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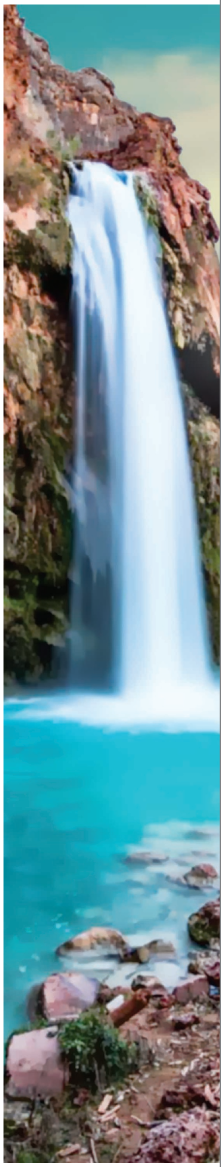

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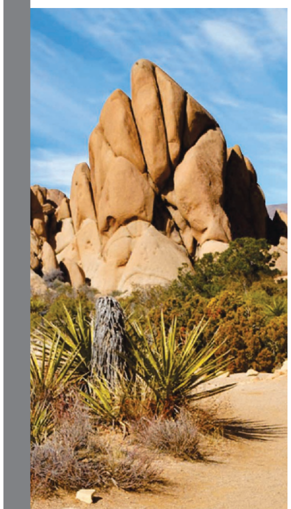

India & World Geography

Class 6-12 *(Old+New)*

Highly Useful for

UPSC, State PSCs

and Other Competitive Exams

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NCERT NOTES

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BEFORE ANYTHING ELSE, PREPARATION IS THE KEY TO SUCCESS.

Civil Services Examinations are the most prestigious and coveted examinations in India. Due to the power, authority, reputation, this career attracts every aspirant to hold the post and become IAS/IPS officer. Union Public Service Commission (UPSC) and State Public Service Commission (SPSC) conduct this examination every year and lakhs of aspirants across the country toil for years together to crack this distinguished exam in the country.

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The most important aspect of this preparation journey are the NCERT books. Every year approximately 35-40 questions directly come from NCERT books.

NCERT books also play a key role in understanding the Basic Concepts; so that aspirants can easily form the basic foundation of the entire syllabus. But due to the demand for many NCERT books which are required for study, it becomes exhausting to cover each and every NCERT book.

NCERT NOTES SERIES presented by Arihant Publications covers complete text from Class 6th to 12th NCERT books (both Old & New) in a comprehensive manner. The series is extremely useful for UPSC and State PSC examinations. The chapter-wise presentation of NCERT text is given in the heading cum-pointer format for quick grasping. The theory in each chapter is facilited with charts, tables, etc. to make the preparation easy and convenient. Exam focused last minute revision topics are also covered in the appendix.

The book is adorned with questions prepared by a team of experts along with a vital role played by the Project Management team with members: Mona Yadav (Project Manager), Divya Gusain (Project Coordinator), Shivani Dixit, Ayush Rajput (Proof readers), Vinay Sharma, Kamal Kishor, Sonu Kumar (DTP coordinators), Shanu and Mazher Chaudhary (Cover and Inner designer).

We hope this book will help the aspirants to achieve their goals of clearing UPSC as well as State PCS exams. Your valuable suggestions have always inspired us to strive for useful, authentic and more trustworthy publications. So your inputs and suggestions are welcomed for subsequent editions.

We wish you all the very best for your preparation and journey!!

Authors

CONTENTS

WORLD GEOGRAPHY

Chapter 1. **Geography as a Discipline** **1-3**
- Geography 1
- Branches of Geography 2

Chapter 2. **The Universe** **4-9**
- Universe 4
- Our Solar System 6

Chapter 3. **The Earth** **10-17**
- Origin of the Earth 10
- Evolution of the Earth 11
- Latitude and Longitude 13
- Motions of the Earth 15

Chapter 4. **Geomorphology** **18-43**
- Interior of the Earth 18
- Earthquake 20
- Volcanoes 22
- Rocks 25
- Major Theories for the Evolution of Landforms 27
- Movements of the Indian Plate 30
- Geomorphic Processes 30
- Earth Movements 31
- Landforms 36
- Mountains 41
- Plains 43
- Islands 43

Chapter 5. **Climatology** **44-66**
- Atmosphere 44
- Insolation and Temperature 47
- Heat Budget of the Earth 49
- Wind 53
- Jet Streams 57
- Cyclone 57
- Thunderstorms and Tornadoes 58
- Water in the Atmosphere 58
- Humidity 58
- Evaporation 59
- Condensation 59
- Clouds 60
- Precipitation 61
- Air Masses 63
- Fronts 63
- Koeppen's Scheme of Classification of Climate 64

Chapter 6. **Oceanography** **67-86**
- Water and Its Distribution 67
- Oceans and Seas 67
- Oceans of the World 69
- Oceanic Circulation and Ocean Currents 69
- Salinity of the Ocean 73
- Ocean Density 74
- Ocean Temperature 74
- Ocean Tides 77
- Ocean Deposits 78
- Coral Reefs 80
- Marine Resources 81
- Maritime Zone 82
- Lakes 84
- Wetlands 85

Chapter 7. **Soil and Natural Vegetation** **87-93**
- Soil 87
- Natural Vegetation 91

Chapter 8. **Agriculture and Animal Husbandry** **94-103**
- Hunting and Gathering 94
- Agriculture 94
- Major Crops of the World 97
- Animal Husbandry 102

Chapter 9. **Mineral Resources** **104-108**
- Minerals 104
- Types of Minerals 105
- Conservation of Minerals 108

Chapter 10. Energy Resources 109-113
- Classification of Energy Resources 109
- Conventional Sources 109
- Non- Conventional Sources of Energy 112
- Nuclear or Atomic Energy 113

Chapter 11. Industries 114-125
- Manufacturing 114
- Classification of Manufacturing Industries 116
- Industrial System 117
- Industrial Regions 117
- Iron and Steel Industry 119

Chapter 12. Transport and Communication 126-133
- Transport 126
- Communication 132

Chapter 13. Population and Settlement 134-146
- World Population 134
- Trends in Population Growth 137
- Demographic Transition 138
- Human Development 140
- Settlement 142
- Human Race 145

Chapter 14. Continents 147-168
- Asia 147
- Africa 152
- Australia 155
- North America 157
- South America 160
- Europe 164
- Antarctica 167

INDIAN GEOGRAPHY

Chapter 15. Location and Structure of India 169-172
- Geographical Location 169
- India and Its Neighbourhood 170
- India and the World 172

Chapter 16. Geological History and Physiography of India 173-183
- Geological History of India 173
- Geological Aspects of India 173
- Physical Divisions of India 175

Chapter 17. Drainage System of India 184-192
- Types of Drainage Pattern 184
- Classification of Drainage Systems of India 185
- Drainage System of India 186
- Lakes 191

Chapter 18. Climate in India 193-202
- Climate and Weather 193
- Climate of India 193
- Indian Monsoon 196
- Nature of Indian Monsoon 196
- Seasons 200

Chapter 19. Natural Vegetation and Soil in India 203-218
- Natural Vegetation 203
- Types and Distribution of Forest 208
- Forest Conservation 208
- Community and Conservation 210
- Soil 210

Chapter 20. Natural Resources of India 219-230
- Natural Resources 219
- Land Resource in India 220
- Water Resource 224

Chapter 21. Indian Agriculture and Irrigation 231-248
- Agriculture 231
- Major Crops Grown in India 233
- Animal Husbandry/Cattle Rearing/Livestock Farming 243
- Irrigation 244

Chapter 22. Energy and Mineral Resources in India 249-258
- Mineral Resources 249
- Energy Resources 253
- Conservation of Resources 258

Chapter 23. Transport and Communication in India 259-272
- Transport 259
- Land Transport 259
  1. Road Transport in India 259
  2. Indian Railways 262
  3. Ports and Waterways 265
  4. Pipelines 269
  5. Airways 269
- Communication 271

Chapter 24. Industries in India 273-287
- Major Industries 275
- Industrial Regions in India 284

Chapter 25. Population and Human Settlement 288-298
- Human Settlement 288
- Population 292
- Demographic Composition 294
- Migration 296
- Tribes of India 297

Chapter 26. Map Studies 299-301
- Map 299
- History of Map Making 299
- Types of Maps 300
- Uses of Maps 300
- Essentials of Map Making 301

ENVIRONMENT AND ECOLOGY

Chapter 27. Environment 302-304
- Types of Environment 302
- Parts of Environment 302
- Human Impact on Environment 304
- Impact of Environment on Human 304

Chapter 28. Ecology, Ecosystem and Biome 305-316
- Ecology 305
- Ecosystem 306
- Trophic Level 311
- Food Chain 311
- Food Web 312
- Ecological Niche 312
- Biogeochemical Cycles 312
- Bioindicators 313
- Ecological Succession 313
- Biomes 315
- Inter-species Interactions 316

Chapter 29. Biodiversity 317-322
- Meaning of Biodiversity 317
- Geographical Biodiversity 319
- Biodiversity Hotspots 320
- Biodiversity Conservation 321

Chapter 30. Biosphere Reserves, National Parks and Wildlife Sanctuaries 323-327
- National Park 323
- Wildlife Sanctuary 323
- Biosphere Reserves 323
- Wildlife Conservation Schemes 325
- Ramsar Convention for Wetland Conservation 327

Chapter 31. Climate Change, Greenhouse Effect and Ozone Depletion 328-334
- Climate Change 328
- Global Warming 329
- Greenhouse Effect 333
- Ozone Layer Depletion 334
- Acid Rain 334

Chapter 32. Environmental Issues 335-340
- Environmental Pollution 335
- Types of Pollution 335
- Soil Erosion and Desertification 339
- Strategies to Control Environmental Pollution 340
- International Efforts to Control Environment Pollution 340

Chapter 33. Sustainable Development 341-343
- Meaning of Sustainable Development 341
- Objectives of Sustainable Development 341
- Sustainable Development Goals 343

Chapter 34. Disaster Management 344-350
- Disaster 344
- Natural Disasters in India 344
- Man-Made Disasters 349
- Disaster Management in India 349
- Government Initiatives for Disaster Management 350

- **APPENDIX** 351-362

CHAPTER 01

Geography as a Discipline

Sources Class-XI New NCERT Chap 1 (Geography as a Discipline), Class-XI Old NCERT Chap 1 (Geography as a Discipline), Class-XII New NCERT Chap 1 (Human Geography : Nature and Scope)

Geography

- Geography is the description of the Earth. The term geography was first coined by a Greek scholar **Eratosthenes** in 276-194 BC.
- The word has been derived from Greek language, *geo* (Earth) and *graphos* (description), which together mean **description of the Earth**.
- The geographical phenomena, both the physical and human, are not static but highly dynamic. They change over time as a result of the interactive processes between ever changing the Earth and untiring and ever-active human beings.
- Thus, geography, is concerned with the study of nature and human interactions as an integrated whole, 'human' is an integral part of 'nature' and 'nature' has the imprints of 'human'. 'Nature' has influenced different aspects of human life.
- Its imprints can be noticed on food, clothing, shelter and occupation. Human beings have come to term with nature through **adaptation** and **modification**.

Definitions of Geography

- According to **Richard Hartshorne**, "Geography is concerned with the description and explanation of the areal differentiation of the Earth's surface."
- According to **Alfred Hettner**, "Geography studies the differences of phenomena usually related in different parts of the Earth's surface."

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 attempts to comprehend the associations of phenomena as related in sections of reality.
- Every discipline, concerned with scientific knowledge is linked with geography as many of their elements vary over space. Geography helps in understanding the reality in totality in its spatial perspective.
- Thus, geography not only takes note of the differences in the phenomena from place to place but integrates them holistically, which may be different at the places.

Geography as Relation to Human and Environment

In early 20th century, geography developed as a mutual relationship between human and environment.

There are two different ideologies related to this, which are as follows :

(i) **Possibilism** According to this, humans can transform their environment accordingly. This ideology was supported by **Vedal de La Blache**.

(ii) **Determinism** According to this, every human activity is decided by environment. This ideology was supported by **Friedrich Ratzel** and **Ellsworth Huntington**.

Concept of Human Environment

There are three concepts of human environment :

(i) **Concept of Determinism** Determinism is based on the notion that the physical environment has a massive and controlling impact on human being. Humans have no option but to follow the dictates of nature.

(ii) **Concept of Possibilism** Possibilism came as a reaction to environmental determinism. This approach attempts to explain the man-environment relationship in a different way, taking man as an active agent.

(iii) **Concept of Neo-Determinism** (Geographer, **Griffith Taylor**) introduced the concept in 1920s which reflects a middle path between the two ideas of environmental determinism and possibilism. He termed it as neo-determinism or 'stop and go determinism'.

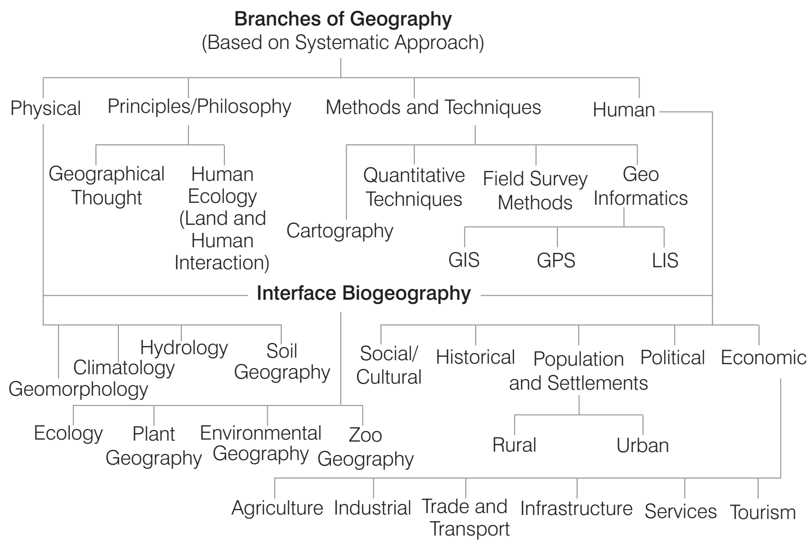
Branches of Geography

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 as follows :

Systematic Approach

- The systematic geography approach is the same as that of general geography. This approach was introduced by a German Geographer, **Alexander Von Humboldt** (1769-1859).
- In systematic approach, 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.

Branches of Geography on the Basis of Systematic Approach



Physical Geography

- **Geomorphology** It is devoted to the study of landforms, their evolution and related process.
- **Climatology** It encompasses the study of structure of atmosphere, elements of weather, climate, its types and regions.
- **Hydrology** It studies the realm of water i.e., oceans, lakes, rivers and other water bodies and its effect on different life forms including human life and their activities.
- **Soil Geography** The geography of soil is concerned with the distribution and variability of soils on terrestrial landscapes ranging from local to global scales.

Human Geography

- **Social/Cultural Geography** It encompasses the study of society and its spatial dynamics as well as the cultural elements contributed by the society.
- **Population and Settlement Geography** (Rural and Urban). It studies population growth, distribution, density, sex ratio, migration and occupational structure etc. Settlement geography studies the characteristics of rural and urban settlements.
- **Economic Geography** It studies economic activities of the people including agriculture, industry, tourism, trade and transport, infrastructure and services etc.
- **Historical Geography** It studies the historical processes through which the space gets organised. Every region has undergone some historical experiences before attaining the present day status. The geographical features also experience temporal changes and these form the concerns of historical geography.
- **Political Geography** It studies political boundaries, space relations between neighbouring political units, delimitation of constituencies, election scenario and develops theoretical framework to understand the political behaviour of the population.

- Political geography studies the spatial distribution of political processes and how these processes are impacted by one's geographical location.

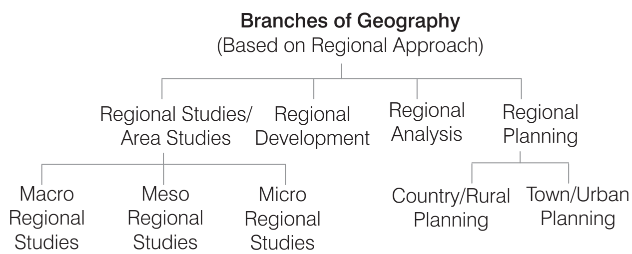
Biogeography

- **Plant Geography** It studies the spatial pattern of natural vegetation in their habitats.
- **Zoo Geography** It studies the spatial patterns and geographic characteristics of animals and their habitats.
- **Ecology / Ecosystem** It deals with the scientific study of the habitats characteristics of species.
- **Environmental Geography** It deals the spatial aspects of interaction between humans and the natural world and its impact of human presence on the environment such as land degradation, pollution, etc. It also raises concerns for conservation which has resulted in the introduction of this new branch in geography.

Regional Approach

- 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 region.
- This approach was developed by German Geographer and a contemporary of Humboldt, **Karl Ritter** (1779-1859).

Branches of Geography on the Basis of Regional Approach



- **Regional Studies / Area Studies** Comprising Macro, Meso and Micro Regional Studies.
- **Regional Planning** Comprising Country/Rural and Town/Urban Planning.
- **Regional Development** It is about geography of welfare and its evolution.
- **Regional Analysis** There are two aspects, which are common to every discipline. These are :

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

(ii) **Methods and Techniques**
 (a) Cartography Including Computer Cartography
 (b) Quantitative Techniques / Statistical Techniques
 (c) Field Survey Methods
 (d) Geo - Informatics Comprising Techniques, such as Remote sensing, GIS, GPS, etc

The above classification gives a comprehensive format of the branches of geography.

Physical Geography and Its Importance

Physical geography comprises the study of Lithosphere, Atmosphere, Hydrosphere and Biosphere.

- **Lithosphere** It is the solid crust or the hard top layer of the Earth. It is an irregular surface with various landforms such as mountains, plateaus, plains, valleys, etc.
- **Hydrosphere** It refers to the domain of water. It comprises various sources of water and different types of water bodies like river, lakes, seas, oceans, etc.
- **Atmosphere** The atmosphere is the thin layer of air that surrounds the Earth. The gravitational force of the Earth holds the atmosphere around it.
- **Biosphere** Plant and animal kingdom together make biosphere or the living world. It is a narrow zone of the Earth where land, water and air interact with each other to support life.

CHAPTER 02

The Universe

Sources Class-VI New NCERT Chap 1 (The Earth in the Solar System), Class-VI Old NCERT Chap 1 (The Earth in our Solar System), Class-XI New NCERT Chap 2 (Origin and Evolution of Earth)

Universe

- The vast and infinite space having millions of galaxies is called **universe**.
- **Star** is a celestial body having its own heat and light. **Galaxy** is a family or system of millions and millions of stars.
- The light of the nearest star (**Proxima Centauri**) to the Sun reaches us in about four years.
- The study of universe is called **Cosmology**.

Origin of the Universe

There are following theories related to the origin of the universe :

Big Bang Theory

- The most popular argument regarding the origin of the universe is the Big Bang Theory. It is also called **expanding universe hypothesis**.
- In 1920, **Edwin Hubble** provided evidence that the universe is expanding. As time passes, galaxies move further and further apart. This theory was proposed by **Georges Edouard Lemaitre** in 1960-1970.
- Scientists believe that only the space between the galaxies is increasing, the galaxies themselves are not expanding.

Stages in the Development of the Universe

- The Big Bang Theory considers the following stages in the development of the universe :
  —In the beginning, all matter forming the universe existed in one place in the form of a 'tiny ball' (**singular atom**) with a small volume, infinite temperature and infinite density
  —At the Big Bang the 'tiny ball' exploded violently and it led to a huge expansion.
- It is now generally accepted that the event of Big Bang took, place 13.7 billion years before the present.
- The expansion continues even to the present day.
- As it grew, some energy was converted into matter.
- There was a particularly rapid expansion within fractions of a second after the bang.
- Thereafter, the expansion has slowed down. Within first three minutes from the Big Bang event, the first atom began to form.
- Within 3,00,000 years from the Big Bang, temperature dropped to 4,500K (Kelvin) and gave rise to atomic matter. The universe became transparent.

Steady-State Theory

- This was an alternative to Big Bang Theory. The most influential papers on steady-state theory were published by **Hermann Bondi**, **Thomas Gold** and **Fred Hoyle** in 1948.
- It considered the universe to be roughly the same at any point of time.
- However, with greater evidence becoming available about the expanding universe, scientific community at present favours argument of expanding universe.

Pulsating Universe Theory

- It is a variation of the Big Bang theory, in which the universe goes through successive periods of expansion and contraction.
- Thus, according to this theory, the universe pulsates endlessly between the Big Bang and the 'Big Squeeze'.
- This theory was proposed by **Allan Sandage**.

Celestial Bodies

- The Sun, the Moon and all those objects shining in the night sky are called celestial bodies.
- These are also called **heavenly bodies**.
- The one who study the celestial bodies and their movement is called as **astronomer**. The Earth on which we live is also a celestial body.
- There are mainly two types of celestial bodies :
  —Some celestial bodies have their own heat and light and are called stars. They are actually very big and hot bodies made of gases.
  —Some celestial bodies do not have their own heat and light. They only reflect the light, which they receive from a star like the Sun. These are called **planets**.
- The word **planet** means **wanderer**.
- Our Earth is also a planet, which receives its light and heat from the Sun.

Galaxies

- Galaxy is a system of stars held together by mutual gravitation and is isolated from similar systems in the vast region of space.
- It also contains a large number of gas clouds, some of which are quite huge. In these gas clouds new stars are born. A galaxy has billions of stars very close to one another.
- Dimensions of Galaxies may be 80,000 to 1,50,000 light years.

Types of Galaxies

Galaxies are of three types :

(i) **Elliptical Galaxies** These are like flattened balls of old stars and contain very little gas. It also includes the most massive galaxies containing a trillion stars.

(ii) **Spiral Galaxies** These have a flattened shape. They have a projection in the centre composed of **old stars surrounded** by a disk of young stars and all arranged in spiral arms.

(iii) **Irregular Galaxies** These have no particular shape. There are billions of galaxies in the universe, the centre of the galaxy releases a huge amount of heat, radiation, radio waves and X-rays.

Major Galaxies

Major galaxies are as follows :

- **The Milky Way** Our solar system is a part of the Milky Way. It is known as Milky Way because it appears as a milky band of light in the sky. Our Milky Way is a large barred spiral galaxy.
- **Andromeda Galaxy** It is also known as Messier 31. It is a barred spiral galaxy approximately 2.5 million light years from the Earth and the nearest large galaxy to the Milky Way.

Galaxy and the Star Formation

- The distribution of matter and energy was not even in the early universe.
- These initial density differences gave rise to differences in gravitational forces and it caused the matters to get drawn together.
- These formed the basis for development of galaxies.
- Galaxies spread over vast distances that are measured in thousands of light years.
- A light year is a measure of distance.
- The distance, the light will travel in one year is taken to be one light year. This equals to $\mathbf{9.461 \times 10^{12}}$ km.
- The mean distance between the Sun and the Earth in terms of light years is **8.311 minutes**. This implies that it takes 8.311 minutes for the light to reach the Earth from the Sun.
- A galaxy starts to form by accumulation of hydrogen gas in the form of a very large cloud called **nebula**.
- Eventually, growing nebula develops localised **clumps of gas**. These clumps continue to grow into even denser gaseous bodies, giving rise to formation of stars.
- The formation of stars is believed to have taken place some 5-6 billion years ago.

Stars

- Stars are huge bodies of glowing gases which have heat and light of their own. The distances of stars are expressed in terms of **light years** (one light year is the distance travelled by light in 1 year at the speed of light which is about 3,00,000 km/s).
- The colour of a star is determined by its surface temperature. Stars which have low temperature appear red, those with higher temperature appear yellow and those with very high temperature are blue.
- With high speed, the stars appear to move from East to West. This is because the Earth rotates from West to East about an imaginary axis that passes through its center. The Earth completes one rotation in 24 hours. Therefore, a star travels an angle of about one degree in 4 minutes.

Life Cycle of Stars

- The age of the stars ranges from millions to billions of years. Stars are like gigantic nuclear furnace.
- The nuclear reactions inside the star convert the hydrogen into helium by the process of fusion and this nuclear reaction gives stars their energy. Stars begin their lives as clouds of dust and gases and are called **nebula**.

- The gravity of a passing star and the shockwave from a nearby **supernova** (explosion of a star) may cause the nebula to contract. Matter in the gas cloud will begin to coalesce into a dense region called **Proto star**.

  As the **Proto star** continues to condense, it heats up. Eventually, it reaches a critical mass and nuclear fusion begins. Thus, begins the main phase of the star. It will spend most of its life in this stable phase.
- The life span of stars depend upon their size. Massive stars burn their fuel much faster than smaller stars. Eventually, stars' fuel will begin to run out. Then they will expand to form the **red giant**.
- This phase lasts until the star exhausts its remaining fuel. At this point, the pressure of the nuclear reaction is not strong enough to equalise the force of gravity and the star collapses.

Constellations

- Constellations are various patterns formed by different groups of stars in the night sky.
- **Ursa Major** or **Big Bear** is one such constellation.
- One of the most easily recognisable constellation is the **Saptarishi** (sapta - seven, rishi stages). It is a group of seven stars that forms a part of Ursa Major Constellation.

Pole Star

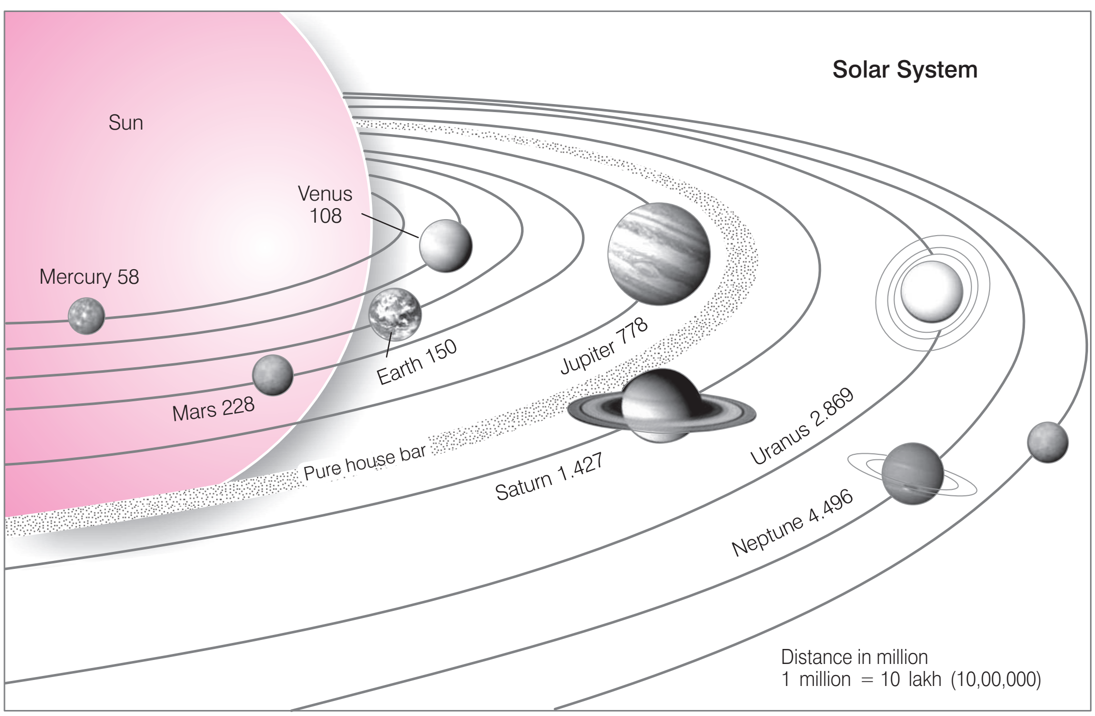
- Since, the Pole Star indicates the North direction, it is also called the **North star**.
- It always remains in the same position in the sky.
- We can locate the position of the Pole Star with the help of the saptarishi.

Chandrasekhar Limit

- The size of a white dwarf star is comparable to that of a planet. The mass of such stars is always less than about 1.44 times the mass of the Sun. This result was proved by **S. Chandrasekhar**. The maximum mass is, therefore, called the **Chandrasekhar limiting mass**.

Our Solar System

- 'Sol' in Roman mythology is the 'Sun God', 'Solar' means related to the Sun'. The family of the Sun is, therefore, called the solar system.
- Our solar system consists of the **Sun** (the star), **8 planets**, **63 moons**, millions of smaller bodies like asteroids, meteoroids and comets and huge quantity of dust-grains and gases.
- Our solar system is a part of milky way galaxy. It is also known as *Akash Ganga*.



Solar System

The Sun

- The Sun is in the centre of the solar system.
- It is made up of extremely hot gases.
- The Sun is the ultimate source of all energy i.e heat and light for the entire solar system.
- The Sun is about 150 million kilometres away from the Earth.

Planets

- There are **eight planets** in our solar system.
- In order of their distance from the Sun, they are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.
- All the eight planets of the solar system move around the Sun elongated in fixed paths called orbits.
- All of them move in the same direction in their revolution.
- The planets also rotate on their own axes.
- Except **Venus** and **Uranus**, all other planets rotate in the same direction in which they revolve.
- As the distance of the planet from the Sun increases, the time taken by it to complete one revolution also increase.
- Since, **Mercury** is nearest to the Sun, it takes only about 88 days to complete one round along its orbit.
- Our **Earth** revolves once in about 365 days and six hours. The amount of heat received by a planet is controlled by the distance of that planet from the Sun.
- In other words, the closer planet to the Sun, the higher its temperature. As Mercury is nearest to the Sun, it receives a great amount of heat from it.
- Out of the eight planets, Mercury, Venus, Earth and Mars are called as the **inner planets** as they lie between the Sun and the belt of asteroids.
- The other four planets i.e Jupiter, Saturn, Uranus and Neptune are called the **outer planets**.

Mercury

- This planet has no water and no gases like CO_2, H_2, N_2 and O_2 on it.
- It is devoid of protective blanket like ozone.

Venus

- It is considered as 'Earths-turn' because its size and shape are very similar to that the Earth.
- Venus is known as the '**evening star**' and **morning star**.
- It is the **hottest planet**.

Earth

- The Earth is slightly flattened at the poles. That is why, its shape is described as a **Geoid**. Geoid means an Earth-like shape.
- From the outer space, the Earth appears blue because its two-thirds surface is covered by water. It is therefore, called a **blue planet**.
- The Earth is a unique planet in the solar system because conditions favourable to support life are probably found only on the Earth. The Earth is neither too hot nor too cold.
- It has water and air, which are very essential for our survival. The air has life supporting gases like oxygen.

Jupiter

- It is the fifth planet from the Sun.
- It is the largest of all planets.
- It is also known as winter planet as its average temperature is very low.
- It lacks well-defined solid surface.

Saturn

- Saturn has bright concentric rings, which are made up of ice and ice-covered dust particles, which revolve around it.
- It is second largest planet and 95 times massive than the Earth.

Uranus

- It is about four times the size of the Earth. It is also called as **God of Heavens**.
- This planet appears greenish in colour because of methane gas present in its atmosphere.

Neptune

- Neptune is very similar to Uranus and can be considered as its twin.
- It is surrounded by methane rings of sub-zero temperature.

Pluto : A Dwarf Planet

Pluto was also considered a planet. However, in a meeting of the International Astronomical Union, (In August, 2006) a decision was taken that Pluto like other celestial objects (Ceres, 2003 UB 313) discovered in recent past may be called 'dwarf planet'.

Terrestrial Planets vs Jovian Planets

Terrestrial Planets	Jovian Planets
Terrestrial means Earth-like.	Jovian means Jupiter-like.
Mercury, Venus, Earth and Mars are called terrestrial planets.	Jupiter, Saturn, Uranus and Neptune are called jovian planets.
They are made up of rock and metals.	They have thick atmosphere, mostly of helium and hydrogen.
They have relatively high densities.	Most of them are much larger than the terrestrial planets.
These planets were formed in the close vicinity of the parent star where it was too warm for gases to condense to solid particles.	Jovian planets were formed at quite a distant location.
The solar wind was most intense near 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.

Planets of the Solar System

Planet	Revolution	Rotation	Moons
Mercury	88 days	58.65	0
Venus	243.02 days	243.02 days	0
Earth	365 days	24 hrs	1
Mars	687 days	24.6 hrs	2
Jupiter	12 years	9.8 hrs	About 53
Saturn	29 years	10.3 hrs	About 53
Uranus	84 years	17.9 hrs	About 27
Neptune	165 years	19.1 hrs	13

Formation of Planets

The following are considered to be the stages in the development of planets :

- The stars are localised clumps of gas within a nebula. The gravitational force within the clumps 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.
- In the next stage, the gas cloud starts getting condensed and the matter around the core develops into small-rounded objects.
- These small-rounded objects by the process of collision develop into planetesimals.
- Larger bodies start forming by collision and gravitational attraction causes the material to stick together.
- In the final stage, these large number of small planetesimals accrete to form a fewer large bodies in the form of planets.

Satellites

- The word ‘satellite’ means a ‘smaller companion to anything’.
- A satellite is a celestial body that moves around the planets in the same way as the planets move around the Sun.
- They also follow them in their revolution around the Sun.
- For instance, the **Moon**, is a satellite of the Earth, which moves around the Earth and around the Sun along with the Earth.
- Except **Mercury** and **Venus**, all the other planets have one or more than one satellites.
- Like planets, the satellites too have no light of their own.
- They just reflect the light received from the Sun.

Man-made Satellite

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

The Moon - The Earth’s Companion

- The Moon is the **only natural satellite** of the Earth.
- Its diameter is only one-fourth of that of the Earth.
- It appears so big because it is nearer to our planet than other celestial bodies.
- It is about 3,84,000 km away from us.
- The light reflected by the Moon reaches us in just one and a quarter seconds.
- The Moon revolves around the Earth in about 27 days and 8 hours.
- It takes exactly the same time for it to complete one rotation about its axis.
- As such we always see only one side of the Moon while the other side always remains away from us.
- The Moon does not have conditions favourable for life. There is no air or water on the Moon.
- It is very hot during the day and very cold during the night.
- There is no soil on the surface of the Moon. The surface of the Moon is very uneven.

- It has mountains, plains and depressions on its surface.
- These cast shadows on the Moon's surface.
- **Neil Armstrong** was the first man to step on the surface of the Moon on 20th July, 1969.
- We can see the full Moon only once in about a month's time. It is full Moon night or *Poornima*.
- A fortnight later, we cannot see it at all. It is a new Moon night or *Amavasya*.
- On this day, we can watch the night sky best, provided it is a clear night.

Theories Related to the Formation of Moon

There are following three theories related to the formation of the Moon :

(i) **Fusion Theory** According to this theory, the Earth was spinning very rapidly and inside 2900 km its surface, an extent of a part was broken away due to fusion. This broken part led to the formation of the Moon.

(ii) **Capture theory** According to this theory, a small planet while moving in an elliptical orbit came very close to the Earth, got capture and put to a circular orbit around the Earth.

(iii) **Theory of Co-existence and Growth** According to this theory, the Earth and Moon are formed together by the accretion of gravitating debris and dust.

Formation of the Moon

- There have been many attempts to explain how the Moon was formed three explanations were suggested in this regard.
- In 1838, **Sir George Darwin** suggested that initially, the Earth and the Moon formed a single rapidly rotating body.
- The whole mass become a dumb-bell shaped body and eventually it broke.
- It was 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 above explanations.
- It is now generally believed that the formation of Moon, as a satellite of the Earth, is an outcome of 'giant impact' or what is described as '**the big splat**'.
- A body of the size of one to three times that of Mars collided into the Earth sometime shortly after the Earth was formed.
- It blasted a large part of the Earth into space.
- This portion of blasted material then continued to orbit the Earth and eventually formed into the present Moon about 41.44 billion years ago.

Other Celestial Objects of the Solar System

- **Asteroids** They are a group of small bodies in between the orbits of Mars and Jupiter, which revolve around the Sun. They are believed to be the pieces of a planet, which probably exploded after its birth.
- **Meteoroids** The small pieces of rocks which move around the Sun are called **meteoroids**. Sometimes these meteoroids come near the Earth and tend to drop upon it. During this process, due to friction with the air they get heated up and burn.

  It causes a flash of light. Sometimes, a meteor without being completely burnt, falls on the Earth and creates a hollow.
- **Comets** A comet is an icy and smaller celestial body which revolves around the Sun in highly elliptical orbit. However, their period of revolution around the Sun is usually very long. They become visible from the Earth only when they come close to the Sun.

  A comet appears generally as a bright head with a long tail. The length of the tail grows in size as it approaches the Sun. The tail disappears again when the comet moves away from the Sun. The tail of a comet is always directed away from the Sun.

  Many comets are known to appear periodically. One such comet is **Halley's Comet** which appears after nearly every 76 years. It was last seen in 1986. The study of comet tail has shown the existence of molecules of carbon, nitrogen and hydrogen.
- **Kuiper Belt** It is region of the solar system beyond the orbit of Neptune. It is believed to contain many asteroids, comets other smaller bodies made of ice.

Black Hole

- It is a region of space time where gravity is so strong that nothing (no particles or even electromagnetic radiation such as light) can escape from it.
- The theory of general relativity predicts that a sufficiently compact mass can deform space time to form a black hole.

Pulsar

- It is rotating neutron star observed to have pulses of radiation at very regular intervals that typically range from milliseconds to seconds. A pulsar is formed when a massive star collapses exhausts its supply of fuel.

CHAPTER 03

The Earth

Sources **Class-VI New NCERT Chap 2** (Globe: Latitudes and Longitudes), **Chap 3** (Motions of the Earth), **Class-VI Old NCERT Chap 3** (Latitudes and Longitudes), **Chap 4** (Motions of the Earth), **Class-XI New NCERT Chap 3** (The Origin and Evolution of the Earth), **Class-XI Old NCERT Chap 2** (The Earth: Its Origin and Evolution)

Earth is not a sphere. It is slightly flattened at the North and the South Poles and bulge in the middle. It moves around its axis, from West to East, which is an imaginary line.

Origin of the Earth

A large number of hypothesis were put forth by different philosophers and scientists regarding the origin of the Earth.

Some of the important hypothesis are as follows :

Monistic Concept (One Star Hypothesis)

- According to this hypothesis, the Solar System originated from one star due to the gradual evolutionary process. The hypothesis of **Kant** and **Laplace** comes under this category.

Gaseous Hypothesis

- One of the earlier and popular arguments was given by German philosopher **Immanuel Kant** in 1755.
- His argument is known as **Gaseous Hypothesis**.
- According to this hypothesis, a system of a few concentric rings separated from a hot and moving nebula due to centrifugal force. By the process of condensation of these rings, the planets of the solar system including the Earth were formed.

Nebular Hypothesis

- It was first put forward by **Immanuel Kant** and later revised by **Laplace** in 1796.
- The hypothesis considered that the planets were formed out of a cloud of material associated with a youthful Sun, which was slowly rotating.
- In 1950, **Otto Schmidt** and **Carl, Weizascar** revised the 'nebular hypothesis.
- They considered that the Sun was surrounded by **Solar Nebula** containing mostly the hydrogen and helium along with what check to be termed as dust.
- The friction and collision of particles led to formation of a disc-shaped cloud and the planets were formed through the process of accretion.

Dualistic Concept

- According to dualistic concept (binary hypothesis), the Solar System originated from two stars. The hypothesis of **James Jeans**, **Chamberlain** and **Moulton**, **Weitzacker's** and **Russell** comes under this category.

Planetesimal Hypothesis

- The Planetesimal Hypothesis of **Chamberlain** (1905) belongs to the dualistic concepts of the origin of the Earth.
- According to Chamberlain initially there were two heavenly bodies (stars) in the universe i.e. Proto-Sun and its Companion Star or Intruding star
- This theory states that when the intruding star came very close to the the Proto-Sun infinite number of small particles were detached from the outer surface of Proto-Sun due to massive gravitational pull exerted by the giant intruding star.
- The matter which is dust, gases, rock fragments eventually accrete forming planets and other celestial bodies that revolve around the Proto-Sun.

Tidal Theory or Hypothesis

- This theory is somewhat similar to **Chamberlain's** theory that an intruding star ejects matter from the proto-sun. Chamberlain, in his theory, had assumed the Proto-Sun to be initially as a cold body whereas the Tidal theory assumes the Proto-Sun to be hot and incandescent.
- According to Tidal theory, the matter ejected are not randomly thrown dust, gases or planetesimal.
- This theory is the best interpretation in explaining the sizes of the planets as they have arranged themselves away from the sun.

Binary Star Hypothesis

- There is a binary star system (two stars coupled together and rotating around a fixed centre of mass).
- This theory is convenient to explain why the composition of planets is different from the Sun.

Supernova Hypothesis

- According to Hoyle initially there were two stars in the universe i.e. **primitive** Sun and **companion** star.
- The companion star was giant and later on became supernova due to nuclear reaction.
- Over time, all of the hydrogen nuclei of companion star were consumed in the process of nuclear reaction and it collapsed and violently exploded.
- The violent explosion of companion star resulted in the spread of enormous mass of dust which started revolving around the primitive Sun in the form of a circular disc.

  Thus, the planets of our solar system were formed due to condensation of the matter of the disc.

Interstellar Hypothesis

- According to this theory, the initial universe comprised of stars and randomly distributed matter filling up the space in between.
- According to **Schmidt**, this dark matter, started to revolve around the primitive rotating Sun and gradually the dark matter stars accreting and condensing and thus forming the solar system.

Evolution of the Earth

- The Earth has a layered structure. Initially, Earth was a barren, rocky and hot object with a thin atmosphere of hydrogen and helium. This is far from the present day picture of the Earth.
- From the surface to deeper depths, the Earth's interior has different zones and each of these contains materials with different characteristics.
- The Earth was mostly in a volatile state during its initial stage. Due to gradual increase in density, the temperature inside it has increased. As a result, the material inside started getting separated on the basis of their densities.
- Heavier materials to sink towards the centre of the Earth and the lighter ones to move towards the surface. With the passage of time, it cooled, solidified and condensed into a smaller size. It later led to the development of the outer surface in the form of a **crust**.
- Through the process of differentiation and partial melting, the Earth forming materials got separated into different layers. Starting from the surface to the center, there are layers like the crust, mantle and core.
- The last phase in the evolution of the Earth relates to the origin and evolution of life. The evolution of life from unicellular bacteria to the modern man can be easily defined by the help of **Geological Time Scale.**
- The Earth is the only planet where some special environmental conditions are responsible for the existence and continuation of life.
- These include the right distance from the Sun, so it has the right temperature range, the presence of water, soil, minerals, suitable atmosphere and a blanket of ozone.

Evolution of Earth's Lithosphere

The main stages in the development of Earth's lithosphere are given as under :

- In its **primordial stages**, Earth was in volatile state.
- With increase in density, the temperature inside the Earth also increased. It resulted into separation of material according to their densities.
- The heavier materials like iron sank towards Earth's center whereas lighter ones moved towards Earth's surface.
- As time passed, Earth cooled down further, solidified and condensed into smaller size. The outer surface of the Earth took the form of crust.
- The Earth's interior divided into different layers *viz.* **crust**, **mantle** and **core**.

Evolution of Earth's Atmosphere

In its process of evolution, the Earth's atmosphere has gone through three different stages :

- **Stage-I** The early atmosphere of the Earth was primarily composed of Hydrogen and Helium.
  It was stripped off from the Earth by solar winds.
  It happened with all terrestrial planets.

- **Stage-II** As Earth cooled down, many gases were released from inside. It contained water vapour, nitrogen, carbon dioxide, methane, ammonia and small amount of oxygen, this process was known as **degassing.**
- **Stage-III** As Earth cooled down further, the water vapour began to condense and heavy rainfall started. It dissolved carbon dioxide into rain water. Therefore, atmosphere lost much of its carbon dioxide.

  As photosynthesis began on the Earth, further absorption of CO_2 occurred and oxygen was released and filled in the atmosphere. That's how, the present compositions of atmosphere came into being.

Evolution of Earth's Hydrosphere

- The earlier rainwater containing carbon dioxide filled the large basins and depressions on the Earth's surface. These water filled basins are known as oceans.
- The oceans were formed within 500 million years from the formation of the Earth.

Evolution of Life on the Earth

- Around 3.8 billion years ago from present, the first sign of life emerged as a result of chemical reactions. It generated complex organic molecules and assembled them. This assemblage had the capacity to duplicate themselves.
- The photosynthesis was started around 3 billion years ago from present. The first life began in form of **unicellular blue algae**.

Geological Time Scale

Eons	Era	Period	Epoch	Age/Years Before Present	Life/Major Events
		Quaternary	Holocene Pleistocene	0-10,000, 10,000-2 million	Modern Man Homo Sapiens
	Cenozoic (From 65 million years to the present times)	Tertiary	Pliocene Miocene Oligocene Eocene Palaeocene	2-5 million 5-24 million 24-37 million 37-58 million 57-65 million	Early Human Ancestor Ape Flowering Plants and Trees Anthropoid Ape Rabbits and Hare Small Mammals Rats - Mice
	Mesozoic 65-245 million Mammals	Cretaceous Jurassic Triassic	—	65-144 million 144-208 million 208-245 million	Extinction of Dinosaurs Age of Dinosaurs Frogs and turtles
	Palaeozoic 245-570 million	Permian Carboniferous Devonian Silurian Ordovician Cambrian	—	245-286 million 286-360 million 360-408 million 408-438 million 438-505 million 505-570 million	Reptile dominate replace amphibians First Reptiles Vertebrates Coal beds Amphibians First trace of life on land Plants First Fish No terrestrial Life Marine Invertebrate
Proterozoic Archean Hadean	Pre Cambrian 570 million - 4.800 million	—	—	570-2,500 million 2,500-3,800 million 3,800-4,800 million	Soft-bodies arthropods Blue-green Algae Unicellular bacteria Oceans and Continents form - Ocean and Atmosphere are rich in Carbon dioxide
Origin of Stars Supernova Big Bang	5,000-13.700 million	—	—	5,000 million 12,000 million 13,700 million	Origin of the Sun Origin of the Universe

Latitude and Longitude

- Both latitudes and longitudes define the relative position of a point in terms of angular distances from Centre of the Earth from North to South and East to West.

Latitude

- Latitude is a measure of the angular distance of a given point from the Equator. It is measured in degrees from the Equator toward either pole.
- One degree (°) is divided into **sixty** equal parts and each unit is called a **minute** ('). A minute is further divided into sixty equal parts and each unit is called a **second** (").

Equator

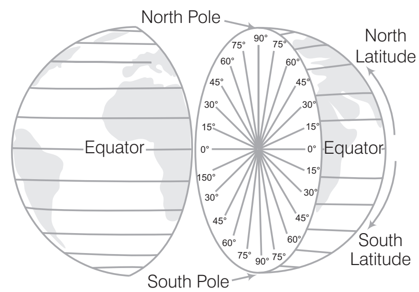
- The Equator is an imaginary circular line that divides the Earth into two equal halves.
- The Northern half of the Earth is known as the **Northern Hemisphere** and the Southern half is known as the **Southern Hemisphere**.
- The Equator represents the **zero degree latitude**. Since the distance from the Equator to either of the poles is one-fourth 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.
- As such, 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 the word North or South. Generally, this is indicated by the letter 'N' or 'S'.
- The Equator is the largest possible circle which can be drawn around the Earth.

Important Parallels of Latitudes

All parallel circles drawn in East-West direction from the Equator up to the poles are called parallels of latitudes.

Besides the Equator (0°), the North Pole (90°N) and the South Pole (90°S), there are following important four parallels of latitudes :

- **Tropic of Cancer** It is an important parallel of latitude in the Northern Hemisphere. It is at an angular distance of 23 1/2 (23° 30′ N) from the Equator.
- **Tropic of Capricorn** It is at a distance of $23\frac{1}{2}°$ (23° 30′) South of the Equator.
- **Arctic Circle** It lies at a distance of $66\frac{1}{2}°$ (66° 30′ N) North of the Equator.
- **Antarctic Circle** It lies at a distance of $66\frac{1}{2}°$ (66° 30′ S) South of the Equator.



Latitudes on the Earth

Heat Zones of the Earth

Torrid and temperate zones are the heat zones of the Earth.

Torrid Zone

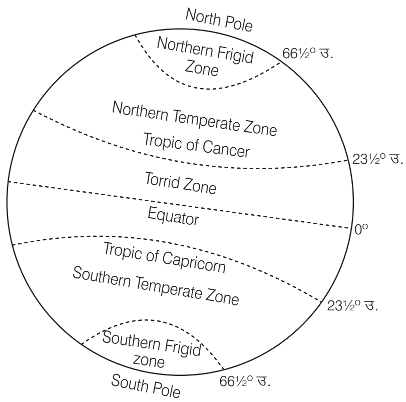
- The extent of this zone is ($23\frac{1}{2}°$ N – $23\frac{1}{2}°$ S).

  The mid-day Sun is exactly overhead atleast once a year on all latitudes in between the Tropic of Cancer and the Tropic of Capricorn.
- Therefore, this area receives the maximum heat and is called the torrid zone.

Temperate Zone

- The extent of this zone is ($23\frac{1}{2}°$ N - $66\frac{1}{2}°$ N and $23\frac{1}{2}°$ S - $66\frac{1}{2}°$ S). 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.
- The areas bounded by the Tropic of Cancer and the Arctic Circle in the Northern Hemisphere, and the Tropic of Capricorn and the Antarctic circle in the Southern Hemisphere, have moderate temperatures.

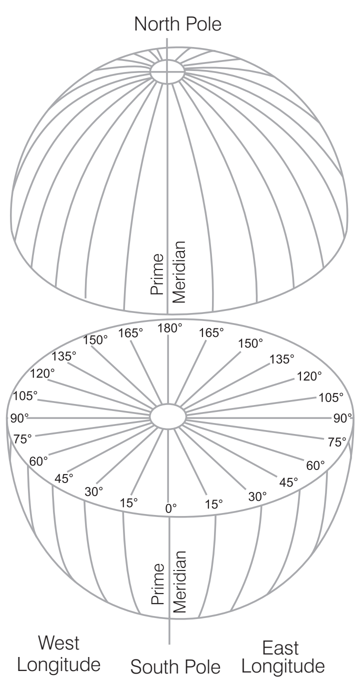
- Therefore, these are called temperate zones.



Heat Zones of the Earth

Longitude

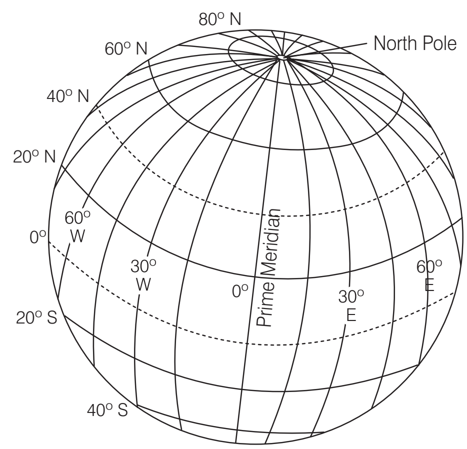
- Longitude is an angular distance of a place from the Prime Meridian.
- The lines running from the North Pole to the South Pole are called the **meridians of longitude** and the distances between them are measured in **degrees of longitude**.
- They are semi-circles and the distance between them decreases steadily polewards until it becomes zero at the poles, where all the meridians meet.
- Unlike parallels of latitude, all meridians are of equal length.



Longitudes on the Earth

Prime Meridian

- It was difficult to number the meridians. Hence, all countries decided that the count should begin from the meridian, which passed through Greenwich, where the **British Royal observatory** is located. This meridian is called the Prime Meridian.
- Its value is 0° longitude and from it we count 180° Eastward as well as 180° Westward.
- The Prime Meridian and 180° meridian divide the Earth into two equal halves, the E-Hemisphere and the W-Hemisphere.
- Therefore, the longitude of a place is followed by the letter E for the East and W for the West.
- It is however, interesting to note that 180° East and 180° West Meridians are on the same line.



Grid of
Prime Meridian

Longitude and Time

- Local time is the time reckoned by the noon-Sun at a given place.
- In other words, local time can be considered by the shadow East by the Sun, which is the shortest at noon and longest at 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.
- The **rate of difference** can be calculated as follows :
  —The Earth rotates 360° in about 24 hours, which means 15° an hour or 1° in four minutes.
  —Thus, when it is 12 noon at **Greenwich**, the time at 15° East of Greenwich will be $15 \times 4 = 60$ minutes, i.e, 1 hour ahead of Greenwich time, which means 1 pm.

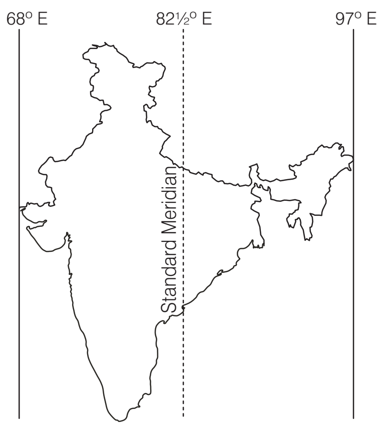
—But at 15° West of Greenwich' the time will be behind Greenwich time by one hour, i.e, it will be 11:00 am.

—Similarly, at 180°, it will be midnight when it is 12 noon Greenwich.

—At any place a watch can be adjusted to reach 12 'O' clock when the Sun is at the highest point in the sky, i.e., when it is mid-day.

—The time shown by such a watch will give the local time for that place.

- All the places on a given meridian of longitude have the same local time.



India : Extent and Standard Meridian

Standard Time

- Standard time is the local time of the Standard meridian of a country.
- In India, the longitude of $82\frac{1}{2}$°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. It is known as the Indian Standard Time (IST).
- India is located **East of Greenwich at 82° 30′E** is 5 hours and 30 minutes ahead of Greenwich Mean Time (GMT).
- Some countries have a great longitudinal extent and so they have adopted more than one standard time. For example, in Russia, there are as many as eleven standard Times.
- The Earth has been divided into twenty-four time zones of one hour each. Each zone thus covers 15° longitude.

International Date Line

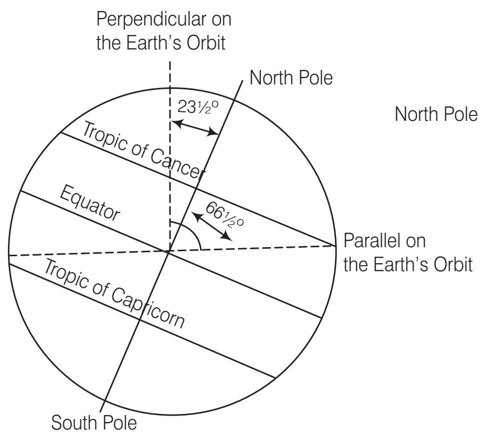
- International Date Line (IDL) marks the place where each day officially begins. At the International Date Line, the West side of the line is always one day ahead of the East side, no matter what time of day it is when the line is crossed.
- The International Date Line has no astronomical or physical meaning. It is an imaginary line drawn at the 180° longitude, avoiding the continuous land parts.
- It is bent at **75° North latitude** towards East to avoid division of Siberia and to separate Siberia and Alaska. Again, it is bent over the Bering Strait towards West. To maintain the continuity of land in the Island of Fiji and New Zealand, the **International Date Line** (IDL) bends towards East in the Southern Pacific Ocean.
- There is a difference of 24 hours in East and West therefore, one day is either gained or lost while crossing this line.
- In the year 2011, **Samoa Islands** and **Tokelau** (South Pacific Islands) as 29th December ended, then fast forwarded by 31st December, missing out on 30th December entirely. It is because of shifting towards West side of IDL for better trading with its neighbours, Australia and New Zealand.

Motions of the Earth

Rotation and Revolution are the two motions of the Earth.

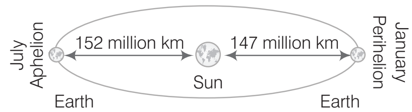
Rotation

- Rotation is the movement of the Earth on its axis.
- The Earth takes about 24 hours to complete one rotation around its axis. The period of rotation is known as the **Earth day**.
- The ancient Indian astronomer **Aryabhata** had stated that 'the Earth is round and rotates on its own axis'.
- The Earth's axis is tilted at an angle of $23\frac{1}{2}°$ from a perpendicular to the orbital plane.
- In other words, the Earth's axis makes an angle of $66\frac{1}{2}°$ with the plane of the Earth's orbit.
- This tilting of the Earth's axis is referred to as the **inclination of the Earth's axis**.
- The Northern end of this axis is called the **North Pole** and the Southern end the **South Pole**.



Tilt of the Earth Axis

- The Earth receives its light and heat from the Sun.
- When the Earth rotates on its axis, one half of it, facing the Sun is lit. The other half remains in darkness.
- Thus each part of the Earth's surface comes into the sunlight for a certain period and then turns away from it in 24 hours.
- The lighted part of the Earth has day, and the other half in darkness has night.
- If the Earth stops rotating the portion of the Earth facing the Sun would always a experience day, thus bringing continuous warmth to the region. The other half would remain in darkness and be freezing cold all the time.
- Thus, it is because of the rotation of the Earth that day and night follow each other in regular succession in all parts of the Earth.



Position of the Earth

Revolution

- The movement of the Earth around the Sun in a fixed path or orbit is called revolution.
- While rotating on its axis, the Earth also moves around the Sun at a speed of about 1,00,000 kilometre per hour.
- The Earth completes one revolution in about 365 days and 6 hours.
- For the sake of our convenience, we consider a year as consisting of only 365 days, and ignore 6 hours.
- Six hours saved every year are added to make one day (24 hours) over a span of four years.
- This surplus day is added to the month of February.
- Thus, every fourth year, February is of 29 days instead of 28 days.
- Such a year with **366 days** is called a **leap year** the Earth goes around the Sun in an **elliptical orbit**.
- On its path around the Sun, the Earth's axis always remains include to one side. i.e. in the same direction.
- Because of this constant inclination in one direction, the Northern Hemisphere remains inclined towards the Sun or faces the Sun during one half of the year. Therefore, a larger part of this hemisphere receives sunlight.
- Every point in this hemisphere takes a longer time to go out of the sunlight, with the result that the days are longer.
- The North pole will always be in Sunlight, which means that it will have a 24 hour day with no night at all.
- In contrast, the Southern hemisphere is away from the Sun. Therefore, it has shorter days and longer night. The South Pole will have a 24 hour night with no day at all.
- During the other half of the year, the Southern Hemisphere is inclined towards the Sun.

  Hence, it has longer days and shorter nights.
- Now the South Pole will have no night and the North Pole will have no day.
- It is only on the Equator that the day and the night are always of equal length.
- On moving away from the Equator, either Northward or Southward, the difference between the length of day and that of night generally goes on increasing.

Slanting and Direct Rays of the Sun

- It is our common experience that the rays of the Sun at noon gives more heat than the rays of the Sun in the morning or in the evening.
- This is because the rays of the Sun are almost vertical at noon and slanting in the morning and in the evening.
- Vertical rays of the Sun fall over a small area, giving it a greater amount of heat.
- Slanting rays, on the other hand, spread over a wide area and give less heat.

Summer Solstice

- On **21st June**, the Northern Hemisphere is tilted towards the Sun.
- 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 longest day and the shortest night at these places occur on 21st June.

- The North Pole is inclined towards the Sun and the places beyond 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.
- At this time in the Southern Hemisphere, all these conditions are reversed. i.e.,

  —It is winter season there.

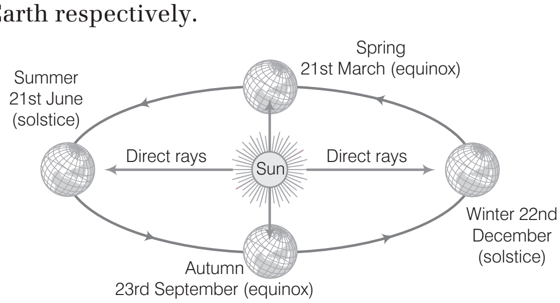
  —The nights are longer than the days.
- This position of the Earth is called the **summer solstice**.

Winter Solstice

- On **22nd December**, 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 ($23\frac{1}{2}^\circ$ 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.
- This position of the Earth is called the winter solstice.

Equinox

- On 21st March and 23rd September, direct rays of the Sun fall on the Equator.
- At this position, neither of the poles is tilted towards the Sun; 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, the opposite happens and it is spring in the Northern hemisphere and autumn in the Southern hemisphere.
- Thus, there are days and nights and changes in the seasons because of the rotation and revolution of the Earth respectively.



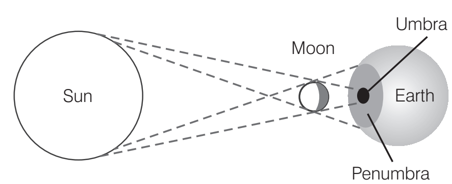
Solstice and Equinox

Eclipse

- An eclipse is a complete or partial obscuration of light from a celestial body as it passes through the shadow of another celestial body.
- Moon's orbital plane inclined 5° to the orbital plane of the Earth, so eclipses do not occur every Full Moon or New Moon positions.
- **Syzygy** is the position of alignment when Earth comes in between Sun and Moon on a straight line; in such position, lunar eclipse occurs. The conjunction is the position when Sun and Moon lie on one side of the Earth and then solar eclipse occurs.
- The portion of the Sun or Moon covered by the vertical shadow of any celestial body like Earth or Moon is called **Umbra** and it is deep dark whereas the faint shadow region is called **Penumbra**.
- During a total eclipse, as the Moon's shadow is short enough to cover the whole of the Sun then the outer region of the Sun still glow and looks bright as a ring as observed from the Earth. Such phenomena is called **diamond ring**.

Solar Eclipse

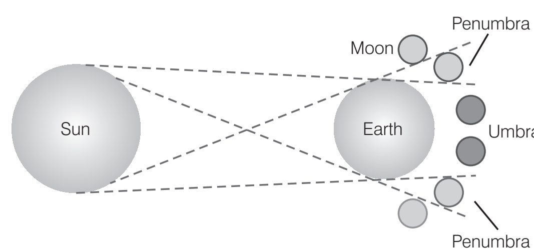
- Solar eclipse occurs near the New Moon position, when the Moon is between the Sun and Earth, thus, obscuring a part of whole of the Sun as viewed from the Earth.



Solar Eclipse

Lunar Eclipse

- Lunar eclipse occurs near the Full Moon position, when the Earth is between the Sun and the Moon and Earth's shadow obscure the Moon as viewed from the Earth.
- Unlike a solar eclipse, which can only be viewed from a certain relatively small area of the world, a lunar eclipse may be viewed from anywhere on the night side of the Earth.



Lunar Eclipse

CHAPTER 04

Geomorphology

Sources **Class-VI New NCERT Chap 6** (Major Landforms of the Earth), **Class-VII New NCERT Chap 2** (Inside Our Earth), **Chap 3 our** (Changing Earth), **Class-VIII Old NCERT Chap 2** (Inside the Earth), **Class-IX Old NCERT Chap 1** (Our Environment : Part and Processes), **Chap 2** (Landforms of the Earth), **Class-XI New NCERT Chap 3** (Interior of the Earth), **Class-XI New NCERT Chap 1** (Land forms and their Evolution), **Chap 4** (Distribution of Continents and Oceans Chap 5 Minerals and Rocks), **Chap 6** (Geomorphic Processes), **Class-XI Old NCERT Chap 5** (Structure of the Earth, Volcanoes and Earthquake)

Interior of the Earth

The structure of the Earth is the result of Geomorphic processes that took place in the interior of the Earth. So, to understand the geomorphology of the Earth, it is important to know about the effect of **Geomorphic Processes**.

Sources to Study Interior of the Earth

- The factual sources concerning the interior of the Earth are not readily available.
- Therefore, the study of the interior of the Earth is based on **direct** and **indirect sources**.

Direct Sources

The important direct sources that give information about the interior of the Earth's are underground mining, deep drilling projects, volcanic eruption, etc.

- **Underground Mines** A large part of the Earth's surface is composed of rocks derived from within the Earth's body. The most important direct source about the interior of the Earth is the solid Earth material in surface rock or the rocks we get from mining areas. e.g., certain Gold mines in South Africa are as deep as 3-4 km. Since, the temperature increases with the depth, it is not possible to go beyond more depth.
- **Deep Drilling Project** There are a number of projects to penetrate deeper depths to explore the conditions in the crustal portions. It provides a large volume of information through the analysis of materials collected at different depths. 'Deep Ocean Drilling Project' and 'Integrated Ocean Drilling Project' are the two major Deep Drilling Projects. The deepest drill is at **Kola**, in the Arctic Ocean, that has reached a depth of 12 km.
- **Volcanic Eruption** The molten material called **magma** is thrown out at the time of volcanic eruption. These are available for laboratory analysis. It indicates that there is a layer which is either molten or in a semi-molten state.

Indirect Sources

Analysis of properties of matter indirectly provides information about the interior of Earth. The important sources that provides details about the interior of the earth are information from the meteors, density, gravitation, magnetic field and seismic activity.

- **Meteors** The material and the structure observed in the meteors are similar to that of the Earth. Hence, meteors are an important source of information about the interior of the Earth.
- **Density** The density and temperature of the material increases with depth. The average density of Earth was calculated as 55 g/cm^3 by using the spherical shape, mean radius and mass of the Earth.

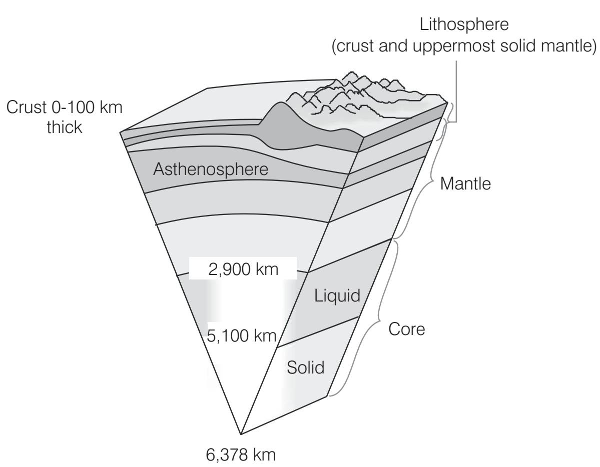
  The density of the Earth is higher at core than all other parts of the Earth. With the help of rate of change of density and temperature and the total thickness of the Earth, it is possible to estimate the values of temperature, pressure and the density of materials at different depths.

- **Pressure** Even though the density increases with pressure, there is a critical limit beyond, which its density cannot be increased. The high density in the core is the result of the presence of heavy metallic material of high density there.
- **Temperature** Heat flows outwards from the interior of the Earth in the form of thermal convective currents. The temperature increases by 1°C for every 32m of depth. This rate of change of temperature is not uniform while going down the surface of the Earth. Relatively higher temperatures are found in tectonically active regions.
- **Gravity** The gravitational force (g) is different at different latitudes on the surface. Since, the distance from the centre to the equator is greater than that from the poles, the gravitational force is greater near the poles and less at the equator. The gravity values also differ according to the mass of material. The reading of the gravity at different places differs from the expected values. Such a difference is called a **gravity anomaly**. Gravity anomalies give us information about the distribution of mass of the material in the crust of the Earth.
- **Magnetic Field** Magnetic surveys provide information about the distribution of magnetic materials in the crustal portion. This provides information about the distribution of materials in this part.
- **Seismic Activity** Seismic waves are generated during earthquakes. There are various types of earthquake waves. The nature of these earthquake waves and their travel speeds reveal the internal layered structure of the Earth.

Structure of the Earth's Interior

- The structure of the Earth's interior is layered. It is broadly classified into three layers such as:

  1. Crust 2. Mantle 3. Core



Layers of the Earth's interior

Crust

- Crust is the brittle outermost solid part of the Earth.
- Crust is mainly divided in two parts, such as **continental crust** and **oceanic crust**.
- The continental crust is thicker than the oceanic crust. It means thickness of oceanic crust is 5 km whereas that of the continental is around 30 km.
- It only possesses less than 1% of the total volume of the Earth.

Continental Crust

- The continental crust is thicker in the areas of major mountain systems. It is about 70 km thick in the Himalayan region.
- It is composed of SiAl, i.e., **Silicon** and **Aluminium**.
- SiAl is a light coloured rock, thus it called **Felsic**. Continental crust is lighter than oceanic crust.

Oceanic Crust

- It is denser and thinner than continental crust.
- It is composed of Sima, made up of Silicon and Magnesium. These are dark coloured mafic crocks.

Lithosphere

- The crust and the uppermost part of the mantle together forms lithosphere.
- It is **100 km** thick. It is the outermost mechanical layer, which behaves as a brittle, rigid solid.
- The lithosphere is broken into a number of plates known as the **Lithospheric plates**.

Mantle

- The mantle is the portion of the interior beyond the crust. It is also known as **Pyrosphere**.
- The thickness of the mantle is about the depth of **2,900 km** from **Moho's discontinuity**.
- It is the bulkiest layer and forms 83% of Earth's volume.
- This layer is rich in magnesium, calcium and iron.
- The lower mantle extends beyond the asthenosphere. It is in solid state.

Asthenosphere

- Asthenosphere is the upper portion of the mantle.
- The word *'astheno'* means 'weak'.
- Asthenosphere is in a plastic state and is the main source of magma. It is considered to be extending up to 400 km.

Core

- The core mantle boundary is located at a depth of 2,900 km. It lies between 2900 - 6400 km depth.
- It is also known as the **Barysphere**. It is about 16% of Earth's volume.
- The core is mainly divided into two, i.e.,
  1. Liquid Outer Core 2. Solid Inner Core
- The core is made up of very heavy material mostly composed of **nickel** (Ni) and **iron** (Fe). It is sometimes referred to as the **NiFe** layer.
- The presence of a metallic core gives magnetic fields to the Earth.
- The heat that keeps the outer core from solidifying is produced by the breakdown of radioactive elements in the inner core.
- This layer has maximum gravitational pull among all three.

Discontinuity

- The change in the speed of **P waves** at different depths suggests the occurrence of discontinuity.
- Important discontinuities are:
  —**Conrad discontinuity** It separates SiAl from SiMa.
  —**Mohorovicic discontinuity** It separates crust from mantle.
  —**Repetti discontinuity** It is found between upper and lower Mantle.
  —**Gutenberg-Weichert discontinuity** It is located between mantle and core.
  —**Lehmann discontinuity** It separates liquid outer core from solid inner core.

Earthquake

- An earthquake is shaking the Earth. It is a natural event caused due to the release of energy, which generates waves that travel in all directions.
- This release of energy occurs along a fault. A fault is a sharp break in the crustal rocks. Rocks tend to move in opposite directions along a fault.
- As a result of this fault, the blocks get deformed and eventually, they slide past one another abruptly. This causes a release of energy. These energy waves (Seismic waves) travel in all directions. The study of **Seismic waves** also help to understand about the interior of the Earth.

Hypocentre and Epicentre

- The point where the energy is released is called the **focus** or the **hypocentre** of an earthquake.
- The energy waves released from the focus travels in all directions to reach the surface of the Earth.
- The point on the surface directly above or nearest to the focus, is called **epicentre**. It is the point on the surface to experience the waves. It is a point of focus.

Earthquake Waves

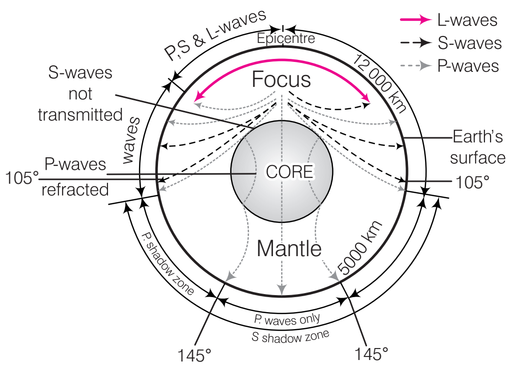
- All-natural earthquakes take place in the lithosphere. An instrument called **seismograph** records the waves reaching the surface.
- A curve of earthquake waves recorded on the seismograph. The curve shows three distinct sections, each representing different types of wave patterns.
- The velocity of waves changes according to the density of material through, which they travel. As the density increases the velocity of seismic waves decreases.
- When seismic waves pass through materials with different densities, their direction will change as a result of their **reflection** or **refraction**.
- Reflection causes waves to rebound whereas refraction makes waves move in different directions.
- These variations in the direction of waves are studied with the help of their record on seismographs.
- Earthquake waves are basically of two types. They are **body waves** and **surface waves**.

Body Waves

- Body waves are generated due to the release of energy at the focus and move in all directions travelling through the body of the Earth.
- There are two types of body waves. They are called **P-waves** and **S-waves**.

P-Waves

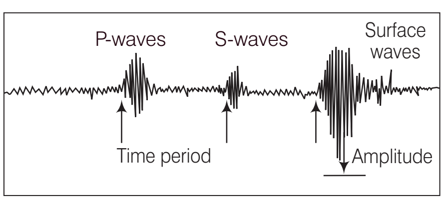
- These are also called **primary waves**. They are short waves of high frequency.
- P-waves move faster than S-waves. It is the first wave to arrive at the surface.
- The P-waves are **longitudinal** similar to sound waves so it can travel through gaseous, liquid and solid materials.
- P-waves have their highest velocity in solid. But their velocity decreases when they passes through liquid or gas.
- P-waves vibrate parallel to the direction of the wave. When P-waves pass through a material, they exert pressure on the material in the direction of the propagation.
- As a result, they creates density differences in the material leading to stretching and squeezing of the material.



Types of Seismic Waves and Shadow Zones

S-Waves

- S-waves are transverse waves which are also called **secondary waves**. S-waves are that they can travel only through solid materials.
- This characteristic of the S-waves helped scientists to understand the structure of the interior of the Earth.
- The direction of vibrations of S-waves is perpendicular to the wave direction in the vertical plane.
- Hence, they create troughs and crests in the material through which they pass.
- They arrive at the surface after the P-wave.



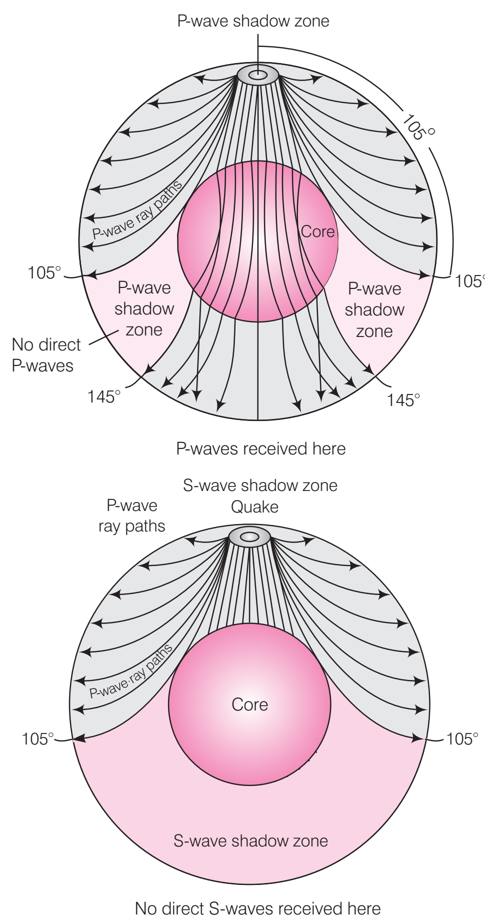
Earthquake Graph

Surface Waves

- The body waves interact with the surface rocks and generate a new set of waves that move along the surface, hence called surface waves.
- The surface waves are the last to report on **seismographs**.
- These waves vibrate perpendicular to the direction of propagation.
- They cause displacement of rocks and hence, the collapse of structures occurs. Surface waves are considered to be the most damaging waves.
- There are two types of surface waves. They are **Love Wave** or **L-wave** and **Rayleigh Wave** or **R-wave**.
- These are of long wavelength and low frequency. They travel slower than body waves.

Shadow Zone

- There exist some specific areas where the earthquake waves are not reported. Such a zone is called the 'shadow zone'.
- The **seismographs** located at any distance within 105° from the epicentre, recorded the arrival of both P and S-waves.
- The seismographs located beyond 145° from epicentre, record the arrival of P-waves, but not that of S-waves.
- A zone between 105° and 145° from epicentre was identified as the shadow zone for both P and S waves.
- The entire zone beyond 105° does not receive S-waves. It is known as the **shadow zone of S-wave**.
- The shadow zone of the S-wave is much larger than that of the P-waves.
- The shadow zone of P-waves appears as a band around the Earth between 105° and 145° away from the epicentre.



Shadow Zone

Magnitude and Intensity of Earthquake

- The magnitude of the earthquake refers to the energy released during the earthquake.
- The magnitude scale is known as the **Richter scale**. The magnitude is expressed in numbers, **0-10**.
- The intensity scale takes into account the visible damage caused by the event.
- The intensity scale is named after **Mercalli**, an Italian seismologist. The range of intensity scale is from **1-12**.

Types of Earthquake

- **Tectonic earthquake** The most common ones are the tectonic earthquakes. These are generated due to sliding of rocks along a fault plane.
- **Volcanic earthquake** It is a special class of tectonic earthquake. However, these are confined to areas of active volcanoes.
- **Collapse earthquake** In the areas of intense mining activity, sometimes the roofs of underground mines collapse causing minor tremors. These are called collapse earthquake.
- **Explosion earthquake** Ground shaking may also occur due to the explosion of chemical or nuclear devices. Such tremors are called explosion earthquakes.
- **Reservoir induced earthquake** The earthquake that occur in the areas of large reservoirs are referred to as reservoir induced earthquakes.

Distribution of Earthquakes

- **Circum-Pacific areas** (70% of earthquakes) with most frequent occurrence along the Pacific ring of fire.
- **Mid-Continental belt** (20% of earthquakes) includes the Mediterranean- Himalayan belt.
- **Mid-Atlantic ridge** (10% of earthquakes) includes the earthquakes of New Madrid, Charleston, Boston, etc.

Effects of Earthquake

Though the actual earthquake activity lasts for a few seconds, its effects are devastating it is more than 5 on the Richter scale.

The immediate hazardous effects of the earthquake are:

- **Ground Shaking** It is a result of the passage of seismic waves through the ground and ranges from quite gentle in small earthquakes to incredibly violent in large earthquakes.
- **Ground rupture** It occurs when the earthquake movement along a fault actually breaks the Earth's surface.
- **Land and mudslides** They are caused by earthquakes both by direct rupture and by **sustained shaking** of **unstable** slopes.
- **Soil liquefaction** Liquefaction is when sediment grains are literally made to float in groundwater, which causes the soil to lose all its solidity.
- **Avalanches** The forces induced by an earthquake can cause an increase in the load down the slope and can also decrease the shear strength and both effects can cause the release of an avalanche.
- **Floods from dam and levee failures** Ground shaking from earthquakes can collapse dams.
- **Fires** Ground rupture and liquefaction can easily rupture natural gas mains and water mains, both contributing to the ignition of fires and **hindering** the efforts to control them.

  —Ground displacement
  —Structural collapse
  —Falling objects
  —Tsunami

Tsunami

- Tsunamis are waves generated by the tremors and not an earthquake in itself.
- The effect of tsunami would occur only if the epicentre of the tremor is below oceanic waters and the magnitude is sufficiently high.

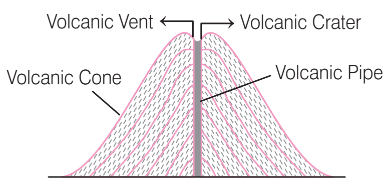
Volcanoes

- Volcanism includes all the phenomena associated with movement of molten material from the interior of the Earth to the surface.
- A volcano is an opening in the Earth's crust through which molten materials come out. It is also the place where gases, ashes and molten rock material escape to the ground.
- The mantle contains a weaker zone called the **asthenosphere**. From the asthenosphere, molten rock material comes out to the surface.
- The material in the upper mantle portion is called **magma**. Once it starts moving towards the crust or it reaches the surface, it is referred to as **lava**.
- The material that reaches the ground includes lava flows, pyroclastic debris, volcanic bombs, ash and dust and gases such as nitrogen compounds, sulphur compounds and minor amounts of chlorine, hydrogen and argon.
- **Bullet Crater** of a volcano is a cylindrical opening through which magma or lava comes out to the surface of the Earth.

- The main causes of volcanic eruption are **plate-tectonics**, weak layer of the crust, high temperature of core and evolution of gases near sea floor.

Parts of Volcano

- **Magma chamber** It is a large underground pool of molten rock under pressure sitting underneath the Earth's crust. Generally, magma chambers are located close to the Earth's surface, usually between 1 km to 10 km deep.
- **Volcanic vent** It is the weak point in the Earth's crust where hot magma has been able to rise from the magma chamber and reach the surface.
- **Volcanic cone** It is made of layers of igneous rocks formed from previous eruptions. Each lava flow add a new layer to the volcanic cone.
- **Volcanic crater** It is depression or hollow from which eruptions expel magmatic material (lava, gas, steam, ash, etc).



Parts of Volcano

Types of Volcano on the Basis of Eruption

- **Hawaiian Type** In this type of volcano, extremely fluid lava comes out on the surface of the Earth. It is mostly basaltic and spreads over large areas.
- **Strombolian Type** Strombolian type is the most typical volcano which are less explosive. There are several small explosive activities, where lava is more viscous.
  It has the power to explode the crust. e.g., Stromboli volcano, Lipari island (North Sicily), Mauna Loa volcano (Hawaiian island).
- **Volcanian Type** In this type, lava is very viscous and the eruptions take place at longer intervals. Large quantities of pyroclastic materials are erupted from them. e.g., volcanoes in Lipari island group of Mediterranean Sea.
- **Vesuvian Type or Plinian Type** In this type, long intervals take place between two eruptions. These are extremely violent and their lava is highly viscous. e.g., volcano that once existed near Naples in Italy.
- **Pelean Type** In this type, lava is viscous and highly destructive and fast-moving mass gets erupted. e.g., Mount Pelee on Martinique island in the West Indies.
- **Fissure Eruption** or **Quiet Eruption** Large quantity of lava quietly flows up from fissures and spreads out over the surrounding areas. Successive flow of lava results in the growth of Lava plateau. e.g., Deccan plateau.

Types of Volcano on the Basis of Activity

- **Active Volcano** A volcano is called an active volcano if the materials mentioned are being released or have been released in the recent past. These volcanoes constantly eject volcanic lava, gas and ashes. e.g., Cotopaxi, Mt. Erebus, Mt. Etna, Strombolian, etc. Due to its recent activity and nearby population, **Mount Etna** has been designated a **Decade Volcano** by the United Nations.
- **Dormant Volcano** These are volcanoes, which were active in past, but for several years have not shown any activity. They can erupt very violently and cause huge damage. e.g., Mt. Krakatoa, Vesuvius (Italy), Fujiyama (Japan), etc.
- **Extinct Volcano** A volcano which erupted in the distant geological past and there is no longer any active volcanicity. They show no indications of future eruptions. e.g., Popa (Myanmar), Mt Demvand and Koh-Sultan (Iran).

Types of Volcano on the Basis of Nature of Eruption

- **Shield Volcanoes** Barring the basalt flows, the shield volcanoes are the largest of all the volcanoes on the Earth. The Hawaiian volcanoes are the most famous examples. Since, the volcanoes are mostly made up of very fluid basalt, this is the reason, these volcanoes are not steep.
  They are characterised by low-explosivity. When water gets into the vent, they become explosive.
  The upcoming lava moves in the form of a fountain and throws out the cone at the top of the vent and develops into a cinder cone.
- **Composite Volcanoes** Composite volcanoes are characterised by the eruptions of cooler and more viscous lavas than basalt. These volcanoes often result in explosive eruptions.
  This material accumulates in the vicinity of the vent openings leading to formation of layers and this makes the mounts appear as composite volcanoes.
- **Caldera** These are the most explosive of Earth's volcanoes. When they erupt, they tend to collapse on themselves rather than building any tall structure.
  The collapsed depressions are called calderas. Their magma chamber supplying the lava is not only huge but is also in close vicinity.
- **Flood Basalt Provinces** These volcanoes outpour highly fluid lava that flows for long distances. There can be a series of flows with some flows attaining thickness of more than 50 m.

The Deccan Traps from India, are a much larger flood basalt province. It is believed that initially the trap formations covered a much larger area than the present.

- **Mid-Ocean Ridge Volcanoes** These volcanoes occur in the oceanic areas. There is a system of mid-ocean ridges more than 70,000 km long that stretches through all the ocean basins. The central portion of this ridge experiences frequent eruptions.

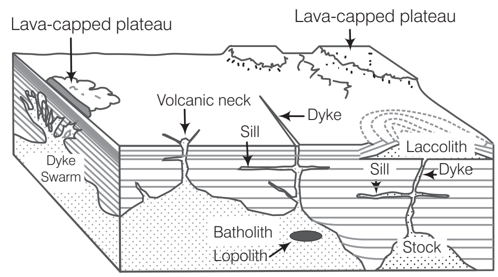
Topographic Features of Volcanoes

- Magma is of two types i.e., **basaltic** and **granitic**. Basaltic magma is fluid while granitic magma is viscous.
- Once magma comes to the surface of the Earth, it is lighter than the adjoining rocks, moves upward towards the surface and gives rise to certain topographic features.
- The cooling of Magma 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 and plutonic rocks.
- When rocks are formed by cooling at the surface it is known as **volcanic rocks**. When by cooling in the crust it is known as **plutonic rocks**.

Intrusive Features

When the volcanic features are formed beneath the surface, they are called intrusive features. Some of the important intrusive features are as follows :

- **Batholiths** These are the cooled portion of magma chambers. A large body of magmatic material that cools in the deeper depth of the crust develops in the form of large domes. These are granitic bodies.
- **Lacoliths** These are large dome-shaped intrusive bodies with a level base and connected by a pipe-like conduit from below. It resembles the surface volcanic domes of composite volcano, only these are located at deeper depths.
- **Lapolith** As and when the lava moves upwards, a portion of the same may tend to move in a horizontal direction wherever it finds a weak plane. It may get rested in different forms. In case it develops into a saucer shape, concave to the sky body, it is called lapolith.
- **Phacoliths** A wavy mass of intrusive rocks, at times, is found at the base of synclines or at the top of anticline in folded igneous country. Such wavy materials have a definite conduit to source beneath in the form of magma chambers. These are called the phacoliths.
- **Sills** The near horizontal bodies of the intrusive igneous rocks are called sill or sheet, depending on the thickness of the material. The thinner ones are called sheets while the thick horizontal deposits are called sills.
- **Dykes** When the lava makes its way through cracks and the fissures developed in the land, it solidifies almost perpendicular to the ground. It gets cooled in the same position to develop a wall-like structure. Such structures are called dykes.



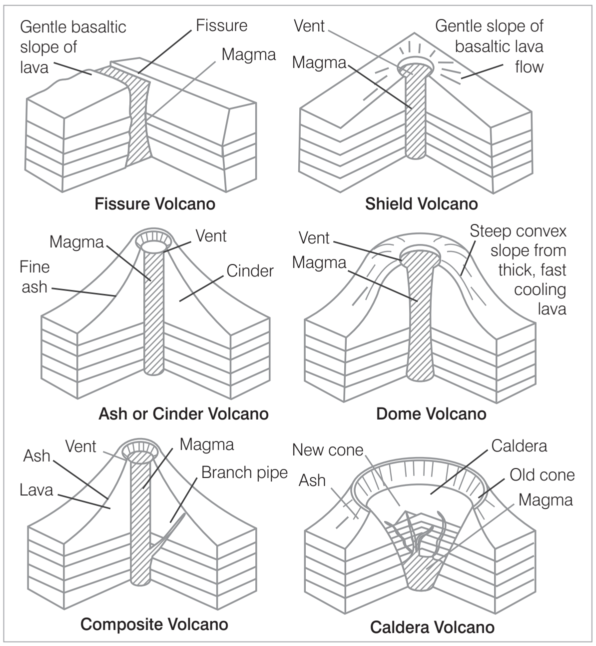
Intrusive Features of Volcano

Extrusive Features

Some of the important extrusive features are as follows :

- **Flood Basalts** These are formed by fissure eruption. Due to the less viscous basaltic lava it erupts with no explosive activity. e.g., Deccan trap.
- **Shield Volcanoes** These are huge domes of basalt. It is formed as a result of continued outpouring of great quantities of highly fluid basaltic lava. e.g., Mt Mauna Kea and Mauna Loa on Hawaii.
- **Ash or Cinder Cone** These are usually of low height and are formed of volcanic dust, ashes and pyroclastic matter. They are formed when the eruption is of central type with a predominance of pyroclastic materials. e.g., Paricutin, Mexico.
- **Shield Type** These volcanoes vary in size from less than 20 m across. Shield volcanoes are formed from low viscosity, runny lava. When lava spreads far from the source and forms a volcano with gentle slopes. Mauna Kea and Mauna Loa are shield volcanoes.
- **Composite or Strata Cone** It is the highest of all volcanic cones. These are formed due to accumulation of different layers of various volcanic materials and hence, called as **strato-cones**. These are built up by alternate layers of lava and fragmental flows. e.g., Pinatubo of Philippines, Fuji in Japan.
- **Parasitic Cone** Several branches of pipes come out from the main centre pipe of the volcano. Lava and other volcanic material will come out from these minor pipes and get deposited around these newly formed vents. The smaller cones formed on major cones are termed as a parasitic cone.

- **Crater** The depression formed at the mouth of a volcanic vent is known as crater or **volcanic mouth**. It is usually funnel shaped.
- **Caldera** It is the enlarged form of a crater. These are either formed by the subsidence of a crater or by the violent and explosive eruption of volcanoes.
- **Hot springs** These are formed when groundwater comes in contact with the magma. When ground water gets heated beyond 36° C, it comes to the surface as a hot spring. e.g., Ladakh, Manali, volcanic regions of Iceland, Yellow Stone National Park.
- **Geyser** It is a special type of hot spring. It ejects steam and superheated water at regular intervals e.g., Old faithful geyser in the USA, which erupts faithfully after every 66 minutes.
- **Fumaroles** They are characterised by full-scale continuous jet-like emission of hot water from a vent. These are the vent through which gases and water vapour are emitted.



Extrusive Features of Volcano

Distribution of Volcanic Belts

Distribution of volcanic belts is uneven in the world. There are following three prominent volcanic belts :

Circum-Pacific Belt

- Circum-Pacific region popularly termed as the '**Pacific Ring of Fire**'.
- It has the greatest concentration of active volcanoes. Volcanic belt and earthquake belt closely overlap along the 'Pacific Ring of Fire'.
- It extends across the Kamchatka Peninsula, Kuril Islands, the Islands of Japan, Philippines, New Guinea, New Zealand and the Solomon Islands.
- It also passes through Antarctica and the Western coast of North and South America.

Mid-Continental Belt

- This belt is formed as a result of convergence between the Eurasian Plate and the Northward-moving African Plate.
- It includes volcanoes of the Alpine mountain chain, the Mediterranean Sea and the fault zone of Eastern Africa of Stromboli, Vesuvius, Etna, Kilimanjaro, etc.

Mid-Atlantic Belt

- These are located on divergent plate boundaries. The Mid-Atlantic Ridge is a volcanic mountain range that rises from the Atlantic abyssal plain, extending from the Arctic to the Antarctic.
- In this belt, the volcanoes are fissure eruption type, e.g., Iceland, Canary Islands, Cape Verde, Azores, etc.

Rocks

- The Earth's crust is composed of rocks. A rock is an aggregate of one or more minerals.
- **Petrology** is the science of rocks. A petrologist studies rocks in all their aspects viz., mineral composition, texture, structure, origin, occurrence, alteration and relationship with other rocks.

Types of Rocks

- On the basis of mode of formation, rocks are grouped under three families. They are:

(i) Igneous Rocks (ii) Sedimentary Rocks
(iii) Metamorphic Rocks

Igneous Rock

- Igneous rocks form out of magma and lava from the interior of the Earth. They are known as **primary rocks**.
- The igneous rocks are formed when magma cools and solidifies. The process of cooling and solidification can happen inside the Earth's crust on the surface of the earth.
- Granite, gabbro, pegmatite, basalt, volcanic breccia and tuff are some of the examples of igneous rocks.

Classification of Igneous Rock Based on Texture

- Texture depends upon size and arrangement of grains or other physical conditions of the materials. Igneous rocks are classified based on texture as coarse grained, fine grained and intermediate grained.
  —**Coarse Grained** If molten material is cooled slowly at great depths, mineral grains may be very large.

—**Fine Grained** Sudden cooling (at the surface) results in small and smooth grains.

—**Intermediate Grained** Intermediate conditions of cooling would result in intermediate sizes of grains making up igneous rocks.

- Some igneous rocks have been produced through two stage of cooling. The large crystals formed by slow cooling called phenocryst are found embedded in a matrix of very small crystals called **porphyry** formed by rapid cooling.

Classification of Igneous Rock Based on Occurrence

On the basis of mode of occurrence igneous rocks are classified into three types:

- **Plutonic or Intrusive Rocks** These are formed due to the cooling of magma very deep inside the Earth. These are coarse grained rocks since, they are formed due to slow cooling. e.g., granite.
- **Hypabyssal Rocks** Intruded rocks occurring at shallow depths. The magma solidifies in different forms depending upon the hollow place such as batholith, laccolith, phacolith, lopolith, sill, dyke etc.
- **Volcanic Rocks** These are formed due to the cooling and solidification of hot and molten lavas at the Earth surface. Because of the rapid cooling it is made up of fine grained crystals.
- **Pyroclastic Rocks** These are accumulated material of explosive volcanic activity. e.g., lava clot, ash and dust.

Classification of Igneous Rock Based on Chemical Composition

On the basis of mineralogical and chemical composition igneous rocks are classified as:

- **Felsic or Silica Rocks** Acidic in nature with over 65 to 85% of silica content. e.g., Granite and Granodiorite.
- **Acid Igneous Rocks** They are hard and relatively resistant to erosion. These are light coloured and light weighted rock.
- **Mafic or Basic Rocks** Basic in nature with 45 to 60% of silica content. e.g., Gabro, Basalt, Dolerite.

  These igneous rocks are dominated by ferro- magnesium minerals. These rocks are heavy and dark coloured.
- **Ultrabasic or Ultramafic Rocks** These rocks contain less than 45% silica content. Peridotite is the typical example of this group of rock.

Sedimentary Rocks

- The word 'sedimentary' is derived from the Latin word *sedimentum*, which means 'settling'.
- Rocks of the earth's surface are exposed to denudational agents and are broken up into various sizes of fragments.
- Such fragments are transported by different exogenous agencies and deposited.
- These deposits through compaction turn into rocks. This process is called **lithification**.
- In many sedimentary rocks, the layers of deposits retain their characteristics even after lithification. Hence, we see a number of layers of varying thickness in sedimentary rocks like sandstone, shale etc.
- Sedimentary rocks are found over about 95% area of the crust, but they contribute only 5% in the formation of the crust.
- Fossils are generally found in sedimentary rocks.

Stages in the Formation of Sedimentary Rocks

- **Stage-I** Weathering of any rock whether igneous, sedimentary or metamorphic.
- **Stage-II** Transportation either involves mass movement or an agent–river, glacier, wind, waves or groundwater.
- **Stage-III** Deposition that takes place in variety of environments– glacial, arid, deltaic, etc.
- **Stage-IV** Lithification is the process of converting sediments into sedimentary rocks.
- **Stage-V** Cementation is the process in which various cementing minerals cause the whole mass to become tightly bound together.

Classification of Sedimentary Rock Based on Mode of Formation

On the basis of **mode of formation sedimentary** rocks are classified into three major groups:

- **Mechanically formed** Rock fragments are formed due to the mechanical or physical disintegration of previously formed rock.
  e.g., sandstone, conglomerate, limestone, shale, loess etc. are examples.
- **Organically formed** These rocks are formed from the organic sediments derived from the disintegration or decomposition of plants and animals e.g., geyserite, chalk, limestone, coal etc.
- **Chemically formed** Chemically derived sediment are formed when chemically active water comes in contact with country rocks. Example are chert, limestone, halite, potash etc. are some examples.

Metamorphic Rocks

- The word 'metamorphic' means 'change of form'.
- Metamorphic rocks form under the action of pressure, volume and temperature changes.
- **Metamorphism** is a process by which already consolidated rocks undergo recrystallisation and reorganisation of materials within original rocks.

Metamorphism occurs when rocks are forced down to lower levels by tectonic processes.

- Metamorphic rocks are also formed when molten magma rising through the crust comes in contact with the crustal rocks or the underlying rocks are subjected to great amounts of pressure by overlying rocks.
- Gneissoid, granite, syenite, slate, schist, marble, quartzite etc., are some examples of metamorphic rocks.
- Metamorphic rocks formed through the igneous rocks are called **meta-igneous** or **ortho-metamorphic rocks**. Gneiss from Granite, Amphibolite from Basalt, Schist from Basalt.
- Metamorphic rocks formed by the further metamorphosis of metamorphic rocks are phyllite from slate, schist from phyllite, serpentine from gabbro.

Metamorphism is of following two types:

Dynamic Metamorphism

- Mechanical disruption and reorganisation of the original minerals within rocks due to breaking and crushing without any appreciable chemical changes is called dynamic metamorphism.

Thermal Metamorphism

- The materials of rocks chemically alter and recrystallise due to thermal metamorphism.

There are two types of thermal metamorphism :

—**Contact Metamorphism** In the process of Contact metamorphism, the rocks come in contact with hot intruding magma and lava and the rock materials recrystallise under high temperatures. Quite often new materials form out of magma or lava are added to the rocks.

—**Regional Metamorphism** In regional metamorphism, rocks undergo recrystallisation due to deformation caused by temperature or pressure or both. In the process of metamorphism, in some rocks grains or minerals get arranged in layers or lines.

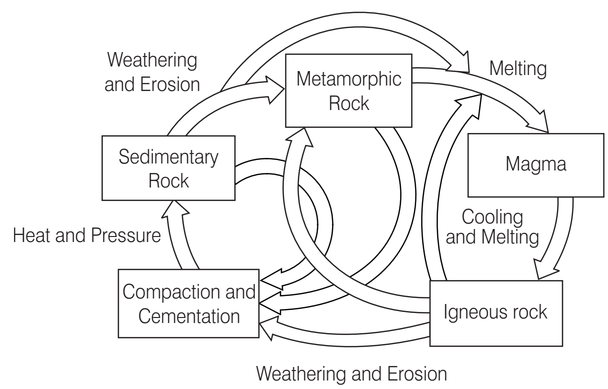
Foliation

- A parallel arrangement of minerals or grains in metamorphic rocks is called foliation or **lineation**.
- Minerals or materials of different groups are arranged into alternating thin to thick layers appearing in light and dark shades. Such a structure in metamorphic rocks is called banding and rocks displaying banding are called banded rocks.
- Types of metamorphic rocks depend upon original rocks that were subjected to metamorphism.
- Metamorphic rocks are classified into two major groups such as:

1. Foliated rocks
2. Non-foliated rocks

Rock Cycle

- Rock cycle is a continuous process through which old rocks are transformed into new ones.
- **Igneous rocks** are primary rocks and other rocks form from these primary rocks. Igneous rocks can be changed into **metamorphic rocks**.
- The fragments derived out of igneous and metamorphic rocks form into sedimentary rocks.
- **Sedimentary rocks** themselves can turn into fragments and the fragments can be a source for formation of sedimentary rocks.
- The crustal rocks such as igneous, metamorphic and sedimentary once formed may be carried down into the mantle through subduction process.
- The same melt down due to increase in temperature in the interior and turn into molten magma i.e., the original source for igneous rocks.



Rock Cycle

Major Theories for the Evolution of Landforms

Many theories have been given for the explanation of evolution of landforms on the surface of the Earth.

- Most important theories for the evolution of landforms are:

—Continental Drift Theory
—Sea Floor Spreading Theory
—Plate Tectonics Theory

Continental Drift Theory

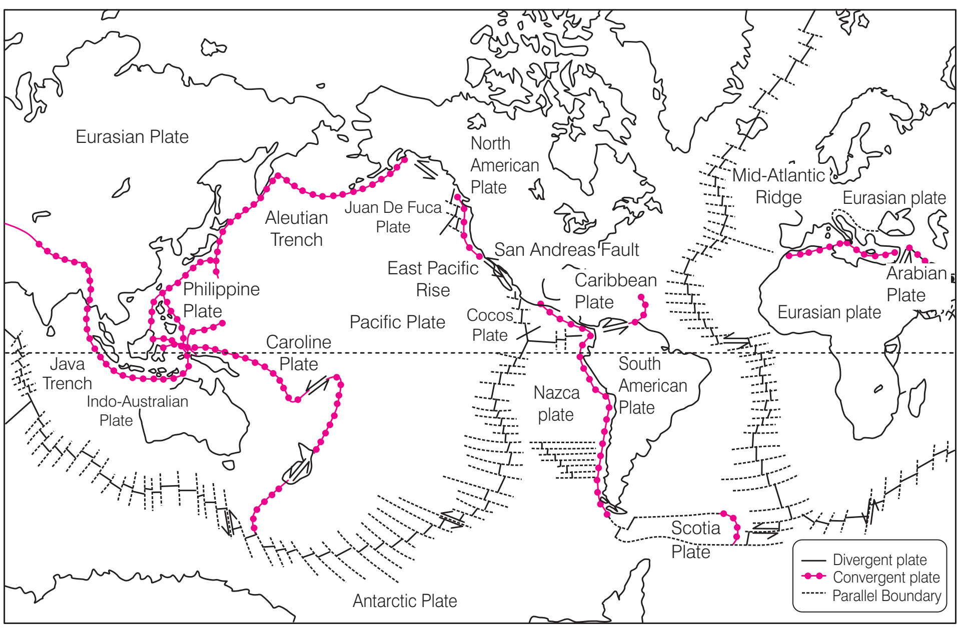
- In 1912, **Alfred Wegener** in a book 'The Origin of Continents and Oceans' put forward the idea of lateral movement of continents or continental drift.

- In this theory, he claimed that the changes in the appearance of the Earth were largely due to the shifting of continents.
- There was only one supercontinent called Pangaea about 250 million years ago. It was surrounded by the super-ocean named **Panthalassa**.
- About 200 million years ago, the Pangaea began to break up into two. They are:
  —**Laurasia** that started floating Northward.
  —**Gondwanaland** that started floating Southward.
- Laurasia and Gondwanaland was intervened by a narrow and shallow water body known as **Tethys sea**.
- Laurasia consisted of present North America and Greenland and Eurasia (without India and Arabia).
- Gondwanaland contained Africa with Arabia attached with South America, Australia, Antarctica and India. The South Pole was located near Durban, near Natal in South Africa.
- Wegner states that the Northward movement was caused by gravitational forces, i.e. because of intense gravitational pull of the poles. Whereas the Westward movement was thought to be caused by the pull of the Moon or tidal forces.
- Later on, Indo-Australian plate started moving Northward. The Indo-Australian plate and Africa caused the sediments deposited in the Tethys to be crushed and deformed. Thus, the **Alpine** and **Himalayan** mountain ranges were formed.
- The **Andes** and **Rockies** are formed due to the Westward movement of America. It also led to the formation of Caribbean Island arcs and widening of the Atlantic Ocean.

Evidence of Continental Drift Theory

The evidences in support of the theory are :

- **Jigsaw Fit of continents** It refers to the similarities between the coastlines of South America and Africa, suggest that these were once joined together.
- **Structural similarities** The continuity of tectonic trends of the block of these countries across their present boundaries.
- **Fossil similarities** The distribution of the fossil plants in Argentina, South Africa, India, Western Australia and Antarctica.
  —Glacial evidence —Mountain ranges
  —Coal deposits —Evidence of glacial striation



Evidence of Continental Drift Theory

Criticism of Continental Drift Theory

- The responsible forces for the whole process of the continental drift were not sufficient enough.
- But still the evidence provided by the Continental Drift Theory provided a platform for future work.

Sea Floor Spreading Theory

- The Sea Floor Spreading hypothesis was proposed by the geophysicist **Harry H Hess**.
- The theory was based on a concept that the age of the rocks of the seafloor is not the same.

- The youngest rocks are found in the central parts of the oceans while older rocks are found towards the margins of the oceans.
- The new crust is formed from the central part of the ocean and spreads towards the margins of the ocean, pushing the older rocks towards the margins. This concept is known as **Sea Floor Spreading**.

Plate Tectonics Theory

- The Plate Tectonics Theory deals with the whole mechanism of evolution, nature of motion of plates and resultant reaction.
- Plate Tectonics Theory explains the large-scale motions of Earth's lithosphere.
- Though, this theory was proposed by **Harry Hess** in 1962, the term plate was first coined by **JT Wilson** in 1965.
- Later the theory was explained scientifically by **WJ Morgan**, **Dan McKenzie**, **Robert I Parker** and **Arthur Holmes**.
- According to this theory, the crust of the Earth is divided into several big and small fragments called plates. These lithospheric plates are about 100 km thick.
- These plates are floating over the semi-molten asthenosphere.

Types of Plates

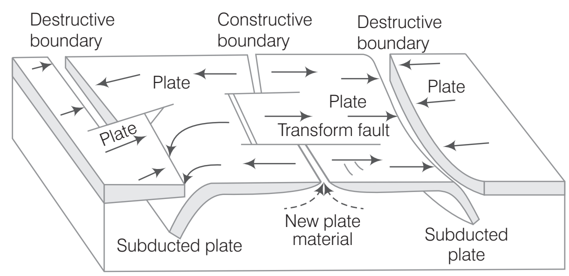
- Lithospheric plates are mainly divided into two. They are **Major Plate** and **Minor Plate**.
- There are **seven major plates** on the Earth. They are Eurasian, Antarctican, North American, South American, Pacific, African and Indian Australian plate.
- Other minor plates are China, Philippines, Arabian, Iran, Nazca, Cocos, Caribbean and Scotia plates.
- The plates are continuously in motion with respect to each other.
- The **Pacific plate** is the largest plate, composed almost entirely of oceanic crust and covers about 1/5th of entire Earth's surface.
- Almost all large plates contain both continental and oceanic crusts. None of the major plates are composed entirely of continental crust.

Cause of Plate Movement

- The lithospheric plates are situated above the asthenosphere which is in a **semi plastic** state.
- Due to the high temperature at the Earth's interior magma in the asthenosphere undergoes continuous convection.
- This convection currents in the asthenosphere causes the movement of lithospheric plates.
- The plates move at a speed of 2 centimetres to 12 centimetres a year. The speed of this movement has not always been uniform.

Plate Boundaries

- Plate boundaries are generally of three types namely:
  1. Constructive Margins or Divergent Plate Boundary.
  2. Destructive Margin or Convergent Plate Boundary.
  3. Conservative Margin or Parallel Boundary or Transform Fault Boundary.



Types of Plate Boundaries

Constructive Plate Margin or Divergent Plate Boundary

- If a plate boundary is said to be Divergent Plate Boundary if two plates move away from each other.
- As a result of this movement, the molten lava from the asthenosphere comes out from the crack that develops between them.
- The surface continuously and after solidification forms a new crust. Hence, such plate boundaries are called **constructive plate margins**.
- The divergence brings in two results:
  (i) The formation of a new crust
  (ii) Formation of submarine mountains or ridges
- The Mid Oceanic ridges are formed as a result of the divergence of oceanic plates. As a result of this divergence magma comes out through the gap formed due this movement.
- This magma solidifies to form mountains. These types of mountains are known as **Mid Oceanic ridges**. e.g., Mid-Atlantic ridge, the East-Pacific ridge and the Chagos- Laccadives ridge in the Indian Ocean.
- Such plate margins passing through the continents result in the formation of **rift valleys**. For example, the rift, which broke Arabia away from Africa and grafted it on to Asia, changed the appearance of both continents and opened up new seas-the Red sea and the Gulf of Aden.
- In these areas, earthquakes and volcanoes are frequent, even though of moderate to low intensity.

Destructive Plate Margin or Convergent Plate Boundary

- When two plates move towards each other, it is known as **Destructive Plate Margin**.
- As two plates collide with each other, the denser one is subducted below the lighter one. The region where the subduction takes place is called **Benioff zone** or **Subduction zone**. This plate margin is also known as **consuming plate margin**.
- The subducting plate is lost in the mantle. It is also called **convergent plate margin** as two plates converge here.
- The convergent plates interact with each other in three different ways :

Oceanic-Continental Convergent Plate

- When one oceanic plate and continental plate collide with each other, the denser oceanic plate gets subducted below the lighter continental plate as it is denser.
- This zone is known as **subduction zone**. Magmas created in this zones comes out breaking the weak part of the crust and results in the formation of volcanoes.
- Trenches are seen associated with these types of margin. For example, the Western side of the American plate, where the Pacific plate is subducted below the American plate. It is the zone of active volcanoes.

Oceanic-Oceanic Convergent Plate

- When the margins of one oceanic plate collide with another, one plate descends under the adjacent plate and melt down to form the part of the mantle. This may lead to the formation of oceanic trenches.
- Convergence of the **Pacific** and the **Philippines plates** explains the formation of island, festoons and chain of volcanoes in that region. e.g., Philippines and Indonesian islands.

Continent-Continent Convergent Plate

- Due to the collision of the plate margins where continents occur on both sides of the plate margin **fold mountains** are formed.
- The **Himalayan ranges** were formed this way. The collision of the Indian plate with the Eurasian plate has formed the Himalayas.

Conservative Margin or Parallel Boundary

- In some regions where two lithospheric plates slide past one another in opposite directions, noticeable changes may not occur.
- But these may cause fissures on the Earth's crust. These are called **zones of faulting**.
- **San Andreas Fault Zone** of California is an example for this. Shear margins are zones of frequent earthquakes of varied intensity.
- It marks the meeting place of two parallel plates, one carrying North America and the other carrying the Pacific Ocean.

Movement of the Indian Plate

- The Indian plate includes Peninsular India and the Australian continental portions. The subduction zone along the Himalayas forms the Northern Plate boundary in the form of continent-continent convergence.
- In the East, it extends through **Rakinyoma** mountains of Myanmar towards the island are along the **Java trench**. The Eastern margin is a spreading Site lying to the East of Australia in the form of an Oceanic ridge in South-West Pacific.
- The Western margin follows **Kirthar** mountain of Pakistan. It further extends along the **Makrana** coast and joins the spreading site from the Red sea rift South-Eastward along the Chagos archipelago.
- India was a large island situated off the Australian coast, in a vast ocean. The **Tethys Sea** separated it from the Asian continent till about 225 million years ago.

Geomorphic Processes

- The endogenic and exogenic forces causing physical stresses and chemical actions on Earth materials and bringing about changes in the configuration of the surface of the Earth are known as geomorphic processes.
- **Diastrophism** and **volcanism** are endogenic geomorphic processes, whereas **weathering**, **mass** movement, **erosion** and **deposition** are exogenic geomorphic processes.
- Any exogenic element of nature (like water, ice, wind, etc.,) capable of acquiring and transporting earth material can be called a **geomorphic agent**. When these elements of nature become mobile due to gradients, they remove the material and transport them over slopes and deposit them at lower level.
- Gravity besides being a directional force activating all downslope movements of matter also causes stresses on the Earth's materials. Indirect gravitational stresses activate wave and tide induced currents and winds.
- Without gravity and gradients there would be no mobility and hence, no erosion, transportation and deposition are possible.