5.2.1 Kinds of Ecosystem

An ecosystem can be natural or artificial, temporary or permanent and large or tiny. Thus, various constituent ecosystems of the biosphere fall into the following categories :

1. **Natural Ecosystems.** These types of ecosystems operate by themselves without any major interference by man. Based upon the particular kind of habitat, these are further classified as :
   (*i*) Terrestrial ecosystems such as forests, grasslands, deserts, a single log, etc.
   (*ii*) Aquatic ecosystems which may be further distinguished as follows :
      (*a*) *Fresh water ecosystems.* These may be lotic (running water as spring, brook, stream or river) or lentic (standing water as lake, pond, pool, puddle, ditch, swamp, etc.).
      (*b*) *Marine ecosystems.* These include salt water bodies which may be deep bodies as an ocean or shallow ones as a sea or estuary.
2. **Artificial Ecosystems.** These are also called *man-made* or *man-engineered ecosystems.* These are maintained artificially by man where, by addition of energy and planned manipulations, natural balance is disturbed regularly, *e.g.,* croplands such as sugarcane, maize, wheat, rice-fields, orchards, gardens, villages, cities, dams, aquarium and manned spaceship.

5.2.2 Structure of Ecosystem

The structure of an ecosystem is basically a description of the species of organisms that are present, including information on their life histories, populations and distribution in space. It is a guide to who's who in the ecosystem. It also includes descriptive information on the non-living (physical) features of environment, including the amount and distribution of nutrients. An ecosystem typically has two major components :

(A) **Abiotic or Non-Living Components.** Abiotic component of the ecosystem comprises of following components :

1. Climatic conditions and physical factor of the given region such as air, water, soil, temperature, light (*i.e.,* its duration or intensity), moisture (relative humidity), pH etc.
2. Inorganic substance such as water, carbon (C), nitrogen (N), sulphur (S), phosphorus (P) and so on, all of which are involved in cycling of materials in the ecosystem (*i.e.,* biogeochemical cycles). The amount of these inorganic substances, present at any given time in an ecosystem, is designated as the standing state or standing quality.
3. Organic substances such as proteins, carbohydrates, lipids, humic substances, etc., present either in the biomass or in the environment, *i.e.,* biochemical structure that link the biotic and abioitc components of the ecosystem.

(B) **Biotic (living) Components.** In the trophic structure of any ecosystem, living organisms are distinguished on the basis of their nutritional relationships, which are discussed as follows :

1. **Autotrophic component.** Autotrophic component of ecosystem includes the *producers* or energy transducers which convert solar energy into chemical energy (that becomes locked in complex organic substances such as carbohydrate, lipid, protein, etc.) with the

help of simple inorganic substances such as water and carbon dioxide and organic substances such as enzymes. Autotrophs fall into following two groups :

(*i*) *Photoautotrophs* which contain green photosynthetic pigment chlorophyll to transduct the solar or light energy of sun, *e.g.*, trees, grasses, algae, other tiny phytoplanktons and photosynthetic bacteria and cyanobacteria (blue green algae).

(*ii*) *Chemoautotrophs* which use energy generated in oxidation-reduction process, but their significance in the ecosystem as producers is minimal, *e.g.*, microorganisms such as Beggiatoa, sulphur bacteria, etc.

2. **Heterotrophic component.** In this the heterotrophic organisms predominate the activities of utilization, rearrangement and decomposition of complex organic materials. Heterotrophic organisms are also called *consumers*, as they consume the matter built up by the producers (autotrophs). The consumers are of following two main types :

(*i*) *Macroconsumers.* These are also called *phagotrophs* (phago meaning to eat) and include mainly animals which ingest other organisms or chunks of organic matter. Depending on their food habits, consumers may either be herbivores (plant eaters) or carnivores (flesh eaters). Herbivores live on living plants and are also known as primary consumers, *e.g.*, insects, zooplanktons and animals such as deer, cattle, elephant, etc. Secondary and tertiary consumers, if present in the food chain of the ecosystem, are carnivores or omnivores, *e.g.*, insects such as preying mantis, dragon flies ; spiders and large animals such as tiger, lion, leopard, wolf etc. Secondary consumers are the carnivores which feed on primary consumers or herbivores. Carnivores are, often, recognized as carnivore order-1 (C_1), carnivore order-2 (C_2) and so on, depending on their food habits.

Ticks and mites, leeches and blood-sucking insects (mosquito, bed-bug) are dependent on herbivores, carnivores and omnivores.

(*ii*) *Microconsumers.* These are also called decomposers, reducers, saprotrophs (*sapro* meaning decompose), osmotrophs (*osmo* meaning to pass through a membrane) and scavengers. Microconsumers include microorganisms such as bacteria, actinomycetes and fungi. Microconsumers breakdown complex organic compounds of dead or living protoplasm, absorb some of the decomposition or breakdown products and release inorganic nutrients in the environment, making them available again to autotrophs or producers. Some invertebrates animals such as protozoa, oligochaeta such as earthworms, etc., use the dead organic matter for their food, as they have the essential enzymes and, hence, can be classified as decomposer organisms.

Pond as an Example of Ecosystem

A pond as whole serves as a good example of an aquatic and freshwater ecosystem (Figure 5.3). In fact, it represents a self-sufficient and self-regulating system. It has following components.

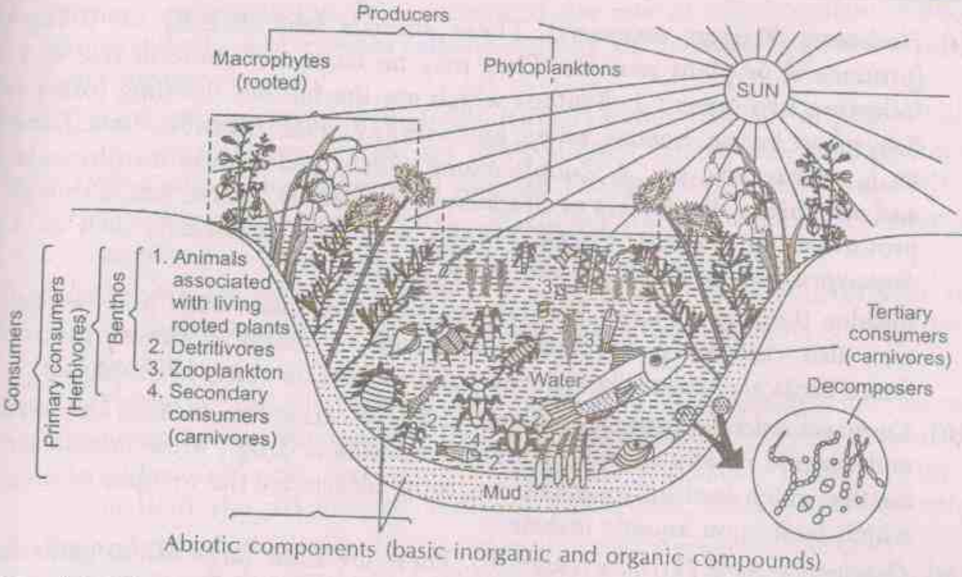


Figure 5.3 *A pond ecosystem showing its basic structural units - the abiotic (inorganic and organic compounds) and biotic (producers, and consumers -herbivores, carnivores and decomposers) components.*

1. **Abiotic component.** The chief, non-living or abiotic substances are heat, light, *p*H value of water, and the basic inorganic and organic compounds, such as water, carbon dioxide, oxygen, calcium, nitrogen, phosphates, amino acids, humic acid, etc. Inorganic salts occur in the form of phosphates, nitrates and chlorides of sodium, potassium and calcium. Some proportion of nutrients exist in solution state but most of them are present as stored in particulate matter as well as in living organisms.
2. **Biotic component.** It include various organisms which are classified into the following types.
   (*a*) *Producers.* These are photoautotrophic green plants and photosynthetic bacteria. The producers fix radiant energy of sun and with the help of minerals derived from water and mud, they manufacture complex organic substances as carohydrates, proteins and lipids. Producers of pond are of following types :
      (*i*) *Macrophytes.* These include mainly the rooted large-sized plants which comprise three types of hydrophytes : partly or completely submerged, floating and emergent aquatic plants. The common plants are species of *Trapa, Typha, Chara, Hydrilla*, etc. Besides these plants, some free floating forms also occur in the pond ecosystem, *e.g., Azolla, Salvinia, Wolffia, Lemna* etc.
      (*ii*) *Phytoplanktons*. These are microscopic (minute), floating or suspended lower plants (algae) that are distributed throughout the water, but mainly in the photic zone. Most of them are filamentous algae such as *Spirogyra, Ulothrix, Cladophora* and *Oedogonium*. There also occur some chlorococcales (*e.g., Chlorefla*), *Closterium, Cosmarium, Eudorina, Scendesmus, Volvox, Diatoms, Microcytis, Oscillatoria, Chlamydomonas, Spriuliria*, etc., and some flagellates.
   (*b*) *Macroconsumers*. They are phagotrophic heterotrophs which depend for their nutrition on the organic food manufactured by producers, the green plants. Macroconsumers are of following three types :

(*i*) *Herbivores (Primary consumers)*. These animals feed directly on living plants (producers) or plant remains. They may be large or minute in size and are of following two types : 1. Benthos which are the bottom dwelling forms such as fish, insect larvae, beetles, mites, molluses (*e.g., Pila, Planorbis, Unio, Lamellidens*, etc.), crustaceans, etc. 2. Zooplanktons which feed mainly on phytoplanktons and are chiefly the rotifers as *Brachiomus*. *Asplanchna, Lecane*, etc., although some protozoans as *Euglena, Coleps, Dileptus*, etc., and crustaceans such as *Cyclops, Stenocypris*, etc., are also present in the pond.

Besides these small-sized herbivores, some mammals such as cow, buffaloes, etc., also visit the pond casually and feed on marginal rooted macrophytes. Some birds also regularly visit the pond to feed on some hydrophytes.

(*ii*) *Carnivore order-1 (Secondary consumers)*. These carnivores feed on the herbivores and include chiefly insects, fish and amphibians (frog). Most insects are water beetles which feed on zooplanktons, some insects are the nymphs of dragonflies which feed upon aquatic insects.

(*iii*) *Carnivore order-2 (Tertiary consumers)*. These are some large fish as game fish that feed on the smaller fish and, thus, become the tertiary (top) consumers.

(*c*) *Decomposers*. They are also called microconsumers, since they absorb only a fraction of the decomposed organic matter. They bring about the decomposition of dead organic matter of both producers (plants) as well as macroconsumers (animals) to simple forms. Decomposers help in returning of mineral elements again to the medium of the pond and in running biogeochemical cycles. Decomposers of pond ecosystem include chiefly bacteria, actiomycetes and fungi. Among fungi, species of *Aspergillus, Cladosporium, Pythium, Rhizopus, Penicillium, Curvularis, Saprolegnia*, etc., are most common decomposers in water and mud of the pond.

5.2.3 Functions of Ecosystem

Function of an ecosystem means how much sunlight is trapped by plants in a year, how much plant material is eaten by herbivores, and how many herbivores are eaten by carnivores. Thus the producers, the green plants fix radiant energy and with the help of minerals (such as C, H, O, N, P, Ca, Mg, Zn, Fe etc.) taken from their edaphic (soil) or aerial environment (the nutrient pool) they build up complex organic matter (carbohydrates, fats, proteins, nucleic acids, etc. Some ecologists prefer to the green plants as convertiers or transducers, since in their view, the most popular and prevalent term 'producer' from energy view point is somewhat misleading. Their view point is that green plants produce carbohydrates and not energy and since they convert or transduce radiant energy into chemical form, they must be better called converters or transducers. The two ecological processes of energy flow and mineral cycling involving interaction between the physio-chemical environment and the biotic communities, may be considered the 'heart' of ecosystem dynamics. In an ecosystem, energy flows in non-cyclic manner (unidirectional) from sun to the dsecomposers *via* producers and macroconsumers (herbivores and carnivores), whereas the minerals keep on moving in a cyclic manner.

5.2.4 Productivity of Ecosystem

The productivity of an ecosystem refers to the rate of production, *i.e.*, the amount of organic matter accumulated in any unit time. It is of following types :

1. **Primary productivity.** It is defined as the rate at which radiant energy is stored by photosynthetic and chemosynthetic activity of producers. Primary productivity is of following types.
   (*i*) *Gross primary productivity* (*GPP*). It refers to the total rate of photosynthesis including the organic matter used up in respiration during the measurement period. GPP depends on the chlorophyll content. The rate of primary productivity are estimated in terms of either chlorophyll content as chl/g dry width/unit area or photosynthetic number, *i.e.*, amount of CO_2 fixed/gchl/hour.
   (*ii*) *Net primary productivity* (*NPP*). It is the rate of storage of organic matter in plant tissues in excess of the respiratory utilization by plants during the measurement period.
   Primary production is measured by the following method – harvest method, oxygen measurement method (or light or dark method), oxygen diurnal curve method, carbon dioxide measurement method (enclosure method), the aerodynamic method, the pH method, radioisotope method, chlorophyll estimation method.
2. **Secondary productivity.** It is the rate of energy storage at consumer's levels-herbivores, carnivores and decomposers. Consumers tend to utilise already produced food materials in their respiration and also convert the food matter to different tissues by an overall process. So, secondary productivity is not divided into gross and net amounts. Secondary productivity, remains mobile (*i.e.*, keeps on moving from one organism to another) and does not live *in situ* like the primary productivity.
3. **Net productivity.** It is the rate of storage of organic matter not used by the heterotrophs or consumers *i.e.*, equivalent to net primary production minus consumption by the heterotrophs during the unit period as a season or year, etc.

5.3 MAJOR ECOSYSTEMS

So far we have discussed the gross structure and function of an ecosystem in general. In biosphere, there are various self sufficient interacting systems such as a pond, a lake, a spring, a stream, an estuary, the sea, a desert, a grassland, a forest etc. operate as individual ecosystems of the nature. In the following sections a brief individual organisational pattern of some of these ecosystems is described.

5.3.1 Pond Ecosystem

Please refer to section 5.2.2.

5.3.2 Marine Ecosystem

The marine ecosystem comprising of seas and oceans occupies 70% of the earth's surface. The abiotic components does not affect the ocean ecosystem because the chemical composition, dissolved oxygen content, light, temperature etc., do not fluctuate. The biotic component of an ocean (marine) ecosystem include :

1. **Producers.** These are autotrophs and also designated as primary producers, since they are responsible for trapping the radiant energy or sun with the help of their pigments. Producers are mainly the phytoplanktons, such as diatoms, dinoflagellates and some microscopic algae. Besides them, a number of macroscopic seaweeds, as brown and red

algae (members of Phacophyceae and Rhodophyceae), also contribute significantly to primary production. These organisms show a distinct zonation at different depths of water in the sea.

2. **Consumers.** These all are heterotrophic macroconsumers, being dependent for their nutrition on the primary producers. These include :
   (*i*) *Primary consumers*. The herbivores, that feed directly on producers, are chiefly crustaceans, molluses, fish etc.
   (*ii*) *Secondary consumers*. These are carnivorous fish, such as Herring, Shad, Mackerel etc., feeding on the herbivores.
   (*iii*) *Tertiary consumers*. Still in the food chain, there are other carnivorous fishes like Cod, Haddock, Halibut, etc., that feed on other carnivores of the secondary consumers level. Thus these are the top carnivores in the food chain.
3. **Decomposers.** The microbes active in the decay of dead organic matter of producers and macroconsumers are chiefly bacteria and some fungi.

5.3.3 Grassland Ecosystem

This ecosystem is found where rainfall is about 25 to 75 cm per year. Grasslands typically occur in the interiors of continents and includes the tall grass prairies, short grass prairies and arid grassland of North America. The steppes of Eurasia, the Veldt of Africa and Pampas of South America (Argentina).

The various components of a grassland ecosystem are :

(A) **Abiotic component.** These are the nutrients present in soil and the aerial environment. Thus, the elements like C, H, O, N, P, S etc., are supplied by carbon dioxide, water, nitrates, phosphates and sulphates etc., present in air and soil of the area. Morever, in addition to the above, some trace elements are also present in soil.

(B) **Biotic component.** These may be categorised as :

1. **Producers.** They are mainly grasses, as species of *Dichanthium, Cynodon, Desmodium, Digitaria, Dactyloctenium, Brachiaria, Setaria, Sporobolus* etc. Besides them a few forbs and shrubs also contribute to primary production.
2. **Consumers.** These occur in the following sequence :
   (*a*) *Primary consumers.* The herbivores feeding on grasses are mainly such grazing animals as cows, buffaloes, deers, sheep, rabbit, mouse etc. Besides them, there are also present some insects as *Leptocorisa, Dysdercus, Oxyrhachis, Cicincella, Coccinella*, some termites and millipeds etc., that feed on the leaves of grasses.
   (*b*) *Secondary consumers.* These are the carnivores feeding on herbivores. These include the animals like fox, jackals, snakes, frogs, lizards, birds etc. Sometimes the hawks feed on the secondary consumers, thus occupying tertiary consumer level in the food chain.
3. **Decomposers.** The microbes active in the decay of dead organic matter of different forms of higher life are fungi, as species of *Mucor, Aspergillus, Penicillium, Cladospordium, Rhizopus, Fusarium* etc., and some bacteria and actinomycetes. They bring about the minerals back to the soil, thus making them available to the producers.

5.3.4 Forest Ecosystem

A forest is any land managed for the diverse purposes of forestry whether covered with trees, shrubs, climbers, etc., or not. The forest ecosystem include a complex assemblage of different kinds of biotic communities. Optimum conditions of temperature and ground moisture responsible for the growth of trees contribute greatly to the establishment of forest communities. Forest communities are recognised by features such as their evergreen nature, whether deciduous or indeciduous, their shape, whether broad leaved or needle like. On the basis of these features and climate conditions, forests may be classifed as tropical forests, sub-tropical forests and temperate forests. Each type of forest has its own flora and fauna.

The different components of forest ecosystem are :

(A) **Abiotic component.** These are the inoganic as well as organic substances present in the soil and atmosphere. In addition to the minerals present in forests we find the dead organic debris – the litter accumulation, chiefly in temperate climate. Moreover, the light conditions are different due to complex stratification in the plant communities.

(B) **Biotic component.** The living organisms present in the food chain occur in the following order :

1. **Producers.** These are mainly trees that show much species diversity, greater degree of stratification especially in tropical moist deciduous forests. The trees are of different kinds depending upon the kind of the forest formation developing in that climate. Besides trees, there are also present shrubs and a ground vegetation. In these forests, dominant members of the flora, the producers, are such trees as *Tectona grandis, Butea frondosa, Shorea rubusta* and *Lagerstroemia parvifiora.* In temperate coniferous forests, shrubs and ground flora are insignificant. In temperature deciduous forests the dominant trees are species of *Quercus, Acer, Betula, Thuja, Picea* etc., whereas in a temperate coniferous forests, the producer trees are species of *Abies, Picea, Pinus, Cedrus, Juniperus, Rhyododendron* etc.
2. **Consumers.** These are as follows :
   (*i*) *Primary consumers.* These are the herbivores that include the animals feeding on tree leaves as ants, flies, beetles, leafhoppers, bugs and spiders etc., and larger animals grazing on shoots and/or fruits of the producers, the Elephants, Nilgai, Deer, Moles, Squirrels, Shrews, Flying foxes, Fruit bats, Mangooses etc.

   (*ii*) *Secondary consumers.* These are the carnivores like snakes, birds, lizards, fox etc., feeding on the herbivores.

   (*iii*) *Tertiary consumers*. These are the top carnivores like lion, tiger etc., that eat carnivores of secondary consumers level.
3. **Decomposers.** These are wide variety of microorganisms including fungi (species of *Aspergillus, Coprinus, Polyporus, Gandoderma, Fusarium, Alternaria, Trichoderma* etc.), bacteria (species of *Bacillus, Clostridium, Pseudomonas, Angiococcus* etc.), and actinomycetes, like species of Streptomyces etc. Rate of decomposition in tropical and subtropical forests is more rapid than that in the temperate ones.

5.3.5 Desert Ecosystem

Deserts are formed in the driest of environments. Temperature may range from very hot as in hot deserts to very cold as in cold deserts. Major hot deserts of the world are situated near the tropics of cancer and capricorn, with rainfall of less than 10 mm. The most important hot desert of world is the Sahara Arabia-Gobi desert complex extending from Africa to central Asia and contains highly irregular and very insignificant rainfall and low humidity due to excessive evaporation. The cold deserts occur at high elevations where the temperatures are low and rainfall scanty as the air losses all its moisture content as it ascends higher and higher. *Cold* deserts occur in Ladhakh regions of Himalayas, Tibet and Bolivia Arctic.

The various biotic components are :

1. **Producers.** These are shrubs, especially bushes, some grasses and a few trees. The shrubs have widespread, branched root system with their stems and branches variously modified. Sometimes a few succulents like cacti are also present. Some lower plants like lichens and xerophytic mosses may also be present.
2. **Consumers.** The most common animals are reptiles and insects, able to live under xeric conditions. In additions to them, there are also found some nocturnal rodents and birds. The 'ship of desert', camels feed on tender shoots of the plants.
3. **Decomposers.** These are very few, as due to poor vegetation the amount of dead oragnic matter is correspondingly less. They are some fungi and bacteria, most of which are thermophilic.

5.3.6 Cropland Ecosystem

A cropland ecosystem is an artificial system aimed primarily to grow a single species of one's choice. We have ecosystems of dominant crop species like wheat, maize, jowar, paddy, sugarcane, vegetable etc., under most suitable conditions of their growth and yield.

In a natural ecosystem, the nature maximizes for gross production, whereas in an artificial ecosystem, man maximizes for net production. In a cropland ecosystem, there is not necessarily an increase in the total dry matter production of the whole plants, but generally most of the production goes into grain and less into leaves, stems and roots. Thus, in agriculture (where all the systems are artificial), there is an objective to achieve high rates of production (P) of readily harvestable products with little standing crop (biomass – B) left in the field for accumulation, or we may say that there is a high P/B efficiency. Nature (natural ecosystem), on the other hand, follows just a reverse efficiency *i.e.,* a high B/P ratio, where the standing crop is generally accumulated to its maximum. The following are the chief components of a maize cropland ecosystem.

(A) **Abiotic component.** These include the climatic conditions of the region, where the crop may grow most successfully, and the various minerals particularly C, H, O, N, P, K in soil and atmosphere. In such field, man generally makes additions of a number of chemical fertilisers to soil. Maize generally grows best in slightly alkaline soil with good aeration.

(B) **Biotic component.** The various living organisms in the food chain occur as follows:

1. **Producers.** The dominant plant species would naturally be *Zea mays.* Besides maize, a number of weeds like *Cynodon dactylon, Launaea nudicaulis, Euphorbia hirta, Cyperus rotundus, Digitaria sp.* and *Alysicarpus sp.* also contribute to primary production of the field.
2. **Consumers.** These are a Primary consumers. These are the herbivores represented by a variety of animals, big as well as small. The smaller animals include chiefly the insects as

aphids, thrips, beetles etc., which feed an lay their eggs on maize leaves. Larger animals are rabbits, rats, birds and man feeding on leaves, flower and fruits of maize.

5.3.7 Estuarine Ecosystem

An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea, thus, strongly affected by tidal action, and within which sea water is mixed with freshwater form land drainage. The various trophic components of esturaine ecosystem are:

1. **Producers.** There are three types of producers the macrophytes (sea-weeds, sea grass and marsh grasses), benthic microphytes and phytoplanktons. The important macrophytes are *Sapartina, Zastera* and *Tholassia.*
2. **Consumers.** A number of zooplankton, crabs, crustanceans and some native species of fishes capable of surviving in estuarine conditions form primary, secondary and tertiatry consumers of the estuarine ecosystem.
3. **Decomposers.** The decomposers include bacteria and fungi like actinomycetes actively take part in the breaking down the complex and dead organic matter.

5.4 FOOD CHAIN

In an ecosystem one can observe the transfer or flow of energy from one trophic level to other in succession. A *trophic level* can be defined as the number of links by which it is separated from the producer, or as the nth position of the organism in the food chain. *The patterns of eating and being eaten forms a linear chain called food chain* which can always be traced back to the producers. Thus, primary producers trap radiant energy of sun and transfer that to chemical or potential energy of organic compounds such as carbohydrates, proteins and fats. When a herbivore animal eats a plant (or when bacteria decompse it) and these organic compounds are oxidized, the energy liberated is just equal to the amount of energy used in synthesizing the substances, but some of the energy is heat and is not useful energy. If this animal, in turn, is eaten by another one, along with transfer of energy from a herbivore to carnivore a further decresase in useful energy occures as the second animal (carnivore) oxidizes the organic substances of the first (herbivore or omnivore) to liberate energy to synthesize its own cellular constitutents. Such transfer of energy from organism to organism sustains the ecosystem and when energy is transferred from individual to individual in a particular community, as in a pond or a lake or a river, we come the energy available decreases with each step. For example:

(*i*) In a typical food chain of an Indian river, a diatom may be eaten by a copepod which is eaten by a small fish, which forms the food source of large fish and so on.

Scenedesmus boligues ⟶ *Brachionus falcatus* ⟶
(phytoplankton) (zooplankton)

Homo sapiens ⟵ *Wallago attu* ⟵ *Amblypharyngodon sp*
(man) (a large fish) (a small fish)

(*ii*) In an Indian pasture, the following food chain operates:

Cynodon dactylon ⟶ *Melanoplus differentiats* ⟶ *Bufo melanostietus*
(a grass species) (a grasshopper) (a toad)

Hawk ⟵ *Zamensis mercosus* ⟵
(a rat snake)

In a simple food chain (Figure, 5.4) out of 1000 calories of energy reaching a plant only 10 calories (1%) are stored by the plant. The remaining calories of energy (90%) are lost to the environment or for plant's own maintenance. Of the 10 calories which are available to the herbivore. 9 calories (99%) are lost at its level and only 1 calorie is passed down to the carnivore. Thus, at each trophic level in a food chain, a large portion of energy is used for its own maintenance and ultimately lost as heat. Consequently, organisms in each trophic level pass on less and less energy than they receive. This tends to limit the number of steps or trophic levels to four or five. The longer the food chain, the less is the energy available to the final member.

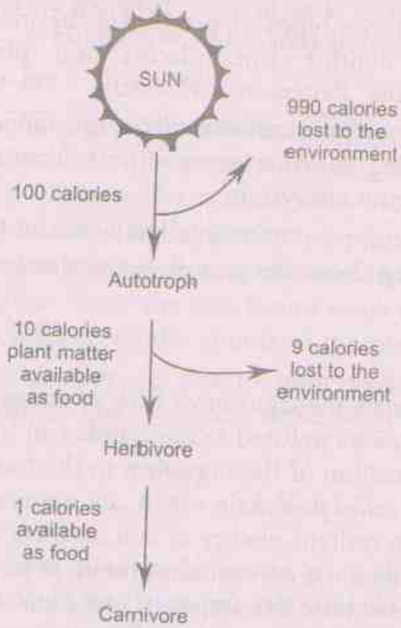


Figure 5.4 *Mode of energy flow through a simple food chain.*

Many direct or indirect methods are employed to study food chain relationships in nature. They include gut content analysis, use of radioactive isotopes, precipitin test, etc.

In nature, basically two types of food chains are recognized–grazing food chain and detritus food chain.

1. **Grazing Food Chain.** This type of food chain (Figure. 5.5) starts from the living green plants, goes to grazing herbivores and on the carnivores. Ecosystems with such type of food chain are directly dependent on an influx of solar radiation. Thus, this type of food chain depends on autotrophic energy capture and the movement of this energy to herbivores. Most of the ecosystems in nature follow this type of food chain. These chains are very significant from every standpoint. The phytoplankton → zooplanktons → fish sequence or the grasses → rabbit → fox sequence are the examples of grazing food chain. Further, the producer → herbivore → carnivore chain is a predator chain. Parasitic chains also exist wherein smaller organisms consume larger ones without outright killing as the case of the predators.

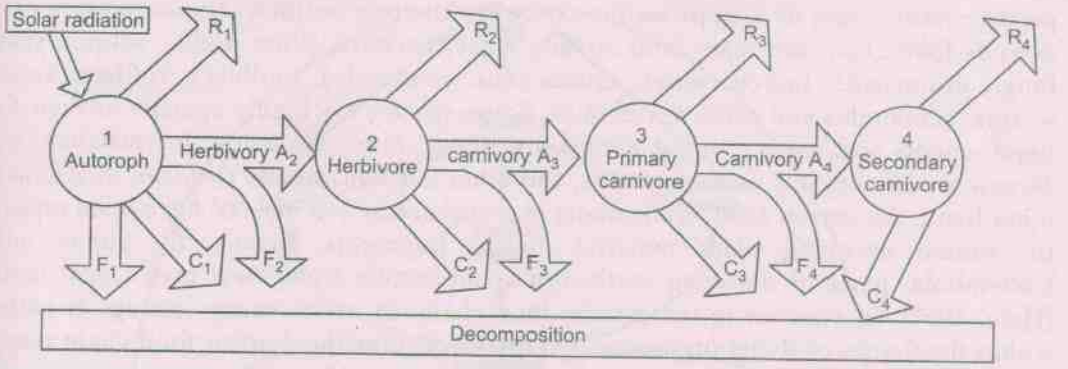


Figure 5.5 *Diagrammatic representation of a grazing food chain. Showing inputs and losses of energy at each trophic level. A-assimilation of food by the organisms at the trophic level ; F-energy lost in the form of faeces and other exretory products ; C-energy lost through decay and R-energy lost to respiration.*

2. **Detritus Food Chain.** The organic wastes, exudates and dead matter derived from the grazing food chain are generally termed *detritus.* The energy contained in this detritus is not lost to the ecosystem as a whole, rather it serves as the source of energy for a group of organisms (detritivores) that are separate from the grazing food chain, and generally termed as the detritus food chain (Figure 5.6). The detritus food chain represents an exceedingly important component in the energy flow of an ecosystem. Indeed in some ecosystems, considerably more energy flows through the detritus food chain than through the grazing food chain. In the detritus food chain the energy flow remains as a continuous

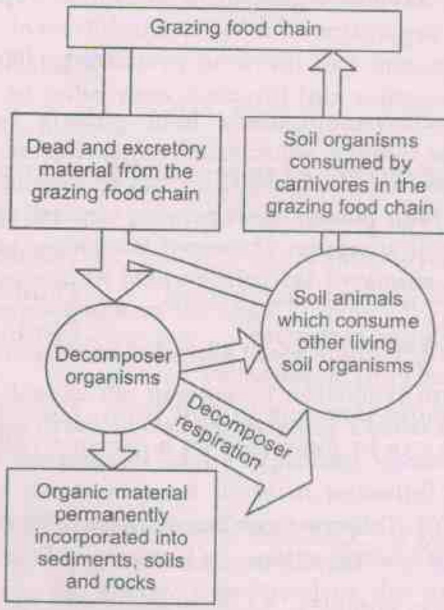


Figure 5.6 *Diagrammatic representation of the detritus food chain, showing energy transfers between it and the grazing food chain, as well as energy losses to the detritus food chain.*

passage rather than as a stepwise flow between discrete entities. The organisms of the detritus food chain are many and include algae, bacteria, slime molds, actinomycetes, fungi, protozoans, insects, mites, crustaceans, centipedes, molluscs, rotifers, annelid worms, nematodes and some vertebrates. Some species are highly specific in their food requirements and some can eat almost any thing. Many Protozoa, for instance, need certain specific organic acids, vitamins, and other nutrients before they can thrive on the other hand, the guts of small Collembola (a group of tiny soil insects) have been reported to contain decaying plant material, fungal fragments, spores, fly pupae, other Collembola, parts of decaying earthworms and cuticle from their own faecal casting (Hale, 1967). In contrast to the grazing food chain, in which energy storage is entirely within the tissues of living organisms, energy storage for the detritus food chain may be largely external to the organisms, and in the detritus itself.

Significance of Food Chain. The food chain studies help understand the feeding relationships and the interaction between organisms in any ecosystem. They also help us to appreciate the energy flow mechanism and matter circulation in ecosystem, and understand the movement of toxic substances in the ecosystem and the problem of biological magnification.

5.5 FOOD WEB

In nature simple food chains occur rarely. The same organism may operate in the ecosystem at more than one trophic level, *i.e.*, it may derive its food from more than one source. Even the same organism may be eaten by several organisms of a higher trophic level or an organism may feed upon several different organisms of a lower trophic level. Usually the kind of food changes with the age of the organism and the food availability. Thus, in a given ecosystem various food chains are linked together and intersect each other to form a complex network called *food web*.

Any complex food web, can be recognised in several different trophic levels :

1. Producers	Green plants	First trophic level
2. Primary consumers	Herbivores	Second trophic level
3. Secondary consumers	Carnivores, insectivores	Third trophic level
4. Tertiary consumers	Higher carnivores, Insect hyperparasites	Fourth trophic level

A given species may occupy more than one trophic level. The complexity of food web can vary greatly, and this complexity can be expressed by a measure called the connectance of the food web :

$$\text{Connectance} = \frac{\text{Actual number of interspecific interactions}}{\text{Potential number of interspecific interactions}}$$

Generally, food webs are not too complex. As more and more species are involved in a food web, the connectance falls. Except in insect communities, omnivores are scarce, and when they occur, they usually feed on species in adjacent trophic levels. Within habitats, food webs are rarely broken up into discrete compartments. The number of species of predators in a food web typically exceeds the number of species of prey by an average of 1.3 predator species per prey species. Commonly occuring food web in terrestrial ecosystem is shown in Figure 5.7.

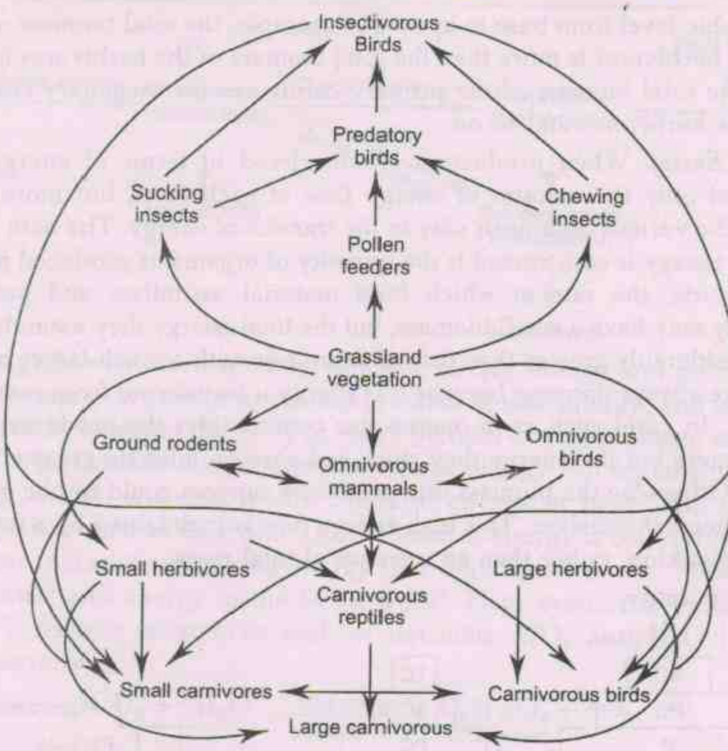


Figure 5.7 *A food web in terrestrial ecosystem.*

5.6 ECOLOGICAL PYRAMIDS

In the successive steps of grazing food chain-photosynthetic autotroph, herbivorous heterotroph, carnivore heterotroph, decay bacteria-the number and mass of the organisms in each step is limited by the amount of energy available. Since some energy is lost as heat, in each transformation the steps become progressively smaller near the top. This relationship is called *ecological pyramid.* The ecological pyramids represent the trophic structure and also trophic function of the ecosystem. In many ecological pyramids, the producer form the base and the successive trophic levels make up the apex.

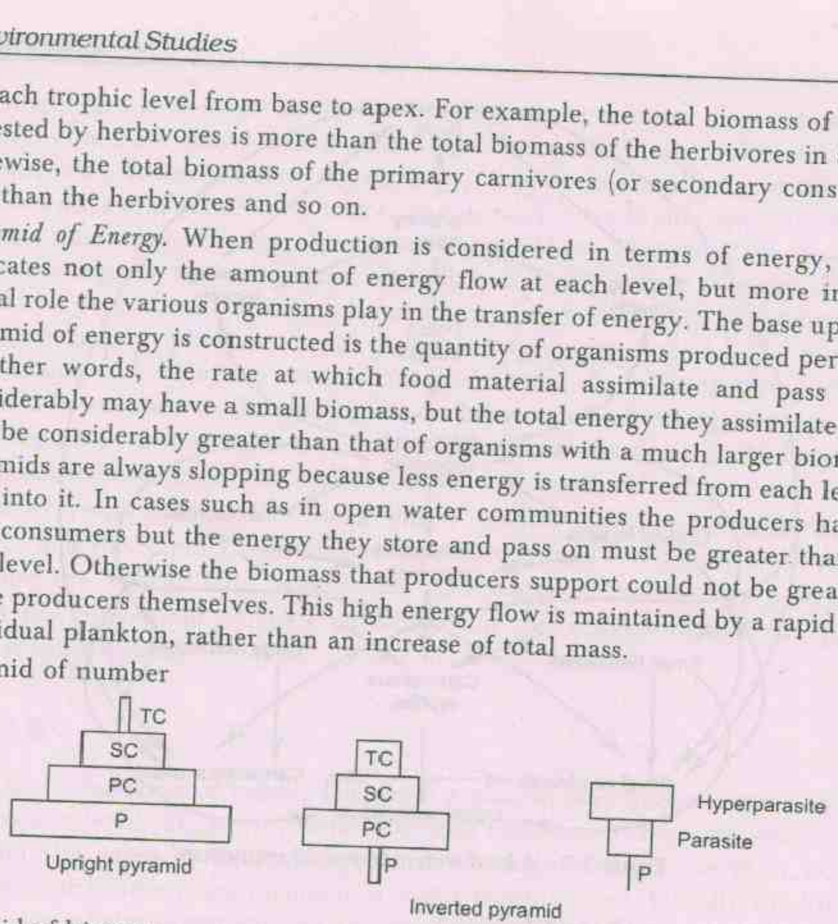
The ecological pyramids may be of following three kinds (Figure 5.9)

(*i*) *Pyramid of Number.* It depicts the number of individual organisms at different trophic levels of food chain. This pyramid was advanced by *Charles Elton* (1927), who pointed out the great difference in the number of the organisms involved in each step of the food chain. The animals at the lower end (base of pyramid) of the chain are the most abundant. Successive links of carnivores decrease rapidly in number until there are very few carnivores at the top. The pyramid of number ignores the biomass of organisms and it also does not indicate the energy transferred or the use of energy by the groups involved. The lake ecosystem provides a typical example for pyramid of number.

(*ii*) *Pyramid of Biomass.* The biomass of the members of the food chain present at any one time forms the pyramid of the biomass. Pyramid of biomass indicates decrease of biomass in each trophic level from base to apex. For example, the total biomass of the producers ingested by herbivores is more than the total biomass of the herbivores in an ecosystem. Likewise, the total biomass of the primary carnivores (or secondary consumer) will be less than the herbivores and so on.

(*iii*) *Pyramid of Energy*. When production is considered in terms of energy, the pyramid indicates not only the amount of energy flow at each level, but more important, the actual role the various organisms play in the transfer of energy. The base upon which the pyramid of energy is constructed is the quantity of organisms produced per unit time, or in other words, the rate at which food material assimilate and pass on, may be considerably may have a small biomass, but the total energy they assimilate and pass on may be considerably greater than that of organisms with a much larger biomass. Energy pyramids are always slopping because less energy is transferred from each level than was paid into it. In cases such as in open water communities the producers have less bulk than consumers but the energy they store and pass on must be greater than that of the next level. Otherwise the biomass that producers support could not be greater than that of the producers themselves. This high energy flow is maintained by a rapid turn over of individual plankton, rather than an increase of total mass.

(A) Pyramid of number



(B) Pyramid of biomass

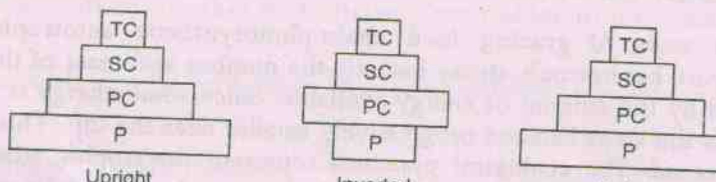


Figure 5.8 *Ecological and Eltonian pyramids : (P = producers ; PC = primary consumers (herbivores) ; SC = secondary consumers (carnivores) ; TC = tertiary consumers (carnivores).*

5.7 ECOLOGICAL ENERGETICS

Energy is the capacity to do work. Biological activities require consumption of energy which ultimately comes from the sun. Radiant energy of sun (or solar energy) is transformed into chemical energy by the process of photosynthesis–this is stored in plant tissues and then transformed into mechanical and heat form of energy during metabolic activities. In the biological world, the energy flows from the sun to plants and then to all heterotrophic organisms, such as microogranisms, animals and man in the following manner :

Similar vegetation types in the tropics exhibit lower net production efficiencies, perhaps 40 to 60 per cent respiration increases relative to photosynthesis at low latitudes.

Table 5.1 Definition of Several Energetic Efficiencies

	1.	Exploitation efficiency $= \dfrac{\text{Ingestion of food}}{\text{Prey production}}$
	2.	Assimilation efficiency $= \dfrac{\text{Assimilation}}{\text{Ingestion}}$
	3.	Net production efficiency $= \dfrac{\text{Production (growth and reproduction)}}{\text{Assimilation}}$
	4.	Gross production efficiency $= \dfrac{\text{Production}}{\text{Ingestion}}$
	5.	Ecological efficiency $= \dfrac{\text{Consumer production}}{\text{Prey production}}$

In comparison to the plant food, animal food is more easily digested. Assimilation efficiency of predators, species vary from 60 to 90 percent. Vertebrates prey are digested more efficiently than insect prey because the indigestible exoskeletons of insects constitute the larger proportion of body than the hair feathers and scales of vertebrates. Assimilation efficiencies of insectivore vary between 70 and 80 percent whereas those of most carnivores are about 90 per cent.

The nutritional value of plant foods depends upon the amount of cellulose, lignin and other indigestible materials present. Herbivores assimilate as much as 80 percent of the energy in seeds and 60 to 70 percent of that in young vegetation. Most grazers and browsers (*e.g.*, cattle, elephants and grasshoppers) assimilate 30 to 40 percent of the energy in their food Millipeds which eat decaying wood composed mostly of cellulose and lignin (and the microorganisms that occur in decaying wood), assimilate only 15 percent.

Maintenance, movement and in warm-blooded animals heat production require energy that otherwise could be utilized for growth and reproduction. Active warm-blooded animals (homeotherms) exhibit low net production efficiency-birds less than 1 percent, small mammals with high reproductive rates up to 6 percent. More sedentary cold-blooded animals (poikilotherms), particularly aquatic species, channel as much as 75 percent of their assimilated energy into growth and reproduction. The extreme high value approaches the biochemical efficiency of egg production and tissue growth, between 70-80% in domesticated animals.

5.9 ENERGY FLOW IN ECOSYSTEMS

Flow of energy in an ecosystem takes place through the food chain and it is this energy which keeps the ecosystem going. The flow of energy through various trophic levels in an ecosystem can be explained with the help of various energy flow models.

1. **Single Channel Ene**
manner through a
carnivores. From the
(*i*) *There is unidirec*
revert back to
herbivores does
way flow of ene
sun) were cut of
(*ii*) *At each trophic le*
by the energy lo
energy.

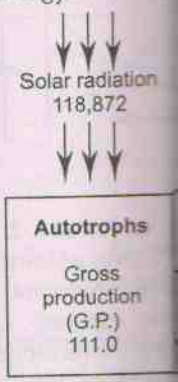


Figure 5.9

Figure 5.10 depicts a s
note that the energy flow
producers (autotrophs) to
the trophic levels and pip
the laws of thermodynam
level (as per first law of th
energy into unavailable h
of the total 3,000 kcal of l
trophic level). 1% (15 k
production is mearly 15 k
to be about 10% at succe
has earlier been mention
levels. Therefore, shorter

1. **Single Channel Energy Flow Model :** The flow of energy takes place in an unidirectional manner through a single channel of green plants or producers to herbvivores and carnivores. From the energy flow model shown in Figure 5.9, two things are clear :

   (*i*) *There is unidirectional flow of energy.* The energy captured by autotrophs does not revert back to solar input but passes to herbivores ; and that which passes to herbivores does not go back to the autotrophs but passes to consumers. Due to one way flow of energy, the system would collapse if the primary sources of energy (*i.e.,* sun) were cut off.

   (*ii*) *At each trophic level, there occurs progressive decrease in energy.* This is accounted largely by the energy lost as heat in metabolic reactions (respiration) coupled with unutilized energy.

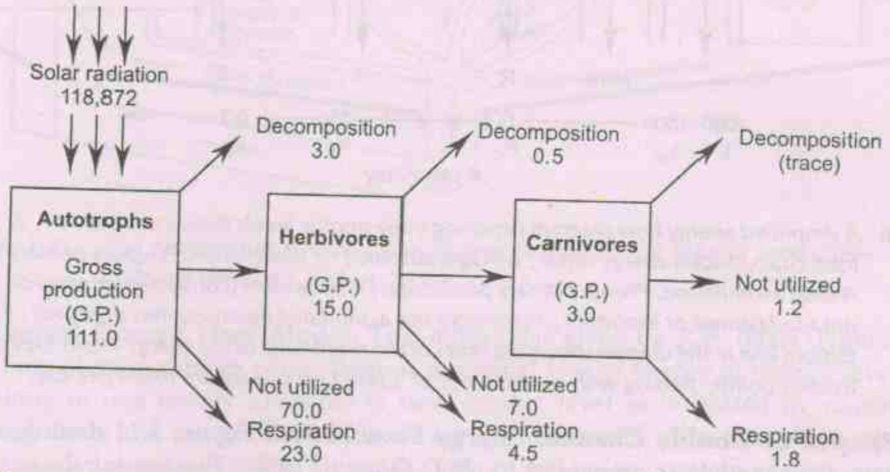


Figure 5.9 *The single channel energy flow models for a freshwater ecosystem in g/cal/cm²/yr (Lindeman's model)*

Figure 5.10 depicts a simplified energy flow model of three trophic levels. One can clearly note that the energy flow is greatly decreased at each successive trophic level starting from producers (autotrophs) to herbivores and then to carnivores. In the Figure 5.11, boxes represent the trophic levels and pipes represent the energy flow in and out of each level. Working of both the laws of thermodynamics is clearly seen as energy inflows balance outflows at each trophic level (as per first law of thermodynamics) and energy transfer is accompanied by dissipation of energy into unavailable heat *i.e.,* respiration as per the second law of thermodynamics. Thus, of the total 3,000 kcal of light falling upon green plants, 1,500 kcal (50%) is absorbed level (first trophic level). 1% (15 kcal) is converted at autotroph level (first trophic level). Thus, net production is mearly 15 kcal. Secondary productivity (shown as P_2 and P_3 in Figure 5.10) tends to be about 10% at successive consumer levels *i.e.,* at herbivore level and carnivore level. As has earlier been mentioned, there is successive decrease in energy flow at successive trophic levels. Therefore, shorter the food chain, greater would be the available food energy.

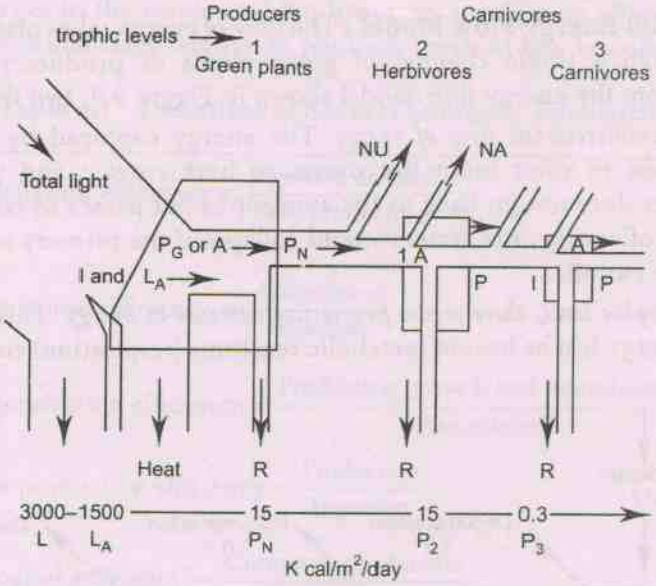


Figure 5.10 *A simplified energy flow diagram depicting three trophic levels (boxes numbered 1, 2, 3) in a linear food chain, 1-total energy input ; LA-Light absorbed by plant cover. PG-gross primary production ; A-total assimilation, PN-net primary production ; P-secondary (consumer) production ; NU-energy not used (stored or exported) ; NA-energy not assimilated by consumers (egested) ; R-respiration. Bottom line in the diagam shows the order of the magnitude of the energy losses expected at major transfer points, starting with a solar input of 3,000 Kcal per square metre per day.*

2. **Y-Shaped or Double Channel Energy Flow Model.** Figure, 5.11 describes Y-shaped energy flow models as pioneered by *H.T. Odum* in 1956. This model shows a common boundary, light and heat flows as well as the import, export and storage of organic matter. Decomposers is placed in a separate box as a means of partially separating the grazing and detritus food chains. In terms of energy levels, decomposers are, in fact, a mixed group.

   The significant part in Y-shaped model is that the two food chains are not isolated from each other.

   Y-shaped energy flow is more realisitc and practical than the single-channel energy flow model because of following points :

   (*i*) It conforms to the basic stratified structure of ecosystems.

   (*ii*) It separates the two chains *i.e.,* grazing food chain and detritus food chain in both time and space.

   (*iii*) Microconsumers (*e.g.,* bacteria, fungi) and the macroconsumers (animals) differ greatly in size-metabolism relations in two models.

nbered 1, 2, 3) in a linear
oss primary production ;
production ; NU-energy
egested) ; R-respiration.
losses expected at major
e per day.

1 describes Y-shaped
del shows a common
d storage of organic
rtially separating the
posers are, in fact, a

are not isolated from

-channel energy flow

s food chain in both

ers (animals) differ

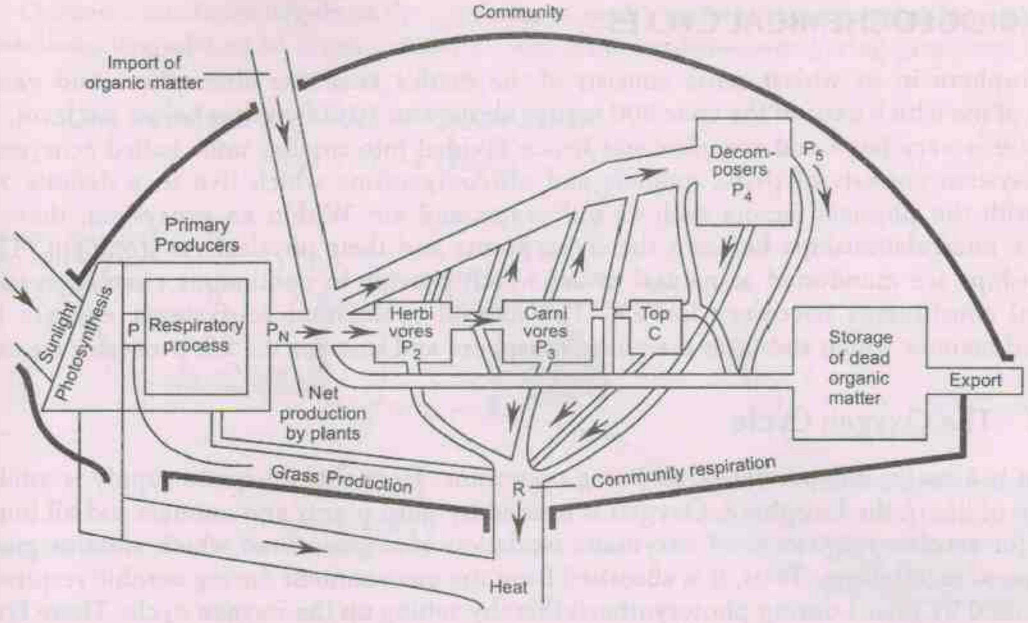


Figure 5.11 *The relationship between flow of energy through the grazing food chain and detritus pathway (After H.T. Odum, 1956).*

3. **Universal Energy Flow Model.** This model was given by *E.P. Odum* (Figure 5.12). As the flow of energy takes place, there is a gradual loss of energy at energy level, thereby resulting in less energy available at next trophic level as indicated by narrower pipes (energy flow) and smaller boxes (stored energy in biomass). The loss of energy is mainly the energy not utilized (NU). This is the energy lost in locomotion, excretion etc., or it is the energy lost in respiration (CR) which is for maintenance. The rest energy is used for production (P).

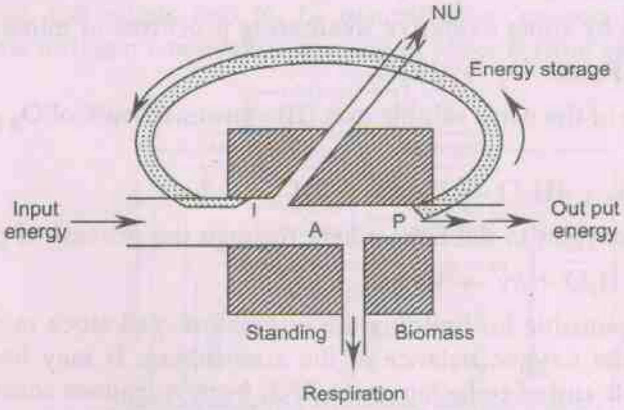


Figure 5.12 *Universal energy flow model applicable to all components. I = Energy input; A = Assimilated energy ; P = Production ; NU = Energy not used. (After E.P. Odum, 1968).*