3.2 CONCEPT OF AN ECOSYSTEM

A biotic community cannot live in isolation. It lives and flourishes in an environment which supplies and fulfills its material and energy requirements and provides other living conditions. The biotic community and its physical (non-living) environment in which matter (chemical elements) cycles and energy flows is called the 'Ecosystem'.

The term 'Ecosystem' was first proposed by A.G Tansley in 1935. He defined it as "the system resulting from the integration of all the living and non-living factors of the environment". He, thus, regarded the ecosystem as including not only the organism-complex, but also the whole complex of physical factors forming the environment. Keeping this in view, we can think of the earth as a 'giant ecosystem', where biotic (living) and abiotic (non-living) components are constantly acting and reacting upon each other bringing forth structural and functional changes in it. This vast ecosystem—the biosphere is, however, difficult to handle. Thus, for convenience, the study of nature is carried out by making its artificial sub-divisions into smaller units *i.e.* ecosystems.

An ecosystem, thus, is the smallest unit of biosphere that has all the characteristics to sustain life. An ecosystem is a natural grouping of nutrients, minerals, plants, animals and their wastes linked together by flow of food, nutrients and energy from one part of the system to another part. Ponds, streams, seas, deserts, grasslands, cities, etc. are all examples of ecosystems. The ecosystems can vary in sizes. An ecosystem can be only a few centimetres square in size, like microbial mats ; or its size can be in kilometres, like Tropical forests.

It is important to note here that, what is common to all ecosystems is not physical structure (*i.e.*, size, shape, variations of borders, etc.) but the existence of the processes—the flow of energy and the cycling of chemical elements.

3.2.1 Types of Ecosystems

The kind of organisms which can live in a particular ecosystem depends upon their physical and metabolic adoptions to the environment of that place/ecosystem and on certain aspects of the history of our planet, which has determined what organisms have been able to travel where. On earth, there are sets of ecosystems within a geographical region which are exposed to same climatic conditions and having dominant species with a similar life cycle, climatic adoptions and physical structure. This set of ecosystems is called a **Biome.** In the biosphere, there are—natural and artificial biomes (ecosystems).

(1) Natural Ecosystems (Biomes)

Natural ecosystems operate by themselves under natural conditions without any interference by man. Natural ecosystems carry out many public service functions for us. Wastewater from houses and industries is often converted to drinkable water by filteration through natural ecosystems, such as soils. Air pollutants from industries and automobiles are often trapped on leaves or converted to harmless compounds by forests. On the basis of particular type of habitat, they are further sub-divided as :

(a) **Terrestrial Biomes (Ecosystems) :** They are often defined by the vegetation types that dominate the community. The types of vegetation affect the climate and soil structure and thus characterize the particular biome. Terrestrial vegetation has a rapid exchange of oxygen, water and carbondioxide. The carbondioxide concentration is affected by terrestrial vegetation seasonally and annually. Terrestrial biomes include tropical rain forests, grasslands, deserts, cultivated lands, etc.

(b) **Aquatic Biomes (Ecosystems) :** They fall into two categories, viz., freshwater and marine.

Freshwater biomes may be *lotic* (running-water) such as streams, rivers and springs ; or *lentic* (standing-water) such as lakes, ponds, and swamps. Whereas, marine biomes include deep sea and oceans.

(2) Artificial Ecosystems (Biomes)

They are maintained artificially by man. A pond constructed as part of a waste water treatment plant is an example of artificial ecosystem. In artificial ecosystems, the management can vary over a wide range of actions. Agriculture can be thought of as partial management of certain kinds of ecosystems. Here, natural balance is disturbed regularly by addition of energy and planned manipulations. For example, wheat, maize and rice-fields, etc., where man tries to control the biotic community as well as the physico-chemical environment. The smallest artificial ecosystems that have been known to sustain life over a long period of time are 'Folsom bottles'. These materially closed ecosystems were created by Prof. Claire Folsom of University of Hawaii by placing water, algae, bacteria and sediment from Honolulu Bay in a liter flask and sealing the top. The sealed bottles were placed near the window so that sun energy be utilized by the biotic components during day time. Some of these have sustained life for nearly twenty years.

3.2.2 Types of Ecosystems based on Energy Resource

Ecosystems rely on two major sources of energy, the sun and chemical or nuclear fuels. So, on the basis of the major input, there can be solar-powered

(iv) **Fuel-powered Ecosystems (or Urban-industrial Ecosystems) :** In these ecosystems, the sun energy is replaced by highly concentrated potential energy of fuel, chemical or nuclear fuel. Examples of these systems are cities, suburbs, industrial parks, etc. These systems are man's wealth generating and also pollution generating systems. In these systems there is no limit of energy input. The energy input varies from 1,00,000 to 30,00,000 kcal/m^2/year and the average being 20 lacs kcal/m^2/year. These systems are parasitic in nature, because they depend on other ecosystems, as here consumption is large and production is bootless. For example, Mughal Gardens, Apughar, etc.

3.3 STRUCTURE AND FUNCTION OF AN ECOSYSTEM OR ORGANISATION OF AN ECOSYSTEM

The structure and function are the two major aspects of an ecosystem. Together they illustrate the organisation of an ecosystem.

Structure of an ecosystem means :

- the composition of biological community including species, population (numbers), biomass, life history, distribution in space, etc. ;
- the quantity and distribution of abiotic (non-living) materials, such as water, soil, nutrients, etc. ; and
- the range of conditions of existence, such as temperature, light, humidity, wind, wave action, etc.

By function of an ecosystem we mean :

- the rate of biological energy flow *i.e.*, the rates of production and respiration of the community ;
- the rate of nutrient (minerals) cycles ; and
- biological or ecological regulation including both regulation of environment by the organisms (*e.g.* nitrogen-fixing bacterias, etc.) and regulation of organisms by environment (*e.g.* photoperiodism, etc.).

3.3.1 Structure

Every ecosystem has two major components, viz., abiotic and biotic.

I. Abiotic component : It is the non-living component of the ecosystem and includes :

Physical or climatic factors such as soil, temperature, light and water ; and

Chemical factors constituting the inorganic and organic substances. The inorganic substances include C, H, N, K, P, S, etc., that are involved in mineral (nutrient) cycles and are present in an ecosystem at any given time. The organic substances include carbohydrates, lipids, proteins and humus, and are present in the biomass or in the environment.

II. Biotic component : It includes the living components of the ecosystem and is made of many different populations of species which are interdependent upon each other in the ecosystem. The biotic component represents the trophic structure of an ecosystem in which the living organisms are distinguished on the basis of their nutritional (feeding) relationships. The living component of an ecosystem includes ;

(1) Autotrophic component : It is the component in which fixation of light energy, use of simple inorganic substances and build up of complex organic substances predominate. The members (organisms) of autotrophic component are *producers* which are autotrops (self-nourishing organisms) such as algae, green plants and photosynthetic bacteria. These producers derive energy from sunlight and make organic compounds from inorganic substances. To some lesser extent, chemosynthetic microbes (like sulphur oxidizing bacteria) also contribute to the built-up of organic matter in an ecosystem.

(2) Heterotrophic component : It is the component in which utilization, rearrangement and decomposition (breakdown) of complex organic substances predominate. The members (organisms) of heterotrophic component are called *consumers* which are heterotrophs (dependent on others for food) such as animals. They consume the organic matter built up by the producers (or autotrophs). The heterotrophs are further categorised as :

(a) **Macroconsumers :** Macroconsumers are heterotrophs, which in an order as they occur in a food chain are—herbivores, omnivores or carnivores. Herbivores, also known as primary consumers, feed directly on living plants or plant residues, *i.e.* they have vegetarian diet. Carnivores are secondary or tertiary consumers which feed on consumers, *i.e.*, they have non-vegetarian diet. While omnivores are consumers which feed on producers as well as on primary consumers, *i.e.*, they have vegetarian as well as non-vegetarian diet.

(b) **Saprotrophs :** These are microconsumers, popularly known as *decomposers*, such as bacteria, fungi, flagellates and actinomycetes. They feed on organic compounds of dead or living protoplasm of plants and animals for their food and energy. They absorb some of the decomposition (or breakdown) products and release inorganic compounds (nutrients) in the ecosystem, making them available again to producers (autotrophs).

3.3.2 Function

The functional aspects of an ecosystem illustrate how an ecosystem works or operate under natural conditions. From the operational point of view, the abiotic (non-living) and biotic (living) components of an ecosystem are so interwoven into the fabric of nature that their separation from each other becomes practically very difficult. The mode of movement of materials and energy in an ecosystem, though very complex, is briefly outlined in simplified form as under.

The chemical elements, including all the essential elements of protoplasm (material that is basis of life in living beings), tend to circulate in the biosphere in characteristic paths from environment to organisms and back to the environment. These more or less circular paths, known as nutrient cycles, provide materials (or minerals) in an ecosystem. The producers (self-nourishing green plants) fix radiant energy and with the help of minerals (C, H, N, O, P, K, S, etc.) taken from the soil and environment (nutrient pool) they build up complex organic matter (carbohydrates, fats, lipids, proteins nucleic acids, etc.). The energy (in the form of food) then flows from producers to macroconsumers and to the decomposers.

In this simplified form the energy flows in non-cyclic manner (unidirectional) from sun to the decomposers via producers and macroconsumers (hetrotrophs), whereas the minerals (nutrients) circulate in a cyclic manner. It should be noted here that the cycling of the minerals is accomplished by different biogeochemical (nutrient) cycles superimposed upon the unidirectional energy flow through the biotic component of the ecosystem. Further, the energy not only flows unidirectionally but also lost from the system in many ways (explained later in this chapter) and that minerals too similarly show a net loss in many ways.

3.4 PRODUCERS, CONSUMERS AND DECOMPOSERS

All organisms in an ecosystem require energy for their life processes and materials for the formation and maintenance of body structures. Food supplies both energy and materials for the sustenance of life. Though, the ecosystems are characterized by a diversity of species ; but for their long term survival, the ecosystems must have representatives from the three functional or metabolic groups, viz., primary producers, consumers and decomposers.

(i) **Primary Producers :** Primary producers are those organisms that derive energy from either sunlight or inorganic compounds and make organic compounds from inorganic compounds (such as CO_2, water and nutrients like sulphate, phosphate and nitrate). For example, many primary producers like green plants, algae, photosynthetic bacteria obtain energy from sunlight for making organic compounds (including carbohydrates, proteins and fats) by photosynthesis ; while other producers such as sulphur oxidizing bacteria use energy stored in the chemical bonds of inorganic compounds for making organic compounds. As the green plants manufacture their own food, they are called as *autotrophs*.

The chemical energy (in the form of organic molecules) stored by the primary producers is utilized partly by themselves for their growth and survival, while the remaining is stored in the plant parts for their future use.

(ii) **Consumers :** Consumers are those organisms which use organic compounds for their food and energy. They cannot make organic compounds from inorganic compounds as they lack chlorophyle ; but they can transform one form of organic compounds into other forms of organic compounds. For example, animals, protozoa and many bacteria. They depend on the producers for their food and are called as *heterotrophs*.

The consumers are of many types, namely :

(a) **Primary consumers :** These are the animals that feed on primary producers and are called as herbivores. For example—Deer, goat, grasshopper, cattle, etc.

(b) **Secondary consumers :** These are the animals that feed on the herbivores and are called as the primary carnivores. For example—hawk, lizard, owl, fox, cat, etc.

(c) **Tertiary consumers :** These are the large carnivores that feed on the primary carnivores (*i.e.* secondary consumers). For example—snake, wolves, etc.

(d) **Quaternary consumers :** These are largest or top carnivores that feed on the tertiary consumers and are not eated up by any other animal. For example—lions, tigers, etc.

(iii) **Decomposers :** Decomposers are those organisms which feed on dead organisms (plants and animals) and transform complex organic compounds back into simple inorganic compounds including water, CO_2 and other nutrients. For example—non-green organisms such as fungi and some bacteria.

The simple inorganic substances released into environment by the decomposers are then reused by the producers. Thus, resulting in a cyclic exchange of materials between the biotic community and the abiotic environment.

In any ecosystem, certain species are more important than others in terms of sustaining the necessary flow of energy and materials for the likely persistence of other life forms. It is also true that diversity of species within an ecosystem insures the long-term survival of that ecosystem because diversity itself provides a redundancy of function. The mass or abundance of a species may be misleading as to its overall function in the ecosystem. Organisms may have effects that are disproportionate to their relative biomass. Ecological communities exhibit temporal heterogeneity, involving changes at time intervals that range from minutes to the thousands of years. Organisms with short generation time can respond to environmental changes rapidly.

A sudden inflow of organics may trigger a boom of micro-organisms within hours. At the other extreme, organisms with long generation time and life spans, may continue to persist long after conditions optimal for them have gone. *Ecosystems, then, are not static, they are dynamic systems in time and space.* They should not be viewed as steady state systems but rather as systems that continue to evolve biologically and change environmentally.

3.4.1 POND—as an Ecosystem

In order to have a better understanding, pond—as an ecosystem is discussed here.

The pond (Fig. 3.1), as an ecosystem, has all the characteristics to sustain life, and has representatives from the three functional groups too. It has the following four basic units :

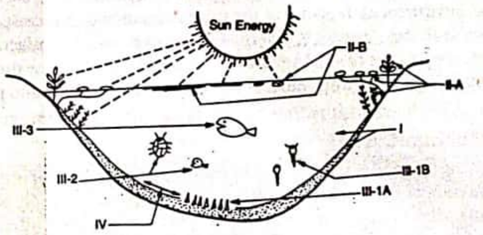


Fig. 3.1.

I. Abiotic substances. These include basic inorganic and organic compounds such as water, CO_2, O_2, calcium, nitrogen and phosphorus salts, amino acids, etc. A small portion of nutrients for the organisms is in solution, but larger portion is in the bottom sediments (as particulate matter) and in organisms themselves.

II. Producer Organisms. In a pond the producers are of two main types :

II-A. Rooted or Large floating plants, which generally grow in shallow water.

II-B. Minute floating plants, mainly algae. They are more important than rooted vegetation in the production of organic compounds or food for the consumers in the ecosystem.

III. Macro-consumer Organisms. These include animals such as insect larvae, fish, etc. The primary macro-consumers are herbivores which feed directly on living plants or plant residues. These are of two types, namely bottom forms (III-IA) and animal plankton (III-IB). The secondary consumers (III-2) are carnivores and feed on primary consumers. For example, insects and small fishes. The tertiary consumers (III-3) are secondary carnivores and feed on secondary consumers. For example, big fishes, etc.

IV. **Saprotropic Organisms.** These include aquatic bacteria, flagellates and fungi and are distributed throughout the pond, mainly along the bottom, where the dead bodies of plants and animals accumulate. They attack the dead bodies of organisms and thus decomposition takes place. The dead bodies are consumed and their nutrients are released for reuse.

3.5 ENERGY FLOW IN THE ECOSYSTEM

Energy flow is the movement of energy through an ecosystem—from the external environment through a series of organisms and back to the external environment. It is one of the most fundamental processes that is common to all the ecosystems. Energy flow in an ecosystem, infact, tells us about the very nature of life. In every ecosystem, the energy flow provides a foundation for life and thus imposes a limit on the abundance and richness of life.

3.5.1 Ecosystem Energy

Living organisms are operated by means of energy. Neither ecosystems nor their component species can survive without a constant supply of energy to maintain the biotic structures and their functions. In almost all cases, sun is the ultimate source of this energy in ecosystems. If the quantity or quality of energy input in an ecosystem, say forest, is reduced, then the forest begins to degrade till it reorganizes itself at the lower level. The non-energy-yielding materials, such as nitrogen, carbon, water, etc. of which living organisms are composed, may circulate many times between living and non-living segments, but energy does not circulate. Energy once used by an organism is converted into heat and is soon lost from the ecosystem, as this degraded form (heat) cannot power life processes. The food eaten by an organism is no longer available once it has been respired. The food demand again arises and so on. All living organisms (or even machines) can keep going only if there is continuous flow of energy from outside. Energy must, therefore, be supplied from an external source to keep biological processes running. It can be utilized to accomplish work as it flows through the system, and it can be stored temporarily in the chemical bonds of the organic molecules ; but eventually it is released and dissipated. Energy, thus, flows in a one-way path through the biological systems and eventually into some low temperature sink such as outer space. This one way flow of energy is a universal phenomenon.

There are two pathways by which energy enters an ecosystem :

(i) **Energy is fixed by organisms (primary producers) that can produce their own food from energy through photosynthesis or from inorganic minerals (Fig. 3.2).**

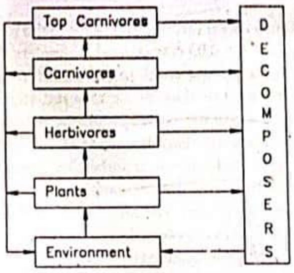


Fig. 3.2.

(ii) Heat energy, from sun transferred by the air or water currents or by convection through soils and sediments, provides warmth to living beings for their survival. For example, when a warm air mass passes over a forest, heat energy is transferred from the warm air mass to the land and to the living beings.

The second pathway is quite different from the first one, in which energy is fixed by autotrophs and is stored in organic molecules.

3.5.2 Routes of Usage

In an ecosystem energy's usage takes place in following ways :

1. The sunshine provides the necessary heat to maintain the required temperature range in which proper physical and chemical processes can take place.
2. Certain bacteria obtain useful energy by oxidation of certain elements such as sulphur and iron. But this is very limited because most of the iron and sulphur on earth surface are already oxidized.
3. In the process of photosynthesis, plants use chlorophyll to transform sunlight into chemical energy, which is stored in chemical compounds (foods). These compounds may be transferred from organism to organism and utilized as a source of energy. The warm blooded animals extend the usage of such foods to provide heat internally in their bodies and thus provide temperature conditions for themselves, which other organisms must get from sun shine energy stored in environment.

3.6 FOOD CHAINS

One of the fundamental ideas to analyze ecosystems is the idea of food chains, which is based on the transfer of energy derived from the sun through the biological system. The transfer of food energy from the source in plants (producers) through a series of organisms (herbivores to carnivores to decomposers) with repeated stages of eating and being eaten is known as the food chain. In any food chain, energy (in the form of food) flows from primary producers to primary consumers (herbivores), from primary consumers to secondary consumers (carnivores), from secondary consumers to tertiary consumers (carnivores/omnivores), and so on. This simple chain of eating and being eaten away is termed as food chain. For example :

(i) Grass $\longrightarrow$ Deer $\longrightarrow$ Lion

(ii) Seeds $\longrightarrow$ Mouse $\longrightarrow$ Owl

(iii) Algae ⟶ Insects ⟶ Fish ⟶ Man
(iv) Sap ⟶ Aphid ⟶ Beetle ⟶ Spider ⟶ Lizard ⟶ Snake ⟶ Hawk $\xrightarrow{\text{Death}}$ Wolf $\xrightarrow{\text{Parasite}}$ Tick $\xrightarrow{\text{Death}}$ Bacteria

In nature, there are two basic types of food chains, viz., grazing food chain and detritus food chain.

I. Grazing Food Chain : It starts from a living green plant base and goes to grazing herbivores (animals that feed on living plants), and on to the carnivores (animal eaters). For example :

(i) Phytoplankton ⟶ Zooplankton ⟶ Fish ⟶ Man
(ii) Grass ⟶ Grasshopper ⟶ Frog ⟶ Snake ⟶ Hawk
(iii) Grass ⟶ Rabbit ⟶ Fox ⟶ Tiger.

Most of the ecosystems (such as grasslands, forests, ponds, etc.) in nature follow grazing food chains. Ecosystems having such type of food chains are directly dependent on an influx of solar energy. These types of food chains thus depend on autotrophic energy capture and movement (or transfer) of this captured energy to herbivores and on to carnivores.

II. Detritus Food Chain : It starts from dead organic matter and goes to detritus feeding organisms (detrivores) and on to their predators. Detrivores are consumers of dead organic matter. For example, bacteria, soil mites, worms, and fungi of decay. Some of the examples of detritus food chains are as under :

(i) Dead organic matter ⟶ Detrivores ⟶ Predators
(ii) Fallen leaves and dead plants ⟶ Soil mites ⟶ Insects ⟶ Fish
(iii) Dead organic matter ⟶ Bacteria ⟶ Protozoa ⟶ Rotifers

Ecosystems having such type of food chains depend chiefly on the influx of organic matter produced in another system. Such ecosystems (like mangrove, and estuarine areas) are thus less dependent on direct solar energy.

Thus, it can be seen that though the detritus food chain ends up in a manner similar to the grazing food chain, but the way in which the two food chains begin is quite different. Further, in detritus food chain, the detritus consumers, in contrast to grazing herbivores, are a mixed group in terms of trophic levels. Detrivores include herbivores, omnivores and primary carnivores. As a group, detrivores obtain some of their energy directly from plant material, most of it secondarily (for example, by eating bacteria), and some tertiarily through carnivores (for example, by eating protozoa that have fed on bacteria that have digested plant material).

It must be noted here that the detritus food chain is simply a sub-component of another ecosystem. Since, in natural conditions, a system must always be self-sufficient, therefore the above discussed two types of food chains (grazing and detritus) in nature are indeed linked together belonging to the same ecosystem.

3.7 TROPHIC LEVEL

An organism's feeding status in an ecosystem can be expressed as its trophic level. All organisms which obtain food from plants in the same number of steps are said to belong to the same trophic level. Producers utilize the solar energy which is transformed to chemical form, ATP (adenosine triphosphate) during photosynthesis. Thus, green plants belong to the first trophic (nutritional) level which is the producers level, and are called the primary producers. The energy (in the form of food) is then utilized by the herbivores, which constitute the second trophic level (or the primary consumer level), and are called the primary consumers. Herbivores in turn are eaten by the carnivores, which constitute the third trophic level (or the secondary consumer level), and are called the secondary consumers. These secondary consumers in turn may be eaten still by other carnivores at tertiary consumer level, *i.e.* by tertiary consumers, and so on (Table 3.1).

Table 3.1. Trophic levels of organisms

Organisms	*Trophic level*
Green plants	First trophic level (Producer level)
Herbivores	Second trophic level (Primary consumer level)
Carnivores	Third trophic level (Secondary consumer level)
Secondary carnivores	Fourth trophic level (Tertiary consumer level)
⋮	
⋮	
and so on.	

It is important to note that the trophic classification is one of functions, and not of species as such. A given species population may occupy one or more than one trophic levels according to the source of energy (food) actually assimilated. Let us take the energy flow diagrams of two food chains :

Wheat ⟶ Man
Algae ⟶ Insect ⟶ Fish ⟶ Man

In the first case, man is at second trophic level ; while in the second case, he is at fourth trophic level. Similarly, there are other organisms which are omnivores *i.e.* eating the producer as well as the herbivores/carnivores at their lower level in the food chain. Such organisms thus may occupy more than one trophic levels depending upon the number of steps required for obtaining energy (food) from plants. Thus, the trophic classification of all the living organisms of an ecosystem is one of their functions and not of species as such. Species that are taxonomically widely different from each other may occupy the same trophic level if they all have the similar function in the food chain. For example, *Chara*, *Nostoc*, *Nymphaea*, *Typha*, photosynthetic bacteria, although taxonomically different but all belong to the producer level, as all have a common function of fixation of solar energy into chemical form.

3.7.1 Position of Man on the Food Chain

Humans are natural omnivores, by history and by habbit. The dental makeup (tooth structure) is an important aspect in understanding the food preferences of animals, and humans are no exception. Human teeth are suited for an omnivorous diet with a combination of cutting and crushing surfaces that are not highly adapted for one specific kind of food, as are the teeth of a tiger (carnivore) or a cow (herbivore).

The diet of man, thus, is composed of a mixture of plant and animal food. For example, man may eat the big fish that eats the little fish that eats the zooplankton that eats the phytoplankton that fixes the sun energy ; or he may eat the goat that eats the grass that fixes the sun energy ; or he may utilize a much shorter food chain by eating the grain that fixes the sun energy. The food chains of all the three cases are as under :

Phytoplankton ⟶ Zooplankton ⟶ Little fish ⟶ Big fish ⟶ Man

Plants (grass) ⟶ Goat ⟶ Man

Plants (wheat) ⟶ Man

By studying all the above three cases, we can say that humans are usually omnivores, and thus occupy an intermediate trophic between primary and secondary consumers.

3.8 FOOD WEBS

In ecosystems, some consumers feed on a single species, but most consumers have multiple food sources. Similarly, some species are prey to single kind of predator, but many species in an ecosystem are beset by several types of parasites and predators. As a result, individual food chains become interconnected to form a *Food Web*. Infact, under natural conditions, the linear arrangement of food chains hardly occurs and these remain indeed interconnected with each other through different types of organisms at different trophic levels.

Fig. 3.3 shows feeding relationships among some of the larger organisms in a typical *terrestrial food web*. In this food web, there may be seen as many as five linear grazing food chains, which in sequence are :

(*i*) Grains, etc. ⟶ Mouse ⟶ Hawk
(*ii*) Grains, etc. ⟶ Mouse ⟶ Snake ⟶ Hawk
(*iii*) Grass ⟶ Insect ⟶ Lizard ⟶ Snake ⟶ Hawk
(*iv*) Grass ⟶ Insect ⟶ Sparrow ⟶ Hawk
(*v*) Grass ⟶ Insect ⟶ Sparrow ⟶ Snake ⟶ Hawk

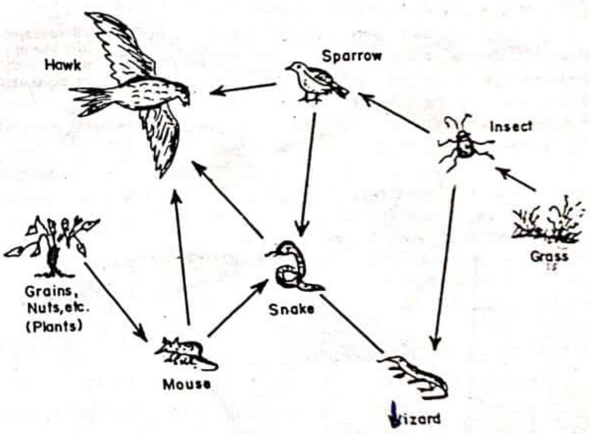


Fig. 3.3. Terrestrial food web.

All the above five grazing food chains are interlinked with each other at different points, forming a food web. Besides those shown in Fig. 3.3, there may also be present some other consumers as owls, vultures, wolves, rabbits, man, etc., and if so, then the food web may be even more complex than shown here.

In the oceans, food webs involve more species and tend to have more trophic levels than they have in springs, ponds or the terrestrial ecosystem. A typical oceanic ecosystem is shown in Fig. 3.4. The first trophic level includes microscopic single-cell planktonic algae. The second trophic level, herbivores, includes small invertebrates called zooplankton and some fish that feed on the algae. The third trophic level, carnivores, includes other fish and invertebrates that feed on the herbivores. The great baleen whales, which primarily feed on small herbivorous zooplankton (mostly crustaceans), are also in the third trophic level. Higher trophic levels are formed by some fish and marine mammals, like killer whales and sharks, that feed on the predatory fish.

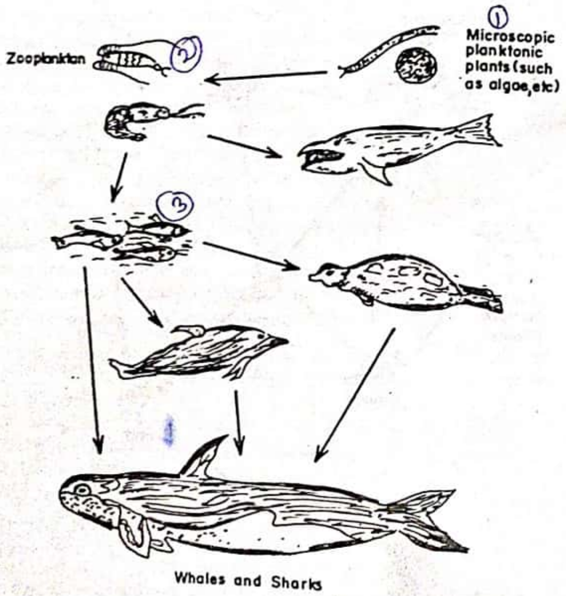
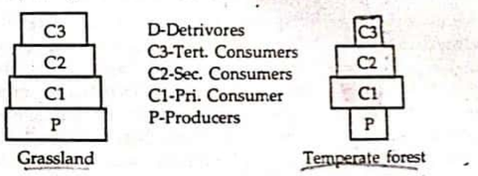


Fig. 3.4. Oceanic Food Web.

3.9 ECOLOGICAL PYRAMIDS

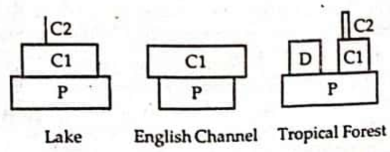
The interaction of the food chain phenomenon (*i.e.*, energy loss at each transfer) and the size metabolism relationship results in communities having definite trophic structure. The graphical representation of the trophic structure and also trophic function is called ecological pyramid. In ecological pyramid, the first or producer level forms the base and successive levels form the tiers which make up the apex. In simple words, if we arrange the organisms in a food chain according to trophic levels, they often form pyramid. The ecological pyramids are of three types, viz., the pyramid of numbers, the pyramid of biomass and the pyramid of energy.

(*i*) **The Pyramid of Numbers.** In this, the number of individual organisms at different trophic levels in an ecosystem are depicted. The total number of individual organisms at producer levels (First tropic levels) form the base of the numbers pyramid, and the population of primary consumers, secondary, tertiary consumers, and so on forms the sucessive tiers of the pyramid of numbers. The length of the bar, at different levels (tiers), represents the numbers (population) of organisms at that particular trophic level, by using convenient scale.

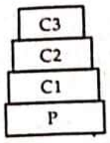


The number pyramid may be inverted or partly so, that is, the base may be smaller than one or more of the upper tiers.

(*ii*) **The Pyramid of Biomass.** It is based on the total dry weight, caloric value, or any other measure of the total amount of living material. In this, the total amount of living material (say in gms. dry wt. per sq. mt.) in organisms at different levels is depicted.



(iii) **The Pyramid of Energy.** In this, the rate of energy flow and/or productivity at successive trophic levels is shown.



Energy flow, in kcal/m^2/year

The energy pyramid always takes a true upright pyramid shape, provided all sources of food energy in the system are considered, because less food energy is available to the top trophic level than is available to preceding level.

3.10 ECOLOGICAL SUCCESSION

Although a typical ecological community (or ecosystem) maintains itself more or less in equilibrium with the prevailing conditions of the environment ; but in nature this is hardly true. Biological communities have a history in a given landscape. They are never stable, but dynamic, changing more or less regularly with respect to time and space. They are never found permanently in complete balance with their component species or with the physical environment. Environment of natural areas (or landscapes) is always kept on changing over a period of time due to disturbances of many kinds, such as, climatic and physiographic variations, and activities of the species of the communities themselves. These disturbances are not always or even usually human-induced ; natural disturbances such as storms and fires have always been a part of the environment. These disturbances bring about marked changes in the dominants of the existing community, which is thus sooner or later replaced by another community at the same landscape. This process continues as a result of which successive biological communities develop one after another over the same area, until the final (or terminal) biological community again becomes more or less stable for a period of time. This process, by which organisms occupy a site and gradually change environmental conditions so that other species can replace the original inhabitants, is called *ecological succession* or *ecological development*.

Odum preferred to call this phenomenon as ecosystem development rather than the more often known ecological succession. He made an elaborate statement to define this phenomenon, and in his own words— ecosystem development as an autogenic process may be defined in terms of the following three parameters :

(i) It is an orderly process of community changes (or development) that involves changes in species structure and community processes with time ; these changes (or development) are directional and, therefore, predictable.

(ii) It results from the modification of the physical environment and population structure by the community.

(iii) It culminates the establishment of as stable an ecosystem as is biologically possible on that particular site.

It must be emphasized that this type of ecological change is community controlled. Each set of organisms changes the physical substrate and the micro-climate (such as, local conditions of light, temperature, etc.) ; while species composition and diversity is altered as a result of competitive and other population interactions. When the community and the site has been modified as much as it can be by biological process, a steady-state develops— at least in theory. The species involved, time required and degree of stability achieved depend on a number of factors such as, geography, climate, substrate, and other physical factors ; but the process of development itself is biological, not physical. Thus, the physical environment determines the pattern of change but does not cause it.

3.10.1 Causes of Ecological Succession

Ecological succession is a process, more precisely a series of complex processes. It is, therefore, natural that there may not be a single cause for ecological succession. Broadly, there are three main types of causes :

(i) **Initial causes.** Initial or initiating causes are climatic as well as biotic. Climatic causes include factors, such as, wind, fire, erosion and deposits, etc. ; while the biotic causes include the various activities of organisms. These causes are responsible in the production of bare areas or in the destruction of the existing population in an area.

(ii) **Ecesis causes.** Ecesis or continuing causes are the processes that include migration, ecesis, aggregation, competition, reaction, and so on which cause successive waves of populations as a result of changes, mainly in the edaphic features of the area.

(iii) **Stabilising causes.** These are responsible for the stabilization of the community. According to Clements, "climate of the area is the chief cause of stabilization, other factors are of secondary value."

3.10.2 Types of Succession

As stated earlier, ecosystems change over time and space. If the fundamental requirements for life are available, areas on Earth without life are soon filled with living things. Over time, ecosystems undergo patterns of development called *ecological succession*. There are two basic kinds of succession : primary and secondary.

1. **Primary Succession.** Primary succession is the initial development of an ecosystem. It occurs when a community begins to develop on a site previously unoccupied by living organisms, such as an island, a sand or silt bed, a body of water, or a new volcanic flow. Forests that develop on new lava flows or at the edge of a retreating glacier are some common examples of primary succession.
2. **Secondary Succession.** Secondary succession is a re-establishment of an ecosystem. In secondary succession, there are remnants of a previous biological community, including such things, as organic matter and seeds in the soil of a forest. It occurs when an existing community is disrupted and a new one subsequently develops at the site. The disruptions may be caused by some natural catastrophe (such as flooding or fire), or by a human activity (such as mining, deforestation or plowing). A forest that develops on an abondoned pasture or one that grows after a flood, fire or hurricane is an example of secondary succession.

Both forms of ecological succession usually follow an orderly sequence of stages as organisms modify the environment in ways that allow one species to replace another. By contrast, in primary succession the remnants of a previous biological community are nonexistent or negligible.

1 In *primary succession* on a terrestrial site (Fig. 3.5), the new site first is colonized by a few hardy pioneer species, generally microbes, mosses and lichens that can withstand harsh conditions and lack of resources. Their bodies create patches of organic matter on the previously unoccupied site in which protists and small animals can live. Organic debris/wastes accumulate in pockets and crevices, providing soil in which seeds can

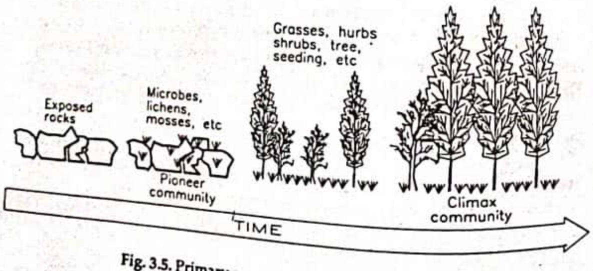


Fig. 3.5. Primary succession on a terrestrial site.

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become lodged and grow. This process of environmental modification by organisms is nothing but ecological development. The community of organisms becomes more diverse and increasingly competitive as development continues and new opportunities appear. The pioneer species gradually disappear as the environmental conditions change and new species combinations replace the preceding community. Infact, the gradual changes brought about by living organisms have created many of the conditions that make life on this planet Earth possible. In a global sense, we could consider evolution to be a very slow, planet wide successional and development process.

2 In *secondary succession* on a terrestrial site, observe an abandoned farm field or burned-over forest in a temperate climate. The bare soil first is colonized by rapidly growing annual plants (those that grow, flower and die in the same year) that have light, wind-blown seeds and can tolerate full sunlight and exposed soil. They are then followed and replaced by perennial plants (those that live for many years), including grasses, non-woody flowering plants, shrubs and trees. As in primary succession, plant species progressively change the environmental conditions. As a result, biomass accumulates and the site becomes richer, better able to capture and store moisture, more sheltered from wind and climatic changes, and biologically more complex. Species that cannot withstand a bare, dry, sunny and open area find shelter and food as the site turns to forest.

Eventually, in either primary or secondary succession, a community develops that seemingly resists further change. Ecologists call this a *climax community* because it appears to be the culmination of the successional process. However, final climax communities may still be changing. It is therefore, probably more accurate to say that the rate of succession is so slow in a climax community that, from the perspective of a single human lifetime, it appears to be stable.

Still some landscapes never reach a stable climax in the traditional sense because they are characterized by and adapted to periodic disruptions. They are called *dis-climax communities* or *equilibrium communities*, for example, grasslands, coniferous forests, etc. which are shaped and maintained by periodic forest-fires that have long been a part of their history. In fact, many of the plant species in these landscapes, which we recognize as dominants in these communities, require fire to eliminate competition. Without fire, the community structure might have been quite different.

Ecological successions are sometimes distinguished as *autotrophic succession* and *heterotrophic succession*.

(1) *Autotrophic succession* is the widespread type in nature that begins in a predominantly inorganic environment. It is characterized by early and continued dominance by autotrophic organisms like green plants. Here the energy flow is maintained indefinitely and there is gradual increase in the organic matter content supported by energy flow.

(2) *Heterotrophic succession* is characterized by early dominance by heterotrophs, such as bacteria, fungi and animals. It occurs in the special case where the environment is predominantly organic. For example, in a stream heavily polluted with sewage or, on a smaller scale, in a fallen log. Energy is maximum at the beginning and declines as succession takes place unless additional organic matter is imported or until an autotrophic regime takes over.

3.10.3 Examples of Succession

There are a number of classic examples of succession. A few of them are discussed as under :

(i) Sand Dune Succession. Plant succession in sand dunes along beaches is a worldwide phenomenon. Sand dunes are geologically unstable. They are continually formed, destroyed and reformed by the action of tides, winds and storms. Dune grasses are the first pioneer plants that survive on a newly formed dune. The dune grasses have long runners that anchor the plants in the sand. The runners have sharp ends that force their way through the sand as they grow. Dune grasses help in the stabilization of the dune, and making it possible for other plants to become established. Then seeds of shrubs and small trees germinate and grow on the stabilized dune. And, eventually a small forest develops on the sand dune.

There are limits to the stability of the dune. Wind and water during a major storm can break through the dune, redistributing the sand and starting the process of succession all over again.

Generally, series of sand dunes are visible on sea-coasts and shores of lakes, extending a considerable distance inland. The dunes nearest to the water are in an early stage of succession ; whereas, the interior dunes were deposited earlier and have an older forest. It is, thus, possible to study the history of sand dune succession simply by walking inland.

(ii) Bog Succession. Bog succession is a classic example of succession in an aquatic ecosystem. A bog is a body of water having little if any surface outflow, so that the waters have little current. Succession in a bog is a process that begins with open water and ends with a forest (Fig. 3.6). The amount of open water in the pond (or lake) gradually decreases as vegetation encroaches from the margins, resulting in gradual community replacement progressing from the edges of the pond toward the centre.

The short-lived sedge plants form floating mats that grow out over the water surface are the pioneers. Their mat of thick, organic matter forms a primitive soil into which seeds of other plant species fall and germinate. Meanwhile, sediments build up on the bottom of the bog. The sediment material includes dead organic matter from aquatic plants and animals as well as organic material that flows in the bog from surface streams or is blown in by the wind.

Slowly and steadily, the bog fills in from the bottom to the top. Eventually, the floating mat and sediments meet to form a firmer base that can support trees. Bog succession proceeds from open water to shallow pond with highly vegetated edges to marshy area with rooted, emergent vegetation and finally to grassland or forest. Though in some cases, open water or a moss-covered wetland with some open water can persist for a long time.

(*iii*) **Succession in Oceans.** In the oceans, succession occurs where there is relative constancy of the environment. It could be between the low and the high tidemarks along a rockyshore or in a coral reef. However, there is no perceptible succession in the middle of the ocean, where the ocean environment is constantly changing as the ocean waters are continually stirred by winds, waves and currents.

3.11 MAJOR ECOSYSTEMS

So far, in this chapter, a detailed account of gross structure and function of an ecosystem in general has been presented along with other related concepts. This topic—major ecosystems, lists and briefly characterizes the major ecological formations or easily recognized ecosystems operating as self-sufficient interacting systems in the biosphere. For example, a forest, a grassland, a desert, a pond, a lake, a river, a stream, an ocean, an estuary, etc. operates as individual ecosystems of nature. Although, all these ecosystems have a more or less similar fundamental plan of their gross organisation (*i.e.* structure and function) ; however, they differ in respect of their species composition, environment (terrestrial or aquatic), geographical location, production rates, etc.

The individual organizational pattern of forest, grassland, desert and aquatic ecosystems (or biomes) with emphasis on types, characteristic features, and structure and function along with their relative importance are described under.

3.12 FOREST ECOSYSTEM

The United Nations Food and Agricultural Organization (FAO) estimates the world's land area as of 1989 to be 13,076 million hectares, of which forests account for about 31% of the world's land area.

Forest ecosystems provide numerous environmental services such as cycling nutrients, producing oxygen, sequestering carbon in the global pool, maintaining biological diversity, providing wildlife habitat, affecting regional rainfall patterns, regulating stream flow, storing water, reducing flooding, moderating wind erosion, reclaiming degraded land and many more. Further, numerous human values are associated with them. Some values are traditional, (*e.g.*, wood, fruits, nuts, herbs, gums, etc.) ; while, other values are of more recent appreciation, *e.g.*, drugs and pesticides.

3.12.1 Types and Characteristic Features

Forest ecosystems (or biome) are characterized by enormous variability. They may differ in soil type, climate, aspect, elevation, age and health as well as species composition and development stage. The major types of forest ecosystem (biome), along with their characteristic features are briefly discussed as under :

1. Taiga or Boreal Forests : The taiga biome includes the northern coniferous forests of the cold climates of high latitudes and high altitudes that extends as an east-west band across North America, Europe and Asia, just below the 60°N latitude. The rainfall ranges from 10 to 35 cm, and the average temperatures are 6°C in the winter to 20°C in the summer. The duration of growing period of plants is just about five months. As the physical conditions are variable, the organisms must be adaptive to temperature fluctuations.

Taiga ecosystems are characterized by dense strands of relatively small trees, typically under 30 m, which are so dense that little light reaches the floor of the forest. They are dominated by conifers, especially pines, spruces, firs, cedars, larches and hemlocks. A few shrubs and broad-leaf species are also found in some areas of boreal forests. The important flowering trees are aspens and birches. Boreal forests are among the most economically important ecosystems as they are the source of much lumber and paper pulp.

The dominant animals of this biome include a few large mammals (elks or moose, deer, wolves, pumas and bears), small rodents (squirrels and rabbits), small carnivores (foxes), many insects, and migratory birds, especially waterfowl and carnivrous land birds (such as owls and eagles).

Disturbances—particularly fires, storms and outbreaks of insects—are common in the taiga forests. Another characteristic feature of this ecosystem (biome) is the presence of numerous lakes.

2. Temperate Forests : Temperate forests are found in climates slightly warmer than those of the taiga forest. These forests occur in the temperature regions of north-central Europe, eastern Asia and eastern United States. The annual precipitation ranges between 75 cm and 150 cm. The dominant vegetation includes tall deciduous trees such as maples, hickories, oaks, elms, beeches and chestnuts. Temperate deciduous forests are important economically for their hardwood trees used for furniture and other building materials. These forests are among the biomes most changed by human beings, as they occur in regions long dominated by human civilizations.

As compared to taiga, large mammals are less common in the temperate deciduous forest. The common large mammals in these forests include deers and bears. The dominant animals include squirrels, frogs, salamanders, snakes, lizards, rabbits and mice. Birds and insects are abundant.

3. Tropical Rain Forest : This biome is located in the equatorial regions wherever the average annual temperature exceeds 18°C and annual rainfall exceeds 140 cm. They are located primarily in south and central America, north-eastern Australia, Congo river basin of Africa, Indonesia, Philippines, Hawaii and parts of Malaysia. These forests cover about one-twelfth of earth's surface but contain more than half of earth's flora and fauna. Species diversity is high, with hundreds of species of trees within a few square kilometers. The warm and humid climate supports broad-leaved evergreen plants. Trees are generally very tall with distinct stratification (layering) of vegetation. The tallest trees (upto 50 m) form an open canopy but the lower crown levels block most of the available sun light from the forest floor.

Animal life is abundant and highly diverse. Mammals tend to be tree-dwellers but some are ground-dwellers. The dominant animals include monkeys, tropical birds, bats and a variety of carnivorous animals. Insects and other invertebrates are abundant and show a high diversity.

These ecosystems exist in regions of low disturbances. And, despite their great diversity and abundance, they appear to be quite fragile under disturbances. Another important characteristic feature of these biomes is very low nutrient content of the soil, except for the dead organic matter at the surface. Most nutrients (chemical elements), infact, are held in the living vegetation.

4. Temperate Shrub Forest : This biome, also known as *mediterranian shrub forest*, occurs under drier climates with low winter rainfall followed by drought in the rest of the year. The temperature is moderate under the influence of cool, moist air of the oceans. The most distinctive feature of this biome is the *Chaparral*, a miniature woodland dominated by dense stands of shrubs that rarely exceed a few meters in height. Chaparrals are found along the Mediterranean, coast of California, Chile, South Africa and South Australia. This biome is characterized by broad-leaved evergreen vegetation. The vegetation is made up of fire adapted resinous plants ; many species regenerate rapidly, and some promote fires by producing abundant quantity of fuel in the form of dead branches and twigs. As a result, they are rarely more than fifty years old. Typical vegetation of this biome is distinctively aromatic, such as scents of sage.

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There are few large animals in this biome ; instead, reptiles and small mammals are its characteristics. Presently, the animals and plants of this biome have little economic value.

5. Tropical Savannah : Tropical savannahs or tropical seasonal forests occur where rainfall is high (100 to 150 cm) but very seasonal (wet seasons alternate with dry season). They are warm climate plains characterized by coarse grass and scattered trees on the margins of tropics. They are located primarily in South and Central America, Africa, Australia, south-east Asia and India. Plants and animals are drought-tolerant and do not show much diversity. This biome has the greatest variety of hoofed herbivore species including giraffe, zebra, elephant and several species of antelope. Kangaroos are found only in the savannahs of Australia.

Disturbances, such as fires and impact of herbivores on the vegetation, are quite common. But such disturbances may be necessary ; otherwise, these savannahs might revert to woodlands in wetter areas or to shrub lands in drier areas.

3.12.2 Structure and Function

Forest is a type of terrestrial ecosystem. The various components of a forest ecosystem are as follows :

Abiotic component : These include basic inorganic and organic compounds present in the soil and atmosphere. In addition, dead organic debris is also found littered in forests. Further, the natural light conditions are different in forests due to complex stratification in the vegetation.

Biotic component : The various biotic components, representatives from the three functional groups, of a forest ecosystem are :

(*i*) Producer organisms : In a forest, the producers are mainly trees that show much species diversity and greater degree of stratification. The trees are of different kinds depending upon the type of the forest developed in that climate. The dominant species of trees (*i.e.* producers) in major types of forest ecosystems have already been stated. Besides various species of trees, there are also present shrubs and ground vegetation.

(*ii*) Consumer Organisms : In a forest, the consumers are of three main types—primary, secondary and tertiary consumers.

The primary consumers are the herbivores which feed directly on producers. These include the smaller animals such as ants, beetles, bugs, spiders, squirrels, mice, mongooses, etc. feeding on tree leaves, and larger animals such as elephants, deer, antelops, girrafes, etc. grazing on shoots and/or fruits of the trees (or producers).

The secondary consumers are carnivores and feed on primary consumers. These include birds, lizards, frogs, snakes, foxes, etc.

The tertiary consumers are secondary carnivores and feed on secondary consumers. These include top carnivores like lion, tiger, etc.

(iii) Decomposers: These include a wide variety of saprotropic micro-organisms like bacteria (*Sp. Bacillus, Sp. Clostridium, Sp. Pseudomonas*, etc.), fungi (*Sp. Aspergillus, Sp. Ganoderma, Sp. Fusarium*, etc.) and actinomycetes (*Sp. Streptomyces*, etc.). They attract the dead or decayed bodies of organisms and thus decomposition takes place. The dead or decayed bodies are consumed and their nutrients are released for reuse. The rate of decomposition in tropical and sub-tropical forests is faster in comparision to temperate forests.

3.13 GRASSLAND ECOSYSTEM

This is a type of terrestrial ecosystem. The principal grasslands include the *Prairies* of Canada and the USA, the *Pampas* of South America, the *Steppes* of Europe and Asia and the *Veldts* of Africa. Temperate grasslands occur in regions too dry for forests and too moist for deserts. The annual rainfall ranges between 25 to 75 cm and is usually seasonal; while, temperatures are moderate. Summer drought and winter blizzards can be severe, with periodic fire devastations in these biomes. The dominant plant species are short and tall grasses and other flowering plants, many of which are perennials with extensively developed roots. The soils of these grasslands often have a deep organic layer.

The highest abundance and the greatest diversity of large mammals are found in these ecosystems. The dominant animal species include wild horses, asses and antelope of Eurasia; herds of bison of Ameria; and the antelope and other large herbivores of Africa. Other animal species include larks, the burrowing owl, jackrabbit, badgers and antelopes.

3.13.1 Structure and Function

The different components of a grassland ecosystem, like others, are as follows:

Abiotic component: The abiotic components are the nutrients present in soil and the aerial environment. The essential elements like C, H, N, O, P, S, etc., thus, are supplied by water, CO_2, nitrogen, nitrates, sulphates, phosphates, etc. present in the soil of the area and in the atmosphere.

Biotic component: The biotic component of a grassland ecosystem has representatives from the three functional or metabalic groups which may be categorised as:

(i) Producer Organisms: In a grassland, the producers are mainly grasses; though, a few forbs and shrubs also contribute to primary production of biomass. Some of the most common species of grasses are *Sp. Brachiaria, Sp. Cynodon, Sp. Desmodium, Sp. Dichanthium, Sp. Digitaria, Sp. Setaria*, etc.

(ii) Consumer Organisms: In a grassland ecosystem, the consumers are mainly of three wo types—primary, secondary and tertiary consumers.

The primary consumers are herbivores feeding directly on grasses. These are grazing animals such as cows, buffaloes, sheep, goats, deer, rabbits, etc. Besides them, numerous species of insects, termites, etc. are also present.

The secondary consumers are the carnivores that feed on primary consumers (herbivores). These include animals like frogs, snakes, lizards, birds, foxes, jackals, etc.

The tertiary consumers include hawks, etc., which feed on secondary consumers.

(iii) Decomposers: The saprotropic organisms that are active in the decomposition of dead or decayed organic matter of different forms of higher life are many species of fungi, bacteria and actinomycetes. These micro-organisms consume the dead bodies of higher life forms and then bring about their nutrients (minerals) back to the soil. Thus, making the nutrients available to the producers in the system.

3.14 DESERT ECOSYSTEM

Deserts occupy about 17% of the land area. They occur where rainfall is extremely low (less than 50 cm per year) and evaporation rate is high. Even the water from the meagre rainfall is not available to plants due to its fast run-off rate. The deserts are characterized by extremely hot days and cold nights. Further, the seasonal fluctuations of temperature are also very wide. The deserts of the world are mainly located in the south-western United States, Mexico, coastal areas of Chile and Peru, North Africa (Sahara), central-western Australia, Asia (Thar, Gobi, Tibet and West Asia). And most of these deserts are situated in the rain shadow areas. Soils of these deserts often have abundant nutrients but little or no organic matter and need only water to become very productive.

Deserts are characterized by scanty flora and fauna. Only those organisms which have specialised structural, physiological and behavioural adaptations to withstand the extremes of temperature and aridity can survive there. The dominant plant species include cacti, acacias, euphorbias and succulents and hardy grasses. There are relatively very few large mammals in deserts, which include cats, rabbits, foxes and jackals. The dominant animals of deserts are non-mammalian vertebrates such as snakes and reptiles. Other desert animals include spiders, lizards, scorpions, wasps, ants, locusts, rats, and a large number of insect-eating birds (like swifts and swallows) and seed-eating quails and doves.

3.14.1 Structure and Function

The different components of a desert ecosystem are as follows :

Abiotic component : The aboiotic component mainly includes the nutrient present in soil and the aerial environment. The characteristic feature of the abiotic component is lack of organic matter in the soil and scarcity of water.

Biotic component : The various biotic components, representing the three functional or metabolic groups, are :

(i) Producer organisms : In a desert, the producers are mainly shrubs or bushes, some grasses and a few trees. The dominant plant species include succulents and hardy grasses. Besides them some lower plants such as lichens and xerophytic mosses are also present.

(ii) Consumers : These include animals such as insects and reptiles which are capable of living under xeric conditions. Besides them, some nocturnal rodents, birds and some mammalian vertebrates like camel, etc. are also found.

(iii) Decomposers : Due to poor vegetation, the amount of dead organic matter is very less. As a result, the decomposers are very few. The common decomposers are some bacteria and fungi, most of which are thermophilic.

3.15 AQUATIC ECOSYSTEMS

There are many types of aquatic ecosystems that differ widely with respect to almost all abiotic factor and biotic components. The aquatic ecosystems range from open ocean to small ponds. The adaptations of organisms to aquatic environment vary in degree and diversity. For example—animals such as fishes live exclusively in water, while others such as frogs, crocodiles, hippopotamus and aquatic birds are amphibious ; again, some animals like the coelenterates and echinoderms live only in saline water, while others like hilsa fish can live both in sea (saline water) and fresh water. Aquatic ecosystems are broadly classified into fresh-water and marine (ocean) ecosystems. But, it should be noted here that the so-called marine and fresh water environments have many ecosystems with overlapping boundaries which cannot be clearly distinguished, for example—estuaries.

3.15.1 Fresh Water Biome

Although fresh water ponds, lakes, rivers and streams make up a very small portion of Earth's surface, but they are critical for our water supply for residential, industrial and agricultural needs. Fresh water biomes are major recreational resources but are easily polluted. The dominant plants are various species of floating algae, referred to as a group as *phytoplankton*. Rooted flowering plants are found along the shores and in shallow areas of these ecosystems.

Generally, animal life is abundant in fresh water biome. The open waters have many species of small invertebrate animals, collectively called *zooplankton*. They are both, herbivores and carnivores. Numerous species of shellfish and finfish are also found in open waters.

Fresh water biomes, thus, are economically important for their fish, for their abundant bird life and for recreation and navigation or transportation.

3.15.2 Lakes and Ponds

These are stagnant fresh water bodies which occur practically in every ecosystem (biome). They vary in size from a few square metres to thousands of square metres. Similarly, their depth varies from a few centimeters to over a hundred metres.

The abiotic components of ponds or lakes depend on location, latitude, altitude and the surrounding ecosystem. In some cases, the lakes may have saline or brackish water, for example—Sambhar Lake of Rajasthan.

The organization (*i.e.* structure and function) of the pond, as a fresh water ecosystem, has already been described earlier in this chapter.

3.15.3 Rivers and Streams

Rivers and streams are flowing fresh water bodies. They are very important in the biosphere as they act as major transporters of materials from the land to the sea/ocean. They not only differ widely in volume of water, but they also differ much in their speed of flow, dissolved oxygen content, temperature and many other physical and chemical parameters. The nature as well as composition of flora and fauna largely depend on the source or origin of the river/stream and the terrestrial ecosystems (biomes) through which they pass.

The perennial rivers/streams originating from melting glaciers have rapid currents of cold water in their higher riches. The plankton populations are generally absent. In the middle reaches, the river becomes wider and the water currents slower. Sediments are deposited on the river-bed. The temperature of river water increases as it gets more of sunlight. As a result, the photosynthesis rate and biological activity become high. Sediments start depositing on the river-bed. In the lower reaches, the water currents diminish further. The plankton, bath phytoplankton and zooplankton, are quite common in this region. And the nature and composition of the fauna resemble that of the lakes. Various species of reptiles, mammals and birds obtain their food from the river water.

3.15.4 Ocean (Marine) Biome

The most distinguish characteristic of marine environment is its high concentration of salt and mineral ions. The salt concentration in an open sea is usually 3.5 per cent ; while the dominant ions are sodium and chloride followed by sulphur, magnesium and calcium. The salinity varies with depths and latitudes. It is less near the poles and river mouths.

The oceans (namely, Pacific, Atlantic, Indian, Arctic and Antarctic) cover about 70 per cent of the earth's surface. Each of these occeans represents a very large and stable ecosystem. Infact, as compared to fresh water, marine environments are more stable in their chemical composition due to salinity.

The biotic components of an ocean ecosystem are as follows :

(i) Producers : The primary producers are autotrophs which trap the radient energy of sun with the help of their pigments. They are mainly the phytoplanktons like the diatoms, dino flagellates and microscopic algae. Besides them, a number of macroscopic seaweeds, such as brown and red algae, also contribute significantly to primary production of organic matter. But these organisms show a distinct zonation at different depths of water in the ocean.

(ii) Consumers : All the consumers are heterotrophic macroconsumers which feed on the primary producers. These include :

—***Primary consumers*** **:** These are the herbivores that include crustaceans, molluscs, fishes, etc. They feed directly on producers.

—***Secondary consumers*** **:** These are the carnivores that feed on the herbivores (primary consumers). These are chiefly various species of fish, such as *Herring*, *Mackerel*, etc.

—***Tertiary consumers*** **:** These are the top carnivores that feed on other carnivores of the secondary consumers level. These are carnivorous fishes like Cod, Haddock, Shark, Whale, etc.

(iii) Decomposers : These are mainly bacteria and some fungi. These micro-organisms bring about the decomposition of complex dead organic matter of producers and consumers.

3.15.5 Estuary

An estuary is the area at the mouth of the river where river joins the sea/ocean. In esturies, the physical conditions are different as the fresh water from the rivers mixes with the sea/ocean water. The esturies are rich in nutrient and usually support an abundance of fish. Due to this, they are important breeding sites for commercially significant fish and as fishing areas.

PROBLEMS

3.1 Write an explanatory note on biosphere.

3.2 What is an ecosystem ? Classify ecosystems on the basis of energy sources.

3.3 What is a biome ? Name and explain the various types of biomes.

3.4 Define ecosystem. Give an account of the structure and function of an ecosystem.

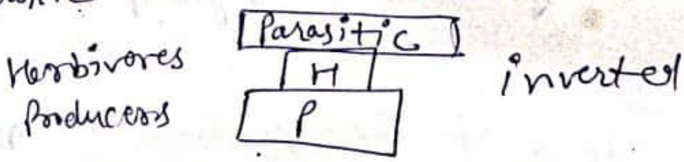
Ecological Pyramid   Charles Elton 1927

Trophic structure of ecosystem through a graph called ecological pyramid.

① **Pyramid of NO.** → shows total no. of individual at each trophic level. It may be upright or inverted.

inverted in case of ⓐ Tree ecosystem

ⓑ Parasitic "

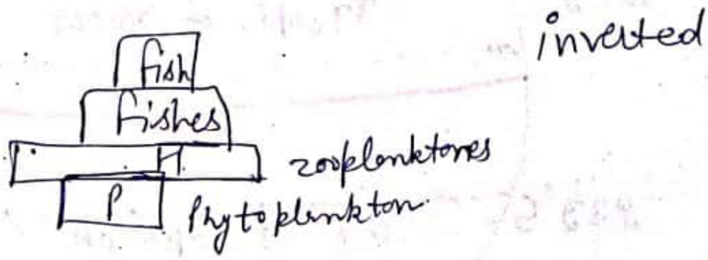


② **Pyramid of Biomass** → unit = dry wt / Area

→ it is based on total dry weight, Calorific value of living material.

→ normally upright

→ inverted in deep water bodies. eg. Pond.
imp



③ **Pyramid of Energy** → Unit = KJ/Area

→ Universal Pyramid

→ always upright becoz 2nd law of thermodynamics

→ also called Pyramid of Productivity imp.

P.T.O

ECOSYSTEM

→ Ist proposed by A.G. Tansley in 1935.

→ He defined as " the system resulting from the integration of all the living and non-living factors of the environment.

→ An ecosystem : smallest unit of biosphere that has all the characteristics ~~of~~ to sustain life.

→ ecosystem a group of nutrients, minerals, plants, animals, their wastes linked together by flow of food, nutrients and energy.

• **Types:** 3 types
- aquatic
- Terrestrial
- Artificial

aquatic, Terrestrial ← Natural ①
Artificial ②

① Natural: (old copy also)

→ operate themselves under natural conditions

① Terrestrial Ecosystem
- forest
- desert
- grass land
- Savannah

② Aquatic
- fresh water eg. Pond
- marine ecosystem eg. estuary

② Artificial: maintained artificially.

eg. waste water pond constructed by man, agricultural ecosystem, Aquarium, green house, Space craft.

Biome: ecosystems set which exposed to same climatic conditions, climatic adoptions, similar life cycle, physical structure is called a biome.

• Structure of Ecosystem:

ecosystem has 2 major components —

① **Abiotic:** non-living component

Physical: soil, temp, light and water

Chemical: inorganic and organic substances

C, H, N, K, P, S — carbohydrates, lipids, proteins, humus

② **Biotic:** all living components of many different populating. It includes

① Autotrophs: producers

- fixation of light energy
- use of simple inorganic substances and build up to complex.
- eg. algae, photosynthetic bacteria, green plants.

② Heterotrophs: consumers or dependent on others

ⓐ Macro consumers:

- Herbivores — 1° consumer eg. (vegetarian) feed from plant
- Carnivores — 2° or 3° " eg. fed from 1° consumer (non-vegetarian)
- omnivores — depend on plants & 1° consumer veg & non-veg. both. eg. humans

ⓑ Saprotrophs: m/o/s known as decomposers i.e bacteria, fungi, flagellates and actinomycetes.

- feed from dead organic matter and release inorganic compounds (nutrients) for producers.

→ Standing state: amt. of nutrient present in soil at a given time.

→ Standing Crop: amt. of living material at each trophic level is called standing crop at a given time

Its Unit is No. of organism present per unit area or dry weight of Biomass per unit area.

Consumers: which uses inorganic compounds for their food and energy.

1° :→ animals that feed plants eg. deer, goat, grasshopper, cattle etc.

2° → feed 1° consumers eg. hawk, lizard, owl, fox

3° → feed 1° carnivores or 2° consumers eg. snake, wolves etc.

4° → the largest carnivores that feed 3° consumers. eg. lions, tigers etc.

Decomposers, feed on dead organisms

→ transform complex org. compound to inorganic like H_2O, CO_2 other.

eg. bacteria, fungi

② Terrestrial Ecosystem:

उष्णकटिबंधीय वर्षा वन
① Tropical Rain forest: (Rainforest Biome)

location
0–10° N/S

→ Rainfall > 250 cm annual, temp. < 2°C
→ contain 40000 plants
→ located in south & central america, Australia, Africa, Malaysia, Philippines.
→ They covers $\frac{1}{12}$th of earth surface but $\frac{1}{2}$ & more of earth's flora and fauna.
→ Species diversity is high, generally trees are very tall (50 m ht also) (covered with vines, creeper, lianas, orchids etc.)
→ nutrients are very low in soil. (normally red & thick)
→ Rainforest of Brazil is called Salvas. It Contribute 50% of total rainforest.

Unique features — Presence of Butter's root
— " " climbing plant
" " Parasitic, epiphytes

*[forest of Africa called Savanna type] → grasses having scattered trees

पतझड़ शीतोष्ण
② Deciduous Forest / Temperate Forest:

→ 10–30° N/S latitude North of equator.
→ warm & cold & rainy also
→ precipitation $\boxed{80-150\text{ cm}}$
→ north-central Europe, eastern Asia, eastern United States
→ due to hardwood tree, these are used for furniture also they changed by humans.

③ **Desert:** 20 – 35° N/S of equator.

→ occupy about 17 % land area.

→ rainfall < 50 cm per year, evaporatⁿ high

→ deserts formed due to subsidense of air at 30° N/S of equator.

→ extremely hot days and cold nights

→ Mexico, Peru, Africa (Sahara), Australia, Asia (Thar etc).

→ soil have nutrient high so need only water for productivity.