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Environmental Biology
(B.Sc.- Zoology Sem. - V)

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Unit I

(Concept of Ecology)

Introduction

Ecology is a branch of biology concerning interactions among organisms and their biophysical environment, which includes both biotic and abiotic components. The word "ecology" was coined in 1866 by the German scientist Ernst Haeckel. Ancient Greek philosophers such as Hippocrates and Aristotle laid the foundations of ecology in their studies on natural history. Modern ecology became a much more rigorous science in the late 19th century.

Abiotic factors

Abiotic factors refer to non-living physical and chemical elements in the ecosystem. The term “abiotic” comes from the root parts “a-” meaning “without,” and “bio,” meaning “life.” These components may differ from region to region, from ecosystem to ecosystem. They are mainly the life supporters. They determine and restrict the population growth, number, and diversity of biotic factors living in that ecosystem. Hence, they are called limiting factors.

Abiotic resources are usually obtained from the lithosphere, atmosphere, and hydrosphere.

Common examples of abiotic factors include:

- Wind
- Rain
- Humidity
- Latitude
- Temperature
- Elevation
- Soil composition
- Salinity (the concentration of salt in water)
- Radiation

- Pollution
- Minerals

Biotic factors

Biotic factors are living or once-living organisms in the ecosystem. These are obtained from the biosphere and are capable of reproduction. Examples of biotic factors are animals, birds, plants, fungi, and other similar organisms.

Biotic factors are grouped by scientists into three major groups, which define their role in the flow of energy which all living things in the ecosystem need to survive. These groups are-

- Producers or autotrophs
- Consumers or heterotrophs
- Decomposers or detritivores.

Producers

Producers – also known as autotrophs, from the Greek words "auto" for "self" and "troph" for "food" – are organisms that make their own food using inorganic materials and energy sources.

Producers are extremely important: without them, no life could exist at all!

The very first life forms on Earth had to learn to make fuel and building materials to make more cells out of non-living materials. That's because when the first life forms appeared, there were no other life forms to feed on! So, the first life forms had to be producers. Producers remain vital today as the life forms that can harness inorganic energy to be used as fuel for life.

There are two major classes of producers:

1. Photoautotrophs are by far the most common type of producer on Earth today. These producers harness energy from sunlight to power their life functions. Green plants, green algae, and some bacteria are photoautotrophs.

Most photoautotrophs use a pigment, such as chlorophyll, to catch photons from the Sun and harvest their energy. They then package that energy into a form that all life

forms can use, and use it to create proteins, sugars, lipids, and more essential materials for life.

In most ecosystems, plants – which are producers that are multicellular, highly complex, and very efficient at turning sunlight into fuel for living organisms – form the bottom of the energy pyramid. All other organisms depend on the energy plants harvest from the Sun to survive.

2. Chemoautotrophs are fairly rare in most ecosystems. They obtain energy from chemicals such as hydrogen, iron, and sulphur, which are not common in most environments. Nonetheless, they can still play an important role in ecosystems because of their unusual biochemistry.

Some methanogens – microorganisms that make methane – are chemoautotrophs. Methane, a greenhouse gas which is much more powerful than carbon dioxide, may play a major role in regulating the planet's temperature. Other chemoautotrophs can produce similarly powerful chemicals with their unique metabolisms.

It is actually not known whether the first forms of life on Earth were photoautotrophs or chemoautotrophs. Photoautotrophs are more common today, but that may simply be because sunlight is more plentiful than the chemicals chemoautotrophs use as their energy source.

Consumers

Consumers, also called "heterotrophs," are organisms that eat other living organisms in order to obtain energy. Their name comes from the Greek "hetero" for "other" and "troph" for "food."

Herbivores who eat plants, carnivores who eat animals, and omnivores who eat both plants and animals, are all heterotrophs.

Heterotrophy probably evolved when some organisms discovered that they could eat autotrophs as a source of energy, instead of creating their own energy and organic materials.

Some autotrophs subsequently evolved symbiotic relationships with consumers, such as angiosperms – plants which produce nectars and fruits to attract animals, who ultimately help them to reproduce.

Most levels of most ecosystems' energy pyramids consist of consumers – herbivores, minor predators, and top predators who eat other organisms.

Decomposers

Decomposers, or detritovores, are organisms that use organic compounds from producers and consumers as their source of energy. They are important to ecosystems because they break down materials from other living things into simpler forms, which can then be used again by other organisms.

Decomposers include soil bacteria, fungi, worms, flies, and other organisms that break down dead materials or waste products from other life forms. They are distinct from consumers, because consumers usually consume other organisms while they are still alive.

Decomposers, on the other hand, metabolize waste products that might not be of interest to consumers, such as rotting fruit and dead animals. In the process they break down these dead things into simpler chemicals that can be used by heterotrophs to thrive and produce more energy for the ecosystem as a whole.

This is the principle behind the practice of composting – where waste scraps of plants and animal products are put into a pile, where decomposers such as bacteria, worms, and flies are allowed to thrive. These decomposers turn the waste products into rich fertilizer for the composter's garden, which then grows bigger and healthier thanks to the decomposers breaking down the waste products in the compost.

Decomposers are the link between the bottom of an ecosystem's energy pyramid and the other levels. Decomposers can take energy and raw materials from dead plants, herbivores, lesser carnivores, and even top carnivores, and break it down into a form that can be used by the ecosystem's producers to make it easier for them to harness sunlight. In this way, the ecosystem's energy cycle is preserved.

Energy Flow

The chemical energy of food is the main source of energy required by all living organisms. This energy is transmitted to different trophic levels along the food chain. This energy flow is based on two different laws of thermodynamics:

- First law of thermodynamics, that states that energy can neither be created nor destroyed, it can only change from one form to another.
- Second law of thermodynamics, that states that as energy is transferred more and more of it is wasted.

The energy flow in the ecosystem is one of the major factors that support the survival of such a great number of organisms. For almost all organisms on earth, the primary source of energy is solar energy. It is amusing to find that we receive less than 50 per cent of the sun's effective radiation on earth. When we say effective radiation, we mean the radiation which can be used by plants to carry out photosynthesis.

The energy flow takes place via food chain and food web. During the process of energy flow in the ecosystem, plants being the producers absorb sunlight with the help of the chloroplasts and a part of it is transformed into chemical energy n in the process of photosynthesis.

This energy is stored in various organic products in the plants and passed on to the primary consumers in the food chain when the herbivores consume (primary consumers) the plants as food and convert chemical energy accumulated in plant products into kinetic energy, degradation of energy will occur through its conversion into heat.

Then followed by the secondary consumers. When these herbivores are consumed by carnivores of the first order (secondary consumers) further degradation will occur. Finally, when tertiary consumers consume the carnivores, again energy will be degraded. Thus, the energy flow is unidirectional in nature.

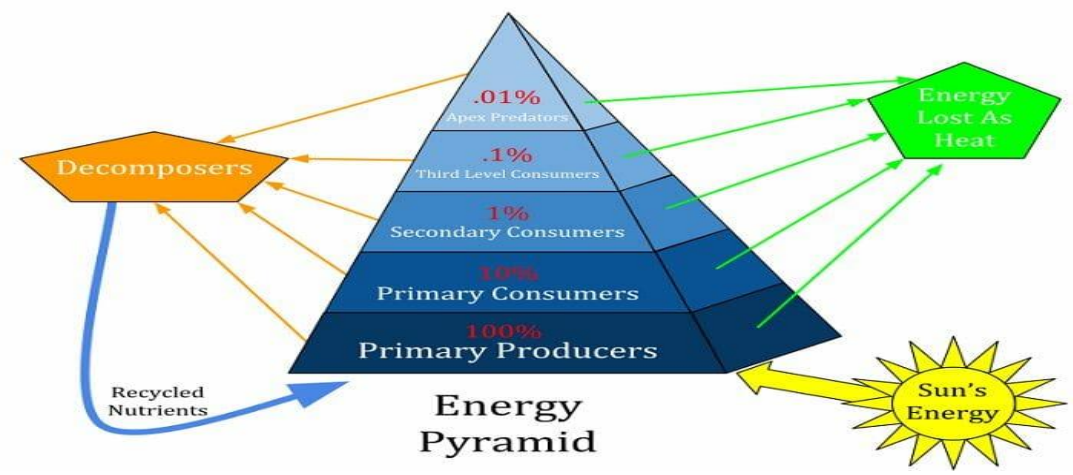
Moreover, in a food chain, the energy flow follows the 10 percent law. According to this law, only 10 percent of energy is transferred from one trophic level to the

other; rest is lost into the atmosphere. This is clearly explained in the following figure and is represented as an energy pyramid.

Trophic level

A trophic level is the group of organisms within an *ecosystem* which occupy the same level in a *food chain*. The producers and consumers in the ecosystem can be arranged into different feeding groups and are known as trophic level or the feeding level.

1. The producers (plants) represent the first trophic level.
2. Herbivores (primary consumers) present the second trophic level.
3. Primary carnivores (secondary consumers) represent the third trophic level
4. Top carnivores (tertiary consumers) represent the last level.



What is the 10 percent law of energy flow?

The 10 percent law of energy flow states that when the energy is passed on from one trophic level to another, only 10 percent of the energy is passed on to the next trophic level.

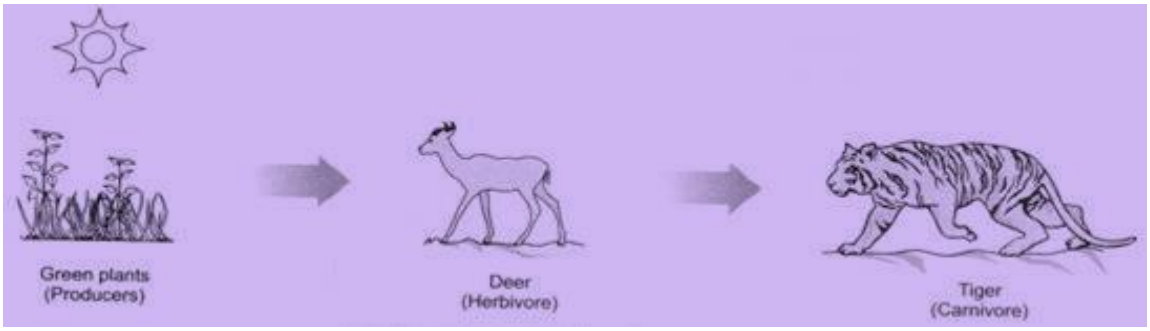
Even though primary consumers feed on producers, they are still getting their energy from the sun. The primary consumers feed on plants and break down the food particles to release the energy.

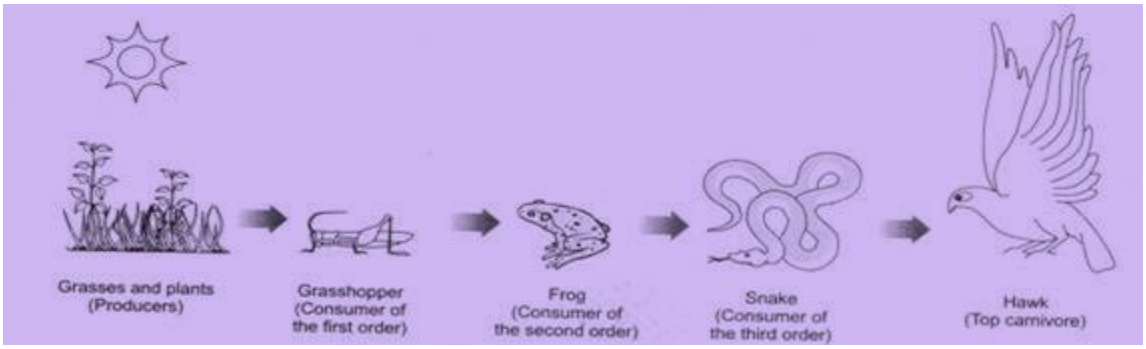
Primary consumers do not get 100% of the sun's energy from the producers or the plants on which they feed. This is because only some amount of the sun's energy is utilised by the plant to synthesise their food.

In fact, they only get 10% of the energy. This is termed as the 10% Rule, which states that only 10 per cent of the energy available gets passed onto the next level of consumers.

Food Chain

A food chain in an ecosystem is a series of organisms in which each organism feeds on the one below it in the series. There are basically different types of food chains in the ecosystem, namely –





- **Grazing food chain (GFC)** – This is the normal food chain that we observe in which plants are the producers and the energy flows from the producers to the herbivores (primary consumers), then to carnivores (secondary consumers) and so on.
- **Saprophytic or Detritus food chain (DFC)** – In this type of food chain, the dead organic matter occupies the lowermost level of the food chain, followed by the decomposers and so on.

- **Parasitic food chain (PFC) –** In this type of food chain, large organisms either the producer or the consumer is exploited and therefore the food passes to the smaller organism.

Some common food chains are mentioned below:

- Plants → Deer → Lion
- Plants → Worm→ Bird → Cat
- Plants→ Grasshopper→ Frog→ Snake→ Hawk
- Algae→ Small→ animal → Small fish → Big fish —> Bird

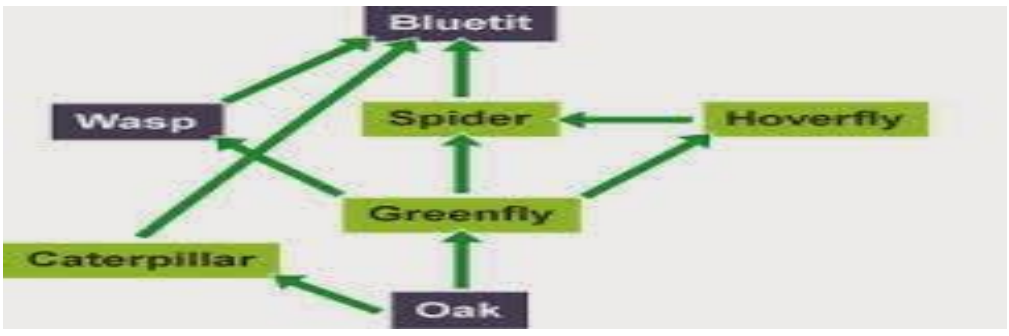
In nature, we mostly observe food web as there are many organisms which are omnivores. As a result, they occupy multiple trophic levels.

Food web

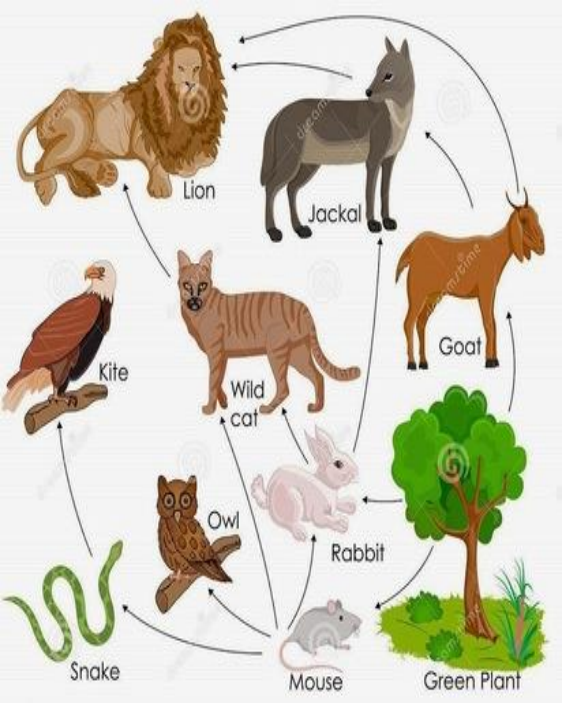
A **food web** (or **food** cycle) is the natural interconnection of **food chains** and a graphical representation (usually an image) of what-eats-what in an ecological community. It **is** a network of interconnected food chains showing the energy flow through part of an ecosystem.

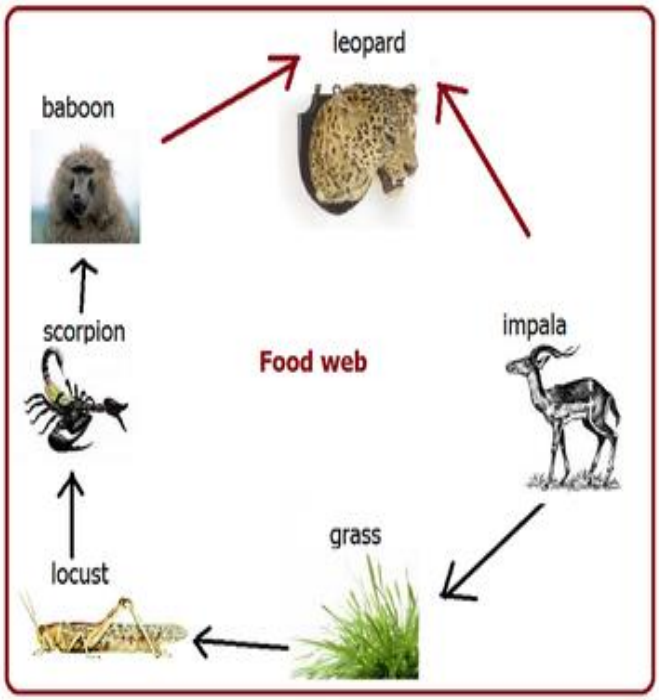
Food webs are easily **unbalanced**, especially if one population of organisms in the web dies or disappears. This may happen for a number of reasons, including:

- over–predation or hunting
- disease
- pollution
- use of pesticides
- lack of food (or other resources)
- emigration.



These are a more accurate way of showing feeding relationships than food chains, because most animals have more than one food source. For example, in the food webs in figure below, the leopard feeds on baboons and impala.





The leopard can be placed at 2 different trophic levels:

- secondary consumer (feeding on impala)
- quaternary or fourth level consumer (feeding on baboons).

For example, in the food web here, if all the baboons were killed by hunters the leopard would have only impala to eat. So, the impala population would decrease. The scorpion population may increase because of less predation by baboons, but if there are more scorpions, they will eat more locusts, reducing the locust population, and so on.

The four characteristics of a food web are as follows:

1.They are formed by interlinking of food chains.

2. They help in the development of the ecosystem.

3. Food webs are never straight.

4. Food web provides alternative Pathways of food availability. For example, if a particular species of producer is destroyed by a disease in an ecosystem the herbivores of that area can feed on other species of producers.

Biogeochemical Cycles

The term bio-geochemical is derived from **"bio"** meaning **biosphere**, **"geo"** meaning the **geological components** and "**chemical**" meaning the **elements that move through a cycle**. The matter on Earth is conserved and present in the form of atoms. Since matter can neither be created nor destroyed, it is recycled in the earth's system in various forms.

The earth obtains energy from the sun which is radiated back as heat, rest all other elements are present in a closed system. The major elements include:

- Carbon
- Hydrogen
- Nitrogen
- Oxygen
- Phosphorus
- Sulphur

These elements are recycled through the biotic and abiotic components of the ecosystem. The atmosphere, hydrosphere and lithosphere are the abiotic components of the ecosystem.

Types of Biogeochemical Cycles

Biogeochemical cycles are basically divided into two types:

- **Gaseous cycles** – Includes Carbon, Oxygen, Nitrogen, and the Water cycle.
- **Sedimentary cycles** – Includes Sulphur, Phosphorus, Rock cycle, etc.

Water Cycle

The water from the different water bodies evaporates, cools, condenses and falls back to the earth as rain.

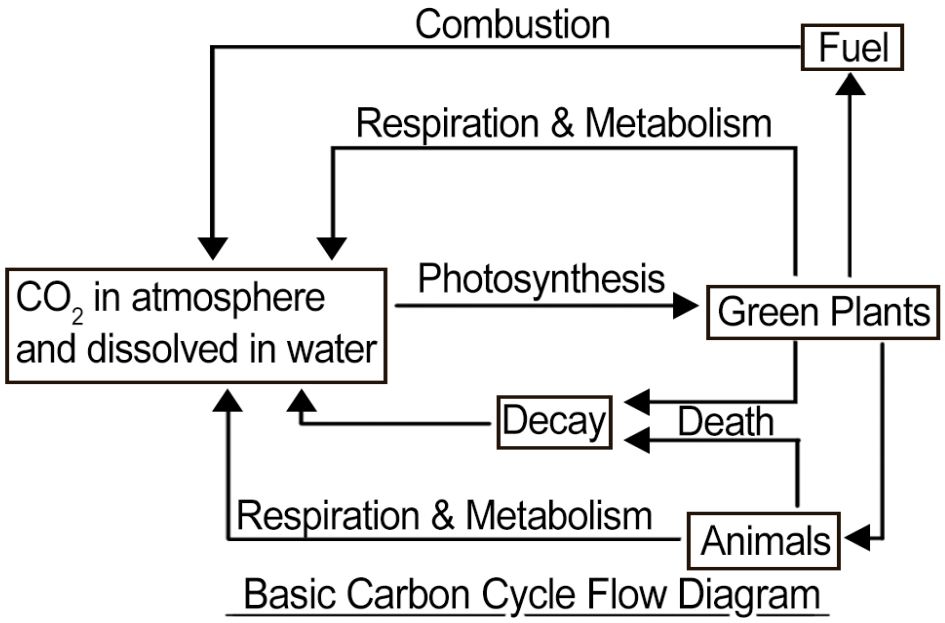
This biogeochemical cycle is responsible for maintaining weather conditions. The water in its various forms interacts with the surroundings and changes the temperature and pressure of the atmosphere.

There's another process called Evapotranspiration (i.e. vapour produced from leaves) which aids this process. It is the evaporation of water from the leaves, soil and water bodies to the atmosphere which again condenses and falls as rain.

Carbon Cycle

It is one of the biogeochemical cycles in which carbon is exchanged among the biosphere, geosphere, hydrosphere, atmosphere and pedosphere.

All green plants use carbon dioxide and sunlight for photosynthesis. Carbon is thus stored in the plant. The green plants, when dead, are buried into the soil that gets converted into fossil fuels made from carbon. These fossil fuels when burnt, release carbon dioxide into the atmosphere.



Basic Carbon Cycle Flow Diagram

Also, the animals that consume plants, obtain the carbon stored in the plants. This carbon is returned to the atmosphere when these animals decompose after death. The carbon also returns to the environment through cellular respiration by animals.

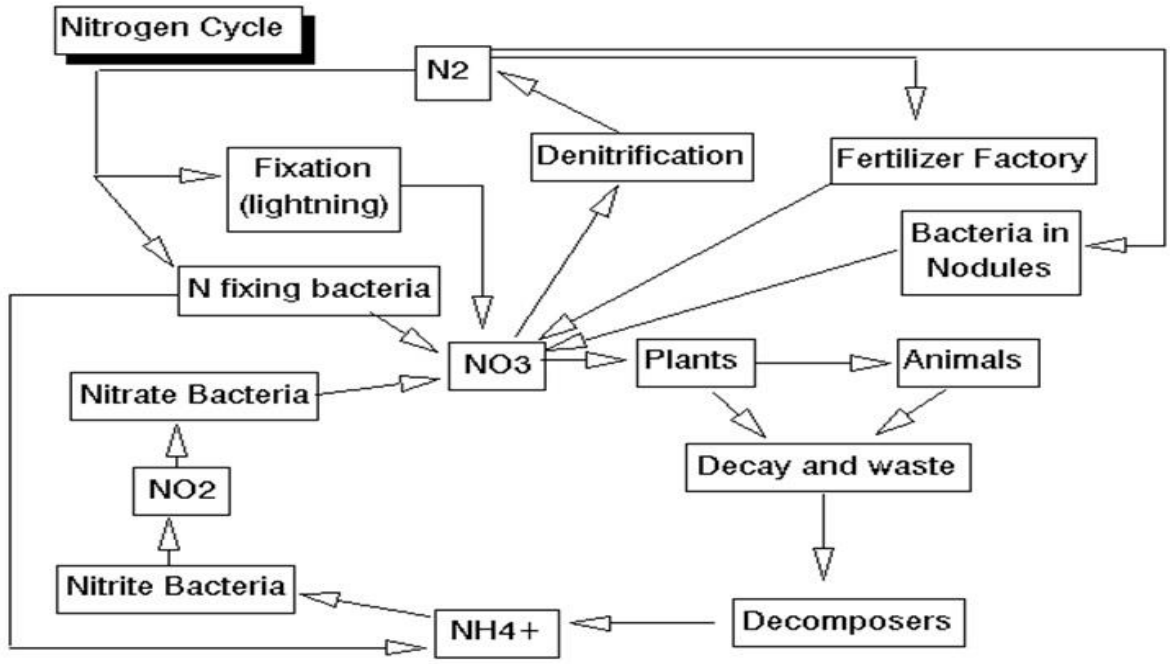
Huge carbon content in the form of carbon dioxide is produced that is stored in the form of fossil fuel (coal & oil) and can be extracted for various commercial and non-

commercial purposes. When factories use these fuels, the carbon is again released back in the atmosphere during combustion.

Nitrogen Cycle

It is the biogeochemical cycle by which nitrogen is converted into several forms as it circulates through the atmosphere, terrestrial and marine ecosystems.

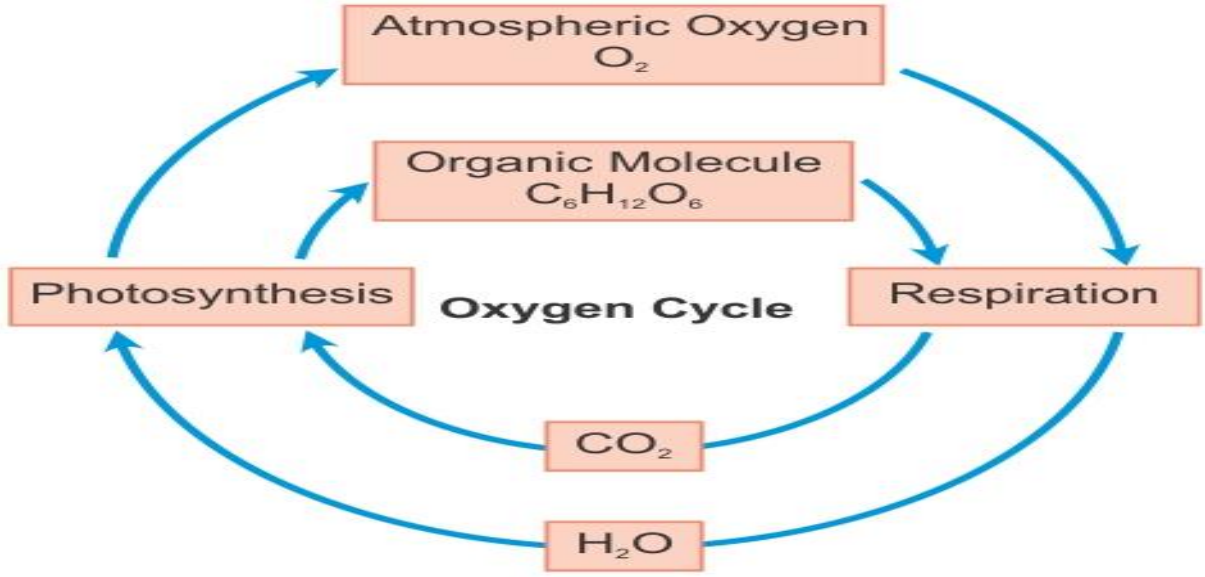
Nitrogen is an essential element of life. The nitrogen in the atmosphere is fixed by the nitrogen-fixing bacteria present in the root nodules of the leguminous plants and made available to the soil and plants.



The bacteria present in the roots of the plants convert this nitrogen gas into a usable compound called ammonia. Ammonia is also supplied to plants in the form of fertilizers. This ammonia is converted into nitrites and nitrates. The denitrifying bacteria reduce the nitrates into nitrogen and return it into the atmosphere.

Oxygen Cycle

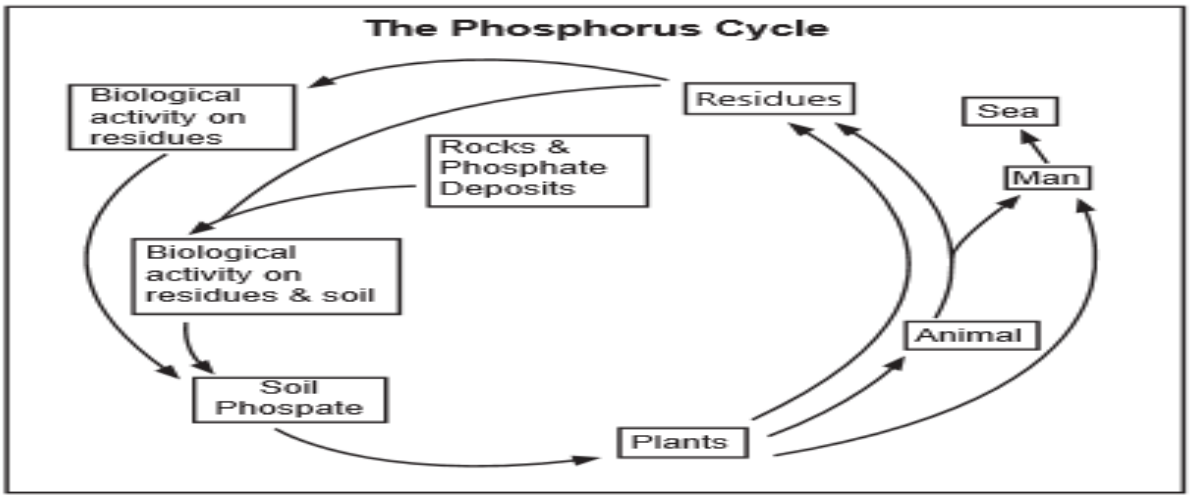
This biogeochemical cycle moves through the atmosphere, the lithosphere and the biosphere. Oxygen is a very abundant element on our Earth. It is found in the elemental form in the Atmosphere to the extent of 21%.



Oxygen is released by the plants during photosynthesis. Humans and other animals inhale the oxygen exhale carbon dioxide which is again taken in by the plants. They utilise this carbon dioxide in photosynthesis to produce oxygen, and the cycle continues.

Phosphorous Cycle

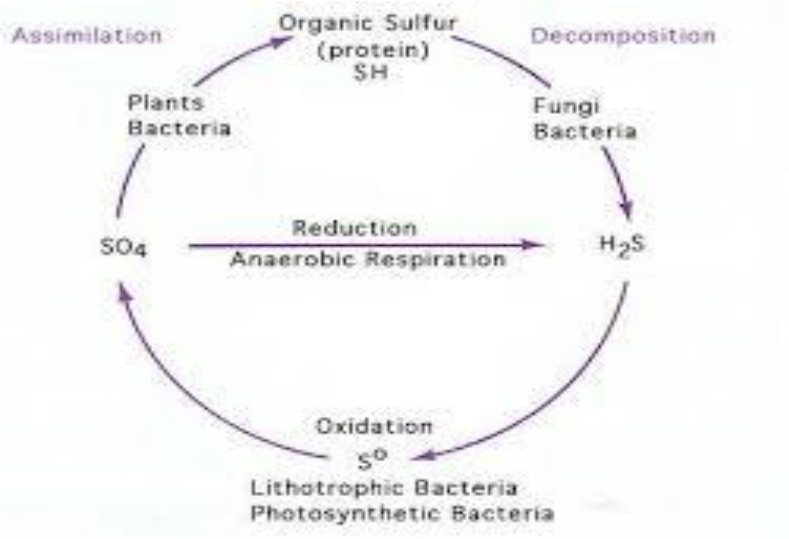
In this biogeochemical cycle, phosphorus moves through the hydrosphere, lithosphere and biosphere. Phosphorus is extracted by the weathering of rocks. Due to rains and erosion phosphorus is washed away in the soil and water bodies. Plants and animals obtain this phosphorus through the soil and water and grow.



Microorganisms also require phosphorus for their growth. When the plants and animals die, they decompose, and the stored phosphorus is returned to the soil and water bodies which is again consumed by plants and animals and the cycle continues.

Sulphur Cycle

This biogeochemical cycle moves through the rocks, water bodies and living systems. Sulphur is released into the atmosphere by the weathering of rocks and is converted into sulphates. These sulphates are taken up by the microorganisms and plants and converted into organic forms. Organic sulphur is consumed by animals through food. When the animals die and decompose, sulphur is returned to the soil which is again obtained by the plants and microbes, and the cycle continues.



UNIT II

Characteristics of population

Important characteristics of population are as follows:

1. Population density
2. Natality
3. Mortality
4. Population growth
5. Age distribution of population

6. Population fluctuations.

1. Population Density:

Population density refers to the size of any population in relation to some unit of space. It is expressed in terms of the number of individuals or biomass per unit area or volume, as for example, 500 teak trees per hectare; 40 lions per 100 km^2, 5 million diatoms per cubic meter of water. Population density is seldom static and it changes with time and space.

Population size can be measured by several methods:

(i) Abundance:

Absolute number of individuals in population.

(ii) Numerical Density:

Number of individuals per unit area or volume. It is expressed when the size of individuals in the population is relatively uniform, as in mammals, insects and birds.

(iii) Biomass Density:

Biomass density is expressed in terms of wet weight, dry weight, volume, and carbon and nitrogen weight per unit area or volume.

Population density can be expressed in two ways:

(i) Crude Population Density:

When the density is expressed with reference to total area at a particular time.

(ii) Ecological Density:

When the density is expressed with reference to total area of habitat available to the species. The distribution between crude density and ecological density becomes important because the patterns of distribution of individuals in nature are different and individuals of some species like *Cassia tora, Oplismenus burmanni* are found more crowded in shady places than in other parts of the same area. Thus, population density calculated in total area would be crude density and the densities for the shade areas and open areas separately would be ecological densities.

Population density can be calculated by the following equation:

D = n/a/t

Where D is population density;

n is the number of individuals;

a is area and t is unit time.

- Density of human population can be obtained by dividing the total number of persons in the area by the total land area of the region.
- Density of population of a country can be obtained by dividing the total number of persons living in the given region by total land area of that region.
- Average population density in developing countries is more as compared to those in developed countries.

Netherlands is smaller than India but its population density is greater (319/km^2 in Netherlands and les/km_2 in India). Area of India is 2.5% of the world but 15% population of the world lives in India alone. The population density of India is 4% higher than that of Europe and more than 7 times that of U.S.A. Population density is affected by a number of environmental factors, such as geographical factors, mortality, natality, emigration and immigration and socio-economic factors.

2. Natality:

Natality refers to the rate of reproduction or birth per unit time. It is an expression of the production of new individuals in the population by birth, hatching, germination or fission.

Natality is calculated by the following formula:

Birth rate or Natality (B) = Number of births per unit time/Average population.

- The maximum number of births produced per individual under ideal conditions of environment is called potential natality. It is also called reproductive or biotic potential, absolute natality or maximum natality.

Natality varies from organism to organism. It depends upon the population density and environmental factors. It is a general rule that if the population density is usually low, the birth rate is also low. This is so because the chances of mating between

males and females are low. If population density is unusually high, the birth rate may also be low due to poor nutrition or physiological or psychological problems related to crowding.

The maximum or absolute natality is observed when the species exists under ideal ecological and genetic conditions. The actual number of births occurring under the existing environmental conditions is much less as compared to absolute natality. It is referred to as ecological natality or realized natality. It is not constant for population and may vary with the size of population as well as with the time.

3. Mortality:

Mortality refers to the number of deaths in population per unit time.

Mortality rate = D/t where D is the number of deaths in the time t.

Mortality can be expressed in the following two ways:

(i) Minimum or Specific or Potential Mortality:

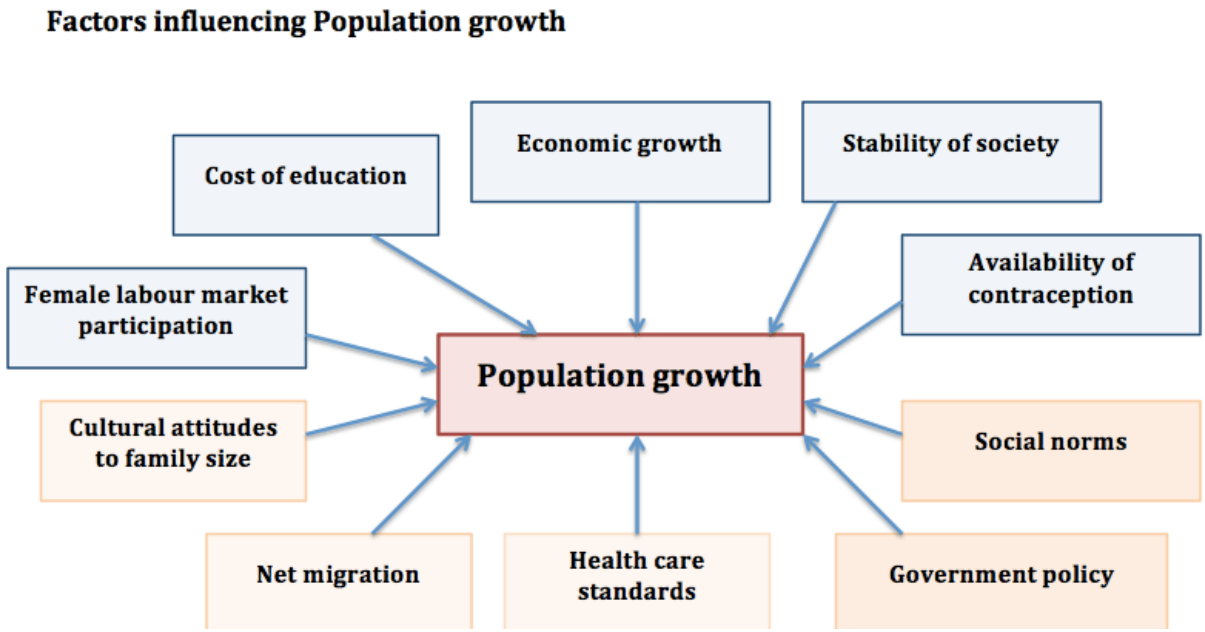
It represents the minimum of theoretical loss of individuals under ideal or non-limiting condition. Thus, even under the best conditions individuals of a population would die of old age determined by their physiological longevity. So, it is constant for a population.

(ii) Ecological or Realized Mortality:

It refers to the death of individuals of a population under existing environmental conditions. Since it varies with environmental conditions, it is never constant. The maximum mortality occurs at the egg, larval, seedling and old age. Mortality is affected by a number of factors, such as, density, competition, disease, predation and environment. Death rates vary among the species and are correlated with birth rates. When the rate of natality is equal to the rate of mortality the population is stationary. A birth death ratio (Births/death x 100) is called vital index. For a population, the survival of individuals is more important than the death. The number of births in relation to the carrying capacity of the habitat is a fundamental factor influencing the mortality rate. When more young are born than the habitat can support, the

surplus must either die or leave the area. Because the number of survivors is more important than the number of dying individuals, mortality is better expressed as survival or as life expectancy. The life expectancy refers to the average number of years the members of a population have left to live.

Factors influencing population growth



- **Economic development**. Countries who are in the early stages of economic development tend to have higher rates of population growth. In agriculturally based societies, children are seen as potential income earners. From an early age, they can help with household tasks and collecting the harvest. Also, in societies without state pensions, parents often want more children to act as an insurance for their old age. It is expected children will look after parents in old age. Because child mortality rates are often higher, therefore there is a need to have more children to ensure the parents have sufficient children to look after them in old age.
- **Education**. In developed countries, education is usually compulsory until the age of 16. As education becomes compulsory, children are no longer economic assets – but economic costs. In the US, it is estimated a child can cost approx.

$230,000 by the time they leave college. Therefore, the cost of bringing up children provides an incentive to reduce family size.

- **Quality of children**. Gary Becker produced a paper in 1973 with H. Gregg Lewis which stated that parents choose the number of children based on a marginal cost and marginal benefit analysis. In developed countries with high rates of return from education, parents have an incentive to have a lower number of children and spend more on their education – to give their children not just standard education but a relatively better education than others. To be able to give children the best start in life, it necessitates smaller families. Becker noted rising real GDP per capita was generally consistent with smaller families.
- **Welfare payments/State pensions**. A generous state pension scheme means couples don't need to have children to provide an effective retirement support when they are old. Family sizes in developing countries are higher because children are viewed as 'insurance' to look after them in old age. In modern societies, this is not necessary and birth rates fall as a result.
- **Social and cultural factors**. India and China (before one family policy) had strong social attachments to having large families. In the developed world, smaller families are the norm.
- **Availability of family planning**. Increased availability of contraception can enable women to limit family size closer to the desired level. In the developing world, the availability of contraception is more limited, and this can lead to unplanned pregnancies and more rapid population growth. In Africa in 2015, it was estimated that only 33% of women had access to contraception. Increasing rates would play a role in limiting population growth.
- **Female labour market participation**. In developing economies, female education and social mobility are often lower. In societies where women gain a better education, there is a greater desire to put work over starting a family. In the

developed world, women have often chosen to get married later and delay having children (or not at all) because they prefer to work and concentrate on their career.

- **Death rates** – Level of medical provision. Often death rates are reduced before a slowdown in birth rates, causing a boom in the population size at a certain point in a country's economic development. In the nineteenth and early twentieth century, there was a rapid improvement in medical treatments which helped to deal with many fatal diseases. Death rates fell and life expectancy increased.
- **Immigration levels.** Some countries biggest drivers of population growth come from net migration. In the UK from 2000 to 2013, around 50% of net population growth came from net international migration. Countries like Japan with very strict immigration laws have seen a stagnation in the population.
- **Historical factors/war**. In the post-war period, western countries saw a 'boom' in population, as couples reunited at the end of the Second World War began having families. The 'baby-boomer' period indicates population growth can be influenced by historical events and a combination of factors which caused a delay in having children until the war ended.

Community concept:

By definition, community represents the population of all species living and interacting in an area at a particular time. Population can, within limits, adapt to changes in environmental conditions. The major driving force of adaptation to environmental changes is believed by most biologists to be biological evolution, the change in a population's genetic make-up through successive generation.

Structure of Community:

Communities may be small, consisting of few species populations in a small space, or large, comprising several species populations in a large area. The community structures, composition and other characteristics can be readily described by visual observation without actual measurement.

This is a qualitative approach which is easier than the quantitative population analysis where measurements are actually made. Communities usually categories by the ecologists in various ways primarily based of habitat features like water availability, high exposure, or other habitat features.

For instance, depending on the amount of water availability, plant communities may be hydrophytic (aquatic habitats), mesophytic (moderately moist soil habitat) and xerophytic (dry or arid habitat).

Similarly, communities growing on conditions of abundant light are called heliophytic and those growing in shade Scio phytic. Identically communities growing on various habitats designated as desert communities, mountain communities and estuarine communities and so on.

In general, a community is dynamic since it changes over time. This dynamic nature is reflected in the succession of organisms in a habitat. A series of changes results in the development of a relatively stable community, which maintains its structure and influences the climate of the area.

Such a stable and mature community is called a climax community, while communities of successional stages are called seral communities. The plant community structures, composition and other characterizes can be described in both qualitative or quantitative means.

Community Dynamics:

Communities are dynamic systems constantly interacting with another system, the environment, which is equally dynamic. The community charges are gradual and imperceptible at any time but easily recognisable if observed at regular intervals over a long period of time. Seasonal changes in plant communities always occur at every place, particularly in areas where temperature variation is significant.

However, in course of very long period of time at many places the communities have reached a peak stage and attained a dynamic balance with the environmental

changes. The process of change in communities and their environment at one place in the course of time is called “ecological succession”.

Succession refers to change in a community following either physical or biological disturbance, when a farmland is abandoned, a forest develops after a series of temporary communities.

In a sense we may think of such temporary communities as developmental stages analogous to the life history stages through which many organisms pass before reaching adulthood.

The concept of succession was largely developed by the botanists Warming (1909) and Cowles (1899), who studied the stages of sand dune development.

It has been further elaborated by Clements (1916, 1936) who proposed a theory of plant succession and community development called the mono-climax hypothesis. Later on, Tansely (1939) and Daubenmire (1966) proposed the poly-climax hypothesis.

Ecological succession

Succession is a unidirectional change in the community structure. In simple words, succession may be defined as natural change in the structure and species composition of a community.

Ecological succession may be defined in terms of the following three parameters:

(a) It is the orderly process of community changes, which are directional and therefore, predictable,

(b) It results from the modification of the physical environment by the community, and

(c) It culminates in the establishment of as stable an ecosystem as is biologically possible on the given site.

According to Kerbs (1994), succession is the universal process of directional change in vegetation and can be recognized by the progressive change in the species

composition of the community. In his words, the development of the community by the action of vegetation on the environment leading to the development of new species is called succession.

It is important to emphasize that the phenomenon of succession is "community controlled". Each group of organisms changes its physical substrate and the microclimate (e.g., local conditions of light, temperature), thereby making conditions favourable for another group of organisms. In other words, we say that each species alters the environment in such a way that it can no longer grow so successfully as others.

When the site has been fully modified by biological processes, an ecological steady state is developed. The species involved, time taken and the degree of stability achieved depend on the topography or climate of the area, and other physical factors. But the process of succession itself is biological, not physical. Thus, the physical environment determines the pattern of succession but does not cause it.

Processes Causing Succession:

Since succession is a series of complex processes, it follows that there can be no single cause for it. The processes causing succession may be distinguished as initiating or initial causes, continuing or ecesic causes, and stabilizing or climatic causes.

The initial causes produce the bare area or destroy the original population in areas already vegetated. The deposition of sediment as alluvial fans at the mouth of a river illustrates the former and the wandering sand dune covering a forest, the latter. The ecesic causes produce the essential character of vegetational development, i.e. The successive plant populations.

They have to do with the interaction of vegetation and habitat and are directive to the highest degree. The climatic causes determine the nature of the climatic climax, i.e., the end point of succession. They have a profound effect in determining the population from the beginning to end, the number and kinds of stages as well as the

reactions of the successive stages. While the process of succession in the tropics is similar to that in temperate regions, the plant populations are often quite different. This is due to the climate.

Ecological indicator

Any organism or group of organism indicative of a particular environment or set of environmental conditions. For example, lichens may be used as indicators of air pollution and fossil assemblages as indicators of past environments.

Plant indicators can be helpful to determine local soil, thus it can be decided which crops should be cultivated in a particular soil and which soil should be left for pasture or other purposes.

Plant indicators are also used to determine optimum use of land resources for forest, pasture, and agricultural crops.

The heredity and environment both are equally important in the expression of phenotypic characters. Heredity performs its action through environment. Species differ in their environmental requirements and establish themselves where conditions are favourable. It is found that certain species of plants, animals and micro-organisms have one or more specific requirements which very much limit their distribution.

The knowledge of plant indicators can be helpful to determine local soil, thus it can be decided which crops should be cultivated in a particular soil and which soil should be left for pasture or other purposes. Plant indicators are also used to determine optimum use of land resources for forest, pasture, and agricultural crops. Many plants also indicate the presence of particular mineral or metal. So, the presence of precious metal can be detected by the growth of the specific plant in an area.

The characteristic features of plant indicators are as follows:

1. On the basis of distribution the indicators may be ‘steno’ species or ‘eury’ species. The ‘steno’ is used to indicate narrow limits of tolerance and ‘eury’ is used to indicate wide limits of tolerance. A plant may show wide limits of tolerance for

certain conditions and narrow limits of tolerance for other conditions. For example, a plant may be indicator of wide limits of tolerance for heat but of narrow limits of tolerance for water. Plants with wide limits of tolerance of heat are called eurythermal and those with narrow limits of tolerance for water are called steno hydric.

2. Plants of large species are better indicator than the plants of small species.

3. Before relying on a single species or group of species as indicators, there should be abundant field evidence.

4. Numerical relationships between species, population and whole communities often provide more reliable indicators than single species

Different Types of Plant Indicators:

Different types of plant indicators have different roles in different aspects which are described below:

Plant indicators for agriculture:

Many plant indicators decide whether soil is suitable for agriculture or not. The growth of a particular crop plant is seen under different environmental conditions and if growth is satisfactory in a particular soil that soil is considered to be suitable for agriculture. For example, growth of the short grasses indicates that water is less in the soil.

UNIT III

Ecosystem

Ecosystem is a complex in which habitat, plants and animals are considered as one interesting unit, the materials and energy of one passing in and out of the others" – Woodbury.

Types of ecosystem

Organisms and environment are two non-separable factors. Organisms interact with each other and also with the physical conditions that are present in their habitats.

"The organisms and the physical features of the habitat form an ecological complex or more briefly an ecosystem." (Clarke, 1954).

The concept of ecosystem was first put forth by A.G. Tansley (1935). Ecosystem is the major ecological unit. It has both structure and functions. The structure is related to species diversity. The more complex is the structure the greater is the diversity of the species in the ecosystem. The functions of ecosystem are related to the flow of energy and cycling of materials through structural components of the ecosystem.

According to Woodbury (1954), ecosystem is a complex in which habitat, plants and animals are considered as one interesting unit, the materials and energy of one passing in and out of the others.

According to E.P. Odum, the ecosystem is the basic functional unit of organisms and their environment interacting with each other and with their own components. An ecosystem may be conceived and studied in the habitats of various sizes, e.g., one square metre of grassland, a pool, a large lake, a large tract of forest, balanced aquarium, a certain area of river and ocean.

All the ecosystems of the earth are connected to one another, e.g., river ecosystem is connected with the ecosystem of ocean, and a small ecosystem of dead logs is a part of large ecosystem of a forest. A complete self-sufficient ecosystem is rarely found in nature but situations approaching self-sufficiency may occur.

Structure of Ecosystem:

The structure of an ecosystem is basically a description of the organisms and physical features of environment including the amount and distribution of nutrients in a particular habitat. It also provides information regarding the range of climatic conditions prevailing in the area.

From the structure point of view, all ecosystems consist of the following basic components:

1. Abiotic components
2. Biotic components

1. Abiotic Components:

Ecological relationships are manifested in physicochemical environment. Abiotic component of ecosystem includes basic inorganic elements and compounds, such as soil, water, oxygen, calcium carbonates, phosphates and a variety of organic compounds (by-products of organic activities or death).

It also includes such physical factors and ingredients as moisture, wind currents and solar radiation. Radiant energy of sun is the only significant energy source for any ecosystem. The amount of non-living components, such as carbon, phosphorus, nitrogen, etc. that are present at any given time is known as standing state or standing quantity.

2. Biotic Components:

The biotic components include all living organisms present in the environmental system.

From nutrition point of view, the biotic components can be grouped into two basic components:

(i) Autotrophic components, and

(ii) Heterotrophic components

The autotrophic components include all green plants which fix the radiant energy of sun and manufacture food from inorganic substances. The heterotrophic components include non-green plants and all animals which take food from autotrophs.

So biotic components of an ecosystem can be described under the following three heads:

1. Producers (Autotrophic components),

2. Consumers, and

3. Decomposers or reducers and transformers

The amount of biomass at any time in an ecosystem is known as standing crop which is usually expressed as fresh weight, dry weight or as free energy in terms of calories/metre.

Producers (Autotrophic elements):

The producers are the autotrophic elements—chiefly green plants. They use radiant energy of sun in photosynthetic process whereby carbon dioxide is assimilated and the light energy is converted into chemical energy. The chemical energy is actually locked up in the energy rich carbon compounds. Oxygen is evolved as by-product in the photosynthesis.

This is used in respiration by all living things. Algae and other hydrophytes of a pond, grasses of the field, trees of the forests are examples of producers. Chemosynthetic bacteria and carotenoid bearing purple bacteria that also assimilate CO_2 with the energy of sunlight but only in the presence of organic compounds also belong to this category.

The term producer is misleading one because in an energy context, producers produce carbohydrate and not energy. Since they convert or transduce the radiant energy into chemical form, E.J. Kormondy suggests better alternative terms ‘converters’ or ‘transducers’ because of wide use the term producer is still retained.

Consumers:

Those living members of ecosystem which consume the food synthesized by producers are called consumers. Under this category are included all kinds of animals that are found in an ecosystem.

There are different classes or categories of consumers, such as:

(a) Consumers of the first order or primary consumers,

(b) Consumers of the second order or secondary consumers,

(c) Consumers of the third order or tertiary consumers, and

(d) Parasites, scavengers and saprobes.

(a) Primary consumers:

These are purely herbivorous animals that are dependent for their food on producers or green plants. Insects, rodents, rabbit, deer, cow, buffalo, goat are some of the common herbivores in the terrestrial ecosystem, and small crustaceans, molluscs,

etc. in the aquatic habitat. Elton (1939) named herbivores of ecosystem as "key industry animals". The herbivores serve as the chief food source for carnivores.

(b) Secondary consumers:

These are carnivores and omnivores. Carnivores are flesh eating animals and the omnivores are the animals that are adapted to consume herbivores as well as plants as their food. Examples of secondary consumers are sparrow, crow, fox, wolves, dogs, cats, snakes, etc.

(c) Tertiary consumers:

These are the top carnivores which prey upon other carnivores, omnivores and herbivores. Lions, tigers, hawk, vulture, etc. are considered as tertiary or top consumers.

(d) Besides different classes of consumers, the parasites, scavengers and saprobes are also included in the consumers. The parasitic plants and animals utilize the living tissues of different plants and animals. The scavengers and saprobes utilize dead remains of animals and plants as their food.

Decomposers and transformers:

Decomposers and transformers are the living components of the ecosystem and they are fungi and bacteria. Decomposers attack the dead remains of producers and consumers and degrade the complex organic substances into simpler compounds. The simple organic matters are then attacked by another kind of bacteria, the transformers which change these organic compounds into the inorganic forms that are suitable for reuse by producers or green plants. The decomposers and transformers play very important role in maintaining the dynamic nature of ecosystems.

Function of Ecosystem:

An ecosystem is a discrete structural, functional and life sustaining environmental system. The environmental system consists of biotic and abiotic components in a habitat. Biotic component of the ecosystem includes the living organisms; plants,

animals and microbes whereas the abiotic component includes inorganic matter and energy.

Abiotic components provide the matrix for the synthesis and perpetuation of organic components (protoplasm). The synthesis and perpetuation processes involve energy exchange and this energy comes from the sun in the form of light or solar energy.

Thus, in any ecosystem we have the following functional components:

(i) Inorganic constituents (air, water and mineral salts)

(ii) Organisms (plants, animals and microbes), and

(iii) Energy input which enters from outside (the sun).

These three interact and form an environmental system. Inorganic constituents are synthesized into organic structures by the green plants (primary producers) through photosynthesis and the solar energy is utilized in the process. Green plants become the source of energy for renewals (herbivores) which, in turn become source of energy for the flesh eating animals (carnivores). Animals of all types grow and add organic matter to their body weight and their source of energy is complex organic compound taken as food.

They are known as secondary producers. All the living organisms whether plants or animals in an ecosystem have a definite life span after which they die. The dead organic remains of plants and animals provide food for saprophytic microbes, such as bacteria, fungi and many other animals. The saprobes ultimately decompose the organic structure and break the complex molecules and liberate the inorganic components into their environment.

These organisms are known as decomposers. During the process of decomposition of organic molecules, the energy which kept the inorganic components bound together in the form of organic molecules gets liberated and dissipated into the environment as heat energy. Thus, in an ecosystem energy from the sun, the input is fixed by plants and transferred to animal components.

Nutrients are withdrawn from the substrate, deposited in the tissues of the plants and animals, cycled from one feeding group to another, released by decomposition to the soil, water and air and then recycled. The ecosystems operating in different habitats, such as deserts, forests, grasslands and seas are interdependent on one another. The energy and nutrients of one ecosystem may find their way into another so that ultimately all parts of the earth are interrelated, each comprising a part of the total system that keeps the biosphere functioning.

Thus, the principal steps in the operation of ecosystem are as follows:

(1) Reception of radiant energy of sun,

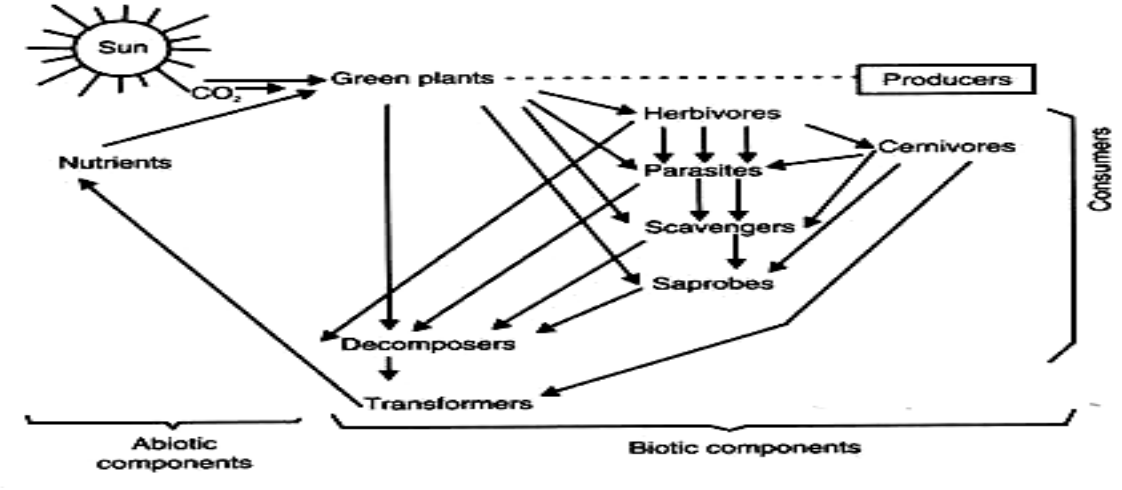
(2) Manufacture of organic materials from inorganic ones by producers,

(3) Consumption of producers by consumers and further elaboration of consumed materials; and.

(4) After the death of producers and consumers, complex organic compounds are degraded and finally converted by decomposers and converters into such forms as are suitable for reutilization by producers.

The principal steps in the operation of ecosystem not only involve the production, growth and death of living components but also influence the abiotic aspects of habitat. It is now clear that there is transfer of both energy and nutrients from producers to consumers and finally to decomposers and transformers levels. In this transfer there is a progressive decrease of energy but nutrient component is not diminished and it shows cycling from abiotic to biotic and vice versa.

The flow of energy is unidirectional. The two ecological processes—energy flow and mineral cycling which involve interaction between biotic and abiotic components lie at the heart of ecosystem dynamics. The principal steps and components of ecosystem are explained below.



Fresh water ecosystems

Pond and lake are fresh water ecosystems in which, like other ecosystems, there are two main components:

(A) Abiotic component

(B) Biotic component

(A) Abiotic component:

Abiotic component of pond consists of water, dissolved minerals, oxygen and carbon dioxide. Solar radiations are the main source of energy.

(B) Biotic component:

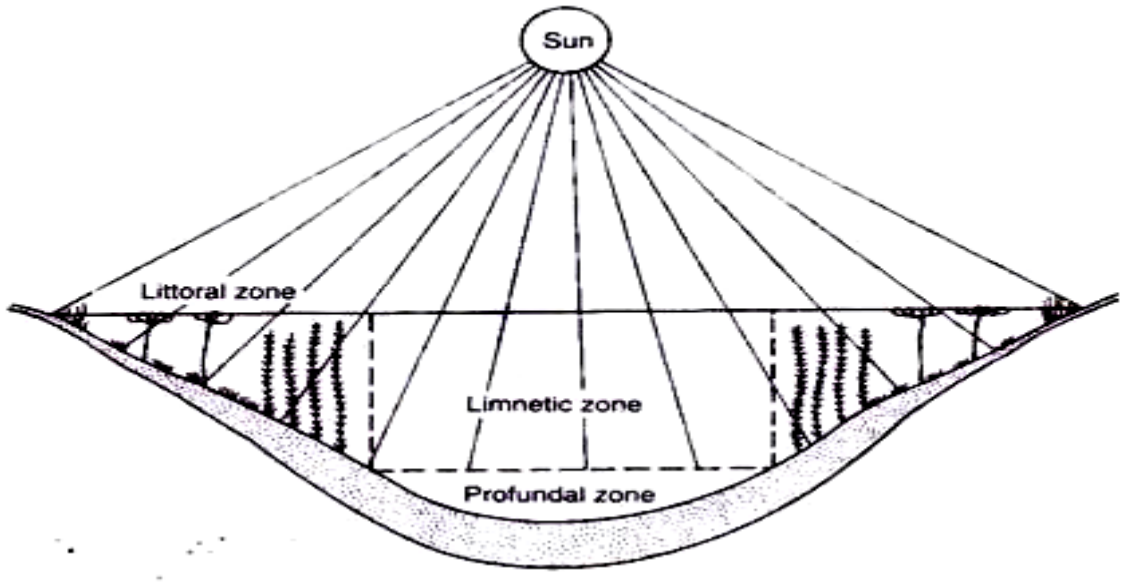
It includes the following:

(i) Producers

(ii) Consumers

(iii) Decomposers and transformers.

On the basis of water depth and types of vegetation and animals there may be three zones in a lake or pond littoral, limnetic and pro-fundal. The littoral zone is the shallow water region which is usually occupied by rooted plants. The limnetic-zone ranges from the shallow to the depth of effective light penetration and associated organisms are small crustaceans, rotifers, insects, and their larvae and algae. The pro-fundal zone is the deep water parts where there is no effective light penetration. The associated organisms are snails, mussels, crabs and worms.



(i) Producers:

The main producers in pond or lake ecosystem are algae and other aquatic plants, such as *Azolla, Hydrilla, Potamogeton, Pistia, Wolffia, Lemna, Eichhornia, Nymphaea, Jussiaea,* etc. These are either floating or suspended or rooted at the bottom. The green plants convert the radiant energy into chemical energy through photosynthesis. The chemical energy stored in the form of food is utilized by all the organisms. Oxygen evolved by producers in photosynthesis is utilized by all the living organisms in respiration.

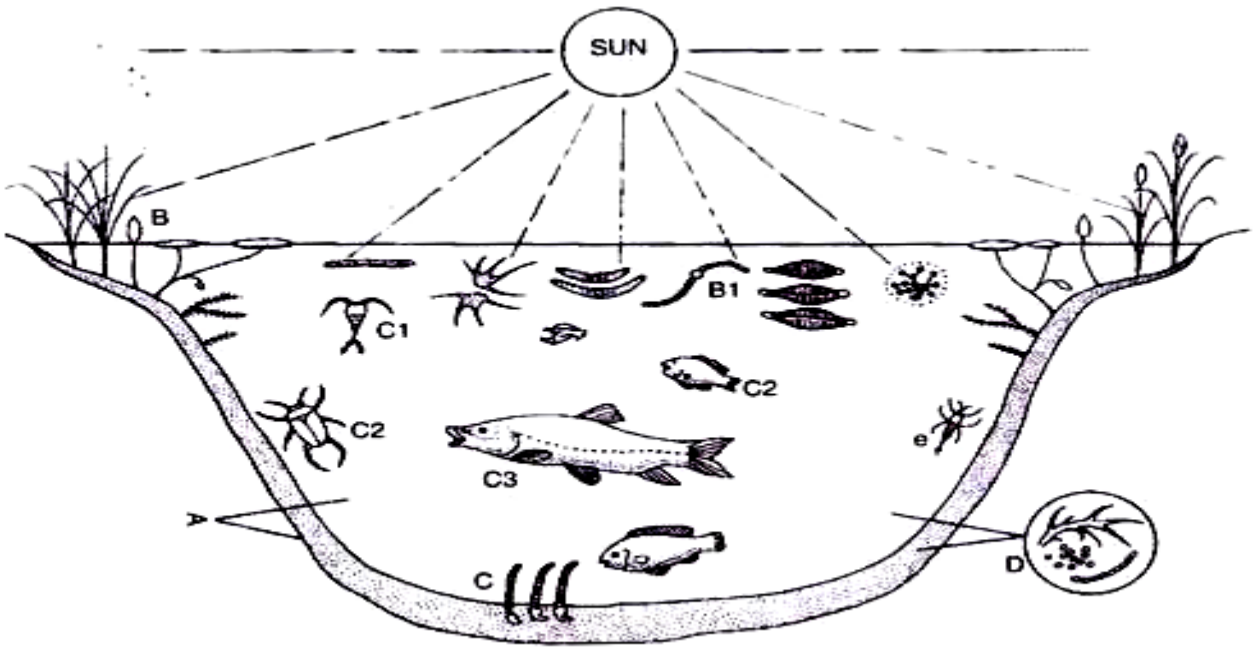
(ii) Consumers:

In a pond ecosystem, the primary consumers are tadpole larvae of frogs, fishes and other aquatic animals which consume green plants and algae as their food. These herbivorous aquatic animals are the food of secondary consumers. Frogs, big fishes, water snakes, crabs are secondary consumers. In the pond, besides the secondary consumers, there are consumers of highest order, such as water-birds, turtles, etc.

(iii) Decomposers and Transformers:

When aquatic plants and animals die, a large number of bacteria and fungi attack their dead bodies and convert the complex organic substances into simpler inorganic compounds and elements. These micro-organisms are called decomposers chemical

elements liberated by decomposers are again utilized by green plants in their nutrition



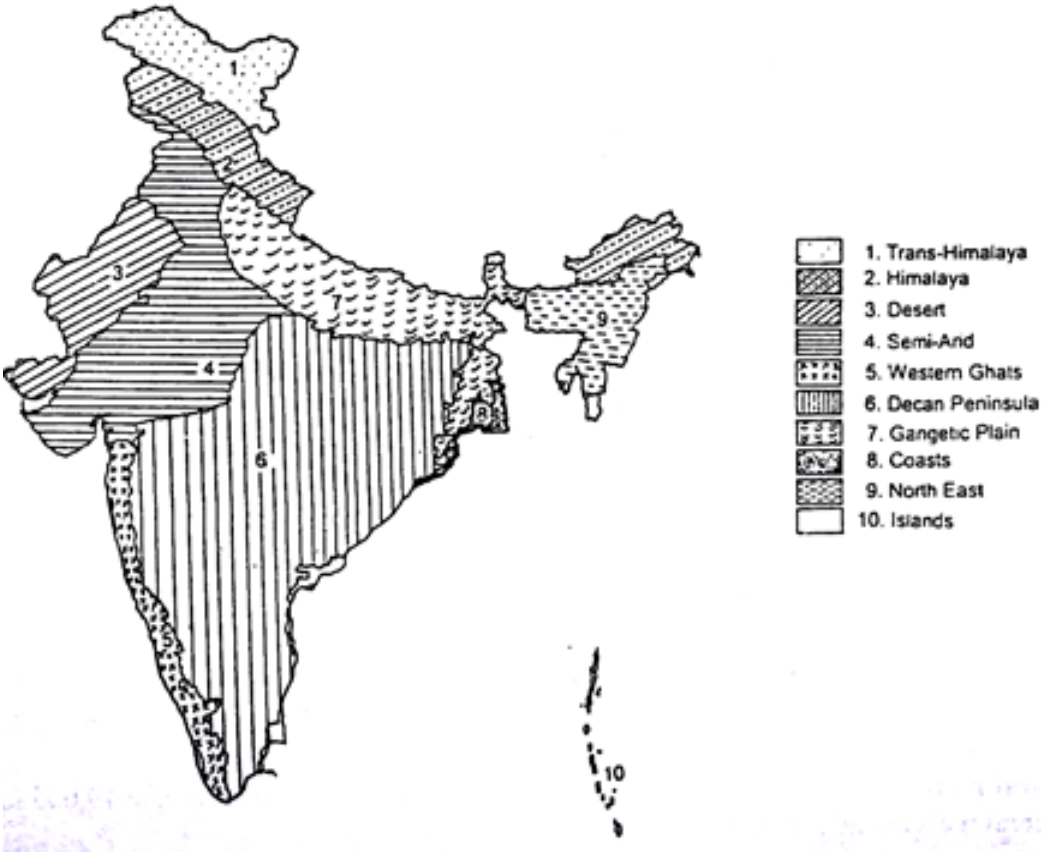
Ecological divisions of India

The bio-geographical zones of India are:

1. Trans-Himalayas
2. Himalayas
3. Desert
4. Semi-Arid
5. Western Ghats
6. Deccan Peninsula
7. Gangetic Plain
8. North-East India
9. Islands
10. Coasts.

1. Trans-Himalayas:

An extension of the Tibetan Plateau, harbouring high-altitude cold desert in Laddakh (J and K) and Lahaul Spiti (H.P.) comprising 5.7 per cent of the country's landmass.



Biographical regions of India (Source WII Dehradun)

2. Himalayas:

The entire mountain chain running from north-western to north-eastern India, comprising a diverse range of biotic provinces and biomes, 7,2 per cent of the country's landmass,

3. Desert:

The extremely arid area west of the Aravalli hill range, comprising both the salty desert of Gujarat and the sand desert of Rajasthan. 6.9 per cent of the country's landmass.

4. Semi-Arid:

The zone between the desert and the Deccan plateau, including the Aravalli hill range. 15.6 per cent of the country's landmass.

5. Western Ghats:

The hill ranges and plains running along the western coast line, south of the Tapti river, covering an extremely diverse range of biotic provinces and biomes. 5.8 percent of the country's landmass.

6. Deccan Peninsula:

The largest of the zones, covering much of the southern and south-central plateau with a predominantly deciduous vegetation. 4.3 percent of the country's landmass.

7. Gangetic Plain:

Defined by the Ganges river system, these plains are relatively homogenous. 11 percent of the country's landmass.

8. North-East India:

The plains and non-Himalayan hill ranges of north eastern India, with a wide variation of vegetation. 5.2 percent of the country's landmass.

9. Islands:

The Andaman and Nicobar Islands in the Bay of Bengal, with a highly diverse set of biomes. 0.03 percent of the country's landmass.

10. Coasts:

A large coastline distributed both to the west and east, with distinct differences between the two; Lakshadweep Islands are included in this with the percent area being negligible.

Conservation of natural resources

The wise and careful use of natural resources is called conservation. We are using these natural resources without thinking, to fulfil our requirements and the results of this is always negative during a period of time.

But it is never too late. Even now if these resources are widely used, conservation is not only wise and careful use of resources but it can maintain and improve their quality and quantity.

Soil:

Soil forms another main natural resource which is essential for survival and development of human beings.

We get our basic requirements as food, clothing and shelter mainly from the plants that grow in the soil or from the animals that feed on such plants. Soil serve as natural habitat for microbes, plants and animals. The word 'soil' is derived from a latin word 'solum' meaning earthly material in which plants grow. Soil is the mixture of inorganic and organic materials.

Air and water occupy the pores between the soil particles which are loosely packed. Soil provides shelter to bacteria, fungi, algae, protozoans, earthworms, snails, ants. Roots of higher plants grow into the soil in search of water and nutrients. Soil is the ultimate source of all food production. Top soil is the uppermost layer which is rich in humus, it makes the soil fertile. Soil fertility is lost due to some activities.

Soil Erosion:

The substance which make up the earth surface is called soil. Soil is a complex mixture of non-living materials and some living things. All the plants grow in the soil. Soil provide support and nutrition to plants. The top soil is very fertile. The top soil is often carried away by strong winds or by heavy rains or by flowing river water. The removal of fertile top soil from a region by wind, rain or river water is called soil erosion. Floods, improper tillage, deforestation, overgrazing, rain, wind and human activities are the cause of soil erosion.

Soil conservation:

The loss of soil fertility occurs mainly due to soil erosion and continuous cropping. The technique and methods which check the loss of soil during erosion is called soil

conservation. Thus, soil conservation means protection, improvement and sustained renewal of soil at any place. Following steps can be taken to conserve soil.

1. Soil erosion can be prevented by intensive cropping means we should grow more crops.

2. Soil erosion can be checked by providing proper drainage canals around the fields to carry out excess rain water.

3. Soil erosion in hilly areas can be prevented by practising step farming (terrace farming) when the sloping fields of the hilly areas are laid down in the form of small steps or terraces, then the speed with which rain water flows down is reduced.

4. Soil erosion is prevented by planting trees and sowing grass; soil should not be left barren.

5. Soil erosion can be checked by constructing strong embankments (baandh) along the river banks by using rocks and stones.

6. Addition of manure prepared from dead organic matter restores the fertility of the soil, as it is rich in humus.

7. Addition of chemical fertilizers like urea, NPK, Ammonium phosphate and super phosphate also improve the soil fertility but the excess use of chemical fertilizers should be avoided as these fertilizers are harmful for organisms living in the soil.

Water:

Water is another important renewable resource. The seas, oceans, rivers, streams lakes, ponds, pools and polar ice caps form the hydrosphere. About 75 percent of earth's surface is covered with hydrosphere. The main component of the hydrosphere is water.

Water is a natural resource. It is a valuable national asset. It forms main requirement of human beings. We depend on water for cleaning, agriculture, transportation and hydropower. There are two kinds of water; salt water and fresh water. Small amount of earth's fresh water is available for use. Fresh water becomes available when water is recycled in the water cycle.

When water falls on the earth, a very small fraction of this water percolates deep into the ground, this is called ground water. The depth in the soil where all the pore spaces of soil particles are saturated with water only, is called water table. The ground water provides soil moisture for plant growth. Ground water is frequently used for human consumption.

Fall of water table level:

The ground water level goes down drastically over a period of a few years. As a result, our wells and hand pumps become dry during summers, tube wells and wells have to be dug deeper to get water. Water level goes down if the rate of pumping out of ground water is more than the rate at which the rain water percolates into the earth, deforestation, overgrazing, construction of roads and buildings are responsible for the reduction of water level. Depletion of water table can cause damage of the standing crops as the roots of these plants are unable to reach up to the water table.

Water conservation:

Water is very precious resource which is required by all living beings.

Water should not be wasted, and conserve by the following methods:

1. Development of integrated water shed plan for drinking, irrigation and industrial uses.
2. Wastage of water should be avoided.
3. Adoption of various flood control methods.
4. Deforestation should be discouraged and afforestation should be encouraged.
5. Drip irrigation method should be adopted in which water is supplied up to the roots drop by drop instead of filling the field with water.
6. Harvesting of rain water technique should be promoted as it is being encouraged by government. Rain water which falls on roofs of buildings is collected into deep trenches in the ground. It, thus replenishes ground water instead of just flowing into open drains.

Air:

Air forms an important renewable natural resource. Air is very essential for all living organisms as human beings require oxygen for survival and plants need carbon dioxide for photosynthesis. There is an envelope of air around the earth which forms atmosphere. Air consists of a mixture of various gases in different proportions. Total volume of air present in atmosphere consists of 78 percent nitrogen, 21 percent oxygen and 1 percent other gases such as carbon dioxide, ammonia, methane, hydrogen, ozone, noble gases such as argon, neon, helium, krypton, xenon and radon.

Forests:

Forests are very important renewable resources. Many kinds of organisms, birds and animals live here. Forests bring rain and prevent soil erosion. Forests give out oxygen and absorb carbon dioxide thus purify the atmosphere.

Forests prevent floods, provide different types of medicines, timber for furniture and buildings, we get gums, latex, resins and pulp for paper industries. Man has done deforestation for his selfish needs such as for building constructions, road making, for getting timber, villagers cut tree to get wood for burning purpose.

Effects of deforestation:

1. Soil erosion is the result of deforestation.
2. Deforestation affects rainfall and water cycle is disturbed.
3. Oxygen carbon dioxide balance is disturbed which may lead to air pollution.
4. Habitat of various animals like birds, insects are destroyed, due to which certain species of animals and birds may extinct.

Forest Conservation:

1. Afforestation of deforested areas becomes necessary to get sufficient rainfall.
2. Forests should be protected from fire. Forest fires can be controlled by spraying fire extinguishing solutions.
3. Overgrazing should be avoided.

4. In reserve forests no commercial exploitation should be allowed, they should be protected from fuel-starved villagers and fodder-starved cattle.

5. Selective cutting of trees in the forest may be allowed rather than cutting all the trees.

Wildlife:

Wildlife conservation and forest conservation are very closely related. When deforestation is done wild animal run here and there as they lost their habitat.

Hunting of animals for food, skin, bones, horns and ivory is responsible for reduction in the number of wild animals. Some animals are gun down only for fun and sports which is very cruel activity. Due to the illegal trade of hides, large number of tigers, leopards, deer snakes and crocodiles are killed. Indian rhinoceros, great Indian bustard, musk deer, blue whale are endangered species.

Indian egg-eating snake, olive ridley turtle, Indian pied hornbill and golden cat are rare species. Hunters and poachers disturb food chain in nature and also balance of environment. For example, killing of snakes which feed on rats and mice, increase the number of these pests and damage of crops is increased.

Conservation of wildlife:

1. Hunting should be discouraged.
2. Deforestation should be prevented.
3. Natural habitat of animals should be protected and maintained.
4. Articles made by hides, fur, ivory and horns should be boycotted.
5. Laws against hunting should be implemented effectively.
6. Poachers should be arrested immediately and should be kept behind the bars.
7. More National parks and bird sanctuaries should be established
8. Indian public should be educated by films, T.V. shows, popular articles in newspapers and magazines regarding the significance of Indian wildlife.

UNIT V

Man, and Environment

Wildlife Conservation:

As the human population increases, more and more lands are brought under its control and, as a result, the amount of natural vegetation has diminished considerably and so also the habitat of various species. The vast expanses of tropical forest and its inhabiting species have become increasingly threatened in the last few decades. Even in the oceans, fishing is so intensive that populations are diminishing rapidly. We have become too efficient as predators.

Sometimes we hunt species for luxury items! For example, the elephants for their tusk, the rhinoceroses for their horns etc. Sometimes we capture exotic species such as various birds, coral reef fishes etc. for the pet trade. Thus, we have become a species which is no longer in co-evolved balance with its environment.

Aldo Leopold (1943) has rightly said that wildlife had once fed us and shaded our culture; it had provided us pleasure for leisure hours. It has now become essential that we support the active conservation of wildlife for reasons which reflect the different facets of our relationship with the natural world

Importance of wildlife in ecology

Wildlife plays a vital role in ecological balance. The autecology of rare or threatened species, the synecology of communities and the role of the abiotic environment in ecosystems are all relevant to conservation. Wildlife is the integral part of any ecosystem.

It maintains a balance in nature through biogeochemical cycles, food chains, population control by positive and negative feedbacks. If a species is lost, the natural balance of the ecosystem is lost and unfavourable incidences result.

Economic Value of wildlife:

Wildlife has a high economic value and is an important natural wealth. It has to be carefully conserved and, if scientifically exploited, can help in improving the national economy.

The economic values of wildlife are:

1. From wildlife we can obtain various products for our daily life use such as timber, firewood, natural rubber, gums, resins, tannins, essential oils, spices, silk, lac, honey, feathers, musk, ivory, wool, egg, meat, milk etc.

2. Wildlife is a source of income for tourism industry. The most popular tourist attractions are the wildlife sanctuaries and national parks. It also attracts foreign tourists and earning of foreign exchange. The zoological gardens and botanical gardens are also sources of earning.

3. Trade in live as well as dead animals not only serves to support thousands of people but also to earn foreign exchange. White tigers and other rare animals can fetch handsome foreign exchange. The rhino horn, ivory of elephants, glands of musk deer, antler of deers etc. all fetches high prices.

People of South America, Far East Asia and others eat the brain and meat of rare breeds of monkeys with an assumption that it cures insane people and gives vitality. People in South India kill peacocks for meat and to extract oil for medicinal value. Fat of tiger, Rhino's urine, Uromastrix oil are used as cure for rheumatoid arthritis, gout, purification of blood and for increasing sexual powers.

Wildlife Protection Act, 1972

This Act provides for the protection of the country's wild animals, birds and plant species, in order to ensure environmental and ecological security. Among other things, the Act lays down restrictions on hunting many animal species. The Act was last amended in the year 2006. An Amendment bill was introduced in the Rajya Sabha in 2013 and referred to a Standing Committee, but it was withdrawn in 2015.

History of wildlife protection legislation in India

- The first such law was passed by the British Indian Government in 1887 called the Wild Birds Protection Act, 1887. The law made the possession and sale of wild birds which were either killed or captured illegal.

- A second law was enacted in 1912 called the Wild Birds and Animals Protection Act. This was amended in 1935 when the Wild Birds and Animals Protection (Amendment) Act 1935 was passed.
- During the British Raj, wildlife protection was not accorded a priority. It was only in 1960 that the issue of protection of wildlife and the prevention of certain species from becoming extinct came into the fore.

Need for the Wildlife Protection Act

Wildlife is a part of 'forests' and this was a state subject until the Parliament passed this law in 1972. Reasons for a nationwide law in the domain of environment particularly wildlife include the following:

1. India is a treasure-trove of varied flora and fauna. Many species were seeing a rapid decline in numbers. For instance, at the turn of the 20th century, India was home to close to 40000 tigers. By the seventies, this number drastically reduced to about 1820.
2. A drastic decrease in the flora and fauna can cause ecological imbalance, which affects many aspects of climate and the ecosystem.
3. The most recent Act passed during the British era in this regard was the Wild Birds and Animals Protection, 1935. This needed to be upgraded as the punishments awarded to poachers and traders of wildlife products were disproportionate to the huge financial benefits that accrue to them.
4. There were only five national parks in India prior to the enactment of this Act.

Salient Features of Wildlife Protection Act

This Act provides for the protection of a listed species of animals, birds and plants, and also for the establishment of a network of ecologically-important protected areas in the country.

- The Act provides for the formation of wildlife advisory boards, wildlife wardens, specifies their powers and duties, etc.

- It helped India become a party to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (**CITES**).
- CITES is a multilateral treaty with the objective of protecting endangered animals and plants.
- It is also known as the **Washington Convention** and was adopted as a result of a meeting of IUCN members.
- For the first time, a comprehensive list of the endangered wildlife of the country was prepared.
- The Act **prohibited the hunting of endangered species**.
- Scheduled animals are prohibited from being traded as per the Act's provisions.
- The Act provides for licenses for the sale, transfer and possession of some wildlife species.
- It provides for the establishment of wildlife sanctuaries, national parks, etc.
- Its provisions paved the way for the formation of the **Central Zoo Authority**. This is the central body responsible for the oversight of zoos in India. It was established in 1992.
- The Act created **six schedules** which gave varying degrees of protection to classes of flora and fauna.
- Schedule I and Schedule II (Part II) get absolute protection and offences under these schedules attract the maximum penalties.
- The schedules also include species which may be hunted.
- The **National Board for Wildlife** was constituted as a statutory organisation under the provisions of this Act.
- This is an advisory board that offers advice to the central government on issues of wildlife conservation in India.
- It is also the apex body to review and approve all matters related to wildlife, projects of national parks, sanctuaries, etc.

- The chief function of the Board is to promote the conservation and development of wildlife and forests.
- It is chaired by the Prime Minister.
- The Act also provided for the establishment of the **National Tiger Conservation Authority.**
- It is a statutory body of the Ministry of Environment, Forest and Climate Change with an overall supervisory and coordination part, performing capacities as given in the Act.
- Its mandate is to strengthen tiger conservation in India.
- It gives statutory authority to **Project Tiger** which was launched in 1973 and has put the endangered tiger on a guaranteed path of revival by protecting it from extinction.

Protected Areas under the Wildlife Protection Act

There are five types of protected areas as provided under the Act. They are described below.

1. **Sanctuaries:**

"Sanctuary is a place of refuge where injured, abandoned and abused wildlife is allowed to live in peace in their natural environment without any human intervention."

1. They are naturally-occurring areas where endangered species are protected from poaching, hunting and predation.
2. Here, animals are not bred for commercial exploitation.
3. The species are protected from any sort of disturbance.
4. Animals are not allowed to be captured or killed inside the sanctuaries.
5. A wildlife sanctuary is declared by the State government by a Notification. Boundaries can be altered by a Resolution of the State Legislature.

6. Human activities such as timber harvesting, collecting minor forest products and private ownership rights are permitted as long as they do not interfere with the animals' well-being. **Limited human activity is permitted.**

7. They are open to the general public. But people are not allowed unescorted. There are restrictions as to who can enter and/or reside within the limits of the sanctuary. Only public servants (and his/her family), persons who own immovable property inside, etc. are allowed. People using the highways which pass through sanctuaries are also allowed inside.

8. Boundaries of sanctuaries are not generally fixed and defined.

9. Biologists and researchers are permitted inside so that they can study the area and its inhabitants.

10. The **Chief Wildlife Warden (who is the authority to control, manage and maintain all sanctuaries)** may grant permission to persons for entry or residence in the sanctuary for the study of wildlife, scientific research, photography, the transaction of any lawful business with persons residing inside, and tourism.

11. Sanctuaries can be upgraded to the status of a 'National Park'.

12. **Examples:** Indian Wild Ass Sanctuary (Rann of Kutch, Gujarat); Vedanthangal Bird Sanctuary in Tamil Nadu (oldest bird sanctuary in India); Dandeli Wildlife Sanctuary (Karnataka).

2. National Parks:

"National Parks are the areas that are set by the government to conserve the natural environment."

1. A national park has more restrictions as compared to a wildlife sanctuary.

2. National parks can be declared by the State government by Notification. No alteration of the boundaries of a national park shall be made except on a resolution passed by the State Legislature.

3. The main objective of a national park is to protect the natural environment of the area and biodiversity conservation.

4. The landscape, fauna and flora are present in their natural state in national parks.
5. Their boundaries are fixed and defined.
6. Here, no human activity is allowed.
7. Grazing of livestock and private tenurial rights are not permitted here.
8. Species mentioned in the Schedules of the Wildlife Act are not allowed to be hunted or captured.
9. No person shall destroy, remove or exploit any wildlife from a National Park or destroy or damage the habitat of any wild animal or deprive any wild animal of its habitat within a national park.
10. They cannot be downgraded to the status of a 'sanctuary'.
11. Examples: Bandipur National Park in Karnataka; Hemis National Park in Jammu & Kashmir; Kaziranga National Park in Assam. See more on List of National Parks in India.

3. Conservation Reserves:

The State government may declare an area (particularly those adjacent to sanctuaries or parks) as conservation reserves after consulting with local communities.

4. Community Reserves: The State government may declare any private or community land as a community reserve after consultation with the local community or an individual who has volunteered to conserve the wildlife.

5. Tiger Reserves: These areas are reserved for the protection and conservation of tigers in India. They are declared on the recommendations of the National Tiger Conservation Authority.

The amended Wildlife Act doesn't allow any commercial exploitation of forest produce in both wildlife sanctuaries and national parks, and local communities are allowed to collect forest produce only for their bona fide requirements.

Environmental degradation

Environmental degradation is the deterioration of the environment through depletion of resources such as air, water and soil; the destruction of ecosystems; habitat destruction; the extinction of wildlife; and pollution. Pollution is the main cause of environmental degradation. For example, air pollution pollutes the air we breathe. Major causes of air pollution are biomass burning, smoke from vehicles, and burning of fossil fuels.

In other words, different type of activities which alters the systems of environment and causes disturbances to air, water, soil, and land this is called environmental degradation.

• Excessive and misuse of natural resources and other human activities are also one of the causes of environmental degradation.

• Deforestation, climatic changes affect Earth's water supply in an enormous way.

• We should take some preventive measures to protect our environment from degradation.

Environmental pollution

Environmental pollution or simply pollution refers to undesirable changes occurring in the physical, chemical, and biological composition of natural environment consisting of air, water, and soil. Pollution also means the presence of harmful pollutants in an environment that makes this environment unhealthy to live in.

According to National Academy of Science, USA (1966), **pollution** is defined as, "An undesirable change in physical, chemical, and biological characteristics of water, air, and soil that may harmfully affect human, animal, and plant life, industrial progress, living conditions and cultural assets.

Pollution is also viewed as 'an unfavourable alteration' in the sustaining and carrying capacity of the natural environment wholly or largely by the by-products of human activities. Natural environment has an inbuilt capacity to replenish the

losses or reduction in its constituents to restore it as sustainable and healthy as required.

Pollutants

A pollutant is defined as any form of energy or matter or action that causes imbalance or disequilibrium in the required composition of natural objects such as air, water, etc. A pollutant creates damage by interfering directly or indirectly with the biogeochemical process of an organism.

Pollutants may be −

- **Natural Pollutants** − Natural pollutants are caused by natural forces such as volcanic eruption and forest fire.
- **Man-made Pollutants** − These refer to the release of excess amount of gases or matter by human activities. For instance, increase in the number of automobiles adds excess carbon monoxide to the atmosphere causing harmful effect on vegetation and human health.

Classification of Pollution

Different types of pollution are classified based on the part of the environment which they affect or result caused by a particular pollution. Each type of pollution has its own distinctive cause and consequences.

The major types of pollution are as follows.

- Air pollution
- Water pollution
- Noise pollution
- Soil or land pollution

Air pollution

Air pollution is one of the most widespread forms of pollution all over the world. Wind is the main agent of air pollution. It gathers and moves pollutants from one area to another, sometimes reducing the concentration of pollutants in one location, while increasing it in another.

Causes of Air Pollution

Apart from the natural causes of pollutants, as stated above, human interaction and resource utilization is perhaps adding more pollutants to the atmosphere.

- **Industrialization** − Industries big or small require steam to run. The steam is produced by burning fossil fuels such as coal, coke, and furnace oil. These fuels while burning release toxic gases in large amount into the atmosphere.
- **Automobiles** − To meet the demands of exploding human population, the number of automobiles is increasing at a great space. The automobile exhausts are responsible for about sixty percent of air pollution. Released carbon monoxide from the automobiles pollutes the air and harms trees and other natural vegetation. It also has ill-effects on human health.
- **Chlorofluorocarbons** − Scientists are now alarmed regarding the increased concentration of chemical substances together called chlorofluorocarbon in the atmosphere. These substances are responsible for creating holes in the ozone layer causing unwanted imbalance in the heat budget. These are produced by modern gadgets such as air conditioners, refrigerators, dyers, etc.

The adverse effects of air pollution appear in the form of poor quality of air, acidic precipitation (rain, snow and hail) and deposition, and other health hazards.

The main pollutants of air are carbon dioxide (CO_2), carbonic acid (H_2SO_2), water (H_2O), nitric acid (HNO_3O), and sulphuric acid (H_2SO_4).

Air pollution has harmful effects on natural vegetation and human health such as respiratory illnesses. Acidic precipitation is highly fatal for aquatic flora and fauna, monuments, and also for natural vegetation.

Control of air Pollution

Air pollution control is an onerous task as there are large number of pollutants involved in air pollution. Some of these are even difficult to detect. However, there can be some basic approaches to control air pollution. They are as follows.

Water pollution

Water pollution may be defined as alteration in physical, chemical, and biological characteristics of water, which may cause harmful effects on human and aquatic life.

Pollutants of Water

Following are some of the reasons for water pollution.

- Disposal of sewage and sludge into water bodies such as river, streams, and lakes.
- Inorganic compounds and minerals by mining and industrial activities.
- Use of chemical fertilizers for agricultural purposes.
- Synthetic organic compounds from industrial, agricultural, and domestic garbage.
- Oil and petroleum from tankers' accident, offshore drilling, combustion engine, etc.
- Radioactive wastes

Water Pollution Control

- **Environmental Education** − Individuals and the masses should be educated about the significance of quality of water and its impact on the economy, the society, and ecology.
- **Sewage Treatment** − The household water should be treated properly to make it environmentally safe. Necessary steps should be taken to ensure that effective sewage treatment process is put in place and contaminated water doesn't get mixed with the fresh water bodies.
- **Accountability of Industrial Units** − The industrial setups should make provisions for treatment of waste materials and water, and for its safe drainage.
- **Afforestation** − Planting trees can reduce the water pollution to a large extent as they check surface soil runoff by running water.

- **Soil Conservation** − Soil conservation add many inorganic substances in the surface and underground water. Soil conservation is, therefore, a useful technique to reduce water pollution.
- **Reduced Use of Chemical Fertilizers** − Chemical fertilizers add nitrates in water bodies. Use of compost manures can help reduce the problem of eutrophication in the water bodies.
- **Financial Support** − Governments should make provisions for adequate funds to the civic bodies for water pollution control.
- **Legislation and Implementation of Stringent Environmental Laws** − The need of the hour is that the government should legislate and implement strict environmental laws for the protection of water bodies, treatment of waste water, etc. The violators of such laws should be given exemplary punishment.

Noise pollution refers to any unwanted and unpleasant sound that brings discomfort and restlessness to human beings. Like air and water pollution, noise pollution is harmful to human and animal life.

Noise pollution is also an important environmental hazard, which is becoming growingly injurious in many parts of the world. Noise beyond a particular level or decibel (unit of noise) tends to become a health and environmental hazard.

Sources of Noise Pollution

- Household appliances such as grinders, electric motor, washing machines
- Social gatherings such as marriages and other social parties
- Places of worship
- Commercial activities
- Construction activities
- Industrial activities
- Automobiles and transport system
- Power generators
- Agricultural equipment

Control of noise Pollution

According to the World Health Organization (WHO), of all the environmental pollution, noise is the easiest to control.

Noise pollution can be checked at home by −

- Turning off sound-making appliances when they are not in use.
- Shutting the door when noisy machines are being used.
- Lowering the volume of appliances such as television to a desirable level.
- Using earplugs while listening to music.

At mass level it can be checked by −

- By planting trees in large number to create vegetation buffer zones, which absorb noise.
- Public awareness about the need of control of noise pollution.
- Application of engineering control techniques such as alteration and modification of design to reduce noise from equipment and machinery, and by construction of sound barriers or the use of sound absorbers in industrial and factory sites can reduce exposure to noise to a great extent.
- Construction of institutions and hospitals away from airports, railways, and highways.
- Improved building design may also reduce the impact of noise pollution.
- Stringent legislations at central and state levels to check air pollution at workplaces, urban centers, etc.

Soil pollution

Soil pollution refers to an undesirable decrease in the quality of soil, either by man-induced sources or natural sources or by both.

Soil is vital not only for the growth of plants and growing food but also cultivating raw materials for agro-based industries. Health soil is a significant prerequisite for human survival.

Causes of Soil Erosion

- Deforestation at large scale
- Over-grazing
- Mining
- Decrease in soil microorganisms
- Excessive use of chemical fertilizers
- Excessive use of irrigation
- Lack of humus content
- Improper and unscientific rotation of crops

Soil pollution leads to many harmful consequences such as decrease in agricultural production; reduced nitrogen fixation; reduction in biodiversity; silting of tanks, lakes and reservoirs; diseases and deaths of consumers in the food chain due to use of chemical fertilizers and pesticides, etc.

Control of soil Pollution

- Adoption of soil-friendly agricultural practices.
- Use of compost manures in place of chemical fertilizers; Use of bio-fertilizers and natural pesticides help in minimizing the usage of chemical fertilizers and pesticides
- Scientific rotation of crop to increase soil fertility.
- Proper disposal of industrial and urban solid and liquid wastes.
- Planting of trees to check soil erosion in slopes and mountainous regions.
- Controlled grazing.
- Reduction in the heaps of garbage and refuse.
- The principles of three R's − **Recycle, Reuse**, and **Reduce** − help in minimizing generation of solid waste.
- Formulation and effective implementation of stringent pollution control legislation.
- Improved sewage and sanitation system in urban areas.

Thermal pollution

The term thermal pollution has been used to indicate the detrimental effects of heated effluent discharge by various power plants. It denotes the impairment of quality and deterioration of aquatic and terrestrial environment by various industrial plants like thermal, atomic, nuclear, coal-fired plants, oil field generators, factories, and mills.

sources of Thermal Pollution

1. Nuclear Power Plant
2. Coal-fired power Plant
3. Industrial Effluents
4. Domestic Sewage
5. Hydro-electric power
6. Thermal Power Plant

The discharged effluents of these sources have a higher temperature than the intake water that reduces the concentration of oxygen from the water which causes the deleterious effects on the marine ecosystem.

Harmful effects of thermal pollution

The harmful effects of the thermal pollution are discussed below:

1. Reduction in dissolved Oxygen

The pollutant from various industrial plants are heated decreases the concentration of oxygen with an increase in the temperature of water.

2. Change in water properties

The decrease in density, viscosity and solubility of gases in water increases the setting speed of suspended particles which seriously affect the food supplies of aquatic organism.

3. Increase in toxicity

The concentrated pollutant causes the rise in the temperature of water which increases the toxicity of the poison present in water. The toxicity in water will increase the death rate in marine life.

4. Disruption of Biological activities

Temperature changes disrupt the entire marine ecosystem because changes in temperature causes change in physiology, metabolism and biological process like respiration rate, digestion, excretion and development of an aquatic organism.

5. Damage of biotic organism

Aquatic organisms like juvenile fish, plankton, fish, eggs, larva, algae and protozoa which pass through screens and condenser cooling system are extremely sensitive to abrupt temperature changes. They are habitual of warmer water may suddenly face increase or decrease in temperature of water bodies and thus die because of sudden changes in the temperature of water.

thermal pollution be prevented?

The following measures can be taken to prevent or control high temperature caused by thermal pollution:

1. Heated water from the industries can treated before discharging directly to the water bodies.

2. Heated water from the industries can be treated by the installation of cooling ponds and cooling towers.

3. Industrial treated water can be recycled for domestic use or industrial heating.

4. Through artificial lakes: In this lake Industries can discharge their used or heated water at one end and water for cooling purposes may be withdrawn from the other end. The heat is eventually dissipated through evaporation.

Hence, we can say any kind of pollution may directly or indirectly affect humans because the loss of biodiversity causes changes that affect all the aspects of the environment

Global Warming

Global Warming is the increase in Earth's mean surface temperature because of the effect of greenhouse gases. These gases absorb longwave radiations and warm the atmosphere, and this process is called a Greenhouse effect.

It had led to many changes on the planet, such as a rise in sea level; massive melting of snow and land ice, elevated heat content of the oceans, increased humidity, change in the timings of seasonal events, and many others.

Effects of Greenhouse Gases (GHGs) on Global Warming

The main greenhouse gases, namely: **Carbon dioxide (CO_2); Methane (CH_4); Nitrous oxide (N_2O); Hydrofluorocarbons (HFCs); Perfluorocarbons (PFCs); and Sulphur hexafluoride (SF_6)**. The impact of any GHG is based on the magnitude of the rise in its concentration, its duration in the atmosphere and the wavelength of radiation that is absorbed.

1. Carbon dioxide is the GHG which is present in the largest concentration in the atmosphere. Its emission chiefly comes from fossil fuel combustion. It is showing a rise of about 0.5% per annum.

2. Chlorofluorocarbons (CFCs) are produced due to anthropogenic activity. Ozone is present in the stratosphere where ultraviolet (UV) radiations convert oxygen into ozone. Hence, the UV rays do not reach the Earth's surface. The CFCs which goes into the stratosphere destroys the ozone, which is evidently seen over Antarctica. The reduction of ozone concentration in the stratosphere is known as the ozone hole. This permits the UV rays to pass through the troposphere.

3. Nitrous oxide is naturally produced by oceans and rainforests. Man-made sources of nitrous oxide include nylon and nitric acid production, the use of fertilisers in agriculture, cars with catalytic converters and the burning of organic matter.

4. Hydrofluorocarbons (HFCs) are used as refrigerants, especially after the ozone-destroying CFCs had been under the Montreal Protocol.

5. Perfluorocarbons (PFCs): Emitted as a result of production of flourites, they have an atmospheric lifetime of more than 1,000 years.

6. Sulphur hexafluoride (SF_6): The most powerful greenhouse gas yet discovered, it is emitted as result of production of flourites.

What is Green Muffler & its relation with pollution?

Global efforts have been started for decreasing the emission of GHGs into the atmosphere. Of the many initiatives, the most important one is the *Kyoto protocol* declared in 1997, and came into effect in 2005, authorized by 141 countries. Kyoto protocol controlled 35 industrialised nations to reduce the emission of GHGs by the year 2012 to 5% less than the levels present in the year 1990.

The concentrations of greenhouse gases are not larger than oxygen and nitrogen, because neither has more than two atoms per molecule, and so they lack the internal vibrational modes that molecules with more than two atoms possess. Both water and CO_2 have these "internal vibrational modes", and these modes of vibrations can consume and resend infrared radiation, which causes the greenhouse effect.

Impacts of Global Warming

1. **Rising Sea level:** Flooding of fresh water marshlands, low-lying cities, and islands with marine water is one of the major effects of global warming.
2. **Changes in rainfall patterns:** In some areas, droughts and fires happen, whereas in other areas, flooding takes place. This all is due to changes in rainfall pattern.
3. **Melting of the ice peaks:** Due to melting of the ice peaks, there is loss of habitat near the poles. Now the polar bears are considered to be greatly endangered by the shortening of their feeding season because of declining ice packs.
4. **Melting glaciers:** There is a significant melting of old glaciers.
5. **Spread of disease:** There is spread of diseases like malaria due to migration to newer and currently warmer regions.
6. **Thinning of Coral Reefs** due to warming seas as well as acidification because of carbonic acid formation: Almost one-third of coral reefs are now severely damaged by warming seas.
7. **Loss of Plankton** owing to warming seas: The large (900 miles long) Aleutian island ecosystems consisting of whales, sea lions, sea urchins, kelp beds, fish, and other aquatic animals, has now reduced due to loss of plankton.

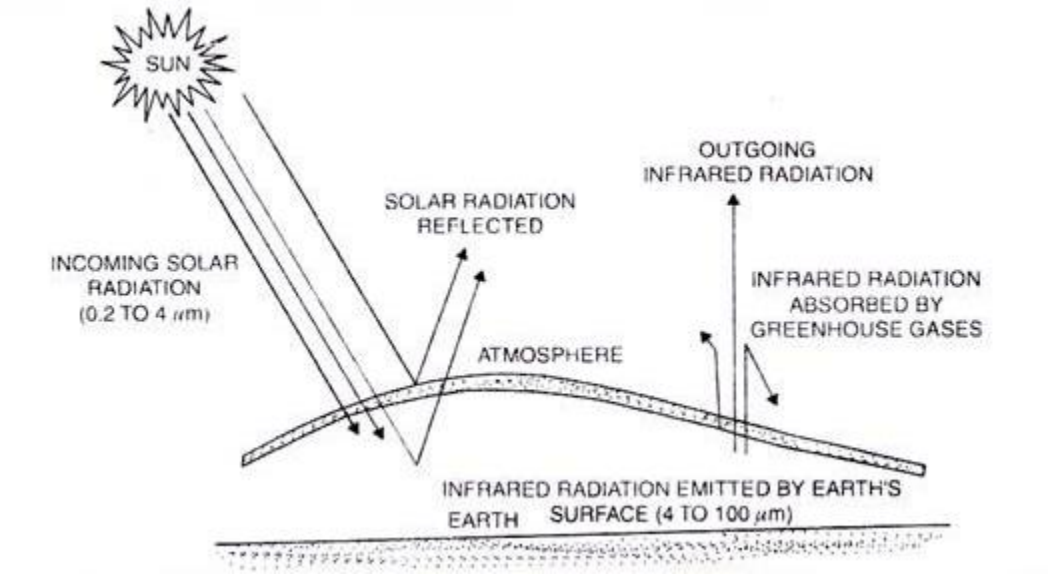
Green-house effect

The green-house effect is a naturally occurring phenomenon which is responsible for heating the earth surface and atmosphere.

Due to green-house effect, the average temperature of earth surface is 15°C and without green-house effect the average temperature would have been – 18°C.

A green-house (also called as glasshouse) is a building in which plants are grown. These structures range in size from small sheds to industrialized buildings.

A greenhouse has different type of covering materials, such as glass or plastic roof and walls. It accumulates temperature and heats up because incoming visible solar radiation from the sun is absorbed by plants, soil and other things inside the building. The absorbed radiation gets accumulated and converted to heat energy (lower frequencies of infrared thermal radiation). Infrared radiation is absorbed by green-house gases and water vapours. Some of the heat rays one reflected by the glass panes and again come back to the surface. Warming effect found in green-house is due to accumulation of heat rays. green-house warm up is similar to the inside of a car parked in the sun for some time.

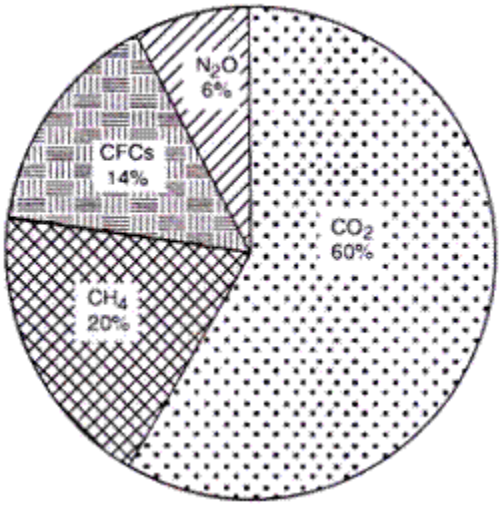


The gases which allow the solar radiations to pass through but retain the long wave heat radiations are called green-house gases. The various green-house gases are CO_2, CH_4, CFCs and N_20 and others of minor significance are water vapours and

ozone. They prevent a substantial part of long wave radiations emitted by earth to escape into space.

(i) Carbon dioxide:

It is considered as the most important green-house gas. Its normal level in atmosphere is 0.03%. Its concentration was 280 ppm (parts per million) 1750, 368 ppm in 2000 and 380 in 2007. The rise of CO_2 is due to large scale deforestation and combustion of fossil fuels. The forest coverage was 33% in the beginning of 20th century but reduced to 19.4% by the end of the century. Excessive use of fossil fuel is adding more CO_2 to atmosphere. About 5 x 10^9 tons of CO_2 is added every year through burning of fossil fuel.



(ii) Methane:

It traps 20 times as much heat as CO_2. Its concentration was 700 ppb (parts per billion) in pre-industrial times but 1750 ppb in the year 2000. CH_4 is produced by incomplete biomass combustion incomplete decomposition mostly by anaerotric methanogens, flooded paddy fields, marshes, enteric fermentation of cattle etc. In arctic regions, methane comes out of earth's interior at many places called methane chimneys.

(iii) Chlorofluorocarbons (CFCs):

These are synthetic gaseous compounds of carbon and halogen which are frequently used as cooling gas in refrigerators and air conditioners (Freon-12). These are odourless, non-toxic, non-inflammable, chemically inert propellants used in aerosol cans and jet fuel, fire extinguishers, plastic foams and room fresheners. They are highly stable and non-degradable. All CFCs liberated into atmosphere slowly move to stratosphere and cause ozone depletion. They trap 1500 to 7000 times as much heat as per molecule of CO_2.

(iv) Nitrous Oxide (N_2O):

It is another green-house gas released in atmosphere through burning of fossil fuels, lightning and thunder, microbial activities, livestock wastes, breakdown of nitrogen fertilizers in soil etc. Its lifespan in atmosphere is about 120 years. It traps about 2000 times as much heat per molecule as CO_2.

(v) Water vapour:

It also helps in heat trapping mechanism in atmosphere and its role as a green-house gas cannot be ignored.

The green-house effects are global warming depletion of ozone layer in stratosphere and CO_2 fertilization effect on plants.

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