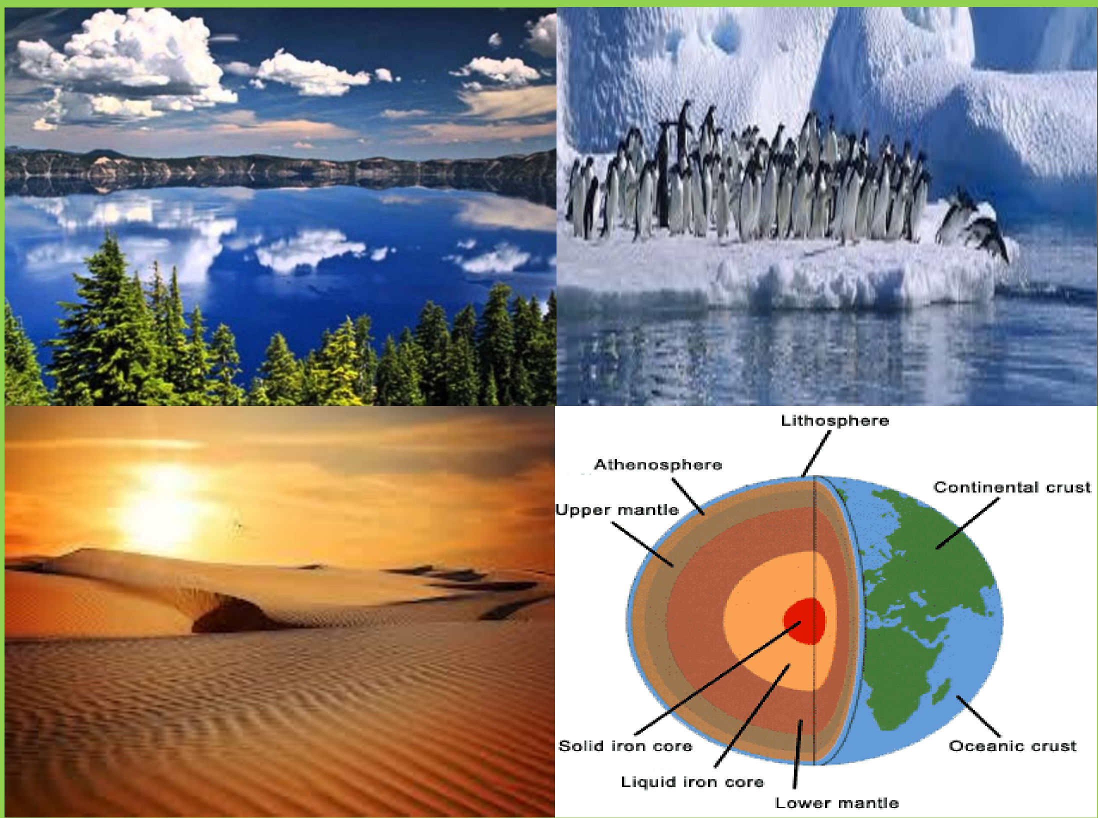
BA/BSCGE-101

FUNDAMENTALS OF PHYSICAL GEOGRAPHY

B.A. / B. Sc. I YEAR



DEPARTMENT OF GEOGRAPHY

SCHOOL OF SCIENCES

UTTARAKHAND OPEN UNIVERSITY, HALDWANI

(Teen Pani Bypass, Behind Transport Nagar, Haldwani (Nainital), 263139)

BA/BSCGE-101

FUNDAMENTALS OF PHYSICAL GEOGRAPHY

DEPARTMENT OF GEOGRAPHY
SCHOOL OF SCIENCES
UTTARAKHAND OPEN UNIVERSITY

Phone No. 05946-261122, 261123
Toll free No. 18001804025
Fax No. 05946-264232, E. mail info@uou.ac.in
htpp://uou.ac.in

FUNDAMENTALS

OF

PHYSICAL GEOGRAPHY

Board of Studies

Programme Coordinators

Dr. RanjuJ.Pandey
Department of Geography
School of Sciences
Uttarakhand Open University
Haldwani, Nainital

Mohd.Akram
Assistant Professor
Department of Geography
School of Sciences
Uttarakhand Open University
Haldwani, Nainital

Units Written By: Unit No.

1. Dr. Amrita Bajaj — 1
Assistant Professor
Department of Geography
ShaheedBhagat Singh (Eve.) College
University of Delhi
Sheik sarai phase II, New Delhi-110017

2. Dr. RanjuJ.Pandey — 2& 3
Department of Geography
School of Sciences
Uttarakhand Open University
Haldwani, Nainital

3.Dr. SnehGangwar — 4, 15
Assistant Professor
Department of Geography
AditiMahavidyalay College
University of Delhi

Delhi Auchandi Road,
Bawana, Delhi-110039

4.Dr.LataKaira 5, 6, 9&10
Assistant Professor
Department Of Geography
PDB Gov. Degree College,Kotdwar

5.Dr. Geeta Rawat 7&8
Assistant Professor
SGRRPG College
Dehradun

6. Dr. Anil Pal 11, 12, 13& 14
AssociateProfessor
Deptt. of Geography
D.B.S. (P.G.) College
Dehradun

7. Dr. Krishna Kumar 16
Assistant Professor
Department of Geography
Shaheed Bhagat Singh (Eve.) College
University of Delhi
New Delhi-110017

Course Editors:

Dr. Ranju J.Pandey
Department of Geography
School of Sciences
Uttarakhand Open University
Haldwani, Nainital

Mr. Mohd.Akram
Assistant Professor
Department of Geography
Uttarakhand Open University
Haldwani, Nainital

Title	:	Fundamentals of Physical Geography
ISBN No.	:	978-93-857-40-61-9
Copyright	:	Uttarakhand Open University
Edition	:	First (2017)

Published By: Uttarakhand Open University, Haldwani, Nainital-263139
Printed By: UttarayanPrakashan, Haldwani

CONTENTS

BLOCK-1 FUNDAMENTAL CONCEPTS OF LITHOSPHERE

UNIT: 1 Nature & Scope of Physical Geography.
UNIT: 2 Origin of the Earth, Earth Interior, Isostasy.
UNIT: 3 Epirogenetic, Orogenetics, Volcanism, Seismicity.
UNIT: 4 Weathering, Erosion, & Associated Landforms.

BLOCK-2 ATMOSPHERE

UNIT: 5 Compositions and Structure of Atmosphere.
UNIT: 6 Insolation & Heat Budget, Vertical & Horizontal Distribution of Temperature.
UNIT: 7 Atmospheric Pressure, Winds, Humidity & Rainfall.
UNIT: 8 Climate& Its Classification- Koppen &Thornthweit.

BLOCK-3 HYDROSPHERE

UNIT: 9 Surface Configuration of Ocean Bottoms.
UNIT:10 Oceanic-Temperature & Salinity.
UNIT:11 Circulation of Ocean Water, Currents & Tides.
UNIT:12 Ocean Deposits & Corals Reefs.

BLOCK-4 BIOSPHERE

UNIT:13 Elements of Biosphere, Habitat & Plant- Animal Association.
UNIT:14 Ecology & Ecosystem.
UNIT:15 Bio-Diversity & Its Depletion.
UNIT:16 Conservation of Biotic Resources.

UNIT I: NATURE & SCOPE OF PHYSICAL GEOGRAPHY

1.1 OBJECTIVES

1.2 INTRODUCTION

1.3 MEANING AND DEFINITION OF PHYSICAL GEOGRAPHY

1.4 NATURE AND SCOPE OF PHYSICAL GEOGRAPHY

1.5 RECENT TRENDS IN PHYSICAL GEOGRAPHY

1.6 CONCLUSION

1.7 SUMMARY

1.8 GLOSSARY

1.9 ANSWER TO CHECK YOUR PROGRESS

1.10 REFERENCES

1.11 SUGGESTED READINGS

1.12 TERMINAL QUESTIONS

1.1 OBJECTIVES

After reading this unit, will help the students in clearing their concepts as regards the following:

- Understanding the definition of Geography.
- Comprehending the development and growth of the subject.
- Learning the scope of Geography as a scientific discipline.
- Gaining knowledge of recent trends in physical geography.
- Discussing the relevance of physical geography.

1.2 INTRODUCTION:

The major aim of this chapter is to introduce the students to a new perspective of the world of physical geography. Geography is amongst the oldest earth science and much of the geographical work is actually the contribution made by different Greek scholars. The word geography was coined by Eratosthenes, a famous Greek scholar in third century B.C. Geography is actually a combination of two words 'Geo' means earth and 'Graphy' means to describe, hence if we look at the literal meaning of term geography then it stands for description of the earth surface. Geography as a discipline concentrates largely on interaction of all human and physical phenomena and the resultant features. Geography is mainly divided into two major branches, Physical and Human geography (Figure1).

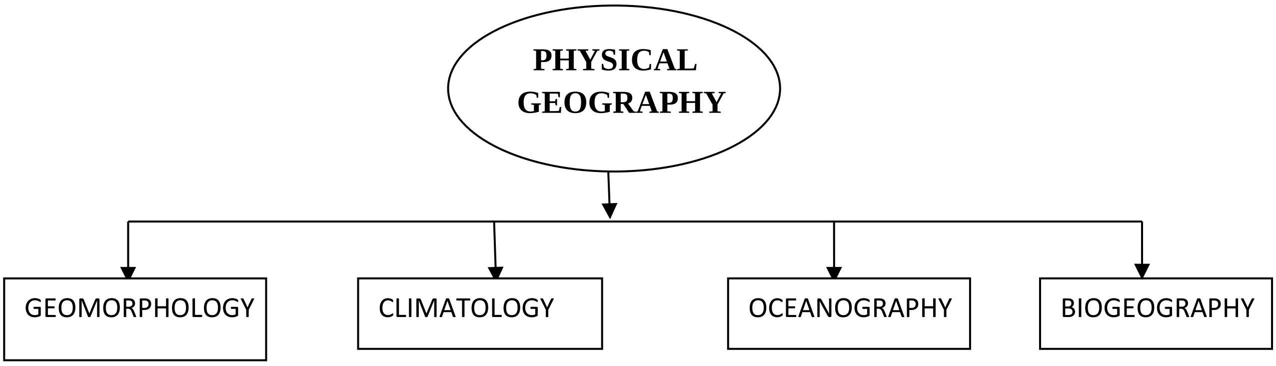


Figure 1: Branches of Physical Geography.

Out of the two major branches of geography, Physical Geography is the most important branch of geography as it forms the basis of all geographical studies.

What have you learnt?

- Geography means the description of the earth surface.
- It is mainly divided into two branches.

INTEXT QUESTION 1.1and 1.2

1. What is Geography?
2. Which are the two major Branches of Geography?

1.3 DEFINITION OF PHYSICAL GEOGRAPHY

Every person on this earth always wonders that, there are areas on this earth which are extremely dry and on the other hand, there are areas which face heavy rain throughout the year. Then, there are areas which are completely plain and on the other hand there are areas dominated by mountains and plateaus. The answers to all these questions lie in physical geography. Thus, a lot of explorers, tourists show a keen interest in the physical geography. There are many people who have a great interest in the physical geography studies but, unfortunately have not got the opportunity in realization of their goals.

Geography has also been defined as "the science of earth as the home of man" by scholars like Kant and Ritter, and has two main branches, physical geography and human geography

There are many scholars who have defined physical geography but, all have done it in their own ways:

Tarr and Von Engeln "Physical geography may be defined as the study of physical features of the earth and their influence on man."

Arthur Holmes has defined physical geography as "The study of physical environment by itself is Physical Geography, which includes consideration of surface relief of the globe (Geomorphology), of the seas and oceans (Oceanography) and of air (Meteorology and Climatology).

According to A.K.Lobeck "The study of physical environment alone constitutes physiography."

A.N.Strahler states that, "Physical geography is simply the study and unification of a number of earth sciences which gives us a general insight into nature of man's environment.

Growth and Development of Physical Geography

The history of geography spans across many centuries and over the time the subject has greatly evolved and developed. A deep analysis of its historical evolution gives a clear insight into the character as well as methodologies of the subject. These valuable insights can help us in a more meticulous understanding of Physical geography. It has already been highlighted that, physical geography has undergone many changes with respect to the meaning and definition, subject matter along with various methods and approaches of study.

Physical geography has seen its development in the study of Greek scholars and further extended by Roman and Indian scholars. The Greeks followed two kinds of traditions in their work. One was the mathematical tradition in which focus was on location of places on the earth's surface, and the other tradition was gathering information through fieldworks.

The Greeks contributed to physical geography through their works on change of climates, winds, rainfall, mountains, delta buildings, earthquake, floods along with their causes, volcanoes and transformation of topographic features. Aristotle discussed phenomena of expansion of land in the shallow seas and the formation of the delta. Herodotus talked about tides in the red sea. The Greeks said that the world can basically be divided into three temperature zones called torrid, temperate and frigid zone.

Strabo was the most outstanding out of all Roman scholars and focused on the fact, earth is spherical and divided it into different zones and the circles upon the sphere i.e equator, the zodiac, the tropics and the arctic circle. He discussed the changes that have occurred over the face of the earth owing to transgression and regression of the sea as well as due to earthquakes and volcanoes.

Indian scholars focused on accurate knowledge of the topography of an area along with its, flora and fauna, natural resources etc of India and adjoining countries. A great deal of geographical information is available in Vedas and Puranas. With fall of the Roman Empire cam the Dark Age were practically no scientific development had taken place. During the medieval period Arabs did made some contribution especially in field of mathematical geography. In present time, American and European Scholars are making a good contribution to the modern physical geography.

Over the years especially by 1950s man realized that, natural resources are highly limited and are being used haphazardly which is ultimately leading to an extinction of many important life forms on this earth. This can lead to an emergence of a great devastating situation including pollution and depletion of essential resources. Such situations have led to a great resurgence in studies in physical geography by researchers worldwide.

By the end of twenty-first century, physical geography developed as a more balanced, integrated and comprehensive discipline. Thus, we can say from the above discussion that, geography has really evolved through various stages of development as regards to the content, methodology and approach to study.

In the beginning physical geography has been usually defined as the study of only the physical environment (namely reliefs, air and water) of the earth e.g. 'The study of physical environment by itself is Physical Geography, which includes consideration of surface relief of the globe (Geomorphology), of the seas and oceans (Oceanography) and of air (Meteorology and Climatology)' (Arthur Holmes).

Physical geography is interdisciplinary in nature and is a mixture of different branches of earth and natural sciences (Figure 2). It has been realized that, physical geography is very vast. Arthus Holmes has further elaborated in 1960 that 'physical geography is simply the study of unification of a number of earth sciences which give us a general insight into the nature of man's environment. Not in itself a distinct branch of science physical geography is a body of basic principles of earth sciences selected with a view to include primarily the environmental influences that vary from place to place over the earth surface'.

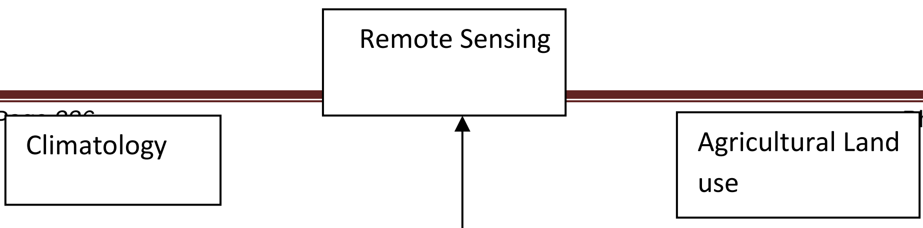


Figure 2: Branches of Geography.

It studies the patterns and interactions between human activities and physical environment analyze the spatial pattern and relationships of environmental components of the globe in a regional context and studies the causes of regional patterns of such relationships. It takes into view both the spatial and temporal aspects of environmental components and their causes.

The main concern of physical geography is biosphere which the layer of the life around the globe which supports the life of all biota (plants and animals) on the earth surface.

The quality of biosphere is determined by the immediate physical environment which consequently is dependent on interactions between the endogentic and exogentic forces. Endogenetic forces are the forces coming from within the earth and exogenetic forces are originating from the atmosphere i.e denudational processes which include the processes of erosion and weathering).

The earth crust is a habitat to a variety of living organisms in the biospheric ecosystem. Different reliefs like mountains, hills plains etc are created on the earth surface by endogenetic forces which introduce diversity in the habitats.

The exogenetic forces originates from the atmosphere in form of carbon, hydrogen, oxygen and nitrogen etc giving rise to different kind of climate's on earth surface. These forces also help in circulation and exchange of heat between the atmosphere and earth surface and on formation of different landforms by various denudational works on one hand and diversity in the habitats formed by endogenetic forces on the other. Thus, physical environment affects the life forms (plants and animals) of the biosphere while man produces a change in the physical environmental conditions through economic activities.

What have you learnt?

- Physical geography has evolved during four periods i.e. ancient, medieval, modern and recent.
- In recent times, it has emerged as a more balanced and comprehensive field of study.
- It is highly interdisciplinary in nature and a perfect amalgamation of natural and earth sciences.
- It concentrates on patterns and interactions between the nature and humans.

INTEXT QUESTION 1.3

1. Which are the two distinct traditions or methodologies followed by the Greeks?
2. Which are the two major forces in Geomorphological studies?

1.4 NATURE AND SCOPE OF PHYSICAL GEOGRAPHY

1.4.1 Nature

In present world, geography is the only discipline which brings a perfect combination of physical and human geography on a common platform. In order to understand the true nature of geography it is essential to know the two major approaches of geography which are systematic and regional geography. Systematic geography is complete study of certain specific natural or human phenomena in all details and regional geography is complete study of a region taking into account all the systematic geographic processes. Physical geography if we notice basically is an amalgamation or mixture of many other branches of earth and natural sciences (Figure 3).

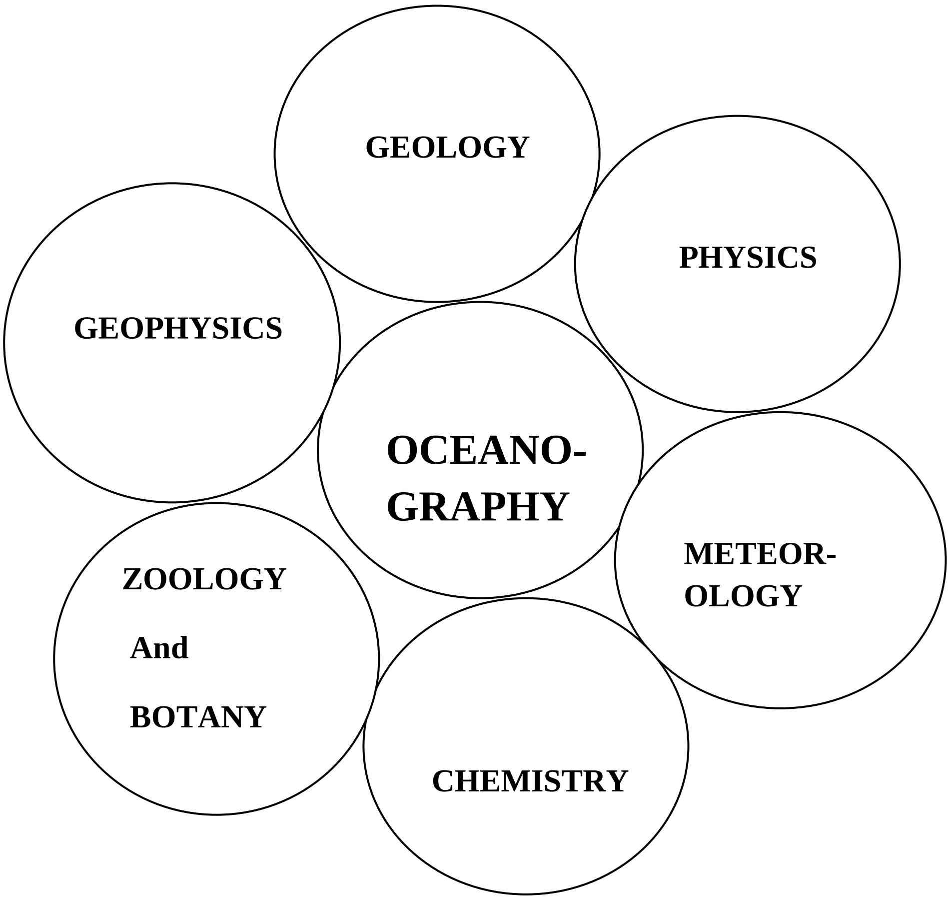


Figure 3: Relationship of Oceanography with other Sciences.

The major branches of physical geography can be classified in the following categories:

1. Geomorphology: is a science which deals with study of landforms and includes Geotectonics and Lithosphere (Landforms). It is highly systematic and organized description of different types of landform on this earth surface. It mainly deals with the study of the physiography and structure of the earth surface and thus includes the study of the continents and ocean basins, great mountain systems, the broad plains, slopes of hills and valleys and so on. Thus, it is mainly focuses on the classification, measurement and description of landforms, along with the history of the processes that have brought these landforms in their present forms.

The field of geomorphological studies is too vast and different views are being expressed by various scholars of physical geography with regard to the definition and scope of the subject. Some of the definitions given by some famous scholars are as follows:

According to Sparks "Geomorphology is essentially the study of the evolution of landforms, especially landforms produced by the process of erosion. The origin of the major features of the earth's crust is usually not considered to be within the sphere of geomorphology".

Worcester claims that "Geomorphology is the interpretative description of the relief features of the earth. In other words geomorphology is the science that describes the surface of the lithosphere, explains its origin and interprets its history."

Strahler has given wider meaning to geomorphology. According to him, Geomorphology is an analysis of origin and evolution of earth's features. It does not study merely the physical, chemical and biological processes affecting the evolution of landforms but also the structure of earth's crust, the geological processes as well as climatic influences, because it is the combined influence of all these factors that determines the landforms."

Looking into the definitions given by these scholars, we can mark that; geomorphology involves a comprehensive understanding of the structure, process and stage as well as types of relief features.

Structure: it is mainly concerned not only with features like rock features like folds, faults and unconformities but also includes the ways by which the earth materials producing landforms differs from one another in their physical and chemical attributes. Phenomena like rock attributes, the presence or absence of joints, hardness and permeability of rocks etc are all part of studying the structure of the landform. Besides there are stratigraphic implications of structure. Structure of a region indicates an appreciation of the rock sequence, both in surface and subsurface, as well as the regional relationships of different rock strata.

Process: Landscape is the result of interplay of a variety of internal and external forces. Internal forces will include forces (earthquakes and volcanoes) and external forces (weathering, moving water, ice, air). Tectonic forces usually leads to crumbling of the rocks and results in pushing up of the continents and mountain ranges. Weathering, on the other hand results in decay and decomposition and transportation of rock to different places. Gravity always plays a universal role in regulating the downward movement of rock material on the surface of the earth. With changes in climatic conditions, vegetation and altitude above or depth below the characteristic of geomorphic process undergoes a massive change.

Stage (Time): The fundamental principles of geomorphology are based on the processes that act and bring a change in the appearance of different kind of landscapes with the passage of time. Stage indicates the phases of development of landforms and the best example to explain this concept is the work of W.M. Davis who has clearly explained this concept in his work of "cycle of erosion", in which he has mentioned that, every landform passes through three stages of development viz., 'youth', 'maturity' and 'old age'.

In geomorphological studies, it can be seen that, there is a clear cut concept of hierarchy of relief features as mentioned by Salisbury (1919) who introduced the concept of hierarchy of relief features by dividing the relief features of the earth into following three orders on the basis of their size:

Relief features of the first order: under this category we have features like continents which accounts for 29.2 percent and ocean basins which accounts for 70.8 percent of the earth surface. These relief features are fairly stable but have shown signs of change in form if there geological history is analyzed. There are evidences of large scale changes in their form, extension and geographical location when we look at their long geological history. As much as 70.8 percent of the earth's surface is covered by water (seas and oceans) and the continents account for only 29.2 percent of the earth's surface.

Relief features of the second order: are called as structural landforms usually super-imposed on continents and ocean basins like mountains, plateaus and plains on the continents, and mid-oceanic ridges, oceanic plains and trenches on the ocean floor along with major features on the continental margins. These relief features are the result of interaction of endogenetic forces (forces working in the interior of the earth) and exogenetic forces (forces acting on the surface of the earth). Relief features of the second order prepare the base for the development of relief features of third order.

Relief features of the third order: Relief features of the third order are formed on the relief features of the second order. These are an outcome of the actions of exogenetic forces like work of running water (river), moving ice (glacier), and wind and sea waves. These forces basically acts as an agents of erosion as well as deposition.On the other hand relief features formed as a result of the erosional work of exogenetic forces are valleys, hanging valleys, roche mountonnees, mushroom or gara, cliffs, bays, promonotaries etc.Relief features formed by the depositional work of the exogenetic forces are alluvial cones and alluvial fans, overflow lakes, natural levees and flood plains, deltas, morains, eskers, kames, drumlins, sand dunes, barkhans, beaches etc. All these features hold an important place as they give the description of the landforms formed on the surface of the earth.

New concepts has come up in the field of Geomorphology

A. Over the years a better relationship has develop between geography, geomorphology and geology. Geomorphology is closely associated with geography and geology. Both geographers and geologists have contributed vastly to the development of geomorphological studies especially work of scholars like Davis, Wooldridge and Morgan and B.W.Sparks who believed that; geomorphology is a part of geology as it has been realized during recent decades that, geomorphology has been more geological than geographical. In Europian nations, there is an increasing trend recognizing geomorphology as a branch of geography and thus there has been an increase in geomorphological studies as several scholars are making significant contribution to the development and growth of geomorphology.

B. Growth of structural Geomorphology: The subject has gained a lot of importance in the recent years, the laws and agents of denudation are gaining importance. There has been a greater trend towards the study of different landform structures created by activities like vulcanicity and tectonic activity, crustal behavior and deformation are becoming highly visible. Since the concepts of sea-floor spreading and plate tectonics have gained popularity; physiography of ocean basins has developed as an important part of geomorphological studies hence, a lot of research is being pursued in this field all across the world.

C. Increasing criticism of Davisian model: Although davisian concept is considered as an important part of geographical studies and all the scholars have included davisian concepts but modern geomorphological st concepts contains no or little davisian thinking.

D. Growth of Climatic Geomorphology: Climatic geomorphology has emerged as an important field as number of scholars believed that climate has a deep impression on the landscape if other things remains the same. Different kinds of landscape emerge with varying climatic conditions. Climate exerts an indirect influence in form of distribution of natural vegetation. Thus, in this sense it is very clear that climate controls process (es) and process (es) control form, therefore, form is the ultimate product of climate.

E. Growth of Applied Geomorphology: deals with the application of geomorphologic knowledge in our day to life. It is comparatively a new branch of geography with a very different and minute vision of the geomorphological processes. Fields like engineering, construction of roads and dams mineral resources, irrigation projects, flood control and regional planning and development, conservation and setting up of human settlements have seen a greater use of geomorphological techniques which shows its much needed importance in human lives. This has given a new dynamism to the world of geomorphological studies.

F. Growth of Quantitative Geomorphology: Geography has always been recognized as a subject based on field studies. Greater improvement in techniques of field surveys, laboratory and other practical experiences, has led to emergence of a new branch quantitative geomorphology. These have drastically improved the standards of research by improving the level of measurement and understanding geomorphic concepts with greater precision and accuracy. So, a new light has been brought in the geomorphological studies with the development of quantitative studies.

1. Climatology: covers the study of Atmosphere (Climate and weather). Weather refers to the sum total of the atmospheric conditions in terms of temperature, pressure, direction and speed of winds, humidity, cloudiness, precipitation, visibility etc of a particular place at a given time. It varies greatly over the entire face of the earth, and hence is a subject of great geographical significance. The term ‘climate’ is closely related to weather because the indicators of both weather and climate like temperature, rainfall, pressure, humidity, wind etc are the same. However, climate differs from weather with respect to time and space. Weather studies are part of a science called Metreology which

The Science of weather is called Meteorology which scientifically studies the atmosphere and different kinds of atmospheric phenomena. The science of metreology can be classified under following five categories:

Aerology: deals with the study of the structure of the atmosphere.

Dynamic or theoretical Meteorology: studies the motions of the atmosphere by analysing the physical variables of pressure, density, temperature and velocity in order to protect the future state of the atmosphere.

Physical Meteorology: covers all physical atmospheric phenomena and amongst which electrical, optical and thermodynamic processes are highly important. It systematically describes the working of different kind of forces in the atmosphere. As a part of natural science, it analyzes concepts of physics, chemistry and dynamics of the entire atmosphere. It also helps in predicting weather accurately along with an understanding of artificial control of the atmospheric phenomena.

Synoptic Metreology: focuses on specific region with a highly analytical and comparative approach. Synoptic charts are usually preferred for weather forecasting. It studies the metrological conditions spread over a wide area and is based on the principle that, certain atmospheric conditions results in a particular type of weather.

Aeronautical Meteorology: It is a category of natural-cum applied science which analyzes the weather conditions suitable for aviation purposes. It has gained a lot of importance over the years especially with the development of aviation industry.

2. Oceanography: deals with the water bodies such as oceans and seas. According to H.A.Marmer, "Ocenaography, the science of the sea, embraces primarily the study of the form and nature of the oceanic basins, the characteristics of the waters in these basins and the movements to which these waters are subjected to." oceanography has also always been an integral part of the studies of physical geography.

Since these water bodies have become a matter of great economic and strategic significance therefore, study of oceanography has gained a lot of importance in recent times with special relevance to applied oceanography. Applied oceanography focuses on delineation, exploitation, mapping utilization and management of marine resources. Marine ecology and marine ecosystem have become the focal theme of oceanography.

'Oceanography' covers all the studies pertaining to seas and oceans. The vastness of the scope of oceanography can be obtained from the studies of many past voyages as well as recent studies in the field of Oceanography which describes the entire complexity of the oceanic system. It is again interdisciplinary in nature and interacts with several other disciplines for a thorough knowledge of oceans and seas. Both deductive and inductive approaches are being followed in order to understand the vast domain oceanic environment.

Oceanography is generally divided into following two broad divisions:

Physical Oceanography: It focuses on the physical properties of the oceanic waters such as temperature, pressure, salinity, density, compressibility, viscosity, water masses and their distributional patterns. It seems to investigate into the thermodynamics of ocean water e.g.

sea waves, currents, tides, tsunamis etc. The theories and principles expressing physical properties and thermodynamics of water is important in study of physical oceanography and as such the application of hydrodynamics carries a great significance.

Just like the study of seas and oceans is important similarly in recent years it has become necessary to study the part which is above the oceans and sea and these are studied under a science called Marine Meteorology. Its development greately owes to the efforts made by Maury of the U.S.Navy.

Marine Biology: studies deeply the animal and plant life present in the sea by investigating the major causes and origin of animal and plant life. This branch has developed greately in recent years as it has been realized that plant and animal resource thriving in the seas and oceans which has great economic significance. The subject matter of Oceanography mainly deals with the chemical composition of sea water, vast domain of oceanic life-plants, plankton, floating animals and their distribution, and the sea as a biological environment.

Oceanography as we have already seen has emerged as a strong and important branch of geography and is interdisciplinary in nature as it is associated with many other sciences like physics, geology, mathematics, meteorology, hydrodynamics, chemistry, zoology and botany

3. Biogeography: It gives a spatial and temporal analysis of distribution of plants and animals on the earth surface. It is the branch too closely associated with human beings as it studies Biosphere, which is called as the life layer since, it supports life. The scope of biogeography is again very vast as it is also interdisciplinary in nature (Figure 4) and hence is a synthetic science and strongly relates to geography, biology, soil science, geology, climatology, ecology and evolution.

The roots of biogeography can be traced in the work of Alfred Russel Wallace and other evolutionary scientists. Wallace studied the distribution of flora and fauna in the Malay Archipelago in the 19th century.

Biogeography again can be divided into two branches:

1. Plant Geography
2. Animal Geography

Plant Geography: it is an important part of biogeographical studies and can be studied through different approaches but two most important approaches are floristic plant geography and ecological plant geography. Floristic geography concentrates on geographic distribution of species and taxonomic units. It has developed because the inherent characteristics of the species are largely responsible for their extent and the location of the area occupied by them. Once these locations are defined, solutions to these problems can be suggested.

It is a universal fact that every species flourishes in environmental conditions that is suitable for their survival and growth. Such studies of plant distributions which analysed them in different environmental conditions is termed as Ecological Plant Geography.

Animal Geography: also popular as Zoogeography, deals with animals below the level of acculturated man. Geographers usually studies zoogeogeography both in terms of region and taxonomy.

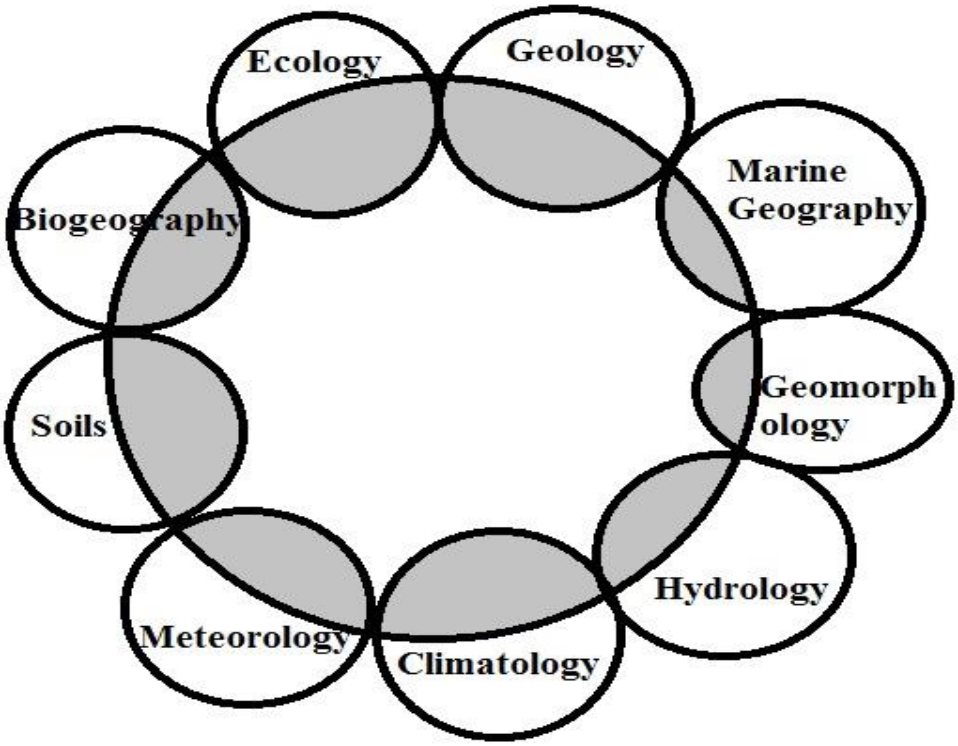


Figure 4: Overlapping of Biogeography with other disciplines.

What have you learnt?

- Physical geography can be subdivided into four major branches i.e geomorphology, climatology, oceanography and biogeography.
- Over the years, the Davisian tradition has lost its importance.
- Alfred Russel Wallace is the pioneer in the works on biogeography.

1.4.1: INTEXT QUESTION

1. Which are the five major classification of climatology?
2. Which are the two based divisions of Oceanography?
3. Why biogeography is an important branch of physical geography studies?
4. Which are the three major relief features in geomorphological studies?
5. Geomorphology is an interplay of which three features?

1.4.2 Scope of physical geography

The main focus of geography has always been on man and environment relationship due to which it has developed a vast scope. Humans are greatly influenced by their physical environment and hence physical geography studies provides an insight into reasons essential for understanding the different cultural patterns that have originated in this world.

The scope and content of physical geography has undergone a sea change during the last few decades for which the following factors have been mainly responsible:

1. Geographers are putting a lot of efforts in order to develop physical geography as useful and meaningful to the humans as possible so that, it can be brought closer to humans to enhance its relevance in present times.
2. There has been a large scale increase in different natural hazards like cyclones, droughts, floods, earthquakes, volcanoes, tsunamis, tides, landslides, avalanches etc all over the world. This has led to a lot of research in this field which is no doubt an important segment of the physical geography studies.
3. There has been introduction of many new methods and techniques for bringing greater precision in measuring various processes in geomorphology, climatology and oceanography. Accuracy of results for different phenomena has made physical geography a more useful discipline.
4. Addition of new dimensions, such as biosphere, ecosystems, hydrology, plate tectonics etc. has further enhance the broad spectrum of physical geography. Thus, over the time the discipline has become more broad-based.
5. Growing emphasis on microspatial and temporal scale in place of macro spatial and temporal scale in the study of environmental processes has made our findings more accurate and enabled physical geography to serve the social cause in a better way.
6. Like earlier years concentration on macro scale both in spatial and temporal analysis, now there is a shift towards micro-level studies. This has led to findings which are more accurate and makes physical geography a more relevant subject for understanding the social causes.
7. With greater development of the subject all over the world, there has been improvement in the techniques of field work, laboratory and other measurement technique. A lot of scope has been generated in the form of instrumentation and measurement of operation of the geomorphological data processes. Along with this a greater use of mathematical and statistical techniques has greatly enhanced the scope of the subject.
8. Thus, the scope of geography is in various disciplines, like armed services, environment management, water resources, disaster management, meteorology, planning, tourism and so on.

- The scope of physical geography has widened to a great extent in terms of methodology, content, and level of study across disciplines.

INTEXT QUESTION 1.4.2

1. What type of shift is there in the scope of physical geography studies?

1.5 RECENT TRENDS IN PHYSICAL GEOGRAPHY

1. There has been a continuous development especially in field of applied physical geography. A lot of work is being carried out in order to solve many human- induced environmental problems.
2. Development in field of Remote Sensing and Geographical Information System has given further impetus in scope of physical geography studies especially in field of monitoring of earth's resources and physical features. The hydrological and geomorphological systems have benefited greatly from remotely sensed data as they have greatly enhanced the applicability in many fields.
3. There has been a great up gradation in the work on biogeography especially at school level as the study of plants and animals have become an integral part of the school syllabus. Biogeography is greatly focusing on ecological processes especially on energy flow and nutrient cycling.
4. There has been a lot of Growth in field of applied geomorphology. This branch which has emerged in the recent years is highly relevant to the human beings as it deals with day to day life events and hence, has greater applicability. Thus, it is closer to the humans.

What have you learnt?

- It has greatly developed both at School as well as University level.
- Emergence of new fields like Applied geomorphology has further enhance the status of this field.

INTEXT QUESTION 1.5

1. What is Applied Geomorphology?

Relevance of physical geography:

1. As regards the relevance of physical geography, it can be claimed that, it has lot of relevance in present times due to its interdisciplinary nature. It is an interesting subject and highly useful in day to day life of human beings.
2. Relevance of Physical geography is explained in the popularity of weather and nature programs all over the world. The tourism industry is highly dependent on the physical geography studies all across the world. A person who goes on different exotic vacations if usually enjoys the uniqueness of the physical landscape in new places.

With a greater insight of physical geography we can enjoy these trips further. We can feel more connected with the immediate world around us.

3. In addition, an understanding of physical geography can help us in building more rational opinions about important environmental issues in our country .Thus; it gives us the scope for becoming better citizens who are capable of protecting the best interests of our society.
4. A carrier as a physical geographer is again an exciting option .A number of excellent, well-paying jobs can be obtained with a specialization in physical geography including environmental analysts, cultural resource managers, conservation agents, teachers, meteorologists and landscape architects.
5. By pursuing a carrier in different fields as a physical geographer, we will have to do a lot of collection, analysis and reporting of geographical data which is a highly rewarding activity.
6. An understanding of the physical geography will help us in understanding our home planed in a much better way, after reading the text on physical geography.

What have you learnt?

- It has emerged as popular subjects especially for certain industries.
- It is capable of providing rational solutions to the environmental problems.
- It is coming up as an exciting carrier.

INTEXT QUESTION 1.6

1. What are the major exciting job opportunities available in physical geography?

1.6 CONCLUSION

Geography has been an important subject as it is very essential in person's everyday life. It not only deals with the study of earth but, where on this earth different activities are located. Physical geography gains much importance here as it describes the distribution of landforms, learning of environmental processes as all these helps in describing different human activities and social, cultural, economic and demographic factors also produce changes in our physical landscape and brings out new and altered landscapes by human interference. Today, our world is full of different problems like food security, environmental pollution, disasters and hazards and so on. All these problems can be tackled with a better understanding of the physical landscape and solving such problems. This will ultimately help in bringing sustainable development.

1.7 SUMMARY

It can be summarized that, geography is an old and important science and a lot of contribution to this subject has been done by ancient scholars during different time periods. It is divided into two major branches physical and human geography. Both these branches can further be subdivided into a number of categories. Physical geography can be classified into four major categories geomorphology, oceanography, climatology and biogeography. Physical geography studies have vast scope and its development over the years has made it more quantitative and applicable in modern world. Thus, thus there is continuous growth in this subject especially in the field of applied physical geography. There has been an increase in overall popularity of this subject because of its increase relevance in different fields.

1.8 GLOSSARY

Disasters: a sudden incident or a natural calamity which causes a great damage or loss to life and property.

Food Security: the condition of having reliable access to a sufficient quantity of, nutritious and reasonable food.

Energy: the strength and vivacity required for performing a sustained physical or mental activity.

Environmental Conservation: it is the act of conserving or preserving the natural resources through proper management. It calls for rational use of the resources wisely and responsibly.

Sustainable Development: Sustainable development means meeting the needs of the present without compromising the ability of future generations to meet their own needs.

Natural Hazards: those elements of the physical environment which are harmful to man and are caused by forces external to him.

Interdisciplinary: involving an amalgamation of academic, scientific, or artistic areas of knowledge.

Natural Resources: are naturally occurring substances that are considered valuable for human beings in their unmodified forms.

Quantitative: relates to measuring, the quantity of something rather than its quality.

Taxonomy: the branch of science concerned with systematic classification especially of organisms.

Hydrodynamics: the branch of science concerned with forces acting on or exerted by fluids (especially liquids).

Thermodynamics: the branch of physical science that deals with the relations between heat and other forms of energy (such as mechanical, electrical, or chemical energy), and, by extension, of the relationships between all forms of energy.

1.9 ANSWERS TO CHECK YOUR PROGRESS

1. Geography is largely the study of the interaction of all physical and human phenomena and landscapes created by such interactions.

2. The two major branches of geography are physical and Human geography.

3. Two distinct traditions and methodologies followed by Greeks are:

    a. Mathematical and Statistical techniques.

    b. Geographic information through travel and field work.

4. The two major forces in geomorphological studies are endogenetic and exogenetic forces.

5. The five major classifications of climatology are:

    a. Aerology

    b. Dynamic or theoretical Meterology

    c. Physical Meteorology

    d. Synoptic Metreology

    e. Aeronautical Meterology

6. Two broad divisions of oceanography are physical oceanography and Marine biology.

7. Biogeography is an important branch of physical geography because it studies the biosphere, which is called as the life layer of the earth.

8. There is a shift towards the applied part in physical geography as compared to the traditional conceptual approach.

9. Applied geomorphology is that branch of geomorphology which deals with day to day life events and is highly relevant to the human beings.

10. The major exciting job opportunities available in the field of physical geography are:

    a. Environmental analysts

    b. Cultural resource managers

    c. Conservation agents

    d. Teachers

    e. Metreologists

    f. Architects

1.10 REFERENCES

- Singh. S, “Nature, Scope and Development of Physical Geography” in *Physical Geography*,

- Gutierrez. M, *Geomorphology*, CRC Press, London, UK, 2013, 1-17.
- Savindra. S, "Nature of Physical Geography" in *Physical Geography*, Prayag Pustak Bhawan, Allahabad, 2012, 1-15.
- "Introduction to physical geography" in *Discovering Physical Geography, Wiley Press, 2-11*.
- Tarr.R.S and Engeln.O.D, *New Physical Geography*, MacMillan Co, New York, 1926.
- Holmes.A, *Principles of Physical Geology*, Thomas Nelson and Sons Limited, 1945.

1.11 SUGGESTED READINGS

- Pidwirny, M. (2006). "Scope of Physical Geography". *Fundamentals of Physical Geography, 2nd Edition*, http://www.physicalgeography.net/fundamentals/1c.html.
- Morrill, R.L. 1983. The nature, unity and value of Geography, Professional Geographer 35(1): 1-9.
- Robinson, J.L. 1976. A new look at the four traditions of Geography. Journal of Geography 75: 520-530.
- Strahler, Alan H. and Arthur Strahler. 2003. Physical Geography: Science and Systems of the Human Environment**.** 2nd Edition John Wiley and Sons, New York.
- Thornbury.W.D, Principles of Geomorphology, Wiley Eastern Limited, 1984, p.2.
- Bloom.A.L, Geomorphology: A Systematic Analysis of Late Cenozoic Landforms, 1992.
- Worcester.P.G, A textbook of Geomorphology, 1965.
- Lobeck.A.K, Geomorphology, Mc Graw Hill Book Company, 1939.

1.12 TERMINAL QUESTIONS

1. Define the term Geography.
2. Define the two major branches of geography.
3. Distinguish between physical oceanography and marine biology.
4. Why geography is called the mother of all sciences.
5. Differentiate between physical geography and biogeography.
6. Discuss the growth of quantitative techniques in physical geography.
7. Highlight the relevance of physical geography in present times.
8. Discuss the two major branches of biogeography.
9. Elaborate on the scope of physical geography.

Discuss the Salisbury concept of hierarchy of relief features

UNIT 2: ORIGIN OF THE EARTH, EARTH INTERIOR, ISOSTASY

2.1 OBJECTIVES

2.2 INTRODUCTION

2.3 THE EARTH: A MEMBER OF OUR SOLAR SYSTEM

2.4 EVOLUTIONARY THEORIES

2.4.1 Gaseous hypothesis of Emmanuel .Kant

2.4.2 Nabular hypothesis of Laplace

2.4.3 Electro-magnetic theory of Alfven

2.5 CATACLYSMIC OR CATASTROPHIC THEORIES

2.5.1 Tidal theories of Jeans and Jeffrey

2.5.2 Nova star hypothesis of Hoyle and Lyttleton

2.5.3 Interstellar dust hypothesis of Otto Schmidt

2.5.4 Big Bang theory

2.6 EVIDENCES OF THE EARTH'S INTERIOR

2.7 CHEMICAL COMPOSITION AND LAYERING SYSTEM OF THE EARTH

2.8 THICKNESS OF THE LAYERS

2.9 MODERN VIEW

2.9.1 Crust

2.9.2 Mantle

2.9.3 Core

2.10 CLASSIFICATION OF ROCKS

2.10.1 Igneous rocks

2.10.2 Sedimentary rocks

2.10.3 Metamorphic rocks

2.11 ISOSTASY: THE CONCEPTS

2.11.1 Model of Airy-Heiskanen

2.11.2 Model of Pratt-Hayford

2.11.3 Vening Meinesz or flexura isostasy model

2.11.4 Global isostatic balance

2.12 CONCLUSION

2.13 SUMMARY

2.14 GLOSSARY

2.15 ANSWER TO CHECK YOUR PROGRESS

2.16 REFERENCES

2.17 SUGGESTED READINGS

2.18 TERMINAL QUESTIONS

UNIT 2: ORIGIN OF THE EARTH, EARTH INTERIOR, ISOSTASY

2.1 OBJECTIVES

Reading this unit will help the students in clearing their concepts as regards the following:

- Understanding our solar system & evolutionary theories.
- Learning the Earth interior.
- Gaining knowledge of rocks.
- Discussing the concepts of Isostasy.

2.2 INTRODUCTION

Geography is the oldest earth science. The major aim of this chapter is to introduce the students to about Solar system & evolutionary theories. How did the earth originate? This chapter is also explains about interior of earth, rocks and Isostasy.

2.3 THE EARTH: A MEMBER OF OUR SOLAR SYSTEM

The congregation of stars and planets is known as **solar system**. Our solar system having a disc-like shape consists of 8 planets (e.g. Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune) and one star (the Sun). Planets are non-luminous bodies whereas stars are luminous bodies of the universe. The rotatory motion of the planets (expect Venus and Uranus) is in the same direction as their revolution around the sun. According to the Titius Bode Rule, the distance of each planet from the sun is approximately twice that of the next planet close to the sun. The diameter of the whole solar system is nearly 1,173 core kilometres. The earth is about 149, 600,000 km ($1.496x10^8$ km) away from the sun. The diameter and average density of the earth are 12,742 km and 5.52 respectively. The following table are shown the average distances from the sun, period of orbital revolution, period of rotation, diameter, average density and number of satellites of the member planets of our solar system. Pluto was discovered in 1930 and was given in 9^{th} planet of the solar system but the International Astronomical Union (IAU) demoted Pluto and recognised it as a **"dwarf planet"** as 134340 Pluto in September 2006. The planets of our solar system are divisible in two groups, (i) the planets of the inner circle or the 'terrestrial planets' (i.e. Mercury, Venus, Earth and Mars) and (ii) the planets of the outer circle or the 'giant planets' (Jupiter, Saturn, Uranus and Naptune). Our solar system is a small part of the system of stars collectively known as the **spiral nebula** or the **galaxy**. The diameter of our galaxy or the Milky Way is about 10^5 light years.

Table: Characteristics of Solar System

Sun And its Family	Average distances from the sun in million kilometre	Orbital period	Rotation period	Radius with reference to the earth's radius (6731 km)	Average density with reference to the density of water (10^3 kgm^{-3})	No. of Satellites	Angle of inclination of axis
Sun	….	….	25.4 days	109 times	1.40	….	….
Mercury	58	88 days	59 days	0.38 "	5.50	0	7◦
Venus	108	225 days	243 days	0.96 "	5.27	0	3.5◦
Earth	150	365.26 days	23 h. 56 m	1.00 "	5.52	1	23.5◦
Mars	228	1.88 years	24 h. 37 m	0.53 "	3.95	2	2◦
Jupiter	779	11.9 years	5 h. 59 m.	11.23 "	1.33	61	1◦
Saturn	1434	29.50 years	10 h. 39 m	9.50 "	0.69	31	2.5◦
Uranus	2873	84.00 years	17 h. 14 m	3.70 "	1.70	21	0◦
Naptune	4495	164.80 years	16 h. 7 m.	3.90 "	1.60	11	2◦

(Source: Physical Geography, Savindra Singh, 2011).

2.4 EVOLUTIONARY THEORIES

2.4.1 Gaseous Hypothesis of Emmanuel Kant

One of the former and popular arguments was by German philosopher Immanuel Kant. He was presented his article entitled 'The General Natural History and Theory of the Heaven or the Essay on the Working and Mechanical Origin of the Entire Universe on the Basis of Newton Law' in 1755. It was based on the principles of Newton's laws of gravitation and rotatory motion. According to him, the hard particles were supernaturally formed and then collided with one another. Further he assumed that the collisions between particles took place because of the mutual gravitational attraction. Due to this process, the heat was generated and the original static and cold matter was converted into a rotating nebula characterised by a strong centrifugal force about its equatorial plane. After that, the successive rings of matter were thrown off, which in course of time and condensed to form the planets. The planets underwent similar spinning and throwing the matter away in the form of rings then to form the satellites.

Evaluation:

This hypothesis was criticised by the scientists because Kant did not explain the source of the origin of the primordial matter. And also he did not explain the source of energy to cause the random motion of cold matter, which was motionless in in the initial stage. The collision among the particles of the primordial matter can never generate rotatory motion in it. So it is an erroneous statement of mechanism. Kant's assumption was against the law of conservation of angular momentum that the rotatory speed of the nebula increased with the increase of its size.

2.4.2 Nebular Hypothesis of Laplace

Marquis de Laplace (1796), a French mathematician said in his book 'Exposition of the World System' assumed that the nebula was already in a rotating state. It appears that Laplace's hypothesis is the modified version of Kant's hypothesis. With gradual cooling, the nebula shrank and started spinning even more rapidly. The spinning motion caused the nebula to flatten to a disk-like shape. Eventually, the centrifugal force around the margin of the disc became sufficient to cause a ring of material to separate and be left behind as the rest of nebula continued to contract. Subsequently, as the shrinking parent disk continued to spin faster, smaller rings separated. In the next stage, condensation of matter started and particles collected in larger aggregates. The aggregates eventually collided and collected in the form of planets and satellites.

Evaluation:

Laplace assumed that initially there was a hot and rotating nebula but he did not describe the source of the origin of the nebula. He could not explain the formation of fixed number of planets i.e., 9 planets. He also said that the planets were formed from the nebula, and then the planets must have been in liquid state in their initial stage. But the planets in liquid state cannot rotate and revolve around the sun properly because the rotatory motion of different layers of the liquid is not always equal. According to this hypothesis, all the satellites should revolve in the direction of their father planets but contrary to this a few satellites of Saturn and Jupiter revolve in the opposite direction of their father planets.

2.5 CATACLYSMIC OR CATASTROPHIC THEORIES

2.5.1 Tidal theories of Jeans and Jeffrey

Sir James Jeans, a British scientist, proposed his 'tidal hypothesis' to explain the origin of the earth in the year 1919 while another British scientist, Harold Jeffreys, suggested modifications in the 'tidal hypothesis'. Tidal Hypothesis is one of the modern hypotheses of the origin of the earth and the solar system. According to Jeans, the solar system was formed from the sun and another intruding star. In the beginning the sun was a big incandescent gaseous mass of matter. Besides the sun, there was another star named as 'intruding star' in the universe. This intruding star was bigger in size than the primitive sun. The primitive sun was stationary and was rotating on its axis. The 'intruding star' was moving along such a path in such a way that it is destined to come nearer to the primitive sun. There was a great impact of the tidal force of the intruding star on the surface of the primitive sun. When the 'intruding star' came nearest to the 'primitive sun' its gravitational force became maximum, with the result a giant cigar-shaped tide, thousands of kilometres in length, was created on the outer surface of the 'primitive sun' and ultimately huge mass of matter, in the shape of cigar was ejected from the primitive sun. Jeans called this cigar-shaped matter as filament which was much thicker in the centre and thinner and sharper at the ends. According to James Jeans, nine planets of our solar system were formed due to cooling and condensation of the incandescent mass of gaseous matter of the filament. The contraction of the filament led its breaking in several pieces and each piece was condensed to form one separate planet. This process led to the formation of nine planets. The filament of incandescent gaseous matter allowed bigger planets to form in its middle portion and smaller ones towards its tapering ends. The remaining parts of the primitive sun became our sun. The satellites of the planets were formed due to gravitational pull and tidal effect exerted by the sun on the outer surfaces of the newly formed planets.

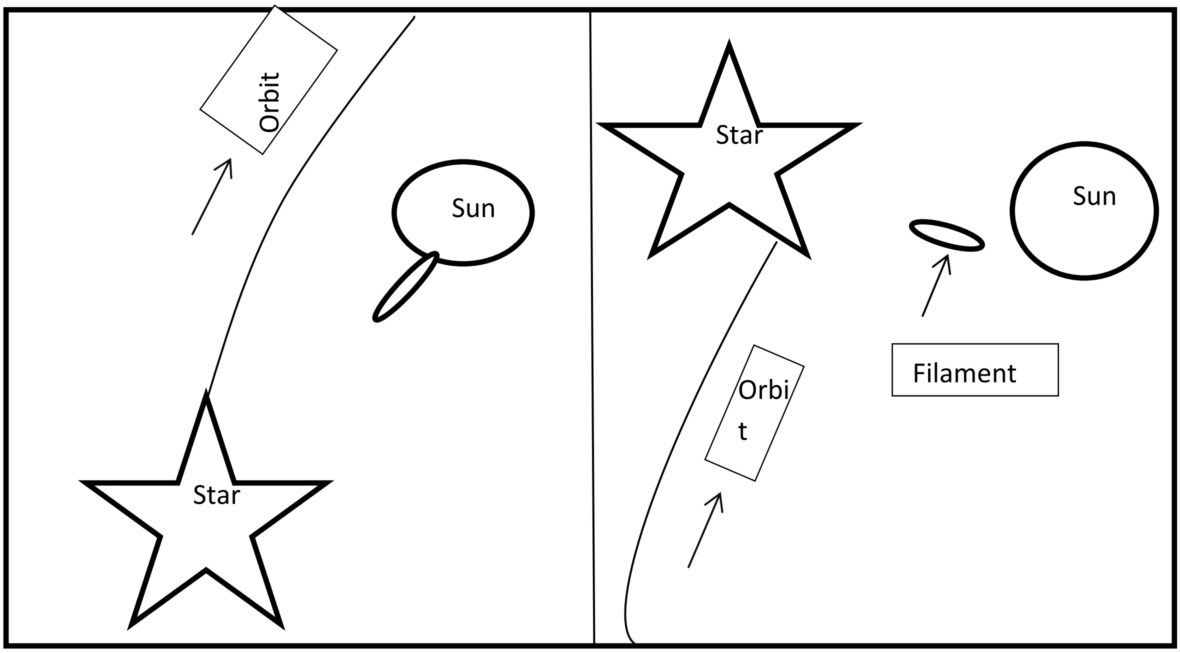


Figure: Formation of planets according to tidal hypothesis

The rate of cooling of the primitive incandescent gaseous planets was dependent upon the size of the planet. The planets of the greater mass cooled very slowly while the smaller planets and satellites condensed to liquid and then to solid forms within very short period. This may be the possible reason for larger number of satellites of bigger planets and fewer numbers of satellites of smaller planets.

Modification by Jeffreys:

Harold Jeffreys, a British scientist, modified the original tidal hypothesis of James Jeans in 1929 and presented his concept as 'collision hypotheses'. According to him, there were three stars in the Universe before the origin of the solar system. One was our primitive sun, the second one was its ‘companion star’ and the third one was ‘intruding star’ which was moving towards ‘companion star’. Thus, the intruding star collided against the ‘companion star’. Due to head-on collision the companion star was completely smashed and shattered, some shattered portions were scattered in the sky while remaining debris started revolving around the primitive sun. The planets of our solar system were formed from the remaining debris of the companion star.

Evaluation:

James Jeans did not explain the where about and density of the intruding star which caused tidal eruption on the surface of the primitive sun in the form of filament. On the basis of the mathematical calculation that tidal hypothesis fails to explain the real distances between the sun and the planets in our present solar system. The planets of our solar system are largely formed of the elements having high atomic weight but the constituent elements of the sun are of lighter atomic weight. But the hypothesis fails to offer convincing explanation for such unusual situation. Also Jeans could not elaborate the process and mechanism of the condensation of matter ejected from the primitive sun.

2.5.2 Nova star hypothesis of Hoyle and Lyttleton

F.Hoyle, a mathematician presented his theory known as ‘supernova hypotheses’ in 1946. His hypothesis was based on the principles of ‘nuclear physics’ and was described in his essay entitled ‘Nature of the Universe’. According to him initially there were two stars in the universe viz.(i) the primitive sun and (ii) the companion star. The companion star was of gaint size and later on became supernova due to nuclear reaction. In the ‘nuclear fusion’ process, the atoms of lighter elements in the star combine under intense heat and pressure to form atoms of heavier elements, releasing vast amount of energy. Due to this process, the companion star was consumed and it collapsed and violently exploded. The gaseous matter coming out due to violent explosion of the companion supernova star changed into a circular moving disc which started revolving around the sun. Hence, the matter of this disc became building material for the formation of future planets. The explosion of the supernova generated intense heat and pressure which formed heavy elements. Thus, the planets of our solar system were formed due to condensation of the matter thrown out of the supernova due to its violent explosion.

Evaluation:

The ‘supernova hypothesis’ of Hoyle attempts to solve the problem of angular momentum of the planets, the problem of great distance between the planets and the sun and the problem of heavier elements of the material of the planets than the sun. But it fails to explain the peculiar arrangement of the planets on the basis of their size, similar direction of rotation as well as the plane of revolution and the path of the planets and the lighter constituent elements of the planets of the outer circle of our solar system.

2.5.3 Inter-stellar dust hypothesis of Otto Schimidt

Otto Schimidt, a Russian scientist, proposed his ‘Inter-Stellar Dust Hypothesis’ in 1943 to explain the complex problems of the origin and characteristics of the solar system and the earth. The scientific researches about the universe have given ample evidences of the presence of ‘dark matter’ in the form of gas and dust particles known as ‘gas and dust cloud’ in the universe. Though Schimidt did explain the mode of origin of this dark matter but it may be safely assumed that these gaseous clouds and dust particles might have been formed from the matter coming out of the stars and meteors. According to him, the sun during its 'galactic revolution' captured the dark matter of the universe. The dark matter of gaseous cloud and dust particles had their own angular momentum. The dark matter after being attracted by the sun during its 'galactic revolution' started revolving around the primitive rotating sun. These dark matters were called 'inter-stellar dusts' by Schimidt. Thus, the dust particles after being combined and condensed and were changed into a flat disc of captured dark matter started revolving around the sun and under the combined impacts of three types of motions i.e. Gravitational force exerted by the sun on the disc of dark matter, the rotational motion of the sun itself and the angular momentum of dark matter of the disc. So, under the combined impact of these three types of motions each and every particle of dark matter of the universe started redistributing itself on the basis of mass, density dimension and the existing amount of centrifugal force tending to push the particles away from the sun and the centripetal force tending to push the particles towards the sun. The intense heat also formed heavy particles which remained in the inner bands of the disc. Collision among the dust particles started the process of aggregation and accretion around the bigger particles which became the embryos of the future planets but the gas particles could not condense as they could not be recognised due to their continued motion. With the passage of time these embryos captured more and more matter and thus grew in grew in size to become asteroids. These asteroids further grew in size due to continuous accretion of nearby matter around them and thus they became planets. The planets of the outer bands of the disc were of low density because they were formed by the 'freezing out' process of the gaseous matter.

Evaluation:

This hypothesis solves almost all of the problems of the peculiar characteristic features of the solar system like(i) near circular and similar planes of orbits of the planets, (ii)revolution in the equatorial plane of the sun closely matching with the orbital planes of the planets, (iii) placement of planets according to their size on the basis of well-founded laws and (iv) high density planets in the outer circle of the solar system and (v) large and peculiar distribution of angular momentum among the planets of solar system. According to the current cosmogonic ideas, there are a few arguments in this hypothesis. The gravitational force of the primitive sun was incapable of capturing dark matter scattered in the universe. There is no trace of remains of dark matter could be discovered either in the archaeological drilling on the earth's surface or on any planets.

2.5.4 Big Bang theory

The Big Bang theory postulated in 1950's and 1960's and validated in 1972 through considerable evidences received from COBE(Cosmic Back-ground Explorer) explains the origin of universe and everything in it including ourselves on the basis that the universe contained many millions of galaxies, each one 'having thousands of millions of stars and each star having numerous planets around them'. According to this theory everything in the universe developed from a point known as singularity, 15 billion years ago. The galaxies moved apart from one another as the empty space between them expanded. In the beginning the universe was much smaller as there was less space between the galaxies. All of the matter in the universe was created in one instant at a fixed moment in time. "As the universe expanded for 15 billion years, the hot radiation in the original fireball also expanded with it, and cooled as a result." It may be summarised that there was a single fireball some 15 billion years ago. 'There were already wispy clouds of matter stretching across vast distances, upwards 500 million light years across. As those clouds collapsed in upon themselves, pulled together by their own gravity, they would have broken up and formed clusters of galaxies with the galaxies themselves breaking up into stars like those of the Milky Way'. The stars might have broken up to form their planets as our earth.

2.6 EVIDENCES OF THE EARTH'S INTERIOR

The sources which provide knowledge about the mystery of the earth's interior of the earth may be classified into 3 groups i.e. Artificial Sources, Evidences from the theories of the origin of the earth and Natural Sources.

Artificial Sources:

Numerous interferences can be drawn about the constitution of the interior of the earth on the basis of density of rocks, pressure of super incumbent load and increasing trend of temperature with increasing depth inside the earth. The satellite studies have revealed the following results about the density of various parts of the earth. It is believed that the outer part of the earth is composed of sedimentary rocks the thickness of which ranges between 0.8 km to 1.6 km. Just below this sedimentary layer of crystalline rocks, the density ranges between 3.0 km to 3.5 km at different places. The average density of the whole earth is about 5.5. Finally, the density of the core of the earth is around 11.0 km. It is evident on the basis of information available from the findings of bore holes and deep mining that temperature increases from the surface of the earth downward at the rate of 2◦ to 3◦C for 100 metres. The following facts may be presented about the thermal condition of the interior of the earth. (1) The asthenosphere is partially molten. The temperature is around 1100◦C at the depth of 100 km which is nearer to initial melting point. (2) The temperature at the depths of 400 km and 700 km has been estimated to be 1,500◦C and 1,900◦C respectively. (3) The temperature at the junction of mantle and outer molten core standing at the depth of 2,900 km is about 3700◦C. (4) The temperature at the junction of outer molten core and inner solid core standing at the depth of 5,100 km is 4,300◦C.

Evidences from the theories of the origin of the earth:

Various exponents of different hypotheses and theories of the origin of the earth have assumed the original form of the earth to be solid or liquid or gaseous. Some examples of these theories are Laplace's 'Nebular Hypothesis', 'Tidal Hypothesis' and 'Planetesimal Hypothesis' etc.

Natural Sources:

The volcanic eruption, earth quake and seismology are the natural evidences for the earth's interior. **Seismology** is the science which studies various aspects of seismic waves generated during the occurrence of earthquakes. Seismic waves are recorded with the help of an instrument known as **seismograph**. The place of the occurrence of an earthquake is called '**focus**' and the place which experiences the seismic event first is called as '**epicentre**', which is located on the earth's surface and is always perpendicular to the 'focus'. The different waves generated during the occurrence of an earthquake are called 'seismic waves' i.e. Primary waves, Secondary waves and Surface waves.

The **primary waves** as also called **longitudinal** or **compressional waves** or simply **'P' wav**es are parallel to sound waves in which particles move both to and fro in the line of the propagation of the ray. It travels with fastest speed through solid materials. Although these also pass through liquid materials but their speed is slowed down. The **secondary waves** also called as **transverse** or **distortional** or simply **S waves**. S waves cannot pass through liquid materials. **Surface waves** are also called as **Long Period waves** or simply **L waves**. These waves cover longest distances of all the seismic waves. Though their speed is lower than P and S waves but these are most violent and destructive.

2.7 CHEMICAL COMPOSITION AND LAYERING SYSTEM OF THE EARTH

According to E.Suess, has thrown light on the chemical composition of the earth's interior. The crust is covered by a thin layer of sedimentary rocks of very low density. This layer is composed of crystalline rocks, mostly silicate matter. Suess has identified three zones of different matter below the outer thin sedimentary cover.

1) **SIAL:**
SIAL located just below the outer sedimentary cover is composed of granites. This layer is dominated by silica and aluminium (SI+AL=SIAL). The average density of this layer is 2.9 whereas its thickness ranges between 50 km to 300 km. This layer is dominated by acid materials and silicates of potassium; sodium and aluminium are abundantly found. Continents have been formed by sialic layer.

2) **SIMA** is located below the sialic layer. This layer is composed of basalt and is the source of magma and lava during volcanic eruptions. Silica (Si) and magnesium (Ma) (SI+MA=SIMA) and magnesium are the dominant constituents. Average density ranges between 2.9 to 4.7 whereas the thickness varies from 1,000 km to 2,000 km. There is plenty of basic matter. The silicates of magnesium, calcium and iron are most richly found.

3) **NIFE** is located just below the 'sima' layer. This layer is composed of nickel (Ni) and ferrium (Fe), (NI+FE = NIFE). This layer is made of heavy metals which are responsible for very high density (11) of this layer. The diameter of this zone is 6880 km. The presence of iron (ferrium) indicates the magnetic property of the earth's interior. This property also indicates the rigidity of the earth.

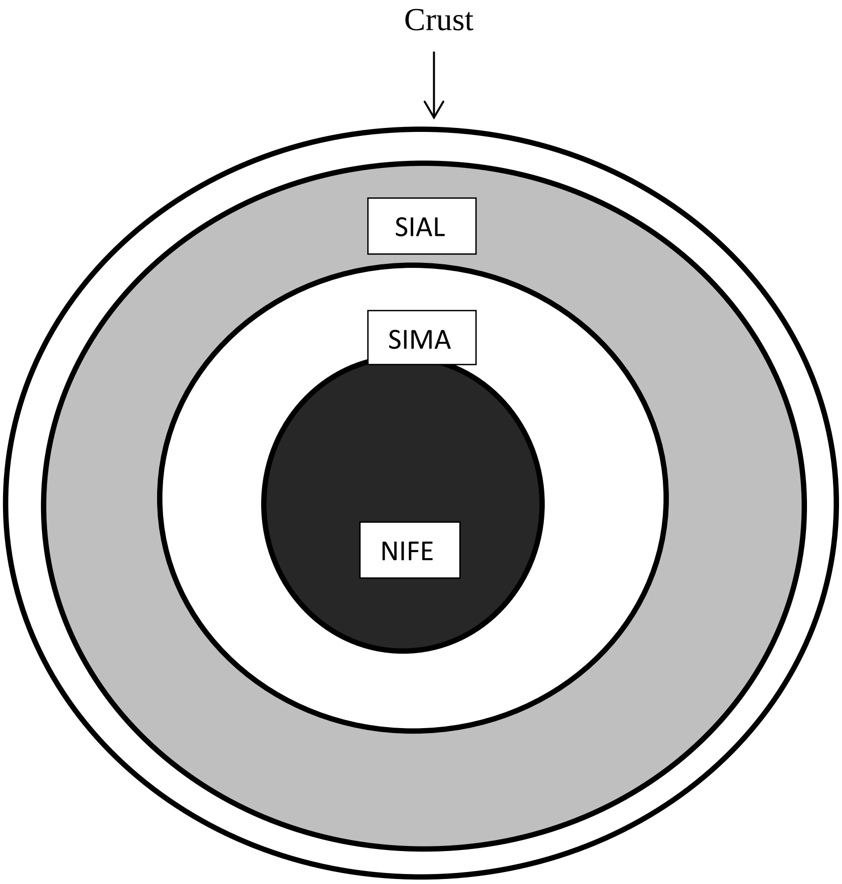


Figure: The layers of earth's interior

2.8 THICKNESS OF THE LAYERS

There are three different layering system of the earth's interior is commonly accepted by majority of the scientists. First one is **Lithosphere** with a thickness about 100 km is mostly composed of granites. In this layer, silica and aluminium are dominant constituents. Average density o this layer is 3.5. The second one, **Pyrosphere** and stretches for a thickness of 2780mkm having an average density of 5.6. The dominant rock of this layer is basalt. The final layer is **Barysphere** and composed of iron and nickel. Average density ranges in between 8 to 11 and this layer gives from 2800 km to the nucleus of the core.

2.9 MODERN VIEW

2.9.1 Crust

This is the solid outer layer of the Earth, and in relative terms, this is equivalent to the skin of an apple. Its depth is usually never more than 1 per cent of the Earth's radius, or averaging 40–50 km, but this varies considerably around the globe. There are two different types: **continental and oceanic crust**.

Table: The differences between oceanic and continental crust

Sl. No.	Continental crust	Oceanic crust
1	Known as SIAL (rich in silica and aluminium)	Known as SIMA (rich in silica, and magnesium)
2	Composed mainly of granitic rocks	Composed mainly of basaltic lavas
3	Average 35–40 km in thickness, bu can be up to 70 km thick unde mountain ranges	Average 6–10 km in thickness
4	Relatively less dense than oceanic crus (average density 2.7–2.8)	Relatively denser than continental crust (average density = 3)
5	Occurs only under large land masses o continental shelves and forms 30–4(per cent of the total crust	Occurs under the oceans and forms 60–70 per cent of the total crust
6	Relatively older than oceanic crust	Relatively younger than continental crust

The boundary between the crust and the mantle is known as the **Mohovoriãiç discontinuity,** or **'Moho'**. At this point, shockwaves (e.g. from earthquakes) initiate to travel faster, indicating a change in structure.

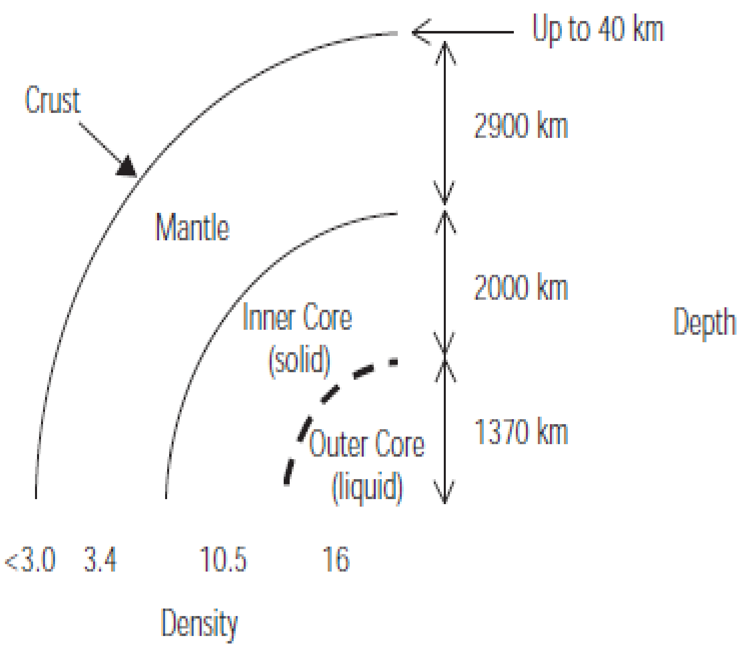


Figure: The Structure of earth's interior

2.9.2 Mantle

This is the zone within the Earth's interior ranging from 25 to 70 km below the surface, to a depth of 2,900 km. It is composed mainly of silicate rocks, rich in iron and magnesium. There are two types in mantle i.e. **upper mantle** and **lower mantle**. Apart from the rigid top layer (the lithosphere, which also includes the crust), the lower mantle (the asthenosphere) remains in a semi-molten state. At the base of the mantle, temperatures may reach up to 5,000°C. These high temperatures may help to generate convection currents which drive plate tectonics. The boundary between the mantle and the core is known as the **Weichert-Gutenberg discontinuity** at the depth of 2900 km.

2.9.3 Core

This is the very centre of the Earth and is composed of iron and nickel. It consists of an **outer core** (semi-molten) and **inner core** (solid). The temperature at the very centre of the Earth (6,300 km below surface) may reach 5,500°C. The density of the outer core is 10.5 and inner core is up to 16.

2.10 CLASSIFICATION OF ROCKS

The crustal rocks are classified on several grounds e.g. mode of formation, physical and chemical properties, locations etc. The rocks are divided into three broad categories on the basis of their mode of formation. They are (1) Igneous rocks, (2) Sedimentary Rocks and (3) Metamorphic rocks.

2.10.1 Igneous rocks

Igneous rocks formed due to cooling, solidification and crystallization of molten earth materials known as magma and lava e.g. basalt, granites etc. The magma is in the below the earth's surface and lava is on the earth's surface. Igneous rocks are also called as **primary rocks** because these were originated first of all the rocks during the formation of upper crust of the earth on cooling, solidification and crystallization of hot and liquid magmas after the origin of the earth. Thus, all the subsequent rocks were formed, whether directly or indirectly, from the igneous rocks in one way or the other. This is why igneous rocks are also called as **parent rocks.**

Characteristics of Igneous rocks:

In all, the igneous rocks are roughly hard rocks and water penetrates with great difficulty along the joints. It is granular or crystalline rocks but there are many variations in the size, form and texture of grains because these properties largely depend upon the rate and place of cooling and solidification of magmas and lavas. It does not have layers like sedimentary rocks. When lava flows in a region occur in several phases, layers after layers of lavas are deposited and solidified one upon another. Since water does not penetrate the rocks easily and hence igneous rocks are less affected by **chemical weathering**. It does not contain any fossils because they formed due to cooling and solidification of very hot and molten lava, thus the remains of plants and animals are destroyed by the temperature.

Classification of Igneous rocks:

The igneous rocks are more commonly classification on the basis of the mode of occurrence into two major groups: (i) Intrusive igneous rocks and (ii) Extrusive igneous rocks.

2.10.2 Sedimentary rocks

Sedimentary rocks are formed due to aggregation and compaction of sediments. Sedimentary rocks are also called as stratified or layered rocks because these rocks have different layers or strata of different types of sediments. The sediments and debris derived through the disintegration and decomposition of the rocks by the agents of weathering and erosion are gradually deposited in water bodies. Continuous sedimentation increases the weight and pressure and thus different layers are consolidated and compacted to form sedimentary rocks. So most of sedimentary rocks are deposited due to continuous deposition of sediments in water bodies like lakes, ponds, basins and seas and land surface like loess, rocks of sand dunes, alluvial fans and cones.

Characteristics of Sedimentary rocks:

Sedimentary rocks are formed of sediments derived from the older rocks, plant and animal remains hence these rocks contain fossils of plants and animals. These rocks are found over the largest surface area of the globe. The deposition of sediments of various types and sizes to form sedimentary rocks takes place in certain sequence and system. Different sediments are consolidated and compressed by different types of strengthening elements e.g. silica, iron compounds, calcite, clay etc. Sedimentary rocks contain several layers or strata but these are seldom crystalline rocks. Layers of sedimentary rocks are rarely found in original and horizontal manner. Sedimentary rocks may be well consolidated, poorly consolidated and even unconsolidated. Sedimentary rocks are characterised by different sizes of joints. The connecting plane between two consecutive beds or layers of sedimentary rocks is called **bedding plane**. Soft muds and alluvia deposited by the rivers during flood period develop cracks are generally of polygonal shapes. Such cracks are called as **mud cracks** or **sun cracks**.

Classification of Sedimentary rocks:

It is classified on the basis of the nature of sediments and the basis of transporting agents. On the basis of the nature of sediments are classified into (i) Mechanically formed or Clastic Rocks i.e. Sandstones, Conglomerates, Clay rock, Shale and Loess, (ii) Chemically formed sedimentary rocks i.e. Gypsum and salt rock, (iii) Organically formed sedimentary rocks i.e. Lime stones, Dolomites, Coals and Peats. On the basis of transporting agents, it is classified into (1) Argillaceous rocks i.e. Marine rocks, Lacustrine rocks and Riverine rocks, (2) Aeolian Sedimentary Rocks i.e. Loess and (3) Glacial Sedimentary Rocks i.e. Till and Moraines.

2.10.3 Metamorphic rocks

‘Metamorphic rocks include rocks that have been changed either in form or composition without disintegration. They are generally formed due to changes in form of sedimentary and igneous rocks. The change in the form of the rocks during the process of metamorphism takes place in two ways: (1) **physical metamorphism** is pertaining to changes textural composition of the rocks and (2) **chemical metamorphism** is leading to changes in the chemical composition of the rocks.

Agents of Metamorphism:

There are three agents played a vital role in metamorphism. **Heat** is the most factors for the development of metamorphic rocks from pre-exiting parent rocks. **Compression** is resulting from convergent horizontal movement caused by endogenic forces causes folding in rock beds. **Solution** is chemically active hot gases and water while passing through the rocks change their chemical composition.

Classification of Metamorphism:

The processes of metamorphism may be classified on the basis of (i) the nature of the agents of metamorphism i.e. Thermal, Dynamic, Hydro-metamorphic and Hydro-thermal metamorphism (ii) Place and area involved in metamorphism i.e. Contact and regional metamorphism and (iii) Composite classification i.e. Contact and thermal metamorphism, Dynamic and regional metamorphism, Hydro-thermal metamorphism.
The examples of important metamorphic rocks are Marbles, Schist, Slate, Gneiss and Quartzite.

2.11 ISOSTASY: THE CONCEPTS

The term "Isostasy" is derived from Isostasions, word of Greek language meaning the state of being in balance. The theory of isostasy explains, the tendency of the earth's crust to attain equilibrium and the distribution of the material in the earth's crust which conforms to the observed gravity values. A great continental mass must be formed of lighter material than that supposed to constitute the ocean – floor. You know that the mountain have many peaks and relatively great heights. Similarly plateaus and plain have flat surfaces and have moderate and lower height. Oceans and trenches have greater depths. There is a great difference in height among these features. Thus our earth is considered to be in isostatic equilibrium.

2.11.1 Model of Airy-Heiskanen

According to Airy, the inner parts of the mountains are not hollow; rather the excess weight is compensated by the lighter materials below. According to Airy the crust of relatively lighter material is floating in the substratum of dense material. Therefore, the continents which are made of lighter sial are floating over the sub-stratum which is built of the denser sima. Thus, Himalaya is also floating in the denser glassy magma. Airy suggested that the lighter sial of the Himalaya is floating over the denser material of sima lying underneath.

2.11.2 Model of Pratt-Hayford

According to Pratt theory, there is a difference in the density of rocks in the crust and at the heights of the crustal blocks are determined by their densities. As such blocks made up of lighter material are at higher elevation than those consisting of denser material.

Lighter material, has therefore, been assumed to lie under mountains and heavier material under ocean and there also exists a boundary, between the upper blocks and the lower dense rocks, at a uniform depth known as the level of compensation.

2.11.3 Vening Meinesz or flexura isostasy model

This hypothesis was suggested to explain how large topographic loads such as seamounts could be compensated by regional rather than local displacement of the lithosphere. This is the more general solution for lithospheric flexure, as it approaches the locally compensated models above as the load becomes much larger than a flexural wavelength or the flexural rigidity of the lithosphere approaches 0.Where the lithosphere acts as an elastic plate and its inherent rigidity distributes local topographic loads over a broad region by bending.

2.11.4 Global isostatic balance

Isostatic balance may occur due to erosion and deposition of sediments. The higher part or the earth surface is subjected to rapid erosion and the eroded materials are deposited on the lower part of the earth surface. As the result of this the weight of the higher part is gradually decreasing and become lighter then the lower part and to rise gradually. In other side, the lower part sink due to deposited materials. These vertical movements occur when larger volumes of materials are eroded or deposited comports of the crust. Thus , in order to maintain isostatic balance between these two features there must be slow flowage of relatively heavier materials towards the lighter materials of the rising column of the mountain at or below the level of compensation. Thus , the process of redistribution of materials ultimately restores the disturbed isostatic condition to complete isostacic balance.

2.12 CONCLUSION

Going thoroughly through this unit, you must have understood about our solar system and evolutionary theories. Studying this chapter, you might have also known about the evidences of earth its interior, rocks, classification of rocks and Isostasy.

2.13 SUMMARY

In the first part of this unit, we tried to understand about Solar system & evolutionary theories. How did the earth originated? After studying the objectives of this unit you have known the evidences of earth interior, classification of rocks, Isostasy. Studying these features, you will be able to understand that structure of earth interior, rocks and Isostasy balance.

2.14 GLOSSARY

Barysphere: represents the innermost zone of the interior of the earth and extends from 2800 km. The average density ranges between 8 and 11.

Core: is the deepest and most inaccessible zone of the interior of the earth and extends from 2900 km to the centre of the earth 6371 km. The average density is 11.

Crust: is the outermost layer of the earth with average density of 2.8 to 3.0 and average thickness of 30 km.
Density: refers to the amount of mass per unit volume of substance, usually measured in gram per cubic centimetre (g/cm^3).
Lithosphere: means rock sphere (lithos-rocks) which represents the solid portion of the continents. It is composed of mostly silicate minerals.
Mantle: represents the second zone of the interior of the earth and extends from 30 km to 2900 km.
Pyrosphere: is the middle zone of the earth with a thickness of 2780 km. having an average density of 5.6.
Seismic waves: the waves generated by the occurrence of earthquakes are called seismic W+aves.
Seismology: is the science that deals with different aspects of seismic waves.
Seismograph: is an instrument which records the seismic waves generated by the occurrence of earthquakes.
Sills: The solidified form of thick sheet of magma parallel to the beds of sedimentary rocks is called sill.

2.15 ANSWER TO CHECK YOUR PROGRESS

1. How much time does a sun ray take to reach earth?
8 minutes.
2. Which planet is nearest to the earth?
Mercury
3. Sun's Chemical Composition:
71% of Hydrogen, 26.5% Helium and2.5% of other elements
4. Which is the largest planet in our solar system?
Jupiter
5. When was the Solar System formed?
Around 4.6 billion years ago.
6. When was the Earth formed?
Approximately 4.54 billion years ago.
7. How many natural satellites of Earth are there?
One, Moon
8. How much larger the Sun is than Earth?
300000 times
9. Who gave the theory of Nebular Hypothesis?
Immanuel Kant
10. The discontinuity between the mantle and core is called
Guttenberg's discontinuity
11. The discontinuity between the crust and the mantle is given by
The mohorovicic discontinuity
12. Example of sedimentary rocks is

Limestone

13. Rocks that are formed of particles of shells, pebbles and sands are classified as

Sedimentary rocks

14. Rocks that are formed through solidification and cooling of lava are classified as

Igneous rocks

15. Example of igneous rocks is

Basalt

2.16 REFERENCES

1. Singh Savindra, 2011, Physical Geography, Prayag Pustak Bhavan, Allahabad, ISBN: 81-86539-29-8.

2. Ettwein V, Maslin M, 2011, Physical geography: fundamentals of the physical environment, University of London, International Studies Guide.

3. http:// knowledgegeo.blogspot.in/2016/09/global-isostatic-adjustment

4. http://www.preservearticles.com/2011103116345/what-is-isostasy.html

5. http://officersiasacademy.blogspot.in/2016/04/concept-of-isostasy.html

6. https://www.revolvy.com/topic/Isostasy&item_type=topic

2.17 SUGGESTED READINGS

1. Singh Savindra, 2011, Physical Geography, Prayag Pustak Bhavan, Allahabad, ISBN: 81-86539-29-8.

2. Ettwein V, Maslin M, 2011, Physical geography: fundamentals of the physical environment, University of London, International Studies Guide.

2.18 TERMINAL QUESTIONS

Question 1- Explain Solar system with diagram?

Question 2- Discuss the various hypothesis of the origin of the earth?

Question 3- Write an essay on the constitution of earth’s interior?

Question 4- Describe in detail the different layers of the earth’s interior?

Question 5- Describe the chemical constitution of the earth’s interior?

Question 6- Describe various rock types on the basis of their origin?

Question 7- Write an essay on Isostasy?

UNIT-3

EPIROGENETIC, OROGENETICS, VOLCANISM, SEISMICITY

3.1 OBJECTIVES
3.2 INTRODUCTION
3.3EARTH'S MOVEMENTS: THE CONCEPT
- **3.3.1 Epeirogenetic Movements**
- **3.3.2 Orogenetic Movements**

3.4 VOLCANISM: THE CONCEPT
- **3.4.1Components Of Volcanoes**
- **3.4.2Erupted Materials**
- **3.4.3 Types Of Volcanoes**
- **3.4.4 Mechanism And Causes Of Volcanism**
- **3.4.5World Distribution Of Volcanoes**
  - **3.4.5.1Circum-Pacific Belt**
  - **3.4.5.2Mid-Continental Belt**
  - **3.4.5.3Mid-Atlantic Belt**
  - **3.4.5.4Intra-Plate Volcanoes**

3.5VOLCANIC FEATURES
3.6HAZARDOUS EFFECTS OF VOLCANIC ERUPTIONS
3.7SEISMICITY: MEANING AND CHARACTERISTICS
- **3.7.1Causes Of Earthquakes**
- **3.7.2Measuring And Locating Earthquakes**
- **3.7.3Classification Of Earthquakes**
- **3.7.4World Distribution Of Earthquakes**
- **3.7.5 India's Seismic Zone Mapping**
- **3.7.6 Effects Of Earthquakes**
- **3.7.7 Prediction Of Earthquake And Preparedness**

3.8 CONCLUSION
3.9 SUMMARY
3.10 GLOSSARY
3.11 ANSWER TO CHECK YOUR PROGRESS
3.12 REFERENCES
3.13 SUGGESTED READINGS

3.14 TERMINAL QUESTIONS

3.1 OBJECTIVES

Reading this unit will help the students in clearing their concepts as regards the following:

- Understanding the Earth's movement concept.
- Learning the volcanism, volcanism features & hazardous effects of volcanism eruptions.
- Gaining knowledge of seismicity.
- Discussing the concepts of India's seismic zone mapping & prediction of earthquake and preparedness.

3.2 INTRODUCTION

As we have studied in the previous unit that the Earth is a member of our solar system. We studied about various evolutionary theories, interior of earth and we also studied about rocks and isostasy. In this unit we will be discussing about Earth's movements, volcanoes & seismicity.

3.3EARTH'S MOVEMENTS: THE CONCEPT

Phenomena related to forces operating within the earth itself, and not to the merely superficial effects of external forces, such as erosion by run-off rainwater.

3.3.1. Epeirogenetic movements

Epeirogenic movements are movements which involv forces acting along a radius from the Earth's centre to the surface, and are characterized by large-scale upliftment or submergence of land areas. The movements involved are often so slow and widespread that no obvious folding or fracturing is produced in the rocks. Epeirogenetic movements can be divided into two types.
(1) Upward movement.
(2) Downward movement.

Upward movement causes upliftment of continental masses in two ways:-
(a) The upliftment of whole continent or part thereof and

(b) The upliftment of coastal land of the continents. Such type of upliftment is called emergence.

Downward movement causes subsidence of continental masses in two ways.

(a) Subsidence of land area. Such type of downward movement is called as subsidence.

(b) Alternatively, the land area near the sea coast is moved downward or subsided below sea level and thus submerged under sea water. Such type of downward movement is called submergence.

3.3.2Orogenetic **movements**

Orogenic or the mountain-forming movements act tangentially to the earth surface, as plate tectonics. Tensions produce fissures (this type of force acts away from a point in two directions) and compression produces folds (because this type of force acts towards a point from two or more directions). In the landforms so produced, the structurally identifiable units are difficult to recognize.

Diastrophic forces have uplifted lands which have predominated forces that lowered them.

Orogenetic movements are caused due to endogenetic forces working in horizontal manner. Orogenetic or horizontal forces work in two ways:-

(a) In opposite directions and

(b) Towards each other.

This is called tensional force. Therefore, when this force operates in opposite directions, tensional forces create rupture, cracks, fracture and faults in the crustal parts of the earth.

3.4 VOLCANISM: THE CONCEPT

Volcanoes are places where magma reaches the earth's surface. Volcanism is the phenomenon of eruption of molten rock (magma) into the earth's surface or solid-surface planet's or moon, where lava, pyroclastics and volcanic gases erupt through a break in the surface called vent. It includes all phenomena's resulting from causing magma within the crust or mantle of the body, to rise through the crust and form volcanic rocks on the surface.

3.4.1Components of volcanoes

Magma - Molten rock beneath Earth's surface.

Parasitic Cone - A small cone-shaped volcano formed by an accumulation of volcanic debris.

Sill - A flat piece of rock formed when magma hardens in a crack in volcano.

Vent - An opening in Earth's surface through which volcanic materials escape's.

Flank - The side of a volcano.

Lava - Molten rocks that erupts from volcanoes and therefore solidifies as it cools.

Crater - Mouth of a volcano [surrounds a volcanic vent].

Conduit - An underground passage through which magma travels.

Summit - Highest point, i.e. (apex).

Throat - Entrance of a volcano. The part of the conduit that ejects lava and volcanic ash.
Ash - Fragments of lava or rock smaller than 2 mm in size that are blasted into the air by volcanic explosions.
Ash Cloud - A cloud of ash formed by volcanic explosions.

3.4.2Erupted materials

Three basic kinds of materials may erupt from a volcano. They are:

(1) Lava,

(2) Rock fragments, and

(3) Gases.

1-Lava is the name for magma that has reached the earth's surface. When lava comes to the surface, it is red hot and may have a temperature of more than 1100 C. Therefore, highly fluid lava flows rapidly down through volcano's slopes. Sticky lava flows more slowly. As the lava cools, it hardens into many different forms. Highly fluid lava hardens into smooth, folded sheets of rock called pahoehoe. Stickier lava cools into rough, jagged sheets of rock called aa. Pahoehoe and aa cover large areas of Hawaii, where the terms originated. The stickiest lava forms flows of boulders and rubble called block flows. It may also form mounds of lava called domes.

2-Rock fragments, generally called tephra, are formed from sticky magma. Such magma is so sticky that its gas cannot easily escape when the magma approaches the surface or central vent. Finally, the trapped gas builds up so much pressure that it blasts the magma into fragments.

Tephra includes, from smallest to largest, volcanic dust, volcanic ash and volcanic bombs. Volcanic dust consists of particles less than 0.25 millimeter in diameter. Volcanic dust can be carried great distances. In 1883, the eruption of Krakatau in Indonesia shot dust 27 kilometers into the air. The dust was carried around the earth several times and produced brilliant red sunsets in many parts of the world. It is likely that large quantities of volcanic dust can affect the climate by reducing the amount of sunlight that reaches the earth. Volcanic ash is made up of fragments less than 0.5 centimeters in diameter. Most volcanic ash falls to the surface and becomes welded together as rock called volcanic tuff. Sometimes, volcanic ash combines with water in a stream and forms a boiling mudflow. Mudflows may reach speeds of 97 kilometers per hour and can be highly destructive. Volcanic bombs are large fragments. Most of them range from the size of a baseball to that of a basketball. The largest bombs may measure more than 1.2 meters across and weigh up to 91 metric tons. Small volcanic bombs are generally called cinders.

3-Gas discharges out of volcanoes in large quantities during most eruptions. The gas is mainly made up steam. But it also includes carbon dioxide, nitrogen, sulfur dioxide, and other gases. Most of the steam comes from a volcano's magma.

3.4.3 Types of volcanoes

Volcanoes are classified into two types:

(1)Classification on the basis of the mode of eruptions.

(i) Explosive eruption type

Explosive type of eruption of lavas, volcanic dusts, volcanic ashes and fragmental materials through a narrow pipe and small opening under the impact of violent gases.

(a) Hawaiin type

Hawaiin type of volcanoes erupts quietly due to less viscous lavas and non-violent nature of gases. Rounded blisters of hot and glowing boll of lavas when caught by a strong wind glide in the air like red and glowing hairs.

(b) Strombolian type

Strambolian type of volcanoes , named after Stromboli volcano of Lipari island in the Mediterranean sea, erupt with moderate intensity. Other volcanic materials like pumice, scoria, bombs are also ejected upto greater height in the sky. These materials again fall down in the volcanic craters.

(c) Vulcanian type

(d) Peleean type

(e) Visuvius type

(ii) Quite eruption type

Quiet type eruption along a long fracture due to weak gases and huge volume of lavas.

(a)Lava flow

(b)Mud flow

(c)Fumaroles

(2) Classification on the basis of periodicity of eruptions

(i)Active volcanoes

(ii)Dormant volcanoes

(iii)Extinct volcanoes

3.4.4 Mechanism and Causes of volcanism

Spreading plate margins

Where plates move away from each other at spreading or divergent plate margins, volcanic eruptions are gentle extrusions of basaltic lava. Most of these occur underwater where magma rises from great depth below to fill the space created by seafloor spreading which occurs at a rate of about 10 centimeters a year.

Sub ducting plate margins

At sub ducting plate margins, one plate is pushed under a neighboring plate as they squeeze together. In addition to the old, weathered plate being forced down and melted, wet sediment and seawater is forced down creating andesitic lava and more violent eruptions containing ash. These volcanoes form classic cone shapes.

Some volcanoes are found at great distances from plate boundaries and are referred to as intraplate, within plate or hot spot volcanoes. These form above hot mantle upwelling’s or plumes which rise from great depths. As the plate overlying the plume moves away from the hot spot and a new volcano is formed, the previous one cools to become dormant and eventually extinct. This sequence forms a volcanic chain such as that currently found in the Hawaiian Islands. Hotspot volcanism forms very large, low gradient shield volcanoes and are similar in composition and eruption style to those found at divergent plate boundaries.

Predicting eruptions

Understanding how volcanoes work and how their eruptions can be predicted is essential for the well-being and preservation of people who inhabit volcanically vulnerable areas. Eruptions can occur without any preceding signals, making them extremely difficult to predict. However, sometimes there are useful clues for judging when a volcano is likely to erupt.

A volcano's eruptive history may provide some clues. However, because only a small number of the world's volcanoes have a known history it is extremely difficult to predict future eruptions, particularly for certain types of volcanoes. This problem is typified by using the repose period, or the time between eruptions to indicate the expected size and strength of an eruption. Consistently long repose periods may indicate that a volcano's eruptions are usually large and explosive. However, sometimes there is no clear relationship in the length of time between eruptions and the nature of the eruptions.

Earthquake activity around a volcano can provide valuable information. An eruption can be preceded by hundreds of small earthquakes know as earthquake swarms. Earthquakes also can indicate that magma is moving beneath a volcano. However, eruptions can occur with no perceivable change in seismic activity.

Small changes in the shape of a volcano such as bulging may indicate that magma is rising. Accurately measuring the summit and slopes of a volcano is one of the most important tools used for forecasting an eruption. Temperature changes in surface lakes or the groundwater near a volcano also can be a valuable early detection tool, although not all large changes in temperature are related to volcanic eruptions.

Gases emitted at, or near a volcano may show that a magma chamber is refilling or that a new composition of magma is rising from depth. Changes in the volume or type of volcanic gases produced also may be an indicator of magma activity.

3.4.5 World distribution of volcanoes

A volcanic belt is a geographical region in which very high levels of volcanic activity are present. Volcanoes are distributed all around the world, mostly along the edges of tectonic Plates, although there are intra-plate volcanoes that form from mantle Hotspots (e.g., Hawaii). Some volcanic regions, such as Iceland, happen to occur where there is both a hotspot and a plate boundary.

3.4.5.1Circum-pacific belt

The Pacific "Ring of Fire" is a string of volcanoes and sites located on most of the Earth's subduction zones having high seismic activity, around the edges of the Pacific Ocean.

The Pacific Plate hits other plates nearby and that causes them to sink because of O-O or O-C convergence. The crust melts producing the magma that feeds the different volcanoes in the Pacific Ring of Fire or it will help produce new volcanoes. The Ring of Fire is the result of plate tectonics. Most tectonic activity in the Ring of Fire occurs in these geologically active zones.

It is believed that the Pacific Ring of Fire has a total of 452 volcanoes. Most of the active volcanoes on The Ring of Fire are found on its western edge, from the Kamchatka Peninsula in Russia, through the islands of Japan and Southeast Asia, to New Zealand.

3.4.5.2Mid-continental belt

This volcanic belt extends along the Alpine mountain system of Europe, north America, through Asia Minor, Caucasia, Iran, afganistan and Pakistan to the Himalayan mountain system, including Tibet, the pamir, Tien-Shan, altai, and the mountains of China, Myammar and eastern Siberia. This zone is characterized by larger volcanoes & earthquakes of shallow origin and some of intermediate origin. Deep focus earthquakes are almost absent in this belt. About 21 per cent of the total earthquakes of the world are recorded in this belt.

This belt includes the volcanoes of Alps mountains, Mediterranean Sea (Stromboli, Vesuvius, Etna, etc.), volcanoes of Aegean Sea, Mt. Ararat (Turkey), Elburz, Hindukush and Himalayas.

3.4.5.3Mid-Atlantic belt

The Mid-Atlantic Ridge is composed of discrete spreading segments that are tens of kilometers long, and offset by transform faults and non transform offsets. The axis of the Mid-Atlantic Ridge is marked by a major rift valley 1 to 1.5 kilometers deep, a central floor 4 to 15 kilometers across, and ranges of crestal mountains on each side of the valley separated by 20 to 40 kilometers. The median valley walls are composed of large faults that move the crust upwards to form the crestal mountains. The central valley floor is the primary site of ocean crust construction, and most segments contain an axial volcanic ridge that runs down the center of the median valley floor. The axial volcanic ridges are themselves made up of smaller ridges, round domes, and a variety of topographic features that all amalgamate into a single larger ridge. Axial volcanic ridges may be 2 to 4 kilometers across and 100 to 600 meters high, and represent a very much larger scale of volcanic relief than found on fast-spreading ridges, which are characterized mainly by flat-lying flows. There are two types of volcanic features: Some are composed of lava hummocks 50 to 200 meters in diameter and at most 10 to 20 meters high, while other features are coated with smooth lava flows that cover most of the median valley floor.

3.4.5.4Intra-plate volcanoes

A third tectonic setting where volcanism occurs is called intraplate- or hot-spot-volcanism, which describes volcanic activity that occurs *within tectonic plates* and is generally not related to plate boundaries and plate movements. Most volcanic activity occurs at plate boundaries, but there are also a large number of volcanoes located with a plate, some of which are exceptionally active. These areas of so-called intraplate volcanism are called hot spots.

3.5VOLCANIC FEATURES

Volcanic landforms are divided into **extrusive and intrusive landforms** based on weather magma cools within the crust or above the crust.

Extrusive Volcanic Landforms

- Extrusive landforms are formed from material thrown out during volcanic activity.
- The materials thrown out during volcanic activity includes lava flows, pyroclastic debris, volcanic bombs, ash and dust and gases such as **nitrogen compounds, sulphur compounds** and minor amounts of **chlorine, hydrogen and argon.**

1-Conical Vent and Fissure Vent

- A conical vent is a narrow cylindrical vent through which magma flows out violently. Conical vents are common in andesitic (composite or stratovolcano) volcanism.
- A fissure vent, also known as a volcanic fissure or eruption fissure, is a narrow, linear volcanic vent through which lava erupts, usually without any explosive activity. The vent is often a few meters wide and may be many kilometers long. Fissure vents are common in basaltic volcanism.

2-Mid-Ocean Ridges

- These volcanoes occur in the oceanic areas. There is a system of mid-ocean ridges more than 70,000 km long that stretches through all the ocean basins. The central portion of this ridge experiences frequent eruptions.
- The lava is basaltic in nature (Less silica and hence less viscous).
- Cools slowly and flows through longer distances.
- The lava here is responsible for sea floor spreading.

3-Composite Type Volcanic Landforms

- They are conical or central type volcanic landforms.
- Along with andesitic lava, large quantities of pyroclastic material and ashes find their way to the ground.
- Andesitic lava along with pyroclastic material accumulates in the vicinity of the vent openings leading to formation of layers, and this makes the mounts appear as composite volcanoes.
- The highest and most common volcanoes have composite cones.
- They are often called strato – volcanoes.

- Stromboli 'Lighthouse of the Mediterranean', Mt. Vesuvius, Mt. Fuji etc. are examples.

4-Shield Type Volcanic Landforms

- The Hawaiian volcanoes are the most famous examples.
- These volcanoes are mostly made up of basalt, a type of lava that is very fluid when erupted.
- These volcanoes are not steep.
- They become explosive if somehow water gets into the vent; otherwise, they are less explosive.
- Example: Mauna Loa (Hawaii).

5-Fissure Type Flood Basalt Landforms [Lava Plateaus]

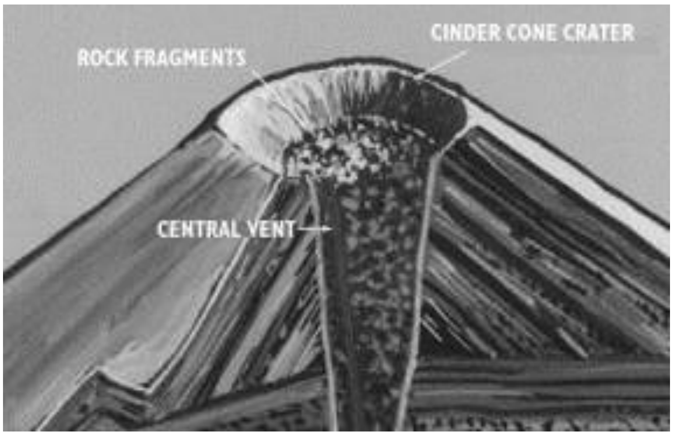
- Sometimes, a very thin magma escapes through cracks and fissures in the earth's surface and flows after intervals for a long time, spreading over a vast area, finally producing a layered, undulating (wave like), flat surface.
- Example: Deccan traps (peninsular India), Snake Basin, U.S.A, Icelandic Shield, Canadian Shield etc.

6-Caldera Lake

- After the eruption of magma has ceased, the crater frequently turns into a lake at a later time. This lake is called a 'caldera'. Examples: Lonar in Maharashtra and Krakatao in Indonesia.

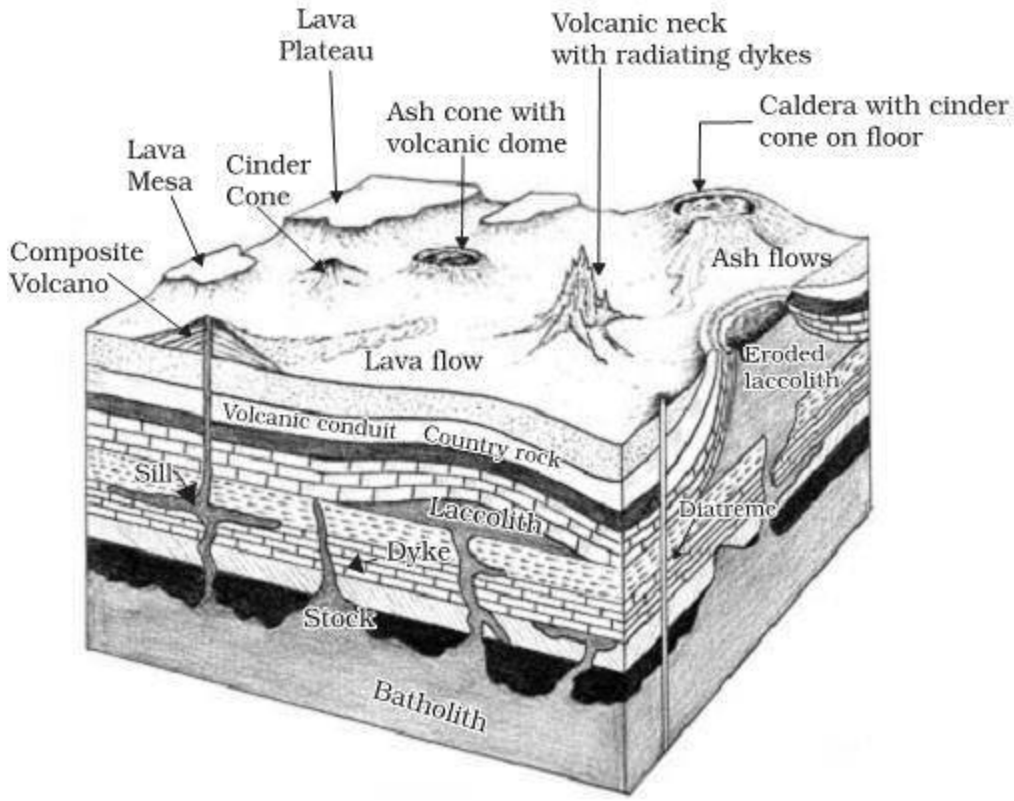
7-Cinder cone

- A cinder cone is a steep conical hill of loose pyroclastic fragments, such as volcanic clinkers, cinders, volcanic ash, or scoria that has been built around a volcanic vent.



Intrusive Volcanic Landforms

- Intrusive landforms are formed when magma cools within the crust **[Plutonic rocks (intrusive igneous rock)]**.
- The intrusive activity of volcanoes gives rise to various forms.



Batholiths

- These are large rock masses formed due to cooling down and solidification of hot magma inside the earth.
- They appear on the surface only after the denudation processes remove the overlying materials.
- Batholiths form the core of huge mountains and may be exposed on surface after erosion.
- These are granitic

Laccoliths

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

Lapolith

- As and when the lava moves upwards, a portion of the same may tend to move in a horizontal direction wherever it finds a weak plane. It may get rested in different forms. In case it develops into a saucer shape, concave to the sky body, it is called Lapolith.

Phacolith

- A wavy mass of intrusive rocks, at times, is found at the base of synclines or at the top of anticline in folded igneous country.
- Such wavy materials have a definite conduit to source beneath in the form of magma chambers (subsequently developed as batholiths). These are called the Phacoliths.

Sills

- These are solidified horizontal lava layers 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.

Dykes

- When the lava 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 dykes.
- 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.

3.6 HAZARDOUS EFFECTS OF VOLCANIC ERUPTIONS

Volcanoes can cause multiple hazards (both primary and secondary hazards). Each hazard can have varying impacts. Below is a summary of volcanoes major hazards and their likely impacts:

Primary Hazards: Hazards that are a direct result of the eruption and are caused by the released of substances during the eruption.

Lava Flow: The most commonly associated hazard with volcanoes. Lava flows are simply rivers of molten rock. Viscous (thick) lava flows are very slow, which means most lava flows can be avoided by humans. However, they can cause massive damage to land and property and trigger fires.

Tephra (Lava Bombs): Any material that is ejected from a volcano during an eruption. As long as you are standing a safe distance, humans should not be effected by tephra although they can damage buildings and start secondary fires.

Pyroclastic Flow: Probably the most dangerous of all volcanic hazards are pyroclastic flows (sometimes called nuee ardentes) which are superheated clouds of ash, gas and small tephra. They can travel at speeds up to 500km/hr and incinerate anything in their path.

Ash Cloud: Ash clouds are normally released into the atmosphere. Although they don't pose much immediate danger they can disrupt air travel and when the ash falls to ground it can crush buildings and bury farmland and also cause the secondary hazard of acid rain.

Poisonous Gases: Often released before a major eruption these gases can be deadly to animals and humans if inhaled in sufficient quantities.

Secondary Hazards: Hazards that happen as a result of primary hazards.

Lahar (mudslide): Volcanoes ash and/or lava can cause snow to melt or they can mix with river/rain water and create mudslides, commonly known as lahars.

Acid Rain: Gases released during an eruption e.g. sulphur dioxide can mix with water vapour in the atmosphere and create acid rain which can damage buildings and change the pH of soils and lakes killing plant and animal life.

Climate Change: Gases released into the atmosphere e.g. sulphur dioxide can enhance the greenhouse effect causing global warming. However, ash released into the atmosphere can also absorb or reflect incoming solar radiation and reduce global temperatures.

Fires: Tephra and lava flows can start fires which can cause widespread damage to buildings and land.

3.7 SEISMICITY: MEANING AND CHARACTERISTICS

Seismicity is a measure which encompasses earthquake occurrences, mechanisms, and magnitude at a given geographical location. As such it summarizes a region's seismic activity. The term was coined by Beno Gutenberg and Charles Francis Richter in 1941.

3.8.1 Causes **of earthquakes**

Earthquakes are usually caused when rock underground suddenly breaks along a fault. This sudden release of energy causes the seismic waves that make the ground shake. When two blocks of rock or two plates are rubbing against each other, they stick a little. They don't just slide smoothly; the rocks catch on each other. The rocks are still pushing against each other, but not moving. After a while, the rocks break because of all the pressure that's built up. When the rocks break, the earthquake occurs. During the earthquake and afterward, the plates or blocks of rock start moving, and they continue to move until they get stuck again. The spot underground where the rock breaks is called the focus of the earthquake. The place right above the focus (on top of the ground) is called the epicenter of the earthquake.

3.7.2Measuring and locating earthquakes

There are two basic kinds of seismic waves:

- Body waves occur inside the earth
- Surface waves travel across the surface

Different types of waves have different ways of travel, different intensity, and different speeds. The medium for seismic waves is almost always solid rock, but occasionally can include water.

Body waves come in two types:

- P-waves
- S-waves

P-waves (pressure waves) are *longitudinal waves*. That means that they occur by compression. All waves move energy in a certain direction, but the particles that carry the wave may move those particles in either the direction of wave travel or in a different direction. S-waves (shear waves) have particle motion at right angles to the wave's travel direction. Seismic waves are measured using a machine called a *seismograph*.

The first major scale used to measure seismic waves was the Richter Scale. This is the name most commonly known among non-geologists. The Richter scale measures the maximum intensity of wave measured by a seismograph located 100 km from the epicenter of an earthquake. It is a logarithmic scale. This means that 4 is not 1 more than 3, 4 is *10* more than 3. Each whole number is ten times as strong as the one below. there are problems with the Richter scale. There is not always a seismograph located 100 km from the epicenter. Strong earthquakes all tend to measure around 7 to 8 on the scale because it loses the ability to measure much past that point. It is very useful for designing safe buildings locally, but not very useful at any particular distance past 100 km from the epicenter. It also doesn't tell how long an earthquake lasts, or how much damage it causes, or how far the ground may have shifted.

First, determine the distance to the epicenter. This is done by comparing the P-wave and S-waves in a seismogram. Because p-waves travel faster than s-waves, and we know how fast they generally do travel in crustal rocks, if you know the amount of time between when they get arrive, you can calculate distance.

3.7.3Classification of earthquakes

BASED ON LOCATION:

Interplate	Intraplate
An interplate earthquake is one that occurs at a plate boundary	An intraplate earthquake is an earthquake that occur in the interior of a tectonic plate
Recurrence time is less	Recurrence time is longer

Interplate Earthquakes are recognized at surface	Intraplate earthquakes are rarely recognized at the surface. This is because the faults are buried under several kilometers of surface materials & the longer recurrence intervals allow any surface expression of faulting to be eroded.
Interplate earthquakes release less stress & are dissipated quickly because of weaker rocks near plate boundaries.	Intraplate earthquakes release more stress. The ground motion caused by intraplate earthquake seismic waves dissipates more slowly. The strong, coherent rocks that make up the interiors of plates transmit seismic energy more efficiently over longer distances than the less coherent, weaker rocks near plate boundaries.

BASED ON FOCAL DEPTH:

Shallow Earthquake	Deep Earthquake
Shallow-focus earthquakes occur at depths less than 70 km	Deep-focus earthquakes occur at greater focal depths of 300 – 700 km.
Shallow focus earthquakes are found within the earth's outer crustal layer	Deep focus earthquakes occur within the deeper subduction zones of the earth
Shallow focus earthquakes are of smaller magnitudes, of a range 1 to 5	Deep focus earthquakes are of higher magnitudes, 6 to 8 or more.
Less energy is released during a shallow focus earthquakes	Tremendous energy accumulates during a deep focus earthquake
Shallow focus earthquakes happen frequently and at random within the earth's crust, often going unrecorded	Deep focus earthquakes occur every 20 to 30 years along a given fault line.
Shallow focus earthquakes are barely perceived and are rarely destructive	Deep focus earthquakes leave a deeper impact on civilisation with widespread destruction and permanent changes within the earth's geology, giving rise to tsunamis.
Shallow-focus earthquakes begin where the crustal plates of the earth are moving against one another	Whereas deep-focus earthquakes begin where one tectonic plate moves under another or sub-ducts,at the boundary of oceanic and continental plates.
During shallow focus earthquakes, rocks and plates buckle, deform and fault.	In the deep focus earthquakes, the rocks being at greater depths and extremely hot under high pressure, deform by flowing, rather than breaking and faulting.
Shallow focus earthquakes are called crustal earthquakes as they exist in the earth's crustal	Deep focus earthquakes are known as intra plate earthquakes, as they are

layer.	triggered off by collision between plates.

BASED ON THE CAUSE:

Non Tectonic Earthquakes: These are due to volcanic activities and manmade reasons e.g, nuclear testing, blasts, construction of large dams, deforestation etc

Tectonic Earthquakes: These are due to sudden slip in the fault of the tectonic plates of the earth.

BASED ON THE MAGNITUDE OF THE EARTHQUAKE:

Class	**Magnituc**
Great	8 or more
Major	7 – 7.9
Strong	6 – 6.9
Moderat	5 – 5.9
Light	4 – 4.9
Minor	3 -3.9

3.7.4World distribution of earthquakes

Earthquakes have a definite distribution pattern. There are three major belts in the world which are frequented by earthquakes of varying intensities. These belts are :

1. The Circum-Pacific Belt

2. The Mid-Atlantic Belt

3. The Mid-Continental Belt

1. The Circum-Pacific Belt:

This belt is located around the coast of the Pacific Ocean. In this belt the earthquakes originate mostly beneath the ocean floor near the coast. The Circum- Pacific Belt represents the convergent plate boundaries where the most widespread and intense earthquakes occur.

This belt runs from Alaska to Kurile, Japan, Mariana and the Philippine trenches. Beyond this, it bifurcates into two branches. One branch is going towards the Indonesian trench and the other towards the Kermac-Tonga trench to the northwest of New Zealand.

This belt is located on the western side of the Pacific Ocean. On the eastern side of the Pacific Ocean, the earthquake belt runs parallel to the west coast of North America and moves on towards the South along the Peru and Chile trench lying on the west coast of South America. This belt has about 66 percent of the total earthquake that are recorded in the world. Most of the earthquakes occurring in this belt are shallow ones with their focus about 25 km deep.

2. The Mid-Atlantic Belt:

This belt is characterized by the sea floor spreading which is the main cause of the occurrence of earthquakes in it. This earthquake belt runs along the mid- oceanic ridges and the other ridges in the Atlantic Ocean.

In this belt most of the earthquakes are of moderate to mild intensity. Their foci are generally less than 70 km deep. Since the divergent plates in this belt move in opposite directions and there is splitting as well, transform faults and fractures are created.

All this becomes the causative factor for the occurrence of shallow focus earthquakes of moderate intensity. The sea floor spreading is the main cause for the occurrence of earthquakes in this belt.

3. The Mid-Continental Belt:

This belt extends along the young folded Alpine mountain system of Europe, North Africa, through Asia Minor, Caucasia, Iran, Afghanistan and Pakistan to the Himalayan mountain system. This belt continues further to include Tibet, the Pamirs and the mountains of Tien Shan etc.

The young folded mountain systems of Myanmar, China and eastern Siberia fall in this belt. This belt happens to be the subduction zone of continental plates. It is in this belt that the African as well as Indian plates sub-duct below the Eurasian plate.

This Mid- Continental belt is characterized by experiencing about 20 per cent of the earthquakes in the world. This belt records earthquakes of shallow and intermediate origin. However, it is true that sometimes earthquakes of great violence occur in this belt.

This belt forms a great circle approximately east and west around the earth, through the Mediterranean, Southern Asia, Indonesia and the East Indies, where the great majority of recorded shocks occur. It may be pointed out that more than 50 percent of all earthquakes are associated with the young folded mountains which are said to be still growing.

3.7.5 India’s seismic zone mapping

Seismic zone map is mainly used by the department of Disaster management of the different state governments in the country. This map helps them in planning for natural disaster like earthquake. An Indian seismic zoning map assists one in identifying the lowest, moderate as well as highest hazardous or earthquake prone areas in India. Such maps are looked into before constructing any high rise building so as to check the level of seismology in any particular area.

3.7.6 **Effects** of earthquakes

(1) Damage to human structures - Earthquakes cause great damage to human structures such as buildings, roads, rails, factories, dams, bridges etc, and thus cause heavy damage to human property.

(2) Landslides-The shocks produced by earthquakes particularly in hilly areas and mountains which are tectonically sensitive cause’s landslides and debris fall on human settlements and transport system on the lower slope segments, inflicting damage to them.

(3) Fires- The strong vibrations caused by severe earthquakes strongly shake the buildings and thus causing severe fires in houses, mines and factories because of overturning of cooking gas, contact of live electric wires, churning of blast furnaces, displacement of other fire related and electric appliances.

(4) Flash Floods- Strong seismic waves cause damage to dams thereby causing severe flash floods. Severe floods are also caused because of blocking of water flow of rivers due to rock blocks and debris produced by severe tremors in the hill slopes facing the river valleys. Sometimes the blockage is so severe that rivers change their main course.

(5) Deformation of Ground surface- severe tremors and resultant vibrations caused by earthquakes result in the deformation of ground surface because of rise and subsidence of ground surface and faulting activity(formation of faults).

(6) Tsunamis- The seismic waves caused by earthquake(measuring more than 7 on Richter scale) travelling through sea water generate high sea waves and cause great loss of life and property.

3.7.7 Prediction of earthquake and Preparedness

Prediction is concerned with forecasting the occurrence of an earthquake of a particular intensity over a specific locality within a specific time limit. Normally prediction is of three types, viz., long, medium and short range prediction.

While long range prediction is concerned with forecasting the occurrence of an earthquake a number of years in advance, medium term prediction is to be done a few months to a year or so and the short term prediction implies forecast ranging from a few hours to some days in advance.

Medium and short range predictions are very useful because they can help in saving the largest population from disaster in terms of life and property. Scientists believe that it is possible to predict major earthquakes by monitoring the seismicity caused by natural earthquakes, mining blasts, nuclear tests, etc.

However, no flawless technique has been developed to predict the earthquakes till date. Most of the methods and models are beyond the scope of the present work and only a few simple methods and models will be discussed here.9 Methods to Predict Earthquake are:

1.Unusual Animal Behaviour, 2. Hydrochemical Precursors, 3. Temperature Change, 4. Water Level, 5. Radon Gas, 6. Oil Wells, 7. Theory of Seismic Gap, 8. Foreshocks, 9. Changes in Seismic Wave Velocity.

Preparedness

Preparedness can consist of survival measures, preparation that will improve survival in the event of an earthquake, or mitigating measures, that seek to minimize the effect of an earthquake. The basic theme behind preparedness is to be ready for an earthquake.

3.8 CONCLUSION

Going thoroughly through this unit, you must have understood about earth's movement concept and eperogenetic & orogenetic movements. Studying this chapter, you might have also known about the volcanism and seismicity.

3.9 SUMMARY

In the first part of this unit, we tried to understand about earth's movement & its concepts. After studying the objectives of this unit you have known about the volcanism & seismicity. Studying these features, you will be able to understand that how did volcanoes formed? Types of volcanoes, features of volcanoes & how did earthquake occur?

3.10 GLOSSARY

Lava: Molten rock above the surface of the earth.
Magma: Molten rock below the surface of the earth.
Magma Chamber: A store of magma found below the surface of the earth. When the pressure becomes too great in the magma chamber, volcanoes occur.
Vent: The main passage by which magma travels from the magma chamber to the crater. You can also get smaller secondary vents that often split off from the main vent.
Crater: A large hole or depression that has been created by a volcano. Lakes will often form in the bottom of lakes, they are known as **crater lakes.**
Eruption: A release of volcanic lava, ash or gas.
Seismology: Science of studying earthquake.

3.11 ANSWER TO CHECK YOUR PROGRESS

1. Volcanoes that erupt frequently are known as— **Active volcanoes**
2. Opening or a hole in Earth's crust through which magma comes to Earth's surface is known as— **Vent**

3. Top of magma is forced onto Earth's surface is known as— **Crater**
4. Volcanoes are generally found where **Tectonic plates** pull apart or are coming together.
6. The hot molten material erupted from a volcano is called— **Lava**

3.12 REFERENCES

http://www.mindfeeders.org/harmful-effects-of-earthquakes/

https://en.wikipedia.org/wiki/Earthquake_preparedness

http://www.jma.go.jp/jma/en/Activities/volcano_1.pdf

http://lorpub.gadoe.org/State%20of%20Georgia/GAVS%20Shared/Science/Geology_Earthquakes_Shared/Geology_Earthquakes_Shared3.html

http://www.duhaime.org/LegalDictionary/E/EarthMovement.aspx

https://www.pmfias.com/volcanic-landforms-extrusive-intrusive-composite-shield-fissure-type-volcano/

https://civildigital.com/classification-earthquakes/

http://www.ga.gov.au/scientific-topics/hazards/volcano/basics/causes

1. Singh Savindra, 2011, Physical Geography, Prayag Pustak Bhavan, Allahabad, ISBN: 81-86539-29-8.

2. Ettwein V, Maslin M, 2011, Physical geography: fundamentals of the physical environment, University of London, International Studies Guide.

3.13 SUGGESTED READINGS

1. Singh Savindra, 2011, Physical Geography, Prayag Pustak Bhavan, Allahabad, ISBN: 81-86539-29-8.

2. Ettwein V, Maslin M, 2011, Physical geography: fundamentals of the physical environment, University of London, International Studies Guide.

3.14 TERMINAL QUESTIONS

Question 1- What is volcanism? Describe the various landforms formed by it?

Question 2- How are the volcanoes caused? Classify the main types and give their distribution?

Question 3- What is seismicity and explain the effects of earthquake?

Question 4- Analyse the causes of earthquakes and describe with illustrations the earthquake regions of the world?

UNIT-4 WEATHERING, EROSION & ASSOCIATED LANDFORMS

4.1 OBJECTIVES
4.2 INTRODUCTION
4.3 WEATHERING: MEANING AND CONCEPT
4.4 FACTORS CONTROLLING WEATHERING
4.4.1 Rock composition and structure
4.4.2 Nature of ground slope
4.4.3 Climate
4.4.4 Floral effects
4.5 Types of weathering
4.5.1 Physical weathering
4.5.2 Chemical weathering
4.5.3 Biological weathering
4.6 Geomorphic importance of weathering
4.7 Erosion: meaning and concept
4.7.1 Erosional processes
4.7.2 Factor effecting erosion rate
4.7.3 Erosional cycle, interruption and rejuvenation
4.8 Associated landforms
4.8.1 Fluvial landforms
4.8.2 Karst landforms
4.8.3 Glacial landforms
4.8.4 Wind and Aeolian landforms
4.8.5 Coastal landforms
4.9 Conclusion
4.10 Summary
4.11 Glossary
4.12 Answer to check your progress
4.13 References
4.14 Suggested readings

4.1 OBJECTIVES

After reading this unit, will help the students in clearing their concepts with regard to:

- Understanding the meaning and types of weathering.
- Learning the factors controlling of weathering.
- Gaining knowledge of geomorphic importance of weathering.
- Discussing the relevance of erosion, erosional cycle and associated landforms.

4.2 INTRODUCTION

The main function of the exogenetic forces on the surface of the earth is denudation which includes the processes of weathering and erosion. Weathering is a static process, whereas erosion is a dynamic one. Physical weathering results into disintegration of rocks materials, whereas chemical weathering results into decomposition of rock materials. In the tropical humid parts, chemical weathering is dominant whereas in tropical dry deserts physical weathering dominates. All the activities involved in removing vertical irregularities on the surface of the earth are termed as equilibrium process. The process of bringing down the higher parts by erosion is called degradation and the reverse process of filling the low lying areas is called aggradation.

4.3 WEATHERING: MEANING AND CONCEPT

The process of disintegration and decomposition of rocks, due to physical, chemical or biological factors, in situ (at their own place) is known as weathering. As soon as the rocks are exposed on the surface and are affected by the climate factors, this process starts.

Weathering as a process of denudation, comprises a number of processes by which surface and subsurface rocks disintegrates into mineral particles or dissolve in water. Weathering includes various processes by which rocks are disintegrated or decomposed for their easy removal and transportation by various processes of denudation such as running water, wind, waves, glaciers and underground water. According to the fact, weathering is the most important step in erosion of land. But by the breakdown or decay or rocks a mantle of waste (regolith) is created which will remain *in situ* until agents of erosion cause it to be moved. So finally it can be conclude that weathering is the breakdown of rock materials in place, involving no movement.

4.4 FACTORS CONTROLLING WEATHERING

The rate at which weathering succeeds in the disintegration and decay of rocks depends upon a variety of conditions and factors, these can be summarized in some of which are as under:

4.4.1 Rock Composition and Structure-

since weathering involves disintegration and decomposition of rocks and hence mineral composition, joint patterns, layering system, faulting, folding etc. largely affects the nature and intensity of weathering. For example, carbonate rocks (e.g. calcium carbonate, magnesium carbonate etc.) having more soluble minerals are easily affected by chemical weathering. Well jointed rocks are more subjected to mechanical disintegration. Rocks having vertical strata are easily loosened and broken down due to temperature changes, frost action, water and wind action. On the other hand, rocks having horizontal beds are more compact and are less affected by the mechanism of disintegration and decomposition.

4.4.2 Nature of Ground Slope-

ground slope controls mechanical disintegration of rocks and mass movement of weathered products down the slope. The rocks in the regions of steep hillslope are easily disintegrated due to mechanical weathering and the weathering materials are instantaneously moved down the hill slopes in the form of rock fall, debris fall and slide etc.

4.4.3 Climatic Variations-

Important controls on weathering rates are climatic elements, such as the amount of precipitation, temperature, and freez-thaw cycles. Mechanical and chemical weathering processes are closely related to climate conditions, specially temperature and annual precipitation. For example, physical or mechanical weathering dominates in drier, cooler climates, whereas chemical weathering dominates in wetter, warmer climates. In hot deserts marked by extreme dryness, weathering is reduced to a minimum. On the contrary, in hot and humid climates (tropical and equatorial) most rocks weather rapidly, and the effect of weathering is carried deep below the surface.

In climates where the diurnal range of temperature is high, and freezing due to nocturnal cooling is common, the freeze –thaw action expands the water in rock crevices (freezing) and then contracts it (thawing). This succession of freeze-thaw action creates forces that are strong enough to mechanically split the rocks.

4.4.4 Floral Effects-

The rate of weathering is also affected to a large extent by the vegetation cover. It may be pointed out that vegetation is partly a factor of weathering and partly a protector of rocks. In fact, vegetations bind the rocks through their network of roots. These roots of vegetation-cover protect rocks from weathering and erosion but the same time the penetration of roots weakens the rocks by breaking them into several blocks.

The absence of vegetation cover in arid regions promotes erosion by wind and running water and exposes the bed rocks to the action by the agents of weathering.

All these factors work in close co-operation and influence weathering to a large extent. However, time is the crucial factor in weathering, for these processes require long period of time to operate.

4.5 TYPES OF WEATHERING

Based on the causes, the process of weathering is classified into three types.

4.5.1 Physical and Mechanical Weathering

i. Due to insolation (temperature)
ii. Due to Frost Action
iii. Due to Friction
iv. Due to Pressure
v. Exfoliation

4.5.2 Chemical Weathering

i. By Oxidation
ii. By Carbonation
iii. By Hydration
iv. Chelation
v. Hydrolysis

4.5.3 Biological Weathering

i. By Plant
ii. By Animal
iii. Due to Human Activities (Anthropogenic)

Although weathering occurs all over the earth's surface it is not always easy to see, especially in new towns. If there are very old stone or brick buildings near to where you live, look at them closely next time you pass by. You will probably see that the surface of the stone or brick is pitted, with bits flaking off. This breakdown of the surface may have been caused by frost action, by rain and wind, by alternate heating and cooling between summer and winter, by the exhaust fumes of cars, by smoke from industrial plants or by a combination of these. This type of breakdown is the result of weathering. The tombstones in old churchyards are sometimes so weathered that it is not possible to read the names of the deceased.

4.5.1 Physical Weathering

By temperature changes when an arid region has high day and low night temperatures, rock surfaces alternately heat and cool. This causes the outer parts of the rocks to expand during the day and to contract during the night setting up powerful internal stresses in the top few centimetres of the rocks. The heating and cooling process does not penetrate far below the surface but once cracks appear, the stresses operate to greater depths. The stresses produce fractures which cause the outer layer of rock to pull away from the layer beneath. In well-jointed rocks, flat or curved plates of rock, (sometimes called shells), break away from the main rock body. When curved plates of rock peel off in this way, it is called *exfoliation* (Fig. 4.1).

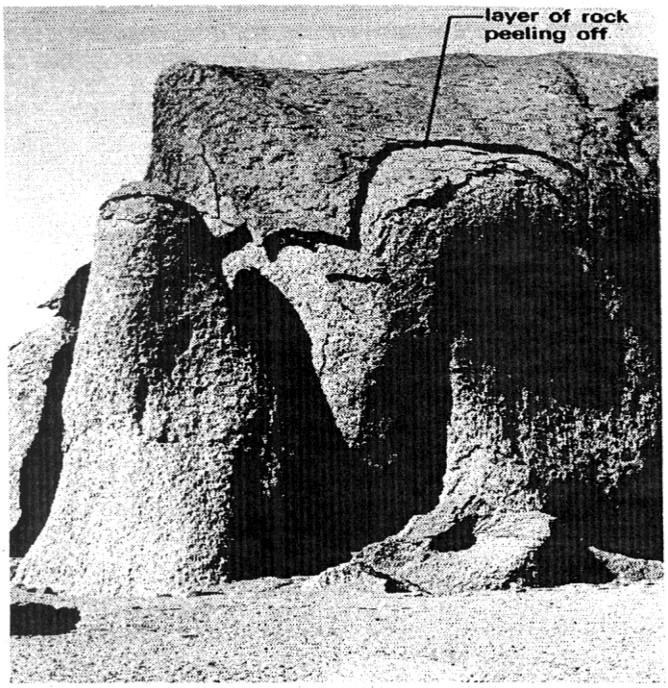


Fig. 4.1 Exfoliation causes thick layers of rock to peel off the sides of desert rocks in Mauritania.

The separated plates fall to the ground and are themselves broken into smaller pieces by forces of alternate expansion and contraction. *By unloading* A large mass of rock formed far low the surface' either as a result of mountain building or igneous intrusion, is compressed by the great pressure of overlying rock. As denudation removes this rock, pressure is reduced and the compressed rock slowly expands causing cracks to develop. This process is called unloading. As denudation continues the rock expands further resulting in large sheets of rock to split away from the main rock body. This process is called sheeting. Eventually a dome-like landform called an exfoliation dome (Fig. 4.2) is produced.

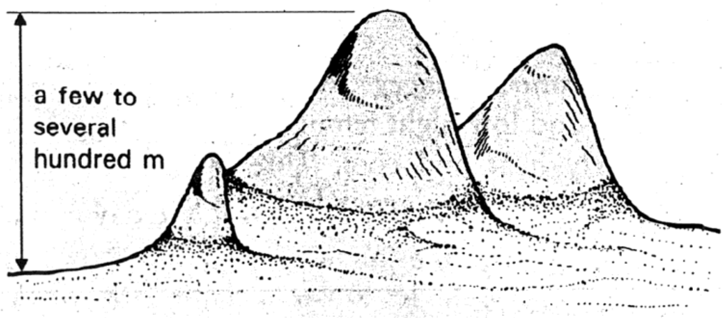


Fig. 4.2 Mounds of rock fragments formed by physical weathering cover the lower slopes of these exfoliation domes

Mechanical weathering takes place at the same time as unloading and sheeting operate and it plays an important part in breaking down the sheets of exfoliation domes into mounds of rock fragments. The mounds accumulate on the lower slopes of the domes. These mounds are called talus, or sometimes scree, but the latter term is better used for angular rock fragments produced by frost action (Fig. 4.4). The mound of rock fragments at the foot of a dome-shaped volcanic plug in the Hoggar Mountains is shown in Fig. 4.1. This is a mound of talus.

There are examples of exfoliation domes in both hot deserts and humid temperate regions. Excellent examples occur in granite masses of Yosemite National Park in the U.S.A. Exfoliation domes also occur in monsoon regions where temperatures and rainfall are ‘high. At one time, exfoliation domes were thought to be the product of rock breakdown through temperature change. While temperature changes play an important part in rock breakdown, it is the process of unloading through pressure release that is responsible for sheeting which is

Note: A large mass of coarsely grained igneous rock can become dome-shaped by granular disintegration. This is the break-up of a granular rock into its separate grains by the absorption of water which causes various minerals to expand and contract at different rates. Because the rock does not have well-developed joints, exfoliation plates do not form, and such a dome is not a true exfoliation dome. Sugar Loaf Mountain of Rio de Janeiro has been formed by granular disintegration.

the characteristic feature of exfoliation domes.

By frost action when water freezes its volume increases. Most rocks contain cracks, and joints. When water enters these and freezes, a tremendous pressure is applied to the sides of the cracks. Repeated freezing and thawing (melting), causes the cracks to get wider and deeper. In time, frost action breaks down rocky outcrops into angular blocks which later break down into smaller fragments. These fragments pile up at the bottom of the slopes to form fan-shaped mounds, called screes. Fig. 4.4 shows screes at the foot of a mountain in the Lake District of England.

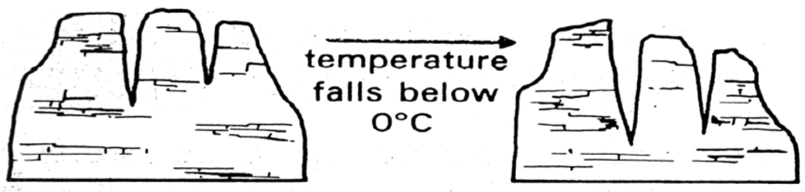


Fig. 4.3 Freeze-thaw action operates in rock cracks.

Frost action occurs in both arctic and cool temperate regions, but it is most marked •in the latter. This is because repeated freezing and thawing is far more common in these regions than it is in arctic regions where water in the rocks tends to be frozen for many months of the year.

Frost action also takes place in some regions in the tropics which have sufficient altitude, including hot deserts, and it is possible that it plays a part in the process of exfoliation.

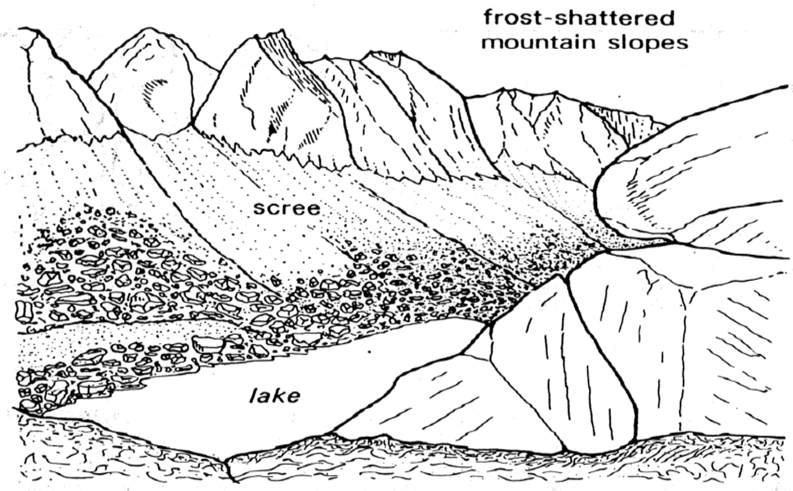


Fig. 4.4 Mountain slopes in the mountainous country known as the Lake District, in north-west England. Screes, consisting of angular rocks, litter the lower slopes. The screes result from frost action on the higher slopes.

Some rocks, especially well-jointed rocks, break down into large rectangular-shaped blocks under the action of mechanical weathering caused by alternate heating and cooling, aided perhaps by frost action. When rocks break down in this manner, it is called block disintegration (Fig. 4.5).

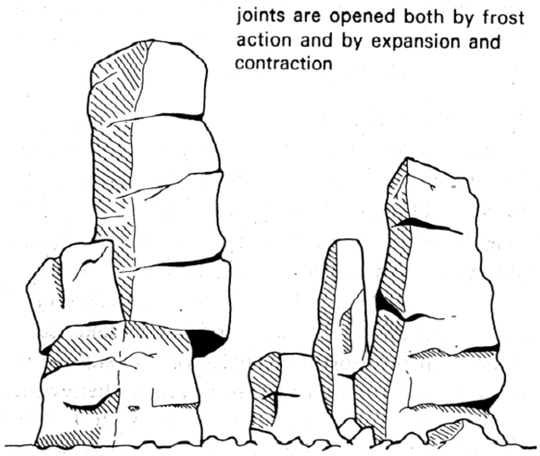


Fig. 4.5 Block disintegration

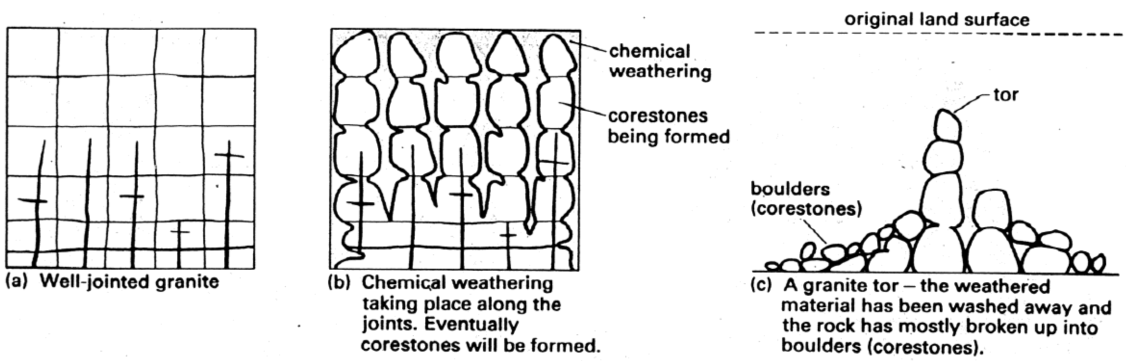


Fig. 4.6 The formation of a granite tor. Unweathered rounded lumps of granite called corestones form a conspicuous feature of a tor

By alternate wetting and drying, all rocks absorb a certain amount of water, but some absorb more conspicuous than others. The absorption of water by surface rocks causes them to swell. When the rocks dry out (and they do this quickly in tropical regions), the outer surface of the rocks shrinks. The alternate wetting and drying weakens the rocks and they begin to crack. This type of physical weathering takes place along the coast, especially on coastal rocks which are alternately wetted and dried with the rise and fall of the tide.

Do You Know?
Question: Explained Weathering with Example
Let’s say you have made your favourite chocolate cake and left it outside. What would happen? May be it would dry up and crack in the hot sun. Or perhaps rain would wash it away. If it froze, it might crake too. This process would probably take just a few days. The earth- and the rocks on the earth is a bit like that cake. The surface of the earth is constantly being changed due to weathering processes. This process can take millions of years or happen relatively quickly.

4.5.2 Chemical Weathering

Some rocks decompose when they come into contact with water (H_2O), or oxygen (O_2) and carbon dioxide (CO_2), two of the gases which make up air. Some minerals in rocks undergo chemical change with water and air, and when this happens, they may be removed from the rocks which results in the rocks being reduced in size, and thus weakened.

Chemical reactions take place on the surface of exposed rocks but they tend to be greater below the surface. They can operate to depths of 200 m or more where water is able to enter via pores, joints and cracks. The upstanding granite masses of Dart- moor and Bodmin Moor, known as tors (Fig. 4.6) have been formed in this way. The action of physical weathering is to break up the surface rocks which results in an increase in the surface area thus making it possible for chemical weathering to be more effective.

When water enters the soil it combines with various acids derived ‘from decomposing organic matter in the soil. The amount of rock disintegration that soil water can effect depends on the corn position and strength of the soil water; the temperature; the minerals dissolved in the soil water and the presence of soil bacteria

Chemical weathering consists of five processes: solution, hydration, hydrolysis, oxidation and carbonation.

- **Solution:**

Only a few minerals are directly soluble in water, but some, especially calcium carbonate, are freely soluble when carbon dioxide is dissolved in water. Rain dissolves both carbon dioxide and oxygen as it falls through the air, so that when it reaches the ground it consists of very weak acid, called carbonic acid. This acid helps to turn many insoluble minerals into minerals that are soluble in water, and which can then be carried away in solution.

In the chemical weathering of limestone rocks, solution causes the joints to become widened and deepened, and on the surface, deep grooves called grikes develop. The grikes are separated by flat- topped ridges, called clints (Fig. 4.7).

Soil water in humid tropical regions often dissolves all minerals except the very stable ones such as iron and aluminium hydroxides. Aluminium hydroxides (bauxite) and iron hydroxides (laterite) get left behind in the top layers of the soil through the process of leaching (downward movement of water containing dissolved minerals, in the soil). Laterites develop best in regions which have a definite dry and wet season. Bauxite is the main source of aluminium.

- **Hydration:**

Some minerals absorb water and in doing so they give rise to new compounds. •For example, haematite, an iron oxide, combines with water ‘to give limonite, another iron compound.

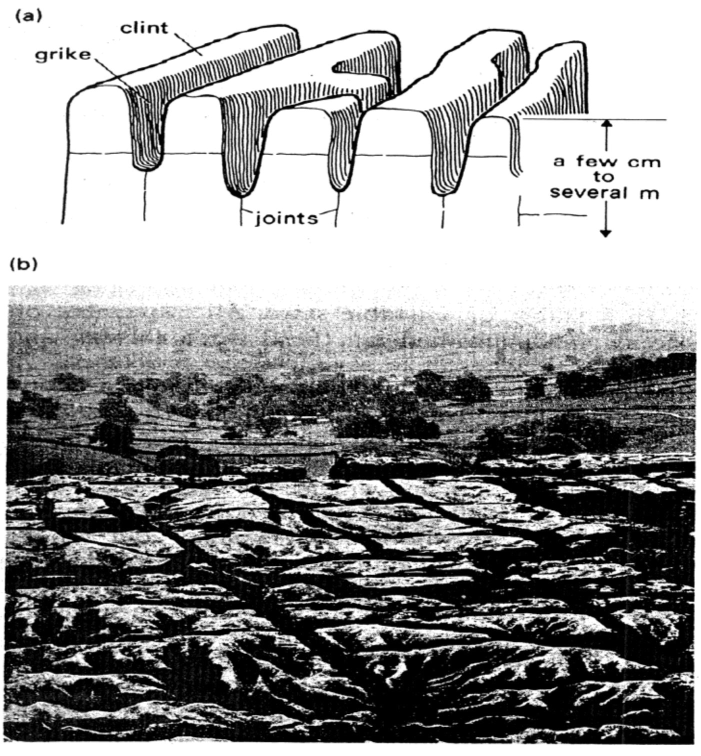


Fig. 4.7 (a) The effects of weathering on the surface of limestone rock; (b) limestone pavement showing grikes (grooves) and clints fridges) near Maiham in Yorkshire.

Another example is the absorption .of water by calcium sulphate to give gypsum. Some hydrated minerals are soluble in water, whereas the minerals from which they are formed are insoluble. Sometimes hydration produces new compounds which are of greater bulk; this again weakens the structure of the rocks.

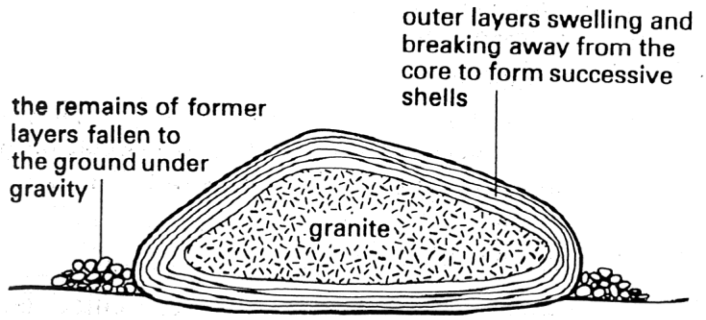


Fig.4.8 Sectional view of a granite boulder showing spheroidal weathering

- **Hydrolysis:**

In this process hydrogen (from water) combines with certain metal ions (from minerals) to form different chemical compounds. Hydrolysis is therefore quite different to hydration e.g. the hydrolysis of potassium feldspar produces kaolin. Hydrolysis causes some rocks to decay to as much as 100 m below the surface, especially in warm humid climates. The tors of Dartmoor experience sub-surface decay as does Bismarck Rock in Tanzania.

Hydrolysis may also produce a type of exfoliation called spheroidal weathering (Fig. 4.8) in fine— grained rocks such as basalt. Weathering attacks the rocks from all sides and. under some climatic conditions it occurs below ground level. In hot humid climates granite weathers to depths of 80 m through spheroidal weathering. In time the granite is turned into a mass of rock particles which contain unweathered, rounded lumps of granite called corestones (Fig. 4.6). Eventually, these become exposed on the surface as the weathered rock mass is removed by erosion.

- **Oxidation:**

This happens when oxygen combines with a mineral. Oxidation takes place actively in rocks which contain iron, .when the oxygen combines with the iron to form iron oxides. Hydrolysis often precedes, and accompanies, oxidation. The new minerals formed by oxidation are often easily attacked by other weathering processes. The structure of a rock in which iron and a silicate are joined, is completely broken down by oxidation of the iron.

- **Carbonation**: This process involves the combination of carbonate or bicarbonate ions with a mineral which produces a soluble compound that is carried away in solution. For example, potassium hydroxide reacts with carbonic acid to give potassium carbonate, which is soluble, and water. Hydrolysis often accompanies carbonation. For example, hydrolysis and carbonation break down feldspar into clay, soluble carbonate and silica.

Note: Usually two or more chemical weathering processes take place at the same time. Chemical weathering is most marked in hot, wet regions.

4.5.3 Biotic Weathering

The roots of plants, especially trees, can force apart joints and cracks in. rocks as shown in Fig. 4.9. In addition, the roots of some plants produce chemicals which cause weathering of the rocks. This chemical weathering is sometimes more extensive than rock break-up caused by root pressure.

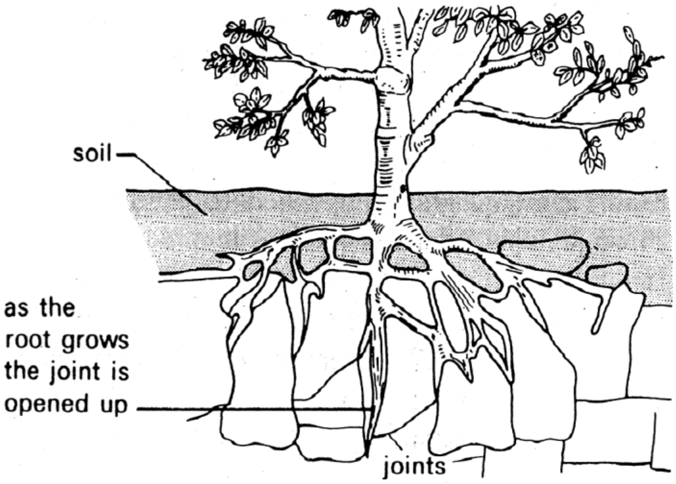


Fig. 4.9: The roots of plants, especially trees, can sometimes help to open the cracks and joints in rocks

Burrowing animals such as the earthworm and rabbit also effect a considerable break-up of surface rocks, while micro-organisms such as bacteria cause both physical and chemical breakdown of rocks. The action of these organisms overlaps with chemical weathering because some organisms exclude chemicals during their digestion or as they move about.

4.6 GEOMORPHIC IMPORTANCE OF WEATHERING

Weathering is a critical base to our ecology, and our existence depends on it, the continents would be bare hard rock, for no soil cover could develop, consequently, earth would be devoid of plants and animal life, weathering produces soil on which agriculture depends, weathering produces some other very practical products. Sand, gravel, and clay deposits, which we use so much are the indirect results of weathering. The weathered materials are very important economically because they help in the process of soil formation. Weathering also generates mass movement of rocks waste down the hill slopes and thus causes damage to human settlements in the foot hills zones, causes obstructions in the river flow and thus forms lakes.

Weathering breaks down a rock into their mineral components. It also creates new compounds through chemical changes. During the prolonged period of time, the weathering processes produce concentrations of valuable mineral ores of iron, manganese, tin, aluminium and uranium etc. for example, by chemical weathering soluble bases and even silica are removed, leaving behind increasingly rich residual concentrations of metallic oxides. This occurs under humid tropical climatic conditions as part of laterization process.

Differential weathering helps in the evolution of different types of landforms. It play an important role in the development of stone lattice, tors, buttes, talus cones, sand stone anvils etc. landforms.

Project Work

Depending upon the topography and materials around you, observe and record climate, possible weathering process and its landforms.

4.7 EROSION: MEANING AND CONCEPT

Erosion refers to the term referring to those processes of denudation which wear away the land surface by mechanical action of the debris which is being transported by the various agents of erosion (glaciers, winds, river, ocean waves and currents). The process of erosion must be distinguished from those of weathering in which no transport is involved. Thus, erosion is not synonymous with denudation as is commonly supposed, but merely part of it. For erosion to occur the agent must be capable of exerting a force on land surfaces greater than its sheer strength.

The main agents of erosion are; (i) running water, (ii) ground water, (iii) wind, (iv) glaciers and (v) sea waves. These are also the agents of transportation and deposition. Each of these agents does erosion by a distinctive process and gives rise to distinctive landforms.

4.7.1 Erosion Process: Different activities which take part in the process of erosion are.

1) Abrasion and Corrosion: when any agent of erosion moves ahead loaded with sand, pebbles and fragments of rocks, the rocks coming in contact of these particles are degraded by the friction. This process is known as Abrasion.
2) Attrition: when the particles flowing with an agent of degradation get reduced in their sizes due to manual friction, the process is known as attrition.
3) Corrosion: when soluble rocks like dolomite, limestone, chalk etc. are separated from the rocks by the action of water, the process is called corrosion. Corrosion occurs mainly, by the action of underground and flowing water. The activity results into the formation of Karst topography.
4) Hydraulic Action: when rocks are broken into pieces by the action of fast flowing water, the pieces by the action of fast flowing water, the process is known as hydraulic action. Hydraulic action is carried out by glaciers, rivers and sea waves.
5) Water Pressure: when any rock is eroded by the pressure exerted by water, it is called water pressure activity. This is, mainly, carried out by sea waves.

6) Plucking: this occurs by the action of glaciers. In this process, the glacier drag aong with in the rocks which come on its way, making them weak enough to disintegrated into large fragments.

7) Deflation: this is process by which wind removes or blows away the unconsolidated sand, silt and clay from the land surfaces, especially in arid and semi-arid regions.

4.7.2 Factors Effecting Erosion Rate

1) The **climatic factors** that influence erosion are rainfall amount, intensity, and frequency. During periods of frequent rainfall, a greater percentage of the rainfall will become runoff. This is due to high soil moisture or saturated conditions. Temperature also influences the amount of organic matter that collects on the ground surface and incorporates with the topsoil layer. Areas with warmer climates have thinner organic cover on the soil. Organic matter protects the soil by shielding it from the impact of falling rain and soaking up rainfall that would otherwise become runoff.

2) Vegetation is probably the most important physical factor influencing erosion. A good cover of vegetation shields the soil from the impact of raindrops. It also binds the soil together, making it more resistant to runoff. A vegetative cover provides organic matter, slows runoff, and filters sediment. On a graded slope, the condition of vegetative cover will determine whether erosion will be stopped or only slightly halted. A dense, robust cover of vegetation is one of the best protections against soil erosion.

3) Physical **characteristics of soil** have a bearing on erodibility. Soil properties influencing erodibility include texture, structure and cohesion.

4) Slope, length, steepness and roughness affect erodibility. Generally, the longer the slope, the greater the potential for erosion. The greatest erosion potential is at the base of the slope, where runoff velocity is greatest and runoff concentrates. Slope steepness, along with surface roughness, and the amount and intensity of rainfall control the speed at which runoff flows down a slope. The steeper the slope, the faster the water will flow. The faster it flows, the more likely it will cause erosion and increase sedimentation.

5) Tectonic processes control rates and distributions of erosion at the Earth's surface. If tectonic action causes part of the Earth's surface (e.g., a mountain range) to be raised or lowered relative to surrounding areas, this must necessarily change the gradient of the land surface. Because erosion rates are almost always sensitive to local slope, this will change the rates of erosion in the uplifted area. Active tectonics also brings fresh, unweatherd rock towards the surface, where it is exposed to the action of erosion.

However, erosion can also affect tectonic processes. The removal by erosion of large amounts of rock from a particular region, and its deposition elsewhere, can result in a lightening of the load on the lower crust and mantle. Because tectonic processes are driven by gradients in the stress field developed in the crust, this unloading can in turn cause tectonic or isostatic uplift in the region.

4.7.3 Erosion Cycle: Interruption and Rejuvenation

The whole process of the formation of relief features by the endogenetic processes and their deformation by exogenetic processes is called cycle of erosion. The endogenetic forces, such as- diastrophic forces, vulcanicity, earthquakes etc. creates vertical irregularities on the surface of the earth. Mountain plateaus and hills are formed due to upliftment of the surface, whereas due to the subduction of the surface, lakes, trenches etc. are created. As soon as the endogenetic forces form vertical irregularities on the surface of the earth, the exogentic forces starts working as levelling agents and during this process various specific landforms are created.

The 'Cycle of Erosion' is the time required for streams to reduce a newly formed land masses to base-level. The geomorphic cycle is the topography developed during the various stages of a cycle of erosion.

The Scottish geologist James Hutton was the first told about uniformities in the landforms. He told 'present is the key to past'. He told that 'there is no trace of the past as well as endless future'. This concept of James Hutton was carried forward by his followers John Playfair and Sir Charles Lyell.

According to the American Geomorphologist, William Morris Davis, there are sequential changes in landforms through time. This has great impact of Darvin's 'Theory of Evolution' (1889) during these sequential changes, the landform passes through the youth, mature and old stages. Various landforms are the results of the combined effects of the structure of the rocks, agents of denudation (process) and time (stages). Davis coined the familiar phrase; 'Landforms are function of Structure, Process and Stage'. This hypothesis of landforms development is knows as Trio of Davis. According to Davis, Structure means not only the attitude, the nature of the dip of the bed, and their folds and faults, but also the lithology of bed, the nature of the rocks, their relative hardness and their relative permeability. Process refers to various kind of weathering and erosion processes such as physical, chemical and biological, various kind of mass movement and work of running water, wind, ice etc. finally stage means the length of time. The characteristics of each of the stages of landscape developing in running water regimes may be summarized as follows.

- **Youth:** streams are few during this stage with poor integration and flow over original slopes showing shallow V-shaped valleys with no flood plains or with very narrow flood plains along the streams. Streams divides are broad and flat with marshes, swamp and lakes. Meanders if present develop over these broad upland surfaces. These meanders may eventually entrench themselves into the uplands. Waterfalls and rapids may exists where local hard rock bodies are exposed.

- **Mature:** During this stage streams are plenty with good integration. The valleys are still V-shaped but deep; trunk streams are broad enough to have wider flood plains within which streams may flow in meanders confined within the valley. The flat and broad inter stream areas and swamps and marshes of youth disappear and the stream divides turn sharp. Waterfalls and rapids disappear.

- **Old:** Smaller tributaries during old age are few with gentle gradients. Streams meander freely over vast flood plains showing natural levees, oxbow lakes etc. divides are broad and flat with lakes, swamps and marshes. Most of the landscape is at or slightly above sea level.

Any type of obstacles in the normal process of cycle of erosion is called interruption of cycle. The main cause of interruption of cycle may be either climatic or tectonic or both. The interruption in cycle of erosion caused by positive movement of base level shortens the cyclic time as it advances forward the stages of cycle of erosion. For example, if the cycle is in the mature stage, it may advance to the youth stage and start on a new cycle. These interruptions can be cause by volcanic, climatic or changes in base level.

Rejuvenation means increase in the erosion power of the fluvial processes river action) caused by numerous factors. Rejuvenation takes place with the relative uplift with respect to sea level of a region which has developed a mature drainage system. The rejuvenation may be caused from a fall in base level, an increase in stream discharge and fall in sea level or an upliftment of land.

According to Davis, Geographical Cycle of Erosion is the period of time during which an uplifted landmasses undergoes its transformation by the process of land sculpture ending into a low, featureless plain- a peneplain. The convex-concave landforms, which remain as residue after the completion of the cycle of erosion are termed as monadnocks.

The German scientist Walter Penck criticised the Davidian model of geographical cycle based on time dependent series of landform development and presented his own model of 'morphological System'. He held that the landform are the result of the intensity of endogenetic processes (the rate of upliftment) and the magnitude of displacement of materials by the exogenetic processes (the rate of erosion and removal of materials). Penck used the term Primarumpf for the upliftment landform. He called the final landform created after the complete cycle of erosion endrumpf.

4.8 ASSOCIATED LANDFORMS

Erosional processes from different various agents' leads to develop many types of landforms in different areas. It can be classified under these head, which is given below in fig. 4.11.

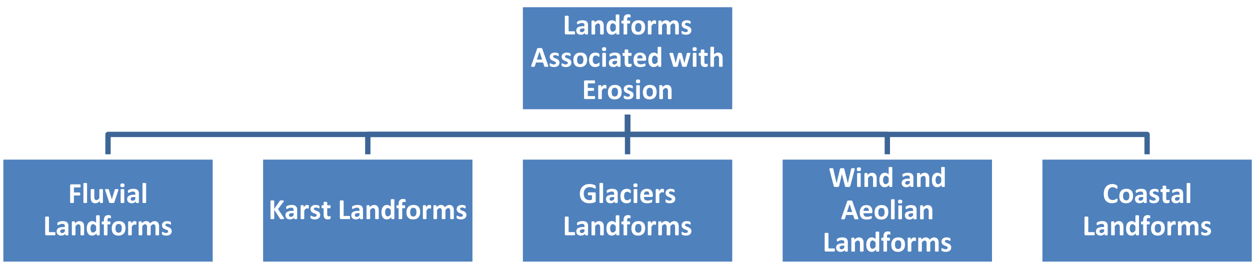


Fig 4.11: Landforms associated with different agents of erosion
Source: Compiled by Author

Table 4.1: The Exogenetic Forces and the Landforms Carved by them

S. No	Agent	Action	Erosional Landforms	Depositional Landforms
1.	Running Water (River)	Attrition, Abrasion, Hydraulic action, Corrosion,	V- shaped Valley, I-Shaped Valley (Gorge or Canyon), Waterfall and Rapids, Meanders, River terraces, Structural Benches, Peneplain, Pot holes	Alluvial Fan, Alluvial Cones, Natural Levees, Flood plains, Delta, Sand Banks, Sand bars
2.	Glaciers	Abrasion, Plucking	U-Shaped Valley, Hanging Valley, Cirques, Aretes, Horns, Nunataks, Roche Mountonnees, Tarn, Fiords, Crag and Tail, Whaleback, Rock Drumlin, glacial stairways, trough lakes, Bumps and Depressions	Moraines, Morainic ridge, drumlins, Eskar, Kames, Kettle, Kettle holes, Outwash Plains, Hummocks
3.	Wind	Deflation, Abrasion, Attrition	Blow out or Deflation Basin, Inselbergs, Mushroom Rocks or Pedestral Rock, Demoiselles, Zeugens, Yardang, Dreikanters, wind Window, Stone Lattice, Ventifacts	Sand dunes, Ripples marks, Barchans, Seif, Sand free corridors, Reg or Hammada, Loess, Bajadas, Playas, Pediments, Bolsons
4.	Sea Water	Hydraulic action, Abrasion, Attrition, Corrosion,	Cliffs, Loves, Caves, Stacks, Chimneys, Arch, Inlets, Wave-cut platforms, indented coastlines, Blow holes, Pillars, Columns	Beaches, Bars and Barriers, Off-shore and longshore bars, Spits, Hooks, Loops, Connecting Bars, Looped Bars, Tombolo, Barriers, Tidal Inlets, Winged head lands, progradation, wave built platform
5.	Ground Water	Corrosion, abrasion, attrition, Hydraulic Action	Lapies, solution holes, sink holes, dolines, poljes, uvalas, James Cockpits, Collapse Sinks, Blind Valley, Karst Valley, Natural Bridge, Ponores, Caves	Traversins, stalactites, stalagmites, Cave Pillars, Drapes, Helicites, Heligmites, Flowstones

Source: Compiled by Author

4.8.1 Glacial Landforms

Glaciers: The moving ice mass down slope under the impact of gravity is called glacier. They are formed due to accumulation of snow above the snowline. Snowline is generally defined as a zone between permanent and seasonal snow. Snow line denotes that height above which these is a permanent snow cover and thus it corresponds to the level where average temperature is always below freezing point even during the warmest month of the years.

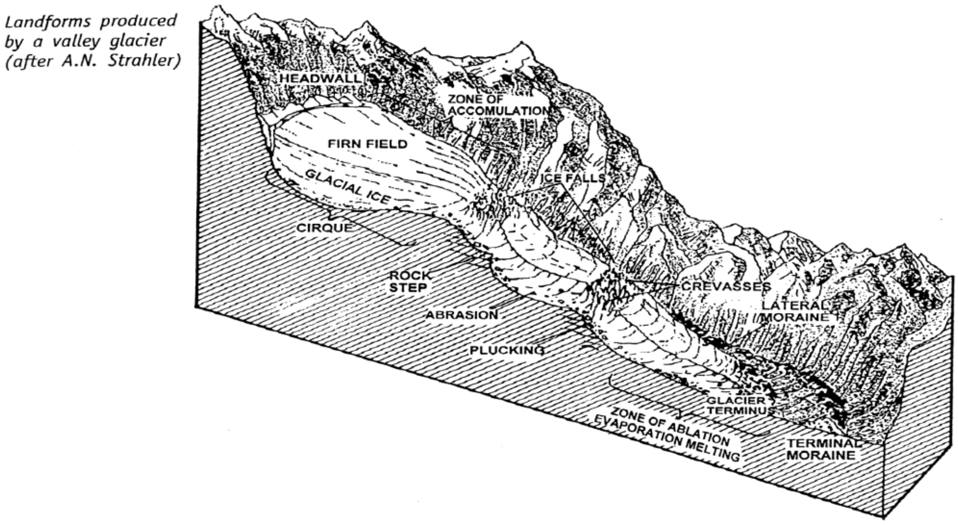


Fig 4.12: Landforms produced by a valley glacier (after A.N. Strahier)

Glaciers are the snow moving rivers of snow or ice. They formed on high mountains are long and narrow because they are formed in an abandoned river valley. These are known as valley glaciers. When the ice mass spreads over a large are, it is called continental glaciers.

The small ice-sheet covering the peaks of the mountain and from which glaciers originates, is known as ice-cap. The dome shaped ice masses spreading generally over the plateaus are known as ice-sheet. The floating ice masses are termed as ice-bergs.

Glaciation generally gives rise to erosional features in the highlands and depositional features on the lowlands, though these processes are not mutually exclusive because a glacier plays a combined role of erosional, transportation and deposition throughout its course. The main features of glaciated highlands are as follows:

Surface Features of Glaciers

In the winter, when glaciers are covered deeply with snow, their surfaces are smooth or rolling and offer little difficulty to properly equipped exploration parties, but in late summer everything may be changed. Crevasses and surface drainage make travel difficult, dangerous and often impossible over very large glaciers. Some of the surface features of glaciers are: (i) the snout (tung), (ii) the firn or neve, (iii) the randkluft, (iv) crevasses, (v) ice-fall, (vi) seracs, (vii) foliation and ogives, (viii) the surface of the glacier, (ix) bergschrund, (x) ice pedestal, (xi) dust-well, and (xii) drainage.

Erosional Landforms of Glaciers

Valley glaciers are powerful erosive agents. The great weight of the moving ice, together with the abundant abrasive tools, helps these glaciers to do tremendous erosional work. Some of the important erosional features have been described as under:

- **Glaciated Valleys:** A glacier modifies the former V-shaped valley into a broad U-shaped valley. Unlike youthful, stream-cut valleys, glaciated valleys have broad floors and relatively smooth, over-steepened sides. The valley floors and lower borders are smooth, littered with debris, deposited during the last retreat of the ice. In most glacial valleys, there are swamps and lakes whose basins were gouged out of the bedrock or were formed by moraines.
- **Hanging Valleys:** The tributary valleys of a glacier are known as hanging valleys. A valley formerly occupied by a tributary valley glacier, which because of its small size, failed to deepen the originally accordant tributary valley at the same rate as the main glacier deepened the main valley. After deglaciation these tributary valleys were left high above the main valley floor, and any drainage they now possess reaches the main valley stream by means of a waterfall. In other words, where great trunk valley glaciers are fed by tributary glaciers, the latter usually come in well above the main valley floors. After the ice of both valleys melts, the tributary valleys hang high above the main ones. Often steep cliffs, which separate the mouth of the tributary from the main valley floor, give rise to beautiful waterfalls. In a drainage basin hanging valleys may occur at any elevation, from a few metres to more than 300 metres above the main valley.
- **Cirques:** 'Cirque' is a French term which has been universally adopted to describe a glacially eroded rock basin with a steep headwall and steep sidewalls, surrounding an armchair-shaped depression. The latter may be occupied by a cirque glacier or a small lake (tarn). If the lake is missing, the cirque floor is composed of ice-polished rock slabs, although these may be buried by moraines. The areas of cirques vary greatly, depending on the size of the snow banks that fed the original glaciers. Some embrace only a few acres, others cover many square kilometres (Fig. 4.13).

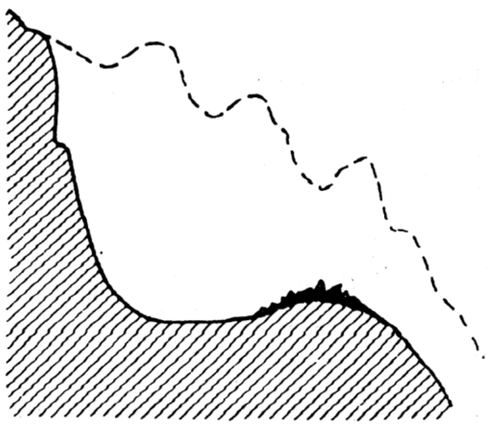


Figure 4.13: Longitudinal section of a glacier corrie

It has been suggested by some of the geomorphologists that cirques developed mainly from pre-glacial fluvially created hollows in highland terrain. These were slowly enlarged by snow-patch erosion (nivation) in which melt water removed the disintegrated rock. It is suggested that the hollow became occupied by a small glacier, setting in motion the freeze-thaw process along the backwall, which progressively retreated and became over-steepened by basal sapping. The rotational slip of the glacier deepened the cirque floor by the process of corrasion, leaving a rock bar or lip across the mouth of the cirque. Thus, the overall dimensions of the glacially eroded hollows have tended to increase and although they vary greatly in size, they generally maintain similar proportions with a length to height ratio of 3:1. Cirques are also called as coire, corrie, cwm, and lear.

- **Horns:** Through headward erosion of the cirque walls, glaciers tend to remove divides. If three or more glaciers cut headward until their cirques meet or almost meet, it often happens that high, sharp-pointed, steep-sided peaks called horns, or matterhorns (after the famous matterhorn In the southern Alps) remain as the only remnants of the original broad highlands. Many such peaks still have glaciers at their bases which remove the debris loosened and dropped onto them by frost action, and thus perpetuate the steep cliff.
- **Cal:** A mountain pass leading from one valley to another.
- **Aretes:** A French term which has been widely accepted to describe a narrow, rocky and often jagged ridge which divides the steep walls of two adjacent cirques.
- **Serrated Ridges:** Another typical feature of glaciated regions is the serrated or saw-toothed ridge, which stands between the heads of present glaciers or between the heads of cirques once occupied by valley glaciers. These ridges, in many cases only one or two metres wide at the top and of extremely irregular surface, are all that remains of broad preglacial divides. Due to the headward sapping of their cirque walls, the glaciers have nearly removed their divides. The narrow ridges continually lose boulders through frost action and gravity. Uplifted sedimentary- and metamorphic rocks may be so greatly eroded that it is impossible for a person to travel over the ridge.
- **Nunataks:** A nunatak is a rock mass surrounded by ice. It may separate two valley glaciers or two lobes of ice sheets. It stands out as an island in the ice. Through lateral erosion by the glaciers, accompanied by frost action, avalanches, etc., the nunatak is soon worn away until a very narrow ridge, merely a remnant of its former size remains.
- **Shifting Divides:** When there is greater precipitation on one side of a mountain range than on the other, or due to less melting and evaporation on the side that receives heat from the morning sun, or due to snow-blown from the windward to the leeward side of a range, a larger number of glaciers may form on one side, with few or none on the other. Where this condition exists, divides will shift through headward erosion towards the side of the range where there are the fewest number of glaciers. This is known as shifting divide in the glacial topography. The crest of Karakoram Range, Zanskar Range, and the Sierra Nevada Range have been shifted to the east.

Lateral as well as headward divides may be shifted in similar fashion, especially by the sideward sapping of cirque wall.

- **Fiords:** Among the most beautiful of all glacial features are the drowned glaciated valleys known as fiords. These are long, steep-sided coastal inlets which have developed as a result of intense glaciation of a previously existing river system in a mountainous area near sea. Valleys were first guided, and then over-deepened, by the ice, until in many cases the fiords were well below sea level. Fjords typically have a threshold (or rock) at their seaward end, which is probably the site of the terminal moraine, or the result of a decrease in the ice's erosive power as it reaches the sea. Fjords occur extensively in New Zealand, Norway, Chile, Labrador, Greenland, British Columbia and Alaska. These long, straight or broadly curved valleys are now filled with sea water, in some cases as much as 2,000 to 3,000 metres. Their glacial origin is plainly indicated by the polished and striated, over-steepened walls, hanging tributary valleys and other characteristic topography.
- **Crag and Tail:** Crag and tail are also the erosional landforms of glaciers. A hill with steep face on one side and a comparatively gentle downward slope on the other, formed where a highly resistant rock mass (the crag) on a valley floor has obstructed the glacier movement and afforded some protection from erosion to the softer sediments (the tail) immediately behind the resistant rock. Alternatively, the resistant rock mass may acquire a tail of glacial debris on its downstream side. The crag portion of these features is commonly a volcanic plug or neck.

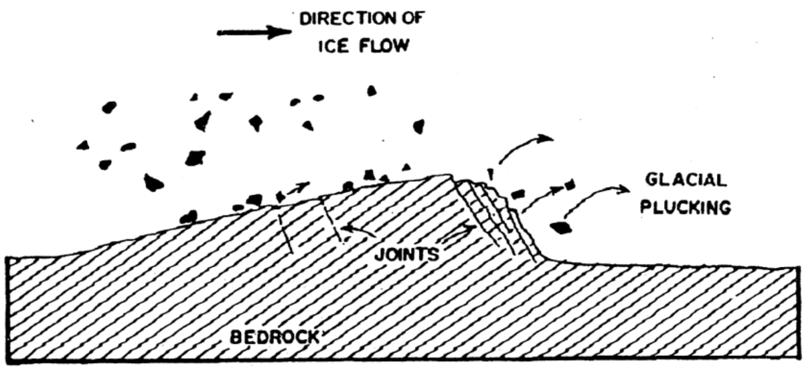


Figure 4.14: Roche moutonnee

- **Roches Moutonnees (French, 'Sheeprocks' from the Similarity to Recumbent Sheep):** It is a glacial erosional feature, consisting of asymmetrical mounds of rock of varying size, with a gradual smooth abraded slope on one side and a steeper rougher slope on the other. They are produced by the action of advancing ice, the smooth slope being on the side of ice advance and the steep face on the lee side, where shattering by ice plucking has occurred. Roches moutonnees commonly occur in swarms, often with a common alignment.

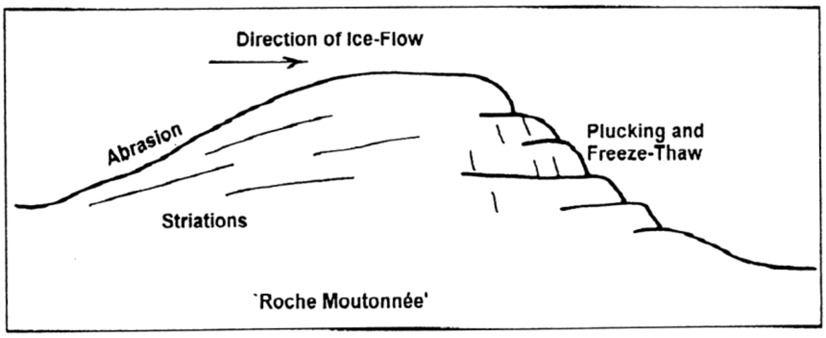


Figure 4.15: A Roche Moutonnee

- **Glacial Stairways (Giant Stairway or Cyclopean Stairs):** One of the most picturesque and puzzling topographic erosional feature of glacier is the glacial stairway. These are glaciated benches, separated by nearly vertical cliffs, all well within 'Roche Moutonnée typically glaciated valleys. Each stair is separated from the other by vertical cliffs measuring 30 to 300 metres.

Depositional Landforms of Glaciers

Glacial deposits are distinctive and seldom need be confused with other types. The debris is usually a mixture of dirt, rock-flour, and sub-angular boulders, unsorted and without stratification. Some of the important depositional landforms of glaciers are described below:

- **Terminal Moraines (End Moraines):** An accumulation of material which has been transported or deposited by ice is known as moraine. A linear ridge of glacial debris, marking the maximum limit of an ice sheet or glacier is known as terminal moraine. Its proximal (inner) slope is usually steeper than its distal (outer) slope, since the former represents the ice-contact slope. The terminal moraines exhibit a characteristic of 'kettle and hummock (low mound of earth)' topography. Lakes and marshes are likely to occupy the depressions (kettles). Large angular boulders are found in terminal moraines.

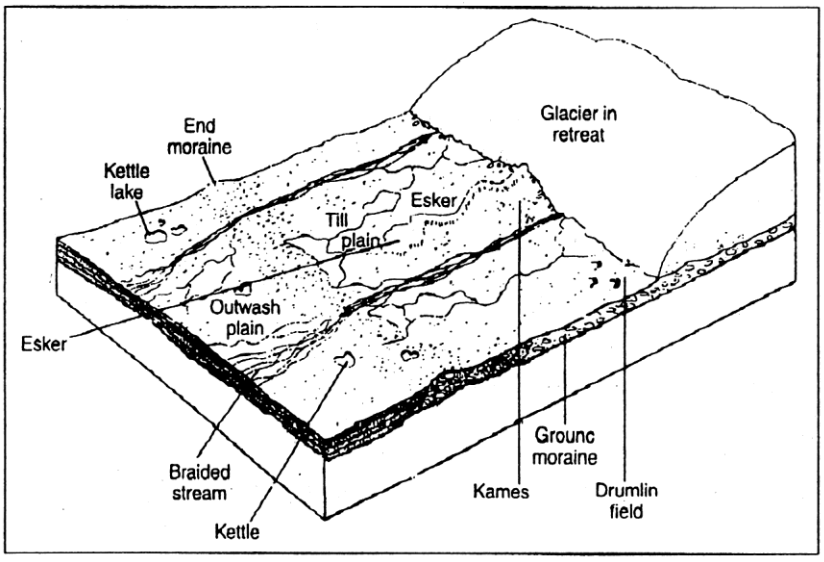


Figure 4.16: Common depositional landforms

- **Glacial Stairways (Giant Stairway or Cyclopean Stairs):** Many of the terminal moraines are partially destroyed by streams that rise within or near the end of the glacier and cut through a low place in the moraine.

- **Lateral Moraines:** A ridge of glacial debris flanking a glacier side or lying along the sides of a valley formerly occupied by a glacier is known as lateral moraine. When ice is present, the lateral moraine may bury under the glacier edge, in which case the debris may protect the ice from surface melting. In this instance the lateral moraine may become ice covered. As a valley glacier downwastes, a series of lateral moraines may be deposited at lower and lower levels down the valley sides. The slopes towards the valley often are remarkably smooth and uniform. The lateral moraines of maximum thickness (350 metres) have been identified in Alaska and Siberia. In many places well-developed lateral moraines join a terminal moraine, thus forming a huge horse shoe-shaped ridge. The composition and structure of the lateral moraine consist of debris—a mixture of dirt, rock-flour and sub-angular boulders which are heaped without stratification. The median moraines are only transient feature of ice surface.

- **Medial Moraines (Median Moraine):** Medial moraine is a linear accumulation of rubbly material extending down the centre of a glacier. It is often ice cored and varies in width from a narrow ridge to a broader spread of morainic material. Medial moraines are caused by the merging of two lateral moraines from the point at which two glaciers unite (ice-cored moraine). They are, however, only transient features of ice surface.

- **Ground Moraines:** Ground moraine is a thick sheet of 'till' forming an undulating surface of low relief. They are deposited when the morainic debris carried in the base of an ice sheet or glacier is released during a phase of melting. It tends to obscure former solid rock.

  In fact, many valley glaciers melt and retreat rapidly after their last advance, leaving an irregular sheet of drift over their valley floors. This debris is called as ground moraine. The thickness and surface topography of the ground moraines varies considerably. Small depressions, knolls, wavy thick belts with scattered boulders, and alluvium deposited by glacial streams are typical features of ground moraines.

- **Sub-glacial Moraines:** Beneath the ice, material which is carried at the base of the glacier and which performs much of the scouring action is known as sub-glacial moraine.

- **Drumlins:** 'Drumlin' is an Irish term that has been widely accepted to describe a streamlined, elongated hummock or whaleback hillock of glacial drift, generally of 'till'. In profile a drumlin has a steeper slope at the upstream end then at the downstream end (in contrast to a roches mouton nee). They commonly occur in swarms in previously glaciated areas of low relief. They were probably formed by a rhythmic moulding action of the ice sheet on newly deposited ground moraine, although no explanation of their origin and occurrence has proved completely satisfactory.

- **Eskers (Osar):** Eskers are long, low, narrow ridges composed of stratified sand, silt and gravel that are found occasionally parallel to the walls of glaciated valleys. They are not to be confused with lateral moraines, which are usually much larger and are always made up of typical till. Eskers are more a characteristic of the continental glacier. Sometimes, a series of swellings are strung along the eskers at regular intervals. Such eskers are called beaded eskers.

- **Kame:** A steep-sided alluvial cone deposited against an ice front. Kames, in fact, are small alluvial cones if deposited on the land or small alluvial deltas if deposited in the lakes. So kames are classified into 'cone kames' and 'delta kames'.

- **Erratics (Boulders):** Erratic is a large rock fragment (boulder) that has been transported by moving ice, away from its place of origin and deposited in an area of dissimilar rock type. The tracing of such erratics back to their sources may yield important information concerning the direction of movement of the ice. It has been suggested that certain erratic blocks found in sediments in circumstances which preclude direct transport by a glacier may have been transported by icebergs, by being attached to giant seaweeds, or as the stomach stones of certain reptiles.

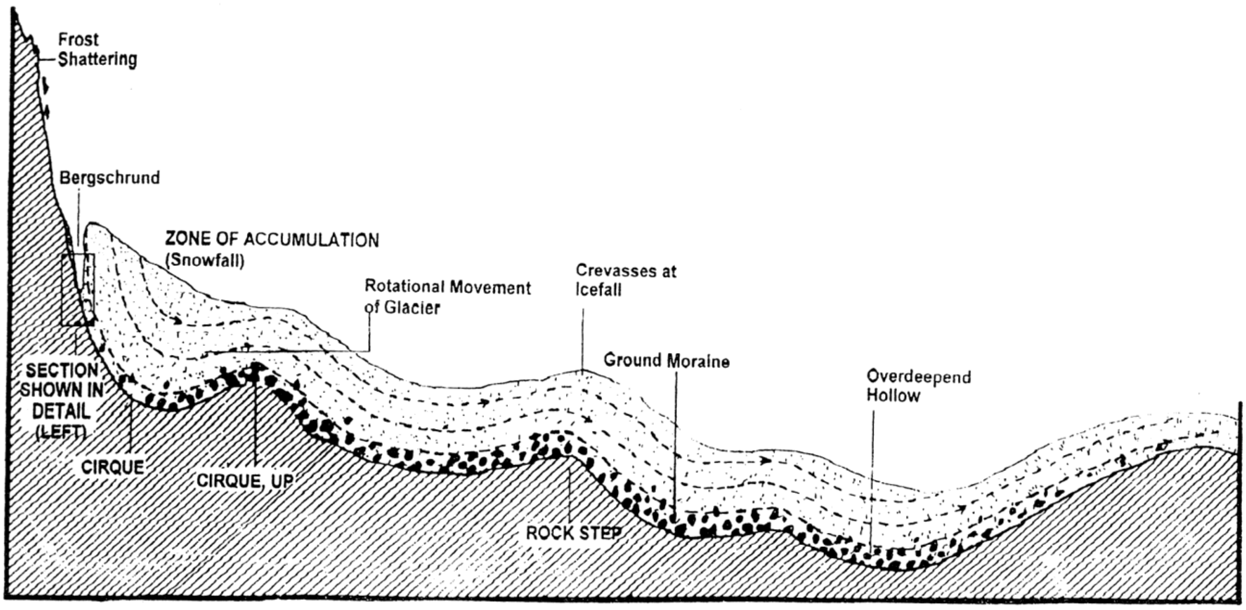


Figure-19.17: Profile of a glacier

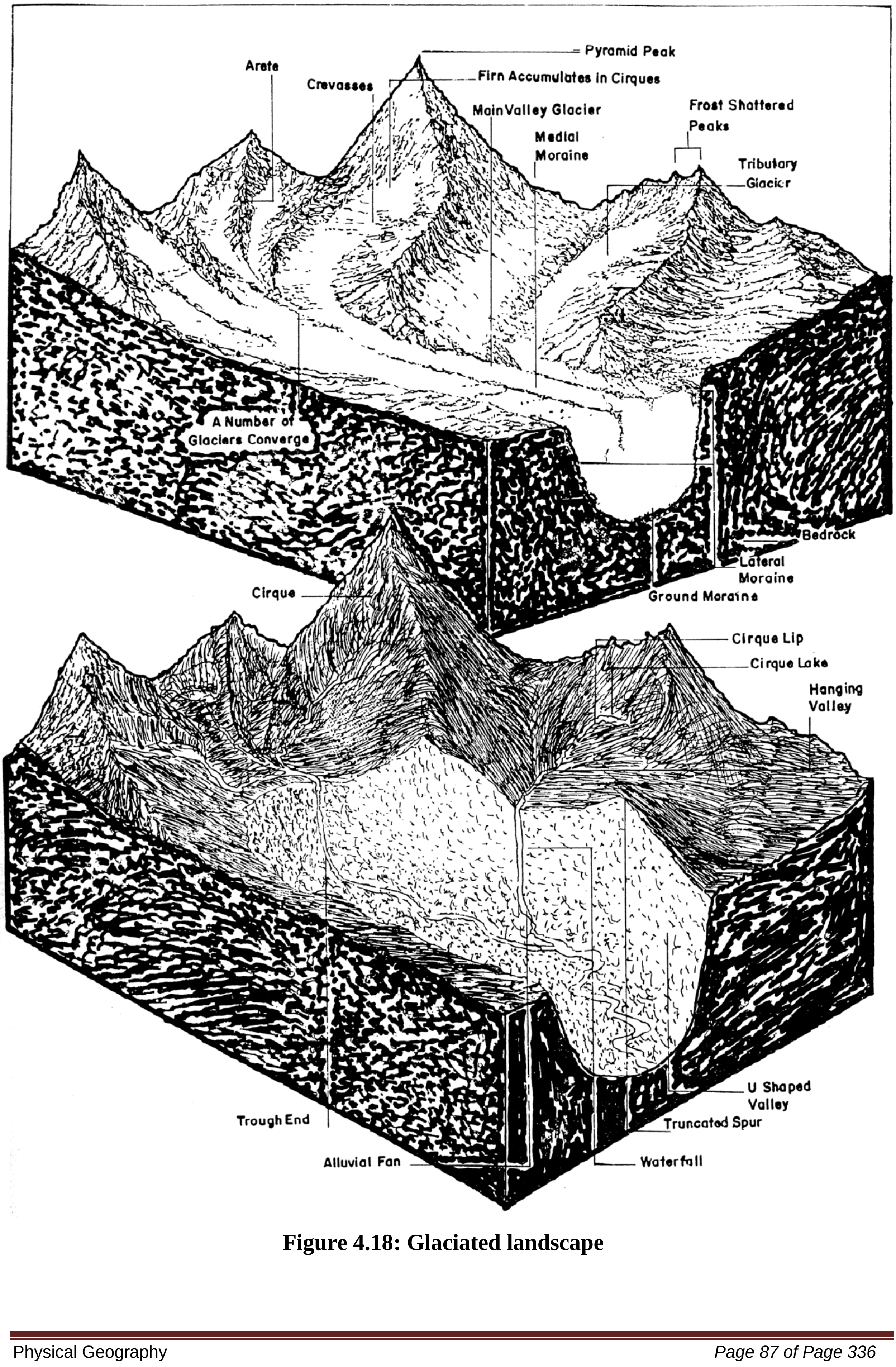


Figure 4.18: Glaciated landscape

- **Outwash Plain (Sandr, Sandar, Sandur):** Outwash plain (sandur) is an Icelandic term which is formed from glaciofluvial material carried out from the front of an ice sheet by meltstreams. Outwash plains appear as extensive accumulations of gravel, sand and silt, crossed by braided streams, in which variations in discharge and debris supply cause alternating periods of net erosion or net accumulation, in part related to seasonal melting and in part to jokulhlaups. Changes in the relative position of the ice front may create ridges or steps across the sandur surface parallel to the ice front and these may represent moraines or ice-contact slopes (Fig. 4.16).

4.7.2 Wind and Aeolian Landforms

The wind is the most active agent of gradation in the arid and semi-arid regions where rainfall is very scanty and the ground surface is covered with loose particles of soil in the absence of both moisture and vegetation cover. The work of wind called eolian (also spelled Aeolian). Wind may be defined as air in motion nearly parallel to the earth's surface. In other words, air in horizontal motion at or near the earth's surface by the sun, which results in difference in air pressure between different areas.

Eolian processes and landforms produced by them characterize the arid regions, where the absence of vegetation not only helps wind erosion, transportation and deposition, but also it enables the resultants landscape to be observed.

Erosional Landforms in Arid Lands

Deflation and abrasion produce a variety of landforms and landscape given below.

- **Blow out-** Blow out depressions are a saucer or though-shaped hollow usually in a sand dune terrain. It is formed by deflation of pre-existing dunes or other loose sand deposits, especially when the protective vegetation cover has been removed or destroyed. The accumulation of sand from the blow out depressions is referred to as a blow-out dune.

  Blow-out depressions range from small indentations of less than a meter upto area of hundreds of meters wide and many meters deep. Chemical weathering is important in the formation of a blow-out. The enormous Quattar depression in the western part of Egypt covers 18000 km^2, and is 130 m below sea level at its lowest point.
- **Desert Pavement-** It is formed by the pebble and gravel concentration left behind after wind deflation and water washes away fine materials, and concentrates and cements remaining rock pieces. Desert pavement protects underlying sediments from further deflation. It has been given various names in other countries. For example, Gibber plain in Australia, Gobi in China and log gravel in Africa.
- **Ventifacts-** Ventifacts are loose stones or pebbles that have been polished and faceted by wind-blown sand in deserts. Rock exposed to wind abrasion appear pitted, grooved, or polished with such characteristics of wind erosion are called Ventifacts. Ventifacts are also called Dreikanter in German, as term used to describe any pebbles or rock boulders that have been shaped by eolian erosion displaying plane faces with three sharp angles or edges bounding them.

- **Yardangs-** Yardangs are sharp-crested elongated ridges aligned in the direction of the prevailing winds in the deserts. The windward face of this feature is rounded, and the leeward extension appears like a long and sharply crested ridge. Its size varies from a few meters to 1 km in length, up to 6 m in height and 35 m in width. There are some yardangs on the earth that are large enough to be detected on satellite imagery. The ice valley of Southern Peru has yardangs reaching 100 m in height and several kilometres in length.

Figure 4.19: Yardangs

- **Zeugens or Rock Mushrooms-** Zeugens is a German term used to describe desert rock pillars, rock mushrooms or such yardangs that are considerably undercut because of differential erosion (abrasion) of their less-resistant beds by wind. Zeugens are characteristics by the presence of a resistant cap-rock, but some are elongated in the direction of the prevailing wind. These landforms are formed by the rocks of varying hardness which are characteristics by horizontal strata. The more resistant cap rocks are attacked by frost action and probably by other agencies which results in the exposure of points of weaknesses in them. Zeugens are also called pilzfelsen. They are known as garas or gours in the Sahara Desert.

Figure 4.20: Zeugen—a weathered rock in Death Valley, California

- **Wind Bridges-** when high velocity strong winds attack a rock again and again, the continuous abrasion results is the formation of holes. Such holes are called wind windows. Further, the combined action of deflation and abrasion makes the wind windows larger and wider which assume an arch-like shape with solid roof over them. Such landforms are called wind-bridges. The rainbow bridge of southern Utah in the Western U.S.A presents a magnificent example of a wind-bridge.

- **Inselberg-** Inselberg is a German term which means an island mountain. This name has been given by German term which means an island mountain. This name has been given by German Geologist to the resistant masses of rock standing above the general surface in the Kalahari Desert. Now, this term has been widely accepted and adopted to describe a prominent steep-sides hill of resistant solid rock rising abruptly from a plain of low relief. It is characteristics of tropical landscape, particularly in the Savanna zone.

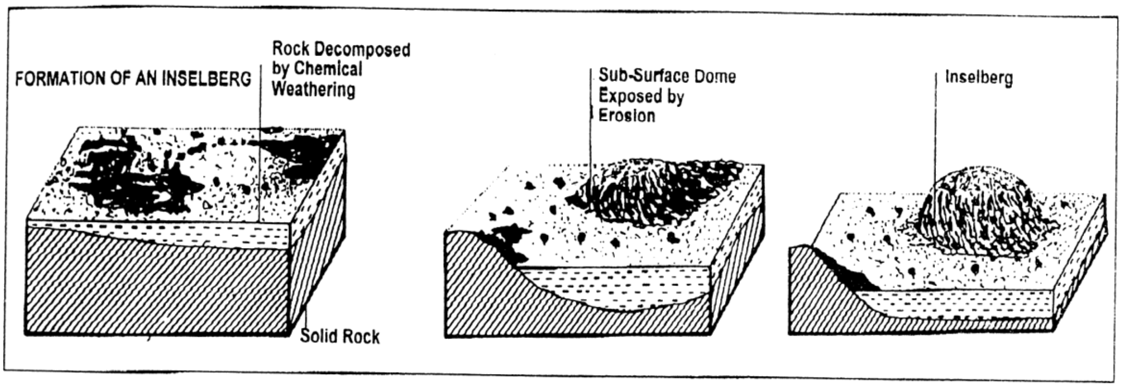


Figure 4.21: Process of formation of an Inselberg

- **Earth Pillars-** It is called a Demoiselle in France. Earth Pillars refers to a column of clay or relatively soft earthly material capped by a boulder which protects it from erosion. Once the boulders fall from the pinnacle, the pillars is soon destroyed. It is found in areas of morain and is also typical of the badland region of the U.S.A.

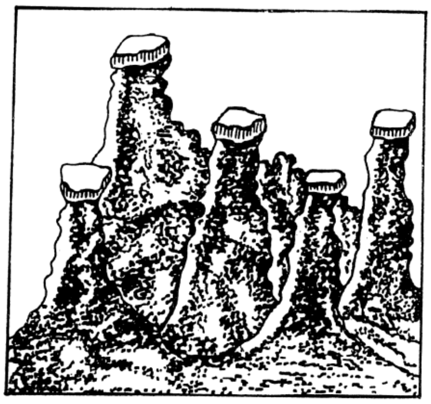


Figure 4.22: Demoiselles

Do You Know?
Question: Wind action is prominent in Desert area. Why?
Wind action can be best seen in the desert areas. Features like sand dunes, Mashroom rocks, etc. are formed by the wind action. Wind acts as an agent of erosion and deposition which leads to the formations of different features. In the deserts we don't find lot of vegetation due to which the wind flows without any disturbance or obstruction. Also, because of the lack of vegetation there is no moisture content in the soil and it is not able to hold itself and becomes very loose (sand). In a wide area with barren land the wind blows with great velocity creating new features especially in the deserts

Depositional Landforms in Arid Region

The following are the main depositional landforms produced by the depositional action of wind in the arid regions.

- **Ripple Marks-** ripple marks are very small features produced in unconsolidated sediments or sand dunes at right angles to the wind direction. They stretch laterally for long distances. Ripples marks are produced where there are some irregularities on the surface. Sand ripples develop transverse to the wind direction. Their wave length is hardly 1 meter. The sand ripples are characteristrized by coarse grains at their crests and finer particles in their troughs. When there are stronger winds, there are no ripple marks on the surface of a sand patch.
- **Sand Shadows and Sand Drifts-** whenever an obstruction fixed in the path of wind checks its velocity, sand particles strikes the obstruction and then fall at its windward base or be swept into the ice of the obstruction, and they accumulate there as a streamlined mound. Both of these landforms are called sand shadows. They are fixed in size and form by the size and shape of the obstruction.
- **Sand Dunes-** The coarser materials are deposited in drifts in the shape of hills or ridges, called dunes. Any mound or ridge of sand with a crest or definite summit is called a dune. An ideal dune has a long windward slope rising to a crest and a much steeper leeward slope. A sand dune may be defined as a mound or ridge of wind-blown sand, rising to various heights upto 50 m. it is found in hot desert and above high-water mark on low-lying coasts where sand is constantly renewed by onshore winds blowing across the sandy beaches. Desert sand dunes are generally characterized by the absence of natural vegetation. For dunes formation certain conditions are necessary such as, (i) a fairly continuous sand supply; (ii) a constant wind strength and direction; and (iii) an obstacle or series of obstacles to trap the sand. Desert dunes are usually formed as wave patterns developed where the air flow interacts with the ground surface to create turbulence with dunes accumulating between the eddies. Sand dunes are undoubtedly the most spectacular features of wind deposition. Sand seas in the Sahara desert are called 'ergs'.

  Sand dunes may be classified as live or fixed. Live dunes change their shape and move further under the effects of the wind. Dunes may also change their shape with the changes in wind direction and strength. Sand dunes also move due to the erosion of their windward slope. Where wind direction and velocity are relatively constant, a dune can move forward while maintaining its form. When wind is not fully loaded with newly acquired sand, it picks up more sand from the windward slope, and drop it over the crest, where it slips down the ‘slip face’. By subtraction of sand from one side and addition to other the dune travels forward. A dune whose shape and position do not change with time is said to fixed. Dunes are generally fixed by vegetation, by the position of wind-breaking obstacles, or by back-and forth movement of the crest due to opposing winds. Stabilized dunes are found along the southern edge of the Sahara Desert. Some basic main type of sand dunes are the following: (i) Barchans (ii) Parabolic Dunes (iii) Transverse Dunes (iv) Longitudinal Dunes (v) Blow-out Dunes

Barchans Dunes: The Barchans are formed where the supply of sand is limited and winds of moderate velocity blow in a constant direction. Typically, they are small, isolated dunes from 1 to 50 m high. The tips (horn) of a barchans point downwind, and sand grains

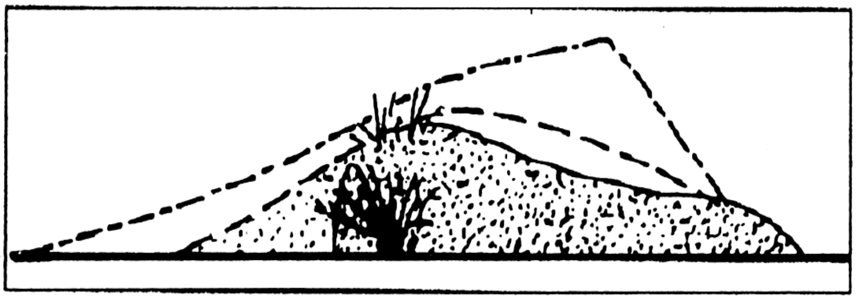


Figure 4.23 Swell turns into barkhan

Table 4.2: Classification of Crescentic Dunes

Class	**Type**	**Description**
Cresentic	Barchan	Crescent-shaped dune with horns pointed downwind. Winds are constant with little directional variability. Limited sand available. Only one slipface. Can be scattered over bare rock or desert pavement or commonly in dune fields.
	Transverse	Asymmetrical ridge, transverse to wind direction (right angle). Only one slipface. Results from relatively ineffective wind and abundant sand supply (e.g. Rub-al-Khali).
	Parabolic	Role of anchoring vegetation important. Open end faces upwind with U-shaped blow out’ and arms anchored by vegetation. Multiple slipfaces, partially stabilised.
	Barchanoid Ridge	A wavy, asymmetrical dune ridge aligned transverse to effective winds. Formed from coalesced Ridge barchans; looks like connected crescents in rows with open areas between them.

Table 4.3: Classification of Linear, Star and other Dunes

Class	Type	Description
Linear	Longitudinal	Long, slightly sinuous, ridge-shaped dune, aligned parallel with the wind direction; two slipfaces. Can be 100 m high and 100 km long. The ‘draas’ at the extreme is up to 400 m high. Results from strong effective winds varying in one direction.
	Seif	After Arabic word for sword’; a more sinuous crest and shorter than longitudinal dunes. Rounded towards upwind direction and pointed downwind.
Star dune	Star	The giant of dunes. Pyramidal or star-shaped with three or more sinuous radiating arms extending outward from a central peak. Slipfaces in multiple directions. Results from effective winds shifting in all directions. Tends to form isolated mounds in high effective winds and connected sinuous arms in low effective winds.
Other	Dome Reversing	Circular or elliptical mound with no slipface. Can be modified into barchanoid forms. Asymmetrical ridge form intermediate between star dune and transverse dune. Wind variability can alter shape between forms.

Source: Christopherson (1995).

- **Loess:** Loess is a wind-blown deposit of fine silt and dust. It is unstratified, non-indurated, calcareous, permeable, homogeneous and generally yellowish in colour. It consists of angular to sub-angular particles of quartz, feldspar, calcite, dolomite and other minerals held together with a montmorillonite hinder. Unweathered bess is usually gray in colour but because of its permeability exposures of unweathered bess are uncommon. The two important sources of bess are the weathered materials in deserts (hot bess) and the very fine powder from regions of glacial outwash (cold bess). The bess deposits are found away from the source regions and outside the deserts. The dust particles of bess are so small that they hold together even when dry and once deposited cannot be easily lifted by the wind. Loess is coherent (bound together) but not cemented and hence is permeable. Lack of stratification is a clear proof of its aeolian origin.

Extensive deposits of bess are found in many parts of the world. Loess covers as much as one-tenth of the world’s land surface and is particularly widespread in semi-arid regions along the margins of great deserts. The bess of China is more than 60 m thick. It is easily eroded and transported in suspension by running water and is responsible for the yellow colour of Hwang Ho and Hwang Hai (The Yellow Sea). Other important areas include East Sudan, North Africa, central U.S.A. and Argentina. The largest known bess deposit is in China. There, caves and houses are carved out of the thick deposits. Much of the bess in North America and Europe appears to have originated by glaciers and deposited as outwash.

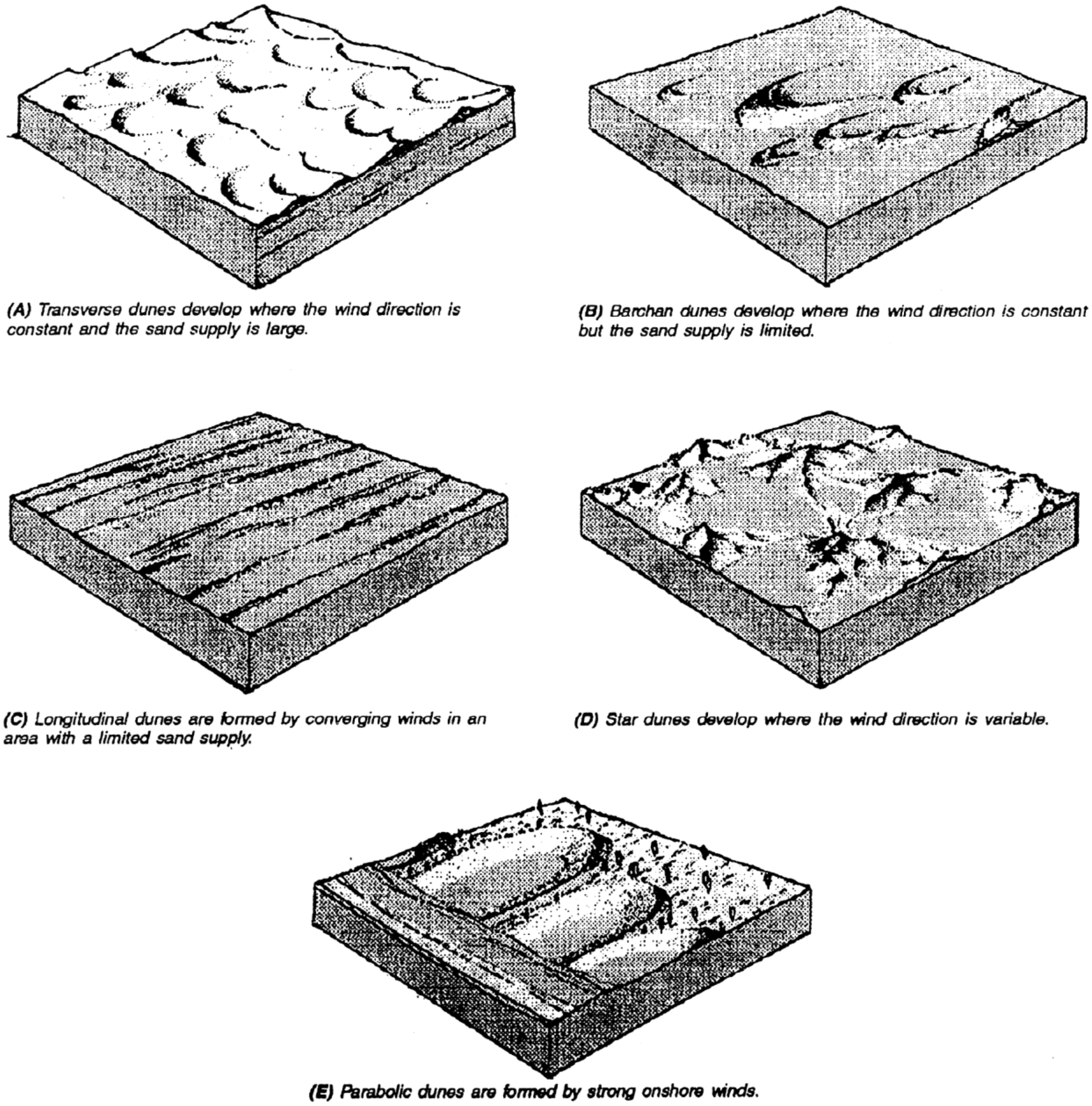


Figure 4.24 Types of dunes (after W.K. Hamblin)

Fluvial Desert Landforms

- **Badland:** Badland is any landscape characterised by deep dissection, ravines, gullies, and sharp-edged ridges which have been created by fluvial erosion on rocks of relatively low resistance occurring in a semi-arid environment. The Chambal ravines present a typical example of badland.

- **Pediments:** A gentle slope, cut in bedrock occurring below a markedly steeper slope and extending at a low gradient down towards a river or alluvial plain is known as pediment. The pediment is separated from the steeper upper slope by a relatively rapid change of slope angle in a transitional zone, termed the pediment zone. The pediment is generally, concave in profile.

- **Bahada (Bajada):** 'Bahada' is a term derived from the Spanish language. It is used to describe the gentle, sloping surface leading down from a mountain front to inland basin in an arid or semi-arid region. It is composed of unconsolidated materials, such as sand, gravel and angular scree, which together mantle the under lyin rock-cut (pediment).

- **Playas:** 'Playa' is a Spanish term referring to a level or almost level area occupying the centre of an enclosed basin in which a temporary lake forms periodically. It is generally composed of stratified beds of clay or silt, deposited within the lake, that usually contain large amounts of soluble salts. The gentle Slopes running down the lake are known as bahada. Lake Lap-Nor is a playa in the Tarim Basin (China). Playa lakes may last for days, weeks or even months before theyare-completely dried up by evaporation.

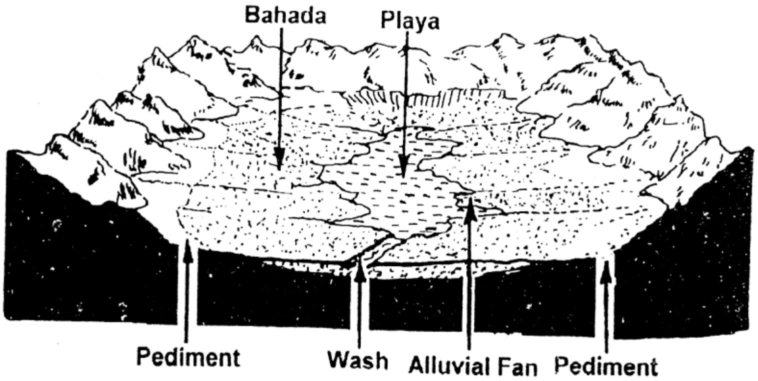


Figure 4.25 Desert landforms Bahada

4.7.3 Fluvial Landforms

When rain falls, part of it sinks into the ground, some is evaporates back into the atmosphere and the rest runs off as rivulets, brooks, streams and tributaries of river that flow down to the sea. This running water forms a potent agent for denuding the earth's surface. The course of river may be divided into three distinct parts. (i) The Upper or mountain course, (ii) The Middle or Valley course, (iii) The lower or Plain Course. Some of the major outstanding features developed in these different course of river are as follows.

- The upper part or mountain course begins at the source of river near the watershed, which is basically the crest of mountain range. The river is very swift as it descends the steep slopes, and the predominant action of the river is vertical corrosion.

River Capture: This is also known as river piracy or river beheading. Its development is dependent on the different rate of back-cutting (headward erosion) into a divide. For instance, if one side of the divide is of greater gradient or receives more precipitation than the other. Its greater erosive power will succeed in enlarging its basin at the eventually break through the divide and capture or pirate stream B. The bend at which the piracy occurred it is termed as the elbow of capture. The beheaded stream is called misfit. The valley below the elbow is wind gap.

Gorges: Gorges is a form of V-shaped valley which is deep and narrow with precipitous rocky walls occupied by a river. It is more steep-sided and enclosed than a ravine. As stated earlier, in the upper course of a river corrasion is greater than deposition. The river, therefore, deepens its channel and forms a valley. If the rocks into which the valley is cut are hard and resistant, the sides or valley walls will be steep and the valley will be narrow. The steepness of the valley walls is also influenced by the amount of rain. It is partly on account of dryness of the climate that the Colorado Canyon is very narrow and its walls are nearly vertical.

Rapids and Waterfalls: these are liable to occur at any part of the river course, but they are most numerous in the mountain course where changes of gradient are more abrupt and also more frequent. Due to the unequal resistance of hard and soft rocks traversed by a river, the outcrop of a band of hard rocks traversed by a river, the outcome of a band of hard rock may course a river to ‘jump’ or ‘fall’ downstream. Rapids are formed.

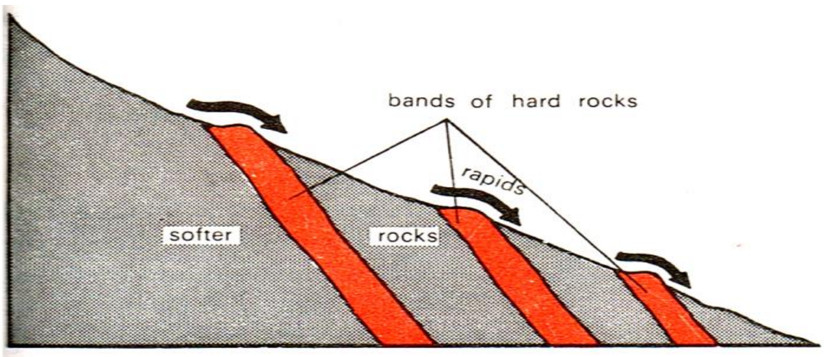


Figure 4.26: Rapids and Cataracts

Waterfall represents a point in the long profile of a stream where the water descends vertically. In fact, they mark the Knick-point of them most impressive kind. Remember that waterfalls and rapids are generally found in mountain and plateau regions. Waterfall may develop when a river flows over a cliff caused either by a fault scarp or by resistant rock encountered by river while deepening its valley. Hanging valley also cause water falls. Streams flowing through plateaus build up by layers of successive lava flows generally develop waterfalls. When a bed of more resistant rock, horizontal or gently inclined upstream, overlies softer rocks, undercutting of the softer bed rocks leads to undermining and recession of the waterfall.

Pot holes: pot holes is a more or less circular holes in the rocky bed of stream formed by the scouring and grinding effects of pebbles roatated in an eddy formed at the base of waterfall. In rapids and at the base of waterfalls, potholes are formed in solids rocks through the grinding action of sand and pebbles which lodge in slight initial depression and are swirled around by the swift water. Their grater pressure and force usually wears out a plunge-pool beneath.

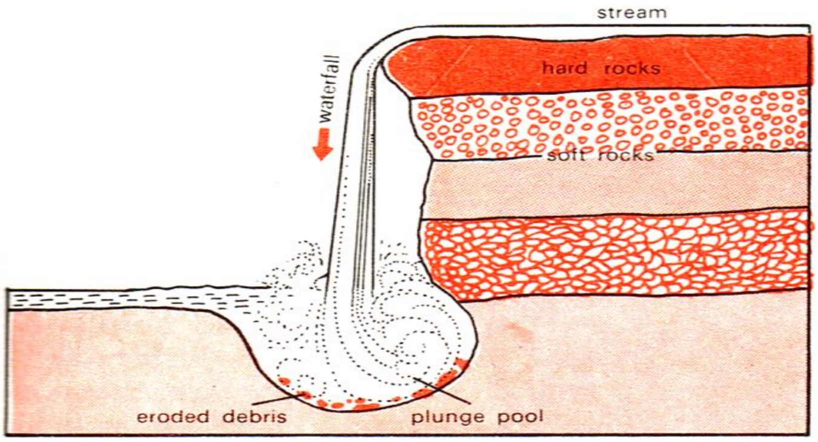


Figure 4.27: A waterfall with Plunge pool

- In the middle part of its course, a river develops mature features, and the valley becomes wider. After crossing the mountainous and hilly regions, the river debouches into the plain. In the plain area the slope is gentle, owing to which the river is slackened. This gently sloping accumulation of course alluvium deposited by braided streams in known as *alluvial fans* or *alluvial cones*. In some cases, the neighbouring alluvial fans may meet and coalesce with each other as they develop and form an extensive alluvial plain in the foot hills or piedmont area. This type of landform is known as piedmont alluvial plains. This type of landforms is known as piedmont alluvial plain. The alluvial fans are built mostly during the rainy season, when the volume of water as well as the sediments are enormous.

Exercise: Difference between River Alluvial plains and Glacial outwash plains.

Bajada is a landform with gentle and sloping surface leading down from a mountain front to an inland basin, in an arid or semi-arid basin. It is composed of unconsolidated materials, such as sand, gravel and angular scree which together mantle the underlying piedmont.

The lateral corrosion tends to replace vertical corrosion. The volume of water increases with the confluence of many tributaries and this increase the river’s load. The work of the river is predominantly transportation with some deposition. Downstream, the *interlocking spurs* that projects both sides of the valley are cut back into a line of bluffs. Rain wash, soil creep, landslides and gullying gradually widen the valley, cutting back the sides. The rivers treble task of valley cutting, bed smoothing and debris removal are being carried out in a more tranquil manner than in the mountain course through the velocity does not decreases.

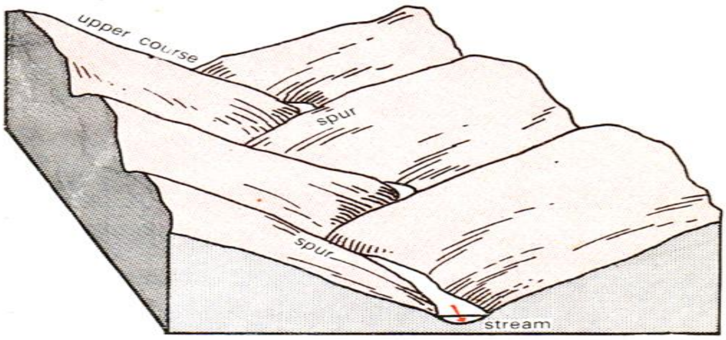


Figure 4.28: Interlocking Spurs

As water flowing down under gravity seldom flows straight for any long distance, a winding course soon develops. The irregularities of the ground force the river to swing in loops, forming meanders, a term derived from the winding river Meanderez in Asia Minor.

The part of river valley having a flood plain but still having definite valley walls, is called mature. The mature river's course is zig-zag forming loops/meanders on the valley floor. It starts eroding its bank on the outside of each meander loop and depositing materials on the inside of each loop. The net result is that the size of the meanders is increased by this act of the river. So flood plain becomes wider.

When the river flows of water, the lateral erosion continues and size of meander will increase. As the water flows round a bend, the river tends to increase the curve, since current acts more strongly on the concave side or outside of the curve, so that the maximum erosion takes place. There is little erosion, and even some deposition on the inside of the bend. Thus the original swing is transformed into a fully developed meander with river cliff overhanging the under-cut bank and a sloping spur, called a slip off shore.

Exercise: What are the differences between incised meanders and meanders over flood delta plains.

- The lower alongside stream channels are relatively flat areas known as floodplains. Floodplains develop when streams over-top their levees spreading discharge and suspended sediments over the land surface during floods. Levees are ridges found along the sides of the stream channel composed of sand or gravel. Levees are approximately one half to four times the channel width in diameter. Upon retreat of the flood waters, stream velocities are reduced causing the deposition of alluvium. Repeated flood cycles over time can result in the deposition of many successive layers of alluvial material. Floodplain deposits can raise the elevation of the stream bed. This process is called aggradation.

Floodplains can also contain sediments deposited from the lateral migration of the river channel. This process is common in both braided and meandering channels. Braided channels produce horizontal deposits of sand during times of reduced discharge. In meandering streams, channel migration leads to the vertical deposition of point bar deposits. Both braided and meandering channel deposits are coarser than the materials laid down by flooding.

A number of other geomorphic features can be found on the floodplain. Intersecting the levees are narrow gaps called crevasses**.** These features allow for the movement of water to the floodplain and back during floods. Topographical depressions are found scattered about the floodplain. Depressions contain the some of the finest deposits on the floodplain because of their elevation. Oxbow lakes are the abandoned channels created when meanders are cut off from the rest of the channel because of lateral stream erosion.

Streams flowing into standing water normally create a delta. A delta is body of sediment that contains numerous horizontal and vertical layers. Deltas are created when the sediment load carried by a stream is deposited because of a sudden reduction in stream velocity. The surface of most deltas is marked by small shifting channels that carry water and sediments away from the main river channel. These small channels also act to distribute the stream's sediment load over the surface of the delta. Some deltas, like the Nile, have a triangular shape. Streams, like the Mississippi, that have a high sediment content and empty into relatively calm waters cause the formation of a birdfoot shaped delta**.** In general, deltas are triangular in shape. But on the basis of shape they may be classified into the following five categories. (i) Arcuate delta, (ii) Bird’s foot delta, (iii) Estuarine delta, (iv) Cuspate or tooth-shaped delta, and (v) Lacustraine delta.

The delta in which the outermost margin exhibits an arc-like form, convex towards the sea, is known as arcuate delta. The delta of Nile river is the typical example of arcuate delta. The deltas of the Ganga, Hwang-Ho, Po and Rhine river are also good example of arcuate delta.

Bird’s foot delta is formed by the outgrowth of natural river levees into a body of water to form a finger-like pattern, reflecting the number of distributary streams. The best example is the delta of Mississippi river.

When the river enters the sea through a single mouth or estuary a long and narrow delta is formed. Normally, the estuary is open and the river sediments are removed by the waves and currents. But when the mouth of the river is submerged below the sea, a narrow linear delta is formed. The deltas of the Amazon and Congo rovers are the typical examples of estuarine delta.

Cuspate delta is symmetrical delta, usually formed where a river debouches in a straight coastline, and in which the sedimentary materials is deposited evenly on either side of the river mouth. The delta of Tiber River is an example of the cuspate delta.

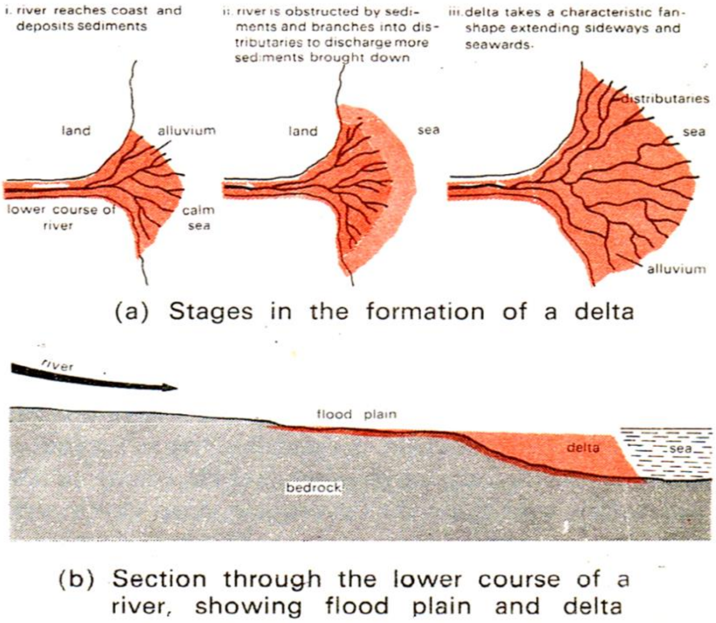


Figure 4.29: The Process of Formation of Delta

A delta build in a lake by a heavily laden of stream is known as lacustrine delta. The biggest lacustrine delta are those which are being built out into the Caspian Sea by Volga, Ural and Kura rivers.

An alluvial fan is a large fan-shaped deposit of sediment on which a braided stream flows over. Alluvial fans develop when streams carrying a heavy load reduce their velocity

Do You Know?

Question: Why are Deltas so Fertile?

A river when approaches towards its last stage of its course before submerging into the seas and oceans becomes very slow. Due to the load of sediments the river is carrying and because of the flat land, it is forced to deposit the sediments near the mouth. The river starts breaking into number of small streams known distributaries. The network of distributaries form a triangular shaped feature called delta. These deltas are most fertile areas in the course of a river. The deposition of sediments in the deltas is a continuous process making these deltas the most fertile areas. Sunderbans delta formed by the Ganga – Brahmaputra river is the biggest delta and also is very fertile

as they emerge from mountainous terrain to a nearly horizontal plain. The fan is created as braided streams shift across the surface of this feature depositing sediment and adjusting their course. The image below shows several alluvial fans that formed because of a sudden change in elevation.

Alluvial terraces are formed as a result of the rejuvenation of streams. Streams which have deposited thick alluvium on flood plains or stream whose valleys have become filled with alluvium may be rejuvenated, thus giving rise to terraces. In fact these terraces are different from normal terraces because they are carved out of alluvium instead of solid rocks. Alluvial terraces are generally regarded as being synonymous with a river terrace. But this interpretation is only possible if one regards the term ‘alluvium’ as including the course sand and gravel as well as the fine-grained deposits.

Structural benches or terraces formed by the rivers due to differential erosion of the hard and soft rocks which lie alternatively in a V-shaped valley in a horizontal manner are called structural benches.

4.7.4 Coastal Landforms

The unequal solar heating of the earth's surface produces a system of permanent global winds. This motion of air in the form of winds, produces sea waves. These waves then expand their energy at coastline, eroding rock, transporting sediment, and depositing them to form numerous erosional and depositional landforms. The world's present shorelines, however, are not the result of present day processes alone. Nearly all coasts were profoundly affected by the rise in sea level, glaciation, volcanism, earth movements, weathering, erosional processes and even the growth of organism.

Marine Erosion

Erosion along coasts results from the abrasive action of sand and gravel, moved by the waves and currents and, to a lesser extent from solution and hydraulic action. The undercutting action of waves and currents typically produces sea cliffs. As a sea cliff recedes, a wave cut platform develops. Minor erosional forms associated with the development of sea cliffs include sea-caves, sea-arches, and sea stacks. Waves, particularly storm waves and tsunamis, are the most important agents of marine erosion. Smaller waves, such as those associated with surf, may carry on attrition of material and minor amounts of abrasion, but, just as a stream during a single flood may do more geological work than it will for months or years at low water stage, so can storm waves during a short period affect more change than ordinary waves will in months. Factors that affect the rate and magnitude of sea waves' erosion are:

1) The nature and hardness of rocks along the shore.
2) Structural features of the rock, like the degree of jointing and fracturing.
3) Tidal range.
4) Openness of shore to wave attack.
5) Depth of water offshore.
6) Configuration of coastline.
7) Presence or absence of protective beach.
8) Abundance and size of abrasive tools.
9) Stability of sea level.

The most important agent shaping coastal landforms is wave action. The energy of waves is expended primarily in the constant churning of mineral particles and water as waves break at the shore. This churning erodes shoreline materials, moving the shoreline landward. The processes involved in marine erosion are; (i) corrosion, (ii) abrasion, (iii) attrition, (iv) hydraulic action, and (v) shock pressure of breaking waves.

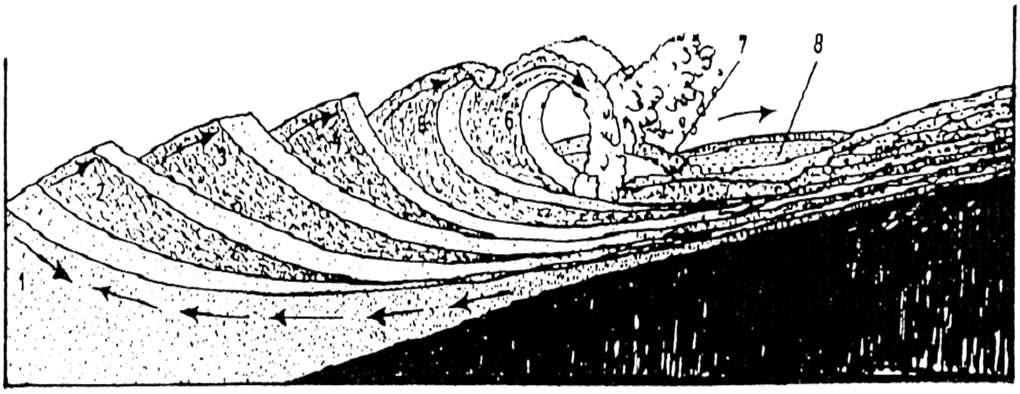


Figure 4.30: The work of sea waves

Marine Erosion Landforms

The major landforms produced by marine erosion are sea cliffs, wave-cut benches, notches, cave, arch, stack and stump.

- **Sea Cliffs:** Sea cliff is a very distinctive feature of marine erosion. It is a steep coastal declivity which may or flay not be precipitous, the slope angle being dependent partly on the jointing, bedding and hardness of the rock and partly on the erosional processes at work. Where the wave attack is dominant, the cliff foot will be rapidly eroded and cliff retreat will take place, especially in unconsolidated materials such as clays, sands, etc. Near vertical cliffs can also be formed in well-jointed rocks. For example, solid massive rocks, granite, basalt and old sandstone are cut back slowly and form steep cliffs, standing out boldly as headlands. Less resistant rocks are more rapidly eroded to form bays.

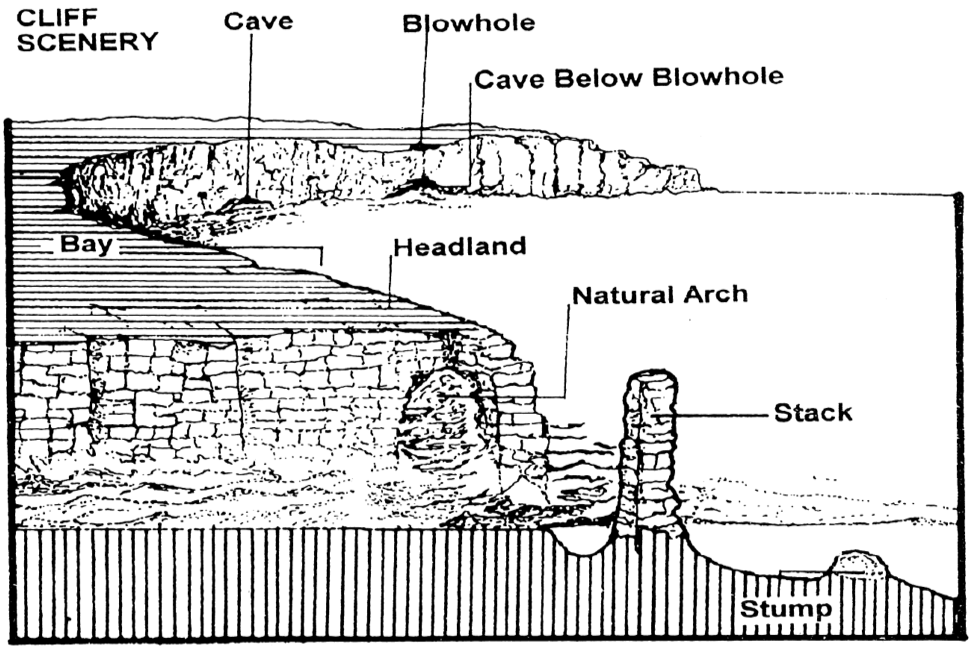


Figure 4.31: Typical features along a sea wave-cut cliff

- **Wave-cut Platform (Abrasion Platform or Beach Platform):** Wave-cut platform is virtually smooth marine platform cut by ocean waves at a coastline. The wave-cut platform extends seaward from the base of the sea cliff and having a slope of less than 5 degrees, its width may extend several hundred metres. The platform (bench) is composed of bare rock or it may contain a temporary deposit of rock debris, pebbles or sand. It is formed by wave erosion, and as the cliff recedes under the impact of marine erosion, so does the width of the wave-cut platform go on increasing. Thus, the platform gets extended towards the land by erosion of the Coast. The debris derived from coastal erosion become smaller by attrition and the undertow transports them towards the sea and deposits them after some distance. In areas of hard rocks the surface of the wave-cut platform consists of bare rock and is relatively flat, but where there is a deposit of shingles, gravels and sand, the slope is concave.

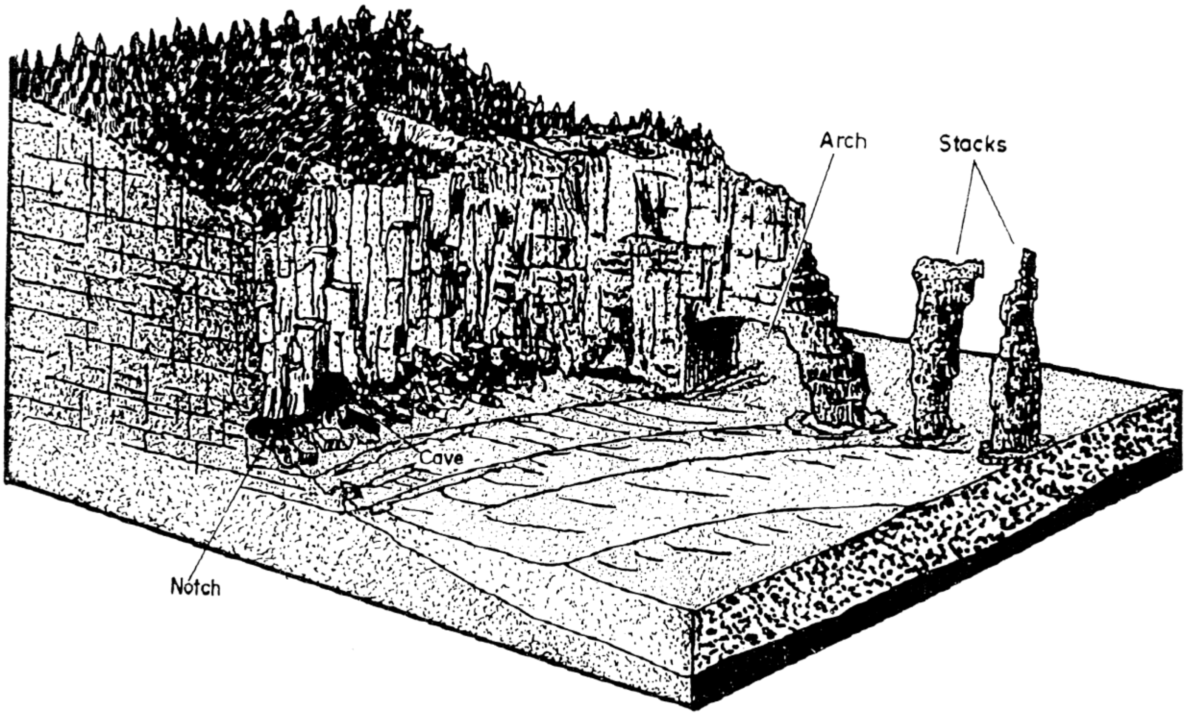


Figure 4.32: Landforms of sea c1ff (after E. Raisz)

- **Sea Caves:** Sea cave is a natural cavity, chamber or recess which develops along the coast due to gradual erosion of weak and strongly jointed rocks by uprushing breaker waves (surf Currents). Sea waves are more frequently formed in carbonate rocks (limestone and chalks) because they are eroded more by solutional processes. Sea caves are, however, not permanent as they are destroyed in due course of time.
- **Sea Arch:** Sea arch is a natural opening through a mass of rock limestone or boulder clay. It is most commonly seen on the sea coast where waves have cut through a

promontory. When the keystone of the marine arch collapses, the feature will become a stack.

- **Stack (Needles, Columns, Pillars, Skerries):** Stack is an isolated rock monolith or pillar rising steeply from the sea. It was formerly part of the adjoining land but has become isolated from it by wave erosion, probably after having formed part of a marine arch. The Old Man of Hoy (137 metres) in the Orkney Island of Scotland is a spectacular example of stack.
- **Goes and Gloups:** The occasional splashing of the waves against the roof of a cave may enlarge the joints when compressed air is trapped inside. A natural shaft is thus formed which may eventually pierce through to the surface. Such a shaft is termed a gloup (form noise made by the water gurgling inside) or blow-hole. The enlargement of blow-holes and the continued action of waves weakens the cave roof. Such deep clefts, which may be 100 feet deep are called goes.

Marine Depositional Landforms

Sediment transported along the shore is deposited in areas of low wave energy and produces a variety of landforms, including beaches, spits, tombolos, bars and barrier islands. Different types of sediments are deposited along the coast. Sometimes, in the form of an accumulation of unconsolidated materials (silt, sand, shingle, etc.) lying between the lowest level of spring tides and the highest level reached by storm waves, which is known as sea beach. A beach is generally located on a wave-cut platform of solid rock and is generally of a low gradient with a gently concave platform. Beaches may extend for hundreds of kilometres. Beaches are generally classified into: (i) sand beach, (ii) shingle beach, and (iii) boulder beach.

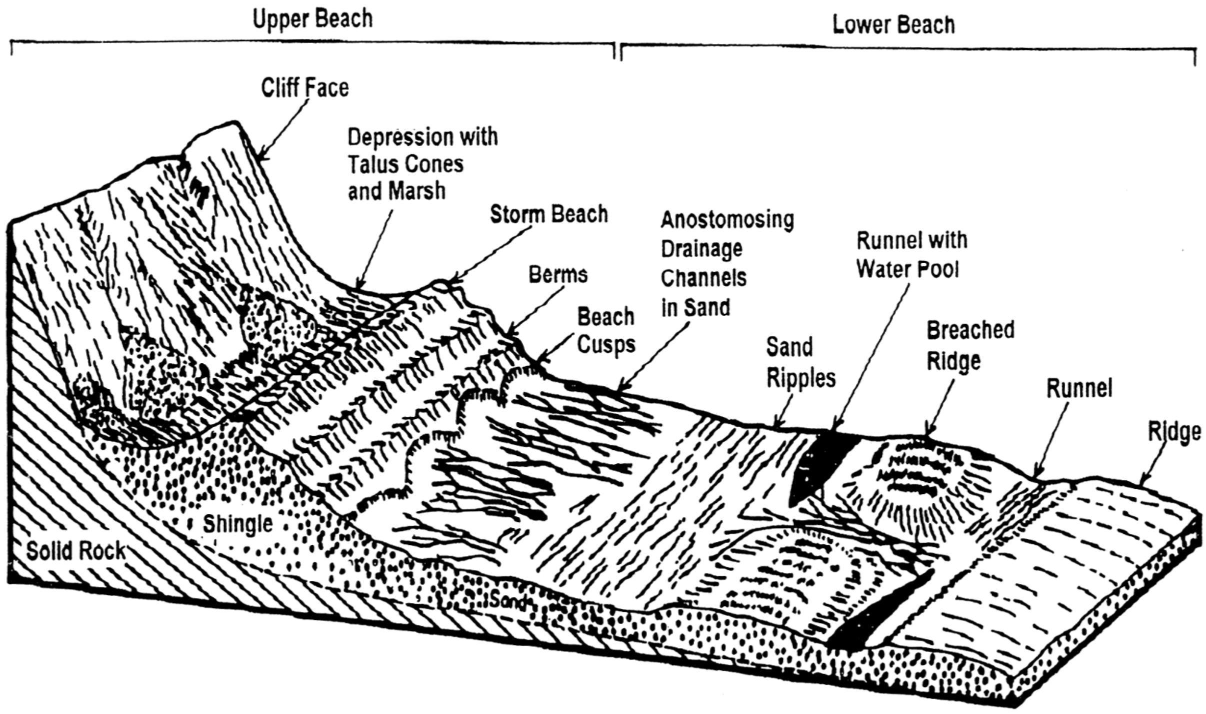


Figure 4.33: Different elements of an ideal beach (after A. Goudie)

- **Bar:**

Bar is an elongated deposit of sand, shingle or mud, occurring in the sea, more or less parallel to the shoreline and sometimes linked to it. Bars may be of submerged or emergent embankments of sand and gravel built along the shore by waves and currents. One of the most common types of bars is that known as spit. Spit is a narrow and elongated accumulation of sand and shingle projecting into a large body of water (sea). It is a ridge or embankment of sediment attached to the land at one end and terminating in open water (sea) at the other. It grows out from a coastline as a result of longshore drift, often at a location where the line 0f the coast changes direction, as at the mouth of an estuary where spits are common.

Connecting bars are formed when bars are so extended that they either join two headlands or islands. When a bar connects the mainland with an island, it is known as tombolo 22.7).

- **Spits:** A sand bar projecting from the mainland into open water. sediment moved by longshore drift.
- **Beaches:** A beach is a shore build of unconsolidated sediment. Sand is the most common material, but some beaches are composed of cobbles and boulders and others of silt and clay.
- **Tombolos:** A beach or bar connecting an island to the mainland. It forms because the island creates a wave shadow zone along the coast, in which longshore drift cannot occur.
- **Barrier Islands:** Barrier islands are long, offshore islands of sediments, tending parallel to the shore. Almost invariably, they form long shorelines adjacent to gently sloping coastal plains, and they typically are separated from the mainland by a lagoon. Most barrier islands are cut by one or more tidal inlets.

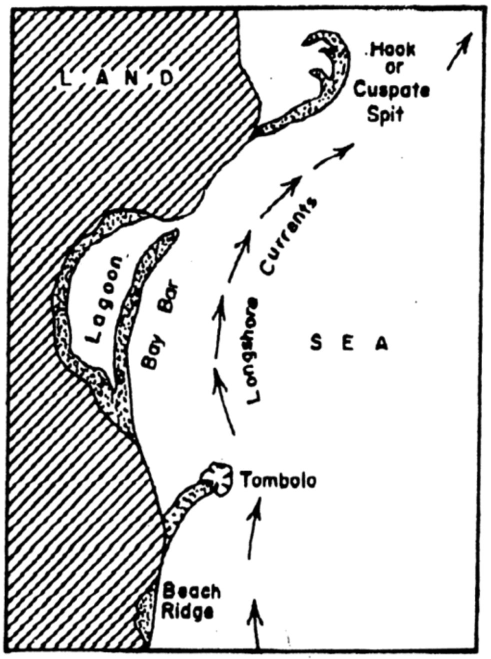


Figure 4.34: Formation of hook, connecting bar, bay bar and tombolo

- **Evolution of Shoreline:** Evolution of shoreline involves a series of stages in which the configuration of the coast is modified by both erosion and deposition processes until, finally, only a minimum of energy is expanded on it. The most stable shoreline form has a smooth straight coast and a wide platform.

- **Types of Coasts:** It is very difficult to provide a satisfactory classification of sea coasts. Davis (1902) divided coasts into: (i) emergence coasts, and (ii) submergence coasts. The classification of coasts as advocated by Valentine (1952) has been widely accepted as a standard classification of coasts. He recognised two main groups: (i) coasts which have advanced, and (ii) coasts which have retreated.

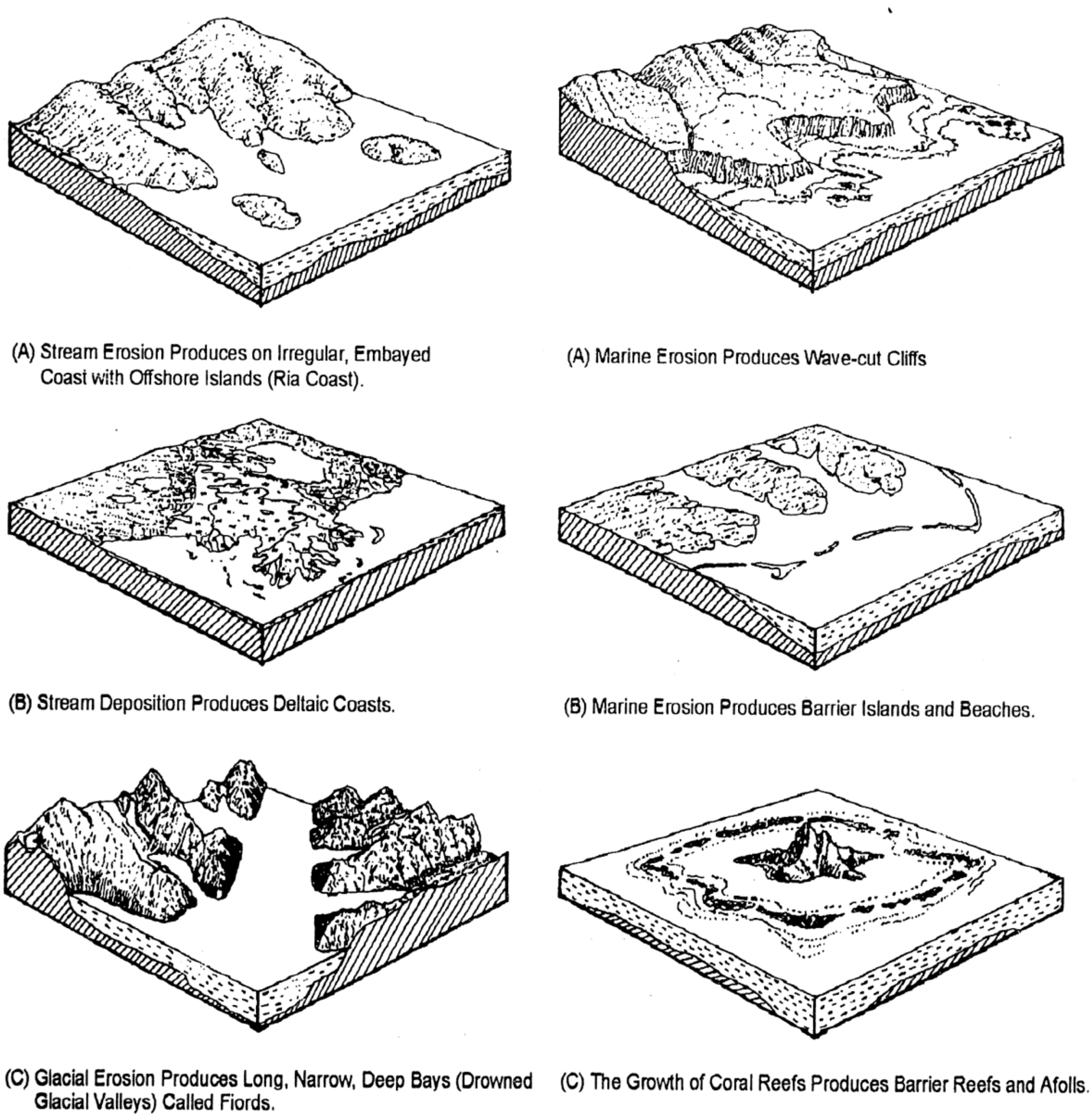


Figure 4.35: Primary Coasts - produced by non-marine processes, e.g. rivers and glaciers (after W.K. Hamblin et al.)

4.7.5 Karst Landforms

Water that occupies pores, cavities, cracks and other spaces in the crustal rocks is known as groundwater, subsuface water or underground water. It includes water precipitated from the atmosphere which has percolated through the soil (meteoric water), water that has risen from deep magmatic sources, liberated during igneous activity (magmatic or juvenile water), and fossil water retained in sedimentary rocks since their formation (connate water). Some underground water may also be derived from the percolation of oceanic water, especially in the coastal areas. The presence of groundwater is necessary for virtually all weathering processes to operate. The slow moving underground water can dissolve huge quantities of soluble rocks and carry them away in solution. In some areas, it is the dominant agent of erosion and produces karst topography, which is charactensed by sink holes, subsidence depressions, collapsed caverns, solution valleys and disappearing streams.

The Movement of Groundwater

The water moves in the ground is proved by the direct and indirect evidences. For example, wells are pumped dry, yet soon re-fill with water. Strong flows of water through fractures in rocks are frequently encountered in mine and railroad tunnels. Underground rivers have been discovered in great caverns. Water may move very long distances underground. Except for the water that flows in such openings as fissures or caverns, the movement of groundwater is very slow.

The Work of Groundwater

Both through its mechanical and chemical work, groundwater profoundly alters the surface of the land. While neither activity is as widespread as are some other physiographic agents, the total results are very great, especially in humid regions where the amount of water in the ground is relatively more. As stated above, groundwater is capable of accomplishing erosion on an enormous scale, but unlike streams, groundwater erodes only by dissolving soluble rocks such as limestone, rock-salt, and gypsum. It then transports the dissolved mineral matter and discharges it into other parts of the hydrologic system or deposits it in the pore spaces within the rock. Groundwater erosion starts with water percolating through joints, faults, and bedding planes and dissolving the soluble rock. in time, the fractures enlarge to form a subterranean network of caves that can extend for many kilometres. The caves grow larger until ultimately the roof collapses, and a crater-like depression, or sinkhole is produced. Solution activity then enlarges the sinkhole to form a solution valley, which continues to grow until the soluble rock is removed completely.

Conditions for the Development of Karst

There are five conditions which contribute to the maximum development of karst landform. These are:

1. There must be present at or near the surface a soluble rock, preferably limestone. The limestone must be massive, thickly bedded, hard, tenacious and well cemented.
2. The soluble rock should be dense, highly jointed, and preferably thinly bedded.

3. The third condition which favours an excellent development of karst is the existence of entrenched valleys below uplands underlain by soluble and well-jointed rocks. This favours ready downward movement of groundwater through the rock.
4. Karst topography is largely restricted to humid and temperate climatic zones. In desert regions, where little rain falls, extensive karst topography will not develop.
5. The region must be one of at least moderate rainfall. In general, arid and semi-arid regions do not exhibit marked development of karst. It is significant that nearly all the notable karst regions of the world are in the areas of moderate to abundant rainfall.

The work of underground water is important in the areas of limestone rocks where it gives rise to distinctive landforms. Like running water, underground water also erodes, transports and deposits.

Karst Erosional Landforms

Slow moving ground water can dissolve huge quantities of soluble rocks and carry it away in solution. In some areas, it is the dominant agent of erosion and produces Karst topography, which is characterized by sinkholes, solution valleys, and disappearing streams. The evolution of Karst topography is shown in fig. 4.36. Initially, water follows surface drainage until a large river cuts a deep valley below the limestone layer. Groundwater then moves through joints and emerges at river banks. With the passage of time the water emerges at the river banks. Finally, the roofs of the caves collapse so numerous sinkholes are produced. This process ultimately develops solution valleys. Most of the original surface is finally dissolved. The following are the unique erosional landforms of a karst region:

- **Karren:** 'Karren' is a German term initially used to describe minor and major solution furrows or funnels cut by surface water (groundwater) into limestone. Now, the term is used for highly corrugated and rough surface of limestone lithology, characterised by low ridges and pinnacles, narrow clefts and numerous solution holes. In French, it is called as lopies.
- **Sinkhole:** A funnel-shaped or cylindrical-shaped hole, depression, or sink in the ground surface of a limestone or chalk terrain. It is equivalent to a ponor of karst country. It is usually dry or exhibits only minor seepage of surface water and should be distinguished from a swallet, which marks the disappearance of a surface stream. A sinkhole is formed by subterranean collapse of a cave system or by surface solution. The depth of the sinkhole varies from a few centimetres to about 10 metres. Some swallow holes are further enlarged due to continuous solution into larger depressions which are called dolines.
- **Caverns (Caves):** Caverns or caves are also one of the important characteristic features of groundwater in limestone regions. Caverns are formed in several different ways. The rocks in which most caves occur are salt, gypsum, dolomite and limestone, with the latter by far the most important.

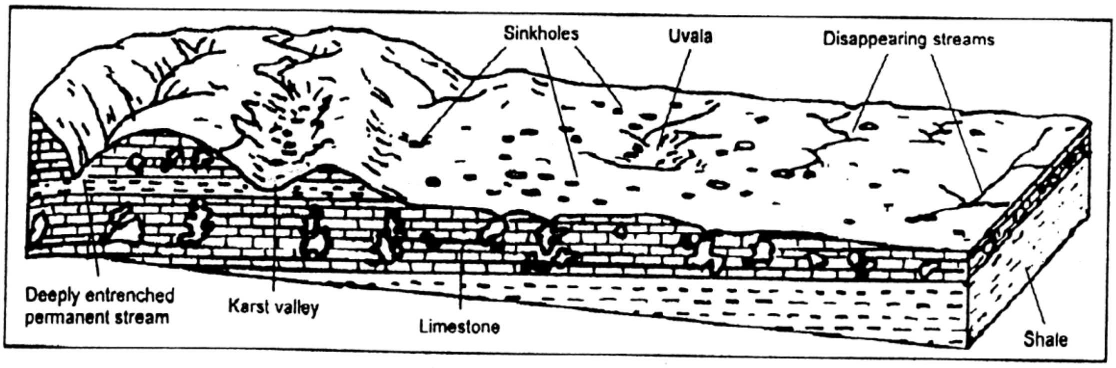


Figure 4.36: Idealised features of karst topography

Groundwater charged with carbon dioxide and other chemicals seeps along stratification and joint planes or other cracks in the rock, and slowly dissolves the soluble rocks. Wholly stagnant groundwater soon become saturated with minerals and loses its effectiveness in the cave-making process. It is, therefore, necessary that there should be such a condition of underground drainage that the saturated water can move away with its chemical load and be replaced with a new supply of water which is capable of continuing the solvent action. The underground drainage is most effective above the water table, but there is abundant evidence of groundwater movement well below this table.

As the solvent action goes on, the caves continue to grow; usually they are irregular in size and shape. Some are huge rooms; others are vast labyrinths of intricate branching passages. In some caves there are pools of standing water, in others, there are large streams of moving water. The Holloch cave with a length of 85 km is the longest cave in the world, followed by Fint Ridge cave (81 km) and Mammoth cave (72 km) of Kentucky (USA).

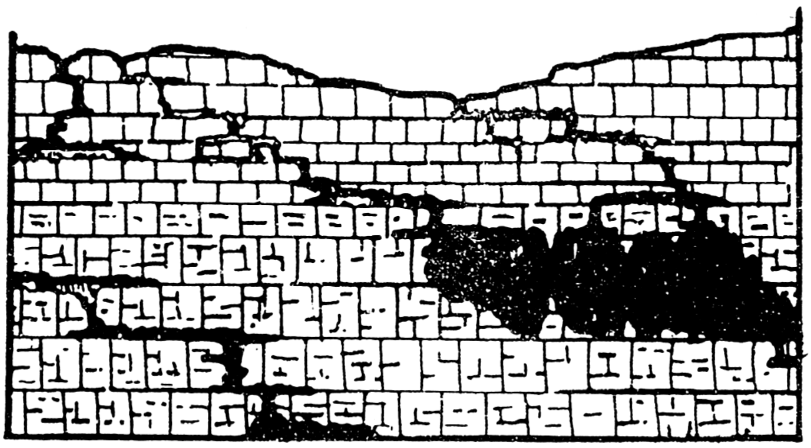


Figure 4.37: Formation of cave

- **Terra Rossa:** When rainwater dissolves part of surface rock and enters the sub-surface, particles of red clay soil are deposited on the surface as well as in the opened joints. This is called terra rossa which resembles to lateritic soil. It may not be present at steep slopes but can be seen in areas which are either flat or have gentle slope. Sometimes it may be several metres thick and may entirely cover the rocky surface.

- **Karst Window:** Karst is formed due to collapse of upper surface of sinkholes or dolines. These windows enable the researchers and geomorphologists to observe sub-surface drainage and other features formed below the ground surface.
- **Uvala:** A large surface depression (several km in diameter) in limestone terrain (karst region) is known as uvala. It is formed by the coalescence of adjoining dolines. It has an irregular floor which is not as smooth as that of poije.
- **Polje:** Polje is a large depression in a karst region with steep sides and a flat floor. If it is drained by surface water soup it is termed as open polje, but if it drains by means of swallow holes, it is a closed polje. The depression is thought to have been formed by the coalescence of collapsed cave systems. Its floor is generally covered with alluvium. The Livno polje of the Balkan region of Europe is 64 km long and 5-11 km wide. In Croatia, Serbia and Bosnia-Herzegovina, cultivation on account of flat surface and easy availability of water.

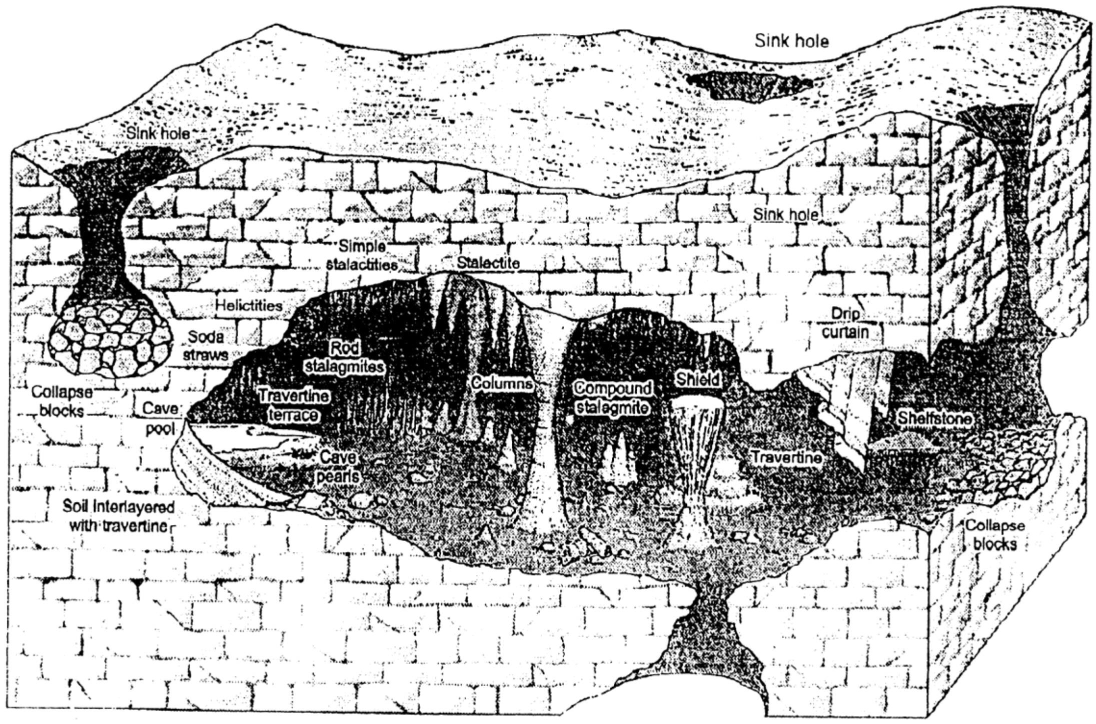


Figure 4.38: Idealized diagram of cave deposits- stalactites, stalagmites and columns

- **Swallet or Swallow Hole:** The point at which a surface stream disappears u,hderground in a limestone (karst) terrain prior to commencing its underground journey is known as a swailet). In France, it is called as embut.
- **Sinking Creek:** The surface of the karst plain looks like a sieve because of numerous, closely spaced sinkholes. When surface water disappears through numerous sinkholes located in a line, the resultant feature is called sinking creek.
- **Blind Valley:** A type of valley in a karstic limestone terrain. It may be occupied by a stream which disappears underground at the valley's lower end as it approaches an enclosing rock-wall. Consequently, the valley looks a dry valley.

- **Aven (Ponores):** 'Aven' is a French term which has been universally adopted to describe a deep shaft-like hole in limestone terrain, leading down into extensive cave systems (karst).
- **Natural Bridge:** Natural bridge is an erosional feature in karst topography. They are formed either due to the collapse of the roofs of caves or clue to the disappearance of surface streams as subterranean streams.

Figure 4.39: Karst topography (after W.K. Hambtin, et al., pp. 342-43)

Depositional Landforms

The mineral matter dissolved by groundwater can be deposited in a variety of ways. The most spectacular deposits are stalactites and stalagmites which are found in caves. Less obvious are the deposits in permeable rocks such as sandstone and conglomerates. Here groundwater commonly deposits mineral matter as a cement between grains. After limestone caverns have formed, it frequently happens that water seeping through the walls or the roofs deposits calcium carbonate in the form of stalactites or stalagmites (sometimes called drip-stones). The deposition from solution is brought about by: (i) evaporation of the water, (ii) reduction in pressure, and (iii) loss of gases. The main depositional features by these processes are called as stalactites and stalagmites.

- **Stalactites:** Stalactites are icicle-like forms that hang from the roofs of caves. In other words, a tapering pendant of concretionary material descending from a cave ceiling, created by the re-precipitation of carbonate in calcite form percolating groundwater is known as a stalactite.

- **Stalagmites:** A columnar concretion ascending from the floor of a cave. It is formed from the re-precipitation of carbonate in calcite form perpendicularly beneath a constant source of groundwater that drips off the lower tip of a stalactite or percolates through the roof of a cave in a karst environment. It may eventually combine with a stalactite to form a pillar.

An almost endless variety of beautiful and interesting adornments may be formed through deposition of calcite in limestone caves, Many stalactites and stalagmites eventually unite to form columns. Water percolating from a fracture in the roof may form a thin, vertical sheet of rock known as drip curtain. Pools of water on the cave floor flow from one place to another, and as they evaporate, calcium carbonate is deposited on the floor, forming travertine terraces.

4.9 CONCLUSION

By concluding it can be said that the external forces, which are working on earth's surface form time to time to wear away the surface, and the interaction of these constructive and destructive forces gives rise to the great diversity of present day landforms.

4.10 SUMMARY

The unit 4, consist the denudation processes in details, which carried out in different phases. It explains the weathering, which is gradual disintegration of rocks by atmosphere or weather forces. Second deals with erosion process by different agents working differently on earth's surface for lowering and levelling out it. It's very active process wearing away of the earth's surface by moving agents like running water, glaciers and waves. Besides this transportation and deposition is also very important phases for development of landforms in any area. The removal of eroded materials in the new area and the dumping of the debris in certain part of the earth creates many new and outstanding features (landforms). All the landforms developed by various agents are dealt in the unit with details.

4.11 GLOSSARY

4.12 ANSWER TO CHECK YOUR PROGRESS

1) What do you understand by the term 'Weathering'?
2) Differentiate mechanical weathering from chemical weathering and give examples from each.
3) "Our earth is playfield for two opposing groups of geomorphic processes." Discuss.
4) Describe and explain with relevant sketches of various types of river deltas.
5) With the aid of diagram, attempts to explain the difference between the following terms connected with glaciation.
    a) Valley glaciers and piedmont glacier

b) Interlocking spurs and truncated spurs

c) Terminal moraine and recessional moraine

6) Explain concisely the processes of deflation, abrasion and deposition by winds. With the aid of diagrams explain two topographical features formed by any two of the above processes.

7) Choose three outstanding features of a karst region. With the help of diagrams describe their appearance and explain how they have been formed.

8) Describe various depositional features made by river or fluvial process in details, with suitable illustrations.

9) What do you understand by marine erosion and deposition? Explain different types of coast with examples in detail.

10) Draw a large diagram of karst region and indicate the following: swallow holes, limestone gorge and dry valley. Describe briefly how they formed.

4.13 REFERENCES

1) Brookfield, M.E. and T.S. Ahlbrandt, 1983, Eoiian Sediments and Process, New York, Elsevier.
2) Christopherson, R.W., 1995, Elemental Geosystems: A Foundation in Physical Geography, Englewood Cliffs, Prentice Hall.
3) Goh Cheng. L., (1974), Certificate Physical and Human Geography. Oxford University Press, New Delhi
4) Hamblin, W.K., 1995, Earth's Dynamic Systems, Englewood Cliffs, Prentice Hall
5) Husain, M (2013). Fundamentals of Physical Geography. Rawat Publication. Jaipur
6) Oliver, J.E., 1979, Physical Geography, Massachusetts, Duxbury Press.
7) Sharp, R.P., 1992, Living Ice, New York, Cambridge University Press.
8) Singh, S (2013). Geomorphology. Prayag Prakashan, Allahabad
9) Strahier, A., 1997, Physical Geography, New York, Wiley.
10) Tarbuck, E.J. et al., 1976, Earth Science, Ohio, Charles E Merril.
11) Thornbury, W.D., 1998, Principles of Geomorphology, New Delhi, New Age International Press.

4.14 SUGGESTED READINGS

UNIT- 5 COMPOSITIONS AND STRUCTURE OF ATMOSPHERE

5.1 OBJECTIVES
5.2 INTRODUCTION
5.3 OVERVIEW OF THE EARTH'S ATMOSPHERE
5.4 COMPOSITION OF THE ATMOSPHERE
5.5 MASS OF THE ATMOSPHERE
5.6 VERTICAL STRUCTURE OF THE ATMOSPHERE
5.7 LAYERS OF THE ATMOSPHERE
5.7.1 Troposphere
5.7.2 Stratosphere
5.7.3 Mesosphere
5.7.4 Thermosphere
5.8 CHEMICAL COMPOSITION OF THE ATMOSPHERE
5.9 CONCLUSION
5.10 SUMMARY
5.11 GLOSSARY
5.12 ANSWER TO CHECK YOUR PROGRESS
5.13 REFERENCES
5.14 SUGGESTED READINGS
5.15 TERMINAL QUESTIONS

5.1 OBJECTIVES

After reading this unit, you should be able to understand the:

- Composition and structure of the atmosphere,
- Different layers of atmosphere
- Vertical structure and chemical composition of the atmosphere

5.2 INTRODUCTION

In earth's atmosphere consists of air a mixture of various gases surrounding the earth to a height of many kilometers. In the other words we can say that the earth is surrounded by an ocean of air. This ocean of air is hanging under the pull of earth's gravitational force. It has a thickness of more than thousands of kilometers above from the earth surface. This thick extensive envelop of gas around the earth is called as atmosphere. Due to the presence of the atmosphere the earth is a unique planet in which life is found.

5.3 OVERVIEW OF THE EARTH'S ATMOSPHERE

Atmosphere is an important component of physical environment and it directly affects our life and activities in different way as discussed below:

1. Atmosphere provides the life of both animals and plant species on the earth surface because it contains oxygen for man and animals and carbon-di-oxide for the plants.
2. It protects earth from the ultra-violet rays which are very harmful to the plants and animals on the earth surface. The ozone gas (O_3) in the atmosphere absorbs these rays and save the earth from the danger of them.
3. It also controls the flow of energy from sun to the earth and from the earth to the space and regulates the temperature on the earth surface.
4. It is the storehouse of water vapours which produce condensation and precipitation on the land and water surface of the earth.
5. It is very useful for the development of communication system through electronic media. Radio-waves transmitted from earth surface, reflect back from the ionosphere in the atmosphere.

5.4 COMPOSITION OF THE ATMOSPHERE

The atmosphere is the composition of different kinds of materials like solid, liquid and gases. These elements in the atmosphere are having their definite contributions in the composition of it and play a vital role in controlling the human activities on this unique planet. The description of different constituents of atmosphere is given below :

Dry Air: The earth's atmosphere is made of different kinds of gases. Nitrogen, Oxygen and CO_2 are the important gases which are found in their uniform or stable proportion with in the lower layer of the earth's surface. Important gases of dry air are described below:

Table 1: Composition of Dry Air by Volume

GAS	PERCENTAGE	GAS	PERCENTAGE
Nitrogen (N_2)	78.08	Neon (N_e)	Trace
Orygen	20.98	Helium (H_e)	Trace
Argon	0.93	Methan (CH_4)	Trace
Carbon dioxide(CO_2)	00.003	Hydrogen (H_2)	Trace
		Ozone (O_3)	Trace

Nitrogen: In the earth's atmosphere Nitrogen (N_2) is very important consistent. It accounts for about 78.08 percent of total volume of dry air. Nitrogen gas works as a diluent and neutralizes the combustion phenomena in the atmosphere by diluting the oxygen. It is also used by plants and trees to make protein which is very useful for their growth but plants cannot make use of free Nitrogen. They use Nitrogen in the form of a compound. The lightning combines Oxygen with Nitrogen and the compounds so formed are swept down to the Earth's surface by rainfall. These Nitrogen, compounds act with soil chemicals and enter the bodies of plants and form their bodies. Green vegetation cannot be green without nitrogen. Nitrogen is also called the base of life because the smallest living organism (living cell) contains Nitrogen in its protoplasm.

Oxygen: This gas is the second important constituent of the atmosphere. It accounts for about 21 percent of the volume of dry air. The Presence of this gas in the atmosphere is very useful. Man and animals inhale Oxygen and exhale the Carbon-di-oxide. In the absence of Oxygen the survival of life on the earth surface is impossible. This gas is essential for burning, when substances react sharply, they are called burning. Human body also depends upon Oxygen. The body cells burns in oxygen to produce heat for the body. This process is called breathing . Many small organisms which are present in the soil and are so small that they are visible only under microscope cannot live without Oxygen and without these microscopic organisms the whole of the organic world will be disbalanced.

Carbon-di-oxide: The accounts of Carbon-di-oxide (CO_2) in the composition of the atmosphere are very insignificant, but it plays an appreciable role on the earth. CO_2 is also consumed by plants because they utilize it in the formation of food through the process of Photosynthesis. The vegetation has a green substance in it. It is called Chlorophyll. In the presence of chlorophyll and sun rays plants taken oxygen from the carbon dioxide and react with water. This process is called Photosynthesis. Carbo-hydrates are produced in these processes which chemically combine with salts brought by the plants from their roots and form protein, fat etc. These chemical compounds form fibers and other parts of plants. Animals derive their food from the plants directly and indirectly.

When the Earth was in her initial stage of formation carbon-di-oxide was the major component of the gases. There were no reserves of coal and graphite in the earth because carbon the main component of coal, petroleum etc., was in the form of carbon-di-oxide. Due to the evolution of plants, the ratio of carbon-di-oxide got reduced gradually. But, after industrialization, urbanization and heavy amount of deforestation have been the important agents of add CO_2 in the atmosphere. CO_2 is increasing at tremendous rate in the atmosphere. From 1890 to 1990 CO_2 has increased more than 10 times. Rising of its content in the atmosphere will cause global warming through greenhouse effect.

Ozone: Ozone (O_3) is very small constituent of dry air in the atmosphere of this planet. It accounts for only 0.00006 percent of volume of dry air. It is formed from Oxygen (O_2) by chemical reactions that absorb ultra-violet radiation, thus sheltering the elevation between 19to 35 km above the earth surface. This organism of the Earth's surface from the damaging effects of Ultra-Violet rays. Ozone lies at the zone is known as Ozonosphere. It is very useful gas for life on the earth. It absorbs the ultra-violet rays and protects us from sun burns. In the absence of this valuable gas, the ultra-violet radiations will reach the earth surface. Ozone layer protects the Earth's surface from this damaging form of radiation. If solar ultra-violet radiation will to reach the Earth's surface at full intensity, bacteria exposed on the Earth's surface would be destroyed and unprotected. Animal tissues would be severely destroyed. The presence of this layer is thus essential to maintaining a viable environment for life on the earth.

Moreover, study reveals that the ozone layer is depleting due to release of nitrogen oxide from supersonic jet planes and CFC (Chloro-floro carbon) from refrigerator industries. This depletion in the amount of ozone gas has resulted in blood cancer, cataract etc. diseases in developed countries like USA, Canada and Germany etc.

Water vapour: Another important component of the atmosphere is water vapour, the gaseous form of water. It is variable element and closed to the earth surface. Due to insolation of the sun, the water of ocean, seas, lakes, rivers etc. go on evaporation into water vapour. This water vapour later on, condenses into rainfall and falls on the earth surface. Most of the water thus, received by the earth reaches the ocean. This cycle of water-vapour is very important for human life. The content of water vapour varies from as little as 0.02 per cent of air in desert environment to over 4 percent in the humid tropics. It is the source of all types of condensation like snow, fogs, clouds, mist etc. and precipitation on the earth surface. It directly determines the type (rain, hail, sleet) and amount of precipitation. It is regulator of the heat on the earth surface. Water vapour is also the source of energy which helps in hearting the atmosphere to some extent. After the condensation of vapour latent heat is released in the atmosphere. This latent heat is also steering the turbulence in the atmosphere and it also affects the rate of cooling of the human body and the amount of vapour in the atmosphere is inversely related with the rate of cooling effect of body.

Dust Particles: Dust Particles are also very useful constituents of the earth's atmosphere. These dust particles are added in the atmosphere by cyclonic storms, volcanic activity, breaking of salt along the sea coast, ploughing of land and so on. The presence of dust particles in the atmosphere is very essential and affects the weather conditions. Dust particles scatter the radiation from the sun in the atmosphere. The varied colours i.e. red and orange at sun set and sunrise in only due to scattering of selective sunlight's. The blue colour of sky is attributed to the scattering of blue light in the atmosphere. Dust particles are in large numbers in dry desert environment and lower in humid environment. In the absence of dust particles, there would have been not formed precipitation for and snow on the earth surface.

5.5: MASS OF THE ATMOSPHERE

The atmosphere has great thickness around the earth surface. Its thickness or height above the earth surface is not still well known. On the basis of some information's from sounding air balloon, radar, satellite, rockets etc., the altitude of atmosphere is accounted up to 10,000 Km from sea level. The air is compressible and is thicker near the earth's surface so that 50 percent of atmosphere lies below 5-6 Km and 90 percent is confined to the height of 29kms.

The atmosphere may be divided into different roughly concentrating layers. The layers may be demarcated on the basis of temperature, air pressure and ionization and chemical properties of the air.

5.6 VERTICAL STRUCTURE OF THE ATMOSPHERE

5.7 LAYERS OF THE ATMOSPHERE

Atmosphere divided into different layers. There is a lot of difference in their properties. These layers are not separated from one another. The properties of layers change slowly. The main layers are described here in detail:

5.7.1 Troposphere

Troposphere is derived from Greek words Tropein (turning or rotating) and spheurous (sphere). It is the lowest atmospheric layer, in which temperature decreases with increasing elevation. It is closest to the earth surface. Since almost all human activity occurs in this layer, it is of primary important to us. Everyday weather phenomena, such as clouds or storms, occur mainly in the troposphere. The height of this layer is variable from equator to poles and from season to season. At the equator, it has maximum (16 Km) height and at poles it is lowest about 6 kms. The maximum height at the equator is due to convectional movement of the air currents. Similarly, its altitude in summer season is higher than in the winter season.

The very important feature of the troposphere is that it contains significant amounts of water vapour. When the water vapour content is high, vapour can condense into water droplets, forming low clouds and fog or the vapour can be deposited as ice crystals, forming high clouds. When condensation or deposition is rapid rain, snow, hail or sleet- collectively termed precipitation- may be produced and fall to earth surface. In desert regions where water vapour is present only in small amounts, precipitation is infrequent. Water vapour and dust particles are also confined to this atmosphere layer. Commercial aircrafts fly in this layer near tropopause.

5.7.2 Stratosphere

This layer is the next important atmospheric strata over the troposphere. This zone of separation is called as Tropopause. The stratosphere extends up to 50 km height from the sea level.

In the lower part of this layer (up to 20km) temperature remains almost uniform and winds are calm. In this layer, between 20 to 35 kms., there is a zone in which ozone gas is found abundantly, hence it is called ozone layer. The gas absorbs the ultra-violet rays of sun and protects the earth surface from the burning. After 30km. altitude temperature starts to increase with height due to presence of ozone layer. Weather elements like cloud formation, storms and eddies, precipitation etc. are almost absent, but only horizontal movement of air can be observed this layer. It is also the home of strong, persistent winds that blow from west to east.

5.7.3 Mesosphere

Mesosphere is the third layer of atmosphere lies above the stratosphere. The former layer is separated from latter by a narrow zone called Tropopause. This layer extends from 50 to 80 kms. above sea level. The main characteristic of this layer is that the temperature decreases with altitude. It reaches up to – 800C at the upper limit 80 km of mesosphere. In mesosphere, there is appearance of clouds in high latitudes region in summer season.

5.7.4 Thermosphere

Thermosphere is the biggest of all the layers of the earth’s atmosphere directly above the mesosphere and directly below the exosphere. Within this layer, ultra-violet radiation causes ionization. The International Space Station has a stable orbit within the middle of the thermosphere, between 320 and 380 kms. Auroras also occur in the thermosphere. Named from the Greek (Thermos) for heat, the thermosphere begins about 80kms above the earth. At these high altitudes, the residual atmospheric gases sort into strata according to molecular mass. Thermospheric temperature increase with altitude due to absorption of highly energetic solar radiation by the small amount of residual oxygen still present. Temperatures are highly dependent on solar activity and can rise to 15000C (2,7300F). Solar activity strongly influences temperature in thermosphere.

5.7.5 Ionosphere

Ionosphere extends between 80 km to 640 km above sea level. It is ionized and electrically charged layer. It is very important atmospheric layer which reflects the radio waves of various frequencies on the earth's surface, so that broad casting communication system is persisted. This layer consisting of different sub-layers:-

- **i- D-Layer –** This layer lies between 60 to 99 km altitude. The main feature of this layer is to reflect the low frequency radio-waves to the earth and to absorb the medium and high frequency waves. It is disappears in the night because it is associated with the sun shine.
- **ii- E-layer-** This layer stretches between 99 to 130 km height above the D-layer. It also appears with the sunrise because it is formed due to reaction between Ultra-violet photon, nitrogen and nitrogen molecules.
- **iii- Sporadic E-layer-** It is occurs occasionally and formed under special condition. Very high frequency waves are reflected.
- **iv- E_2 layer-** This layer lies up to 150 km. It is formed by interaction between ultra-violet photon and oxygen molecules. It is disappears after the sunset.
- **v- F-Layer-** This layer overlies the E-layers and is known as Appleton layer. This layer exists in night. F-layer is significant for long distance broadcasting communication as it reflects medium and high frequency waves in both days and nights. This layer is also divided into F_1 and F_2 layers. F_1 extends between 145-240 kms and F_2 between 240-965 kms.

5.8 CHEMICAL COMPOSITION OF THE ATMOSPHERE

In the lowest 25 km of the atmosphere we find a mixture of permanent gases, certain variable, gases, solids and liquid particles. Water vapour is the most important gas and can account for as much as 4% of the atmosphere by volume. This "minor" constituent plays a most important role in the dynamics of the atmosphere. We can divide the atmosphere into that part in which the gaseous composition is nearly constant and a second part (above the first) in which the composition varies with altitude and time of year. The homosphere is the bottom part of the atmosphere (below 80km.) where there is general home geneity of atmosphere composition (excluding water vapour which is highly variables). The heterosphere is the top part of the atmosphere (above 80km) where there is general heterogeneity of atmospheric composition (the means molecular weight varies with altitude above 80Km.)

Atmospheric Composition

Average composition of dry atmosphere (mole fractions)

GAS	AS PER NASA
Nitrogen, N_2	78.084%
Oxygen, O_2	20.946%
Argon, Ar	0.934%

MINOR CONSTITUENTS (MOLE FRACTIONS IN PPM)	
Carbon-di-oxide, CO_2	400
Neon, N_e	18.18
Helium, H_e	5.24
Mehthane, CH_4	1.70
Krypton, K_2	1.14
Hydrogen, H_2	0.55
Water Vapour	
Water Vapour	Highly variables; typically makes up about 1%

Notes: The concentration of CO_2 and CH_4 vary by season and location. The mean molecular mass of air is 28.97g/mol.

5.9 CONCLUSION

Atmosphere is more important to human beings than any other part of the environment. Man cannot live for more than a few minutes in the absence of air. It is impossible to think of season or weather without the existence of atmosphere. In fact, even the marine life is existing from this atmosphere.

5.10 SUMMARY

The atmosphere covers the Earth like a blanket 640 kms thick. In this chapter we discuss about the origin and composition of the earth's atmosphere in detail. Mass of the atmosphere and vertical structure is also described very well. As we all know the atmosphere has great thickness around the earth surface. The whole atmosphere is divided into different layers. Every part, every layer and every particle which exists in the atmosphere is very important and also plays a vital role for earth's surface.

5.11 GLOSSARY

Chloro-fluorocarbons, CFCs : Chemical compounds which, although essentially stable at ground level, undergo an exothermic photochemical reaction in the upper atmosphere, releasing free chlorine radicals which break down ozone in the ozone layer; a reaction potentially hazardous to human health.

Chlorophyll: The green substance in plants that takes in light from the sun to help them grow.

Cataract: A white area that grows over the eye as a result of disease.

Condensation: The process of conversion of water vapours into water droplets or ice crystals at the dew point is called as condensation, dew, fog, mist and clouds are difference forms of condensation.

Conventional movement: A method of transmission of energy in which heat is transferred through the movement of particles. Such process is common in equatorial region where air is heated and moves upwards. Cold air moves from different sides to take the place of displaced warm air.

Deforestation: The complete clearance of forests by cutting and/or burning. **Eddies (Eddy):** A roughly circular movement within a current of air, dust and water.

Precipitation: The falling of water droplets and ice crystals from the clouds under the effect of gravitational force is termed as precipitation.

Photon: A unit of a certain type of energy (electromagnetic energy), for example light.

Photosynthesis: The Process by which green plants turn carbon-di-oxide and water into food using energy from sunlight.

Microscope: A piece of equipment that makes very small objects looks big enough for you to be able to see them.

Radar: A system that uses radio waves for finding the position of moving objects for example ships and planes.

Satellites: An electronic device that is sent into space and moves around the earth or another planet for a particular purpose, a weather/communication satellite.

5.12 ANSWER TO CHECK YOUR PROGRESS

1. What is the significance of Stratosphere?
2. What is the structure of Atmosphere?
3. What is the vertical structure of the atmosphere?
4. Write a note on the significance of water vapour and dust particles in the earth's atmosphere.

5.13 REFERENCES

Barry, R.G. and Chorley, R.J. (1982), *Atmosphere, Weather and Climate*, Methuen, London.
Batse, D.R. (1958), *The Earth and its atmosphere*, Basic Books, New York.
Critchfield, H. (1961), *General Climatology*, Prentice Hall, New York.
Das, P.K. (1968), *The Monsoon*, Arnold, London.
Gates, E.S. (1979), *Meteorology and Climatology*, George, H.Harrap & Co. Ltd. London.
Kellaway, G.P. (1957), *A Background of Physical Geography*, Macmillan and Co., London.
Khan Nizamuddin (2001), *An Introduction to Physical Geography*, Concept Publishing Company, New Delhi.
Strahler A. and Strahler A. (2003), *Introducing Physical Geography*, John Wiley and Sons, Inc.
Singh Savindra, (2004), *Bhautik Bhoogol*, Vasundhara Prakashan, Gorakhpur.
Tikka, R.N. (1994), *Physical Geography*, Kedar Nath Ram Nath and Co. Meerut.

5.14 SUGGESTED READINGS

1. Batse, D.R. (1958)
The Earth and its atmosphere, Basic Books New York.
2. Donn, W.L. (1951)
Meteorology, Mc Graw-Hill Book Co. New York.
3. Singh Savindra (Hindi & English) (2004), *Physical Geography*, Vasundhara Prakashan, Gorakhpur.

5.15 TERMINAL QUESTIONS

1. Write a note on stratosphere and the weather.

2. What is the Atmosphere? Describe the structure and characteristics of various layers of the atmosphere.

3. Describe the composition of the earth's atmosphere.

4. Describe the chemical composition of the atmosphere in brief.

UNIT-6 INSOLATION AND HEAT BUDGET, VERTICAL & HORIZONTAL DISTRIBUTION OF TEMPERATURE

6.1 OBJECTIVE
6.2 INTRODUCTION
6.3 INSOLATION: MEANING AND CONCEPT
6.4 MECHANISM OF SOLAR RADIATION
6.5 DISTRIBUTION OF INSOLATION
6.6 FACTORS AFFECTING THE DISTRIBUTION OF INSOLATION
6.7 HEAT BUDGET OF THE EARTH AND THE ATMOSPHERE
6.7.1 Net radiation and global energy balance.
6.8 HEATING AND COOLING OF ATMOSPHERE.
6.9 DISTRIBUTION OF TEMPERATURE.
6.9.1 Vertical distribution of temperature.
6.9.2 Horizontal distribution of temperature.
6.10 CONCLUSION
6.11 SUMMARY
6.12 GLOSSARY
6.13 ANSWER TO CHECK YOUR PROGRESS
6.14 REFERENCES
6.15 SUGGESTED READINGS
6.16 TERMINAL QUESTIONS

6.1 OBJECTIVES

After reading this particular unit, you should be able to understand:

- Meaning, concept and distribution of Insolation
- Heat budget of the earth,
- Vertical and horizontal distribution of temperature,
- Heating and cooling of atmosphere.

6.2 INTRODUCTION

We all know that the sun is the main source of energy for all the planets of the solar system. A little heat is obtained from the interior parts of the Earth but it is significant. The temperature of the surface of the sun is about 6000^0C. Sun radiates energy is huge amount per second from its surface due to atomic fusion process. The earth is about 150,000,000 kms away from the sun. Due to such long distance only minute fraction of solar energy reaches to the earth surface. The energy which strikes with the earth is 1/20,000,000 part of energy emitted by the sun's surface. This insignificance amount of solar energy is responsible for different kinds of physical, chemical and biological phenomena taking place on the earth surface.

6.3 INSOLATION: MEANING AND CONCEPT

The heat and energy emitted in the radiation by the sun is called Insolation. Insolation refers to the flow rate of incoming solar radiation. Insolation is a flow rate and has units of watts per square meter (w/m^2). It is high when the sun is high in the sky. Insolation reaches the Earth from the sun in the form of waves but we can see only a small fraction of this insolation and the rest of the energy is invisible to our eyes. The solar radiations travel as a speed of 300,000 kms per second from the sun's surface in 8 minutes and 20 seconds. Thus the incoming solar radiations received by earth's surface are known as insolation. The average amount of solar radiation or energy received by one square an area in one minute is 1.94 calories. This energy from the sun is expended in the movement of winds and ocean currents and in weather formations. It's because of this energy that Earth has become suitable for the habitation of man.

6.4 MECHANISM OF SOLAR RADIATION

The whole of the insolation falling on the earth is not received on its surface. A lot of energy is lost in absorption, reflection and scattering. X-Rays, Gamma Rays and Ultra-violet rays are absorbed in the upper layers of the atmosphere and when insolation passes through atmospheric layers 18 to 45 km high, all the ultra-violet rays are absorbed.

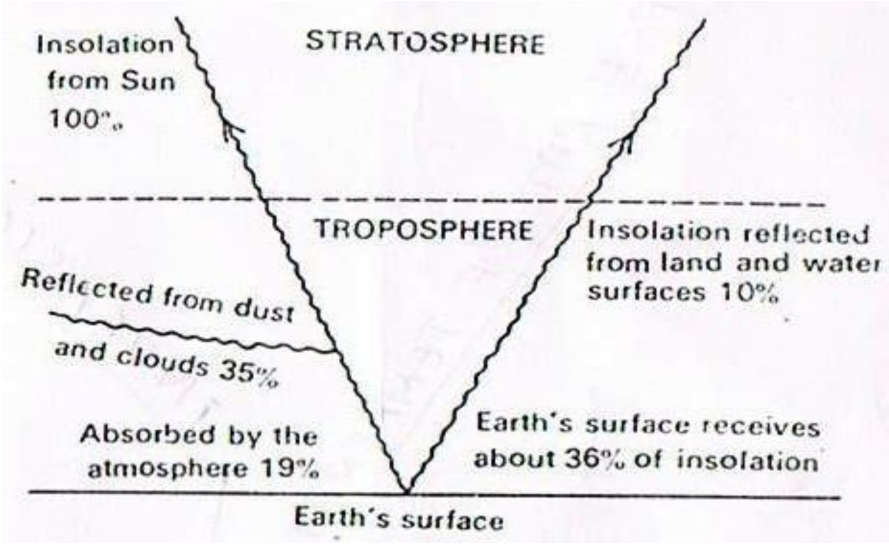


Fig 6.1 Solar Radiation

Ozone gas which is exist in ozonosphere absorbs these 35% of solar radiation is reflected back by dust and clouds. Only 19% of the insolation is absorbed in the atmosphere. The surface of the sea and the earth also reflect back 10% of insolation. It is therefore clear that only 36% of the insolation reaches the Earth's surface.

Insolation Spectrum

Wave-Length (Smallest Waves)	**Length of wave**	**Percentage of the total Energy**
X-rays and Gamma Rays	1/2000 to 1/100 micron	9%
Ultra-violet Rays	0.2 to 0.4 micron	
Visible Light Rays	0.4 to 0.7 micron	41%
Infra-red Rays (Longest Waves)	0.7 to 3.0 micron	50%
Heat Rays	3.0 to 3,000 micron	

Source: Dr. .N. Tikka, Physical Geography 1994-95.

6.5 DISTRIBUTION OF INSOLATION

On the earth surface the amount of insolation is the product of various factors like angle of sun rays, length of days, transparency of the atmosphere etc. these all factors are directly or indirectly related with the distribution of the latitudes. The amount of insolation decreases from equator to poles. Insolation is maximum at equator and minimum at poles. These are three latitudinal zones of insolation i.e., tropical, temperature and polar zones.

Tropical zone intends between tropic of Cancers (23 ½ ^{O}N) and tropic of Capricorn (23½^{O}S). This zone receives maximum insolation due to the sun shines vertically twice a year. Two maximum and two minimum amounts of insolation are received here due to apparent movement of sun is northern and southern hemisphere according to the season.

Temperate zone lies between 23½^{O} and 66½^{O} in both hemisphere. Maximum insolation is received once a year by every point of this zone on summer solstice (21st June) in northern hemisphere and on winter solstice (23rd September) in southern hemisphere. In this zone there is no day is free from the sun shine. Seasonal variation in amount of insolation is greater, while the minimum insolation occurs on winter solstice in northern hemisphere and on summer solstice in southern hemisphere.

Polar zone extends between Arctic Circle (66½^{O}N) and North Pole in northern hemisphere and between Antarctic Circle (66 ½^{O}S) and south poles in southern hemisphere. This zone received maximum insolation in northern hemisphere on 21st June and 23rd September in southern hemisphere. While the day of winter solstice in northern hemisphere and day of summer solstice in southern hemisphere receive minimum insolation.

6.6 FACTORS AFFECTING THE DISTRIBUTION OF INSOLATION

The insolation does not reach the earth's surface directly and uniformly. The amount of insolation on the earth surface is not evenly distributed with time and space and varies from place to place. The unevenness in insolation distribution is attributed to the following factors:

1. Angle of sun rays: The axis of the earth is inclined by 66 ½ ^{O} angle to the plane of the earth's orbit. The sun's rays strike on the different latitudes at different angles. In the table given below, the angle is described of sun's rays controls the amount of insolation on different places into two ways:

Table: 1: Distribution of Angle of Sun Rays on the Earth's surface on Summer and Winter Solstice.

Latitude	**Angle between the rays of the sun at noon day and the surface of the earth at summer solstice**	**Angle between rays of the sun at noon day and surface of the earth at the winter solstice**	**Difference**
90^{O}N	33½ ^{O}	0^{O}+	23 ½ ^{o}
70^{O}N	43 ½ ^{O}	0^{O}+	23 ½ ^{o}
66 ½ ^{O}N	47^{O}	0^{O}*	47^{O}
50^{O}N	63 ½ ^{O}	16 ½ ^{O}	47^{O}
23 ½ ^{O}N	90^{O}	43^{O}	47^{O}
20^{O}N	86 ½ ^{O}	46 ½ ^{O}	40^{O}
10^{O}N	76 ½ ^{O}	56 ½ ^{O}	20^{O}
0^{O}	66 ½ ^{O}	66 ½ ^{O}	0^{O}
20^{O}S	46 ½ ^{O}	86 ½ ^{O}	40^{O}
23 ½ ^{O}S	43^{O}	90^{O}	47^{O}
50^{O}S	16 ½ ^{O}	63 ½ ^{O}	47^{O}
66 ½ ^{O}S	0^{O}*	47^{o}	47^{O}
80^{O}S	0^{O}+	33 ½ ^{O}	33 ½ ^{O}

*Source: An Introduction Physical Geography, Nizammuddin khan, pp.209.** Rays are just horizontal, + Rays are below the horizon

The sun rays strike with the earth surface at sight angle, they cover small unit area and the minimum area is heated and received insolation while the other hand when the sun rays strike at acute angle, they cover relatively larger area and the intensity of heating is rather lesser. Consequently, the amount of received insolation decreases.

Vertical rays have to pass through smaller passage than the inclined ones. Atmosphere absorbs very little heat from the vertical than the inclined sun rays. It is why that the days with a longer duration of sunlight in higher latitudes give less heat than those with less duration of sunlight in lower latitudes. It is because the rays are more inclined in higher than in lower latitudes.

2. Length of the Days:

The earth is inclined at an angle of 66½^O at its orbital plane. Earth rotates around its axis and revolves around the sun. The length of the days or duration of sun shine is not uniform on every latitudes in a given time. On the equator days and nights are equal throughout the year because the circle of illumination divides the equator into the equal parts in all seasons. The circle of illumination passes through the two poles of the earth on March 21 and September 23. This creates day and night equal on these dates on the earth.

On June 21 the sun rays are vertical at 23½^{O}N and the circle of illumination crosses the North Pole and reaches 66 ½^{O}N (Arctic Circle). On this day, all the places beyond 66 ½^{O}N will remain in sunlight. Therefore, the day will be of more than 24 hours.

24 hours duration of days occur on Arctic Circle and six months day on the North Pole. Thus the length of days is longer on all latitudes in northern hemisphere during summer while the nights are longer in the southern hemisphere during the same season. In winters situation is totally reversed in both hemisphere.

At the equator, the sun rays are mostly vertical throughout the year. Hence days and nights are usually of 12 hours duration each.

The duration of sunshine determine the amount of insolation it all the other conditions are constant, therefore the higher latitude should have higher amount of insolation in summer season in northern hemisphere. But the reality is exactly reversed. The slanting rays, which fall in higher latitudes and snow capped surface, reduce the net amount of insolation received by earth surface. In the lower latitudes amount of insolation received is greater due to relatively vertical sun shine. Hence, the area of longer duration of days with vertical rays of the sun receives maximum amount of insolation.

3. Atmospheric Transparency:

Atmospheric transparency means the capacity of atmosphere to transmit the light from the sun to the earth and vice versa. Dust particles, water vapors and some gases present in the air absorb, reflect and scatter insolation. The degree of transmission of light through the atmosphere depends on the composition of the atmosphere. The atmosphere becomes opaque for different wavelengths of solar radiation and terrestrial radiations.

When atmosphere is free from the moisture, dust particles and clouds, the loss of solar radiation through the atmosphere is lower due to low rate of reflection, scattering and absorption of light in the atmosphere.

Insolation reached on the earth surface is relatively greater in the area of low moisture and clear sky. For example, subtropical high pressure (20^{O}–40^{O}) latitude received greater proportion of insolation due to low moisture and clear sky throughout the year.

4. The Distance between the Sun and the Earth:

The distance between the sun and the earth is not constant but goes on changing. The orbit of the earth is in ecliptical form. The distance between these two changes from time to time throughout the year. The mean distance between earth and sun is about 149 million km. on July 4; maximum distance (152 million km.) is found between them this distance is known as Aphelion. While, January 3 records minimum distance between the earth and sun. This minimum distance is called Prehelion.

In the summer the month of July maximum insolation is received in the northern hemisphere and minimum insolation is recorded in the southern hemisphere while in winters the month of January maximum insolation is received in southern hemisphere and minimum in the result of variation in angle of sun rays and the length of the days.

5. Sun Spots:

It is the minor factor to affecting the distribution of insolation on the earth surface. The number of sun spots on the surface of the sun also influences the amount of insolation reaches on the earth. Number of these spots changes every year. They are due to the internal disturbances and explosion, in the sun's surface. The amount of insolation is depend upon the amount of insolation is depend upon the number of spots. Larger the number of sun spots, higher the amount of insolation received on the earth surface and vice-versa.

6.7 HEAT BUDGET OF THE EARTH AND THE ATMOSPHERE

Heat budget may be defined as balance between incoming short wave radiation on the earth from sun and outgoing radiation from the earth surface. It may be classified as positive heat budget and negative heat budget. The amount of incoming short wave radiation exceeds the outgoing terrestrial radiation is described as positive heat budget and when terrestrial radiation exceeds the amount of short wave radiation is called negative heat budget.

Heat Budget

Here, the amount of insolation strikes the top of atmosphere is 100 units. Out of which 27 units are reflected by clouds, 6 units are scattered and diffused by dust particles in the atmosphere and 2 units are reflected back by earth surface as short wave to the space. Thus 35 units of short wave radiation do not reach the earth surface and it is described as Albedo of the earth. Albedo is an important property of a surface because it measures how much incident solar energy will be absorbed. A surface with a high albedo such a snow or ice (0.45 to 0.85) reflects much or most of the solar radiation and absorbs only a smaller amount. The following diagram described the heat budget on the earth surface:

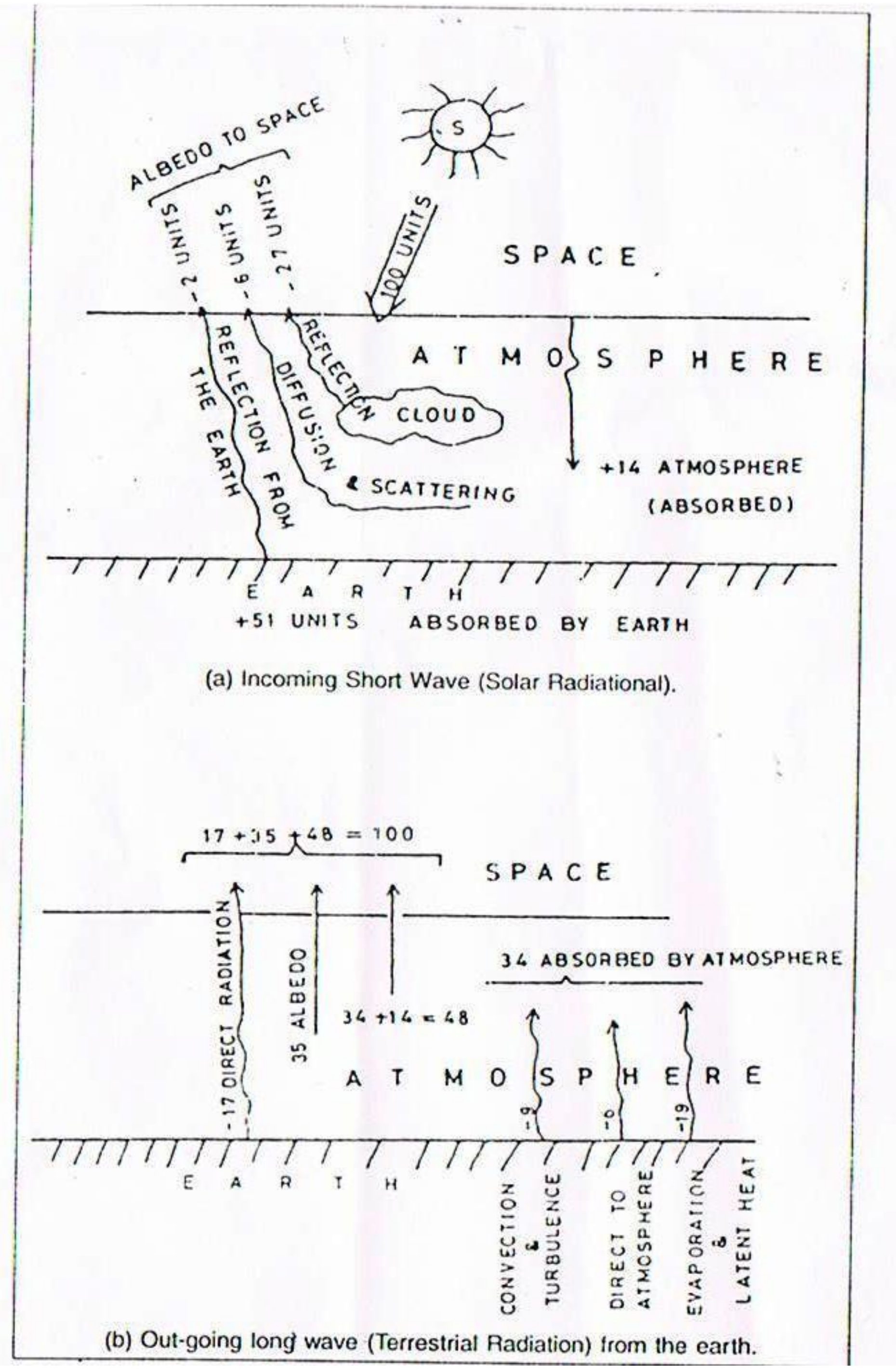


Figure 6.2

A surface with a low albedo, such as black pavement (0.03), absorbs nearly all the incoming solar energy. Besides, 14 units are absorbed by atmosphere. Only 51 units of short wave radiations are received and absorbed by the earth surface. After the absorption of solar radiation, the earth emits the energies in the form of long wave radiation. Out of 51 units absorbed by earth 17 units are directly returned to the space, 19 units are used by water vapour and 9 units are spent by convection and turbulence. Besides 6 units of long wave radiation is directly absorbed by atmosphere, Thus 48 units of long wave radiation are absorbed by atmosphere by one or other ways. Moreover, the radiation are absorbed by atmosphere (14 short wave radiations – 48 long wave radiations) are finally returned to the space and at last a balance is set in heat budget.

There is an important principle of physics that, except for nuclear reactions, energy is neither created nor destroyed. It is therefore possible to follow the initial stream of solar energy and account for its diversion into various system pathways and its conversion into various energy forms. A full accounting of all the important energy flows among the sun, atmosphere, earth surface and space forms the energy budget of the atmosphere and surface.

6.7.1 Net Radiation and Global Energy Balance

Earth's net radiation, sometimes called the Flux, is the balance between incoming and outgoing energy at the top of the atmosphere. It is the total energy that is available to influence the climate. Energy comes into the system when sunlight penetrates the top of the atmosphere. Energy goes out in two ways : reflection by clouds, aerosols, or the Earth's Surface; and thermal radiation – heat emitted by the surface and the atmosphere, including clouds. The global average net radiation must be close to zero over the span of a year or else the average temperature will rise or fall.

Solar energy is received by earth and because some of it is absorbed, the energy level of earth tends to rise. Earth also radiates energy into outer space, this process that tends to reduce the energy level of the earth. These incoming and outgoing radiation flows must balance for the earth as a whole. However, incoming and outgoing flows do not have to balance at any given surface location. At night there is no incoming radiation, yet the earth's surface and atmosphere still emit outgoing radiation.

Net radiation is the difference between all incoming radiation and all outgoing radiation. Where radiant energy flows is faster than it flows out, net radiation is a positive quantity in those places and providing an energy surplus. Where radiant energy is flowing out faster than it is flowing in, net radiation is a negative quantity, yielding and energy deficit.

At latitudes lower than 40^0, annual net radiation is positive, while it is negative at higher latitudes. This imbalance creates pole ward heat transfer of latent and sensible heat in the motions of warm water and moist warm air and thus provides the power that drives ocean currents and broad scale atmospheric circulations patterns.

Global energy balance is describes as a sensitive one involving a number of factors that determine how energy is transmitted and absorbed. Industrial activities already altered the components of the global energy balance. An increase in carbon di oxide increase the absorption of long wave radiation by the atmosphere, enhancing the greenhouse effect.

An increase in atmospheric particles at upper levels of the atmosphere will increase the scattering of incoming shortwave radiation and thus reduce the shortwave energy available to warm the surface and the other side, increased dust particles at low levels will act to absorb more longwave radiation and after this the surface temperature is automatically raised.

Human activities through cultivation, industrialization and urbanization have profoundly altered the land surfaces of the earth. These anthropogenic changes affect surface albedo and the transfer of latent and sensible heat to the atmosphere and modified the global energy balance.

6.8 HEATING AND COOLING OF ATMOSPHERE

The atmosphere is indirectly heated by the earth surface. The incoming short wave radiation is absorbed by the earth and then it is radiated by the earth's surface into form of long wave radiation.

The long wave radiations are directly responsible for the hearting of the atmosphere. The atmosphere is hearted from the earth surface temperature by these following processes

Radiation:

Radiation is very important process of heating of the atmosphere. In this process, medium is not needed for the transmission of heat energy from one body to another. It can transmit through vaccum of air. The upper part of the atmosphere is heated mainly by this particular process. This process follows few principles given below –

1- Either hot or cool, every object radiates energy;
2- Wavelength of energy emitted by an object is inversely related with temperature of bodies;
3- Amount of radiation emitted by a body is directly proportional to the temperature of bodies;
4- Good absorber of energy is also good emitter of the radiation.

Conduction:

In this process of transmission of heat, energy moves from particle to particle. This process is continued unless the both ends of a body are heated equally. The lower layer of air closed to earth surface is heated by conduction process. Upper portion of the atmosphere is not affected by this process.

Convection:

Convection is also very efficient process of heating of upper air. It is a process in which air is heated due to molecular movement of air. Earth surface is excessively heated by this process and then heated air becomes lighter and move upward and the cold upper air moves downward to take place of displaced hot air. Hence, the upper part of the atmosphere is heated by this process.

Latent Heat of Condensation:

Water vapour is an important phenomenon of the atmosphere. Water vapour contains latent heat when it is converted from liquid water to gaseous form. The water vapour condense into various forms like clouds, fog and dew etc. when the temperature of the earth surface reaches at dew points the condensation of water vapour causes the release of latent heat is added to atmosphere. About 19 units of total terrestrial energy is added to the atmosphere by condensation of latent heat. It is also a very important process of heating and cooling of the atmosphere.

6.9 DISTRIBUTION OF TEMPERATURE

The earth receives the insolation in short wave radiation. It is absorbed by earth surface and converted into form of energy. This energy heats up the earth surface as well as the atmosphere. The degree of hotness of the atmosphere and earth surface is described as temperature. The temperature is measured by Thermometer and recorded either in Fahrenheit or Centigrade.

6.9.1 Vertical Distribution of Temperature

The temperature distribution on the earth is divided into two major types, i.e.

1. Vertical distribution and
2. Horizontal distribution

There are two types of trends about the vertical distribution of temperature between the earth and troposphere. They are: (i) Normal lapse of temperature, and (ii) inversion of temperature.

Normal Lapse Rate of Temperature:

As we rise from the surface of the earth, temperature falls with increasing height at a rate of 1^0C for 165 meters or 6.5^0C for 1000 meters. This rate of change of temperature with altitude is described as normal lapse rate.

Inversion of Temperature:

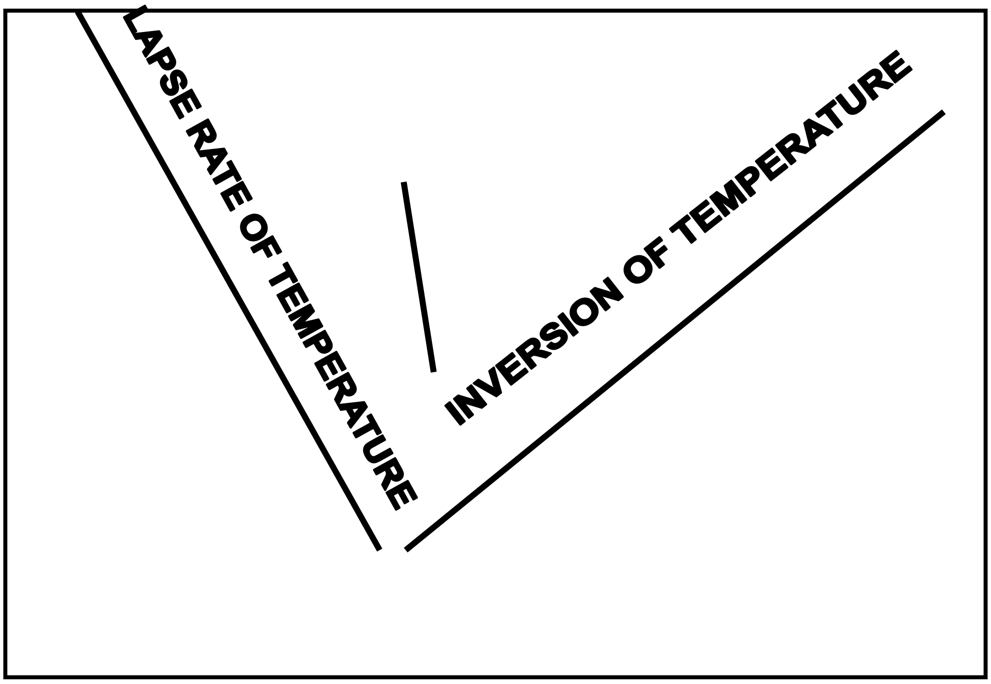
The temperature also increases with increasing height instead of decreasing temperature due to some certain reasons. This kind of event is described as inversion of temperature in meteorological field. On the basis of reasons involved for such types of vertical distribution of temperature, inversion of temperature may be divided into following types:

(i) Surface or Radiational Inversion

(ii) Advectional Inversion, and
(iii) Valley Inversion

(i) Surface or Radiational Inversion

During long and cold night, clear sky and calm wind condition, the rate of long wave radiation (terrestrial radiation) is rather faster, the earth and the lower layer of air is chilled and temperature falls to considerable extent. While the temperature of the overlying air is relatively higher and inversion of temperature happens lower and this type of inversion is known as surface or radiational inversion.



Lapse Rate and Inversion of Temperature

(ii) Advectional Inversion

When warm air mass moves into cold region the temperature of overlying air becomes relatively higher than that of overlying air. The movement of cold air into warm region also lowers the ground temperature and the air at higher level has higher temperature. This type of inversion is known as Advectional inversion of temperature.

(iii) Valley Inversions

During the day time, the upper part of valley is heated up and low pressure is developed there. When the bottom remains rather cooler and high pressure occurs then mountain breeze move up the slope. While in the night, the upper slope of the valley is chilled up and high pressure is occurs there. The bottom of the valley is relatively warmer and low pressure region. Hence, cold heavy air moves down the valley slope to the bottom. The warm air is displaced from the bottom to upper slope of the valley. Thus the upper slope occurs high temperature than the and the inversion of temperature develops, this is called valley inversion of temperature. This type of inversion is confined to the valley region.

6.9.2 Horizontal distribution of Temperature

The horizontal distribution of temperature depicts the study of temperature across the latitude or the changing pattern of temperature from equator to poles. The amount of insolation along the latitude is uniform thus the latitudinal distribution of temperature is the best expression. The horizontal distribution of temperature is shown by Isotherms. Isotherm is an imaginary line which is drawn connecting the place of equal temperature reduced to sea level. These lines show usually east and west parallel to the latitudes. Isotherm are having some spatial distance which indicates the steepness of the change of temperature gradient Isotherm take sudden bands where land water contrast is maximum.

6.10 CONCLUSION

Sun is the main source of energy for all planets of the solar system. The earth is 150,000,000 kms away from the sun but due to such long distance only minute fraction of solar energy reaches to the earth surface. This energy is an important element for the life of the earth. The energy emitted in the radiation by the sun is known as Insolation. Insolation travel as a speed of 300,000 kms/ second from the sun and they reach in 8 minutes and 20 seconds on the earth surface. The amount of insolation is the product of various factors. Insolation is maximum at equator and minimum at poles. There are three latitudinal zones of insolation that is tropical, temperate and polar zones. There are various factors affecting the distribution of insolation.

In this part of the study we discuss about net radiation and global energy balance in short. Heating and cooling of atmosphere are processed by radiation, conduction, convection and condensation.

6.11 SUMMARY

This unit describes the sun as the source of energy. Earth receives its energy and reflected in the atmosphere. We understand the meaning, concept and distribution of Insolation. Mechanism of solar radiation is also described. Angle of sun rays, length of the days, atmospheric transparency, distance between the sun and the earth and sun spots are the major factors affecting the distribution of insolation. Heat budget of the earth and the atmosphere is also explained in upper written unit. Heat budget may be defined as the balanced between incoming short wave radiation on the earth from the sun and outgoing radiation from the earth surface. It may be classified as positive and negative.

Earth’s net radiation, sometimes called the flux, is the balance between incoming and outgoing energy at the top of the atmosphere. It is the total energy that is available to influence the climate. While global energy balance is describes as a sensitive one involving a number of factors that determine how energy is transmitted and absorbed.

Heating and cooling of atmosphere is also described here. Radiation, conduction, convection and condensation are the main processes which are responsible for heating and cooling.

Distribution of temperature is also discussed in this unit. The degree of hotness of the atmosphere and earth surface is described as temperature. The temperature distribution on the earth is divided in two major types that one is vertical and second is horizontal distribution. This unit described all the factors and components related to insolation, energy budget and temperature etc.

6.12 GLOSSARY

Absorption : The process of a liquid, gas or other substance being taken in.

Anthropogenic Change: Change brought about by human agency.

Antartic Circle: The parallel or live of latitude 66^{O}32'S, commonly assumed to be 66^{O}30'S. Owing to inclination of earth's axis, the sun does not set here one day (22 December) of the year. Similarly, one day (21 June) sun does not rise too along this line.

Aphelion: The position of the earth on its orbit when the maximum distance 152,000,000 km. is found between the sun and the earth.

Arctic Circle: The parallel or line of latitude at 66^{O}32'N, commonly assumed to be 66^{O}30'N. Owing to the inclination of earth's axis, the sun does not set on one day (21st June) of the year and sun does not rise on one day (22nd December) of the year.

Axis: A line we imagine through the middle of an object, around which the object turns or rotate.

Centigrade: The name of a scale for measuring temperatures, in which water freezes at 0^{O} and boils at 100^{O}.

Condensation: The process of conversion of water vapors into water droplets or ice crystals at the dew point is called as Condensation. Dew, fog, mist and clouds are different forms of condensation.

Conduction: The transfer of heat from one body to another through movement of heat from one body to another through movement of heat from one particle to another. This process continued until the both bodies get uniform temperature.

Convection: The process whereby heat is transferred from one past of a liquid or gas to another, by movement of the fluid itself. Convection carries excess heat from the earth's surface and distributes it through the troposphere.

Conversion: The act or process of changing from one form, system or use to another.

Equator: The imaginary great circle around the world at latitude 0^{O}. The equator is equidistant between the North and South poles. It has a length of 40076 km.

Fahrenheit: The name of a scale which measures temperatures.

Flux: A continuous movement.

Gamma Rays: Also gamma radiation. Rays that are sent out by some dangerous (radioactive) substances.

Global Energy Balance: The difference between the total influx of solar radiation to the earth's surface and the loss of this energy via terrestrial radiation, evaporation and the dissipation of sensible heat into the ground.

Heat Budget: Balance between the amount of incoming solar (short wave) radiation and outgoing earth's long wave (terrestrial) radiation.

Infrared Rays: Rays (used about light) that is produced by hot objects but cannot be seen.

Inversion of Temperature: It is an atmospheric condition when temperature increases with height instead of falling a normal laps rate.

Isotherm: An imaginary line drawn by connecting the places of equal temperature reduced to sea level.

Latitude: Parallels of latitude are imaginary circles drawn round the earth parallel to the equator.

Meteorology: The study of the character of the atmosphere and the events and processes within it, together with the inter action between the atmosphere and the face of the earth.

Net Radiation: Also known as net radioactive balance, this is the balance of incoming solar radiation and outgoing terrestrial radiation, which varies with latitude and season. Net radiation is generally positive by day and negative by night.

Ocean Current: The flow of huge amount of water from tropical to polar and vice versa in a definite direction.

Ozone Gas: A form of oxygen and an atmospheric trace gas, made by natural photo chemical reaction associated with solar ultra-violet radiation. Ozone has three atoms of oxygen combined in one molecule, rather than two atoms, as in free oxygen. The proportion of ozone in the atmosphere is very small, but it is of vital importance in absorbing solar ultra violet radiation.

Ozonosphere: It is an ozone-rich band of the atmosphere, at 10 – 20 km above the earth but is at its most concentrated between 20 and 25 km. It is also known as Ozone layer.

Radiation: The emission of energy in different wave lengths is termed as radiation. Everybody radiates energy. The amount and wavelength or radiations depend upon the temperature of the body. Solar and terrestrial radiation control the heat balance and the temperature on the earth's surface.

Solstice: The time (21 June or 22 December) at which the overhead sun is furthest from the equator and appears to stand still before returning towards the equator. The longest day occurs at the summer solstice; the shortest day at the winter solstice.

Stratosphere: The second layer of atmosphere above the troposphere. Temperature increases with height. It extends from tropopause to 50 kms height from sea level.

Sub–tropical: The term is used loosely to refer either to regions which experience some features of tropical meteorology during part of the year, or to regions of near – tropical climate.

Other side those areas lying between the Tropic of Cancer and 40^{O}N and the Tropic of Capricorn and 40^{O}S.

Sunspots: A dark patch on the surface of the Sun. Sunspots usually occur in cluster and last about two weeks. It has been suggested that the sun is 1% cooler when it has no spots ant that this variations in solar radiation night affect the climates of the earth.

Terrestrial Radiations: The heat radiated from the earth. Short wave solar radiation reaching the earth does not heat the atmosphere it passes through but does not heat the atmosphere it passes through but does heat the earth's surface. In turn, and particularly on clear nights, much of this heat is radiated out from the earth. The earth also absorbs terrestrial radiation reflected from the overlying opaque atmospheric layer.

Troposphere: The lowest layer of the atmosphere in which different kinds of weather phenomena are confined. It is the closest to the earth. Temperature decreases with altitude at the normal laps rate of 6.5^{O}C/km.

Ultra Violet: Radiation (rays) with wavelength from 0.2 to 0.4 micrometers.

Weather: The average conditions of weather elements of shorter period and smaller area.

X-Rays: A kind of light that makes it possible to see inside solid objects.

6.13 ANSWER TO CHECK YOUR PROGRESS

1. Write a short note on Insolation and its concept.
2. What are the factors on which Insolation depends?
3. Explain the heating and cooling of the atmosphere.
4. Horizontal and vertical distribution of temperature, explain in brief.
5. What are Net Radiation and Global Energy Balance?

6.14 REFERENCES

Barry, R.G. and Chorley, R.J.(1982), *Atmosphere, Weather and climate*, Methuen, London.
Critchfield, H. (1961), *General Climatology*, Prentice Hall, New York.
Das, P.K. (1968), *The Monsoon*, Arnold, London.
Gates, E.S. (1979), *Meteorology and Climatology*, George, H. Harrap & Co., Ltd., London.
Koeppe, C.E. and Delong, G.C.(1958), *Weather and Climate*, Mc-graw Hill Book Co., New York.
Khan Nizamuddin(2001), *An Introduction to Physical Geography*, Concept Publishing Company, New Delhi.
Trewartha, G.T. (1954), *an Introduction to Climate*, Mc-Graw Hill Book, New York.
Strahler Alan, Strahler Arthur (2003), *Introducing Physical Geography*, John Wiley 2 Sons, Inc.
Tikka, R.N. (1994), *Physical Geography*, Kedar Nath Ram Nath & Co., Meerut.

6.15 SUGGESTED READINGS

1. Trewartha, G.T. (1954)

An Introduction to Climate, Mc-Graw Hill Book, New York.

2. Strahler, A.N. (1960)

Physical Geography, John Willey Co., London.

3. Blair, T.A. (1948)

Weather Element's Solar Energy: Its Nature, Transmission and Distribution, Prentice Hall, New York.

4. Kendrew, W.G. (1953)

The Climates of the Continents, Ox ford University Press, London.

6.16 TERMINAL QUESTIONS

1 Write short notes on:

1. Lapse Rate 2. Ozone layer depletion

2. Give the horizontal distribution of temperature over the Northern hemisphere. In the winter season and discuss the factors influencing such distribution.

3. What do you understand by Insolation? What factors effect insolation, explain it.

4. Is there any change you feel in climate of your area? Explain with causes and examples.

UNIT – 7 ATMOSPHERIC PRESSURE, WINDS, HUMIDITY AND RAINFALL

7.1 Objectives

7.2 Introduction

7.3 Atmospheric Pressure: Meaning and concept

7.4 Horizontal distribution of air pressure and pressure belt

7.1 Objectives

After studying this unit, you should be able to understand:

- The meaning atmospheric pressure and horizontal distribution of air pressure and pressure belt.
- Different pressure belts, winds and its types with world distribution.
- Humidity and types of rainfall.
- World distribution of rainfall.

7.2 Introduction

An atmosphere derived from Greek word atmospa, atmos meaning 'vapour' and pa meaning 'sphere' is a layer of gasses surrounding the earth or other material body that is held in place by the gravity of that body. It is subject to high if the temperature of atmosphere low. Thus surrounding the earth, in each latitude, over land and sea, is a gaseous envelope which is spoken of as the air or the atmosphere. Its presence when at rest is unperceived, though when moving it becomes apparent, since it imparts its motion to leaves and other bodies free to move.

7.3 Atmospheric Pressure: Meaning and concept

Atmospheric pressure is the force per unit area that is applied perpendicularly to a surface by the surrounding gases present in the atmosphere and thus it has its own weight. The air exerts pressure through its weight. Air pressure is, defined as total weight of a mass of column of air above per unit area at sea level. It is maximum at sea level. It is determined by a planet's gravitational force in combination with the total mass of a column of gas above a location. On Earth, units of air pressure are based on the internationally recognized standard atmosphere, which is defined as 101.325 kPa. It is measured with a barometer. The standard air pressure at sea level is 1013.25 mb. The lines joining the places of equal pressure at sea level are called isobars. Air pressure decreases with increasing altitudes at the rate of 3.4 mb per 600 feet but this rate of decrease is confined to the altitude of a few thousand feet only. Normally, half of the total atmospheric pressure is confined to the altitude of 1800 feet.

The distribution of air pressure is controlled by altitude, temperature, air circulation, rotation of the earth, water vapour etc. The rate of change of pressure per unit horizontal distance is called pressure gradient.

7.4 Horizontal distribution of air pressure and pressure belt

The distribution of atmospheric pressure across the latitudes is termed global horizontal distribution. Its main feature is its zonal character known as pressure belts. It is studied on the basis of **isobars**. There are seven pressure belts on the globe. The pressure belts are discontinued in the northern hemisphere and several centers of pressure belts are developed but the pressure belt are found more or less in regular pattern in the southern hemisphere. On the basis of mode of genesis pressure belts are divided into two broad categories e.g. 1. Thermal induced pressure belts (e.g. equatorial low pressure belt and polar high pressure belt), and 2. dynamically induced pressure belts (e.g. subtropical high pressure belt and sub polar low pressure belt) .

7.4.1 Equatorial Low Pressure Belt

The equatorial low pressure belt is located on either side of the geographical equator in a zone extending between 5^0N and 5^0S latitudes but this zone is not stationary because there is seasonal shift of this belt with the northward (summer solstice) and southward (winter solstice) migration of the sun .During northern summer this belt extends up to 20^0N in Africa and to the north of tropic of Cancer in Asia while during southern summer this low pressure belt shift to 10^0 to 20^0S latitude. The equatorial low pressure belt is thermally induced because the ground surface is intensely heated during the day due to almost vertical sun's rays and thus the lowermost layers of air coming in contact with the heated ground surface also gets warmed. Thus, warmed air expands, becomes light, and consequently rises upwards causing low pressure. Because of frequent calm conditions this belt is called a belt of calm or doldrums.

7.4.2. Sub-Tropical High Pressure Belt

Sub-tropical high pressure belt extends between the latitudes of 25^0-35^0 in both the hemispheres. This high pressure belt is not thermally induced because this zone, besides two to three winter months, receives fairly high temperature throughout the year. Thus, this belt owes its origin to the rotation of the earth and sinking and settling down of winds. It is thus, apparent that the sub-tropical high pressure belt is dynamically induced. This zone of high pressure is called 'horse latitude' because of prevalence of frequent calms. In ancient times, the merchants carrying horses in their ships, had to throw out some of the horses while passing through this zone of calm in order to lighten their ships . This is why this zone is called horse latitude. This zone of high pressure is not a continuous belt but is broken into a number of high pressure centers or cells.

7.4.3 Sub – Polar Low Pressure Belt

This belt is located between 60^0-65^0 latitudes in both the hemispheres. The low pressure belt does not appear to be thermally induced because there is low temperature throughout the year and such there should have been high pressure belt instead of low pressure belt. Thus, this low pressure belt is dynamically produced, the surface air spreads outward from this zone due to rotation of the earth and low pressure is caused. It may be pointed out that this factor should be more effective at the poles but the effects of the rotation is neglected due to exceptionally low temperature prevailing throughout the year at the poles .The sub–polar low pressure belt is more developed and regular in the southern hemisphere while it is broken in the northern hemisphere because of over dominance of water(oceans) in the southern. It may be noted that due to great contrasts of temperature of the continents and oceans during northern summer the low pressure belt becomes discontinuous and is found in a few low pressure cells while the temperature contrast between the continents and oceans is much reduced during winter and hence low pressure belt becomes more or less regular and continuous in the northern hemisphere.

7.4.4 Polar High Pressure Belt

High pressure persists at the poles throughout the year because of prevalence of very low temperature (below freezing point) all the year round yet both the factors, thermal and dynamic, operate at the poles. There is thinning out of layers of air due to diurnal rotation of the earth as the air spreads outward due to this factor but this effect is neglected by thermal factor and hence high pressure is produced due to very low temperature as below freezing point even in summer.

7.5 Shifting of Pressure Belts

The surface pattern of the air pressure as discussed in above lines and find it seldom remains stationary in its latitudinal zone .There are daily, seasonal and annual changes in air pressure because of northward and southward movement of the overhead sun (summer and winter solstices), contrasting nature of the heating and cooling of land and water etc. The lowest pressure is developed between 2 to 4 P.M. during the day due to maximum temperature while highest pressure is recorded between 4-6 A.M. due to minimum temperature during night. Coastal land records low pressure while adjoining oceanic area has high pressure during day. This situation is reversed during night time. Except polar high pressure belt all the pressure belts move northward with the northward with the northward movement of the sun during summer solstice. On the other hand, except the polar high pressure belt, all the belts move southward due to southward movement of the sun during winter solstice, when the sun is vertical at the tropic of Capricorn. The pressure belts occupy their normal ideal position at the time of vernal equinox (21 March) and autumnal equinox (23 September) when the sun is vertical at the equator.

7.6 Wind: the concept

Wind is simply air in motion, usually in a horizontal direction. The cause of the wind is the pull of gravity upon air of different weights and the resulting displacement of lighter by heavier air. Wind may therefore, be said to be due essentially to differences in the weight of pressure of different parts of the atmosphere. Wind always blows from a place of high pressure to one where the pressure is lower. And the pressure of the atmosphere varies from place to place and since air naturally moves for readjustment of pressure. Thus, if the difference of pressure is same so the winds are permanent here throughout the year. They are periodic if the pressure differences only arise at definite intervals. Variable in pressure disturbances which may ensure from local peculiarities of situation or from any other cause. Thus the general effect of unequal isolation, effect of the extra-tropical belt of high pressure, unequal heating of land and water and atmospheric disturbances are few important causes for birth of wind.

7.7 Classification of winds and their distribution

The winds blowing almost in the same direction throughout the year are called prevailing or permanent winds. These are also called an invariable or planetary winds because they involve larger areas of the globe. These winds includes trade winds, westerlies and polar winds. On the other hand, winds with seasonal changes in the directions are called seasonal winds (e.g. monsoon winds). Winds blowing in a particular locality are called local winds (e.g. chinook, harmattan, mistral, blizzard, loo etc.). Winds blowing from hill tops to the valleys and from valley floor to the hill tops are called mountain and valley breezes. Winds blowing from land to sea and from sea to land are called land and sea breezes.

7.7.1 Tropical winds

Generally, the areas extending between 30^0N and 30^0S latitudes are included in tropical zone. It has discovered that trade winds blow with regularity only some parts of the tropical oceans (mainly over the eastern parts). The weather conditions in the tropics are not calm and uniform but they are frequently interrupted by atmospheric disturbance (cyclones, hurricanes, typhoons etc.). Thus, the tropical zone is characterized by doldrum, equatorial westerlies and trade winds.

7.7.1.1 Doldrum and equatorial westerlies

A belt of low pressure, popularly known as equatorial trough of low pressure extends along the equator within a zone of 5^0N and 5^0S latitudes. This belt is called the belt of calm or doldrums because of light and variable winds.

7.7.1.2 Inter-tropical convergence (ITC)

ITCZ, known by sailors as the doldrums, is the area encircling the earth near the equator where the northeast and southeast trade winds converge. The ITCZ was originally identified from the 1920s to the 1940s as the ”Intertropical Front” (ITF), but after the recognition in the 1940s and 1950s of the significance of wind field convergence in tropical weather production, the term “ITCZ” was then applied. When the ITCZ is drawn into and merges with a monsoonal circulation, it is sometimes referred to as a monsoon trough, a usage more common in Australlia and parts of Asia. According to Seaman the zone is referred to as the doldrums because of its erratic weather patterns with stagnant calms and violent thunderstorms. The ITCZ is effectively a tracer of the ascending branch of the Hadley cell, and is wet. The northern and southern boundaries of ITC are called NITC and SITC respectively.

7.7.1.3 Trade winds

There is more or less regular inflow of winds from subtropical high pressure belts to equatorial low pressure belt. These tropical winds have north-easterly direction in the northern hemisphere while they are south-easterly in the southern hemisphere. These winds are called trade winds because of the fact that they helped the sea merchants in sailing their ships as their direction remains more or less constant and regular. According to Farrel's law trade winds are deflected to the right in the northern hemisphere and to the left in the southern hemisphere. There are much variations in the weather conditions in the different parts of trade winds.

7.7.2 Mid-latitude wind

The mid-latitudes are between the tropics and the Arctic and Antarctic polar regions, known as temperate zones. Fronts and extra tropical cyclones are usually found in this area. The prevailing winds in the middle latitudes are often very strong. These parts of the world also see a wide variety of fast changing weather as cold air masses from the poles and warm air masses from the tropics push up and down over them, sometimes alternating within hours of each other.

7.7.2.1 Horse latitude

The dynamically induced subtropical high pressure belt extends between 30^0- 35^0 latitudes in both the hemispheres. Thus, this belt separates two wind systems viz. trade winds and westerlies. It is also apparent that the subtropical high pressure belt is the source for the origin of trade winds and westerlies because winds always blow from high pressure to low pressure. The air after being heated near the equator ascends and after blowing in opposite direction to the surface trade winds descends in the latitudinal zone of 30^0- 35^0 . Thus, the descent of winds from above causes high pressure on the surface which in turn causes anticyclonic conditions. This is why the anticyclonic conditions cause atmospheric stability, dry condition and very weak air circulation. Thus, this zone is characterized by weak and variable winds and calm. This belt of calm is very popularly known as horse latitudes because of the fact that in ancient times the merchants had to throw away some of the horses being carried in the ships in order to lessen the weight so that the ships could be sailed through the calm conditions of these latitudes. Anticyclones are produced due to subsidence of air currents in the horse latitudes. These anticyclones are known as 'subtropical anticyclones.

7.7.2.2 Westerlies

Westerlies is known as mid-latitude winds. These are the permanent winds blowing from the subtropical high pressure belts to the subpolar low pressure belts (60^0-65^0)in both the hemispheres are called westerlies. The general direction of the westerlies is S.W to N.E in the northern hemisphere and N.W to S.E in the sourthern hemisphere. There is much variation in the weather conditions in their poleward parts where there is convergence of cold and denser polar winds and warms and lighter westerlies. The general characteristic features of the westerlies are largely modified due to cyclones and anticyclones associated with them. Because of the dominance of land in the northern hemisphere the westerlies become more complex and complicated and become less effective during summer seasons and more vigorous during winter season. They brings good precipitation in the western parts of the continents as they pick up plenty amount of moisture while passing over the vast stretches of the oceans. The velocity of the westerlies becomes so great that they are called roaring forties between the latitudes of 40^0-50^0S, furious fifties at 50^0S latitude and shrieking sixties at 60^0 S latitude.

7.7.3 Polar winds

The winds blowing from polar high pressure belts to sub-polar low pressure belts between 60^0-65^0 in both hemispheres, are known as polar winds. This belt of low pressure is more persistent in summer season but generally disappears in winter season. The zone of polar winds shrinks due to northward shifting of pressure belts at the time of northern summer in the northern hemisphere but extended up to 60^0 N latitude during northern winter.

7.8 Seasonal shifting of wind belts and their climatic significance

The relative position of the earth with the sun changes within a year due to earth's revolution and thus the position of all the pressure belts except the polar high pressure belts changes with the northward and southward migration of the sun. At the time of summer solstice the sun is vertical over the tropic of Cancer and therefore all the pressure belts except the northern polar high pressure belt shift northward. The equatorial low pressure belt prevails between 0^0 latitude and 10^0 N latitude, subtropical high pressure belt extends between 30-40 N latitude. Thus, all the wind belts associated with these pressure belts also shift northward. The sun becomes vertical over the equator at the time of autumnal equinox and hence all the pressure belts which shifted to the north occupy their normal positions. After this there is southward migration of the sun which becomes vertical over the tropic of Capricorn at the time of winter solstice and hence the pressure and wind belts shift southward except the southern polar high pressure belt. Thereafter the sun again becomes vertical over the equator at the time of vernal equinox and hence all the pressure and hence all the pressure and wind belts occupy their normal positions thus, there is shifting in the position of the pressure and wind belts due to seasonal changes of position of the earth in relation to the sun.

7.9 Tricellular Meridional Circulation of the atmosphere

The modern school envisages a three- cell model of meridional circulation of the atmosphere, popularly known as tricellular meridional circulation of the atmosphere, wherein it is believed that there is cellular circulation of air at each meridian (longitude) .Surface winds blow from high pressure areas to low pressure areas but in the upper atmosphere the general direction of air circulation is opposite to the direction of surface winds. Thus, each meridian has three cells of air circulation in the northern hemisphere e.g. (1) tropical cell or Hadley cell, (2) polar front cell or midlatitude cell or Ferrel cell, and (3) polar or subpolar cell.

7.10 Monsoon winds

The word 'monsoon' is used to indicate the winds in the areas where they change their direction twice each year. The word 'monsoon' which has been derived from Arabic word ‘Mausim’ refers to such an atmospheric circulation which reverses its direction completely every 6 months or say during summer and winter seasons .The world ‘Mausim’ was first used by Arab navigators for the wind blowing over the Arabian Sea between Arab and India wherein they blow from north–east to south–west for 6 months during winter season and from south–west to north–east during summer season .On this basis, the word monsoon was applied to all those winds of the globe which had directional change from summer season to winter season and vice–versa. It may be pointed out that there are many such places on the globe where there is complete seasonal reversal in the wind direction e.g. the region lying between 60^0-70^0 latitudes in the northern hemisphere is characterized by northern polar winds during winter season and by south-west westerlies during summer season but these winds are not called monsoon .It is apparent that directional change of the winds in not the only criterion of monsoons. In fact, the monsoons are surface convective systems which are originated due to differential heating and cooling of the land and water (oceans) and thermal variations. The regions dominated by monsoon winds are called ‘monsoon climatic regions’ which are more developed in Indian sub-continent, south-east Asia, parts of China and Japan. Besides, southern USA, northern Australia, western Africa etc.

7.11 Local winds

Local winds are small scale convective winds of local origin caused by temperature and pressure differences. They are limited to small areas and are known by local names in that area. Land and sea breezes, slope and valley winds, thunderstorm, loo, harmattan and chinook are few examples of local winds.

Types of Local Winds

Wind type	**Nature and Region**
Chinook	It is a warm dry wind blows down the east side of the Rocky mountain at the end of winter.
Foehn	It is a hot southerly wind blows on the northern slopes of the Alps.
Harmattan	It is a very hot and dry, dusty easterly or north-easterly wind on the West African coast, occurring from Dec to February.
Khamsin	It is a hot and dry south-easterly wind blowing in Egypt in spring.
Mistral	It is a strong cold north-westerly wind blows through the Rhine valley, southern France.

7.12 Jet stream

The strong and rapidly moving circumpolar westerly air circulation in a narrow belt of a few hundred kilometers width in the upper limit of troposphere is called jet stream. The circulation of westerly jet stream is confined between poles and 20^0 latitudes in both the hemispheres at the height of 7.5-14km. Jet stream was discovered during second world war when American jet bomber fighter planes while flying towards Japan (from east to west) found obstructions of an air circulation which was moving in opposite direction (west to east) resulting into marked reduction in the velocity of jet fighter planes, these planes registered marked increase in their velocity while they used to return to their bases (west to east). After careful study of this phenomenon, it was found that there was a strong upper air circulation from west to east in the upper portion of troposphere which presented obstruction in the free movement of jet fighter planes. Based on this fact, westerly strong meandering upper air circulation was called as jet stream.

Properties

The jet streams are characterized by the following properties

1- Generally, their circulation is observed between poles and 20^0 latitudes in both the hemispheres. These are also called circum-polar whirl because these move around the poles in both the hemispheres.
2- There is seasonal change in the wind velocity in jet streams wherein these become strong during winter season and the wind velocity becomes twice the velocity during summer season. Maximum wind velocity is 480 km (per hour).

7.13 Humidity: The concept

Humidity refers to the content of water vapour present in the air in gaseous form at a particular time and place. The atmospheric humidity is expressed in a number of ways e.g. absolute humidity, specific humidity, relative humidity etc.

Humidity Capacity - The moisture content (humidity) of the air is measured in grain per cubic foot or in gram per cubic centimeter. Humidity capacity becomes higher during summer months than during winter months and during daytime than nights. Humidity capacity decreases from equator to poleward.

Absolute Humidity - The total weight of moisture content (water vapour) per volume of the air at definite temperature is called absolute humidity.

Specific Humidity - It is defined as the mass of water vapour in grams contained in a kilogram of air and it represents the actual quantity of moisture present in a definite air.

Relative Humidity- It is also defined as a ratio of the amount of water vapour a actually present in the air having definite volume and temperature to the maximum amount the air can hold (i.e. humidity capacity). Generally it is expressed in percentage. It decreases with increasing temperature and increases with decreasing temperature.

7.14 Rainfall

Rainfall results from clouds when condensation has gone on for a sufficiently long time, or when the cloud has been pushed up sufficiently high to enable the formation of big drops of water, the drops fall from the clouds as rain. The Rain gauge is an equipment to measure the amount of rain. It is the most common form of precipitation.

7.15 Types of rainfall

Rain is the most common form precipitation and both are classified on the basis of conditions and mechanisms of upward movement of air. There are three ways in which air is forced to move upward movement of air. There are three ways in which air is forced to move upward and thus cools according to adiabatic lapse rate e.g. 1- Thermal convection, 2- Ascent of air over an orographic barrier, and 3- Uplift of air associated with low pressure system, known as cyclonic. Thus Rainfall is classified into the following four types:

7.15.1 Convectional rainfall - Occurring due to thermal convection currents caused due to insolational heating of ground surface. This type of rainfall is most common in the equatorial regions.

7.15.2 Orographic rainfall - Occurring due to ascent of air forced by mountain barrier. The rainfall that takes place at the foot hills of the Himalayas in India, is of such type.

7.15.3 Cyclonic rainfall - Occurring due to upward movement of air caused by convergence of extensive air masses. The rainfall in Tamilnadu and Andhra Pradesh in winter season is the example of this type of rainfall.

7.15.4 Man – induced rainfall

It is also known as artificial rainfall and pluviculture. It is the act of attempting to artificially induce or increase precipitation, usually to stave off drought and to increase reservoir irrigation water or water supply capacity, or to increase water levels for power generation.

7.16 World distribution pattern of precipitation

Rainfall is highly correlated with air temperature and atmospheric humidity while humidity is closely related with temperature through the process of evaporation .The regions having high temperature and abundance of surface water for evaporation receive higher amount of annual rainfall, Equatorial regions are typical example of such situation. Subtropical region are also characterized by above conditions but the western part of the continents receives least rainfall because there anticyclonic conditions due to descent of air air. Middle latitudes also have favourable conditions for sufficient rainfall but polar areas receive their precipitation on the form of snowfall instead of rainfall .Before attempting to describe world distribution of rainfall it is necessary to discuss certain facts related to rainfall distribution e.g. total amount of annual rainfall, seasonal distribution, and variability of rainfall.

Mean annual rainfall for the whole globe is 970 mm but this means annual amount is unevenly distributed on the earth's surface. Some places receives less than 100 mm of means annual rainfall (for example, tropical hot deserts like Sahara, thar, Atacama, Kalahari etc.) while some places receives more than 12000 mm of annual rainfall (e.g. Cherrapunji of India). Not only this, there is much temporal variation of annual rainfall in a particular area. Most of the annual amount of rainfall is received during a few months of the year while most of the months either remain dry or receive little rainfall. For example, 12000 mm of rainfall at Cherrapunji is received only in 159 days. The equatorial regions receive rainfall throughout the year but other areas are characterized by seasonal rainfall. For example, more than 80 per cent of annual rainfall in India is received during 3 wet summer monsoon months (July, August and September). On the other hand, the Mediterranean regions receive most of their annual rainfall during winter months while summer season remains dry. Since air moisture depends upon temperature and horizontal distribution of temperature is found in zonal patterns and hence rainfall distribution is also characterized by zonal pattern. Based on above considerations, 6 major zones of rainfall distribution are identified on the earth's surface.

Equatorial zone of maximum rainfall - This zone extends up to 10^0 latitudes on either side of the equator and falls within intertropical convergence characterized by warm and moist air masses .The mean annual rainfall ranges between 1750 mm and 2000 mm. Most of the rains are received through convectional rainfall accompanied by lighting and cloud thunder. There is daily rainfall in the afternoon. The rainfall intensity is very high as it occurs in form of heavy showers. .

Trade wind rainfall zone - extends between 10^0-20^0 latitude in both the hemisphere and is characterized by north- east and south – east trade winds. These winds yield rainfall in the eastern parts of the continents because they come from over the oceans and hence pick up sufficient moisture but as they move westward in the continents they become extremely dry and deserts. The monsoon region located in this zone receives much rainfall. Summers receive most of the mean annual rainfall.

Subtropical zone of minimum rainfall - extends between 20^0 and 30^0 latitudes in both the hemispheres, where descending air from above induced high pressure and winds diverge in opposite direction at the ground surface, with the result anti-cyclones are formed. This condition is not conducive for rainfall and hence dry condition prevails over large areas. Mean annual rainfall is 900mm. It may be pointed out that the entire tropical hot desert are located in this zone where mean annual rainfall is below 250mm. The average annual rainfall becomes for the whole zone, higher (900 mm) than the average value for the desert because the eastern parts of the continents receive more rainfall from relatively moist trade winds which come from over the oceans. Most of annual rainfall occurs during summer months while winter season is dry.

Mediterranean rainfall zone- extends between 30^0-40^0 latitudes in both the hemisphere where rainfall occurs through westerlies and cyclone during winter season while summers remain dry because this zone comes under the influence of trade winds due to northward shifting of wind and pressure belt during northern summer (summer solstice). Mean annual rain fall is 1000mm.

Mid-latitudinal zone of high rainfall - extends between 40^0-50^0 latitudes in both the hemispheres where rainfall occurs through westerlies and temperate cyclones. Mean annual rainfall ranges between 1000 mm and 1250 mm. The western parts of the continents receive more rainfall. It decreases from the western coastal areas to inland. Southern hemisphere records more rainfall than northern hemisphere because of dominance of oceans in the former. Winter season receives maximum precipitation through temperate cyclones .The precipitation is of long duration but occurs in the form of light showers.

Polar zone of low precipitation – Precipitation decreases from 60^0 latitude to pole ward in both hemispheres. Mean annual precipitation becomes only 250mm beyond75^0 latitude. Most of the precipitation occurs in the form of snowfall.

7.17 Conclusion

Thus we can say that atmospheric pressure is a most important phenomena and completely responsible for all weather activities as wind, rain, cyclone etc. Sometimes it also called as barometric pressure, is the pressure within the atmosphere of Earth. In most circumstances atmospheric pressure is closely approximated by the hydrostatic pressure caused by the weight of air above the measurement point. As elevation increases, there is less overlying atmospheric mass, so that atmospheric pressure measures force per unit area decreases. Variation in temperature, distribution of land and water, nature of the land etc. are few important responsible factors for existence of pressure. In all, there are seven pressure belts on the globe.

Winds are the result of unequal insolation and variation in pressure of an area. Wind is simply air in motion, usually in a horizontal direction. It is commonly classified on the basis of spatial scale as it's speed, the types of forces, the region in which it occur, and it's effect etc. The broad categories of classified winds on the globe are Permanent winds, seasonal winds and local winds. Whereas, trade winds, westerlies and polar winds are sub type of permanent winds. Monsoon winds are the example of seasonal winds. Chinook, Foehn, Khamsin and Mistral are local winds types. Jet stream is the strong and rapidly moving circumpolar westerly air circulation in a narrow belt of a few hundred kilometers width in the upper limit of troposphere.

Humidity express to the content of water vapour present in the air in gaseous form at a particular time and place. Humidity and rainfall are interconnected atmospheric phenomena convectional, orographic and cyclonic are the major natural types of rainfall. Whereas, man-induced rainfall also includes under it. Equatorial region receives maximum rainfall and as we move towards poles it decreases. Yet Mid-latitudinal zone lies under good rainfall region in both hemisphere because of westerlies and temperate cyclones.

7.18 Summary

What do we infer? All the contents of the unit, such as the concept of atmospheric pressure and various components related to it, wind and wind type seasonal shifting of wind belts and their climatic significance, different mechanism such as tricellular meridional circulation of atmosphere, humidity, rainfall types with world distribution are interlinked with each other. All the sub topics are essential to study the atmosphere, an important part of physical geography.

7.19 Glossary

Absolute humidity: The total weight of moisture content per volume of air at definite temperature and point of time is called absolute humidity, generally expressed in gram per cubic meter volume.

Chunook/ Foehn : Warm and local dry winds blowing on the leeward slopes of the mountains are called 'chinook' in the USA and 'foehn' in Switzerland.

Doldrum : A belt of low pressure, popularly known as equatorial trough of low pressure extending discontinuously within a zone of 5^0 N and 5^0 S latitude is called the belt of calm or doldrum.

Humidity: The state of the atmosphere with respect to the water vapour present in it.

Humidity capacity: The moisture retaining capacity or simply humidity capacity refers to the capacity of a parcel of air having certain volume at certain temperature and point of time to hold maximum amount of moisture content. It is directly proportional to air temperature.

Hadley cell: The tropical convrctive cell, one each in the northern and the southern hemispheres, is called Hadley cell (named after George Hadlely).

Ferrel's law : is related to deflection of winds. The law states that if one stands with one's back towards the direction from where winds are coming they are defected to the right in the northern hemisphere and to the left in the southern hemisphere..

Jet stream: The strong and rapidly moving circumpolar upper air westerly air circulation in a narrow belt of a few hundred kilometers width in the upper limit of the troposphere is called jet stream.

Monsoon: The word is used to indicate the wind system in the regions where they change their directions twice a year.

Pressure gradient: The rate of change of pressure per unit horizontal distance is called pressure gradient.

Relative humidity: The ratio between the actual amount of water vapour in a given volume of the air and the amount that would be present if the air were saturated at the amount that would be present if the air were saturated at the same temperature, generally expressed as percentage

Saturated air : The parcel of air with definite volume at given temperature at given moment of time having moisture content equal to its humidity capacity is called saturated air.

7.20 Answer to check your progress

Q.1 What is atmospheric weight and pressure?

Q.2 Discuss the horizontal distribution of atmospheric pressure.

Q. 3 How many pressure belts are found on the globe?

Q. 4 What do you mean by wind?

Q.4 What are the causes of winds?

Q.5 Give a brief account of the classification of winds.

Q.6 What are the permanent winds of the world?

Q.7 Define Monsoon?

Q.8 Write the types and world distribution of rainfall?

7.21 References

Singh, Savindra : Climatology, Prayag Pustak Bhawan, University Road, Allahabad.
Aguado Edward and Burt J.E: Weather and Climate, Printice Hall, New Jersey.
Hartmann D.L., Global Physical Climatology, 1993.
Lydolph P.E., Weather and Climate, 1985
Trewartha G.T. & Horn L.H., An Introduction to climate, New-York, 1980

7.22 Suggested readings

Singh, Savindra : Climatology, Prayag Pustak Bhawan, University Road, Allahabad.

Trewartha G.T. & Horn L.H., An Introduction to climate, New-York.

7.23 Terminal Questions

Q.1 What is Jet stream theory?

Q.2 Write the difference between Absolute humidity and Relative humidity?

UNIT- 8 CLIMATES AND ITS CLASSIFICATION- KOPPEN & THORNTHWEIT

8.1 OBJECTIVES
8.2 INTRODUCTION
8.3 CLIMATE & CLIMATIC CLASSIFICATION
8.4 CLIMATIC CLASSIFICATION OF KOPPEN
8.4.1 GROUP A: Tropical/mega thermal climates
8.4.2 GROUP B: Dry (arid and semiarid) climates
8.4.3 GROUP C: Mild Temperate/ meso thermal climates
8.4.4 GROUP D: Continental/micro thermal climate
8.4.5 GROUP E: Polar climate
8.4.6 Evaluation of the Köppen's scheme
8.5 CLIMATIC CLASSIFICATION THORNTHWEIT
8.5.1 1931 classification
8.5.2 1948 classification
8.5.3 Evaluation of the Thornthwaite's scheme
8.6 CONCLUSION
8.7 SUMMARY
8.8 GLOSSARY
8.9 ANSWER TO CHECK YOUR PROGRESS
8.10 REFERENCES
8.11 SUGGESTED READINGS
8.12 TERMINAL QUESTIONS

8.1 Objectives

After going through this chapter, you will have learnt

- Climate & its classification
- Climate classification of Koppen
- Evaluation of the Thornthwaite's scheme
- Climate classification scheme presented by Thornthwaite
- 1931 classification and 1948 classification
- Evaluation of the Thornthwaite's scheme

8.2 Introduction

Climate is one of the most imortant phenomina in physical geography. Climate classification systems work as key to understand the physical and cultural geography. It was first published by Russian German climatologist Wladimir Koppen in 1884, with several later modifications republished in 1918 and 1936 Where as C.W.Thornthwaite also published and republished the world climate classification in 1931 and1948. The detail description is given below.

8.3 Climate and Climate Classification

Climate is the statistics of weather, usually over a 30 years interval. It is measured by assessing the patterns of variation in temperature, humidity, atmoshpheric pressure, wind, precipitation, etc. atmospheric condition of a vast region. Climate covers the vast area where as weather describes the short-term atmoshpheric conditions in a small area. Thus a region's climate is generated by climate system, which has five components: atmoshphere, hydrosphere, lithosphere, cryosphere (snow covered area), and biosphere.

Thornthwaite system was introduced in 1931 and published that climate of a location is affected by its latitude, terrain and altitude, as well as nearby water bodies and their currents. Climate can be classified according to the average and the typical ranges of different variables, most commonly temperature and precipitation. The most commonly used classification scheme was the Koppen climate classification 1948, incorporates evapotranspiration and is diversity and how climate change affects it. along with temperature and precipitation information used in studying biological diversity and how climate change affects it.

8.4 Climate classification of Koppen

The German botanist and climatologist Wladimir Koeppen presented the descriptive scheme of the classification of world climates first in 1900 based on vegetation zones of French plant physiologist Candolle presented in 1874. He revised his scheme in the year 1918 wherein he paid more attention to monthly and annual averages of temperature and precipitation and their seasonal distribution. He again modified his scheme in 1931 and 1936.

Koeppen used five major vegetation zones of the world as identified by Candolle in 1874. The basis of classification of world climates is on the belief that the distribution of natural vegetation was the best indicator of the total picture of climate of a region concerned. Thus he divided the world climates into 5 principal types and represented them by capital letters A to E. The detail description about scheme symbols of climate types are as-

The Koppen climate classification scheme divides world climates into five main groups:

A (tropical climate)

B (dry climate)

C (temperate climate)

D (contintal climate)

E (polar climate)

The second letter indicates the seasonal precipitation type, while the third letter indicates the level of heat.

8.4.1 Group A: Tropical / megathermal climates

This type of climate has every month of the year with an average temperature of 18^0C (64.4 ^{0}F) or higher, with significant precipitation.

Af = Tropical rainforest climate; average precipitation of at least 60 mm (2.4in) in every month.

Am = Tropical monsoon climate; driest month with precipitation less than 60 mm, but more than 4% the total annual precipitation.

Aw or ***As*** = Tropical wet and dry or savanna climate; with the driest month having precipitations less than 60 mm (2.4 in) and less than 4 % of the total annual precipitation.

8.4.2 Group B: Dry (arid and semiarid) climates

This type of climate is defined by little precipitation.

Multiply the average annual temperature in Celsius by 20, then add

(a) 280 if 70% or more of the total precipitation is in the spring and summer months (April –
(b) 140 if 30% - 70% September in the Northern Hemisphere, or October-March in the Southern), or of the total precipitation is received during the spring and summer, or
(c) 0 if less than 30% of the total precipitation is so received.

If the annual precipitation is less than 50% of this threshold, the classification is BW (arid: desert climate); if it is in range of 50%-100% of the threshold, the classification is BS (semi- arid: steppe climate).

A third letter can be included to indicate temperature. Originally, h signified low- latitude climate (average annual temperature below 18^0C (64.4*F) while k signified middle- latitude climate (average annual temperature below 18^0C), but the more common practice today, especially in the United States, is to use h to mean the coldest month has an average temperature above 0^0C (32^0F), with K denoting that at least one month's averages below 0^0C .

BWh = Hot desert climate
BWk = Cold desert climate
BWn = Mild desert climate
BSh = Hot semi-arid climate
BSk = Cold semi-arid climate
BSk = Cold semi-arid climate
BSn = Mild semi- arid climate

8.4.3 Group C: Mild Temperate / mesothermal climates

This type of climate has the coldest month averaging between 0^0C (32^0 F) and at least one month averaging above 10^0C (50^0F).
Cfa = Humid subtropical climate; coldest month averaging above 0^0C (32^0 F) and at least one month's average temperature above 22^0C (71.6^0 F) and at least four months averaging above a 10^0C (50^0F). No significant precipitation difference between seasons.No dry months in the summer.

Cfb = Temperate oceanic climate; coldest month averaging above 0^0C (32^0 F), all months with average temperatures below 22^0C (71.6^0 F), and at least four months averaging above10^0C (50^0F). No significant precipitation difference between seasons. abovementioned set of conditions fulfilled).

Cfc = Subpolar oceanic climate; coldest month averaging above 0^0C (32^0 F) and 1-3 months averaging above 10^0C (50^0F). No significant precipitation difference between seasons.

Cwa = Monsoon-influenced humid subtropical climate, coldest month averaging above 0^0C (32^0 F) and at least one month's average temperature above 22^0C (71.6^0 F). at least four months averaging above 10^0C (50^0F). At least ten times as much rain in the wettest month of summer as in the driest month if winter (70% or more of average annual precipitation is received in the warmest six months).

Cwb = Subtropical highland climate or temperate oceanic climatic with dry winters; coldest month averaging above 0^0C (32^0 F), all months with average temperature below 22^0C (71.6^0 F), and at least four months averaging above 10^0C (50^0F). At least ten times as much rain in the wettest month of summer as in the driest month of winter (70% or more of average annual precipitation received in the warmest six months).

Cwc = Cold subtropical highland climate or subpolar oceanic climate with dry winters; coldest month averaging above and 0^0C (32^0 F) and 1-3 months averaging above 10^0C

(50^0F). At least ten times as much rain in the wettest month of summer as in the driest month of winter (70% or more of average annual precipitation is received in the warmest six months).

Csa = Hot summer Mediterranean climate; coldest month averaging 0^0C (32^0 F), and at least one month's average temperature above 22^0C (71.6^0 F) and at least four months averaging above 10^0C (50^0F). At least three times as much precipitation in the wettest month of winter as in the driest month of summer, receives less than 30 mm.

Csb = Warm-summer Mediterranean climate; coldest month averaging above 0^0C (32^0 F), all months with average temperatures below 22^0C (71.6^0 F), and at least four months averaging above 10^0C (50^0F). At least three times as much precipitation in the wettest month of winter as in the driest month of summer, and driest month of summer receives less than 30 mm.

Csc = Cool-summer Mediterranean climate; coldest month averaging above 0^0C (32^0 F), and 1-3 months averaging above 10^0C (50^0F). At least three times as much precipitation in the wettest month of winter as in the driest month of summer, and driest month of summer receives less than 30 mm.

8.4.4 Group D: Continental/ microthermal climates

This type of climate has at least one month averaging below 0 ^{0}C (32^0 F), and at least one month averaging above 10 ^{0}C (50^0 F),

Dfa = Hot-summer humid continental climate; coldest month averaging below 0^0C (32^0 F), and at least one month's average temperature above 22^0C (71.6^0 F), and at least four months averaging above 10^0C (50^0F). No significant precipitation difference between seasons.

Dfb = Warm-summer humid continental climate; coldest month averaging below 0^0C (32^0 F), all months with average temperatures below 22^0C (71.6^0F). No significant precipitation difference between seasons.

Dfc = Subarctic climate; coldest month averaging below 0^0C (32^0 F), and 1-3 months averaging above 10^0C (50^0F). No significant precipitation difference between seasons.

Dfd= Extremely cold subarctic climate; coldest month averaging below -38^0C (-36.4^0F) and 1-3 months averaging above 10^0C (50^0F). No significant precipitation difference between seasons.

Dwa = Monsoon- influenced hot- summer humid continental climate; coldest month averaging below 0^0C (32^0 F), and at least one month's average temperature above 22^0C (71.6^0 F) and at least four months averaging above 10^0C (50^0F). At least ten times as much rain in the wettest month of summer as in the driest month of winter.

Dwb = Monsoon-influenced warm-summer humid continental climate; coldest month averaging below ^{0}C (32^0 F), all months with average temperatures below ,and at least four months averaging above 10^0C (50^0F). At least ten times as much rain in the wettest month of summer as in the driest month of winter.

Dwc = Monsoon-influenced subarctic climate; coldest month averaging below 0^0C (32^0 F), and 1-3 months averaging above 10^0C (50^0F). At least ten times as much rain in the wettest month of summer as in the driest month of winter.

Dwd = Monsoon- influenced extremely cold subarctic climate; coldest month averaging below -38^0C (-36.4^0F) and 1-3 months averaging above 10^0C (50^0F). At least ten times as much rain in the wettest month of summer as in the driest month of winter.

Dsa = Hot, dry-summer continental climate; coldest month averaging below 0^0C (32^0 F), and at least one month's average temperature above 22^0C (71.6^0 F). and at least four months averaging above 10^0C (50^0F). At least three times as much precipitation in the wettest month of winter as in the driest month of summer, and driest month of summer receives less than 30 mm.

Dsb = Warm, dry-summer continental climate; coldest month averaging below 0^0C (32^0 F), all months with average temperatures below 22^0C (71.6^0 F), and at least four months averaging above 10^0C (50^0F). At least three times as much precipitation in the wettest month of winter as in the driest month of summer, and driest month of summer receives less than 30 mm.

Dsc = Dry-summer subarctic climate; coldest month averaging below 0^0C (32^0 F), and 1-3 months averaging above 10^0C (50^0F). At least three times as much precipitation in the wettest month of winter as in the driest month of summer, and driest month of summer receives less than 30 mm.

Dsd = Extremely cold, dry-summer subarctic climate; coldest month averaging below -38^0C (-36.4^0F) and 1-3 months averaging above 10^0C (50^0F). At least three times as much precipitation in the wettest month of winter as in the driest month of summer, and driest month of summer receives less than 30 mm.

8.4.5 Group E: Polar climates

This type of climate has every month of the year with average temperatures below 10^0C (50^0F).

ET = Mild tundra climate; all 12 months of the year with average temperatures between 0^0C (32^0 F), and 10^0C (50^0F).

ETf = Cold tundra climate; at least one month with an average temperature below 0^0C (32^0 F).

EF = Ice cap climate; eternal winter, with all 12 months of the year with averagetemperature below 0^0C (32^0 F).

8.4.6 Evaluation of Koeppens's Scheme

Koeppen used two easily measurably weather elements e.g. temperature and precipitation as the basis for statistical parameters for the delineation of different climatic regions. So these elements are used by him most frequently and they also control the climatic condition. He also paid due consideration to the loss of moisture through evaporation as he included effective precipitation, which depends on the rate of potential evapotranspiration, in his scheme. Koeppen's scheme appealed more to geographers because the scheme recognized association between vegetation types and climatic types. Besides, this scheme is descriptive, generalized and simple and hence it was widely acclaimed.

Yet Koeppen's climate classification has good scope but sometimes it also suffers from some serious drawbacks. As he focused only on mean monthly temperature and precipitation where as neglected other weather elements such as winds, amounts of cloudiness and number of rainy days etc. He made his scheme more descriptive, generalized and ignored the consideration of causative factors of climate.The use of different letter symbols to indicate different climatic types and their secondary and tertiary subtypes makes the scheme very difficult to memorise.

8.5 climate classification of Thornthwaite

C.W.Thornthwaite, was an American climatologist, presented his first scheme of classification of climates of North America in 1931. Later he extended this scheme and presented full scheme in 1933. He further modified his scheme and presented the revised second scheme of classification of world climates in 1948. It is also a popular scheme for geographers.

8.5.1 1931 Classification

Thornthwaite also considered natural vegetation of a region as the indicator of climate of that region as Koeppen. He used the concept that the amount of precipitation and temperature had paramount control. Thus Thornthwaite used two factors, as precipitation effectiveness and temperature effectiveness, for the delimitation of boundaries of different climatic regions.

(i) Precipitation Effectiveness

Precipitation effectiveness refers to only that amount of total precipitation which is available for the growth of vegetation. He used precipitation efficiency ratio for the calculation of this amount of water available to vegetation. This ratio is calculated by dividing total monthly precipitation by monthly evaporation and precipitation efficiency index is derived by summing the precipitation efficiency ratios for 12 months of a year. Since it is difficult to obtain data of evaporation for every centre and hence he calcutate the precipitation efficiency index and precipitation efficiency ratio as-

$$P\backslash E \text{ Ratio} = 11.5\ (r/t - 10)^{10/9}$$

Where, r = mean monthly rainfall in inches, t= mean monthly temperature in ^{0}F

He identified 5 humidity zones on the basis of P/E Index and boundary values for the major vegetation zones.

Humidity Zone	Vegetation	P\E Index
A (Wet)	Rainforest	127
B (Humid)	Forest	64-127
C (Subhumid)	Grassland	32-63
D (Semiarid)	Steppe	16-31
E (Arid)	Desert	<16

Thornwthwaite further subdivided each humidity zone into 20 subhumidity zones on the basis of seasonal distribution of precipitation.

1-Ar	5- Br	9- Cr	13- Dr	17- Er
2- As	6- Bs	10- Cs	14- Ds	18- Es
3-Aw	7- Bw	11- Cw	15- Dw	19- Ew
4- Ad	8- Bd	12- Cd	16- Dd	20- Ed

Where r = adequate rainfall in all seasons

s= rainfall deficient in summer

w= rainfall deficient in winter

d= rainfall deficient in all seasons

(ii) Thermal Effectiveness- He believed that temperature had important contribution in the growth of vegetation. Thus divised an index of thermal efficiency or temperature effectiveness, expressed by positive departure of monthly mean temperatures from freezing point, and for the better result suggested the following formula-

(i) Thermal Efficiency Ratio (T – E Ratio) = (t-32) /4

(ii) Thermal Efficiency Index (T – E Index) = $\sum_{i=1}^{12}$ (t-32) /4

Where t = mean monthly temperature in ^{o}F.

T-E Index is the sum of thermal efficiency ratio for 12 months.

On the basis of T-E Index Thornthwaite divided the world into 6 temperature provinces –

Temperature Provinces	T – E Index
A' – Tropical	127
B' – Mesothermal	64-127
C' – Microthermal	32-63
D' – Taiga	16-31
E' – Tundra	1.15
F' – Frost	0

Thus, on the basis of precipitation effectiveness, thermal efficiency, and seasonal distribution of rainfall there may be 120 probable combinations and hence climatic types on theoretical ground but he depicted only 32 climatic types on the world map as given below-

1. A A'r tropical wet climate with rainfall adequate in all seasons
2. A B'r mesothermal wet climate with adequate rainfall in all seasons
3. A C'r microthermal wet climate with adequate rainfall in all seasons
4. B A'r tropical humid climate with adequate rainfall in all seasons
5. B A'w tropical humid climate with rainfall deficient in winter
6. B B'r mesothermal humid climate with adequate rainfall in all seasons
7. B B'w mesothermal humid climate with rainfall deficient in winter seasons
8. B B's mesothermal humid climate with rainfall deficient in summer seasons
9. B C'r microthermal humid climate with adequate rainfall in all seasons
10. B C's microthermal humid climate with adequate rainfall in all seasons
11. C A'r tropical subhumid climate with adequate rainfall in all seasons
12. C A'w tropical subhumid climate with deficient rainfall in winter seasons
13. C A'd tropical subhumid climate with rainfall deficient in all seasons
14. C B'r mesothermal subhumid climate with adequate rainfall in all seasons
15. C B'w mesothermal subhumid climate with rainfall deficient in winter seasons
16. C B's mesothermal subhumid climate with rainfall deficient in summer season
17. C B'd mesothermal subhumid climate with rainfall deficient in all seasons
18. C C'r microthermal subhumid climate with rainfall deficient in all seasons
19. C C's microthermal subhumid climate with rainfall deficient in summer season
20. C C'd microthermal subhumid climate with rainfall deficient in all seasons
21. D A'w tropical semiarid climate with deficient rainfall in all seasons
22. D A'd tropical semiarid climate with rainfall deficient in all seasons
23. D B'w mesothermal semiarid climate with rainfall deficient in winter season
24. D B's mesothermal semiarid climate with rainfall deficient in summer season
25. D B'd mesothermal semiarid climate with rainfall deficient in all seasons
26. D C'd microthermal arid climate with rainfall deficient in all seasons
27. E A'd tropical arid climate with rainfall deficient in all seasons
28. E B'd mesothermal arid climate with rainfall deficient in all seasons
29. E C'd microthermal arid climate with rainfall deficient in all seasons
30. D' taiga type climate
31. E' tundra type climate
32. F' Permanently snow-covered polar climate

8.5.2 1948 Classification

Thorthwaite presented his modified scheme of climatic classification in 1948. Though he reused three indices of precipitation effectiveness, thermal efficiency and seasonal distribution of precipitation in the second classification but in different way. Now the new scheme of climatic classification was based on the concept of potential evapotranspiration (PE) which is an index of thermal efficiency and water loss because it represents the amount of transfer of both moisture and heat to the atmosphere from soils and vegetation. It may be pointed out that potential evapotranspiration is calculated from the mean monthly temperature with corrections for day length of the day. The PE for a 30 days month is calculated as follows-

PE (in cm) = $1.6\ (10t/I)^a$

Where PE = Potential Evapotranspiration

I = the sum for 12 months of $(t/5)^{1.514}$

a = a further complex functuion of I

t = temperature in ^{0}C

Thornthwaite developed four indices to determine boundaries of different climate types e.g. (i) moisture index (Im), (ii) potential evaportranspiration or thermal efficiency index (PE), (iii) aridity and humidity indices, and (iv) index of concentration of thermal efficiency or potential evapotranspiration.

(i) **Moisture Index (Im)-** Moisture index refers to moisture deficit or surplus and is calculated according to the following formula -

Im = (100S-60D) /PE

where Im = monthly moisture index

S = monthly surplus of moisture

D = monthly deficit of moisture

The sum of the 12 monthlly values of Im gives the annual moisture Index.

Annual Moisture Index = $\sum_{i=1}^{12}(100S - 60D)/PE$

(ii) **Thermal Efficiency Index** – Thermal efficiency is simply the potential evapotranspiration expressed in centimetres as expressed above. It is, thus, apparent that the thermal efficiency is derived from the PE in itself is a function of temperature.

(iii) **Aridity and Humidity Indices-** These indices are used to determine the seasonal distribution of moisture adequacy. These are calculated as follows-

Aridity Index = in moist climates annual water deficit taken as a percentage of annual PE becomes aridity index.

Humidity Index = in dry climates annual water surplus taken as a percentage of annual PE becomes humidity index.

(iv) **Concentration of thermal efficiency** refers to the percentage of mean annual potential evapotranspiration (PE) accumulating in three summer months.

On the basis of moisture index (Im) Thornthwaite identified 9 moisture or humidity provinces.

	Moisture Index	Humidity provinces
1	100 and above	A perhumd
2	80 to 100	B_4 Humid
3	60 to 80	B_3 Humid
4	40 to 60	B_2 Humid
5	20 to 40	B_1 Humid
6	0 to 20	C_2 Moist subhumid
7	-33.3 to 0	C_1 Dry subhumid
8	-66.7 TO33.3	D Semiarid
9	-100 to -66.7	E Arid

On the basis of thermal efficiency (potential evapotranspiration) 9 thermal provinces were recognized.

Thermal Efficiency Index (cm)		Thermal Provinces (Type)
1.	114 and above	A’ Megathermal
2.	99.7 to 114.0	A’ Mesothermal
3.	85.5 to 99.7	B’4 Mesothermal
4.	71.2 to 85.5	B’2 Mesothermal
5.	57.0 to 71.2	B’1 Mesothermal
6.	42.7 to 57.0	C’2 Microtherma

7.	28.5 to 42.7	C'1 Microthermal
8.	14.2 to 28.5	D' Tundra
9.	Below 14.2	E' Frost

On the basis of summer concentration of thermal efficiency the world was further divided into 8 provinces-

Summer Concentration of Thermal Efficiency (%)		Type
1	Below 48.0	a'
2	48.0 – 51.9	b'
3	51.9 – 56.3	b'_3
4	56.3 – 61.6	b'_2
5	61.6 – 68.0	b'_1
6	68.0 – 76.3	c'_2
7	76.3 – 88.0	c'_1
8	Above 88.0	d'

On the basis of seasonal moisture adequacy 2 major and 10 subclimatic types were identified-

Moist Climates (A,B,C_2)		Aridity Index
1.	r little or no water deficit	0 to 10
2.	s moderate summer deficit	10 o 20
3.	w moderate winter deficit	10 o 20
4.	s_2 large summer deficit	above 20
5.	w_2 large winter deficit	above 20
	Dry Climates (C_1,D,E)	Humidity Index

6.	d little or no water surplus	0 to 16.7
7.	s moderate winter surplus	16.7 to 33.3
8.	w moderate summer surplus	16.7 to 33.3
9.	s_2 large winter surplus	above 33.3
10.	w_2 large summer surplus	above 33.3

The climate of a place, thus is determined by combining the aforesaid elements of the climatic classification e.g. moisture index, thermal efficiency index, summer concentration of thermal efficiency and seasonal moisture adequacy. Thus, the climate of a place is represented by four letters. For example- A A' a'r climate = Perhumid (A) megathermal (A') climate with summer concentration of annual thermal efficiency of less than 48% (a') and little or no water deficit (r) etc. On the basis of above indices the classification system becomes so complex due to large number of climatic types that it becomes difficult to represent them cartographically.

8.5.3 Evaluation of Thornthwaite's Schemes

Thus in many ways the 1931 classification scheme of Thornthwaite was almost similar to Koeppen's scheme because both had a few common points. (i) Thornthwaite's scheme is also empirical as well as quantitative as the boundaries of different climates are determined on the basis of quantitative parameters derived from precipitation and temperature, (ii) Vegetation is made as the basis of quantitative parameters derived from precipitation and temperature, (ii) Various letter combinations are used to designate different climatic types etc. Thornthwaite's scheme is also popular in geographers.

The Thornthwaite's scheme differs from the Koeppen's scheme in that the former used two indices of precipitation efficiency and thermal efficiency for differentiation of different climatic types but the delimitation of climatic boundaries on the basis of these two indices becomes difficult and vague. Thus the lack of adequate climate data makes it difficult for the precise demarcation of climatic boundaries.

Though 1948 scheme of climatic classification of Thornthwaite was thoroughly revised and modified and was based on 4 important indices of moisture index, seasonal moisture adequacy and summer concentration of thermal efficiency but no world map of different climatic types could be prepared. It may be pointed out that it becomes very difficult to cartographically represent a large number of climatic types identified quantitatively on the basis of aforesaid indices, Moreover, the data of potential evapotranspiration are not available for all the places for a worldwide classification of climates. They also involve a lot of calculations for determining the climatic type of a particular place. Thus this scheme could not get more popularity and recognition.

8.6 Conclusion

Thus we can say that climate is a long term calculation or study of the atmoshpheric condition by a climatologist with the help of weather instruments.and very early attempts by the ancient Greeks at classifying climate were logic- based, and resulted in paramenides' identification of three principal climate regions; the Frigid Zone, the Temperate Zone, and the Torrid Zone. In modern time sir koppen and Thornthwaite classified the world climate into various region on the basis of different parameters. And both's scheme are most popular in geographers.

8.7 Summary

The objectives for the unit were to study the Climate & its classification;

Climate classification of Koppen; Evaluation of the Koppen's scheme; Climate classification scheme presented by Thornthwaite; 1931 classification and 1948 classification and finally Evaluation of the Thornthwaite's scheme. Climate is a study of weather records over a long time period of a vast area. Different elements of climate such as temperature, rainfall, humidity etc., which vary from place to place because of shape, rotation and other man made causes. It is very useful tool for geographers. Dr. Wladimir Koeppen presented the modified climatic classification scheme with the utilizes of monthly temperature and precipitation data in making calculations upon which the classification scheme is based –

- koppen identified five main climatic groups. A (tropical), B (arid), C (mesothermal), D(microthermal or mild – latitude cold), and E(polar).
- In general, the A, C, and D climates support the growth of trees, whereas the B and E climates do not, being either too dry or too cold, respectively.
- In the case of A, C, and D climates that are wet year- round, "s" indicating summer dry climates, "W" representing winter dry climates, and "m" representing tropical monsoon conditions).
- For B climates, the second- order subdivision is "s" if the dry climates are only semi-arid, and "w" if the dry climates are true deserts
- In the case of "E" climates, the second- order subdivision is "T" for the milder Tundra sun-type of polar climate, while "F" (frozen) is used to represent the ice cap subtype
- For the mesothermal and microthermal climares, third-order subdivisions identify the characteristics of summer temperature, with "a" representing hot summers. "b" used for warm summers,"c" indicating mild summers, and the rare "d" indicating cool summers.
- Arid climates have a third-order subdivision of "h" and"k" which are used to denote "hot" and "cold" arid or semi- arid regions, respectively.
- The Thornthwaite climatic classification system is built on the physical interactions between local moisture and temperature rather than only the precipitation and

temperature data. It represents a more sophisticated and precise scheme of classification based on local surface water balance.

- Thornthwaite devised a number if specific indices to quantify necessary climatic components, including the moisture index (MI) and the potential evapotranspiration (PE) rate for a location.
- He also derived a Thermal Efficiency Index (T/EET) of the ration of temperature (T) to a calculated evapotranspiration (ET) value, and a Dryness Index (DI) and Humidity Index (HI) to identify the times of the year with water deficit or surplus.

8.8 Glossary

Weather : refers to the condition of the atmosphere at a certain time or over a certain short period, as described by various meteorological phenomena.

Climate : refers to the average weather conditions of a place or region throughout the seasons. It depends on latitude position.

Climatology : The science that deals with the various climates of the earth, and their influence on the natural environment.

Evapotranspiration : A term signifying the total loss of moisture from the soil in the form of water vapour, including tha lost by evaporation from bodies of open water, e.g., lakes, reservoirs, and from the surface of soils and also that lost by transpiration from growing plants.

Transpiration : refers to the process whereby plants, having taken in moisture though their roots, return it to the atmosphere through the stomata of their leaves in the form of water vapour.

8.9 Answer to check your progress

8.10 References

1.Koppen, Wladimir (1918). “Klassification der Klimate nach Temperatur, Niederschlag and Jahreslauf”. Petermanns Geographische Mitteilungen.

2.Critchfield, Howard J (1983). General Climatology (4th ed.) New Delhi: Prentice Hall. pp. 154-161.

3.Singh, Savindra, (2015). Physical Geography Prayag Pustak Bhawan, University Road, Allahabad.

4.Singh, Savindra, Cimatology, Prayag Pustak Bhawan, University Road, Allahabad.

8.11 Suggested readings

Cimatology by Singh, Savindra,

8.12 Terminal Questions

Q.1 What is climate? What are the basis of its classification.

Q.2 Write a note on climatic classification by Koppen ?

Q.3 Discuss the climatic regions according to Thornthwaite?

UNIT -9 SURFACE CONFIGURATION OF OCEAN BOTTOMS

9.1 OBJECTIVES
9.2 INTRODUCTION
9.3 SURFACE CONFIGURATION OF OCEAN BOTTOMS
9.3.1 Bottom Relief of The Atlantic Ocean
9.3.2 Bottom Relief of The Pacific Ocean
9.3.3 Bottom Relief of The Indian Ocean
9.4 CONCLUSION
9.5 SUMMARY
9.6 GLOSSARY
9.7 ANSWER TO CHECK YOUR PROGRESS
9.8 REFERENCES
9.9 SUGGESTED READINGS
9.10 TERMINAL QUESTIONS

9.1 OBJECTIVES

After reading this unit, you should be able to understand the:

- Difference between sea and ocean,
- Sea level and the causes of sea level changes,
- Description about continental shelf, continental slopes, deep ocean basins, ocean deeps and submarine canyons etc.

9.2 INTRODUCTION

Hydrosphere is far more extensive than lithosphere on the surface of the earth. It is calculated that about 71% of the earth's surface is occupied by seas and oceans. The oceans have a greater extent of water in the southern hemisphere than in the northern one.

An extension of saline water on earth is called sea. Large sea areas are called oceans. Seas are separated from oceans by a series of peninsulas or land pieces.

A great success has been achieved in unravelling the mystery of seas and oceans because divers have reached very deep areas of the oceans with the help of scientific equipments. Nowadays, the floors of the oceans have been charted on maps. Two scientists descended into the deepest trench in January, 1960 to a depth of 11.9 Km. This trench is situated in western Pacific ocean and is called Mariana Trench.

Sea level: The sea level is used as a standard for measuring heights of landforms. This is because the sea level is considered to be fixed. In fact, the sea level is not fixed. Many land areas have risen above sea and many land areas which were once above sea level are now submerged under the sea. There are two reasons for this phenomenon :-

1) The sea level is rising.
2) The land is subsiding in comparison with sea.

Whatever be the reason, one thing is clear that the sea level is not stationary by continues to change.

Causes of Sea Level Changes

1. **Glaciers –** Due to change of climate the glaciers contract by melting or expand on freezing. Melting of glaciers causes rise of sea level and the expansion of glaciers lowers the sea level.
2. **Uplift and subsidence –** Due to the uplift or subsidence of coastal areas, the sea level undergoes a change of level, i.e., the sea level rises on subsidence but falls on the uplift of land.
3. **Shape of seas –** Due to subsidence and uplift of land the shape of sea changes and causes change in the level of sea.

There is another reason for the sea to have uneven surface. Sea is a spherical cover on the earth. Many mountains situated close to the sea make the sea surface comparatively high at those places. For example, the Himalayas and the Andes which are close to excess mass in mountains. Tide and heavy rainfall have a temporary effect and have no extensive effect of sea level.

About three fourth or 71% of the surface of the earth consists of water and this is known as the Hydrosphere. It consists of a number of oceans, seas, bays, gulfs and lakes. The five important oceans, in order of size, are the Pacific, Atlantic, Indian, Antarctic and the Arctic. Of these, the most important is the Atlantic ocean, being flanked on both sides by Europe and the U.S.A.

The oceans are of varying depths. Within the same ocean, depth varies from place to place. The depth of the oceans is measured in Fathoms, each fathom being of 6 feet. For sounding the depths of the oceans a fathom line is used. It consists of a rope with a leaden weight tied at one end. In deeper oceans fathoms meter is used. It has an automatic drum which produces a sound on reaching the bottom and it reaches the ears of the observers through a headphone. Thereafter the depth is computed on the basis of the fact that the sound waves travel through the water at the rate of 4,840 feet per second.

Area, Volume and Depth of Earth's Oceans

Ocean	**Ocean Area (Sq.Km.-(Sqmi)**	**Earth's area inCu^{km} (Cu mi)***	**Voloume in meter (feet)**	**Mean depth of Main Basin**	**Deepest point in meter (feet)**
Pacific 48%	179,670 (69,370)	724,330 (173,700)	4820 (14,040)	Mariana Trench	11, 033 (36,198)
Atlantic 28%	106,450 (41,100)	355,280 (85,200)_	3,930 (12890)	Puerto Rico Trench	8,605 (28,224)
Indian 20%	74,930 (28,930)	292,310 (70,100)	3960 (12,900)	Java Trench	7125 (23,376)
Arctic 4%	14,090 (5,440)	17,100 (4,100)	1205 (3950)	Eurasian Basin	5450 (17,876)

Data in thousands ('000); includes all marginal seas.

9.3 SURFACE CONFIGURATION OF OCEAN BOTTOMS

Some different topographic features of ocean and sea floor give us an idea of the surface configuration of ocean bottoms. According to depth, the ocean is divided into these sections or zones are given below:

The structure, configuration and relief features of the different oceans vary from each other. The oceans ridges are the most remarkable and obvious features. An oceanic ridge is a mountain chain of young basaltic rock at the active spreading centre of an ocean. Stretching 65,000 km, more than 1.5 times the earth's circumference, oceanic ridges girdle the globe like seams surround a softball. The rugged ridges, which often are devoid of sediment, rise about 2km above the sea floor. In places they project above the surface to form islands such as Iceland, the Azores and Easter Islands. Oceanic ridges and their associated structures account for about 23% of the world's solid surface area (all the land above the sea level accounts for 29%). Although these features are often called mid-ocean ridges, less than 60% of their length actually exists at mid-ocean.

The surface beneath the water is characterised by a great diversity of relief features, i.e., the towering mountain chains, deep canyons, flat plains, oceanic ridges, trenches, island arcs, sea mounts and guyots. The submarine relief has, however, been classified under the following major categories: i) Continental shelves, ii) Continental slopes, iii) Deep ocean basins (abyssal plains), and iv) Trenches and island arcs.

Continental margins have two main divisions: i) a shallow, nearly flat continental shelf close to shore, and ii) a more steeply slope continental slope towards the sea.

1. Continental Shelf

Oceans are full of water. Some of it spreads on to the neighboring land. The portion of the land which are submerged under sea water constitute Continental Shelf. The continental shelf is shallow and its depth is not more than 200 meters. Its slope from the land to the sea is about 2 meters per km. The breadth of the continental shelf is not the same everywhere. The extent of the continental shelf depends upon the physical configuration of the bordering landmass. If the coastal region is a plain area, the continental shelf will be several miles in width. On the contrary, if the coastal region is hilly and mountainous, the continental shelf will be narrow.

The continental shelf is not flat everywhere. Had it been flat, dunes, river valleys, depressions, etc., would not have been found on the shelf. Some areas of the shelf are composed of hard rocks. Mud, sand and glacial deposits are found on the continental shelf in New England and Canada. Many drumlins rise above sea surface and appear as islands.

These continental shelves are rising as also subsiding at different places. Sediments are deposited on them by river, wind and ocean waves and currents. Sunlight penetrate to some depth into the sea water and support animal and vegetation lives on sea floors. The world famous fisheries are situated in these areas. The continental shelves have become increasingly important because of exploration for natural resources. Numerous deposits of oil and natural gas are found in the continental shelves which are being prospected and extracted. Moreover, the waters of the continental shelves will be even more important geopolitically and economically as the fast growing population of the developing countries will look towards the sea for its food, minerals and raw material requirements. Types of continental shelves –

A few important types of continental shelves are described in order to have a proper idea of shelves.

(i) **Glaciated shelves –** These are the shelves where a lot of glacial action had taken place. Some hills rise from it. The shallow sea near New England is a continental shelf. The breadth of this type of shelves is about 150km. Moraines, drumlins, etc. are found on them.

(ii) **Broad river shelves –** When delta is not formed the big develop a broad continental shelves. The interior edges of the shelves are uniformly flat but the outer ones are studded with hills. The shelves of yellow sea and the Gulf of Siam belong to this type.

(iii) **Coral Shelves –** These shelves have been built by corals. The depth of the outer edge is 20 meters. The shelves are shallow. Continental shelves in Eastern Australia are an example of this type.

2. Continental Slope

The continuously sloping portion of the continental margin, seaward of the continental shelf, and extending down to the deep sea floor of the abyssal plain, is known as continental slope. The continental slope is beyond the continental shelf, where the sea floor slopes downwards. This is abrupt and its depth is sometimes as much as 2000 fathoms. The continental slopes mark the beginning of the true sea bed.

At the outer edge of the continental shelf, the slope suddenly steepens. This is found to be 35 to 61 metres per km. The value of the slope is much more adjacent to the fold mountains than that near the coastal plains. One end of the slope connects it with continental shelf while the other one merges into the ocean floors. The area occupied by continental slope is 8.5% of the total ocean area.

The continental slopes characterised by gradients of 2° - 5°. The continental slope makes a boundary between the continental crust and the ocean crust. The depth of water over the continental slope varies from 200 to 2,000 metres. The bottom of the continental slope is the true edge of a continent.

Generally, the steep gradient of the continental slopes does not allow any marine deposits on them. The most significant relief features of the continental slope are submarine canyons.

3. Deep Ocean Basins of Floors

Deep ocean basins or floors are situated on the base of the continental slope. About 2/3 or ocean surface is occupied by deep ocean basins or floors. The depth varies from 3000 to 6000 metres. These basins are not as levelled and flat as they were considered by older scholars. Many long zig-zag ridges, plateaus, volcanic summits, etc., exist on the basins. Many mountain tops rise steeply from the ocean floors and emerge out of sea as islands. Such mountain tops are found in Indonesia and in Pacific Ocean. Many pelagic deposits and oozes are found on the basins.

4. The Ocean Deeps

Ocean deeps are the deepest portion of the ocean. These are limited in area and consist of very steep gradient. These are most common near the coasts where volcanic and earthquake disturbances are quite frequent. A depression, long and narrow, existing on the deep ocean basins are called ocean deeps. The deeps are commonly found in Caribbean sea and Pacific ocean. The depth of these deeps is found to range from 7000 to 9000 meters. The deeps are also called trenches and troughs. Sometimes their name suggests that the trenches have a steep slope. Due to the non-existence of sediments, the deeps are almost empty. The slopes of their walls is, however much steeper than that of any other feature. The origin of the ocean deeps is attributed to the endogenetic forces which have produced the mountains.

Major trenches of the world

Name	**Location**	**Depth (in metres)**
1. Mariana or Challenger Trench	North Pacific Ocean	11022
2. Tonga or Aldrich Trench	Central South Pacific Ocean	10882
3. Japan Trench (Ramapodeep)	North Pacific Ocean	10554
4. Kurile Trench	Off Sakhalin Kamchatka	10498
5. Philippines or Swire Trench	North West Pacific	10475
6. Puerto Rico or Narer Trench	Near West Indies Islands	8385
7. Aleutia Trench	North Pacific Ocean	7682
8. Atacama Trench	South Pacific Ocean	7635
9. Romanche or Tizard Trench	South Atlantic	7631
10. Java Trench (Sunda Trench)	East Indian Ocean	7454

5. Submarine Canyons

These are depressions with walls of steep slopes and have V-shape. They exist on the continental slopes and the shelves. They are found to have a length of 16 km., at the maximum and have a dendritic pattern. The canyons are found to be close to river mouths such as those of the Congo, the Hudson, the Delaware, the Columbia, etc. the depth varies from 1800 metres to 2800 metres. Coarse deposits are found in the Canyons.

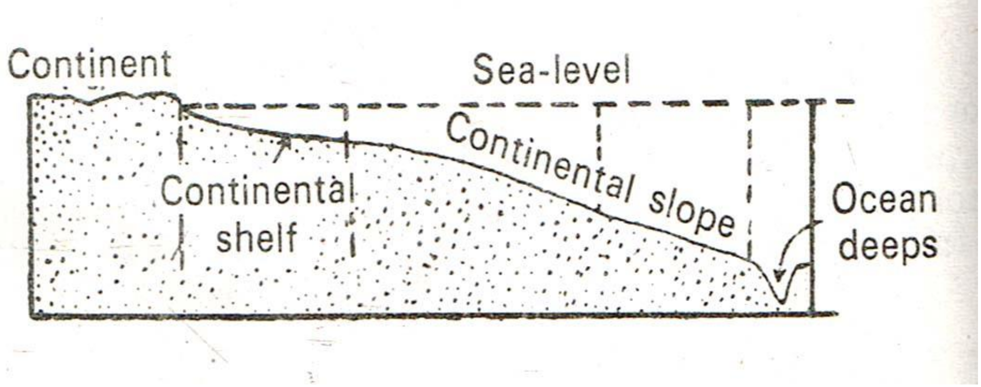
These canyons are found in Asia in Aleutian Island, Japan, Philippines, etc., in Europe near the Mediterranean sea, in North America at the coasts of Mexico and California and along the eastern coasts from Cape Hatteras to the middle of Canada.

6. Sea Mounts and Guyots

There are many mountains found on ocean floors. The mountains which are above 1000 metres in height and have conical summits are known as sea mounts but if the summits are flat, they are known as guyots.

The ocean floor is dotted with thousands of islands that do not rise above the sea. These projections are called sea mounts. Sea mounts are circular or elliptical, more than a kilometer (0.6 mile) in height, with relatively steep slopes of 20 to 25 degrees. Sea mounts may be found alone or in groups of 10 to 100. Though many form at hot spots, most are thought to be submerged active volcanoes that formed at spreading centres. As many as 10,000 sea mounts are thought to occur in the pacific, about half the world total.

Many sea mounts are found in the Gulf of Alaska. Patton, Prat, Faris etc., are well known sea mounts. Some of them attain a height of 3000 metres.



Continental shelf, continental slope, ocean deeps, etc.

Guyots were discovered by a Swiss scientist Guyots, A.H. near Mariana deep and Hawaii Islands in Pacific Ocean. An ordinary guyot has a diameter of 20-25 km. The tops of guyots are 1200 to 1800 metres below sea level.Some scientists think that many volcanic crests were eroded by ocean currents and formed guyots on submergence.Some scientists think that guyots are remnants of atolls.

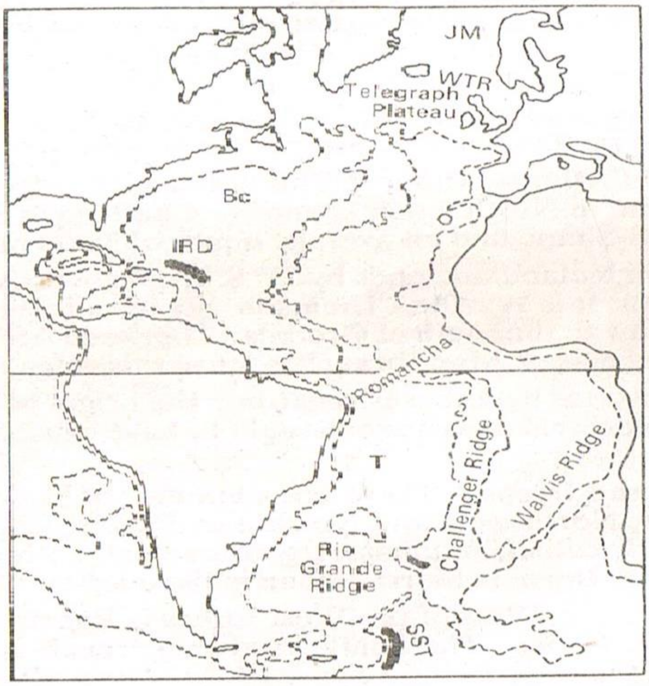
7. **Ocean Ridges**

These ridges are submerged under sea water. Some important ridges in North and South Atlantic ocean are Dolphin and Challenger and are thousands of metres high as measured from the ocean floors. The Mid-Atlantic ridge is famous. No such ridge exists in Pacific ocean. Some ridges in the form of small plateaues have been located in the eastern part. North to south ridges exist in the Indian ocean.

9.3.1 BOTTOM RELIEF OF THE ATLANTIC OCEAN

Similar bottom relief and topographic features are not found in all the oceans. Though the ocean floors have not been studied with the detail with which land surface has been studied yet a lot of knowledge has been accumulating throwing light on the topography of ocean floors.

1. **Shape and size –** It has the shape of the English alphabet- S. It has 1/6 of the area of the earth or ½ of that of the Pacific. Its area in 82 million sq.km. The broadest part is 6000km along 35° south. It is surrounded by Europe and Africa on the east and north and South America on the west.
2. **Depth –** About ¼ of the ocean is less than 1000 meters deep. It is because of the shallowness of the marginal seas.
3. **Island –** The British Island and New Zealand are the raised portions of continental shelf. The West Indies Islands are situated between the North and the South America. Greenland and the northern Scotland are situated on the Mid-Atlantic ridge. Other important islands are Faukland, South Archaes, Shettland, Sandwich, Ascension, Tristan de Cunha, Bermuda, Madeira, Canaries etc.



The Atlantic Ocean (Topography)

4. **Marginal seas –** There are almost no marginal seas in South Atlantic Ocean but there are many in the north in European area. The Baltic and the North seas are no more than 200 metre deep. The depth near Denmark Islands is not more than 20 metres. The depth of this sea is about 400 metres near Gibraltar strait. The sea is the deepest (5066 metres) between Greece and Crete. The Dardanelles the Marmara sea and the Bosporous are narrow water areas between the Black sea and the Mediterranean sea.

   On the American coast less than 200 metre deep are other marginal seas, like the Baffin Bay, Hudson Bay, Davis strait, etc., and relate the Atlantic Ocean with the Arctic Ocean. The deepest deeps in Mexico Gulf and Caribbean seas are 4160 and 7907 metre deep respectively.
5. **Continental Shelf –** A continental shelf, about 200 metre deep, is situated along the continents. The breadth of the shelf is 250 to 400 km and is found along the north-eastern part of North America and North – west of Europe. Dogger Banks and Grand Banks are situated on the shelf. The Adriatic sea is almost wholly situated on the shelf.

   The shelf spreads from South America towards Europe and the Antarctica. Patagonian shelf is conspicuous near the Argentinean coast.
6. **The Mid- Atlantic Ridge –** This submarine ridge is known by the name of Dolpin in North Atlantic and by challenger in South Atlantic Ocean. It has a, S- shape and an average depth of 3000 netres.

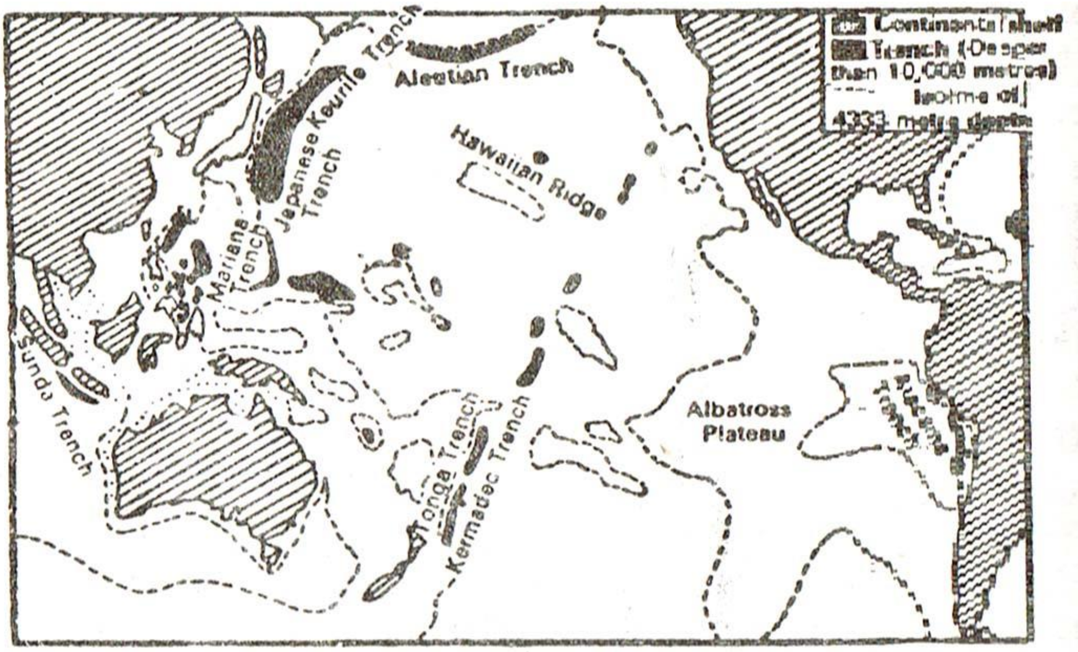
   It starts from Iceland and ends by 55°S. It is known by different names at different places. It is Wyville – Thomson between Iceland and Scotland, Telegraph Plateau to the south of Greenland between Africa and America. It subsides at few places. Many branches leave this ridge at various places.

7. **Basins and Deeps –** There are a number of basins situated in the ocean. Labrador, North – west and North – east Pacific, Cape Verde, Sierra Leone, Guniea, Brazilian, Agulhas, Argentinean and other basins area well known. Ramanche deep in Sierra Leone is the deepest (19,290.4 metres).

   Trenches are few. West of the West Indies is Puerto Rico and to the west is Caymon trench. The south sandwich trench is situated in the southern part of the ocean.

9.3.2 BOTTOM RELIEF OF THE PACIFIC OCEAN

The Pacific Ocean is the largest and deepest of all water bodies. Together with its associated seas, it covers about one third of the earth's surface and exceeds the total land area of the world in size. The average depth is generally around 7300 meters.



Pacific Ocean (Topography)

1) **Shape and Size** – Pacific Ocean along with its marginal seas occupies about one- third of the earth's surface. It looks like a triangle whose vertex is situated in the north in the Bering Strait while its base lies on the edges of the Antarctica continent in the south.

   Its length as measured from Bering Strait in the north to Cape Adare in the South is 14,880 km.Its length along the Equator is about 16,000 km.
2) **Depth –** The average depth of this ocean in 5000 metres but the average depth of the floor is 5000 metres.
3) **Islands –** There are about 20,000 islands in the Pacific Ocean. Among the submerged islands Aleutian, British Columbia, etc., are well known. There are also some Island Arcs which are volcanic and have an arc form. New Zealand, Indonesia, Japan, etc., belong to this type. Some scattered islands like cook Island, Society Island, Polynesian Island, etc are like dots in the ocean.

The Hawaii Islands are famous in the North Pacific Ocean. The north – East Ocean appears to be a big mass of water.

4) **Marginal seas –** Such seas are mostly found in the western part of the ocean. Here the marginal seas are deep but narrow. Bering, Okhotsk, Japan, China, Sulu, Celebes and other seas are well known. The number is much less in the west and the seas are shallow. Some of the well known seas are California and Aleutian seas.
5) **Continental Shelf –** The western shelf is broad as compared to that in the east. The eastern shelf is about 80 km. broad while the width in the west ranges from 150 to 1500 km. the Japan sea, the Yellow sea, etc., stand over the shelf.
6) **Submarine Ridges –** More submarine ridges are found in the east then in the west – Albatros plateau is one such ridge. Albatros is 4000 meter deep and its length is 1500km. Howaii ridge, Marcuo, Neeker, etc., are other ridges suitable for mention.
7) **Ocean Basins –** Famous basins are Aleutian, Phillipines, Carolina, Fiji, South-east Pacific basin, etc.
8) **The Deeps and the Trenches –** The famous trenches are Aleution, Keurile, Mariana, Togo- Kermadec, Chile, etc.

The deepest deep in Mariana trench is 28,018.55 metre deep Cape Johnson (26,665 metres) in Phillipines trench, Vityez (26,360 metres) in Keurile trench, Aldrich (23,407 metres) in Togo – Kermadec Milne Edward (15,906 metres) in Peru trench etc. are some of the important deeps in Pacific Ocean.

9.3.3 BOTTOM RELIEF OF THE INDIAN OCEAN

This ocean is smaller and less deep than the Atlantic Ocean since it is completely blocked in the north by the Asian land mass, it can be considered only half an ocean. It has few marginal seas, Linear deeps are almost absent. The only exception is Sunda Trench, which lies to the south of the island of Java.

1) **Location –** Asia to the north, Australia to the east and Africa towards west surrounded this ocean. It meets Atlantic Ocean and Pacific Ocean in the south but it extends to Tropic of Cancer in the north.
2) **Shape and Size –** It has a compact shape. It is the third ocean in order of size. It is narrow in the north and broad in the south.
3) **Depth –** Its depths ranges from 4000 to 6000 metres in 60% of the Indian Ocean. Its average depth is thought to be about 4000 metres.
4) **Islands** – Islands of this ocean can be divided into three parts –
   - **(i) Medium sized Island –** Madagascar Sri Lanka, Sumatra, Java etc.
   - **(ii) Small sized Islands –** The Andaman & Nikobars, Socotra, Zanzibar, Comoro, Mauritius, Kerguelen, etc.

(iii) Tiny Islands- Chagos, Maldives, Seychelles, Amrantes, Cocos, St. Paul, Diego Garcia, etc.

Indian Ocean (Topography)

5) **Marginal Seas –** There are very few marginal seas in the Indian Ocean. The largest are the Bay of Bengal and the Arabian sea. Small marginal seas are Persian Gulf, Red Sea, Gulf of Aden, Andaman Sea, etc. Very small marginal seas are the Gulf of Oman, Gulf of Kutch, Gulf of Cambay, etc.
6) **Continental Shelf –** The breadth of the shelf is not the same everywhere. Shelf is the broadest in the Arabian Sea and the Bay of Bengal. It extends to 600 Km. in these areas but is about 159 Km. in the east. It is narrow near Antarctica, Australia and Indonesia. Africa has a medium sized shelf.
7) **The Central Ridge –** Like the Mid-Atlantic ridge, a central ridge exists in the Indian Ocean but it is comparatively broad and less deep. It has various names at different places. Some islands like Lakshadweep, Maldive etc., are situated on the northern part of the Central Ridge, St. Paul Island and Chagos stand on its middle section. The southern part of the ridge is very wide and is called Amsterdam- St. Paul plateau.
8) **Basins, Deeps and Trenches -** There are few deeps and trenches and some small basins. Some important basins are those of the Oman, Arab, Somali, S.W. Madagascar, Natal, Agulhas, Andaman, Cocus- Keeling, etc.

9.4 CONCLUSION

Oceanography involves the considerations a wide range of oceanic phenomena, both physical and biological. From the point of view of the physical geographer, the most important feature is the extent and shape of the ocean basins, for the distribution of land and sea is for him a fundamental concept. The structure and relief of the ocean floor and of the marginal seas afford contributory evidence towards the structure of the earth, concerned as we are with the permanence or otherwise of the oceans and continents, the problem of continental drift, changes of sea level, the distribution of volcanoes and earthquake zones and the accumulation of sediments on the sea floor which may ultimately from sedimentary rocks.

The movements it sea-water, in the form of waves, tides and currents, affect the coast line with which they come in contact and warm and cool currents may powerfully modify the climates of coastal areas. When we speak of the topography of the ocean floor, we mean the various shapes that the bottom of the ocean can take. We tend to picture the ocean floor as being as flat and sandy as the beaches with which we are familiar. Fortunately, the ocean floor is not quite simple, predictable, or boring. Though the bottom of the ocean is hidden from our sight by vast quantities of water, it's anything but boring, flat and featureless. As our technological expertise increases, so does our ability to visualize these distant landscapes. We find basically that the ocean floor has all the same shapes, bumps, mountains, valleys, plateaus and such that we are more familiar with on the surface. When you consider that three quarters of our planet's surface is covered by ocean water, you soon realize that there's more land "down there" than we have "up here". It really is not all that different from the land on which we live.

9.5 SUMMARY

Seen from space, our planet's surface appears to be dominated by the colour blue. The earth appears blue because large bodies of saline water known as the oceans dominate the surface. Oceans cover approximately 70.8% or 361 million sq. kms. of earth's surface with a volume of about 1370 million cubic kilometers. The average depth of these extensive bodies of sea water is about 3.8 kilometers. Maximum depths can exceed 10 kilometers in a number of areas known as ocean trenches.

The oceans contain 97% of our planet's available water. The other 3% is found in atmosphere, on the Earth's terrestrial surface or in the Earth's lithosphere in various forms and stores. The oceans are of varying depths. Within the same ocean, depth varies from place to place. This unit is totally dedicated to explain the configuration and structural features of ocean bottoms of the earth's surface.

9.6 GLOSSARY

Sea.	The salt water that covers large parts of the surface of the earth.
Ocean.	The mass of salt water that covers most of the surface of the earth.
Sea level.	The average level of the sea, used for measuring the height of places on land.
Continental Shelf.	The gently sloping submarine fringe of a continent.
Hydrosphere.	All the water on , or close to, the surface of the earth.
Hemisphere.	One half of the earth.
Peninsula.	A piece of land jutting into and almost surrounded by the sea.
Glacier.	A mass of ice which may be moving , or has moved, overland; when enough ice has accumulated, a glacier will start to move forwards.
Subsidence.	To sink down into the ground
Configuration.	The way in which the parts of something, or a group of things, are arranged.
Dunes.	A hill or ridge of sand accumulated and sorted by wind action.
Drumlins.	A long hummock or hill, egg shaped in plan and deposited and shaped under an ice sheet or very broad glacier while the ice was still moving.
Coral.	An offshore ridge, mainly of calcium carbonate, formed by the secretions of small marine animals.
Oozes.	A deep, sea floor deposit either of tiny organisms such as diatoms (a type of algae) or of fine inorganic sediments.
Atolls.	A coral reef, ring or horseshoe shaped, enclosing a tropical lagoon.

9.7 ANSWER TO CHECK YOUR PROGRESS

Q1. Describe the ocean bottom of Pacific Ocean.
Q2. Write an account of continental shelf, its origin and development.
Q3. Write a short note on ocean deeps.
Q4. What do you understand by ocean floor? Describe its various parts. What is its importance to man?
Q5. Describe the configuration of the bottom of the Indian Ocean.

9.8 REFERENCES

Ahmad, A.: Physical geography, Rawat Publication, Jaipur, 1993
Bharatdwaj, K.: Physical Geography: A landscape Appreciation, Discovery Publishing House Pvt. Ltd., New Delhi, 2009.
Tikka, R.N.: Physical Geography, Kedar Nath Ram Nath & Co., Meerut, 1994-95.
Dasgupta, A., Kapoor, A.N.: Principles of Physical Geography, S. Chand & Company Ltd., New Delhi – 55, 1995.

Lebon, J.H. : An Introduction to Physical Geography, Hutchinson, London, 1969.
Mathur, S.M. : Physical Geology of India, National Book Trust, New Delhi, 1994.
Bembrick, S. : The Cambridge Encyclopedia of Physical Geography, Cambridge University Press, New York, 1994.
Basham, A.L. : A Handbook of Physical Geography, Grove Press, New York, 1959.

9.9 SUGGESTED READINGS.

1. Monkhouse, F.J. (1962)
   Principles of Physical Geography, pp. 276-294, Varsity of London Press, London.
2. Shepard, F.P. (1948)
   Submarine Geology, New York , Harper and Bros.
3. Bhartdwaj , K. (2009)
   Physical Geography: A Landscape Appreciation , Discovery Publishing House Pvt. Ltd.

9.10. TERMINAL QUESTIONS

Q1. Describe the ocean relief either of the Atlantic Ocean and the Pacific Ocean.
Q2. Write a not eon continental shelf.
Q3. Write a note on ocean deeps.

UNIT-10 OCEANIC TEMPERATURE AND SALINITY

10.1 OBJECTIVES

10.2 INTRODUCTION

10.3 TEMPERATURE OF THE OCEAN WATER: DAILY AND ANNUAL RANGES

10.4 CONTROLLING FACTORS OF DISTRIBUTION OF TEMPERATURE

10.5 HORIZONTAL DISTRIBUTION OF TEMPERATURE

10.6 VERTICAL DISTRIBUTION OF TEMPERATURE

10.7 COMPOSITION OF THE SEA WATER

10.8 SOURCES OF OCEAN SALINITY

10.9 CONTROLLING FACTORS OF SALINITY

10.10 HORIZONTAL DISTRIBUTION OF THE SALINITY

10.11 VERTICAL DISTRIBUTION OF SALINITY

10.12 CONCLUSION

10.13 SUMMARY

10.14 GLOSSARY

10.15 ANSWER TO CHECK YOUR PROGRESS

10.16 REFERENCES

10.17 SUGGESTED READINGS

10.18 TERMINAL QUESTIONS

10.1 OBJECTIVES

After reading this unit, you should be able to understand the:

- Salinity and temperature of oceanic water
- Horizontal and vertical temperature of ocean water
- Controlling factors of distribution of temperature
- Composition of the sea water and sources of oceanic salinity
- Horizontal and vertical distribution of ocean water salinity
- Controlling factors of salinity in oceans.

10.2 INTRODUCTION

The temperature of oceanic water is important for marine organisms including plants (phyto plankton) and animals (zoo plankton). The temperature of sea water also affects the climate of coastal lands and plants and animal therein. The study of both, surface and sub-surface temperature of sea water is significant. Standard type of thermometer is used to measure the surface temperature while reversing thermometers and thermographs are used to measure the sub surface temperature. These thermometers record the temperature up to the accuracy of $\pm$ 0.02° centigrade. With respect to temperature, there are three layers in the oceans from surface to the bottom in the tropics viz;

(i) The first layer represents the top-layer of warm oceanic water and is 500 m thick with temperature ranging between 20° and 25°C. This layer is present within the tropics throughout the year but it develops in mid-latitudes only during summer.

(ii) The thermocline layer represents vertical zone of oceanic water below the first layer and is characterized by rapid rate of decrease of temperature with increasing depth.

(iii) The third layer is very cold and extends up to the deep ocean floor. The polar areas have only one layer of cold water from the surface (sea level) to the deep ocean floor.

The major source of the temperature of the oceanic water is the sun. The radiant energy transmitted from the photosphere of the sun in the form of electromagnetic short waves and received at the ocean surface is called insolation. Besides, some energy, below the bottom and through the compression of sea water. The amount of insolation to be received at sun’s rays, length of day, distance of the earth from the sun and effects of the atmosphere. The mechanism of the heating and cooling of ocean water differs from the said mechanism on land because besides horizontal and vertical movements of water, the evaporation is most active over the oceans.

10.3 TEMPERATURE OF THE OCEAN WATER: DAILY AND ANNUAL RANGES

The difference of maximum and minimum temperature of a day (24 hours) is known as daily range of temperature. The daily range of temperature of surface water of the oceans is almost insignificant as it is around 1℃ only. On an average, the maximum and minimum temperature of sea surface water are recorded at 2 P.M. and 5 A.M. respectively. The daily range of temperature is usually 0.3℃ in the low latitudes and 0.2℃ to 0.3℃ in high latitudes.

The diurnal range depends on the conditions of sky (cloudy or clear sky), stability or instability of air and stratification of sea water. The heating and cooling of ocean water is rapid under clear sky (cloudless) and hence the diurnal range of temperature becomes a bit higher than under overcast sky and strong air circulation. The high density of water below surface water causes very little transfer of heat through conduction and hence the diurnal range of temperature becomes low.

Annual range of Temperature

The maximum and minimum annual temperature of ocean water are recorded in August and February respectively (in the northern hemisphere). Usually, the average annual range of temperature of ocean water is -12℃ (10°F) but there is a lot of regional variation which is due to regional variation in insolation, nature of seas, prevailing winds, location of seas etc.

Annual range of temperature is higher in the enclosed seas than in the open seas (Baltic Sea records annual range of temperature of 4.4℃ or 40°F) the size of the oceans and the seas also affects annual ranges of temperature e.g., bigger the size, lower the annual range and vice-versa. The Atlantic Ocean records relatively higher annual range of temperature than the Pacific Ocean.

10.4 CONTROLLING FACTORS OF DISTRIBUTION OF TEMPERATURE

The distributional pattern of temperature of ocean water is studied in two ways viz. (i) horizontal distribution (temperature of surface water) and (ii) vertical distribution (from surface water to the bottom). Since the ocean has three dimensional shape, the depth of oceans, besides latitudes in also taken into account in the study of temperature distribution.

The following factors affect the distribution of temperature of ocean water:-

1. **Latitudes:** Temperature of surface water decreases from equator towards the poles because the sun's range become more and more salting and thus the amount of insolation decreases poleward accordingly. The temperature of surface water between 40°N and 40°S is lower than air temperature between 40th latitude and the poles in both the hemisphere.

2. **Unequal distribution of land and water:** The temperature of ocean water various in the northern and the southern hemisphere because of dominance of land in the former and water in the latter. The oceans in the northern hemisphere receive more heat due to their contact with larger extent of land than their counter- parts in the southern hemisphere and thus the temperature of surface water is comparatively higher in the former than the latter. The isotherms are not regular and do not follow latitudes in the northern hemisphere because of the existence of both warm and cold land masses where as they (isotherms) are regular and follow latitudes in the southern hemisphere because of the dominance of water. The temperature in the enclosed sea in low latitudes becomes higher because of the influence of surrounding land areas than the open seas e.g., the average annual temperature of surface water at the equator is 36.7°C (80°F) wthere as it is 37.8°C (100°F) in the Red Sea and 34.4°C (94°F) in the Persian Gulf.
3. **Prevailing wind:** Wind direction largely affects the distribution of temperature of ocean water. The winds blowing from the land toward the oceans and seas (e.g., offshore winds) drive warm surface water away from the coast resulting into upwelling of cold bottom water from below. Thus, the replacement of warm water by cold water introduces longitudinal variation in temperature. Contrary to this, the onshore winds pile up warm water near the coast and thus raise the temperature. For example, trade winds cause low temperature (in the tropics along the eastern margins of the oceans or the western coastal regions of the continents) because they blow from the land towards the oceans where are these trade winds raise the temperature in the western margins of the oceans or the eastern coastal areas of the continents because of their onshore position, similarly, the eastern margins of the oceans in the middle latitudes (western coasts of Europe and North America) have relatively higher temperature than the western margins of the oceans because of onshore position of the Westerlies.
4. **Ocean Currents:** Surface temperatures of the oceans are controlled by warm and cold currents. Warm currents raise the temperature of the affected areas whereas cool currents lower down the temperature. For example, the Gulf Stream raises the temperature near the eastern coasts of North America and the western coasts Europe. Kuroshio drives warm water away from the eastern coast of Asia and raises the temperature near Alaska. Labrador cool current lowers down the temperature near northeast coast of North America. Similarly, the temperature of the eastern coast of Siberia becomes low due to Kurile cool current. It may be mentioned that warm currents raise the temperature more in the northern hemisphere than in the southern hemisphere which is apparent from the fact that the 5°C isotherms reaches 70° latitude in the northern Atlantic Ocean whereas it is extended upto only 50° latitude in the southern Atlantic Ocean. This is because of more dominant effects of the warm Brazil current in the southern Atlantic Ocean.
5. **Minor factors include:** (i) submarine ridges (ii) local weather conditions like storms, cyclones, hurricanes, fog, cloudiness, evaporation and condensation and (iii) location and shape of sea. Longitudinally more extensive seas in the low latitudes have higher temperature than the latitudinal more extensive seas as the Mediterranean Sea records higher temperature than the Gulf of California. The enclosed seas in the low latitudes record relatively higher temperature than the open seas whereas the enclosed seas have

lower temperature than the open seas in the high latitudes (Baltic Sea records 0℃ (32°F) and open seas have 4.4℃ or 40°F)

10.5 HORIZONTAL DISTRIBUTION OF THE TEMPERATURE

The horizontal temperature distribution is shown by isothermal lines, i.e., lines joining places of equal temperature. The sea surface isotherms in February, for the Atlantic Ocean, reveal that the isothermal lines are closely spaced in the south of Newfoundland, near the west coast of Europe and North Sea and then an isotherm widen out to make a buldge towards the western coast of Europe and raises the temperature of the west coast of Europe.

In the south western part of the Atlantic, isotherms buldge towards south-west due to warm Brazil Current but in the eastern part of south Atlantic isotherm bend towards north-west due to cold Bengula current. Further south, isotherms are parallel owing to constant prevailing west wind drift.

The distribution of temperature in the north and the south Atlantic is not symmetrical. For example, in north Atlantic, 5℃ isotherm touches 70°N latitude whereas in the southern half of the Atlantic it never crosses 50° South latitude because the warm Gulf Stream is more powerful and it reaches to much higher latitude than the cold Brazil current. Moreover, there is a considerable difference between the eastern and western parts of the Atlantic. In the western part near Labrador coast, 0℃ to 13℃ temperature is found on the west coast of Europe.

In the marginal seas, temperature varies due to latitude and location, e.g., the Mediterranean records higher temperature than the neighboring Atlantic Ocean but Baltic and the Hudson Bay are colder than the Atlantic.

In the northern half of the Pacific, isotherms and latitudes are almost parallel, but on the coast of North America isotherms bend slightly northward under the influence of the warm Kuroshio Current and along the coast Japan isotherms are closely spaced due to the cold Oyashio Current.

In the equatorial region of the western part of the Pacific, high temperatures are recorded as the warm equatorial current flows towards south. In the eastern part of the Pacific, low temperatures prevail due to the influence of cold Peru Current. In the south Pacific, isotherms make minor loops due to the warm Peru or Humboldt Current.

In the Indian Ocean, the isotherms of 25℃, 27℃ and 28℃ occupy the central location of the ocean. Towards south no difference is observed with the Pacific as the isotherms roughly follow the parallels except a minor loop near the Cape of Good Hope due to the cold Agulhas Current. The isotherms bend southward near the coast of North Africa due to a cold current which flows south-westward from Cape Guardafui.

The same isotherm bends northward in the Arabian Sea when it enters the Indian peninsula, but in the Bay of Bengal it bends towards south due to the effect of monsoon drift.

The enclosed water bodies like the Red Sea have higher temperature towards south due to the mixture of open ocean water. The Persian Gulf records lower temperature than the Indian Ocean under the influence of cold land area.

The August condition is markedly different from that of February isothermal conditions. In the Atlantic the ice in the Arctic melts away resulting in north ward loop of all the isotherms in the Davis Strait. The sharp northward bends of isotherms on the Norwegian coast are absent in August. On an average the isotherms in the north Atlantic Shift northward in August. The southern Pacific shows isothermal lines and latitudes placed parallel. Towards west, the adjacent ocean of Australia- Asia region witnesses temperature as high as 28℃ as the westerly flowing equatorial current draws warm water towards west Pacific.

In the Indian Ocean, the highest surface, temperature of 28℃ is recorded over the Arabian Sea and the Bay of Bengal. In August, the enclosed seas like the Red Sea and the Persian Gulf show higher temperature (30° to 33°C) than the open ocean due to their contant with warm land areas.

10.6 VERTICAL DISTRIBUTION OF TEMPERATURE

The temperature in the oceans falls steeply with depth except in polar seas. The falls of temperature upto a depth of 300 to 800 meters is distinctly visible but the temperature from 1000 to 1600 metres is so low that it is difficult to measure it. It is estimated that 5/6 of ocean water has a temperature ranging from 1.5° to 4.5°C.

There is an inversion of temperature in polar seas. The water obtained from melting of polar ice floats over comparatively warm water of the ocean but the fall of temperature becomes distinct only below 400 metres.

Factors affecting the vertical distribution of temperature –

1. **Latitudinal Expanse –** The temperature of sea level is high in equatorial countries. The rate of fall of temperature is high with depth. The temperature of the water of sea surface in polar areas is low and, therefore, the rate of fall of temperature is also low. There is an inversion of temperature in polar areas. At a certain depth the temperature of ocean water in equatorial and polar areas are equal.
2. **Open and enclosed seas –** In the enclosed or partially enclosed seas where the floor is shallow, the fall of temperature is different as compared to that open sea. The Red Sea and the Indian Ocean are separated from each other by the strait of Bab-el-Mandev. The floor of Bab-el-Mandev is only 400 metres below the sea surface. Though the basin of Red Sea is 2,400 metre deep yet it's temperature is about 21℃ from top to bottom. In Indian Ocean, the temperature is 1.5℃ at a depth of 2,400 metres. The reason is that the cold water of the Indian Ocean cannot enter the Red Sea.

Similarly, the Mediterranean Sea and the Atlantic Ocean are separated by Gibralter Strait. Hence, the water of the Atlantic Ocean cannot enter the Mediterranean Sea freely.

This strait is about 400 metre deep. The temperature at the bottom of the Mediterranean is 13℃.

The Wyville-Thomson is submerged hill and separated the Arctic and Atlantic Oceans. The temperature to the north of the submerged hill in Norwegian Sea is 1.5℃ and the temperature at the same depth in the Atlantic Ocean is 7℃.

3. **The Effect of Depth -** The rate of the fall of temperature in an ocean is not uniform at all depths. It can be generally surmised that the fall of temperature is very low upto a depth of 1000 metres (3000ft) in an open ocean but beyond this the fall of temperature is very steep. It continues upto 3,000 metres. After this the temperature remains almost fixed beyond this depth and ranges from 1.5℃ to 7℃.
4. **The Effect of Rain –** In areas of the oceans where the rain is heavy, the temperature of the sea water is a bit high. For example, the daily rain fall in equatorial areas keeps the temperature higher than those in higher latitudes.
   There is a gradual decrease of temperature with increasing descent. Normally, 90 percent of the solar heat is absorbed in the topmost 15.6 metre (60 feet) of water. The sea water temperature corresponds to the surface temperature only up to a depth of about 100 metre, and, will further descent, temperature generally decreases.

In tropical oceans and seas, three layers can be recognized from surface to bottom. The first layer is about 500 m thick with temperature varying between 20° and 25℃. In mid-latitude regions this top layer is found only during summer. The thermocline layer is found just below the first layer. It is characterized by rapid decrease of temperature with increasing depth. The third layer is very cold and extended up to the ocean floor.

In contrast to the tropical oceans, in Polar Regions only one layer of cold water is identified. It extends from the surface to the bottom.

As the temperature decreases in water with increasing descent, some scientists have divided the oceans into two broad zones: (i) Photic and Euphotic zone which extends from the upper surface to 200 metres; the photic zone receives adequate solar insolation; and (ii) Aphotic zone extending from 200 m to the ocean bottom; this zone does not receive adequate sunrays.

10.7 COMPOSITON OF THE SEA WATER

Sea water or salt water, is water from a sea or ocean. On an average, sea water in the world's oceans has a salinity of about 3.5% (35 g/L, or 0.600M). this means that every kilogram (roughly one litre by volume) of sea water has approximately 35 frams (1.2oz) of dissolved salts (predominantly sodium (Na+) and chloride (Cl-) ions). Average density at the surface is 1.025 kg/l. sea water is denser than both fresh water and pure water (density 1.0 kg/l at 4℃ (39°F)) because the dissolved slats increase the mass by a larger proportion than the volume. The freezing point of sea water decreases as salt concentration increases. At typical salinity, it freezes at about -2℃ (28°F). The coldest sea-water ever recorded (in a liquid state) was in 2010, in a stream under an Antarctic glacier and measured -2.6℃ (27.3°F). Seawater pH is typically limited to a range between 7.5 and 8.4. However, there is no universally accepted reference pH-scale for seawater and the difference between measurements based on different reference scales may be up to 0.14 units.

Oceans have a great amount of water but it is not suitable for drinking. The main cause for it to be unsuitable for drinking purpose is the presence of slats in the ocean water. It would be proper if we call the ocean water a dilute solution of salts. The presence of salts in ocean water causes salinity which is known as the salinity of ocean water. Salinity is expressed by the amount of salts dissolved in 1000 gms. of sea water. The salinity is expressed as 21%.

Salinity is the amount of solid substance (expressed in gms) present in one kilogram of sea water when all the carbonates are converted into oxides, bromine and iodine replaced by chlorine and the inorganic substances are oxidized.

The river and sea waters are much different from each other from the point of view of mineral substances. One thousand tonnes of sea water contains on any average, 34.75 tonnes of salt. According to Joly, 50,000 million tones of salt are present in the oceanic waters. This salt, it dried, will cover the entire globe with a layer 50 metre thick. If this salt is spread over land areas, the thickness will be more than 150 metres. The sea level will fall by about 30 metres if the salt is entirely withdrawn from the oceans.

River water has a lot of calcium and bicarbonates but has very low quantity of sodium, Magnesium and Chlorides. The case is just the reverse in sea water.

Gases are also dissolved in sea water. The main gases are Nitrogen, Oxygen and Carbon-di-oxide. It is estimated that the amount of Carbon-di-oxide in atmosphere is 2,200 billion tones but according to T. Schloesing the quantity of Carbon-di-oxide in oceans is 18 to 27 times that in atmosphere.

Chemical composition of Ocean Water – The salts and their composition in water is given in the following table: -

S. no.	Name of the Salt	Chemical Formula	Salt%
1	Sodium Chloride	NaCl	23
2	Magnesium Chloride	$MgCl_2$	5
3	Sodium Sulphate	Na_2So_4	4
4	Calcium Chloride	$CaCl_2$	1
5	Potassium Chloride	KCl	0.7
6	Other Salts		0.8
Total Salinity			**34.5%**

About half of the known elements are found in sea water. All the gases present in atmosphere are also found dissolved in sea water to some extent . According to weight, 55 % Chlorine and 31% Sodium constitute the mineral content of oceans. Besides the five salts mentioned above, some important elements present in sea water are Bromine, Carbon, Strontium, Boron, Silicon, Fluorine, etc.

If the various specimens of sea water of different parts of oceans and seas are considered, the ratio of the main slats is almost the same built there is a variation in the salinity in them. Isohalines are drawn on the sea surface or at any depth of water to express salinity. Isohaline is an imaginary line drawn to join places having equal salinity.

10.8 SOURCES OF OCEAN SALINITY

Salt in the ocean comes from rocks on land. The rain that falls on the land contains some dissolved carbon-di-oxide from the surrounding air. This causes the rain water to be slightly acidic due to carbonic acid (which forms from carbon dioxide and water).

1. Sea water is a weak, but complex solution made up of many things including mineral salts and decayed biologic matter from marine organism. Most of the ocean's salts are derived from gradual processes, such as weathering and erosion of the earth's crust and mountains by the dissolving action of rains and streams.

Some of the ocean's salts have been dissolved from rocks and sediments below the sea floor, while other have escaped from the Earth's crust though volcanic vents as solid and gaseous materials.

Salts become concentrated in the sea because the sun's heat evaporates almost pure water from the surface of the ocean, leaving the salts behind. This process is part of the continual exchange water between the Earth and the atmosphere, called the hydrologic cycle.

Water vapour rises from the ocean surface through evaporation and in carried landward by the winds in the form of clouds and humidity. When the vapor in the cloud collides with a colder mass of air, the moisture condenses (changes from a gas to a liquid) and falls to Earth as rain.

The rain runs off into streams or underground as ground water, both of which transport water back to the sea.

Evaporation from both the land and the ocean again causes water to return to the atmosphere as vapour and the cycle starts anew.

Natural products like dissolved salts are not the only chemicals that are transported by rivers to the sea.

Rivers and surface runoff are not the only source of dissolved salts. Hydrothermal vents are recently discovered features on the crest of oceanic ridges that contribute dissolved minerals to the oceanic. These vents are the exit point on the ocean floor from which sea water that has seeped into the rocks of the oceanic crust has become hotter, has dissolved some of the minerals from the crust and then flows back into the ocean. With the hot water comes large amount of dissolved minerals. Estimates of the amount of hydrothermal fluids now flowing from these vents indicate that the entire volume of the oceans could seep through the oceanic crust in about 10 million years. Thus, this process has a very important effect on salinity. The reactions between sea water and oceanic basalt, the rock of ocean crust, are not one way, however; some of the dissolved salts react with the rock and are removed from sea water.

A final process that provides salts to the oceanic submarine volcanism, the eruption of volcanoes under water. This is similar to the previous process in the sea water is reacting with hot rock a dissolving some of mineral constituents.

10.9 CONTROLLING FACTORS OF SALINITY

Salinity determines compressibility, thermal expansion, temperature, density, absorption of insolation, evaporation and humidity. It also influences the composition and movement of the sea water and the distribution to fish and other marine resources.

- The salinity of water in the surface layer of oceans depends mainly on evaporation and precipitation.
- Surface salinity is greatly influenced in coastal regions by the fresh water flow, rivers and in polars by the processes of freezing and thawing of ice.
- Wind, also influences salinity of an area by transferring to other areas.
- The ocean currents contribute to the salinity variations.
- Salinity, temperature and density of water are interrelated. Hence, any change in the temperature or density influences the salinity of an area.

10.10: HORIZONTAL DISTRIBUTION OF THE SALINITY

The salinity for normal Open Ocean ranges between 33 and 37. In the land locked Red Sea (don’t confuse this to Dead Sea which has much greater salinity) it is as high as 41. In hot and dry regions, where evaporation is high, the salinity sometimes reaches to 70. In the estuaries (enclosed mouth of a river where fresh and saline water get mixed) and the Arctic, the salinity fluctuates from 0-35 seasonally (fresh water coming from ice caps).

The salinity variation in the Pacific Ocean is mainly due to its shape and lager areal extent.

In the Atlantic Ocean the average salinity of the Atlantic Ocean is around 36-37. The equatorial region of the Atlantic Ocean has a salinity of about 35. Near the equator, there is heavy rainfall, high relative humidity, cloudiness and clam air of the doldrums. The polar areas experience very little evaporation and receive large amounts of fresh water from the melting of ice. This leads to low levels of salinity, ranging between 20 and 32. Maximum salinity 37 is observed between 20° North and 30° West to 60° West. It gradually decreases towards the north.

In the Indian Ocean the average salinity of the Indian Ocean is 35. The low salinity trend is observed in the Bay of Bengal due to influx of river water by the River Ganga. On the contrary, the Arabian Sea shows higher salinity due to high evaporation and low influx of fresh water.

Marginal Seas

- The North Sea, inspite of its location in higher latitudes, records higher salinity due to more saline water brought by the North Atlantic Drift.
- Baltic Sea records low salinity due to influx of river waters in large quantity.
- The Mediterranean Sea records higher salinity due to high evaporation.
- Salinity is, however, very low in Black Sea due to enormous fresh water influx by rivers.

Inland Seas and Lakes

- The salinity of the inland Seas and lakes is very high because of the regular supply of salt by the rivers falling into them.
- Their water becomes progressively more saline due to evaporations.
- For instance, the salinity of the Great Salt Lake, (Utah, USA), the Dead Sea and the Lake Van in Turkey in 220, 240 and 230 respectively.
- The oceans and salt lakes are becoming more salty as time goes on because the rivers dump more salt into them, while fresh water is lost due to evaporation.

Cold and warm water mixing zones

- Salinity decreases from 35-31 on the western parts of the northern hemisphere because of the influx of melted water from the Arctic region.

Sub – Surface Salinity

- With depth, the salinity also varies, but this variation again is subject to latitudinal difference. The decrease is also influenced by cold and warm currents.
- In high latitudes, salinity increases with depth. In the middle latitudes, it increases upto 35 metres and then in decreases. At the equator, surface salinity is lower.

10.11 VERTICAL DISTRIBUTION OF SALINITY

- Salinity changes with depth, but the way it changes depends upon the location of the Sea.
- Salinity at the surface increase by the loss of water to ice or evaporation, or decreased by the input of fresh waters, such as from the rivers.

- Salinity at depth is very much fixed, because there is no way that water is ‘lost’, or the salt is ‘added’. There is a marked difference in the salinity between the surface zones and the deep zones of the oceans.
- The lower salinity water rests above the higher salinity dense water.
- Salinity, generally, increases with depth and there is a distinct zone called the halocline (compare this with thermocline), where salinity increases sharply.
- Other factors being constant, increasing salinity of sea water causes its density to increase. High salinity sea water, generally, sinks below the lower salinity water. This leads to stratification by salinity.

10.12: CONCLUSION

The main source of heat for the oceans is the sun but due to certain special characteristics, the heating of water is quite different from that of land. That specific heat of water is five times as much as that of land. Besides, evaporation, which is always going on over the surface of the ocean, is a cooling process. Because of these reasons, water takes longer time to be heated and cooled. Therefore in comparison with land area, the water is heated after a longer time and so it cools off late as well. The result is that in winters oceans are warmer than the surrounding land areas and summers find them a little cooler.

The temperature of the ocean water varies according to latitude, depth and salinity. Besides these, the prevalent winds, currents and continental margins also modify the temperature of the ocean water. The temperature varies with salinity. The greater the salinity the higher is the temperature.

The water of the sea is brackish or saline. This is due to (1) the rivers, which bring huge amounts of mineral salts dissolved in water; (2) evaporation, which transforms water into vapour and makes the mineral content of the ocean increase every year; (3) the meager amount of fresh water coming into the oceans through precipitation.

As these factors are not the same everywhere, the salinity of the ocean differs from place to place. Along with salinity, the density of ocean waters also varies. In hot deserts, where the rainfall is meager and evaporation excessive, density is high, the percentage of salinity being very large. The percentage of salinity and density of the ocean water is low in those cold regions, where large amounts of fresh water are added by the melting of ice.

Although the salinity of the ocean water is 36% on an average, it is the highest near the Tropics of Cancer and Capricorn, it is the lowest near the polar region but it varies widely in open oceans and those bound by land.

The salinity of the water not only affects the density but also its colour and temperature. It the salinity is high, the colour of water will be deep blue but if it is less, the colour will be green. The temperature of saline water is higher. Therefore, the lower the mineral content of the water, the lower will be its temperature.

10.13 SUMMARY

Two of the most important characteristics of sea water are: temperature and salinity– together they control its density, which is the major factor governing the vertical movement of ocean waters. Because the seawater signature of temperature and salinity are acquired by processes occurring at the air-sea interface, we can also state that the density characteristics of a parcel of sea water are determined when it is at the sea surface. Temperatures of sea water vary widely (-1 to 30℃), where as the salinity range is small (35.0 $\pm$ 2.0). The North Atlantic contains the warmest and saltiest water of the major oceans, the Southern Ocean (the region around Antarctica) is the coldest, and the North Pacific has the lowest average salinity.

Relation between Oceanic Temperature and Salinity

Water Mass	Temp (℃)	Salinity
North Atlantic Central water	8-19	35.1- 36.5
Antarctic Circumpolar water	0-2	34.6-34.7
Antarctic Intermediate water	3-7	33.8-34.7
North Pacific Intermediate water	4-10	34.0-34.5
North Atlantic Deep water	2-4	34.8-35.1
Antarctic Bottom water	-0.4	34.7

Temperature and salinity both affect the density of water. Hence all those things which affect temperature and salinity also affect density of ocean water.

10.14: GLOSSARY

Electromagnetic. Waves of energy propagated through space at the speed of light.

Insolation From incoming solar radiation, this is the solar radiation received at the earth's surface. The amount of insolation varies with latitude, since the angle of the sun's rays and the duration of daylight change with latitude and season.

Diurnal Of or during the day. Active during the day, daytime.

Strait A narrow passage of water connecting two seas or two other large areas of water.

Inversion The increase of air temperatures with height. (This is the reverse of the more common situation in which air cools with

	height.
Photic zone	Those upper levels of a body of water which are penetrated by light.
Euphotic zone	The upper layer of a body of water receiving light and thus where photosynthesis is possible. Unlike the epilimnion, the euphotic zone is defined solely by light input, and not by temperature.
Aphotic zone	In any watery environment, the deeper zone, which is not penetrated by light.
Thermocline	A thermocline is the transition layer between the warmer mixed water at the surface and the cooler deep water below.
Hydrothermal	Relating to or produced by hot water, especially water heated underground by the Earth's internal heat. Hydrothermal energy is power that is generated using the Earth's hot water.
Estuaries	That area of a river mouth which is affected by sea tides. An estuary differs from a delta in that the former debouches into the sea whereas the latter progrades seaward.
Isohaline	These lines are join points of equal salinity in an aquatic system. Isohaline position refers to the distance (kilometers) of a near bottom isohaline from the mouth of a coastal waterway.

10.15 ANSWER TO CHECK YOUR PROGRESS

Q.1 Write a geographical account of the surface distribution to temperature over the oceans.

Q.2 What is the meant by ocean salinity? Account for the difference in ocean salinity and describe its effects on ocean currents.

Q.3 Describe the controlling factors of distribution of temperature of ocean water.

Q.4 Describe the controlling factors of salinity of ocean water.

10.16 REFERENCES

Ahmed, A. : Physical Geography, Rawat Publication, Jaipur, 1993

Bembrick, S. : The Cambridge Encyclopedia of Physical Geography, Cambridge university Press, New York, 1994

Bharatdwaj, K : Physical Geography: A Landscape Appreciation, Discovery Publishing House Pvt. Ltd., New Delhi, 2009

Tikka, R.N. : Physical Geography, Kedar Nath Ram Nath & Co., Meerut, 1994-95

10.17 SUGGESTED READINGS

1. Savindra singh , (2004) Physical Geography, Vasundhara Prakashan, Gorakhpur.
2. Tikka, R. N. (1995) Physical Geography, Kedar Nath Ram Nath & Co., Meerut.
   1994-95.

10.18 TERMINAL QUESTIONS

Q.1 Write short note on the following:

(a) Salinity of the ocean

(b) Composition of ocean water

(c) Vertical distribution of temperature of ocean water

Q.2 Explain: “The Salinity in the ocean water is not the same everywhere.”

Q.3 Explain with illustration the factors that influence the horizontal distribution of temperature on the land surface.

Q.4 Describe the temperature of the ocean water with the special reference of daily and annual ranges.

UNIT 11: CIRCULATION OF OCEAN WATER, CURRENTS & TIDES

11.1 OBJECTIVES

11.2 INTRODUCTION

11.3 CIRCULATION OF OCEAN WATER: CONCEPT

11.4 OCEAN WAVES

11.5 OCEAN CURRENTS: MEANING

11.5.1 Origin of the Currents

11.5.2 Currents of Atlantic Ocean

11.5.3 Currents of Pacific Ocean

11.5.4 Currents of Indian Ocean

11.6 TIDES: MEANING AND CONCEPTS

11.6.1 Time of Tides

11.6.2 Types of Tide

11.6.3. Theories of the Origin of Tides

11.7 CONCLUSION

11.8 SUMMARY

11.9 GLOSSARY

11.10 ANSWERS TO CHECK YOUR PROGRESS

11.11 REFERENCES

11.12 SUGGESTED READINGS

11.13 TERMINAL QUESTIONS

11.1 OBJECTIVES

- To know about the various oceanic phenomena
- Differentiate between currents, waves and tides
- Know about the different types of currents
- To know about the world distribution of ocean currents
- To know the origin of tides and their importance

11.2 INTRODUCTION

Can we think of life without water? It is said that water is life. Water is an essential component of all life forms that exist over the surface of the Earth. The creatures on the Earth are lucky that it is a water planet; otherwise we all would have no existence. Water is a rare commodity in our solar system. The Earth fortunately has an abundant supply of water on its surface. Hence our planet is called the *"Blue Planet'*. The water on Earth is also of very types. We will read about ocean water, in particular, in this chapter.

The ocean water is dynamic. Its physical characteristics like temperature, salinity, density and the external forces like the sun, moon and the winds influence the movement of ocean water. The horizontal and vertical motions are common in water bodies. The horizontal motion refers to the ocean currents and waves. The vertical motion refers to tides. Ocean currents are the continuous flow of huge amount of water in a definite direction while the waves are the horizontal motion of water. Water moves ahead from one place to another through ocean currents while the water in the waves does not move, but the wave trains move ahead. The vertical motion refers to the rise and fall of water in the oceans and seas. Due to attraction of the sun and the moon, the ocean water is raised up and falls down twice a day. The upwelling of cold water from subsurface and the sinking of surface water are also forms of vertical motion of ocean water.

11.3 CIRCULATION OF OCEAN WATER: CONCEPT

Incomplete

11.4 OCEAN WAVES

Waves are actually the energy, not the water as such, which moves across the ocean surface. Water particles only travel in a small circle as a wave passes. Wind provides energy to the waves. Wind causes waves to travel in the ocean and the energy is released on shorelines. The motion of the surface water seldom affects the stagnant deep bottom water of the oceans. As a wave approaches the beach, it slows down. This is due to the friction occurring between the dynamic water and the sea floor. And, when the depth of water is less than half the wavelength of the wave, the wave breaks. The largest waves are found in the open oceans. Waves continue to grow larger as they move and absorb energy from the wind.

Most of the waves are caused by the wind driving against water. When a breeze of two knots or less blows over calm water, small ripples form and grow as the wind speed increases until white caps appear in the breaking waves.

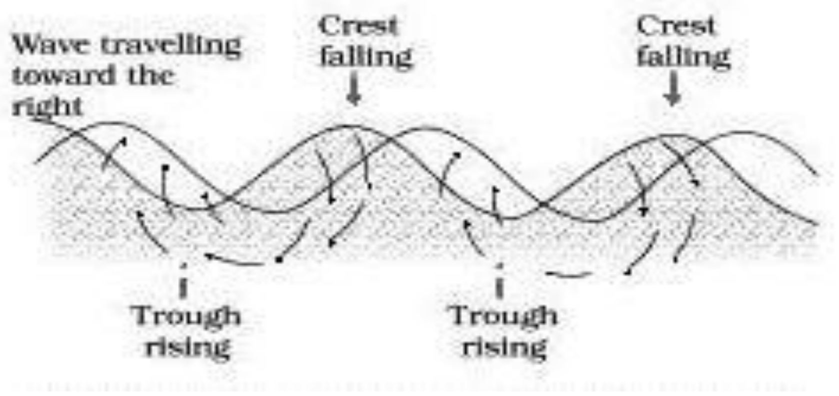


Figure 11.1

Motion of waves and water molecules

Waves may travel thousands of km before rolling ashore, breaking and dissolving as surf. A wave's size and shape reveal its origin. Steep waves are fairly young ones and are probably formed by local wind. Slow and steady waves originate from faraway places, possibly from another hemisphere. The maximum wave height is determined by the strength of the wind, i.e. how long it blows and the area over which it blows in a single direction. Waves travel because wind pushes the water body in its course while gravity pulls the crests of the waves downward. The falling water pushes the former troughs upward, and the wave moves to a new position(Figure 11.1). The actual motion of the water beneath the waves is circular. It indicates that things are carried up and forward as the wave approaches, and down and back as it passes. Some characteristic features of waves are as follows:

1. **Wave crest and trough:** The highest and lowest points of a wave are called the crest and trough respectively.
2. **Wave height:** It is the vertical distance from the bottom of a trough to the top of a crest of a wave.
3. **Wave amplitude:** It is one-half of the wave height.
4. **Wave period:** It is merely the time interval between two successive wave crests or troughs as they pass a fixed point.
5. **Wavelength:** It is the horizontal distance between two successive crests.
6. **Wave speed:** It is the rate at which the wave moves through the water, and is measured in knots.
7. **Wave frequency:** It is the number of waves passing a given point during a one second time interval.

11.5 OCEAN CURRENTS: MEANING

Ocean currents are like river flow in oceans. They represent a regular volume of water in a definite path and direction. The general movement of a mass of oceanic water in a definite direction is called ocean current. Ocean currents are the most powerful of all the dynamics of oceanic waters because these drive oceanic waters for thousands of kilometers away. Ocean currents are influenced by two types of forces namely:

i. Primary forces that initiate the movement of water.
ii. Secondary forces that influence the currents to flow.

Ocean currents are divided on the basis of:

i. Temperature: a) warm currents and b) cold currents
ii. Velocity, dimension and direction: a) drifts, b) currents and c) streams

The forward movement of the surface water of the oceans under the influence of prevailing winds is called drift, whereas currents movement of a mass of oceanic water in a definite direction with greater velocity. Ocean stream involves the movement of larger mass of oceanic water like big rivers of the continent in a definite direction with a greater velocity than a drift or current, e.g., Gulf Stream.

11.5.1 Origin of the Currents

The pattern of oceanic circulation is produced by the interaction of a number of factors. The main factors which produce ocean currents are:

1. Planetary Winds (Trade Winds, Westerlies and Polar Winds)

The prevailing planetary winds (trade winds, westerlies and polar winds) play vital roles in the origin and development of ocean currents. Most of the Earth's surface energy is concentrated in each hemisphere's trade winds and westerlies. Tiny irregularities in the sea surface, called *capillary waves*, transfer some of the energy from the moving air to the water by friction. This tug of wind on the ocean surface begins a more rapid mass flow of water. As a rule, the friction of wind blowing for atleast ten hours will cause surface water to flow downward at about 2% of wind speed. The water flowing beneath the wind forms the surface current.

Because of the Coriolis Effect, the Northern Hemisphere currents flow to the right of the wind direction while in the Southern Hemisphere currents flow to the left. Intervening continents and basin topography often block continuous flow and help to deflect the Moving water into a circular pattern. This flow around the periphery of an ocean basin is called *gyre* (gyros=circle). Two gyres are shown in Figs. 11.2, 11.3 and 11.4. Most of the ocean currents of the world follow the direction of prevailing, permanent and planetary winds. For example, the equatorial current flow westward at a speed of 40 km (25 miles) per hour, under the impact of the trade winds.

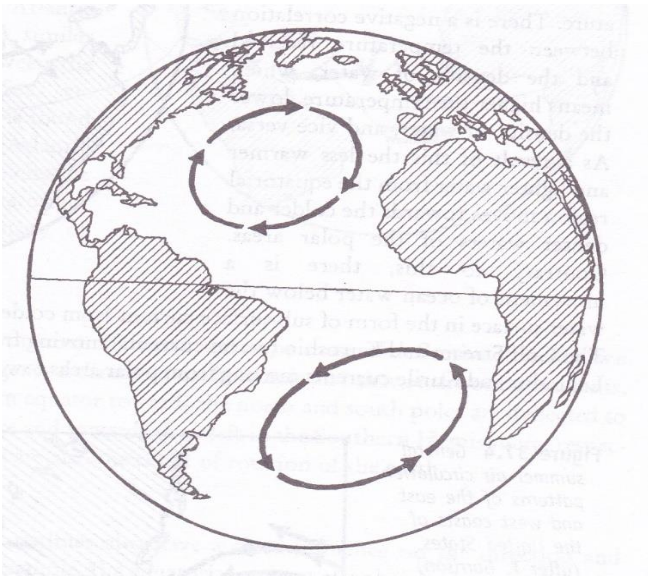


Figure 11.2

A combination of Four Forces-the sun's heat, winds, the Corolis Effect and Gravity-circulates the ocean surface clockwise in the Northern Hemisphere and anti-clockwise in Southern Hemisphere. Gyres thus formed are shown.

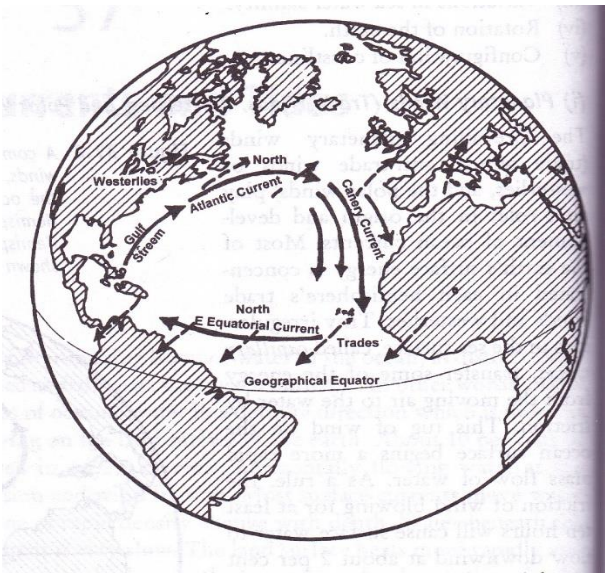


Figure 11.3

The North Atlantic Gyre, a series of four interconnecting currents each with different flow, characteristics and temperatures

The Gulf Stream in the Atlantic Ocean and Kuroshio in the Pacific Ocean move in the North-eastern direction under the influence of the anti-trade (westerlies) winds (Figure 11.5). Many of the ocean currents are drifts caused by the friction between the winds and the surface water. They move more or less in the direction of the wind and vary in position and strength with the seasonal winds, e.g., Indian Monsoons.

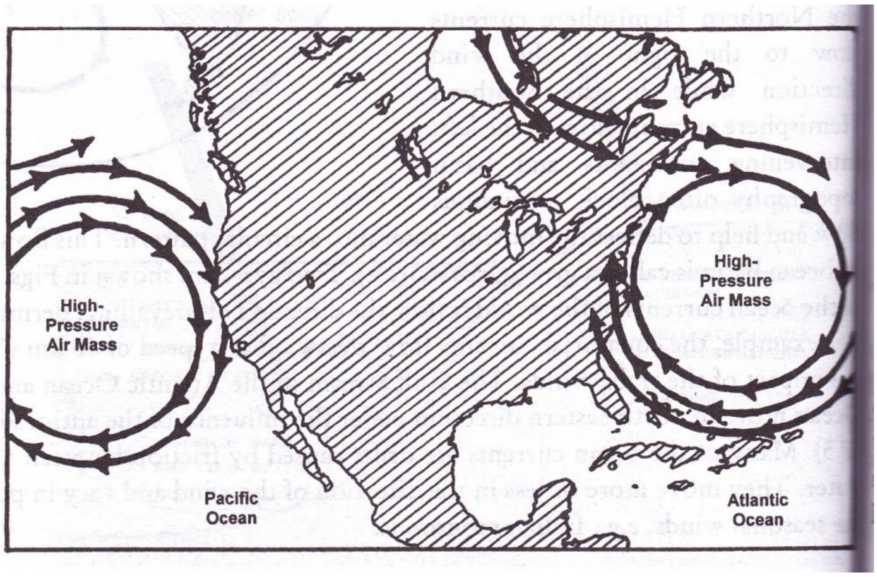


Figure 11.4

General summer air circulation patterns of the east and west coasts of United States

2. Variations in Sea Water Temperatures

There is a marked variation in the horizontal and vertical distribution of the oceans. In general, the temperature decreases from the equator towards the poles and from the surface towards the bottom of the seas and oceans. Thus, in the equatorial region the density of water decreases due to high temperature. There is a negative correlation between the temperature received and the density of water, which means higher the temperature, lower the density of water, and vice versa.

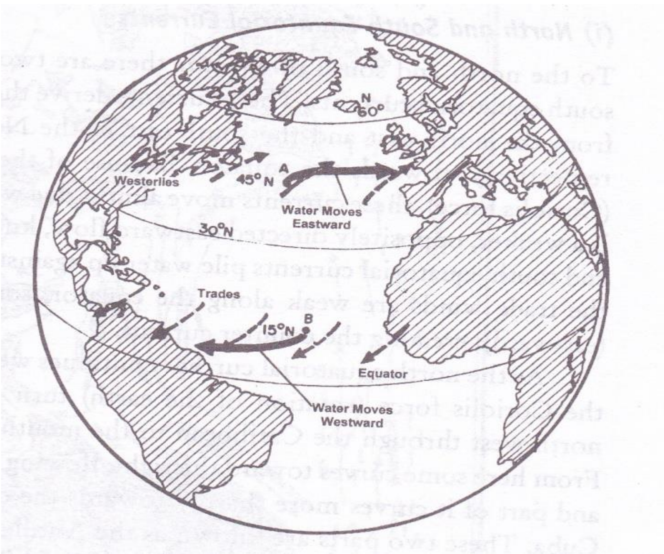


Figure 11.5

Surface water blown by winds at a point 'A' will veer to the right of its initial path and continue eastward. Water at point 'B' veers right and continues westward

As a result of this the less warm and lighter water from the equatorial region moves toward the colder and denser water of the polar areas. Contrary to this, there is a movement of ocean water below the water surface in the form of sub-surface current from the colder polar areas to warmer equatorial areas. The Gulf Stream and Kuroshio (warm currents) moving from equator towards North Pole and the Labrador and Kurile currents moving from polar areas towards equator are some of such examples.

3. Variations in Sea Water Salinity

The amount of salts contained in sea water does not vary from one part of the ocean to another. Water with a high salinity is denser than that with lower amounts of salts. The high salinity water tends to subside and move below the water of less salinity to the areas of high salinity. There is marked variation in the salinity of Atlantic Ocean and the Mediterranean Sea. Because of this variation, the ocean currents flow from the Atlantic Ocean to the Mediterranean Sea. A similar ocean current may be observed between the Indian Ocean and the Red Sea via Bab-el-Mandeb. An identical pattern is found in the Baltic Sea and the North Sea. The Peru Current may also be cited as an example of a current which has its origin because of the variation in the density of water.

4. Rotation of the Earth

The Earth rotates on its axis, from west to east. The rotation is the cause of deflective force known as '*Corolis Force',* which deflects the general direction of the winds and that of the ocean currents. For example, the currents flowing from equator towards the north and south poles are deflected to their right in the Northern Hemisphere and towards their left in the Southern Hemisphere, respectively. The counter-equatorial currents are also the result of rotation of the Earth.

5. Configuration of the Coastlines

The shape and configuration of the coastlines also have a close influence on the direction and movementof the ocean currents. For example, the equatorial current after being obstructed by the Brazilian coasts is bifurcated into two branches. The northern branch is known as the Caribbean current flowing along the northern coast of South America, while the southern branch moves along the eastern coast of Brazil, which is known as the Brazilian current. In the India Ocean, the monsoon currents closely follow the coastlines.

In addition to the shape of coastline, the configuration of the bottom relief also modifies the direction of movementof the ocean currents. Generally, the ocean currents while crossing over a submarine ridgeare deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. For Example, the North Atlantic Drift is deflected to the right when it crosses the Wyville-Thomas ridge. Similarly, the north equatorial currentis deflected to the right while crossing over mid-Atlantic ridge.

11.5.2 Currents of the Atlantic Ocean

1. North Equatorial Current (warm)

Normally, the north equatorial current is formed between the equator 10ºN latitude. This current is generated because of upwelling of cold water near the west coast of Africa. This warm current is also pushed is also pushed westward by the cold Canary current. On an average, the north equatorial warm current flows from east to west but this saline current is deflected northward when it crosses the Mid-Atlantic Ridge near 15ºN latitude. It again turns southwards after crossing over the ridge. This current after being obstructed by the land barrier of the east coast of Brazil, is bifurcated into two branches-Antilles current and Caribbean current. The Antilles current is diverted northwards and flows to the east of West Indies islands, and helps in the formation of Sargasso Sea, while the second branch known as the Caribbean current enters the Gulf of Mexico and becomes Gulf Stream.

2. South Equatorial Current (warm)

South Equatorial Current flows from the western coast of Africa to the eastern coast of South America between the equator and 20ºS latitude. This current is more constant, stronger and of great extent than the north equatorial current. In fact, this current is the continuation of the Benguala current. The warm current is bifurcated into two branches due to obstruction of and barrier in the form of the east coast of Brazil. The northward branches after taking north-westerly course merges with the north equatorial current near Trinidad while the second branch turns southward and continues as Brazil warm current parallel to the east coast of South America. This current is basically originated under the stress of trade winds.

3. Counter-equatorial Current (warm)

The Counter-equatorial Current flows from west to east between the westward flowing strong north and south equatorial currents. This current is less developed in the west due to stress of trade winds. In fact, the counter current mixes with the equatorial currents in the west but it's more developed in the east where it is known as the Guinea Stream.

4. Gulf Stream (warm)

The Gulf Stream is a system of several currents moving in north-easterly direction along the eastern coast of North America. It is the largest of the western boundary currents of the North Atlantic Ocean. Thisiswarm water current which originates in the Gulf of Mexico around 20ºN and under the impact of the westerlies, it reaches the western coasts of Europe upto 70ºN.

Along the coastof Florida, the average surface temperature of the Gulf Stream reads about 25ºC. Moving northward at 30ºN, the surface temperature decrease to about 10ºC. The general direction of flow of the Gulf Stream, north of the 30ºN latitude, is northward, but beyond Cape Hatteras it bends slowly to the right, passing the 350 km south of Natucket until the south of Halifax the flow is nearly due east. Where the Gulf Stream leaves the continental shelf at Cape Hatteras, its average width is about 82 km. Eastward, it widens gradually, becoming 120 km wide in the longitude of Halifax. The temperature of water near the coasts of 40ºN ranges between 4ºC and 10ºC. Moving along the east coast of the United States, it is strengthened by the prevailing westerly winds and is deflected to the east between 35ºN and 45ºN latitudes. Near Newfoundland its water mixes with that of the cold water current of Labrador which results in formation of dense fog. The dense foggy conditions around the Newfoundland are hazardous to the navigation of ships. Gulf Stream flows in 55 million cubic meters water per second, about 300 times the usual flow of Amazon, the greatest of rivers.

As the Gulf Stream continuous north-eastward beyond the Grand Bank, it gradually widens and decreases its speed until it becomes a vast, slow moving current known as the North Atlantic Drift. As the North Atlantic Drift approaches Western Europe, it splits. Part of it moves northward, past Great Britain and Norway. The other part is deflected southward as the cool Canaries current.

The warm water current of the Gulf Stream modifies the weather conditions of the eastern coast of U.S.A. and Canada, and the western coast of Europe. The temperature of the eastern coast of U.S.A. becomes significantly high during the summer months. On the western coast of Europe, the warm water of this current keeps the sea port open upto 70ºN, even in the severe winter season and make the climate and weather milder.

5. Canary Current (cold)

It is a cold current flowing along the western coast of North Africa between Maderia and Cape Verde. In fact this current is the continuation of the North Atlantic Drift which turns southward near the Spanish coast and flows to the south along the coast of Canaries Island. The average velocity of this current is 8 to 30 nautical miles per day. This current brings cold water of the high latitudes to the warm water of the low latitudes and finally merges with the north equatorial current. The Canary cold current ameliorates the otherwise hot weather conditions of the western coast of North Africa.

6. Labrador Current (cold)

It originates in the Baffin Bay and Davis Strait and after flowing through the coastal waters of Newfoundland and Grand Bank merges with the Gulf Stream around 50ºW longitude. The flow discharge rate of the current is 7.5 million m^3 of water per second. This current along with it bring a large number of big icebergs as far as south as Newfoundland and Grand Bank. These icebergs present effective hindrances in the oceanic navigation. Dense fogs are also produced due to the convergence of the Labrador cold current and the Gulf Stream near Newfoundland.

7. Brazil Current (warm)

Along the eastern coast of Brazil flowing from north to south upto 40ºS is the warm water current of Brazil. The surface temperature of the current reads about 25ºC in the north and about 15ºC at 40ºS. The average speed of the current varies between 28 km per day. It ameliorates the weather conditions along the eastern coast of Argentina.

8. Falkland Current (cold)

The Falkland Current has its origin in the Antarctic Ocean around 65ºS. It flows from south to north. The average speed of this current is about 18 km per day. It brings large sized icebergs from the Antarctic Ocean to make the Falkland and eastern coast of south Argentina cold.

9. Benguela Current (cold)

The Benguela Current flows from south to north along the western coast of South Africa. In fact, the South Atlantic Drift turns northward due to the obstruction caused by the southern tip of Africa. Further northwards this current merges with the South Equatorial Current.

10. South Atlantic Drift (cold)

The eastward movement of the Brazilian Current is known as the South Atlantic Drift. It develops at 40ºS owing to the impact of the westerlies which are known as the roaries forties. Consequently, it is also known as the westerlies drift or the Antarctic Drift.

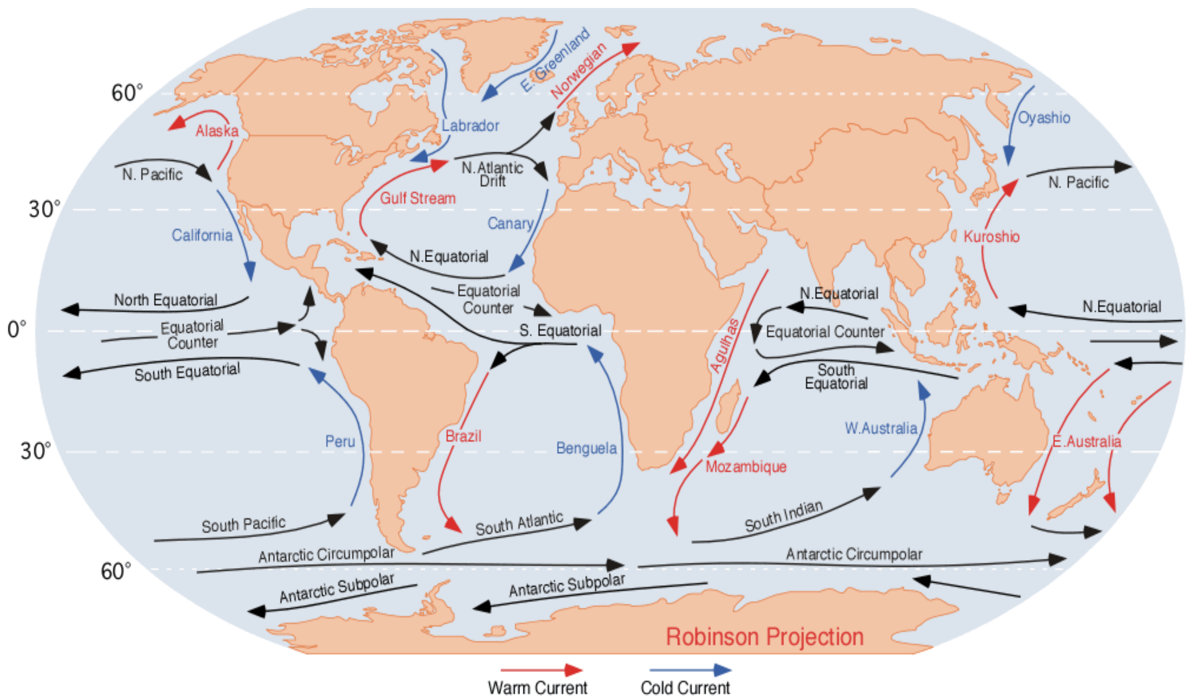


Figure 11.6
World Ocean Currents

11.5.3 Currents of the Pacific Ocean

1. North and South Equatorial Currents(warm)

The north equatorial current flows westward which originates around 10ºN to the west of Mexico (North America). Moving westward, almost parallel to the line of equator, it reaches the coasts of Philippines after covering a distance of about 12,000 km. The Pacific Ocean is too wide in the lower latitudes and, therefore, a greater volume of water is involved. After reaching the coast of Philippines, under the impact of Corolis force, it takes a northerly direction. Its surface temperature varies between 25ºC to 30ºC. The speed of the currents ranges between 10 km and 25 km per day.

Under the impact of south-east trade winds, the south equatorial current originates to the west of Peru around 10ºS latitude. It is one of the strongest currents. The speed of the current varies between 16 km to 30 km per day. The surface temperature of its water reads between 20ºC to 25ºC.

Both the north and south equatorial current flows westward, with a compensatory counter-current flowing in the reverse direction between them along a line about 5ºN. The counter-equatorial current reaches upto Panama.

2. Kuroshio Current (warm)

Kuroshio is the most important warm water current of the North Pacific Ocean. It is analogous to the Gulf Stream of the Atlantic Ocean. It develops partly due to the Corolis force and partly due to the obstruction of the Philippines in the flow of the north equatorial current. The average surface temperature of these current remains around 18ºC. It moves at a speed of about 30 km per day. It keeps the eastern coast of Japan warm even in the coldest month (January) when snowing is frequent in Honshu and Hokkaido.

An offshoot of Kuroshio Current, also known as Tsushima current, enters into the Sea of Japan along the west coast of the islands. The relatively warm water of Tsushima current keeps the western coast of Japan warm. Around 35ºN, the Kuroshio current under the impact of westerlies, leaves the coast of Japan and adopts a north-easterly direction, and reaches the western coast of North America around 150ºW. Further north it is known as the Aleutian current.

3. Kurile or Oyashio Current (cold)

This cold current originates from the Bering Strait and moving in southerly direction touches the island of Kurile, wherefrom it is called Kurile Current. It transports the cold water of the Arctic Sea into the Pacific Ocean. Near 50ºN latitude this current is bifurcated into two branches. One branch turns eastward and merges with the Aleutian and Kuroshio Currents. The second branch moves upto the Japanese coasts. This current is comparable to the cold Labrador Current of the North Atlantic Ocean. The convergence of cold Oyashio (Kurile) and warm Kuroshio Current causes dense fog which become potential hazards for navigation.

4. California Current (cold)

The California Current,an example of cold current, is similar to the Canary current of Atlantic Ocean in most of its characteristics. In fact, his current is the eastward extended portion of the North Atlantic Drift. The cold California Current is generated because of the movement of oceanic water along the Californian coast from north to south in order to compensate the loss of water which is caused due to large-scale transport of water off the coast of Mexico under the influence of trade winds in the form of north equatorial current. The current after reaching the Mexican coast turns westward and merges with the north equatorial current.

5. Peru or Humboldt Current (cold)

The cold current flowing along the western coast of South America from south to north is called Peru Current or Humboldt Current. This current is known as Peru coastal current while it is called Peru oceanic current off the coast. Mean annual temperature ranges between 14ºC and 17ºC and the average velocity of moving water is 15 nautical miles (27 km) per day. The temperature of the sea water increases from the coast towards the ocean.

6. East Australian Current (warm)

It is a branch of the south equatorial current which moves from north to south along the eastern coast of Australia. Around 40ºS, under the impact of Corolis force, it is deflected towards east and touches the coasts of New Zealand. It raises the temperature along the eastern coast of Australia and the coasts of New Zealand.

7. West Wind Drift (cold)

To the south of Tasmania and New Zealand flows water almost from west to east, which is known as the west wind drift. The water drift is largely confined between 40ºS to 50ºS latitudes. Under the influence of roaring forties this current achieves a great speed reaching upto 30 km per day.

11.5.4 Currents of Indian Ocean

1. Indian Equatorial Current (warm)

The currents of the southern Indian Ocean are least affected by the seasonal changes in the direction of monsoon winds. The Indian equatorial current flows from east to west between 10ºS and 15ºS latitudes from Australian coast to African coast. After being obstructed by Madagascar this current is divided into many branches. One major branch flows southward in the name of Agulhas Current (warm) while the other branch is directed towards the north.

2. Mozambique Current (warm)

One branch of southern equatorial current moves southwards through Mozambique Channel, also known as Mozambique current. The current joins the Agulhas current near 30ºS latitude and moves up to the southern tip of Africa and is ultimately diverted eastward.

3. South-west Monsoon Current (warm)

In the summer season in the northern parts of Indian Ocean, the monsoon winds blow from south-west to north-east. Consequently, the ocean currents follow the general direction of summer monsoon.

4. North-east Monsoon Current (warm)

In the winter season the monsoon winds blow from north-east to south-west. Influenced by the direction of winds, the ocean currents flow from north-east to south-west. In brief, in the Indian Ocean, the ocean currents are closely controlled by the south-west and north-east monsoons.

5. Indian Counter Current (warm)

In the winter season, under the impact of north-east monsoon, a counter-current develops around 5ºS. It flows from Zanzibar to Sumatra.

6. West Wind Drift (cold)

Like Pacific and Atlantic Oceans eastwards flowing current, known as west wind drift, is also generated in the Indian Ocean. The current is produce due to eastward blowing westerlies along 40ºN latitude is known as 'roaring forties'. This current bifurcates in two branches near 110ºE longitude. One branch turns northward and flows as West Australia cold current along the western coast of Australia and near the Tropic of Capricorn turns towards west and north-west and ultimately merges with the south equatorial current near 100ºE longitude. The second branch of the west wind drift turns southward.

Check Your Progress I

Q.1 Differentiate between waves and tides.

____
____
____
____
____
____

Q.2 What do you mean by 'Coriolis Effect'?

____
____
____
____

Q.3 What do you understand by the term ‘roaring forties’?

____

11.6 TIDES: MEANING AND CONCEPT

The periodical rise and fall of the sea level, once or twice a day, mainly due to the attraction of the sun and the moon, is called a tide. The study of tides is very complex, spatially and temporally, as it has great variations in frequency, magnitude and height. The moon’s gravitational pull to a great extent and to a lesser extent the sun’s gravitational pull, are the major causes for the occurrence of tides. Another factor is centrifugal force, which is the force that acts to counter the balance the gravity. Together, the gravitational pull and the centrifugal force are responsible for creating the two major tidal bulges on the earth. On the side of the earth facing the moon, a tidal bulge occurs while on the opposite side though the gravitational attraction of the moon is less as it is farther away, the centrifugal force causes tidal bulge on the other side (Figure 11.7).

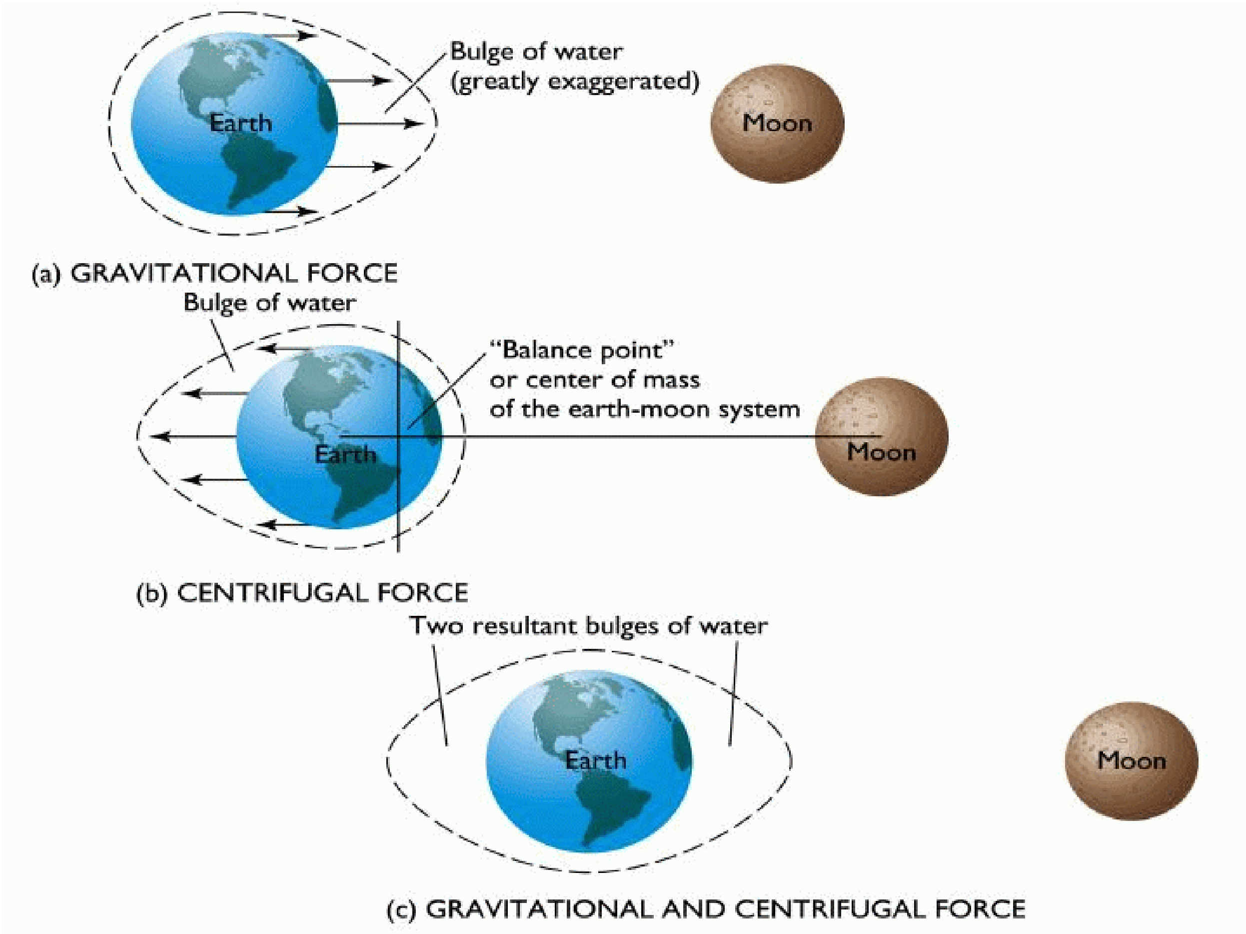


Figure 11.7

Relation between Gravitational Force and Tides

The 'tide-generating' force is the difference between these two forces; i.e. the gravitational attraction of the moon and the centrifugal force. On the surface of the earth, nearest the moon, pull or the attractive force of the moon is greater than the centrifugal force, and so there is a net force causing a bulge towards the moon. On the opposite side of the earth, the attractive force is less, as it is farther away from the moon, the centrifugal force is dominant. Hence, there is a net force away from the moon. It creates the second bulge away from the moon. On the surface of the earth, the horizontal tide generating forces are more important than the vertical forces in generating the tidal bulges.

The tidal bulges on wide continental shelves have greater height. When tidal bulges hit the mid-oceanic islands they become low. The shape of bays and estuaries along a coastline can also magnify the intensity of tides. Funnel-shaped bays greatly change tidal magnitudes. When the tide is channeled between islands or into bays and estuaries they are called tidal currents.

11.6.1 Time of Tides

On an average, every place experiences tides twice a day. Since the Earth completes is rotation in roughly 24 hours, every place should experience tides after 12 hours but this never happens. Each day tide is delayed by 26 minutes because the moon also rotates on its axis while revolving around the Earth. Since the Earth rotates from west to east and hence the tide centre shifts westward. When the centre completes one round, the moon's position is ahead of the tide's centre by that time because the moon also revolves around the Earth, with the result the tide centre takes another 52 minutes to come under the moon. Thus, a particular tide centre takes 24 hours 52 minutes to come under the moon but by that time there is another tide centre and this happens after 12 hours and 26 minutes.

Let us understand this process with the help of a diagram (Figure 11.8).

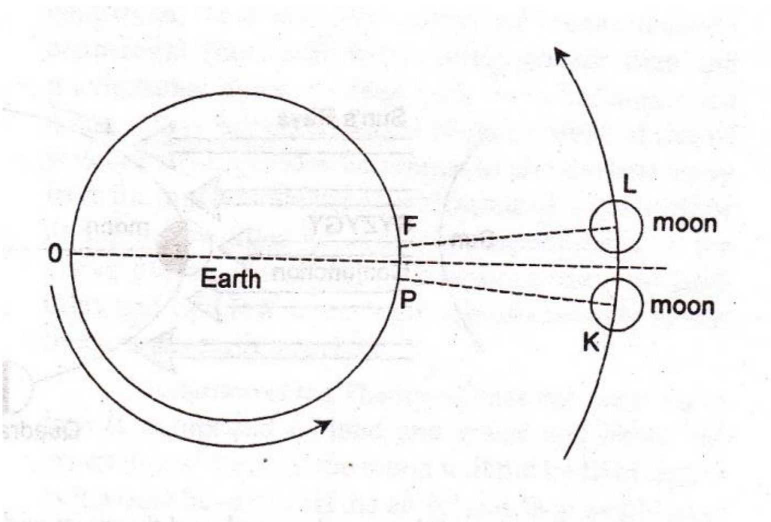


Figure 11.8

Time of Tides

Suppose if 'P' experiences first tide at 4 p.m., the second tide will occur at 4:26 a.m. and the next tide will be experienced at 4:52 p.m. The moon is at 'K' location and the place 'P' on the Earth's water surface under the moon (K) will experience the tide at 4 p.m. The place 'P' after completing its full rotation in 24 hours to come to its original place but by that time the moon moves to 'L' position which is above 'F' place on the Earth's surface. Now the place 'P' has cover extra distance P-F so that it may come under L position of the moon and 'P' may experience next tide. The earth has to spend 52 minutes to cover P-F distance. The moon completes its one revolution around the Earth in 27 days, 7 hours, 43 minutes and 17.5 seconds (average 27.5 days). Thus, the P-F distance is $2/55^{th}$ part of the moon's orbit. The place 'P' will take 24×60×2/55=52 minutes to cover the distance of 2/55 (P-F) part of the moon's orbit, therefore, the place 'P' will experience next tide at 4:26 a.m. when it is at 'O' place and subsequent tide occur s 4:52 p.m. It is evident that at each place every day tide occurs after 12 hours 26 minutes and after the tide, ebboccurs after 6 hours 13 minutes. It may be pointed out that each place experiences tide twice a day, i.e., when the place is under the moon and when the place is at the opposite side of the moon and thus each tide at particular place is delayed by 26 minutes.

11.6.2 Types of Tides

Tides vary in their frequency, direction and movement from place to place and also from time to time. Tides may be grouped into various types based on their frequency of occurrence in one day or 24 hours or based on their height.

1. Tides based on Frequency

i. **Semi-diurnal tide:** The most common tidal pattern, featuring two high tides and two low tides each day. The successive high or low tides are approximately of the same height.

ii. **Diurnal tide:** There is only one high tide and one low tide during each day. The successive high and low tides are approximately of the same height.

iii. **Mixed tide:** Tides having variations in height are known as mixed tides. These tides generally occur along the west coast of North America and on many islands of the Pacific Ocean.

2. Tides based on the Sun, Moon and the Earth Positions:

The height of rising water (high tide) varies appreciably depending upon the position of sun and moon with respect to the earth. Spring tides and neap tides come under this category.

i. **Spring tides:** The position of both the sun and the moon in relation to the earth has direct bearing on tide height. When the sun, the moon and the earth are in a straight line, the height of the tide will be higher. These are called spring tides and they occur twice a month, one on full moon period and another during new moon period.

ii. **Neap tides:** Normally, there is a seven day interval between the spring tides and neap tides. At this time the sun and moon are at right angles to each other and the forces of the sun and moon tend to counteract one another. The Moon's attraction, though more than twice as strong as the sun's, is diminished by the counteracting force of the sun's gravitational pull.

Once in a month, when the moon's orbit is closest to the earth (perigee), unusually high and low tides occur. During this time the tidal range is greater than normal. Two weeks later, when the moon is farthest from earth (apogee), the moon's gravitational force is limited and the tidal ranges are less than their average heights.

When the earth is closest to the sun (perihelion), around 3rd January each year, tidal ranges are also much greater, with unusually high and unusually low tides. When the earth is farthest from the sun (aphelion), around 4th July each year, tidal ranges are much less than average.

The time between the high tide and low tide, when the water level is falling, is called the *ebb.* The time between the low tide and high tide, when the tide is rising, is called the *flow* or *flood.*

11.6.3 Theories of the Origin of the Tides

A number of theories have been put forward about the origin of tides. The important theories about their origin are:

1. The Equilibrium Theory

This theory was put forward on the basis of Newton's law of Gravitation (1686), which states that each body in the universe attracts every other body with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between them measures from their centres of mass along a line joining these centres. In other words, the celestial bodies attract each other through their gravitational force in such a way that they remain in equilibrium. The sun, the moon, and the Earth are also in equilibrium due to their respective pull towards each other. Though the gravitational force of the sun is far greater than that of the moon, but the lunar gravitational force has more effect on the Earth than the sun because of its nearness to the Earth. As a result of this, the water of the Earth's surface under the moon is attracted and pulled and high tide is caused. The opposite side of the Earth's surface also experiences tide because of the centrifugal or reactionary force. Because of the force of gravitation, the highest point of rise of water (high tides) lies nearest to and farthest away from the moon, while the lowest points of the water surface (low tides) lie at places perpendicular to the above places.

The theory has not been universally accepted as it does not explain some of the points about the occurenc3 of tides. For example, the Earth's surface is composed of land (29%) and oceans (71%). Owing to the nature of composition of the earth's surface, the moon will not be as effective as it would have been, if the Earth's surface would have been composed of only water.

The theory also does not explain how the tides occur in the areas of oceans where the horizontal movement of water is absent or insignificant. According to the scientists, the bulge of water may not be possible unless some sort of horizontal movement of tide is involved.

In addition to these, one more criticism about the equilibrium theory is about the time of occurrence of tides. For example, the time of high tide should be the same at all places along each meridian but this never happens.

In view of the above weaknesses Airy opposed this theory and declared it erroneous as it does not explain the origin of tides as a result of the gravitational force.

2. The Progressive Wave Theory

This theory was propounded by William Whewell in 1883. It is based on the following facts:

- The Earth is a heterogeneous body and not a perfect fluid (surrounded by water on all sides).
- Tides occur at different times at different places on the same longitude.
- There is a lagging of time of tides away from the source.
- There is variation in the intensity of tides at different places.
- Tide is in the form of tidal waves which travels from east to west. The crests and troughs of such tidal waves become tides and ebbs respectively.
- The tidal waves are originated in the oceans under the influence of tidal force of the moon.
- The length and speed of the tidal waves depend on the depth of seas and oceans.
- In a globe completely surrounded by water, tidal waves would travel freely from east to west but the position of land and water hinders the speed and direction of these waves.
- Since the continents roughly stretch from north to south, they hamper the free movement of thetidal waves. These waves are least hampered in the oceans surrounding the Antarctic Ocean, owing to the non-availability of land in the higher latitudes of the Southern Hemisphere.

Because of the above facts, the tidal waves are generated in the oceans of the Southern Hemisphere, under the influence of tide-producing force of the moon. These waves are called as the *primary waves* which move from east to west in the form of force waves.

The primary waves are obstructed by the continents and are consequently refracted northward. Consequently, the *secondary waves* are generated when the westward movement of primary waves is obstructed by land masses. The northward moving secondary waves are also called as the *derived waves*. Further minor waves are generated from these secondary waves, which may be termed as the *tertiary waves.* The secondary and tertiary waves move northward with decreasing intensity and magnitude but generate tides everywhere. It may be mentioned that the primary waves are influenced by the moon but the tertiary or minor waves move freely.

Thus, the tidal waves after being originated in the oceans of Southern Hemisphere, Progressively move northward with continuous lag of time and dissipation of wave energy. In other words the arrival of these progressive waves at successive places northward along the same longitude is also progressively delayed. This explains the delay in the occurrence of tide at different places on the same longitude. Thus, the time of tide is progressively delayed northward along the longitude. These progressive waves become insignificant and ineffective after reaching the North Pole. Moreover, the crests and troughs of these waves after reaching the coasts cause tides and ebbs respectively.

The progressive wave theory is, however, not free from criticism. According to this theory, the age of tides increases northwards. In other words, if the tide is generated in the south on a particular longitude, it reaches quite late at the points located further north on the same longitude. Normally, the tides are local or regional phenomena rather than phenomena originating in the southern ocean and moving progressively northward. At some of the latitudes, both the daily and semi-diurnal types of tides are observed. Moreover, there is spatial variation in the irregularity of tides in different oceans. These variations cannot be explained on the basis of the progressive wave theory.

3. The Stationary Wave Theory

This theory was propounded by R. A. Harris of the Geodetic Survey of U.S.A. This theory, which was developed as a reaction to the progressive wave theory, gives an unsatisfactory explanation for the locational differences and variations in tides.

In the opinion of Harris, the phenomenon of tide is not due to progressive waves which originate in the oceans of Southern Hemisphere as claimed by Whewell, but because of the stationary waves which originate independently in each ocean. In other words, tides are regional phenomena.

In the huge water bodies of oceans, the sun and the moon cause oscillations, but the oscillation does not occur along straight lines. This process results in the formation of waves. Every stationary wave has a definite time of its oscillation. The oscillation system and process are affected by the depth, configuration, length and breadth of the ocean basin. These waves, after their origin, move towards the coasts. The forward movement of these waves is, however, hampered by the continental peninsulas, islands, bays, gulfs and straits. Reaching the coasts, the crests and troughs of the waves cause tides and ebbs, respectively. Thus, there is a positive correlation between the depth of the oceans and the height of the tides. In other words, greater the depth of the ocean, higher the stationary waves generated which lead to high or spring tides. Low tides are caused in the shallow seas because, of the lower heights of the stationary waves. The main advantage of the stationary wave theory lies in the fact that it helps in making reliable prediction about the magnitude of tides.

Check Your Progress II

Q.1 Which forces are responsible for the origin of the tides?

____

____

____

____

____

Q.2 What do you mean by 'ebb'?

____

____

____

____

11.7 CONCLUSION

The chapter states the different types of oceanic currents and the areas which are affected by them. There are beneficial acceptances of the currents as well as some of them create problems. The major different between tides and waves is clarified and various kinds of tides along with their origin theory are explained. All this is done to know about our oceans more deeply and know about the various phenomenons they possess.

11.8 SUMMARY

- Waves are actually the energy, not the water as such, which moves across the ocean surface.
- The general movement of a mass of oceanic water in a definite direction is called ocean current. Ocean currents are the most powerful of all the dynamics of oceanic waters because these drive oceanic waters for thousands of kilometers away.
- Ocean currents are divided on the basis of:
    i. Temperature: a) warm currents and b) cold currents
    ii. Velocity, dimension and direction: a) drifts, b) currents and c) streams
- The rotation of Earth is the cause of deflective force known as '*Corolis Force',* which deflects the general direction of the winds and that of the ocean currents.
- The periodical rise and fall of the sea level, once or twice a day, mainly due to the attraction of the sun and the moon, is called a tide.
- Together, the gravitational pull and the centrifugal force are responsible for creating the major tidal bulges on the earth.
- The time between the high tide and low tide, when the water level is falling, is called the *ebb.*

- The time between the low tide and high tide, when the tide is rising, is called the *flow* or *flood.*
- The equilibrium theory was put forward on the basis of Newton's law of Gravitation (1686), which states that each body in the universe attracts every other body with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between them measures from their centres of mass along a line joining these centres.
- In other words, the celestial bodies attract each other through their gravitational force in such a way that they remain in equilibrium.

11.9 GLOSSARY

Apogean Tides: The low tides caused at the time when the moon is at the farthest distance from the Earth, are called Apogean tides, which are 20%lower than the normal tides.

Centrifugal Force: Force that works outward on a body rotating about an axis

Currents: The movement or circulation of ocean water in definite direction with greater velocity is called current.

Drifts: The surface ocean currents moving forward under the influence of prevailing winds are called drifts.

Ebb: The fall of sea water and its movement away from the coast, i.e., towards the sea is called an ebb.

Gyres: The closed circulation pattern of current flows in the oceans is called gyre.

Ocean Currents: The general movement of mass of ocean water in a definite direction is called ocean current, which is more or less similar to water stream (river)) draining on the land surface of Earth.

Perigean Tide: The tide generated at the nearest position of the moon with the Earth is called Perigean tide, which is 15 to 20 % higher than the normal tides because the tidal force of the moon is most powerful.

Streams: Ocean streams involve movement of enormous volume of ocean water like big rivers of the continents, in a definite direction with greater velocity.

Surface Ocean Currents: The ocean currents of surface water of the oceans upto the depth of 100 meters are called surface ocean currents which involve only 10% of the total water mass of all the oceans.

11.9 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress I

Ans.1 Waves are actually the energy provided by wind, to travel in the oceans; whereas the periodical rise and fall of the sea level, once or twice a day, mainly due to the attraction of the sun and the moon, is called a tide.

Ans.2 It is an effect caused due to rotation of earth which deflects the direction of surface winds.

Ans.3 The eastward blowing westerlies along the 40ºN latitude are known as the 'roaring forties'.

Check Your Progress II

Ans.1 Gravitational and Centrifugal Force.

Ans.2 The fall of sea water and its movement away from the coast, i.e., towards the sea is called an ebb.

11.11 REFERENCES

Bascom, W., 1959, "Ocean Waves", *Scientific American*, August: 89-97

Bascom, W., 1980, *Waves and Beaches*, New York, Anchor/ Doubleday.

Defant, A.,1958, *Ebb and Flow: the Tides of Earth*, Air and Water, Michigan, University of Michigan.

Grolier *Encyclopedia of Knowledge*, Vol. 3 & 4, 1999.

Shopmmel, H., 1987, *AView of the Sea*, New Jersey, Princeton University Express.

Wiebe, P., 1982, "Rings of the Gulf Stream", *Scientific American*, March 60-79.

Shephard, F. P., 1969, *The Earth Beneath the Sea*, New York, Athneum.

11.12 SUGGESTED READINGS

Von Arx, W.S., 1962, *An Introduction to Physical Oceanography*, New York, Addison Wesley.

Kapion, D., 1989, *The Book of Waves*, Santa Barbara, Arpel Graphics.

Garrison, T., 1955, *Essentials of Oceanography*, New York, Wadsworth.

11.13 TERMINAL QUESTIONS

Q.1 Explain the factors responsible for the origin of currents.

Q.2 Discuss the different types of currents in the Atlantic Ocean.

Q.3 Give details about the different types of tides.

Q.4 Evaluate any one theory, of your choice,based on the origin of tides.

UNIT 12: OCEAN DEPOSITS AND CORALS REEFS

12.1 OBJECTIVES

12.2 INTRODUCTION

12.3 MARINE DEPOSITS

12.4 SOURCES AND TYPES OF OCEAN DEPOSITS

- **12.4.1 Terrigenous Deposits**
- **12.4.2 Volcanic Matter and Deposits**
- **12.4.3 Biotic Matter and Deposits**
- **12.4.4 Abiotic Matter and Deposits**

12.5 CLASSIFICATION OF OCEAN DEPOSITS

- **12.5.1 Classification Based on Location**
- **12.5.2 Classification Based on Depth**
- **12.5.3 General Classification**
- **12.5.4 Classification Based on Origin of Sediments**

12.6 DISTRIBUTION OF OCEAN DEPOSITS

12.7 CORAL REEFS: ORIGIN OF CORAL REEFS, MEANING

- **12.7.1 Origin of Coral Reefs**

12.8 CONDITIONS FOR THE GROWTH OF CORAL POLYPS

12.9 TYPES OF CORAL REEFS

- **12.9.1 Fringing Reefs**
- **12.9.2 Barrier Reefs**
- **12.9.3 Atolls**

12.10 CORAL BLEACHING

12.11CONCLUSION

12.12 SUMMARY

12.13 GLOSSARY

12.14 ANSWER TO CHECK YOUR PROGRESS

12.15 REFERENCES

12.16 SUGGESTED READINGS

12.17 TERMINAL QUESTIONS

12.1 OBJECTIVES

After studying this chapter, you should be able:

- To know about the physiography of the Oceans
- To know the physical processes which are involved into making an entire distinct marine world
- To know about different types of marine deposits
- To know their importance and their classification along with distribution
- To know about coral reefs, origin and types
- To understand Corals' importance in our environment and how they are being harmed.

12.2 INTRODUCTION

The Earth is majorly divided into continents and oceans. The landmasses turn out to be a major living habitat whereas; the oceans are the living habitat of only the aquatic group of worldwide plants and animals. However, the oceans provide a single different world in itself. The physiography and biological phenomenon of the oceans is not at all lesser than that of the terrestrial ecosystem. Here we will learn today the different types of sediments and depositional factors which make this thing happen.

12.3 MARINE DEPOSITS

The study of marine deposits includes the consideration of types of sediments, their sources, methods of their transportation, horizontal distribution, lithological successions or vertical variation in their distribution and composition, etc. The unconsolidated sediments, derived from various sources deposited at the sea floors are included in ocean deposits. Excepting a few areas of exposed rocks ad coral reefs, the ocean is mantled with sediments. The sediments worn from landmasses are deposited in the oceans; here they accumulate in large thickness together with their materials such as remains of plants and animals (fossils) that either lives on the sea floor in or on the surface of water.

12.4 SOURCES AND TYPES OF OCEAN DEPOSITS

The sediments deposited in the oceans and the seas are derived from four major sources viz. 1) Terrigenous sources, 2) Volcanic eruptions, 3) Marine plants and animals and 4) Abiotic matters. The sediments derived from these sources are of many types and hence, the ocean bottom deposits are classified into the following categories on the basis of sources.

12.4.1 Terrigenous Deposits

Terrigenous deposits are those derived from the erosion of rocks on land; that is, they are derived from *terrestrial* (as opposed to marine) environments. Consisting of sand, mud, and silt carried to sea by rivers, their composition is usually related to their source rocks; deposition of these sediments is largely limited to the shelf. Sources of terrigenous sediments include volcanoes, weathering of rocks, wind-blown dust, grinding by glaciers, and sediment carried by icebergs.

Terrigenous deposits are responsible for a significant amount of the salt in today's oceans. Over time rivers continue to carry minerals to the ocean but when water evaporates, it leaves the minerals behind. Since chlorine and sodium are not consumed by biological processes, these two elements constitute the greatest portion of dissolved minerals. There is much variation in the size of shape of these materials, therefore, there is marked gradation of these materials when they are deposited in the oceans, i.e. boulders, cobbles and pebbles; the larger and coarser sediments are deposited near the coast and the smaller and finer sediments are deposited away from the coast. Very fine sediments are kept in suspension in the offshore regions. On the basis of size, composition and chemical characteristics terrigenous deposits are divided into gravel, sands and silt, clay and muds.

- **Gravels: -** The diameter of gravels ranges from 2mm to 256mm. There is a marked gradation in the size of gravels. The sub-types of gravels on the basis of diameter of particles are boulders (256mm), cobbles (64mm), pebbles (4mm), granules (2mm), etc. These sediments get deposited near the shore on the continental shelf, due to their large size. However, they are further reduced in size due to further disintegration activities by the sea waves. The gravels are brought to the sea by the rivers.

- **Sands: -** The sediments varying in diameter from 1mm to 1/16mm are termed as sands. On the basis of size of grains sands are classified as: (i) very coarse sands (1mm), (ii) coarse sands (0.5mm), (iii) medium sands (0.25mm), (iv) fine sands (0.125mm), and (v) very fine sands (0.0625mm). The disintegration of continental rock fragments into fine sediments produces sands which are deposited in the oceans by the rivers, surface wash and winds. There is a marked gradation of sand deposits in the oceans i.e. coarser sands are deposited close to the coast while fine sands are deposited away from the coast.

- **Silt, Clay and Mud: -** The finer sediments ranging in diameter from 1/32 mm to 1/8192 mm are grouped under the category silt, clay and mud. Silt comes under 1/32 mm to 1/256 mm whereas clay under 588/8/87/256 to 1/8192 mm. Mud is much finer than clay as clay is a cementing element. Clay and mud are deposited in calm seawater. Generally, these deposits are found at the depth of 100 to1000 fathoms (600 to 6000 feet). Murray has divided mud into three types on the basis of colour:

  i. **Blue mud** includes the materials derived through the denudation of rocks rich in iron sulphide and organic elements. These are generally found at the greater depths of the continental shelves. The original colour of blue mud s bluish black and it contains 35% of calcium carbonate. Blue mud predominates in the Atlantic Ocean, Mediterranean Sea, Arctic Sea and enclosed seas.

ii. **Red mud** sediments are derived through the rocks rich in iron oxides (FeO) form red mud. The reddish colour is mainly due to the dominance of iron content. It contains 32% of calcium carbonate. The deposit of red mud is confined mostly to the Yellow Sea, Brazillian Coast and the floors of Atlantic Ocean.

iii. **Green mud** is formed due to the chemical weathering wherein the colour of blue mud is changed to green mud due to the reaction of seawater. It contains green silicates of potassium and glauconite (form of iron) which constitutes 7-8% of total mineral composition whereas calcium carbonates ranges from 0- 56%. The deposits of green mud are found along the Atlantic and Pacific coasts of N. America, off the coasts of Japan, Australia and Africa. These are generally found at the depths of 100 to 900 fathoms (600 to 5,400 ft).

TABLE 12.1

Particle Size and Settling Rate in Sediment

Type of Particle	Diameter	Settling Velocity	Time to Settle 4km (2.5 ml)
Boulder	>256 mm (10 in.)	-	-
Cobble	64-256 mm (>2.5 in.)	-	-
Pebble	4-64 mm (1/6-2.5 in.)	-	-
Granule	2-4 mm (1/12-1/6 in.)	-	-
Sand	0.062-2 mm	2.5 cm/sec (1 in./sec)	1.8 days
Silt	0.004-0.062 mm	0.025 cm/sec (1/100 in./sec)	6 months
Clay	<0.004 mm	0.00025 cm/sec	50 years*

* Though the theoretical settling time for individual clay particle is very long, clay particles in the ocean can interact chemically with sea water, clump together, and fall at a faster rate.

Source: *Garrison (1995: 78)*

12.4.2 Volcanic Matter and Deposits

Volcanic matter deposited in the marine environment is derived from two sources.

i. Volcanic eruptions on the land-the volcanic materials through violent central eruptions become very fine due tocollision among themselves and due to further denudation. Fine volcanic materials nearer to the coastal lands are blown by the wind and are carried to the oceans while volcanic materials in istant6 laces are brought by the rivers via overland flow, rain wash, rill and small rivulets.

ii. Volcanic eruptions in the oceans and the seas- in such cases volcanic materials are directly deposited. Volcanic materials resemble blue mud and are grey and black in colour.

12.4.3 Biotic Matters and Deposits

The source of organic materials is sea itself. They include skeletons of marine organisms and plant remains. These materials are grouped in two categories:

i. Neritic matters deposited mainly on the continental shelves and are generally covered by terrigenous materials. Shells of mollusks and their fragments, skeletons of radiolarian and spicules of sponges, calcareous and siliceous plant remains.
ii. Pelagic matters are the deposits derived from algae and are mostly in the form of liquid mud, generally known as ooze. These oozes of pelagic materials are divided into two categories on the basis of lime and silica contents in them.

- **Calcareous oozes:** contain lime contents in abundance and are seldom found at greater depths because of their high degree of solubility. They are generally found at the depths of the sea floor ranging from 1000 fathoms to 2000 fathoms, i.e., 6000-12000 ft. On the basis of principal organisms, calcareous oozes are further divided into two sub-types:
- **Pteropod Ooze:** They are generally conical in shape with half an inch of average diameter. These cones are formed by the floating pteropod molluscs having thin shells. It is found in the tropical seas and oceans at the depths of 300-1000 fathoms. It decreases with greater depths and practically disappears beyond 2000-fathom bar. It contains 80% calcium carbonate and are found mostly in the region of corals. Pacific Ocean, Canary Island, Mediterranean submarine ridge, Indian Ocean, etc are some main locations of pteropod ooze.
- **Globigerina Ooze:** Though this ooze is formed from the shells of a variety of foraminifera but most of such oozes are formed of, germs called globigerina. Its chemical composition is somewhat 64.46% of calcium, 1.64% of silica and 3.33% of minerals. Found mainly at the depths of 2000-4000 fathoms, the deposit dries up and becomes dirty white powder, giving the ooze a milky white colour. Besides having a milky white colour, it is also blue, grey, yellow and green in colour. Globigerina is found mostly in tropical and temperate zones of Atlantic Ocean, eastern and western continental shelves of the Indian Ocean and eastern Pacific Ocean.
- **Siliceous Ooze:** is formed when the silica is obtained in abundance from a group of protozoa and radiolarians and benthic animals mainly sponges. The ooze does not dissolve as compared to calcareous ooze because of less calcium carbonate and dominance of silica. Due to this, these oozes are found in both warm and cold water at greater depths. This group is also divided into two sub-types on the basis of dominance of a particular organism:
- **Radiolarian ooze:** This ooze is formed by the shells of radiolarian and foraminifera. It changes to dirty grey powder when dried. Silica is predominant but calcium carbonate is also present between 5-2%. Lime content decreases with increased depths and absolutely disappears at greater depths. The ooze is found up to 2000-5000 fathoms covering the largest areas in the Pacific Ocean. The ooze is the home of tropical oceans and seas.

- **Diatom ooze:** The diatom ooze contains the shells of microscopic plants having silica in abundance. It also has some clayey content whereas calcium content varies from 3-30%. The diatom ooze is found mainly at greater depths in high latitudes. It is blue near the land and the colour changes yellow or cream away from the land and it becomes a coherent white powder when dried. The areas of this deposit include the zone around Antarctica and the belt from Alaska to Japan in the N. Pacific at depth of 600-2000 fathoms.

12.4.4 Abiotic Matters and Deposits

Majority of inorganic elements are the precipitates which fall from the above. They fall both on the ocean and on the ground. Some of these elements get transported from the land to the oceans by various agencies. The inorganic precipitates include dolomite, amorphous silica, iron, manganese oxide, phosphates, barite, etc. Besides gluconite, phosphorite, feldspar, phillipsite and clay minerals are also found. The organic and inorganic elements are so mixed together due to the chemical processes that it becomes very difficult to isolate them from each other.

Red Clay, previously considered to be of organic origin, is the most significant inorganic matter and very important member of the pelagic deposits. It covers the largest area of the deep sea deposits. Red clay is widely distributed to the intense depths in the oceans. Silicates of alumina and and oxides of iron are the chief constituents of red clay. Besides, calcium, siliceous organisms and a few areas also present. It also contains decomposed volcanic material. It is pointed out that red lay contains more radioactive substances than any other marine deposit. Its texture is soft, plastic and greasy and becomes reddish brown in colour when dried. Its chief locations include the zone between 40ºN and 40ºS in the Atlantic Ocean, eastern part of the Indian Ocean and the North Pacific Ocean covering 129 million km^2.

12.5 CLASSIFICATION OF OCEAN DEPOSITS

Ocean deposits are mainly classified on different bases:

1. On the basis of location
2. On the basis of depth
3. On the basis of origin of sediments

12.5.1 Classification based on location

This classification is based on typical locations of particular marine sediment. Though several scientists have attempted to classify ocean deposits on the basis of their location, the classification of Sir John Murray and J. T. Jenkins are widely acclaimed.

Generally ocean deposits are locationally classified into the following two categories:

- Shelf deposits

- Pelagic deposits

Shelf deposits include the deposition of marine sediments of the variable origin on the floors of continental shelve, while pelagic deposits consists of sedimentation of fine particles on the floors of deep sea plains.

Classification of Murray: Sir John Murray has classified the ocean deposits into to broad categories viz. (a) terrigenous deposits, and (b) pelagic deposits.

S. No.	Terrigenous Deposits	Pelagic Deposits
1.	They are found mainly on the continental shelves and slopes.	They are predominant on the deep sea floor
2.	They are composed of coarser materials and are derived from the continents through weathering and erosional processes and are transported to the oceans by various agencies.	These deposits consist of the materials formed of skeletons and shells of marine organisms and a few inorganic substances.
3.	They may have blue, yellow, grey or red colour.	They are generally blue, grey or red in colour.

Classification of Jenkins: Jenkins has divided marine deposits into three groups viz (a) deep sea deposits, (b) shallow water deposits, and (c) littoral deposits.

12.5.2 Classification based on Depth

1. **Deep Sea Deposits** (below 100 fathoms)
    a) Pelagic deposits
    - Red clay
    - Radiolarian ooze
    - Diatom ooze
    - Globigernia ooze
    - Pteropod ooze

    b) Terrigenous deposits
    - Blue mud
    - Red mud
    - Green mud
    - Coral mud
    - Volcanic mud
2. **Shallow Sea Deposits** (between low tide water and 100 fathoms)
    a) Gravels
    b) Sands
    c) Mud
3. **Littoral Deposits** (between high and low tide water)
    a) Gravels

b) Sands
c) Mud

12.5.3 General Classification

1. **Terrigenous Deposits**
    - **a)** Littoral Deposits
    - **b)** Shallow Water Deposits
    - **c)** Terrigenous Mud
2. **Neritic Deposits**
    - **a)** Shallow Water Neritic Deposits
    - **b)** Deep Seawater Neritic Deposits
    - **c)** Pelagic Deposits
    - **d)** Radiolarian Ooze
    - **e)** Globigerina Ooze
    - **f)** Pteropod Ooze

12.5.4 Classification based on Origin of Sediments

1. **Littoral Deposits** (derived from land)
    - **a)** Shore Deposits
    - **b)** Shelf Deposits

2. **Hemi pelagic Deposits** (partly from land and partly from marine origin)
    - **a)** Green Mud
    - **b)** Volcanic Mud
    - **c)** Coral Mud

3. **Eupelagic Deposits** (of marine and cosmic origin)
    - **a)** Red clay

12.6 DISTRIBUTION OF OCEAN DEPOSITS

The sediments of continental margin are generally different in quantity, character and composition from these on the deeper basin floors. Continental shelf sediments-called *neritic (nerites*=of the coast*)*-consist primarily of the terrigenous materials. Deep-ocean floors are covered by finer sediment than those of the continental margins, and a greater proportion of deep-sea sediments are of biogenous of origin. Sediments of the slope, rise and deep-ocean floor that originate in the ocean are called *pelagic* sediments *(Pelagius*=of the sea*)*. The distribution and average thickness of the marine sediments in each of the oceanic region are given in Table 12.2. It may be seen from the Table 12.2 that 41% of the total volume of marine sediments lie on the continental slope, followed by continental rise 31% and continental shelves 15%. The average thickness of marine sediments is maximum on continental slope being 9 km, followed by continental rise 8 km and continental shelves 2.5

km. It may also be seen from the data that 72% of all marine sediment is associated with continental slopes and continental rises.

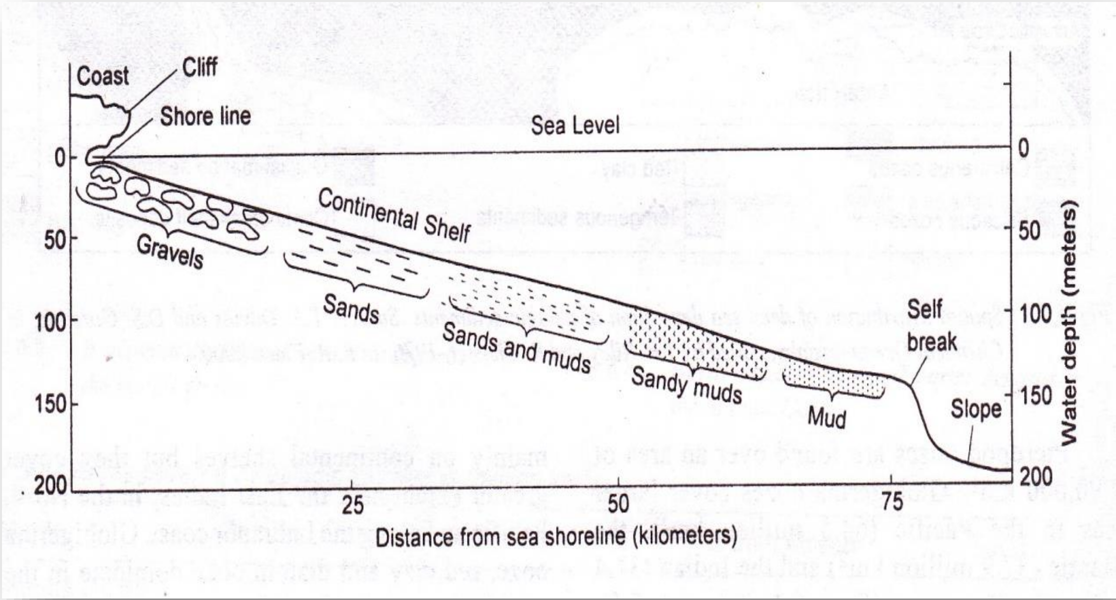


Figure 12.1

Sequence of Deposition of Marine Sediments on Continental Shelves

Distribution of ocean deposits may be attempted in various ways:

- Vertical distribution of ocean deposits.
- Regional distribution or ocean-wise distribution.
- Marine province-wide distribution, such as ocean deposits on continental shelves, and on deep sea plains.
- Sediment-wise distribution as such pelagic and terrigenous deposits.

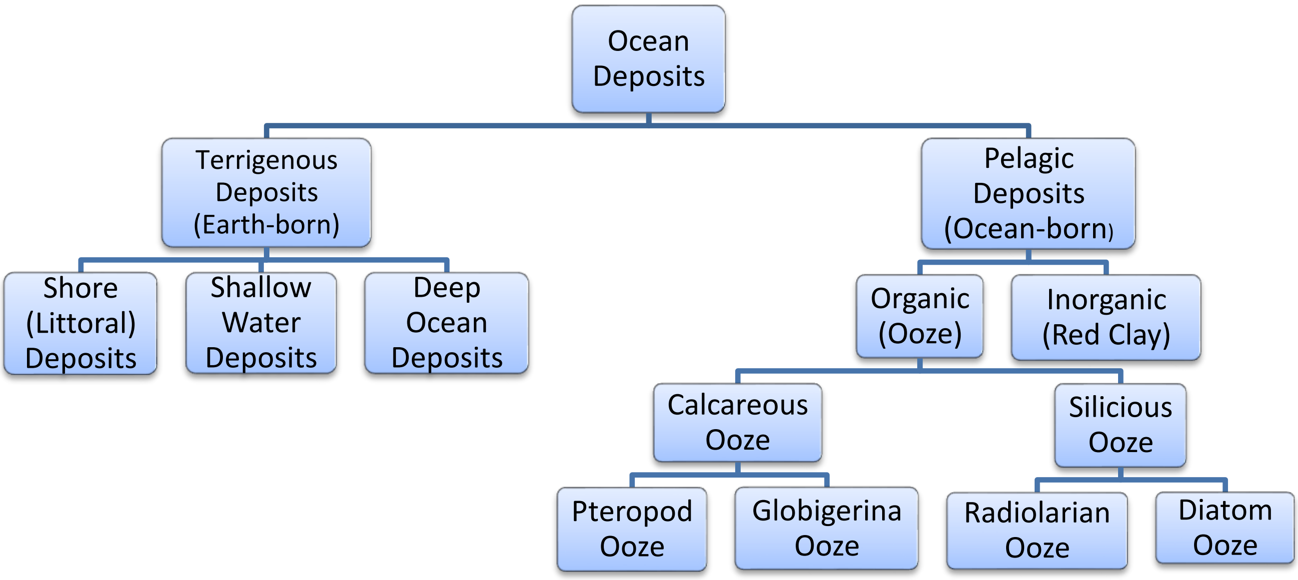
TABLE 12.2

Distribution and Average Thickness of Marine Sediments

Region	Percent of Ocean Area	Percent of Total Volume of Marine Sediments	Average Thickness
Continental Shelves	9%	15%	2.5 km (1.6 miles)
Continental Slopes	6%	41%	9 km (5.6 miles)
Continental Rises	6%	31%	8 km (5 miles)
Deep-ocean Floors	78%	13%	0.6 km (0.4 miles)

Source: Emery in Kennett (1982), Weihaupt (1979), and Sverdrup, Johnson and Fleming (1942)

12.6.1 Sediment-wise Distribution



---

1. Terrigenous Deposits

As stated earlier, they are basically the material which is “of the coast”, mainly consisting of gravel, sand, silt, clay and mud, in sequence from the coast. There is a marked gradation of these sediments when they are deposited in the oceans, however, the ocean current and waves often disturbs the gradation process and sequence of the sediments. These material deposits are mainly gravels, sand, volcanic materials, etc which are derived through the erosion and weathering of the continental rocks. They are basically divided into three categories:

- Littoral Deposits
- Shallow Water Deposits
- Deep Water Deposits

The explanation of these deposits is already given in the unit 12.5.

2. Pelagic Deposits

The greater part of Deep Ocean is covered by pelagic sediments. The pelagic deposits include:

i. All the very fine grained material of lithogenous origin carried by suspension in the air or ocean water for long distances.

ii. The organic remains that settle slowly to the ocean floor.

iii. The hydrogenous minerals such as phillipsite and montomorillonite, an

iv. The fine grained meteoric dust found in the sediments of the deep ocean basins.

The pelagic deposits have been classified into organic and inorganic deposits as follows:

Inorganic Deposits

Less than 30% organic material is present in these deposits. These deposits are known as red clay. The iron oxide present displays a brown or somewhat red colour to it. Red clay constitutes 3.1% of the total oceanic deposits. It is distributed over an area of 129 million km^2 of all the oceans

Organic Deposits

These deposits contain more than 30% organic matter. The common term used for these deposits is 'Ooze'. Oozes are named after the dominant remnant organisms contributing their remains to the deep-sea. Oozes are small, single-celled, drifting plant-like organisms and the single celled organism that feed on them. The hard shell and skeletal remains of these creatures are of relatively dense glass-like silica or calcium carbonate (limey) substance. When these organisms die, their shells settle slowly toward the bottom, mingle with fine grained terrigenous silts and clays, and accumulate as ooze. These deposits are classified on the basis of their chemical composition, and also on the basis of organism which predominates them. Hence the oozes have been classified as calcareous-pteropod and globigerina and siliceous ooze-radiolarian and diatom ooze.

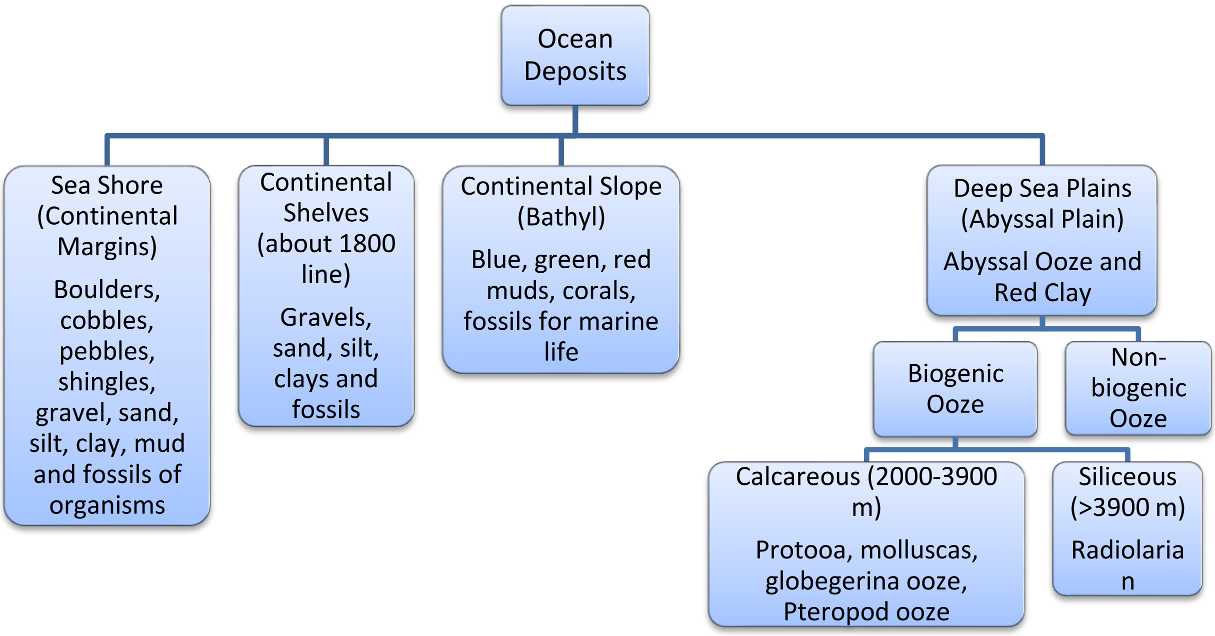
The pelagic oozes cover about 75.5% of the ocean areas. Pteropod, diatom and radiolarian oozes cover 0.4, 6.4 and 3.4 percent areas of all the oceanic deposits respectively.

Pteropod oozes are found over an area of 12, 90,000 km^2. Globegerina oozes cover larger areas in the Pacific (64.5 million km^2), the Atlantic (37.9 milion km^2) and the Indian 31.4 million km^2) oceans, shown in Figs. 12.2 A and B.Radiolarian oozes are found over an area of 5.16 million km^2 in the Pacific and Indian oceans. Diatom oozes are spread over an area of 1,03,000 km^2 in the North Pacific Ocean and 27.6 million km^2 in the southern oceans.

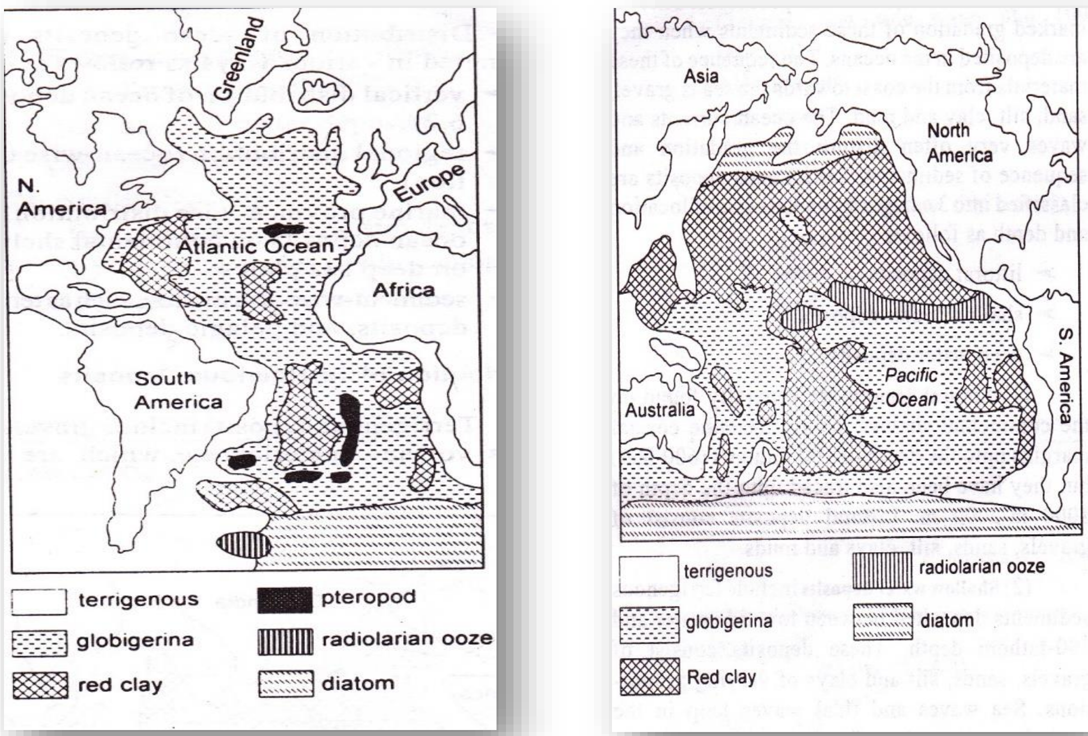
It is apparent from the Figs. 12.2, 12.3, 12.4 that terrigenous deposits are found along the coasts mainly on the continental shelves but they cover greater extent near the East Indies, in the North Pacific and along the Labrador Coast. Globigerina ooze, red clay and diatom ooze dominates in the western, eastern and southern parts of the Indian Ocean whereas it contains maximum areal extent in the Pacific Ocean.

12.6.2 Marine Province-wise Distribution

1. **Sediments of the Continental Margins/Shelves**
   Sediment of the continental margins are generally found between the high and the low water spring tide lines. The bulk of these sediments is eroded and carried to streams, where it is transported to the ocean. These are generally confined to continental shelves up to a depth of about 200 meters. These deposits on the shelves consist of boulders, cobbles, pebbles, gravel, sand, clays, mud and fossils.



Marine Province-wise Distribution



A **B**

Figure 12.2
Horizontal Distribution of Marine Deposits in (A): Atlantic Ocean and (B): Pacific Ocean

The rate of sediment deposition on the continental shelves is variable, but it is almost always greater than the rate of sediment deposition in the deep ocean. Near the mouth of large rivers, one metre (about 3 feet) of sediment may accumulate every 1000 years.

In addition to terrigenous material, the continental margins almost always contain biogenous or organic sediments. Organic productivity in coastal water is often quite high, and the skeletal remains of creatures living on the bottom or in the water above mix with the terrigenous materials.

2. **Shallow Sea Deposits**
   The shallow Sea Deposits occur from the low water mark to about 180 metre line,i.e., about the edge of the continental shelf. These deposits consist mainly of gravel, sands, silt, clays, mud biogenous matter.

3. **Bathyl Deposits**
   The bathyl deposits occur on the continental slope. These sediments consist of blue, green and red muds, corals and fossils of marine organisms.

4. **Sediments of Deep-Ocean Basins**
   The abyssal deposits are found on the deep-sea plains and in the ocean deeps. They consist mainly of remain of the organism in the form of different types of oozes and red clays. Ooze is a fine sediment form at a greater height of 2000 meters depth and so in the abyssal zone and ocean deeps.

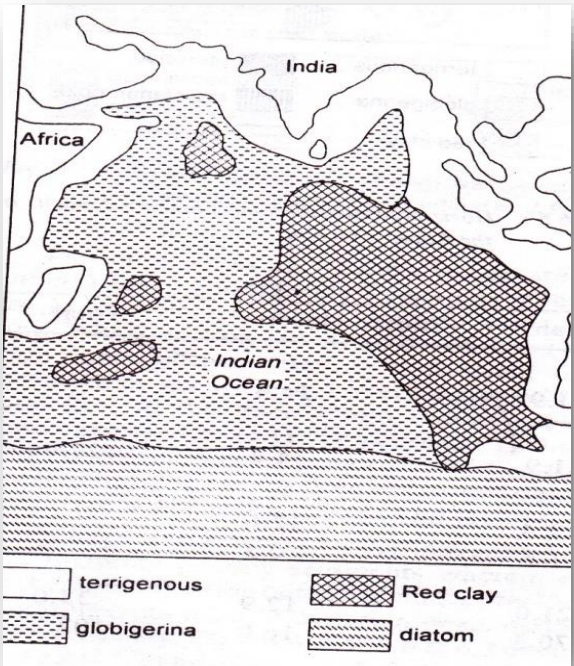


Figure 12.3
Horizontal Distribution of Marine Deposits in Indian Ocean

About 38% of deep-sea sediments are clays and terrigenous sediments. The finest terrigenous sediments are easily transported by wind and water currents. Microscopic water-borne particles are tiny bits of wind-borne dust and volcanic ash settle slowly deep ocean floor, forming fine brown, olive-coloured or reddish clays. Terrigenous sediment accumulation on the deep-ocean floor may be less than a millimeter every thousand years. However, pelagic sediments dominates the entire area of deep-ocean sediments. The percentages of these deposits have been shown in Table 12.3.

TABLE 12.3

Distribution of Deep-Sea Ocean Deposits (pelagic sediments) *(in percentage)*

Types of Sediments	Composition	Atlantic Ocean	Pacific Ocean	Indian Ocean	Whole Globe
Globigerina Ooze	Carbonate	65	36	54	47
Pteropod Ooze	Arbonate	2	0.1	-	0.5
Diatom Ooze	silica	7	10	20	12
Radiolarian Ooze	Silica	-	5	0.5	3
Red Clay	Aluminium silicate	26	49	25	38

Source: W.H. Berger, 1982

The Atlantic Ocean bottom is covered by sediments to an average thickness of about one km (3,300 feet), while the Pacific Ocean floor has an average sediment thickness of less than 0.5 km (1,650 feet). The difference occurs because the Atlantic Ocean is smaller in area and is fed by more large, sediment-laden rivers, and because in the Pacific Ocean many oceanic trenches trap sediments moving toward the basin centres. The composition ad thickness of pelagic sediments also vary with location, being thickest on the abyssal plains and thinnest (or absent) on the oceanic ridge.

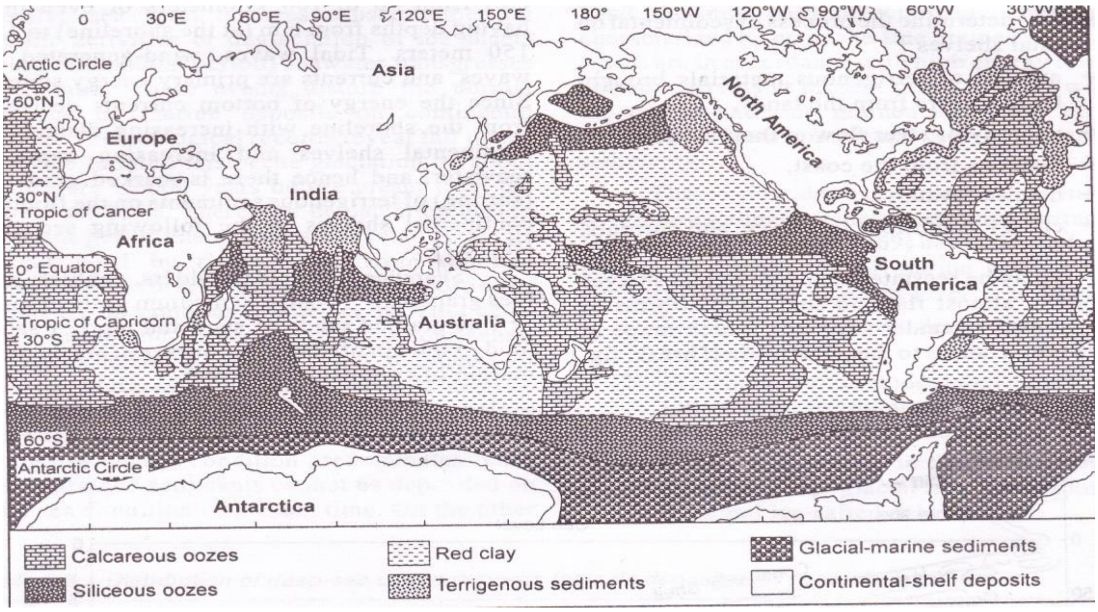


Figure 12.4
Spatial Distribution of Deep Sea Deposition of Pelagic Sediments

Check Your Progress I

Q.1 Distinguish between Terrigenous Deposits and Pelagic Deposits.

____
____
____
____
____
____

Q.2 Differentiate between Organic and Inorganic Deposits.

____
____
____
____
____
____

12.7 CORAL REEFS: ORIGIN OF CORAL REEFS, MEANING

Coral reefs are significant marine features. These are formed due to accumulation and compaction of skeleton of lime secreting organisms known as coral polyps. Coral polyp thrive in the tropical oceans confined between 25ºN-25ºS latitudes and live on lime. Numerous coral polyps live at a place, in groups in the form of a colony and form calcareous shells around them. Coral reefs are formed due to formation of one shell upon another shell along submarine platforms at suitable depth. Since coral polyps cannot survive above water level and hence coral reefs are always found either upon the sea level or below it. They are generally attached to submarine platforms or islands submerged under seawater. It may be mentioned that coral reefs are more diverse than tropical rainforests because the coral reefs have about 1,000,000 species of which onlyn10% have been studied. This is why these are called **rainforests of the oceans.**

12.7.1Origin of Coral Reefs

Several theories and hypothesis have propounded about the origin of coral reefs however not a single theory has been considered adequate to account for explaining the varying conditions under which the reefs have been formed. Some of the important theories have been explained under:

1. The Subsidence Theory of Charles Darwin

In 1842, Charles Darwin proposed a theory to explain the origin of atolls. The theory is based on the relative subsidence of a volcanic island. Darwin suggested that coral reefs are originally established as fringing reefs along the shores of new volcanic islands. As the island gradually subsides the coral reef grows upward along its outer margins. The rate of upward growth essentially keeps the pace with subsidence. With the continued subsidence the area of the island becomes smaller, and the reef becomes a barrier reef. Ultimately the island is completely submerged and the upward growth of the reef forms an atoll. Erosional debris from the atoll fills the enclosed area of the atoll to form a shallow lagoon.

Darwin's subsidence theory on the whole finds confirmation from the recent seismic studies and drilling in the Pacific Atolls. The conditions in which corals grow have been told by Darwin which you will read in Unit 12.8.

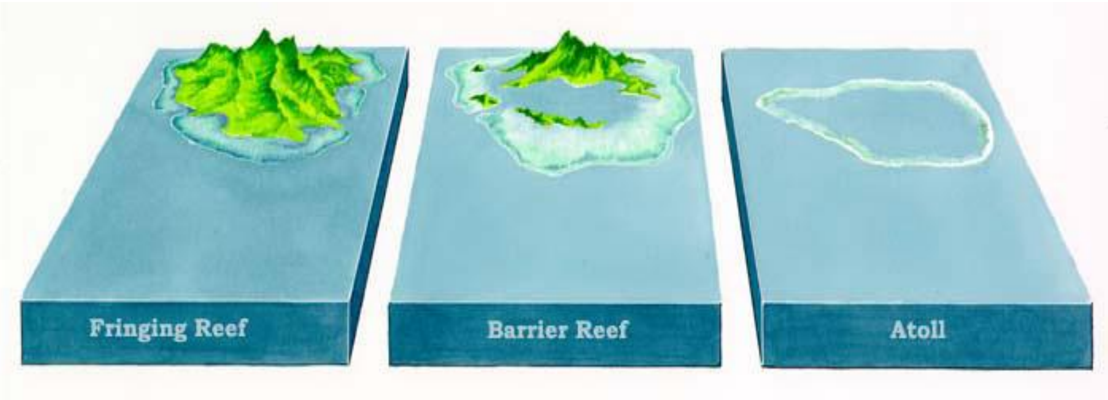


Figure 12.5
Reef Formation: Darwin Subsidence Theory

2. The Glacial Control Theory of R. A. Daly

This theory was UT forward by R. A. Daly. In his opinion atolls are the results of the influence of the changing sea levels of the Pleistocene period. In other words, the submergence was entirely post-glacial owning to the rise of the sea level which resulted from the melting of Pleistocene ice sheets. The main points of Daly's theory are:

- **i.** The depth of the lagoons back of the atolls and barrier reefs is remarkably uniform and rarely exceeds 80 to 90 meters, which implies a cause worldwide in nature.
- **ii.** Glacial conditions would result in a worldwide chilling of the seas and increased turbidity of the oceanic waters as a result of the churning up of muds formerly below the reach of waves and thus would kill off reef-building organisms.
- **iii.** The destruction of these organisms permitted marine abrasions to attack the islands and banks upon which they had grown and produce at a lowered sea level a great number of truncated islands or benches around islands.
- **iv.** In the interglacial phase, the sea level rose. The relatively warmer and cleared waters favoured the re-establishment of corals and associated organisms upon submerged platforms which resulted in the development of an atoll or barrier reef. In such a situation, corals establish themselves around the periphery of a platform and gradually drew upward and forward as sea level rose, until their bases were ultimately submerged about 250 to 300 feet.

Daly's theory about the origin of the reefs was criticized by the geologists. Some of the main criticisms are:

a. Many of the platforms are too broad to have been cut by marine abrasion during the glacial age.

b. Lagoon depths are hardly as uniform a have been claimed.

c. It is doubtful if the low-level marine abrasions could form the low-level platforms.

d. It is difficult to suppose that the low temperatures could be extended in the lower latitudes from the glaciated areas.

12.8 CONDITIONS FOR THE GROWTH OF CORAL POLYPS

The following conditions are required for the growth and survival of coral polyps:

- Corals are temperature-sensitive. They cannot thrive in either cold or very warm sea temperatures. Corals can grow in a temperature range of 20ºC-30ºC and hence are found mainly in tropical oceans and seas.
- Corals do not live in deeper waters i.e. not more than 200-250 feet (60-77m) below sea level because they die in waters deeper than 77m due to lack of sufficient amount of sunlight and oxygen which is very much required for the growth of coral polyps.
- High turbidity of seawater i.e. high concentration of suspended materials, both organic and inorganic, does not allow growth of corals because their mouths are clogged by muddy water and hence corals cannot get food and ultimately die of starvation.
- It may be pointed out that though coral polyps require sediment-free water but fresh water is also injurious for the growth of corals. This is why corals avoid coastal lands and live away from the areas of river mouth.
- High salinity of water is injurious for coral growth because such waters contain very less amount of calcium carbonate whereas lime is an important food for coral polyps. The oceanic salinity ranging between 27% and 30% is most ideal for the growth and development of coral polyps.
- Ocean currents and waves are favourable for corals because they bring necessary food supply for the polyps. It is obvious that corals grow in open seas and oceans but they die in lagoons and small enclosed sea because of lack of supply of food. Currents and waves also determine the shapes of coral reefs.
- There should be extensive submarine platforms for the formation of the colonies by the coral polyps. Such platform should not be more than 91 meters below the sea level.
- There should be pollution free coastal water for the survival and growth of corals, because lack of them causes fatal diseases to the corals. Recent studies have shown that 58% of the world's coral reefs are threatened by human activities.
- Coral bleaching caused by the sudden increase in the temperature of seawater due to the anthropogenic sources such as emission of greenhouse gases and resultant global warming, results in mass deaths of coral polyps.

12.9 TYPES OF CORAL REEFS

Generally the tropical reef structures are classified into the following three types:

12.9.1 Fringing Reefs

Generally ranging from 0.5 to 1 km wide, these are attached to such landmasses as the shores of volcanic islands. The corals grow seaward, towards their food supply. Beyond its seaward margin the ocean water deepens rapidly. The fringing reefs are generally not very wide, and where a river enters the sea from the land, they become broken and discontinuous. Such reefs are common along many tropical coasts.

Fringing reefs form in the areas of low rainfall run-of primarily on the downward idea of tropical islands. The greatest concentration of living material will be at the reefs' seaward edge, where planktons and clear water of normal salinity are dependably available. Most new islands available anywhere in the tropics have fringing reefs as their first reef form. Permanent fringing reefs are common in Hawaiin Islands and in similar areas near the boundaries of the tropics.

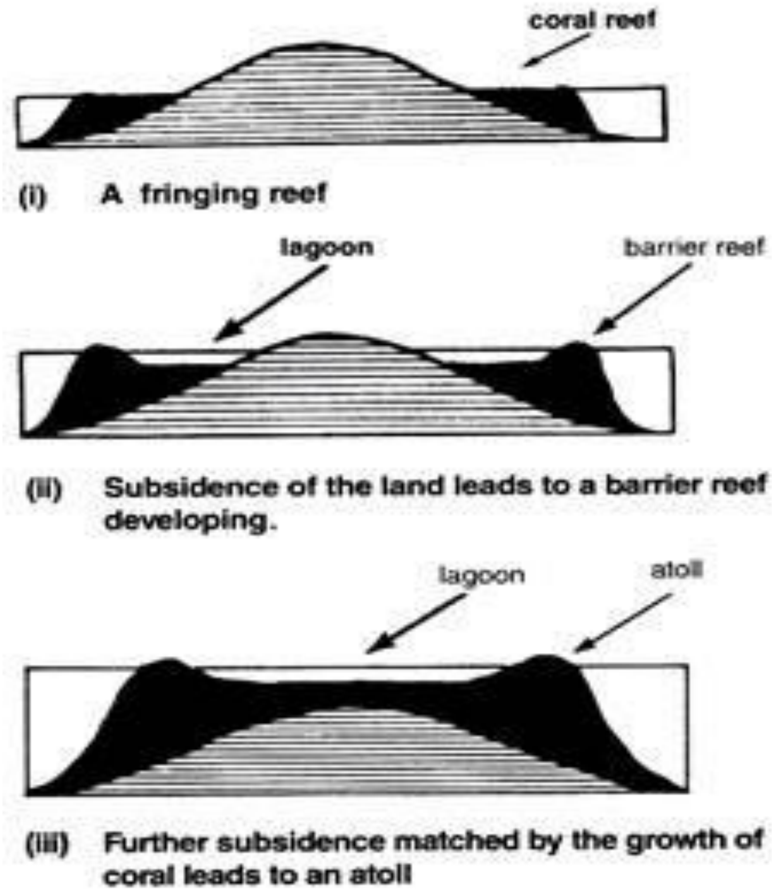


Figure 12.6
Types of Reefs

12.9.2 Barrier Reefs

This is an elongated accumulation of corals lying at low-tide level parallel to the coast, but separated from it by a wide and deep lagoon or strait. The deep lagoon does not permit coral growth. The lagoon may vary in width from a narrow channel to 20 km wide.

They tend to occur at lower islands or in lines parallel to continental shores. The outer edge- the barrier- is raised because the seaward part of the reef is supplied with more food and is able to grow more rapidly than the shore side. The lagoon may be from a few meters deep to 60 m (200 feet) deep, and it may separate the barrier from the shore only by tens of meters or by 300 km. In the case of north-eastern Australia's *Great Barrier Reef,* coral grows slowly within the lagoon because fewer nutrients are available and because sediments and fresh water runoff from the shore.

12.9.3 Atoll

A ring of narrow growing corals of horseshoe shape and crowded with palm trees is called an atoll. It is generally found around an island which has subsided or in elliptical form on a submarine platform. There is a lagoon in the mid of the coral ring. The depth of the lagoon ranges between 40 to 70 fathoms (240-420 feet). Atolls are divided into three types:

a. **True Atolls** characterized by circular reef enclosing a shallow lagoon but without island.
b. **Island Atolls** having an island n the central part of the lagoon enclosed by a circular reef.
c. **Coral Island or Atoll Island** does not have an island in the beginning but later on island is formed due to erosion and deposition by marine waves.

Atolls are found near Antilles Sea, Red Sea, China Sea, Australian Sea, and Indonesian Sea. *Funfutti Atoll of Ellice Island* is a famous atoll. The enclosed lagoon is 12.8 km wide and 19.2 km long.

12.10 CORAL BLEACHING

Coral bleaching refers to the lack of algae from the corals resulting into the white colour which is indicative of death of corals. Global warming has been reported to be a major factor of coral bleaching. The coral bleaching during 1997-98 has been recorded as the most catastrophic event as it accounted for large scale death of corals in the tropical oceans of 60 countries and island nations. Though coral bleaching was observed y Alfred Mayer as back as 1919 but it was the year 1998 when large scale coral bleaching accounting 70% death of corals off the coasts of Kenya, Maldives, Andaman's and Lakshadweep Islands in the Indian Ocean and 75% death in the Seychelles Marine Park System and the Mafia Marine Plant of Tanzania was reported by Clive Wikinson of the Global Coral Reef Monitoring Network

(GCRMN) of Townsville (Australia). He indentified four overlapping levels of coral bleaching:

i. **Catastrophic Bleaching** adversely affecting 95% of shallow water corals in Bahrain, the Maldives, Sri Lanka, Singapore and Tanzania.
ii. **Severe Bleaching** accounting for 50-70% death of corals in Kenya, Seychelles, Japan, Thailand and Vietnam.
iii. **Moderate Bleaching** resulting into 20-50% coral morality but with quick recovery.
iv. **Insignificant Bleaching** or no bleaching.

The cases of large scale coral bleaching have been reported in the Andaman and Nicobar Islands of India. It may be pointed out that the areal coverage of coral reefs in India has been estimated to be 18,000 km^2. The corals have mainly colonized around the Lakshadweep and the Andaman and Nicobar Islands. Besides, small patches of coral reefs are found in the Gulf of Kutch and Gulf of Mannar. According to the study conducted by the Society of Andaman and Nicobar Ecology (SANE) based at Port Blair there has been mass coral bleaching (in 1998) around the Andaman reefs and 30-70% bleaching round the Nicobar reefs. The bleaching is related to 2ºC rise in temperature from the normal temperature in the Andaman Sea in 997-1998. According to the study by National Institute of Oceanography (NIO) based at Goa, the coral reefs of the Kavaratti and Kadamat Islands in Lakshadweep have suffered great damage from coral bleaching due to the bacterial diseases and warmer sea temperatures. The corals in the Gulf of Kutch have been bleached due to siltation.

1. Most of the scientists have acknowledged global warming as the most significant factor of coral bleaching causing large scale coral deaths. According to the Global Coral Reef Alliance 'every known mass bleaching occurred when temperatures were just 1ºC higher than normal during the warmest summer months' (down to Earth, 1999).
2. El Nino phenomenon has also been related to coral bleaching. It may be mentioned that the warmest year of 1998 was also associated with the strongest El Nino phenomenon causing further warming of the Pacific Ocean waters. It may be pointed out that El Nino accounts for coral bleaching in certain localities only but the phenomenal increase in coral bleaching in the years 1983, 1987 and 1988 was also associated with strong El Nino weather phenomenon.
3. The outbreaks of coral diseases (black band diseases (black band disease, coral plague, aspergillosis and white band disease) cause coral death.
4. Local factors like increase in siltation of sea waters due to mass flux o sediments and nutrients brought by the streams from the erosion of high islands consequent upon land use changes; pollution of sea waters caused by industrial effluents, urban sewage and oil slicks; destructive fishing practices, over-fishing; clearing of marine forests around coral reefs; filling of wetlands (marine forests and wetlands trap sediments and filter pollutants and thus save corals from degradation); mining of coral rocks for

building materials; collection of rare coral species, etc. are also responsible for coral degradation at local and regional level.

It may be mentioned that corals also have recovery characteristics. In the past inspite of large scale climatic changes since Mesozoic Era (200 million years ago) like Ice Age (Pleistocene Ice Age), fluctuations in solar activities and several environmental stresses corals have managed to survive and recover. 'Reefs will not become extinct in the long term, but a single bleaching event will take reefs between 30 to 100 years to recover', (Down to Earth, August 15, 1999). It is suggested that proper investigations and studies of coral ecosystems are necessary to understand the holistic view of association between coral ecosystems, global warming and coral bleaching so that the corals may be rejuvenated.

Check Your Progress II

Q.1 Why corals are called the 'rainforests of the oceans'?

____
____
____
____

Q.2 Differentiate between fringing reef, barrier reef and atoll.

____
____
____
____
____

12.11 CONCLUSION

It is concluded that the marine ecosystem is vivid and cultured in its own way like the terrestrial ecosystem. The different kinds of physical processes along with the biogeochemical processes, marine animals, their types, plants and their contribution in making all this happen makes it a beautiful and a mysterious area to find out and most importantly to protect it from getting exploited or damaged.

12.12 SUMMARY

- The unconsolidated sediments, derived from various sources deposited at the sea floors are included in ocean deposits.
- The sediments deposited in the oceans and the seas are derived from four major sources viz. 1) Terrigenous sources, 2) Volcanic eruptions, 3) Marine plants and animals and 4) Abiotic matters.
- Terrigenous deposits are those derived from the erosion of rocks on land; that is, they are derived from *terrestrial* (as opposed to marine) environments. They are responsible for the significant amount of salt in todays's oceans.

- Continental shelf sediments-called *neritic (neritos*=of the coast*)*-consist primarily of the terrigenous materials. Deep-ocean floors are covered by finer sediment than those of the continental margins, and a greater proportion of deep-sea sediments are of biogenous of origin. Sediments of the slope, rise and deep-ocean floor that originate in the ocean are called *pelagic* sediments *(pelagios*=of the sea*)*.
- Coral reefs are more diverse than tropical rainforests because the coral reefs have about 1,000,000 species of which onlyn10% have been studied. This is why these are called **rainforests of the oceans.**
- Coral bleaching refers to the lack of algae from the corals resulting into the white colour which is indicative of death of corals.

12.13 GLOSSARY

Atoll: A ring of narrow growing coral animals of horseshoe shape and crowned with palm trees.

Barrier Reef: The largest coral reefs off the coastal platforms of the continents but parallel to them.

Biogenic Sediments: The sediments formed through the deposition of skeletal remains of marine organisms on sea floors, which have atleast 30% by volume of remains of marine organisms.

Continental Shelf: The brad, flat, shallow and gently sloping sea floor extending from the coasts to the point of shelf break or upper part of the continental slope.

Continental Slope: Steeply sloping submerged sea bottom extending from the outer margin of continental shelf or from the point of shelf break and ending into deep sea trenches.

Coral Banks: The isolated and shapeless corl reefs.

Coral Bleaching: Coral bleaching refers to the lack of algae from the corals resulting into the white colour which is indicative of death of corals.

Coral Reefs: The reefs of cemented and compacted rigid massive structures of numberless corolites (skeletons) of dead coral animals.
Corals: The living organisms of the category of marine animal and related to jellyfish, which are responsible for building coral reefs.

Diatoms: Single-celled microscopic phytoplanktons which are responsible for bulk primary production in marine environment.

Foraminifera: They are marine protozoans having test c0mposed of calcium carbonate, and linear or spiral or concentric shells perforated by mall holes or pores.

Fringing Reefs: Coral reefs developed along the continental margin or along the islands

Gravels: They are coarse-grained terrigenous materials consisting of boulders, cobbles, pebbles and granules.

Hydrogenous Sediments: The sediments derived from precipitation of dissolved substance s due to chemical reactions such a phosphorites, metal sulphides, gypsum, salts, etc.

Lagoon: A small pool.

Lithogenous Sediments: The sediments derived from the weathering and erosion of rocks either on land or in oceans.

Littoral Zone: The zone of benthic province between high and low tide waters.

Macro-biogenic Sediments: These are the sediments which are derived from the shells, bones and teeth of marine animals.

Micro-biogenic Sediments: These are the small particles of microscopic marine animals.

Neritic Sediments: The marine sediments deposited on the floors of continental shelves.

Ocean Deposits: The consolidated marine sediments in the form of sedimentary layers on sea floors.

Pelagic Matter: The sediments deposited on deep sea floors through slow sedimentation.

Phosphorites: The hydrogenic deposits having the nodules of phosphorus (P_2O_5).

Radiolaria: These are unicellular marine animals having siliceous composition and belong to planktonic and benthos community.

Shelf Break: It is the outer edge of the continental shelves from where starts the continental slope.

Terrigenous Sediments: They are those marine sediments which are derived through the weathering and erosion of continental rocks and brought to the oceans by rivers.

12.14 ANSWER TO CHECK YOUR PROGRESS

Check Your Progress I

Ans.1 Refer to section 12.5.1.

Ans.2 Refer to section 12.6.1.

Check Your Progress II

Ans.1 Coral reefs are more diverse than tropical rainforests because the coral reefs have about 1,000,000 species of which onlyn10% have been studied. This is why these are called **rainforests of the oceans.**

Ans.2 Refer to section 12.9.

12.15 REFERENCES

Daly, R. A., 1934, *The Changing World of the Ice Age,* New Haven, Yale University Press.

Groiler Encyclopedia of Knowledge, Vol. 3 & 4, 1999.

Daly, R. A., 1942, *The Floor of the Ocean,* University of North Carolina Press.

Dana, J. D., 1879, *Corals and Coral Islands,* New York, Dodd Mead & Co.

12.16 SUGGESTED READINGS

Garrison, T., 1995, *Essentials of Oeanography,* New York, Wadsworth.

Shephard, F. P., *Submarin Geology,* New York, Harper and Brothers.

12.17 TERMINAL QUESTIONS

Q.1 Explain the sources and types of Marine Deposits.

Q.2 Categorize the marine deposition in accordance to their province.

Q.3 Explain the Darwin Theory of Origin of Reefs along with the known conditions of growth of reefs.

Q.4 What do you mean by coral bleaching? Explain its effect on the world scenario.

UNIT 13: ELEMENTS OF BIOSPHERE, HABITAT AND PLANT-ANIMAL ASSOCIATION

13.1 OBJECTIVES
13.2 INTRODUCTION
13.3 BIOSPHERE: MEANING AND CONCEPT
13.4 ELEMENTS OF BIOSPHERE
13.4.1 ABIOTIC ELEMENTS
13.4.2 BIOTIC ELEMENTS
13.5 HABITAT
13.6 PLANT KINGDOM
13.6.1 VERTICAL STRATIFICATION OF PLANT COMMUNITIES
13.7 ANIMAL KINGDOM
13.8 HABITAT AND PLANT-ANIMAL ASSOCIATION
13.9 CONCLUSION
13.10 SUMMARY
13.11 GLOSSARY
13.12 ANSWER TO CHECK YOUR PROGRESS
13.13 REFERENCES
13.14 SUGGESTED READINGS
13.15 TERMINAL QUESTIONS

13.1 OBJECTIVES

After studying this chapter, you will be able:

- To know about the biosphere
- To recognize its elements
- To know the meaning of habitat
- Distinguish between the flora and fauna kingdom
- To know about the interdependence of plant and animals

13.2 INTRODUCTION

Earth is the only known life sustaining planet in the universe. It has great diversity of flora and fauna and is able to show the various forms of life altogether in a single bunch. It is the only planet to be having all the life-sustaining things like adequate temperature, air to breathe, water for utilization and what not; all blended upon so well that all its components help each other in maintaining the well-being of each other. They are all interdependent on each other and form a cycle of life sustaining elements going.

13.3 BIOSPHERE: MEANING AND CONCEPT

The biosphere is a life supporting layer which surrounds the Earth and makes plant and animal life possible without any protective device.

Theorganic world or biosphere is that part of the earth which contains the living organisms-the biologically inhabited soil, air and water' **-J. Tivy, 1982**

The biosphere consists of the entireliving organism (the biotic component), energy (the energy component) and the physical environment (the abiotic component)and there are continuous interactions between the living organisms and the physical environment and among the living organisms themselves. The average thickness of the biosphere or life supporting layer consisting of air, water, soil and rock is about 30 km. The upper limit of the biosphere is determined by the availability of oxygen, moisture, temperature and air pressure with increase in height in the atmosphere limits the upper boundary of the biosphere. Though the NASA has discovered the presence of bacteria up to the height of 15 km in the atmosphere but the lower layer of the atmosphere upto a few hundred meters accounts most of the living organisms becausefavourable environmental conditions are available for the growth and development of living organisms in the lower part of the atmosphere.

The lower limits of the biosphere are determined by the availability of the required amount of oxygen and light which can sustain life. Thus, the depth of the biosphere over the land is upto the depth of the deepest roots of the trees or the depth at which lie the parent rock-beds. The biosphere extends upto greater depths in the oceans. The existence of life has been detected upto a depth of 9,000m in the deep oceanic trenches and deep sea plains (Fig 13.1)

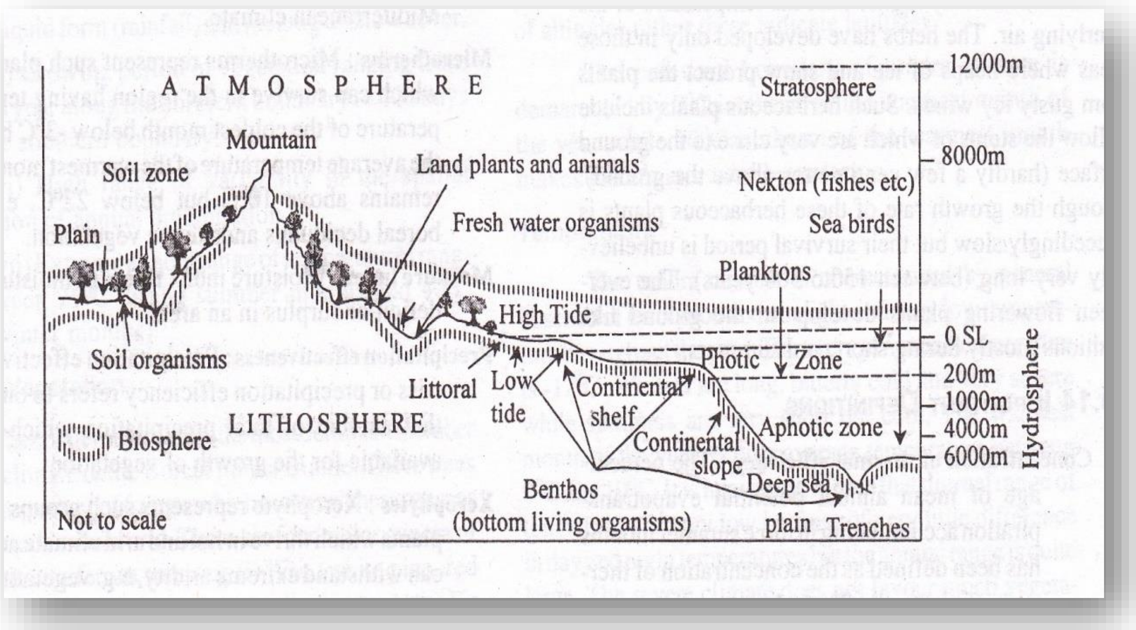


Figure 13.1
Extent of Biosphere (life supporting layer)

13.4 ELEMENTS OF BIOSPHERE

If we consider the whole biosphere as an ecosystem at global scale, the components of the biosphere and the biospheric ecosystem becomes the same. The total physical environment at global scale also contains the same components as those of the biosphere and the ecosystem (biospheric ecosystem). The biosphere, the ecosystem and the environment consists of the three components viz. (i) inorganic or abiotic or physical components, (ii) energy component and (iii) biotic or organic component. It may be pointed out that energy component may also be considered with abiotic components.

13.4.1 Abiotic Elements

The abiotic or inorganic or physical components of the biosphere or the ecosystem represents physical environment of the whole biosphere or part thereof. This component, on an average, includes the lithosphere, the atmosphere and the hydrosphere. Generally these are considered as land and or soil, air and water respectively. If the whole of the biosphere is taken to be as an ecosystem at global scale, these three physical or abiotic components are considered as the sub-systems of the biosphere system.

In other words, abiotic components of the biosphere consist of three sub-components which are explained as under:

1. Lithosphere or Land Component

Lithosphere or Land Component consists of (from smaller to higher) elements (ion, oxygen, nitrogen, hydrogen, carbon, etc.), minerals (hematite, dolomite, feldspar, etc.), rocks and soils, micro-landforms (relief features of 3rd order), meso- landforms (relief features of 2nd order) and macro- landforms (relief features of 1st order).

The lithosphere accounts for about 29% of the total surface area of the globe. The landforms of various sizes as mentioned above provide a variety of habitat for the plants and animals. Thus, it is necessary to study the main characteristics of lithospheric components and all the physical processes, whether exogenetic or endogenetic, which affect the lithosphere- the surface of the Earth. The geological cycle involving a set of processes and sub-cycles, e.g., tectonic cycle, rock cycle, geochemical cycle, water cycle, etc, is responsible for the creation, maintenance, changes or destruction of the materials of the Earth, for example, elements, minerals, rocks, soils, water and landform assemblage.

Soil system is a very important component because soils acts as vital pathways of energy in the biosphere and are very important for the biological cycles of nutrients. The soil system acts as very important biological furnace between the vegetation cover and unweathered parent rocks. Soil environment also provides habitats of various sorts o the largest community of organic life (biological community). On the other hand, sols act as nutrient reservoirs for living organisms. Soil facilitates the process of root osmosis for the transfer of their nutrients to the plants through their roots in solution form. Soil system is also called as the *biological factory or laboratory* because the processes of creation of nutrients, their consumption and their return are confined to soils.

2. Atmospheric or Air Component

The atmosphere is a significant component of the biospheric ecosystem because it provides all the gases necessary for the sustenance of all life forms of the biosphere. It also filters the incoming solar radiation and thus prevents the ultraviolet solar radiation waves to reach the Earth's surface and hence protects it from becoming too hot. The atmospheric component includes the consideration of the composition and structure (troposphere, stratosphere, mesosphere, thermosphere, ionosphere and exosphere) of the atmosphereand the elements of weatherand climate (insolation, temperature, air pressure, winds, humidity and precipitation, airmasses, frontogenesis and fronts, cyclones and anti-cyclones,etc.)

The atmosphere helps in the process of photosynthesis and drives hydrological cycle,

3. Hydrospheric or Water Component

The water or hydrospheric component is very important component of the abiotic or physical components because it is a very essential element for all types of life in the biosphere. Water plays a very important role in the circulation of nutrients in the various components of the ecosystems and it makes biogeochemical cycles effective in the biosphere.

The water component consists of surface water, subsurface or ground water and oceanic water.

- **a. Surface water** of the Earth surface is found in static state (e.g. water of lake, tanks, ponds, reservoirs, etc.) and in dynamic (in motion) state (e.g. surface runoff, streams, springs, etc.)
- **b. Groundwater** is found in the pore spaces of regolith known as *Aquifers.*
- **c. Oceanic water** or hydrosphere covers about 71% of the total surface f the area of the globe. On the basis of size and location the hydrosphere is divided into oceans, seas, small enclosed seas, bays, etc. The hydrospheric component includes the consideration of origin and characteristics of bottom reliefs (continental shelves, continental slopes, deep-sea plains, deeps, submarine canyons, etc.), temperature, salinity, ocean deposits, waves and currents, coral reefs and atolls because these determine different types of habitats of marine organisms.

13.4.2 Biotic Elements

Biotic or organic elements of the biosphere consist of three sub-systems- (i) plant system, (ii) animal system including man and (iii) micro-organisms. Of these three sub-systems plants are the most important because plants alone produce organic matters which are used by animals including micro-organisms either directly or indirectly. Plants also make the cycling and recycling of organic matter and nutrients possible in different components of the biospheric system.

1. Plant Component

Social grouping of plant species is called *plant community* and plants are basic unit of this community. Plantsare found on any land in different forms, e.g., woodland, forest, meadow, bogs, grasslands, marshlands, etc. These different forms of plants are collectively known as vegetation. In other words-

> *'All the plants that grow in an area form its vegetation, the character of which depends not just on the different species present but on the relative proportions in which their members are represented.'*
>
> **-Joy Tivy, 1982**

Thus, the vegetation of any particular habitat consists of groupsof plants of different species or of the same species which are ecologically related, meaning thereby different plant groups are able to occupy the same habitat because of their competitive ability and range of tolerance. Plant community has been defined in a variety of ways by the ecologists and biogeographers, some examples are as follows-

- **a.** Social groupings of plant species are called plant community.
- **b.** Plant community represents groups of plants which occur together and possess a certain degree of unity of individuality.

- **c.** Plant community is a group of plants which occupy a definite physical habitat.
- **d.** Plant community refers to groups of plant species which have distinctive characteristics of their composition and structure in relation to their physical habitat.

There are certain characteristics of the plant community. The major ones are explained as under:

- **i.** Plant community consists of two or more different species of plants.
- **ii.** The plant species of plant community are capable of growing together in a particular physical habitat, which they inhabit and thus different members (species) of a plant community are ecologically interrelated.
- **iii.** A plant community has a well-defined composition and structure which are attained over time through the interaction between different plant species and between plant and their physical environment.
- **iv.** Plant community represents the ecological conditions of a region or an area or a physical habitat.
- **v.** The structures, composition and growth form of different species of a given plant community reveal the effects of both mutually interacting biotic and abiotic environments on them.

In other words, this is a well-known fact the species of plants, their structure, composition and growth form depend upon the nature of mutual interaction between the abiotic and biotic components of the environment, it is easier to understand the nature and pattern of mutual interactions of factors (components, both abiotic and biotic) which affect the species, their structure, composition and growth form. Out of the abiotic or physical factors, climate and soil mostly affect the species of plants, their structure and growth form. In turn, plants also affect and control the properties of soils and climatic conditions of their physical habitat. It appears that plant community not only affects but also determines the productivity of the land and their habitat.

Plants are **primary producers** because they produce their food themselves through the process of **photosynthesis**. Thus, plants are also called **autotrophs**. It is evident that the plants are the major source of food and energy supply to animals including man.

2. Animal Components

On a functional basis, the biotic or organic components of the biosphere ecosystem are divided into two broad divisions:

- **a.** The Autotrophic Component-which represents plants.
- **b.** The Heterotrophic Component-which includes those animals which depend upon autotrophic green plants for their food.

It must be noted that it is not necessary that the autotrophic component must have roots. This is the reason why, some bacteria fall under this category as they are able to produce their food themselves.

The main function of the heterotrophic component or the animals (primary consumers or herbivores) includes:

i. To use organic matter made available by the autotrophic green plants.
ii. To rearrange the organic matter/elements.
iii. To decompose organic elements, etc.

Organic matters are available to animals in three forms:

i. From living plants and animals.
ii. From partially decomposed plant and animals.
iii. From organic compounds in solution form.

Thus the heterotrophic component is classified into three broad categories on the basis of the availability of organic matter to them:

a. **Saprophytes** are those animals which live on organic compounds in the solution form derived from dead plants and animals.
b. **Parasites** are those animals which depend upon other living organisms for food and life.
c. **Holozonic**animals are those who take their food through their mouths. All the big animals like elephants, cows, camels, lions, etc. are included in this category.

3. Micro-organisms

Micro-organisms are also known as **decomposers** because these decompose the dead plants and animals and other organic matter in different forms. During the process of decomposition of organic matter, micro-organismsobtain their food as well as they differentiate and separate complex organic matters and thus make them simple so that these may be again used by autotrophic primary producer green plants. A large number of micro-bacteria and fungi are included in the category of micro-organisms.

Check Your Progress I

Q.1 How is biosphere formed?

____
____
____
____
____
____

Q.2 Write the sub systems of biotic elements of biosphere.

____
____
____

13.5 HABITAT

A habitat is an ecological or environmental area that is inhabited by a particular species of animal, plant, or other type of organism. The term typically refers to the zone in which the organism lives and where it can find food, shelter, protection and mates for reproduction. It is the natural environment in which an organism lives, or the physical environment that surrounds a species population.

A habitat is made up of physical factors such as soil, moisture, range of temperature, and light intensity as well as biotic factors such as the availability of food and the presence or absence of predators. Every organism has certain habitat needs for the conditions in which it will thrive, but some are tolerant of wide variations while others are very specific in their requirements. A habitat is not necessarily a geographical area, it can be the interior of a stem, a rotten log, a rock or a clump of moss, and for a parasitic organism it is the body of itshost, part of the host's body such as the digestive tract, or a single cell within the host's body.

Habitat types include polar, temperate, subtropical and tropical. The terrestrial vegetation type may be forest, steppe, grassland, semi-arid or desert. Fresh water habitats include marshes, streams, rivers, lakes, ponds and estuaries, and marine habitats include salt marshes, the coast, the intertidal zone, reefs, bays, the open sea, the sea bed, deep water and submarine vents.

Habitats change over time. This may be due to a violent event such as the eruption of a volcano, an earthquake, a tsunami, a wildfire or a change in oceanic currents; or the change may be more gradual over millennia with alterations in the climate, as ice sheets and glaciersadvance and retreat, and as different weather patterns bring changes of precipitation and solar radiation. Other changes come as a direct result of human activities; deforestation, the ploughing of ancient grasslands, the diversion and damming of rivers, the draining of marshland and the dredging of the seabed. The introduction of alien species can have a devastating effect on native wildlife, through increased predation, through competition for resources or through the introduction of pests and diseases to which the native species have no immunity.

13.5.1 Types of Habitats

Terrestrial habitat types include forests, grasslands, wetlands and deserts. Within these broad biomes are more specific habitats with varying climate types, temperature regimes, soils, altitudes and vegetation types. Many of these habitats grade into each other and each one has its own typical communities of plants and animals. A habitat may suit a particular species well, but its presence or absence at any particular location depends to some extent on chance, on its dispersal abilities and its efficiency as a coloniser.

Freshwater habitats include rivers, streams, lakes, ponds, marshes and bogs. Although some organisms are found across most of these habitats, the majority have more specific requirements. The water velocity, its temperature and oxygen saturation are important factors, but in river systems, there are fast and slow sections, pools, bayous and backwaters which provide a range of habitats. Similarly, aquatic plants can be floating, semi-submerged, submerged or grow in permanently or temporarily saturated soils besides bodies of water. Marginal plants provide important habitat for both invertebrates and vertebrates, and submerged plants provide oxygenation of the water, absorb nutrients and play a part in the reduction of pollution.

Marine habitats include brackish water, estuaries, bays, the open sea, the intertidal zone, the sea bed, reefs and deep water zones.[11]Further variations include rock pools, sand banks, mudflats, brackish lagoons, sandy and pebbly beaches, and sea-grass beds, all supporting their own flora and fauna. The benthic zone or seabed provides a home for both static organisms, anchored to the substrate, and for a large range of organisms crawling on or burrowing into the surface. Some creatures float among the waves on the surface of the water, or raft on floating debris, others swim at a range of depths, including organisms in the demersal zone close to the seabed, and myriads of organisms drift with the currents and form the plankton.

A desert is not the kind of habitat that favours the presence of amphibians, with their requirement for water to keep their skins moist and for the development of their young. Nevertheless, some frogs live in deserts, creating moist habitats underground and hibernating while conditions are adverse. Couch's spadefoot toad (*Scaphiopuscouchii*) emerges from its burrow when a downpour occurs and lays its eggs in the transient pools that form; the tadpoles develop with great rapidity, sometimes in as little as nine days, undergo metamorphosis, and feed voraciously before digging a burrow of their own.

Other organisms cope with the drying up of their aqueous habitat in other ways. Vernal pools are ephemeral ponds that form in the rainy season and dry up afterwards. They have their specially-adapted characteristic flora, mainly consisting of annuals, the seeds of which survive the drought, but also some uniquely adapted perennials. Animals adapted to these extreme habitats also exist; fairy shrimps can lay "winter eggs" which are resistant to desiccation, sometimes being blown about with the dust, ending up in new depressions in the ground. These can survive in a dormant state for as long as fifteen years. Some killifish behave in a similar way; their eggs hatch and the juvenile fish grow with great rapidity when the conditions are right, but the whole population of fish may end up as eggs in diapause in the dried up mud that was once a pond.

Many animals and plants have taken up residence in urban environments. They tend to be adaptable generalists and use the town's features to make their homes. Rat and mice have followed man around the globe, pigeons, peregrines, sparrows, swallows and house martins use the buildings for nesting, bats use roof space for roosting, foxes visit the garbage bins and squirrels, coyotes, raccoons and skunks roam the streets. About 2,000 coyotes are thought to live in and around Chicago.

A survey of dwelling houses in northern European cities in the twentieth century found about 175 species of invertebrate inside them, including 53 species of beetle, 21 flies, 13 butterflies and moths, 13 mites, 9 lice, 7 bees, 5 wasps, 5 cockroaches, 5 spiders, 4 ants and a number of other groups. In warmer climates, termites are serious pests in the urban habitat; 183 species are known to affect buildings and 83 species cause serious structural damage.

13.6 PLANT KINGDOM

Plants play a very dominant role in the biosphere because these are the primary producers in the biosphere and provide directly and indirectly food to all the terrestrial and aquatic animals including man. The social grouping of the plants is known as the plant community, of which plant is the basic fundamental unit. Plnt directly receive and trap solar energy and prepare their ownood with the hlp of sunlight through the process of photosynthesis. Thus, solar enery converted into food or chemical energy is transferred to different trophic levels of food chain. Thus, plants are the intermediateries between biotic and abiotic components of the biosphere. On the basis of importance and dominant role of plants in the biosphere the study of plants is given more significance. The study of plants has been developed as an important branch of geography which is called as **plant geography** which includes the study of classification of plants, their spatial distribution, origin and development, dispersal and extinction and functions. The main functions of plants are to trap the solar energy and prepare their food with the help of photosynthesis and to circulate and transfer energy and nutrients among the organisms of different trophic levels of the food chain.

Now, we all know what vegetation is. As studied earlier, the group of association of plant communities of any region is called vegetation. . In other words-

‘all the plants that grow in an area form its vegetation, the character of which depends not just on the different species present but on the relative proportions in which their members are represented.’ **-Joy Tivy, 1982**

For example, two habitats may have similar floras but their vegetation may vary from one another and two habitats having different floras may have similar vegetation. For instance, if there are two similar habitats wherein both have grasses and sal trees but there is overwhelming dominance of grasses nd sparse distribution of sal trees in the first habitat whereas the second habitat is characterized by dense sal trees and sparse distribution of grasses, the vegetation of the first habitat will be grasses whereas the vegetation of the second habitat will be sal forest.

13.6.1 Vertical Stratification of Plant Communities

Different species of plants are evolved in a habitat having favourable environmental conditions wherein different species of plant community grow together having different life-forms. The development of different species of plant community of a given region takes place through the process of **adaptation, competition** and **natural selection.**This results in the development of various strata or layers between the soil surface or ground surface and the tree canopy. This vertical layering pattern or vertical stratification of plants is a result of competition among various species of plant community to get sunlight because it is the primary source of energy for photosynthesis through which these plants manufacture their food. It is obvious that the availability of sunlight is mainly responsible for the development of vertical stratification of plants wherein the height of different species of plants varies significantly. On an average, there are four vertical strata of plant community in a given region mainly in the deciduous forests of the temperate region.

1. **Dominant Layer** represents the topmost layer of the plant community (Fig, 13.2) which is determined by the canopy of the largest trees. The uppermost stratum is also called crown or canopy which represents the highest limit of plant community in a given region. A secondary very often called as co-dominant layer is formed just below the crown or dominant layer by those large trees which are relatively shorter than the larger trees (Fig 13.2).

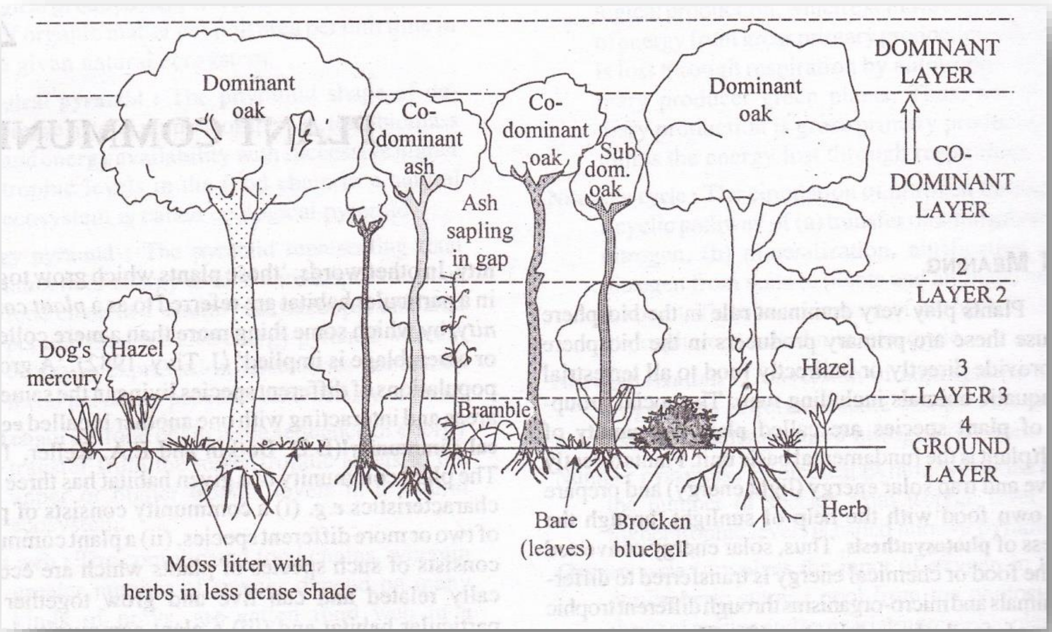


Figure 13.2
Vertical Stratification of Plant Kingdom (with respect to temperate deciduous forest)

2. **Secondary Layer** is located below the dominant layer or crown layer and is represented by plants of shrubby life-form. This is also called the **shrub layer.**
3. **Third Layer**is formed by the herbaceous plants and is also called the **herb layer.**
4. **Fourth Layer**represents mosses on the ground surface and is also called as **moss layer** or **ground layer.**

13.7 ANIMAL KINGDOM

The geographical study of animals is called **zoogeography** which includes the consideration of classification, historical evolution and spatial distribution of different kinds of animals to be found in the biosphere. All these require the identification and determination of all animals of a particular region or habitat having certain environmental conditions, their classification on various bases and considerations, and their distributional patterns. The most important variations between plants and animals are related to their mobility and stability. Almost all plants are static at their places except a few floating aquatic plants which move to some extent under the influence of water movement whereas animals (both land and water animals) are very much mobile. The following characteristics of animals differentiate them from plants:

1. The metabolism of animals is not photosynthetic as in case of plants. It means that animals do not prepare their own food rather they depend upon the plants for their food. Thus, animals are consumers and heterotrophs whereas plants are producers and autotrophs. Animals also depend on herbivorous animals for their food. Thus, animals can derive their food from various sources:
   - **a.** From autotrophic plants (as herbivores grazing animals like cows, goats, deers, etc.)
   - **b.** From herbivorous animals (carnivorous animals like lions, tigers, wolves, man, etc.)
   - **c.** From autotrophic plants (in the form of vegetables, food crops, etc.) as well as from herbivorous animals (omnivorous animals like man).
   - **d.** From dead parts of plants and animals (deterivorous microscopic organisms or microbes or decomposers.)

2. Animals have maximum mobility but the degree of mobility ranges from one group of animals to the other group whereas plants are mostly static in their places.

3. Every animal has a complete life-cycle wherein it attains its definite adult for in a definite time-span.

4. There is absence of cell vacuoles (empty spaces in cells) and rigid cell walls in the animals while most of the cellular and multi-cellular plants are characterized by these characteristic features.

5. There is a quick and rapid response among the animals to the external stimuli. In other words, the animals are very much sensitive to the external stimulation events.

13.8 HABITAT & PLANT-ANIMAL ASSOCIATION

A habitat, as explained earlier, is a place where an organism makes its home. A habitat meets all the environmental conditions an organism needs to survive. For an animal, that means everything it needs to find and gather food, select a mate, and successfully reproduce.

For a plant, a good habitat must provide the right combination of light, air, water, and soil. For example, the prickly pear cactus, which is adapted for sandy soil, dry climates, and bright sunlight, grows well in desert areas like the Sonoran Desert in northwest Mexico. It would not thrive in wet, cool areas with a large amount of overcast (shady) weather, like the U.S. states of Oregon or Washington.

The main components of a habitat are shelter, water, food, and space. A habitat is said to have a suitable arrangement when it has the correct amount of all of these. Sometimes, a habitat can meet some components of a suitable arrangement, but not all.

For example, a habitat for a puma could have the right amount of food (deer, porcupine, rabbits, and rodents), water (a lake, river, or spring), and shelter (trees or dens on the forest floor). The puma habitat would not have a suitable arrangement, however, if it lacks enough space for this large predator to establish its own territory. An animal might lose this component of habitat—space—when humans start building homes and businesses, pushing an animal into an area too small for it to survive.

Space

The amount of space an organism needs to thrive varies widely from species to species. For example, the common carpenter ant needs only a few square inches for an entire colony to develop tunnels, find food, and complete all the activities it needs to survive. In contrast, cougars are very solitary, territorial animals that need a large amount of space. Cougars can cover 455 square kilometers (175 square miles) of land tohunt and find a mate. A cougar could not survive in the same amount of space that a carpenter ant needs.

Plants need space, too. Coast redwood trees, like the ones in Redwood National Park in the U.S. state of California, can reach more than 4.5 meters (15 feet) in diameter and 106 meters (350 feet) in height. A tree that massive would not have enough space to grow and thrive in a typical community park or yard.

Space is not the same as range; the range of an animal is the part of the world it inhabits. Grassland, for example, is the habitat of the giraffe, but the animal's range is central, eastern, and southern Africa.

Food

The availability of food is a crucial part of a habitat's suitable arrangement. For example, in the northern part of the U.S. state of Minnesota, black bears eat mostly plants, like clover, dandelions, and blueberries. If there were a drought, plants would become scarce. Even though the habitat would still have space (large forest), shelter (caves, forest floor), water (streams and lakes), and some food, it wouldn't have enough to eat. It would no longer be a suitable arrangement.

Too much food can also disrupt a habitat. Algae isa microscopic aquatic organism that makes its own food through the process of photosynthesis. Nutrients like phosphorous contribute to the spread of algae. When afreshwater habitat has a sharp increase in phosphorous, algae "blooms," or reproduces quickly. Algae also die very quickly, and the decaying algae produce an algal bloom. The algal bloom can discolor the water, turning it green, red, or brown. Algal blooms can also absorb oxygen from the water, destroying the habitat of organisms like fish and plants. Excess nutrients for algae can destroy the habitat's food chain.

Water

Water is essential to all forms of life. Every habitat must have some form of a water supply. Some organisms need a lot of water, while others need very little. For example, dromedary camels are known for their ability to carry goods and people for long distances without needing much water. Dromedary camels, which have one hump, can travel 161 kilometers (100 miles) without a drink of water. Even with very little access to water in a hot, dry climate, dromedary camels have a suitable arrangement in northern Africa and the Arabian Peninsula.

Cattails, on the other hand, are plants that grow best in wet areas, like marshes and swamps. Dense colonies of these tall, spiky plants grow directly in the mudbeneath lakes, stream banks, and even neighborhoodponds. A cattail habitat's suitable arrangement depends on water. Imagine a pond at the bottom of a dirt-covered cliff. If enough loose dirt slid down into the pond, it could fill up the pond and absorb the water, not leaving enough for the cattails to grow.

Shelter

An organism's shelter protects it from predators and weather. Shelter also provides a space for eating, sleeping, hunting, and raising a family. Shelters come in many forms. A single tree, for example, can provide sheltered habitats for many different organisms. For acaterpillar, shelter might be the underside of a leaf. For a mushroom fungus, shelter might be the cool, damparea near tree roots. For a bald eagle, shelter may be a high perch to make a nest and watch for food.

Plants and animals interact with each other in the environment. They also interact with the environment itself. The plants and animals depend on each other.

Animals and humans depend on plants. Animals need food, protection and shelter. In human terms, it is food, clothing and shelter.

Plants benefit to animals/humans:

- Plants are used as sources of food and goods for humans.
- They can be used for shelter.
- They provide shade for protection from the hot sun.

- Humans use plants for fuel. We also use plants to make cloth, dyes and medicines.

Some people use plants and plant material as decoration to make themselves attractive.

Animals and humans depend on other animals. In the food chain, some animals eat other animals and use them for food. Humans also use animals as sources of food and clothing.

Plants benefit from animals:

- Animals are used by some plants to disperse seeds.
- Some animals can eat other plant-eating animals.
- Bees and other insects help pollinate flowers.
- Earthworms aerate the soil so that the roots of plants can better obtain oxygen.

This so can be seen that the same habitat for both the plant and animals remains sustainable with each other's support, association and thorough interdependence.

Check Your Progress II

Q.1What do you mean by vegetation?

____

____

____

____

____

____

Q.2 What is the most basic difference between a plant and an animal?

____

____

____

____

____

____

13.9 CONCLUSION

It is so concluded that all the biotic components and abiotic components and even the biotic components themselves depend upon each other for sustaining their lives. With time everything changes, but the quality of adaption, competitiveness and natural selections of environment makes this world to go on with time. The differences in the habitats and vegetations makes different areas in the world in which very diverse kind of plants and animals flourish helping each other on the way of survival altogether.

13.10 SUMMARY

- The biosphere is a life supporting layer which surrounds the Earth and makes plant and animal life possible without any protective device.
- The biosphere consists of the entire living organism (the biotic component), energy (the energy component) and the physical environment (the abiotic component) and there are continuous interactions between the living organisms and the physical environment and among the living organisms themselves.
- The abiotic or inorganic or physical components of the biosphere or the ecosystem represents physical environment of the whole biosphere or part thereof. This component, on an average, includes the lithosphere, the atmosphere and the hydrosphere.
- The lithosphere accounts for about 29% of the total surface area of the globe. The landforms of various sizes as mentioned above provide a variety of habitat for the plants and animals.
- Soil system is also called as the *biological factory or laboratory* because the processes of creation of nutrients, their consumption and their return are confined to soils.
- The atmosphere is a significant component of the biospheric ecosystem because it provides all the gases necessary for the sustenance of all life forms of the biosphere.
- It also filters the incoming solar radiation and thus prevents the ultraviolet solar radiation waves to reach the Earth's surface and hence protects it from becoming too hot.
- . Water plays a very important role in the circulation of nutrients in the various components of the ecosystems and it makes biogeochemical cycles effective in the biosphere.
- Biotic or organic elements of the biosphere consist of three sub-systems- (i) plant system, (ii) animal system including man and (iii) micro-organisms.
- Of these three sub-systems plants are the most important because plants alone produce organic matters which are used by animals including micro-organisms either directly or indirectly.
- Social grouping of plant species is called *plant community* and plants are basic unit of this community.
- All the plants that grow in an area form its vegetation, the character of which depends not just on the different species present but on the relative proportions in which their members are represented.
- On a functional basis, the biotic or organic components of the biosphere ecosystem are divided into two broad divisions:
    - The Autotrophic Component-which represents plants.

- The Heterotrophic Component-which includes those animals which depend upon autotrophic green plants for their food.

- **Saprophytes** are those animals which live on organic compounds in the solution form derived from dead plants and animals.
- **Parasites** are those animals which depend upon other living organisms for food and life.
- **Holozonic**animals are those who take their food through their mouths. All the big animals like elephants, cows, camels, lions, etc. are included in this category.
- Micro-organisms are also known as **decomposers** because these decompose the dead plants and animals and other organic matter in different forms.
- A habitat is an ecological or environmental area that is inhabited by a particular species of animal, plant, or other type of organism. The term typically refers to the zone in which the organism lives and where it can find food, shelter, protection and mates for reproduction. It is the natural environment in which an organism lives, or the physical environment that surrounds a species population.
- The development of different species of plant community of a given region takes place through the process of **adaptation, competition** and **natural selection.**
- The most important variations between plants and animals are related to their mobility and stability. Almost all plants are static at their places except a few floating aquatic plants which move to some extent under the influence of water movement whereas animals (both land and water animals) are very much mobile.

13.11: GLOSSARY

Abiotic Component: It is the physical component of the biospheric ecosystem which includes physical environment such as land, air, water, soils, energy, etc.

Biogeography: The study of biosphere consisting of abiotic (land, soils, air, water, energy, etc.) and biotic (plants, animals and micro-organisms) components is called biogeography.

Biosphere: It is a life-supporting layer which surrounds the Earth and makes plants and animal life possible without any protective device. The biosphere consists of abiotic, energy and biotic components.

Biotic Component: They are the organic components of the biospheric ecosystem comprise plants, animals and micro-organisms.

Consumers: They are the heterotrophic organisms of the biospheric ecosystem which includes animals including man, which are further divided into primary consumers or *herbivores,* secondary consumers as *carnivores.*

Decomposers: They are the micro-organisms living in the soils which decompose and consume dead plants and animals and are also called *deterivores.*

Holozonic: They are those animals who take their food through their mouths. All the big animals like elephants, cows, camels, lions, etc.

Parasites: They are those animals which depend upon other living organisms for food and life.

Primary Producers: Plants are primary producers because they produce their own food though the process of photosynthesis. They are also called *autotrophs* or *phototrophs.*

Plant Community: The social groupings of plant species, of which plant is the fundamental basic unit.

Saprophytes: Those animals which live on organic compounds in the solution form derived from dead plants and animals.

Vegetation: The association or group of plant communities of any region.

Zoogeography: The systematic study of classification, evolution, extriction, dispersal and distribution of different kinds of animals of both terrestrial and aquatic environments.

13.12 ANSWER TO CHECK YOUR PROGRESS

Check Your Progress I

Ans.1 Biosphere is formed of the life sustained area of the all the three layers of the environment, i.e., lithosphere, hydrosphere and atmosphere.

Ans.2 Refer to section 13.4.2.

Check Your Progress II

Ans.1 The association or group of plant communities of any region is called vegetation.

Ans.2 Refer to section 13.7.

13.13 REFERENCES

The Columbia Encyclopedia, Sixth Edition. Columbia University Press. 2004.

Hogan, C. Benito (2010). *"Abiotic factor". Encyclopedia of Earth.Washington,D.C.:* National Council for Science and the Environment

"Abiotic Components". Department of Biodiversity and Conservation Biology, University of the Western Cape.

13.14 SUGGESTED READINGS

Richard J. Huggett (2004). *Fundamentals of Biogeography*. Psychology Press.

Singh, S. (1991): *Environmental Geography*, Allahabad Press.

Dev, S. (2002): *Physical Geography.*

13.15 TERMINAL QUESTIONS

Q.1 What do you mean by biosphere? Explain the major elements of biosphere.

Q.2 Draw critical analyses of the plant and animal kingdom, showing their dissimilarities yet their interdependence on each other.

UNIT 14: ECOLOGY AND ECOSYSTEM

14.1 OBJECTIVES
14.2 INTRODUCTION
14.3 ECOLOGY AND ECOSYSTEM: MEANING AND CONCEPT
14.4 ECOLOGICAL PRINCIPLES
14.5 PROPERTIES OF ECOSYSTEM
14.6 TYPE OF ECOSYSTEMS
14.7 FUNCTIONING OF ECOSYSTEMS
14.8 CONCLUSION
14.9 SUMMARY
14.10 GLOSSARY
14.11 ANSWERS TO CHECK YOUR PROGRESS
14.12 REFERENCES
14.13 SUGGESTED READINGS
14.14 TERMINAL QUESTIONS

14.1 OBJECTIVES

After studying this chapter, you will be able:

- To know about our ecosystem
- To get in depth knowledge of their types
- To know its functioning and properties
- To know about ecology and its principles
- To gain knowledge about the trophic levels, energy flow and different cycles functioning in the ecosystem

14.2 INTRODUCTION

Why are there so many living organisms on Earth, and so many different species? How do the characteristics of the non-living environment, such as soil quality and water salinity, help determine which organisms thrive in particular areas? These questions are central to the study of ecosystems— communities of living organisms in particular places and the chemical and physical factors that influence them. Here we will learn how scientists study ecosystems to predict how they may change over time and respond to human impacts.

14.3 ECOLOGY AND ECOSYSTEM: MEANING AND CONCEPT

Ecology is the scientific study of relationships in the natural world. It includes relationships between organisms and their physical environments (physiological ecology); between organisms of the same species (population ecology); between organisms of different species (community ecology); and between organisms and the fluxes of matter and energy through biological systems (ecosystem ecology). In simpler words, ecology is a science that studies the interdependent, mutually reactive and inter connected relationships between the organisms and their physical environment on one hand and among the organisms on the other hand.

The term ecology has been derived from *'oecology',* made by two Greek words *'oikos'* means house or dwelling as habitat and *'logos'* meaning the study of; by a German biologist Ernst Haeckel in 1869, to understand the relationship between organisms and their environment. It may be pointed out that Darwin's concepts of the *'evolution of species'* through natural selection involving interactions between biological species and habitat was the key stone of the formulation of the various terms and concepts of inter-relationship between organisms and their physical environment in one way or the other. The following sentences of Haeckel throw light on various aspects of oecology:

'*By oecology we understand the science of oeconomy, of the domestic affairs of animal organization. It enquires into the whole relation of animals with their inorganic and organic surroundings, and above all their friendly and hostile relations with such animals and plants as they come into direct or indirect contact with, or in shot with all the involved interdependences that Darwin designated as the condition of the struggle for existence.*

-Ernst Haeckel, 1869, 1870

Though this termed was coined in 1869, but the concept of organism and environment relationship is a very old one. In a simple term ecology can be stated as that science which studies, interrelationships between abiotic and biotic components of the biosphere on one hand, and among biotic component on the other hand. However, along with ecology comes another term, i.e., ecosystem. The term ecosystem was first used by A.G. Tansley in 1935 who defined ecosystem as:

'A particular category of physical systems, consisting of organisms and inorganic components in a relatively stable equilibrium, open and of various sizes and kinds.'

According to Tansely the ecosystem comprises of two major parts viz. biome (the whole complex of plants and animals of a particular spatial unit) and habitat (physical environment) and thus:

'all parts of such an ecosystem-organic and inorganic, biome and habitat, may be regarded as interacting factors which in a mature ecosystem , are in approximate equilibrium, it is through their interactions that the whole system is maintained.'

Many more definitions regarding the ecosystem are given below:

'A functioning interacting system composed of one or more living organisms and their effective environment, both physical and biological.'

-F. R. Fosberg, 1963

'Any system composed of physical-chemical-biological processes, within a space-time unit of any magnitude.'

-R. L. Linderman, 1942

'The total assemblage of components interacting with a group of organisms is known as ecological system or more simply, ecosystem. Ecosystems have inputs of matter and energy, used to build biological structure, (the biomass, to produce and to maintain necessary internal energy levels). Matter and energy are also exported from an ecosystem. An ecosystem tends to achieve a balance of the various processes and activities within it.'

-A. N. Strahler and A. H. Strahler, 1976

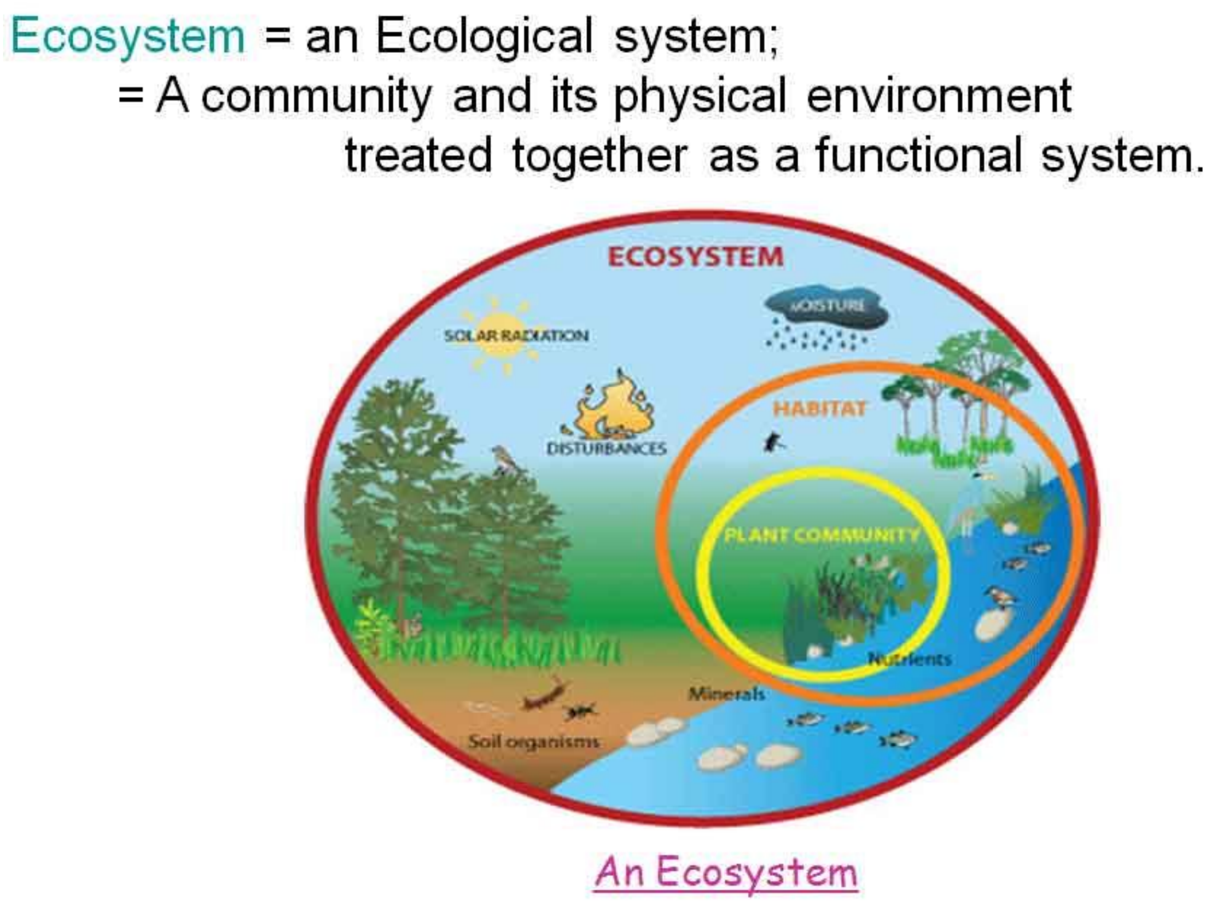


Figure 14.1

An Illustration of an Ecosystem

Stressing the importance of ecosystems is regarded as the basic units of ecology by many ecologists because they are complex, interdependent and highly organized systems and because they are basic building blocks of biosphere.

Ecologists study all these interactions in order to understand the abundance and diversity of life within Earth's ecosystems—in other words, why there are so many plants and animals, and why there are so many different types of plants and animals. To answer these questions they may use field measurements, such as counting and observing the behavior of species in their habitats; laboratory experiments that analyze processes such as predation rates in controlled settings; or field experiments, such as testing how plants grow in their natural setting but with different levels of light, water, and other inputs. Applied ecology uses information about these relationships to address issues such as developing effective vaccination strategies, managing fisheries without over-harvesting, designing land and marine conservation reserves for threatened species, and modeling how natural ecosystems may respond to global climate change.

Change is a constant process in ecosystems, driven by natural forces that include climate shifts, species movement, and ecological succession. By learning how ecosystems function, we can improve our ability to predict how they will respond to changes in the environment. But since living organisms in ecosystems are connected in complex relationships, it is not always easy to anticipate how a step such as introducing a new species will affect the rest of an ecosystem.

14.4 ECOLOGICAL PRINCIPLES

1. The ecosystem is the fundamental unit of ecological studies.
2. The physical and biological processes follow the principle of uniformitarism.
3. All living organisms and elements of physical environment are mutually active.
4. Ecosystem functions through the input of energy obtained from the sun.
   The energy flow and pattern is governed by the first and second law of thermodynamics:
   Law I: In any system of constant mass, energy is neither created nor destroyed but it can be transferred from one type to another type. The energy flow or input in a system is balanced by energy outflow.
   Law II: When work is done, energy is dissipated and the work is done when one form of energy is transformed into another form.
5. The circulation of energy in the biospheric ecosystem is unidirectional. There is increase in the relative loss of energy through respiration with increasing trophic levels.
6. Circulation of matter in the biosphere is accomplished through cyclic pathways, e.g., through geochemical cycles. The materials are cycled in such a way that their total mass remains almost constant.
7. There is inbuilt self-regulatory mechanism known as homeostatic mechanism, in natural ecosystem. Any change brought in the natural ecosystem is counter-balanced by this mechanism and ecosystem and ecological stability is re-established.
8. If changes brought by external factors are so immense that they exceed the resilience of ecosystem stability and adjustment of ecosystem to such changes become difficult, the ecosystem becomes unstable and several environmental problems are created.
9. There is a successional development of plant community in a habitat of given environmental conditions. The successional development of vegetation is of two types; primary succession and secondary succession.
10. Man modifies ecosystem through exploitation of natural resources.
11. The successive communities and species are reduced in umber and eight.
12. The ultimate goal of ecological study is to make environment and ecology sustainable.

Check Your Progress I

Q.1 What are regarded as the basic unit of ecology and why?

____

____

____

____

Q.2 What is the benefit of learning how the ecosystems function?

____

14.5 PROPERTIES OF ECOSYSTEM

The following are the basic properties of an ecosystem:

1. Ecosystem of any given space-time unit represents the sum of all living organisms and physical environment.
2. It is composed of three basic components viz. energy, biotic (biome) and abiotic (habitat) components.
3. It occupies certain well defined area of earth-space ship (spatial distribution).
4. It is viewed in terms on time unit (temporal dimension).
5. There are complex sets of interactions between biotic and abiotic components (including energy component) on the one hand and between and among the organisms on the other hand.
6. In an open system which is characterized by continuous input and output of matter and energy.
7. It tends to be in relatively stable equilibrium unless there is disturbance in one or more controlling factors (limiting factors).
8. It is powered by energy of various sorts but the solar energy is the most significant.
9. It is a functional unit wherein the biotic components (plants, animals including man and micro-organisms) and abiotic components (physical environment including energy component) are intimately related to each other through a series of large-scale cyclic mechanisms viz. energy flow, water cycle, biogeochemical cycle, mineral cycle, sediment cycle, etc.
10. Ecosystem has its own productivity which is the process of building organic matter based on the availability and amount of energy passing through the ecosystem. The productivity refers to the rate of growth of organic matter in the areal unit per time-unit.
11. Ecosystems have scale dimensions, i.e., it varies in spatial coverage. It may be as small as a cowshed, a tree or even a part of a tree having certain micro-organisms. The largest unit is the whole biosphere. Thus, the ecosystems may be divided into several orders on the basis of spatial dimension. Hence, it is clear that:
    ‘*the ecosystem is a convenient scale at which to consider plants and animals and their interaction because it is more localized and thus more specific than the*

biosphere in its entirely, and it includes a sufficient wide range of individual organisms to make regional generaisation feasible and valuable'

-C. C. Park, 1980

12. There are different sequences of ecosystem development. The sequence of ecosystem development in terms of a particular suite of physical and conditions called as 'sere'. A **sere** represents the development of a series of sequential successions starting from primary succession and culminating into the last succession in a sere as *'climax'* or *'climatic climax'* which is the most stable situation of an ecosystem. Thus, the study of ecosystem development may help in environmental planning from ecological point of view.

13. Ecosystems are natural resource systems.

14. Ecosystem concept is monistic in that environment (abiotic component), man, animals, plants and micro-organisms (biotic component) are put together in a single framework so that it becomes easy to study the patterns of interactions among these components.

15. It is structured and well organized system.

16. Ecosystem, for convenience, may be studied as a *'black box model'* by concentrating on the study of input variables and related output variables while the internal variables may be ignored to reduce the complexity.

14.6 TYPES OF ECOSYSTEM

Ecosystems may be identified and classified on various bases, with different purpose and objectives as outlined below:

1. On the Basis of Habitats

The habitats exhibit the physical environmental conditions of a particular spatial unit of the biosphere. These physical conditions determine the nature and characteristics of of biotic communities and therefore there are spatial variations in the biotic communities. Based on the premise, the world ecosystems are divided into two major categories:

i. **Terrestrial Ecosystems:** There are further variations in the terrestrial ecosystems in terms of physical conditions and their responses to biotic communities. Therefore, the terrestrial ecosystems are further divided into sub-categories of:

- **a.** Upland or Mountain Ecosystems
- **b.** Lowland Ecosystems
- **c.** Warm desert Ecosystems
- **d.** Cold Deserts Ecosystems

These sub-ecosystems may be further divided into descending order depending on specific purpose and objectives of studies.

ii. **Aquatic Ecosystems:** The aquatic ecosystems are subdivided into two broad categories:

a. Freshwater Ecosystems
- River Ecosystems
- Lake Ecosystems
- Pond and Tank Ecosystems
- Marsh and Bog Ecosystems

b. Marine Ecosystems
- Ocean Surface Ecosystems
  - ❖ Open Ocean Ecosystems
  - ❖ Coastal Estuarine Ecosystems
- Ocean Bottom Ecosystems
  - ❖ Coral Reef Ecosystems

2. On the Basis of Ecoclines

Ecocline means a broad transition between two different ecosystems of mainly plant communities. Infact an ecocline represents gradient along which biotic communities mainly plant community and abiotic conditions change. The study of ecocline representing the changing conditions, across an ecosystem boundary is known as 'gradient analysis' which implies the plotting of variations of plant community in a particular direction and the analysis thereof and division of world ecosystem. Based on the above consideration, R. C. Whittaker (1970) has drawn four profile ecoclines on a major world scale viz.:

i. From Appalachians to southern Texas (USA) on the basis on increasing aridity.
ii. From equatorial rainforest to desert area, on the basis of increasing aridity.
iii. From ground surface to higher altitudes of the Andes on the basis of increasing altitude.
iv. From tropical rainforests to Tundra on the basis of decreasing temperature.

Thus, on the basis of above gradient profiles and associated ecoclines the following types of ecosystems in the aforesaid four situations may be identified:

i. From mountains with relatively more moisture to the areas of increasing aridity:
- **a.** Mesophytic Forest Ecosystem
- **b.** Oak-Hickkory Forest Ecosystem
- **c.** Oak Woodland Ecosystem
- **d.** Prairie Ecosystem
- **e.** Dry Grassland Ecosystem
- **f.** Desert Ecosystem

ii. From the areas of high moisture (equatorial areas) to the areas of lowest moisture (desert):
- **a.** Tropical Rainforest Ecosystem
- **b.** Ever-green Seasonal Deciduous Forest Ecosystem
- **c.** Thorn Forest Ecosystem

d. Desert Scrub Ecosystem

iii. From lower to higher altitudes (in the Andean area of South America):

a. Tropical Rainforest Ecosystem
b. Lower Montane Rainforest Ecosystem
c. Montane Rainforest Ecosystem
d. Elfine Woodland Ecosystem
e. Paramos Ecosystem

iv. From equatorial hot and moist areas to cold tundra:

a. Tropical Forest Ecosystem
b. Temperate Deciduous Forest Ecosystem
c. Temperate Mixed Forest Ecosystem
d. Boreal Forest Ecosystem
e. Tundra Ecosystem

3. On the Basis of Spatial Scales

On the basis of spatial scales ecosystems are divided into different types of various orders on the basis of spatial dimensions required for specific purposes. The largest ecosystem in the whole biosphere which is sub-divided into two major types:

i. Continental Ecosystems
ii. Marine or Oceanic Ecosystems.

The spatial scales may be brought down from a continent to a single biotic life (plant or animal).

4. On the Basis of Uses

E. P. Odum (1959) has divided the world ecosystems on the basis of use of harvest methods and net primary production into two broad categories viz.:

i. **Cultivated Ecosystems:** They are further sub-divided into several categories on the basis of cultivation of dominant crops, e.g., wheat field ecosystem, rice field ecosystem, fodder field ecosystem, etc.

ii. **Non-cultivated Ecosystem:** They are also further sub-divided into, e.g., forest ecosystem, tall grass ecosystem, short grass ecosystem, desert ecosystem, seaweeds ecosystem, etc.

5. On the Basis of Source and Level of Energy

Ecosystems can be classified on the basis of source, type and level of energy available in the ecosystem on the basic premises that the main driving force of the ecosystem s for their functioning is energy. E. P. Odum (1975) has classified the ecosystems into four categories:

i. **Unsubsidized Natural Solar-powered Ecosystems** are those which are driven by solar energy only wherein incoming solar radiation is used to fix chemical energy. Open oceans, upland forests, wide and deep lakes may be cited typical examples of such ecosystems. The annual energy flow ranges between 1000-10,000 Kcal/m^2/yr (kilocalories per square metre per year) whereas estimated average energy is about 2000 Kcal/m^2/yr.

ii. **Natural –subsidized Solar-powered Ecosystems** represent tidal estuaries, lowland forests, coral reefs, etc. Natural processes like tides, waves, surface runoff, wind, etc. supplement solar energy input because these processes bring additional organic matter and biogeochemical cycles help in recycling of nutrients in the aforesaid ecosystems and thus solar energy is augmented to produce organic matter through primary producers (phototroph and chemotroph plants) so much so that these ecosystems become the most productive natural ecosystems. The annual energy flow in such ecosystems ranges between 10,000-50,000 Kcal/m^2/yr and average estimated energy flow is 20,000 Kcal/m^2/yr.

iii. **Man-subsidized Solar-powered Ecosystems** are those where additional energy is supplemented by human activities (e.g. farming). In other words, man applies additional energy in the form of fertilizers both natural and chemical, machines, irrigational water, etc. to make the land more productive. Thus, he produces more food and fibre crops ((food and fibre producing ecosystems) in a simple farming system. In a highly mechanized farming ecosystems, man increases the productivity through the use of chemical fertilizers, pesticides and herbicides (fossil energy to provide energy to crops, kill insects and unwanted plants so that maximum energy is utilized by field crops), irrigational water and by developing new hybrid high yielding varieties of seeds so that the plant remains dwarf and require relatively low amount of solar energy and can make maximum use of solar energy to prepare food through photosynthesis and thus can yield more production. The use of machines like tractors, hoes, etc, also helps in augmenting the natural processes of biogeochemical cycles. The examples of such ecosystems are simple crop and fibre farming systems and highly advanced mechanized farming systems for agriculture and some forms of aquaculture. The annual energy flow is from 10,000-50,000 Kcal/m^2/yr and average estimated energy flow is 20,000 Kcal/m^2/yr.

iv. **Fuel-powered Ecosystems** are represented by urban and industrial areas where fuel energy fully replaces solar energy. The fuel energy is derived through the fossil fuels like coal and petroleum which are obtained from underground quite away from the centres of utilization. Besides energy is also supplied through hydroelectricity, nuclear power and wood coal. These ecosystems are basically wealth generating systems. These ecosystems also generate pollutants and thus are potential sources of environmental pollution in the cities and town, sub-urban areas, industrial areas as well as the rural atmospheric environment of even very distant places. These fuel-powered urban-industrial ecosystems though generate material wealth of the economy of the society but these depend for life support (oxygen supply and food supply) fully on solar-powered natural ecosystems and man-subsidized solar-powered ecosystems.

The annual flow of energy ranges between 100,000-3,000,000 Kcal/m^2/yr, the estimated average being 2,000,000 Kcal/m^2/yr. Thus these ecosystems are powered by largest amount of energy which comes from non-solar sources.

6. **On the Basis of Stages of Ecosystem Development** and characteristics of different stages of ecological succession, in terms of community structure, life history, nutrient cycling and overall homeostasis, the following four major types of ecosystems are identified:
   - **i. Early Succession Ecosystems** are those which are characterized by high net community production, low biomass supported/unit energy ratio, linear food chain (plants›→grazing animals→carnivores), small total organic matter, extra biotic inorganic nutrients, low biotic diversity, short size of organism, simple life cycles, rapid rate of nutrient exchange, unimportant role of detritus in the regeneration of nutrients, undeveloped mutual relationship among community species, poor nutrient conservation, high entropy (disordered biotic community), etc.
   - **ii. Mature Ecosystem** are those which are characterized by low net community production, complex web like food chain (besides major plants and animals, decomposers also play important roles), large total organic matter, intra biotic inorganic nutrients, high community diversity, large size of organisms, long and complex life cycles, closed mineral cycles, important roles played by detritus in regeneration of nutrients, quality production, developed mutual relationships among the community species, good conservation of nutrients, low entropy (ordered structure of communities),etc.
   - **iii. Mixed Ecosystems** represent the overlapping characteristics of early succession ecosystems consequent upon general environmental change.
   - **iv. Inert Ecosystems** represents the destroyed ecosystems. These may result from the destruction of either early succession ecosystems or mature ecosystems due to volcanic eruptions or onset of ice ages resulting into complete destruction of life.

7. **On the Basis of Stability or Instability:** This concept has been elaborated in different but contrasting ways by various scientists. In a very general sense stability of an ecosystem is defined in terms of relationships between input and output of matter and energy functioning of biogeochemical cycles. An ecosystems in homeostatic or dynamic equilibrium state is that which represents:
   - **i.** Balance in the input and output of energy
   - **ii.** Excess of resource pool in comparison to the matter being cycled
   - **iii.** Functioning of soils, micro-climate and biogeochemical cycle as buffers against sudden changes in external conditions
   - **iv.** Minimization of instability due to diversity within the ecosystem.

Based on this premise, ecosystems may be classified into:

- **i.** Simple stable ecosystems

ii. Complex unstable ecosystems

But this classification is highly controversial and debatable because there are a lot of variations in opinions regarding the concept of system stability. For example, if the stability is defined by frequency of fluctuations of species population, stability has been reported to increase with succession whereas if stability of an ecosystem is defined in terms of time to be taken for a community to return to its former condition, stability may actually decrease through time.

14.7 FUNCTIONING OF ECOSYSTEMS

The functioning of an ecosystem depends upon the pattern of energy flow because all aspects of living components of an ecosystem depend on energy flow which also helps in the distribution and circulation of organic matter within the ecosystem. While the energy flow follows cyclic paths. Here, a brief discussion is presented so as to have a general idea of the functioning of ecosystem.

The energy pattern and flow are governed by the first and second law of thermodynamics. **The first law of thermodynamics states** that in any system of constant mass, energy is neither created nor destroyed but it can be transferred from one type to another type (example, electrical energy can be converted into mechanical energy). In terms of ecosystem the energy flow or input in a system is balanced by energy outflow. **The second law of thermodynamics** states that when work is done, energy is dissipated and the work is done when one form of energy is transformed into another form. In the context of ecosystem there is dissipation of energy from each transfer point (trophic level) and thus the dissipated or lost energy is not again available to the ecosystem.

Solar radiation is the basic input of energy entering the ecosystem. The radiant solar energy is received by the green plants. Most of the received solar energy is converted into heat energy and is lost from the ecosystem to the atmosphere through plant communities. Only a small portion of radiant solar energy is used by plants to make food through the process of photosynthesis. Thus, green plants transform a part of solar energy into food energy or chemical energy which is used by the green plants to develop their tissues and thus store d in the primary producers or autotrophs at the bottom of the trophic levels. The chemical energy stored at trophic level one becomes the source of energy t the herbivores at trophic level two of the food chain. Some portion of energy is lost from trophic level one through respiration and some portion is transferred to plant-eating (herbivores) animals at trophic level two. The transfer of energy from trohic level one (green plants) to trophic level two (herbivores) is performed through the intake of organic tissues (which contain potential chemical energy) of green plants by the herbivores. Thus the chemical energy consumed by herbivores helps in the building of their own tissues and is stored at trophuc level two and becomes the source of energy for carnivores at trophic level three. A substantial portion of chemical energy is released by carnivores at trophic level three through respiration because more energy is required for the work to be done by the carnivores at trophic level three (building of tissues, growing, movement, etc.).

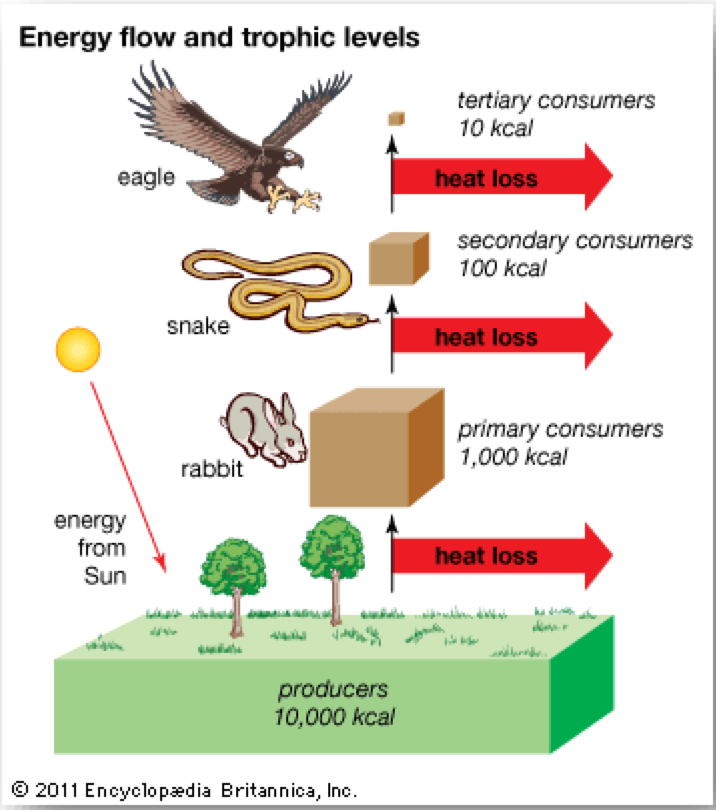


Figure 14.2
An Example of Energy Flow in Ecosystem

Some portion of potential chemical energy is transferred from trophic level three to trophic level four or top trophic level represented by omnivores (those animals which eat both plants and animals, man is the most important example of omnivores). The animals at trophic level four mainly man also take energy from trophic levels one and two. Again some portion of energy is released by omnivores through respiration. The remaining stored chemical energy in plants and animals is transferred to decomposers when they (plants and animals) become dead. The decomposers release substantial amount of energy through respiration to the atmosphere. It may be pointed out that at each trophic level the available potential chemical energy to be transferred to the next tropic level decreases as more energy is released through respiration to the atmosphere from each trophic level. Respiration means the chemical breakdown of food in the body and thus respiration releases heat which is transferred to the atmosphere.

Based on the above statement it may be summarized in the words of P. A. Furley and W. W. Newey:

'*Apart from the energy released to the atmosphere through respiration, the remaining energy is transferred in successive cosnumer stages known as trophic (literally nourishment) levels from autotrophs to heterotrophs. Ultimately, all the energy is passed on the deterivores, or decomposer animals.'*

-P. A. Furley and W. W. Newey, 1983

The circulation of elements or matter or nutrients (organic and inorganic both) is made possible through energy flow. In other words, energy flow is the main driving force of nutrient circulation in the various biotic components of the ecosystem. The organic and inorganic substances are moved reversibly in the biosphere, atmosphere, hydrosphere and lithosphere through various closed system of cycles in such way that total mass of these substances remains almost the same and are always available to biotic communities. In other words:

'the materials that make up the biosphere are distributed and redistributed by means of an infinite series of cyclic pathways motored by the continuous input of energy.'

-P. A. Furley and W. W. Newey, 1983

The materials or nutrients involved in the circulation within an ecosystem are grouped into three categories:

i. Macro elements- which are required in large quantities by the plants, e.g., oxygen, hydrogen, carbon, etc.
ii. Minor or Micro elements- which are required by plants in relatively smaller amounts, e.g., nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, etc.
iii. Trace elements- plants require a very small amounts of about 100 elements, important being iron, zinc, manganese, cobalt, etc.

Besides these inorganic chemical elements, there are organic materials as well which comprise:

i. Decomposed parts of either alive or dead plants or animals.
ii. Waste materials released by animals.

A few chemical elements act as organic catalysts or enzymes because they help chemical reactions but seldom undergo chemical change themselves. Such chemical elements are hydrogen, oxygen and nitrogen which belong to gaseous phase (that is they are found in the atmosphere is gaseous state-atmospheric reservoir or pool) and phosphate, calcium or sulphur which belong to sedimentary phase (that is they are found in weathered rocks and soils-sedimentary reservoirs or pool).

Thus these elements, derived from atmospheric and sedimentary reservoirs, are pooled into soils from where these are taken by plants in solution from through the process of root osmosis. The plants then convert these elements into such forms which are easily used in the development of plant tissues and plant growth by biochemical processes (generally photosynthesis). Thus, the nutrients driven by energy flow pass into various components of biotic communities through the process known as **'biogeochemical cycles'.** In a generalized form the biogeochemical cycles include the uptake of nutrients or inorganic elements by the plants through their roots in solution from the soils where these inorganic elements, derived from sedimentary phase, are stored. The nutrients are transported to various trophic levels through energy flow. Here the nutrients become organic matter and are stored in the biotic reservoirs of organic phase.

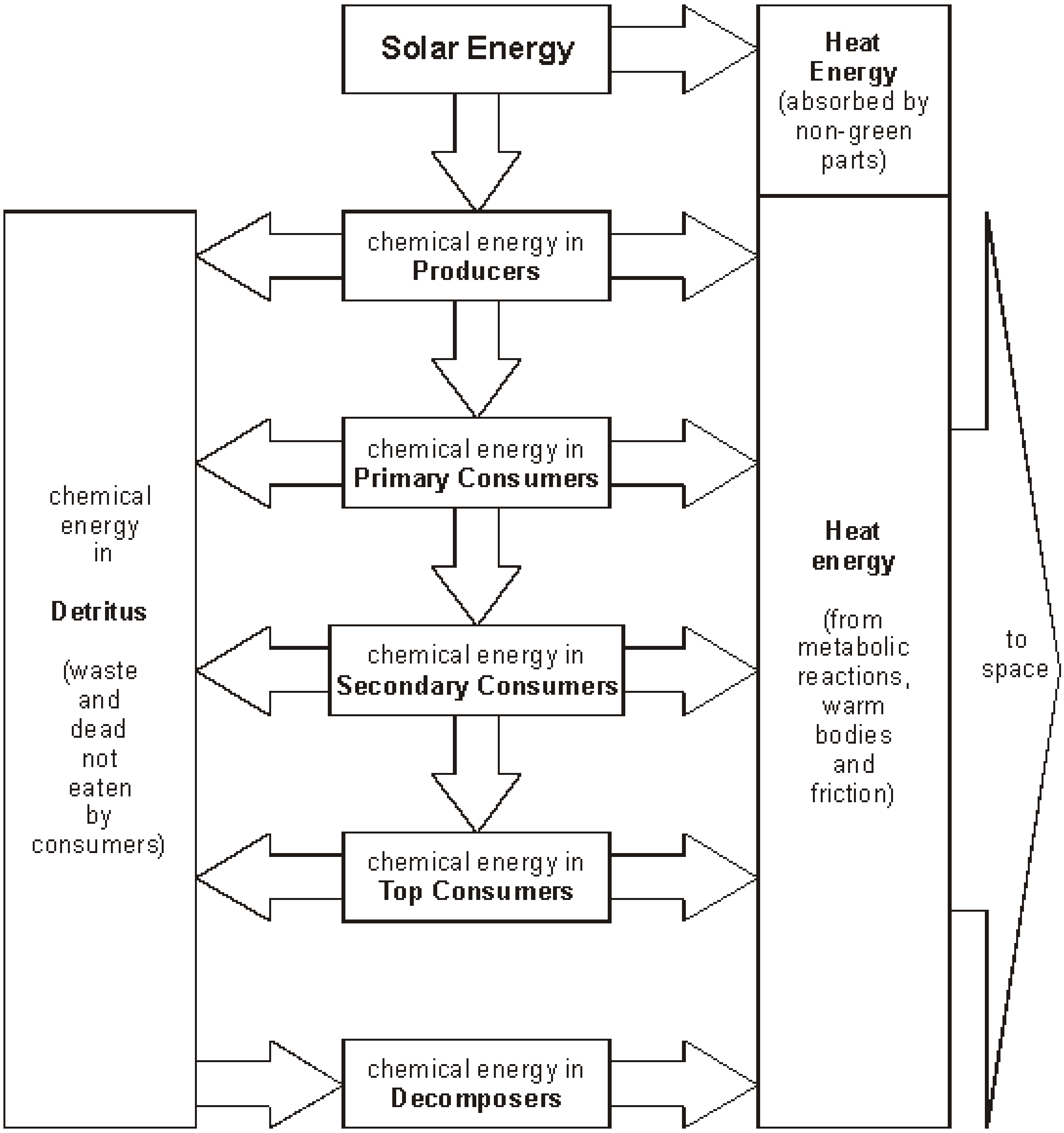


Figure 14.3

Diagrammatic representation of Energy Flow in an Ecosystem

The organic elements of plants and animals are released in a variety of ways:

i. Decomposition of leaf falls from the plants, dead plants and animals by decomposers and their conversion into soluble inorganic form.

ii. Burning of vegetation by lightning, accidental forest fires or deliberate action of man. The portions of organic matter on burning are released to the atmosphere and these again fall down, under the impact of precipitation, on the ground and become soluble inorganic form of element to join soil storage, while some portions in the form of ashes are decomposed by bacterial activity and join soil storage.

iii. The waste materials released by animals are decomposed by bacteria and find their way in soluble inorganic form of soil storage

Thus, biogeochemical cycles involve the movement and circulation of soluble inorganic substances (nutrients) derived from sedimentary and atmospheric phases of inorganic substances (the two basic components of inorganic phase) through biotic phase and finally their return to inorganic state. The study of biogeochemical cycles may be approached on two scales:

i. The cycling of all the elements together, or

ii. Cycling of individual elements, e.g., carbon cycle, oxygen cycle, nitrogen, phosphorus cycle, sulphur cycle, etc. Besides, hydrological cycle and mineral cycles are also included in the broader biogeochemical cycles.

Check Your Progress II

Q.1 Differentiate the types of ecosystems on the basis of source and level of energy.

____
____
____
____
____
____
____

Q.2 What do you mean by biogeochemical cycles?

____
____
____
____
____
____

Q.3 Explain the two laws on which the energy flow work in an ecosystem.

____
____
____
____
____
____

14.8 CONCLUSION

It makes us clear that the environment, habitat or ecosystem we live in is not as simple as it seems. It is much more complex all tied up together to perform specific functions altogether which help the ecosystem or the ecology to flourish. Any type of disturbance created in a small phase may result in a drastic change over time and affects almost all the link-ups of the chain. This clarifies that everything is bounded to each other, hence, to support it and conserve it is the very need of everyone on this planet.

14.9 SUMMARY

- Ecology is a science that studies the interdependent, mutually reactive and inter connected relationships between the organisms and their physical environment on one hand and among the organisms on the other hand.
- The term ecology has been derived from *'oecology',* made by two Greek words *'oikos'* means house or dwelling as habitat and *'logos'* meaning the study of.
- Ecosystem is 'A particular category of physical systems, consisting of organisms and inorganic components in a relatively stable equilibrium, open and of various sizes and kinds.'
- The term ecosystem was first used by A.G. Tansley in 1935.
- Ecosystems are regarded as the basic units of ecology by many ecologists because they are complex, interdependent and highly organized systems and because they are basic building blocks of biosphere.
- By learning how ecosystems function, we can improve our ability to predict how they will respond to changes in the environment.
- The nutrients driven by energy flow pass into various components of biotic communities through the process known as **'biogeochemical cycles'.**
- A **sere** represents the development of a series of sequential successions starting from primary succession and culminating into the last succession in a sere as *'climax'* or *'climatic climax'* which is the most stable situation of an ecosystem.

14.10 GLOSSARY

Biogeochemical cycle: The circulation and movement of soluble organic matter (nutrients) derived from sedimentary and atmospheric phases and reservoirs through organic phase of various biotic components and finally their return to inorganic phase is collectively called biogeochemical cycles.

Ecological Productivity: refers to the rate of growth of organic matter per unit area per unit time in a given natural ecosystem.

Food Chain: It is a sequence of energy transfer from the lower trophic levels to the higher trophic levels in a natural ecosystem.

Gross Primary Production: It is the total amount of energy produced by the autotrophs at trophic level one.

Homeostatic Mechanism: The 'inbuilt self-regulatory mechanism' in the environment or biospheric ecosystem, which counterbalances the changes in the natural factors by responses of the system to the changes and ultimately the ecosystem stability is restored, is called homeostatic mechanism.

Net Primary Production: The amount of energy or organic matter fixed or stored at trophic level one is called net primary ecological production, which excludes the amount of energy from gross primary production which is lost through respiration by the autotrophs. Thus, net primary production is gross primary production minus the energy lost through respiration.

Sere: A **sere** represents the development of a series of sequential successions starting from primary succession and culminating into the last succession in a sere as *'climax'* or *'climatic climax'* which is the most stable situation of an ecosystem.

14.11 ANSWER TO CHECK YOUR PROGRESS

Check Your Progress I

Ans.1 Ecosystems are regarded as the basic units of ecology by many ecologists because they are complex, interdependent and highly organized systems and because they are basic building blocks of biosphere.

Ans.2 By learning how ecosystems function, we can improve our ability to predict how they will respond to changes in the environment.

Check Your Progress II

Ans.1 Refer to section 14.6, point 5.

Ans.2 The nutrients driven by energy flow pass into various components of biotic communities through the process known as **'biogeochemical cycles'.** In a generalized form the biogeochemical cycles include the uptake of nutrients or inorganic elements by the plants through their roots in solution from the soils where these inorganic elements, derived from sedimentary phase, are stored. The nutrients are transported to various trophic levels through energy flow.

Ans.3 The energy flow and pattern is governed by the first and second law of thermodynamics:

Law I: In any system of constant mass, energy is neither created nor destroyed but it can be transferred from one type to another type. The energy flow or input in a system is balanced by energy outflow.

Law II: When work is done, energy is dissipated and the work is done when one form of energy is transformed into another form.

14.12 REFERENCES

Wilson, E. O., 1992. *The Diversity of Life,* Cambridge, Harvard University Press.

World Resources, 1998-1999, joint publication by the World Resource Institute (WRI), UNEP, UNDP and the World Bank, Oxford University Press, 1998.

Leith, Helmut and R. H. Whittakar, (eds.), 1995, *The Primary Production of Biosphere,* New York, Springer-Velag.

Peters, R. L. and T. E. Lovjoy, (eds.), *Global Warming and Biological Diversity,* New Haveen, Yale University Press.

Odum, 1985, *Ecology,* London.

14.13 SUGGESTED READINGS

Christopherson, R. W., 1995, *Elemental Ecosystems,* New Jersey, Prentice Hall.

Husain M., 1999, *Human Geography,* Jaipur, Rawat Publications.

Husain M., 1998, *Systematic Agricultural Geography,* Jaipur, Rawat Publications.

Strahler, A., 1996, *Physical Geography,* New York, John Wiley & Sons.

14.14 TERMINAL QUESTIONS

Q.1 What do you mean by Ecology? Explain it by the reference of its principles.
Q.2 What is an ecosystem? Write special characteristics of ecosystem
Q.3 Explain the Different types of ecosystems.
Q.4 Give a detailed account of the functioning of ecosystem, alon with a simplified diagrammatic representation.

UNIT 15 -BIO -DIVERSITY AND ITS DEPLETION

15.1 OBJECTIVES

15.2 INTRODUCTION

15.3 BIO-DIVERSITY: MEANING AND CONCEPT

15.4 DISTRIBUTION OF BIODIVERSITY

15.5 BIODIVERSITY DEPLETION AND ITS CAUSES

- **15.5.1 Habitat destruction**
- **15.5.2 Introduced and invasive species**
- **15.5.3 Genetic pollution**
- **15.5.4 Overexploitation**
- **15.5.5 Hybridization, genetic pollution/erosion and food security**
- **15.5.6 Climate change**
- **15.5.7 Human overpopulation**

15.6 CONSERVATION

15.7 PROTECTION AND RESTORATION TECHNIQUES

15.8 CONCLUSION

15.9 SUMMARY

15.10 GLOSSARY

15.11 ANSWER TO CHECK YOUR PROGRESS

15.12 REFERENCES

15.13 SUGGESTED READINGS

15.14 TERMINAL QUESTIONS

15.1 OBJECTIVES

After studying this unit, you should be able to:

- Understand the concept of Biodiversity and Define genetic, species and ecosystem diversity.
- Describe the hot-spots and threats to biodiversity.
- Differentiate In-situ and Ex-situ conservation of biodiversity

15.2 INTRODUCTION

Biodiversity or biological diversity is the foundation of life on the earth. It is crucial for the functioning of ecosystem which provides us with products and services without which we couldn't live. Biodiversity is extremely complex, dynamic and varied like other features of the earth. Its innumerable plants, animals and microbes physically and chemically unite the atmosphere, geosphere and hydrosphere into one environmental system which makes it possible for millions of species, including people, to exist.

The increasing interest in biodiversity is a result of concern regarding species extinction, depletion of genetic diversity and disruption in the atmosphere, water supplies, fisheries and forests.

15.3 BIODIVERSITY: MEANING AND CONCEPT

Biodiversity is a combination of two words 'biological' and 'diversity'. Biologist most often defines biodiversity as the 'totality of genes, species and ecosystem of a region'. A few definition of biodiversity are given in Box 15.1.

In brief, biodiversity is that part of nature which includes the differences in genes among individuals of a species, the variety and richness of all the plant and animals species at different scales in space-locally, in a region, in the country and the world; and the types of

Box 15.1: Definitions of Biodiversity

1. 'Biodiversity is the full variety of the biosphere. All the species of living organism, including plants, animals and microorganism. Biodiversity also includes the genetic variability within species and the biotic communities in which they interacts'. (Joseph Kerski and Simon Ross,2005)
2. 'A term describing the variety of species, both flora and fauna, contained within an ecosystem'. (John Small and Michael Withesick, 1995)
3. 'The variability among living organism from all sources, including, "inner alia", terrestrial, marine and other aquatic ecosystem and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystem'. (United Nations Earth Submit, 1992)

ecosystem, within a defined area.

The Biodiversity is abbreviated form of Biological Diversity. The term first coined by Walter G. Rosen in 1986. As a concept, it has aggravated the debate and understanding among the general public and academician alike. A lot has been discussed on the subject since its first appearance at the National Forum on Biodiversity in September, 1986. But what is biodiversity, what threatens it, why is it important and what are we geographers doing to better understand it?

The Biodiversity is defined as *the variety of life on Earth, it includes all organisms, species, and populations; the genetic variation among these; and their complex assemblages of communities and ecosystems.*

Further it also refers to the interrelatedness of genes, species, and ecosystems and in turn, their interactions with the environment.

15.3.1 Types of Biodiversity

The expression of biodiversity is the biological resources (genes, species, organisms, ecosystems) and ecological processes of which they are part. Biodiversity is therefore considered at 3 major levels: genetic, species and ecosystem diversity.

1. **Genetic Diversity:** This is the variety of genetic information contained in all of the individual plants, animals and microorganisms occurring within populations of species. Simply it is the variation of genes within all the different genes contained in all the living species, including individual plants, animals, fungi, microorganisms and populations.

2. **Species Diversity**: This is the variety of species or the living organisms. *Species Richness* - This refers to the total count/number of species in a defined area. Various indices are used including the Mangalet index and Menhink index. *Species Abundance* - This refers to the relative numbers among species. If all the species have the same equal abundance, this means that the variation is high hence high diversity, however if the one species is represented by 96 individuals, whilst the rest are represented by 1 species each, this is low diversity. Taxonomic or phylogenetic diversity - This considers the genetic relationships between the different groups of species. The measures are based on analysis, resulting into a hierarchical classification representing the phylogenetic evolution of the taxa concerned. Is all the different species, as well as the differences within and between different species?

3. **Ecosystem Diversity** is all the different habitats, biological communities and ecological processes, as well as variation within individual ecosystems. There is large variety of different ecosystems on the earth, each having their own complement of distinctive interlinked species based on differences in the habitat. Ecosystem diversity can be described for a specific geographical region, or a political entity such as country,

a state or a taluka. Distinctive ecosystem includes landscape like forests, grasslands, deserts, mountain etc. as well as aquatic ecosystem like river, lakes and seas. Each region also has man modified areas such as farmland of grazing pastures.

15.3.2 Importance of Biodiversity

The value and importance of biodiversity are viewed in terms of benefits we get directly or indirectly from biological communities comprising plants, animals and micro-organism. Biodiversity provides a variety of environmental services through its species and ecosystem that are essential at the global, regional and local level. The production of oxygen, reduction of carbon dioxide, maintaining the water cycle, and protecting soil are some important services. The world now acknowledges that the loss of biodiversity contributes to global climate changes.

1. Direct Use Value: refers to the assignment of value to those ecological products which are directly harvested from plants and animals such as food, seeds, timber, skins, furs etc.
2. Indirect Use Value: is assigned to those ecological resources which are intangible and not directly exploited and consumed, such as sight-seeing, bird watching, animal watching (eco-tourism) etc. the other items of indirect use of biodiversity include ecological services such as purification of air and water, moderation of weather and climate, absorption of emission of carbon dioxide from anthropogenic sources, regulation of hydrological cycle, creation and maintenance of soils and enrichment of soil fertility etc.

15.4 DISTRIBUTION OF BIODIVERSITY

Biodiversity is not evenly distributed; rather it varies greatly across the globe as well as within regions. The spatial distribution of the organisms, species, and populations depends on a number of factors and their complex temporal relations. The major factors which affect the biodiversity of the region include the climate, altitude, soils, presence of other species etc. Different regions on the planet have specific sets of environmental conditions, which results in differences in predominant vegetation.

Generally, there is an increase in biodiversity from the poles to the tropics. Thus, locations at lower latitudes have more species than localities at higher latitudes. This is often referred to as the latitudinal gradients in species diversity. Even though terrestrial biodiversity declines from the equator to the poles, some studies claims that this characteristic is unverified in aquatic ecosystem, especially in marine ecosystem. Species residing in different regions are characterized by specific adaptations that allow success under the particular set of environmental conditions of the region. Regions can be broadly divided into terrestrial biomes and aquatic ecosystems

The Biome is abbreviation of Biological Home. The environmentalists are not unanimous over the universal definition as well as classification of biome. A Biome is a large geographical area of distinctive plant and animal groups, which are adapted to that particular environment. Here, all the biota has the minimum common characteristics and all the areas of biomes are characterized by more or less uniform environmental conditions. Although, a biome includes both plant and animal communities but a biome is usually identified and named on the basis of its dominant vegetation, which normally constitutes the bulk of the biomass. These vegetations are most obvious and conspicuous visible component of the landscape. Biomass is the total weight of all living organisms' viz. plants and animals, found in the biome. A biome is not an ecosystem. If you take a closer look, you will notice that different plants or animals in a biome have similar adaptations that make it possible for them to exist in that area. There are many major biomes on earth.

Major Biomes of the world

In first order classification, the major biomes of the world can be classified into two in first order classification.

Classification of Biomes

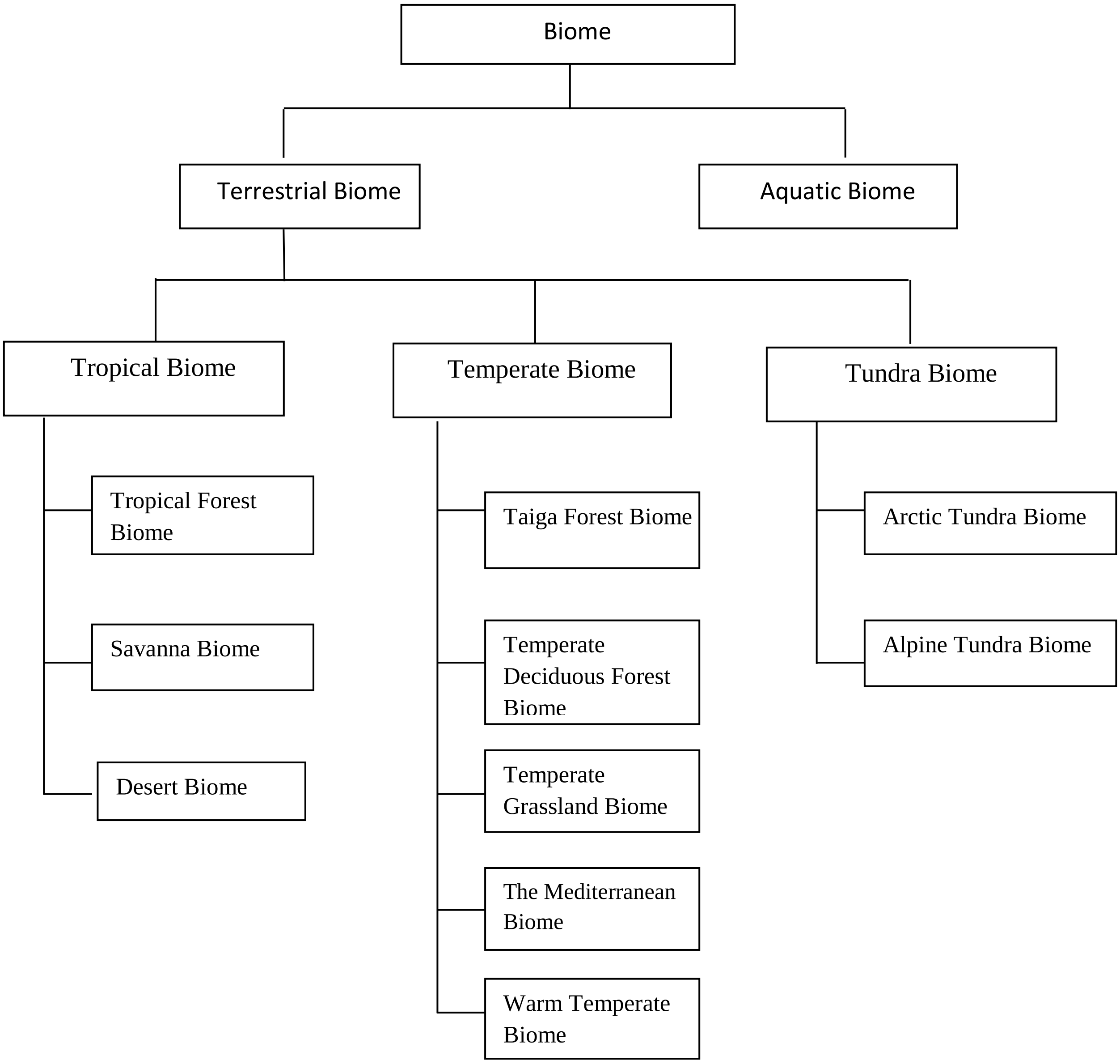


Figure 15.1

Terrestrial Biomes

Terrestrial biomes are distinguished primarily by their predominant vegetation, and are mainly determined by temperature and rainfall. There is a close relationship between the world distributional patterns of plants and animal species and the climatic types of the world. Thus, based on this relationship the terrestrial biomes have been divided into 3 major biome types:

A. Tropical Biomes **B.** Temperate Biome **C.** Tundra Biome

Tropical biomes are further categorized into 3 types:

1. Tropical Forest Biome
2. Savanna Biome
3. Desert Biome

Tropical Forest Biome in next order categorization can be further arranged as following:

a) Evergreen Rain Forest Biome
b) Semi- Evergreen Forest Biome
c) Deciduous Forest Biome
d) Semi- Deciduous Forest Biome

World distribution of Tropical Rain Forest

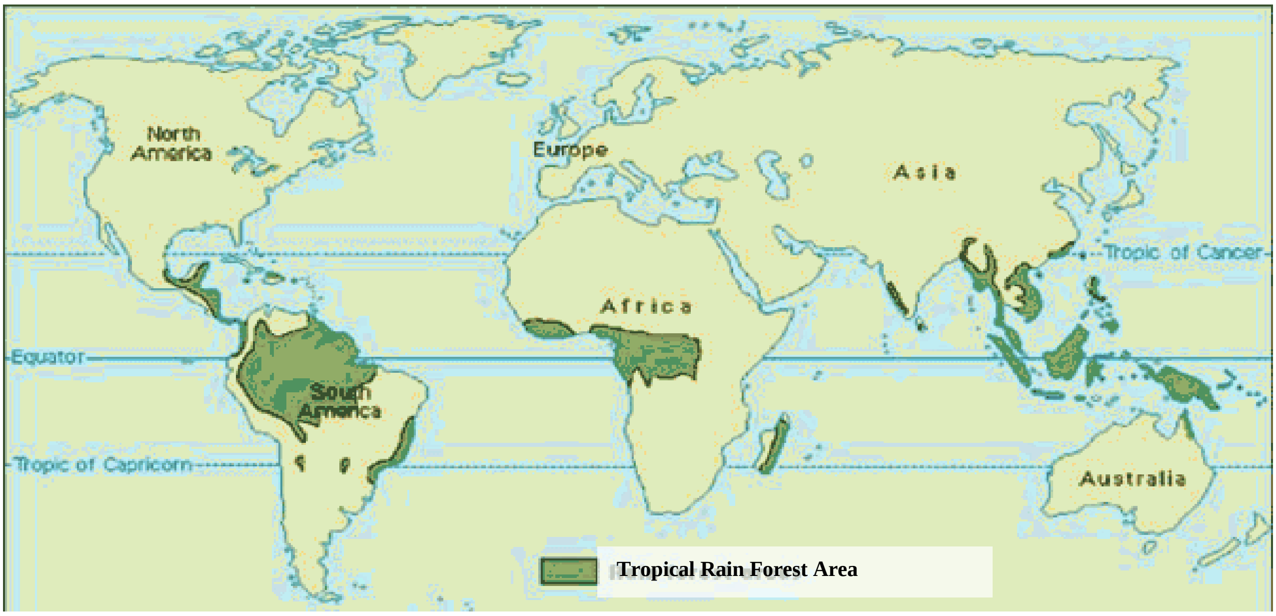


Figure 15.2

Among these, the Tropical Evergreen Rain Forest Biome is encompassing largest biodiversity and being discussed in detail in following section:

Tropical Evergreen Rain Forest Biome: The tropical rainforests are primarily located in the tropics, a band around the equator from 23.5ºN to 23.5ºS. Tropical rainforests are found in the world's hottest and wettest areas. Tropical rainforests are characterized in two words: warm and wet. Mean monthly temperatures exceed 18 °C (64 °F) during all months of the year. Average annual rainfall is no less than 168 cm (66 in) and can exceed 1,000 cm (390 in) although it typically lies between 175 cm (69 in) and 200 cm (79 in).

The tropical rainforest is earth's most complex biome in terms of both structure and species diversity. Tropical forests contain 70% of the world's vascular plants, 30% of all bird species and 90% of all invertebrates. The reason is that the tropical forest occurs under optimal growing conditions: abundant precipitation and year round warmth. Climates where tropical rain forests develop (in Walter's equatorial climate zone) are always warm and receive at least 200 cm of precipitation throughout the year, with no less than 10 cm during any single month. These conditions prevail in three important regions within the tropics (Figure 15.2). First, the Amazon and Orinoco basins of South America, along with additional areas in Central America and along the Atlantic coast of Brazil, constitute the Neotropical rain forest. Second, the area from southernmost West Africa and extending eastward through the Congo River basin makes up the African rain forest (with an added area on the eastern side of the island of Madagascar). Third, the Indo-Malayan rain forest covers parts of Southeast Asia (Vietnam, Thailand, and the Malay Peninsula); the islands between Asia and Australia, including the Philippines, Borneo, and New Guinea; and the Queensland coast of Australia. The tropical rain forest climate often exhibits two peaks of rainfall centered on the equinoxes, corresponding to the periods when the intertropical convergence lies over the equator. Rain forest soils are typically old and deeply weathered oxisols. Because they are relatively devoid of humus and clay, they take on the reddish color of aluminum and iron oxides and retain nutrients poorly.

In spite of the low nutrient status of the soils, rain forest vegetation is dominated by a continuous canopy of tall evergreen trees rising to 30–40 m. Occasional emergent trees rise above the canopy to heights of 55 m or so. Because water stress on emergent trees is great due to their height and exposure, they are often deciduous, even in a mostly evergreen rain forest. Tropical rain forests typically have several understory layers beneath the canopy, containing smaller trees, shrubs, and herbs, but these are usually quite sparse because so little light penetrates the canopy. Climbing lianas, or woody vines, and epiphytes, plants that grow on the branches of other plants and are not rooted in soil, are prominent in the forest canopy itself. Species diversity is higher than anywhere else on earth. Per unit of area, the biological productivity of tropical rain forests exceeds that of any other terrestrial biome, and their standing biomass exceeds that of all other biomes except temperate rain forests. Because of the continuously high temperatures and abundant moisture, plant litter decomposes quickly, and the vegetation immediately takes up the released nutrients. This rapid nutrient cycling supports the high productivity of the rain forest, but it also makes the rain forest ecosystem extremely vulnerable to disturbance. When tropical rain forests are cut and burned, many of the nutrients are carted off in logs or go up in smoke. The vulnerable soils erode rapidly and fill the streams with silt. In many cases, the environment degrades rapidly and the landscape becomes unproductive.

The tropical rainforest has dense vegetation. The combination of heat and moisture make this biome as perfect environment for a great variety of plants and animal species. A tropical rainforest is typically divided into four main layers, each with different plants and animals adapted for life in that particular area: the emergent, canopy, understory and forest floor layers.

The emergent layer contains a small number of very large trees called emergent, which grow above the general canopy, reaching heights of 45–55 m, although on occasion a few species will grow to 70–80 m tall. They need to be able to withstand the hot temperatures and strong winds that occur above the canopy in some areas. Most of them are hard wood trees like ebony, Mahogany, rose wood, sandalwood, cinchona, etc. **The canopy layer** contains the majority of the largest trees, typically 30–45 m tall. The densest areas of biodiversity are found in the forest canopy, a more or less continuous cover of foliage formed by adjacent treetops. The canopy, by some estimates, is home to 50 percent of all plant species, suggesting that perhaps half of all life on Earth could be found there. Epiphytic plants attach to trunks and branches, and obtain water and minerals from rain and debris that collects on the supporting plants. The most important plant of this group is palm trees.

Layers of diversity in tropical rain forest biomes

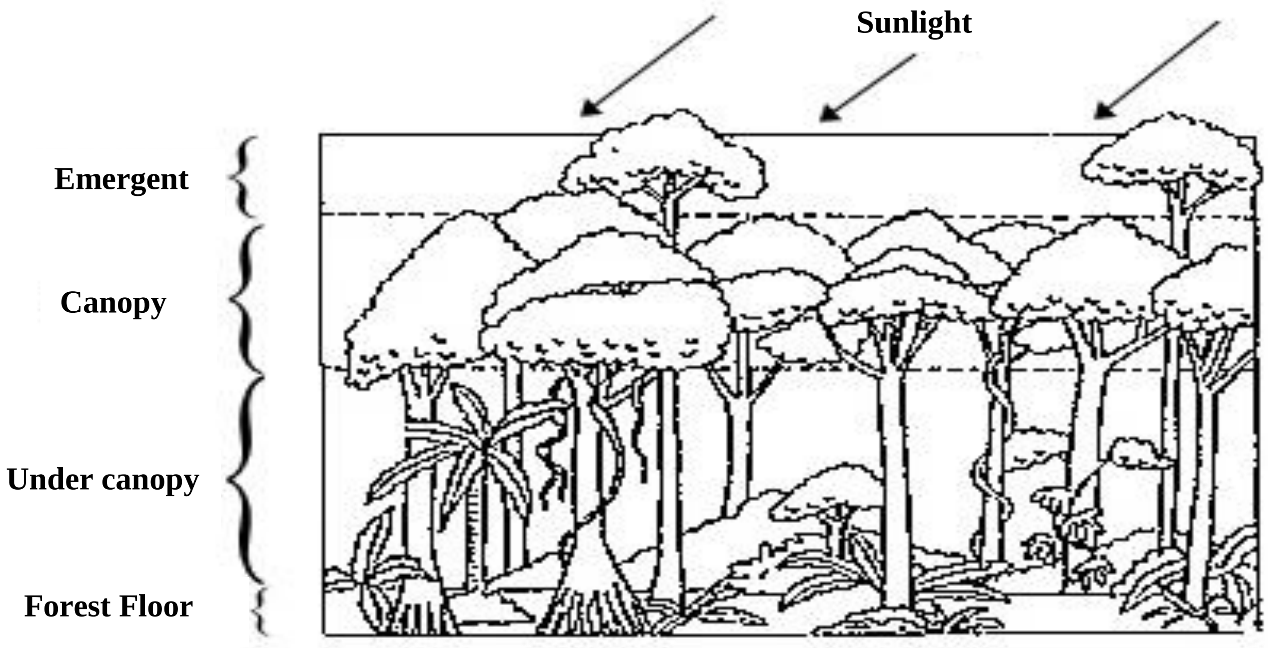


Figure 15.3

The under canopy layer lies the under canopy (between the canopy and the forest floor). The under canopy (or understory) is home to a number of birds, snakes and lizards, as well as predators such as jaguars, boa constrictors and leopards. The leaves are much larger at this level. Insect life is also abundant.

Animal diversity is also highest in this biome, with an almost incomprehensible variety of insects possible in a few hectares of rain forest. As in plants, many species are rare (few per unit area) and specialized. Large mammals are not diverse in primary forest, as locomotion is hindered by dense vegetation, but a few major orders (Chiroptera, Primates) are especially well represented. Other characteristic mammalian groups include tree shrews, squirrels, cavies, sloths, pangolins, forest deer and antelope, civets, and cats. Birds reach their greatest diversity in this zone, with over 500 species of birds recorded at single tropical localities of restricted extent. Characteristic groups include pigeons, parrots, hummingbirds, hornbills, toucans, ovenbirds, antbirds, cotingas, pittas, birds-of-paradise, babblers, bulbuls, and tanagers. Lizards, snakes, and frogs also exhibit their greatest diversity in the rain forest, including many groups restricted to it. Caecilians are a major amphibian group restricted to the tropics, mostly in forested areas. With so much water available, there is also a tremendous diversity of aquatic animals in this zone with alligators, tactless, fishes, frogs,

Box No. 15.2: Why Biodiversity Rich in Tropics?

- Over geological times the tropics have had a more stable climate than the temperate zones. In tropics, therefore, local species continued to live there itself, whereas in temperate they tend to disperse to other areas.
- Tropical communities are older than temperate ones and, therefore, there has been more time for them to evolve. This could are allowed them greater degree of specialization and local adaptation to occur.
- Warm temperature and high humidity in most tropical areas provide favorable conditions for many species that are unable to survive in temperate areas.
- In tropics, there may be greater pressure from pests, parasites and diseases. This does not allow any single species to dominate and thus there is opportunity for many species to co-exist. On the contrary in temperate zones there is reduced pest pressure due to cold, and there is one or a few dominating species that excludes many other species.
- Among plants, rates of outcrossing appear to be higher in tropics. Higher rates of outcrossing may lead to higher level of genetic variability.
- Tropical areas receive more solar energy over the year. Thus tropical communities are more productive or greater resource base that can support a wider range of species.

Hippopotamus etc., although the temperate-to-tropical diversity gradient is not as extreme as in most terrestrial groups.

Temperate Grassland Biome

Temperate grasslands are composed of a rich mix of grasses and forbs and underlain by some of the world’s most fertile soils. Temperate grasslands are located north of the Tropic of' cancer and south of the Tropic of Capricorn to up to 50 ^{o}- 55^{o} North and South. Grasslands are found on every continent except Antarctica and have local names. The major temperate grassland include the ‘steppes’ of' Eurasia, ‘prairies’ of North America, the 'pampas' of South America, ‘veld’ of Africa, and the ‘downs’ of Australia.

Temperatures in this biome vary greatly between summer and winter. The summers are hot and the winters are cold, it’s surprising how hot the grassland summers can get!

Sometimes the temperature is more than 100°F (37.8°C) while the winter temperature can be as low as -15°C. Rain in the temperate grasslands usually occurs in the late spring and early summer. The yearly average is about 20 - 35 inches (55 - 95 cm), but much of this falls as snow in the winter. Grasses are the dominant vegetation. Trees and large shrubs are largely absent. Seasonal drought, occasional fires and grazing by large mammals all prevent woody shrubs and trees from becoming established. A few trees such as cottonwoods, oaks and willows grow in river valleys, and a few hundred species of flowers grow among the grasses. The various species of grasses include purple needle grass, blue grama, buffalo grass, and galleta. Flowers include asters, blazing stars, coneflowers, goldenrods, sunflowers, clovers, psoraleas, and wild indigos.

All grasslands share a lack of shelter from predators, and an abundance of grass for food; therefore, grassland animal populations are similar throughout the world. The dominant vertebrates in grasslands are herbivorous or plant-eating grazers called ungulates. Ungulates are mammals with hoofs, like horses and deer. Their long legs help them run fast to escape grassland predators.

World's distribution of Temperate Grassland Biome

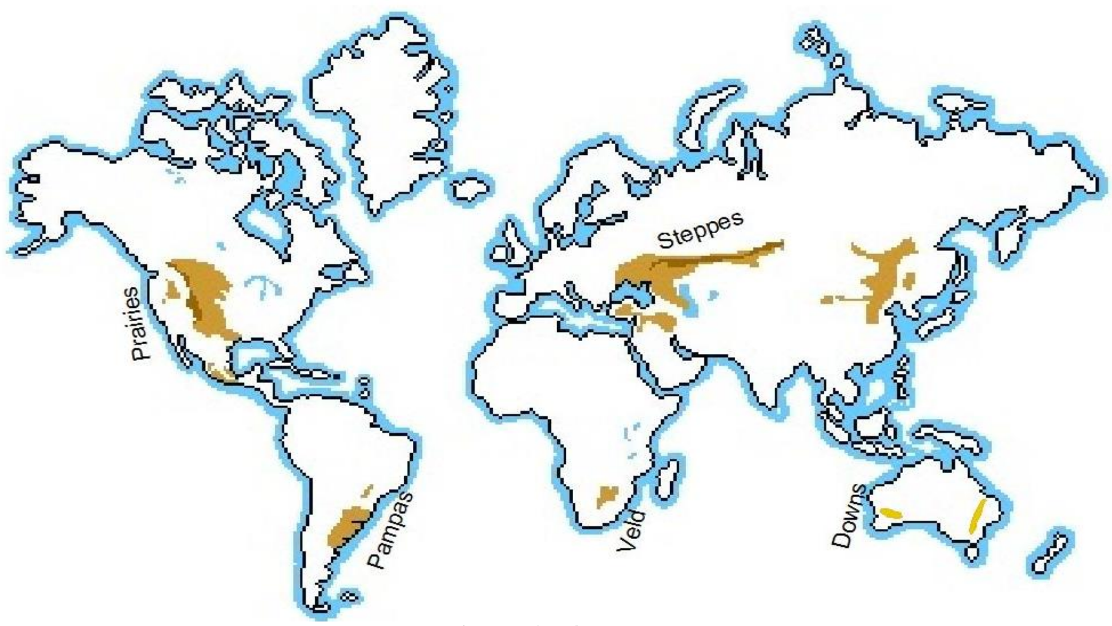


Figure 15.4

The temperate grassland fauna is very low in diversity, especially in comparison with the tropical grasslands. In North America the dominant herbivores are bison Bison bison) and pronghorn (the sole member of the Nearctic endemic family, Antilocapridae). Rodent herbivores include the pocket gopher (another Nearctic endemic), ground squirrels, and the prairie dog. Carnivores include coyote (actually an omnivore), badger, and the federally endangered black-footed ferret, the last two members of the weasel family. Birds include grouses, meadowlarks, quails, sparrows, hawks and owls. On the Russian steppes the fauna formerly included wisent (Bison bonasus), tarpan or wild horse, and saiga antelope, among others. Mole rats, fossorial members of one of the two mammal families endemic to the

Palearctic, are conspicuous by virtue their many mounds. Polecats and other members of the weasel family are among the larger, extant carnivores.

Table 15.1: Number of Species all over the World

Major Taxonomic Group	Number of Species
Higher Plants	2,70,000
Algae	40,000
Fungi	72,000
Bacteria	4,000
Viruses	1,550
Mammals	4,650
Birds	9,700
Reptiles	7,150
Fish	26,950
Insects	1,025.000
Worms	25,000
Other	110,000

Source: Gibbs, W (2011)

Arctic Tundra Biome

The Arctic tundra is the biome that lies between the edge of the taiga (or boreal forest), or tree line, and the permanent ice caps closer to the North Pole or the Arctic Ocean. Often thought of as a barren and somewhat rocky biome, the tundra surrounds the pole and is the dominant biome in the Arctic and Subarctic regions. The word "tundra" comes from a word used by the Sami people of northwestern Russia that means "barren land" or "treeless land." The tundra is the world's youngest biome, having formed about 10,000 years ago at the end of the last ice age.

Arctic Tundra Biome

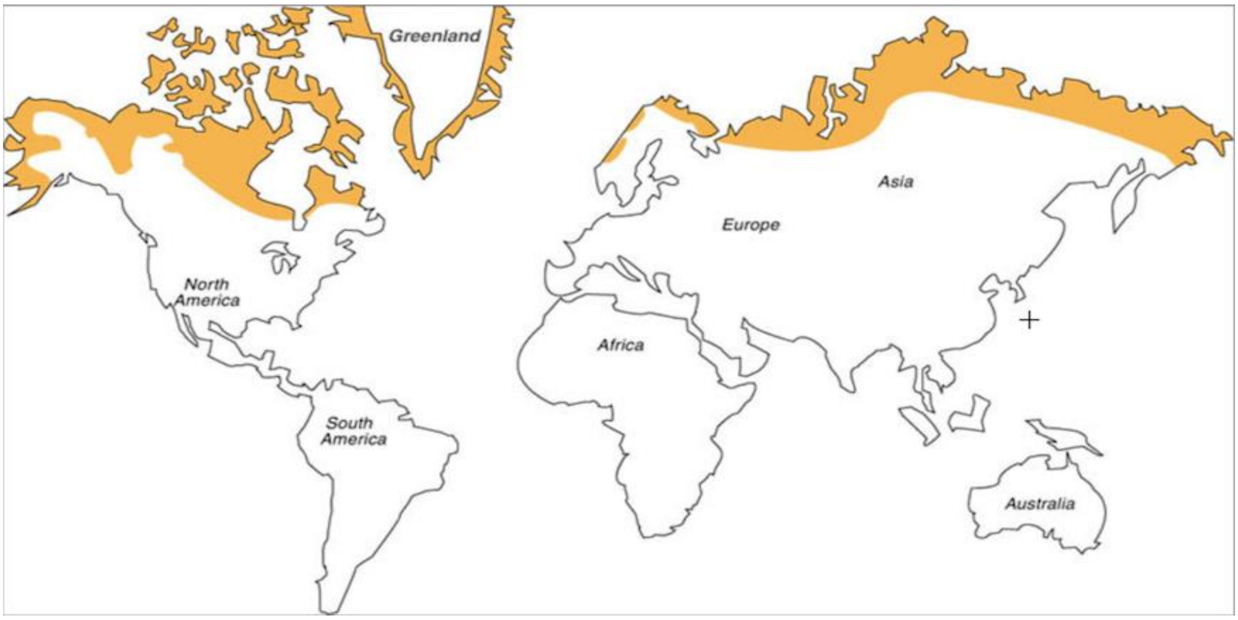


Figure 15.5

The climate of the Arctic is largely determined by the relatively low solar angles with respect to the earth. Differences in photoperiod between summer and winter become more extreme toward the north. Beyond the Arctic Circle, the sun remains above the horizon at midnight on midsummer's day and remains below the horizon at midday on midwinter's day. The arctic is known for its cold, desert-like conditions. The growing season ranges from 50 to 60 days. The average winter temperature is -34° C (-30° F), but the average summer temperature is 3-12° C (37-54° F) which enables this biome to sustain life. Rainfall may vary in different regions of the arctic. Yearly precipitation, including melting snow, is 15 to 25 cm (6 to 10 inches). Soil is formed slowly. A layer of permanently frozen subsoil called permafrost exists, consisting mostly of gravel and finer material. The permafrost itself can reach between 300 to 1,500 feet deep. The permafrost severely hinders makes plant growth in the tundra. When water saturates the upper surface, bogs and ponds may form, providing moisture for plants. There are no deep root systems in the vegetation of the arctic tundra; however, there are still a wide variety of plants that are able to resist the cold climate. There are about 1,700 kinds of plants in the arctic and subarctic, and these include low shrubs, sedges, reindeer mosses, liverworts, and grasses, 400 varieties of flowers, crustose and foliose lichen.

All of the plants are adapted to sweeping winds and disturbances of the soil. Plants are short and group together to resist the cold temperatures and are protected by the snow during the winter. They can carry out photosynthesis at low temperatures and low light intensities. The growing seasons are short and most plants reproduce by budding and division rather than sexually by flowering. The fauna in the arctic is also diverse; the herbivorous mammals include lemmings, voles, caribou, arctic hares and squirrels etc.; the Carnivorous mammals include arctic foxes, wolves, and polar bears etc.; migratory birds include ravens, snow buntings, falcons, loons, sandpipers, terns, snow birds, and various species of gulls etc.; the insects include mosquitoes, flies, moths, grasshoppers, black flies and arctic bumble bees etc.; among fishes cod, flatfish, salmon, etc. The trout animals are adapted to handle long, cold winters and to breed and raise young quickly in the summer. Animals such as mammals and birds also have additional insulation from fat. Many animals hibernate during the winter because food is not abundant. Another alternative is to migrate south in the winter, like birds do. Reptiles and amphibians are few or absent because of the extremely cold temperatures. Because of constant immigration and emigration, the population continually oscillates.

Aquatic Biome

Water is the common link among the five biomes and it makes up the largest part of the biosphere, covering nearly 75% of the Earth's surface. Aquatic regions house numerous species of plants and animals, both large and small. In fact, this is where life began billions of years ago when amino acids first started to come together. Although water temperatures can vary widely, aquatic areas tend to be more humid and the air temperature on the cooler side. The aquatic biome can be broken down into two basic regions, freshwater (i.e., ponds and rivers) and marine (i.e., oceans and estuaries). We are discussing here the marine region of aquatic biome. Marine regions cover about three fourths of the Earth's surface and include oceans, coral reefs, and estuaries. Marine algae supply much of the world's oxygen supply and take in a huge amount of atmospheric carbon dioxide. The evaporation of the seawater provides rainwater for the land.

The largest of all the ecosystems, oceans are very large bodies of water that dominate the Earth's surface. Like ponds and lakes, the ocean regions are separated into separate zones: intertidal, pelagic, abyssal, and benthic. All four zones have a great diversity of species. Some say that the ocean contains the richest diversity of species even though it contains fewer species than there are on land. The **intertidal zone** is where the ocean meets the land—sometimes it is submerged and at other times exposed, as waves and tides come in and out. Because of this, the communities are constantly changing. On rocky coasts, the zone is stratified vertically. Where only the highest tides reach, there are only a few species of algae and mollusks. In those areas usually submerged during high tide, there is a more diverse array of algae and small animals, such as herbivorous snails, crabs, sea stars, and small fishes. At the bottom of the intertidal zone, which is only exposed during the lowest tides, many invertebrates, fishes, and seaweed can be found. The intertidal zone on sandier shores is not as stratified as in the rocky areas. Waves keep mud and sand constantly moving, thus very few algae and plants can establish themselves—the fauna include worms, clams, predatory crustaceans, crabs, and shorebirds.

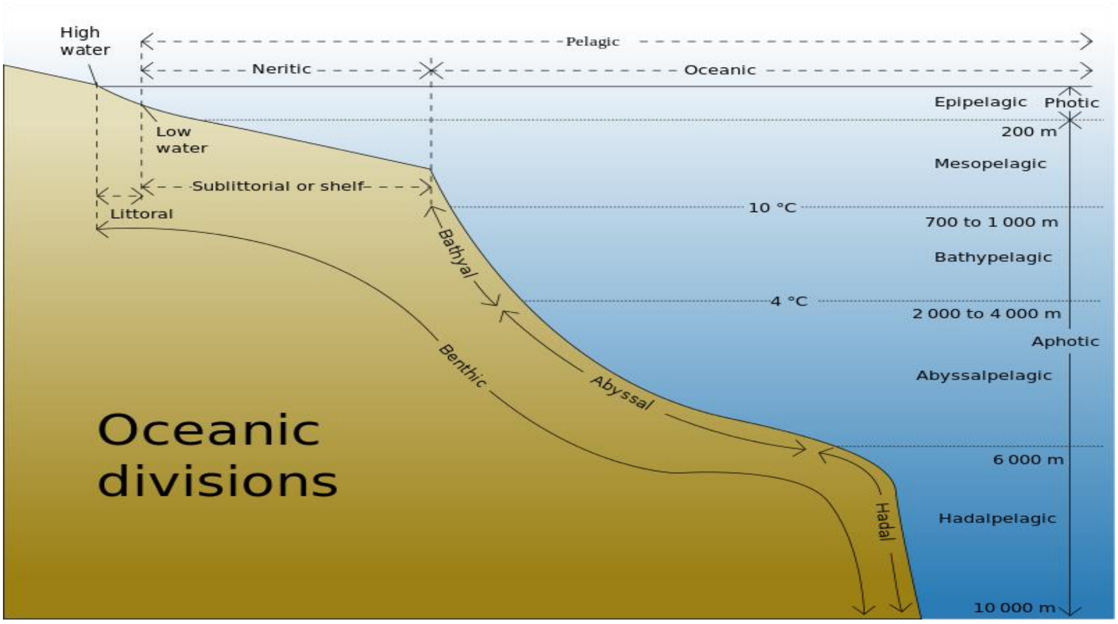


Figure 15.6: Zones of Aquatic Biome

The pelagic zone includes those waters further from the land, basically the open ocean. The pelagic zone is generally cold though it is hard to give a general temperature range since, just like ponds and lakes, there is thermal stratification with a constant mixing of warm and cold ocean currents. The flora in the pelagic zone include surface seaweeds. The fauna include many species of fish and some mammals, such as whales and dolphins. Many feed on the abundant plankton.

The benthic zone is the area below the pelagic zone, but does not include the very deepest parts of the ocean (see abyssal zone below). The bottom of the zone consists of sand, slit, and/or dead organisms. Here temperature decreases as depth increases toward the abyssal zone, since light cannot penetrate through the deeper water. Flora are represented primarily by seaweed while the fauna, since it is very nutrient rich, include all sorts of bacteria, fungi, sponges, sea anemones, worms, sea stars, and fishes.

The deep ocean is the abyssal zone. The water in this region is very cold (around 3° C), highly pressured, high in oxygen content, but low in nutritional content. The abyssal zone supports many species of invertebrates and fishes. Mid-ocean ridges (spreading zones between tectonic plates), often with hydrothermal vents, are found in the abyssal zones along the ocean floors. Chemosynthetic bacteria thrive near these vents because of the large amounts of hydrogen sulfide and other minerals they emit. These bacteria are thus the start of the food web as they are eaten by invertebrates and fishes.

Coral reefs are widely distributed in warm shallow waters. They can be found as barriers along continents (e.g., the Great Barrier Reef off Australia), fringing islands, and atolls. Naturally, the dominant organisms in coral reefs are corals. Corals are interesting since they consist of both algae (zooanthellae) and tissues of animal polyp. Since reef waters tend to be nutritionally poor, corals obtain nutrients through the algae via photosynthesis and also by extending tentacles to obtain plankton from the water. Besides corals, the fauna include several species of microorganisms, invertebrates, fishes, sea urchins, octopuses, and sea stars. Estuaries are areas where freshwater streams or rivers merge with the ocean. This mixing of waters with such different salt concentrations creates a very interesting and unique ecosystem. Microflora like algae, and macroflora, such as seaweeds, marsh grasses, and mangrove trees (only in the tropics), can be found here. Estuaries support a diverse fauna, including a variety of worms, oysters, crabs, and waterfowl.

Box No. 15.3: Measuring Biodiversity

At its simplest level, diversity can be defined as the number of species found in a community, a measure is known as species richness. Many methods of calculating diversity have been propped that combine these two types of information. Mathematically indices of biodiversity have also been developed to connate species diversity at different geographical scales as follows.

1. Alpha Diversity: this refers to number of species in a single community. This diversity comes closest to the popular concepts of species richness and can be used to compare the number of species in different ecosystem types.

2. Beta Diversity: this refers to the degree to which species composition changes along environmental gradients. Beta diversity is high for example, if the species composition of mass communities changes at successively higher elevations on a mountain slope, but it low if the same species occupy the whole mountain side.

3. Gamma Diversity: this applies to larger geographical scales and defined as "the rate at which additional species are encountered as geographical replacements within a habitat type in different localities. Thus gamma diversity is a species turnover rate with

Biodiversity Hotspot

The term 'biodiversity hotspot' was first coined and used by Nornam Myers, a British ecologist, in the year 1998. He defined biodiversity hotspot as those areas which have rich biological communities including plants, animals and microorganism wherein endemic species predominate. He identified 10 such very rich biodiversity areas i.e. tropical rainforest biomes.

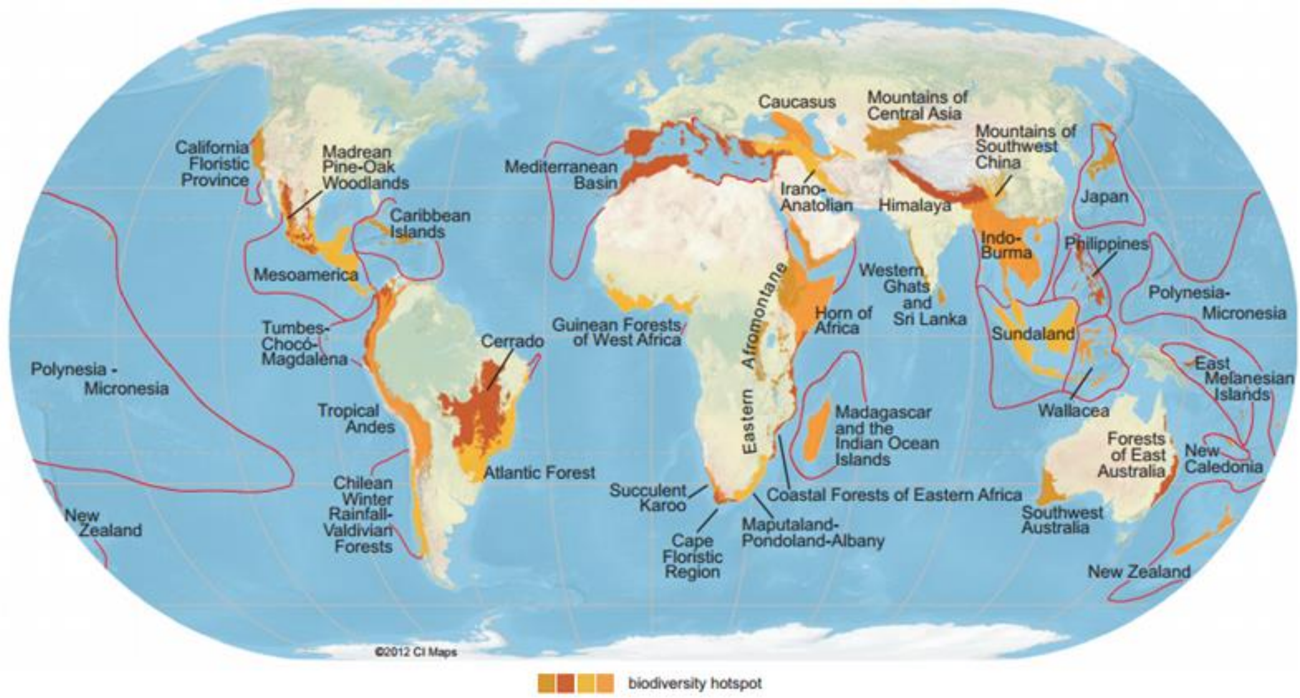


Figure 15.7: Biodiversity Hotspot around World

The regions or areas having richest biodiversity are called 'biodiversity hotspot' or 'mega-diversity regions'. The hotspot of biodiversity are, in fact, such areas which are characteristics by high level of biological diversity and large percentage of endemic species such as Amazonia, Malaysian Peninsula, New Zealand, Madagascar, South Africa, North-eastern Australia, Western Ghats of India, Philippines, Tropical Andes, Eastern Himalaya, Mediterranean region etc. in all, about 34 hot spot of rich biodiversity have been identified in the world of which 3 hot spots are found in India e.g. (1) Western Ghats, (2) North-Eastern India, and (3) Himalayas.

According to Mora and Colleagues, the total number of terrestrial species is estimated to be around 8.7 million, while the number of oceanic species is much lower, estimated at 2.2 million.

According to the Global Taxonomy, initiatives and the European Distributed Institute of Taxonomy the total number of species for some phyla may be much higher than what is shown in table 15.2.

- 10-30 million insects; (of some 0.9 million we know today)
- 5-10 million bacteria
- 1.5 million fungi;

- 1 million mites

Table 15.2: Estimated Species on Earth and Oceans

Species	Earth			Ocean		
	Catalogued	Predicted	SE	Catalogued	Predicted	SE
Animalla	9,53,434	7,770,000	958,000	171,052	2,150,000	145,000
Chromista	13,033	27,500	30,500	4,859	7,400	9,640
Fungi	43,271	611,000	297,000	1,097	5,320	11,100
plantae	215,644	298,000	8,200	8,600	16,600	9,130
Protozoa	8,118	36,400	6,690	8,118	36,400	6,690
Bacteria	10,860	10,100	3,630	652	1,320	436

Source: Mora, C (2011)

Taxonomists are aware that their work in finding and describing new species is incomplete. Whatever the number, the plants biodiversity represents an amazing and diverse storehouse of biological wealth.

Biodiversity of India

India is one of the twelve mega-biodiversity countries. Each of the ten biogeographic zones of the country has characteristics biota, and broadly represents similar climatic conditions and constitutes the habitat for diverse species of flora and fauna. Based on a survey of about two-third of the geographical area of the country, the Ministry of Forest and Environment reported that India have at present about 45,000 plants and 77,000 of animals species representing about 7 percent of the world flora and 6.5 percent of the global biodiversity.

Table 15.3: Biodiversity of India and its World Ranking

	India's world ranking	Number of species
Mammals	8^{th}	350
Birds	8^{th}	1,200
Reptiles	5^{th}	453
Amphibian	15^{th}	182
Angiosperms	15^{th}	14,500

India has 350 different mammals (rated the eighth highest in the world), 1,200 species of birds (eighth in the world), 453 species of reptiles. These includes, especially, high species diversity of ferns (1,022 species) and orchids (1,082 species). India has 50,000 known species of insects, including 13,000 butterflies and moths. It is estimated that the number of known species could be several times higher.

It is estimated that 18 percent of Indian plants are endemic to the country and found nowhere else in the world. Among the plants species, the flowering plants have much higher degree endemism, a third of these are not found elsewhere in the world. Among amphibians found in India, 62 percent are unique to this country.

India is also considered one of the world's eight centers of origin of cultivated plants. It has 51 species of cereals and millets, 104 species of fruits, 27 species of spices and condiments, 55 species of vegetables and pulses, 24 species of fibre crops, 12 species of oilseeds and various wild strains of tea, coffee, tobacco and sugar cane. India also has significant indigenous livestock diversity, with 27 breeds of cattle, 40 breeds of sheep and 22 breeds of goats

Among the 34 hotspot of the world, three Indian biodiversity hotspot extend to neighboring countries. In eastern Himalayas, numerous primitive angiosperm families as magnoliaceae and Winteraceae with primitive genera like Magnolia and Betula are found. Asian Elephants, Indian tigers and lion-tailed macaque are found in the Western Ghats.

The Himalayas and Western Ghats are the two Indian mountain biodiversity global hotspot. These both show rich and unique biodiversity in terms of rich species endemism. The richness and uniqueness of biodiversity in Himalayan hotspot 15.4.

Table 15.4: Some features of Indian Biodiversity

Attributes	Eastern Himalaya	Indo-Burma	Western Ghats	Andaman & Nicobar
Original area	741,706	2,373,057	189,611	1501,063
Vegetation Area	185,427	118,653	43,611	10,0571
Endemic Plant Species	3,160	7,000	3,049	15,000
Endemic threatened Birds	8	18	10	43
Endemic Threatened Mammals	4	25	14	60
Extinct Species	0	1	20	4
Protected area	112,578	235,758	26,130	179,723

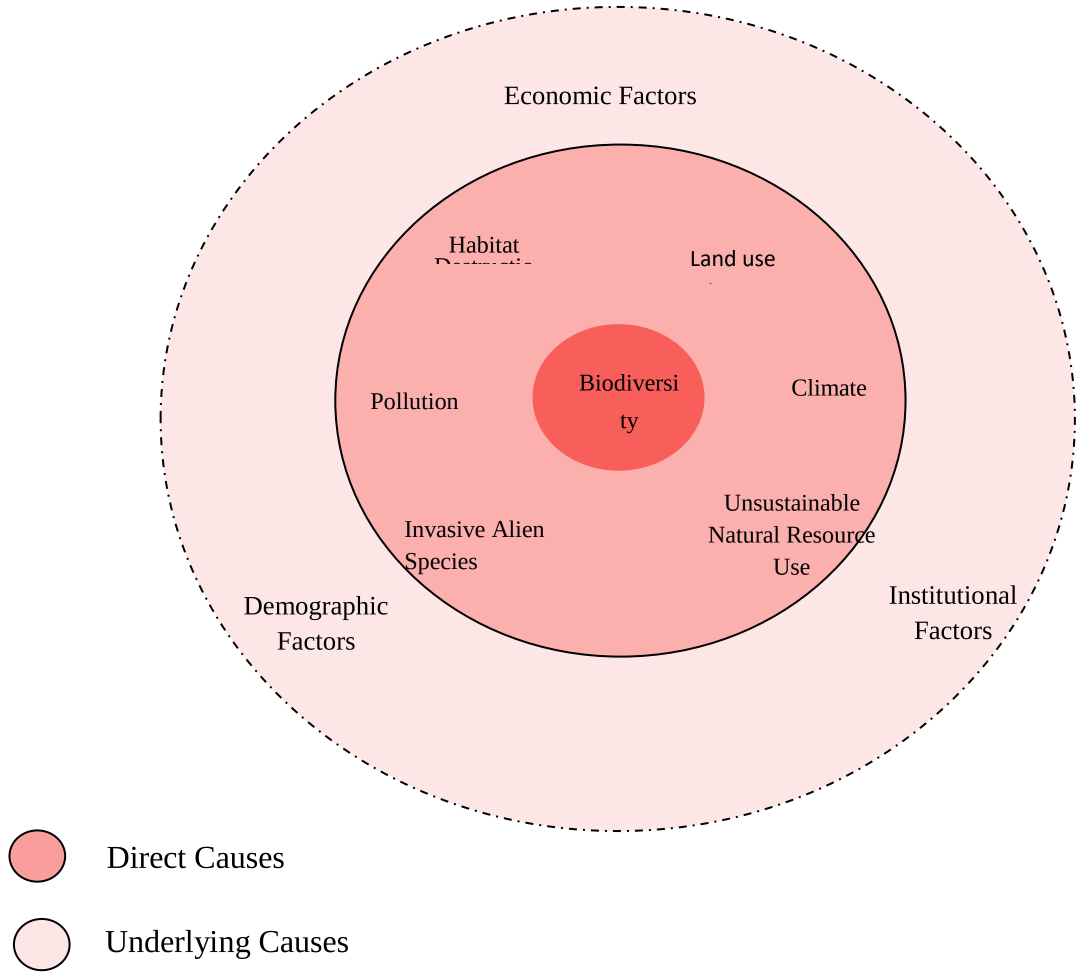
15.5 BIODIVERSITY DEPLETION AND ITS CAUSES

Biodiversity is vital to the sustenance of many ecosystem services such as food production, supply of raw materials, water provision, nutrients' recycling, biological control of populations of flora and fauna, regulation of chemical composition of the atmosphere, use of genetic resources, leisure activities and others. Biodiversity continues to deplete at unprecedented pace as human development and expansion result in the fragmentation and loss of habitat for flora and fauna. The loss of biodiversity is expected in most scenario studies to continue at an increasing pace in the coming decades.

The extinction of several species or loss of biodiversity is a major problem of the international world. Species are disappearing rapidly and there is growing consensus within the international community that a system should be put in place to slow or halt the process of extinction. All the species are the integral part of ecosystem and extinction of some species diminishes the well-being of the remaining species, including human being. The concern about biological diversity is the shrinking genetic pool. It is estimated that tropical forests contain at least 50 percent and perhaps, 90 percent of the world's species. According to an estimated, 20-75 species are becoming extinct each day because of deforestation in the tropics.

Before the appearance of economic man on this planet earth species extinction was caused only by natural processes but now anthropogenic processes of species extinction has outplayed natural process. For example, the rate of extinction of species has increased phenomenally after 1850 due to increased human activities, the average rate of extinction was two to three species per decade between 1600 and 1850 but the thereafter the rate increased to 1,000 species per decade. As per estimates of Paul Ehrlich, one third to two third of all species currently existing on this planet earth may become extinct by 2050.

The World Conservation Monitoring Centre has evaluated and described the threat to about 88,000 plants and 2,000 animal species in its series of Red Data Book. However, there are also species of fish (343), amphibians (50), reptiles (170), birds (1,037), and mammals (497).



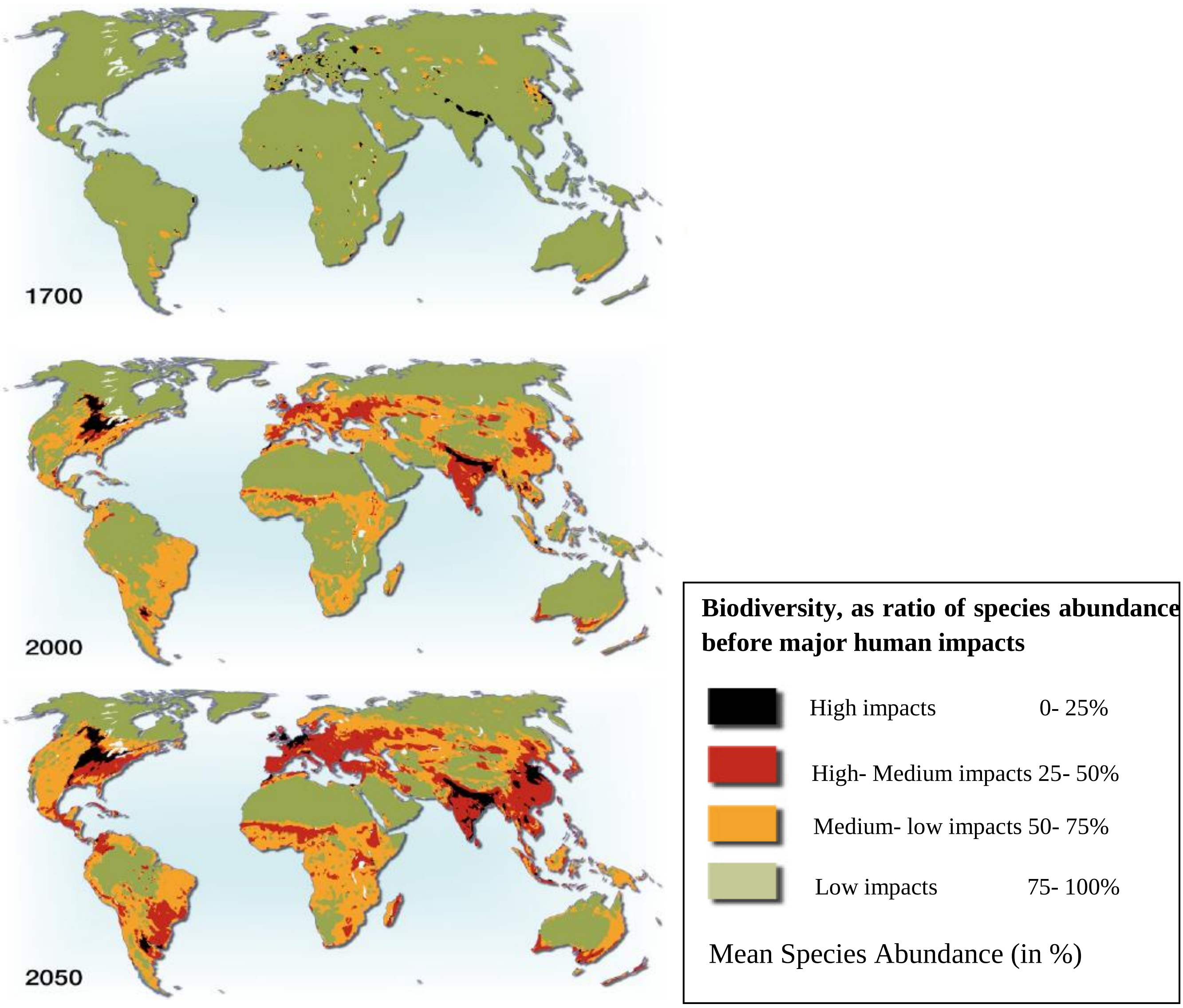


Figure No 15.9: Loss of biodiversity with continued agricultural expansion, pollution, and Climate change and infrastructure development

The major direct causes of human-induced biodiversity loss are the fragmentation, degradation or loss of habitats the over-exploitation of natural resources; pollution of air and water; the introduction of non-native (alien, or exotic) species and climate change-induced biodiversity loss; these factors being inextricably linked with some or all of the other direct causes and in turn are driven by underlying causes.

1. **Natural Cause:** As stated above biodiversity loss is a natural process of evolution of biological communities. With time some species become extinct and some new species evolved. Among the natural factor of biodiversity loss important cause are climate change at global level, prolonged drought and famine conditions, collision of earth with celestial bodies such as asteroids and meteoroids, volcanic eruptions and continental drift etc.

2. **Habitat Destruction and Land-use change:** Habitat loss is by far the leading factor of biodiversity loss. At least three-quarters of all threatened bird species are in trouble because human activities have transformed and fragmented unique habitats. Apparently stable areas of habitat may suffer from fragmentation, with significant impacts on their biodiversity. Fragmentation is caused by natural disturbance (such as fires or wind) or by land use change and habitat loss, such as the clearing of natural vegetation for agriculture or road construction, which divides previously continuous habitats. Larger remnants, and remnants that are close to other remnants, are less affected by fragmentation. Small fragments of habitat can only support small populations, which tend to be more vulnerable to extinction. Moreover, habitat along the edge of a fragment has a different climate and favors different species to the interior. Small fragments are therefore unfavorable for those species that require interior habitat, and they may lead to the extinction of those species. Species that are specialized to particular habitats and those whose dispersal abilities are weak suffer from fragmentation more than generalist species with good dispersal ability. Fragmentation affects all biomes, but especially forests and major freshwater systems**.** More than 40,000 large dams and hundreds of thousands of smaller barriers plug up the world's rivers, altering water temperatures, sediment loads, seasonal flow patterns, and other river characteristics to which native fish are adapted. Levees disconnect rivers from their floodplains, eliminating backwaters and wetlands that are important fish spawning grounds. Engineering projects alter river inflows, and agricultural and industrial pollution of waterways further reduces fish habitat**.**

3. **Pollution:** Any undesirable change in the natural qualities of environment due to addition of physical, chemical and biological factors is called as pollution. The factors that contribute to pollution are called pollutants. Pollution of air, water and soil has a direct or indirect impact on the human, animal and plant life. Pollutants like pesticides, radioactive material, SO2, oxides of nitrogen, heavy metals, chlorofluorocarbon, chlorofluoro methane, silt and sewage etc., have become a cause for elimination many sensitive life forms. Air pollution affects biodiversity on a great scale. The atmosphere, lithosphere, and hydrosphere are all negatively affected by pollution. Pollution can be derived from two kinds of sources namely, stationary and multiple point sources. Stationary point sources include for example wood-burning fires (on a small scale) and the burning of coal in coal-fired electrical power plants (on a large scale). Multiple point sources are usually mobile and include automobiles and other vehicles. The vehicles are the most important source of atmospheric pollutants as they release carbon monoxide. This is followed by Industrials sources which release sulphur oxides, steam and electric power plants, space heating and lastly refuse burning.

Most water pollution is the result of the introduction of various substances into water bodies that have negative effects on ecosystems. In most modern industrial societies industry is the greatest source of pollution, accounting for more than half the volume of all water pollution and for the most deadly pollutants. Thousands of manufacturing facilities use huge quantities of freshwater to carry away wastes of many kinds. The waste-bearing water, or effluent, is discharged into streams, lakes, or oceans, which in turn disperse the polluting substances. Water pollution has, among other consequences, the tendency to cause long-term modifications of biodiversity. Eutrophication is one of the most noticeable long-term alterations. This phenomenon occurs within aquatic environments that are fed only little new water: lakes, ponds, slow rivers, river mouths. Some techniques, such as phyto-remediation, have been implemented in order to limit eutrophication.

Coastal waters and zones are the most biologically diverse marine environments; this applies to the water column, the shoreline and the seabed. These are also the areas in which spilled oil naturally tends to accumulate29. Taking this into consideration, one can easily see why large and very visible damage occurs to coastal zones in case an oil spill reaches the shoreline. Seabirds breeding and feeding in coastal areas are faced with a high rate of mortality. The same applies to various mammal species although their mortality rates are usually lower. Benthic organisms are usually heavily damaged, as are fish spawning areas and coastal and seabed vegetation. Human assets, such as aquaculture installations, tourism and leisure facilities but also infrastructure and industrial installations are affected in the short and medium term. On a more general level, this might even lead to an interference of work and social life.

4. **Climate Change:** Changes in climate throughout our planet's history have, of course, altered life on Earth in the long run ecosystems have come and gone and species routinely go extinct. But rapid, manmade climate change speeds up the process, without affording ecosystems and species the time to adapt. For example, rising ocean temperatures and diminishing Arctic sea ice affects marine biodiversity and can shift vegetation zones, having global implications. Climate change is a rapidly increasing stress on ecosystems and can exacerbate the effects of other stresses, including habitat fragmentation, loss and conversion, over-exploitation, invasive alien species, and pollution. Overall, climate is a major factor in the distribution of species across the globe; climate change forces them to adjust. But many are not able to cope, causing them to die out.

Climate change poses a major threat to the Arctic Ocean because it will dramatically affect its specific characteristics in turn affecting its fauna. In the Coral Triangle area, activities such as deforestation contribute to the emission of gases which stimulate climate change. Climate change is perhaps one of the main threats to biodiversity in the Coral Triangle. Although other factors have been mentioned, such as sedimentation, pollution and changes in salinity, climate change is most widely reported as the cause of coral bleaching. But also from other areas it is reported that that climate change affects the habitat quality and population dynamics of several species. Further, desertification may increase in some other areas and as a consequence some species could also become more vulnerable to extinction. Climate change has also been implicated in the decline of amphibians in tropical montane forests.

5. **Invasive Alien Species:** The introduction of non-native species into an ecosystem can threaten endemic wildlife (either as predators or competing for resources), affect human health and upset economies. An example of that is an infamous extinction of the dodo - a

bird native to the island of Mauritius in the Indian Ocean. Invasive alien species have been a major cause of extinction, especially on islands and in freshwater habitats, and they continue to be a problem in many areas. In freshwater habitats, the introduction of alien species is the second leading cause of species extinction, and on islands it is the main cause of extinction over the past 20 years, along with habitat destruction. Awareness about the importance of stemming the tide of invasive alien species is increasing, but effective implementation of preventative measures is lacking. Several aspects of environmental degradation facilitate the establishment of invasive species, like the transformation of coastlines and changes in land use. Another underlying cause is in connection with the management of flora and fauna, such as forestry, agriculture, horticulture and gardening, aquaculture, angling, the pet and aquarium industry and the leather industry. These economic activities contribute either to spread the species or to modify the ecosystems. Many of them have secondary effects since they appropriate a part of the primary productivity and introduce biological 'pollutants' such as genetically modified organisms (GMO).

6. **Unsustainable natural resource use:** Overexploitation remains a serious threat to many species and populations. Among the most commonly overexploited species or groups of species are marine fish and invertebrates, trees, and animals hunted for meat. Most industrial fisheries are either fully or overexploited, and the impacts of overharvesting are coupled to destructive fishing techniques that destroy habitat, as well as associated ecosystems such as estuaries and wetlands. Even recreational and subsistence fishing has contributed to what is known as the "shifting baselines" phenomenon, in which what we consider the norm today is dramatically different from pre-exploitation conditions. Many of the current concerns with overexploitation of bush meat (wild meat taken from the forests by local people for income or subsistence) are similar to those of fisheries, where sustainable levels of exploitation remain poorly understood and where the off take is difficult to manage effectively. Although the true extent of exploitation is poorly known, it is clear that rates of off take are extremely high in tropical forests. The trade in wild plants and animals and their derivatives is poorly documented but is estimated at nearly $160 billion annually. It ranges from live animals for the food and pet trade to ornamental plants and timber. Because the trade in wild animals and plants crosses national borders, the effort to regulate it requires international cooperation to safeguard certain species from overexploitation**.** The impact of mining on the environment largely depends on the method of mining adopted, the geo-mining conditions of the area in question, and the size and duration of the mining operations. In contrast to underground mining, open-cast mining usually results in extensive damage to the environment.

7. **Co-extinction:** The co-extinction of parasite and their host species is considered a common phenomenon in the current global extinction crisis. When a species becomes extinct, the plant and animal species associated with it in an obligatory way also become extinct. The case of a coevolved plant-pollinator mutualism where extinction of one invariably leads to the extinction of the other is a good example of it.

8. **Demographic Factors:** The world's population has more than tripled in the 20th Century, and continued growth is assured over the next 50 years, especially in the developing countries. Humankind's burgeoning numbers have an increasingly voracious appetite: people use or destroy about 40 percent of the net primary productivity of terrestrial and aquatic plants. At the present pace, the Earth's renewable resources are rapidly being depleted; the probable doubling of the world's population over the next 50 years will greatly increase these pressures. The issue of population is not only a matter of numbers, but also of patterns and levels of resource consumption. The average resident of an industrialized nation uses 15 times as much paper, 10 times as much steel, and 12 times as much fuel as a person in a developing country. Population growth and increasing resource consumption affect biodiversity in two ways: they create pressure to convert wildlife habitat into agricultural and urban land, and they produce wastes that pollute habitat and poison wildlife. These trends can be offset by stabilizing populations, using resources more efficiently, recycling, and controlling pollution.

9. **Economic Factors:** The structure of economic activity and how unequal a society is are also important underlying properties that drive biodiversity loss. The ‘economic footprint’ (the size of the economy relative to the country area), together with ‘income inequality’ were the best predictors of the proportion of threatened species. For instance, most of the countries in South East Asia are developing countries, with substantial numbers of people living below national poverty lines. Marine resources still directly sustain the lives of over 120 million people, while overfishing is regarded the most pervasive threat to coral reef biodiversity.

10. **Institutional Factors:** Institutional and governmental factors are regarded as crucial to improve biodiversity policies. Although in most western countries extensive legislative frameworks exist, biodiversity policy is far from successful. Failure of actors include, among others, a lack of political will of governments, international cooperation, and implementation of the measures and involvement of stakeholders. Especially developing countries face many challenges.

Biodiversity has declined over the years partly due to the lack of adequate governance that is required to make informed choices in connection to decision-making processes at different levels. Specifically, the failure to create institutions that can internalise the values of biodiversity within the decision-making of countries and individuals making conversion decisions is at the heart of the governance issue.

It is generally recognized that the current governance mechanisms at international level such as the CBD, the WTO and other for a include provisions for biodiversity conservation, but that the major difficulty lies in establishing the rights of indigenous people and communities who are the local custodians of biodiversity. Of particular concern is their right to participate in decision making, to access the biological resources on which they depend, and to receive an equitable share of the benefits and costs of using and protecting these resources. Although the CBD’s Articles 8(j) and 10(c) for example recognise the special role of indigenous and local communities in conservation and sustainable use, and provisions clearly recognise the importance of community knowledge for biodiversity decision-making and the need to respect community rights to customary use of biodiversity resources, the implementation of such principles in practice is far from satisfaction.

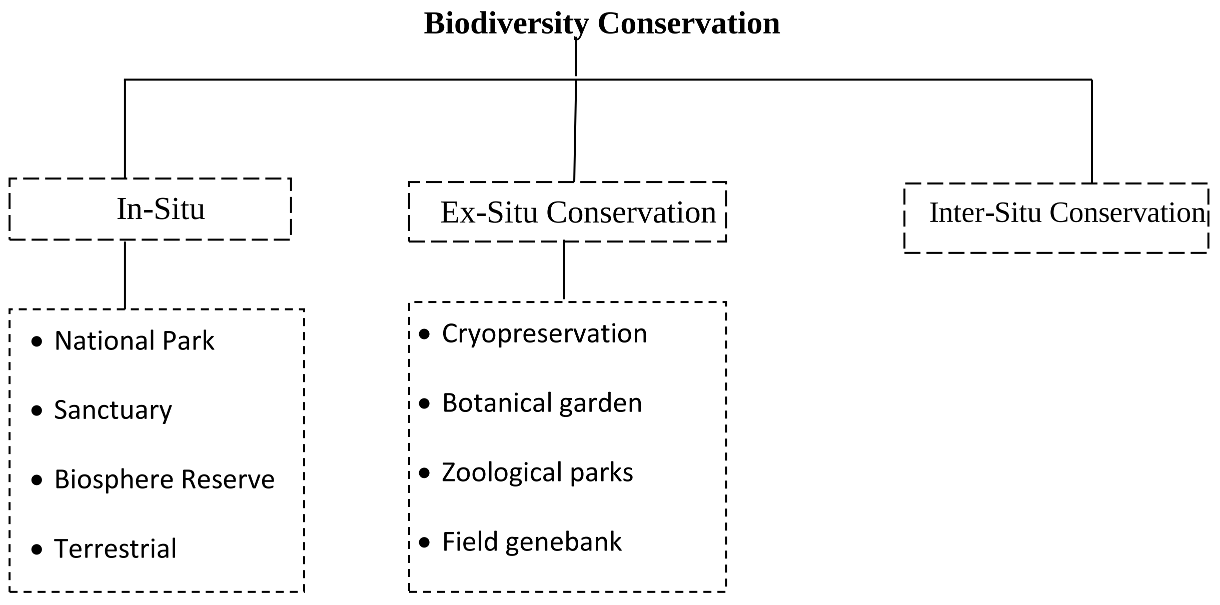
15.6 CONSERVATION

Why to conserve Biodiversity?

Biodiversity has an intrinsic value that is worth protecting regardless of its value to humans. The argument for conservation of biodiversity often emphasizes the need to facilitate continued evolution. As humans are and were part of nature, they benefited from the evolutionary process. The tenet that humans are part of nature questions whether humans should endanger their own milieu and the process from which they stem. While intrinsic arguments for protection of biodiversity are compelling, it is ultimately arguments of human benefit that pragmatic conservationists find most appealing: as humans, we are inextricably and wholly dependent on this diversity of living things for survival. Biodiversity, encompassing genetic diversity, species, populations, communities and ecosystems, and landscapes and regions, provides countless benefits to humans at all these scales Biodiversity performs a number of ecological services for humankind that have economic, aesthetic or recreational value.

Conservation of biodiversity is protection, upliftment and scientific management of biodiversity so as to maintain it at its threshold level and derive sustainable benefits for the present and future generation. In other words, 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 so as to meet the needs of the future generations.

Figure 15.10: Methods of Biodiversity Conservation



A. **In-situ conservation:** The conservation of ecosystems, natural habitats and the maintenance of viable species of plants and animals in their natural surroundings are known as in-situ conservation. Biodiversity of plant and animal species are preserved in-situ by setting up of protected areas like National Parks and Wildlife Sanctuaries. They include avariety of ecosystems and habitats. Some have been created in order to protect highly endangered species of wild plants and animals found nowhere else in the world. As a result, the population of the great Indian bustard, tiger, lion, elephant, crocodile etc., has increased.

Biosphere reserves cover very large areas, often more than 5000 km^2. They are used to protect species for a long time.

A national park is an area dedicated for the conservation of wildlife along with its environment. It is usually a small reserve covering an area of about 100 to 500 square kilometers. Within biosphere reserves, one or more national parks may also exist.

A ***wild sanctuary*** is an area which is reserved for the conservation of animals only while a *gene sanctuary* is an area where plants are conserved.

B. **Ex-situ conservation:** The conservation of plant and animal species outside their natural habitat is known as ex-situ conservation. The endangered species (wild plants or animals) which have reached a point of extinction in their natural habitat are transferred to other favourable habitat to ensure their survival. Therefore, ex-situ conservation, areas are established outside its natural habitat in a carefully controlled situation. This leads to the establishment of botanical garden for plants or a zoological park for animals. There is also another form of preserving a plant by preserving its germ plasma in a gene bank so that it can be used if needed in future. However the most important step of a successful breeding program is the reintroduction of a species into its original wild habitat.

Under *Cryopreservation*, the storage of seeds, pollen, tissue, or embryos in liquid nitrogen. This method can be used for virtually indefinite storage of material without deterioration over a much greater time-period relative to all other methods of *ex situ* conservation. Cryopreservation is also used for the conservation of livestock genetics through Cryoconservation of animal genetic resources. Technical limitations prevent the cryopreservation of many species, but cryobiology is a field of active research, and many studies concerning plants are underway.

The storage of seeds in a temperature and moisture controlled environment. This technique is used for taxa with orthodox seeds that tolerate desiccation. *Seed bank* facilities vary from sealed boxes to climate controlled walk-in freezers or vaults. Taxa (a group of one or more populations of an organism or organisms seen by taxonomists to form a unit) with recalcitrant seeds that do not tolerate desiccation are typically not held in seed banks for extended periods of time.

Somatic tissue can be stored for short periods of time in vitro for short periods of time. This is done in a light and temperature controlled environment that regulates the growth of cells. As a e*x situ* conservation technique *tissue culture* is primary used for clonal propagation of vegetative tissue or immature seeds. This allows for the proliferation of clonal plants from a relatively small amount of parent tissue.

An extensive open-air planting used maintain genetic diversity of wild, agricultural, or forestry species. Typically species that are either difficult or impossible to conserve in seed banks are conserved in *field gene banks*. Field gene banks may also be used grow and select progeny of species stored by other *ex situ* techniques.

C. Inter situ conservation is **o**pening a "third front" in the battle to save the biodiversity. The basic idea is to conserve rare species by reintroducing them to sites where they once grew, but have been eliminated in recent decades or centuries by human agencies such as, here in Hawaii, the highly destructive impact of introduced goats, pigs, and rats. The *inter situ* approach is spreading rapidly to various places as a very effective method of biodiversity conservation.

15.7 PROTECTION AND RESTORATION TECHNIQUES

The establishment of protected areas is one of the strategies used in the management of environmental resources, terms, and approaches changing significantly in the past decade, the international community involved in protected areas policy, planning and management considered it necessary to review the definition of a protected area, to ensure that the definition embraces the wide range of areas under or requiring protection. This definition was first derived at the 4^{th} World Congress on National Park and Protected Areas held in Caracas, Venezuela in 1992.

A protected area is, therefore, defined as ‘an area of land especially dedicated to the protection and maintenance of biological diversity, and managed through legal or other effective means’ (IUCN).

Protected areas can be established in many ways. The two most common mechanism are, government action (often at a national level, but also regionally or locally) and purchase of land carried out by private conservation organizations. The IUCN has developed the following systems of classification for protected areas that range from minimal to intensive allowed use of the habitat by man: scientific reserves and strict natural reserves, national parks, national monuments and landmarks, managed wildlife sanctuaries and nature reserves, protected landscape, national biotic areas and multiple use management areas etc.

Another valuable approach has been to identify 12 megadiversity countries that together contain 60-70 percent of the world’s biodiversity: Mexico, Columbia, Brazil, Peru, Zaire, Madagascar, Indonesia, Malaysia, India, China and Australia.

Attempt to determine international priorities and global hotspots very often overlap considerably. There is general agreement on the need for enhanced conservation efforts in the following areas of the world.

- Latin America- coastal forests of Ecuador, Atlantic coasts forest of Brazil
- Africa- Mountain forests of Tanzania and Kenya, Island of Madagascar
- Asia- southwestern Sri Lanka, Eastern Himalayas, Indo-China, Vietnam,
- Oceania- New Caledonia

Red List

The IUCN Red List of Threatened Species (also known as the IUCN Red List or Red Data List or Red Data Book), founded in 1964, is the world's most comprehensive inventory of the global conservation status of biological species. A Red Data Book of International Union for the Conservation of Nature (IUCN) contains lists of species whose continued existence is threatened. Species are classified into different categories of perceived risk. Each Red Data Book usually deals with a specific group of animals or plants. These are now being published in many different countries and provide useful information on the threat status of the species.

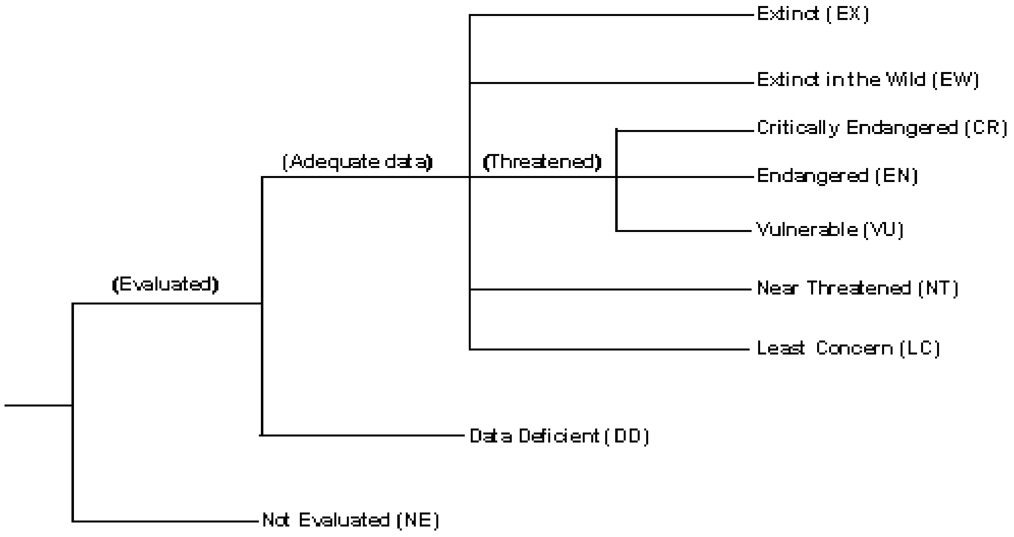


Figure 15.11: Structure of the categories.

Under the IUCN Red list the species are classified into nine categories. The Criterion based on various parameters such as rate of decline, population size, area of geographic distribution, and degree of population and distribution fragmentation.

Convention on Biological Diversity

The Convention on Biological Diversity (CBD) is a multilateral treaty. The Convention is having 3 main objectives:

- conservation biological diversity;
- sustainable use of its components; and

- fair and equitable sharing of benefits arising from genetic resources

In other words, its objective is to develop national strategies for the conservation and sustainable use of biological diversity. It is often seen as the key document regarding sustainable development.

The Convention was opened for signature at the Earth Summit in Rio de Janeiro on 5 June 1992 and entered into force on 29 December 1993.

Germplasm Banks

Germplasm bank also called gene banks are established for ex-situ conservation of species. Such gene bank include botanical gardens, animal zoos, genetic resource centres, culture collections etc. in plant species seeds, pollen grains, vegetable propagative parts, tissues etc. are collected and stored in such germplasm banks. Several international organizations could take up the task of ex-situ conversation through establishment of such gene banks. One such major international group is CGIAR (Constructive Group on International Agricultural Research) supporting a network of a number of international agricultural research centres dealing with important crop plants. These research centres could manage ex-situ collection of nearly 600,000 crop gene pools. A network of gene banks to conserve a variety of medicinal and aromatic plants has also been established by the G-15 countries (Argentina, Algeria, Brazil, Egypt, India, Malaysia, Mexico, Peru, Nigeria, Malaysia etc.) this network would ensure conservation of seeds, embryos, pollen and cultured tissues of important plants species.

Legal protection of Species and Habitat

Natural resources can be legally protected at local, national as well as international level. In many countries there are private conservation organizations which acquire land for conservation efforts. National governments and national organizations play a leading role in conservation.

CASE STUDY
Orissa – Olive Ridley Turtles

Every year at Gahirmatha and two other sites on the Orissa coast, hundreds of thousands of Olive Ridley turtles congregate on the beach, between December and April, for mass nesting. This was the largest nesting site for the Olive Ridleys in the world. In 1999 by the end of March it was estimated that around 200,000 turtles had nested at the Gahirmatha beach. Marine biologists believe that only one out of every 1000 eggs actually matures into an adult.

There are severe threats to these nesting sites. Shrinking nesting sites, construction of roads and buildings close to these rookeries, and other infrastructure development projects hamper nesting. Trawler fishing is another large threat to the turtles. After its 'discovery' in 1974, the beach was notified as a Sanctuary (the Bhitarkanaika Sanctuary) and was closed for hunting. Recognising the threats to turtles from fishing by large trawlers, the Orissa Marine Fisheries Regulation Act was passed in 1982. This Act prohibits trawling within 10 km of the coastline throughout the state and makes it mandatory for all trawlers to use Turtle Excluder Devices (TEDs). In 2001, the State Government of Orissa declared that a five month period between January to May should constitute a no-fishing season for a distance of 20 km from the coastline.

Apart from these initiatives, Operation Kachhapa is being coordinated by the Wildlife Protection Society of India, Delhi and Wildlife Society of Orissa with many local NGOs as partners. The Orissa Forest Department, WII, Dehra Dun and the Coast Guard are also involved in the Project.

There are international agreements for the protection of species. The single most important treaty protecting species at international level is the convention on international Trade in Endangered Species (CITES) established in 1973 in association with UNDP. The treaty is currently endorsed by 118 countries. CITES established lists of species whose international trade is to be controlled.

There are also international agreements for the protection of habitat. Three of the most important conventions are the Ramsar Convention on Wetlands of International Importance (1971) especially as Waterfowl Habitat; the convention concerning the protection of the World Cultural and Natural Heritage (1984) and the UNESCO Biosphere Research Programme. Legal and administrative measures thus includes: Strict control on habitat, extraction for trade and industry, total ban on collection of endangered species and maintenance of germplasm pool.

Public Programme

These include:

- involving educational institutions
- training for scientific skills
- awareness about importance of local plant resources, potential uses and their sustainable use
- Knowledge about value added products derived from plants.
- Active participation of people through co-operatives, voluntary organization, mahila mandals and nature club.

Forests and wildlife

1) **The Forest (Conservation) Act, 1980**

This Act was adopted to protect and conserve forests. The Act restricts the powers of the state in respect of de-reservation of forests and use of forestland for non-forest purposes includes clearing any forestland for cultivation of cash crops, plantation crops, horticulture or any purpose other than re-afforestation.

2) **The Wildlife (Protection) Act, 1972, Amendment 1991**

The WPA (Wildlife Protection Act), 1972, provides for protection to listed species of flora and fauna and establishes a network of ecologically-important protected areas. The WPA empowers the central and state governments to declare any area a wildlife sanctuary, national park or closed area. There is a blanket ban on carrying out any industrial activity inside these protected areas. It provides for authorities to administer and implement the Act; regulate the hunting of wild animals; protect specified plants, sanctuaries, national parks and closed areas; restrict trade or commerce in wild animals or animal articles; and miscellaneous matters. The Act prohibits hunting of animals except with permission of authorized officer when an animal has become dangerous to human life or property or so disabled or diseased as to be beyond recovery (WWF-India, 1999). The near-total prohibition on hunting was made more effective by the Amendment Act of 1991.

3) Biosphere Reserve

Biosphere reserves are areas of terrestrial and coastal ecosystems promoting solutions to reconcile the conservation of biodiversity with its sustainable use. They are internationally recognized, nominated by national governments and remain under sovereign jurisdiction of the states where they are located. Biosphere reserves serve in some ways as 'living laboratories' for testing out and demonstrating integrated management of land, water and biodiversity.

Collectively, biosphere reserves form a World Network. Within this network, exchanges of information, experience and personnel are facilitated. There are over 480 biosphere reserves in over 100 countries. To prevent loss of biodiversity, the Government of India is setting up 17 biosphere reserves in different parts of the country. (Ministry of Environment and Forests)

- These are multipurpose protected areas to preserve the genetic diversity in different Ecosystems.
- Seven of the seventeen biosphere reserves are a part of the World Network of Biosphere reserves, based on the UNESCO Man and the Biosphere (MAB). Programme list. Namely, Nilgiri, Gulf of Mannar, Sundrbans, Nanda Devi, Nokrek, Pachmarhi, and Similipal Biosphere Reserves

15.8 CONCLUSION

After explaining all the aspects of biodiversity it can be said that biodiversity is combined diversity of all the levels of biological diversification. And it is not evenly distributed across the planet but shows a rather uneven distribution, certain ecosystems and regions contain far more species than others. Tropical rainforest, coral reefs, the deep sea, and large tropical lakes appear to be the most species rich ecosystems on the planet. But with growing population and exploitation of resources causing threats to habitats and reduction in species. Based on degree of threat face by the species, species are categories into different conservation categories.

15.9 SUMMARY

Biodiversity is the variation of living organism and occurs at three level: genetic, species and community. It includes not only the number of type at each level but also their function and structure. Unique and rare representatives at each level are given special emphasis by managers because of their vulnerability to being lost and the resulting threat of a decrease in biodiversity.

15.10 GLOSSARY

i. Biodiversity: simply means variety of living species of organism of both plants and animals in an ecosystem having certain specific environmental conditions.

ii. Biodiversity Hotspot: are defined as those areas which have rich biological communities including plants and animals wherein endemic species predominate.

iii. Species Extinction: extinction of species is a biological process of complete elimination of a species of biological community from natural habitat as well as from cultivation or captivity as zoos and protected areas.

15.11 ANSWER TO CHECK YOUR PROGRESS

Q. 1. Briefly mention about—(a) Genetic diversity, (b) Species diversity, (c) Ecological diversity.

Ans. **(a) Genetic diversity:** The occurrence of single species in high diversity at the genetic level over its distributional range is called as genetic diversity. Such as in Rauwolfia vomitoria in Himalaya region, 50,000 varieties of rice, 1,000 varieties of mango in India.

(b) Species diversity: The occurrence of diversity as the species level in a geographical region is called species diversity, e.g. Western Ghats have more amphibian species diversity than in Eastern Ghats.

c) Ecological diversity: A geographical region having different ecosystems will have more ecologically diverse organisms one having one or two types only. For example, India has more ecological diversity than Norway.

Q. 2. Explain with examples—latitudinal gradients.

Ans. The decrease in the species diversity from equator towards the poles is latitudinal gradient in diversity. This can be justified by following examples:

(i) Colombia located near equator has nearly 1,400 species of birds, New York at 41 °N has 105 species and Greenland at 71 °N has 56 species only. India has 1,200 species.

(ii) Equador's forest has upto 10 times more species than mid-west of USA for vascular plants.

Q. 3. Give three hypotheses for explaining why tropics show greatest levels of species richness.

Ans. The following three hypotheses for greatest levels of species richness are—

(a) Speciation: It is the function of time. The tropical latitudes have remained undisturbed for millions of years and had a long time for evolution among species diversification as compared to temperate regions that frequented for glaciations in past.

(b) Tropical environment: It is more constant, less seasonal and predictable, than the temperate ones. This provides rich specialization and leads to greater species diversity.

(c) Solar energy: There is presence of more solar energy and it contributes more productivity and in turn more diversity.

Q. 4. How is biodiversity important for ecosystem functioning?

Ans. Biodiversity is very important for the ecosystem functioning and its stability. It also is responsible for the health of the ecosystem but the very survival of human in the ecosystem on this planet.

Q. 5. How is a stable community identified?

Ans. The following points if observed suggest that the community is stable—

(a) It must not show too much variation in the productivity from year-year.

(b) It must be resistant or resistant to occasional disturbances caused by nature and man-made.

(c) It must be resistant to invasions by alien species.

Q. 6. How much mass extinction of species are there on records since the origin and diversification of life on earth? How is the present episode different? What is the result of loss of biodiversity in a region?

Ans. There were 5 episodes of mass extinction of species. The present sixth episode is in progress. The current rates of extinction are estimated to be faster than the pre-human times because of our activities. It is estimated to be faster 100-1000 times. General loss is:

(a) Decline to plant production.

(b) Lowered resistance to environmental disturbances such as droughts.

(c) Increased variability in certain ecosystem processes.

Q. 7. Briefly give the views regarding the reasons for conserving biodiversity.

Ans. There are the following views:

(a) Narrowly utilitarian: We humans derive countless direct economic benefits from nature. Such as food, medicines and many more utility things.

Nations with rich biodiversity can expect to reap enormous benefits from the increasing resources put into bioprospecting.

(b) Broadly utilitarian: It says that biodiversity plays a major role in many ecosystem services that nature provides. There are many intangible benefits that we derive from nature, including aesthetic pleasures.

(c) Ethical values: All living beings that share this planet have equal right to live as do humans. We must realize that every species has an intrinsic value, even if we do not have any current economic value. We have to maintain the biological legacy in good order for future generations.

Q. 8. What are sacred groves? What is their role in conservation?

Ans. India has a history of religious and cultural traditions that emphasized protection of nature. In many cultures, tracts of forests are set aside and trees, animals are given total protection. Such forests are called sacred groves. Such forests are called sacred groves which help us to preserve, protect the forests, wildlife and other rare, threatened and vulnerable species.

Q. 9. Among the ecosystem services are control of floods and soil erosion. How is this achieved by the biotic components of the ecosystem?

Ans. Control of floods and soil erosion are done by preserving the forests. There must be a balance between the plants and animals to maintain the biodiversity.

15.12 REFERENCES

1. Heywood VH, ed. 1995. Global Biodiversity Assessment. Cambridge (UK): Cambridge University Press.
2. Heywood, V.H., and R.T. Watson, Eds., 1995: *Global biodiversity assessment*. Cambridge University Press, Cambridge, 1140 pp. [Global; Biodiversity]
3. Levin, S. A. 2001. Encyclopedia of Biodiversity. Vol. 1 – 5. Academic Press.
4. Mayr, Ernst (1963). Animal Species and Evolution. Cambridge: Belknap Press of Harvard University Press.797pp.
5. R.H. Whittaker. 1972. Evolution and measurement of species diversity. Taxon, 21:213_251
6. M. Jnr. Hunter. 2002. Fundamentals of Conservation Biology. Second Edition. Blackwell Science, Massachusetts, U.S.A.
7. L.A. Nielsen R.L. Knight Meffe, G.K. and D.A. Schenborn. 2002. Ecosystem management: adaptive, community-based conservation. Island Press, Washington, D.C.,
8. Borang, A. 2004. Birds of Arunachal Pradesh in North East India – the check list and distribution in protected areas (unpublished). Forest Zoology Division, SFRI, Itanagar.
9. Tripathi, R S and Barik, S K (2003) National Biodiversity Strategy and Action Plan Report for Northeast India. Ministry of Environment and Forests, New Delhi.
10. Mao, A. A., Singh, K. P. and Hajra, P. K. 2001. Rhododendron. In: *Floristic diversity and Conservation Strategies in India*. Vol. IV (eds. K. P. Singh and N. P. Singh), pp. 2167-2202. Botanical Survey of India, Kolkata.
11. Williams, P. H. and Humphries, C. J. 1996. Comparing character diversity among biotas. Biodiversity. A biology of number and differences. (ed. Gatson, K. J.). Blackwell Science, Oxford U.K., pp. 54-76.
12. Alkemade, R., M. van Oorschot, L. Miles, C. Nellemann, M. Bakkenes, and B. ten Brink. 2009. GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss. Ecosystems 12:374-390.
13. Peter M.Vitoasek, Paul R.Ehrlich.Anne H.Ehrlich *et al.*, "Human Appropriation of the Products of Photosynthesis," *BioScience, Vol.* 36, No. 6 (1986), pp. 368-373.
14. Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC. Copyright © 2005 World Resources Institute

15.13 SUGGESTED READINGS

1. Bansereau, B.M. (1957), Biogeography: An Ecological Perspective. Ronald Press: New York
2. Hugget, R.J. (2004), Fundamental of Biogeography. Routledge: London and New York
3. Singh, S (2010), Biogeography. Prayag Pustak Bhawan: Allahabad

15.14 TERMINAL QUESTIONS

1. Sometime introduction of an exotic species upset native species of the ecosystem. Substantiate the statement with two examples.
2. How do zoological parks differ from National park concerned with species conservation?

   Ans: Zoological park – ex-situ conservation, National park – in-situ conservation.
3. The accelerated rate of species extinction that the world is facing now is largely due to human activities. Group such activities under four major heads and explain.
4. A survey of latitudinal gradients of bio-diversity of birds is as follows:

   India –8^{o} North -----1200 Species

   Greenland –71^{o} North ----55 Species

   By analysing the above data what does it indicate about the distribution of birds?

   Ans: Species diversity decreases from equator towards the poles.
5. Why Biodiversity do not have political boundaries?

   Ans: Conservation is the collective responsibility of all the Nations.

Long Questions

1. Biodiversity has various benefits to mankind- Discuss.
2. Explain the causes of biodiversity loss in detail.

   Hints: Manmade & natural.
3. Discuss various threats and causes of loss of biodiversity in detail.
4. What are Hot spots of biodiversity?
5. Write three reasons for maximum biodiversity in tropical rain forest.
6. What are sacred groves? Where are they found in India? Name any four. What is their characteristic feature?

UNIT-16 CONSERVATION OF BIOTIC RESOURCES

16.1 OBJECTIVES

16.2 INTRODUCTION

16.3 BIOTIC RESOURCES: MEANING AND CONCEPT

16.4 PROTECTION, MANAGEMENT AND CONSERVATION

16.5 APPROACHES TO BIOTIC RESOURCE

16.5.1 Survey of biological resources

16.5.2 Evaluation of biological resources

16.5.3 Preservation and conservation of biological resources

16.6 BIOLOGICAL RESOURCES CONSERVATION IN INDIA

16.7 CONCLUSION

16.8 SUMMARY

16.9 GLOSSARY

16.10 ANSWER TO CHECK YOUR PROGRESS

16.11 REFERENCES

16.12 SUGGESTED READINGS

16.13 TERMINAL QUESTIONS

16.1 OBJECTIVES

The prime objective of this unit is to make you understand the concept and the importance of biotic resources. In recent time it has been noticed that the natural resources are getting depleted at an alarming rate and thus causing lots of concerns like depletion of biodiversity, ecosystem, and natural resources like coal, petroleum etc. which are very useful for our survival. Long term impact like climate change is also related to it. After studying this unit you will be able to:

- Learn about different types of resources including biotic resources
- Learn about distribution of resources around the world
- Understand the protection and conservation techniques of resources
- Know about biological resource conservations in India.

16.2 INTRODUCTION

Natural resources are highly valued because human beings are dependent on them to fulfill their fundamental needs that changes with time. While natural resources are distributed throughout the world, specific resources often require particular conditions and so not all natural resources are spread equally. Consequently, nations trade their natural resources to make certain that their needs can be fulfilled.

In simple term, natural resources are material and constituent formed within environment or any matter or energy that are resulting from environment, used by living things that humans use for food, fuel, clothing, and shelter. These comprise of water, soil, minerals, vegetation, animals, air, and sunlight. People require resources to survive and succeed. Everything which happens naturally on earth are natural resources that is minerals, land, water, soil, wind that can be used in many ways by human being. It can be explained by several environmentalist scholars that a natural resources is any kind of substance in its natural form which is needed by humans.

The general classifications of natural resources are minerals for example as gold and tin and energy resources such as coal and oil. The air, forests and oceans can also be categorized as natural resources. Theoretical studies have documented that land and water are the natural resources, which include biological resources, such as flower, trees, birds, wild animals, fish etc., mineral resources, such as metals, oil, coal, building stones and sand, and other resources, like air, sunshine and climate (UNEP, 1987). Natural Resources are used to make food fuel and raw materials for the production of finished goods (Adriaanse, 1993). Natural resources change in value over time, depending on what a society most needs or considers most valuable.

16.3 BIOTIC RESOURCES: MEANING AND CONCEPT

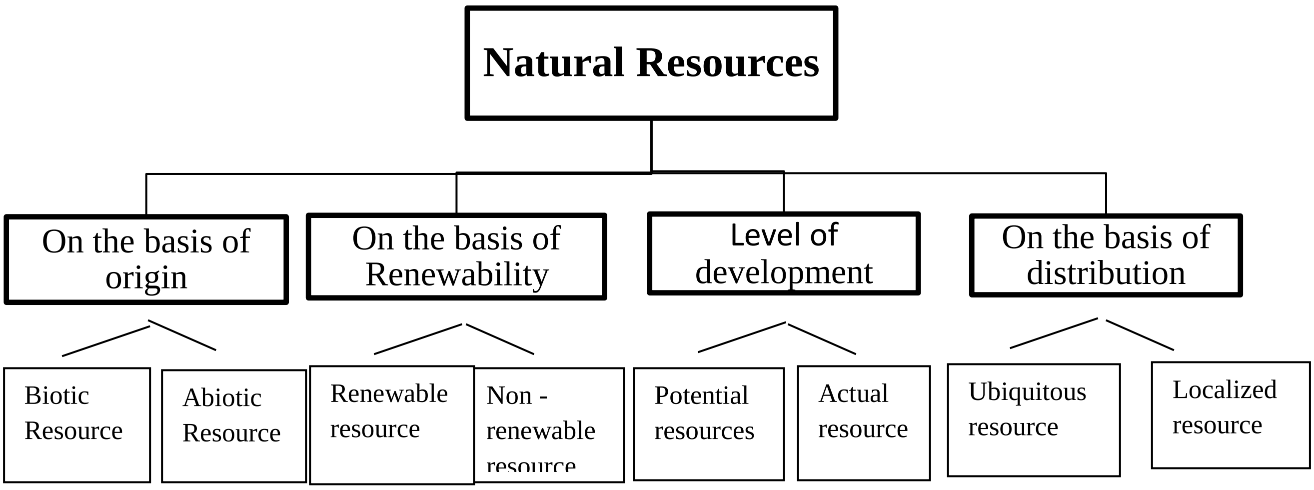
16.3.1 Resources: meaning and types

Resources satisfy our needs and wants. Any material which we can utilize or is useful to us, we call it a resource. Resource derived from nature is called natural resource, e.g. tree, air, water, sunlight etc. Resource created by humans is known as manmade or cultural resources. Humans are also resource as with our ideas, knowledge, technology we can create more resources.

Our earth is a storehouse of variety of resources. For instance land, water, air, minerals etc. all are important physical or abiotic resources and wildlife, vegetation, fisheries etc. are biological or biotic resources. Even fossil fuels such as coal, petrol, natural gas formed by decaying of plants and other organic matters are biotic resources.

Besides the known resources, our earth has many such materials, which due to lack of our knowledge and technology are not yet utilized. Such materials are not called a resource, till we start utilizing those material. For instance, wind has always been there, may be from the inception of the earth. However wind as a resource for generating electricity was developed much later with advancement of technology.

Natural resources are further classified on the **basis of their origin, renewability, level of development and distribution.**



On the basis of Origin, natural resources are called biotic or abiotic resources:

Biotic resources: It comprises of all living organisms in our environment, which has life and is useful to us. Plants, animals, birds, forest products, marine organisms, fishes, coal, natural oil etc. are all biotic resources. Coal, natural oil is non-renewable biotic resources. Biotic resources are part of the biosphere.

Abiotic resources: It comprises of all the non-living elements, which are useful to us. For instance land, air, water, minerals etc.

On the **basis of renewability natural resources are defined as renewable and non-renewable**:

Renewable resource: Those resources, which can be utilized again and again and get replenished within our life time, are renewable resources such as water, forests, sunlight etc. Renewable resources get replenished naturally. Renewable resources such as sunlight, wind, water provides green energy. Utilization of renewable energy promotes sustainability. Though these resources are renewable but wastage or misuse of these resources can affect its distribution and availability.

Non-renewable resources: These resources can get exhausted with over exploitation. These resources take million years to replenish, hence are called non-renewable, e.g. coal, natural oil, gas etc. Nonrenewable resources have limited supply and these resources takes longer time period to replenish naturally. Fossil fuels, nuclear fuel are example of non-renewable natural resources derived from the earth. For faster industrialization and growth humans have been over utilizing fossil fuels, faster than earth's capacity to replenish these resources within our life time.

Thus for sustainable development and growth fossil fuels need to be judiciously used and dependency on renewable sources of energy need to be increased.

On the **basis of level of development natural resources are defined as potential and actual resource**

Potential Resource are those resource, which are not yet fully realized but have the potential to be used in the future. The quantity and distribution of such resources are not yet known. For instance many places in India may have petroleum deposits, till those deposits are utilized, it is potential resource.

Actual resources are those resources, which we are utilizing and we know about their actual distribution. The quantity of these resources is known. For instance, oil deposits in Middle East countries.

On the **basis of distribution, natural resources are defined as localized and ubiquitous.**

Localized resources are found specific to some area and not everywhere. For instance, copper, iron etc. are found in some areas.

Ubiquitous resources are present everywhere for instance land, water, air are found everywhere, which are very important resource.

16.3.2 Biotic Resources- Concept

Biotic resources include plants, animals and micro-organisms. We get our basic food from plants and animals. For instance food like fruits, vegetables, tea, medicines, etc. is obtained from plants. Similarly eggs, meat etc. are obtained from birds and animals. Besides, we get wood, timber from vegetation which are further used for making furniture. A plant gives us oxygen and absorbs carbon dioxide. Plants and trees provide us shelter, controls weather conditions and soil erosion. Even dead and decayed plants forms humus, which provide nourishment to the soil.

From animals we not only get food but they are useful for other services as well hence are important biotic resource. For instance some animals like horse, cattle, and goat are used for transport, some for agricultural purposes like cow, bull etc. cow dung is also a very good quality manure. Some animals and birds work as scavengers and help maintain the ecosystem by getting rid of dead matters such as pig, vulture, jackal etc.

Micro-organisms are also important biotic resource. Microorganisms are food for some animals and also act as decomposers and maintain balance in the ecosystem. Some bacteria's are also used for medicinal purposes. Hence are important biotic resources.

16.3.3 Distribution of natural resources in India and the world

Distribution of resources is the spatial arrangement of resources. Availability or occurrence of resource depends on two factors one is natural availability and the other is technological capability of humans. On the first factor we humans have no say; it is determined by the physical laws. However the second factor is cultural in nature, with humans' knowledge, ideas and capabilities distribution of resources can be managed. Different climatic conditions and physical process since the formation of earth are some factors behind the varied distribution of natural deposits of resources. For instance coal is mostly found in locations, which were originally swampland during the coal formation period.

The varied distribution of natural resources is marked by physical and climatic conditions. Not all countries have adequate distribution of all the important resources. Hence countries, which have rich deposits of some important resources export additional quantity to other countries and import those resources that they lack.

Resource rich regions, areas and countries attract more population. Since ages it has been noticed that people settle near deposits of mineral and natural resources. Such as near water bodies, near alluvial soil, near rich cover of vegetation's etc. people settle earlier and then move to other parts. Thus Asia, Europe and North America, which have rich deposits of variety of resources have more population than Australia, Africa and South America. Even within a country or state people migrate to such location where natural resources are found in abundance. Often economic activities are associated with the available resource of the region. For instance, in India Punjab, Haryana, UP have large cultivable lands conducive for agricultural, hence in these state agriculture contributes greatly to the state's economy.

Distribution of natural resources in India: India is one of the Asian countries blessed with immense variety of resources both biotic and abiotic resources. Such as mineral deposits, tropical weather conditions, fertile soil, marine resources and presence of many rivers and water bodies. However the challenge is uneven distribution of resources and over exhaustion of resources by rapidly growing population.

Source: Maps of India

Northern plain of India is very productive here rice, wheat, maize, sugarcane, jute, etc. are grown in huge quantity. India's relief and climatic condition has supported varied forest type thus tropical forest, mangrove, alpine forest etc. are found across India. Besides, India has many national parks, wildlife sanctuaries, which are home to variety of plants, animals and birds. India has about 75,000 variety of animal species and have 1200 variety of species. India's majestic elephants are mainly found in Assam, Karnataka and Kerala jungles and lions in Gir forest in Gujarat. The one horned rhinos are found mainly in Assam. India has wide variety of livestock's as well. About 57% of world's buffaloes are found in India. India has long coastline which has many marine organism and many rivers where more than 1800 variety of fish species are found. The given map shows the distribution of resources in India.

As per estimates in 2010, India had approximately about 125 Million metric tons of crude oil reserves; most of it is found in Mumbai High. India also has about 1,437 billion cubic meters of natural gas reserves. Mumbai high complex has maximum production of natural gas followed by onshore fields in Andhra Pradesh, Assam, and Gujarat states. Coal is attained from states like Orissa, Chhattisgarh, Andhra Pradesh, Madhya Pradesh, west Bengal, Meghalaya and Tamil Nadu. Minerals such as copper, iron ore, bauxite, limestone, mica, etc. are also found across the country. India produces about 7% of world's production of iron ore. Jharkhand, Orissa, Chhattisgarh, Karnataka. Maharashtra, Goa and Andhra Pradesh produces maximum of India's iron ore. India's stock of livestock and their contribution in improving economic status of rural population is also immense. Besides, India's climatic conditions favor agricultural and horticultural activities on large scale.

Natural resources are found across the world, however there are still some countries which have more deposits of important resources than others.

In Asia, the southeast countries are major producers of palm oil, rubber, tin, petroleum and even tropical fruits such as Papaya, Mango and Pineapple. India is the largest producer of mango in the world. Countries like Indonesia and Thailand are world's major pineapple producing nations. West Asian countries like Iran, Iraq, UAE, Qatar and Saudi Arabia have rich deposits of natural oil. Siberia in Russia has rich deposit of natural gas and coal. China also has high quality coal reserve. Country like Kyrgyzstan has rich deposit of Uranium ore. India and Indonesia have rich deposit of good quality iron ore.

Countries like China, Malaysia and Indonesia also have large forested lands. In fact China majorly exports wooden products and paper. Indonesia and Malaysia are major timber producing countries.

China's estimated total forest area is about 175 million hectares mainly concentrated in southwest, southeast and northeast region. It also has an extensive grassland. China's cultivable land is mainly distributed in North and northeast China, Sichuan basin, Pearl River Delta etc. China has immense stock of mineral resources. There are many proven reserves in china including metallic, non-metallic and energy mineral resources. China has rich deposit of coal but natural gas and petroleum is comparatively less in proportion. Western and northern region has huge deposit of coal. China's metallic mineral resources covering large reserves are mainly tin, tungsten, rare earth and antimony. China is one of the few countries in the world with huge non -metallic deposits. China also has large quantity of marine resources mainly concentrated in the offshore waters. Many Asian countries including China, Myanmar, India, Japan, Indonesia, and Philippines are also major producers of fish in the world.

Studies show in terms of distribution of natural resources other continents have uneven distribution of natural resources.

Australia has many mineral deposits. It has huge coal deposits, even more in quantity than its own requirement, hence additional coal is generally exported to countries like Japan, Taiwan, and Korea, which lacks it. Sydney and Bowen basin are two major sites of coal reserves. Besides, minerals like bauxite, iron ore, gold, copper, diamond, lead, zinc and mineral sands deposits are also found in large quantity mainly in Western Australia and Queensland. Australia has huge deposits of uranium, which it export to many countries in the world for nuclear power. Its reserves of natural gas are mainly found in western and central part of the country. Australia's huge land and fertile soil supports agriculture and its huge forests provide good quality wood and many other services to the nation and its economy.

Many **African** countries have rich deposits of minerals such as gold, diamond, copper, bauxite, uranium, petroleum, titanium, silver etc. However, due to use of old technology most potential mineral resource base are un-exploited. Many mineral bases are found in central and southern Africa. South Africa, Egypt, Zimbabwe have rich deposit of gold and diamond is found in central and South African region. Further, the tropical climatic conditions in Africa supports growth of wide variety of plants and trees.

Europe also has major deposits of natural gas and oil in Norway, Netherlands, Germany and

United Kingdom and mineral deposits are spread across the continent. Spain has huge deposits of coal, uranium, potash etc. France has many mines containing coal, gypsum, iron ore and zinc. Western European countries have many manufacturing minerals sites as well. Such as Belgium has a huge silica sand deposit. Eastern and northern European countries also have many natural resources. Europe's Mediterranean and marine coastal climates favor growth of variety of agricultural products such as wheat, potatoes, olives, rapeseeds, grapes etc. In fact, Italy, Greece and Spain are the world's top three producers of olives and Spain, France and Italy produces maximum grapes in the world, which is used for wind productions

South America has huge deposits of Iron ore and copper. Chile is world's major copper exporter. Oil and natural gas are majorly found in Venezuela's El Tigre region and Lake Maracaibo. South America has plentiful of freshwater which support growth of fisheries.

North America's fertile soil and freshwater and tropical climatic conditions particularly in the southern part and temperate climatic conditions helps in growth of variety of agricultural products; such as apple, peach, corn, wheat etc. Besides, North America also has rich mineral deposits such as coal, nickel, bauxite, and iron ore. USA and Canada have large deposits of oil and natural gas as well.

Most countries are blessed with abundance of natural resources and rich ecological diversity. However over excessive population and economic growth threatens the regions rich stock of resources. People of these countries need to understand the value and importance of the natural resources. If the natural resources are maintained and sustainably utilized, most countries would achieve their developmental goals fast.

Exercise A:

Make a list of 10 biotic and 10 abiotic natural resources that you and your family require daily.

Practice Question

Q1. Define resource?

Q2. What is the difference between potential and actual resource?

Q3. Which state of India has maximum number of one Horne Rhinos?

16.4 PROTECTION, MANAGEMENT AND CONSERVATION

Our daily requirements from food, shelter, clothing, medicines, and energy to even infrastructures all are obtained from nature. Thus, land, air, water, forests, minerals and even birds and animals are important resources for us. On land we grow our crops for food, we get oxygen from air, from forest we get food, medicines, timber etc. Wildlife, birds, plants maintain the ecological diversity, which is important to maintain food chain and webs. Like humans all other living organisms depend on nature for their reproduction, growth and survival.

Thus, natural resources, both biotic and abiotic, renewable and non-renewable needs maintenance. Non-renewable resources such as fossil fuel are known to get exhausted with over utilization. However post industrial revolution fossil fuels have been utilized extensively as a source of energy/electricity. The industrialized countries to achieve their growth over utilized the fossil fuels followed by the developing countries. As the fossil fuel takes million years to replenish, conserving these resources is very essential. The renewable resources like forest, water etc. though get renewed but over exploitation and wastages can cause immense damages. Hence protection and conservation of both biotic and abiotic resources is of utmost importance.

In the last few decades the concern about the natural resources have increased because of growing awareness and knowledge about the limited resources. The growing difficulties to avail clean air and water, and other important resources are making people realize the importance of conservation of resources. If the resources are not conserved our future generation will have nothing to survive. Hence, there is a need of sustainable development.

Even biotic resources, which are mostly renewable needs protection from damages and need to be conserved. Protection and conservation of natural resources is must for sustainable development of the earth. The 1987 Brundtland commission report suggested about integration of natural resources protection and management along with economic development. In 1992 in Rio, Brazil Agenda 21 on environment and development and sustainable management of forest were adopted by 178 countries.

Protecting the natural resources is necessary for community sustainability. As we humans are depleting our resources, we only need to protect it from further damages. Protection of species including plants and animals involves protection of their community, their ecosystem and their habitat. Natural resource management involves protecting our land, water, air, forest, wild life etc. Natural resource management involves protecting the quality and quantity of the resources for present as well as future generation. Natural resource can be maintained by sustainable and judicious usage of resources.

Resource like water is essential for living organisms, though 71% of the earth is covered with water, less than 1% is only usable fresh water. With growing population, demand for water consumption is also increasing. Hence, conserving and protecting this natural resource is very essential. Protection of surface and ground water from pollution and contamination and limiting wastage of water is important.

Forest another important resource though renewable needs to be conserved, as it takes about 10 to 15 years to replenish. Forest maintains ecology, control soil erosion, air pollution, conserve water and support food chain and web. Thus forest depletion should be controlled. If trees are fell for developmental purposes, then the same should be compensated with afforestation at other places and deforestation should be avoided.

Fossil fuels though non-renewable and increases pollution it is one of the most essential resource for development as we get energy from these fuels. Fossil fuels usages cannot be completely replaced, because for faster industrialization, fuels like natural oil, gas and coal will be used. However dependence on fossil fuels can be reduced with usage of alternative source of energy such as solar energy, hydro energy, geo thermal energy, wind energy etc. These sources of energy are renewable as well as cause less pollution. The energy through theses alternative sources though is comparatively less productive than fossil fuels, these renewable sources of energy should be used more to preserve the fossil fuels for future.

Air is the most important resource for survival of living organisms including humans, birds animals etc. Birds and animals get oxygen from air and plants get CO2 for survival. But due to excessive burning of fossil fuels the air quality is getting deteriorated. Quality of the air can be maintained by using renewable sources of energy.

Wildlife, marine life, birds and other biotic resources are equally important, different kind of species maintains biodiversity, which is essential for creating sustainability and ecological balance. Rich biodiversity conserve the ecosystem and protect the environment.

All resources are important and to conserve them. Three simple R’s of conservation are:

Reduction of wastages: we need to reduce the wastage of resources by limiting their usage. Resources saved are a way of earning more resource. For example switching off of lights when not required, using public transport as much as possible etc. are ways of reducing usages and wastages of resources.

Reuse the resource as much as possible.

Recycle the discarded product into something new and usable.

16.5 APPROACHES TO BIOTIC RESOURCE

In the 1987 UN conference, the concept of sustainable development was defined as “sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs”. This definition highlighted the deteriorating conditions of human environment and natural resources for the sake of economic development. The definition clearly meant that depletion of the resources is a global phenomenon, which can be controlled when all nations act locally to address the issue of conservation of the nature.

There are various approach to natural resource management including both biotic and abiotic resources. Biotic resource management usually have the following approaches such as:

Community based approach combines the objective of conservation of resources with economic benefits for the rural communities. In this approach local communities participate in resource management and prioritize the conservation of the resources based on their economic benefits.

Adaptive approach is a way of managing resources and learning about the same. In this approach the stakeholders directly influences the decision for conservation and their learning. Recognizing the stakeholders’ interests and involvement is important for learning based management.

Through **integrated resource management approach** the multiple aspect of natural resources (such as socio-political, biophysical and economic) meet the goals of the direct users and producers. This approach focuses on sustainability.

16.5.1 Survey of biological resources

One of the important step for management of biological resource is to know about actual quantity of biological resources and their location. The survey of biological resources is generally done through field surveys. Map showing boundaries of the area to be surveyed, survey routes, wildlife corridors are identified before the survey. Description of any unique species and information about habitats of listed plants and animals are gathered thorough survey. The basis for evaluation or assessment of biological resources or health of an ecosystem is field surveys and inventories of plants, animals, microorganisms, marine organisms, birds etc. and their habitats. This comprises of either qualitative or quantitative sampling and often follows protocols, guidance of published state or federal methods.

Biological resources surveys are undertaken to identify the types of organisms that exist in a given area. The data gathered is generally used for monitoring endangered species, evaluating conservation priorities of an organism and bioprospecting. Despite the importance of survey, there is no set rule for performing surveys as goals, time, area and available resources varies from place to place. The survey goal is very important to ensure the result in usable for conservation of biological community.

Standardization is a basic survey step, in this sampling for survey is kept consistent. Generally data is collected by different surveyors from different areas. So standardization of sampling ensures, differences between different areas are significant. Another way of standardization is by identifying the species correctly by experts.

Another method of surveying **is sampling effort**. It is expressed in many different ways, such as survey done as per given time in different sites; within a given distance; or total number of sites needed to find a pattern. For instance, with a set time limit survey will be more standardized and result can be compared on yearly basis.

Scale used for a survey depends on the goals of the project. The scale need to be appropriate to the organism to be surveyed. Such as large scale is needed for organisms or animals, which acquire larger habitat

Monitoring is other surveying method, it is essential for conservation purposes. It involves repeated survey of an area for a longer time period to examine changes, if any. Growing population put excessive pressure on the natural resources. Survey depends on the objectives of the project and the nature of the species. However, too many survey in short time span can disturb the species, thus surveying should be properly planned.

16.5.2 Evaluation of biological resources

Evaluation of the surveyed data is important for conservation of the biological resources. Post field survey the collected data is evaluated. Identification of species and their habitat are basis of biological evaluation. Information about the species and their habitats help in priority ranking of the species and their communities for conservation. For instance endangered species and their habitats are ranked top and are given more priority for conservation. Evaluation of biological resources is based on strong biological concept and method for evaluation ideally is appropriate for the region and the habitat of the species. The objective of the project is to be taken into consideration for evaluation. Defined objective and detailed analysis of the survey result helps in chalking out appropriate plans for conservation.

16.5.3 Preservation and conservation of biological resources

Survey of biological communities and evaluation of the collected data is done to save and conserve the biotic resources. Preservation and conservation are two different terms used for saving and protecting the biological resources. Preservation generally means no interference of humans or untouched. Whereas conservation is a more practical term used for sustainable consumption and management of biotic resources. Conservation usually focuses on the interests and needs of the present and future generations for their biological, cultural, economic and recreational values.

The need for conservation is arising because of over exploitation of the resources by humans for personal need and greed. The destruction of plants and animal species is not only impacting biodiversity but also impacting the potential resources for humans in the form of food, medicines, economic values etc. The extinction of animals and plants impact the functioning of an ecosystem, which can have impact on human welfare and the economy. Human factors such as habitat destructions, fragmentation, over exploitation of species due to fishing and hunting, competitions, pollutions, ecosystem destruction and predation by invasive species are some of the factors responsible for destruction of biological resources.

Due to increasing deterioration of biological resources, different conservation methods are followed to save biodiversity. Biodiversity is very important for survival of humans and for economic development. In situ conservation and ex situ conservation are two commonly used methods of conservation.

In situ conservation means conservation of the species in their natural locations, sites or habitats. It is a very important method of conserving biological resources. Conserving the species and their habitats or location protects the ecological community. Protected areas such as national parks, biosphere reserves, wildlife sanctuaries etc. are examples of in situ conservation. In India around 4.2% of total land is used for In situ conservation.

Exercise B:

Make a list of in-situ and ex-situ conservation centers in your state.

Practice Question

Q4. What are the three basic approaches to biotic resource management?
Q5. Define biodiversity?
Q6. Give two examples of in-situ conservation?

Ex situ Conservation method preserves the biological resources and their diversity outside their natural habitat. For instance, seed bank, zoo, botanical garden etc. are home away from home. Ex situ conservation provides research opportunities on biological resources. Ex situ conservation methods complement in- situ conservation. Reintroduction of plants and animals to their natural habitat from ex-situ conservation centres helps to rebuild the community of the endangered species.

16.6 BIOLOGICAL RESOURCES CONSERVATION IN INDIA

India is one of the mega diverse countries of the world. We have vast pool of natural resources. We have fertile lands, tropical and sub-tropical climate to support wide variety of vegetation, several major rivers, plateau region, coastal regions, high lofty mountains etc. which supports variety of biological resources. Presence of wide variety of biological resources is essential to maintain ecological balance. Biodiversity maintains soil fertility, water cycle, and is a source of raw materials for many medicines. Besides, biological resource provides base for livelihood and economies for millions of people. Conservation of biological resources means conserving the environment. In the past few decades over population growth and exploitation of resources have caused immense damages to these resources, hence the need for conservation.

Measures have been taken nationally and globally to conserve biological resources. In India various steps and policies have been defined to conserve biological resources. India' about 4.2% of land is demarcated as protected areas for in situ conservation of species.

In India, many acts are there to conserve natural resources. In article 48(a) and 51(g) of Indian constitution environment protection concept is clearly mentioned. India has many acts such as Environment Act 1986, Forest (Conservation) Act, 1980, Wildlife (Protection) Act 1972 and Wildlife (Protection) Amendment Act 1991. These acts are meant to conserve the environment and biological resources. Besides, Indian states have their own laws to protect natural resources.

India has over 80 national parks to protect and conserve plants and animals in their natural habitats. Corbett National park was first established in 1936. Inside national parks human habitation is not allowed. India has 18 biosphere reserves, where locals are allowed to live and perform their traditional activities but no hunting or other activities are allowed. Some of the biosphere reserves demarcated by Indian government are Nilgiri (Kamataka, Kerala, Tamil Nadu), Nanda Devi (Uttar Pradesh), Sundarbans (West Bengal), Great Nicobar (Andaman & Nicobar Islands), Nokrek (Meghalaya), etc. India has about 537 wildlife sanctuaries for protection of birds and animals. Out of which 49 are tiger reserves meant for conservation of tiger. Besides the in-situ conservation methods, India has many ex-situ conservation sites for conservation of species. Many seed banks, botanical garden, zoological gardens are there to protect plants and animals outside their natural habitat.

16.7 CONCLUSION

To conclude, it can be said that ever growing population and economic developments put excessive pressure on the natural resources. The natural resources renewable or non-renewable need to be conserved. Non-renewable resources like fossil fuels once extracted and used takes millions of years to replenish. Resources like water, forests etc. even though renewable need to be judiciously used and wastages should be avoided. The demand for resources is increasing faster than nature's capacity to meet all demands, hence judicious usages is required. Biological resource conservation maintains biodiversity. Biodiversity is required for maintaining ecological balance. Biological conservation protects species from getting extinct and thus maintains the food chain and food web. Conservation is a way of recognizing the dynamic nature of biological communities and letting them grow, change and evolve naturally. Reducing total dependency on natural resources is a way of conserving resources. Nationally and globally many resolutions have been passed to protect both biotic and abiotic resource. Apart from acts and laws public awareness is very important for conservation. Everyone need to realizes the value of natural resources and our dependence on them, then only the resources can be conserved.

16.8 SUMMARY

In this unit on conservation of biotic resources, you learnt in detail about all the natural resources, concept of biotic resources; their different types and distribution in the world. Protection, management and conservation of natural resources have also been explained in detail here. The three simple R's of conservation reduce, reuse and recycling have been simply described. Detail description of different approaches to biotic resource conservation is given in this unit. Surveying techniques including field survey; different steps of surveying such as standardization, sampling effort, scale, monitoring and frequency of survey have all been explained in detail. Evaluation of survey result, preservation and conservation methods including in situ and ex situ conservation have been covered in this module. Also, conservation of biological resources in India have been elaborated here.

16.9 GLOSSARY

Biodiversity: variety of plants and animals

Bioprospecting: is a process of extracting information about biological resources for medical or commercial usages.

Biosphere: is the sphere of the earth where life grows and survives

Ecosystem: an area where interrelation between biotic and abiotic factors support life.

Humus: it is dark color organic manure found in soil formed by decaying of plants and animals

Module End Questions

Q1. What is sustainable development?
Q2. What is standardization and why is it important for surveying?
Q3. Give 3 examples of biosphere reserves in India.
Q4. What is the difference between preservation and conservation of natural resources ?
Q5. What are the three R's of conservation? Explain them.

Answers to Module End Questions

Ans:1 Sustainable development is meeting the needs of the present without compromising the ability of future generations to meet their own needs.

Ans:2 Standardization is a basic survey step, in this sampling for survey is kept consistent. As data is generally collected by different surveyors from different areas. So standardization of sampling ensures, differences between different areas are significant.

Ans:3 Nanda Devi (Uttar Pradesh), Sundarbans (West Bengal) and Nokrek (Meghalaya) are three of the 18 biosphere reserves in India.

Ans:4 Preservation of natural resources generally means no interference of humans or untouched resources. Whereas conservation is a more practical term used for sustainable consumption and management of resources.

Ans:5 The three R's of conservation are Reduce, Reuse and Recycle. Reduce the unnecessary usages and wastages of resources to conserve. Reuse the resource as much as possible before discarding. Recycle the discarded product into something new and usable.

Answers to Practice Questions

Ans:1 Resource is anything that satisfy our needs and wants. Any material which we can utilize or is useful to us, we call it a resource.

Ans:2 Potential Resource are those resource, which are not yet fully realized but have the potential to be used in the future. The quantity and distribution of such resources are not yet known.

Actual resources are those resources, which we are utilizing and we know about their actual distribution.

Ans. 3: One Horne Rhinos are found maximum in the state of Assam in India.

Ans. 4: There are three basic approaches to biotic resource management.

1. Community based approach combines the objective of conservation of resources with economic benefits for the rural communities.
2. Adaptive approach is a way of managing resources and learning about the same.
3. Integrated resource management approach through this approach the multiple aspect of natural resources meet the goals of the direct users and producers. This approach focuses on sustainability.

Ans. 5: Biodiversity is the variety of plants and animals. Biodiversity is required for healthy ecological balance.

Ans. 6: National parks and wildlife sanctuaries are two examples of in-situ conservation method.

16.11 REFERENCES

Bernhardt, T "Biological surveys", Quebec Biodiversity Website, Redpath Museum.

http://redpath-museum.mcgill.ca/Qbp/2.About%20Biodiversity/surveys.htm

Eugen Coca website.

http://www.ecoca.ro/meteo/tutorial/Sustainability/Older/Conservation and Preservation.html

Guidelines for preparing biological resource studies or assessments, Office of the agricultural commissioner, Sonoma county, California.

http://www.sonoma-county.org/agcomm/pdf/biological_resource_study_or_assessment_guidelines.pdf

MapsofIndia.com. www.mapsofindia.com/india-natural-resources

National Geography. http://nationalgeographic.org/encyclopedia/north-america-resources/

Rice, J "Science dimensions of an Ecosystem Approach to Management of Biotic Ocean Resources (SEAMBOR)", Marine Board-ESF Position Paper 14.

http://www.esf.org/fileadmin/Public_documents/Publications/seambor.pdf

Raven,P,H "A biological survey for the nation", National Academy Press, Washington DC, 1993.

Sharaky, A,M "Mineral Resources and Exploration in Africa" Department of Natural Resources Institute of African Research and Studies, Cairo University, Egypt.

Spellerberg, I "Evaluation and Assessment for Conservation: Ecological guidelines for determining priorities for nature conservation" Chapman and Hall, London

Surkar, D "Conserving Biodiversity of India", vigyanprasar.gov.in

www.vigyanprasar.gov.in/Radioserials/**Conserving_Biodiversity**2.pdf

Sustainable Communities Online for a more sustainable future.

http://www.sustainable.org/environment

Young, A "Land Resources: Now and for the Future", Cambridge University Press.

16.12 SUGGESTED READINGS

Bharucha, E "Textbook for environmental studies for undergraduate courses", University Press., Hyderabad, India.

Spellerberg, I "Evaluation and Assessment for Conservation: Ecological guidelines for determining priorities for nature conservation" Chapman and Hall, London

Young, A "Land Resources: Now and for the Future", Cambridge University Press.