

**CHAPTER - 01**

**ENVIRONMENT,  
ECOLOGY AND MAN**

## **ENVIRONMENT**

The earth is the only planet known to support life, as we know it. It supplies us with all the resources, the materials we use and the food that we eat or drink. All living organisms have a specific surrounding or medium with which they continuously interact, from which they derive substance and to which they are fully adopted. This surrounding is generally called their environment.

### **Meaning**

Usually by “Environment” we mean surroundings, conditions, influences and circumstances. It can be broadly defined as the sum total of physical, chemical and biological condition, which surrounds an organism or a group of organism.<sup>1</sup>

According to **Webster Dictionary of the English language** “The aggregate of all conditions affecting the existence, growth, and welfare of an organism or group of organisms is called environment.”<sup>2</sup>

**Oxford Advanced Learner’s Dictionary** states “Environment is the conditions, circumstances etc. affecting a person’s life.”<sup>3</sup>

According to the **Hutchinson Dictionary of Ideas** “Environment in ecology, the sum of conditions affecting a particular organism, including physical surrounding, climate, and influences of other living organism. In common usage, ‘the environment’ often means the total global environment, without reference to any particular organism.”<sup>4</sup>

The **American Heritage Dictionary of the English language** states about environment:

1. “The circumstances or conditions that surround one, surroundings.
2. The totality of circumstances surrounding an organism or group of organism specially;
  - (a) The combination of external physical conditions that affect and influence the growth, development and survival of organism.
  - (b) The complex of social and cultural conditions affecting the nature of an individual or community.”<sup>5</sup>

According to **Kernerman English Learner's dictionary** Environment is “a set of surrounding conditions, especially those influencing development or growth.”<sup>6</sup>

**Dictionary of Ecology and Environment** presents environment as “The region, surroundings or circumstances in which anything exists; everything external to the organism. The environment of an organism includes:

- (i) The purely physical or abiotic milieu in which it exists, e.g. geographic location, climate conditions, and terrain.
- (ii) The organic or biotic milieu including nonliving organic matter and all other organisms, plants and animals in the region including the particular population to which the organism belongs.

“The effective environment is everything external to the organism.”<sup>7</sup>

Thus, as a whole it can be said that environment is the sum total of living and non-living components, influences and events surrounding an organism. A human being's environment includes such factors as temperature, food supply, and other people that surround him. A plant's environment may be made up of soil, sunlight, and animals that will eat the plant. A rock's environment may be made up of seaweed, water and fish.

Broadly environment has two components namely abiotic and biotic. Living components are called biotic, while nonliving are called abiotic components. Both abiotic and biotic environment interact to make up the total environment to living and nonliving things.

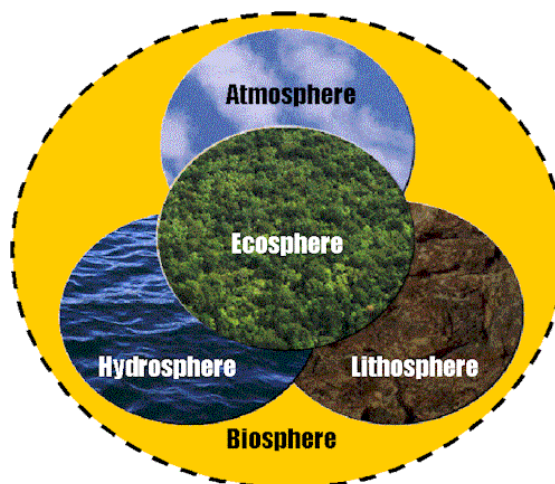
**Table : 1.1. : Components of the Environment**

<b>Abiotic</b>	<b>Biotic</b>
Light (Energy, Radiation)	Microbes
Atmospheric Gases and Wind	Plants
Temperature and Heat Flow	Animals (including Human beings)
Water	
Gravity	
Topography	
Geological Substratum Soil	

Abiotic environment includes such factors as soil, water, atmosphere, and radiation. The abiotic environment is made-up of many objects and forces that influence one another and the surrounding community of living things. The weather is an important group of abiotic factors as the living and nonliving things are highly influenced by rain, snow, hot or cold temperature, evaporation of water, humidity (amount of water vapour in the air), wind and numerous other weather conditions. Other abiotic factors include the amount of living space and certain nutrients available to an organism.

Biotic component includes food, plants, animals and their interaction among one another and the abiotic environment. Man's survival and well being depend largely on his intake (food, water etc) and his association with other living things.<sup>8</sup>

Living beings normally cannot exist more than a few kilometers between the surface of the earth, or more than a few kilometers above it. Life occupies an incredibly thin skin at earth surface. This is known as biosphere. Biosphere is defined as that part of the earth and atmosphere in which many smaller ecosystems exist and operate. Three main subdivision of the biosphere are lithosphere (solid matter); hydrosphere (liquid matter), and atmosphere or the gaseous envelope of the earth, which extends up to height of 22.5 km. Figure shows the idealized scheme of biosphere in relation to hydrosphere, atmosphere and lithosphere. The area of contact and interaction between components is very important for life, for it is here the entire life is confined and basic processes of life like photosynthesis and respiration occur.



**(Picture – 1 : Biosphere)**

The biosphere includes four major environmental categories or habitats – marine, estuarine, fresh water and terrestrial. The terrestrial habitat is further classified in biomes. Biomes are the major subdivision of the terrestrial portion of the biosphere each recognizable by the characteristic structure of its dominant vegetation. The earth's dozen or more biomes are spread over millions of square miles and span entire continents. No two climates, exactly alike, the average weather conditions in a given region determine the boundaries of a biome and the abundance of plants and animals found in each one. The types of biomes are grasslands, desert, coniferous forests, deciduous forest, tropical forests, tundra, fresh water and marine environment.<sup>9</sup>

### **Types of Environment**

The Environment is basically divided into three types as follows:

- 1. Natural Environment** – The natural environment commonly referred to simply as the environment, encompasses all living and non-living things accruing naturally on earth or some region thereof. Complete ecological units that function as natural systems without massive human intervention, including all vegetation, animals, microorganisms, soil, rocks, atmosphere and natural phenomena that occur within their boundaries are considered within natural environment. Moreover, all the universal natural resources and physical phenomena that lack clear cut boundaries, such as air, water, and climate as well as energy, radiation, electric charge, and magnetism, not originating from human activity, are the part of natural environment. In any of these natural environment the climate, physiological, edaphic (soil-related) and biotic factors interact with each other and influence the life forms.
- 2. Man-made Environment** – There are some components of environment, which are created by humans, like crops field, cities, industrial spaces etc. These are places made artificially by human through manipulation. Cities are the best example of man-made environment. The city environment is created by man himself. One of the most important components of life, i.e. water is not taken from streams directly. It is filtered and purified, and then used for drinking and to other municipal purposes.

- 3. Socio-cultural Environment** – We all live in a society, which has culture of its own and possess people having their own life style. The socio cultural environment means the environment, which is created by the man through his various social and cultural activities. The historical, cultural, political, moral, economic aspects of human life constitute to the socio-cultural environment. Social environment includes cultural norms and values. Political economics and religious institutions constitute an important part of the social milieu and often decide how the environmental resources will be utilized by people, and for whose benefit these will be utilized. The socio- cultural environment affects the social culture of human being and hence it is of the great significance.<sup>10</sup>

## **ECOLOGY**

The word ‘ecology’, derived from the Greek word ‘oikos’, meaning “house or place to live”- is the study of the relationship between organisms and their environment or, broadly speaking, their houses. It is the science of the inter-relationship between living organisms and their environment.<sup>11</sup> In other words, it is scientific study of the distribution and abundance of life and the interaction between organisms and their natural<sup>12</sup> environment – it is the body of knowledge concerning with the economy of nature - the investigation of the total relation of the animal both to its inorganic and to organic environment including above all, its friendly and inimical relation with those animals, and plants with which it comes directly or indirectly into interaction.<sup>13</sup>

The term ‘ecology’ was first coined in the later half of the nineteenth century by German biologist Ernst Haeckel in 1866. Hanns Reiter has been the first for its connotation. He combined the Greek word ‘oikos–house and Logos – study of’, to form the term ecology. Before this many great men of the biological renaissance had contributed to the subject, even though the label ‘ecology’ was not in use. In 1863, Isodore Geoffrey St. Hilair, a French Zoologist had proposed the term ‘ethology’ for the study of the relations or the organism within the family and society in its aggregate and in community. Later on ethology became a synonym for the study of animal behaviour. In 1884, St. George Jackson Mivart, an English naturalist coined the term ‘lexicology’, he defined it to be devoted to the study of

the relation which exist between the organism and their environment as regards the nature of the locality they frequent, the temperatures and the amounts of light which suit them, and their relation to other organism as enemies, rivals or accident and involuntary benefactors.” Later on, Chales Elton, a British ecologist, defined ecology as “Scientific natural history” concerned with the “sociology and economics of animals”. Fredrick Clements, an American plant ecologist, defined ecology as “the science of the community”. Karl Frederick, a German ecologist, took it as “the science of the environment” In the same period Eugene Odum, an American ecologist, analysed it as “the study of the structure and function of nature”. However, ecology is multi-disciplinary and almost boundless in its concern as stated by A. Macfadyen, a British ecologist: “Ecology concerns itself with the inter-relationship of living organism, plants or animals and their environment, these are studied with a view of discovering the principles which govern the relationship. That such principles exist is a basic assumption- and an act of faith of the ecologist. His field of enquiry is no less wide than the totality of the living conditions of the plant and animals under observations, their systematic position, their reaction to the environment and to each other, and the physical and the chemical nature of their inanimate surroundings..... . It must be admitted that the ecologist is something of a chartered libertine. He roams at will over the legitimate preserves of the plant and animal biologist, the taxonomist, the physiologist, the behaviorist, the meteorologist, the geologist, the physicist the chemist and even the sociologist; he poaches from all these and from other established and respected disciplines. It is indeed a major problem of the ecologist, in his own interest; he set bounds to his divagations.”<sup>14</sup>

### **Disciplines of Ecology**

In regard to sub-division or disciplinary of ecology, it is often broadly divided into:

- (i) **Plant Ecology** – It includes the study of plants in relation to environment;
- (ii) **Animal Ecology** – It is the study of animals in relation to environment;
- (iii) **Autecology** includes the study of the ecology of an individual or a particular species of organism;

- (iv) **Synecology or Community ecology** includes the study of communities or entire population. It deals with the inter-relationship between plants and animals and this forms the basis of community;
- (v) **Habitat ecology:** This branch of ecology depends upon the study of habitats and their effects on the living organisms on earth. It includes forest ecology, grass land ecology, cropland ecology, desert ecology, fresh water, marine ecology etc.
- (vi) **Population ecology** includes the study of the inter-relationship of different groups of organism, including the manner of growth, structure and distribution of population. Population ecology is also called the demecology.
- (vii) **Ecosystem ecology** deals with the study and analysis of ecosystem including soil formation, nutrient cycle, energy flow, and productivity.
- (viii) **Paleo-ecology** deals with the study of the organisms in their environment in geological past. It helps us to trace the gaps in the evolutionary lines and origin of various groups of plants and animals.
- (ix) **Physiological ecology** deals with the effect of environmental factors on the functional aspect of organism. It also includes the survival of populations as a result of functional adjustments of organism with different ecological conditions.
- (x) **Taxonomic ecology** includes the ecology of various taxonomic groups as insect ecology, avian ecology, human ecology, microbial ecology, invertebrate ecology etc.
- (xi) **Production ecology** is concerned with the gross and net production of different ecosystems like fresh water, agriculture, horticulture, etc. The productivity is measured both in gross and net values. The total organic production is called gross production, while the actual gain after deducting the loss due to respiration is called net production.
- (xii) **Space ecology** is the youngest branch of ecology and is concerned with the development of partial or completely regenerating ecosystems for



supporting life of man during long space flights or during extended exploration of extra terrestrial environments.

(xiii) **Gene ecology** is concerned with the genetic make up of a species or population in relation to environment. It deals with the origin and inheritance of adaptation in plant and animals.

(xiv) **Human ecology** deals with the man's effects on the biosphere and the implication of these effects on man. It deals with the environment of man.<sup>15</sup>

## **ECOSYSTEM**

A species or an organism can never live alone. They are always influencing each other and organising themselves into communities; besides they have functional relationship with their external environment. This structural and functional system of communities and their environment is called 'ecosystem'.

Ecosystems are dynamic interaction between plants, animals, and microorganisms and their environment working together as a functional unit. Ecosystem in nature works the same way. All the parts work together to make a balanced system. Ecosystems are composed of organisms interacting with each other and with their environment such that energy is exchanged and system-level processes, such as the cycling of elements, emerge. Ecosystem is a core concept in Biology and Ecology, serving as the level of biological organization in which organisms interact simultaneously with each other and with their environment.<sup>16</sup>

According to Wikipedia "The term ecosystem refers to the combined physical and biological components of an environment. An ecosystem is generally an area within the natural environment in which physical (abiotic) factors of the environment such as rocks and soil, function together along with interdependent (biotic) organisms, such as plants and animals, within the same habitat."<sup>17</sup>

**Britannica Concise Encyclopedia** states "Ecosystem is complex of living organism, their physical environment, and all their interrelationship in a particular unit of space."<sup>18</sup>

**Sci-Tech Encyclopedia** defines ecosystem as a "functional system that includes an ecological community of organism together with the physical environment

interacting as a unit. Ecosystems are characterized by flow of energy through food webs, production and degradation of organic matter, and transformation and cycling of nutrient elements.”<sup>19</sup>

**Geography Dictionary** defines ecosystem as a community of plants and animals within defines ecosystem as a particular physical environment, which is linked by a flow of materials through the non-living as well as the living sections of the system.<sup>20</sup>

**Archaeology Dictionary** defines ecosystem as “the set of relationship between living and non-living things in nature on a specific natural community, including the interaction of climate, soil, rivers and all forms of animals and plants.”<sup>21</sup>

Thus, in short, ecosystem can be defined as a system formed by the interaction of a community of organism with their environment. Ecosystem includes living organisms, the dead organic matter produced by them, the abiotic environment within which the organisms live and exchange elements (soil, water, atmosphere), and the interaction between these components. The central theme of ecosystem is that at any place where an organism live, there is a continuous interaction between the living and non-living components, i.e. between plants, animals and their environment. They continuously produce and exchange materials. The interaction between living and non-living components of an ecosystem involves input, transfer, storage and output of energy and essential materials through the system. Each of these processes is energy-dependent. As a result of these complex interactions, the ecosystem has to adjust these changes and attains a state of equilibrium. An ecosystem, therefore, is a system that is self-regulatory based on feed-back information about the population and the limiting factors which control the living and non-living components.<sup>22</sup>

### **History of the Ecosystem Concepts**

The term ‘ecosystem’ was first coined by Royclapham in 1930, but it was ecologist Arthur Tansley, who fully defined the ecosystem concept. In his classic article of 1935, Tansley defined ecosystem “The whole system .... including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment.”<sup>23</sup>

The concept of ecosystem is very broad, and emphasizes the obligatory relationship, the causal relationships and interdependence of biotic and abiotic components. In 1954, Woodbury described the ecosystem as the approach in which habitat, plants and animals are all considered as one interacting unit, materials and energies of one passing in and out of the others. Ecologists use the term 'ecosystem' to indicate a natural unit of living and non living parts that interact to produce a stable system in which exchange of materials between living and nonliving follow a circular path.<sup>24</sup> E.P. Odum, one of the founders of the science of ecology, stated "Any Unit that includes all of the organism (i.e. the community) in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity, and material cycle (i.e. exchange of materials between living and non-living parts) within the system is an ecosystem."<sup>25</sup> In 1974, S. Mathanam described the ecosystem as 'an ecological system, is a sum total of living organisms, the environment and the processes of interaction between and within all parts of the system.'<sup>26</sup>

### **Structural Components of the Ecosystem**

Ecosystem may be observed in many possible ways, so there is no one set of components that make up ecosystems. However, all ecosystems must include both biotic and abiotic components, their interaction and some source of energy. The simplest (and least representative) of eco-system might therefore contain just a single living plants (biotic component) within a small terrarium exposed to light to which a water solution containing essential nutrients for plant growth has been added (biotic components). The other extreme would be the biosphere, which comprises the totality of earth's organisms and their interaction with each other and the earth system (abiotic environment). And of course, most ecosystem fall somewhere in-between these extremes of complexity. Generally, an ecosystem has two components - the biotic components, consisting of living things, and the abiotic portion, consisting of elements that are not alive. The non-living constituents are said to include the following categories: habitat, gases, solar radiation, temperature, moisture, and inorganic and organic nutrients. The living organisms may be sub-divided into producers, consumers and decomposers according to their specific role in keeping the ecosystem operating as a stable interacting whole.<sup>27</sup>

## **Abiotic Components of the Ecosystem**

The abiotic components or the non-living environment includes the following categories: habitat, gases, solar radiation, temperature, moisture and inorganic and organic nutrients. Habitat is the physical environment in which organisms live, including biotic and abiotic components. There are two major habitat types, terrestrial and aquatic. The major habitats are able to support ecosystem because they contain all the essential abiotic elements that organisms require.

- (a) **Terrestrial environment:** Soil is the major life-supporting element of the terrestrial environment. Soil is composed of mineral matter interspersed with varying quantities of organic substances, air, and water. Soil generally consists of three layers. At the surface is the topsoil, which contains particular mineral matter as well as appreciable quantities of organic substances that give the layer a darkish hue. Beneath the topsoil is the subsoil, a layer of mineral matter comparatively devoid of organic substances. The bed rock layer composed of rocks - is the lowest of the three. The topsoil is of key importance to most terrestrial habitats.
- (b) **Aquatic environment:** Approximately 70 percent of the earth's surface consists of aquatic habitats, of which there are three major types - fresh water, salt water, and estuarine. Fresh water habitats include lakes, ponds, streams, rivers, swamps and springs. Saltwater habitats, which comprise most of the planet's aquatic environment, include the seas and the oceans. Intermediate between the freshwater and the saltwater habitats is the estuary - a river mouth where salt waters and fresh waters mix.

## **Gases**

Almost all organisms require certain gases in order to live. Green plants need CO<sub>2</sub> to carry on photosynthesis, all respiring organisms require oxygen for oxidative phosphorylation, and certain organisms utilize gaseous nitrogen and sulphur compounds as part of their metabolic activities. Essential gases are dissolved in water and present in pockets in the soil, but the major source of gases, is of course, the atmosphere. The atmosphere is a mixture of gases; 78% nitrogen, 21% oxygen,

and 0.04% carbondioxide. Hydrogen, helium, and methane are present in trace amounts.

### **Inorganic and Organic Nutrients**

All living organisms require certain minerals and salts which are essential to their vital life functioning such as protein synthesis, enzyme activity, photosynthesis etc. Plants absorb salts from the water in their habitat and acquired by animals from water or food. Minerals such as nitrogen, phosphorus, sulphur, calcium, magnesium, potassium, and iron salts, which are required in large amounts, are called the macronutrients. Those required in trace amount are the trace elements or micronutrients. Manganese, copper, and cobalt are the chief micronutrients. Autotrophs absorb inorganic as well as organic substances from their aquatic environment and synthesize their own nutrients, and as far as heterotrophs are concerned, they acquire organic nutrients by consuming autotrophs.

All organisms depend upon their abiotic environment for survival, and they all will survive only if the various abiotic factors are maintained within critical limits. Any factor within the ecosystem that tends to determine growth is called a limiting factor. The organisms in an ecosystem have upper as well as lower limits of tolerance. Each species has its own limits of tolerance for each abiotic factor. This is illustrated by the fact that small amounts of arsenic in the human diet have a toxic effect, but large doses are fatal. Within the limits of tolerance, whether narrow or wide, there is also an optimal range at which the organism functions or grows best.

### **Energy**

The energy is like light, heat, and stored energy in chemical bonds, etc. The solar energy is continuously trapped by the green plants on the one hand, and lost in space through respiration, decomposition, and loss of heat by all types of organisms, on the other. There are two major energy circuits in any ecosystem: the grazing circuit, in which animals eat living plants, or parts of plants, and the contrasting organic detritus circuit, in which dead materials accumulate and are decomposed by bacteria and fungi. From an operational standpoint, the living and non-living parts of ecosystems are tightly interwoven and difficult to separate. Both inorganic and organic compounds not only are found within and without

living organisms, but also are in a constant state of flux between living and nonliving conditions.

### **Microclimates**

The climate that matters for any animal is obviously the climate in which it actually lives. This may be very different from the general climate of the geographical region constituting the range of the species. An insect living on tree tops lives in a veritable desert, compared with the insect living on the forest floor where evaporation is only about seven percent of that near the tops of the trees. Condition under stones, on the north side of the boulders, or a few inches under the sand of a beach are almost always quite different from those of the general surroundings.<sup>28</sup>

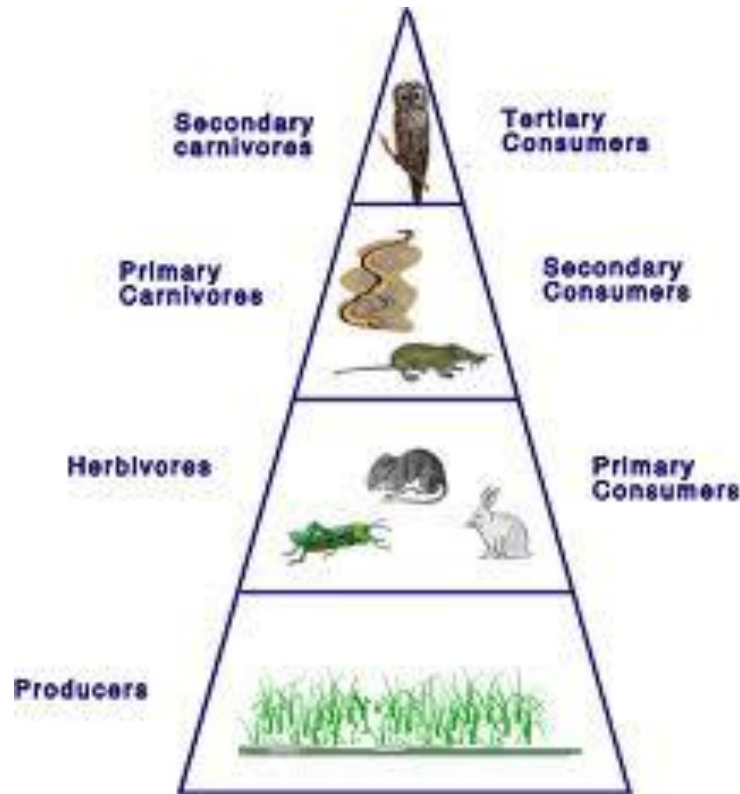
### **Biotic Components of the Ecosystem**

An ecosystem consists of two biotic components; the autotrophic components, and the heterotrophic components.

**Autotrophic components** are the self-nourishing components in which fixation of light energy, use of simple inorganic substances, and manufacture of complex materials predominates.

**Heterotrophic components** are the other nourishing components and consume the products of the autotrophs. They also attack the dead bodies of the organisms.

The interaction of autotrophic and heterotrophic components is a universal feature of all ecosystems, whether they are located on land, in fresh water or in the ocean. Frequently the autotrophic and heterotrophic components are partially separated spatially. The greatest amount of autotrophic metabolism occurs in a “green belt” stratum in which light energy is available. Below this lies a “brown belt” in which the most intense heterotrophic metabolism takes place. In the brown belt organic matter tends to accumulate both in soils and in sediments. The two functions may also be partially separated in time, for there may be a considerable delay in the heterotrophic utilization of the products of autotrophic organisms. In a forest, for example, the products of photosynthesis tend to accumulate in the form of leaves, wood and the food stored in seeds and roots. A relatively long time may elapse before these materials become litter and soil and available to the heterotrophic system.



(Picture – 2 : Biotic Components)

From a structural viewpoint three biotic components have been recognized:

- (i) **Producers** : The producers are the autotrophic organisms, chiefly green plants, that utilize radiant energy to manufacture food from simple inorganic substances like water, carbon dioxide, salts etc. They are the only organisms that can take energy from the non-living environment and make it available to all living organisms. They convert the light energy of the sun into chemical energy in the form of organic compounds. In terrestrial ecosystems, the major autotrophs are the flowering plants; in the oceans, they are the microscopic phytoplankton, especially the diatoms; and in lakes and ponds, the producers are rooted or large floating plants, algae and other phytoplankton. Phytoplanktons are the tiny plants and are usually not visible unless they are present in great abundance and give the water a greenish tinge. They are usually much more important as producers for the lake than are the more readily visible plants.

**(ii) Consumers:** Consumers are heterotrophic organisms (primarily animals), and are either directly or indirectly dependent upon autotrophs for food. The herbivores remain dependent upon the green plants for their food and are the primary consumers. However, the primary consumers also vary with the kind of the ecosystem. Elton gave the name “Key industry animals” to the herbivores because life of other prominent animals of a community depends upon these herbivores. The herbivores are used as food for primary carnivores or secondary consumers. Water beetles, dragonfly, nymphs and other predaceous insects in pond feed on primary consumers. The secondary consumers or the primary carnivores in turn, may be utilized as food for the tertiary consumers or the secondary carnivores. Fish that eats water beetles and dragonfly nymphs are an excellent example of tertiary consumers. However, some ecosystems may have the top carnivores like lion, vulture and osprey etc., which are not killed or rarely killed and eaten by other animals. Consumers that feed on both animals and plant materials are called omnivores.

Parasites are the organisms feeding upon the various living tissues of animals and plants. Dead parts of the body of animals and plants are eaten up by scavengers and saprophytes. The interaction between organisms and between the biotic and abiotic environment, gives a system of checks and balances which results in the continued existence of ecosystem.

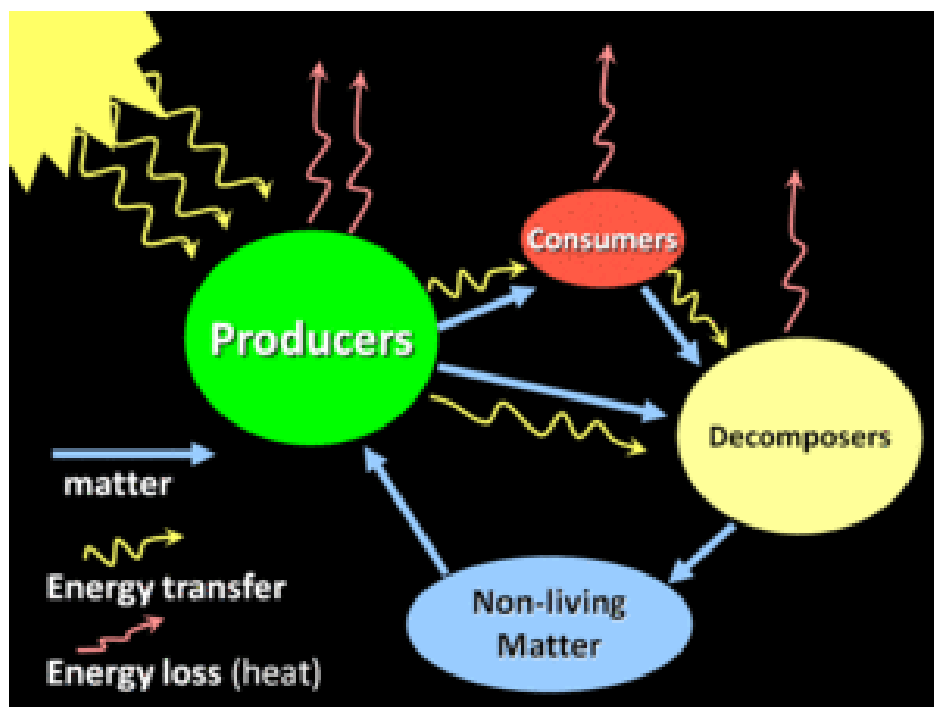
**(iii) Decomposers:** Like consumers, the decomposers are the heterotrophic organisms. They feed on dead protoplasm, breaking down its complex organic components of cells from dead producers and consumer organisms either into small organic molecules; which they utilize themselves as saprophytes, or into inorganic substances that can be used as raw materials by green plants. Thus, the continuous functioning of an ecosystem hinges on the activity of decomposers in recycling organic matters. This category includes bacteria (*Bacillus*, *Pseudomonas*, *Clostridium*, etc.) and fungi (*Agaricus*, *Mucor*, *Aspergillus*, *Fusarium*, *Alternaria*, *Coprinus*, *Helminthosporium*, etc.)<sup>29</sup>



**Functional Components of an Ecosystem** – Energy flow, food chains and food webs, nutrient cycles and internal regulation are functional properties of an ecosystem.

**(a) Energy Flow**

All the functions of the ecosystem are in some way related to the growth and regeneration of its plant and species. These interlinked processes can be depicted as the various cycles; all these process depend on energy from sunlight. Following flow chart interprets the functional aspect of an ecosystem or the interaction between various components, which involve the flow of energy of cycling of materials



**(Picture. – 3: Energy Flow)**

Implicit on the system, such as autotrophs to heterotroph, producer to consumers, herbivore– carnivore relationship, is the direction of energy movement through ecosystem. In this process, solar energy is converted into chemical energy through photosynthesis by plants, which also incorporate into their protoplasm a number of inorganic elements and compounds. These green plants are grazed subsequently by heterotrophs. This means that not only is the chemical energy in the form of carbohydrate facts and proteins are transferred into herbivores, but a host of other nutrients also. This process continues up to the decomposer level through the

carnivores. Another feature of the process is that the energy trapped by green plants when transferred from one food level or trophic level to another also depicts energy losses at each transfer along the chain.<sup>30</sup> (See picture 3)

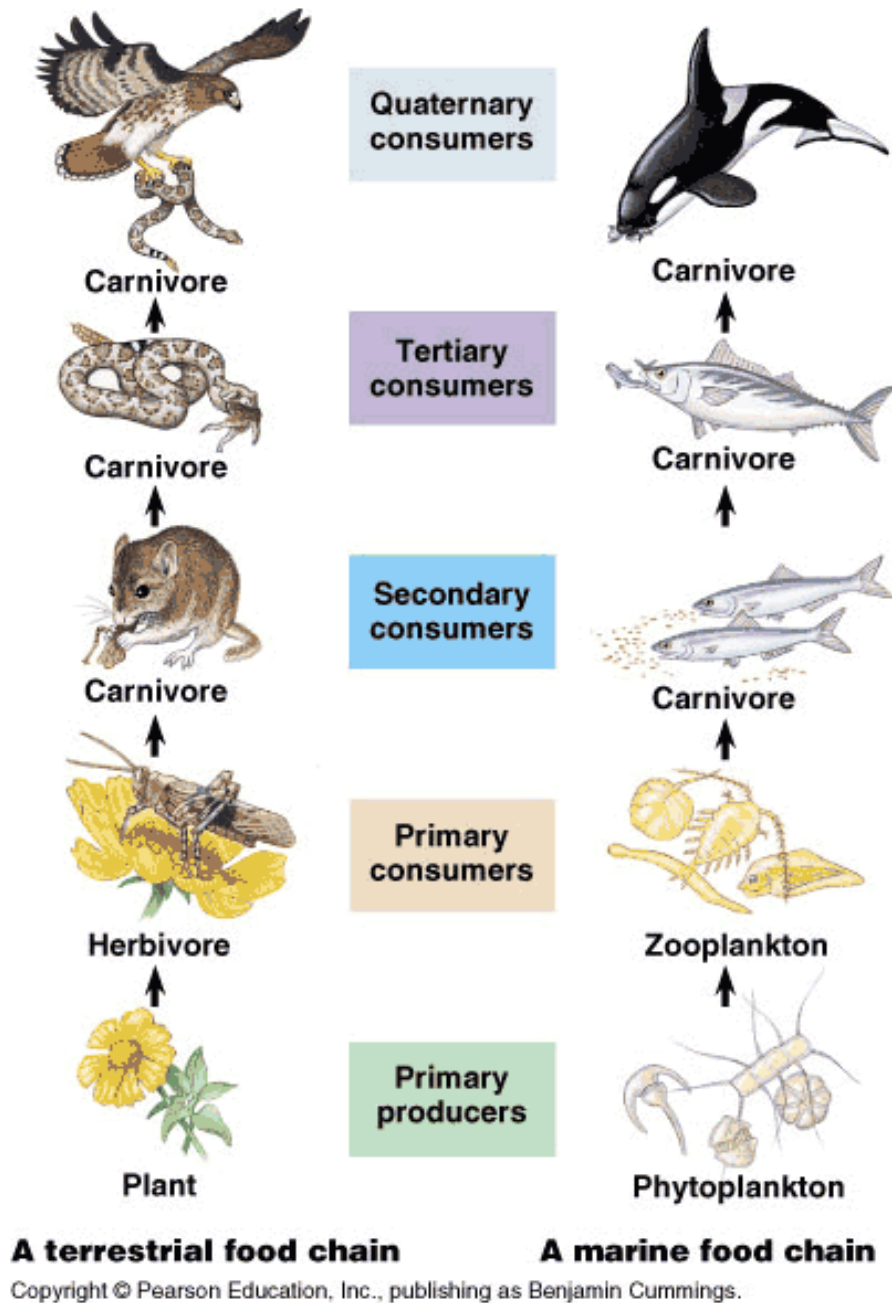
From the above diagram we can conclude that energy movement is unidirectional unlike nutrients/materials in the ecosystem, i.e. the initial energy trapped by an autotroph does not revert back to solar input. Secondly energy that passes from herbivore to carnivore does not pass back to herbivore from carnivore.<sup>31</sup>

However, transfer of nutrients along with chemical energy does not indicate loss of nutrients like that of energy. This is because the fecal matter, excretory products and dead bodies of all plants and animals are broken down into inorganic materials by decomposers and eventually returned to the ecosystem for reuse by the autotrophs.

An ecosystem is, therefore, a system of regularly interacting and interdependent components forming a unified whole. The interaction of its components involves the flow of energy and cycling of materials.<sup>32</sup>

#### **(b) Food chain and Trophic levels**

The second important part of functional process of ecosystem includes food chain and food web. Organic nutrients are transferred from producers to consumers and decomposers as organisms eat and in turn are eaten by other organisms. This succession is called a food chain. The food chain is divided into trophic levels comprised of all the organisms that obtain their food by an identical number of steps. A given species population may have one or more than one trophic levels according to the source of energy actually assimilated. At each transfer of energy from one generation to another or from one trophic level to another, a large part of the energy is degraded into heat. As some energy is always dispersed into unavailable heat energy, no spontaneous transformation can be hundred percent efficient. The shorter the food chain, or the nearer the organism to the beginning of the food chain, the greater is the available food energy.<sup>33</sup>



(Picture – 4 : Food Chain and Trophic Levels)

The producers or the autotrophs or the green plants comprise the first trophic level. The herbivores, those organisms that consume the plants, comprise the second trophic level. Carnivores that consume the herbivores constitute the third trophic level. There may be higher trophic levels as well. Carnivores which consume third level carnivores comprise the fourth trophic level, and so on. All food chains begin at the producer level, and all end at the decomposer level.

In a pond ecosystem, the food chain consists of phytoplankton, herbivores, zooplankton, small carnivore fishes, large carnivore fishes and finally the decomposers. In a grassland ecosystem, the food chain consists of grasses, grasshoppers, frogs, snakes, vultures, and decomposers. Many organisms are at the same time herbivores and carnivores of different orders, and hence they occupy several positions in the food chain. In most ecosystems, many different food chains are possible, and they overlap and are intertwined with one another to form what is called a 'community food web'. Food web is simply a diagram of all the trophic relationships among and between its component species. A food web is generally composed of many food chains, each of which represents a single pathway up to the food web. Thus, the populations within the food web are linked by the various food chains through which organic nutrients are transferred. The alternate pathways in a food web help to maintain the stability of the living community. The greater the number of alternate pathways a food web has, the more stable is the community of living things which make up the web.<sup>34</sup> The inter-relationship between consumers, producers and decomposers remained the same even the organism not existent at present. Green plants remained primary producers and animals remained primary and secondary consumers.

### **(c) Ecological Pyramids:**

An ecological pyramid is a sort of graphical representation showing relationships between the various trophic levels of a community. Graphs have been made to show number of individuals, energy, and biomass, and because all of these have a triangular shape they have been termed ecological pyramids.

#### **Pyramid of Numbers**

In most food chains, the number of organisms decreases in each succeeding stage, a large number of small animals occur at the base, a few large ones at the top. The pyramid may be upright or inverted depending upon the size of the producers in the community. Large producers such as the oak tree, will be fewer in number than the smaller organisms, such as phytoplankton and grasses. This happens due to the difference in growth of population and predation upon small organisms by large ones.

The base of a pyramid always represents the numbers of primary producers and the subsequent structures on this base are represented by the number of consumers of successive levels, the top representing the number of top carnivores in that ecosystem.

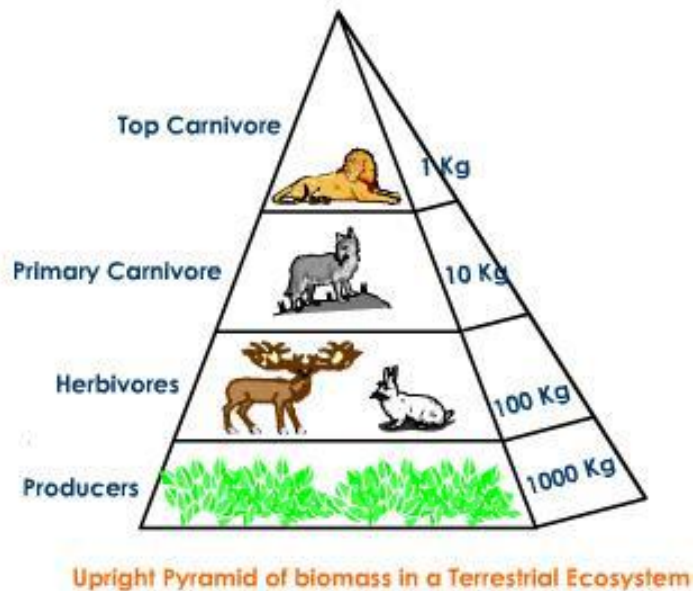
This pyramid can be well illustrated by taking pond as an example. The lowest trophic level is represented by algae and diatoms, which are largest in number. The second trophic level is occupied by herbivore zooplanktons which are numerically less abundant. Third and fourth trophic levels are occupied by smaller and larger fishes, respectively. There is a considerable reduction in the number of individuals from the base to the top of the pyramid.<sup>35</sup>

In food chains involving parasites, the size relationships are reversed because the parasite is smaller than its host, and hyperparasites must be still smaller. For this reason the pyramid of numbers is reversed for the successive steps of parasite dependency, and the parasites of each link are generally more numerous than their hosts.

So in an inverted pyramid of numbers, the number of primary consumers (herbivores birds feeding upon tree fruits) is always greater than the number of primary producers (a tree), and the number of parasites living and feeding upon the bird's body is still greater. Thus, the pyramid appears inverted.<sup>36</sup>

### **Pyramid of Biomass**

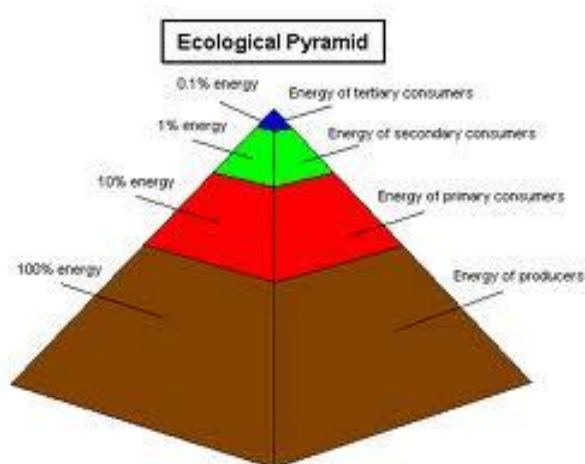
Biomass refers to the total weight of dry matter or caloric value present in the ecosystem at any time. The pyramid of biomass can be prepared by using the weights of the organisms in the different trophic levels. The biomass of a single tree is naturally very high than the biomass of a number of birds feeding upon the tree. Similarly, the biomass of even a very large number of bird parasites is lesser than that of the birds. The biomass pyramid may be inverted if the turnover rate of the producers is much more rapid than that of the consumers, as in the case of many aquatic ecosystems.



**(Picture – 5: Upright Pyramid of Biomass in a Terrestrial Ecosystem )**

In the terrestrial ecosystem, the biomass of the vegetation existing at the moment of observation is commonly the greatest, and the biomasses of herbivores, carnivores and further links in the food chain are progressively smaller. (See picture – 5)

In the lake environment, phytoplankton's are the organisms which have the basic trophic level and the next trophic level is occupied by bottom flora. The 3rd, 4th and 5th trophic levels are taken by bottom, zooplankton and fishes. In both terrestrial as well as lake ecosystem the biomass falls in a graded fashion.<sup>37</sup>



**(Picture – 6: Ecological Pyramid)**

## **Pyramid of Energy**

The pyramid of energy represents the total amount of energy utilized by different trophic level organisms of an ecosystem in unit area over a set period of time. The pyramid of energy depicts the amount of energy flow to each successive trophic level in a community. Because energy is always lost in transfer, each successive trophic level receives less total energy than the level below. Greater amount of energy is available at the producer level than at the consumer level. The energy production of the primary consumers is greater than that of the secondary consumers. The energy at the tertiary consumer level is produced in minimum level. Thus, the producer level always forms a wide pyramid base and successive levels narrow to an apex at the highest trophic level.<sup>38</sup> (See picture – 6)

## **Types of Ecosystem**

Basically two types of ecosystem are considered on our earth. Broadly, these two major types are the terrestrial and the aquatic ecosystems. Aquatic ecosystems can be subdivided into freshwater, estuarine and marine systems. These are differentiated on the basis of major chemical differences in water content. Terrestrial Ecosystems consist of several major biomes such as forest, grass land, tundra etc. These are determined largely by variations in climatic conditions between the poles and equator. These biomes can be differentiated on the basis of their predominant types of vegetation such as grasses, shrubs or trees. From another point of view, three main types of ecosystem are as follows:

- (i) **Natural ecosystem or self-maintaining, self-controlling ecosystems.**  
These include the ecosystem in which relative stability is maintained by changes taking place within ecosystem. In an ecosystem, self regulation is very important for maintaining a species and by adopting itself to the living and inanimate environment the species fluctuates with a definite quantitative limits.
- (ii) **The degraded ecosystem** (meadows, pastures) where the self-controlling equilibrium has almost ceased. It is characteristic of these that their phytomass and productivity have also decreased. In contrast to the number of herbivorous and carnivorous consumers, the number of their individual increases. The ecosystem is less varied and both the

diversity of species and the relative stability of the ecosystem declines, the food chain become shorter.

- (iii) In the third group of **cultural ecosystem**, the self-controlling equilibrium has entirely ceased. The whole ecosystem is maintained by human activity and man who by various method – tries to reduce the number of herbivorous pests, is the only consumer of the increased production.<sup>39</sup>

## **ROLE OF SPECIES IN ECOSYSTEM**

One fascinating attribute of an ecosystem is the diversity of species that make up the system. A diversity of functional groups is naturally to be expected because the food webs in an ecosystem involve autotrophs, herbivores, carnivores, detritivores, and so on. But surprisingly, a diversity of species exists within each functional component. Diversity of living organism appears to be a feature of our entire biosphere, something that attracted the attention of naturalist for centuries. When one realizes that there are more than three lakh different species of beetles on this planet, nearly 20,000 species of fishes, and probably many more waiting to be discovered, one naturally becomes curious about the evolutionary and ecological factors that had been responsible for such great diversification.

The types and quantities of plant and animal species living in a given ecosystem are dependent upon abiotic (nonliving) factors such as water, light, temperature, soil, and on biotic (living) factors such as complementary or comparative plants, and animals. Usually a few species comprises the majority of the total population, but there are a large number of other species present with very few individuals. The diversity of species to be greatest under moderate physical environment conditions and decreases under more harsh environment conditions. Tropical rainforests and tundra serve as examples of extreme differences in physical environment with concurrent differences in species diversity.<sup>40</sup>

All species play a role within ecosystem as (i) primary producers (ii) primary consumers (iii) predators (iv) decomposers. Primary producers absorb energy from the environment mainly from sunlight and inorganic substances  $\text{CO}_2$  and  $\text{H}_2\text{O}$ , produce organic molecules such as  $\text{C}_6\text{H}_{12}\text{O}_6$  in their living cells which contain pigments. The primary consumers feed on them, they are herbivores. The



predators consume flesh meat of herbivores. Decomposers decompose dead organic materials into inorganic particles and contribute for the material cycle.<sup>41</sup>

Generally, species are categorized into four types:

1. **Native species**, which normally live and thrive in a particular ecosystem.
2. **Immigrant, or alien species**, which migrate into an ecosystem or which are deliberately or accidentally introduced into an ecosystem by humans. Some of these species are beneficial, while other can take over and eliminate many native species.
3. **Indicator species**, which serve as easy warnings that a community or an ecosystem is being damaged. For example, the present decline of migratory, insect eating songbirds in North America indicates that their summer habitats there and their winter habitats in the tropical forests are rapidly disappearing.<sup>42</sup>
4. **Key Stone species**, which affects the survival and abundance of many other species in the community in which they live. The removal of such species can have profound effect on the ecosystem in which they live, and sometimes even on the physical structure of the environment. And often the importance of these species is not evident until they disappear. Keystone species are less abundant, but they exert strong effects on the community they inhabit. There are Four types of key stone species, (i) Organisms Controlling Dominants (ii) Resource Providers (iii) Keystone Mutualisms (iv) Ecosystem Engineers.

**Organisms Controlling Dominants** promote coexistence by reducing competition among other species for limiting resources in an Eco-system. Best examples are Predators which control the herbivores population and herbivores which control the plant composition. **Resource Providers** provide continuous reliable source of food for many kinds of creatures. If it is removed unable to bridge the gap of supply. The best example is Fig tree. **Mutualism** is an interaction between two organisms. Both are interdependent. They depend for pollination (plants and animals) and dispersal (plants and animals). If it fails it can be led to reproductive failures, loss of genetic diversity, change in plant and

animals population dynamics, local extinction without replacement, loss of animal species reliant on fruits and seeds, long terms species loss (trees). **Ecosystem Engineers** are keystone species who physically modify habitats. Best example is Elephants which maintain grasslands. Most exotic invasive species are ecosystem engineers in their invaded locations. <sup>43</sup>

Loss of a Key Stone Species can create a series of linked extinction events known as extinction cascade. Returning the keystone species to the community may not necessarily restore the community, if other components species & physical environment have already lost.

The ecological, or simply niche of a species is its total way of life or its role in an ecosystem. It includes all physical, chemical and biological conditions a species needs to live and reproduce in an ecosystem. On this basis species can be broadly classified as specialist or generalist, according to their niches. Specialist species have narrow niches. They may be able to live in only one type of habitat, tolerate only a narrow range of climatic environmental conditions, or use only a few type of food. Examples of specialist are Tiger Salamanders which can bear only in fishless ponds so their larvae won't it be eaten. Generalist species have broad niches. They can live in many different places, eat a variety of foods, and tolerate a wide range of environmental conditions. Flies, cockroaches, mice, rats, whitetail deer, raccoons and humans are all generalist species. <sup>44</sup>

When environmental conditions are fairly constant, such as in a tropical rain forest, specialists have an advantage because they have fewer competitors. When environments are changing rapidly, however the adaptable generalist is usually better of than the specialist.

When any two species in an ecosystem have some activities or requirements in common they may interact to some degree. The principle types of species interactions are: -

- (i) Inter-specific competition in which parts of the fundamental niches of different species overlap significantly. When the fundamental niches of two competing species do overlap, one species may occupy more of its fundamental niche than the other species.

- (ii) The most obvious form of species interaction in food chain and webs is predation. Members of predator species feed on parts or all of an organism of a prey species, but do not live on or in the prey.

Another three of these interactions parasitism, mutualism, commensalisms are symbolic relationship in which two or more kinds of organism live together in an intimate association, with members of one or both species benefiting from the association. In mutualism and commensalisms, neither species is harmed by the interaction.<sup>45</sup>

Species play an important role in ecosystems. Elimination of species decreases diversity and, possibly decreases the ecosystem stability. Each species has a function in the system. Stability of the ecosystem is believed to increase as diversity of species increases. The more species present, the greater the possibility for adaptation to changing environment. Species populations, which remain relatively constant from year to year, tend to be associated with moderate environmental conditions and great species diversity. Greater diversity also provides for better “checks and balances” through regulatory interactions of the functions of individual species in the ecosystem. Elimination of a species in the ecosystem can create an imbalance, which has pronounced effects on the ecosystem. Since individual species have tolerance limits, their elimination from a given ecosystem can be brought by changes in the environment.<sup>46</sup>

Man’s activities have set a trend toward making the environment less suitable for life and eliminating some species. These activities could lead to population fluctuations, which would mean sooner or later a population rash for man.

It may be foolish to suggest maintaining reasonably stable population sizes of the various species when that of one, *Homo sapiens*, has grown and continues to grow at a tremendous rate. Can one species population grow at a much greater rate than others without causing a serious imbalance? It seems reasonable that increased productivity resulting from input, which enhances the life support cycles could be used to the benefit of one species without seriously jeopardizing others. Activities, which overload or interrupt the life support cycles or those actions, which result in extermination of other species could lead to ultimate disaster and should be avoided.<sup>47</sup>

The rich variety of flora and fauna we have around us is part of our natural heritage, and we have to ensure that human activities do not despoilate this great diversity and leave a poorer biosphere for the next generation. One way to monitor the species diversity of ecosystem that are subjected to the ravages of human influence such as pollution and deforestation. Like energy transfer and productivity, species diversity of a community is also a measure of its health and well-being.

Above all, the study of ecology suggests that we should have a healthy respect for all forms of life. While the “good guys” and the “bad guys” may be clearly distinguishable on the dramatic stage, such is not the case in real life. Many seemingly useless organisms turn out to be useful. In fact, it is fortunate for man that the biosphere is populated with such a variety of organisms that some of them can tolerate even severe pollution and thus keep a bad situation from becoming worse. Man needs to think more in terms of the control and the utilization of nature, and not so much in terms of wholesale extermination, except in the case of a few species that are direct parasites or competitors. Conservation of the ecosystem rather than conservation of this or that species, as is now the current emphasis, would seem to be the most sensible approach. Until we have real scientific evidence to the contrary, it is clearly in our interest to preserve some of the remarkable diversity of taxa that have developed during the evolution of the biosphere over millions of years. The diversity of life should be looked upon as a national and international treasury.

### **MAN AND NATURE RELATIONSHIP**

The fostering nature of mother earth proved one of the most important prerequisite for the survival of mankind. Although, mankind in his techno-age, has been developed to that extent, that he now thinks to be a more vital power than nature, but, by pondering over man and nature relationship, this can be educated that the existence of man from ape-age to techno-age lasted due to the quenching the surviving demands of mankind by nature. This relation of man and nature can be explored through analyzing various ages of mankind from ape age to techno-age. Before analyzing the origin of relationship, let us ponder over the origin of nature or genesis of planet earth. The theory put forth to explain the origins of the universe, our solar system, and our planet is called the Big Bang Theory, which

says that all matter in the universe was, at one time, concentrated in a giant mass (a black hole) that blew apart 10 to 20 billion years and is still expanding.<sup>48</sup> Over time, these atoms collected and combined to create planet, smaller stars, asteroids, and numerous other solid bodies. The earth was one of the planets formed from the collapse of the first star. However it was unique in many ways, since it is the only planet with visible surface water and different seasons because Earth's axis is tilted appx 23<sup>0</sup>. Earth's atmosphere is also unique as it contains oxygen which is essential for life forms. The age of Earth is approximately one third age of the universe (4.6 billion year ago).<sup>49</sup> In course of time the temperature of Earth increased and consequently differentiated into core, the mantle and the crust. Later on with the separation of gases and water, the atmosphere and the hydrosphere were formed. For millions of years, the earth's atmosphere was not suitable for life. Scientists believe that primitive micro-organs first evolved about 3.5 billion years ago and the simplest life-forms gradually formed during the 2.5 – 3.0 billion years.<sup>50</sup> Land plants first appeared about 400 million years ago. The invertebrate and vertebrate animals gradually evolved through different geological periods in accordance with the development of suitable environment. The last geological period began approximately 1.5 million years ago including the present in which the species Homo Sapiens (human) evolved around 0.25 to 0.5 millions years back. Though there exists different opinion about time period of evaluation of human beings, it is well established scientifically that human beings evolved from ape-like ancestors about 2 to 3 million years ago.<sup>51</sup>

The earliest form of humans known as Homo habilis, lived in Southern Africa<sup>52</sup> about 1.6 to 2.2 million years ago. They probably survived mostly by scavenging meat from the bodies of dead animals and gathering and eating wild plants. They may have done some hunting for food. They were the first hominids to use tools.<sup>53</sup> They were followed by two other species, Homo erectus and Homo sapiens. Homo erectus lived between 2 to 0.4 millions years ago. They developed tools, weapons and fire and learned to cook their food. Evidence indicates that these early humanoids were hunter-gathers who got their food by gathering edible plants and hunting wild game from the nearby environment. They traveled out of Africa into China and Southeast Asia and developed clothing for northern climates.<sup>54</sup> Homo sapiens archaic are a bridge between Homo erectus and Homo sapiens.<sup>55</sup>

Between 200,000 and 100,000 years ago there appeared in the fossil record a large number of hominoids with brains as large as modern man's, but with possible evidence of less well developed neural structure. Cultural behaviour, however, was developing. The Neanderthal variety of these early Homo sapiens people buried their dead, used pigment for ornamentation. Homo sapiens neanderthalensis lived in Europe and the Middle East between 1,50,000 and 35,000 years ago. They co-existed with Homo sapiens archaic and Homo sapiens. It was not known whether they were of the same species and disappeared into the Homo sapiens sapiens gene pool or Homo sapiens may have killed them off.<sup>56</sup> By at least 50,000 years ago,<sup>57</sup> some say 40,000<sup>58</sup>, the modern variety of man Homo sapiens had appeared in the fossil records, and with him the cultural behaviour not different that exhibited by modern hunting and food collecting tribal peoples. During the first 30,000 years,<sup>59</sup> we survived as mostly nomadic hunter gatherer and in due course of time the mankind and its society faced various paradigm shift, i.e. animal domestication and pastoralism, plant domestication and agriculture, and science technology and industrialization.

### **Hunting and Food Gathering Societies**

During about three fourth of our 40,000 years existence, we were hunter-gatherers who survived by gathering edible wild plants and by hunting and fishing including shellfish (Paleolithic or Old Stone Age). Archaeological and anthropological evidences indicate that our hunter gatherer ancestors lived in small bands of rarely more than 50 people who worked together to get enough food to survive. If food became scarce, they picked up their few possessions and moved on.<sup>60</sup>

The earliest hunter-gatherers survived by only having expert knowledge about their natural surroundings. Their knowledge of nature enabled them to predict weather and find water any where around them. They discovered variety of plants and animals that could be eaten and used as medicines. They used stone-sharpened and shaped sticks, other stones and animals bones as primitive weapons for hunting and as tools for cutting plants and scraping hides for clothing and shelter. These dwellers in nature had three energy resources (i) sunlight captured by plants (which also served as food for the animals they hunted), (ii) fire, and (iii) their own muscles power.<sup>61</sup>

Although women typically gave birth to four or five children in their life span, usually one or two survived to childhood. Infant deaths from infections disease and infanticides led to an average life expectancy of about 30 years. This helped keep the population size in balance with food supplies.

Early hunter-gatherer exploited their environment for food and other resources – as do all forms of life. But their number was small; most of them wandered from place to place when their food supplies were exhausted, and they used only their own muscles energy to modify the environment. There were no surpluses, and the regenerative capacity of nature took care of the food supplies year after year. Thus their environmental impact was small and localized.<sup>62</sup>

Gradually the hunter gatherers (advanced) refined their tools and hunting practices. Some worked together to hunt herds of reindeer, woolly mammoth, european bison, and other big game. They used fire to flush game from thickets towards waiting hunters and to stampede herds into traps or over cliffs. Some learned that burning vegetation promoted the growth of food and forage plants.

Advanced hunter gatherers had a greater impact on their environment than did early hunter gatherers, especially using fire to convert forests into grasslands. There is also evidence that they contributed to and perhaps even caused the extinction of some large game animals.<sup>63</sup> Because of their small numbers, nomadism, and dependence on their own muscle power to modify the environment, their environmental impact was fairly limited and localized. Both early and advanced hunter gatherers were dwellers in nature, which trod lightly on the earth because they were not capable of doing more. They survived by being keenly aware of their intimate dependence on nature and with one another.

### **Agricultural Societies**

Some 10,000-12,000 years ago a cultural shift known as the Agricultural Revolution began in several regions of the world like Middle East, on the hilly flanks of the Syrian mountains,<sup>64</sup> where the wild ancestors of wheat, barley, and millet grew. This food producing revolution (the Neolithic or new stone age), was perhaps the most important development in the history of culture. This food producing revolution involved a gradual move from a lifestyle based on nomadic hunting and gathering bonds to one of settled agricultural communities, where

people learned how to domesticate wild animals and cultivate wild plants. This shift may have resulted from climate changes that forced humans either to adopt or perish.<sup>65</sup>

Archaeological evidence indicates that the first type of plant cultivation, which is now known as horticulture (art or science of gardening), probably began in tropical forests areas. People discovered that they could grow various wild food plants from roots or tubers (fleshy underground stems). To prepare planting they cleared small patches of forests by cutting down trees and other vegetation, and then burning under brush. The ashes fertilized the nutrient poor soil. This was slash and burn cultivation.

These early growers also used shifting cultivation. After a garden had been used for several years, the soil would be depleted of nutrients or reinvaded by the forests. Then the growers moved and cleared a new plot. Each abandoned patch had to be left fallow (unplanted) for 10-30 years before the soil became fertile enough to grow again. By doing these early growers practiced sustainable cultivation.<sup>66</sup>

These societies practiced subsistence agriculture growing only enough food to feed their families. Their dependence on human muscle power and crude stone or slick tools meant that they could cultivate only small plots, thus they had relatively little impact on their environment. True agriculture (as horticulture) began about 7000 years ago with the invention of metal plough, pulled by domesticated animals and steered by the farmer. Animal pulled plough greatly increased crop productivity. They allowed farmers to cultivate larger plots of land and to break up fertile grassland soils, which previously could not be cultivated because of their thick and widespread root system. In some arid (dry) regions early farmers further increased crop output by diverting water from nearby stream into hand dug ditches and canals to irrigate crops.<sup>67</sup>

The gradual shift from hunting and gathering to farming had several significant effects.

- Populations began to increase because of a larger, more constant food supply.<sup>68</sup>



- People cleared increasingly larger areas of land and began to control and shape the surface of the earth to suit their needs.
- People began accumulating material goods. Nomadic hunter-gatherers could not carry many possessions in their travels, but farmers living in one place could acquire as much as they could afford.
- Farmers could grow more than enough food for their families. They could use the surplus to barter with crafts people who specialized in weaving, tool making, and pottery.<sup>69</sup>
- Urbanization – the formation of cities began because a small number of farmers could produce enough food to feed their families with a surplus that could be traded with other people. Many former farmers moved into permanent villages. Some villages gradually grew into town and cities, which served for trade, government and religion.<sup>70</sup>
- Specialized occupation and long distance trade developed former farmers in villages and towns learned crafts such as weaving, tool making, and pottery to produce handmade goods that could be exchanged for food.
- Conflict between societies became more common as ownership of land and water rights became a valuable economic resource. Armies and their leaders rose to power and conquered large areas of land. These rulers forced powerless people – slaves and landless peasants to do the hard disagreeable work of producing food and constructing things such as irrigation system, temples, and walled fortresses.
- The survival of wild plants and animals, once vital to humanity no longer seemed to matter. Wild animals competing with livestock for grass and feeding on crops became enemies to be killed and driven from their habitats. Wild plants invading crop fields become weeds to be eliminated.

About 5,500 years ago, the trade interdependence between rural farmers and urban dwellers led to the gradual development of a number of agriculture based urban societies.<sup>71</sup> Until this point, the kind of agriculture practiced was such that the

requirements could be fulfilled within the frontiers of agrarian society. For the sake of convenience this type of agriculture can be called as traditional agriculture.

By this time it was possible to produce enough to meet the food requirement of much larger number of people than those directly involved in agriculture. With the passage of time, the non-essential consumption needs i.e. ornaments, clothes, agriculture implements and accessories, multiplied. These could only be met with by import of raw materials from areas beyond the frontiers of agrarian societies. As a result, the size of commodity-producing sector increased. The off site demand for agricultural produce continued to rise because people not directly involved in agriculture, continued to multiply and lean more and more heavily upon agrarian or agro-pastoral systems for food production.

These agrarian sectors depended heavily upon agriculture for their sustenance. They had surplus crops, which were used for trade or commerce. They herded animals and managed pastures ranges nearby their houses for their consumption. With the onset of small fieldoms, alongside commodity production and rular system, the agrarian sector also started bartering their produce with craftsman for various commodities. This processes played a major role in providing agriculture produce to the urban societies. The trade in food and manufactured goods created wealth and the need for a managerial class to regulate the distribution of goods, service and land.<sup>72</sup>

The rise of agriculture based urban societies created a much greater environmental impact than that of hunting and gathering societies and early subsistence farmers. The growing population<sup>73</sup> of the emerging civilizations needed more food and more wood for fuel and buildings. To meet these needs wast areas of forest were cut down and grasslands were ploughed. Some massive land clearing destroyed and degraded the habitat of many forms of plant and animal wildlife, causing or hastening their extinction.<sup>74</sup> Domestication of animals occasionally caused an imbalance in the ecosystem. Animals were protected from their predators by providing shelter and killing the predators.<sup>75</sup>

Poor management of many of the cleared areas led to greatly increased deforestation and soil erosion. Overgrazing of grassland by huge herds of sheep, goats, and cattle led to the desertification of the once fertile land. The topsoil that

washed off these barren areas polluted streams, rivers, lakes and irrigation canals, making them useless.

The concentration of large numbers of people and their wastes in cities helped spread infectious human diseases and parasites. The gradual degradation of the vital resource base of soil, water, forests, grazing land, and wildlife was a major factor in the downfall of many great civilizations.<sup>76</sup>

The gradual spread of agriculture meant that most of the world's human population shifted from hunter-gatherers in nature to shepherds. Their aim was to tame and control wild nature and to gain power and wealth by controlling other humans. Many analysts believe that this change is a major cause of today's environmental problems.<sup>77</sup>

### **Industrial Societies: The Industrial Revolution.**

It was a period from the 18<sup>th</sup> to 19<sup>th</sup> century where major changes in agriculture, manufacturing, mining, transport, and technology had a profound effect on socio-economic, cultural and environmental conditions starting in the United Kingdom, then subsequently throughout Europe, North America, and eventually the world.

The industrial revolution marks a major turning point in human history; almost every aspect of life was eventually influenced in some way. The invention of steam engine by James Watt proved a milestone in man-nature relationship. The introduction of steam power fuelled primarily by coal, wider utilization of water wheels, and powered machinery (mainly in textile manufacturing) underpinned the dramatic increase in production capacity.<sup>78</sup> The development of all-metal machine tools in the first two decades of the 19<sup>th</sup> century facilitated the manufacture of more production machines for manufacturing in other industries. The effects spread throughout Western Europe and North America during the 19<sup>th</sup> century, eventually affecting most of the world a process that continues as industrialization. The impact of this change on society was enormous.<sup>79</sup> It multiplied energy consumption per capita and thus the power of humans to shape the Earth to their will and to fuel economic growth. Production, trade, and distribution of goods all expanded.

The industrial revolution occurred when England had used up most of its forests. People began substituting coal for wood fuel. Coal fed the furnaces and foundries,

which were often located near coal mines to minimize transportation, thus the industrial revolution represented a shift from dependence on renewable wood and flowing water as energy resources to dependence on nonrenewable forest fuels.

The availability of coal led to the invention of steam engines to pump water and perform other tasks, and eventually to an array of new machines powered by coal and later by natural oil and natural gas. Within few decades these innovations changed agriculture based societies in Western Europe and North America into even more urbanized early industrial societies. These societies and the more advanced ones that followed were based on using human ingenuity to increase the average amount of energy used per person.

The new machines led to a switch from small scale, localized production of handmade goods to large-scale production of machine-made goods in centralized factories in rapidly growing industrial cities.

The growth in industries increased the flow of mineral raw materials, fuels, timbers, and food into the cities that served as industrial centers. As a result environmental degradation increased in non-urban areas supplying these resources. Industrialization also produced greater outputs of smoke, ash, garbage and other wastes in urban areas.

Fossil fuels powered farm machines, commercial fertilizer, and new plant breeding techniques greatly increased the yield of crops per acre of cultivated land. Greater agricultural activity reduced the number of people needed to produce food and increased the number of former farmer migrating from rural to urban areas. Many found jobs in the growing number of mechanized factories. There they worked long hours for low pay. Most factories were noisy, dirty, and dangerous places to work in.<sup>80</sup>

### **Advanced Industrial Societies**

After the First World War (1914-19), more efficient machines and mass production techniques were developed, forming the basis of present day advanced industrial societies in the United States, Japan and other more developed countries. These societies were characterized by

- Greatly increased production and consumption of goods, stimulated by mass advertising to induce people to buy things (consumerist society).

- Greatly increased dependence on non-renewable resources such as oil, natural gas, coal and various metals.
- A shift from dependence on natural materials, which are degradable, to synthetic materials, many of which break down slowly in the environment.
- A sharp rise in the amount of energy used per person for transportation, manufacturing, agriculture, lighting, heating and cooling.

Advanced industrial societies benefit most people living in them. These benefits include:-

- Creation and mass production of many useful and economically affordable products.
- Significant increase in the average Gross National Production per person.
- A sharp increase in average agricultural productivity per person because of advanced industrialized agriculture in which a small number of farmers produce large amounts of food.
- A sharp rise in average life expectancy from improvements in sanitation, hygiene, nutrition, medicine and birth control.
- A gradual decline in the rate of population growth because of improvement in health, birth control, education, average income and old age security.<sup>81</sup>

Along with their many benefits, advanced industrialized societies have intensified many existing problems related to resource use and the environment, and created new ones. These problems are threatening human beings and whole planet at all levels, local (contamination of soil, ground water and air with toxic pollutants), Regional level (Damage to forests and degradation of lakes and rivers caused by pollutants) and global level (population growth, climate change, global warming, depletion of ozone layer etc.) All these problems will be discussed in next chapter.

The combination of industrialized agriculture, increased mining and urbanization has increased the degradation of potentially renewable topsoil, forests and grasslands, and wildlife populations.

Industrialization has given people much greater control over nature and has decreased the number of people caring for the land. As a result, people, especially in more developed countries and urban areas, have intensified the view that their role is to take control of nature.<sup>82</sup>

Thus, from the above account of man's journey from cave-man up to techno-man, it can be deduced that man's attitude to nature has gone through several stages. In the beginning the natural forces of the elements of air, water, fire, and earth appeared to be terrific to him, and he had no knowledge of controlling them. Nature was looked upon as all-powerful and man had only to yield to the forces of nature. He was not in condition to harm nature. Gradually as man started understanding nature and its forces, his attitude changed from fear to scientific curiosity. He began harnessing natural sources in different ways. In due course of time, instead of submitting to nature, he made nature to submit to his demands. Nature was now at his back and call. He became master and nature his most obedient servant. Through scientific discoveries and inventions, technology to harness was developed. Through technological advancements industrial development took place, and through that mankind's economic progress. His basic wants, which were difficult to satisfy in earlier age of ignorance, now were more than satisfied. Not only that his wants increased and even those could be satisfied. And he has reached a stage of affluence.

In the present industrial and technological advancement some unforeseen consequences have taken place. With the greater and greater control of natural environment, man has so intervened in the natural process that the original balance of nature has been lost and he has inadvertently given rise to the problems of environmental crisis which is indeed proving to be suicidal.

With the success in the advancement of scientific knowledge and its application to industries, he had formerly developed an attitude to the conquering of nature. But he soon realized that what he thought is the conquering of nature in effect proving to be otherwise. He has so damaged nature in the process of his technological control of it that it has led to his own

strangulation and the consequent environmental suffocation of man and life. This journey of mankind has put a question mark on his so called developmental advancement. Has man conquered nature or has nature in the end conquered him?

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