KARNATAKA STATE OPEN UNIVERSITY

MUKTHAGANGOTHRI, MYSORE – 570 006

M.Sc. in Environmental Science

(FIRST SEMESTER)

Course: MESDSC 1.1 **Block I**

FUNDAMENTALS OF ENVIRONMENTAL SCIENCE

Karnataka State Open University

Mukthagangotri, Mysuru - 570 006

Department of studies in Environmental science

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First Semester
(CBCS Mode)

Course: MESDSC 1.1

Fundamentals of Environmental Science

Block I: Unit 1, 2, 3, 4

MESDSC 1.1: Fundamentals of Environmental Science

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BLOCK I

INTRODUCTION

The fundamentals of environmental science are referred to the introduction to environmental study. It primarily takes into account all the areas that are concerned with the physical, chemical and the biological surroundings in which the organisms live. It draws deeply upon the aspects of life and the earth sciences. On the other hand, there are some overlaps that are unavoidable. The individuals, who are interested in studying and learning about the environments will acquire understanding of the fundamentals of environmental science in this research paper. Environmental science is a broad area, it provides concise, non-technical explanations of physical processes and systems and the effects of human activities.

The block I consists of four units. Unit 1 gives you about the Introduction to the Environmental Science such as definition, perspective, scope. In Unit 2, Hydrosphere is discussed with its importance, distribution and sources, and properties of water. Water budget with consumption use and water pollution is discussed. Unit 3 elaborates on lithosphere, with internal structure of earth. Unit 4 describes the biosphere, here it is elaborated with biome and aquatic life zones, interacting components of natural and social environment.

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UNIT 1: INTRODUCTION TO ENVIRONMENTAL SCIENCE

STRUCTURE

1.0 Objectives

1.1 Introduction

1.2 General Perspectives of Environmental Science

1.3 Multidisciplinary Facets of Environment

1.4 Principles and Scope of Environmental Science

1.5 Evolution of environment

1.6 Earth's Atmosphere - Troposphere, stratosphere, mesospehere; thermosphere; ionosphere;

1.7 Energy transfer in Atmosphere; Radiation; Conduction; Convection.

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1.9 Keywords

1.10 Questions for Self Study

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1.0 OBJECTIVES

After studying this unit, you will be able to

- explain general perspectives of environmental science
- describe the multidisciplinary facets of Environmental Science
- explain the scope of Environmental Science
- discuss how evolution of environment took place
- describe the Earth's atmosphere with different layers.
- explain the energy transfer in the atmosphere

1.1 INTRODUCTION

Environmental science encompasses many interconnected issues involving human population, earth's natural resources, environmental pollution etc. and combines information from many disciplines, such as biology, geography, geology, chemistry, physics, economics, sociology, demography (the study of populations), cultural anthropology, natural resources management, agriculture, engineering, law, politics, and ethics.

A critical observation of your surroundings might have ignited an array of questions in your mind, at least once. How did life and its surroundings originate on earth? How did this life branch out leading to the current diversity on earth? What is the significance of our surrounding? Is it changing because of our intervention? Should we do something to restore homeostasis of the surroundings? So on and so forth. Before trying to answer the above questions let us understand the basics of 'Environmental Science' which in turn would address these issues. The word "environment" originates from "environ" and refers to the 'things that surround'. The environment of an organism consists of all the physical and biological surroundings and their interactions (Environment Protection Act). Environment can also be defined as the sum total of all conditions and influences that affect the development and life of all organisms on earth.

Ecology is a branch of biology and a basic tool of environmental science and aims at the study of interrelationships between organisms and their environment. The word 'ecology' is derived from the Greek *oikos*, meaning "household," and *logos*, meaning "study." Thus, the study of the environmental house includes all the organisms in it and all the functional processes that make the house habitable. Ecology might therefore be thought of as the study of the 'home life' of living organisms. The environment of an organism consists of all those factors and phenomena outside the organism that influence it, whether these are physical and chemical (abiotic) or other organisms (biotic). In common usage, "environmental science" and "ecology" are often used interchangeably, but technically, ecology refers only to the study of organisms and their interactions with each other and their environment (fig-1shows the levels of organization of matter in nature. Ecology focuses mainly on organisms, populations, community, ecosystem and biosphere). In practice, there is considerable overlap between the work of ecologists and other environmental scientists.

1.2 GENERAL PERSPECTIVES OF ENVIRONMENTAL SCIENCE

Frontier economics thinking is an environmental perspective that prevailed in industrial economies of developed countries until the rise of environmentalism around the 1960s. This environmental perspective is founded on the belief that nature is an infinite supply of physical resources including raw materials, energy, water, soil, and air. These resources are present mainly for human benefit. Nature is treated as an infinite sink of resource consumption by-products in the form of pollution and ecological degradation. Adherents of this environmental perspective do not recognize a biophysical "environment" to be managed because it is considered irrelevant to the economy.

The environmental protection perspective came into focus with Rachel Carson's (1962) Silent Spring book that revolutionized the environmental movement. The book was instrumental in the creation of the now well-known US Environmental Protection Agency (EPA). Rachel Louise Carson was an American marine biologist and conservationist whose book Silent Spring and other writings are credited with advancing the global environmental movement. Her work along with other scientists linked synthetic pesticides like Dichlorodiphenyltrichloroethane (DDT) with near extinction of bird species. Shell thinning of bird eggs due to DDT caused death of birds through bioaccumulation; thus, silent spring ensued as there are no birds to sing their melodious songs. To address problems of environmental pollution, the environment must be protected.

The resource management environmental perspective appears to be the ideal approach to environmental management nowadays. It promotes wise use of resources through regulation of human behavior and activities. Natural resources, both tangible and intangible, are used in an organized and efficient manner. Resources referred to here, include land, water, labor, capital, organization, skills, as well as people's belief systems. It is believed that traditional ways are compatible uses of the environment because these practices have evolved through time and are desirable for continued survival. Greater emphasis is given on long-term sustainability of resource use and development activity. This environmental perspective encourages energy efficiency, resource conservation, pollution prevention, ecological restoration, ecosystem and social health monitoring, and "polluter pays" principle. The economy is embedded within the ecosystem.

Nevertheless, the eco-development environmental perspective champions restructuring of the relationship between society and nature into a “positive sum game” through sophisticated symbiosis. Economic restructuring incorporates ecological principles. It integrates all the concerns of other perspectives. Man and nature should co-evolve. It advocates “green development “where land use planning includes consideration of community-wide or regional environmental implications of development, as well as site-specific concerns.

1.3 MULTIDISCIPLINARY FACETS OF ENVIRONMENT

An interdisciplinary academic subject concerned with the inquiry, research, and extension of knowledge about the living and physical environment, environmental sciences comprises a variety of disciplines. The ability to better understand environmental, natural, political, technical, economic, social, and cultural factors is also aided by this skill.

The term "multidisciplinary" refers to the fact that it encompasses more than one branch of study or discipline. Environmental Science in diverse domains are more effective when they are multi-sectoral and multi-dimensional.

Environmental Studies is vital in understanding our natural environment and occurrences. Several issues highlight the significance of the multidisciplinary nature of environmental studies.

- It aids in learning about current environmental challenges.
- It teaches us to solve environmental problems, including pollution, global warming, and climate change.
- It helps maintain ecological balance by teaching basic environmental systems and processes.
- It tells us about anthropogenic changes in the environment.
- It also teaches us how to analyse different environmental strategies and changes caused by human activity. It aims to conserve biodiversity.
- It familiarises us with varied flora and wildlife.
- It shows us how to preserve and safeguard them.
- It makes us aware of our environmental responsibilities.
- It also teaches us the urgent necessity to address environmental challenges.
- Environmental studies address concerns like energy conservation, hazardous emissions, water conservation, waste disposal, global warming, and many more.

- It aids in creating insights into human processes, natural events, and environmental changes.

Environmental Science include several components. These are:

- Biology is the study of living things. Physico-chemical processes, molecular interactions and evolution are all covered. Environmental Science is linked to biology since it concerns live beings' natural habitat.
- Chemistry is the study of chemicals and the components of matter. Understanding Environmental Science natural phenomena require chemistry understanding.
- Computer Science: As the world advanced, computers became essential. The EPA uses computers to track contaminants in soil and water.
- Geology is the study of Earth's physical structures and substances, as well as their history and processes. Environmental Science also studies the planet and environment.
- Economics studies the production, consumption, and distribution of goods and services. Various economic techniques have been devised to protect the environment from pollution, global warming, and climate change.
- Physics studies energy, matter, and their interactions in space and time. Physics addresses concerns about the environment.
- Sociology is the study of social life, change, causes, and consequences. It also discusses the relationship of modern civilisation to the environment.
- Statisticians gather, analyse, interpret, and present quantitative data. It also analyses data to identify patterns and recommends the best environmental growth.

1.4 PRINCIPLES AND SCOPE OF ENVIRONMENTAL SCIENCE

A critical observation of your surroundings might have ignited an array of questions in your mind, at least once. How did life and its surroundings originate on earth? How did this life branch out lead to the current diversity on earth? What is the significance of our surrounding? Is it changing because of our intervention? Should we do something to restore homeostasis of the surroundings? So on and so forth. Before trying to answer the above questions let us understand the basics of 'Environmental Science' which in turn would address these issues. The word "environment" originates from "environ" and refers to the 'things that surround'. The environment of an organism consists of all the physical and biological surroundings and their interactions (Environment Protection Act). Environment can also be defined as the sum total of all conditions and influences that affect the development and life of all organisms on earth.

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The environment science provides detailed information about our surroundings, its importance and influence on organisms, including human beings. It even talks about the protection and conservation of our surroundings, which is being destroyed/altered due to human intervention. At present a great number of environment issues, have grown in size and complexity, threatening the survival of mankind on earth. Man is himself an organism within an environment. Like other animals, man is influenced by the physical features of his environment and absolutely dependent upon other species for his food, clothing, medicine, and other similar aspects and he has to adjust to other individuals of his own species. Therefore, the basic laws of ecology apply well to him and its fundamental knowledge is must for man for his own existence on this planet (Earth). Man almost always has a modifying influence, and without proper regulation he often has a destructive effect. For instance, by applying certain ecological principles to such fields as agriculture, biological surveys, game management, pest control, forestry, horticulture, and fishery biology, he has received tremendous economic gains. Its knowledge is found critically important for intelligent conservation whether in relation to soil, forest, wildlife, water supply or fishery resources.

Further, rapid growth of urbanization and fast rate of multiplication of human population have resulted in fatal threat of scarcity of wild life, food, open space, and of survival. There are certain other ecological problems. Agriculture and now forestry are concentrating upon monoculture or single species ecosystems–in spite of the difficulties and dangers associated with unnaturally simplified ecosystems that lack a diversity of species. Over much of the world, especially in the grasslands, we continue to disrupt the energy balance through overgrazing and end up with eroded mountain sides, silt-clogged streams and lakes, and a scarcity of water. Therefore, future of human life on earth demands more knowledge about the ecosystems and other ecological problems.

Environmental Science encompassed with current scientific knowledge and it is very important to better manage the natural resources.

Ecology and soil pollution: involves understanding relationships among the organism in the environment & understanding the nature and cause of soil contamination.

Marine/Aquatic Biology: studying and understanding marine ecosystems and their management.

Earth system science: The study of our environment's linked components—the atmosphere, hydrosphere, lithosphere, cryosphere, and biosphere—and how they interact to generate an integrated whole.

Environmental and conservation biology: studies of nature and biodiversity conservation to safeguard species, habitats, and ecosystems from extinction and the erosion of biotic interactions.

Climate Change and Energy: the study of energy and climate issues from various perspectives, including physical and social disciplines, to identify practical answers and strategies for both problems.

Management of Water Resources: The programme studies hydrological and biogeochemical processes in watersheds and bodies of water that flow into them.

Pollution Avoidance and Remediation: Upon completion of the programme, one will be able to identify pollutants, describe the extent and implications of pollution in the environment, and identify and assess remediation and prevention approaches.

Management of Natural Resources: intends to offer students with expert knowledge in techniques to efficiently manage natural resources in the context of more significant sustainability challenges and environmental management.

1.5 EVOLUTION OF ENVIRONMENT

As mentioned earlier, environment refers to the things that surround us. Let us briefly understand the evolution of our surroundings. Though there are many theories on the formation of this universe, we will consider the Big Bang model, or theory, which explains the early development of the universe. The theory tries to explain some of the earliest events in the universe (but not the absolute earliest state of things, or where it comes from). Our universe was once in an extremely hot and dense state that expanded rapidly (a "Big Bang"-remember there was no explosion). Big Bang caused the young universe to cool and resulted in the present diluted state that continues to expand today. Based on the best available measurements as of 2010, the original state of the universe existed around 13.7 billion years ago, which is often referred to as the time when the Big Bang occurred. The theory is the most comprehensive and accurate explanation supported by scientific evidence and observations.

Georges Lemaître proposed what became popularly known as the Big Bang theory of the origin of the universe. 'Hypothesis of the primeval atom' was the name given by him for his theory. The framework for the model relies on Albert Einstein's general relativity and on simplifying assumptions. The governing equations had been formulated by Alexander Friedmann. When the universe was less than 10-43 seconds old, the almost infinitely dense universe experienced some quantum fluctuations, which determined the whole future course of universal history. By 10 microseconds after the birth of the universe, protons and neutrons had formed. When the universe was one millisecond old, it was denser than the nucleus of an atom, consisting neither of energy nor matter as we know them today. As the universe expanded and cooled, particles, then hydrogen atoms, formed. Almost equal amounts of matter and antimatter were produced and canceled each other out; the slight excess of matter (one part in 100 billion) that survived is what the universe is made of. During early moments matter was an ultra super dense brew of particles called 'quarks'. This mixture had sparkling electrons, photons and other light elementary particles. At this time the temperature was more than 10000 times hotter than the suns core.

Out of this brew plasma rather than a gas evolved. For a long time, heat prevented chemical combination of protons. It is speculated that the early universe would have appeared as a dense mass of fog. When temperature was around 3000K, atoms were formed by combinations. As a result of this the universe became transparent. After the combinations, the ordinary matter in the universe consisted entirely of neutral hydrogen and helium with a little bit of lithium. The universe was still hot, extremely dense and dark as there was no star to emit visible light. This period is known as Dark Age. At some stage, dark matter particles experienced only gravity and began pulling themselves together into clumps. Gravity would have attracted the neutral atoms of hydrogen and helium to the clumps, leading eventually to a very vast cloud consisting of both forms of matter in the center of which the first massive star was born. Our solar system is calculated to have originated by condensation from a rotator mass of gas and dust about 4.6 billion years ago. Inside the larger stars, additional fusion reactions produced atoms larger than helium. These stars gradually expand and become dimmer. At some point, most stars explode. The largest stars explode into supernovae. One supernova can release as much energy as an entire galaxy. Gravity began to pull these atoms together again in a flat, circular, swirling mass. The hydrogen in the dense center of the circle ignited once again in fusion reactions about five billion years ago. This was the birth of the Sun. The atoms away from the center formed clusters (planetesimals), some of gases, others of heavier elements. The gaseous clusters never produced sufficient pressure to ignite; they became the gas giant planets Jupiter, Saturn, Uranus, and Neptune. The clusters of heavier elements became the remaining planets, including our 'Earth'. More than 150 planets have been detected revolving around other stars. Eventually the Sun will cool to a red color and expand, becoming a red giant. Life on Earth will have ended before this. About the time, five billion years from now, that the Sun explodes, the Milky Way galaxy will collide with the Andromeda galaxy. Although galaxies are mostly empty space, gravitation will draw stars together in many colorful explosions.

Most mythologies contain a nearly instantaneous creation of the Earth by one or more gods, followed shortly thereafter by the creation of humankind. As the documentation of fossils began, it became apparent that there was a time early in the history of the Earth when complex life-forms did not yet exist. Radiometric dating has become a very precise method of determining the periods of time in which different fossilized species lived, the times at which major Earth catastrophes occurred and of the age of the Earth. The Earth formed about 4.6 billion years ago. Its initial heat, plus the impacts of extraterrestrial debris prevented the formation of oceans until about 3.8 billion years ago. According to most evolutionary scientists, life began shortly after the oceans formed.

Earths first atmosphere which consisted of hydrogen and helium did not last. A secondary atmosphere arose between 4.2 and 3.8 billion years ago largely from volcanic out gassing. But comets were the sources of many gases especially water vapour. Major constituent of secondary atmosphere is thought to have been water vapour and CO_2; other gases probably include hydrogen (H_2), carbon monoxide (CO), nitrogen (N_2), ammonia (NH_3), methane (CH_4), hydrogen sulphide and hydrochloric acid. As the time went on, earth's surface temperature cooled and liquid water formed allowing CO_2 to be absorbed by oceans and to react with silicates to produce carbonates and reduced CO_2 in atmosphere. A number of noble gases such as neon, argon, xenon also may have been prevalent and should have persisted. Earth today is a layered structure. But when the earth was formed, collisions and radioactive decay of elements already present caused the temperature to increase substantially. As a result earth became molten, heavier elements particularly iron sunk inwards while lighter materials gravitated towards the surface.

Until recently the oldest rocks found on Earth were about 3,800 million years old, leading scientists to believe for decades that Earth's surface had been molten until then. Accordingly, they named this part of Earth's history the Hadean eon, whose name means "hellish". However analysis of zircons formed 4,400 to 4,000 million years ago indicates that Earth's crust solidified about 100 million years after the planet's formation and that the planet quickly acquired oceans and an atmosphere, which may have been capable of supporting life. Soil, a combination of mineral particles and decomposed organic matter, did not exist. Land surfaces would have been either bare rock or unstable sand produced by weathering. Water and any nutrients in it would have drained away very quickly.

Origin of life

One of the greatest challenges to evolutionary science has been to explain how life began. Cells were probably in existence by 3.5 billion years ago, which was not very long after the oceans themselves formed. Evolutionary scientist J. William Schopf has found evidence, albeit controversial, of cells in rocks of the 3.5- billion-year-old Apex chert of Australia. Schopf claims to have recognized at least 11 different kinds of cells, which resemble modern cyanobacteria (Eg., blue green algae). The oldest sedimentary rocks in the world—3.8 billion years old—come from the Isua formation of Greenland. These rocks contain no fossils but do contain carbon compounds with an isotope ratio that suggests that it is of biological origin. Until 3.9 billion years ago, the solar system was filled with errant asteroids and comets that crashed into the planets. On Earth, evidence of this bombardment has been largely erased by erosion; however, on the Moon, the craters (hollow or depression) have been preserved. Collisions with asteroids may have vaporized any oceans, and any life they might have contained. It appears that the origin of life is bracketed between 3.9 billion years ago, before which life would have been eliminated, and 3.8 billion years ago, by which time life was already in existence.

There are three possibilities for where life originated:

1. Life evolved on Earth only

According to the Rare Earth hypothesis, the conditions necessary for complex life are so uncommon that the Earth may in fact be the only planet on which complex life has evolved. They also assume that bacterial life might be common in the universe.

2. Life evolved someplace else, and was then transported to the Earth

This hypothesis is called panspermia ("seeds everywhere"). Swedish chemist Svante Arrhenius brought up this idea early in the 20th century. Astronomers Fred Hoyle and Chandra Wickramasinghe have quite seriously suggested that the first cells came to the Earth from outer space, from a "life cloud". The Martian meteorite, ALH84001 contains organic molecules, and structures that may be bacterial fossils. Despite these suggestions, it is unlikely that Martian bacteria would have survived being ejected from Mars, the journey through outer space, and falling through the atmosphere. It is therefore unlikely that meteorites brought the molecules of life to the Earth.

3. Life evolved on Earth, but also in other places

This idea is popular among scientists because the universe is, in fact, full of organic molecules. On the Earth today, all organic molecules have a biological origin: Even petrochemicals are the products of plants that died millions of years ago. But organic molecules can be produced during the same processes that form stars and solar systems. Organic chemicals (for example, naphthalene) are common in nebulae. There are at least 27 kinds of organic molecules, some quite complex, in the tails of Halley's and Hale-Bopp comets. The Murchison meteorite, a carbonaceous meteorite that fell in Australia in 1969, contained at least 74 kinds of molecules, of which eight are amino acids found today in living cells, as well as fatty acids, glycerol, and purine and pyrimidine bases (found in nucleic acids such as DNA). This was also true of the Tagish Lake meteorite, which fell in Canada in 2000. Careful analysis discounted the possibility that these molecules were terrestrial contaminants.

The presence of organic molecules in outer space does not explain where terrestrial organic molecules came from. It demonstrates that the universe has produced immense amounts of the very kinds of organic molecules from which life is made—and this could have happened on the early Earth as easily as anyplace else in the universe. Because organic molecules are so common in the universe, the presence of PAH (polycyclic aromatic hydrocarbons) in the famous Mars meteorite is not itself evidence of life. [The study of life outside of the Earth is called astrobiology ("star-life"), formerly called exobiology ("outside life")].

A. Producing the molecules.

Biological molecules can form from inorganic molecules. Jons Berzelius, one of the most famous chemists of the early 19th century, said in 1827 that organic molecules could not be made from inorganic sources. The very next year, his friend and former student Friedrich Wohler synthesized urea, known at that time only from kidneys, simply by heating ammonium cyanate. Louis Pasteur showed that life comes only from life today and under normal conditions (the law of biogenesis), but many 19th- and early 20th-century scientists speculated about the abiotic origin of life (abiogenesis)

1. What was the energy source?

To make simple inorganic molecules into complex organic molecules, energy is necessary. The early Earth had numerous sources of energy for the synthesis of organic molecules: lightning, ultraviolet light, cosmic radiation, and heat from asteroid bombardments and volcanoes, to name a few.

During the mid-20th century, the atmosphere of the early Earth was assumed to be reducing, consisting of molecules such as methane, ammonia, water vapor, and hydrogen. By the late 20th century most scientists believed that the early Earth atmosphere was neutral, consisting largely of carbon dioxide. Recent evidence suggests that the atmosphere might have contained a substantial amount of methane after all. Based on studies of siderite minerals from the earliest sedimentary rocks, some scientists have suggested that the atmosphere could not have contained enough CO_2 to have produced the greenhouse effect that was known to have prevailed on the Earth at that time, and that methane, a potent greenhouse gas, might have been largely responsible for the warmth of the atmosphere and Earth. The only fact on which there is universal agreement is that the atmosphere of the early Earth contained virtually no oxygen.

Many scientists assume that life must have originated in shallow seas. One problem with this hypothesis is that the same ultraviolet radiation that would provide energy to organic syntheses would also have destroyed the molecules. Some scientists, such as geologist John Corliss, have asserted that life originated in deep ocean vents, where water meets lava. This has the disadvantage that the heat itself could have destroyed the organic molecules as easily as it created them. Some bacteria that live under those conditions today have special adaptations that prevent the heat from disrupting their molecules. The deep sea vents have abundant ferrous ions, which would have produced a reducing environment and encouraged the synthesis of organic molecules.

Evidence for the origin of organic molecules on the early earth

Many scientists, starting with Aleksandra Ivanovich Oparin in Russia and J. B. S. Haldane in England, have suggested that organic molecules came into existence under the conditions of the primordial Earth. During the second half of the 20th century, numerous simulations of early Earth conditions have been conducted in laboratories. The earliest, and still most famous, of these simulations was conducted by biochemist Stanley Miller in 1953. He put a mixture of reducing gases (including methane and ammonia) into glassware that circulated the gases through water and past an electric spark. Organic molecules accumulated in the flask. Interestingly, the product was dominated by a few molecules: formic acid, glycine, glycolic acid, alanine, lactic acid, acetic acid, and propionic acid, in descending order. In much smaller quantities were urea, aspartic acid, and glutamic acid. Four of these were amino acids (glycine, alanine, aspartic acid, and glutamic acid). In 1960, chemist John Oro conducted a similar experiment that produced adenine. All of these molecules are used by organisms today. Amino acids are the building blocks of proteins, which are largely responsible for the complexity of life processes. The world was astounded that the building blocks of life could be so easily produced by simple chemical reactions.

Producing all of the necessary molecules

Although many organic molecules can be formed in laboratory simulations, many of the molecules that are essential to life today had not been formed in these simulations. Ribose, a component of RNA, would have been especially difficult to form. In order to obtain the different molecules necessary for life, very different conditions of acidity and temperature are needed. For example, freezing conditions are necessary to preserve adenine and guanine, while for cytosine and uracil warm evaporative conditions are needed.

Synthesis of large molecules from small precursors.

The production of small organic molecules may have been easy on the primordial Earth. But, the assemblage of these small molecules into polymers like proteins, nucleic acids etc is a difficult task. But, there are two processes that may have allowed the formation of large molecules on the primordial Earth:

1. Activated precursors.

Regular amino acids do not polymerize into proteins in water very well, but amino acids in the amide form do. As biochemist James Ferris explains, carboxyanhydrides can form into protein-like molecules in water.

2. Adsorption on mineral surfaces

Small molecules bumping into one another in watery swirls would be unlikely to form the complex molecules characteristic of life. In many chemical reactions, solid surfaces allow the orderly catalysis of reactions. J. D. Bernal, a British biochemist, first proposed the possibility that the synthesis of large molecules from small ones may have occurred on clay mineral surfaces. Clays certainly provide an enormous amount of surface area for such reactions to take place. Leslie Orgel calls this possibility "life on the rocks" and has demonstrated that RNA molecules of length up to 40 bases can be produced on a mineral surface. RNA molecules of this size would be long enough to get the RNA world started.

Assembly of complex chemical systems-Modern life, even of the simplest bacteria, is too complex to have arisen directly. In modern cells, DNA stores genetic information, which is transcribed into RNA, which directs the formation of proteins. As microbiologist Carl Woese proposed in 1967, scientists realize that a simpler genetic system of life must have preceded that of DNA in the modern cell. Once modern DNA cells came into existence, they would have outcompeted the more primitive form which, therefore, no longer exists.

- The first genetic molecule may have been something like TNA (threonucleic acid) or PNA (peptide nucleic acid). The formation of such molecules could have occurred more readily on the early Earth (in particular, TNA contains no ribose); it works in a fashion similar to DNAand RNA; and it can bind with DNA and RNA, which means that it could have transferred its genetic information to RNA during the evolution of a new RNA-based life-form. In 2000, Israeli scientists proposed that the first genetic system may have consisted of lipid-like molecules that can not only form cell-like structures that grow, but also pass information into the new cells.

- It is widely accepted, following the lead of biochemist Manfred Eigen, that an RNA-based genetic system would have preceded a DNA-based system, for several reasons. Biochemists Thomas Cech and Sidney Altman, who won the Nobel Prize for Chemistry in 1989, showed that RNA can act as an enzyme (they are called ribozymes). That is, RNA can be both genotype and phenotype. Some organisms, such as the protista *Tetrahymena thermophila*, use ribozymes. Many scientists consider the ribosome, which is built of both RNA and protein, and in which it is the RNA that has catalytic activity, to be a remnant of the time when RNA was the blueprint of life, and in the laboratory, RNA can catalyze its own reproduction. Strings of RNA containing guanine result when RNA molecules containing cytosine are used as a template.

Chemist Walter Gilbert proposed the 'RNA world' scenario in 1986. In this scenario, the primordial seas were filled with RNA molecules that replicated themselves and therefore constituted a primitive form of life. Later, according to evolutionary biologists John Maynard Smith and Eors Szathmary, these RNA molecules were assisted by amino acids, which resulted in the origin of the genetic code. Still later, complex DNA replaced simple RNA as a more stable form of genetic information—but living cells never got rid of the RNA completely.

Formation of the first cells

The final step in the origin of life would be to explain how the life reactions could have been isolated into cells—a step necessary to keep the waves of the ocean from separating and diluting them. Most modern cell membranes are made from phospholipids, which are molecules that can bridge the gap between fatty and watery molecules. Lipid-like molecules are today found in sea foam. Some scientists suggest that this sea foam, in shallow primordial ponds, may have formed the first cell membranes. Other scientists have formed micelles, which are clusters of molecules that carry out chemical reactions and replicate themselves, in the laboratory, and they propose that the first cells may have resembled these micelles. At some point, the origin of cells must be explained. Life may have been in operation for a long time before it was compartmentalized into cells, according to Carl Woese, who has described a life state that preceded life-forms. In conclusion, scientific research has illuminated many possibilities for the origin of life, in particular answers to the questions of when and where; but for now scientists will have to be satisfied with not knowing a definite answer to the questions of how.

The earliest widely-accepted animal fossils are rather modern-looking cnidarians (the group that includes jellyfish, sea anemones and hydras), possibly from around 580 million years ago, although fossils from the Doushantuo Formation can only be dated approximately. Their presence implies that the cnidarian and bilaterian lineages had already diverged. Tetrapods, vertebrates with four limbs, evolved from other rhipidistian fish over a relatively short timespan during the Late Devonian, between 370 million years ago and 360 million years ago

Spores of land plants, possibly rather like liverworts, have been found in Mid Ordovician rocks dated to about 476 million years ago. In Mid Silurian rocks 430 million years ago there are fossils of actual plants including clubmosses such as Baragwanathia; most were under 10 centimetres (3.9 in) high, and some appear closely related to vascular plants, the group that includes trees. By the Late Devonian 370 million years ago, trees such as Archaeopteris were so abundant that they changed river systems from mostly braided to mostly meandering, because their roots bound the soil firmly. There is fossil evidence that flowering plants diversified rapidly in the Early Cretaceous, between 130 million years ago and 90 million years ago, and that their rise was associated with that of pollinating insects.

1.6 EARTH'S ATMOSPHERE - TROPOSPHERE, STRATOSPHERE, MESOSPEHERE; THERMOSPHERE; IONOSPHERE

Earth's atmosphere has a series of layers, each with its own specific traits. Moving upward from ground level, these layers are called the troposphere, stratosphere, mesosphere, thermosphere, and exosphere. The exosphere gradually fades away into the realm of interplanetary space. The layers of the atmosphere is given in Fig. 1.

Troposphere

The troposphere is the lowest layer of atmosphere of the Earth and the layers to which changes can greatly influence the floral and faunal environments. The troposphere extends from the surface of the Earth to a height of approximately 10 km above sea level. The troposphere is bounded above by the tropopause, a boundary marked in most places by a temperature inversion (i.e. a layer of relatively warm air above a colder one), and in others by a zone which is isothermal with height.

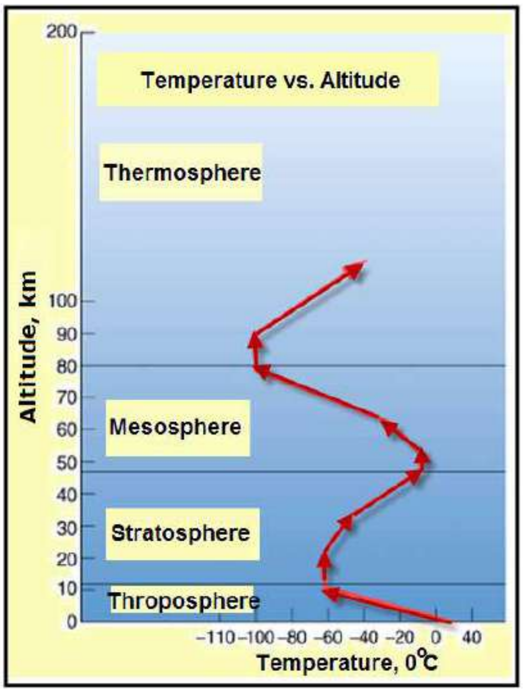

Fig. 1: The atmospheric layers of the Earth

Although variations do occur, the temperature usually declines with increasing altitude in the troposphere because the troposphere is mostly heated through energy transfer from the surface. Thus, the lowest part of the troposphere (i.e. the surface of the Earth) is typically the warmest section of the troposphere, which promotes vertical mixing. The troposphere contains approximately 80% of the mass of the atmosphere of the Earth. The troposphere is denser than all its overlying atmospheric layers because a larger atmospheric weight sits on top of the troposphere and causes it to be most severely compressed.

Air present in the troposphere, have various mixture of gases. The composition of air is given in the Table 1.

Table 1: Composition of Air

Element	Volume %	Weight %	PPM (Volume)	Element	Molecular Weight of the element
Nitrogen	78.08	75.47	780790	N_2	28.01
Oxygen	20.95	23.20	209445	O_2	32.00
Argon	0.93	1.28	9339	Ar	39.95
Carbon Dioxide	0.040	0.062	404	CO_2	44.01
Neon	0.0018	0.0012	18.21	Ne	20.18
Helium	0.0005	0.00007	5.24	He	4.00
Krypton	0.0001	0.0003	1.14	Kr	83.80
Hydrogen	0.00005	Negligible	0.50	H_2	2.02
Xenon	8.7×10^{-6}	0.00004	0.087	Xe	131.30

Stratosphere

The next layer up is called the stratosphere. The stratosphere extends from the top of the troposphere to about 50 km (31 miles) above the ground. The infamous ozone layer is found within the stratosphere. Ozone molecules in this layer absorb high-energy ultraviolet (UV) light from the Sun, converting the UV energy into heat. Unlike the troposphere, the stratosphere actually gets warmer the higher you go! That trend of rising temperatures with altitude means that air in the stratosphere lacks the turbulence and updrafts of the troposphere beneath. Commercial passenger jets fly in the lower stratosphere, partly because this less-turbulent layer provides a smoother ride. The jet stream flows near the border between the troposphere and the stratosphere.

Mesosphere

Above the stratosphere is the mesosphere. It extends upward to a height of about 85 km (53 miles) above our planet. Most meteors burn up in the mesosphere. Unlike the stratosphere, temperatures once again grow colder as you rise up through the mesosphere. The coldest temperatures in Earth's atmosphere, about -90° C (-130° F), are found near the top of this layer. The air in the mesosphere is far too thin to breathe (the air pressure at the bottom of the layer is well below 1% of the pressure at sea level and continues dropping as you go higher).

Thermosphere

The layer of very rare air above the mesosphere is called the thermosphere. High-energy X-rays and UV radiation from the Sun are absorbed in the thermosphere, raising its temperature to hundreds or at times thousands of degrees. However, the air in this layer is so thin that it would feel freezing cold to us! In many ways, the thermosphere is more like outer space than a part of the atmosphere. Many satellites actually orbit Earth within the thermosphere! Variations in the amount of energy coming from the Sun exert a powerful influence on both the height of the top of this layer and the temperature within it. Because of this, the top of the thermosphere can be found anywhere between 500 and 1,000 km (311 to 621 miles) above the ground. Temperatures in the upper thermosphere can range from about 500° C (932° F) to 2,000° C (3,632° F) or higher. The aurora, the Northern Lights and Southern Lights, occur in the thermosphere.

Exosphere

Although some experts consider the thermosphere to be the uppermost layer of our atmosphere, others consider the exosphere to be the actual "final frontier" of Earth's gaseous envelope. As you might imagine, the "air" in the exosphere is very, very, very thin, making this layer even more space-like than the thermosphere. In fact, the air in the exosphere is constantly - though very gradually - "leaking" out of Earth's atmosphere into outer space. There is no clear-cut upper boundary where the exosphere finally fades away into space. Different definitions place the top of the exosphere somewhere between 100,000 km (62,000 miles) and 190,000 km (120,000 miles) above the surface of Earth. The latter value is about halfway to the Moon.

Ionosphere

The ionosphere is not a distinct layer like the others mentioned above. Instead, the ionosphere is a series of regions in parts of the mesosphere and thermosphere where high-energy radiation from the Sun has knocked electrons loose from their parent atoms and molecules. The electrically charged atoms and molecules that are formed in this way are called ions, giving the ionosphere its name and endowing this region with some special properties.

The behavior of Temperature in the atmosphere

Temperature increases as you gain altitude in the stratosphere and the thermosphere. Temperature decreases as you gain altitude in the troposphere and mesosphere. Air temperature varies in complicated ways with altitude. The curve looks like a sigmoid as shown in Fig. 1.

1.7 ENERGY TRANSFER IN ATMOSPHERE; RADIATION; CONDUCTION; CONVECTION

There are three types of thermal energy transfer, they are radiation, conduction, and convection.

Radiation

The Sun's energy reaches Earth through the process of radiation. Radiation is the transfer if energy by electromagnetic waves. Ninety-nine percent of the radiant energy from the Sun consists of visible light, UV light, and infrared radiation.

As Sun's energy passes through the atmosphere about 20% of energy is absorbed by gases and particles, oxygen, ozone, and water vapour absorb UV light, and water and CO_2 absorb some infrared radiation. Earth's atmosphere cannot absorb visible light, however, it must be converted to IR radiation before it can be absorbed.

Some amount of energy reflected back into space, about 25 percent of energy reflected back by clouds and other small particles. About 30 percent of all radiation that enters into atmosphere reflect back into space, out of which reflected about 20 percent absorbed by the atmosphere, only about 50 percent of incoming solar radiation reaches Earth. Earth's surface then absorbs it (Fig. 2).

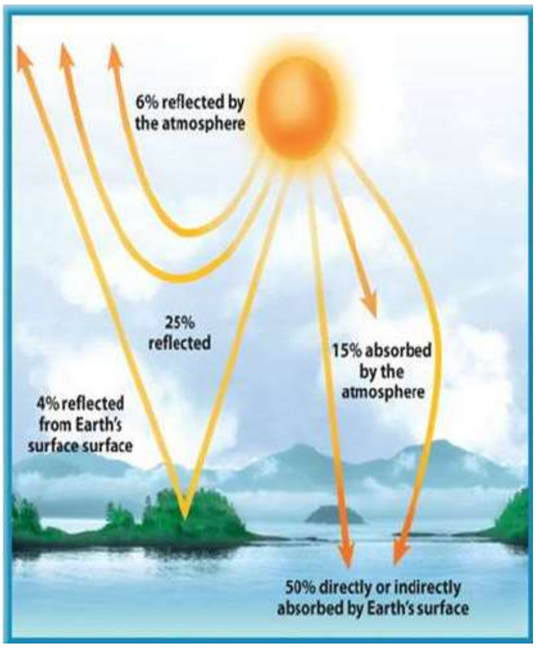

Fig. 2. Energy Transfer in the Atmosphere

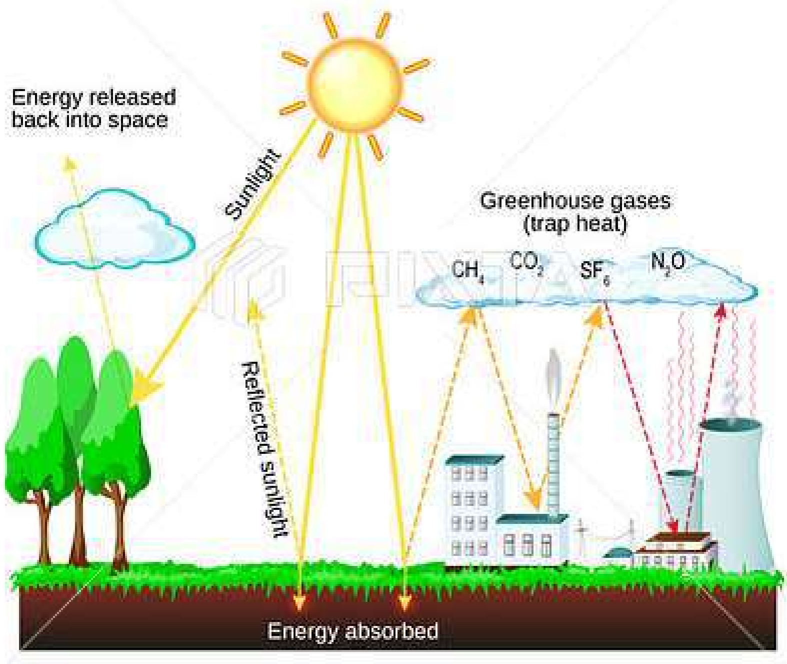

Fig. 3. Greenhouse effect

Some of the greenhouse gases like methane, CO_2, water vapour etc let sunlight pass through, but they stop IR energy from escaping. These gases direct radiation back toward Earth's surface, warms Earth's atmosphere. This effect is called greenhouse effect and it causes global warming (Fig. 3).

Conduction

The transfer of thermal energy from one object with a higher temperature to another object with a lower temperature. Conduction is the transfer of thermal energy by collisions between particle of matter. Particles must be close enough to touch to transfer energy by conduction.

Convection

As molecules of air in the atmosphere close to Earth's surface g=heat, they spread apart, and air becomes less dense. This air rises and transfers thermal energy to higher altitudes. The transfer of thermal energy by the movement of matter from one place to another is called convection. This occur in the atmosphere when conduction heats air close to Earth's surface.

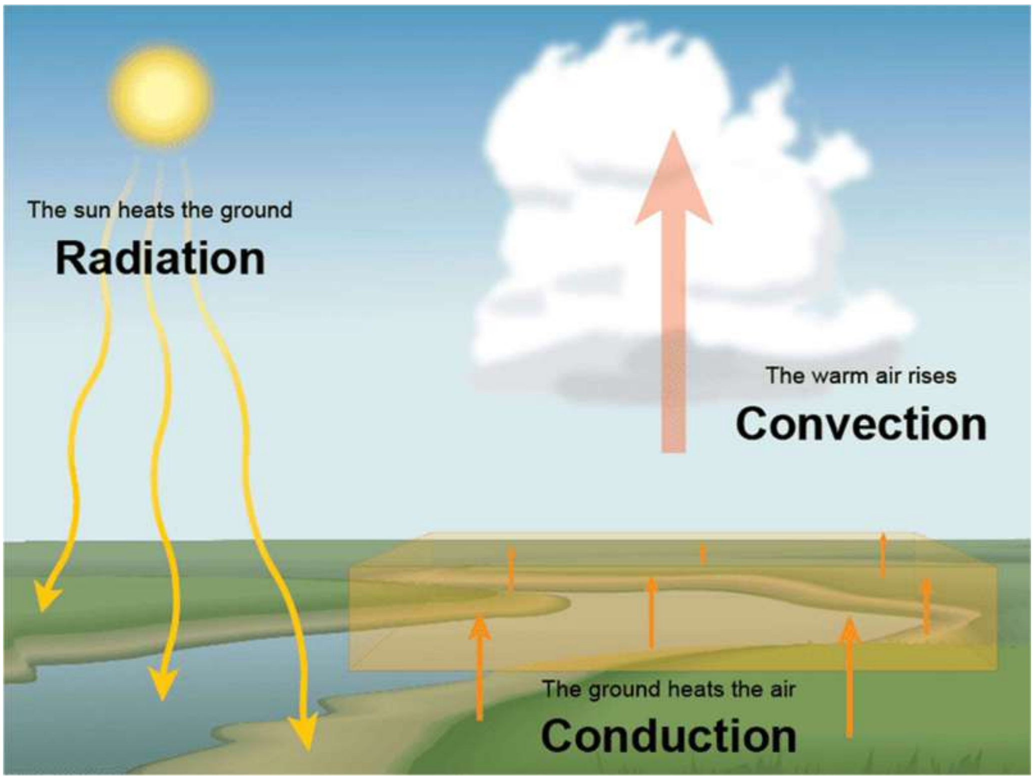

Fig. 4. Radiation, conduction and convection in the atmosphere.

1.8 SUMMARY

Environmental science encompasses many interconnected issues and it deals with the study of many multidisciplinary subjects. There is wide scope to study environmental science like ecology, environmental pollution, EIA, climate change and many important aspects. This unit also describe the evolution of environment, where the formation of cells and organisms was well explained. Earth's atmosphere is divided into troposphere, stratosphere, mesosphere, thermosphere and ionosphere. Most of the air present in the troposphere. The solar radiation falls on the earth and spread through radiation, conduction and convection.

1.9 KEYWORDS

Scope of Environmental Science	Atmosphere	Troposphere
Stratosphere	Thermosphere Mesosphere	
Ionosphere	Radiation	Conduction

1.10 QUESTIONS FOR SELF STUDY

1. Give a general perspectives of Environmental Science.
2. Explain the multidisciplinary facets of Environmental Science
3. Briefly explain the scope of Environmental Science
4. Discuss how evolution of environment took place.
5. Describe the Earth's atmosphere with different layers.
6. Explain the energy transfer in the atmosphere.

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UNIT 2: HYDROSPHERE

STRUCTURE

2.0 OBJECTIVES

After studying this unit, you will be able to

- explain the importance of water
- describe the distribution and sources of water
- discuss the properties of water
- explain the water budget
- describe water cycle
- discuss the factor causing water pollution and types of water pollution

2.1 INTRODUCTION

Water is the basic component of all the living beings including flora and fauna. It is well known that human and plant body consists of approximately 60% to 90% water, respectively. After the oxygen water is one of the most essential natural resources for sustaining life on earth. It is impossible to think existence of life without water. We require 3 to 5 liter of water/day and it is the basis of life and is the foundation for human survival and development. Water is used for various purposes like drinking, washing clothes, bathing, cleaning, cooling, irrigation and in industry. Water is consumed, it is no longer available for reuse in the local area because of evaporation, storage in the living matter of plants and animals, contamination or seepage into the ground. Almost three-fourths of the water withdrawn each year throughout the world is used for irrigation. The remainder is used for industrial processing, energy production, cooling electric power plants, for domestic and industrial activities. The main sources of water on earth include: the precipitation, surface water i.e. streams, rivers, ponds, lakes and groundwater. The distribution of water varied from place to place and even varied from time to time at a particular place e.g. in India maximum fresh water is available during rainy season. The earth's water resources consist of the oceans and seas, the ice and snow of polar regions and mountain glaciers, the water contained in surface soils, and underground, the water in lakes, rivers and streams. These water resources collectively form hydrosphere. Less than 1% of these resources consist of freshwater, about 2% is freshwater ice located mainly in the Polar Regions and remaining 97% consists of sea water**.**

2.2 IMPORTANCE OF WATER

It is well known fact that early human civilizations have grown and flourished on the banks of rivers. We cannot think about life without water, the other name of water is life. It is assumed that life first appeared in the water (in the seas, 3.5 billion years ago). It is most important and abundant component of protoplasm in the cells of all living being. Moreover, metabolic and biochemical reactions in the body of all the living beings including human being occur in the presence of water. The green plants which act as producer in the ecosystem pick up nutrients from the soil transport to different parts with the help of water. After sun light water is second most important component required for photosynthesis. The huge amount of water present in the oceans act as a sink for carbon dioxide i.e., helps to control global warming likewise forests. These giant water bodies provide protein rich diet to the world's people in the form of fish. Water is habitat for aquatic animals and plants which run the food chain in aquatic ecosystem. It also helps in control of climate of a particular place. Beside this water is required for agriculture, domestic needs, navigation, industrial processing, recreational use, power generation and many more etc.

In India more than 70% of population depends upon agriculture for livelihood which uses maximum fresh water. Few studies explained that, per capita exploitable water availability in India in 1951 and 2010 was 3000 and 938 m^3, respectively and these are projected to reduce further to 814 and 687 m^3 by the years 2025 and 2050 respectively. Water is a precious natural resource and limited in quantity and unequally distributed.

2.3 DISTRIBUTION AND SOURCES

About two-thirds of the Earth's surface is covered with water. The total amount of water on the Earth is about 1400 million km3 (UNEP, 2002). Of this, around 97.5% by volume is held in the oceans and is salt water. Only 2.5% (or about 35 million km3) is fresh water. Fig. 1. shows the proportions of Earth's water found in different parts of the environment. Fresh water is water with a dissolved salt concentration of less than 1%. Globally, fresh water is distributed unevenly. About three-quarters of global annual rainfall occurs in countries containing less than one-third of the world's population. About 80% of the world's water run-off is concentrated in countries in northern and equatorial regions, which have relatively small populations.

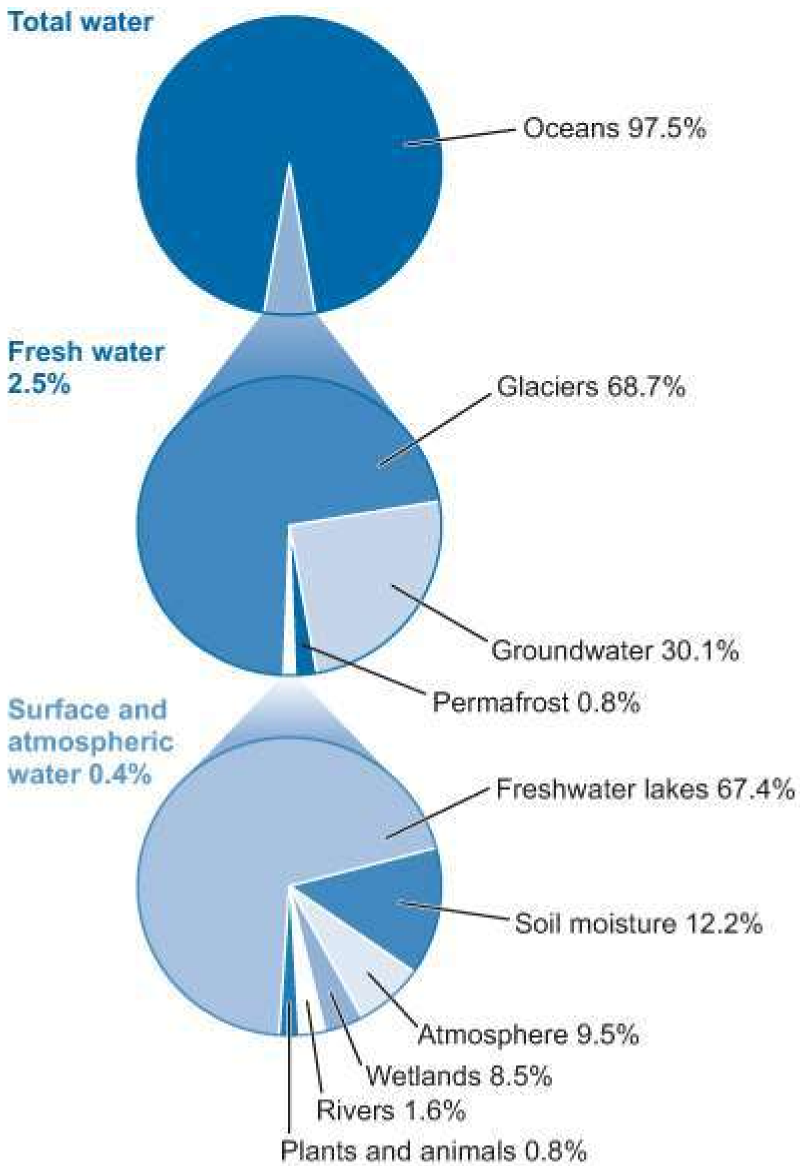

Fig. 1. Distribution of Water Resources on Earth.

Sources of Water

Our main sources of water for drinking, washing, agriculture and industry are surface water, groundwater and collected rainwater, all of which are dependent on rain and snow falling on the Earth's surface.

Surface water

Rivers, streams, lakes, and ponds are widely used as water sources in Ethiopia, especially in rural areas (Figure 4.5). The amount of available surface water depends largely on rainfall. When rainfall is limited, the supply of surface water will vary considerably between wet and dry seasons and also between years. One way to overcome this problem is to construct a dam across a river to create a reservoir that provides water storage. Large surface water reservoirs may be used for hydroelectric power generation, regulating water releases to control river flows, for recreational purposes and to provide water for agricultural, municipal and industrial uses. Smaller dams are also used to enable irrigation. The water collects behind the dam and flows under gravity into irrigation channels leading to the fields.

Groundwater

An aquifer is an underground layer of water-bearing rock. Water-bearing rocks are permeable, meaning that liquids and gases can pass through them. Groundwater is the water contained in aquifers. This is replenished or recharged by precipitation that percolates through the soil to the water table, and by water seeping from streams, as well as other bodies of surface water, such as lakes and wetlands.

The water table is the top of the groundwater below the land surface. Its level fluctuates seasonally and from year to year as the inputs from precipitation and the outputs vary. The depth of the water table also varies with location, from being near to the land surface in areas close to surface water bodies and in humid climates, to being hundreds of metres below the land surface in drier regions.

Groundwater reaches the surface naturally through springs or artificially through wells. Springs typically rise up where the water table meets the land surface. Springs are important sources of water to feed streams and are attractive cultural and landscape features in themselves. Wells and boreholes are dug by hand or drilled by machine. These have to be deep enough to extend below the water table so that water can be drawn up by bucket or by pumping.

Rainwater

Rainwater is also an important source of water, although on a relatively small scale. Collecting rain from roofs or other hard-surfaced areas and storing it until it is needed can provide a valuable source of water for many purposes.

Water resources of India

The various researchers have estimated that the water resources of India are 1880 bcm and Central Water Commission (CWC) has reported that total utilizable water resources of the country is 1110 bcm. The water resources of India is given in Table 1.

Table: 5 Water resources of India

S.No.	Water Resources	Quantity
1	Annual Precipitation	4000 BCM
2	Available water resources	1869
3 i. ii.	Utilizable Surface water (Storage and diversion) Groundwater (Replenishable)	1122 690 432
4	Present utilization (Surface water 63%,groundwater37%)	605
5	Irrigation	501
6	Domestic	30
7	Industry, energy and other uses	74

2.4 PROPERTIES OF WATER

The properties of water as follows:

Water is polar. Water molecules are polar, with partial positive charges on the hydrogens, a partial negative charge on the oxygen, and a bent overall structure. This is because oxygen is more *electronegative*, meaning that it is better than hydrogen at attracting electrons.

Water is an excellent solvent: Water has the unique ability to dissolve many polar and ionic substances. This is important to all living things because, as water travels through the water cycle, it takes many valuable nutrients along with it!

Water has high heat capacity: It takes a lot of energy to raise the temperature of a certain amount of water by a degree, so water helps with regulating temperature in the environment. For example, this property allows the temperature of water in a pond to stay relatively constant from day to night, regardless of the changing atmospheric temperature.

Water has high heat of vaporization: Humans (and other animals that sweat) use water's high heat of vaporization to cool off. Water is converted from its liquid form to steam when the heat of vaporization is reached. Since sweat is made mostly of water, the evaporating water absorbs excess body heat, which is released into the atmosphere. This is known as *evaporative cooling*.

Water has cohesive and adhesive properties: Water molecules have strong *cohesive* forces due to their ability to form hydrogen bonds with one another. Cohesive forces are responsible for *surface tension*, the tendency of a liquid's surface to resist rupture when placed under tension or stress. Water also has *adhesive* properties that allow it to stick to substances other than itself.

These cohesive and adhesive properties are essential for fluid transport in many forms of life. For example, they allow nutrients to be transported to the top of a tree against the force of gravity.

Water is less dense as a solid than as a liquid: As water freezes, the molecules form a crystalline structure that spaces the molecules further apart than in liquid water. This means that ice is less dense than liquid water, which is why it floats.

2.5 WATER BUDGET AND CONSUMPTION USE OF WATER

Water Budget

Water budgeting is a principal activity for proper management of water resources. Actually 'water budget' is an accounting of water inputs, outputs and storage of water e.g. in lithosphere, atmosphere and oceans. Hence, Water Budget means – the balance between the available water in the country and the water under use. Hence, it is balance between the accessible water and the water underutilization.

The solar radiations evaporate water from oceans and land and transpiration of water from plants introduce moisture into the atmosphere which returns to earth as precipitation. It is estimated that about 525100 km3 water introduce into the atmosphere and from this about 21.6% water vapors comes to earth as precipitation over land surface. The water budget calculation includes the different mechanism used in water cycle e.g. precipitation, evaporation, evapotranspiration, surface and subsurface flow. The Table 2 presents the Annual water budget of planet earth.

Table 2. Annual water budget of planet earth

S. No.	Particulars	Water (km^3)
1	Total evaporation from sea surface	4,52,600
2	Total evaporation from land surface	72,500
3	Total precipitation on ocean surface	4,11,600
4	Total precipitation on land surface	1,13,500
5	Total surface and ground water flow	41,000
6	Total evaporation from land and sea surface	5,25,100
7	Total precipitation on land and sea surface	5,25,100

It is evident from Table 2 that world's oceans impart about 4,52,600 km^3 water annually to atmosphere while get only 4,11,600 km3 as precipitation. However, this deficit is balanced by 41,000 km^3 of surface and subsurface runoff, which they receive. This excess water ultimately flows back to oceans under the influence of gravity (Roggers, 1991). Moreover, the amount of water presents in oceans, on land, groundwater and water present in atmosphere in vapors form etc. are in a state of dynamic equilibrium.

Water Budget of India

India has 18% population of the world and having only 4% fresh water resources of the earth. Moreover, the reserves of our surface and underground water are approximately 23840 billion cubic metres and only 10860 billion cubic metres are required for utilization. The unit of measurement of amount of water is cubic metre or hectare metre. If water standing one-metre-deep on a perfectly level area of one square metre, then the total volume of whole of that water would be one cubic metre. In the same way, if water standing one-metre-deep on a perfectly level area of one hectare then the total volume of water would be one hectare metres.

There is a great variation in the distribution of water resources in space and time e.g. water is available in adequate amount during monsoon season in India. As the dry season sets in, there is a scarcity of water. Even though India is one of the wettest countries in the world, the accessibility of water to the people with time and space is extremely bumpy. On an average, it receives about 1150 mm of rainfall annually, which is highest in the world for a country having only 2.5% geographical area of the world. Yet, its distribution is highly uneven e.g. average number of rainy days in a year is only 40. Consequently, there is a lengthy curse of dry period in a year. Also, the rainfall is as high as 13 m in some areas of North-East regions and as a low as 20 cm in certain parts of Rajasthan. This irregular circulation of rainfall results in water shortage in several parts of our nation. India receives on an average about 4000 billion cubic metres (bcm) of rainfall every year. According to an estimate more than half of this quantity is lost to the atmosphere through evapotranspiration or through deep percolation in to groundwater and only about 1869 bcm flow in the rivers as surface flow. This is estimated to be the water resources potential of the country. Approximately 690 bcm of surface water and 432 bcm of groundwater are available for use per year. According to National Commission on Integrated Water Resource Development (NCIWRD), it is expected that the population of India would be 1581 million by the year 2050. Keeping in view the increased demand for domestic use, industrial purpose, energy production etc. and above all for agricultural production there will be more demand of fresh water. The Central Water Commission has enumerated water demand scenarios up to the year AD 2050 for different sectors as depicted in Table 3.

Table 3. Sector-wise Demand Scenarios of Water in India (billion cubic metres).

S. No.	Sector	2010	2025	2050
1	Irrigation	688	910	1072
2	Drinking (including Livestock)	56	73	102
3	Industrial	12	23	63
4	Energy	05	15	130
5	Others (Forestry, Pisciculture, Tourism, Navigation etc)	52	72	80
Total		813	1093	1447

Consumption Use of Water

Annual flow of water available for human use after allowing for evapo-transpiration and minimum required ecological flow, vary considerably. The water budget derived from Ministry of Water Resources estimates, which are summarized in the first column in Table 1 show utilizable water of 1,123 billion cubic metres (BCM) against current water use of 634 BCM suggesting more than adequate availability at the aggregate level given current requirements. This is based on the Central Water Commission's estimates of India's water resource potential as 1,869 BCM. The standing sub-committee of MoWR estimates total water demand rising to 1,093 BCM in 2025, thus reaffirming a comfortable scenario.

Table 1. India's Water Budget, 2009.

	Analysis Based on Estimates of Ministry of Water Resources	Estimates Based on Worldwide Comparison
Annual rainfall	3,840	3,840
Evapo-transpiration	3,840–(1,869 + 432) = 1,539 (40 per cent)	2,500 (65 per cent) Worldwide Comparison
Surface run-off	1,869 (48.7 per cent)	Not used in estimate
Groundwater recharge	432 (11.3 per cent)	Not used in estimate
Available water	2,301 (60 per cent)	1,340 (35 per cent)
Utilizable water	1,123 (48.8 per cent of 2,301)	654 (48.8 per cent of 1,340)
Current water use	634	634

2.6 WATER CYCLE OR HYDROLOGICAL CYCLE

Water is continually moving around the Earth and continuously changing its physical form. The hydrological cycle, or water cycle, is the continuous circulation of water between oceans, atmosphere and land (Fig. 2). The sun and wind cause water to evaporate (change its physical state from liquid to gas) from land and water bodies (oceans, lakes and rivers). Also, plants take up liquid water and give off water vapour through pores in their leaves in a process called transpiration. The water vapour moves high above the Earth's surface on rising currents of air through the atmosphere. Eventually as the water vapour reaches the cooler air higher up in the atmosphere, it condenses (changing from gas to liquid) to form clouds and falls back to Earth in the form of rain and snow (together these are called precipitation). Precipitation that falls on land can flow over the surface as run-off into rivers and streams, and can also percolate (trickle down) through the soil into underground rocks to become groundwater.

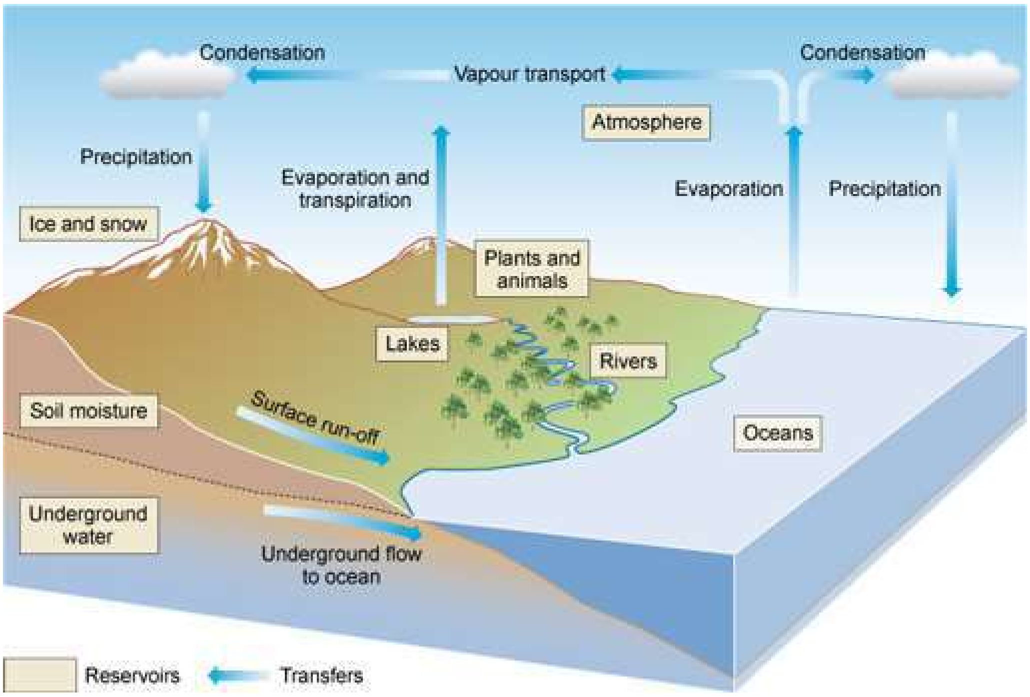

Fig. 2. The Hydrological Cycle or Water Cycle.

Water is held in reservoirs and moves between them in transfer processes. ('Reservoirs' here refers to all stores or reserves of water, not just water held behind a dam.) The water transfer processes continue in an ongoing cycle through evaporation and transpiration, transportation of water vapour in the atmosphere, precipitation, and water flowing off and through the land back to the sea.

2.7 WATER POLLUTION – POINT AND NON-POINT SOURCES

A large amount of water is discharged back after domestic and industrial usage. This is contaminated with domestic waste and industrial effluents. When this contamination reaches beyond certain allowed concentrations, it is called pollution and the contaminants are called the pollutants. Water pollution may be defined as the contamination of streams, lakes, seas, underground water or oceans by substances, which are harmful for living beings. If the concentration of substances naturally present in water increases then also the water is said to be polluted.

Water pollution may be defined as '*the contamination of streams, lakes, seas, underground water or oceans by substances, which are harmful for living beings. Industrialization and population explosion are two important factors for water pollution'*.

Water may be called polluted when the following parameters stated below reach beyond a specified concentration in water.

i) **Physical parameters:** Colour, odour, turbidity, taste, temperature and electrical conductivity constitute the physical parameters and are good indicators of contamination.

   For instance, colour and turbidity are visible evidences of polluted water while an offensive odour or a bitter and difference than normal taste also makes water unfit for drinking.

ii) **Chemical parameters:** These include the amount of carbonates, sulphates, chlorides, fluorides, nitrates, and metal ions. These chemicals form the total dissolved solids, present in water.

iii) **Biological parameters:** The biological parameters include matter like algae, fungi, viruses, protozoa and bacteria. The life forms present in water are affected to a good extent by the presence of pollutants. The pollutants in water may cause a reduction in the population of both lower and higher plant and animal lives. Thus, the biological parameters give an indirect indication of the amount of pollution in water

Classification of Water Pollution

Water pollutants refer to the substances which are capable of making any physical, chemical or biological change in the water body. These have undesirable effect on living organisms. As mentioned earlier, the water used for domestic, agricultural and industrial purposes is discharged with some undesirable impurities in it. This contamination leads to the pollution of water, which is generally called the fresh water pollution. Fresh water pollution may be classified into two types: surface water pollution and ground water pollution.

The water pollution has a number of sources. These can categorized as:

- Point and Non-point Sources
- Natural and Anthropogenic Sources

i. Point Sources

The well-defined sources that emits pollutants or effluents directly into different water bodies of fresh water are called point sources. Domestic and industrial waste are examples of this type.

Domestic Sources

The sewage contains garbage, soaps, detergents, waste food and human excreta and is the single largest sources of water pollution. Pathogenic (disease causing) microogranisms (baccteria, fungi, protozoa, algae) enter the water system through sewage making it infected. Typhoid, chloera, gastroenteritis and dysentery are commonly caused by drinking infected water. Water polluted by sewage may carry certain other bacteria and viruses cannot grow by themselves, but reproduce in the cells of host organisms. They cause a number of diseases, such as, polio, viral hepatitis and may be cancer which are resistant to like the organic matter are oxygen demanding substances. They are responsible for deoxygenation of water-bodies which is harmful for aquatic life.

Other ingredients which enter the various water bodies are the plant nutrients, i.e., nitrates and phosphates. They support growth of algae, commonly called algal bloom (blue-green species).

Industrial Pollution

Many industries are located near rivers or fresh water streams. These are responsible for discharging their untreated effluents into rivers like highly toxic heavy metals such as chromium, arsenic, lead, mercury, etc. along with hazardous organic and inorganic wastes (e.g., acids, alkalies, cyanides, chlorides, etc.). River Ganges recives wastes from textile, sugar, paper and pulp mills, tanneries, rubber and pesticide industries. Most of these pollutants are resistant to breakdown by microorganisms (called nonbiodegradable), therefore damage the growth of crops and the polluted water is unsafe for drinking purposes.

Factories manufacturing plastic, caustic soda and some fungicides and pesticides release mercury (a heavy metal) along with other effluents in nearby water body. Mercury enters the food chain through bacteria, algae, fish and finally into the human body. The toxicity of mercury became evident by the Minamata Bay tragedy in Japan during the period 1953-60. Fish died due to mercury consumption and those who ate fish were affected by mercury poisoning and quite a few died. The milder symptoms of mercury poisoning are depression and irritability but acute toxic effects can cause paralysis, blindness, insanity, birth defects and even death. The high concentration of mercury in water and in fish tissues results from formation of soluble monomethylmercury ion, (CH_3, $Hg+$) and volatile dimethylmercuty [$(CH_3)_2$ Hg] by anaerobic bacteria in sediments.

ii. Non-Point Sources

Non-point sources of water pollution are scattered or spread over large areas. This type of sources deliver pollutants indirectly through environmental changes and account for majority of the contaminants in streams and lakes. For example, the contaminated water that runs off from agriculture farms, construction sites, abandoned mines, enters streams and lakes. It is quite difficult to control non-point sources.

Agricultural Waste

Manure, fertilizers, pesticides, wastes form farms, slaughterhouse, poultry farms, salts and silt are drained as run-off from agricultural lands. The water body receiving large quantities of fertilizers (phosphates and nitrates or manures becomes rich in nutrients which leads to eutrophication and consequent depletion of dissolved oxygen. Consumption of water rich in nitrates is bad for human health especially for small children.

Pesticides (DDT, dieldrin, aldrin, malathion, carbaryl etc.) are used to kill insect and rodent pests. Toxic pesticide residues enter the human body through drinking water or through food chain (biomagnification). These compounds have low solubility in water but are highly soluble in fats. For example, the concentration of DDT in river water may be very low but some fish over a period of time accumulate so much of DDT that they become unfit for human consumption. The use of pesticides in our country is increasing very rapidly. Some of these chemicals which are highly toxic become metabolised by animals that graze on fields.

Therefore, these poisonous chemicals have been often observed in the humanfood chain. The presence of these chemicals in humans even in minute amounts can cause hormonal imbalance and may lead to cancer.

iii. Natural and Anthropogenic Sources

An increase in the concentration of naturally occurring substances is also termed pollution. The sources of such an increase are called natural sources.

Siltation (which includes soil, sand and mineral particles) is one such natural source. It is a common natural phenomenon, which occurs in most water bodies. Indiscriminate deforestation makes soil loose and flood waters bring silt from mountains into streams, rivers and lakes.

On the other hand, the human activities that result into the pollution of water are called anthropogenic or man-made sources of water pollution. For example, domestic (sewage and waste water), industrial and agricultural wastes that goes into the rivers, lakes, streams and seas are anthropogenic sources. Certain materials that are leached from the land by run-off water and enter the various water bodies also belong to this category.

2.8 SUMMARY

Water is the basic component of all the living beings including flora and fauna. It is assumed that life first appeared in the water. About two-thirds of the Earth's surface is covered with water on the Earth and available as surface and groundwater. Water has several properties as it is polar, solvent, it takes lot of heat, vapourizes and have cohesive and adhesive properties. In this unit, water budget is also described. The hydrological cycle is the continuous circulation of water between oceans, atmosphere and land and it is well explained here. Water pollution is caused due to point and non-point sources of pollution. Examples for point sources are domestic wastewater and industrial pollution, and for non-point sources are agricultural activities.

2.9 KEYWORDS

Importance of water	Sources of water	Properties of water
Water budget	Hydrological cycle	Water pollution
Types of water pollution	Point Sources	Non-point sources

2.10 QUESTIONS FOR SELF STUDY

1. Explain the importance of water and its various uses.
2. Describe the distribution and sources of water on Earth.
3. Discuss the properties of water.
4. Explain the water budget.
5. Describe the hydrological cycle or water cycle with neat diagram.
6. Discuss the factor causing water pollution and explain types of water pollution with their sources.

2.11 REFERENCES FOR FURTHER READING

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UNIT 3: LITHOSPHERE

STRUCTURE

3.0 Objectives

3.1 Introduction

3.2 Internal structure of earth – crust, mantle, core.

3.3 Minerals – sources and types.

3.4 Rocks – types; rock cycle.

3.5 Soil – formation, classification criteria and types, soil profile

3.6 Summary

3.7 Keywords

3.8 Questions for Self Study

3.10 References for Further Reading

3.0 OBJECTIVES

After studying this unit, you will be able to

- explain the internal structure of Earth with their layers such as crust, mantle and core
- define minerals and explain its sources and types
- define rock and explain its types
- describe the rock cycle
- define soil
- describe the formation of soil and classify the soil
- explain soil profile

3.1 INTRODUCTION

The Earth is composed of layers of different composition and physical properties, principally the solid central core, the fluid peripheral core, the viscous mantle, and the solid lithosphere. The lithosphere is comprised of the upper mantle and the crust, the outer shell of the Earth. There are two types of lithosphere, according to the crust resting on the solid mantle lithosphere (lithospheric mantle): the oceanic lithosphere has a 5 to 8km thick oceanic crust (with a basaltic composition) and the continental lithosphere has a 30km to 40km thick granitic-dioritic crust. The lithosphere is fragmented into pieces of variable shape and size, the plates. The edges of the plates are called plate boundaries. The Earth has 7 major plates (Africa, Antarctica, Australia, Eurasia, North America, South America and Pacifica) and several minor ones (Adria, Arabia, Caribbean, Nazca, Philippines and others). Most of the plates are composed of continental and oceanic lithosphere. These plates move independently relative to one another, with a restricted independence from the 7 large plates, however (see Fig. 1.). The relative, horizontal movements are ideally described as rigid body motions that produce space and friction problems at the contacts between adjacent plates. Plate boundaries are not fixed; they also move and change shape. The global mosaic of plates periodically reorganizes itself and new plate boundaries form while others close up. Plate tectonics, the study of such relative motions and their consequences, allows relating surface, geological and geophysical structures with quantified movements attributed to deep processes of the Earth's heat engine: The interior is hot, space is cold; the second law of thermodynamics states that this gradient will drive spontaneous convection processes in pursuit of equilibrium. The motion of lithospheric plates is a considerable consequence of thermally-driven mass movements on the Earth.

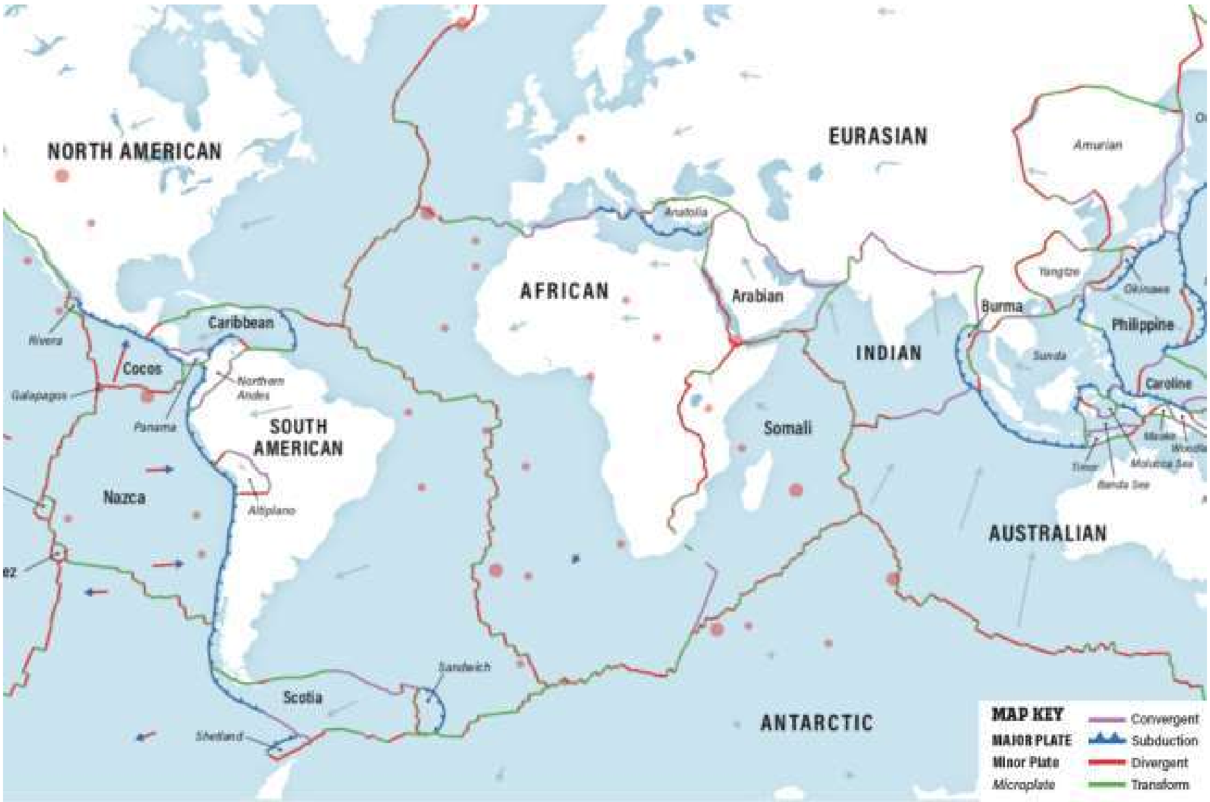

Fig. 1. Plates and their boundaries and their direction of movement.

Alfred Wegener proposed the hypothesis that the continents were once assembled together as a supercontinent he named Pangaea. He noted that opposing coastlines were similar on opposite sides of the Atlantic Ocean, mountains belts matched when continents were reassembled, fossils matched between different continents, and climate evidence suggested continents were once in different locations.

3.2 INTERNAL STRUCTURE OF EARTH – CRUST, MANTLE, CORE

The Earth has three main divisions based on its chemical composition, chemical makeup. Indeed, there are countless variations in composition throughout the Earth, but only two significant changes occur, leading to three distinct chemical layers. The internal structure of the Earth is fundamentally divided into three layers – crust, mantle and core (Fig. 2). The core accounts for almost half of Earth's radius, but it amounts to only 16.1% of Earth's volume. Most of Earth's volume (82.5%) is its mantle, and only a small fraction (1.4%) is its crust.

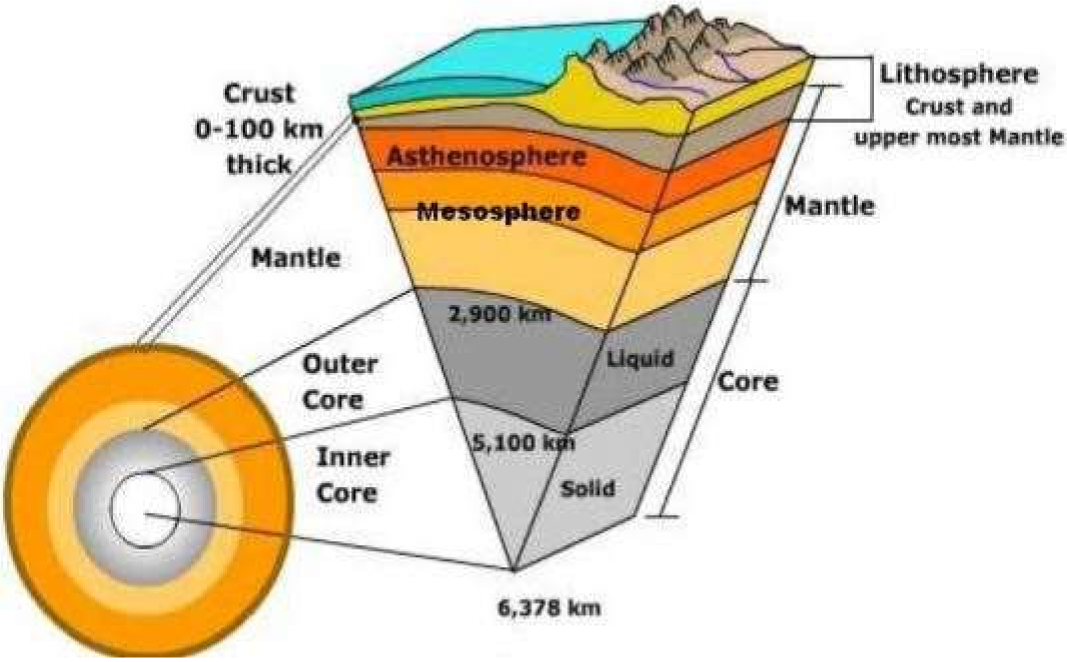

Fig. 2. Internal Structure of the Earth.

Evidences for internal structure of Earth

Seismic waves can tell us a lot about Earth's interior, including where the lithosphere and asthenosphere are located.

During an earthquake, primary (P) and secondary (S) waves spread out through the Earth's interior, according to Columbia University. Special stations situated around the world detect these waves and record their velocities as well as the direction of wave travel and whether they have been refracted (bent). Seismic waves travel faster through dense material like solid rocks and slowdown in liquids.

Relative differences in arrival times of waves at several recording stations reveal their velocities and subsequently the density of the material they have traveled through, according to the University of California, Santa Barbara. S waves for example cannot travel through liquids and do not travel through Earth's outer core implying that this layer is liquid, according to the University of California, San Diego.

Crust

The lithosphere is the outermost layer of Earth, composed of the crust and the brittle part of the upper mantle. The term lithosphere is derived from the Greek words "lithos," meaning stone, and "sphaira," meaning globe or ball. Lithospheric temperatures vary from 32 degrees F (0° C) at the crust to 932 degrees F (500° C) at the upper mantle.

Crust is broken into large lithospheric (also known as tectonic) plates. Convection currents in the lower mantle and asthenosphere help to move the rigid lithospheric plates. The slow "floating" movement of the lithosphere on the asthenosphere drives plate tectonics and subsequent processes such as earthquakes, volcanic eruptions and the formation of mountains.

The crust can be further divided into oceanic crust and continental crust. The boundary between the brittle part of the upper mantle and the crust (both oceanic and continental) is known as the Mohorovičić Discontinuity (Moho). The Moho depth varies from about 5 miles (8 km) below oceanic crust to 20 miles (32 km) below continental crust.

Oceanic crust and continental crust differ in their composition, density and age, according to World Atlas. Oceanic crust is primarily composed of dark basalt rocks rich in elements such as silicon and magnesium whereas continental crust is made of light-colored granite rocks containing oxygen and silicon. Oceanic crust is denser than continental crust and when two lithospheric plates — one oceanic and one continental — meet, the oceanic plate always subducts beneath the more buoyant continental plate.

Asthenosphere

The asthenosphere is a 110 miles (180 km) thick layer of the upper mantle that sits between the lower mantle and the lithosphere, according to the U.S. Geological Survey (USGS). The term asthenosphere originates from the Greek "asthenes" meaning weak. The "weak" layer is denser and more "fluid" than the lithosphere above, and pressure and heat are so high that rocks in the asthenosphere flow extremely slowly with a highly viscous molten fudge-like consistency.

Temperatures in the asthenosphere are around 2,732 degrees F (1,500 degrees C). Rocks in the asthenosphere are "on the verge" of melting, but due to the high pressure, they behave in a more ductile manner.

Mantle

The mantle is the largest and thickest layer of Earth, making up 84% of the planet's total volume. The mantle can be further divided into the upper and lower mantle (also known as the mesospheric mantle), with the upper mantle containing two distinct regions: the asthenosphere and the lower portion of the lithosphere.

The lower mantle refers to the layer between the outer core and asthenosphere. It makes up 55% of Earth by volume and experiences pressure from 237,000 atm to 1.3 million atm towards the outer core. Heat and pressure in the lower mantle are much greater than in the upper mantle. The immense pressure keeps this layer solid despite the high temperatures capable of softening the rocks. Though geologists are yet to agree on a definitive structure of the lower mantle.

According to the Gemological Institute of America, diamonds are forged within the mantle approximately 93 to 124 miles (150 to 200 km) below the surface. They are brought to the surface by magma churned up from the depths due to tectonic processes such as plates splitting apart.

Temperatures in the mantle ranged between 6,692° F to 1,832° F (3,700° C to 1,000° C) and the thickness of the layer is approximately measures 1,800 miles (2,900 km) and made of Magnesium, Silicon and Oxygen.

Core

Earth's outer core is sandwiched between the inner core and the mantle. The boundary between the inner and outer core is known as the Lehman Seismic Discontinuity. The outer core is approximately 1,367 miles (2,200 km) thick and composed of liquid iron and nickel. Temperatures in the outer core are between 8,132° F and 9,932 degrees F (4,500° C and 5,500° C).

Earth's interior is gradually cooling over time. As it cools, the liquid outer core crystallizes and becomes part of the solid inner core. Remarkably, the inner core "grows" by about 0.039 inches (one millimeter) every year, which equates to the solidification of 8,820 tons (8,000 tonnes) of molten iron every second. The solidification of the outer core releases heat which drives convection currents in the outer core that helps to generate Earth's magnetic field.

The swirling motion of the outer core generates Earth's magnetic field in a process called geodynamo, according to NASA Earth Sciences. Magnetism inside Earth's core is approximately 50 times stronger than it is on the surface. Eventually, the entire core will solidify and Earth's magnetic field will cease to exist. That will be bad news for our planet as the magnetic field protects us from harmful cosmic radiation. We still have a few billions of years of protection left though.

3.3 ROCKS – TYPES; ROCK CYCLE.

Rocks on the Earth may be composed of hundreds of possible minerals but only 20 to 30 minerals are common in the majority of rocks.

Definition**:** A rock is any naturally occurring solid mass or aggregate of minerals or mineraloid matter.

Minerals are made up of combinations of nearly a hundred different elements, yet only eight elements make up over 98% of the Earth's crust. An atom is the smallest particle of an element that retains the characteristics of the element. All atoms are composed of neutrons, protons, and electrons. The protons and neutrons are present in the atom’s nucleus that is surrounded by electrons.

Rocks can be hard or soft, as small as a grain or as large as a hillock. Combined with the effects of tectonics, weathering and vegetation, rocks define the natural landscapes we see around us. The minerals and metals we find in rocks are essential to the prosperity and cultural splendor of human civilization. There are many kinds of rock, and they can be classified in a number of ways.

Types of Rocks

There are mainly three types of rocks viz., igneous, sedimentary and metamorphic rocks.

i. Igneous rocks

Igneous rocks (from the Latin word for fire) form when hot, molten rock crystallizes and solidifies. The melt originates deep within the Earth near active plate boundaries or hot spots, then rises toward the surface. Igneous rocks are divided into two groups, intrusive or extrusive, depending upon where the molten rock solidifies.

Intrusive Igneous Rocks: Intrusive, or plutonic, igneous rock forms when magma is trapped deep inside the Earth. Great globs of molten rock rise toward the surface. Some of the magma may feed volcanoes on the Earth's surface, but most remains trapped below, where it cools very slowly over many thousands or millions of years until it solidifies. Slow cooling means the individual mineral grains have a very long time to grow, so they grow to a relatively large size. Intrusive rocks have a coarse grained texture.

Extrusive Igneous Rocks: Extrusive, or volcanic, igneous rock is produced when magma exits and cools above (or very near) the Earth's surface. These are the rocks that form at erupting volcanoes and oozing fissures. The magma, called lava when molten rock erupts on the surface, cools and solidifies almost instantly when it is exposed to the relatively cool temperature of the atmosphere. Quick cooling means that mineral crystals don't have much time to grow, so these rocks have a very fine-grained or even glassy texture. Hot gas bubbles are often trapped in the quenched lava, forming a bubbly, vesicular texture.

Examples of igneous rocks are Andesite, Basalt, Dacite, Granite, Obsidian, Pegmatite, Peridotite etc.

ii. Sedimentary rocks

Sedimentary rocks are formed from pre-existing rocks or pieces of once-living organisms. They form from deposits that accumulate on the Earth's surface. Sedimentary rocks often have distinctive layering or bedding. Many of the picturesque views of the desert southwest show mesas and arches made of layered sedimentary rock.

Common Sedimentary Rocks: Common sedimentary rocks include sandstone, limestone, and shale. These rocks often start as sediments carried in rivers and deposited in lakes and oceans. When buried, the sediments lose water and become cemented to form rock. Tuffaceous sandstones contain volcanic ash.

Clastic Sedimentary Rocks: Clastic sedimentary rocks are the group of rocks most people think of when they think of sedimentary rocks. Clastic sedimentary rocks are made up of pieces (clasts) of pre-existing rocks. Pieces of rock are loosened by weathering, then transported to some basin or depression where sediment is trapped. If the sediment is buried deeply, it becomes compacted and cemented, forming sedimentary rock. Clastic sedimentary rocks may have particles ranging in size from microscopic clay to huge boulders. Their names are based on their clast or grain size. The smallest grains are called clay, then silt, then sand. Grains larger than 2 millimeters are called pebbles. Shale is a rock made mostly of clay, siltstone is made up of silt-sized grains, sandstone is made of sand-sized clasts, and conglomerate is made of pebbles surrounded by a matrix of sand or mud.

Biologic Sedimentary Rocks: Biologic sedimentary rocks form when large numbers of living things die. Chert is an example for this type of rock, and this is one of the ways limestone can form. Limestone can also form by precipitating directly out of the water.

iii. Metamorphic rocks

Metamorphic rocks started out as some other type of rock, but have been substantially changed from their original igneous, sedimentary, or earlier metamorphic form. Metamorphic rocks form when rocks are subjected to high heat, high pressure, hot mineral-rich fluids or, more commonly, some combination of these factors. Conditions like these are found deep within the Earth or where tectonic plates meet.

Process of Metamorphism: The process of metamorphism does not melt the rocks, but instead transforms them into denser, more compact rocks. New minerals are created either by rearrangement of mineral components or by reactions with fluids that enter the rocks. Pressure or temperature can even change previously metamorphosed rocks into new types. Metamorphic rocks are often squished, smeared out, and folded. Despite these uncomfortable conditions, metamorphic rocks do not get hot enough to melt, or they would become igneous rocks!

Common Metamorphic Rocks: Common metamorphic rocks include phyllite, schist, gneiss, quartzite and marble.

Foliated Metamorphic Rocks: Some kinds of metamorphic rocks -- granite gneiss and biotite schist are two examples -- are strongly banded or foliated. (Foliated means the parallel arrangement of certain mineral grains that gives the rock a striped appearance.) Foliation forms when pressure squeezes the flat or elongate minerals within a rock so they become aligned. These rocks develop a platy or sheet-like structure that reflects the direction that pressure was applied.

Non-Foliated Metamorphic Rocks: Non-foliated metamorphic rocks do not have a platy or sheet-like structure. There are several ways that non-foliated rocks can be produced. Some rocks, such as limestone are made of minerals that are not flat or elongate. No matter how much pressure you apply, the grains will not align! Another type of metamorphism, contact metamorphism, occurs when hot igneous rock intrudes into some pre-existing rock. The pre-existing rock is essentially baked by the heat, changing the mineral structure of the rock without addition of pressure.

Rock cycle

The rock cycle links the principal sedimentary, metamorphic, and igneous rocks together in an idealized view of the sequential evolution of rocks in Earth's crust.

The rock cycle represents a simplified view of the formation of different rocks to illustrate the potential interaction between rock types (Fig. 3). Minerals and elements in Earth's crust can be recycled through several different rocks during their lifetime.

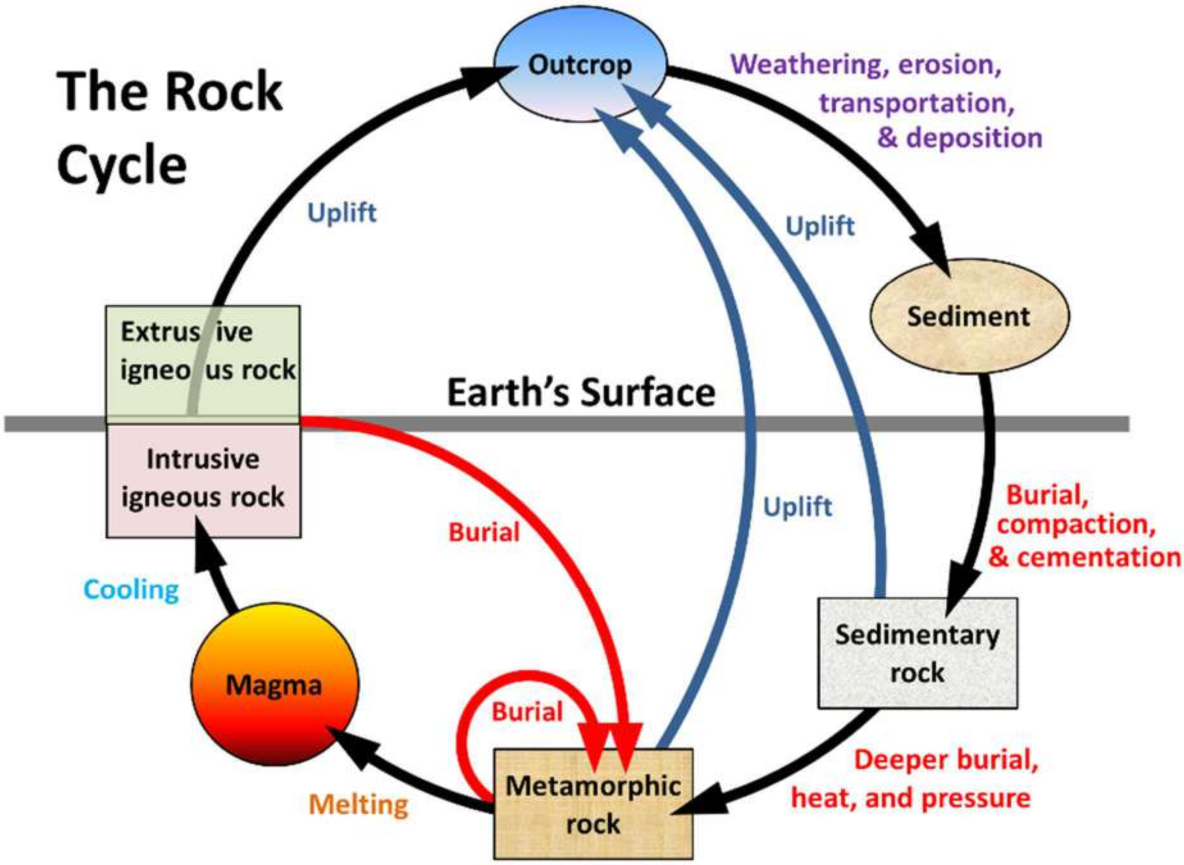

Fig. 3. Rock cycle.

There are main processes take place in rock cycle and are as follows:

1. Weathering

Simply put, weathering is a process of breaking down rocks into smaller and smaller particles without any transporting agents at play. Factors like temperature extremities, biological involvement of nature and water plays the main role.

It can be broken down into chemical, physical and biological influencing agents.

i. Physical: Mainly change of temperature rapidly or at extreme levels causes weathering. IT happens when rocks freeze and thaw. Another scenario is when tectonic plates pressure changes suddenly causing fissures. Usually occurs in rocky or mountainous places.

ii. Chemical: Usually occurs with rainwater trying to react with the rock minerals and create other minerals or chemical compounds. Usually happens in damp and warm places since reactions take place at higher temperatures.

The major reactions in this process are hydrolysis, oxidation and solution.

iii. Biological: The living world contributes to rock breakdown by-

Boring through rocks for protection

Cracking rocks under pressure while growing.

Breaking down rocks o build houses.

Releasing acid in order to extract nutrients from rocks for survival.

2. Erosion and Transport

Erosion too is the natural process of breaking down rocks into sand-like particles. The only difference between weathering to erosion is the presence of agents like water and wind. In the previous one, water was only present as a factor for reactions to take place while in erosion, it acts as a transporting agent too. Various events like attrition, abrasion and solution, wind transportation give rise to caves, new tributaries, and cracks in big rocks while wind transportation gives rise to thinned down rocks.

3. Deposition of Sediment

Sediment is the constant deposition or settling down of small particles of sand, pebbles, etc. that is broken down from rocks. It is usually done by-

Wind and water- Water in the rivers and glaciers from mountains slowly erode sand particles and create layers of sediments.

Biological Influence- Living organisms die and get sedimented under great pressure to form rocks.

Evaporation- Chemicals like $CaCO_3$ and NaCl are sedimented in troughs and seashores to create limestones and rock salts respectively.

4. Burial and Compaction

The next step to the process of sedimentation is burial and Compaction. The process is very simple. Once the sand particles are sedimented, they create layers which are soon covered by another layer of new sediments and the process goes on. This gives rise to pressure on the sedimented layers below. Meanwhile, the minerals in the water act as a slow cohesive agent between the particles. Thus, soft layers turn into solid rocks with minerals inside.

5. Crystallization of Magma

Magma is basically lava that remains dormant inside the volcanoes. Magma is the liquid form of rocks under great pressure and temperature due to heat from the earth core. Magma can be both sticky or less viscous. It depends on factors like temperature and amount of dissolved gas. The less viscous erupt and form porous rocks with fine grains while the more viscous ones form solid rocks with distorted grains.

6. Melting

The reverse of the previous process is melting. As soon as the rocks reach the bottom of the earth, the more the temperature rises and so does the pressure. Soon, they melt and give rise to melted rocks called lava. This, in turn, is erupted only to cool down at the surface to form rocks. Some rocks do not erupt and are forced to change characteristics to give rise to new forms of rock.

7. Uplift

The process of forming a crust of earth upwards due to natural forces causing movements in the tectonic plates is called uplifting. This is how mountains rise higher while new islands come up in the middle of the oceans.

8. Deformation and Metamorphism

The constant pressure and sudden movements put some sedimentary and igneous rocks under great pressure. Such forces can create folds or fissures among the rocks and among all these events, rocks deform to create metamorphic rocks. Deformation basically means folding and faulting of rocks. This is caused by compression and tension.

The result of the above processes causing the formation of different rocks. Igneous rocks are formed from cooled magma and are often either very rigid or porous depending on the place of cool down. They have minerals in the form of crystals which are often very visible. When Igneous, Sedimentary or Metamorphic rocks undergo immense pressure and heat, the shape of the rocks change. Under such circumstances, some of the properties of the rocks change giving rise to new forms of rock known as metamorphic rocks. The process might even repeat on metamorphic rocks again. Rocks that are formed from constant sedimentation followed by increased pressure and heat. Meanwhile, the minerals act as a cohesive agent and thus, sedimentary rocks are formed. The constructing particles can range from sand to pebbles. The main feature is undoubtedly visible strata and beds.

3.4 MINERALS – SOURCES AND TYPES

Minerals are the naturally occurring solid substance having definite chemical composition. These minerals may be in the form of crystalline or amorphous in nature. There are some other minerals, which are known as Synthetic Minerals and Artificial Minerals. The synthetic minerals are man-made minerals, simulating the natural conditions in the laboratory. These synthetic minerals possess properties of natural minerals. Whereas, Artificial minerals are the replica of the natural minerals, but do not possess the properties of natural minerals.

Physical properties of Minerals

Color is often useful, but should not be relied upon. Different minerals may be the same color.

Luster describes the reflection of light off a mineral's surface. Mineralogists have special terms to describe luster. One simple way to classify luster is based on whether the mineral is metallic or non-metallic. Minerals that are opaque and shiny, such as pyrite, have a metallic luster. Minerals such as quartz have a non-metallic luster.

Streak is the color of a mineral's powder. Streak is a more reliable property than color because streak does not vary. Minerals that are the same color may have a different colored streak.

Density describes how much matter is in a certain amount of space: density = mass/volume.

Hardness is the strength with which a mineral resists its surface being scraped or punctured. In working with hand samples without specialized tools, mineral hardness is specified by the Mohs hardness scale. The Mohs hardness scale is based 10 reference minerals, from talc the softest (Mohs hardness of 1), to diamond the hardest (Mohs hardness of 10). It is a relative, or nonlinear, scale. A hardness of 2.5 simply means that the mineral is harder than gypsum (Mohs hardness of 2) and softer than calcite (Mohs hardness of 3).

Hardness	Index Minerals
1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Feldspar
6	Apatite
7	Quartz
8	Topaz
9	Corundum
10	Diamond

Cleavage is the tendency of a mineral to break along certain planes to make smooth surfaces. Halite breaks between layers of sodium and chlorine to form cubes with smooth surfaces.

Fracture is a break in a mineral that is not along a cleavage plane. Fracture is not always the same in the same mineral because fracture is not determined by the structure of the mineral.

Classification of Minerals

Minerals are classified based on their crystal form and chemistry. Minerals are divided into two types namely metallic and non-metallic.

Metallic Minerals

Metallic minerals exhibit lustre in their appearance and consist of metals in their chemical composition. These minerals serve as a potential source of metal and can be extracted through mining. Examples of metallic minerals are Manganese, iron ore and bauxite are Metallic minerals and be divided into ferrous and non-ferrous metallic minerals.

Ferrous minerals are one that contains iron and non-ferrous are one that does not contain iron.

Non-metallic minerals

Non-metallic minerals are minerals which either show a non-metallic lustre or shine in their appearance. Extractable metals are not present in their chemical composition. Limestone, gypsum, and mica are examples of non-metallic minerals.

Bauxite ore mostly exists in deeply weathered rocks. Volcanic rocks contain bauxite deposits in some regions.

Iron metal extracted from iron ore. It never exists in pure form and has to be extracted from iron ore by eliminating the impurities.

Gold is the oldest and most precious element to be known.

Manganese ore is a silvery brittle or grey-white metallic ore occurs in many forms and found worldwide.

Other classification of minerals

Generally, minerals are classified into eight mineral classes.

1) Native Elements: This is the category of the pure metals. Most of the minerals are made up of combinations of chemical elements. e.g., element like the Copper (Cu) is found in a naturally pure form. There are about 40 elements, which are known to occur in a native state in the nature as relatively pure minerals. The finding of elements in a native state is related to structure of their atoms having inconvertible electronic shells. Although, occurrence of gold (Au), argentum (Ag), platinum (Pt) in native state are rare but most carbon (C), sulphur (S) and copper (Cu) are commonly found.

2) Silicates: Silicates are made from the metals which combine with the silicon and oxygen atoms. This is the largest group of minerals and most abundant in the Earth's crust than the sum of all the mineral groups. Silicate minerals are composed largely of silicon and oxygen, with the addition of ions such as aluminium, magnesium, iron, and calcium. Some important rock-forming silicates include feldspar, quartz, olivine, pyroxene, amphibole, garnet, and mica.

We shall discuss about the silicate minerals in detail in the next section. It includes important rock-forming silicates such as feldspar, quartz, olivine, pyroxene, amphibole, garnet, and mica.

3) Oxides: Oxides form from the combination of a metal with oxygen. The oxide class includes the oxide and the hydroxide minerals. This group ranges from dull ores like bauxite to gems like rubies and sapphires. The most widespread minerals of this group are oxides of silicon, aluminium, iron, manganese and titanium. Oxides are considered extremely important as they form many of the ores from which valuable metals can be extracted. Oxide minerals commonly occur either as precipitates at or near the Earth's surface, or as oxidation products or as accessory minerals in igneous rocks found in the crust and mantle. Some of the common oxides are hematite (iron oxide), magnetite (iron oxide), chromite (iron chromium oxide), rutile (titanium dioxide), and ice (hydrogen oxide). This class also includes the oxide and the hydroxide minerals.

4) Sulfides: Sulfides are made up of compounds of sulfur usually with a metal. They tend to be heavy and brittle. Several important metal ores come from this group like pyrite. Sulphide minerals generally have metallic luster, high density and low hardness. Many of the sulfide minerals are economically important for metals. Sulphides of copper, lead, zinc, argentum, antimony, etc. are common such as pyrite (iron sulfide), chalcopyrite (copper iron sulfide), pentlandite (nickel iron sulfide), and galena (lead sulfide). It also includes selenides, tellurides, arsenides, antimonides, bismuthinides, and sulfosalts (sulfur and a second anion such as arsenic).

5) Sulfates: Sulfates contain the sulfate anion, $(SO_4)^{2-}$. They are large group of minerals, which are made up of compounds of sulfur combined with metals and oxygen. Sulfate minerals tend to be soft, and translucent like barite (barium sulfate). They commonly form in evaporitic setting, in hydrothermal veins as gangue minerals along with the sulfide ores and also as secondary oxidation products of the original sulfide minerals. Some of the common examples of sulfate minerals are anhydrite (calcium sulfate), barite (barium sulfate), gypsum (hydrated calcium sulfate) and celestine (strontium sulfate). This class also includes chromate, molybdate, selenate, sulfite, tellurate, and tungstate minerals.

6) Halide group of minerals form from halogen elements like chlorine, bromine, fluorine, and iodine combined with metallic elements. They are very soft and easily soluble in water e.g. sodium chloride commonly known as table salt. Halides minerals form natural salts and include fluoride, chloride, bromide and iodide minerals such as fluorite (calcium fluoride), sylvite

(potassium chloride), and sal ammoniac (ammonium chloride), etc. Similar to the sulfates, halides are also commonly found in evaporitic settings such as playa lakes and landlocked seas such as the Dead Sea and Great Salt Lake or in artificial salt pans. This class includes fluoride, chloride, and iodide minerals.

Table 1. Summary of the chemical classification of minerals.

Chemical Class / Mineral Group	Anion or Anionic Complex	Description	Representative Minerals
Native elements	-	Naturally pure; only one kind of element is present	S-sulfur, Au-gold, Hg-silver, Cu-copper, C-diamond, C-graphite
Sulfides	S^{-2}	A metal bonds directly with sulfur as the nonmetal	FeS2-pyrite, PbS-galena, ZnS-sphalerite, CuFeS2- chalcopyrite
Oxides	O^{-2}	A metal bonds directly with oxygen as the nonmetal	hematite, magnetite, chromite
Halides	Cl^{-1}, F^{-1}	A metal bonds with a halogen	(Cl, F, Br or I) as a nonmetal NaCL-halite, CaF2-fluorite
Sulfates	$(SO_4)^{-2}$	A metal bonds with the SO_4 complex ion acting as a nonmetal	CaSO4-anhydrite, CaSO4.2H2O-gypsum, BaSO4-barite
Carbonates	$(CO_3)^{-2}$	A metal bonds with the CO_3 complex ion acting as a nonmetal	CaCO3-calcite, CaMg(CO3)2-Dolomite
Phosphates	$(PO_4)^{-3}$	A metal bonds with the PO_4 complex ion acting as a nonmetal	Ca5(PO4)3(F,OH,Cl)-Apatite
Silicates	$(SiO_4)^{-2}$	A metal bonds with the SiO_4 complex ion acting as a nonmetal	SiO2-quartz, (Na,Al,C)Si3O8-Feldspar

7) Carbonate group of minerals are made up of carbon, oxygen and a metallic element. They contain (CO3)2- anions. The common minerals are calcite and aragonite (both calcium carbonate), dolomite (magnesium/calcium carbonate) and siderite (iron carbonate). Carbonates minerals are commonly formed in marine settings, where shells settle and accumulate on the sea floor, and in the evaporitic settings (e.g. the Great Salt Lake, Utah) and also in karst regions. It also includes the nitrate and borate minerals.

8) The phosphate group of minerals are made up of minerals having PO_4 complex ions acting as a non-metal with a metallic element. The most common example is apatite found in teeth and bones of many animals. This class includes phosphate, arsenate, vanadate, and antimonite minerals.

3.5 SOIL – FORMATION, CLASSIFICATION CRITERIA AND TYPES, SOIL PROFILE

Soil is a natural resource. It is considered to be the "skin of the earth". It is formed as a product of weathering from various parent rocks or as transported materials from far off places by the action of water, wind, glaciers and other agents. Soil is an essential component of biotic resources, on land. The site, location and pattern of distribution of soils and their types are studied in various disciplines. Soil may be defined as a thin layer of the earth's surface, serving as a natural medium for plants to grow and organisms to survive. It is the most important natural resource. Soils are influenced by genetic and environmental factors, like parent material, climate, organisms and topography all acting over a period of time. Soils differ from the parent rocks in the morphological, physical, chemical and biological properties. Soils are the reservoirs of nutrients and water for crops. Rocks are the chief sources as the parent materials to produce soils. Soil is capable of supporting plant life and all life on earth. Soil is an unconsolidated heterogenous, mineral or organic natural medium, suitable for the growth of natural vegetation and crops.

3.5.1 Functions of Soil

Soil performs 7 major functions in several ecosystems:

They are:

1. Soils serve as a medium for the growth of all kinds of plants.
2. Soils modify the atmosphere by emitting and absorbing gases (carbon dioxide, methane, water vapor, and the like) and dust.
3. Soils provide a suitable habitat for animals that live in the soil (such as groundhogs and mice) to organisms (such as bacteria and fungi), that account for most of the living things on Earth.
4. Soils absorb, hold, release, alter, and purify most of the water received from precipitation and snow melt, on land.
5. Soils process recycled nutrients, including carbon, so that living things can use them over and over again.

6. Soils serve as engineering media for construction of foundations, roadbeds, dams and buildings, and artifacts of human use.
7. Soils act as a living filter to clean water before it moves into an aquifer.

3.5.2 Soil Formation

Soils are the products of mineral-weathering reactions. Soil formation is a set of complex processes including physical and chemical transformation of parent rocks. The processes of soil formation include

the addition of organic and mineral species

the loss of these materials from the soil

the translocation of materials from one place to another and

the transformation of mineral and organic substances within the soil.

Weathering: Weathering and soil formation are influenced by genetic and environmental factors. Soil development depends on the kind and intensity of weathering and processes of soil formation.

Pedogenesis: It is the process of soil development. It is a process in which the living organisms of soil bring about changes in the geochemical biochemical and biophysical properties of soils. During this process various compounds are added to the mineral content of soils. The organisms involved are lichens, bacteria, fungi, algae and molluscs. Weathering refers to the physical and chemical disintegration and decomposition of rocks which are not under equilibrium under temperature, pressure and moisture conditions.

Natural breakdown:

In simple terms, weathering is defined as the natural breakdown of rocks into fragments, soil or sediments. Several modifications are made by mechanical forces, chemical reactions and biological interactions. These changes take place in geologic materials exposed at or near the surface of the Earth.

Factors of Weathering process:

Rock structure, climate, topography and vegetation

The agents of physical weathering are

Temperature

Water

Wind

Plants and animals.

The chemical composition of rocks is brought about by solution, hydration, hydrolysis, carbonation, oxidation and reduction. The process as such involves two stages as Weathering and Soil development (or) Pedogenesis.

Factors Affecting Soil Formation:

Both genetic and environmental factors affect the process of soil formation. They are governed by the parent rocks, their interaction with climate, topography and organic life. These are divided into passive and active factors.

Passive factors

The passive factors are parent rocks, topography (relief) and time.

The Physical constitution of the parent material - has a profound effect in soil formation. It influences soil aeration, leaching and texture.

Landforms - are the reflections of topography and relief. Relief plays a significant role. Slopes are limiting factors. Steep slopes discourage soil development. Erosion and mass wasting are prevalent situations on slopes.

Time – Controls the soil formation. It may take several hundreds to thousands of years for a mature soil to develop. One foot of soil formation may take Ten thousand years.

ii) **Active factors**

Active factors include two major aspects, as climate and living organisms.

Climate – Climate has the major impact on Physical and chemical weathering. Climate affects soil formation. It regulates the amount of water entering the soil and plant growth. Macro and micro climates of a region is responsible for soil transformation.

Living organisms – Soil microbiology is the scientific study of living organisms present in the soil. The macro and meso fauna also affect and modify the soil properties through various activities like burrowing, transporting and mixing of organic and inorganic compounds. The macro modifiers are Rabits, bearers, rats, moles, dogs and squirrels. The meso modifiers include earthworms, mites and termites.

3.5.3 Classification Criteria and Types

Soil types may be classified on the basis of their geological origin. The origin of a soil may refer either to its constituents or to the agencies responsible for its present status. Based on constituents, soil may be classified as:

Inorganic soil/ Organic soil. Based on the agencies responsible for their present state, soils may be classified under following types:

Residual Soils.

Transported Soils: Alluvial or sedimentary soils/Aeolian soils /Glacial soils

Deposited Soils=Lacustrine soils/Marine soils

i. Classification based on grain-size

In the grain-size classification, soils are designated according to the grain-size or particle-size. Terms such as gravel, sand, silt and clay are used to indicate certain ranges of grain-sizes. Since natural soils are mixtures of all particle-sizes, it is preferable call these fractions as sand size, silt size, etc. The range of particle sizes encountered in soils is very large: from boulders with dimension of over 300 mm down to clay particles that are less than 0.002 mm. Some clays contain particles less than 0.001 mm in size which behave as colloids, i.e. do not settle in water. In the Indian Standard Soil Classification System (ISSCS), soils are classified into groups according to size, and the groups are further divided into coarse, medium and fine sub-groups. The grain-size range is used as the basis for grouping soil particles into boulder, cobble, gravel, sand, silt or clay.

Very coarse soils	Boulder size		> 300 mm
	Cobble size		80 - 300 mm
Coarse soils	Gravel size (G)	*Coarse*	20 - 80 mm
		Fine	4.75 - 20 mm
	Sand size (S)	*Coarse*	2 - 4.75 mm
		Medium	0.425 - 2 mm
		Fine	0.075 - 0.425 mm
Fine soils	Silt size (M)		0.002 - 0.075 mm
	Clay size (C)		< 0.002 mm

Gravel, sand, silt, and clay are represented by group symbols G, S, M, and C respectively.

Unified soil classification system:

Unified soil classification system was originally developed by Casagrande (1948) and was known as airfield classification system. It was adopted with some modification by the U.S. Bureau of Reclamation and the U.S. Corps of Engineers. This system is based on both grain size and plasticity characteristics of soil. Coarse grained soils are those with more than 50% of the material larger than 0.075mm size. Coarse grained soils are further classified into gravels (G) and sands (S). The gravels and sands are further divided into four categories according to gradation, silt or clay content. Fine grained soils are those for which more than 50% of soil finer than 0.075 mm sieve size. They are divided into three sub-divisions as silt (M), clay (C) and organic salts and clays (O). based on their plasticity nature they are added with L, M and H symbol to indicate low plastic, medium plastic and high plastic respectively.

These are the Examples with their notations:

GW – well graded gravel	GP – poorly graded gravel
GM – silty gravel	SP – poorly graded sand
SW – well graded sand	SC – clayey sand
SM – silty sand	OH – organic silt and clays of high plastic.
CL – clay of low plastic	CI – clay of medium plastic
CH – clay of higher plastic	ML – silt of medium plastic
MI – silt of medium plastic	MH – silt of higher plastic
OL – organic silt and clays of low plastic	OI – organic silt and clays of medium plastic

Fine grained soils have been sub-divided into three subdivisions of low, medium and high compressibility instead of two sub-divisions of the original Unified Soil Classification System.

ii. USDA 7th Approximation of Soil groups:

Soil Taxonomy has six categories. These are, from top to bottom, order, suborder, great group, subgroup, family and series. Ten classes are in the order level. Criteria used to differentiate orders are highly generalized and based more or less on the kinds and degrees of soil-forming processes. Mostly these criteria include properties that reflect major differences in the genesis of soils. A suborder category is a subdivision of an order within which genetic homogeneity is emphasized. Soil characteristics used to distinguish suborders within an order vary from order to order. The great group category is a subdivision of a suborder. They are distinguished one from another by kind and sequence of soil horizons. All soils belonging to one of the suborders will have more horizons.

Soils having these additional horizons are placed in separate great groups. Great group categories are divided into three kinds of subgroups: typic, intergrade and extragrade. A typic subgroup represents the basic concept of the great group from which it derives. An intergrade subgroup contains soils of one great group, but have some properties characteristic of soils in another great group or class. These properties are not developed or expressed well enough to include the soils within the great group toward which they grade. Extragrade subgroup soils have aberrant properties that do not intergrade to any known soil.

A soil family category is a group of soils within a subgroup that has similar physical and chemical properties that affect response to management and manipulation. The principal characteristics used to differentiate soil families are texture, mineralogy and temperature.

Family textural classes, in general, distinguish between clayey, loamy and sandy soils. For some soils the criteria also specify the amount of silt, sand and coarse fragments such as gravel, cobbles and rocks. The soil series is the narrowest category in soil taxonomy.

Soil Orders

To identify, understand, and manage soils, soil scientists have developed a soil classification or taxonomy system. Like the classification systems for plants and animals, the soil classification system contains several levels of detail, from the most general to the most specific.

The most general level of classification in the United States system is the *soil order*. There are 12 orders of soils categorized by the U.S. Department of Agriculture. Each order is based on one or two dominant physical, chemical, or biological properties that differentiate it clearly from the other orders. Each order is based on one or two dominant physical, chemical, or biological properties that differentiate it clearly from the other orders. The 12 soil orders all end in "sol" which is derived from the Latin word "solum" meaning soil or ground. Most of the orders also have roots that tell you something about that particular soil. For example, "molisol" is from the Latin "mollis" meaning soft.

Gelisols: Gelisols (from the Latin *gelare* – to freeze) are soils that are permanently frozen (contain “permafrost”) or contain evidence of permafrost near the soil surface. Gelisols are found in the Arctic and Antarctic, as well as at extremely high elevations. Permafrost influences land use through its effect on the downward movement of water and freeze-thaw activity (cryoturbation) such as frost heaves. Permafrost can also restrict the rooting depth of plants. Gelisols make up about 9% of the world’s glacier-free land surface.

Histosols: Histosols (from the Greek *histos* – tissue) are dominantly composed of organic material in their upper portion. The Histosol order mainly contains soils commonly called bogs, moors, peat lands, muskegs, fens, or peats and mucks. These soils form when organic matter, such as leaves, mosses, or grasses, decomposes more slowly than it accumulates due to a decrease in microbial decay rates. This most often occurs in extremely wet areas or underwater; thus, most of these soils are saturated year-round. Histosols can be highly productive farmland when drained; however, drained Histosols can decompose rapidly and subside dramatically. They are also not stable for foundations or roadways, and may be highly acidic. Histosols make up about 1% of the world’s glacier-free land surface.

Spodosols:

Spodosols (from the Greek *spodos* – wood ash) are among the most attractive soils. They often have a dark surface underlain by an ashy gray layer, which is subsequently underlain by a reddish, rusty, coffee-colored, or black subsoil horizon. These soils form as rainfall interacts with acidic vegetative litter, such as the needles of conifers, to form organic acids. These acids dissolve iron, aluminum, and organic matter in the topsoil and ashy gray (eluvial) horizons. The dissolved materials then move (illuviate) to the colorful subsoil horizons. Spodosols most often develop in coarsely textured soils (sands and loamy sands) under coniferous vegetation in humid regions of the world. They tend to be acidic, and have low fertility and low clay content. Spodosols occupy about 4% of the world's glacier-free land surface.

Andisols: Andisols (from the Japanese *ando* – black soil) typically form from the weathering of volcanic materials such as ash, resulting in minerals in the soil with poor crystal structure. These minerals have an unusually high capacity to hold both nutrients and water, making these soils very productive and fertile. Andisols include weakly weathered soils with much volcanic glass, as well as more strongly weathered soils. They typically occur in areas with moderate to high rainfall and cool temperatures. They also tend to be highly erodible when on slopes. These soils make up about 1% of the glacier-free land surface.

Oxisols: Oxisols (from the French *oxide* – oxide) are soils of tropical and subtropical regions, which are dominated by iron oxides, quartz, and highly weathered clay minerals such as kaolinite. These soils are typically found on gently sloping land surfaces of great age that have been stable for a long time. For the most part, they are nearly featureless soils without clearly marked layers, or horizons. Because they are highly weathered, they have low natural fertility, but can be made productive through wise use of fertilizers and lime. Oxisols are found over about 8% of the glacier-free land surface.

Vertisols : Vertisols (from the Latin *verto* – turn) are clay-rich soils that contain a type of "expansive" clay that shrinks and swells dramatically. These soils therefore shrink as they dry and swell when they become wet. When dry, vertisols form large cracks that may be more than one meter (three feet) deep and several centimeters, or inches, wide. The movement of these soils can crack building foundations and buckle roads. Vertisols are highly fertile due to their high clay content; however, water tends to pool on their surfaces when they become wet. Vertisols are located in areas where the underlying parent materials allow for the formation of expansive clay minerals. They occupy about 2% of the glacier-free land surface.

Aridisols: Aridisols (from the Latin *aridus* – dry) are soils that occur in climates that are too dry for "mesophytic" plants (plants adapted to neither too wet nor too dry environments) to survive. The climate in which Aridisols occur also restricts soil weathering processes. Aridisols often contain accumulations of salt, gypsum, or carbonates, and are found in hot and cold deserts worldwide.

They occupy about 12% of the Earth's glacier-free land area, including some of the dry valleys of Antarctica.

Ultisols: Ultisols (from the Latin *ultimus* – last) are soils that have formed in humid areas and are intensely weathered. They typically contain a subsoil horizon that has an appreciable amount of translocated clay, and are relatively acidic. Most nutrients are held in the upper centimeters of Ultisol soils, and these soils are generally of low fertility although they can become productive with additions of fertilizer and lime. Ultisols make up about 8% of the glacier-free land surface.

Mollisols: Mollisols (from the Latin *mollis* – soft) are prairie or grassland soils that have a dark colored surface horizon, are highly fertile, and are rich in chemical "bases" such as calcium and magnesium. The dark surface horizon comes from the yearly addition of organic matter to the soil from the roots of prairie plants. Mollisols are often found in climates with pronounced dry seasons. They make up approximately 7% of the glacier-free land surface.

Alfisols: Alfisols (from the soil science term *Pedalfer* – aluminum and iron) are similar to Ultisols but are less intensively weathered and less acidic. They tend to be more inherently fertile than Ultisols and are located in similar climatic regions, typically under forest vegetation. They are also more common than Ultisols, occupying about 10% of the glacier-free land surface.

Inceptisols: Inceptisols (from the Latin *inceptum* – beginning) exhibit a moderate degree of soil development, lacking significant clay accumulation in the subsoil. They occur over a wide range of parent materials and climatic conditions, and thus have a wide range of characteristics. They are extensive, occupying approximately 17% of the earth's glacier-free surface.

Entisols: Entisols (from *recent* – new) are the last order in soil taxonomy and exhibit little to no soil development other than the presence of an identifiable topsoil horizon. These soils occur in areas of recently deposited sediments, often in places where deposition is faster than the rate of soil development. Some typical landforms where Entisols are located include: active flood plains, dunes, landslide areas, and behind retreating glaciers. They are common in all environments. Entisols make up the second largest group of soils after Inceptisols, occupying about 16% of the Earth's surface.

3.5.4 Soil Profile

Soils are considered to be independent natural bodies, each with a unique morphology and resulting from a unique combination of climate, living matter, parent rock materials, relief, and time. The morphology of each soil, as expressed in its profile, reflected the combined effects of the particular set of genetic factors responsible for its development. The vertical distribution of soils shows some variations due to duration and extent of weathering, geomorphic conditions, and strength of parent rocks. It also varies from place to place. There is also minute vertical variation within the layers of soil mass. Hence, they are called as soil horizons. A soil containing a set of distinct horizons is called as a soil profile. Soil "horizons" are typically distributed as layers parallel to the ground surface. In some soils, they show some evidences of their source rocks and the soil forming processes.

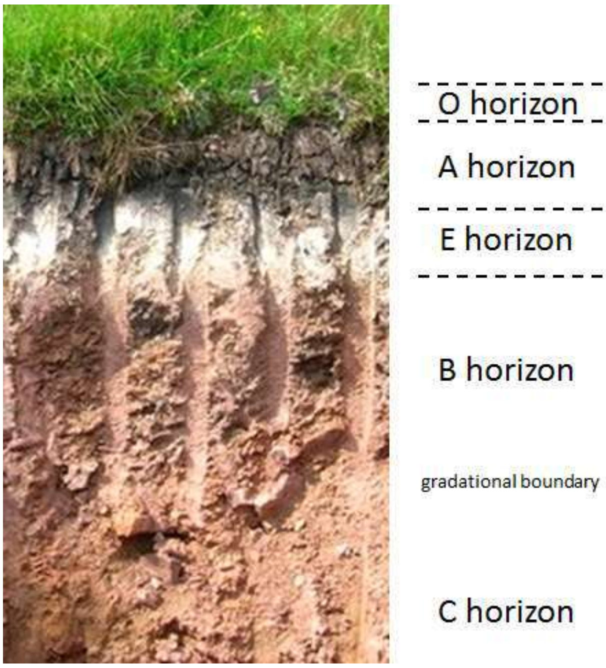

Fig. 1. Soil Profile

Soils are landscapes as well as profiles. If we dig a massive trench (hole) of about 2 to 6 m vertically downwards into the ground, we will notice various layers of soil horizons. A look at these layers from a distance, gives a cross-sectional view of the ground (beneath the surface) and the kind of soils and rocks that make up the soil profile. This cross sectional view is called as the Soil Profile. The profile is made up of layers, running parallel to the surface, called Soil Horizons. Each soil horizon(layer) may be slightly or very much different from the other layer existing above or below it. Each horizon also tells a story about the makeup, age, texture and other characteristics of that layer. The layers are divided as top soil layer, sub-soil layer and the bed rock layers. There are more minor subdivisions in soil horizons. Most of the soils have five major horizons. These are designated as O, A, B, C, E and R. The A, B, C horizons are further subdivided into micro-layers as A1, A2, A3, B1, B2, and B3. In some profiles, the letter E is not used in the zonation process.

The O-Horizon (humus + litter layer): The O horizon is very common in many surfaces with lots of vegetative cover. It is the layer made up of organic materials such as dead leaves and surface organisms, twigs and fallen trees. It has about 20% organic matter. It is possible to see various levels of decomposition occurring here (minimal, moderately, highly and completely decomposed organic matter). This horizon is often black or dark brown in colour, because of its organic content. It is the layer in which the roots of small grass are found.

The A-Horizon (Top soil + Root Zone): The A horizon may be seen in the absence of the O horizon, usually known as the topsoil. It is the top layer soils for many grasslands and agricultural lands. Typically, the A horizons are made of sand, silt and clay with high amounts of organic matter. This layer is most vulnerable to wind and water erosion. It is also known as the **root zone**.

The E-Horizon: The E horizon is usually lighter in color, often occurring below the O and A horizons. It is often **rich in nutrients** that are leached from the top A and O horizons. It has a lower clay content. It is common in forested lands or areas with high quality O and A horizons.

The B-Horizon (Mineral dominated zone): The B-horizon has some similarities with the E-horizon. This horizon is formed below the O, A and E horizons and may contain high concentrations of silicate clay, iron, aluminum and carbonates. It is also called the **illuviation zone** because of the accumulation of minerals. It is the layer in which the roots of big trees exist.

The C-Horizon (saprolite layer): C horizons are mineral layers which are not bedrock and are little affected by pedogenic processes and lack properties of O, A, E or B horizons. The C horizon lacks all the properties of the layers above it. It is mainly made up of broken bedrock and no organic material. It has cemented sediment and geologic material. There is little activity here although additions and losses of soluble materials may occur. The C horizon is also known as saprolite.

The R-Horizon: The R horizon is bedrock horizon. It contains materials that are compacted and cemented by the weight of the overlying horizons. It is the hard layer of unweathered parent material. All kinds are rock types exist as basement.

3.6 SUMMARY

The Earth is composed of layers of different composition and physical properties, principally the solid central core, the fluid peripheral core, the viscous mantle, and the solid lithosphere. Rocks on the Earth may be composed of hundreds of possible minerals but only 20 to 30 minerals are common in the majority of rocks. Minerals are made up of combinations of nearly a hundred different elements, yet only eight elements make up over 98% of the Earth's crust. There are mainly three types of rocks, igneous, metamorphic and sedimentary rocks. The rock cycle links the principal sedimentary, metamorphic, and igneous rocks together in an idealized view of the sequential evolution of rocks in Earth's crust. Soil is a natural resource and is formed as a product of weathering from various parent rocks or as transported materials from far off places by the action of water, wind, glaciers and other agents. Soil performs several function in ecosystem. Soil profile indicate the different layers with different composition. Soils are classified based on different criteria.

3.7 KEYWORDS

Crust	Mantle	Core
Aesthenosphere	Minerals	Rocks
Soils	Soil Profile	Soil classification

3.8 QUESTIONS FOR SELF STUDY

1. Explain the internal structure of Earth with diagram explain the components of each layer.
2. Define rock and explain its types
3. Describe the rock cycle with diagram.
4. Define mineral. Explain its physical properties.
5. Classify the minerals based on the chemical composition
6. What is soil? Describe the formation of soil.
7. Explain the classification criteria and soil types.
8. Describe the soil profile with diagram.

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UNIT 4: BIOSPHERE

STRUCTURE

4.0 OBJECTIVES

- After studying this unit, you will be able to
- state the elements of biosphere
- explain components of biosphere
- describe biomes and aquatic life zones
- discuss the interacting components of natural and social environment

4.1 INTRODUCTION

Biosphere refers to the narrow zone of the earth in which all life forms exist. They are land (lithosphere), air (atmosphere) and water (hydrosphere), In other words, this narrow zone is a place where lithosphere, atmosphere and hydrosphere meet.

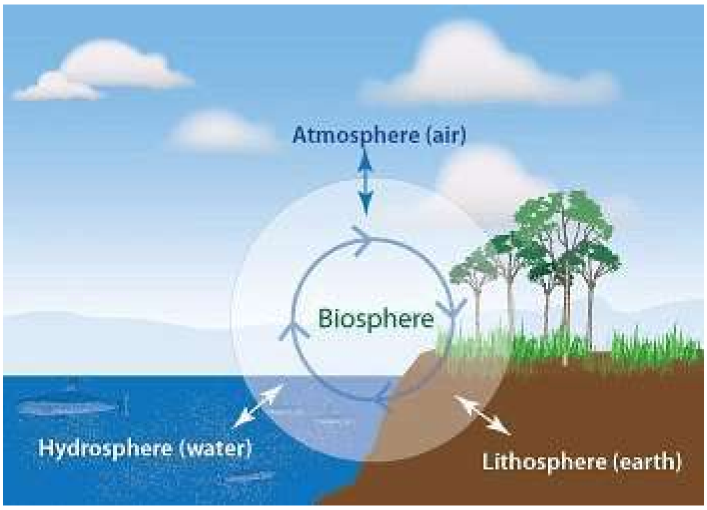


Fig. 1. Biosphere

It extends vertically into the atmosphere to about 10km, downward into the ocean to depths of about 10.4 km and into about 27,000 ft of the earth's surface where maximum living organism have been found. There are some life forms which are found in extreme conditions. Two examples of this type are algae and thermophillic. Algae which is supposed to be one of the earliest forms of life can exist even in the most hostile environment such as frozen Antarctica. On the other extreme side, thermophillic (heat loving) bacteria usually inhabit deep sea volcanic vents having a temperature of more than 300° C. In fact, these bacteria cannot survive in a temperature below boiling point. The situation was not like this when the life form began. About 700 million years ago, it is believed to have been only a narrow discontinuous land encompassing only shallow parts of the oceans. As per the trend of expansion of area in terms of the availability of life form, it can be predicated that may be after a few million years, the expanse of the biosphere gets extended beyond the upper troposphere. This shows that biosphere has been evolving over the time. Till now we have discussed about the vertical expansion, but horizontally the biosphere covers the entire globe, though the life may not be possible in some of the hottest and the coldest parts. However, most living things are confined to a narrow band which permits the capture of solar energy through the process of photosynthesis, which is essential for any organic life. This narrow region extends from about 180-200 feet below sea level to the highest value of snowline in Tropical and sub-tropical mountain ranges (say 6,550M above sea levels). When it extends beyond this line, life forms become very limited.

4.2 COMPONENTS OF BIOSPHERE

Biosphere has three basic components. These are (A) abiotic (physical and inorganic) components; (B) biotic (organic) components and (C) energy components.

(A) Abiotic Components:

These components broadly consist of all non-living elements which are essential for the survival of all living organisms. These are (i) lithosphere (solid part of the earth crust), (ii) atmosphere and (iii) hydrosphere. Mineral nutrients, certain gases and water are the three basic requirements of organic life. Soils and sediments constitute the chief reservoir of mineral nutrients. Atmosphere constitutes the chief reservoir of gases essential for organic life. Ocean constitutes the chief reservoir of liquid water, where all these three reservoirs intermingle and that area becomes the most fertile area for organic life. The upper layer of the soil and shallow parts of the ocean constitute the most important areas, box sustaining organic life. The upper layer of soil, permits easy penetration of gases and percolation of moisture, while shallow parts of oceans, allow penetration of sunlight, inter-mingling of dissolved gases and nutrients from land surface and ocean bottoms.

(B) Biotic Components

Plants, animals and human beings including microorganisms constitute the three biotic components of environment. In a way these can be called as the three sub-systems.

(i) Plants: Plants are most important among biotic components. They are the only primary producers as they produce their own food through the process of photo synthesis and hence are called autotrophs. Not only plants alone produce all kinds of organic matter but also help in cycling and recycling of organic matters and nutrients. Thus, plants are the major source of food as well as energy for all organisms.

(ii) Animals: While plants are the primary producers, the animals are the main consumers. Therefore, animals are heterotrophs. There are three main functions of animals: (i) to use organic matter made available by plants as food. (ii) to transform the food into energy and (iii) to utilize the energy for growth and development.

(iii) Micro-organisms: These consist of a variety of micro-bacteria, fungi etc. Their numbers are unlimited and are popularly known as decomposers. As the name suggest, these organisms decompose the dead plants and animals and other organic matters. It is through this process they obtain their food. Through this process of decomposition, they differentiate and separate the complex organic matter, so that the same could be put to re-use by the primary producers i.e., the plants.

(C) Energy: This is the third and vital component of the biosphere without which life could not have been possible on this planet. It is essential for generation and reproduction of all biological life on this planet. All organisms in the biosphere are like machines which use energy to work and also to convert one form of energy into another. But do you know the source of such energy required for the functioning of the biosphere? Sun is the major source of energy without which we cannot think about the existence of the biosphere.

4.3 BIOME AND AQUATIC LIFE ZONES

Based on the predominant vegetation and characterized by adaptations of organisms, biomes are mainly classified into two biomes.

i. Terrestrial Biomes or Land Biomes

ii. Aquatic Life Zones or Water Biomes

i. Terrestrial Biomes

The terrestrial or the land biomes are categorized and termed consistent with the climate and therefore the climax vegetation of the region during which they're found. The climax vegetation is also called the biological community of plants, animals, birds and other living species that's stable and dominant after the various years of evolutionary development.

Since plants are an important source of nutrition and are the producers in the ecosystem, they determine the nature of the inhabiting animal population. Therefore, the climax vegetation governs the animal population.

The Major Kinds of Terrestrial Biomes Within the World are discussed here:

a. Tundra

The tundra is characterized by permafrost, a layer of permanently frozen sub-soil. During the short, cool summer, the ground thaws to a depth of a few centimetres and becomes soggy and wet. In winter, the topsoil freezes again. This cycle of thawing and freezing, which rips and crushes plant roots, is one reason that tundra plants are small and stunted. Cold temperatures, high winds; the short growing season, and humus-poor soils also limit plant height.

The region having strong winds with low precipitation, short and soggy summers, and the winter is long, cold, and dark. The soils are poorly developed and also with permafrost. The vegetation include ground-hugging plants such as mosses, lichens, sedges, and short grasses. The fauna in the Tundra region have a few resident birds and mammals that can withstand the harsh conditions; migratory waterfowl, shore birds, musk ox, Arctic foxes, and caribou; lemmings and other small rodents. The geographic location of Tundra area are northern North America, Asia, and Europe.

b. Desert

All deserts are dry, in fact, a desert biome is defined as having annual precipitation of less than 25 centimeters. Beyond that, deserts vary greatly, depending on elevation and latitude. Many undergo extreme temperature changes during the course of a day, alternating between hot and cold. The organisms in this biome can tolerate the extreme conditions.

The region having low precipitation with variable temperatures, and soils are rich in minerals but poor in organic material. The vegetation is dominated by cacti and other succulents, creosote bush and other plants with short growth cycles. Animals present in this area are predators such as mountain lions, gray foxes, and bobcats, and herbivores such as mule deer, pronghorn antelope, desert bighorn sheep, and kangaroo, rats, bats, birds such as owls, hawks, and roadrunners; insects such as ants, beetles, butterflies, flies, and wasps; reptiles such as tortoises, rattlesnakes, and lizards. The deserts are distributed in Africa, Asia, the Middle East, United States, Mexico, South America, and Australia.

c. Savana

Savanna areas receiving more seasonal rainfall than deserts but less than tropical dry forests, tropical savannas, or grasslands, are characterized by a cover of grasses. Savannas are spotted with isolated trees and small groves of trees and shrubs. Compact soils, fairly frequent fires, and the action of large animals such as rhinoceros prevent some savanna areas from turning into dry forest.

The area having warm temperatures with seasonal rainfall, the soils are compact, and because of the grass vegetation, frequent fires set by lightning. The vegetation falls in this area are tall and perennial grasses, sometimes drought-tolerant and fire resistant trees or shrubs are found. The fauna include predators such as lions, leopards, cheetahs, hyenas, and jackals, aardvarks, herbivores such as elephants, giraffes, antelopes, and zebras, and baboons; birds such as eagles, ostriches, weaver birds, and storks; insects such as termites. The Savanna are dominant in large parts of eastern Africa, southern Brazil, northern Australia.

d. Tropical Rain Forests

Tropical rain forests are home to more species than all other land biomes combined. The leafy tops of tall trees which are extending up to 70 meters above the forest floor and form a dense covering called a canopy. In the shade below the canopy, a second layer of shorter trees and vines forms an understory. Organic matter that falls to the forest floor quickly decomposes and the nutrients are recycled.

The climate of this area is hot and wet round the year, soils are thin with poor nutrient. The vegetation is dominated by broad-leaved evergreen trees; ferns; large woody vines and climbing plants; orchids and bromeliads. The animals present in this region are herbivores such as sloths, tapirs, and capybaras; predators such as jaguars can be seen, and also anteaters, monkeys, and birds such as toucans, parrots, and parakeets are present. Insects such as butterflies, ants, and beetles; piranhas and other freshwater fishes, and reptiles such as frogs, caymans, boa constrictors, and anacondas are seen here. Tropical rain forests are distributed in the parts of South and Central America, Southeast Asia, parts of Africa, southern India, and northeastern Australia.

e. Temperate Grasslands

Characterized by a rich mix of grasses and underlaid by some of the world's most fertile soils, temperate grasslands – such as plains and prairies – once covered vast areas of the Midwestern United States. Since the development of the steel plow, however, most have been converted to agricultural fields. Periodic fires and heavy grazing by large herbivores maintain the characteristic plant community.

The area having warm to hot summers and cold winters, rainfall is moderate and seasonal precipitation. The soils are fertile and area facing occasional fires. The plants include lush, perennial grasses and herbs; most are resistant to drought, fire, and cold. Dominant wildlife include predators such as coyotes and badgers -- historically included wolves and grizzly bears; herbivores such as mule deer, pronghorn antelope, rabbits, prairie dogs, and introduced cattle -- historically included bison; birds such as hawks, owls, bobwhite, prairie chicken, mountain plover; reptiles such as snakes; insects such as ants and grasshoppers. Temperate grasslands are distributed in central Asia, North America, Australia, central Europe, and upland plateaus of South America.

f. Temperate Deciduous Forest

Temperate forests contain a mixture of deciduous and coniferous trees. Coniferous trees, or conifers, produce seed-bearing cones and most have leaves shaped like needles. These forests have cold winters that halt plant growth for several months. In autumn, the deciduous trees shed their leaves. In the spring, small plants burst out of the ground and flower. Soils of temperate forests are often rich in humus, a material formed from decaying leaves and other organic matter that makes soil fertile.

The area with cold to moderate winters and warm summers, the area receives the rainfall throughout the year an soils are fertile. Vegetation include broadleaf deciduous trees; some conifers; flowering shrubs; herbs; a ground layer of mosses and ferns. Animals found here are **d**eer; black bears; bobcats; nut and acorn feeders, such as squirrels; omnivores such as raccoons and skunks; numerous songbirds; turkeys. The temperate deciduous forests are distributed in eastern United States; southeastern Canada; most of Europe; and parts of Japan, China, and Australia.

g. Taiga or Boreal Forest

Along the northern edge of the temperate zone are dense evergreen forests of coniferous trees. These biomes are called boreal forests, or taiga. Winters are bitterly cold, but summers are mild and long enough to allow the ground to thaw. The word boreal comes from the Greek word for "north," reflecting the fact that boreal forests occur mostly in the Northern Hemisphere.

The area having long and cold winters, and short and mild summers. The region receives moderate precipitation, having high humidity. The soils are acidic and poor in nutrient. The plants in this area are needleleaf coniferous trees such as spruce and fir; some broadleaf deciduous trees; small, berry-bearing shrubs Dominant wildlife include predators like lynx and timberwolves and members of the weasel family; small herbivorous mammals; moose and other large herbivores; beavers; songbirds and migratory birds. Boreal forests are distributed in North America, Asia, and northern Europe.

h. Northwestern Coniferous Forest

Mild, moist air from the Pacific Ocean provides abundant rainfall to this biome. The forest is made up of a variety of conifers, ranging from giant redwoods, along the coast of northern California to spruce, fir, and hemlock farther north. Moss often covers tree trunks and the forest floor. Flowering trees and shrubs such as dogwood and rhododendron are also abundant. Because of its lush vegetation, the northwestern coniferous forest is sometimes called a "temperate rain forest".

The area facing mild temperatures and abundant precipitation during fall, winter, and spring, and the area is relatively cool with dry summer. The area is rocky with acidic soils. Dominant plants are Douglas fir, Sitka spruce, western hemlock, redwood. Dominant wildlife are bears; large herbivores such as elk and deer; beavers; predators such as owls, bobcats, and members of the weasel family. The area under coniferous forests are Pacific coast of northwestern United States and Canada, from northern California to Alaska Boreal Forest.

i. Temperate Woodland and Shrubland

This biome is characterized by a semiarid climate and a mix of shrub communities and open woodlands. In the open woodlands, large areas of grasses and wildflowers such as poppies are interspersed with oak trees. Communities that are dominated by shrubs are also known as chaparral. The growth of dense, low plants that contain flammable oils makes fires a constant threat.

The areas are hot with dry summers, winters are cool and moist. Soils are thin and nutrient-poor and the area facing periodic fires. Dominant plants with woody evergreen shrubs with small, leathery leaves; fragrant, oily herbs that grow during winter and die in summer. Dominant wildlife include predators such as coyotes, foxes, bobcats, and mountain lions; herbivores such as blacktailed deer, rabbits, squirrels, and mice; birds such as hawks, California quail, western scrub jay, warblers and other songbirds; reptiles such as lizards and snakes; butterflies; spiders The regions falls under Temperate Woodland and Shrubland are western coasts of North and South America, areas around the Mediterranean Sea, South Africa, and Australia.

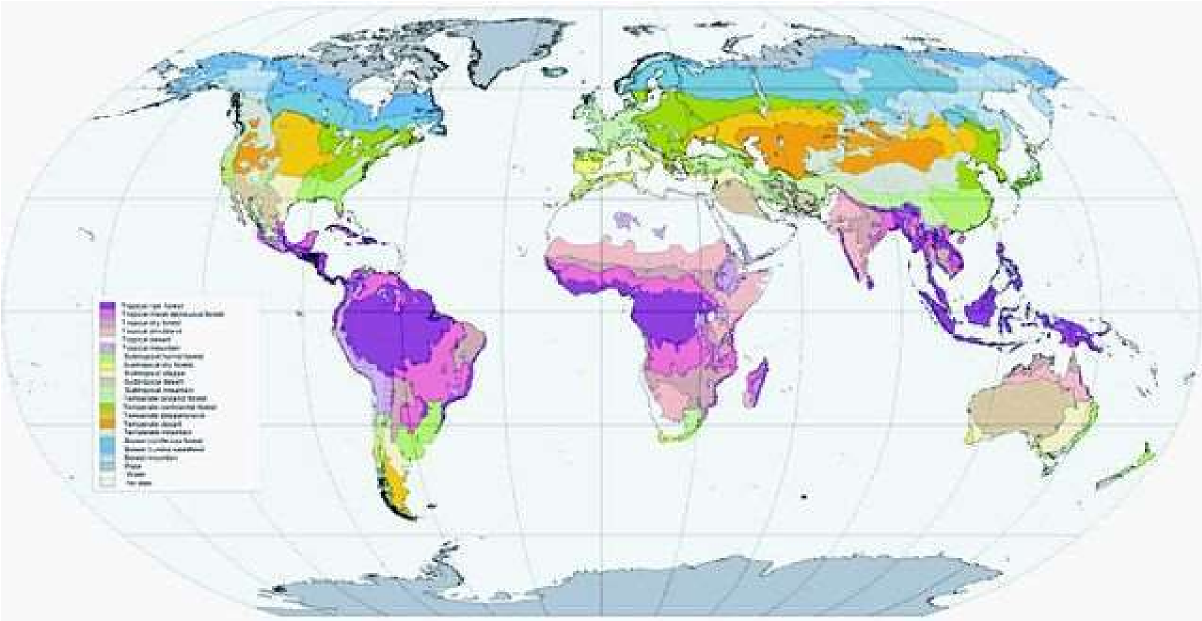


Fig. 1. Biomes of the World

ii. Aquatic Life Zones or Water Biomes

Water is the most vital and essential element among the biological community. The total earth's surface is covered by water which is nearly 70 to 80 per cent. Therefore, aquatic biomes are the most important and widest biome within the world. There are numerous species of aquatic plants and animals, both large and little. According to the taxonomy records, the marine habitats are older than the terrestrial habitats, as life originated in the oceans about billions of years ago.

Aquatic biomes are the foremost stable ecosystems on this planet and with the absence of water, most of the life forms would be unable to sustain themselves and therefore the Earth would be a lifeless and desert-like place.

Even though the water temperature varies, the aquatic areas tend to be more humid and the temperature of the air on the cooler side. This water biome mainly consists of aquatic plants and animals.

The aquatic biome provides a huge array of habitats, which support a staggering diversity of species. Scientists believe that they form the basis of aquatic food webs and contribute between 70 to 85 percent of the oxygen in Earth's atmosphere.

As much as 80 to 85 percent of the atmospheric oxygen and the food and production (photosynthesis) takes place in water. There are two major sorts of aquatic biomes within the world:

Aquatic Life Zones

Aquatic life zones are equivalents to biomes on land.

The key factors determining biodiversity in aquatic systems are:

1. **Temperature**
2. **Dissolved oxygen content**
3. **Availability of food**
4. **Availability of light and nutrients necessary for photosynthesis**
5. **Salinity or the amount of dissolved salts(Mainly NaCl) in the water**

Aquatic life zones are categorized into two major types:

1. **Saltwater or marine** which include: oceans, estuaries, coastal wetlands, shorelines, coral reefs, and mangrove forests.
2. **Freshwater** which include: lakes, rivers, streams, and inland wetlands.

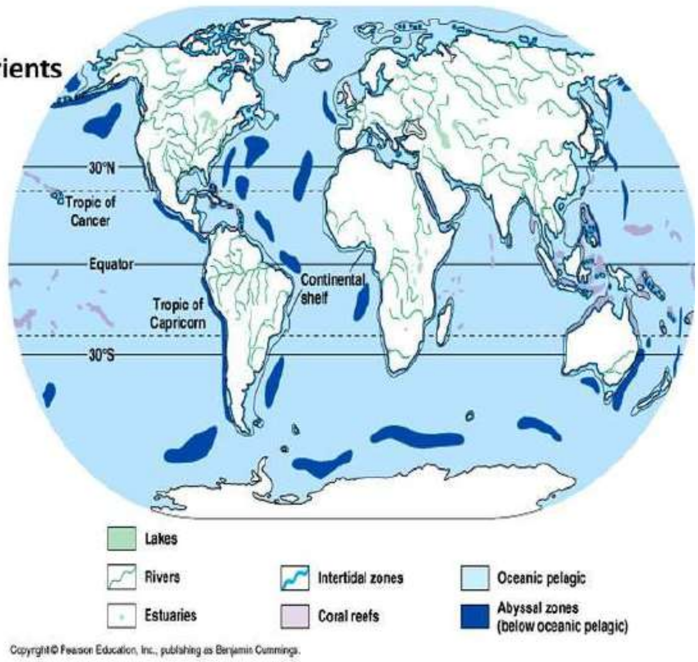


Fig. 2. Aquatic Life Zones of the World.

Freshwater Biomes

Low levels of dissolved salts characterize the freshwater biomes. The salt content of fresh water about 0.005 percent. The freshwater biomes consist of inland bodies of standing water like lakes, reservoirs, pods and wetlands as well as the flowing waters of the streams and rivers. Their nature does not depend as much on global climate, but on the individual site where they occur.

A lake or a body of standing waters can be divided into three zones according to penetration of sunlight in the water body, littoral, limnetic and profoundal. The littoral zone is the area where light penetrates to the bottom. Aquatic life in the littoral The open water zone is called the limnetic zone. This represents the zone or depth of the water up to which sunlight can penetrate. Phytoplankton along with algal forms, various zooplankton species and fish abound in this zone. The deep water zone lying below the limnetic zone is called profoundal zone. It is relatively cool and dark, having low dissolved oxygen content and is inhabited by fish which can tolerate such stressful conditions. The bottom of the lake is inhabited by bacteria, fungi, blood worms and other decomposers which live on dead plants, organic matter including remains of animals and their metabolic wastes.

Precipitation that does not evaporate or penetrate the soil remains on the soil surface resulting in run off which flows down from the mountains in the form of streams and rivers which ultimately discharge into the sea. The downward flow of the river comprises of three phases. The first phase, when the stream with cold clear water rushes down steep slopes having high dissolved oxygen content. Most organisms which are adapted to cold temperatures and need high amounts of dissolved oxygen are found here. In the second phase the stream flows over gentle slopes and through wider valleys. Here the temperature of water is warmer and supports a wide variety of cold water and warm water fish that require slightly lower dissolved oxygen. At the point where river discharges into sea, the river may divide into many channels, forming the delta.

Rivers and brookes which are flowing fresh water bodies differ from lakes and ponds in three major aspects.

1) current is the major controlling and limiting factor
2) land -water interchange is greater because of the smaller size and depth of moving water systems
3) oxygen is always abundant except in case of excessive pollution in river stretches.

Plants and animals living in streams and rivers are usually attached to surfaces. The free swimming animals are exceptionally strong swimmers. The freshwater communities are utilised as a major source of food, for recreational purposes and for waste disposal as well as waterways for transport. In this manner we exert a significant impact on individual freshwater ecosystems and their communities.

Marine Biomes

The marine biomes consist of the earth's oceans and its associated areas like the shorelines, islands reefs and estuaries. The marine waters contain about 3.5 percent salt mostly sodium chloride and the organisms inhabiting these waters are profoundly adapted to these salty conditions. As land livers we generally think of the earth as being mostly land and tend to forget that 71% of the surface of our planet is covered by oceans. In fact, often our planet is referred to as the 'water planet!'.

Oceans

The oceans play a' major role in determining the climate and sustaining the life on earth. Oceans help to redistribute the solar energy, through ocean currents and evaporation; they are huge reservoirs of carbon dioxide, oxygen and other minerals and help to regulate the ambient temperature and also help in maintaining atmospheric composition and serve as sources of various natural resources.

The world's seas and oceans are all inter-connected forming a World Ocean. The average depth of the ocean is 3.7 km. In some parts of the world the ocean is 11.5 km deep. Compare this with the height of Mount Everest that is 8848m above sea level.

Most marine life is found in the shallower regions of the ocean and seas along the continental shelves, coral reefs and oceanic islands. Life at greater depths is limited by darkness, cold temperatures and pressure. Animal life at great depth; comprises mainly of scavengers and predators that feed on the detritus rain and dead organic matter. The food that supports the large and diverse communities of the ocean is produced in the open water by phytoplankton in upper regions of the ocean where sunlight can reach. The average depth of the lighted zone of the sea is 200 meters in clean areas.

The marine habitat faces destruction due to pollution and resource use. Shorelines and open waters are subject to human activities such as fishing, recreational use, real estate development, garbage and effluent disposal, oil spills, radioactive waste disposal and exploitation of marine natural resources.

Shorelines, Oceanic Islands and Reefs

Ocean shorelines include rocky coasts and sandy beaches that are particularly rich in diverse life forms. Rocky shorelines support a diversity of organisms that grow attached to some solid substratum. Sandy shorelines provide home to organisms that can live in burrows in sandy substratum.

Sandy beaches are important in our context as some of the finest tourist resorts and residences are built along them.

Oceanic Islands are interesting and somewhat specialised biomes. Islands which have broken away from the main continents have similarity of flora and fauna related to the continental source, volcanic and coral islands show results of chance colonization.

Coral Reefs - form in clear warm tropical seas and are particularly well developed in the South Pacific. They are formed by accumulation of calcareous skeletons of tiny colonial animals called Cora$, over generations. Coral reefs usually form along the shallow submerged shelves and their depth is limited to a depth up to which sunlight can diffuse. Coral reef communities in terms of species diversity, number of organisms, brilliance of colours and interesting life forms are comparable with tropical forest communities.

Wetlands and Estuaries

Wetlands and estuaries are transitional biomes. Land that remains flooded either part of the year or permanently with fresh or salt water is known as wetland. Bogs, swamps, marshes are covered by freshwater and found inland. These are known as inland wetlands those found on the coast and covered by seawater are known as coastal wetlands. Wetlands provide a variety of fish and wildlife and are major breeding, nesting and migration staging areas for water birds and shorebirds. Importance of wetlands cannot be underestimated as they act as traps and filters for water that moves through them reducing flooding. As a result, sediments are deposited and chemical interactions in wetlands neutralise and detoxify substances in water and slow seeping of water into the ground helps to replenish the underground water reserves.

Estuaries are enclosed or semi closed bodies of water formed where a river meets the sea forming an area of mixed fresh and seawater. Estuaries usually contain rich sediment forming mud flats. The estuaries are very productive areas with high species diversity. They are important nurseries for ocean fish including all economically important fish and molluscs. The estuaries extend inland to form the coastal wetlands. In temperate areas, coastal wetlands usually consist of a mix of bays, lagoons and salt marshes, while in tropical areas we find mangrove swamps dominated by mangrove trees, the mangrove forests consist of evergreen, broad - leaf trees growing in brackish water in tropical areas.

4.4 INTERACTING COMPONENTS OF NATURAL AND SOCIAL ENVIRONMENT

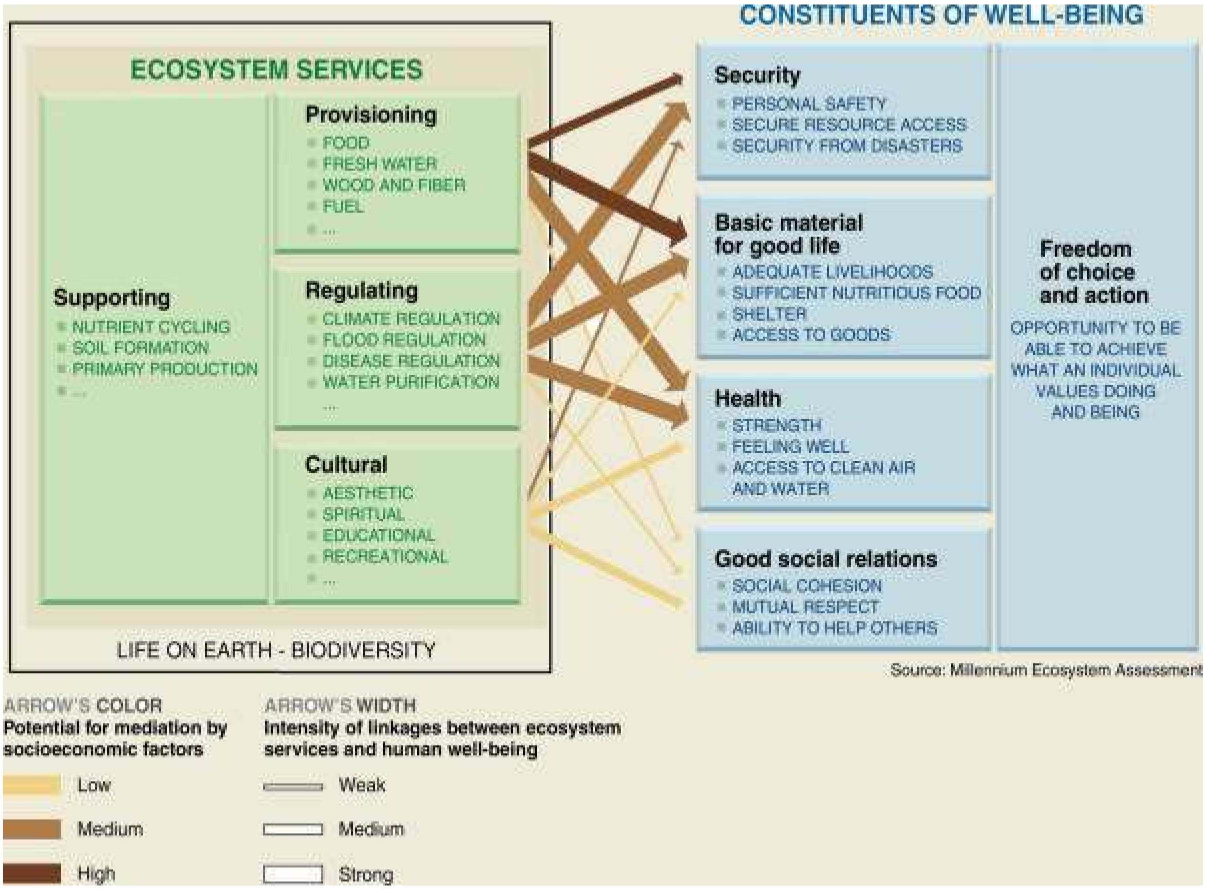
Human Environmental Interactions can be defined as interactions between the human social system and the ecosystem. Human social systems and ecosystems are complex adaptive systems. Complex because ecosystems and human social systems have many parts and many connections between these parts. Adaptive because they have feedback structures that promote survival in a constantly changing environment.

Human social system

In order to analyse Human Environmental Interactions it is important to be aware of specific characteristics of the human social system. The type of society strongly influences peoples' attitude towards nature, their behaviour and therefore their impact on ecosystems. Important characteristics of human social systems are population size, social organization, values, technology, wealth, education, knowledge and many more. Especially values and knowledge strongly influence peoples "view of life" and consequently define the way people act. The choice of possible actions is then limited by the available technology.

People modify the environment for their purposes and obtain benefits (Ecosystem Services) from it. These **Ecosystem Services** are essential for **human well-being** and include for example the provision of resources like water, timber, food, energy, information, land for farming and many more. Obviously by using these resources people affect the environment in a lot of ways. Furthermore, people often reorganize existing ecosystems to achieve new ones that seem to be more effective in serving their needs.

The **Millenium Ecosystem Assessment (MA)** analysed how Ecosystem Services and constituents of **human well-being** are interlinked. The MA research programme was launched with support from the United Nations in 2001.



Coevolution and Coadaptation

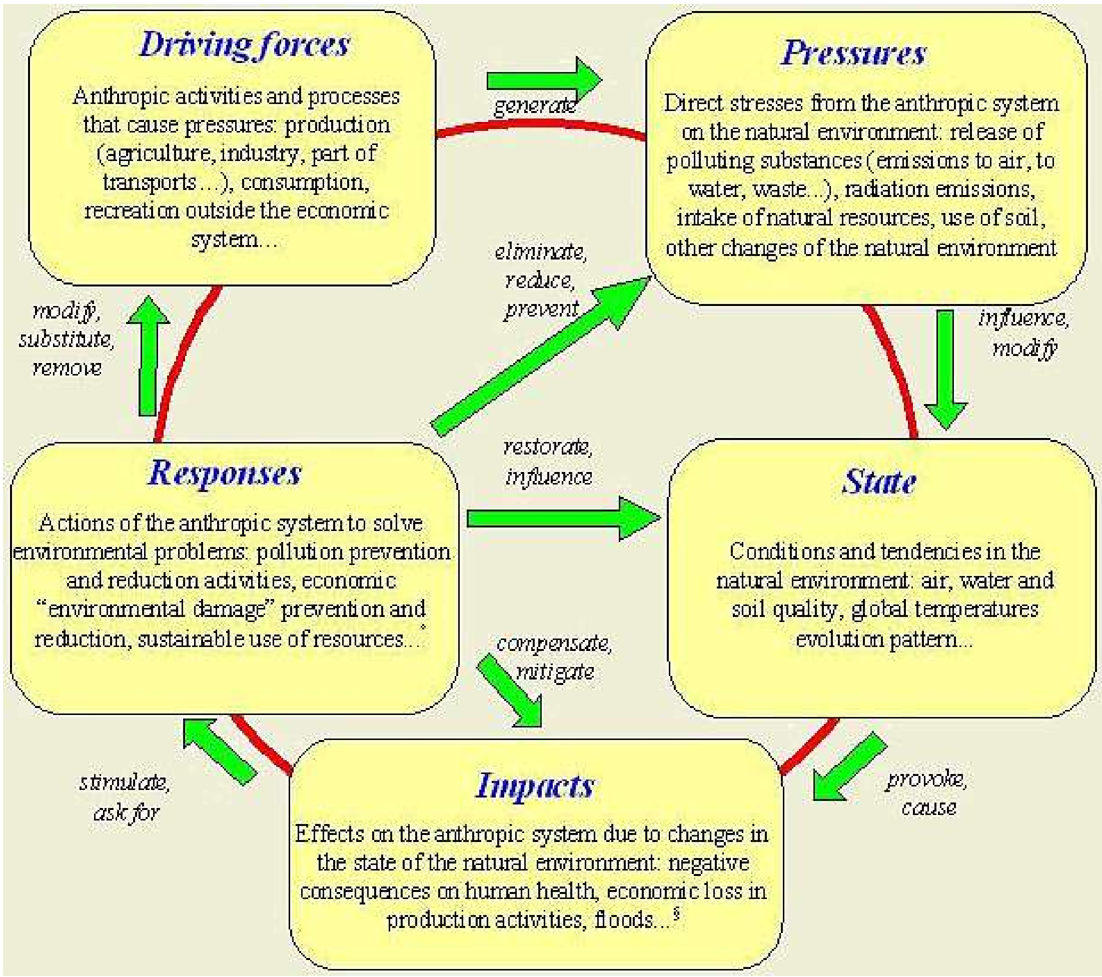
The terms coevolution and coadaptation describe the never-ending process of mutual adjustment and change between human social systems and the environment. Peoples actions have consequences on the environment. But also the environment influences human activities.

Human social systems have to adapt to their specific environment. Natural phenomena like storms, earthquakes force people to react. These natural phenomena can either be directly or not primarily caused by human actions and again influence human behaviour as people have to respond to a new situation.

Drivers-Pressures-State-Impact-Response

The Drivers-Pressures-State-Impact-Response (DPSIR) model was originally developed by the European Environmental Agency (EEA) and is used to assess and manage environmental problems. Many national and European institutions adopted this conceptual framework. It identifies the various causal chains of links between human activities and environmental degradation. The model distinguishes several categories of indicators in order to explain how the state of the environment is changed due to human activities. Human activities increase or mitigate pressure on the environment. The driving forces which initiate human activities are mainly socio-economic and socio-cultural forces.

The following graphic explains the DPSIR process:



4.5 SUMMARY

Biosphere constitutes the part of lithosphere, atmosphere and hydrosphere, where life exist. Biosphere has abiotic, biotic and energy components. Based on the predominant vegetation and characterized by adaptations of organisms, biomes are mainly classified into Terrestrial Biomes or Land Biomes and Aquatic Life Zones or Water Biomes. Terrestrial biomes include tundra, desert, savannah, tropical rain forests, temperate grasslands, temperate deciduous forests, taiga, coniferous forests and temperate woodland. Aquatic life zone constituted by freshwater bodies and marine waters. Human social systems and ecosystems are complex adaptive systems. Complex because ecosystems and human social systems have many parts and many connections between these parts. Adaptive because they have feedback structures that promote survival in a constantly changing environment.

4.6 KEYWORDS

Biosphere	Terrestrial biomes	Aquatic life zones
Tundra	Desert	Savannah
Tropical Rain Forests	Temperate Grasslands	Temperate Deciduous Forests
Taiga	Coniferous Forests	Temperate Woodland

4.7 QUESTIONS FOR SELF STUDY

1. What is biosphere? Explain the components of biosphere.

2. What are biomes? Mention its types.

3. Briefly explain the following:

a. Tundra	b. Desert	c. Savannah
d. Tropical Rain Forests	e. Temperate Grasslands	f. Deciduous Forests
g. Taiga	h. Coniferous Forests	i. Temperate Woodland

4. Discuss the interacting components of natural and social environment.

4.8 REFERENCES FOR FURTHER READING

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