Environmental Sciences

ENE – 112

Lecture Notes

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Origin & evolution of earth, segments of environment – lithosphere, hydrosphere, atmosphere & biosphere, Biogeochemical cycles – geologic, hydrological, oxygen, nitrogen, carbon & phosphate cycles.

Unit II | Ecosystem
Concept of ecosystem, biotic & abiotic components, types of ecosystem, functional components of ecosystem – biodiversity, productivity, food chains & food webs, material cycling and energy flow, different ecosystems – forest, grassland, desert, aquatic.

Unit III | Water Pollution
Water quality, physical, chemical & biological characteristics of water & waste water, ground water pollution, water borne diseases.

Unit I - Introduction to Environment

Solar System: The **congregation** of stars and planets is known as Solar System. The diameter of the whole solar system is around 1173 crore km. It consists of **Terrestrial Planets or Inner Circle Planets** (Mercury, Venus, Earth and Mars) and **Giant Planets or Outer Circle Planets** (Jupiter, Saturn, Uranus, and Neptune)

Earth:	Age of earth	4.6 Billion Years
Mass		5.976×10^{24} kg
Volume		1.083×10^{24} l
Mean Density		5.52 kg/m^3 with reference to water (1000 kg/m^3)
Shape		Oblate Spheroid

We are on Earth which is around 150 million km away from the Sun. Light travels at nearly 300, 000 km in 1 second. So the light from the Sun takes a little more than 8 minutes to reach us. The furthest object in our solar system is Pluto (no more a planet) which is around 6000 million km away from the Sun and the sunlight takes nearly 5 ½ hours to reach Pluto. The time taken by light to come to Earth from other nearby stars is of the order of a few years. So the light from the stars that we see on the sky are really many years old. The distances among the stars are so great that it is useful consider the unit of 'light year' which is the distance covered by light in one year.

Our Sun (and the solar system) is a member of a bigger system, the Milky Way Galaxy. There are approximately 100,000 million other stars in this galaxy. In fact, our Sun is only a very ordinary star; there are many massive stars, much bigger than the Sun in Milky Way. The Sun lies at a distance of about 30,000 light years from the centre of the Milky Way galaxy, around one third of the dimension of the galaxy. Our galaxy is not even a special one! It is estimated that there are 3000 million other galaxies in the universe that could be searched so far. The dimension of our universe is around 10,000 million light years.

Time scales and Masses are also equally enormous. Our earth takes a year to complete one trip round the sun. The Jupiter takes 12 years. The Sun and other stars are also orbiting around the centre of the galaxy. They take around 200 million years to complete one trip round the galactic centre. Mass can be so enormous that the masses of stars and even bigger objects are not measured in kg or other known units. The unit that is used is one solar mass. If a star is two times heavier than the Sun, for example, it is called 2 solar mass etc

Origin of Earth

1. **Religious Concepts** – Don't have any logical and scientific basis. For example, the view of Archbishop Usher (1664) that the earth was created at 9:00 A.M. on October 26, 4004 B.C.
2. **Scientific Concepts**
   a. **Hot origin concepts**- Earth is believed to have been formed from the matter which was either initially hot or was heated up in the process of the origin of the earth.
   b. **Cold origin concepts** – Earth was formed of the matter which was either initially cold or always remained cold. After the formation, only the interior of the earth might have been heated up.

- **Monistic Concept** (Involving one heavenly body)
- **Dualistic Concept** (Involving two heavenly bodies)
- **Binary Star or Tri-hybrid Concept** (Involving more than two heavenly bodies)

Hypothesis Related to Origin of Earth

1. Gaseous Hypothesis
2. Nebular Hypothesis
3. Planetesimal Hypothesis
4. Tidal Hypothesis
5. Binary Star Hypothesis
6. Supernova Hypothesis
7. Inter-Stellar Dust Hypothesis
8. Big Bang Theory, etc.

The Big Bang Theory:

Infinitely hot matter of infinite density was thought to be concentrated in an infinitesimally small volume (a point) at the moment of the creation of the universe. Around 15-20 billion years ago a tremendous explosion started the expansion of the universe. This explosion is known as Big Bang.

The Big Bang theory tells us that our Universe originated from a **'singularity'**. Singularity is a concept (a mathematical concept) which defies our understanding of physical reality and imagination! What existed prior to the moment of Big Bang is completely unknown and is a matter of pure speculation. The space, time, matter, or energy everything was created with Big Bang.

The origin of the Big Bang theory can be credited to Edwin Hubble (1889-1953). Hubble made the observation that the universe is continuously expanding. Matter was created out of Big Bang and energy propagated at the speed of light (300,000,000 meter per second). The temperature of the universe just after a tiny fraction of a second after the Big Bang explosion was of the order of 1000 trillion degree Centigrade (1 trillion = 1000 billion) as estimated. As the universe quickly expanded, it had also undergone a rapid cooling enabling the creation of matter from energy. Universe back then was too hot for anything other than the most fundamental particles – such as quarks and photons. About one ten-thousandth of a second after the Big Bang, protons and neutrons formed, and within a few minutes these particles stuck together to form atomic nuclei, mostly hydrogen and helium. Hundreds of thousands of years later, electrons stuck to the nuclei to make complete atoms.

The evidences supporting the Big Bang theory:

- Experimental observations reveal that the galaxies appear to be moving away from us at speeds proportional to their distance (This is called "Hubble's Law," named after Edwin Hubble.). This observation supports the expansion of the universe and suggests that the universe was once compacted. Since the Big Bang, the universe has been continuously expanding and, thus, there has been more and more distance between clusters of galaxies. This phenomenon of galaxies moving farther away from each other is known as the red shift.

- If the universe was initially extremely hot as the Big Bang suggests, we should be able to find some remnant of this heat. In 1965, Arno Penzias and Robert Wilson discovered Cosmic Microwave Background radiation (CMB), which seems to be coming from the farthest reaches of the universe and that is supposed to be left over from the Big Bang.
- Even more recently, NASAs COBE satellite was able to detect cosmic microwaves emanating from the outer reaches of the universe. These microwaves were remarkably uniform which illustrated the homogeneity of the early stages of the universe.
- Finally, the abundance of the "light elements" Hydrogen and Helium found in the observable universe are thought to support the Big Bang model of origins.

In Short:

- A massive cloud, called solar nebula, was disturbed by the shock wave coming from a nearby supernova. The cloud then collapsed under its own gravitational attraction and the sun was formed in the central region.
- The planets were formed from the outer regions of the accretion disk.
- The initial collapse of solar nebula is supposed to take less than 100,000 years.
- The age of formation of solar system is estimated to be little more than 4.5 billion year

Two older theories of origin of solar system:

1. **The meteorite theory of Immanuel Kant (1755):**
The German philosopher Immanuel Kant (1724 - 1804) put up a theory which is believed to be the oldest meteorite theory. Kant believed that a huge cloud of meteorites existed at the beginning of our solar system. This cloud turned slowly around itself. Through this circling the cloud got a disc shape. Through their attraction under each other the meteorites started to form a mass-centre. Then it became so hot through contractions that it started to glow. That could have been the birth of the Sun. In some distance from the sun there some other, smaller mass-centers which started to rotate around the sun – they are the planets.

2. **The Nebular theory of Laplace (1796):**
The French mathematician Pierre Simon Marquis de Laplace (1749 - 1872) developed the ideas of Kant further. Because of this his theory is also known as the Kant-Laplace Nebular theory. Laplace believed that in the beginning there was a huge cloud of hot gas which rotated slowly. It started to condense while it cooled off. Through this the gravitation of the particles got big enough and formed a discus-shaped 'pre-sun'. Through further condensing, the centre of the pre-sun became hot again and the rotation speed became faster. So the more the gas cloud condenses, the hotter the centre became and the faster became the rotation speeds. Because of this the centrifugal force became stronger than the gravitational pull, so a ring would detach itself. Because of the different attractions of the particles in the ring it would tear apart and from the different pieces, the planets would form that are still circling the sun.

EVOLUTION OF LIFE ON EARTH

Period and its length	Time	Development of life on the Earth	Remarks
CENOZOIC ERA			
QUARTERNARY PERIOD			
Holocene Epoch	10,000	Hunting and taming animals, development of agriculture, use of metals and others minerals.	Cultivated plants
Pliestocene Epoch	2 million	Modern human being developed. Large animals flourished, which died towards the end of the epoch.	Human beings
TERTIARY PERIOD			
Pliocene Epoch	5 million	Modern type of sea life, many birds and mammals also became like today. Human like creatures appeared.	Horses
Miocene Epoch	24 million	Apes in Asia and Africa. Flowering plants and trees resembled the modern types.	Apes
Oligocene Epoch	38 million	Primitive apes appeared. Huge rhino like animals disappeared. Camels, cats, dogs, horses, elephants, developed.	Early horses
Eocene Epoch	55 million	Birds, amphibians, small reptiles and fish presents in large numbers. Primitive mammals and whales appeared.	Grasses
Paleocene Epoch	63 million	Flowering plants became common, invertebrates, fish, reptiles and mammals were also common.	Small mammals
MESOZOIC ERA			
CRETACEOUS PERIOD	138 million	Flowering plants appeared, invertebrates and amphibians were common and dinosaur died at the end of this period.	Flowering plants
JURASSIC PERIOD	205 million	Cone bearing trees were common, dinosaurs attained their largest size and mammals were small and primitive. First birds appeared.	Birds
TRIASSIC PERIOD	240 million	Cone bearing trees were common; many fish resembled today's types. Insect were common and dinosaur, first mammals and turtles appeared.	Dinosaurs
PALEOZOIC ERA			
PERMIAN PERIOD	290 million	Cone bearing trees appeared. Fish, amphibians and reptiles were common.	Seed plants
CARBONIFEROUS PERIOD	330 million	Scale trees and ferns etc. were common and so were fish amphibians. First reptiles appeared. Forest provided habitat to large insects.	Reptiles
UPPER CARBONIFEROUS PERIOD	360 million	Crustaceans, fish and amphibians were common. Coral reefs were formed and trilobites had died out.	Amphibians
LOWER CARBONIFEROUS PERIOD	410 million	The first forests grew in swamps. Water bodies contained many types of fish. Amphibians and insects appeared.	Fish
DEVONIAN PERIOD	435 million	Spore bearing land plants came into existence. Trilobites and molecules were common. Coral reefs were also formed.	Corals

SILURIAN PERIOD	500 million	Trilobites, moluscs were corals were common. Small animals called graptolites were also found.	Graptolites
ORDOVICIAN PERIOD	570 million (appx.)	Fossils were numerous for the first time. Shell animals and some moluscs were common and jawless fish appeared.	Trilobites
CAMBRIAN PERIOD	4.5 billion (appx.)	Coral, jellyfish and worms lived in the sea about 1100 million years ago while bacteria lived about 3.5 billion years ago. No other life appears probable.	Bacteria
PRE-CAMBRIAN TIME			

SEGMENTS OF ENVIRONMENT

- ✓ Atmosphere
- ✓ Lithosphere
- ✓ Hydrosphere
- ✓ Biosphere

Assignment

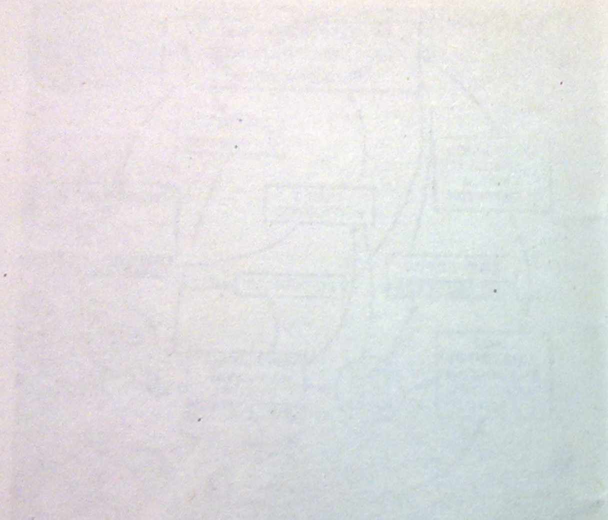
BIOGEOCHEMICAL CYCLES

Several chemical elements including carbon, hydrogen, oxygen, phosphorus, potassium, and calcium are essential to the functioning of living organisms and therefore ecological systems. Various biogeochemical cycles have evolved to ensure that plants, animals, and microbes have suitable amounts of these vital elements. Biogeochemical cycles both conserve the vital elements and keep them in circulation in the ecosystem. In need, the mortality of living organisms keeps the vital elements in circulation, enabling the ecosystem to evolve and adapt to new and changing environments. These biogeochemical cycles are themselves a product of evolution in the living system.

1. GEOLOGIC CYCLE

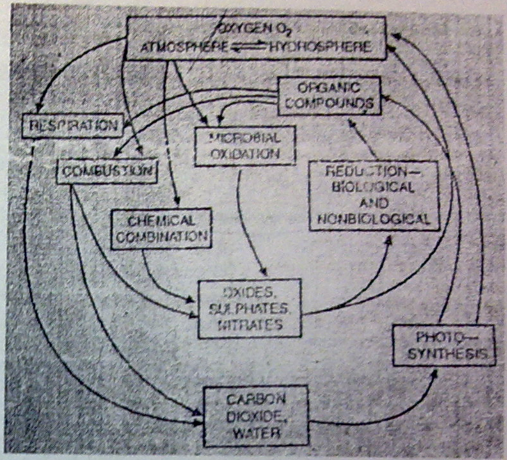
- Majority of chemical elements found in the environment are derived from parent material rocks and soil, namely igneous or sedimentary rocks
- Parent rocks are broken are broken down to finer particles by the process of weathering. These particles might be soluble or insoluble. Weathering is caused by environmental factors such as temperature, rain, wind, etc. and also by certain activities of living organisms.
- The weathered material enters the streams, river and lakes through leaching and erosion. These elements then get deposited at the bottom sediment of oceans.
- After a long period of time, they become the parent materials from which new rocks are formed again and cycle gets completed.

2. HYDROLOGIC CYCLE



- Hydrologic cycle refers to the movement of water from hydrosphere to other segments of environment.
- Solar energy is the driving force behind water cycle, which is maintained by the balance between precipitation and evaporation.
- Solar energy causes water from oceans, lakes, streams, etc. to evaporate.
- Water vapour enters the atmosphere and gathers in form of clouds and at higher altitudes, the moist air becomes cool and water vapour gets condensed
- After condensation, water precipitation as rain or snow.
- This constant movement of water from earth into the atmosphere and back to earth is known as water cycle or hydrological cycle.

3. OXYGEN CYCLE



Reservoir:

- Atmosphere holds the free O_2 that supports life on earth.
- Water and carbon dioxide are also main reservoirs of oxygen.
- Ozone in stratosphere possesses a smaller fraction of it.
- Oxygen is a vital component in organic molecules of plants and animals.
- O_2 bounded with chemical compounds in the rocks such as oxides and carbonates.
- Un-decomposed organic matter in the form of fossil fuels and carbon in sedimentary rocks also represents some reservoirs.

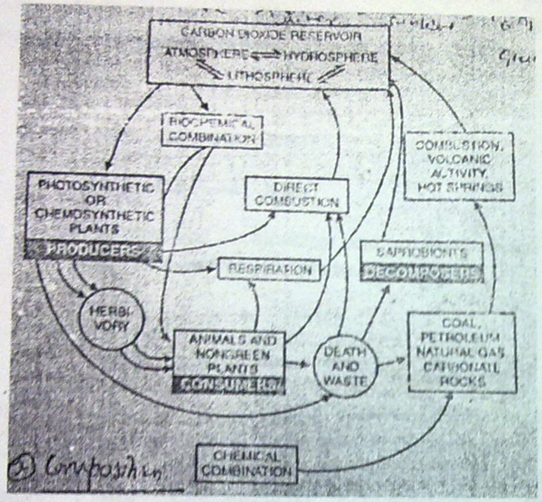
Cycling of oxygen

- Water molecules in the atmosphere are dissociated to produce hydrogen and oxygen.

$$2H_2O \dashrightarrow O_2 + 2H_2$$

- Oxygen is produced in photosynthesis in plants (presence of sunlight to breakdown water molecules to produce energy and oxygen that is released into the atmosphere)
- Removal of O_2 for the respiration of organisms including decomposers.
- Geological processes such as oxidation of sedimentary rocks.

4. CARBON CYCLE

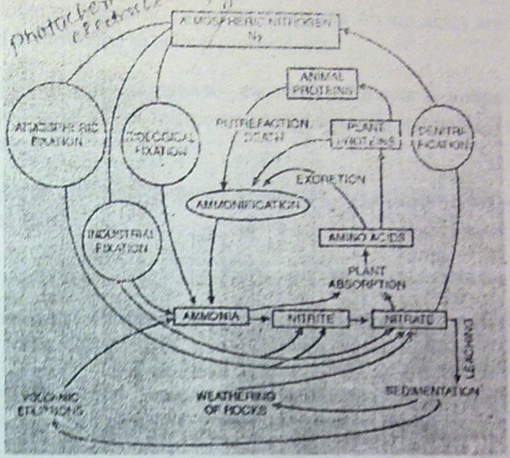


Carbon cycle consists of two phases, the organic & the inorganic phase. These two phases are closely linked and the elements moves rapidly from one phase to another.

Cycling of carbon

- Assimilation of carbon by plants through photosynthesis.
- Consumption of plant and animal matter by animals.
- Release of carbon as CO_2 during respiration of organisms.
- Conversion of organic carbon in decaying matter into inorganic forms by mineralization.
- Temporary removal of carbon from circulation due to incomplete oxidation of organic carbon and $CaCO_3$ found in oceanic sediments.

5. NITROGEN CYCLE



- In nature, nitrogen is available in its elemental form in the atmosphere and cannot be used by living organisms. It has to be 'fixed' i.e. combined with other elements such as H, C, or O_2 to become usable for the green plants.
- Useful nitrogen is nitrates and ammonia.
- Nitrogen is required for the synthesis of amino acids, proteins, enzymes.

The nitrogen cycles through the various segments of environment in six phases

1. Nitrogen fixation
2. Nitrogen Assimilation
3. Ammonification
4. Nitrification
5. Denitrification
6. Sedimentation

<u>Nitrogen fixation</u>: It is the method by which atmospheric N_2 is charged into biologically accepted form. It is of three types-

#Atmospheric Fixation: also known as electrochemical & photochemical fixation. O_2 combines with atmospheric nitrogen in presence of electric storm, lightening and UV rays. It produces different types of nitrogen oxides.

$$N_2 + O_2 \longrightarrow 2NO$$

$$2NO + O_2 \longrightarrow 2NO_2$$

$$2NO + O2 \longrightarrow N_2O_5$$

These oxides get dissolved in rainwater and are washed down to the earth where they react with other salts to form nitrates.

$$N_2O_5 + H_2O \longrightarrow 2HNO_3$$

$$2HNO_3 + CaCO_3 \longrightarrow Ca\,(NO_3)_2 + CO_2 + H_2O$$

#Biological fixation: Nitrogen fixing organisms are prokaryotes, bacteria & cyanobacteria (blue green algae). They include both - free living (azotobacter, clostridium, rhodosprillium) & symbiotic form (rhizobium, frankia, xanthomonas), cyanobacteria – anabaena, nostoc, aulasira.

N_2 fixing organisms pick up gaseous N_2 from respiratory pathways to form ammonia. Ammonia reacts with organic acid to form amino acid from which protein & other chemical produced.

#Industrial Fixation: Ammonia is produced industrially by direst combination of nitrogen with hydrogen (from water) at high temperatures and pressures. It is converted into various types of fertilizers including urea.

Nitrogen Assimilation: nitrate or ammonia is absorbed by green plants to produce organic compounds of N_2. Nitrate is first reduced to ammonia which combined with organic acids to form amino acids. The later are used in synthesis of protein, enzymes, etc.

Animals obtain their organic N_2 from plant proteins. They are first broken down to amino acids during digestion. Amino acids are then absorbed & converted to animal proteins, etc.

Ammonification: The nitrogenous excretion of plants & animals are acted upon by a no. of microorganisms especially actinomycetes & species bacillus.

These release ammonia & utilize remaining organic compounds for their metabolism.

$$\text{Protein} \xrightarrow{H_2O} R \longrightarrow NH_2 \xrightarrow{H_2O} ROH + NH_3$$

Some ammonia is liberated by atmospheric by volcanic eruptions.

Nitrification: Ammonia is oxidized to produce nitrites & then nitrates. The common nitrite bacteria include nitrosomonas, nitrococcus, nitrospira. $NH_4^+ + 2O_2 \longrightarrow NO_2 + 2H_2O - \text{energy}$

The nitrites are changed to nitrates by penicillium species & bacteria nitrobacter & nitrocystis.

$$2NO_2 + O_2 \longrightarrow 2NO_3 + \text{energy}$$

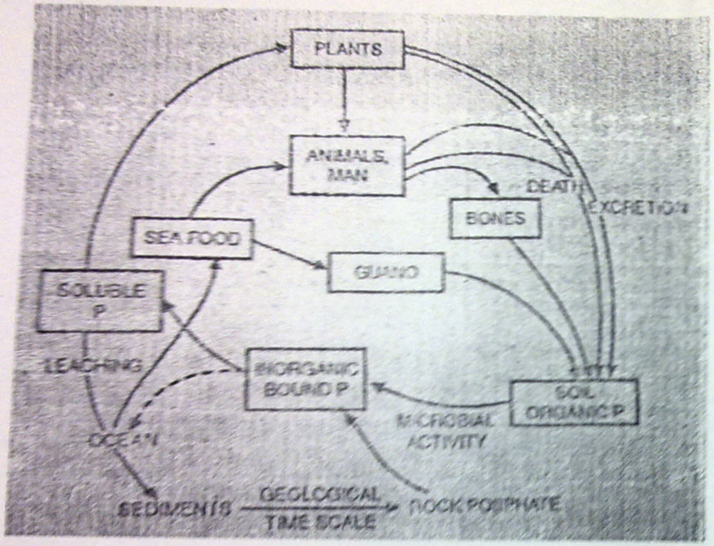
Denitrification: It occurs in some water logged soils with the help of certain bacteria e.g. thiobacillus denitrificans, micrococcus denitrificans, pseudomonas aeruginosa.

Bacteria reduce the nitrate into gaseous forms of nitrogen. They escape into atmosphere.

$$\underset{\text{(Nitrate)}}{2NO_3} \longrightarrow \underset{\text{(Nitrite)}}{2NO_2} \longrightarrow 2NO \longrightarrow N_2O \longrightarrow N_2$$

Sedimentation: Rainwater takes away a lot of nitrates & ammonium salts from soil into water bodies. Water bodies also receive the salts from industrial effluents & other wastes and settle down at the bottom.

6. PHOSPHOROUS CYCLE



- Phosphorus is 2nd most important vital element for growth of plants & animals.
- Weathering of rocks adds phosphate to soil & water.
- It is added to soil as rock phosphate, bone meal, fish meal, mud from lakes & shallow sea beds, guano & phosphate rich industries waste.
- Inorganic phosphate usually occurs in insoluble form. It is dissolved by excretion of microorganisms and roots.
- Dissolved fraction is absorbed by plants & converted into organic form.
- From plants it travels in various trophic levels.
- In animals it is deposited as part of skeleton.
- Organic phosphate is returned to soil after death of plants & animals.
- Several industries wastes contain inorganic phosphates & used in many detergents.
- Excess of fertilizer of phosphate flow with rainwater in ponds, lakes & cause eutrophication.
- Lots of phosphate is also lost through leaching.
- They become available only after long geological periods when sediments come to the earth's surface as constituent of rocks.

Unit 2 - Ecosystem

ECOLOGY comes from Greek words **oikos** (home) and **logos** (study), hence literally it stands for study of life at the home or the surrounding or environment. It can be defined as the study of interconnections and interdependence of plants, animals, and the environment.

CONCEPT OF ECOSYSTEM: Plants and animal communities of any region influence each other and interact with one another. They together form a biome or a biotic community. In a biotic community, plants, animals, microbes and the non-living environment are constantly interacting and exchanging material. Trees provide shelter to birds. Birds help in pollination and dissemination of fruits and seeds. Plants purify atmosphere. Animals provide carbon dioxide to the plants for photosynthesis. Microorganisms decay the dead plants and animals thereby returning the minerals to the soil for plants to absorb. These minerals enter animals through plants. These are just a few examples.

LEVELS OF ORGANIZATION IN NATURE

Universe
↑
Solar System
↑
Biosphere
↑
Ecosystem
↑
Community
↑
Species
↑
Population
↑
Organism
↑
Organ
↑
Tissue
↑
Cell
↑
Protoplasm
↑
Molecule
↑
Atom

In short, the living and non-living components in nature together form a stable system. In this system, different components, like the well oiled parts of a machine, are coordinated to form a single unit. This is an ecosystem. A natural unit of living communities and the non-living environment interacting and exchanging materials between themselves is called an ecological system or an ecosystem.

Ecosystem is the basic functional unit of ecology. Eco means **environment**; and system means an **interacting interdependent complex**.

SIZE OF ECOSYSTEM: There is no fixed size for ecosystems. They can be very small or large or very large. An ecosystem may be as large as grassland or a river or a desert or an ocean. It may be as small as water in a ditch, a small lump of soil or a single fallen leaf. A forest is an ecosystem; a single tree is also an ecosystem; a single fallen leaf is an ecosystem too.

A single fallen leaf as an ecosystem: It is being decomposed by thousands of microorganisms. Environmental factors of different types act. Climatic factors like light, temperature, wind, rain; edaphic factors like soil, water, soil temperature, soil pH, soil acidity, and alkalinity, and all other factors related to soil; topographic factors like exposure to sun and wind and rain; biotic factors like competition among the microbes, interrelationships among them, etc. are all working together on the dead leaf fallen on the soil. Thus it is an ecosystem.

Forest, grassland, deserts, croplands, ponds, lakes, streams, rivers, seas, oceans, estuaries, marshes, etc. are all large ecosystems. The largest ecosystem is the whole earth. This is called the biosphere, the biggest ecosystem possible on earth.

Ecological niche: Each organism, weather plant, animal, or microorganism, plays a definite role and occupies a definite position in the structure and operation of an ecosystem. This status or role of an organism within an ecosystem is called an ecological niche.

Biomass and standing crop: The total amount of living organisms present in an ecosystem is called biomass. This varies at different times of the day and in seasons. The total amount of living material in an ecosystem at a given time is called standing crop.

STRUCTURE AND FUNCTIONS OF ECOSYSTEMS

Structure includes:

1. The composition of the living beings (Biotic Component) of the ecosystem, like the species, their numbers, life history, spatial distribution, etc. The living beings may be producers, consumers, or decomposers.
2. The quality and distribution of the non-living materials like water, inorganic and organic nutrients, etc.
3. The range of climatic conditions like temperature, light, etc.

The functional aspects of ecosystem include:

1. Food chains
2. Food webs
3. Ecological pyramids
4. Biogeochemical cycles
5. Energy flow, etc.

COMPONENTS OF AN ECOSYSTEM: The two main components of an ecosystem are abiotic component and the biotic component

ABIOTIC COMPONENT: This is the non-living component of the ecosystem. The abiotic component influences the biotic component and is also influenced by it. The abiotic component comprise of three parts - inorganic, organic and physical.

A. Inorganic: The inorganic part includes water, minerals, gasses, etc. These form the nutrients or raw material for the green plants Chlorophyll- the green pigment that functions in photosynthesis- is also an important inorganic chemical. The amount of inorganic substances like phosphorus, sulphur, carbon, nitrogen, hydrogen, etc. present in the environment of an ecosystem at any given time is called the standing state or standing quantity.

B. Organic: The organic component includes compounds like carbohydrates, fats, and proteins belonging to the dead animals and plants and the excreta of animals in the ecosystem. The intermediates or end products of decomposition these substances are also part of the organic component. Decomposition by bacteria and fungi ultimately converts these organic compounds into inorganic form, which are reutilized by the plants. Bacteria and fungus thus link the biotic and abiotic component of the ecosystem.

C. Physical: The physical components include climatic factors like light, temperature, wind, etc. In water bodies, in addition to these, there is also the pH of water, wave action, etc. The most important physical component is the solar energy which flows through the entire biotic community.

BIOTIC COMPONENT: The biotic component includes living plants, animals, and microorganisms. They all need food to survive. Ultimately, all energy comes from the sun. Organisms in an ecosystem can be divided into producers, consumers, and decomposers. All these organisms are placed in different energy levels (food levels). Each energy level in an ecosystem is called a trophic level; different trophic levels differ from one another in the relative distance which separates them from the primary source of energy, i.e. the sun.

Based on nutritional level, the biotic component is again divided into autotrophic and heterotrophic components.

A. Autotrophic Component: This component includes the autotrophs. Photosynthetic plants which can manufacture their own food are called autotrophs. This includes all plants that contain green pigment chlorophyll and also photosynthetic bacteria containing bacteriochlorophyll. Chemosynthetic bacteria are also autotrophic. All these autotrophs fix energy and build up complex substances from simple substances.
In an ecosystem, the autotrophic plants are the producers or primary producers (P or PP) and these form the first trophic level (T1).

B. Heterotrophic Component: Heterotrophs are the organisms that do not have chlorophyll and therefore cannot prepare their own food. Organisms that cannot make their own food and gets their food from the green plants directly or indirectly are the consumers.

Animals, fungi and a majority of bacteria are consumers. They take in complex food materials and break them down into simple form of food. Conversion of one compound into another by rearrangement also takes place inside the bodies of consumers. The Consumers are of two types - macro consumers and micro consumers.

1. Macro-Consumers: are large sized consumers. They include the herbivores, carnivores and top carnivores.
   i. Herbivores: Animals and parasitic plants which feed directly on the green plants are called herbivores. They are consumers of the first order (C1) and belong to the second trophic level (T2). They consume only food manufactured by the producers. Insects like grasshoppers, bees, butterflies; and animals like cows, buffaloes, goats, rabbits, meadow, mice, deer, elephants, camel, monkey, etc.; and birds like parrots, koels, bulbuls, etc. are examples of herbivores.
   ii. Carnivores: Animals eating herbivores are called carnivores. They are consumers of the second order (C2) and constitute the third trophic level (T3). Insects like praying mantis, beetles and crickets; animals like small fishes, frogs, lizards, snakes, etc.; and birds like sparrows, crows, woodpecker, mynahs, etc. are carnivores.
   ii. Top Carnivores: Top Carnivores are animals that are not killed and eaten by other animals. They are tertiary consumers (C3) and constitute the fourth trophic level (T4). Top carnivore eats carnivores and herbivores while carnivores eat herbivores only. Animals like tiger, lions, sharks, crocodiles, etc.; birds like hawks, kites, owls, kingfishers, gulls, etc. are examples of top carnivores. The animals of T3 and T4 are also called predators.

The trophic levels of some animals are not clear. Best example being man. He uses both plants and all types of animals as food and is an omnivore

2. Micro-Consumers: are the decomposers. These are the saprophytic fungi and bacteria that live on or near the soil level. They obtain food from dead organisms and animal excreta. On the land, fallen leaves and twigs and in water, dead algae and parts of other water plants that fall to the bottom of the water body form the detritus. The detritus is eaten by animals like protozoa, nematodes, snails, etc. and these are called detritus eaters.
   The functions of microbes like bacteria, fungi, etc. and the detritus eaters are similar; they are all decomposers.
   Decomposers (D) are the top consumers (C4) and occupy the 5th trophic level (T5). They have a very important role in functioning of ecosystem.

BIODIVERSITY

Life originated on earth millions of years ago. It is believed that some organic molecules like simple nucleic acids were the first to evolve. Gradually, the simplest forms of life developed from them. The organisms to appear first were unicellular (organisms made up of only one cell). After thousands of years, multi-cellular organisms (made up of many cells) made their appearance. They evolved along so many lines that the whole pattern of evolution became a complicated web. The result out of this is the biological diversity or biodiversity that we see today. *Biodiversity can be defined as the totality of genes, the species, the ecosystems in a given region of the world. In a broad sense, it stands for all life on earth.*

LEVELS OF BIODIVERSITY

Biodiversity is visible at three levels in nature

- Genetic diversity: In any organism, weather unicellular or multi-cellular, the cell contains some types of hereditary material. This is in the form of nucleic acids. Most of the organisms have deoxyribonucleic acids (DNA) as their hereditary material. Each DNA molecule is made of many genes. Thus genes are the bearers of hereditary characters. The characters that pass on from one generation to the next of any organism are controlled by genes.
- Species diversity: Individuals resembling each other in all important external characters, both vegetative and reproductive

and reproductive, constitute a species. Areas rich in species biodiversity are called hotspots.

- Community or ecosystem diversity: Ecosystem are of different types. Natural ecosystems are seen in the wild while manmade ecosystems are seen in inhabited areas. As ecosystems are in general large sized, when we speak of ecosystem biodiversity, we refer to countries or states or districts. Ecosystems undisturbed by human activities have more chances of having greater species diversity. Biodiversity is the basis of stability in ecosystems. Reduction in the number of individual or specie reduces its stability. Therefore protection of single specie at cost of other species is not advisable. The whole ecosystem of which it is a part must be conserved. Overuse and also misuse of ecosystems will have long standing harmful effects on the envorinment.

THREATS TO BIODIVERSITY

- Habitat destruction
- Habitat fragmentation
- Introduction of alien species
- Desertification
- Wrong policies
- Extinction of species

PRODUCTIVITY

The rate of synthesis of energy containing organic matter by any trophic level per unit area in unit time is described its productivity. Productivity is of following types-

PRIMARY PRODUCTIVITY: The amount of energy accumulated in green plants through the process of photosynthesis is known as primary productivity. It is to two sub-types:

(a) *Gross Primary Productivity (GPP):* The total organic matter synthesized by the producers in the process of photosynthesis per unit time and area is known as gross primary productivity. It includes the weight of organic matter added in body of the producers plus the losses suffered by them due to respiration, grazing and other damages

(b) *Net Primary Productivity (NPP):* It is the weight of the organic matter stores by the producers in a unit area / volume per unit time, Net primary productivity is equal to the rate of organic matter created by photosynthesis minus the rate of respiration and other losses.

SECONDARY PRODUCTIVITY: The rate of resynthesis of organic matter by the consumers is known as secondary productivity. It depends upon the loss while transferring energy containing organic matter from the previous trophic level plus the consumption due to respiration. Respiration loss is about 20% for autotrophs, 30% for herbivores and upto 60% for case of carnivores. Therefore, net productivity decreases with each trophic level.

Yield of an ecosystem depends upon the trophic level exploited by man. It is usually T_2 or second trophic level (herbivore) which is exploited on land for protein while in ocean the trophic levels harvested by man are T_3, T_4, or T_5.

TROPHIC LEVELS

All organisms need food to survive. Ultimately, all energy comes from the sun. Organisms in an ecosystem can be divided into producers, consumers, and decomposers. All these organisms are placed in different energy levels (food levels). Each energy level in an ecosystem is called a trophic level; different trophic levels differ from one another in the relative distance which separates them from the primary source of energy, i.e. the sun. It also shows the transfer of matter (material), energy, nutrients, and minerals.

FOOD CHAIN

A food chain is a series of populations through which food and the energy contained in it passes in an ecosystem. A food chain is simple if it it has only one trophic level besides the decomposers, e.g. Eichornia in eutrophic pond. A complex food chain has both producer and consumer trophic levels. Trophic levels are various steps in the passage of food. There are three main types of food chain: (i) predator food chain; (ii) saprophytic food chain; (ii) auxiliary food chain.

PREDATOR OR GRAZING FOOD CHAIN

It is a food chain characterized by predation or catching and killing for feeding. A predator food chain consists of both autotrophs and heterotrophs. Autotrophs are producers while heterotrophs are consumers, e.g.

Grass ⟶ Rabbit ⟶ Fox ⟶ Wolf ⟶ Tiger

SAPROPHYTIC OR DETRITUS FOOD CHAIN

It is a food chain based on organic wastes, dead parts (e.g. fallen leaves) and dead bodies.

The dead organic matter (e.g., leaf litter, fallen twigs, decaying roots, corpses, dung, etc.) are acted upon by three types of organisms – scavengers, detrivores and decomposers. Scavengers feed on dead bodies (e.g. vultures), Detrivores are organisms which directly feed on organic fragments e.g. termites, worms, beetles, insects (in terrestrial ecosystems), insects larvae, copepods, nematodes, amphipods, etc. (in aquatic ecosystems). Decomposers solublise organic remains through excretion of digestive enzymes. The solubulised food is absorbed. Mineralization occurs in the process. The decomposers include bacteria, actinomycetes and fungi. The latter are in turn preyed upon by several small animals including protozoans. These animals are consumed by smaller carnivores which in turn become the food of larger carnivore and so on. E.g.

Detritus ⟶ Earthwork ⟶ Sparrow ⟶ Falcon

AUXILIARY OR SUBSIDIARY OR ACCESORY FOOD CHAIN

A common auxiliary food chain is parasitic food chain. It is terminated by parasitic. Parasitic is an organism that feeds on another living organisms called host. Depending upon the trophic levels of the host, the chain may be long of short, e.g.

Green plant ⟶ Sheep ⟶ Liver Fluke

FOOD WEB

Food does not always pass from one population to others in a linear sequence as in a food chain. An organism can operate at more than one trophic level and obtain its requirement of food from different sources. Similarly organisms may be eaten by a number of different organisms. In certain cases the kind of food changes with age and easy availability. Food Web or Food Net is the interlocking of different food chains by developing interconnections at various trophic levels so as to form a number of feeding interactions in a biotic community

Unit 3 – Water Pollution

WATER QUALITY
PHYSICAL CHARACTERISTICS OF WATER
CHEMICAL CHARACTERISTICS OF WATER
BIOLOGICAL CHARACTERISTICS OF WATER
PHYSICAL CHARACTERISTICS OF WASTE WATER
CHEMICAL CHARACTERISTICS OF WASTE WATER
BIOLOGICAL CHARACTERISTICS OF WASTE WATER
GROUND WATER POLLUTION
WATER BORNE DISEASES