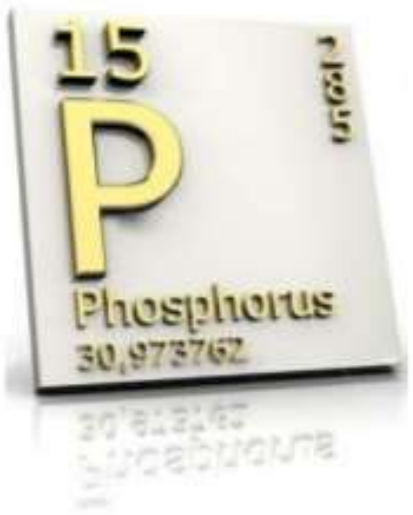
Introduction

- The phosphorus cycle is the movement of phosphorus from the environment to organisms and then back to the environment.
- The phosphorus cycle may also be referred to as the *mineral cycle or sedimentary cycle.*
- Unlike the other cycles, phosphorus cannot be found in air in the gaseous state.
- The phosphorus cycle is the SLOWEST cycle.
- The atmosphere does not play a significant role in the movement of phosphorus, because phosphorus and phosphorus-based compounds are usually solids at the typical ranges of temperature and pressure found on Earth.
- On the land, phosphorus (chemical symbol, P) gradually becomes less available to plants over thousands of years, because it is slowly lost in runoff.

- Low concentration of P in soils reduces plant growth, and slows soil microbial growth.
- Soil microorganisms act as both sinks and sources of available P in the biogeochemical cycle.
- Locally, transformations of P are chemical, biological and microbiological: the major long-term transfers in the global cycle, however, are driven by tectonic movements in geologic time.
- Humans have caused major changes to the global P cycle through shipping of P minerals, and use of P fertilizer, and also the shipping of food from farms to cities, where it is lost as effluent.

PHOSPHORUS



A multivalent pnictogen, phosphorus as a mineral is almost **always present in its maximally oxidized state, as inorganic phosphate rocks.** Elemental phosphorus exists in two major forms—**white phosphorus** and **red phosphorus**—but due to its high reactivity, phosphorus is never found as a free element on Earth.

In nature, Phosphorus exists in form of **phosphate**.

PHOSPHORUS FUNCTIONS

- **Biological Function**
  - The primary biological importance of phosphates is as a component of nucleotides, which serve as energy storage within cells (ATP) or when linked together, form the nucleic acids DNA and RNA..

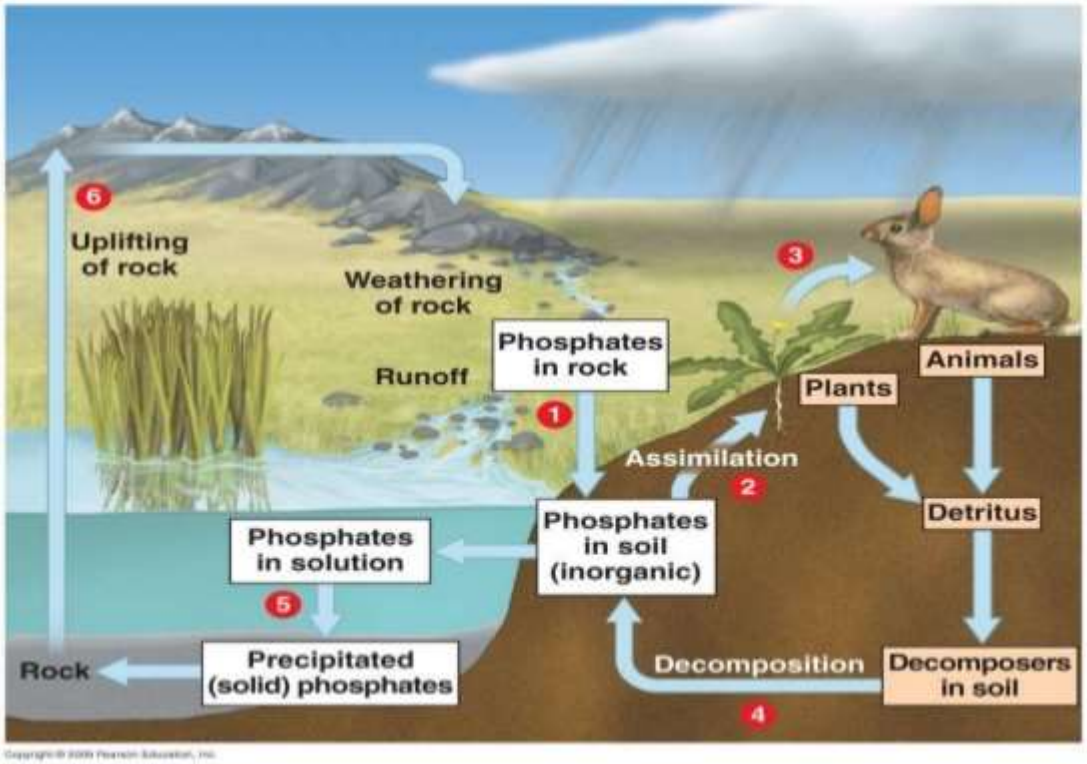
PHOSPHORUS IMPORTANCE

- It is an essential nutrient for plants and animals.
- It is a part of DNA-molecules and RNA-molecules, molecules that store energy (ATP and ADP)
- It is also a building block of certain parts of the human and animal body, such as the bones and teeth.

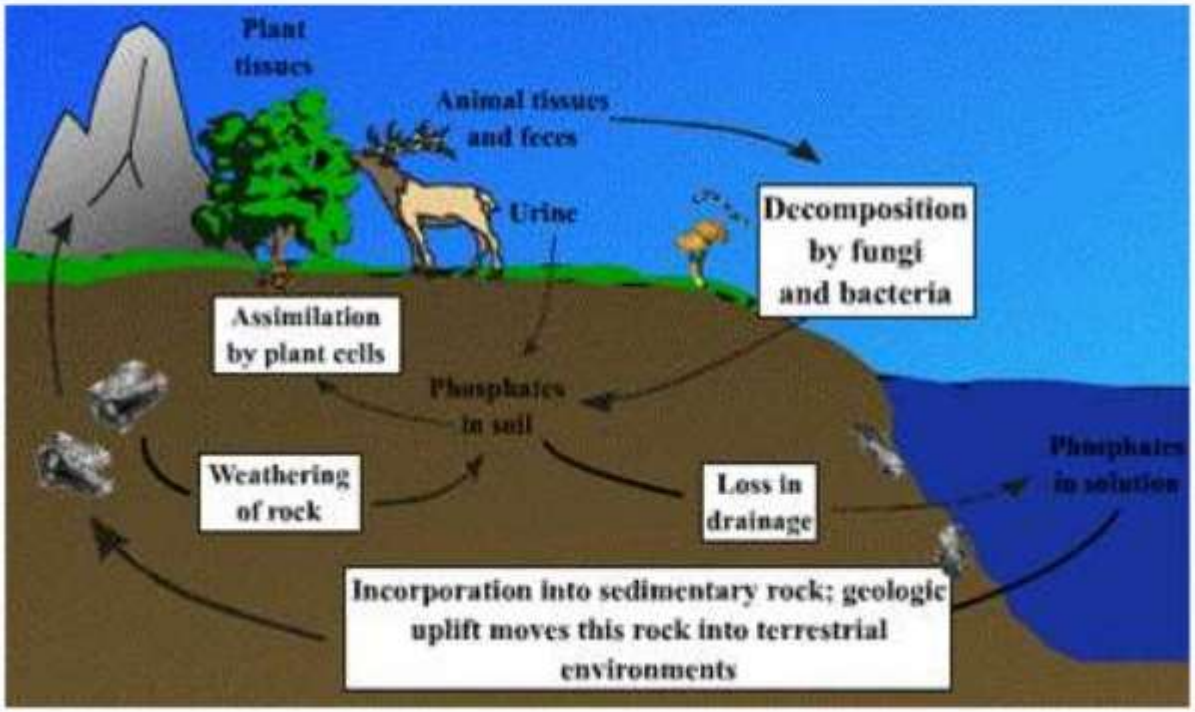
Phosphorus Cycle

The biogeochemical cycle that describes the movement of phosphorus through the lithosphere, hydrosphere, and biosphere. Unlike many other biogeochemical cycles, the atmosphere does not play a significant role in the movement of phosphorus, because phosphorus and phosphorus-based compounds are usually solids at the typical ranges of temperature and pressure found on Earth.

Phosphorus Cycle



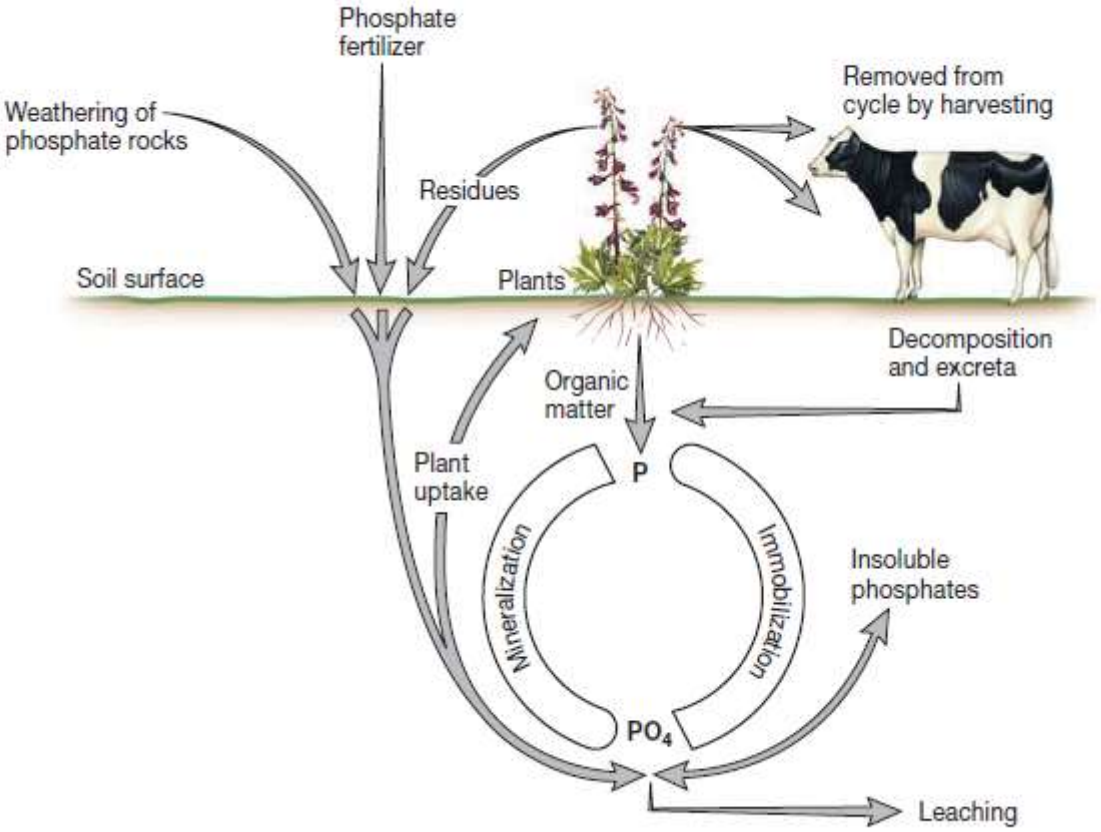
Phosphorous cycle



Mechanism of Phosphorus solubilization

- Organisms are *Pseudomonas*, *Bacillus*, *Aspergillus Penicillium, Trichoderma*
- Bacteria and fungi secrete organic acids.
- Organic acids dissolve insoluble phosphorus present in soil.

Figure 27.5 A Simplified Phosphorus Cycle. Phosphorus enters soil and water through the weathering of rocks, phosphate fertilizer, and surface residue of plant degradation. Plants and microbes rapidly convert inorganic phosphorus to its organic form, causing immobilization. However, much of the soil phosphorus can leach great distances or complex with cations to form relatively insoluble compounds.



Microbiological importance of phosphorous

- Phosphorus is a macronutrient necessary to all living cells. It is an important component of adenosine triphosphate (ATP), nucleic acids (DNA and RNA), and phospholipids in cell membranes.
- It may be stored in intracellular volutin granules as polyphosphates in both prokaryotes and eukaryotes.
- It is a limiting nutrient for algal growth in lakes. The average concentration of total phosphorus (inorganic and organic forms) in wastewater is in the range 10–20 mg/L.
- The major transformations of phosphorus in aquatic environments are described below :

➢ Mineralization

➢ Assimilation.

➢ Precipitation of Phosphorus Compounds.

➢ Microbial Solubilization of Insoluble Forms of Phosphorus.

Mineralization :

- Organic phosphorus compounds (e.g., phytin, inositol phosphates, nucleic acids, phospholipids) are mineralized to orthophosphate by a wide range of microorganisms that include bacteria (e.g., B. subtilis, Arthrobacter), actinomycetes (e.g., Streptomyces), and fungi (e.g., Aspergillus, Penicillium).
- Phosphatases are the enzymes responsible for degradation of phosphorus compounds.

Assimilation :

- Microorganisms assimilate phosphorus, which enters in the composition of several macromolecules in the cell.
- Some microorganisms have the ability to store phosphorus as polyphosphates in special granules

Precipitation of Phosphorus Compounds:

- The solubility of orthophosphate is controlled by the pH of the aquatic environment and by the presence of Ca^{2+},Mg^{2+}, Fe^{3+} and Al^{3+}.
- When precipitation occurs, there is formation of insoluble compounds such as hydroxyapatite (Cal0(PO4)6(OH)2 , vivianite Fe3(PO4)2 . 8H2O or variscite AlPO4 . 2H2O .

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- Mineralization
- Assimilation.
- Precipitation of Phosphorus Compounds.
- Microbial Solubilization of Insoluble Forms of Phosphorus.

Microbial Solubilization of Insoluble Forms of Phosphorus:

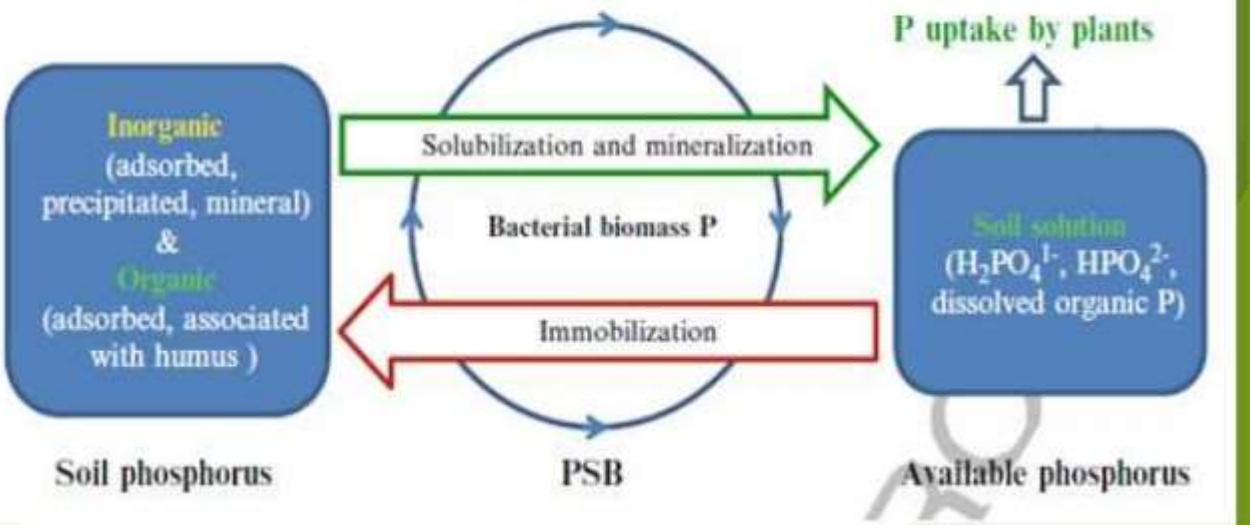
- Through their metabolic activity, microorganisms help in the solubilization of P compounds.
- The mechanisms of solubilization are metabolic processes involving :
  - enzymes,
  - production of organic and inorganic acids by microorganisms (e.g., succinic acid, oxalic acid, nitric acid, and sulfuric acid),
  - production of CO_2 , which lowers pH,
  - production of H_2S,which may react with iron phosphate and liberate orthophosphate, and
  - the production of chelators, which can complex Ca, Fe, or Al.

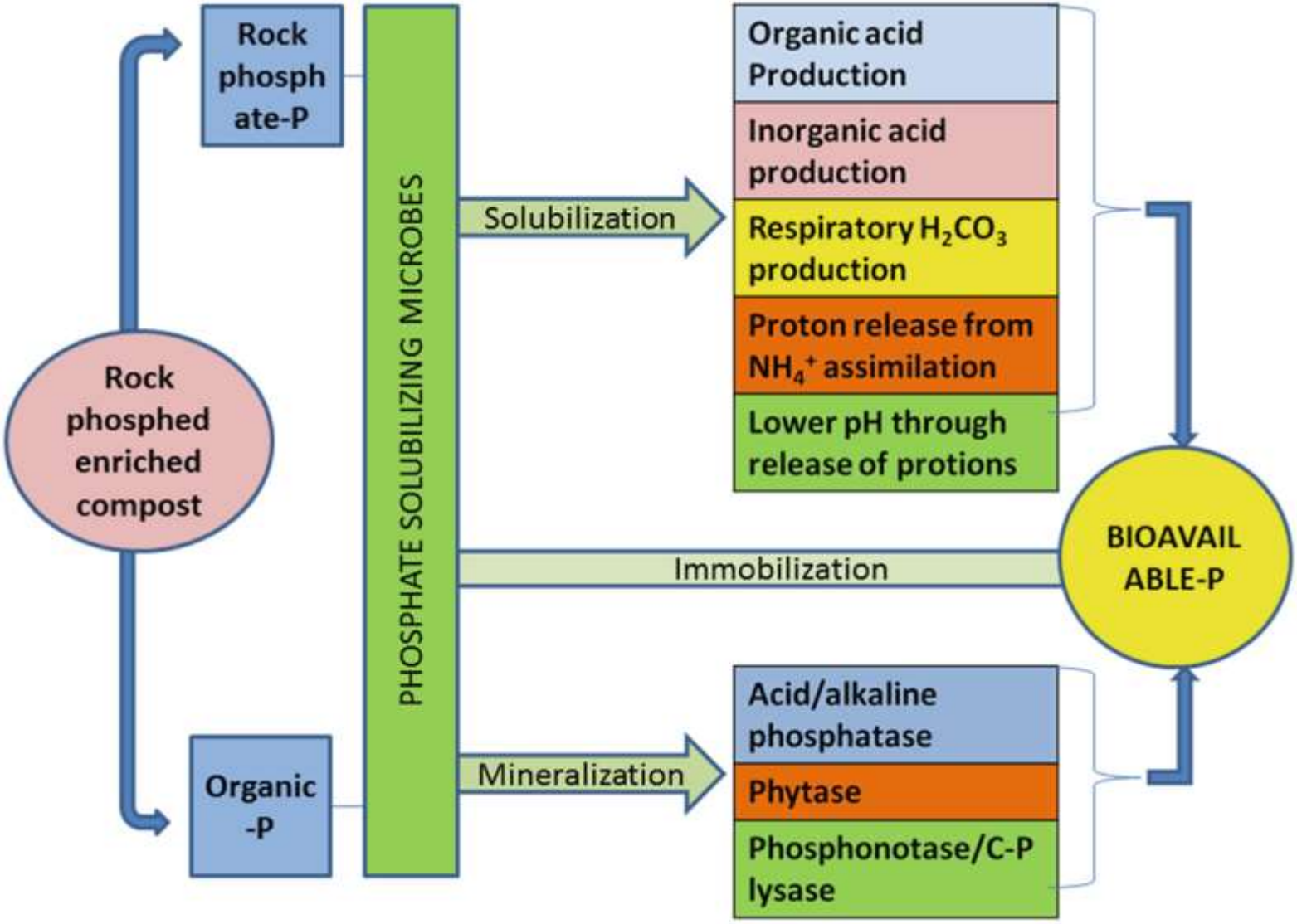
Phosphatic minerals

- The availability of phosphorus in an ecosystem is restricted by the rate of release of this element during weathering.
- The release of phosphorus from apatite dissolution is a key control on ecosystem productivity.
- The primary mineral with significant phosphorus content, apatite [$Ca_5(PO_4)_3OH$] undergoes carbonation.
- Little of this released phosphorus is taken by biota (organic form) whereas, large proportion reacts with other soil minerals leading to precipitation in unavailable forms.
- Available phosphorus is found in a biogeochemical cycle in the upper soil profile, while phosphorus found at lower depths is primarily involved in geochemical reactions with secondary minerals.
- Plant growth depends on the rapid root uptake of phosphorus released from dead organic matter in the biochemical cycle. Phosphorus is limited in supply for plant growth.
- Phosphates move quickly through plants and animals; however, the processes that move them through the soil or ocean are very slow, making the phosphorus cycle overall one of the slowest biogeochemical cycles.
- Low-molecular-weight (LMW) organic acids are found in soils. They originate from the activities of various microorganisms in soils or may be exuded from the roots of living plants.

- Several of those organic acids are capable of forming stable organo-metal complexes with various metal ions found in soil solutions.
- These processes may lead to the release of inorganic phosphorus associated with aluminium, iron, and calcium in soil minerals.
- The production and release of oxalic acid by mycorrhizal fungi explain their importance in maintaining and supplying phosphorus to plant.
- The availability of organic phosphorus to support microbial, plant and animal growth depends on the rate of their degradation to generate free phosphate.
- There are various enzymes such as Phosphatases, nucleases, and phytase involved for the degradation.
- Some of the abiotic pathways in the environment studied are hydrolytic reactions and photolytic reactions.
- Enzymatic hydrolysis of organic phosphorus is an essential step in the biogeochemical phosphorus cycle, including the phosphorus nutrition of plants and microorganisms and the transfer of organic phosphorus from soil to bodies of water.

SOIL PHOSPHOROUS MOBILIZATION AND IMMOBILIZATION BY BACTERIA




Rock phosphate-P
Rock phosphed enriched compost
Organic -P
PHOSPHATE SOLUBILIZING MICROBES
Solubilization
Organic acid Production
Inorganic acid production
Respiratory H_2CO_3 production
Proton release from NH_4^+ assimilation
Lower pH through release of protions
Immobilization
BIOAVAILABLE-P
Mineralization
Acid/alkaline phosphatase
Phytase
Phosphonotase/C-P lysase