Chapter 4

ENERGY FLOW IN ECOSYSTEM

4.1 INTRODUCTION

Every living organism requires a certain amount of enefgy for growth, survival and reproduction, This energy is used in the following ways.

i. to perform metabolic activity

ii. for repair and renewal of tissues

iii. to allow for the movement of mobile animals i.e. energy expended through activity

iv. a part is used for the growth and formation of new protoplasm

v. to supply the necessary structures for reproduction i.e. embryos, seeds, etc, and

vi. a small part of energy is stored as reserve food, for example, in the form of starch in plants, and fats in animals.

Living organisms take in energy from outside and convert it into some useful form. A portion of that useful energy is then released to perform the above referred life processes, after which it leaves the organisms once again and is dispersed into environment in the form of heat.

In the following account we shall define and discuss the kinds, source', behaviour, quality and flow of energy in an ecosystem.

Q. What is the total area of world's land surface?

4.2 ENERGY: TYPES, FORMS AND QUALITY

Energy is defined as "the ability to do work" or to transfer heat. The word "work" has a very specific meaning. Work is done on a body when the body is forced to move. For example, suppose you are holding a stone in your hand that requires an application of force, but this is not work because the stone is not being moved. Lifting a stone or throwing a stone, however, is work. Similarly, climbing a mountain, running a car, stretching a spring, circulation of blood, transmission of nerve impulse, etc., is work, because all these activities force something to move.

Energy exists in two general states, **Potential** and **Kinetic.** Potential energy is the energy that is stored, or inactive, or at rest. It has the potential to perform work, if allowed. For example, a stick of dynamite; sugars or fats in your body; a car with petrol filled tank ……… all represents a great deal of potential energy but doing no work, unless oxidized or burned. Kinetic energy is the energy of motion and results in work, performed at the expense of potential energy. The meaning of two types of energy can be understood from Hle following example.

A large stone resting on top of a hill has potential energy in it but is doing no work. If it is given a slight push, it will tumble down, doing work by hitting other objects during its decent …… i.e. potential energy is released as kinetic energy. But the time the stone has reached bottom of the hill, all its potential energy (in relation to the hill) has been exhausted. For the stone to get back at the top of the hill, its potential energy must be restored. This can happen only if an input of energy comes from outside agent (such as someone pushing the stone back to the top of the hill).

There are several forms of energy. For example, **Chemical** energy can put atoms together to form compounds or breakdown compounds to form individual atoms; **Mechanical** energy can move objects; **Light** energy can boost electron to outer shell; **Thermal or Heat** energy can increase the motion of molecules; **Atomic** energy is the energy originating within atoms. Atomic energy may be released spontaneously by radioactive atoms. Like other forms of energy, atomic or nuclear energy can be stored or released.

Ans: 132 million square kilometers (about 29% of the total earth's surface).

All these different forms of energy are inter-related and inter-convertible. For example, electrical energy is converted to mechanical energy when we plug in a clock or turn on a juicer; chemical energy is converted to heat and light energy when kerosene oil is burned in an oil heater; atomic energy can be converted to electrical energy, and so on. Living forms are also capable of energy conversion. For example, green plants perform photosynthesis, a process by which solar energy (kinetic form) is converted to chemical (potential form) energy that is stored in organic molecules, such as glucose, starch or cellulose. Thus if you eat an apple and walk to the school, the chemical energy (stored in apple in the form of carbohydrates and proteins) is converted into mechanical energy (that mobilize 'your limbs).

The conversion of one form of energy into another goes on continuously in our biosphere. It is the basis upon which all organisms maintain their life. Life on earth is thus possible only because of a continuous flow of energy that arrives from the sun daily. At the same time, large amount of heat lea\:le the earth daily and is dumped in outer space.

Energy varies in its quality and ability to do useful work. Energy quality is a measure of energy usefulness. High quality energy is organised or concentrated and has great ability to perform useful work. Examples of these useful forms of energy are electricity, coal, petrol, concentrated sunlight and heat concentrated in fairly small sample of matter so that its temperature is high.

By contrast, low quality energy is disorganised or dispersed and has little ability to do useful work (Fig. 4.1).

As an example, heat is dispersed in the moving molecules of a large amount of matter (say air or ocean) so that its temperature is low. Thus even though the total amount of heat (low quality energy) stored in Atlantic ocean is greater than the amount of high quality energy stored in all the oil deposits of Saudi Arabia, the ocean heat is so widely dispersed that it can not be used to move things or heat things at high temperature.

Q. What are the major uses of world's land surface?

Sources of Energy	Relative Energy	Energy tasks
Electricity; High temperature heat greater than 2500° C; nuclear fission; high velocity wind; concentrated sunlight	Very High	For industrial processes and producing electricity
High temperature heat (1000 - 2500° C); hydrogen gas; petrol; diesel; coal; food .	High	Mechanical motion; high temperature heat (1000 - 2500° C) for industrial processes and electricity
Normal sunlight; moderate velocity wind; high velocity water flow; geothermal energy; moderate heat 100 - 1000° C; wood and crop wastes.	Moderate	Moderate temperature heat (100 - 1000° C) for industrial processes; cooking; producing steam, electricity and hot water
Dispersed low temperature (100° c or lower)	Low	Low temperature heat (100° C or less) for space heating

Fig. 4.1 Categories of the quality (usefulness for performing various energy tasks) of different sources of energy.

Heat refers to the total kinetic energy of all the randomly moving atoms, ions or [TIolecules within a given substance excluding the overall motion of the whole object. Temperature is a measure of the average speed of motion of the atoms, ions or molecules in a sample of matter at a given moment.

A substance can have a high heat content (much mass and many moving atoms, ions or molecules) but a low temperature. for example, the total heat content of a lake is enormous, but its average temperature is very low. Other sample of matter can have a low heat content and a high temperature, for example, a cup of hot tea has much lower heat content (compared to lake) but it has a much higher temperature.

Ans: 11% cropland; pasture 26%; forests 32%; and others 31%.

4.3 LAWS OF THERMODYNAMICS

The behaviour of energy is governed by the following laws. The First law **of Thermodynamics** (also referred as the Law of Conservation of Energy) states that energy is neither created nor destroyed. It may change form, pass from one place to another, or act upon matter in various ways, but regardless of what transfers or transformation takes place, no gain or loss in total energy occurs.

> *The total amount of energy in universe remains constant. More energy cannot be created.. And existing energy cannot be destroyed.. It can only undergo conversion from one form to another.*

Energy is simply transferred from one place to another. For example. when wood is burned, the potential energy present in the molecules of the wood equals to tlie kinetic energy released and heat which spreads out in ttle atmosphere. This is an **exothermic** reaction.

Potential Energy = Kinetic Energy + Heat

On the other hand, energy from the surrounding may be paid into reaction. Here too, the first law holds true. For example, in photosynthesis, the molecules of the product store more energy than the reactants. The extra energy is acquired from the sunlight but again there is no loss or gain in total energy. When energy is put into a system from' surrounding to raise it to higher energy state, the reaction is said to be **endothermic.**

The **Second Law of Thermodynamics** states that whenE!ver energy is transformed from one form to another, there is always decrease in the amount of useful energy as some en~rgy is degraded into heat and is dissipated to the atmosphere and finally to the outer space. **In** other words, according to this law, the 'more energy we use, the more disordered low grade energy (i.e. heat) we add to this environment..

Q. What metals are consumed in greatest quantity in world industry?

Consider following example of the second energy law to action. First when a car is driven, only about 10% of high quality chemical energy available in its petrol is converted into mechanical energy (which propels the car). The remaining 90% is degraded to low quality heat which escapes from general body suriace of car and exhaust pipe into the environment and eventually lost to outer space.

Another example is that when coal is burned in a boiler to produce steam, some of the potential energy of coal creates steam that periorms work (e.g. engine moves) but most of the energy is dispersed as heat to the surrounding and is no longer useful and not transferable. This so called "unusable energy" has a special name ...... **"the entropy".**

> *The second law of Thermodynamics says that whenever energy is transformed from heat to work, some must always be wasted. Concentrated or high temperature, heat energy has the ability to do work (for example, if a lamp of coal is burned, the heat energy can be used to warm a room, but at the same time a large amount of low grade heat is dispersed to its surrounding which does not perform any work) it can be neither gathered up nor converted to any other form.*

4.4 THE CONCEPT OF ENTROPY

As stated earlier, whenever energy is exchanged, some usable energy is inevitably lost. **In** other words, the energy available to periorm additional work decreases. What happens to this additional energy? A significant portion is "wasted" by increasing the random movement of atoms arid molecules. The measure of this thermodynamic disorder, which is often a result of the release of low grade heat, is called Entropy.

Entropy can be illustrated from the following examples.

Ans: Iron (740), Aluminum (40), Manganese (22), Copper (8) and nickel (0.7) million metric tons.

For example, the chemical energy that goes into an automobile engine is more highly ordered energy than the mechanical and heat energy that comes out of it,

Another example should help clarify the concept of entropy. When we heat a bathtub full of water with an oil heater, we convert the chemical energy (stored in small volume of fuel) to heat energy and transfer it into a very large volume of water in the tub. The heat energy is now quite disorganized. It can not drive a turbine, it can not even heat a can of soup above the temperature of bath water itself. About all it can do is to raise the temperature of the air in bathroom by a few degrees. Nor is there any way to transfer this heat energy in bath water back into a more cpncentrated (ordered) form. For all purposes, this unusable energy called entropy. is lost forever.

Thus, according to the Second Law of Thermodynamics, the amount of energy is l.)navailable to do work is gradually increasing. The ultimate destination of the universe is therefore a state of maximum entropy. It is feared that when the entropy of universe will reach its maximum value, everything will be at the same temperature and there will be no way to convert heat energy into useful mechanical or any other form of energy .... all animals and plants will die (i.e. we might face "heat death"), but scientists say that we should not worry as it may nbt happen in near future ...... it will take several million years.

4.5 ENERGY SOURCE

All ecosystems are maintained by a continuos flow of energy which is unidirectional.. Again, a unidirectional flow of energy is possible only when there is a "energy source" and an energy "sink". For earth, the energy source is SUN, and the sink is OUTER SPACE.

Sun is the original source of energy on earth. According to an estimate, everyday, earth is bombarded by 10^{22} joules of solar radiation. This energy is equivalent to 100 million atomic bombs. The amount of solar radiations that reaches a place depends on the moisture, concentration of ozone layer, dust particles in air, altitude and location on the planet..

Q. What is meant by a resource?

Sun is the star round which earth revolves. It is 1382 thousand kilometers in diameter and lies at a distance of 14i3' million kms from the earth. It is composed of intensely hot gases, mainly hydrogen. The hydrogen is continuously changing some of its kind into helium arid thereby a huge amount of *energy is released in the form* of *solar radiations.*

The radiant energy from the sun travels through space in the form of. electromagnetic waves, consisting of 4% *ultraviolet radiations,* 44% *visible light, and* 52% *infrared radiations. The surface temperature of sun is 600(J'* C. *The temperature in the center or interior is around* 15 *million degree centigrade. The solar energy is produced by nuclear reactions that result in the conversion* of *hydrogen into helium, with a steady loss* of *sun's mass around* 4 *million tons per second.*

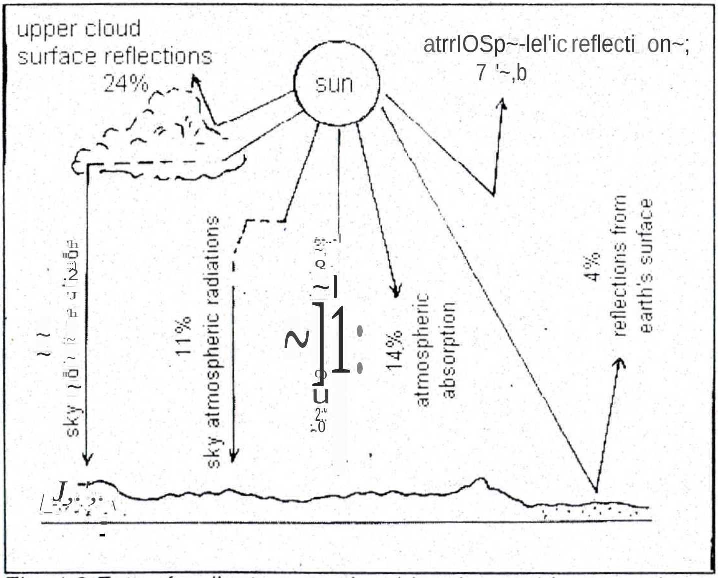

Fig. 4.2 Fate of radiant energy reaching the earth's atmosphere.

Ans: Anything we get from non-living or living environment to meet our needs and wants.

Of the total sunlight energy that is intercepted by earth's atmosphere, apparently 35% is reflected bacK into space (24% by clouds; 7% by dust particles in atmosphere; and 4% by reflecting surfaces of earth like snow, sand, etc.). Another 14% or so of the solar radiations never reaches to earth's surface as it is absorbed by the atmospheric gases (Fig. 4.2).

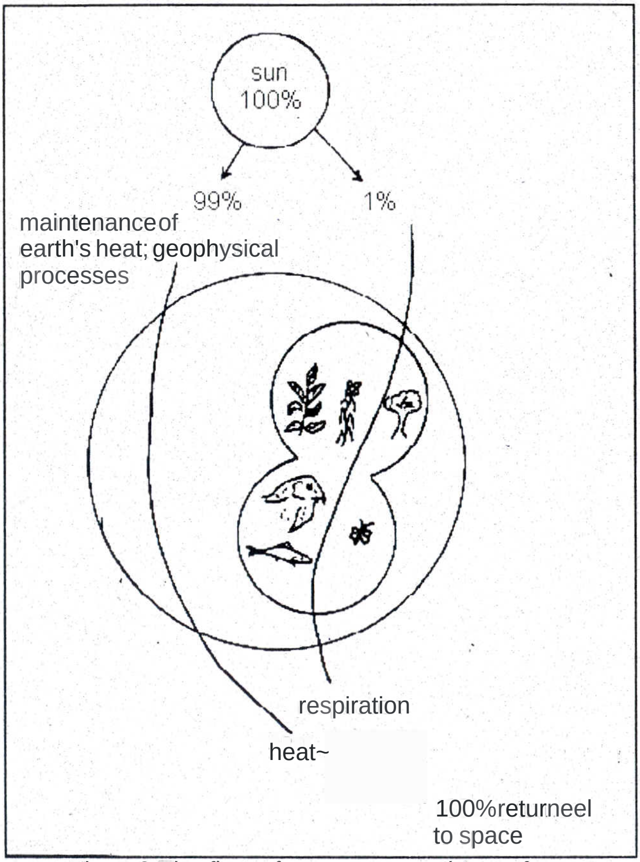

Fig. 4.3 The flow of energy on earth's surface. Approximately 1% of the incident energy is absorbed by plants, but only 0.3% of that radiation is converted to net productivity.

Q. What is geo-thermal energy?

Of the remaining 51%, about 26% comes directly to earth's surface while the rest (i.e. 25%) is first scattered by clouds, dust and so forth, but eventually this too is radiated to earth. The solar radiations that pass through the atmosphere and is absorbed at the earth's surface is spent in a variety of processes. 99% of solar radiations are consumed in melting of ice, evaporation of water, formation of clouds, flow of winds, generation of waves and currents. Thus, of the total solar radiations, only 1% is trapped by plants. It is interesting to note that out of the 1% of the incident energy that falls on plants, only 0.3% of solar energy is converted into organic food by photosynthetic process (Fig. 4.3). Although the fraction of the total incoming radiations which is ultimately trapped by plants, algae and phytoplankton is very small, the primary productivity on earth creates about 170 billion tons of organic matter per year.

4.6 ENERGY FLOW

The continuous flow of energy from the sun through organisms to outer space maintains the life on earth. The solar energy (radiant and kinetic) is converted to organic food (chemical and potential energy) by photosynthesis in plants. The photosynthesis formula (in its simplest form) is represented in Fig. 4.4.

Input → Photosynthesis (chlorophyll) Output →

$6CO_2$ + $12H_2O$ + solar energy → $C_6H_{12}O_6$ + $6O_2$ + $6H_2O$

carbondioxide water energy → sugar oxygen water

Fig. 4.4 Photosynthesis

Six carbondioxide and twelve water molecules are changed by means of sunlight and chlorophyll, into one sugar molecule (glucose) six oxygen molecules and six water molecules. The carbon formally present in the atmosphere is now part of the glu~ose. Compounds containing carbon are called "Organic compounds". All living organisms contain organic compounds in their cells, hence they are commonly spoken of as "organism$".

Ans: Energy derived from Earth's interior.

In the *above* reaction, the glucose is the organic molecule that is storing potential chemical energy in the plant cell. This simple monosaccharide sugar molecule (i.e. glucose) can *have* several destinations:

i. it can be stored as such in plant cell, or

ii. it can combine to other sugar molecules to form more complex sugars, such as sucrose (a dissacharide), or starch or cellulose (polysaccharides), or

iii. it can combine with other nutrients such as, nitrogen, sulphur, phosphorus, etc. to build more complex organic molecules like proteins, enzymes, hormones, pigments and so on.

iv. It may be oxidized to release ATP.

#All the *above* stated reactions are necessary for normal growth and maintenance of body tissues and functions of plants. All require energy which is provided by oxidation of some of the sugar molecules produced by photosynthesis to *give* CO_2, H_20, usable chemical energy ATP, and unusable energy in the form of low-grade heat.. As shown in Fig. 4.5, the oxidation of glucose or any other organic molecule to get usable energy is called Respiration. The reaction is as follows:

Input → **Respiration** → Output

$CSH_{12}0S$ (Sugar) + 60_2 (oxygen) → ~6ATP (high chemical energy) + $.6C0_2$ (carbondioxide) + $6H_20$ (water) + Heat (low quality energy)

Fig. 4.4 Respiration

As shown in *above* equation, the oxidation of organic molecule results in the production of usable energy (ATP) and release of heat (the unusable energy) which is lost permanently to the outer space. The carbondioxide and water are produced as bye-products.

Q. What is a land fill?

ATP (Adenosine triphosphate) is one of the most important compound found in all living organisms. ATP is a neucleotide, made up of sugar (ribose), a nitrogenous base (adenine), and three phosphate groups linked to one another. ATP is the molecule in which all cells temporarily store the chemical energy used to run various cell's activities. These small usable amounts of energy are stored in a form that is instantly accessible as the energy is needed.

For this reason, ATP is often said to be "the energy currency" or "biological currency" of the cell. ATP is spent on various energy requiring tasks, such as, i) the assembly of macromolecules, ii) the contraction of muscles, iii) build up of ions on the opposite sides of plasma membrane, and so on.

The energy embodied in an ATP molecule is not stored for long at all. Typically an ATP molecule is consumed in few seconds of its formation. ATP supplies, however, are continuously replenished. One ATP releases about 3 - 7 kcal per molecule.

As seen above, the primary producers (i.e. plants) trap radiant (kinetic energy) energy of sun and transfer that to chemical (potential) energy of organic compounds such as, carbohydrates, proteins and fats. When a herbivore animal eats a plant, these organic compounds are oxidized, the energy liberated is just equal to the amount of energy used in synthesizing the substances (this proves the First Law of Thermodynamics), but some of the energy is heat and not usable or usi3ful (this follows the Second Law of Thermodynamics). If this animal, in turn, is eaten by another one, a further decrease in the useful energy occurs as the second animal (or carnivore) oxidizes the organic substances of the first consumer (i.e. herbivore) to liberate energy to synthesize its own protoplasm.

Thus at each level in transfer of energy from one organism to another, a large part of energy is degraded in the form of heat.. Eventually all the energy trapped by plants in photosynthesis is converted to heat and dissipates to outer space (Fig. 4.3).

Ans: Where solid waste is dumped.

B6th the First and Second Laws of Thermodynamics are demonstrated in the one way flow of energy through the biosphere in Fig. 4.6. The First law insists that the total amount of energy in the universe remain constant while the Second Law insists that concentrated, usable energy must continually diminish.

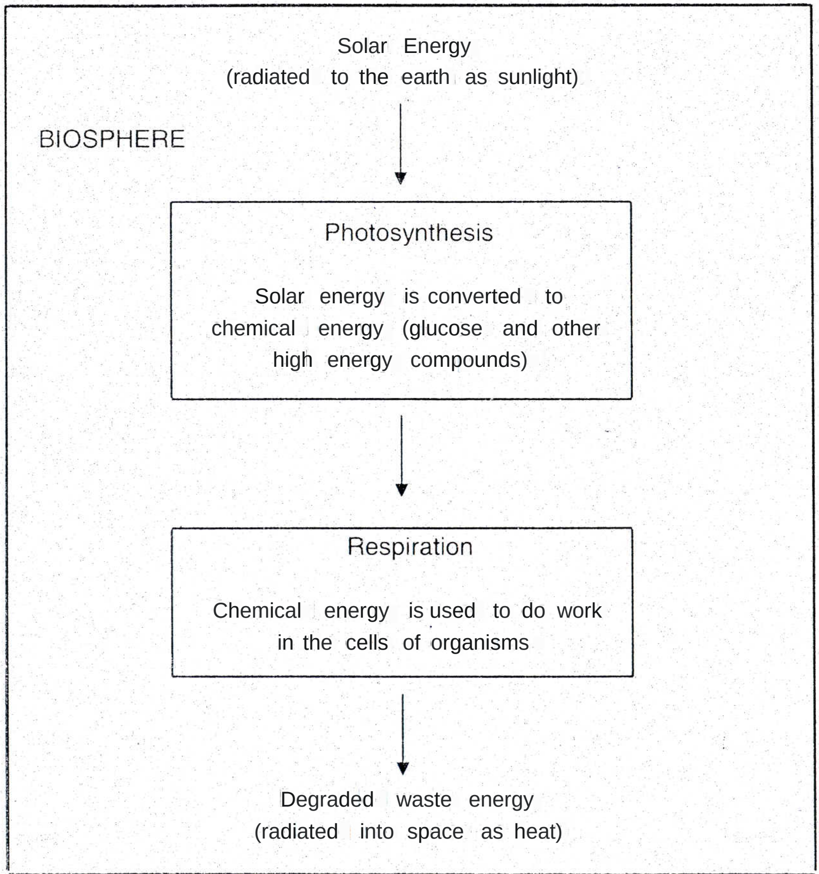

Fig. 4.6 Energy flow and transformation in the biosphere

Q. What is the effect of oil pollution in oceans on avian and mammalian fauna?

4.7 TROPHIC LEVEL

Ecologists assign every organism in an ecosystem to a trophic (feeding) level depending on whether it is a producer or a consumer and depending on what it eats or decomposes. For example, green plants utilize the solar energy to produce organic compounds. Thus green plants in the food chain occupy, the First trophic level, and are called Producers. Th'e plants (whether dead or alive) are then consumed by herbivores which constitute, the Second trophic level and are termed as Primary consumers. Herbivores, in turn, are eaten by carnivores which constitutes, the Third trophic level and are known as Secondary consumers. These may again be eaten by still large carnivores that form the Fourth trophic level or Tertiary consumers. Some organisms (eg. bears, pigs, man) are omnivores i.e. eating the producers as well as the carnivores at their lower level in the food chain. A special class of consumers, "Detritivores" obtain energy and materials from detritus accumulated from all trophic levels (Fig. 4.7).

This classification of all living organisms of any ecosystem is one of their functions and not of species. SpeCies that are taxonomically different from each other may occupy the same trophic level as they all have one common function in the food chain. For example, *Typha* (a macrophyte), *Nostoc* (an alga), *Alfa a/fa* (a grass) and photosynthetic bacterium, although are much different taxonomically but all belong to the same trophic level (i.e. all are producers and occupy First trophic level) as all have a common function or role i.e. the fixation of solar energy into chemical form. Similarly a herbivore or primary consumer may belong to any taxa; it may be a worm, insect, fish, bird or mammal, etc.

Fig. 4.8 shows a simple linear feeding pathway. It begins with producer (plants), which provide food for a primary consumer (the moth), which is eaten by a secondary consumer (the frog), which is eaten by a tertiary consumer (the snake, and so on, until the final consumer dies and it is decomposed by decomposers. each step along a feeding pathway is called TROPHIC LEVEL (trophic = feeding).

Ans: As many as 2m birds & 0.1m mammals (like dolphin, whales, sea-lions, seals) die each year.

Autotrophs	Heterotrophs
Make their own organic matter from inorganic nutrients and an energy source	Must feed on organic matter for energy

Producers	Consumers	Detritus Feeders
Photosynthetic green plants; use chlorophyll to absorb light energy	Primary consumer: herbivores that feed exclusively on plants	Decomposers: fungi and bacteria that cause rotting
Photosynthetic bacteria; use purple pigment to absorb light energy	Omnivores: animals that feed on both animals and plants	Primary detritus feeders: organisms that directly feed on detritus
Chemosynthetic bacteria; use high energy inorganic chemical such as hydrogen sulphide	Secondary consumers: animals that feed on primary consumers	Secondary and higher orders of detritus feeders: organisms that feed on primary detritus feeders
	Higher orders of consumer / top carnivores that feed on other carnivores	
	Parasites: plants or animals that become associated with another plant or animal and feed on it over an extended period of time	

Fig. 4.7 A summary of how living organisms are ecologically categorized according to feeding attributes

Q. What is the commercial importance of a forest?

Tropical lev!?l	Functional role	Food cham
'l	Producers	Pl'~
~	Prirnar~" con:::urner	moth
;3	Secondary consurner	frog
4	T~r1iary consurner	snake
5	Quar1ernary consumer	hawk
6	Decornposer	bacteria & fungi

Fig, 4.8. A simplified feeding path. Energy and nutrients flow through the biotic community as food passes from tropic level to trophic level. Trophic level numbers indicate the order of flow.

The sequence of trophic level maps out the course of energy and nutrient (food) flow between functional group of organisms (producers, primary consumers, secondary consumers and so on),

As illustrated in Fig, 4,9, trophic levels are numbered consecutively to indicate the order of energy flow, Trophic level 1 is always populated by producers and Trophic level 2 is always populated by primary consumers, Level of consumers beyond the primary consumer are then numbered sequentially. The final carnivore or the so called "top carnivore" eventually dies and is decomposed by bacteria and fungi.

Thus, a trophic level can be defined as the number of links by which it is separated from the producers, Organisms can be regarded as belonging to the same trophic level when they are separated from the primary producers in a food chain by the same number of steps. Some animals may appear on several trophic levels. This is typically true for omnivores which feed on different prey.

Ans: Forests provide timber, firewood, pulp for paper, medicines, etc. worth $ 3 billion each year.

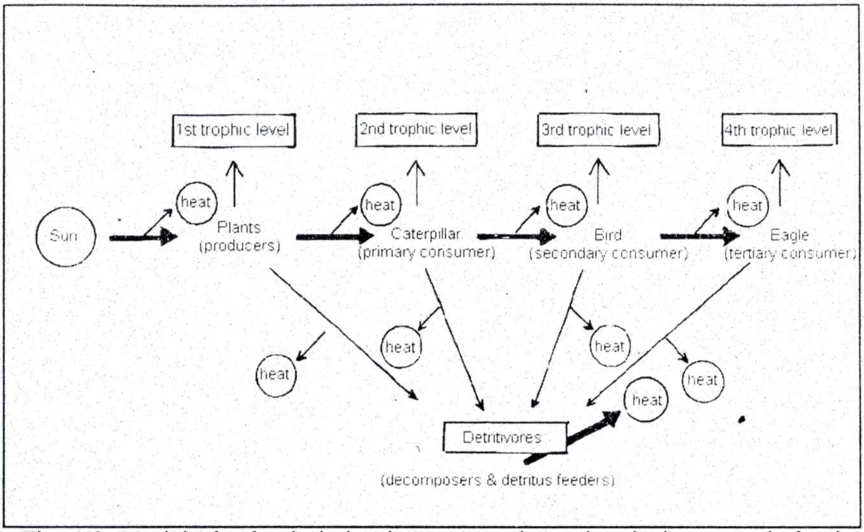

Fig. 4.9. Model of a food chain; the arrows show chemical energy in food flows through various trophic levels or energy transfers, most of the energy is degraded to low quality heat in accordance with the Second Law of Thermodynamics. Food chains rarely have more than 4 trophic levels.

For example, in a forest ecosystem, the bear (an omnivore) may feed directly on fruits (which being producers occupy First trophical level) ...... or it may prey upon rabbit (which being a herbivore occupy Second trophic level) ...... or it may hunt a fox (which occupies Third trophic level) ...... or it may lurk near the edge of a stream and consume a game fish (which being a tertiary consumer, occupies Forth trophic level).

The bear, thus, occupy Second trophic level in the first instance, Third trophic level in the second instance, and so on.

Q. Describe the First Law of Thermodynamics.

4.8 FOOD CHAIN

In an ecosystem, the flow of food energy progresses through a food chain in which one step follows another. Following are some of the examples:

a. In a grassland ecosystem (Fig. 4.10), the plant (i.e. producer) is eaten by locust (a primary consumer). The locust is eaten by a mouse (i.e. a secondary consumer). This, in turn, may be fed upon by a snake (i.e. tertiary consumer). The snake may be eaten by a still larger or top carnivore, the hawk (i.e. quaternary consumer).

b. In a pond ecosystem, unicellular algae and plants (i.e. producers) are eaten by zooplankton, insects, molluscs, herbivores fish, etc. (the primary consumers). These herbivores, in turn, are consumed by large predaceous insects, frogs, carnivores fishes, etc. (the secondary consumers). These may then be ea(en by secondary carnivores, such as, game fish, otters, fish eating birds (i.e. tertiary consumers).

c. In a typical forest ecosystem, trees and shrubs are eaten by herbivores like fruit eating birds, caterpillars, insects, deers, elephants, giraffe, etc. -These, in turn, may be eaten by carnivores like wolves, hyenas, lions, tigers, etc.

Thus, as is clear from the above example, the transfer of food energy from the producers through a series of organisms (producers ... herbivores ... carnivores ... decomposers) with repeated eating and being eaten is known as Food Chain.

Basically two types of food c,hains are recognized. 1. Grazing or Predator food chain, 2. Detritus food chain. The first begins with living plants which are eaten by herbivores, and the second one begins with dead plants and animals which are consumed by detritivores.

Ans: Energy can neither be created nor destroyed; it may change form or move from one place to another.

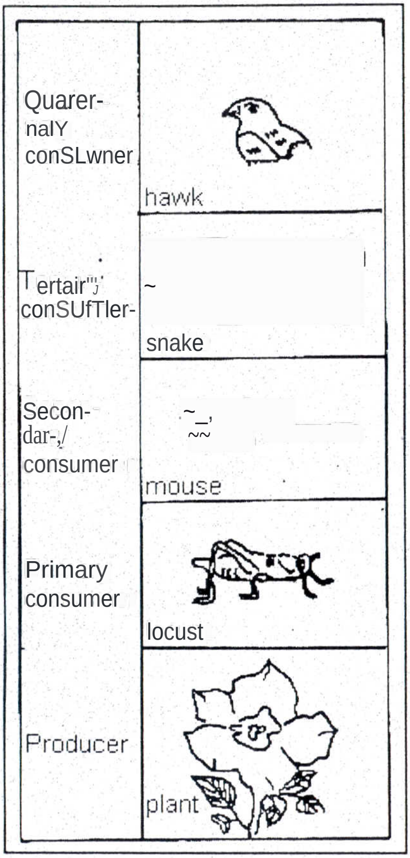

Fig. 4.10 A simplified food chain in a grassland ecosystem

I. GRAZING OR PREDATOR FOOD CHAIN

This type of food chain starts from living green plants that are grazed or preyed upon by herbivores (hence the name "grazing" or "predator" food chain). The energy flow can be described as follows:

Q. Describe the Second Law of Thermodynamics.

Autotrophs	Producers	Grass
~	~	~
Herbivores	Primary consumers	Locust
~	~	~
Primary carnivores	Secondary consumers	Shrew
~	~	~
Secondary carnivores	Tertiary consumers	Snake
~	~	~
Tertiary carnivores	Quaternary consumers	Hawk
~		~
Decomposers		Bacteria, fungi

Ecosystems with such type of food chains are directly dependent on solar radiation energy. Most ecosystems in nature follow this type of food chain.

A special, but common, variation of the above-mentioned food chains includes PARASITE FOOD CHAIN. From the energy point of view, there is no difference between predator and parasite food chains, since both parasites and predators are primary consumers. A distribution, however, can be made between the two on following points.

A typical predator food chain is as under:

mango tree → aphids → ladybirds → spiders → small insectivore birds → hawks

Examples of parasite food chain are as follows:

1	Vegetable	→	nematodes	→	bacteria
2	Cow	→	fleas	→	*Leptomonas*

Ans: Whenever energy is transferred from heat to work, some must always be wasted.

From the above examples, it may be seen that,

a. In predator food chain, generally, larger organisms consume smaller ones with outright killing whereas in parasite food chain, mostly the smaller organisms consume large one without outright killing.

b. Predator food chains are relatively longer (in our example, there are fiye transfers) than parasitic food chain which involves few transfers.

c. In parasitic food chain, the members starting with host become progressively smaller in size and more numerous with each level in the food chain. As can be seen in example (1) the roots of vegetation crops are parasitized by hundreds of nematodes which, in turn, may be attacked by millions of bacteria or as in example (2) a single mifmmal acts as a host to hundreds of fleas. Each flea, in turn, harbors thousands of flagellated protozoans belonging to the genus *Leptomonas.* In predator food chain, on the other hand, individuals become .progressively larger in size and less in number. In our example, hawks are lesser in number and bigger in size than insectivore birds; birds are less in number a[ld larger in size than spiders and so on.

II. DETRITUS OR SAPROPHYTIC FOOD CHAIN

This type of food chain in contrast to grazing type, starts from dead organic matter into microorganisms and then to organisms feeding on detritus and other predators, as shown below:

In a pond ecosystem, for example, the detritus food chain follows this path,

detritus → detritivores → small fish → carnivore

In a forest ecosystem, for example, the detritus food chain is shorter,

detritus → soil bacteria → earthworms

Q. What is mutualism?

The term "detritus" refers to the particulate dead organic matter (i.e. when a plant or animal is dead, it decays and disintegrates into small fragments or bits). The decomposition is carried out by bacteria and fungi. The particles of dead organic matter are called detritus, and the organisms feeding on it are referred to as **detritivores.**

The difference in "grazing" and "detritus" food chains, therefore, is that in the former, the source of energy is sunlight from sun while in the latter, the source of energy is dead organic matter. The detritus food chain account for more energy flow,than the grazing type of food chain because more organisms die without being eaten.

In the deeper zones of lakes, abyssal regions of oceans, and caves where green plants are absent due to the absence of sunlight, the food chains are entirely based on detritivores.

Decayed or disintegrated fragments of dead animals, dead plant material such as, fallen leaves, trunk of dead trees. dead grass, fecal waste is *called Detritus.*

Many organisms are specialized to feed on detritus and we call such consumers as *Detritivores. Examples include earthworms, millipedes, termites, ants, wood beetles, slugs. nematodes, etc (in* a *typical terrestrial ecosystem) while animals like crabs, shrimps, molluscs, worms, some fishes, etc. act* as *detritivores (in* a *typical aquatic ecosystem).*

The detritivores may be classified as *Primary detritus feeders (those that feed directly on detritus) and Secondary detritus feeders (those that feed on Primary detritus feeders). An extremely important group of primary detritus feeders in Decomposers, viz. bacteria and fungi. Much of the detritus in an ecosystem, particularly dead leaves and logs* of *dead trees does not appear to be eaten* as *such but rot away. Rotting is the result of the metabolic activity of fungi and bacteria. Even though fungi and bacteria are called decomposers because of their unique behaviour, we group them with detritus feeders because their function in the ecosystem* is *the same. In turn, decomposers are fed upon by such secondary detritus feeders* as *protozoans, worms, mites, etc. When fungus .or other decomposer dies, its body becomes part of the detritus.*

Ans: It is a relationship that is favourable and necessary for both species.

4.9 FOOD WEB

In nature simple food chain occurs 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 high trophic level or an organism may feed upon several different kind of organism of a lower trophic level. Again, the kind of food changes with the age of organism, availability of food and season. Thus, in a given ecosystem, various food chains are linked together, and intersect with each other to form a complex network called **Food** Web.

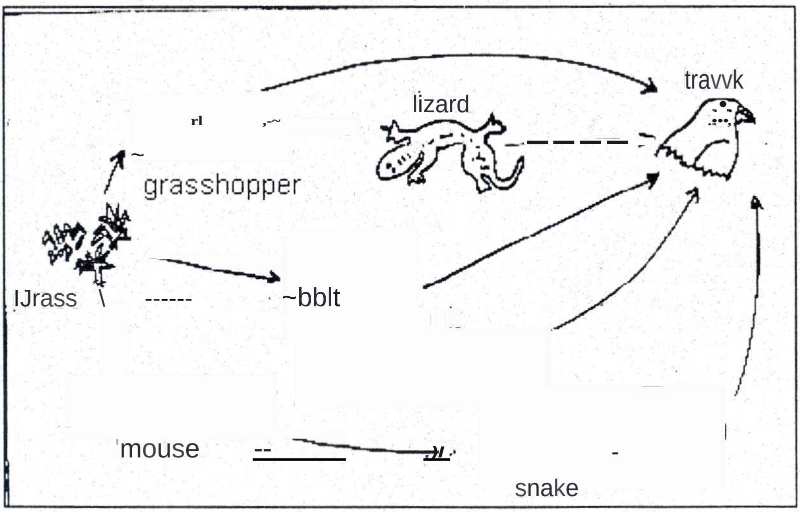

Fig. 4.11: Food web in a grassland ecosystem.

In a grassland ecosystem (Fig. 4.11), for example, the grass is eaten by a grasshopper, the grasshopper is consumed by the lizard, the lizard by the hawk. Thus, we have a relationship that can be written as follows:

Grass → Grasshopper → Lizard → Hawk

Q. What is predation?

But as the diagram indicates, no one organism livEiwholly on another, the resources are shared, especially at the beginning of the food chain. The grass is eaten by a variety of animals (such as, grasshopper, mouse, rabbit, etc) and some of the animals are consumed by several predators. Thus, in the absence of grasshopper, the grass may be eaten by rabbit. The rabbit, in turn, may be eaten directly by hawk or by snake first which is eaten by hawk. In nature, therefore, are found many alternatives, which all together constitute some sort of interlocking pattern, the Food Web.

In our example, there may be seen as many as *five* different linear food chains, which in sequence are:

i.	grass	-7 grasshopper	-7 hawk	
ii.	grass	-7 grasshopper	-7 lizard	-7 hawk
iii.	grass	-7 rabbit	-7 hawk	
iv.	grass	-7 mouse	-7 snake	-7 hawk
v.	grass	-7 mouse	-7 hawk	

Beside these shown in Fig. 4.11, there may also be present some other consumers like sheep, cattles, chickens, vultures, foxes, *wolves,* dogs, cats or *even* man in grasslands and if so, the food web may be *even* more complex than shown here.

In another example, Fig. 4.12, different parts of a single shrub provide energy and nutrients for at least *five* independent food chains. A food web illustrates all possible transfers of energy and nutrients among the organisms in an ecosystem, where a food chain traces only one pathway in the food web.

Food webs may intersect within ecosystems. For example, in a grassland, energy and nutrients may flow betwee~ a grazing food web and a detritus food web. In the grazing food web, living tissues of photosynthetic grasses are consumed by a *var!lety* of herbivores, which may then be eaten by a variety of carnivores. But not all plants, or all herbivores or carnivores are eaten, so when these organisms *have* natural death, their bodies enter the detritus web. Even before they die, arimals excrete organic waste that also enters the detritus web, where earthworms, insects, millipedes, fungi and bacteria eventually breakdown organic matter to simple inorganic molecules.

Ans: It is an interaction in which certain individuals eat others.

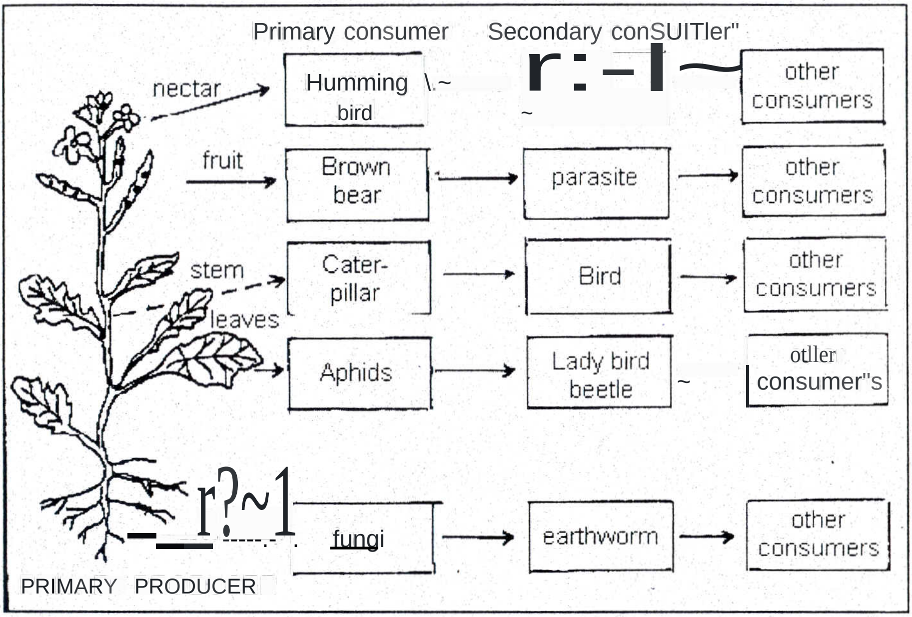

Fig. 4.12: The primary producer for many food chains, including the five drawn here

The food webs are very important in maintaining the stability of an ecosystem. In nature, for example, in a grassland ecosystem, the decrease in the population of rabbit would naturally cause an increase in the population of an alternative herbivore, the mouse. This may decrease the population of the consumer (the carnivore) that prefers to eat rabbit. Thus alternatives or substitutes serve to maintain the stability of the ecosystem. A balanced ecosystem is essential for the survival of all living or9.anisms of the system. For instance, if primary consumers (i.e. grasshoppers, rabbits, mice, etc) had been in nature, the producers (i.e. the grasses) would have perished due to overcrowding and competition. Similarly, the survival of primary consumers is linked with secondary consumers and so on. Thus, each species of any ecosystem is indeed kept under some sort of check so that system may remain balanced.

Q. What is commensalism?

4.10 ECOLOGICAL EFFICIENCY

Ecological efficiency is the percentage of energy transferred from one trophic level to the next. Ecological efficiencies vary greatly among organisms, usually ranging from 5% to 20%. In other words, 80% - 95% of the energy avaiiable at one trophic level never transfers to the next.

The basic trend of energy flow declining significantly with each higher trophic level holds good for all ecosystems. Thus, not all of the chemical energy stored as biomass *by plants can be converted to the chemical energy of consumers. Much of the energy is lost from the ecosystem* as *heat.*

Less *energy is found at each succeeding trophic level for the following reasons:*

i. *Of the food available, only a certain amount is captured and eaten by the next trophic level. After all prey are adapted in many ways escaping their predators*

ii. *Some of the food that* is *eaten cannot be digested. and exits thtJ digestive tracts* as *waste or fecal matter, and*

iii. *Only a portion of the food that* is *digested becomes the part of organism's' body. The rest* is *used* as *a source qf energy, which eventually* escapes as *heat. It* is *generally stated that only about 10% of the energy available at a particular trophic level* is *incorporated. in the* tissues *of the next level.*

Ans: It is a relationship in which one species benefits from an unaffected host.

For example, say green plants (e.g. grasses) during photosynthesis absorb 10,000 units of energy. Of this, only 1000 units of energy is transformed into organic food; most of it goes into heat.

When a cow eats the grass, a great deal of the bulk consumed does not contribute to the nourishment of the cow. Much of it is indigestible and returned back to the environment in the form of feces, in addition, the cow must move, reproduce, and carryon a great many other energy consuming ,activities. This means that much of the energy value of carbohydrates contained in the grass must go to support such functions. Only a small amount of about 100 units is stored in the animal tissue. In turn, when the cow is eaten by a lion, only 10 units will be available for the carnivore production. Thus, at each step, the organisms are able to use only 10% of the total energy available from the preceding level. This is called **Ten Percent** Law. The ten-percent law places the limit on the number of trophic levels in the food chain. This limit is reached when organisms can no longer obtain enough energy to keep themselves alive and reproduce. This is why most food chains have only 4 or 5 trophic levels.

4.11 ECOLOGICAL PYRAMIDS

In the successive steps of food chain i.e. autotrophs ...... heterotrophs (herbivore) ...... heterotrophs (carnivore) ...... decomposers, the number and biomass of the organisms in each step is limited by the amount of energy available. As described earlier, at each step up in the food chain, the organisms are able to use only 10% (in general) of the total energy available form the preceding level (as 90% of energy is lost as heat).

Thus, in each transformation, the step becomes progressively smaller near the top. This relationship is called Ecological Pyramid (the dictionary meaning of "pyramid" is any structure with a square base and triangular sloping sides at the apex or top).

The ecological pyramids are only graphic representations of the trophic structure and functions of the ecosystems. In many ecological pyramids, the base of pyramids, represents the producer trophic level; the apex represents tertiary or some high level corisumer, and the other consumer trophic levels are in between. Ecological pyramids may be of three different types:

Q. What is competition?

i. **Pyramid of Number:** this shows the number of individuals at each trophic level.

ii. **Pyramid of Biomass:** shows the total dry weight of the total amount of living matter present at anyone time or caloric value. To calculate the biomass of each trophic level, first an average weight of the organism at each level is determined and then the number of organisms at each level is estimated. Now, multiplying the average weight by average number gives the approximate biomass for each trophic level.

iii. **Pyramid of Energy:** shows the rate of energy flow productivity at successive trophic level. A pyramid of energy must be based on determination of the actual amount of energy that individuals take in, how much they burn up during metabolism, how much remains in their waste products and how much they store in their body tissues.

The pyramids of number and biomass may be "upright" or "inverted" depending on the nature of fodd chain in the particular ecosystem, whereas pyramids of energy are always "upright".

I. PYRAMID OF NUMBERS

They show the relationship between producers, herbivores and carnivores at successive levels in 't,erm of their numbers. The pyramids of numbers in three different kinds of ecosystems are shown in Fig. 4.13.

In a grassland ecosystem (Fig. 4.13 a), the, producers (mainly grasses and ~mall shrubs) are always maximum in number. This number then shows as gradual decrease towards apex, as the primary consumers (such as, insects, rabbits, mice, ungulates, Gtc) are lesser in number than the grasses and shrubs; the secondary consumers (such as, lizards, snakes, cats, foxes) are lesser in number than the mice, rabbits and insects. Finally the top carnivores or tertiary consumers (such as hawks and other predators) are least in number, Thus, the pyramid becomes "upright".

Ans: It is an interaction in which two or more individuals try to gain control of the same resources.

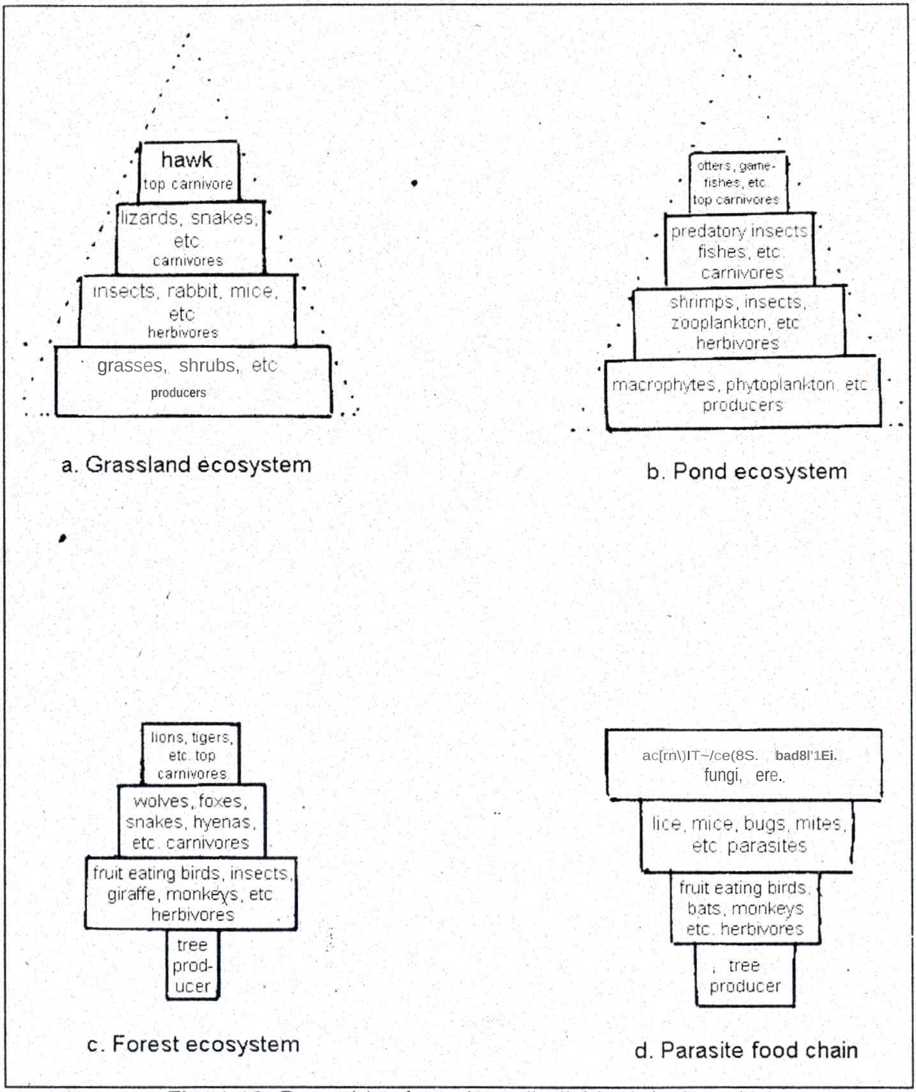

Fig. 4.13: Pyramids of numbers (individuals/unit are).

Q. What is biome?

Similarly in a pond ecosystem, the pyramid is "upright". (Fig. 4.13 b). Here the producers (mainly macrophytes, algae and phytoplankton) are maximum in number; the herbivores (consisting of insects, molluscs, zooplankton, herbivorous fish, etc) are lesser in number than producers; and the secondary consumers (like predaceous insects, small carnivorous fishes, etc) are lesser in number than herbivores. Finally, the top carnivores (like big game fish, otters, fish-eating birds) are least in number.

In a forest ecosystem, however, the pyramid of number is somewhat different in shape (Fig. 4.13 c). The producers (mainly large size trees and shrubs) are lesser in number and form a shortened base of pyramid. This is due to the fact, that a single large tree harbours many kind of insects, fruit eating birds, bats, squirrels, etc. and furthermore, it is browsed upon by a number of large herbivores like giraffes, elephants, deers, zebras, rhinoceros, etc. Thus, the herbivores are much larger in number as compared to the producers (i.e. trees and shrubs). Then, there is again a gradual decrease 1n the numbers of successive primary and secondary carnivores, thus making the pyramid upright again.

In parasitic chain, however, the pyramids are always inverted. This is because of the fact that a single large tree supports hundreds of herbivores (Fig. 4.13 d). Each herbivore, in turn, harbours thousands of ecto and endo parasites (e.g. lice, bug, mites, worms, etc .). Each ectoparasite supports million of bacteria, fungi and \3.ctinomycetes. Thus, from producers towards consumers there is a reverse position i.e. the number of organisms show a gradual increase, making the pyramid inverted in shape.

Actually the pyramids of number do not give true picture of the food chain as they are not functional. . They give equal importance to all individuals irrespective of size and weight.. For example, one elephant would be counted as a single herbivore as would a single insect ...... even though an elephant eats far more than the insect ever would. Hence this method of representatiqn is rarely used, as data giving only number present in an ecosystem has little value.

Ans: A group of ecosystems characterized by similar vegetation and climate.

II. PYRAMID OF BIOMASS

Biomass is defined as the total quantity of living material, expressed in dry weight, present at a given time for a particular area. Pyramids of biomass are comparatively more functional as they, instead of geometric factor, show quantitative relationship of the standing crop. The pyramids of biomass in different types of ecosystems are shown in Fig. 4.14 a - d).

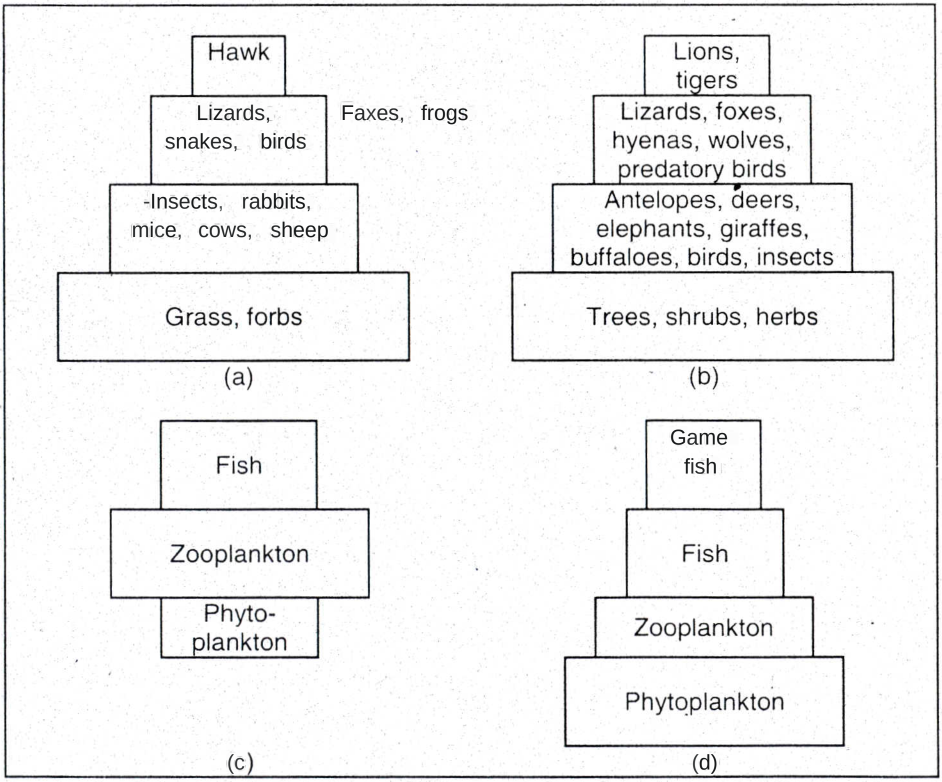

Fig. 4.14 (a - d). Pyramids of Biomass (gms dry weight per unit area).

Q. How many species are there on earth?

In grasslands and ponds ecosystems (Fig. 414 a & b), the total biomass of the producers is more than the biomass of the primary consumers in ecosystem. Likewise, the total biomass of the primary carnivores (or secondary consumers) will be less than the herbivores in each ecosystem. The top carnivores (i.e. tertiary consumers) are least in total weight, thus making pyramids upright.

In some aquatic ecosystems, however, the situation is different.. They may have primary consumers out-weighting producers. For example, in the waters of English Channel, the biomass of zooplankton is five times the weight of phytoplankton. Such situations occur because of the fact that the zooplankton consume the phytoplankton so quickly that the producers never develop a large population size or standing crop. Nevertheless, the productivity of phytoplankton is much higher than the zooplankton.

Similarly in an ocean where 'producers are microscopic phytoplankton and consumers range in size from zooplankton to fish to whales, the biomass of consumers may temporarily exceed that of primary producers if data is taken when the number of phytoplankton is low. During such sampling periods, the pyramid of biomass could look as shown in Fig. 4.14 c).

If samples are taken during the spring, however, when phytoplankton populations are immensely large, the pyramid of biomass assumes the upright shape (Fig. 4.14 d).

III. PYRAMID OF ENERGY

" Of the three types of ecological pyramids, the energy pyramids give the best picture of overall nature of ecosystem. Here, the number and weight of organisms at any level depends not on the amount- of 'ixed energy present at any one time in the level just below but rather on the rate at which food is produced. The pyramid of numbers and biomass show the picture of standing crop (i.e. the number or weight of organiSfJls present at any given time). Whereas, the pyramid of energy is a picture of rate pf passage of food mass through the food chain. Some organisms may have a smaller biomass, but the total energy they assimilate and pass on, may be cQnsiderably greater than that of organism~ with much larger biomass, for example, the phytoplankton.

Ans: 40-100 million (however, till to date, 1.75 million species have been identified and recorded .

In other words, the energy pyramids not only indicate the amount of energy flow at each level, but more important, the actual role of the various organisms played in the transfer of energy. **In** shape, the energy pyramid is always upright since as stated in Second Law of Thermodynamics, there is always a gradual decrease in the energy content at successive trophic levels fr0rt:l producers to higher trophic levels.

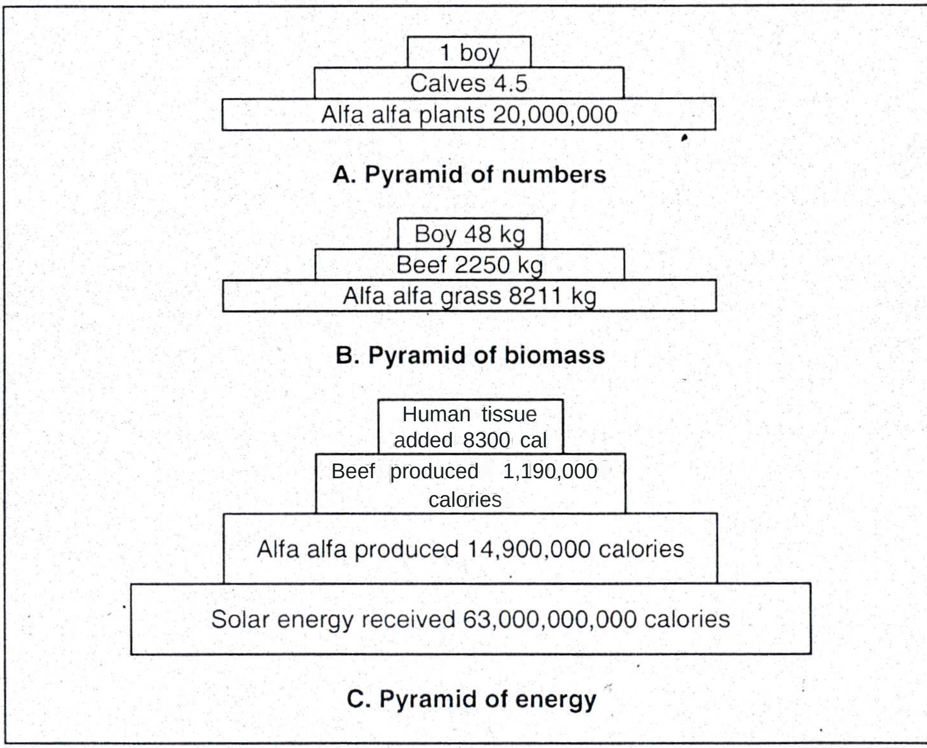

Fig. 4.15: Ecological pyramids of numbers (A), biomass (B) and energy (C), for a hypothetical ecosystem based on a field of alfa alfa grass eaten by five calves which are themselves eaten by a boy over a period of one year (modified after Odum, 1971).

Q. Upon what two processes does life on earth depend?

Fig. 4.15 a - c show hypothetical examples of three types of pyramids given by Odum (1971). **In** these examples, hypothetical food chains between *Alfa alfa* (a kind of grass), a calf, and a boy is computed, based on the assumption that ten acres of *Alfa alfa* was grown for one year. The *Alfa alfa* grass is the only diet for calves which in turn, would provide beef for a 12 year boy acting as a secondary consumer.

The Fig. 4.15 a, the pyramid of number, shows that about 20 million alfa alfa plants are required to support 5 calves needed to feed a boy of 12 years age for one year.

The Fig. 4.15 b, the pyramid of biomass, shows that 8211 kg of total weight of alfa alfa grown in one year is converted to 1035 kg of beef. The 1035 kg of beef received as food by boy is only partially used to construct human tissues of about 48 kg in one year. .

From energy point of view, it may be seen from Fig. 4.15 c, that out of 63 billion unit (calories) of solar energy received from the sun, plants were able to fix only 14.9 million units in the form of potential energy. The calves, in turn, were able to assimilate only 1.1 million units of energy from plants. The human tissues added to boy is about 0.0083 million calGries. Thus, each successive link from plant to calf and from calf to boy represents progressively less of the system's total energy. In the above example, a very small fraction of total solar energy was made available to the boy in one year.

This is clearly a hypothetical model, since in nature, neither calves subsist entirely on Alfa alfa grass, nor the boy (who is an omnivore) subsist on beef. This hypothetical example merely serves as an illustration of energy flow in an ecosystem.

The energy flow pyramids explain why a larger population of people can be supported if people eat at lower trophic levels by consuming grains directly (for example, rice or wheat) rather than eating meat of those animals that feed on grains and grasses.

Ans: Flow of energy and cycling of nutrients.

Why meat is luxury for humans?

The dynamics of energy flow apply to the human population as much as to other organisms. Like other consumers, we depend entirely on plants for our food. As omnivore, we eat both plant material and meat. When we eat cereals, fruits or grains, we are primary consumers, when we eat meat of some herbivore animals, we are secondary consumers, when we eat fish, say trout (which eat small insects) we are tertiary or quaternary consumers.

The energy pyramid (Fig. 4.16 A) indicates energy flow from primary producers to humans as vegetarians (herbivores). The energy in the producer trophic level comes from soybean and corn crop. The pyramid on right illustrates energy flow from the same corn crops, with humans as secondary consumers, eating beef of cow. These pyramids are generalized models, based on the rough estimates that about 10% of the energy available in a trophic level appears at the next higher trophic level. Thus, the pyramids indicate that the human pbpulation has about ten times more energy available to it when people eat grain than when they process the same amount of grain through another trophic level and eat grain-fed beef. Put it another way, the pyramids indicate that it takes about ten times more energy to feed the human population when we eat meat than we eat plants directly.

Eating meat of any kind is an expensive luxury, both economically and environmentally. In many countries peoples can not afford to buy much meat or their country can not afford to produce it, and people are vegetarian by necessity. If meat is eaten, it means to grow more grain for cattles, you require more land for cultivation; more water for irrigation; more fertilizers and more pesticides. As human population is increasing exponentially, meat consumption will become even more of a luxury in future, than it is today.

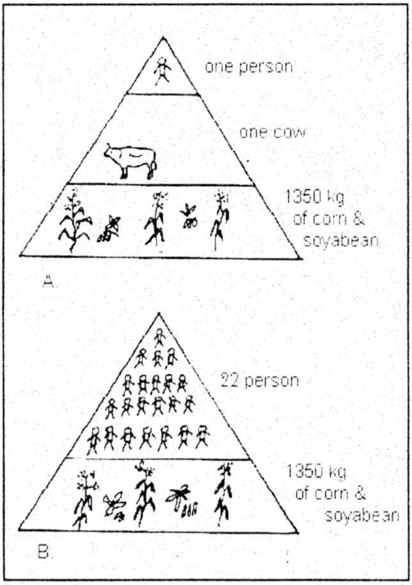

Fig. 4.16: The relative efficiencies of vegetarian and carnivores diets for human beings (A) In a vegetarian diet, 1350 kg of plant matter can support 22 peoples for the same length of time (B) 1350 kg of plant matter can support one person who eats only meat.

Q. What is recycling?

4.12 PRODUCTIVITY

The rate at which plants (i.e. producers) convert solar energy in organic food (i.e. chemical energy) by photosynthesis is known as **Primary Productivity.** It is usually expressed either in terms of energy stored (calories / per square meter / per year) or in terms of the mass of living material called biomass (grams / square meter / per year). The total amount of energy taken bythe producers is known as' **Gross Primary Productivity** (GPP). Only ab'out half of the gross primary productivity accumulates as new plant matter because the rest of it is metabolized in the plant's own respiration and released to the environment as heat. The material not used by plant in respiration is called its **Net Primary Productivity** (NPP). The net primary productivity appears as plant growth and is available for consumption by heterotrophs.

GPP = NPP + Respiration

Or

NPP = GPP - Respiration

1. The ra'te at which the plants fix solar energy in organic compounds is called Primary Productivity.

2. The Gross Primary Productivity is the total rate of photosynthesis for the ecosystem .

3. The Net Primary Productivity is the rate of energy stored in excess *bf* the rate of respiration during the measured time interval. OR NPP ~Sthe difference between the yield of photosynthesis and the consumption 'of organic fuel in respiration.

4. The rate at which the primary consumers convert the chemical energy of the plant food they eat into their own biomass is called Secondary Primary Productivity.

Ans: The process whereby waste materials are reused for the manufacture of new products.

The primary productivity of different ecosystems varies greatly depending upon the location of ecosystem, availability of sunlight and nutrients, temperature, photoperiod, rainfall, predation, etc.

Another variable affecting the net primary productivity is the age of ecosystem. For example, when a forest is young and trees are small, the annual primary productivity is high. The older and larger trees get, the more the energy captured by photosynthesis is channeled into maintaining the existing plant parts and thus little is left over for growth.

Some data from different ecosystems are presented in Table 4.1

Types of Ecosystems	Average Net Productivity (Kcal/m^2/year)
Estuaries	9000
Swamps and Marshes	9000
Tropical rain forests	9000
Temperate forest	6000
Coniferous forest	3600
Savanna	3000
Agricultural land	2800
Woodland	2600
Temperate grasslands	2000
Lakes and streams	2000
Continental shelves	1500
Tundra	500
Open ocean	400
Desert	200

Table 4.1 Estimated annual average net productivity of producers per unit area in principal types life-zones and ecosystems. Values are given in Kcal/m^2/year. The values are only approximations and are subject to marked fluctuations because of variations in temperature, fertility, rainfall and sunlight.

Q. What is aquifer?

Tropical rain forests are among the most productive terrestrial ecosystems, because photosynthesis proceeds more rapidly when sunlight and rainfall is abundant and temperatures are high. The coral reefs, estuaries, swamps and areas of ocean close to shores also have a high productivity, but their contribution to the global productivity is relatively small because these ecosystems are not extensive. Productivity in open oceans is low because the nutrients from the remains of animals and plants sink to the bottom where there is no light to support photosynthesis. However, its contribution towards global production is considerable because of its large size (covering vast area of earth's surface). In fre~hwater ecosystems, as in the open ocean, light intensity and its variation with depth appear to be important determinants of productivity. The availability of inorganic nutrients may also limit the production in freshwater ecosystems as it does in the ocean. Deserts and tundras have a very low productivity.

An estimated 59% *of earth's annual net primary productivity occurs on land, the remaining* 41% is *produced in oceans and other aquatic ecosystems. Estuaries, swamps, marshes and tropical forests are highly productive; open oceans, tu'ndras and deserts are the least productive.*

Most human food comes directly or indirectly from agriculture. As shown in Table 4.1, although agricultural land is capable of high productivity that exceeds those of many natural communities, the differences are somewhat illusionary. 'The input of energy in natural ecosystems comes almost directly from the sun that shines on them. Whereas, in agriculture, in order to get a high yield, there must not only an input of sunlight energy but also inputs of fertilizer, irrigation water, pesticides and mechanical energy is needed to plow the soil as well as to harvest the crop. The manufacture of fertilizer and pesticides, the pumping of irrigation water, the use of tractors and threshers, the transportation of products to market, processing and cooking of food ... all require input of fuel energy (either gas, petrol, coal, or electricity). It has been estimated that input of nine calories (in order to grow, process, marketing and cooking) are required to produce one calorie of food that is presented to you on your dining table.

Ans: An underground layer of rock that store significant amount of water.

It is tempting to conclude that we should clear tropical forests (as they have high productivity) to grow crops and that we should harvest plants growing in estuaries, swamps and marshes to help feed the growing human population ...... but it is wrong ...... one reason is that the plants, mostly grasses, in marshes, swamps and estuaries can not be eaten by humans and, on the other hand, they are extremely important for food resources of fish, shrimps and other forms of aquatic life that serve us and other consumers with proteins. So we should not harvest or destroy these plants.

In tropical forests, most 0f nutrients are stored in the trees and other vegetation rather than in the soil. When trees are cleared, the low levels of nutrients in the exposed soil are rapidly depleted by frequent rains and by growing crops. Thus the food crops require enormous expensive input of commercial fertilizer. So we should protect and not cut down the forests.

It has been estimated that 21×10^{20} kj of radiant energy enter 'the earth's atmosphere each year. This can be divided into 5.9×10^{20} kj falling on the land. and 15×10^{20} kj on the oceans. The annual net productivity of the whole earth is 170 billion metric tones of organic matter. Of this total, about 115 billion tones are produced on land and 55 billion tones is produced in the oceans. Of this total productivity, humans harvest only 1.2 billion tones per year as plant food.

These are enormous quantities, but for several reasons, they actually represent the use of a tiny fraction of the incoming solar radiations. First, much of the solar energy reaching the earth is reflected back at once into space. Only about 51% of the incoming solar radiations reach the earth's surface. Again, of the total radiations reaching the ground on a clear day only about 45% is visible light that can be used in photosynthesis. Furthermore, plants can only use a fraction of this available light. In general, the av.erage net productivity over the globe represents the use of only about 0.3% of the radiant energy reaching the earth's surface as visible light.

Secondary productivity is defined as the rate of formation of new organic matter by heterotrophs OR the rate at which an ecosystem's consumers convert the chemical energy of the plant food they eat into their own biomass.

Q. What is the greatest threat to wildlife?

Consider the transfer of organic matter from producers (i.e. plants) to herbivores (the primary cons·umers). In most ecosystems, the herbivores manage to eat only a small fraction of plant material produced, and, furthermore, they can not digest all the organic matter that they do ingest. For example, of the net primary productivity available, say in a forest ecosystem, herbivores (e.g. caterpillars, insects, deers, etc.) only eat about 1 to 3 percent. In other communities as much as 15% of vegetation may be eaten (an average figure is about 10% for both herbivores and carnivores ... see Section 4.10J.

Fig. 4.17 is a simplified diagram of how the energy a consumer obtains as food might be partitioned. In our example, say, a caterpillar consumes the leaves containing 200 joules of energy.

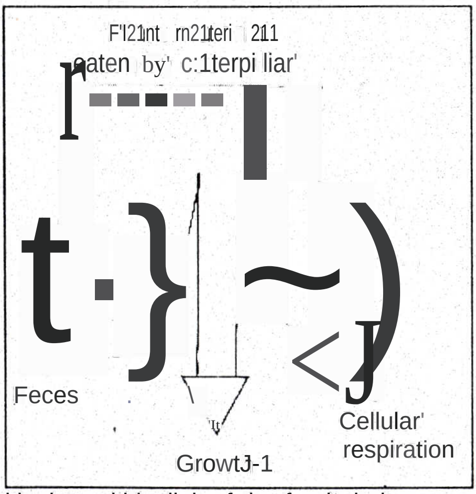

Fig. 4.17: Energy partitioning within link of the food chain; caterpillars digest and absorb only about half of what they eat, passing t~e rest as feces. Thus, if a caterpillar cons~med leaves containing 200 joules of energy, 100 joules would be lost in feces. Approximately 2/3 of absorbed food or 67 joules would be' used in maintenance, as fuel for cellular respiration, which degrades food molecules to inorganic waste products and heat. The remaining 33 joules would be converted into caterpil1ar biomass, and would therefore be available to the next trophic level.

Ans: Loss of habitats by human activities.

According to International System of Units, the unit of energy is joule (it is about the amount of work required to lift a 100 gm weight to a height of one meter).

The commonly used energy unit for heat is calorie (= 4.18 joules). One calories just enough energy to warm one gram of water by 1° C. The more common unit used in measuring food energy is the kilo-calorie (kcal), the quantity of heat required to heat 1000 gms of water to 1° C. Calorie spelled with capital letter "C" means kcal. If of)e says that an apple has 130 calories (written with small "c") ... it is wrong ... it shoulq say 130 Calories (with capital "C'? or written as 130 kcal.

.only about half of wh at eaten is actually digested and absorbed. The other half is not digested and passes as feces. Of course, the energy contained in feces is not lost from ecosystem, it can still be consumed by decomposers. Of the 50% food absorbed by the caterpillar, about 2/3 (i.e. 67 joules) is used in cellular respiration, so that only 15% (orenergy worth 33 Joules) of ingested food appears as secondary productivity. When a predator eats the caterpillar, the same process is continued and 10- 15 % of the total energy consumed (i.e. 3.3 joules to 5 joules) is converted to the biomass of predator.

The energy used for respiration is ultimately lost from the ecosystem as heat. Thus, while solar radiation is the ultimate source of energy for most ecosystems, respiratory heat loss is the ultimate sink. This is why energy is said to flow thrbugh, not cycle within, ecosystems.

Q. What life style an environmental factor cause the most deaths and sufferings?