

Ecosystem: Concept, Structure and Functions

What is an Ecosystem?

The ecosystem is the structural and functional unit of ecology where the living organisms interact with each other and the surrounding environment. In other words, an ecosystem is a chain of interaction between organisms and their environment. The term “Ecosystem” was first coined by A.G.Tansley, an English botanist, in 1935.

Living organisms cannot live isolated from their non-living environment because the latter provides materials and energy for the survival of the former i.e. there is interaction between a biotic community and its environment to produce a stable system; a natural self-sufficient unit which is known as an ecosystem.

Read on to explore the structure, components, types and functions of the ecosystem in the ecosystem notes provided below.

Types of Ecosystems

An ecosystem can be as small as an oasis in a desert, or as big as an ocean, spanning thousands of miles. There are two types of ecosystems:

- Terrestrial Ecosystem
- Aquatic Ecosystem

Terrestrial Ecosystems

Terrestrial ecosystems are exclusively land-based ecosystems. There are different types of terrestrial ecosystems distributed around various geological zones. They are as follows:

1. Forest Ecosystems
2. Grassland Ecosystems
3. Tundra Ecosystems
4. Desert Ecosystem

Forest Ecosystem

A forest ecosystem consists of several plants, animals and microorganisms that live in coordination with the abiotic factors of the environment. Forests help in maintaining the temperature of the earth and are the major carbon sink.

Grassland Ecosystem

In a grassland ecosystem, the vegetation is dominated by grasses and herbs. Temperate grasslands, savanna grasslands are some of the examples of grassland ecosystems.

Tundra Ecosystem

Tundra ecosystems are devoid of trees and are found in cold climates or where rainfall is scarce. These are covered with snow for most of the year. The ecosystem in the Arctic or mountain tops is tundra type.

Desert Ecosystem

Deserts are found throughout the world. These are regions with very little rainfall. The days are hot and the nights are cold.

Aquatic Ecosystem

Aquatic ecosystems are ecosystems present in a body of water. These can be further divided into two types, namely:

1. Freshwater Ecosystem
2. Marine Ecosystem

Freshwater Ecosystem

The freshwater ecosystem is an aquatic ecosystem that includes lakes, ponds, rivers, streams and wetlands. These have no salt content in contrast with the marine ecosystem.

Marine Ecosystem

The marine ecosystem includes seas and oceans. These have a more substantial salt content and greater biodiversity in comparison to the freshwater ecosystem.

Structure of an Ecosystem:

Each ecosystem has two main components:

- (1) Abiotic
- (2) Biotic

(1) Abiotic Components:

The non-living factors or the physical environment prevailing in an ecosystem form the abiotic components. They have a strong influence on the structure, distribution, behaviour and inter-relationship of organisms.

Abiotic components are mainly of two types:

(a) Climatic Factors:

Which include rain, temperature, light, wind, humidity etc.

(b) Edaphic Factors: includes soil, pH, topography minerals etc.

The functions of important factors in abiotic components are given below:

Soils are much more complex than simple sediments. They contain a mixture of weathered rock fragments, highly altered soil mineral particles, organic matter, and living organisms. Soils provide nutrients, water, a home, and a structural growing medium for organisms. The vegetation found growing on top of a soil is closely linked to this component of an ecosystem through nutrient cycling.

The atmosphere provides organisms found within ecosystems with carbon dioxide for photosynthesis and oxygen for respiration. The processes of evaporation, transpiration and precipitation cycle water between the atmosphere and the Earth's surface.

Solar radiation is used in ecosystems to heat the atmosphere and to evaporate and transpire water into the atmosphere. Sunlight is also necessary for photosynthesis. Photosynthesis provides the energy for plant growth and metabolism, and the organic food for other forms of life.

Most living tissue is composed of a very high percentage of water, up to and even exceeding 90%. The protoplasm of a very few cells can survive if their water content drops below 10%, and most are killed if it is less than 30-50%.

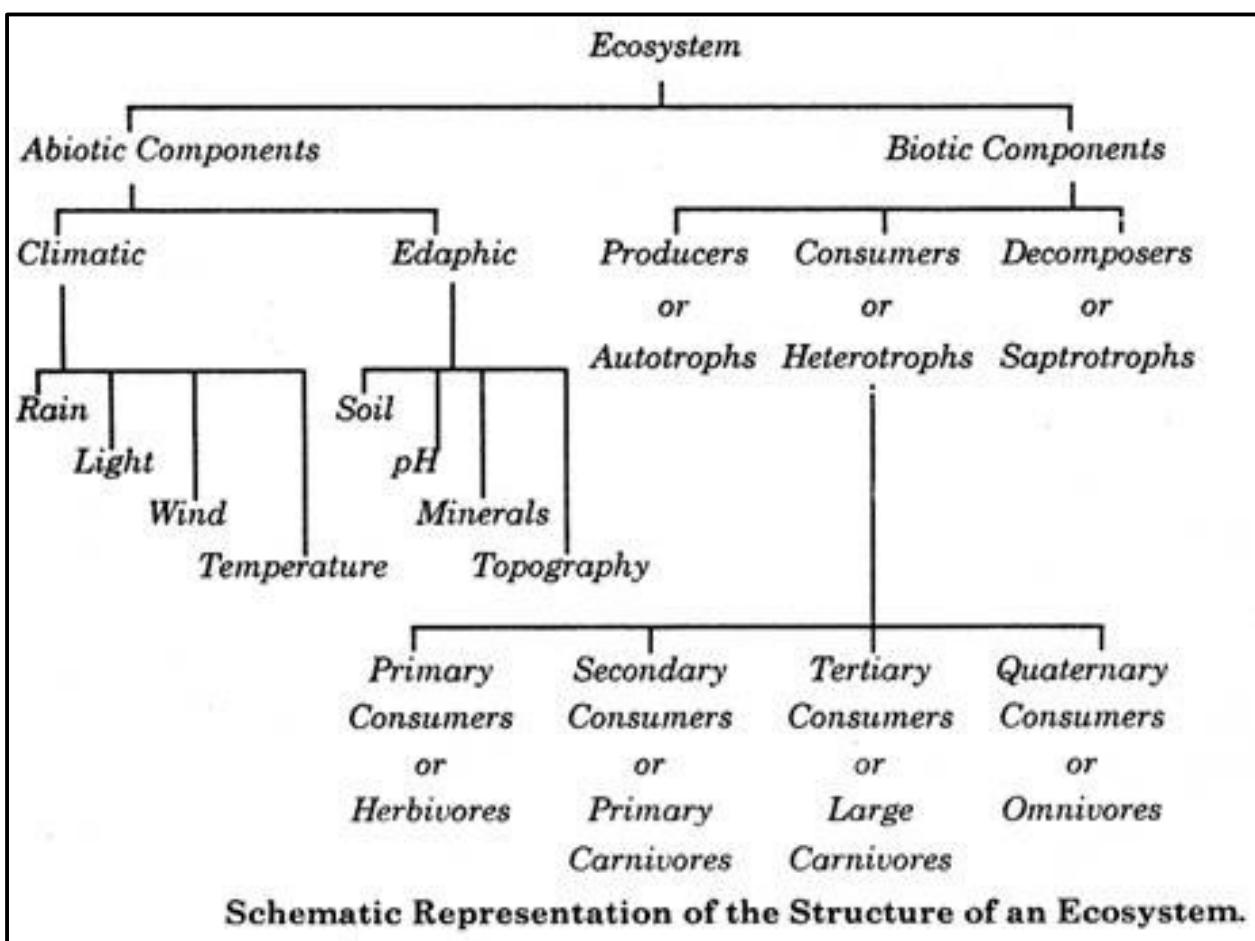
Water is the medium by which mineral nutrients enter and are trans-located in plants. It is also necessary for the maintenance of leaf turgidity and is required for photosynthetic chemical reactions. Plants and animals receive their water from the Earth's surface and soil. The original source of this water is precipitation from the atmosphere.

(2) Biotic Components:

The living organisms including plants, animals and micro-organisms (Bacteria and Fungi) that are present in an ecosystem form the biotic components.

On the basis of their role in the ecosystem the biotic components can be classified into three main groups:

- (A) Producers
- (B) Consumers
- (C) Decomposers or Reducers.



(A) Producers:

The green plants have chlorophyll with the help of which they trap solar energy and change it into chemical energy of carbohydrates using simple inorganic compounds namely water and carbon dioxide. This process is known as photosynthesis. As the green plants manufacture their own food they are known as Autotrophs (i.e. auto = self, trophos = feeder)

The chemical energy stored by the producers is utilised partly by the producers for their own growth and survival and the remaining is stored in the plant parts for their future use.

(B) Consumers:

The animals lack chlorophyll and are unable to synthesise their own food. Therefore, they depend on the producers for their food. They are known as heterotrophs (i.e. heteros = other, trophos = feeder)

The consumers are of four types, namely:

(a) Primary Consumers or First Order Consumers or Herbivores:

These are the animals which feed on plants or the producers. They are called herbivores. Examples are rabbit, deer, goat, cattle etc.

(b) Secondary Consumers or Second Order Consumers or Primary Carnivores:

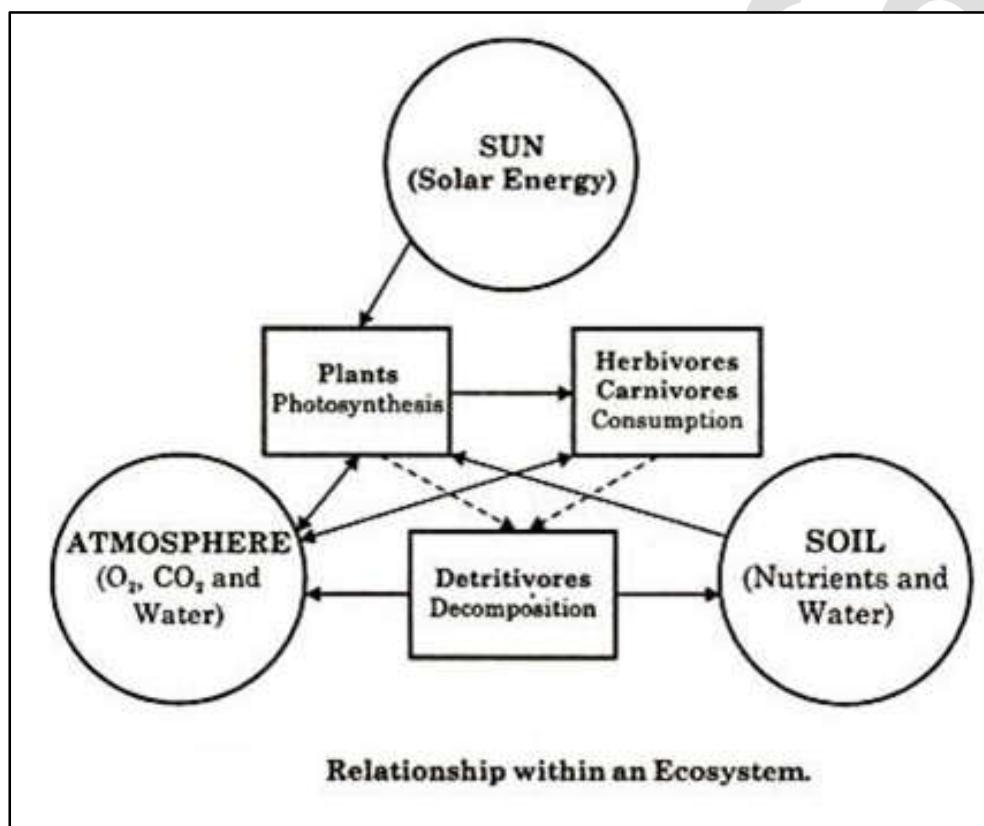
The animals which feed on the herbivores are called the primary carnivores. Examples are cats, foxes, snakes etc.

(c) Tertiary Consumers or Third Order Consumers:

These are the large carnivores which feed on the secondary consumers. Example are Wolves.

(d) Quaternary Consumers or Fourth Order Consumers or Omnivores:

These are the largest carnivores which feed on the tertiary consumers and are not eaten up by any other animal. Examples are lions and tigers.



(C) Decomposers or Reducers:

Bacteria and fungi belong to this category. They breakdown the dead organic materials of producers (plants) and consumers (animals) for their food and release to the environment the simple inorganic and organic substances produced as by-products of their metabolisms.

These simple substances are reused by the producers resulting in a cyclic exchange of materials between the biotic community and the abiotic environment of the ecosystem. The decomposers are known as Saprotrophs (i.e., sapros = rotten, trophos = feeder)

Functions of Ecosystem

The functions of the ecosystem are as follows:

1.

1. It regulates the essential ecological processes, supports life systems and renders stability.

2. It is also responsible for the cycling of nutrients between biotic and abiotic components.
3. It maintains a balance among the various trophic levels in the ecosystem.
4. It cycles the minerals through the biosphere.
5. The abiotic components help in the synthesis of organic components that involves the exchange of energy.

Important Ecological Concepts

1. Food Chain

The sun is the ultimate source of energy on earth. It provides the energy required for all plant life. The plants utilise this energy for the process of photosynthesis, which is used to synthesise their food.

During this biological process, light energy is converted into chemical energy and is passed on through successive levels. The flow of energy from a producer, to a consumer and eventually, to an apex predator or a detritivore is called the food chain.

Dead and decaying matter, along with organic debris, is broken down into its constituents by scavengers. The reducers then absorb these constituents. After gaining the energy, the reducers liberate molecules to the environment, which can be utilised again by the producers.

2. Ecological Pyramids

An ecological pyramid is the graphical representation of the number, energy, and biomass of the successive trophic levels of an ecosystem. Charles Elton was the first ecologist to describe the ecological pyramid and its principals in 1927.

The biomass, number, and energy of organisms ranging from the producer level to the consumer level are represented in the form of a pyramid; hence, it is known as the ecological pyramid.

The base of the ecological pyramid comprises the producers, followed by primary and secondary consumers. The tertiary consumers hold the apex. In some food chains, the quaternary consumers are at the very apex of the food chain.

The producers generally outnumber the primary consumers and similarly, the primary consumers outnumber the secondary consumers. And lastly, apex predators also follow the same trend as the other consumers; wherein, their numbers are considerably lower than the secondary consumers.

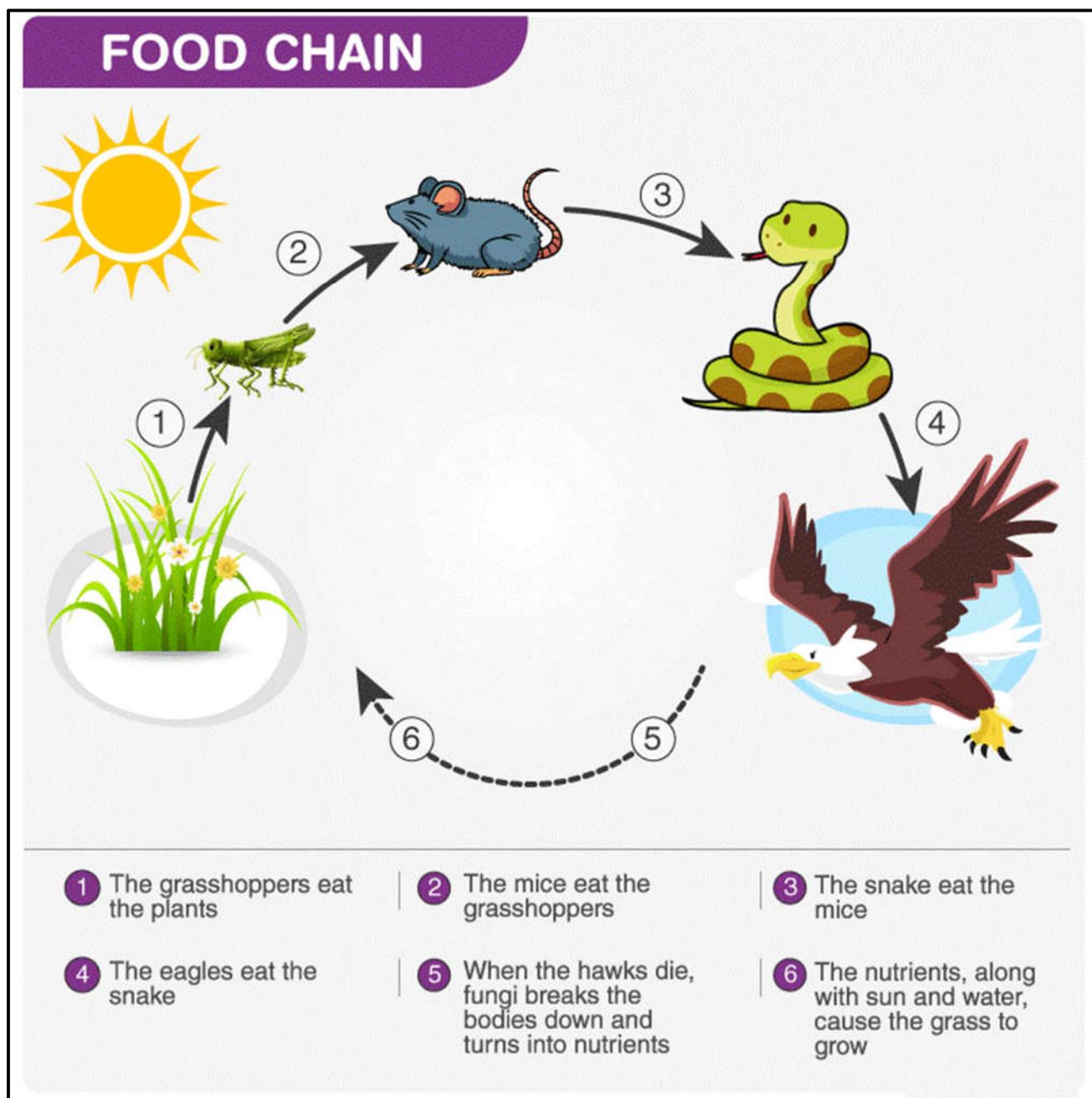


FIGURE: A classic example of a food chain in an ecosystem

For example, Grasshoppers feed on crops such as cotton and wheat, which are plentiful. These grasshoppers are then preyed upon by common mice, which are comparatively less in number. The mice are preyed upon by snakes such as cobras. Snakes are ultimately preyed on by apex predators such as the brown snake eagle.

In essence: **Grasshopper → Mice → Cobra → Brown Snake Eagle**

3. Food Web

Food web is a network of interconnected food chains. It comprises all the food chains within a single ecosystem. It helps in understanding that plants lay the foundation of all the food chains. In a marine environment, phytoplankton forms the primary producer.

Functions of an Ecosystem

Ecosystem function is the capacity of natural processes and components to provide goods and services that satisfy human needs, either directly or indirectly. Ecosystem functions are subset of ecological processes and ecosystem structures. Each function is the result of the natural processes of the total ecological sub-system of which it is a part. Natural processes, in turn, are the result of complex interactions between biotic (living organisms) and abiotic (chemical and physical) components of ecosystems through the universal driving forces of matter and energy.

There are four primary groups of ecosystem functions

- (1) regulatory functions,
- (2) habitat functions,
- (3) production functions and
- (4) information functions. This grouping concerns all ecosystems, not only for forests.

General characterization of ecosystem functions are:

(1) Regulatory functions: this group of functions relates to the capacity of natural and semi-natural ecosystems to regulate essential ecological processes and life support systems through bio-geochemical cycles and other biospheric processes. In addition to maintaining the ecosystem (and biosphere health), these regulatory functions provide many services that have direct and indirect benefits to humans (i.e., clean air, water and soil, and biological control services).

(2) Habitat functions: natural ecosystems provide refuge and a reproduction habitat to wild plants and animals and thereby contribute to the (in situ) conservation of biological and genetic diversity and the evolutionary process.

(3) Production functions: Photosynthesis and nutrient uptake by autotrophs converts energy, carbon dioxide, water and nutrients into a wide variety of carbohydrate structures which are then used by secondary producers to create an even larger variety of living biomass. This broad diversity in carbohydrate structures provides many ecosystem goods for human consumption, ranging from food and raw materials to energy resources and genetic material.

(4) Information functions: Since most of human evolution took place within the context of an undomesticated habitat, natural ecosystems contribute to the maintenance of human health by providing opportunities for reflection, spiritual enrichment, cognitive development, recreation and aesthetic experience.

Components of an ecosystem: Complete ecosystem consists of four basic components such as producers, consumers, decomposers and abiotic components e.g. Pond. If anyone of these four components are lacking, then it is grouped under incomplete ecosystem e.g. Ocean depth or a cave.

Productivity in the Environment: The productivity of an ecosystem is the rate at which solar energy is fixed by the vegetation of the ecosystem; it is further classified into primary productivity, secondary productivity and net productivity.

Primary productivity refers to the rate at which radiant energy is stored by photosynthetic and chemosynthetic activity of producers; it is further distinguished as gross primary productivity (GPP) and net primary productivity (NPP). It is expressed in terms of weight ($\text{g/m}^2/\text{yr}$) or energy (kcal/m^2). Secondary productivity refers to the rates of energy storage at consumer levels. An understanding of ecology is essential in the management of modern industrialized societies in ways that are compatible with environmental preservation and enhancement. The branch of ecology that deals with predicting the impacts of technology and development and making recommendations such that these activities will have minimum adverse impacts, or even positive impacts, on ecosystems may be termed as Applied Ecology. It is a multidisciplinary approach.

Interactions among living organisms are grouped into two major groups viz.,

I. Positive interactions

II. Negative interactions

I. Positive interactions

Here the populations help one another, the interaction being either one way or reciprocal. These include (i) Commensalism, (ii) Proto co-operation and (iii) mutualism.

1. Commensalism

In this one species derives the benefits while the other is unaffected. Eg. (i) Cellulolytic fungi produce a number of organic acids from cellulose which serve as carbon sources for non-cellulolytic bacteria and fungi.

(ii) Growth factors are synthesised by certain microorganisms and their excretion permits the proliferation of nutritionally complex soil inhabitants.

2. Proto-cooperation

It is also called as non-obligatory mutualism. It is an association of mutual benefit to the two species but without the co-operation being obligatory for their existence or for their performance of reactions. Eg. N_2 can be fixed by *Azotobacter* with cellulose as energy source provided that a cellulose decomposer is present to convert the cellulose to simple sugars or organic acids.

3. Mutualism: Mutually beneficial interspecific interactions are more common among organisms. Here both the species derive benefit. In such association there occurs a close and often permanent and obligatory contact more or less essential for survival of each. Eg. (i) Pollination by animals. Bees, moths, butterflies etc. derive food from nectar, or other plant product and in turn bring about pollination.

(ii) Symbiotic nitrogen fixation: Legume - *Rhizobium* symbiosis. Bacteria obtain food from legume and in turn fix gaseous nitrogen, making it available to plant.

II. Negative interactions

Member of one population may eat members of the other population, compete for foods, excrete harmful wastes or otherwise interfere with the other population. It includes (i) Competition, (ii) Predation, (iii) Parasitism and (iv) antibiosis.

(i) Competition

It is a condition in which there is a suppression of one organism as the two species struggle for limiting quantities of nutrients O₂ space or other requirements. Eg. Competition between *Fusarium oxysporum* and *Agrobacterium radiobacter*.

(ii) Predation

A predator is free living which catches and kills another species for food. Most of the predatory organisms are animals but there are some plants (carnivorous) also, especially fungi, which feed upon other animals.

Eg.	(i) (ii)	Grazing and browsing by animals on plants. Carnivorous plants such as <i>Nepenthes</i> , <i>Darlingtonia</i> , <i>Drosera</i> etc. consume
insects and other small animals for food. feeding on bacteria.	(iii)	Protozoans

(iii.) Parasitism

A parasite is the organism living on or in the body of another organisms and deriving its food more or less permanently from its tissues. A typical parasite lives in its host without killing it, whereas the predator kills its upon which it feeds.

Eg. Species of *Cuscuta* (total stem parasite) grow on other plants on which they depend for nourishment. Parasitism may occur even within the species. Hyperparasites which are chiefly fungi growing parasitically on other parasites, (ie) Parasite on a parasite. Eg. *Cicinnobolus cesatii* is found as hyperparasite on a number of powdery mildew fungi.

(iv) Antibiosis

The phenomenon of the production of antibiotic is called as antibiosis. Antibiotic is an organic substance produced by one organism which in low concentration inhibits the growth of other organism. Eg. Streptomycin - *S.griseus* , Penicillin - *P. notatum* , *Trichoderma harzianum* inhibits the growth of *Rhizoctonia* sp.

Energy and cycles of energy

Biogeochemical cycles and virtually all other processes on Earth are driven by energy from the sun. The sun acts as a blackbody radiator with an effective surface temperature of 5780 K (Celsius degrees above absolute zero). It transmits energy to earth as electromagnetic radiation. The maximum energy flux of the incoming solar energy is at a wavelength of about 500 nanometers, which is in the visible region of the spectrum. A 1 square meter area perpendicular to the line of solar flux at the top of the atmosphere receives energy at a rate of 1,340 watts, sufficient, for example, to power an electric iron. This is called solar flux.

Energy in natural systems is transferred by heat, which is the form of energy that flows between two bodies as a result of their difference in temperature, or by work, which is transfer of energy that does not depend upon a temperature difference, as governed by the laws of thermodynamics. The first law of thermodynamics states that, although energy may be transferred or transformed, it is conserved and is not lost. Chemical energy in the food ingested by organisms is converted by metabolic processes to work or heat that can be utilized by the organisms, but there is no net gain or loss of energy overall. The second law of thermodynamics describes the tendency toward disorder in natural systems. It demonstrates that each time energy is transformed; some is lost in the sense that it cannot be utilized for work, so only a fraction of the energy that organisms derive from metabolizing food can be converted to work; the rest is dissipated as heat.

Energy Flow and Photosynthesis

Whereas materials are recycled through ecosystems, the flow of useful energy may be viewed as essentially a one-way process. Incoming solar energy can be regarded as high-grade energy because it can cause useful reactions to occur, the most important of which in living systems is photosynthesis. Solar energy captured by green plants energizes chlorophyll, which in turn powers metabolic processes that produce carbohydrates from water and carbon dioxide. These carbohydrates represent stored chemical energy that can be converted to heat and work by metabolic reactions with oxygen in organisms. Ultimately, most of the energy is converted to low-grade heat, which is eventually reradiated away from Earth by infrared radiation.

Succession

Environment is always kept on changing over a period of time due to (1) variations in climatic and physiographic factors, (2) the activities of the species of the communities themselves. These influences bring about marked changes in the dominants of the existing community, which is thus sooner or later replaced by another community at the same place. This process continues and successive communities develop one after another over the same area until the terminal final community again becomes more or less stable for a period of time. It occurs in a relatively definite sequence. This orderly change in communities is referred as succession. Odum called this orderly process as ecosystem development/ecological succession.

Succession is an orderly process of community development that involves changes in species structure and community processes with time and it is reasonably directional and therefore predictable. Succession is community controlled even though the physical environment determines the pattern.

Causes of succession

Succession is a series of complex processes, caused by

- (I) Initial/initiating cause: Both climatic as well as biotic.
- (II) Ecesis/continuing process ecesis, aggregation, competition reaction etc.
- (III) Stabilizing cause: Cause the stabilization of the community. Climate is the chief cause of stabilization and other factors are of secondary value.

Types of succession

Primary succession: Starts from the primitive substratum where there was no previously any sort of living matter. The first group of organisms establishing there are known as the pioneers, primary community/primary colonizers. Very slow is the series of community changes that takes place in disturbed areas that have not been totally stripped their soil and vegetation.

Secondary succession: Starts from previously built up substrata with already existing living matter. Action of and external force, as a sudden change in climatic factors, biotic intervention, fire etc, causes the existing community to disappear. Thus area becomes devoid of living matter but its substratum, instead of primitive is built up. Such successions are comparatively more rapid.

- **Autogenic succession:** Community - result of its reaction with the environment, modified its own environment and thus causing its own replacement by new communities. This course of succession is autogenic succession.

- **Allogenic succession:** Replacement of the existing community is caused largely by any other external condition and not by the existing organisms.

- **Autotrophic succession:** Characterized by early and continued dominance of autotrophic organisms like green plants. Gradual increase in organic matter content supported by energy flow.

- **Heterotrophic succession:** Characterized by early dominance of heterotrophs, such as bacteria, actinomycetes, fungi and animals. There is a progressive decline in the energy content.

General Process of succession

(i) **Nudation:** Development of barren area without any form of life. Cause of nudation: It may be (a) Topographic soil erosion by wind (b) Climatic - storm, frost etc. (c) Biotic - man, disease and epidemics.

(ii) **Invasion:** Successful establishment of a species in a barren area. This species actually reaches this new site from any other area by (i) Migration, (ii) Ecesis and (iii) Aggregation.

Slow soil development by weathering, activities of tolerant species Pioneer Species Retrogressive succession:

Pioneer Species: Continuous biotic influences have some degenerating influence on the process. Due to destructive effects of organisms, the development of disturbed communities does not occur. Process of succession, instead of progressive, it becomes retrogressive. (Eg.) Forest may change to shrubby or grassland community.

Deflected succession: Sometimes due to changes in local conditions as soil character or microclimate the process of succession becomes deflected in a different direction than that presumed under climatic conditions of the area.

Thus the climax communities are likely to be different from the presumed climatic climax community. In India, with a monsoon type of climate, in some habitats like temporary ponds, Pools etc. It is common to observe each year, the development of different kinds of communities in different seasons of the year - seasonal succession. But such changes are simply recurrent and not developmental and should not be designated as successful. Species do not remain unchanged indefinitely. In course of time many species become extinct and disappeared forever. Or a species may form one or more new species that differ from the original one. All these changes are result of evolution (ie) by the process of evolution organism arise by modification from ancestral forms of life.

Questions

1. What is the ecosystem?

The ecosystem is the community of living organisms in conjunction with non-living components of their environment, interacting as a system.

2. What are the different types of ecosystems?

The different types of the ecosystem include:

- Terrestrial ecosystem
- Forest ecosystem
- Grassland ecosystem
- Desert ecosystem
- Tundra ecosystem
- Freshwater ecosystem
- Marine ecosystem

3. Which ecosystem do we live in?

We live in a terrestrial ecosystem. This is the ecosystem where organisms interact on landforms. Examples of terrestrial ecosystems include tundra, taigas, and tropical rainforests. Deserts, grasslands and temperate deciduous forests also constitute terrestrial ecosystems.

4. What is the structure of the ecosystem?

The structure of the ecosystem includes the organisms and physical features of the environment, including the amount and distribution of nutrients in a particular habitat. It also provides information regarding the climatic conditions of that area.

5. Which is the largest ecosystem in the world?

The largest ecosystem in the world is the aquatic ecosystem. It comprises freshwater and marine ecosystem. It constitutes 70% of the surface of the earth.

6. What is the major function of an ecosystem?

The ecosystem is the functional unit of the environment system. The abiotic components provide the matrix for the synthesis of organic components. This process involves the exchange of energy.

7. What makes a good ecosystem?

A good ecosystem consists of native plants and animal species interacting with each other and the environment. A healthy ecosystem has an energy source and the decomposers that break down dead plants and animal matter, returning essential nutrients to the soil.

8. What all include the non-living things in an ecosystem?

The non-living things in an ecosystem include air, wind, water, rocks, soil, temperature and sunlight. These are known as the abiotic factors of an ecosystem.