UNIT 3 LECTURE 3
FOOD CHAIN, FOOD WEB, ECOLOGICAL PYRAMID

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SLIDE 1

Definition of food chain
The transfer of food energy from the source in plants through a series of organisms with repeated eating and being eaten is referred to as the food chain (Odum, 1971).

The ecosystem is characterized by the energy flow and the circulation of materials through its members. In other words, the biotic factors of the ecosystem are linked together by food. For e.g., the producers form the food for the herbivores which in turn form the food for the carnivores. The sequence of the eaters being eaten is called food chain.

SLIDE 2

The primary source of energy in an ecosystem is the sun. Only the autotrophs (green plants) trap the radiant energy and store that in the form of chemical or potential energy in foodstuffs. The food stuffs form the primary source of energy, supply to all other living organism. The autotrophic plants are, therefore, known as **producers**. The producers are directly eaten by the herbivores, which are called **primary consumers**. The next step in the food chain is occupied by **secondary consumers** (primary carnivores). Secondary consumers are dependent upon the primary consumers. A step above this remains occupied by **tertiary consumers** (secondary carnivores). Thus, a survey of a food chain reveals the position of an organism in a food chain. The various steps in a food chain are called **trophic levels.** The final consumer in a food chain will eventually die due to old age, injury, disease or any other factors. The producers, consumers and the waste products of the consumers finally become exposed to the final elements of the food chain. These final elements are the **decomposers**. The decomposers transform the dead organic materials into raw materials, which are used again by the producers of the food chain.

The number of steps in a food chain is limited to four or five and at each step or transfer in the chain, a large proportion of the potential energy is lost as heat.

SLIDE 3

Mainly, there are two types of food chains.

1. Grazing food chain
2. Detritus food chain

SLIDE 4

Grazing food chain – it starts from green plants (autotrophs or producers) and ends to carnivores by passing through herbivores. Thus, the gross production of plants may need three fates.

- It may be oxidized in respiration
- It may be eaten by herbivores
- It may die and decay.

In herbivores, the assimilated food may be stored as carbohydrate, protein or fat or rebuilt by the animals into simple or very complex organic molecules. The energy required to perform these transformations is supplied by respiration. The disposition of energy in herbivores follows three routes.

- Respiration
- Decay of organic matter by decomposers
- Consumption by carnivores.

SLIDE 5

The primary and secondary carnivores assimilate energy derived entirely from the tissue of the herbivores and its disposition is entirely analogous with that of herbivores. Thus, the energy flow through grazing food chain is:

SLIDE 6

The grazing food chain is of two types, namely,

- Predator chain
- Parasitic chain

Predator chain *– here one animal captures and devours another animal. The animal, which is being eaten, is called* ***prey*** *and the animal, which eats it, is called* ***predator****.* The predator chain is formed of plants, herbivores, primary carnivores, secondary carnivores and so on.

Parasitic chain – *the plants and animals of the grazing food chain are infected by parasites.* When the smaller organisms (parasites) consume larger ones without outright killing of the host, the food chain is called parasitic food chain.

SLIDE 7

Detritus food chain – *the organic wastes, exudates and dead matter derived from the grazing food chain are usually called* ***detritus***. The energy contained in this detritus serves as the source of energy for a group of organisms (detritivores) that are separated from the grazing food chain and generally termed the detritus food chain. It has the following characteristics:

1. *In some ecosystems more energy flows through the detritus food chain than through the grazing food chain.*
2. *In the detritus food chain the energy flow remains as a continuous passage rather than as a stepwise flow between discrete entities.*
3. *Energy storage for detritus food chain may be largely external to the organisms and the detritus itself.*

The organisms of the detritus food chain are algae, bacteria, actinomycetes, fungi, protozoa, insects, mites, crustacea, centipedes, mollusks, rotifer, annelids, nematodes, etc. the detritus organisms gradually break down the complex organic molecules present in the organic waste or dead tissues into much simpler compounds (humic acids). The detritus food chain exists in every ecosystem and is very important for the circulation of materials.

SLIDE 8

The two main food chains cannot operate independently. They are interconnected at various levels. The stability of the ecosystem is directly proportional to the number of such links. The detritus feeders obtain energy from the dead bodies of plants and animals, which are components of the grazing food chain. Again, some of the detritus feeders are eaten by the consumers of the grazing food chain. For e.g., in a pond ecosystem earthworms belonging to the detritus food chain are eaten by fishes belonging to the grazing food chain.

SLIDE 9

Food chain studies help in:

- *Understanding the feeding relationships and the interaction between the organisms in any ecosystem.*
- *Apprehending the energy flow mechanism and matter circulation in ecosystems,*
- *Understanding the movement of the toxic substances in the ecosystem and understanding the problem of biological magnification.*

Certain harmful substances may get injected into plants and / or animals, which may not be broken down in the body or excreted easily. Instead, they accumulate and their concentration increases as they pass from one trophic level to the next. Since man is an omnivore and has access to all trophic levels for food, he gets the toxic substances into his body in large amounts. Secondary and tertiary consumers located on top of

the food chain also get the poison into their body. This phenomenon is called biological magnification.

SLIDE 10

In an ecosystem, the various food chains are interconnected with each other to form a network. The interlocking of many food chains is called food web (Odum, 1971).

SLIDE 11

Example – in a grassland ecosystem, grass is eaten by grasshoppers, rabbit and mouse. Grasshopper is eaten by lizard, which is eaten by hawk. Rabbit is eaten by hawk. Mouse is eaten by snake, which is eaten by hawk. In addition, hawk also directly eats grasshopper and mouse. Thus, there are five linear food chains, which are interconnected to form a food web.

SLIDE 12

Five linear food chains of a grassland food web

SLIDE 13

Food webs are very important in maintaining the stability of an ecosystem. For e.g., the deleterious growth of grasses is controlled by the herbivores. When one type of herbivore becomes extinct, another type increases in number and control the vegetation. Similarly, when one type of herbivorous animal becomes extinct.

SLIDE 14

The interaction of the food chain phenomenon and size-metabolism relationship result in communities having a definite trophic structure. Trophic structure may be measured and described either in terms of standing crop per unit area or in terms of energy fixed per unit area per unit time at successive trophic levels. The trophic structure and also the trophic function of the ecosystem may be shown graphically by means of Ecological Pyramids. In many ecological pyramids, the producer form the base and the successive trophic levels make up the apex. *There are three types of ecological pyramids:*

1. *The pyramid of number*
2. *The pyramid of biomass*
3. *The pyramid of energy.*

SLIDE 15

The pyramid of number *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 organisms involved in each step of the food

chain. In such a pyramid, the more abundant species occupy the base of the pyramid and the less abundant species remain near the top. The pyramid of number ignores the biomass of organisms and it also does not indicate the energy transferred on the use of energy by the groups involved.

Example: in a lake ecosystem, the base of the pyramid i.e., the lowest trophic level is occupied by the producers such as diatoms and algae. They are more in numbers than the herbivores. The second trophic level is represented by zooplanktons, which are primary consumers and are less abundant. The third trophic level is occupied by a still smaller number of carnivores i.e., medium sized fishes and the apex by large sized carnivores i.e., large sized fishes, which are only a few in number.

Inverted pyramid of number: *In food chain involving parasites, the pyramid of number is reversed for the successive steps of parasite dependency and the parasites are more numerous than their hosts.* For e.g., a single tree (producer) contains many fruit eating herbivore birds which in turn support a still larger number of parasite like bugs and lice. The amount of matter in each of the trophic levels or in component population is called a standing crop, which is usually expressed as the number per unit area or in terms of the biomass.

Actually, the pyramid of number is not very fundamental or instructive as an illustrative device since the relative effects of the "geometric", "food chain", and "size" factors are not indicated. The form of the numbers pyramid will vary widely with different communities, depending on whether producing individuals are small or large. Likewise, numbers vary so widely that it is difficult to show the whole community on the same numerical scale. Hence it may not convey much meaning about the functional aspects of an ecosystem.

This difficulty faced is removed to a large extent if the biomass of a trophic level is considered in place of numbers, since the "geometric" factor is eliminated, and the quantitative relation of the "standing crop" are well shown.

Slide 16

The pyramid of biomass: *The total weight of living matter per unit area of an ecosystem is called biomass. The pyramid of biomass indicates gradual decrease of biomass in each trophic level and from the base to apex.* The total biomass of the producers ingested by the herbivores is more than the total biomass of the primary carnivores (or secondary consumer) will be less than the herbivores and so on.

The pyramid of biomass is of more fundamental interest since the "geometric" factor is eliminated, and the quantitative relations of the "standing crop" are well shown. In general, the biomass pyramid gives a rough picture of the overall effect of the food chain relationships for the ecological group as a whole. When the total weight of individuals at successive trophic levels is plotted, a gradually sloping pyramid may be expected as long as the size of the organism does not differ greatly.

1. **Example**: In grassland the biomass of grasses is maximum and it gradually decreases towards the consumer level in the following order:

2. **Example**: In Forest the biomass of trees is maximum and the biomass of the top carnivores is the minimum. The decrease of biomass occurs in the following order:

SLIDE 17

Inverted pyramid of biomass : *If organisms of lower levels average much smaller than those of higher levels, the biomass pyramid may be inverted.* Here, the size of the producers is very small and that of the consumers is large, the total weight of the latter may be greater at any one moment. In such cases, even though more energy is being passed through the producer trophic level than through consumer levels, the rapid metabolism and turn over of the small producer organisms accomplish a larger output with a smaller standing crop biomass.

It occurs in a pond or lake ecosystem where the biomass diatoms and phytoplanktons are negligible as compared to that of crustaceans and small fishes. In lakes and in the sea the plants usually outweigh their grazers during periods of high primary productivity, as during the spring but at other times, as in winter, the reverse may be true.

SLIDE 18

The pyramid of energy

When production is considered in terms of energy, the pyramid indicates not only the amount of energy flow at each trophic level but also the actual role of various organisms in the transfer of energy. The base upon which the pyramid of energy is constructed is the quantity of organisms produced per unit time, i.e., the rate at which food materials passes through the food chain. Some organisms may have small biomass, but the total energy they assimilate and pass on may be considerably greater than that of organisms with a much larger biomass. The energy flows in an ecosystem from the producer level to the consumer level. At each trophic level 80 – 90% of energy is lost. Hence, the amount of energy decreases from the producer level to the consumer level.

Example*: in a pond, maximum energy is trapped by phytoplankton. Then the amount of energy decreases towards the top consumer level.*

Of the three types of ecological pyramids, the energy pyramid gives by far the best overall picture of the functional nature of communities since the number and weight of organisms that can be supported at any level in any situation depends not on the amount of fixed energy present at any one time in the level just below but rather on the rate at

which food is being produced. In contrast with the number and biomass pyramids, which are pictures of the standing states, the energy pyramid is the picture of the rates of passage of the food mass through the food chain. Its shape is not affected by the variation in the size and metabolic rate of individuals, and, if all sources of energy are considered, it must always be “right side up”.