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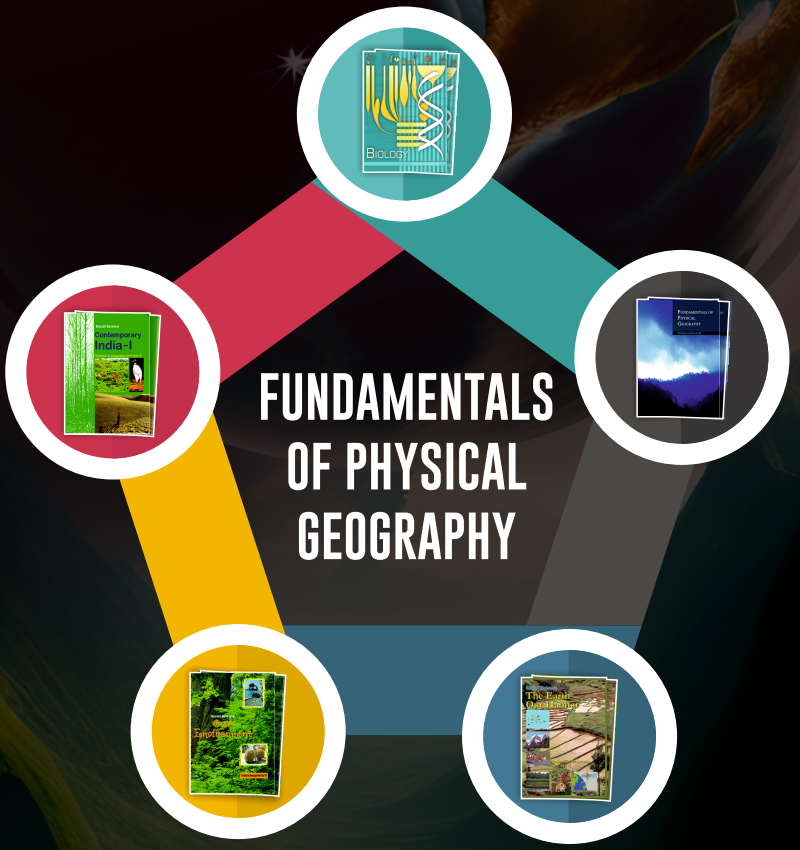


## FOR CIVIL SERVICES EXAMINATION

ONLYIAS BY PHYSICS WALLAH

# NCERT WALLAH

## ONE STOP Solution

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# FUNDAMENTALS OF PHYSICAL GEOGRAPHY

FOR CIVIL SERVICES EXAMINATION

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# PREFACE

A highly skilled professional team of PW ONLY IAS works arduously to ensure that the students receive the best content for the UPSC exams. A plethora of UPSC Study Material is available in the market but PW ONLY IAS professionals are continuously working to provide supreme quality study material for our UPSC students.

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**Alakh Pandey**

Every chapter consists of 'Points to Ponder', where our leaders raise thinking points for the students to go beyond the confines of the book. The students are expected to think about and find out possible answers to these points. The Caricatures used are inspired by Alakh Pandey Sir and Sumit Rewri Sir.

**Sumit Rewri**

# CONTENTS

# 1 Geography as a Discipline

**Bibliography:** This chapter encompasses the summary of Chapter 1 - XI NCERT book Fundamentals of Physical Geography.

## Introduction

Geography is studied as an **independent subject**. A pertinent question to be asked while studying Geography is — **Why should we study geography?** The answer is that we live on the surface of the earth and our lives are affected by our surroundings in many ways and a study of Geography equips us to appreciate diversity and investigate into the causes responsible for creating such variations over time and space.

## Geography: An Overview

### Geography Word Origin

The English word, Geography has its origin in Greek, which relates to description of the Earth. It is made of two greek words "GEO" meaning "Earth" and "graphia" meaning "Writing".

- The earth's surface is not uniform. It has variations in its **physical features**. There are mountains, hills, valleys, plains, plateaus, oceans, lakes, deserts, etc.
- There are variations in its **social and cultural features** also. There are villages, cities, roads, railways, ports, markets and many other elements created by human beings across the entire period of their cultural development.
- The variation on earth provides a clue to the understanding of the relationship between the physical environment and socio/cultural features.
- Geography is the description of the earth.
- The term geography was first coined by **Eratosthenes, a Greek scholar** (276-194 BC). The word has been derived from two roots from Greek language **geo (earth) and graphos (description)**. Some Scholars have also defined geography as, "the description of the earth as the abode of human beings.

- Geography is concerned with the description and explanation of the aerial differentiation of the earth's surface. - **Richard Hartshorne**
- Geography studies the differences of phenomena usually related in different parts of the earth's surface. - **Hettner**

## Geography as an Independent Discipline

- Geography is different from other sciences in its subject matter and methodology but at the same time, it is closely related to other disciplines. Geography derives its data base from all the natural and social sciences and attempts their synthesis.

- It studies the various phenomena that exists on earth. It is, therefore, logical to perceive geography as the study of **areal differentiation**. Thus, geography was perceived to study all those phenomena which vary over space.
- Geographers do not study only these variations in the phenomena over the earth's surface (space) but also study the associations with the other factors which cause these variations.
- Thus, the concern of geography is to find out the causal relationship between any two phenomena or between more than one phenomenon. It not only helps in interpretation but also foresees the phenomena in future.

## Interdependence Between Nature & Humans

- The geographical phenomena, both the physical and human, are not static but **highly dynamic**. The study of Nature and Human interactions is an integrated whole.
- 'Human' is an integral part of 'nature' and 'nature' has the imprints of 'human' sustenance. Present societies have modified their natural environment by inventing and using technology and thus, have expanded the utilization of the resources provided by nature.

**POINTS TO PONDER**

Initially, the discipline of Geography was limited to Physical Geography alone. In due course, Human Geography was considered as an integral part of the discipline. Can you think of the ways in which the Physical Landscape drives the evolution of human culture and ways in which the culture is acting as the modifier of the physical landscape?

- **Technology** has helped in increased labour efficiency and provided leisure to human beings to attend to the higher needs of life. It has also **increased the scale of production** and the mobility of labour. With the help of technology, human beings have moved from the stage of necessity to a stage of freedom. We now find **humanised nature and naturalised human beings** and geography studies this interactive relationship. Therefore, as a social science discipline, geography studies the **'spatial organisation' and 'spatial integration'**.

## Questions that Concern Geography

- **Geography as a discipline is concerned with three sets of questions:**
  - Identification of the **patterns of natural and cultural features** as found over the surface of the earth. These are the questions about what?
  - Some questions are related to the **distribution of the natural and human/cultural features** over the surface of the earth. These are the questions about where?
  - The **causal relationships between features and the processes** and phenomena. This aspect of geography is related to the question, why?
- Geography as a discipline is related to space and takes note of spatial characteristics and attributes. It studies the patterns of distribution, location and concentration of phenomena over space and interprets them providing explanations for these patterns.

## Geography as an Integrating Discipline

- Geography is a discipline of **Synthesis**. It attempts spatial synthesis, and history attempts temporal synthesis. Its approach is holistic in nature. It recognises the fact that the **world is a system of interdependencies**.
- Geography as an integrating discipline has interfaces with numerous natural and social sciences (Refer to Figure 1.1). All the sciences, whether natural or social, have one basic objective, i.e., understanding the reality.
- Geography helps in understanding the reality in totality in its spatial perspective. It also attempts to comprehend the associations of phenomena as related in sections of reality.

- Thus, a geographer is required to have a broad understanding of all the related fields, to be able to logically integrate them. **Integration of fields** helps us to comprehensively understand a particular situation or scenario.
- **For example:** In India, **Himalayas** have acted as great barriers and provided protection but the passes have also provided routes to the migrants and invaders from Central Asia. The sea coast has encouraged contact with people from East and Southeast Asia, Europe and Africa. Navigation technology helped European countries to colonise a number of countries of Asia and Africa, including India.
- The **geographical factors have modified the course of history** in different parts of the world.
- Every geographical phenomenon undergoes change with time and can be explained temporally. It is for this reason; **time is an integral part of geographical studies** as the fourth dimension.

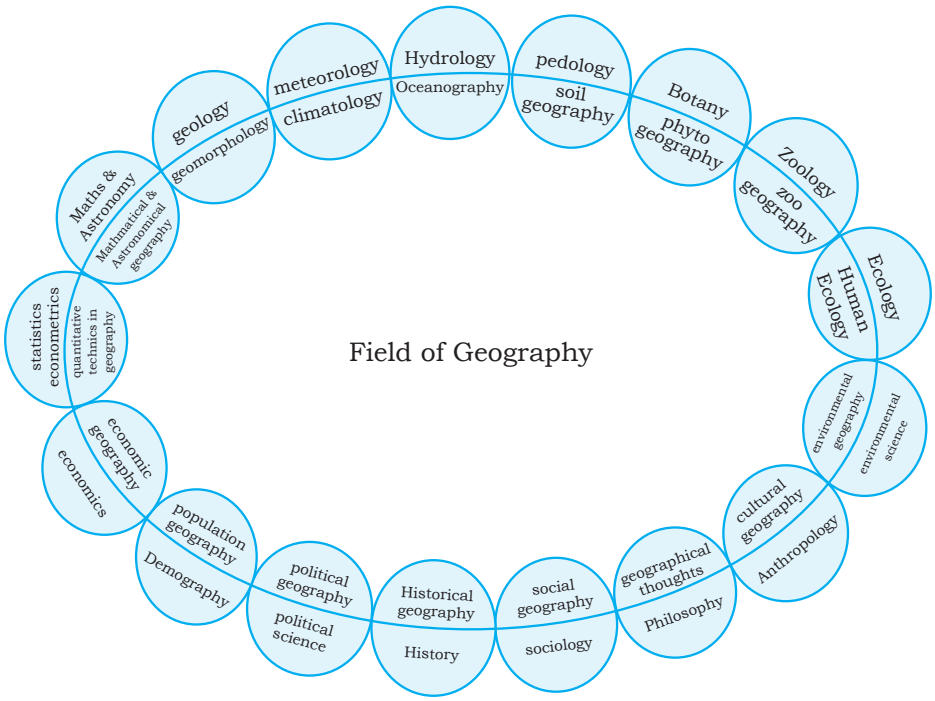



**Figure 1.1: Geography and its Relation with other Disciplines**

## Branches of Geography

Geography is an interdisciplinary subject of study. The study of every subject is done according to some **Approach**. The major approaches to study geography have been (i) **Systematic** and (ii) **Regional**.

- **Systematic Geography approach:** This approach was introduced by **Alexander Von Humboldt**, a German geographer (1769-1859). In systematic approach (Refer to Figure 1.2), a phenomenon is studied world over as a whole, and then the identification of typologies or spatial patterns is done. For example, if one is interested in studying natural vegetation, the study will be done at the world level as a first step.
- **Regional Geography approach:** It was developed by another German geographer and a contemporary of Humboldt, **Karl Ritter** (1779-1859). In the regional approach, the world is divided into regions at different hierarchical levels and then all the geographical phenomena in a particular region are studied. These regions may be natural, political or designated regions. The phenomena in a region are studied in a holistic manner searching for unity in diversity.

One of the main characteristics of geography is **Dualism**, it depends on the aspect emphasised in the study. Earlier scholars laid emphasis on physical geography. But human beings are an integral part of the earth's surface. They are part and parcel of nature. Thus, Human Geography developed with emphasis on human activities.

### Branches of Geography (Based on Systemic Approach)

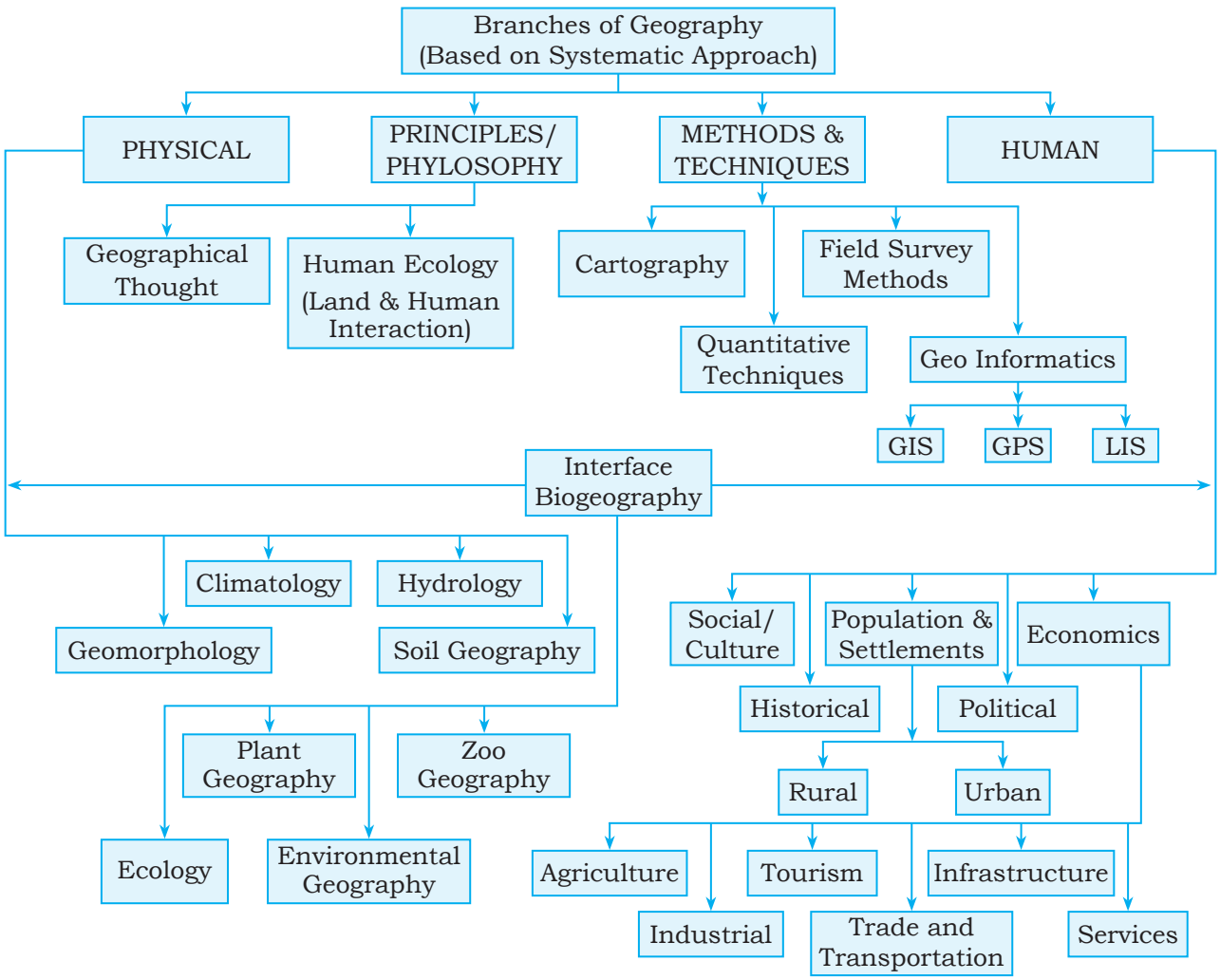



**Figure 1.2: Branches of Geography Based on Systematic Approach**

### Physical Geography

(i) **Geomorphology** is devoted to the study of landforms, their evolution and related processes.

(ii) **Climatology** encompasses the study of structure of atmosphere and elements of weather and climates and climatic types and regions.

(iii) **Hydrology** studies the realm of water over the surface of the earth including oceans, lakes, rivers and other water bodies and its effect on different life forms including human life and their activities.

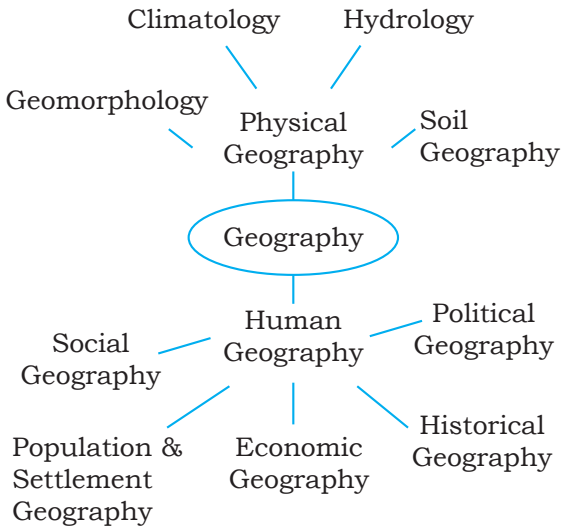
(iv) **Soil Geography** is devoted to study the processes of soil formation, soil types, their fertility status, distribution and use.

## Human Geography

(i) **Social/Cultural Geography** encompasses the study of society and its spatial dynamics as well as the cultural elements contributed by the society.

(ii) **Population and Settlement Geography (Rural and Urban)** studies population growth, distribution, density, sex ratio, migration and occupational structure etc. Settlement geography studies the characteristics of rural and urban settlements.

(iii) **Economic Geography** studies economic activities of the people including agriculture, industry, tourism, trade, and transport, infrastructure and services, etc.




(iv) **Historical Geography** studies the historical processes through which the space gets organised.

(v) **Political Geography** looks at space from the viewpoint of political events and studies boundaries, space relations between neighbouring political units, delimitation of constituencies, election scenarios and develops a theoretical framework to understand the political behaviour of the population.

## Biogeography

The interface between physical geography and human geography has led to the development of Biogeography which includes:

(i) **Plant Geography:** It studies the spatial pattern of natural vegetation.

(ii) **Zoo Geography:** It studies the spatial patterns and geographic characteristics of animals and their habitats.

(iii) **Ecology/Ecosystem:** It deals with the scientific study of habitat characteristics of species.

(iv) **Environmental Geography:** This subfield focuses on the interactions between human activities and the environment, including issues related to environmental degradation, conservation, pollution, and sustainability.

## Branches of Geography (Based on Regional Approach)

- **Regional Studies/Area Studies:** Comprises Macro, Meso and Micro Regional Studies.
- **Regional Planning:** Comprises Country/Rural and Town/Urban Planning.
- **Regional Development/Regional Analysis** has two aspects which are common to this discipline, these are:

(i) **Philosophy**
- Geographical Thought
- Land and Human Interaction/Human Ecology

(ii) **Methods and Techniques**
- Cartography including Computer Cartography
- Quantitative Techniques/Statistical Techniques
- Field Survey Methods
- Geo-informatics comprising techniques such as Remote Sensing, GIS, GPS, etc

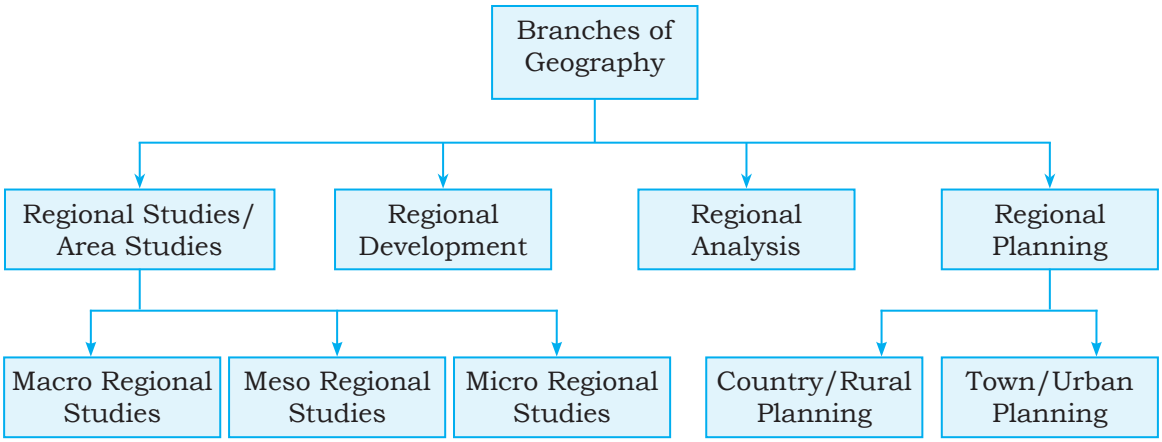



**Figure 1.3: Branches of geography based on regional approach.**

The above classification gives a comprehensive format of the branches of geography. But this format is not static. Any discipline is bound to grow with new ideas, problems, methods and techniques.

For example, **new technology has enabled scholars to handle large quantities of data**. The internet provides extensive information. Thus, the capacity to attempt analysis has increased tremendously.

**GIS** has further opened vistas of knowledge. **GPS** has become a handy tool to find out exact locations. Technologies have enhanced the capacity of attempting synthesis with sound theoretical understanding.

## Physical Geography & its Importance

- Physical geography is of paramount importance as it provides a **foundational understanding** of the earth's natural environment and its interactions with human society. Physical geography includes the study of **Lithosphere, Atmosphere, Hydrosphere and Biosphere**.
- **Soils** are formed through the process of **Pedogenesis**. Time provides maturity to soils and helps in the development of soil profiles. Soils are important for all biological activity as they support micro-organisms and plants and animals.

**POINTS TO PONDER**

Geography plays a profound role in the progress and development of any region. Do you agree that the geographical conditions of the United States of America predispose it to assume the role of a superpower? Do you also agree that many contemporary political crises across the world, like the Russia-Ukraine conflict, can be explained through a Geographical lens?

- **Landforms** provide the base for human activities like plains are used for agriculture, mountains provide pastures, forests, tourist spots etc.
- **Climate** influences our lifestyle, clothing, and food habits. It also impacts vegetation of an area.
- **Temperature and precipitation** ensure forest density and quality of agriculture and grasslands.

## Conclusion

The knowledge is fundamental for addressing environmental challenges, such as climate change, deforestation, and habitat loss. Understanding of Physical geography is essential for sustainable development and better resource management. Physical geography's importance lies in its contribution to environmental conservation, resource management, disaster preparedness, scientific advancement, and informed decision-making. It plays a pivotal role in addressing global challenges and improving the quality of life on Earth.

***Glossary:***

- **Meteorology:** It is the study of weather and climate.
- **Demography:** It is the scientific study of the changing number of births, deaths, diseases, etc. in a community over a period of time.
- **Pedology:** It is the branch of science concerned with the formation, nature, ecology, and classification of soil; soil science.
- **Areal Differentiation:** It refers to the study of regional differences in human geography. It involves analyzing the characteristics and processes that shape the physical and cultural landscapes of different regions.

❐❐❐

# 2 The Origin and Evolution of the Earth

**Bibliography:** This Chapter encompasses a summary of Chapters 1, 2 and 3 - VI NCERT (The Earth: Our Habitat) and Chapter 2 - XI NCERT (Fundamental of Physical Geography).

## Introduction

It is wonderful to watch the sky after sunset. One would see the shining objects – some are bright, while others are dim. They all appear to be twinkling. Along with these bright objects, one may also see the moon. In this chapter, we will learn how these "twinkling little stars" were formed, the story of origin and evolution of the earth. With that, we will eventually read about our solar system.

## Early Theories

### Origin of the Earth

- A large number of hypotheses were given by different philosophers and scientists regarding the origin of the earth.
- **Nebular Hypothesis:** German philosopher **Immanuel Kant** gave the theory known as **Nebular Hypothesis** and Mathematician **Laplace revised** it in 1796. The hypothesis considered that the planets were formed out of **slowly rotating clouds of material** associated with a youthful sun.
- **Revised Nebular Hypothesis:** In 1950, **Otto Schmidt (Russia) and Carl Weizascar (Germany)** revised the 'nebular hypothesis', though differing in details. They considered that the **sun was surrounded by solar nebulae** containing mostly hydrogen and helium along with what may be termed as dust. The friction and collision of particles led to formation of a disk-shaped cloud and the planets were formed through the **Process of Accretion**.

## Modern Theories

### Origin of the Universe

- **Big Bang Theory or expanding universe hypothesis: Edwin Hubble,** in 1920, discovered that the distance between the galaxies is found to be increasing and thereby, the universe is considered to be expanding.
- Scientists believe that though the space between the galaxies is increasing, observations do not support the expansion of galaxies themselves.
- The theory considers the following stages in the development of the universe:
  - In the beginning, all **matter existed in one place** in the form of a "tiny ball" **(singular atom)** with an unimaginably small volume, infinite temperature and infinite density.

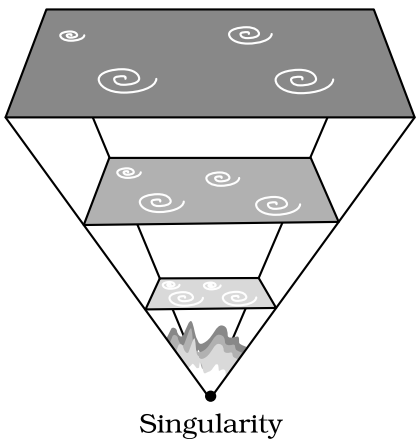



**Figure 2.1: The Big Bang**

- ✧ At the Big Bang (13.7 billion years before the present) the **"tiny ball" exploded** violently, and the expansion continues even to the present day (Refer to Figure 2.1).
- ✧ As it grew, some energy was converted into matter. After the event, there was rapid expansion within fractions of a second. Thereafter, it has slowed down. Within the first three minutes from the bang, the **first atom began to form**.
- ✧ Within 300,000 years from the Big Bang event, **temperature dropped** to 4,500K and gave rise to atomic matter such as **hydrogen and helium**. The universe became transparent.

- ✤ An alternative to the expansion of the universe was **Hoyle's concept of steady state** which considered the universe to be roughly the same at any point of time.
- ✤ At present, the scientific community favours the argument of **expanding universe** due to greater evidence available about the same (Refer to Figure 2.1).

### Formation of Stars

- ✤ The initial density differences of matter and energy in the early universe gave rise to differences in gravitational forces and it caused the matter to get drawn together. These formed the bases for the development of galaxies.
- ✤ A galaxy starts to form by accumulation in the form of a very large cloud of hydrogen gas called **a nebula** and the galaxy contains a large number of stars.
- ✤ Eventually, growing nebulae develop localised clumps of gas and continue to grow into even denser gaseous bodies, giving rise to formation of stars.

**Do You Know?**

- ➢ Galaxies spread over vast distances that are measured in thousands of light-years.
- ➢ The diameters of individual galaxies range from 80,000-150,000 light years.
- ➢ A light year is a measure of distance.
- ➢ **Light travels at a speed of 300,000 km/s.** Thus **a light year equals to 9.461 × $10^{12}$ km.**
- ➢ The **mean distance between the sun and the earth is 149,598,000 km** and in terms of light years, it is 8.311 minutes to reach the earth.

### Formation of Planets

- ✤ **First Stage:** The stars are localised lumps of gas within a nebula. The gravitational force within the lumps leads to the formation of a core to the gas cloud and a huge rotating disc of gas and dust develops around the gas core.
- ✤ **Second Stage:** Now, the gas cloud starts getting condensed and the matter around the core develops into small rounded objects. By the **process of cohesion** these small-rounded objects develop into **Planetesimals**. Larger bodies start forming by collision, and gravitational attraction causes the material to stick together.
- ✤ **Third Stage:** Finally, these large numbers of small planetesimals accrete to form fewer large bodies in the form of planets.

### Formation of Moon

- ✤ In 1838, **Sir George Darwin** suggested that initially, the earth and the moon formed a single rapidly rotating body and the whole mass became a dumb-bell-shaped body and eventually it broke.
- ✤ It was also suggested that the material forming the moon was separated from what we have at present the depression occupied by the Pacific Ocean.
- ✤ However, the present scientists do not accept either of the explanations.
- ✤ It is now generally believed that the formation of the moon is an outcome of **'Giant Impact'** or what is described as **"The Big Splat"**.

- A body of the size of 1-3 times that of Mars collided into the earth shortly after the earth was formed. It blasted a large part of the earth into space, continued to orbit the earth and eventually formed into the present moon about 4.44 billion years ago.

## Evolution of the Earth

- Initially, the planet earth was a barren, rocky and hot object with a thin atmosphere of **hydrogen and helium**.
- The period, between 4,600 **million years and the present, led to the evolution of life** on the surface of the planet, making it a beautiful planet with ample amount of water and conducive atmosphere from rocky, barren and hot earth.
- The **earth has a layered structure** from the outermost end of the atmosphere to the centre of the earth. The **material is not uniform** throughout.
- The matter of the atmosphere **has the least density**.
- The earth's **interior has different zones** from the surface to core and each of these contains materials with different characteristics.

**POINTS TO PONDER**

The earth and solar system are a result of many cosmic processes. Can you trace the impact of these processes on the structure and composition of the earth's interior and physiography of the earth?

### Evolution of Lithosphere

- Lithosphere is the solid, outer part of the earth. During the primordial stage, the earth was mostly in a volatile state.
- The **temperature increased** due to gradual increase in density. As a result the **material inside started getting separated** depending on their densities for example heavier materials (like iron) sinked towards the centre and the lighter ones moved towards the surface of the earth.
- With passage of time **it cooled further and solidified and condensed into a smaller size** which later led to the development of the outer surface in the form of a crust.
- During the formation of the moon, due to the giant impact, the earth was further heated up and through the **process of differentiation**, the earth forming material got separated into different layers (Refer to Figure 2.2).

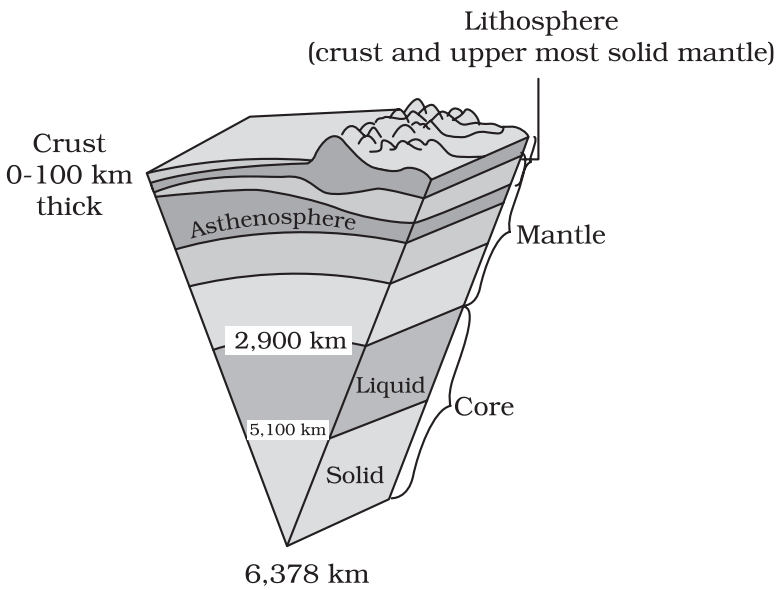
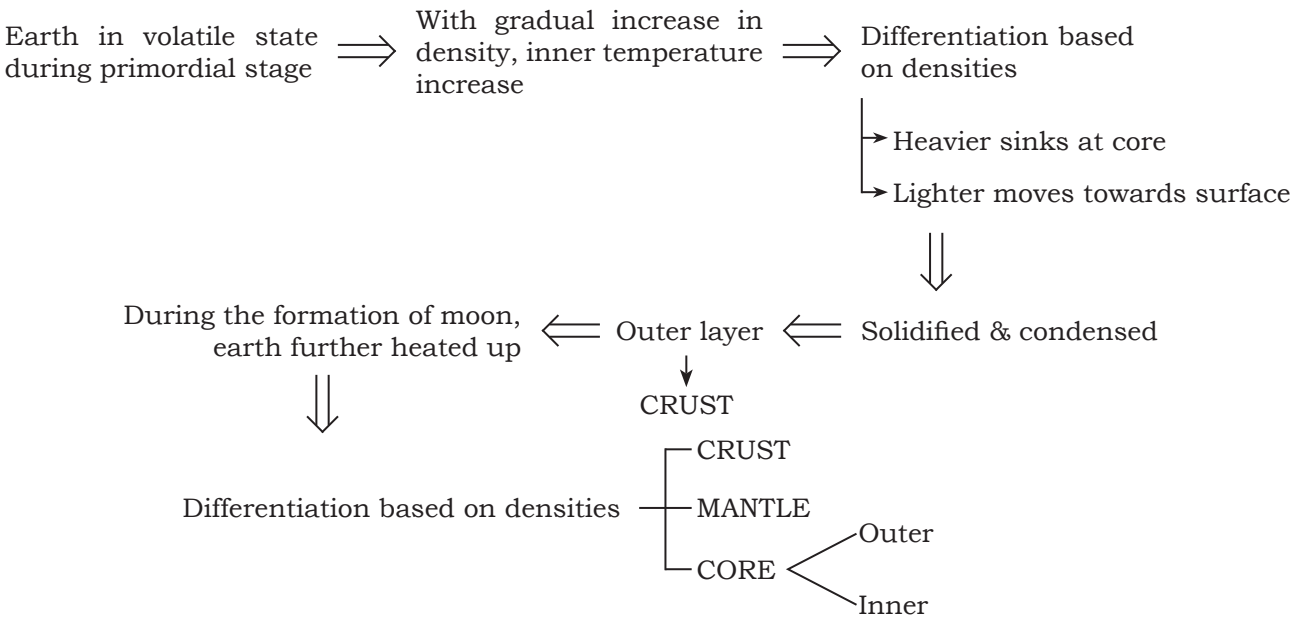


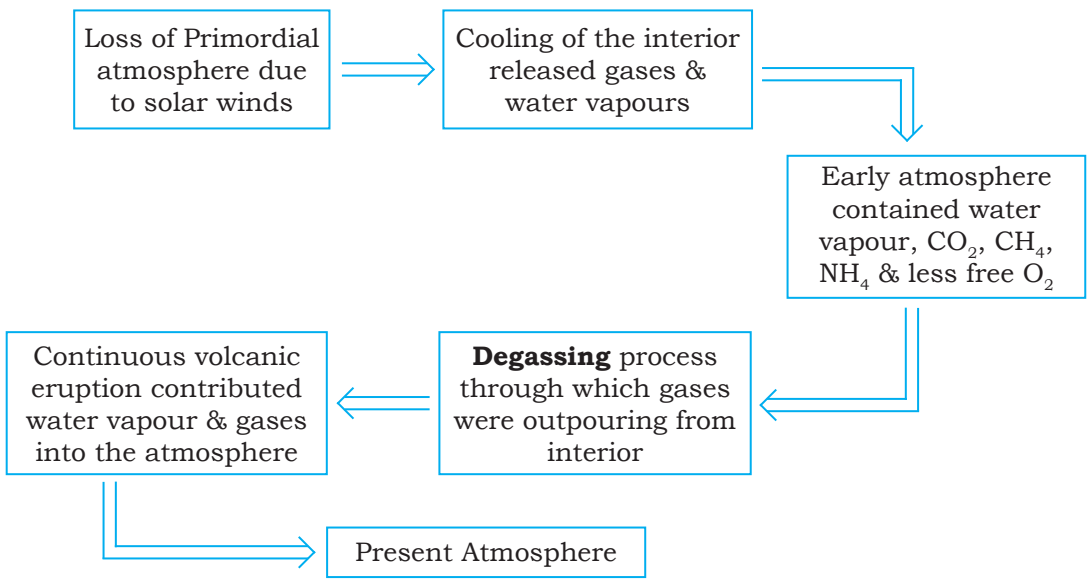

**Figure 2.2: The Interior Layers of the Earth**




**Evolution of Lithosphere**

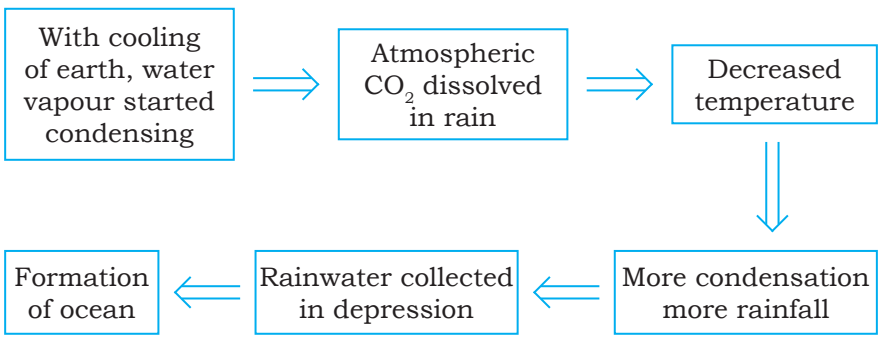
## Evolution of Atmosphere and Hydrosphere

- The present composition of earth's atmosphere is mainly **nitrogen and oxygen**. There are three stages in the evolution of the present atmosphere:
  1. The **loss of primordial atmosphere**.
  2. The **hot interior of the earth** contributed to the evolution of the atmosphere.
  3. The composition of the atmosphere was modified by the living world through the process of **photosynthesis**.




**Evolution of Atmosphere**

- The early atmosphere of earth, with hydrogen and helium, and all the terrestrial planets with their primordial atmosphere were supposed to have been lost through the impact of solar winds.
- During the cooling of the earth, gases and water vapour were released from the interior solid earth by the process called **degassing** which started the evolution of the present atmosphere.
- The early atmosphere largely contained **water vapour, nitrogen, carbon dioxide, methane, ammonia and very little of free oxygen**.
- Continuous volcanic eruptions contributed water vapour and gases to the atmosphere. As the earth cooled, the water vapour released started getting condensed.
- The carbon dioxide present in the atmosphere got dissolved in rainwater and the temperature further decreased causing more condensation and more rains.
- The rainwater got collected in the depressions to give rise to oceans and were formed within 500 million years from the formation of the earth (i.e. oceans are 4,000 million years old).




**Evolution of Hydrosphere**

- Life began to evolve, sometime around 3,800 million years ago.
- However, the process of photosynthesis evolved, around 2,500-3,000 million years ago.
- Life was confined to the oceans for a long time and oceans began to have the contribution of oxygen through the process of photosynthesis.
- Eventually, oceans were saturated with oxygen, and around 2,000 million years ago, oxygen began to flood the atmosphere.

### Origin of Life

- The origin and evolution of life is the last phase in the evolution of the earth. Initially the earth or even the atmosphere of the earth was not conducive for the development of life.
- Modern scientists refer to **the origin of life as a chemical reaction**, which first generated complex organic molecules and assembled them.
- This assemblage could duplicate themselves converting inanimate matter into living substance.
- The record of life that existed on earth in different periods is found in rocks in the form of **fossils**.
- The microscopic structures closely related to the present form of **blue algae** have been found in geological formations much older than some 3,000 million years.
- So, it can be assumed that life began to evolve sometime 3,800 million years ago (Refer to Table 2.1).

**Table 2.1: Geological Time Scale**

| Eons | Era | Period | Epoch | Age/Years Before Present | Life/Major Events |
|---|---|---|---|---|---|
| Phanerozoic | Cenozoic (From 65 mya to the present times) | Quaternary | Holocene | 0-10,000 years | Modern Man |
| | | | Pleistocene | 10,000-2 mya | Homo Sapiens |
| | | Tertiary | Pliocene | 2-5 mya | Early Human Ancestor |
| | | | Miocene | 5-24 mya | Ape, Flowering Plants and Trees |
| | | | Oligocene | 24-37 mya | Anthropoid Ape |
| | | | Eocene | 37-58 mya | Rabbits and Hare |
| | | | Palaeocene | 57-65 mya | Small Mammals: Rats-Mice |
| | Mesozoic 65-245 mya | Cretaceous | | 65-144 mya | Extinction of Dinosaurs |
| | | Jurassic | | 144-208 mya | Age of Dinosaurs |
| | | Triassic | | 208-245 mya | Frogs and turtles |
| | Palaeozoic 245-570 mya | Permian | | 245-286 mya | Reptile dominate-replace amphibians |
| | | Carboniferous | | 286-360 mya | First Reptiles: Vertebrates: Coal beds |
| | | Devonian | | 360-408 mya | Amphibians |
| | | Silurian | | 408-438 mya | First trace of life on land: Plants |
| | | Ordovician | | 438-505 mya | First Fish |
| | | Cambrian | | 505-570 mya | No terrestrial Life: Marine invertebrate |
| Proterozoic | | | | 570-2,500 mya | Soft-bodied arthropods |
| Archean | | | | 2,500-3,800 mya | Blue green Algae: Unicellular bacteria |
| Hadean | Pre-Cambrian 570 mya-4,800 mya | | | 3,800-4,800 mya | Oceans and Continents form - Ocean and Atmosphere are rich in Carbon dioxide |
| Origin of Stars | 5,000-13,700 mya | | | 5,000 mya | Origin of the sun |
| Supernova | | | | 12,000 mya | Origin of the universe |
| Big Bang | | | | 13,700 mya | |

***mya = million years ago***

## Our Solar System

### Celestial Bodies

- The sun, the moon and all the objects shining in the night sky are called celestial bodies.

### Stars

- Some celestial bodies are very big and hot made up of gases. They have their **own heat and light,** which they emit in large amounts. These celestial bodies are called stars, for example the sun.
- In ancient times, people used to determine directions during the night with the help of stars.
- The North star or the Pole Star indicates the north direction, and always remains in the same position in the sky. **(Refer Figure 2.3).**

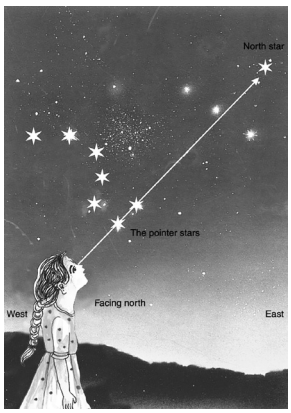



**Figure 2.3: Saptarishi and the Pole Star**

### The Solar System

- The **nebula** from which our Solar system is supposed to have been formed, started its collapse and core formation around 5-5.6 billion years ago and the planets were formed about 4.6 billion years ago.
- In Roman mythology **'sol'** is the **'Sungod'**. **'Solar'** means **'related to the sun'**. The family of the sun is, therefore, called the solar system with the sun as its Head.
- The sun, eight planets, satellites and millions of other smaller celestial bodies like asteroids, meteoroids and huge quantities of dust-grains and gases form the solar system (Refer to Figure 2.4).

**Constellation**

Various patterns formed by different groups of stars are called constellations. Some examples are **Ursa Major or Big Bear, Saptarishi** (Sapta-seven, rishi-sages) which is a group of seven stars that forms a part of Ursa Major Constellation. We can locate the position of the Pole Star with the help of the Saptarishi.

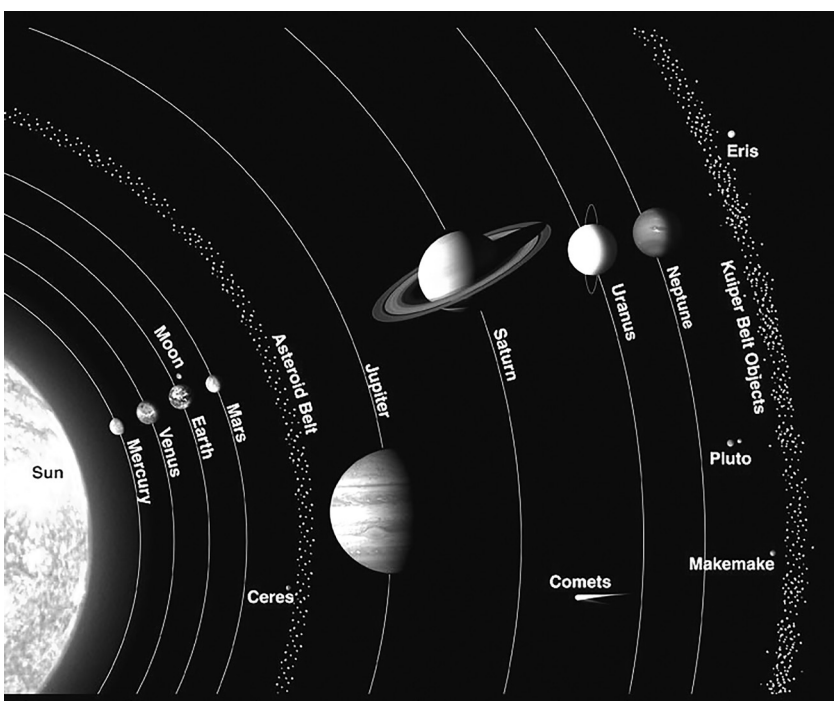



**Figure 2.4: The Solar System**

**Table 2.2: The Solar System**

| The Solar System | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Mercury** | **Venus** | **Earth** | **Mars** | **Jupiter** | **Saturn** | **Uranus** | **Neptune** |
| Distance* | 0.387 | 0.723 | 1.000 | 1.524 | 5.203 | 9.539 | 19.182 | 30.058 |
| Density@ | 5.44 | 5.245 | 5.517 | 3.945 | 1.33 | 0.70 | 1.17 | 1.66 |
| Radius # | 0.383 | 0.949 | 1.000 | 0.533 | 11.19 | 9.460 | 4.11 | 3.88 |
| Satellites% | 0 | 0 | 1 | 2 | 95 | 146 | 27 | 13 |

* Distance from the sun in astronomical unit i.e. average mean distance of the earth is 149,598,000 km = 1
@ Density in gm/cm$^3$
# Radius: Equatorial radius 6378.137 km = 1
% Number of Satellites as of 2023

## The Sun

- The sun is in the centre of the solar system.
- It is huge and made up of extremely hot gases.
- It provides the pulling force that binds the solar system.
- The sun is the **ultimate source of heat and light**.
- The sun is about **150 million km away from the earth**.

## The Moon

- Our earth has only one natural satellite, i.e, the moon.
- Its diameter is only 1/4th that of the earth.
- It appears so big because it is nearer to the earth (about **3,84,400 km away**) than other celestial bodies.
- It moves around the earth in about **27 days** and takes exactly the same time to complete one spin. As a result, **only one side of the moon is visible** to us on the earth.
- There are no conditions favourable for possibility of life on the Moon.
- It has **mountains, plains and depressions** on its surface which cast shadows on the moon's surface.
- It appears in different shapes and at different positions. One can see the **full moon night or Poornima** only once in about a month's time. A fortnight later, one cannot see it at all as it is a **New moon night or Amavasya**.

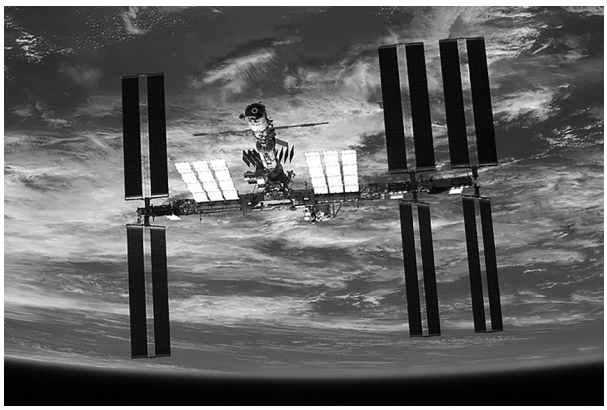


**Figure 2.5: A Human made satellite**

**Do You Know?**

- A Human made satellite is an artificial body designed by scientists to gather information about the universe or for communication.
- It is carried by rocket and placed in the orbit around the earth.
- Some Indian satellites in space are INSAT, IRS, EDUSAT, etc.

## Asteroids

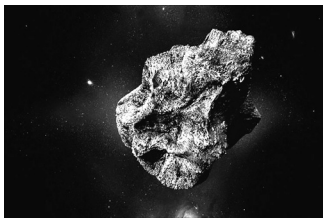


**Figure 2.6: Asteroid**

- There are numerous other tiny bodies that move around the sun called asteroids (Refer to Figure 2.6).
- They are found between the **orbits of Mars and Jupiter**.
- Scientists are of the view that asteroids are parts of a planet which exploded many years back.

## Meteoroids

- The small pieces of rocks which move around the sun are called meteoroids.
  - **Meteor:** Sometimes these meteoroids come near the earth and tend to drop upon it and due to friction with the air they get heated up and burn with a flash of light called Meteors.
  - **Meteorite:** A meteor without being completely burnt, falls on the earth and creates a hollow called a Meteorite.

## Planets

- Some celestial bodies do not have their own heat and light and they are lit by the light of the stars. Such bodies are called planets.
- The word 'planet' comes from the Greek word **"Planetai"** which means **'wanderers'**.
- There are a total of eight planets in our solar system: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. They get heat and light from the sun and some of them have their moons too.
- All the eight planets of the solar system move around the sun in fixed elongated paths called **orbits**.
- Out of the eight planets, mercury, venus, earth and mars are called the **inner planets** (also called **Terrestrial planets** meaning **earth-like** as they are made up of rock and metals, and have relatively high densities) as they lie between the sun and the belt of asteroids. The other four planets are called the **outer planets** (also called **Jovian means Jupiter-like or Gas Giant planets) (Refer to Table 2.3)**.

**Do You Know?**

- Venus is considered as **'Earth's-twin'** because its size and shape are very much similar to that of the earth.
- Jupiter, Saturn and Uranus have rings of small debris around them. These rings may be seen from the earth with the help of powerful telescopes.
- Pluto stopped being a planet after the decision taken by the International Astronomical Union, reclassified as a dwarf planet like other celestial objects (Ceres, 2003 UB313).

**Table 2.3: Difference Between Terrestrial and Jovian Planets**

| Terrestrial Planets | Jovian Planets |
|---|---|
| These were formed in the close vicinity of the parent star where it was too warm for gases to condense to solid particles. | These were formed at quite a distant location. |
| The solar wind was most intense nearer the sun, so it blew off lots of gas and dust from the terrestrial planets. | The solar winds were not all that intense to cause similar removal of gases from the Jovian planets. |
| They are smaller and their lower gravity could not hold the escaping gases. | They are larger planets. |

## The Earth

- The earth is the 3rd nearest planet to the sun and 5th largest planet in size.
- It is slightly flattened at the North and the South Poles and bulges in the middle. That is why its shape is described as a **Geoid** which means an earth-like shape.
- The earth is neither too hot nor too cold. It has water and air (life supporting gases like oxygen), which are very essential for our survival.
- From outer space, the earth appears blue because its 2/3rd surface is covered by water. It is, therefore, called a **blue planet**.
- It gets all its heat and light from the sun, which is our nearest star.

**Globe**

These may be of varying size and type – big ones, which cannot be carried easily, small pocket globes, and globe-like balloons, which can be inflated and are handy.

It is not fixed and can be rotated.

On the globe, countries, continents and oceans are shown in their correct size.

## Latitude and Longitudes

- To find the location of places on the Earth we need certain points of reference and lines. These lines are called latitudes and longitudes.
- **Axis:** It is a tilted **imaginary line passing through two poles,** North Pole and South Pole and the earth moves around this axis. **Aryabhatta,** an ancient astronomer had stated that 'the earth is round and rotates on its own axis'.
- **Equator:** An **imaginary circular line which divides the earth into two equal parts,** the northern half (known as the **Northern Hemisphere**) and the southern half (known as the **Southern Hemisphere**).

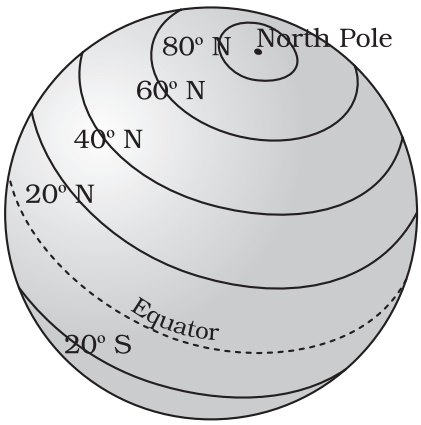



**Figure 2.7: Latitude**

### Latitudes

- All parallel circles from the equator up to the poles are called **parallels of latitudes**.
- Latitudes are measured in degrees and the equator represents the zero degree latitude.
- Since the distance from the equator to either of the poles is 1/4th of a circle round the earth, it will measure 1/4th of 360° i.e. 90°.
- Thus, 90° north latitude marks the North Pole and 90° south latitude marks the South Pole.
- All parallels north of the equator are called **'north latitudes.'** and all parallels south of the equator are called **'south latitudes.'**
- The value of each latitude is, therefore, followed by either north (N) or south (S). For example, Chandrapur in Maharashtra (India) and Belo Horizonte in Brazil (South America) are situated at 20° N latitude and 20° S latitude respectively.
- As we move away from the equator, the size of the parallels of latitude decreases but the distance between each latitude is constant (Refer to Figure 2.7).

**Do You Know?**

By measuring the angle of the Pole Star from your place, you can know the latitude of your place.

**POINTS TO PONDER**

The inception of a grid pattern on the earth system in the form of latitude and longitude has revolutionised the tracing of locations and eased travelling. Can you identify the methods that were used for the same purpose before such a grid pattern was established? Was long distance travel during those times a systemic venture or mere voyages by chance?

## Important Parallels of Latitudes

- **Tropic of Cancer (23½° N)** in the Northern Hemisphere.
- **Tropic of Capricorn (23½° S)** in the Southern Hemisphere.
- **Arctic Circle at 66½° north** of the equator.
- **Antarctic Circle at 66½° south** of the equator (Refer to Figure 2.8).

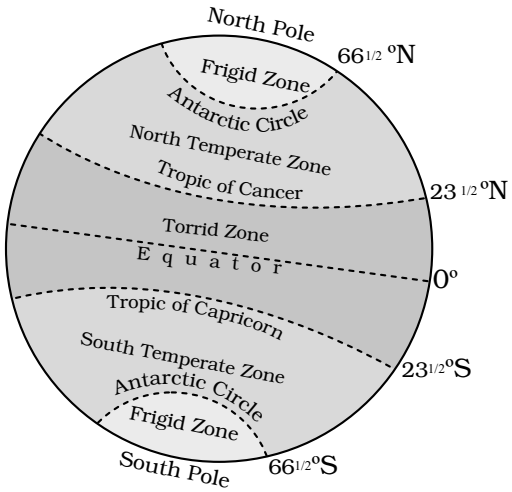



**Figure 2.8: Important Latitudes and Heat Zones**

## Heat Zones of the Earth

- **Torrid Zone:** The mid-day sun is exactly overhead at least once a year on all latitudes in **between the Tropic of Cancer and the Tropic of Capricorn**. This area, therefore, receives the maximum heat and is called the Torrid Zone.
- **Temperate Zones:** The mid-day sun never shines overhead on any latitude beyond the Tropic of Cancer and the Tropic of Capricorn. The angle of the sun's rays goes on decreasing towards the poles. As such, the areas **bounded by the Tropic of Cancer and the Arctic Circle,** and the **Tropic of Capricorn and the Antarctic Circle,** have moderate temperatures are, therefore, called Temperate Zones.
- **Frigid Zones:** Areas lying between the **Arctic Circle and the North Pole** and the **Antarctic Circle and the South Pole,** are very cold. It is because here the sun does not rise much above the horizon, its rays are always slanting and provide less heat. These are, therefore, called Frigid Zones (very cold) (Refer to Figure 2.8).

## Longitudes

- They are semicircles running from the North Pole to the South Pole and the distance between them decreases steadily polewards until it becomes zero at the poles, where all the meridians meet. These lines of references are called the **meridians of longitude**, and the distances between them are measured in 'degrees of longitude.'
  - Each degree is further divided into minutes, and minutes into seconds.
- Unlike parallels of latitude, all meridians are of equal length (Refer to Figure 2.9).
- **Prime Meridian:** Its value is **0° longitude** which passes through **Greenwich**, where the British Royal Observatory is located and from here, we count 180° eastward as well as 180° westward. The Prime Meridian and 180° meridian divide the earth into two equal halves, the Eastern Hemisphere (E) and the Western Hemisphere (W). Both 180° East and 180° West meridians are on the same line.

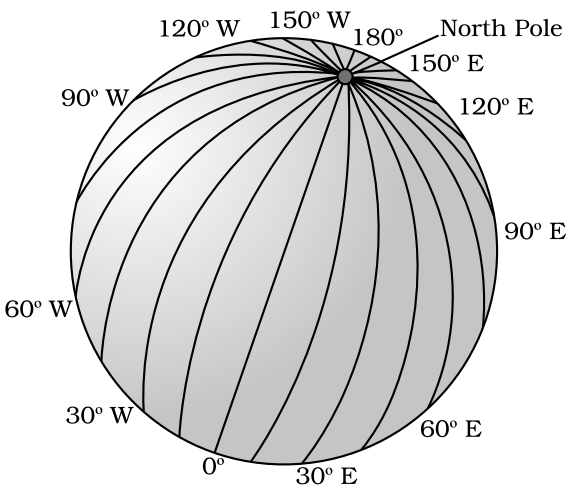



**Figure 2.9: Longitude**

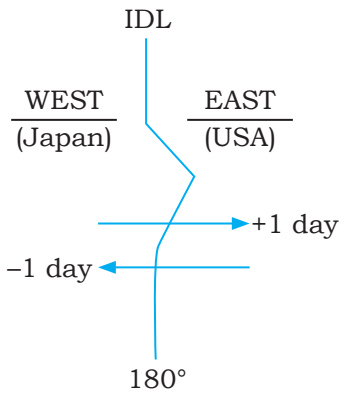
✤ **Longitude and Time:** The best means of measuring time is by the movement of the earth, the moon and the planets. Local time can be reckoned by the shadow cast by the sun, which is the shortest at noon and longest at the time of sunrise and sunset. When the Prime Meridian of Greenwich has the sun at the highest point in the sky, all the places along this meridian will have mid-day or noon. As the earth rotates from west to east, those places east of Greenwich will be ahead of Greenwich time and those to the west will be behind it. All the places on a given meridian of longitude have the same local time.

The earth has been divided into 24 time zones of one hour each and each zone covers 15° of longitude. In other words, the earth rotates 360° in about 24 hours, which means; 1 hour → 15° or 4 minutes → 1°

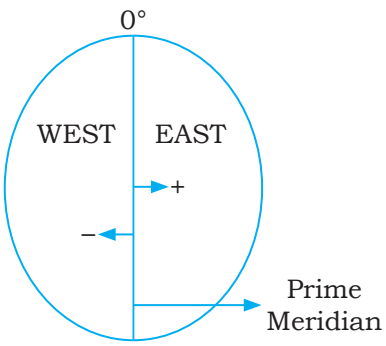
When it is 12 noon at Greenwich, the time at 15° east of Greenwich will be 15 × 4 = 60 minutes, i.e., 1 hour ahead of Greenwich time, which means 1 p.m.

But at 15° west of Greenwich, the time will be behind Greenwich time by one hour, i.e., it will be 11.00 a.m.

Similarly, at 180°, it will be midnight.




**International Date Line**




**Time Zone**

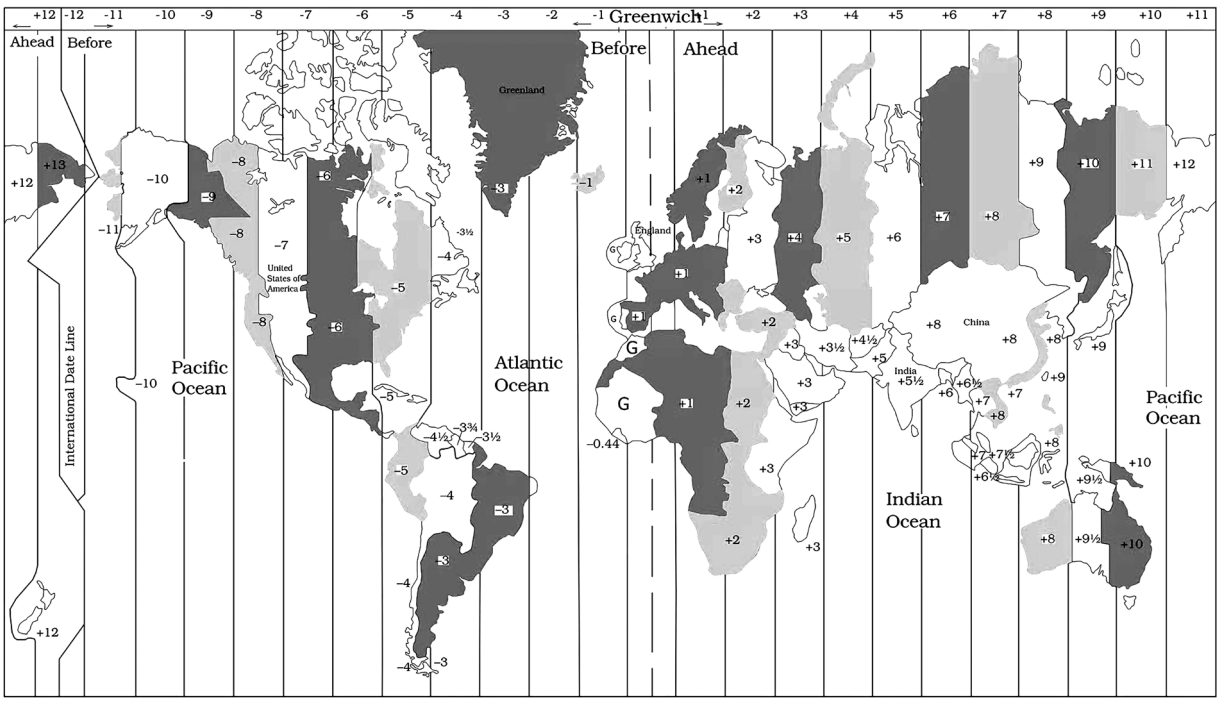



**Figure 2.10: Time Zones of the World**

## Standard Time

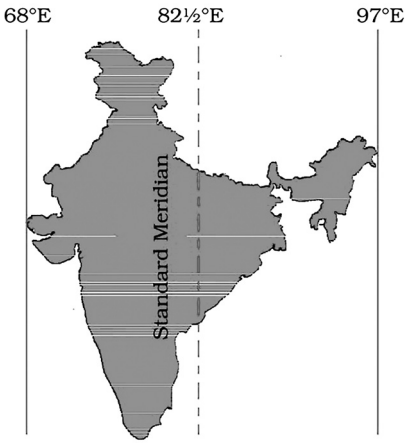



**Figure 2.11: Indian Standard Meridian**

- **Need for Standard Time:** The local time of places which are on different meridians are bound to differ. For example, it will be difficult to prepare a time-table for trains which cross several longitudes. In India, for instance, there will be a difference of about 1 hour and 45 minutes in the local times of Dwarka in Gujarat and Dibrugarh in Assam. It is, therefore, necessary to adopt the local time of some central meridian of a country as the standard time for the country.
- **Indian Standard Time (IST):** In India, the **longitude of 82½° E (82° 30' E)** is treated as **the standard meridian**. The local time at this meridian is taken as the standard time for the whole country and is known as the Indian Standard Time (IST). India located east of Greenwich at 82°30' E is 5 hours and 30 minutes ahead of GMT (Refer to Figure 2.11).
- Some countries have a great longitudinal extent. So, they have adopted more than one standard time. For example, Russia has eleven standard times (Refer to Figure 2.10).

## Motions of Earth

The earth has two types of motions, namely rotation and revolution.

### Rotation of Earth

- It is the movement of earth on its axis. This is the daily motion of the earth.
- The earth takes about 24 hours to complete one rotation around its axis. The period of rotation is known as the **earth day** (Refer to Figure 2.13).
- **If the earth did not rotate:** The portion of the earth facing the sun would always experience day, thus bringing continuous warmth to the region and the other half would remain in darkness and be freezing cold all the time. Life would not have been possible in such extreme conditions.

**Do You Know?**

- The plane formed by the orbit is known as the orbital plane.
- The axis of the earth makes an angle of 66½° with its orbital plane (Refer Figure 2.12)
- Due to the spherical shape of the earth, only half of it gets light from the sun at a time. The portion facing the sun experiences day while the other half away from the sun experiences night.
- The circle that divides the day from night on the globe is called the circle of illumination which does not coincide with the axis.

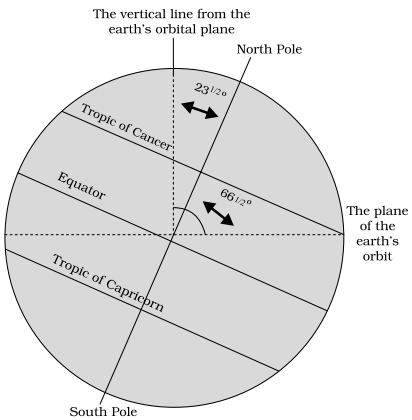



**Figure 2.12: Inclination of the Earth's Axis and the Orbital Plane**

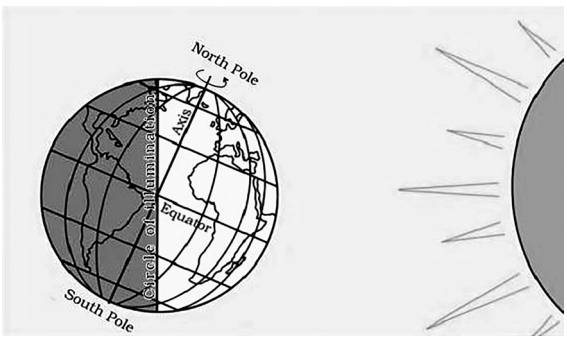



**Figure 2.13: Day and Night due to Rotation**

## Revolution of Earth

- The movement of the earth around the sun in a fixed path or elliptical orbit is called Revolution. The Earth takes **365¼ days (one year)** to revolve around the sun. Throughout its orbit, the earth is inclined in the same direction.We consider a year as consisting of 365 days only and ignore six hours for the sake of convenience.
- Six hours saved every year are added to make one day (24 hours) over a span of four years and this surplus day is added to the month of February. Thus every 4th year, February has 29 days instead of 28 days and such a year with 366 days is called a **Leap Year**.
- A year is usually divided into summer, winter, spring and autumn seasons and these seasons change due to the change in the position of the earth around the sun (Refer to Figure 2.14).

**POINTS TO PONDER**

Most heavenly bodies rotate and revolve. Both spinning around the axis and elliptical motions are a recurrent theme in the realm of the universe. What is the force that drives these motions? Do you think this will ever slow down and ultimately stop completely? Imagine the impact it can have on our life, if at all humans survive, if the earth stops rotating and revolving?

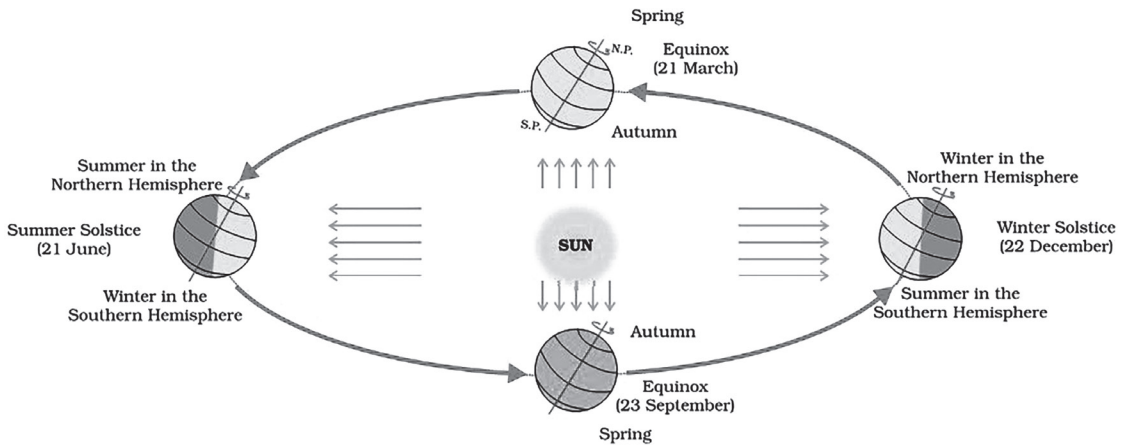



**Figure 2.14: Revolution of the Earth and Seasons**

## Summer Solstice

- On **21st June**, the position of the earth is called the Summer Solstice as the **Northern Hemisphere is tilted towards the sun** and the rays of the sun fall directly on the Tropic of Cancer. As a result, these areas receive more heat.
- The areas near the poles receive less heat as the rays of the sun are slanting.
- The North Pole is inclined towards the sun and the places north of the Arctic Circle experience continuous daylight for about six months.
- Since a large portion of the Northern Hemisphere is getting light from the sun, it is summer in the regions north of the equator.
- The longest day and the shortest night at these places occur on 21st June.
- At this time in the Southern Hemisphere it is winter season there. The nights are longer than the days (Refer to Figure 2.15).

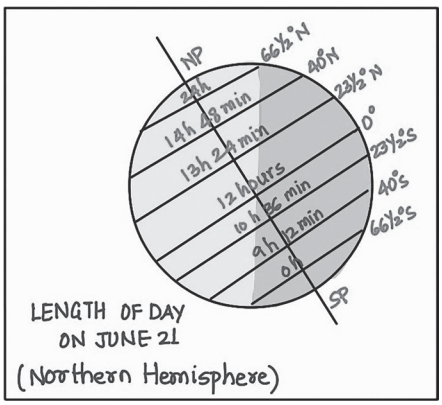



**Figure 2.15: Length of day on June 21 (Northern Hemisphere)**

### Winter Solstice

- On **22nd December**, the position of the earth is called the Winter Solstice as the Tropic of Capricorn receives direct rays of the sun as the South Pole tilts towards it.
- As the sun's rays fall vertically at the Tropic of Capricorn (23 1/2° S), a larger portion of the Southern Hemisphere gets light. Therefore, it is summer in the Southern Hemisphere with longer days and shorter nights.
- The reverse happens in the Northern Hemisphere (Refer to Figure 2.14).

### Equinox

- On **21st March and September 23rd**, neither of the poles is tilted towards the sun and direct rays of the sun fall on the equator. So, the whole earth experiences equal days and equal nights. This is called an equinox.
- On 23rd September, it is autumn season in the Northern Hemisphere and spring season in the Southern Hemisphere.
- On 21st March, it is spring in the Northern Hemisphere and autumn in the Southern Hemisphere (Refer to Figure 2.14).

## Conclusion

The origin and evolution of the earth is a complex and ongoing process that has occurred over billions of years. In this process of evolution, life appeared on earth. Astronomers and scientists started exploring the universe and we have come very far. But we still haven't fully figured out the truth of the Universe.

| Timeline | Event |
|---|---|
| 13.7 billion years ago | The event of Big Bang |
| 5-6 billion years ago | Formation of Stars |
| 4.6 billion years ago | Planets were formed |
| 4.4 billion years ago | Moon was formed |
| 4000 million years ago | Formation of Oceans |
| 3800 million years ago | Life began to evolve |
| 2500-3000 million years ago | Process of Photosynthesis got evolved |

***Glossary:***

- **One Light Year:** The distance travelled by light in one year is one light year.
- **Planetesimals:** Planetesimals are a large number of smaller bodies formed in the early solar system collisions with other objects in the solar system.
- **Photosynthesis:** It is the process by which plants in the presence of sunlight, use water and carbon dioxide to create oxygen and energy.
- **Astronomers:** Those who study celestial bodies and their movements are called astronomers. Aryabhatta was the famous astronomer who said that the moon and the planets shine due to reflected sunlight.
- **Satellite:** It is a celestial body that moves around the planets.
- **Globe:** Globe is a true model (miniature form) of the earth.

❐❐❐

# 3 Interior of The Earth

**Bibliography:** The chapter encompasses the summary of Chapter 5- VI NCERT (The Earth: Our Habitat), Chapter 2- VII NCERT (Our Environment) and Chapter 3- XI NCERT (Fundamentals of Physical Geography).

## Introduction

Earth, a celestial body in the vast expanse of the universe, is an intricate tapestry of systems and layers, each integral to its essence and vitality. Beneath our feet lies a dynamic world, with molten magma churning at its core, giving rise to phenomena such as earthquakes and volcanoes. Above, the gaseous envelope of the atmosphere serves as our protective shield, while the lithosphere, our solid ground, cradles lakes, rivers, and vast landscapes. The hydrosphere, covering over 70% of the Earth, teems with life and plays a crucial role in regulating our climate. Binding all these domains is the biosphere, a testament to Earth's unparalleled capacity to support life.

## Major Domains of the Earth

The Earth, unique in its ability to support life, possesses key elements: **Land, Water, and Air**. These elements manifest in four primary domains:

### Lithosphere

- Lithosphere is the solid part of Earth, comprising rocks and soil. It includes Continents.
- The Earth has **seven continents** (Refer to Figure 3.1): Asia, Europe, Africa, North America, South America, Australia, and Antarctica.

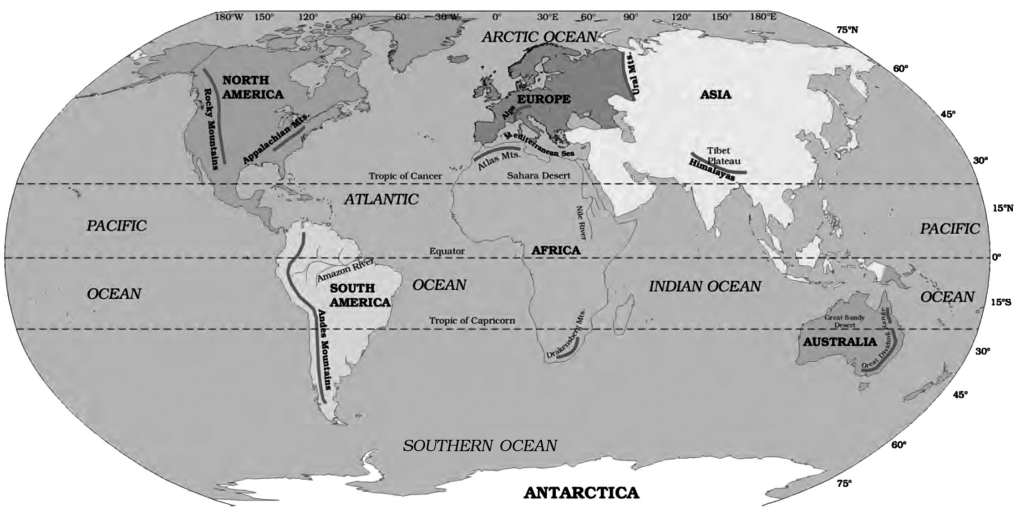



**Figure 3.1: The World: Continents and Oceans**

- **Asia:** The largest continent, which covers one-third of the total land area. It is separated from Europe by the Ural Mountains. The Tropic of Cancer passes through this continent.
- **Europe:** This continent is West of Asia and is bounded by water on three sides. The Arctic Circle traverses it. Europe and Asia are together called Eurasia.
- **Africa:** The second largest continent. The Sahara Desert, the world's largest hot desert, is here, as is the Nile, the world's longest river. Africa is the only continent traversed by Tropic of Cancer, Tropic of Capricorn and The Equator.
- **North America:** The third largest continent, it is connected to South America by the Isthmus of Panama (Refer to Figure 3.2).

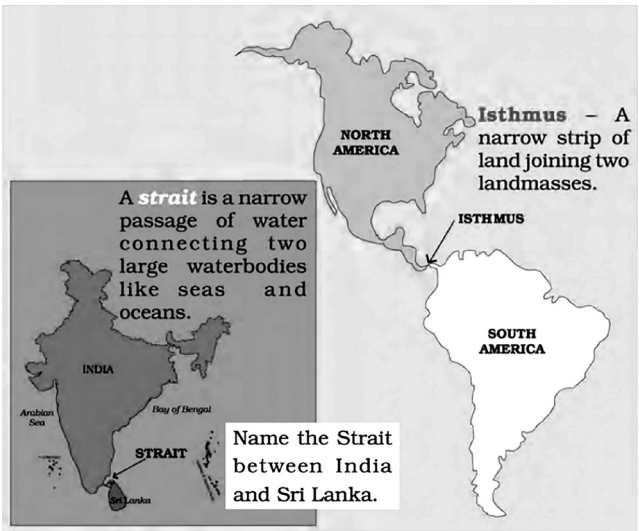



**Figure 3.2: Isthmus and Strait**

- **South America:** Primarily in the Southern Hemisphere, it is home to the Andes mountain range and the Amazon River.
- **Australia:** It is entirely in the Southern Hemisphere, this smallest continent is often called an Island continent.
- **Antarctica:** Devoid of human settlements except for research stations, Antarctica is found entirely in the Southern Hemisphere, and houses the South Pole and is covered with thick ice sheets. **Maitri and Bharati** are Indian research stations here.

**Fascinating Earth Facts**

- Sea level is the standard for measuring land elevation. Mount Everest, the highest peak, stands at 8,848 metres, while the Mariana Trench in the Pacific Ocean is the deepest point at 11,022 metres.
- Most of the land mass is situated in the Northern Hemisphere.

## Hydrosphere

- It encompasses all forms of water — ice, water, and water vapour — and makes up a vast portion of Earth's surface.The earth fondly referred to as the '**blue planet**', owes its title to the vast expanses of water covering its surface.
- About 71% of the Earth's surface is submerged underwater, making up the hydrosphere, which comprises oceans, rivers, lakes, glaciers, underground water, and atmospheric water vapour.

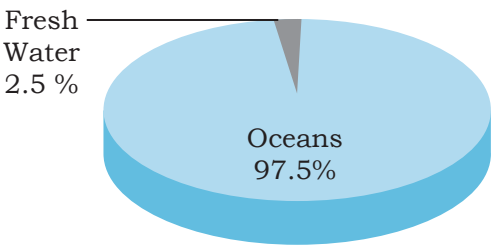



**Figure 3.3: Distribution of earth's water**

- **Water Distribution:** Though water is abundant, over 97% of it is saline and present in the oceans (Refer to Figure 3.3), making it unsuitable for direct human consumption. Only a minuscule percentage is available as freshwater. The rest is either trapped in glaciers, ice sheets, or stored underground.
  - The paradox is that while Earth is predominantly covered in water, freshwater scarcity is a significant concern.

### A Dive into the Oceans

- **Pacific Ocean:** The most expansive of all oceans, the Pacific Ocean sprawls across one-third of Earth. Its notable feature, the Mariana Trench, is the deepest part known on Earth. It has an almost circular shape, surrounded by continents like Asia, Australia, and the Americas.
- **Atlantic Ocean:** Ranked as the second-largest, the Atlantic Ocean spots an 'S' shape. It's sandwiched between the Americas on its west and Europe and Africa on the east. Its highly indented coastline offers the perfect spots for natural harbours and ports, making it a commerce hub.
- **Indian Ocean:** Unique in its nomenclature, the Indian Ocean is the only one named after a country. Its triangular shape is bordered by Asia, Africa, and Australia.

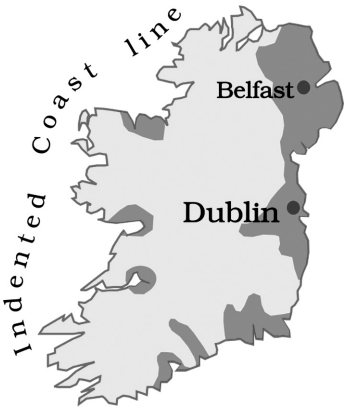


**Figure 3.4: Indented Coast Line**

- **Southern Ocean:** This ocean girdles the Antarctic continent and reaches up to the 60-degree south latitude.
- **Arctic Ocean:** Positioned within the Arctic Circle, this ocean envelopes the North Pole. A narrow, shallow stretch, the Bering Strait, connects it to the Pacific Ocean. It's flanked by the northern coastlines of North America and Eurasia.

### Atmosphere: Earth's Vital Shield

The gaseous layer enveloping the Earth contains essential gases like oxygen, nitrogen, and carbon dioxide. The atmosphere acts as a shield, providing the air essential for life and safeguarding us from the Sun's harmful ultraviolet rays.

- **Composition and Layers:**
  - **Extent:** The atmosphere stretches up to roughly 1,600 kilometres from the Earth's surface.
  - **Divisions:** It is divided, based on various characteristics, into five layers (Refer to Figure 3.5):
    - Troposphere
    - Stratosphere
    - Mesosphere
    - Thermosphere
    - Exosphere
- **Constituents:** Predominantly, the atmosphere consists of nitrogen (78%) and oxygen (21%). Trace gases, including carbon dioxide and argon, make up the remaining 1%.

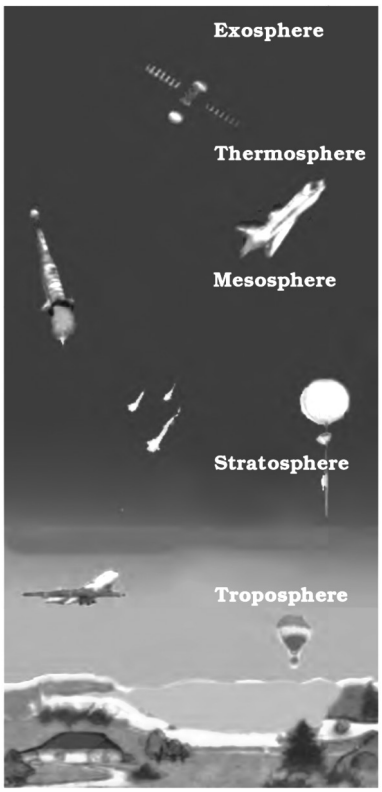


**Figure 3.5: Layers of the Atmosphere**

- **Importance**
  - Oxygen sustains life, allowing organisms to respire.
  - Nitrogen aids in the growth of organisms.
  - Carbon dioxide, although in traces, has a dual role: maintaining Earth's warmth and facilitating plant growth.
- **Characteristics with Altitude:**
  - **Density of Atmosphere:** It's densest at sea level and diminishes with altitude. This decreased density at higher altitudes poses challenges for climbers, necessitating oxygen cylinders.
  - **Temperature of Atmosphere:** There is a decrease in temperature with an increase in altitude.
- **Atmospheric Pressure:**
  - Atmospheric pressure varies across different regions, leading to movement of air from high-pressure to low-pressure areas, which we recognize as wind.

## Biosphere: Cradle of Life

The biosphere, a confluence of land, water, and air, is the unique realm where life thrives. Within it exist myriads of organisms, ranging from minuscule microbes to colossal mammals (Figure 3.6).

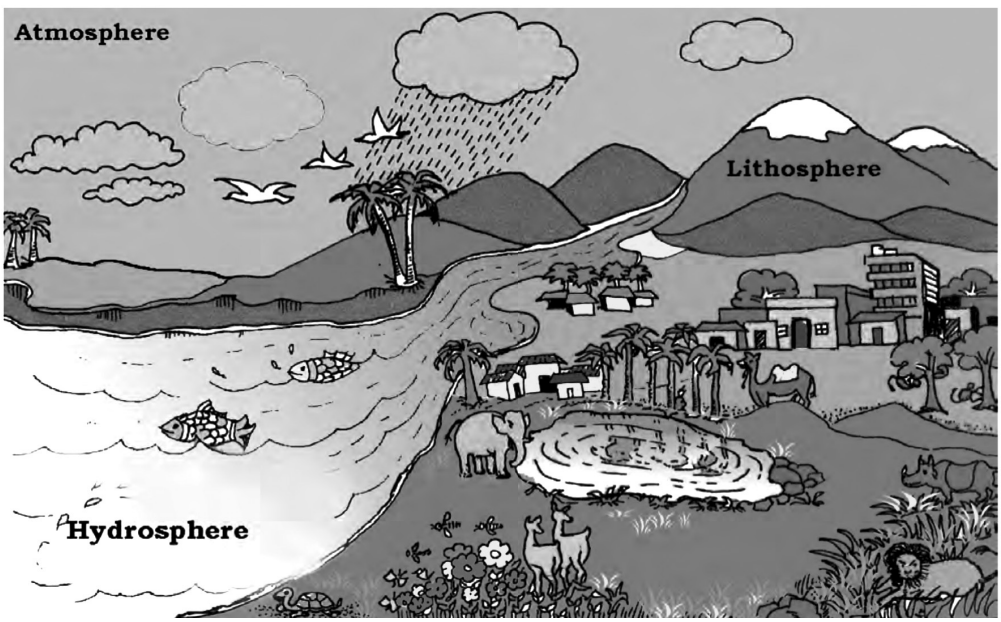



**Figure 3.6: The Biosphere**

- **Diversity of Life:** The biosphere encompassing both the plant and animal kingdoms, it is a testament to the vast biodiversity on Earth.
- **Interactions:** Every domain on Earth interacts, impacting one another.
  - Deforestation, for instance, may accelerate soil erosion, while natural disasters like earthquakes can reshape Earth's surface. Tsunamis, as seen in the recent past, submerged parts of the Andaman & Nicobar islands.
  - Human actions often lead to unintended consequences. Industrial waste pollutes water sources, and emissions exacerbate air pollution.

- **Challenges:** Activities that increase $CO_2$ levels contribute to global warming. Balancing resource utilisation to ensure harmony between the lithosphere, atmosphere, and hydrosphere is imperative for our planet's health.

**After comprehending the vast expanse and varied components of our planet's exterior, it's intriguing to delve beneath the surface. The hidden depths below offer insights into the Earth's constitution, setting the stage for a deeper exploration of its interior dynamics.**

## Scope of Studying Earth's Interior

- The Earth's interior is understood primarily through indirect evidence.
- The surface configuration of the earth is influenced by processes operating inside the earth.
- Both Exogenic and Endogenic processes continually shape the landscape.
- A proper understanding of any region's physiography is incomplete without considering the effects of endogenic processes.
- The knowledge of the earth's interior helps in understanding phenomena like earthquakes and tsunamis.

## Structure of the Earth's Interior

The Earth's interior is organised into layers, each with distinct properties and characteristics. A closer look at these layers reveals the intricacies of our planet's composition (Figure 3.7 and 3.8):

### The Crust

- **Definition:** This is the Earth's outermost layer, which is solid and brittle.
- **Thickness:** The crust's depth varies depending on its location. In oceanic regions, it averages about 5 km thick, while the continental crust has an average thickness of 30 km. However, in areas with major mountain systems like the Himalayas, the crust can be as thick as 70 km.
- **SIAL/SIMA:** Continental crust is called "**SIAL**" (silica and alumina), while oceanic crust is termed "**SIMA**" (silica and magnesium).

**POINTS TO PONDER**

We find Silica, Aluminium, Magnesium dominating the upper layers of the earth. In contrast we find Nickel and iron concentrating as we go deep down towards the Earth's centre. Why so?

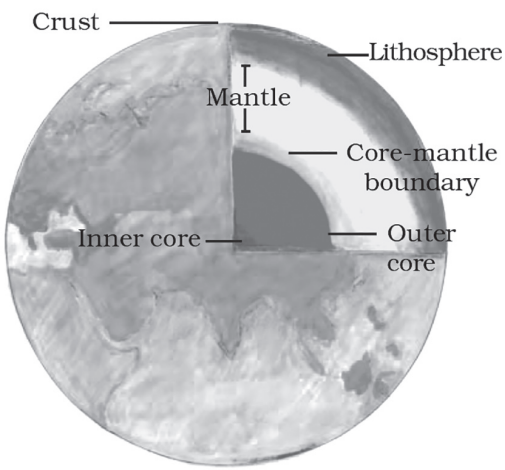



**Figure 3.7: The interior of the Earth**

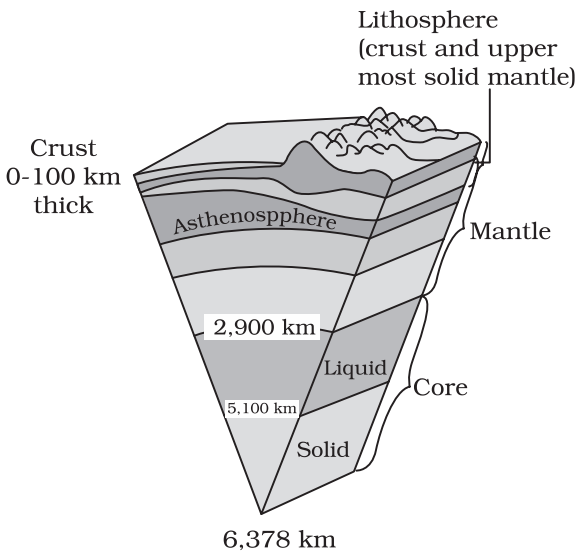


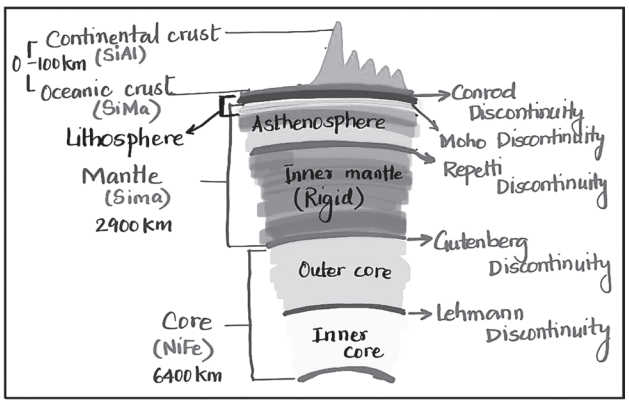

**Figure 3.8: The Interior Layers of the Earth**

## The Mantle

- **Definition:** It is located beneath the crust, and extends up to 2900 km below the crust.
- **Asthenosphere:** The upper section of the mantle, reaching up to 400 km in depth, is termed as the asthenosphere. Derived from a word meaning "weak," this semi-fluid layer is the primary source of magma that rises to the Earth's surface during volcanic eruptions.
- **Lithosphere:** This solid layer comprises the crust and the uppermost part of the mantle. Its thickness varies between 10 km and 200 km.
- **Lower Mantle:** Positioned below the asthenosphere, the lower mantle remains solid, extending down to the Earth's core.

## The Core

- **Definition:** This central part of the Earth, starting at a depth of 2,900 km, is split into the outer and inner core.
- **State:** The outer core is liquid, mainly because of its high temperature, while the inner core remains solid despite even greater temperatures due to the immense pressures at this depth.
- **Composition:** Predominantly made up of heavy materials, particularly nickel and iron, it is sometimes termed as the **"nife"** layer, referring to its principal constituents (ni-nickel and fe-ferrous).




### POINTS TO PONDER

Human life on earth is dependent on multitudes of factors and phenomena. In this context, can you think of the role played by Outer Core's composition, structure and movement ?

### Interesting Facts

- The world's deepest mine is in South Africa, approximately 4 km deep.
- To reach the Earth's centre, a 6000 km deep hole would need to be dug on the ocean floor.
- Earth's crust makes up only 1% of its volume; the mantle constitutes 84%, and the core, 15%.
- The Earth's radius is 6371 km.

## Composition of the Earth: Rocks and Minerals

- Earth's crust contains diverse rocks, defined as any natural mineral matter constituting the earth's crust.
- **Igneous Rocks:** Formed from cooled molten magma.
- **There are two types:**
  - **Extrusive Igneous Rocks:** Formed when molten lava from volcanoes cools rapidly on the Earth's surface. These rocks are composed of very fine grains. Deccan plateau is made up of basalt rocks. Example: basalt.
  - **Intrusive Igneous Rocks:** Formed when magma cools deep within the crust. These are composed of very large grain because of slow cooling. e.g., Granite.

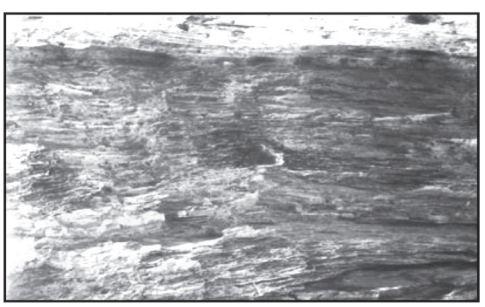


**Figure 3.9: Sedimentary rock turned into a Metamorphic rock**

- **Sedimentary Rocks:** Formed from compressed and hardened sediments like sandstone. They might contain fossils.
- **Metamorphic Rocks:** Igneous and sedimentary rocks that have transformed due to heat and pressure become Metamorphic rock (Figure 3.9). For instance, clay transforms into slate or limestone into marble.
- **Rock Cycle:** Rock Cycle is the transformation process where one rock type can change into another, like igneous to sedimentary to metamorphic, and vice versa (Refer to Figure 3.10).

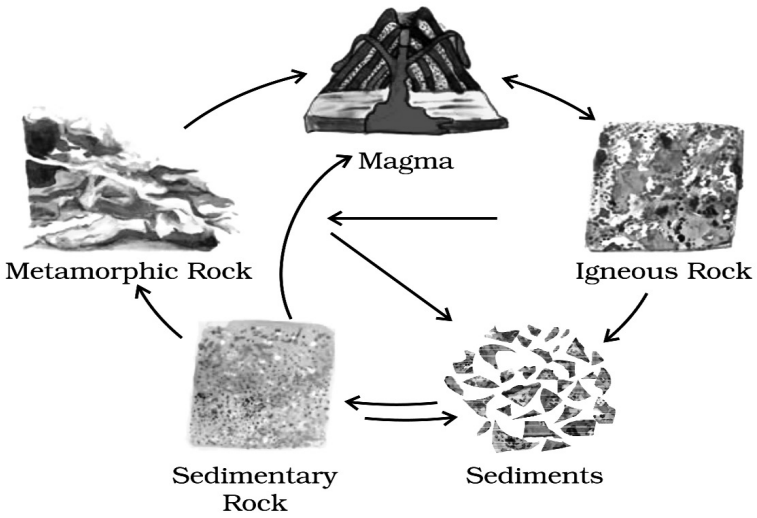



**Figure 3.10: Rock Cycle**

### Use of Rocks and Minerals

- Rocks have various applications, such as in construction.
- Minerals, the constituents of rocks, have diverse uses, from fuels like coal and natural gas to industrial applications like iron and aluminium.

## Sources of Information about the Interior

- Reaching the centre of the Earth to make direct observations or collect samples is currently impossible.
- Most of our understanding of the earth's interior is based on estimates, inferences, and indirect evidence, though some information is derived from direct observations and analysis of materials.
  - **Direct Sources:** The most readily available material from the earth is surface rock and the rocks obtained from mining.
    - Gold mines in South Africa reach depths of 3-4 km; it becomes too hot to mine beyond these depths.
    - The key projects that have aimed to explore deeper depths include the "Deep Ocean Drilling Project" and the "Integrated Ocean Drilling Project."
    - The deepest drilling, located at Kola in the Arctic Ocean, has reached a depth of 12 km.
    - Direct information can also be obtained from the molten material (magma) during volcanic eruptions. However, the exact depth of the magma source remains uncertain.
  - **Indirect Sources:** Properties of matter can hint at conditions in the earth's interior. The rate of change of these properties allows for estimations about conditions at various depths within the earth.

- Through mining, it's observed that temperature, pressure, and density increase with depth.
- **Meteors:** Meteors, sometimes on reaching earth, offer another source of indirect information. While they don't provide material from the earth's interior, their composition is believed to be similar to the earth.
- **Other Indirect Sources:**
  - **Gravitation:** Differences in gravitational force at different latitudes (gravity anomalies) can hint at the distribution of mass within the earth's crust.
  - **Magnetic Field:** Magnetic surveys provide details about the distribution of magnetic materials in the crust.
  - **Seismic Activity:** This is a crucial source of information about the Earth's interior and will be discussed in detail in the subsequent sections of the chapter.

## Earthquakes

- **Definition:** An earthquake is the shaking of the earth caused by waves emanating from a source of disturbance inside the earth. It's a natural event triggered by the release of energy which creates waves radiating in all directions.
- **Cause of Earthquakes:** The energy is released along a fault, a sharp break in the crustal rocks. Due to frictional resistance, rocks on either side of a fault are locked, but when this locking is overcome, the energy is released causing an earthquake.

### Key Terms Related to Earthquakes

- **Focus/Hypocentre:** The point inside the earth where the earthquake originates.
- **Epicentre:** The point on the earth's surface directly above the focus. It's the first point to feel the earthquake waves.

### Earthquake Waves

- **Origin:** All natural earthquakes arise within the lithosphere i.e. up to a depth of 200 km from the earth's surface.
- **Recording:** A seismograph records the earthquake waves(Refer Figure 3.11). The recorded graph displays distinct wave patterns indicating different types of waves.

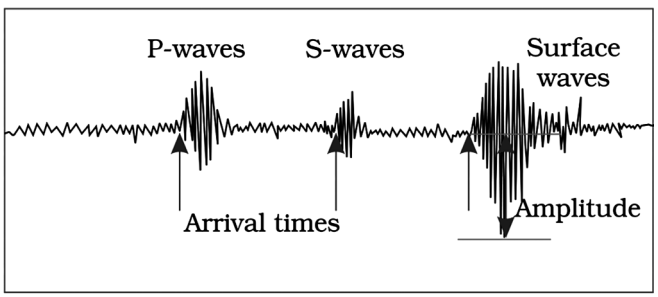
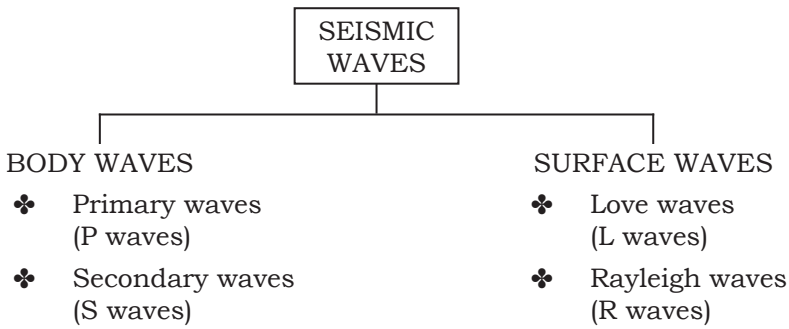



**Figure 3.11: Earthquake Waves**

- **Types of Earthquake Waves:**
  - **Body Waves:** These waves emanate from the focus and traverse through the earth. The velocity of the waves changes as they travel through materials with different densities. Denser the material, the higher is the velocity. They split into:



- **P-Waves (Primary Waves):** They are the fastest, moving through gas, liquid, and solids. They resemble sound waves.
- **S-Waves (Secondary Waves):** They follow P-waves but can only pass through solids. This feature is of significant importance and has aided scientists in comprehending the Earth's interior structure.
- **Propagation of P and S Waves:** P-waves vibrate parallel to their direction, causing pressure changes in the medium. S-waves create troughs and crests due to their perpendicular vibration to their direction. P-waves vibrate parallel to the direction of the wave. This exerts pressure on the material in the direction of the propagation. As a result, it creates density differences in the material leading to stretching and squeezing of the material.

- **Surface Waves:** Originating from the interaction of body waves with the surface, these are recorded last on the seismograph, they move along the earth's surface and are more destructive.

## Shadow Zone

- **Definition:** It is an area on the earth's surface where certain earthquake waves aren't detected.
- **Characteristics:**
  - Seismographs within 105° of the epicentre detect both P and S-waves.
  - Beyond 145°, only P-waves are recorded.
  - Hence, the zone between 105° and 145° is the shadow zone for both waves, with the S-wave shadow zone being larger.

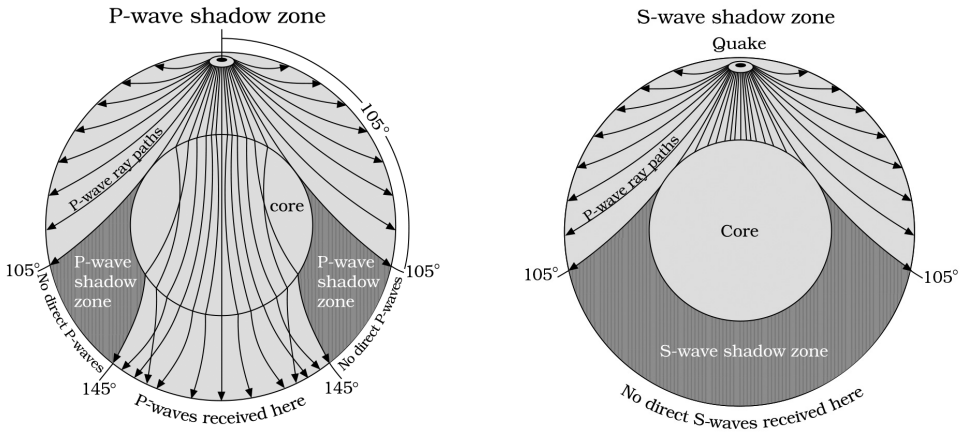



**Figure 3.12: and 3.13: P-Wave and S-Wave Shadow Zone**

## Types of Earthquakes

- **Tectonic Earthquakes:** These are the most prevalent types of earthquakes. They are generated due to the movement or sliding of rocks along a fault plane and can occur anywhere but are especially frequent at tectonic plate boundaries.
- **Volcanic Earthquakes:** A subset of tectonic earthquakes, specifically linked to volcanic activity. They are triggered by the movement of magma beneath the Earth's crust and are restricted to areas with active volcanoes.
- **Collapse Earthquakes:** These are relatively minor quakes. They are caused by the sudden collapse of underground mine shafts or cavities and are regions of intense mining activity.
- **Explosion Earthquakes:** These are Human-induced seismic activities. They result from the explosion of nuclear or chemical devices and can be induced at specific testing sites or unintentionally in areas of conflict or accidents.

- **Reservoir-Induced Earthquakes:** Seismic activities can be triggered by the substantial weight of water stored in large dams and reservoirs. This significant mass places stress on the Earth's crust. Notably, areas surrounding large reservoirs often experience such seismic shifts, particularly soon after they have been filled.

### Measuring Earthquakes

- **Magnitude (Richter Scale):** It measures the energy released and is expressed numerically, ranging from 0 to 10.
- **Intensity (Mercalli Scale):** It assesses the visible damage, scale spanning from 1 to 12.

### Effects of Earthquake

An earthquake is a potent natural hazard that can have a myriad of consequences, both immediate and long-term **(Refer to Figure 3.14 and 3.15)**. Its immediate impacts are listed as under (of these effects, the first six have direct implications on the Earth's landforms):

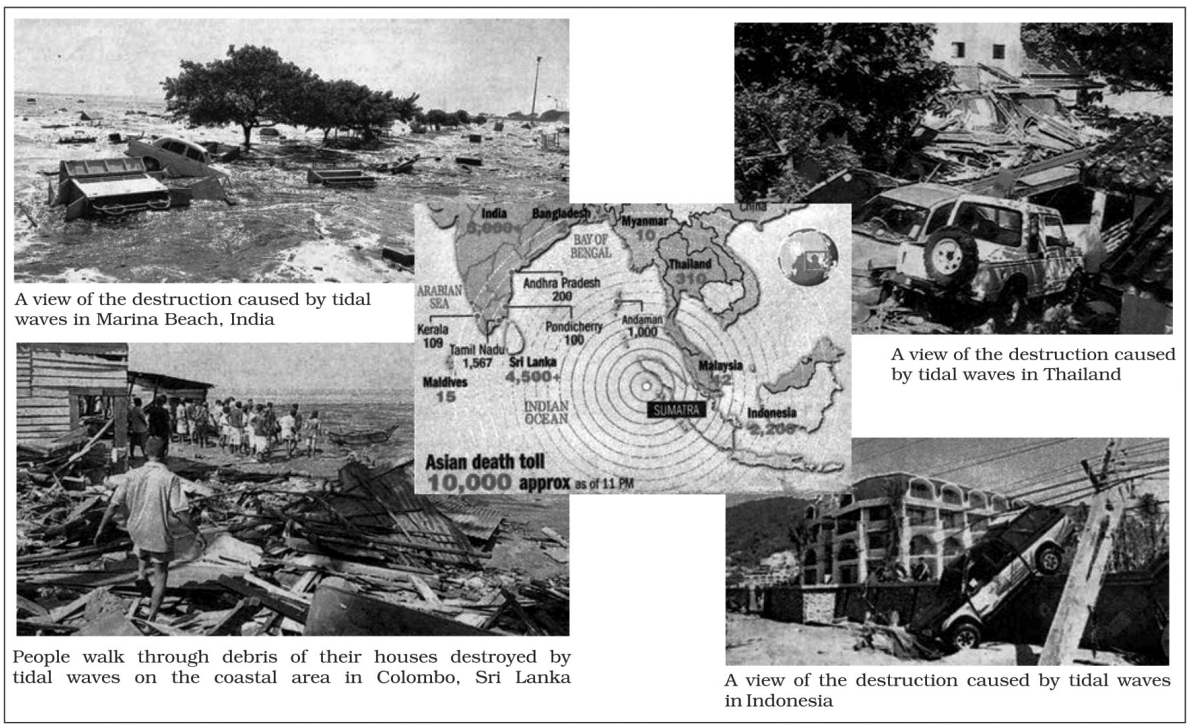



**Figure 3.14: Impact of Earthquake**

- **Ground Shaking:** The most noticeable effect, causing buildings, trees, and other structures to shake.
- **Differential Ground Settlement:** Uneven settling of the ground, potentially destabilising structures.
- **Land and Mudslides:** Slopes become unstable and slide, particularly in hilly or mountainous areas.
- **Soil Liquefaction:** Ground loses its strength and behaves like a liquid, especially in areas with saturated soils.
- **Ground Lurching:** Sudden horizontal or vertical ground movements.
- **Avalanches:** Snow or rock masses suddenly descend down mountain slopes.
- **Ground Displacement:** The ground shifts vertically or horizontally.

- **Floods from Dam and Levee Failures:** Structural failure of dams or levees, leading to sudden flooding.
- **Fires:** Resulting from ruptured gas lines or electrical faults.
- **Structural Collapse:** Buildings, bridges, or other structures collapse.
- **Falling Objects:** Items inside buildings or loose exterior structures can fall, posing risks.
- **Tsunami:** Seismic sea waves triggered, especially if the earthquake's epicentre is underwater. Notably, a tsunami is an outcome of an earthquake and not an earthquake itself.

**Figure 3.15: A view of the damaged Aman Setu at the LOC in Uri, due to an earthquake**

### Frequency and Distribution of Earthquakes

- Severe earthquakes that can cause extensive damage are fortunately less common, but they do happen. Conversely, minor tremors, often imperceptible to humans, occur almost every minute globally.
- It is crucial to understand that not all regions are equally prone to seismic activities. Some areas experience significant quakes once every few years, while others might never feel such powerful tremors in a lifetime.

## Volcanoes and Volcanic Landforms

- A volcano is a geological feature from which molten rock material, gases, ash, and other debris escape to the Earth's surface. The Earth's structure plays a pivotal role in the formation and activity of volcanoes.
- Beneath the solid crust lies the mantle, denser than the crust. Within the mantle is a weaker, semi-fluid region called the **asthenosphere**. This is the source from which molten rock materials or Magma arise.
- When magma moves towards or breaks through the Earth's crust, it is termed as **Lava**.

**Classification of Volcanoes based on Frequency of Eruption**

- **Active volcanoes** have recently erupted or show signs of potential eruptions, like gas emissions or seismic activity.
- **Dormant volcanoes** are currently inactive but can erupt again in the future.
- **Extinct volcanoes** haven't erupted for an extended time and are unlikely to erupt again.

### Materials Accompanying Eruption

- The volcanic eruptions eject various materials, including:
  - **Lava flows:** Liquid magma that spills over the volcano's rim.
  - **Pyroclastic debris:** Fragmented material produced by a volcanic blast.
  - **Volcanic bombs:** Large chunks of lava thrown out in an explosive eruption.
  - **Ash and dust:** Fine particles of volcanic rock and glass.
  - **Gases:** These can include nitrogen and sulphur compounds, and smaller quantities of chlorine, hydrogen, and argon.
- The movement and ejection of these materials contribute to the diverse volcanic landforms found on the Earth's surface.

## Volcanoes: Classification and Types

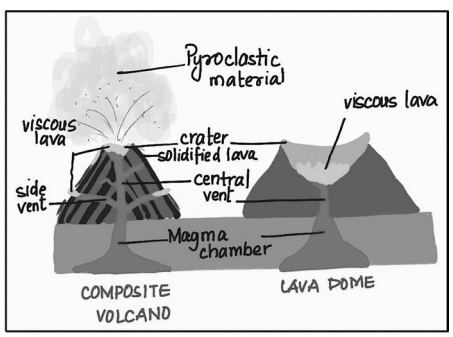
Volcanoes are categorised based on the type of eruption they exhibit and the surface features they develop.

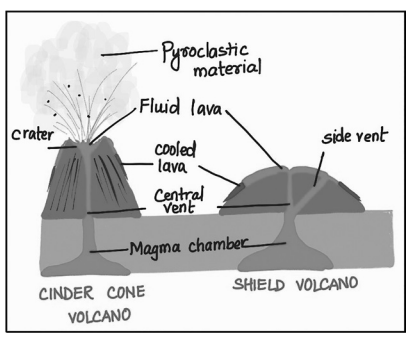
- **Shield Volcanoes:** These are among the Earth's largest volcanoes, with famous examples like the **Hawaiian volcanoes** (Figure 3.16).
  - They are composed mainly of basalt, a fluid type of lava, making these volcanoes not very steep.
  - They generally have low-explosivity unless water enters the vent.
  - Lava, of these volcanoes, emerges like a fountain, forming a cinder cone at the vent's top (Refer to Figure 3.17).
- **Composite Volcanoes:** They erupt cooler and more viscous lavas than basalt, leading to explosive eruptions that include large amounts of pyroclastic material and ashes.
  - Accumulation of these materials near the vent forms layered structures, giving these volcanoes their "composite" name (Refer to Figure 3.18).
- **Caldera:** Caldera are among the most explosive volcanoes. They tend to collapse post-eruption, forming depressions known as calderas.
  - The high explosiveness suggests large magma chambers close to the surface.
- **Flood Basalt Provinces:** Such volcanoes emit highly fluid lava that can flow over vast distances. Some regions have extensive areas covered with thick basalt lava flows, with individual flows sometimes exceeding 50 m in thickness.
  - The **Deccan Traps in India**, covering much of Maharashtra, are a prominent example of a vast flood basalt province.
- **Mid-Ocean Ridge Volcanoes**
  - These volcanoes are observed in oceanic regions.
  - Central part of a vast system of mid-ocean ridges, spanning over 70,000 km across ocean basins, witnesses regular volcanic eruptions.

**Figure 3.16: Shield Volcanoes**

**Figure 3.17. Cinder Cone**

**Figure 3.18. Composite Volcano**



## Volcanic Landforms

### Intrusive Forms

- The lava that is released during volcanic eruptions on cooling develops into igneous rocks.
- The cooling may take place either on reaching the surface or also while the lava is still in the crustal portion.
- Depending on the location of the cooling of the lava, igneous rocks are classified as **volcanic rocks** (cooling at the surface) and **plutonic rocks** (cooling in the crust).
- The lava that cools within the crustal portions assumes different forms. These forms are called **intrusive forms** (Figure 3.19):

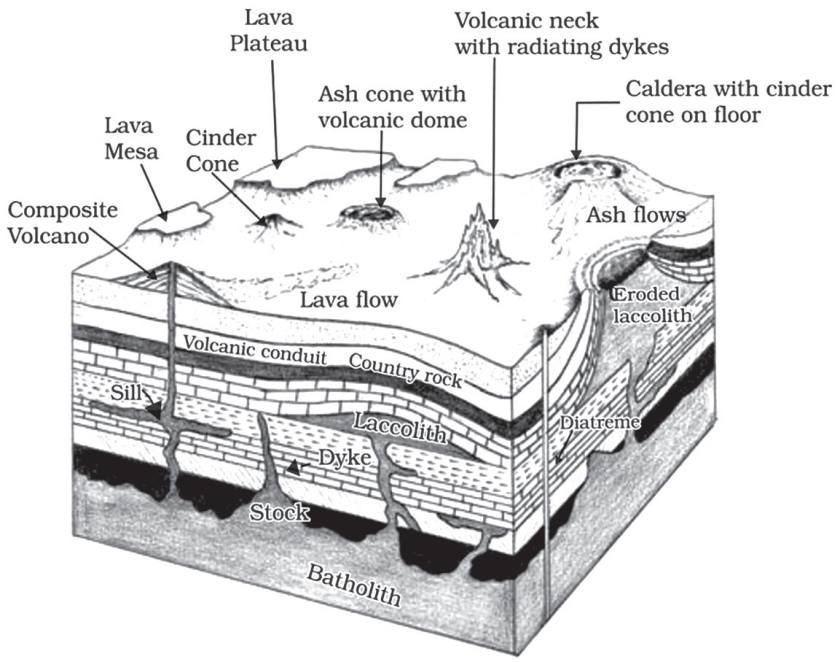



**Figure 3.19: Volcanic Landforms**

- **Batholiths:** Magmatic material cools deep within the crust to form large domes known as batholiths, i.e. these are the cooled remnants of magma chambers.
  - Batholiths, often several kilometres deep, are granitic bodies that only appear on the surface after removal of overlying layers through denudational processes.
- **Laccoliths:** Laccoliths are underground formations resembling dome shapes, characterised by a flat underside and connected through a conduit, similar to surface volcanic domes but positioned at greater depths.
  - They act as localised origins of lava that can reach the surface.
  - In the Karnataka plateau, numerous granite dome-shaped hills serve as examples of laccoliths or batholiths.
- **Lapolith, Phacolith and Sills**
  - Lava moving horizontally in weak planes can form saucer-shaped bodies called **lapoliths**.

**POINTS TO PONDER**

Granitic rocks are found beneath the surface of earth as intrusive landforms while Basaltic rocks are found as extrusive landforms on the surface of the earth. What are the properties of these rocks due to which they are found as intrusive or extrusive forms?

- ❒ Wavy masses of intrusive rocks at the base of synclines or top of anticlines, connected to magma chambers, are termed **phacoliths**.
- ❒ Horizontal intrusive igneous rocks are classified as **sills** (thicker deposits) or sheets (thinner layers).

✧ **Dykes:** Lava, on its way through cracks and the fissures of the land, when solidified almost perpendicular to the ground like a wall, is called **Dyke**.

- ❒ Found in abundance in western Maharashtra area, these are considered the eruptions that led to the development of the Deccan traps.

## Conclusion

The interplay between the lithosphere, hydrosphere, atmosphere, and biosphere forms the intricate tapestry of our planet. The earthquakes that shake its foundation and the volcanoes that sculpt its landscapes are manifestations of the dynamic processes occurring within. It is evident that our Earth, with its myriad complexities, is not just a static sphere in space but a living, breathing entity. It is our collective responsibility to comprehend its workings, appreciate its beauty, and ensure its well-being for generations to come.

***Glossary:***

- ➢ **Lithosphere:** The solid outermost shell of Earth, consisting of the crust and the rigid upper part of the mantle.
- ➢ **Hydrosphere:** All of the Earth's water, including oceans, lakes, rivers, underground water, and glaciers.
- ➢ **Atmosphere:** The gaseous envelope surrounding the Earth, comprising mainly nitrogen and oxygen.
- ➢ **Biosphere:** The global ecological system integrating all living beings and their relationships.
- ➢ **Igneous Rocks:** Rocks formed from the solidification of molten magma.
- ➢ **Sedimentary Rocks:** Rocks formed from compressed and hardened sediments.
- ➢ **Metamorphic Rocks:** Rocks that have undergone transformation due to heat and pressure.
- ➢ **Troposphere:** The lowest atmospheric layer where weather phenomena occur.
- ➢ **Stratosphere:** The atmospheric layer above the troposphere, containing the ozone layer.
- ➢ **Mesosphere:** The layer above the stratosphere, where temperatures decrease with altitude.
- ➢ **Thermosphere:** An atmospheric layer with high temperatures due to absorption of high-energy solar radiation.
- ➢ **Exosphere:** The outermost layer of the Earth's atmosphere.
- ➢ **Volcano:** A geological feature from which molten rock material, gases, ash, and other debris escape to the Earth's surface.

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# 4 Distribution of Oceans and Continents

**Bibliography:** The chapter encompasses the summary of Chapter 5- VI NCERT (The Earth: Our Habitat) and Chapter 4- XI NCERT (Fundamentals of Physical Geography).

## Introduction

Oceans and continents are not fixed; they've been moving and changing for millions of years. This chapter explores the idea proposed by Wegener that continents once formed a single landmass called **Pangaea**. We will dive into the mysteries beneath our oceans, uncover the evidence of shifting continents, and understand the mighty tectonic plates that drive these movements. From the ocean floors to the peaks of the Himalayas, this journey reveals the ever changing layout of our planet.

## Earth: A Glimpse of Continents and Oceans

### The Solid Earth - Lithosphere

- The Earth's firm outer shell, consisting of the crust and rich soil layers, forms the bedrock of our living environment.
- **Contrasting Elevation and Depth:** While the majestic Mt. Everest towers at 8,848 metres, the Mariana Trench's enigmatic depth plunges down to 11,022 metres below sea level.

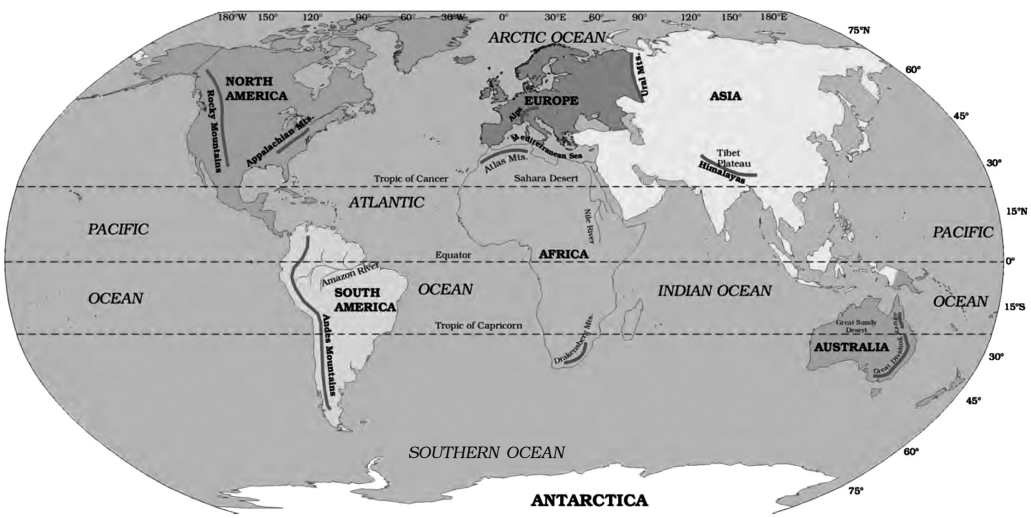



**Figure 4.1: The World: Continents and Oceans**

### Continental Tapestry: The Earth's Major Land Masses

- The Earth is adorned with seven remarkable continents, namely, Asia, Africa, North America, South America, Antarctica, Australia and Europe (Refer to Figure 4.1).

### The Blue Expanse: Hydrosphere

- Earth's allure is magnified by its vast water bodies, which occupy a staggering 71% of its surface.
  - Although a watery world, over 97% of Earth's water is the salty embrace of the oceans. Freshwater, vital for life, forms just a tiny fraction. (Refer to Figure 4.2)

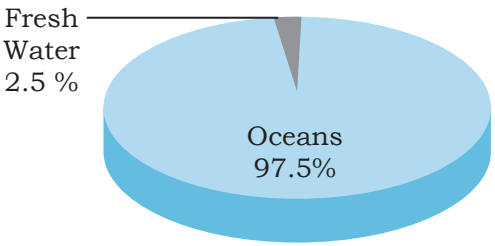



**Figure 4.2: Distribution of earth's water**

### Oceans: Earth's Majestic Water Bodies

- The lifeblood of our blue planet, oceans regulate climate, sustain life, and connect lands.
  - **Pacific Ocean:** Majestically vast, it spans one-third of our planet, cradling the Mariana Trench's mysterious depths.
  - **Atlantic Ocean:** The bustling water highway of the world, its 'S'-shaped stretch is bordered by diverse continents and dotted with natural harbours.
  - **Indian Ocean:** Proudly bearing India's name, its waters touch Asia, Africa, and Australia in a near-triangular embrace.
  - **Southern Ocean:** Circling Antarctica, it's cold waters are guardians of the southernmost continent.
  - **Arctic Ocean:** A frozen marvel around the North Pole, it provides a chilly bridge between North America and Eurasia.

**The Earth's surface comprises 29% land and 71% water. Over time, these formations have shifted and evolved, leading us to the significant theory of Continental Drift.**

## Continental Drift

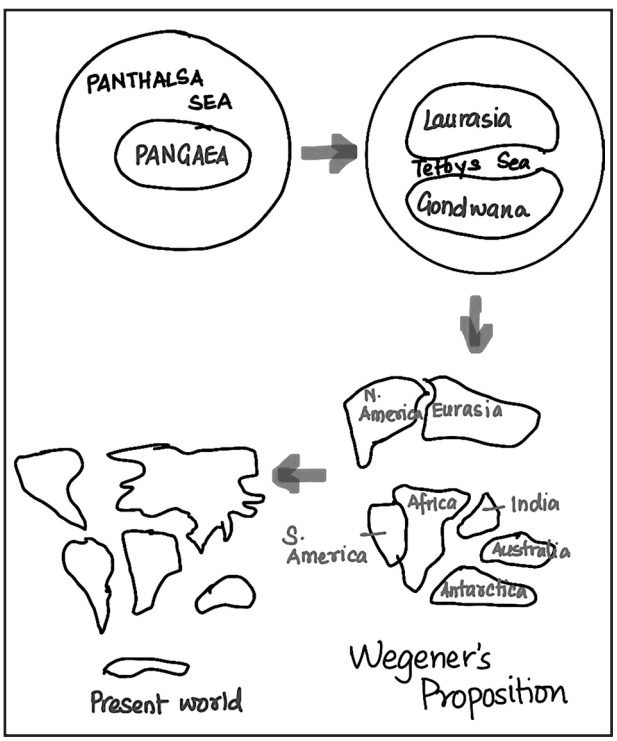
An intriguing aspect of our planet's geography is the symmetry of the Atlantic Ocean's coastline. This alignment spurred numerous scientific curiosities.

### Historical Perspectives

- **Abraham Ortelius (1596):** He ignited the debate by suggesting that the Americas, Europe, and Africa might have previously been a single landmass.
- **Antonio Pellegrini:** Building upon Ortelius's idea, he illustrated a map showing these three continents interconnected.
- **Alfred Wegener (1912):** Wegener not only embraced this idea but evolved it into the comprehensive "continental drift theory," shedding light on the redistribution of oceans and continents.

### Wegener's Proposition

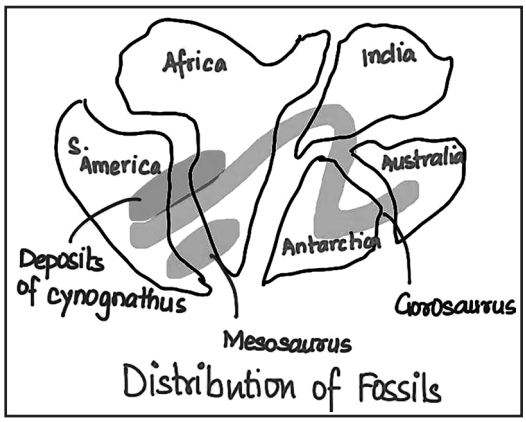
- Wegener theorised that a time existed when all continents merged into a gigantic land formation termed **PANGAEA**.
- This colossal continent was bordered by an expansive ocean named **PANTHALASSA**.



- Around 200 million years ago, Pangaea began its fragmentation journey, initially splitting into **Laurasia** (northern) and **Gondwanaland** (southern).
- These divisions further evolved into the continents we are familiar with today.

### Evidence in Support of the Continental Drift:

- **The Matching of Continents (Jig-Saw-Fit):** The shorelines of Africa and South America display a remarkable alignment, suggesting a past connection. This alignment was algorithmically verified by Bullard in 1964.
- **Rocks of the Same Age across the Oceans:** Advanced radiometric dating techniques have highlighted interesting correlations. A 2,000-million-year-old rock belt from Brazil, for instance, has similar formations as in western Africa. The initial marine deposits in these regions trace back to the Jurassic Age, indicating the absence of large oceans before this period.
- **Tillite:** Tillite, which originates from glacier deposits, offers insightful data. Notably, Gondwana sediments from India have counterparts in regions like Africa, Madagascar, and Antarctica, implying shared geological histories.
- **Placer Deposits:** The rice gold deposits of Ghana coast are intriguing, especially given the absence of a gold source rock. Conversely, Brazil boasts gold bearing veins, hinting that Ghana's gold might trace back to when these continents were adjacent.
- **Distribution of Fossils:** Fossil distribution further underscores the theory of continental drift. Lemurs, for instance, are found across India, Madagascar, and Africa. Similarly, the Mesosaurus's remains are only discovered in South Africa and Brazil, even though these places are now separated by thousands of kilometres of ocean.




### Force for Drifting

#### Wegener's Proposition on Drifting Forces

- **Pole-Fleeing Force:** This force emanates from the Earth's rotation. As the Earth isn't a perfect sphere and has an equatorial bulge, this force relates to the effects of this bulge which occurs due to Earth's rotation.
- **Tidal Force:** Attributable to the gravitational pull exerted by the moon and the sun, this force is responsible for the oceanic tides.

Despite Wegener's theories, many scholars felt these forces were insufficient to drive continental drift over long periods.

## Post-drift Studies

### Evidence Collection

- While earlier studies and evidence supporting continental drift predominantly focused on data from continents, like the distribution of flora, fauna, and specific deposits (like tillite), the post–World War II era expanded this understanding by introducing data from the ocean floors.

### Convectional Current Theory:

- **Holmes's Contribution (1930s)**
  - Arthur Holmes introduced a pivotal theory suggesting the operation of convection currents within the Earth's mantle.

- ✧ These currents are believed to originate due to the thermal differences caused by radioactive elements present within the mantle.
- ✧ Holmes proposed a system of these currents throughout the mantle, offering an alternative theory to explain the force that drives continental drift – a point of contention that led many contemporaneous scientists to discard the continental drift theory.

✤ **Mapping of the Ocean Floor (Post-World War II):**

- ✧ Contrary to the perception of the ocean floor being a monotonous plain, in-depth research showcased a diverse relief beneath the waters.
- ✧ Investigations revealed submerged mountain ranges, deep trenches (primarily located near continental margins), and notably active mid-oceanic ridges known for their volcanic activities.
- ✧ A striking observation was the age of rocks from the oceanic crust. They were considerably younger than their continental counterparts. Further, rocks flanking the crests of oceanic ridges, equidistant from the crest, shared remarkable similarities in composition and age.

## Ocean Floor Configuration

The ocean floor can be segmented into three based on depth and relief: Continental margins, deep-sea basins, and mid-ocean ridges. (Refer to Figure 4.3)

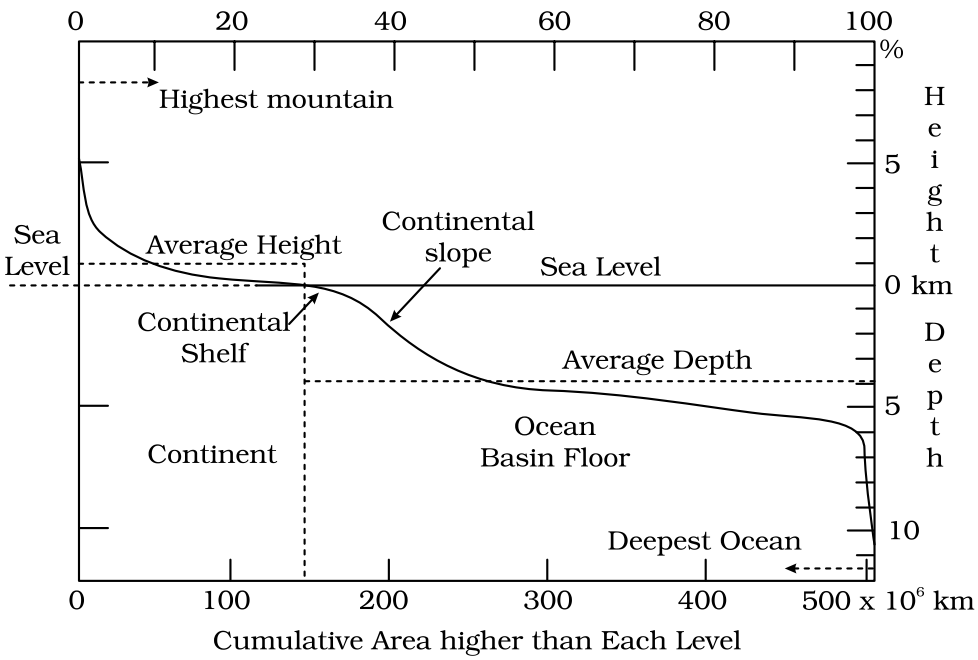



**Figure 4.3: Ocean Floor**

### Continental Margins

✤ **Definition:** These are transition zones between continental shores and deep-sea basins.

✤ **Components:**

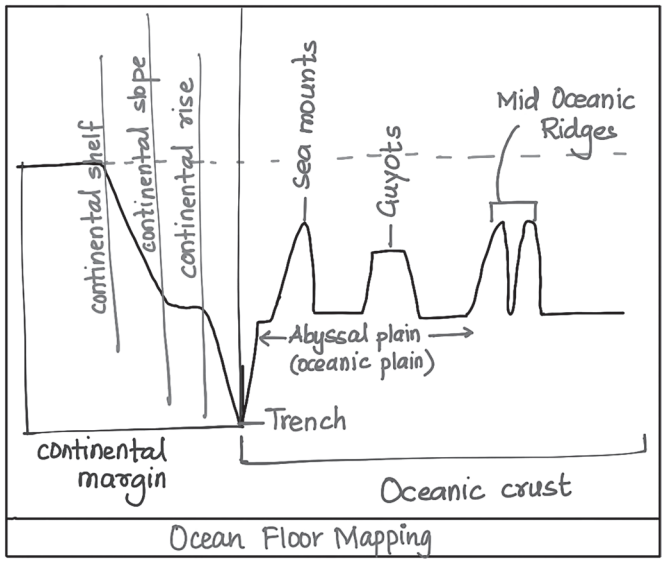
- ✧ Includes continental shelf, slope, rise, and deep-oceanic trenches.
- ✧ The deep-oceanic trenches are especially significant for the study of ocean and continent distribution.

### Abyssal Plains

- **Position:** Located between the continental margins and mid-oceanic ridges.
- **Significance:** Areas where continental sediments that move beyond the margins accumulate.

### Mid-Oceanic Ridges

- The longest submerged mountain-chain on Earth.
- They are characterised by a central rift system, a fractionated plateau, and flank zones.
- The Rift system at the crest is a hub of volcanic activity, known as mid-oceanic volcanoes.




## Distribution of Earthquakes and Volcanoes

### Observations

- A visible line of seismic activity dots in the Atlantic, extending to the Indian Ocean, corresponds with the mid-oceanic ridges. (Refer to Figure 4.4)
- Another concentrated shaded belt aligns with the Alpine-Himalayan system and the Pacific Ocean rim.

### Depth of Seismic Activity

- Earthquakes in mid-oceanic ridge areas are shallow, while those along the Alpine-Himalayan belt and Pacific rim are deep-seated.

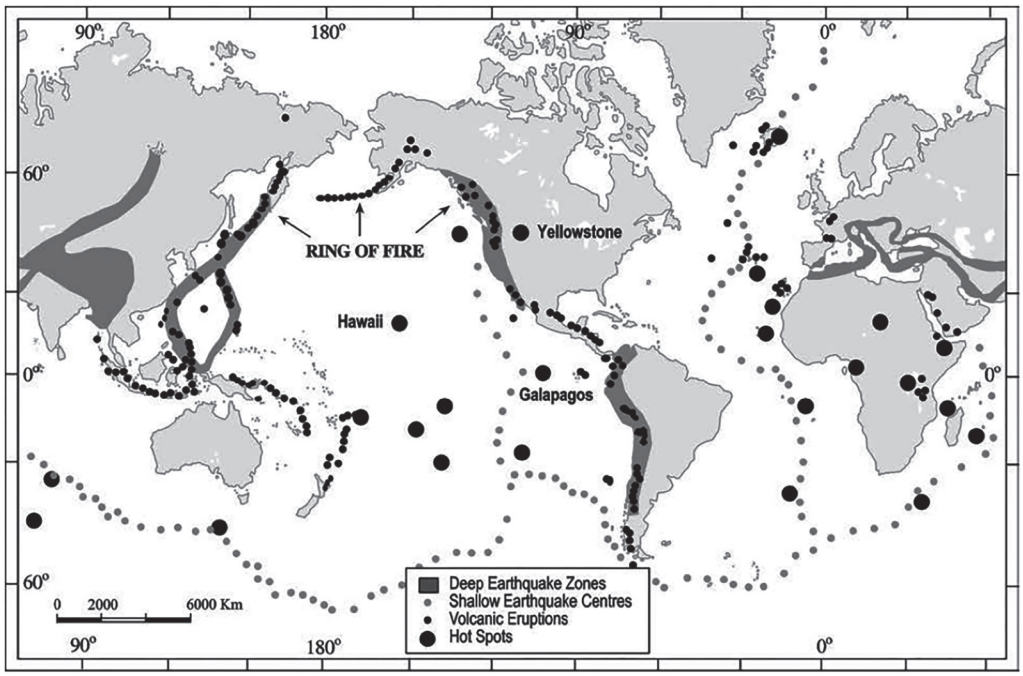
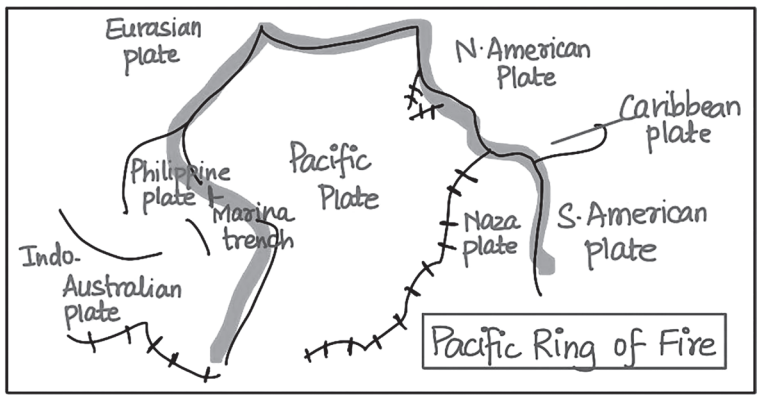



**Figure 4.4: Distribution of Earthquakes and Volcanoes**

### Volcanic Activity

- The map pattern of volcanoes matches that of seismic activity.
- The Pacific rim, dubbed the "**rim of fire**", hosts numerous active volcanoes.




## Concept of Seafloor Spreading

- Post-drift studies brought forth significant data, largely missing during Wegener's proposition of continental drift. Particularly, ocean floor mapping and paleomagnetic rock studies from oceanic regions brought to light crucial observations (Refer Figure 4.5):

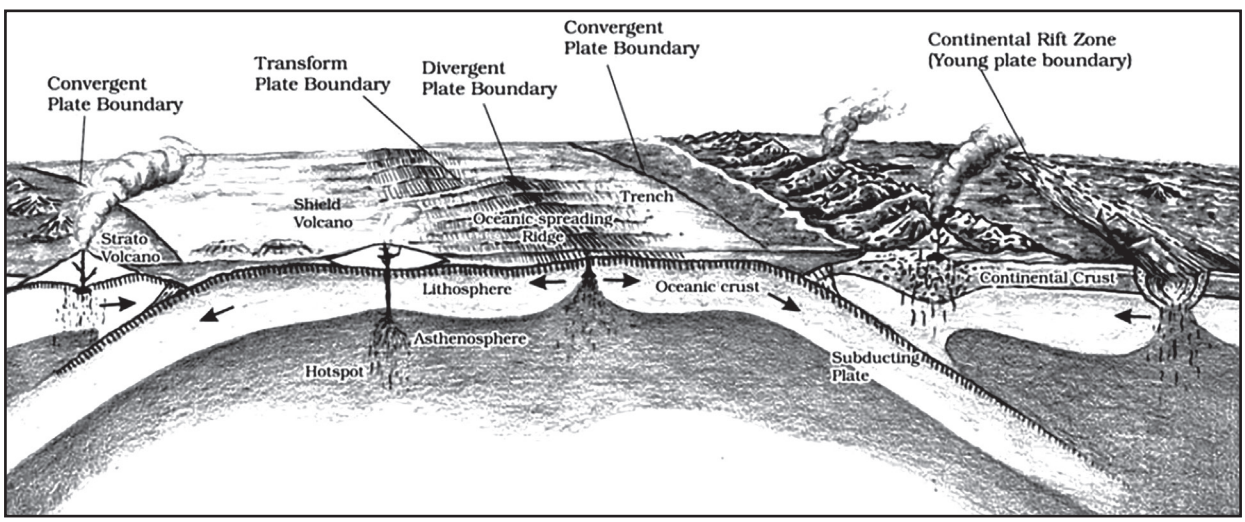



**Figure 4.5: Sea floor Spreading**

- **Volcanic Activity on Mid-Oceanic Ridges:** Mid-oceanic ridges experience frequent volcanic eruptions, spewing vast amounts of lava on the surface.
- **Similarities in Rocks on Either Side of Mid-Oceanic Ridges:** The rocks, equidistant from the mid-oceanic ridge crest, display striking similarities in formation time, chemical compositions, and magnetic properties. Rocks nearest to the ridges possess normal polarity and are the most recent. Their age escalates with distance from the crest.

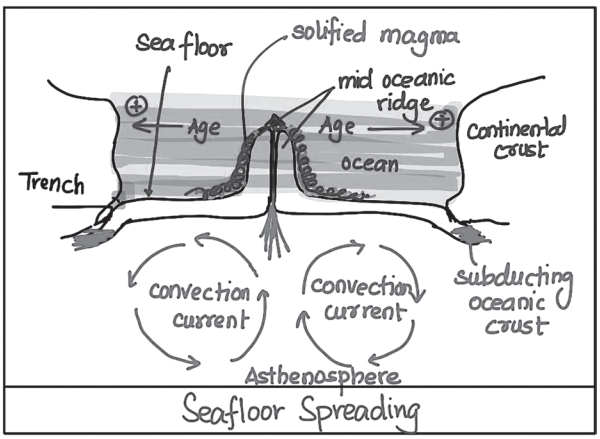
**POINTS TO PONDER**

Travelling away from the Mid Oceanic Ridge, we find alternating patterns of rocks with opposite magnetic alignment. Stripes of normal polarity and reversed polarity alternate across the ocean bottom on both sides of the ridge. Can you think of the possible reasons behind this phenomenon?

- ✧ **Age Discrepancy between Oceanic and Continental Rocks:** Ocean crust rocks are substantially younger than continental rocks. The former's age doesn't exceed 200 million years, while some continental rocks date back as far as 3,200 million years.
- ✧ **Surprisingly Thin Ocean Floor Sediments:** Contrary to expectations of a thick sediment layer if ocean floors were as ancient as continents, sediment columns on the ocean floor were found to be no older than 200 million years.
- ✧ **Earthquake Depths:** Deep trenches are the epicentres for profound earthquakes, whereas the mid-oceanic ridge areas witness quakes with shallow foci.

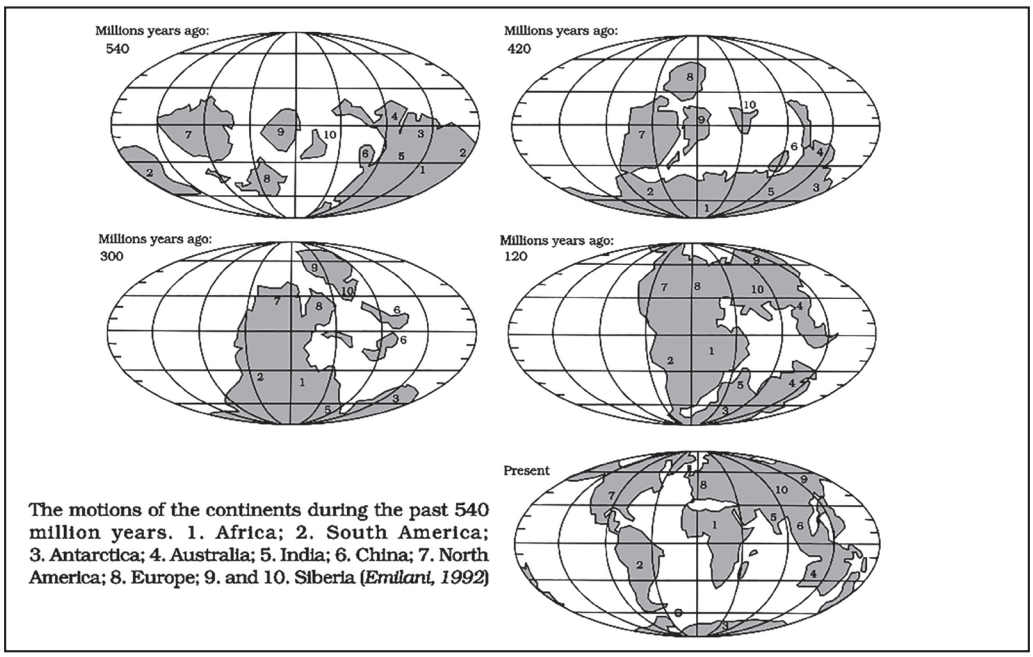
### Hess's Seafloor Spreading Hypothesis (1961)

- ✤ Based on detailed rock magnetic studies, Hess proposed the "seafloor spreading" theory in 1961. (Refer to Figure 4.5)
- ✤ He theorised that continuous volcanic eruptions at mid-oceanic ridges cause breaks in the oceanic crust.
- ✤ Emerging lava from these eruptions pushes the crust apart, leading to the ocean floor's expansion.
- ✤ Noting the youthfulness of the oceanic crust and the fact that one ocean's widening doesn't shrink another, Hess concluded that the spreading ocean floor eventually sinks at trenches and gets absorbed.




## Plate Tectonics

Plate tectonics, an innovative concept, emerged after the introduction of seafloor spreading, rekindling interest in the arrangement of continents and oceans. Proposed independently by McKenzie, Parker, and Morgan in 1967, this theory fundamentally changed our understanding of Earth's surface.




The motions of the continents during the past 540 million years. 1. Africa; 2. South America; 3. Antarctica; 4. Australia; 5. India; 6. China; 7. North America; 8. Europe; 9. and 10. Siberia (*Emilani, 1992*)

**Figure 4.6: Position of continents through geological past**

### What is a Tectonic Plate?

- A tectonic or lithospheric plate is a vast slab of solid rock. Comprising both continental and oceanic lithosphere, these plates glide over the asthenosphere as cohesive units.
- The lithosphere encapsulates the crust and the upper mantle. While its thickness varies from 5-100 km in oceanic regions, it stretches up to 200 km in continental zones.
- A plate's classification as 'continental' or 'oceanic' depends on which type dominates it. For instance, while the Pacific plate is mainly oceanic, the Eurasian plate is predominantly continental.

### Division of Plates

- Earth's lithosphere is partitioned into seven primary plates and several minor ones, (Refer to Figure 4.7) with each major plate delineated by Trenches, Young Fold Mountain Ridges, or Faults.

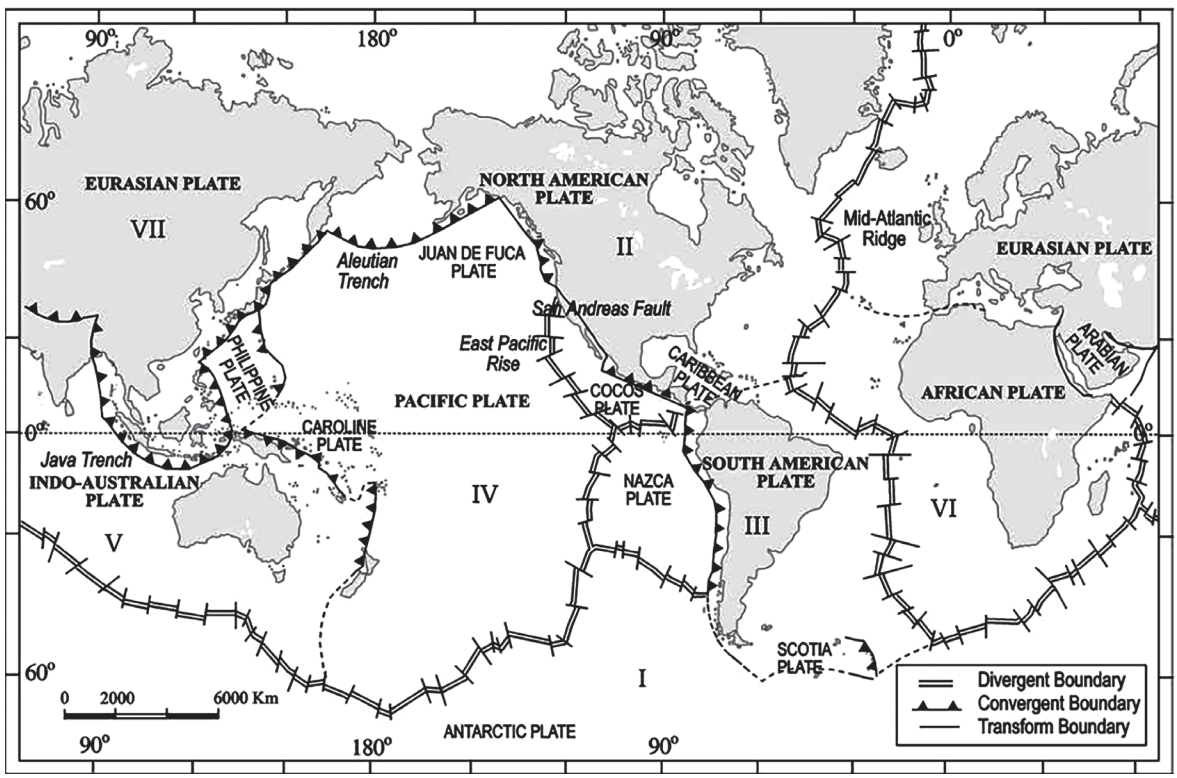



**Figure 4.7: Major and Minor Plates of the World**

- **Major Plates:**
  - Antarctica and its adjacent oceanic plate.
  - North American plate (with a part of the western Atlantic floor, distinct from the South American plate along the Caribbean islands).
  - South American plate (separate from the North American plate along the Caribbean islands)
  - Pacific plate.
  - India-Australia-New Zealand plate.
  - African plate (including the eastern Atlantic floor).
  - Eurasia plate, along with its neighbouring oceanic portion.

- **Some Notable Minor Plates**
  - **Cocos Plate:** Situated between Central America and the Pacific Plate.
  - **Nazca Plate:** Lies between South America and the Pacific Plate.
  - **Arabian Plate:** Primarily the Saudi Arabian landmass.
  - **Philippine Plate:** Positioned between the Asiatic and Pacific Plate.
  - **Caroline Plate:** Nestled between the Philippine and Indian plate (north of New Guinea).
  - **Fuji Plate:** Located to the northeast of Australia.

**POINTS TO PONDER**

You might have found a list of major and minor plates in the chapter. Do you think the existence of these plates is permanent or dynamic? Does African rift valley answer this query?

## Plate Movement

- Contrary to Wegener's belief that continents move, it is the plates that shift, with continents being integral components of these plates.
- Historical data suggests plates have always been in motion and will continue to do so.
- Although Wegener envisioned an original supercontinent, Pangaea, subsequent findings indicate that continental masses, residing on plates, have been mobile throughout Earth's history.
- Pangaea was just a culmination of various continental masses converging, each being part of distinct plates.
- Paleomagnetic data helps determine the positions of present day continents in different geological eras.
- The Indian subcontinent's location, particularly Peninsular India, has been discerned from rock studies in the Nagpur region.

## Plate Boundaries

- There are three primary types of plate boundaries (Refer to Figure 4.8).

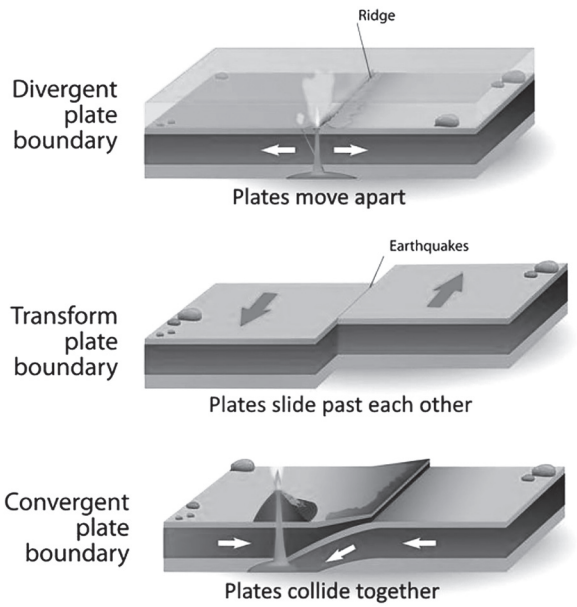



**Figure 4.8: Types of plate Boundary Interaction**

- **Divergent Boundaries:** Here, new crust forms as plates drift apart, creating spreading sites like the Mid-Atlantic Ridge, where the American Plate separates from the Eurasian and African Plates.
- **Convergent Boundaries:** At these sites, one plate submerges under another at subduction zones. Convergence happens in three ways: between an oceanic and a continental plate, between two oceanic plates, and between two continental plates.
- **Transform Boundaries:** Plates slide horizontally, neither creating or destroying crust. Due to differential movements, separated plate portions can experience effects from Earth's rotation.

**POINTS TO PONDER**

Earthquakes and Volcanoes are generally frequent at the convergent plate boundaries. Why do you think volcanism is found in the Andes Mountain ranges but is missing in Himalayan region considering that both the ranges are at convergent boundaries?

### Rates of Plate Movement

- Magnetic fields alongside mid-oceanic ridges reveal plate movement rates. While the Arctic Ridge moves below 2.5 cm/yr, the East Pacific Rise exceeds 15 cm/yr.

### Force behind Plate Movement

- Contrary to early beliefs of a static Earth, it is now known that the planet is dynamic.
- Plates move due to the slow churn of the mantle below them, called convective flow, driven by heat from radioactive decay and residual heat.
- This theory, rooted in ideas from the 1930s, asserts that this mantle movement propels plate tectonics.

## Movement of the Indian Plate

### Indian Plate Boundaries

- **Northern Boundary:** The Himalayas represent a continent-continent convergence zone.
- **Eastern Boundary:** Extends from the Rakinyoma Mountains to the Java Trench, featuring a spreading site near Australia in the SW Pacific.
- **Western Boundary:** Begins at the Kirthar Mountains, stretches along the Makrana coast, and connects to the Red Sea rift via the Chagos Archipelago.
- **Southern Boundary with Antarctica:** Defined by an oceanic ridge that merges near New Zealand.

### Historical Progression of the Indian Plate

- **Initial Stance:** Once positioned near Australia, India was separated from Asia by the Tethys Sea until about 225 million years ago.
- **Movement Post-Pangaea:** It began its northern trajectory around 200 million years ago after Pangaea's breakup.
- **Asian Collision:** Approximately 40-50 million years ago, India's collision with Asia precipitated the swift emergence of the Himalayas.

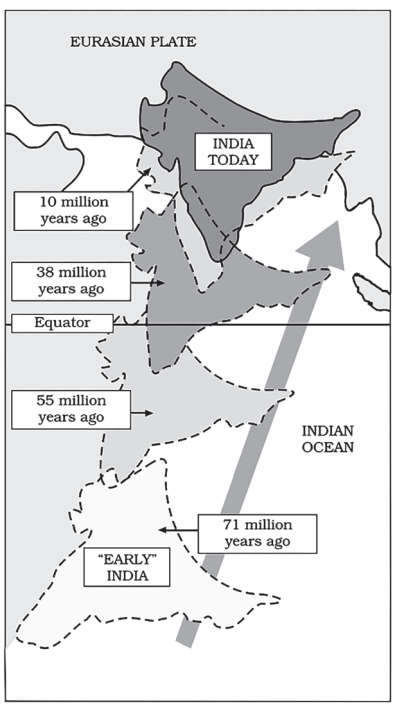



**Figure 4.9: Movement of the Indian Plate**

### Key Geological Events

- **Geographical Evolution:** From 71 million years ago to the present, depicted in Figure 4.9.
- **Deccan Traps Event:** Around 60 million years ago, significant lava eruptions formed the Deccan Traps.
- **Elevation of the Himalayas:** Initiated nearly 40 million years ago, this uplift continues today, with the mountain range still ascending.

## Conclusion

The Earth's crust has always been in motion, ever-shifting and reshaping our world. Our understanding of the planet's layout has evolved significantly, progressing from the early musings about drifting continents to the intricate dance of tectonic plates. These theories, underpinned by geological, paleomagnetic, and oceanographic evidence, illuminate the past, inform the present, and provide a glimpse into the future.

***Glossary:***

- **Continental Drift:** The theory suggests continents were once connected and have since drifted apart.
- **Pangaea:** A hypothetical supercontinent that existed during the late Paleozoic and early Mesozoic eras.
- **Tectonic Plates:** Massive slabs of Earth's crust that move due to convective currents in the mantle.
- **Mid-Oceanic Ridges:** Submerged mountain ranges formed by upwelling magma, typically located at divergent boundaries.
- **Plate Boundaries:** Zones where tectonic plates meet, leading to various geological activities.
- **Divergent Boundaries:** Boundaries where plates move apart.
- **Convergent Boundaries:** Boundaries where plates move toward one another, often resulting in one plate diving beneath another.
- **Transform Boundaries:** Boundaries where plates slide horizontally past each other.
- **Convective Flow:** The circular movement within a fluid, caused by temperature differences, is responsible for the movement of tectonic plates.
- **Paleomagnetic Data:** Information obtained from rocks that reveals the direction and intensity of Earth's magnetic field in the past.
- **Holmes's Convection Current Theory:** The proposal that the Earth's mantle contains convection currents that influence the movement of tectonic plates.
- **Sea Floor Spreading:** The process where new oceanic crust is formed at mid-ocean ridges and destroyed at deep-sea trenches.
- **Deccan Traps:** A vast plateau in west-central India formed by volcanic eruptions.

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# 5 Geomorphic Processes

**Bibliography:** This Chapter encompasses the summary of Chapter 5- XI NCERT (Fundamentals of Physical Geography) and Chapter 3-VII NCERT (Our Environment).

## Introduction

The lithosphere, composed of rigid plates known as lithospheric plates, undergoes slow movement driven by circulating molten magma beneath the Earth's surface. These movements **(Refer to Figure 5.1)**, classified as endogenic and exogenic forces, give rise to transformative phenomena like earthquakes and volcanoes. It emphasizes that the Earth's surface, vital for all life, is a complex system influenced by these intricate forces. Grasping these mechanisms is essential for the responsible care of our planet, enabling us to harmonize utilization and preservation for the well-being of generations to come.

## Geomorphic Processes

- Geomorphic processes, an interplay of endogenic and exogenic forces **(Refer to Figure 5.1)**, causing physical stresses and chemical actions on earth materials and bringing about changes in the configuration of the surface of the earth.
- **Endogenic forces**, such as diastrophism and volcanism, arise internally. **Exogenic forces**, like weathering, mass wasting, erosion, and deposition, stem from external factors.

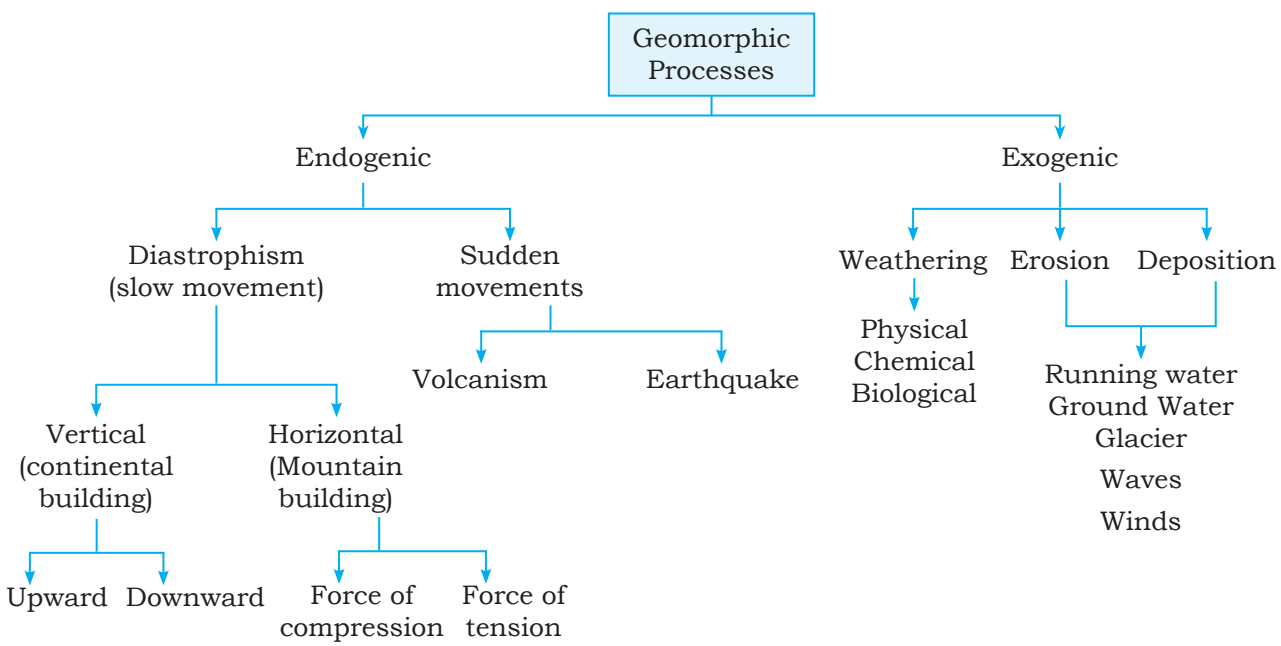



**Figure 5.1: Geomorphic Processes**

## Endogenic Forces

Endogenic forces occur due to the energy emanating from within the earth surface which can result in either diastrophism or sudden movements such as earthquakes and volcanoes.

**POINTS TO PONDER**

Geomorphic processes are a result of many factors which are endogenic and exogenic? Do you think these can be affected by anthropogenic factors? Can you find a few instances of the same across the globe?

## Diastrophism

- It includes all processes that move, elevate or build up portions of the earth's crust come under diastrophism. They include:
  - **Orogenic:** Orogenic processes involving mountain building through severe folding and affecting long and narrow belts of the earth's crust.
  - **Epeirogenic:** Epeirogenic processes involving uplift or warping of large parts of the earth's crust.
  - **Plate Tectonics:** Plate tectonics involving horizontal movements of crustal plates.

## Volcanism

- Volcanism **(Refer to Figure 5.2)** involves magma movement towards the Earth's surface.
- It results in various volcanic forms, both intrusive and extrusive.

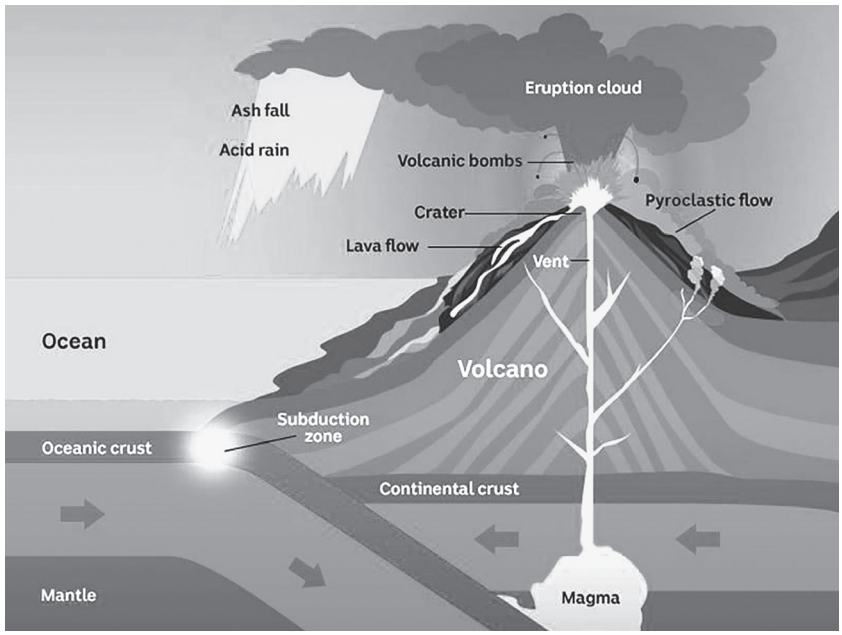



**Figure 5.2: A Volcano Epicentre**

## Earthquake

- An earthquake is the shaking of the earth caused by the release of seismic energy which is generated due to lithospheric plates movement, creating vibrations in the Earth.
- It originates at the focus within the crust (Refer to Figure 5.3), with the epicentre directly above on the surface which is the most severe point for damage and it diminishes with distance.

**Do You Know?**

There are three types of earthquake waves:

- P waves or longitudinal waves
- S waves or transverse waves
- L waves or surface waves

- Predicting earthquakes remains challenging, emphasizing the importance of readiness. Local methods, such as observing animal behavior (e.g., agitated fish, surfacing snakes), can serve as indicators.

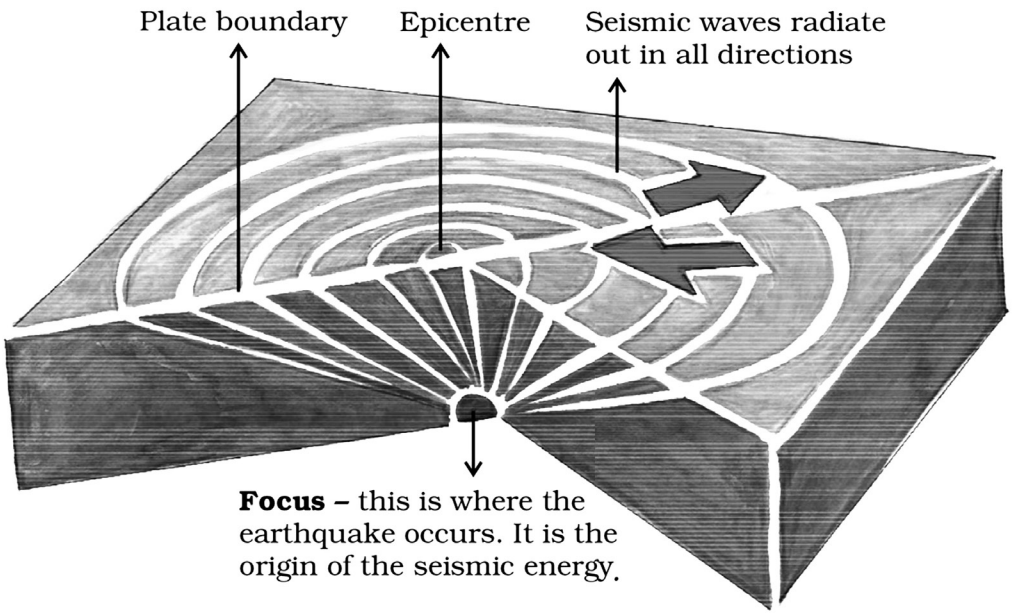



**Figure 5.3: Origin of an Earthquake**

### Landslide

- Landslides involve movement of a mass of rock, debris, or earth down a slope.
- The detached mass's size and shape depend on rock discontinuities, weathering, and slope steepness.

### Exogenic Force

- Exogenic forces, which are influenced by solar energy and tectonic gradients, draw energy from the atmosphere. It also includes the following:
- **Gravitational force:** It acts on sloping surfaces, causing downslope movement of materials.
- **Stress:** It refers to the force applied per unit area, induces deformation in solids through pushing or pulling. It includes:
  - **Shear Stress:** It acts along material faces, breaks rocks and induces slippage.
  - **Molecular Stress:** It is caused by factors like temperature changes, crystallization, and melting that further affect materials.
- **Chemical process:** It weakens bonds, and dissolves minerals, or cementing materials, contributing to weathering and erosion.
- **Climatic factors:** Temperature, precipitation, insolation, wind patterns, and other climatic factors are critical for governing these processes.
- **Denudation forces** (Refer to Figure 5.4) such as weathering, mass movements, erosion, and transportation.
- **Rock Type and Structure** also significantly affect the intensity of exogenic processes.

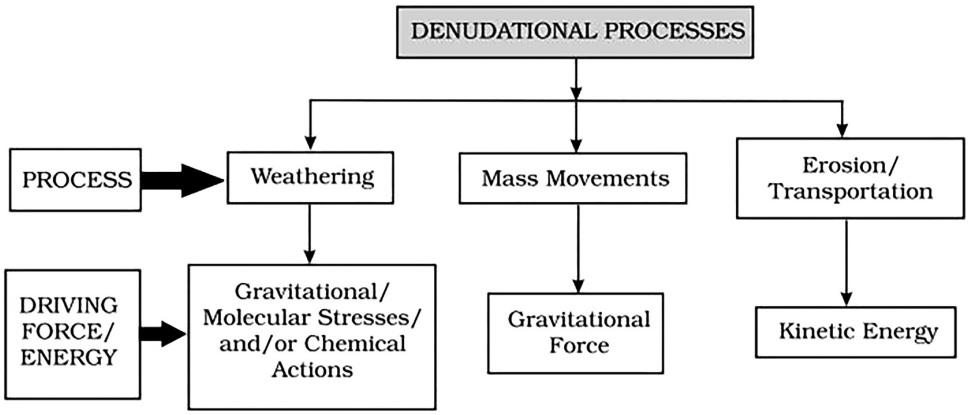



**Figure 5.4: Denudational Processes**

## Weathering

- Weathering is defined as mechanical disintegration and chemical decomposition of rocks through the actions of various elements of weather and climate.
- Weathering results from the effects of weather and climate on earth materials.
- It encompasses various processes acting individually or in combination to break down materials into fragments.
- **In-Situ Process:** Weathering occurs in place without significant material movement.
- **Factors Influencing Weathering:**
  - Geological, climatic, topographic, and vegetative factors play complex roles in shaping weathering processes.
  - Climate **(Refer to Figure 5.5)** holds particular significance, influencing both the type and depth of the weathering mantle.

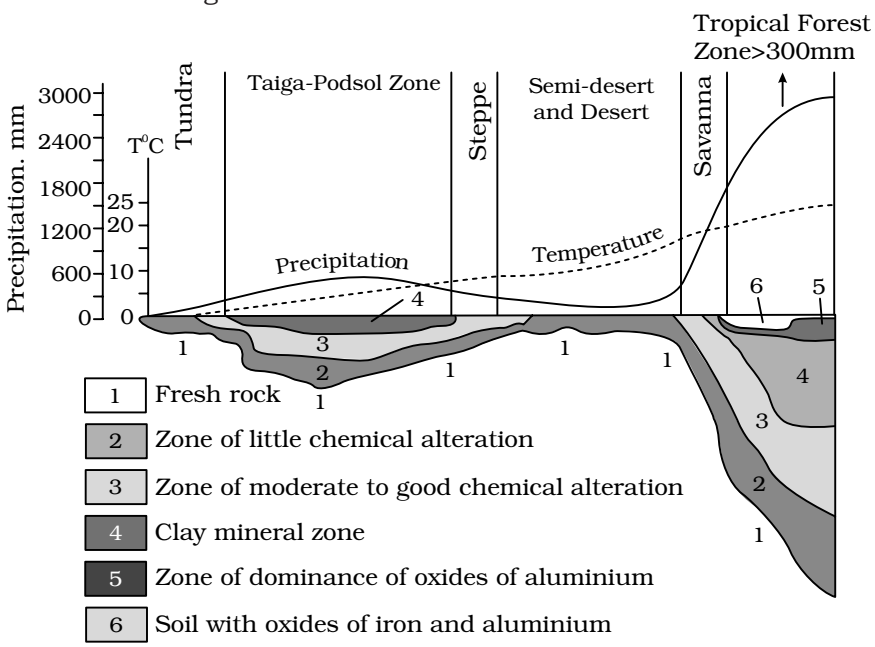



**Figure 5.5: Climatic regimes and depth of weathering mantles (adapted and modified from Strakhov, 1967)**

Weathering Processes are classified into the following categories:

### Chemical Weathering Processes

- It refers to weathering processes that include solution, carbonation, hydration, oxidation and reduction act on rocks.
- They decompose, dissolve, or reduce rocks to fine clastic states through chemical reactions with oxygen, water, and acids.
- **Essential Factors**
  - Water, air and heat are vital for accelerating chemical reactions.
  - Decomposition of plants and animals contributes additional carbon dioxide, intensifying chemical reactions underground.

**POINTS TO PONDER**

You must have heard of India reaching the moon's surface in recent times through the Chandrayaan project. Find out the details observed about the lunar surface and its features. Compare and contrast it with major features of the earth. Can you think of the different geomorphic processes of the earth which may also be operating on the moon? Can you guess the variations in these processes which may be found on the moon ?

### Physical or Mechanical Weathering Processes

- Physical or mechanical weathering refers to a process that relies on applied forces. These forces could be:
  - **Gravitational forces** like overburden weight, load, and shearing stress.
  - **Expansion forces** from temperature shifts, crystal growth, or animal activity also play a role.
  - Water pressures lead to significant rock damage due to repeated contraction and expansion.

### Biological Weathering

- **Biological weathering involves organisms** contributing to or removing minerals and ions from the environment. It Includes:
  - **Organism Growth:** It involves burrowing and wedging activities by living creatures like earthworms, termites, and rodents expose fresh surfaces to chemical reactions, aiding moisture and air penetration.
  - **Organic Matter Decay:** Decomposing plant and animal matter generates humic, carbonic, and other acids, promoting the decay and solubility of certain elements.
  - **Root Pressure:** Plant roots exert significant mechanical pressure, mechanically breaking apart earth materials.

### Exfoliation

- Exfoliation occurs when curved sheets of material peel away from rocks due to temperature-induced expansion and contraction.
- This phenomenon forms smooth, rounded surfaces, with exfoliation domes (Refer to Figure 5.6) from unloading and tors from thermal expansion.

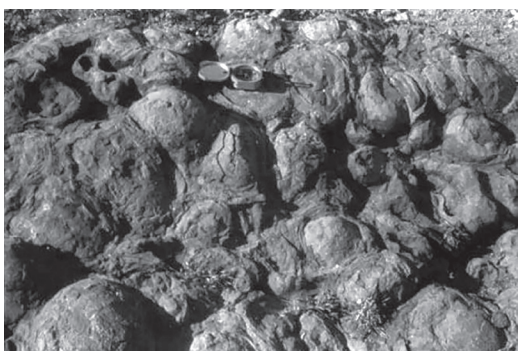


**Figure 5.6: Exfoliation (Flacking) and granular disintegration**

### Significance of Weathering

- Weathering processes break down rocks into smaller fragments. They pave the way for the formation of regolith, soils, erosion, and mass movements.
- It plays a vital role in enriching forests and biodiversity, while also being essential for significant erosion and crucial in soil formation.

- It also contributes to mass wasting and changes in landforms due to erosion.
- It enriches and concentrates valuable ores like iron, manganese, aluminium, and copper which are vital for the **national economy**.

## Mass Movements

- Mass movements involve the transfer of rock debris down the slope under the direct influence of gravity that influences all matter, from bedrock to weathering products.
- **Factors favoring mass movements** include weak materials, steep slopes, rainfall, and lack of vegetation.
- Mass movements can be slow (creep, heave) or rapid (flow, slide), categorized by their speed.

### Slow Movements

- Slow movement is a movement occurring on moderately steep, soil-covered slopes.
- It involves extremely gradual and imperceptible material displacement, such as soil or rock debris.
- Creep has important effects that can be observed in slow movement. It includes soil creep, talus creep, rock creep, and rock-glacier creep.
- Solifluction, another form of creep, consists of slow downslope flow of saturated soil or fine-grained rock debris.It occurs in moist temperate areas due to surface melting of frozen ground and prolonged rainfall.

**Preceding Causes of Mass Movements**

- Removal of support from below to materials above through natural or artificial means.
- Increase in gradient and height of slopes.
- Overloading due to heavy rainfall, saturation and lubrication of slope materials.
- Removal of material or load from over the original slope surfaces.
- Occurrence of earthquakes, explosions or machinery.
- Excessive natural seepage.
- Heavy drawdown of water from lakes, reservoirs and rivers leading to slow outflow of water from under the slopes or river banks.
- Indiscriminate removal of natural vegetation.

### Rapid Movements

**It is the downslope movement** of water-saturated clay or silt along a hill such as earthflows, mudflows and debris avalanche.

- **Earthflow is** the movement of water-saturated clayey or silty materials down low-angle terraces or hillsides.
- **Mudflows** occur when heavy rainfall saturates thick layers of weathered materials, flowing slowly or rapidly down channels like a stream of mud.
  - Mudflows can be destructive when they reach piedmonts or plains, engulfing roads, bridges, and houses, and are common around erupting volcanoes.
- **Debris avalanches** are fast-moving mass movements, occurring in narrow tracks on steep slopes, resembling snow avalanches.

These all phenomena are more prevalent in humid regions and can have significant geological and environmental impacts.

## Landslide

- Landslide refers to rapid and perceptible movements. The materials involved are relatively dry.
- The size and shape of the detached mass depends on the nature of discontinuities in the rock, the degree of weathering and the steepness of the slope.
- **Depending upon the type of movement of materials,** several types are identified in this category. These are following:
  - **Slump (Refer to Figure 5.7)** is the slipping of one or several units of rock debris with a backward rotation with respect to the slope over which the movement takes place.
  - **Rapid rolling or sliding** of earth debris without backward rotation of mass is known as debris slide.
  - **Sliding of individual rock** masses down bedding, joint or fault surfaces is rockslide.
  - **Rockslide** is the sliding of individual rock masses along bedding, joint, or fault surfaces, especially over steep slopes.
  - **Rockfall** is free falling of rock blocks over steep slopes while maintaining some distance from the slope's surface.

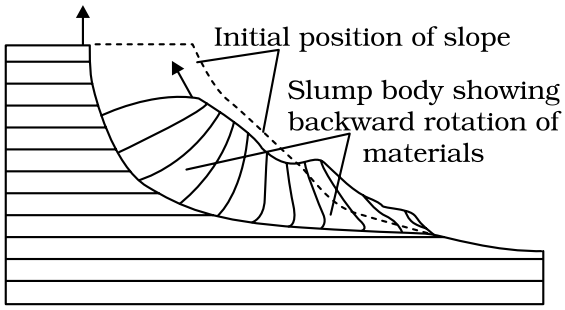



**Figure 5.7: Slumping of debris with backward rotation**

## Erosion and Deposition

### Erosion

- **Erosion** involves the acquisition and transportation of rock debris by various geomorphic agents.
- When massive rocks break into smaller fragments through weathering and other processes, erosional geomorphic agents like running water, groundwater, glaciers, wind and waves remove and transport it to other places.
- Abrasion by rock debris carried by these geomorphic agents also aids greatly in erosion.
- Erosion is responsible for continuous changes in the Earth's surface and is controlled by kinetic energy.
- **Geomorphic agents of erosion** include wind, running water, glaciers, waves, and groundwater.

### Deposition

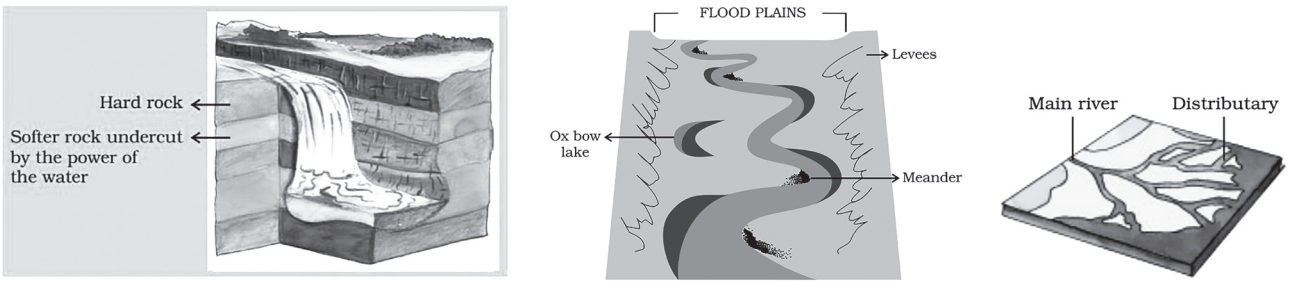
- Deposition is a consequence of erosion when erosional agents lose velocity on gentler slopes, causing materials to settle.
- Deposition occurs in the reverse order of particle size, with coarser materials depositing first.
- Deposition fills depressions and leads to landscape aggradation.
- The same agents of erosion, such as running water, glaciers, wind, waves, and groundwater, can also act as depositional agents.
- Erosion and deposition processes significantly shape the Earth's surface, leading to various landforms, which will be discussed further in the next chapter.

## Major Landforms Formed by Exogenic Forces

- The landscape undergoes continuous transformation through two fundamental processes: weathering and erosion, giving rise to various landforms, as listed below:

### Landforms by River

- **Waterfall:** Weathering of steep terrain or hard rocks can lead to the formation of waterfalls **(Refer to Figure 5.8a)**
- **Meanders:** Upon entering plains, rivers form large meanders or bends **(Refer to Figure 5.8b)**.
- **Oxbow lake:** Continuous erosion and deposition at meander sides bring the loops closer, eventually forming cut-off lakes or oxbow lakes **(Refer to Figure 5.8b)**.
- **Levees:** Occasional riverbank overflows result in flooding, depositing fertile sediments, and forming flat floodplains with raised banks, known as levees **(Refer to Figure 5.8b)**.
- **Delta:** When the river's speed diminishes near the sea, causing it to split into distributaries, each creating its own mouth. The sediments collected by all distributary mouths accumulate to form a delta **(Refer to Figure 5.8c)**.




(a) (b) (c)

**Figure 5.8: Landforms by River**

### Landforms by Sea

- **Sea Caves:** It is formed when wave action strikes rocks, causing cracks to form and expand over time. This process results in the creation of hollow sea caves **(Refer to Figure 5.9).**
  - Continued erosion enlarges these caves, forming sea arches.
  - Further erosion breaks the roof, leaving behind wall-like features called stacks.

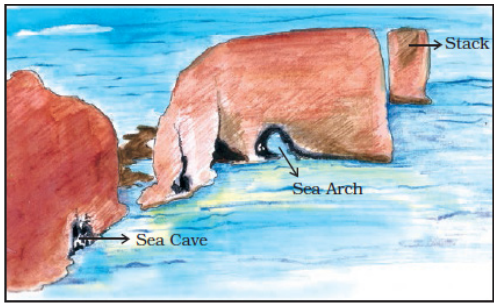



**Figure 5.9: Features made by sea waves**

### Landforms by Ice

- **Glaciers:** Often referred to as "rivers of ice", these contribute to landscape erosion **(Refer to Figure 5.10)**. The debris carried by glaciers, including rocks and sediments, form glacial moraines.

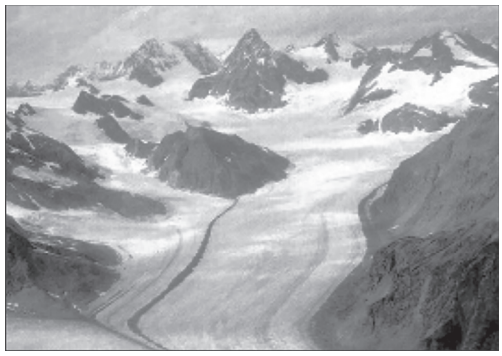


**Figure 5.10: Glacier**

### Landforms by Wind

- **Wind Landforms:** Significant erosion and deposition in deserts formed wind landforms. It includes:
  - **Mushroom rocks,** with a narrower base and wider top, are common desert formations due to wind erosion.

- **Sand dunes** form **(Refer to Figure 5.11)** when wind carries and deposits sand, forming low hill-like structures called as sand dunes.
- **Loess** formed when fine, light sand can be carried over extensive distances by strong winds, leading to the formation of large areas of loess.

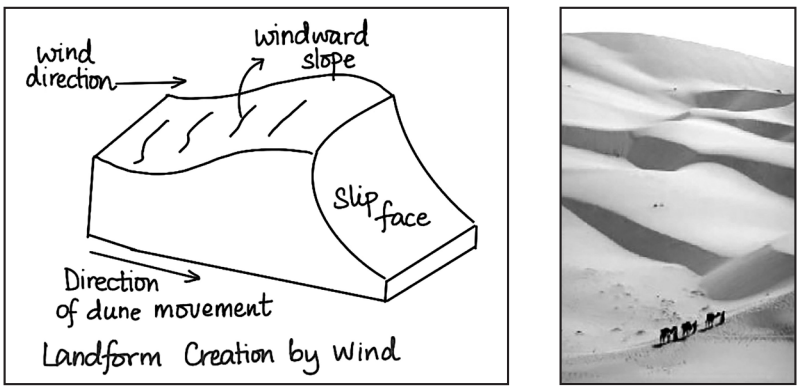



**Figure 5.11: Sand Dunes**

## Soil Formation

Soil, a dynamic medium on Earth's surface, contains living and dead matter, supporting plant growth. It undergoes constant chemical, physical, and biological changes, influenced by seasons and long-term factors like climate, landform, and vegetation, impacting its chemistry, organic content, flora, fauna, temperature, and moisture.

### Process of Soil Formation

- Soil formation, known as **pedogenesis**, begins with **weathering**. It is this weathering mantle (depth of the weathered material) which is the basic input for soil to form.
- Then bacteria, mosses, lichens, and various organisms colonize the weathered material or deposits.
- Dead organisms and plants contribute to humus accumulation.
- Initially, minor grasses and ferns may grow, followed by bushes and trees carried by birds and wind.
- Plant roots and burrowing animals enhance soil porosity, enabling water retention and air passage. Eventually, a mature soil, a complex blend of minerals and organic matter, is established through these processes.

### Factors Controlling Soil-Formation

Five basic factors control the formation of soils:

- **Parent Material**
  - Parent material is a passive factor in soil formation, encompassing in-situ weathered rock debris (residual soils) or transported deposits (transported soils).
  - Soil development relies on factors like texture (debris size), structure (particle arrangement),
- **Topography**
  - **Topography**, another passive factor, influences soil formation through sunlight exposure and drainage.
  - Steep slopes yield thin soils, while flat uplands support thicker soils.
  - Gentle slopes with slow erosion and good water percolation favour soil formation.

- Flat areas may develop clay-rich soils with dark color.
- South-facing slopes differ from north-facing slopes in vegetation and soil characteristics, especially in middle latitudes.

- **Climate**
  - **Climate** is a significant active factor in soil formation, influenced by moisture and temperature.
  - **Moisture** elements like intensity, frequency, duration of precipitation, evaporation, and humidity play a role.
  - **Precipitation** provides soil moisture vital for chemical and biological activities.
  - **In wet equatorial** areas with high rainfall, excess water leads to desilication, removing silica from the soil.
  - **Dry climates with high temperatures** cause evaporation to exceed precipitation, leading to salt deposits called hardpans.
  - In tropical regions with intermediate precipitation, calcium carbonate nodules (kanker) may form.
  - **Temperature affects** chemical and biological activity, with higher temperatures increasing chemical processes and colder temperatures reducing them, except for carbonation.
  - **Frozen tundra** soils mainly consist of mechanically broken materials due to freezing conditions.
- **Biological Activity**
  - **Vegetative cover and organisms** on parent materials contribute to soil development by adding organic matter, retaining moisture, and aiding mineral decomposition.
  - **Dead plants** create humus, finely divided organic matter, which releases organic acids during humification to break down minerals.
  - **Bacterial activity** varies with climate; slow in cold climates, leading to humus accumulation, and rapid in humid tropical climates, resulting in low humus content.
  - **Soil organisms** like bacteria perform nitrogen fixation, converting atmospheric nitrogen into a chemical form usable by plants. Rhizobium bacteria in leguminous plant root nodules aid nitrogen fixation.
- **Time**
  - Time is a critical factor in soil formation, influencing maturation and profile development.
  - Mature soils result from extended operation of soil-forming processes.
  - Soils originating from recent deposits like alluvium or glacial till are considered young with poorly developed horizons.
  - No fixed timeframe exists for soils to mature; it varies depending on local conditions and processes.

## Conclusion

The dynamic interplay of endogenic and exogenic forces shapes the Earth's surface, giving rise to essential geological phenomena. Earthquakes, volcanoes, and the continuous transformation of landforms exemplify the profound impact of these forces. This knowledge is not only vital for disaster preparedness but also underscores the importance of responsible stewardship of our planet. By understanding and respecting these processes, we pave the way for a sustainable coexistence with the Earth, ensuring a thriving legacy for generations to come.

***Glossary:***

- **Lithosphere:** The lithosphere is Earth's rigid outer layer, encompassing the crust and uppermost part of the mantle.
- **Endogenic forces:** Endogenic forces originate within Earth, shaping its structure through processes like tectonic plate movement and volcanism.
- **Geomorphic processes:** Geomorphic processes shape Earth's surface, including erosion, weathering, deposition, and tectonic movements, influencing landscapes and landforms.
- **Diastrophism:** Earth's crustal movements causing landform changes, including folding, faulting, and mountain building, over geological time.
- **Volcanism:** Earth's process where molten rock, ash, and gasses are expelled through volcanic activity, shapes landscapes.
- **Earthquake:** Sudden ground shaking due to shifting lithospheric plates, releasing seismic energy, causing tremors and potential devastation.
- **Landslide:** Sudden downhill movement of soil, rock, or debris due to gravity, often triggered by heavy rain or earthquakes.
- **Gravitational force:** Force of attraction between two objects, proportional to their mass and inversely proportional to distance.
- **Molecular stresses:** Molecular stresses refer to forces acting at the molecular level, affecting a material's structural integrity and behavior
- **In-Situ Process:** In-situ process occurs on-site, without removal, maintaining the original location or position of an object.
- **Biological Weathering:** Processes where living organisms contribute to the breakdown and alteration of rocks.
- **Sea Waves:** Ocean's rhythmic undulations, driven by wind, shaping coastlines and playing a vital role in Earth's climate.
- **Rapid Movements:** Swift, sudden actions or shifts, often occurring abruptly and with notable speed or velocity.
- **Biological Activity:** Living organisms' interactions within ecosystems, influencing growth, decay, and nutrient cycling, are collectively termed biological activity.

❐❐❐

# 6 Landforms and their Evolution

**Bibliography:** This chapter encompasses the summary of **Chapter 7** of Class-XI NCERT (Fundamentals of Physical Geography).

## Introduction

**Landforms** are the different shapes and features on the Earth's surface, and they change over time because of things like water, wind and other natural forces, creating a constantly evolving landscape.

In this chapter, we will study different landforms and geographical agents which play a major role in forming these landforms.

## Formation of Landforms

Fluvial Processes

Erosion → Transportation

Deposition

- Each landform possesses distinct physical characteristics, materials, and results from specific Geomorphic Processes and Agents.
- Geomorphic agents such as **Running Water, Groundwater, Glaciers, Wind and Waves,** interact with Earth's surface materials.
- These agents initiate changes on the Earth's surface such as Erosion, the wearing away of Earth's surface, and Deposition, where eroded materials are transported and settled in new locations.
- Landforms undergo stages of transformation, akin to the stages of life - youth, maturity, and old age.
- Evolution involves the gradual transition from one landform type to another or the transformation of individual landforms.
- These stages reflect the dynamic nature of landforms as they evolve and change over geological time scales.

**POINTS TO PONDER**

"Landforms are functions of structure, processes and time." Can you identify one of the factors mentioned above as the most dominant one or do you think that all the factors have played a crucial role in the evolution of landforms on the earth?

*Let's study these geomorphic agents and landforms formed by them in detail.*

## Running Water

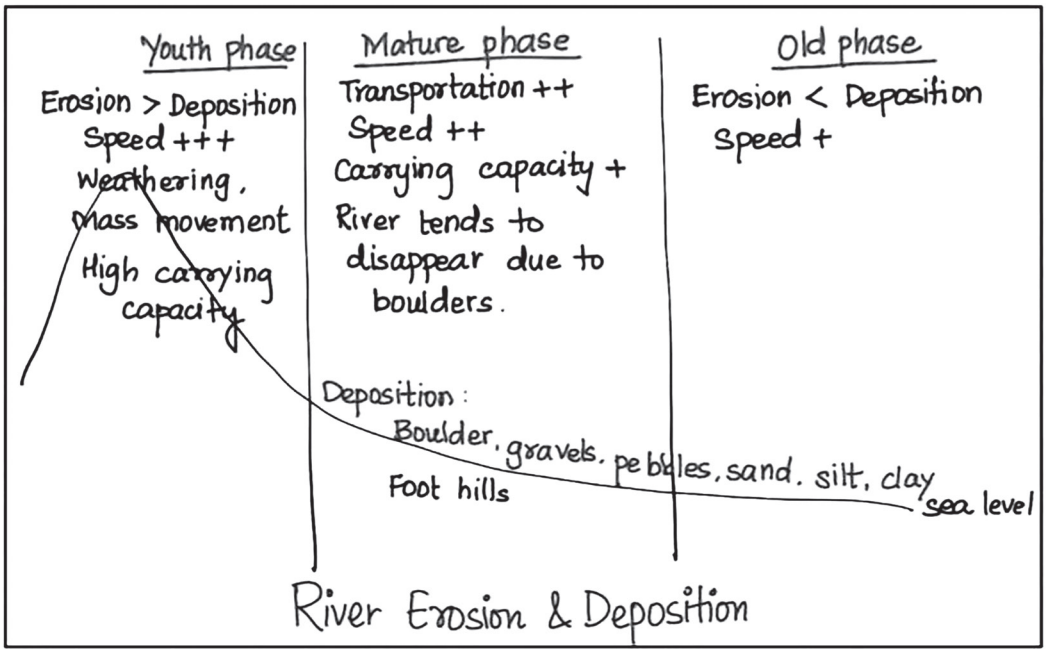
- In rainy areas, running water, like rivers and streams, significantly shape the land.
- This **running water has 2 components,** one is Overland Flow or Sheet and another is Linear Flow as streams and rivers in valleys.
- Initially, fast-flowing rivers create deep valleys and waterfalls due to vertical erosion. As they slow down due to continuous erosion, they deposit sediment, forming flatter plains.

**Figure 6.1: The Valley of Kaveri river in the form of gorge**

- Over time, this process can create lowlands with rocky remnants called **Peneplain,** in which some sturdy rock remnants, known as **Monadnocks** can be seen.

**Landforms** formed due to running water develops in **3 stages:**

- **Youth Stage**
  - In this stage, streams are limited, poorly integrated, and flow over original slopes which form shallow V-shaped valleys.
  - The stream divides are broad, flat, and often include marshes, swamps, and lakes.
  - Meanders may be present in entrenched forms.
  - Waterfalls and rapids exist in hard rocks.




- **Mature Stage**
  - In this stage, the number of streams increases and their integration improves.
  - Valleys remain V-shaped but with broader streams allowing for wider floodplains where streams form meanders within the valleys **(Refer to Figure 6.2)**.

**Figure 6.2: An entrenched meander loop of river Colorado in the USA showing step-like side slopes of its valley typical of a canyon**

- ✧ Swamps and marshes from the Youth stage disappear, and stream divides become more defined.
- ✧ Waterfalls and rapids also become less prominent.

- ✤ **Old Stage**
  - ✧ This stage is characterized by extensive floodplains with Natural Levees and Oxbow Lakes.
  - ✧ The divides are broad and flat, often with lakes, swamps, and marshes. Much of the landscape is at or slightly above sea level.

## Erosional Landforms Formed by Running Water

### Valleys

- ✤ Valleys evolve from small, narrow rills to long, wide gullies and eventually to valleys.
- ✤ Various types of valleys, such as V-shaped valleys, Gorges, and Canyons, may form depending on rock type and structure.
  - ✧ **Gorges** have steep sides and are equal in width at top and bottom. On the other hand, **Canyons** exhibit steep, step-like slopes and tend to be wider at the top than at the bottom.

### Potholes and Plunge Pools

- ✤ Potholes are circular depressions formed on rocky streambeds due to erosion and the abrasion of rock fragments.
- ✤ They start as small depressions that collect pebbles and boulders, gradually deepening and widening.
- ✤ Plunge pools, similar depressions, form at the base of waterfalls due to the force of the water.

### Incised or Entrenched Meanders

- ✤ Incised or entrenched meanders found in initial stages in developments of streams which form looping patterns.
- ✤ Due to continuous erosion, these meanders further widens and deepens and forms deep gorges and canyons in hard rock areas.

### River Terraces

- ✤ River terraces represent old valley floor or floodplain levels, either as bedrock surfaces or alluvial terraces with stream deposits.
- ✤ They result from vertical erosion by the stream into its own depositional Floodplain and may occur at same heights on either side of rivers, known as **Paired Terraces.**
- ✤ When terraces present at one side only or present at different elevations, are called **Unpaired Terraces**.

## Depositional Landforms Formed by Running Water

### Alluvial Fans

- ✤ They are created by mountain streams carrying heavy coarse sediment when they reach low-gradient foot slope plains.
- ✤ Streams often carry a load too heavy for gentler gradients, leading to the deposition of a Cone-shaped alluvial fan **(Refer to Figure 6.3)**.
- ✤ Streams frequently change positions, forming multiple channels called Distributaries.

**Figure 6.3: An alluvial fan deposited by a hill stream on the way to Amarnath, Jammu and Kashmir.**

- Alluvial fans in humid regions have gentle slopes, while arid regions exhibit steep, high cones.

### Deltas

- Deltas occur at the meeting point of rivers and the sea **(Refer to Figure 6.4)**.
- River sediment accumulates and forms a low cone-shaped delta at the coast.
- Deltas have well-sorted and stratified deposits with coarse materials settling first, while finer fractions like silts and clays are carried to the sea.
- Further, river distributaries expand as the delta extends into the sea.

**Figure 6.4: A satellite view of part of Krishna river delta, Andhra Pradesh.**

### Floodplains

- Deposition occurs as river channels transition to gentler slopes, depositing finer materials like sand, silt, and clay in plains.
- Floodplains comprise an **active floodplain** (riverbed with river deposits) and an **inactive floodplain** above the banks.
  - Inactive floodplains contain flood and channel deposits gradually filled by abandoned channels.
- These deposits consist of finer materials like silt and clay.
- Floodplains within deltas are referred to as **delta plains**.

### Natural Levees and Point Bars

- Natural Levees are linear ridges of coarse deposits found along large riverbanks **(Refer to Figure 6.5)**. They can appear as individual mounds.
  - These are high nearer the banks and slope gently away from the river.
- **Point Bars (Meander Bars)** are linear sediments deposited by flowing water on the concave side of meanders in large rivers. They have a nearly uniform profile and width, and contain mixed sizes of sediments.

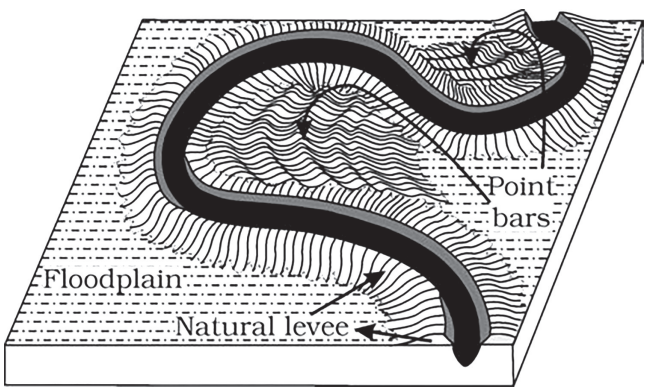



**Figure 6.5: Natural levee and point bars.**

### Meanders

- Meanders are **loop-like channel patterns** found on large floodplains and delta plains.
- They form due to low channel gradients, unconsolidated alluvial deposits, and the impact of coriolis force on water flow.
- Meanders develop as water works laterally on banks, creating slight irregularities that deepen into bank curvatures **(Refer to Figure 6.6)**.
- Deposition occurs along the concave bank of these bank curvatures, while erosion takes place along the convex bank.
- Features of meanders include cut-off banks with steep scarps and long, gentle convex banks.
- Cut-off meanders can further evolve into **oxbow lakes**.

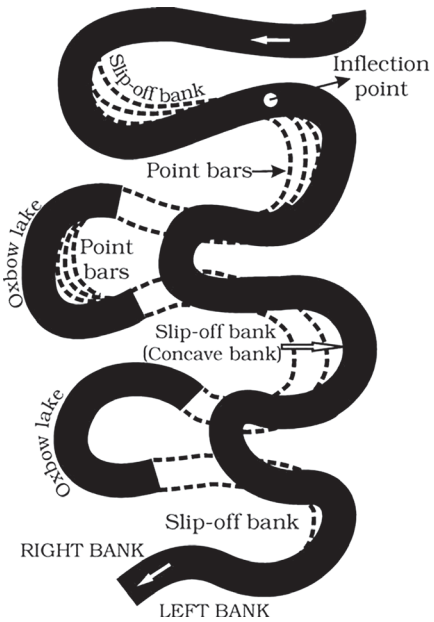



**Figure 6.6: Meander growth and cut-off loops and slip-off and undercut banks.**

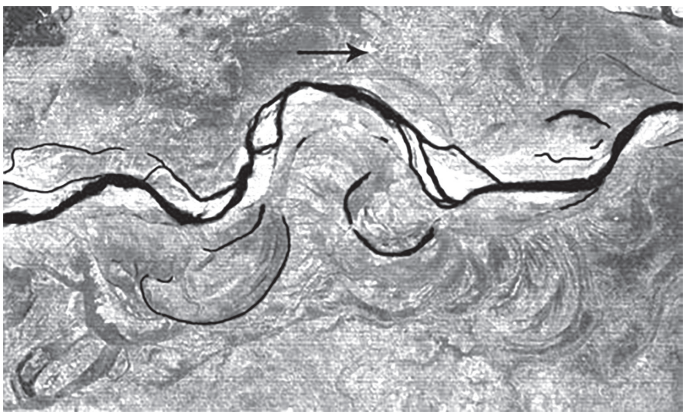


**Figure 6.7: A satellite scene showing meandering Burhi Gandak river near Muzaffarpur, Bihar, showing a number of oxbow lakes and cut-offs.**

## Groundwater

- Groundwater plays a significant role in eroding landmasses and shaping landforms, especially in regions with **calcium carbonate-rich rocks like limestone and dolomite**.
- Key groundwater processes involve solution and deposition of precipitation.
- Groundwater activity forms a distinctive landform known as **Karst topography (Refer to Figure 6.8)**.

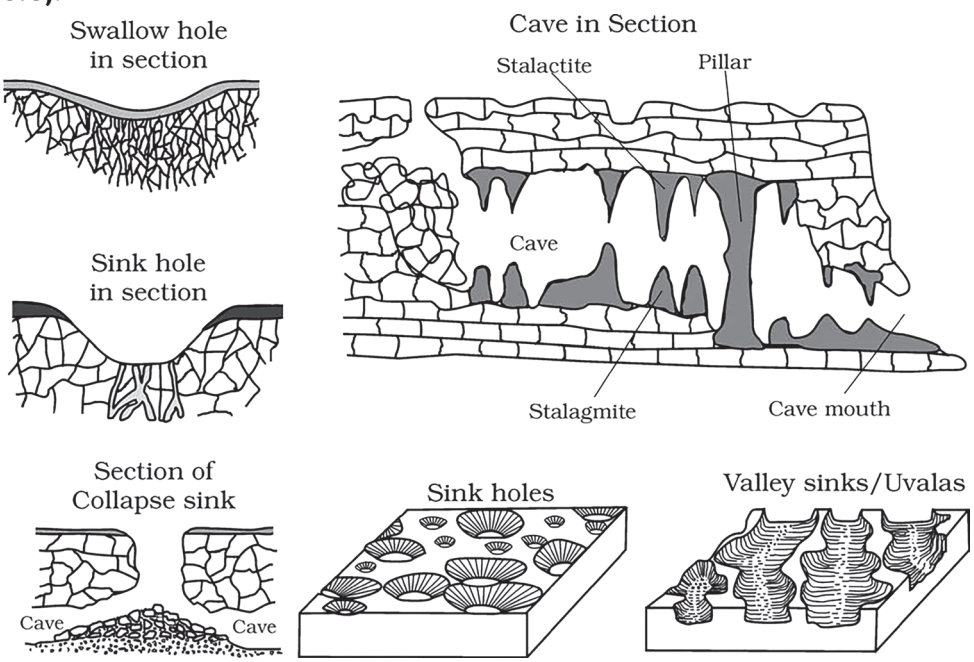



**Figure 6.8: Various Karst Topographic features.**

**Karst Topography**

- Karst topography is characterized by unique landforms resulting from groundwater action in limestone or dolomitic regions.
- Erosional landforms include sinkholes, caves, and underground rivers.
- Karst topography is named after the typical topography found in the **Karst region in the Balkans,** adjacent to the Adriatic Sea.
- It showcases both erosional and depositional landforms, making it a fascinating landscape shaped by groundwater processes.

## Erosional Landforms Formed by Groundwater

### Swallow Holes

- These are small to medium-sized, round or sub-rounded shallow depressions found on the surface of limestone terrains.
- They develop through the dissolution of limestone by water.

### Sinkholes

- These are depressions circular at top and funnel shaped at the bottom.
- These are formed in two ways:
  - **Solution Sinks**, formed solely through the solution process, where limestone dissolves over time, creating depressions.
  - **Collapse Sinks or dolines**, occurs when the roof of an underground void or cave collapses, leaving a noticeable depression or hole on the surface.

### Valley Sinks or Uvalas

- When sinkholes and dolines merge due to slumping of materials or collapse of cave roofs, they form long, narrow to wide trenches known as valley sinks or uvalas.

### Lapies

- These are irregular limestone surfaces characterized by a maze of points, grooves, and ridges.
- They develop due to differential solution activity along parallel or subparallel joints in the limestone.

### Caves

- Caves form in areas with alternating rock layers (like limestone sandwiched between other rock types) or where there are dense, massive limestone beds.
- In caves, water percolates through the rock, dissolving the limestone along bedding planes.
- Some caves even have openings at both ends, earning them the name "**tunnels**."

## Depositional Landforms Formed by Groundwater

### Calcium Carbonate Deposition

- Limestone primarily consists of calcium carbonate, which is easily soluble in carbonated water (rainwater with dissolved carbon dioxide).
- When this water trickles over rough rock surfaces and evaporates, it deposits calcium carbonate which results in different landforms.

### Stalactites

- Stalactites resemble icicles, hanging from the cave ceiling **(Refer to Figure 6.9)**.
- They vary in diameter, are broad at their base, and taper towards the free-hanging ends.

### Stalagmites

- These formations rise from the cave floor, typically originating from dripping water from the cave ceiling **(Refer to Figure 6.9).**

### Pillars:

- Stalactites and stalagmites can fuse together, creating larger formations such as columns and pillars, each with unique dimensions and shapes.

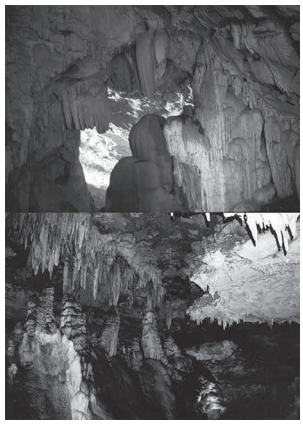


**Figure 6.9: Stalactites and stalagmites in limestone caves.**

## Glaciers

- Glaciers are masses of ice that move over the land in various forms.
- For instance, Continental glaciers cover vast plains at the foot of mountains, while piedmont glaciers spread over plains.
- Also Mountain and valley glaciers **(Refer to Figure 6.10)** flow linearly down mountain slopes in trough-like valleys.
- They move at a slow pace, typically ranging from centimetres to metres per day, driven primarily by gravity.

**Figure 6.10: A glacier in its valley.**

**Do You Know?**

- There are many glaciers in our country moving down the slopes and valleys in Himalayas and higher reaches of Uttaranchal, Himachal Pradesh and Jammu and Kashmir.
- River Bhagirathi is fed by meltwaters from under the snout (Gaumukh) of the Gangotri glacier.
- The Alkapuri glacier feeds water to the Alaknanda river.
- Rivers Alaknanda and Bhagirathi join to make river Ganga in Devprayag.

- They are powerful agents of erosion due to the immense weight of the ice.
- They pluck large angular blocks and fragments from the land, causing substantial damage through abrasion and plucking. Even un-weathered rocks can be significantly eroded by glaciers, leading to the transformation of high mountains into lower hills and plains.
- As glaciers continue to move, they remove debris, lower divides, and ultimately reduce slopes.
- This process results in the formation of low hills, vast outwash plains, and other depositional features.

## Glacial Erosional Landforms

### Cirque

- Cirques are deep, long, and wide troughs or basins typically located at the heads of glacial valleys.
- Cirques often contain lakes known as cirque or tarn lakes.

**Do You Know?**

The highest peak in the Alps, Matterhorn and the highest peak in the Himalayas, Everest are in fact horns formed through headward erosion of radiating cirques.

### Horns and Serrated Ridges

- Horns are pointed peaks formed through headward erosion of cirque walls.
- When multiple radiating glaciers cut headward until their cirques meet, sharp, pointed peaks called horns develop.
- Further, the divides between cirque side walls or head walls narrow due to progressive erosion, which forms serrated or saw-toothed ridges called arêtes.

### Glacial Valleys/Troughs

- Glaciated valleys are U-shaped valleys with broad floors and relatively smooth, steep sides. These valleys may contain debris or moraines, and sometimes, lakes.
- Hanging valleys can also be found at higher elevations on the sides of the main glacial valley.
- In high latitudes, deep glacial troughs filled with seawater create fjords or fiords.

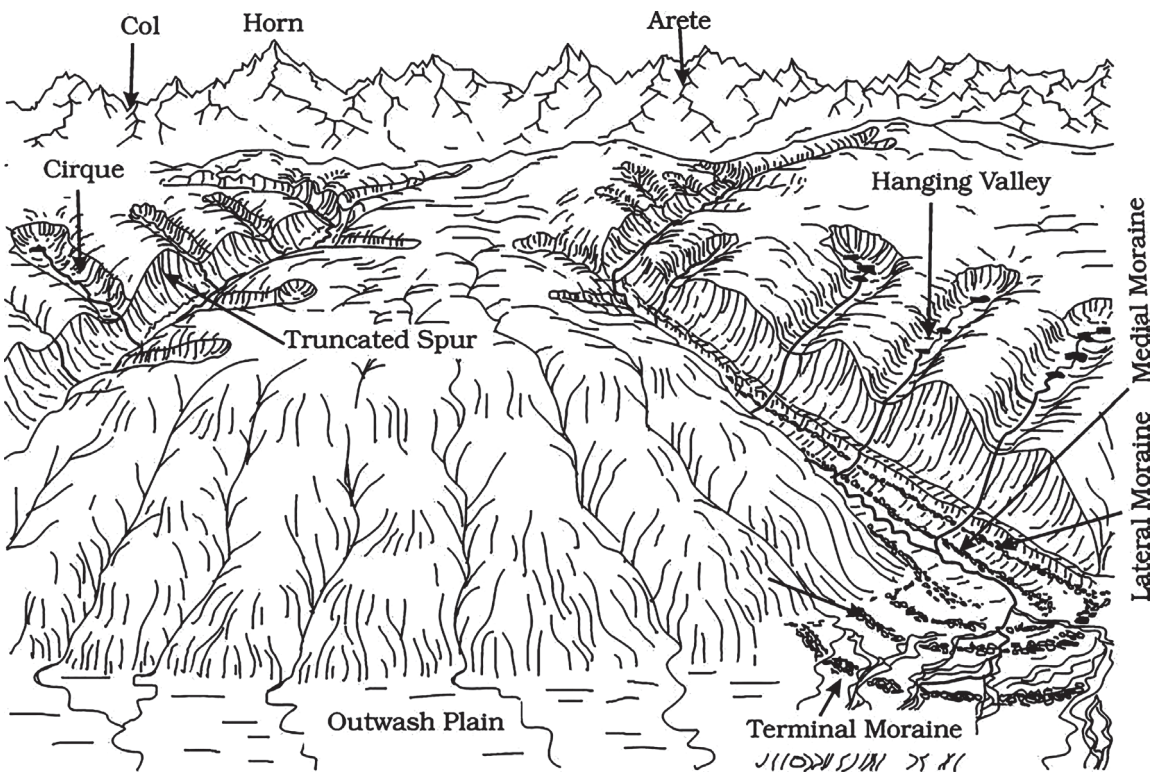



**Figure 6.11: Some glacial erosion and depositional forms.**

## Glacial Depositional Landforms

### Glacial Till

- Glacial till is unsorted coarse and fine debris left behind as glaciers melt.
- It mainly consists of angular to sub-angular rocks.

### Outwash Deposits

- These are glacio-fluvial deposits formed by meltwater streams, characterized by stratification and assortment of materials.
- Rock fragments in outwash deposits have somewhat rounded edges.

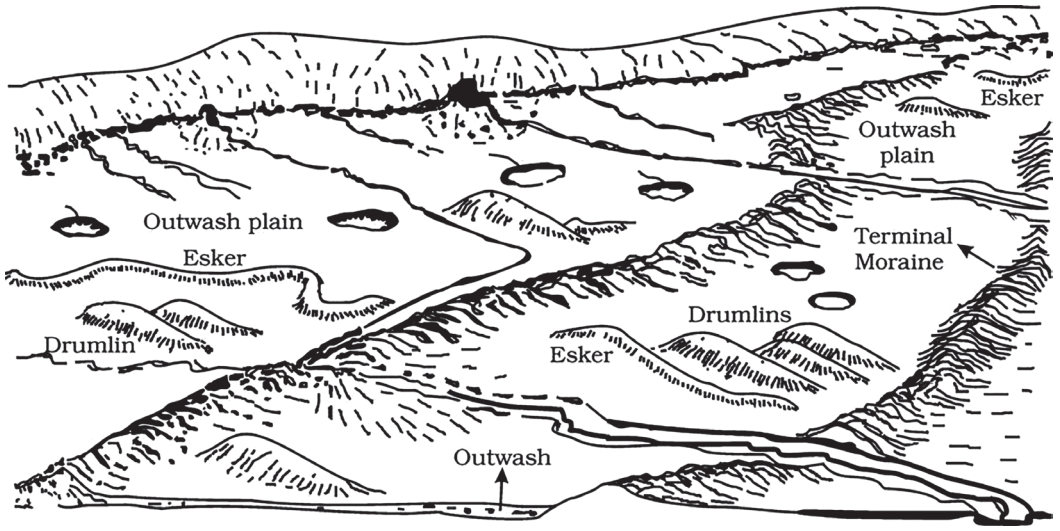



**Figure 6.12: A panoramic diagram of glacial landscape with various depositional landforms.**

### Moraines

- Moraines are long ridges of glacial till deposits.
- They are named differently **on basis of locations** they found;
  - **Terminal moraines** are found at the end (toe) of glaciers, while **lateral moraines** form along the sides parallel to glacial valleys. These moraines may join to create horse-shoe-shaped ridges.
  - Valley glaciers retreating rapidly, often leave irregular sheets of till called **ground moraines** on their valley floors.
  - **Medial moraines** are found in the center of glacial valleys, flanked by lateral moraines, although they are less well-defined and may resemble ground moraines.

### Eskers

- These are sinuous ridges formed by water flowing beneath melting glaciers.
- When glaciers melt, water gathers beneath them and carries coarse materials. As the glacier vanishes, these materials form ridges called eskers.

### Outwash Plains

- The plains at the foot of the glacial mountains are covered with glacio-fluvial deposits in the form of broad flat alluvial fans which join to form outwash plains of gravel, silt, sand and clay.

### Drumlins

- These are smooth, oval-shaped hills made of rocks and dirt. These hills have two ends. One end, called the stoss end, is flatter and steeper, while the other end is called the tail.
- Drumlins can tell us which way the glaciers were moving because they point in the same direction as the ice flow.

## Waves and Currents

- Waves play a central role in shaping coastlines, causing erosion and deposition.
- Waves break with force on coastlines, leading to shoreline changes. Further, storm and tsunami waves can have significant impacts.

- Along with action of caves, coastal landforms also depend on land and seafloor configuration and nature of the coast i.e. whether the coast is **advancing (emerging) or retreating (submerging)**.
- **Two types of coasts** are mainly seen:
  - **High Rocky Coasts** where erosional features dominate and;
  - **Low Sedimentary Coasts** where mainly deposition can be seen.

### High Rocky Coasts

- In this, the rivers appear to have been drowned with highly irregular coastline.
- Waves break forcefully against rocky coasts, forming cliffs. Constant wave impact causes cliffs to recede, creating wave-cut platforms where eroded material is deposited.
- Over time, wave-built terraces develop in front of wave-cut terraces. Eroded materials supply longshore currents, forming beaches and submerged bars.
- Barrier bars and spits can block bays, forming lagoons that may fill over time, creating coastal plains.

### Low Sedimentary Coasts

- At these coasts, rivers extend their length by building coastal plains and deltas.
- These coasts have a smooth appearance with lagoons and tidal creeks. The land gently slopes into the water, and marshes and swamps may be present.
- Waves breaking over such coasts churn and move bottom sediments.This process builds bars, barrier bars, spits, and lagoons.
- Lagoons can transition into swamps and eventually coastal plains.
- Large rivers that carry sediments contribute to the formation of deltas along these coasts.

## Coastal Erosional Landforms

- **Wave cut cliffs:** They are steep and tall rock formations along the shore, reaching heights of up to 30 meters.
- **Wave cut terraces:** Flat platforms made of rock debris at the base of cliffs, elevated above the average wave height.Wave-cut cliffs and terraces are major landforms where erosion is the dominant process.
- **Caves:** Hollows formed by the impact of waves and rock debris against cliffs. Roofs of these caves collapse giving way for stacks.
- **Sea Stacks:** Resilient rock masses, originally part of cliffs or hills, standing alone just off the shore. They are temporary and will eventually erode into narrow coastal plains.

## Coastal Depositional Landforms

### Beaches

- These are shoreline areas primarily formed by deposition. Sediments on beaches are often sourced from land carried by rivers or waves.
- Beaches are not permanent and can change in size and composition seasonally.
- Most beaches consist of sand-sized materials, while others may have smaller pebbles and cobbles, known as **shingle beaches**.

**Figure 6.13: A satellite picture of a part of Godavari river delta showing a spit**

### Dunes

- Sand lifted and sorted from the beach surface is deposited just behind the beach, forming sand dunes.
- These dunes are commonly found along low sedimentary coasts and appear as long ridges parallel to the coastline.

### Off-shore Bar

- It is a ridge of sand and shingle that forms in the sea in the off-shore zone, typically running parallel to the coast.

### Barrier Bar

- It is an off-shore bar that becomes exposed due to the accumulation of sand.

### Spit

- It is a type of barrier bar that may extend from the mainland to an island, headland, or across the entrance of a bay.
- These features often develop at the mouth of a river or bay. Over time, they can extend and restrict the opening of a bay into the sea, eventually leading to the formation of a lagoon. Lagoons gradually fill up with sediment from the land and the beach, creating a wide coastal plain.

**Do You Know?**

The **coastal off-shore bars** offer the first buffer or defense against storm or tsunami by absorbing most of their destructive force. Then come the **barriers, beaches, beach dunes and mangroves,** if any, to absorb the destructive force of storm and tsunami waves. So, if anything is done which disturbs the 'sediment budget' and the mangroves along the coast, these coastal forms will erode away leaving human habitations to bear the first strike of storm and tsunami waves.

## Winds

- Wind is a major force in hot deserts. Desert surfaces heat up quickly due to their arid nature, causing the air above them to rise, creating turbulence and various wind patterns.
- These winds can move rapidly across the desert floor, leading to turbulence when they encounter obstacles.
- Storm winds, which are occasionally present, can be highly destructive.
- Winds contribute to erosion through deflation, abrasion, and impact.
  - **Deflation** involves lifting and removing dust and small particles from rock surfaces. During transportation, sand and silt act as effective tools, **abrading** the land.
  - **Impact**, on the other hand, is the sheer force generated when sand collides with rock surfaces, similar to a sand-blasting operation.
- Desert landscapes are also shaped by occasional torrential rain, despite the region's low overall precipitation. These heavy rains cause mass wasting and sheet flooding.
- Desert rocks, exposed to extreme diurnal temperature fluctuations, weather quickly, and torrential rain helps wash away weathered material.
- Thus, wind-driven erosion and deposition create distinctive features in deserts.

## Desert Erosional Landforms

### Pediments and Pediplains

- Desert landscape evolution primarily revolves around the creation and expansion of pediments.
- **Pediments** are gently inclined rocky surfaces found near the bases of mountains, sometimes covered with a thin layer of debris. They get formed through a combination of lateral erosion by streams and sheet flooding.

- Erosion occurs along the steep margins of landmasses or steep sides of tectonically controlled incision features. Pediments consist of a steep wash slope and a cliff or free face above it.
- Erosion of these features involves a process called **parallel retreat of slopes,** where the wash slope and free face gradually move backwards.
- This process leads to the extension of pediments at the expense of mountain fronts. Over time, the mountains reduce in size, leaving behind **inselbergs** as remnants. Ultimately, the high-relief desert areas transform into low, featureless plains known as **pediplains**.

**POINTS TO PONDER**

The earth's landforms are a result of several processes. The processes that operate today seem to have existed before too. The intensity of these processes, however, appear to vary across the geological time scale. Can you envisage the change in intensity of these processes and the factors that must have affected the intensity of these processes ?

### Playas

- Playas are shallow lakes formed at the center of basins surrounded by mountains and hills.
- Playas have short-lived water retention due to high evaporation rates and often contain salt deposits. Playa plains covered with salts are called **alkali flats**.

### Deflation Hollows and Caves

- Deflation Hollows are shallow depressions created by wind-blown sand and persistent wind currents.
- Wind-driven sand impacts and abrades rock surfaces, forming blowouts that may develop into caves.

### Mushroom, Table, and Pedestal Rocks

- Resistant rock remnants polished by wind erosion take on various shapes such as,
  - Mushroom rocks which have a slender stalk and a rounded, pear-shaped cap.
  - Table rocks have broad, flat tops.
  - Pedestal rocks stand tall like pillars.

## Desert Depositional Landforms

- Wind, while performing depositional activities, acts as a sorting agent, transporting grains of different sizes based on wind velocity.
- Grains settle out of suspension when wind slows down, leading to good grain sorting.
- Wind-driven deposition can occur in arid regions with constant wind and a sand source.

### Sand Dunes

- Dry, hot deserts are ideal for sand dune formation. Dune formation requires both sand availability and obstacles.

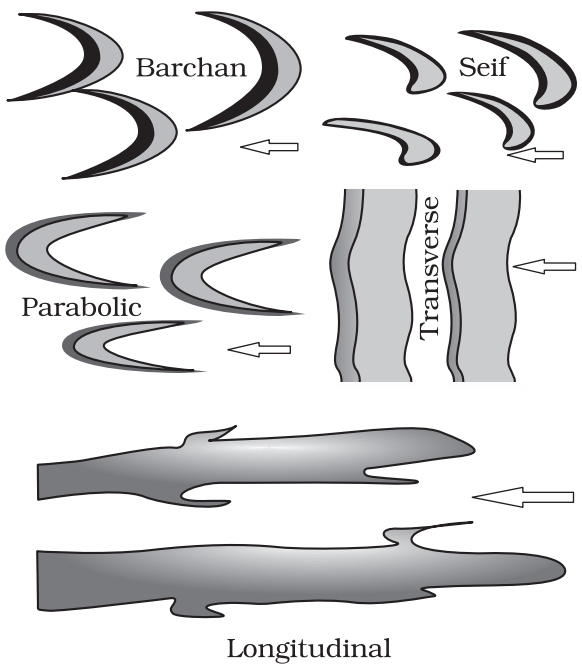



**Figure 6.14: Various types of sand dunes. Arrows indicate wind direction.**

- **Various dune forms include**
  - **Barchans:** These are crescent shaped dunes with wings directed away from wind direction.
  - **Parabolic dune:** It is formed when the sandy surface is covered with vegetation.

- ✧ **Seif:** It is similar to barchans but having only one wing due to shift in wind conditions.
- ✧ **Longitudinal dunes:** They appear as long ridges but are low in height.
- ✧ **Transverse dunes:** It is aligned perpendicular to wind direction.

✤ Dunes may coalesce when sand is abundant, and some dunes stabilize over time, especially near human settlements.

## Conclusion

All these processes of erosion and deposition over mountains, plains, valleys, deserts and coasts, whether gradual or rapid, remind us that our planet is in a state of continuous change. By studying these natural forces and the landforms they create, we gain a deeper insight into the dynamic nature of Earth and the complex processes that shape our Earth.

***Glossary:***

- ➢ **Diurnal temperature:** The diurnal temperature range (DTR) reflects the temperature variation within a day and is defined as the difference between daily maximum and minimum temperatures.
- ➢ **Oxbow lake:** Oxbow lakes are the remains of the bend in the river. Oxbow lakes are stillwater lakes. Oxbow lakes often become swamps or bogs, and they often dry up as their water evaporates.
- ➢ **Sand-blasting:** When wind loaded with sand grains erodes the rock by grinding against its walls is called abrasion or sandblasting.

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# 7 Composition and Structure of Atmosphere

**Bibliography:** This chapter encompasses the summary of Chapter 5 of Class VI NCERT (The Earth, Our Habitat), Chapter 4 of Class VII NCERT (Our Environment), and Chapter 8 of Class XI NCERT (Fundamentals of Physical Geography).

## Introduction

The earth is the only planet which has **life**. The surface of the earth is a complex zone which has **three main components** of the environment viz. **Lithosphere, Hydrosphere and Atmosphere**. These three meet, overlap and interact and form a narrow zone called a **Biosphere** which sustains life (Refer to Figure 7.1). Along with land and water, air is a main part of this biosphere which plays a major role in regulating atmospheric activities. In this chapter, we will deal primarily with this atmosphere and its major components.

**Word Origin**

- In the Greek language,
- Lithos means Stone (Lithosphere);
- Atmos means Vapour (Atmosphere);
- Hudor means Water (Hydrosphere); and Bios means Life (Biosphere).

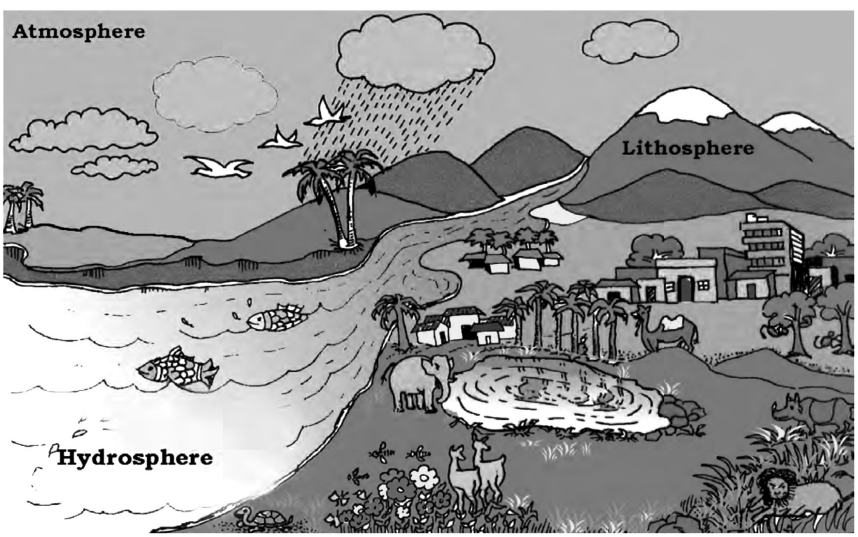



**Figure 7.1: Biosphere**

## Atmosphere

- The Earth's atmosphere is a gaseous layer surrounding the earth, which comprises a mixture of **gases, water vapour, and dust particles**.
- Notably, **99%** of the atmosphere's total mass is concentrated within a range of **32 kilometres** from the Earth's surface.

## Composition of the Atmosphere

- The atmosphere consists mainly of **Nitrogen**(78%) and **Oxygen** (21%) and other gases (Refer to Figure 7.2).
- **Nitrogen** is essential for plant growth and **Oxygen** is indispensable for humans and animals for survival. At an altitude of 120 kilometres, oxygen becomes almost negligible.
- **Carbon dioxide**, another critical gas, **regulates** Earth's temperature and is transparent to incoming solar radiation but **acts as a greenhouse gas**, contributing to the greenhouse effect. Carbon dioxide and water vapour are found only up to 90 km from the surface of the earth. In recent decades, carbon dioxide levels have been on the rise, mainly due to the burning of fossil fuels.

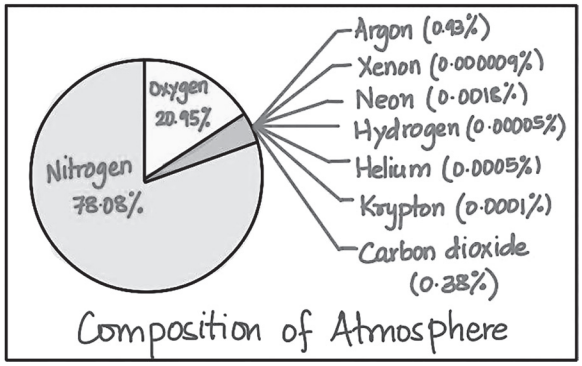



**Figure 7.2: Composition of Atmosphere**

- **Ozone**, located between 10 and 50 kilometres (stratosphere) above the Earth's surface, plays a crucial role in absorbing harmful **ultraviolet rays** from the sun. Hence, this ozone layer acts as a protective shield, safeguarding life on Earth.
- The atmosphere also contains **dust particles**, including sea salts, fine soil, smoke-soot, ash, pollen, and dust from disintegrated meteors. Dust particles are more concentrated in **subtropical** and **temperate** regions due to dry winds. They also act as hygroscopic nuclei for water vapour, producing clouds after condensation.

### Additional Information

Increased $CO_2$ levels, from sources like factory emissions and car fumes, cause global warming by intensifying heat retention. This leads to the melting of polar ice, rising sea levels and causing coastal floods. Such drastic climate changes can lead to the extinction of certain plant and animal species over time.

## Layers of Atmosphere

The Earth's atmosphere is divided into five distinct layers, each with its own characteristics (Refer to Figure 7.3).

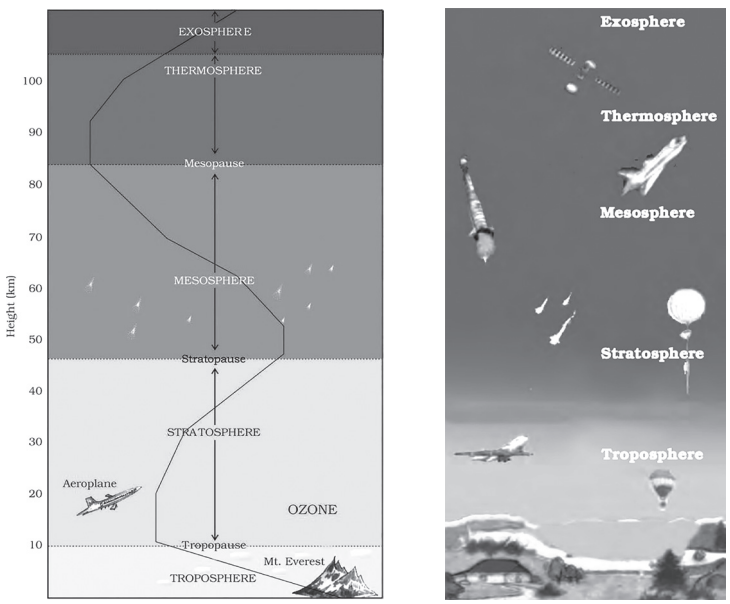



**Figure 7.3: Layers of Atmosphere**

**1. Troposphere**

- It is the **lowest layer** with an average height of 13 kilometres.
- It extends up to approximately 8 kilometres near the poles and about 18 kilometres at the equator.
- All weather and climate related changes and biological activities occur in this layer.
- In the Troposphere, temperature decreases at a rate of 1°C for every 165 metres of height.

**2. Stratosphere**

- It is located above the **tropopause** (-80 °C at Equator, -45°C at Poles) and extends to a height of 50 kilometres.
- It contains the **ozone layer**, which absorbs harmful ultraviolet radiation from the sun, protecting life on Earth.

**3. Mesosphere**

- It extends up to 80 kilometres, and is characterised by decreasing temperatures with altitude, reaching as low as minus 100°C at its upper boundary, known as the **mesopause**.

**POINTS TO PONDER**

In the troposphere moving upward we see a decrease in temperature while when we move upwards in the stratosphere, the temperature increases. Why is such variation in temperature witnessed and what impact does it have on atmospheric pattern? Can you think of any impact of this variation in temperature on the movement of aeroplanes?

**4. Ionosphere:**

- This region spans from 80 to 400 kilometres above the Here, temperaturerises very rapidly with
- increasing height.
- It contains electrically charged particles called **ions** this layer reflects radio waves back to Earth.

**5. Exosphere:**

- It is the **uppermost layer** of the atmosphere, where the atmosphere gradually merges with outer space.
- This layer contains extremely rarefied contents like Helium, Hydrogen, etc.

## Other Key Concepts Related to Atmosphere

**Variation of Air Density, Temperature, and Pressure in the Atmosphere:**

- **With Height**
  - **Air Density:** Decreases with altitude, affecting oxygen availability and aviation.
  - **Temperature:** Decreases in troposphere, increases in stratosphere, influencing weather patterns.
  - **Pressure:** Decreases with altitude, driving atmospheric circulation.
- **With Latitude**
  - **Air Density:** Higher near equator due to warmth, affecting climate zones.
  - **Temperature:** Warmer at lower latitudes, varying at higher latitudes, impacting global climate.
  - **Pressure:** Lower near equator, higher towards poles, influencing winds and ocean currents.

**Weather and Climate**

- **Weather** is the **day-to-day condition** of the atmosphere, affecting our daily lives and activities.
- It can change dramatically and includes factors like temperature, air pressure, wind, and humidity (Refer to Figure 7.4).

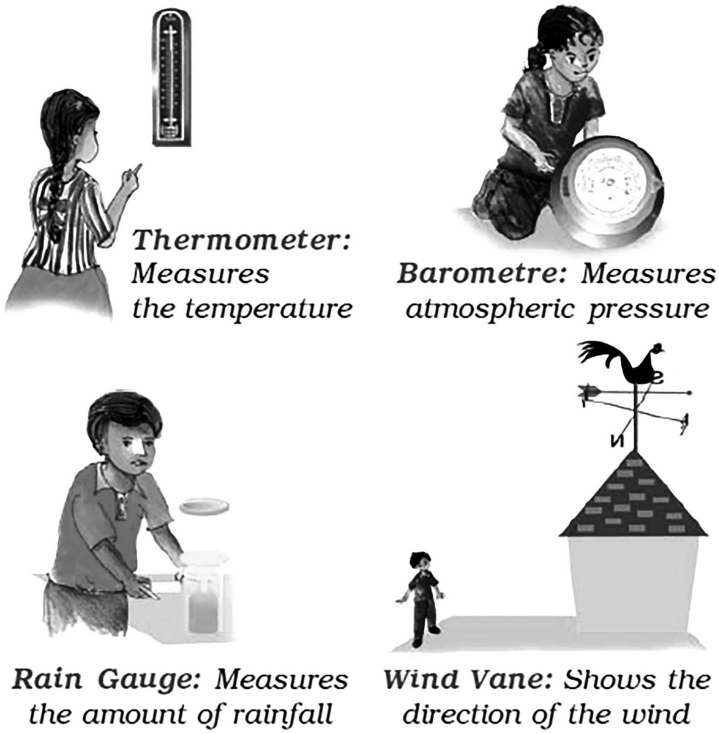



**Figure 7.4: Weather Instruments**

- **Climate**, on the other hand, represents the **long-term average** weather patterns of a place.
- Studies related to weather and climate help us plan and adapt to changing conditions.

### Temperature

- Temperature indicates the degree of hotness or coldness in the air.
- It varies between **day and night** and **from season to season**, with summers being hotter than winters.
- **Insolation**, the incoming solar energy, affects temperature distribution, decreasing from the equator to the poles.

**Do You Know?**

The standard unit of measuring temperature is degree Celsius. It was invented by Anders Celsius. On the Celsius scale, the water freezes at 0°C and boils at 100°C.

### Air Pressure

- Air exerts a **force** on our bodies, but we do not feel it because it presses from all directions, countered by our bodies.
- This air pressure is defined as the **weight of air on Earth's surface**, with the highest at sea level and decreasing with height.
- Temperature influences **horizontal air pressure distribution** - warm air rises, creating low-pressure areas with cloudy skies, while cold air sinks, creating **high-pressure areas with clear skies**.

**Do You Know?**

When air is heated, it expands, becomes lighter and goes up. Cold air is denser and heavy. That is why it tends to sink down. When hot air rises, cold air from the surrounding area rushes there to fill in the gap. That is how air circulation takes place.

## Wind

- **Wind is air in motion**. It can be observed in various forms, from gentle breezes to strong gusts, capable of causing problems like uprooting trees or making it difficult to hold umbrellas.

> Wind is named after the **direction from which it blows**, e.g. the wind blowing from the west is called **westerly**.

- Winds are **categorised into three types**:
  - **Permanent winds** - They blow constantly throughout the year in a particular direction. **The trade winds, westerlies, and easterlies** are permanent winds (Refer to Figure 7.5).

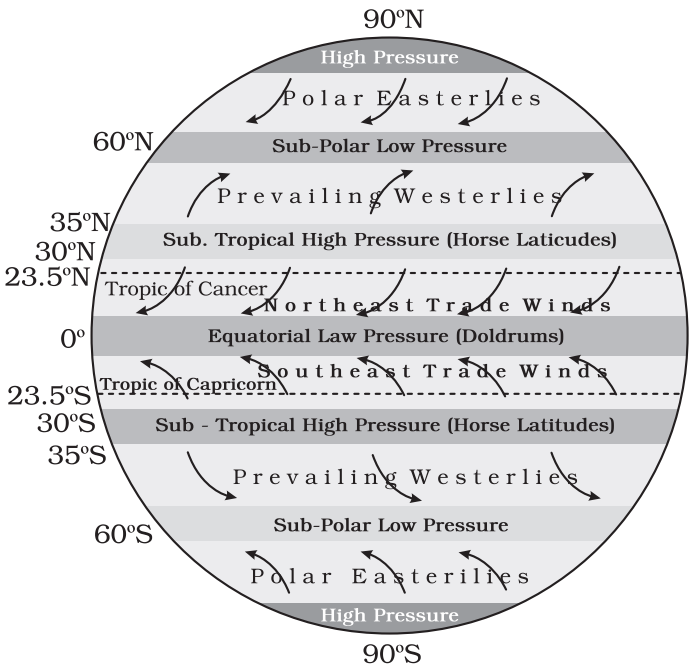



**Figure 7.5: Major Pressure Belts and Figure Wind System**

  - **Seasonal winds** - They change their direction in different seasons (e.g., **monsoons**).
  - **Local winds** - These blow only during a particular period of day or year in a small area (e.g., **land and sea breezes, loo,** hot and dry wind of northern plains of India).

- Intensified movements of wind over oceans leads to development of violent storms called **Cyclones**, which causes large-scale destruction in coastal areas.

> **POINTS TO PONDER**
>
> Can you think of reasons, how trade winds got their name? Do you know most of the deserts are found in trade wind belts? Ponder over this inter relationship between trade wind and deserts?

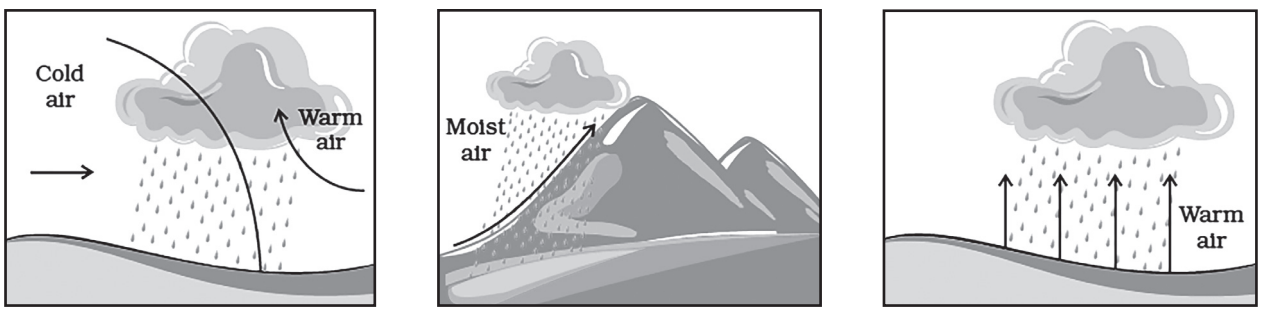
> **Cyclone - Nature's Fury!**
>
> Odisha, located on India's eastern seacoast, is prone to cyclones originating in the Bay of Bengal. In October 1999, a cyclone hit five districts of Odisha, followed by a **super cyclone** on October 29, 1999. The damages were primarily caused by three factors viz. high wind velocity (up to 260 km/h for over 36 hours), heavy rain lasting for three days, and a tidal surge. The cyclonic winds caused heavy damage in Odisha. The cyclone originated as a **depression** in the Gulf of Thailand and intensified into a supercyclone, hitting Odisha on October 29, 1999. The super cyclone affected the entire Odisha coast, including cities like Bhubaneswar and Cuttack, impacting around 13 million people.

### Moisture

- Moisture refers to **water vapour in the air**, and humidity is the measure of its presence.
- **Water vapour** is a variable gas in the atmosphere, with higher concentrations in warm and wet tropical regions, where it can account for approximately four percent of the air by volume. In contrast, in dry and cold regions like deserts and polar areas, water vapour may be less than one percent of the air. Hence, water vapour concentration decreases from the equator to the poles (latitudinal variation). Also, water vapour decreases with altitude (altitudinal variation).
- Water vapour plays a significant role in temperature regulation by absorbing insolation thereby acting as like a blanket as well as a natural thermostat making the Earth neither too hot nor too cold and hence contributes to air stability. and contributes to air stability.
- Warm air can hold more moisture, resulting in higher humidity. High humidity levels make clothes dry slowly and cause discomfort due to reduced sweat evaporation.
- Rising water vapour cools and condenses into water droplets, forming clouds which causes rainfall.

### Precipitation

- Precipitation, such as rain, occurs when droplets become too heavy to remain in the air.
- Rainfall (precipitation in liquid form), is crucial for plant and animal survival, providing fresh water to the Earth's surface.
- Inadequate rainfall leads to water scarcity and drought, while excessive rainfall can cause floods.
- Apart from rain, other forms of precipitation are **snow, sleet, and hail**.




Cyclonic Rainfall | Relief Orographic Rainfall | Convectional Rainfall

**Figure 7.6: Types of Rainfall**

## Impacts of Human activities on Atmosphere

- Human activities like **deforestation and industrial emissions** impact the lithosphere, hydrosphere as well as atmosphere.
- Human actions can lead to **environmental problems** such as pollution, loss of biodiversity, and climate change.
- **Rise in concentration of greenhouse gases** like carbon dioxide contribute to global warming by trapping heat in the atmosphere.
- **Global warming** can lead to climate change, affecting weather patterns and ecosystems.

**POINTS TO PONDER**

Did you observe while travelling from city to countryside stark differences in temperature especially in the evening? Can you think of the causes of such differences in temperature? Do you think it has some relationship with our lifestyle and the way in which we plan our cities? Do you think that planting more trees can be a way to minimise this difference?

Hence, there is a need to **maintain Earth's balance** by responsible resource management and conservation efforts.

**Protecting Earth's domains** will ensure the continued health and stability of the planet.

## Conclusion

Earth's harmony depends on the **balance of its land**, **water, and air**. Humans need to take care of our planet by making responsible choices to ensure a healthy and stable environment for us and future generations. The Earth's **atmosphere** is a **complex** and **vital** part of our planet, supporting life and influencing weather and climate. Understanding the atmosphere's layers, composition, and interactions is crucial for environmental preservation and climate management.

***Glossary:***

- **Space Exploration:** The study and exploration of outer space, including the atmosphere's role in space travel.
- **Supercyclone:** An extremely intense tropical cyclone with high wind velocities and heavy rain.
- **Wind Patterns:** The movement of air driven by temperature differences in the atmosphere.

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# 8 Solar Radiation, Heat Balance and Temperature

**Bibliography:** This chapter encompasses the summary of chapter 8 of class XI NCERT (Fundamentals Of Physical Geography).

## Introduction

The Earth receives almost all of its energy from the sun. The earth in turn radiates back to space the energy received from the sun. As a result, the earth neither warms up nor does it get cooled over a period of time. Thus, the amount of heat received by different parts of the earth is not the same. This variation causes pressure differences in the atmosphere. This leads to the transfer of heat from one region to the other by winds.

## Solar Radiation

- The earth's surface primarily receives energy in **short wavelengths**, which is termed as "**incoming solar radiation**" or "**insolation**".
- The Earth resembles a **geoid shape** (oblate spheroid or simply sphere-like shape). The sun's rays fall slantwise at the top of the atmosphere. Out of this, the Earth intercepts a small portion of the sun's energy.
- On average, the earth receives **1.94 calories per sq. cm per minute** at the top of the atmosphere.

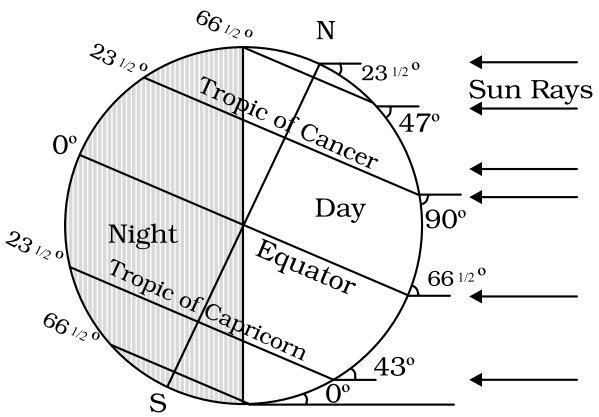



**Figure 8.1: The Passage of Solar Radiation through the Atmosphere**

### Distribution of Solar Radiation

- The changing distance **between the Earth and the Sun** varies the solar output throughout the year.
- The annual insolation on 3rd January is slightly more than on 4th July is due to perihelion.

**Do You Know?**

- Earth is farthest (152 million km) from the sun on **4th July (Aphelion)**
- Earth is closest (147 million km) to the sun on **3rd January (Perihelion).**

- The Earth's axis is angled at **66½°** with its orbital plane. This angle significantly influences insolation received at different latitudes.
- The amount of insolation is also determined by the angle of the sun's rays which depends on the latitude of a place. The higher the latitude the less is the angle they make with the surface of the earth resulting in slant sun rays which cover more area and energy get distributed and the net energy received per unit area decreases.

**Factors Influencing Insolation Variability**

- Rotation of the earth on its axis.
- Angle of inclination of the sun's rays.
- Length of the day.
- Transparency of the atmosphere.
- Configuration of land.

- Moreover, slant rays pass through a greater depth of the atmosphere, leading to more absorption, scattering, and diffusion.

### Atmospheric Influence on Insolation

- The atmosphere is mostly **transparent to short-wave solar** radiation. As solar radiation passes through the atmosphere, gases like **water vapour and ozone** absorb much of the near-infrared radiation.
- Small particles in the troposphere scatter the visible spectrum of the light. This scattering results in the blue colour of the sky and the red colour of the rising and setting sun.

### Spatial Distribution of Insolation on Earth's Surface

- Subtropical deserts receive the highest insolation due to minimal cloudiness.
- The equator receives less insolation compared to the tropics.
- At the same latitude, continents generally receive more insolation than oceans.
- During winter, middle and higher latitudes receive less radiation compared to summer.

## Heating and Cooling of Atmosphere

There are different ways of heating and cooling of the atmosphere. These are the following:

### Conduction

- The air in contact with the land gets heated slowly and the upper layers in contact with the lower layers also get heated due to the transfer of heat from the warmer to the cooler body. This process is called **conduction**.
- This process continues until both bodies reach the same temperature or contact is broken. The **conduction primarily heats the atmosphere's lower layers**.

### Convection

- Air in contact with the earth **rises vertically when heated**, forming currents that transmit atmospheric heat. This **vertical heating** process is termed as **convection**.
- The convection-based energy transfer is limited to the **troposphere**.

### Advection

- The transfer of heat through **horizontal movement** of air is called advection. Horizontal air movement is more important than vertical movement.
- **In middle latitudes,** daily weather variations (diurnal) are mainly due to advection. In tropical regions, especially in northern India during the summer, local winds like 'loo' result from the advection process.

### Terrestrial Radiation

- The earth absorbs insolation in **short waveforms,** warming its surface.
- Once heated, the earth becomes a radiator, emitting energy back to the atmosphere in long waveforms. This emitted energy is termed "**terrestrial radiation**".

### Earth's Role as a Radiator

- The atmosphere absorbs **long-wave radiation,** especially from gases like carbon dioxide and other greenhouse gases.
- This means the atmosphere gets its warmth **indirectly** from the earth's radiation rather than directly from the sun.
- After absorbing this energy, the atmosphere then radiates heat back into space.
- This ensures a balance, where the heat the earth receives from the sun is eventually returned to space, maintaining a constant temperature both on the earth's surface and in the atmosphere.

## Heat Budget of the Planet Earth

The earth maintains a constant temperature by ensuring the **heat it receives (insolation) equals the heat it emits (terrestrial radiation)**. Thus, earth as a whole neither accumulates nor loses heat, hence it maintains its temperature.

### Absorption Pattern

- **Total Input:** The earth receives 100% insolation. As insolation travels through the atmosphere, it undergoes reflection, scattering, and the remaining part of insolation finally reaches the Earth's surface.
- **Earth's Albedo:** Roughly about 35 units of the insolation are reflected into space before reaching the Earth's surface. Of these, 27 units are reflected back from the top of the clouds and 2 units from the snow and ice-covered areas of the earth.The reflected amount of radiation is called the **albedo of the earth**.

### Terrestrial Radiation Pattern

- The remaining 65 units are absorbed, 14 units within the atmosphere and 51 units by the earth’s surface.
- The earth radiates back 51 units in the form of terrestrial radiation.
- Of these, 17 units are radiated to space directly and the remaining 34 units are absorbed by the atmosphere (6 units absorbed directly by the atmosphere, 9 units through convection and turbulence and 19 units through latent heat of condensation).
- From the Atmosphere 48 units (14 from insolation + 34 from terrestrial radiation) are radiated back into space.
- Thus, the total radiation returning from the earth and the atmosphere respectively is 17+48=65 units which balance the total of 65 units received from the sun. This is termed **the heat budget or heat balance of the earth**.

This equilibrium in heat intake and release ensures the earth's temperature remains stable, preventing it from either warming up or cooling down excessively despite the vast heat transfers occurring. This is shown in the following figures:

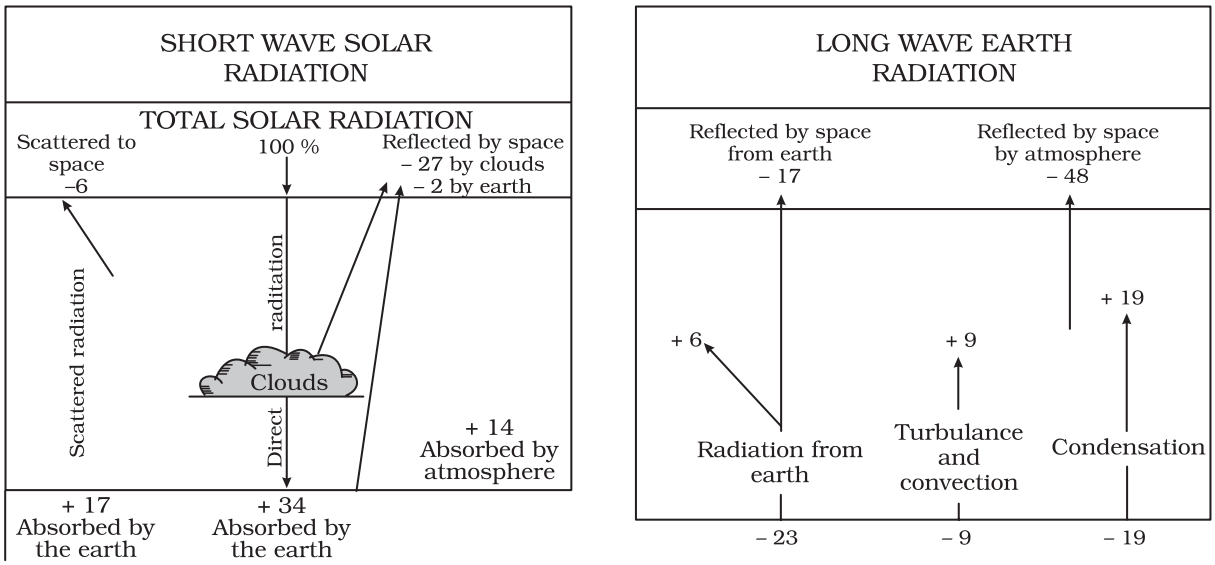



**Figure 8.2: Heat budget of the Earth**

## Variation in the Net Heat Budget at the Earth's Surface

- The Earth's surface experiences diverse radiation levels, leading to areas with either a surplus or a deficit in their radiation balance. This is primarily influenced by the **latitude of the region**.
- **Latitudinal Radiation Distribution:** As shown in Figure 8.3, there's a distinct pattern in the net radiation balance across the Earth and its atmospheric system. Specifically:
  - Between 40 degrees north and south, there is a notable **surplus** in radiation balance.
  - In contrast, regions closer to the poles face a radiation **deficit**.

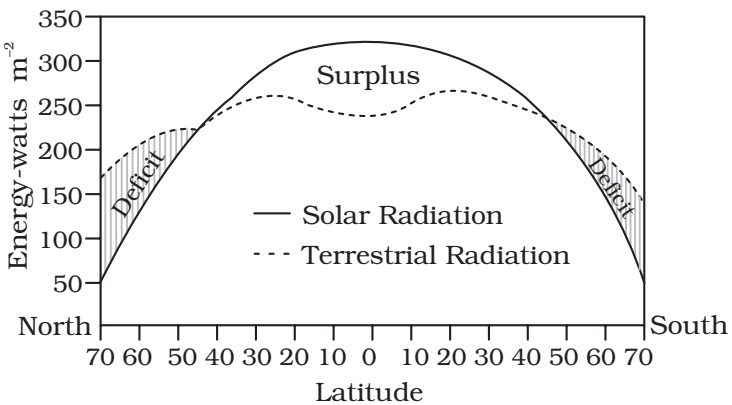



**Figure 8.3: Latitudinal variation in net radiation balance**

- **Natural Heat Redistribution:** This imbalance does not lead to extreme temperature variations, thanks to Earth's natural heat redistribution mechanism. The excess heat from the tropics is systematically moved towards the poles. This ensures:

**POINTS TO PONDER**

The solar system has the sun as its major heat reservoir. The heat budget of the earth thus takes into consideration the solar insolation as its only factor. With primordial heat stored in the earth and the geothermal energy in the picture, can you find out the reason why this heat is not taken into account while estimating the heat budget? Has the effect of this heat source increased or decreased in the context of the geological time scale?

- ✧ The tropics avoid excessive heating from accumulated heat.
- ✧ The colder regions near the poles don't become permanently frozen due to a consistent lack of heat.

## Temperature

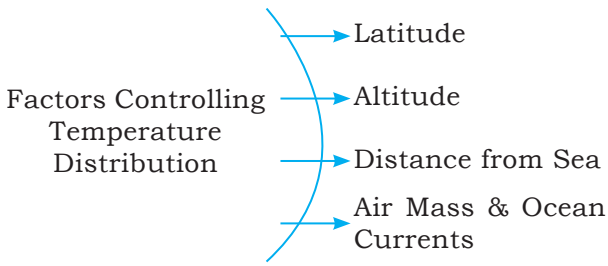
Temperature and heat are closely related but distinct concepts resulting from the interaction of insolation with our atmosphere and the Earth's surface. Specifically:

- ✤ **Heat:** It signifies the energy stemming from the molecular movement of particles within a substance.
- ✤ **Temperature:** This is a measure, expressed in degrees, indicating how hot or cold an object or location is.

In simpler terms, while heat delves into the energy and motion of particles, temperature provides a tangible measure of an object's warmth or coldness.

### Factors Controlling Temperature Distribution

The temperature at any location is not just a random number; it is influenced by a combination of **geographical and atmospheric elements**. Here's a breakdown of factors influencing temperature distribution:




- ✤ **The Latitude:** The amount of insolation a place receives is largely determined by its latitude. Simply put, different latitudes receive varying amounts of sunlight, which directly impacts their temperatures.
- ✤ **The Altitude:** Places closer to sea level tend to be warmer. This is because the atmosphere gets its warmth from the Earth's surface. As we climb higher, the temperature generally drops. For every 1,000 meters of ascend, a drop of about 6.5°C temperature occurs, this phenomenon is known as the normal lapse rate.
- ✤ **Distance from the Sea:** Land heats and cools faster than water. Thus, areas near the sea experience milder temperature fluctuations due to the sea's moderating influence and the regular land and sea breezes.
- ✤ **Air mass and Ocean currents:** The type of air mass passing over a place can raise or lower its temperature. Warm air masses boost temperatures, while cold ones do the opposite. Similarly, coastal areas with warm ocean currents will be warmer than those with cold currents.

### Global Temperature Distribution

Temperature distribution across the globe is not uniform. It is a dynamic pattern influenced by various factors, and it changes with seasons.

- ✤ **Isotherms:** Isotherms are lines that connect places with the same temperature. They give us a visual representation of temperature distribution. Maps often use isotherms to depict temperature variations, especially for specific months like January and July.
- ✤ **Latitude's Influence:** Generally, isotherms tend to run parallel to latitudes. This means places at the same latitude often have similar temperatures. However, there are variations, as visible, especially in January in the northern hemisphere due to the larger land area s compared to Southern Hemisphere.
- ✤ **Land vs. Ocean Dynamics:** The vast landmass in the northern hemisphere causes significant temperature deviations. For instance, warm ocean currents like the Gulf Stream push isotherms northward in the North Atlantic Ocean. But over continents, temperatures drop sharply, causing isotherms to bend southward, as seen in Europe and the Siberian plane.

✤ **Temperature Range:** In **January (Refer to Figure 8.4)**, equatorial oceans are warm, with temperatures over 27°C. The tropics over around 24°C, middle latitudes between 2°C and 0°C, and the chilly Eurasian interior plunges to between –18°C and –48°C. The southern hemisphere, with its oceanic dominance, sees more gradual temperature changes. The isotherm of 20° C, 10° C, and 0° C runs parallel to 35° S, 45° S and 60° S latitudes respectively. By July **(Refer to Figure 8.5)**, isotherms in both hemispheres run more parallel to latitudes, with subtropical regions in Asia even crossing The equatorial oceans record warmer temperature, more than 27°C and along the 40° N, runs the isotherm of 10° C and along the 40° S, the temperature is 10° C.

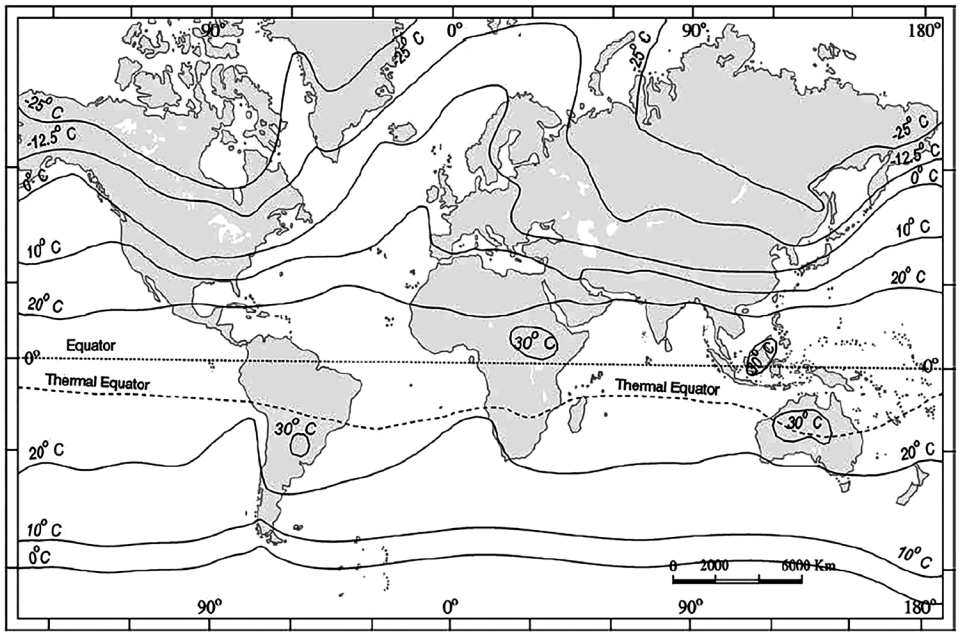



**Figure 8.4: The distribution of Surface Air Temperature in the Month of January**

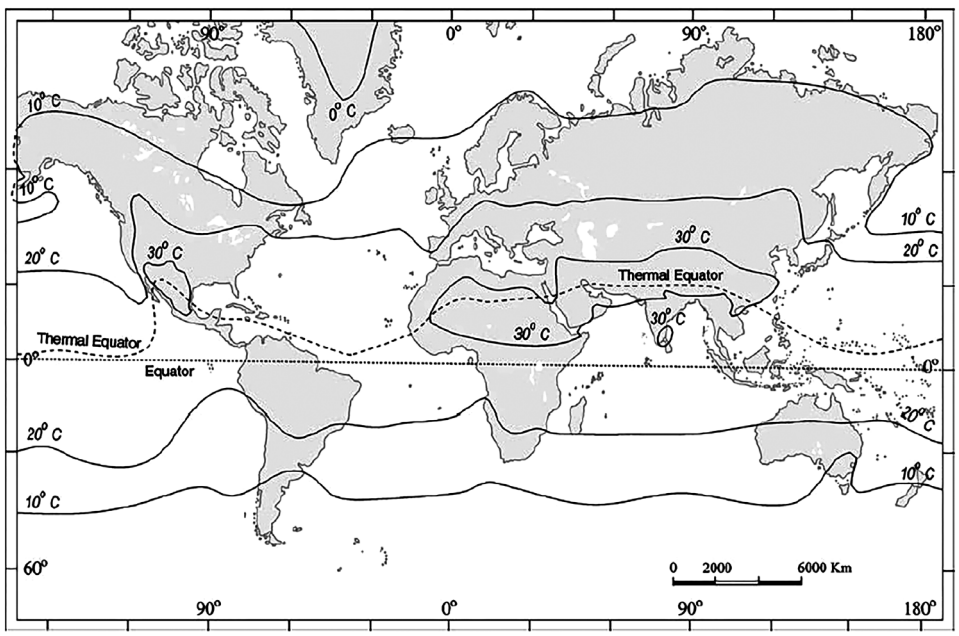



**Figure 8.5: The distribution of surface air temperature in the month of July**

- **Temperature Extremes:** Figure 8.6 shows the difference in temperatures between January and July can be stark in some regions. North-eastern Eurasia experiences a massive range of over 60°C, attributed to its continental nature. Meanwhile, the region between 20° S and 15° N sees a minimal range of just 3°C.

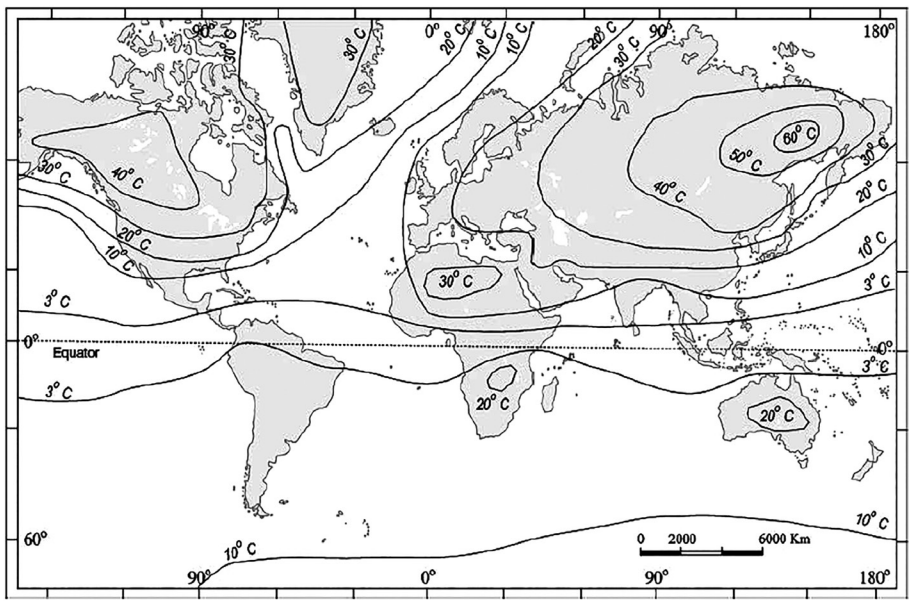



**Figure 8.6: The range of temperature between January and July**

## Temperature Inversion

Temperature inversion is an atmospheric phenomenon that flips our usual understanding of how temperature behaves with altitude.

- Usually, as altitude increases, the **temperature drops (6.5 °C per 1000 m)**, this decrease is known as the **normal lapse rate**. However, in certain conditions, this trend gets reversed, leading to what's called a **temperature inversion**.
- A long, clear winter night with the air standing still is an ideal condition for temperature inversion. As the night progresses, the earth loses the heat that is absorbed during the day. By dawn, the ground becomes cooler than the air above it.
- **In polar regions**, temperature inversion is normal throughout the year.

**Do You Know?**

- Plank's law states that hotter a body, the more energy it will radiate and shorter the wavelength of that radiation.
- Specific heat is the energy needed to raise the temperature of one gram of substance by one Celsius.

## Effects of Surface Temperature Inversion

- When inversion occurs, the lower atmosphere becomes stable. This stability traps smoke, dust, and other particles beneath the inversion layer, causing them to spread out and fill the lower atmosphere. This phenomenon is why **dense fog** often greets us on winter mornings. However, as the sun rises and warms the earth, this inversion typically disperses.
- In hilly and mountainous terrain, inversion can occur due to a process called **air drainage**. At night, cold air forms over the slopes. Acting much like a liquid, this dense, chilly air flows downwards, accumulating in valleys and low areas. Above this cold layer, warmer air resides. This downward flow of cold air, termed air drainage, acts as a protective shield for plants, saving them from frost damage.

## Conclusion

The Earth's temperature is a harmonious interplay of multiple factors, from insolation at varying latitudes to the influence of oceans and altitude. Phenomena like temperature inversion further underscores the complexity of our planet's thermal processes. Understanding these intricacies is crucial as they not only shape our daily weather but also influence long-term climatic patterns.

***Glossary:***

- **Perihelion:** It refers to the point in the orbit of a planet or other astronomical body, at which it is closest to the sun.
- **Aphelion:** It is the point at which an orbiting body is farthest from the sun.
- **Troposphere:** It is the lowest layer of the Earth's atmosphere in direct contact with the Earth's surface.
- **Albedo:** It is an expression of the ability of surfaces to reflect sunlight (heat from the sun).
- **Isotherms:** Isotherms are lines that connect places with the same temperature.
- **Air Mass:** It is a large body of air with generally uniform temperature and humidity.
- **Oceanic Currents:** It is the movement of water from one location to another.

❐❐❐

# 9 Atmospheric Circulation and Weather Systems

**Bibliography:** This chapter encompasses the summary of Chapter 10 - XI NCERT (Fundamentals of Physical Geography).

## Introduction

**Air expands** when heated and gets compressed when cooled, generating **atmospheric pressure**. This change in atmospheric pressure sets the air in **horizontal motion, called wind**. This wind **redistributes** the heat and moisture across the planet, thereby maintaining a constant temperature for the planet as a whole. The **vertical rise** of moist air cools it down to form clouds and bring precipitation.

## Atmospheric Pressure

- The weight of a column of air contained in a unit area from the mean sea level to the top of the atmosphere is called the **atmospheric pressure**.
- The atmospheric pressure is expressed in units of millibar. At sea level, the average atmospheric pressure is **1,013.2 millibar**.
- Due to the gravitational force, the air near the Earth's surface becomes more compact, resulting in higher pressure. As one ascends in altitude, the pressure diminishes.
- This pressure difference, which fluctuates with location, serves as the main driver of air movement, i.e., wind, which flows from regions of high pressure to those of low pressure.

### Vertical Variation of Pressure

- In the lower atmosphere, there is a swift decline in pressure as one goes higher. This decline is roughly 1 millibar for every 10 meters of elevation gain. Although, it is important to note that this rate of decrease is not uniform.
- The vertical pressure gradient force is significantly greater than the horizontal pressure gradient force. However, it is typically counteracted by an almost equal and opposite force of gravity. As a result, we do not encounter strong upward winds. Table below shows the average pressure and temperature at different altitudes for a standard atmosphere.

| Altitude | Pressure in mb | Temperature C |
|---|---|---|
| Sea Level | 1,013.25 | 15.2 |
| 1 km | 898.76 | 8.7 |
| 5 km | 540.48 | –17.3 |
| 10 km | 265.00 | –49.7 |

## Horizontal Distribution of Pressure

- Small pressure variations are crucial for wind patterns. Isobars, lines connecting equal pressure areas, are used to study horizontal pressure distribution.
- The adjoining image **(Refer to Figure 9.1)** shows the patterns of isobars corresponding to pressure systems. The Low Pressure system is enclosed by one or more isobars with the lowest pressure in the center. High-pressure system is also enclosed by one or more isobars with the highest pressure in the center.

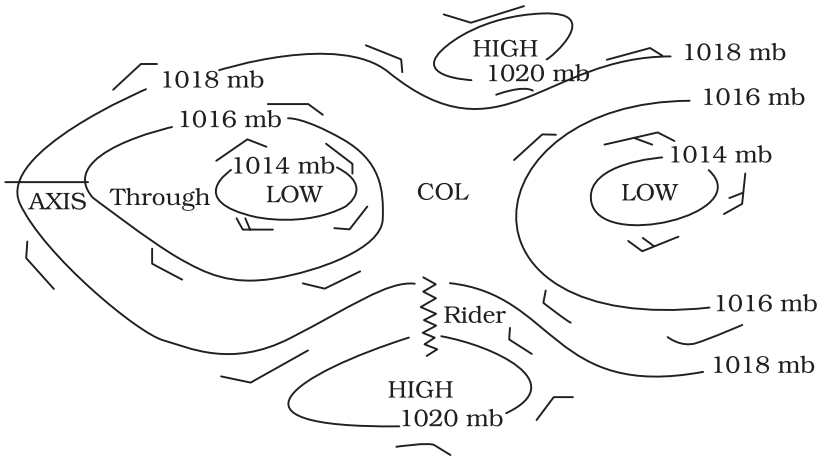



**Figure 9.1: Isobars, pressure and wind systems in Northern Hemisphere**

## World Distribution of Sea Level Pressure

- Based on the latitudinal pressure distribution, regions/strips of varying pressure are found. These are called Pressure Belts. These are listed as under:
  - **Equatorial Low:** It is the region close to the equator where sea level pressure is low.
  - **Subtropical Highs:** This is the high-pressure area along 30° N and 30° S latitude.
  - **Sub-Polar Lows:** These are the low-pressure belts towards the pole along 60° N and 60° S latitude.
  - **Polar High:** It is the high pressure region close to the poles.

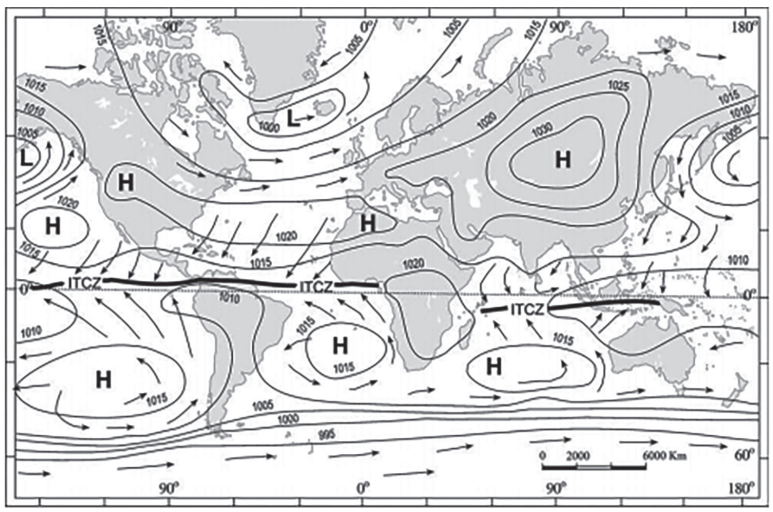



**Figure 9.2: Distribution of pressure (in millibars) — January**

- The pressure belts are not fixed; they shift with the apparent sun movement. **In the northern hemisphere, they shift southward in winter and northward in summer.**

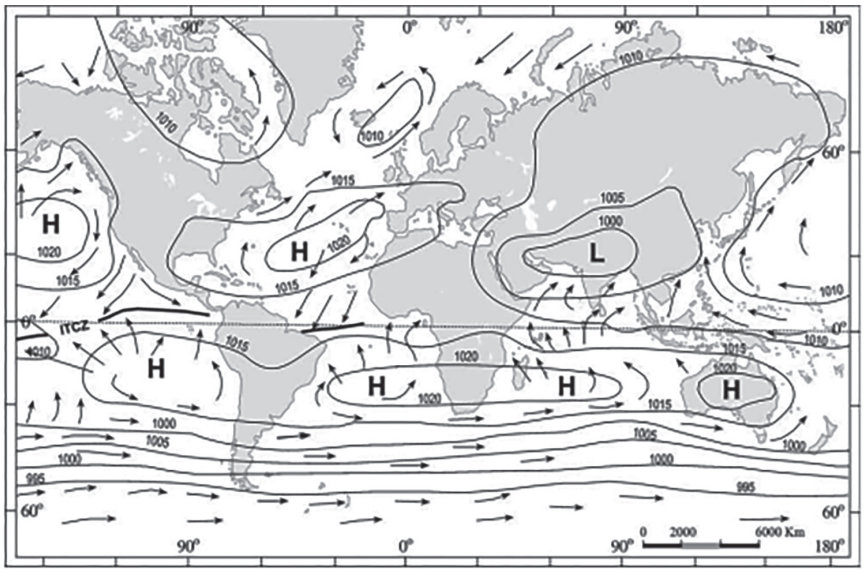
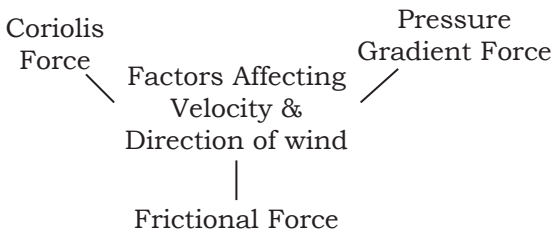



**Figure 9.3: Distribution of pressure (in millibars) — July**

## Forces Affecting the Velocity and Direction of Wind

The horizontal winds near the earth's surface are influenced by the combined effect of three forces: **the pressure gradient force, the frictional force, and the Coriolis force.**

1. **Pressure Gradient Force**
   - The rate of change of pressure with respect to distance is called the pressure gradient, which is fueled by the force generated due to the difference in atmospheric pressure.
   - The pressure gradient is strong where the isobars are close to each other and is weak where they are apart.




2. **Frictional Force**
   - The movement of wind over the earth's surface causes friction which affects the speed of the wind.
   - Frictional force is greatest at the surface and minimal over the sea surface and generally extends up to an elevation of 1 - 3 km.
3. **Coriolis Force**
   - The rotation of the earth about its axis produces a force affecting the direction of the wind, this force was called Coriolis force named after a French physicist who identified it in 1844.
   - This force deflects the wind to the **right direction in the northern hemisphere** and to the **left in the southern hemisphere,** which directly depends on the wind velocity (Higher the wind velocity, higher is the deflection).

**POINTS TO PONDER**

The study of atmospheric circulation points to a critical factor in the face of Coriolis force? Find out whether the Coriolis force is actually a force or just a misnomer? If not, how do you explain it as a force?

- The Coriolis force is **directly proportional to the angle of latitude**, that is maximum at the poles and is absent at the equator.
- The Coriolis force acts perpendicular to the pressure gradient force, higher the pressure gradient force, the more is the velocity of the wind and the larger is the deflection in the direction of wind.
- At the equator, cyclones are not formed because the Coriolis force is zero making the wind blow perpendicular to the isobars, hence the low pressure gets filled instead of getting intensified.

## Pressure and Wind

- The winds in the upper atmosphere, 2 - 3 km above the surface, are free from frictional effect of the surface and are controlled mainly by the pressure gradient and the Coriolis force. When isobars are straight and there is no friction, the pressure gradient force is balanced by the Coriolis force making the wind blow parallel to the isobar, this wind is known as the **geostrophic wind** (Refer to Figure 9.4).

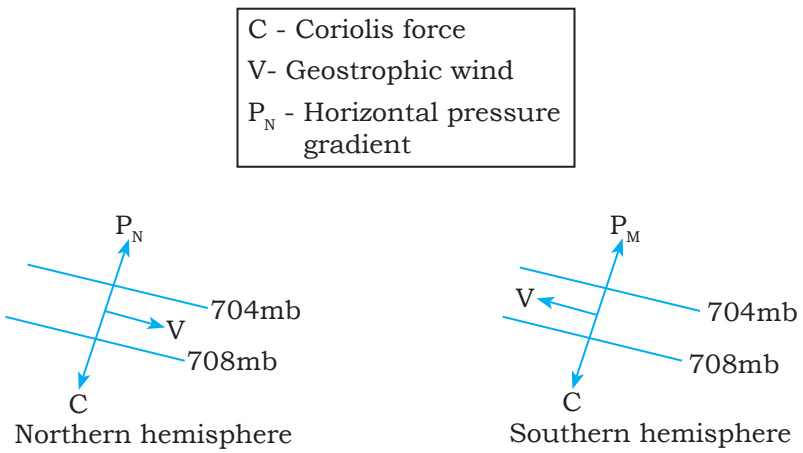



**Figure 9.4: Geostrophic Wind**

- This wind circulation around a low pressure system is called **cyclonic circulation** and around a high pressure system is called **anticyclonic circulation**. This circulation is further influenced by their presence in different hemispheres i.e. **towards right in north and towards left in south.**
- The surface wind patterns around low and high-pressure areas are often linked to the wind patterns at higher altitudes. (Refer to Figure 9.5)

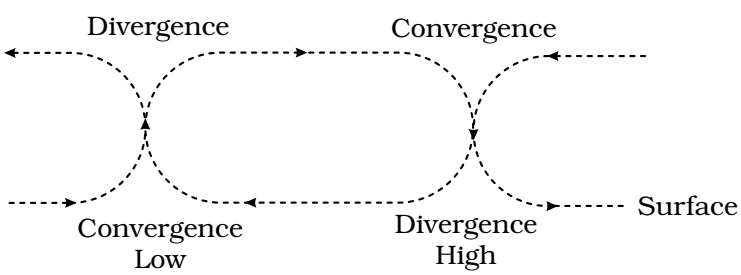



**Figure 9.5: Convergence and divergence of winds**

- Over low pressure areas the air will **converge and rise.**
- Over high pressure areas the air will **subside from above and diverge** at the surface.

- Apart from convergence, other phenomena like eddies, convection currents, orographic uplift and uplift along fronts cause the rising of air, which is essential for the formation of clouds and precipitation.

## General Circulation of the Atmosphere

- The pattern of the movement of the planetary winds is called the general circulation of the atmosphere.
- The pattern of planetary winds largely depends on:
  - Latitudinal variation of atmospheric heating
  - Emergence of pressure belts
  - The migration of belts following apparent path of the sun
  - The distribution of continents and oceans
  - The rotation of earth
- The general circulation of the atmosphere also sets in motion the ocean water circulation and they together influence the earth's climate. (Refer to Figure 9.6)

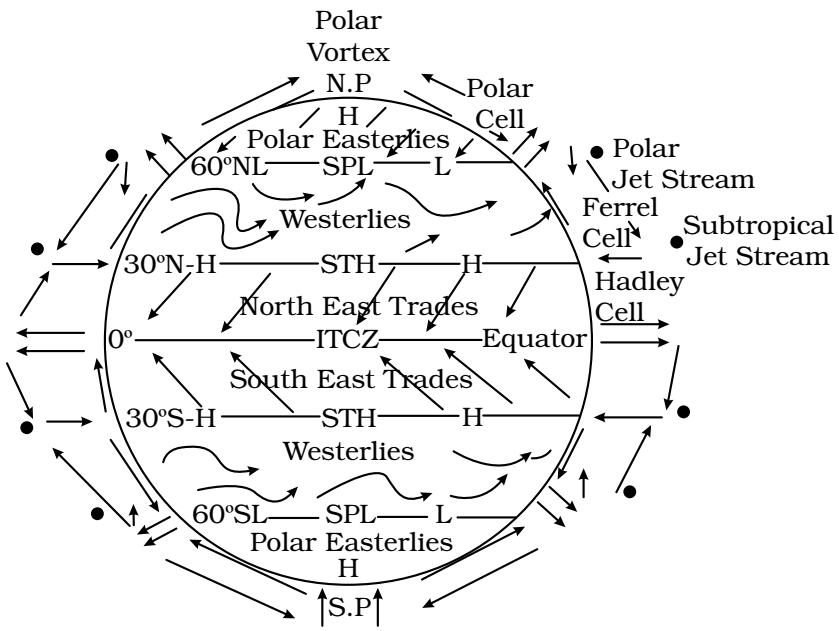



**Figure 9.6: Simplified general circulation of the atmosphere**

1. **Inter-Tropical Convergence Zone (ITCZ)**
   - Low pressure forms due to air convection driven by intense sunlight.
   - Winds from the tropics converge into this low-pressure area, ascend within the convective cell, reach the troposphere's upper limit (approximately 14 km), and subsequently travel poleward, accumulating around 30°N and 30°S latitudes.
2. **Hadley Cell**
   - A portion of the gathered air from the Inter-Tropical Convergence Zone (ITCZ) descends due to pressure and cooling, creating a subtropical high-pressure system.
   - This sinking air near the Earth's surface moves towards the equator as the easterly winds. These easterlies, originating from both sides of the equator, meet and converge in the ITCZ.
   - These vertical and surface-to-atmosphere circulations are known as cells, and in tropical regions, they are referred to as Hadley Cells.

**General Atmospheric Circulation and its Effects on Oceans**

Warming and cooling of the Pacific Ocean is most important in terms of general atmospheric circulation. The warm water of the central Pacific Ocean slowly drifts towards South American coast and replaces the cool Peruvian current. Such appearance of warm water off the coast of Peru is known as the EI Nino. The EI Nino event is closely associated with the pressure changes in the Central Pacific and Australia. This change in pressure condition over Pacific is known as the southern oscillation. The combined phenomenon of southern oscillation and EI Nino is known as ENSO. When ENSO is strong, large-scale variations in weather occur around the world. The arid west coast of South America receives heavy rainfall, drought occurs in Australia and sometimes in India and floods occur in China. This phenomenon is closely monitored and is used for long-range forecasting in major parts of the world.

3. **Ferrel Cell**
   - ✧ In the middle latitudes sinking cold air from the poles and the rising warm air from the subtropical high completes the circulation.
   - ✧ These winds blowing at the surface are called westerlies and the cell is known as the Ferrel cell.

**POINTS TO PONDER**

The atmosphere is a complex and integrated web of circulations, surface and upper tropospheric winds. Whatever changes occur in the system at one place affects the other parts of it. Find out the mechanism through which such changes are transmitted to other parts of the atmosphere? Can you establish the link between Indian monsoon and global air circulation based on the same lines?

4. **Polar Cell:** In polar regions, frigid, heavy air descends near the poles and moves towards the middle latitudes as the polar easterly winds, forming the polar cell.

- ✤ These three cells form the basis for the global atmospheric circulation. This circulation, in return, influences the oceans by initiating widespread, slow-moving ocean currents.
- ✤ These currents, in turn affect atmospheric circulation by introducing energy and moisture into the air, but these interactions occur slowly across expansive oceanic areas.

## Seasonal Winds

- ✤ The general wind circulation pattern changes with seasons as regions of maximum heat, pressure, and wind belts shift, leading to what we refer to as seasonal winds.
- ✤ The most significant impact of these seasonal winds is observed during monsoons, particularly in Southeast Asia.

## Local winds

Differences in the heating and cooling of earth surfaces and the cycles that develop daily or annually can create several common, local or regional winds. This is another example of the deviation from the general circulation system.

### Land and Sea Breezes

- ✤ During the day the land heats up faster than the sea creating a low pressure area over the land, while the sea remains relatively cooler maintaining high pressure. Thus, a pressure gradient from sea to land is created and the wind blows from the sea to the land as the sea breeze (Refer to Figure 9.7).
- ✤ In the night the reversal of the above condition takes place, making the land lose heat faster and is cooler than the sea. Thus, the pressure gradient is from the land to the sea and wind blows from the land to the sea as land breeze (Refer to Figure 9.7).

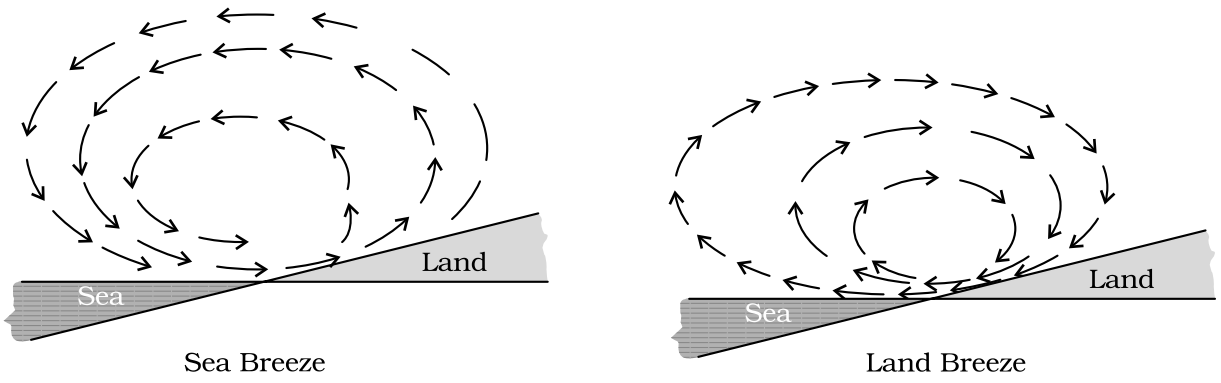
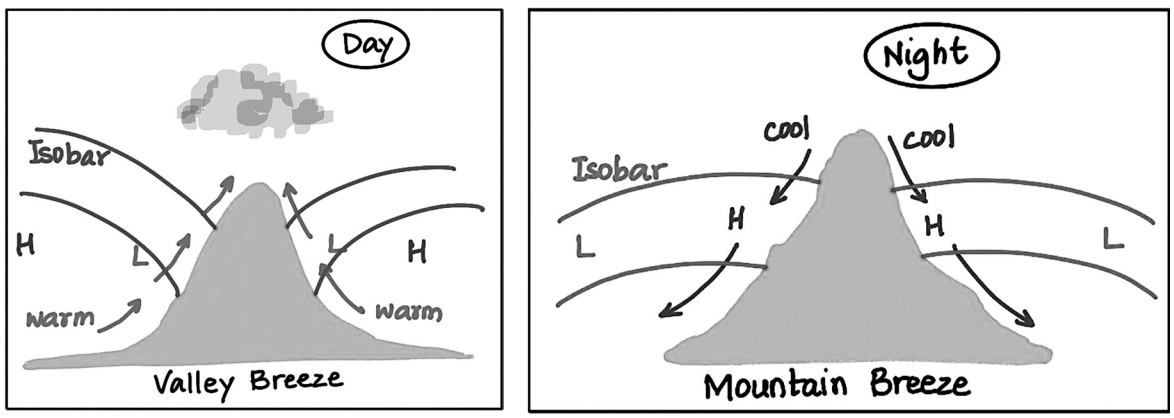



**Figure 9.7: Land and sea breezes**

### Mountain and Valley Winds

- **Valley Breeze:** In mountainous areas, daytime heating causes air to move upslope, drawing air from the valley, creating what we call the Valley Breeze.
- **Mountain or Katabatic Wind:** At night, as slopes cool, dense air descends into the valley, known as the Mountain or Katabatic Wind.
- When air crosses the leeward side of mountains, it condenses and precipitates. As it descends further, it warms through **adiabatic processes**, which can rapidly melt snow.




## Air Masses

- The air with distinctive characteristics in terms of temperature and humidity and having a large body of air with little horizontal variation is called an air mass. Tropical air masses are warm and polar air masses are cold.
- **Source Regions:** These are the homogeneous surfaces, over which air masses form. Air Masses are classified on the basis of source regions as follows:
  - Warm tropical and subtropical oceans;
  - The subtropical hot deserts;
  - The relatively cold high latitude oceans;
  - The very cold snow covered continents in high latitudes;
  - Permanently ice covered continents in the Arctic and Antarctica.

- Accordingly, following types of air masses are recognised:
  (i) Maritime tropical (mT);
  (ii) Continental tropical (cT);
  (iii) Maritime polar (mP);
  (iv) Continental polar (cP);
  (v) Continental arctic (cA).

**Fronts**

- When two distinct air masses converge, the region where they meet is termed as a front, and this formation process is called frontogenesis.
- These fronts, typically found in mid-latitudes, feature sharp temperature and pressure gradients, resulting in sudden temperature shifts and the ascent of air to create clouds and precipitation.
- Types of Fronts (Refer to Figure 9.8):
  - **Stationary Front:** When a front doesn't move, it is termed a stationary front.
  - **Cold and Warm Front:** When cold air advances toward warm air, it is a cold front. When warm air advances toward cold air, it is a warm front.
  - **Occluded Front:** If an air mass is lifted entirely off the land surface, it is known as an occluded front.

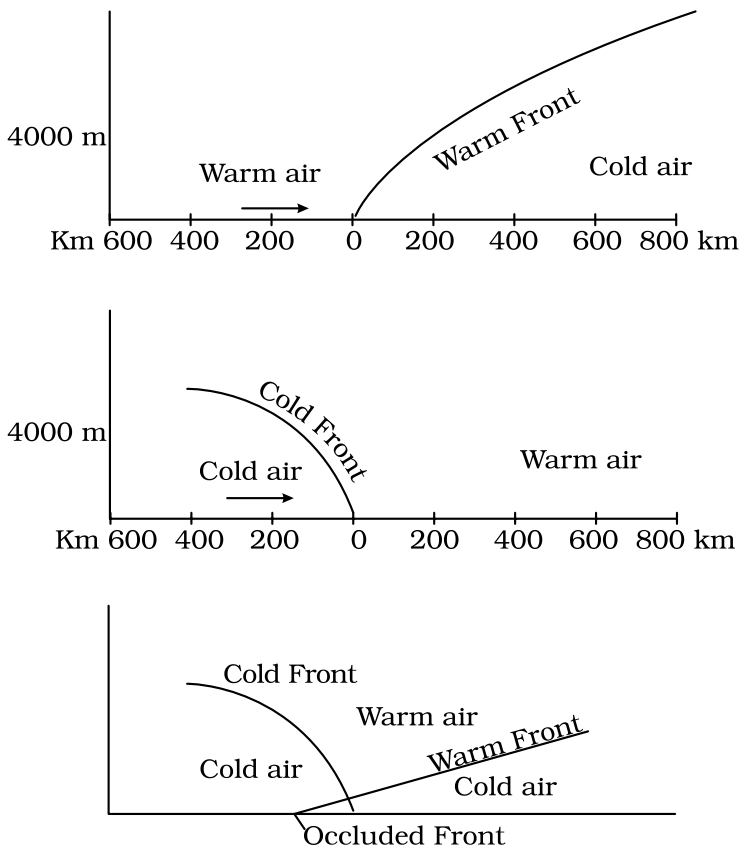



**Figure 9.8: Vertical Sections of : (*a*) Warm Front; (*b*) Cold Front; (*c*) Occluded Front**

## Extra Tropical Cyclones

- The systems developing in the mid and high latitude, beyond the tropics are called the middle latitude or extra tropical cyclones (Refer to Figure 9.9).

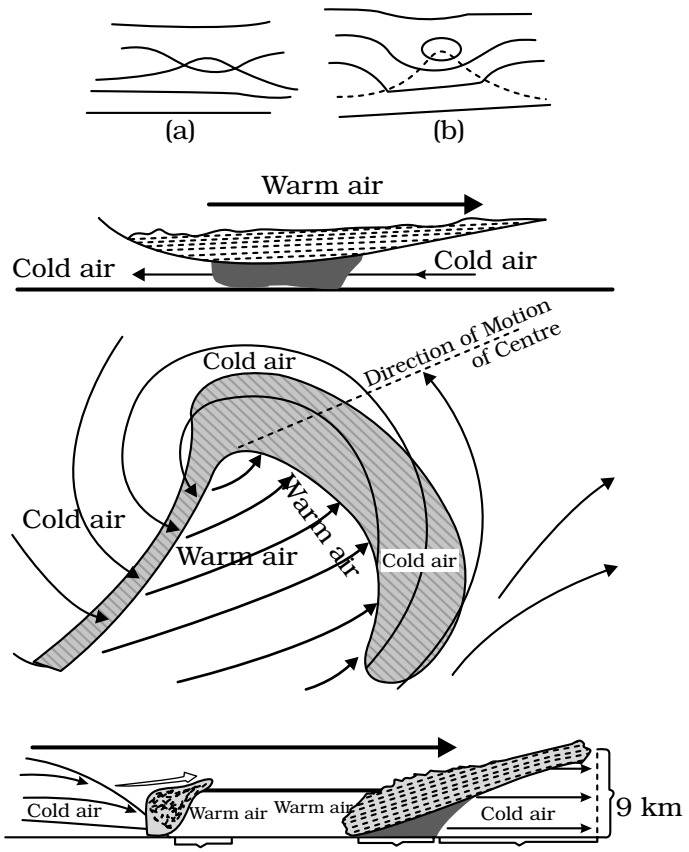



**Figure 9.9: Extra tropical cyclones**

- **Process of Formation:**
  - As the pressure drops along the polar front, the warm air (coming from south) moves northwards and the cold air (coming from north) moves towards south setting in motion an anticlockwise cyclonic circulation;
  - This cyclonic circulation leads to a well developed extra tropical cyclone, with a warm front and a cold front;
  - The warm air glides over the cold air and a sequence of clouds appear over the sky ahead of the warm front and cause precipitation;
  - As the cold front pushes the warm air up completely the front gets occluded and the cyclone dissipates.

## Tropical Cyclones

- Tropical cyclones are violent storms that originate over oceans in tropical areas and move over to the coastal areas.
- This is one of the most devastating natural calamities as it brings about large scale destruction caused by violent winds, very heavy rainfall and storm surges.

- They are known as **Cyclones in the Indian Ocean, Hurricanes in the Atlantic, Typhoons in the Western Pacific and South China Sea, and Willy-willies in the Western Australia.**
- **The conditions favorable for the formation and intensification of tropical storms are:**
  - (i) Large sea surface with temperature higher than 27° C;
  - (ii) Presence of the Coriolis force;
  - (iii) Small variations in the vertical wind speed;
  - (iv) A pre-existing weak low-pressure area or low-level-cyclonic circulation;
  - (v) Upper divergence above the sea level system.

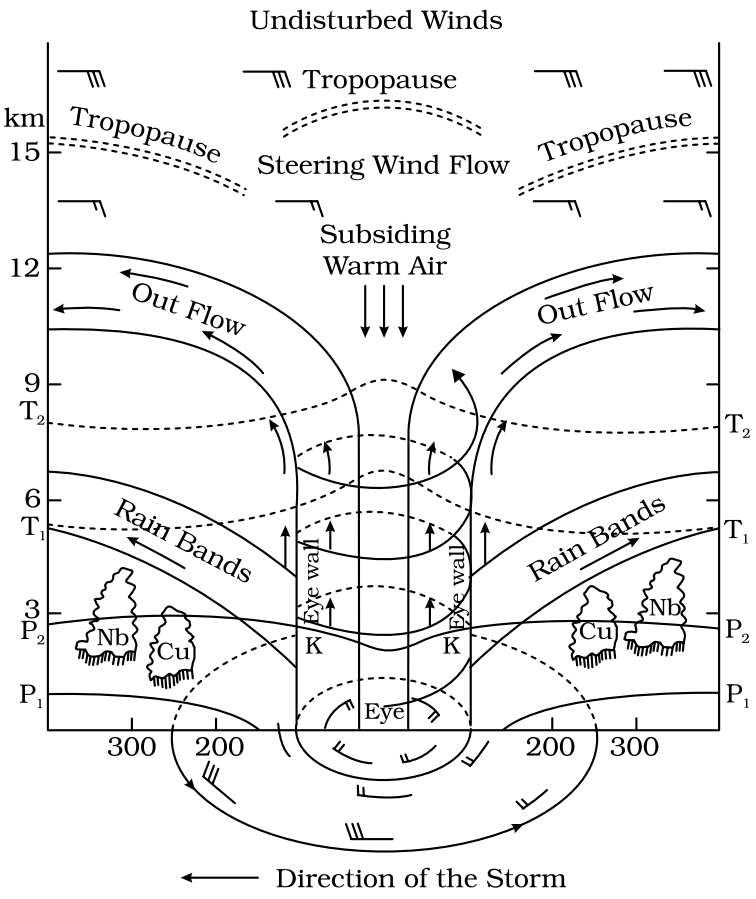



**Figure 9.10: Vertical section of the tropical cyclone (after Rama Sastry)**

- The condensation process in the towering cumulonimbus clouds, surrounding the center of the storm, along with continuous supply of moisture from the sea keep feeding the storm's intensity.
- Once a cyclone reaches the land the moisture supply is cut off and the storm dissipates this phenomenon is called the landfall of the cyclone.
- A schematic representation of the vertical structure of a mature tropical cyclonic storm is shown in figure 9.10:
  - Strong spirally circulating wind around the center is called the eye, which is a region of calm with subsiding air.

- Around the eye is the eye wall, where there is a strong spiraling ascent of air reaching a velocity of 250 km/hr resulting in torrential rains. The diameter of thecirculating system can vary between 150 and250 km.

| Tropical Cyclones | Extra Tropical Cyclones |
|---|---|
| ➢ No clear frontal system | ➢ Have a clear frontal system |
| ➢ Originate only over the seas and on reaching the land they dissipate | ➢ Can originate over land as well as sea |
| ➢ Smaller in area comparatively | ➢ Affects a much larger area as compared to the tropical cyclone |
| ➢ Wind velocity is higher and destructive | ➢ Wind velocity is relatively weaker |
| ➢ Move from east to west | ➢ Move from west to east |

## Thunderstorms and Tornadoes

Thunderstorms and tornadoes are **brief but highly destructive**, typically limited to a small area. These intense storms result from the atmosphere's response to changing energy distribution. *They convert potential and heat energy into kinetic energy before the atmosphere returns to a stable state.*

- **Thunderstorms:** Thunderstorms result from intense convection during hot, humid conditions, featuring mature cumulonimbus clouds that produce thunder and lightning.
  - When these clouds reach altitudes with sub-zero temperatures, hailstones form and fall as hailstorms. In cases of limited moisture, thunderstorms can create dust storms.
  - Thunderstorms are identified by strong updrafts of warm, rising air, causing cloud growth and increased altitude, resulting in precipitation.
- **Tornadoes:**
  - Sometimes severe thunderstorms generate a spiraling wind with very low pressure at the center that descends like the trunk of an elephant, causing massive destruction on its way. Such a phenomenon is called a tornado.
  - Tornadoes generally occur in middle latitudes.
  - The tornados over the sea are called **waterspouts**.

## Conclusion

Atmospheric circulation and weather systems are intricately connected, driving the complex dynamics of our planet's climate. The movement of air masses, the formation of pressure systems, and the interaction of various factors like temperature, humidity, and geography all play crucial roles in shaping our weather patterns. Understanding these processes is essential for meteorologists and climate scientists to predict and study weather events, from the daily forecast to severe storms and long-term climate trends.

***Glossary:***

- **Pressure Gradient:** The rate of change of pressure with respect to distance is the pressure gradient.
- **Coriolis Force:** The rotation of the earth about its axis produces a force affecting the direction of the wind, this force is called Coriolis force.
- **Ferrel Cell:** In the middle latitudes, the general circulation of the atmosphere cycle is called the Ferrel cell.
- **ITCZ:** It is a low pressure zone located at the equator around 20°N-25°N latitudes where trade winds converge.
- **Isobars:** Isobars are lines connecting places having equal pressure.
- **Land Breeze:** Wind blowing from the land to the sea due to the pressure gradient generated in the day time.
- **Sea Breeze:** Wind blowing from the sea to the land due to the pressure gradient generated in the night time.
- **Katabatic Wind:** The cool air from the high plateaus and ice fields draining into the valley is called katabatic wind.
- **Air Masses:** A body of air whose temperature and humidity characteristics, acquired in source region, remain relatively constant over a horizontal distance of hundreds to thousands of km.

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# 10 Water in the Atmosphere

**Bibliography:** This chapter encompasses the summary of Chapter 10-XI NCERT (Fundamental of Physical Geography), Chapter 5- VII NCERT (Our Environment) and Chapter 5- VI NCERT (The Earth: Our Habitat).

## Introduction

The amount of water vapor in the air ranges from zero to four percent by volume and has a significant impact on weather events. Water exists in the atmosphere in three states: as **gas, liquid, and solid**. The moisture present in the air comes from the evaporation of water bodies and the transpiration of plants. Consequently, there is an ongoing interchange of water among the atmosphere, oceans, and land through the processes of evaporation, transpiration, condensation, and precipitation.

## Water Cycle

- The continuous transformation and circulation of water among oceans, the atmosphere, and land is referred to as the water or hydrological cycle (Refer to Figure 10.1).
- The heat from the sun triggers the evaporation of water, turning it into vapor. When this vapor cools and condenses, it creates clouds. Eventually, the water in these clouds returns to the land or sea in the form of rainfall, snow, or sleet.
- Freshwater primarily originates from rivers, ponds, springs, and glaciers.

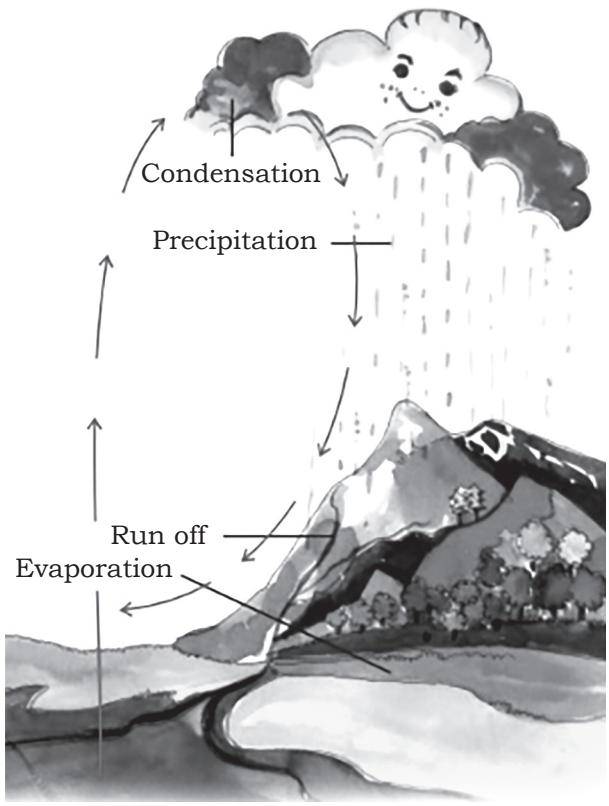
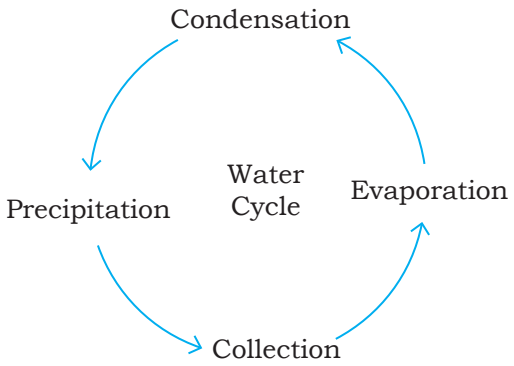



**Figure 10.1: Water Cycle**

## Humidity

- Water vapor present in the air is known as humidity.
- **Absolute Humidity:** This is the actual amount of the water vapor present in the atmosphere, it depends entirely on the temperature of air.
  - It represents the mass of water vapor in one cubic meter of air and is measured in grams per cubic meter.
  - The air's capacity to retain water vapor is solely determined by its temperature.
  - Absolute humidity varies from one location to another across the Earth's surface.

- **Relative Humidity:** This is the percentage of moisture present in the atmosphere as compared to its full capacity at a given temperature.
  - The capacity of air to retain moisture is greatly affected by its temperature, hence influencing its relative humidity, which is **greater over the oceans and least over the continents**. When relative humidity is 100%, it signifies saturation of air column and leads to percipitation.




- **Saturation and Dew Point:** When air holds the maximum amount of moisture possible at a particular temperature, it is described as saturated air. In other words, at that specific temperature, the air cannot accommodate any more moisture.
  - **Dew Point:** The temperature at which this saturation happens within a specific air sample is referred to as the dew point.

## Evaporation and Condensation

### Evaporation

- Evaporation is a process by which water is transformed from liquid to gaseous state and the temperature at which the water starts evaporating is referred to as the boiling point of water. Amount of heat needed to convert one unit of liquid water into water vapour is called latent heat of vaporization.
- The quantity of water vapor in the atmosphere changes through the processes of evaporation and condensation. The rate of evaporation is influenced by **variations in temperature, moisture levels, and the movement of air**.
  - Higher temperatures lead to increased water absorption and retention capacity in a given volume of at every.
  - Air with lower moisture content has the ability to absorb and retain moisture.
  - The movement of air replaces saturated air with unsaturated air, which promotes evaporation.
  - Consequently, greater air movement results in higher rates of evaporation.

### Condensation

- The process of transformation of water vapor into water is called **condensation** and is caused by the **loss of heat**.
- **Sublimation:** Sublimation is the process of condensation of gas (water vapor) directly into the solid form.
- **Conditions for Condensation**
  - When the temperature of the air is reduced to dew point with its volume remaining constant;
  - When both the volume and the temperature are reduced;
  - When moisture is added to the air through evaporation.
- Condensation is influenced by the **amount of cooling and the relative humidity** of the air and also by the **volume of air, temperature, pressure and humidity**.

### Forms of Condensation

Forms of condensation can be classified on the basis of temperature and location as dew, frost, fog and clouds as follows.

- **Dew:** During condensation, when the moisture is deposited in the form of water droplets on cooler surfaces of solid objects (rather than nuclei in air above the surface) such as stones, grass blades and plant leaves, it is known as dew.
  - The ideal conditions for its formation are **clear sky, calm air, high relative humidity, and cold and long night**.
  - It is necessary that the **dew point is above the freezing point,** else it will get converted into frost.
- **Frost: When condensation takes place below freezing point** (0°C) water gets directly converted to ice called frost.
  - The ideal conditions for the formation of white frost are the same as those for the formation of dew, except that the **air temperature must be at or below the freezing point**.
- **Fog and Mist:** Fog is essentially a cloud that forms either at or extremely close to the Earth's surface. It occurs when the temperature of an air mass, which holds a substantial amount of water vapor, suddenly drops, leading to condensation on tiny dust particles within the air mass itself.
  - **Mist:** Mist contains more moisture than the fog that is frequent over mountains. While the fog is drier than mist it is prevalent in areas where warm currents of air come in contact with cold currents.
  - **Smog:** When fog is mixed with smoke, it is described as smog.

## Clouds

- A cloud is a collection of small water droplets or tiny ice crystals that result from the condensation of water vapor in the open atmosphere at a significant altitude.
- Clouds are categorized into four types—cirrus, nimbus, stratus, and cumulus—based on their elevation, size, density, and whether they are transparent or opaque.

**Figure 10.2: Cumulus Cloud**

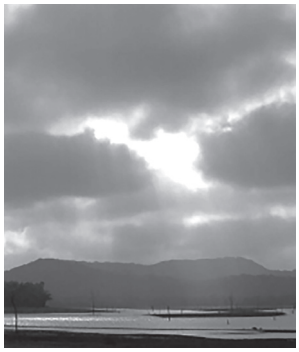


**Figure 10.3: Stratus Cloud**

1. **Cirrus:** Cirrus clouds develop at elevated heights, typically ranging from 8,000 to 12,000 meters. They are thin, separate clouds with a delicate, feather-like appearance and maintain a consistent white coloration.
2. **Nimbus:** Nimbus clouds are formed at intermediate altitudes or extremely close to the Earth's surface, occasionally appearing as though they touch the ground. These clouds have a dark, black, or deep gray coloration, and they possess an exceptionally dense and sun-blocking opacity.

**POINTS TO PONDER**

Differences between the shape of different cloud types are quite evident in the form of Cirrus, stratus and cumulus clouds. Have you ever thought about the factors which play a role in giving clouds their distinctive characteristic shape?

3. **Stratus:** These are extensive layered clouds that envelop significant sections of the sky. These cloud formations typically result from either heat dissipation or the interaction of air masses with varying temperatures.
4. **Cumulus:** Cumulus clouds look like cotton wool and have a flat base. They are generally formed at a height of 4,000 - 7,000 m and exist in patches.

- A combination of these four basic types can give rise to the following types of clouds:
  - **High clouds:** Cirrus, cirrostratus, cirrocumulus;
  - **Middle clouds:** Altostratus and altocumulus;
  - **Low clouds:** Stratocumulus and nimbostratus;
  - **Cumulus and Cumulonimbus:** Clouds with extensive vertical development.

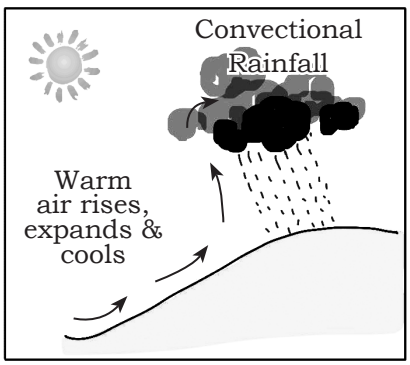
## Precipitation

- Precipitation refers to the release of moisture that occurs after the condensation of water vapor. Rainfall is the term used when precipitation is in the form of liquid water, while when the temperature is below freezing (0°C), precipitation takes the form of fine **snowflakes** and is called **snowfall**. In addition to rain and snow, other forms of precipitation include:
  - **Sleet:** Sleet consists of frozen raindrops or refrozen melted snow-water. It occurs when there's a layer of air with a temperature above freezing above a sub-freezing layer near the ground.
  - **Hailstones:** Hailstones are formed when rainwater droplets solidify into small, rounded pieces of ice while passing through colder layers. Hailstones typically have multiple concentric layers of ice and are relatively rare, occurring sporadically in both time and location.

## Types of Rainfall

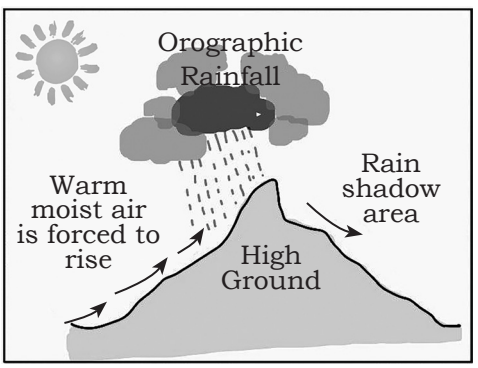
On the **basis of origin**, rainfall may be classified into three main types – the convectional, orographic or relief and the cyclonic or frontal.

### Convectional Rain



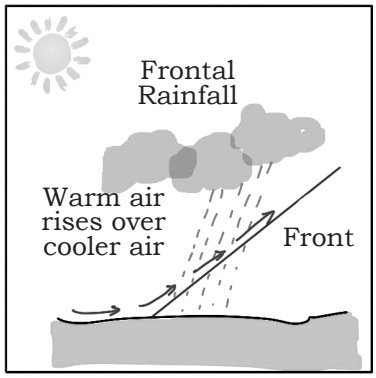

- This type of rainfall occurs when warm air rises due to convection currents, expands, cools down, and subsequently undergoes condensation, resulting in precipitation.
- This rainfall pattern is prevalent during the summer or in the warmer hours of the day. It is particularly common in equatorial regions and the inner regions of continents, especially in the northern hemisphere.
- Heavy rainfall accompanied by thunder and lightning occurs, but it tends to be of shorter duration.

### Orographic Rain (Relief Rain)




- This rain type occurs when a moisture-saturated air mass encounters a mountain and is compelled to rise. As it ascends, it expands and cools, resulting in condensation and precipitation.
- The key feature of this type of rainfall is that the windward slopes of the mountain receive more rainfall, while on the leeward side, temperatures increase, allowing for greater moisture absorption and resulting in dry conditions without rain.

- The region on the leeward side, receiving less rainfall, is known as **the rain-shadow area**.




### Cyclonic (Frontal) Rain

- Cyclonic rainfall occurs when warm, moist air meets cold air, causing rising, cooling, and condensation, resulting in prolonged and widespread precipitation associated with weather fronts and cyclones.
- It includes tropical and extra-tropical cyclonic rain.

## World Distribution of Rainfall

- Various regions across the Earth experience differing annual rainfall patterns, which also vary by season. Rainfall diminishes steadily from the equator toward the poles.
- Equatorial and western cool temperate regions receive consistent year-round rainfall.
- Coastal areas receive more rainfall than inland regions, with oceans receiving more than landmasses.
- Between latitudes **35° and 40° N and S**, eastern coasts get heavier rainfall due to easterly winds, decreasing westward. Between **45° and 65° N and S**, westerly winds bring rainfall first to western continental margins, decreasing eastward.
- Based on annual precipitation, major precipitation zones are categorized, such as the **equatorial belt**, the **windward slopes** of the mountains along the western coasts in the cool temperate zone and the **coastal areas** of the monsoon land, which receive heavy rainfall of **over 200 cm per annum**.
- Interior continental areas get moderate rainfall (100-200 cm). Central parts of tropical land and eastern/interior parts of temperate regions receive 50-100 cm annually.
- Rain shadow zones in continental interiors and high latitudes receive less than 50 cm per year.

## Conclusion

Water in the atmosphere is a dynamic and vital component of Earth's climate system. It exists in various forms, including water vapor, liquid droplets, and ice crystals, and plays a crucial role in weather and climate patterns. The hydrological cycle, with processes like evaporation, condensation, and precipitation, continuously redistributes this moisture. Geographical variations result in diverse rainfall patterns, from heavy equatorial rains to arid desert climates. Understanding atmospheric water is essential for predicting weather events, managing water resources, and addressing climate change challenges, making it a fundamental element in Earth's complex environmental puzzle.

***Glossary:***

- **Water cycle:** The continuous transformation and circulation of water among oceans, the atmosphere, and land is referred to as the water cycle.
- **Humidity:** Water vapor present in the air is known as humidity.
- **Evaporation:** A process by which water is transformed from liquid to gaseous state.
- **Condensation:** The process of transformation of water vapor into water is called condensation.
- **Precipitation:** Release of moisture that occurs after the condensation of water vapor.
- **Hailstones:** It is a type of precipitation received in the form of ice pellets or hail stones. The size of hailstones can be between 5 and 190 mm in diameter.

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# World Climate and Climate Change

**Bibliography:** The chapter encompasses the summary of **Chapter 6 and Chapter 7** - Class VII NCERT (Our Environment), and **Chapter 11** - Class XI NCERT (Fundamentals of Physical Geography).

## Introduction

This chapter provides a comprehensive overview of climate, covering Koeppen's classification of climate zones worldwide, and the different types of world climates. We'll further analyze the climates of tropical and subtropical regions, studying the unique ecosystems that thrive there and finally we will discuss the crucial topic of climate change and Global warming.

## World Climate and its Classification

The world climate can be studied by classifying it into **three broad approaches** - empirical, genetic and applied. **Empirical classification** is based on observed data, particularly temperature and precipitation. **Genetic classification** attempts to organize climates according to their causes and **applied classification** is for a specific purpose. The Koeppen climate classification is the most widely used system to catalog climate types in the world.

### Koeppen's scheme of classification of climate:

- The Koeppen climate classification was developed by **Wladimir Koppen**, a botanist, who identified a close relationship between climate and vegetation.
- He selected certain values of temperature and precipitation and related them to the distribution of vegetation and used these values for classifying the climates.
- It is an empirical classification based on mean annual and mean monthly temperature and precipitation data.
- Koeppen introduced the use of capital and small letters to designate climatic groups and types into **five major climatic groups** namely A, B, C, D and E (Refer Figure 11.1), where, A, C, D and E delineate humid climates and; B represents dry climates.

| Group | Characteristics |
|---|---|
| A - Tropical | Average temperature of the coldest month is 18°C or higher |
| B - Dry Climates | Potential evaporation exceeds precipitation |
| C - Warm Temperate | The average temperature of the coldest month of the (Mid-latitude) climates years is higher than minus 3°C but below 18°C |

| | |
|---|---|
| D - Cold Snow Forest Climates | The average temperature of the coldest month is minus 3 °C or below |
| E - Cold Climates | Average temperature for all months is below 10°C |
| H - High Land | Cold due to elevation |

**Figure 11.1: Climatic Groups According to Koeppen**

### Sub-division of Koeppen's classification of climate:

- The Koppen climate classification is **subdivided into types** (Refer Figure 11.2), designated by small letters, based on seasonality of precipitation and temperature characteristics.
- The seasons of dryness are indicated by the small letters : f, m, w and s, where f corresponds to no dry season, m - monsoon climate, w - winter dry season and s - summer dry season.
- The small letters a, b, c and d refer to the degree of severity of temperature.
- The B - Dry Climates are subdivided using the capital letters S for steppe or semi-arid and W for deserts.

| Group | Type | Letter Code | Group |
|---|---|---|---|
| A-Tropical Humid Climate | Tropical wet<br>Tropical monsoon<br>Tropical wet and dry | Af<br>Am<br>Aw | No dry season<br>Monsoonal, short dry season<br>Winter dry season |
| B-Dry Climate | Subtropical steppe<br>Subtropical desert<br>Mid-latitude steppe<br>Mid-latitude desert | BSh<br>BWh<br>BSk<br>BWk | Low-latitude semi arid or dry<br>Low-latitude arid or dry<br>Mid-latitude semi arid or dry<br>Mid-latitude arid or dry |
| C-Warm temperate (Mid-latitude Climates) | Humid subtropical<br>Mediterranean<br>Marine west coast | Cfa<br>Cs<br>Cfb | No dry season, warm summer<br>Dry hot summer<br>No dry season, warm and cool summer |
| D-Cold Snow-forest Climates | Humid continental<br>Subarctic | Df<br>Dw | No dry season, severe winter<br>Winter dry and very severe |
| E-cold Climates | Tundra<br>Polar ice cap | ET<br>EF | No true summer<br>Perennial ice |
| H-Highland | Highland | H | Highland with snow cover |

**Figure 11.2: Sub-division of Koeppen's climate classification**

### Group A : Tropical Humid Climates

- **Location:** Tropical humid climates exist between Tropic of Cancer and Tropic of Capricorn.
- **Climate Type:** The sun being overhead throughout the year and the presence of Inter Tropical Convergence Zone (ITCZ) make the climate hot and humid.
- Annual range of temperature is very low and annual rainfall is high.
- The tropical group is divided into **three types:**
  - Af - Tropical wet climate;
  - Am - Tropical monsoon climate;
  - Aw - Tropical wet and dry climate.

**Table 11.1: Types of Tropical Humid Climates**

| Climate | Feature |
|---|---|
| Tropical Wet Climate (Af) | ✤ Mainly found near the equator. The major areas are the Amazon Basin in South America, western equatorial Africa and the islands of East Indies.<br>✤ Rainfall occurs in every month of the year as thunder showers in the afternoon.<br>✤ The temperature is uniformly high and the annual range of temperature is negligible. The maximum and minimum temperature range on any day is around 30°C and 20°C respectively.<br>✤ Tropical evergreen forests with dense canopy cover and large biodiversity are found. |
| Tropical Monsoon Climate (Am) | ✤ Mainly found over the Indian sub-continent, North Eastern part of South America and Northern Australia.<br>✤ Heavy rainfall occurs mostly in summer.<br>✤ Winter is mostly dry. |
| Tropical Wet and Dry Climate (Aw) | ✤ Mainly occurs north and south of Af type climate regions. It is found to the north and south of the Amazon forest in Brazil and adjoining parts of Bolivia and Paraguay in South America, Sudan and south of Central Africa.<br>✤ It borders a dry climate on the western part of the continent.<br>✤ The annual rainfall is considerably less than that in Af and Am climate types.<br>✤ The wet season is shorter and the dry season is longer with severe droughts.<br>✤ Temperature is high throughout their year and diurnal ranges of temperature are the greatest in the dry season.<br>✤ Deciduous forest and tree-shredded grasslands occur. |

### Group B : Dry Climates

- ✤ Dry climates are characterized by very low rainfall and occur between 15° and 60° N and S of the equator.
- ✤ At low latitudes, from 15° to 30°, they occur in the area of subtropical high pressure zone where subsidence and inversion of temperature do not produce rainfall.
- ✤ On the western margin of the continents, they extend more equatorwards and occur on the coast, particularly over the west coast of South America.
- ✤ In middle latitudes they range from 35° to 60° north and south. They are confined to the interior of continents where maritime-humid winds do not reach and to areas often surrounded by mountains.
- ✤ **Dry climates are divided into two types**, namely steppe or semi-arid climate (BS) and desert climate (BW).
- ✤ They are further **subdivided** as:
  - ✧ Subtropical steppe (BSh) and subtropical desert (BWh) at latitudes between 15° and 35°;
  - ✧ Mid-latitude steppe (BSk) and mid-latitude desert (BWk) at latitudes between 35° and 60°.

**Table 11.2: Types of Dry Climate**

| Climate | Feature |
|---|---|
| Subtropical Steppe Climates (BSh) | ✤ Subtropical steppe (BSh) and Subtropical desert (BWh) have common precipitation and temperature characteristics.<br>✤ This region is located between humid and dry climates.<br>✤ The subtropical steppe receives more rainfall than the desert, adequate enough for the growth of sparse grasslands.<br>✤ The rainfall is highly variable. |
| Subtropical Desert Climates (BWh) | ✤ Rain occurs in short, intense thundershowers in deserts and is ineffective in building soil moisture.<br>✤ Fog is common in coastal deserts bordering cold currents.<br>✤ Maximum temperature in the summer is very high.<br>✤ The rainfall in this type of climate is highly variable.<br>✤ The annual and diurnal ranges of temperature are also high. |

## Group C : Warm Temperate (Mid-Latitude) Climates

- ✤ These climates extend from 30° to 50° of latitude mainly on the eastern and western margins of continents.
- ✤ They have warm summers with mild winters.
- ✤ They are grouped into four types:
  - ✧ **Cwa** - Humid subtropical, i.e. dry in winter and hot in summer;
  - ✧ **Cs** - Mediterranean;
  - ✧ **Cfa** - Humid subtropical, i.e. no dry season and mild winter;
  - ✧ **Cfb** - Marine west coast climate.

**Table 11.3: Subdivision Warm Temperate (Mid-Latitude) Climates**

| Climate | Feature |
|---|---|
| Humid Subtropical Climate (Cwa) | ✤ Mainly occurs poleward of Tropic of Cancer and Tropic of Capricorn.<br>✤ It is found mainly in North Indian plains and South China interior plains.<br>✤ The climate is similar to Aw climate except that the temperature in winter is warm. |
| Mediterranean Climate (Cs) | ✤ Occurs around the Mediterranean sea, along the west coast of continents in subtropical latitudes between 30° - 40°, covering regions of Central California, Central Chile, along the coast in south eastern and south western Australia.<br>✤ These areas come under the influence of subtropical high in summer and westerly wind in winter.<br>✤ The climate is characterized by hot, dry summers and mild, rainy winters.<br>✤ Monthly average temperature in summer is around 25° C and in winter below 10°C.<br>✤ The annual precipitation ranges between 35 - 90 cm. |
| Humid Subtropical Climate (Cfa) | ✤ Mainly lies on the eastern parts of the continent in subtropical latitudes, covering eastern United States of America, southern and eastern China, southern Japan, northeastern Argentina, coastal South Africa and eastern coast of Australia.<br>✤ Here, air masses are generally unstable and cause rainfall throughout the year.<br>✤ The annual averages of precipitation vary from 75 to 150 cm.<br>✤ Thunderstorms in summer and frontal precipitation in winter are common.<br>✤ Mean monthly temperature in summer is around 27°C, and in winter it varies from 5° to 12° C.<br>✤ The daily range of temperature is small. |

| | |
|---|---|
| Marine West Coast Climate (Cfb) | ✤ Marine west coast climate is located poleward from the Mediterranean climate on the west coast of the continents.<br>✤ The main areas where this climate is found are Northwestern Europe, west coast of North America, north of California, southern Chile, southeastern Australia and New Zealand.<br>✤ Due to marine influence, the temperature is moderate and in winter, it is warmer than usual.<br>✤ The mean temperature in summer months is between 15°to 20°C and in winter 4°to 10°C.<br>✤ The annual and daily ranges of temperature are small.<br>✤ Precipitation occurs throughout the year. Precipitation varies greatly from 50-250cm. |

### Group D : Cold Snow Forest Climates (D)

- ✤ Cold snow forest climates occur in the large continental area in the northern hemisphere between 40°-70° north latitudes in Europe, Asia and North America.
- ✤ Cold snow forest climates are divided into two types:
  - ✧ **Df** - cold climate with humid winter;
  - ✧ **Dw** - cold climate with dry winter.

**Table 11.4: Subdivision of Cold Snow Forest Climates**

| Climate | Feature |
|---|---|
| Cold Climate with Humid Winters (Df) | ✤ Cold climate with humid winter occurs poleward of marine west coast climate and mid latitude steppe.<br>✤ The winters are cold and snowy.<br>✤ The frost free season is short.<br>✤ The annual ranges of temperature are large.<br>✤ The weather changes are abrupt and short.<br>✤ Poleward, the winters are more severe. |
| Cold Climate with Dry Winters (Dw) | ✤ Cold climates with dry winters occur mainly over Northeastern Asia.<br>✤ The development of winter anticyclone and its weakening in summer sets in monsoon like reversal of wind in this region.<br>✤ Poleward, summer temperatures are lower and winter temperatures are extremely low with many locations experiencing below freezing point temperatures for up to seven months in a year.<br>✤ Precipitation occurs in summer. The annual precipitation is low from 12-15 cm. |

### Group E : Polar Climates

- ✤ Polar climates exist poleward beyond 70° Latitude.
- ✤ This type of climate is further subdivided in two types:
  - ✧ **ET** - Tundra Climate;
  - ✧ **EF** - Ice Cap Climate

**Table 11.5: Subdivision of Polar Climates**

| Climate | Feature |
|---|---|
| Tundra Climate (ET) | ✤ The Tundra climate (ET) is so called after the types of vegetation, like low growing mosses, lichens and flowering plants.<br>✤ This is the region of permafrost where the subsoil is permanently frozen.<br>✤ The short growing season and water logging support only low growing plants. During summer, the tundra regions have a very long duration of daylight. |
| Ice Cap Climate (EF) | ✤ The Ice Cap climate (EF) is found in Greenland and Antarctica.<br>✤ The temperature is below the freezing point in summer.<br>✤ This area receives very little precipitation.<br>✤ The snow and ice get accumulated and the mounting pressure causes the deformation of the ice sheets and they break. They move as icebergs that float in the Arctic and Antarctic waters. |

### Group H : Highland Climates (H):

- ✤ Highland climates are governed by topography.
- ✤ In high mountains, drastic changes in mean temperature occur over short distances.
- ✤ Precipitation types and intensity also vary spatially across highlands.
- ✤ There is vertical zonation of layering of climatic types with elevation in the mountain environment.

**POINTS TO PONDER**

Koeppen's classification is the most widely accepted classification of climate with close linkage to vegetation. Do you think the classification remains valid in the changing context of climate change? Don't you think climate change is being induced faster whereas vegetation patterns lags behind with slower rate of change. Do you think the vegetation pattern is destined to a disastrous end or will it reconfigure itself in the emerging climate pattern?

## Climate Change

Climate change refers to long-term shifts in temperatures and weather patterns. Such shifts can be natural, due to changes in the sun's activity or large volcanic eruptions, or due to anthropogenic activities such as unsustainable industrialization, urbanization and deforestation etc.

### Variations observed in climate

- ✤ Our earth has witnessed many variations in climate since the beginning. Geological records show alteration of glacial and inter-glacial periods.
- ✤ The geomorphological features, especially in high altitudes and high latitudes, exhibit traces of advances and retreats of glaciers.
- ✤ The sediment deposits in glacial lakes also reveal the occurrence of warm and cold periods.
- ✤ The rings in the trees provide clues about wet and dry periods.

**Do You Know?**

India also witnessed alternate wet and dry periods. Archaeological findings show that the Rajasthan desert experienced wet and cool climate around 8,000 B.C. The period 3,000 - 1,700 B.C. had higher rainfall. From about 2,000 - 1,700 B.C., this region was the center of the Harappan civilisation. Dry conditions have accentuated since then.

Many such historical records describe the vagaries in climate. All these evidences indicates that change in the climate is a natural and continuous process. But since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels like coal, oil and gas and uncontrolled industrial activities.

### Climate in the recent past:

- Extreme weather events were prevalent during the 90's decade of the last century. The 1990s recorded the warmest temperature of the century and some of the worst floods around the world. The worst devastating drought in the Sahel region, south of Sahara desert, from 1967-1977 is one such variability.

**Additional Information**

Around 500 - 300 million years ago, the earth was warm. During the Pleistocene epoch, glacial and interglacial periods occurred. The last major peak glacial period was about 18,000 years ago. The present inter-glacial period started 10,000 years ago.

- During the 1930s, dust bowl severe drought occurred in southwestern Great Plains of the United States.
- Europe has also witnessed the "Little Ice Age" from 1550 to 1850.
- From about 1885-1940 world temperature showed an upward trend. And after 1940, the rate of increase in temperature slowed down gradually.
- The annual average near-surface air temperature of the world is approximately 14 degree Celsius. The greatest warming of the 20th century was during the two periods, 1901-44 and 1977-99. Over each of these two periods, global temperatures rose by about 0.4 degree Celsius.

### Causes of Climate Change

Mainly astronomical and terrestrial factors are responsible for climate change.

**Table 11.6: Causes of Climate Change**

| Cause | Description |
|---|---|
| Astronomical | ✤ These include changes in solar output associated with sunspot activities. Sunspots are dark and cooler patches on the sun that increase and decrease in a cyclical manner.<br>✤ When the number of sunspots increases, cooler and wetter weather and greater storminess occur, while decrease in sunspot numbers is associated with warm and drier conditions.<br>✤ Another astronomical theory is Milankovitch oscillations, which refer to cycles in the variations in the earth's orbital characteristics around the sun, the wobbling of the earth and the changes in the earth's axial tilt. These alter the amount of insolation received from the sun. |
| Terrestrial | ✤ It mainly includes Volcanism, which throws up lots of aerosols into the atmosphere. These aerosols remain in the atmosphere for a considerable period of time, reducing the sun's radiation reaching the Earth's surface. After the Pinatoba and El Cion volcanic eruptions, the average temperature of the earth fell to some extent for some years.<br>✤ Major terrestrial cause is an anthropogenic effect that is causing an increase in concentration of GHGs, leading to global warming. |

## What is Global Warming?

- The atmosphere transmits the incoming solar radiation but also absorbs the vast majority of long-wave radiation emitted upwards by the earth's surface, resulting in the warming of the atmosphere. This is referred to as the greenhouse effect.
- This leads to long term warming of the planet's temperature, called as global warming, which is rising alarmingly in the last few decades mainly due to the rising concentration of GHGs.

### How was the term Greenhouse derived?

The term greenhouse is derived from the analogy to a greenhouse used in cold areas for preserving heat. A greenhouse is made up of glass. The glass which is transparent to incoming shortwave solar radiation is opaque to outgoing long wave radiation. The glass, therefore, allows in more radiation and prevents the long wave radiation going outside the glass house, causing the temperature inside the glasshouse structure warmer than outside

- For instance, the globally averaged annual mean temperature at the end of the 20th century was about 0.6 degree Celsius above that recorded at the end of the 19th century.
- The year 1998 was the warmest year, probably not only for the 20th century but also for the whole millennium.
- Rise in the sea level due to melting of glaciers and ice-caps and thermal expansion of the sea may inundate large parts of the coastal area and islands, leading to social problems.

## Greenhouse Gasses (GHGs):

- The major GHGs are carbon dioxide ($CO_2$), Chlorofluorocarbons (CFCs), methane ($CH_4$), nitrous oxide ($N_2O$) and ozone ($O_3$).
- Some other gases such as nitric oxide (NO) and carbon monoxide (CO) easily react with GHGs and affect their concentration in the atmosphere.
- The effectiveness of any given GHG molecule depend on the magnitude of the increase in its concentration, its lifetime in the atmosphere and the wavelength of radiation that it absorbs.
- Due to these reasons, the chlorofluorocarbons (CFCs) are highly effective.

### What is the Ozone Hole?

The ozone hole is a region of severe ozone depletion in the stratosphere, primarily over Antarctica. It results from the release of ozone-depleting substances, including CFCs. The impact includes increased harmful ultraviolet (UV) radiation reaching Earth, posing health risks, and harming ecosystems.

- Ozone is very effective in absorbing terrestrial radiation when it is present in the lower troposphere.
- The largest concentration of GHGs, in the atmosphere, is carbon dioxide. The emission of $CO_2$ comes mainly from fossil fuel combustion (oil, gas and coal).
- Forests and oceans are the sinks for carbon dioxide. Forests use $CO_2$ in their growth. So, deforestation also increases the concentration of $CO_2$.
- The time taken for atmospheric $CO_2$ to adjust to changes in sources to sinks is 20-50 years. It is rising at about 0.5 percent annually.

### POINTS TO PONDER

Climate change is impacting all climatic groups around the world. Can you find out the most vulnerable and the most resilient climatic group vis a vis the emerging climate change crisis?

## Efforts initiated for reducing the emission of GHGs into the atmosphere:

- There are global frameworks and agreements to deal with climate change, such as the Sustainable Development Goals, the UN Framework Convention on Climate Change and the Paris Agreement, Kyoto Protocol etc.

- The most important one among these is the Kyoto protocol, proclaimed in 1997. This protocol went into effect in 2005 and was ratified by 141 nations. Kyoto protocol binded the 35 industrialized countries to reduce their emissions by the year 2012 to 5 percent less than the levels prevalent in the year 1990.

Global experiences have highlighted the need for a collaborative effort to address climate change. Many such initiatives can deliver economic benefits while improving our lives and protecting the environment.

## Life In the Tropical and the Subtropical Region

### Life in the Amazon Basin

**Region:**

- This region lies close to the equator; between 10°N and 10°S.
- Numerous tributaries join the Amazon River to form the Amazon basin (Refer Figure 11.3). The river basin drains portions of Brazil, parts of Peru, Bolivia, Ecuador, Columbia and a small part of Venezuela.

**Climate:**

- Both days and nights are almost equally hot and humid.
- The skin feels sticky. It rains almost everyday.
- The day temperatures are high with very high humidity. At night the temperature goes down, but the humidity is high.

**Forests and Vegetation:**

- The forests are so thick that the dense "roof" created by leaves and branches does not allow the sunlight to reach the ground. The ground remains dark and damp.
- Only shade-tolerant vegetation may grow here. Cash crops like coffee, maize and cocoa are also grown. Orchids, bromeliads grow as plant parasites.

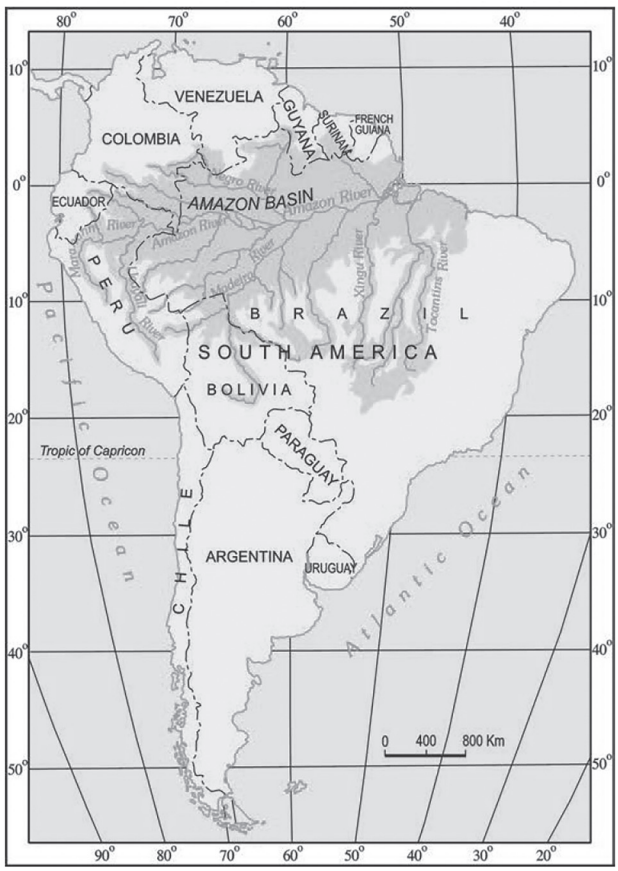



**Figure 11.3: The Amazon Basin**

**Fauna:**

- The rainforest is rich in fauna.
- Birds such as toucans, hummingbirds, macaws are found.
- Animals like monkeys, sloth and ant-eating tapirs are found.
- Various species of reptiles and snakes also thrive in these jungles. Crocodiles, snakes, pythons, anaconda and boa constrictor are some of the species.
- Several species of fishes including the flesh-eating Piranha fish are also found in the river.

**Do You Know?**

When Spanish explorers discovered the Amazon river, they were attacked by a group of local tribes wearing headgear and grass skirts.

These people reminded them of the fierce tribes of women warriors known in the ancient Roman Empire as the Amazons. Hence, it was named the Amazon river.

### People of the Rainforest:

- People grow their food in small areas after clearing some trees in the forest.
- As hunting and fishing are uncertain, the women keep their families alive by feeding them the vegetables they grow. They practice "slash and burn agriculture".
- The staple food is manioc, also known as cassava that grows under the ground like the potato.
- They also eat queen ants and egg sacs.

**Do You Know?**

Bromeliads are special plants that store water in their leaves. Animals like frogs use these pockets of water for laying their eggs

### Changing Scenario:

- Developmental activities in the Amazon Basin are leading to destruction of biologically diverse rainforest. Deforestation (Refer Figure 11.4) is turning lush forests into barren landscapes.

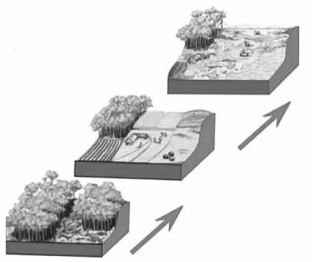


**Figure 11.4: Gradual Destruction of Forests**

## Life in the Ganga-Brahmaputra Basin

### Region:

- The Ganga-Brahmaputra basin (Refer Figure 11.5) lies in the sub-tropical region that is situated between 10°N to 30°N latitudes.
- The tributaries of the river Ganga like the Ghaghra, the Son, the Chambal, the Gandak, the Kosi and the tributaries of Brahmaputra drain this region.

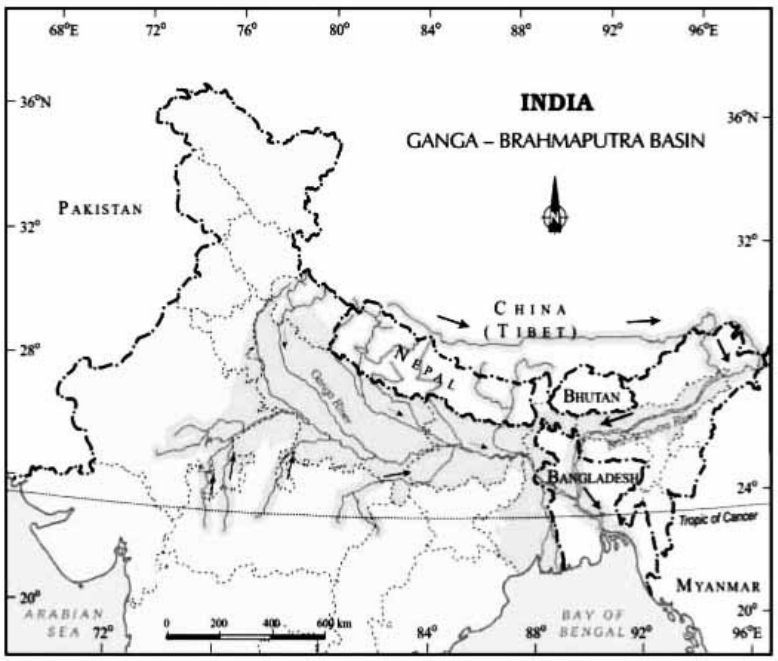



**Figure 11.5: Ganga - Brahmaputra Basin**

### Climate:

- The area is dominated by monsoon climate. The monsoon brings rains from mid-June to mid-September.
- The summers are hot and the winters cool.

**Forests and Vegetation:**

- The soil is fertile, hence agriculture is the main occupation of the people where flat land is available to grow crops.
- The main crop is paddy, and other crops grown are wheat, maize, sorghum, gram and millet.
- Cash crops like sugarcane and jute are also grown. Banana plantations are seen in some areas of the plain.
- In West Bengal and Assam, tea is grown on plantations.
- Silk is produced through the cultivation of silk worms in parts of Bihar and Assam.
- In the mountains and hills, where the slopes are gentle, crops are grown on terraces.

**Flora and Fauna:**

- The vegetation cover of the area varies according to the type of landforms. In the Ganga and Brahmaputra plain tropical deciduous trees grow, along with teak, sal and peepal.
- Thick bamboo groves are common in the Brahmaputra plain.
- The delta area is covered with mangrove forests.

**Additional Information**

In the fresh waters of River Ganga and River Brahmaputra, a variety of dolphin locally called Susu (also called blind dolphin) is found. The presence of Susu is an indication of the health of the river. The untreated industrial and urban wastes with high amounts of chemicals are killing this species.

- In parts of Uttarakhand, Sikkim and Arunachal Pradesh, coniferous trees like pine, deodar and fir can be seen.
- There is a variety of wildlife in the basin. like Elephants, tigers, deer and monkeys. The one-horned rhinoceros is found in the Brahmaputra plain. In the delta area, Bengal tiger and crocodiles are found. Aquatic life abounds in the fresh river waters, the lakes and the Bay of Bengal Sea. The most popular varieties of the fish are the rohu, catla and hilsa.

**Do You Know?**

Terraces are built on steep slopes to create flat surfaces on which crops are grown. The slope is removed so that water does not run off rapidly.

**People of the Basin:**

- The environment plays a dominant role in the distribution of the population. The mountain areas with steep slopes have inhospitable terrain. Therefore less number of people live in the mountain area of the Ganga- Brahmaputra basin.
- The plain area provides the most suitable land for human habitation. The population density of the plains is very high.
- The Ganga-Brahmaputra plain has several big towns and cities such as Allahabad, Kanpur, Varanasi, Lucknow, Patna and Kolkata.

**Life in the Hot Desert - Sahara**

**Region:**

- The Sahara desert is located in the continent of Africa (Refer Figure 11.6), having an area of around 8.54 million sq. km. It is the world's largest desert.
- It touches eleven countries - Algeria, Chad, Egypt, Libya, Mali, Mauritania, Morocco, Niger, Sudan, Tunisia and Western Sahara.

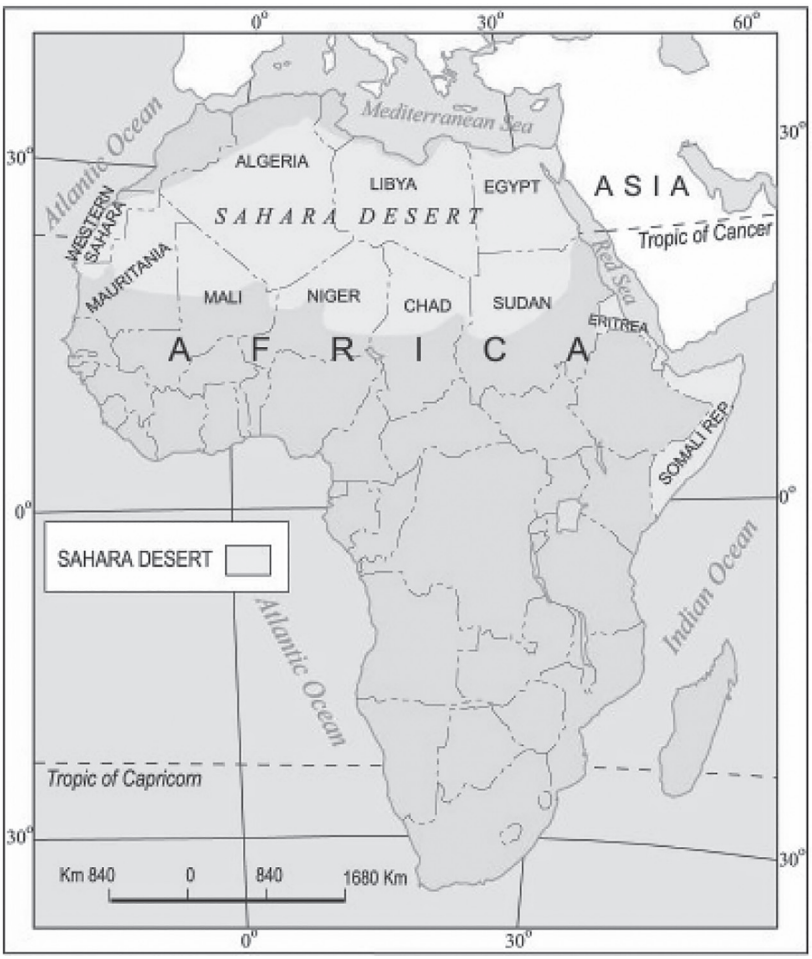



**Figure 11.6 : The Sahara Desert in Africa**

## Climate:

- The climate of the Sahara desert is scorching hot and parch dry.
- It has a short rainy season. The sky is cloudless and clear. The moisture evaporates faster than it accumulates.
- Days are extremely hot. The temperatures during the day may soar as high as 50°C and the nights may be freezing cold with temperatures nearing zero degrees.

## Forests and Vegetation:

- The vegetation here includes cactus, date palms and acacia.
- In some places there are oasis – green islands with date palms surrounding them.
- Crops such as rice, wheat, barley and beans are also grown. Egyptian cotton, which is famous worldwide, is grown here.
- Camels, hyenas, jackals, foxes, scorpions, many varieties of snakes and lizards are the prominent animal species living there.

**Additional Information**

Al Azizia in the Sahara desert, south of Tripoli, Libya recorded the highest temperature of 57.7°C in 1922.

**People:**

- The Sahara desert is inhabited by Bedouins and Tuaregs. These groups are nomadic tribes rearing livestock such as goats, sheep, camels and horses.
- These animals provide them with milk, hides from which they make leather for belts, slippers, water bottles; hair is used for mats, carpets, clothes and blankets.
- They wear heavy robes as protection against dust storms and hot winds.
- The oasis in the Sahara and the Nile Valley in Egypt supports settled population
- The discovery of oil in Algeria, Libya and Egypt is transforming the Sahara desert. Other minerals of importance that are found in the area include iron, phosphorus, manganese and uranium.

**Do You Know?**

Present day Sahara once used to be a lush green plain. Cave paintings in the Sahara desert show that there used to be rivers with crocodiles. Elephants, lions, giraffes, ostriches, sheep, cattle and goats were common animals. But the change in climate has changed it to a very hot and dry region.

**Life in the Cold Desert - Ladakh**

**Region:**

- Ladakh is a cold desert lying in the Great Himalayas (Refer Figure 11.7), on the eastern side of Jammu and Kashmir.
- The Karakoram Range in the north and the Zanskar mountains in the south enclose it.
- Several rivers, including the Indus, flow through Ladakh. The rivers form deep valleys and gorges.

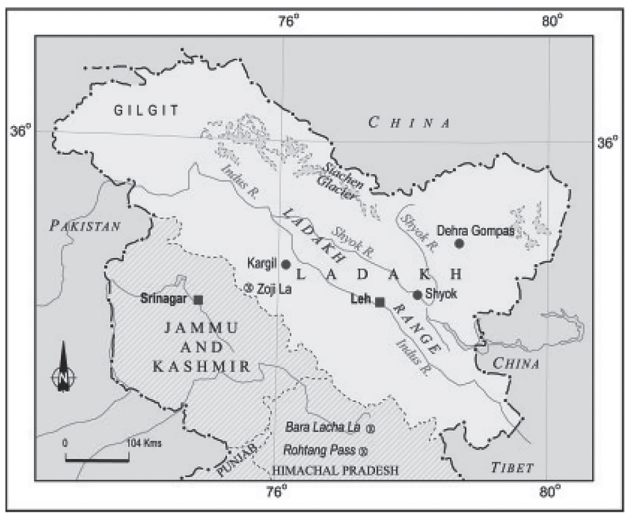



**Figure 11.7: The Cold Desert Ladakh**

**Climate:**

- The altitude in Ladakh varies from about 3,000m to 8,000m with an extremely cold and dry climate. The air at this altitude is very thin.
- The day temperatures in summer are just above zero degrees and the night temperatures well below –30°C.
- There is little rainfall, as low as 10 cm every year, because it lies in the rain shadow area of the Himalayas.

**Additional Information**

Ladakh is also known as Khapa-chan which means snow land.

Drass, one of the coldest inhabited places on earth is located in Ladakh.

**Forests and Vegetation:**

- In this region vegetation is sparse. There are scanty patches of grasses and shrubs.
- Groves of willows and poplars are seen in the valleys.
- During the summers, fruit trees such as apples, apricots and walnuts bloom.
- Several species of birds like Robins, redstarts, Tibetan snowcock, raven and hoopoe are seen in Ladakh.

**Do You Know?**

The Chiru or the Tibetan antelope is an endangered species. It is hunted for its wool known as shahtoosh, which is light in weight and extremely warm.

- The animals of Ladakh are wild goats, wild sheep, and yak. These animals are reared to provide for milk, meat and hides.

**People:**

- The people here are either Muslims or Buddhists.
- Several Buddhists monasteries are present here - Hemis, Thiksey, Shey and Lamayuru.
- In the summer season the people are busy cultivating barley, potatoes, peas, beans and turnips. The climate in winter months is extremely harsh and people keep themselves engaged in festivities and ceremonies.

## Conclusion

In this chapter, we explored Koeppen's climate classification system, delving into the diversity of climates around the world. We also examined life in tropical and subtropical regions, highlighting the unique challenges and biodiversity found in these areas. Finally, we discussed the global implications of climate change, underscoring the urgent need for collective action to address this pressing issue and safeguard our planet's future.

***Glossary:***

- **Equator:** A line notionally drawn on the earth equidistant from the poles, dividing the earth into northern and southern hemispheres and constituting the parallel of latitude 0°.
- **Climate change:** It refers to the long term shifts in temperatures and weather patterns.
- **Global warming:** The long term warming of the planet's overall temperature.
- **Ozone hole:** The depletion of ozone concentration in the stratosphere is called the ozone hole.
- **Tributaries:** These are small rivers that join the main river. The main river along with all its tributaries that drain an area forms a river basin or the catchment area. The Amazon Basin is the largest river basin in the world.
- **Population density:** It means the number of persons that live in one sq. km. of area. For example, the population density of Uttarakhand is 189 while that of West Bengal is 1028.
- **Desert:** It is an arid region characterized by extremely high or low temperatures and has scarce vegetation.

❐❐❐

# 12 Ocean and its Movement

**Bibliography:** The chapter encompasses the summary of **Chapter 5 - Class VI NCERT** (The Earth: Our Habitat), **Chapter 5 - Class VII NCERT** (Our Environment), and **Chapter 12 and Chapter 13 - Class XI NCERT** (Fundamentals of Physical Geography).

## Introduction

As we have studied, the **surface of the earth is a complex zone** consisting of the **lithosphere, atmosphere and hydrosphere** which combinely facilitates the survival of life in the form of **biosphere**. In earlier chapters, we have analysed properties of lithosphere and atmosphere. Now, we will focus on the hydrosphere which encompasses vast expanses of Earth's water bodies, which is a critical component of our planet's dynamic systems. We will further study oceans, the composition and properties of ocean water, and the intricate movements that shape this aquatic domain.

## Hydrosphere

- Hydrosphere consists of **water in all its forms**. We know that Water is a substance composed of the chemical elements hydrogen and oxygen and exists in gaseous, liquid, and solid states.
- The running water in oceans and rivers and in lakes, ice in glaciers, underground water and the water vapour in the atmosphere, all comprise the **hydrosphere** (Refer Figure 12.1).
- In small quantities water appears colourless, but water actually has an intrinsic **blue colour caused by slight absorption of light at red wavelengths**, like we see in the oceans.
- Water is a rare commodity in our solar system. Fortunately, the earth has an abundant supply of water on its surface. Hence, our planet is called the **'Blue Planet'**.

**Do You Know?**

The highest mountain peak Mt. Everest is 8,848 metres above sea level. The greatest depth of 11,022 metres is recorded at Mariana Trench in the Pacific Ocean.

## Ocean Water

### Composition of Water on Earth

- More than **97% of the earth's water is found in the oceans** and is too salty for human use (Refer Figure 12.2). A large proportion of the rest of the water is in the form of **ice sheets** and **glaciers** or under the ground and a very small percentage is available as freshwater for human use.
- Nearly **59 percent** of the water that falls on land returns to the atmosphere through evaporation from over the oceans as well as from other places. The remainder runs-off on the surface, infiltrates into the ground or a part of it becomes glacier.

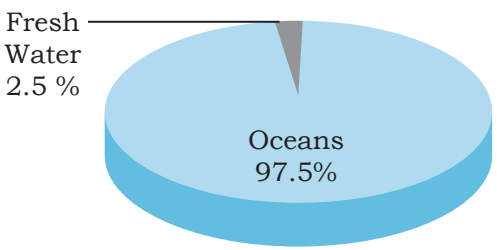



**Figure 12.2: Distribution water**

- The **renewable water on the earth is constant** while the demand is increasing tremendously.

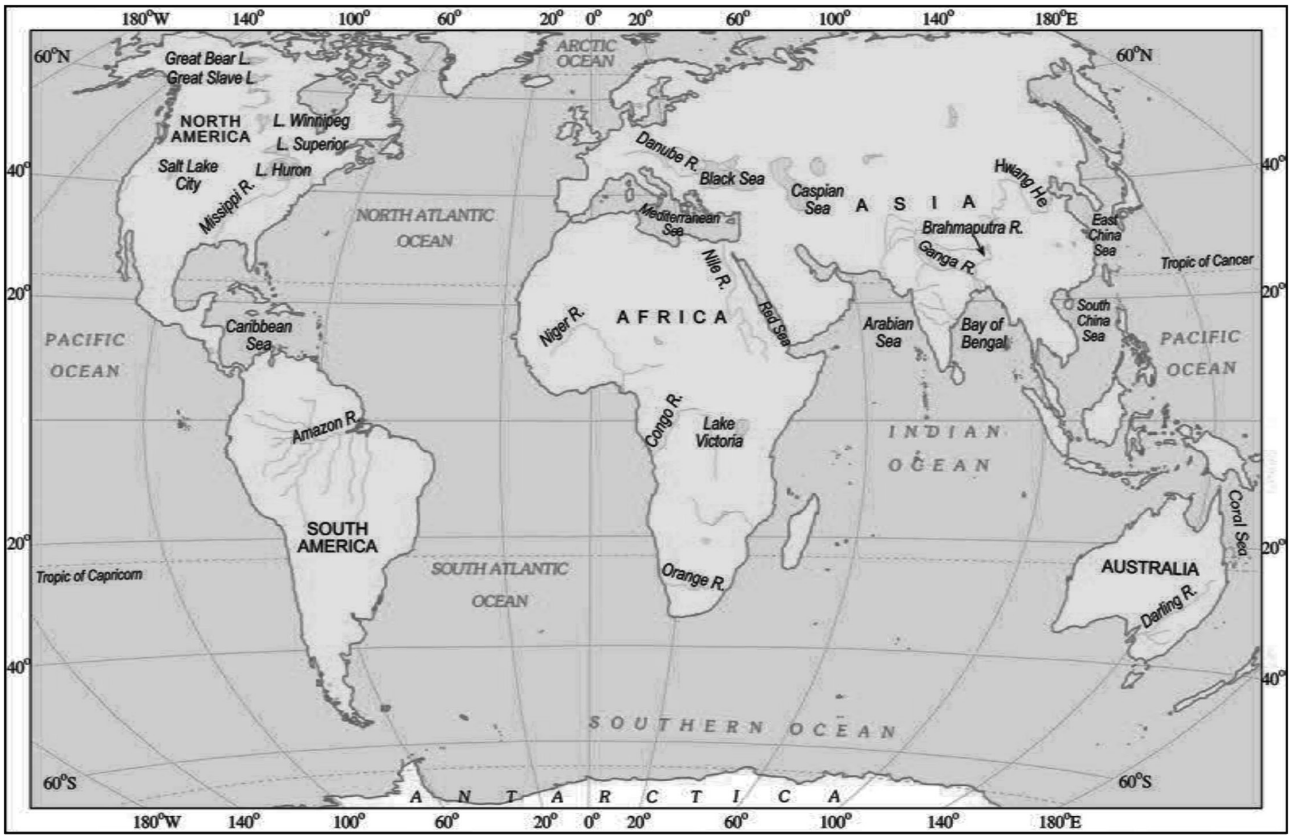



**Figure 12.1: World — Major Seas, Lakes and Rivers**

## The Water Cycle

- The process by which **water continually changes its form** and circulates between oceans, atmosphere and land is known as the **water cycle** (Refer Figure 12.3 and 12.4).
- Water from the oceans is **evaporated** into the form of **water vapour** due to the sun's heat.
- When the water vapour cools down, it **condenses and forms** clouds. From there it may fall on the land or sea in the form of **rain, snow or** sleet.
- *The earth is like a terrarium, which means that the same water that existed centuries ago still exists today.*

| Components | Processes |
|---|---|
| **Water storage in oceans** | ➢ Evaporation Evapotranspiration Sublimation |
| **Water in the atmosphere** | ➢ Condensation Precipitation |
| **Water storage in ice and snow** | ➢ Snowmelt runoff to streams |
| **Surface runoff** | ➢ Stream flow freshwater storage infiltration |
| **Groundwater storage** | ➢ Groundwater discharge springs |

**Figure 12.3: Components and Processes of the Water Cycle**

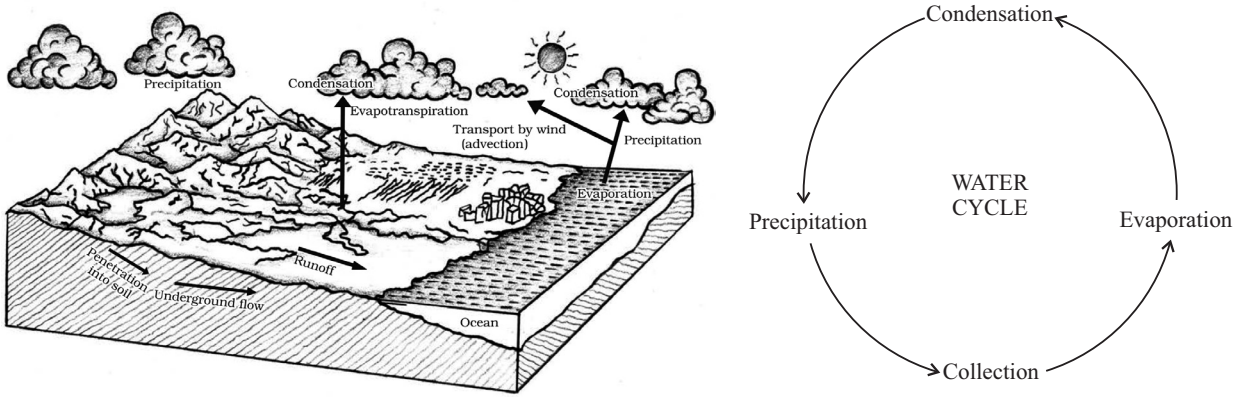



**Figure 12.4: The Water Cycle**

### Major Oceans of the Earth

The oceans are **confined to the great depressions of the earth's outer layer**. The water of the earth are further divided into **five oceans:**

- **The Pacific Ocean:** It is the **largest ocean**, spread over one-third of the earth. **Mariana Trench**, the deepest part of the earth, lies in the Pacific Ocean. The Pacific Ocean is almost circular in shape. Asia, Australia, North and South Americas surround it.
- **The Atlantic Ocean:** it is the **second largest Ocean** in the world. It is **'S' shaped**. It is flanked by the North and South Americas on the western side, and Europe and Africa on the eastern side. The coastline of the Atlantic Ocean is highly indented. This irregular and indented coastline provides an **ideal location for natural harbours and ports.**
- **The Indian Ocean:** The Indian Ocean is the only ocean named after a country, that is, India. The shape of the ocean is almost **triangular**. In the north, it is bound by Asia, in the west by Africa and in the east by Australia.
- **Southern Ocean:** The Southern Ocean **encircles the continent of Antarctica** and extends northward to 60 degrees south Latitude.
- **The Arctic Ocean:** The Arctic Ocean is located within the Arctic Circle and surrounds the North Pole. It is connected with the Pacific Ocean by a narrow stretch of shallow water known as Berring strait. It is bound by the northern coasts of North America and Eurasia.

The **floors** of **the oceans are rugged** with the **world's largest mountain ranges, deepest trenches and the largest plains.** These features are formed by the factors of **tectonic, volcanic and depositional processes.**

## Relief of the Ocean Floor

- A major portion of the **ocean floor** is found between **3-6 km below the sea level.** The 'land' under the ocean floor exhibits complex and varied features as those observed over the land.
- The ocean floors can be further divided into **four major divisions** (Refer Figure 12.5):
  - the Continental Shelf;
  - the Continental Slope;
  - the Deep Sea Plain;
  - the Oceanic Deeps.
- Besides these divisions there are also **major and minor relief features** in the ocean floors like **ridges, hills, sea mounts, guyots, trenches, canyons,** etc.

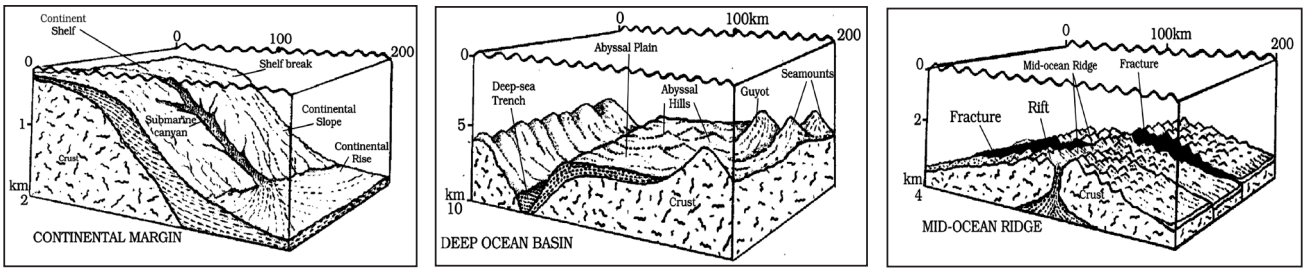



**Figure 12.5: Relief features of ocean floors**

**Table 12.1: Major Divisions of the Ocean Floors**

| | |
|---|---|
| **Continental Shelf** | ➢ The continental shelf is the **extended margin of each continent** occupied by relatively **shallow seas and gulfs**.<br>➢ It is the **shallowest part of the ocean** showing an **average gradient of 1° or even less**.<br>➢ The **shelf typically ends at a very steep slope**, called the **shelf break**. The average width of continental shelves is **about 80 km**. The shelves are almost absent or very narrow along some of the margins like the coasts of Chile, the west coast of Sumatra, etc.<br>➢ On the contrary, the **Siberian shelf in the Arctic Ocean**, **the largest in the world**, stretches to **1,500 km in width.**<br>➢ The **depth of the shelves also varies**. It may be as shallow as 30 m in some areas while in some areas it is as deep as 600 m.<br>➢ The continental shelves are covered with **variable thicknesses** of sediments brought down by rivers, glaciers, wind, from the land and distributed by waves and currents.<br>➢ **Massive sedimentary deposits** received over a long time by the continental shelves, become the **source of fossil fuels**. |
| **Continental Slope** | ➢ The continental slope **connects the continental shelf and the ocean basins.**<br>➢ It begins where the bottom of the **continental shelf sharply drops off into a steep slope**.<br>➢ The gradient of the slope region varies between 2°-5°.<br>➢ The depth of the slope region varies between 200 m and 3,000 m.<br>➢ The slope boundary indicates the **end of the continents**.<br>➢ Canyons and trenches are observed in this region. |
| **Deep Sea Plain** | ➢ Deep sea plains are gently **sloping areas of the ocean basins**.<br>➢ These are the **flattest and smoothest regions of the world**.<br>➢ The depths vary between **3,000 and 6,000 m**.<br>➢ These plains are **covered with fine-grained sediments like clay and silt**. |
| **Oceanic Deeps or Trenches** | ➢ These areas are the **deepest parts of the oceans**.<br>➢ The trenches are **relatively steep sided, narrow basins**.<br>➢ They are some **3-5 km deeper** than the surrounding ocean floor.<br>➢ They **occur at the bases of continental slopes and along island arcs** and are **associated with active volcanoes and strong earthquakes**. That is why they are very **significant in the study of plate movements**.<br>➢ As many as 57 deeps have been explored so far; of which 32 are in the Pacific Ocean; 19 in the Atlantic Ocean and 6 in the Indian Ocean. |

### Minor Relief Features

**Table 12.2: Minor Relief Features of the Ocean Floors**

| | |
|---|---|
| **Mid-Oceanic Ridges** | ➢ A mid-oceanic ridge is **composed of two chains of mountains** separated by a large depression.<br>➢ The mountain ranges can have peaks as high as 2,500 m and some even **reach above the ocean's surface**.<br>➢ For eg: Iceland, a part of the mid- Atlantic Ridge. |
| **Seamount** | ➢ It is a **mountain with pointed summits**, rising from the seafloor that does not reach the surface of the ocean.<br>➢ Seamounts are **volcanic** in origin.<br>➢ These can **be 3,000-4,500 m** tall.<br>➢ For eg: the Emperor seamount, an extension of the Hawaiian Islands in the Pacific Ocean. |
| **Submarine Canyons** | ➢ These are **deep valleys,** some comparable to the Grand Canyon of the Colorado river.<br>➢ They are sometimes **found cutting across the continental shelves and slopes**, often extending from the mouths of large rivers.<br>➢ For eg: The Hudson Canyon is the best known submarine canyon in the world. |
| **Guyots** | ➢ It is a **flat topped seamount.**<br>➢ They show evidence of **gradual subsidence** through stages to become flat topped submerged mountains.<br>➢ It is estimated that more than 10,000 seamounts and guyots exist in the Pacific Ocean alone. |
| **Atoll** | ➢ These are **low islands found in the tropical oceans** consisting of coral reefs surrounding a central depression.<br>➢ It may be a part of the sea (lagoon), or sometimes form enclosing a body of fresh, brackish, or highly saline water. |

**POINTS TO PONDER**

There are underlying unity and divergences between the physiography of land and ocean . Can you identify them? Can you think of the factors shaping the ocean floor physiography and find the differences, if any , when compared to landforms.

## Temperature of Ocean Waters

### Factors Affecting Temperature of Ocean Waters

- **Latitude:** The **temperature of surface water decreases from the equator towards the poles** because the amount of insolation decreases poleward (Refer Figure 12.6).
- **Unequal distribution of land and water:** The **oceans in the northern hemisphere receive more heat** due to their contact with larger extent of land than the oceans in the southern hemisphere.
- **Prevailing wind:** The **winds blowing from the land towards the oceans drive warm surface water away from the coast** resulting in the upwelling of cold water from below. It results in the **longitudinal variation in the temperature.** Contrary to this, the onshore winds pile up warm water near the coast and this raises the temperature.
- **Ocean currents: Warm ocean currents raise the temperature in cold areas while the cold currents decrease the temperature in warm ocean areas.** For example, the Gulf stream (warm current) raises the temperature near the eastern coast of North America and the West Coast of Europe, while the Labrador current (cold current) lowers the temperature near the north-east coast of North America.

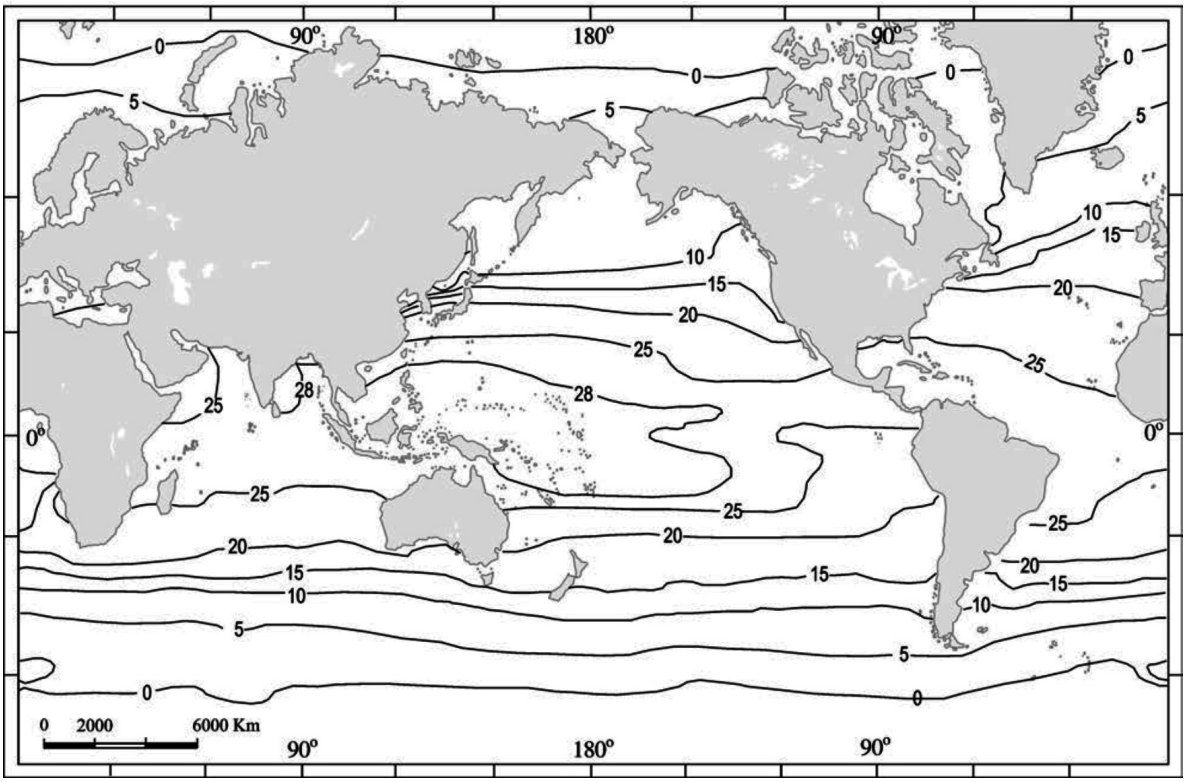



**Figure 12.6: Spatial pattern of surface temperature of the Oceans**

All these factors influence the temperature of the ocean currents. Ocean waters get heated up by solar energy just as land. The process of **heating and cooling of the oceanic water is slower than land**. The enclosed seas in the low latitudes record relatively higher temperature than the open seas; whereas the enclosed seas in the high latitudes have lower temperature than the open seas.

## Vertical Distribution of Temperature in Oceans

- In oceans, the **temperature decreases with increasing depth.** This can be understood by the **temperature-depth profile.**
- The temperature **falls very rapidly up to the depth of 200 m** and thereafter, the rate of decrease of temperature is slowed down.
- The profile shows a boundary region between the surface waters of the ocean and the deeper layers.
- The **boundary usually begins around 100 - 400 m below the sea surface** and **extends several hundred metres downward.**

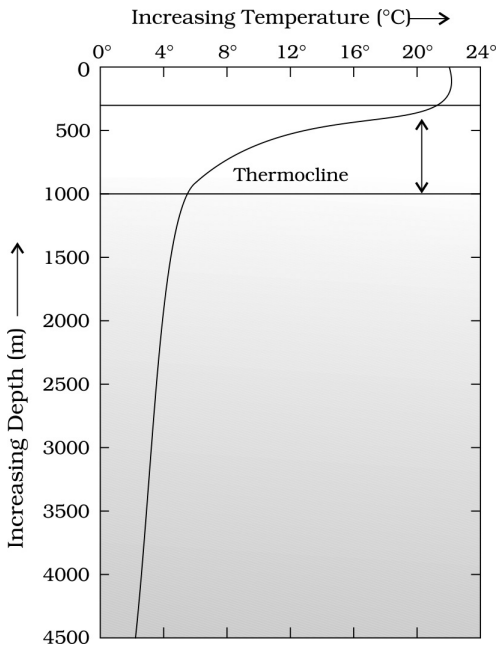



**Figure 12.7: Thermocline**

- This boundary region, from where there is a **rapid decrease of temperature,** is called the **thermocline** (Refer Figure 12.7).
- About **90 percent of the total volume of water is found below the thermocline** in the deep ocean. In this zone, **temperatures approach 0° C.**

- The temperature structure of oceans over middle and low latitudes can be described as a **three-layer system from surface to the bottom.**
  - **First Layer:** The first layer represents the **top layer of warm oceanic water** and it is about 500 m thick with temperatures ranging between **20° and 25° C.** This layer, within the tropical region, is present throughout the year but in mid latitudes it develops only during summer.
  - **Second Layer:** The second layer called the **thermocline layer** lies below the first layer and is characterised by **rapid decrease in temperature with increasing depth.** The thermocline is **500-1,000 m** thick.
  - **Third Layer:** The third layer **is very cold and extends upto the deep ocean floor.** In the Arctic and Antarctic circles, the surface water temperatures are close to 0° C and so the **temperature change with the depth is very slight.** Here, **only one layer of cold water exists,** which extends from surface to deep ocean floor.

**POINTS TO PONDER**

Do you know about the sinking of the Titanic ship? The icebergs which are in abundance in the Atlantic were the prime reason for its disaster. On the other hand we find relatively very limited occurrences of icebergs in the pacific ocean . Why do you think the icebergs are found in abundance in the Atlantic ocean vis a vis the Pacific?

**Temperature Variations in the Ocean Waters**

- The **average temperature of surface water of the oceans** is about 27°C and it **gradually decreases from the equator towards the poles.**
- The **rate of decrease in temperature with increasing latitude** is generally **0.5°C per latitude.**
- The average temperature is around **22°C at 20° latitudes, 14° C at 40° latitudes and 0° C near poles.**
- The **oceans in the northern hemisphere record relatively higher temperatures** than in the southern hemisphere.
- The **highest temperature is not recorded at the equator but slightly towards north of it.**
- The **average annual temperatures** for the northern and southern hemisphere are around **19° C and 16° C respectively.**
- This variation is due to the **unequal distribution of land and water** in the northern and southern hemispheres.
- The **maximum temperature of the oceans is always at their surfaces** because they directly receive the heat from the sun and the **heat is transmitted to the lower sections** of the oceans through the process of **convection.**

## Salinity of Ocean Waters

- We have read earlier that all the waters on earth contain **dissolved mineral salts.**
- **Salinity** is the **total content of dissolved salts in seawater.** It is calculated as the amount of salt (in gm) dissolved in 1,000 gm (1 kg) of seawater.
- It is usually expressed **as parts per thousand (o/oo) or ppt.**
- Salinity of **24.7 o/oo** is the upper limit to demarcate **'brackish water'.**

**Do You Know?**

Salinity is the amount of salt in grams present in 1000 grams of water. The average salinity of the oceans is 35 parts per thousand.

### Factors affecting ocean salinity

- The salinity of water in the surface layer of oceans depends on **evaporation and precipitation.**
- Surface salinity is greatly influenced in coastal regions by the **freshwater flow from rivers,** and in polar regions by the processes of **freezing and thawing of ice.**

- **Wind** also influences salinity of an area by **transferring water 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 water in an area.**

### Horizontal Distribution of Salinity

- The salinity for the ocean ranges between **33 o/oo and 37 o/oo.** In the **land-locked Red Sea**, it is as high as 41 o/oo, while in the estuaries and the Arctic, the salinity fluctuates from 0-35 o/oo (Refer Figure 12.8).
- In **hot and dry regions**, where evaporation is high, the salinity reaches 70 o/oo.
- The salinity variation in the **Pacific Ocean** is mainly due to its shape and larger areal extent.
- Salinity **decreases** from 35 o/oo - 31 o/oo in the **western parts of the northern hemisphere** because of the **influx of melted water from the Arctic region.** In the same way, after **15° - 20° south**, it **decreases** to 33 o/oo .
- The average salinity of the **Atlantic Ocean** is around 36 o/oo.
- The **highest salinity** is recorded **between 15° and 20° latitudes. Maximum** salinity (37 o/oo) is observed between **20° N and 30° N and 20° W - 60° W.** It gradually **decreases towards the north.**

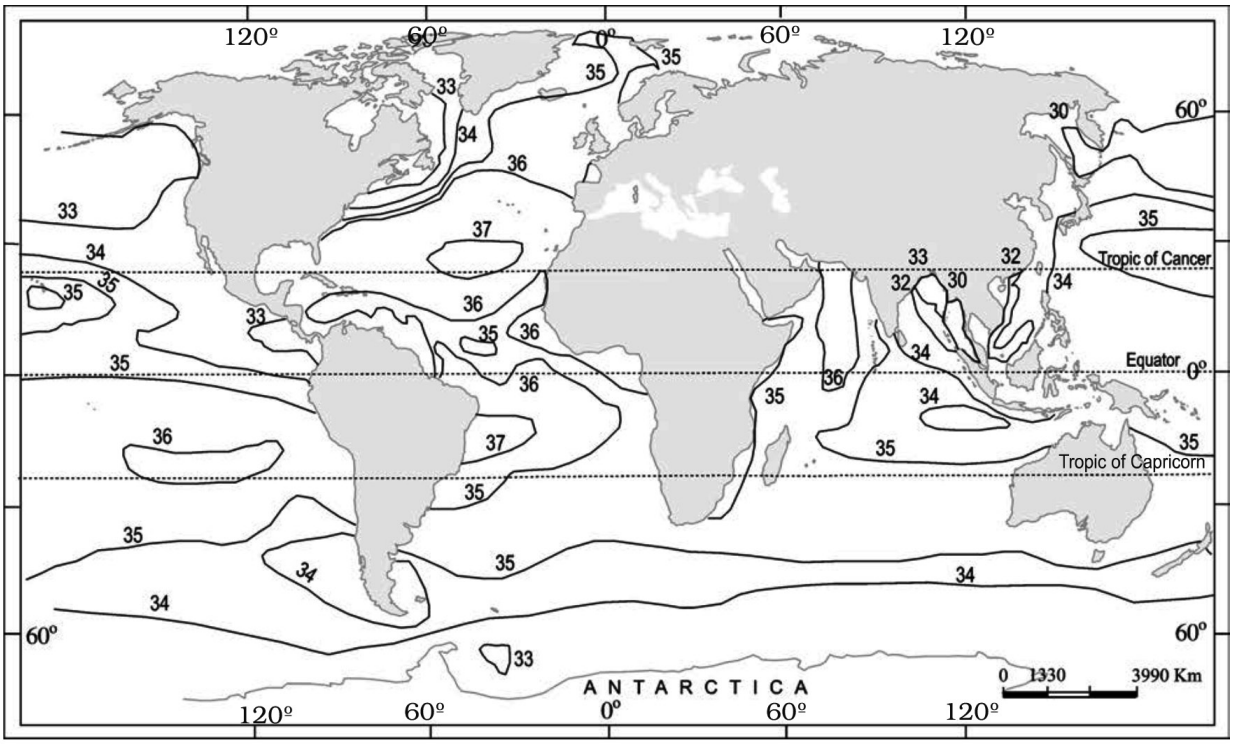



**Figure 12.8: Salinity Distribution in Oceans**

### Vertical Distribution of Salinity

- **Salinity changes with depth**, but the way it changes depends upon the location of the sea.
- Salinity at the **surface increases by the loss of water to ice or evaporation**, or **decreased by the input of fresh waters**, such as from the rivers.
- **Deep into the water, salinity is almost fixed** because water is neither lost nor 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 increases with depth and there is a distinct zone called the **halocline, where salinity increases sharply.**
- If other factors are kept constant, **increasing salinity of seawater causes its density to increase.** High salinity seawater, generally, sinks below the lower salinity water. This leads to **stratification by salinity.**

### Salinity of Water in Various Seas:

- **The North Sea records higher salinity** due to more saline water brought by the North Atlantic Drift.
- **The Baltic Sea records low salinity** due to the influx of river waters in large quantities.
- **The Mediterranean Sea records higher salinity** due to high evaporation.

**Do You Know?**

The Dead sea in Israel has a salinity of 340 grams per litre of water. Swimmers can float in it because the increased salt content makes it dense.

- Salinity is, however, **very low in Black Sea** due to enormous freshwater influx by rivers.
- The average salinity of the **Indian Ocean** is 35 o/oo. The **low salinity trend is observed in the Bay of Bengal** due to influx of river water. On the contrary, the **Arabian Sea shows higher salinity** due to high evaporation and low influx of fresh water.

## Ocean Water Circulation

### Movement of Ocean Water

- Until now we have understood that ocean water is dynamic, it keeps moving continuously in horizontal as well as vertical directions.
- The physical characteristics of ocean water like **temperature, salinity, density** and the external forces like of the **sun, moon** and the **winds influence its movement.**

**Do You Know?**

The areas having Highest salinity are:

**Lake Van** in Turkey (330 o/oo);

**Dead Sea** (238 o/oo);

**Great Salt Lake** (220 o/oo)

- The horizontal and vertical motions are common in ocean water bodies.
- **Horizontal motions** are of ocean currents and waves. Water moves 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, in the form of tides, due to the attraction of the sun and the moon.
- The upwelling of cold water from subsurface and the sinking of surface water are also forms of vertical motion of ocean water.

The movements that occur in oceans can be categorised as **waves**, **tides and currents**. Let us examine each of these in detail:

### Waves

- Waves are the energy that move across the ocean surface. Waves are formed when **winds scrap across the ocean surface.**
- Waves slow down, as it approaches the beach, due to friction between water and the sea floor.

**Additional Information**

Tsunami is a Japanese word that means "Harbour waves" as the harbours get destroyed whenever there is a tsunami.

The first indication that a tsunami is approaching is the rapid withdrawal of water from the coastal region, followed by destructive waves.

- Wave's **size and shape** reveal its origin. **Steep waves** are young and formed by local wind, whereas **slow and steady** waves originate from far away places, even from another hemisphere.
- An **earthquake**, a **volcanic eruption** or **underwater landslides** can shift large amounts of ocean water. As a result a **huge tidal wave called tsunami is formed**. A tsunami may be as high as 15m. The **largest tsunami** ever measured was **150 metres** high. These waves travel at a speed of more than 700 km per hour.

### Characteristics of waves:

- **Wave crest and trough:** The highest and lowest points of a wave are called the crest and trough respectively (Refer Figure 12.9).
- **Wave Height:** It is the vertical distance from the bottom of a trough to the top of a crest of a wave.
- **Wave Amplitude:** It is one-half of the wave height.
- **Wave Period:** It is merely the time interval between two successive wave crests or troughs as they pass a fixed point.
- **Wavelength:** It is the horizontal distance between two successive crests.
- **Wave Speed:** It is the rate at which the wave moves through the water, and is measured in knots.

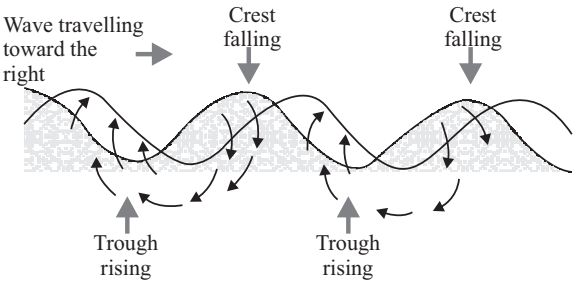



**Figure 12.9: Motion of waves and water molecules**

- **Wave Frequency:** It is the number of waves passing a given point during a one second time interval.

### Tsunami - The Earth's Pandemonium

- On **December 26, 2004**, Tsunami wave caused widespread destruction in the Indian ocean. The wave was the **result of the earthquake** that had its **epicentre close to the western boundary of Sumatra.** The magnitude of the earthquake was 9.0 on the Richter scale. As the **Indian plate went under the Burma plate**, there was a **sudden movement of the sea floor**, causing the earthquake. The ocean floor was displaced by about 10 – 20m and **tilted in a downward direction**. A **huge mass of ocean water flowed to fill in the gap** that was being created by the displacement. This marked the **withdrawal of the water mass from the coastlines of the landmasses in south and southeast Asia**. After thrusting off the Indian plate below the Burma plate, the **water mass rushed back towards the coastline**. Tsunami travelled at a speed of about **800 km. per hour** and washed away some of the islands in the Indian ocean. The **Indira point in the Andaman and Nicobar** islands that marked the southernmost point of India got completely submerged.
- While the **earthquake cannot be predicted** in advance, **it is possible to give a three-hour notice of a potential tsunami**. Such early warning systems are in place across the Pacific ocean, but not in the Indian Ocean. Tsunamis are rare in the Indian Ocean as the seismic activity is less as compared to the Pacific.

### Tides

- The **rhythmic rise and fall of ocean water twice in a day** is called a **tide**. The **strong gravitational pull** (Refer Figure 12.10) **exerted by the sun and the moon** on the earth's surface causes the tides.
- Movement of water caused by **meteorological effects** (winds and atmospheric pressure changes) are called **surges.**
- The **water of the earth closer to the moon gets pulled under the influence of the moon's gravitational force** and causes **high tide**.

- 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.

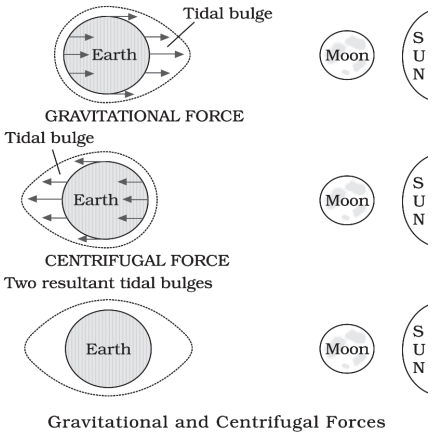



**Figure 12.10: Forces acting on Tides**

## Types of Tides:

- **Semi-diurnal tide:** This features two high tides and two low tides each day. The successive high or low tides are of the same height.
- **Diurnal tide:** There is only one high tide and one low tide during every day. The successive high and low tides are approximately of the same height.
- **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.

## Tides based on Sun, Moon and Earth Positions

- **Spring tides:** 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 (Refer Figure 12.11) and they occur twice a month, one during the full moon period and another during the new moon period.
- **Neap tides:** A neap tide is a type of tide that occurs when the gravitational pull of the moon is perpendicular to that of the sun, resulting in lower high tides and higher low tides. It typically happens during the first and third quarters of the moon, resulting in minimal tidal variation
- Further, once in a month, when the moon's orbit is closest to the earth **(perigee)**, unusually high and low tides occur. 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.

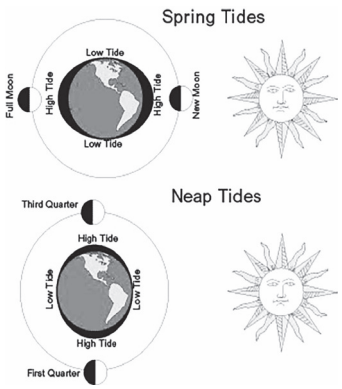



**Figure 12.11: Spring Tide and Neap Tide**

- Similarly, when the earth is closest to the sun **(perihelion)**, around **3rd January** each year, tidal ranges are also much greater. When the earth is farthest from the sun **(aphelion)**, around **4th July** each year, tidal ranges are much less than average.

**POINTS TO PONDER**

Some places on earth experience more than two tides within 24 hours. Find out some examples of such places. Can you identify the reasons for the same?

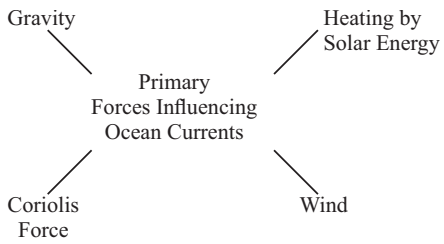
- The time between the high tide and low tide, when the water level is falling, is called the **ebb**. The time between the low tide and high tide, when the tide is rising, is called the **flow or flood**.

## Significance of Tides

- Since tides are caused by the earth-moon-sun positions, tides can be predicted well in advance. This helps the navigators and fishermen to plan their activities.
- Tides are also helpful in desilting the sediments and in removing polluted water from river estuaries. They are used to generate electrical power.

## Currents

- The streams of water flowing constantly on the ocean surface in definite directions are called **ocean currents**.
- **The primary forces that influence the currents are:** (i) heating by solar energy; (ii) wind; (iii) gravity; (iv) coriolis force.
- Heating by **solar energy** near the equator causes expansion of water which creates a slight gradient causing water to flow down the slope.
- Further, **wind** pushes the ocean water to move and **gravity** pulls the water down the pile and creates gradient variation.
- Subsequently, the **Coriolis force** causes the water to move to the right in the northern and to the left in the southern hemisphere, creating circular movements of water in the form of **gyres**.




## Characteristics of Ocean Currents:

- Currents are referred to by their **"drift"**. Drift is measured in terms of knots.
- Usually, the currents are strongest near the surface and decrease its strength or speed with depth.
- Differences in water density affect **vertical mobility** of ocean currents. Water, with high salinity or cold in nature is denser, hence tends to sink.

## Types of Ocean Currents:

- **Based on Depth:**
  - **Surface Currents:** These constitute about **10 percent** of all the water in the ocean, these waters are the **upper 400 m of the ocean.**
  - **Deep Water Currents:** These make up the other **90 percent** of the ocean water. These waters **move around the ocean basins due to variations in the density and gravity.**
- **Based on Temperature:**
  - **Warm Ocean Currents:**
    - Generally, they originate near the equator and move towards the poles.
    - They are usually observed on the **east coast of continents in the low and middle latitudes** (true in both hemispheres).
    - In the northern hemisphere they are found on the **west coasts in high latitudes.**
  - **Cold Ocean Currents:**
    - The cold currents carry water from polar or higher latitudes to tropical or lower latitudes.
    - These currents are usually found on the **west coast of the continents in the low and middle latitudes** (true in both hemispheres) and on the **east coast in the higher latitudes** in the Northern Hemisphere (Refer Fig. 12.12).

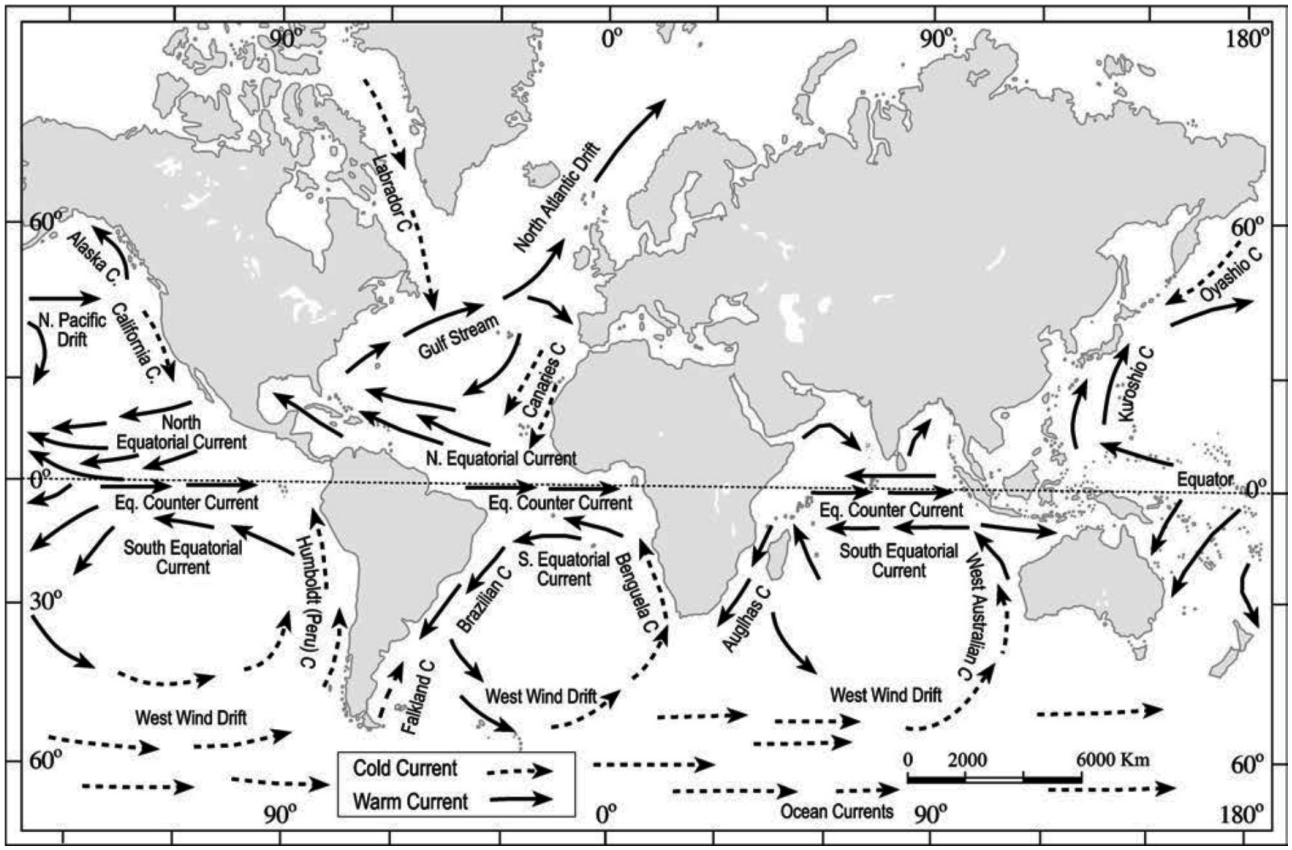



**Figure 12.12: Major Ocean Currents of the World**

### Effects of Ocean Currents

- The ocean current influences the temperature conditions of the area. For example, coasts with cold currents, like west coasts of continents in tropical and subtropical regions, experience low temperatures with signs of aridity. Similarly, west coasts of the continents in the middle and higher latitudes are bordered by warm waters, which experience a distinct marine climate with cool summers and mild winters.
- Further, the areas where the warm and cold currents meet provide the best fishing grounds of the world. For example, seas around Japan and the eastern coast of North America are such examples.
- The areas where a warm and cold current meet also experience foggy weather making it difficult for navigation.

## Conclusion

This chapter has provided a comprehensive overview of the hydrosphere, focusing on the vast and dynamic world of the ocean. We have analysed the key factors influencing ocean movement, including tides, currents, and wind-driven processes, highlighting their crucial roles in shaping our planet's climate and ecosystems. Understanding the intricate dynamics of the ocean is essential for appreciating its profound impact on Earth's environment and sustaining life as we know it.

***Glossary:***

- **Lithosphere:** The lithosphere is the solid, outer part of Earth. The lithosphere includes the brittle upper portion of the mantle and the crust, the outermost layers of Earth's structure. It is bounded by the atmosphere above and the asthenosphere (another part of the upper mantle) below.
- **Atmosphere:** An atmosphere is made of the layers of gases surrounding a planet or other celestial body. Earth's atmosphere is composed of about 78% nitrogen, 21% oxygen, and one percent other gases.
- **Hydrosphere:** It is the total amount of water on a planet. The hydrosphere includes water that is on the surface of the planet, underground, and in the air. A planet's hydrosphere can be liquid, vapour, or ice. On Earth, liquid water exists on the surface in the form of oceans, lakes, and rivers.
- **Biosphere:** The biosphere is a global ecosystem made up of living organisms (biota) and the nonliving (abiotic) factors that provide them with energy and nutrients. The biosphere is a narrow zone on the surface of the earth where soil, water, and air combine to sustain life. Life can only occur in this zone.
- **Relief:** 'Relief' is the term used for the differences in height from place to place on the land's surface and it is greatly affected by the underlying geology. Relief relies on the hardness, permeability and structure of a rock.
- **Salinity:** Salinity is the dissolved salt content of a body of water. It is a strong contributor to conductivity and helps determine many aspects of the chemistry of natural waters and the biological processes within them.
- **Waves:** Ocean Waves are disturbances in the surface of the ocean. They can be created by wind, gravity, or other displacements of water.
- **Tides:** Tides are very long-period waves that move through the ocean in response to the forces exerted by the moon and sun. Tides originate in the ocean and progress toward the coastlines where they appear as the regular rise and fall of the sea surface.
- **Currents:** An ocean current is a continuous, directed movement of seawater generated by a number of forces acting upon the water, including wind, the Coriolis effect, breaking waves, cabbeling, and temperature and salinity differences.
- **Terrarium:** It is an artificial enclosure for keeping small house plants.

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# 13 Ecosystem

**Bibliography:** This Chapter encompasses a summary of Chapter 12 - XII NCERT (Biology).

## Introduction

- An ecosystem is a **functional unit of nature,** where living organisms interact among themselves and with the surrounding physical environment. Ecosystem varies greatly in size from a small pond to a large forest or a sea. Many ecologists regard the entire **biosphere as a global ecosystem,** as a composite of all local ecosystems on Earth. Since this system is too much big and complex, it is convenient to divide it into two basic categories, namely:
  - **Terrestrial ecosystems:** Forest, grassland and desert.
  - **Aquatic ecosystems:** Pond, lake, wetland, river and estuary.
- Crop fields and aquariums form man-made ecosystems. In this chapter we will look at the structure of the ecosystem, the input (matter and energy), transfer of matter and energy (food chain/web, nutrient cycling) and the output (degradation and energy loss). With that we will eventually look at the relationships – cycles, chains, webs – that are created as a result of these matter and energy flows within the system and their inter- relationship.

## Ecosystem - Structure and Function

- The **flow of energy** takes place within various components of the environment i.e. abiotic and biotic which affect each other and their surroundings.
- **Interaction of biotic and abiotic components** result in a physical structure that is the characteristic for each type of ecosystem.
- Identification and enumeration of flora and fauna species of an ecosystem gives its **species composition**.

### Additional Information

**Stratification:** Vertical distribution of different species occupying different levels is called stratification. For example, trees occupy the top vertical strata or layer of a forest, shrubs occupy the second and herbs and grasses occupy the bottom layers.

- The components of the ecosystem are seen to function as a unit when we consider the following aspects: (i) Productivity; (ii) Decomposition; (iii) Energy flow; and (iv) Nutrient cycling.
- Let us take a small **pond** to understand the ethos of an aquatic ecosystem. This is fairly a self-sustainable unit that explains even the complex interactions that exist in an aquatic ecosystem. A pond is a shallow water body in which all the four basic components of an ecosystem are well exhibited:
  - **Abiotic Component:** It includes **water** with all the **dissolved inorganic and organic substances** and the rich **soil** deposit at the bottom of the pond. The solar input, the cycle of temperature, day-length and other climatic conditions regulate the rate of function of the entire pond.

- **Autotrophic Components:** It includes the **phytoplankton**, some algae and the floating, submerged and marginal plants found at the edges.
- **Consumers:** It includes the **zooplankton**, the free swimming and bottom dwelling organisms.
- **Decomposers:** It includes the fungi, bacteria and flagellates especially abundant in the bottom of the pond.
- This system performs all the functions of any ecosystem and of the biosphere as a whole, i.e., conversion of inorganic into organic material with the help of the radiant energy of the sun by the autotrophs; consumption of the autotrophs by heterotrophs; decomposition and mineralisation of the dead matter to release them back for reuse by the autotrophs. These events are repeated over and over again.
- There is **unidirectional movement of energy** towards the higher trophic levels and its dissipation and loss as heat to the environment.

**POINTS TO PONDER**

A lot has been documented over the role of ecosystems and ecology in shaping the life of living organisms which is true essentially. But do you think that the living beings are a mere recipient from the ecosystem? Do you think these organisms have a role to play in the formation and sustenance of ecosystems? If yes, what are the means and methods through which such symbiotic relationship is maintained?

## Productivity

- A constant input of solar energy is the basic requirement for any ecosystem to function and sustain.
- **Productivity:** The rate of biomass production is called productivity. It is expressed in terms of **g $m^{-2}$ $yr^{-1}$ or (kcal $m^{-2}$) $yr^{-1}$** to compare the productivity of different ecosystems. It can be divided into **Gross Primary Productivity (GPP) and Net Primary Productivity (NPP) (Refer Table 13.1)**.

**Do You Know**

Primary productivity varies in different types of ecosystems because it depends on the plant species inhabiting a particular area and on a variety of environmental factors, availability of nutrients and photosynthetic capacity of plants.

The annual net primary productivity of the whole biosphere is approximately 170 billion tons (dry weight) of organic matter. Of this, despite occupying about 70% of the surface, the productivity of the oceans is only 55 billion tons and the rest is on land.

- **Primary Productivity:** It is the amount of biomass or organic matter produced per unit area over a time period by plants during **photosynthesis**. It is expressed in terms of **weight (gm$^{-2}$) or energy (kcal m$^{-2}$)**.
- **Secondary Productivity:** It is the rate of formation of new organic matter by consumers.

**Table 13.1: Difference between GPP and NPP**

| Gross Primary Productivity (GPP) | Net Primary Productivity (NPP) |
|---|---|
| ✤ Gross primary productivity of an ecosystem is the rate of production of organic matter during photosynthesis.<br>✤ A considerable amount of GPP is utilised by plants in respiration. | ✤ Net primary productivity is the available biomass for the consumption to heterotrophs (herbivores and decomposers).<br>✤ Gross primary productivity minus respiration losses (R), is the net primary productivity (NPP).<br>**NPP = GPP – R** |

## Decomposition

- Decomposers break down complex organic matter into inorganic substances like carbon dioxide, water and nutrients and the process is called **decomposition**.

> The earthworm is referred to as the farmer's 'friend' because they help in the breakdown of complex organic matter as well as in loosening of the soil.

- Dead plant remains such as leaves, bark, flowers and dead remains of animals, including faecal matter, constitute **detritus**, which is the raw material for decomposition.
- The **important steps in the process of decomposition** are:
  - **Fragmentation:** By the process of fragmentation, detritivores (e.g. earthworm) break down detritus into smaller particles.
  - **Leaching:** By the process of leaching, water soluble inorganic nutrients go down into the soil horizon and get precipitated as unavailable salts.
  - **Catabolism:** By the process of catabolism, bacterial and fungal enzymes degrade detritus into simpler inorganic substances.
  - **Humification:** It leads to accumulation of a dark coloured amorphous substance called humus that is highly resistant to microbial action and undergoes decomposition at an extremely slow rate. Being colloidal in nature it serves as a reservoir of nutrients.

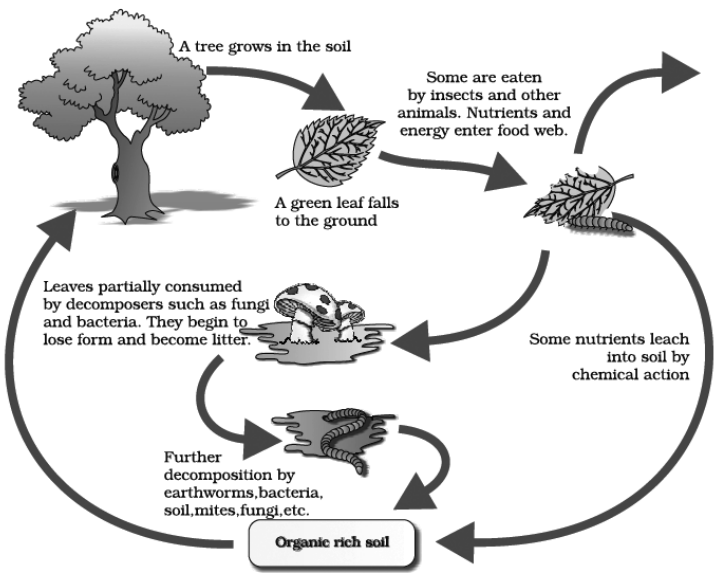



**Figure 13.1: Decomposition cycle in a terrestrial ecosystem**

  - **Mineralisation:** The humus is further degraded by some microbes and release of inorganic nutrients occurs by the process known as mineralisation (Refer Figure 13.1).
- Humification and mineralisation occur during decomposition in the soil.
- Decomposition is largely an **oxygen-requiring process**.
- The rate of decomposition is controlled by chemical composition of detritus and climatic factors.
  - In a particular climatic condition, decomposition rate is slower if detritus is rich in lignin and chitin, and quicker, if detritus is rich in nitrogen and water-soluble substances like sugars.

> **Note:** All the above steps in decomposition operate simultaneously on the detritus.

  - Temperature and soil moisture are the most important climatic factors that regulate decomposition through their effects on the activities of soil microbes.
  - Warm and moist environments favour decomposition whereas low temperature and anaerobiosis inhibit decomposition resulting in build up of organic materials.

## Energy Flow

- Except for the deep-sea hydro-thermal ecosystem, the sun is the only source of energy for all ecosystems on Earth. All organisms are dependent for their food on producers, either directly or indirectly. Thus, the flow of energy is unidirectional i.e. from the sun to producers and then to consumers as per the First Law of Thermodynamics.

**Photosynthetically Active Radiation (PAR):**

Of the incident solar radiation less than 50% of it is photosynthetically active radiation (PAR).

Plants and photosynthetic bacteria (autotrophs), fix Sun's radiant energy to make food from simple inorganic materials.

Plants capture only 2-10 % of the PAR and this small amount of energy sustains the entire living world.

- Further, ecosystems are not exempt from the **Second Law of Thermodynamics**. They need a constant supply of energy to synthesize the molecules they require, to counteract the universal tendency toward increasing disorderliness.
- **Producers/Autotrophs:** The green plants in the ecosystem are called producers. In a terrestrial ecosystem these are herbaceous and woody plants and in an aquatic ecosystem these are phytoplankton, algae and higher plants.
- **Consumer/Heterotrophs:** Animals who depend on plants (directly or indirectly) for their food needs are called consumers or heterotrophs.
  - **Primary Consumers:** If animals feed on the producers (the plants), they are called primary consumers or herbivores. These are insects, birds and mammals in the terrestrial ecosystem and molluscs in aquatic ecosystems.

| | | Examples |
|---|---|---|
| Tertiary Consumer | Fourth Trophic level (Top Carnivore) | Man, lion |
| Secondary Consumer | Third Trophic level (Carnivore) | Birds, fishes, wolf |
| Primary Consumer | Second Trophic level (Herbivore) | Zooplankton, grasshopper and cow |
| Primary Producer | First Trophic level (Plants) | Phytoplankton, grass, trees |

**Figure 13.2: Diagrammatic Representation of Trophic Levels**

  - **Secondary Consumers:** If the animals eat other animals which in turn eat the plants (or their produce) they are called secondary consumers or carnivores, or more correctly **primary carnivores** (though secondary consumers).
  - **Secondary Carnivores:** Those animals that depend on the primary carnivores for food are labelled secondary carnivores (Refer Figure 13.2).
- **Food Chain or Web:** Starting from the plants (or producers) food chains or rather webs are formed such that an animal feeds on a plant or on another animal and in turn is food for another. The chain or web is formed because of this interdependency.
  - The energy trapped by the producer is either passed on to a consumer or released back into the environment at some point after the organism dies. No energy that is trapped into an organism remains in it forever.
  - A simple **Grazing Food Chain (GFC)** is depicted below.

**Grass (Producer) ⟶ Goat (Primary Consumer) ⟶ Man (Secondary Consumer)**

- ✧ The **Detritus Food Chain (DFC)** begins with dead organic matter. It is made up of decomposers which are heterotrophic organisms, mainly fungi and bacteria.
- ✧ **Decomposers**, also known as **Saprotrophs** (sapro: to decompose), meet their energy and nutrient requirements by degrading dead organic matter or detritus. They secrete digestive enzymes that break down dead and waste materials into simple, inorganic materials, which are subsequently absorbed by them.
- ✧ In an aquatic ecosystem, **GFC** is the major conduit for energy flow, as against this, in a terrestrial ecosystem, a much larger fraction of energy flows through the Detritus Food Chain (DFC).
- ✧ **Detritus food chain may be connected with the grazing food chain** at some levels. Some of the organisms of DFC are prey to the GFC animals, and in a natural ecosystem, some animals like cockroaches, crows, etc., are omnivores. These natural interconnections of food chains make it a food web.

✤ **Trophic Level:** Organisms occupy a place in the natural surroundings or in a community according to their feeding relationship with other organisms. Based on the source of their nutrition or food, organisms occupy a specific place in the food chain known as their trophic level (Refer Figure 13.3).

- ✧ Producers belong to the first trophic level, herbivores (primary consumers) to the second and carnivores (secondary consumers) to the third.
- ✧ The amount of energy decreases at every successive trophic levels.
- ✧ When any organism dies it is converted to detritus or dead biomass that serves as an energy source for decomposers.

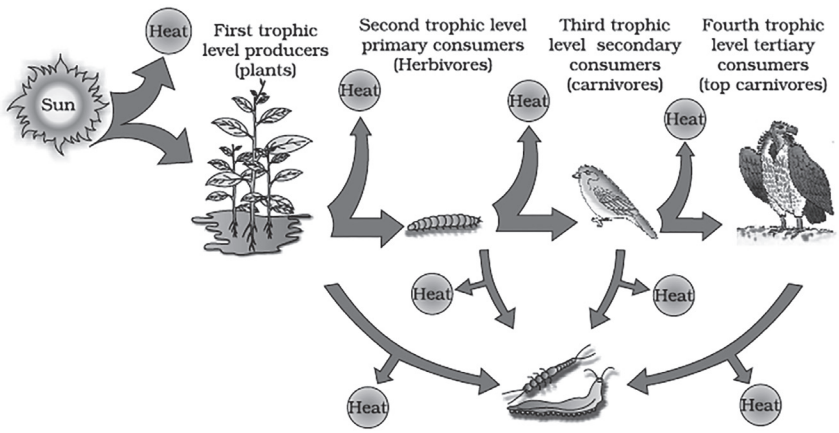


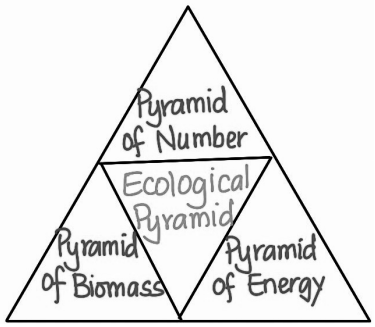

**Figure 13.3: Energy flow through different trophic levels**

- ✧ Organisms at each trophic level depend on the lower trophic level for their energy demands.
- ✧ Each trophic level has a certain mass of living material at a particular time called the **standing crop**.
- ✧ The biomass of a species is expressed in terms of fresh or dry weight (measurement in terms of dry weight is more accurate).
- ✧ The number of trophic levels in the grazing food chain is restricted as the transfer of energy follows **10% Law – only 10% of the energy is transferred to each trophic level from the lower trophic level**.
- ✧ In nature, it is possible to have so many levels – producer, herbivore, primary carnivore, secondary carnivore in the grazing food chain (Refer Figure 13.3).

## Ecological Pyramids

✤ The Ecological Pyramid depicts a **link between the numbers, biomass and energy** of different trophic levels in an ecosystem.

- The trophic level represents a functional level, not a species as such.
- Also a given species may occupy more than one trophic level in the same ecosystem at the same time; for example, a sparrow is a primary consumer when it eats seeds, fruits, peas, and a secondary consumer when it eats insects and worms.




- In most ecosystems, all the pyramids, of number, of energy and biomass are **upright**, i.e., producers are more in number and biomass than the herbivores, and herbivores are more in number and biomass than the carnivores. Also energy at a lower trophic level is always more than at a higher level. One gets a similar shape of a pyramid with a broad base and narrows towards the apex, if it expresses the food or energy relationship between organisms at different trophic levels. The base of each pyramid represents the producers or the first trophic level while the apex represents tertiary or top level consumer.

## Pyramid of Number

- It represents the number of organisms at each trophic level.
- It is an **upright** pyramid in case of terrestrial and aquatic ecosystems. Whereas, in case of parasites, it can be inverted. The reason for the **upright** pyramid is that there must always be enough food at the bottom. Otherwise, the entire food chain will collapse.

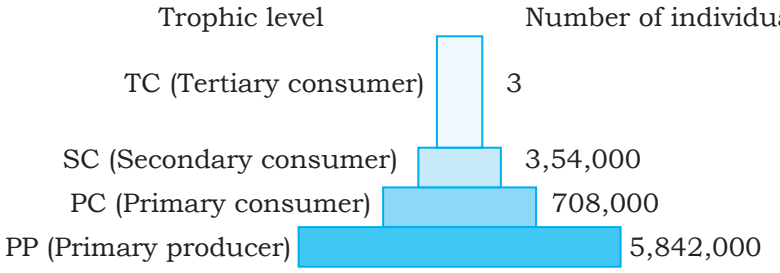



**Figure 13.4: Pyramid of Number**

**Only three top-carnivores are supported in an ecosystem based on production of nearly 6 millions plants**

- At the higher level the number of tertiary consumers should be less in numbers **(Refer Figure 13.4)**.

## Pyramid of Biomass

- It represents biomass or organic matter of living organisms present at each trophic level.
- It can be upright or inverted. It is **upright** in case of **terrestrial ecosystems**. Whereas, in **aquatic ecosystems** it is generally **inverted** because the biomass of fishes far exceeds that of phytoplankton (Refer Figure 13.5 and 13.6).

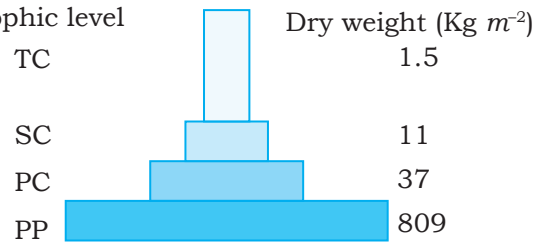



**Figure 13.5: Pyramid of Biomass - Terrestrial**


**Figure 13.6: Pyramid of Biomass - Aquatic**

## Pyramid of Energy

- It represents energy in terms of calories or joules present at each trophic level.
- **Pyramid of energy is always upright** and can never be inverted, because when energy flows from a particular trophic level to the next trophic level, some energy is always lost as heat at each step.
- Each bar in the energy pyramid indicates the amount of energy present at each trophic level in a given time or annually per unit area (Refer Figure 13.7).

### Limitations of Ecological Pyramids

- It does not take into account the same species belonging to two or more trophic levels.
- It assumes a simple food chain, something that almost never exists in nature.
- It does not accommodate a food web.
- Saprophytes are not given any place in ecological pyramids even though they play a vital role in the ecosystem.

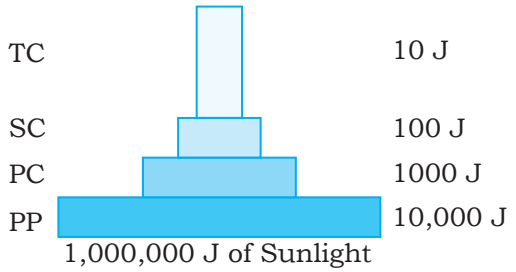
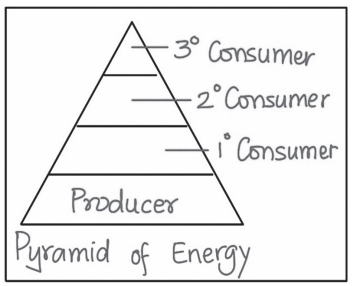



**Figure 13.7: Pyramid of Energy. Observe that primary producers convert only 1% of the energy in the sunlight available to them into NPP**

## Ecological Succession




- All communities constantly change their composition and structure in response to the changing environmental conditions.
- These changes are orderly and sequential, parallel with the changes in the physical environment, which lead finally to a community that remains stable as long as the environment remains unchanged called a **climax community**.
- Thus, the process of gradual and predictable change in the species composition of a given area is called **ecological succession**.
- During ecological succession some species colonise an area and increase their populations, whereas populations of other species decline and even disappear. Thus, in a given area, the entire sequence of communities that undergo changes are called **sere(s)** and the individual transitional communities are called **seral stages or seral communities**.

Pioneer Species → Intermediate Species → Climax Community

**Ecological Succession**

- In the successive seral communities there is a change in the diversity of species, increase in the number of species and organisms and in the total biomass.
- The present day communities have come due to succession that has occurred over millions of years since life started on earth. At that time succession and evolution would have been parallel processes.
- Succession can be of two types:
  - **Primary Succession:** It is a process that starts where no living organisms are there. These areas could be bare rock, cooled lava, newly created ponds or reservoirs. Depending mostly on the climate, it takes several hundred to several thousand years to produce fertile soil on bare rock. Thus, the establishment of a new biotic community is generally slow in primary succession.
  - **Secondary Succession:** It begins in areas that, somehow, lost all the natural biotic communities that existed there

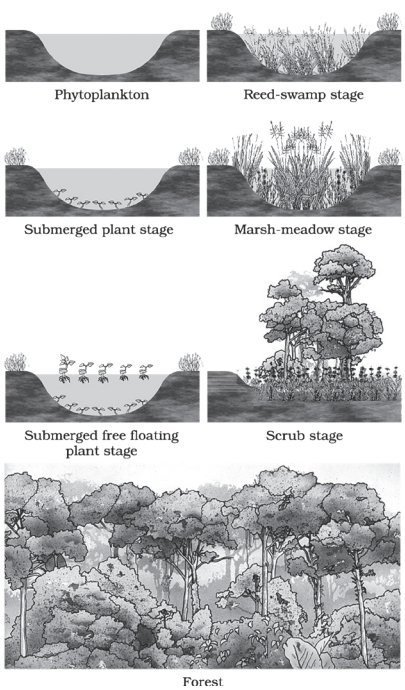



**Figure 13.8: Representation of Primary Succession**

such as in abandoned farm lands, burned or cut forests, lands that have been flooded. Since some soil or sediment is present, secondary succession is faster than primary succession.

- The description of ecological succession usually focuses on changes in vegetation, which in turn affect food and shelter for various types of animals. Thus, as succession proceeds, the numbers and types of animals and decomposers also change.
- At any time during primary or secondary succession, natural or human induced disturbances such as fire, deforestation, etc., can convert a particular seral stage of succession to an earlier stage and can create new conditions that encourage some species and discourage or eliminate other species.

### Succession of Plants

- Based on the nature of the habitat, succession of plants can be **hydrarch or xerarch**.
- **Hydrarch succession:** It takes place in wetter areas and the successional series progresses from hydric to the mesic conditions.
- **Xerarch succession:** It takes place in dry areas and the series progresses from xeric to mesic conditions.
- Both hydrarch and xerarch succession lead to medium water conditions (mesic) – neither too dry (xeric) nor too wet (hydric).
- In primary succession on rocks **pioneer species** (species that invade a bare area ) are usually lichens which are able to secrete acids to dissolve rock, helping in weathering and soil formation.
- These later pave the way to some very small plants like bryophytes. Later, succeeded by bigger plants, and after several more stages, ultimately a stable climax forest community is formed.

**Note:**

Succession, particularly primary succession, is a very slow process, taking maybe thousands of years for the climax to be reached and all succession whether taking place in water or on land, proceeds to a similar climax community – the mesic.

- With time the xerophytic habitat gets converted into a mesophytic one.
- In primary succession in water, the pioneers are the small phytoplanktons which are replaced with time by free-floating angiosperms, then by rooted hydrophytes, sedges, grasses and finally the trees. Ultimately the climax forest community is formed. With time the water body is converted into land (Refer Figure 13.8).
- In secondary succession, the species that invade depend on the condition of the soil, availability of water, the environment as also the seeds or other propagules present. Since soil is already there, the rate of succession is much faster and hence, climax is also reached more quickly.

## Nutrient Cycling

- All organisms need a constant supply of nutrients to grow, reproduce and regulate various body functions.
- The amount of nutrients, such as carbon, nitrogen, phosphorus, calcium, etc., present in the soil at any given time, is referred to as the **standing state**. It varies in different kinds of ecosystems and also on a seasonal basis.
- Nutrients are never lost from the ecosystem. The storage and movement of nutrient elements through the various components of the ecosystem is called **nutrient cycling or Biogeochemical Cycle** (bio: living organism, geo: rocks, air, water). Nutrients are repeatedly used through this process.

- Nutrient cycles are of two types:
  1. **Gaseous:** Atmosphere or hydrosphere is the reservoir for the gaseous type of cycle (e.g. carbon and nitrogen cycle).
  2. **Sedimentary:** Earth's crust is the reservoir for sedimentary type (e.g., sulphur and phosphorus cycle).
- Environmental factors, such as soil, moisture, pH, temperature, etc., regulate the rate of release of nutrients into the atmosphere and the function of the reservoir is to meet with the deficit which occurs due to imbalance in the rate of influx and efflux.

## Carbon Cycle

- Carbon constitutes **49% of the dry weight of organisms** and is next only to water. Of the total quantity of global carbon, 71% carbon is found dissolved in oceans and the atmosphere contains only about 1%. This **oceanic reservoir regulates the amount of carbon dioxide** in the atmosphere (Refer Figure 13.9).

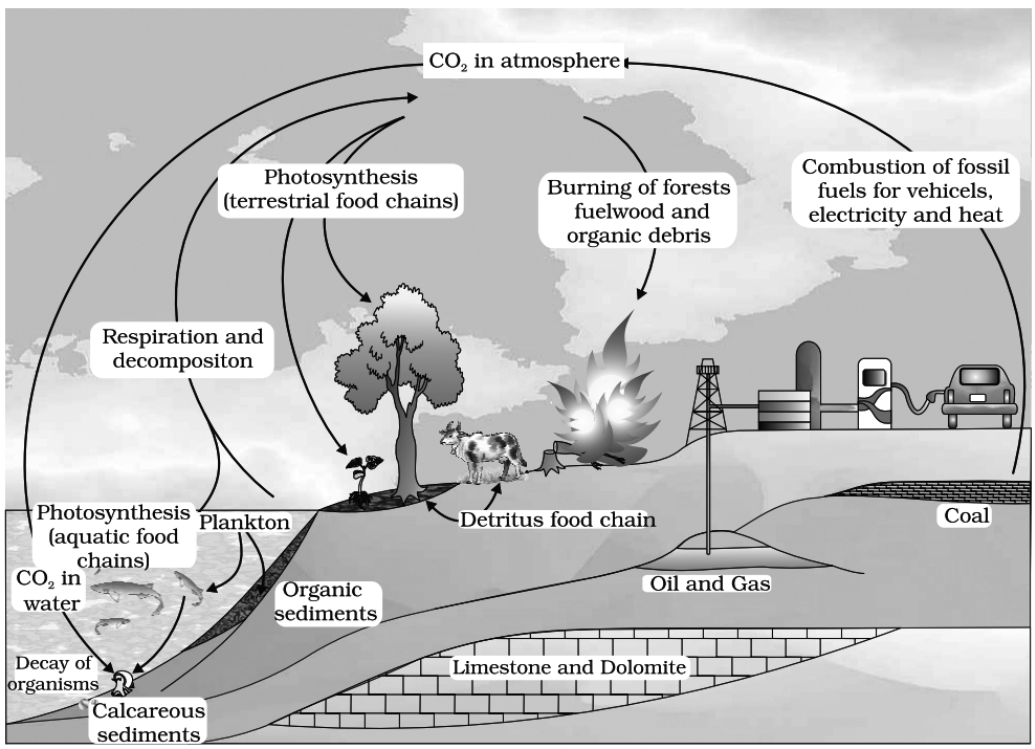



**Figure 13.9: Carbon Cycle in the Biosphere**

- Fossil fuel also represents a reservoir of carbon.
- Carbon cycling occurs through the atmosphere, ocean and through living and dead organisms.
- According to one estimate **$4 \times 10^{13}$ kg of carbon is fixed in the biosphere** through photosynthesis annually.
- A considerable amount of carbon returns to the atmosphere as $CO_2$ through respiratory activities, decomposers also contribute to $CO_2$ pool by processing of waste materials and dead organic matter of land or oceans.
- Some amount of the fixed carbon is lost to sediments and removed from circulation. Burning of wood, forest fire and combustion of organic matter, fossil fuel, volcanic activity are also adding $CO_2$ in the atmosphere.

- Humans have influenced the carbon cycle by the process of rapid deforestation and massive burning of fossil fuel for energy and transport which has increased the rate of release of carbon dioxide into the atmosphere.

### Phosphorus Cycle

- Phosphorus is a major constituent of biological membranes, nucleic acids and cellular energy transfer systems. Many animals also need large quantities of phosphorus to make shells, bones and teeth.
- The natural reservoir of this element is rock, which contains phosphorus in the form of phosphates.
- When rocks are weathered, minute amounts of these phosphates dissolve in soil solution and are absorbed by the plants. Further the element is obtained by the herbivores and other animals from plants.

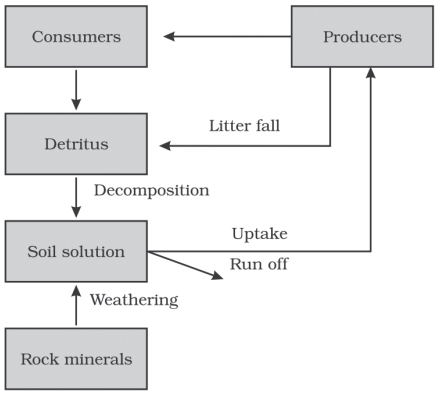



**Figure 13.10: Phosphorus Cycling in a Terrestrial Ecosystem**

- At last, the waste products and the dead organisms are decomposed by phosphate-solubilising bacteria releasing phosphorus (Refer Figure 13.10).

**Table 13.2: Difference between Carbon Cycle and Phosphorus Cycle**

| Carbon Cycle | Phosphorus Cycle |
|---|---|
| ✤ Respiratory activities release carbon into the atmosphere. | ✤ There is no respiratory release of phosphorus into the atmosphere. |
| ✤ The atmospheric inputs of carbon through rainfall are much larger. | ✤ The atmospheric inputs of phosphorus through rainfall are much smaller than carbon inputs. |
| ✤ There are gaseous exchanges of carbon between organisms and the environment. | ✤ Gaseous exchanges of phosphorus between organism and environment are negligible. |

## Ecosystem Services

- The products of ecosystem processes are named as ecosystem services, for example, healthy forest ecosystems purify air and water, mitigate droughts and floods, recycle nutrients, generate fertile soils, provide wildlife habitat, maintain biodiversity, pollinate crops, provide storage sites for carbon and also provide aesthetic, cultural and spiritual values.
- Though the value of such services of biodiversity is difficult to determine, **Robert Constanza** and his colleagues have tried to put price tags on nature's life-support services.
  - ✧ Researchers have put an average price tag of US $ 33 trillion a year on these fundamental ecosystem services while global GDP in 2022 was approximately 100 trillion USD.
- Out of the total cost of various ecosystem services, the soil formation accounts for about 50%. Contributions of other services like recreation and nutrient cycling, are less than 10% each and the cost of climate regulation and habitat for wildlife are about 6% each.

**POINTS TO PONDER**

The ecosystem services are being highly affected by climate change. Can you think of a scenario where these services are damaged beyond repair? What according to you can be the impact of such a situation? Can you think of any alternate means or ways to ensure the function carried out by the ecosystem?

## Conclusion

Healthy ecosystems are the basis for a wide range of economic, environmental and aesthetic goods and services. Every organism living on the earth depends on the ecosystem and products of ecosystem processes named as ecosystem services. The stability in the ecosystem is very much essential to maintain its structure and functions such as water and nutrient cycling and biomass productivity over a long period of time. A wide range of producers, consumers and decomposers living together are interdependent. If one element is imbalanced, then the whole system will be imbalanced. Thus, a healthy ecosystem is extremely important for sustainable life.

***Glossary:***

- **Ecosystem:** It is a structural and functional unit of nature and it comprises abiotic and biotic components.
- **Primary Productivity:** It is the rate of capture of solar energy or biomass production of the producers.
- **Secondary Productivity:** It is the rate of assimilation of food energy by the consumers.
- **Nutrient Cycling:** The storage and movement of nutrient elements through the various components of the ecosystem is called nutrient cycling.
- **Standing Crop:** Each trophic level has a certain mass of living material at a particular time called the standing crop which is measured as the mass of living organisms (biomass) or the number in a unit area.

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# 14 Biodiversity and Conservation

**Bibliography:** This Chapter encompasses a summary of Chapter 5 - VI NCERT (The Earth, Our Habitat), Chapter 1 and 6 - VII NCERT (Our Environment), Chapter 14 - XI NCERT (Fundamentals Of Physical Geography), and Chapter 13 - XII NCERT (Biology)).

## Introduction

What makes our earth so unique is the **diversity of life** present here. There are more than 20,000 species of ants, 3,00,000 species of beetles, 28,000 species of fishes and nearly 20,000 species of orchids. **But diversity in species is not equally distributed.** It is **highest in tropics** and decreases towards the poles. Even vegetation differs from one place to another, the difference in the depth of the weathered mantle produces diversity in vegetation. And depending upon the input of solar energy and water, even biodiversity changes.

## Environment

- **Environment** comes from the **French word Environer/Environner meaning "neighbourhood".** The place, people, things and nature that surround any living organism is called the environment. It is a combination of natural and human made phenomena (Refer Figure 14.1).
- **Biodiversity** is a part of the **natural environment** but it is affected by the **human environment.** And in recent times the human environment has made numerous changes to it.
- In small quantities water appears colourless, but water actually has an intrinsic **blue colour caused by slight absorption of light at red wavelengths**, like we see in the oceans.

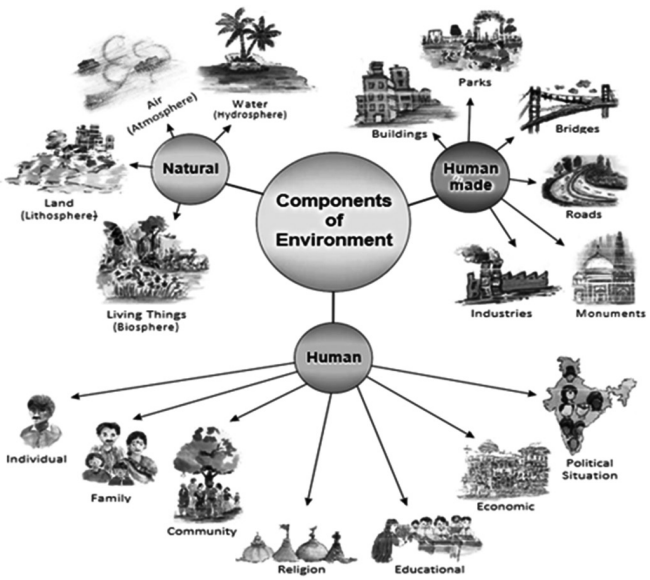



**Figure 14.1: Components of Environment**

- Water is a rare commodity in our solar system. Fortunately, the earth has an abundant supply of water on its surface. Hence, our planet is called the **'Blue Planet'**.

### I. Natural Environment

- The natural environment refers to both biotic and abiotic conditions existing on the earth.
- **Biotic** means the world of living organisms, e.g., plants and animals. **Abiotic** refers to the world of non-living elements, e.g., land.

- Land, water, air, plants and animals comprise the natural environment. It includes the **lithosphere, hydrosphere, atmosphere and biosphere.**

## More about the Abiotic Elements of Natural Environment

- **Lithosphere**
  - It is the **solid crust** or the hard top layer of the earth. It is made up of rocks and minerals and covered by a thin layer of soil.
  - It is an **irregular surface** with various landforms such as mountains, plateaus, plains, valleys, etc.
  - Landforms are found over the continents and also on the ocean floors.
  - It is the domain that provides us with forests, grasslands for grazing, land for agriculture and human settlements. It is also a **source of mineral** wealth.
- **Hydrosphere**
  - It is the domain of water. It comprises various sources of water and different types of water bodies like rivers, lakes, seas, and oceans.
  - **Our earth** is called the **blue planet** as more than 71 percent of earth is covered with water. But more than 97 percent of earth's water is found in the oceans and it is too salty for human consumption. Hence only a small percentage of water is available as fresh water.
- **Atmosphere**
  - It is the thin layer of air that surrounds the earth. The gravitational force of the earth holds the atmosphere around it.
  - It consists of a number of gases, dust and water vapour. The changes in the atmosphere produce changes in the weather and climate.
  - The atmosphere extends up to a height of about 1,600 kilometres.
  - It is divided into five layers: **Troposphere, Stratosphere, Mesosphere, Thermosphere and Exosphere (Refer Figure 14.2)**.
  - The atmosphere is composed mainly of **Nitrogen (78 percent), oxygen (21 percent)** and other gases like carbon dioxide, argon and others (1 percent).
  - The density of the atmosphere is maximum at the sea level and decreases with increase in height. The temperature also decreases as we go upwards.

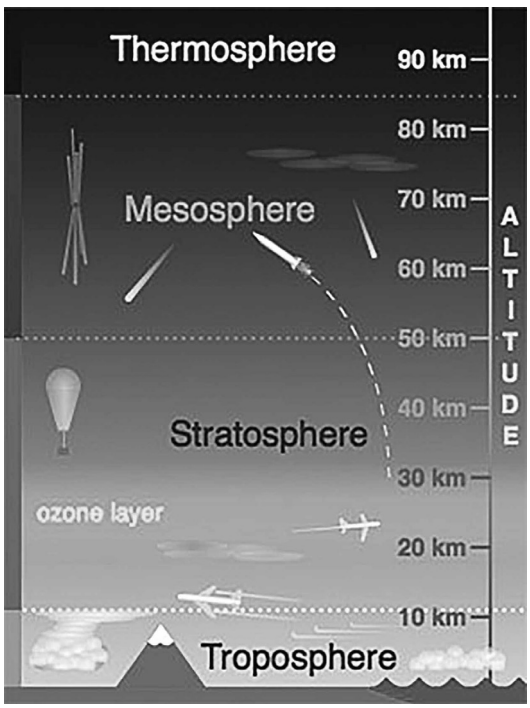



**Figure 14.2: Layers of the Atmosphere**

- **Biosphere**
  - It is the narrow zone of contact between the land, water and air.
  - This zone supports life on earth, and all organisms are linked to each other for survival.
  - The plant and animal kingdom in the biosphere interact and affect the three domains of the earth **(Refer Figure 14.3)**.

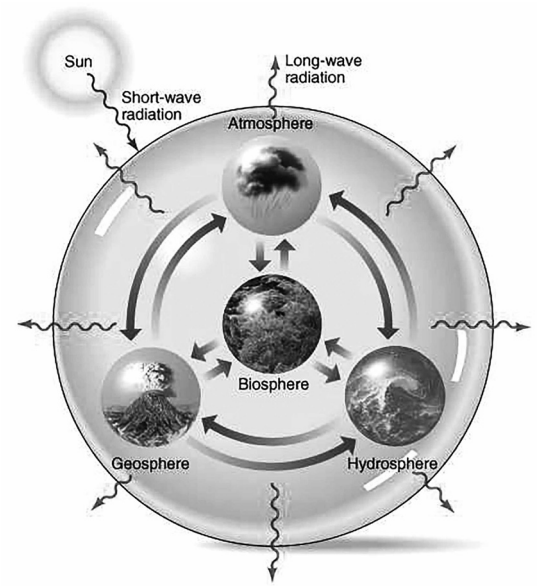



**Figure 14.3: Biosphere**

## II. Human Environment

- Human environment is the interaction between human beings and the environment. It is the **relationship of people with the natural and physical environment** around them.
- When human beings interact with the environment, they modify it according to their needs.
- With time, human needs grew and became more varied and humans learned new ways to use and change the environment. They learn to grow crops, domesticate animals and lead a settled life.
- The Industrial Revolution enabled large scale production, transportation became faster, Information Revolution made communication easier and faster across the world. Thus, the human environment was rapidly modified.

### Ecosystem

- It is a system formed by the interaction of all living organisms with each other and with the physical and chemical factors of the environment in which they live, all linked by **transfer of energy and material.**
- All plants, animals and human beings depend on their immediate surroundings and are also **interdependent** on each other. This relation between the living organisms, as well as the relation between the organisms and their surroundings form an ecosystem.
  - Example: Ecosystem of large rainforest, grassland, desert, mountains, lake, river, ocean and even a small pond.

**Interesting Aspects of Earth's Biodiversity**

- More than 70 percent of all the species recorded are animals, while plants (including algae, fungi, bryophytes, gymnosperms and angiosperms) comprise no more than 22 percent of the total.
- Among animals, insects are the most species-rich taxonomic group, making up more than 70 percent of the total. That means, out of every 10 animals on this planet, 7 are insects.
- The number of fungi species in the world is more than the combined total of the species of fishes, amphibians, reptiles and mammals.

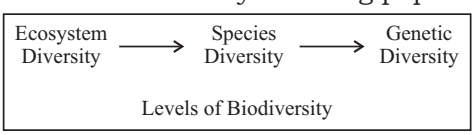
### Biodiversity

- Biodiversity is a combination of two words, Bio **(life) and diversity (variety)**. In simple terms, biodiversity is the number and variety of organisms found within a specified geographic region.

- It relates to the **variability among living organisms** on the earth, including the variability within and between the species and within and between the ecosystems.
- It varies from region to region; it is generally **richer in the tropics** and decreases as one moves to the poles.
- In our biosphere immense diversity (or heterogeneity) exists not only at the species level but at all levels of biological organisation ranging from macromolecules within cells to biomes.
- Biodiversity is the term popularized by the sociobiologist **Edward Wilson** to describe the combined diversity at all the levels of biological organization.

### Levels of biodiversity

- **Genetic Diversity:** Genetic biodiversity refers to the **variation of genes within species**. A single species can show high **diversity at the genetic level.**
  - Example: The medicinal plant **Rauwolfia Vomitoria** growing in different Himalayan ranges might differ in terms of the potency and concentration of the active chemical (reserpine) that the plant produces.
  - India has more than 50,000 genetically varied strains of rice, 1000 varieties of mango.
  - Genetic diversity is essential for a healthy breeding population of the species.




- **Species Diversity:** Species diversity refers to the **variety of species** and relates to the number of species in a defined area.
  - It is the diversity at species level. Example: **Western ghats have greater amphibian species diversity than the eastern ghats.**
  - Groups of individual organisms having certain similarities in their physical characteristics are called **species**.
  - The diversity of species can be measured through their richness, abundance and types. Some areas are richer in species than others. These areas are called diversity **"hotspots".**
- **Ecological/Ecosystem Diversity:** It refers to the variety of different ecosystems or habitats within a specific geographic area or on a global scale.
  - It encompasses a wide range of environments, including forests, grasslands, wetlands, deserts, oceans, and more.
  - The demarcation of ecosystem boundaries is difficult and complex because the boundaries of communities are not rigidly defined.
  - At the ecosystem level **India has greater ecosystem diversity than a Scandinavian nation** like Norway. India has deserts, rainforests, mangroves, coral reefs, wetlands, etc.

### Patterns of Biodiversity

- **Latitudinal Gradients:** The diversity of plants and animals are not uniform around the world, there is an uneven distribution.
  - In general, species diversity decreases as we move away from the equator towards the poles. With very few exceptions, tropics (latitudinal range of 23.5° N to 23.5° S) harbour more species than temperate or polar areas.

**POINTS TO PONDER**

Some species are found in a wide range of climate and regions with huge natural resource variability. Then there are other species which are found in a very specific area with specific climate and vegetation. What according to you generates huge adaptability to variations in some species and lacks in others?

- ✧ Example: A forest in a tropical region like Ecuador has up to 10 times as many species of vascular plants as a forest of equal area in a temperate region like the Midwest of the USA.
- ✧ The reason for species richness in tropical regions is that the tropics had more evolutionary time, provided a relatively constant environment and received more solar energy which contributes to greater productivity.

✤ **Species Area Relationships:** German naturalist and geographer **Alexander Von Humboldt** observed that within a region species richness increased with increasing explored area, but only up to a limit.

- ✧ The relation between species richness and area for a wide variety of taxa (angiosperm plants, birds, bats, freshwater fishes) turns out to be a rectangular hyperbola.
- ✧ On a logarithmic scale, the relationship is a straight line described by the equation;

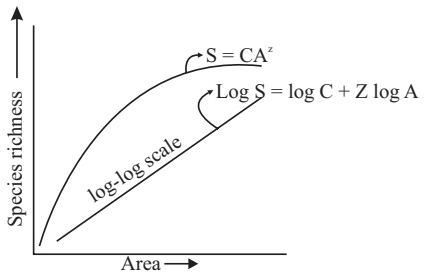



**Figure 14.4: Species-Area**

$$\log S = \log C + Z \log A,$$

Where,

S = Species richness,

A = Area,

Z = Slope of the line (regression coefficient),

C = Y-intercept (Refer Figure 14.4).

- ✧ Ecologists have discovered that the value of Z lies in the range of 0.1 to 0.2, regardless of the taxonomic group or the region.
- ✧ On analysing the species-area relationships among very large areas like the entire continents, it is found that the slope of the line is much steeper (Z values are in the range of 0.6 to 1.2).
- ✧ Example: For frugivorous (fruit-eating) birds and mammals in the tropical forests of different continents, the slope is found to be 1.15.

## Number of Species on Earth and in India

✤ According to the **International Union for Conservation of Nature and Natural Resources (IUCN)** (2004), the total number of plant and animal species discovered so far is slightly more than 1.5 million.

✤ According to some estimates, many taxonomic groups, species inventories are more complete in temperate than in tropical countries. These estimates are based on the statistical comparison made of the temperate-tropical species richness.

✤ According to **Ecologist Robert May**, the global species diversity is 7 million (Refer Figure 14.5).

✤ India has only 2.4 per cent of the world's land area, but its share of the global species diversity is 8.1 percent. Hence it is listed as one of the 12 megadiversity nations of the world.

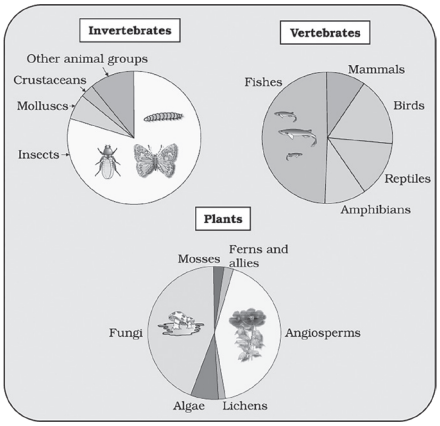



**Figure 14.5: Global biodiversity, proportionate number of species of major taxa of plants, invertebrates and vertebrates.**

- By applying May's estimates, there are more than 1,00,000 plant species and more than 3,00,000 animal species that are yet to be discovered in India.
- These estimates do not give any figures for prokaryotes. Because the conventional taxonomic methods are not suitable for identifying microbial species and many species are simply not culturable under laboratory conditions.

### Importance of Species Diversity to the Ecosystem

- A stable biological community is one that does not allow much variation in productivity from year to year, it must be **resilient to occasional disturbances** (natural or human-made), and it must also be resistant to alien species.
- **David Tilman** conducted ecosystem experiments with outdoor plants and found that plots with more species showed less year-to-year variation in total biomass. Also, increased diversity contributed to higher productivity.
- A rich biodiversity is essential for the ecosystem health but also **imperative for the survival of the human race**. Different species in an ecosystem provide a wide range of ecosystem services, such as pollination, nutrient cycling, and water purification. These services are essential for human well-being and agriculture.

### Causes of Biodiversity Loss

There are four major causes (**'The Evil Quartet'** is the sobriquet used to describe them).

- **Habitat Loss and Fragmentation:** Tropical rainforests which once covered more than 14% of the earth's land surface, now cover only 6% of land.
  - Amazon rainforest is being cut and cleared for cultivation of soybeans and for conversion to grasslands for cattle.
  - Habitat fragmentation affects all plants and animals and birds populations who are dependent on that ecosystem directly or indirectly.
- **Over-Exploitation:** When need turns into greed, it leads to exploitation of natural resources. Presently, many marine fishes are over harvested, endangering their continued existence. Growth in the human population has **increased the rate of consumption of natural resources.** Over-exploitation of resources and deforestation have become rampant to fulfil the needs of a large population.
- **Alien-Species Invasion:** Alien species introduced deliberately or unintentionally can become a threat to indigenous species.
  - Example: **Nile Perch** introduced in Lake Victoria led to extinction of **Cichlid fish**. **Carrot grass, Lantana** and **Water Hyacinth** have also posed a threat to native species.
- **Co-Extinction:** When a species becomes extinct, the plant and animal species associated with it in an obligatory way also become extinct.
  - Example: **When a host fish species becomes extinct, its unique assemblage of parasites also meets the same fate.**
- **Natural calamities** such as earthquakes, floods, volcanic eruptions, forest fires, droughts, etc. cause damage to the flora and fauna of the earth, bringing change to the biodiversity.
- **Pesticides and other pollutants** such as hydrocarbons and toxic heavy metals.
- **Hunting** of animals by the poachers for their horn, tusks, hides, etc. has resulted in the rendering of certain types of organisms in the endangered category.

## IUCN Classifications

- **The International Union for Conservation of Nature (IUCN)** has classified the threatened species of plants and animals into **nine categories** for the purpose of their conservation. The IUCN publishes information about endangered species world-wide as the Red List of threatened species.
- *Examples of recent extinctions include:* **Dodo** (Mauritius), **Quagga** (Africa), **Thylacine** (Australia), **Steller's Sea cow** (Russia) and **three subspecies of Tiger** (Bali, Javan, and Caspian).
- **Nine categories:**
  - **Data Deficient (DD):** When there is scarce information or data to make an assessment of the risk of extinction.
  - **Least Concern (LC):** When the taxon is evaluated against the available red list category and it does not qualify for being Endangered, Critically Endangered, Near Threatened or Vulnerable.
  - **Near Threatened (NT):** When the species is close to being qualified in the threatened category in the near future.
  - **Vulnerable (VU):** When the best available evidence indicates that the species meets any of the vulnerability criteria given, it is considered to be facing high risk of extinction in the wild.
  - **Endangered (EN):** Species that possess a very high risk of extinction based on the Endangered category parameters.
  - **Critically Endangered (CR):** When the species faces extremely high risk of extinction in the wild.
  - **Extinct in the Wild (EW):** When the species is only known to survive in cultivation, in captivity or as a naturalised population. And when surveys have not registered any of those species in their expected habitat, it is expected to be EW.
  - **Extinct (EX):** When it is beyond doubt, through exhaustive surveys, that the last individual of that genus/species has died.
  - **Not Evaluated (NE):** When there are no surveys or data collected for a species. This species is not listed in the IUCN Red List. (Refer to figures 14.6, 14.7 and 14.8)

**Figure 14.6: Red Panda an Endangered Species**

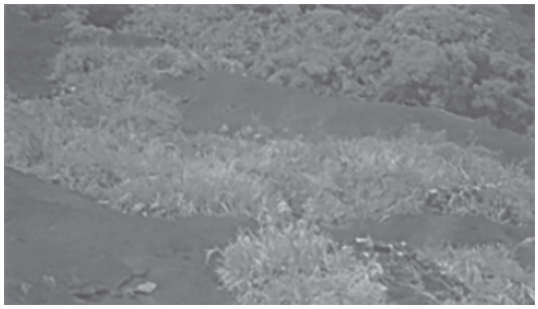


**Figure 14.7: Zenkeria Sebastinei - Critically Endangered grass in Agasthiyamalai peak (India)**

**Figure 14.8: Humbodtia Decurrens Bedd - Highly Rare Endemic Tree of Southern Western Ghats (India)**

**Rare Species**

- Population of these species is very small in the world; they are confined to limited areas or thinly scattered over a wider area.

## Importance of Biodiversity

- Biodiversity has contributed in many ways to the development of human culture and, in turn, human communities have played a major role in shaping the diversity of nature at the genetic, species and ecological levels. Biodiversity majorly plays the following roles: Ecological, Economic and Scientific.
- **Ecological role of biodiversity:** All species perform some or the other function in an ecosystem.
  - Biodiversity **increases the overall productivity of ecosystems**. Different species have different ecological functions, and a diverse community of plants, animals, and microorganisms can more efficiently capture and use resources like sunlight, water, and nutrients, fix atmospheric gases and help regulate the climate.
  - Diverse ecosystems are often better able to withstand and **recover from disturbances** such as natural disasters, disease outbreaks, and human activities.
- **Economic role of biodiversity:** Biodiversity is seen as a reservoir of resources to be drawn upon for the manufacture of food, pharmaceuticals, and cosmetic products. Some of the important economic commodities that biodiversity supplies to humankind are food crops, livestock, forests, fish, medicinal resources, etc.
  - Biodiversity is essential for **agriculture and food production**. It provides crop diversity, which is also called **agro-biodiversity.**
  - This concept of biological resources is responsible for the deterioration of biodiversity. It has also led to new conflicts of commercialization and appropriation of natural resources.
- **Scientific role of biodiversity:** It serves as a vast and invaluable **reservoir of knowledge** and information.
  - Provides opportunities to study evolution, including mechanisms of adaptation, natural selection, speciation, and genetic variation within and among populations.
  - Helps scientists understand the genetic basis of traits, adaptability to environmental changes, and the potential for future evolution.

## Biodiversity Conservation

*There are three broad categories of reasoning for biodiversity conservation:*

- **Narrowly Utilitarian Arguments:** Humans derive numerous economic benefits from nature- food (cereals, pulses, fruits), firewood, fibre, construction material, industrial products (tannins, lubricants, dyes, resins, perfumes) and products of medicinal importance. With **'bioprospecting'** (exploring molecular, genetic and species-level diversity for products of economic importance), nations endowed with rich biodiversity can expect to reap enormous benefits.

**POINTS TO PONDER**

Earth is already facing a massive resource crunch. In such a scenario isn't it wise to less other animal diversity perish so that mankind has a larger share of natural resources at its disposal. Do you think it is the right call to protect biodiversity? What benefits can humans derive from the endeavours of biodiversity conservation?

- **Broadly Utilitarian Argument:** Biodiversity plays a major role in many ecosystem services that nature provides. Amazon forest is estimated to produce, through photosynthesis, 20 percent of the total oxygen in the earth's atmosphere. These are intangible benefits that we derive from nature that cannot be economically calculated.

- **The Ethical Argument:** We owe to millions of plants, animals and microbe species, who share the planet with us. Every species has an intrinsic value and we have a moral duty to conserve them and pass our biological legacy to future generations.

### Approaches to Conserve Biodiversity

*There are majorly two approaches for this- In Situ and Ex Situ conservation:*

- **In-Situ Conservation:** In this approach, threatened animals and plants are conserved in its natural habitat.
  - It is not economically feasible for nations to conserve all biological wealth because of the resource crunch. Hence conservationists have identified certain '**biodiversity hotspots**' regions with very high levels of species richness and **high degree of endemism (that is, species confined to that region and not found anywhere else) (Refer Figure 14.9).** These hotspots are also regions of accelerated habitat loss.
  - In India, biodiversity-rich regions are legally protected as biosphere reserves, national parks and wildlife sanctuaries. Indian traditional practices worship nature and thus in many parts of India, trees and wildlife are conserved in Sacred groves. They are found in Khasi and Jaintia hills of Meghalaya, Aravalli hills of Rajasthan, etc.
  - India now has **18 biosphere reserves, 106 national parks and 567 wildlife sanctuaries.**
- **Ex-Situ Conservation:** In this approach, threatened animals and plants are taken out from their natural habitat and placed in special settings where they can be protected and given special care.
  - **Zoological parks, botanical gardens and wildlife safari parks** are such examples.
  - In recent years ex-situ conservation has also come to include **seed banks** where genetic strains of commercially viable plants can be kept for a long period of time.

### Ways to Conserve Biodiversity

- Biodiversity is our living wealth and it is important for human existence. All forms of life are so closely interlinked that disturbance in one gives rise to imbalance in the others.
- There is an urgent need to educate people to adopt environment friendly practices which are sustainable and do not hurt the environment.
- **Involvement and cooperation of local communities** is essential to develop sustainable practices. For this, the development of institutional structures at local levels is necessary.
- India is a signatory to the **Convention of Biodiversity** at the **Earth Summit** held at **Rio de Janeiro, Brazil in June 1992.** Here it was agreed that efforts should be made to preserve the species that are endangered; International trade in wild plants and animals be regulated.
- The Government of India passed the **Wild Life (Protection) Act, 1972,** to preserve and protect the variety of species in India.
- There are **17 mega-diversity countries,** namely the United States, India, China, South Africa, Brazil, Mexico, Madagascar, Congo, Indonesia, Malaysia, Ecuador, Philippines, Venezuela, Peru, Colombia, and Papua New Guinea and Australia. This is done in order to maximize efforts to conserve biodiversity in these regions.
- **Conservation International** has also identified certain areas as **biodiversity hotspots.** India has four of these hotspots namely the **Western Ghats, the Himalayas, Andaman & Nicobar Islands (part of The Sundalands), and the Indo-Burma region** (Refer Figure 14.9).

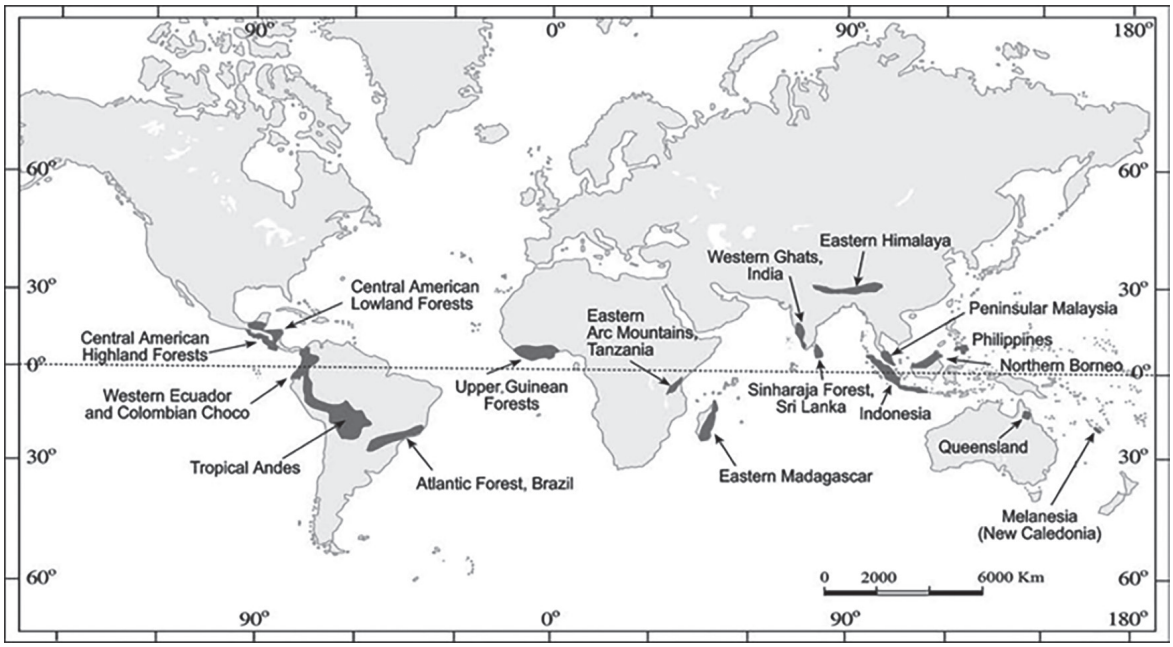



**Figure 14.9: Some Biodiversity Hotspots of the World**

## Case Studies: Human Interactions in Tropical and the Subtropical Region and Effect on Biodiversity in the Recent Past

Irrespective of where people live, all have the same basic needs of life: food, clothing and shelter. Depending on the environment of a place, the food, clothing and shelter choices vary. Therefore, it is said that the natural environment in a way dictates the human environment of any place. Today, we are also witnessing the impact of human interactions with the environment and its negative effect on Biodiversity. Following are two case studies to expound this relationship and interaction better.

### I. Life in the Amazon Basin

- It is a tropical region which lies very close to the equator; between 10°N and 10°S. So, it is referred to as the equatorial region. **(Refer Figure 14.10)**
- The **river Amazon** flows through this region. The river basin drains portions of Brazil, parts of Peru, Bolivia, Ecuador, Columbia and a small part of Venezuela. The Amazon Basin is the largest river basin in the world.
- Climate here is characterized by hot **and wet weather** throughout the year. Both day and night are almost equally hot and humid.
- **Heavy rains** make thick forests grow here. The ground remains dark and damp. Only shade tolerant vegetation may grow here. Orchids, bromeliads grow as plant parasites.


**Figure 14.10: Amazon Basin in South America**

**Do You Know?**

Bromeliads are special plants that store water in their leaves. Animals like frogs use these pockets of water for laying their eggs.

- This basin is extraordinarily rich in a variety of flora and fauna.
- Birds such as Toucans, hummingbirds, macaws; animals such as monkeys, sloths and ant-eating Tapirs are also found here. **(Refer Figure 14.11 and 14.12)**
- Crocodiles, pythons, snakes, and piranha fish are also abundant.

**Figure 14.11: Toucans**

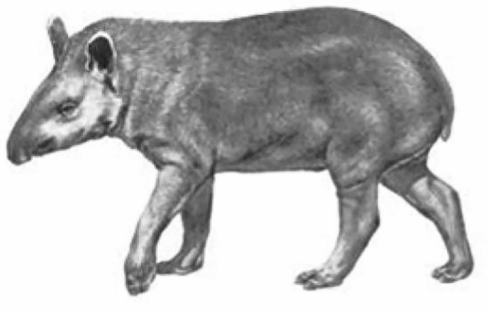


**Figure 14.12: Tapir**

### People of the Rainforest

- Most people grow their own food in forest cleared areas. Men usually hunt and fish, and women grow agricultural crops. **Slash and burn agriculture** is practiced here.
- Life of the people of the Amazon basin is slowly changing. In 1970 the Trans Amazon highway made all parts of the rainforest accessible. Aircrafts and helicopters are also used for reaching various places now.
- The **developmental activities have pushed the indigenous population out of the area.** Large parts of forests have disappeared. And the lush green forest is slowly turning barren **(Refer Figure 14.13).**

**Do You Know?**

**Slash and Burn**

It is a way of cultivating land where farmers clear a piece of land by slashing or cutting down trees and bushes. These are then burnt, which releases the nutrients into the soil. Now crops have grown in this cleared field for a few years. After repeatedly using the patch of land, the soil loses its nutrients. So it is abandoned. Then they clear another plot of land to plant. In the meantime young trees grow in the old field. In this way soil fertility is restored. People can then return to it and start cultivating it again.

### II. Life in the Ganga-Brahmaputra Basin

- The tributaries of rivers Ganga and Brahmaputra together form the Ganga-Brahmaputra basin in the Indian subcontinent. It lies in the subtropical region, situated between 10°N to 30°N latitudes. **(Refer Figure 14.14).**
- The Ganga and Brahmaputra plains, ox-bow lakes, the mountains and the foothills of the Himalayas and the Sundarbans delta are the main features of this basin.
- This basin is dominated by monsoonal climate. It rains from mid-June to mid-September.
- Summers here are hot while winters are cool.
- The basin area has varied topography. The mountains have steep slopes and have inhospitable terrain. Therefore, fewer people live in the mountain area. The plains are more populated.

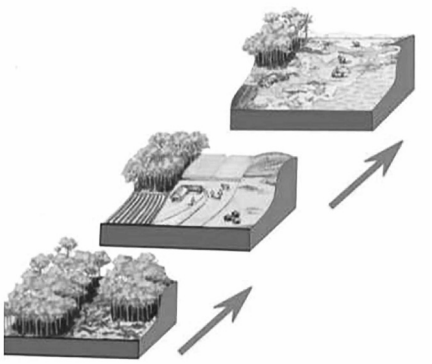


**Figure 14.13: Gradual Destructure of Forest**

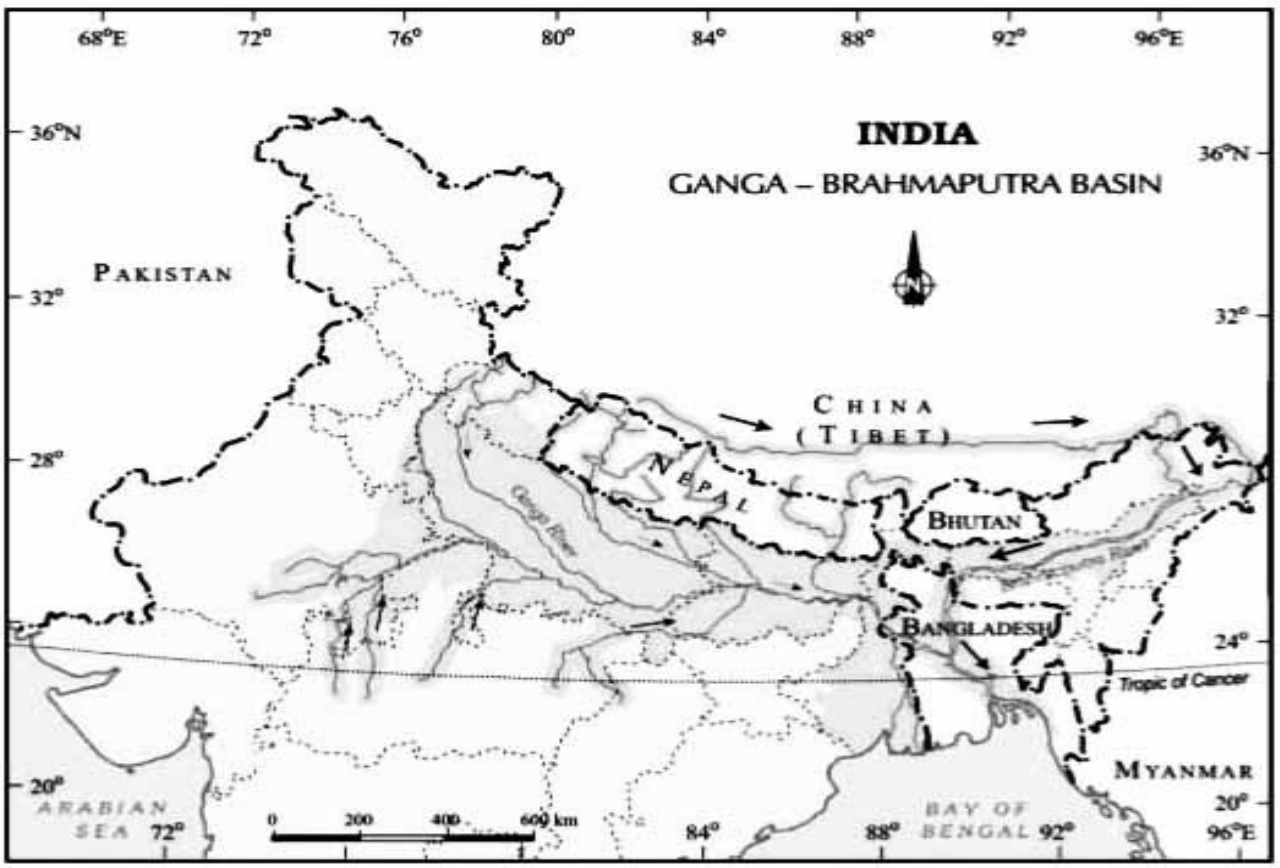



**Figure 14.14: The Ganga-Brahmaputra Basin**

- In the fresh waters of River Ganga and River Brahmaputra, a **variety of dolphin locally called Susu** (also called **blind dolphin**) is found. Its presence is an indication of the health of the river (Refer Figure 14.15).
- Wheat, maize, sorghum, gram, millets and paddy cultivation is done in these fertile plains. Cash crops like sugarcane and jute are also grown. In West Bengal and Assam, tea is grown in plantations. (Refer Figure 14.16 and 14.17)

**Figure 14.15: Blind Dolphin-Susu**

**Figure 14.16: Tea Garden in Assam**

**Figure 14.17: Paddy Cultivation**

- There is a variety of wildlife in the basin. Elephants, tigers, deer, monkeys are common. One-horned rhinoceros is found in the Brahmaputra plain **(Refer Figure 14.18)**.
- In the delta area, crocodiles and Bengal tigers are found **(Refer Figure 14.19)**. The most popular fishes are Rohu, Catla and Hilsa.

**Figure 14.18: One-Horned Rhinoceros**

**Figure 14.19: Crocodiles**

### The Biggest Concern: Pollution

- The cities of Allahabad, Kanpur, Varanasi, Lucknow, Patna and Kolkata, situated on the Ganga-Brahmaputra are densely populated cities.
- Untreated wastewater from these towns and industries is discharged into the rivers. This has led to chemical poisoning of the rivers and loss of aquatic life.

## Conclusion

Biodiversity knows no political boundaries and its conservation is therefore a collective responsibility of all nations. The historic **Convention on Biological Diversity ('The Earth Summit')** held in Rio de Janeiro in 1992, called upon all nations to take appropriate measures for conservation of biodiversity and sustainable utilisation of its benefits. Because conserving biodiversity is crucial for maintaining the health and well-being of the planet and all its inhabitants, including humans. It is not only an ethical imperative but also essential for our continued survival and prosperity. Today, **high population pressures** have exerted the need for more resources and thus clearing of forest land for wood, setting up of industries, etc. have decimated forests and increased waste. Only **sustainable use of land, waste-water management and protection of indigenous people's rights** and use of their traditional knowledge, can remedy the situation. In India, **Swachh Bharat Mission** was launched by the prime minister on October 2, 2014 to spread awareness about sanitation. Similarly, **Namami Ganga** has been initiated to clean Ganga river. Many such initiatives and programmes are needed to generate awareness about Biodiversity and its conservation.

***Glossary:***

- **Bromeliads:** A plant of tropical and subtropical America, typically having short stems with rosettes of stiff, spiny leaves. Some kinds are epiphytic and many are cultivated as pot plants.
- **Tributaries:** These are small rivers that join the main river. The main river along with all its tributaries that drain an area forms a river basin or the catchment area. The Amazon Basin is the largest river basin in the world.
- **Population Density:** It means the number of persons that live in one sq. km. of area.
- **Straits:** A narrow piece of sea that joins two larger seas.
- **Isthmus:** A narrow piece of land, with water on each side, that joins two larger pieces of land.
- Atmosphere Density: The density of air or atmospheric density, is the mass per unit volume of Earth's atmosphere. Air density, like air pressure, decreases with increasing altitude. It also changes with variations in atmospheric pressure, temperature and humidity.

- **Industrial Revolution:** In modern history, the process of change from an agrarian and handicraft economy to one dominated by industry and machine manufacturing.
- **Biodiversity Hotspots:** Regions that contain a high level of species diversity, many endemic species (species not found anywhere else in the world) and a significant number of threatened or endangered species.
- **Utilitarian:** Designed and intended to be practical and useful rather than attractive.
- **Topography:** The physical characteristics of an area of land, especially the position of its rivers, mountains, etc.
- **Seed Banks:** A seed bank or germplasm bank is a place where suitable conditions are maintained to conserve seed specimens of different plant species (wild or cultivated). The objective is to ensure the preservation of as many plants as possible for posterity.
- **Bryophytes:** It is an informal division that consists of three groups of nonvascular plants, namely mosses, liverworts, and hornworts. Prominent bryophytes characteristics are the absence of true roots, stems and leaves.
- **Angiosperms:** Plants that produce flowers and bear their seeds in fruits. They are the largest and most diverse group within the kingdom Plantae, with about 300,000 species.

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