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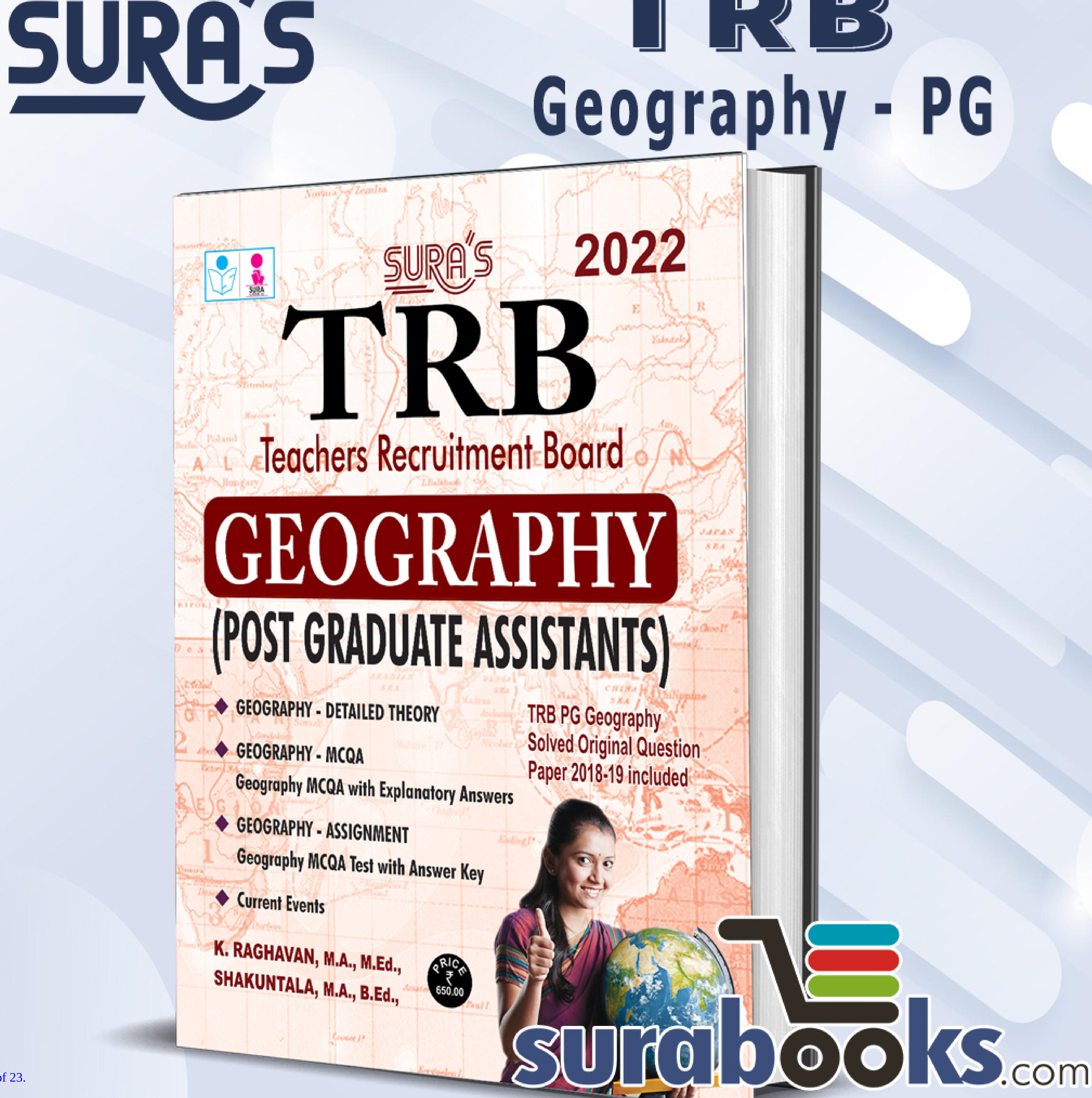
Contents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GEOGRAPHY

Introduction

The term 'Geography' was coined by the Greek scholar **Eratosthenes** who combined two Greek words 'Geo' (The Earth) and 'Graphien' (to describe). Therefore, in the literary sense, geography is the description of the Earth. Over the ages, geography has become the art and science of studying the physical characteristics of the earth and man's role in adapting to and modifying the environment.

Geography had evolved over a long period of time. Some of the earliest geographical studies go back about four thousand years ago through explorations. The early explorers travelled and tried to map the new places. The Romans, the Arabs, the Indians, the Chinese, the Germans, the French, the British and the American geographers have contributed to the development and enrichment of the subject. 'Five themes of Geography' has been widely accepted by geographers worldwide. The themes are location, place, human–environment interaction, movement and regions.

Today the discipline is not only concerned with descriptions but also with analysis as well as prediction. There are two distinct approaches or methods to study geography. They are: 1. Systematic approach and 2. Regional approach. **Systematic or nomothetic approach** was introduced by Alexander Von Humbolt, a German geographer (1769-1859). The study of specific natural or human phenomenon that gives rise to certain spatial patterns and structures on the earth surface is called systematic study. **Regional Approach or ideographical approach** was developed by Carl Ritter (1779 – 1859), a contemporary of Humbolt. The regions could be classified based on a single factor like relief, rainfall, vegetation, percapita income or there could also be multifactor regions formed by the association of two or more factors. Administrative units like states, districts and taluks can also be treated as regions.

Branches of Geography

Based on content and the available techniques, the discipline can be divided into three major domains. Each one has many sub divisions which deal with specific objectives

a. Physical Geography,

b. Human Geography and

c. Geographic Techniques.

Physical Geography

It is the study of natural features of the earth such as land, water, air and living organisms. The changes taking place within and among these natural features and their resultant features are studied under its various branches. The branches of physical geography are:

i. **Geomorphology** deals with the distribution of land forms, their origin and the forces causing changes over these landforms. Geology provides basic information to the study of geomorphology.

ii. **Soil Geography** is a study related to soil formation, soil profile, soil types, their fertility level and distribution. Soil erosion and conservation measures are also dealt in this branch.

iii. **Climatology** deals with the study of global and regional weather and climatic conditions by analysing relevant statistical data. Meteorology provides basic information on the composition, structure and the changes in the atmosphere.

iv. **Hydrology** encompasses the study of earth's realm of water such as oceans and surface water bodies like rivers, reservoirs and ponds. It also makes a study of underground water and its recharge and also pollution of water bodies.

v. **Oceanography** is the study of seas and oceans. The shape, size, depth and bottom relief of ocean, distribution of oceans, ocean currents and various life forms existing in ocean are also studied under oceanography.

vi. **Biogeography** is a study of ecosystems over geographical space. It also analyses the changes in the ecosystems. Phytogeography or plant Geography, Zoo Geography or animal geography and Ecology are the branches of biogeography.

vii. **Environmental Geography** is the study of environmental issues arising out of misuse of various spheres of the earth and their implications. The ozone layer depletion, global warming, melting of polar ice caps, rising sea level and other related aspects are also given due importance. It also tries to give sustainable solutions to these problems.

Human Geography

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

i. **Population Geography** is the study of distribution and density of population, the changing patterns in age and sex composition, birth and death rates, life expectancy, literacy level and dependency ratio, migrations at national and international level and the causes and consequences of migration.

ii. **Settlement Geography** deals with the characteristics of rural and urban settlements and transportation network. It seeks better understanding of the present landscape and plans for the future. The study is more important for town and country planning.

BRANCHES OF GEOGRAPHY

- **PHYSICAL GEOGRAPHY** →
  - GEOMORPHOLOGY
  - SOIL GEOGRAPHY
  - CLIMATOLOGY
  - HYDROLOGY
  - OCEANOGRAPHY
  - BIO-GEOGRAPHY
  - ENVIRONMENTAL GEOGRAPHY
- **HUMAN GEOGRAPHY** →
  - HISTORICAL GEOGRAPHY
  - ANTHROPO GEOGRAPHY
  - CULTURAL GEOGRAPHY
  - SOCIAL GEOGRAPHY
  - POPULATION GEOGRAPHY
  - SETTLEMENT GEOGRAPHY
  - POLITICAL GEOGRAPHY
  - ECONOMIC GEOGRAPHY
  - MEDICAL GEOGRAPHY
- **GEOGRAPHIC TECHNIQUES** →
  - MATHEMATICAL GEOGRAPHY
  - STATISTICAL GEOGRAPHY
  - CARTOGRAPHY
  - REMOTE SENSING
  - G.I.S
  - G.N.S.S

iii. **Historical Geography** tries to picturise the geography of an area or region as it was in the past and studies how it has evolved over time. The forces involved in transforming region such as colonisation by the Europeans or a natural disaster are also included in the study.

iv. **Anthropo Geography** deals with the distribution of human communities on the earth in relation to their geographical environment.

v. **Cultural Geography** gives emphasis on the location and diffusion of customs and cultural traits such as food habits, skills, clothing and beliefs and social organisations and their developments in different parts of the earth.

vi. **Social Geography** is closely related to cultural geography. It examines the relationships among the social groups and their social relationships in the places of their living.

vii. **Political Geography** tries to understand the countries and their neighbours, problems of resources sharing, boundaries and territorial limits. This branch is also concerned with understanding the political behaviour of the population, relations between independent states, and patterns of voting and delimitation of electoral constituencies.

viii. **Economic Geography** deals with the distribution of economic activities such as, primary, secondary and tertiary. The primary activities include food gathering, hunting, animal rearing, agriculture, and mining. The secondary activities include manufacturing and the tertiary activities include the service sectors such as trade, transport, communication and other related areas.

xi. **Medical Geography** mainly deals with study of geographical aspects of origin, diffusion and distribution of various communicable diseases and health care planning.

Geographic Techniques

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

i. **Mathematical Geography** deals with the study of earth's size and shape, motions of the earth, concept of time and the time zones.

ii. **Statistical Geography** is concerned with the practice of collecting, analysing and presenting data that has a geographic or areal dimension, such as census data.

iii. **Cartography** is the study of making maps of various scales using authentic information.

iv. **Remote Sensing** is the art, science and technique of capturing the earth surface features using sensors or cameras in airplanes or satellites, processing and presenting the spatial information to users.

v. **Geographic Information System (GIS)** is a computer-based tool of the recent decades for geographical studies. It is used for storing, retrieving, transforming, analysing, and displaying data to prepare useful thematic maps.

vi. **Global Navigation Satellite System (GNSS)** is used to pinpoint the geographic location of a user anywhere in the world. Airlines, shipping, travel agencies and automobile drivers use the system to track the vehicles and follow the best routes to reach the destination in the shortest possible time.

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PHYSICAL GEOGRAPHY

The study of physical geography is emerging as a discipline of evaluating and managing natural resources. Physical geography includes the study of lithosphere (landforms, drainage, relief and physiography), atmosphere (its composition, structure, elements and controls of weather and climate: temperature, pressure, winds, precipitation, climatic types, etc.), hydrosphere (oceans, seas, lakes and associated features with water realm) and biosphere (life forms including human being and macro-organism and their sustaining mechanism, viz. food chain, ecological parameters and ecological balance).

GEOMORPHOLOGY

Geomorphology can be defined as the branch of physical geography that is concerned with the study of the configuration of the surface of the earth. In simplest words it can be defined as the study of landforms. Since it is concerned with the process of landform evolution, it is also concerned with the materials constituting the earth's crust and the processes and forces in the interior of the earth. This branch of physical geography is closest to geology.

THE UNIVERSE

The Universe comprises Galaxies that are huge congregation of stars held together by the forces of gravity. Optical and ratio telescope studies indicate the existence of about 100 billion galaxies in the visible universe. Galaxies occur in three structural forms: Spiral, Elliptical and Irregular. Spiral galaxies have a central nucleus with great spiralling arms trailing around them, examples include our Milky Way and the Andromeda galaxies. Elliptical galaxies are without spiralling arms and irregular ones have no clear shape.

In 1925 American astronomer Edwin P. Hubble (1889-1953)– pointed out that there were galaxies in the Universe and that the Universe actually consisted of millions of galaxies like the Milky Way. In 1929 Hubble proved that these galaxies are flying away from each other and that the farther they are, the faster they fly.

Hubble's Law

Edwin Hubble in 1924 showed that nebulae were distant galaxies. In 1929, he found the speed of a galaxy moves away from earth depends on its distance from earth. If a galaxy is 5 times as far away as another, it is moving away 5 times faster.

Doppler Effect

The movement of a star or a galaxy effects its light as seen by an observer. If the star is moving towards the observer, its light will be shifted towards the blue end of the spectrum, if the star or galaxy is moving away from the observer its light will be shifted to the red end of the spectrum. This is known as the 'Doppler Effect or Shifts'. The Doppler Shifts of galaxies show that they are receding and that the Universe is in a state of rapid expansion.

SPACE THEORIES

The Expanding Universe

It is a general law that all material bodies are heated when compressed and cooled when expanded. The primordial Universe, being highly compressed, must have experienced high temperatures. Heat, as we know, tends to expand matter. High temperatures, therefore, must have, at some point, started an expansion of the Universe. It is this expansion which is continuing even now. All theories of space (Universe) seek to explain the nature and consequences of this expansion.

Big-Bang Theory

Opposing cosmological theories, the first credit goes to a Belgian astronomer-priest, Abbe Georges Lemaitre. He explained this process of expansion, in what is known as 'the evolutionary theory' or 'the big-bang theory'. He argued that billions of years ago, cosmic matter (Universe) was in an extremely compressed state, from which expansion started by a primordial explosion. This explosion broke up the superdense ball and cast its fragments far out into space, where they are still travelling at thousands of miles per second. It is from these speeding fragments of matter that our galaxies have been formed. The formation of galaxies and stars has not halted the speed of expansion. And, as it happens in all explosions, the farthest pieces are flying the fastest.

The primordial explosion is the hallmark of the big-bang theory. It also differs from other theories in two important respects: (i) it disagrees with the Steady State claim, that new matter is being continuously created in the Universe, (ii) it differs from the Pulsating theory, in that, it does not admit, that matter will revert to the original congestion point, from which the primordial explosion started.

Steady State Theory

This theory originally advanced by two astronomers, Hermann Boudi and Thomas Gold, has since received support from the British astronomer of Cambridge University. According to this theory, which is also known as the Continuous Creation Theory, galaxies recede from one another but their spatial density remains constant. The Universe everywhere remained relatively uniform, unchanged, without beginning or end. That is to say, as old galaxies move apart new galaxies are being formed in the vacancies. These new galaxies are formed from new matter which is being continuously created to replace old matter that is being dispersed. This concept, designed to get around the philosophic hurdle of a Universe with finite beginning and end, is known as the 'Steady State Theory'.

Pulsating (Oscillating) Universe Theory

According to this theory, advocated among others by Dr. Alan Sandage, the Universe expands and contracts alternately between periods running into tens of billions of years. Dr. Sandage thinks that some 12 billion years ago a great explosion occurred in the Universe and that the Universe has been expanding ever since. It is likely to go on expanding for 29 billion years more, when gravitation will halt further expansion. From then on, all matter will begin to contract or collapse upon itself in a process known as 'implosion'. This will go on for 41 billion years compressing matter into an extremely superdense state and then it will explode once again. This is the latest theory of the evolution of the Universe.

The Anti-Universe

Existence of anti-Universe, somewhere in the cosmos, with its characteristics reversed to those normally found in this Universe, is now considered a possibility. This has caused a star in the scientific world today. Recent discoveries of particles of anti-matter have led scientists to consider the possibility of the existence of an anti-Universe somewhere in the cosmos. The highly abstruse theoretical physics dealing with the principles of Symmetry Laws suggested that processes, phenomena and events happening in this Universe must have their counterparts in the reverse manner in another Universe which we may call 'anti-universe'.

If a fundamental particle exists in this Universe, we must have a similar particle somewhere in the cosmos but will be like one as seen by reflecting it in a mirror. The 'time-event' will also be in a reverse manner, that is, the reel of time will be functioning in the reverse direction to that going on in our Universe. The 'Future-events' in the anti-Universe are perhaps the 'past-events' in this Universe.

The Open or Closed Universe

That the Universe is expanding is today considered established. A question that remains unsettled is whether the expansion will continue for ever or whether the receding galaxies will some day stop and then reverse their motion, eventually falling together in a great collapse. The answer to this question determines the geometrical character of the Universe, that is, it determines the nature of space and time. If the expansion continues perpetually the Universe is 'open'. If it will some days stop and reverse direction, the Universe is 'closed'.

THE OUTER SPACE

The units of measurement we use on earth are too small to measure the vast distances of outer space.

The units evolved for this purpose are:

- **Light Year:** It is the distance covered by light in one year in vacuum travelling at a speed of 3×10^5 km/s.
- **Astronomical Unit (A.U.):** It represents the mean distance between Earth and the Sun. It is used to measure distances within the Solar system.
- **Parsec:** It is the distance at which the mean radius of Earth's orbit subtends an angle of 1 second of an arc. It is equivalent to 3.26 light years

Galaxies

Galaxies are huge congregations of stars that are held together by force of gravity. Our Earth and the Solar System are contained in the galaxy called 'Milky Way' which belongs to a cluster of galaxies called the 'local group' covering an area of about 3 million light years in diameter. A peculiar feature of this galaxy is a bright band of light that runs almost in a perfect circle through it. As seen from the earth this band looks like a river of light following through the sky. Galaxies are in three major forms:

1. **Spiral Galaxies:** It consists of a flat and rotating disk of stars, gases and dust. It has a central concentration of stars known as the 'bulge'. The Milky Way and the Andromeda are spiral galaxies.
2. **Elliptical Galaxies:** It contains older stars with fewer gases. Messier89 galaxy is an elliptical galaxy.
3. **Irregular Galaxies:** They are youthful galaxies with more dust and gases. This can make them very bright. Large Magellanic Cloud is an example of irregular galaxy.

Star and Constellations

Stars account for most of the galactic mass. They tend to form groups called constellations. Lone stars are a rarity. They go through a definite evolutionary sequence. After a star is born, it enters the main sequence stage. This stage is marked by a helium core becoming increasingly heavy, accompanied with expanding outer layers. At this stage, it is considered an Adult Star. The process continues until it becomes a massive Red Giant. Depending on the mass of the star, one of the two possible sequences of development can occur. (i) if the mass is relatively small, like that of our sun, the gases that reach the outer layer are expelled. As these expelled gases cool and contract, the star becomes a White Dwarf. (ii) if the star is larger, the final stages of its giant star phase end either in a supernova explosion which sometimes leaves behind neutron stars called pulsars or collapse and compact to form black holes.

The Solar System

The Sun, the eight planets along with their respective satellites, the asteroids, the meteoroids, the comets, the interplanetary dust and the electrically charged gases called plasma, together make up the Solar System. The Solar System is believed to have been formed about 4.6 billion years ago. The Solar System is tucked away in a corner of the Milky Way at a distance of about 30,000 to 33,000 light years from the centre of the galaxy.

THE SUN

The Sun is at the centre of our solar system. It is a yellow dwarf star, with a hot ball of glowing gases. Its gravity holds the solar system together and it keeps everything from the biggest planets to the smallest particles of debris in its orbit. Electric currents in the Sun generate a magnetic field that is carried out through the solar system by the solar wind. The Sun accounts for 99.85% of mass of the solar system. The immense gravitational pull of the Sun keeps the planets rotating around it in definite orbits.

Structure of the Sun

The Sun is made up of about 70.6% hydrogen and 27.4% helium. The Sun has six regions:

i. The **core** is at the centre. It is the hottest region, where the nuclear fusion reaction to give the sun power.

ii. Moving outward next come the **radioative (or radiation) zone**. Its name is derived from the way energy is carried outward through this layer, carried by photons as thermal radiation.

iii. The solar interior is named the **convective (or convection) zone**. It is also named after the dominant mode of energy flow in this layer.

iv. The glowing surface of the Sun, which we see (or the visible part of the Sun's surface), is called **Photosphere**.

v. Above the photosphere, is the **Chromosphere**, so called because of its reddish colour. The reddish colour being due to emission by hydrogen, the most important component.

vi. Beyond Chromosphere is the magnificent **Corona** of the Sun which is visible during eclipses only, as a remarkable sliver-pearly radiant glow around the Sun.

All about Sun

- It continuously gives off energy in the form of visible light, infra red, ultra violet, X-rays, gamma rays, radio waves and plasma.
- The period of revolution of the Sun around the galactic centre is 250 million years. This period is called a **Cosmic** or **Galactic Year**.
- Like all other stars, the Sun is mainly composed of hydrogen and helium. Nuclear fusion in the core of the Sun is source of all its energy.
- The constituent particles of solar wind are trapped by the earth's magnetic field and enter the earth's upper atmosphere as auroral displays described as Aurora borealis in the northern hemisphere and Aurora Australis in the southern hemisphere.
- The surface of the Sun changes continuously. Bright spots called Plages and dark spots called Sunspots frequently form and disappear.

• Distance from the Earth	149.8 million km
• Diameter	1384000 kilometre
• Core Temperature	15000000 K
• Photosphere Temperature	5700 K
• Chemical Composition	Hydrogen 81.76%
	Helium 18.17%
	Oxygen 0.03%
	Magnesium 0.02%
	Nitrogen 0.01%
	Other Elements 0.01%

Solar Flares

The solar flares are spectacular-hot ionised gas rolling out as enormous clouds, 20 to 40 times the size of the Earth at speeds of around 100 kilometre per second through the outer layer of the Sun's atmosphere, the corona

A Red Giant

Like all other stars, the Sun is composed mainly of hydrogen. Its energy is generated by nuclear collisions in its interior. It is calculated that the Sun consumes about a trillion pounds of hydrogen every second. At this rate, it is expected to burnt out its stock of hydrogen in about 5 billion years and turn into a RED GIANT.

When the Sun turns into a Red Giant, it would have swelled a hundred times in diameter and increased a thousand times in brightness – "bright red". It will then occupy about 25 per cent of the horizon. The nearest planets, Mercury and Venus, would melt. The oceans of the earth would remain a barren rock, heated to melting point of lead. All life on earth would cease. The Sun will survive as a 'red-giant', for about a hundred million years more, slowly dissipating its enlarged outer shell leaving a tiny core. This core will be a faint, white dwarf-sun no larger than the present planet Mars. Around this tiny star, the burnt-out earth will continue to revolve.

Sunspots

"Even the Sun is not without spots". The Sun does have spots, but not always. These are dark patches noticed on the surface of the Sun. They appear dark because they are cooler (around 1500°C) than the surface of the Sun which has a temperature of about 6000°C. The largest spot ever measured (April 1974) covered 18130 million square kilometre or approximately 0.7 per cent of the Sun's visible surface. The life periods of these spots also vary. They may last a few hours to many weeks.

The sunspots show strong magnetic fields and reach a maximum every eleven years. During the maximum of sunspot period, the Sun shows marked activity in shorter "wave lengths" like x-rays and ultraviolet radiations. Frequent solar eruptions and solar flares occur. These produce great reactions on the Earth and its atmosphere, such as, "ionospheric disturbances", "magnetic storms", "interruptions of radio communications", "unusual auroral displays" and "a lowering of the average cosmic ray intensity".

THE PLANETS

The word planet in Greek means 'wanderer'. Planet is the celestial body which does not have light or heat of its own. A planet should possess the following qualities:

a. It should orbit around the sun.
b. It should not be a satellite of any planet
c. Due to its own mass and self-gravity, it should get a spherical shape and
d. Any other celestial body should not cross in its orbit.

The planets are classified in order of their distance from the sun and based on their characteristics. They are:

1. The **inner planets** or terrestrial planets or rocky planets. Mercury, Venus, Earth and Mars are called inner or terrestrial planets.
2. The **outer planets** or gaseous planets or giant planets. Jupiter, Saturn, Uranus and Neptune are called outer or gaseous planets.

The Planets

Inferior Planets { Mercury, Venus

Superior Planets { Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto *

Mercury, Venus, Earth, Mars } Inner Planets

Jupiter, Saturn, Uranus, Neptune, Pluto * } Outer Planets

* Pluto lost planet status in 2006

Mercury

- Diameter – 4,849.6 km
- Moons – None
- Average Distance to the Sun – 57.6 million km
- Time to Orbit the Sun – 88 days
- Tiny Mercury slightly larger than Earth's Moon, races along its elliptical orbit at 1,76,000 km/hr (1,10,000 miles). This speed keeps it from being drawn into the Sun's gravity field.
- The created planet has no atmosphere: Days are scorching hot and Nights, frigid.

Venus

- Diameter – 12,032 km
- Moons – None
- Average Distance to the Sun – 107.52 million km
- Time to Orbit the Sun – 225 days

- Earth's twin in size and mass, searingly hot venus is perpetually yield behind reflective sulphuric acid clouds.
- Probes and radar mapping have pierced the clouds and carbon dioxide environment to reveal flat, rocky plains and signs of volcanic activity.
- It's surface temperature rises as high as 500°C.
- It rotates about its axis "in opposite direction to that of the other planets" i.e. east to west direction.

Mars

- Diameter – 6755.2 km
- Moons – 2
- Average Distance to the Sun – 225.6 million km
- The viking probes failed to find any sign of life.
- Beneath its thin atmosphere, Mars is barren covered with pink soil and boulders.
- Long ago it was more active the surface is marked with dormant volcanoes and deep chasms where water once freely flowed.
- Time to Orbit about the Sun once in 687 Earth-days (or 668 Mars-days).
- Mars is 1.5 times farther away from the Sun than the Earth, and it receives about half as much heat from it than the earth.
- In the warmest season, the temperature reaches 15°-20°C, but by sunset it drops to freezing temperatures and at night it falls to –100°C or lower.

Jupiter

- Diameter – 1,41,968 km
- Moons – 16
- Average Distance to the Sun – 772.8 million km
- Time to Orbit the Sun – 11.9 Years
- Jupiter is 300 times more massive than the Earth.
- The lightest gases, hydrogen and helium, account for up to 40 per cent of Jupiter's mass.
- The temperature in the planet's centre may be as high as 100,000°C. (estimated)
- At the same time, on the outside, due to heat losses, Jupiter may be as cold as we observe it from the Earth-about –140°C.
- Jupiter rotation period is 9 hours 50 minutes.
- Jupiter radiates 2.5 more heat than it receives from the Sun.

Saturn

- Diameter – 1,19,296 km
- Moons – 18 or more
- Average Distance to the Sun – 1,417.6 million km
- Time to Orbit the Sun – 29.5 Years
- Specific Gravity less than 1.0 (If a large ocean were available, Saturn would float in it).

Titan Factfile

Titan is Saturn's largest moon and the second largest (after Ganymede of Jupiter) in the solar system. It is the only moon in the solar system with clouds and a dense, planet-like atmosphere.

Distance from Saturn	1 221 870 km
Distance from Sun	1 427 000 000 km
Diameter (atmosphere)	5550 km
Diameter (surface)	5150 km
Mass	1/45 that of Earth
Average density	1.881 times water
Surface temperature	94K(-180°C)
Atmospheric pressure	1500 mbar (1.5 times at surface Earth's)
Atmospheric composition	Nitrogen, methane, traces of ammonia, argon, ethane
Titanic day	15.95 Earth days

- The celebrated rings of the golden giant Saturn are composed of thousands of rippling, spiralling bands just 100 feet thick.
- All the bright Saturnian moons, with the exception of Titan, revolve around it facing it with the same side.
- The most interesting Saturn's moons are PHOEBE, which moves in a retrograde sense, and TITAN, the only moon in the solar system with an atmosphere of its own-it consists of methane with, perhaps, some ammonia.
- Saturn's rings vanishes every 15 years.

Uranus

- Diameter - 52,096 km
- Moons - 18
- Average Distance to the Sun - 2,852.8 million km
- Time to Orbit the Sun - 84 Years
- Watery Uranus is the only planet that lies on its side; one pole, than the other, faces the Sun as it orbits.
- Voyager-2 found nine dark, compact rings around the planet and a corkscrew-shape magnetic field that stretches for millions of kilometres.
- Observations of its radio emission at a wavelength of 1.9 centimetres yields an average temperature of –100°C and –170°C at 11 centimetres.
- Uranus's axis is inclined at 98° to its orbital plane, and so it rotates, as it were, lying on its side, it also rotates along east to west direction.
- The rotation period of Uranus is 10 hours 50 minutes.

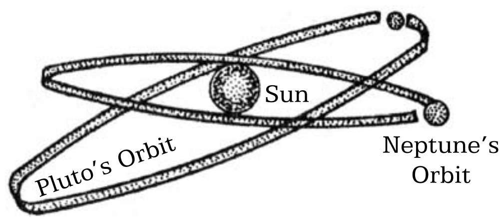
Neptune

- Diameter - 49,000 km
- Moons - 8
- Average Distance to the Sun - 4,497 million km
- Time to Orbit the Sun - 165 Years
- Neptune's atmosphere appears blue in colour
- It has no air and is very cold, dark and desolate.

Pluto (Now it lost the planet status)

- Discovered in 1930
- Diameter - 3,040 km
- Moons - 1
- Average Distance to the Sun - 5,865.6 million km
- Time to Orbit the Sun - 248 Years
- Pluto is 40 times farther away from the Sun than the Earth.

Which is the Farthest, Neptune or Pluto?



For most of its orbit, the tiny planet Pluto revolves farther from the sun than any of the other eight planets, including Neptune. But Pluto's path is highly elliptical, or stretched out; at is closest approach to the sun, it is 4.4 billion kilometre away, but at its farthest approach it is fully 7.3 billion kilometre distant.

As a result of Pluto's eccentric habits, Neptune claims the title of "farthest planet" whenever Pluto's path crosses inside Neptune's. That's the current situation; since 1979 (and lasting until 1999) Neptune has been the most distant planet. Then it will be Pluto's turn again, and for the next 228 years Neptune will revert to its usual position as the eighth planet from the Sun.

- By observing the regular changes in its brightness it was found that the rotation period of Pluto is 6 days 9 hours and 17 minutes.
- It lost the planet status in 2006 as per International Astronomical Union (IAU) resolution since it failed to meet one of the 3 conditions for the term "Planet".

Planet	Symbol	Mean Distance from Sun (in mn km)	Relative Period of Revolution	Relative Period of Rotation (Earth = 1 day)	Diameter ('000 km)	Relative Mass (Earth = 1)	Other details
Mercury	☿	58	88^d	59^d	4.9	0.06	Nearest to the Sun and fastest planet
Venus	♀	108	224^d	243^d	12	0.8	Brightest, hottest and closest to earth
Earth	⊕	150	365^d	$23^h56^m04^s$	12.8	1	Most dense
Mars	♂	228	687^d	$24^h37^m23^s$	7	0.1	
Jupiter	♃	778	12^{yr}	$\sim 9^h50^m$	143	318	Largest Planet
Saturn	h	1427	29.5^{yr}	$\sim 10^h25^m$	121	95	Least dense
Uranus	⛢	2869	84yr	$\sim 17^h20^m$	47	15	
Neptune	♆	4498	165^{yr}	$\sim 16^h$	45	17	
Pluto*	♇	5900	248^{yr}	6.4d	2.4	0.01	Smallest, coldest, and slowest to move round the Sun

* Now, Pluto lost the planet status.

SATELLITES OR MOONS

The word 'Satellite' means companion. The Satellites or Moons revolve round their mother planets or primaries. They do not have own light, but reflect the light of the Sun. They have no atmosphere and water. The Solar System is known to have 64 satellites or moons. Of these Jupiter claims 16, Saturn 18, Uranus 18, Neptune 8, Mars 2, Earth 1 and Pluto 1. Mercury and Venus have no satellites or Moons.

Of Saturn 18 moons 10 had already been discovered in 1976. Three were discovered by earthbased telescopes in 1979-80. The rest were discovered by Voyager 1 and 2. The new moons have not been named. They are presently known by numbers such as, 1981 S1, SS3, S6, S13, S25, S26, S27 and S28.

Apollo 11

Apollo 11 was the first manned mission to land on the Moon sent by NASA. Two American Astronauts Neil Armstrong and Edwin Aldrin set foot on the moon's surface on the waterless Sea of Tranquility on 20th July, 1969. They stayed there for 21 hours 38 minutes and 21 seconds on the moon. Michael Collins piloted Apollo 11.

The Earth's Moon

The moon is the fifth largest natural satellite in the solar system. The moon was likely to be formed after a Mars sized body collided with Earth. There are many craters, high and steep mountains of different sizes which cast shadows on the Moon's surface. Our Moon is one-fourth of the size of the Earth. The light which is reflected by the Moon will reach the Earth in just one and a quarter seconds.

Distance from Earth	3.84 lakh km
Diameter	3500 km
Circumference	11,000 km
Surface Temperature	134ºC – 170ºC
Revolution time	27 1/3 days
Revolution Velocity	3,700 kmph
Age	4.6 b years
Gravitational pull	1/6th that of the Earth

The best known Comet, Halley's Comet, appears once in every 76 years. The Halley's Comet was seen last in 1986 and it will be seen again on 28th July 2061.

The collision of comet Shoe-maker Levy-9 with Jupiter was one of the most spectacular events in space.

THE COMETS

The word Comet is derived from the Greek word Aster Kometes meaning 'Long Haired Star'. Comets may originate in a huge cloud called the Oort cloud that is thought to surround the solar system. A comet is an icy body that releases gas or dust. It consists of solid nucleus (core) surrounded by a cloudy atmosphere called the Coma and one or two tails. They revolve around the Sun. But their orbits are irregular. Sometimes they get very close (Perihelion) to the sun and in other times they go far away (Aphelion) from the sun.

THE ASTEROIDS

Asteroids are small rocky celestial bodies that revolve around the Sun, like other planets. They are also called 'Minor Planets'. There are lots of asteroids in the solar system. Larger asteroids are called Planetoids. These are found in between the planets Mars and Jupiter. This belt is known as 'Asteroid belt'. The diameter of the asteroids varies from 100 km to a size of a pebble. The asteroids may be the fragments of a planet exploded in the past or some parts of comets. The new asteroids are being discovered continuously.

METEOROIDS OR SHOOTING STAR

Meteoroids are small fragments of rock and metal travelling through space. When drawn into the Earth's gravitational field, they become white-hot through friction as they fall through the atmosphere, and they seen as Meteors or Shooting Stars. Upon reaching the Earth's surface they are called Meteorites. Most meteors burn up by the time they reach 75 km above the Earth. Some 8000 million meteors enter the Earth's atmosphere every day, many no larger than sand grains.

Examples for Meteorite Fall: Meteor crater in Northern Arizona and Lake Lonar in Buldhana District of Maharastra in India were created by meteor impacts.

THE ORIGIN OF THE EARTH

Our Earth is a member planet of the Universe which consists of numerous stellar systems. The age of the Earth is about ten thousand million years to ten billion years. Before this huge age, gaseous matter filled the universe. In this gaseous state of matter a disturbance occurred and as a result condensation was started.

As a result of condensation the latent heat was released and it increased the temperature from 500 degrees to 5000 degrees. The disturbance in the universe and the condensation has been a subject of great discussion and speculation. As such, numerous theories have been advanced with regard to the composition, rotation, and condensation of the spiral nebulae.

Geocentric Theory

The earliest systematic theory of the Earth was the "Geocentric (geo = earth) theory". According to this theory, the earth was the unmoving centre of the universe, round which the sun and the stars and all other heavenly bodies revolved. The final formulation of the theory was made by **Claudius Ptolemy**, a Greek astronomer of Alexandria. He brought out an encyclopedic work on astronomy in about 140 A.D. This work, later known by its contracted Arabic name 'Almagest', remained the Bible of astronomy for another 1400 years. It had two attractive features. First, it agreed with the apparent (not real) movements of the heavenly bodies. Second, it flattered man's vanity to think that his abode the Earth–was the centrepiece of the universe.

Heliocentric Theory

The Heliocentric Theory (Helios = sun) was first advanced by **Nicolaus Koppernigk** (1473–1543), a Polish astronomer, better known by his Latinised name **Copernicus**. In 1543, he set out the theory that the sun was the centre of the universe and the earth and other planets revolved round it.

The Italian astronomer, **Galileo Galilei** (1564–1642), supported this theory. **Sir Issac Newton** (1642–1726) formulated the "law of gravitation" and correlated it with his laws of motion. This marked a turning point in the history of astronomical thought.

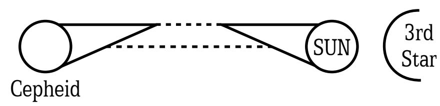
Nebular Theory

The French mathematician **Marquis de Laplace** supported the nebular hypothesis. He stated that primordial matter in the beginning existed in the form of intensely hot and rotating gaseous mass called **Nebula**. This mass started cooling down and in the process lost some of its volume. Because of a reduced size, the rotational speed of the nebula increased. This had a cascading effect as the centrifugal force of its mass also increased. As a result, the mass of the nebula started concentrating along its equator. This mass was, on the other hand, being pulled inwards by a gravitational pull. But, as the centrifugal force increased further, some of the mass from the equator separated from the main nebula in the form of a ring which was also rotating. This ring, when cooled down and condensed, gave rise to planets and sub-planets, as it got broken into many smaller rings. The remaining mass became the Sun.

Inter-Stellar Dust Hypothesis

Otto Schmidst, a Russian Scientist (1943), believed that there are lot of dust particles in the space in addition to stars, planets, etc. The dust particles being attracted by the Sun about six billion years ago, began to revolve round the Sun.

In the beginning, these particles revolved in different and uncertain orbit but later they collided with one another and assumed the form of the saucer. Due to 'inelastic collisions', their speed decreased and the particles united to form planetesimals which later produced large planets. Some matter remained unconsolidated even after the planets were born. Sub-planets were formed from this unconsolidated material and began to revolve round the planets.



Cepheid Theory

Bannerjee, A.C. suggested that there is a star in the constellation Cepheid and its brightness changes regularly so that maximum and minimum alternate with each other. This regular change is due to contraction and expansion which is almost regular. If the oscillation is not small, the star will become unstable and it will begin to grow larger and larger. The subatomic source of energy would force the matter to be thrown out. Similar conditions existed at the beginning of the Universe.

In that oscillating stage another star approached at a moderate distance and the material is thrown out at a distance. When it began to condense, the Sun and the Cepheid separated–the Sun went one way and the Cepheid another. Sun stole away two-fifths of the energy from the planet Cepheid and this confirmed by mathematical findings which show the Sun to have twenty times more energy than that possessed by the planet Cepheid.

THE AGE OF THE EARTH

Modern scientific methods have been employed only during the last 200 years. Scientists think that the age of the Earth may range between two to five billion years.

Holmes estimated the age of the Earth of the basis of sediments accumulated in the bottom of the ocean as 3.5 × 10^8 years, that is, 350,000,000 years.

The Tidal Method

The tide which rise in the seas and oceans reduce the rotational speed of the Earth. As a result, the Moon gets further away from the Earth at the same rate. Scientific calculations have proved that the Moon is receding from the Earth at a speed of 13 centimetre per year. The time that took the Moon to recede from the Earth by 385,000 km was calculated. According to this calculation, the age of the Earth should be about 4 billion years.

Sedimentation Method

When the Earth cooled from the liquid state, a solid layer appeared over the surface of the Earth. This solid cover began to be attacked by external forces like water, wind, snow, etc. The sediment thus eroded ultimately reaches the seas and oceans. If the rate of the deposition of the sediment in the seas and oceans and the total thickness of the sediment could be calculated.

$$\text{The age of the Earth} = \frac{\text{The thickness of sediment}}{\text{The rate of deposition of the sediment}}$$

At the time of the deposition of the sediment, the lower layer are subjected to great pressure by the layers lying above them. This result into compression and their thickness is reduced. The age of the Earth calculated by this method come to 400 million years. It cannot be accepted as correct.

Scientists think that erosion could not have started at least for one billion years after its birth. These facts have been tested by many methods.

The American Institute for Geology has brought into light another fact. Through the old method of study it has been discovered that the process of erosion had started 4 billion years from the present. Hence, the age of the Earth should be about 5 billion years.

(The Hindustan Times, April 13, 1965, p.12, column 6.)

Glacial Deposition Method

A curious and rather precise method for determining the absolute duration of geological time has been suggested in connection with the study of Glacial Deposits of the Quarternary. The general complex of diverse deposits associated with the activity of continental ice which in the recent past covered vast spaces of northern Europe, contains fine clays with characteristic lamination. It is presumed that these so-called "varved" clays accumulated in lakes as a result of thawing of glacier ice, the fine bands having been deposited in winter, and the coarser ones, in summer. By the estimates from different data the age of the Earth may be put at a figure of the order of from one to two million years.

The Salinity Method

It is known that the ocean water contains large amount of salts, particularly common salt, NaCl. The bulk of these salts, probably, has been brought into the oceans by rivers which eroded the bedrocks. The quantity of salt carried annually by rivers into the ocean is known. Estimates made by the salt method give figures between 0.3 to 1.5 thousand million years (since the beginning of Paleozoic).

Jolly calculated that the mass of the salt brought by the rivers to the seas comes to 1.56 million metric tonnes per year. According to this calculation, the total amount of salt deposited in the seas is 12.6 billion metric tonnes. This gives us the age of the Earth to be 2 billion years.

Evolution of Life on Earth

Man was not present from the early years of this Earth. The early parents of man were one-celled organism which belonged to both animal and vegetation world. Slowly this single-called life became more complex. Animal and vegetation life became multicellular. In this process of evolution, Man appeared on the

Earth. It is possible to estimate the age of the Earth by studying the process of evolution. The studies based upon this method give a life of one billion years which is considered to be an under estimation.

Rocks Dating Method

Rocks usually contain a certain, even if infinitesimal, amount of "radioactive elements" such as uranium (U), radium (Ra), thorium (Th), potassium (k), etc. and their isotopes. With time these elements undergo spontaneous decay, changing into other elements–lead (Pb) and helium (He).

The decay is spontaneous and not affected by external forces. Careful and delicate analysis of a rock enables us to establish how many new atoms of lead or helium appeared in it since it was formed, how much undecayed radioactive elements it still contains, and in this way to compute the age of the rock.

The proportions of uranium, thorium and lead in average igneous rocks are given respectively as 6.15 and 7.5 parts in a million. If we assume that rocks contains 2.2 and 3.8 per million of uranium and thorium lead. Applying the method of these separately we get the age of the Earth's crust as :

i. According to thorium lead ratio, the age of the Earth is 4,600,000,000 years.

ii. According to uranium lead ratio, the age of the Earth is 2,250,000,000 years.

Radioactive Decay Method

- About 4×10^9 years have passed since the beginning of the Archean Era and 570×10^6 years since the Proterozoic.
- The age of the Earth as a planet is estimated at approximately 4.5 thousand million years.
- The age of the Sun is estimated at 4.6 billion years.

Nuclear Method

Nuclear methods of dating geological objects has become major importance. The time intervals to which various methods of this type are applicable are as follows :

With reference to carbon 14	–	from 2,000 to 30,000 years;
With reference to potassium argon	–	10,000 and more years;
By using the rubidium-strontium method	–	5 and more million years;
By that of uranium-lead	–	200 and more million years;
With reference to uranium 238	–	1 to 4 thousand million years.

According to their deductions, based on the study of rocks, the age of the Earth is estimated to be around 4,600 million (4.6 billion) years.

Movements of the Earth

The Earth has three basic movements : (i) Galactic movement, (ii) Rotation, and (iii) Revolution.

Galactic Movement

This is the movement of the Earth with the sun and the rest of the solar system in an orbit around the centre of the Milky Way Galaxy. This movement has little effect upon the changing environment of the Earth.

Rotation of the Earth

The Earth rotates (spins) around its axis. The axis is an imaginary line passing through the centre of the Earth. Its two ends on the surface are called North and South Poles. The Earth completes a rotation in 24 hours (23 hours, 56 minutes, 4.09 seconds to be exact).

The Earth rotates in an eastward direction opposite to the apparent movement of the sun, moon and stars across the sky. Looking down on a globe from above the North Pole, the direction of rotation is counterclockwise (anticlockwise direction).

The velocity of rotation on the Earth varies depending on the distance of a given place from the **Equator** (the imaginary circle around the Earth halfway between the two poles). The rotational velocity at the poles is nearly zero.

Rotation accounts for our alternating days and nights. While one half of the Earth receives the light and energy of solar radiation, the other half would have been in darkness. The line around the Earth separating the light and dark halves is known as the **Circle of Illumination**.

Revolution of the Earth

Earth also revolves around the Sun in an elliptical, almost circular, orbit at an average distance from the sun of about 149,000,000 km. This motion is called **Revolution**. The path on which the Earth describes its motion is called **Orbit**. Because of the elliptical shape of the orbit the distance varies from time to time.

About January 3 the Earth is closest to the Sun and is said to be at Perihelion (from Greek : 'peri' = close to; 'helios' = sun); its distance then from the sun is approximately 147 million km. Around July 4 the Earth is about 152 million km from the Sun. It is then that the Earth has reached its furthest point from the Sun and is said to be at Aphelion (Greek : 'ap' = away; 'helios' = sun).

Speed of Revolution

The mean speed of the Earth is its orbit is 107,000 km per hour. The speed comes around 29.72 km per second. The bullet from a gun travels with a speed of 9 km per second.

The Period of Revolution

The period of time the Earth takes to make one revolution around the Sun determines the length of one year (i.e. 365 days and 6 hours or 365¼ days). Because of the difficulty of dealing with a fraction of the day, it has been decided that a year would have 365 days and that in every fourth year, called **Leap Year**, an extra day would be added in February.

Plane of Ecliptic, Inclination and Parallelism

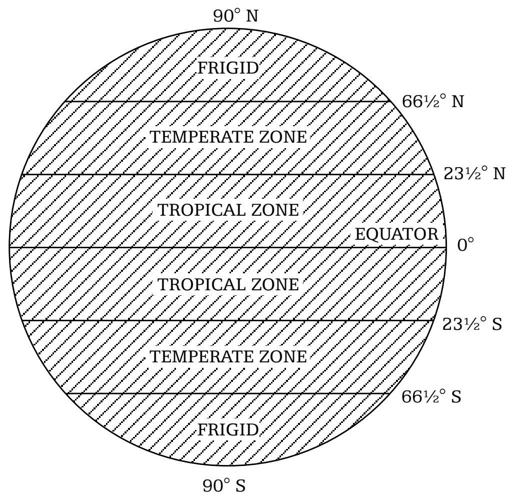
The Earth in its orbit around the sun moves in a constant place. This plane is called the **Plane of the Ecliptic**. The plane of the Earth's equator makes an angle of 23½° with the plane of the ecliptic. Thus the imaginary Earth axis, being perpendicular to the equator, has a constant **Angle of Inclination**, as it is called, of 66½° with the plane of the ecliptic. In addition to a constant angle of inclination, the Earth's axis maintains another characteristic called **Parallelism**. As the Earth revolves around the Sun, the Earth's axis remains parallel to its former position. That is, at every position in the Earth's orbit the axis remains pointed towards the same spot in the sky. For the North Pole that spot is close to the star we call the **North Star** or **Polaris**. Thus, the Earth's axis is fixed with respect to the stars outside our solar system, but not with respect to the Sun.

COORDINATES OF THE EARTH

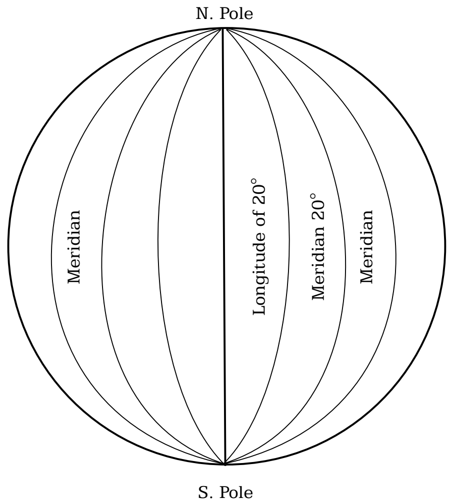
Zones between Parallels

Areas of the Earth which are situated between certain parallels are called **Zones**.

1. **Tropical Zone or Torrid Zone:** It is situated between 23½° North and 23½° South Torrid or Tropical Zone is a warm or hot area. The Sun is vertical at least once in a year at every place in this zone.
2. **Temperate Zone:** It is situated between 23½° to 66½° in both the Northern and Southern Hemisphere. Temperate means neither hot nor cold. The Sun is never vertical at this zone.
3. **Frigid Zone:** It is situated between 66½° to 90° (Pole) in both the Hemispheres. The length of day or night at least once in a year is of 24 hour duration. The poles have days and nights of 6 month duration each. It is a very cold area.



Zones between Parallels



Meridians and Longitude

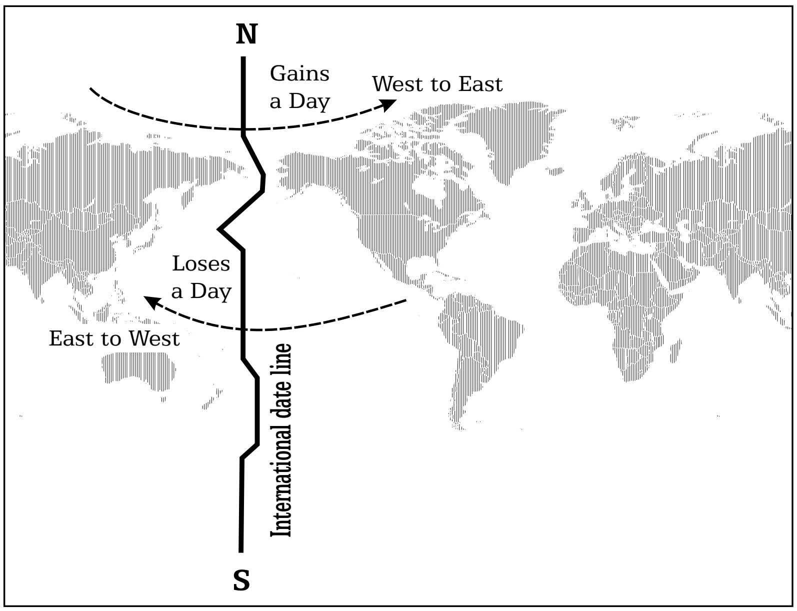
Meridians and Longitude

On the globe there is an another set of lines. They are semi-circles which swing from pole to pole. These lines are **Meridians**, joining the north and south poles. They are, infact, imaginary lines. The meridian which passes through an observatory situated at **Greenwich (UK)**, is called the **Prime Meridian** or **Zero Degree Meridian**. You can count left or right, west or east from it to see how far around the world a spot is. That's its **Longitude**. Longitude of a place or station is the angular distance between the meridian of the place and the standard or prime meridian.

The meridian passing through Greenwich has been adopted internationally as the Standard meridian. This meridian divides the sphere into two hemispheres, one the Eastern and the other the western. The longitude is measured from zero degree to 180 degree either towards the west or towards the East. The west longitudes are considered as "positive" and east longitudes as "negative".

Standard Time and Time Zones

A system of standard time is observed by all countries. Most countries adopt their standard time from the central meridian of their countries. The Indian government has accepted the meridian of 82.5° east for the standard time which is 5 hours 30 minutes ahead of Greenwich Mean Time. The whole world has in fact been divided into 24 Standard Time Zones, each of which differs from the next by 15° in longitude or one hour in time.



The International Date Line

The International Date Line: A traveller going eastwards gains time from Greenwich until he reaches the meridian 180°E , when he will be 12 hours ahead of G.M.T. Similarly in going westwards, he loses 12 hours when he reaches 180°W. There is thus a total difference of 24 hours or a whole day between the two sides of the 180° meridian. This the International Date Line where the date changes by exactly one day when it is crossed.

Nautical Mile

A Nautical Mile is the distance measured along the Great Circle joining two points which subtend one minute of arc at the centre of the Earth. Taking the radius of the Earth to be equal to 3960 miles :

$$\text{One Nautical Mile} = \frac{\text{Circumference of the Great Circle}}{360^\circ \times 60} \text{ or } 1.85 \text{ kilometres}$$

The distance between two points in Nautical Miles measured along the parallel of Latitude is called the **Departure**.

Seasons

The Earth revolves around the Sun with two characteristics :

i. Its axis of rotation is inclined to the orbital plane at an angle of 66½°.

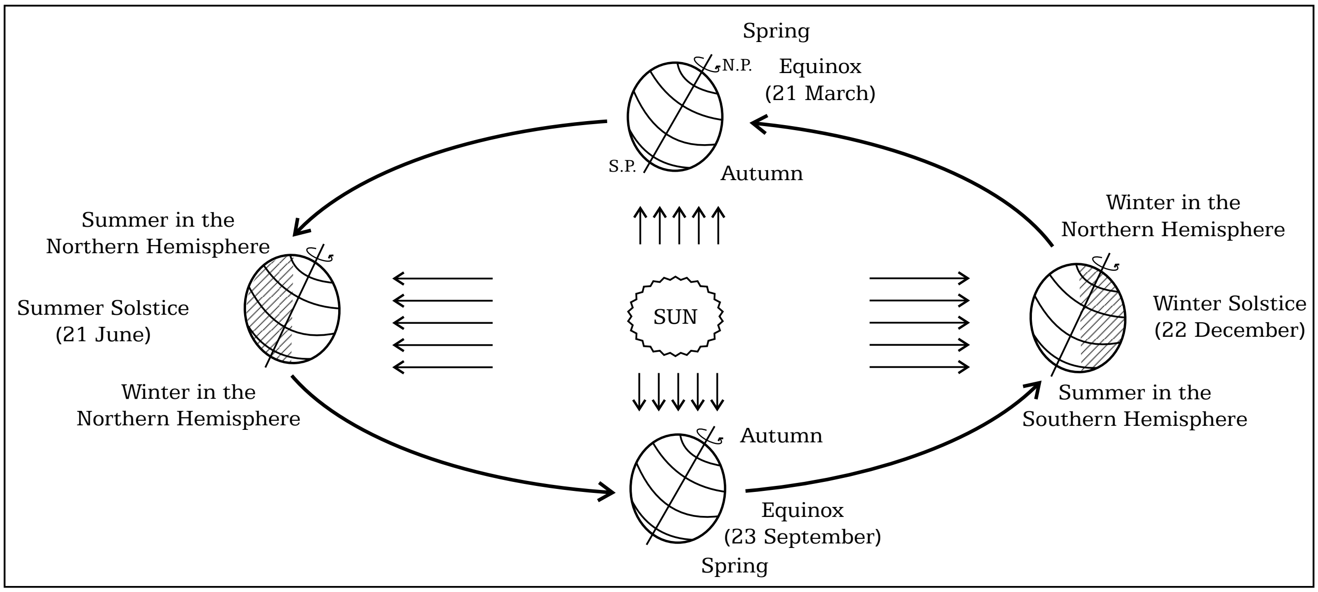
ii. The northern end of the axis of rotation points towards the pole star wherever the Earth be in the orbital path.

There are four positions of Solstices and Equinoxes. Hence, there are the following four seasons according to the positions of the Earth in one complete revolution of the Earth around the Sun.

Summer Solstice

On June 21, the northern hemisphere is 'inclined towards' the Sun while the southern hemisphere is 'inclined away' from the Sun. The sun rays are vertical at 23½° North. As a result the norther hemisphere becomes hot. The season is called Summer Season.

In the southern hemisphere, the conditions are opposite to that in the northern hemisphere. It is winter season there. Nights are longer than days and the number of nights with a duration of 24 hours increase as we move farther towards south pole.



Revolution of the Earth and Seasons

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Autumn Equinox

On September 23 the northern and southern hemisphere are equally inclined towards the Sun. The Sun rays are vertical at Equator. As a result, the season is neither hot nor cold. It is a situation between summer and winter seasons. It is called Autumn Season. In the southern hemisphere similar conditions prevail except that the transition is from Winter to Summer.

Winter Solstice

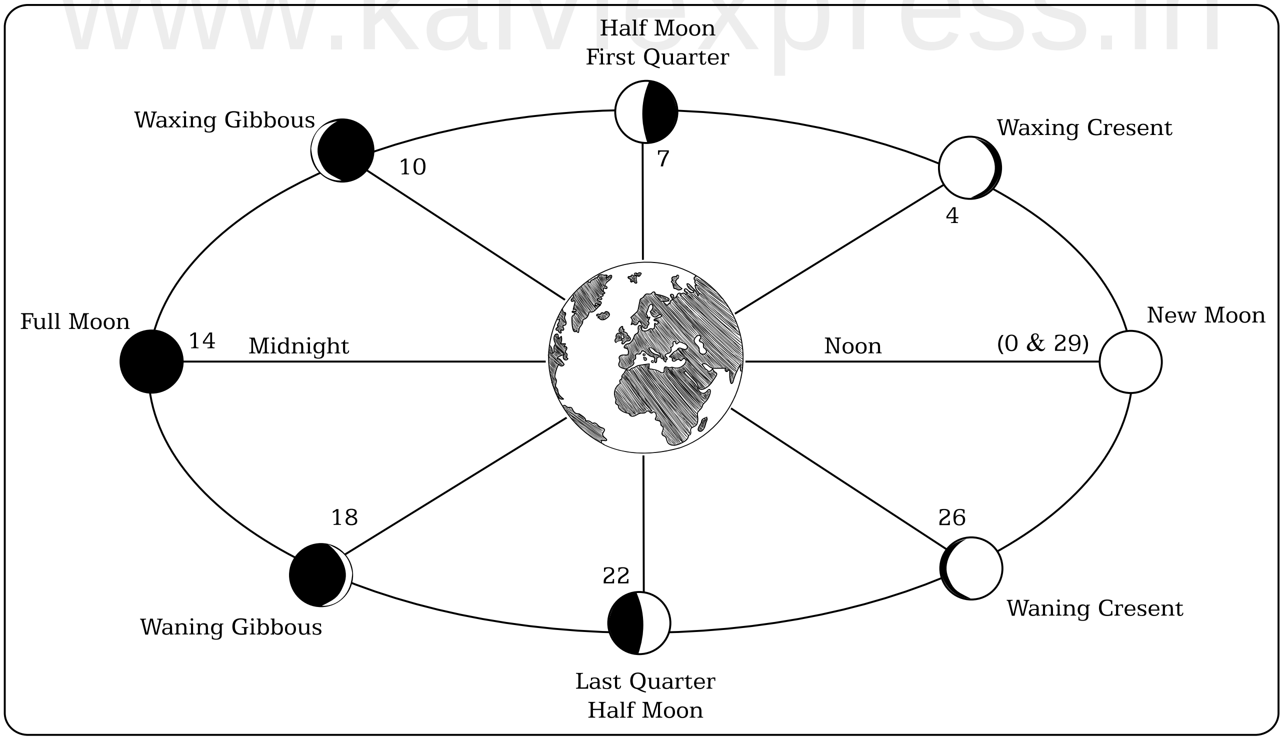
On December 22, the conditions are just like those on June 21 except that the southern hemisphere is 'titled towards' the Sun and the northern hemisphere is 'away from' the Sun. The Sun is vertical at 23½° South, on the line of Capricorn. It is winter season in the Northern hemisphere and summer season in the Southern hemisphere.

Spring Equinox

On March 21, the northern and southern hemisphere are equally inclined towards the Sun. The conditions are similar to that of Autumn equinox.

Phases of the Moon

The changing angles between the earth, the sun and the moon determine the phases of the moon. Phases of the moon start from the 'New Moon' every month. Then, only a part of the Moon is seen bright called 'Crescent', which develops into the 'first quarter'. With the increasing brightness it turns into three quarters known as 'Gibbous' and then it becomes a 'Full Moon'. These stages are the waxing moon. After the full moon, the moon starts waning or receding through the stages of Gibbous, last quarter, crescent, and finally becomes invisible as dark New Moon.



Phases of the Moon

Eclipses

An eclipse is a complete or partial obscuration of light from a celestial body and it passes through the shadow of another celestial body. The eclipses are of two types. They are:

Solar Eclipse: It occurs on New Moon days, when the moon is between the Sun and the Earth. Thus it obscures a part of the Sun viewed from the Earth, but only from a small area of the world. It lasts only for a few minutes. A partial solar eclipse happens when the moon partially covers the disc of the sun. An annular solar eclipse occurs when the moon passes centrally across the solar disc. During a total solar eclipse, the moon's shadow is short enough to cover the whole sun. The outer regions still glow and look bright as a ring. Such a phenomenon is called Diamond Ring.

Lunar Eclipse: It occurs on a Full Moon position when the earth is between the sun and the moon. The earth's shadow obscures the moon as viewed from the earth. A partial lunar eclipse can be observed when only a part of the moon's surface is obscured by earth's umbra. A penumbral lunar eclipse happens when the moon travels through the faint penumbral portion of the earth's shadow. A total lunar eclipse occurs when the earth umbra obscures the entire the moon's surface. Lunar eclipse can be seen from anywhere on the night side of the Earth. It lasts for a few hours due to the smaller size of the moon.

INTERIOR OF THE EARTH

The knowledge of interior of the Earth is derived from the studies and evidences based upon the density, the temperature and the earthquake waves.

i. **Evidences based upon density:** The relative density of the Earth is 5.5. The upper rocks have a relative density of 2.7. The rocks below the surface come out in the form of lava from the volcanoes. The relative density of the lower rocks should be more than 5.5. It is estimated that the rocks of the interior part of the Earth is about 11 or 12.

ii. **Evidence based upon temperature:** There is a rise of one degree celcius temperature with every 32 metres of depth. The study of volcanic lava indicates that the lava which is ejected by the volcanoes comes from a depth of 50 km should be around 1500°C.

iii. **Evidences based upon earthquake waves:** Earthquakes are produced due to some disturbances in the interior part of the Earth. It has been experimentally proved that three types of waves are produced at the time of earthquake.

   a. **Primary waves:** These are longitudinal, push or also known as p-waves. Their velocity is greater than secondary waves. These waves travel with a speed varying from 5 to 12 km per second.

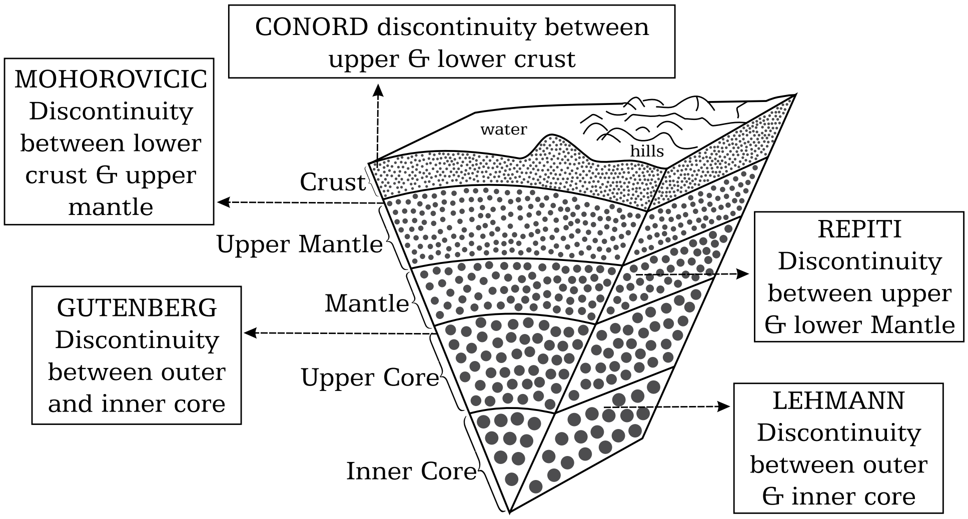
   b. **Secondary waves:** These are known as transverse, share or s-waves. They move slower than p-waves and the speed of s-waves is considered to be about 60 per cent of p-waves.

   c. **Surface waves:** There are also known as l-waves and they propagate on surface only. These waves cannot travel to a long distance.

   This proves that there are various layers of different densities which split the waves into many parts. It is meant that the Earth is made up of varies Shells.

Layers of the Earth

The centre of the Earth is a solid core – **the inner core**. The inner core is about 1300 km thick and is surrounded by an **outer core** of around 2080 km. The outer core appears to be molten. The outer core is surrounded by the **mantle** which has a thickness of around 2900 km. The mantle is topped by the **crust** of the Earth, which varies widely in thickness from 12 to 60 km.



Layers of the Earth

The mantle is important in many ways. It accounts for nearly half the radius of the Earth (2900 km), 83 per cent of its volume and 67 per cent of its mass. The dynamic processes which determine the movements of the crust plates are powered by the mantle. The mantle is a shell of red hot rock and separates the Earth's metallic and partly melted core from the cooler rocks of the Earth's crust.

Mohorovicic Discontinuity: The discontinuity between the Earth's crust and mantle is known as Mohorovicic discontinuity, so called after the scientist A. Mohorovicic, discovered it in 1909 while studying a Balken earthquake. The discontinuity greatly affects the speed at which earthquake waves travel. The Mohorovicic discontinuity lies at a depth of about 20 miles under the continents, but at only 4 to 6 miles under the oceans.

Gutenberg Discontinuity: The discontinuity at a depth of about 2900 km from the surface of the Earth, between the mantle and the core is called Gutenberg discontinuity, after the scientist B. Gutenberg, who discovered it in 1914. At this depth the s-waves of earthquakes disappear, while the p-waves travel on at a reduced speed, that is, it is likely that Gutenberg discontinuity marks a change from solid to a liquid medium, though of much greater density and under enormous pressure.

Isostasy: The term Isostasy is derived from Greek words meaning 'equal standing'. The term was coined by C.E. Dutton in 1889. Isostasy is the state of gravitational equilibrium between Earth's crust and mantle such that the crust "floats" at an elevation that depends on its thickness and density. The crust of the Earth which tops the lithosphere virtually floats on the asthenosphere. Like other floating bodies the crust seeks an equilibrium riding deeper where it is heavier and riding higher where it is lighter. The mountains on the crust have deep roots of light material to support them and when the load on any part of the crust changes, the surface responds by rising or sinking to restore the equilibrium.

Zoning of the Earth's Interior

Prof. Edward Suess divides the Earth's interior into three parts :

i. **Barysphere:** This is the core or the central region of the Earth. The rocks of this layer are composed of iron and nickel.

ii. **Pyrosphere:** This is the middle layer, surrounds the core on all sides. It is composed of silicon and magnesium.

iii. **Lithosphere:** This is an outer layer, surrounds the pyrosphere. It is composed of silicon and aluminium. This is mainly composed of Granite.

Prof. R.A. Daly divides the Earth into four layers :

(i) **Centrosphere :** It is crystalline and rigid with density of 11.0.

(ii) **Mesosphere :** It is comparatively rigid and 400 km deep. The average density of this zone is calculated from 9 to 11.0, a mixed zone of iron and silicate material.

(iii) **Asthenosphere :** It is soft and 350 km deep. The average density of this zone is 4.5 to 9.

(iv) **Lithosphere :** It is the exterior, rigid and about 8 km deep, mostly made up of silicate material, with a density of 3.0.

The Outer Surface

The outer surface of the earth is divided into four 'spheres'.

Lithosphere means the entire top crust of the earth and includes not only the land surface but also the ocean floor.

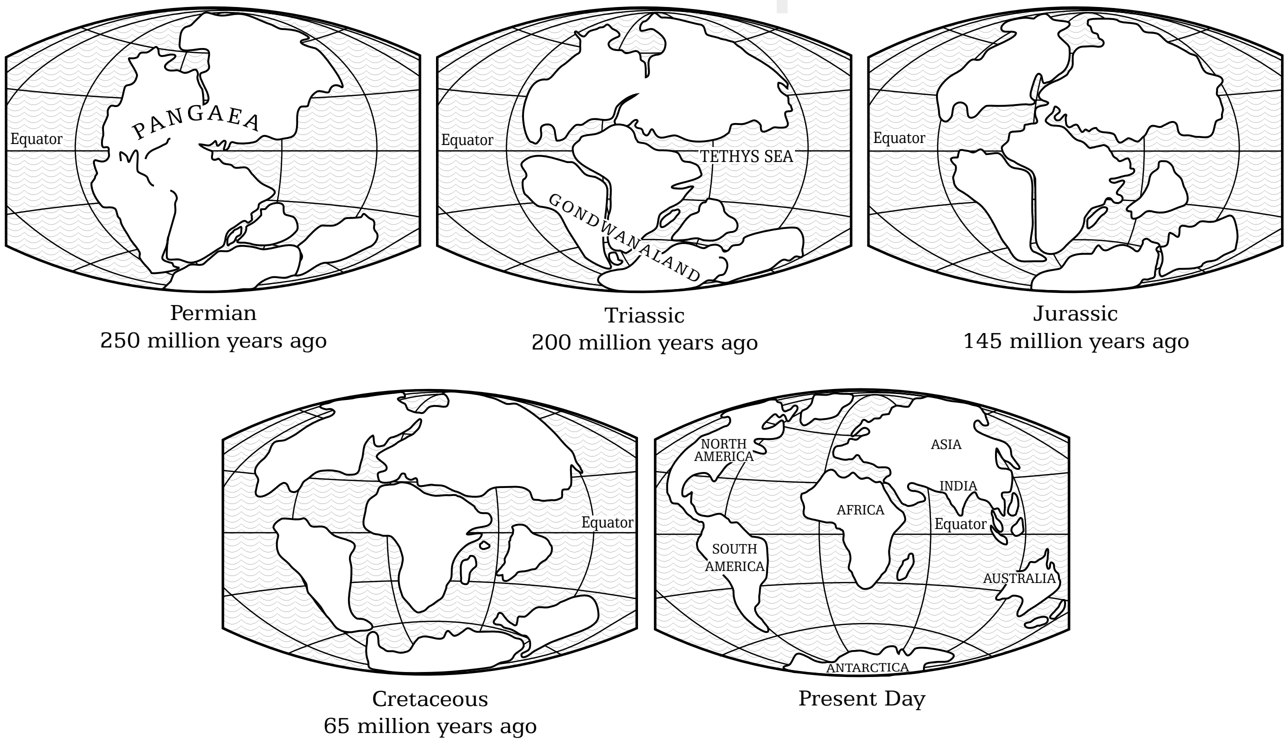
Hydrosphere is the water surface which includes the oceans, lakes and rivers. It rests on the lithosphere.

Atmosphere is the blanket of the air that envelops the earth. It covers both the land surface and the water surface.

Biosphere is the sphere of life which spreads over all the three spheres, lithosphere, hydrosphere and atmosphere.

Continental Drift

In 1915, Alfred Wegener advanced the theory of Continental Drift. According to this theory, there was only one continent and one ocean about 250 million years ago. Wegener named this continent **PANGAEA** (meaning all lands) and the ocean **PANTHALASSA** (meaning universal ocean). Pangaea was a supercontinent, which contained all our present continents. Pangaea covered an area of about 150 million sq. km. The break-up which has resulted in the formation of present-day continents and oceans began about 200 million years by two extensive rifts in the north and south.



The Continental Drift

The Northern rift cut Pangaea from east to west, along a line slightly north of the equator creating Laurasia in the north and Gondwana in the south. Laurasia consisted of North America and Greenland and Eurasia (without India and Arabia), while Godwana contained Africa with Arabia attached, South America, Australia, Antarctica and India. The rift opened up the Atlantic Ocean. The southern rift cut up Gondwana into (i) South America and Africa-cum-Arabia, and (ii) Antarctica, Australia and India. This rift opened up Indian Ocean.

About 135 million years ago, a y-shaped rift liberated India from the Antarctica complex and India started on a long voyage to the north. Some 65 million years ago, North America separated from Eurasia, and South America from Africa. The two Americas drifted west while Africa edged towards the north. Later, the drifting Americas (North and South) came together united by the Isthmus of Panama, while Australia cut a drift from Antarctica and moved northwards. About 20 million years ago, Arabia split from Africa to merge into Asia. This brought into existence the Red Sea and the Gulf of Aden.

On the way to north, the Indian plate encountered a hot spot. Balastic magma from the earth's mantle, poured out (through the hot spot) on the Indian sub-continent over its western edge. The basalts of the Deccan plateau were thus formed. Then India moved on and earthened into South Asia about 45 million years ago.

The northern margin of the Indian Plate dipped into the Tethys Sea and slid under the southern edge of the Asiatic place. This subduction produced vast geological transformations in South Asia :

i. It lifted up the Tethys sea at the eastern end and thus formed a land mass in the place of the sea. The western end of the Tethys sea remained unaffected and subsequently emerged as the Mediterranean Sea.

ii. It put up the Tibetan plateau and the Himalayan mountains. It created the major seismic belt in India, which extends along the Himalayas and turns South-west, culminating in the Ranns of Kutch.

iii. The land mass which replaced the eastern end of the Tethys Sea formed a depression between the high-rising Himalayas and the Deccan plateau. This depression was filled up by alluvial soil, brought down by the Himalayan rivers – Indus, Ganga and Brahamputra, the fertile Indo-Gangetic plain thus came into being.

Plate Tectonics

The discoveries of the sixties, supporting the continental drift, have given birth to a new concept in geology – Plate Tectonics. The top crust of the earth is not an unbroken shell of granite and basalt, but a mosaic of several rigid segments, called plates. The word tectonic is derived from the Greek word tekton meaning builders. They have an average thickness of 100 kms. They float on upper mantle of the earth called Asthenosphere and carry the continents and oceans. All these plate are in constant motion relative to one another at the rate of 20 cm a year.

Sea Floor Spreading

This is term coined by Robert S. Dietz, an American geologist, to explain the mechanism of plate movements. Seafloor spreading is a process that occurs at mid-ocean ridges, where new oceanic crust is formed through volcanic activity and then gradually moves away from the ridge. Basaltic magma rises up the fractures and cools on the ocean floor to form new sea floor.

When a new crust is formed, it pushes the old crusts. As the old crust plates are pushed, they in turn push neighbouring plates which press on their neighbours and so on, round the globe. The creation of the new crust

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

is set off or balanced by the destruction of the old crusts. This process of continuous creation and destruction keeps the top crust of the earth in a state of perpetual renewal.

Indian plate, Pacific plate, American plate, African plate, Eurasian plate and Antarctica plate are the major plates. Arabian plate, Philippines plate, Cocos plate, Caribbean plate, Nasca plate or East Pacific plate and Scotia plate are the minor plates.

Plate Movements

Plate movements are complex and varied. Plates may (i) diverge, (ii) converge, or (iii) move in parallels.

i. **Diverging Plates:** Plates are said to diverge when two adjacent plates move apart. As the plates diverge, hot magma comes up through the cracks and solidifies. This magma forms ridges on either side almost symmetrically. The Mid-Atlantic ridge, the East Pacific ridge and the Chagos-Laccadives ridges in the Indian Ocean and other oceanic ridges have come into being in this manner.

ii. **Converging Plates:** Plates are said to converge when they come together and collide. Such collision boundaries are known as Subduction Zone. In a subduction zone, many things happen e.g. melting of old plates, mountain building and uplifting, earthquakes and volcanoes.

iii. **Parallel Plates:** Parallel plates, as they slide past each other along a common boundary, do not create a new crust or destroy the old. They butt and jostle against each other and produce what are called Transform Faults. Transform faults are fractures in rock formations. The San Andreas Fault in California marks the meeting place of two parallel plates, one carrying North America and the other carrying the Pacific Ocean.

CLASSIFICATION OF ROCKS

The earth's crust is made up of various types of rocks differing from one another in texture, structure, colour, permeability, mode of occurrence and degree of resistance to denudation. Rocks also form the basis for soil, and determine to some extent the type of natural vegetation and land use. Generally speaking, all rocks may be classified into three major groups—igneous, sedimentary and metamorphic, according to their origin and appearance.

Igneous Rocks

Igneous rocks are formed by the cooling and solidification of molten rock (magma) from beneath the earth's crust. They are normally crystalline in structure. In terms of origin there are two main classes of igneous rocks.

i. **Plutonic rocks:** These are igneous rocks formed at some depth in the earth's crust. They have cooled and solidified slowly so that large, easily-recognized crystals have been able to form. These intrusive rocks, such as granite, diorite and gabbro, are exposed at the surface by the processes of denudation and erosion.

ii. **Volcanic rocks:** These are molten rocks poured out of volcanoes as lavas. They solidify rapidly on the earth's surface and the crystals are small. E.g. the Deccan Plateau in India.

Most igneous rocks are extremely hard and resistant. For this reason, they are quarried for road-making and polished as monuments and gravestones.

Intrusive Igneous Rocks

Intrusive Igneous rocks are formed when magma rises and cools within the crust. The intrusive activity of volcanoes gives rise to various forms.

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

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

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

Examples of Various Rocks

Igneous Rocks	**Metamorphic Rocks**
Mica	Schist
Granite	Gneiss
Gabbro	Surpentine
Sedimentary Rocks	Quartz
Lime stone	Marble
Shale	Slate

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

Dyke: When the magma makes its way through cracks and the fissures developed in the land, it solidifies almost perpendicular to the ground. It gets cooled in the same position to develop a wall-like structure. Such structures are called dikes. These are the most commonly found intrusive forms in the western Maharashtra area. These are considered the feeders for the eruptions that led to the development of the Deccan traps.

Sedimentary Rocks

Sedimentary rocks are formed from sediment accumulated over long periods, usually under water. They are distinguished from the other rock types in their characteristic layer formation and are termed stratified rocks. The materials that form sedimentary rocks may be brought by streams, glaciers, winds or even animals. They are non-crystalline and often contain fossils of animals, plants and other micro-organisms. Sedimentary rocks may be classified under three major categories in accordance with their origin and composition.

i. **Mechanically formed sedimentary rocks:** They rocks have been formed from the accumulation of materials derived from other rocks which have been cemented together. E.g. sandstones. The finer sedimentary materials form clay, widely used for brick-making.

ii. **Organically formed sedimentary rocks:** These rocks are formed from the remains of living organisms such as corals or shellfish. The most common rocks formed in this way are of calcareous type. They include limestones and chalk.

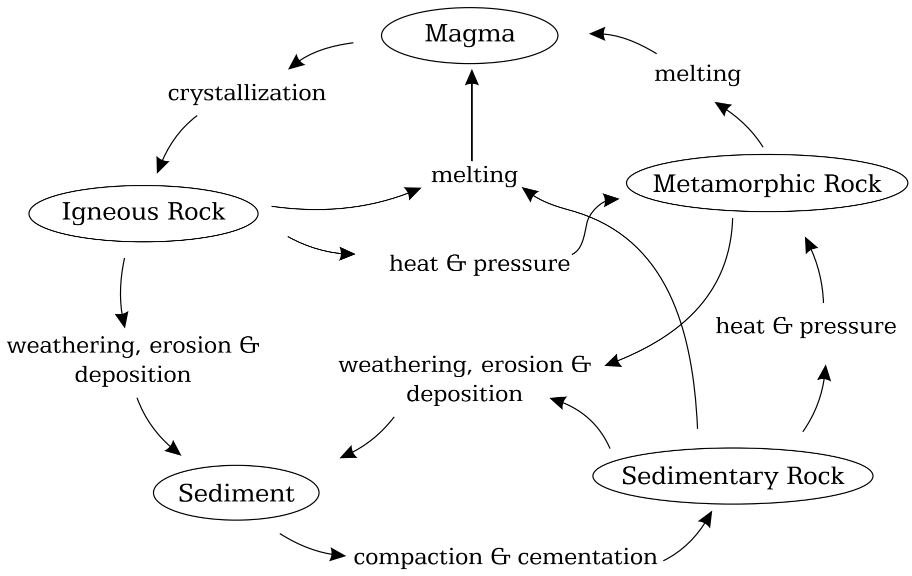
iii. **Chemically formed sedimentary rocks:** Such rocks are precipitated chemically from solutions of one kind or another. Rock salts are derived from strata which once formed the beds of seas or lakes. Calcium sulphate is obtained from the evaporation of salt lakes. In similar ways, potash and nitrates may be formed.

Metamorphic Rocks

All rocks whether igneous or sedimentary may become metamorphic or changed rocks under great heat and pressure. Their original character and appearance may be altered during intense earth movements. Clay may be metamorphosed into slate, limestone into marble and coal into graphite.

Rock Cycle

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



The Rock Cycle

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

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. Weathering, mass wasting, erosion and deposition are exogenic geomorphic processes.

Any exogenic element of nature (like water, ice, wind, etc.,) capable of acquiring and transporting earth materials can be called a geomorphic agent. When these elements of nature become mobile due to gradients, they remove the materials and transport them over slopes and deposit them at lower level. Geomorphic processes and geomorphic agents especially exogenic, unless stated separately, are one and the same.

A process is a force applied on earth materials affecting the same. An agent is a mobile medium (like running water, moving ice masses, wind, waves and currents etc.) which removes, transports and deposits earth materials. Running water, groundwater, glaciers, wind, waves and currents, etc., can be called **geomorphic agents**.

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. So, gravitational stresses are as important as the other geomorphic processes. Gravity is the force that is keeping us in contact with the surface and it is the force that switches on the movement of all surface material on earth. All the movements either within the earth or on the surface of the earth occur due to gradients — from higher levels to lower levels, from high pressure to low pressure areas etc.

Endogenic Processes

The energy emanating from within the earth is the main force behind endogenic geomorphic processes. This energy is mostly generated by radioactivity, rotational and tidal friction and primordial heat from the origin of the earth. This energy due to geothermal gradients and heat flow from within induces diastrophism and volcanism in the lithosphere. Due to variations in geothermal gradients and heat flow from within, crustal thickness and strength, the action of endogenic forces are not uniform and hence the tectonically controlled original crustal surface is uneven.

Diastrophism

All processes that move, elevate or build up portions of the earth's crust come under diastrophism. They include:

i. orogenic processes involving mountain building through severe folding and affecting long and narrow belts of the earth's crust;

ii. epeirogenic processes involving uplift or warping of large parts of the earth's crust;

iii. earthquakes involving local relatively minor movements;

iv. plate tectonics involving horizontal movements of crustal plates.

In the process of orogeny, the crust is severely deformed into folds. Due to epeirogeny, there may be simple deformation. Orogeny is a mountain building process whereas epeirogeny is continental building process. Through the processes of orogeny, epeirogeny, earthquakes and plate tectonics, there can be faulting and fracturing of the crust. All these processes cause pressure, volume and temperature (PVT) changes which in turn induce metamorphism of rocks.

Volcanism

Volcanism includes the movement of molten rock (magma) onto or toward the earth's surface and also formation of many intrusive and extrusive volcanic forms.

EARTH MOVEMENTS AND THE MAJOR LANDFORMS

The face of the earth is constantly being reshaped by the agent of denudation – running water, rain, frost, sun, wind, glaciers and waves. But these agents only modify the patter of mountains, plateaux and plains which have been modelled by movements of the earth's crust.

Types of Plains

A plain is an area of lowland, either level of undulating. It seldom rises more than a few hundred feet above sea level. There may be low hills which will give a typical rolling topography. Population and settlements are normally concentrated here, and when plains are traversed by rivers, their economic importance may be even greater. E.g. Indo-Gangetic plain. Plains may be grouped into three major types based on their mode of formation.

1. **Structural Plains:** These are structurally depressed areas of the world,that make up some of the most extensive natural lowlands on the earth's surface.

2. **Depositional Plains:** These are plains formed by the deposition of materials brought by various agents of transportation. Some of the largest depositional plains are due to deposition by large rivers. Active erosion results in large quantities of alluvium to form extensive alluvial plains, flood plains and deltaic plains. They form the most agricultural plains of the world, intensively tilled and very densely populated. E.g. the Ganges delta for rice and jute growing.

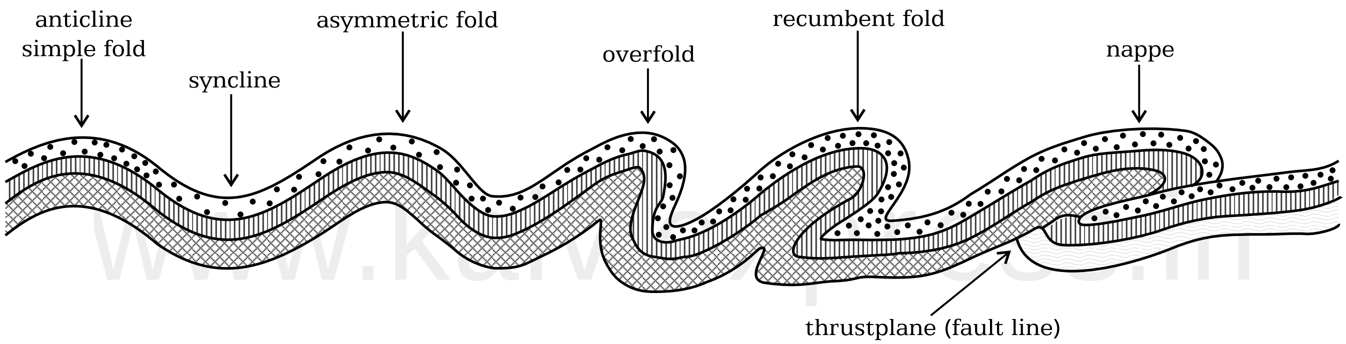
   Glaciers and ice-sheets may deposit a widespread mantle of unsorted fluvio-glacial sands and gravels in the outwash plain or may drop boulder clay to form a till plain or drift plain. In coastal regions, waves and winds often drive beach materials, mud, sand and deposit them on the coastal plain. Winds may blow aeolian deposits —very fine particles known as loess—from interior deserts, barren surfaces and deposit them upon hills, valleys or plains forming a loess plateau. Many of the loess covered plains in the world are fertile agriculture regions.

3. **Erosional Plains:** These plains are carved by the agents of erosion. Rain, rivers, ice and wind help to smooth out the irregularities of the earth's surface. Such plains of denudation are described as peneplains meaning 'almost plains'. In glaciated regions, glaciers and ice-sheets scoured and levelled the land forming ice-sourced plains. In arid and semi-arid regions, wind deflation sweeps away much of the eroded desert materials, lowering the level of land and forming extensive plains. Mechanical weathering in arid and semi-arid areas wears back the mountain slopes to leave a gently sloping pediments or pediplains.

Types of Mountains

Mountains make up a large proportion of earth's surface. Based on their mode of formation four main types of mountains can be distinguished.

1. Fold Mountains



They are caused by large-scale earth movements, when stresses are set up in the earth's crust. Such stresses may be due to the increased load of the overlying rocks, flow movements in the mantle, magmatic intrusions into the crust, or the expansion or contraction of some part of the earth. When such stresses are initiated, the rocks are subjected to compressive forces that produce wrinkling or **folding** along the lines of weakness. Folding shortens the earth's crust creating a series of 'waves'. The upfolded waves are called **anticlines** and the troughs or downfolds are **synclines**. E.g. Himalayas and Alps.

When the crest of a fold is pushed too far, an **overfold** is formed. If it is pushed still further, it becomes a **recumbent fold**. In extreme cases, fractures may occur in the crust, so the upper part of the recumbent fold slides forward over the lower part along a **thrust plane**, forming an **overthrust fold**. The over-riding portion of the thrust fold is termed a **nappe**. The fold mountains contain many active volcanoes. They also contain rich mineral resources such as tin, copper, gold and petroleum.

2. Block Mountains

When the earth's crust bends folding occurs, but when it cracks, faulting takes place. Faulting may be caused by tension or compression, forces which lengthen or shorten the earth's crust, causing a section of it to subside or to rise above the surrounding level. E.g. Hunsruck Mountains, Black Forest of the Rhineland.

Compressional forces set up by earth movements may produce a thrust or reverse fault and shorten the crust. The faults may occur in series and be further complicated by tilting and other irregularities. Denudation through the ages modifies faulted landforms.

3. Volcanic Mountains

These are, in fact, volcanoes which are built up from material ejected from fissures in the earth's crust. The materials include molten lava, volcanic bombs, cinders, ashes, dust and liquid mud. E.g. Mount Fiji (Japan), Mount Mayon (Philippines).

4. Residual Mountains

These are mountains evolved by denudation. Where the general level of the land has been lowered by the agents of denudation. E.g. Mt. Manodnock in U.S.A. Residual mountains may also evolve from plateaux which have been dissected by rivers into hills and valleys.

Hills

Low mountains in one place often resemble in elevation, relief, and slope the high hills of another place. As a general rule hills have more level land, larger summits, shorter and less steep slopes than mountains. Compared to plains, on the other hand, hills have more land in slope, steeper slopes, and usually greater local relief. Many Hill areas, such as the Central European Highlands, were once rougher steeper and higher mountains, but the long-continued activity of various weathering and erosional processes have gradually reduced the mountains to more subdued forms.

Types of Plateaux

Plateaux are elevated uplands with extensive level surfaces, and usually descend steeply to the surrounding lowland. Like all highlands, plateaux are subjected to erosional processes. As a result, their original characteristics may be greatly altered. According to their mode of formation and their physical appearance, plateaux may be grouped into the following types:

1. **Tectonic Plateaux:** These are formed by earth movements which cause uplift, and are normally of a considerable size, and fairly uniform altitude. They include continental blocks like the Deccan Plateau in India.
2. **Volcanic Plateaux:** Molten lava may arise from the earth's crust and spread over its surface to form successive sheets of basaltic lava. These solidify to form a lava plateau. The north-western part of the Deccan Plateau.
3. **Dissected Plateaux:** Through the continual process – weathering, erosion, stream action and sometimes glaciation – cut deep, narrow valleys in the plateaux. E.g. Scottish Highlands. Abrasion by winds will dissect the plateau into steep-sided tabular masses termed mesas and buttes, intersected by deep canyons.

Plateaux have rich mineral resources. The African Plateau yields gold, diamonds, copper, manganese and chromium. The Deccan Plateau has deposits of manganese, coal and iron.

Deserts

Desert is a part of Earth's surface that is too dry to support plant or animal life and is usually sparsely inhabited or uninhabited by man. Climatic features and aeolian processes determine the existence of different desert types.

- Sandy Deserts are the ones that prevail mostly. E.g. Sahara desert, Kara-Kum in Turkmenistan.
- Stony Deserts is covered with diverse fragments of rocks in the form of rock debris and rock blocks. These are gloomy, black deserts. They have a black tarnish coating representing an extremely fine ferruginous-manganese crust called Desert Varnish.

- Loess Deserts range at the outskirts of deserts, bordering on mountains, or change over into steppe.
- Salt Deserts or Shors emerge: a) at the site of dried out, or periodically running dry lakes; b) with shallow occurrence of underground waters. Underground water rises to the surface along capillary channels, undergoes an intensive evaporation, as a result of which the surface becomes covered over a relatively short time with a white crust of salt, underneath a mixture of dust and salts is formed known as Puffy Solonchak.
- Gypsum deserts appear secondary to the work of wind and as a result of complicated chemical reactions.

Islands

An island is a piece of land surrounded by water, smaller than a continent. Islands are broadly divided into four types –

1. **Continental Islands** are those islands that rise from the continental shelf for example the British Isles. These islands have the same geological structure, as the continents to which they are related.
2. **Oceanic Islands** are those that rise from the bottom of the oceans. Their geographical structure will have no geological relation to that of the nearest shores. They are very often the tops of submarine mountains or submarine volcanoes. E.g. St. Helena.
3. **Tectonic Islands** are created by the movements in the Earth's crust. When one plate is pushed under another plate, the top plate may scrape off pieces of the bottom plate. Over millions of years, this material piles up to form an island. E.g. Barbados in the West Indices.
4. **Coral Islands** are the work of minute sea organisms called Coral Polyps. They congregate in large colonies. When the organisms die,their skeletons, which are made of substance resembling limestone, form big clusters, some of which rise above the water.

VOLCANOES

A volcano is an opening in the earth's crust through which gases, molten rocks materials (lava), ash, steam etc. are emitted outward in the course of an eruption. Such vents or openings occur in those parts of the earth's crust where the rock strata are relatively weak. Volcanic activity is an example of endogenic process. Depending upon the explosive nature of the volcano, different land forms can be formed such as a plateau (if the volcano is not explosive) or a mountain (if the volcano is explosive in nature).

Magma vs Lava: The Difference

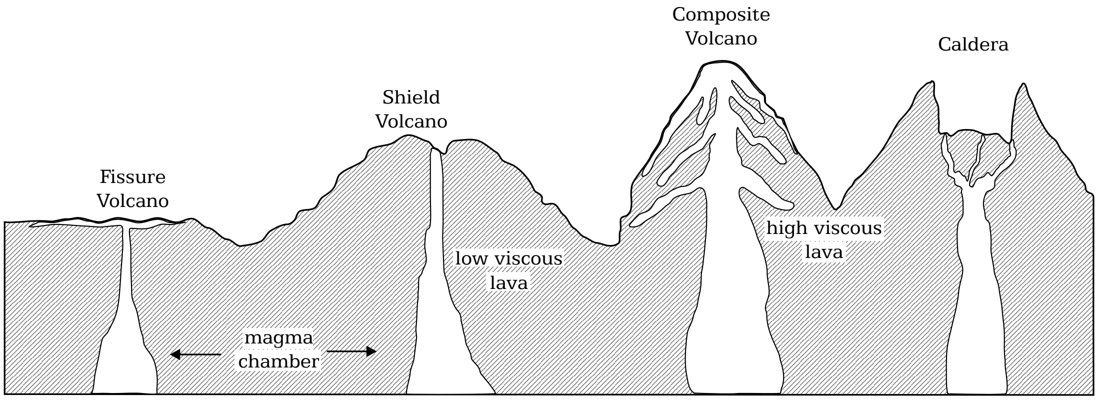
Magma is the term used to denote the molten rocks and related materials seen inside earth. A weaker zone of the mantle called asthenosphere, usually is the source of magma. Once this magma came out to the earth surface through the vent of a volcano, it is called as the Lava. Therefore, Lava is nothing but the magma on earth surface. The process by which solid, liquid and gaseous material escape from the earth's interior to the surface of the earth is called as Volcanism.

Types of Volcanoes

Volcanoes are classified on the basis of nature of eruption and the form developed at the surface.

Shield Volcanoes

- How to identify: They are not very steep but are far and wider. They extend to great height as well as distance.
- They are the largest of all volcanoes in the world as the lava flows to a far distance. The Hawaiian volcanoes are the most famous examples.



Types of Volcanoes

- Shield volcanoes have low slopes and consist almost entirely of frozen lavas.
- If you were to fly over top of a shield volcano, it would resemble a warrior's shield, hence the name.
- These volcanoes are mostly made up of basalt (less viscous), a type of lava that is very fluid when erupted. For this reason, these volcanoes are not steep.
- They are of low explosive in general, but if somehow water gets into the vent they may turn 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 cinder cone

Cinder Cone Volcanoes

- Cinders are extrusive igneous rocks. A more modern name for cinder is Scoria.
- Small volcanoes.
- These volcanoes consist almost entirely of loose, grainy cinders and almost no lava.
- They have very steep sides and usually have a small crater on top.

Composite Volcanoes

- Shape: Cone shaped with moderately steep sides and sometimes have small craters in their summits.
- Volcanologists call these "strato-" or composite volcanoes because they consist of layers of solid lava flows mixed with layers of sand- or gravel-like volcanic rock called cinders or volcanic ash.
- They are characterized by the eruption of a cooler and more viscous lavas than basalt.
- These volcanoes often result in explosive eruptions.
- Along with lava, large quantities of pyroclastic materials and ashes find their way to the ground.
- This material accumulates in the vicinity of the vent openings and leading to the formation of layers, and this makes the mount appears as composite volcanoes.

Caldera

- These are the most explosive of the earth's volcanoes.
- They are usually so explosive that when they erupt they tend to collapse on themselves rather than building any tall structure. The collapsed depressions are called calderas.
- Their explosiveness indicates that its magma chamber is large and in close vicinity.
- A caldera differs from a crater in such a way that a caldera is a huge depression caused by a collapse after a large-scale eruption, whereas a crater is a small, steep side, volcanic depression bored out by an eruptive plume.

Flood Basalt Provinces

- These volcanoes outpour highly fluid lava that flows for long distances.
- The Deccan Traps from India, presently covering most of the Maharashtra plateau, are a much larger flood basalt province.

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.

Mt. Krakatau

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

Cotopaxi in Ecuador is the world's highest active volcano.

Volcanoes can also be classified based on the frequency of eruption, mode of eruption and characteristic of lava.

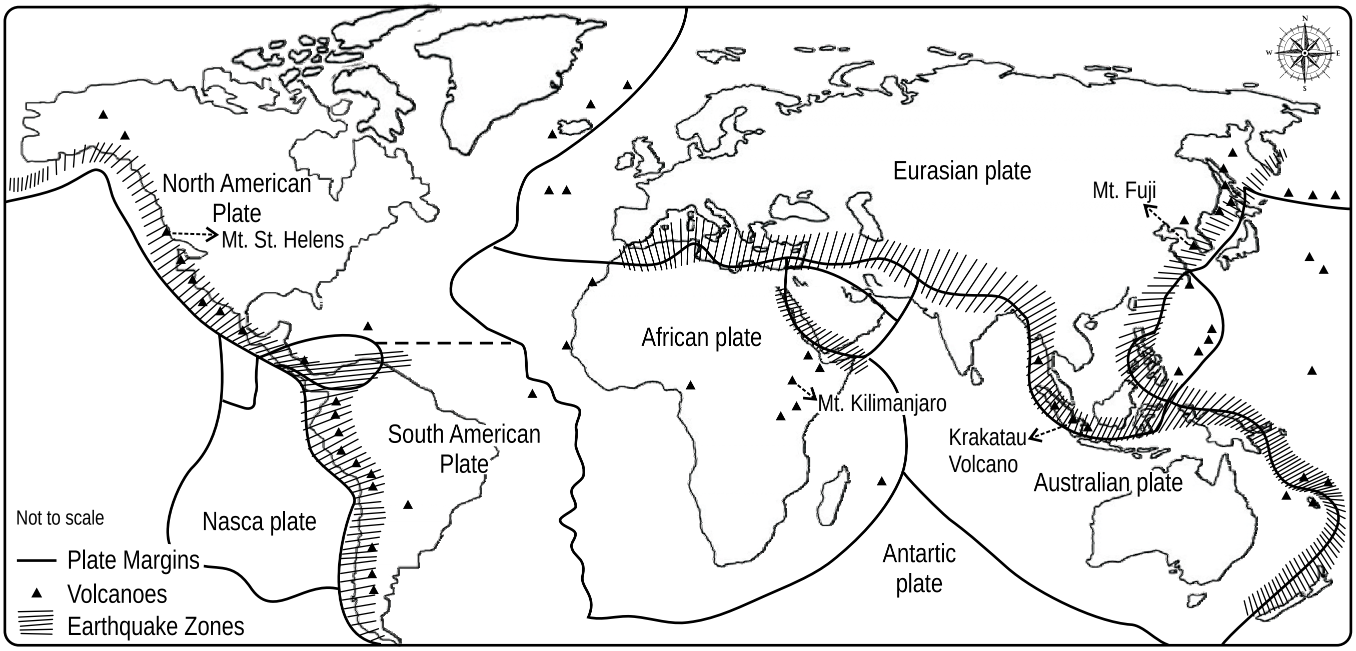
Classification of Volcanoes		
Based on the frequency of eruption	**Based on the mode of eruption**	**Based on the characteristics of lava**
Active Volcanoes (Erupt frequently or have erupted recently or are in action currently. E.g. Barren Islands) **Dormant Volcanoes** (Not erupted in recent times but atleast erupted once in human history) **Extinct Volcanoes** (Not erupted in human history)	**Centre Type Volcanoes** (Eruption through a vent or opening. Forms different types of hills or conical forms. Most of the volcanoes of the world are of this type) **Fissure Type Volcanoes** (Magma flows through a deep elongated crack. Forms thick, horizontal sheet of lava or low dome shaped volcano with a broad base. E.g. Deccan Traps)	**Volcanoes of Basic Lava** (Lava will be rick in metallic minerals and has low melting point. Hence it has greater fluidity, i.e., less viscousity. Lava flows far and wide with greater speed. They form Shield Volcanoes **Volcanoes with Acidic Lava** (Rich in silica and has a relatively high melting point. They are highly viscous and solidifies quickly. They form high volcanic structures with steep slope known as Composite Volcanoes.)

Distribution of Volcanoes across the World

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

1. **Pacific Ring of Fire:** Circum-Pacific region, popularly termed the 'Pacific Ring of Fire', has the greatest concentration of active volcanoes. Volcanic belt and earthquake belt closely overlap along the 'Pacific Ring of Fire'. It is estimated to include two-thirds of the world's volcanoes.
2. **Mid Atlantic Region:** The Mid Atlantic Region coasts has comparatively fewer active volcanoes but many dormant or extinct volcanoes, example. St. Helena, Cape Verde Islands and the Canary Islands. But the volcanoes of Iceland and the Azores are active.
3. **The Great Rift valley of Africa:** In Africa some volcanoes are found along the East African Rift Valley. Kilimanjaro and Mt. Kenya are extinct volcanoes. The only active volcano in West Africa is Mt. Cameroon.

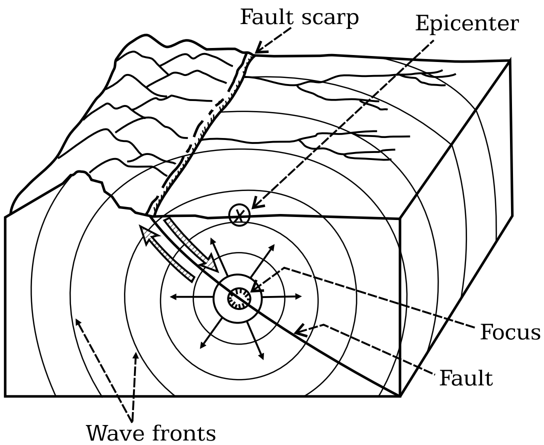
4. **Mediterranean Region:** Volcanoes of the Mediterranean region are mainly associated with the Alpine folds. Example, Mt. Vesuvius, Mt. Stromboli (known as the Light House of the Mediterranean Sea).
5. **Other Regions:** Elsewhere in the interiors of continents of Asia, North America and Europe active volcanoes are rare. There are no volcanoes in Australia.



World Distribution of Earthquakes and Volcanoes

EARTHQUAKES

An earth quake can be defined as a sudden violent shaking of the ground as a result of movements in the earth's crust or volcanic action. These movements result in the release of energy along a fault and cause the earth to shake. An earthquake, like volcanoes is a type of endogenic processes. The earthquake of January 26, 2001 which flattened parts of Gujarat was also caused by the growing 'in-plate stress' in the region. In fact, the whole Kutch is a fault.



- The network of seismographic (seismograph is the instrument used to measure earthquakes) stations all over the world record dozens of earthquakes every day. Most of them are not felt by human beings as they are minor quakes only.
- The occurrence of a severe earthquake is limited to a few regions in the world.
- The point within the earth's crust where an earthquake originates is called as the focus or hypocenter or seismic focus. It generally lies within a depth of 6 kms in the earth crust.
- The point vertically above the focus on the earth's surface is called as the epicenter.
- The intensity of earthquake will be highest in the epicenter and decreases as one moves away.
- All natural earthquakes take place in the lithosphere (i.e, the region which constitutes the earth's crust and rigid upper part of the mantle).

Earthquake Waves or Seismic Waves

The earthquake which originates in the lithosphere propagates different seismic waves or earthquake waves. Earthquake waves are basically of two types – body waves and surface waves.

Seismic Waves
- **Body Waves**
  - **Primary Waves (P-waves)**
  - **Secondary Waves (S-waves)**
- **Surface Waves**
  - **Love Waves (L-waves)**
  - **Rayleigh Waves (R-waves)**

Body Waves

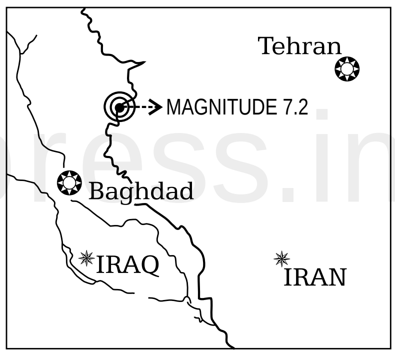
They are generated due to the release of energy at the focus and moves in all directions traveling through the body of the earth. Hence, the name – body waves. They travel only through the interior of the earth. Body waves are faster than surface waves and hence they are the first to be detected on a seismograph. There are two types of body waves as primary waves and secondary waves.

Primary waves (p-waves): Primary waves are the fastest body waves (twice the speed of s-waves) and are the first to reach during an earthquake. They are similar to sound waves, i.e, they are longitudinal waves, in which particle movement is in the same direction of wave propagation. They travel through solid, liquid and gaseous materials. They create density differences in the earth material leading to stretching and squeezing.

Secondary waves (s-waves): They arrive at the surface with some time-lag after primary waves. They are slower than primary waves and can pass only through solid materials. This property of s-waves led seismologists to conclude that the earth's outer core is in a liquid state (the entire zone beyond 105° from the epicenter does not receive s-waves).

Earthquake – Middle East

Near the Iran/Iraq border on 12th November, 2017, 9:18 pm local time with a magnitude of 7.2 on the Richter scale.



Areas affected	:	Iran and Iraq
Max. intensity	:	VIII (Severe)
Fault	:	Arabian and Eurasian plates.
Casualties	:	630 dead; above 8,100 injured; above 70,000 homeless
Depth	:	19.0 km

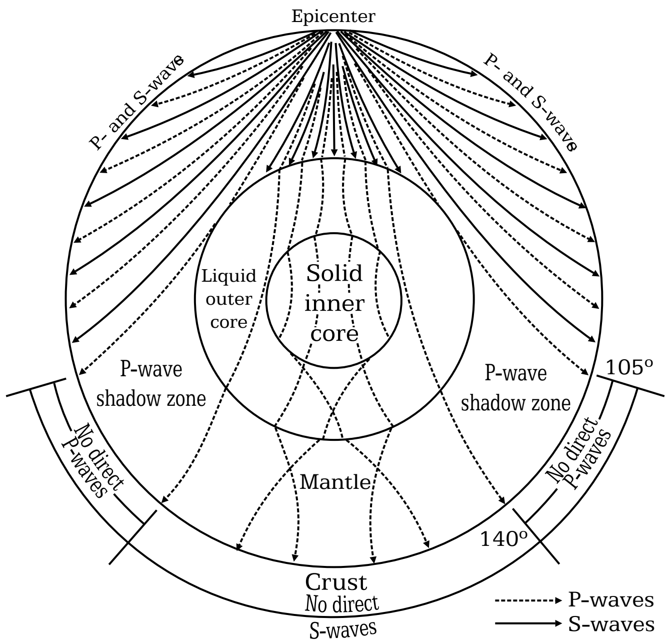
They are transverse waves in which directions of particle movement and wave propagation are perpendicular to each other.

Surface Waves

When the body waves interact with surface rocks, a new set of waves is generated called as surface waves. These waves move along the earth surface. Surface waves are also transverse waves in which particle movement is perpendicular to the wave propagation. Hence, they create crests and troughs in the material through which they pass. Surface waves are considered to be the most damaging waves. Two common surface waves are Love waves and Rayleigh waves.

Love waves: This kind of surface waves causes horizontal shifting of the earth during an earthquake. They have much slower than body waves but are faster than Rayleigh. They exist only in the presence of semi-infinite medium overlain by an upper finite thickness. Confined to the surface of the crust, Love waves produce entirely horizontal motion.

Rayleigh waves: These waves follow an elliptical motion. A Rayleigh wave rolls along the ground just like a wave rolls across a lake or an ocean. Because it rolls, it moves the ground up and down and side-to-side in the same direction that the wave is moving. Most of the shaking felt from an earthquake is due to the Rayleigh wave, which can be much larger than the other waves.



Shadow Regions of Waves

Shadow Regions of Waves

Even though p-waves pass through all mediums, it causes reflection when it enters from one medium to another. The variations in the direction of waves are inferred with the help of their record on seismographs. The area where the seismograph records no waves is called as 'shadow zone' of that wave. Accordingly, it is observed that the area beyond 105° does not receive s-waves and the area in between 105° to 140° does not receive p-waves.

Measuring Earthquakes

- **Seismometers** are the instruments which are used to measure the motion of the ground, which including those of seismic waves generated by earthquakes, volcanic eruptions, and other seismic sources.
- A **Seismograph** is also another term used to mean seismometer though it is more applicable to the older instruments.
- The recorded graphical output from a seismometer/seismograph is called as a **seismogram**. (Note: Seismograph is an instrument while seismogram is the recorded output)
- There are two main scales used in the seismometers: Mercalli Scale and Richter Scale.

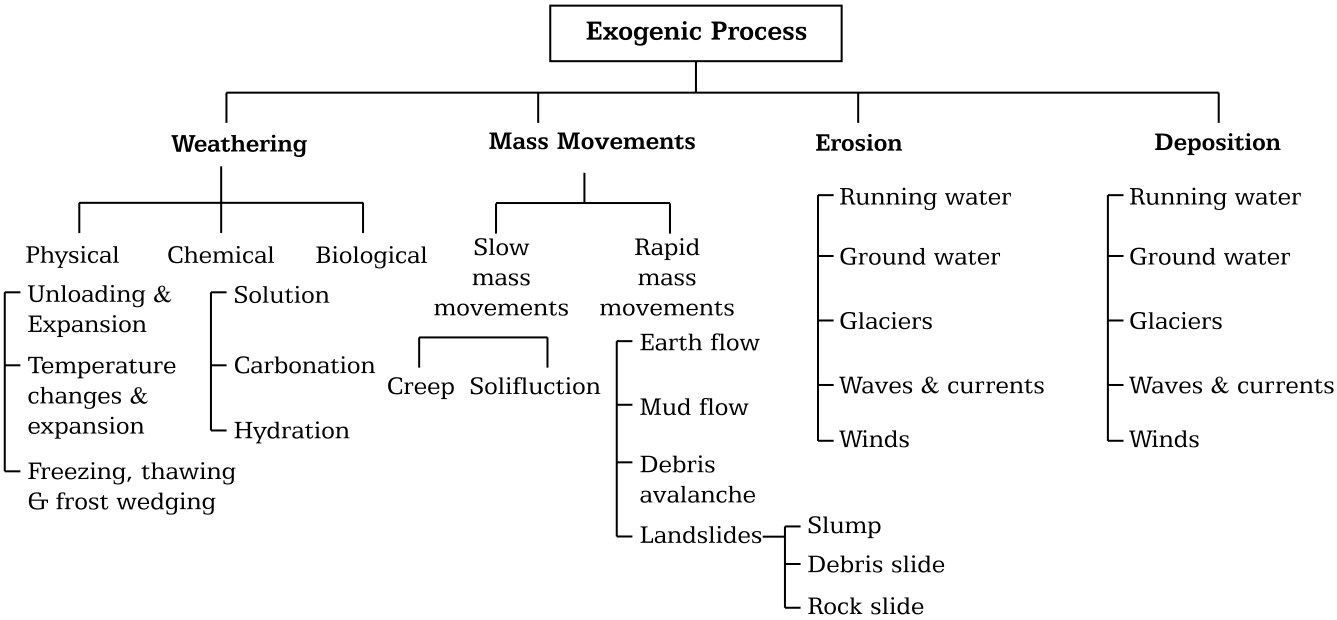
  Mercalli Scale: The scale represents the intensity of earthquake by analyzing the after effects like how many people felt it, how much destruction occurred etc. The range of intensity is from 1-12.

  Richter Scale: The scale represents the magnitude of the earthquake. The magnitude is expressed in absolute numbers from 1-10. Each whole number increase in Richter scale represents a ten times increase in power of an earthquake.

Distribution of Earthquakes

There are two well-defined belts where earthquakes frequently occur – The Circum-Pacific Belt and The Mid-World Mountain Belt. About 68% of earthquakes in the world occur in the Circum-Pacific Belt. Mid-World Mountain belt extends from the Alps with their extension into Mediterranean, the Caucasus, and the Himalayan region and continues to Indonesia. 21% of earthquakes are occurring in this belt. The remaining 11% occur in the other parts of the world.

Exogenic Processes



The exogenic processes derive their energy from atmosphere determined by the ultimate energy from the sun and also the gradients created by tectonic factors.

Gravitational force acts upon all earth materials having a sloping surface and tend to produce movement of matter in down slope direction. Force applied per unit area is called stress. Stress is produced in a solid by pushing or pulling. This induces deformation. Forces acting along the faces of earth materials are shear stresses (separating forces). It is this stress that breaks rocks and other earth materials. The shear stresses result in angular displacement or slippage. Besides the gravitational stress earth materials become subjected to molecular stresses that may be caused by a number of factors amongst which temperature changes, crystallisation and melting are the most common. Chemical processes normally lead to loosening of bonds between grains, dissolving of soluble minerals or cementing materials. Thus, the basic reason that leads to weathering, mass movements, and erosion is development of stresses in the body of the earth materials.

As there are different climatic regions on the earth's surface the exogenic geomorphic processes vary from region to region. Temperature and precipitation are the two important climatic elements that control various processes.

All the exogenic geomorphic processes are covered under a general term, denudation. The word 'denude' means to strip off or to uncover. Weathering, mass wasting/movements, erosion and transportation are included in denudation.

As there are different climatic regions on the earth's surface owing thermal gradients created by latitudinal, seasonal, and land and water spread variations, the exogenic geomorphic processes vary from region to region. The density, type and distribution of vegetation which largely depend upon precipitation and temperature also exert influence indirectly on exogenic geomorphic processes. Within different climatic regions there may be local variations of the effects of different climatic elements due to altitudinal differences, aspect variations and the variation in the amount of insolation received by north and south facing slopes as compared to east and west facing slopes. Further, due to differences in wind velocities and directions, amount and kind of precipitation, its intensity, the relation between precipitation and evaporation, daily range of temperature, freezing and thawing frequency, depth of frost penetration, the geomorphic processes vary within any climatic region.

Climatic factors being equal, the intensity of action of exogenic geomorphic processes depends upon type and structure of rocks. The term structure includes such aspects of rocks as folds, faults, orientation and inclination of beds, presence or absence of joints, bedding planes, hardness or softness of constituent minerals, chemical susceptibility of mineral constituents; the permeability or impermeability etc. Different types of rocks with differences in their structure offer varying resistances to various geomorphic processes. A particular rock may be resistant to one process and nonresistant to another. And, under varying climatic conditions, particular rocks may exhibit different degrees of resistance to geomorphic processes and hence they operate at differential rates and give rise to differences in topography. The effects of most of the exogenic geomorphic processes are small and slow and may be imperceptible in a short time span, but will in the long run affect the rocks severely due to continued fatigue.

Finally, it boils down to one fact that the differences on the surface of the earth though originally related to the crustal evolution continue to exist in some form or the other due to differences in the type and structure of earth materials, differences in geomorphic processes and in their rates of operation.

The earth's crust is constantly undergoing geological changes caused by **internal forces**, which create new relief features. Orogenesis build new mountain ranges, uplift or depression of particular areas is caused by folding or faulting and volcanic disturbances also modify the landscape. Meanwhile eternal forces are working vigorously to wear away the surface, the interaction of these constructive and destructive forces gives rise to the great diversity of present-day landforms. The process of wearing away the earth causes a general lowing and levelling out of the surface. It is known as denudation and is carried out in four phases.

1. **Weathering:** the gradual disintegration of rocks at atmospheric or weather forces;
2. **Erosion:** the active wearing away of the earth's surface by moving agents like running water, wind, ice and waves;
3. **Transportation:** the removal of the eroded debris to new positions;
4. **Deposition:** the dumping of the debris in certain parts of the earth, where it may accumulate to form new rocks.

All four phases of the denudation process are taking place simultaneously in different parts of the world at different rates, much depending on the nature of the relief, the structure of the rocks, the local climate and interference by man.

WEATHERING

The work of weathering in breaking up the rocks is of two kinds, namely chemical and physical or mechanical weathering, but the processes involved in each are closely interrelated.

1. Chemical Weathering

Chemical weathering is the basic process by which denudation proceeds. It is extremely slow and gradual decomposition of rocks due to exposure to air and water. Air and water contain chemical elements, which though they may be in small quantities, are sufficient to set up chemical reactions in the surface layers of exposed rocks. Such reactions may weaken or entirely dissolve certain constituents of the rock, thus loosening the other crystals and weakening the whole surface.

When the surface of a rock is weathered some of the material which is loosened is removed by erosive agents such as wind or running water thus exposing a fresh surface to weathering, but much of the weathered material or regolith (remains of the rock) may stay in position forming the basis of soil. Regolith is simply the mineral remains of decomposed rocks, but soil contains organic materials, such as the roots of plants, fallen leaves, small animals such as worms, bacteria and so on.

When a soil cover exists, chemical weathering of the underlying rocks does not cease; on the contrary it is usually enhanced. This is because the soil absorbs rain-water and keeps the underlying rocks in contact with this moisture. The rain-water absorbs organic acids from the soil and thus becomes a stronger weathering agent than pure rain-water acting on bare rock. The wearing away of rocks by chemical processes is called Corrosion.

For example, in Malaysia, the surface of granite which has been exposed to the weather is found to be pitted and rough. This is because the granite is made of three main minerals: quartz, felspar and mica. The felspar is more quickly weathered than the quartz and thus the feldspar crystals are wore away. The quartz crystals are eventually loosened in this way and form a coarse sandy residue.

Chemical weathering comprises :

a. **Solution:** The state of a substance being dissolved in a liquid in called Solution. Many minerals are dissolved by water, especially when, as with rain-water, it contains enough carbon dioxide to make it a weak acid. Solution is the most potent weathering process in limestone regions because the rain-water attacks and dissolves the calcium carbonate of which the rock is chiefly formed. The dissolved calcium carbonate is carried away by the water, joints and cracks in the rock are quickly widened and whole systems of caves and passages are worn out.

   All rocks are subject to solution to some extent, though the process is much slower than with limestone. The rate at which solution takes place is affected not only by the mineral composition of the rock but also by its structure. The density of joints or cracks in the rock is also crucial to the speed of weathering. In tropical countries, where the heavy rainfall and warm climate both promote rapid chemical reactions, weathering often proceeds very rapidly. This produces the very deep regoliths or soils overlying the solid rocks.

   Rates of weathering are also affected by climate. Warm wet climates promote rapid chemical weathering, while dry climates inhibit chemical weathering. Dry climates, however, provide good conditions for physical or mechanical weathering.

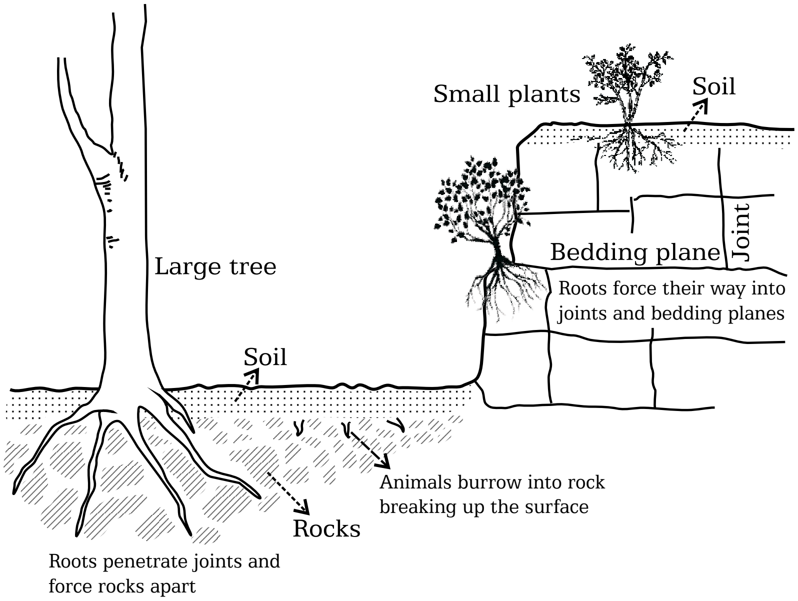
b. **Oxidation:** Oxidation is the reaction of oxygen in air or water with minerals in the rock. For example, most rocks contain a certain amount of iron, which when it comes in contact with air is changed to iron oxide, familiar brownish crust or rust. Iron oxide crumbles easily and is far more easily eroded than the original iron. It is thus removed, loosening the overall structure of the rocks and weakening them.

c. **Decomposition by organic acids:** Within the soil which covers most rocks are bacteria which thrive on decaying plant or animal material. These bacteria produce acids which, when dissolved in water, help to speed up the weathering of the underlying rocks. In some cases micro-organisms and plants like mosses or lichens can live on bare rock, so long as the surface is damp. These absorb chemical elements from the rocks as food and also produce organic acids. They are thus agents of both chemical and mechanical weathering.

2. Physical or Mechanical Weathering

Mechanical weathering is the physical disintegration of a rock by the actual prising apart of separate particles. The processes of physical weathering are able to work much more easily when the surface of the rock has already been weakened by the action of chemical weathering. Mechanical weathering takes place in several ways.

a. **Repeated temperature changes:** In deserts, rocks are exposed to the blazing sun during the day and are intensely heated. The outer layers expand much faster than the cooler interior of rocks and tend to pull away from the rest. At nightfall the temperature drops rapidly and the outer layers contract more rapidly than the interior, setting up internal stresses. Such stresses, repeated every day for months and



Plant roots as agents of mechanical weathering

years, cause the rocks to crack and split. Well-bedded and jointed rocks tend to split along the joints or cracks, breaking up into rectangular blocks. Fragments broken from large rock outcrops fall by gravity to the foot of the slope. They may form screes or may form a litter of angular chips and small boulders on the flatter ground.

Stresses and pressures will naturally be greatest near the surface and where there are sharp angles in the rocks. Rectangular blocks are thus gradually rounded by the splitting away of sharp corners. When the surface layers of rounded boulders gradually split off the process is called onion peeling. The technical term for this process is exfoliation.

b. **Repeated wetting and drying:** Exfoliation is not confined to desert areas. Similar stresses may be set up on rocks by repeated wetting and drying of the surface layers. This takes place especially in tropical regions. When rocks are wetted the outer layers absorb a certain amount of moisture and expand. When they dry this moisture evaporates and they quickly shrink. When this happens repeatedly the outer layers split off.

c. **Frost action:** In temperate latitudes frost is a potent rock breaker. All rocks contain cracks and joints, or pore spaces, and after a shower water or snow collects in such places. When the temperature drops at night or during the winter, this water freezes. When water freezes it expands by one-tenth its volume and exerts a bursting pressure of almost 140 kg per square cm. Repeated freezing of this kind will deepen and widen the original cracks and crevices and break the rock into angular fragments. On mountain peaks this process creates sharp pinnacles and angular outlines. Such peaks are described as frost-shattered peaks.

d. **Biotic factors:** Small fragments of rock loosened by either chemical or mechanical weathering lodge in cracks and crevices in the rock and plants may sprout in such crevices. As they grow their roots penetrate the rocks below, usually along joints and other lines of weakness, prising them apart.

Men, in the course of mining, road construction and farming, also contribute to mechanical weathering by excavating the rocks and rendering them more vulnerable to the agents of denudation.