DSE paper for SEM IV

Unit I

Ecosystems: Definition, concept, structure and functions

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Ecosystems: Definition, concept, structure and functions.

Ecology is the science that deals with the relationships between living organisms with their physical environment and with each other. Ecology can be approached from the viewpoints of (1) the environment and the demands it places on the organisms in it or (2) organisms and how they adapt to their environmental conditions. An ecosystem consists of an assembly of mutually interacting organisms and their environment in which materials are interchanged in a largely cyclical manner. An ecosystem has physical, chemical, and biological components along with energy sources and pathways of energy and materials interchange. The environment in which a particular organism lives is called its habitat. The role of an organism in a habitat is called its niche.

For the study of ecology it is often convenient to divide the environment into four broad categories.

1. Terrestrial environment - The terrestrial environment is based on land and consists of biomes, such as grasslands, one of several kinds of forests, savannas, or deserts.
2. Freshwater environment - The freshwater environment can be further subdivided between *standing-water habitats (*lakes, reservoirs) and *running-water habitats (*streams, rivers).
3. Oceanic marine environment - The oceanic marine environment is characterized by saltwater and may be divided broadly into the shallow waters of the continental shelf composing the neritic zone
4. Oceanic region - The deeper waters of the ocean that constitute the oceanic

region. Two major subdivisions of modern ecology are

- Ecosystem ecology - which views ecosystems as large units, and
- Population ecology - which attempts to explain ecosystem behavior from the properties of individual units.

In practice, the two approaches are usually merged. Descriptive ecology describes the types and nature of organisms and their environment, emphasizing structures of ecosystems and communities and dispersions and structures of populations. Functional ecology explains how things work in an ecosystem, including how populations respond to environmental alteration and how matter and energy move through ecosystems.

Ecosystems are broadly divided into natural and artificial. *Natural ecosystems* are those that are existing in nature; they are further classified into terrestrial and aquatic. Terrestrial includes hot desert, grass land, tropical and temperate rainforest and *aquatic* includes ponds, river, streams, lakes, estuaries, oceans, mangroves, swamps and bays etc. However these two ecosystems are self regulating, open system with a free exchange of inputs and outputs with other systems. Artificial ecosystems are simple, human-made, unstable and subjected to human intervention and manipulation. Usually it is formed by clearing a part of the forest or grassland e.g. crop field, agricultural land.

Structure and Function of an ecosystem

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 category, habitat, gases, solar radiation, temperature, moisture and inorganic and organic nutrients. The living organisms may be sub divided into producers, consumers and decomposers. Abiotic Components include basic inorganic and organic components of the environment or habitat of the organism. The inorganic components of an ecosystem are carbon dioxide, water nitrogen, calcium phosphate all of which are involved in matter cycle (biogeochemical cycles). The organic components of an ecosystem are proteins, carbohydrates, lipids and amino acids, all of which are synthesized by the biota (flora and fauna) of an ecosystem and are reached to ecosystem as their wastes, dead remains etc. the climate 'microclimate' temperature, light soil etc. are abiotic components of the ecosystems.

Functions of an Ecosytem

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 ($g/m^2/yr$) 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*.,

- Positive interactions
- 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 hectar, 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 O_2 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) Grazing and browsing by animals on plants.
(ii) Carnivorous plants such as *Nepenthes, Darligtoria, Drosera* etc. consume insects and other small animals for food.
(iii) Protozoans feeding on bacteria.

(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 with in 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.

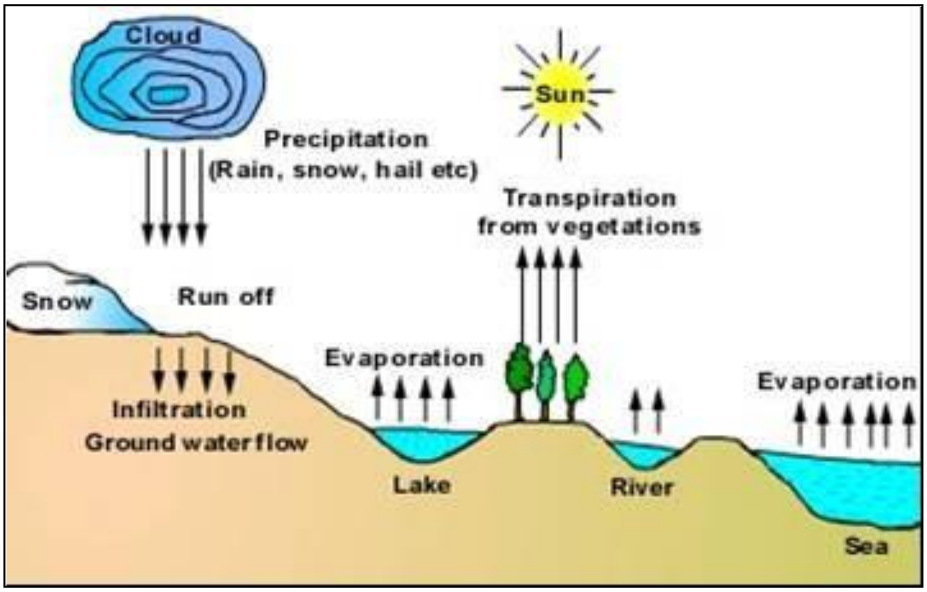
(iv) Antibiosis

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.

Matter and cycles of matter

Biogeochemical cycles describe the circulation of matter, particularly plant and animal nutrients, through ecosystems. These cycles are ultimately powered by solar energy, fine-tuned and directed by energy expended by organisms. In a sense, the solar-energy-powered hydrologic cycle acts as an endless conveyer belt to move materials essential for life through ecosystems.

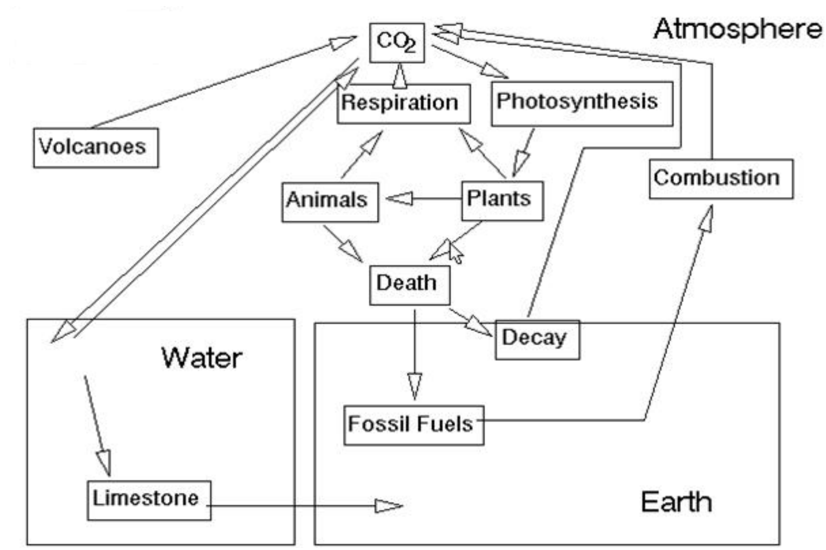


Most biogeochemical cycles can be described as elemental cycles involving nutrient elements such as carbon, oxygen, nitrogen, sulfur and phosphorus. Many are gaseous cycles in which the element in question spends part of the cycle in the atmosphere – O_2 for oxygen, N_2 for nitrogen, CO_2 for carbon. Others, notably the phosphorus cycle, do not have a gaseous component and are called sedimentary cycles. All sedimentary cycles involve salt solutions or soil solutions that contain dissolved substances leached from weathered minerals that may be deposited as mineral formations or they may be taken up by organisms as nutrients. The sulfur cycle, which may have H_2S or SO_2 in the gaseous phase or minerals ($CaSO_4$ $2H_2O$) in the solid phase, is a combination of gaseous and sedimentary cycles.

Carbon Cycle

Carbon, the basic building block of life molecules, is circulated through the carbon cycle. This cycle shows that carbon may be present as gaseous atmospheric CO_2, dissolved in groundwater as HCO_3 or molecular CO_2 (aq), in underlying rock strata as limestone ($CaCO_3$), and as organic matter, represented in a simplified manner as (CH_2O). Photosynthesis fixes inorganic carbon as biological carbon, which is a constituent of all life molecules.

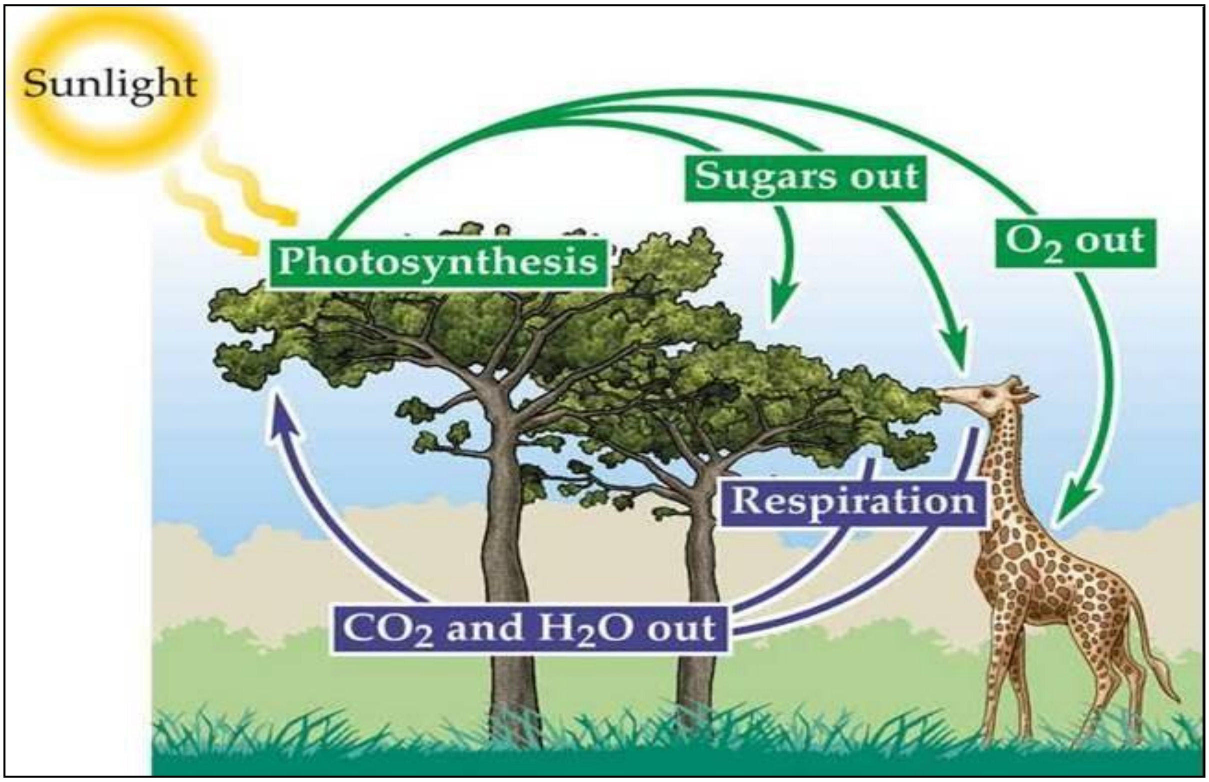
An important aspect of the carbon cycle is that it is the cycle by which energy is transferred to biological systems. Organic or biological carbon, (CH_2O), is an energy-rich molecule that can react biochemically with molecular oxygen, O_2, to regenerate carbon dioxide and produce energy. This can occur in an organism as shown by the "decay" reaction or it may take place as combustion, such as when wood is burned.



Carbon Cycle

Oxygen Cycle

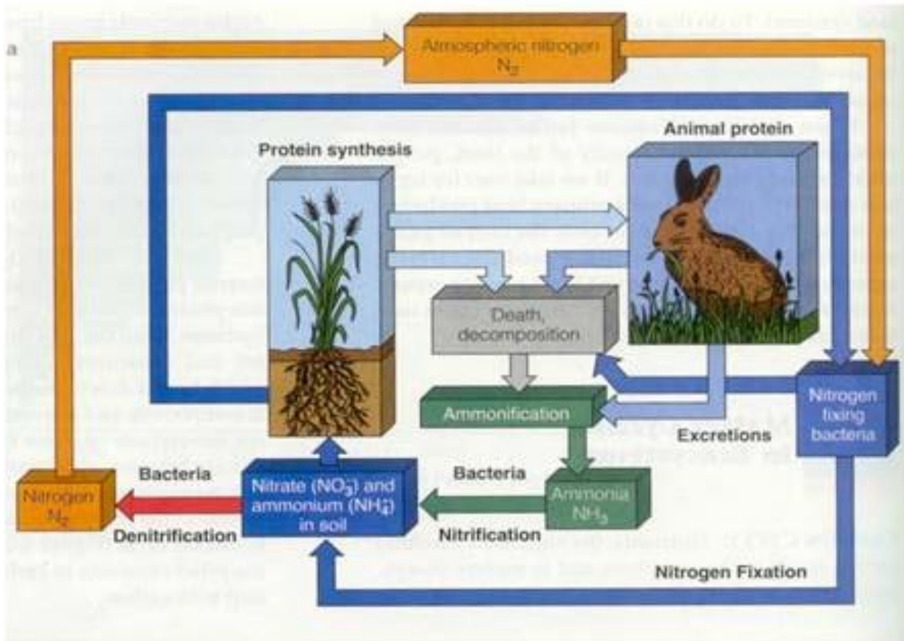
The oxygen cycle involves the interchange of oxygen between the elemental form of gaseous O_2 in the atmosphere and chemically bound O in CO_2, H_2O, and organic matter. Elemental oxygen becomes chemically bound by various energy-yielding processes, particularly combustion and metabolic processes in organisms. It is released during photosynthesis.



Oxygen Cycle

Nitrogen Cycle

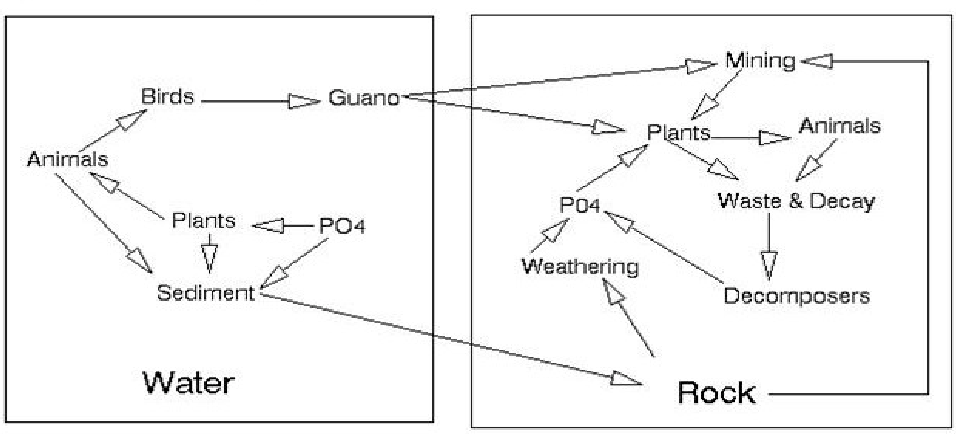
Nitrogen, though constituting much less of biomass than carbon or oxygen, is an essential constituent of proteins. The atmosphere is 78% by volume elemental nitrogen, N_2 and constitutes an inexhaustible reservoir of this essential element. The N_2 molecule is very stable so that breaking it down to atoms that can be incorporated in inorganic and organic chemical forms of nitrogen is the limiting step in the nitrogen cycle. This does occur by highly energetic processes in lightning discharges such that nitrogen becomes chemically combined with hydrogen or oxygen as ammonia or nitrogen oxides. Elemental nitrogen is also incorporated into chemically bound forms or fixed by biochemical processes mediated by microorganisms. The biological nitrogen is returned to the inorganic form during the decay of biomass by a process called mineralization.



Nitrogen Cycle

Phosphorus cycle

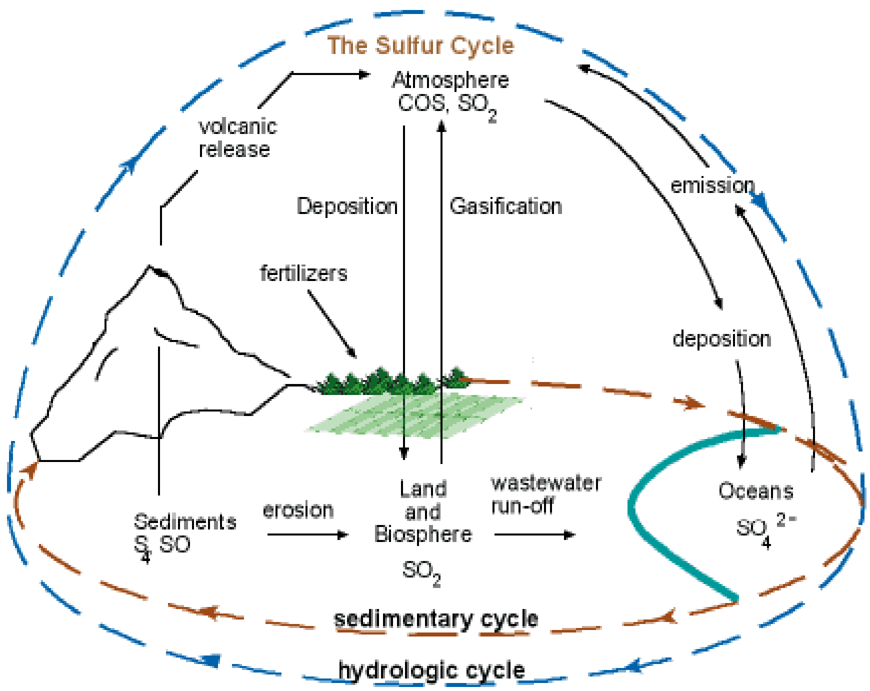
The phosphorus cycle is crucial because phosphorus is usually the limiting nutrient in ecosystems. There are no common stable gaseous forms of phosphorus, so the phosphorus cycle is strictly sedimentary. In the geosphere phosphorus is held largely in poorly soluble minerals, such as hydroxyapatite, a calcium salt. Soluble phosphorus from these minerals and other sources, such as fertilizers, is taken up by plants and incorporated into the nucleic acids of biomass. Mineralization of biomass by microbial decay returns phosphorus to the salt solution from which it may precipitate as mineral matter.



Phosphorus cycle

Sulfur cycle

The sulfur cycle is relatively complex. It involves several gaseous species, poorly soluble minerals, and several species in solution. It is involved with the oxygen cycle in that sulfur combines with oxygen to form gaseous sulfur di oxide (SO_2) an atmospheric pollutant, and soluble sulfate ion, (SO_4^{2-}). Among the significant species involved in the sulfur cycle are gaseous hydrogen sulfide, H_2S; mineral sulfides, such as PbS; sulfuric acid, H_2SO_4, the main constituent of acid rain; and biologically bound sulfur in sulfur-containing proteins.



Sulfur cycle

It should be obvious that material cycles, often based on elemental cycles, are very important in the environment.

Energy and cycles of energy

Biogeochemical cycles and virtually all other processes on Earth are drive 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 re- radiated 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, actinomyces, 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:

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.