Chapter 8

Ecosystem

Chapter Contents

Introduction

Wide range of living organisms are present on earth surface. All living organisms such as plants, animals and microorganisms interact among themselves and also with the surrounding physical environment and maintains a balance in nature. This forms a self-sustaining or functional unit of the living world called as ecosystem. Thus, an ecosystem consists of interaction of biotic component comprising living organisms and abiotic components comprising physical factors like temperature, rainfall, wind, soil and minerals.

TYPES OF ECOSYSTEM

Ecosystem varies greatly in size from a small pond to a large forest or a sea. Many ecologists regard the entire biosphere as a global ecosystem as a composite of all local ecosystems on earth. Since this system is too much big and complex to be studied at one time, so to make the study easier, it is broadly divided into two basic categories :

(i) **Terrestrial Ecosystem :** It occurs over land *e.g.*, forest, grassland, desert.

(ii) **Aquatic Ecosystem :** It occurs in water bodies *e.g.*, pond, lake, river (fresh water), wet land, sea, estuaries (salt water).

Similarly, w.r.t. human interference the ecosystems are of two types:

(i) **Natural ecosystem :** It develops in nature without human support or interference *e.g.*, forests, marine ecosystem.

(ii) **Anthropogenic ecosystem or man-made ecosystem :** It is the one which is created and maintained by human beings *e.g.*, crop fields, garden, aquarium. **Agroecosystem or agriculture is the largest man-made ecosystem.**

Characteristics of anthropogenic ecosystem :

(i) Do not possess self regulatory mechanism

(ii) Have little diversity

(iii) Simple food chain

(iv) High productivity

(v) Little cycling of nutrients

Example 1 : *Which is global ecosystem? To make its study easier it is divided into how many categories?*

Solution : Global ecosystem is biosphere and the two categories are terrestrial and aquatic.

Try Yourself

Ecosystem: Forest, Grassland, Estuaries, Pond, Lake, Wetland.

1. From the above given options, how many can be categorised into terrestrial and aquatic ecosystem respectively?
2. Amongst these which is smallest ecosystem?

ECOSYSTEM - COMPONENTS

An ecosystem is made up of two components *i.e.*, abiotic and biotic.

I. Abiotic Components

The non-living factors or the physical environmental factors prevailing in an ecosystem constitute the abiotic components. They are mainly of three types *i.e.*, climatic, edaphic, topographic factors which you have studied in detail in previous chapter. So, here only main points are mentioned below.

(i) **Climatic factors :** It includes temperature, water, light, wind, humidity, air currents.

(ii) **Edaphic factors :** It includes factors related to the structure and composition of soil, including its physical and chemical properties.

(iii) **Topographic factors :** It includes factors related to physical features of earth like slope, valley, mountain and plain etc.

II. Biotic Components

All living organisms *i.e.*, plants, animals and microorganisms that are present in environment constitute the biotic components of the ecosystem. On the basis of their role in the ecosystem, these can be classified into three main groups:

(i) **Producers :** They are green photosynthetic plants that entrap solar energy through chlorophyll to synthesise organic food from inorganic raw materials. So, they are called **autotrophs** (self-nourishing).

In **terrestrial ecosystem**, major producers are herbaceous and woody plants.

In **aquatic ecosystem**, chief producers are phytoplanktons, algae and the floating, submerged and marginal plants found at the edges.

Producers are also known as **"converters"** or **"transducers"** because they convert solar energy into chemical energy stored in the bonds of sugars.

(ii) **Consumers :** They are the animals that are not capable of synthesizing the food materials. They are dependent on producers directly or indirectly for their survival. Thus, they are called **heterotrophs**. Consumers are of following types :

(a) **Primary Consumers (PC) or First Order Consumers :** These animals directly feed on producers. They are also called herbivores or **key industry animals**. (Convert plant matter into animal matter)

Terrestrial ecosystem : Common herbivores are grasshopper, cow and deer.

Aquatic ecosystem : Common herbivores are molluscs, tadpole and mosquito larvae.

(b) **Secondary Consumers (SC) or Second Order Consumers or Primary Carnivores :** They are animals which feed on herbivores.

Terrestrial ecosystem : Toad, spiders, lizards, centipedes and insectivorous birds.

Aquatic ecosystem : *Hydra*, frog and some fishes.

(c) **Tertiary Consumers (TC) or Third Order Consumers or Secondary Carnivores :** Carnivores which feed upon secondary consumers *e.g.*, large fishes (aquatic ecosystem), snake (terrestrial ecosystem). There may be quarternary or fourth order consumers which prey upon secondary carnivores.

(d) **Top Carnivores:** The carnivores which are not eaten by others are called top carnivores. They may belong to the category of primary, secondary, tertiary carnivores. *e.g.*, tiger, lion, panthers and falcon,peacock.

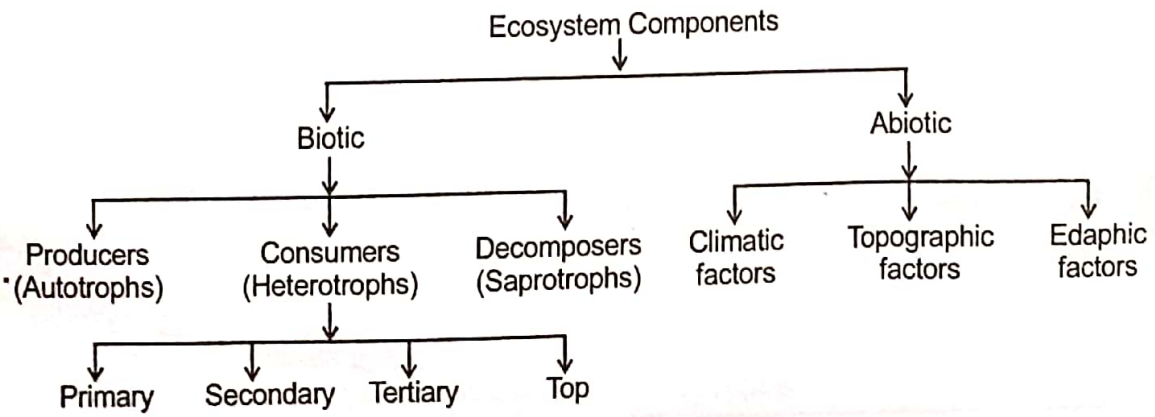
(iii) **Decomposers :** They are saprophytic microorganisms deriving their food material from organic matter present in dead remains of plants and animals.They secrete digestive enzymes which convert complex organic substances into simpler ones. A part of the digested organic matter is assimilated by the microorganisms and the rest is broken down into simpler inorganic compounds for recycling. They bring about cyclic exchange of materials between biotic community and the environment. They are thus, very essential components of an ecosystem. They are also called **reducers** as they are capable of degrading the dead organisms. These are the fungi, bacteria and flagellates especially abundant in the bottom of the pond. Decomposition involves the following conversions :

Complex organic substances → Simple organic substances → Inorganic compounds

Functions of decomposers in ecosystem :

1. They are natural scavengers as they reduce organic remains of earth.
2. Replenish the soil naturally with minerals that are essential for growth of plants and hence, maintenance of ecosystem.

Some workers differentiated few other categories of living beings amongst the biotic components of an ecosystem. They are **scavengers**, **detrivores** and **parasites**. Parasites belong to diverse groups, *e.g.*, bacteria, fungi, protozoans, worms etc. Detrivores are animals which feed on detritus *e.g.*, termites, earthworm etc. They are helpful in quick disposal of the dead bodies. Scavengers are animals that feed on dead or injured animals and they clean the earth of organic garbages *e.g.*, carrion beetles, marabou storks, crow and vultures (full-time scavengers).



Example 2 : *How many main groups are categorized under biotic components of ecosystem? Mention their names.*

Solution : Three categories can be distinguished under biotic component of ecosystem *i.e.*, producers, consumers, decomposers.

Try Yourself

3. Mention name of major producers in terrestrial ecosystem.
4. Chief producer in aquatic ecosystem is _____.
5. Which biotic component is involved in maintaining soil fertility?
6. Choose odd one out w.r.t. consumers.

   Insects, Chemosynthetic bacteria, Tadpole.

ECOSYSTEM - STRUCTURE

Interaction of biotic and abiotic components result in a physical structure that is characteristic for each type of ecosystem. Important structural features include :

(i) Species Composition :

It is the identification and enumeration of plant and animal species of an ecosystem. For example, tropical rain forest is dense with amazing number of biological species. On the other hand, vegetation is sparse in the desert ecosystem.

(ii) Stratification :

Vertical distribution of different species occupying different levels. It is the structure as recognizable pattern in spatial arrangement of the members of the communities. For example, in a forest following vertical subdivisions are present.

(a) Top layer – Trees.

(b) Second layer – Shrubs.

(c) Bottom layer – Grasses and herbs.

Example 3 : *Mention two important structural features of ecosystem.*

Solution : Species composition, Stratification.

Try Yourself

State True or False

7. Vertical stratification is more diverse in grassland than desert ecosystem.
8. Maximum species diversity is associated with tropical rain forest.

ECOSYSTEM - FUNCTION

Ecosystem possesses a natural tendency to persist. This is made possible by a variety of functions (activities undertaken to ensure persistence) performed by the structural components. The components of the ecosystem are seen to function as a unit to ensure its persistence. The key functional aspects of the ecosystem are:

(I) Productivity

(II) Decomposition

(III) Energy flow

(IV) Nutrient cycling

(I) Productivity

It is the rate of biomass production. Productivity in ecosystem is of two types – Primary and Secondary productivity.

1. **Most productive ecosystem** are coral reefs, tropical rain forest, sugarcane field.
2. **Least productive ecosystem** – Desert and deep sea.

(i) **Primary Productivity :** It is the rate at which biomass or organic matter is produced by plants or producers during photosynthesis per unit area over a time period or it refers to rate at which sunlight is captured by producers for the synthesis of energy-rich organic compounds through photosynthesis.

It is expressed in terms of weight as $(gm\ m^{-2})yr^{-1}$ or energy as $(Kcalm^{-2})yr^{-1}$ to compare the productivity of different ecosystems. It can be further divided into two categories :

(a) **Gross Primary Productivity (GPP) :** Rate of production or synthesis of organic matter by producers during photosynthesis per unit time and area. Energy-captured process is operating in the green tissues; these as well as other tissues are consuming photosynthates in respiration. So, considerable amount of GPP is utilised by plants in respiration.

(b) **Net Primary Productivity (NPP) :** Gross primary productivity minus respiratory losses (R). So you can say, it is rate of organic matter build up or stored by producers in excess of respiratory utilization per unit time and area.

$$NPP = GPP - R$$

Net primary productivity is the available biomass for the consumption to heterotrophs *i.e.*, both herbivores and decomposers.

Factors affecting primary productivity : Several biotic and abiotic factors given below affects magnitude of primary productivity.

(i) Photosynthetic capacity of producers which means the ability to utilise incident solar radiation to raise gross primary productivity.

(ii) Solar radiations available

(iii) Temperature

(iv) Soil moisture

(v) Availability of nutrients

Productivity of biosphere : Annual NPP of whole biosphere is approximately 170 billion tons (dry weight) of organic matter. Of this, despite occupying about 70% of the surface, the productivity of oceans are only 55 billion tons and for terrestrial ecosystem is 115 billion tons.

Reasons for the low productivity of oceans : In deep marine habitats two main limiting factors are there.

(i) **Light :** It decreases with depth.

(ii) **Nutrients : Most limiting nutrient** of marine ecosystem is **nitrogen.**

(ii) Secondary productivity :

It is the rate of formation of new organic matter by consumers.

Example 4 : *How many most important functional aspects of ecosystem are there? Which one is associated with rate of biomass production?*

Solution : Four, productivity is the rate of biomass production.

Try Yourself

9. Rate at which sunlight is captured by autotrophs represents _____.
10. Global area occupied by oceans is _____ but productivity contribution is _____.

State True or False:

11. Only biotic factors affect the magnitude of primary productivity.
12. Value of net primary productivity is considerably higher than gross primary productivity.

II. Decomposition

While productivity involves synthesis and building processes, decomposition is equally important, which concerns with breakdown of complex organic matter to inorganic raw materials like CO_2, H_2O, and various nutrients by decomposers. **The major site of decomposition is the upper layer of soil in terrestrial habitats and bottom of water bodies.** Dead remains such as leaves, bark, flowers and dead remains of animals including faecal matter constitute **detritus** which is the raw material for decomposition.

(A) Decomposition Processes : There are three important steps in the process of decomposition, viz., fragmentation, leaching and catabolism. These processes occur simultaneously.

(i) Fragmentation of Detritus : Small invertebrate animals called **detritivores** feed on detritus, *e.g.*, earthworms, termites. They bring about its fragmentation. A part of detritus eaten by detrivores comes out in highly pulverised state in their faeces. Due to fragmentation during eating and pulverisation in digestive tracts, detritus is changed into fine particles which have a large surface area and can be easily acted upon by enzymes.

(ii) Leaching : Part of water-soluble substances present in the fragmented and decompoing detritus (*e.g.*, sugars, inorganic nutrients) go down into the soil horizon by percolating water and get precipitated as unavailable salts.

(iii) Catabolism : It is carried out by **saprotrophic bacteria and fungi**. They secrete digestive enzymes over the fragmented detritus. The enzymes change complex organic compounds into, simple compounds; inorganic substances are released in this process. They act as **"nature's scavengers"**.

The rate of catabolic action or breakdown of different complex substances is different. This differential decomposition produces two substances, humus and inorganic nutrients, by process called humification and mineralisation respectively.

(a) **Humification :** It is the process of decomposition of detritus to form **humus. Humus is a dark-coloured, amorphous, more or less decomposed organic matter rich in cellulose, lignin, tannins, resin, etc. and is highly resistant to microbial action.** It undergoes decomposition at an extremely slow rate. Humus is slightly acidic, colloidal and functions as **reservoir** of nutrients.

(b) **Mineralisation :** It is the release of inorganic substances (*e.g.*, CO_2, H_2O, minerals) from organic matter or humus during the process of decomposition. They are formed alongwith simple and soluble organic substances when digestive enzymes are poured over organic matter by saprotrophic microbes.

Fragmentation, leaching and catabolism in decomposition operate simultaneously on the detritus. Humification and mineralisation occur during decomposition in soil.

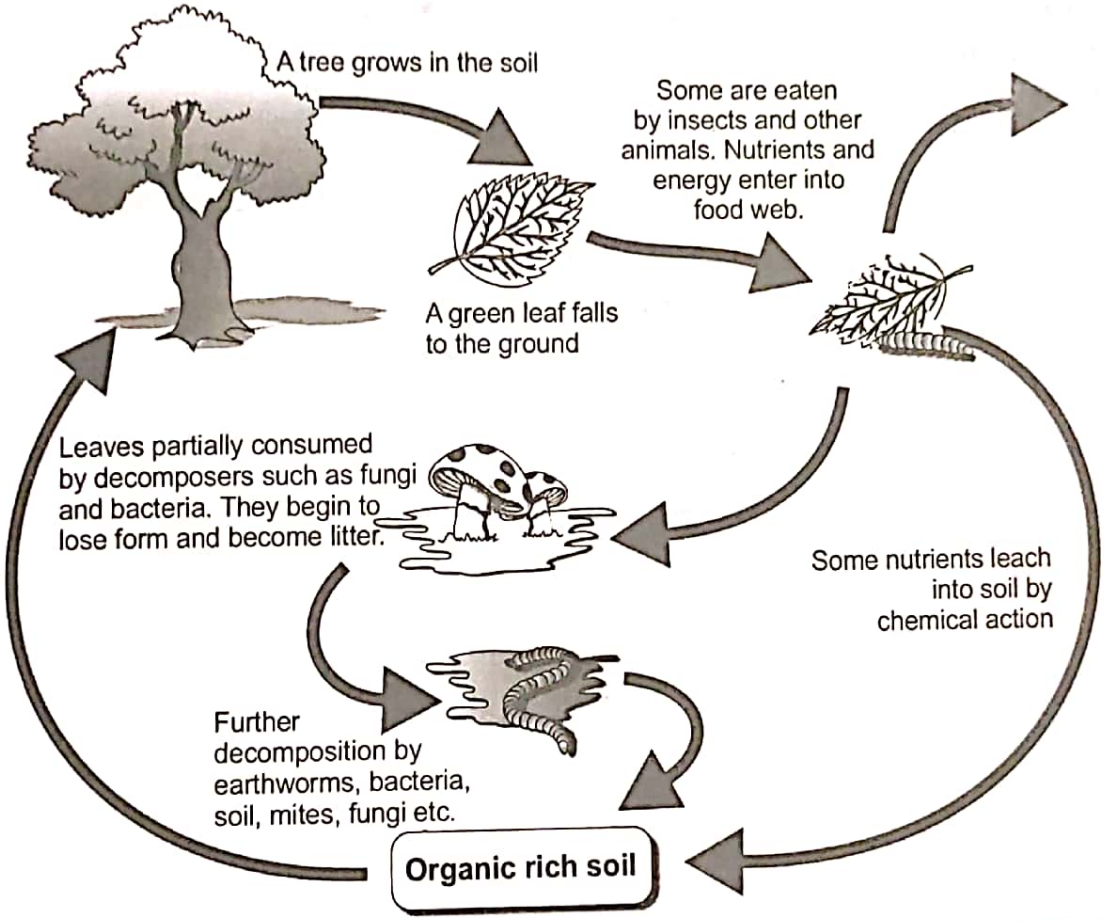


Fig.: Diagrammatic representation of decomposition cycle in a terrestrial ecosystem

(B) Factors Affecting Decomposition : Decomposition is largely an oxygen requiring process. The rate of decomposition of detritus is controlled by chemical nature of detritus and a number of climatic factors given below :

(i) **Chemical nature of detritus.** Decomposition of detritus is slow if it contains lignin, chitin, tannins (phenolics) and cellulose. It is rapid, if detritus possesses more of nitrogenous compounds (like proteins, nucleic acids) and water-soluble reserve carbohydrates or sugars.

(ii) **Temperature.** At a temperature of more than 25°C, decomposers are very active in soils having good moisture and aeration. In humid tropical regions, it does not take more than 3–4 months for complete decomposition of detritus. However, under low temperature conditions (< 10 °C) of soils, the rate of decomposition is very slow even if moisture and aeration are optimum.

(iii) **Moisture.** An optimum moisture helps in quicker decomposition of detritus. Reduction in moisture reduces the rate of decomposition as in areas of prolonged dryness like tropical deserts where, otherwise, the temperature is quite high. Excessive moisture also impedes decomposition.

Temperature and soil moisture are the most important climatic factors that regulate decomposition through their effects on the activities of soil microbes.

(iv) **Aeration.** It is required for activity of decomposers and detrivores. A reduced aeration will slow down the process of decomposition.

So, from this discussion it can be enumerated that **warm and moist environment favour decomposition whereas low temperature and anaerobiosis inhibit decomposition** resulting in build up of organic materials.

(C) **Nutrient Immobilisation : The phenomenon of incorporation of nutrients in living microbes is called nutrient immobilisation**. After death of microbes, the immobilised nutrients become available again for solubilisation. Immobilisation protects the nutrients from being washed out and lost from ecosystem.

Example 5 : *Mention the raw material of decomposition. Which step of decomposition is performed by detrivores?*

Solution : Raw material of decomposition is detritus. Fragmentation is performed by detrivores resulting in breakage of larger size organic matter into smaller one which increases surface area for action of microbes.

Try Yourself

13. Which of the following terms are **not** associated with humus?

    Amorphous, Light coloured, Acidic, Colloidal, Labile, Reservoir of nutrients.

14. Mention the name of two major decomposers.

15. How many among the factors given below result in piling up of organic matter?

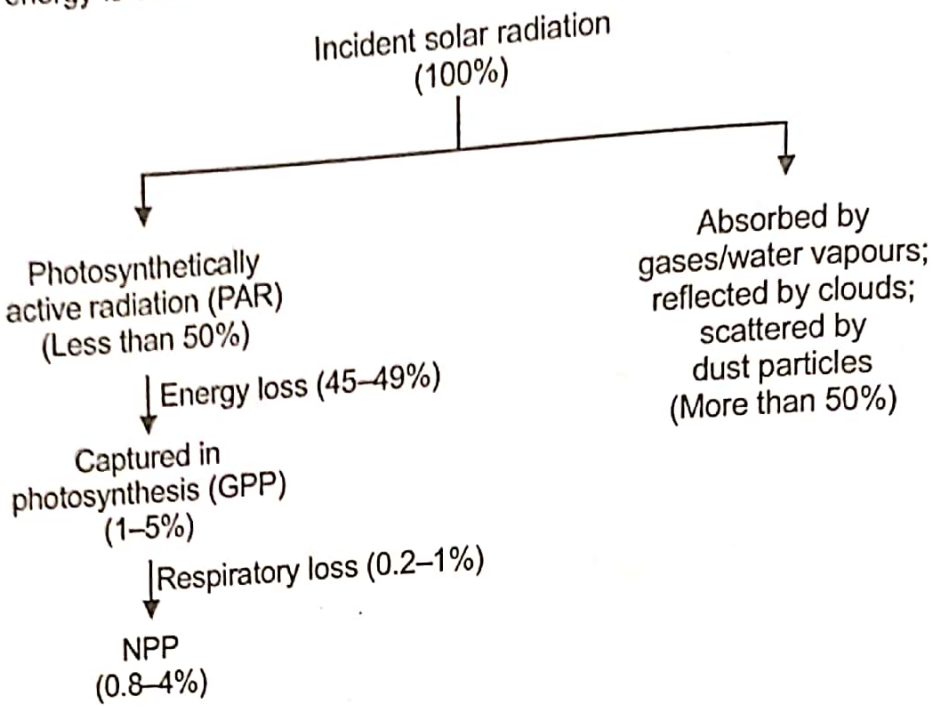
    Warm environment, Anaerobic condition, Low moisture, < 10°C temperature.

State True or False

16. Rate of decomposition is controlled by climatic factors only.

III. Energy Flow

Energy flow is sequential process of the movement of energy in an ecosystem through a series of organisms. Sun is the only source of energy for all ecosystems on earth (except for deep sea hydrothermal ecosystem). Flow of incident energy is shown below.



Source of Energy :

Of the incident solar radiation less than 50% of it is photosynthetically active radiation (PAR). Plants capture only 2–10% of PAR or 1–5% of incident solar radiation in synthesis of organic matter. Roughly 20% of it is consumed in respiration so that net primary productivity is 0.8–4% of incident radiation or 1.6–8% of PAR.

Energy does not remain trapped permanent in any organisms. It is either passed on to the higher trophic level or becomes available to detrivores or decomposers after the organism dies. Herbivores feed on producers. Part of the energy is wasted in digestion and assimilation. Some of the assimilated food is broken down to release energy for performing body activities. A very small proportion becomes part of the body of herbivore. Herbivores are eaten by primary carnivores, latter by secondary carnivores and so on. So, energy flow in an ecosystem is always **unidirectional** or one way *i.e.*,

Solar radiation → Producers → Herbivores → Carnivores.

Thus energy which passes from autotrophic plants to the herbivores does not pass back to the autotrophs.

Energy flow follows laws of thermodynamics:

This large expenditure of energy in the ecosystem is based on two basic laws of thermodynamics. In accordance with the **first law of thermodynamics** (which states that energy is neither created nor destroyed, but can be transformed from one state to another), energy of sunlight can be transformed into energy of food and heat. According to **second law of thermodynamics**, no transfer of energy occurs unless and until it is accompanied by degradation or dissipation of energy from concentrated to dispersed form. The transfer of energy from one organism to another is accompanied by degradation and loss of major part of food energy as heat. Energy of food is concentrated form while its highly dispersed form is heat.

Example 6 : *Energy of sunlight is fixed by green plants and trapped in C–C bond of sugars through process of photosynthesis. This explains which law of thermodynamics?*

Solution : First law of thermodynamics.

Try Yourself

State True or False :

17. Energy transfer is cyclic.
18. Value of PAR is > 50% of solar radiation.
19. Exception to source of energy is hydrothermal ecosystem.
20. Give a scheme or flow chart representing flow of energy in an ecosystem.

IV. Food Chain

It is a sequence of living organisms which involves transfer of food energy from producers, through a series of organisms with repeated eating and being eaten is called food chain. Each level or step in a food chain where transfer of energy takes place is called **trophic level**.

Types of Food Chain :

(i) Grazing Food Chain (GFC) or Predator food chain

(ii) Detritus Food Chain (DFC) or Saprophytic food chain

(iii) Parasitic Food Chain (PFC) or Auxilliary food chain

(i) Grazing Food Chain (GFC) : Consists of producers, consumers and decomposers. Source of energy for such food chain is sun.

(a) Primary Producers (PP) : They are autotrophic organisms which fix up the solar energy and manufacture their own food from inorganic raw material. So, they form the base of food chain constituting first trophic level (T_1).

(b) Primary Consumers (PC) or Herbivores : These are animals which feed on green plants or plant products, so they constitute second trophic level (T_2).

(c) Secondary Consumers (SC) or Primary Carnivores : These are animals which feed on herbivores and form third trophic level (T_3).

(d) Tertiary Consumers (TC) or Secondary Carnivores : These are animals which feed on secondary consumers and constitute the fourth trophic level (T_4) and so on.

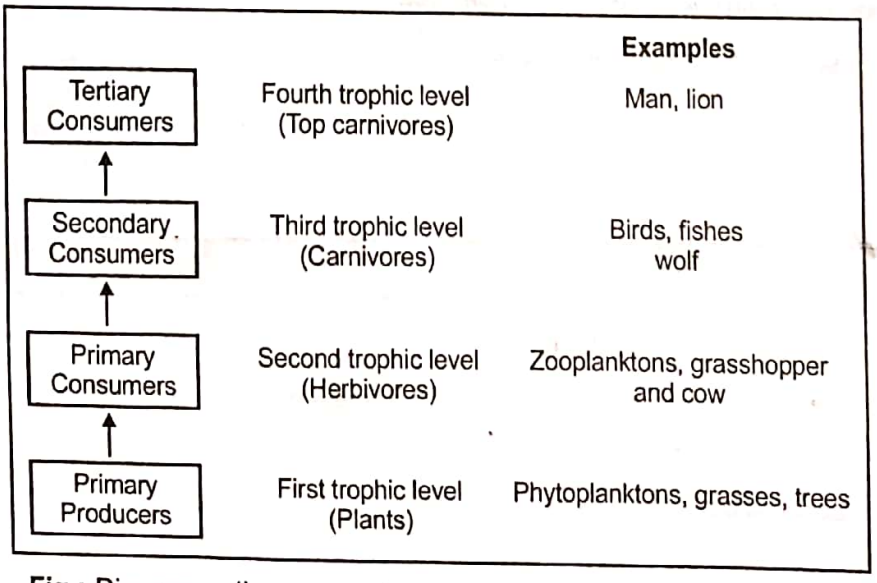


Fig.: Diagrammatic representation of trophic levels in an ecosystem

Terrestrial food chain:

Grass	→	Grasshopper	→	Frog	→	Snake	→	Eagle
PP		PC		SC		TC		Top consumer
T_1		T_2		T_3		T_4		T_5

Aquatic food chain :

Phytoplankton	→	Zooplankton	→	Small fish	→	Large fish
PP		PC		SC		TC
T_1		T_2		T_3		T_4

GFC is major conduit of energy flow in aquatic ecosystem. Size of organisms commonly increase at higher trophic levels.

(ii) **Detrius Food Chain (DFC) :** Begins with detritus or dead organic matter. **It is made up of decomposers** which are heterotrophic organisms mainly fungi and bacteria. Detrivores act over it. Therefore food energy present in detritus passed into them. Detrivores and decomposers are consumed by smaller carnivores which in turn become food for larger carnivores and so on.

A common detritus food chain with earthworm as detrivore is given below.

Detritus → Earthworm → Sparrow → Falcon.

In terrestrial ecosystems, a much larger fraction of energy flows through the DFC than through the GFC.

(iii) **Parasitic food chain/Auxilliary food chain :** Size of the organisms finally reduces at higher trophic level (parasite).

e.g., Tree → herbivore birds → lices and bugs.

Example 7 : *What type of food chain it is?*

Grass → Rabbit → Wolf → Tiger .

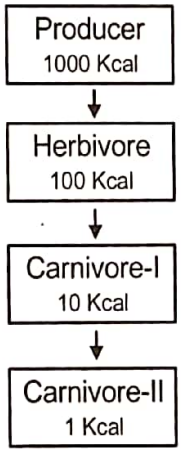
Solution : Predatory or Grazing food chain.

Food Web :

DFC may be connected with GFC at some levels. Some of the organisms of DFC are prey to the GFC animals. In ecosystem, linear food chains as shown above seldom exists, because every organism has alternate source of food. An animal may have preference for a particular prey, but if the latter has a small population, it may feed upon some other prey. Single animal may be eaten by different animals and thus, different food chains get interconnected and one animal may be a link in more than one food chain. The network of interconnected food chains at different trophic levels in a biotic community is termed **food web**. **Occurrence of food webs provides stability to ecosystem**. Food webs operate because of taste preference for particular food and unavailability of food. One animal may feed upon organism of even different trophic level like, snakes may feed upon mice (herbivore) and frogs (carnivore), **jackals are both carnivores and scavengers**. Sparrow is a primary consumer when it eats seeds, fruits etc. and a secondary consumer when it eats insects and worms.

Ten Percent Law of Energy Transfer :

The law was proposed by **Lindeman** in 1942. The transfer of energy from one trophic level to another trophic level is accompanied by loss of energy at each level or step. When the plants are eaten by herbivore about 10% of energy in the food is fixed into animal flesh while 90% is consumed in ingestion, respiration, maintenance of body heat and other activities. Similarly, when a carnivore consumes that herbivore, again about 10% of energy is fixed. Therefore, at each transfer only 10% of the total energy is actually available to the next trophic level. It is called 10% law.



So, you can see residual energy decreases drastically within 2–3 trophic levels. **As a result an ecosystem can support only a limited number of trophic levels hardly, 3–5. Respiratory loss gradually increases** in successive trophic levels. It is **20%, 30% and 60%** respectively at **producer, consumer and top carnivore** level.

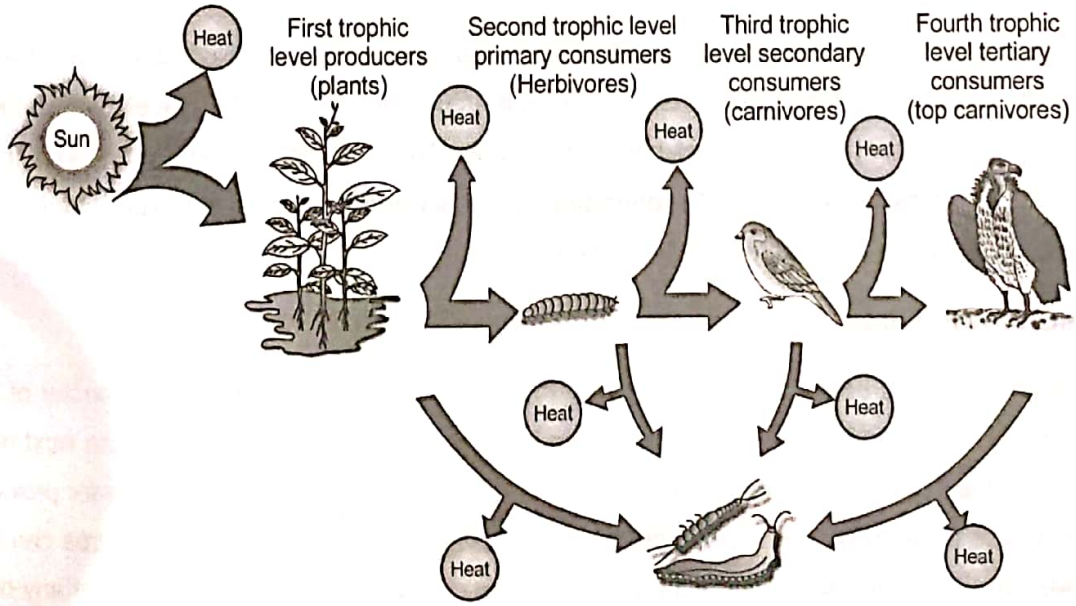


Fig.: Energy flow through different trophic levels

Standing state or quality : Amount of all the inorganic substances present in an ecosystem per un at a given time.

Standing crop : Amount of living material present in different trophic levels at a given time. It is expr as the numbers or biomass of organisms per unit area. The biomass of a species is expressed in ter either fresh or dry weight. Measurement of biomass in terms of dry weight is more preferred to avoid vari in weight due to seasonal moisture differences in biomass.

Example 10 : *How does food web provide stability to ecosystem?*

Solution : (i) Provide alternate pathway of food availability, so none get starved if preferred species reduced.

(ii) No species is exploited beyond the degree of its recovery.

Try Yourself

23. Mention names of two omnivores.

24. What is the magnitude of energy at T_2 and T_3 level in the given figure?