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# GEOGRAPHY, ENVIRONMENT & DISASTER MANAGEMENT

**For UPSC, State PSC Civil Services & other exams**

**Volume – 1**

**World Geography, Indian Geography & Disaster Management**

SIERRA INNOVATIONS

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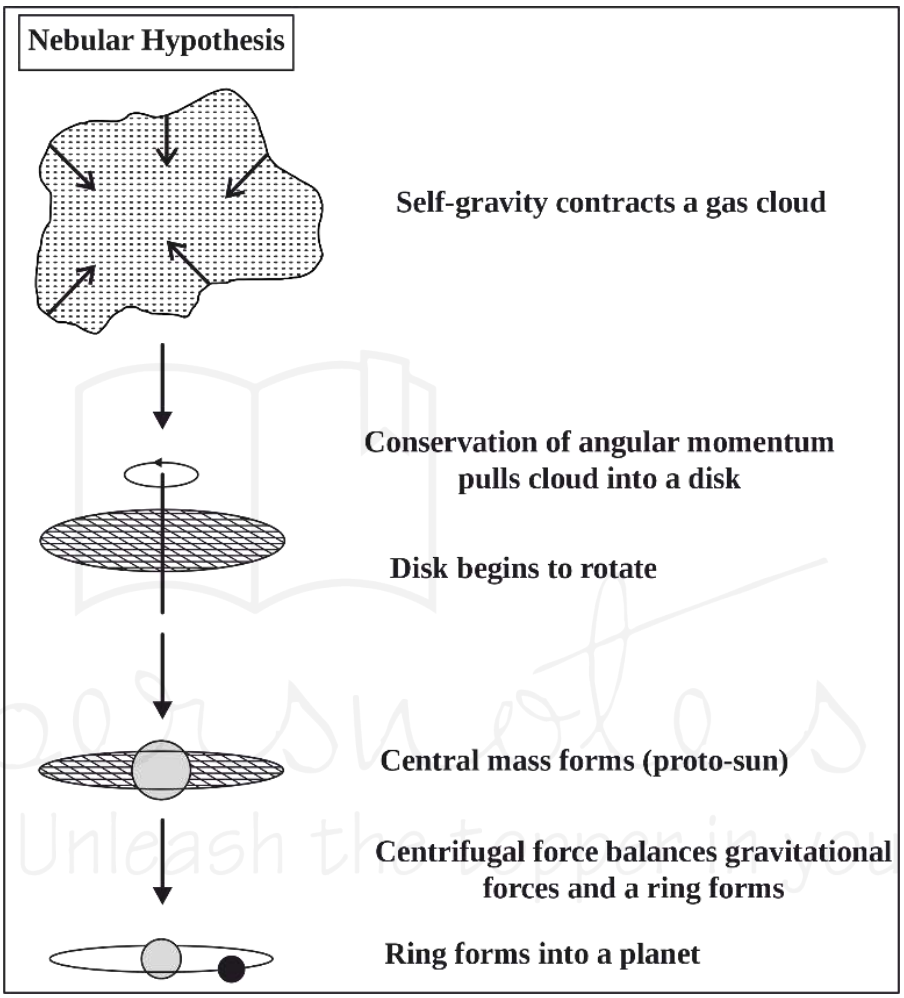
# 1 CHAPTER

# Introduction and Origin of the Earth

Earth formed about 4.6 billion years ago from dust and gas in the solar system. Over time, its surface and atmosphere developed, making life possible. Understanding Earth's origin helps us learn about its changes and evolution.

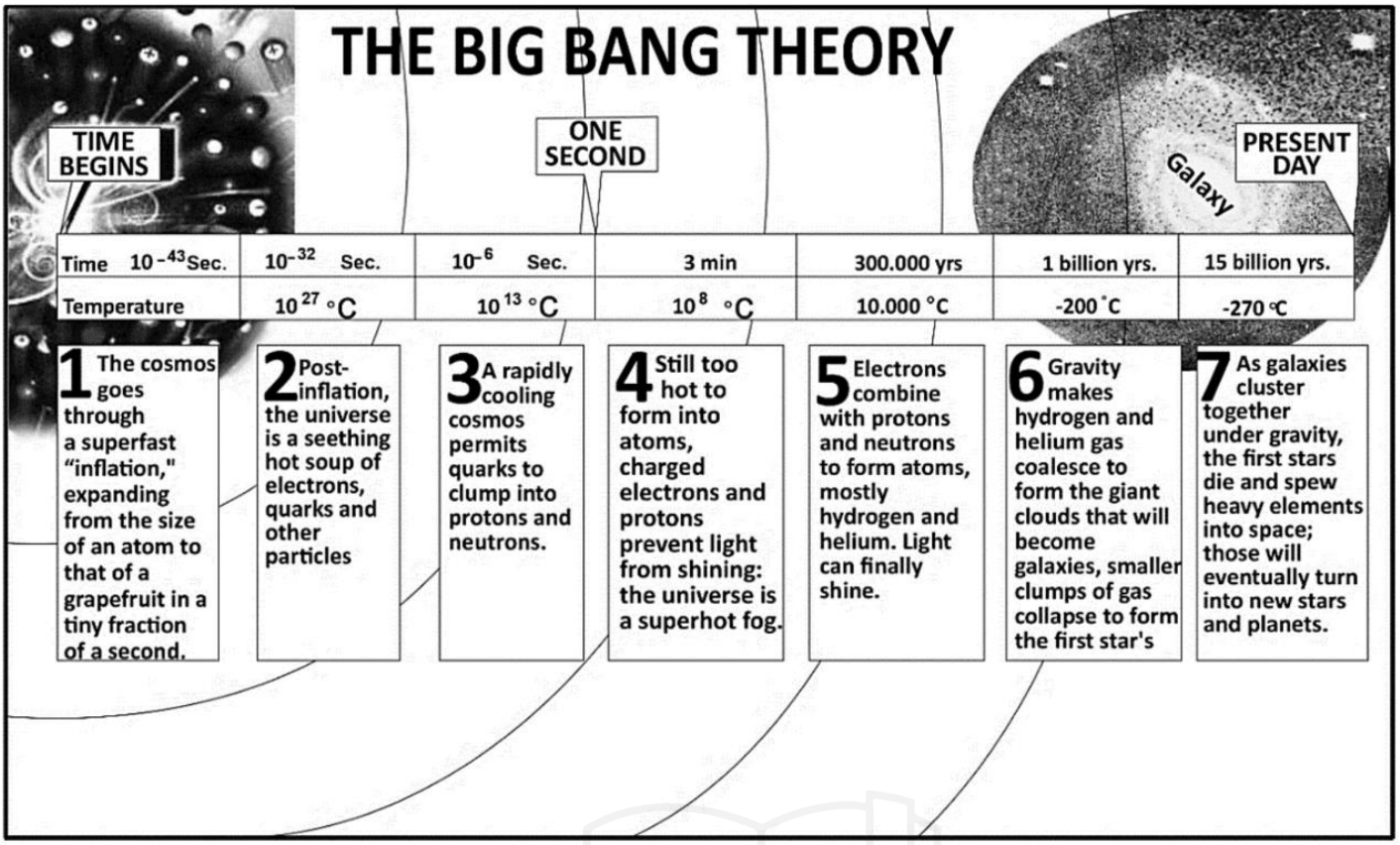
## A. Origin of the Earth: Nebular Hypothesis




- Propounded by: Immanuel Kant (revised by Pierre-Simon Laplace)
- The solar system evolved from a rotating cloud of gas & dust (solar nebula).
- Process:
  - ✓ Sun formed at the center of the nebula
  - ✓ Surrounding material formed a rotating disk.
  - ✓ Planets formed by accretion (gradual clumping of particles).
- Modified versions: Carl Weizsacker and Otto Schmidt
- Matter underwent friction & collision → disk-shaped cloud → gradual clumping into planets.
- A major limitation of this theory is that it fails to explain the uneven distribution of angular momentum between the Sun and the planets.

## B. Origin of the Universe: Big Bang Theory

- Propounded by: Georges Lemaitre (1927) and strengthened by Edwin Hubble's observations (1929).
- The universe began 13.8 billion years ago from a dense, hot singularity.
- Key Concepts:
  - ✓ The universe is continuously expanding.
  - ✓ Galaxies move away from each other but do not expand themselves.




**DID YOU KNOW?**

**Jayant Vishnu Narlikar** co-developed the **Hoyle–Narlikar Theory of Gravity**, which supports the Steady-State Theory of Cosmology. This model proposes that as the universe expands, new matter is continuously created, maintaining a constant average density over time. This idea contradicts the Big Bang Theory.

## Other relevant theories -

### Planetesimal Hypothesis:

- Proposed by Chamberlain and Moulton, this theory states that a passing star came close to the Sun and pulled out material from it.
- This material later condensed into small solid bodies called planetesimals, which eventually formed the planets.
- However, due to the high temperature of the early Earth, gases would have escaped instead of condensing, making the theory less convincing.

### Tidal Hypothesis:

- Proposed by Jeans and Jeffrey, this theory suggests that the Sun was once part of a binary star system.
- The gravitational pull of a nearby star caused tidal forces that drew material out of the Sun, which later condensed to form planets.
- The theory does not adequately explain the internal forces and stability of the Sun.

### Protoplanet Hypothesis:

- According to this theory, the rotating nebular material formed large swirling masses called vortexes.
- These vortexes attracted surrounding matter due to gravity and gradually formed protoplanets.
- Smaller vortexes within them may have formed satellites.

Each of these theories contributes to our understanding of Earth's origin, but none is completely satisfactory. Continuous scientific discoveries and research keep refining our knowledge, making the origin of Earth an evolving area of study.

## C. Stages of Universe Development

1. All matter in a tiny dense ball.
2. Big Bang explosion → rapid expansion.
3. Within 300,000 years, temperature dropped to 4,500K → atomic matter formed.
4. The universe became transparent to radiation.

## D. Galaxy

- A Galaxy is a vast system of billions of stars, which also contain a large number of gas clouds (mainly of hydrogen gas) and dust, isolated in space from similar systems.
- There are about 100 billion galaxies in the universe and each galaxy has on average 100 billion stars.
- The Milky Way Galaxy is the home of the Earth and our solar system & is spiral in shape.
- The latest known galaxy discovered is the Dwarf Galaxy.

## E. Star Formation

- After the Big Bang, tiny density variations caused matter to clump under gravity, forming the seeds of large-scale structures.
- These matter concentrations grew into vast hydrogen-gas nebulae, the birthplaces of galaxies.
- Within a nebula, certain regions became especially dense and began gravitational collapse. As a clump contracted, its core temperature rose dramatically.
- Once the core reached roughly ten million K, hydrogen nuclei began to fuse. Nuclear fusion ignition marked the birth of a new star, shining steadily thereafter.
- Over millions of years, innumerable stars formed and came to illuminate their host galaxies.
- **Process Summary:** Irregular density distribution → gravity pulled matter into clumps → Nebula → localized clumps → gaseous bodies → stars.

## F. Planet Formation

- Stars formed in nebulae → gas clouds around them began rotating.
- Gravitational attraction led to formation of gas cores and surrounding discs.
- Dust and particles coalesced → planetesimals development → continued to merge and accrete, eventually forming larger bodies → planets formation.

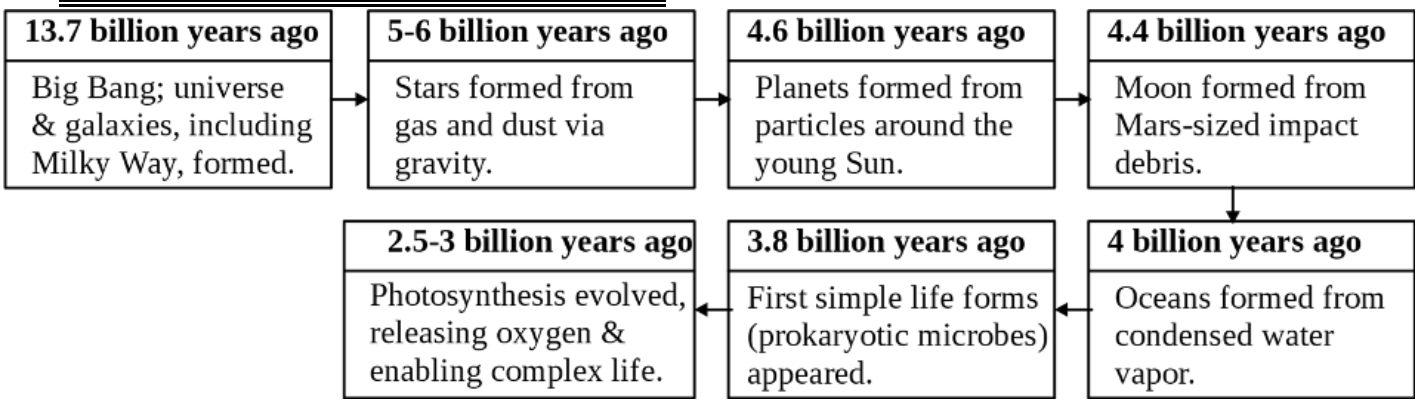
## G. Formation of Moon

1. **George Darwin's Fission Theory**
   - ✓ Earth and Moon were originally part of a single rotating mass.
   - ✓ Rapid rotation caused the mass to become dumbbell-shaped, eventually leading to separation.
   - ✓ The Moon split from Earth, forming a depression that later became the Pacific Ocean.
2. **Modern Giant Impact Theory (Big Splat)**
   - ✓ Moon formed due to a collision between early Earth & a Mars-sized celestial body (3 times Mars' mass).
   - ✓ The impact ejected material into orbit, which later accreted to form the Moon.
   - ✓ The Earth experienced partial heating and differentiation, leading to layered internal structure during this process.

**DID YOU KNOW?**

The **Moon has no significant atmosphere** because it cannot retain gas molecules on its surface as its escape velocity is very low (about 2.38 km/s). On the other hand, the rms (root mean square) velocity of gas molecules at typical temperatures can be higher than the escape velocity. As a result, gas molecules escape into space, and the Moon fails to retain an atmosphere.

# H. Timeline of Earth's Formation

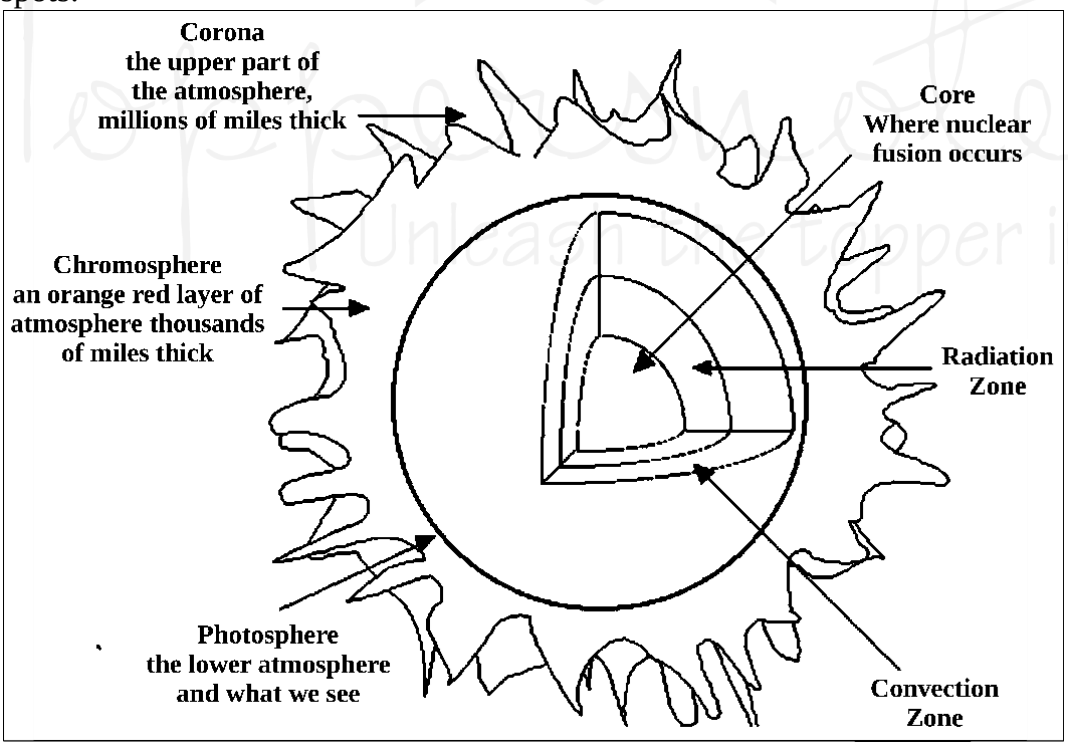



# I. Solar System Overview

- Composed of: Sun, 8 planets, 200+ moons, asteroids, comets, dust, gas
- Inner Planets (Terrestrial): Mercury, Venus, Earth, Mars – solid, rocky
- Outer Planets (Jovian): Jupiter, Saturn, Uranus, Neptune – gaseous, large, ringed
- **Key Concept:** The gravitational pull of the sun keeps all the planets and other objects revolving around it. Thus the motion of all the members of the solar system is governed mainly by the gravitational force of the sun.

**1. Structure of the Sun**

- ✓ The size of the sun is 13 lakh times that of the earth.
- ✓ It is composed of 71% hydrogen, 26.5% helium and 2.5% other elements.
- ✓ A storm of hot atoms which dissipates from the photosphere of the sun overcomes its gravity and goes into outer space, known as Solar flares.
- ✓ The regions from where the solar flares originate some dark spots are seen and these are called Sun spots.

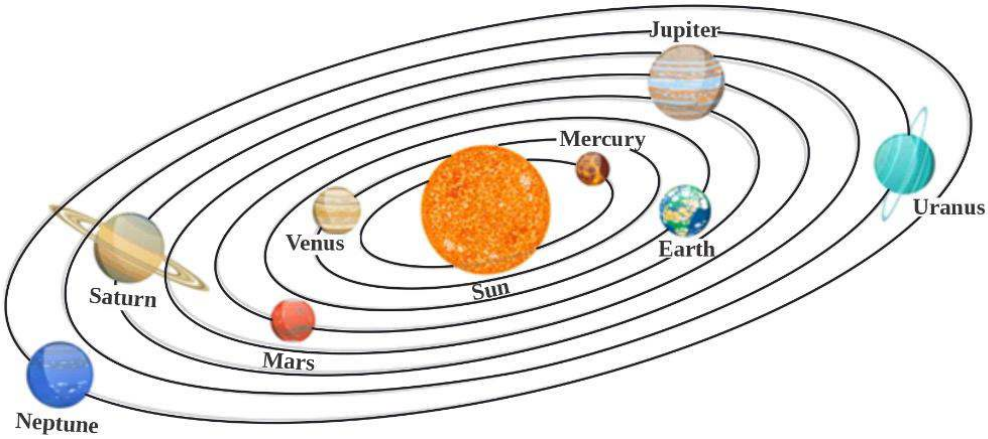



| Components | Description |
|---|---|
| Photosphere | Bright outer surface layer; emits most of the Sun's visible light |
| Chromosphere | Thin layer above photosphere; consists of burning gases |

| | |
|---|---|
| Corona | Outermost layer; hot plasma, visible during total solar eclipse |
| Sunspot | Cooler, darker patches on photosphere |
| Solar wind | Charged particles emitted from sun's upper atmosphere |
| Solar flares | Bright eruptions due to magnetic storms |

## 2. Planets of the Solar System

- ✓ The planets are opaque bodies which continuously revolve around and are lighted by the sun.
- ✓ Planets are classified into the following two groups: inner and outer planets. These are separated by the asteroid belt.




### 2.1. Inner Planets (Terrestrial/rocky planets)

- ✓ **Mercury:** Closest to the sun, smallest and lightest, no moon, fastest revolution around the Sun, presence of magnetic field
- ✓ **Venus:** Earth's twin, retrograde rotation, no moon, hottest planet, morning star & evening star, slowest rotation. Surrounded by thick cloud cover so called Veiled planet
- ✓ **Earth:** Only planet supporting life, 1 moon, blue planet, average distance from the Sun is approximately 93 million miles, goldilocks zone (habitable zone).
- ✓ **Mars:** Red planet, 2 moons (Phobos & Deimos), cold & dry, home to largest volcano in the solar system (Olympus Mons), Partially in goldilocks zone .

### 2.2. Outer Planets (Jovian/gaseous planets)

- ✓ **Jupiter:** Largest and heaviest planet, 95 moons, faint rings composed of silicates, mostly hydrogen & helium, fastest rotation the solar system- Ganymede, largest moon in the Solar System.
- ✓ **Saturn:** Prominent rings, lightest density, 274 moons- Titan largest moon.
- ✓ **Uranus:** Rotates on side, 28 moons, methane atmosphere, green planet
- ✓ **Neptune:** Farthest, 16 moons, strongest winds, coldest planet, atmosphere made of hydrogen, helium and methane. Twin of uranus

## 3. Other Celestial Bodies

- ✓ **Asteroids (Planetoids):** Rocky bodies mainly between Mars and Jupiter (Asteroid Belt). It may be spherical, elongated or irregular in shape.
- ✓ **Kuiper Belt:** It is a distant icy region of the outer solar system beyond Neptune (30–55 AU), containing dwarf planets like Pluto, Haumea, & Makemake etc. and composed mainly of frozen volatiles like methane and ammonia.

- ✓ **Dwarf Planets:** Orbit the sun, roughly spherical, haven't cleared orbit path, less mass, less gravitational pull (e.g. Pluto, Ceres).
- ✓ **Exoplanets:** It is a planet outside our solar system that orbits a star within the Milky Way galaxy. They are as gas giants, Neptunians, super-Earths & terrestrial planets. Notable ex: **Barnard's Star b**, a super-Earth at least 3.2 times the mass of Earth, which orbits a red dwarf & receives only 2% of the sunlight Earth gets.
- ✓ **Comets:** Made of Ice & dust bodies with glowing tail when near the Sun (e.g. Halley's Comet- comes in approximately every 76 years). A comet becomes visible only when it travels close to the sun. The tail always points away from the Sun.
- ✓ **Meteors:** Asteroids entering Earth's atmosphere; known as "shooting stars".
- ✓ **Meteorites:** Meteor fragments that survive and hit Earth's surface.
- ✓ **White Dwarfs:** Remnants of stars like the sun after exhausting their nuclear fuel.
- ✓ **Nebulae:** Huge interstellar clouds of gas and dust that appear as faint, misty patches of light scattered all over the sky.
- ✓ **Black Hole:** Regions of spacetime with gravitational forces so strong that even light cannot escape. Formed from collapsing massive stars beyond the Chandrasekhar Limit (1.4 solar masses).
- ✓ **Pulsars:** Rapidly spinning neutron stars that emit regular pulses of radio waves & electromagnetic radiation.
- ✓ **Quasars:** Extremely luminous active galactic nuclei powered by supermassive black holes, emitting enormous energy across the electromagnetic spectrum.
- ✓ **Supernova:** A powerful & luminous explosion marking the death of a massive star.
- ✓ **Neutron stars:** Compact remnants of massive stars that exploded as supernovae. Composed mostly of neutrons.
- ✓ **Event horizon:** Boundary around a black hole beyond which nothing, not even light, can escape its gravity. It marks the **point of no return**, separating the black hole from the rest of the universe.
- ✓ **Singularity:** Central point of a black hole with zero volume but infinite density where gravity becomes infinite, and is hidden behind the event horizon.

**Status of Pluto**

- ➢ Discovered: 1930; once classified as the 9th planet of the solar system.
- ➢ Declassified: In 2006, the International Astronomical Union (IAU) redefined planetary criteria and revoked Pluto's planet status.

**IAU Criteria for Planethood**

- ➢ Must orbit the Sun independently.
- ➢ Must be massive enough to assume a nearly spherical shape (*hydrostatic equilibrium*).
- ➢ Must have cleared its orbit of other celestial bodies.

**Why Pluto Fails?**

- ➢ Pluto shares its orbit with other objects in the Kuiper Belt.
- ➢ It is only 0.07 times the mass of surrounding objects—not dominant enough gravitationally. Hence Pluto = Dwarf Planet.

# J. Geological Time Scale of the Earth

| Eon | Era | Period | Epoch | MYA | Life Forms | North American Events |
|---|---|---|---|---|---|---|
| Phanerozoic | Cenozoic | **Quaternary (Q)** | Holocene (H) | 0.01 | Extinction of large mammals and birds, Modern humans | Ice age glaciations, glacial outburst floods |
| | | | Pleistocene (PE) | 2.6 | | Cascade volcanoes, Isthmus of Panama |
| | | **Neogene (N)** | Pliocene (PL) | 5.3 | Spread of grassy ecosystems | Columbia River Basalt eruptions, Basin and Range extension (W) |
| | | | Miocene (MI) | 23.0 | | |
| | | **Paleogene (PG)** | Oligocene (OL) | 33.9 | | |
| | | | Eocene (E) | 56.0 | Early primates | |
| | | | Paleocene (EP) | 66.0 | Mass extinction | Laramide Orogeny ends (W) |
| | Mesozoic | **Cretaceous (K)** | | 145.0 | Placental mammals, Early flowering plants, Dinosaurs diverse and abundant | Laramide, Western Interior Seaway (W), Sevier Orogeny (W) |
| | | **Jurassic (J)** | | 201.3 | First dinosaurs, First mammals, Flying reptiles | Nevadan, Elko Orogeny (W) |
| | | **Triassic (TR)** | | 251.9 | Mass extinction, Breakup of Pangaea begins | Sonoma Orogeny (W) |
| | Paleozoic | **Permian (P)** | | 298.9 | Mass extinction | Supercontinent Pangaea intact |
| | | **Pennsylvanian (PN)** | | 323.2 | Coal-forming swamps, Sharks abundant, First reptiles | Ouachita (S), Appalachian (E), Orogeny (E), Rocky Mts (W) |
| | | **Mississippian (M)** | | 358.9 | Mass extinction, First amphibians, First forests | Antler Orogeny (W), Acadian (E-NE) |
| | | **Devonian (D)** | | 419.2 | First land plants | |
| | | **Silurian (S)** | | 443.8 | Primitive fish | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | **Ordovician (O)** | | 485.4 | Mass extinction, Trilobite maximum, Rise of corals | Taconic Orogeny (E-NE) |
| | | **Cambrian (C)** | | 541.0 | Early shelled organisms | Extensive oceans cover proto-North America (Laurentia) |
| **Proterozoic** | | **Precambrian (PC, W, X, Y, Z)** | | 2500 | Complex to simple multicelled organisms | Supercontinent rifted, Grenville Orogeny (E), Iron deposits |
| **Archean** | | | | 4000 | Early bacteria and algae (stromatolites) | Oldest known Earth rocks |
| **Hadean** | | | | 4600 | Origin of life | Formation of Earth's crust, Formation of the Earth |

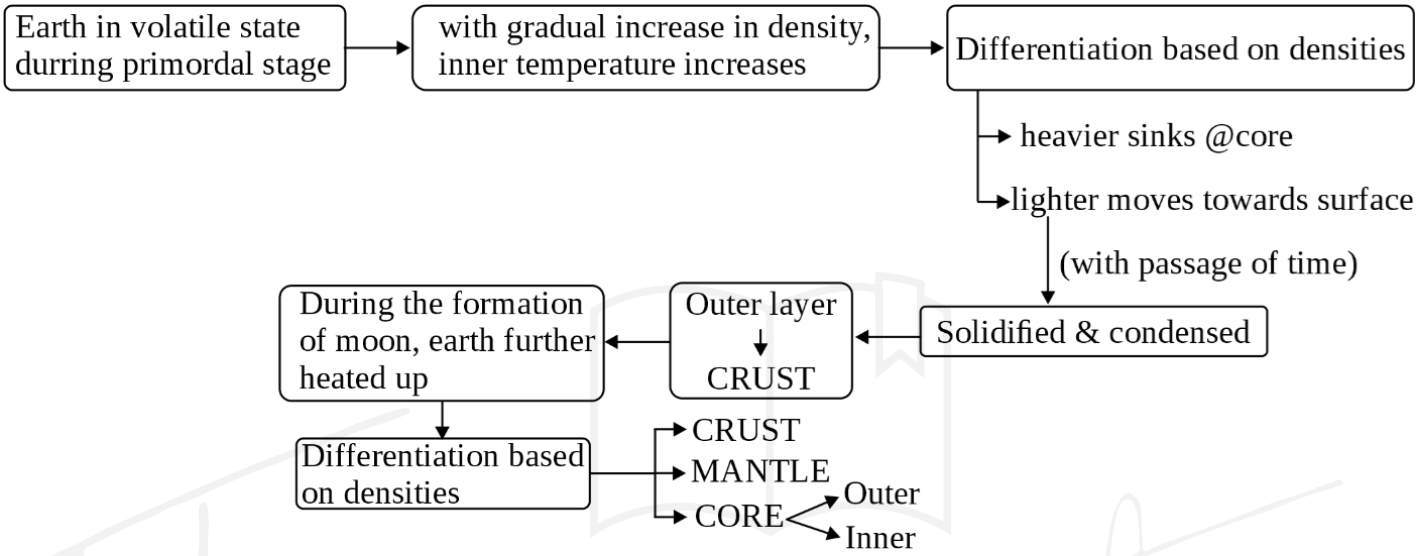
The Earth's origin marks the beginning of a dynamic and evolving planet shaped by complex geological and atmospheric processes. Understanding Earth's formation helps us appreciate the conditions that made life possible and provides insights into its continuous changes over billions of years.

# 2 CHAPTER

# Evolution of Earth

Earth formed about 4.5 billion years ago from cosmic dust & gas around the young Sun. Initially a hot, molten mass, it gradually cooled, forming a solid crust & oceans. Heavy elements sank to form the core, while lighter materials created the surface layers. Volcanic activity & gas emissions shaped the early atmosphere & hydrosphere. These processes laid the foundation for life & the planet's dynamic geology.

## A. Evolution of Lithosphere




## B. Evolution of Atmosphere

- Three stages of atmospheric evolution:
  - ✓ Loss of primordial atmosphere.
  - ✓ Hot Earth interior released gases (degassing), mainly water vapor, nitrogen, $CO_2$, methane, ammonia.
  - ✓ Photosynthesis by early life added free oxygen, changing atmospheric composition.
- Continuous volcanic eruptions contributed gases to the atmosphere.

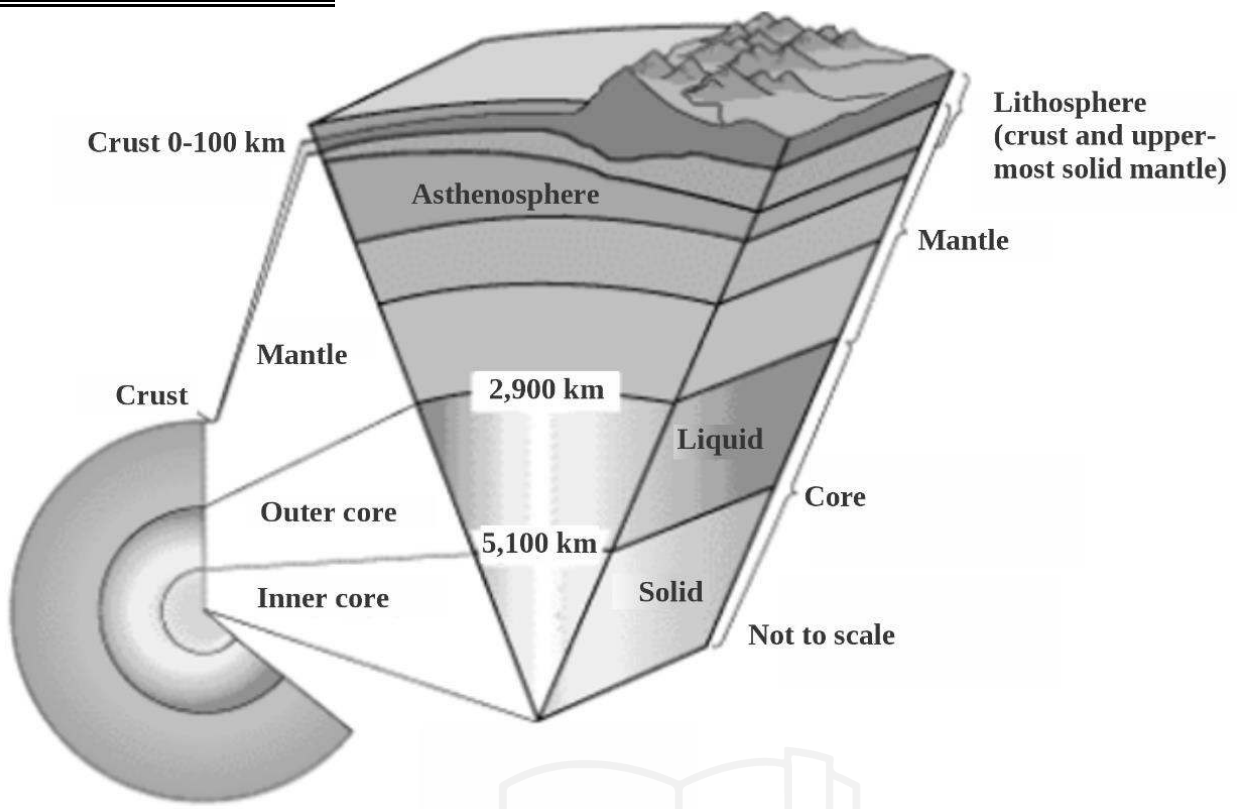
**DID YOU KNOW?**

Early Earth's atmosphere was virtually oxygen-free and rich in $CO_2$, $N_2$ and other gases; $O_2$ only rose after photosynthetic life.

## C. Evolution of Hydrosphere

- As the early Earth cooled, water vapor condensed, leading to the formation of liquid water bodies.
- This process began after volcanic outgassing released water vapor and gases into the atmosphere.
- $CO_2$ dissolved in rainwater, further cooling Earth and increasing rainfall.
- Oceans formed within 500 million years of Earth's formation.
- Early oceans were hot and acidic, but they acted as carbon sinks, helping stabilize temperatures.
- Photosynthesis in oceans led to oxygen saturation and later excess oxygen began accumulating in the atmosphere, triggering the Great Oxidation Event.

## D. Structure of Earth




| Layer | Thickness | Composition | State | Key features |
|---|---|---|---|---|
| Crust | 5-70 km | Sial (Continents) Sima (Oceans) | Solid | Thin outer layer; divided into oceanic (dense) and continental (light) crust. |
| Mantle | 2900 km | Solid rock, magma | Mostly Solid | 83% of Earth's volume; includes plastic Asthenosphere (up to 400 km). |
| Core | 2900-6400 km | Nickel and iron (NiFe layer) | Outer-liquid,Inner-solid | 16% of Earth's volume; has metallic properties. . |

**DID YOU KNOW?**

1. Scientists aboard the US research vessel ***JOIDES Resolution*** set a new record by drilling 1.2 km below the seafloor at the Atlantis Massif, far surpassing the previous depth of 201 meters. This mission, part of the **International Ocean Discovery Program** with India as a funding partner, aimed to explore the Earth's mantle, which makes up over 80% of the planet's volume and is typically inaccessible except at mid-ocean ridges.
2. Researchers have uncovered a vast reservoir of water, dubbed the "**Ringwoodite Ocean**," concealed within the Earth's mantle, over 700 kms beneath the surface.

## E. Composition of Earth's Crust

| Element | Weight % |
|---|---|
| Oxygen | 46.60 |
| Silicon | 27.72 |
| Aluminium | 8.13 |

| | |
|---|---|
| Iron | 5.00 |
| Calcium | 3.63 |
| Sodium | 2.83 |
| Potassium | 2.59 |
| Magnesium | 2.09 |
| Others | 1.41 |

# F. Composition of Entire Earth

- Overall Chemical Composition: Iron (32.10%), oxygen (30.10%),silicon (15.10%), Magnesium (13.9%), sulfur (2.90 %), nickel (1.80 %), calcium (1.50%), aluminum (1.40 %), other elements(1.20 %).

# G. Mantle Plumes

Mantle plumes are major geological features that are essential for understanding **plate tectonics** and the **internal dynamics of the Earth**. A mantle plume is a localized upwelling of **hot, buoyant mantle material** rising from deep within the Earth.

### Characteristics of Mantle Plumes

- **Morphology:**
  - ✓ Typically exhibits a **mushroom-shaped head** followed by a narrow **tail or conduit** connected to its deep source.
- **Thermal and geochemical traits:**
  - ✓ Plume material is **100–300°C hotter** than the surrounding mantle.
  - ✓ Displays **distinct geochemical signatures**, indicating deep mantle origin.

## Structure and Formation

**Primary Components**

- **Plume head:**
  - ✓ Large bulbous structure with a diameter of about **800–1000 km**.
- **Plume tail:**
  - ✓ Narrow conduit, approximately **100–200 km** wide, supplying hot material upward.
- **Source region:**
  - ✓ Commonly traced to the **core–mantle boundary**.

## Role in Plate Tectonics

**Hotspot Formation**

- Produces surface hotspots such as **La Réunion** and **Comores** in the Indian Ocean.
- Leads to the formation of **volcanic chains and seamounts** through sustained magma supply.

**Lithospheric Modification**

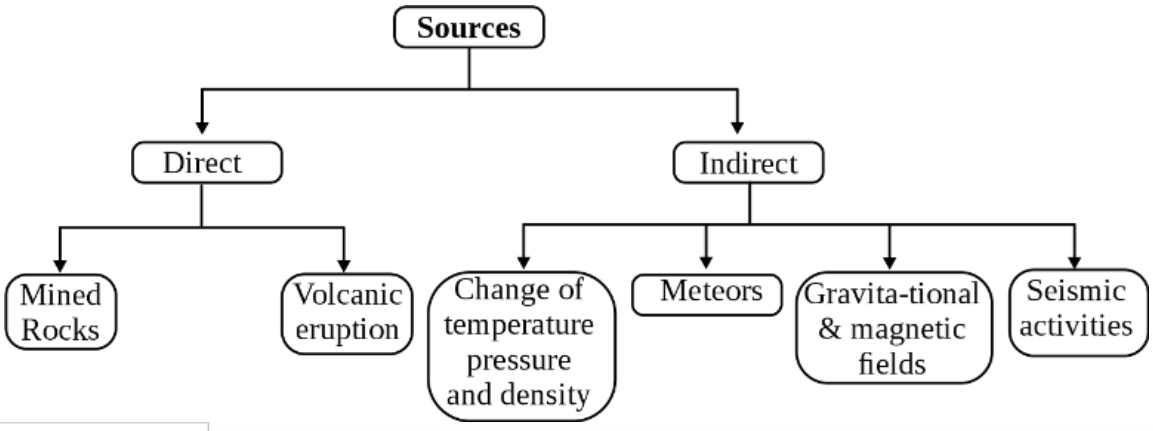
- Causes strong **thermo-mechanical erosion** of the continental lithosphere.
- Recent studies indicate that the **Réunion plume** thinned the Indian craton by up to **130 km**.

**Influence on Plate Motion**

- Alters plate velocities through **basal heating** and **mechanical weakening** of the lithosphere.
- The acceleration of the **Indian Plate since about 65 million years ago** is linked to plume–lithosphere interaction.

Mantle plumes act as fundamental drivers of plate tectonic processes, influencing continental break-up, hotspot volcanism, and plate motion. Advances in **seismic tomography** and **geochemical analysis** continue to refine our understanding of these deep Earth processes, especially in regions like the **Indian Ocean**, where multiple mantle plumes interact with tectonic plates.

## H. Sources of Information on Earth's Interior

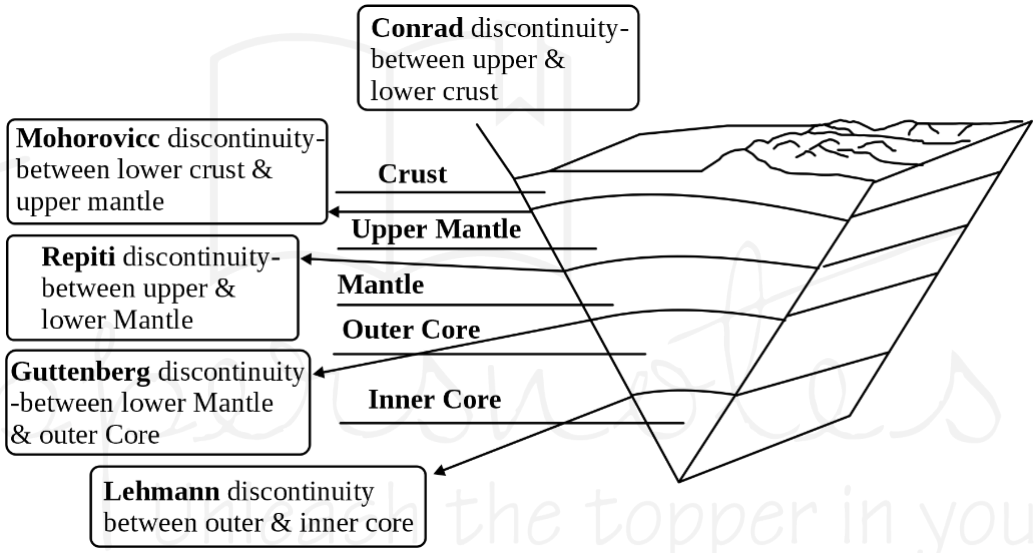



**DID YOU KNOW?**

**Isostasy** is a key geological concept stating that Earth's lighter crust "floats" on the denser mantle, much like icebergs in water. This explains varying topographic heights on the surface. In an ideal state, the crust and mantle remain in **isostatic equilibrium**, undisturbed by external forces. Natural processes like glaciation, erosion & volcanism disturb this balance, altering the lithosphere's structure. Understanding isostasy helps geologists study complex Earth processes like mountain formation, sedimentary basins, and continental drift.

## I. Discontinuities

The Earth's interior is divided into distinct layers with unique physical and chemical properties. These layers differ in aspects like temperature and density. They are separated by transition zones called **discontinuities**, where sudden changes occur.




- **List of Major Discontinuities**

| Discontinuity | Between | Key Features |
|---|---|---|
| Conrad Discontinuity | Upper Crust - Lower Crust | Present in continental crust only, at 15–20 km depth |
| Mohorovicc Discontinuity (Moho) | Crust - Mantle | Depth: ~35 km under continents, 8 km under oceans; abrupt P-wave jump |
| Repiti Discontinuity | Outer Mantle - Inner Mantle | Less well-defined; internal mantle boundary |
| Gutenberg Discontinuity | Mantle - Outer Core | At 2900 km; P-wave slows, S-wave vanishes (liquid outer core) |
| Lehmann Discontinuity | Outer Core - Inner Core | At ~5150 km; increase in P- and S-wave velocities |

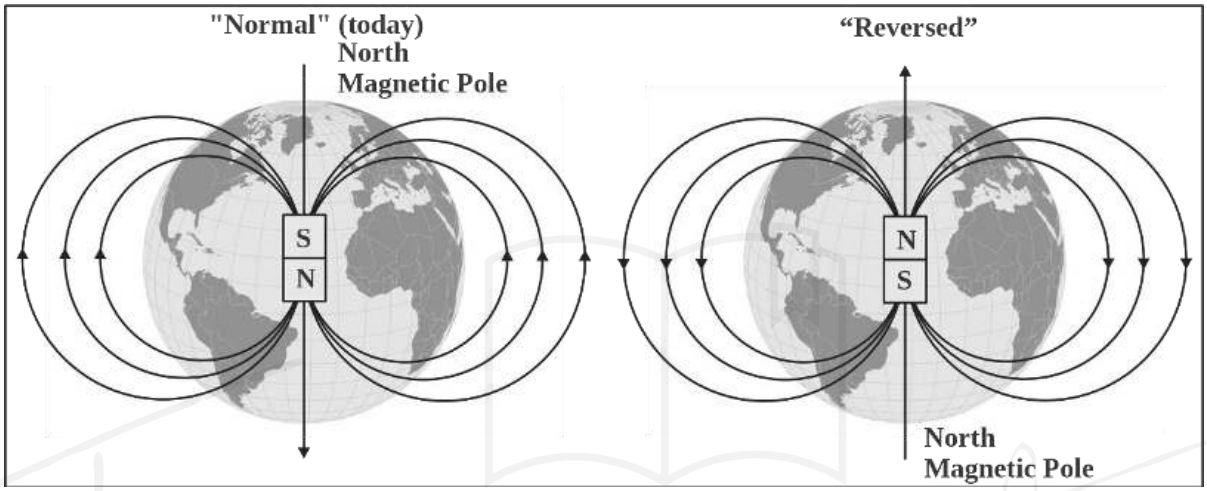
## J. Earth's Magnetic Field

- **Generated by:** Convection currents of molten iron & nickel in Earth's outer core
- **Process:** The Geodynamo Effect, movement of conductive material produces electric currents, generating a magnetic field.

- **Region created:** Magnetosphere – protects Earth from solar wind.
- **Geographic Poles:** Fixed, based on Earth's rotational axis (Arctic & Antarctica).
- **Magnetic Poles:** Varying, based on magnetic field lines:
  - ✓ Magnetic North Pole: Also called North Dip Pole, currently near Ellesmere Island, Canada.

The Earth has three different North Poles: the **Geographic North Pole**, the **Magnetic North Pole**, and the **Geomagnetic North Pole**.

- **Geographic North Pole:** This is the physical top of the Earth. It is the point where the Earth's axis of rotation meets the Earth's surface.
- **Magnetic North Pole:** This is the point in the Northern Hemisphere where the Earth's magnetic field points vertically downward. It is not fixed and keeps shifting due to changes in the Earth's magnetic field.
- **Geomagnetic North Pole:** This is the northernmost point of the Earth's geomagnetic field, which represents the idealized magnetic field of the Earth. It is associated with the magnetosphere that protects the Earth from charged particles coming from the Sun.




## Magnetic Pole Reversal

- A phenomenon where Earth's magnetic north and south poles switch places.
- **Reason:** Caused by instabilities or fluctuations in the movement of molten metal in the outer core.
- **Frequency:** Occurs roughly every 300,000 years. The last full reversal, called the Brunhes–Matuyama reversal, occurred about 780,000 years ago.
- **Effects:**
  - ✓ The magnetic field weakens (up to 90%), but does not disappear.
  - ✓ May slightly increase exposure to solar radiation at Earth's surface.
  - ✓ No evidence of catastrophic biological or climatic effects.
- **Modern concern**: Potential disruption to satellites, power grids, and communication systems, but such effects would be gradual, not sudden.

### DID YOU KNOW?

Recent research on ancient rocks from South Africa and Brazil suggests weakening of Earth's magnetic field during the Ediacaran period (635 - 541 mn years ago).

## Aurora-

**Aurora Borealis and Aurora Australis**

- The Aurora Borealis (Northern Lights) and Aurora Australis (Southern Lights) are spectacular natural light displays occurring in Earth's polar regions.
- These phenomena have gained increased attention during the ongoing solar maximum period (2024–2026).

- **Basic formation:**
  - ✓ Auroras form when charged particles from the Sun (solar wind) interact with Earth's magnetic field and upper atmosphere.
- **Location:**
  - ✓ Northern Lights are mainly visible around the Arctic Circle.
  - ✓ Southern Lights are observed over Antarctica and surrounding regions.
- **Colours:**
  - ✓ Green light is produced by oxygen molecules.
  - ✓ Red emissions are associated with nitrogen.
  - ✓ Blue hues are linked to hydrogen.

**Triggering Mechanism**

- **Solar wind interaction:**
  - ✓ Solar wind particles colliding with Earth's magnetosphere create geomagnetic storms.
  - ✓ Storm strength is measured using the Kp index, which ranges from 0 to 9.
  - ✓ Strong storms (Kp 6–9) allow auroras to appear at lower latitudes.
- **Particle collision process:**
  - ✓ Charged particles from the Sun excite atoms and molecules in Earth's atmosphere.
  - ✓ As these excited particles return to their normal energy state, they emit light.
  - ✓ Different atmospheric gases produce different auroral colours.

**Recent Observations and Research**

- **Solar activity:**
  - ✓ NASA predicts intense auroral displays through 2025 and early 2026 due to heightened solar activity.
- **New findings:**
  - ✓ Fragmented Aurora-like Emissions (FAEs) have been identified near the poleward boundary of auroras.
  - ✓ Satellite data has revealed carbon dioxide auroras emitting infrared radiation globally.
- **Scientific initiatives:**
  - ✓ Projects such as Aurorasaurus are improving real-time monitoring and public participation.
- **Significance:**
  - ✓ The increasing frequency and intensity of auroral events during the current solar maximum provide a valuable opportunity for scientific research and public observation.Top of FormBottom of Form

# K. Motions of Earth

**1. Rotation**

- ✓ **Direction:** Earth rotates west to east (counterclockwise when viewed from above the North Pole).
- ✓ **Axis Tilt:** Tilted at 23.5° from the vertical relative to its orbital plane (**ecliptic**).
- ✓ One rotation = 24 hours → day and night cycle.
- ✓ Circle dividing day and night = circle of illumination.
  - Imaginary line dividing the sunlit (day) side and the dark (night) side.
  - Shifts slightly with the seasons due to axial tilt.

- ✓ **Effects of Rotation:**
  - **Day & Night:** Different parts of the Earth face the Sun & then rotate away.
  - **Coriolis Effect:** Deflects winds and ocean currents to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.
  - **Tidal effects** due to gravitational interaction with the Moon and Sun.
  - **Time zones:** Earth's rotation divides the globe into 24 time zones, each roughly 15° of longitude apart.
  - **Earth's Shape:** Due to rotation, the Earth is slightly bulged at the equator and flattened at the poles.
  - **Apparent Movement of Celestial Bodies:** Rotation creates the apparent movement of the Sun, Moon, and stars across the sky.

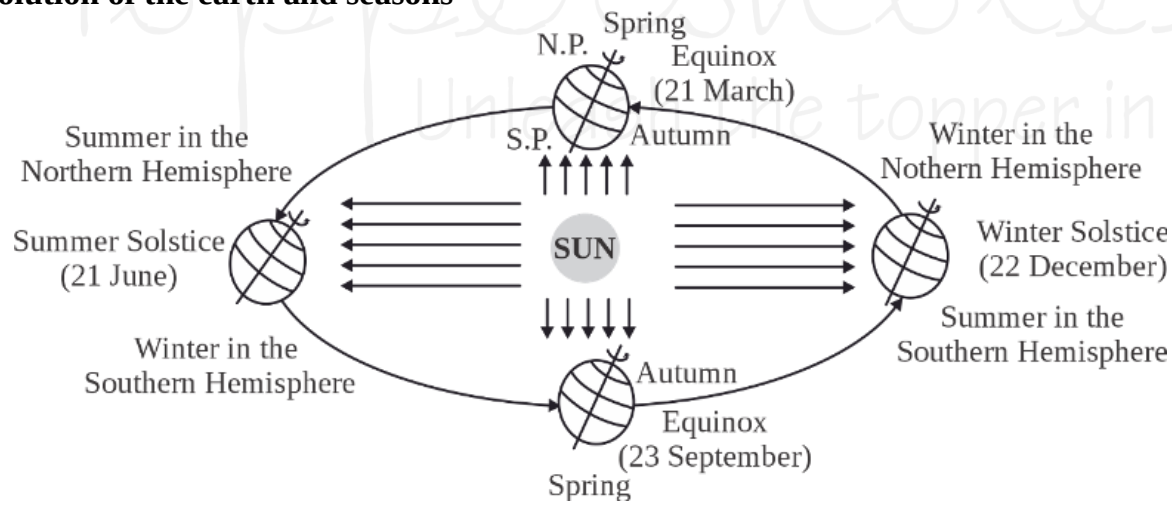
**2. Revolution**

- ✓ **Path:** Earth revolves around the Sun in an elliptical (oval-shaped) orbit.
- ✓ **Duration:** 365 1⁄4 days (365.2422 days) for 1 complete orbit → defines year.
- ✓ Leap year compensates for the extra ¼ day every year by adding 1 day every 4 years (Feb 29).
- ✓ **Effects of Revolution:**
  - **Seasonal Changes:** The tilt of Earth's axis combined with revolution causes the change of seasons, as different regions receive varying amounts of solar radiation during the year.
  - **Variation in Day Length:** Daylight hours vary with seasons—days are longer in summer and shorter in winter in the respective hemispheres.
  - **Shifting of Wind Belts:** Earth's revolution leads to the seasonal shifting of global wind belts, which influences weather and climate patterns worldwide.

**DID YOU KNOW?**

- Melting polar ice redistributes mass toward the equator, changing Earth's moment of inertia & thus slightly shifting its rotation axis.
- Researchers have shown that increased ice melting may have delayed the need for adding negative leap seconds.

➢ **Revolution of the earth and seasons**



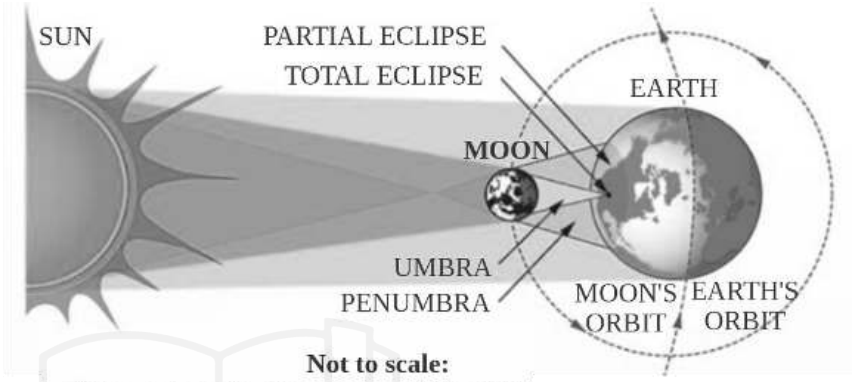

| Event | Date | Description |
|---|---|---|
| **Summer Solstice** | 21 june | Both Tropic of Cancer and Arctic Circle experience more than 12 hours of sunlight. Sun rays fall on the Tropic of Cancer; longest day & shortest night in the Northern Hemisphere; summer starts north of equator. Regions beyond the Arctic Circle experience 6 months of daylight. |

| | | |
|---|---|---|
| **Winter Solstice** | 22 December | Sun rays fall on the Tropic of Capricorn; summer in the Southern Hemisphere; winter in the Northern Hemisphere. Longest day & shortest night in the Southern Hemisphere. |
| **Equinox** | 21 March<br>23 September | Sun rays fall directly on the equator; equal day and night globally; seasons change (spring/autumn). These are the only times when the Earth's axis is not tilted toward or away from the Sun. It occurs twice a year- on 21st March (Spring/Vernal Equinox) & 23rd September (Autumnal Equinox). |

# L. Solar and Lunar Eclipse

1. **Solar Eclipse (Surya Grahan):** Occurs when the Moon comes between the Earth & the Sun, blocking sunlight partially or fully.

**1.1. Types:**



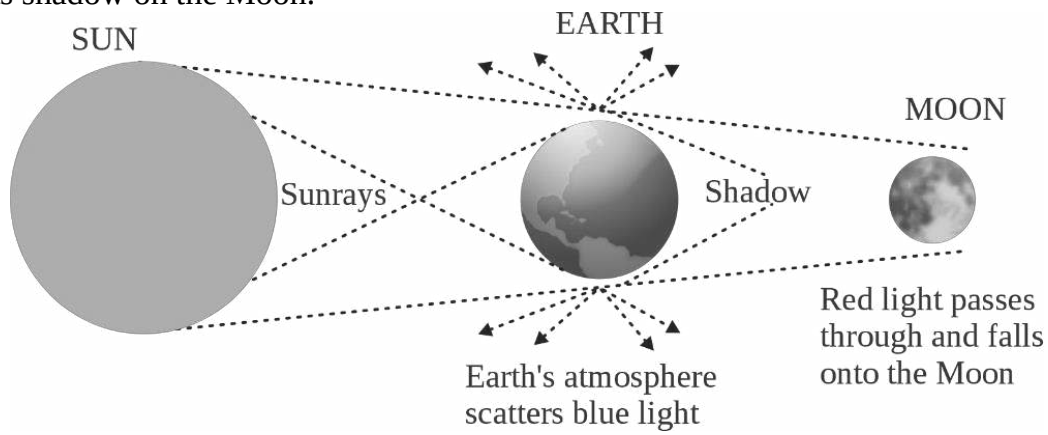

**Not to scale:**
If drawn to scale, the moon would be 30 Earth diameters away from Earth. The sun would be 400 times that distanco.

- ✓ **Total Solar Eclipse**:
  - The moon completely covers the Sun.
  - Seen from the umbra region (darkest part of the shadow).
  - Daylight temporarily turns into darkness.
- ✓ **Partial Solar Eclipse**:
  - The Moon covers only part of the Sun.
  - Seen from the penumbra region (lighter shadow).
  - Appears as a "bite" taken out of the Sun.
- ✓ **Annular Eclipse**:
  - Moon is farther from Earth, appears smaller
  - Doesn't cover the entire Sun.
  - Results in a glowing **"**Ring of Fire**"** around the Moon.

**1.2. Conditions:**

- ✓ Occurs only on Amavasya (New Moon).
- ✓ Requires perfect alignment in the order: Sun – Moon – Earth.
- ✓ **Visibility:** Only from specific regions on Earth within the eclipse path.
- ✓ Solar eclipses never last more than 7.5 minutes at any single location.

2. **Lunar Eclipse (Chandra Grahan):** Occurs when the Earth comes between the Sun & the Moon, casting its shadow on the Moon.



**2.1. Types:**

- ✓ **Total Lunar Eclipse**:
  - The entire Moon enters Earth's umbra.
  - The Moon appears reddish in color — often called a Blood Moon.
  - Caused by Rayleigh scattering and refraction of sunlight through Earth's atmosphere.
- ✓ **Partial Lunar Eclipse**:
  - Only a part of the Moon enters the umbra.
  - Appears as a visible dark "bite" taken out of the Moon.
- ✓ **Penumbral Eclipse**:
  - The moon passes through Earth's penumbra.
  - Very subtle dimming, often not noticeable to the naked eye.

**2.2. Conditions:**

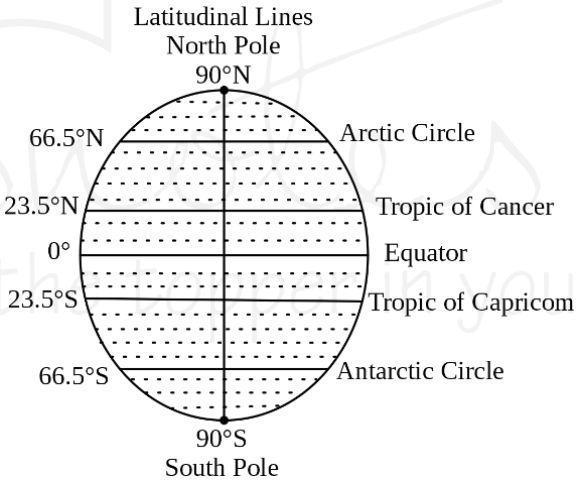
- ✓ Occurs only on Purnima (Full Moon).
- ✓ Moon, Earth & Sun must be perfectly aligned (Sun–Earth–Moon).
- ✓ Visible from anywhere on Earth where the Moon is above the horizon.
- ✓ Lunar eclipses can last for several hours and are safe to view with the naked eye.

**DID YOU KNOW?**

Bengaluru recently experienced a Zero Shadow Day, when the Sun was directly overhead and vertical objects cast no shadow. This phenomenon occurs twice a year, around the summer and winter solstices, in regions between the Tropic of Cancer and the Tropic of Capricorn, with the exact dates varying by location.

# M.Latitudes and Longitudes

## 1. Latitude




- ✓ Angular distance north or south of the Equator (0° latitude), measured in degrees.
- ✓ Varies from 0° at equator to 90° at poles.
- ✓ **Lines of Latitude**: Also called parallels because they run east-west and are parallel to each other.
- ✓ Important latitudes:
  - **Tropic of Cancer (23.5°N):** Northern limit of the tropical zone.
  - **Tropic of Capricorn (23.5°S):** Southern limit of the tropical zone.
  - **Equator (0°):** Divides Earth into Northern and Southern Hemispheres.
  - **Arctic Circle (66.5°N):** Marks boundary of Northern Frigid Zone.
  - **Antarctic Circle (66.5°S):** Marks boundary of Southern Frigid Zone.
- ✓ Divides Earth into Torrid (tropical), Temperate & Frigid zones.
  - **Torrid Zone:** Between Tropic of Cancer and Tropic of Capricorn. The hottest zone which receives direct sun rays most of the year.
  - **Temperate Zones:** Between Tropics and Circles. Moderate climate and sun rays are slanting.
  - **Frigid Zones:** Within Arctic and Antarctic Circles. Very cold climate, receives indirect sunlight.