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 *n*th 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 decompose it) and these organic compounds are oxidized, the energy liberated is just equal to the amount of energy used in synthesizing the substances (first law of thermodynamics), but some of the energy is heat and not useful energy (second law of thermodynamics). If this animal, in turn, is eaten by another one, along with transfer of energy from a herbivore to carnivore a further decrease in useful energy occurs as the second animal (carnivore) oxidizes the organic substances of the first (herbivore or omnivore) to liberate energy to synthesize its own cellular constituents. 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 across the food chains. The number of steps in a food chain are always restricted to four or five, since the energy available decreases with each step. For example, 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 (**Dash**, 1993) :

Scenedesmus boligues (phytoplankton) → *Brachionus falcatus* (zooplankton) ↓

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

In an Indian pasture, the following food chain operates:

Cynodon dactylon (a grass species) → *Melanoplus differentialis* (a grasshopper) ↓

Hawk ← *Zamensis mucosus* (a rat snake) ← *Bufo melanostictus* (a toad)

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 starts from the living green plants, goes to grazing herbivores and on to 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 energy standpoint. The phytoplanktons → 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.

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 in 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**. 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 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, Protozoa, insects, mites, Crustacea, centipedes, molluscs, rotifers, annelid worms, nematodes and some vertebrates. Some species are highly specific in their food requirements and some can eat almost anything. 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.

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**.

In any complex food web, one can recognize 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,	Fourth trophic level
	insect hyperparasites	

A classification of organisms by trophic levels is one of function and not of species as such. A given species may occupy more than one trophic level. The complexity of food web can vary greatly, and we express this complexity by a measure called the **connectance** of the food web:

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

Generalizations about food web. 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.

ECOLOGICAL PYRAMIDS

In the successive steps of grazing food chain–photosynthetic autotroph, herbivorous heterotroph, carnivores 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 pro- gressively smaller near the top. This relationship is sometimes 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. Thus, communities of terrestrial ecosystems and shallow water ecosystems contain gradually sloping ecological pyramids because these producers remain large and characterized by an accumulation of organic matter. This trend, however, does not hold for all ecosystems. In such aquatic ecosystems as lakes and open sea, primary production is concentrated in the microscopic algae. These algae have a short-cycle, multiply rapidly, accumulate little organic matter and are heavily exploited by herbivorous zooplankton. At any one point in time the standing crop is low. As a result, the pyramid of biomass for these aquatic ecosystems is inverted: the base is much smaller than the structure it supports.

TYPES OF ECOLOGICAL PYRAMIDS

The ecological pyramids may be of following three kinds:

1. **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.

2. **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 trophical 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 con- sumer) will be less than the herbivores and so on.

3. **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 passes through the food chain. Some organisms 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 turnover of individual plankton, rather than an increase of total mass.

ECOLOGICAL EFFICIENCY

Ecological efficiency is the product of efficiencies with which organisms exploit their food resources and transform them into biomass which becomes available to the next higher trophic level. Because most biological production is consumed, **exploitation efficiency** is 100 per cent overall, and ecological efficiency depends on two factors : the proportion of assimilated energy incorporated in growth, storage and reproduction. The first proportion is called the **assimilation efficiency** and the second, the **net production efficiency**. The product of the assimilation and net production efficiencies is the **gross production efficiency**: the proportion of food energy that is transformed into consumer biomass energy.

Net production efficiency for the plants is defined as the ratio of net to gross production. This index has been found to vary between 30 and 85 per cent, depending on habitat and growth form. Rapidly growing plants in temperate zones, whether trees, old-field herbs, crop species, or aquatic plants, have constantly high net production efficiencies (75 to 85 per cent). 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. The nutritional value of plant foods depends upon the amount of cellulose, lignin, and other indigestible materials present. Herbivores assimilate as much as 80 per cent of the energy in seeds, and 60 to 70 per cent of that in young vegetation (**Chew** and **Chew**, 1970). Millipedes, which eat decaying wood composed mostly of cellulose and lignin (and the microorganisms that occur in decaying wood), assimilate only 15 per cent (**O'Neil**, 1968).

The **gross production efficiency** (*i.e.,* biomass production efficiency within a trophic level) is the product of assimilation efficiency and net production efficiency. Gross production efficiencies of warm-blooded terrestrial animals rarely exceed 5 per cent, and those of some birds and large mammals fall below 1 per cent (**Turner**, 1970). Gross production efficiencies of insects lie within the range of 5 to 15 per cent, and those of some aquatic animals exceed 30 per cent.