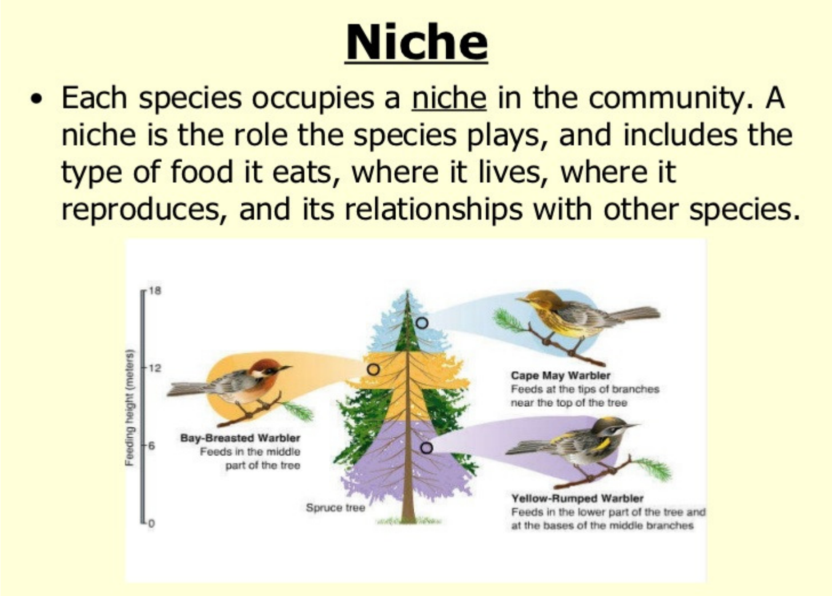
GEO-A-CC-4-10-TH-SOIL AND BIO GEOGRAPHY

UNIT II: BIO GEOGRAPHY

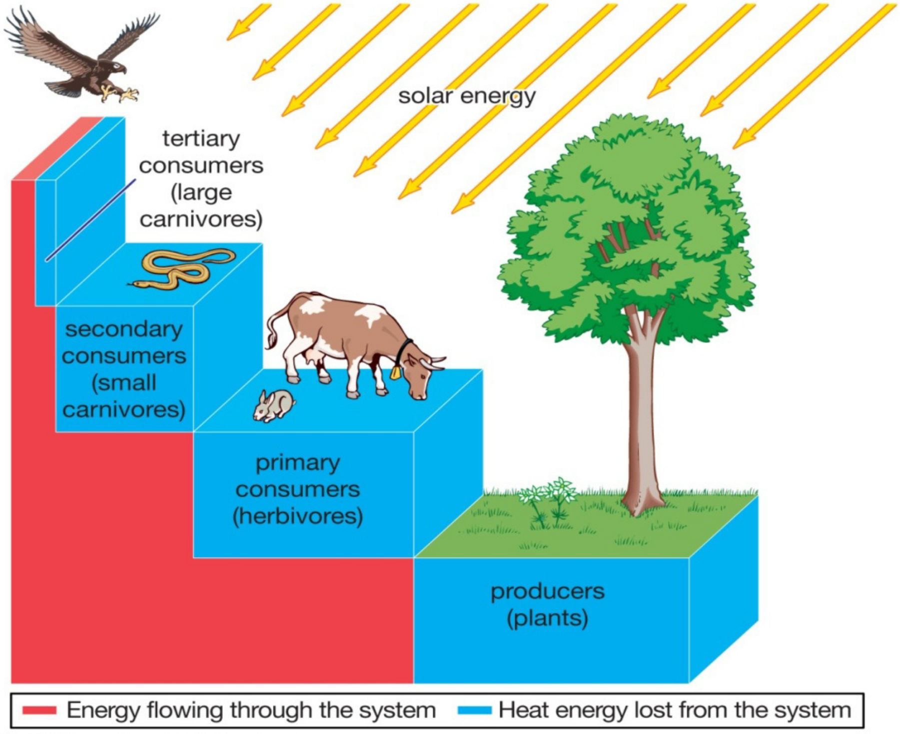
TOPICS COVERED: 1.ECOLOGICAL NICHE

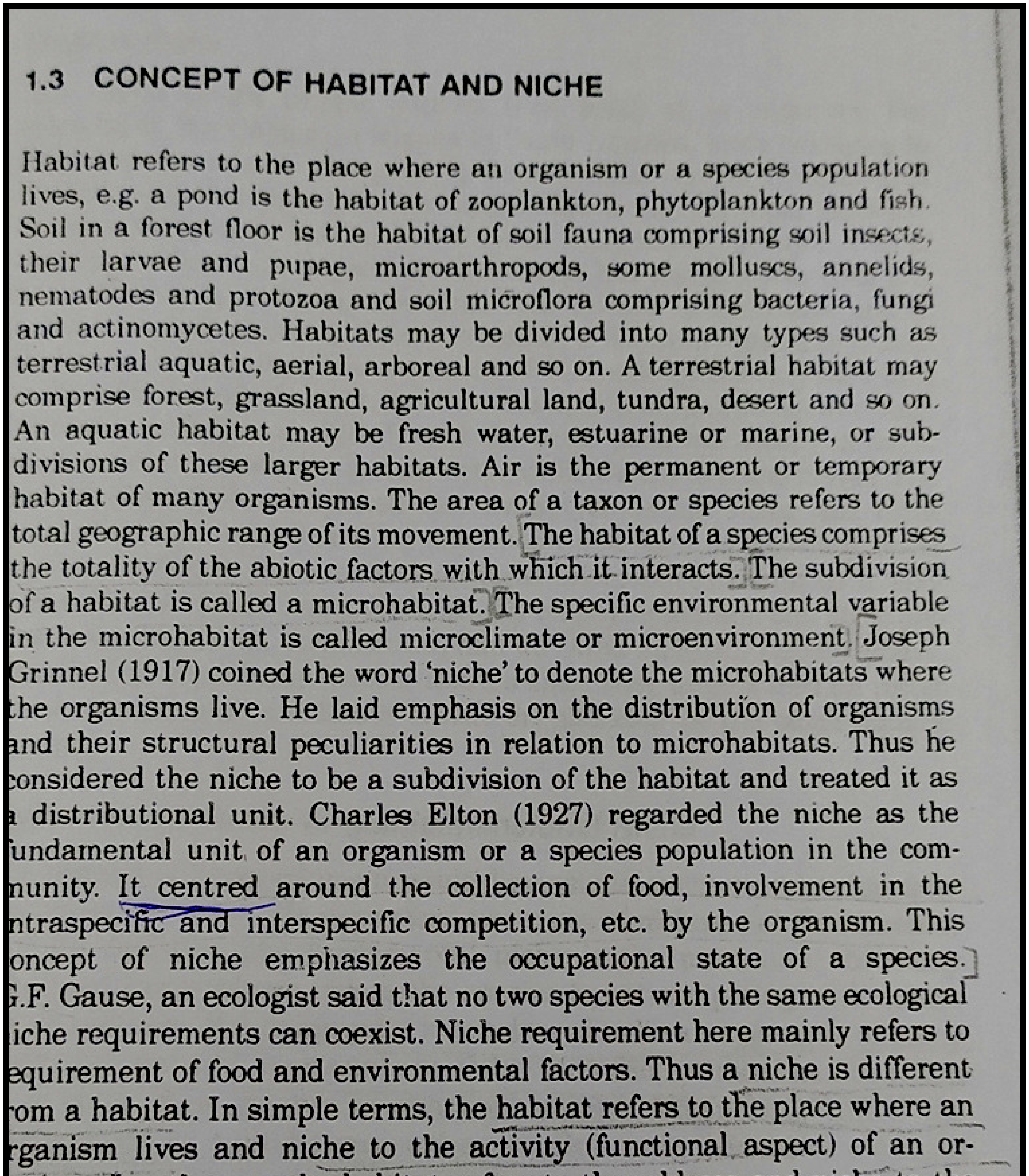


Niche

- Each species occupies a niche in the community. A niche is the role the species plays, and includes the type of food it eats, where it lives, where it reproduces, and its relationships with other species.

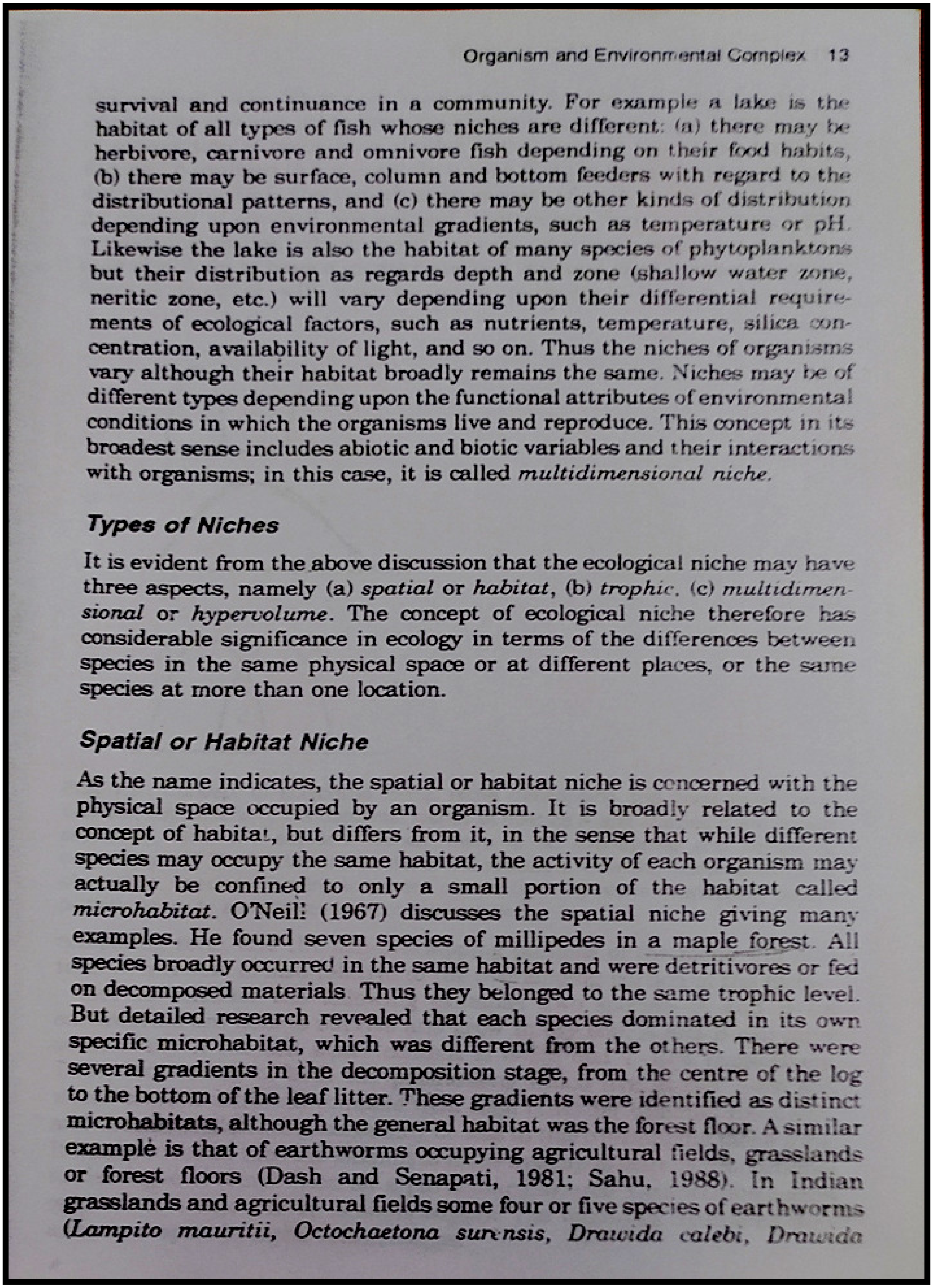
2.ENERGY FLOW





1.3 CONCEPT OF HABITAT AND NICHE

Habitat refers to the place where an organism or a species population lives, e.g. a pond is the habitat of zooplankton, phytoplankton and fish. Soil in a forest floor is the habitat of soil fauna comprising soil insects, their larvae and pupae, microarthropods, some molluscs, annelids, nematodes and protozoa and soil microflora comprising bacteria, fungi and actinomycetes. Habitats may be divided into many types such as terrestrial aquatic, aerial, arboreal and so on. A terrestrial habitat may comprise forest, grassland, agricultural land, tundra, desert and so on. An aquatic habitat may be fresh water, estuarine or marine, or subdivisions of these larger habitats. Air is the permanent or temporary habitat of many organisms. The area of a taxon or species refers to the total geographic range of its movement. The habitat of a species comprises the totality of the abiotic factors with which it interacts. The subdivision of a habitat is called a microhabitat. The specific environmental variable in the microhabitat is called microclimate or microenvironment. Joseph Grinnel (1917) coined the word 'niche' to denote the microhabitats where the organisms live. He laid emphasis on the distribution of organisms and their structural peculiarities in relation to microhabitats. Thus he considered the niche to be a subdivision of the habitat and treated it as a distributional unit. Charles Elton (1927) regarded the niche as the fundamental unit of an organism or a species population in the community. It centred around the collection of food, involvement in the ntraspecific and interspecific competition, etc. by the organism. This oncept of niche emphasizes the occupational state of a species. G.F. Gause, an ecologist said that no two species with the same ecological iche requirements can coexist. Niche requirement here mainly refers to equirement of food and environmental factors. Thus a niche is different rom a habitat. In simple terms, the habitat refers to the place where an organism lives and niche to the activity (functional aspect) of an organism. In other words, habitat refers to the address and niche to the rofession of the organism. Kendeigh (1974) considered the niche as a mbination of the habitat and biotic interactions of a species for its



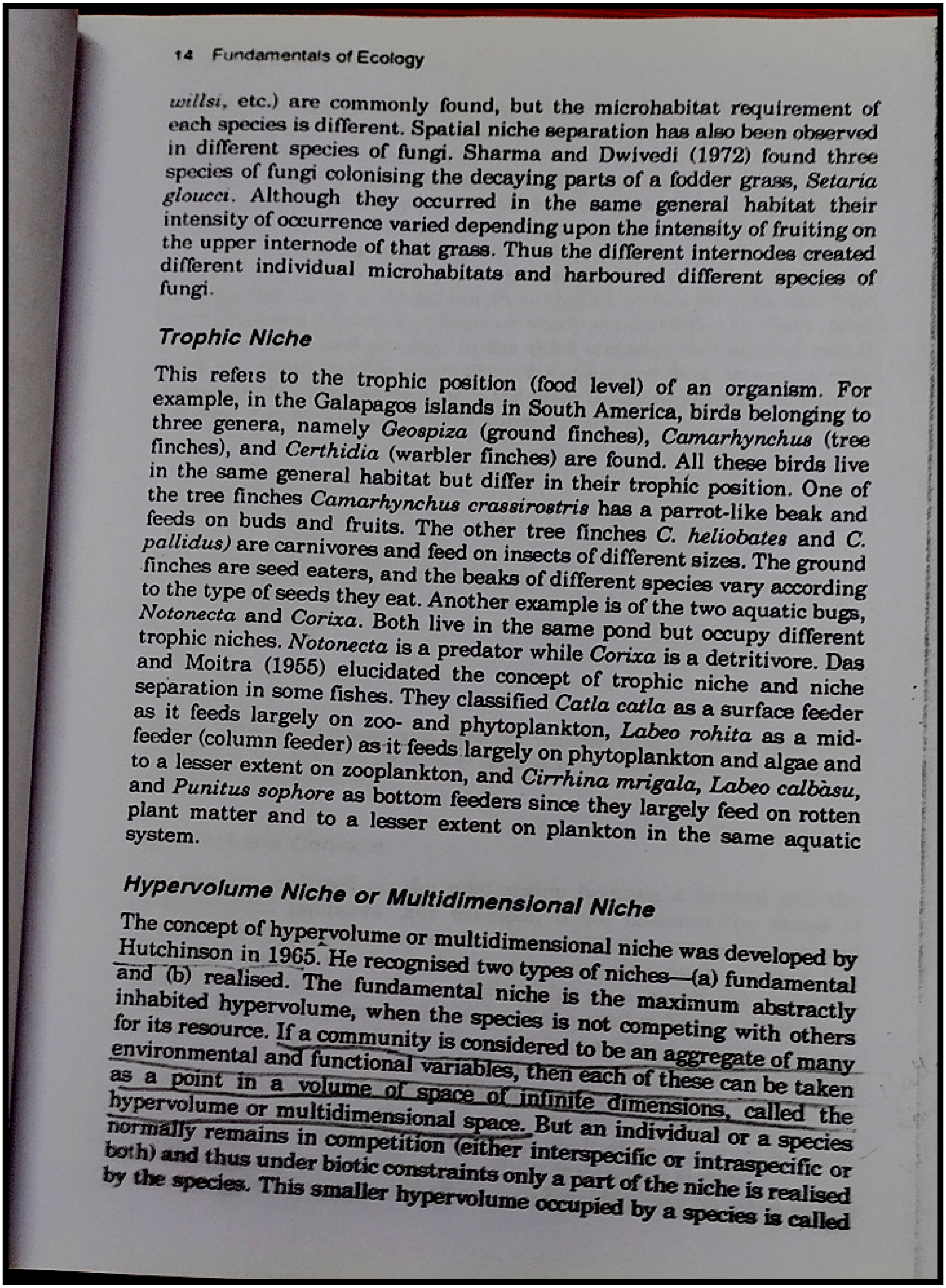
survival and continuance in a community. For example a lake is the habitat of all types of fish whose niches are different: (a) there may be herbivore, carnivore and omnivore fish depending on their food habits, (b) there may be surface, column and bottom feeders with regard to the distributional patterns, and (c) there may be other kinds of distribution depending upon environmental gradients, such as temperature or pH. Likewise the lake is also the habitat of many species of phytoplanktons but their distribution as regards depth and zone (shallow water zone, neritic zone, etc.) will vary depending upon their differential requirements of ecological factors, such as nutrients, temperature, silica concentration, availability of light, and so on. Thus the niches of organisms vary although their habitat broadly remains the same. Niches may be of different types depending upon the functional attributes of environmental conditions in which the organisms live and reproduce. This concept in its broadest sense includes abiotic and biotic variables and their interactions with organisms; in this case, it is called *multidimensional niche*.

Types of Niches

It is evident from the above discussion that the ecological niche may have three aspects, namely (a) *spatial* or *habitat*, (b) *trophic*, (c) *multidimensional* or *hypervolume*. The concept of ecological niche therefore has considerable significance in ecology in terms of the differences between species in the same physical space or at different places, or the same species at more than one location.

Spatial or Habitat Niche

As the name indicates, the spatial or habitat niche is concerned with the physical space occupied by an organism. It is broadly related to the concept of habitat, but differs from it, in the sense that while different species may occupy the same habitat, the activity of each organism may actually be confined to only a small portion of the habitat called *microhabitat*. O'Neill (1967) discusses the spatial niche giving many examples. He found seven species of millipedes in a maple forest. All species broadly occurred in the same habitat and were detritivores or fed on decomposed materials. Thus they belonged to the same trophic level. But detailed research revealed that each species dominated in its own specific microhabitat, which was different from the others. There were several gradients in the decomposition stage, from the centre of the log to the bottom of the leaf litter. These gradients were identified as distinct microhabitats, although the general habitat was the forest floor. A similar example is that of earthworms occupying agricultural fields, grasslands or forest floors (Dash and Senapati, 1981; Sahu, 1988). In Indian grasslands and agricultural fields some four or five species of earthworms (*Lampito mauritii, Octochaetona surensis, Drawida calebi, Drawida*



willsi, etc.) are commonly found, but the microhabitat requirement of each species is different. Spatial niche separation has also been observed in different species of fungi. Sharma and Dwivedi (1972) found three species of fungi colonising the decaying parts of a fodder grass, *Setaria gloucci*. Although they occurred in the same general habitat their intensity of occurrence varied depending upon the intensity of fruiting on the upper internode of that grass. Thus the different internodes created different individual microhabitats and harboured different species of fungi.

Trophic Niche

This refers to the trophic position (food level) of an organism. For example, in the Galapagos islands in South America, birds belonging to three genera, namely *Geospiza* (ground finches), *Camarhynchus* (tree finches), and *Certhidia* (warbler finches) are found. All these birds live in the same general habitat but differ in their trophic position. One of the tree finches *Camarhynchus crassirostris* has a parrot-like beak and feeds on buds and fruits. The other tree finches *C. heliobates* and *C. pallidus)* are carnivores and feed on insects of different sizes. The ground finches are seed eaters, and the beaks of different species vary according to the type of seeds they eat. Another example is of the two aquatic bugs, *Notonecta* and *Corixa*. Both live in the same pond but occupy different trophic niches. *Notonecta* is a predator while *Corixa* is a detritivore. Das and Moitra (1955) elucidated the concept of trophic niche and niche separation in some fishes. They classified *Catla catla* as a surface feeder as it feeds largely on zoo- and phytoplankton, *Labeo rohita* as a mid-feeder (column feeder) as it feeds largely on phytoplankton and algae and to a lesser extent on zooplankton, and *Cirrhina mrigala, Labeo calbàsu,* and *Punitus sophore* as bottom feeders since they largely feed on rotten plant matter and to a lesser extent on plankton in the same aquatic system.

Hypervolume Niche or Multidimensional Niche

The concept of hypervolume or multidimensional niche was developed by Hutchinson in 1965. He recognised two types of niches—(a) fundamental and (b) realised. The fundamental niche is the maximum abstractly inhabited hypervolume, when the species is not competing with others for its resource. If a community is considered to be an aggregate of many environmental and functional variables, then each of these can be taken as a point in a volume of space of infinite dimensions, called the hypervolume or multidimensional space. But an individual or a species normally remains in competition (either interspecific or intraspecific or both) and thus under biotic constraints only a part of the niche is realised by the species. This smaller hypervolume occupied by a species is called the *realised niche*. Thus each species has a *fundamental niche* within a community to which it is adapted in the evolutionary process, but because of competition it occupies a similar niche, namely the realised niche. Figure 1.5 explains this concept. In it zone-C is the competing zone where due to competition, the reproductive success of each species, and hence its chances of survival are reduced. Individuals from populations with overlapping niches, which remain outside the overlapping competitive zone are likely to have a greater survival rate and reproductive success. Natural selection will tend to favour individuals lying in the non-competing zone, and the non-overlapping portions of the niche will also tend to increase in size relative to the overlapping portion of the niche.

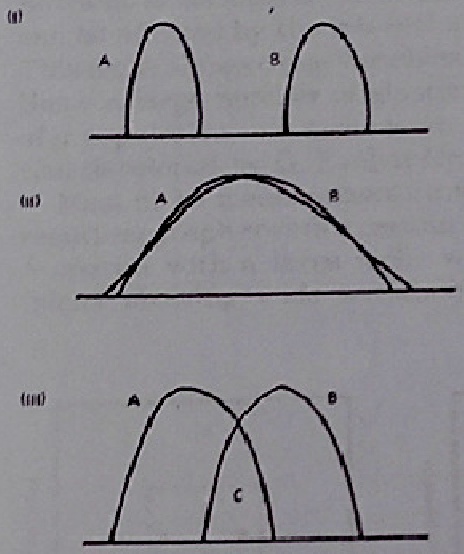


FIG. 1.5 Concept of ecological niche: niche overlapping and competition zone between populations (i) Fundamental niches of species A and species B are shown separately. Both are adjacent niches, there is no overlapping and hence no competition. (ii) The fundamental niche of one species is within the fundamental niche of another species , leading to severe competition. (iii) Niche overlapping occurs partially, leads to a moderate level of competition

Let us consider the following example. Two species—A and B—of earthworms are able to survive and grow in dry soil. A and B can grow successfully if the soil water content is 5–8% and 7–10% respectively. Thus, individuals of both the populations which live in the 7–8% soil water content zone will compete with each other for common resources, and their reproductive success may be less in this overlapping niche zone. It has been found that the amount of niche overlap is usually proportional to the degee of competition for a particular resource. Competition occurs only when a resource is in short supply. The following conditions may arise in respect of niche relationships.

1. Niches may be adjacent to each other but not overlap.
2. The fundamental niche of one species may be completely within the fundamental niche of another species.
3. In a majority of cases, the niches may overlap.

In the first case, competition will be minimised since the niches are different. In the second case there will be severe competition for space, but the species may not compete for food if their trophic niches are different. For example, the black and the white rhinoceroses live in the same habitat niche in Africa but their trophic niches are different. The black rhino is a browser and feeds on woody plants while the white rhino grazes on herbs and grasses. In the third instance (overlapping niche) there will be an intense competition for space and food. In such a case either one of the species will leave the niche (niche separation) or remain subdued. Figure 1.6 explains the three situations.

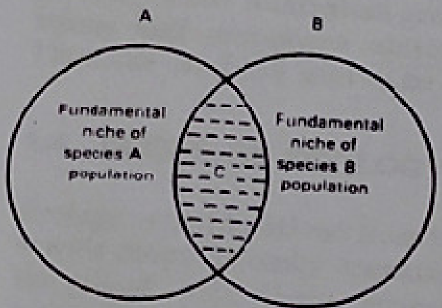


FIG. 1.6 Concept of fundamental niche and realised niche; A—fundamental niche of species A; B— fundamental niche of species B; C—competition zone. Unshaded portions are realized niches

Hypervolume Concept

This concept is based on the relationship between a species and the environmental gradients. For example, if we measure the range of environmental temperature over which a particular species can live and reproduce and do the same for another environmental gradient like humidity, and then plot these relationships on a graph, we obtain an enclosed space representing the niche of the species. Since two environmental factors are considered, the niche is considered to be two-dimensional. It will be multidimensional if more than two environmental variables are taken into account. Since many environmental factors are closely related to each other and each organism interacts with many factors of the environment, the tolerance limit of each species is determined by taking into consideration all the interacting factors.

For example, temperature and relative humidity may be taken as two environmental factors and a particular population's tolerance to these factors can be studied. Assuming these environmental factors to be independent, the population's niche with respect to temperature and relative humidity can be shown in a two-dimensional box (Fig. 1.7A). But it is known that temperature and relative humidity are not independent of each other in respect of their biological effects. Tolerance to higher temperatures may be associated with an increase in relative humidity. Thus, the population's niche with respect to the interaction of temperature and relative humidity may be represented in a better manner by an ellipse (Fig. 1.7B). If another variable, such as the availability of a nutrient is considered, then the tolerance to levels of available nutrient can be affected by the interaction of temperature and relative humidity. This niche shows three variables (Fig. 1.7C) or a three-dimensional figure. Since a large number of abiotic and biotic factors affect the functioning of a population, the niche is an *n* dimensional hypervolume, an abstraction developed by G. Evelyn Hutchinson of Yale University.

Most niche measurements involve plotting along at least two axes. The resulting graph covers a certain area along an axis called the *niche width*. A species with a large niche width is considered a generalised species (niche showing wide variability), while one with a narrow niche is

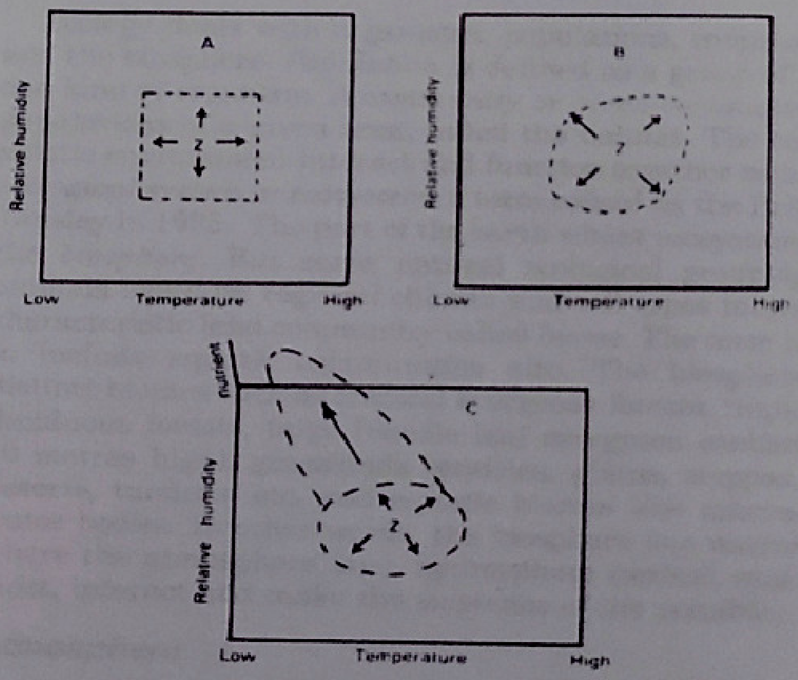
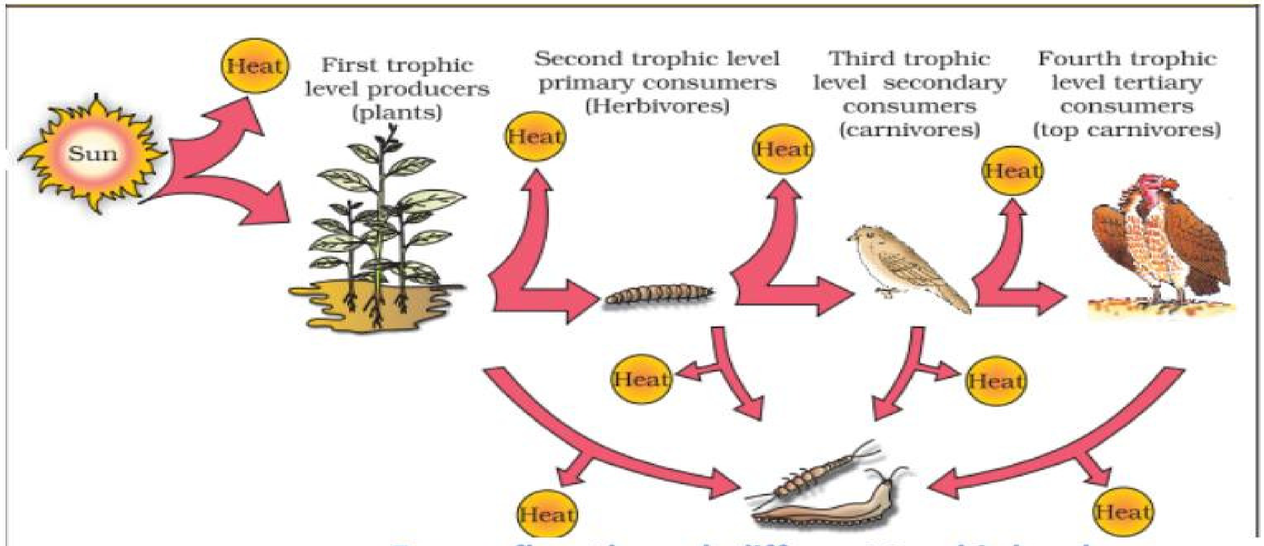
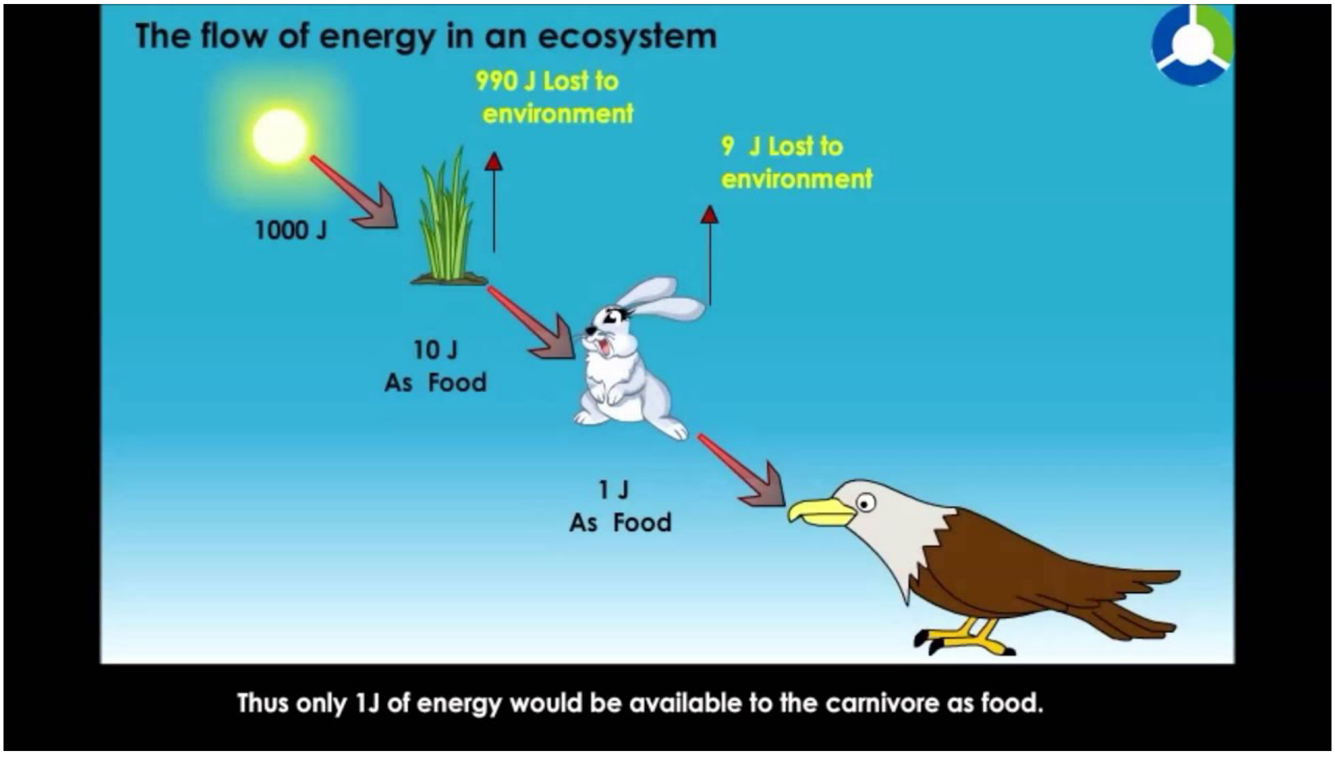


FIG. 1.7 Multidimensional or hypervolume niche: A—two-dimensional niche with independent variables; B—two-dimensional niche with interdependent variables; C—a three-dimensional niche.

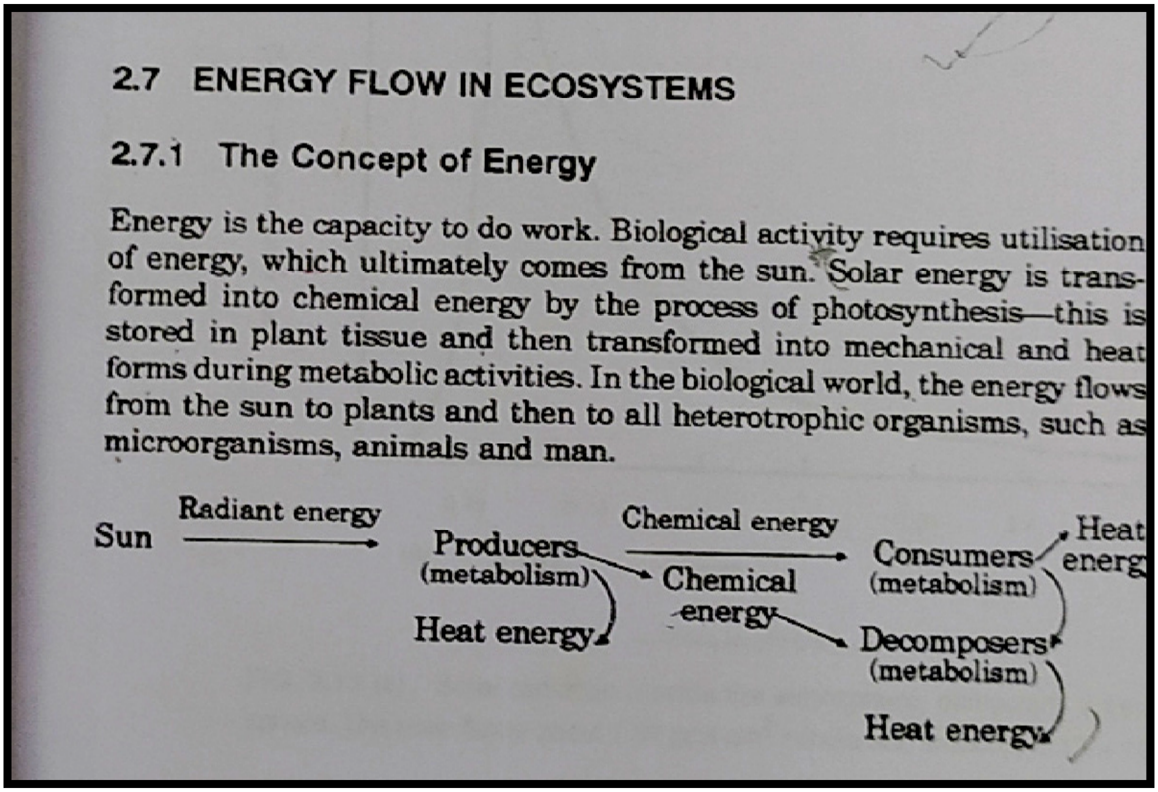
ENERGY FLOW IN AN ECOSYSTEM



Energy flow through different trophic levels


The flow of energy in an ecosystem

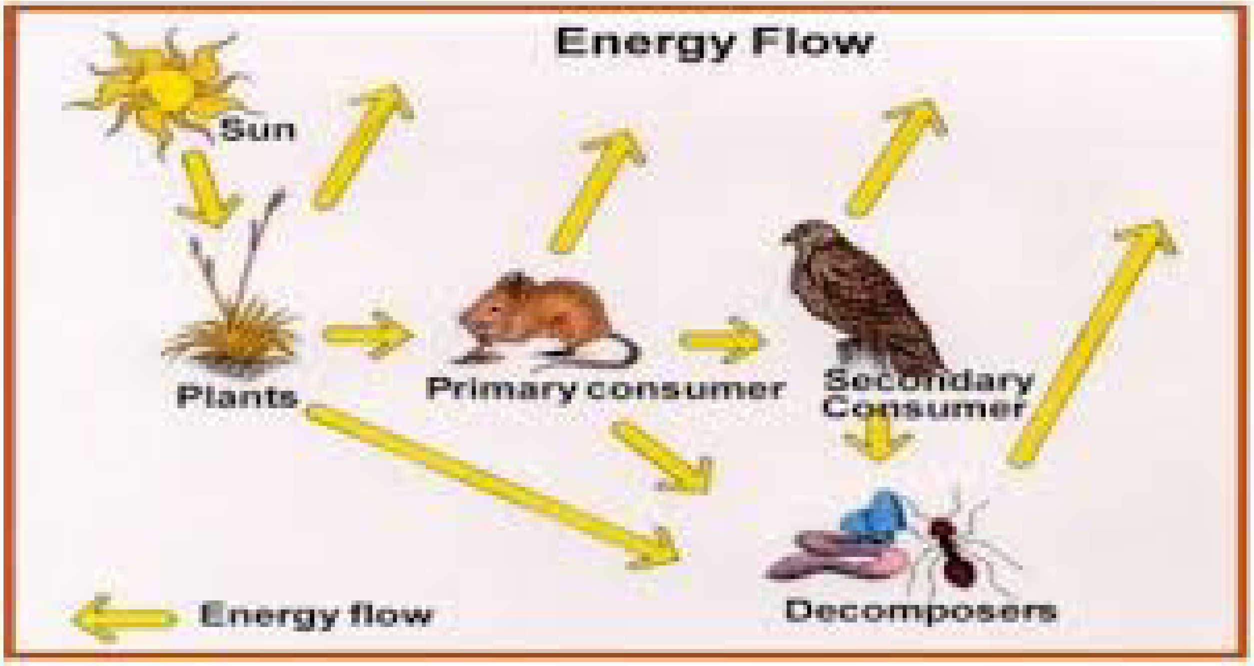
Thus only 1J of energy would be available to the carnivore as food.

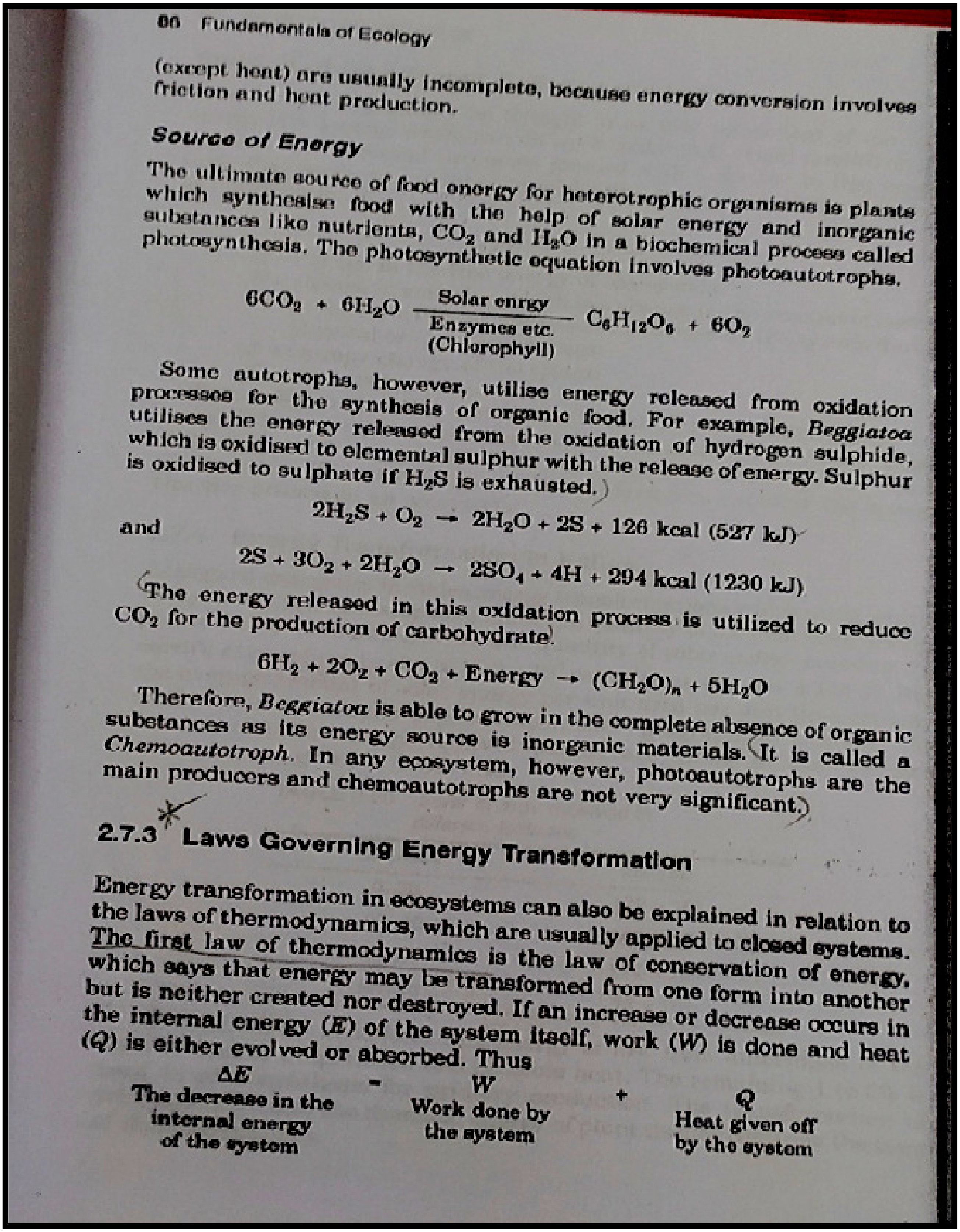


2.7 ENERGY FLOW IN ECOSYSTEMS

2.7.1 The Concept of Energy

Energy is the capacity to do work. Biological activity requires utilisation of energy, which ultimately comes from the sun. Solar energy is transformed into chemical energy by the process of photosynthesis—this is stored in plant tissue and then transformed into mechanical and heat forms during metabolic activities. In the biological world, the energy flows from the sun to plants and then to all heterotrophic organisms, such as microorganisms, animals and man.





(except heat) are usually incomplete, because energy conversion involves friction and heat production.

Source of Energy

The ultimate source of food energy for heterotrophic organisms is plants which synthesise food with the help of solar energy and inorganic substances like nutrients, CO_2 and H_2O in a biochemical process called photosynthesis. The photosynthetic equation involves photoautotrophs.

$$6CO_2 + 6H_2O \xrightarrow[\text{Enzymes etc. (Chlorophyll)}]{\text{Solar enrgy}} C_6H_{12}O_6 + 6O_2$$

Some autotrophs, however, utilise energy released from oxidation processes for the synthesis of organic food. For example, *Beggiatoa* utilises the energy released from the oxidation of hydrogen sulphide, which is oxidised to elemental sulphur with the release of energy. Sulphur is oxidised to sulphate if H_2S is exhausted.

$$2H_2S + O_2 \rightarrow 2H_2O + 2S + 126 \text{ kcal } (527 \text{ kJ})$$

and

$$2S + 3O_2 + 2H_2O \rightarrow 2SO_4 + 4H + 294 \text{ kcal } (1230 \text{ kJ})$$

The energy released in this oxidation process is utilized to reduce CO_2 for the production of carbohydrate.

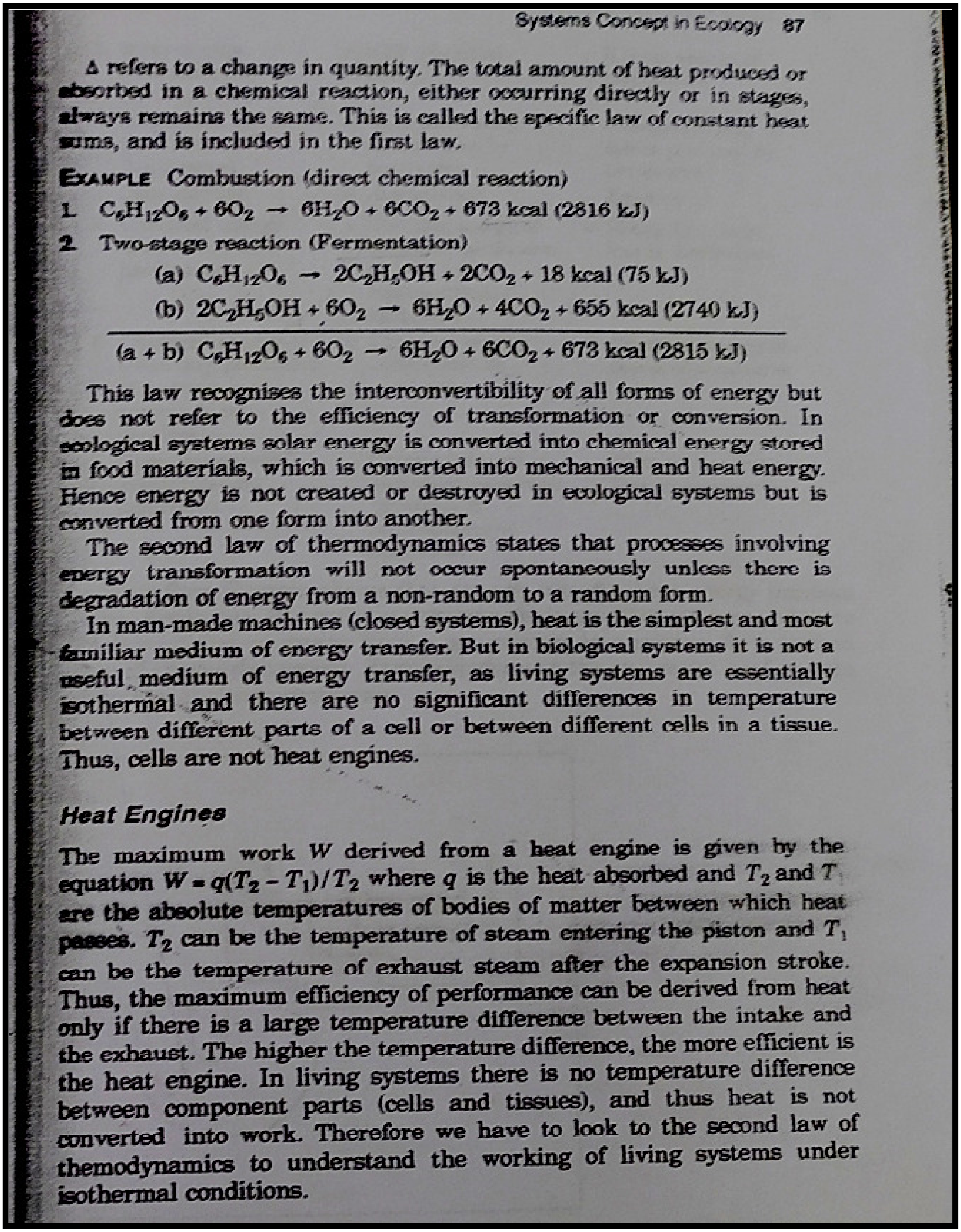
$$6H_2 + 2O_2 + CO_2 + \text{Energy} \rightarrow (CH_2O)_n + 5H_2O$$

Therefore, *Beggiatoa* is able to grow in the complete absence of organic substances as its energy source is inorganic materials. It is called a *Chemoautotroph*. In any ecosystem, however, photoautotrophs are the main producers and chemoautotrophs are not very significant.

2.7.3 Laws Governing Energy Transformation

Energy transformation in ecosystems can also be explained in relation to the laws of thermodynamics, which are usually applied to closed systems. The first law of thermodynamics is the law of conservation of energy, which says that energy may be transformed from one form into another but is neither created nor destroyed. If an increase or decrease occurs in the internal energy (E) of the system itself, work (W) is done and heat (Q) is either evolved or absorbed. Thus

$$\underset{\substack{\text{The decrease in the}\\ \text{internal energy}\\ \text{of the system}}}{\Delta E} = \underset{\substack{\text{Work done by}\\ \text{the system}}}{W} + \underset{\substack{\text{Heat given off}\\ \text{by the system}}}{Q}$$



Δ refers to a change in quantity. The total amount of heat produced or absorbed in a chemical reaction, either occurring directly or in stages, always remains the same. This is called the specific law of constant heat sums, and is included in the first law.

Example Combustion (direct chemical reaction)

1. $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$ + 673 kcal (2816 kJ)
2. Two-stage reaction (Fermentation)

$$\begin{array}{rl} \text{(a)} & C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + 18\ \text{kcal}\ (75\ \text{kJ}) \\ \text{(b)} & 2C_2H_5OH + 6O_2 \rightarrow 6H_2O + 4CO_2 + 655\ \text{kcal}\ (2740\ \text{kJ}) \\ \hline \text{(a + b)} & C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + 673\ \text{kcal}\ (2815\ \text{kJ}) \end{array}$$

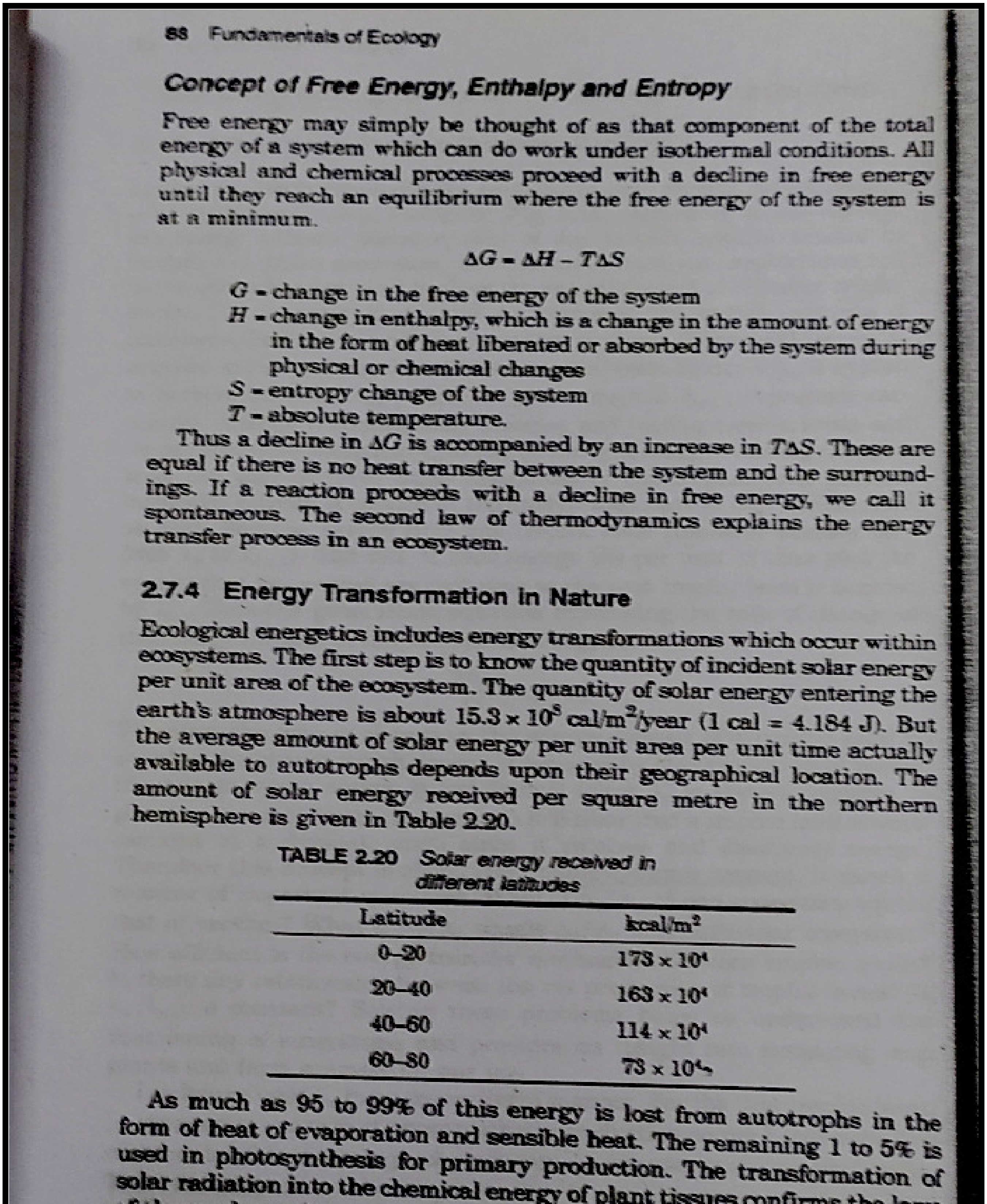
This law recognises the interconvertibility of all forms of energy but does not refer to the efficiency of transformation or conversion. In ecological systems solar energy is converted into chemical energy stored in food materials, which is converted into mechanical and heat energy. Hence energy is not created or destroyed in ecological systems but is converted from one form into another.

The second law of thermodynamics states that processes involving energy transformation will not occur spontaneously unless there is degradation of energy from a non-random to a random form.

In man-made machines (closed systems), heat is the simplest and most familiar medium of energy transfer. But in biological systems it is not a useful medium of energy transfer, as living systems are essentially isothermal and there are no significant differences in temperature between different parts of a cell or between different cells in a tissue. Thus, cells are not heat engines.

Heat Engines

The maximum work W derived from a heat engine is given by the equation $W = q(T_2 - T_1)/T_2$ where q is the heat absorbed and T_2 and T_1 are the absolute temperatures of bodies of matter between which heat passes. T_2 can be the temperature of steam entering the piston and T_1 can be the temperature of exhaust steam after the expansion stroke. Thus, the maximum efficiency of performance can be derived from heat only if there is a large temperature difference between the intake and the exhaust. The higher the temperature difference, the more efficient is the heat engine. In living systems there is no temperature difference between component parts (cells and tissues), and thus heat is not converted into work. Therefore we have to look to the second law of themodynamics to understand the working of living systems under isothermal conditions.



Concept of Free Energy, Enthalpy and Entropy

Free energy may simply be thought of as that component of the total energy of a system which can do work under isothermal conditions. All physical and chemical processes proceed with a decline in free energy until they reach an equilibrium where the free energy of the system is at a minimum.

$$\Delta G = \Delta H - T\Delta S$$

G = change in the free energy of the system
H = change in enthalpy, which is a change in the amount of energy in the form of heat liberated or absorbed by the system during physical or chemical changes
S = entropy change of the system
T = absolute temperature.

Thus a decline in ΔG is accompanied by an increase in $T\Delta S$. These are equal if there is no heat transfer between the system and the surroundings. If a reaction proceeds with a decline in free energy, we call it spontaneous. The second law of thermodynamics explains the energy transfer process in an ecosystem.

2.7.4 Energy Transformation in Nature

Ecological energetics includes energy transformations which occur within ecosystems. The first step is to know the quantity of incident solar energy per unit area of the ecosystem. The quantity of solar energy entering the earth's atmosphere is about 15.3×10^5 cal/m^2/year (1 cal = 4.184 J). But the average amount of solar energy per unit area per unit time actually available to autotrophs depends upon their geographical location. The amount of solar energy received per square metre in the northern hemisphere is given in Table 2.20.

TABLE 2.20 *Solar energy received in different latitudes*

Latitude	kcal/m^2
0–20	173×10^4
20–40	163×10^4
40–60	114×10^4
60–80	73×10^4

As much as 95 to 99% of this energy is lost from autotrophs in the form of heat of evaporation and sensible heat. The remaining 1 to 5% is used in photosynthesis for primary production. The transformation of solar radiation into the chemical energy of plant tissues confirms the laws of thermodynamics.

1. Solar energy assimilated by photoautotrophs = NPP (chemical energy) + R (heat energy of respiration)
2. NPP eaten by heterotrophs (herbivores) Consumption = Chemical energy of assimilation by herbivores = Assimilation + Chemical energy of faeces produced by herbivores + Egestion
3. Chemical energy assimilated by herbivores = Chemical energy of secondary production (growth and reproduction) of herbivores. + Metabolic energy loss by herbivores
4. Chemical energy of secondary production of herbivores consumed by carnivores = Chemical energy assimilated by carnivores + Chemical energy of faeces of carnivores.
5. Chemical energy assimilated by carnivores = Chemical energy of secondary production (growth and reproduction) of carnivores + Metabolic energy loss by carnivores

This flow diagram shows that at each transfer, heat energy (random form) dissipates. Hence the energy transfer is not 100% efficient and there is degradation of energy from a non-random to a random form (second law of thermodynamics). Each transfer and the end result confirms the first law of thermodynamics.

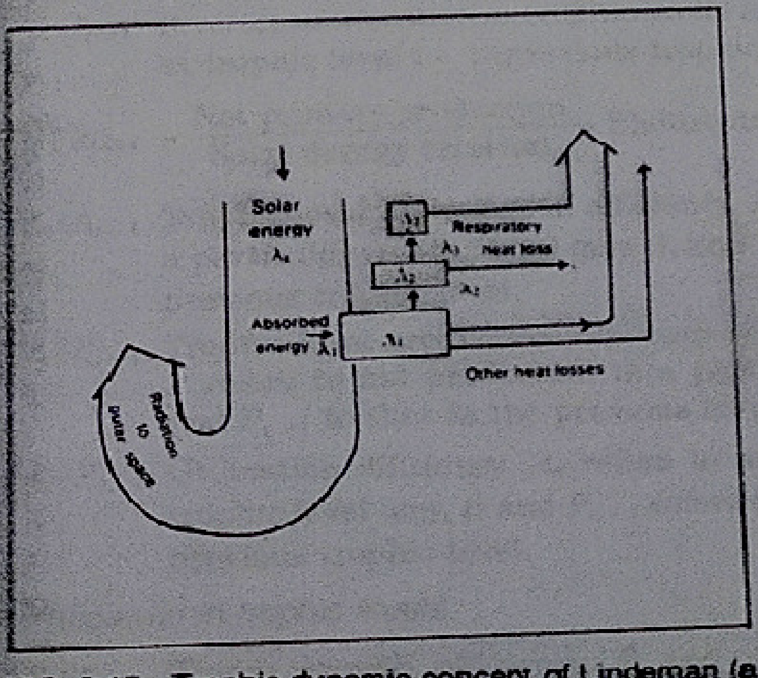


FIG. 2.15 Trophic dynamic concept of Lindeman (a diagrammatic representation)