Eco-system and Energy flow, Ecological succession

■ **Defination of Ecosystem – Whole biotic community and abiotic environment in particular area is called ecosystem.**

The term ecosystem was coined by Tansley (1935)

Types of ecosystem -

Ecosystem is formed due to interaction of all living organisms among themselves and their environment. There are two main kinds of ecosystem.

I. **Natural Ecosystem –** These ecosystems operate under natural conditions without any major interference of man. They may be terrestrial or aquatic. **Terrestrial : -** as forest, grassland, desert etc.

Aquatic : - as pond, river, lake, wetland, estuary etc.

II. **Artificial Ecosystem –** These ecosystems are man made and artificially maintained by addition of energy and planned manipulations.

e.g. Cropland and an aquarium.

► **Structure and Function of Ecosystem.**

Structure – Structure of ecosystem includes

1) Biological community. i.e. – species, numbers, biomass and distribution.
2) The quantity and distribution of non-living materials as nutrients, water etc.
3) The range or gradient of conditions of existence such as temperature, light etc.

► **Components of ecosystem – has two main components.**

1) **Abiotic Components** – Non-lining elements of ecosystem are called abiotic components such as climate, Organic compounds as proteins, carbohydrate lipids etc and inorganic substances like Ca, Mg, Fe, P, S, C, N etc.
2) **Biotic Components** – Living organisms of an ecosystem are called biotic components. They may be autotrophic or heterotrophic organisms.

Autotrophs – as green plants or photosynthetic or chemosynthetic micro organisms.

Heterotrophs – Heterotrophic organisms are of two types macro-consumers and micro-consumers.

a) **Macro-consumers** – They are herbivores and carnivores or omnivores (eat both plants and animals). The herbivores are primary consumers while the carnivores or omnivores may be secondary or tertiary consumers.

b) **Micro-consumers** – They are decomposers. They are saprophytes and includes bacteria, actinomycetes and fungi. They play an important role in releasing the inorganic nutrients back in the environment by decomposing the complex compounds from dead or living protoplasm.

· **Functions of ecosystem** - The functions of ecosystem mean the biological energy flow i.e. the production and respiration rates of the community, nutrient cycles and regulation of environment by the organisms.

Spatial pattern – Biotic and abiotic components differ as the locations vary in space and time. The variation due to space results in spatial pattern.

♦ **Types of spatial pattern –**

1) **Stratification** – Vertical distribution of different species of plants and animals occupying different levels is known as **stratification**.

e.g. trees occupy top vertical strata layer or layer of a forest, shrubs the second and herbs and grasses occupy the bottom layer. Similar stratification is also observed in the open seas as epipelagic mesopelagic, bathy-pelagic and benthic zones.

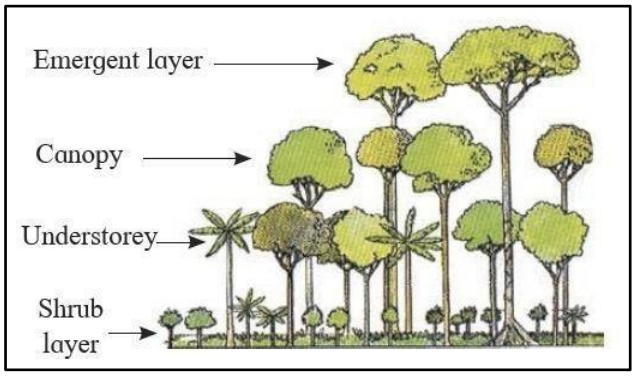


Fig : Stratification of plants in forest

2) **Zonation** – Horizontal distribution of plants and animals on land or in water is called **zonation**. Zonation is observed in aquatic (wetlands) as well as terrestrial ecosystems but it is easily seen at the junction of the two. Edges of a large lake or beach show pronounced zonation in the form of Inter-tidal, Littoral, Sub-littoral zones.

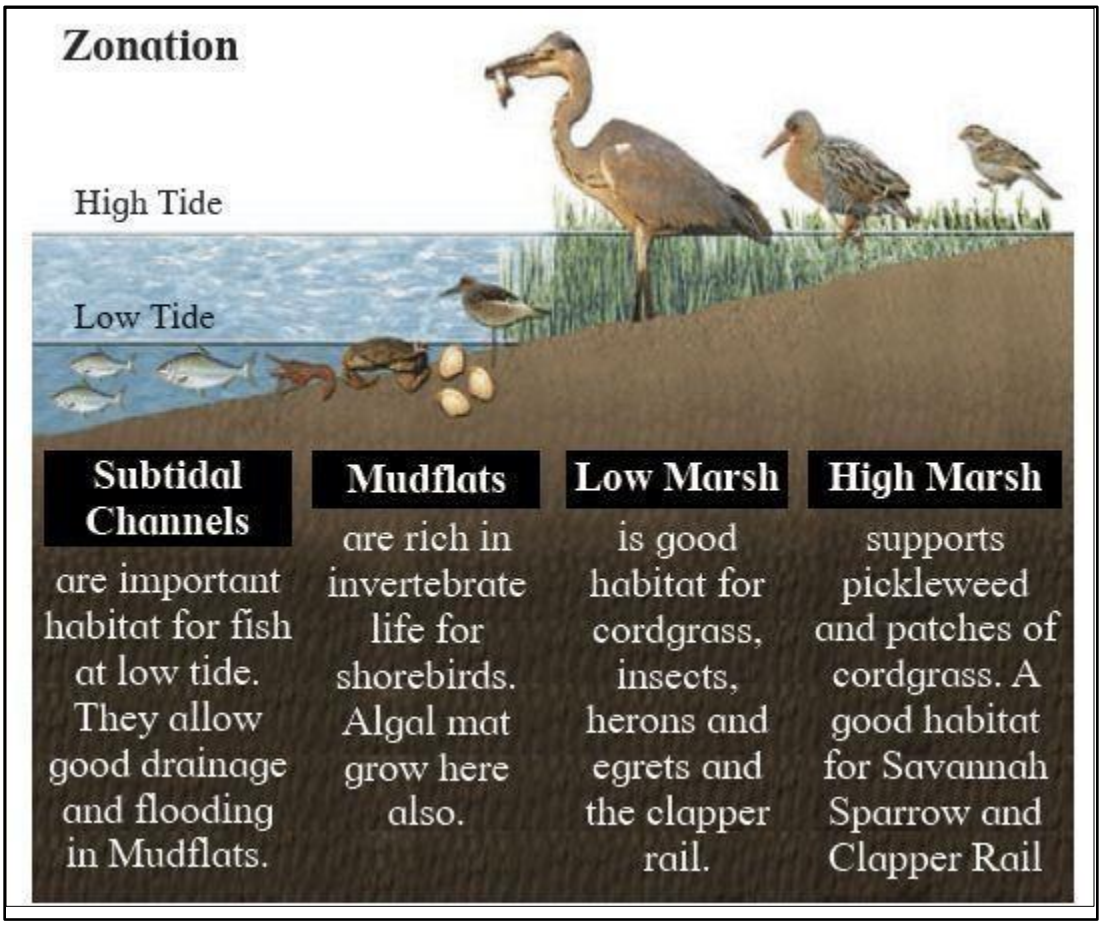


Fig : Zonation in wetland

The biotic and abiotic components of an ecosystem are all linked together to function as an '**ecosystem unit**' through various processes like Productivity, Decomposition, Nutrient cycling and Energy flow. These are functional aspects of ecosystem.

l) Productivity -

1) The Process of productivity involves conversion of inorganic chemicals in to organic materials with the help of radiant energy of the sun by autotrophs and consumption of autotrophs by heterotrophs.
2) Productivity refers to the rate of generation of biomass in an ecosystem.
3) It is expressed in units of mass per unit surface (or volume) per unit time for instance grams per square meter per day ($g/m^2/day$). The mass unit may relate to dry matter or to the mass of carbon generated.
4) Productivity may be classified as primary productivity, secondary productivity and net productivity.

♦ Primary productivity -

1) It is associated with autotrophic organisms which may be green plants or micro-organisms.
2) Autotrophs may be photosynthetic or chemosynthetic.
3) It can be considered as the rate at which the radiant energy is converted and stored by the producers. It can be further classified in to two categories such as,

a) **Gross primary productivity** – It is the total rate of photosynthesis including the organic matter used up during respiration. It is estimated in terms of either chlorophyll content as ch/g dry wt/unit area or photosynthetic number as CO_2 fixed/gchl/hour.

b) **Net Primary Productivity** – It is the actual amount of organic matter stored by green plants apart from its use in respiration. It is thus the rate of increase in biomass. It refers to the balance of gross photosynthesis and respiration and other plant losses as death etc.

GPR - R = NPR

♦ **Secondary productivity** – It is the rate of energy storage at the level of consumers. The consumers use the food materials directly or indirectly from the producers and simply convert it in to different forms.

♦ **Net productivity** – It is the rate of storage of organic matter which is not used by the consumer. It is equivalent to net primary production minus consumption by the heterotrophic organisms. It is generally expressed as 'production of Carbon/m2/day'

II) Decomposition –

Decomposers mostly bacteria, actinomycetes and fungi break down complex organic matter in to inorganic substances like carbon dioxide, water and nutrients and the process is called **decomposition**.

The important steps in the process of decomposition.

1) **Fragmentation** – Detritivores (e.g. earthworm) breakdown detritus in to smaller fragments or particles. This process is called **fragmentation**.
2) **Leaching** – The water soluble inorganic nutrients go down in to the soil horizon get precipitated as salts, this process is called **leaching**.
3) **Catabolism** – Fungal and bacterial enzymes degrade detritus into simple inorganic substances this is called **catabolism**. Fragmentation, Leaching and Catabolism operate simultaneously on the detritus.
4) **Humification** – Partially decomposed organic matter is called **humus**. **Humification** is formation of humus which is a dark coloured amorphous substance. It is reservoir of nutrients. Humus is resistant to microbial activity and undergoes decomposition at extremely slow rate. Humus holding changes soil texture and increase water holding capacity of soil.
5) **Mineralization** – The degradation of humus by some microbes release inorganic nutrients and this process is called **mineralization**.

Decomposition as a process requires oxygen. Temperature and soil moisture are the most important factors that regulate decomposition indirectly to help soil microbes warm and moist environment favours decomposition where as low temperature and anaerobic conditions inhibits decomposition.

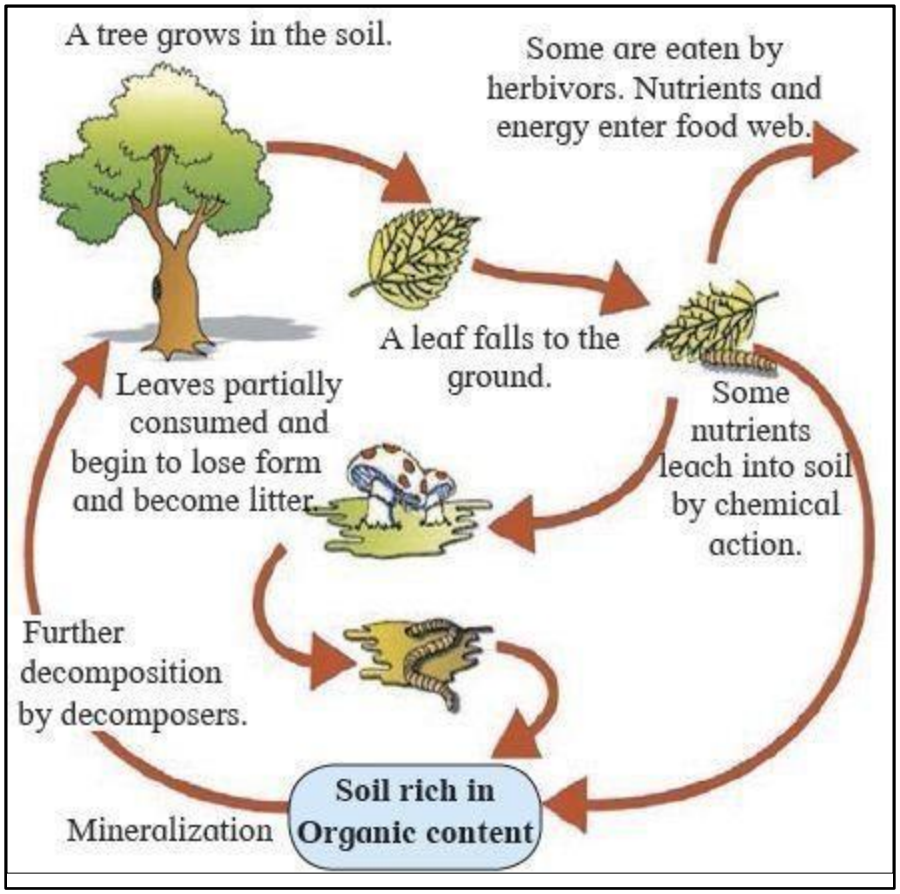
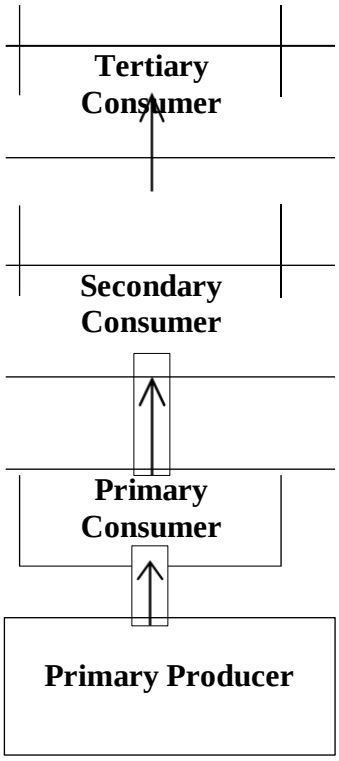


Fig : Decomposition cycle

- **Energy Flow** :-

1) Sun is the only source of energy for all ecosystems except deep sea ecosystems.
2) OF the total incident solar radiation, less than 50% of it is **photosynthetically active radiation** (PAR).
3) Plants capture only 2-10 % of the PAR and this small amount of energy sustains the entire living world.
4) Directly or indirectly, all organisms are dependent for their food on producers.
5) There is **unidirectional flow of energy** from sun to producers and then to consumers. The direction cannot be reversed. Energy can be used only once in the ecosystem.
6) The autotrophs are called **producers**.
7) In terrestrial ecosystem, major producers are herbaceous and woody plants.
8) In aquatic ecosystem producers are phytoplankton & algae
9) All animals directly or indirectly depend on plants for their food. They are hence called **consumers** (heterotrophs).
10) If they directly feed on plants they are called primary consumers. And if the animals eat other animals which eat plants, they are called **secondary consumers**. Secondary consumers eaten by **tertiary consumers**.

The primary consumers are also called as **herbivores**. Some common herbivores are insects (grasshopper, aphids), birds (parrot) and some mammals (sheep, cattles, goat, donkey) in terrestrial ecosystem and molluscs in aquatic ecosystem. The consumers that feed on these herbivores are **carnivores** (Secondary consumer). Those animals that depend on the primary carnivores for food are called **secondary carnivores**.



Fourth Trophic level (Top Carnivore)	→	Man, Lion
Third Trophic level (Carnivores)	→	Birds, Fish and wolf
Second Trophic level (Herbivores)	→	Zooplankton, Grasshopper and Cow
First Trophic level	→	Phytoplankton grass, trees

Trophic levels

Food Chain – Food chains are always straight and have four or five trophic levels. There are three types of food chains.

1) Grazing Food Chain.
2) Detritus Food Chain.
3) Parasitic Food Chain.

A simple **Grazing Food Chain** (GFC) is as

Grass	→	Deer	→	Leopard
Producer		Primary consumer		Secondary consumer

Detritus Food chain –

The detritus food chain (DFC) begins with dead organic matter. It is composed of decomposers which are heterotrophic organisms, mainly fungi and bacteria. They get their energy and nutrients by degrading the detritus. These are known as **saprotrophs**. Decomposers secrete enzymes that breakdown dead organic materials in to simple inorganic materials which are absorbed by them. Detritus food chain may be connected with the grazing food chain at some levels. In a natural ecosystem some animals like cockroaches, crows, bears, man etc are **omnivores** which eat producers as well as consumers. These natural interconnection of food chains make it a food web.

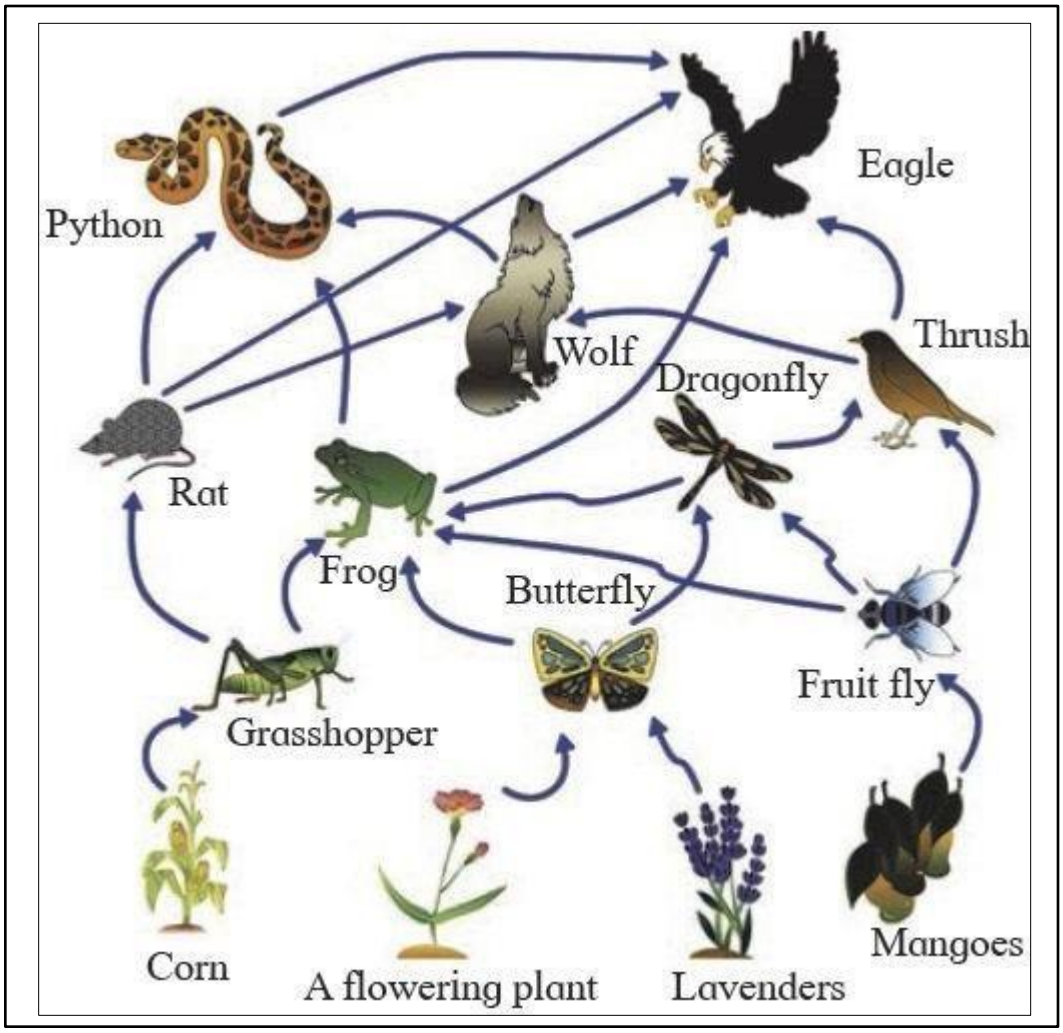


Fig : Food Web

♦ **Trophic level** –

Organisms occupy a specific place in the food chain that is their **trophic level**.

Producers belong to the **first** trophic level.

Herbivores (Primary consumer) to the **second** trophic level. Carnivores (Secondary consumer) to the **third** trophic level.

· **Energy loss with increasing trophic level**

The amount of energy available decreases at each successive trophic level. The number of trophic levels in any food chain is restricted as the transfer of energy follows **10 % Law** (R. Lindermann 1942).

The law states that only 10 % of the energy is transferred to each trophic level as net energy, from the previous trophic level.

Why food chains do not exist in isolation, but are always interconnected to form food web.

In nature there are different trophic levels producer, herbivore, primary, carnivore, secondary carnivore, tertiary carnivore and ultimate carnivore.

Beyond secondary carnivores, however amount of energy available is too less, hence there is no tertiary carnivore that feeds exclusively on secondary carnivore even though the secondary carnivore many times will feed on herbivores directly.

▲ **Ecological Pyramids** –

Defination – Ecological pyramid is a graphic representation of the relationship between the organisms of various successive trophic levels with respect to energy, biomass and number.

This concept was developed by C.Elton in 1927. The three ecological pyramids which are usually studied are

I) Pyramid of number

1. The relative number of individuals per unit area at different trophic levels, constitutes the number pyramid.
2. It shows relationship between producers, herbivores and carnivores at successive trophic levels, in terms of their number.
3. In grassland, the producers which are mainly grasses are always more in number.
4. This number goes on reducing from base to apex of the pyramid.
5. The primary consumers as rabbits, mice etc are lesser than the number of grasses.
6. As we go in upward direction i.e. to secondary, tertiary/ top level consumers as hawk or other birds their number will be least. Thus the pyramid is **upright**.

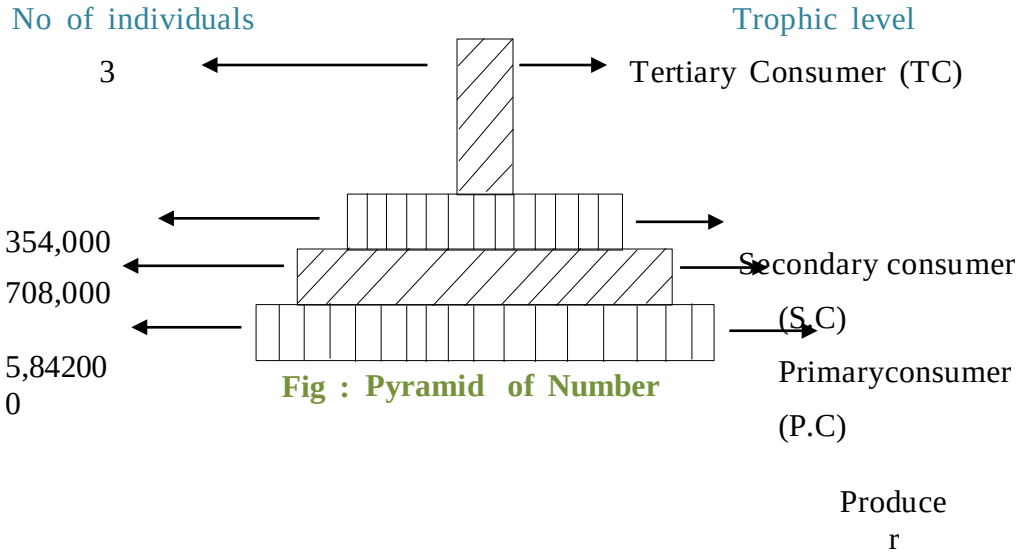


Fig : Pyramid of Number

II) Pyramid of Biomass –

1. In most of the ecosystems, pyramid of biomass is upright like pyramid of numbers.
2. Producers are always more in biomass than herbivores and herbivores are more in biomass than the carnivores.
3. However there are exceptions to this generalization.

4. The pyramid of biomass in sea is also inverted because the biomass of fishes is more than that of phytoplanktons.

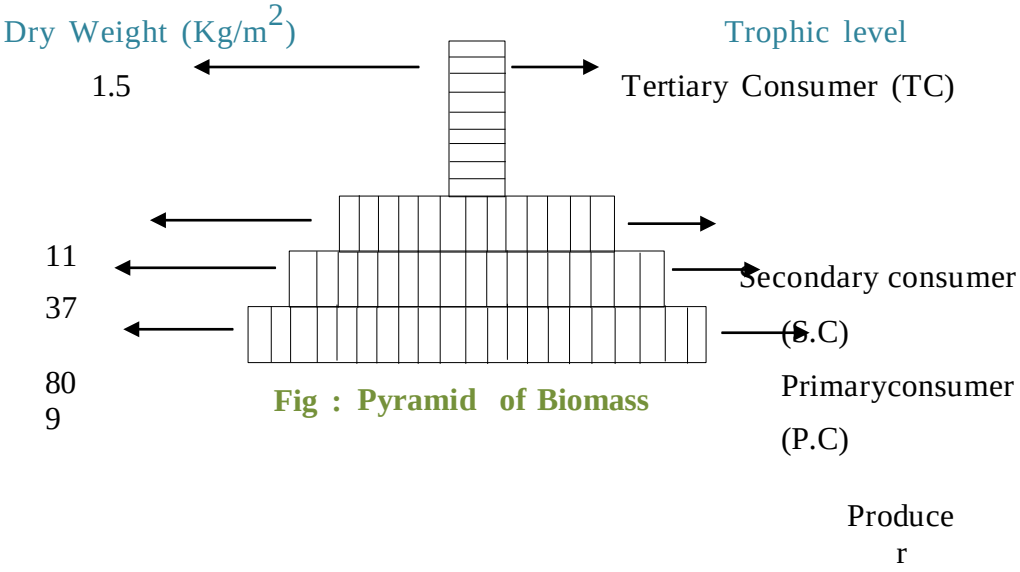


Fig : Pyramid of Biomass

III) **Pyramid of Energy** -

1. Pyramid of energy is always upright, can never be inverted, because when energy flows from a particular trophic level to the next trophic level some energy is always lost as heat at each step.
2. In smaller food chains,more energy is available than in the longer food chains.

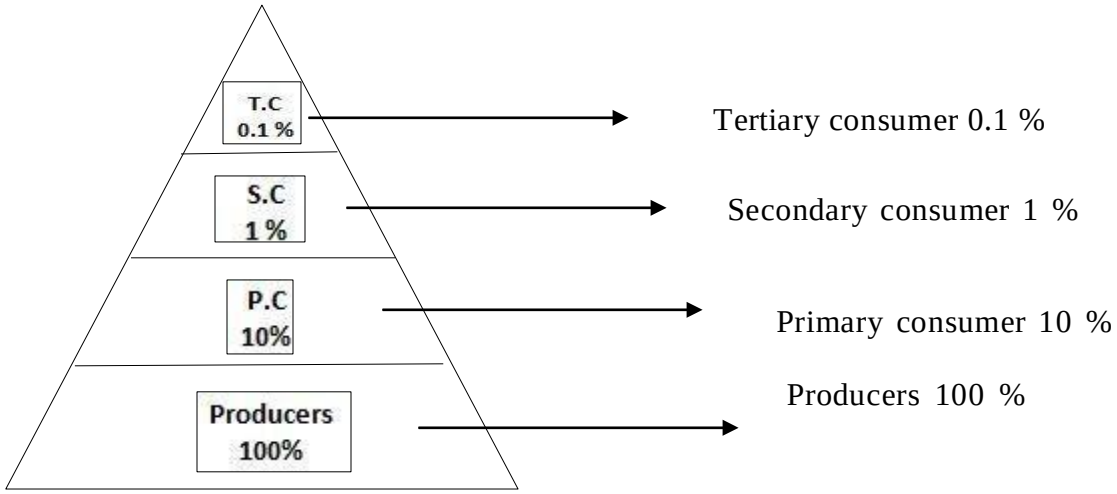


Fig : Pyramid of Energy

▲ Limitations of ecological pyramids

1) It assumes a simple food chain, sometimes that almost never exists in nature.
2) It does not accommodate a food web.
3) Moreover saprophytes are not given any place in ecological pyramids even though they play a vital role in the ecosystem.
4) A given species may occupy more than one trophic levels in the same ecosystem at the same time, e.g. sparrow is a primary consumer when it eats seeds, fruits, peas and a secondary consumer when it eats insects and worms.

♦ Nutrients cycles

Defination – The movement of nutrient element through the various components of an ecosystem is called **nutrient cycling** or **biogeochemical cycle**.

The nutrients which are never lost from the ecosystems are recycled indefinitely.

Types of Nutrient cycles

There are two types of nutrient cycles

a) **Gaseous** b) **Sedmimentary**.

The reservoir for gaseous type of nutrient cycles (e.g. nitrogen, carbon cycle) is atmosphere.

For the sedimentary cycle (e.g. phosphorus cycle) the reservoir is earth's crust.

I) Carbon cycle -

1) Carbon constitutes 49 % of dry weight of organisms out of total quantity of global carbon 71 % is found dissolved in oceans. Thus ocean is reservoir of carbon. Fossil fuels like oil, coal and natural gas also represents a reservoir of carbon.
2) These long term storage places are known as '**sinks**'.
3) Carbon as CO_2 moves from the atmosphere to plants Through the process of photosynthesis, CO_2 is pulled from the air to produce food.
4) Carbon moves from plants to animals through food chains, i.e. carbon present in plants moves to the animals.
5) Carbon moves from living things to the atmosphere. Each time you exhale, you are releasing CO_2 in to the atmosphere.
6) Decomposers also contribute CO_2 in atmosphere by their processing of waste materials and dead organic matter of land and oceans.
7) When fossil fuel burns to power factories, power plants motor vehicles, most of the carbon quickly enters the atmosphere as CO_2. Each year 5.5 billiono tons of carbon is released through combustion of fossil fuels. Of this 3.3 billion tons stays in atmosphere. Most of the remainder is dissolved in sea water and deposited as calcium or magnesium carbonate compounds which make up shells of marine animals.
8) Burning of wood, forest fire and combustion of organic matter, fossil fuel and volcanic activity are additional sources for releasing CO_2 in atmosphere.
9) Carbon moves from the atmosphere to the oceans. The oceans and other water bodies absorb some carbon in the form of co_2 from the atmosphere. The carbon is dissolved in to the oceanic water. Some amount of the fixed carbon is lost to sediments and removed from circulation.

10) Fossil fuels represent a reservoir of carbon. Carbon cycling occurs through atmosphere, ocean and through living and dead organisms. Human activities have influenced the carbon cycle.

11) Rapid deforestation and massive burning of fossil fuel for energy and transport have increased the rate of release of co_2 in to atmosphere. Thus the entire carbon cycle is run by basic processes viz. Photosynthesis, Respiration, Decomposition, Sedimentation and Combustion.

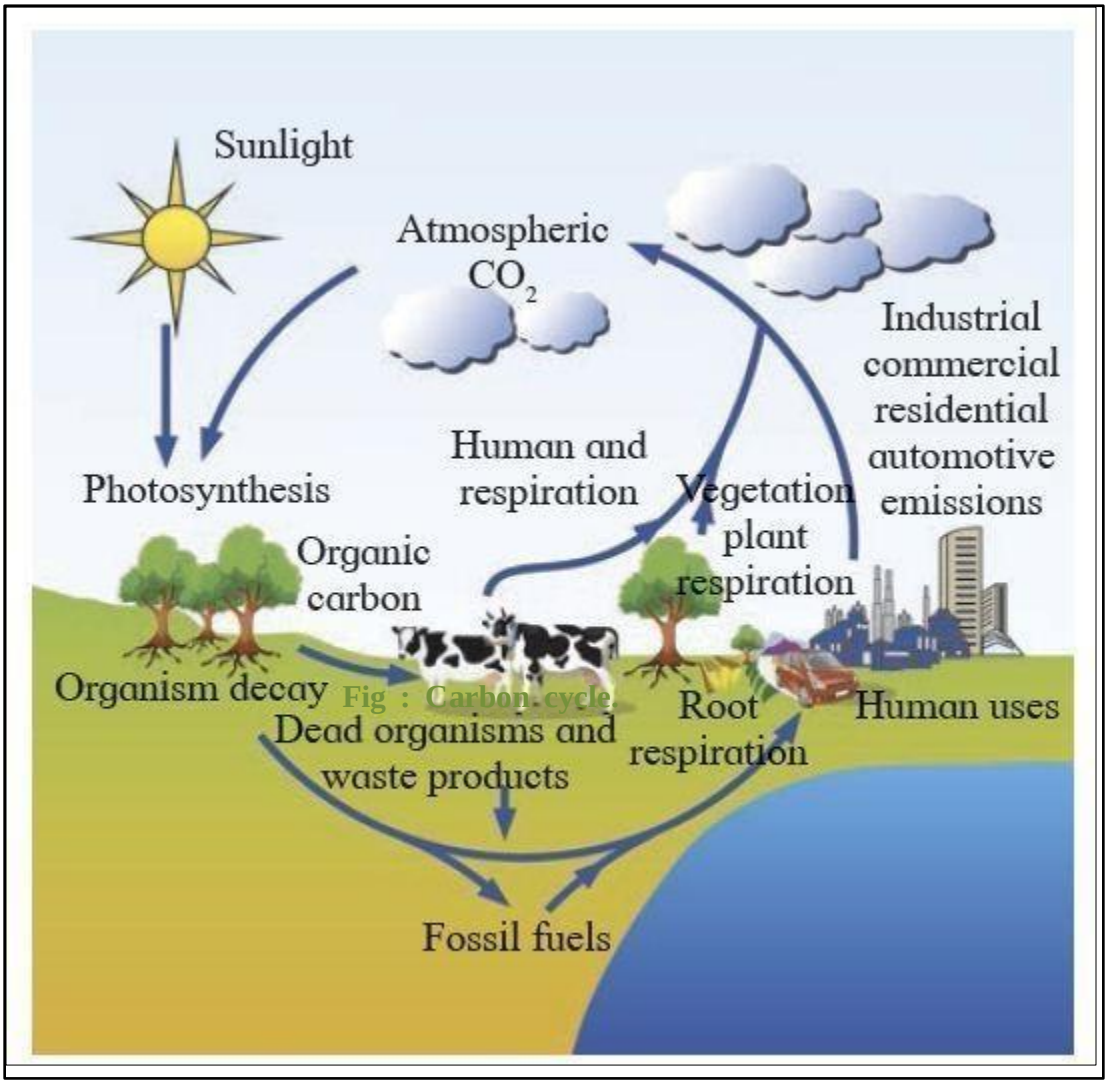
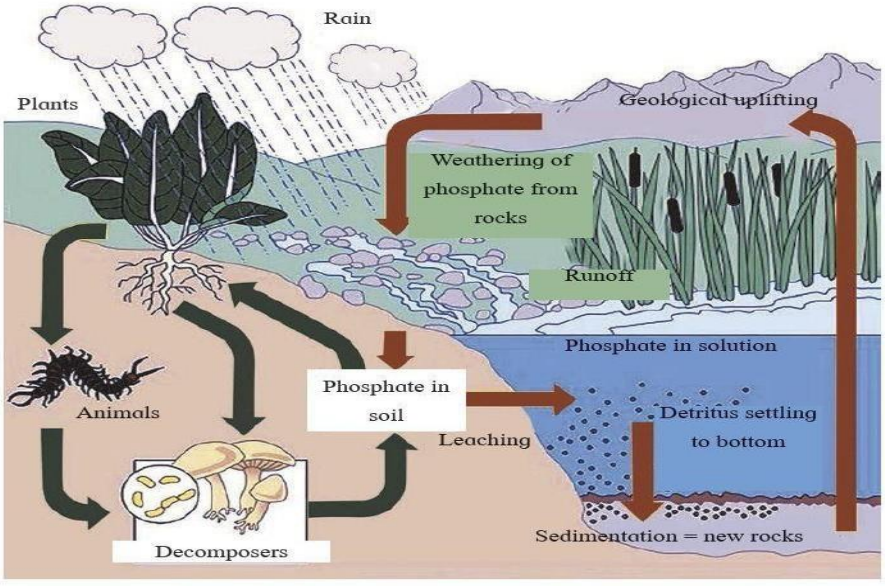


Fig : Carbon cycle

II) Phosphorus Cycle -

Cyclic movement of phosphorus through hydrosphere, lithosphere and biosphere constitutes phosphorus cycle.

1) Phosphorus is a major constituent of biological membranes, nucleic acids and cellular energy transfer systems. Many animals need this element to make shells, bones, hooves and teeth.
2) The natural reservoir of phosphorus is rock, which contains phosphorus in the form of phosphates.
3) When rocks are weathered, minute amounts of these phosphates dissolve in soil solution and are absorbed by the roots of the plants.
4) Herbivores and other animals obtain this element from plants.
5) The waste products and the dead organisms are docomposed by phosphate solublilizing bacteria releasing phosphorus.
6) Sudden influx of phosphorus in the form of agricultural runoff or industrial effluents rich in phosphate content leads to **eutrophication** in water bodies.
7) Eutrophication is due to overgrowth of algae which use up all the oxygen in water and kill other aquatic life.
8) Marine birds play unique role in phosphorus cycle. These birds eat marine fish, which is rich in phosphorus. Their excreta called guano deposits contain high levels of phosphorus and thus marine birds return phosphorus from the ocean to the land.



■ Ecological Succession

Defination – The gradual and predictable change in the species composition of a given area is called **ecological succession**. The change is sequential and environmentally regulated.

Process of succession involves sequential steps like

Nadation – The process of removing covering or uncovered.

Invasion – Establishment, spread & ecological impact of species translocated from one region or continent to another by human.

Ecesis – The process of successful establishment of plant or animal species in a habitat that was barren previously or left barren due to some reason.

Aggregation – a group composed of many distinct individuals.

Competition – An interaction between organisms or species in which both are harmed or in limited supply any one survive.

Co-action – Any relationship between organisms within a community.

Reaction and stabilization –

Sere – The entire sequence of communities that successively change in a given area, is called sere.

Seral community – It is an entire gradient of organisms from pioneer stage to climax stage. The transitional communities are termed as seral community.

Type of ecological succession

There are two types of succession

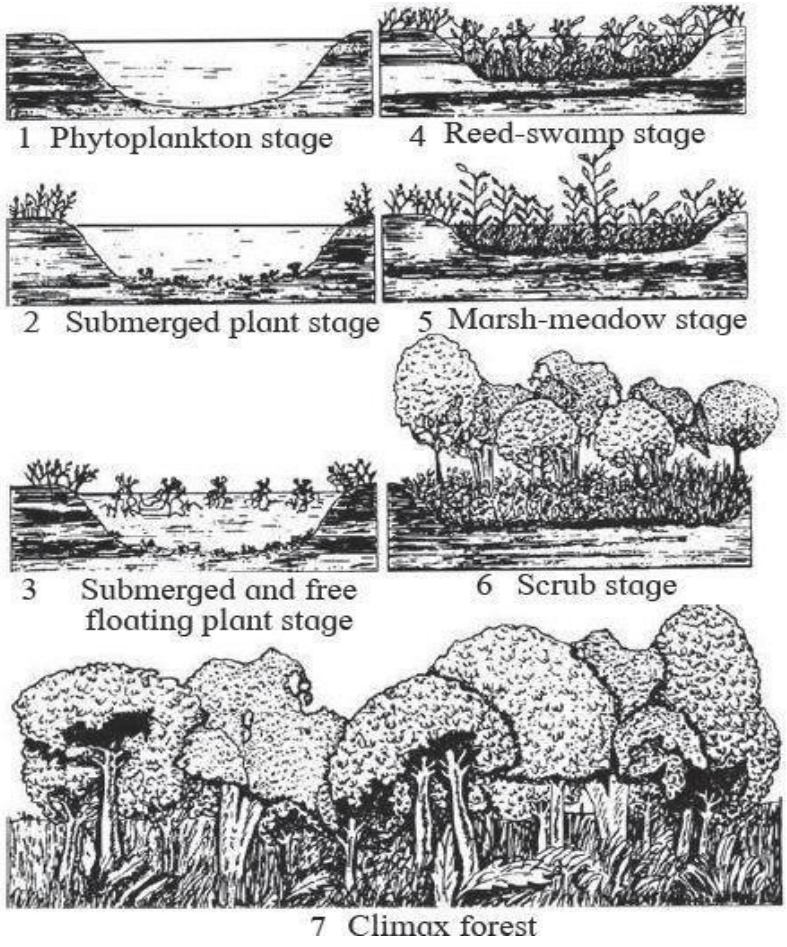
1) **Primary Succession –** The primary succession newly starts in the area where no living organisms ever existed like on a newly formed volcanic islands bare rock, newly formed pond or newly cooled lava etc. The establishment of a new biotic community is generally very slow. Depending on climate, it takes natural processes, several hundred to several thousand years to produce fertile soil on bare rock.

2) **Secondary Succession** – Secondary succession begins in areas where natural biotic communities have been destroyed such as an abandoned farm lands, burned or cut forests, lands that have been flooded etc. some soil or sediment is present. Secondary succession is faster than primary succession.

Succession of Plants

Based on the nature of the habitat, whether it is water or it is on very dry areas succession of plants is called hydrarch (hydrosere) or xerarch (xerosere) respectively.

Hydrarch succession – occurs in the areas where water is present in abundance. It begins with small phytophanktons followed by submerged and free floating plants and then rooted hydrophyles sedges, grasses and finally the trees. The transformation takes place from pool of water to swamp then marsh and then mesic condition.



Xerarch succession – occurs in desert areas It begins with growth of lichens which produce acid to dissolve rocks and brings about weathering of rocks that results in soil formation. Then small plants like mosses can inhabit followed by herbs, shrubs and then trees. Ultimately stable climax forest community evolves.

Both hydrarch and xerarch successions lead to mesic conditions (neither too dry nor too wet)

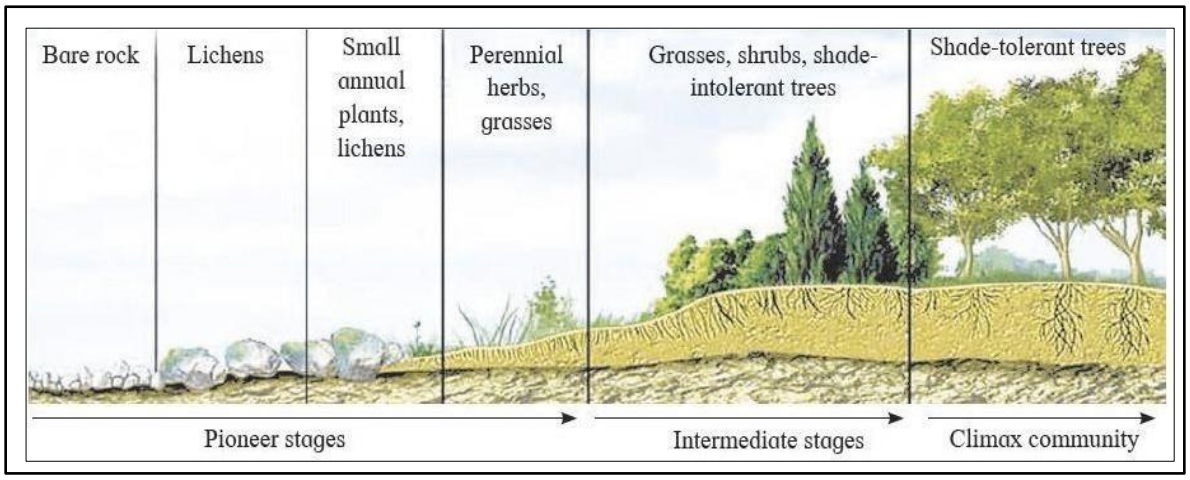


Fig : Xerarch succession of plants.

Ecosystem Services

Defination – The products of processes are termed as ecosystem services.
E.g. healthy forest ecosystems purify air and water.

The Millennium Ecosystem Assessment report 2005 defines Ecosystem services as benefits people obtain from ecosystems and indentifies four categories of ecosystem services as

1) **Supporting services** – include services such as nutrient cycling, primary production, soil formation, habitat provision and pollination maintaining balance of ecosystem.

2) **Provisioning services** - include food (seafood) raw materials (including timber, skins, fuel wood), genetic resources (including crop improvement genes and health care), water medicinal resources and ornamental resources (furs, feathers, ivory, orchids, butterflies) etc.
3) **Regulating services** – include carbon sequestration, Predation regulates prey populations. Waste decomposition and detoxification, Purification of water and air and pest control.
4) **Cultural services** – include cultural, spiritual and historical, recreational experiences, science and education and Therapeutics (including animal assisted therapy)

Following are the main ecological services

1) **Fixation of atmospheric CO2 and release of O2** - are the most important services provided by an ecosystem. Photosynthetic activity of photoautotrophs absorb carbon (in CO_2 form) from the atmosphere and releases O_2 as a by product. O_2 not only purifies air but is also used for respiration by all aerobes.
2) **Pollination** – of plants brought about by wind, water or other biotic agencies is also and important. Ecosystem service, without which there would be no crops and no fruits.