TWO MODELS OF FOOD CHAINS

BY

DR. POULAMI ADHIKARY MUKHERJEE
ASSISTANT PROFESSOR
DEPARTMENT OF ZOOLOGY
NARAJOLE RAJ COLLEGE

ZOOLOGY: SEM- I, PAPER- C2T: ECOLOGY, UNIT 4: ECOSYSTEM

Models of Flow of Energy in an Ecosystem:

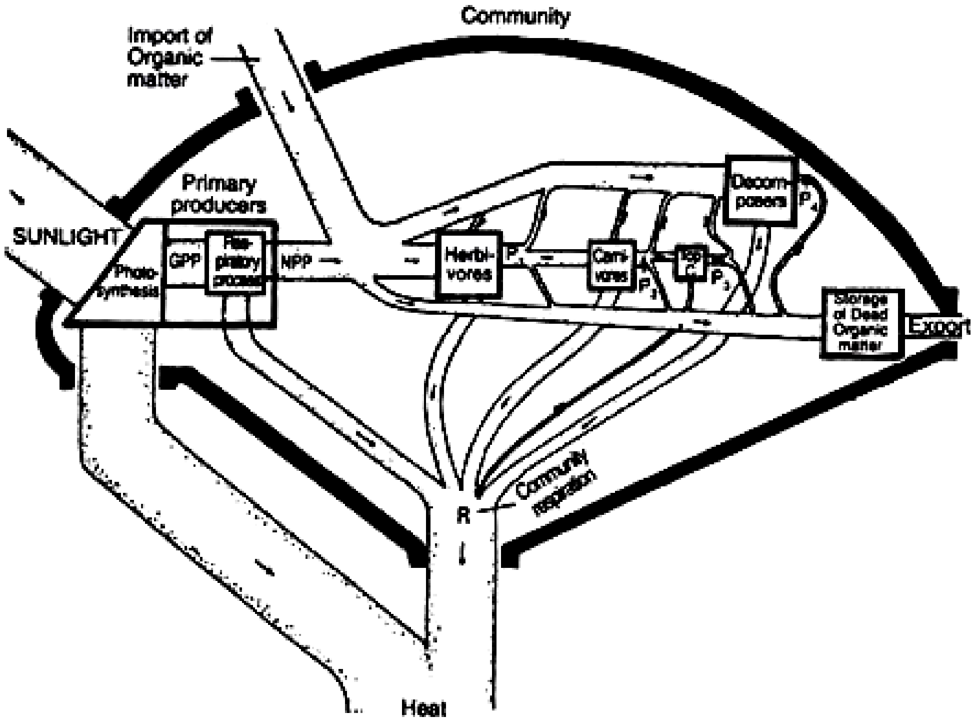
The Flow of Energy can be explained by means of three models namely:

1. **Single Channel Energy Flow model,**
2. **Y-shaped/ Two Channel Energy Flow Model, and**
3. **Universal Model.**

1. Single-Channel Energy Models:

The single or linear channel energy flow model is one of the first published models pioneered by H. T. Odum in 1956. This model depicts a community boundary and, in addition to light and heat flows, it includes import, export, and storage of organic matter.

Decomposer organisms are placed in a separate box as a means of partially separating the grazing and detritus food chains. Decomposers are actually a mixed group in terms of energy levels and their importance in this energy flow model is overlooked. This model will suffice as long as only the imports and exports are considered.



Single or linear channel energy-flow diagram (P_1, P_2, P_3 and P_4 – secondary production of the indicated level (H. T. Odum, 1956)

The principle of food chains and the working of the two laws of thermodynamics can be better made clear by means of, energy flow diagrams shown in Figures given below.

As shown in Figure 1 out of the total incoming solar radiation (118,872 gcal/cm2/yr), 118,761 gcal/cm2/yr remain un-utilised, and thus gross production (net production plus respiration) by autotrophs is 111 gcal/cm2/yr with an efficiency of energy capture of 0.1 0 per cent. It may also be noted that 21 percent of this energy or 23 gcal/cm2/yr is consumed in metabolic reactions of autotrophs for their growth, development, maintenance, and reproduction.

It may be seen further, that 15 gcal/cm2/yr are consumed by herbivores that graze or feed on Autotrophs-this amounts to 17 per cent of net autotroph production.

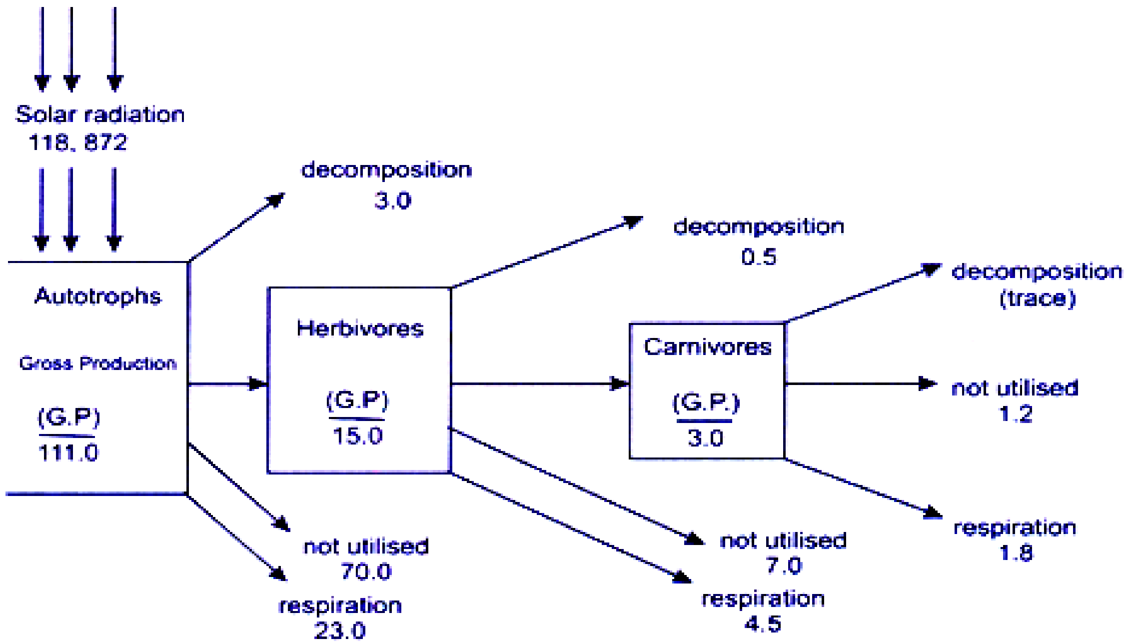


Fig. 1 Energy flow diagram for a lake (freshwater ecosystem) in g cal/cm2/yr

Decomposition (3 $gcal/cm^2yr$) accounts for about 3.4 per cent of net production. The remainder of the plant material, 70 $gcal/cm^2/yr$ or 79.5 per cent of net production, is not utilised at all but becomes part of the accumulating sediments. It is obvious, then that much more energy is available for herbivore than is consumed.

It may also be noted that various pathways of loss are equivalent to an account for energy capture of the autotrophs i.e. gross production. Also, collectively the three upper 'fates' (decomposition, herbivore and not utilised) are equivalent to net production, of the total energy incorporated at the herbivores level, i.e. 15 $gcal.cm^2/yr$, 30 percent or 4.5 $gcal/cm^2/yr$ is used in metabolic reactions. Thus, there is considerably more energy lost via respiration by herbivores (30 percent) than by autotrophs (21 per cent).

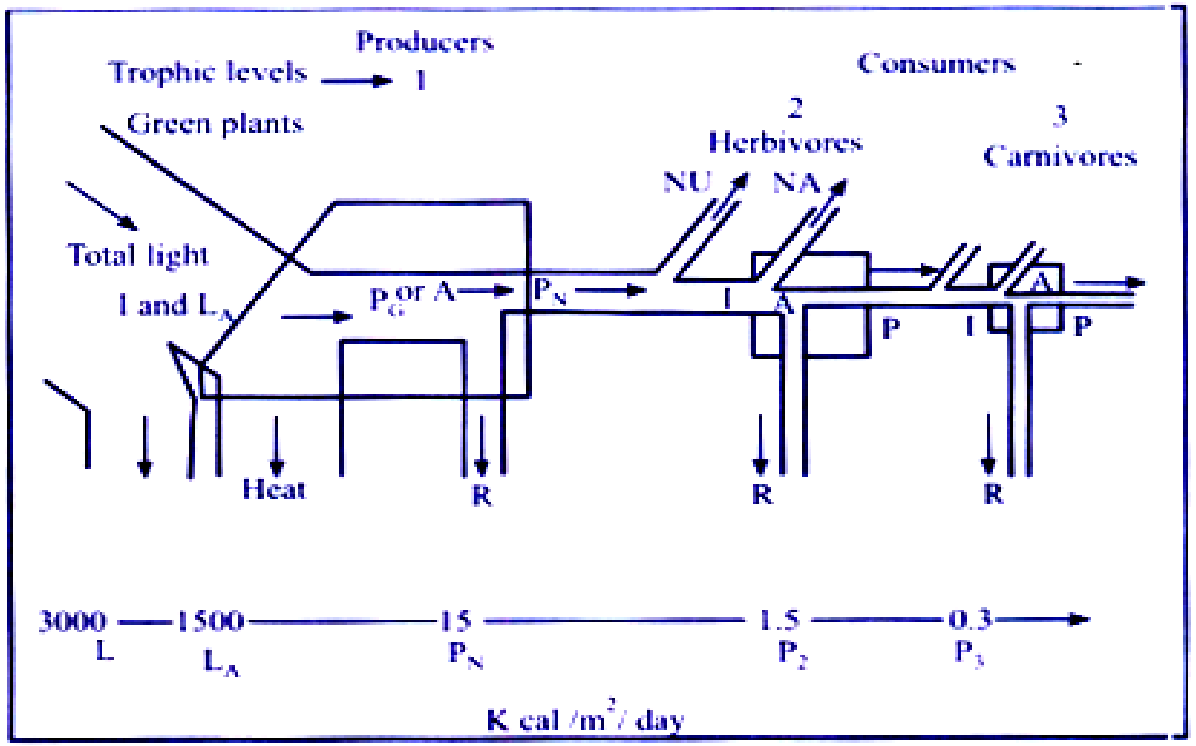


Fig. A simplified energy flow diagram depicting three trophic levels

Again there is considerable energy available for the carnivores, namely 10.5 gcal/cm^2/yr or 70 per cent, which is not entirely utilised; in fact only 3.0 gcal/cm^2/yr or 28.6 per cent of net production passes to the carnivores. This is more efficient utilisation of resources than occurs at autotroph-herbivore transfer level.

At the carnivore level about 60 percent of the carnivores' energy intake is consumed in metabolic activity and the remainder becomes part of the not utilised sediments; only an insignificant amount is subject to decomposition yearly. This high respiratory loss compares with 30 per cent by herbivores and 21 per cent by autotrophs in this ecosystem.

From the energy flow diagram shown in Figure above, two things become clear. Firstly, there is one-way street along which energy moves (unidirectional flow of energy). The energy that is captured by the autotrophs does not revert to solar input; that which passes to the herbivores does not pass back to the autotrophs. As it moves progressively through the various trophic levels it is no longer available to the previous level. Thus due to one-way flow of energy, the system would collapse if the primary source, the sun, were cut off.

Secondly, there occurs a progressive decrease in energy level at each trophic level. This is accounted largely by the energy dissipated as heat in metabolic activities and measured here as respiration coupled, with un-utilised energy. In Figure above the "boxes" represent the trophic levels and the 'pipes' depict the energy flow in and out of each level.

Energy inflows balance outflows as required by the first law of thermodynamics, and energy transfer is accompanied by dispersion of energy into unavailable heat (i.e. respiration) as required by the second law. Figure presents a very simplified energy flow model of three tropic levels, from which it becomes evident that the energy flow is greatly reduced at each successive trophic level from producers to herbivores and then to carnivores.

Thus at each transfer of energy from one level to another, major part of energy is lost as heat or other form. There is a successive reduction in energy flow whether we consider it in terms of total flow (i.e. total energy input and total assimilation) or secondary production and respiration components. Thus, of the 3,000 Kcal of total light falling upon the green plants, approximately 50 per cent (1500Kcal) is absorbed, of which only 1 per cent (15 Kcal) is converted at first trophic level.

Thus net primary production is merely 15 Kcal. Secondary productivity (P2 and P3 in the diagram) tends to be about 10 per cent at successive consumer trophic levels i.e. herbivores and the carnivores, although efficiency may be sometimes higher, as 20 per cent, at the carnivore level as shown (or P3= 0.3 Kcal) in the diagram.

It becomes evident from the two Figures that there is a successive reduction in energy flow at successive trophic levels. Thus shorter the food chain, greater would be the available food energy as with an increase in the length of food chain there is a corresponding more loss of energy.

2. Y-shaped Energy Flow Models:

In this type of energy flow model, the grazing and detritus food chains are shown as separate flows. The Y-shaped model further indicates that the two food chains namely the grazing food chain and detritus food chain are in fact, under natural conditions, not completely isolated from one another. The grazing food chain beginning with green plant base going to herbivores and the detritus food chain beginning with dead organic matter acted by microbes, then passing to detritivores and their consumers.

For instance, dead bodies of small animals that were once part of the grazing food chain become incorporated in the detritus food chain as do the feces of grazing food animals. Functionally, the distinction between the two is of time lag between the direct consumption of living plants and ultimate utilisation of dead organic matter. The importance of the two food chains may differ in different ecosystems, in some grazing is more important, in others detritus is major pathway.

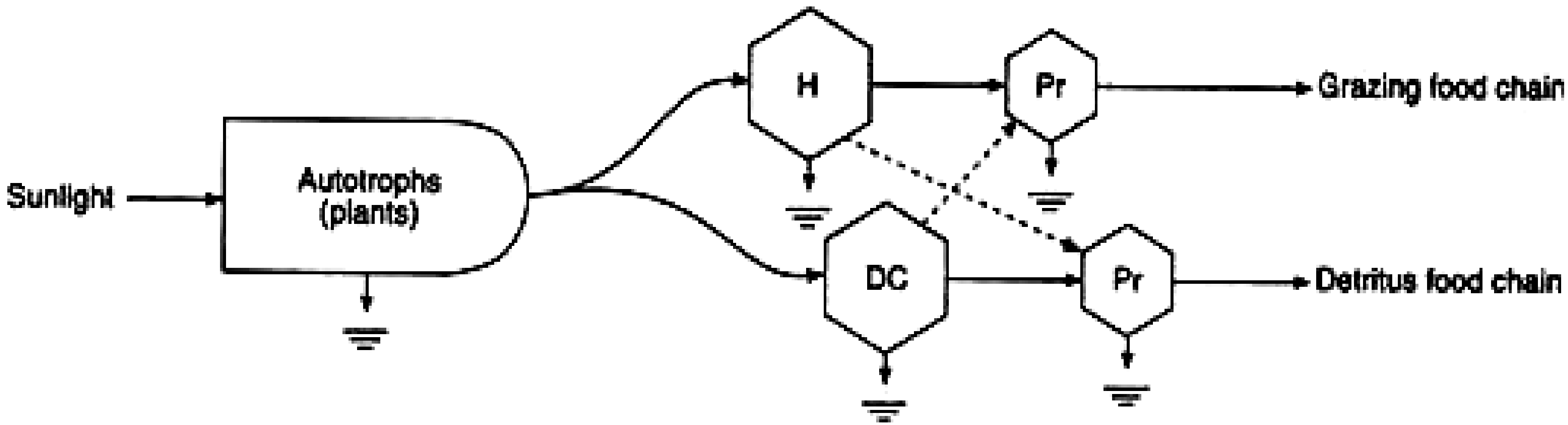
This is a more practical working model than the single channel model mainly because:

(1) It relates to the basic stratified structure of ecosystem;

(2) The direct consumption of living plants and dead organic matter are usually separated in both time and space; and

(3) The macro consumers and micro consumers differ greatly in size-metabolism relations and in the techniques required for studying them.

The grazing and detritus food chains are inter-connected. Moreover, not all food eaten by grazers is actually assimilated, as some (feces containing undigested material) is diver-ted to the detritus pathway. Also, the amount of net production energy that flows down the two pathways varies in different kinds of ecosystems and, often in the same ecosystem; it may vary seasonally or annually.



Y-shaped energy flow model. It shows linkage between grazing and detritus food chain (H = herbivores; DC = detritus consumers; Pr = predators)

The energy flow in case of shallow waters and heavily grazed pastures or grassland shows larger energy flow via the grazing food chain than in the detritus pathway. The reverse is true in case of the forest, marshes and oceans.

Most natural ecosystems operate as detrital system, where 90 percent or more of the autotrophs' production is not con-sumed by heterotrophs until the leaves, stems and other plant parts die and are processed into particulate and dissolved organic matter in water, soil and sediments.

This delayed consumption increases the structural com-plexity and biodiversity. It also increases the storage and buffering capacities of ecosys-tems. For example, there would be no forests if all free seedlings were grazed uponThe important point in Y-shaped model is that the two food chains are not isolated from each other. This Y- shaped model is more realistic and practical working model than the single-channel model because,

(i) it confirms to stratified structure of ecosystems,

(ii) it separates the grazing and detritus chains (direct consumption of living plants and utilization of dead organic matter respectively) in both time and space, and

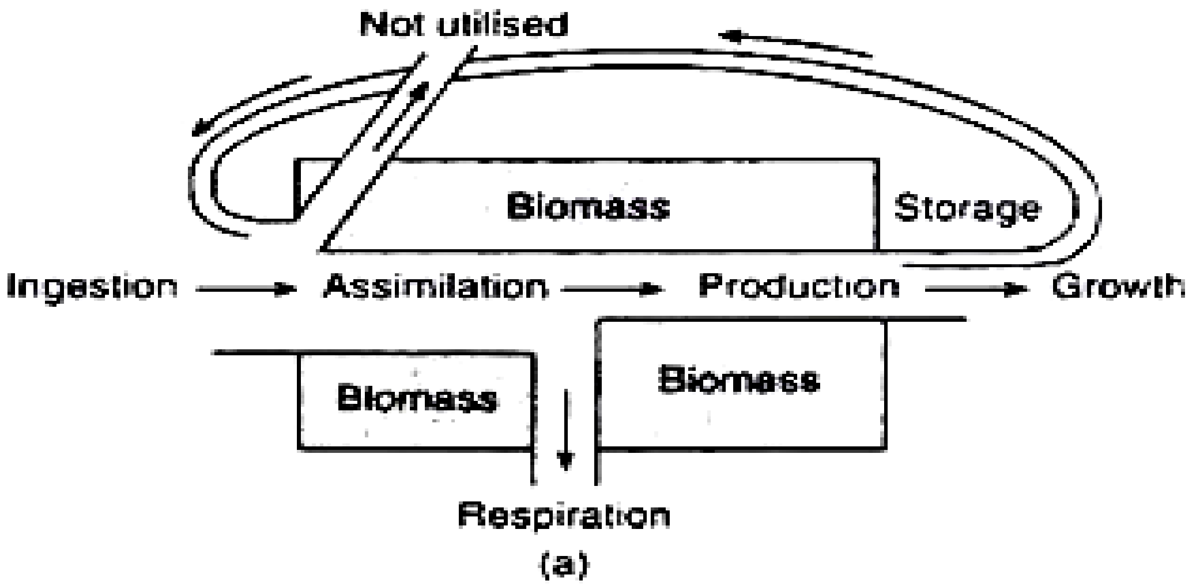
(iii) that the micro-consumers (absorptive bacteria, fungi) and the macro-consumers (phagotrophic animals) differ greatly size-metabolism relations. (E-P> Odum. 1983).

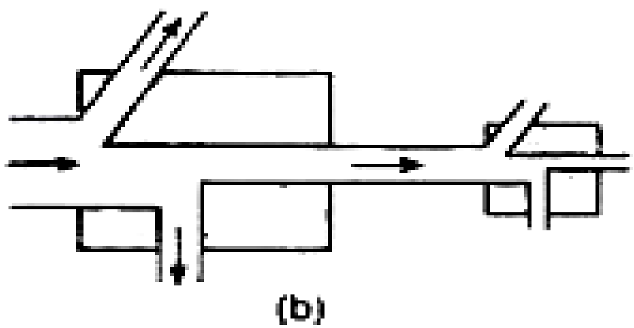
It must however, be remembered that these models depict the basic pattern of energy flow in ecosystem. In practice, under natural conditions, the organisms are interrelated in a way that several food chains become interlocked results into a complex food web. We have already referred to food webs in grassland and in pond ecosystems. The complexity of food web depends on the length of the food chains.

Thus in nature there operates multi-channel energy flows, but in these the channels belong to either of the two basic food chains i.e., will be either a grazing or a detritus food chain. Interlocking pattern of such several chains in food web of an ecosystem would lead to a multi-channel flow of energy. Thus in practice, under field conditions, we might face difficulties in measuring energetic of ecosystem.

3. Universal Model:

The universal model is applicable to any living component, which may be plant, animal, microorganism, individual, population or trophic group.





Universal model of energy flow : (a) Energy flow in one trophic level. (b) A link between trophic levels in a food web

The shaded box represents the living, standing crop biomass (generally measured as some kind of weight, such as dry weight, wet weight etc.) of the component which should be expressed in calories, so that its relation with rates of energy flow can be established. The total energy input or intake or ingestion varies. For strict autotrophs, it is light, while, for strict heterotrophs, it is organic food.

A key feature of the model is the separation of assimilated energy (A) into the production (P) and respiration (R) components. R is the energy that is lost as heat (maintenance energy) and P is the portion transformed to new or different organic matter and is the part that is available to the next trophic level.

At the same time, the non- assimilated component (NU – not utilised), such as feces, enters the detritus food chain. It is important to note that P component is energy that is available to the next trophic level while NU component is energy that is still available at the same trophic level.

The universal energy flow can be used in two ways:

(1) The model can represent a species population with appropriate energy inputs and its link with other species, and

(2) The model can represent a discrete energy level, where the biomass and energy channels represent all or part of many populations supported by the same energy source. For example, foxes

obtain their food partly by eating plants (fruits) and partly by eating herbivore animals (rabbit, mice etc.).

So a single box diagram can be used to represent the whole population of foxes if intra-population energetics were to be stressed.

On the other hand, two or more boxes would be employed if the fox population is considered in two trophic levels according to the proportion of plant and animal food consumed. In this way, the fox population can be placed into the overall pattern of energy flow in the community.

Liner food chain:

- It is a linear sequent of organisms in which nutrients and energy travel as one organism and eats another.
- "Various tropical levels" defined by how many energy transfers separate it from the basic input of the chain.
- This inefficiency limits the length of food chains.

Y-shaped food chain:

- Y-shaped model of the flow of "energy in ecosystems".
- Considering a single food chain the energy travelled by either grazing is termed as a single-chain model.
- The lower food chain of "plant—>termite—>aardvark" is a part of the "grazing food chain".

THANK YOU