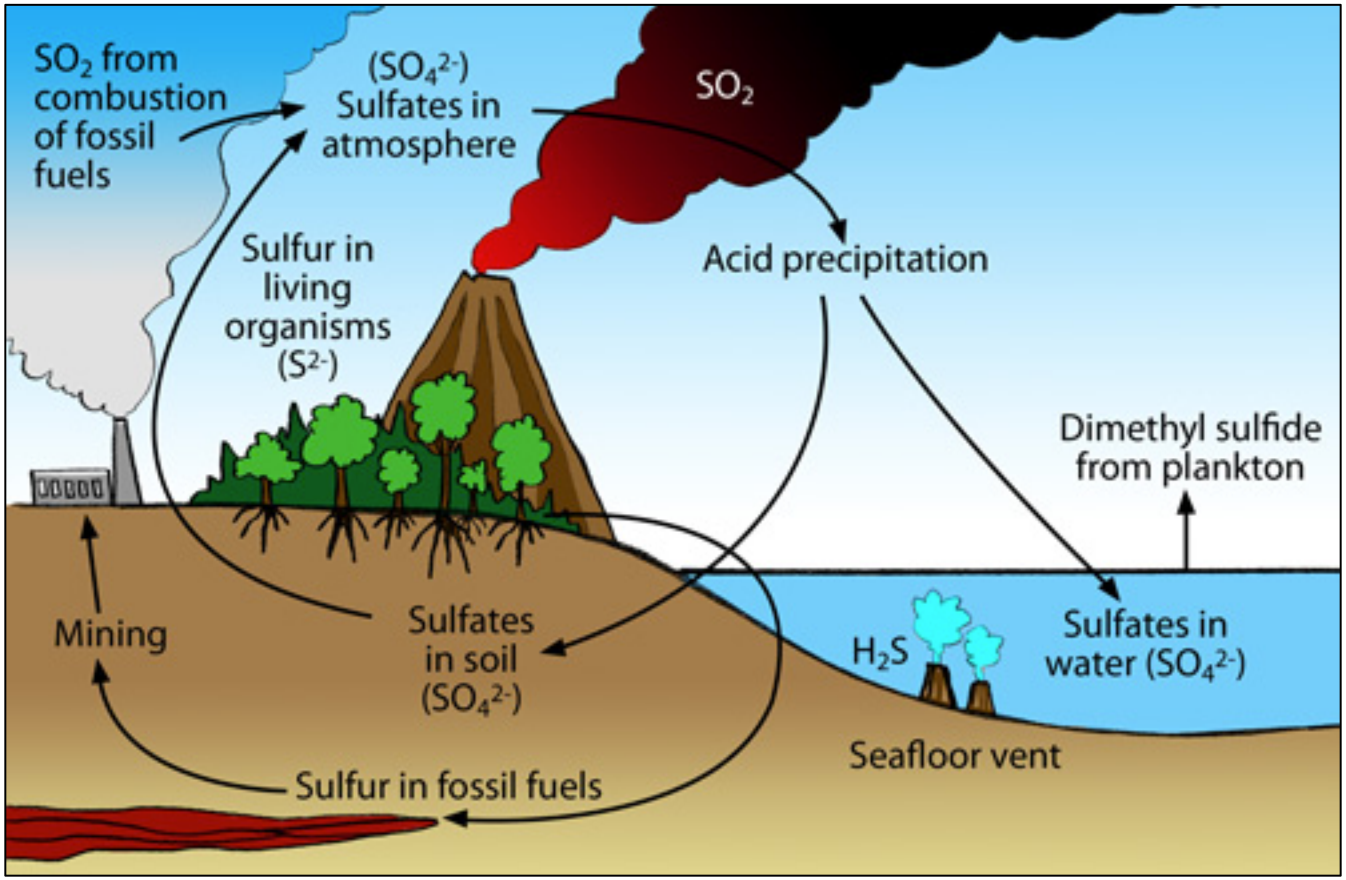




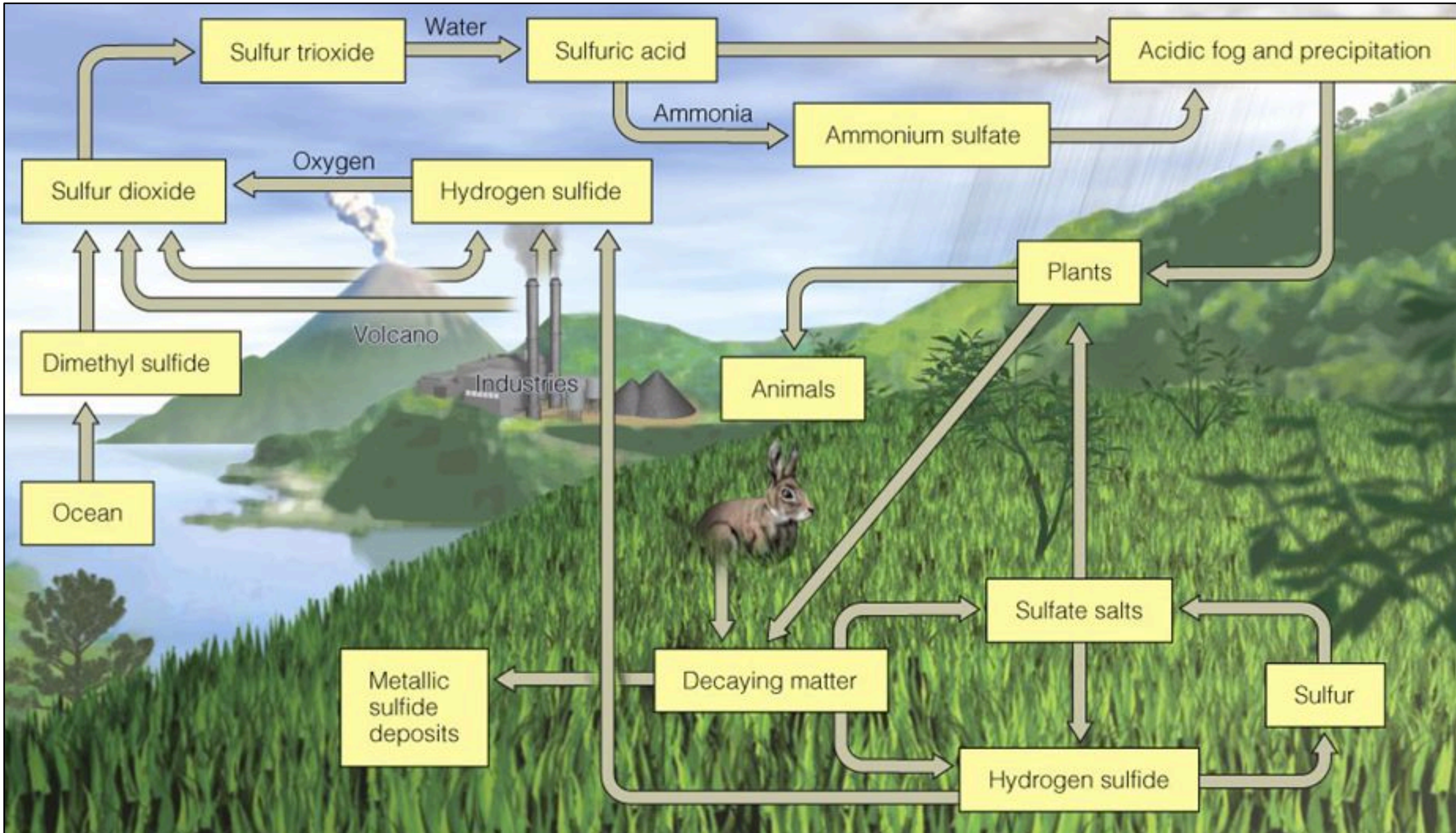
Sulfur dioxide in atmosphere
Smelting
Burning coal
Refining fossil fuels
Sulfuric acid and Sulfate deposited as acid rain
Dimethyl sulfide a bacteria byproduct
Sulfur in animals (consumers)
Sulfur in plants (producers)
Mining and extraction
Uptake by plants
Decay
Sulfur in ocean sediments
Decay
Sulfur in soil, rock and fossil fuels
Process
Reservoir
Pathway affected by humans
Natural pathway

Fig. 3-22, p. 74

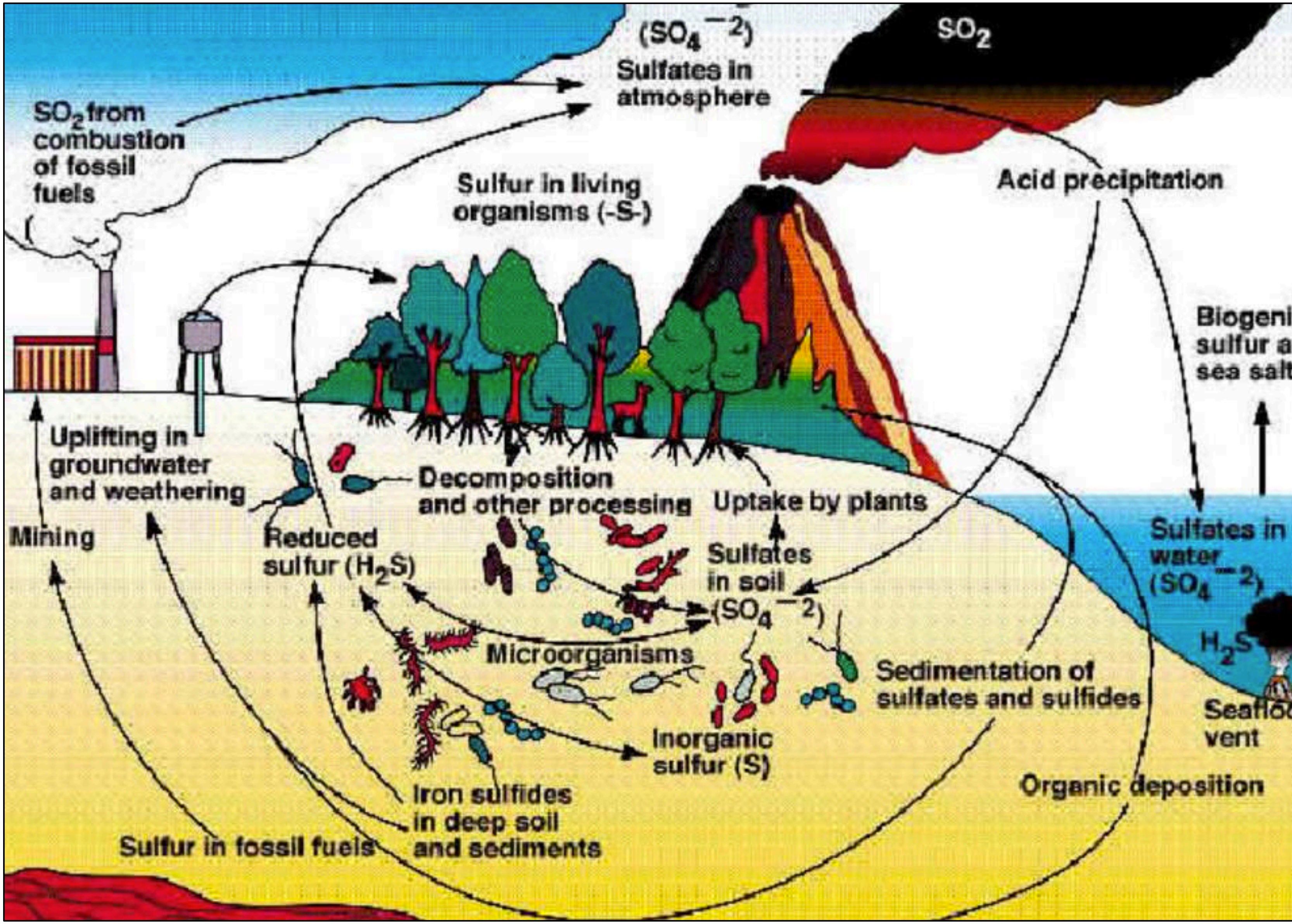
Biogeochemical Cycles: The Sulfur Cycle



Biogeochemical Cycles: The Sulfur Cycle



Biogeochemical Cycles: The Sulfur Cycle



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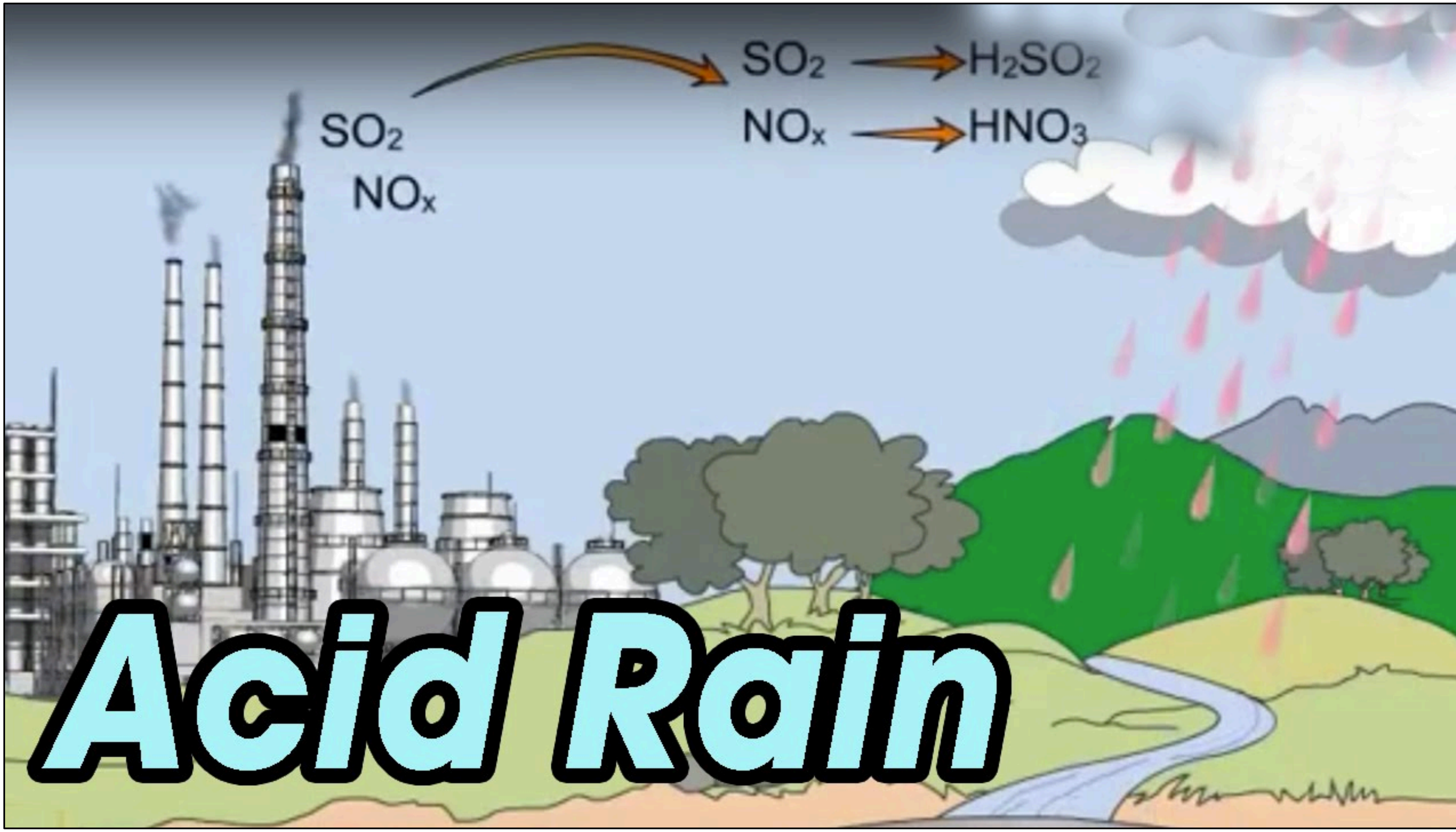
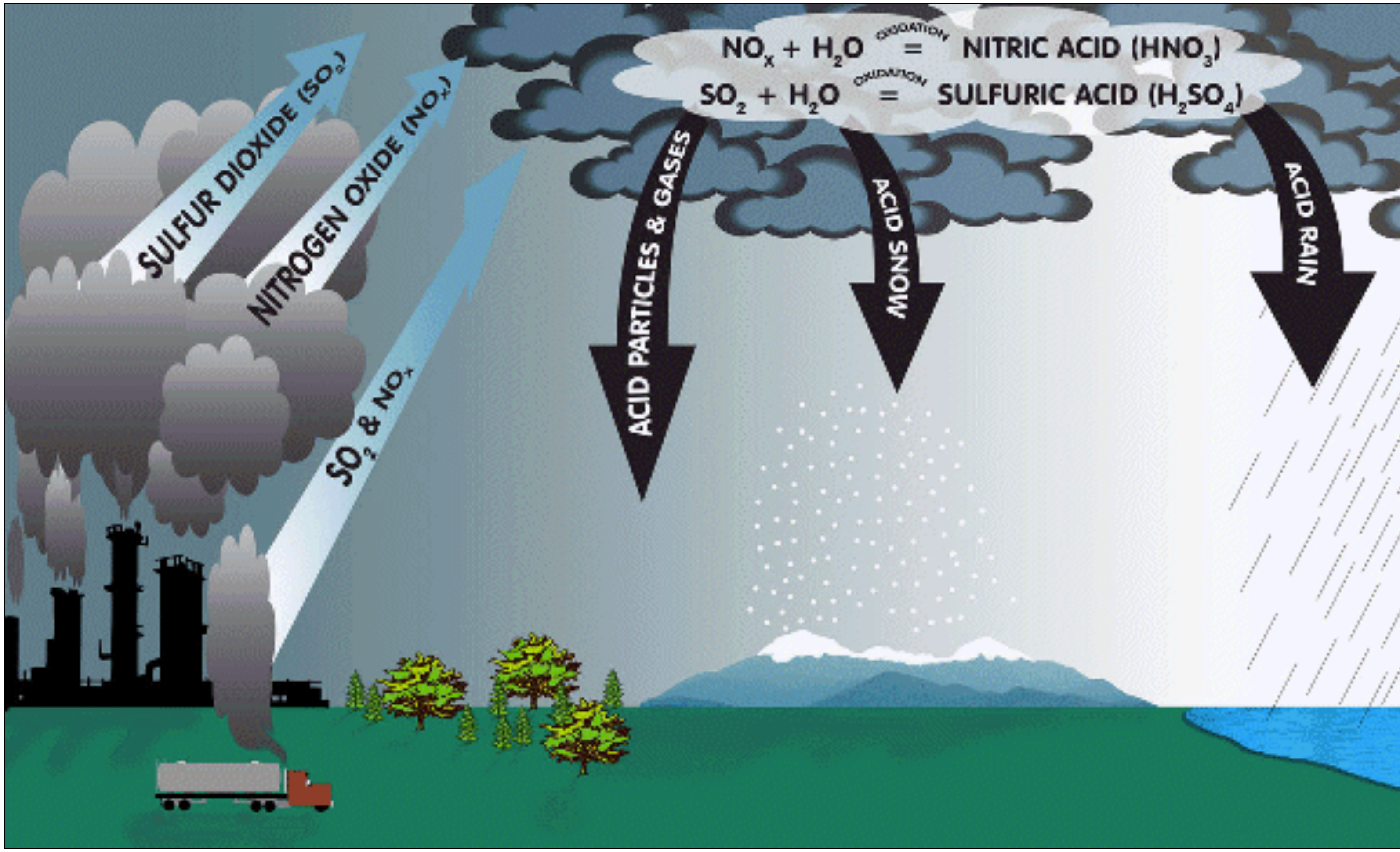


Biogeochemical Cycles: The Sulfur Cycle



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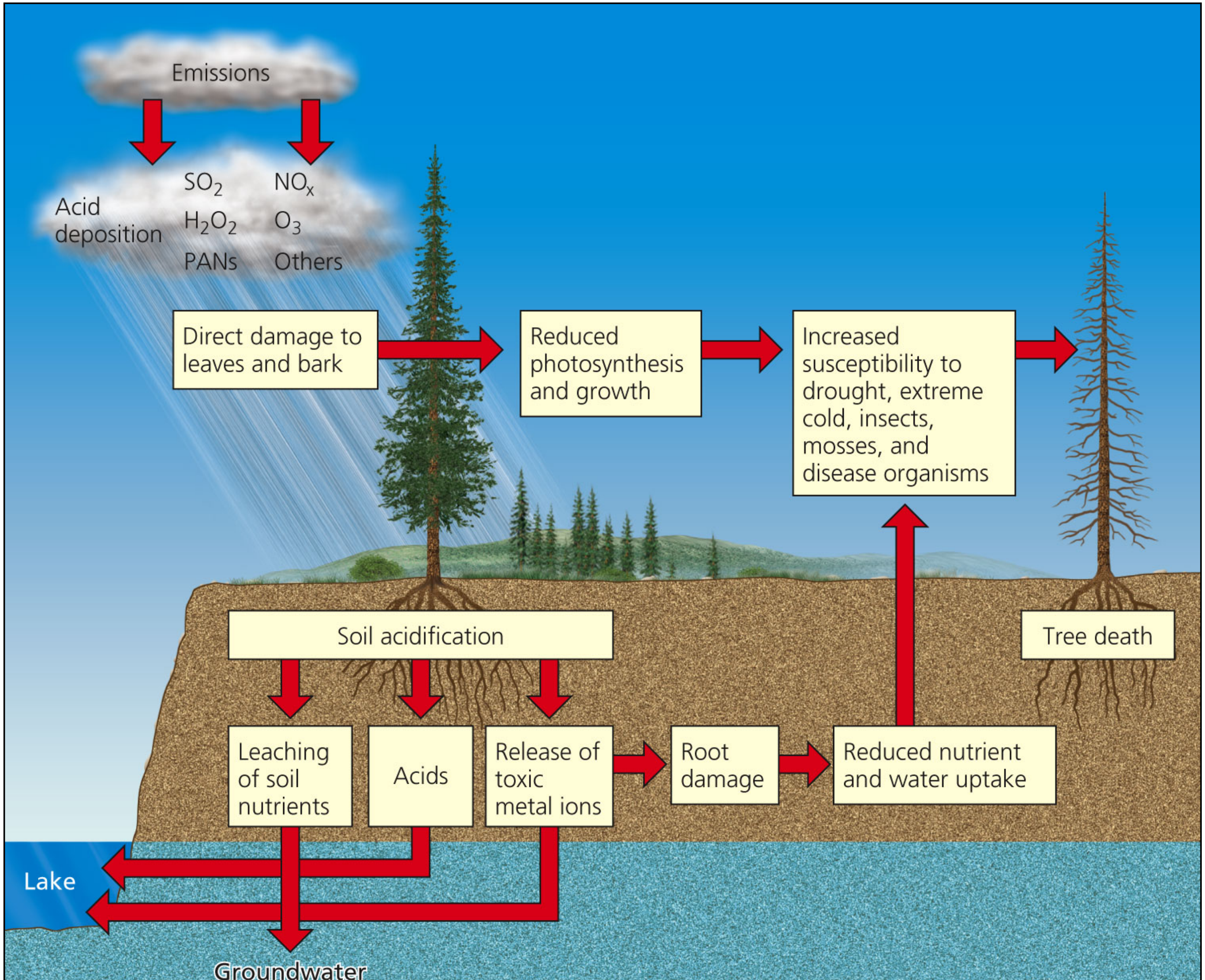

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