Environment and its important components

Dr. (Mrs.) Anjana Kapoor
Department of Microbiology
Swami Shraddhanand College
Alipur, Delhi – 1100 36

04-Oct-2006 (Revised 11-Sep-2007)

CONTENTS

Introduction
Components of the Environment
Air
Water
Soil
Ecosystem
Cycling of Nutrients/Minerals
Food Chain & Food Web
Biogeochemical Cycling
  Carbon Cycle
  Nitrogen Cycle
  Phosphorous Cycle
  Sulphur Cycle

Keywords

Environment; Air; Water; Soil; Ecosystem; Food chain; Food web; Biogeochemical cycles; Carbon cycle; Nitrogen cycle; Phosphorus cycle; Sulphur cycle.
Introduction

Everything which surrounds us may collectively be termed as the environment. Thus the air that we breathe, the land on which we stand, water that we drink and all living and non-living things surrounding us make up the environment. It has taken millions of years for the development of the present day environment and it forms our life support system.

Environment has played a key role in the evolution of the biological spectrum by the process of natural selection and elimination.

The environment has influenced and shaped our lives since time immemorial. The environment provides us with our daily requirement essential for our existence.

The evolution of earth’s environment and life on earth has gone hand in hand. The environmental conditions at the time of the beginning of life on earth were very much different from what they are today.

In nutshell we can say that environment is a complex of our surroundings and the interactions occurring among the living component and the influence of the external factors affecting them.

Components of the Environment

Since the environment comprises of living as well as non living things, therefore, the components of the environment are as follows:-

1. Atmosphere - refers to air.
2. Hydrosphere – refers to water.
3. Lithosphere – refers to rocks & soil.
4. Biosphere – refers to the living component.

The above components of the environment are elaborated under the respective headings.

Air

This component is referred as the earth’s atmosphere. It is an important component of the environment. There is no defined boundary present between the earth’s atmosphere and the outer space. The atmosphere is a mixture of gases which are retained by the earth’s gravity.

![Fig. 1: Composition of air on Earth’s surface](image)

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>78.084%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>20.946%</td>
</tr>
<tr>
<td>Argon</td>
<td>0.934%</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>0.038%</td>
</tr>
<tr>
<td>Water vapor</td>
<td>1%</td>
</tr>
<tr>
<td>Other</td>
<td>0.002%</td>
</tr>
</tbody>
</table>

Fig. 1: Composition of air on Earth’s surface
It consists of mainly nitrogen, oxygen, carbon dioxide, hydrogen etc. along with water vapour and particulate matter (dust particles, pollen grains). The life on earth is protected by the atmosphere as it absorbs the ultraviolet rays of solar system by ozone layer present in the stratosphere radiations. The atmosphere also reduces the extremes of temperature between day and night.

The temperature of the earth’s atmosphere varies with altitude (height). The variation in temperature is the basis for dividing the earth’s atmosphere into the following zones starting from the base as shown if Fig.2.

![Fig. 2: Structure of Earth’s atmosphere](image)

1. **Troposphere** – This is the lowest layer of the atmosphere. It begins at the surface and extends up to 7 Km at poles and 17 Km at equator. This layer shows lot of vertical mixing because of the solar heating at the surface. Due to this heating the air mass warms and further rises up. The temperature of air decreases with height in this region due to expansive cooling. In this layer all events occur like cloud formation, lightening, thundering storm etc. This layer also shows a decline in atmospheric pressure. The concentration of available oxygen and organic carbon also decreases with height in this region. Water vapour is also part of this region.

2. **Stratosphere** – This is next to troposphere or we can say this is the second layer of the atmosphere present above troposphere. In this region slow mixing of gases is observed. This extends up to around 50 Km. Here the temperature increases with height. This region harbours the ozone layer. This layer is relatively stable and also relatively dry.

3. **Mesosphere** – This is the third layer of the atmosphere. It is present above the stratosphere and extends upto 40 Km (approx.) above it in height. A decrease in temperature with height is seen in this region.
The mesosphere merges with the Ionosphere. The ionosphere is that part of the atmosphere where ionized gases and free electrons are present because of solar radiation.

4. **Thermosphere** – This is present above the mesosphere. Here temperature increases with height. Most gases are found in ionised form in this region of the atmosphere.

The boundaries between these regions are called as tropopause, stratopause, mesopause and thermopause respectively.

The atmospheric pressure varies with time and location as the air present above the earth shows variation, Atmospheric pressure is found to decrease with height because of the decrease in mass of gases. Atmospheric temperature is not uniform, therefore, the exact determination of atmospheric pressure at a particular location becomes complex. Atmospheric density decreases with increase in height.

The circulation of air in the atmosphere requires energy changes. This air circulation depends upon temperature and humidity of the atmosphere. The concept of air mass thus comes into effect.

In terms of climatology the basic cause of regional climatic difference is due to role played by AIR MASSES.

An air mass is a large, horizontal, homogenous body of air that may cover thousands of square kilometers and extend upward for thousands of meters. Air masses derive their properties from the surface from which they originate and are therefore classified as:

- Polar Continental - CP
- Polar Maritime - MP
- Tropical Continental - CT
- Tropical Maritime - MT
- Equatorial - E

The atmosphere on earth has no boundaries, it gradually thins and fades out into the outer space. About three fourths of the atmospheric mass is present in the lowest layer of the atmosphere (troposphere). This layer gets heated up by the Sun’s energy. This results in expansion of the air. This low density warm air rises up and gets replaced by high density cool air. This causes atmospheric circulation that results in the climate and weather changes of a region based on redistribution of heat energy.

Air currents referred as wind are an important part of the atmosphere. The wind movements help in regulating rainfall distribution on the surface of earth.

**Importance of Atmosphere**

Atmosphere plays an important role on the surface of the earth. The equilibrium on earth’s surface is maintained because of the occurrence of the following processes:-

1. It regulates the temperature of the earth by absorbing radiations of long wavelength. These radiations are mainly absorbed by the carbon dioxide gas.
2. The harmful ultraviolet radiations are absorbed by the ozone layer which otherwise would damage the terrestrial life present on earth.
3. The atmosphere helps in maintaining the temperature and pressure on earth. Thus resulting in biotic community development.
4. It also acts as a media for quick and effective dissemination of gaseous wastes because of air currents and vertical temperature gradient.
5. It also helps in the removal of pollutants as they come down with snow/dew/rain.

Water

Water is a common chemical substance that is essential to all known forms of life. In typical usage, water refers only to its liquid form or state, but the substance also has the solid state-ice, and gaseous state-water vapor. Water covers over 71% of earth’s surface. Saltwater oceans hold 97% of surface water, glaciers and polar ice caps 2.4% and other land surface water such as rivers and lakes 0.025%. Water in these forms moves perpetually through the water cycle of evaporation and transpiration, precipitation, and runoff usually reaching the sea. Winds carry water vapor over land at the same rate as runoff into sea.

Clean fresh water is essential to humans and other land-based life. In many parts of the world, it is in short supply. Many very important chemical substances, such as salts, sugars, acids, alkalis, some gases (especially oxygen) and many organic molecules dissolve in water. Outside of our planet, a significant quantity is thought to exist underground on the planet Mars.

It is an important constituent of our environment. Three Fourth of the Earth is occupied by water. We may call water as the aqueous environment, which is distinguished into Marine and Fresh water habitats.

Water as we are aware is essential for all living organisms on our planet Earth. All the biochemical reactions of the organisms occur in this medium. It is one of the most decisive factor for the growth and survival of any organism in a habitat. Terrestrial areas with abundant water have green vegetation while those with low availability of water gradually turn into deserts. In the process of vaporization much of the solar energy is used up that would have otherwise raised the global temperature. Water vapour acts as a green house gas because it helps in regulating the Earth’s temperature by absorbing the solar radiations of long wavelength.

Whatever may be the quantity of water on the surface of Earth, only 5% of it is available for use. The water of ocean is not usable as it is highly salty. Fresh water sources comprise of rivers, lakes etc. These are formed by the precipitation of water in the form of dew or rain or by snow etc.

Water Cycle

The movement of water around, over and through the Earth is called the Water Cycle. The Earth’s water is always in movement, and the Water Cycle, also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the surface of the Earth. Since the water cycle is truly a “cycle,” there is no beginning or end. Water can change states among liquid, vapor, and ice at various places in the water cycle, with these processes happening in the blink of an eye and over millions of year. Although the balance of water on Earth remains fairly constant over time, individual water molecules can come and go.
**Description of Hydrologic Cycle**

The water cycle has no starting or ending point. The sun, which drives the water cycle, heats water in the oceans. Some of it evaporates as vapour into the air. Ice and snow can sublimate directly into water vapour. Rising air currents take the vapour up into the atmosphere, along with water from evapotranspiration, which is water transpired from plants and evaporated from the soil. The vapour rises into the air where cooler temperatures cause it to condense into clouds. Air currents move clouds around the globe, cloud particles collide, grow, and fall out of the sky as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousand of years. Snow packs in warmer climates often thaw and melt when spring arrives, and the melted water flows overland as snowmelt. Most precipitation falls back into the oceans or into land, where, due to gravity, the precipitation flows over the ground as surface runoff. A portion of runoff enters river in the valleys in the landscape, with stream flow moving water towards the oceans. Runoff, and ground-water seepage, accumulate and are stored as freshwater in lakes. Not all runoff flows into rivers. Much of it soaks into the ground as infiltration. Some water infiltrates deep into the ground and replenishes aquifers (saturated subsurface rock), which store huge amount of freshwater for long periods of time. Some infiltration stays close to the land surface and can seep back into surface – water bodies (and the ocean) as ground water discharge, and some ground water finds opening in the land surface and emerges as freshwater springs. Over time, the water continues flowing, some to reenter the oceans, where the water cycle renews.

![The Water Cycle](image)

**Fig. 3: Movement of water in an the ecosystem**

In summary water is continuously circulated on Earth. It is referred as the hydrological cycle. Water evaporates from the surface of earth and water bodies forming water vapour in the atmosphere which condenses in the form of clouds and precipitates on Earth as rain.

We can categorize atmosphere water as follows:

1. Invisible form i.e. vapour
2. Visible form i.e. cloud, fog etc.

Water vapour as atmosphere is referred as Relative humidity. The capacity of atmosphere to hold water in vapour depends on the atmospheric temperature. The evaporated water precipitates as rain in the different regions of the Earth. The amount of rainfall received by a
region depends on the Geographical feature and availability of moisture that is taken by winds.

Humidity and relative humidity are the two terms relating to atmospheric moisture. Humidity is the moisture content of the atmosphere. This is also called as absolute humidity while relative humidity is the percentage of water vapour present in the atmosphere. The amount of water vapour held by the atmosphere depends on the amount of moisture present and also on the temperature of that particular area.

Type of vegetation depends upon the rainfall. The rain water is either held by the soil or it percolates down, when the clay particles occupy the pore space water move horizontally instead of percolating down.

The vertical and horizontal movement of water depends on the soil properties. Vegetation is able to absorb rain-water and also prevent soil erosion and leaching of useful minerals from the soil. The rain-water retained is used by the plants later.

Depending on the availability of water in the habitat, the flora and fauna present in that habitat adapt themselves according to the environmental parameters present in the habitat. They are categorized as hydrophilic-hydrophytes, mesophilic-mesophytes and xerophilic-xerophytes.

**Effect of Water on Life**

From a biological stand point, water has many distinct properties that are critical for the proliferation of life that set it apart from other substances. It carries out this role by allowing organic compounds to react in ways that ultimately allow replication. All known forms of life depend on water. Water is vital both as a solvent in which many of the body’s solutes dissolve and as an essential part of many metabolic processes within the body. Metabolism is the sum total of anabolism and catabolism. In anabolism, Water is removed from molecules (through energy requiring enzymatic chemical reactions) in order to grow larger molecules (e.g. starches, triglycerides and proteins for storage of fuels and information). In catabolism, water is used to break bonds in order to generate smaller molecules (e.g. glucose, fatty acids and amino acids to be used for fuels for energy use or other purposes). Water is thus essential and central to these metabolic processes.

Water is also central to photosynthesis and respiration. Photosynthetic cells use the sun’s energy to split waters’ hydrogen from oxygen. Hydrogen is combined with CO2 (absorbed from air or water) to form glucose and release oxygen. All living cells use such fuels and oxidize the hydrogen and carbon to capture the sun’s energy and reform water and CO2 in the process (cellular reparation).

**Water Bodies**

The water bodies (marine as well as freshwater) are stratified like the atmosphere. The water bodies get heated due to the solar radiations reaching the Earth. Thus due to heating of the upper layers the warm water goes down and cooler strata comes up on the surface. As a result convection current circulates in the water body.
Organic matter or waste normally causes pollution of water bodies as it gradually and naturally gets disintegrated. High proportions of waste produced, results in pollution of any water body. The water bodies have sufficient amount of dissolved oxygen to allow many organism to inhabit. But more organic matter of waste especially nitrogen and phosphorus results in excessive growth of mainly micro-organism. This cause depletion of the oxygen resulting in increased demand for oxygen. Since the oxygen is needed by biological system for it’s chemical activities or release of the energy, this is called a Biochemical Oxygen Demand (BOD).

**Classification of Water Bodies**

The classification of water bodies is done differently depending on its characteristics: The first category is as follows:
1. Marine
2. Fresh Water

Further, the classification of fresh water is as follows:
1. **Lentic aquatic system** – Stagnant water bodies for e.g. ponds, lakes, puddles.
2. **Lotic aquatic system** – Comprise of flowing water bodies for e.g. streams, rivers,

With reference to temperature the water body is divided into different layers or strata. Each having different temperature. These layers are as follows:
1. Epilimnion
2. Intermediate Zone (thermocline)
3. Hypolimnion

![Figure 4: Stratification of water body based on temperature](image)

On the basis of productivity and fertility a water body could be differentiated into following two zones:
1. **Eutrophic** – High Productivity – Shallow
2. **Oligotrophic** – Poor Productivity – Deep
Fig. 5: Shows the cycling of water in the uppermost layer of the water body

According to the availability of light the water body has the following zones:-
1. **Littoral Zone** – Where light penetrates to bottom usually the shallow regions of the water body.
2. **Liminetic** – light is just sufficient for the growth of organisms.
3. **Benthos** – This is the bottom most region of the water body having least amount of life.

Fig. 6: Organisms inhabiting the different zones of a water body based on light penetration

Marine water bodies have a different terminology for it’s strata’s. Marine water bodies have horizontal zones which are:-
1. Littoral Zone – occurs at the seashore.
2. Sublittoral Zone – Is present below littoral zone.
3. Pelagic – Is used for open waters.
4. Benthic – Is the bottom region of the water body.
Vertically the marine water body is divided into:
1. **Euphotic Zone** – This is the area of effective light penetration.
2. **Disphotic/Aphotic Zone** – Here light does not penetrate.

The deep waters are mostly inhabited by micro-organisms as well as lower plants and animals. These organisms are capable of surviving in such habits as in course of time they have got adopted to this environment. The temperature of the marine water bodies varies in different regions and according to the conditions the organisms inhabit it. Since microbes are decomposers they recycle the nutrient of the aquatic flora and fauna.

**Soil**

The word soil originated from the Latin word “Solum” which means the “floor” hence soil is earth’s floor. The present day definition is “Soil is a natural body of minerals and organic constituents differentiated into horizons which differ among themselves in morphology, physical make up, chemical properties and biological characteristics.

“Soil is an integral part of the environment as it supplies the organisms with essential minerals, water and nutrients.

**Composition of Soil**

In the beginning the soil was considered as an inert material, but with detailed studies it has been proved that soil is vital for life forms.

Soil comprises of:
1. **Solid Phase**: Minerals derived from parent rock, organic matter from dead organisms
2. **Liquid Phase**: Water present between the soil particles.
3. **Gaseous Phase**: Soil air present between the soil particles. Besides these the soil has microbial population present in it and is a medium for anchorage of plants.

**Soil Components**

Soils have the following components:

1. Mineral Matter
2. Soil organisms
3. Soil water
4. Soil atmosphere
5. Organic Matter or Humus.

(1) **Mineral Matter**: It constitutes about 90% of the soil. It is formed by the disintegration of the parent rock which may be IGNEOUS, SEDIMENTARY OR METAMORPHIC ROCK. Theses rocks vary in their composition. The minerals present in soil may be essential or accessory for the soil organisms. These soil minerals can be grouped into two categories:
   a) Primary Mineral eg. Feldspar, Quartz and Mica etc.

Primary minerals are inherited from the parent rock. The decomposition of primary minerals results in the formation of secondary crystalline minerals which are essentially clay minerals.

(2) **Soil Organisms**: The soil organisms present cause changes in the nature and structure of soil, thus soil is said to be a living system, which was initially thought to be an inert matter. These comprise of both the flora and fauna. Among them are bacteria, fungi, algae, lichens, and soil animals like Protozoans, nematodes, earth worm, insects, reptiles and burrowing mammals. These organisms influence the soil property and help in the decomposition of dead organic matter, and aeration.

(3) **Soil Water**: It is an essential substance as it regulates all the physical/chemical and biological activities of the organisms. Water present in soil could be:
   a) Hygroscopic.
   b) Capillary
   c) Gravitation and/or
   d) Water Vapour

(4) **Soil Atmosphere**: Air is present in the spaces between the soil particles along with water. It is necessary for the survival and growth of the organisms present in soil. Soil air shows fluctuations in composition, and marked seasonal variations. The air comprises of O\(_2\), CO\(_2\) and N\(_2\). In soil, oxygen is in lower percentage, CO\(_2\) is in higher percentage while N\(_2\) is also in lower percentage when compared with atmosphere. The percentage of O\(_2\) & N\(_2\) is less since they are being utilized by the soil population.

(5) **Organic Matter or Humus**: The organic matter is complex part of the soil which mainly consist of dead remains of the organisms belonging to Flora & fauna in the soil. The finally broken organic matter is a dark coloured homogenous amosphous, odourless complex substance which has lost its structure through decay and decomposition called as HUMUS and process of it’s formation is called Humification. Humus is not quickly mineralized in cold conditions while in moist and warm conditions it gets quickly converted to CO\(_2\), water & minerals. This process is known as mineralisation. Organic matter is the source of most of the
nutrients required for the growth of organisms especially plants which needs to be mineralized.

*Formation of Soil*

The formation of soil is called as pedogenesis which results from rocks. The formation of soil involves two processes which are as follows:

1. Weathering
2. Development of soil Profile.

Weathering could be physical, chemical or biological.

**In physical weathering** - The parent rock breaks into smaller pieces, creating crevices. Physical weathering also causes disintegration of the rocks. This is caused by mechanical forces acting on the rocks (parent rocks) for eg. temperature fluctuations, beating rainfall etc.

While, **chemical weathering** could be the result of hydration/hydrolysis/carbonation/oxidation/reduction. Water plays an important part in this process because it can bring about changes due to dissolution or reaction of the rock material. Basically chemical weathering has two phases as follows:-

1. Disappearance of some minerals.
2. Formation of new products.

**Biological weathering** - Strictly speaking, there is nothing like biological weathering. It is basically physical, chemical weathering by biological system or in other words by living organisms. The flora and fauna accelerate the weathering process. It starts with the growth of lichens on the rocks by their chemical secretions. Carbon dioxide liberated during respiration forms carbonic acid with the action of water. Lichens are followed by the growth of other lithophytes which corrode the rock through their secretions. Roots widen the cracks and the crevices of the rocks thus increasing the free percolation of water. The gliding action of the worms also helps in the reduction of stony particles in soil.

*Soil Profile*

The process of soil formation results in the development of soil profile. Weathering of rocks results in soil formation that occurs over a period of time. Because of this, layers of strata’s or horizons develop one over the other which may vary in thickness. These different horizons form the soil profile which can be defined as the vertical section of any soil from top to bottom. The different layer present in soil profile differ from each other in:

1. Texture of mineral particles
2. Color of the soil
3. Microbial activities
4. Water holding capacity and
5. Percentage of organic matter.

The different horizons of soil are O₁, O₂ (topmost) followed by A, B, C, with finally bedrock at the bottom. These horizons are further subdivided as shown in the Fig. 8.
Fig. 8: Soil Profile (vertical section of the soil showing different horizons)

(1) **Climate**: This affects directly as well as indirectly. Rainfall and temperature play a very important role. Rain water i.e. precipitation affects percolation and leaching since percolating water is responsible for dissolution and translocation of constituents of the parent rock material resulting in their deposition at another region.

Low temperature does not allow percolation in long winters. Percolation does not occur due to higher evaporation. No evaporation condition leads to the formation of lakes, swamps, peat and muck deposits.

(2) **Organisms**: Plant roots penetrate the rocks creating space for movement of air and water. These dying roots produce many organic & inorganic acids. These substances produced react through the column of the parent material thus modifying the profile and soil constitution. Micro-organisms play an important role in these reactions for example the burrowing animals dig the soil, thus mixing the material in horizons, as a result soil profile is disturbed.

(3) **Parent Material**: This is a passive factor. Same conditions of decomposition will give rise to the same type of soil profile. Once the factor of decomposition changes then same parent material may give a different type of soil profile.

(4) **Time**: This also plays an important part but the age of the soil is judged in terms of maturity stage of development of the profile rather than the geological age of the parent material.

Soil development in different climatic conditions varies. It is of the following types:-

1. Laterization
2. Podsolization
3. Calcification
4. Gleization
**Laterization**: The term Laterite has been derived from Latin word LATUS meaning brick. There soil are reddish brown in colour and are found in warm and humid climates including India.

**Podsolization**: This takes place in cool, humid climate. Leaching results into grey ash like surface leading to the term Podsol. Which in Russian means:

Pod = Under
Zole = Ash -- Under Ash

**Calcification**: This is a common process in North India. It is process in which accumulation of calcium carbonate occurs in the soil profile.

**Gleization**: This takes place in predominantly ice covered regions like the arctic. Where soil is not saline, peat accumulates on the surface. Tundra soils are common example of gleization.

**Soil Characteristics & Types of Soil**

Soil characteristic & types of soil very much depend on its physical properties mainly texture, porosity, colour, temperature etc. By texture we mean the different particle constituents present in the soil. These are gravel, sand, clay, and silt. Soil could be coarse or fine textured depending on the proportions in which the above particles are present. Color and porosity also depend on the types of particles and their proportions in the soil, also mineral and organic matter. Soil texture is determined by the soil texture triangle.

![Soil texture triangle](Image)

**Fig. 9: Soil texture triangle showing different textural classes of the soil based on the percentage of sand, silt and clay**

Texture refers to different size of particles present in any soil type, this is given in the following table:

- **Gravel**: More than 2mm in diameter
- **Course Sand**: 2mm to 0.2mm in diameter
- **Fine Sand**: 0.2mm to 0.02mm in diameter
- **Silt**: 0.02mm to 0.002mm in diameter
- **Clay**: less than 0.002mm in diameter
Apart from the physical properties certain chemical properties of soil are also important like pH, salts present in soil etc. The chemical nature of soil depends on parent rock which has provided the soil minerals after weathering and disintegration. Organic matter also contributes to the soil micronutrients present in soil. The nutrients depend on the decomposition of the dead remains of both the plants and animals.

The soil characteristics play a vital role in determining the organisms inhabiting it especially the microbial population.

**Ecosystem**

The first principle of Ecology is that each organism has an ongoing and continual relationship with every other element that makes up its environment. Living organisms have a tendency of thriving in association with others. In doing so they interact among themselves and also with the environment. This interrelationship of organisms with the environment, both structural as well as functional, is called as Ecological system. A continuous interaction occurs among the organisms and the environment for production and exchange of materials and also for the survival. The ecosystem has two components one living and other non-living. Our planet earth is the biggest ecosystem in itself and it is called the Biosphere. (Fig.7) It is made of a number of smaller ecosystems. The two components are constantly interacting. As it is difficult to handle this big a system, hence the biosphere has been divided into smaller units. These ecosystems could be natural or artificial ecosystems. Natural Ecosystems – are those which under natural conditions operate by themselves.

1. Terrestrial Ecosystem
2. Aquatic Ecosystem

Terrestrial Ecosystem can be further subdivided into following:
1. Forest Ecosystem
2. Grassland Ecosystem
3. Desert Ecosystem

Similarly, Aquatic ecosystem comprises of the following:
1. Fresh Water Ecosystem
2. Marine Ecosystem

Fresh water ecosystem is further sub-divided into the following:
1. River Ecosystem
2. Pond Ecosystem
3. Lake Ecosystem

Depending upon the water body and are named accordingly.

Marine ecosystem is divided into two categories:
1. Sea Ecosystem
2. Ocean Ecosystem

Sea has only one ecosystem. While Ocean Ecosystem is further divided into two categories which are as follows:
1. Deep Water Bodies Ecosystem
2. Estuary Ecosystem (Shallow Water Bodies)

Artificial Ecosystem – These are created by man e.g. cropland ecosystem like wheat, maize, rice fields. Aquarium, spaceship etc.

Any natural ecosystem is in a well balanced state or we can say in a state of equilibrium as it is self sufficient. The self regulatory mechanisms of the ecosystem consists of various checks and balances – this is referred to as homeostasis.

**Cycling of Nutrients/Minerals**

One of the most important processes occurring in the ecosystem to maintain stability is cycling and exchange of material between the living world and the environment. Within the ecosystem, species are connected by food chains or food webs. Energy from the sun, captured by primary producers via photosynthesis, flows upward through the chain to primary consumers (herbivores), and then to secondary and tertiary consumers (carnivores and omnivores), before ultimately being lost to the system as waste heat. In the process, matter is incorporated into living organisms, which return their nutrients to the system via decomposition, forming biogeochemical cycles such as the carbon and nitrogen cycles. In the plants the organic material are synthesized by them from the raw-material present in the environment which are later returned back. In any ecosystem the materials are continuously cycling i.e. they enter the living system through soil and atmosphere starting from producers and then reaching the consumers. From producers and consumers the materials are returned back to the soil and atmosphere by the process of the death and decay. Thus see that cycling is a continuous process in nature. The other or the second process is the Energy flow – the energy required, is absorbed from the Sun by the green plants also called producers. The energy from these producers is transferred to other organisms on Earth who are also called as consumers in the form of nutrition. This energy is transferred to other organisms in the same way. The energy from Sun is trapped and absorbed on Earth. The energy (some part) is also lost in space by the process of respiration and as heat by the living organisms apart from being entrapped. The flow of energy in the biosphere is always in one direction i.e. unidirectional.

An ecosystem involves the structural and functional aspects of its components. The structural component refers to the biological community, composition, distribution and quantity of the nutrients water etc. and conditions like temperature, light etc. and the range of conditions. The functional aspect involves – the rate of production i.e. photosynthesis and respiration of an ecosystem, rate of nutrient cycle, regulation of environment by the organisms.

The ecosystem has two components the biotic and the abiotic components.

**Biotic Component**

These are living components.
1. **Autotrophs** – Those who manufacture their food themselves with the help of sunlight, water and carbon dioxide. These also called as producers (green plants).
2. **Heterotrophs** – Those who derive their food from others. These are incapable of manufacturing their own food as they lack chlorophyll. They are known as consumers. These include herbivores (1º order) and carnivores (2º order).
3. **Decomposers or Reducers or Scavengers** – These groups of organisms derive their nutrition from dead organic waste. During the process of decomposition, they form simple inorganic substance from where they derive their energy/nutrition.

4. **Parasites** – They live at the expense of the other living organisms for e.g. fungus.

5. **Predators** – Organisms that prey on other organisms like protozoans preying on bacteria.

There is likelihood of occurrence of interaction among the members of biotic component. These interactions could be as follows:-

1. **Positive** – Those benefiting one or both of the interacting populations but cause no harm to the other population.
2. **Negative** – Those which have detrimental or harmful effect on one of the interacting population.

The biotic component in the soil mainly comprises of the microbes which help in maintaining the soil properties (physical and chemical). Thus the microbial population occupies a key position as they help in the survival of life forms on earth by maintaining a conducive environment.

**Abiotic Component**

These are the non living component and basically comprise of following:

1. **Energy** – Solar or light or heat energy of chemical bonds.
2. **Materials** – Water or mineral or salts or atmospheric gases etc.

Now tropic relations would be discussed. As already mentioned, ecosystem maintains a dynamic steady state through dynamic process. The population of any ecosystem may change at any point of time which would indicate towards the changing environment of that ecosystem.

The energy received as radiation energy from the sun in the form of solar radiations is entrapped by the green plants (about 1/5) which are the PRODUCERS. This radiant energy is converted to chemical energy in the form of carbohydrates with the help of chlorophyll, water and carbon dioxide and forms the biomass of the organisms. This energy, which is in the form of nutrition, is transferred from the producers to the CONSUMERS. The producers and consumers form the different tropic levels of an ecosystem and are part of the food chain and food web. The consumers may be primary or of the first order (herbivores) or secondary or of the second order (carnivores) followed by top carnivores.

In an ecosystem, the connections between species are generally related to food and their role in the FOOD CHAIN. There are three categories of organisms:

- **Producers** – Usually plants which are capable of photosynthesis but could be other organisms such as bacteria around ocean vents that are capable of chemosynthesis.
- **Consumers** – Animals, which can be primary consumers (herbivorous), or secondary or tertiary consumers (carnivorous and omnivores).
- **Decomposers** – Bacteria, fungi which degrade organic matter of all categories, and restore minerals to the environment.

These relations form sequences, in which each individual consumes the preceding one and is consumed by the one following, in what are called food chains.
Fig. 10: Pyramid of life- shows producers at the base which are consumed by consumers (herbivores and carnivores)

Fig. 11: Depicts unidirectional energy flow in a food chain
Fig. 12: Represents the different trophic levels of the food chain

Energy present in all the trophic levels is utilized for their metabolic activities and dissipated as heat energy. The energy flowing in an ecosystem decreases at each trophic level since it is lost in respiration by the organisms and also lost as heat energy. There is a 10% LAW proposed as it is observed that when energy is transferred from one trophic level to another actually approximately 10% of it only goes to the next trophic level in the food chain. That is why there cannot be more than 4 or 5 tropic levels in any food chain.

Fig. 13: Representation of the 10% law in a food chain in the ecosystem
**Food Chain & Food Web**

The food chain is different in different ecosystems. So is the food web. Food web is the network of food chains operating in an ecosystem. Food chain is one in which an organism fixing energy (say the green plants) or microbes are eaten up by the herbivores (consumers) who in turn are being eaten by the carnivores of the next trophic level (consumers) and so on. Food chains are of two types as follows:

1. **Grazing Food Chain:** This type starts with producers passing through herbivores to carnivores and then to the top carnivores. Here the organisms are eaten alive. For e.g.

   - **Green Plants** → **Cattle (Grass Land)**
   - **Deer** → **Lion (Carnivore)**

2. **Detritus Food Chain:** This chain starts with the dead organic matter comprising the dead remains of both producers and consumers. The dead organic matter being fed by the decomposers i.e. the microbial population. Here the detritus food chain also comprise of those that feed on decomposers.

   - **The grazing and the detritus food chains are interrelated as the predators of the detritus food chain are fed upon by carnivores of the grazing food chain.**

In both the terrestrial and aquatic ecosystem, microbes are responsible for the decay and decomposition of the dead remains. Most of the terrestrial and shallow aquatic ecosystems are dominated by the flora i.e. plants which are producers. In such habitats the 80-90% of energy flow is through detritus chain where microbial populations is involved because most of the energy here in the grazing chain is entrapped in the bodies of the organisms and exists as biomass.

In aquatic ecosystem the food chains as well as food web function by the help of microbial forms. In oceans, most of the primary production is carried out by the phytoplanktons (algae, cyanobacteria) which amount to about half of the total photosynthesis occurring on this planet Earth i.e. biosphere. Shorter food chains are more efficient as the total energy loss at intermediate trophic level would be lesser compared to longer food chains.

The trophic level of the ecosystem and also food chains of the ecosystem can be represented in the shape of a pyramid as their exists a relationship between the producers and consumers regarding number, biomass and energy. These are called ecological pyramids and are of the following three types:

   1. **Pyramid of Number**
   2. **Pyramid of Biomass**
   3. **Pyramid of Energy**

The pyramids of number and biomass may be upright or inverted but the pyramid of energy is always upright. This pyramid represents the energy utilized per unit area in a given time (say a year) by the organisms of different trophic levels.
Biogeochemical Cycling

Biogeochemical cycling describes the movement and conversion of materials by biochemical activities throughout the atmosphere, hydrosphere and lithosphere. This occurs both within ecosystem and on a global basis. Biogeochemical cycles include physical transformation such as dissolution, precipitations, volatalization and fixation. Chemical transformation such as biosynthesis, biodegradation and various combinations of physical and chemical changes.

Most elements are subject to some degree of biogeochemical cycling. The intensity or rate of biogeochemical cycling for each element roughly correlates to the amount of the elements in the chemical composition of biomass.

The major elemental components of living organisms are Ex.:– C, H, O, N, P & S they are cycled most intensely. Minor element (Mg, K, Na), halogens and trace elements (such as B, Co, Cr, Cu, Mo, Ni & Zn etc) which are required in small quantities and not by every form of life are cycled less intensely.

Though the energy flows in one direction but there is a continuous exchange of material nutrients among the components of the ecosystem i.e. the organisms and the environment surrounding them. This exchange occurs in a cyclic manner. The cycles are together referred as the biogeochemical cycle. Bio refers to the living organisms involved which are mainly microbes. Geo means Earth which may involve lithosphere or atmosphere or hydrosphere. Chemical refers to chemical reactions occurring during the process. These are two types:–

1. Gaseous Cycle – In such type the reservoir of the nutrient is present in the atmosphere or hydrosphere and the element is mostly in gaseous form, viz., Hydrogen, Nitrogen etc.
2. **Sedimentary Cycle** – In such cycle the nutrient reservoir is present in the Earth’s crust and the element is not in gaseous form e.g. Phosphorus, Sulphur etc.

All the cycles operate in nature with the help of the micro-organisms. The microbes also play a vital role in mineralisation and humification. During the process of cycling of various elements, physical changes take place along with physical transformations (precipitation, fixation) and chemical transformation (biodegradation, biosynthesis etc). During operation of these cycles energy is absorbed, converted, stored for short duration and finally dissipated in the ecosystem.

**Carbon Cycle**

One of the major Biogeochemical cycles is Carbon cycle. It is a part of cycles of three major elements cycle, namely Carbon, Hydrogen and Oxygen. All three of which are cycled by the same two opposing process of photosynthesis and respiration.

The small atmospheric CO₂ reservoir is influenced by human activities. This has assumed considerable importance due to the GREEN HOUSE EFFECT which is warming global climate.

![Carbon Cycle Diagram](image)

*Fig. 15: Carbon Cycle*

In any element cycle its reservoir is an important aspect. When we talk of the reservoir – its size and how actively it is cycled should be taken into account. In case of carbon the atmosphere is the main source in the form of carbon dioxide. This carbon dioxide is also present in soil and water. All organic compounds synthesized naturally have carbon in them. Carbon is also locked up in fossil fuels in the form of carbonates. The part of carbon cycle involving weathering of rocks and dissolution of carbonates in soil and water is a slow process while the microbial population makes the process faster by decomposing the dead organic matter. The decomposition process in the carbon cycle plays a pivotal role as it provides both energy for growth and supplies carbon for formation of new cell materials. The microbial population degrades carbohydrate, sugars, lignin, fats, waxes, hydrocarbons etc.
Most of the organic matter comprises of plant residues from animal tissues and various excretory products are also present. The microbial population degrading the organic matter comprise mainly of bacteria, fungi, and actinomycetes.

Carbon is transferredmostly through the trophic levels i.e. food chain and food web. In living organisms, all of them depend on primary producers. Autotrophic organisms help in fixation of carbon dioxide as organic compounds. Beside the green plants, photosynthetic and chemolithotrophic microbes fall in this category (autotrophs) while the rest of them are heterotrophs. Whatever carbon is fixed by the organisms (whether micro) is returned back as carbon dioxide through the process of respiration by the living organisms into the pool.

![Fig. 16: Amount of carbon present in different forms in the cycle](image)

The organic matter is recycled both aerobically and anaerobically. Aerobic degradation is carried out from simple organic nutrients (such as starch) by the organisms but anaerobic degradation (fermentation) is carried out by the microbial population only. Most of the carbon transformation takes place under aerobic conditions. A compound may not be available to the degrading organisms in a habitat and as a result it would get accumulated but the same compound could be available for degradation in another habitat, thus becoming a source of energy and carbon. Organisms gain more energy by respiration compared to fermentation or in other words aerobic process yields more energy than anaerobic process.
Methanogens (bacteria) convert carbon dioxide to methane using hydrogen liberated during fermentation

\[ \text{CH}_4 \rightarrow \text{CH}_3\text{OH} \rightarrow \text{CHO} \rightarrow \text{HCOOH} \rightarrow \text{CO}_2 \]

The microbes also cycle carbon monoxide. Carbon monoxide is released in the atmosphere as a result of photochemical oxidation of methane and other hydrocarbons. Carbon monoxide is converted to carbon dioxide in the atmosphere by photochemical reaction and by the microbial population of soil and water. Carbon dioxide is metabolized both aerobically as well as anaerobically by microorganisms capable of doing so. Aerobically e.g. *Pseudomonas carboxidoftava, Pseudomonas carboxydehydrogena.*

\[ \text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2 \]

Anaerobically e.g. *Methanosarcina barkeri*

\[ \text{CO}_2 + \text{H}_2 \rightarrow \text{CH}_4 + \text{H}_2\text{O} \]

*Clostridium thermoaceticum* reduce carbon monoxide to acetate. Reaction is as follows:-

\[ 2\text{CO} + 2\text{H}_2 \rightarrow \text{CH}_3\text{COOH} \]

The degradation and decomposition of the organic matter is accomplished mainly by the microbial community present in that habitat. This results in the conversion of complex compounds into simple ones and release of energy as well as utilization of stored energy, thus helping in the cycling process. Organic matter largely comprises of residues of plant origin which is an important part of carbon cycle. The plant remains comprise of cellulose (15-60%), hemicellulose (10-30%), lignin (5-30%), Sugars, amino acids, organic acids (5-30%) which are water soluble. Fat, oils, resins which are soluble in organic solvents such as alcohol/ether, proteins (10%), mineral constituents present vary from (1-13%).

**Cellulose** degradation is carried out by fungi in humid soil in semi arid conditions the task is accomplished by bacteria.

Cellulose decomposition could be aerobic or anaerobic. During aerobic process carbon dioxide is the major product formed while under anaerobic conditions carbon dioxide, ethanol and various organic acids (e.g. acetic, lactic, succinic) are formed.

**Hemicellulose** is another major component which is very much different from cellulose. Many enzymes are reported to breakdown this polymer. Degradation of hemicellulose is slowed by Calcium, Iron, and Aluminium because of the formation of complexes.

Fungal and bacterial population both take part in it’s degradation. The end products of hemicellulose degradation are carbon dioxide, cell biomass and simple carbohydrates (monomers or dimers).

**Starch** is also an important component since it is the reserve food material of the plants. Starch decomposes rapidly by most of the soil microbial population. Starch has \( \alpha \) linkages which easily get hydrolysed by the microbial enzymes compared to \( \beta \) linkages of cellulose. Starch is broken into simpler units by the extracellular hydrolytic enzyme amylase.
Lignin is supposed to be one of the major constituent of the plant tissue. It is resistant to degradation and is highly branched with no defined structure. Lignin degrades in nature at a much slower rate. Lignin is degraded by the action of fungi.

The enzyme degrading lignin are called as ligninase. The decomposition of lignin is the result of secondary metabolism of the organisms. In wet condition which are not anaerobic, soft rot fungi helps in its degradation. Lignin decomposition results in the formation of phenols, aromatic alcohols. Some of these products eventually get converted to carbon dioxide and water while the phenolic compounds may form humic compounds.

Chitin is another important component. It is the constituent of fungal cell walls and exoskeleton of insects. The enzymes degrading chitin are known as chitinase. Actinomycetes play a major role in chitin degradation.

Pectin is another plant component degraded with the help of enzyme Pectinase.

The organic matter in aquatic habitats is a bit different from the terrestrial habitat. It is lower in amount and less complex in aquatic habitats. Some limiting factors in the biodegradation process of carbon compounds are lack of oxygen, high acidity, high concentration of phenolic compounds and tannins e.g. histosols (muck soils) peat deposits and some of the aquatic sediments. As a result carbon gets locked up and finally gets depleted from the cycle as fossil fuel deposits. In soil, the humic substance present are found to be quite stable and they are observed to persist for a longer duration in peat and muck soils. Humic acid in soil reduces the rate of cycling and even at times immobilizes carbon and also the stored energy.

Degradation of compounds present in the organic matter results in the formation of simple organic compounds. During the decomposition process the physical state of some compounds gets changed like production of carbon dioxide or methane or change from liquid to solid state, this brings about change in the availability of the carbon source to the organisms in any habitat.

In nutshell the carbon cycle involves formation of CO2 along with many other carbon products mentioned above. This carbon dioxide is utilized by plants in the process of photosynthesis. If we summarise this cycle it is – carbon is present in atmosphere as carbon dioxide. This carbon dioxide is fixed by photosynthesis into carbohydrate and other compounds. These compounds are metabolized aerobically to carbon dioxide and anaerobically to methane and carbon dioxide.

Nitrogen Cycle

Nitrogen is an important element required by plants and animals as it a constituent of the cells. It is present in cells as organic molecules – proteins. The living organisms are incapable of taking in nascent Nitrogen. It is taken in combined form mainly nitrates. Gaseous nitrogen present in large quantity in the atmosphere of the earth is fixed by the micro organisms. Sometimes it becomes a limiting factor, as it is absorbed by the producers (green plants) of the ecosystem in inorganic combined form and later on passed to the consumers through food chain and food web. Inorganic combined form of nitrogen is ammonium or nitrate while the organic state of the elemental nitrogen in nature is humus, proteins, nucleic acid etc.

Main source of nitrogen is atmosphere. Nitrogen is found in geochemical deposits – rock having salts of ammonia, nitrite, nitrates gradually get converted to soil by weathering. These
In the nitrogen cycle, two important steps occur which are as follows:

1. **Mineralisation** – In this process, the microbes convert unavailable organic form of nitrogen to simpler assimilable form of nitrogen. This involves the processes of both ammonification and nitrification.

2. **Immobilisation** – In this process, the available form of nitrogen (i.e., ammonia and nitrate) is utilized by the living organisms, basically plants and microbes, who convert it into bound organic form. Thus, the nitrogen gets immobilized.

In summary, the nitrogen cycle involves ammonification, nitrification, and denitrification.
The micro-organisms helping in the operation of ammonification are among bacteria – *Pseudomonas*, *Bacillus*, *Clostridium*, *Serratia* and *Fungi-Alternaria*, *Aspergillus Penicillium*, *Mucor*. The end products of aerobic decomposition of protein are carbon dioxide, ammonia, water, sulphates while anaerobic decomposition (putrefaction), liberates hydrogen sulphide, mercaptans etc. Bacteria are found to liberate more ammonia compared to fungi.

Urea + water $\rightarrow$ Ammonia + Carbon dioxide.

Microbes involved are – *Bacillus*, *Proteus*, *Micrococcus*, *Sarcina* etc. Amines are acted upon by *Pseudomonas*, *Protoaminobacter* and the enzyme involved – aminooxidases. Amides are converted to ammonia by the enzyme amidase e.g. *Chlorella* (algae).

Ammonification is a predominant phenomenon in aerobic soils with more organic residues. In acidic soils the process is carried out by fungi, therefore less ammonia production. In soils having carbohydrate, ammonia production is low as the microbes have a preference to carbohydrates compared to nitrogenous compounds.

Besides the microbial population, animals are also capable of metabolizing nitrogenous compounds e.g. production of uric acid. Nitrogenous compounds are source of carbon, nitrogen and energy for the organisms.

Ammonia is a volatile compound and is positively charged. Hence it either gets dispersed or may bound to the negatively charged clay particles in soil. Thus ammonia may get readily oxidized leading to Nitrification which is the next step of the Nitrogen cycle.

The **Nitrification** process is oxidation of Ammonia $\rightarrow$ Nitrite $\rightarrow$ Nitrate.

It is of two types:

1. **Heterotrophic Nitrification**
   This is carried out by heterotrophic bacteria and fungi occurring usually in acidic soils e.g. *Pseudomonas*, *Corynebacterium*, *Aspergillus*, *Nocardia* etc. This process does not make significant conversion of Ammonia $\rightarrow$ Nitrite $\rightarrow$ Nitrate.

2. **Chemoautotrophic Nitrification**
   This is a bacterial process occurring in neutral $\rightarrow$ alkaline type of soils. The process of nitrification completes in the following two steps –
   - **Step 1**: Ammonia is oxidized to nitrite mediated by *Nitrosomonas*.
   - **Step 2**: Nitrite is further oxidized to nitrate mediated by *Nitrobacter*.

   Since the above two steps are closely coupled, therefore nitrite does not accumulate. Both the steps are aerobic and release energy. The microbes carrying out the process are chemoautotrophs. Other bacterial species capable of converting ammonia to nitrite are *Nitrosospira*, *Nitrosococcus*, *Nitrosolobus*, *Nitrosovibrio* while *Nitrospira*, *Nitrospina*, *Nitrococcus converts nitrite $\rightarrow$ nitrate.

   In aquatic system nitrification is carried by *Nitrosococcus*, *Nitrosolobus*, *Nitrobacter*, *Nitrospira*, *Nitrospina*, *Nitrococcus*.

Organisms with prefix Nitroso are Ammonia oxidisers. While with prefix Nitro are Nitrite oxidisers. *Nitrosomonas* and *Nitrobacter* are common in nature and are found to occur in close association. As conversion of nitrite to nitrate is a fast process, thus the level of nitrite does not rise. Hence it is beneficial for the plants since nitrite is phytotoxic.
Fig. 18: Interconversion of different nitrogenous compound present in nitrogen cycle

The nitrification process is found to be pH sensitive. Oxygen is also important because the nitrifiers are obligate aerobes. Nitrification rate declines in moist soils. Nitrifiers are incapable of tolerating arid conditions therefore moisture is required. The organisms are mesophilic, so nitrate production is high at 30-35°C. Nitrifications is dependent on carbon : nitrogen ratio. It proceeds at a faster rate when organic matter has higher nitrogen content.

Plants roots readily take up nitrate ions for organic compound assimilation. Since nitrite and nitrate ions are negatively charged they do not bound to the clay particles which are also negatively charged. As a result they at times leach down into the groundwater through soil column. Leached down nitrite and nitrate cause pollution problems. The level of nitrate should not exceed 10ppm in drinking water. The accumulation of nitrate in tissues (water, vegetables, fruits) causes infant methaemoglobinemia (blue baby syndrome) and animal methaemoglobinemia. Nitrite which is phytotoxic on reacting with secondary amines in environment or in foods, forms – N- nitrosamines which are carcinogenic in nature.

Nitrate Reduction: In this process nitrate is reduced to nitrite and then to ammonia. The nitrate reduction process could be assimilatory or dissimilatory.

1. **Assimilatory**: This occurs in aerobic conditions and is carried out by heterogenous microbial population comprising of bacteria, fungi and algae. This process is inhibited by excess of ammonia. Here oxygen is the electron acceptor.

2. **Dissimilatory**: This occurs under anaerobic conditions also known as nitrate respiration. The process is carried out by facultative anaerobic bacteria e.g. *Bacillus, Achromobacter, Flavobacterium, Nocardia, Spirillum*. Here nitrate ion acts as electron acceptor. This is not inhibited by excess of ammonia. The process is important in stagnant waters, water logged soils, sediments and sewage plants.
Denitrification

It is the process whereby fixed Nitrogen i.e. nitrite and nitrate are converted back to molecular Nitrogen. The sequence of events occurring in this process are –

Nitrate → Nitrite → Nitric oxide → Nitrous oxide → Nitrogen (molecular)

Thus in this process Nitrogen is released back in the atmosphere, thus becoming unavailable to the organisms. Bacterial denitrifiers are heterotrophs. The process is anaerobic and organisms are facultative anaerobes. The organisms are *Pseudomonas, Bacillus, Alcaligenes, Paracoccus, Micrococcus*.

*Thiobacillus denitrificans* is a chemoautotrophs which reduces nitrate → molecular Nitrogen.

Denitrification depends on number and efficiency of the denitrifying organisms present and environmental parameters, viz, soil temperature, moisture content, oxygen status, organic matter, pH of the soil and nitrate concentration.

Denitrification differs from dissimilatory nitrate reduction (DNR) process that Nitrate → Nitrogen gas in denitrification while nitrate is reduced to ammonia in DNR process.

Nitrogen Fixation: This occurs biologically. Atmospheric Nitrogen (molecular Nitrogen) is fixed biologically non-symbiotically or symbiotically. This is carried out with the help of the enzyme nitrogenase. Organisms involved in this phenomenon are basically prokaryotic microbes. They are either bacteria or cyanobacteria or Actinomycetes. Symbiotically fixed nitrogen is higher than fixed by free living nitrogen fixers though they are wide spread in soil. In aquatic habitats, cyanobacteria play a key role in nitrogen fixation while actinomycates show symbiotic association with non-leguminous plants and bacteria with legumes.

Microbes which fix atmospheric nitrogen in soil or aquatic habitat or those inhabiting the rhizosphere are known as diazotrophs (azo means nitrogen i.e. they are molecular nitrogen fixer). Microbial population present in the rhizosphere may show enhanced nitrogen fixation since organic compounds are available to them from the root exudates. As a result the environment around the rhizosphere becomes conducive/congenial for growth of the microbial population. Among the free nitrogen fixers (asymbiotic) some are aerobes (*Azotobacter*) while others are anaerobic (*Clotridium*) or microaerophilic (*Azospirillum*).

Cyanobacteria shows both symbiotic as well as non symbiotic association. Some filamentous cyanobacteria (BGA-Blue green algae) possess specialized cells known as heterocyst which are site for nitrogen fixation. Some filamentous non heterocystous cyanobacteria are capable of fixing nitrogen e.g. *Oscillatoria, Trichodesmium, Lyngbya, Microcoleus*. Certain cyanobacteria form symbiotic associations in which they occur as endophytes e.g. *Anabaena* or *Nostoc* in coralloid roots of Cycas.

Cyanobacteria also form symbiotic association with the water fern *Azolla* (*Anabaena-Azolla*). They are also reported to be associated with the thallus of *Anthoceros* (Bryophytes). Their association in the paddy fields of the tropics is well documented. The heterocystous cyanobacteria like *Anabaena, Nostoc* fix nitrogen symbiotically as well as asymbiotically in nature.
Nitrogen fixation is also found to be associated with grasses like *Paspalam notatum*. Symbiotic nitrogen fixation occurs in the nodules of leguminous plants. Best known example of this association is the (bacteria) *Rhizobium* legume association. *Rhizobium* is known to even form stem nodules where it is called as *Azorhizobium* and the plants are *Sesbania rostrata, and Aeshynomene*. *Rhizobium* is also reported to be associated with a non leguminous plant e.g. *Trema*.

*Actinomycetes (Frankia)* – are also known to form nodules in non-leguminous plants e.g. *Casuarina, Alnus* etc. This is known as actinorrhizal association. Lichens can also be accounted for nitrogen fixation. Here nitrogen is fixed by the algal partner called as phycobiont.

Mycorrhiza also help in nitrogen fixation as their spores are reported to harbour non-symbiotic nitrogen fixing bacteria. Nitrogen fixers are reported from the phylloplane (leaf surface) also apart from being associated in the rhizosphere (root region). Some bacteria are reported to form leaf nodules which are capable of nitrogen fixation in the members belonging to family Rubiaceae (*Psychotria*) and Myrsianaceae (*Ardisia*). These nodules are reported to harbour the bacteria *Klebsiella*.

The environment factors affecting biological nitrogen fixation (BNF) are temperature, water stress, water logging, salinity, pH, availability of nutrients like P, K, Mo, Fe Nitrogen fixation also depends on the organic content of the soil.

Fig. 19: Represents biological nitrogen fixation and the organisms involved in the process
Phosphorous Cycle

Phosphorous is one of the key elements of the biosphere. It is an essential component of the cell viz. DNA, RNA and also of those ATP and phospholipids. So, it is the requirement of all the living organisms irrespective of being micro-organisms or macro-organisms.

![Phosphorous Cycle Diagram](image)

Phosphorous reservoir are mostly in the form of rock deposits. It is not present in gaseous form in the biosphere. Thus it is a sedimentary biogeochemical cycle. Phosphorous is present in the environment as phosphates of Calcium and Iron which are usually insoluble. As a result Phosphorous is not available to the living organisms. The dead remains of the flora and fauna including microbes act as the source of phosphorous to the soil environment. In atmosphere phosphorous is present as phosphine which is a volatile gas and is toxic. This phosphine ignites with a greenish glow. Phosphine is formed as a result of the activity of the microbes when they use phosphate as a terminal electron acceptor. Phosphate which enters the aquatic ecosystem does not return back and becomes part of the marine sediment. As a result the marine environment becomes rich in phosphate.

Phosphorous precipitates at neutral and alkaline pH in the presence of bivalent metals like calcium or magnesium. Phosphorous is present in soil as insoluble salts of Iron, Magnesium, Aluminium. Plants and microbes assimilate organic phosphate from soluble inorganic phosphate. The phosphorus cycle has two main steps:

1. Dissolution of inorganic phosphorous and then its conversion to organic phosphate. This involves the process of solubilisation and mineralisation which is operated by the soil microbial population mostly belonging to the rhizosphere e.g. *Bacillus, Micrococcus, Pseudomonas*. Phosphorous converts into soluble form by chelation, iron reduction and acidification. Phosphorous that enters the cell needs to be mineralized to prevent its immobilization. Mineralisation occurs with the help of enzymes-phytases and phosphatases. Phosphorous mineralisation is mainly carried out by the microbial population present in the ecosystem.
Besides the bacterial population fungi are also involved in the solubilisation of phosphorous, for e.g. *Aspergillus*, *Penicillium*. If phosphate solubilising microbial population is present in that rhizosphere region then phosphate assimilation might increase in higher plants. VAM are reported to enhance the mobilization of soluble phosphorous. Phosphorous solubilisation is affected by a number of factors such as temperature, pH, aeration, carbon and nitrogen source etc.

Fig. 21: Phosphorous cycle as it occurs in environment

In marine environment the availability of phosphorous depends on the temperature of the surface water. The dissolved phosphorous present gets incorporated in the phytoplanktons. The phosphorous present deeper in the ocean is not available to the biotic component. When phosphorous is transported to the surface layer from sediments it becomes available to the biota.

Phosphorous is excreted out as a waste also in the form of urine and faecal matter. This phosphorous has to be recycled to make it available to the biotic community of the ecosystem which is done by the micro organisms.

**Sulphur Cycle**

It is another element of the sedimentary biogeochemical cycle. It is an essential nutrient component of the biotic community as a trace element. It is part of certain amino acids and proteins. Sulphur cycle is basically an oxidation reduction cycle. Fig. 22.

Soil is the largest reservoir of sulphur, others are oceans, swamps, marshes, volcanoes etc. Sulphur is present in three forms in the biosphere:
1. **Elemental Sulphur** – Which is available as sulphur deposits and sulphide ores.

2. **Inorganic Sulphur** – Which is available as sulphate in aerobic soil environment and as sulphide in anaerobic soil environment.

3. **Organic Sulphur** – Is present in the form of amino acids and plants/animal residues.

Sulphur is mineralized, assimilated, oxidized and reduced in the ecosystem by a variety of microbes. Mineralisation of sulphur involves the decomposition of organic sulphur compounds finally getting converted to simpler inorganic compounds. Sulphates are formed by mineralisation under aerobic condition while hydrogen sulphide and mercaptans are formed in anaerobic conditions (a process referred as desulphuration). Major decomposition product in marine environment is dimethylsulphide.

Sulphur is assimilated by the plants, algae and also most heterotrophic microbes of the ecosphere in the form of sulphate under aerobic atmosphere. Some anaerobes are capable of assimilating reduced sulphur as hydrogen sulphide under anaerobic conditions produced in low amounts.

The above two processes (mineralisation and assimilation) involves the oxidation and reduction of sulphur in the ecosystem.

The oxidation process supports the population of chemolithotrophs like *Beggiatoa, Thiothrix, Termothrix* (thermophile). Species of *Thiobacillus* (*T.thioparus* and *T.novellas*) are also involved. *Thiobacillus thiooxidans*, an acid tolerant, oxidizes elemental sulphur to sulphuric acid. The archaen genus *sulfolobus* inhabiting hot acidic environment oxidizes elemental sulphur. The oxidation of sulphur results in solubilisation and mobilization of phosphorous and mineral nutrients because of the production of mineral acids thus benefiting the microbial population and plants. Temperature conducive for sulphur oxidation ranges between 34-37ºC.

The reductive sulphur operates in the ecosystem with the help of anaerobic chemolithotrophic bacterial population; viz. *Desulfovibrion desulfuricans, desulfovibrio giga, desulfuromonas acetoxidans, Desulfohabacter curvatum* (Desulfo-refers to sulphur reducing organisms).
Microbes like *Thermoproteus* and *Pyrodictium* which have been isolated from hydrothermal vents showed capability of sulphur respiration with hydrogen gas. These organisms are extreme thermophiles and have the advantage of sulphur being present in molten state in the region of hydrothermal vents otherwise it is hydrophobic solid at room temperature.

The obligate anaerobic bacteria that carry out the dissimilatory sulphate reduction process are called as sulphate reducers or hydrogen sulfodogens (these reduce sulphate liberating sulphide) *Desulfovibrio, Desulfotomaculum*. Some others belonging to this category are *Desulfohaber, Desulfobulbus, Desulfococcus, Desulfosarcina*. Besides the above mentioned genera a few others reported to belong to this category are *Bacillus, Pseudomonas* (bacteria) and *Saccharomyces* (Yeast).

The sulphur reducing process could be assimilatory or dissimilatory. In assimilatory sulphur reduction hydrogen sulphide produced is immediately incorporated into organic compound by the organisms. On the contrary, in dissimilatory sulphur reduction hydrogen sulphide is released in the environment.

The hydrogen sulphide is toxic to aerobic population of any habitat as it reacts with the heavy metals of the cytochrome. Hydrogen sulphide is found to kill nematodes and other animals in water logged conditions.

Environment acts as a sink of volatile sulphur. Compounds like hydrogen sulphide, dimethyl sulphide and other volatile reduced sulphur compounds on reaching the atmosphere are subjected to oxidation and photo-oxidation, as a result they get converted to sulphate. *Thiobacilli* are capable of rapid oxidation of hydrogen sulphide and other reduced sulphur compounds to sulphate under aerobic soil conditions and sediments.

**Suggested Reading**

2. Coyne, Mark S. 2001 Indian Reprint, Soil Microbiology : An exploratory Approach, Delmerhompson Learning
4. [www.google.com](http://www.google.com)