CHAPTER 2

Environmental and Ecosystem Processes

2.1 INTRODUCTION

The planet earth is 4.5 billion years old originated in the universe. The atmosphere envelope, an air surrounding on the earth, significantly responsible for chemical evolution for origin of life and evolution and diversification of biota. Primitive prebiotic earth had an anaerobic atmosphere which is consequently transformed into oxygen rich condition resulted into arrival of human on the earth.

2.2 ORIGIN OF THE EARTH

2.2.1 The Universe

The vast surrounding space is called universe. The universe includes everything that exists i.e. the stars, planets, satellites as well as earth and all the objects on it. The universe was created 13.73± 0.12 billion years ago in a colossal explosion that we now refer to as the Big Bang. At this point all matter and energy of the observable universe was concentrated in one point of infinite density. After the Big Bang, the universe started to expand to its present form. About one billion years after the Big Bang, the first stars and galaxies were formed from primordial H and He. In some of the most massive stars, heavier elements such as C, N, and O were "cooked" inside these gigantic nuclear furnaces. Shortly after their creation (within a few million years), these massive stars died in violent Supernovae explosions, scattering the heavy elements into space. About 3 billion years after the Big Bang, a spiral galaxy began to form from these elements in a part of the Universe just like any other. This galaxy — the Milky Way — is our home.

Our Galaxy: The Milky Way

Galaxies are large systems of stars and interstellar matter consisting of several million to some trillion stars. They come in a variety of shape and size i.e., spiral, lenticular, elliptical and irregular. Besides simple stars, they typically contain various types of star clusters and nebulae.

Constellations

The stars, which appear in the form of closed groups and form recognizable shapes and patterns, are known as constellations. In moon-less night, some of these stars are visible arranged in groups or patterns. About 88 constellations (star groups) are known. Some of the important constellations are: Ursa major (or Great bear), Ursa minor (or Little bear), Orion (or Hunter), Scorpio, Pleides and Cassiopeia.

Stars

Stars are heavenly bodies like the sun that are extremely hot and have light of their own. Every star is a huge mass of hot gases and big flames are coming out of it. Stars are made up of vast clouds of hydrogen gas, some helium, and dust in which hydrogen atoms are continuously being converted into helium atoms, and a large amount of nuclear energy in the form of heat and light is released during the process. The stars are classified according to their physical characteristics like size, colour, brightness and temperature. The stars are born, mature, grow old and finally die. Our universe contains millions and millions of stars. Stars are formed by protostars. In the beginning, the gases in the galaxies, mainly hydrogen and helium, condensed by gravitational contraction and formed protostars. Protostars do not emit light. The collisions of hydrogen atoms raise the temperature of protostar more and more. In this process, four small hydrogen nuclei fuse to produce a bigger helium nucleus and tremendous amount of energy is produced in the form of heat and light. In the final stage of its life, a star enters the red-giant star in which hydrogen gets converted to helium, and core shrinks and outer shell expands. Red giant stars form into white dwarf stars having mass similar to the sun. In this case, in red giant stars, the helium core gradually shrinks into an extremely dense ball of matter due to gravitation. Because of enormous shrinkage of the helium core, the temperature of core would raise greatly and start another set of nuclear reaction in which helium is converted into heavier elements like carbon, and an extremely large amount of energy is released, known as white dwarf stars. But if the mass of red giant stars is much more than the sun, the big core made up of helium continues to contract under the action of gravity producing higher and higher temperature. At this stage carbon is formed by fusion of helium in the core and tremendous amount of nuclear energy is produced very rapidly, which causes the outer shell or envelop of the red-giant stars to explode. This type of exploding stars is called supernova stars and neutron stars. Spinning neutron stars emit radio waves and are called pulsar. The black holes are formed by indefinite contraction of heavy neutron star under the action of their own gravity. A black hole is an object with such a strong gravitational field that even light cannot escape from its surface.

Solar System

Five billion years ago, a cloud of hot swirling dust and hydrogen gas gave birth to our Sun, head of the solar system, and its eight planets. As the cloud spun and collapsed inwards, it flattened into a central mass with a surrounding disk. Dust and gases in the disk formed small condensations, each spinning about its own centre. Gravitation condensed and heated the central mass. Density increased dramatically and nuclear fusion began. Energy was released and our Sun flared into existence. The solar wind of the newly ignited Sun blew away leftover dust and gas in the vicinity of the inner condensations, leaving the rocky inner planets: Mercury, Venus, Earth and Mars. In the outer regions of the disk, the solar wind was weaker. The remaining dust and gas condensed into the larger gaseous planets: Jupiter, Saturn, Uranus and Neptune, just as any other star was formed when gravity pulled together a cloud of interstellar gas. The rotating ball collapsed into a thin disk about 4.5 billion years ago, with the Protosun (cloud of gas that will develop into the Sun) located at the centre. The sun is at the centre of the solar system and all these bodies are revolving around it. The sun holds them together by its great gravitational pull.

The Sun

The sun is a star. It is the star around which the earth and the other seven planets of our solar system revolve. The sun appears to be larger and brighter because it is much more nearer to the earth than any other star. Though sun is the nearest star to the earth, even then it is at a distance of 150×10^6 kilometres from the earth and light, travelling at a great speed of 300,000 kilometres per second, takes about 8 minutes to reach us from the sun. The sun is a mass of hot gases, about 109 times bigger in size than the earth; 330,000 times as heavy as the earth and about 150×10^6 kilometers away from the earth. The sun is a big ball of fire. The temperature

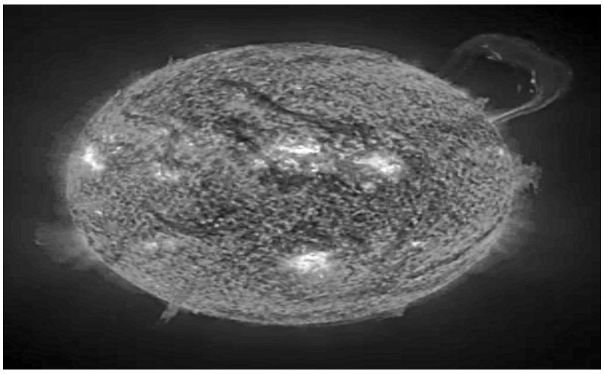

Figure 2.3 The sun—Ultraviolet Imaging Telescope (UIT) image containing dense plasma suspended in the Sun's hot, thin corona. Emission in this spectral line shows the upper chromosphere at a temperature of about 60,000 degrees K; hottest areas appear almost white, while the darker red area is comparatively cooler.

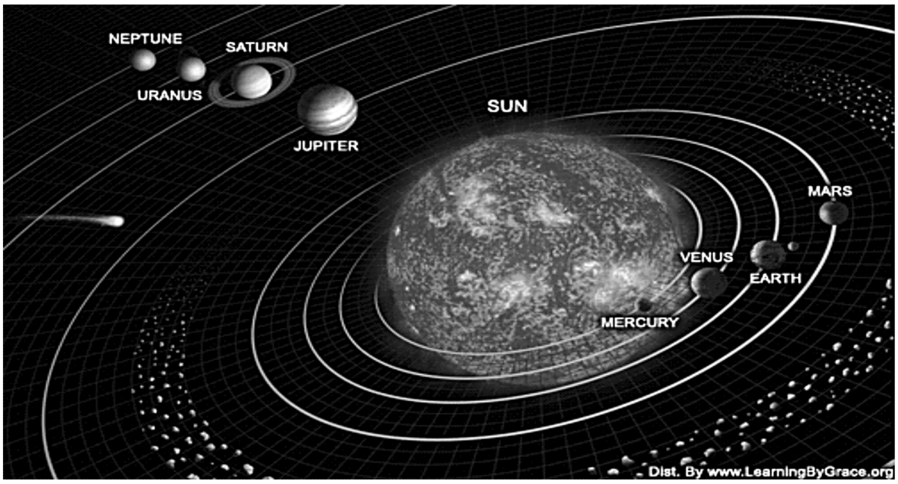

Figure 2.4 Planets of the solar system. The four smaller inner planets: Mercury, Venus, Earth and Mars, also called the terrestrial planets, are primarily composed of rock and metal. The four outer planets, Jupiter, Saturn, Uranus and Neptune, also called the gas giants, are composed largely of hydrogen and helium and are far more massive than the terrestrials.

much thinner under the oceans than continents. The boundary between the crust and mantle is called the Mohorovicic discontinuity (or Moho); it is named in honor of the man who discovered it, the Croatian scientist Andrija Mohorovicic.

The Mantle

The Mantle region lies under the crust and is approximately 2900 km thick. The mantle is much denser than the crust (which is why the crust floats on top) and has a texture much like tar. The rock in this region is rich in compounds made from iron, magnesium, and silicon, therefore it is denser than the crust. The upper mantle, including the tectonic plates, is derived from analyses of earthquake waves, heat flow, magnetic, and gravity studies, and laboratory experiments on rocks and minerals. Between 100 and 200 kilometers below the Earth's surface, the temperature of the rock is near its melting point; molten rock erupted by some volcanoes originates in this region of the mantle. This zone of high yielding rocks has a slightly lower velocity of earthquake waves and is presumed to be the layer on which the tectonic plates ride. Below this low-velocity zone is a transition zone in the upper mantle. It contains two discontinuities caused by changes from less dense to more dense minerals. The chemical composition and crystal forms of these minerals have been identified by laboratory experiments at high pressure and temperature. The lower mantle, below the transition zone, is made up of relatively simple iron and magnesium silicate minerals, which change gradually with depth to very dense forms. Going from mantle to core, there is a marked decrease (about 30 percent) in earthquake wave velocity and a marked increase (about 30 percent) in density.

The Core

This region is divided into two parts. The outer part is called the Outer Core. It is about 2100 km thick and made up of liquid nickel and iron. The inner part is called the Inner Core and it is the real centre of the Earth. This outer part is about 2800 km in diameter and is made of solid iron and nickel. The outer core is presumed to be liquid because it does not transmit shear (S) waves and the velocity of compressional (P) waves that pass through it is sharply reduced. The inner core is considered to be solid because of the behavior of P and S waves passing through it. There is a balance that exists between the level of the crust and the mantle. If the crust builds up in one area, it will push down on the mantle with more force causing some of the material to move away. If material is moved off the crust, the mantle pushes up harder causing that area of land to rise and another area (where the material of the mantle came from) to sink. This process goes on constantly and always maintains a balance of downward forces from the crust with the upward forces from the mantle. This process is called isostasy. Isostasy is not a process or a force. It is simply a natural adjustment or balance maintained by blocks of crust of different mass or density. Isostasy describes vertical movement of land to maintain a balanced crust. It does not explain or include horizontal movements like the compression or folding of rock into mountain ranges.

2.3 THE ATMOSPHERE

The origin of the word *atmosphere* is Greek, from *atmos* meaning vapour and *sphaira* meaning sphere. Literally, it is a sphere of vapour, or a gaseous envelope, surrounding a sphere or globe.

appearance of proteins, polysaccharides and nucleic acids. Harold C. Urey (1893 - 1981), an astronomer, accorded the first adequate recognition of Oparin-Haldane's view on the origin of life in 1952. Stanely L. Miller, a biochemist, replicated the primordial atmosphere as propounded by Oparin and Haldane. Miller (1953) made the first successful simulation experiment to assess the validity of the claim for origin of organic molecules in the primordial Earth condition. The high temperature prevailing in early Earth would have easily fulfilled the second condition, i.e., the requirement of mutation. The thermal motion would have continually altered the prebiotic molecules.

The third condition, partial isolation, has been attained within aggregates of artificially produced prebiotic molecules. These aggregates called protobionts can separate combinations of molecules from the surroundings, maintain an internal environment but are unable to reproduce. Two important protobionts are coacervates and microspheres. Oparin (1924) observed that a mixture of a large protein and polysaccharide is shaken, coacervates form. Microspheres form when mixtures of artificially produced organic compounds are mixed with cool water. In the presence of lipids, the surface of the microsphere consists of lipid layer, similar to the lipid bilayer of cell membrane. Sydney Fox (1950) obtained protenoid microsphere by heating a mixture of dry amino acid between 130 to 180^{o}C and latter cooling them in water.

2.4.1 Chemistry of Life

Any material in the universe that has mass and occupies space is defined as matter. The building blocks of matter are atoms. Atoms aggregate and constitute elements. An element is a substance that contains one type of atom. There are more than 100 elements occurring in nature. Of these, only 25 are essential to life. About 98 percent of the mass of every living organism is composed of six elements, such as carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulphur. Other elements present in small amount in living body are calcium (Ca), potassium (K), sodium (Na), magnesium (Mg), Iodine (I), etc. Such elements that are required by an organism in minute quantities are considered as trace elements. They are of immense value. The basic chemical organizations of living things are complex but remarkably similar. The same materials and principles form the basis of both living and non-living things. Life is chemically based on the universal physicochemical laws and obeys them. Atoms combine to form molecules. A molecule may be defined as two or more atoms linked together by chemical bonds. A chemical bond is an attractive force that links two atoms to form a molecule. Molecules that exhibit charge separation are called polar molecules because of their magnetic poles. Water is a polar molecule. In the water molecule, the oxygen atoms bear a partial negative charge, and each hydrogen atom a partial positive charge. In liquid water, the negatively charged oxygen atom of one molecule of water is attracted to the positively charged hydrogen atom of another molecule of water. The bond resulting from this attraction is called a hydrogen bond. Life on earth is totally dependent on water. Life originated in water and evolved there for about 3 billion years. Organisms require water-rich environment for their growth and reproduction. About two-thirds of our body is formed of water.

All the building blocks of life, the organic molecules, including the monomers (amino acids, monosaccharides) and polymers (polynucleotides, polysaccharides), gather closely around a and others. Fats and oils are made up of two kinds of molecules: glycerol (a type of alcohol with a hydroxyl group on each of its three carbons) and three fatty acids joined by dehydration synthesis. Since there are three fatty acids attached, these are known as triglycerides. The "tail" of a fatty acid is a long hydrocarbon chain, making it hydrophobic. The "head" of the molecule is a carboxyl group that is hydrophilic. Fatty acids are the main component of soap, where their tails are soluble in oily dirt and their heads are soluble in water to emulsify and wash away the oily dirt. However, when the head end is attached to glycerol to form a fat, the whole molecule is hydrophobic. Fats store energy and provide insulation, cushioning and protection to the body. Lipids may also contain elements like phosphorous and nitrogen. The membranes of cells are formed of modified lipids called phospholipids, which contain one unit of glycerol, two units of fatty acids and a phosphate group at one end, often linked with a nitrogen-containing group. Cell membrane often contains steroids, which contains four-carbon ring. The steroid cholesterol is present in animal membrane. Other kind of steroids is hormones like testosterone and estrogen. Terpenes present in plant, and prostaglandins act as chemical messenger in many vertebrate tissues.

Protein

All proteins are formed of subunits called amino acids. Amino acid is primarily made up of carbon, hydrogen, oxygen and nitrogen. An amino acid is a molecule containing amino group, carboxyl group, and a hydrogen atom, all bonded to a central carbon atom. The amino acids are building blocks linked together by covalent bonds called peptide bonds. Each amino acid unit is called a peptide, and a chain of many such units makes up a polypeptide chain. Protein molecules often consist of more than one polypeptide chain. The chains may be held together by weak hydrogen bonds (e.g., the protein hemoglobin), both hydrogen and covalent bonds (the protein hormone insulin). Proteins perform many functions. They make-up the main structural and functional components of cells. About 50 per cent of the dry weight of living matter is protein. Most organisms have between 1000 to 50,000 different types of protein. They also form structural elements like collagen (which forms matrix of bone cells skin.) and muscle proteins like actin and myosin (which play the key role in muscle contraction). Biological catalyst or enzymes (e.g., hydrolytic enzymes, which cleave polysaccharides), hormones (e.g., insulin, which controls blood sugar), immunoglobulins (e.g., antibodies) and transporters (e.g., hemoglobin) are proteins.

Nucleic acid

The nucleic acid is a linear polymer (polynucleotide) made up of monomer units called nucleotides. Each nucleotide is formed of a pentose sugar, a phosphate group, and an inorganic nitrogenous base (purines and pyrimidines). The sugar is ribose in ribonucleic acid (RNA) and deoxyribose in deoxyribonucleic acid (DNA). There are four types of nitrogenous bases, two of purines, adenine (A) and guanine (G), and two of pyrimidines, cytosine (C) and thymine (T). In RNA, thymine is replaced by uracil. DNA molecules are formed of two polynucleotide chains (double-stranded) that are held together by weak hydrogen bonds between adjacent bases. The two chains are oriented in opposite directions and are arranged side by side like a ladder. The nitrogenous bases form the cross-rings of the ladder. The entire double-stranded structure becomes coiled spirally or helically, transforming the double-stranded structure into a double helix. Most RNA molecules consist of one polynucleotide chain (single-stranded). One readily apparent commonality is that all living things consist of similar organic (carbon-rich) compounds. Another shared property is that the proteins found in present-day organisms are fashioned from one set of 20 standard amino acids. These proteins include enzymes (biological catalysts) that are essential for development, survival and reproduction. Further, contemporary organisms carry their genetic information in nucleic acids— RNA and DNA — and use essentially the same genetic code. This code specifies the amino acid sequences of all the proteins each organism needs. More precisely, the instructions take the form of specific sequences of nucleotides, the building blocks of nucleic acids. The bases constitute the alphabet, and triplets of bases form the words. As an example, the triplet CUU in RNA instructs a cell to add the amino acid leucine to a growing strand of protein.

From such findings we can infer that our last common ancestor stored genetic information in nucleic acids that specified the composition of all needed proteins. It also relied on proteins to direct many of the reactions required for self-perpetuation. Nowadays nucleic acids are synthesized only with the help of proteins, and proteins are synthesized only if their corresponding nucleotide sequence is present. It is extremely improbable that proteins and nucleic acids, both of which are structurally complex, arose spontaneously in the same place at the same time. In the late 1960s, Carl R. Woese of the University of Illinois, Francis Crick, then at the Medical Research Council in England, and others independently suggested a way out of this difficulty. He proposed that RNA might well have come first and established what is now called the RNA world — a world in which RNA catalyzed all the reactions necessary for the precursor of life's last common ancestor to survive and replicate. He also postulated that RNA could subsequently have developed the ability to link amino acids together into proteins. There are few reasons to favour RNA over DNA as the originator of the genetic system, even though DNA is now the main repository of hereditary information. One consideration was that the ribonucleotides in RNA are more readily synthesized than the deoxyribonucleotides in DNA. Moreover, it was easy to envision ways that DNA could evolve from RNA and then, being more stable, take over RNA's role as the guardian of heredity.

2.4.2 Energy Transfer Devices of Life

Cellular activities such as growth, motion and active transport of ions across the cell membrane require energy. No cell manufactures energy but all organisms take in energy and transforms it into another kind to do many kinds of work. Green plants and bacteria take in solar energy to produce their own chemical energy (food). Animals take food from outside and break it to obtain energy for performing the different physiological functions. Where there is energy to be tapped, the potential for work is present, be it weight of water stored behind a dam, covalent bonds of glucose, an electron excited into a higher orbital by sunlight or tightly bound nuclei of nuclear plants. All atoms possess energy. It takes work to keep the electrons in the orbital of an atom. Virtually, all the energy for living organisms comes as radiation in the form of photons from the sun and is captured by electrons. Organisms reap and use this energy to fuel all the processes of life. The loss of an electron is called oxidation, whereas the gain of electron is regarded as reduction. Oxidation-reduction (redox) reactions play a key role in the flow of energy through biological systems. In each step of the hierarchy of biological organization, chemical reactions play the intricate and key role by a constant flow of energy. All the daily activities like running, walking, moving, etc. require change in the form of energy. However, within a living system, the potential chemical energy may be converted into other forms, such as kinetic energy (a measure for random motion of molecules) in the form of light or electricity.

2.4.3 Sources of Variation

The mutation, recombination, gene migration, genetic drift and natural selection are the causes of variation at genetic level. Mutation is a sudden heritable change. These mutations are random (indiscriminate) with respect to the adaptive needs of organisms. Most mutations are harmful or with no effect (neutral) on their bearers. If the environment changes, however, previously harmful or neutral alleles may become advantageous. Natural selection is the most critical evolutionary process that leads to changes in allele frequencies and favors or promotes adaptation. During meiosis, crossing over causes gene combinations, which provide new arrangement and transfer of existing genes and alleles. Gene migration occurs if one population is isolated from other population at the time of migration. If the migrating population breeds within the new population, the immigrants will add new alleles to the local gene pool of the host population. If there are random changes in the allele frequencies occurring by chance, it is called genetic drift. Natural selection is the most critical evolutionary process that leads to change in allele frequencies and promotes adaptation as a product of evolution. Natural selection is the differential reproduction leading to differential contribution of genotypes to the gene pool of the next generation.

2.4.4 Organization of life

All living plants and animals and the non-living substances, such as stones and rocks, are formed of matter. The first living organisms, having arisen in a sea of organic molecules and in contact with an atmosphere lacking oxygen (reducing atmosphere) presumably obtained energy by the fermentation of some of these organic molecules. However, long before the supply of existing organic molecules was exhausted, some of the heterotrophs might have evolved into autotrophs. These organisms were capable of producing their own organic molecules by chemosynthesis or photosynthesis. One of the by-products of photosynthesis is gaseous oxygen. The emergence of photosynthesis was a turning point because this process changed the atmosphere of the Earth. Evidence points to bacteria flourishing 3.8 billion years ago, so this means that life got under way about 700 million years after the Earth was created. Such early forms of life existed in the shallow oceans close to thermal vents. These vents were a source of heat and minerals. A billion years later, these primitive life forms then took the next evolutionary step and started to photosynthesize (using sunlight to convert carbon dioxide and water to food energy and oxygen). It was teeming with organisms resembling blue-green algae. This was an important turning point in the Earth history because the carbon dioxide in the atmosphere was being converted to oxygen. These green plants went on producing oxygen (and removing the CO_2). Most of the carbon from the carbon dioxide in the air became locked up in sedimentary rocks as carbonates and fossil fuels. Carbon dioxide also dissolved into the oceans. The ammonia and methane in the atmosphere reacted with the oxygen. Nitrogen gas was released, partly from the reaction between ammonia and oxygen, but mainly from living organisms such as denitrifying bacteria (as nitrogen is not a very reactive gas and it has built up slowly). This continued until about 2.1 billion years ago when the concentration of oxygen increased markedly.

In the beginning, the living organisms were grouped into plants and animals. This is also known as Two Kingdom System of classification. The debatable position of fungi, bacteria and viruses led to the replacement of two kingdom grouping by a five kingdom classification proposed in 1969 by R.H Whittaker. The five kingdoms are Monera, Protista, Fungi, Plantae and Animalia. The main criteria for classifying organisms into five kingdoms are complexity of cell structure, body organization, mode of nutrition, life style and the phylogenetic relationships. The mode of nutrition also diverged in the multicellular kingdoms *viz.* plantae, fungi and animalia. The ecological role of these three multicellular kingdoms was also established as producers, consumers and decomposers, respectively. The organisms, according to the Five Kingdom System, are redistributed in the additional three kingdoms while retaining the two kingdoms — plant and animal. Living matter lies in the biosphere and interacts with its surrounding non-living lithosphere, hydrosphere and atmosphere. The living organisms and their nonliving

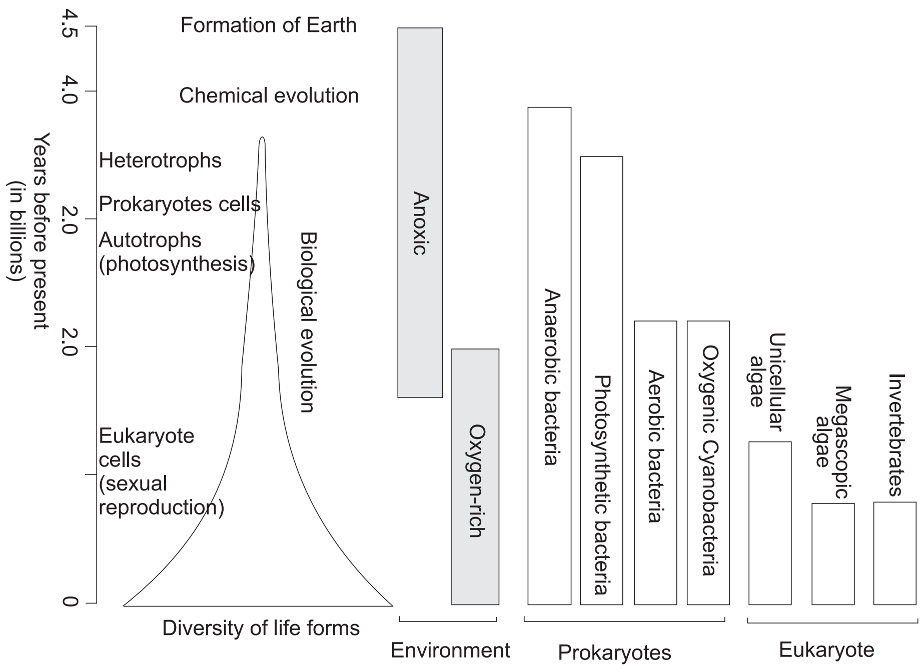

Figure 2.6 Evolution of life and diversity of organisms with geological time scale

cytoskeleton composed of microtubules, microfilaments, and intermediate filaments, which play an important role in defining the cell's organization and shape. Eukaryotic DNA is divided into several linear bundles called chromosomes, which are separated by a microtubular spindle during nuclear division. Cell division in eukaryotes is different from organisms without a nucleus (prokaryotes). It involves separating the duplicated chromosomes through movements directed by microtubules.

Eukaryotes are distinguished from Archaea and Eubacteria in many different ways, but most importantly, the cells of eukaryotes display a much greater degree of structural organization and complexity. The known diversity of morphological characters in eukaryotes is simply staggering and can be attributed to the vast multitude of possible solutions to basic biological problems, such as nutrition/feeding, locomotion, defense, refuge, mate selection and reproduction. The origin of the eukaryotic cell was a milestone in the evolution of life, since they include all complex cells and almost all multicellular organisms. Most eukaryotes are now included in one of the following super groups (phylogenetic tree indicated below), although the relationship between these groups and the monophyly of each group is not yet clear.

Our understanding of eukaryotic relationships has been transformed by the use of molecular data to reconstruct phylogenies. Prior to that, the diversity of microbial eukaryotes was vastly underestimated, and the relationships between them and multicellular eukaryotes were difficult to resolve. Early molecular phylogenies based on small subunit ribosomal RNA (SSU rRNA) gene sequences suggested a ladder of basal lineages topped by a 'crown' composed of multicellular groups (animals, plants, and fungi) together with a subset of the purely microbial lineages.

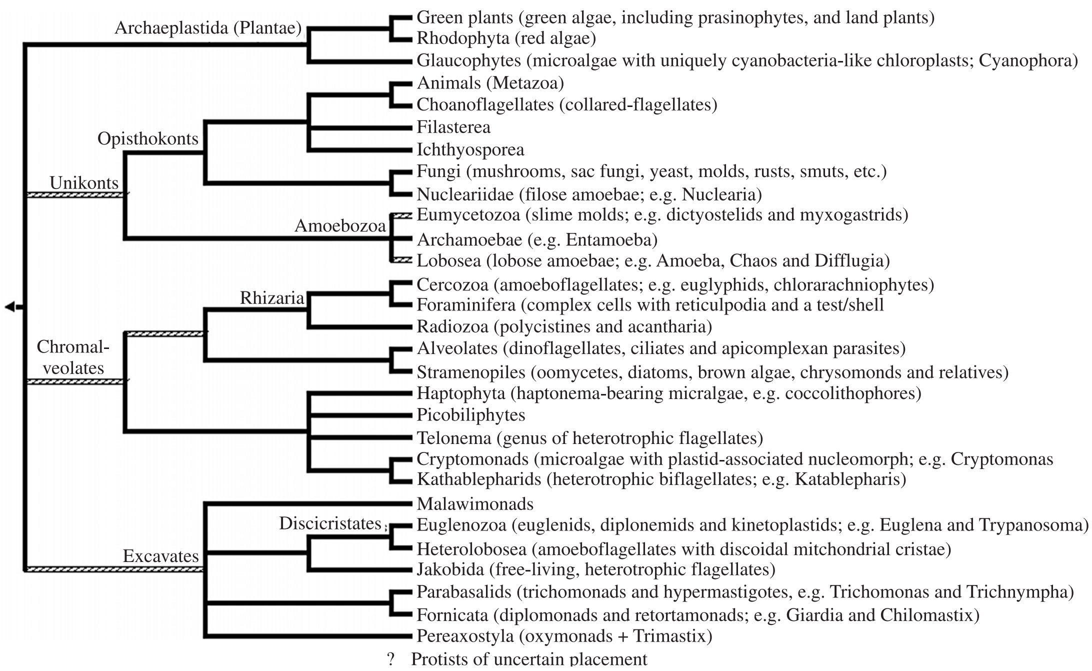

Figure 2.8 Phylogenetic tree of eukaryotes showing the diversity

A great number of relationships revealed by SSU rRNA phylogeny have stood the test of time, but subsequent analyses based on protein coding genes and more recently very large datasets composed of hundreds of protein coding genes have led to a revision of the overall structure of the tree. The current view of eukaryotic phylogeny is of a small number of large 'supergroups', each comprising a spectacular diversity of structures, nutritional modes, and behaviours.

Another proposal is that eukaryotes can be classified into two larger clades, the unikonts and the bikonts that derive from an ancestral uniflagellar organism and a biflagellate, respectively. In this system, the opisthokonts and amoebozoans are considered unikonts, and the rest bikonts.

2.5 ECOSYSTEMS

The cell is regarded as the basic structural and functional unit of life. Cells combine to form tissues, tissues combine to form organs, organs combine to form system, and system makes an individual. Individuals of all kind of organisms invariably aggregate to form population and species. A geographically localized group of individuals of the same kind at a particular time represents a population. The species and population are the most universal and stable units. Organisms having similar structural and functional features, capable of breeding among themselves constitute a species. Members of a species may show individual variation, sexual dimorphism, and may occur as varieties. All species show various cooperative and competitive interactions among their members. A population is a unit of cooperative aggregation of individuals. It is a stable aggregation of organisms of the same species living in a defined area at a given time. The total number of individuals in a given space at a given time constitutes the population size and the number of organisms per unit space indicates its population density. An association of several populations belonging to different species interacting with one another living in a common environment is called a biotic community. Interspecific relation within a community has evolved through interactions based on various requirements and resources in the form of food, shelter and habits. The composition of a community varies according to both living and non-living components of the environment. Every community in a particular environment undergoes a series of gradual changes, and a group of organisms becomes successfully established in the area. This is known as succession. Succession brought both changes in living organism and its physicochemical conditions of the environment.

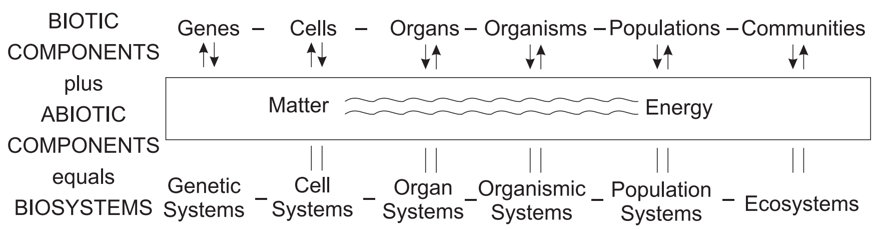

Figure 2.9 Concept of ecosystem related to interaction of both biotic and abiotic components

The biotic community together with its physical environment forms an interacting system called the ecosystem. A.G.Tansley proposed the term "ecosystem" in 1935. An ecosystem has a definite organization having biotic and abiotic structural components. Structural components are responsible for composition of community including species, numbers, biomass, life history and distribution in the presence of ecological factors. However, functional component includes the rate of biological energy flow i.e., the production and respiration rates of the community, the rate of materials or nutrient cycles, and biological and ecological regulatory mechanisms.

2.5.1 Abiotic Component

The amount of inorganic substances involved in material cycle is known as abiotic component. The amount of these inorganic substances present at any given time in an ecosystem is known as standing state or standing quality.

2.5.2 Biotic Component

Biotic component gives trophic structure of any ecosystem related to basic nutritional relationships, known as autotrophic and heterotrophic components. The members of autotrophic components are known as producers, which fix light energy by using simple inorganic substances into complex instances. Heterotrophic components are known as consumers, in which utilization, rearrangement and decomposition of complex materials occur. Heterotrophic components may be divided into macroconsumers and microconsumers. Herbivores (primary consumers) and carnivores (secondary and tertiary consumers) are micro consumers. Therefore, in biotic components of any natural ecosystem, both material and energy enters through the producer (green plant), passes to consumers and finally enters into decomposers, making a trophic structure in which each food level is known as trophic level.

The amount of living material in different trophic levels or in a component population is known as standing crop. The standing crop may be expressed in terms of number of organisms per unit area or biomass i.e., organism mass in unit area, which is measured by living weight, ash free dry weight or carbon weight, or calories based. Chemical energy is transferred in the living world through food chain in trophic level.

2.5.3 Ecological Pyramids

Trophic structure and function at successive trophic levels, i.e., producers, herbivores, carnivores, and decomposer may be represented by ecological pyramids, which are divided into pyramids of number, pyramids of biomass and pyramids of energy. Pyramids of number indicate the relationship between producer, consumer and decomposers at successive trophic levels in terms of their number. These pyramids do not give actual picture of food chain, as they are not very functional. Pyramids of number may be upright or inverted. In a grassland, pond and forest ecosystem, it is upright, however in parasitic food chain the pyramid is inverted. Pyramids of biomass indicate the total dry weight and total amount of living matter. Pyramids of energy show

2.5.4 Food Chains in Ecosystems

The transfer of food energy from producers through a series of organisms (consumers and decomposers) with repeated eating and being eaten is known as a food chain. In nature, there are two general types of food chains. A food chain is the path of food from a given final consumer back to a producer. For instance, a typical food chain in a field ecosystem might be:

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

Phytoplankton ? Water fleas ? Small fish ? Big fish ? Birds ? Large animals (Pond ecosystem)

1. Grazing food chain. This type of food chain starts from living green plants, goes to grazing herbivores and on to carnivores and finally ends to decomposers.

2. Detritus food chain. This type of food chain starts from dead organic matter into microorganisms, and then to the organism feeding on detritus and their predators.

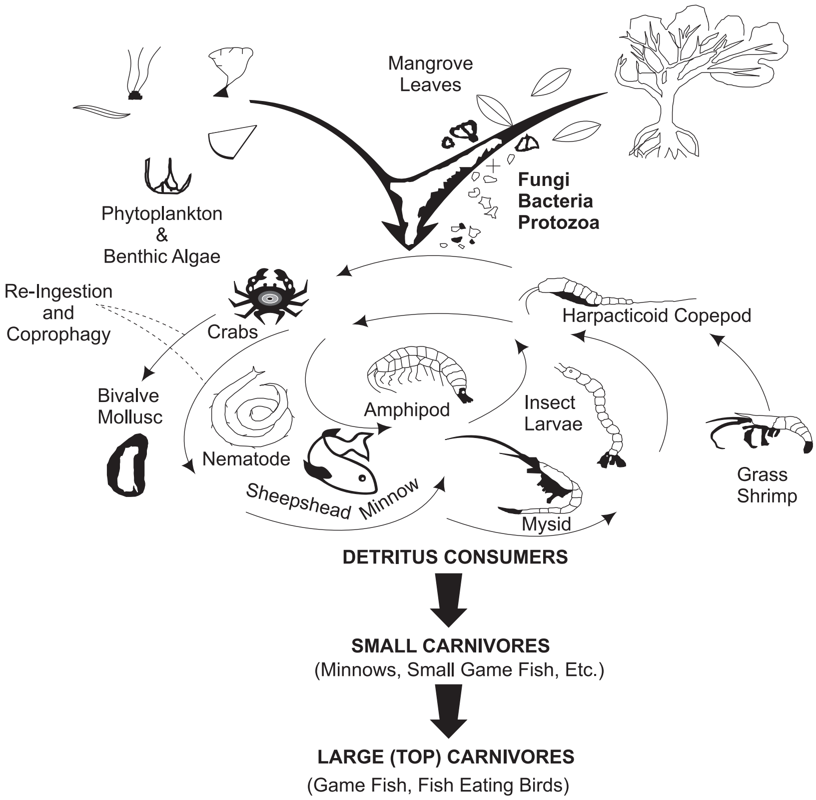

Figure 2.11 A detritus food chain based on mangroves leaves falling into shallow estuary water (Based on W. E. Odum, 1970)

2.5.5 Food Webs

Food chains in natural condition never operate as isolated sequences, but are interconnected with each other forming a sort of interlocking pattern known as food webs. Depending upon the availability and choice of food, different organisms at each level have food relationship. Thus a network of food chains exists and forms food web. In nature, there is an alternative sort of interlocking pattern of food chain called food web. The food webs become more complicated depending upon the variability in taste and preference, availability and compulsion, and several others factors at each level. The availability of food is the main factor, which maintains the balance of nature. While many organisms do specialize in their diets (ant eaters come to mind as a specialist), other organisms do not. Hawks do not limit their diets to snakes, snakes eat things other than mice, mice eat grass as well as grasshoppers, and so on. A more realistic depiction of who eats whom is called a food web. An example is shown below:

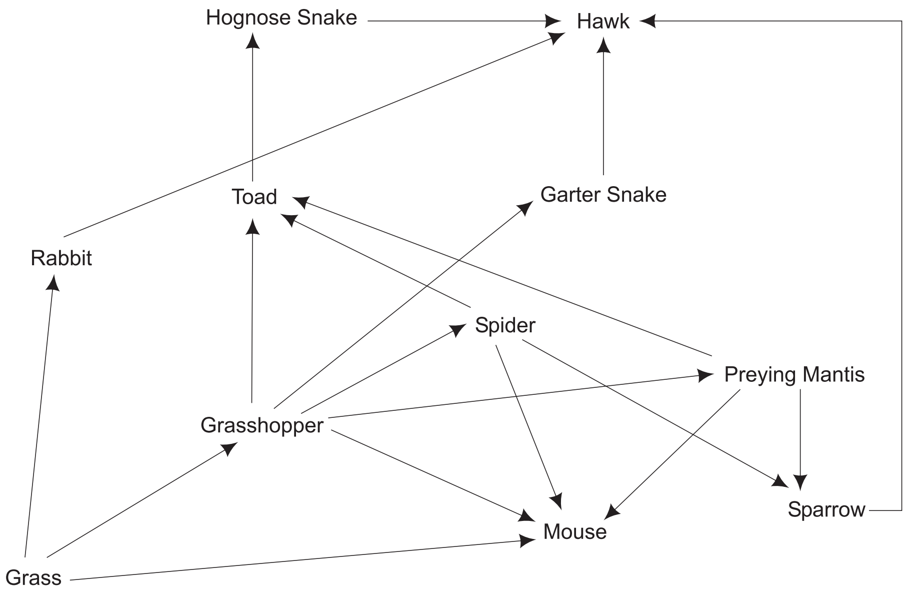

Figure 2.12 Diagrammatic sketch showing a food web in a grassland ecosystem

2.5.6 Habitat and Niche

A habitat is a specific place or locality where an organism lives. It is a physical entity comprising total abiotic factors to which a species is exposed. Habitat usually refers to a relatively large area such as pond, forest and ocean. Each species of a community lives in a very specific part of a habitat and performs certain functions. The habitat together with the functions forms the niche of the species.

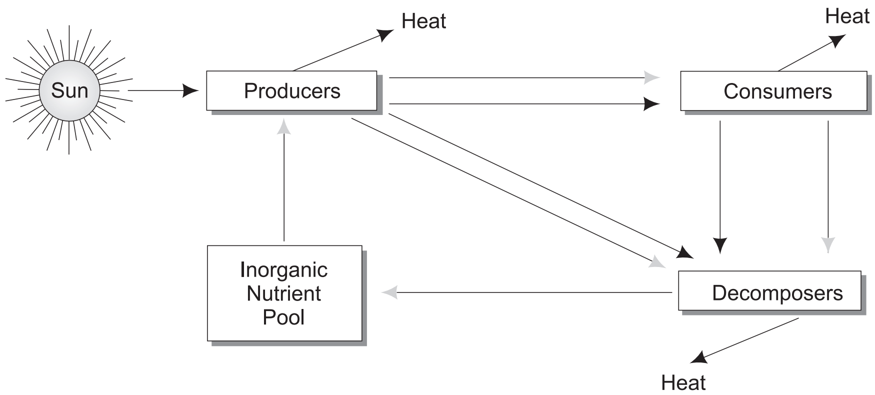

Figure 2.13 Transfer of energy and material in the ecosystem

2.5.7 Energy Flow in Ecosystem

Producers (green plants) capture energy from the sun by the process of photosynthesis and use it to make food. Most of this energy is used to carry on the plant's life activities. The rest of the energy is passed on as food to the next level of the food chain (consumers). At each level of the food chain, about 90% of the energy is lost in the form of heat. The total energy passed from one level to the next is only about one-tenth of the energy received from the previous organism. Therefore, as you move up the food chain, there is less energy available. Animals located at the top of the food chain need a lot more food to meet their energy needs.

The diagram above shows how both energy and inorganic nutrients flow through the ecosystem.

When respiration occurs, the carbon-carbon bonds are broken and the carbon is combined with oxygen to form carbon dioxide. This process releases the energy, which is either used by the organism (to move its muscles, digest food, excrete wastes, think, etc.) or the energy may be lost as heat. The dark arrows represent the movement of this energy. Note that all energy comes from the sun, and that the ultimate fate of all energy in ecosystems is to be lost as heat. Energy does not recycle. The other component shown in the diagram is the inorganic nutrients. They are inorganic because they do not contain carbon-carbon bonds. These inorganic nutrients include the phosphorus in the teeth, bones, and cellular membranes; the nitrogen in amino acids (the building blocks of protein); and the iron in the blood (to name just a few of the inorganic nutrients). The open arrows represent the movement of the inorganic nutrients. The autotrophs obtain these inorganic nutrients from the inorganic nutrient pool, which is usually the soil or water surrounding the plants or algae. These inorganic nutrients are passed from one organism to other organism as later consumes previous organism. Ultimately, all organisms die and become detritus, food for the decomposers. At this stage, the last of the energy is extracted (and lost as heat) and the inorganic nutrients are returned to the soil or water to be taken up again. The inorganic nutrients are recycled, however, the energy is not. The flow of energy and inorganic nutrients through the ecosystem can be summarized as follows:

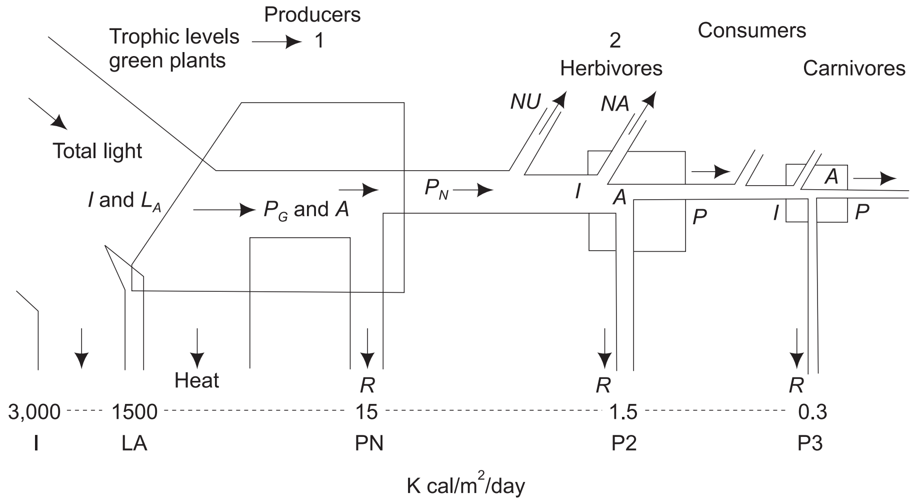

Figure 2.14 A simplified energy flow diagram depicting three trophic levels (boxes numbered 1,2,3) in a linear food chain. I-total energy input; LA-light absorbed by plant cover; PG-gross primary productivity; A-total assimilation; PN-net primary production; P-secondary (consumer) production; NU-energy nor used (stored or exported); NA-energy not assimilated by consumers (egested); R-respiration. Bottom line in the diagram shows the order of the magnitude of energy losses expected at major transfer point, starting with a solar input of 3,000Kcal per square meter per day. (After E.P. Odum)

1. The ultimate source of energy (for most ecosystems) is the sun
2. The ultimate fate of energy in ecosystems is for it to be lost as heat.
3. Energy and nutrients are passed from organism to organism through the food chain as one organism eats another.
4. Decomposers remove the last energy from the remains of organisms.

The behavior of energy in ecosystem can be termed energy flow due to unidirectional flow of energy. Three models have been proposed for energy flow:

1. Single-channel energy model: This model is proposed where the nutritional availability of the energy source in high, and transfer efficiencies can be much higher. Both plants and

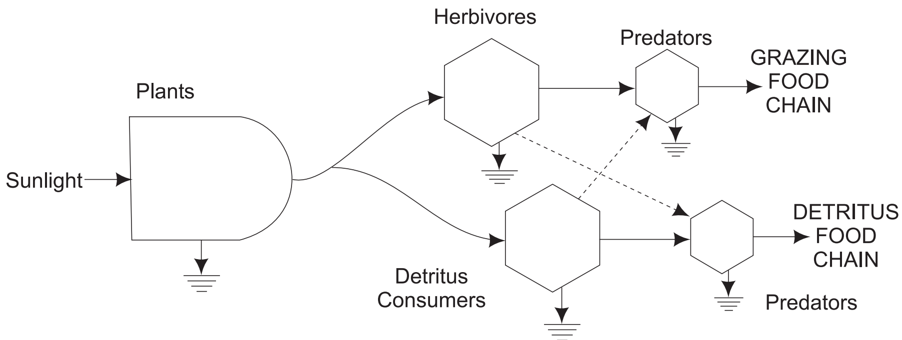

Figure 2.15 The Y-shaped energy flow model showing linkage between the grazing and detritus food chains. (After E.P. Odum, 1983)

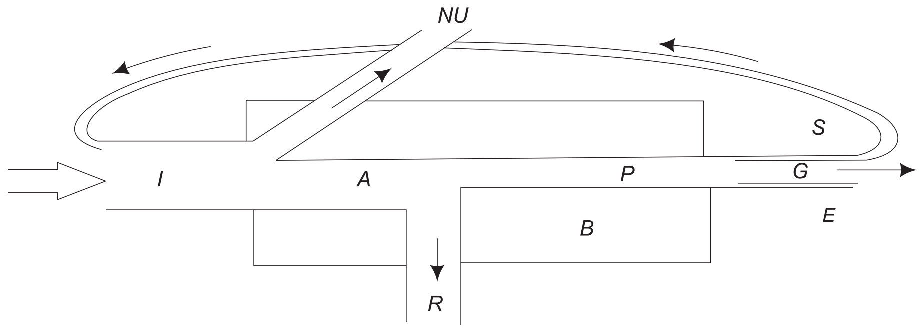

Figure 2.16 Components of a "universal" model of energy flow. I, input or ingested energy; NU, not used; A, assimilated energy; P, production; R, repiration; B, biomass; G, growth; S, stored energy; E, excreted energy. (Afetr E.P. Odum, 1968)

animals produce enzymes to digest organic matter (cellulose, lignin chitin) together with chemical inhibitors, the average transfers between whole trophic levels average 20 percent or less. This model suggests one-way flow of energy, and there is progressive decrease in energy level at each trophic level.

2. Y-shaped energy flow model: In Y-shaped energy flow model, one arm represents the herbivore food chain, and the other, the decomposer (detritus) food chain. The two arms differ fundamentally in which they can influence primary producers. This model is more realistic than the single-channel model because it conforms to the basic stratified structure of ecosystem, direct consumption of living plants and utilization of dead organic matter and macro consumers (phagotrophic animals) and micro consumers differ greatly in size of metabolic relations.

3. Universal model of energy flow: It is applicable to any living component of plants, animals, microorganisms, individuals, population, or trophic group. This model represents a species population in which case energy inputs and links with other species would be shown as a conventional species oriented food web diagram, or the model represent a direct energy level in which the biomass and energy channel represents all or parts of many populations supported by same energy source.

The study of ecosystem mainly consists of energy flows and cycle of materials. Elements such as carbon, nitrogen, or phosphorus enter living organisms in a variety of ways. Plants obtain elements from the surrounding atmosphere, water, or soils. Animals may also obtain elements directly from the physical environment, but usually they obtain these mainly as a consequence of consuming other organisms. These materials are transformed biochemically within the bodies of organisms, but sooner or later, due to excretion or decomposition, they are returned to an inorganic state. During decomposition, these materials are not destroyed or lost, so the earth is a *closed system* with respect to elements. The elements are cycled endlessly between their biotic and abiotic states within ecosystems by the chemistry and geology of the natural world through biogeochemical cycle. All the nutrients, such as carbon, nitrogen, oxygen, and phosphorus are recycled instead of being lost and replenished constantly in ecosystems by living organisms operating in a closed system, whereas the energy of an ecosystem occurs in an open system; the sun constantly gives the planet energy in the form of light, while it is eventually used and lost in the form of heat throughout the trophic levels of a food web. The most important biogeochemical cycles are the carbon cycle, the nitrogen cycle, the oxygen cycle, the phosphorus cycle, and the water cycle. The cycling of materials and elements are dependent upon element ratios, mass balance, and element cycling. The cycling of material plays significant role in the control of ecosystem processes. There are two dominant theories of the control of ecosystems known as bottom-up control and top-down control. The bottom-up control states that it is the nutrient supply to the primary producers that ultimately controls how ecosystems function, whereas top-down control states that predation and grazing by higher trophic levels on lower trophic levels ultimately controls ecosystem function.

The ecosystem process brings a diverse range of skills to bear on acquiring the knowledge necessary to examine community, population and functional perspectives, and their interactions. Homeostasis defined by Walter Bradford Cannon (1929-1932) is the property of a system, either open or closed, which regulates its internal environment and tends to maintain a stable, constant condition of the ecosystem. Multiple dynamic equilibrium adjustment and regulation mechanisms make homeostasis possible. All homeostatic control mechanisms have three interdependent components— the receptor, the control centre and the effector. Receptor monitors and responds to changes in the environment. When the receptor senses a stimulus, it sends information to a control center, the component that sets the range at which a variable is maintained. The control center determines an appropriate response to the stimulus. In most homeostatic mechanisms, the control center is the brain. The control center then sends signals to an effector, which can be muscles, organs or other structures that receive signals from the control center. After receiving the signal, a change occurs to correct the deviation by either enhancing it with positive feedback or depressing it with negative feedback. James Lovelock stated the Gaia hypothesis as the entire mass of living matter on Earth (or any planet with life) functions as a vast homeostatic superorganism that actively modifies its planetary environment to produce the environmental conditions necessary for its own survival. In this view, the entire planet maintains homeostasis. Positive and negative feedback loops are being discovered that maintain a metastable condition proved the Gaia hypothesis within very broad range of environmental conditions.

2.5.8 Major Ecosystems

Ecosystems are divided into natural and man made ecosystem. Natural ecological grouping of plants and animals is extended over large areas of land and water. Each of these major distinctive terrestrial areas with their group of climax plants and animals are recognized as Biomes. The major biomes are Tundra, North conifer Forest, Deciduous Forest, Tropical rain forest, and chaparrals, Tropical Savannah, Grassland and Desert. There are many types of aquatic ecosystems that differ widely with regard to abiotic factors. Aquatic ecosystem has marine environment and fresh water environment. The marine environment is characterized by its high concentration of salt and mineral ions. Lakes, ponds, streams and river are aquatic fresh water ecosystem. Man has changed the environment to a far greater extent than any other species. The villages and cities, orchards and plantations, garden and parks with their plants and animals are man made ecosystems. Large dams and reservoirs, lakes, canals, small fishery tanks and aquaria are examples of man made aquatic ecosystem. Man has converted large areas of forest and food available if one fails. A final problem associated with agroecosystems is inorganic nutrient recycling. In a natural ecosystem, when a plant dies, it falls to the ground and rots, and its inorganic nutrients are returned to the soil from which they were taken. In human agriculture, however, after harvesting the crop with inorganic and organic nutrients and chemicals including pesticides and fertilizers, water pollution problems occurs.

The word "biome" is used to describe a major vegetation type such as tropical rain forest, grassland, tundra, etc., extending over a large geographic area. It always refers to a vegetation category that is dominant over a very large geographic scale, and so is somewhat broader than an ecosystem. Biome distributions are determined largely by temperature and precipitation patterns on the Earth's surface.

2.6 BIOLOGICAL MAGNIFICATION

Biological magnification is the tendency of pollutants to become concentrated in successive trophic levels. Often, this is detrimental to the organisms in which these materials concentrate, since the pollutants are often toxic. Biomagnification occurs when organisms at the bottom of the food chain concentrate the material above its concentration in the surrounding soil or water. Producers take in inorganic nutrients from their surroundings. Since a lack of these nutrients can limit the growth of the producer, producers will go to great lengths to obtain the nutrients. They will spend considerable energy to pump them into their bodies. They will even take up more than they need immediately and store it, since they cannot be "sure" of when the nutrient will be available again. The problem comes up when a pollutant, such as DDT or mercury, is present in the environment. Chemically, these pollutants resemble essential inorganic nutrients and are brought into the producer's body and stored "by mistake". This is the first step in biomagnification; the pollutant is at a higher concentration inside the producer than it is in the environment.

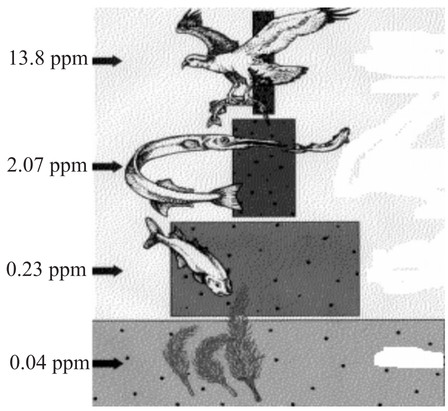

Figure 2.18 Biomagnifications of pesticide (DDT) in different trophic layers of food chain i.e., producers and different types of consumers by increase in concentration of chlorinated organic compounds.