



**UPSC CSE**



**PRE & MAINS**

**Union Public Service Commission**

**GS PAPER - 1**

**VOLUME - 5**

**Geography of World**



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### Previous Year Questions

<b>Year</b>	<b>Question</b>
<b>2013</b>	Bring out the causes for more frequent landslides in the Himalayas than in Western Ghats
<b>2013</b>	Major hot deserts in northern hemisphere are located between 20-30 degree north and on the western side of the continents. Why?
<b>2013</b>	There is no formation of deltas by rivers of the Western Ghat. Why?
<b>2013</b>	The recent cyclone on the east coast of India was called "Phailin". How are the tropical cyclones named across the world?
<b>2013</b>	What do you understand by the theory of continental drift? Discuss the prominent evidences in its support.
<b>2013</b>	What do you understand by the phenomenon of temperature inversion in meteorology? How does it affect the weather and the habitants of the place?
<b>2013</b>	Bring out the causes for the formation of heat islands in the urban habitat of the world.
<b>2013</b>	It is said the India has substantial reserves of shale oil and gas, which can feed the needs of country for quarter century. However, tapping of the resources doesn't appear to be high on the agenda. Discuss critically the availability and issues involved.
<b>2013</b>	With growing scarcity of fossil fuels, the atomic energy is gaining more and more significance in India. Discuss the availability of raw material required for the generation of atomic energy in India and in the world.
<b>2014</b>	Why are the world's fold mountain systems located along the margins of continents? Bring out the association between the global distribution of Fold Mountains and the earthquakes and volcanoes.
<b>2014</b>	Tropical cyclones are largely confined to South China Sea, Bay of Bengal and Gulf of Mexico. Why?
<b>2014</b>	Explain the formation of thousands of islands in Indonesian and Philippines archipelagos.
<b>2014</b>	Bring out the relationship between the shrinking Himalayan glaciers and the symptoms of climate change in the Indian sub-continent.
<b>2014</b>	Most of the unusual climatic happenings are explained as an outcome of the El-Nino effect. Do you agree?
<b>2014</b>	How does India see its place in the economic space of rising natural resource rich Africa?
<b>2014</b>	Critically evaluate the various resources of the oceans which can be harnessed to meet the resource crisis in the world.
<b>2015</b>	How far do you agree that the behavior of the Indian monsoon has been changing due to humanizing landscapes? Discuss.

<b>2015</b>	The states of Jammu and Kashmir, Himachal Pradesh and/Uttarakhand reaching the limits of their ecological carrying capacity due to tourism. Critically evaluate.
<b>2015</b>	India is well endowed with fresh water resources. Critically examine why it still suffers from water scarcity.
<b>2015</b>	What are the economic significances of discovery of oil in Arctic Sea and its possible environmental consequences?
<b>2016</b>	"The Himalayas are highly prone to landslides." Discuss the causes and suggest suitable measures of mitigation.
<b>2016</b>	Discuss the concept of air mass and explain its role in macro-climatic changes.
<b>2016</b>	In what way micro-watershed Development projects help in water conservation in drought prone and semi-arid regions of India.
<b>2016</b>	Enumerate the problems and prospects of inland water transport in India.
<b>2016</b>	Present an account of the Indus Water Treaty and examine its ecological, economic and political implications in the context of changing bilateral relations.
<b>2016</b>	South China Sea has assumed great geopolitical significance in the present context. Comment.
<b>2016</b>	The effective management of land and water resources will drastically reduce the human miseries. Explain
<b>2017</b>	How does the Juno Mission of NASA help to understand the origin and evolution of the Earth?
<b>2017</b>	What characteristics can be assigned to monsoon climate that succeeds in feeding more than 50 percent of the world population residing in Monsoon Asia?
<b>2017</b>	In what way can flood be converted into a sustainable source of irrigation and all-weather inland navigation in India?
<b>2017</b>	Account for variations in oceanic salinity and discuss its multi-dimensional effects.
<b>2017</b>	How does the cryosphere affect global climate?
<b>2017</b>	Mention the advantages of the cultivation of pulse because of which the year 2016 was declared as the International Year of Pulses by the United Nations.
<b>2017</b>	In spite of adverse environmental impact, coal mining is still inevitable for development." Discuss.
<b>2018</b>	Define mantle plume and explain its role in plate tectonics.
<b>2018</b>	Why is Indian Regional Navigational Satellite System (IRNSS) needed? How does it help in navigation?
<b>2018</b>	What are the consequences of spreading of 'Dead Zones' on marine ecosystem?
<b>2018</b>	Why is India taking keen interest in resources of Arctic Region?
<b>2019</b>	What is water stress? How and why does it differ regionally in India?
<b>2019</b>	How can the mountain ecosystem be restored from the negative impact of development initiatives and tourism?

<b>2019</b>	Discuss the causes of depletion of mangroves and explain their importance in maintaining coastal ecology.
<b>2019</b>	How do ocean currents and water masses differ in their impacts on marine life and the coastal environment? Give suitable examples?
<b>2019</b>	Assess the impact of global warming on coral life system with examples.
<b>2019</b>	Can the strategy of regional-resource based manufacturing help in promoting employment in India?
<b>2020</b>	The process of desertification does not have climatic boundaries. Justify with examples.
<b>2020</b>	Discuss the geophysical characteristics of Circum-Pacific Zone.
<b>2020</b>	How will the meeting of Himalayan glaciers have a far-reaching impact on the water resources of India?
<b>2020</b>	Examine the status of forest resources of India and its resultant impact on climate change.
<b>2020</b>	India has immense potential of solar energy though there are regional variations in its development. Elaborate.
<b>2020</b>	The interlinking of rivers can provide viable solutions to the multi-dimensional interrelated problems of droughts, floods and interrupted navigation. Critically examine.
<b>2021</b>	Mention the global occurrence of volcanic eruptions in 2021 and their impact on regional environment.
<b>2021</b>	Why is India considered as a subcontinent? Elaborate your answer
<b>2021</b>	Differentiate the causes of landslides in the Himalayan region and Western Ghats.
<b>2021</b>	Briefly mention the alignment of major mountain ranges of the world and explain their impact on local weather conditions with examples.
<b>2021</b>	What are the environmental implications of the reclamation of water bodies into urban land use? explain with examples?
<b>2021</b>	How do the melting of Arctic ice and glaciers of the Antarctic differently affect the weather patterns and human activities on earth? Explain.
<b>2021</b>	Discuss the multidimensional implications of uneven distribution of mineral oil in the world.
<b>2022</b>	Describe the characteristics and types of primary rocks.
<b>2022</b>	Discuss the meaning of color-coded weather warnings for cyclone-prone areas given by the India Meteorological Department.
<b>2022</b>	The troposphere is a very significant atmospheric layer that determines weather processes. How?
<b>2022</b>	Discuss the natural resource potentials of Deccan Trap'.
<b>2022</b>	Examine the potential of wind energy in India and explain the reasons for their limited spatial spread.

2022	Describing the distribution of rubber producing countries, indicate the major environmental issues faced by them.
2023	How are the fjords formed? Why do they constitute some of the most picturesque areas of the world?
2023	Why is the South-West Monsoon called 'Purvaiya' (easterly) in Bhojpur region? How has this directional seasonal wind system influenced the cultural ethos of the region?
2023	Identify and discuss the factors responsible for diversity of natural vegetation in India. Assess the significance of wildlife sanctuaries in rain forest regions of India.
2023	Discuss the consequences of climate change on the food security in tropical countries.
2023	Why is the world today confronted with a crisis of availability of and access to freshwater resources?
2023	Comment on the resource potentials of the long coastline of India and highlight the status of natural hazard preparedness in these areas.
2024	What is sea surface temperature rise? How does it affect the formation of tropical cyclones?
2024	What is the phenomenon of 'cloudbursts'? Explain.
2024	What are aurora australis and aurora borealis? How are these triggered?
2024	What is a twister? Why are the majority of twisters observed in areas around the Gulf of Mexico?
2024	The groundwater potential of the gangetic valley is on a serious decline. How may it affect the food security of India?
2025	What are Tsunamis? How and where are they formed? What are their consequences? Explain with examples.
2025	How are climate change and the sea level rise affecting the very existence of many island nations? Discuss with examples.
2025	Discuss the distribution and density of population in the Ganga River Basin with special reference to land, soil and water resources.
2025	Explain briefly the ecological and economic benefits of solar energy generation in India with suitable examples.

# Introduction and Origin of the Earth

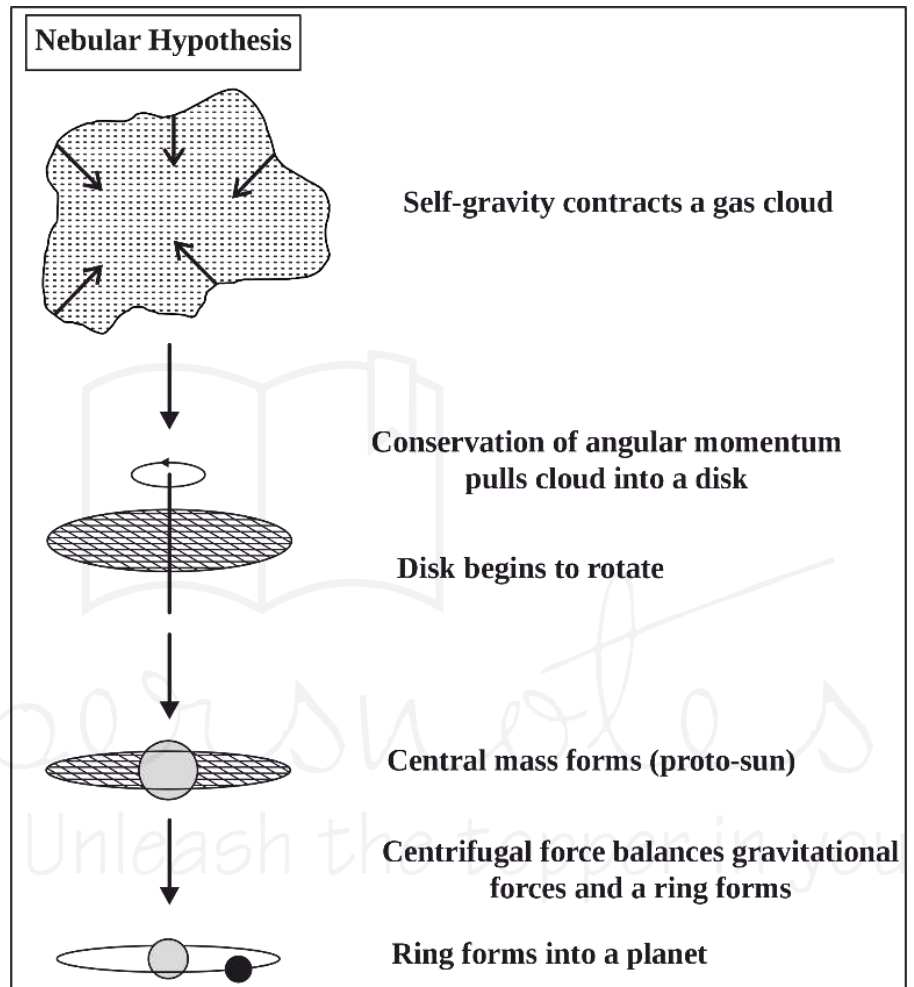


Earth formed about 4.6 billion years ago from dust and gas in the solar system. Over time, its surface and atmosphere developed, making life possible. Understanding Earth's origin helps us learn about its changes and evolution.

## A. Origin of the Earth:

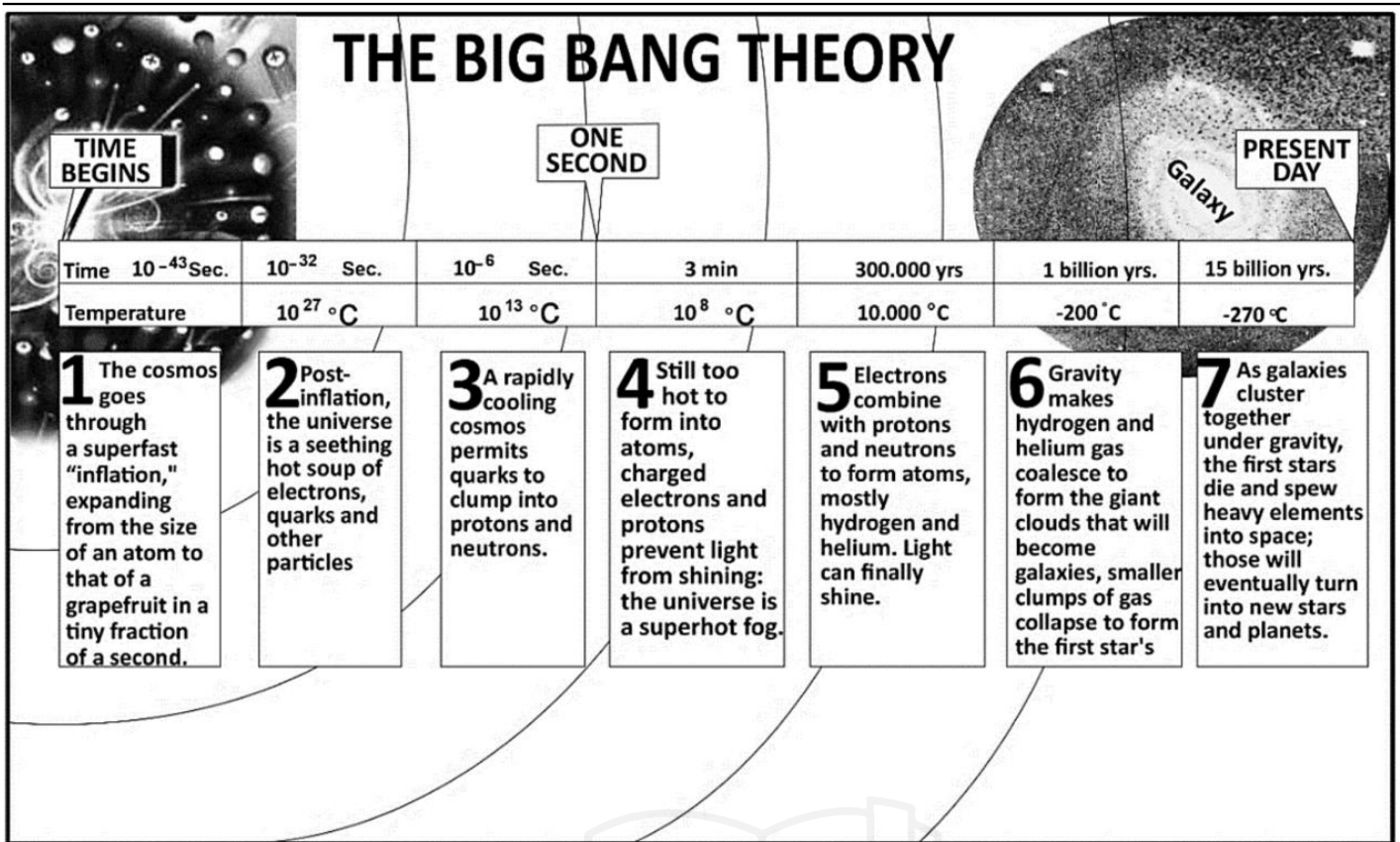
### Nebular Hypothesis

- 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.

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## 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)

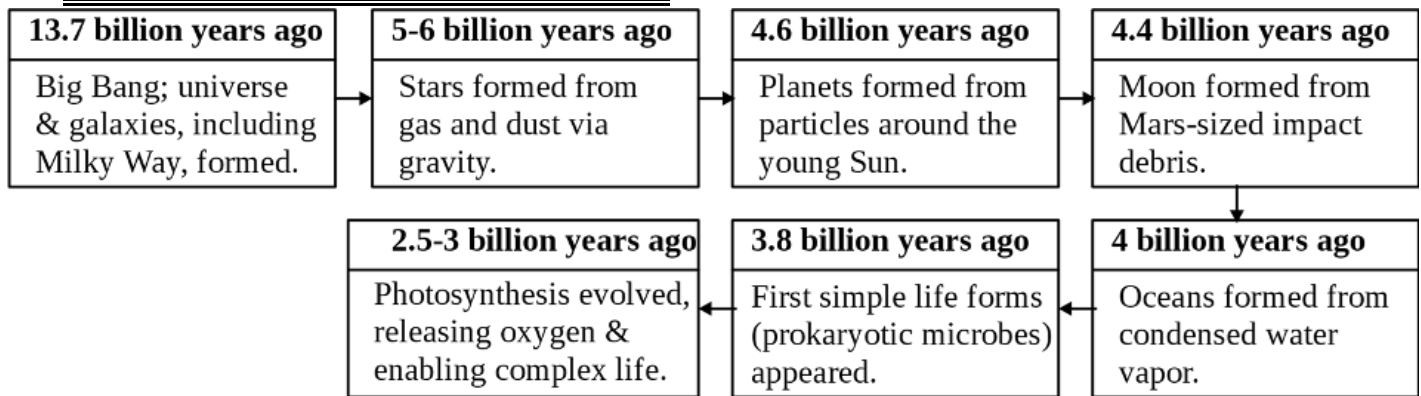
- ✓ Moon formed due to a collision between early Earth & a Mars-sized celestial body (3 times Mars' mass).
- ✓ The impact ejected material into orbit, which later accreted to form the Moon.
- ✓ The Earth experienced partial heating and differentiation, leading to layered internal structure during this 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

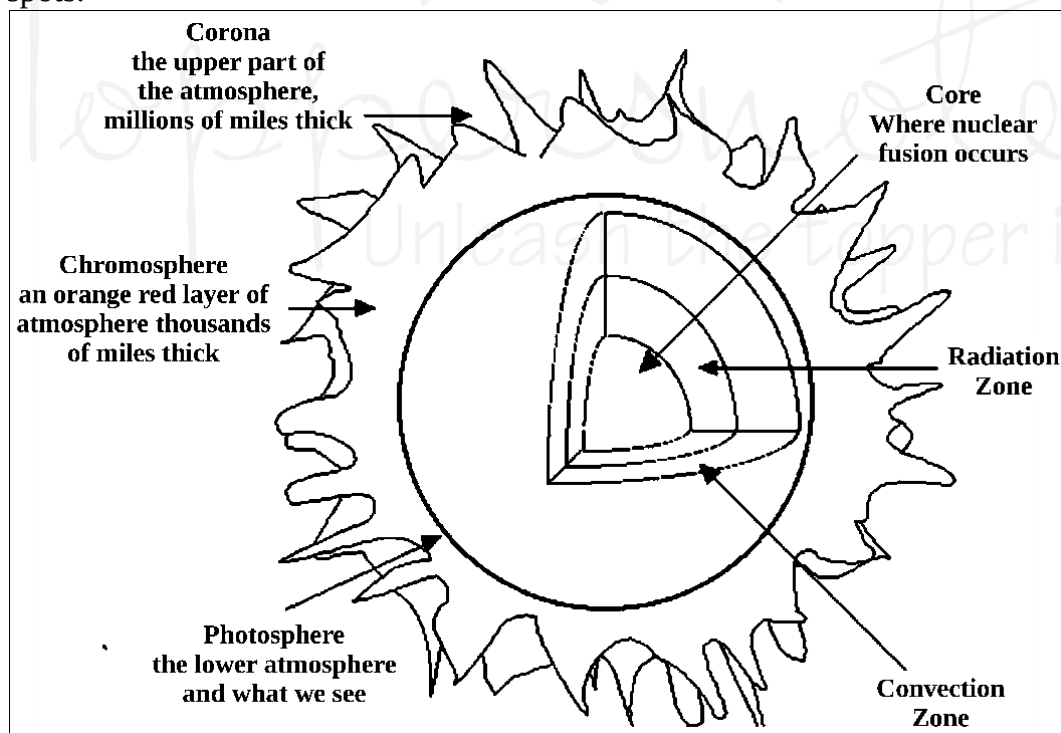


## I. Solar System Overview

- 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.



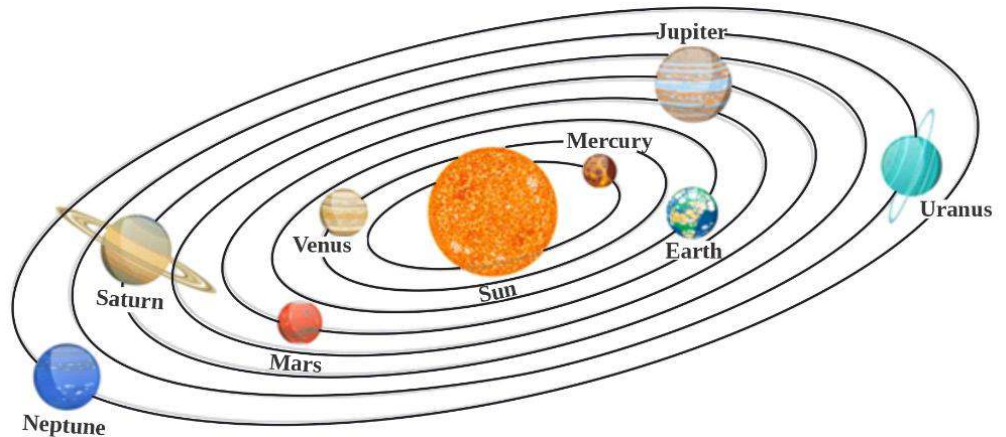
Components	Description
Photosphere	Bright outer surface layer; emits most of the Sun's visible light
Chromosphere	Thin layer above photosphere; consists of burning gases

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	

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

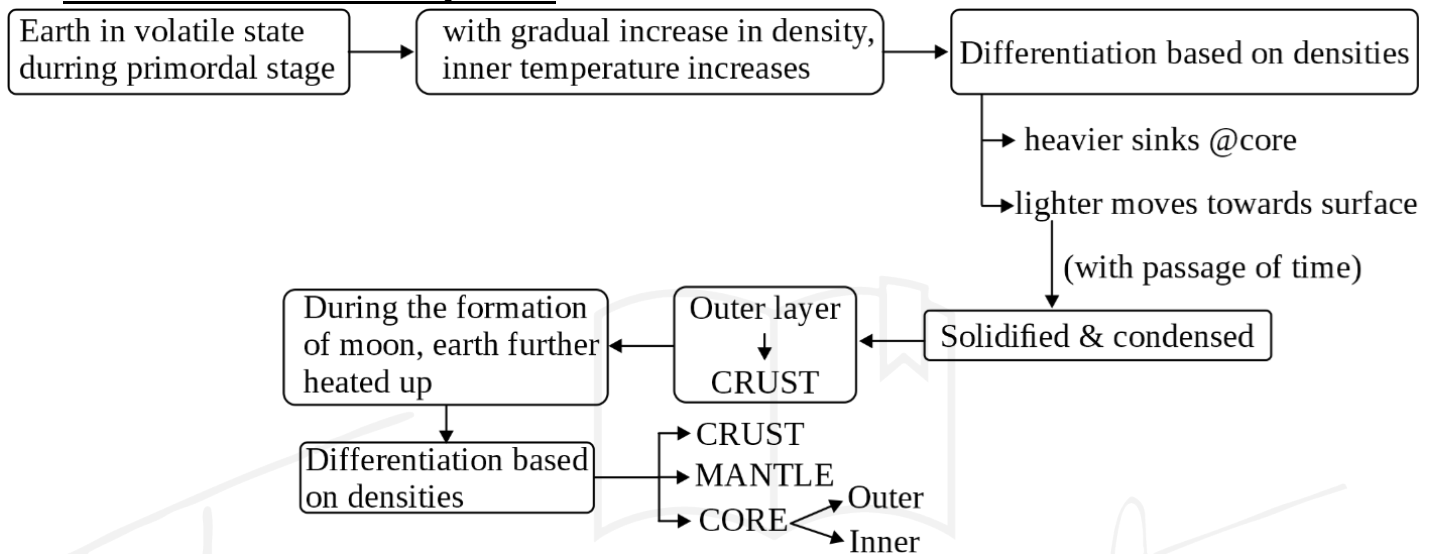
## CHAPTER

# 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<sub>2</sub>, methane, ammonia.
  - ✓ Photosynthesis by early life added free oxygen, changing atmospheric composition.
- Continuous volcanic eruptions contributed gases to the atmosphere.

#### DID YOU KNOW?

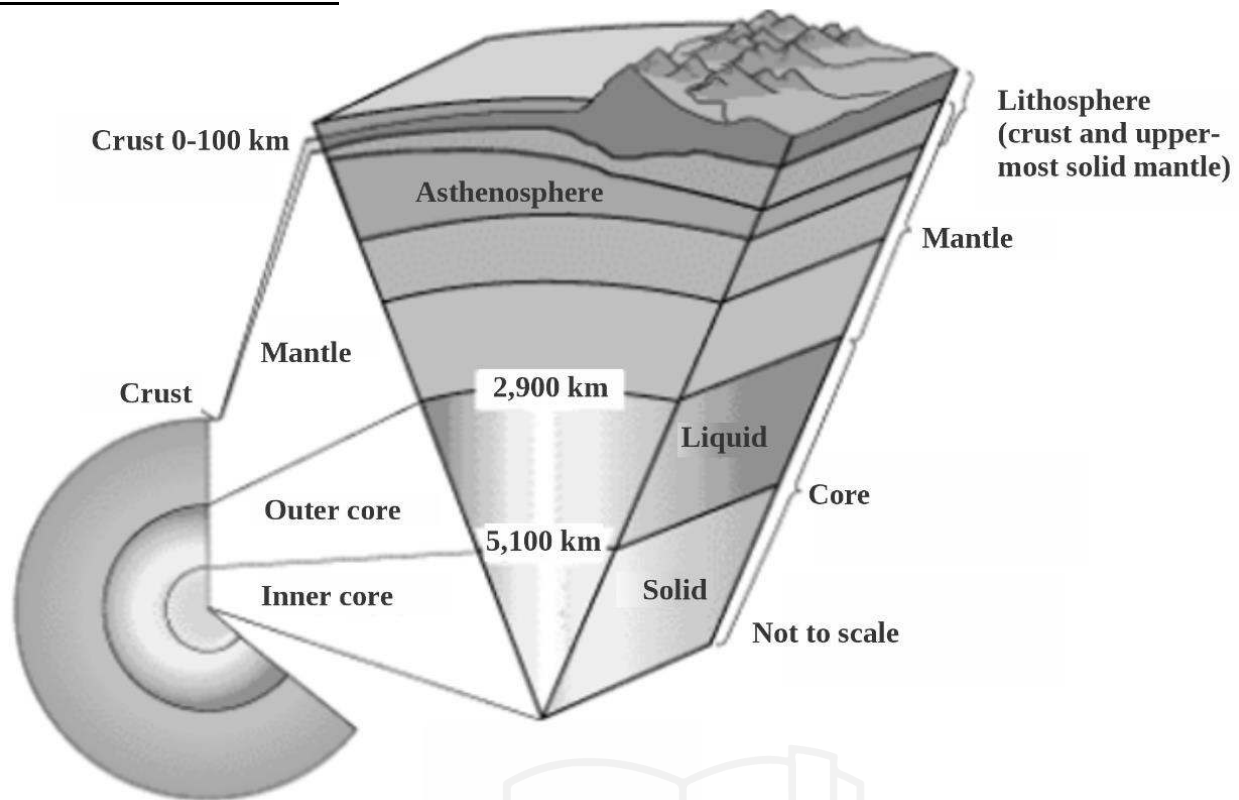
Early Earth's atmosphere was virtually oxygen-free and rich in CO<sub>2</sub>, N<sub>2</sub> and other gases; O<sub>2</sub> only rose after photosynthetic life.



### 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<sub>2</sub> 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**

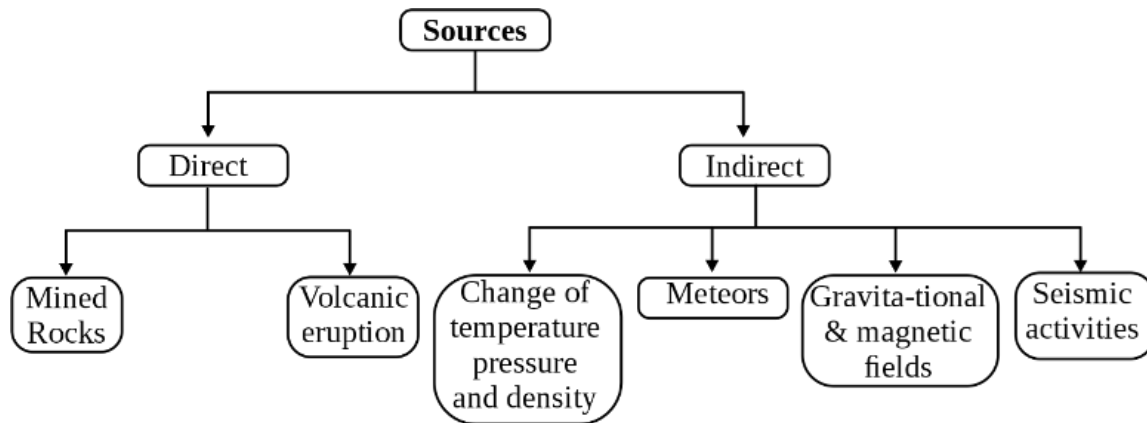
- Causes strong **thermo-mechanical erosion** of the continental lithosphere.
- Recent studies indicate that the **Réunion plume** thinned the Indian craton by up to **130 km**.

#### **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



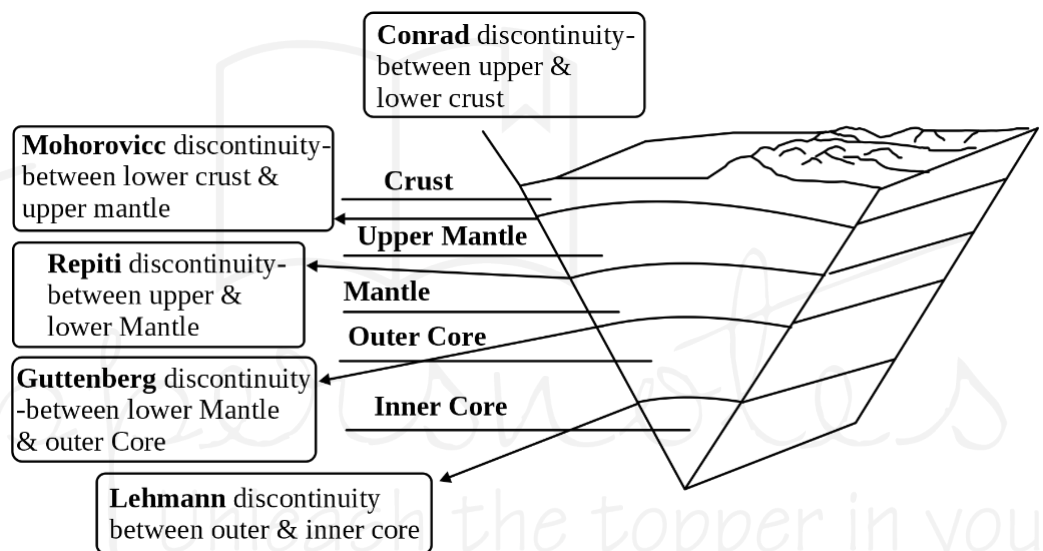
### DID YOU KNOW?

**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
Guttenberg 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

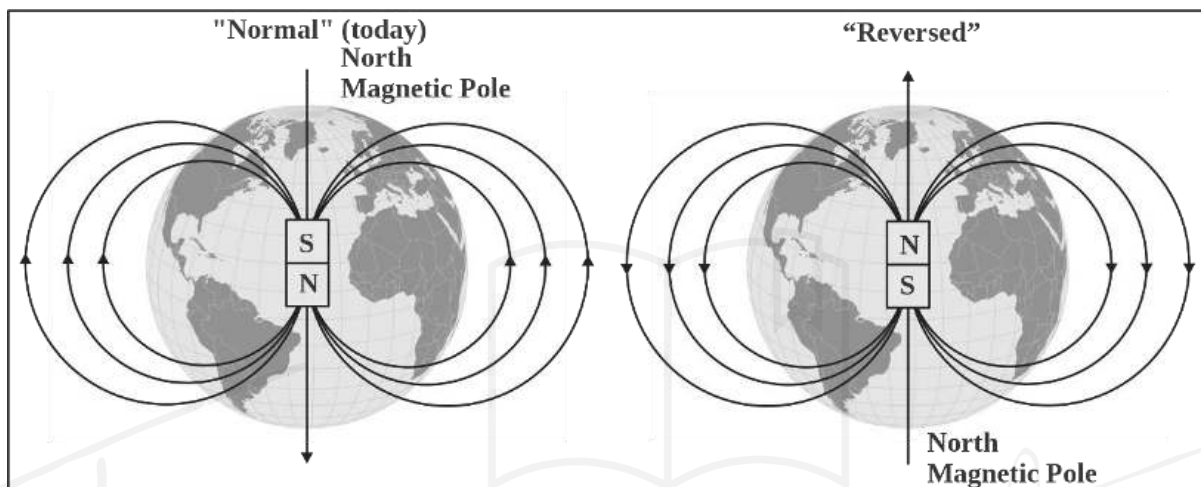
## J. Earth's Magnetic Field

- **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.

## K. Motions of Earth

### 1. Rotation

- ✓ **Direction:** Earth rotates west to east (counterclockwise when viewed from above the North Pole).
- ✓ **Axis Tilt:** Tilted at  $23.5^\circ$  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.