Physical Features
Part – II
6th Term I
Unit-2 Land and Oceans
11th standard

Unit 1. Fundamentals of Geography

Introduction

- "The study of Geography is about more than just memorising places on a map. It is about understanding the complexity of our world, appreciating the diversity of cultures that exists across continents. And in the end it is about using all that knowledge to help bridge divides and bring people together" - Barak Obama, Former President of USA. The subject 'Geography' was considered as 'The Mother of all Sciences' as most streams of sciences took root from geography.

- It is a subject much needed in everyday life .Unfortunately, in the recent past it has been demoted to the back seat in most parts of the world, while certain other sciences hold prominent places in the society. Just as an intellectual understands the value of a library, a financier understands the value of money, a parent understands the value of their child a geographer understands the value of our planet earth and the wealth of resources it offers to us.

- A society that lacks sufficient geographic knowledge cannot be expected to exhibit its strength of resource potentials and empowerment to make decisions in real-world context. Therefore, the knowledge of geography is very much vital for the care and concern of the earth, growth and development of every country and for minimising the issues related to human activity. In this context, the National Geographic Society, USA defines geographic literacy as being equipped to understand the complexity of the world, how our decisions affect others (and vice versa), and the interconnectedness of this rich, diverse, and not-so-large world.

- This unit introduces the student to the foundations over which the subject had developed in the past, the content it offers now and the changes that it had undergone. It also opens the door to the world of physical geography and the practical skills to be acquired to understand geography which are explained in the units following this.

Defining Geography

- Geography is one of the oldest earth sciences and its roots date back to the works of the early Greek scholars. The term 'Geography' was coined by the Greek scholar Eratosthenes who combined two Greek words 'Geo' (The Earth) and 'Graphing' (to describe). Therefore, in the literary sense, geography is the description of the Earth. Over the ages, geography has become the art and science of studying the physical characteristics of the earth and man's role in adapting to and modifying the environment.

- Geography was born through explorations and discoveries. Earlier, the aim of geography was to discover new lands, sea routes, prepare maps and describe them. Later, its emphasis had shifted to scientific investigation of earth's landforms, oceans and atmosphere, as well as the interactions with human beings and the environment.

- In essence, geography can be defined as a multifaceted discipline studying intra and inter relationships of various spheres of the earth, collects and analyses relevant data, applies the latest tools and methods to prepare maps and visuals and provides sustainable solutions to human and environmental issues of the earth.

Evolution of Geography

- Geography had evolved over a long period of time. Some of the earliest geographical studies go back about four thousand years ago through explorations. The early explorers travelled and tried to map the new places. The evidences of such explorations come from the archaeological discovery of a Babylonian clay tablet map that dates back to 600 BCE. During this time, Phoenician, Chinese and Egyptian civilisations were in the beginning to explore places outside their homelands. It was the ancient Greek scholars who laid the foundations and gave a solid form to geographic studies and on these foundations, the pillars of modern geography were erected by others in the subsequent ages. The Romans, the Arabs, the Indians, the Chinese, the Germans, the French, the British and the American geographers have contributed to the development and enrichment of the subject.

- The Greek philosophers and scientist focused on the spatial nature of human and physical features of the Earth. The first Greek geographer was Herodotus (484 - 425 BCE) who wrote a number of volumes on the human and physical geography of the Persian Empire. The other early Greek contributors to geography are, Thales, Aristotle and Eratosthenes (276 - 194 BCE).

- The earlier geographers were descriptive geographers concerned with answering questions like 'what is where' on the earth and the question like 'why it is there' came later. Geographers study the location of the activities, carefully identify patterns using maps and find out the reasons for these patterns. The areas are then described based on the distribution of land forms, population, housing and agriculture. They discover the linkages and movements between places and are able to infer the spatial processes that are working in these areas.

- The development of geography can be summarised in three phases namely (1) The age of discovery (1400-1800), (2) The period between 1800 and 1950 and (3) The period after 1950.

The age of discovery between 1400 - 1800

- The period between 1400 and 1800 was when the subject matter and the methodology of geography were not fully developed. The discipline was in an embryonic stage. Tis period was characterized by exploration, discovery and conquest through the voyages of Vasco da Gama and Christopher Columbus. Numerous journeys of geographical exploration were commissioned by a number of Nations in Europe (Figure. 1.1, 1.2, 1.3 and 1.4). Most of these voyages were financed because of the potential commercial returns from resource exploitation. The voyages also provided an opportunity for scientific investigation and discovery. Making of maps (cartography) was important in the discipline of geography due to the emphasis on location of phenomena on the earth surface, e.g. location of trade routes, relief features and settlements.

The period between 1800 -1950

- The period between 1800 and 1950 was characterized by the work of various individual philosophers who helped to expand the scope of geography. The discipline of geography became more distinct as a subject matter. Geographic knowledge saw strong growth in Europe and the United States in the 1800s. Tis period also saw the emergence of a number of societies interested in geographic issues. In Germany, Alexander Von Humboldt, Carl Ritter and Friedrich Ratzel made substantial contributions to human and physical geography. Humboldt's publication 'Kosmos' in 1844, examines the geology and physical geography of the earth. Tis work is still considered by many academics as a milestone contribution to geography.

- There are two schools of thought that emerged during this period as an attempt to explain the relationship between human beings and their environment. These were environmental determinism and possibilism. Proponents of environmental deterministic school of thought such as Mackinder, Ellen Semple and Huntington believed that human actions and activities were moulded by the physical (natural) conditions. In several developing countries, human beings are susceptible to natural disasters such as drought, famine, floods and earthquakes. Human beings under such natural conditions usually surrender to nature. A good example of environmental determinism is the influence of the natural environment on human activities such as nomadic pastoralism. Nomadic pastoralism is so much dependent on the natural environment. Pastoralists do very little to modify their environment.

- The proponents of possibilistic school of thought, such as Vidal de la Blache saw the environment as a limiting factor rather than as a deterministic force. According to the possibilism school of thought, human beings have several alternatives in their environment and their actions are influenced by the decisions they make in the environment. For instance, humans can survive in hot or extremely cold conditions due to their ability to modify the environment to suit them. A good example is that in many arid countries such as Israel, humans have overcome the constraints set by the natural environment such as low rainfall, high temperatures and poor soils.

The period after 1950

- Until 1950s, geography was more of an art subject where facts were established by casual observation in the field rather than by careful measurement and hypothesis testing. In the 1950s there was a new development in the discipline and several laws were established to explain geographical phenomena. Using the laws, it is possible to predict what will happen in the future. If we can predict successfully, we can plan and limit the extreme possibilities.

- One of the important developments in this period was the use of quantitative techniques in physical and human geography. These techniques refer to various statistical tools that are used to synthesise the data from maps, field, laboratories and questionnaires. Quantification came about as a result of the expanding scope of the discipline as well the need to understand the processes that were becoming more diversified and complicated.

- This quantitative revolution was referred to as a revolution because it marked a new beginning in the way the subject matter of geography was to be studied. The quantitative revolution involves the use of statistics, mathematical equations and the use of deterministic models. Many geographers believed that numbers are more precise, and therefore perceived as more scientific compared to words. The map, both as graphic language and visual representation, continues to be used as a geographical tool and at present with the valuable assistance of remote sensing and Geographical Information Systems, map making has become digital and easier especially due to advances in computer and software technologies.

Themes of Geography

- In any subject there will be certain themes, around which the scholars work and contribute. In this way, geography subject also has certain traditional themes. Let us look at them carefully. In 1963, William D. Pattison identified the core themes of geographic studies as 'The Four Traditions of Geography'. These distinct, but related, traditions, of the discipline are: Spatial tradition (areal distributions

and spatial patterns. Examples: Population movement) Area studies tradition, (hierarchy of areas, small to large) Man-land tradition (relationship between man and his physical environment) and Earth science tradition (processes of the earth).

- Like the major traditions identifed in geography, the signifcant themes of the subject are also identifed. Te Association of American Geographers put forward the 'Five themes of Geography' and it has been widely accepted by geographers worldwide (Figure1.5). Te themes are location, place, human – environment interaction, movement and regions.

Five Themes in Geography

Themes of Geography are the educational tools for understanding the geography subject in detail. It was adopted in the year 1984 by the Association of American Geographers and these five themes were published in the National Council for Geographic Education/Association of American Geographers' publication Guidelines for Geographic Education.

Location

Every point on earth has a location. The location can be described in two different ways:

- Absolute location is a location as described by its latitude and longitude on the earth. For example, the coordinates of Chennai Central Railway station are 13°04'56" N latitude and 80°16'32" E longitude.
- Relative location is the position of a place in relation to another well-known landmark. For example, Kallanai Dam or Grand Anicut is located roughly 350 km south –southwest of Chennai City. The absolute and relative location related surveys and studies fall under this category.

Place

- A place is an area that is defined by everything in it. All places have features that give them personality to distinguish them from

other places. A number of place names in Tamil Nadu, like Redhills, Fort St. George, Mint, and George Town are examples to this theme.

- Toponym: A place name, especially one derived from topographical feature.
- Site: An area of ground on which a town, building, or monument is constructed.
- Situation: The location and surroundings of a place.

Human-Environment Interaction

The theme describes how people interact with the environment and how the environment responds. These are studied with reference to the following three key concepts:

- Dependency: How humans depend on the environment (Example: For water, fresh air, sunlight etc.)
- Adaptation: How humans adapt to the environment (Example: Life in polar or desert regions)
- Modifcation: How humans modify the environment (Example: Construction of Underground Metro rail, Agriculture in Israel).

Movement

- Movement is the network of travel of people, goods and ideas from one location to another. Examples: Rural-urban migration and metro train commuting in Chennai. Air transport which carries people and goods and the internet that allows access to ideas and knowledge across the world are also examples of this kind.

Region

- Regions are areas with distinct homogenous characteristics such as climate (Monsoon regions), natural vegetation (Tropical rain forests), crops (Corn Belt of USA), major landforms (Himalayan region), industries (Chota-Nagpur plateau) etc.

Geography's Relation with Physical and Social Science Disciplines

- While defining geography, we have seen that some branches of geography have strongest affiliations with subjects like mathematics and environmental sciences, while others have very close connection with history and sociology. Some subjects deal with distinctive type of phenomena while geography examines several kinds of phenomena together. Te diagram (Figure 1.6) gives clear idea about the relationship of geography with other disciplines.

Relations with Physical Sciences

Astronomy, Mathematics, Computer Science and Geography:

- Astronomy basically deals with the celestial bodies including stars, planets, satellites, their motions, constellations, as well as different kinds of phenomena occurring in the outer space. The precise location, nature of movements, form and size of celestial bodies, including those of the solar system, have been accurately measured with the help of mathematics. The interaction of astronomy, mathematics and computer science with geography has paved way for the development of modern cartography and GIS.

Geology and Geography:

- Geology is the study of rocks, their types, distribution, mineral content, petroleum, etc. The subject investigates all these phenomena, classify them and put them in a sequence. Geography interacts with the subject in studying the distribution of exposed rocks, interaction with climate and human activities, economic prospects of the minerals and so on. Interaction between geology and geography leads to formation of the new branch of study called geomorphology, the study of landforms.

Physics, Chemistry and Geography:

- As geography is the study of variable phenomena on the earth's surface, the dynamic mechanism of the phenomena requires to be studied within the framework of physics. The physics of atmosphere is

studied under climatology and the physics of hydrosphere through oceanography, and both the subjects investigate, interpret and explain the atmospheric and hydrological processes. The chemical contents of rocks, soil, surface and groundwater, atmosphere are the interests of the geographers. They study how the physical and chemical contents are disturbed by human activities and vice versa.

Botany, Zoology and Geography:

- The systematic branches of botany and zoology have traditionally been confined to the classification and description of various kinds of species on the earth's surface. Geography, being the study of the spatial section of earth's surface, attempts to study the distributional aspects of fora and fauna especially with reference to climate and relief. The integration among these subjects has given birth to biogeography.

The study of 'apartheid' (a system of institutionalised racial segregation as existed in South Africa) is an example of anthropo-geographic study.

Relationship with Social Sciences

Economics and Geography:

- Economics is concerned with how human needs and wants are satisfied with the available resources. Economic geography is concerned with the study of resources endowment and patterns of utilisation. The economic activities of the human beings including agriculture, fishing, forestry, industries, trade and transport are studied in this branch. The economic activities are highly influenced by the relief and climatic factors of the region or the country. Therefore, economics and geography have close links with each other, especially for integrated resources development.

Sociology and Geography:

- Sociology is mainly concerned with the institutional aspects of the society. A number of investigations including social behaviour, movement of people between rural-urban areas, spatial interactions between social groups, the relations between innovation and tradition in rural and urban areas etc., have been jointly undertaken by

sociologists and geographers in different countries of the world. Social geography is the logical expression of the interaction between sociology and geography as it studies social phenomena in spatial context.

Anthropology and Geography:

- Anthropology attempts to study human races and their classification. Both anthropology and geography seek to identify and classify the human races on the basis of their habitat and cultural traits and attempt to study the variable racial phenomena on the spatial context of the earth's surface. The relationship between anthropology and geography has resulted in the development of 'anthropogeography' or geography of humans.

History and Geography:

- History is a framework of events as per time and place. Geography attempts to study these events with reference to the physical earth and depict the places of historical events using thematic maps. Anyone who attempts to study any historical events of India should always integrate the temporal and the spatial phenomena of that period together to arrive at a conclusion.

Tamil Rulers and Geographic Knowledge

History reveals to us that how the Great rulers like Raja Raja Chola or Rajendra Chola had trade relations with other countries of the world, especially South Asian countries by understanding the relief, seasons, ocean current movements etc., The sailors would have been experts in every aspect of geography to move their troops, sail overseas and trade with all known nations of that time. They also utilised the ocean currents to transport teak and other valuable timbers from Indonesia, Myanmar, and other countries to South India.

Approaches to the Study of Geography

- Geography has undergone several changes in its approach. Te earlier geographers were descriptive geographers. Later, geography came to be developed as an analytical science. Today the discipline is not only concerned with descriptions but also with analysis as well as

prediction. There are two distinct approaches or methods to study geography. They are: 1. Systematic approach and 2. Regional approach

Systematic Approach:

- Systematic or nomothetic approach was introduced by Alexander Von Humbolt, a German geographer (1769-1859). In this approach a particular phenomenon is considered for detailed understanding. Te study of specifc natural or human phenomenon that gives rise to certain spatial patterns and structures on the earth surface is called systematic study. Generally, systematic geography is divided into four main branches.

i. Physical Geography: Study of various elements of earth systems like atmosphere (air), hydrosphere (water), lithosphere (rock) and biosphere (life) and their distributions.
ii. Biogeography, including environmental geography: It focuses on various kinds of forests, grasslands, distribution of flora and fauna, human-nature relationships, quality of the living environment and its implications for human welfare.
iii. Human Geography: It describes the human culture, population, dynamic socio economic and political aspects.
iv. Geographical methods and techniques: It is concerned with methods and techniques for field studies, qualitative, quantitative and cartographic analysis.

Regional Approach:

- It is otherwise called as ideographical approach. It was developed by Carl Ritter (1779 – 1859), a contemporary of Humboldt. The regions could be classified based on a single factor like relief, rainfall, vegetation, percapita income or there could also be multi-factor regions formed by the association of two or more factors. Administrative units like states, districts and taluks can also be treated as regions. The main sub branches of regional geography are : i) Regional studies ii) Regional analysis iii) Regional development and iv) Regional planning.

Born on 14 September 1769 Alexander Von Humboldt was a Prussian polymath, geographer, naturalist, explorer. Humboldt's quantitative work on botanical geography laid the foundation for the field of biogeography Humboldt resurrected the use of the word cosmos from

the ancient Greek and assigned it to his multi-volume treatise, Kosmos. He was the first person to describe the phenomenon and cause of human-induced climate change, in 1800. He described the Guanoco asphalt lake as "The spring of the good priest". Humboldt and Bonpland discovered dangerous electric eels, whose shock could kill a man. His stay in Ecuador was marked by the ascent of Pichincha and their climb of Chimborazo, where Humboldt and his party reached an altitude of 19,286 feet (5,878 m). This was a world record at the time. U.S President, Jefferson later referred to Humboldt as the most scientific man of the age.

Geographical Data Matrix:

- The matrixis a simple method of arranging information in rows and columns for better understanding of complex spatial problems. Brian J.L. Berry adopted this method from anthropology for studying geography more effectively. Geographic data can be arranged in a rectangular array or matrix. Row-wise group of variables represent the systematic or topical branches of geography while, regions are represented by columns. Berry has explained that regional synthesis could be derived with the help of a series of geographic matrices in correct temporal sequence. Each time period has been taken to be equivalent to a 'slice' of the three-dimensional cake. The diagram of 'Third Dimension' makes it possible to examine rows and columns, cutting across time.

Branches of Geography

- Based on content and the available techniques, the discipline can be divided into three major domains. Each one has many sub divisions which deal with specific objectives (Figure 1.7).
  a. Physical Geography
  b. Human Geography and
  c. Geographic Techniques.

Physical Geography

- It is the study of natural features of the earth such as land, water, air and living organisms. The changes taking place within and among

these natural features and their resultant features are studied under its various branches. The branches of physical geography are:

i. **Geomorphology** deals with the distribution of land forms, their origin and the forces causing changes over these landforms. Geology provides basic information to the study of geomorphology.
ii. Soil Geography is a study related to soil formation, soil profile, soil types, their fertility level and distribution. Soil erosion and conservation measures are also dealt in this branch.
iii. Climatology deals with the study of global and regional weather and climatic conditions by analysing relevant statistical data. Meteorology provides basic information on the composition, structure and the changes in the atmosphere.
iv. Hydrology encompasses the study of earth's realm of water such as oceans and surface water bodies like rivers, reservoirs and ponds. It also makes a study of underground water and its recharge and also pollution of water bodies.
v. Oceanography is the study of seas and oceans. The shape, size, depth and bottom relief of ocean, distribution of oceans, ocean currents and various life forms existing in ocean are also studied under oceanography.
vi. Biogeography is a study of ecosystems over geographical space. It also analyses the changes in the ecosystems. Phytogeography or plant Geography, Zoo Geography or animal geography and Ecology are the branches of biogeography.
vii. Environmental Geography is the study of environmental issues arising out of misuse of various spheres of the earth and their implications. The ozone layer depletion, global warming, melting of polar ice caps, rising sea level and other related aspects are also given due importance. It also tries to give sustainable solutions to these problems.

Human Geography

- Human Geography is concerned with the changes made by the humans over the natural or physical landscape. The ethnic and political aspects are taken into consideration. The issues like climatic change, natural and anthropogenic disasters are also the major concerns.

i. Population Geography is the study of distribution and density of population, the changing patterns in age and sex composition, birth and death rates, life expectancy, literacy level and dependency ratio, migrations at national and international level and the causes and consequences of migration.
ii. Settlement Geography deals with the characteristics of rural and urban settlements and transportation network. It seeks better understanding of the present landscape and plans for the future. The study is more important for town and country planning.
iii. Historical Geography tries to picturise the geography of an area or region as it was in the past and studies how it has evolved over time. The forces involved in transforming region such as colonisation by the Europeans or a natural disaster are also included in the study.
iv. Anthropo Geography deals with the distribution of human communities on the earth in relation to their geographical environment.
v. Cultural Geography gives emphasis on the location and diffusion of customs and cultural traits such as food habits, skills, clothing and beliefs and social organisations and their developments in different parts of the earth.
vi. Social Geography is closely related to cultural geography. It examines the relationships among the social groups and their social relationships in the places of their living.
vii. Political Geography tries to understand the countries and their neighbours, problems of resources sharing, boundaries and territorial limits. This branch is also concerned with understanding the political behaviour of the population, relations between independent states, and patterns of voting and delimitation of electoral constituencies.
viii. Economic Geography deals with the distribution of economic activities such as, primary, secondary and tertiary. The primary activities include food gathering, hunting, animal rearing, agriculture, and mining. The secondary activities include manufacturing and the tertiary activities include the service sectors such as trade, transport, communication and other related areas.
ix. Medical Geography mainly deals with study of geographical aspects of origin, diffusion and distribution of various communicable diseases and health care planning.

Geographic Techniques

- Geography has developed a number of methods and tools to investigate and identify the spatial structures and patterns. Besides, it also lends or borrows some methods and tools to measure and investigate precise understanding of the spatial locations and patterns.

i. Mathematical Geography deals with the study of earth's size and shape, motions of the earth, concept of time and the time zones.
ii. Statistical Geography is concerned with the practice of collecting, analysing and presenting data that has a geographic or areal dimension, such as census data.
iii. Cartography is the study of making maps of various scales using authentic information.
iv. Remote Sensing is the art, science and technique of capturing the earth surface features using sensors or cameras in airplanes or satellites, processing and presenting the spatial information tousers.
v. Geographic Information System (GIS) is a computer-based tool of the recent decades for geographical studies. It is used for storing, retrieving, transforming, analysing, and displaying data to prepare useful thematic maps.
vi. Global Navigation Satellite System (GNSS) is used to pinpoint the geographic location of a user anywhere in the world. Airlines, shipping, travel agencies and automobile drivers use the system to track the vehicles and follow the best routes to reach the destination in the shortest possible time.

Global Navigation Satellites System

GNSS is the standard generic term for satellite navigation systems that provide geo-spatial positioning with global or regional coverage. This term includes the GPS (USA), GLONASS (Russia), Galileo (Europe), Beidou (China), IRNSS (India) and other systems. The GPS was the first GNSS system of the United States and originally used for military applications. Today it is commonly used in mobiles, vehicles, agriculture and other areas that allow us to use it in all fields of mapping.

- Geography is undergoing frequent changes to tackle the challenges of the dynamic world. The subject is more flexible and accommodates many principles of related subjects. At the same time, it lends concepts and knowledge to many related disciplines. Owing to

these changes, the subject is attaining more refinement, accuracy, precision, depth and scientific rationale.

Geographical Tools and Skills

- Every day the news media report several geographically significant events of near-by or faraway places. Such reports include the occurrence of earthquakes, floods, forest fire, landslides etc., which trigger the interests of everyone to recollect their geographic knowledge they had acquired earlier. The essential tools of geography are maps and globes and now the digital versions of aerial photographs, satellite images, Geographical Information Systems (GIS) and Global Navigation Satellite System (GNSS).These tools have become an integral part of geography and these products help us to visualise the spatial patterns over the surface of the earth.

- The GIS technique has enhanced the skills and capabilities to compare and overlay the digital layers to create maps quickly and efficiently. It helps us to study the areas affected by floods or cyclones or forest fire and the damages can be assessed accurately and losses be estimated within a very short span of time. The navigation satellites provide accurate location of these occurrences.

- In recent years, geography aims to develop a set of marketable skills to the students rather than preparing the students only for the teaching in educational institutions.

- The job market is changing frequently. Therefore, the teaching methodology of the subject is to be adapted to the changing trends of the society and provides a couple of specialisations to the students so that they could be acquainted with the global market and get suitable employment. The maps still remains an important visual medium for geographers although the microchip revolution is expanding exponentially to address a number of societal issues.

Cartography:

- Geographers who specialise in this branch make traditional maps, digital maps, atlases, charts, globes and models. Quantification and

cartography are considered as two sides of the 'geography coin'. Owing to quantitative and computer revolutions, handling of spatial data become easier, not only for the preparation of 'instant maps' but also for statistical graphs, graphic images and models. Preparation of the computer-aided-maps and updating the existing ones become easier and faster. Creation of three dimensional models, changing the viewing angle of these models and plotting the images are made possible due to the introduction of computer expertise in cartography.

Land use Studies:

- For studies of quickly changing phenomena on the earth surface, such as foods, drought, forest fires, etc, remote sensing data provide accurate information in different scales. The remote sensing organisations employ geographers who have the knowledge to process the frequently changing earth's surface features. Even before the introduction of satellites in remote sensing, aerial photographs were widely used by geographers for natural resources surveys and urban and regional planning. The satellite data from Landsat, SPOT, IRS and other satellites made it possible to repeatedly view each part of the earth surface at frequent intervals and thereby geographers' 'data thirst' is considerably quenched.

Geospatial Analysis:

- A geospatial analyst designs databases, analyses geographical data, uses appropriate GIS software to a wide range of applications including defence, real estate, pollution and government administrations. The skill helps to identify optimum size and ideal location, establish new or relocate existing facilities like hospitals, police station, banks, shopping centres etc.,

Environmental Impact Assessment:

- This investigation requires voluminous data related to physical, social, economic and other aspects of the area under study. The data are collected from maps, satellites and field and synthesised to provide meaningful visual results. Such complex thematic visual results allow the decision makers to take appropriate steps to tackle the day to day and long term environmental issues.

Regional Planning:

- A planner who is responsible for planning an urban or a regional unit needs to have an overall view of the area. They should be able to synthesise the issues from multiple perspectives. The problems are increasingly concerned with balancing different, sometimes contradictory, interests into functional and sustainable suggestions and proposals. Tis specialisation is concerned with planning, housing, and smart city development projects. The regional land use maps are to be prepared to locate facilities and optimise the existing land for various uses.

Weather Forecasting / Now casting:

- At present the meteorologists are using ground data and satellite data to forecast the wind direction, rainfall possibilities and cyclone movement. However, with the advancement of satellite sensors, navigation satellites and GIS technology it is possible to now cast the weather conditions and provide live cyclone movement tracts, otherwise known as weather now casting. Geographers are utilising spatial and non–spatial data to analyse weather and climate parameters and conduct research concerning climate and climate changes and forecast the earth's future climate and weather conditions and their implications.

Surveying, Utilising Large Scale Maps/Sketches:

- Surveying with instruments, starting from chain survey to differential GPS (DGPS), are an integral part of geography curriculum. The students survey and prepare sketches of various features in an area. They also survey the campuses with advanced survey instruments and prepare large scale maps. The geographical knowledge and training enable the students to interpret large scale maps of India and other countries of the world. Ground Penetrating Radar (GPR), one of the emerging field survey instruments, is gaining importance not only in earth sciences discipline but also in archaeology, civil engineering, city planning and other related fields.

- The students of geography undergo special trainings in their college level studies and seek employment in the areas of their specialisation. Depending upon their area of specialization; geographers are employed as scientists in national and state planning commissions, water resources organizations, and land use planning units, agricultural or economic institutes or as demographers in government and research organizations.

- The geographers are also employed as climatologists, geomorphologists, GIS specialists and hydrologists. Geography background is an asset for careers in travel and tourism, particularly for 'Travel Journalism'. Besides these, the geography graduates apply for civil services examinations conducted by various States of India and also the UPSC. Recent developments in geography are technological in nature and mostly computer oriented. The average geography graduate is therefore well versed in the use of computers, and as they are trained in understanding patterns and relationships over space.

Geography in Tamil Nadu

- A number of institutions of higher learning in Tamil Nadu have been offering graduate and post graduate programmes in geography for several decades. Some of the Departments are recognized as research centers and these are engaged in undertaking national and international research projects besides conducting research programmes in geography. The departments are also engaged in organizing short term and long term training programmes and workshops to disseminate the latest geographic knowledge and technology for the benefit of students, researchers and teachers of geography.

Annual Geography Talent Tests for College / University Students and School Students of Tamil Nadu

The Indian Geographical Society is conducting talent test examination to final year UG and PG geography students across the State and present awards and cash prizes to a tune of Rs. 15,000 (top three M.Sc. students) and Rs. 10,000 (top three B.Sc. students) in the

names of the IGS Founder Prof N. Subrahmanyam and the former Head of the Department of Geography of University of Madras Prof. A. Ramesh, respectively.

The Association of Geography Teachers of India conducts Annual Geography Talent Tests to the school students. The talent test is conducted at two levels: Students of classes 7 and 8 take Junior Level test while the students of classes 9 and 10 take it at the Senior Level. Prizes and certificates are awarded to top ranking candidates.

- Two geographical Associations are functioning in Tamil Nadu to disseminate geographic knowledge to the students and teachers of schools, colleges and universities through publishing journals, organizing workshops and conduct talent tests to the geography students.

Databases for Geography Teaching and Learning

- Geographers are concerned about certain global and local issues like disasters, environmental problems, natural resources and other related aspects. Often these issues are discussed in the classrooms. Data relating to the issues are necessary for better understanding of the same and for seeking real world solutions. A number of organizations in India are engaged in disseminating such valuable information through special publications, especially to the student community. The schools, colleges, universities and research institutions can write to the following organizations and enroll themselves to receive the published materials like booklets, pamphlets, satellite images, manuals etc. They can also enroll for short term trainings / field visits / workshops arranged by these organizations.

Awards to Geography Teachers and Scientists

The Indian Geographical Society has instituted Awards in the names of renowned Geographers Prof. B. M. Thirunaranan, Prof. A.R. Irawathy and Prof. V. L. S. Prakasa Rao to the leading geographers who work in the areas of geomorphology, remote sensing and regional planning respectively.

- The students can make use of the free software available from these organizations to visualize the earth's surfaces from space and

map the existing and changing land cover details, traffic density, pollution levels etc., A number of spatial information, including satellite images can be downloaded freely for educational purposes such as classroom teaching, preparation of maps, for project work, field work and other activities.

Glossary

1. **Absolute Location:** The exact position of an object or place stated in spatial coordinates of a grid system designed for the location purposes. In geography, the reference system is the global grid of parallels of latitudes north or south of equator and of meridians of longitude east or west of the Prime meridian.

2. **Cartography:** The art, science and technology of making maps.

3. **Field Measurement Book (F.M.B):** The FMB depicts the dimensions of each field boundaries and the sub divisions. In FMB the individual survey number maps are maintained at a scale of 1:1000 or 1:2000. Each survey number is divided into several sub divisions. Each sub division is owned by a owner. The FMB's also depicts the dimensions of each field boundaries and the sub divisions.

4. **Global Positioning System (GPS):** A method of using satellite observations for the determination of extremely accurate location information.

5. **Greenhouse Effect:** The heating of the earth's surface as shortwave solar energy passes through the atmosphere, which is transparent to it but opaque to reradiated long wave terrestrial energy. It also refers to increasing the opacity of the atmosphere through the addition of increased amounts of carbon dioxide, nitrous oxide, methane and chlorofluorocarbons.

6. **Greenwich Mean Time (GMT):** Local time at the prime meridian (Zero degree longitude), which passes through the observatory at Greenwich, England.

7. **Map Projection:** A method by which the curved surface of the Earth is shown on a flat surface map. As it is not possible to show all the Earth's features accurately on a flat surface, some projections aim to show direction accurately at the expense of area, some the shape of the land and oceans, while others show correct area at the expense of accurate shape.

    a. One of the projections most commonly used is the Mercator projection, devised in 1569, in which all lines of latitude are the same length as the equator. This results in increased distortion of area, moving from the equator towards the poles. This projection is suitable for navigation charts.

    b. The Mollweide projection shows the land masses the correct size in relation to each other but there is distortion of shape. As the Mollweide projection has no area distortion it is useful for showing distributions such as population distribution. The only true representation of the Earth's surface is a globe.

8. **Nation:** A culturally distinctive group of people occupying a particular region and bond together by a sense of unity arising from shared ethnicity, beliefs and customs.

9. **Natural Resource:** A physically occurring item that a population perceives to the necessary and useful to its maintenance and well-being.

10. **Ozone Layer:** A gas molecule consisting of three atoms of oxygen (O3) formed when diatomic oxygen (O2) is exposed to ultraviolet radiation. In the lower atmosphere, it constitutes a damaging component of photochemical smog; in the upper atmosphere, it forms a normally continuous, thin layer that blocks ultraviolet light. A layer of ozone in the atmosphere (stratosphere) protects life on earth by absorbing ultraviolet radiation from the sun.

11. **Prime Meridian:** An imaginary line passing through the Royal Observatory at Greenwich, England, serving by agreement as the zero degree line of longitude.

12. **Region:** In geography, the term applied to an area of the earth that displays a distinctive grouping of physical or cultural phenomena or is functionally united as a single organisational unit.

13. **Relative Location:** The position of a place in relation to a well-known place.

14. **Site:** The place where something is located; the immediate surroundings and their attributes.

15. **Situation:** The location of something in relation to physical and human characteristics of a larger region.

16. **Toponym:** A place name with reference to topography.

Unit III Lithosphere Endogenic Processes

Introduction

- Do you know that the Russians tried to dig through the centre of the Earth? It indeed is a daring attempt.

- While the famous Voyager 1 satellite took 26 years to exit our Solar System (16.5 billion km away), almost the same amount of time (24 years) was taken for man to dig out a mere 12.3 km into the earth's surface.

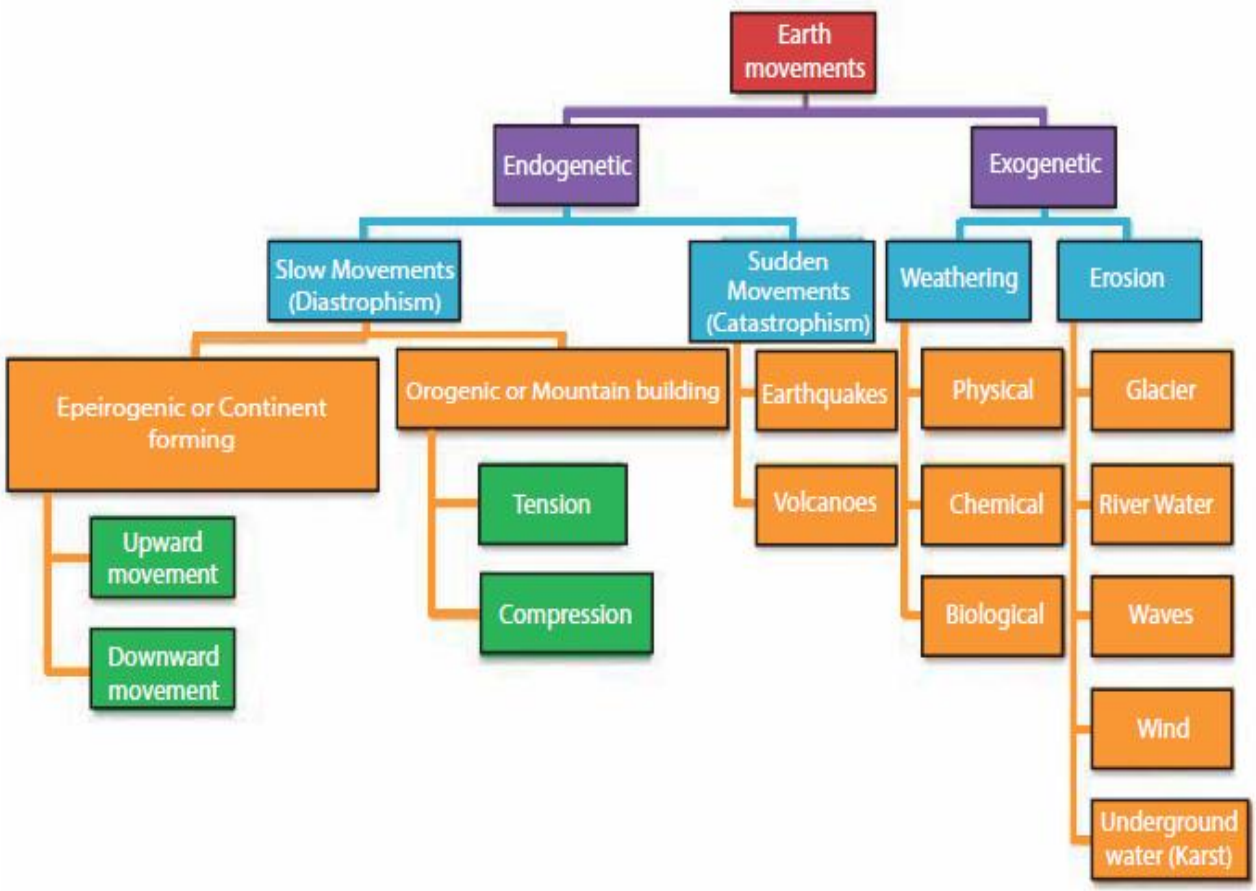
- Russia drilled Kola Super Deep bore hole between 1970 and 1994. The deepest part of it, named 'SG-3 (Star Gate), extends 12.3 km into the Earth. Look at figure 3.2 and amaze the highest and deepest points of the earth.

- The earth's surface is being continuously reshaped by both the internal (Endogenic forces) and external forces (Exogenic forces). The changes that the endogenic and exogenic forces bring about in the appearance of the surface of the earth are collectively known as geomorphic processes. (figure. 3.3)

- The process by which the earth's surface is reshaped through rock movements and displacement is termed as diastrophism. Diastrophism includes both orogenic and epeirogenic processes.

- Our knowledge of the earth is mostly limited to its surface. But the earth has a complicated interior. The earth is composed of lithosphere, atmosphere, hydrosphere, and biosphere.

- The lithosphere is the outermost rigid rocky shell of the earth. It comprises the crust and the upper portion of the mantle. The word lithosphere is derived from the Greek words lithos meaning rocky and sphaira meaning sphere. The term lithosphere was introduced by Joseph Barrel, an American Geologist.



Interior of the Earth

- The interior of the earth is composed of many minerals both in the solid and liquid state. The temperature in general increases at the rate of 1° C for every 32 metres towards the earth's interior. Look at the figure.3.4 the layers of the earth. Earth's interior can be divided into the crust, upper mantle, lower mantle, outer core, and inner core.

The Crust

- The crust is further divided into upper crust (continental crust), composed of silica and aluminium (sial) and the lower crust (oceanic crust) made up of silica and magnesium (sima). The boundary between the upper crust and the lower crust is termed as 'Conorod boundary'. The thickness of the crust varies from oceanic areas to continental areas. Oceanic crust is thinner when compared to the continental crust. The mean thickness of oceanic crust is 5 km while the continental crust is around 30 km. The continental crust is thicker in the areas of major mountain systems. It is as much as 70 km thick in the Himalayan region. The density of the crust is less than 2.7 g/cm3.

The mantle

- The mantle is composed of silica, magnesium and iron. It lies between the lower crust and the outer core. It extends for about 2,900 km. It is divided into upper mantle and lower mantle. The mantle generally is in a solid state. The upper part of the mantle is called asthenosphere. The word Asthen in Greek means weak. It extends up to 400 km and it is the main source of magma. The Mohorovicic is the boundary which divides the lower crust and the upper mantle. The density of the mantle is 3.9 g/cm3.

The core

- The core forms the centre of the earth. Its density is 13.0 g/cm3. Its temperature is about 5500° C to 6000° C. The core has two parts namely the outer core and the inner core. The boundary between the lower mantle and the outer core is called Guttenberg margin.

- The outer core and inner core are separated by Lehmann boundary. The outer core is in the liquid state while the inner core is in the solid state. Generally, the core is composed of Nickel and Ferrous (Iron) which is called NiFe (Barysphere). The core is extended from 2,900 km to 6,370 km from the surface of the earth.

Continental Drift Theory

- In 1912 Alfred Wegener (1880-1930) postulated that all the continents once were together forming a single continent. According to him, about 250 million years ago, the earth was made up of a single landmass called Pangaea (meaning "all lands"), and a single ocean surrounding it called as Panthalassa. Over a long period of time, probably 220 million years ago, they drifted apart and gradually moved to form their present position. First, Pangaea broke into two landmasses namely Laurasia in the north and Gondwana in the south.

- Laurasia further split into Eurasia and North America. Gondwana land split into Africa, South America, Antarctica, Australia, and India.

Wegener put forward certain evidences to support the continental drift theory. Let us deal with it in detail.

Evidences to support continental drift theory

- The continental drift theory is supported by the following evidences

1. Certain identical rare fossils have been found in different continents.
   The fossils of Mesosaurus (a small Permian reptile), for example, have been found only in Africa and South America.
2. The fossil of a Fern tree, about 360 million year old, has been found only in India and Antarctica.
3. Rocks of similar type, formation, and age have been found in Africa and Brazil.
4. Geological structure in Newfoundland matches with that of Ireland, Scotland and Scandinavia. Geological Structure of Appalachian Mountains matches with Morocco and Algeria in North Africa.
5. The corresponding edges of the continents fit together. For example, the western side of Africa and the eastern side of South America fit together.

Enchanted rock in the Texas Hill Country is about a billion years old. The Hawaiian Islands are the youngest lava forms of the Hawaiian hotspot.

Plate Tectonics

- Have you heard about diving between two continents? It is possible in the Silfra rift of Iceland. Look at Figure.3.7. It is located in the Tingvellir National Park. It is in the boundary between the North American plate and the Eurasian plate. It is the visible boundary between these two plates.

Plate boundaries

- Plate boundaries are the zones where two or more plates move about. Plate tectonics describes the distribution and motion of the plates. The earth's surface is composed of rigid lithospheric slabs

technically called "plates". The word Tectonic is derived from the Greek word tekton meaning builders.

GNSS (Global navigation satellite System) measures the speed of plate movement. Rate of seafloor spreading ranges from 1 to 2 centimetres per year along the oceanic ridge in the northern Atlantic Ocean to more than 15 cm per year along the East Pacific Rise.

- Lithospheric plates are sometimes called as crustal plates or tectonic plates. Earth's lithosphere is divided into a series of major and minor mobile plates. Eurasian plate, Into-Australian platen North, American plate, Pacific plate, African plate and Antarctic plate are the major plates. Arabian plate, Caribbean plate, Cocas plate and Scotia plate are the examples of minor plates. Plates move at the rate of 2 to 3 centimetres per year.

- Plates are composed of the continental or oceanic landmass. The subduction of the oceanic plates results in the occurrence of earthquakes and volcanoes adjacent to trenches.

- Plate margins mark the occurrence of the most significant landforms, including volcanoes, fold mountains, island arcs and deep-sea trenches. There are three principal types of plate boundaries. They are divergent, convergent, and transform boundaries.

Divergent plate boundaries

- Divergent plate boundary is the margin where two plates move apart. For instance, the African plate and South American plate move apart and form a divergent plate boundary. Narrow oceans represent young divergent boundaries and wide oceans are indications of old ocean basins. Ocean ridges are the boundaries between plates of the lithosphere.

Atlantic Ocean is widening at an estimated rate of 1 to 10 cm a year

- A fissure is created when oceanic lithosphere separates along the oceanic plate boundary. The gap is filled by magma that rises from the asthenosphere. The magma cools and solidifies to create a new oceanic

crust. Hence, the divergent plate boundary is termed as the constructive plate boundary. It is also called as accreting plate margin.

- Let us see what happens in the divergent plate boundary. Firstly, submarine mountain ridge is formed through the fissures in the oceanic crust when the plates move apart. The Mid-Atlantic Ridge is an ideal example of a submarine mountain ridge in the Atlantic Ocean. It is the longest mountain ridge in the world.

- It extends for about 16,000 km, in a 'S' shaped path, between Iceland in the north and Bouvet Island in the south. It is about 80 to 120 km wide. It reaches above the sea level in some places thus forming the islands such as the Azores, Ascension, St. Helena and Tristan da Cunha.

Secondly, rift valley is formed when two plates move apart. If a divergent boundary runs through the continent, the continent splits apart and rift valley is formed. The African Rift Valley of East Africa is an example.

Convergent plate boundary

- Convergent plate boundary is the margin where two plates collide with one another. For instance, the South American plate and Nazca plate collide with each other. There are two kinds of surface features associated with the convergent margin. The first is the ocean trench that forms a line between the two colliding plates.

Wadati-Benioff zones are nothing but Subduction zone

- A trench is a narrow and deep depression of the ocean floor. It is formed when the oceanic plate slides down underneath continental plate as the oceanic plate is denser than the continental plate. For instance, Mariana Trench in the Pacific Ocean, is the deepest trench in the world. It is formed when the Pacific plate sinks down the Eurasian plate. It is about 10,994 metres (10.99 km) deep. Mariana Trench stretches for more than 2,540 km with a width of 69 km.

- You could take Mount Everest and sink it in the Mariana Trench, the deepest point in the ocean, and still you have a km of depth to reach the surface of the ocean. When a continental plate and an oceanic

plate collide with each other, denser oceanic plate sinks below the lighter continental plate, subduction zone is formed.

- A subduction zone is a boundary where one plate sinks under the other plate. It was first identified by Kiyoo Wadati and Benioff. Secondly fold mountain is formed when two plates collide each other. For instance, the Himalayas were formed when the Indian plate collided with the Eurasian plate. The zone marking the boundary of the two colliding plates is known as suture line.

- As the crust is less dense than the mantle, the newly formed magma will tend to rise to the Earth's surface, where it may form volcanoes. The area in the subduction zone where most earthquakes occur is known as the Benioff zone.

Transform plate boundaries

- Transform plate boundary is the margin where two plates move side by side. The lithosphere is neither destroyed nor created by the transform plate boundary. Hence it is called as the Conservative or passive plate boundary. The San Andreas Fault, California, is a transform boundary that separates the North American plate and Pacific Plates.

Convection Cell

- Now you may think why plates keep moving. The plate movements are caused by the convection cells. Convection cell is the circulation of the molten materials caused by the heat derived from the core. When looking at the figure.3.13 you will understand how and why plates move in different directions.

- When the molten materials(magma) circulate in different directions, they push or pull the plates in different directions. Thus, the plates move towards each other, move away from one another and move side by side. The plate movements cause the formation of fold, fault, earthquake, and volcano to occur. Let us see the cause, effects, and distribution of the internal forces.

Internal forces

- The internal forces are also called as the tectonic forces. They generally occur in the plate boundaries. They are caused by convection cell and plate movement. They form fold, fault, earthquake and volcano.

Fold

- Horizontal movements are produced by forces of compression and tension. Folding is the bending of rock strata due to compression. Folding on a large scale results in mountain building generally referred to as orogeny.

Parts of a Fold

- Up thrown part of a fold is called anticline. Down thrown part of a fold is syncline. The side of the fold is a limb. The top of the fold is the crest. The plane which bisects the angle between two limbs is called the axis of fold or axial plane. The fold is formed by the plate movements.

Types of Folds

- The type of fold depends on the nature of the rock, the intensity of compression forces, etc. The types of the fold can be many but we will deal with five of the following.

1. When compressional force is equal from both sides, the angle of the limb is same on both sides. Such a fold is called symmetrical fold.
2. When compressional force is more from one end, one limb is steeper than the other. Such a fold is called asymmetrical fold.
3. Isoclinal folds are similar to symmetrical folds, but these folds both have the same angle and are parallel to each other. 'iso' means 'the same' (symmetrical), and 'cline' means 'angle,' so this name literally means 'the same angle.' So isoclinal folds are symmetrical and aligned in a parallel fashion.
4. When one limb of the fold is pushed over the other limb of the fold, it is called as over turned fold. Limbs are seldom horizontal.
5. When one side of the fold is pushed so much that it lies positioned over the other, such a fold is called recumbent fold.

- When plates converge, the weak rocks and sediments lying between two plates get squeezed and folded. Parallel folds form long chains of fold mountain ranges with high peaks. The fold mountains are characterised by peaks and valleys. The tops of anticlines become the peaks and synclines become the valleys. Intermontane plateaus (plateau surrounded by the mountain ranges all sides) may be found between the high ranges. Example, Tibet.

Fault

- A fault is a break in earth's crust where blocks of rock crust slide past each other. Usually it occurs along plate boundaries, where the forces of plate motion compress, pull or shear the crust that breaks the crust. Energy release associated with rapid movement on active faults is the cause of most earthquakes.

- The fault plane is the flat surface along which broken blocks of rock slide past one another. A fault dip is an angle between the fault plane and horizontal plane. Up thrown side represents the uppermost block of a fault. Down thrown side represents the lowermost block of a fault. Sometimes it becomes difficult to find out, which block has really moved along the fault plane. Hanging wall is the upper wall of a fault. Foot wall represents the lower wall of a fault.

- A fault scarp is the steep wall like slope caused by faulting of the crustal rocks. Sometimes the fault scrap is so steep that it resembles a cliff.

Types of Faults

- Based on how plates move about, the fault can be divided into as follow:

Normal Fault

- Vertical displacement of the crust is called a normal fault. The normal fault is caused by tensional forces where plates diverge. One block lies above the other (hanging wall). The other block lies below

the fault (footwall). When movement occurs along a normal fault, the hanging wall slips downward.

Landforms made by Normal fault are:

1. Rift Valley or Graben

- When a narrow block of land drops or subsides between two parallel normal faults, rift valley (Graben) is formed. Graben originates from the German word meaning 'trough'. A Rift Valley may subsequently get filled by water and a river may flow through it. Normally, a rift valley is long, narrow and very deep. For example,

i. Rhine rift Valley is flanked by two Block Mountains namely the Vosges and the Black Forest.
ii. The rift of River Narmada in India lies between the Vindhyas and Satpura block mountains.
iii. The great rift valley of Africa.

- The Great Rift Valley of Africa is the longest rift valley in the world. It stretches for 6,400 km from Mozambique in the south to Syria in the north. The depressions have become lakes. The lakes of Africa, Dead Sea of Israel and the Red Sea form the parts of the Great Rift Valley.

2. Horst

- When a block of land between two faults is pushed up, block mountain or horst is formed. In this case, the central block is not only up thrown but the side blocks are also relatively downthrown so that the whole central mass appears like a dome.

- In India, specifically the mountain ranges of Vindhya and Satpura found in the central western part of the India are block mountains.

Reverse Fault

- A reverse fault is a horizontal displacement of the crust. It is formed where two fractured blocks move towards each other. It is

caused by compressional forces along convergent plate boundaries. One side of the fault lies at an angle above the other.

Shear Fault / Transform Fault/ Strike – Slip Fault

- It is created by shearing along transform boundaries. Rocks on either side of fault slip past each other sideways with little up or down motion. It mostly occurs in the ocean basin and connects offsets in the mid ocean ridge.

Earthquake

- Earthquake is a sudden shaking of the earth's surface. **Focus** is the location inside the earth where the earthquake originates. **Epicenter** is the point on the earth's surface vertically above the focus of an earthquake. Earthquake results from the sudden release of pressure which has slowly built up within the earth's crust. Energy is released in the form of shockwaves known as seismic waves. The seismic waves can broadly be classified into two types namely Body waves and surface waves.

I. **Body Waves** are the waves that travel through the interior of the earth. They are further divided into the following.

   a. P or Primary or Compressional waves are the fastest seismic waves (6 km/ sec. in the upper crust). They cause the matter to oscillate forward and backward, parallel to the motion of the seismic wave front. P waves push (compress) and pull (dilate) the rock that they pass through. They pass through all medium.
   b. S or Secondary or Shear waves are slower than the primary waves (3.5 km/sec. in the upper crust). They cause matter to oscillate side to side, perpendicular to the motion of the wave front. S waves shear the rock that they pass through. They pass through only solid medium.

II. Surface Waves are the waves that travel along the earth's surface. They are slower than body waves. They cause damage during earthquakes.

   Love waves shake the ground side to side like S wave.

Rayleigh waves displace the ground like rolling ocean waves. The ground rolls forward and up and then down and backwards. This is similar to a p wave but with the extra up-down motion.

Measuring the earthquake

- It is estimated that about 100,000 earthquakes occur but all cannot be felt. A few earthquakes may be severe causing huge damage to property. Earthquake magnitude is measured on the Richter scale (named after the seismologist who devised it), which rates them on a scale of 1 to 10. Earthquake intensity is measured on the modified Mercalli scale, which ranges from 1 to 12, depending upon the intensity. The seismograph is an instrument used to detect and record seismic waves created by the earthquakes.

Causes of Earthquakes

- There are many factors controlling the occurrence of the earthquake. Some of the major factors include:

1. Plate Tectonic Movements
2. Volcanic Eruptions.
3. Construction of large dams results in earthquake. Example. Koyna dam, Maharashtra.
4. Other Reasons: The nuclear explosions also release massive energy to cause tremors in the earth crust. When underground cave collapses, earthquake may occur.

Effects of the Earthquakes

1. Damage to buildings, roads, rails, factories, dams, bridges etc.

2. Landslides caused by earthquakes damage infrastructure.

3. Fires in the forest and urban areas.

4. Flash floods.

5. Tsunami - The high amplitude oceanic waves caused by submarine earthquake (measuring more than 7 on Richter scale). The seismic waves travel through seawater generates high sea waves. They cause severe loss of life and property. For instance, on 26th December 2004, a tsunami originating from a magnitude 8.9 earthquake in northern Sumatra killed over 1,50,000 people in countries surrounding the Indian Ocean.

Distribution of earthquakes

1. Circum-Pacific region: This region includes all the coastal areas around the Pacific Ocean. It extends through the coasts of Alaska, Aleutian Islands, Japan, Philippines, New Zealand, west coast of North and South America. This zone accounts for 68% of all earthquakes on the surface of the earth.

2. Mediterranean-Himalayan region: This region extends from Alps mountain to the Himalayan Mountains and Tibet to China. About 31% of world's earthquakes occur in this region.

3. Other Areas: These include Northern Africa and Rift Valley areas of the Red Sea and the Dead Sea.

Volcano

- A volcano is an opening in the earth's crust through which magma, gases and ash are released to the earth's surface. The molten rock material found in the interior of the earth is called magma. It can be noted that when magma reaches the earth's surface, it is known as lava (Figure. 3.25). Vent is an opening or mouth of a volcano. Fumaroles are the gushing fumes through the gap in the volcano. Crater is a saucer shaped depression in the mouth of a volcano. When the crater is widened, it is called as Caldera. Volcanic ash consists of fragments of pulverized rock, minerals and volcanic glass, created during volcanic eruptions. Volcano generally erupts either through the vent (E.g. Mt. Fujiyama, Japan) or fissure (The Deccan Plateau, India). Pumice is a volcanic rock produced when lava with a very high content of water and gases is discharged from a volcano.

Causes of Volcanic Eruptions

The following are the causes of volcanic eruptions:

- Weak Zones in the Earth Crust: The parts of the earth where two tectonic plates collide against or drift apart from each other are considered very weak. Volcanoes may erupt in such zones, for example, African and Eurasian plates.

- Magma Saturated with Gases: The magma, in the interior of the earth, is often found saturated with gases like carbon dioxide, and hydrogen sulfide. These gases together with water vapour make the magma highly explosive. Magma is forced out as lava on the surface of the earth due to the pressure exerted by these gases.

Mt. Krakatau

- The greatest volcanic explosion known to humans is perhaps Mt. Krakatau in August 1883.
- Krakatau is a small volcanic island in the Sunda Straits, between Java and Sumatra.
- The explosion could be heard in Australia, almost 4,000 km away.
- The vibration set up enormous waves over 30 m high which drowned 36,000 people in the coastal districts of Indonesia.

Cotopaxi in Ecuador is the world's highest active volcano

.

Types of Volcanoes

Based on the frequency of eruption, there are three types of volcanoes:

1. **Active Volcanoes:** Volcanoes which erupt frequently are called active volcanoes. Generally, their vent remains open. Mount Etna of Italy, Cotopaxi in Ecuador are some examples.

2. **Dormant Volcanoes:** These volcanoes may not have erupted in the recent past but there is a possibility of eruption at any time. In other words, they may lie dormant awaiting active eruption anytime. Sometimes gases and steam come out of them. They

cause great destruction to life and property once they become active again. Mt. Vesuvius of Italy and Mt. Fujiyama of Japan are examples.

3. **Extinct Volcanoes**: These volcanoes have exhausted their energy and have not erupted during the known geological period. The vent of these volcanoes remains closed with solidified lava. The formations such as craters may be filled with water and crater lakes may be formed. The slopes of these landforms may be covered with vegetation. Popa in Myanmar and Mt. Kenya in eastern Africa are the examples of extinct volcano.

- On the basis of nature of eruption and form developed on the surface, they are classified into following types:

1. **Shield Volcanoes**: These are made up of basalt, a type of lava that is very fluid when erupted. They become explosive when water gets into the vent. They develop into a cinder cone. Hawaiian volcano is an example of this category.

2. **Composite cone volcanoes**: They are also called 'strato volcanoes'. They are cone-shaped volcanoes composed of layers of lava, ash and rock debris. Mount Vesuvius and Mount St. Helens are examples of composite volcanoes.

3. **Cinder Cone Volcano** : It forms when magma is thrown out to the surface, cooled in to ash and cinders and settled around the mouth of volcano. It is less dangerous than other volcanoes.

4. **Lava Dome**: Unlike composite and shield volcanoes, lava domes are of significantly smaller structure. They are formed when the lava is too viscous to flow to a great distance. As the lava dome slowly grows, the outer surface cools and hardens as the lava continues to pile within. Eventually, the internal pressure can shatter the outer surface, causing loose fragments to spill down its sides.

Effects of Volcanic Activities Destructive effects of volcano

- Showers of cinders and bombs can cause damage to life and properties. Sometimes ash can precipitate under the influence of rain and completely cover large areas.

- The volcanic gases pose potential hazard to people, animals; agriculture, while sulfur dioxide gas can lead to acid rain and air pollution.

Positive Effects of Volcanoes

- Volcanism creates new landforms. Volcanic rocks yield very fertile soil upon weathering and decomposition. The Kimberlite rock of South Africa, the source of diamonds, is the pipe of an ancient volcano.

- In the vicinity of active volcanoes, waters in the depth are heated from contact with hot magma giving rise to springs and geysers. The Puga valley in Ladakh region and Manikaran (Himachal Pradesh) are promising spots in India for the generation of geothermal electricity.

Distribution of Volcanoes across the World

- Most known volcanic activity and the earthquakes occur along converging plate margins and mid-oceanic ridges. The major regions of volcanic distributions are as follows.

1. Pacific Ring of Fire

- Circum-Pacific region, popularly termed the 'Pacific Ring of Fire', has the greatest concentration of active volcanoes. Volcanic belt and earthquake belt closely overlap along the 'Pacific Ring of Fire'. It is estimated to include two-thirds of the world's volcanoes.

2. Mid-Atlantic Region

- The Mid-Atlantic Region coasts has comparatively fewer active volcanoes but many dormant or extinct volcanoes, example. St. Helena,

Cape Verde Islands and the Canary Islands. But the volcanoes of Iceland and the Azores are active.

3. The Great Rift valley of Africa

- In Africa some volcanoes are found along the East African Rift Valley. Kilimanjaro and Mt. Kenya are extinct volcanoes. The only active volcano in West Africa is Mt. Cameroon.

4. Mediterranean Region

- Volcanoes of the Mediterranean region are mainly associated with the Alpine folds. Example, Mt. Vesuvius, Mt. Stromboli (known as the Light House of the Mediterranean Sea).

5. Other Regions

- Elsewhere in the interiors of continents of Asia, North America and Europe active volcanoes are rare. There are no volcanoes in Australia.

Volcanoes in India

- There are no volcanoes in the Himalayan region of India. However, Barren Island, lying 135 km north-east of Port Blair became active in 1991 and 1995.

- However, the other volcanic island in Indian Territory is Narcondam (Andaman and Nicobar Islands) It is probably extinct. Its crater wall has been completely destroyed.

Rocks

- Rock is the solid mineral material forming the surface of the earth. Petrology is the science of rocks. The age of the rock is determined based on Carbon-14 dating.

Rock Types

- Based on their origin, the rocks are classified as follows:

1. Igneous Rocks

- Igneous rocks are formed out of magma and lava and they are known as primary rocks. If the magma cools slowly at great depths, mineral grains increase in their size. Sudden cooling (at the surface) results in small and smooth grains. The igneous rocks are the oldest of all the rocks. Granite, pegmatite, basalt, etc are some of the examples of igneous rocks. There are two types of igneous rocks: intrusive rocks (Granite) and extrusive rocks (Basalt-Deccan Traps).

Granite is less dense and is lighter in colour than basalt rocks.

1. Intrusive Igneous rocks

- Intrusive Igneous rocks are formed when magma rises and cools within the crust. The intrusive activity of volcanoes gives rise to various forms. We see them one by one as follow.

i.Batholiths

Batholiths are large rock masses formed due to cooling and solidification of hot magma inside the earth. It is granitic in origin.

ii. Laccoliths

Laccoliths are large dome-shaped intrusive rock connected by a pipe-like conduit from below. These are basically intrusive counterparts of an exposed domelike batholiths. The Karnataka plateau is spotted with dome hills of granite rocks. Most of these, now exfoliated, are examples of laccoliths.

iii. Lapoliths

When the magma moves upwards, a saucer shape, concave shaped body called Lapolith is formed.

iv. Sill

Sill is a solidified sheet-like horizontal lava layer inside the earth. The near horizontal bodies of the intrusive igneous rocks are called sill or sheet, depending on the thickness of the material. The thinner ones are called sheets while the thick horizontal deposits are called sills.

v. Dyke

When the magma makes its way through cracks and the fissures developed in the land, it solidifies almost perpendicular to the ground. It gets cooled in the same position to develop a wall-like structure. Such structures are called dikes.

These are the most commonly found intrusive forms in the western Maharashtra area. These are considered the feeders for the eruptions that led to the development of the Deccan traps.

2. Sedimentary Rocks

- Sedimentary rocks are also called as detrital rocks. They are formed as a result of denudation. These deposits through compaction turn into sedimentary rocks. They occupy only 5 percent of the earth. They are layered or stratified of varying thickness. Example: sandstone, shale etc. Ice deposited sedimentary rocks is called Till. Wind-deposited sediments are called Loess. Depending upon the mode of formation, sedimentary rocks are classified into

1. Mechanically formed sedimentary rocks: sandstone, conglomerate, limestone, shale, loess, etc.
2. Organically formed sedimentary rocks: geyserite's, chalk, limestone, coal etc.
3. Chemically formed: halite, potash, etc.

3. Metamorphic Rocks

- The word metamorphic means 'change of form'. The metamorphic rocks form under the action of pressure, volume and temperature (PVT) change.

- Metamorphism is a process by which the already consolidated rocks undergo recrystallisation and reorganization of materials within original rocks. Gneiss, slate, schist, diamond, marble, quartzite etc. are some examples of metamorphic rocks. The igneous and metamorphic rocks together account for 95 percent of the earth.

Rock Cycle

- Rock cycle is a continuous process through which old rocks are transformed into new ones. Igneous rocks can be changed into sedimentary or metamorphic rocks. The fragments derived out of igneous and metamorphic rocks form into sedimentary rocks.

- Igneous and sedimentary rocks can change into metamorphic rocks. The crustal rocks (igneous, sedimentary and metamorphic) may be carried down into the mantle (interior of the earth) through subduction process and the same melt and turn into magma, the original source for igneous rocks. In this way the rock cycle is a continuous process.

Glossary

1. **Orogeny:** structural deformation of lithosphere due to interaction between tectonic plates.
2. **Conorod boundary:** Margin between the upper crust and the lower crust.
3. **Shearing fault:** the fault is created by shearing along the plate boundary.
4. **Laccoliths:** are large dome-shaped intrusive rock connected by a pipe.
5. **Lapolith:** When the magma moves upwards, a saucer shape, concave shaped body called lapolith.
6. **Syncline:** down slope of a fold
7. **Crest:** the top of the fold.

8. **Catasrophism:** sudden movements of the earth caused by plate movements.
9. **Metamorphism:** the process by which both igneous and sedimentary rocks get changed into metamorphic rocks.
10. **Rock cycle:** a continuous process through which old rocks are transformed into new ones.

Unit -5
Lithosphere Exogenic Processes

Introduction

- Let's recall that you have learned in the previous chapter about geomorphic processes - Endogenic processes in detail. Now we deal with the exogenic processes. The forces which act on the earth's exterior are called as exogenic forces or external forces. The action of exogenic forces results in wearing down the rock and hence, they are considered as land wearing forces.

Exogenic Processes

- The processes which occur on earth's surface due to the influence of external forces are called as exogenic processes. Weathering, mass wasting and denudation are the major exogenic processes. The elements of nature capable of doing these exogenic processes are termed as gradational agents. For instance, the wind, river, glacier, waves and ground water.

Weathering

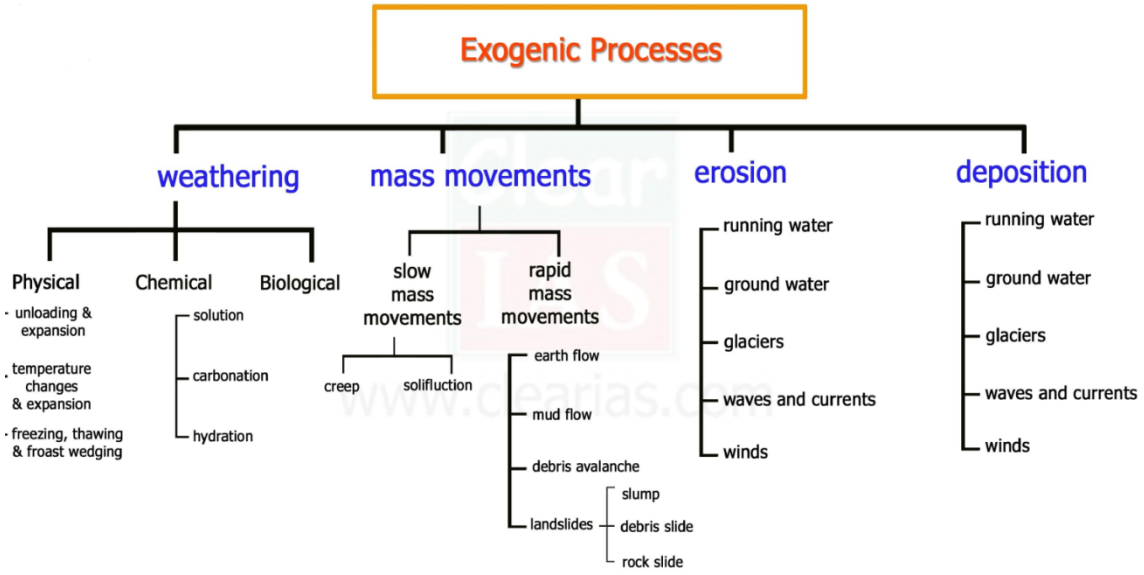
- Weathering is the process of disintegration and decomposition of rocks. It is due to the action of climate, plants, animals and other living organisms which cause the rocks to break down physically, chemically and biologically.

- There are three types of weathering. They are physical weathering, chemical weathering and biological weathering.

Physical weathering

- Physical Weathering is the disintegration of rock mainly induced by elements of weather. It produces smaller, angular fragments of the same rock. It is caused by the change in temperature, pressure, water and wind. Physical weathering is further divided into different

categories. They are thermal weathering, frost wedging and exfoliation.



Thermal weathering

- In arid and semi-arid areas, the temperature increases, heat up and expand the rocks during the day and contract the rock materials when cooling at night. Under extreme temperature conditions, due to alternate expansion and contraction, the rocks crack and eventually split. The thermal weathering's are of two types. They are;

  (a) Granular disintegration and
  (b) Block disintegration

- Alternate expansion and contraction of minerals of varying properties in the rocks due to temperature changes, makes the rocks break down into small pieces (Figure 4.2). Due to this, the breakup of rocks occurs, grain by grain. This is known as granular disintegration.

- Block disintegration occurs in rocks such as granite rock. So in the areas of jointed igneous or layered sedimentary rocks due to the great diurnal range of temperature, the rocks may break up along the joints and cracks into a large rectangular shaped blocks.

Frost Wedging

- Almost all liquids contract when frozen, but when water freezes it becomes larger in size or takes up more space. As water expands it puts great pressure on rocks. When water enters into the cracks of rocks and freezes, the pressure exerted on the rock is enough to wedge the walls of the crack farther apart, thus expanding and deepening the crack. Thus, frost wedging results in weathering of rock.

Exfoliation

- Rocks generally heat or cool more on the surface layers. The alternate changes in temperature could cause their outer layers to peel off from the main mass of the rock in concentric layers just as the skin of an onion. The process by which curved layers of rock breakaway from the rock beneath them leaving behind dome shaped monoliths is called exfoliation (Figure 4.2). It is also called as 'onion weathering'. Exfoliation occurs commonly in the arid areas.

Chemical Weathering

- Chemical weathering is the decomposition of rock. For example it creates altered rock substances, such as kaolinite (china clay) from granite. The types of chemical weathering are as follows:

1. **Solution:** Some soluble minerals in the rock get dissolved when come in contact with water. Over a long period minerals get washed away from rock and sometimes leading to the formation of caves.

2. **Oxidation:** When oxygen combines with water and iron, it weakens the rock and breaks it. Example, rusting of iron.

3. **Hydrolysis:** It is the chemical breakdown of a rock substance when combined with water and forms an insoluble precipitate like clay mineral. The most common example of hydrolysis is feldspar found in granite changing to clay.

4. **Carbonation:** Carbonation is the mixing of water with carbon dioxide to make carbonic acid. This acid reacts with minerals in the rocks. This type of weathering is important in the formation of caves.

5. **Hydration:** It is the absorption of water into the mineral structure of the rock. Hydration expands volume and also results in rock deformation. A good example of hydration is the absorption of water by anhydrite, resulting in the formation of gypsum.

Biological Weathering

- Biological weathering is the alteration of rock by the action of plants, animals, and man. Burrowing and wedging by organisms like earthworms, termites, rodents, etc., help in exposing the rock surfaces to chemical changes with the penetration of moisture and air. Human beings by removing vegetation for agriculture and other activities also help in mixing and creating new contacts between air, water, and minerals in the rock materials. Plant roots make a great pressure on the rock materials mechanically breaking them apart.

Mass wasting

- Mass wasting is the movement of a large mass of rock, soil and debris downward by the pull of gravity. It is also called a mass movement or slope movement. It may happen suddenly or slowly. Generally, mass wasting is classified by the type of material involved (mud, soil, and rock) and type of motion (fall-free-falling pieces, slide-material moves along the rock slope and flow–material mixed with water).

Types of Mass Wasting

Following are the types of mass wasting:

Rock falls

- Rock falls occur when pieces of rock break from a cliff. Frost wedging may also eventually loosen large blocks causing them to fall. Te accumulation of rock debris at the base of a steep slope is called talus.

Rockslides

- Rockslides usually follow a zone of weakness. Presence of water increases slippage. Collisions down the slope generally break the rock mass into rubble that eventually results in rockslides.

Landslides

- Landslides occur when a large piece of rock breaks off and slides down -hill. It is often initiated by earthquakes and very heavy rain.

Slump

- Great mass of bed rock moves downward by rotational slip from a high cliff is known as slump. Most common reason for slumping is erosion at the base of the slope which reduces the support for overlying sediments.

Debris Slide

- Debris slide is more extensive and occurs on a larger scale than slump but there is a little amount of water. The materials involved in debris slide are a mixture of soils and rock fragments.

Debris flows

- Debris flow is defined as mass wasting event in which turbulence occurs throughout the mass. Debris flow includes earth flows, mudflows, and debris avalanches. Debris flow occurs when the rock or soil mass loses coherency when lots of water is involved. Debris becomes mixed up completely and flows as liquid mud. It often carries large boulders which can be very destructive. When earth material

moves down a hillside as a fluid-like mass, it is called an earth flow. These flows typically occur in humid areas on steep slopes with thick, clay-rich soil that becomes saturated with water during storms.

A mudflow

- Mudflow is a liquid mass of soil, rock debris and water that moves quickly down a well-defined channel. They occur most often in mountainous semiarid environments. A mudflow originating on a volcanic slope is called a lahar.

Debris avalanche

- The deadliest type of debris flow is the debris avalanche. It is a rapidly churning mass of rock debris, soil, water, and air that moves down steep slopes. The trapped air may increase the speed of an avalanche by acting as a cushion between the debris and the underlying surface

Creep

- Creep is a slow and gradual movement of soil downhill. Its velocity is typically less than a centimetre per year. Freezing and thawing contribute the soil creep by progressively moving soil particles down the hill. Creep is manifested at the surface by things like tilted utility poles, fences and trees Vegetation helps reduce the rate of soil creep.

Gradational Processes

- Gradation is the process by which the earth's surface gets levelled. It can be further divided into degradation, the process of eroding the earth's elevated surface and aggradations, the process of filling up the earth's depressions.

Gradational Agents

- The forces which act on the surface of the earth are termed as Gradational agents. Water, wave, wind, ice are the important

gradational agents. Let us now discuss the gradational agents one by one.

The River

- The streams have a huge capacity to erode the rock over which they flow. In fact, the formation of the river channel is the result of the erosional capacity of the stream. The erosional capacity of the stream depends on its volume of water and velocity of flow. The river performs three types of work. They are erosion, transportation and deposition.

1. **Erosion:** The breaking of rocks by the river in along its course is called erosion. Erosional work of a river is performed mechanically and chemically. River erosion is carried out in the following ways:

    i. **Hydraulic action:** It refers to the physical force of the moving water which breaks the rocks in its course.
    ii. **Corrasion (abrasion):** It refers to the breaking of rock in the bed and on the bank by fragments carried by the stream.
    iii. **Corrosion (solution):** It refers to the dissolving process of soluble minerals by the splashing of stream water.
    iv. **Attrition:** It refers to the eroded materials carried by the stream strike against each other.

2. **Transportation:** Stream carrying the fragmented materials broken by the stream is called transportation. After erosion, the eroded materials get transported alont with the running water. This transportation of eroded materials is carried in four ways:

    i. Traction: The heavier and larger rock fragments like gravels, pebbles etc are forced by the flow of the river to roll along its bed. These fragments can be seen rolling, slipping, bumping and being dragged. This process is called as traction and the load transported in this way are called traction load.

    ii. Saltation: Some of the fragments of the rocks move along the bed of a stream by bouncing continuously. This process is called as saltation.

iii. Suspension: The holding up of small particles of sand, silt, and mud by the water as the stream flows is called suspension.

iv. Solution: Some parts of the rock fragments dissolve in the river water and transported. This type of transportation is called solution transportation.

3. **Deposition:** When the velocity of the stream decreases, the stream deposits sand, silt and other fragments. It is called as the deposition. When a river moves in a gentle slope, its speed reduces and river begins to deposit its load. The river starts depositing larger materials first and smaller and finer materials are carried further down to the mouth of the river.

Stages of the River

- The course of a river includes the upper stage, the middle stage, and the final stage. Each stage of the river is dominated by a kind of work. Let's discuss the stages of a river, the main work and the landforms made in each stage.

1. The Upper Stage

- The upper stage of a river is also called the youthful stage or mountain stage. The velocity and speed of the stream are very high because the slope here is steep. The vertical erosion is the most dominant work here. The valley is formed here. The place where a river starts is called a **source**. In the mountain stage, the number of small streams originates from different locations. They are called **Tributaries**. The place where two rivers join is called as the confuence. The mountain which has two river systems draining on either side of the slope is termed as the water divide.

2. The Middle Stage

- Middle stage is the matured stage of a river. Vertical erosion or deepening of the valley is significantly reduced. Lateral erosion is the dominant work. Due to the lateral erosion of this stage, the widening of

the valley occurs. The volume of the river water increases and the slope of river is moderate. The depth of the river is deep here.

3. The Lower Sage

- This is the final stage of a river where the valleys are extremely broad and it has generally gentle slope. The valley becomes almost fat which is called a pen plain. Most of the pen plain forms low residual hills with steep slopes which are called as Monadnocks. T e main work of the river in this stage is the deposition. The depth of the river is shallow here. When the main river splits into many small rivers, they are called as the distributaries. The place where the river ends is called mouth of the river. (for example: Sea coast, Lake.)

4. Landforms by the Erosional Work of River

- The significant landforms resulting from erosion by rivers include gorge, canyon, V-Shaped Valley, waterfall, pothole, structural bench, river terrace, river meander, ox-bow lake, peneplain, etc.

Gorges are formed due to active down cutting of the valleys. So, a Gorge is a narrow and deep river valley which has steep slopes.

Canyons are extended form of gorges. Canyons represent very deep, narrow but long valleys. The steepness of the valley sides depends on the nature of the rocks. The Grand Canyon of the Colorado River in the state of Arizona, USA having a length of 482.8 kilometers and depth of 2088.3 meter is the largest canyon in the world. The Canyon of Gandikota is situated on the Pennar River in Andhra Pradesh is known as the Grand Canyon of India.

V-Shaped Valley The valleys made by the rivers are erosional landforms. The valley is formed in the youthful stage of the river erosion. Due to the steep slope and large volume of water, the river cuts its bed vertically forming narrow and deep river valley. This is called as V-shaped valley.

Rapids and waterfalls Rapids are stream sections with extremely strong currents, numerous obstacles, and steps in their streambeds. A waterfall is a vertical drop in a streambed. Both water fall and rapids are

formed by vigorous erosion. Series of a waterfall in a river is called as Cascade.

Plunge pool A plunge pool is a deep depression in a stream bed at the base of a waterfall. It is created by the erosional forces of falling water at the base of a waterfall.

Angel Falls, in Venezuela, is Earth's highest waterfall (979 m). Hogenakal falls, Dharmapuri, Tamil Nadu some times is called as the Niagara of India.

Grooves

- Long and narrow depression at the base of a waterfall made by river runoff is called a groove. The grooves are created by water eroding soil from a hill or mountain in a short period of time.

- The swirling movement of the water falling into the plunge pool is called eddying.

Interlocking spurs

- An interlocking spur, also known as an overlapping spur, is a projecting ridge that extends alternately from the opposite sides of a V-shaped valley. A river with a winding course flows down the interlocking spur.

Pot Holes

- The kettle-like small depressions in the rocky beds of the river valleys are called potholes. They are always cylindrical in shape. Potholes are generally formed in coarse-grained rocks such as sandstones and granites.

River Terraces

- The narrow step like flat surfaces on either side of the valley floor are called river terraces. They represent the level of former valley floors.

Landforms by the deposition of river

1. Alluvial fan

- Alluvial fans are often found at the foot of arid or semiarid mountain ranges where intermittent streams flow. An alluvial fan is a fan shaped deposit of gravel, sand and other smaller particles of sediment. Alluvial fans are found in Kosi river, Himalayan region, Death Valley National Park and along the sides of the Colorado River at Grand Canyon National Park, U.S.

2. Pen plains

- Pen plains represent low featureless plain having undulating surface and remnants of convex-concave residual hills.

3. Meander

- A meander is a winding curve or bend in a river. Meanders are the result of both erosional and depositional processes. They are typical landform of the middle and lower course of a river. This is formed by vertical erosion, lateral erosion, and deposition within the floodplain.

4. Oxbow lake

- Oxbow lake is a free standing body of water formed when the meander is cut off from the main river. This landform is so named because it resembles horse shoe

5. Levees:

- Raised bed and a bank of the river due to frequent flooding and deposition of the sediments is called levees.

6. Flood Plain

- A flood plain is a flat area of land adjacent to a river. It stretches from the bank of its channel to the base of the enclosing valley walls which experiences flooding during the period of high discharge.

7. Estuary

- The word "estuary" is derived from the Latin word aestuarium meaning tidal inlet of the sea, which is derived from the term aestus, meaning tide. An estuary is a partially enclosed coastal body of brackish water with one or more rivers flowing into it, and with a free connection to the open sea. The inflow of both sea water and fresh water provide high levels of nutrients both in the water column and in sediment. Hence, it makes estuaries among the most productive natural habitats in the world. Narmada river estuary is located in Gujarat.

8. Delta

- Delta is found in the old stage of a river. It is the triangular shaped landform made up of alluvial deposition in the mouth of the river. It is named after the fourth Greek alphabet called delta. Example, The Ganges Brahmaputra delta is the largest delta in the world. Types of Delta: Delta is classified into the following based on the shape and kind of the load deposited by the river.

1. **Arcuate Delta:** A bowed or curved delta with the convex margin facing the body of water. It is also known as fan-shaped delta. Example, River Nile Delta in Egypt and Ganga Delta in India.

2. **Estuarine Delta** : it is formed at the mouth of submerged rivers depositing down the sides of the estuary. Example, Seine River of France.

3. **Birds foot Delta:** They are formed due to deposition of finer materials by river water. Deposited alluvial material divides the river into smaller distributaries. Such delta is also called as finger delta. Example, Mississippi river delta, the USA.

4. **Lacustrine Delta:** It is formed when a river flows into a lake. Example, Lough Leanne river delta, Ireland.

5. **Truncated Delta:** Sea waves and ocean currents modify and even destroy deltas deposited by the river through their erosional work. Thus, eroded and dissected deltas are called truncated deltas.

6. **Abandoned Delta:** when the river shifts its mouth, the delta already made is left abandoned. Such a delta is called abandoned delta. Example, Yellow river delta, China and the Western part of Ganga delta made by Hoogly river, India.

7. Cuspate delta is a tooth shaped delta formed when a single distributary flows through and deposits its load on its either side. Example, Tiber River of Italy

Glacier

- A glacier is a huge mass of ice that moves slowly along the mountain slope. The term "glacier" comes from the French word glace which means ice. Glaciers are often called "rivers of ice". It forms where the accumulation of snow exceeds its ablation over many years.

- The places where the snow lies for the whole year are called snowfields. The imaginary line above which there is a permanent snowfield is known as the snow line. The snowfields are always situated above the snow line. The snow line differs according to latitude, amount of snowfall, the direction of the wind and the physical features of the region. Snow starts melting below the snow line. Under the pressure of the upper layers, the lower layers of the snow field begin to melt causing the mass of snow to move down slope as glacier. Glacier moves at an average speed of 1meter per day. Over 96 percent of the glaciers occur in Antarctica and Greenland.

The worlds largest glacier is the Lambert Glacier in Antarctica, more than 96 km wide and 435 km long and 2,500 metres deep.

Types of Glaciers

The Glaciers are of three types. They are;

1. Continental Glaciers
2. Ice Caps

3. Mountain and Valley Glaciers

1. Continental Glaciers

- The continental glaciers are found in polar regions. In these areas, all the precipitation is in the form of snow. The snow that falls from year to year gradually gets accumulated. As a result, these regions are covered by an extensive ice mass. This is known as ice sheet or continental glacier. It is estimated that the maximum thickness of the ice sheets of Greenland is 3,400 meter, while the maximum thickness of the ice sheet of Antarctica is 4776 meter. Sometimes, the ends of the ice sheet projects outwards over the sea. The waves of the sea strike against them and break the ice sheets into blocks of floating ice known as Icebergs.

2. Ice Caps

- It is the covering of snow and ice on the oceans of poles. The ice caps can cover vast areas with the extensive accumulation of snow and ice. Example, Svartissen ice cap in Northern Norway.

3. Mountain and Valley Glaciers

- These are also known as Alpine glaciers. They flow like tongues of ice down through the mountain valleys from the ice caps. The piedmont glaciers form continuous ice sheets at the base of mountains. The valley glaciers or Alpine glaciers are found in higher regions of the Himalayas and on all such high mountain ranges of the world.

Characteristics of Glaciers

- A moving ice mass or glacier possesses certain characteristics of movement, speed, and surface structure. The rate of movement of the glacier is very slow.

- Terate of movement or the speed of a glacier depends upon the size of the glacier and the slope of the valley. Sometimes, the surface of the glacier forms cracks known as **Crevasses**. Crevasses are the deep

fissure of variable width in the surface of a glacier. These crevasses are dangerous to the Mountaineers.

Action of glaciers

- The glacier performs three actions namely erosion, transportation and deposition. A glacier erodes its bedrock by the action of 1. Plucking and 2. Abrasion

1. **Plucking**

- The glacier plucks big pieces of rocks from the valley floor and creates large grooves or hollows. These pieces are dragged along the valley floor as the glacier moves. The boulders and rocky floor are grounded by mutual contact.

2. **Abrasion**

- Pure ice is capable of wearing down massive rocks when equipped with angular rock fragments. The glacier can groove, scratch, and chisel the rock surface. It has a powerful abrasive effect. As a result, a glacier during its lifetime creates various landforms which may be classified into erosional and depositional landforms.

Erosional landforms of Glaciers

- The landforms created by glaciers are mainly found in the mountainous regions. The chief erosional landforms by the glaciers are as follow:

1. **U-Shaped Valley**

- U-Shaped Valley is a typical glacial feature. Since glacial mass is heavy and slow moving, erosional activity is uniform in all directions. A steep-sided curved bottom valley has a U shaped profile.

2. **Hanging Valley**

- Hanging valley is formed when tributary glaciers are unable to cut as deeply as main ones and remain "hanging" at higher levels than the

main valley as discordant tributaries. These tributary valleys appear hanging over the main valley and enter the main valley at some height.

3. Cirque and Tarn

- A Cirque or Corrie is an amphitheater-shaped hollow basin cut into a mountain ridge. It has a steep-sided slope on three sides, an open end on one side and a flat bottom. When the ice melts, the Cirque may develop into a Tarn Lake and the whole thing appears like a big armchair.

4. Aretes

- It is a steep-sided, sharp-tipped saw toothed ridges which have undergone glacial erosion from two sides. These comb like ridges are called as arete.

5. Horn

- If the summit of the Arete is roughly inclined, it gives rise to pyramidal peaks which are known as horns. Example, Matterhorn of Alps-Switzerland.

6. Roche Moutonnees or Sheep Rock

- Roche Moutonnees or sheep rock is a glaciated bedrock surface, usually in the form of rounded knobs. The upstream side of a roche moutonnee has been subjected to glacial scouring that has produced a gentle, polished, and striated slope and the downstream side has been subjected to glacial plucking that has resulted in a steep, irregular and jagged slope.

7. Nunataks

- A rock mass surrounded by ice is called Nunatak. It stands out as an island in the ice.

8. **Fjord**

- The fjord is formed as a steep-sided narrow entrance like feature at the coast of a glaciated region where the stream meets the coast. Fjords are common in Norway, Greenland and New Zealand.

Depositional landforms of glaciers

- When the glaciers melt or recede they deposit the rock material, brought by them, forming hillocks of various shapes

and sizes. The depositional landforms of the glaciers are;

1. **Moraines:** Moraines are the piles of dirt and rock that are deposited by a glacier as it moves across the landscape. These debris fields exist in places where glaciers have moved through in the past. There are many kinds of glacial moraines that form. Moraines are generally classified based on their location.

   a. Lateral Moraines

   Lateral moraines are ridges of debris that run parallel to the sides of a glacier. This is often accompanied by scraping of the valley sides which means the debris from the moraine creates high ridges above the glacier.

   b. Ground Moraines

   Ground moraines are glacial depositions formed on the floor of glacial valley. Ground moraines can be deposited in between lateral moraines in the case of many alpine glaciers.

   c. Medial Moraines

   Medial moraines are ridges of debris that are left down a valley floor at the middle of two glaciers. Both glaciers merge together and their debris combine to form a consistent moraine field along their borders. They are actually the merging of two lateral moraines which continue as medial moraines.

d. Terminal or End Moraines

Terminal or end moraines are left by the end of a glacier. The slower a glacier moves the bigger the moraine will be as the glacier has more time to accumulate outside debris.

e. Recessional Moraines

This recessional moraine runs across the landscape behind a terminal moraine. They are caused by times when the glacier slows or stops in its movement. It is formed because the receding glacier pauses in certain places for a long time before continuing its movement.

2. Outwash Plain;

When the glacier reaches its lowest point and melts, it leaves behind a layered deposition of rock debris, clay, sand, gravel, etc. This layered surface is called as an Outwash Plain.

3. **Esker:**

It is a winding ridge of depositions of rock, gravel, clay, etc, running along a glacier in an outwash plain. The Eskers resemble the feature of an embankment and are often used for laying roads.

4. Drumlins:

It is an inverted boat-shaped deposition in an outwash plain caused by deposition.

5. Kames:

Kames are the number of ridges formed along the ice front.

Ground water (Karst Topography)

- The word "karst" literally means "rocky mountain" comes from a region in former Yugoslavia that includes Croatia and Slovenia. The word is derived from the Slavic word Kras.

What does Groundwater do?

- Any limestone, dolomite or gypsum region showing typical landforms produced by the action of groundwater through the process of solution and deposition is called as Karst Topography (Karst region in the Balkans).

Erosional Landforms due to Groundwater

- Following are the erosional landforms formed due to the action of groundwater

1. **Sinkholes**

   A sinkhole is an opening more or less circular at the top and funnel-shaped towards the bottom. When as sinkhole is formed solely through the process of solution, it is called as a solution sink.

2. **Doline**

   A doline is a closed depression draining underground in karst areas. It can be cylindrical, conical, bowl or dish shaped. The diameter ranges from a few meters to many hundreds of meters. The name doline comes from doline, the Slovenian word meaning valley.

3. **Lappies**

   Lappies are the irregular grooves and ridges formed when most of the surfaces of limestone are removed by solution process.

4. **Uvala**

   Series of smaller sinkholes coalesce into a compound sinkhole is called uvala.

5. **Polje**

   Polje is an elongated basin having a fat floor and steep walls. It is formed by the coalescence of several sinkholes. The basins often cover 250 square km and may expose "disappearing streams." Most of these basins have steep enclosing walls that range from 50 to 100 meter in height, giving rise to the name "blind valley."

6. **Caves**

   Caves normally have an opening through which cave streams are discharged. Caves having an opening at both the ends are called tunnels.

Depositional Landforms due to Ground water

The following depositional features are formed within caves.

1. **Curtains**

   Rain water drips from long crack in a cave roof forms a continuous strip of calcites. It is called as curtains.

2. **Stalactite**

   Drops of water containing dissolved limestone seep down through cracks in the cave roof. Drops of water lose carbon dioxide and deposit calcite. Overtime deposition of calcite forms pillars hanging down from the roof of the cave. It is called as stalactite and where the stalactite stretches towards the sides are known as Helactites.

3. **Stalagmite**

   Deposition of calcite forming icicles growing upward from the cave floor is called as stalagmite. Stalactites are calcium carbonate deposits hanging as icicles while Stalagmites are calcium carbonate deposits which rise up from the floor.

4. **Pillar**

When both the stalagmite and stalactite join together, it is known as pillar.

Wind

- The wind is the main geomorphic agent in the arid region. Wind in arid region has greater speed which causes erosional and depositional activities in the desert. The landforms which are created by erosional and depositional activities of wind are called as Aeolian Landforms.

Action of the wind

The action of the wind is carried in the following ways;

1. **Deflation:** Removal of sand and dust particles by wind. It forms depression in the desert. When depression is filled with water, it is called as Oasis

2. **Abrasion:** Action of wind in which sand particles carried by the wind strike against the rock.

3. **Attrition:** Sand particles carried by the wind striking each other is known as attrition.

Erosional Landforms of Wind

1. **Deflation Hollows**

- When deflation causes a shallow depression by persistent movements of wind, they are called as deflation hollows.

2. **Mushroom Rock**

- A mushroom rock, also called rock pedestal, or a pedestal rock, is a naturally occurring rock whose shape, as its name implies, resembles a mushroom.

- In deserts, a greater amount of sand and rock particles are transported close to the ground by the winds which cause more erosion in the lower part of the rock than the top. These result in the formation of rock pillars shaped like a mushroom with narrow pillars with broad top surfaces.

3. **Yardang**

- Yardangs are extensively grooved, fluted, pitted and irregular rock ridges or reliefs of about 1 to 10 meters high running parallel to the prevailing winds. They are caused by differential erosion. When the sand-laden wind corrades zones of softer or weaker rock between harder vertical ridges from old lake sediment where soft, consolidated rock and bedrock surfaces are eroded into alternating ridges and furrows. Large-scale yardangs are found in Egypt (near Kom Ombo, north of Lake Aswan).

Zeugen

- Zeugen is a landscape of alternate horizontal ridges and furrows made by the action of wind abrasion. It may be as high as 30 m height.

Depositional Landforms of Wind

1. **Sand dunes**

Dry hot deserts are good places for sand dune formation. According to the shape of a sand dune, there are varieties of sand dune forms like Barchans, Seif dune, etc. The barchan is one of the classic desert landforms. It is a crescent-shaped dune with the horns of the crescent stretching out in the leeward direction. Barchan dunes may reach more than 27 meter in height. Seif dunes are long ridges of sand. In general they are aligned in the direction of the prevailing wind. The slip face of seif dunes are probably formed by eddies. The depressions between seif dune ridges are swept clear of sand by the winds. The ridges run for long distances, sometimes several kilometres.

2. **Loess**

- In several large areas of the world, the surface is covered by deposits of wind transported silt that has settled out from dust storms over many thousands of years. These depositions are called as Loess.

3. Pedi plains

- When the high relief structures in deserts are reduced to low featureless plains by the activities of wind, they are called as Pedi plains.

Waves (Coast)

Horizontal movement of sea water caused by the wind, rotation of the earth, etc., are called waves.

How do Waves Erode?

Waves carry out the erosive work in the following ways.

1. **Abrasion:** The waves striking against the coast with eroded materials is called abrasion. Abrasion is also called as the corrasion.

2. **Hydraulic action:** The waves force water and air into the cracks in the rock. The parcel of air can be compressed by the surging water and the waves retreat, air expands explosively, weakening the joints and cracks and causing the rock to break. This is called the Hydraulic action.

3. **Corrosion:** The action of dissolving soluble rocks by waves is termed as the corrosion or solution.

4. **Attrition:** Eroded materials like boulders and rocks knock together to wear out into smaller particles. This is called attrition.

Landforms by the Erosion of Waves

- Erosional landforms dominate rocky coasts but are also found in association with predominantly depositional landforms.

1. Sea cliff is steep rocky coast rising almost vertically above seawater is called sea cliff.

2. Wave Cut Platform: Rock cut flat surfaces in front of a cliff are called wave-cut platform. They are slightly concave upward. It is also formed when blowhole is collapsed.

3. A sea cave is a hollow excavated by waves in a zone of weakness on a cliff. The cave depth is greater than the entrance width.

4. Sea caves usually form at points of geological weakness, such as bedding planes, joints, and faults. A 90 meter long sea cave is found in the Loliem beach in Canacona in Goa. The world's most extensive cave is 1.5 km long Matainaka cave in New Zealand.

5. A blowhole may form in the roof of a sea cave by the hydraulic and pneumatic action of waves, with fountains of spray

6. emerging from the top. If blowholes become enlarged, they may collapse.

5. Arch is formed when the sea cave is cut right through by wave action. The arch is termed as sea tunnel if it is comparatively longer.

6. The stack is a steep and often vertical column of rock in the sea near a coast, formed by wave erosion.

7. It is formed when the natural arch is collapsed. It is also called chimney rock, needles, columns, pillars, skerries, etc,

7. Stump is the worn out stack. 4.10.3 Transportation Work of Waves

8. The eroded materials are transported by the waves in different ways. The materials involved in the transportation by sea waves include silt, sand, gravel, cobble, pebble and boulder.

Landforms by the deposition of waves

Depositional landforms developed by the sea waves include the beach, bar, lagoon, spit, tombolo, barrier island, etc. Let us see one by one in detail

1. Beach is an elongated stretch of sands, pebbles, gravels, etc deposited along the coast. It can be a sandy beach or pebble beach. Praia da Cassino beach in Brazil is the world's longest beach stretching for 200 km from the Rio Grande to the border with Uruguay. Marina beach, Chennai is the second longest beach in the world.
2. The Bar is a stretch of sand deposition off the shoreline. The larger form of a bar is called barrier.
3. The Lagoon is enclosed seawater between the bar and the coast. For example, Pulicat lake, located in the Tamil Nadu and Andhra Pradesh is a lagoon.
4. Spit is a long, narrow ridge of sand or pebble with one end connected to the coast and the other end running into the sea. For example, Rameshwaram, Tamil Nadu.
5. A Tombolo is a bar connecting an island with the coast.

Glossary

1. **Streambed:** A chanel in which a stream flow or formerly flowed
2. **Cataracts**: water fall with volume of water.
3. **The Ice Caps**:It is the covering of Snow and Ice on the oceans of poles.
4. **Offshore** is the zone shallow bottom of the continental shelf.
5. **Source of a river:** place where river starts.
6. **Water Divide:** relief having two river systems.
7. **Oasis:** depression in the desert filled with rain water.
8. **Desert:** waste land unfit for human use at the moment.
9. **Snow line**: an imaginary line below which snow starts melting.
10. **Delta**: A triangular shaped fertile land built by river at the mouth.

Unit V Hydrosphere

Introduction

"World cannot survive without water and morality cannot exist without rain"

- As thirukkural quotes, water is the most important resource in the world. Over 90% of the world's supply of fresh water is in Antarctica. You must know that 85% of the world population lives in the driest half of the planet. Now we shall learn about the hydrosphere in detail.

70% of human brain is water.

- Water is the most common substance found on earth. It is an important constituent of all life forms on the earth. Hydrosphere is one among the four spheres of the earth. The hydrosphere includes the water on the surface of the earth, the water below the surface called ground water and the water in the atmosphere above earth's surface. Oceans, rivers, lakes and glaciers form part of surface water. There is substantial amount of water under the surface of the earth. The atmosphere has water in all the three forms. The total amount of water on the earth does not change over time. Water is constantly in motion within the spheres of the earth which is being transformed and reused all over the earth. The earth's hydrosphere, thus, acts as a closed system.

Distribution of Land and Water in the Earth

- Earth is covered by land and water. About 70.8% of its area (361million sq km) is covered by water and 29.2% (148 million sq km) of its area by land. About 96.5% of water is salty found in seas and oceans. Fresh water occupies only 2.5%. Saline ground water and saline lakes together form 1%.

Fresh water

Fresh water is defined as water with a salinity of less than1% compared to that of the oceans (i.e. below 0.35%). Water with salinity between 0.35‰ and 1‰ is typically referred to as marginal water because it is marginal for many uses by humans and animals.

- Considering the distribution of fresh water 68.6% of it is locked in Glaciers and icecaps. About 30.1% is stored as ground water and the remaining 1.5% is available as surface water.

- Surface water includes ice and snow on the land and sea, water in the lakes, rivers, swamps and marshes, moisture in soil, atmosphere and biosphere. Rivers and lakes are the major sources of fresh water around the world, and are vital to the communities they serve.

- **Rivers:** Rivers generally have a source on a mountain either from a glacier, a spring or a lake. River Ganga has its source from Gangotri glacier in the Himalayas. River Cauvery has its source from a spring in Talacauvery located in Kodagu district of Karnataka. River Nile has its source near Lake Victoria in Uganda. The river flows through confined channel between two banks and ends up at the mouth which is either on a sea or lake. When rivers drain their water into a lake or an inland sea, it is said to be an inland drainage.

- The Nile River in Africa is the longest river in the world. The Nile River flows through Egypt, Uganda, Ethiopia, Kenya, Tanzania, Democratic Republic of the Congo, Rwanda, Burundi, Sudan and Eritrea drains and into the Mediterranean Sea forming a delta to the north of Cairo city.

- The river Amazon in South America, is the second longest river, and has the largest drainage basin of any river. The Amazon River flows through Peru, Colombia, and Brazil and drains into the Atlantic Ocean forming an estuarine delta.

- The Yangtze River, which flows in China, is the longest river in Asia, and the third longest river in the world. The longest river system

in the United States, the Mississippi-Missouri system is considered the fourth longest river in the world.

263 rivers either cross or demarcate international political boundaries.

- The total volume of water in rivers in the world is estimated at 2,120 km3. Asia excluding Middle East, has the largest run off of 13,300 km3/year followed by North America with 12,000 km3 per year.

A nationwide water resources information system, "Generation of Database and Implementation of Web Enabled Water Resources Information System (India-WRIS) in the country" contain all aspects of water resources and related data provide data and information in public domain through India-WRIS Web GIS portal.

Lakes:

- Lakes are larger bodies of water with outlet through a river or stream. Lake may have their origin through tectonic activity, volcanic activity, river, glacier and wave action or sometimes meteoric origin. Caspian Sea, Lake Baikal and Wular Lake have been formed by earth movements. Lake Baikal is the deepest freshwater lake in the world. Caspian Sea is the largest salt water lake in the world.

Tmc ft, is the abbreviation for one thousand million cubic feet (1,000,000,000 = 1 billion), commonly used in India with reference to volume of water in a reservoir or river flow.

- Lagoon lakes are formed by wave deposition. Chilika Lake is the largest lagoon lake in India. Lonar Lake in Maharashtra is believed to be formed by depression created by meteor impact which hit during Pleistocene Epoch.

- Lake Toba on the island of Sumatra is the largest resurgent caldera on Earth.
- Sambhar Lake in Rajasthan is the largest salt water lake in India.
- Finland is known as land of thousand lakes.

Wetlands:

- Wetlands are areas of marsh, fen, peat land or water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres. Marshes are shallow wetlands around lakes, streams, or the ocean where grasses and reeds are common, without trees. Rann of Kutch in India is a salt marsh. A swamp is a wetland with lush trees and vines found in a low-lying area beside slow-moving rivers. Pallikaranai wetland is a fresh water swamp adjacent to the Bay of Bengal situated in the southern part of Chennai.

Groundwater

- Groundwater is the most valuable resource for any country. The rain water that falls on the earth cither runs off as surface water or percolates into the ground to recharge the groundwater. The permeable rocks that can hold water and allow water to pass through them are called aquifers. The upper part of the saturated zone of the aquifer is called the water table. The level of water table fluctuates according to seasons (Figure 5.1).

Saltwater intrusion

If excessive water is taken from the aquifers along the coast, the sea water enters the coastal aquifer. This process is termed as saltwater intrusion.

Cryosphere

- Cryosphere includes the water in frozen state. Glaciers, ice sheets, ice caps, lake and river ice, permafrost, seasonal snow and ice crystals in the atmosphere together form cryosphere. Earth's climate is highly influenced by the extent of cryosphere as it controls the energy budget of the earth (Figure 5.2).

- Perennial ice cover is found in Greenland and Antarctica as ice sheets, as mountain glaciers and as permafrost in higher latitudes.

Permafrost is the condition prevailing when water freezes above and below the ground, (including rock or soil) for more than two consecutive years. Most permafrost regions are located in high latitudes, but alpine permafrost may exist at high mountains in much lower latitudes.

Mount Kilimanjaro (5895m) in Tanzania, Africa, located closer to the equator has permafrost.

- Seasonal snow and ice crystals are confined to middle latitudes and high mountains in lower latitude. Sea ice is frozen ocean water. Its formation, growth and melting are all confined to the ocean. An ice shelf is a thick, floating slab of ice that forms where a glacier or ice flows down a coastline. The world's largest ice shelves are the Ross Ice Shelf and the Filchner-Ronne ice shelf in Antarctica. An iceberg is ice floating in open water that has broken off from glaciers or ice shelf.

Interaction of cryosphere with other spheres

- Cryosphere is a climate indicator. Cryosphere with its high albedo influences the energy balance of the whole planet. Changes in cryosphere will alter land cover, surface temperature, soil moisture, air temperature, radiation, air circulation, clouds, precipitation, sea level, sea surface temperature, salinity, ocean current, fauna, flora and microbes. There is a complex interaction and balance among the spheres of the earth which makes life to flourish in the earth. If there is a change in one sphere it affects the other spheres as well. Nature maintains this balance. Understanding this complex interactions and living in harmony with nature will help to mitigate the environmental problems faced by the earth.

Carbon is removed from the atmospheric cycle by cryosphere during the formation of ice and is released when the ice melts.

Oceans and Seas

- The water in the oceans and seas is termed as marine water. Continuous water body that surrounds the continents, created by

earth's internal force is known as Ocean. The term ocean takes its origin from the Greek word 'Oceaonus' meaning enormous river encircling the earth. The area of the World Ocean is 361 million square kilometre. The earth has at present five major oceans: The Pacific Ocean, the Atlantic Ocean, the Indian Ocean, the Arctic Ocean, and the Southern ocean (Figure 5.3). All these oceans are interconnected to form one Global Ocean or World Ocean. This nature of water to level up quickly has made it as a reference point to measure the height of the land features and the depth of the sea features.

Mean Sea Level (MSL) is the average height of the surface of the sea for all stages of the tide. MSL is reference point to measure the height of land features and depth of the sea features.

- **Sea** is a body of saline water (generally a division of the world ocean) partly or fully enclosed by land. Marginal sea is a sea partially enclosed by islands, archipelagos, or peninsulas and extension of oceans towards land. They are generally shallow. Andaman Sea, Arabian Sea, Bay of Bengal, Java Sea, Persian Gulf and Red Sea are marginal seas of the Indian Ocean.

- **Bay** is a water body surrounded on three sides by land and the fourth side (mouth) wide open towards an ocean. Gulf is a large body of water, **with** a narrow mouth, that is almost completely surrounded by land. The world's largest gulf is the Gulf of Mexico. Sound, creek, bight and cove are bays which vary in size and depth.

- Strait is a narrow channel of water, connecting two larger bodies of water. Palk Strait connects Gulf of Mannar and Bay of Bengal. Isthmus is a narrow strip of land connecting two larger land masses. Isthmus of Suez connects Africa and Asia.

- Enclosed **seas** are seas that reach very deep into the continent stay connected with one or the other ocean of the world through straits. Mediterranean Sea is the best example for enclosed sea. Partly Enclosed Seas are those types of seas that are connected to the oceans by a very wide opening and have similar characters of the adjacent ocean. A series of islands may also occur between

a partly enclosed sea and the ocean to which it is connected. Caribbean Sea is a perfect example.

- **Landlocked Seas** are completely surrounded by landmass on all sides without any natural outlet. They are actually hyper saline lakes. Dead Sea and Caspian Sea are good examples of landlocked seas. Jordon River and Volga River flow into Dead Sea and Caspian Sea respectively. Fjord is a long indented bay with steep slope that has been created by the submergence of U shaped glacial valley. Example: sogne Fjord in Nor way (203 km).

- **Ria** is an indented bay with gradual slope formed by the submergence of V shaped river valley. George River in Sydney is the best example for Ria.

Oceans of the world

1. The Pacific Ocean

- Pacific Ocean is the largest ocean in the world. It is bigger than all continents put together. Portuguese explorer Ferdinand Magellan in 1521 named the ocean Pacific Ocean meaning 'peaceful' because he felt the ocean to be calm after sailing from the Atlantic Ocean through the stormy and dangerous Strait of Magellan. Average depth of this ocean is 4,280 meters.

There is life cycle for oceans too! It is known as Wilson cycle.

2. The Atlantic Ocean

- Atlantic Ocean is the second largest ocean of the world. The Atlantic Ocean's name refers to Atlas of Greek mythology. The North Atlantic Ocean was formed by the break-up of the supercontinent Pangaea and the south Atlantic was formed when the Gondwana land broke in the geological past.

The Suez Canal, an artificial sea-level waterway in Egypt, connecting the Mediterranean Sea to the Red Sea through the Isthmus of Suez was officially opened on November 17, 1869.

3. The Indian Ocean

- The Indian Ocean is the third-largest in the world. It is named after India. Its calm open water has encouraged the sea trade earlier than the Atlantic or the Pacific Ocean.

4. The Southern Ocean

- The Southern Ocean is the worlds fourth largest ocean. The Southern Ocean is the youngest ocean and was formed 30 million years ago when South America moved away from Antarctica, opening the Drake Passage (Figure 5.4). This ocean has the boundary where cold, northward flowing water from the Antarctic mixes with warmer sub Antarctic water. During summer in southern hemisphere over half of the Southern Ocean is covered with ice and icebergs.

5. The Arctic ocean

- The Arctic Ocean is shallower and smaller than the other four oceans. It is completely surrounded by Eurasia and North America. It is covered by ice completely in winter. The Arctic Oceans surface temperature and salinity vary seasonally as the ice cover melts and freezes alternatively. Its salinity is the lowest on an average of the five major oceans. Bering Strait connects the Arctic Ocean with the Pacific Ocean while the Greenland Sea and the Labrador Sea connects it with the Atlantic. The deepest point is Litke Deep in the Eurasian Basin, at 5,450 m.

The International Hydrographic Organization (IHO) is the inter-governmental organisation that surveys and produces charts for the world's seas, oceans and navigable waters.

Maritime zones

- The low-tide line forms the base line for marking maritime zones. Water landward of the baseline in defined as internal waters over which the state has complete sovereignty. A country's territorial sea extends up to 12 nautical miles (22.2 km) from its baseline (Figure 5.5). The contiguous zone is a zone of water extending from the outer

edge of the territorial sea up to 24 nautical miles (44.4 km) from the baseline.

- An Exclusive Economic Zone (EEZ) extends from the base line to a maximum A nautical mile is based on the circumference of the earth, and is equal to one minute of latitude which is equivalent to one sixtieth of a degree of latitude. A nautical mile is a unit of measurement defined as 1,852 metres. Nautical miles are used in Navigational charts.

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Relief of ocean

- The bottom of the ocean has a variety of landforms just as it is seen on the earth's surface. There are large mountain ridges, deep depressions, flat plains, basins and volcanoes. The configuration of an ocean floor is shown with the help of a Indian National Centre for Ocean Information Services (INCOIS) with its Marine Satellite Information Services uses the remotely sensed sea surface temperature (SST) to identify the locations of fish aggregation. The details of the Potential Fishing Zones (PFZ) are then disseminated to the fishermen once in every three days along the Indian Coast by displaying the details in the Lighthouse in their respective regional language (Figure 5.6).

Indian National Centre for Ocean Information Services (INCOIS) with its Marine Satellite Information Services uses the remotely sensed sea surface temperature (SST) to identify the locations of fist aggregation. The details of the Potential Fishing Zones (PEZ) are then disseminated to the fishermen once in every three days along the Indian Coast by displaying their respective regional language

'Hypsometric curve' or 'Hypsographic curve'. It is a graph denoting the proportion of a landmass standing above or below the sea level (Figure 5.7).

Continental shelf

- Continental shelf is the seaward extension of land that lies under the sea water. It occupies 7% of the sea floor. The continental shelf slopes gently away from the land and is covered with shallow seas with an average depth of 200 fathoms. The width of the continental shelf varies according to the nature of the rock beneath the crust. If the crust is dynamic then the shelf would be narrow and vice versa. Continental shelves are formed due to either any one or combination of the factors like fluvial deposits, marine erosion, tectonic forces, and the fluctuations in sea level in the past. Continental shelves are well known for oil, natural gas, mineral deposits and coral reefs. World famous fishing grounds like Grand Bank are situated here. The world's widest continental shelf (1210 km long) is located along the coast of Siberia, in Russia.

- Continental shelf on the east coast of India is formed by deltas of the Ganga, the Godavari, the Krishna and the Cauvery. On the West coast of India the continental shelves are formed due to faulting and consequent submergence.

Continental Slope

- The zone of steep slope extending from the continental shelf to the deep sea plain or abyssal plain is called continental slope. The slope angle varies from 5° to 60°. It occupies 9% of sea floor. This is the region in oceans where landslides, turbid currents, large sediment slumps, under water canyons, gorges cut by the currents and rivers occur. The deposit from the continental shelves immediately falls down here. The origin of continental slope is believed to be due to erosional, tectonic and aggradational processes.

Continental rise

- The area between the continental slope and the sea floor is known as the continental rise. This part is noted for the accumulation of sediments similar to the alluvial fans near the foot hills in the land. It represents the boundary between continents and abyssal plain. It constitutes about 5% of the oceanic area.

Abyssal plain

- The Abyssal plain is the vast area of flat terrain in the bottom of the oceans. It is the largest part of ocean relief covering more than 50% of the total area. There is an accumulation of very fine sediments on the floor. The sediments are combinations of fine particles of clay and microorganisms. As in the case of sedimentary rocks of earth's surface these sediments are in layers and are used to trace geological events in the past.

Mid oceanic ridges

- The mid-ocean ridges are submarine mountains. They are continuous and are connected to form a single global mid-oceanic ridge system. They are formed by the tectonic forces acting from within the earth. Mid oceanic ridges are located on the divergent plate boundaries where magma flows through the fissure to form new oceanic crust. They form the longest mountain range in the world extending for more than 56,000 km long and has a maximum width of 800–1,500 km.

Ocean trench

- The long, narrow, steep-sided depressions formed by tectonic forces beneath the abyssal plain are called Ocean trenches. Oceanic trenches actually extend 3 to 4 km below the level of the abyssal plain. There are 26 oceanic trenches in the world: 22 in the Pacific Ocean, 3 in the Atlantic Ocean and only one in the Indian Ocean. The Challenger Deep in the Mariana Trench, (10,994 m) in the Pacific Ocean is the deepest part of the earth. A trench forms along the convergent boundary where one plate subducts below the other (Figure 5.9).

Island

- An island is a landmass surrounded by water on all sides. Islands may be formed on the continental shelf or as oceanic islands. Most of the oceanic islands are volcanic in origin. Group of islands Ocean deep is grouped into two categories based on their size.

- Very deep but less extensive depression are called deeps. Long narrow linear and more extensive depressions are called 'trenches'. formed by subduction of ocean plate are known as archipelago. Islands of Japan form an archipelago.

- Marine organisms, the coral polyps colonize the tropical warm water and form islands known as coral islands. Lakshadweep Island in Indian Territory is made of corals. Andaman Nicobar islands are of volcanic origin.

Guyots

- Flat topped volcanic hills submerged under the sea water are called guyots. It is a part of an underwater chain of volcanic mountains produced by slow plate movement.

Seamounts

- Seamounts are conical, volcanic hills submerged under ocean water. It does not reach to the water's surface. It is an isolated rise with an elevation of thousand metres or more from the surrounding sea floor and with a limited summit area. It occupies 4.39 percent of ocean region. Seamounts and guyots are most abundant in the North Pacific Ocean.

Bottom relief of Pacific Ocean

- Continental shelf of the Eastern Pacific Ocean is very narrow due to the presence of trenches while those on the western coast are wide. Continental shelf adjoining coasts of Australia and Indonesia varies in width from 160 to 1,600 km. In the Pacific Ocean, the abyssal plains are very vast. Absence of mid oceanic ridges is the main reason for deep sea plains. Prominent submarine ridges of the Pacific Ocean are

Albatross plateau, Cocas ridge and Aleutian ridge. Tasmania basin (New Zealand) and east pacific basin are major basins of Pacific Ocean. Pacific Ocean has about 25,000 islands. There are number of archipelagos both in north and south Pacific Ocean. The Hawaii islands were formed by hotspot. The challenger deep in Mariana trench is the deepest part of Pacific Ocean (10994m).

Bottom relief of Atlantic Ocean

- In the North Atlantic Ocean, extensive continental shelves are found around the
- shores of Newfoundland (Grand bank) and British islands (Dogger Bank). In the South Atlantic Ocean, a very extensive continental shelf is found between Bahia Blanca and Antarctica (Figure 5.10).

- The most striking relief feature which is the 'S' shaped Mid–Atlantic ridge which extends for 16,000 km from Iceland in the north to Bouvet Island in the south. The ridge separates the Eurasian Plate and North American Plate in the North Atlantic, and the African Plate from the South American Plate in the South Atlantic. Iceland and Faroe are the few peaks of the Mid-Atlantic ridge.

- The mid-Atlantic ridge divides the Atlantic Ocean into two major basins, i.e., East and West Atlantic basins. Other basins are Spanish basin, north and south Canary basin, Guinea basin, Brazilian basin and Labrador basin. Puerto Rico Deep (8,380 m) is the deepest of all deeps in the Atlantic Ocean. Other deeps are Romanche Deep and South Sandwich Trench.

- The West Indies is an island archipelago near the main land of North America. British Isles and Newfoundland are famous islands, formed on the continental shelf in the North Atlantic Ocean. Sandwich island, Georgia Island, Falkland and Shetland islands are islands in the South Atlantic Ocean.

Bottom Relief of the Indian Ocean

- The Indian Ocean has continental shelf of varying width. Continental shelf along the coast of Arabian Sea, the Bay of Bengal and

Andaman varies in width from 192km to 280km. A variety of coral reefs thrive in the warm tropical water of the Indian Ocean.

- Indian Ocean has a continuous central ridge called the Arabic Indian ridge. Other important ridges include the East Indian ridge, West Australian ridge, South Madagascar ridge. Basins of Indian Ocean include Comoro basin, North Australian basin, South Indian basin and the Arab basin (Figure 5.11).

- The average depth of the Indian Ocean is 3890m. Sunda deep near Java is the deepest part of this ocean (7450m). Madagascar and Sri Lanka are the most prominent islands present in Indian Ocean. Andaman and Nicobar islands in the Bay of Bengal are the raised part of mountains that are the extension of Arakan Yoma which forms a part of Himalayas. Reunion Island is located on a Hot spot.

Ocean Temperature

- The measurement of degree of hotness or coldness of ocean water is referred to as ocean temperature. Temperature is normally measured in the unit of degree Celsius by thermometers. The major source of heat energy for ocean water is the radiation from sun. The heating and cooling capacity of water differs significantly from that of land.

Factors affecting horizontal distribution of ocean temperature

The factors affecting distribution of ocean temperature are latitude, prevailing winds, ocean currents and local weather.

1. Latitude: The temperature of surface water decreases from equator towards the poles because of the slanting rays of the Sun pole ward.
2. Prevailing wind: Direction of the wind affects the distribution of temperature of ocean water. The off shore winds blowing from the land towards ocean or sea raise the temperature of ocean water. Winds blowing from snow covered regions in winter lower the surface temperature. In trade wind belt, the off shore winds initiate upwelling of cooler water from beneath and on shore

winds pile up warm water to increase the temperature to certain extent.

3. Ocean currents: Warm currents raise the temperature of the oceans where they flow whereas cold currents lower down the temperature. Gulf Stream (warm current) increases the temperature of the eastern part of North America and the west coast of Europe. Labrador cold current reduces the temperature near north eastern coast of North America.
4. Apart from these, some minor factors like submarine ridges, local weather conditions like storms, cyclones, hurricanes, fog, cloudiness, evaporation and condensation also affect the surface temperature of ocean water.

- These images show the sea surface temperature in Celsius. The Figure 5.12 shows the sea surface temperature in July and the Figure 5.13 in January. Cold temperatures are shown in purple, moderate temperatures in aquatic green and warm temperatures in yellow to red. Landmass is shown by black colour. The diurnal range and annual range of temperature of ocean is much less than that of the land. The temperature of the sea surface is highest (27°C to 30°C) not near Equator but few degrees north of the Equator. The lowest temperature recorded is -1.9°C near the poles. The maximum and minimum annual temperatures of ocean water are recorded in August and February in the Northern hemisphere and reverse in case of the southern hemisphere.

Vertical distribution of temperature in oceans

- The uppermost layer of ocean water is warm and well mixed surface layer with average temperature between 20° and 25°C. The depth of this layer varies according to seasons. On an average this layer extends up to 200 m in tropical region. Beneath this layer lies the thermocline layer. This layer varies in depth between 200 metre to 1000 metre. This layer is unique that the temperature decreases rapidly with increasing depth. Below the thermocline temperature decrease is gradual up to 4000m. Beneath this depth the temperature of ocean water is constant at 4°C (Figure 5.14).

Salinity of the ocean

- Salinity is defined as the ratio between the weights of dissolved salts (in grams) per 1000 grams of water. It is expressed as part per thousand (‰) and has no units. Example: 30‰ means 30 grams in 1,000 grams of sea water. The average ocean salinity is 35%

- Sources of salt in the ocean: Sea water is a weak but complex solution made up of many things including mineral salts and decayed biological marine organisms. Most of the ocean salts are derived from weathering and erosion of the earth's crust by the rivers. Some of the ocean salts have been dissolved from rocks and sediments below the sea floor, while others have escaped from the earth's crust through volcanic vents as solid and gaseous materials.

In partially enclosed seas, their bottom relief and the submarine ridges with shallow water do not allow free mixing of open sea water. The temperature at the depth of 1800m in the Red Sea is higher than the temperature recorded at the same depth in the Indian Ocean.

Depth of water is measured in the unit 'Fathom'. One fathom is equal to 1.8 metre (six feet)

Factors affecting the salinity of ocean water

The salinity of ocean water depends upon

a. The rate of evaporation
b. Amount of precipitation,
c. Addition of fresh water flow from rivers
d. Ice in Polar Regions
e. Upwelling of deep water initiated by prevailing winds and
f. Mixing of water by ocean currents.

Distribution of salinity

- On an average the salinity decreases from equator towards the poles. The highest salinity is observed between 20° and 40° north

latitudes because this zone is characterized by high temperature, high evaporation but less rain than the equatorial region.

- The marginal areas of the oceans bordering the continents have lower salinity than their interior due to addition of fresh water to the marginal areas through the rivers (Figure 5.15).

- Very high salinity is recorded in Lake Von, Turkey (330%) Dead Sea (238%) and Great Salt Lake, Utah, USA (220%).

Raking refers to the use of a rake, a traditional wooden tool with the long handle and long pointed wooden toothed spade at the bottom for collecting salt.

Isohaline is an imaginary line drawn to join places having equal salinity. Salinity of Dead Sea is 8.6 times saltier than other oceans. The shore of Dead Sea is 423m below sea level. It has the lowest elevation on land. The sea is 377m deep. The high salt content will make people float on the sea. The high salt content has made the Dead Sea devoid of life in it

Ocean movements

- Water in the ocean is never in a state of rest. Ocean water is always in motion. It moves horizontally as well as vertically. The movement of ocean water takes place in three different ways as waves, tides and ocean currents.

Waves

- The waves are oscillating movements in the ocean water which transfer energy from place to place. They are caused by friction of wind on the surface of water or any other disturbances' on the sea bottom.

Parts of Waves

1. **Crest:** The upper or highest part of a wave is called the crest
.
2. **Trough:** The lowest part of a wave is called the trough.

3. **Wave height**: The vertical distance between the crest and the trough is known as wave height.

4. **Wave length**: The horizontal distance between two crests or two troughs is known as wave length.

5. **Wave amplitude**: Wave amplitude is one-half of the wave height.

6. **Fetch:** The distance of open water across which the wind can blow without interruption is called fetch.

7. **Frequency:** The number of wavelengths that pass a fixed point per unit of time is frequency. Example, 100 waves per sec per cm.

8. **Period:** The time taken by one wavelength to pass a fixed point is known as period.

9. **Velocity**: Refers to speed and direction.

10. **Steepness:** Steepness of the wave is equal to the height divided by length.(H/L)

Tides

- The rhythmic rise and fall of the sea water due to gravitational pull of the moon and the sun is called a Tide. Isaac Newton (1642– 1727) was the first person to explain tides scientifically. The rise of seawater towards the land is known as High tide or flow tide. The fall of seawater more towards sea is known as 'Low tide water' or ebb tide. On any day there will be two high tides and two low tides. The highest high tide occurs on full moon day and new moon day. It is known as spring tide (Figure 5.17). Spring tide happens when the sun, earth and moon aligned in straight line. The lowest low tide is known as neap tide. It happens when the sun, earth and moon are positioned at right angles.

- The movement of ocean water as a result of tidal action is known as a tidal current. In places of narrow coastal inlet these tidal currents flow rapidly through the mouth with greater height and velocity. For example in the Bay of Fundy, between Nova Scotia and New

Brunswick of Canada, the difference between high and low tides is as high as 14m. Ports which utilize the tidal current for entry and exit of ships from
the harbour are known as tidal ports. In India Kolkatta and Kandla are examples of tidal harbours.

- The Gulf of Cambay and the Gulf of Kutch in Gujarat on the west coast have the maximum tidal range of 11m and 8m with average tidal range of 6.77m and 5.23m respectively. Tides help to clear the sediments deposited by rivers on their bed and thus prevent siltation of harbours. The energy of the tides is used to generate electricity. Tidal power stations have been set up in UK, Canada, France and Japan. In India Gulf of Khambhat, Gulf of Kutch and Sundarbans have scope for tidal energy production.

A harbour is a sheltered water body where ships are anchored. A port is the area at the edge of a water body where boats and ships are docked, where transfer of goods and passengers take place and where trading is facilitated.

Ocean currents

- Large mass of moving water from one part of the ocean to another in a definite direction is called as ocean current. The movement is produced due to earth's rotation, temperature difference of ocean water, salinity, density and some extent due to air pressure and winds. Ocean currents can be classified on the basis of mode of origin, volume and velocity and boundaries.

- In the order of velocity ocean currents can be classified as drifts, currents and streams. Drifts are movement of surface water of low velocity influenced by prevailing winds, currents are movement of oceanic water in definite direction and greater velocity and streams are larger mass of water moving in a definite direction and much greater velocity than the drifts and currents. Ocean currents are distinguished by the temperature they possess. When ocean currents originate f rom equator it is ter med as warm current. Likewise when a current starts from polar region it is termed as cold current.

- Vertical circulation of ocean water takes place due to difference in salinity and temperature between the surface and the water deep below. Upwelling is an oceanographic phenomenon that involves movement of dense, cooler, and usually nutrient-rich water towards the ocean surface, replacing the warmer, usually nutrient-depleted surface water. Down welling is the process of accumulation and sinking of cold high saline water beneath warmer or fresher water.

Major ocean currents of the world

- In every ocean, there is circulation of ocean water from Equator to pole and from pole to equator. The warm currents from the equator flows over the surface of ocean towards the pole and sink to the bottom of the ocean floor in the higher latitudes due to high density and flow towards the equator to complete the circulation. This large scale circulation is known as gyre.

- The gyre circulates is clockwise in the northern hemisphere and anti-clockwise in the southern hemisphere.

a. Ocean currents of the Pacific Ocean

1. North Equatorial current.

North equatorial current originates from Revilla Gigedo island west of Mexico and flows towards the Philippines Island covering a distance of about 12,000 km from east west. It is a warm current. It derives from its water from the Californian current and the South east Monsoon drift which flows north along the Mexican coast. The volume of water increases from east to west as many small currents join it from right. It gets divided into two and the northern branch joins the Kuroshio Current and the southern branch abruptly turns and forms the Pacific counter current.

2. South equatorial current.

South equatorial current is originated due the action of the trade winds from east to west. It is a warm current. It extends for about 13,600km from east to west. It is stronger than the

North equatorial current. It is further divided into many branches due to the presence of many islands and uneven surface topography.

3. Kuroshio current (Black Tide)

It is a warm ocean current flowing in north easterly direction up to 30o N latitude and it carries warm water off the Formosa coast. It flows towards north and meets Oyashio cold current off the Kuril Islands. It is also called as Japan current.

4. Oyashio Current(Parental Tide)

It originates from the Bering Strait and flows towards south carrying cold water. It is a cold current. It meets with Kuroshio warm current and Aleutian current.

5. Californian Current.

Californian current is flowing towards south along the west coast of U.S.A between 48o N and 23o N latitudes. It is cold current which exhibits great amount of up welled water. When it enters the region of Trade winds, it is deflected to the right and joins the equatorial current.

6. Peru Current.

Peru Current is perhaps the best studied ocean current of the Pacific Ocean. Alexander Von Humboldt in 1802 noted the details of the Peru Current. Hence, it is also known as Humboldt Current. It is a cold current. It is flowing towards north along the west coast of South America carrying cold water from northerly deflection of the Sub-Antarctica water moving in 40° S.

7. El Nino or Counter current.

It is a warm counter ocean current of the pacific equatorial waters flowing south ward at 400 m depth to a distance about 180 km.

8. West Wind Drift.

It is an easterly moving drift in the Pacific Ocean extending from Tasmania to the South American coast. It is a cold current. The speed of the drift is greater under the influence of Roaring Forties. It splits into two branches and one moves south around the Cape Horn into the Atlantic Ocean and the Other one moves northward along the Peruvian coast due to deflection and joins the Peru Current.

b. Currents of the Atlantic Ocean

1. North equatorial current.

North equatorial current is flowing from east to west. It is a warm current. It is situated between 5o – 20o N latitudes. After leaving the west coast of Africa, it attains its main characteristics. When it reaches the east coast of South America, it splits into two branches and one branch called Antilles current is moving along the coast of West Indies and other branch is diverted into the Caribbean sea.

2. South Equatorial current.

It is flowing south of equator within 0o – 12o S latitude in between the coast of Africa and South America. It is a warm current. It is a northern continuation of Benguela current. It is stronger than the North equatorial ocean current. It is caused by the action of Trade winds.

3. Gulf Stream.

Gulf Stream starts from the Gulf of Mexico and carries warm waters into the colder latitudes. It is a warm current. It bends with the coastline up to 40th parallel after which the direction is almost to the east, due to the force and the direction of the westerlies and the deflective force of the earth. It joins the labrador cold current near New Found land, Canada after

passing through the strait of Florida. The Gulf Stream was discovered by Ponce de Leon in 1513.

4. **Canaries Current**.

The ocean current flowing along the Western coast of North Africa between Maderia and Cape verde is known as the Canaries Current. It is a cold current. It is flowing towards south and merging with the North equatorial current.

5. **Labrador Current**.

In the north Atlantic, a cold current flows from the Baffin Bay and Davis Strait towards south. It brings cold waters from polar zone and moves along the coast of green land.

6. **Benguela current**.

It is a cold current flowing northward along the western coast of Africa is known as the Benguela current. It carries cold waters from sub-Antarctica surface water and mixes with south equatorial current.

The Sargasso Sea - Sea with landless border

The Sargasso Sea occupies about two thirds of the North Atlantic Ocean, stretching seven hundred miles wide and two thousand miles long. The only "sea" with absolutely no land around it, the Sargasso Sea got its name from common brown seaweed called Sargassum that floats in vast mats in its waters. The Sargasso Sea is surrounded only by ocean currents. It lies within the Northern Atlantic Subtropical Gyre. The Gulf Stream establishes the Sargasso Sea's western boundary, while the Sea is further defined to the north by the North Atlantic Current, to the east by the Canary Current, and to the south by the North Atlantic Equatorial Current. Since this area is defined by boundary currents, its borders are dynamic

c. Currents of the Indian Ocean

- The south Indian gyre is formed by south equatorial current, Madagascar current west wind drift and west Australian current. To the north of equator the currents in the Arabian Sea and Bay of Bengal flow in the clockwise direction as southwest monsoon drift and in the anti-clockwise direction as northeast monsoon drift due to the influence of monsoon winds.

- The Antarctic circumpolar current flows between 40 to 60° S latitude. It flows from west to east influenced by the westerly and circles around entire Antarctica. There is a counter west ward current within this circum polar current.

d. Currents of the Southern ocean

- The southern ocean surrounds the continent of Antarctica. The large oceans, the pacific, the Atlantic and the Indian Ocean merge into this circum-global zone of water to their south. The movement of water in the southern ocean is in one sense a relatively simple, generally west-east circum-polar drift caused under the influence of northwesterly winds. This general flow sends offshoots to the three major oceans to its north. The Peru or Humboldt Current in the Pacific Ocean, the Falkland Current and the Benguela Current in the Atlantic Ocean and the West Australian Current in the

- Indian Ocean receive a part of their cold waters from the Southern Ocean. Besides the surface currents, there is also a very complex system of subsurface currents between the southern Ocean and the oceans to its north.

- Generally the water moves from this ocean towards the equator on the surface and at great depths but at in remediate depth, there is a movement of water from the equatorial areas towards the Southern Ocean.

The significance of Ocean Currents

1. Ocean currents play an important role in the earth's climate. They distribute energy and nutrients within the ocean.

2. Fog is formed where warm current and cold current meet. For example, when the Gulf Stream and Labrador Current meet near New Found land one of the densest fogs is formed.
3. The warm ocean current increases the temperature of an area where it flows to and Cold Ocean current decreases the temperature of the area.
4. The warm current brings heavy rainfall when the wind blows over it becomes warm while the cold current brings drought when the wind blows over it becomes cold and dry. For example, the wind blowing over the Peru Current is cold and dry causing the formation of the Atacama Desert located on the west coast of Peru.
5. It regulates the global temperature. It gives free navigation. The Gulf Stream keeps ports & harbours of Russia and Scandinavia navigable throughout the year. The Kuroshio Current makes ports on Japan navigable during winter.
6. It distributes minerals and pollution added to it becomes highly diluted and later negligible.
7. It helps in growth of juveniles of certain fish and its distribution to other countries - from its place of origin. Some up welling and down welling are due to currents which bring minerals to photic zone used by phytoplankton. Major fishing grounds are located in the zones where cold current and warm current meet.

Normal Situation	El Nino Situation
• Near equator the water of the Pacific Ocean is warmer in the western side and cooler in the eastern side due to upwelling of the cold current. • Air (Walker) circulation is dominant in the western Pacific Ocean. The air ascends in the western side and descends over the cooler eastern side • Heavy rain is experienced in the western warmer region and dry conditions prevail in the cooler region.	• Near equator the warm water in the Pacific Ocean extends from western side to eastern side suppressing the • upwelling of the cold water. • Air (Walker) circulation is dominant in the eastern part of Pacific Ocean. The air ascends in the warm eastern Pacific Ocean. • Heavy rain is experienced in the eastern warmer region and dry condition prevails in the western part. • Southeast Asia and Australia

• The Southeast Asia and Australia receive heavy rain on normal years. • West coast of South America experiences dry weather.	experience dry weather conditions. • West coast of South America receives heavy rainfall.

El Nino

- El Nino is a phenomenon that occurs in the equatorial Pacific Ocean characterized by a positive sea surface temperature departure from normal (1971-2000 base period) in the region lying within the latitude 5°N to 5°S and longitudes 120° W to 170°W . This phenomenon occurs every two to seven years (Figure 5.19).

El Nino happens when

- Sea surface temperature increases between the central and eastern equatorial Pacific Ocean between the country Ecuador and the International Date Line
- The increase in temperature is sustained for a period of eighteen months to Two years.
- The temperature increase is up to 30 m beneath the ocean surface.
- When there is a modified vertical air circulation above the Pacific Ocean

Global influence of El Nino

- El Nino effect is experienced at Global level. The change in air circulation affects the economy of different countries also. Global weather patterns are altered to such an extent that they affect eco system, agriculture, tropical cyclone, drought, forest fire, floods and flood related health hazards. El Nino influences the jet streams. Due to this phenomenon California experiences heavy rainfall, northern Europe experiences dry winter, Southern Europe experiences mild wet winters, there are less number of cyclones in Sea of Japan, and heavy rain in East Africa. South East Asia experiences severe drought and forest fire. Peru in South America receives heavy rainfall during El Nino.

- Increase of temperature in the east Pacific Ocean is correlated with normal monsoon conditions in India while the increase of temperature in the central Pacific has high correlation with drought conditions in India. When temperature increases further to the west it suppresses the Indian Monsoon.

La Nina

- La Nina is just the opposite to the condition of El Nino. When trade winds are strong, colder water up wells on the East Pacific Ocean, walker air circulation is confined to the west Pacific, wet condition in Southeast Asia and dry weather in South America is observed.

- The difference in the atmospheric pressure between the west and east tropical Southern Pacific Ocean is referred to as Southern Oscillation. Meteorologists have established a close inter link between Southern Oscillation and occurrences of El Nino and La Nina events. The acronym 'ENSO'(El Nino Southern Oscillation) is often used to study both the phenomena.

Peruvian fishermen named the weather phenomenon El Nino meaning 'little boy' or 'New born Christ' and La Nina meaning 'Little girl' as the phenomenon was first noticed during Christmas time.

Thermohaline circulation

- As the name indicates there is a large scale churning of ocean water due to difference in temperature and salinity. The down welling of ocean water occurs in the extreme ends of Atlantic Ocean one near the Norwegian coast and another at Weddell Sea. Upwelling of cold water occurs in the North Pacific Ocean and in the Indian Ocean. This cycle of water movement within the Global Ocean is also known as Conveyor Belt (Figure 5.20). The slow, steady and three dimensional flow of water in the conveyor belt distributes dissolved gases and solids, mixes nutrients and carries it to various ocean basins. This cycle provides a stabilizing effect on climate of the earth. If it is disturbed, it is capable of causing sudden climatic change within the period of a few

decades. The conveyor belt is a simplified version of actual circulation in the oceans.

Glossary

1. **Abyssal plains:** An extremely large, flat, under water plain on the deep ocean floor.
2. **Continental rise:** is area between the continental slope and the sea floor.
3. **Exclusive Economic Zone (EEZ):** extends from the base line to a maximum of 200 nautical miles (370.4 km).
4. **Isthmus:** A narrow steep of land that connects two large land masses and separates two bodies of water.
5. **Hot spot:** An area is the mantle from where rocks melt and magma rises through circular to form volcano.
6. **Permafrost:** is the condition prevailing when water freezes above and below the ground, (including rock or soil) for more than two consecutive years
7. **Trace elements**: A chemical element present in minute amount in a particular sample or environment.
8. **Isohaline:** is an imaginary line drawn to join places having equal salinity
9. **Swell:** is a type of wind-generated waves that is not affected by the local wind.
10. **Thermohaline circulation**: is large circulation of ocean water due to difference in temperature and salinity.

Unit 6
Atmosphere

Introduction

You must have heard people, in the countryside, saying

"When sheep collect and huddle,
Tomorrow will puddle!"
"If ants march in a straight line,
expect rain"

- Phrases like 'a cold morning', 'sunny day', 'cloudy day' and rainy day refer to the weather. Weather refers to the state of atmosphere at a particular place at any given time denoting the short term variations of atmosphere in terms of temperature, pressure, wind, moisture, cloudiness, precipitation and other elements. Weather is highly variable from time to time, day to day and place to place. Weather is not constant. It is always changing within hours or a day.

- On the other hand, climate is the average weather conditions of an area for a long period of time. The World Meteorological Organisation (WMO) has suggested data for a period of 30 consecutive years to be referred for calculating the climatic averages of various weather elements. Climate is constant. It is a permanent condition of a place.

- The ancient Greeks called the tilt of latitude as 'klima', literally meaning 'slope' or 'inclination'. Then the earth was divided into seven latitudinal regions, called 'klimata'. The word came into modern European languages as clime or 'climate', denoting the average weather condition.

Composition of the Atmosphere

- The atmosphere is essential for the survival of all the organisms on the earth. The atmosphere is a blanket of gases and suspended particles that entirely envelope the earth. It extends outward over thousands of kilometres from the earth's surface. Water vapour, aerosols and tiny

solid particles occur in varying quantities as suspended material. Tese are responsible for weather phenomena as they have ability to absorb and release heat energy.

- The atmosphere is composed of mixture of many gases, water vapour and other solid particles. The major components are nitrogen (78%), oxygen (21%) and other gases (1%). Argon, Carbon dioxide, Neon and the other gases found in the atmosphere (Figure 6.1).

Layers of the Atmosphere

- The atmosphere is divided into five distinct layers (Figure.6.2) based on the temperature variations. They are,

1. Troposphere
2. Stratosphere
3. Mesosphere
4. Ionosphere(Thermosphere) and
5. Exosphere

Troposphere

- The troposphere (Figure 6.2) is the lower most layer of the atmosphere. It extends approximately to a height of 8 km from the poles and 18 km from the equator. The height of the troposphere changes seasonally also. It increases during summer and decreases during winter.

- All weather phenomena occur in this layer as it has dust particles and water vapour. This layer has clouds which produce precipitation on the earth. The Sun's rays directly fall on the earth and then they are reflected back into the atmosphere. The temperature decreases in the troposphere with increase in altitude at the rate of 1 °C for 165 metre or 6.5 °C for every 1000 metres of ascent. This is known as lapse rate of temperature. This is the densest layer as it contains 70 to 80 percent of gases. The outer boundary of the troposphere is called tropopause, which is about 1.5 kilometre thick.

Stratosphere

- It is the second layer of the atmosphere found above the troposphere. It approximately extends up to a height of 50 km from the earth's surface. Temperature is constant up to a height of 20 km and increases gradually up to the stratopause where temperature is nearly -4°C. The lower part of this layer is highly concentrated with ozone gas which is called as 'ozonosphere'. It prevents the ultra-violet rays from the Sun to enter into the lower part of the atmosphere as the rays are highly harmful it causes skin cancer and other ill effects to living organisms. But the ozone layer safeguards the life on the earth.

Mesosphere

- The mesosphere is the third layer of the atmosphere found approximately up to a height of 85 km above the surface of the earth. It is the coldest layer of the atmosphere. The temperature decreases with increase of altitude due to the absence of ozone. Its upper boundary is called mesopause where temperature reaches — 90°C. Luminous noctilucent clouds form here due to the presence of cosmic dust. Meteors falling from the space get burned in this layer. It is because when meteors hit the air, the air gets compressed and heated up causing meteors to burn out.

Ionosphere (Thermosphere)

- The ionosphere is the fourth layer of the atmosphere extending approximately up to a height of 400 km. The temperature increases rapidly up to 1,000°C. It is due to the absorption of very short wave and high energy solar radiation by the atoms of hydrogen and oxygen gases. When light energy is transformed into heat energy some gas molecules lose or gain electrons and become the charged particles called ions. The charged particles forming the lower part of the thermosphere as a zone, is called Ionosphere (Figure 6.4). These ionised particles create auroras at higher latitudes. Ionosphere can reflect radio waves back to the earth. This facilitates long distance wireless satellite communication. The credit of discovering ionosphere goes to Kennelly and Heaviside.

Exosphere

- The upper most layer of the atmosphere which extends into the outer space from above 400 km up to 1600km. It has rarefied contents. It contains mainly oxygen and hydrogen atoms. These atoms can travel hundreds of kilometres without colliding with one another. Thus, the exosphere has no longer behaves like a gas. The temperature increases with increase of altitude and it ranges as high as 1650 °C. The gravitational pull is minimal in this layer. Tis layer gradually merges with the space.

Ozone and Ozone Depletion

- Ozone (O3) is form of oxygen that combines three atoms into each molecule. It absorbs and filters the harmful ultraviolet B radiation coming from the sun. This way the ozone layer protects all life on earth. However, ozone is harmful when it develops near the ground. It causes health problems like asthma and other respiratory illness.

Ozone Depletion: A steady decline in the concentration of ozone in the earth's stratosphere (the ozone layer) is called ozone depletion.

- **Ozone depletion** occurs when chloro fluoro carbon (CFC) and halon gases, formerly found in aerosol spray cans and refrigerants are released into the atmosphere and they cause chemical reactions that break down ozone molecules and reduce the concentration of them. Nitrogen oxide released by emitted by supersonic aircrafts can also destroy the ozone molecules to break down. Ozone-depleting substances are present throughout the stratospheric ozone layer because they are transported great distances by atmospheric air motions. The severe depletion of the Antarctic ozone layer known as the "ozone hole" occurs because of the special atmospheric and chemical conditions that exist there and nowhere else on the globe. The very low winter temperatures in the Antarctic stratosphere cause polar stratospheric clouds (PSCs) to form. Special reactions that occur on PSCs, combined with the relative isolation of polar stratospheric air, allow chlorine and bromine reactions

to produce the ozone hole in Antarctic springtime.

- Satellite images of the earth over last decades observed that the atmospheric ozone layer is getting thinner. On October 2, 2015, the ozone hole was recorded to its maximum size of 28.2 million sq.km over Antarctica (Figure 6.5). The size of the ozone hole is larger than the size of continent of North America. The ozone holes over Antarctica allow the ultraviolet radiation to enter and cause global warming, skin cancer, eye cataract and even blindness.

- Depletion of the ozone layer has consequences on human, animal, plants and micro-organisms. This typically results from higher UV levels reaching us on earth. Research confirms that high levels of UV rays cause non-melanoma skin cancer.
- To protect the ozone layer for our future generation, avoid using products which are emitting pollutants such as aerosol sprays, blowing agents for foams and packing materials, as solvents and as refrigerants.

The Dobson Unit (DU) is the unit of measurement for total ozone

Temperature and Heat Budget

- Air temperature of a particular place denotes the degree of hotness or coldness of air at a given place. It is measured in Celsius. Let us understand how the earth is heated. The surface of the earth is heated by the sun's rays in the form of short wave radiation. The heat received by the earth is called 'Solar Radiation' or 'Insolation'. Heating of atmosphere is an indirect process. The processes are:

a. Terrestrial radiation

- The solar radiation reflected by the earth's surface is called 'Terrestrial radiation'. Terrestrial radiation supplies more heat energy to the atmosphere due to its long wave length.

b. Conduction

- The heat energy from the earth's surface is transferred to the lower atmosphere which is directly in contact with the surface by the process of conduction.

c. Convection and advection

- The movement of air molecules in vertical and horizontal direction is called as 'convection and advection' respectively. Tis movement carries heat energy to the various parts of the earth and at different altitudes.

Heat budget

- The heat energy reflected, absorbed and radiated back into the space equals the energy received by the earth. Incoming radiation and the outgoing radiation pass through the atmosphere. The earth maintains its optimum temperature.

- When 100% solar radiation reaches the earth's atmosphere, 35% is reflected back to space by clouds, water bodies and ice covered areas. This heat does not heat either the earth or atmosphere.

- Of the remaining 65% of heat, 14% are absorbed by the atmosphere and 51% are absorbed by the earth's surface (34% of direct solar radiation and 17% from scattered radiation). 51% received by the earth are radiated back to the space directly as terrestrial radiation.

- In total, 17% are radiated to space directly and 48% are absorbed by the atmosphere (14% from insolation and 34% from terrestrial radiation) are radiated back to space gradually. Therefore, 65% heat received from the sun is balanced by the 65% radiated by the earth. This balance between the incoming and the outgoing heat energy is called the global heat energy balance.

Distribution of Temperature

Distribution of temperature varies both horizontally and vertically. Let us study it under

a. Horizontal Distribution of Temperature
b. Vertical Distribution of Temperature

a. Horizontal Distribution of Temperature

- Distribution of temperature across the latitudes over the surface of the earth is called horizontal distribution of temperature. On maps, the horizontal distribution of temperature is commonly shown by isotherms. Isotherms are line connecting points that have an equal temperature at mean sea level.

The average time taken by the solar radiation to reach the earth's surface is 8 minutes 20 seconds.

Factors Affecting the Horizontal Distribution of Temperature

- The horizontal distribution of temperature on the earth's surface varies from place to place. Following are the factors affecting the horizontal distribution of temperature of the earth:

a. **Latitude:** The angle formed by the solar radiation to the ground is called 'angle of incidence'. The solar radiation passes vertically along the equator. The angle of incidence decreases from equator towards the poles. The area heated by the solar radiation increases towards the poles and therefore, temperature decreases from the equator to the poles.

b. **Distribution of land and water**: Land is heated and cooled at a faster rate due the conduction process whereas water is heated and cooled at slower rate due to convection process. Water takes 2.5 times of heat energy to heat a unit area compared to land. Thus, the land will have higher temperature than the water in summer and vice versa during the winter. So more land mass in northern hemisphere (15.28C) leads to higher average temperature than the southern hemisphere (13.38C).

c. **Ocean currents**: Warm ocean currents carry warm water from the tropical region towards the poles and increase the temperature while cold ocean currents carry cold water from Polar Regions and reduce the temperature along the coasts.

d. **Prevailing winds**: Warm winds like trade wind and westerly, that carry higher heat energy, increase the temperature while cold polar easterlies carry lower heat energy from polar region reduces the temperature.

e. **Cloudiness:** The cloudy sky obstructs the solar radiation from the sun to earth and reduces the temperature. But the clear sky during the day allows more solar radiation to reach the earth's surface and increases the temperature. Meanwhile clear sky at night allows more terrestrial radiation to escape. For example, the tropical hot deserts experience higher temperature at day and lower temperature at night.

f. **Nature of the surface**: The reflection from surface varies based on the nature of land cover. The more reflection from the snow surface leads to low temperature accumulation. But the dense forest, which reflects less heat energy and absorbs more heat energy, leads to higher temperature.

g. **Mountain barriers:** If a wind or air mass blows towards the mountain, it influences the distribution of temperature on either side of the mountain. For example, polar easterlies and blizzards are obstructed by Himalayas in Asia and Alps in Europe respectively. This leads to lower temperature in the northern slopes and higher temperature in the southern slopes of the respective mountains.

Factors Affecting the Vertical Distribution of Temperature

- We all know that the temperature decreases with increasing altitude from the surface of the earth. The vertical decrease in temperature of troposphere is called as 'Normal Lapse Rate' or 'vertical temperature (Figure 6.7) gradient' at which the temperature reduces at the rate of 6.5 8C per 1000 meter of ascent. This is influenced by the following factor

a. Amount of terrestrial radiation reaching the altitude and
b. Density of air to absorb the heat energy at higher altitude.

As both the above said factors decrease with altitude, the temperature also decreases (Figure 6.5).

Inversion of Temperature

- The condition at which the temperature increases with altitude is called as 'inversion of temperature'. In this condition, warm air lies over cold air. The conditions for inversion of temperature are:

a. **Long winter nights:** The bottom layer of the atmosphere in contact with the ground is cooled and the upper layer remains relatively warm.

b. **Cloudless sky:** The higher amount of terrestrial radiation reaches the higher altitude which leads to lower temperature at low level due to clear sky.

c. **Dry air near the surface:** the dry air absorbs less terrestrial radiation and allows them to escape into space.

d. **Snow covered ground:** During night, due to terrestrial radiation and higher albedo, most of the heat is lost to the atmosphere and the surface is cooled.

e. **Formation of fronts:** the movement of warm air over the cold air during the formation of the various fronts leads to inversion condition.

f. **Mountain wind:** The subsidence of cold mountain wind at the early morning leads to the displacement of warm air from the valley to higher altitude. This type of inversion is called as 'valley inversion'.

Albedo is the amount of solar radiation reflected from the surface. The variation is based on the nature of the earth's surface. Snow has higher albedo compared to forest.

Measurements of Temperature

Unit of Temperature	Scientist	Year
Fahrenheit	Gabriel Fahrenheit	1714
Celsius	Andrew Celsius	1742
Kelvin	Lord Kelvin	1848

Conversion of Units	
Celsius to Fahrenheit Ex. 20°C, F = (C × 1.8) + 32 F = (20×1.8) + 32, F = 36 + 32, F = 68	**Celsius to Kelvin Ex.20°C,** K = C + 273.15 k K = 20° + 273.15k, K = 293.150k

Heat Zones of the World

- The earth has been divided into three heat zones according the amount of insolation received. These are the Torrid Zone, the Temperate zone and the Frigid Zone.

Torrid Zone (23 ½ °N to 23 ½ °S)

- The zone lying between the Tropic of cancer and Tropic of Capricorn is called 'Torrid zone' (Figure 6.8). The sun's rays are vertical throughout the year and it receives maximum insolation. Thus, this is the hottest zone.

Temperate Zone (23 ½ °N to 66 ½ °N and 23 ½ °S to 66 ½ °S)

- The temperate zone lies between the Tropic of Cancer and Arctic Circle in the northern hemisphere and the Tropic of Capricorn and Antarctic circle in the southern hemisphere. This region never experiences over-head sun light but experiences longer days and shorter nights during summer and vice versa during winter. This region experiences moderate temperature and is therefore called as Temperate zone'.

Polar Zone (Frigid Zone - 66 ½ °N to 90°N and 66 ½ S to 90°S)

- The region between North pole and Arctic Circle in the northern hemisphere and South pole and Antarctic Circle in the southern hemisphere is called 'Polar Zone'. This region always receives more oblique rays of the sun and so the temperature is very low. It is the coldest zone. This region experiences 24 hours of day and night during peak summer and winter respectively.

- **Annual Temperature:** The average annual temperature of a region for a year.
- **Mean Annual Temperature:** The average of 30 years of annual temperature of the region.
- **Range of Temperature**: Difference between highest and lowest temperature of a place.
- **Annual Range of Temperature:** The difference between highest and lowest temperature of a place in a year.
- **Diurnal range of Temperature**: The difference between highest temperature and lowest temperature of a place in a day.

From the above discussion, it is clear that the energy for the earth is from the sun.

Green House Effect: As seen in the heat budget, the longer wavelengths are absorbed by greenhouse gases in the atmosphere, increases the temperature of atmosphere. These greenhouse gases act like a green-house and retains some of the heat energy would otherwise be lost to space. The retaining of heat energy by the atmosphere is called the 'greenhouse effect'.

Global Warming

- Global warming is observed in a century scale. The temperature increase over the years has been due to the greenhouse gas concentration such as carbon dioxide (CO_2), water vapour, methane and ozone. Greenhouse gases are those gases that contribute to the greenhouse effect. The largest contributing source of greenhouse gas is the burning of fossil fuels leading to the emission of carbon dioxide from industries, automobiles and domestic.

Urban Heat Island (UHI)

- An urban heat island is an urban area or metropolitan area that is significantly warmer than its surrounding rural area due to high concentration of high rise concrete buildings, metal roads, sparse vegetation cover and less exposure of soil. These factors cause urban regions to become warmer than their rural surroundings, forming an "island" of higher temperatures (Figure. 6.9).

Ways to reduce the impact of urban heat island:

1. Increase shade around your home: Planting trees and other vegetation, provides shade and cooling effect through evapotranspiration and it lowers the surface and air temperature.
2. Install green and cool roofs.
3. Use energy-efficient appliances and equipments.
4. Shift all industries away from the urban area.
5. Reduce emission from automobiles.

Atmospheric Pressure and Winds

- Atmospheric pressure is defined as the force per unit area exerted against a surface by the weight of the air molecules above the earth surface. In the Figure below (Figure 6.10), the pressure at point 'X' increases as the weight of the air increases. The atmospheric pressure is not distributed uniformly over the earth. The amount of pressure increases or decreases, according to the amount of molecules that exerts the force on the surface.

- When temperature of the air increases, the air expands and reduces the number of molecules over the unit area. It leads to reduction in pressure. Similarly, when the temperature falls, the air contracts and the pressure increase. Therefore, the temperature and atmospheric pressure are inversely related.

Atmospheric pressure is measured by an instrument called 'Barometer'

Vertical Distribution of Atmospheric Pressure

- The relationship analysis between altitude and atmospheric pressure is very peculiar. The upper atmosphere is thin and less dense. The pressure at sea level is highest and keeps decreasing rapidly with increasing altitude because of the progressive reduction of the mass Isobar is an imaginary line connecting the places of uniform atmospheric pressure reduced to mean sea level above the point where it is measured (Figure 6.12). Relationship between Standard Pressure and Altitude

Altitude in m	Atmospheric pressure in m b
Sea level	1013.25
1,000	898.76
2,000	795.01
3,000	701.01
4,000	616.60
5,000	540.48
10,000	264.0

Horizontal Distribution of the Atmospheric Pressure

- When the air gets heated it expands, becomes light and rises vertically. As air rises, the pressure it exerts on the earth surface is reduced, causing a low pressure area (Figure 6.13).

- On the other hand, cool air is dense and heavy. As a consequence it sinks vertically. It results in additional weight and pressure which cause a high pressure area to occur on the ground.

The rotation of the earth affects the moving objects on the earth surface. Free moving objects, affected by the rotation of the earth, do not follow a straight line. In the northern hemisphere they drift towards right and towards left in the southern hemisphere. A car travelling down a straight road at 95 km/hr in northern hemisphere would drift to the right of the path if the friction between surface and tyre is absent. The tendency is called as Coriolis Effect as it was discovered by G.G. Coriolis. This is the reason why racket launching stations are located on the east coastal areas. Example: Sriharihota, French Guyana.

Pressure Belts of the Earth

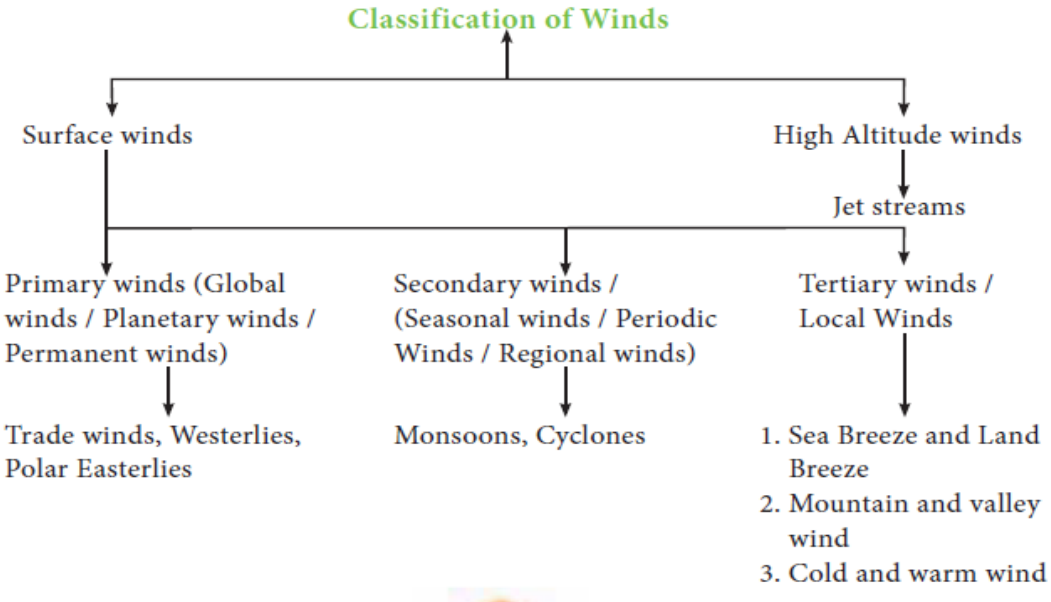
- The atmospheric pressure belts envelope on the surface of the earth. They are equatorial low pressure belt, sub-tropical high pressure belts, sub polar low pressure belts and polar high pressure belts

Wind Systems

- Wind is the horizontal movement of air molecules from areas of high pressure to areas of low pressure to maintain the atmospheric equilibrium. The wind always moves perpendicular to isobars. If the earth did not rotate, the winds would blow in a straight path. Then the rotation of the earth results in corilois effect and it deflects the direction of the wind. Wind direction is identified by an instrument called Wind Vane and wind speed is measured by Anemometer.

Types of Winds

Winds are classified based on the nature and area of influence as follows;



General Atmospheric Circulation, Pressure Belts and Primary Wind System

- From the equator to the poles, each hemisphere has four pressure belts and totally there are seven belts on the globe. The pressure belts lead to formation of primary wind system as follows (Figure 6.14):

a. The equatorial low pressure belt (between 58°N and 58°S):

- This is the region of calm, weak and changeable winds. Due to the high temperature over this region, the air gets heated expands and become lighter and rises upward and creates low pressure over the region. This region is a belt of calm and referred to as the 'Doldrums'. The winds blow from the sub-tropical high pressure belt towards the equatorial low pressure belt. Due to Coriolis Effect these winds are deflected to the right in the northern hemisphere and to the left in the southern hemisphere. As winds are named after the direction from which they originate they are called as the North East and South east trade winds. As the winds favoured trading ships they are called as 'Trade winds'.

b. The sub-tropical high pressure belt (25° to 35° N and S):

- Air begins to cool when it reaches higher altitude over equatorial region and flows towards the poles. This wind collides with the wind coming from the polar region at higher altitude and subsides down over sub-tropical latitudes. This leads to formation of high pressure belt along the sub-tropical region. It is said that to avoid the slowing down of ship due to high pressure the horses were thrown into the sea. So this belt is called as 'Horse latitude'. The sinking air bifurcated in to two branches towards the equator and poles, they are called as trade winds and westerly respectively. Westerlies flow towards the pole from sub tropics and turn towards right and left in northern hemisphere and southern hemisphere respectively.

c. The sub polar low pressure belt (50° to 60° N and S):

- The warm westerly wind from sub-tropical region moves towards the pole and collide with the cold polar easterly wind from polar high pressure region and raises up to form sub polar low pressure belt.

d. Polar high pressure belt (80° N and S to pole):

- The constant low temperature at the poles due to inclined solar radiation and reduced insolation leads to the formation of polar high pressure belt on both poles.

Ocean is dominant in the southern hemisphere between the latitudes 40ºand 60ºS. Hence the westerlies are so powerful and persistent that the sailors used such expressions as "Roaring Forties", "Furious Fifties" and "Screeching Sixties" for these high velocity winds in the latitudes of 40º, 50º and 60º respectively.

- The high pressure on the surface always coincide with the low pressure at higher altitude while the low pressure on the surface always coincide with higher pressure on the higher altitude. High pressure always has divergence of air masses from the centre but low pressure has convergence of air.

Basis of Formation of Pressure Belts

There are two important bases on which the pressure belts are formed. They are;

a. **Temperature:** The equatorial low pressure and polar high pressure belts are formed due to high and low temperature respectively. So they are called as 'Thermally formed pressure belts!
b. **Dynamism:** The sub-tropical high and sub polar low pressure belts are formed due to movement and collision of wind system. So they are called as 'Dynamically formed pressure belt system'.

Meridional Cell System

- The cell along with trade winds, equatorial low and sub-tropical high pressure belts is called as 'Hadley cell", meanwhile the cell formed by westerly wind along with sub-tropical high and sub polar low pressure belt is called Terrell's cell'. The cell at polar formed by polar easterlies with polar high and sub polar low pressure belt is called as 'Polar cell'(Figure 6.15).

ITCZ - Inter Tropical Convergent Zone

- The region where both trade wind systems meet is known as 'Inter Tropical Convergent Zone'

Shifting of Pressure Belts and Primary Wind System

- These pressure belts and primary wind systems are dynamic in character as they shift 58 north and 58 south from their position along with the apparent movement of the sun.

Secondary Wind System

- Both monsoon and cyclones are considered as secondary or regional wind systems.

Monsoons

- The word 'Monsoon' is derived from the Arabic word, 'Mausin, which means 'Season'. Monsoons are seasonal winds which reverse their direction due to unequal heating and cooling of the land and the water.

Mechanism of Monsoon

- The land absorbs more heat energy during summer, which leads to the formation of low pressure over continent. But the ocean will have relatively lower temperature than the continent leading to the formation of high pressure system over ocean. So, the wind blows from sea to land during summer season. Meanwhile the land reradiates more heat energy to space during winter leading to the formation of high pressure above the continent. But the ocean will have relatively higher temperature than the continent leading to formation of low pressure system over ocean. So, wind blows from land to sea during the winter season. T is mechanism has an important effect on rainfall received over the region.

Nature of Monsoon System

- There are three distinct characteristics related to monsoon wind system which differentiates it from other wind systems. They are;

1. Minimum 1608 reversal of wind direction between seasons.
2. They affect a large part of the continents and oceans.
3. The formation of low and high pressure systems over land and water and their interchange between the seasons.

- Monsoon system is classified into two groups based on the location. They are;

a. Asian Monsoon
b. South Asian Monsoon

a. Asian Monsoon

- The Asian monsoon system is divided into two components based on season it flows. The presence of high temperature with low pressure in the lake Baikal region and low temperature with high pressure in the Aleutian islands region leading to flow of wind from Pacific Ocean to interior part of Asia during summer is called 'Summer

- Monsoon of Asia'. This leads to rainfall in the east coast of Asia. Meanwhile, in winter the low temperature and high pressure in the Lake Baikal region and high temperature and low pressure in the Aleutian Island region leading to flow of wind from Central Asia to Pacific Ocean is known as 'Winter Monsoon of Asia'. As the wind system flows off shore, the rainfall does not occur in the continent of Asia except western coast of Japan.

b. South Asian Monsoon

- South Asian Monsoon includes the countries in the southern part of Himalayas, that is India, Pakistan, Bangladesh, Sri lanka, Maldives, Nepal and Bhutan. This monsoon system has been classified into two groups based on the direction of origin of wind namely south west monsoon and north east monsoon (Figure 6.16).

South West Monsoon

- During summer the Indian peninsula is heated more than the sea around it. Intense low pressure is formed in the region of Peshawar of Pakistan. At the same time, the Indian Ocean has higher pressure due to relatively low temperature. So the wind blows from Indian Ocean

towards South Asia as Southeast Winds. The wind turns towards right due to Coriolis Effect and blows as south west winds which bring heavy rains around four months of the year. This is known as south west monsoon in Indian Sub-continent. This wind system bifurcates into two branches as Arabian Sea branch and Bay of Bengal branch.

Arabian Sea Branch

- The Arabian Sea branch strikes the Western Ghats at perpendicular direction and rises over it. The orographic effect by the Western Ghats results in heavy rainfall in the windward side and low rainfall in the leeward side. So the west coast of India receives high rainfall when compared to the eastern side of the Western Ghats. Kerala is the first state to receive rainfall from the south west monsoon in India, which occurs during first week of June. Ten, the wind gradually moves towards the north of the western coast and leads to gradual development of the monsoon in parts of Karnataka, Goa, Maharashtra, Gujarat and Rajasthan. The wind further advances towards foot hill of the Himalayas and creates orographic rainfall in the Himalayan states, Punjab and Haryana. The other part of the Arabian Sea branch moves towards the east and results in onset of monsoon in Uttar Pradesh and Bihar. Here, it unites with the Bay of Bengal branch and leads to heavy rainfall and food.

Bay of Bengal Branch

- Bay of Bengal branch flows from south west which results in orographic rainfall in Sri Lanka and reaches Andaman and Nicobar Islands and results in orographic rainfall. Indira point in the Great Nicobar is the first place which receives rainfall during south west monsoon in India during middle of May. The wind flows parallel to the east coast of India and Eastern Ghats. So Coromandel Coast of India doesn't get enough rainfall during south west monsoon. The wind strikes Arakanyoma Mountain in Myanmar and results in heavy rainfall in western coast of Myanmar. The wind funnels towards north eastern part of India after defected by the Arakanyoma Mountain in Myanmar. This wind strikes Meghalaya plateau which leads to heavy rainfall in Bangladesh and North eastern part of India. Mawsynram, the wettest place (highest annual rainfall) in the world, is located in the windward side of Meghalaya plateau.

- The wind further advances towards the Himalayas where it creates heavy rainfall in the southern slopes. This leads to flood in River Brahmaputra. The wind gradually moves towards the west and results in onset of monsoon in Bhutan, Sikkim, West Bengal, Nepal and Bihar. It joins with Arabian Sea branch in Bihar and results in heavy rainfall and flood.

- The south west monsoon gradually withdraws from south Asian continent due to apparent movement of the Sun towards the southern hemisphere. This is called as 'Withdrawal of South West Monsoon'.

North East Monsoon

- During winter the Indian Subcontinent becomes colder than the Indian Ocean. As a result the wind blows from Northeast to South West direction. This is dry wind system and it does not produce rainfall in the coastal region of south Asia except the Coromandel Coast of India and Sri Lanka.

Mawsynram, world's wettest place!

''It was the kind of rain you wouldn't see anywhere else. We could barely see four feet ahead of us. We could touch the clouds, smell the clouds, and taste the clouds'' said a local resident. Yes, it is about Mawsynram which is located in Meghalaya's East Khasi Hills, with the cluster of about 1,000 homes. It holds the Guinness Record for "the wettest place on earth". The average annual rainfall is 11,861mm, according to the Guinness website.

However, the soil in the limestone plateau doesn't absorb water. "There is barely any forest cover, so a lot of erosion of top soil happens. All of it flows down into Bangladesh. The irony is that "the wettest place on earth" grapples with an acute water shortage after monsoon ends around October. Hence, people call world's rainiest place Mawsynram, which is also world's wettest desert.

- This is known as North East Monsoon or Retreating Monsoon in South Asia. Agriculture in India mostly depends on the rainfall brought by the monsoons.

- During the El Nino year the temperature of the ocean water increases. Tis weakens the high pressure over Indian Ocean thereby reduces the strength of south west monsoon over south Asia. However during winter, it induces the low pressure over the ocean resulting in severe depressions and cyclones.

Tertiary Winds

- The tertiary winds are formed due to pressure gradients which may develop on a local scale because of differences in the heating and cooling of the earth's surface.

Sea and Land Breezes

- During daytime, land heats up much faster than water. The air over the land warms and expands leading to form low pressure. At the same time, the air over the ocean becomes cool because of water's slower rate of heating and results in formation of high pressure. Air begins to blow from high pressure over ocean to the low pressure over the land. This is called as 'Sea breeze'. During night time, the wind blows from land to sea and it is called as 'Land breeze' (Figure 6.17).

Sea breeze and land breeze influence the movement of boats near the coastal region and fisher men use these winds for their daily fish catching. Fishermen go for fishing at early morning along the land breeze and return to the shore in the evening with the sea breeze.

Mountain and Valley Breezes

- A valley breeze develops during the day as the sun heats the land surface and air at the valley bottom and sides. As the air gets Mountain and valley wind systems influence the weather pattern of the mountain top and valley bottom. Mountain top can be seen clearly at early morning and valley bottom at evening. But mountain top will be covered with clouds at evening due to rising of valley wind system

and valley bottom would be covered by clouds at early morning due to arrival of mountain wind system. These clouds are sometimes called as 'fog' which is used for cultivation in the dry regions like Yemen. heated it becomes less dense and begins to blow gently up the valley sides. This is called as 'valley wind'. Tis process reverses at night leading to blow of wind from mountain top to valley bottom referred to as 'mountain wind' (Figure 6.18).

Local Winds

Local wind systems influence the weather pattern where ever they blow (Figure 6.19). Some important local winds are;

1. **Bora**: North easterly from eastern Europe to north eastern Italy
2. **Chinook:** Warm dry westerly off the Rocky Mountains
3. **Fohn:** Warm dry southerly off the northern side of the Alps and Switzerland.
4. **Harmattan:** Dry northerly wind across central Africa
5. **Karaburan:** 'Black storm' a spring and summer katabatic wind of central Asia
6. **Khamsin**: South easterly from North Africa to the eastern Mediterranean
7. **Loo:** Hot and dry wind which blows over plains of India and Pakistan.
8. **Mistral:** Cold northerly from central France and the Alps to Mediterranean.
9. **Nor'easter:** Strong winds from **the** northeast **in** the eastern United States, especially New England
10. **NorVester:** Wind that brings rain to the West Coast, and warm dry winds to the East Coast of New Zealand's South Island, caused by **the** moist prevailing winds being uplifted over the Southern Alps, often accompanied by a distinctive arched cloud pattern.
11. **Pampero:** Argentina, very strong wind which blows in the Pampa.
12. **Simoom:** Strong, dry, desert wind that blows in the Sahara, Israel, Jordan, Syria, and the desert of Arabia.
13. **Sirocco**: Southerly from North Africa to southern Europe.
14. **Zonda wind:** On the eastern slope of the Andes in Argentina.

Jet Streams

- Jet streams are high altitude westerly wind system blows at a height of 6 to 14 km, with very high speed up to 450 km/h in wavy form at both hemispheres. As they encircle the poles they are called as 'Circum polar wind system' (Figure 6.20).

The wavy structure of the Jet stream **is** represented as 'Ross by waves'.

- Although the jet streams flow at higher altitude they also influences the surface weather pattern of the Earth.

Jet streams were discovered during the Second World War as the jet pilots felt the strong obstruction in the higher altitudes.

The Major impacts of Jet streams

1. **Creation of Polar vortex:**
   Polar westerly jet stream will carry cold polar air masses towards temperate region which creates severe cold waves in North America and Eurasia during winter.

2. **Sudden burst of South west monsoon:**
   Sudden withdrawal of polar westerly jet stream from Indian sub-continent to northern part of Pamir, leads to sudden burst of South west monsoon into Indian Sub-continent.

3. **Late and early monsoon in South Asia:**
   Rate of with drawl of polar westerly jet stream decides the onset of south west monsoon. Slower and faster rate of with drawl leads to late and early onset of south west monsoon.

4. **Intensity of monsoon rainfall:**
   The arrival of tropical easterly jet stream influences the intensity of south west monsoon. This leads to increasing intensity of rainfall during south west monsoon.

5. **Bringing rainfall to India by western disturbances:**

   Polar westerly jet stream carries rainy clouds from cyclones formed over Mediterranean Sea during winter towards India. These clouds piles up on the Himalayas and results in rainfall over the states of Punjab and Haryana. This assists in the cultivation of wheat in India.

6. **Development of super cyclone**:

   The condition at which the speed of the jet stream is transferred to tropical cyclone may leads to development of super cyclone.

Humidity, Condensation and Clouds

- Humidity is the amount of water vapour in the atmosphere. Temperature of the air controls the capacity of the air to hold moisture. The maximum amount of moisture that can be hold by the air in the particular temperature is called as Humidity Capacity. As the volume increases with the temperature of the air, it can hold more moisture. So, humidity capacity increases with temperature. It is measured as weight of humidity or volume of the air.

Humidity of the air can be expressed in the following ways.

a. **Absolute Humidity:** This measures the total amount of water vapour present in the air at particular time. It is highly variable based on the surface on which the air moves. It is measured as weight of humidity volume of the air. Hygrometer is used to measure the relative humidity of a region.

b. **Relative Humidity (RH%):** This is the ratio of Absolute humidity and humidity capacity in term of percentage. It reveals the condition of air to get saturated. This is controlled by both temperature and moisture content of the air. The condition is that when the temperature increases RH% decreases. But when absolute humidity increases RH% increases.

Process of Condensation

- Condensation is the change of the physical state of water vapour (gas state) into water (liquid state). The following process explains mechanism of condensation in the atmosphere.

- If an air reaches 100% relative humidity, it means that the air is completely filled with moisture content. It indicates that both the absolute humidity and the humidity capacity of the air are in same level. This condition is called 'saturation of air' which can be attained by reducing the temperature of the air or increasing the moisture content. The temperature at which the air gets saturated is called as 'dew point'. The RH crosses the 100% when the temperature of the air drops below its dew point. This condition is called as 'super saturation' of the air. In this condition the air releases the excess moisture out of it in the form of tiny water droplets which floats and form clouds in the atmosphere.

- If the same process occurs on the surface of the earth, it is called as 'fog' or cloud on the ground.

The moisture in the atmosphere is based on the following processes:

a. Evaporation - Water changes from liquid state to gaseous (vapour) state.
b. Transpiration - Water state changes from liquid in to (gas) vapour state due to the activity of plants.
c. Evapotranspiration - This denotes that the total amount of (liquid) water state changed in to (gas) vapour state due to evaporation and the activity of plants transpiration.

Clouds and its Types

Clouds are tiny water droplets suspended in the air formed due to the condensation.

Isonephs - The imaginary line connecting the places having equal amount of cloudiness.

- The clouds can be classified based on their form, height and appearance as follows: (Figure 6.22)

a. **High clouds:**

- Mainly cirrus (Ci) which are feathery form at 6 km above the ground.

i. Cirrus (Ci) – This looks fibrous and appears as wisps cotton in the blue sky. It indicates fair weather and gives brilliant sun set.
ii. Cirro Cumulus (Cc) – This appears as white globular masses, forming a mackerel sky.
iii. Cirro Stratus (Cs) – Tis resembles a thin white sheet. The sky looks milky and the sun and moon shines through this clouds and form a 'halo'.

b. **Middle Clouds:**

- Mainly Alto (Alt) clouds at 2 km to 6 km above the ground.

i. Altocumulus (Alt-Cu): These are woolly, bumpy clouds arranged in layers appearing like waves in the blue sky. They indicate fine weather.
ii. Altostratus (Alt-St): These are denser and have watery look.

c. **Low Clouds:**

- Mainly Stratus or sheet clouds below 2 km height.

i. Stratocumulus (St-Cu): This is rough and bumpy clouds with wavy structure.
ii. Stratus (St): This is very low cloud, uniformly grey and thick, appears like highland fog. It brings dull weather and light drizzle. It reduces the visibility and is a hindrance to air transportation.
iii. Nimbostratus (Ni-St): This is dark dull cloud, clearly layered, as it brings rain, snow and sleet and it is called as rainy cloud.

d. Clouds with vertical extent:

These are mainly cumulus clouds whose heights extend from 2 km to 10 km approximately.

i. Cumulus (Cu): This is vertical cloud with rounded top and horizontal base, associated with convectional process in the tropical region. It also called as 'fair weather cloud'.

ii. Cumulonimbus (Cu-Ni): This is over grown cumulus cloud with great vertical extent, with black and white globular mass. The cauliflower top spreads like an anvil. This is formed due to heavy convection in the tropical regions. It is accompanied by lightning, thunder and heavy rainfall.

Fog, Mist and Smog

- **'Fog'** is defined as almost microscopic droplets of water condensed from super saturated air and suspended over or near the surface of the earth. Fogs reduce the visibility to less than 1 km. Fog occurs during calm or light wind conditions. It is more common in the areas near to the ocean due to the supply of more moisture by sea breeze. In the interior of the continents fog is formed due to reduction of temperature to extreme low during the winter nights.

- If the fog has higher visibility due to lesser water drops near the surface it is termed as 'mist'.

- In large industrial areas the air is more polluted. If the fog forms in that area it mixes with the pollutants and turns into smog (smoke 1 fog 5 smog) which is more hazardous to the health of the people.

Hydrological Cycle

- Continuous movement of water among the three spheres is known as Hydrological Cycle. Hydrological cycle involves evaporation, condensation, precipitation, advection, interception, evapotranspiration, infiltration, percolation and runoff to the ocean (Figure 6.24).

Evaporation is the process by which water in liquid state changes into vapour state using heat energy from Sun. Evaporation is maximum

when the temperature is high, on the large expanse of water and when dry winds blow over water surface.

Condensation is the process by which water vapour cools to form water droplet by lossing temperature. The condensation occurs when dew point is reached in the atmosphere.

Precipitation is the process by which all forms of water particles fall from the atmosphere and reach the ground.
The rain drop that falls may get evaporated before it reaches the ground in an extremely arid region.

Air Masses and Fronts

- The study of air mass is very important part of Meteorology. Air always takes some of the properties of the area over which it lies. This parcel of air may remain stationary for several days and develops its own characteristics. Under this situation, the air becomes recognisable as an air mass.

- An air mass is defined as 'an immense body of air several kilometres in length and breadth and thickness which is characterised by homogeneous physical properties (like temperature, moisture) in horizontal direction at any level'.

- Such an extensive portion of the surface area over which air mass has acquired its qualities is called as 'Air mass source region'. The source region may be land or water body. For example, Sahara desert, Siberia, the Great Plain of North America, Northern Plain of Europe, Western Australia, Antarctica, Green Land, Arctic Ocean, Northern and Southern Pacific, Atlantic Oceans are favourable locations as source region for air masses.

The air masses can be classified based on the following factors;

a. Latitude - Tropical(T) and Polar (P) air masses
b. Nature of the surface – Continent (c) and marine (m) air masses
c. Temperature – warm (w) and Cold (k) air masses
d. Stability – stable (s) and unstable (u) air masses

- Air masses normally migrate from their source region to other regions, which have different surface properties, mostly along with primary winds. As the air masses move out from their source regions, they not only modify the weather of the areas they occupy, but also modify themselves according to the surface over which it moves.

Fronts

- When two air masses with different physical characters meet, there is usually Utile mixing of the air. The zone of transition between two contrasting air masses is called as 'Fronts*. As heavier air mass always tends to push up the lighter air mass, the front always slopes over the cold air mass.

- If cold air mass moves forward rapidly and causes the warm air to rise vertically, it leads to the formation of steep slope called as 'Cold front*. Cold fronts result in the formation of cumulo nimbus clouds with heavy rainfall associated with lightning and thunder.

- If warm air is moving over cold air mass, it produces a gentle slope called as 'Warm front*. Warm fronts result in the formation of stratus and nimbo stratus clouds and cover over large areas, leading to moderate rainfall (Figure 6.26).

Condition for Formation of Fronts:

1. There must be two air masses with contrasting physical characters.
2. There must be collision of air masses.

At the equatorial low pressure belt although two trade wind systems meet, they do not form any front, because the air masses are of similar physical characteristics (both warm) and they do not collide with each other. Whereas the sub polar low pressure belt contrasting air masses collide with each other forming fronts.

Precipitation

- Precipitation is the product of condensation of atmospheric water vapour that falls under gravity and reaches the surface of the earth. In order to fall as rain drop or snow, the tiny drop lets in a cloud must grow larger. The droplets accumulate over the nuclei and combine to

grow large enough to fall and reach the surface of the earth due to gravity.

Acid Rain

Acid rain is a rain that is unusually acidic, it has elevated levels of hydrogen ions. It is caused by a chemical reaction of compounds like sulphur dioxide and nitrogen oxides that are released into the air from anthropogenic activities and from volcanic eruptions. These substances can rise very high into the atmosphere, where they mix as hygroscopic nuclei and react with water vapour, oxygen, and other gases to form more acidic water which falls to the ground as acid rain. It is harmful for plants, animals, human and environment. Normally the rainfall is slightly acidic because of the presence of dissolved carbonic acid. The pH of normal rain has been given a value of 5.6. Acid rain has the pH value of less than 5.6. A great way to reduce acid rain is by using renewable energy resources, such as solar and wind power and reducing the use of fossil fuels.

- If the drop is smaller it falls slowly so that it evaporates before it reaches the ground. Ice crystals in cloud also cause precipitation. Each ice crystal grows by cooling so that they become large in size and fall to the ground. They melt on the way due to friction with the atmosphere and fall as rain.

Forms of Precipitation

- The precipitation has various forms based on the condition of occurrence (Figure 6.27). The various forms are;

Rainfall: When water droplets of more than 0.5 mm diameter falls from the atmosphere to the ground it is called as 'Rainfall'. If the diameter is less than 0.5mm, it is called as 'Drizzle'.

Hail: When precipitation occurs at sub zero temperature, the water droplets crystallise and fall as ice pellets with the size of 5 to 50 mm or some times more. This is called as 'Hail'.

Sleet: Precipitation occurs as falling of raindrop along with ice pellets less than 5 mm diameter or snow, called as 'Sleet'.

Snow: Precipitation occurs at below freezing point and falls as thin ice flakes or powdery ice, called as 'Snow'.

Dew: Condensation of water droplets on the objects at the surface of the earth such as leaves and grasses are called as 'Dew'.

Cloud Seeding or Artificial Rainfall

People have always wanted to create rain, so that they would not suffer from drought. Modern science has been successful in causing rain in a limited way through cloud seeding. This method is based on the knowledge of growing ice crystals in clouds.

One method to cause rainfall from clouds is to introduce particles of dry ice (solid CO2) into the cloud from an air plane. The dry ice causes ice crystals to form in the cloud. These ice crystals coalesce, grow, melt and fall as rain. Cloud seeding will not be successful unless the cloud is already saturated with water vapour.

Types of Precipitation (Rainfall):

- Precipitation can be classified based on the causes for the rising up of air,
  1. Convectional rainfall
  2. Orographic or Relief rainfall
  3. Cyclonic or Frontal rainfall

Convectional Rainfall:

- As a result of heating of the surface air, the warm moist air expands and is forced to rise to a great height. As the air rises, it cools, reaches dew point and condenses to form clouds. This process influences the upper tropospheric circulation. By further cooling, precipitation takes place as rainfall. This rainfall occurs throughout the year near the equator in the afternoon. It is called as 4 'O' clock rainfall region. In middle latitudes, convectional rainfall occurs in early summer in the continental interiors (Figure 6.29).

Orographic or Relief Rainfall

- It occurs when large mass of air is forced to rise across land barriers, such as high mountain ranges, plateaus, escarpments, or over high hills. On the windward side of the region the warm moist air raises, temperature of the air falls below its dew point, forming clouds which give subsequent rainfall. As the wind moves to the leeward side it has emptied itself of moisture and thus descends the slope as warm dry winds. The leeward side of the mountain therefore is called as the rain shadow region (Figure 6.30).

Cyclonic or Frontal Rainfall

- This type of precipitation is associated with a cyclonic activity (Tropical and Temperate) and also occurs along the frontal zone. Cyclonic rainfall is associated with Cumulo Nimbus (CuNi) clouds. The rainfall is very heavy and accompanied with lightning and thunder and high speed winds which has the potential to cause damage.

- 'Frontal rainfall' is associated with fronts which form due to collision of different air masses. Warm front is formed due to advent of warm air masses which leads to moderate rainfall. In the same way cold front is formed due to advent of cold air mass which leads to heavy rainfall with lightning and thunder.

An isohyets or isohyetal line is a line joining points of equal rainfall on a map in a given period. A map with isohyets is called an isohyetal map.

When altitude increases, the rainfall also increases in orographic pattern. But the rainfall decreases with altitude, once the amount of moisture reduces in the air after a point where it reaches maximum rainfall which is called as 'Maximum Rainfall Line'. This condition where the rainfall decreases with altitude is called 'Inversion of Rainfall'.

Cloud Burst

- A 'cloud burst' is a sudden aggressive rainstorm falling in a short period of time limited to a small geographical area. Meteorologists say

that the rain from a cloud burst is usually of the heavier rain with a fall rate equal to or greater than 100 mm (3.94 inches) per hour. Generally cloudbursts are associated with thunderstorms. The air currents rushing up words in a rain storm hold up a large amount of water. For example cloud bursts in the region of Uttarkhand (2013) and Chennai (2015).

Lightning and Thunder are caused by differences in the electrical charge of different parts of the cloud. The top of the cloud becomes positively charged and the bottom is mostly negatively charged. When the difference is great lightning occurs. Differences in the charge between cloud and the earth surface also cause lightning.
Thunder is caused by rapid expansion of the air that is heated as the lightning passes through it.

Atmospheric Disturbances (Cyclone and Anti Cyclone)

- The atmospheric disturbances which involve a closed circulation of air around a low pressure at centre and high pressure at periphery, rotating anticlockwise in northern hemisphere and clockwise in southern hemisphere is called 'Cyclones' (Figure 6.31). Cyclones may be classified into two types based on latitude of its origin.

They are: a. Tropical cyclone b. Temperate cyclone

A. Tropical Cyclone

- Cyclone formed in the low latitudes is called as Tropical cyclone. They form over warm ocean waters in the tropical regions. The warm air rises, and causes an area of low air pressure.

6.8.1 Stages of Development of Tropical Cyclone

- As per the criteria adopted by the World Meteorological Organisation (W.M.O.), India Meteorological Department classifies the low pressure systems in to vary classes based on wind speed

1. Tropical Disturbances
2. Tropical depressions Low winds with a speed between 31 and 61 km ph.

3. Tropical cyclone wind speed from 62 to 88 km ph and it is assigned a name.

4. Severe Cyclonic Storm (SCS) wind speed is between 89 to 118 km ph

5. Very SCS wind speed between 119 to 221 km ph and

6. Super Cyclonic Storm when wind exceeds 221 km ph.

Origin of Tropical Cyclone

- Tropical cyclones have certain mechanism for their formation. These are

A source of warm, moist air derived from tropical oceans with sea surface temperature normally near to or in excess of 27 °C (Figure 6.32)
Wind near the ocean surface is blowing from different directions converging and causing air to rise and storm clouds to form. Winds which do not vary greatly with height are known as low wind shear. This allows the storm clouds to rise vertically to high level; Coriolis force is induced by the rotation of the Earth. The mechanisms of formation vary across the world, but once a cluster of storm clouds starts to rotate, it becomes a tropical depression. If it continues to develop it becomes a tropical storm, and later a cyclone/ super cyclone.

Characteristics of the Tropical Cyclone

- The centre of the cyclone where the wind system converges and vertically rises is called as Eye. The eye is a Calm region with no rainfall and experiences highest temperature and lowest pressure within the cyclonic system (Figure 6.32).

- Cyclone wall is made up of Cumulo Nimbus clouds with no visibility, higher wind velocity and heavy rain fall with lightning and thunder.

- Tropical cyclones mostly move along with the direction of trade wind system. So they travel from east to west and make land fall on the eastern coast of the continents (Figure 6.33).

Landfall: The condition at which the eye of the tropical cyclone crosses the land is called 'Land fall' of the cyclone (Figure 6.34).

Naming of Tropical Cyclones

- The practice of naming storms (tropical cyclones) began years ago, in order to help in the quick identification of storms in warning messages because names are presumed to be far easier to remember than numbers and technical terms (Figure 6.35).

- In the pursuit of a more organized and efficient naming system, meteorologists later decided to identify storms using names from a list arranged alphabetically. Since 1953, Atlantic tropical storms have been named from lists originated by the National Hurricane Centre. They are now maintained and updated by an international committee of the World Meteorological Organization (WMO).

- Large scale destruction caused by Odisha cyclone in 1999, triggered the issue of naming tropical cyclones developed in the North Indian ocean. As a result, naming conventions for storms that develop in the Indian Ocean began in 2004. WMO (World Meteorological Organisation)had informed each of the eight South Asian member countries to submit a list of their own eight names for the cyclones.

Condition of Super Cyclone Formation
1. Longer travel or stay of low pressure system over warm ocean water.
2. The speed of jet stream may influence the formation of super cyclone.

Tornado and Water Spouts

It is a very small intense, funnel shaped very speed whirl wind system. Its speed and direction of the movement are erratic (Figure 6.36). The winds are always as fast as 500 km ph. The fast moving air converges in the middle and rises up. The uplift is capable of rising dust, trees and other weaker objects in its path. South and western part of Gulf States of USA experiences frequent tornados.

- Water spouts are formed over water body similar to tornados in the formation and structure. This sometimes leads to fish rain, if the mass of fish comes under the water spout.

B. Temperate Cyclone

- The cyclone formed in the mid-latitudes is called as temperate cyclone. As they are formed due to movement of air masses and front, they are called as 'Dynamic cyclone' and 'Wave cyclone'. This cyclone is characterised by the four different sectors, which are varied with their weather patterns (Figure 6.37).

Stages in the Formation of Temperate Cyclone

a. Frontogenesis –Formation of front due to collision of two contrasting air masses (Figure 6.38).
b. Cyclone genesis – Formation of cyclone due to conversion of fronts into various sectors.
c. Advancing Stage – The stage where cold front advances towards warm front.
d. Occlusion stage - The stage where the cold front over takes warm front
e. Frontalysis – The last stage where fronts disappear and cyclone ends its life.

Characters

- Unlike tropical cyclone, temperate cyclone forms over both land and water in all seasons. It covers larger area than tropical cyclone and stays for a longer period.

Track

- Temperate cyclone moves along with the westerly wind system from west to east.

Anti-Cyclones

- Anti-cyclone is a whirlwind system in which high pressure area at the centre and surrounded by low pressure at periphery rotating

clockwise in northern hemisphere and anti-clock wise in southern hemisphere(Figure 6.39).

- This is the largest among the whirl wind systems. Normally, they are associated with high pressure belts of sub-tropical and polar region.

Anti-cyclones are classified as warm core and cold core, based on their temperature, which are resulted in aridity and cold waves respectively.

Glossary

1. **Buoyant**: Able to keep afoot on the top of air or liquid.
2. **Collision:** Hit by accident when moving.
3. **Equilibrium:** A balanced state of molecules where the acting forces are equal.
4. **Escarpment:** A long, steep slope especially one of the edge of a plateau or surface.
5. **Expansion:** The action of becoming larger or more extensive.
6. **Funnelling:** Guided through the area that has widening at front and narrow at the end.
7. **Hygroscopic:** Tending to observe moisture from air.
8. **Insolation:** Amount of solar radiation reaching a given area.
9. **Meteorology:** is a branch of the atmospheric sciences which includes atmospheric physics and chemistry, with a major focus on weather forecasting.
10. **Molecules:** A group of atoms bonded together.
11. **Permeable:** Allowing liquids or gases to pass through it.
12. **Subsistence:** The gradual movement of air molecules from higher altitude to lower altitude.
13. **Torrid:** Region of Very hot and dry condition.
14. **Vortex:** A whirling or rotating mass of fluid or air.

Unit - 7
The Biosphere

- "Man's attitude towards nature is today critically important simply because we have now acquired a fateful power to alter and destroy nature is inevitably a war against himself".

-Rachel Carson

Introduction

- The earth was formed 4.6 billion years ago. Geographers are concerned about the earth and its various spheres. These spheres did not exist on the primitive earth as they are today. They evolved over a long period of time after the earth was formed. There was no life on earth for a very long time. Scientists believe that the first life forms on earth came into existence about 3.5 billion years ago. Which marked, 'The birth of the biosphere'.

- Since then life has multiplied in numbers and varieties and evolved to the present biosphere that we are part of and which we are gifted with.

- In the last 100 years, man has had used, overused and misused the natural resources of the earth. This has disturbed the ecological balance of the earth. The realization about the damage caused to earth by our action came when we began to experience global warming, desertification, increase in disease and distress and recurrence of severe natural disasters.
- It was in 1962 that Rachel Carson published the book 'Silent Spring' which inspired an environmental movement that led International agencies to focus their attention on protecting and sustaining the biosphere.

- In 1971, UNESCO launched the Man and the Biosphere Programme to study our impact on nature and how it could be minimized. Even after several decades the programme still continues to shape the future of sustainability of the earth.

Biosphere

- The word Biosphere originates from the Greek words bios = life and sphaira = sphere. Earth is the only planet in the solar system that supports life. There are many reasons that contribute to this and the most important being the earth's distance from the sun, the presence of oxygen in the atmosphere and the presence of water. The above factors, along with the existence and interaction of the three spheres of the earth (the lithosphere, hydrosphere and atmosphere) gives rise to the fourth sphere which is the life sphere or biosphere (Figure 7.1). The term Biosphere was coined by Eduard Suess in 1875. Later contributions to the study of biosphere were from, Charles Darwin and many other scientists.

- Thus, in the biosphere, life exists on land, water and air and life forms range from microorganisms to plants, animals, birds, amphibians, reptiles and mammals including human beings. The biosphere is formed of biotic components. It consists of organisms, population, community and ecosystem.

Ecosystem

Organism - includes animals, plants and micro-organisms.
Population - is a group of similar plants or animals living in an area.
Community - refers to all the plants and animals living in an area.
Ecosystem - all living and non-living things and their interaction within an area.

- Life cannot exist in isolation. It flourishes in an environment which supplies and fulfills its material and energy requirements. A biotic community and its physical environment in which matter and energy flow and cycle is called as ecosystem.

- The term ecosystem was first proposed by Arthur George Tansley in 1935. Tansley defined ecosystem as, 'the system resulting from the integration of all living and non-living factors of the environment'. The ecosystems can vary in size. It can be very small, extending to about a few square centimeters or it can extend over many square kilometres. Example; tropical forests.

Major components of an ecosystem

- The ecosystem is made up of two main components:

A. Abiotic Component and
B. Biotic Component

A. **Abiotic Component:** This component of the ecosystem includes the non-living substance of the environment. Example; light, air, soil, water, climate, minerals, etc. Sun is the main source of energy for the earth.

B. **Biotic Component:** This includes a variety of living organisms such as microorganisms, plants and animals. The biotic component of an ecosystem can be further divided into producers, consumers and decomposers based on their capacity to sustain themselves (Figure 7.2).

a. **Producers:** Organisms that can produce or manufacture their own food are known as producers. Plants that have green pigments or chlorophyll, produce their own food in the presence of CO^2 in the atmosphere, water from the soil and sunlight through a process called 'photosynthesis'. These green plants are called as 'autotrophs' (auto – self; trophs – nourishing) as they manufacture their own food.

b. **Consumers:** Consumers are organisms that cannot manufacture their own food and get their food and nutrients from producers directly or from other organisms. They are called as 'heterotrophs' (hetero – others; trophs – nourishing).

- Consumers can be divided into primary, secondary and tertiary consumers.

1. Primary Consumers

- Organisms that feed on producers (green plants) are called primary consumers. They are also called as 'herbivores' or plant eating organisms. Examples of terrestrial herbivore are grasshopper,

sheep, goats, cow, rabbit, deer, elephant etc. Examples of aquatic herbivores are zoo plankton, krill, squid, small fish, sea urchin, etc.

2. **Secondary Consumers**

- Animals that kill and eat the herbivores or plant eating animals are called secondary consumers. They are also called as 'carnivores', Example; lion, tiger, foxes, frogs, snakes, spider, crocodiles, etc.

3. **Tertiary Consumers**

- They are top predators in a food chain. They are carnivores at the topmost level in a food chain that feed on other carnivores or secondary consumers. Example: an owl eats a snake but an owl is eaten by a hawk, therefore a hawk is a tertiary consumer. Tertiary consumers that occupy the top trophic level, and are not predated by any other animals are called 'apex predators'. However, when they die their bodies will be consumed by scavengers besides the decomposers Example; alligator and hawk.

- Some organisms eat both plants and animals. These animals are called as 'omnivores. Example; cockroach, foxes, seagull and human. Some omnivores are 'scavengers', which eat food that other animals have left behind Example; hyena and vultures.

- Plants and animals that live on or inside other plants or animals are called as Parasites. Example; mistletoe lives on other plants. Other examples are tapeworms, round worms, lice, ticks, flea etc. 'Detritivores' are consumers that feed on detritus. Detritus includes fallen leaves, parts of dead trees and faecal wastes of animals. Ants, termites, earthworms, millipedes, dung beetle, fiddler crabs and sea cucumbers are detritivores.

4. **Decomposers:**

- Decomposers are organisms that help decompose dead or decaying organisms. Decomposers are also heterotrophs. Decomposers are nature's built-in recycling system. By breaking down materials – decomposers return nutrients to the soil. They, in turn, create another

food source for producers within the ecosystem. Mushrooms, yeast, mould, fungi and bacteria are common decomposers.

The earthworm is called as the friend of the farmer. Find out the reason why?

Food Chain and Food Web

- Every living creature in an ecosystem has a role to play. Without producers, the consumers and decomposers would not survive because they would have no food to eat. Without consumers, the populations of producers and decomposers would grow out of control. And without decomposers, dead producers and consumers would accumulate as wastes and pollute the environment.

- All organisms of an ecosystem depend on one another for their survival. Each organism living in an ecosystem plays an important role in the flow of energy within the system. Organisms need energy for respiration, growth, locomotion, and reproduction. This movement of energy is usually understood through food chains or food webs. While a food chain shows one path along which energy can move through an ecosystem, food webs show all the overlapping ways that organisms live with and depend upon one another.

A. Food Chain

- A food chain describes the flow of food in an ecosystem. This flow or feeding structure in an ecosystem is called 'trophic structure'. Each level in this structure is called a trophic level. A food chain starts the movement of energy from one trophic level to the next (Figure 7.3). Example; Plant (primary producer) is eaten by a rabbit (herbivores, primary consumer), rabbit is eaten by a snake (carnivores, consumer or primary carnivore) and the snake is eaten by a hawk (tertiary consumer).

Food Web

- A Food Web is a complex network of interconnected food chains. Food chains show a direct transfer of energy between organisms. A chain might involve a mouse eating some seeds on the forest floor, a

snake eating the mouse and later an eagle eating the snake. With each step, some of the energy from the sun, which is trapped within the seeds, is getting passed on.

- In a food web, the mouse might eat seeds, but it also might eat some grains, or maybe even some grass. The mouse might be eaten by a snake, or the eagle, or even a fox. The snake could be eaten by the eagle, but also might be eaten by a fox in the forest. Since each organism can eat multiple organisms and be eaten by multiple organisms, a food web is a much more realistic scheme of the transfer of energy within an ecosystem (Figure 7.4). Food chains and food webs are found in both terrestrial and aquatic ecosystems.

- Organisms in a food chain or food web are linked and dependent on one another for survival. If organisms in one trophic level become threatened, it impacts the organisms in other trophic levels. Primary consumers get less food due to loss or destruction of habitat. This in turn means less primary consumers for secondary and tertiary consumers to feed on. The plant and animal species in such an environment could become endangered or even extinct. For this reason, it is vital that an ecosystem remains balanced containing an appropriate proportion of producers and consumers.

Energy Flow in an Ecosystem

- Energy in an ecosystem flows from producers to consumers. The available energy in a food chain decreases with each step or trophic levels up in the food chain. As such, there is less energy available to support organisms at the top of the food chain. That is why the tertiary and quaternary consumers are far less in number in an ecosystem than organisms at lower trophic levels.

Energy Pyramids

- Energy pyramids are another tool that ecologists use to understand the role of organisms within an ecosystem. As you can see, most of the energy in an ecosystem is available at the producer level. As you move up on the pyramid, the amount of available energy decreases significantly. It is estimated that only about 10% of the

energy available at one trophic level gets transferred to the next level of the energy pyramid. The remaining 90 percent of energy is either utilized by the organisms within that level for respiration and other metabolic activities or lost to the environment as heat. The energy pyramid shows how ecosystems naturally limit the number of each type of organism it can sustain (Figure 7.5).

Cycles in an Ecosystem

- Nutrients move through the ecosystem in cycles is called 'biogeochemical cycles'. A biogeochemical cycle is a circuit or pathway by which a chemical element moves through the biotic and the abiotic components of an ecosystem. All life processes are associated with the atmosphere by important cycles such as the Carbon, Oxygen, Nitrogen cycles etc. Through these cycles energy and materials are transferred, stored and released into various ecosystems. Let us discuss one of biogeochemical cycles in detail - the Carbon cycle.

The Carbon Cycle

- Carbon is exchanged, or cycled among all the spheres of the earth. All living organisms are built of carbon compounds. It is the fundamental building block of life and an important component of many chemical processes. Living things need carbon to live, grow and reproduce. Carbon is a finite resource that cycle through the earth in many forms.

- Carbon is an essential element in all organic compounds and since there is only a limited amount available it must be recycled continuously. This takes place in the biosphere. Atmospheric carbon is fixed in green plants through photosynthesis.

- This carbon is passed on to other living organisms through the food chain. The carbon food compound is utilized and later released to the atmosphere through the process of respiration. By-products of respiration are carbon-dioxide and water which are returned to the air.

A carbon cycle is completed by decomposers like bacteria and fungi which break down dead plants and animal tissues there by releasing some carbon to the air, water and soil.

- All producers and consumers are not decomposed. The organic matter of some of them is preserved in fossil fuels such as coal and petroleum for millions of years. In a carbon cycle (Figure 7.6), carbon moves between reservoirs. Carbon reservoirs include the atmosphere, the oceans, vegetation, rocks, and soil.

- Today, the carbon cycle is changing. Human activities have added more carbon into the atmosphere. More carbon is moving to the atmosphere when fossil fuels, like coal and oil, are burned. More carbon is moving to the atmosphere as humans destroy the forest. This increase in carbon in the atmosphere causes the earth to warm up more than the normal level, leading to climate change and many problems connected with it.

- A carbon sink is a natural or artificial reservoir that accumulates and stores carbon for an indefinite period. The process by which carbon sinks remove carbon dioxide (CO^2) from the atmosphere is known as carbon sequestration. The main natural carbon sinks are plants, the ocean and soil.

Biomes

- An ecosystem as already explained consists of a biological community and an abiotic environment. Ecosystem may be broadly divided into land or terrestrial ecosystem and water or aquatic ecosystem. The aquatic ecosystem can be further divided into freshwater and marine ecosystem. An ecosystem becomes a biome when it extends over a large area. According to I.G. Simmons (1982) the most extensive ecosystem unit which is convenient to designate is called a 'Biome'. It may be concluded that a biome is in fact a large ecosystem where we study the total assemblage of plant and animal communities. Since vegetation is the most dominant component of a biome and as vegetation and climate are very intimately related, the world is divided into a number of biomes based on major world climatic types (Figure 7.7).

Types of Biomes

- World Biomes are mega ecosystems existing and operating over large areas. These divisions are based on climate pattern, soil types,

and the animals and plants that inhabit an area. Basically, biomes are classified into two major groups such as Aquatic biomes and Terrestrial biomes. Wetlands are transition zones between aquatic and terrestrial biomes To understand the earth biomes, it is necessary to understand the following:

1. The characteristics of regional climates.
2. Aspects of the physical environment.
3. The type of soil and the processes contributing to soil development.
4. The distribution of flora in the area.
5. The distribution of fauna in the area and their adaptation to the environment.

A. Aquatic Biomes

- The aquatic biomes are the most important of all the biomes as, the water forms the vital resource and is essential for any life form. Since many types of species live in the water, it is one of the most important natural resources that need to be protected.

Aquatic Biome is further divided into:

a. Fresh Water Biome and
b. Marine Biome

a. Fresh Water Biome

- These biomes are spread over all parts of the earth and have different set of species depending on their location and climate. Fresh water biomes include areas of ponds, lakes, streams, rivers and wetlands. Lakes and ponds are stagnant water bodies and are smaller in their area. The diversity of life forms in river changes with increasing water volume. For example, Dolphins are found in the river Ganges, Brahmaputra and the Indus which carry huge volumes of water.

b. Marine Biome

- Marine biome is an aquatic biome which is salt water biome occupying seas and oceans of the world. Marine biome plants have various roles, plants such as sea grasses and macro algae give shelter and nutrient for many animals.

- Marine plants are sources of nutrients for the corals and help corals to build up reefs. The reefs are kept intact by plants like coralline algae.

- Corals are marine invertebrates which live in compact colonies. They inhabit tropical oceans and seas. Corals cannot survive in waters below 20°C but grow optimally in temperatures between 23°–29° Celsius. Coral reefs are marine ecosystems which are held together by structures made of calcium carbonate secreted by the corals. Coral reefs are mainly classified into three types – Fringing reef, Barrier reef and Atoll.

Sea grasses are plants that live in saltwater. There are over 50 species of sea grasses. Sea grasses have flowers, roots, and specialized cells to transport nutrients within a plant. This makes them similar to land plants and different from algae or seaweeds.

Fringing reefs grow seaward from the shore along the coast forming a fringe. They are the common type of reefs.

Barrier reefs also border the shoreline but are separated from the coast by an expanse of water or lagoon.

Atolls are coral reefs that are circular in shape enclosing a lagoon with absence of an island in the center.

Marine biome includes fishes, whales, crustaceans, molluscs, sea anemones, fungi and bacteria. Marine species are continuously impacted by change in climatic condition and the oceans are frequently disturbed by ocean waves and currents.

c. Wetlands:

- A wetland is an area of land which is permanently or periodically saturated with water and exists as a distinct ecosystem. Wetlands play many roles in the environment, such as water purification, flood control, carbon sink and shoreline stability. Wetlands are home to a wide range of aquatic plants and animal life. Wetlands can be freshwater, brackish, or saltwater. Examples of aquatic vegetation that thrive in wetlands are milkweed, bald cypress trees, mangroves and cattails.

- **Crustaceans** are chiefly aquatic arthropods having a body covered with a hard shell or crust and several pairs of legs. Example: crab, lobsters, crayfish, barnacles shrimps, krill etc.
- **Molluscs** are organisms with soft bodies. Often their bodies are covered by hard shells. Example: snail, slug, squid, cuttlefish, mussel, clams, oysters, octopuses etc.

B. Terrestrial Biome

Terrestrial biomes are very large ecosystems over land and they vary according to latitude and climate. They can be divided into numerous sub-types. In this lesson they are broadly divided into eight types.

- **A Bog** is a type of wetland ecosystem characterized by wet, spongy, poorly drained peaty soil formed from dead plants specially moss. Bogs have moss, sedges, grasses, such as cotton grass; insectivorous plants like pitcher plants; and many orchids. The gradual accumulation of decayed plant material in a bog functions as a carbon sink.

- **A Fen** is a low land that is covered wholly or partly with water. They receive nutrients from ground water and have peaty alkaline soil. Their characteristic floras are sedges and reeds.

- **Mangrove swamps** are coastal wetlands found in tropical and subtropical regions. These wetlands are often found in estuaries, where fresh water meets salt water. Mangrove trees dominate this

wetland ecosystem due to their ability to survive in both salt and fresh water. The Sundarbans is the largest Mangrove region in the world and a UNESCO World Heritage Site.

- **Mangrove forests of Tamil Nadu:** Mangrove forests are found along the coast of Tamil Nadu in Pichavaram, Muthupet, Ramnad, Gulf of Mannar and Punnakayal.

i. Tropical Evergreen Rain Forest Biome

- Tropical Evergreen Rain Forest Biome extends between 10° North and South of the equator (Figure 7.8). This biome is seen in the Amazon Basin of South America, Congo Basin of Africa and the Indo Malaysian Region of Southeast Asia (Java, Sumatra, Borneo, Malaysia and Guinea)

This biome receives direct sunlight throughout the year and so temperatures are high year round. The average annual temperature is 20°C to 30°C. The average annual rainfall of the tropical evergreen rain forest is 200cm.

- The Tropical Evergreen Rain Forest Biome has the largest number of plant and animal species. Broad leaved, tall evergreen hard wood trees are found in this biome. Trees grow up to 20 to 35 meters high. The forest is characterized by thick undergrowth and creepers. The main trees in this biome are mahogany, rose wood, ebony, cinchona, rubber, coconut palm, cane, bamboo etc. This forest biome has innumerable insects, birds, reptiles and furless animals. At the edge of the forest animals like gorilla, and monkey are found.

- Important tribes inhabit this biome, for example the Pygmies in the jungles of Africa and the Yanomani and Tikuna tribes of the Amazon region. Traditionally they live by hunting and gathering food. In the recent years in South East Asia, the tropical evergreen rainforest has been slowly replaced by rubber and sugarcane plantations. The human settlements in this biome are small and scattered.

The forests of the Silent Valley National Park in Kerala on the Western Ghats are the last remaining tropical evergreen forests in India. It is part of the Nilgiris Biosphere Reserve

ii Tropical deciduous Forest/Monsoon Forest

- Tropical deciduous forest is found in the regions experiencing monsoon climate. This biome is also called as the dry forest or monsoon forest biome.

- This is found in South and South East Asia in parts of India, Myanmar, Vietnam, Thailand, Cambodia and southern coastal China. It is also found in eastern Brazil and in smaller areas in South and Central America, the West Indies, southeastern Africa, and northern Australia.

- In this biome, the temperature varies from one season to another season. In summer the maximum temperature ranges from 38°C to 48°C. Summer season is warm and humid. In the dry winter season temperature ranges between 10°C to 27°C. The total amount of precipitation is 75 to 150 cm/year and this affects the natural vegetation of the tropical deciduous forest biome.

- The plants shed their leaves during the dry season. Trees here have huge trunks with thick rough barks. The plants grow at three different levels. The common trees are teak, sal, sandalwood, mahua (illupai), Mango, Wattle, Bamboo, semal (Illavamaram), sheesham (Karuvellamaram) and banyan.

- The animals of this biome are elephant, lion, tiger, leopards, bison, tapier, hippopotamus, wild boar, flying squirrel along with a wide variety of bird species. This biome faces rapid rate of deforestation and is, therefore, one of the most disturbed ecosystem in the world. Large tracts of forests have been destroyed for agriculture and urban development. Several species of precious animals have now become endangered Example: lions, tigers, leopards, etc.

iii. Temperate Deciduous Forest Biome

- The temperate deciduous forest is a biome that is always changing. This biome lies in the mid- latitude areas of the earth, between the tropics and Arctic Circle i.e., between 30° and 50° north and south of

the equator. The temperate deciduous forest biome can be seen in the eastern United States, most parts of Europe, China, Japan, North and South Korea (Figure 7.9). The average annual temperature is 10°C.

- These biomes have four seasons such as winter, spring, summer and fall. Winters are cold and summers are warm. As winter approaches, the duration of day light decreases. In this biome, deciduous trees shed their leaves in the fall. The production of chlorophyll in the leaves slows and eventually stops revealing leaves having bright red, yellow and orange colors. These forests are also known as broad leaved forest, because the trees have wide flat leaves. Some important trees found here are oak, maple, beech, hickory, cedar and chestnut. On the forest floors that receive very little sunlight are found mosses, azaleas and mountain laurels.

- Inhabiting the temperate deciduous forest are ants, insects, flies, bees, wasps, cicadas, walking sticks, moths, butterfly, dragon flies, mosquitoes and praying mantises.

- Frogs, toads, snakes and salamanders are some of the reptiles in this biome. Common birds found in this biome are woodpecker, robin, jays, cardinals, owls, turkeys, hawks and eagles. Small mammals like rabbits, otters, monkeys, beavers, squirrels and porcupine are also seen in this biome along with bears, grey fox, wolves, white tailed deer and moose. Animals that live in this biome adapt to the changing seasons. Some animals migrate or hibernate in winter.

- Most of these forests on the earth are cleared for agriculture. The soil here is very fertile. This is one of the most important agricultural regions of the world.

Grasslands

- Grasslands are found bordering the deserts and make up for one fourth of the natural vegetation of the earth. Those that lie in the low latitudes are called tropical grasslands and the ones which lie in the mid-latitudes are called temperate grasslands.

iv. Tropical Grassland Biome or Savanna Biome

- The tropical grass land biome is generally referred to as the Savanna biome. A savanna is a rolling topography that features vast open grasslands scattered with small shrubs and isolated trees. It is found between the tropical rainforest and desert biome. Tropical grassland biomes are mainly found in Africa, South America and Australia. Tropical grasslands in Africa is known as the savannas. Tropical grasslands are called as llanos in Columbia and Venezuela and as Campos in Brazil of South America.

- Savanna biomes experience warm temperature year around. It has very long and dry winter season and a very wet summer season. The grass here is very tall often one or two metres tall scattered with small shrubs and isolated umbrella shaped trees like the acacia and the baobab trees which store water in their trunks.

- Most of the animals in the savanna have long legs, like the giraffe and kangaroo. The carnivorous animals like lions, leopards, cheetahs, jackal and hyenas live in this biome. Zebras and elephants are also found in this biome.

- In many parts of the savannas of Africa people have started using the grassland for grazing their cattle and goats. Due to overgrazing in this region most of the tropical grasslands here are lost to the Sahara desert year after year.

v. Temperate Grassland Biome or Steppe

- The temperate grassland biomes are generally found in the interior of the continents in the mid-latitudes. These grassland biomes are found in the transitional zone between the humid coastal areas and the mid latitude deserts.

- The temperate grasslands are known as Steppes in Europe and Asia, Prairies in North America (Canada and USA), Pampas in South America, Veldts in South Africa, Downs in Australia and Puszta in Hungary. The annual range of temperature is quite large with summer

temperature reaching as high as 38°C and winter temperatures falling down to -40° C. The rainfall is moderate from 25 cm to 50 cm. Grasses form a major part of the vegetation in the temperate grasslands.

- The height of the grasses depends upon the amount and distribution of rainfall. The animals in this area include the bison, wolves of the Prairies of North America. The other animals and birds are coyotes, prairie dog, foxes, mice, rabbits, badgers, rattle snakes, pocket gophers, weasel, grasshoppers, quails and hawks.

vi. Tropical Desert Biome

- A tropical desert is the hottest and driest place on earth where rainfall is very scanty and irregular. This biome is typically found in the western parts of the continents within the tropics.

- In the northern hemisphere, the Afro – Asian deserts form the longest belt which includes the Sahara desert, Arabian desert and the That deserts. In North America the tropical deserts cover, California, Arizona and New Mexico states of USA and it further extends to Mexico. The deserts in the southern hemisphere are, the Atacama desert west of Andes mountains in South America, the Namibian and the Kalahari deserts in southern Africa and the Great Australian desert in the central and southern parts of Australia.

- The tropical deserts are not conducive for the growth of vegetation due to shortage of water. The plants found here are the xerophytes which have their own moisture conserving methods such as long-roots, thick barks, waxy leaves, thorns and small leaves so as to avoid evapotranspiration.

- The main trees and bushes found in this region are acacia, cacti, date palm, kikar, babul etc. The animals in this biome are limited in number. They are able to bear the drought and the heat of the desert. Animals like the camel, antelopes, fox, spotted hyena, fallow deer, cape hare, hedgehog etc., live in the desert.

- The tropical desert biomes are agriculturally unproductive except in and near the oasis. In the oasis, cultivation is carried through

irrigation either from streams or from underground sources. Date palms are widely grown here.

- The people in the deserts are generally nomads living in tents and moving from place to place. They are the Berbers of North Africa, the Bedouins of the Arabian deserts, the Damara in Namibia, the Bushman of the Kalahari Desert and the Aborigines of Australia. They practice food gathering and hunting while some herd cattle, goats and camel and some of them practice very simple subsistence farming.

- One of the toughest foot races in the world is held in Sahara every year in April. This race is called The Marathon des Sables (MDS) and participants have to cover a distance of 250km over Sahara desert in southern Morocco in a span of 7 days. About 1500 participants aged between 16 to 79 from all over the world participate in this race.

Source: Morocco World News

vii. Taiga or Boreal Forest Biome

- The taiga biome is the largest terrestrial biome and extends across Europe, North America and Asia. The taiga biome is also known as coniferous forest or boreal forest biome. It extends from about 50° to 55° North to 65 ° to 70° North latitudes. This region lies between the temperate grassland in the south and the polar tundra in the north. The taiga region is absent in the southern hemisphere mainly because of the narrowing of continents towards the South Pole.

- This biome has short wet summer and long cold winters. The taiga region has low mean annual precipitation ranging between 35 cm and 60 cm and the rainfall occurs mostly in summer. It receives plenty of snow during winter. The taiga or boreal forest biome consists mainly of evergreen coniferous forests. The important coniferous trees in this biome are pines, spruces, firs, maples and cedars. During the short summer season snow melts and this helps lichens, mosses and short grasses to grow and cover the ground. These are called 'meadows'.

- Taiga is the home of some larger animals like moose, deer, and bears, while smaller animals like bobcats, squirrels, chipmunks, ermine, and moles are also found. Animals of the taiga have

specialised adaptation including lot of thick fur or feathers and the ability to change colours during different seasons example ermine. The ermine is a small mammal, which is covered with thick dark brown fur in summer. This changes to white in the winter, an adaptation which helps the ermine to blend into its surroundings and makes it more difficult for the predators to spot them.

- Lumbering is the main occupation of the people in areas which are easily accessible. The softwood from the coniferous forests is widely used in the manufacture of wood pulp and paper, newsprint, matches, furniture and building materials.

- The hunting of fur bearing animals like musk rats, ermine, and silver fox are important economic activities. The taiga forest is endangered due to logging and mining by humans. When trees are cut down in the taiga it takes a very long time to restore itself because of the very short growing season.

viii Tundra Biome

- Tundra is a Finnish word which means barren land. The tundra region is a vast bowl lying beyond the Arctic Circle (66.5° North latitude) in the northern hemisphere along the shores of the Arctic Ocean. The Arctic tundra extends southwards from North Pole to the Taiga forest. Tundra is also found in the high altitudes especially in the Alpine region. Due to long and severe cold winters, this region is treeless and has very little vegetation. The growing season for plants is very short. Natural vegetation mainly consists of shrubs, sedges, grasses, mosses and lichens.

- The main features of this climate in the tundra region are the general absence of insolation and presence of very low temperature throughout the year. The average annual temperature is about -12°C. The ground surface is covered with snow for at least 8 to 9 months in a year. In this biome, the sub soil remains permanently frozen and is known as permafrost. Permafrost tundra covers vast barren areas of northern Russia and Canada. Algae and fungi are found on the rocky cliffs and rosette plants grow in rock and gravel beds. Spongy turf and lichen develop in the drier inland tundra.

- Animals common to Arctic tundra are the polar bear, arctic wolf, arctic fox, arctic hare and arctic weasel. Large herbivores such as musk oxen, caribou and reindeer are found. Lemmings are also found in this Biome. Insects like moths, butterflies, beetles, mosquitoes and black flies are common in the Arctic tundra. Migratory birds include tundra swans, harlequin ducks, sand pipers, plovers, geese and gulls.

- The Antarctic region is covered with ice sheets. It is too cold and dry to support vegetation. However, some portions of the continent have areas of rocky soil that support plant life. Vegetation comprises of mosses, lichens and liver worts. This area is referred to as Antarctic tundra. Seals and Penguins inhabit the shore areas of Antarctica.

Biodiversity

- The term biological diversity was used as early as 1968 by wildlife conservationist Raymond F. Dasmann. Latter in 1988, entomologist E.O. Wilson used the term Biodiversity and this term has been used since then. Biodiversity refers to the variety of life on Earth. This includes the number of species of plants, animals and microorganisms along with the diversity of genes in these species. Moreover, it embodies the different ecosystems on the planet, for example forests, deserts, coral reefs and wetlands.

- Biodiversity is the variability among living organisms. This includes diversity within species, between species, and between ecosystems. The variety of biodiversity or the number of species in a given area is referred to as species richness. Normally variety of life increases with size of area.

Biodiversity can be identified at three levels:

A. Genetic diversity
B. Species diversity
C. Ecosystem diversity

A. **Genetic diversity** refers to the total number of genetic characteristics in the genetic makeup of a species. Example: Each

human being is very different from others. Genetic diversity helps the population to adapt to changes in the environment or adapt to different environments. Domestication of dogs can be taken as a common example.

B. **Species diversity** is the number of different species of plants and animals that are present in a region. A community with more number of species enjoys species richness. Naturally undisturbed forests have greater species richness than reforested areas or plantations. There are three types of Species:

   a. **Endemic species** - is one whose habitat is restricted only to a particular area because of which it is often endangered. It differs from "indigenous," or "native," which although it occurs naturally in an area, is also found in other areas.
   b. **Exotic Species** - is any species intentionally or accidentally transported and released by man into an environment outside its original range. These are often the most severe agents of habitat alteration and degradation, and a major cause of the continuing loss of biological diversity throughout the world.
   c. **Cosmopolitan Species –** It is a species that is found to be distributed over most regions of the earth example: cats, dogs, human beings. The killer whale is considered as the most cosmopolitan species in the world.

C. **Ecosystem diversity** refers to the variety of life forms in a prescribed ecosystem. Ecosystems may be both terrestrial and aquatic. Distinctive terrestrial ecosystems include forests, grasslands, deserts, etc. while aquatic ecosystems are rivers, lakes, oceans etc.

- In understanding biodiversity, the most common question that arises in our mind is how many different plant and animal species are there on earth? There can be no definite answer to this question. At present the conservation scientists have identified over 8.7 million species worldwide. Of this only about 2 million are known to us ranging from microorganisms to giant mammals and reptiles. New species are being discovered while many species are also disappearing from the face of the earth.

Biodiversity hotspots

- Areas that are rich in species diversity are called as "Hotspots". The hottest spots for species diversity are the tropical rainforests. Tropical rainforests comprise of only 7% of all land on earth, yet are home to nearly 50% of all the species on Earth! India is among the World's 17 nations that are exceptionally rich in species diversity.

- The British biologist Norman Myers coined the term 'biodiversity hotspot' in 1988. According to him, a biodiversity hotspot is a biogeographic region characterised both by exceptional levels of plant endemism and by serious levels of habitat loss. Conservation International (CI) adopted Myers concept of 'hotspots' and it made an extensive global study of hotspots in 1999. According to CI, to qualify as a hotspot a region must meet two strict criteria: (i) It must contain at least 1,500 species of endemic plants, and (ii) It must have lost at least 70% of its original habitat. In 1999, CI's book 'Hotspots: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions', identified 34 biodiversity hotspots in the different countries of the world.

- Currently there are 34 biodiversity hotspots that have been identified and, most of them occur in tropical forests (Figure 7.10). They represent just 2.3% of Earth's land surface, but between them they contain around 50% of the world's endemic plant species and 42% of all terrestrial vertebrates. India has 4 biodiversity hotspots: the Western Ghats, the Himalayas, the Indo-Burma region and the Sundaland [includes Nicobar group of Islands].

Norman Myers (born 24 August 1934) is a British environmentalist specialising in Biodiversity hotspots. Professor Norman Myers was the first to alert global community to tropical deforestation, the mass extinction underway and environmental security.

- Endemism is an ecological word meaning that a plant or animal lives only in a particular geographical location, such as a specific island, habitat type, country or any defined zone. For example, The Asiatic Lion of the Gir forest of Gujarat. The Kashmir Stag known as Hangul, which is found in the riverine forests of Kashmir Valley and

Chamba in Himachal Pradesh. The Lion Tailed Macaque is India's most threatened monkey which is endemic to the Western Ghats of South India.

The 34 biodiversity hotspots of the World	
1. The Tropical Andes	18. The Philippines
2. Mesoamerica	19. Indo-Burma
3. The Caribbean Islands	20. The Mountains of Southwest China
4. The Atlantic Forest	21. Western Ghats and Sri Lanka
5. Tumbes-Chocó-Magdalena	22. Southwest Australia
6. The Cerrado	23. New Caledonia
7. Chilean Winter Rainfall-Valdivian Forests	24. New Zealand
8. Chilean Winter Rainfall-Valdivian Forests	25. Polynesia and Micronesia
9. Madagascar and the Indian Ocean Islands	26. The Madrean Pine-Oak Woodlands
10. The Coastal Forests of Eastern Africa	27. Maputaland-Pondoland-Albany
11. The Guinean Forests of West Africa	28. The Eastern Afromontane
12. The Cape Floristic Region	29. The Horn of Africa
13. The Succulent Karoo	30. The Irano-Anatolian
14.The Mediterranean Basin	31. The Mountains of Central Asia
15. The Caucasus	32. Eastern Himalaya
16. Sundaland	33. Japan
17. Wallacea	34. East Melanesian Islands

- **Conservation International** (CI) is an American non-profit environmental organization founded in 1987 in Virginia. Its goal is to protect nature as a source for food, fresh water, livelihood and a stable climate.
- CI has helped to support 1,200 protected areas across 77 countries, safeguarding more than 601 million hectares of marine and coastal areas.

Endangered species

- Rare, endangered or threatened plants and animals are elements of our natural heritage that are declining rapidly. If we cherish these

species, like we do other rare and beautiful objects, these living organisms become treasures of the highest magnitude.

- The International Union for the Conservation of Nature (IUCN) has identified and classified species based on the nature of their depleting numbers. The IUCN's Red List of Threatened Species, identified in 1964, is the world's most important inventory of the global conservation status of biological species. Species are classified by the IUCN Red List into nine groups specified through criteria such as rate of decline, population size, area of geographic distribution, and degree of population and distribution fragmentation (Figure 7.11).

- Extinct (EX) – The species has disappeared and no known individuals remaining
- Extinct in the wild (EW) – Known only to survive in captivity, or as a naturalized population outside its historic range
- Critically Endangered (CR) – Species that have drastically dwindled and are at extremely high risk of extinction in the wild
- Endangered (EN) – High risk of extinction in the wild
- Vulnerable (VU) – High risk of endangerment in the wild
- Near threatened (nt) – Likely to become endangered in the near future.
- Least concern (lc) – Lowest risk widespread and abundant
- Conservation dependent (cd) – This group has now merged with near threatened.
- Data deficient (dd) – Not enough data to assess the risk of extinction of the species.
- Not evaluated (ne) – Species not yet been evaluated against the criteria.

- In the context of the IUCN Red List, 'threatened' embraces the three categories of Critically Endangered, Endangered, and Vulnerable.
- According to the IUCN those species that have dwindled drastically are called as Critically Endangered and are included as Red List. Species that have disappeared are called as extinct species. In the Red List of 2012 that was released on 19 July 2012 at Rio+20 Earth Summit 19,817 species were threatened with extinction.

The IUCN Red List of Threatened Species (also known as the IUCN Red

List or Red Data List), founded in 1964, is the world's most comprehensive inventory of the global conservation status of biological species. The International Union for Conservation of Nature (IUCN) is the world's main authority on the conservation status of species. A series of Regional Red Lists are produced by countries or organizations, which assess the risk of extinction to species within a political management unit.

- A Hawaiian plant species called Alula locally referred to as cabbage on a stick has moved from Critically Endangered to Extinct in the Wild. It is one of the 38 Red Listed Hawaiian plant species with less than five wild individuals remaining. It used to grow on the windy sea cliffs of Kauai. Alula was destroyed by hurricanes Iwa and Inki in 1982 and 1992 leaving only less than 10 plants alive.

- The majority of the great ape species are now Critically Endangered. The Eastern Gorilla the largest living primate is endemic to the Eastern Democratic Republic of Congo, south western Uganda and Rwanda. This species which was listed as Endangered has moved to Critically Endangered in 2016 due to an on-going population decline. This decline is due to illegal hunting and destruction of forests for agriculture. If this trend continues, around 93% of Eastern Gorillas will be eliminated by 2054.

- The Pygmy Hog: It is the smallest and rarest wild pig on earth and it is a Critically Endangered species previously spread across Bangladesh, Bhutan, India and Nepal. but now only found in Assam, India. In 1995, the Pygmy Hog Conservation Programme was started by Goutam Narayan of Ecosystems-India, with the help of the Assam government and now their numbers have increased to about 150. There are many other critically endangered species in India and some of them are listed below

Critically Endangered species in India 2016

Arthropod

- Rameshwaram parachute spider

- Peacock tarantula

Birds

- White-bellied heron
- Great Indian bustard
- Forest owlet
- Spoon-billed sandpiper
- Siberian crane
- Indian vulture
- Himalayan quail
- Pink-headed duck

Fish

- Wayanad mahseer
- Pondicherry shark
- Ganges shark
- Pookode Lake barb
- Common sawfish

Insects

- Pygmy Hog Sucking Louse

Reptiles and amphibians

- Madras spotted skink
- Gharial
- Toad-skinned frog
- Charles Darwin's frog
- White-spotted bush frog
- Munnar bush frog
- Ponmudi bush frog
- Anaimalai flying frog

Mammals

- Asiatic cheetah
- Namdapha flying squirrel

- Himalayan wolf
- Andaman shrew
- Nicobar shrew
- Northern Sumatran rhinoceros
- Chinese pangolin
- Pygmy hog
- Indian Javan rhinoceros
- Malabar large-spotted civet

- The plant Alliumiatrouinum of the Mediterranean, belonging to the onion family was added to the IUCN Red List as Critically Endangered (CR) in 2017. Currently this plant is known to exist only on Mount Ochi in the southern part of Evvia Island, Greece. It is understood that the threat was from the numerous wind parks and wind turbines developed in the area. An endemic species of small trees growing at low altitudes in New Caledonia called Pittosporum brevispinium has declined causing it to move from Endangered to Critically Endangered in 2017. The species decline has been attributed to conversion of dry forests to pasture land and degradation of forest by the Rusa deer.

- The Red-legged Fire Millipede is found in the rainforests of Madagascar. It entered the IUCN Red List in 2017 as, Critically Endangered (CR).The degradation of its habitat due to slash and burn agriculture and cutting of trees for firewood by local communities has caused its decline. The IUCN Red List in 2017 declared the Christmas Island Whiptail-skink endemic to Christmas Island as Extinct. The last known individual died in captivity in 2014. This dramatic decline and extinction was due to the impact of the introduction of Yellow Crazy Ant, Indian Wolf Snake and other new species on Christmas Island along with deforestation due to mining.

The status of the Rodrigues Flying Fox moved from Critically Endangered to Endangered in 2017. This was due to a number of conservation measures taken, such as, captive breeding programme involving 46 zoos around the world, restoration of natural habitat, watershed protection, and awareness rising through education programmes. Its population has increased from 4,000 in 2003 to about 20,000 individuals in 2016. The future survival of this species will

depend on continued conservation efforts.

Causes of Extinction of Species

- Extinction is defined as the permanent disappearance of an organism from the face of the earth. In other words, all members of a species have died. This means a loss of biodiversity. Extinction of species may take place (Figure 7.12) due to a variety of causes as given below:

- Sudden and rapid changes of environmental conditions

1. The sudden outbreak of disease and pest infections.
2. Some sudden events like forest fires, volcanic eruption etc.
3. Direct hunting and persecution of species leading to 'selective mass extinction.
4. Ecological substitution by other species of large carnivorous animals which compete for the same food resources.
5. Climatic change accelerates the competition between large mammals for shelter and food.
6. Extinction of weak species during the course of competition with more powerful and stronger species.
7. Man-induced environmental changes also cause species extinctions.

Between 1600 and 1900 it is estimated that one species went extinct every four years. In modern times, the rate is soaring. The graph below (Figure 7.12.) shows how the rate of extinction of species has increased over the past 50 years. This could be attributed to the rapid increase in population during the same period of time. According to IUCN the rate of extinction of mammals and birds had started much earlier by 1700 itself at a much faster rate as shown in the graph below (Figure 7.13).

Major Threats to Biodiversity

- The following are some of the major threats to biodiversity:

a. Habitat destruction and degradation

b. Invasive alien species-these can destroy native species Example, lantana Camera plant in India.
c. Climate Change- Example, bleaching and loss of coral reefs due to global warming
d. Pollution of air, water and soil – Pollution can alter the growth and life of organisms in a great way.
e. Over exploitation of one resource – Over exploitation through Hunting or Poaching, Deforestation etc., can influence the life of all the interdependent species.

- Despite rapid efforts in protecting terrestrial and marine habitats, world's diversity of species is still dwindling. Since the 1960's over 100,000 'protected areas' have been established. This represents 11,265,408 sq.km of land and 1,609,344 sq.km of ocean. Yet, terrestrial and marine species have declined over the same period. This suggests that the common conservation strategy of protecting areas of land and sea is inadequate.

Conservation of Biodiversity

- Conservation of bio-diversity is the proper management of the biosphere by human beings in such a way that it gives maximum benefits for the present generation and also develops its potential to meet the needs of the future generations.

- The three basic objectives of biodiversity conservation are :

a. To maintain essential ecological processes and life supporting systems.
b. To preserve the diversity of species.
c. To make sustainable utilization of species and ecosystems.

- There are two types of conservation methods (Figure 7.15) namely in-situ and ex-situ conservations. In-situ conservation means the conservation of species within their natural habitats. This strategy involves identification of species rich areas and adopting methods to protect it in the form of National Park or Wildlife Sanctuary or Biosphere Reserve etc. In this way biodiversity can be conserved in their natural habitat from human activities.

- Ex-situ conservation involves maintenance and breeding of endangered plants and animals under partially or wholly controlled conditions in specific areas like zoo, gardens, nurseries etc. Other examples of ex-situ conservation include:

i. Seed gene bank
ii. Field gene bank
iii. Botanical gardens

Biodiversity conservation in India

- India is one of the 17 mega bio-diverse countries of the world (according to Conservation International). With only 2.4% of the world's land area, 16.7% of the world's human population and 18% of livestock, it contributes about 8% of the known global biodiversity. India has a number of globally important endangered species like Asiatic lion, Asian elephant, one-horned rhinoceros, Gangetic river dolphin, snow leopard, Kashmir stag, dugong, gharial, great Indian bustard, lion tailed macaque etc. The following steps have thus been taken to protect and manage the wildlife of the country.

1. The Government of India enacted the Wild Life (Protection) Act 1972 with the objective of effectively protecting the wild life of this country and to control poaching, smuggling and illegal trade in wildlife and its derivatives.

2. The National Board for Wildlife (NBWL) chaired by the Prime Minister of India provides for policy framework for wildlife conservation in the country.

3. The National Wildlife Action Plan (2002–2016) was adopted in 2002, emphasizing the people's participation and their support for wildlife conservation.

4. The Indian Constitution lays the subject of forests and wildlife in the Concurrent list thus laying the responsibility of wildlife conservation on both the Centre and the State.

5. Specialised projects: To save the endangered species of animals, specialised projects are being implemented with international

cooperation (WWF, UNDP, UNEP, IUCN) as well as on a stand-alone basis like the following: (Table 7.1) More recently, the Black Buck (chin kara) the Great Indian Bustard and the snow leopard have been given full or partial legal protection against hunting and trade throughout India.

6. **The Protected Areas of India** Protected areas are those in which human occupation is small and exploitation of resources is limited. These are defined according to the categorization (Table 7.2).

There are 4 categories of the Protected Areas in India.

- National Parks,
- Wildlife Sanctuaries,
- Conservation Reserves, and
- Community Reserves.

Protected Areas	Number	Total Area in sq Km	% of the Country
National Parks (NPs)	103	40500	1.2
Wild life Sanctuaries (WLSs)	537	118005	3.6
Conservation Reserves (CRs)	67	2350	0.1
Community Reserves	26	47	0.01
Total Protected Areas (PAs)	733	160902	4.91

Source: ENVIS Centre on Wildlife & Protected Areas (http://www.wiienvis.nic.in/Database/ConservationAreas_844.aspx)

National Park

1. National parks in India are IUCN category II protected areas.
2. A National park is an area with ecological, geomorphological and natural significance with rich fauna and flora, designed to protect and to develop wildlife or its environment.
3. Activities like grazing, hunting, forestry or cultivation etc. are strictly prohibited.
4. No human activity is permitted inside the national park.
5. India's first national park was established in 1936 as Hailey National Park, now known as Jim Corbett National Park, Uttarkhand.

6. There are 103 national parks in India (National Wildlife Database, April 2015).

Wildlife Sanctuary

1. The difference between a Sanctuary and a national park lies mainly in the rights of people living inside. In a Sanctuary, certain rights are allowed but in a national park, no rights are allowed for grazing of any livestock. In a wildlife Sanctuary, the Chief Wildlife Warden may regulate, control or prohibit certain activities.
2. There are a total of 537 wildlife sanctuaries in India.

Conservation reserves and community reserves in India:

1. These terms denote the protected areas of India which typically act as buffer zones between established national parks, wildlife sanctuaries and reserved and protected forests of India.
2. They are called as 'Conservation Reserves' if they are uninhabited and completely owned by the Government of India but used for subsistence by communities.

They are called 'Community Reserves' if a part of the land is privately owned.

7. **Biosphere Reserves**: A biosphere reserve is an area of land or water that is protected by law in order to support, sustain and conserve ecosystems. Biosphere Reserves of India protect very large areas of natural habitat that are much bigger than national parks or wildlife sanctuaries. Biosphere reserves may cover multiple national parks, sanctuaries and reserves which are contiguous.example, the Nilgiri Biosphere covers: Bandipur National Park, Mudumalai Tiger Reserve, Silent Valley National Park, Nagarhole National Park and Mukurthi National Park. (Figure 7.16)

- Biosphere reserves are traditionally organized into 3 interrelated zones, known as: Core area, Buffer zone, and Transition zone.

- Presently, there are 18 notified biosphere reserves in India. Ten out of the eighteen biosphere reserves are a part of the World Network of Biosphere Reserves, based on UNESCO's Man and the Biosphere (MAB) Programmed list.

8. Some Other Important Conservation Sites

1. Tiger Reserves – Project Tiger was launched by the Government of India in the year 1973 to save the endangered species of tiger in the country. Starting from nine (9) reserves in 1973 the number has now grown to fifty (50) in 2016. Table 7.2. gives a list of conservation sites and their numbers in India.

9. **Role of communities:** Communities are playing a vital role in the conservation and protection of wildlife in India, example:
    1. **Sariska Tiger Reserve:** In Sariska tiger reserve Rajasthan villagers have fought against mining by citing the wildlife protection act. In many areas, villagers themselves are protecting habitats and explicitly rejecting government involvement.
    2. **Bhairodev Dakav Sonchuri:** The inhabitants of five villages in the Alwar district of Rajasthan have declared 1200 hectares of forests as the Bhairodev Dakav Sonchuri declaring their own set of rules and regulation which do not allow hunting, and are protecting the wildlife against any outside encroachments.
    3. **Bishnoi villages:** In and around Bishnoi villages in Rajasthan, herds of blackbuck, nilgai and peacocks can be seen as an integral part of the community and nobody harms them.

The Role of GIS in Conservation of Nature

- Recently Geographic Information System (GIS) has been used as a tool to identify new areas that need to be conserved. In the last 15 years Remote Sensing and GIS has been used to developed gap analysis as a method to identify biodiversity (i.e., species, ecosystems and ecological processes) that is not adequately conserved within a protected area network or through other effective and long-term conservation

measures. Gap analysis is a method of comparison of actual performance with potential or desired performance. It was thus developed in response to recognition that protected areas of all types and in all parts of the world do not fully protect biodiversity. Gap analysis is usually applied to fairly large areas of study.

Reserves/Conservation Sites	Numbers	Total Area in Sq km
Tiger Reserves	50	71027
Elephant Reserves	32	69583
Biosphere Reserves	18	87492
RAMSAR Wetland Sites	26	12119
Natural World Heritage Sites	07	11756
Important Coastal and Marine Biodiversity Areas	107	10773
Marine Protected Areas	131	9801
Potential/ Important Bird Areas	563	-
Source: ENVIS Centre on Wildlife & Protected Areas (http://www.wiienvis.nic.in/Database/ ConservationAreas_844.aspx)		

Highlight: In 1798, in a small village called Vedanthangal near Chennai, the British soldiers shot some storks in the local wetland. The villagers stormed the Collector's office and made him issue an order not to harm the nesting birds. This took place long before the concept of conservation of biosphere entered our thoughts. India has experienced many such incidents only some of which have been recorded.

- Biodiversity is necessary for our existence as well as valuable in its own right. This is because it provides the fundamental building blocks for the goods and services that provide us with a healthy environment. Biodiversity includes fundamental things to our health like fresh water clean air and food products, as well as many other products like timber, medicine and fibre.

- Biodiversity also includes various other important things and services such as cultural, recreational and spiritual nourishment that play an important role in maintaining our personal life and social life.

It is therefore the duty of every citizen to conserve this valuable life on earth, the most precious gift we can pass on to the future generations.

The Asiatic Cheetah of India Becomes Extinct

- Cheetah is found in Africa and Asia. It is the fastest land animal on Earth. The Asiatic cheetah, is slightly smaller than the African cheetah. It has a fawn-coloured body with black spots and distinctive black "tear marks" running from the corner of each eye down the side of its nose.
- The Asiatic cheetah also known as the Iranian cheetah is a Critically Endangered subspecies surviving today only in Iran. It was once found in the Arabian Peninsula, Near East, Kyzyl-Kum desert, Caspian region, Pakistan and India.
- Asiatic cheetahs were once widespread across the continent but were eradicated in India, where they were hunted for sport. The spread of farming also greatly reduced their numbers in the 19th and 20th centuries. Eventually the animal was wiped out in Asia to which it was once native.
- Cheetah has been known to exist in India for a very long time. They were kept by Kings and princes, but hunting led to their extinction in the country. In 1948, Maharajah Ramanuj Pratap Singh Deo shot three of the last cheetahs in India, in Surguja, State of Madhya Pradesh which is present day Northern Chhattisgarh.
- The Indian government had plans to reintroduce cheetahs back in India in 2009 but this project has not yet been taken up.

Glossary

1. **Boreal:** Relating to the region of the earth just south of the Arctic, especially its plants and animals.

2. **Coral polyps:** Tiny, soft-bodied organisms related to sea anemones and jellyfish. At their base is a hard, protective limestone skeleton called a calicle, which forms the structure of coral reefs. Reefs begin when a polyp attaches itself to a rock on the sea floor, then divides, or buds, into thousands of clones.

3. **Ecologist:** A person who studies the natural relationships between the air, land, water, animals, plants, etc.

4. **Endemic:** Native or restricted to a certain place.eg. Lion-tailed macaque endemic to the Nilgiris.

5. **Entomologist:** A person who studies or is an expert in the branch of zoology concerned with insects.

6. **Ex-Situ Conservation:** Ex-situ conservation is the preservation of components of biological diversity outside their natural habitats. This involves conservation of genetic resources using many techniques and facilities.

7. **Habitat:** The natural home or environment of an animal, plant, or other organism.

8. **Lagoon:** A stretch of salt water separated from the sea by a low sandbank or coral reef.

9. **Oasis:** A small area in a desert that has supply of water and is able to support vegetation. An oasis forms when groundwater lies close enough to the surface to form a spring or to be reached by wells.

10. Permafrost: A thick subsurface layer of soil that remains below freezing point throughout the year, occurring chiefly in Polar Regions.

11. **Poaching:** Trespassing, especially on another's game reserve, in order to steal animals or to hunt.

12. **Sedges:** Any grass like plant, typically growing on wet ground and having rhizomes, triangular stems, and minute flowers. Sedges are found to grow in cold regions,
Vulnerable: Exposed to the possibility of being attacked or harmed or destroyed;