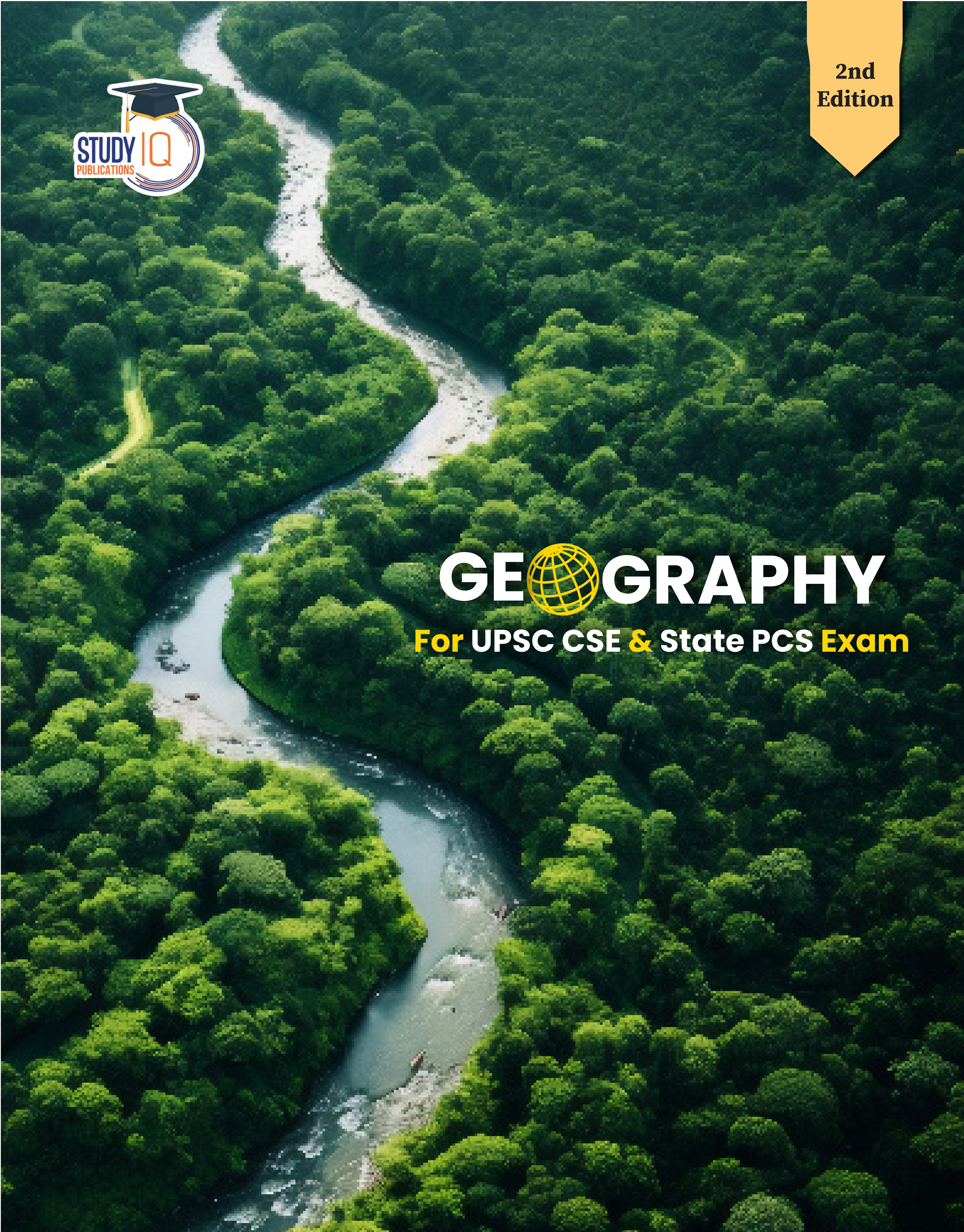

2nd Edition

GEOGRAPHY

For UPSC CSE & State PCS Exam

Fundamentals of Geography

A Complete Guide on the Concepts of Geography for UPSC CSE and State PCS Examinations

Study IQ Education Pvt. Ltd.
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From the Editor's Desk

Dear Aspirants,

We are incredibly grateful for the wonderful response we received for our Polity, History, Economy, and first edition of Geography books. Inspired by this positive feedback, we are thrilled to announce the release of the second edition of our book titled "Fundamentals of Geography".

The General Studies Paper I of the UPSC Mains examination demands a comprehensive understanding of geography, covering areas such as geomorphology, climatology, oceanography and economic geography. However, there is a dearth of consolidated and updated material and students have to rely on multiple sources, making their preparation more difficult. This book serves as a one-stop solution, offering a structured approach to the subject.

This book is an honest attempt to tackle these problems and improve students' knowledge base, saving their precious time during their preparation and eliminating many academic misunderstandings that they encounter.

Special Features of This Book

This book aims to make your preparation focused and relevant based on UPSC's current trend and pattern, revision friendly, and up-to-date.

- The requirements of the UPSC Civil Services Examination are the exclusive focus of this book.
- We have taken great care to ensure that the materials are written in a clear and easy-to-understand, so that students may learn and recall the concepts to their advantage.
- Wherever necessary, we've incorporated diagrams and maps on various geographical aspects to make learning interactive and easy.
- We have also included important current affairs topics of the last 2 years along with case studies and on various topics.
- We have incorporated the relevant previous year's questions at the end of each chapter so that the students can test their knowledge while understanding the trend of the question.

With all sincerity and humility, the Study IQ team wishes you the best in your preparation, and we are hopeful that this book will help you in your journey.

Happy Learning!!

Team StudyIQ

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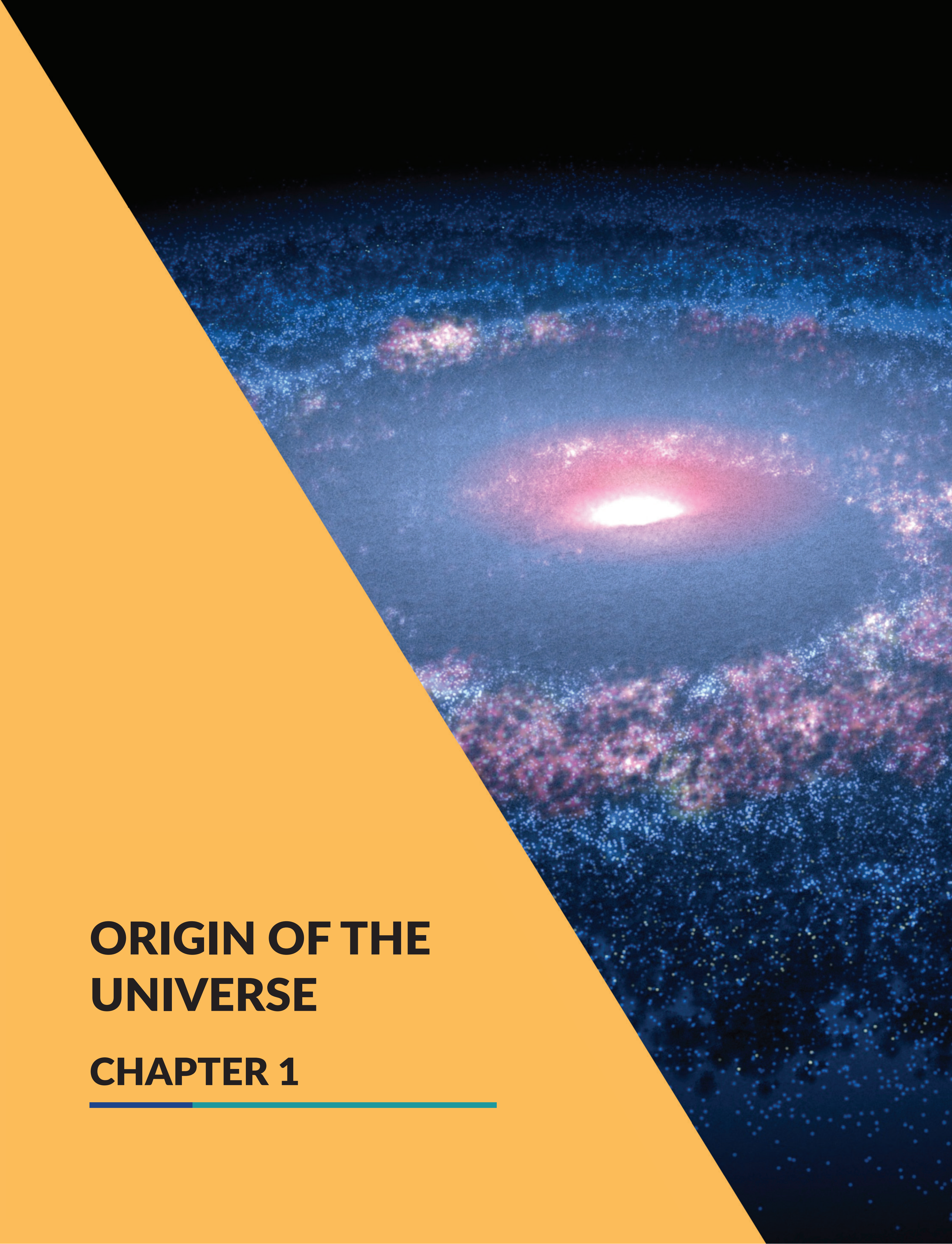

ORIGIN OF THE UNIVERSE

CHAPTER 1

ORIGIN OF THE UNIVERSE

The universe is the vast expanse of all matter, energy, time, and space that exists. It encompasses everything we know, including galaxies, stars, planets, and all forms of matter and energy. According to scientists, the universe is 13.8 billion years old. Scientists have determined this number by measuring the age of the oldest stars and the rate at which the universe is expanding.

Different Views on the Universe

The study of the Universe started back during ancient times. During the Golden Age of Greek civilization, people held two different views on the Universe: the geocentric view and the heliocentric view.

Geocentric View (Earth-Centric): According to this view, the earth was at the centre of the universe. The world was considered a spherical, motionless body with a transparent hollow sphere surrounding it. This hollow sphere was known as the **celestial sphere**. The stars were located in this sphere, and they moved around the earth daily. Aristotle and Ptolemy supported this view on the Universe.

Heliocentric View (Sun-Centric): Aristarchus of Samos, a Greek philosopher and astronomer who lived in the 3rd century BCE, was the first Greek philosopher to put forward a heliocentric view of the universe. According to this view, the Sun is at the center of the universe, and the Earth and the other planets revolve around it. Aristarchus' heliocentric view did not gain widespread acceptance during his time.

Modern astronomy: The academic contributions by Nicolaus Copernicus, Johannes Keppler, Galileo Galilei, and Sir Isaac Newton have been constructive in our understanding of the Universe. They were called the **"Founders of Modern Astronomy."**

- **Nicolaus Copernicus:** He upheld the heliocentric view of the universe and reconstructed the solar system with Sun at the center and all the planets orbiting around it.
- **Johannes Kepler:** He proved that the orbit of each planet around the Sun is elliptical, rather than circular as previously believed. This insight came to be known as **Kepler's First Law of Planetary Motion**, or the **Law of Ellipses.**
- **Galileo Galilei**. He supported Copernicus's theory of the sun-centered solar system. He noticed that Jupiter had four small bodies in orbit around it, which we now know as the Galilean moons (Io, Europa, Ganymede, and Callisto). This discovery directly challenged the geocentric model, which held that all celestial bodies revolved around the Earth.
- **Sir Isaac Newton:** He was the first to explain why planets were moving around the Sun. He was credited with conceptualizing the force of gravity. He put forward the law of **universal gravitation** which states that all particles in the universe exert an attractive force on every other particle. This force is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. Consequently, as the distance between the particles increases, the gravitational force between them decreases.

Big Bang Theory

The Big Bang theory is the most acceptable explanation on the origin and evolution of the universe. It proposes that around 13.8 billion years ago, the universe came into existence as an incredibly hot and dense state. The universe has been expanding ever since.

- **Singularity:** The universe originated from a **singularity**- infinite mass with zero volume; therefore, it has infinite density. Thus, the universe began as an infinitely hot and dense single point. This single point appeared from nowhere for reasons unknown.
- **Inflation**: During the "Big Bang," the single point inflated and exploded violently. A rapid expansion known as **cosmic inflation** occurred. This expansion happened in an extremely short period, causing the universe to grow exponentially in size.
- **Quark-Gluon Plasma:** As the universe continued to expand and cool, it entered a phase where quarks and gluons, the fundamental particles that make up protons and neutrons, roamed freely. This state lasted for a fraction of a second after the Big Bang.
- **Formation of Protons and Neutrons:** With the decrease in temperatures, the quarks and gluons combined to form protons and neutrons.
- **Nucleosynthesis:** This stage occurred approximately three minutes after the Big Bang. The protons and neutrons combined to form the nuclei of light elements like hydrogen and helium.
- **Recombination:** It occurred around 380,000 years after the Big Bang, when the universe had cooled enough for atoms to form. Through the process of recombination,

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electrons combined with nuclei to form neutral atoms. The universe also became transparent to light.

- **Structure Formation:** As the universe continued to expand, slight irregularities in density gave rise to the formation of structures. Gravity facilitated the clumping of matter together, eventually leading to the formation of stars and galaxies.

Evidences in Support of Big Bang Theory

- **Cosmic Microwave Background Radiation:** It is the faint, uniform light spread throughout the universe. It was discovered in 1965 by American radio astronomers Arno Penzias and Robert Wilson. The light arises from the heat radiation. The heat is supposed to be left over from the Big Bang event. Its discovery and observed properties, such as its uniformity and the presence of slight temperature variations, provide strong evidence for the Big Bang Theory.
    - **Red Shifting of Galaxies:** In 1929, Edwin Hubble discovered that the universe was expanding. The galaxies appeared to be moving away at speeds proportional to their distance. This is called Hubble's law, named after Edwin Hubble. Visible light consists of different colours, and red has the longest wavelength and shortest frequency. When light emitted as white from one galaxy is observed as red in another galaxy, it indicates an increase in the distance between the galaxies. This change in wavelength is caused by the light travelling a greater distance from its origin over time, resulting in a shift to a redder wavelength, known as "redshift."

Red Shift: When an object is moving away from us, the light from the object is known as redshift.

Blue Shift: When an object is moving towards us, the light from the object is known as blueshift. Astronomers use redshift and blueshift to deduce how far an object is away from Earth.

Galaxies

A galaxy is a huge collection of gas, dust and billions of stars and their solar systems (NASA). They are bound together by gravitational force.

Types of Galaxies

- **Spiral Galaxies:** They are flat, disc-shaped with curved spiral arms. These galaxies exhibit a high concentration of stars at their centre and are known for their active star formation. An example of a spiral galaxy is our very own Milky Way.
- **Elliptical Galaxies:** The shapes of elliptical galaxies vary from almost circular to highly elongated. They contain relatively little gas and dust and primarily consist of older stars, lacking ongoing star formation. They are the most abundant in the universe.
- **Irregular Galaxies:** They defy the typical disk-like or elliptical shape. Irregular galaxies possess minimal amounts of dust and often showcase peculiar structures.

The Milky Way

The Milky Way is the galaxy where our solar system is situated. It is a huge collection of stars, dust and gas.

- **Size:** Around 1,00,000 light-years across (1 light year= 9,460 billion kilometres).
- **Age:** Around 13.6 billion years.
- **Type:** Spiral Galaxy.
- **Structure:**
    - **Sagittarius A***: It is a supermassive black hole. Located in the middle of the Milky Way Galaxy. Everything in the galaxy revolves around this black hole.
    - **Galactic Bulge**: In the immediate surrounding of the Sagittarius A*, there is a tightly packed region of gas, dust, and stars. This space is known as the galactic bulge.
    - **Galactic Disc**: Beyond the bulge, there is the galactic disc. The galactic disc hosts billions of stars, including our Sun.
- **Closest Neighbouring Galaxy**: Andromeda (spiral galaxy).

Stars

A star is a giant, glowing ball of gas and dust held together by gravity. They are mainly composed of hydrogen and helium. They vary in size, mass, and temperature. The color of the star is determined by its temperature. The hottest stars appear blue, while the coldest stars appear red.

Life Cycle of a Star

The life cycle for a particular star depends on its size.

- **Nebula:** A star forms from massive clouds of dust and gas in space, also known as a nebula. Popularly known as the birthplace of the star, nebulae are mostly composed of hydrogen. Gravity begins to pull the dust and gas together.
- **Protostar:** As matter gravitationally collapses, it undergoes an increase in temperature. A star is formed when the temperature becomes sufficiently high for hydrogen nuclei to undergo fusion, resulting in the formation of helium. The release of energy from fusion sustains the star's core temperature.
- **Main sequence star:** The force of gravity holding the star together is balanced by higher pressure due to the high temperatures in the core. This balance between gravity and pressure allows the star to maintain its stable size and energy output.

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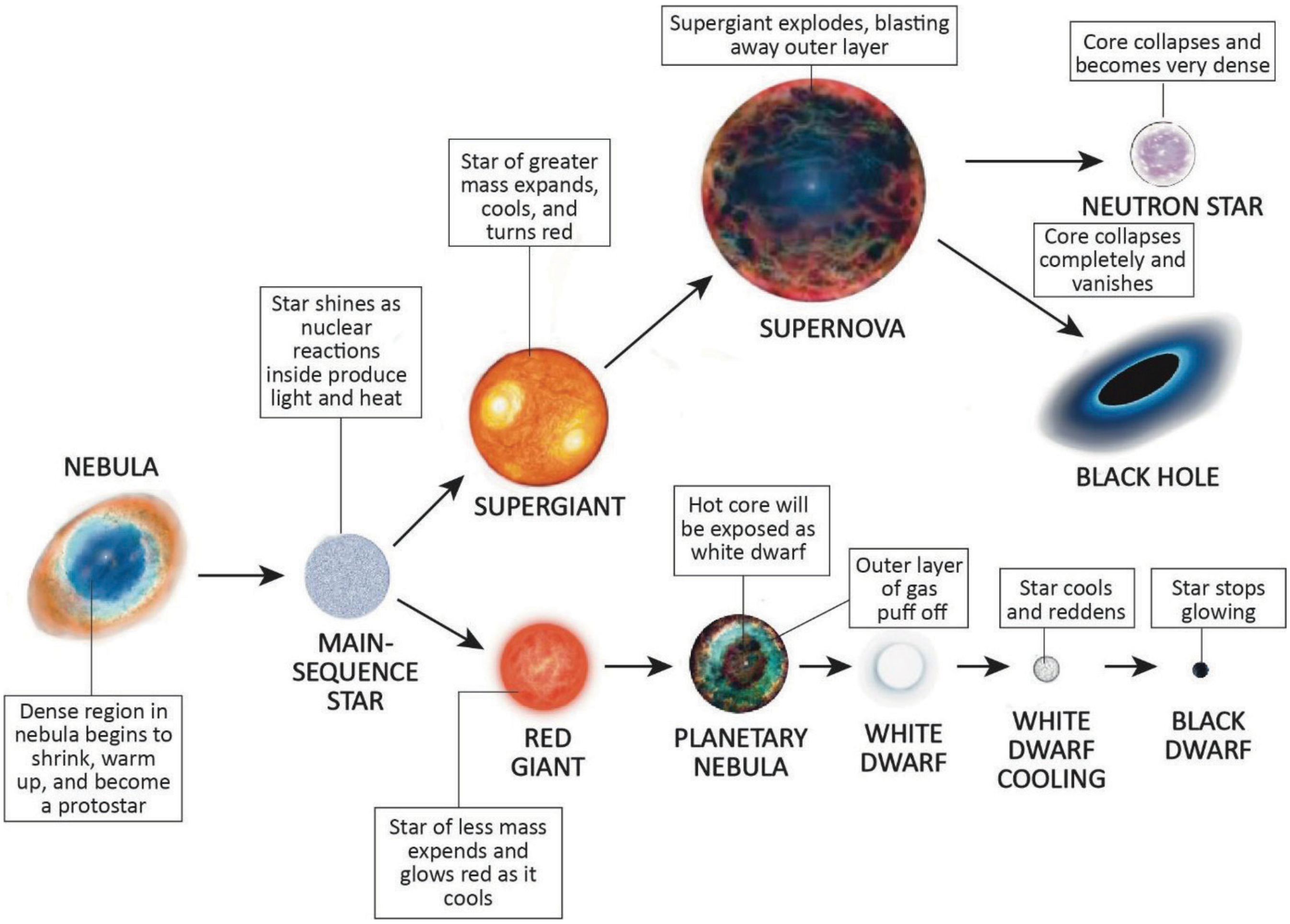
- **Red giant star:** When all the hydrogen has been used up in the fusion process, larger nuclei begin to form and the star may expand to become a red giant.
- **White dwarf:** When all the nuclear reactions are over, a small star like the Sun may begin to contract under the pull of gravity. In this instance, the star becomes a white dwarf. These white dwarf stars eventually stop emitting any heat or light and turn into **Black Dwarf.**
- **Supernova:** A larger star with more mass will go on making nuclear reactions, getting hotter and expanding until it explodes as a supernova.
- **Neutron star or black hole:** Depending on the mass at the start of its life, a supernova will leave behind either a neutron star or a black hole.
  - After the explosion, the core of the star remains. If the surviving core is between 1.5 - 3 solar masses, it contracts to become a **Neutron Star.**
  - If the surviving core is larger than 3 solar masses, it may form a **Black Hole.**

Black Holes

These are places in space that are so dense and have such immense gravity that even light cannot pass through them. The boundary that marks the outer edge of black holes is called the **Event Horizon.**

Types of Black Holes

- **Stellar Black Holes**: These form when massive stars collapse under their own gravitational pull after exhausting their nuclear fuel. Stellar black holes have a mass several times greater than that of our Sun but are compressed into a tiny volume, creating a gravitational pull from which even light cannot escape.
- **Intermediate Black Holes:** These black holes have masses ranging from a hundred to several hundred thousand times that of our Sun. Intermediate black holes are less common, and their formation process is still a subject of ongoing research.
- **Supermassive Black Holes:** These are significantly larger than stellar black holes, with masses millions or even billions of times greater than that of our Sun. Supermassive black holes reside at the centers of most galaxies, including our own Milky Way.



Life cycle of a star

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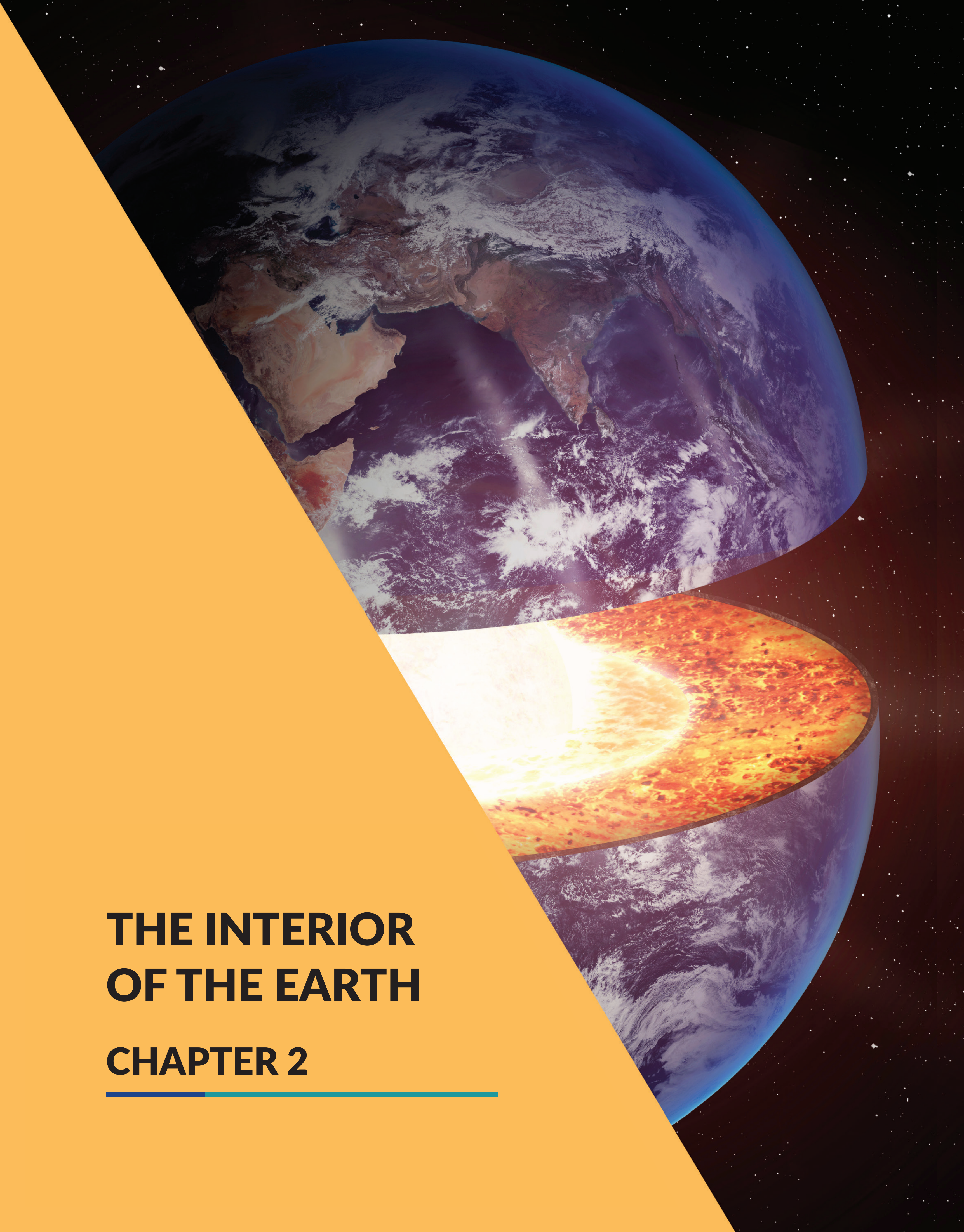

THE INTERIOR OF THE EARTH

CHAPTER 2

THE INTERIOR OF THE EARTH

The earth's interior and exterior have a layered structure. The earth's exterior consists of five major spheres. All these spheres are continuously interacting with each other to make life possible on earth. The different spheres of earth's exterior include:

- The atmosphere (the gaseous envelope covering the earth)
- The hydrosphere (the layer of water)
- The lithosphere (the stony shell of the earth)
- The cryosphere (the frozen water part of the earth)
- The biosphere (the layer containing living organisms).

Most of our studies on understanding the earth have focused on the earth's outer layers. In contrast, our knowledge about the earth's interior has remained limited because of the lack of direct access to the earth's interior.

Significance of Studying Earth's Interior

The study of the interior is essential to have a holistic understanding of the geographic system of the earth. The interior helps us understand what we see on the earth's surface. It also helps us understand the earth's magnetic field, its climatic history and aids our understanding of other planets and stars.

- **Understanding Physical features on land: The** mountains, plateaus, seas, etc., as we see today, have been shaped by forces operating within the earth. Geophysical phenomena like vulcanicity, earthquakes, and tsunamis result from endogenic (internal) forces of the earth.
- **Understanding evolution of life:** Materials from the earth's interior - the rocks and the fossils help us understand the development of the life on earth. In the 19th century, scientists put forward the geological timescale based on the fossils found in the rock strata.
- **Aids in Mineral Exploration:** The understanding of the earth's interior helps us explore and extract minerals and energy, as we get to know how and where to find them and extract them sustainably.
- **Insights into Earth's climate history:** Earth's interior study helps us understand how and why Earth's climate has changed in the past. This past knowledge aids in understanding the present natural and human-induced climate change.
- **Understanding of other planets:** A holistic understanding of earth helps study and understand other planets in the solar system and distant stars. For example, we get to know that just like earth, other rocky planets like Mercury, Venus and Mars are made of rock. They have common minerals like feldspars and metals like aluminium.
- **Earth's magnetic field:** Studies of the earth's interior also help understand the earth's magnetic field.

Sources of Information on Earth's Interior

The present studies of the earth's interior primarily rest upon seismological investigations, estimation, and inferences made by scientists based on indirect sources. The different sources of information on the earth's interior are mainly classified into two: Direct Sources and Indirect Sources.

Direct Sources

These are sources that have physical proof have physical proof like the rocks, the magma from the volcanos, etc. These sources are derived from mining, drilling, and studying vulcanism, and faults in the crust.

- **Mining and Drilling:** Deep earth mining and drilling reveal the nature of rocks deep down the surface. However, drilling and mining also have physical restrictions. Beyond a certain point, mining becomes impossible. Two major projects viz. "**Deep Ocean Drilling Project"** (1968) and **"Integrated Ocean Drilling Project"** (2003) have provided a large volume of information through the analysis of materials collected at different depths. These ocean drilling projects helped us understand the changes in the Earth's magnetic field, the structure of the oceanic crust and the upper mantle. They have also provided insights into the processes that generate major earthquakes and tsunamis. The various information gathered from these projects also provides us clues about Earth's climate history.
- **Vulcanism:** Volcanic eruption forms another major source of direct information about the earth's interior. During a volcanic eruption, molten magma comes out as lava to the earth's surface. The lava cools down to form various types of volcanic rocks. These rocks, when analyzed, give us valuable information about the earth's interior. The rocks provide us with in- formation about the different minerals present in the earth's interior, the temperature conditions etc.

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Indirect Sources

The present technological advancement has enabled humans to reach only a few kilometers inside the earth through mining and drilling. Moreover, the rocks and materials derived from mining mainly give information about the upper layer of the earth-the crust. Therefore, to better understand the earth's interior, we have relied upon various indirect sources such as the study of the Meteorites, the earth's Gravitational field, the magnetic field, and the variations in temperature and pressure with depth and the seismic waves.

- **Study of meteorites:** Since all space matter had a common beginning, meteorites help understand the earth's materials composition. There are three main types of meteorites:
  - **Stony meteorites** are made up of rocks.
  - **Iron meteorites** have a high proportion of iron.
  - **Pallasites:** Containing both rocks and iron.
    - ✓ The rocks of stony meteorites are very similar to those found in the earth's crust and mantle. Iron meteorites help us understand why we find iron in the earth's interior. According to scientists, when planets were first formed there was an abundance of iron on the surface. With time, this iron gradually sunk under the force of gravity. Therefore, we find iron in the earth's core (the innermost layer).
- **Study of the earth's gravitational field:** Gravitational force is a force that attracts any two objects with mass. The greater the material mass, the stronger the gravitational pull. The uneven distribution of mass in different materials greatly influences gravitational force. For example, granite is dense and has a high mass. Therefore, it has a higher gravitational pull than a less dense material of the same volume, such as water. This variation in gravity is known as a gravitational anomaly. Such anomalies help us determine the distribution of different materials within the earth.
- **Study of earth's magnetic field:** It helps in understanding the presence and distribution of magnetic materials inside the earth. The changes in magnetic fields also provide information about the core-the source of the magnetic field.
- **Seismic Waves:** Scientists have applied the knowledge of how seismic waves interact with different materials to understand the earth's internal structure.

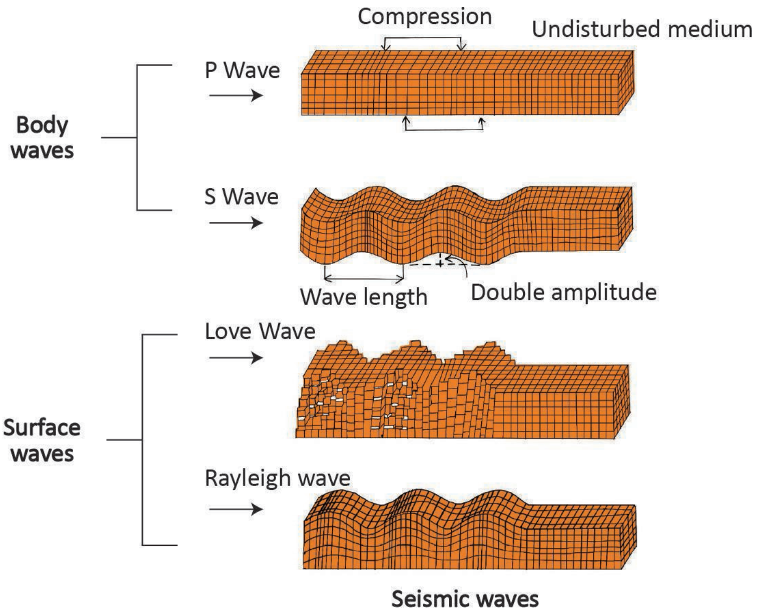
Seismic Waves

An earthquake is caused by the sudden release of energy built between crustal plates. This energy is released in the form of waves that travel throughout the earth's interior. The waves generated by an earthquake are called **seismic waves**. These seismic waves travel through the earth in the form of vibrations. The vibrations are recorded and measured by an instrument called the seismometer. The seismometer produces a graph called a seismogram which shows these vibrations.

Types of Seismic Waves

The seismic waves are broadly classified into two types, viz. **Body waves and Surface waves**. This classification is based on place of travel of the seismic waves. The body waves originate from inside the earth and travel through different layers of the earth. When these waves react with rocks on the earth's surface, they produce surface waves. The surface waves travel on the earth's surface. The body waves are further divided into two types, primary waves and secondary waves. They are called primary or secondary based on when they are recorded at the seismometer.

- **Primary Waves:** These waves are the fastest-travelling seismic waves; they attain a speed of 5 to 14 km per second. They are the first to reach the earth's surface and, hence, called Primary waves or "P" waves. The waves travel through a medium by compression and expansion. As a result, they push and pull the material as they travel through it, leading to a change in volume and density. Due to this type of movement, the P waves are also called compressional waves. When a particle is subjected to P wave, they move in the same direction as the wave is travelling in.



Seismic Waves

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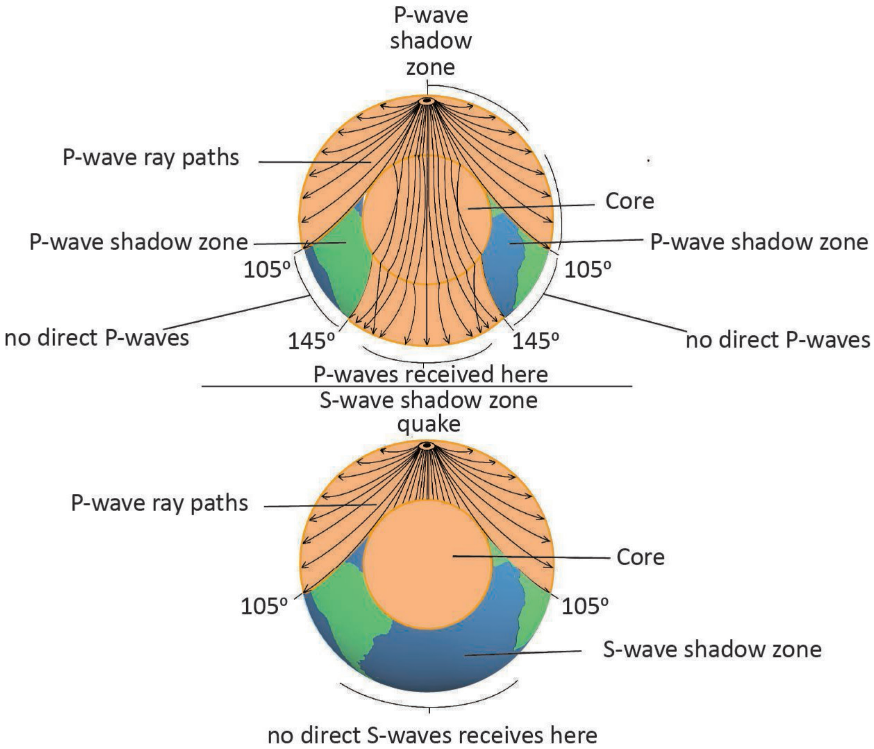
- **Secondary Waves:** These waves have a speed lower than P waves, around 3.5-7.2 km per second. They move in up and down motion, perpendicular to the wave direction. Thus, they are also called transverse waves. They deform and change the material through which they pass through. Hence, they are also called shear waves.
- **Surface Waves:** They are also called Long Period Waves or "L" waves, because they cover the longest distances of all seismic waves. They are the last to reach the earth's surface. They only affect the surface of the earth and act obliquely. Furthermore, they are the most violent and destructive of all seismic waves. There are two types of surface waves:
  - **Love waves**: They have been named after A.E.H. Love, a British mathematician who first predicted their existence in 1911. It is the fastest surface wave. It moves the ground from side to side.
  - **Rayleigh waves:** They have been named after Lord Rayleigh, who discovered them in 1885. These waves roll over the ground like waves in oceans or seas, causing the ground to move in an elliptical motion.

Observations made from Seismic Waves

If the earth was composed of homogenous materials, the seismic waves would have traveled in straight lines. However, this is not the case. As the seismic waves move through the earth's interior, they are reflected and refracted. Observations from the seismometer:

- The P waves were the first to be recorded in the seismometer.
- The P waves travelled through the entire earth's interior.



Shadow zone of P and S waves

- No P waves were recorded in the seismometer between 105 degrees to 145 degrees from the epicentre of an earthquake. The zone where seismic waves from an earthquake are not recorded in the seismometer is known as the **shadow zone.**
- After 140 degrees, the P waves were again recorded in the seismometer.
- The S waves were recorded after the P waves in the seismometer
- No S waves were recorded in the seismometer between 105 degrees to 145 degrees from the epicentre of an earthquake.
- The S waves never resurfaced again.

Based on the above observations, i.e., the absence of S waves beyond 104 degrees, and the slowing of the P waves; the scientists concluded that the outer core is liquid.

Beyond 145 degrees, the P waves again emerged. The speed of the P wave also increased. This helped scientists conclude that the inner core is solid.

Comparison between Primary, Secondary, and Surface Seismic Waves

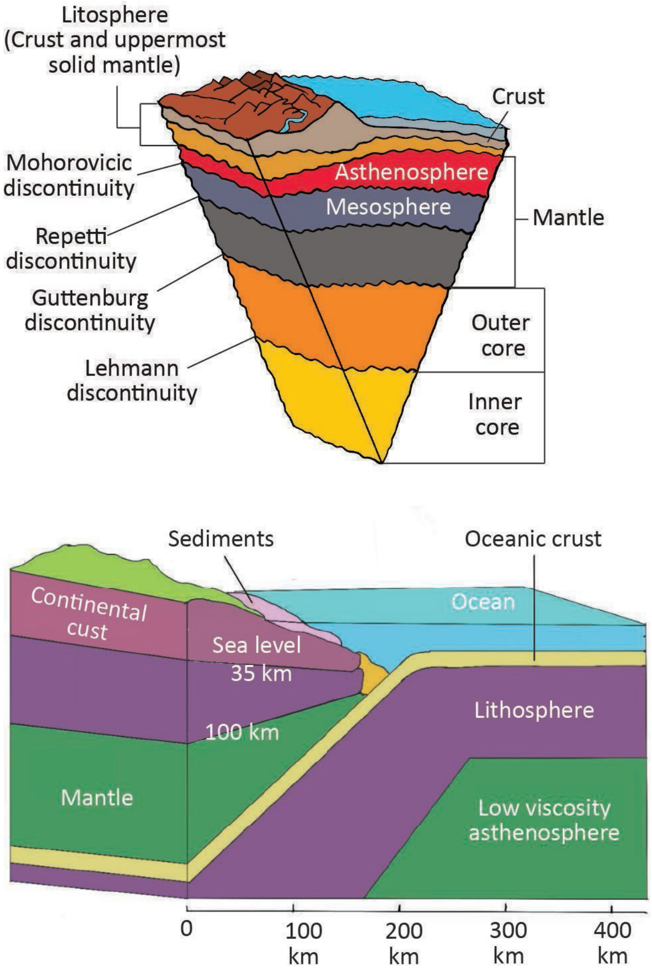
Criteria	Primary Waves	Secondary Waves	Surface Waves
Time to reach the earth's surface	They are the first to strike the crust of the earth.	After the primary wave, the secondary wave reaches the earth's crust.	They reach the earth's crust last.
Wavelength	The wavelength is very short in nature.	The wavelength is of medium size.	The wavelength is the longest.

Criteria	Primary Waves	Secondary Waves	Surface Waves
Direction	It strikes a parallel direction on the structure of rock where tremor occurs.	It strikes at a right angle. Hence, it acts obliquely.	It also acts obliquely.
Movement through different materials	They can move through solid, liquid and gaseous substances of the earth's interior.	It can move only through solid substances.	It can move only through solid materials.
Speed	It has the highest speed-about 5 to 14 km per second.	The speed is lower than 'P' wave- 3.5-7.2 km per second.	It moves slower than 'P' and 'S' waves-about 3 to 5 km per second.

Structure of the Earth

Scientists have divided the earth into concentric layers based on the data collected from seismic studies. The structure of the earth is divided into three main layers-the very thin and brittle outer shell called the crust, the middle shell named the mantle, and the inner layer called the core. The crust covers 1% of Earth's volume, the mantle covers 84% and the core covers 15%.

Crust



Seismic Discontinuity and Oceanic and Continental Crust

It is the uppermost and thinnest layer of the Earth. It is a broad mixture of different types of igneous, metamorphic, and sedimentary rocks.

The crust is further divided into two distinct parts, the upper and the lower crust. The upper crust is granitic and forms the continental landmasses. It is primarily composed of silica and alumina and is called **"sial".** The lower part of the crust is a continuous zone of dense basaltic rocks that forms the ocean floors. It is mainly composed of silica and magnesium, and hence commonly referred to as the **"sima."** The continental crust or the "Sial" is lower in density (2.7g/cm3) as compared to the oceanic crust or the "Sima" (3.5g/cm3).

The thickness of the crust varies under the oceanic and continental areas. The average thickness of the crust below the ocean is 5 km, whereas that of the continent is around 30 km. The transition between sial and sima is called the **Conrad discontinuity.**

Mantle

It lies between the Earth's crust and its core. Below the crust, there is a narrow zone called the **Mohorovicic or Moho's discontinuity.** The discontinuity is due to a change in the composition of minerals. The mantle extends from Moho's discontinuity to a depth of 2,900 km. The density of the mantle is about 4.5 g/cm3.

The mantle is subdivided into the Upper mantle and lower mantle. The depth of the upper mantle ranges from 403 to 660 km from the crust. The depth of the lower mantle is around 660 to 2,891 km. The temperature at the upper mantle ranges from 500 to 900 degrees Celsius. On the other hand, the lower mantle is much hotter, reaching 74,000 degrees Celsius. Also, the upper mantle is more viscous than the lower mantle, as there is less pressure than the lower mantle. The **Repetti discontinuity** separates the upper and lower mantle.

The upper mantle contains a weaker zone called the asthenosphere. It extends up to 400 to 500 km from the surface. It is the primary source of magma that flows out to the surface during volcanic eruptions. The crust and the uppermost part of the mantle above the Asthenosphere are collectively called the **Lithosphere.** The mantle comprises

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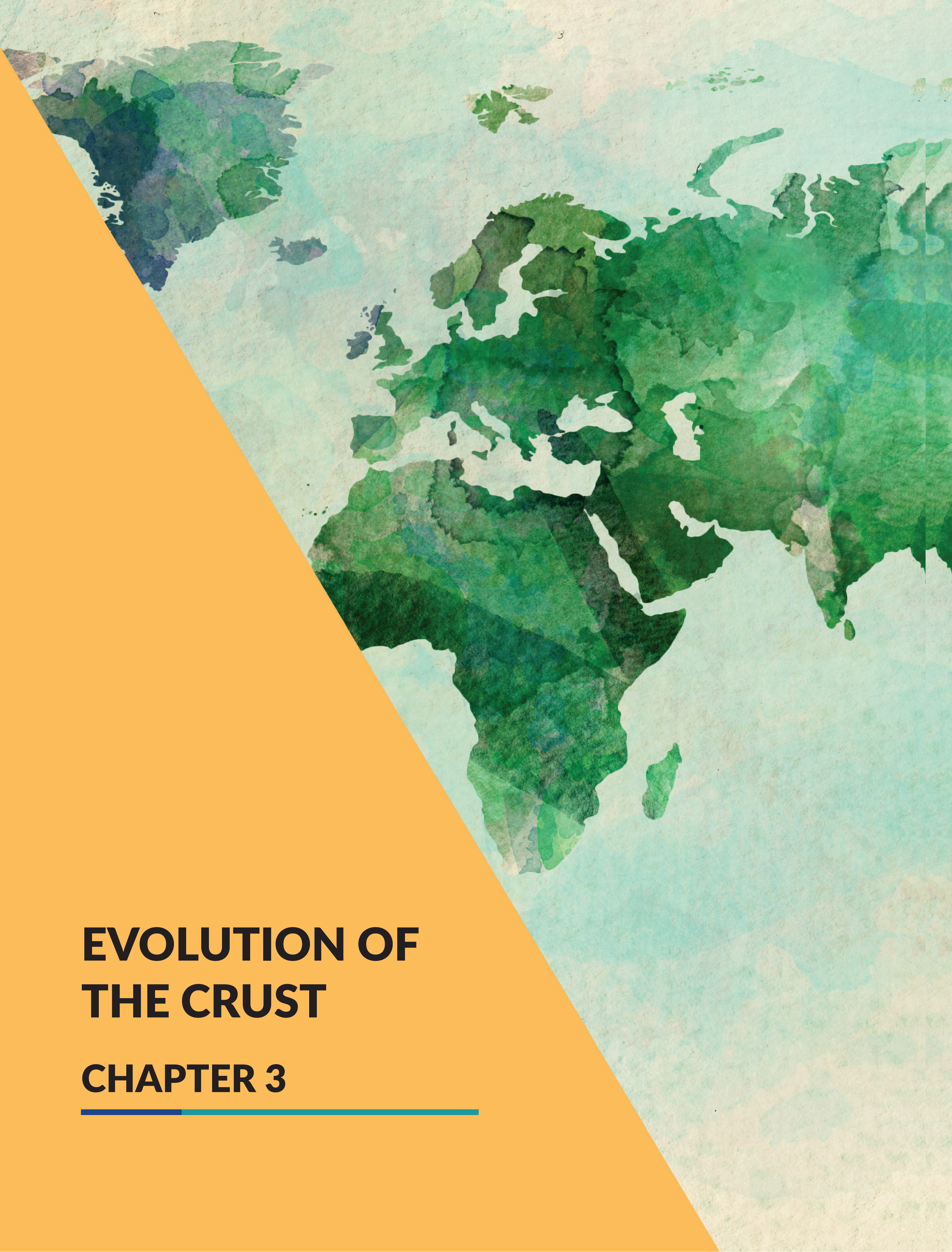


EVOLUTION OF THE CRUST

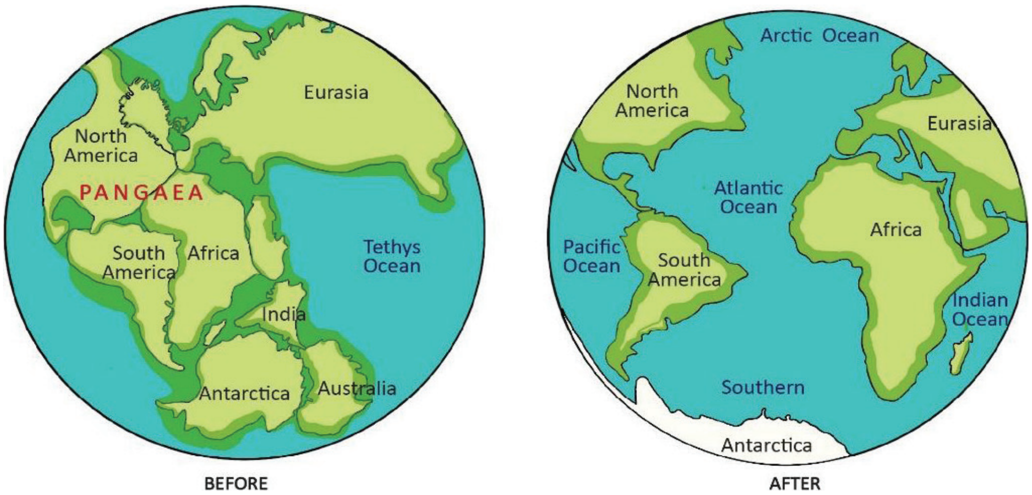
CHAPTER 3

EVOLUTION OF THE CRUST

Over the course of history, several theories have emerged to explain the arrangement of continents and oceans. The theory of continental drift was among the first attempts to explain the present arrangement. However, it has been replaced by the more comprehensive theory of Plate Tectonics, which provides a more detailed understanding of how Earth's lithospheric plates interact and shape the planet's features.

Theory of Continental Drift

Alfred Wegner, a German astronomer, propounded the theory of Continental Drift in 1912. According to this theory, the continental landmasses were drifting across the earth. This movement of the continents was termed continental drift. According to the theory, all the landmasses were united into a large, single supercontinent called the **Pangaea.** The Pangaea was surrounded by a massive body of water called the **Panthalassa.**



Continental Drift

Some 200 million years ago, the Pangaea began to split. At first, it broke into two large masses-**Laurasia** to the north and **Gondwanaland** to the South. The Laurasia comprised present-day North America, Greenland, and all of Eurasia north of the Indian subcontinent. At the same time, the Gondwanaland comprised present-day South America, Africa, Madagascar, India, Arabia, Malaysia, Australia and Antarctica. The Laurasia and Gondwanaland were separated by a long shallow inland sea called the **Tethys Sea.** Later, Laurasia and Gondwanaland split and drifted away to form the present-day continents.

Direction of Movement

According to Wegner, the continents drifted in two directions, towards the west and the equator.

- **Equatorward Movement**: Due to the equatorward movement, Africa and Eurasia came closer. As a result, the Tethys Sea was squeezed, and the deposits of the sea were raised to form the fold mountains of the Alps, Atlas, Zagros, Himalayas, etc. Further, the Indian peninsula and Africa got separated from Antarctica and Australia. Wegner attributed this equatorward movement to the gravitational attraction caused by Earth's equatorial bulge.
- **Westward Movement**: Due to the westward movement, North and South America separated from Europe and Africa, and the Atlantic Ocean was formed. This westward movement was attributed to the tidal force of the Sun and the moon on the continents.

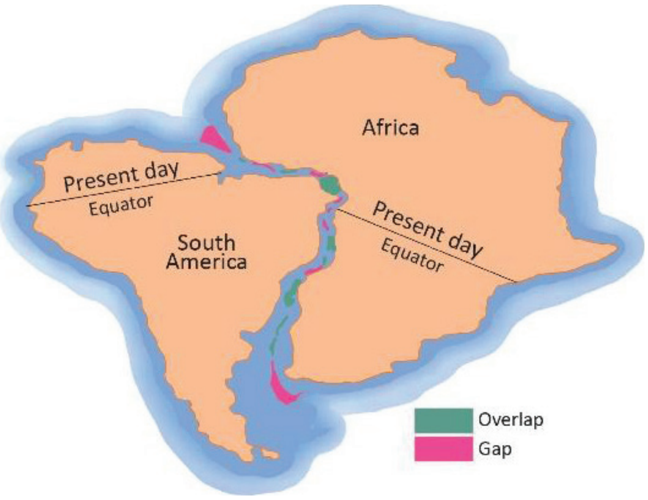
Continent

A continent is a large, continuous mass of land separated from other landmasses by an expanse of water. When a continent is identified, all the islands associated with it are also included. For example, the island of Japan is part of Asia. Greenland and Caribbean islands are considered to be a part of North America. All the continents, together, cover 148 million square kilometres of land. The continents are, from largest to smallest: Asia, Africa, North America, South America, Antarctica, Europe, and Australia.

Microcontinent: It is a landmass that has broken off from a main continent.

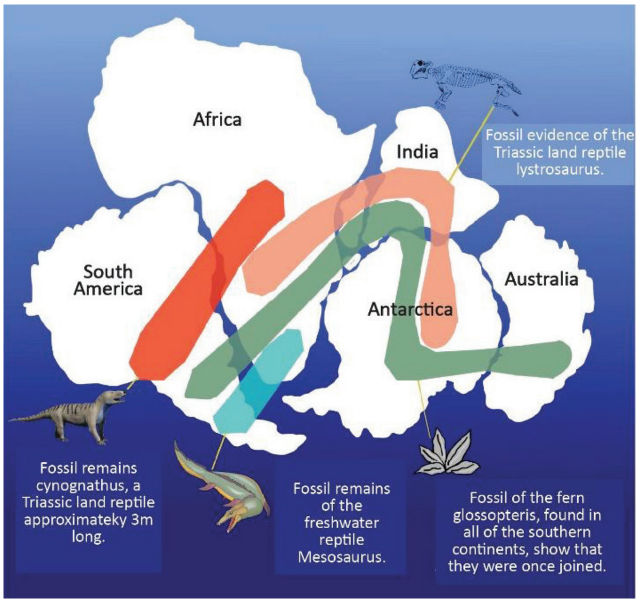
Evidences in Support of Continental Drift

Wegner collected geomorphological, climatological, and palaeontological evidence to support his theory. The major evidence supporting the continental drift are as follows:



Jigsaw fit of Continents

- **"Jigsaw" fit of the opposite coasts of the Atlantic Ocean**: The outlines of the coasts on either side of the Atlantic Ocean-coastlines of South America and Africa are such that they can be joined together. They fit like a jig-saw puzzle, indicating that they were joined together at a point in time in geological history.
- **Paleoclimatic Evidence**: There are coal deposits in the mid-latitude regions, stretching from North America to Europe to China. Wegner advocated that these regions had an equatorial location in the past and were covered by vegetation that later turned into coal.



Fossil Evidence of Continental Drift Theory

- **Palaeontological or Evidence from Fossils:** Similar fossils have been found on continents located on either side of the Atlantic Ocean. For example, the fossil remains of Cynognathus (a Triassic reptile) have been found in Argentina and South Africa. According to Wegner, this similarity can only exist if the continents were once connected.
- **Geological Evidence:** Opposite coasts of the Atlantic Ocean also have similar rock types of the same age, suggesting that they were unified at a point in time.
- **Tillite Deposits**: The Gondwana system of sediments are found in Madagascar, Africa, Antarctica, Falkland Island, Australia, and India. It consists of tillite deposits- a form of sedimentary rock formed by glacial deposition during the glaciation in the Carboniferous period. These deposits in regions close to the Equator indicated that the glaciers either covered the entire globe or were found in the middle of the ocean. Today, glaciers are only found on land at high altitudes or near the poles. Wegner suggested that the glaciers were centred over the Gondwanaland close to the South Pole. The continents, later on, moved to their current position.
- **Polar Wandering:** When scientists found 400-million-year-old magnetite rock in Europe, it pointed to a different north magnetic pole than the same-aged magnetite in North America. This suggested that if the continents had remained fixed while the north magnetic pole moved, there must have been two separate north poles. However, there is only one magnetic north pole. Therefore, the only possible explanation is that the magnetic pole remained fixed, but the continents drifted.

Scientists largely rejected Wegner's theory of Continental Drift. The primary reason for rejection was that the theory failed to explain the mechanism of how continental drift actually works and why did the continents drift apart. Gravitational attraction and tidal forces are not strong enough to drift continents apart. Further, the theory was loosely based on assumptions and did not rationalize why the drift started only 200 million years ago and not before. Nevertheless, the Continental Drift theory was an essential milestone in studying tectonic movement and set the ground for the theory of Plate Tectonics.

Convection Current Theory

English geologist Arthur Holmes put forward the Convection Current Theory in 1928-1929. Holmes theorized that convection currents move through the mantle the same way heated air circulates through a room, and radically reshape the Earth's surface in the process.

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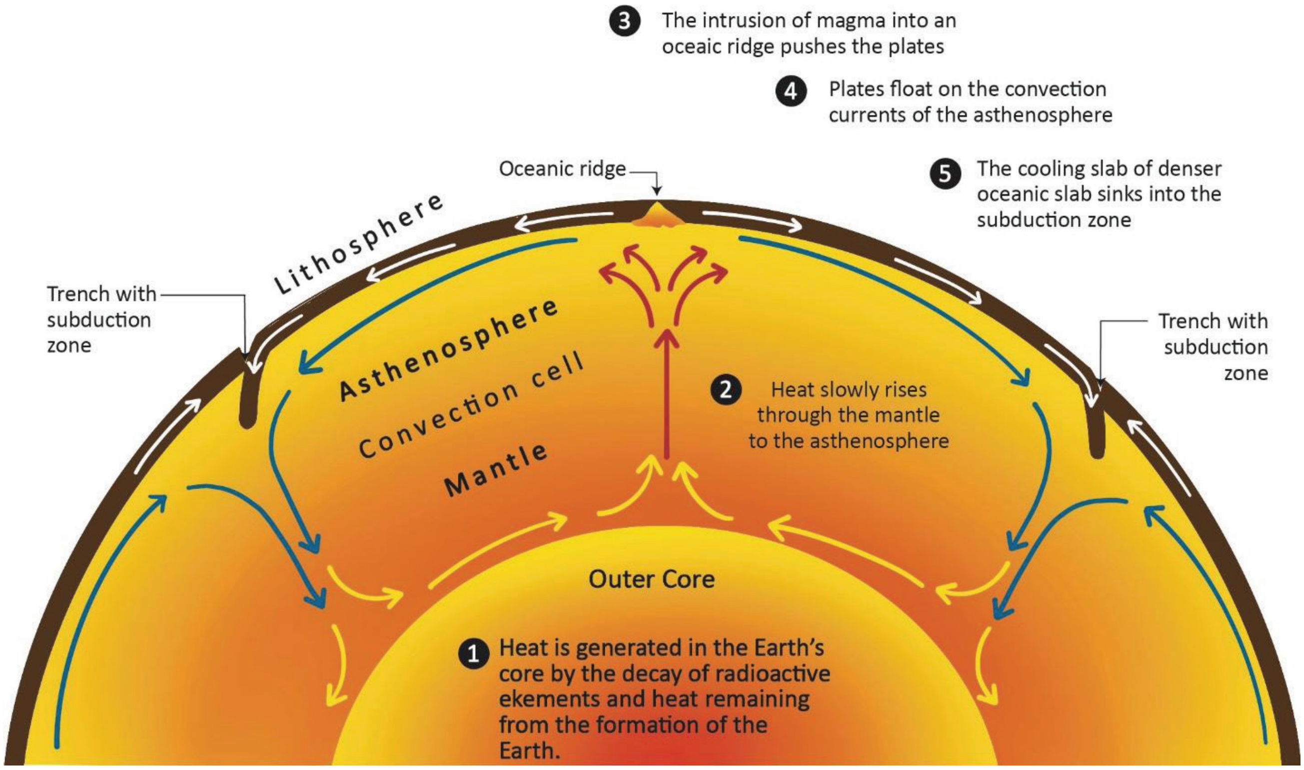
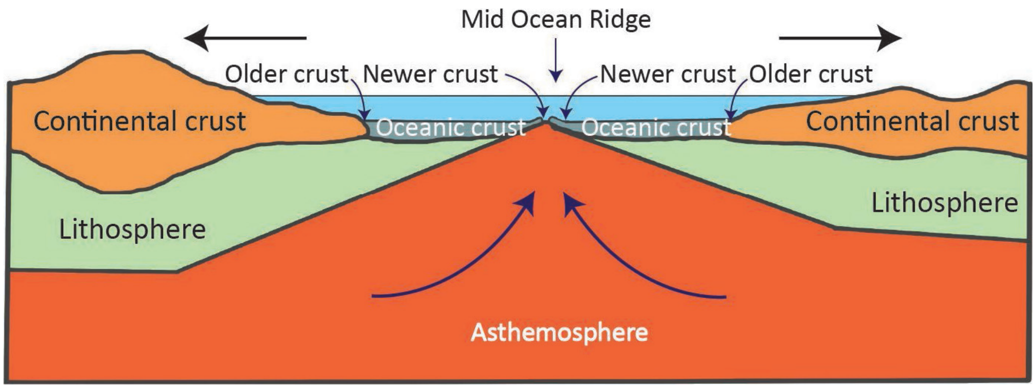
According to this theory, the Earth's mantle undergoes convective motion due to the heat generated by radioactive decay in the interior. When rocks in the Earth's interior are heated by radioactivity, they rise buoyantly towards the surface from deep within, and subsequently descend as they cool down and become denser. Divergent convective currents move crustal blocks in opposite directions, giving rise to seas and oceans. On the other hand, convergent convective currents cause subsidence in crustal zones, leading to the formation of geosynclines and the closure of seas. This process eventually leads to the creation of island arcs, mountains, and other landforms.



Convection Current Theory

Theory of Sea Floor Spreading

In the 1960s, Harry Hess and Robert S Dietz put forward the hypothesis of Sea Floor Spreading. According to this theory, the seafloor is spreading, resulting in the formation of mountains and the drifting of continents. Convection current within the mantle results in the rising of the molten magma. Eventually, when the crust is fractured, magma spills out and covers the crust when the crust is fractured. The molten magma cools down to form igneous rock basalt, forming new seafloor. As this process continues, the existing rocks from the ridge are pushed equally in both directions. A younger, less dense oceanic crust is formed near the ridge. As oceanic crust forms and spreads, moving away from the ridge crest, it pushes the continent away from the ridge axis. When the oceanic crust reaches a deep-sea trench, it sinks into the trench and is lost in the mantle.



Sea Floor Spreading

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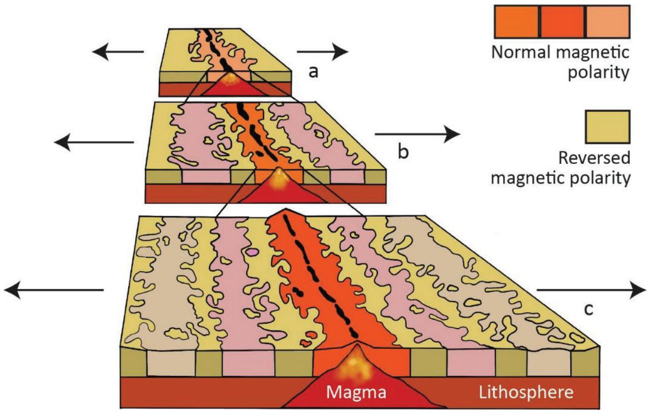
Evidences in Support of Seafloor Spreading

There are four critical pieces of evidence in support of seafloor spreading:

- **Geology of the Ocean Floor:** In the 1950s, Mary Tharp and Bruce Heisen developed the first bathymetric map of the Atlantic Ocean. They used sonar technology to map the ocean's depth accurately over a large area. It was observed that the seafloor was not flat, plain land. Instead, it was an active area with giant peaks, cracks, and active volcanoes. Robert Deitz and Hary Hess further described fascinating geological structures found at the bottom of the ocean. An irregular, central mountain ridge was located in the middle of the Atlantic Ocean. Based on this, Hess developed the idea that magma came out to the surface along this ridge. This process pushed the rock slabs on either side away from one another.
- **Age of Rocks:** Scientists found young rocks right along the ridge. The rocks got older with distance on either side of the ridge. Thus, the age of the seafloor increases as we move further away from the mid-oceanic ridge. This phenomenon could only be explained if the seafloor was spreading.



Paleomagnetism of Earth's Crust

- **The thickness of Sediments:** The thickness of the layer of sediments deposited on the ocean floor increases as we get further away from the mid-oceanic ridge. This is because older rocks got more time to disintegrate and accumulate sediments.
- **Paleomagnetism:** the magnetic north and south poles periodically switch-the phenomena known as magnetic reversal or polar reversal. This happens fairly regularly throughout the earth's geological history. These magnetic reversals are captured on solidified rocks on either side of the mid-oceanic ridge. As the magma swells up through the ridge and hits the cold ocean water, it solidifies into rock. The minerals within the magma align with the earth's magnetic field. The study of the Earth's magnetic field record in rocks and sediments is called **paleomagnetism.** The pattern of the magnetism matches perfectly on either side of the ridge. The only possible way the pattern could match on either side of the ridge is when the seafloor spreads uniformly.

Theory of Plate Tectonics

The theory of plate tectonics is the outcome of years of research on global tectonics (movement of the earth's crust) that began with Wegner's Continental Drift Theory, followed by the theory of Seafloor spreading. The plate tectonics theory was put forward by D.P. McKenzie, R.L Parker, W.C Morgan and X. Le Pichon in 1967-168. It is the most universally accepted theory and provides the best explanation for nearly all tectonic and volcanic phenomena.

The basic concept of Plate Tectonics is that the earth's lithosphere is divided into several rigid slabs or plates. These plates are moving horizontally over the viscous asthenosphere of the mantle. Due to this movement of the plates, various deformations such as stretching, folding, etc., occur along the plates' margins or boundaries.

The term **Tectonics** is derived from the Greek word **"Tektonikos,"** which means building or construction. It refers to deformations on the earth's crust due to internal forces.

Plates

These are slabs or portions of the lithosphere moving horizontally over the asthenosphere. There are two main types of plate: continental plates and Oceanic plates. Oceanic plates are made up of the oceanic crust called "sima." Continental plates comprise the continental crust called "sial." Plates are on an average 125 km thick. The Continental plates are thicker (200km) while the oceanic plates are thinner (50 to 100km).

The earth's lithosphere comprises seven major plates and numerous minor plates. The major plates are the African, South American, Indo-Australian, Antarctic, Eurasian, North American, and the Pacific plate. Some of the important minor plates include the Cocos plate, Arabian Plate, Nazca plate, Juan de Fuca Plate, Somali plate, Madagascar plate, Scotia plate, Nubian plate, etc. Some plates are large enough to consist of both continental and oceanic crustal portions (e.g., the African or South American plates) whilst the Pacific Plate is almost entirely oceanic.

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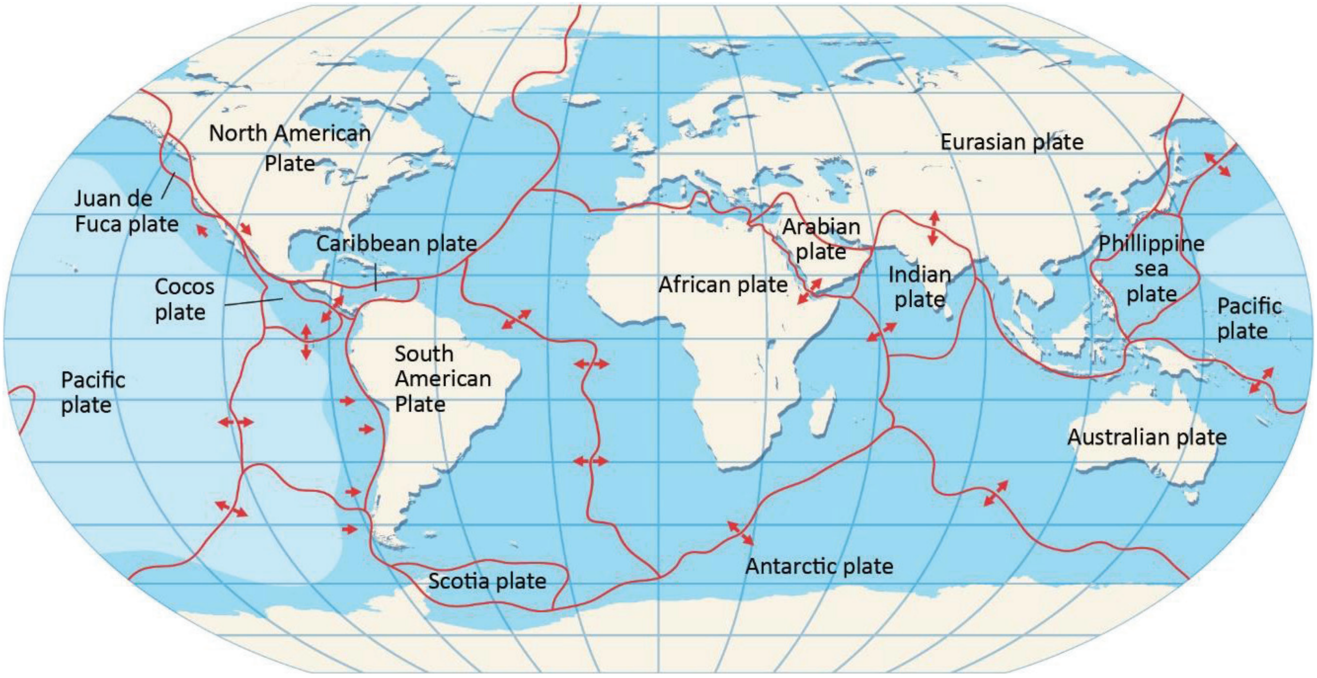


Crustal Plates

Why do plates move?

The surface of the earth and the interior of the earth are not static but dynamic and are continuously moving. The earth's lithosphere (divided into rigid plates) is moving because of the convection currents generated inside the earth's mantle.

Imagine cooking noodles in a pot. You have noticed that the noodles move upward in the middle of the pot where the temperature is higher. It then moves downward on the edges of the pot where the temperature is lower.

A similar convection cell exists in the earth's mantle as well. The heated materials rise up to the surface through a process called upwelling. The rising magma current then diverges to either direction at a crustal point. As it rises, it creates a tangential force on the crust and subsequently cools. The comparatively cooler magma within the mantle then sinks back into deeper depths in the mantle.

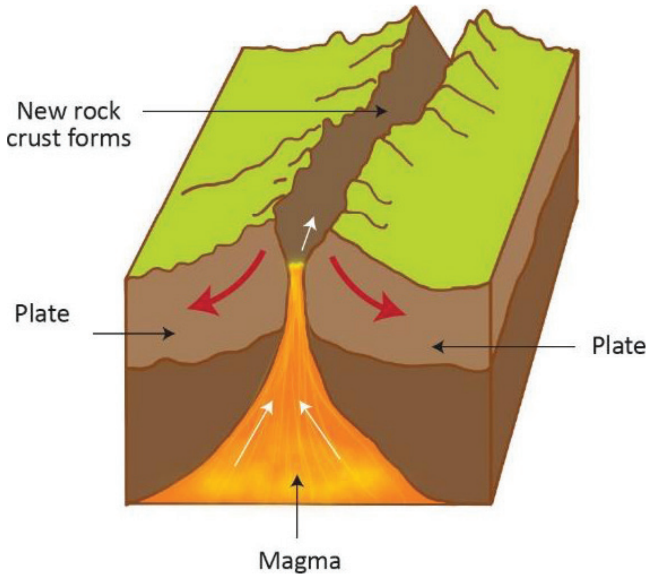
Plate Margins and Plate Boundaries

Plate margin is the edge or marginal part of a particular plate. On the other hand, the plate boundary is the surface zone of motion between two adjacent plates. Therefore, two neighbouring plate margins meet at a common plate boundary.

Types of Plate Boundaries

Constructive Plate Boundaries

These plates are also called divergent plate boundaries. Here, the plates are moving away from each other. Mid-oceanic ridges characterize these plates. At such plate boundaries, molten magma comes out of the fissures, and the new material is added to the surface, thereby constructing the lithosphere. As new material is added, it is called a constructive plate boundary. For example, the Mid-Atlantic Ridge is the boundary between the African and American plates.



Constructive Plate Boundary

Destructive Plate Boundaries

They are also called convergent plate boundaries, as the plates move and collide against each other. There can be three types of collision: Continent-Ocean Collision, Continent-Continent Collision, and Ocean-Ocean Collision.

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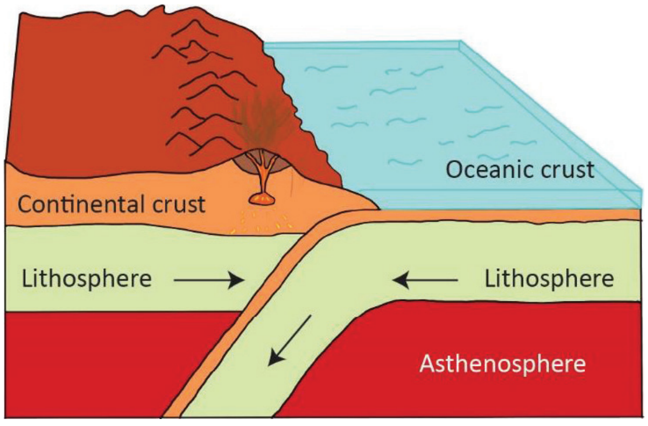
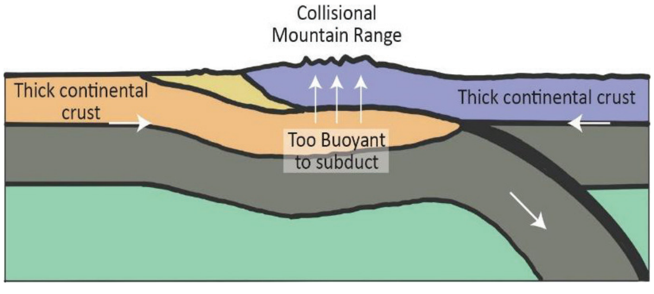


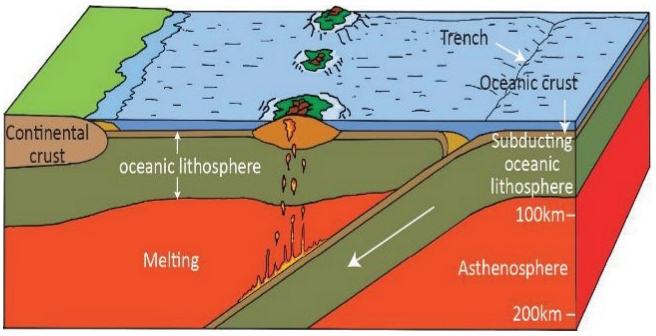
Continent-Ocean Collision

- **Continent-Ocean Collision:** When Continental and oceanic plates exist on either side of the boundary, the oceanic plate is overridden by the continental plate. The oceanic plate being the heavier plate sinks into the mantle. As it sinks into the asthenosphere, it gets destroyed. It gets destroyed as it melts under the intense heat of the mantle. The place where the sinking of a plate occurs is called a subduction zone or sink. It results in the formation of oceanic trenches.
  - On the other hand, the continental edge is uplifted and folded to form mountains. For example, when the South American plate collided with the Nazca plate, the Nazca plate plunged beneath the South American plate. The Nazca plate sank as it is an oceanic plate and is heavier than the South American plate. The collision resulted in the formation of the Andes Mountains.
- **Continent-Continent Collision:** Convergent boundaries can occur on land. They occur when two continental plates collide. The continental plates do not sink, but are narrowed down. This is because the sediments on the margins get squeezed and uplifted. For example, when the Indian plate collided with the Eurasian plate, the sediments on the continental margins were squeezed and uplifted resulting in the formation of the Himalayas.



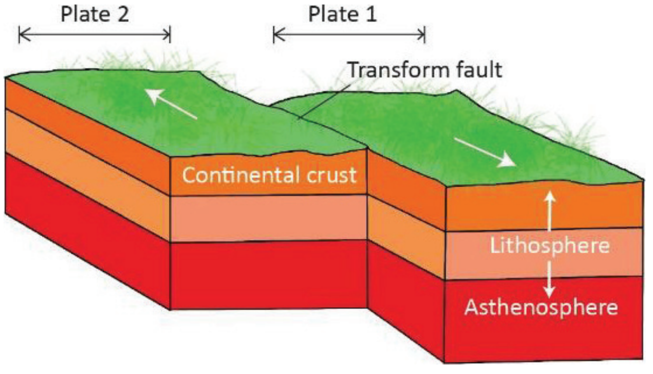
Continent-Continent Collision

- **Ocean-Ocean Collision:** This type of collision occurs when oceanic plates are on either side of the convergent plate boundary. The denser oceanic plate is subducted below the lighter oceanic plate as the two plates collide. An oceanic trench is thus formed along the boundary. The rocks in the denser oceanic plate get metamorphosed under high heat and pressure inside the earth. Eventually, after reaching a depth of 100km, the plate starts melting under high heat. The melted part of the plate and the metamorphosed rocks together form magma.



Ocean- Ocean Collision

  - The magma, possessing a lower density compared to its surroundings, is buoyed up by the surrounding medium, causing it to ascend. This persistent ascent of magma leads to volcanic eruptions beneath the ocean floor. As the magma flows continuously, layers of rocks are formed. Over time, these volcanic rocks give rise to landforms that may emerge above the ocean floor. Along the plate boundary, these volcanic landforms come together to form chains of islands known as island arcs. Prominent examples include the Japanese island arc, Philippines island arc, etc.



Conservative Boundary

Conservative Plate Boundaries: They are also called sheer plate boundaries. Along these boundaries, the continental crust is neither created nor destroyed. Here, the two plates pass or slide past one another. These plate boundaries are represented by transform faults. A famous example of a transform fault is the San Andreas Fault in California, USA.