2.19 ECOLOGICAL EFFICIENCY

Ecological efficiency of an ecosystem is defined as the ratios between energy flows at different points along the food chain expressed as percentage.

2.20 BIOGEOCHEMICAL CYCLE

The cycling of chemical elements required by life between the living and nonliving parts of the environment. Some examples of these chemical elements are H_2O, P, S, N_2, O_2 and C.

Bio-Living Organism

Geo-soil and Rock

Chemical-Nutrients

Cycle-Circular movement

So biogeochemical may be defined as a circular movement of nutrient compounds between organisms and soil or rock. The characteristic pathway of macro and micro nutrients circulation between the organisms and its environment in the biosphere is called as biogeochemical cycle.

Biogeochemical cycle in the environment is the cyclic pathway in which a regular and continuous transition of elements occurs from the environment into the organism and from organism into the environment. Nutrients essential and available for plant are in the form of macro or micro types

Macro-nutrients: Ca, Mg, S, K, P, which required in large quantities.

Micro-nutrients: Fe, Mn, Zn, Cu, Cl etc.

These elements cycle in either a gas cycle or a sedimentary cycle; some cycle as both a gas and sediment.

2.20.1 Types of Bigeochemical Cycle

Biogeochemical cycles are generally of two types:

1. *Gaseous Cycle*

In a gas cycle elements move through the atmosphere. The elements have a main reservoir in the gaseous phase, which is very important in the cycle. Carbon cycle, Nitrogen cycle and Oxygen cycle are the examples of gaseous cycle.

Water occurs in three phases, in the liquid phase it is vital for the existence of life on the planet, the gaseous phase is important for cycling so the water cycle is considered separately as Hydrological cycle.

2. *Sedimentary Cycle*

In a sedimentary cycle elements move from land to water to sediment. Elements fixed under this cycle do not have a gaseous phase. Sulphur cycle (an exception), phosphorous cycle is the example of sedimentary cycle.

Both types of cycles involve biotic and abiotic agents. Both are driven by the flow of energy and both are tied to the water cycle or hydrological cycle.

2.21 HYDROLOGICAL OR WATER CYCLE

Water is indeed a most essential commodity for human consumption and without it no life can exist, it is one of the most important vital substance in the biosphere which is required for the metabolism, circulation, movement and cycling of nutrients in the body of living organisms.

It is mostly employed for supporting life as a general purpose carrier to maintain active systems. Water removes unwanted material, transport minerals and energy in various organs of the body.

Water is also required in industries for power generation, navigation, irrigation of crops and disposal of sewage etc.

Thus water chemistry provides the knowledge of multidimensional aspect of aquatic environment which involves the sources, composition, chemical reactions and transport of water. The chemistry of water exposed to the atmosphere has been quite different from that of water at the bottom of rivers and lakes.

Water is very essential for the function of an ecosystem because:

1. Plants can synthesise their food in the presence of water.
2. Plants use excess of water to maintain their hydrostatic skelton and movement of chemicals from root hair to the apex of the plant.
3. Plants absorb nutrients in aqueous form form the soil.

There exists a continuous exchange or circulation of water between the earth and the atmosphere, commonly referred to as hydrological cycle.

The hydrological cycle may be having either a long or numerous short cycles.

Short Cycle

Water from the water bodies get evaporated and water from plants get transpired by the solar energy of the sun. In the atmosphere the water remains in the form of vapour and it forms clouds. Condensation of clouds by cold air produces rainfall over land surface and water bodies

Rainfall over land surface runoff and part of the rainfall leaches through the soil and is collected as ground the water by an impervious layer of rock. A part of the ground water is used by man for domestic, agriculture and industrial process. Some portion of the rainfall runs down the drain and ultimately reaches the water bodies

Long Cycle

The major store houses are the oceans which constitute 97.5% of the earth's water. A portion of the water evaporates into the atmosphere and winds carry the moisture-laden air over the land in the form of rain, hail or snow.

The balance of the cycle is maintained by water flowing from the land as surface run off into rivers and back to oceans.

2.21.1 Stages of the Hydrological Cycle

1. Evaporation and Condensations

Water vapours get evaporated from the oceans and condense around nuclei, suspended in air. The nuclei may be particles of spores, pollens, organic substances or fine mineral particles and dust or smoke particles. Small droplets (0.04 mm) of condensed liquid remain as clouds in the atmosphere. Finally they get precipitated and reach over soil in the form of rain water.

2. Run Off, Stream Flow and Infiltration

A part of the rain water is caused by vegetation. This process is called as interception. This water readily gets re-evaporated. The remainder of the water sinks into the soil by a process known as infiltration while surface run off gets discharged into streams.

3. Transpiration

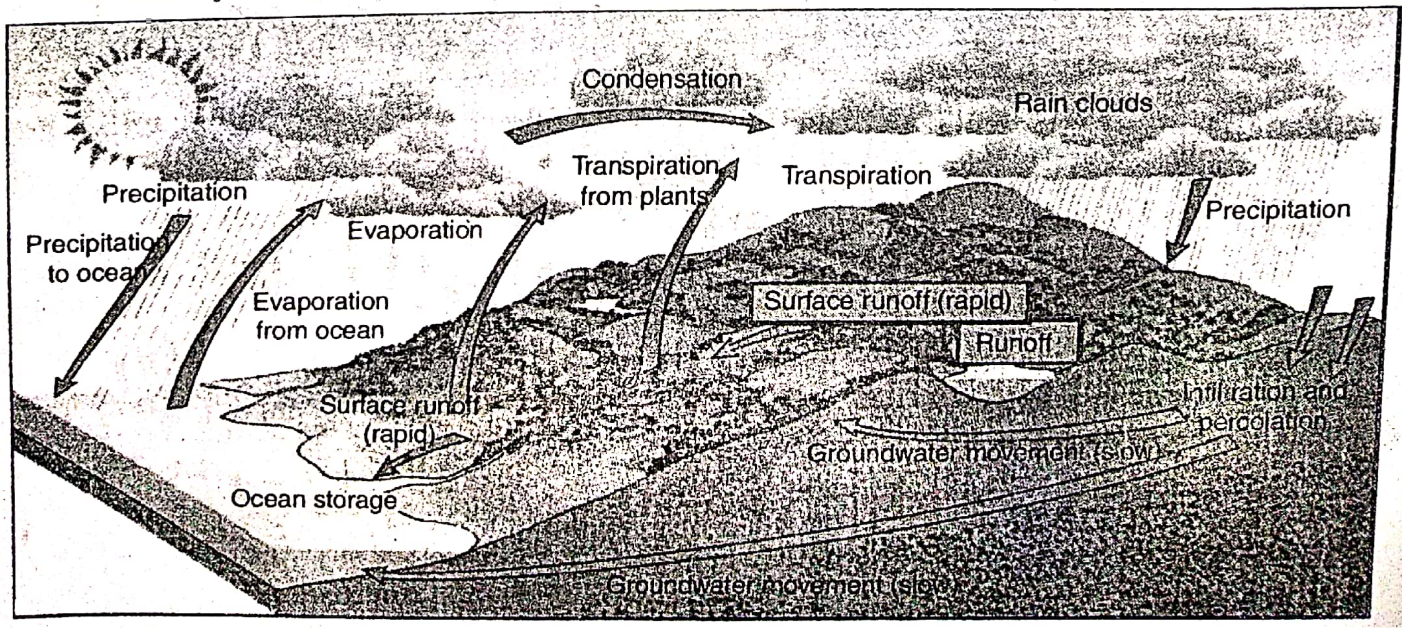
The precipitated water gets transformed into vapour by evaporation and transpiration. During transpiration, plants and aquatic vegetation release water vapour to the atmosphere.

4. Ground Water

The hydrological cycle gets completed when water returns to the earth's surface by springs, transpiration and surface seepage etc. Most micro-organisms originally present in ground water are filtered out as it seeps through the ground water are filtered out as it seeps through the ground and can be used for domestic purpose. In this way the cycle repeats itself perpetually.

Some important points of water cycle are summarised as follows:

1. There is a circulation of water and moisture that is maintained between living organisms, atmosphere and earth. This is termed as water cycle or hydrological cycle.
2. Water is very important and also a significant environmental factor and without water or hydrological cycle, biological cycles may not occur.
3. Without hydrological cycle even ecosystem could not function and life could not be sustained.
4. Water is an important factor for ecosystem, because it provides a medium by which nutrients can be introduced into plants,
5. It is an important part of living tissue, either in the form of liquid water or as part of essential organic molecules.
6. It acts as a means of thermal regulation for plants as well as animals.
7. The hydrological cycle is driven by solar energy and gravity.



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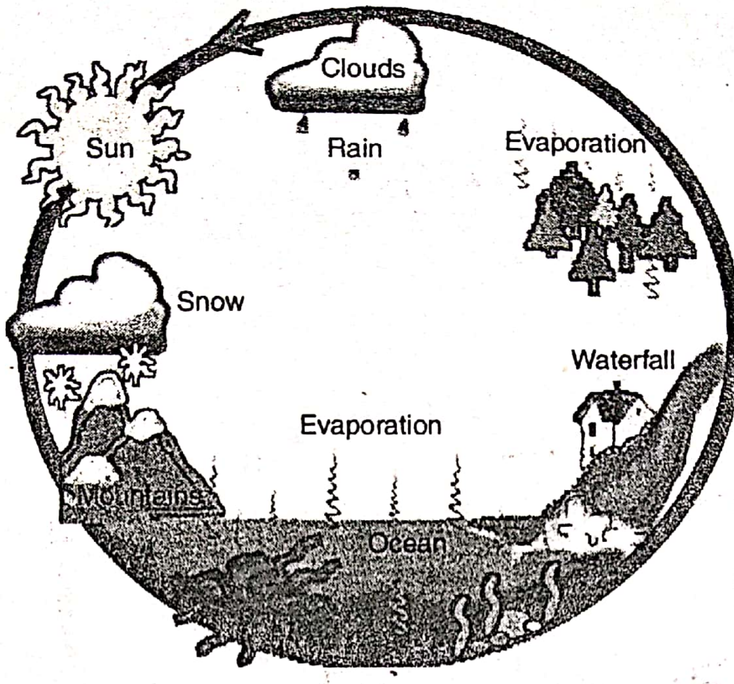


(b)

Fig. 2.30 ***(a)* and *(b)*** Typical hydrological cycle of an environment

8. Water is not uniformly distributed throughout the earth. 95% of the total water on earth is bound chemically into rocks and does not cycle. Of the remaining 5%, about 97.3% is in the ocean, about 2.1% exists as ice in the polar caps and glaciers and the rest is fresh water that is present in various forms such as atmospheric water, vapour, ground water, soil water or inhaled surface water.
9. The hydrological cycle over the oceans is simple. The water gets evaporated from the surface of the ocean and water vapours form the clouds which when cool down precipitate the water in the form of rainfall. But several routes are open to precipitation that fall on land. These are direct evaporation, transpiration, entry of water into ground water system and run off.

2.22 NITROGEN CYCLE

Nitrogen is a very important nutrient for organisms, being one of the most abundant elements in their tissues, and an integral component of many biochemicals, including amino acids, proteins, and nucleic acids.

Generally plants obtain their nitrogen by assimilating it from their environment, mostly as nitrate or ammonium dissolved in soil water that is taken up by roots, or as gaseous nitrogen oxides (N_2, N_2O) that are taken up by plant leaves from the atmosphere. However, some plants live in a symbiotic relationship with micro-organisms that have the ability to fix atmospheric nitrogen into ammonia, and these plants benefit greatly from access to an increased supply of nitrogen.

In the atmosphere, nitrogen exists in many forms among that it is principally in the form of molecular nitrogen N_2 with small amount of nitrous oxide N_2O.

Enormous amount of energy produced from lightening of clouds breaks the nitrogen molecule and fix it in the form of nitrates, which is a nitrogen attached with three oxygen. Fertilizer industries are producing nitrogen fertilizers mostly in the form of ammonia. Most of the plants can take up the atmospheric nitrogen and nitrates and convert them to amino acids.

Animals take the amino acids when eat plants or animals. When plants or die or release waste the nitrogen is returned to the soil in the form of organic nitrogen. The decomposers such as bacteria and fungi in soil and water convert the organic nitrogen into NH_3 is a toxic material Nitrite bacteria and water take up the ammonia and convert the nitrite into nitrate NO_3^-.

Nitrification

The process of converting ammonia into nitrate is called as nitrification. Ammonia is converted into nitrite first in the presence of bacteria such as *Nitrosomonas bacteria, Nitrospira, Nitrosogloea and Nitrococus are responsible for converting ammonia into nitrite, subsequently, other bacteria like Nitrobactor* and *Nitrocystis* are responsible for the conversion of nitrite into nitrate. These two steps involve energy yielding reaction. The energy released in this process is utilized in carbon assimilation by bacteria.

$2NH_3 + 3O_2$ Nitrite bacteria (*nitrosomonas bacteria*) $\rightarrow 2NO_2^- + 2H^+ + 2H_2O$

$2NO_2^- + O_2$ Nitrate bacteria (*nitrobactor bacteria*) $\rightarrow 2NO_3^-$

Denitrification

The process in which the nitrite and nitrates are converted back into free nitrogen is called as denitrification. This process is accomplished with the help of soil bacteria called *Pseudomonas, Basillus licheniformis, Pseudomonas denitrificans, Micrococus, Achromobacter and Thiobacillus denitrificans.*

Denitrifying bacteria under anaerobic conditions, reducing nitrate back into N_2 and N_2O, completing the nitrogen cycle.

Nitrogen Fixation

The process of converting the atmosphere free nitrogen gas into compound of N_2 is called nitrogen fixation.

This can be achieved by two ways.

1. Biological Nitrogen Fixation

Natural nitrogen can be obtained from lightning of cloud and bacteria's and fungi present in water and soil.

Biological methods involving micro-organisms which convert gaseous nitrogen into nitrates.

Free living bacteria important for nitrogen fixation are *Azobacter, Clostridium, Rhizobium* etc. The bacteria are non-symbiotic forms *Rhizobiumspm are symbiotic bacteria which are very important nitrogen fixers.*

2. Non Biological Nitrogen Fixation

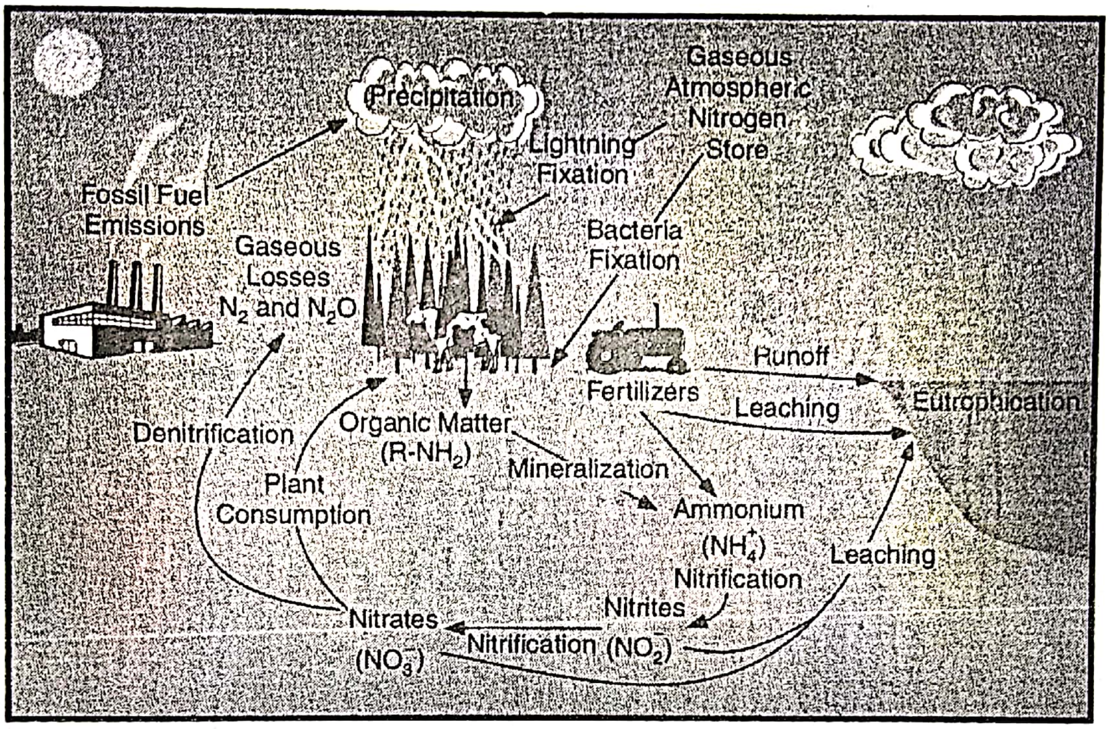
Artificial fixation of N_2 is obtained with the help of fertilizer of fertilizer industries, which convert the atmosphere nitrogen into NH_3. Non biological method such as electrochemical method during thunderstorms and lightning. Due to thunder storm in rainy season, the nitrogen and oxygen of the atmosphere combine to form nitric oxide, which is finally oxidized to dioxide. The latter combines with rainy water to form nitric acid in the presence of oxygen of the atmosphere. This nitric acid form nitrates which are basic foods of the plants in the soil.

$$N_2 + O_2 \longrightarrow 2NO$$
$$2NO + 2H_2O + O_2 \longrightarrow 2NO_2$$
$$4NO_2 + 2H_2O + O_2 \longrightarrow 4HNO_3$$
$$HNO_3 + NH_3 \longrightarrow NH_4NO_3$$

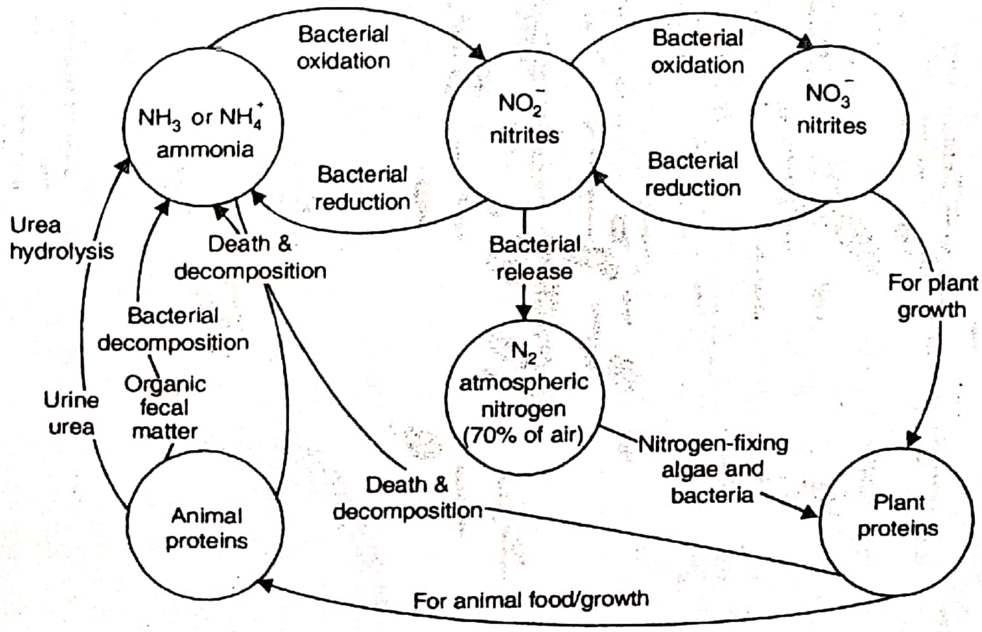
$$HNO_2 + NH_3 \longrightarrow NH_4NO_2$$
$$CaO \;\; 2HNO_3 \longrightarrow Ca(NO_3)_2 + H_2O$$

Ammonification

Organic matter of plant and animal origin is decomopsed by micro-organism in the soil, and in the process ammonia and amino acids are released. The ammonia may escape to the atmosphere or be retained in the soil, and under certain condition may be oxidized into nitrates. Conditions such as low cation exchange capacity, alkalinity, high temp. and dryness favour the release of NH_3 as gas into the air. The responsible microorganisms are *Bacillus subtilis, Bacillus mesentericus,*



(a)



(b)

Fig. 2.31 (a) and (b) Nitrogen cycle

The activities of humans have severely altered the nitrogen cycle. Some of the major processes involved in this alteration include:

1. The application of nitrogen fertilizers to crops has caused increased rates of denitrification and leaching of nitrate into groundwater.
2. The additional nitrogen entering the groundwater system eventually flows into streams, rivers, lakes, and estuaries. In these systems, the added nitrogen can lead to eutrophication.
3. Increased deposition of nitrogen from atmospheric sources because of the combustion of fossil fuel and forest burning. Both of these processes release a variety of solid forms of nitrogen through combustion.
4. Livestock release a large amounts of ammonia into the environment from their wastes. This nitrogen enters the soil system and then the hydrologic system through leaching, groundwater flow, and runoff.
5. Sewage waste and septic tank leaching.

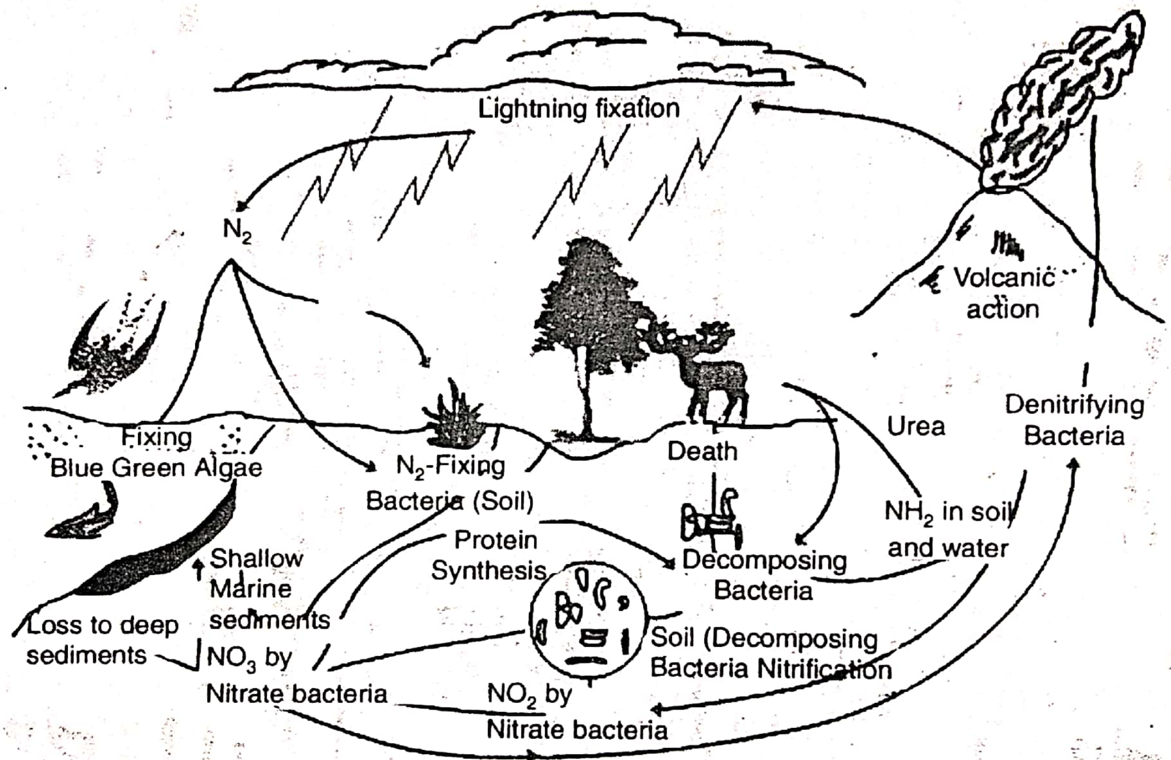


Fig. 2.31 (c) Nitrogen cycle

2.23 OXYGEN CYCLE

Oxygen is the major component of all living organisms. Hence its adequate supply is vital for substance of life in the biosphere. Oxygen is needed by most plants and animals and all human beings for aerobic respiration of enzymatic oxidation of organic food which sustains growth and general metabolism.

Thus, it is absorbed from the environment during aerobic respiration but released by plants during photosynthesis thereby setting up the oxygen cycle. There is also continuous exchange of O_2 biosphere is relatively constant so that the oxygen cycle is stable. The oxygen cycle is based on the exchange of O_2 among the environment segments- atmosphere, hydrosphere, lithosphere and biosphere. It plays a vital role in atmospheric chemistry, geochemical transformation as well as life process. Oxygen contributes largely to the process on the earth's surface.

It participates in combustion reaction such as burning of fossil fuels

$$C + O_2 \longrightarrow CO_2$$

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

Oxygen is consumed by some oxidative weathering process of minerals also such as-

$$4FeO + O_2 \longrightarrow 2Fe_2O_3$$

In the primitive stage of the earth soluble iron (II) consumed bulk of O_2 giving large deposits of Fe_2O_3.

$$4Fe^{2+} + O_2 + 4H_2O \longrightarrow 2Fe_2O_3 + 8H+$$

Green plants return oxygen to the atmosphere through the process of photosynthesis

$$CO_2 + H_2O + h\nu \longrightarrow [CH_2O] + O_2$$

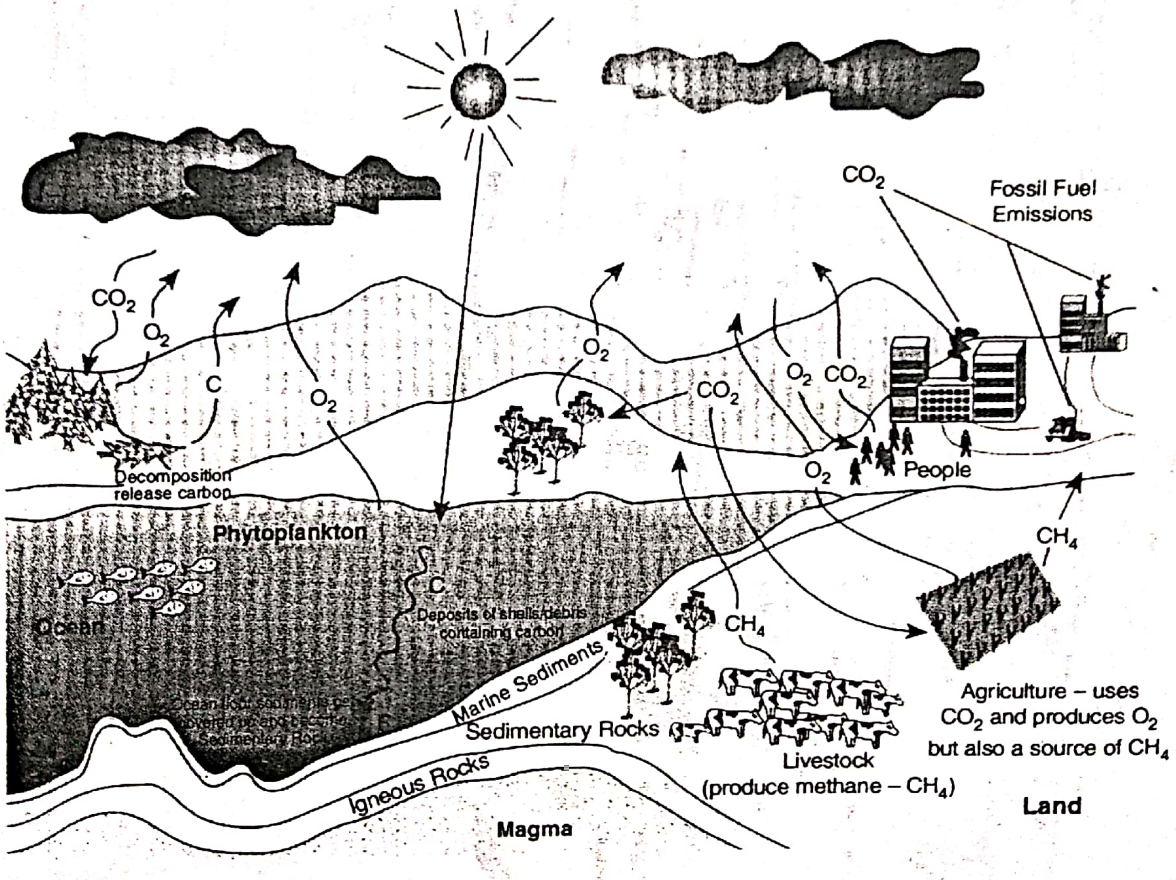


Fig. 2.32 ***(a)*** Oxygen cycle in environment

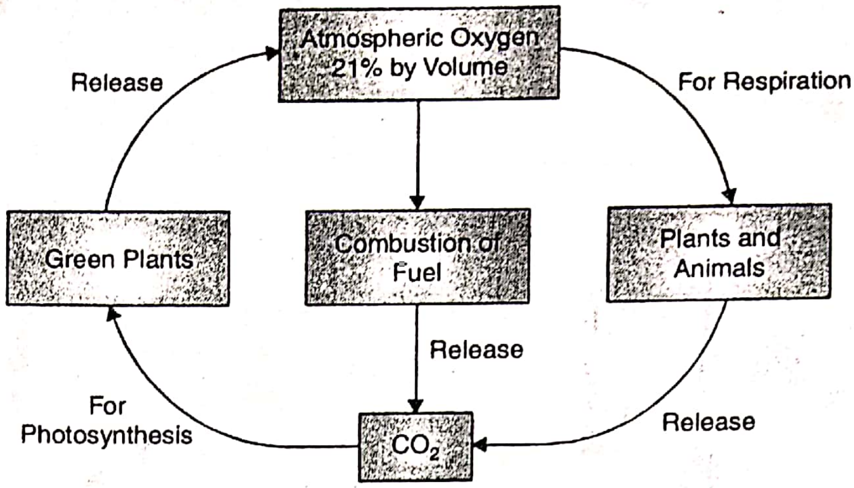


Fig. 2.32 (*b*) Flow diagram of oxygen cycle

2.24 CARBON CYCLE

Carbon is an essential constituent of carbohydrates, proteins, fats and a large number of organic compounds. The major form of existence of carbon in the atmosphere is carbon dioxide. Volcanic eruption can also produce more carbon dioxide into the atmosphere. The green plants take the carbon dioxide and with the help of solar energy from the sun and in the presence of water, they produce carbohydrates and oxygen this process is termed as photosynthesis. In doing so the green plants lock the radiant energy of the sun in the synthesized food. This energy stored in plants is utilized by all living things for their own activities.

The carbon available in the green plants has three possible ways of movements:

1. The green plants can be eaten by animals.
2. The process of respiration of plants and animals librates carbon dioxide into the atmosphere.
3. It can be retained in the body of plants and animals when they die.

The carbon available in the dead body of plants and animals has two possible ways of movement:

1. It can be taken by the decomposers. On digestion of dead body, carbon dioxide can be released into the atmosphere.
2. It can be converted as fossil fuel.

Mining and burning of fossil fuel, release more amount of carbon dioxide to the atmosphere.

The evolved oxygen in the process of photosynthesis is used by most of the living things, the plants and animals. Thus all animals depend for their food on plants directly or indirectly. All organic compounds are also oxidized to CO_2 and water, both of which are utilized by plants in the process of photosynthesis. All organic compounds are also oxidized to CO_2 and water, both of which are utilized by plants in the process of photosynthesis.

All the carbon of plants, herbivores, carnivores and decomposers is not respired, but some is fermented and some is stored. The carbon compounds such as methane (CH_4) that are lost to the food chain after fermentation, are readly oxidised to CO_2 by a number of reactions occurring in the atmosphere.

1. As for the storage of carbon in sediments.
2. The combustion of fossil fuels is the most important factor of recycling sedimentary carbon much faster than natural weathering.
3. Small amount of carbon in the sea is not present as fixed carbon but as carbonate ions, CO_3^{2-}, especially $CaCO_3$.

The CO_3^{2-}, is formed in the following way:

1. The rate of carbon utilization depends on its availability. If excess amounts of carbon are taken up in any one phase of carbon cycle, other phases of activity may be slowed down or ever inhibited.
2. If the pH of water is greater than 7, more carbon is tied up in a carbonate and less in the solution. This removal of carbon in solution would upset the equilibrium that has been established between the atmospheric CO_2 and dissolved CO_2 and it would result in the movement of CO_2 into solution until equilibrium is re-established.

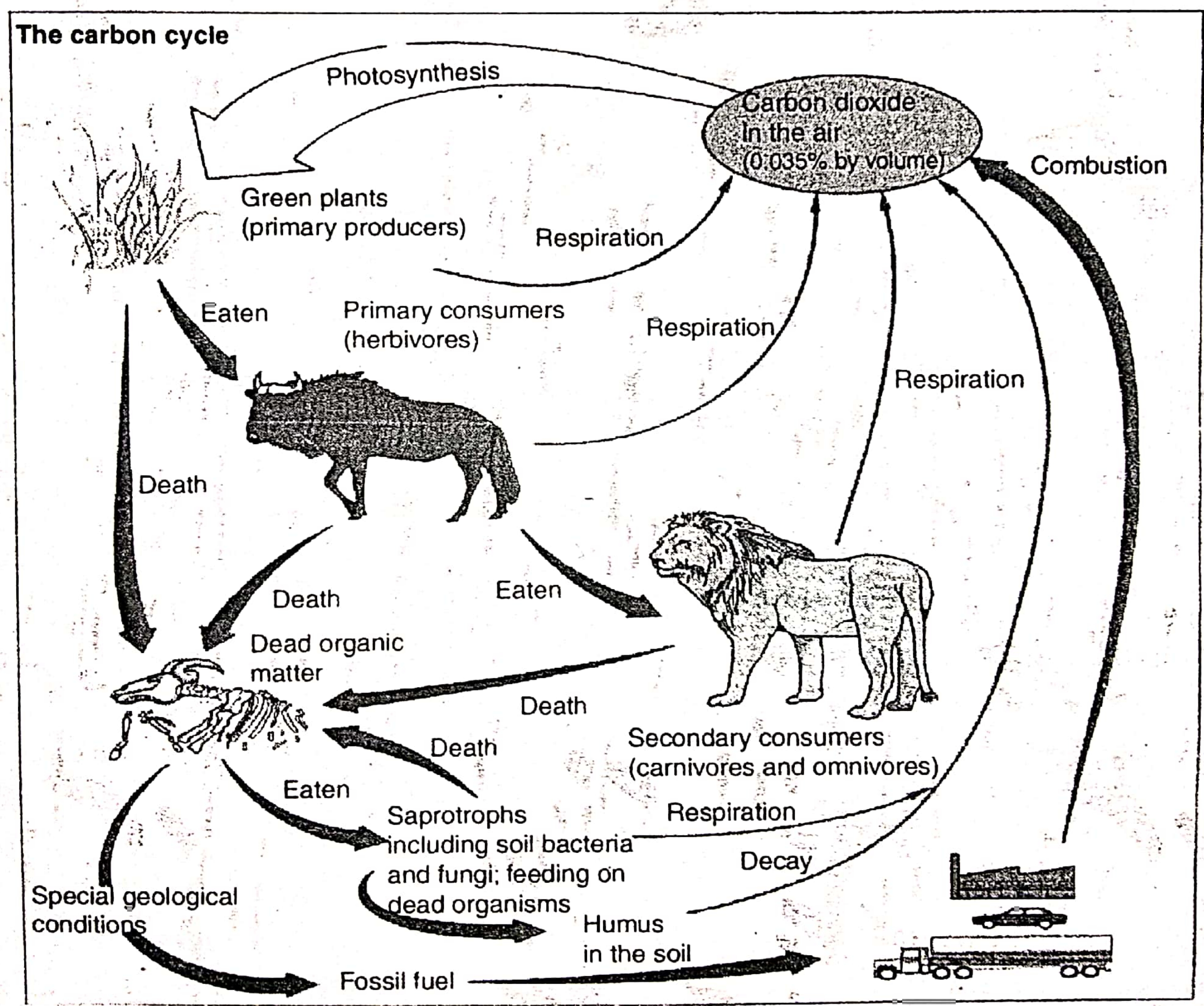


Fig. 2.33 (*a*) Basic Carbon Cycle Flow Diagram

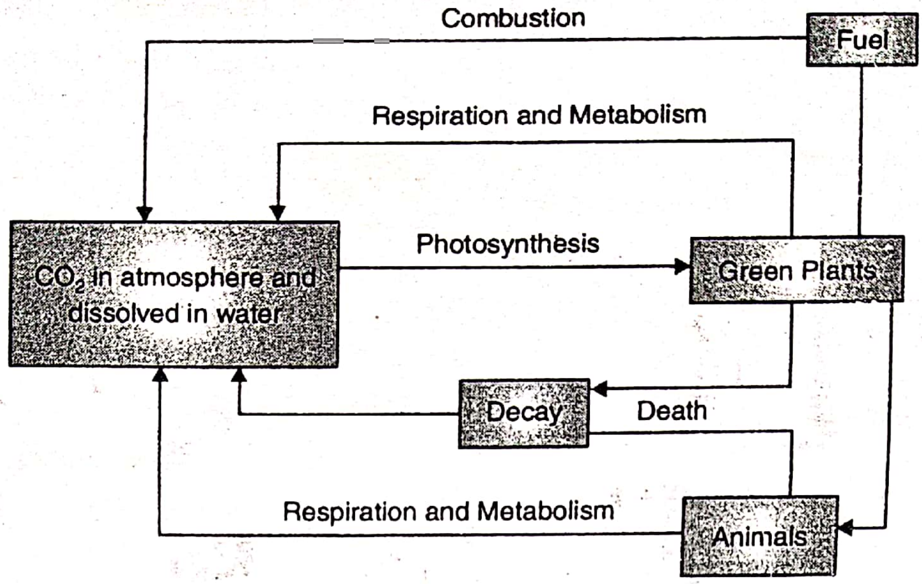


Fig. 2.33 (*b*) Flow diagram of carbon cycle

2.25 SEDIMENTARY CYCLE

In sedimentary cycle the main reservoirs are soil and rock. The elements classified under this cycle do not have a gaseous phase. Both gaseous as well as sedimentary cycles involve biotic and abiotic agents. Both cycles are driven by the flow of energy and they are tied to the water cycle. Phosphorous cycle and sulphur cycles are the example of sedimentary cycle.

2.26 PHOSPHORUS CYCLE

Phosphorous is the most important element because it is vital component of DNA, RNA and ATP, and in this way related with genetic and energy producing molecules of the life and therefore necessary to all living cells. Phosphorus present in sedimentary rock, which is only available to basic cycle in small amounts as a result of weathering.

The cycle does not have a major gaseous phase and therefore moves at a very slow. Weathering and erosion of phosphoric rock provide availability of phosphorus on soil. Phosphorous cycle is a very important sedimentary nutrient cycle. The reservoir of phosphorus lies in the rocks, fossils etc.

The phosphorus available in the form of phosphate is taken up by the plants (autotrophs) through their roots, where it is incorporated into living tissues. Then it is passed to the consumers through grazing food chain.

Decay and/or decomposition of the excreta and dead body of consumers and dead plants release the phosphates in the soil.

Bones and teeth from dead body of the consumers take water soluble phosphate to shallow marine sediments.

This available form of phosphate rock by fishes and aquatic organism or deep marine sediments.

In turn this may from the phosphoric rock through volcanic eruption.

From the phosphoric rock, man produced fertilizers containing phosphate are used to produce more productivity in fields.

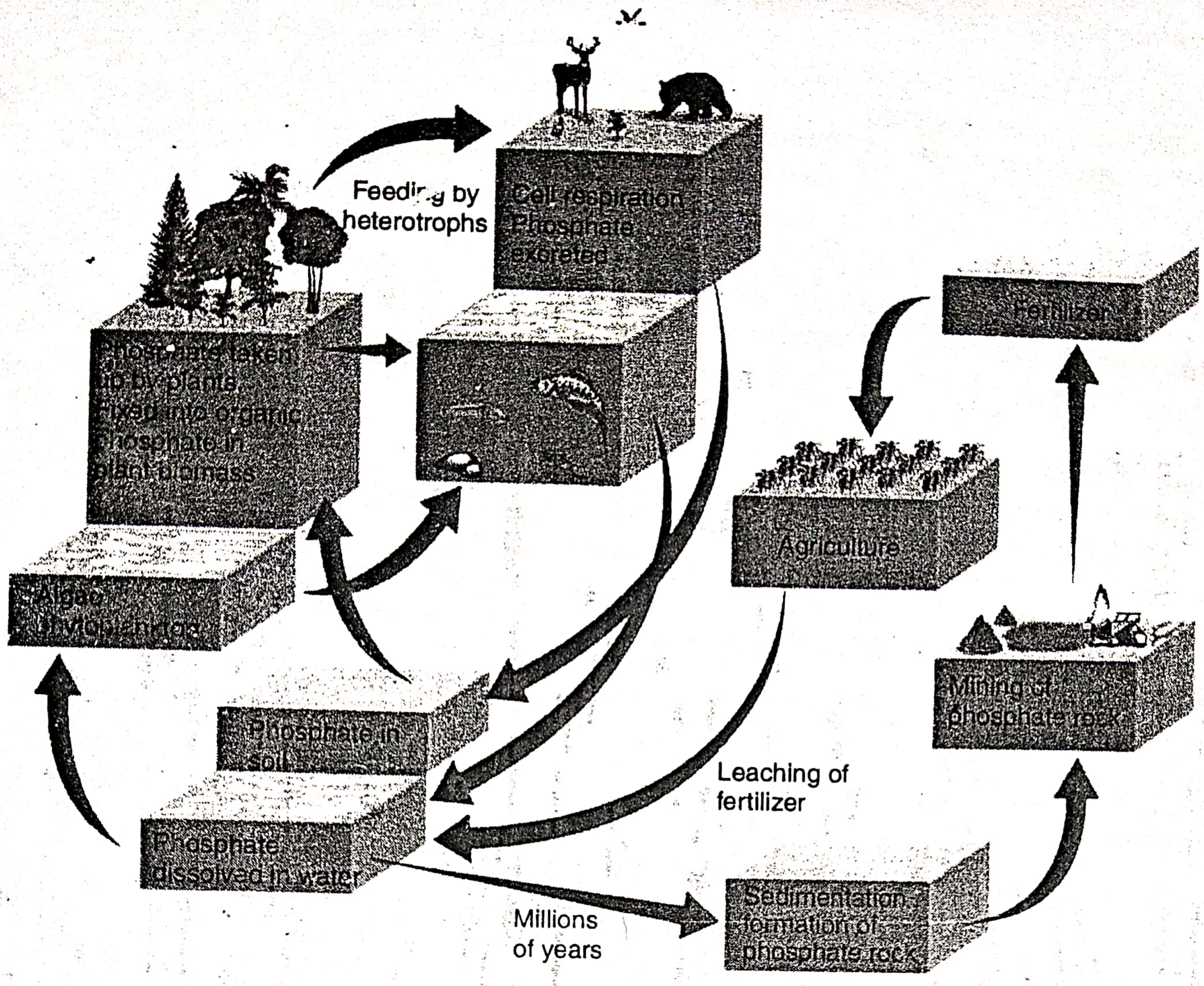


Fig. 2.34 ***(a)*** Phosphorous cycle

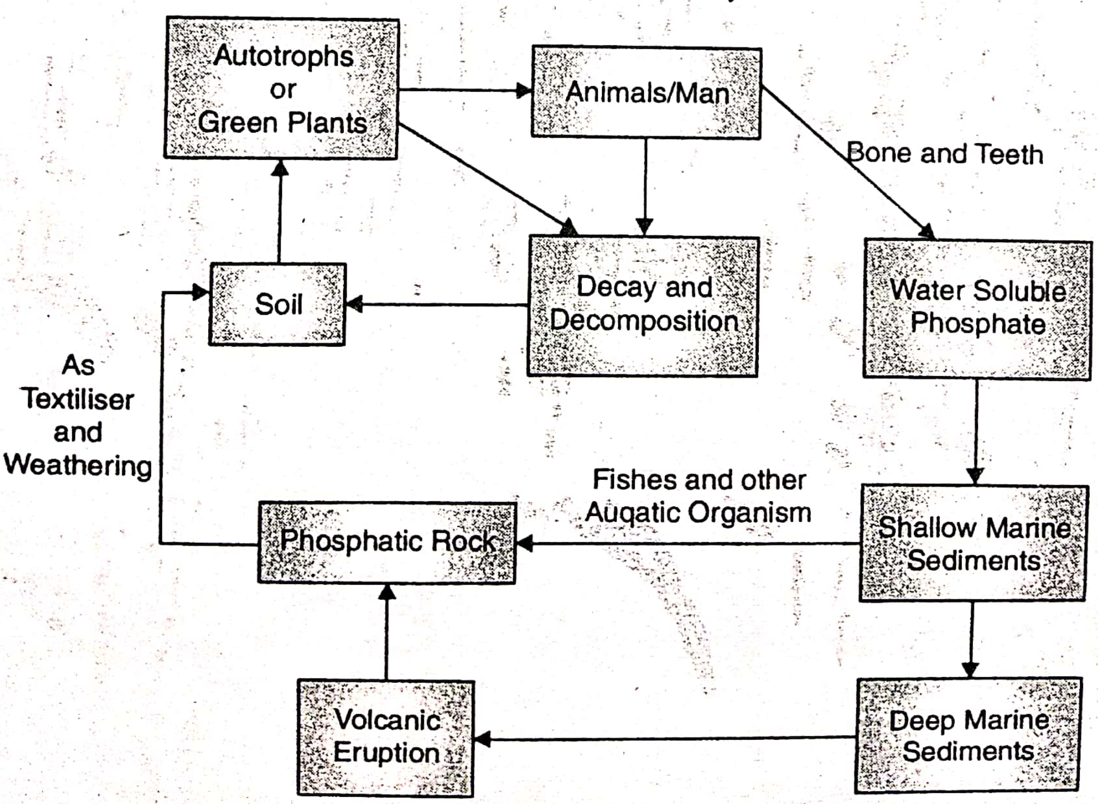
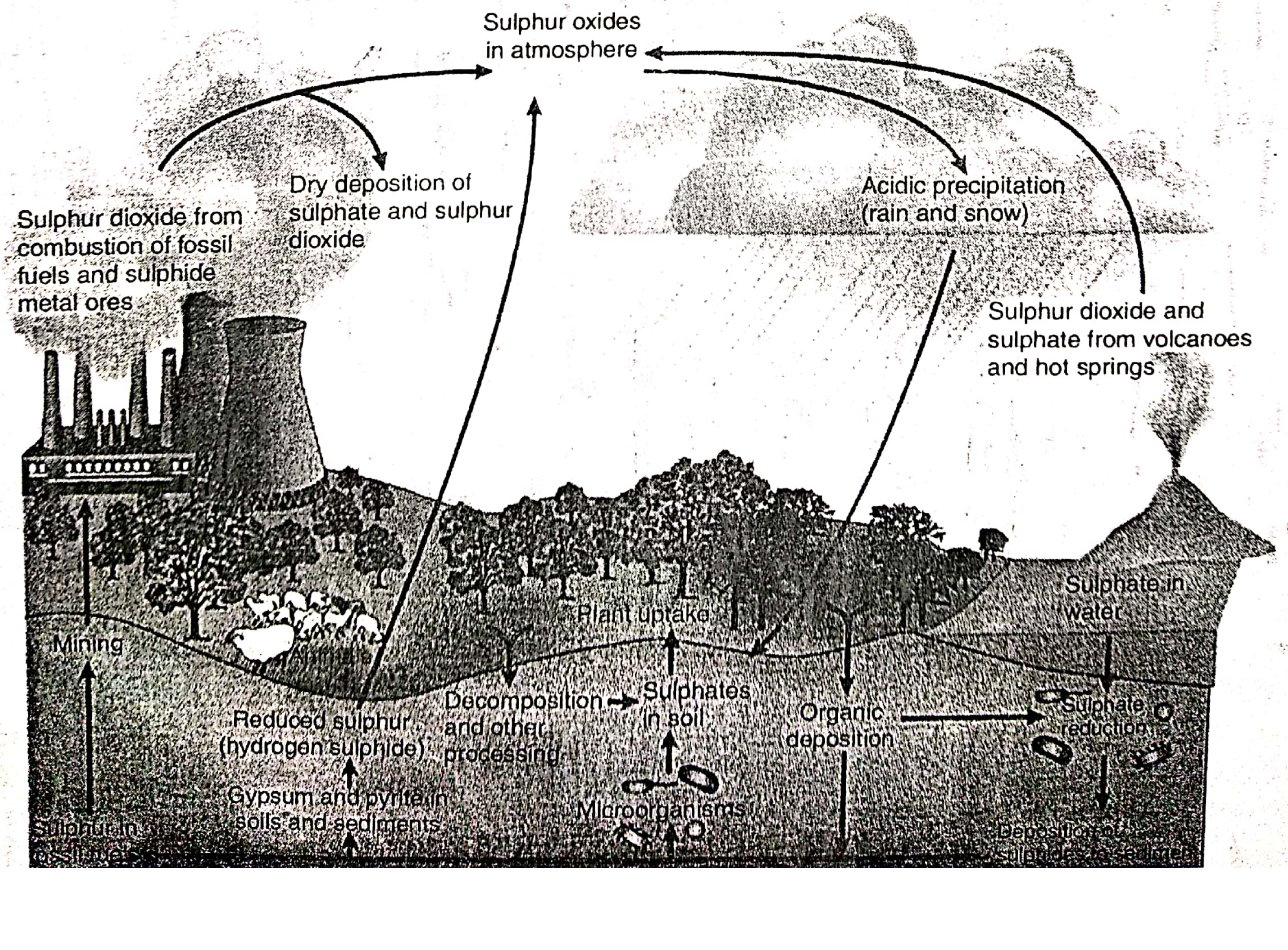


Fig. 2.34 ***(b)*** Flow diagram of phosphorous

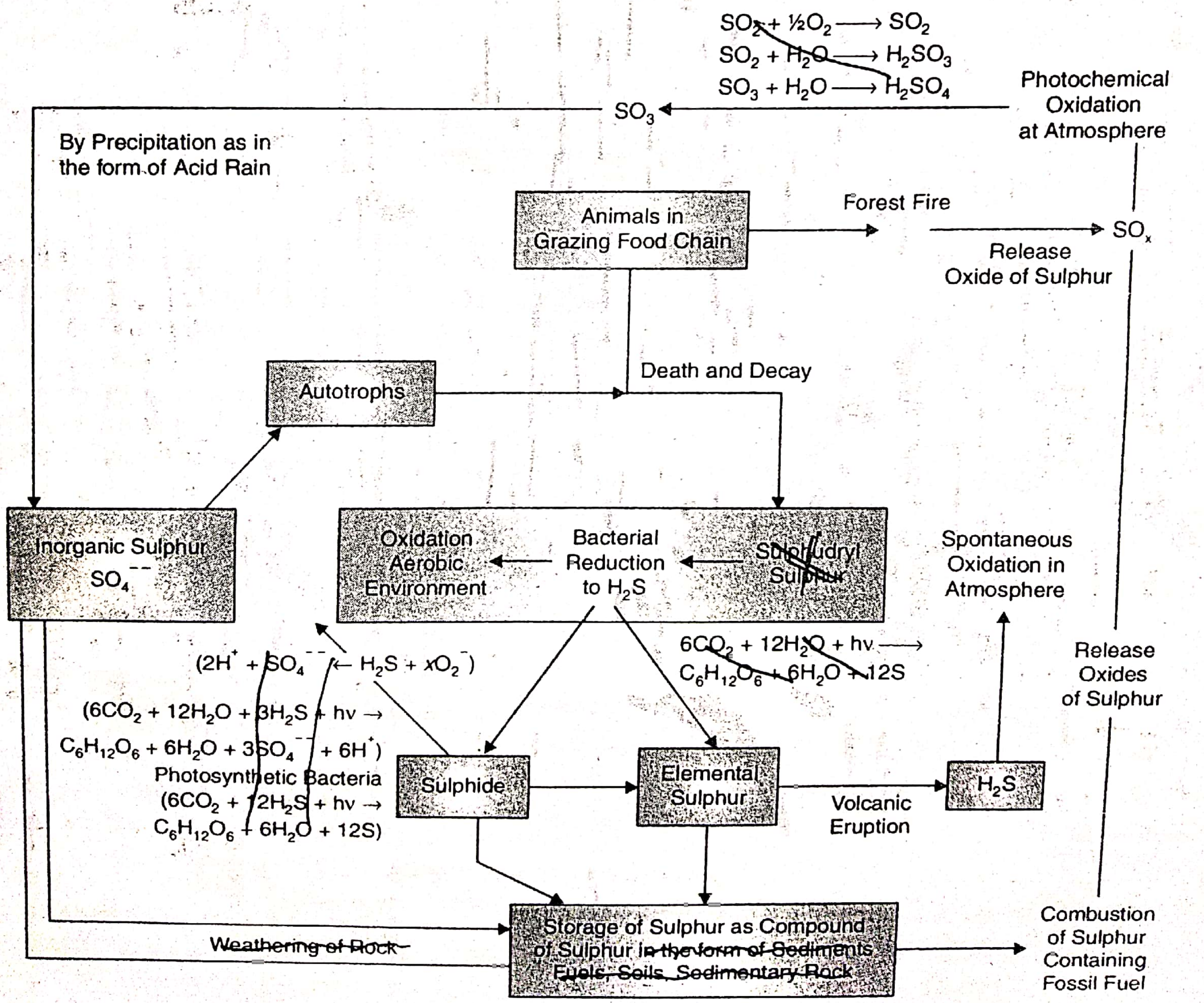
2.27 SULPHUR CYCLE

In sedimentary cycle main reservoir are soil and rock. The elements classified under this cycle denote have gaseous phase. Sulphur cycle is an exception. They are usually found in soil and sediments and Sulphur has a gaseous phase in SO_2 and H_2S. But its resident time in gaseous phase is very small, so it is considered as sedimentary cycle.

1. Plants usually take sulphur from the soil in which it is usually present the form of sulphate. Bacteria present in soil can use elemental sulphur.
2. In the solid form it is available in the form of sulphate, sulphide and organic sulphur.
3. Like nitrogen sulphur is an essential part of the protein and amino acid.
4. From the producers, the sulphur in amino acids is transferred to the consumer animals.
5. Excretion and death carry sulphur in living material back to the soil and also to the bottom of water bodies where the organic matter interacts with bacteria of detritus food chain.
6. In the latter, the –SH group of amino acids gets separated from rest of the molecule as H_2S by the most decomposing bacteria as a normal part of the degradation of proteins.
7. H_2S is oxidized in an aerobic environment to SO_4 by the bacteria specially adapted to perform this change.



8. The sulphate so formed can then be used by Autotrophs again.
9. In the bottom of certain lakes and ponds, where there exists an anaerobic environment, it is usually not easily possible to oxidise sulphide by the above process because of absence of oxygen. But if UV radiation is present in these environments, photo synthetic bacteria are capable of using sulphide (H_2S) in the manufacture of carbohydrates and oxidize H_2S to sulphur or to sulphate.
10. Some amount of sulphur always forms in sediments.
11. Hence sulphur is included in the sedimentary cycle along with phosphorus.
12. Burning of fossil fuels and volcanic eruption produces more oxide of sulphur into the atmosphere.
13. From the atmosphere hydrogen Sulphide and Sulphur dioxide return to the soil as sulphate or sulphuric acid along with acid rain. The sulphur present in the plants is taken by the consumers. The process of decay or decomposition of excreta and dead body of animal and dead plants results return of sulphur to the soil. The responsible fungi for decomposition in aerobic condition are aspergillus and Neurospore and the responsible bacteria is Escherichia



Photosynthetic Bacteria

$$6CO_2 + 12H_2O + hv \longrightarrow C_6H_{12}O_6 + 6H_2O + 12S$$

$$6CO_2 + 12H_2O + 3H_2S + hv \longrightarrow C_6H_{12}O_6 + 6H_2O + 3SO_4^- + 6H^+$$

Photosynthetic Bacteria

$$2S + 3O_2 \longrightarrow 2SO_4^- + 4H^+ + 12S$$

If nitrate is present sulphur is also oxidised to sulphate by bacteria under anaerobic conditon.

$$6NO_3 + 5S + 2CaCO_3 \longrightarrow 2CaSO_4 + 6CaSO_4 + 3SO_4^{-} + 2CO_2 + 3N_2$$

Fig. 2.35 (*b*) Flow diagram of sulphur cycle

2.28 ARTIFICIAL ECOSYSTEM

An aquarium is a glass container with water. It has soil with some water plants rooted in it. A few fish roam about within its walls. You could even have a couple of snails in it. And, the most important is the electric bulb providing the light energy for the aquatic plants to produce food. The food chains are established in it. The CO_2 given out by fishes is used by the green plants to produce food in light and the oxygen given out by the plants is used by the fishes for respiration. The excreta of fish provide nutrients in the soil for the plants. Some decomposers (bacteria) may be present in the soil to break down the dead organic matter (for Example broken or dead leaves). Thus an aquarium is a balanced ecosystem.

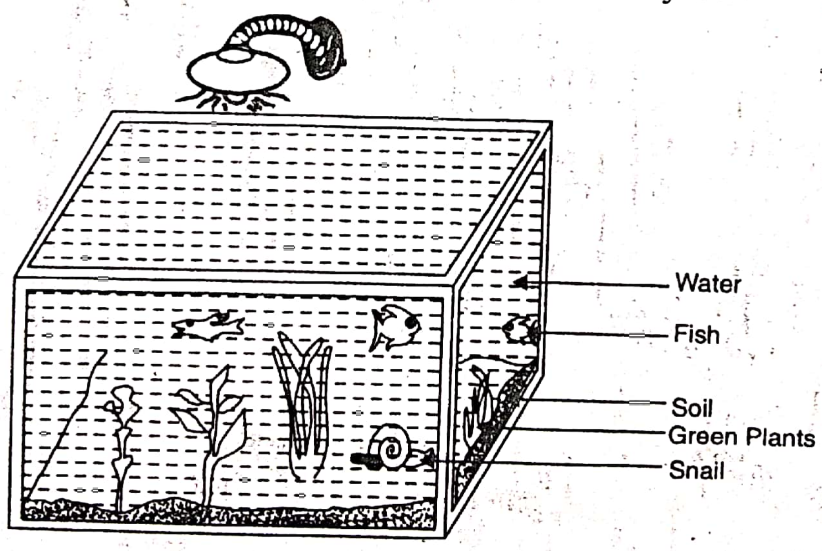


Fig. 2.36 Artificial ecosystem

2.29 PRODUCTIVITY OF AN ECOSYSTEM

The rate of organic matter or biomass production is called productivity.

The productivity of an ecosystem is of two types:

- Primary Productivity
- Secondary Productivity

Primary Productivity

The rate at which radiant energy is captured by the producers for the synthesis of organic compounds through photosynthesis is called primary productivity. It is expressed as gm-2 year-1 for dry matter and kcal m-2 year-1 for energy. The primary productivity is further distinguished *as gross primary productivity* or GPP and net primary productivity or NPP.

GPP is the rate of total capture of energy or the rate production of organic matter or biomass by the producers per unit area and time. NPP is the rate at which energy or organic matter stored by the producer after respiration and maintenance per unit area and time.

Net primary productivity is the balance energy or biomass left after meeting the cost of respiration and maintenance of producers.

Net primary productivity = Gross primary productivity – Loss due to respiration and maintenance

Secondary Productivity

The rate of increase in the biomass of consumers per unit area and time is called secondary productivity or SP.

2.30 EVOLUTION OF ECOSYSTEM

The long term evolution of the ecosystem is shaped by interaction of allogenic geological and climatic changes and the autogenic process resulting from the activity of the living components of the ecosystem. Initially, the life begins on Earth roughly three billion years ago. The atmosphere contained the gases CO_2, ammonia, methane and hydrogen sulphide. The oxygen was not available in the free form. Hence the first living organism might be heterotrophic which collected its food from organic compounds through abiotic processes. Due to evolution autotrophy were evolved in the next stage. They consumed the CO_2 in the atmosphere for the photosynthesis and released O_2 gas. This paved the way for the evolution of complex and diverse organisms through long geological ages. Ecosystem contains well defined biotic and abiotic components evolved.

These ecosystems influenced and controlled the atmosphere by their activities and in the course of millions of years complex and diversified living systems ~~evolved~~. It also influenced convergence, divergence and evolution of natural communities in relation to environmental conditions.

2.31 ECOLOGICAL SUCCESSION

Ecosystem is not static in nature. It is dynamic and changes its structure as well as function with time and quite interestingly, these changes are very orderly and can be predicted. It is observed that one type of community is totally replaced by another type of community over a period of time during this period of time several changes occurs. This process is called as ecological succession. Ecological succession can be defined as an orderly process of changes in the community structure and function with time mediated through modification in a stabilized ecosystem known as climex. The modification of the environment may be in turn allow additional species to become established. The whole sequence the communities which are