

EWCE 131
Ecology and Environmental Pollution

Lecture 7

Instructor

Maj Dr. Kazi Shamima Akter, Engrs

Department of EWCE, MIST

Lecture outline

Biogeochemical Cycles

Topics

- Nitrogen cycle
- Phosphorus cycle
- Sulphur cycle

Nitrogen Cycle

- Nitrogen is essential to life in proteins and DNA.
- Free or diatonic nitrogen (N_2 uncombined with any other element) makes up approximately 78% of Earth's atmosphere.
- However, no organism can use molecular nitrogen directly.
- Some organisms, such as animals, require nitrogen in an organic compound. Others, including plants, algae, and bacteria, can take up nitrogen either as the nitrate ion (NO_3^-) or the ammonium ion (NH_4^+).

Nitrogen Cycle

- The nitrogen cycle is one of the most important and most complex of the global cycles.

- The process of converting inorganic, molecular nitrogen in the atmosphere to ammonia or nitrate is called nitrogen fixation.

- Once in these forms, nitrogen can be used on land by plants and in the oceans by algae.

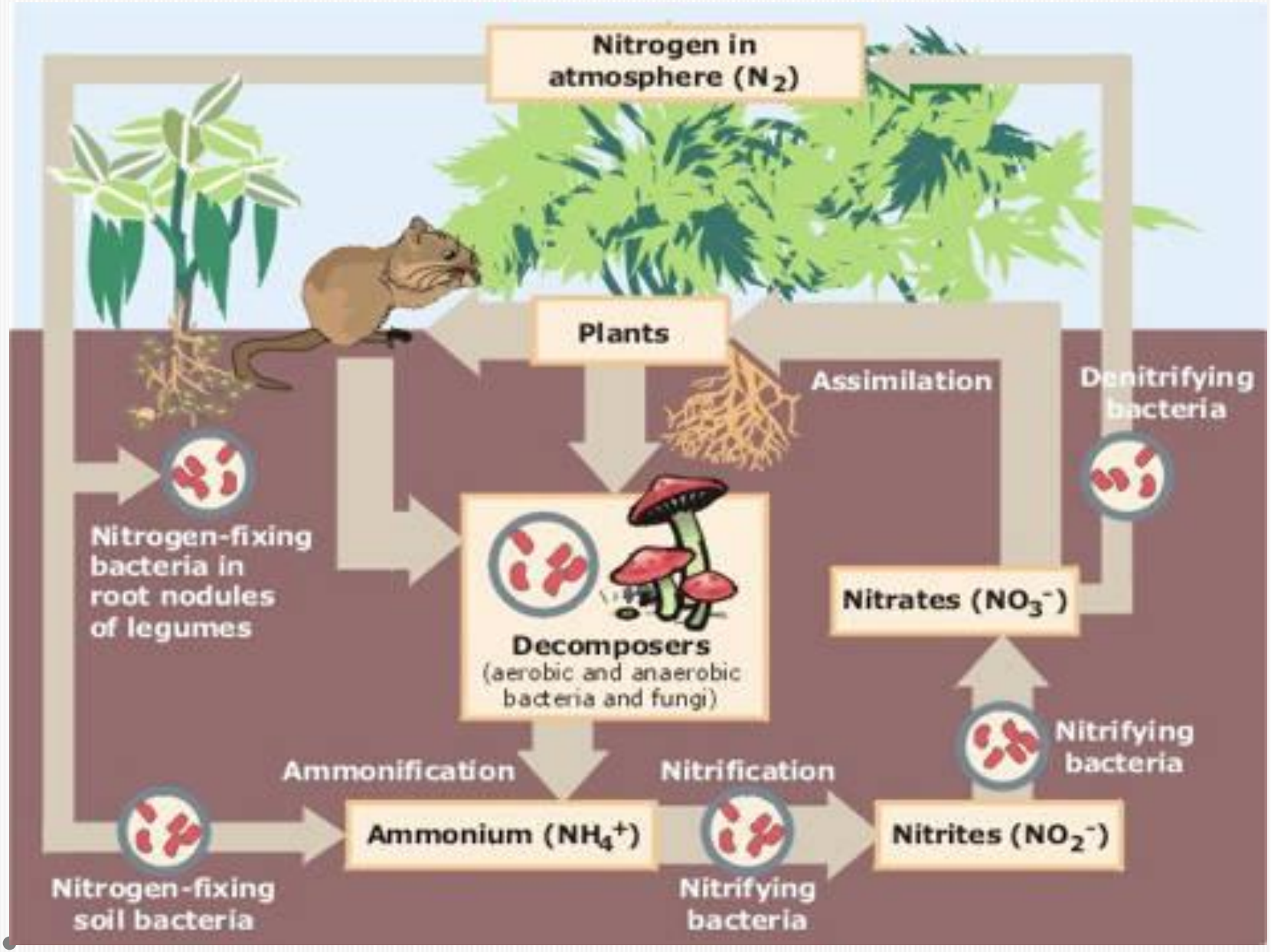
- Bacteria, plants, and algae then convert these inorganic nitrogen compounds into organic ones through chemical reactions, and the nitrogen becomes available in ecological food chains.

Nitrogen Cycle

- When organisms die, bacteria convert the organic compounds containing nitrogen back to ammonia, nitrate, or molecular nitrogen, which enters the atmosphere.

- The process of releasing fixed nitrogen back to molecular nitrogen is called denitrification.

Nitrogen Cycle



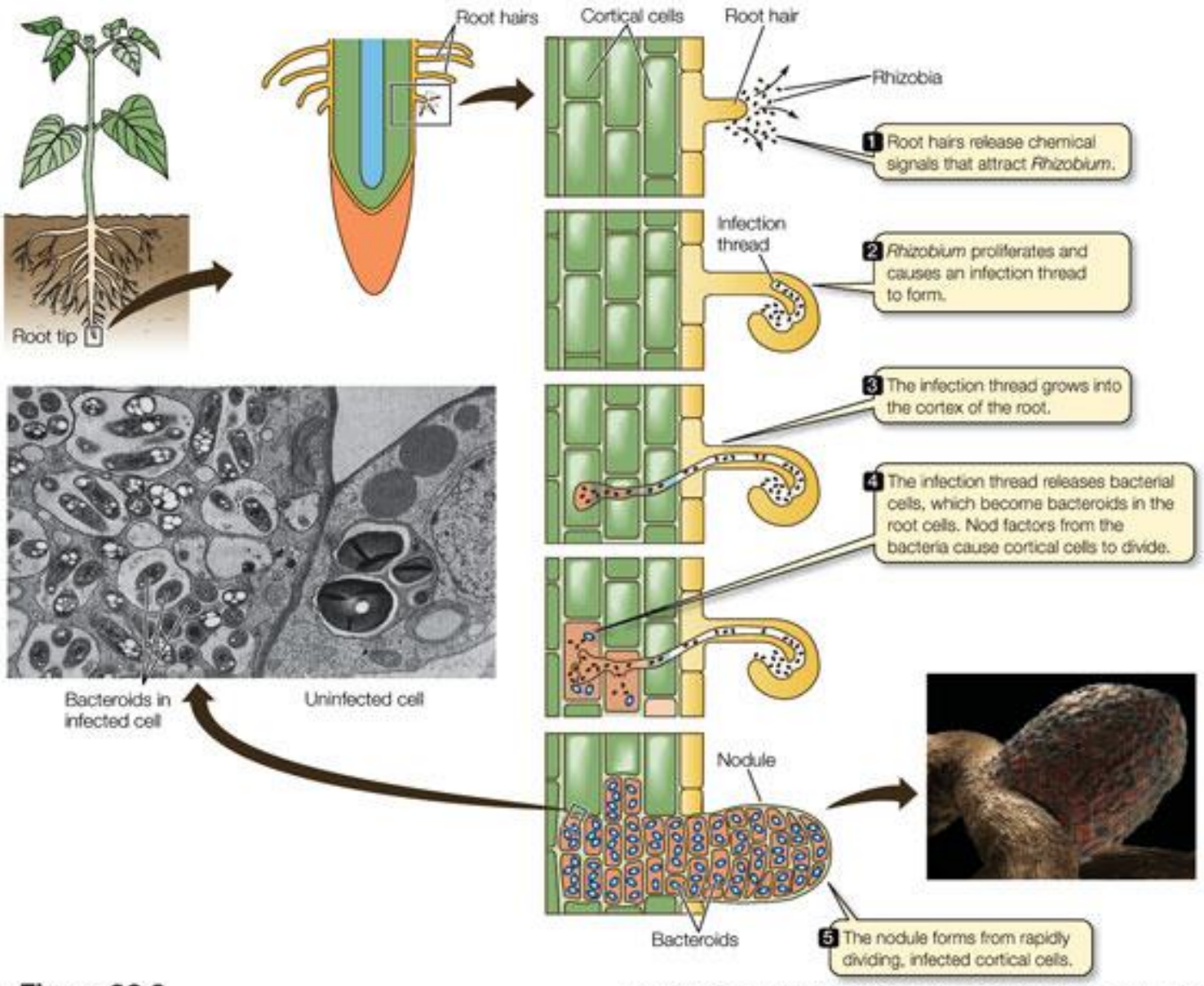
Nitrogen Cycle

- Thus, all organisms depend on nitrogen-converting bacteria.

- Some organisms, including termites and ruminant mammals, such as cows, goats, deer etc have evolved symbiotic relationships with these bacteria.

- For example, the roots of the pea family have nodules that provide a habitat for the bacteria. The bacteria obtain organic compounds for food from the plants, and the plants obtain usable nitrogen.

Symbiotic Relation between Bacteria and Plants



***LIFE 8e*, Figure 36.9**

LIFE: THE SCIENCE OF BIOLOGY, Eighth Edition © 2007 Sinauer Associates, Inc. and W. H. Freeman & Co.

Nitrogen Cycle

- **Reservoir**

– atmosphere (as N_2); soil as NH_4^+ (ammonium), NH_3 (ammonia), NO_2^- (nitrite), and NO_3^- (nitrate)

- **Assimilation**

– plants absorb nitrogen as either NH_4+ or as NO_3^-,

– animals obtain nitrogen by eating plants and other animals.

The stages in the assimilation of nitrogen are as follows:

✓ Nitrogen Fixation: N_2 to NH_4^+ by nitrogen-fixing bacteria (prokaryotes in the soil and root nodules), N_2 to NO_3^- by lightning and UV radiation.

Nitrogen Cycle

- ✓ **Nitrification**: NH_4^+ to NO_2^- and NO_2^- to NO_3^- by various nitrifying bacteria.

- **Release**

– Denitrifying bacteria convert NO_3^- back to N_2 (denitrification);

– detrivorous bacteria convert organic compounds back to NH_4+ (ammonification); animals excrete NH_4^+ (or NH_3) urea, or uric acid.

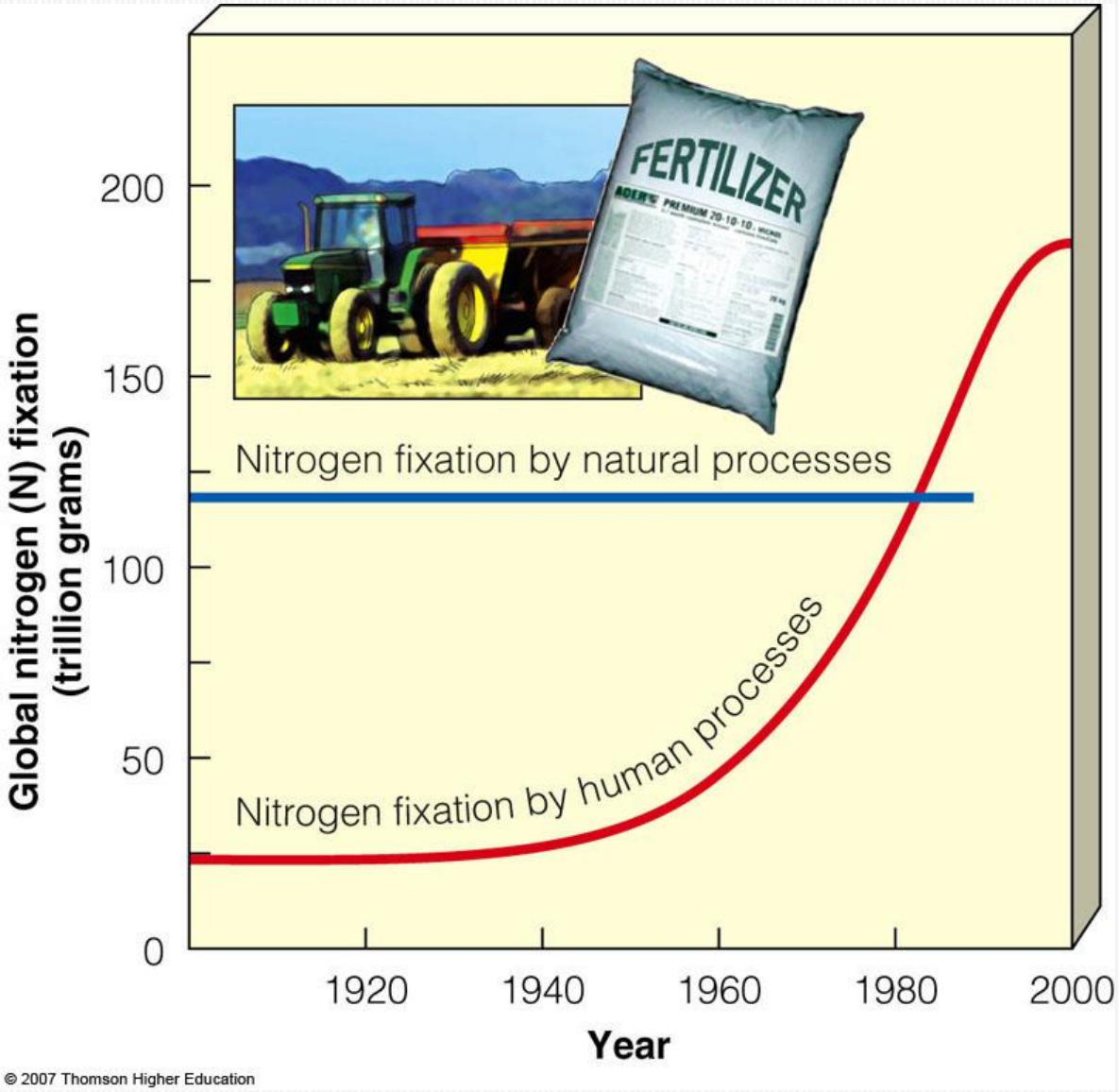
Impacts of Human Activities on Nitrogen Cycle

We alter the nitrogen cycle by:

- Adding gases that contribute to acid rain.
- Adding nitrous oxide (NO) to the atmosphere through farming practices which can warm the atmosphere and deplete ozone.
- Contaminating ground water from nitrate ions (NO_3^-) in inorganic fertilizers.
- Releasing nitrogen into the troposphere through deforestation.

Impacts of Human Activities on Nitrogen Cycle

- Human activities such as production of fertilizers fix more nitrogen than all natural sources combined.



Phosphorus Cycle

- Phosphrus, one of the “big six” elements required in large quantities by all forms of life, is often a limiting nutrient for plant and algae growth.

- The phosphorus cycle is significantly different from the carbon and nitrogen cycles.

- Unlike carbon and nitrogen, phosphorus does not have a gaseous phase on Earth; it is found in the atmosphere only in small particles of dust.

Phosphorus Cycle

- In addition, phosphorus tends to form compounds that are relatively insoluble in water, so phosphorus is not readily weathered chemically.

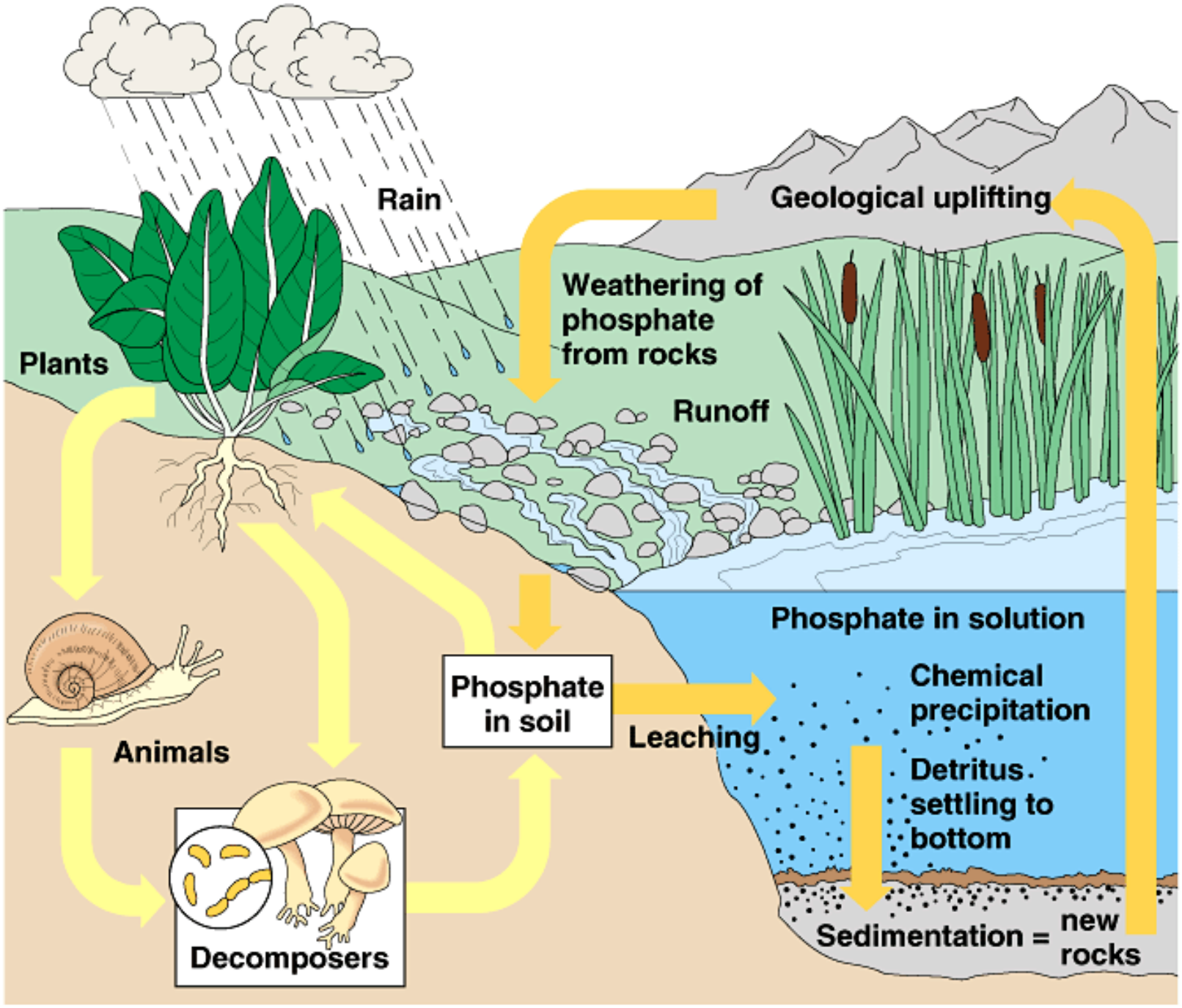
- It occurs commonly in an oxidized state as phosphate, which combines with calcium, potassium, magnesium, or iron to form minerals.



White P - highly flammable in air, kept under water

Red P - Stable in air

Phosphorus Cycle



Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.

Phosphorus Cycle

- **Reservoir**

– erosion transfers phosphorus to water and soil;

– sediments and rocks that accumulate on ocean floors return to the surface as a result of uplifting by geological processes

- **Assimilation**

– plants absorb inorganic PO_4^{3-} (phosphate) from soils;
– animals obtain organic phosphorus when they eat plants and other animals

- **Release**

– plants and animals release phosphorus when they decompose;

– animals excrete phosphorus in their waste products

Impacts of Human Activities on Phosphorus Cycle

We alter the phosphorus cycle by:

- Removing large amounts of phosphate from the earth to make fertilizer.
- Reducing phosphorous in tropical soils by clearing forests.
- Adding excess phosphates to aquatic systems from runoff of animal wastes and fertilizers.

Sulfur Cycle

The essential steps of the **sulfur cycle** are:

- Mineralization of organic sulfur to the inorganic form, hydrogen sulfide, H_2S.

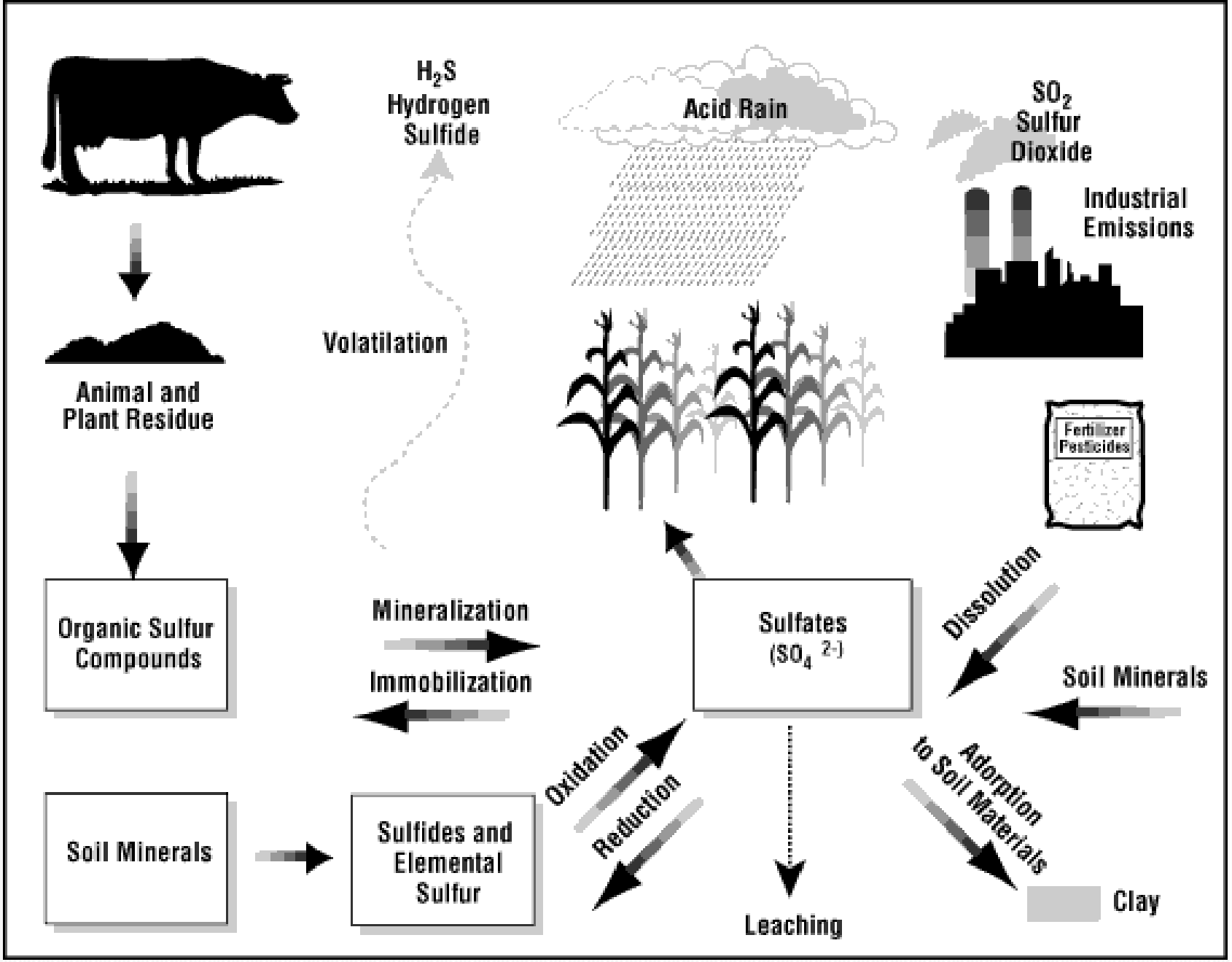
- Oxidation of sulfide and elemental sulfur (S) and related compounds to sulfate, SO_4^{2-}.



- Reduction of sulfate to sulfide.

- Microbial immobilization of the sulfur compounds and subsequent incorporation into the organic form of sulfur.

Sulfur Cycle



- http://www.agnr.umd.edu/users/agron/nutrient/Factshee/sulfur/Sulfur.html

Sulfur Cycle – S Reservoirs

- The largest **physical reservoir** is the Earth's crust where sulfur is found in –
  - ✓gypsum ($CaSO_4$) and
  - ✓ pyrite (FeS_2).

- The largest reservoir of **biologically useful sulfur** is found in the ocean as –
  - ✓ sulfate anions (2.6 g/L),
  - ✓ dissolved hydrogen sulfide gas, and
  - ✓ elemental sulfur.

Sulfur Cycle – S Reservoirs

- **Freshwater reservoirs** –

  ✓ contains sulfate, hydrogen sulfide and elemental sulfur

- **Land reservoirs** –

  ✓ contains sulfate

- **Atmospheric reservoirs** –

  ✓ contains sulfur oxide (SO_2) and methane sulfonic acid ($CH_3SO_3^-$);

  ✓ volcanic activity releases some hydrogen sulfide into the air.

Impacts of Human Activities on Sulphur Cycle

- Human impact on the sulfur cycle is primarily in the production of sulfur dioxide (SO_2) from industry (e.g. burning coal) and the internal combustion engine (e.g. burning fossil fuel).

- SO_2 can –

  ✓ precipitate onto surfaces, where it can be oxidized to sulfate (SO_4^{2-}) in the soil (it is also toxic to some plants),

  ✓ reduced to sulfide in the atmosphere, or

  ✓ oxidized to sulfate in the atmosphere as sulfuric acid (H_2SO_4), a principal component of **acid rain**.

Acid Rain

Formation of sulfuric acid by radical chemistry

- In the gaseous phase, SO_2 is oxidized by reaction with the hydroxyl radical (OH·) through a intermolecular reaction:

$$SO_2 + OH\cdot \rightarrow HOSO_2\cdot$$

(OH·) is generally formed by reaction of atmospheric O_2 with H_2O vapor.

which is followed by:

$$HOSO_2\cdot + O_2 \rightarrow HO_2\cdot + SO_3$$

- In the presence of water sulfur trioxide (SO_3) is converted rapidly to sulfuric acid:

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)$$