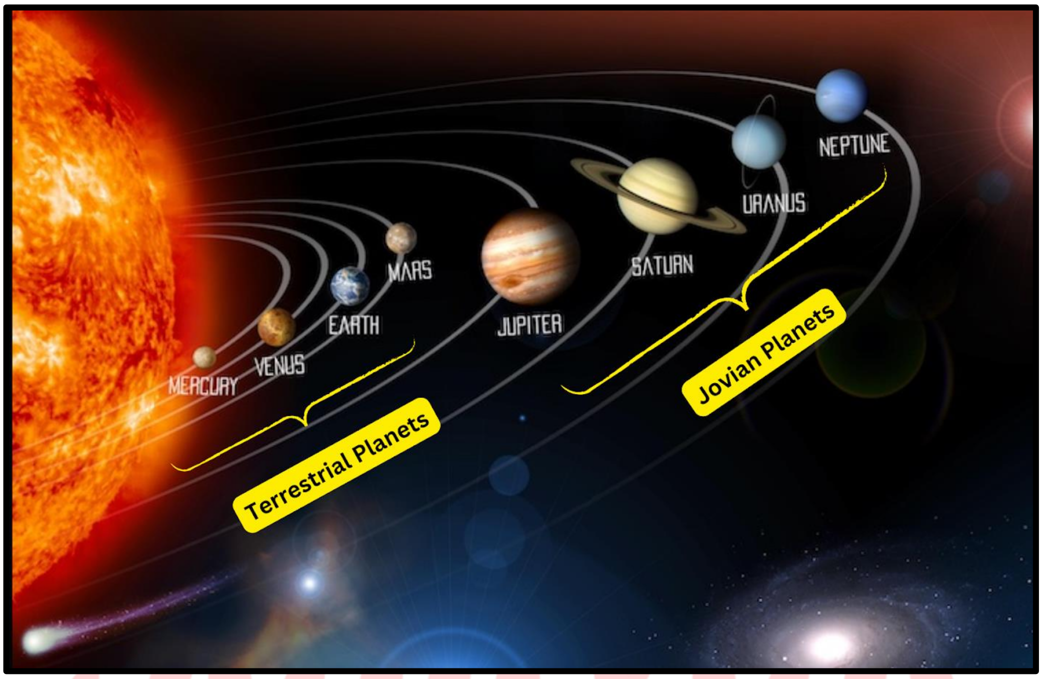
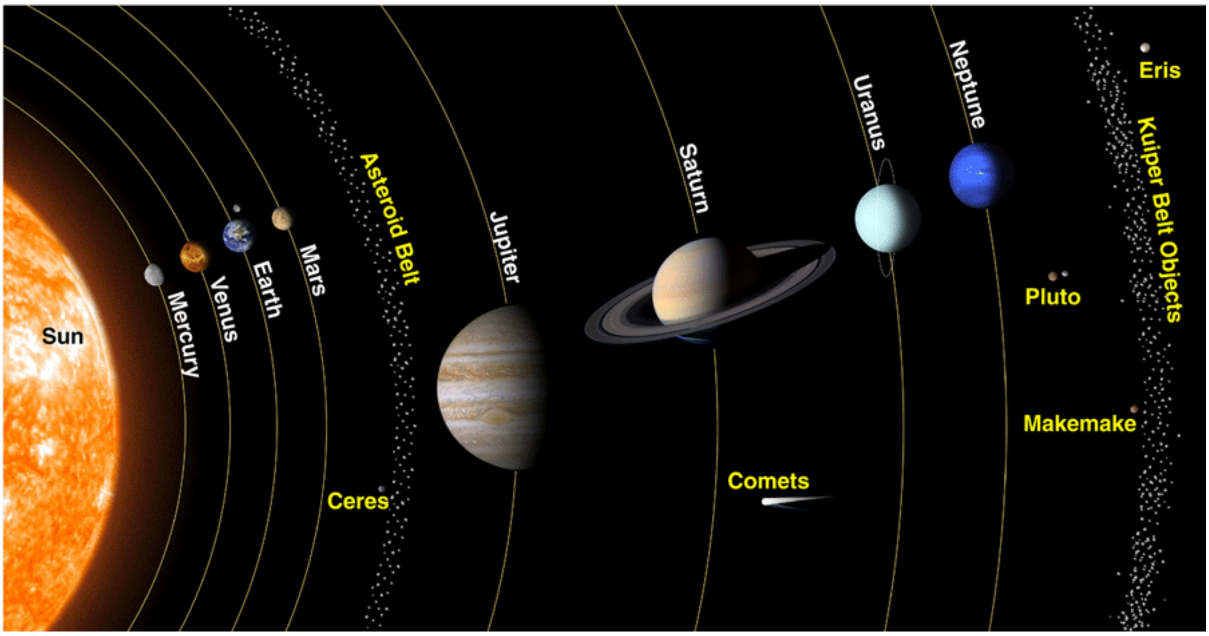
Samyak
An Institute For Civil Services

LECTURE 1 – UNIVERSE AND GEOMORPHOLOGY

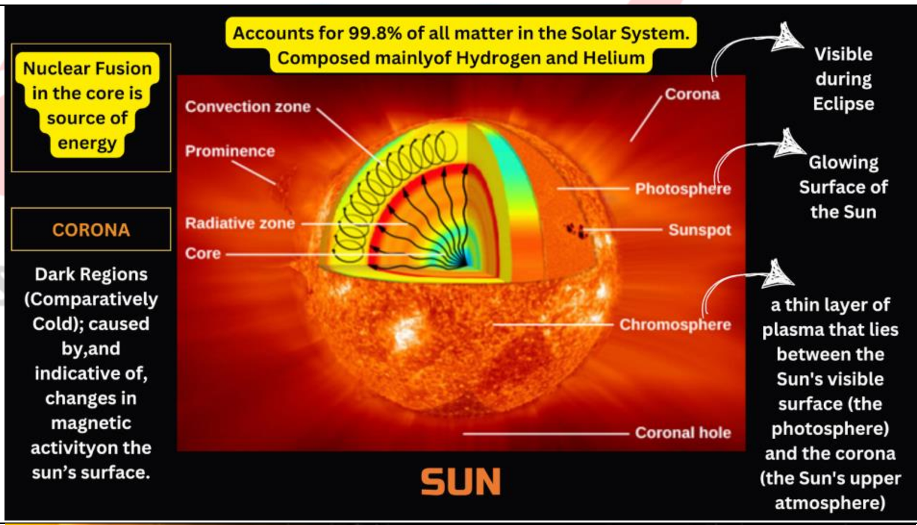
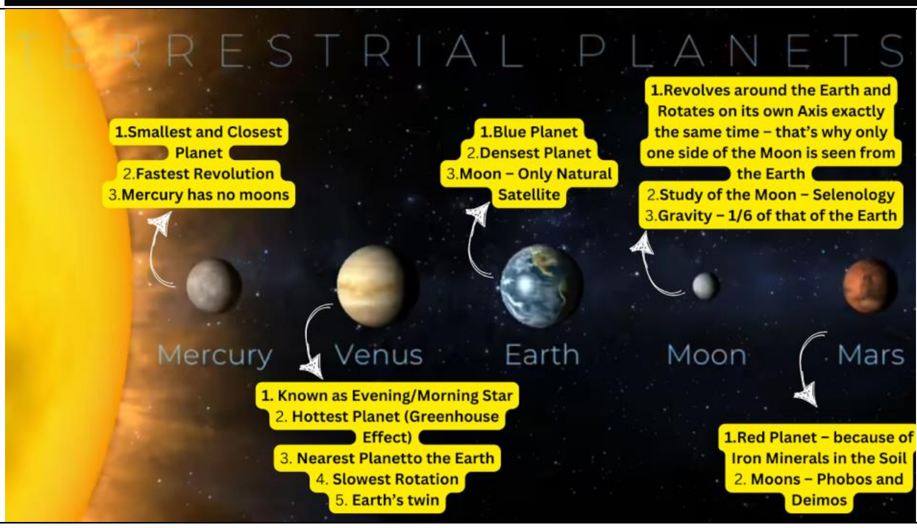
SOLAR SYSTEM

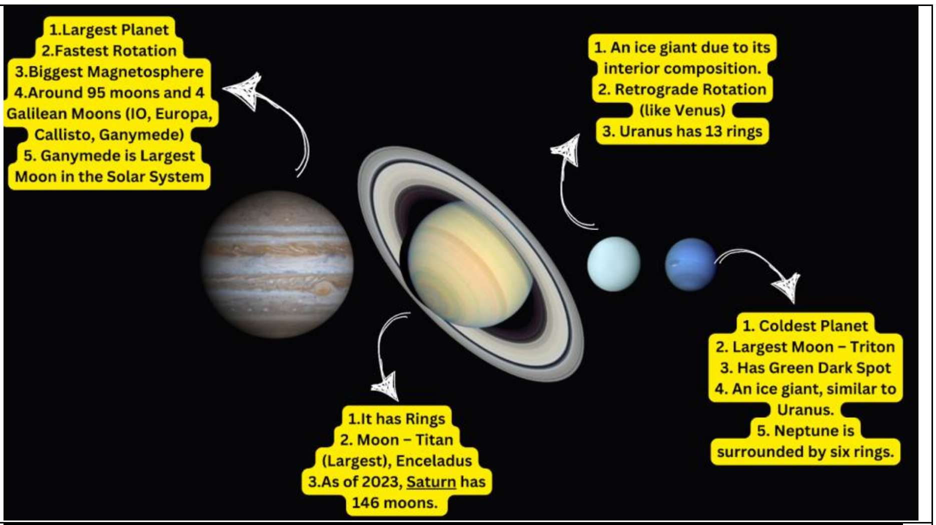
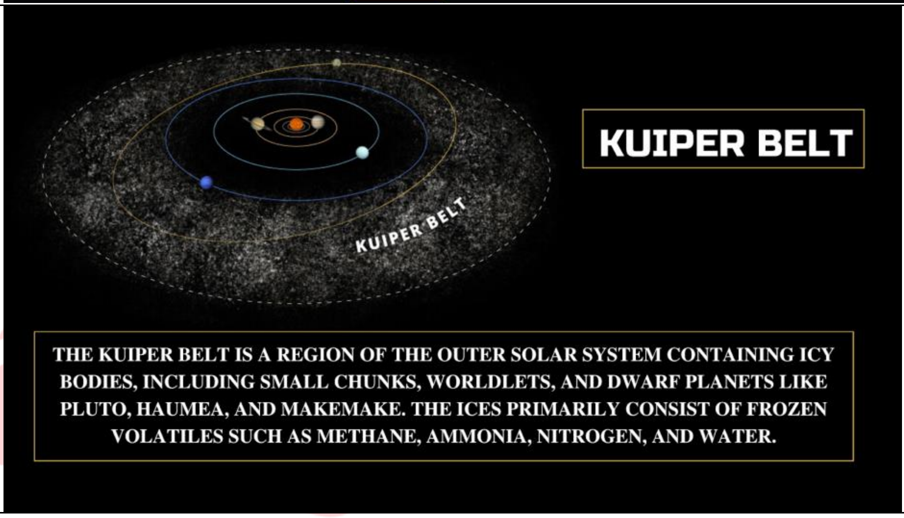


Characteristics	Terrestrial Planets	Jovian Planets
Planets	Mercury, Venus, Earth and Mars	Jupiter, Saturn, Uranus, Neptune
Distance from one Planet to the Next	Closely Spaced Orbits	Widely Spaced Orbits
Density	Highly Dense	Less Dense
Rotation	Slower	Faster
Atmosphere	Thin or no Atmosphere	Thick
Composition	Rocky and Metallic	Gaseous
Size	Small Masses and Radii	Large Masses and Radii
Magnetic Field	Weak	Strong
Moons	Few	Many



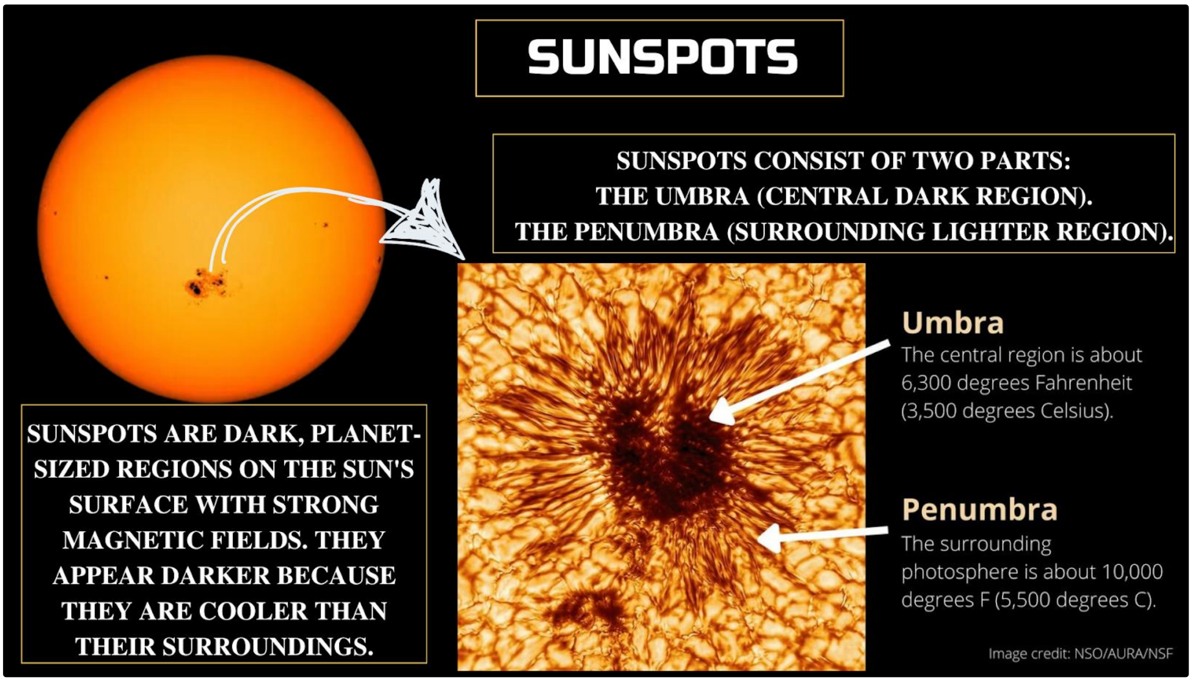
FACTS ABOUT SOLAR SYSTEM

Celestial Bodies	Features
Sun	
Terrestrial Planets	

Jovian Planets	
Kuiper Belt	

Solar storms occur when the Sun releases massive bursts of energy in the form of solar flares and coronal mass ejections. These occurrences propel a flow of electrical charges and magnetic fields towards Earth, hurtling at a velocity of around three million miles per hour.

Upon impact with Earth, a solar storm frequently **generates a captivating exhibition of "northern lights"** in specific regions of the atmosphere, visible in proximity to the Arctic Circle. Furthermore, solar storms have the potential to **interfere with satellites** and diverse types of **electronic communication**.



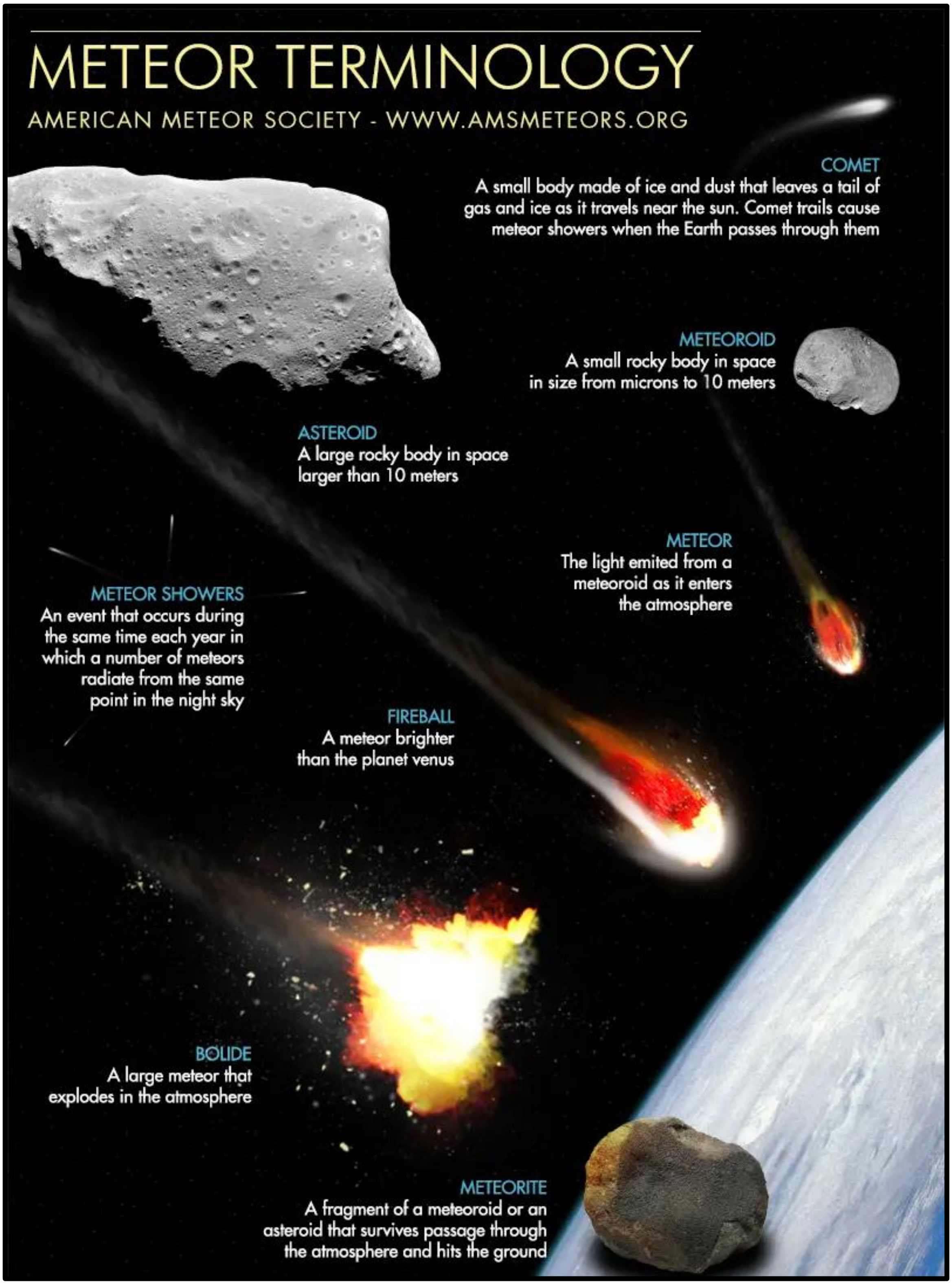
ASTEROIDS/METEOROID/COMETS

Asteroids	➢ Solid, Rocky and irregular Bodies – leftover of a Planet ➢ Lies between the orbit of **Mars and Jupiter**
Meteoroid	➢ Smaller **disintegrated** element of comet or asteroid.
Meteor	➢ Meteoroids **break down in the earth's atmosphere** which results in the flash of light known meteors.
Meteorite	➢ Meteor which doesn't burn in the atmosphere completely and land on the earth.
Comets	➢ Made of dust, rocks, and ice ➢ Their tail points away from the Sun.
Dwarf Planets	➢ A 'dwarf planet' is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, (c) has not cleared the neighborhood around its orbit, and (d) is not a satellite ➢ E.g. Pluto, Ceres, Eris, Makemake, Haumea

THE NEW DEFINITION OF PLANET

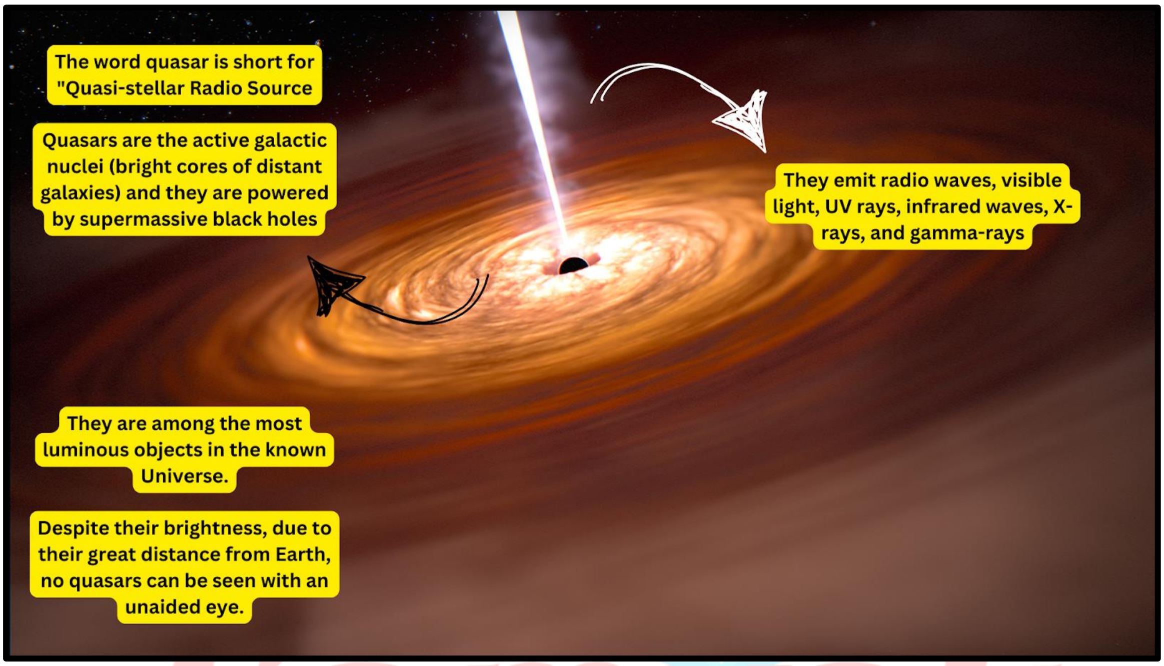
As per the IAU planets and other bodies, except satellites, in our Solar System be defined into three distinct categories in the following way

1. A planet is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighborhood around its orbit.

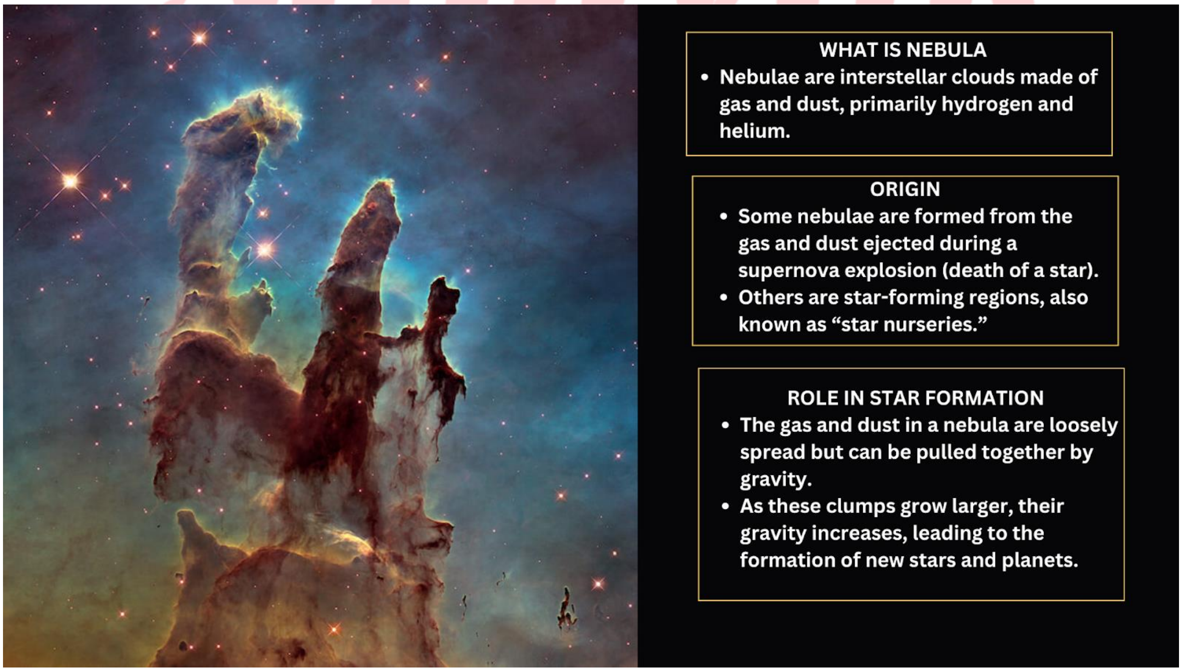

METEOR TERMINOLOGY
AMERICAN METEOR SOCIETY - WWW.AMSMETEORS.ORG
COMET
A small body made of ice and dust that leaves a tail of gas and ice as it travels near the sun. Comet trails cause meteor showers when the Earth passes through them
METEOROID
A small rocky body in space in size from microns to 10 meters
ASTEROID
A large rocky body in space larger than 10 meters
METEOR
The light emited from a meteoroid as it enters the atmosphere
METEOR SHOWERS
An event that occurs during the same time each year in which a number of meteors radiate from the same point in the night sky
FIREBALL
A meteor brighter than the planet venus
BOLIDE
A large meteor that explodes in the atmosphere
METEORITE
A fragment of a meteoroid or an asteroid that survives passage through the atmosphere and hits the ground

OTHER IMPORTANT COMPONENTS

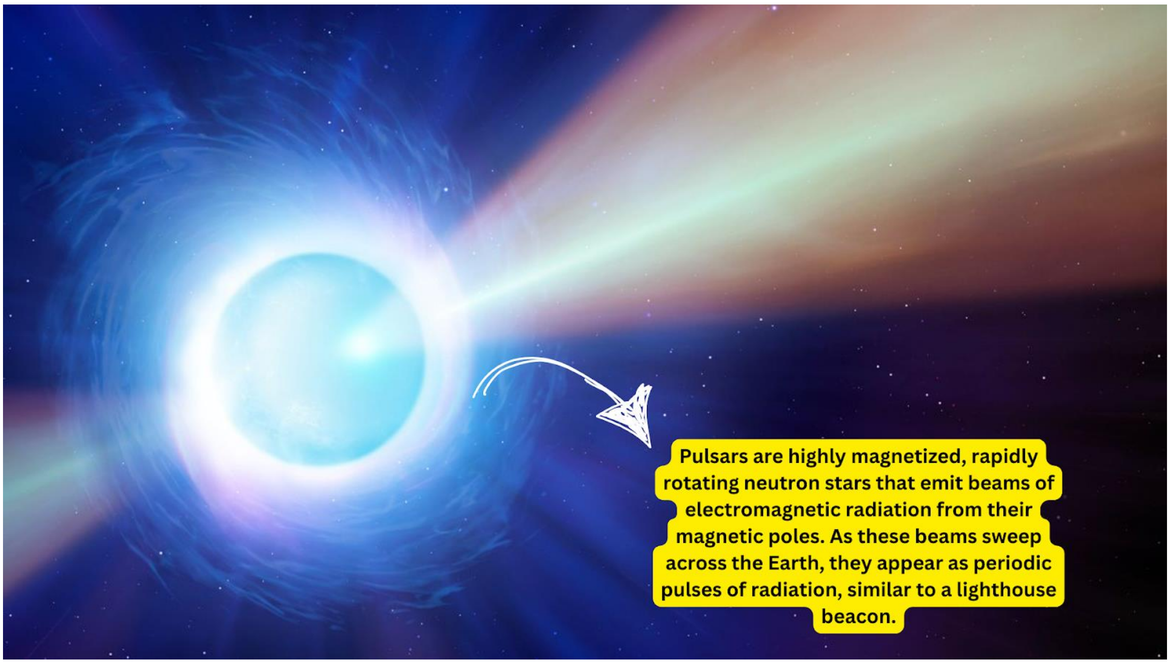
QUASARS



NEBULA

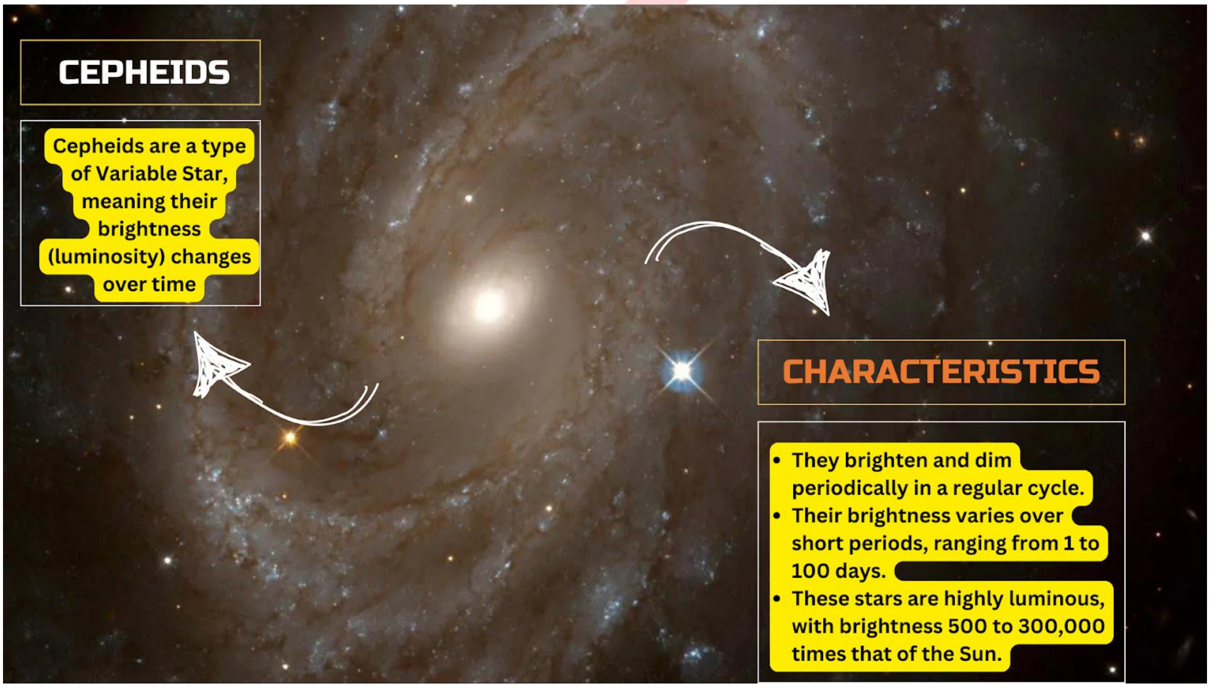


PULSARS



Sagittarius A* is a supermassive black hole located at the center of our spiral galaxy the Milky Way. Sagittarius A* is mostly dormant and only occasionally absorbs gas or dust but nonetheless has an estimated mass millions times that of our sun

CEPHEIDS



ABOUT EARTH

SIZE AND SHAPE OF THE EARTH – OBLATE SPHEROID/GEOID

- **Geodesy** is the science that studies the shape and size of the Earth.
- The Earth is nearly spherical but slightly flattened at the poles and bulging at the equator. This shape is known as an **oblate spheroid** due to the unequal equatorial and polar radii. The rotation of the Earth on its axis causes the equatorial bulge.
- **Centrifugal Force----- > Earth is bulged out at equator and flattered at poles**

Earth has Oblate Spheroid Shape

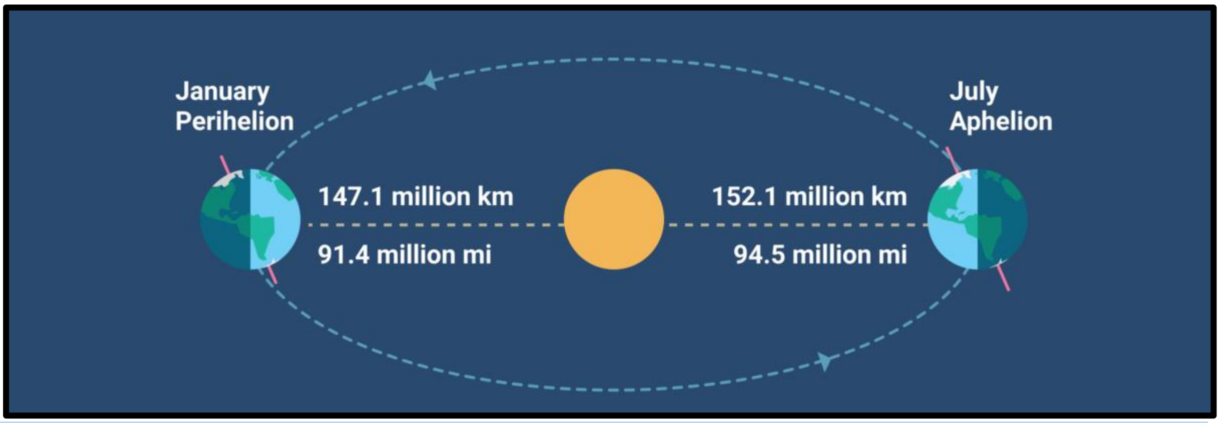
MOTIONS OF THE EARTH

- The Earth is constantly in motion, **revolving around the Sun and rotating on its axis.**

Motions of the Earth	Meaning	Features
Rotation	➢ Circular movement of the Earth around its axis. ➢ Earth Rotates from West to East and has **23.45° tilt of axis.**	➢ **Mean Solar Day** – 24 hours ➢ **Sideral Day** – 23 hours, 56 minutes and 4 seconds ➢ **Causes Day and Nights** ➢ The circle that divides the day from night on the globe is called the **circle of illumination.**
Revolution	➢ Movement of the Earth around the Sun in a counter clockwise direction.	➢ **Solar Year** – 365.25 days to revolve. ➢ The orbit of the Earth around the sun is **elliptical** ➢ Cause change in **Seasons.**

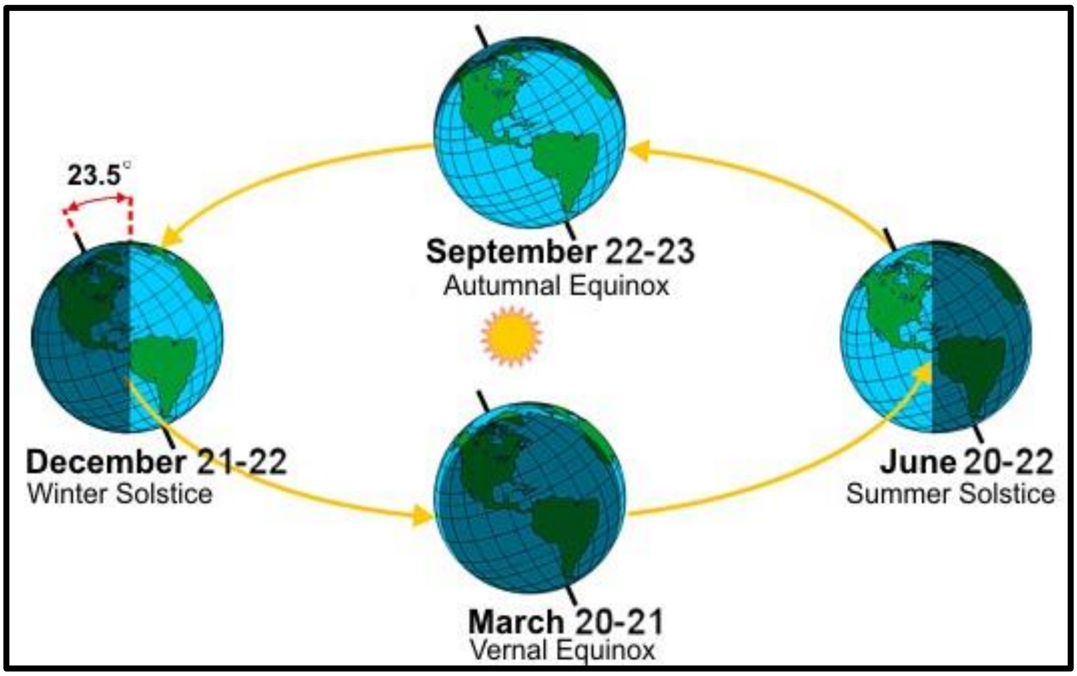
PERIHELION AND APHELION

- Because orbit of the Earth around the Sun is Elliptical.
- **Perihelion - When this distance between Earth and the Sun is minimum** (around January 3)
- **Aphelion -** When the **distance is the maximum** (around July 4).



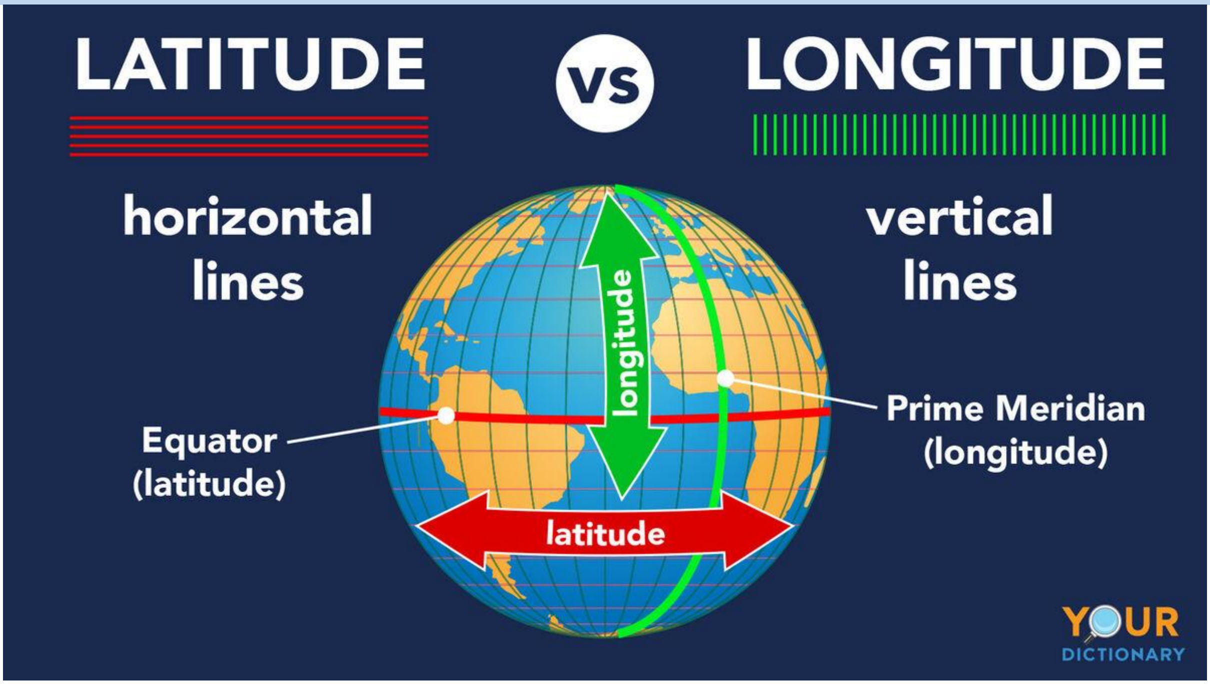
EQUINOXES AND SOLSTICES

- As Earth revolves around the Sun, E**arth attains four critical positions with reference to the sun.**



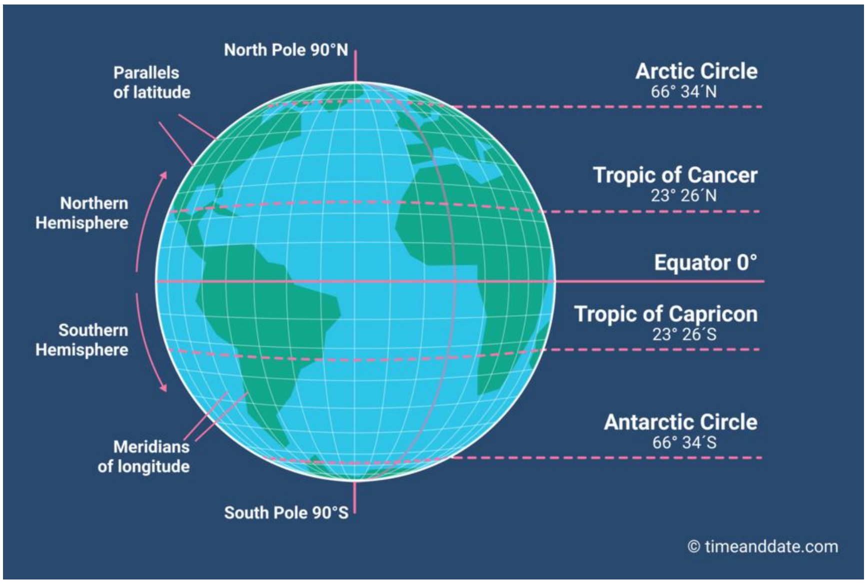
EQUINOXES	SOLSTICES
➢ Sun Rays fall **vertically over Equator**	➢ Sun Rays fall **vertically over Tropics**
➢ **Spring Equinox** – March21st ➢ **Autumnal Equinox** – September 23rd	➢ **Winter solstice** on December22 – Sun rays vertically over Tropics of Capricorn ➢ **Summer solstice** on June 21 – Sun rays vertically over Tropic of Cancer
➢ **Equal duration of day and night at all latitudes**	➢ **Summer Solstice** – Longest day in Northern Hemisphere ➢ **Winter Solstice** – Longest Day in Southern Hemisphere.

LATITUDE AND LONGITUDE



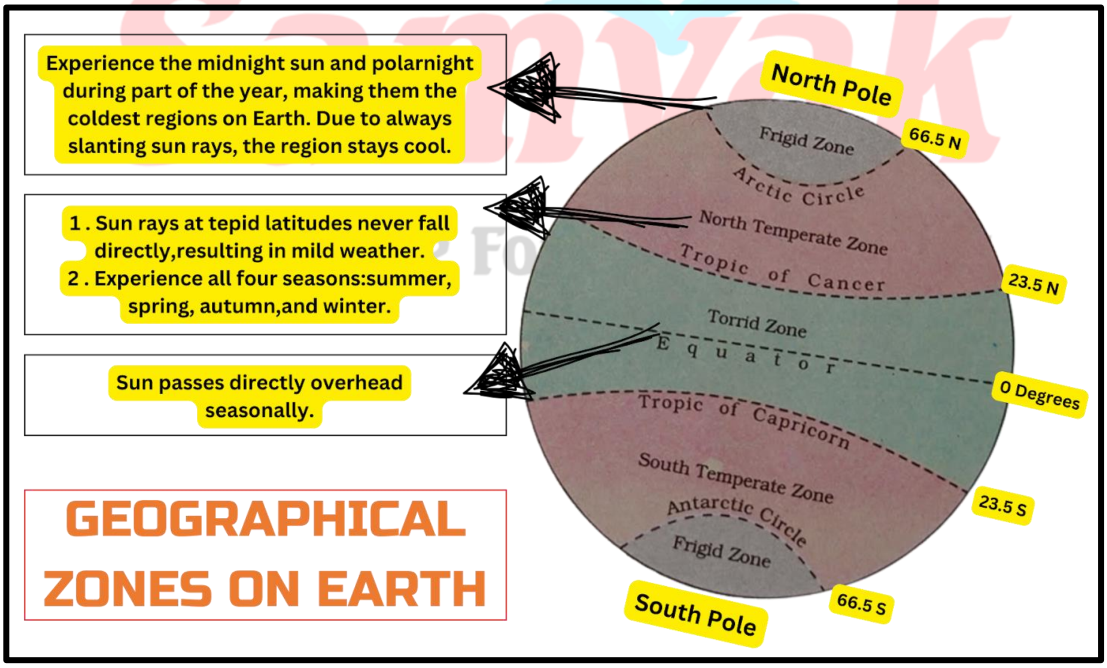
- **Latitude** is the imaginary horizontal lines drawn parallel to the equator, running in an east-west direction on the Earth's surface
    - Measure the distance north or south of the equator in degrees (°).
    - The Equator (0° latitude) divides the Earth into the Northern Hemisphere and Southern Hemisphere.
    - Helps to determine climate zones and the location of places on Earth's surface
- **Longitude** is the imaginary vertical lines drawn from the North Pole to the South Pole, converging at the poles.
    - It measure the distance east or west of the Prime Meridian (0° longitude) in degrees.
    - The Prime Meridian runs through **Greenwich**, England, and divides the Earth into the **Eastern Hemisphere and Western Hemisphere.**
    - There are 180 vertical east longitudes of the Prime Meridian and 180 vertical west longitudes of the Prime Meridian.
- **Parallels of Latitude:** The parallels of latitude refer to the angular distance, in degrees, minutes and seconds of a point north or south of the Equator. Lines of latitude are often referred to as parallels.
- **Meridians of Longitude:** The meridians of longitude refer to the angular distance, in degrees, minutes, and seconds, of a point east or west of the Prime (Greenwich) Meridian. Lines of longitude are often referred to as meridians.

MAJOR PARALLEL OF LATITUDES

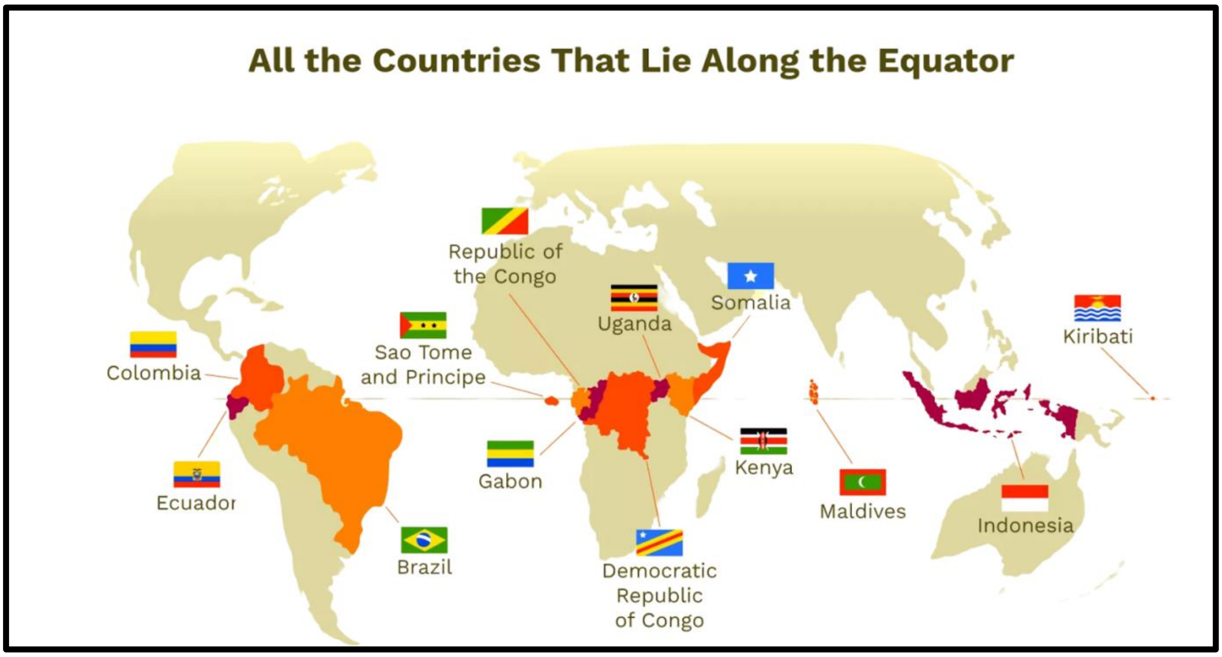


GEOGRAPHICAL ZONES ON EARTH

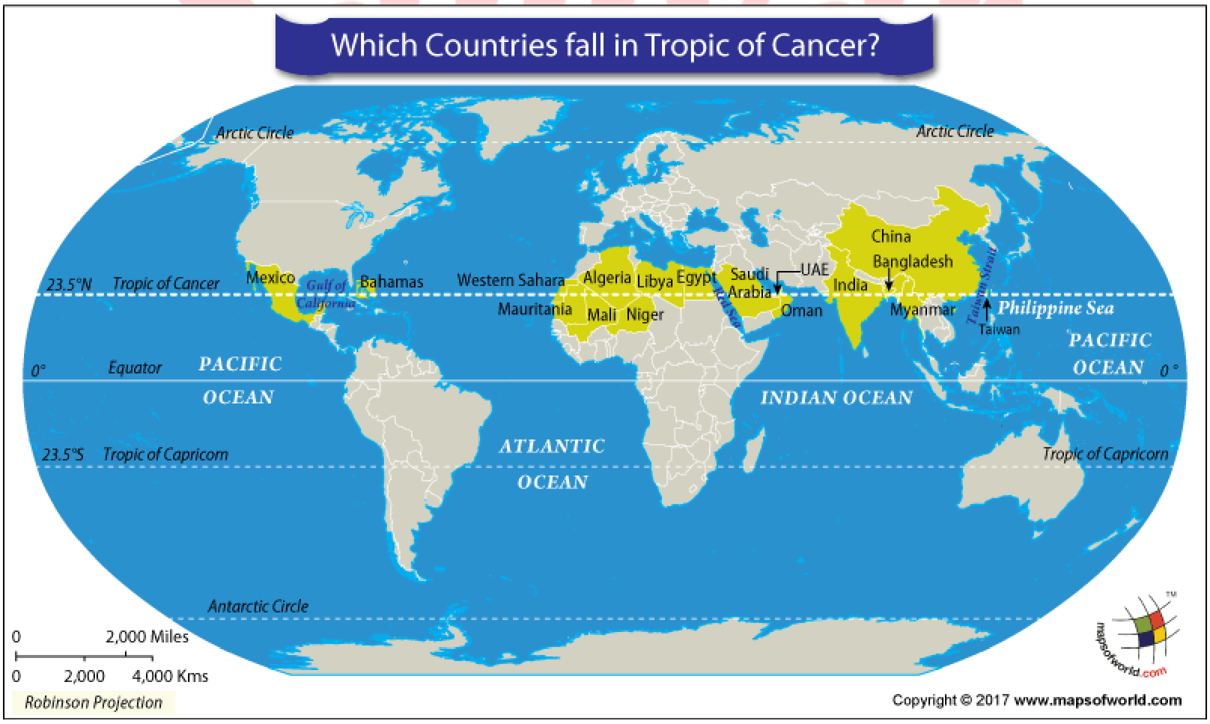
➢ The Geographical zones are also identified on the basis of Latitudes



MAJOR LATITUDES:



COUNTRIES THAT LIE ON TROPIC OF CANCER AND CAPRICORN



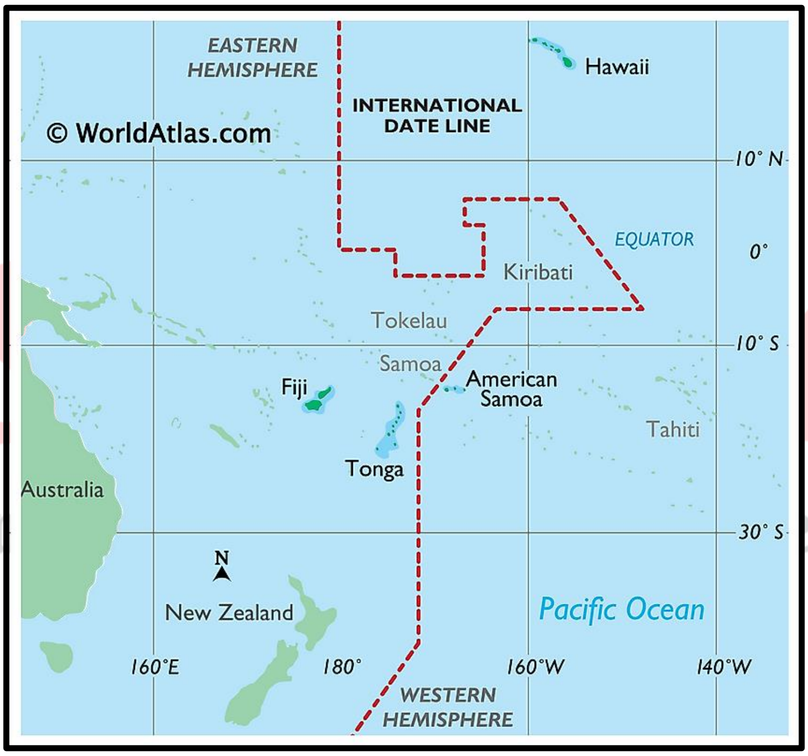
LONGITUDE AND TIME

- The Earth takes 24 hours to complete one Rotation. And, longitudes are 360 in number. Thus, the earth rotates 1-longitudnal degree in four minutes or 15-degree of Longitude per hour.
- The calculation of time stands like this: When it is noon at Greenwich, time at 15-degree east of Greenwich will be (15*4=60 minutes) which is 1 hour ahead of Greenwich Time.

- Earth is divided into twenty-four time zones of one hour each and Each zone Covers 15° of longitude.

STANDARD TIME AND TIME ZONES

- To keep uniform the time range in all the territorial limits of the country, the central meridian is regarded as the Standard Meridian whose local time is considered as the standard time for the whole country.
- In India, the longitude of 82½° E (82° 30′ E) is treated as the standard meridian. The local time at this meridian is taken as the standard time for the whole country. It is known as the Indian Standard Time (IST) which is 5 hours 30 mins, ahead of Greenwich Mean Time.
- The larger country like the USA, Canada, and Russia which have a great east-west stretch, it would be difficult to follow a single time zone, therefore, these countries have to adopt several time zones for a practical purpose.
- Country with maximum number of time Zones – France



INTERIOR OF THE EARTH

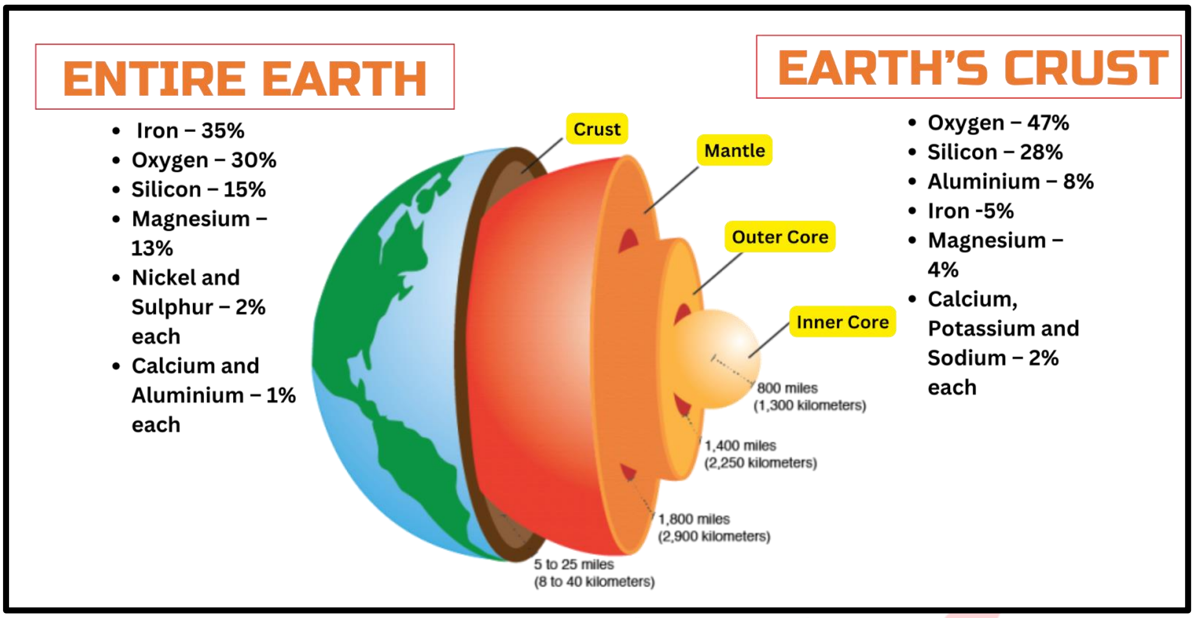
SOURCES TO STUDY THE EARTH'S INTERIOR

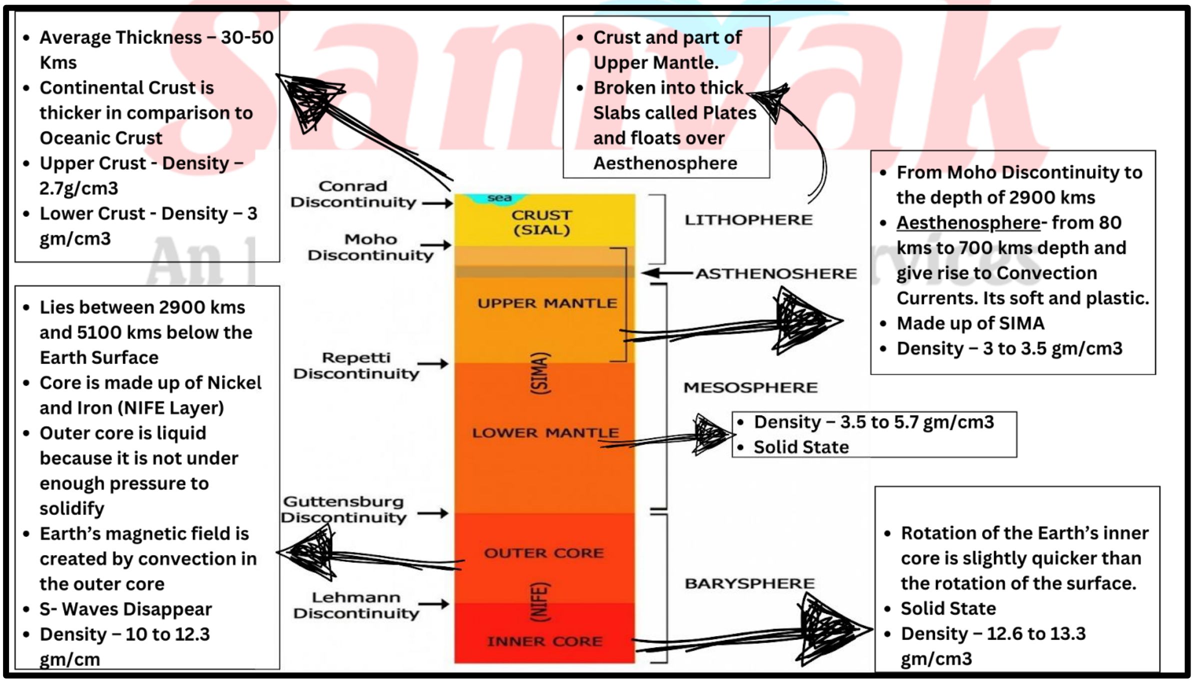
The sources which provide knowledge about the interior of the earth may be classified into 2 sources-

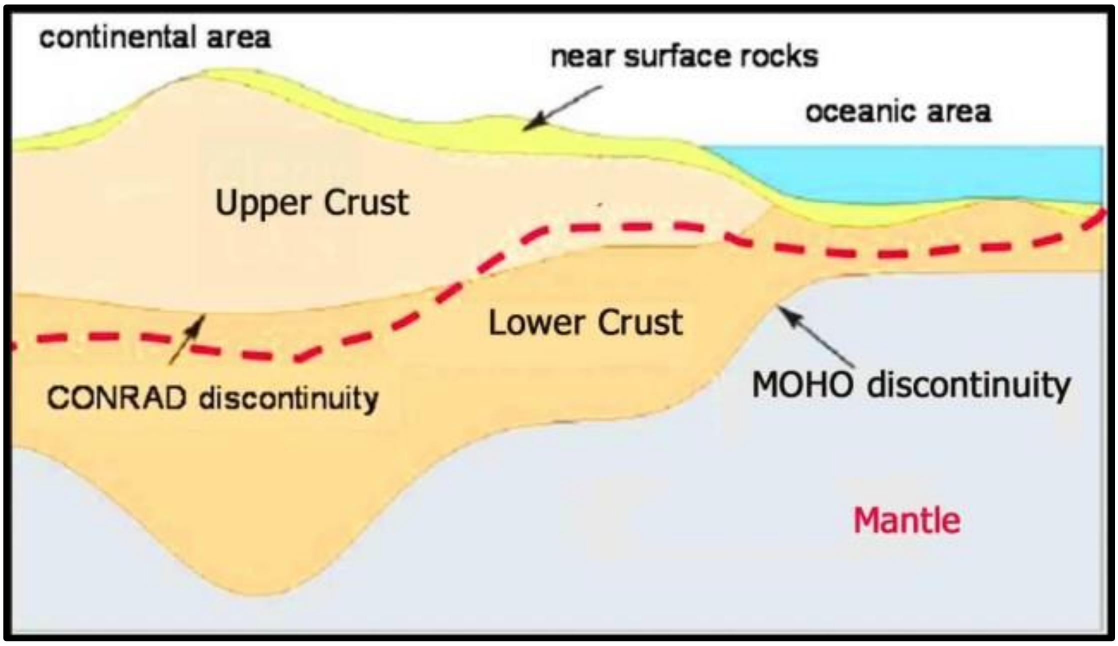
Direct Sources	Indirect Sources
➢ Surface rock ➢ Volcanos ➢ Mining Projects ➢ Drilling Projects ➢ Deep Ocean Drilling Project ➢ Integrated Ocean Drilling Project	➢ Temperature and pressure variation – Temperature and Pressure increases with Depth ➢ Seismic activities ➢ Meteorites ➢ Gravitation ➢ Magnetic field

STRUCTURE OF EARTH'S INTERIOR

The structure of the earth's interior is made up of several concentric layers. Structure of Interior Of the Earth is divided into three layers-







SEISMIC WAVES AND EARTH'S INTERIOR

- **Earthquake:** In simple words is shaking of the earth. It caused due to the release of energy due to folding and faulting
- **Seismic Waves –** Waves generated during an Earthquake that travel in all directions.
- An instrument called '**seismograph'** records the waves reaching the surface.
- The point where the energy is released is called the focus of an earthquake alternatively, it is called the **Hypocenter.**
- The energy waves traveling in different directions reach the surface. The point on the surface, nearest to the focus, is called the epicenter. It is the first one to experience the waves. It is a point directly above the focus.

THEORIES

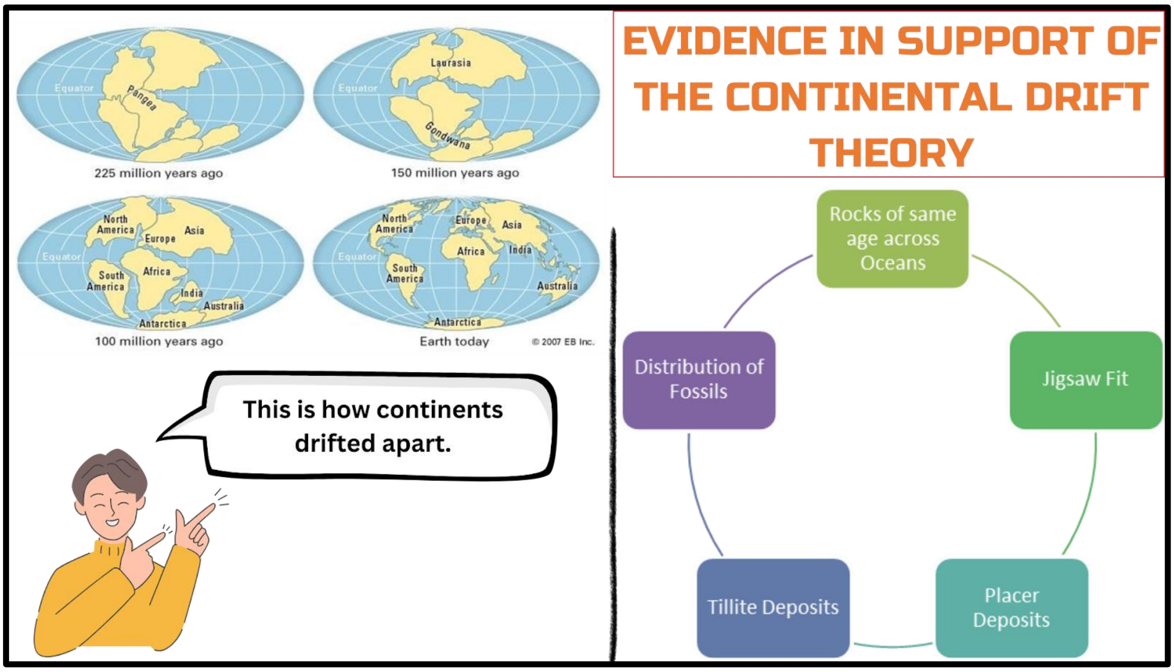
CONTINENTAL DRIFT THEORY

- **Continental Drift:** The movement of continents across the ocean bed is known as continental drift. This drifting takes millions of years to complete this process.
- Given by - **Alfred Wegener**

VARIOUS STAGES OF CONTINENTAL DRIFT THEORY

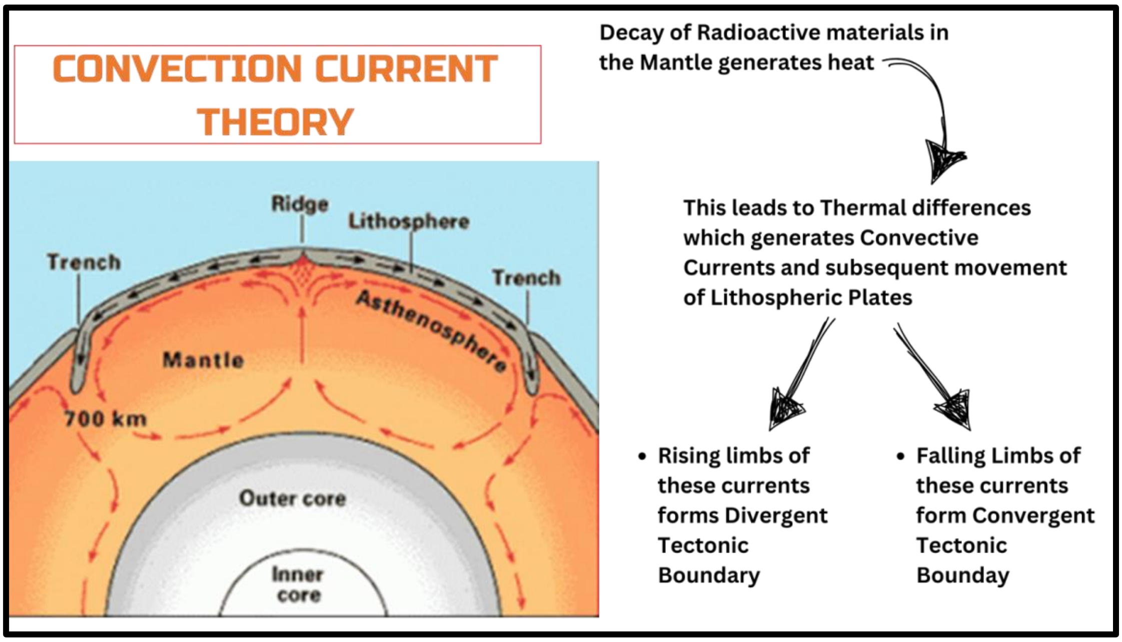
Stages	What happened
First Stage	➢ Occurred during the **Carboniferous period.** ➢ **Pangea, a supercontinent**, was encircled by **Panthalassa, a mega-ocean.**
Second Stage	➢ Occur around 200 million years ago in the **Jurassic period**. ➢ The supercontinent, Pangaea, began to split. ➢ Pangaea first broke into large continental masses as **Laurasia and Gondwanaland** forming the northern and southern components respectively.
Third Stage	➢ **During Mesozoic Epoch** ➢ **Tethys Sea** progressively filled the area between Laurasia and Gondwanaland during the Mesozoic epoch
Fourth Stage	➢ around 100 million years ago **when North and South America drifted westward**, resulting in the **emergence of the Atlantic Ocean**. ➢ The **Rockies and Andes were formed** by the westward drift of North and South America.
Fifth Stage	• The **Orogenetic Stage** in which mountain-building activity took place is the fifth stage.
FORCES RESPONSIBLE FOR CONTINENTAL DRIFT	
For Equator ward Movement	➢ **Gravitational Force, Pole – Fleeing Force and Buoyancy Force** because Earth is not perfectly round and has a bulge at the Equator ➢ Pole-Fleeing force is because of increase in Centrifugal Force from the Poles towards the Equator
For Westward Movement	➢ **Tidal Currents** caused because of Earth's Movements

- However, these forces were later discovered to be insufficient.



CONVECTION CURRENT THEORY

- The **Convection Current Theory**, proposed by **Arthur Holmes in the 1930s**, attempted to explain the force driving **continental drift** and **plate tectonics**. He suggested that **heat-driven currents in the Earth's mantle** move the continents over time.
- **Convection currents** occur due to heat differences in a fluid, leading to continuous circulation.
- In the mantle, these currents arise due to heat from radioactive decay, creating density variations in molten rock.
- These currents move slowly, reshaping Earth's surface over millions of years.



SIGNIFICANCE OF THE CONVECTION CURRENT THEORY

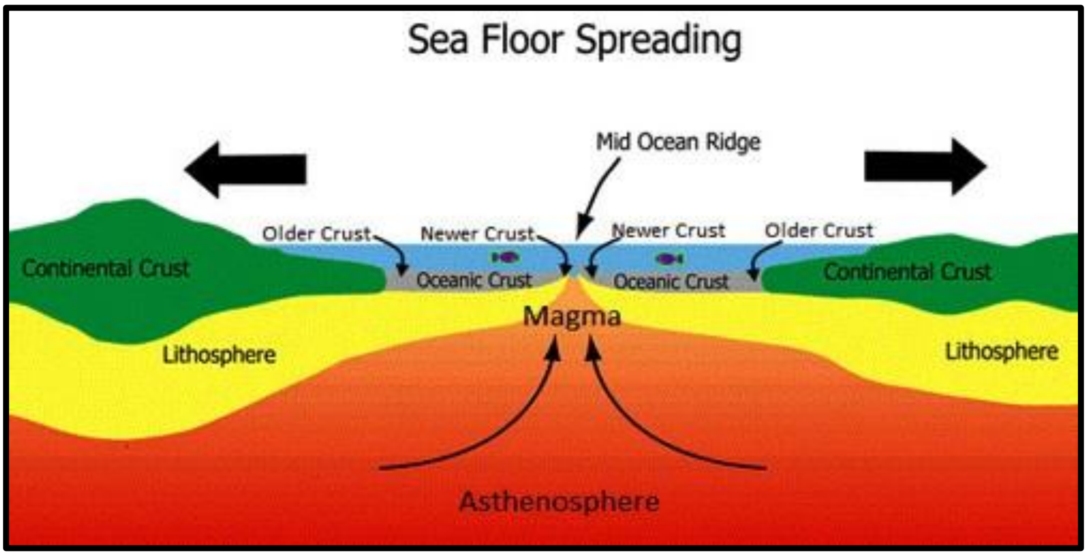
- **Explains Plate Tectonics**: Provides a **mechanism for continental drift** and **plate movement**.
- **Predicts Geological Events**: Helps forecast **earthquakes** and **volcanic eruptions**.
- **Explains Geological Features**: Accounts for **mountains, ocean trenches, and mid-ocean ridges**.
- **Aids Earth Science**: Enhances understanding of **mantle and core processes**.
- **Influences Climate & Weather**: Affects **heat distribution** on Earth's surface.

CRITICISMS OF THE CONVECTION CURRENT THEORY

- **Dependence on Unknown Factors**: Early 20th-century knowledge of **mantle dynamics** was limited.
- **Doubt on Heat Source**: Questions about whether **radioactive decay alone** provides enough energy.
- **Weakness of Horizontal Flow**: Some argue that horizontal **convection currents** beneath continents **lack sufficient heat**.
- **Metamorphism & Density Issues**: Debate over whether **sinking rocks** become **dense enough** to drive convection.
- **Selective Origination of Currents**: Uneven distribution of convection cells raises questions about **why currents originate in specific regions**.

SEA-FLOOR SPREADING THEORY

- **Given By – Harry Hess**
- Seafloor spreading is a process that occurs at mid-ocean ridges, where **new oceanic crust is formed** through volcanic activity and then gradually moves away from the ridge.
- The tectonic Plates move because of Convection Current in the mantle.
- Wherever **rising limbs** of these currents meet, **oceanic ridges** are formed on the seafloor and, wherever the **failing limbs meet, trenches are formed.** This Adds new material to the ocean floor while pushing older rocks away from the ridge.
- New ocean floor forms along cracks in the ocean crust as molten material erupt from the mantle spreading out and pushing older rocks to the sides of the crack.
- The **new ocean floor is continually added by the process of sea-floor spreading**.



WHY IS SEAFLOOR SPREADING SIGNIFICANT?

- **Influences Sea Levels**: Faster spreading leads to **higher sea levels**, while slower spreading causes **sea levels to drop**.
- **Affects Carbon Cycle**: Increased spreading releases **volcanic gases**, influencing **global climate**.
- **Supports Marine Life Studies**: Helps understand deep-sea **ecosystems and hydrothermal vent communities**.

EARTH'S MAGNETIC FIELD

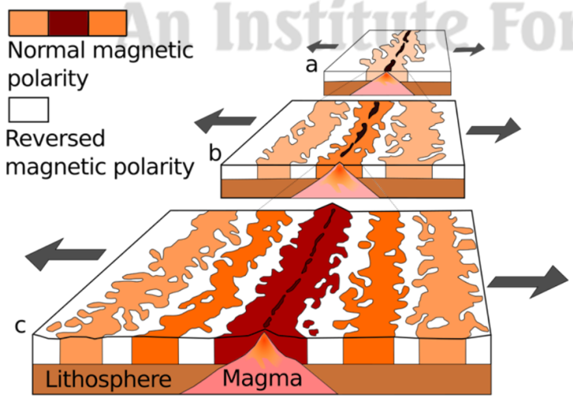
- The Earth's magnetic field is a fundamental feature that influences various natural and technological processes. It plays a key role in protecting the planet and supporting navigation.

GENERATION OF EARTH'S MAGNETIC FIELD

- The Earth's magnetic field is primarily produced by the movement of molten iron and nickel in the outer core, a process known as the geodynamo.
- This movement is driven by the heat from radioactive decay and the cooling of the core.

MAGNETIC POLARITY

- The Earth has a north and south magnetic pole, similar to a bar magnet, but they do not perfectly align with the geographic poles.
- Over geological time, these poles shift and sometimes reverse, a phenomenon recorded in rocks as magnetic striping.



PALEOMAGNETISM

- Paleomagnetism is the study of Earth's ancient magnetic fields as recorded in rocks, sediments, and archaeological materials. It provides critical insights into the history of Earth's geomagnetic field, plate tectonics, and even planetary science.

HOW IT WORKS?

- Certain magnetic minerals in rocks retain the direction and intensity of Earth's magnetic field at the time of their formation.
- This magnetic record helps scientists understand geomagnetic reversals and the movement of tectonic plates over time.
- Volcanic and sedimentary rocks preserve magnetic signals that are used in magnetostratigraphy, a geochronological tool for dating rock sequences.

ABOUT THE PROCESS

- Mid Oceanic Regions are region of divergent Plate Boundaries where Sea-Floor is spreading.
- The fissure or vent (in between the ridge) between the plates allowed the magma to rise and harden into a long narrow band of rock on either side of the vent.
- Rising magma which is made up of Basalt (contains magnetic minerals) assumes the polarity of Earth's geomagnetic field at the time before it solidifies on the oceanic crust.

- As the conventional currents pull the oceanic plates apart, the solidified band of rock moves away from the vent (or ridge), and a new band of rock takes its place a few million years later when the magnetic field was reversed. This results in this magnetic striping where the adjacent rock bands have opposite polarities.
- This process repeats over and over giving rise to a series of narrow parallel rock bands on either side of the ridge and alternating pattern of magnetic striping on the seafloor.
- Paleomagnetic studies of rocks have demonstrated that the orientation of the earth's magnetic field has frequently alternated (geomagnetic reversal) over geologic time.
- Hence, paleomagnetic rocks (paleo: denoting rocks) provides the most important evidence to the concept of Sea Floor Spreading.

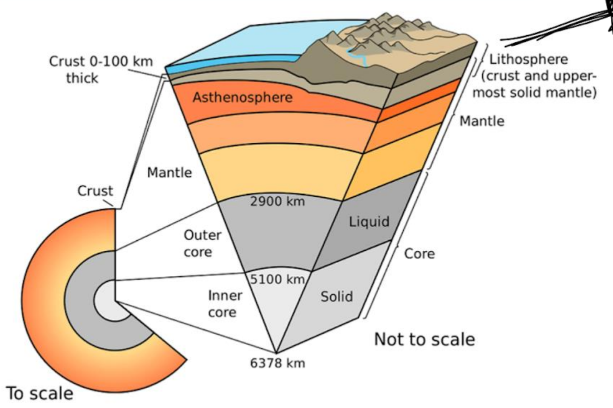
IMPORTANCE OF PALEOMAGNETISM IN PLATE TECTONICS

- **Revival of Continental Drift Hypothesis:** Evidence from paleomagnetism played a crucial role in the acceptance of **plate tectonics** as a modern scientific theory.
- **Apparent Polar Wander Paths:** These provided the first geophysical proof that **continents move** over time.
- **Seafloor Spreading:** Marine magnetic anomalies confirmed the process of **ocean floor expansion**, supporting the theory of **plate tectonics**.
- **Tracking Ancient Continents:** Paleomagnetic data helps reconstruct the **past positions and movements of continents** and **terranes (continental fragments)**.

PLATE TECTONIC THEORY

- The term plate tectonics was first used by **Tuzo Wilson**
- The Plate Tectonics theory was first published by W.J Morgan of the Princeton University in 1962.
- Plate tectonics is a scientific theory describing the large-scale motion of Major and Minor Plates
- This theory is based on the 2 principle hypothesis – Arthur Holmes convection current hypothesis, and the concept of seafloor spreading' advocated by Hess.

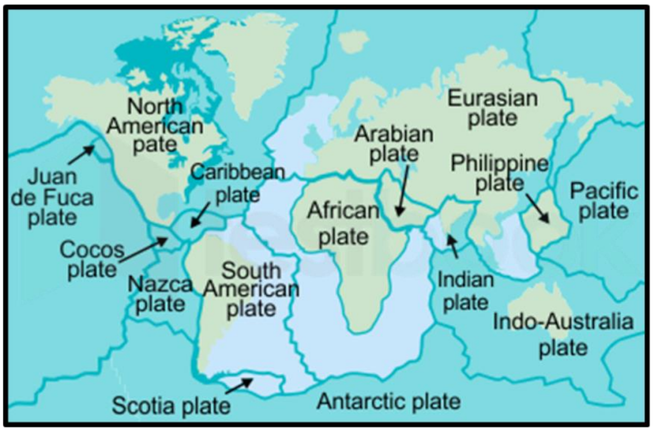
PLATE TECTONIC THEORY: BASICS



- **Lithosphere is divided into thick slabs called Plates which floats over Aesthenosphere because of Convection Current in the mantle.**
- **Plates can be classified into: Continental plates and Oceanic plates or combination of both Continental and Oceanic Plates.**
- **The Oceanic plates are denser in comparison to Continental Plates.**
- **Along the margins of the plates are the sites of considerable geologic activity such as seafloor spreading, volcanic eruptions, crustal deformation, mountain building, and continental drift and landforms development.**
- **La Pichon divided the earth into Seven Major and Nine Minor plates**

MAJOR TECTONIC PLATES

MAJOR TECTONIC PLATES



1. **Antarctica and the surrounding oceanic plate – (Surrounded by divergent boundaries.)**
2. **North American plate – (shifting westwards, It is half oceanic—half continental)**
3. **South American plate – (shifting westwards, Half continental — half oceanic)**
4. **Pacific plate – (Truly oceanic plate)**
5. **India-Australia-New Zealand plate**
6. **Africa with the eastern Atlantic floor plate**
7. **Eurasia and the adjacent oceanic plate – (mostly continental, shifting eastwards**

MALPELO PLATE

- It is a new tectonic micro plate off Ecuador's coast in the eastern Pacific Ocean.
- Malpelo microplate is located west of the Galapagos Islands off the coast of Ecuador.
- It is wedged in-between the Nazca, Cocos, and Caribbean minor plates.
- It is linked to a nearby oceanic ridge along the Ring of Fire.
- Earlier it was assumed that most of the region east of the known Panama transform fault was part of the Nazca plate.
- But recent study showed that it is different tectonic plate moving independently in a different direction.

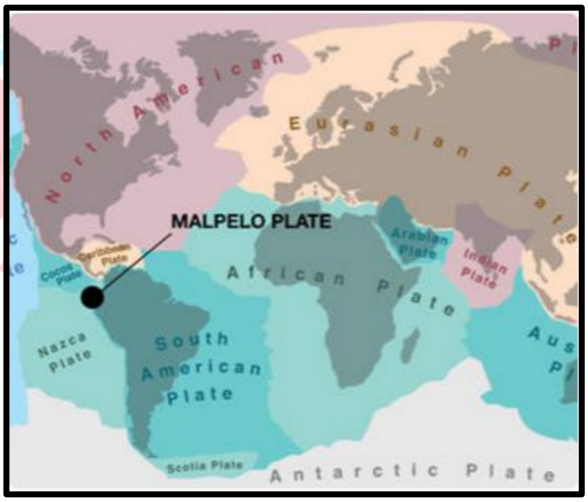
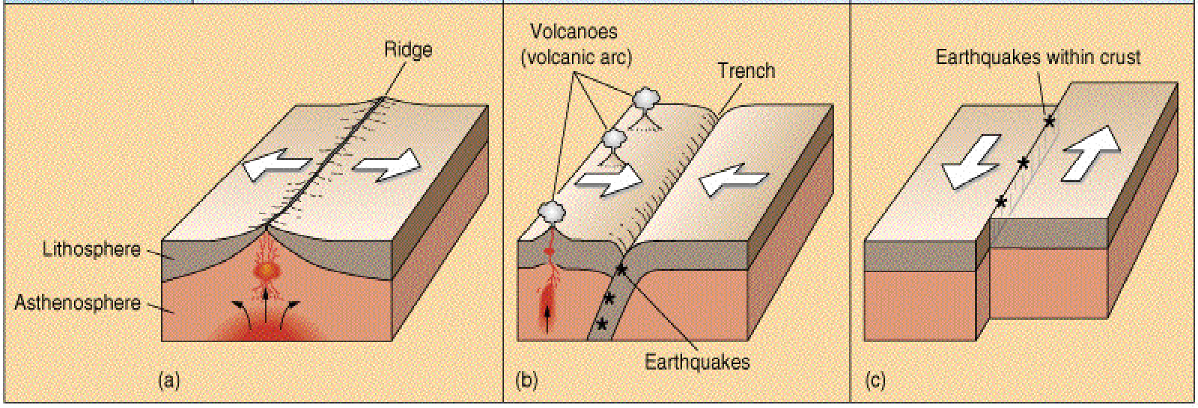


PLATE BOUNDARIES/MARGINS

Type of Margin	Divergent	Convergent	Transform
Motion	Spreading	Subduction	Lateral sliding
Effect	Constructive (oceanic lithosphere created)	Destructive (oceanic lithosphere destroyed)	Conservative (lithosphere neither created or destroyed)
Topography	Ridge/Rift	Trench	No major effect
Volcanic activity?	Yes	Yes	No

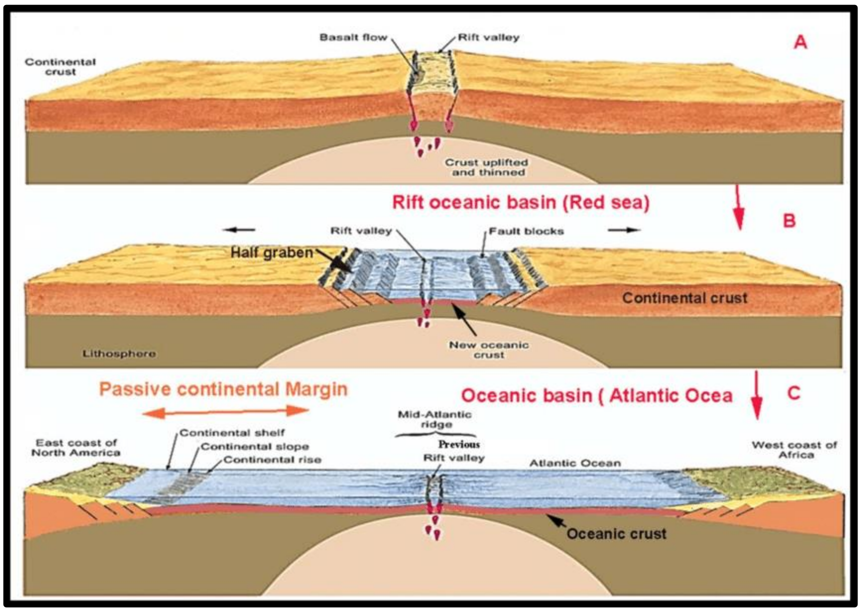


DIVERGENT BOUNDARIES

- A divergent boundary occurs when two tectonic plates move away from each other.
- Along these boundaries, lava gradually rises upwards from the mantle and solidifies into solid basalt, forming new crust at the edges of the plates.

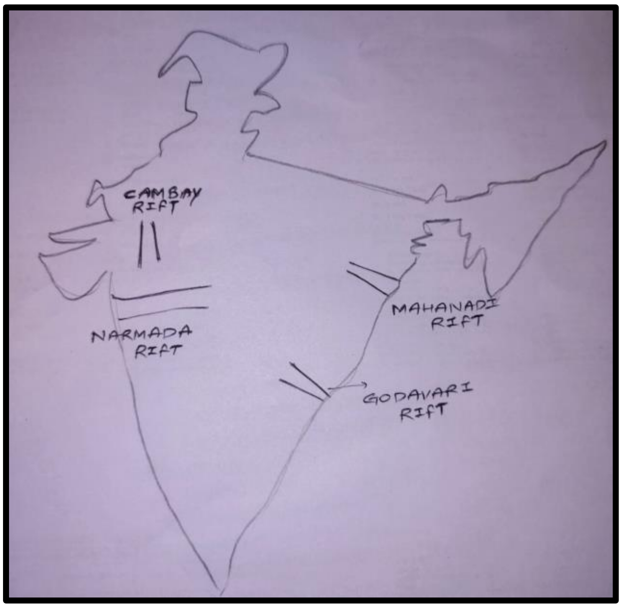
Features of Divergent Boundaries –

- Mid-ocean ridges
- Rift valleys
- Fissure volcanoes



CONTINENTAL RIFT VALLEYS

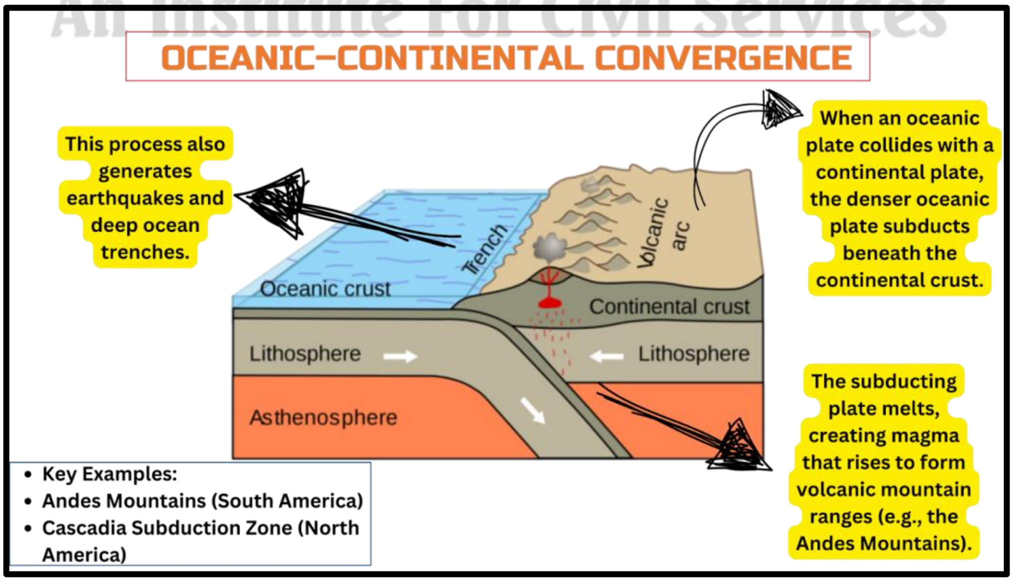
- Divergent boundaries can also develop within a continent resulting in a continental rift valley such as The East African Rift, the Baikal Rift Valley, the West Antarctic Rift, and the Rio Grande Rift



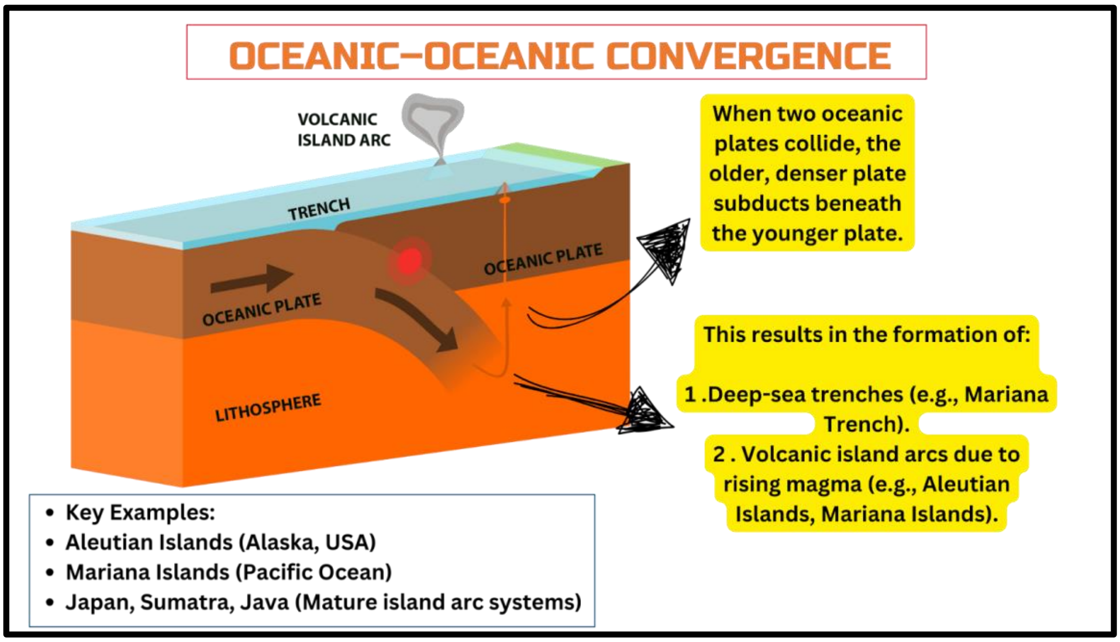
CONVERGENT BOUNDARIES

- When two plates move towards each other, it is known as a convergent boundary.
- **Subduction Zone**: When two Plates collide, the denser plate subducts beneath the lighter plate into the mantle where it begins to melt. The Sediments at the Plate margins buckled up, squeezed and folded to form Fold Mountains.
- Magma rises into and through the other plate, solidifying into new crust. Magma formed from melting plates solidifies into granite, a light colored, low-density rock that makes up the continents.Thus, at convergent boundaries, continental crust, made of granite, is created, and oceanic crust is destroyed.
- The three types of convergent boundaries are –
  - Oceanic–continental convergence,
  - Oceanic–oceanic convergence,
  - Continental–continental convergence.

OCEANIC–CONTINENTAL CONVERGENCE



OCEANIC–OCEANIC CONVERGENCE



CONTINENTAL-CONTINENTAL CONVERGENCE