UNIT

25

MAN AND HIS ENVIRONMENT

KEY CONCEPTS

Environment is defined as the surroundings in which the organism lives. The environment may be the physical environment, the chemical environment or the biological environment. Organisms are dependent on the environment to fulfill their needs; man is also constantly interacting with the environment in order to fulfill his needs. These needs include the basic needs of oxygen, food and shelter etc. The things that man requires for his survival and comfort are called the resources. The environment is a reservoir of resources. Maintaining the natural resources of the environment and their careful use is called conservation. The conservation of environment involves the conservation of the natural resources. A healthy environment is an absolute necessity for the well-being of all organisms, including man. All our needs, big and small are being met by the environment. However, man having reached the pinnacle of evolution is trying to bring about changes in the environment to suit his convenience. Unfortunately, this convenience is temporary. In the long run, man is losing out on a healthy environment.

25.1 BIOGEOCHEMICAL CYCLES

The flow of chemical elements and compounds between living organisms and the physical environment is called **biogeochemical cycle.** Chemicals absorbed or ingested by organisms are passed through the food chain and returned to the soil, air, and water by such mechanisms as respiration, excretion, and decomposition. As an element moves through this cycle, it often forms compounds with other elements as a result of metabolic processes in living tissues and of natural reactions in the atmosphere, hydrosphere, or lithosphere. Of the 92 elements produced in nature, only six are critical to the life of organisms: hydrogen, carbon, nitrogen, oxygen, phosphorus, and sulfur. Though these elements account for 95% of the mass of all living things, their importance extends far beyond the biosphere. Hydrogen and oxygen, chemically bonded in the form of water, are the focal point of the hydrosphere, while oxygen and nitrogen form the bulk of the atmosphere. All six are part of complex biogeochemical cycles in which they pass through the biosphere, atmosphere, hydrosphere, and aerosphere. These cycles circulate nutrients through the soil into plants, microbes, and animals, which return the elements to the earth system through chemical processes that range from respiration to decomposition.

25.1.1 Water Cycle

Water is an integral part of life on this planet. It is an odorless, tasteless, substance that covers more than three-fourths of the Earth's surface. Most of the water on Earth, 97% to be exact, is salt water found in the oceans. We can not drink salt water or use it for crops because of the salt content. We can remove salt from ocean water, but the process is very expensive. Only about 3% of Earth's water is fresh. Two percent of the Earth's water (about 66% of all fresh water) is in solid form, found in ice caps and glaciers. Because it is frozen and so far away, the fresh water in ice caps is not available for use by people or plants. That leaves about 1% of all the Earth's water in a form useable to humans and land animals. This fresh water is found in lakes, rivers, streams, ponds, and in the ground (a small amount of water is found as vapor in the atmosphere).

The hydrologic cycle begins with the evaporation of water from the surface of the ocean. As moist air is lifted, it cools and water vapour condenses to form clouds. Moisture is transported around the globe until it returns to the surface as precipitation. Once the water reaches the ground, one of two processes may occur; 1) some of the water may evaporate back into the atmosphere or 2) the water may penetrate the surface and become groundwater. Groundwater either seeps its way to into the oceans, rivers, and streams, or is released back into the atmosphere through transpiration.

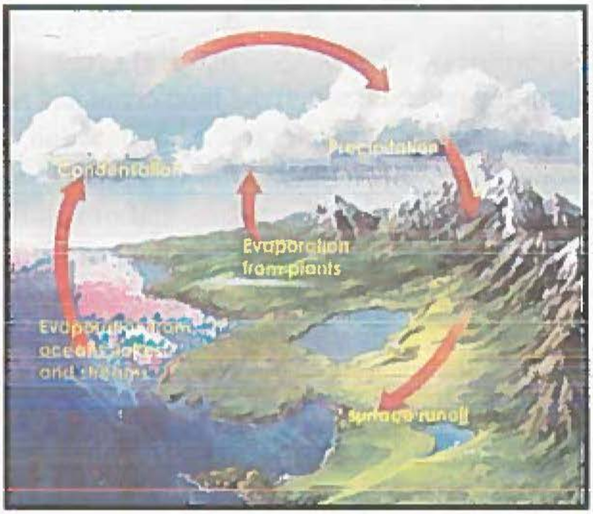

Fig: 25.1 Water Cycle in nature.

The balance of water that remains on the earth's surface is runoff, which empties into lakes, rivers and streams and is carried back to the oceans, where the cycle begins again.

25.1.2 The Nitrogen Cycle

Various processes are responsible for recycling the chemicals necessary for life on Earth. The nitrogen cycle is the most complex of these. Carbon, sulfur and phosphorus are the other main cycles. We are going to explore how nitrogen is cycled and the important role of microbes in this cycle.

Nitrogen:

Nitrogen is required by all living organisms for the synthesis of organic molecules such as amino acids, nucleic acids and proteins. The Earth's atmosphere contains almost 80 % nitrogen gas. It cannot be used in this form by most living organisms until it has been fixed, that is reduced (combined with hydrogen), to ammonia. Green plants, the main producers of organic matter, use this supply of fixed nitrogen to make proteins that enter and pass through the food chain. Micro-organisms (the decomposers) break down the proteins in excretions and dead organisms, releasing ammonium ions. These two processes form part of the nitrogen cycle.

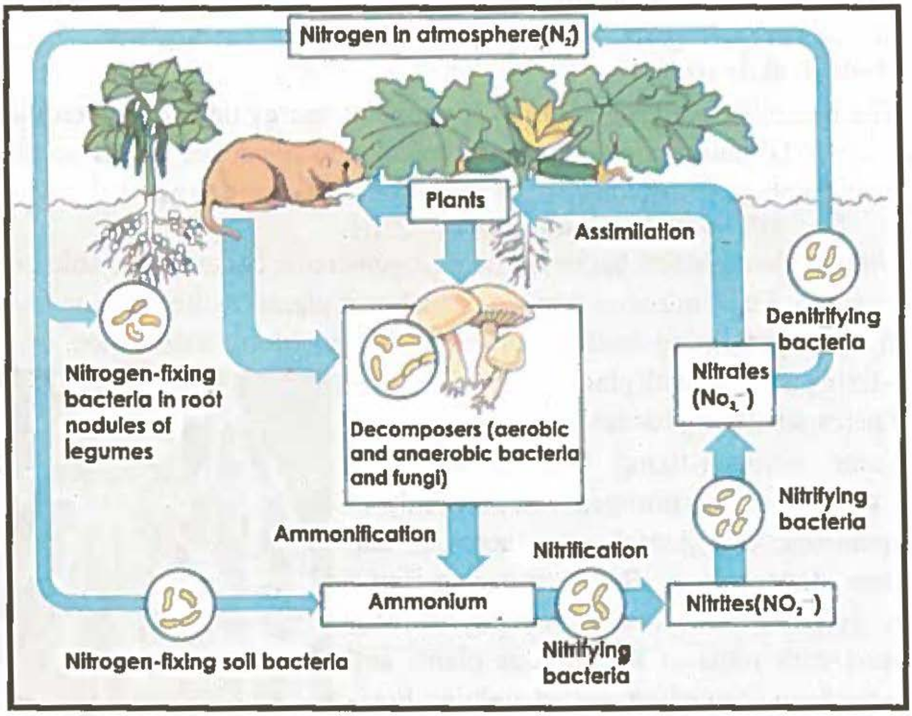

Fig: 25.2 Nitrogen cycle

The nitrogen cycle is the movement of nitrogen between the earth and the atmosphere. It consists of a series of processes that convert nitrogen gas to organic substances and these back to nitrogen in nature. It is a continuous cycle maintained by the decomposers and other bacteria. The nitrogen cycle can be broken down into four types of reaction and micro-organisms play roles in these entire.

i. Nitrogen fixation:

Nitrogen gas is composed of two atoms of nitrogen linked by a very strong triple bond. This makes it chemically non reactive and large amounts of energy are required to break the bond. Nitrogen gas can be fixed in three ways.

- **Atmospheric fixation:** This occurs spontaneously by lightning; a small amount (5–8 %) only is fixed this way. Lightning allows nitrogen and oxygen to combine to produce various oxides of nitrogen. These are carried by the rain into the soil where they can be used by plants.
- **Industrial fixation:** The Haber process is used to make nitrogen-containing fertilizers. This is a very energy inefficient process.
- **Biological fixation:** Nitrogen-fixing bacteria fix 60 % of nitrogen gas in the atmosphere.

ii. Biological fixation:

The reduction of nitrogen gas to ammonia is energy intensive. It requires 16 molecules of ATP and a complex set of enzymes to break the bonds so that the nitrogen can combine with hydrogen. Its reduction can be written as:

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

Only a relatively few bacteria (the nitrogen-fixing bacteria) are able to carry out this reaction. Fixed nitrogen is made available to plants by the death and lysis of free-living nitrogen-fixing bacteria or from the symbiotic association of some nitrogen-fixing bacteria with plants.

Types of nitrogen-fixing bacteria:

Some nitrogen-fixing bacteria are free-living in the soil, fixing nitrogen independently of other organisms, e.g. *Azotobacter* (aerobic) and *Clostridium* (anaerobic). Some nitrogen-fixing bacteria (e.g. *Rhizobium*) form symbiotic associations with roots of leguminous plants and appear in the form of swellings called nodules. Free-living rhizobia invade the legume through an infection thread formed in the root hair of the plant.

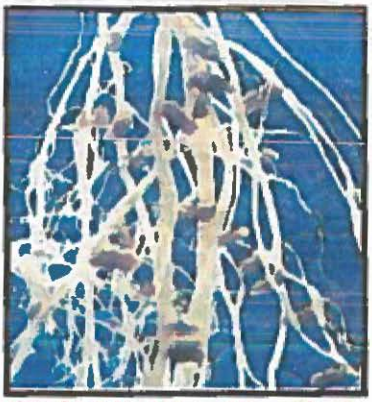

Fig: 25.3 Nodules of leguminous Plant.

The infection thread is constructed by the root cells and not the bacteria and is formed only in response to infection. The infection thread grows through the root hair cells and penetrates other root cells nearby, often with branching of the thread. The root cells then proliferate to form a root nodule. Within a week of infection small nodules are visible to the naked eye. Each root nodule is packed with thousands of living *Rhizobium* bacteria. Root-nodulated non-legume is a diverse group of woody species such as alder with e.g. Frankia. These filamentous bacteria infect the roots of plants forming actinorhizal root nodules.

Anabaena azollae is a cyanobacterium that infects new leaves of *Azolla* as they develop from the stem. Strings of *Anabaena* get caught in tiny leaf hairs that grow from a dimple on the developing leaf. The dimple grows larger into a pouch-like structure that eventually closes up, locking the *Anabaena* inside the leaf.

Fig: 25.4 *Anabaena azollae*

Adapting to their environment

Nitrogen-fixing bacteria contain an enzyme complex called nitrogenase which catalyses the conversion of nitrogen gas to ammonia. It supplies hydrogen as well as energy from ATP. The nitrogenase complex is sensitive to oxygen, becoming inactivated when exposed to it. This is not a problem with the free-living anaerobic bacteria such as Clostridium. Free-living aerobic bacteria have a variety of different mechanisms for protecting the nitrogenase complex, including high rates of metabolism and physical barriers. Azotobacter overcomes this problem by having the highest rate of respiration of any organism, thus maintaining a low level of oxygen in their cells.

For Your Information

Rhizobium contains leghaemoglobin. Leghaemoglobin functions similarly to hemoglobin, i.e. it binds to oxygen. This provides sufficient oxygen for the metabolic functions of the bacteroids, but prevents the accumulation of free oxygen that would destroy the activity of nitrogenase. Frankia and Anabaena are able to exclude oxygen by carrying out the fixation in specialized structures known respectively as a vesicle and a heterocyst. The thick walls of the vesicle and heterocyst form an oxygen diffusion barrier.

ii. Nitrification:

This is the oxidation of ammonium compounds to nitrites and then to nitrates by the nitrifying bacteria. During these oxidation reactions energy is released. The nitrifying bacteria are chemoautotrophs and are able to use this source of energy to produce organic compounds from inorganic ones. (Photoautotrophs use light energy to produce organic compounds from inorganic ones.) Nitrification is a two-step process:

- Bacteria of the genus *Nitrosomonas* convert ammonium ions to nitrites (NO_2^-). (Nitrite is toxic to plants and animals in high concentrations.)
- Bacteria of the genus *Nitrobacter* convert nitrites to nitrates (NO_3^-). The nitrates can then be taken in by plants.
- Nitrification occurs in well drained and aerated soils at neutral pH.

iii. Denitrification:

This is the conversion of nitrates into primarily nitrogen gas but also nitrous oxide gas by the denitrifying bacteria, e.g. Pseudomonas.

$$NO_3^- \longrightarrow N_2 + NO_2$$

Denitrifying bacteria transform nitrate in extremely wet soils and swampy grounds, where there is very little oxygen, i.e. the conditions are anaerobic.

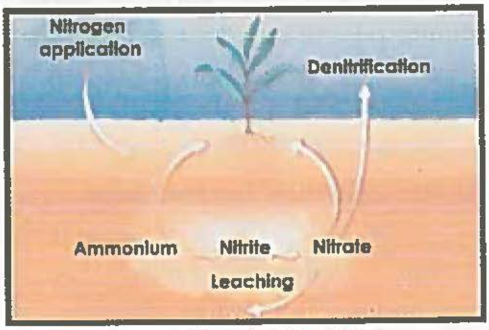

Fig: 25.5 Denitrification

The bacteria get the oxygen they need for respiration from the breakdown of nitrates. The gases that are formed escape into the atmosphere completing the nitrogen cycle. This can be a harmful process as fixed nitrogen is removed from the soil making it less fertile.

iv. Ammonification

This is the conversion of organic forms of nitrogen (e.g. in dead organisms and their excretions) into inorganic nitrogen. A wide range of soil fungi and bacteria called the decomposers carry out the ammonification process. The decomposers consume the organic matter and the nitrogen contained in the dead organism is converted to ammonium ions. The ammonium is then converted to nitrates by the nitrifying bacteria.

25.2 ENERGY FLOW THROUGH AN ECOSYSTEM

Ecosystems maintain themselves by cycling energy and nutrients obtained from external sources. At the first trophic level, primary producers (plants, algae, and some bacteria) use solar energy to produce organic plant material through photosynthesis. Herbivores—animals that feed solely on plants—make up the second trophic level. Predators that eat herbivores comprise the third trophic level; if larger predators are present, they represent still higher trophic levels. Organisms that feed at several trophic levels (for example, grizzly bears that eat berries and salmon) are classified at the highest of the trophic levels at which they feed. Decomposers, which include bacteria, fungi, molds, worms, and insects, break down wastes and dead organisms and return nutrients to the soil.

Decomposers process large amounts of organic material and return nutrients to the ecosystem in inorganic form, which is then taken up again by primary producers. Energy is not recycled during decomposition, but rather is released, mostly as heat.

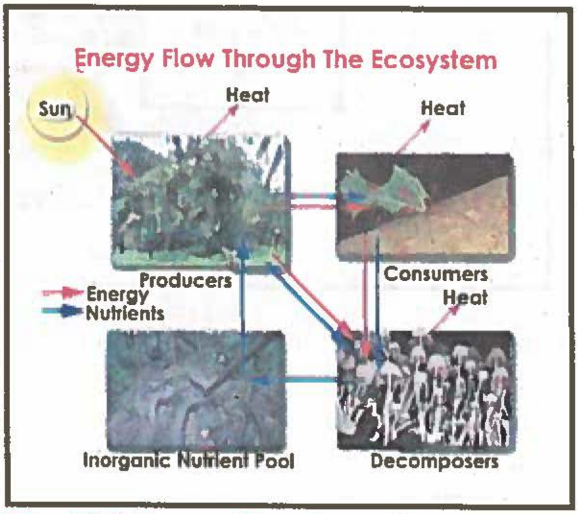

Fig: 25.6 Energy flow through ecosystem.

On average about 10 percent of net energy production at one trophic level is passed on to the next level. Processes that reduce the energy transferred between trophic levels include respiration, growth and reproduction, defecation, and nonpredatory death (organisms that die but are not eaten by consumers). The nutritional quality of material that is consumed also influences how efficiently energy is transferred, because consumers can convert high-quality food sources into new living tissue more efficiently than low-quality food sources.The low rate of energy transfer between trophic levels makes decomposers generally more important than producers in terms of energy flow.

25.2.1 Gross & Net primary productivity:

An ecosystem's gross primary productivity (GPP) is the total amount of organic matter that it produces through photosynthesis. **Net primary productivity**

(NPP) describes the amount of energy that remains available for plant growth after subtracting the fraction that plants use for respiration. Productivity in land ecosystems generally rises with temperature up to about 30°C, after which it declines, and is positively correlated with moisture. On land primary productivity thus is highest in warm, wet zones in the tropics where tropical forest biomes are located. In contrast, desert scrub ecosystems have the lowest productivity because their climates are extremely hot and dry.

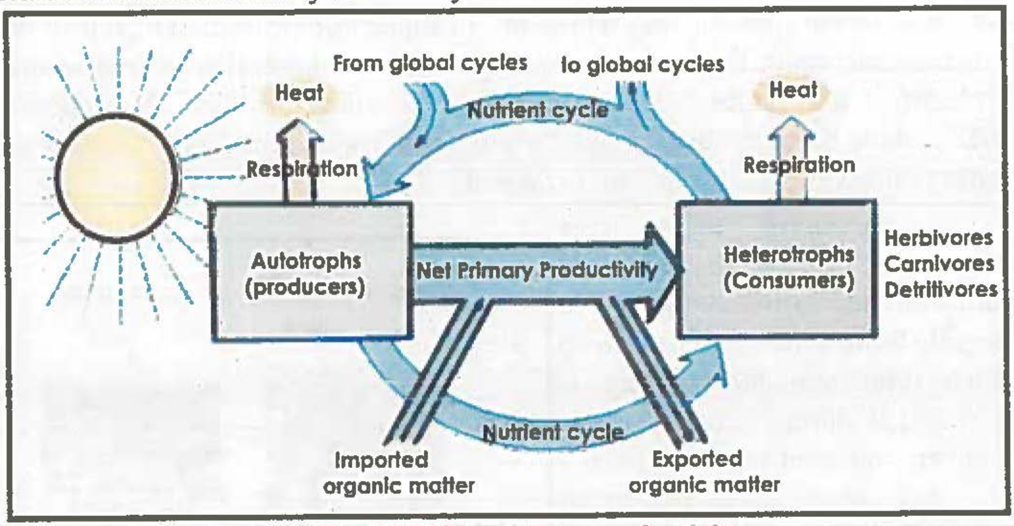

Fig: 25.7 Net primary productivity.

In the oceans, light and nutrients are important controlling factors for productivity. "Oceans," light penetrates only into the uppermost level of the oceans, so photosynthesis occurs in surface and near-surface waters. Marine primary productivity is high near coastlines and other areas where upwelling brings nutrients to the surface, promoting plankton blooms. Runoff from land is also a source of nutrients in estuaries and along the continental shelves. Among aquatic ecosystems, algal beds and coral reefs have the highest net primary production, while the lowest rates occur in the open due to a lack of nutrients in the illuminated surface layers.In contrast to land, where vascular plants carry out most primary production, most primary production in the oceans is done by microscopic algae.

25.2.2 Ecological pyramids:

An ecological pyramid is a graphical representation designed to show the number of organisms, energy relationships, and biomass of an ecosystem. They are also called Eltonian pyramids after Charles Elton, who developed the concept of ecological pyramids.

Producer organisms (usually green plants) form the base of the pyramid, with succeeding levels above representing the different trophic levels (respective position of the organisms within ecological food chains).

Succeeding levels in the pyramid represent the dependence of the organisms at a given level on the organisms at lower level. There are three types of pyramids: of numbers, of biomass, and of energy.

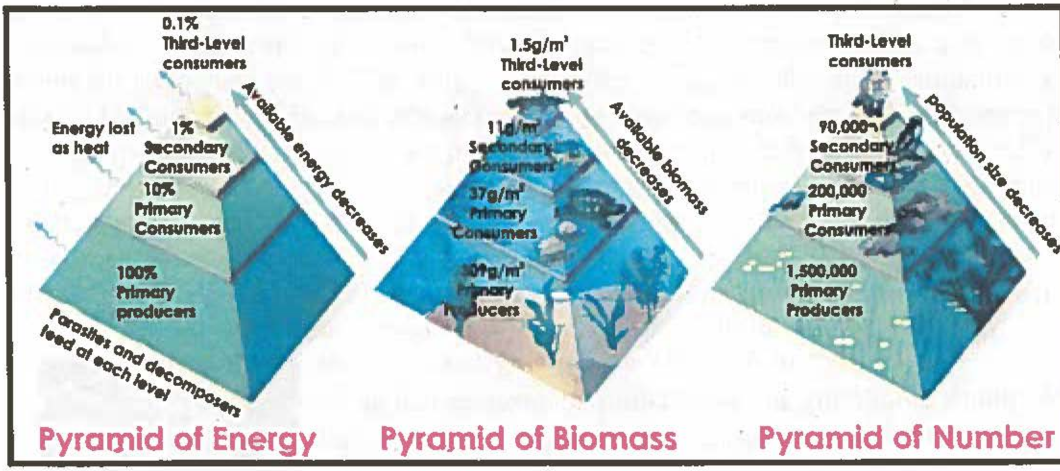

Fig: 25.8 Ecological Pyramids

Pyramid of Biomass:

Biomass is renewable organic (living) material. A pyramid of biomass is a representation of the amount of energy contained in biomass, at different trophic levels for a particular time. It is measured in grams per meter^2 or calories per meter^2. This demonstrates the amount of matter lost between trophic levels. Each level is dependent on its lower level for energy; hence the lower level determines how much energy will be available to the upper level. Also, energy is lost in transfer so the amount of energy is less high up the pyramid.

Pyramid of Numbers:

The pyramid of numbers represents the number of organisms in each trophic level. This pyramid consists of a plot of relationships between the number herbivores (primary consumers), first level carnivore (secondary consumers), second level carnivore (tertiary consumers) and so forth. This shape varies from ecosystem to ecosystem because the number of organisms at each level is variable

Pyramid of Energy:

The pyramid of energy represents the total amount of energy consumed by each trophic level. An energy pyramid is always upright as the total amount of energy available for utilization in the layers above is less than the energy available in the lower levels. This happens because during energy transfer from lower to higher levels, some energy is always lost.

25.3 ECOLOGICAL SUCCESSION

Succession is a directional, non-seasonal cumulative change in the types of plant species that occupy a given area through time. It involves the processes of colonization, establishment, and extinction which act on the participating plant species. Most successions contain a number of stages that can be recognized by the collection of species that dominate at that point in the succession. Succession begins when an area is made partially or completely devoid of vegetation because of a disturbance. Some common mechanisms of disturbance are fires, wind storms, volcanic eruptions, logging, climate change, severe flooding, disease, and pest infestation. Succession stops when species composition changes no longer occur with time, and this community is said to be a climax community.

The concept of a climax community assumes that the plants colonizing and establishing themselves in a given region can achieve stable equilibrium. The idea that succession ends in the development of a climax community has had a long history in the fields of biogeography and ecology. One of the earliest proponents of this idea was Frederic Clements who studied succession at the beginning of the 20th century.


Fig: 25.9 lichens on a rock

25.3.1 Types of Succession:

On the basis of origin, ecological succession may be of following two types

- **Primary succession** – It is the establishment of plants on land that has not been previously vegetated. It begins with colonization and establishment of pioneer species.
- **Secondary succession** – It is the invasion of a habitat by plants on land that was previously vegetated. Removal of past vegetation may be caused by natural or human disturbances such as fire, logging, cultivation, or hurricanes.

Whereas on the basis of location, ecological succession may be xerarch or hydrarch:

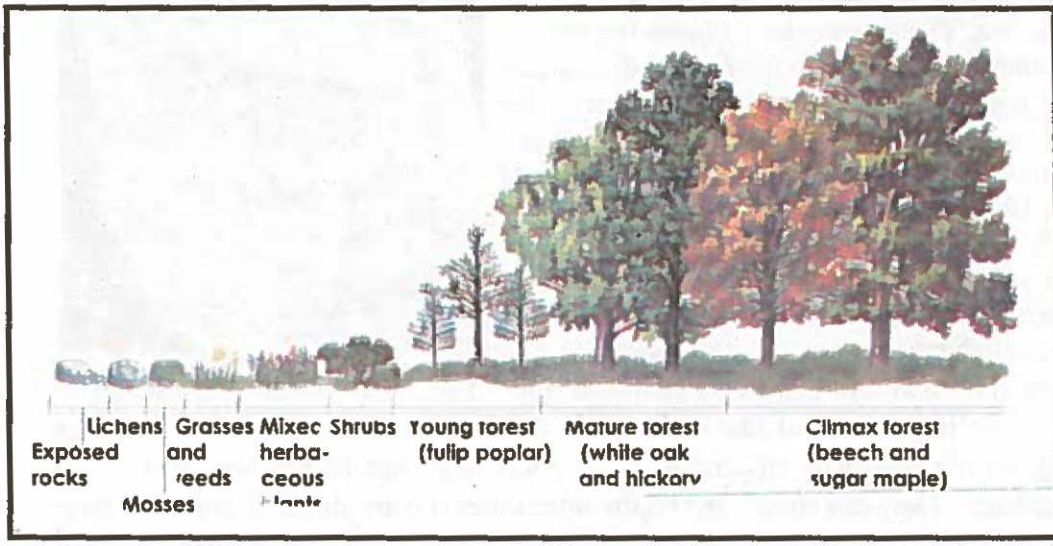

Fig: 25.10 Ecological succession

Xerarch Succession:

Plant succession starting on bare ground or rock and culminating in a mature climax forest is called xerarch succession. The pioneer species, such as lichens and mosses, result in the gradual accumulation of soil.

The lichen colonies on these boulders are the first step in xerarch succession. Along with mosses, they trap dust particles and form a layer of soil on the rock surface that allows other plants, such as grasses and herbs, to become established.

Hydrarch:

Plant succession starting on relatively shallow water, such as ponds and lakes, and culminating in a mature forest is termed as hydrarch.

25.3.2 Xerosere

The term xerosere refers to changes in community structure during xerarch succession. It includes the different stages in a xerarch succession of ecological communities originated in extremely dry conditions such as sand deserts, sand dunes, salt deserts, rock deserts etc. A xerosere may include lithoseres on rocks and psammoseres on sand. Following are the stages of lithosere:

Stage 1: Crustose Lichen Stage:

A bare rock consists of solid surface or very large boulders and there is no place for rooting plants to colonize. The crustose lichens can adhere to the surface of rock and absorb moisture from atmosphere.

Therefore these colonize the bare surfaces of rock fast. The propagules of these lichens are brought by the air from the surrounding areas. These lichens produce acids which corrode the rock and their thalli collect windblown soil particles among them that help in formation of thin film of soil. When these lichens die their thalli decomposed to humus. This promotes soil building and the cnvironment becomes suitable for growth of foliose and fruiticose type of lichens.

Fig: 25.11 Crustose Lichen Stage.

Stage 2: Foliose and Fruiticose Lichen Stage:

Foliose have leaf like thalli while the fruiticose lichens are small bushes. They are attached by the substratum at one point only. Therefore do not cover the soil completely. They can absorb and retain more water and are able to accumulate more dust particles. Their dead remains are decomposed to humus which mixes with soil particles and help building substratum and improving the soil moisture contents further. The shallow depreciation in the rocks and crevices become filled with sold and top soil layers increase further. These autogenic changes favor growth and establishment of mosses. This community includes Parmelia and Dermatocarpon etc which have large leaf like thalli.

Stage 3: Moss Stage

The spores of xerophytic mosses are brought to the rock where they succeed lichens. Their rhizoids penetrate soil among the crevices, secretes acids and corrode the rock. The bodies of mosses are rich in organic and inorganic compounds. When they die they add these compounds to the soil to increase the fertility of the soil. Since mosses develop in patches they catch soil particles from air and help increasing substratum. The changing environment leads to migration of lichens and help invasion of herbaceous vegetation.

Stage 4: Herb Stage:

Herbaceous weeds mostly annuals such as asters and evening primroses invade the rock. Their roots penetrate deep down, secrete acids and enhance the process of weathering. Leaf litter and death herbs add humus to the soil. Shading of soil results in decrease in evaporation and there is slight increase in temperature. As a result the xeric conditions begin to change and biennial and perennials herbs and xeric grasses begin to inhabit. These climatic conditions favor growth of bacterial and fungal populations resulting in increase in decomposition activity.

Stage 5: Shrub Stage:

Fig: 25.12 *Rhus typhina*

Herb and grass mixture is invaded by shrub species such as Rhus and others. Early invasion of shrub species is slow but once a few bushes have become established birds invade this area and help dispersal of shrub seeds. This results in dense shrub growth shading the soil and making conditions unfavorable for the growth of herbs which begin to migrate. The soil formation continues and its moisture contents enhance. The environment becomes mesic or moderately moist.

Stage 6: Tree Stage:

Changes in environment favor colonization of tree species. The tree saplings begin to grow among the shrubs and establish themselves. The kind of tree species inhabiting this area depends upon the nature of the soil. In poorly drained soils oaks establish themselves. The trees form canopy and shade the area. Shade loving shrubs continue to grow as secondary vegetation. Leaf litter and decaying roots weather the soil further and add humus to it making the habitat more favorable for growth of trees. Mosses and ferns make their appearance and fungi population grows abundantly.

Stage 7: Forest or Climax Stage:

The succession culminates in a climax community, the forest. Many intermediate tree stages develop prior to establishment of a climax community. The forest type depends upon climatic conditions.

25.4 POPULATION DYNAMICS

Population dynamics is the branch of life sciences that studies short-term and long-term changes in the size and age composition of populations, and the biological and environmental processes influencing those changes. Population dynamics deals with the way populations are affected by birth and death rates, and by immigration and emigration, and studies topics such as aging populations or population decline.

25.4.1 Characteristics of Population:

A population ecologist studies the interaction of organisms with their environments by measuring properties of populations rather than the behavior of individual organisms. Properties of populations include;

- Population size
- Population density
- Patterns of dispersion

- Demographics
- Population growth Limits on population growth

Population size:

A population's size depends on how the population is defined;

- If a population is defined in terms of some degree of reproductive isolation, then that population's size is the size of its gene pool.
- If a population is defined in terms of some geographical range, then that population's size is the number of individuals living in the defined area.

Ecologists typically are more concerned with the latter means of defining a population since this is both easier to do and is a more practical measure if one is interested in determining the impact of a given population on a given ecosystem, or vice versa. Although we can determine an average population size for many species, the average is often of less interest than the year-to-year or place-to-place trend in numbers.

Population density:

Population density may be defined as number of individual organism per unit area. Different species, of course, exist at different densities in their environments, and the same species may be able to achieve one density in one environment and another in a different environment. Population densities may additionally be determined in terms of some measure other than population size per unit area such as population mass per unit area.

Population Distribution:

Individual members of populations may be distributed over a geographical area in a number of different ways including

- Clumped distribution (attraction)
- Uniform distribution (repulsion)
- Random distribution (minimal interaction/influence)

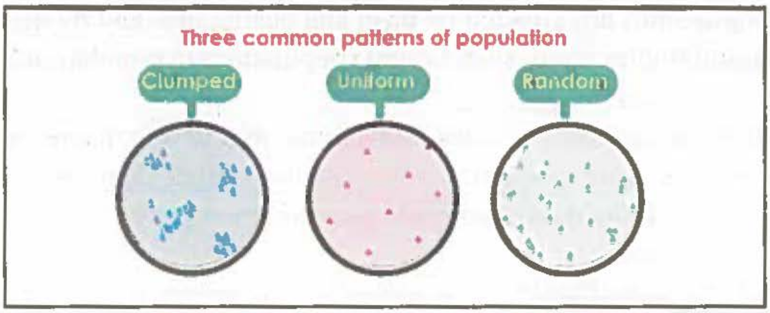

Fig: 25.13 Dispersion Patterns within Population.

Clumping may result either from individual organisms being attracted to each other, or individual organisms being attracted more to some patches within a range than they are to other patches; the net effect is that some parts of the range will have a large number of individuals whereas others will contain few or none.

Fig: 25.14 Clumping bamboo

A uniform distribution means that approximately the same distance may be found between individual organisms; uniform distributions result from individual organisms actively repelling each other.

A random distribution means that where individual organisms are found is only minimally influenced by interactions with other members of the same population, and random distributions are uncommon; "Random spacing occurs in the absence of strong attractions or repulsions among individuals of a population."

Population Growth:

The simplest case of population growth is that which occurs when there are no limitations on growth within the environment. In such situations two things occur;

1. The population displays its intrinsic rate of increase
2. The population experiences exponential growth

Intrinsic rate of population increase (rmax):

The intrinsic rate of population increase is the rate of growth of a population when that population is growing under ideal conditions and without limits, i.e., as fast as it possibly can.

A population with a higher intrinsic rate of increase will grow faster than one with a lower rate of increase. The value of rmax for a population is influenced by life history features, such as age at the beginning of reproduction, the number of young produced, and how well the young survive.

Exponential growth

Exponential growth simply means that a population's size at a given time is equal to the population's size at an earlier time, times some greater-than-one number

For example, if a population increased in size per unit time in the following manner: 1, 2, 4, 8, 16, 32, 64, 128, etc. (or, e.g., 1, 3, 9, 27, or 1, 5, 25, 125, etc.) then the population is displaying exponential growth, each unit time the population is increasing by a factor of 2 (or 3 or 5 in the other examples; note that exponential growth is occurring so long as the rate of increase per unit time is greater than a factor of 1, e.g., 2 or 4 or 10 or 1.2, etc.)

Limits on population growth:

Exponential growth cannot go on forever; sooner or later any population will run into limits in their environment.

25.4.2 Carrying capacity (K): Populations subsist on a finite amount of available resources, and as the population becomes more crowded, each individual has access to an increasingly smaller share. Ultimately, there is a limit to the number of individuals that can occupy a habitat. Ecologists define carrying capacity as the maximum stable population size that a particular environment can support over a relatively long period of time. Carrying capacity, symbolized as K, is a property of the environment, and it varies over space and time with the abundance of limiting resources. Generally, as population size approaches carrying capacity, the amount of some key resource declines per capita to the point where individuals experience either a higher death rate or a lower fecundity; thus, as population size approaches carrying capacity, the rate of population growth declines towards zero.

25.4.3 Problems Related to Rapid Growth in Human Population:

As the world population continues to grow geometrically, great pressure is being placed on arable land, water, energy, and biological resources to provide an adequate supply of food while maintaining the integrity of our ecosystem. According to the World Bank and the United Nations, from 1 to 2 billion humans are now malnourished, indicating a combination of insufficient food, low incomes, and inadequate distribution of food. This is the largest number of hungry humans ever recorded in history.

In China about 80 million are now malnourished and hungry. Based on current rates of increase, the world population is projected to double from roughly 6 billion to more than 12 billion in less than 50 years.

Fig: 25.15 Malnutrition leads to millions of death each year.

More than 99 per cent of the world's food supply comes from the land, while less than 1 per cent is from oceans and other aquatic habitats. The continued production of an adequate food supply is directly dependent on ample fertile land, fresh water, energy, plus the maintenance of biodiversity. As the human population grows, the requirements for these resources also grow. Even if these resources are never depleted, on a per capita basis they will decline significantly because they must be divided among more people.At present, fertile crop land is being lost at an alarming rate. For instance, nearly one-third of the world's cropland (1.5 billion hectares) has been abandoned during the past 40 years because erosion has made it unproductive. Solving erosion