Matter and Cycles of Matter

Endogenic and Exogenic Cycles :

Materials cycles may be divided broadly between **endogenic cycles**, which predominantly involve subsurface rocks of various kinds, and **exogenic cycles**, which occur largely on Earth's surface and usually have an atmospheric component.

In general, sediment and soil can be viewed as being shared between the two cycles and constitute the predominant interface between them.

Most biogeochemical cycles can be described as **elemental cycles** involving **nutrient elements** such as carbon, nitrogen, oxygen, phosphorus, and sulfur. Many are exogenic cycles in which the element in question spends part of the cycle in the atmosphere—O_2 for oxygen, N_2 for nitrogen, CO_2 for carbon. Others, notably the phosphorus cycle, do not have a gaseous component and are endogenic cycles. All sedimentary cycles involve **salt solutions** or **soil solutions** that contain dissolved substances leached from weathered minerals; these substances may be deposited as mineral formations, or they may be taken up by organisms as nutrients.

Carbon Cycle

Carbon is circulated through the carbon cycle shown in Figure (1).This cycle shows that carbon may be present as gaseous atmospheric CO_2 , constituting a relatively small but highly significant portion of global carbon. Some of the carbon is dissolved in surface water and groundwater as HCO_3^- or molecular CO_2(aq). A very large amount of carbon is present in minerals, particularly calcium and magnesium carbonates such as $CaCO_3$. Photosynthesis fixes inorganic C as biological carbon، represented as {CH_2O}, which is a constituent of all life molecules. Another fraction of carbon is fixed as petroleum and natural gas, with a much larger amount as hydrocarbonaceous kerogen (the organic matter in oil shale), coal, and lignite, represented as CxH_2x. Manufacturing processes are used to convert hydrocarbons to xenobiotic compounds with functional groups containing halogens, oxygen, nitrogen, phosphorus، or sulfur. Though a very small amount of total environmental carbon, these compounds are particularly significant because of their toxicological chemical effects.

An important aspect of the carbon cycle is that it is the cycle by which solar energy is transferred to biological systems and ultimately to the geosphere and anthrosphere as fossil carbon and fossil fuels. Organic, or biological, carbon ،CH_2O}, is contained in energy-rich molecules that can react biochemically with molecular oxygen, O_2, to regenerate carbon dioxide and produce energy. This can occur biochemically in an organism through aerobic respiration , or it may occur as combustion, such as when wood or fossil fuels are burned.

Microorganisms are strongly involved in the carbon cycle, mediating crucial biochemical reactions. Photosynthetic algae are the predominant carbon-fixing agents in water; as they consume CO_2 to produce biomass , the pH of the water is raised enabling precipitation of $CaCO_3$ and $CaCO_3$•$MgCO_3$.

Organic carbon fixed by microorganisms is transformed by biogeochemical processes to fossil petroleum, kerogen, coal, and lignite. Microorganisms degrade organic carbon from biomass, petroleum, and xenobiotic sources, ultimately returning it to the atmosphere as CO_2. Hydrocarbons such as those in crude oil and some synthetic hydrocarbons are degraded by microorganisms. This is an important mechanism for eliminating pollutant hydrocarbons, such as those that are accidentally spilled on soil or in water. Biodegradation can also be used to treat carbon-containing compounds in hazardous wastes.

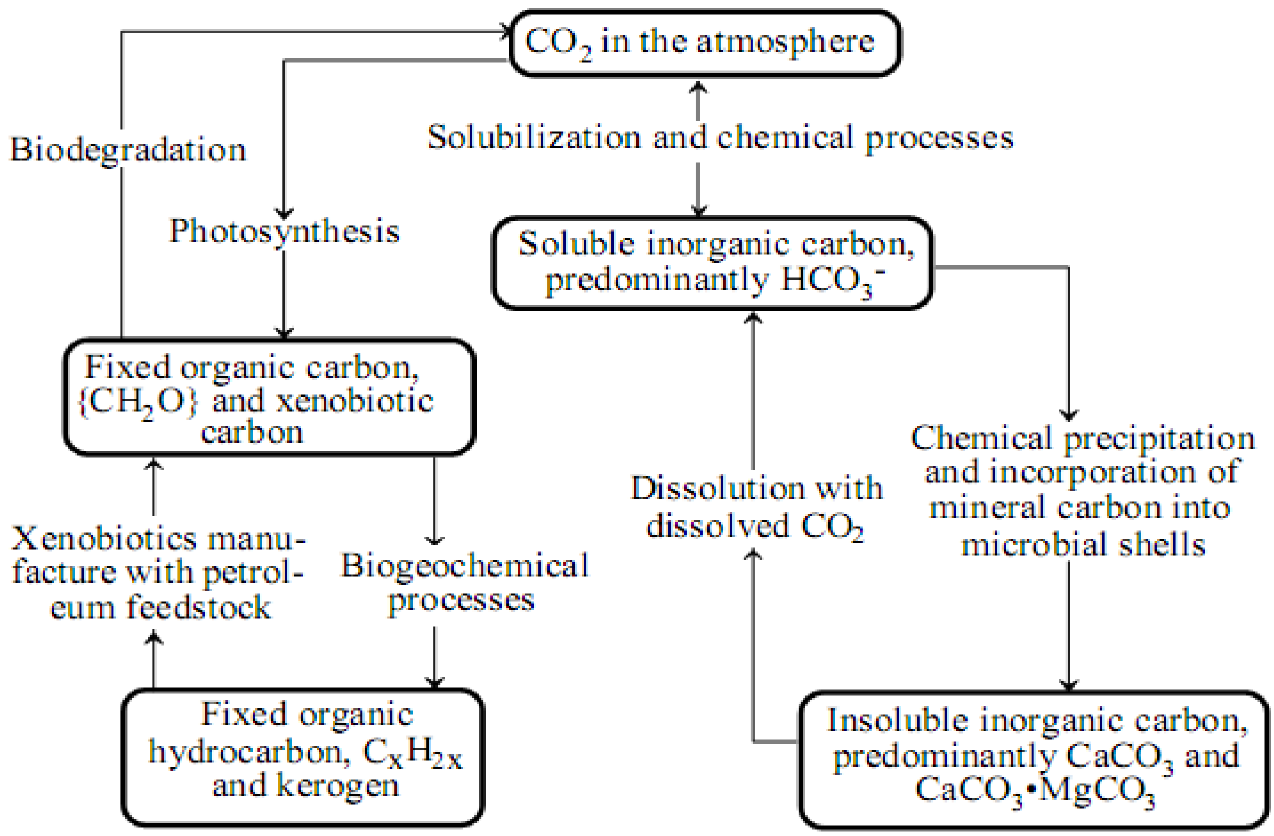

Figure (1). The carbon cycle. Mineral carbon is held in a reservoir of limestone, $CaCO_3$, from which it may be leached into a mineral solution as dissolved hydrogen carbonate ion, HCO_3^-, formed when dissolved $CO_2(aq)$ reacts with $CaCO_3$. In the atmosphere carbon is present as carbon dioxide, CO_2. Atmospheric carbon dioxide is fixed as organic matter by photosynthesis, and organic carbon is released as CO_2 by microbial decay of organic matter.

The Nitrogen Cycle

As shown in Figure(2), nitrogen occurs prominently in all the spheres of the environment. The atmosphere is 78% elemental nitrogen, N_2, by volume and comprises an inexhaustible reservoir of this essential element. Nitrogen, though constituting much less of biomass than carbon or oxygen, is an essential constituent of proteins. The N_2 molecule is very stable so that breaking it down into atoms that can be incorporated with inorganic and organic chemical forms of nitrogen is the limiting step in the nitrogen cycle. This does occur by highly energetic processes in lightning discharges that produce nitrogen oxides. Elemental nitrogen is also incorporated into chemically bound forms, or **fixed** by biochemical processes mediated by microorganisms. The biological nitrogen is mineralized to the inorganic form during the decay of biomass. Large quantities of nitrogen are fixed synthetically under high temperature and high pressure conditions according to the following overall reaction:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

The production of gaseous N_2 and N_2O by microorganisms and the evolution of these gases to the atmosphere completes the nitrogen cycle through a process called **denitrification**.

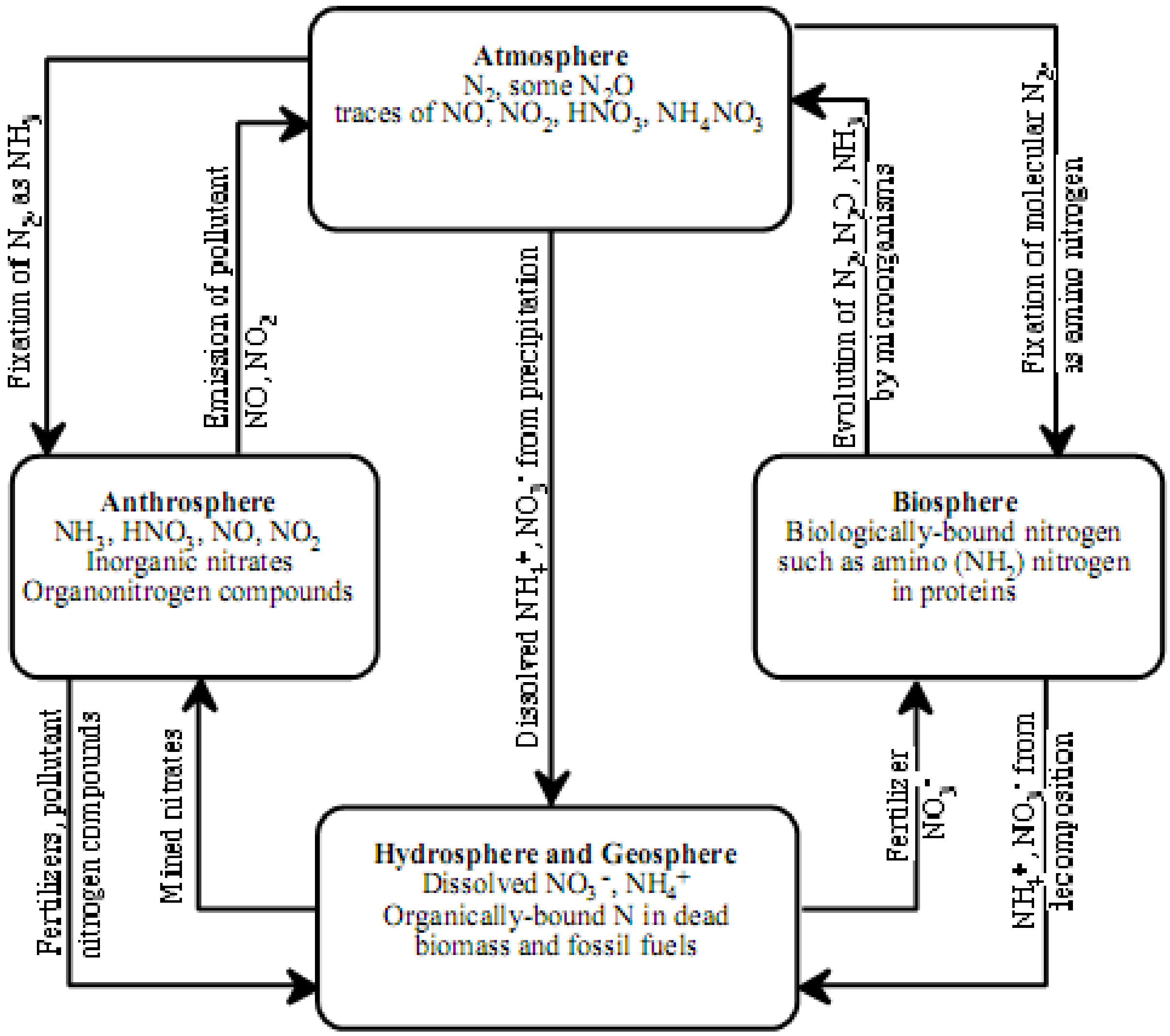

Figure (2): The nitrogen cycle.

The Phosphorus Cycle

The phosphorus cycle, Figure (3), is crucial because phosphorus is usually the limiting nutrient in ecosystems. There are no common stable gaseous forms of phosphorus, so the phosphorus cycle is endogenic. In the geosphere, phosphorus is held largely in poorly soluble minerals, such as hydroxyapatite a calcium salt, deposits of which constitute the major reservoir of environmental phosphate. Soluble phosphorus from phosphate minerals and other sources such as fertilizers is taken up by plants and incorporated into nucleic acids which make up the genetic material of organisms. Mineralization of biomass by microbial decay returns phosphorus to the salt solution from which it may precipitate as mineral matter.

The anthrosphere is an important reservoir of phosphorus in the environment. Large quantities of phosphates are extracted from phosphate minerals for fertilizer, industrial chemicals, and food additives. Phosphorus is a constituent of some extremely toxic compounds, especially organophosphate insecticides and military poison nerve gases.

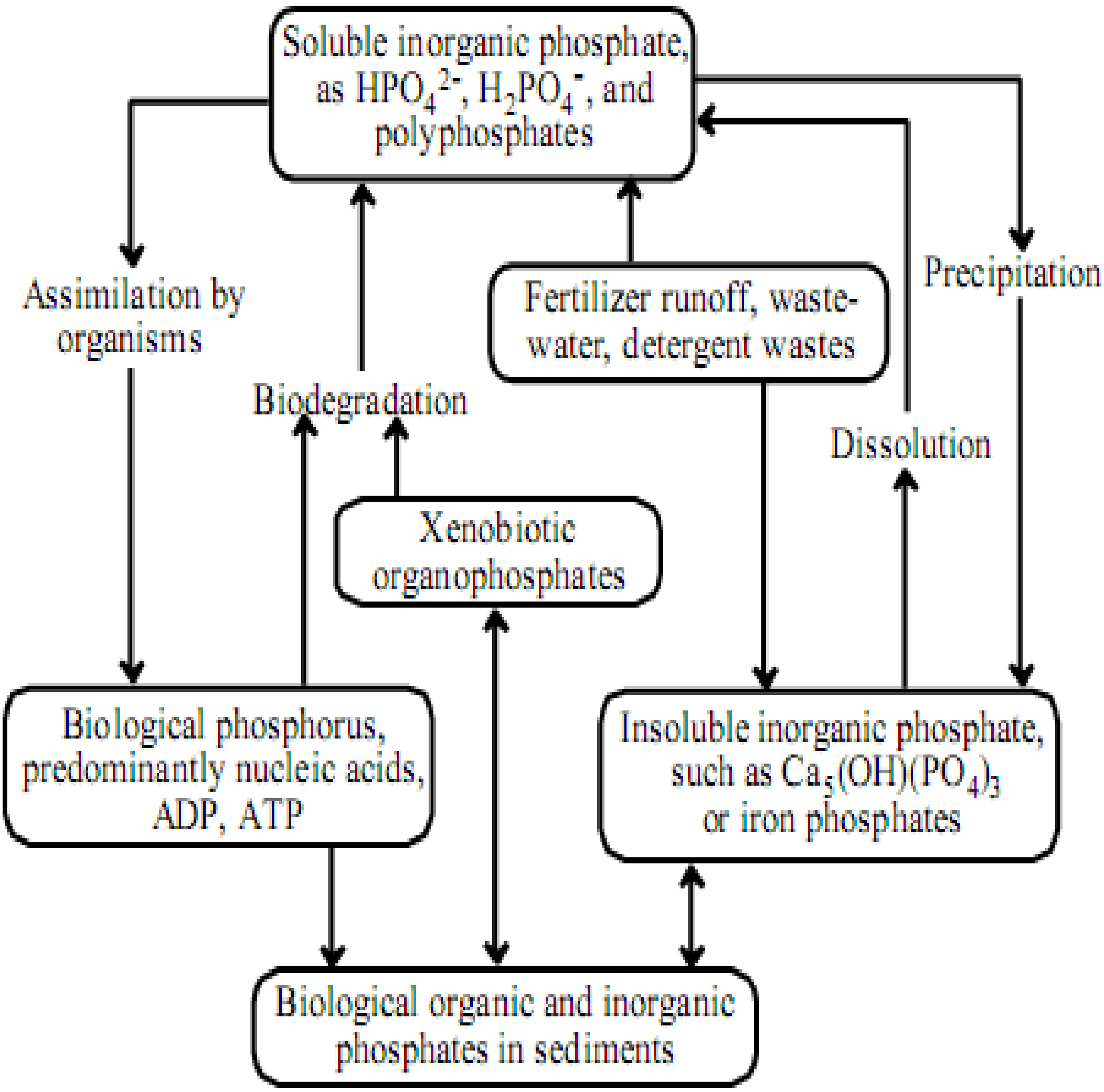

Figure (3): The phosphorus cycle.

The Sulfur Cycle

The sulfur cycle, which is illustrated in Figure (4), is relatively complex in that it involves several gaseous species, poorly soluble minerals, and several species in solution. It is tied with the oxygen cycle in that sulfur combines with oxygen to form gaseous sulfur dioxide, SO_2, an atmospheric pollutant, and soluble sulfate ion, SO_4^{2-}.

Among the significant species involved in the sulfur cycle are gaseous hydrogen sulfide, H_2S; mineral sulfides, such as PbS, sulfuric acid, H_2SO_4, the main constituent of acid rain; and biologically bound sulfur in sulfur-containing proteins. Insofar as pollution is concerned, the most significant part of the sulfur cycle is the presence of pollutant SO_2 gas and H_2SO_4 in the atmosphere . The former is a somewhat toxic gaseous air pollutant evolved in the combustion of sulfur-containing fossil fuels.

The major detrimental effect of sulfur dioxide in the atmosphere is its tendency to oxidize in the atmosphere to produce sulfuric acid. This species is responsible for acidic precipitation, "acid rain," .

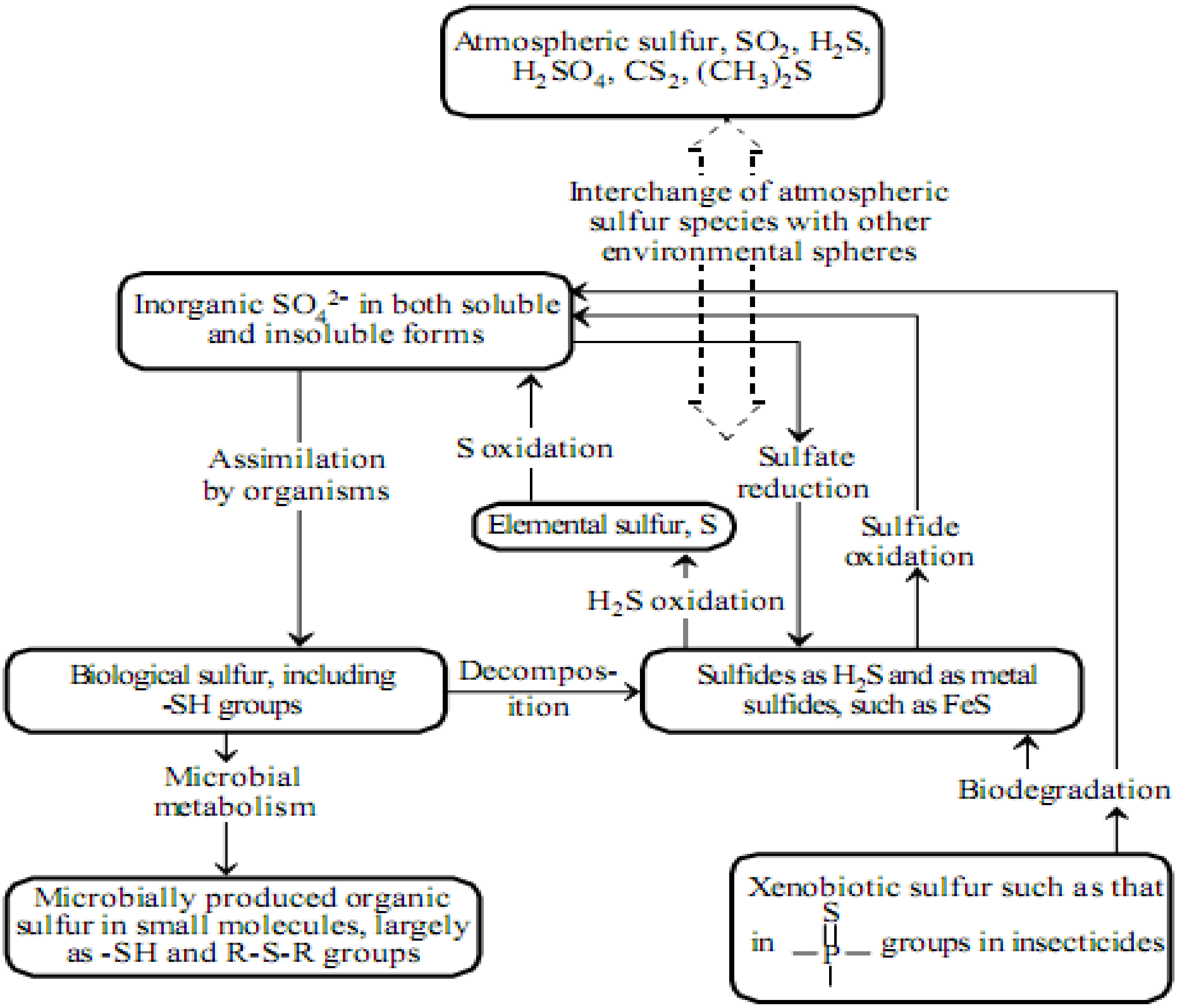

Figure (4):The sulfur cycle.

General Questions

Q1: What are the main differences between Endogenic and Exogenic Cycles .

Q2: In what important respect does the phosphorus cycle differ from cycles of other similar elements such as nitrogen and sulfur?

Q3: What are the main features of the carbon cycle?

Q4: Show in a diagram the sulfur cycle , carbon cycle , ...etc.

Q5: Describe the role of organisms in the nitrogen cycle.
Q6: What are the main nitrogenous compounds at the atmosphere .

Q7: What are the main sulfur compounds at the atmosphere .