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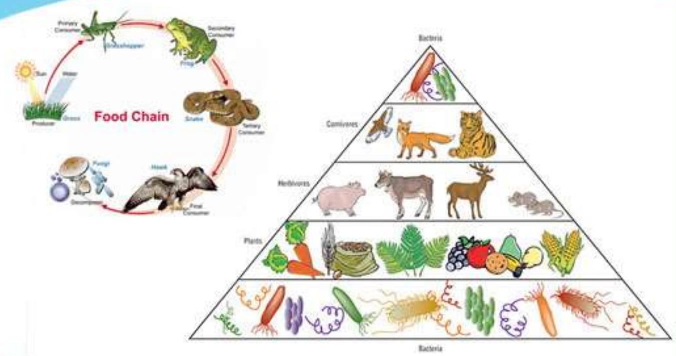
Subject: Environmental Sciences



Production of Coursework
- Content for Post-Graduate Courses

Paper No: 01 Ecosystem Structure & Functions

Module: 02 Ecosystems: Concept, Structure and Functions – Part 2

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Description of Module	
Subject Name	**Environmental Sciences**
Paper Name	Ecosystem Structure & Function
Module Name/Title	2. Ecosystems: Concept, Structure and Functions – Part 2
Module Id	EVS/ESF-I/2
Pre-requisites	
Objectives	• To learn about ecosystem functions. • To understand the concept of food chains, food web, energy flow and nutrient cycling in an ecosystem. • To learn about various processes taking place in ecosystem at cellular levels. • To understand the concept of herbivory and carnivory.
Keywords	Ecosystem, food chain, food web, trophic levels, energy flow, nutrient cycling, photosynthesis, respiration, decomposition, herbivory, carnivory.

Module 2: Ecosystem: Concept, Structure and Functions – Part 2

Contents

2. Ecosystem Functions

Ecosystem functions are the physical, biological and geochemical processes that take place or occur within an ecosystem. Or simply, we can say ecosystem functions relate to the structural components of an ecosystem (e.g. plants, water, soil, air and other living organisms) and how they interact with each other, within ecosystem and across ecosystems. Every ecosystem performs under natural conditions in a systematic way. It receives energy from sun and passes it on through various biotic components and in fact, all life depends upon this flow of energy. Besides energy, various nutrients and water are also required for life processes which are exchanged by the biotic components within themselves and with their abiotic components within or outside the ecosystem. The biotic components also regulate themselves in a very systematic manner and show mechanisms to encounter some degree of environmental stress.

The structure and function of ecosystems are very closely related and influence each other so intimately that they need to be studied together. Despite the broad spectrum and great variety of functions in nature, the simple ***autotroph–heterotroph–decomposer*** classification is a good working arrangement for describing the ecological structure of a biotic community. Production, consumption and decomposition are useful terms for describing overall functions. These and other ecological categories pertain to functions and not necessarily to species as such, because a particular species population may be involved in more than one basic function. For example, individual species of bacteria, fungi, protozoa and algae may be quite specialized metabolically, but collectively these lower phyla organisms are extremely versatile and can perform numerous biochemical transformations. Table 2.1 represents various structural and functional aspects of an ecosystem.

Table 2.1: Structural and Functional aspects of an Ecosystem

Structural Aspects	Functional Aspects
a) Biotic components Producers, consumers and decomposers. **b) Abiotic components** Inorganic substances (C, H, O, N, P, S, etc.), organic compounds (proteins, amino acids, lipids, carbohydrates, humic substances, etc.), climate and its components (temperature, humidity, moisture, sunlight, rainfall, wind, air etc.), edaphic and other factors (minerals, soil, topography, pH, etc.)	**a) Food chains and food webs** **b) Energy flow** **c) Nutrient cycling** **d) Ecosystem processes to explain interactions among the components of ecosystem** **e) Ecosystem development** **f) Ecosystem regulation and stability** **g) Ecosystem services**

2.1. Food chains and food webs

The flow of energy is mediated through a series of feeding relationships in a definite sequence or pattern i.e. from producers to primary consumers to secondary consumers and to tertiary consumers. Nutrients too move in along this food chain. **The sequence of eating and being eaten in an ecosystem is known as food chain.** All organisms, living or dead are potential food for some other organism and thus, there is essentially no waste in the functioning of a natural ecosystem.

Some common examples of food chains are:

Grass → Grasshopper → Frog → Snake → Hawk (Grassland ecosystem)

Plants → Deer → Lion (Forest ecosystem)

Phytoplanktons → Zooplanktons → Small fish → Large fish (Pond ecosystem)

Each organism in the ecosystem is assigned a feeding level or trophic level depending on its nutritional status (Fig 2.1). Thus, in grassland food chain, grass occupies 1st trophic level, grasshopper the 2nd, frog the 3rd, snake the 4th and hawk 5th trophic level. At each trophic level some energy is lost as heat and respiration, as a result available energy decreases moving away from the first trophic level. Therefore, the number of trophic levels in a food chain is limited. The decomposers consume the dead organic matter of all these trophic levels.

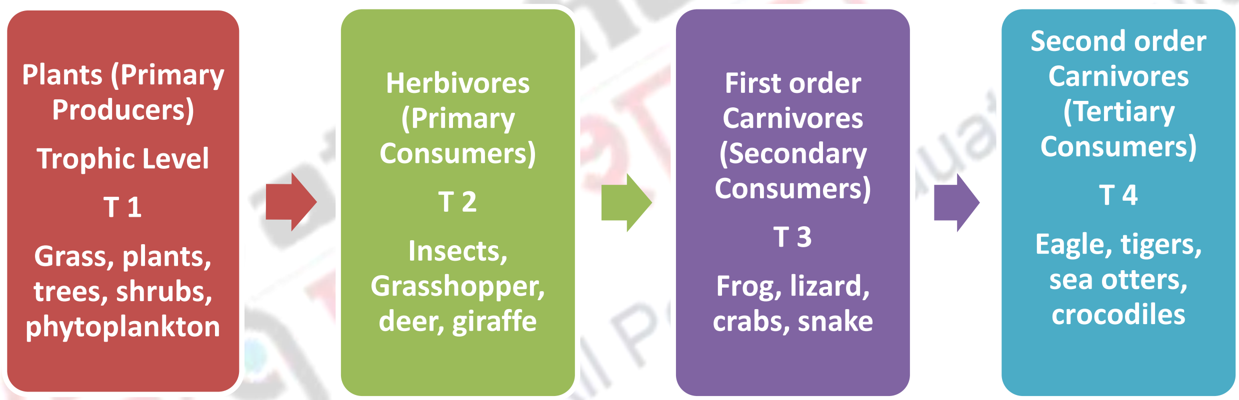

Fig. 2.1: Trophic Levels (T) of a food chain

The food chains can be of two types –

1. **Grazing food chain:** The food chain that starts from green plants and ends in a consumer.

   Some examples are:

   Grass → Insect → Sparrow → Eagle

   Tree → Bird → Snake → Hawk

   Plants → Deer → Tiger

2. **Detritus food chain:** In many cases, the principal energy input is not green plants but dead organic matter. These are called detritus food chains. The detritus food chains are commonly found in forest floors, salt marshes and the ocean floors in very deep areas.

   Example of detritus food chain is as follows:

   Leaf litter → Bacteria → Protozoa → Small fish → Large fish

It is very important to know about the food chains, because certain animals eat only particular type of animals or plants. A balance is maintained in the entire ecosystem through these feeding relationships. The food chains keep a check on the population size of organisms. If in a grassland ecosystem, the deer population increases, grass reduces; but when grass reduces, the deer that feed on it will also be checked in their population size. So, the grass and other plants will get time to grow again.

The food chains also exhibit the property of biomagnification or biological magnification. Certain chemicals, heavy metals or pesticide are either slowly degradable or non-biodegradable in nature. As they enter the food chain in low concentrations, they tend to accumulate at each trophic level and as a result, an increase in their concentrations is exhibited with increase in trophic level of a food chain. In this way, the top trophic level is worse affected due to high accumulation of the chemicals in organisms.

The real world is more complicated than a simple food chain. While many organisms specialize in their diets (e.g. anteaters), other organisms do not. Hawks don't limit their diets to snakes, snakes eat things other than mice, mice eat grass as well as grasshoppers. A more realistic representation of who eats whom is called a food web. **A food web is defined as a network of interwoven food chains with numerous producers, consumers and decomposers operating simultaneously at each trophic level so that there are a number of options of eating and being eaten at each trophic level** (Fig 2.2).

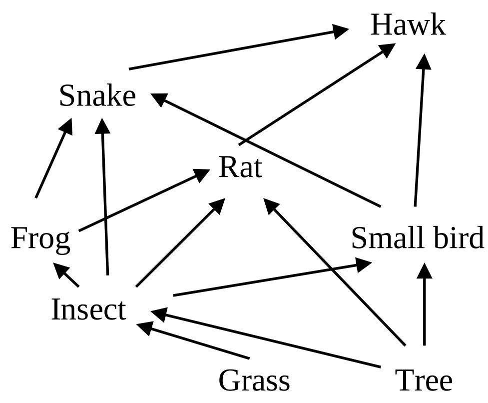

Fig 2.2: A Food Web

Food webs can get quite complex with several interconnected food chains. They give greater stability to an ecosystem. In a linear food chain, if one species become extinct or one species suffers, then the species in the subsequent trophic levels are also affected. In a food web, on the other hand, there are a number of options available at each trophic level. So if one species is affected, it does not affect other trophic levels so seriously.

2.2. Energy Flow

Everything that organisms do in ecosystems (breathing, running, burrowing, growing) all require energy. So, how do they get it? In an ecosystem, there is a continuous interaction between plants, animals, and their environment to produce and exchange materials. The energy needed for this material cycling comes from the sun. Sun is the ultimate source of energy, directly or indirectly, for all other forms. The green plants capture the solar energy and convert it through the process of photosynthesis into chemical energy of food (organic matter) and store it into their body. This process is called as **primary production.** The rate of total organic matter production by green plants (primary producers) is known as **gross primary productivity.** The green plants use some of the energy in the process of respiration. Rest amount of energy is called as **net primary production**, the amount of energy left for the heterotrophic organisms. In this stored form, other organisms take the energy and pass it on further to other organisms. During this process, a reasonable proportion of energy is lost out of the living system. At the consumer level, the rate of assimilation of energy is called **secondary**

productivity. The whole process is called as flow of energy. *The most important feature of this energy flow is unidirectional or one-way or non-cyclic flow*. It flows from producer to herbivores to carnivores organisms; it is never reused back in the food chain unlike the nutrients which move in a cycle (Fig. 2.3). As the flow of energy takes place, there is a gradual loss of energy at each level.

Primary productivity of an ecosystem depends upon the solar radiations, availability of water, nutrients and upon the plants and their chlorophyll content. Productivity of tropical rainforest and estuaries is highest. The greater productivity of tropical rainforests to a large extent is due to the favourable combination of high incident solar radiation, warm temperatures, abundant rainfall, and rich diversity of species. These factors result into longer, almost year-round growing season. In estuaries, the natural wave currents bring lots of nutrients with them congenial for growth. On the other hand, desert ecosystems have limitations of adequate water supply while tundra ecosystems have low water temperature as limiting factor and hence show low primary production.

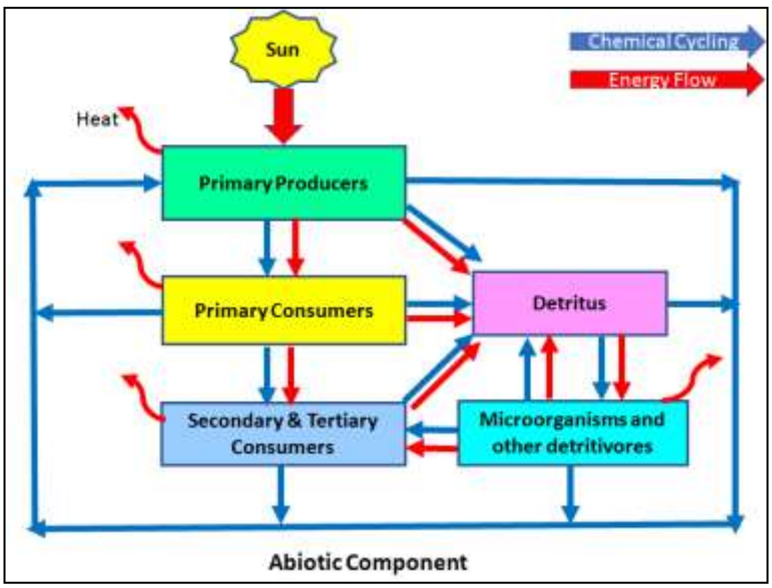

Fig. 2.3: Schematic diagram showing unidirectional flow of energy and nutrients cycling in an ecosystem.

2.3 Nutrient cycling

We have already seen that while energy does not recycle through an ecosystem, nutrients do. Since the inorganic elements move through both the biological and geological world, we call them biogeochemical cycles**.** Of the 30 to 40 elements necessary to life, six rank as the most important: carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus. These nutrients move from non-living to the living and back to the non-living again in a cyclic manner (Fig.2.3).

Each element has its own unique cycle, but all the cycles do have some things in common. **Reservoirs** are those parts of the cycle where the chemical is held in large quantities for long periods of time. In **exchange pools** the chemical is held for only a short time. The length of time a chemical is held in an exchange pool or a reservoir is known as **residence time**. The oceans are the reservoir for water, while a cloud is an exchange pool. Water may reside in an ocean for thousands of years, but in a cloud for a few days only. The biotic community includes all living organisms. This community may serve as an exchange pool and serve to move chemicals from one stage of the cycle to another. For example, the trees of the tropical rain forest bring water up from the forest floor to be evaporated into the atmosphere. The energy from most of the transportation of chemicals from one place to another is provided either by the sun or by the heat released from the mantle and core of the earth.

The biogeochemical cycles are of two basic types: – i) ***gaseous cycles*** - such as nitrogen and carbon, the reservoir is in the atmosphere or hydrosphere (ocean); ii) ***sedimentary cycles*** – such as phosphorus cycle, the reservoir is in the lithosphere.

The nutrients are first taken up by the producers, bound in the organic compounds (carbohydrates, proteins, lipids, etc.) and move along the food chain to heterotrophic level and ultimately from all trophic levels, with the detritus, to the decomposers. The decomposers break down the complex organic compounds and release the nutrients back to the soil from where they are again taken up by the plants, thus making the cycle complete. These biogeochemical cycles give an insight in how human activities lead to eutrophication in water bodies and global climate change.

2.4 Ecosystem Processes

Ecosystem processes include the processes by which transfer of energy and nutrients take place in between biotic and abiotic components of ecosystem. The storage and fluxes are two main paths of ecosystem processes. Storage means accumulation of chemical compounds in the ecosystem components and flux indicates the conversion or movement of stored chemicals from one component to another e.g. via food chains and food webs. These processes mainly include synthesis of food by the producers, transfer of energy and nutrients contained in food through different levels of food chains and food webs, returning back of nutrients to the soil by decomposers. The various ecosystem processes and their controlling factors are briefly described as follows:

2.4.1 Photosynthesis

The primary function of photosynthesis is to convert solar energy into chemical energy, mediated by the plants. The planet's living systems are powered by this process. In the presence of sunlight, green plants take carbon, hydrogen and oxygen from carbon dioxide and water, and then recombine them into glucose molecule and O_2 as a byproduct.

In the process of photosynthesis, carbon dioxide is fixed (or reduced) to carbohydrates (glucose; $C_6H_{12}O_6$) and water is split in the presence of light to release O_2 molecule. It is to mention here that O_2 released comes from the water molecule and not from CO_2.

The overall photosynthesis process can be written as:

Carbon Dioxide + Water + Light ⟶ Carbohydrate + Oxygen

and can be represented by the following chemical equation:

$$6CO_2 + 12H_2O \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

Energy is stored in the bonds of glucose molecule ($C_6H_{12}O_6$). This energy is transferred into animals and humans when they consume plants. Further, O_2 released in the process is used by plants and animals during respiration. Thus, photosynthesis and respiration go hand in hand (Fig. 2.4). The process of respiration breaks apart the glucose molecule and the released energy is then used for all metabolic processes.

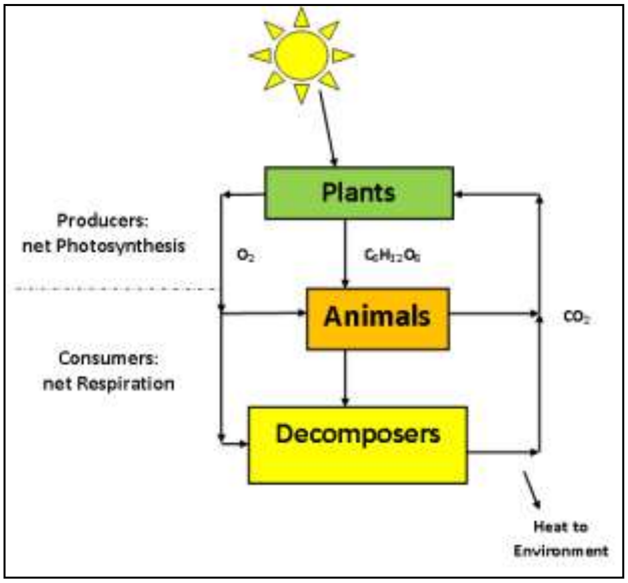

Fig. 2.4.: Schematic diagram of Photosynthesis at trophic level

Photosynthesis at cellular level: All photosynthesis reactions take place inside chloroplasts, small organelles present in mesophyll cells in leaves and stem. Chloroplasts are green due to the presence of chlorophyll pigment. The chloroplasts have a highly ordered array of membranes arranged in stacks called thylakoid membranes. The later acts as a solar panel with a large surface area and organize the pigments chlorophyll and carotenoids to absorb light energy. The chlorophyll is the principle pigment involved in the process. It is a large molecule and absorbs light maximally in the violet blue and red region in visible spectrum and reflects green light and thus leaf appear green in colour. Carotenoids (carotene and xanthophyll) absorb light in the regions of the spectrum not absorbed by chlorophylls and transfer that energy to chlorophyll to be used in photosynthesis.

Chlorophyll-a (a special type of chlorophyll) is the main pigment that traps solar energy and converts it into chemical energy. Chlorophyll-a (chl-a) is present in all autotrophic plants except photosynthetic bacteria. Thus, chl-a is called the *essential photosynthetic pigment* and act as the reaction centre. All other pigments such as chl-b and carotenoids are collectively called *accessory pigments* since they pass on the absorbed light energy to chl-a molecule to be utilized for photosynthesis. These pigments, that is the reaction centres (Chl-a) and the accessory pigments (harvesting centre) are packed into functional clusters called photosystems.

Photosynthesis involves two different processes - Light dependent (light reaction) and light independent (dark reaction) reactions. The structure of chloroplast is such that both these clusters of reactions take place at different sites in the same organelle (Fig. 2.5).

1) Light reactions:

The light absorption part of photosynthesis is referred to as the light reactions. It relies on energy from the sun, so it occurs during the day in thylakoid membrane of chloroplasts. In light reaction, water is split and oxygen released, but more importantly, it provides the chemical energy to fix CO_2 into carbohydrate in the carbon reactions. It involves two photosystems (PS) - PSI and PSII. Each photosystem contains different forms of chl-a in their reaction centres. In PSI, chl-a with maximum absorption at 700 nm (P_{700}) and in PSII, chl-a with peak absorption at 680 nm (P_{680}), act as reaction centres. The primary function of the two photosystems, which interact with each other, is to trap the solar energy and convert it into the chemical energy, also called assimilatory power (ATP and $NADPH_2$).

After receiving light, PSII absorbs light energy and passes it on to its reaction centre, P_{680}. When P_{680} absorbs light, it is excited and its electrons are transferred to an electron acceptor molecule (primary electron acceptor i.e. pheophytin) and it itself comes to the ground state. However, by losing an electron P_{680} is oxidised and splits water molecule to release O_2. This light dependent splitting of water is called photolysis. With the breakdown of water, electrons are generated which are then passed on to the electron deficient P_{680} (which had transferred its electrons earlier). Thus, the oxidised P_{680} regains its lost electrons from water molecules. The reduced primary acceptor now donates electrons to the downstream components of the electron transport chain. The electrons are finally passed onto the reaction centre P_{700} or PSI. During this process, energy is released and stored in the form of ATP.

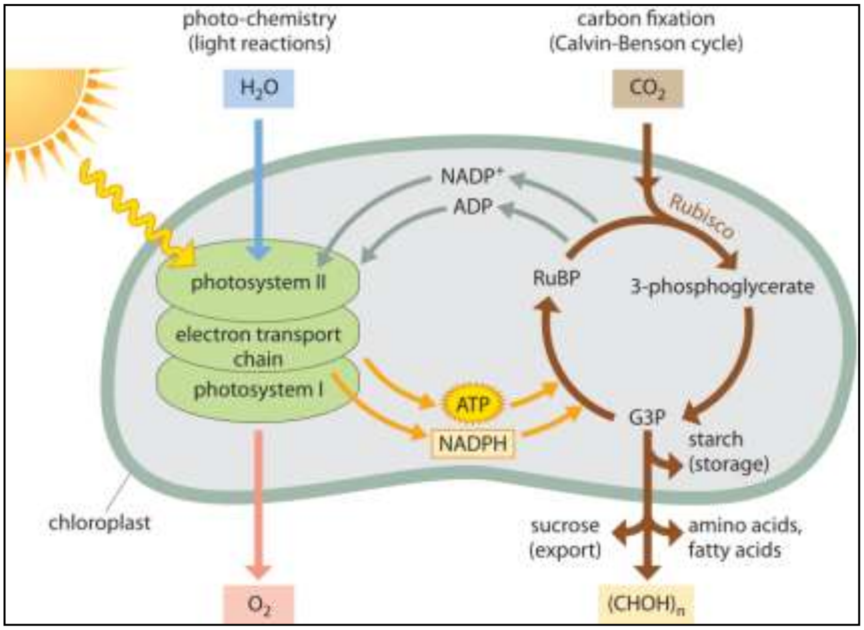

Fig. 2.5: Light and Dark Reactions during photosynthesis

http://book.bionumbers.org/how-much-energy-is-carried-by-photons-used-in-photosynthesis/

Similarly, PSI also gets excited when it absorbs light and P_{700} gets oxidised as it transfers its electrons to another primary acceptor molecule. While the oxidised P_{700} draws its electrons from PSII, the reduced primary acceptors molecule of PSI transfers its electrons via other electron carrier to NADP (Nicotinamide Adenine Dinucleotide Phosphate) to produce $NADPH_2$ a strong reducing agent. Thus, we see that there is a continuous flow of electrons from H_2O molecules to PSII to PSI, and finally to the NADP molecule which is reduced to $NADPH_2$. $NADPH_2$ is then utilised in reduction of CO_2 to carbohydrates in the biosynthetic pathway.

Reduction of CO_2 to carbohydrate also requires ATP, which too are generated via electron transport chain. As the energy rich electrons pass down the electron transport system, it releases energy which is sufficient to bind inorganic phosphate (Pi) with ADP to form ATP. This process is called photophosphorylation.

2) Carbon or Dark reactions:

The carbon reactions occur in the stroma of the chloroplast and uses enzyme Rubisco (ribulose bisphosphate carboxylase/oxygenase). Rubisco is the most abundant protein in plants, therefore, the major consumer of nitrogen. This is why when plants are deficient in nitrogen, they are not productive and turn yellow because they stop photosynthesizing.

Both $NADPH_2$ and ATP produced during light reaction are essential requirements for synthesis of carbohydrates. These series of reactions which catalyse the reduction of CO_2 to carbohydrates (also called fixation of CO_2) are independent of light, but can continue in light as well if products of the light reaction are available. The carbon fixation reactions produce sugar in the leaves of the plant from where it is exported to other tissues of the plant as source of both organic molecule and energy for growth and metabolism. The dark reactions above are found in more than 95 percent of the plants on earth. There are two major pathways by which CO_2 fixation takes place:

a) C_3 photosynthesis (Calvin cycle)

In this cycle, initially the atmospheric CO_2 is accepted by a 5-carbon sugar ribulose bisphosphate (RuBP) resulting in the generation of two molecules of 3-carbon compound, 3-phosphoglyceric acid (PGA). This 3-carbon molecule is the first stable product of this pathway and hence the name C_3 cycle is given. Formation of PGA is called carboxylation. This reaction is catalysed by Rubisco enzyme.

Further, PGA is reduced to 3-carbon carbohydrate called triose phosphate using $NADPH_2$ and ATP (from light reaction). Much of these molecules are then diverted from the C_3 cycle and used for synthesis of other carbohydrates such as glucose and sucrose. To complete the cycle, the initial 5-carbon acceptor molecule, RuBP is regenerated from the triose phosphates using ATP molecule, thus, the C_3 cycle continues to regenerate the CO_2-acceptor (RuBP). Some examples of C_3 plants are given in Fig. 2.6.

Fig. 2.6: C_3 Plants – Wheat, Rice and Potato

b) C_4 Cycle (or Hatch Slack Cycle)

The C_4 cycle mainly occurs in the plants growing under dry hot environment. Such plants can photosynthesise even in the conditions of very low CO_2 concentration and under partial closure of stomata. Therefore, these are efficient in growing at low water content, high temperature and high light intensity. Sugarcane and maize are some examples. The C_4 Plants minimize photorespiration (oxidation of RuBP in presence of O_2) and water loss through a specialized cellular architecture in the leaves: light reactions occur in one cell type and the carbon reactions occur in cells called bundle sheath cells not in direct contact with air.

In C_4 plants, the initial acceptor of CO_2 is phosphoenol pyruvic acid or PEP, a 3-carbon compound. It combines with CO_2 in presence of an enzyme Phosphoenol pyruvate carboxylase (PEP carboxylase) and forms a C_4 acid, oxaloacetic acid (OAA). This fixation of CO_2 occurs in the cytosol of the mesophyll cells of the leaf. OAA is the first stable product of this cycle which is a 4 carbon compound and hence the name C_4 pathway is given.

OAA then travels from mesophyll cells to the chloroplasts of bundle sheath cell where it releases the fixed CO_2. C_3 cycle operates within these cells and this CO_2 immediately combines with RuBP in C_3 cycle producing sugars. C_4 species dominate many warm, high-light environments, particularly tropical grasslands and savannas (Fig 2.7).

Fig. 2.7: C_4 Plants - Sorghum, Corn and Sugarcane

c) CAM Photosynthesis

Plants with crassulacean acid metabolism (CAM) photosynthesis pathway, such as cacti and all other succulents, minimize photorespiration and water loss by keeping their stomata completely closed during the day so no water is lost. This also means they cannot take in CO_2 during the day. CAM plants take in CO_2 through the stomata at night and store it as a molecule called malate. Then during the day, with the sun shining and the stomata closed, rubisco converts the malate to useful carbohydrate. Although this enables CAM plants to grow under extremely heat and dry conditions, they have low photosynthetic productivity and grow slowly. About 10% of the earth's flora possesses CAM photosynthesis (Fig. 2.8).

Fig. 2.8: Succulents with CAM Photosynthesis

2.4.2. Respiration

The organic matter produced in the process of photosynthesis is oxidized back to CO_2 by all sources including combustion or by the respiration of plants, animals, and microbes. Respiration is the exergonic biochemical process in which glucose and oxygen combines to release CO_2, water, and energy. The released energy in form of ATP is utilized by the cells to perform the physiological activities of the organisms (Ricklefs and Miller, 2000; Taiz and Zeiger; 2006 and Singh et. al., 2014).

Respiration may be aerobic (with oxygen) or anaerobic (without oxygen). Aerobic Respiration is reverse of photosynthesis. It is the process by which organic matter (CH_2O) is decomposed back to CO_2 and H_2O with a release of energy. The equation of aerobic respiration is written as follows:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$$

All the higher plants and animals obtain their energy for maintenance and for formation of cellular material in this manner. During photosynthesis, solar energy is captured and stored in high energy bonds in carbohydrate (such as glucose, $C_6H_{12}O_6$). The later is used by the plants or ingested by the heterotrophs. The energy contained in carbohydrates is released during respiration via glycolysis and the Kreb's cycle, carbon dioxide and water are also released. In virtually all ecosystems, photosynthetic autotrophs provide energy for the total system. Thus, the ultimate source of energy in the system is the Sun. A sketch of the ecosystem respiration is illustrated in Figure 2.9.

Anaerobic respiration occurs in saprophages, such as bacteria, yeasts, molds, protozoa, etc. The methane bacteria are examples of obligate anaerobes that decompose organic compounds with the release of methane gas. *Desulfovibrio* and other variety of sulphate reducing bacteria are ecologically important examples of anaerobic respiration because they reduce SO_4 to H_2S gas in deep sediments and in anoxic waters. The H_2S gas rises to the surface where it can be oxidized by other organisms (for example, photosynthetic sulphur bacteria). Many bacteria, like *Aerobacter*, are capable of both aerobic and anaerobic respiration, but the end products of these reactions is different and amount of energy released is very less in anaerobic conditions.

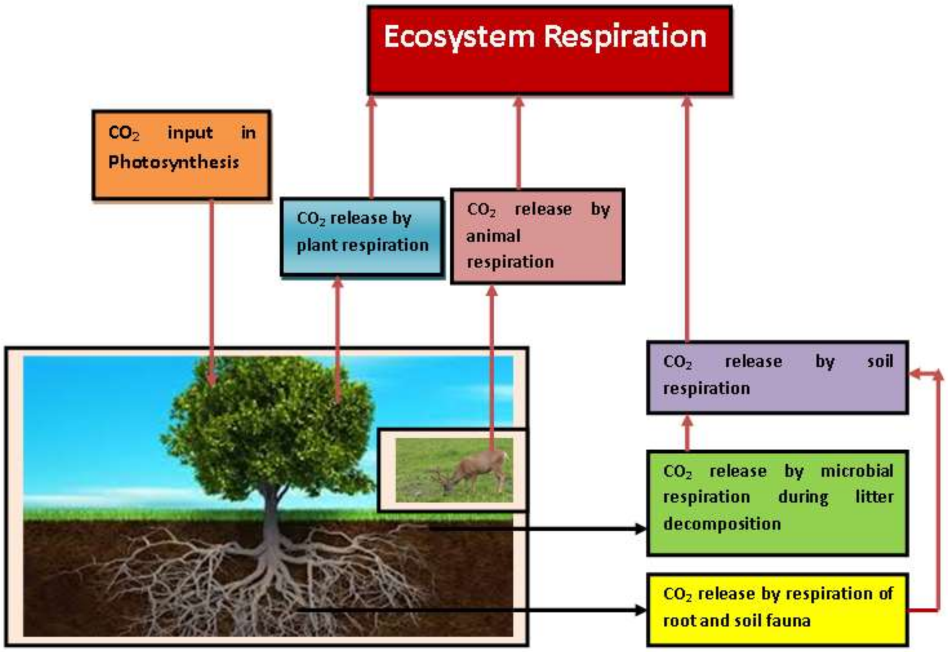

Fig 2.9: Schematic diagram of Ecosystem Respiration

Respiration at cellular level: Respiration is the stepwise oxidation of complex organic molecules and release of energy as ATP for various cellular metabolic activities. It takes sugar either directly from photosynthesis or from breakdown of storage compounds like starch or lipids (oils), and uses its stored chemical energy to make energy currency (ATP). It involves exchange of gases between the organism and the external environment. The green as well as non-green plants obtain oxygen from their environment and return carbon dioxide and water vapors into it. This mere exchange of gases is known as **external respiration** or breathing in case of animals. It is a physical process.

The biochemical process, which occurs within cells and oxidizes food to obtain energy, is known as **cellular respiration.** The whole process of respiration may be divided into several steps. Various enzymes (biocatalysts) catalyze this process. The process by which cells obtain energy from complex food molecules depends upon whether or not oxygen is present in their environment and utilized.

The first step is called glycolysis which literally means sugar splitting. This occurs in the cytoplasm of the cell and does not use oxygen and produces a small amount of ATP. Glycolysis also serves as the central primary metabolic pathway on which most other secondary metabolic pathways depend. This means that crucial plant biomolecules such as proteins, lipids, starch, cellulose, DNA, RNA, chlorophyll, other pigments, plant hormones, and many others are intricately related with metabolic flux through glycolysis. The other parts of respiration occur in specialized organelles called mitochondria. This is where the bulk of the ATP is released in processes requiring oxygen.

2.4.3 Decomposition

Decomposition is a biological process of breakdown of complex organic materials (carbohydrates, proteins, amino acids, nucleic acids, etc.) into the simpler one (CO_2, H_2O and inorganic nutrients like N, P, S, etc.). It results from both biotic and abiotic processes. For example, forest fire release large quantities of CO_2 and other gases into atmosphere and minerals into the soils. The grinding action of freezing and thawing and water flow break down the organic materials by reducing the particle size. However, by and large, the heterotrophic microorganisms or decomposers or saprophages ultimately act on the dead bodies of plants and animals and release of nutrients is done by bacteria and fungi. In the process, bacteria and fungi obtain food for themselves. Decomposition, therefore, occurs through energy transformations within and between organisms. If it did not occur, all the nutrients will be locked in the dead bodies and no new life could be produced. Decomposition is a process of equivalent importance as photosynthesis and needs to be understood in its full detail (Heal et al., 1997). The process of decomposition keeps the ecosystem going by release of nutrients back in the soil from where they are taken up by the producers again. The decomposers are usually considered as nature's recyclers.

The microbial cells are having the enzymes necessary to carry out specific chemical reactions. These enzymes are secreted into dead matter; some of the decomposition products are absorbed into the organism as food, whereas other products remain in the environment or are excreted from the cells. There is a wide variety of decomposer species in nature which act upon dead organic matter. The decomposition rate of different organic compounds varies. Fats, sugars and proteins are decomposed readily, while the cellulose of plants, the lignin of wood, the chitin of insects, the bones of animals are decomposed very slowly. The more resistant products of decomposition result in humus or humic substances.

There are four stages of decomposition (Fig. 2.10): i) ***initial leaching*****,** the loss of soluble sugars and other compounds that are dissolved and carried away by water; ii) ***fragmentation*** of particulate detritus by physical and biological action accompanied by the release of dissolved organic matter; iii) ***rapid production of humus*** and release of additional soluble organics by saprotrophs; and iv) the ***slower mineralization of humus*****.** Mineralization is the release of organically bound nutrients into inorganic forms for the use of plants with the help of ammonifying, nitrifying and other microbes (Smith, 1996; Juma, 1998; Singh et al, 2014). Humus is dark brown or yellowish brown colloidal substance having the nutrients in readily available forms to plants. Detritus, humic substances and other organic matter undergoing decomposition are important for soil fertility.

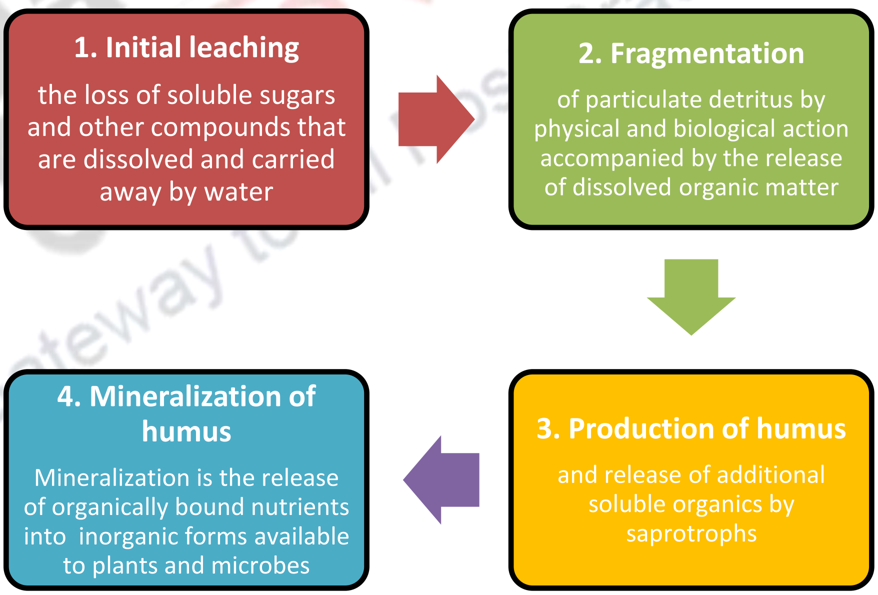

Fig. 2.10: Four stages of decomposition of organic matter

In aquatic muds, sediments and in the rumen of ungulate herbivores decomposition is carried out by the anaerobic bacteria (facultative as well as obligate anaerobes) through the process of anaerobic respiration or fermentation. In the decomposition process, the role of litter feeding organisms mainly protozoans (microfauna), mites (mesofauna), nematodes (macrofauna) and megafauna comprised of snails, earthworms, millipedes, mollusks and crabs includes the fragmentation of large materials into smaller particles. Their absence in overall decomposition may slow down the rate of process. During the process of litter decomposition, a large proportion of carbon is lost as respiration of decomposer organisms and nutrients are released during mineralization.

Decomposition is highly regulated by fire, moisture, temperature and by the drivers of global climate change. A moistened and fairly temperature increase the rate of decomposition. Too less as well as too much soil moisture and temperature, severity of climate and global climate change factors reduce the rate of decomposition.

2.4.4 Herbivory and carnivory

Herbivory refers to ingestion of autotrophs such as plants, algae, and photosynthesizing bacteria by the heterotrophs. Herbivores can be of two types: i) ***monophagous*** – are organisms that exclusively eat one plant species, and the survival of these organisms is dependent on the survival of the primary food source. They are immune to the plant's defenses. For example, Giant Panda feeds on bamboo and Koala Bears who feed on Eucalyptus leaves; ii) ***polyphagous* -** feed on more than one type of plant. Most herbivores are polyphagus in nature. Further, there are different subgroups of herbivores animals depending on type of food they consume. ***Frugivores* -** eat primarily fruit; ***folivores* -** eat leaves; ***nectarivores*** - feed on nectar; ***Granivores*** - grain eaters; ***Graminivores*** - grass eaters; ***Palynivores* -** pollen eaters.

Herbivory is a beneficial process for plants as well. Fruit seeds are dispersed over wide areas as the herbivore moves. Tough seed coatings are removed in the digestive tract of the herbivore, and its dung fertilizes the soil, providing an ideal environment for seed germination. , low level herbivory can remove aging roots and leaves, allowing new growth of young roots and shoots. The new roots and shoots that grow provide better nutrients for absorption and reproduction.

The highest rates of herbivory occur in rainforests due to presence of an increased number of young expanding plant life in the understory of rainforests which are more acceptable to insects, pathogens, and folivores mammals. In a typical terrestrial ecosystem, herbivory may remove about 10% of net primary productivity; though percentage varies in different types of ecosystems. For example, the herbivory in different ecosystems amount to 2-3% for desert scrub, 4-7% for forest, 10-15% for temperate grasslands, 30-60% for tropical grasslands and grasslands managed for cattle raising (Singh et al., 2015).

Carnivory is the ingestion of animals or herbivores by other organisms. Organisms that prefer meat over plants are accordingly called carnivores. Carnivores predators kill and eat their prey. For example, a lion or a tiger hunting smaller animals like rabbits or deer, sea otters hunting sea stars or blue whales consuming zooplanktons and fishes. The carnivores habits can occur in plants and fungi that feed on insects or microscopic invertebrates. Studies have indicated that consumers play an active role in the maintenance and regulation of energy flow through the ecosystem and hence contribute to its persistence.

Summary

1. The structure and function of ecosystems are very closely related and influence each other so intimately that they need to be studied together. The simple autotroph–heterotroph–decomposer classification represents the structure and functions of an ecosystem.

2. The sequence of eating and being eaten in an ecosystem is known as food chain. All organisms, living or dead are potential food for some other organism and thus, there is essentially no waste in the functioning of a natural ecosystem.

3. A food web is defined as a network of interwoven food chains with numerous producers, consumers and decomposers operating simultaneously at each trophic level so that there are a number of options of eating and being eaten at each trophic level.
4. The energy flow in an ecosystem is unidirectional or one-way or non-cyclic flow. It flows from producer to herbivores to carnivores organisms; it is never reused back in the food chain unlike the nutrients which move in a cycle. As the flow of energy takes place, there is a gradual loss of energy at each level.
5. The biogeochemical cycles are of two basic types - gaseous cycles (such as nitrogen and carbon, the reservoir is in the atmosphere or hydrosphere (ocean); sedimentary cycles – such as phosphorus cycle, the reservoir is in the lithosphere.
6. The primary function of photosynthesis is to convert solar energy into chemical energy, mediated by the plants. The planet's living systems are powered by this process. In the presence of sunlight, green plants take carbon, hydrogen and oxygen from carbon dioxide and water, and then recombine them into glucose molecule and O_2 as a byproduct.
7. The organic matter produced in the process of photosynthesis is oxidized back to CO_2 by all sources including combustion or by the respiration of plants, animals, and microbes. Respiration is the exergonic biochemical process in which glucose and oxygen combines to release CO_2, water, and energy. The released energy in form of ATP is utilized by the cells to perform the physiological activities of the organisms.

8. Decomposition is a biological process of breakdown of complex organic materials (carbohydrates, proteins, amino acids, nucleic acids, etc.) into the simpler one (CO_2, H_2O and inorganic nutrients like N, P, S, etc.). It results from both biotic and abiotic processes.
9. Herbivory refers to ingestion of autotrophs such as plants, algae, and photosynthesizing bacteria by the heterotrophs. Carnivory is the ingestion of animals or herbivores by other organisms. Studies have indicated that consumers play an active role in the maintenance and regulation of energy flow through the ecosystem and hence contribute to its persistence.

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