B.Sc 1st Year
Subject: Environment & Water Management

Unit - III

Ecosystem: Concepts and Types

In nature several communities of organisms live together and interact with each other as well as with their physical environment as an ecological unit. We call it an **ecosystem**. The term 'ecosystem' was coined by A.G. Tansley in 1935. An ecosystem is a functional unit of nature encompassing complex interaction between its biotic (living) and abiotic (non-living) components. For example- a pond is a good example of ecosystem.

Components of an ecosystem

Components of ecosystem: They are broadly grouped into:-

(a) Abiotic and (b) Biotic components

Components of Ecosystem

- **Abiotic components**
  - **Physical factors**: Temperature, Humidity, Light, Atmospheric pressure
  - **Inorganic substances**: Water, Oxygen, Carbon dioxide, Nitrogen
  - **Organic substances**: Proteins, Carbohydrates, Lipids
- **Biotic components**
  - Producers (Green plants)
  - Consumers (Animals)
  - Decomposers (Microorganisms)

(a) Abiotic components (Nonliving): The abiotic component can be grouped into following three categories:-

(i) Physical factors: Sun light, temperature, rainfall, humidity and pressure. They sustain and limit the growth of organisms in an ecosystem.

(ii) Inorganic substances: Carbon dioxide, nitrogen, oxygen, phosphorus, sulphur, water, rock, soil and other minerals.

(iii) Organic compounds: Carbohydrates, proteins, lipids and humic substances. They are the building blocks of living systems and therefore, make a link between the biotic and abiotic components.

(b) Biotic components (Living)

(i) Producers: The green plants manufacture food for the entire ecosystem through the process of photosynthesis. Green plants are called autotrophs, as they absorb water and nutrients from the soil, carbon dioxide from the air, and capture solar energy for this process.

(ii) Consumers: They are called heterotrophs and they consume food synthesized by the autotrophs. Based on food preferences they can be grouped into three broad categories. **Herbivores** (e.g. cow, deer and rabbit etc.) feed directly on plants, **carnivores** are animals which eat other animals (eg. lion, cat, dog etc.) and **omnivores** organisms feeding upon both plants and animals e.g. human, pigs and sparrow.

(iii) Decomposers: Also called **saprotrophs.** These are mostly bacteria and fungi that feed on dead decomposed and the dead organic matter of plants and animals by secreting enzymes outside their body on the decaying matter. They play a very important role in recycling of nutrients. They are also called **detrivores or detritus feeders**.

Functions of ecosystem

Ecosystems are complex dynamic system. They perform certain functions. These are:-

(i) Energy flow through food chain

(ii) Nutrient cycling (biogeochemical cycles)

(iii) Ecological succession or ecosystem development

(iv) Homeostasis (or cybernetic) or feedback control mechanisms

Ponds, lakes, meadows, marshlands, grasslands, deserts and forests are examples of natural ecosystem. Many of you have seen an aquarium; a garden or a lawn etc. in your neighbourhood. These are manmade ecosystem.

5.1.3 Types of ecosystems

Ecosystems are classified as follows:

(i) Natural ecosystems (ii) Man made ecosystems

(i) Natural ecosystems

(a) Totally dependent on solar radiation e.g. forests, grasslands, oceans, lakes, rivers and deserts. They provide food, fuel, fodder and medicines.

(b) Ecosystems dependent on solar radiation and energy subsidies (alternative sources) such as wind, rain and tides. e.g tropical rain forests, tidal estuaries and coral reefs.

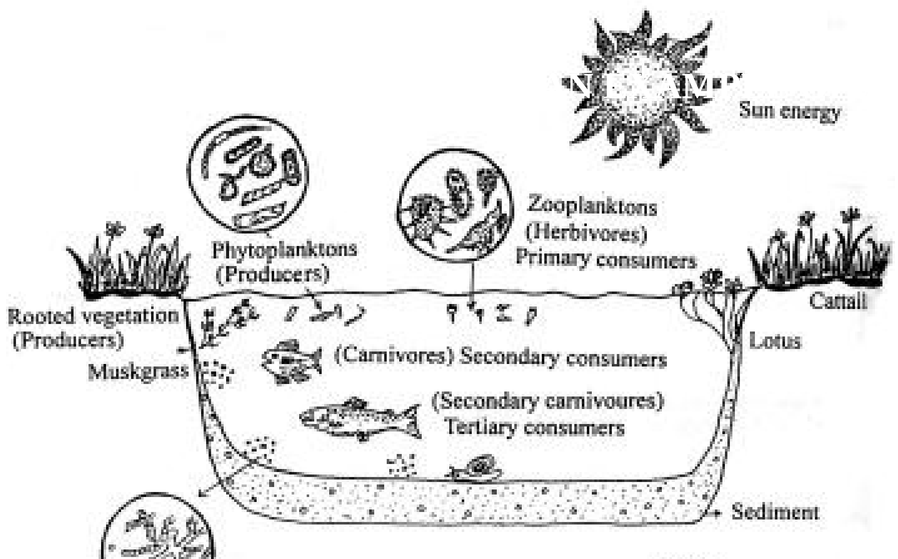
(ii) Man made ecosystems

(a) Dependent on solar energy-e.g. Agricultural fields and aquaculture ponds.

(b) Dependent on fossil fuel e.g. urban and industrial ecosystems.

Pond as an example of ecosystem

A pond is an example of a complete, closed and an independent ecosystem. It is convenient to study its basic structure and functions. It works on solar energy and maintains its biotic community in equilibrium. If you collect a glass full of pond water or a scoop full of pond bottom mud, it consists of a mixture of plants, animals, inorganic and organic materials. Following components are found in a pond ecosystem.



Bacteria and fungi (Reducers)

Fig. 3.1: *Pond ecosystem*

(a) Abiotic components

(i) **Light**: Solar radiation provides energy that controls the entire system. Penetration of light depends on transparency of water, amount of dissolved or suspended particles in water and the number of plankton. On the basis of extent of penetration of light a pond can be divided into **euphotic** (eu=true, photic=light), **mesospheric** and **aphotic** zones. Plenty of light is available to plants and animals in euphotic zone. No light is available in the aphotic zone.

(ii) **Inorganic substances**: These are water, carbon, nitrogen, phosphorus, calcium and a few other elements like sulphur depending on the location of the pond. The inorganic substances like O_2 and CO_2 are in dissolved state in water. All plants and animals depend on water for their food and exchange of gases- nitrogen, phosphorus, sulphur and other inorganic salts are held in reserve in bottom sediment and inside the living organisms. A very small fraction may be in the dissolved state.

(iii) **Organic compounds**: The commonly found organic matter in the pond are amino acids and humic acids and the breakdown products of dead animals and plants. They are partly dissolved in water and partly suspended in water.

(b) Biotic components

(i) **Producers or autotrophs:** synthesize food for all the heterotrophs of the pond. They can be categorized into two groups:-

(a) Floating microorganisms and plants

(b) Rooted plants

(a) Floating microorganisms (green) and plants are called **phytoplankton** ("phyto"- plants, "plankton" – floating). They are microscopic organisms. Sometimes they are so abundant in pond that they make it look green in colour e.g. *Spirogyra, Ulothrix, Cladophora,*
Diatoms, *Volvox.*

(b) Rooted plants: These are arranged in concentric zones from periphery to the deeper layers. Three distinct zones of aquatic plants can be seen with increasing deapth of water in the following order:

i) **Zone of emergent vegetation:** eg. *Typha*, Bulrushes and *Sagittaria*

ii) **Zone of rooted vegetation with floating leaves**. eg. *Nymphaea*

iii) **Zone of submergent vegetation:** eg. All pond weeds like *Hydrilla, Rupia*, musk grass etc.

(ii) **Consumers/Heterotrophs** are animals which feed directly or indirectly on autotrophs eg. Tadpole, snails, sunfish, bass etc.

Pond animals can be classified into the following groups

(a) **Zooplanktons** are floating animals. Cyclops, Cypris

(b) **Nektons** are the animals that can swim and navigate at will. Eg. fishes

(c) **Benthic animals** are the bottom dwellers: beetle, mites, mollusks and some crustaceans.

(iii) **Decomposers:** They are distributed throughout the entire in the whole pond but in the sediment most abundant. There are bacteria and fungi. (*Rhizopus, Penicillium, Curvularia ,Cladosporium)* found at the bottom of the pond.

Energy flow in an Ecosystem

Food chains and energy flow are the functional properties of ecosystems which make them dynamic. The biotic and abiotic components of an ecosystem are linked through them.

Food Chain

Transfer of food energy from green plants (producers) through a series of organisms with repeated eating and being eaten is called a food chain. e.g.

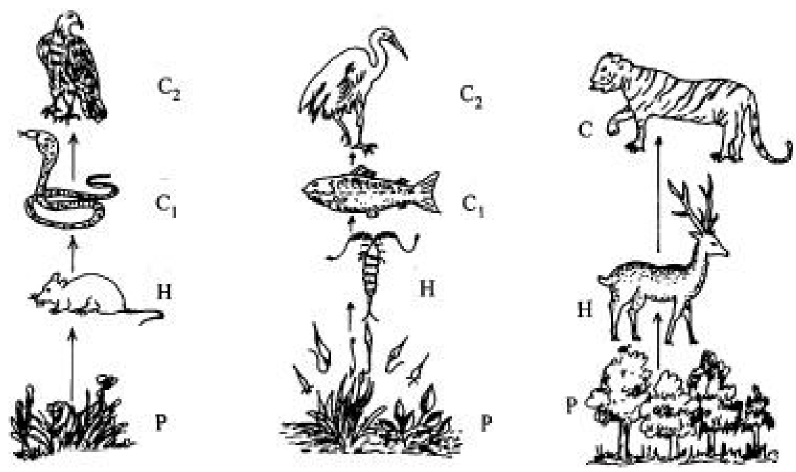
Grasses → Grasshopper → Frog → Snake → Hawk/Eagle

Each step in the food chain is called **trophic level**. In the above example grasses are 1^{st}, and eagle represents the 5^{th} trophic level.

Some more example of food chain are given in fig**.** 5.2.

During this process of transfer of energy some energy is lost into the system as heat energy and is not available to the next trophic level. Therefore, the number of steps are limited in a chain to 4 or 5. Following trophic levels can be identified in a food chain.

(1) **Autotrophs:** They are the producers of food for all other organisms of the ecosystem. They are largely green plants and convert inorganic material in the presence of solar energy by the process of photosynthesis into the chemical energy (food). The total rate at which the radiant energy is stored by the process of photosynthesis in the green plants is called **Gross Primary Production** (GPP). This is also known as total photosynthesis or total assimilation. From the gross primary productivity a part is utilized by the plants for its own metabolism. The remaining amount is stored by the plant as **Net Primary Production** (NPP) which is available to consumers.



P = Producer, H = Herbivore, C = Carnivore, C_1 = First level carnivore, C_2 = Top Carnivore

Fig. 5.2: *Some examples of food chain*

(2) **Herbivores:** The animals which eat the plants directly are called primary consumers or herbivores e.g. insects, birds, rodents and ruminants.

(3) **Carnivores:** They are secondary consumers if they feed on herbivores and tertiary consumers if they use carnivores as their food. e.g. frog, dog, cat and tiger.

(4) **Omnivores:** Animals that eat both plant and animals e.g. pig, bear and man

(5) **Decomposers:** They take care of the dead remains of organisms at each trophic level and help in recycling of the nutrients e.g. bacteria and fungi.

There are two types of food chains:

(i) **Grazing food chains:** which starts from the green plants that make food for herbivores and herbivores in turn for the carnivores.

(ii) **Detritus food chains:** start from the dead organic matter to the detrivore organisms which in turn make food for protozoan to carnivores etc.

In an ecosystem the two chains are interconnected and make y-shaped food chain. These two types of food chains are:-

(i) Producers → Herbivores → Carnivores

(ii) Producers → Detritus Feeders → Carnivores

Food web

Trophic levels in an ecosystem are not linear rather they are interconnected and make a food web. Thus food web is a network interconnected food chains existing in an ecosystem. One animal may be a member of several different food chains. Food webs are more realistic models of energy flow through an ecosystem (Fig. 5.3).

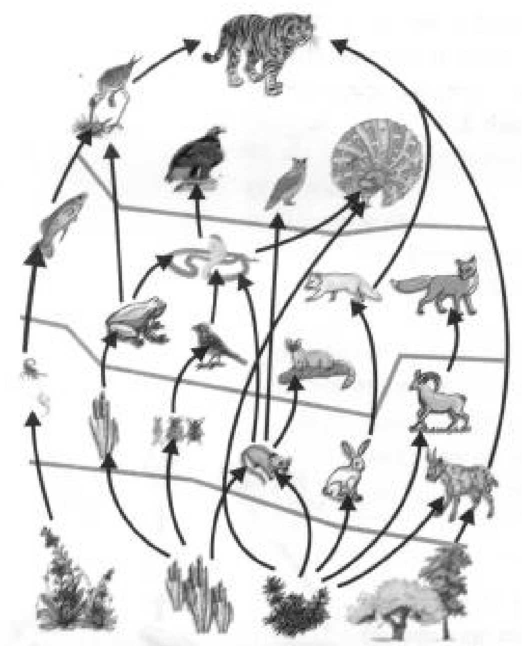
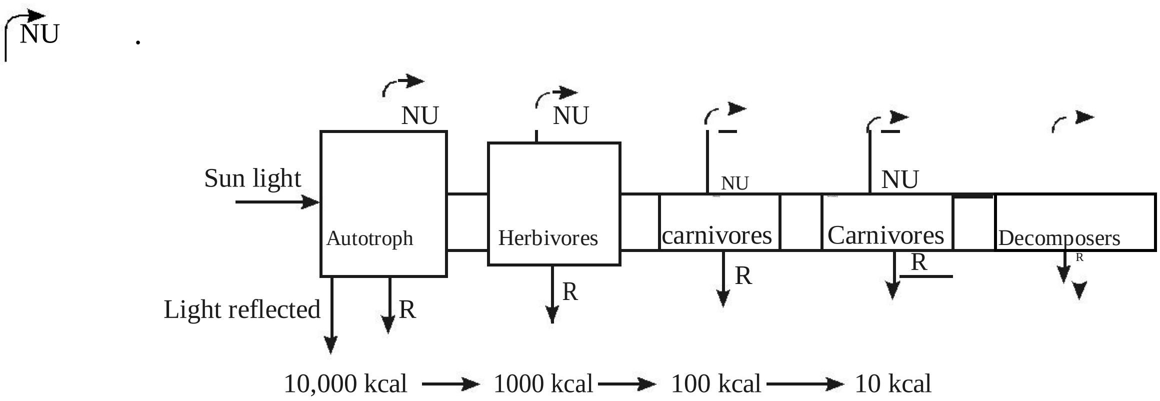


Fig. 5.3: *Simple food web*

The flow of energy in an ecosystem is always linear or one way. The quantity of energy flowing through the successive trophic levels decreases as shown by the reduced sizes of boxes in fig. 5.4. At every step in a food chain or web the energy received by the organism is used to sustain itself and the left over is passed on to the next trophic level.



NU = Not utilized R = Respiration

Fig. 5.4: *Model of energy flow through an ecosystem. Boxes indicate the standing crop biomass and pipes indicate the energy flowing. (NU = Not utilized, R = Respiration)*

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5.3.3 Ecological pyramid

Ecological pyramids are the graphic representations of trophic levels in an ecosystem. They are pyramidal in shape and they are of three types: The producers make the base of the pyramid and the subsequent tiers of the pyramid represent herbivore, carnivore and top carnivore levels.

i) **Pyramid of number:** This represents the number of organisms at each trophic level. For example in a grassland the number of grasses is more than the number of herbivores that feed on them and the number of herbivores is more than the number of carnivores. In some instances the pyramid of number may be inverted, i.e herbivores are more than primary producers as you may observe that many caterpillars and insects feed on a single tree. (see fig. 5.5a)

ii) **Pyramid of biomass:** This represents the total standing crop biomass at each trophic level. Standing crop biomass is the amount of the living matter at any given time. It is expressed as gin/unit area or kilo cal/unit area. In most of the terrestrial ecosystems the pyramid of biomass is upright. However, in case of aquatic ecosystems the pyramid of biomass may be inverted e.g. in a pond phytoplankton are the main producers, they have very shortlife cycles and a rapid turnover rate (i.e. they are rapidly replaced by new plants). Therefore, their total biomass at any given time is less than the biomass of herbivores supported by them. (see fig. 5.5b).

iii) **Pyramid of energy:** This pyramid represents the total amount of energy at each trophic level. Energy is expressed in terms of rate such as kcal/unit area /unit time or cal/unit area/unit time.eg. in a lake autotroph energy is 20810 kcal/in/year(see fig. 5.5c). Energy pyramids are never inverted.

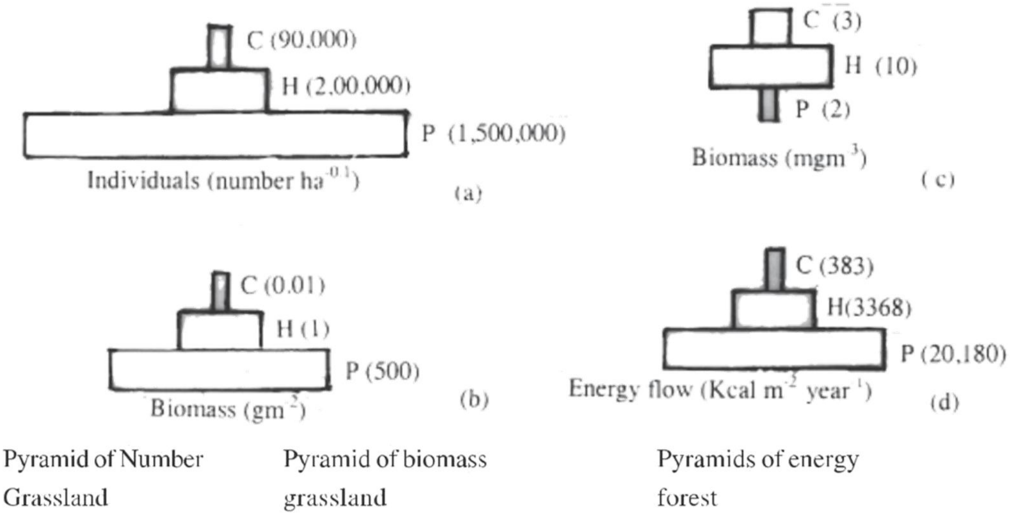

Fig. 5.5: Ecological pyramids

Note : P = Producer; C_1= herbivore; C_1= Carnivore ; C_2= Top carnivore

Significance of studying food chains

1) It helps in understanding the feeding relations and interactions among different organisms of an ecosystem.

2. It explain the flow of energy and circulation of materials in ecosystems.
3. It help in understanding the concept of biomagnification in ecosystems.

BIOGEOCHEMICAL CYCLES

In ecosystems flow of energy is linear but that of nutrients is cyclical. This is because energy flows down hill i.e. it is utilized or lost as heat as it flows forward The nutrients on the other hand cycle from dead remains of organisms released back into the soil by detrivores which are absorbed again i.e. nutrient absorbed from soil by the root of green plants are passed on to herbivores and then carnivores. The nutrients locked in the dead remains of organisms and released back into the soil by detrivores and decomposers. This recycling of the nutrients is called biogeochemical or nutrient cycle (Bio = living, geo = rock chemical = element). There are more than 40 elements required for the various life processes by plants and animals. The entire earth or biosphere is a closed system i.e. nutrients are neither imported nor exported from the biosphere.

There are two important components of a biogeochemical cycle

(1) **Reservoir pool** - atmosphere or rock, which stores large amounts of nutrients.

(2) **Cycling pool or compartments of cycle**-They are relatively short storages of carbon in the form of plants and animals.

5.5.1 **Carbon cycle**

The source of all carbon is carbon dioxide present in the atmosphere. It is highly soluble in water; therefore, oceans also contain large quantities of dissolved carbon dioxide.

The global carbon cycle consists of following steps-

• Photosynthesis

Green plants in the presence of sunlight utilize CO2 in the process of photosynthesis and convert the inorganic carbon into organic matter (food) and release oxygen. A part of the food made through photosynthesis is used by plants for their own metabolism and the rest is stored as their biomass which is available to various herbivores, heterotrophs, including human beings and microorganisms as food. Annually 4-9 x10 ^{13} kg of CO2 is fixed by green plants of the entire biosphere. Forests acts as reservoirs of CO2 as carbon fixed by the trees remain stored in them for long due to their long life cycles. A very large amount of CO_2 is released through forest fires.

Respiration

Respiration is carried out by all living organisms. It is a metabolic process where food is

Oxidized to liberate energy, CO2

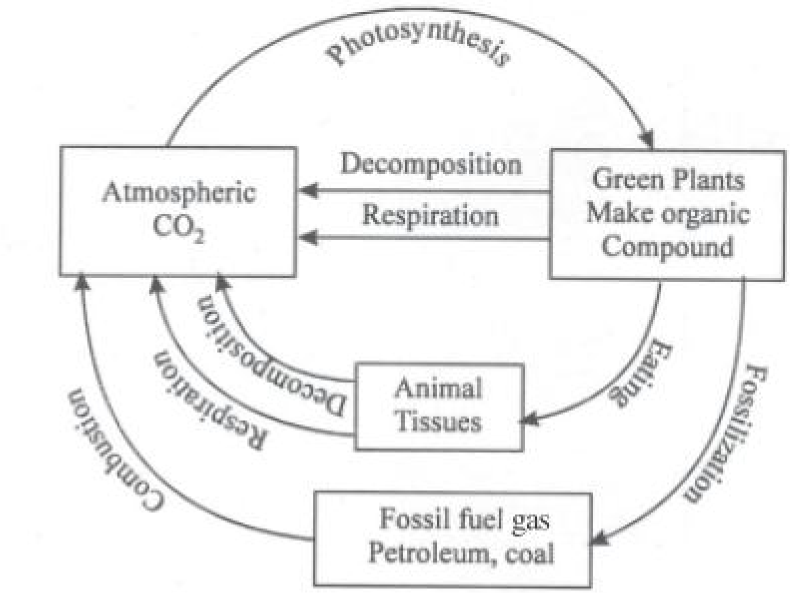

Fig. 5.6: Carbon cycle

and water. The energy released from respiration is used for carrying out life processes by living organism (plants, animals, decomposers etc.).

Thus CO2 is released into of the atmosphere through this process.

• Decomposition

All the food assimilated by animals or synthesized by plant is not metabolized by them completely. A major part is retained by them as their own biomass which becomes available to decomposers on their death. The dead organic matter is decomposed by microorganisms and CO2 is released into the atmosphere by decomposers.

• Combustion

Burning of biomass releases carbon dioxide into the atmosphere.

• Impact of human activities

The global carbon cycle has been increasingly disturbed by human activities particularly since the beginning of industrial era. Large scale deforestation and ever growing consumption of fossil fuels by growing numbers of industries, power plants and automobiles are primarily responsible for increasing emission of carbon dioxide.

Carbon dioxide has been continuously increasing in the atmosphere due to human activities such as industrialization, urbanization and increasing use and number of automobiles. This is leading to increase concentration of CO2 in the atmosphere, which is a major cause of global warming.

5.5.2 Nitrogen cycle

Nitrogen is an essential component of protein and required by all living organisms including human beings. Our atmosphere contains nearly 79% of nitrogen but it cannot be used directly by the majority of living organisms. Broadly like carbon dioxide, nitrogen also cycles from gaseous phase to solid phase then back to gaseous phase through the activity of a wide variety of organisms. Cycling of nitrogen is vitally important for all living organisms. There are five main processes which essential for nitrogen cycle are elaborated below.

(a) **Nitrogen fixation:** This process involves conversion of gaseous nitrogen into Ammonia, a form in which it can be used by plants. Atmospheric nitrogen can be fixed by the following three methods:-

(i) **Atmospheric fixation:** Lightening, combustion and volcanic activity help in the fixation of nitrogen.

(ii) **Industrial fixation:** At high temperature (400 ^{0}C) and high pressure (200 atm.), molecular nitrogen is broken into atomic nitrogen which then combines with hydrogen to form ammonia.

(iii) **Bacterial fixation:** There are two types of bacteria-

(i) Symbiotic bacteria e.g. Rhizobium in the root nodules of leguminous plants.

(ii) Freeliving or symbiotic e.g. 1. Nostoc 2. Azobacter 3. Cyanobacteria can combine atmospheric or dissolved nitrogen with hydrogen to form ammonia.

(b) **Nitrification:** It is a process by which ammonia is converted into nitrates or nitrites by Nitrosomonas and Nitrococcus bacteria respectively. Another soil bacteria Nitrobacter can covert nitrate into nitrite.

(c) **Assimilation:** In this process nitrogen fixed by plants is converted into organic molecules such as proteins, DNA, RNA etc. These molecules make the plant and animal tissue.

(d) **Ammonification:** Living organisms produce nitrogenous waste products such as urea and uric acid. These waste products as well as dead remains of organisms are converted back into inorganic ammonia by the bacteria. This process is called ammonification. Ammonifying bacteria help in this process.

(e) **Denitrification:** Conversion of nitrates back into gaseous nitrogen is called denitrification. Denitrifying bacteria live deep in soil near the water table as they like to live in oxygen free medium. Denitrification is reverse of nitrogen fixation.

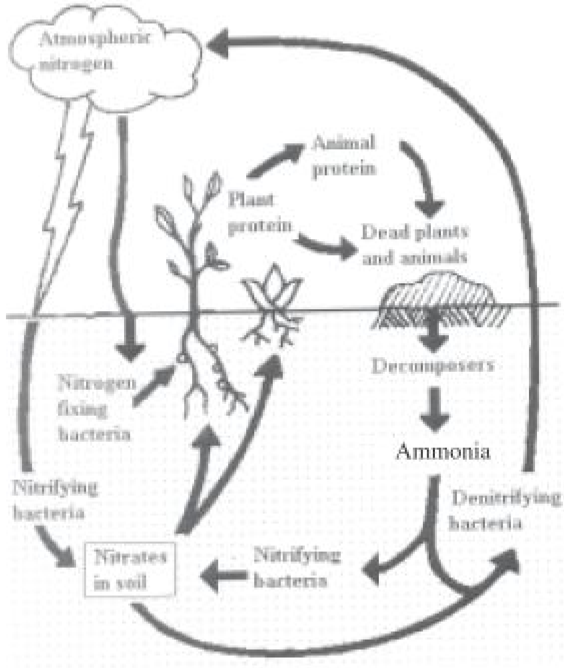

Fig. 5.7: *Nitrogen Cycle*

Phosphorus Cycle

Phosphorus is a major constituent of biological membranes, nucleic acids and cellular energy transfer systems. Many animals also need large quantities of this element to make shells, bones and teeth. The natural reservoir of phosphorus is rock, which contains phosphorus in the form of phosphates. When rocks are weathered, minute amounts of these phosphates dissolve in soil solution and are absorbed by the roots of the plants (Figure 14.7). Herbivores and other animals obtain this element from plants. The waste products and the dead organisms are decomposed by phosphate-solubilising bacteria releasing phosphorus. Unlike carbon cycle, there is no respiratory release of phosphorus into atmosphere. Can you differentiate between the carbon and the phosphorus cycle? The other two major and important differences between carbon and phosphorus cycle are firstly, atmospheric inputs of phosphorus through rainfall are much smaller than carbon inputs, and, secondly, gaseous exchanges of phosphorus between organism and environment are negligible.

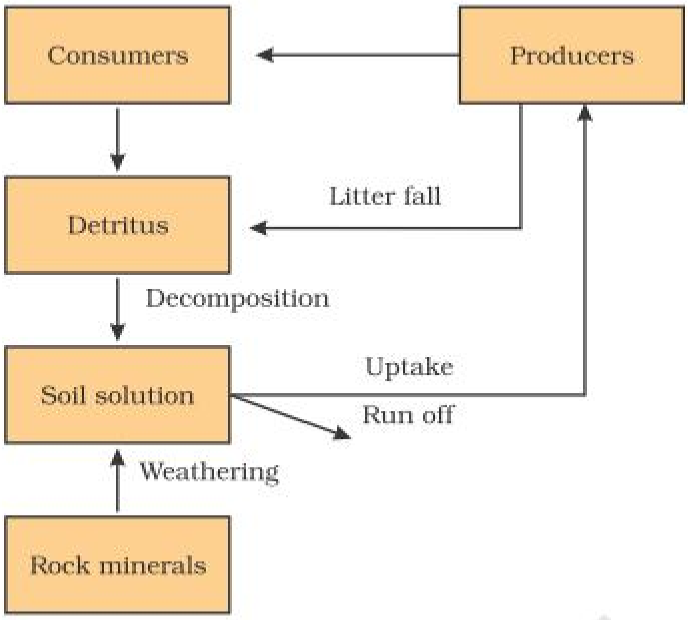

Figure 14.7 A simplified model of phosphorus cycling in a terrestrial ecosystem

Sulphur cycle

Organic sulfur compounds such as proteins in living organisms cycle with inorganic sulfate ions in soil or water. Most sulfur is bound up in rocks and salts or buried in deep ocean sediments. Decomposers break down organic sulfur compounds to gases such as hydrogen sulfide which enter the atmosphere and are oxidised to sulfur dioxide. Sulfur dioxide dissolves in water droplets in the atmosphere to give solutions of sulfurous acid, H2SO3. SO2(g) + H2O(l) ⇌ H2SO3(aq) Sulfurous acid is a weak acid and only partially ionises in water H2SO3(aq) ⇌ H + (aq) + HSO3 − (aq) Phosphorus compounds in plants Phosphorus compounds in consumers Phosphate in rocks and fossils Fertilisers Ocean sediments Phosphate in soil and water Mining Erosion and weathering Leaching, run-off and sedimentation Figure 1 The phosphorus cycle. Death and decay Feeding 2 This is oxidised in water droplets in clouds to form sulfuric acid, H2SO4. Sulfuric acid is washed into the soil by rain. Sulfate ions form which can be absorbed and utilised by plants. Sulfuric acid can also be formed from DMSP (dimethyl sulfonioproprionate) which is formed by plankton species and gives the seaside it characteristic smell. Photosynthetic sulfur bacteria are able to form free sulfur from hydrogen sulfide gas. Industrial processes, including burning fossil fuels and volcanoes liberate hydrogen sulfide and sulfur dioxide gases. Sulfate ions are easily leached out of the soil.

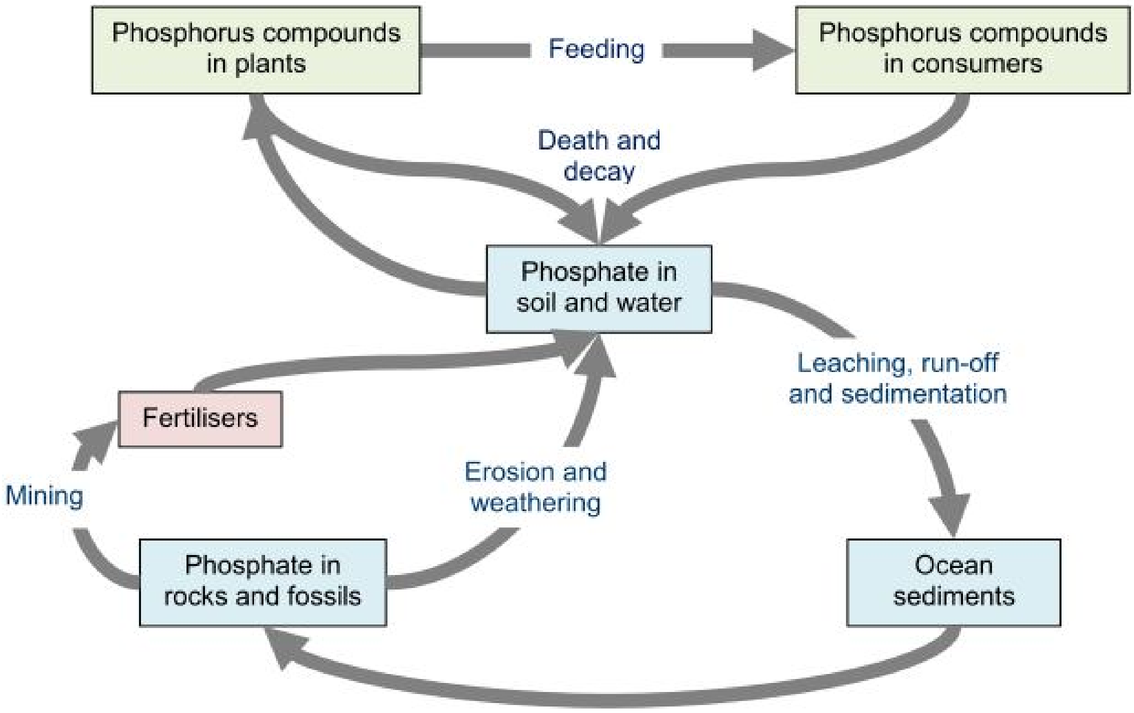

Figure 1 The phosphorus cycle.