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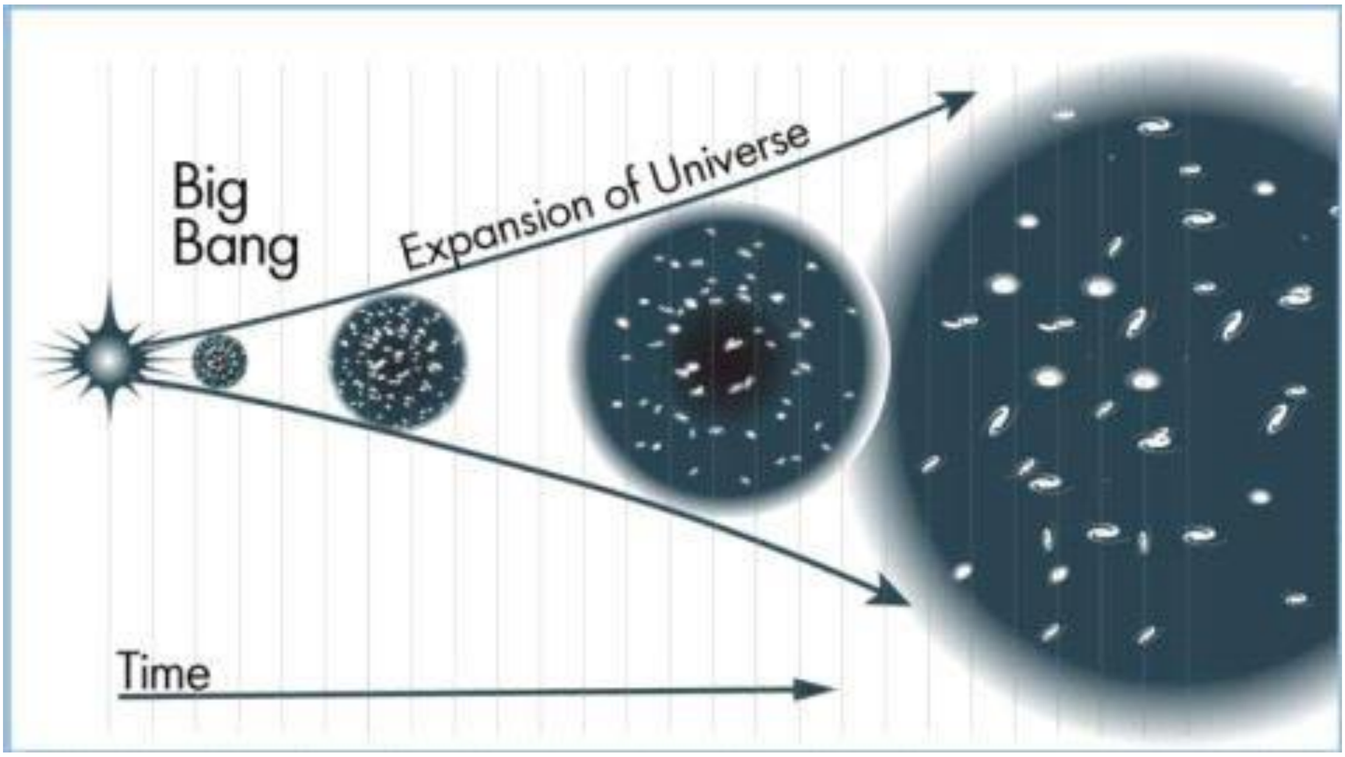
Solar System

Big Bang Theory or Expanding Universe Hypothesis

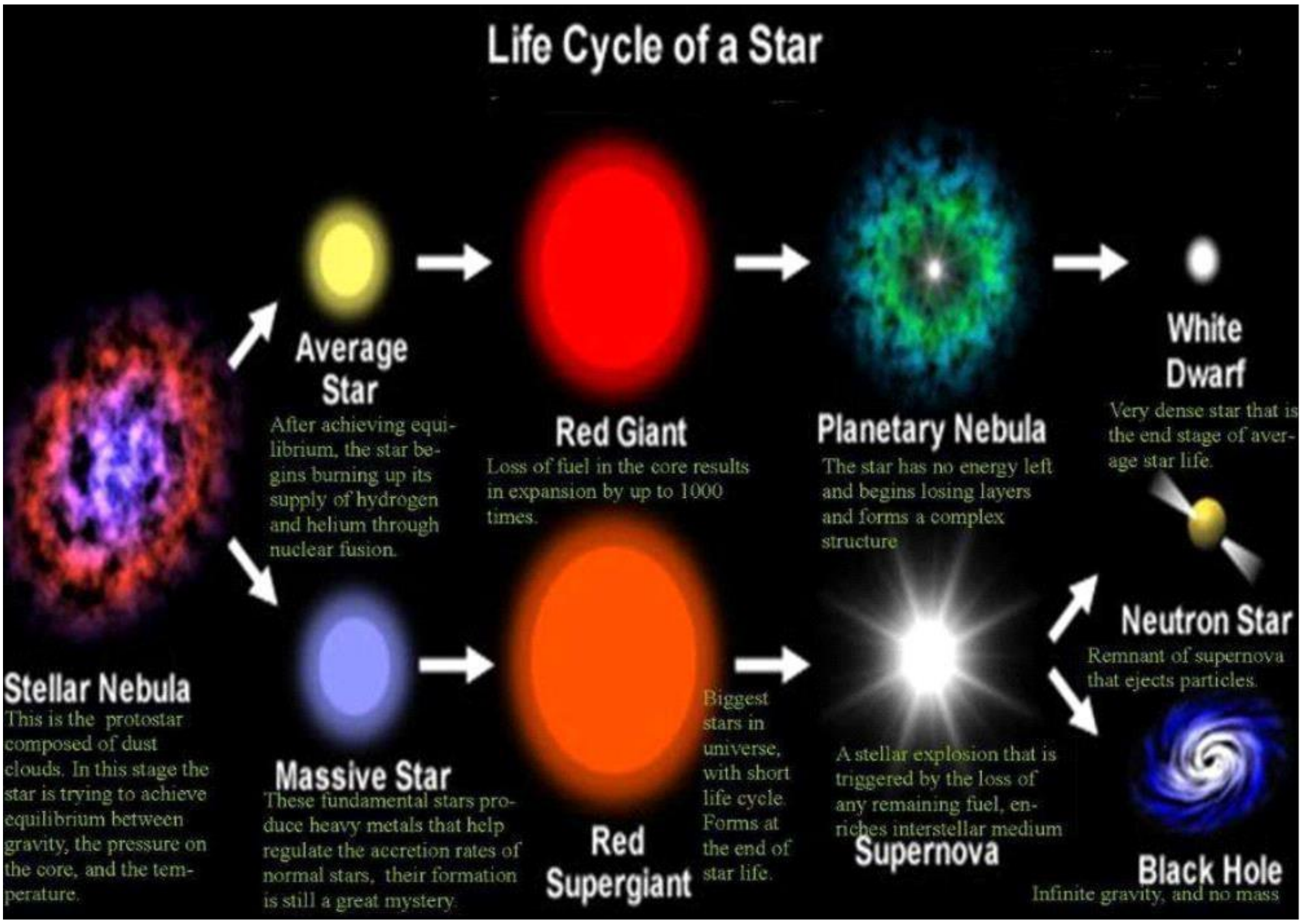
- Initially, there was a "Tiny Ball" (singular atom) with an unimaginably small volume, infinite temperature, and infinite density.
- Violent explosion of "Tiny Ball" (Big Bang took place 13.7 billion years before the present).
- Rapid expansion within fractions of a second after the bang then the expansion has slowed down.
- Scientists believe that though the space between the galaxies is increasing, observations do not support the expansion of galaxies.



Solar System

Formation of Stars and its life cycle

- The formation of stars is believed to have taken place some 5-6 billion years ago.
    - Growing nebula develops localised clumps of gas that continue to grow into even denser gaseous bodies, giving rise to formation of stars.
- A galaxy contains a large number of stars.
- Galaxies spread over vast distances that are measured in thousands of light-years.



Solar System

Constellations

- Constellations are the various patterns formed by different groups of stars.
  - Example: Ursa Major or Big Bear
  - Small bear or Saptarishi is a group of seven stars that forms a part of the large Ursa Major Constellation
- The North star:
  - Indicates the north direction
  - It is also called the Pole Star
  - It always remains in the same position in the sky
  - We can locate the position of the Pole Star with the help of the Saptarishi

Asteroids

- Asteroids are a class of small rocky object of Solar System orbiting around the Sun.
- They have also been called planetoids, especially the larger ones.
- They are found between the orbits of Mars and Jupiter
- The largest asteroid is the Ceres

Solar System

Difference between meteor, meteoroid and meteorite?

- They're all related to the flashes of light called "shooting stars" sometimes seen streaking across the sky. But we call the same object by different names, depending on where it is.
- Meteoroids are objects in space that range in size from dust grains to small asteroids.
- When meteoroids enter Earth's atmosphere (or that of another planet, like Mars) at high speed and burn up, the fireballs or "shooting stars" are called meteors.
- When a meteoroid survives a trip through the atmosphere and hits the ground, it's called a meteorite.

Sun

- Sun is star at the center of the solar system
- Primarily made up of hot gases
- Important sources of energy for life on Earth are produced from nuclear fusion of hydrogen nuclei.

Solar System

Solar Winds:

- Ejections of plasma (extremely hot charged particles) that originate in the layer of the Sun known as the corona (outer most layer, hidden due to sun's light, visible in solar eclipse).

Solar/Stellar Flare

- It is a dramatic increase in brightness of a star due to the magnetic energy stored in the star's atmosphere
- Occur in active regions around sunspots.
- Often accompanied by coronal mass ejection.
- Solar flare ejects clouds of electrons, ions and atoms along with electromagnetic radiations.
- Impact:
  - When flare is ejected in the direction of the earth, the particles hitting the upper earth's atmosphere may cause Aurora Australis
  - X-rays and UV rays may affect ionosphere and disrupt long range radio Communication
  - Radiation risks posed by flares are one of the major hurdles in manned space missions

Solar System

Sun-spot Cycle

- Amount of magnetic flux that rises up to the Sun's surface varies with time in a cycle called the solar cycle
- This cycle lasts 11 years on average cycle and is sometime referred as the sunspot cycle
- Sun spots are darker, magnetically strong,cooler areas on the surface of the sun (photosphere)
- Not pesent all over the sun, present between 25°-30° latitude

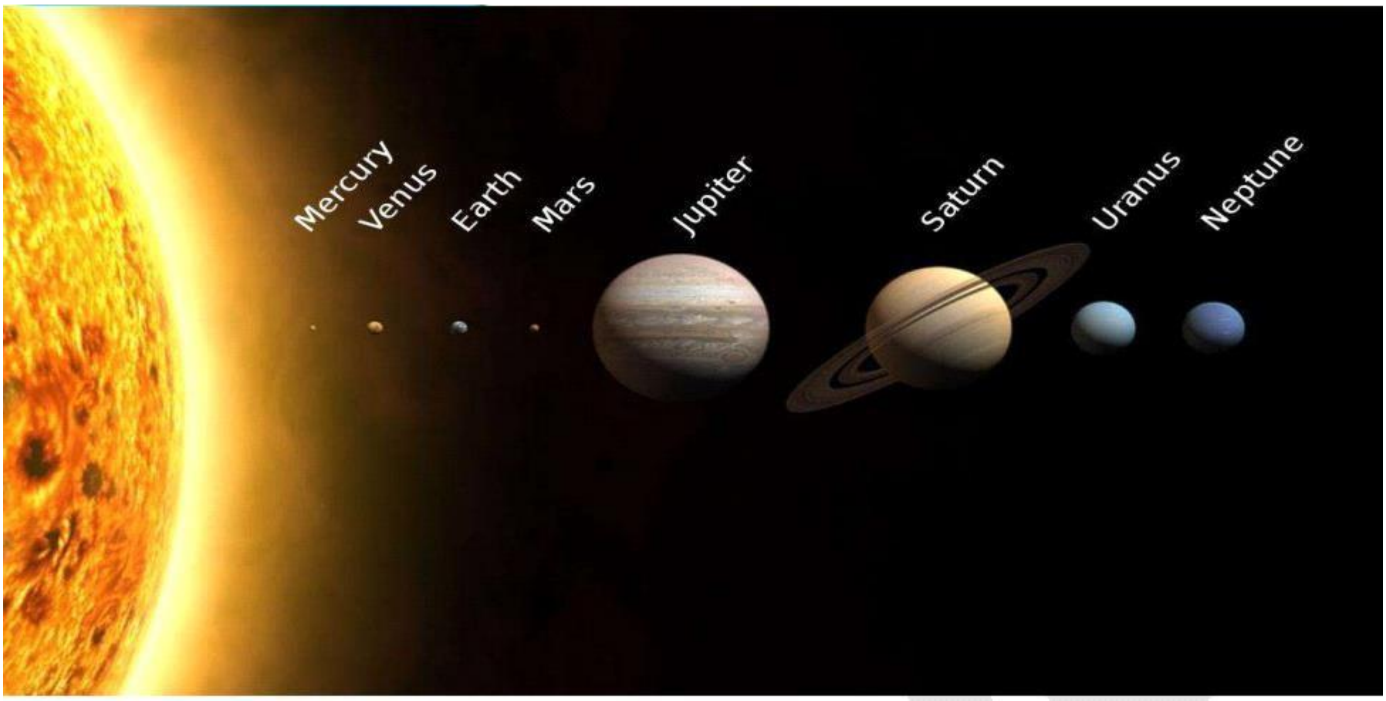
Comet

- Cosmic snowballs of frozen gases, rock and dust that orbit the Sun.
- When a comet's orbit brings it close to the Sun, it heats up and spews dust and gases into a giant glowing head larger than most planets.
- The dust and gases form a tail that stretches away from the Sun for millions of miles.
- There are likely billions of comets orbiting our Sun in the Kuiper Belt and even more distant Oort cloud.

Solar System

Planet

- According to the International Astronomical Union in 2006, a planet must do 3 things:
  - It must orbit a star
  - It must have sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly spherical) shape.
  - It must be big enough that its gravity clears away any other objects of a similar size near its orbit around the Sun.



Solar System

Mercury

- The smallest planet in our solar system and closest to the Sun.
- Second densest planet.
- No moons or rings.
- Second hottest planet (Venus hottest).
- Lack of seasons on its surface due to the smallest tilt than all other planets.
- Only slightly larger than Earth's Moon.
- Fastest planet, zipping around the Sun every 88 Earth days.

Venus

- Sister of Earth due to proximity, mass and size.
- Surface of Venus is hidden by an opaque layer of clouds which are formed from sulphuric acid.
- A thick atmosphere traps heat in a runaway greenhouse effect, making it the hottest planet in our solar system.
- Venus spins slowly in the opposite direction from most planets.
  - Rotate clockwise (other planets: counter clockwise)

Solar System

   - Referred as "morning star", "evening star" (due to brightness).

Earth

- Largest of all the terrestrial planets.
- Most dense planet in the solar system.
- It's also the only planet in our solar system with liquid water on the surface.
- Ozone Layer protects it from harmful solar radiation.

Mars

- Mars is a dusty, cold, desert world with a very thin atmosphere.
- There is strong evidence Mars was—billions of years ago—wetter and warmer, with a thicker atmosphere.
- Mars is the only other planet besides Earth that has polar ice caps.
- Seasons like Earth, but they last twice as long.
- Red Planet without any magnetic field.

Solar System

Jupiter

- Jupiter is more than twice as massive as the other planets of our solar system combined.
- Giant planet's Great Red spot is a centuries-old storm bigger than Earth. Shortest day and highest gravity among the eight planets.
- Atmosphere: 90% hydrogen and 10% helium, nearly the same as the Sun's.
- Notable moons: Europa, Ganyemede (largest moon in the solar system), Callisto

Saturn

- "The Ringed Planet": The other giant planets have rings, but none are as spectacular as Saturn's.
- Second largest planet (diameter and mass).
- Gives off more energy than it receives from the Sun.
- Saturn appears pale yellow in colour because upper atmosphere contains ammonia crystals.
- Least density in solar system.
- Notable Moons: Titan, Rhea, and Enceladus

Solar System

Uranus

- It rotates at a nearly 90-degree angle from the plane of its orbit. This unique tilt makes Uranus appear to spin on its side.
- Coldest planet in the solar system.
- Uranium (discovered in 1789) was named after it.
- Voyager 2: only spacecraft to have flown by it
- Notable moons: Oberon, Titania, Miranda, Ariel, and Umbriel

Neptune

- Second largest gravity of any planet.
- It was the first planet located through mathematical calculations.

Dwarf Planet

- It is a celestial body that
  - Is in orbit around the Sun.
  - Has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape.
  - Has not cleared the neighbourhood around its orbit.
  - Is not a satellite.

Solar System

Some prominent dwarf planets

- Pluto
- Ceres
- Makemake
- Haumea
- Eris

Theories of Formation of Planets

Nebular Hypothesis

- Nebula is the accumulation of hydrogen gas in the form of a very large cloud
- Pockets of dust and gas began to collect into denser regions due to the gravitational collapse at the center of the cloud (Result of a passing star from the solar surface.
- As the passing star moved away, the separated material of solar surface continued to revolve around the sun and slowly condensed into planets.
- Leftover debris that never became planets congregated in regions such as the Asteroid Belt, Kuiper Belt, and Oort cloud.

Solar System

Binary Theories

- According to these theories, the sun had a companion.
- Chamberlain and Moulton considered that a wandering star approached the sun resulting in separation of a cigar-shaped extension of material from the solar surface.
- As the passing star moved away, the separated material of solar surface continued to revolve around the sun and slowly condensed into planets.

Evolution of Earth

- Earth initially was a Barren, rocky and hot object with a thin atmosphere of hydrogen and helium.
- Life originated 4.6 billion years ago on Earth
- The earth has a layered structure with non-Uniform materials from the outermost end of the atmosphere to the center of the earth.
- The atmospheric matter has the least density.
- The earth's interior has different zones from the surface to deeper depths. Each of these contains materials with different characteristics.

Solar System

Development of Lithosphere

- Volatile state during primordial stage → Temperature inside has increased (Due to gradual increase in density) → Material inside started getting separated depending on densities (Heavier materials like iron sunk towards the centre) → It cooled further and solidified and condensed with passage of time.
- The gases and water vapor were released from the interior as the earth cooled down.
  - The process through which the gases were outpoured from the interior is called degassing.
  - Continuous volcanic eruptions contributed water vapor and gases to the atmosphere.

Evolution of Hydrosphere

- As the earth cooled, the released water vapor started getting condensed.
- The carbon dioxide in the atmosphere got dissolved in rainwater. This further decreased temperature causing more condensation and more rain.

Solar System

- The rainwater falling onto the surface got collected in the depressions to give rise to oceans.
- The earth's oceans were formed within 500 million years from the formation of the earth.

Development of Atmosphere

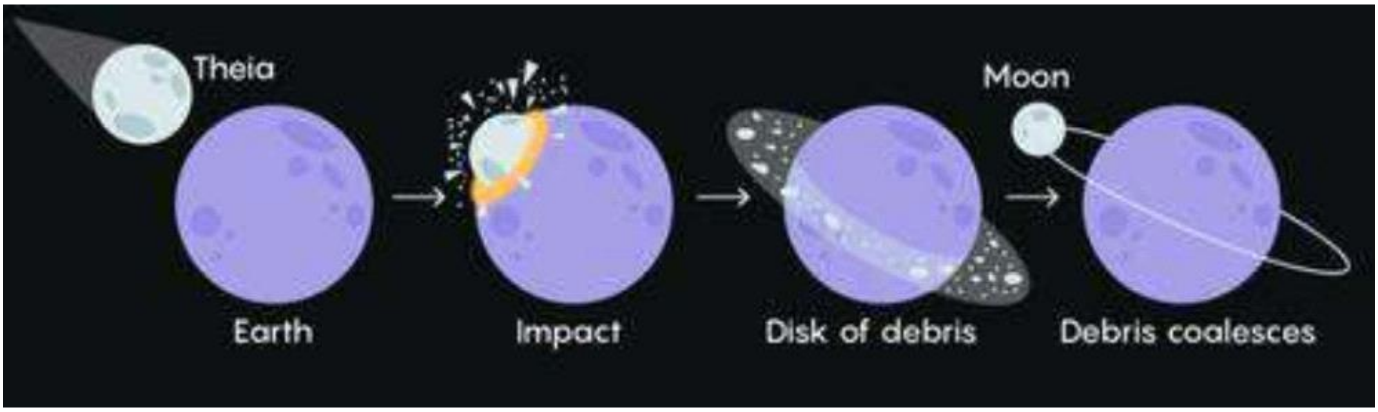
- The early atmosphere, with hydrogen and helium, is supposed to have been stripped off as a result of the solar winds.
- The present composition of earth's atmosphere is chiefly contributed by nitrogen and oxygen.
- There are three stages in the evolution of the present atmosphere.
    - Loss of primordial atmosphere.
    - Evolution of the atmosphere by hot interior of the earth.
    - Modification of atmospheric composition by the living world through the process of photosynthesis.

Solar System

Formation of Moon

1. **Fission Theory**
   - Single rapidly rotating body possessing the Earth and the Moon → Whole mass became a dumbbell shaped body → Separation
     - Material forming the moon was separated from what we have at present the depression occupied by the Pacific Ocean

2. **Giant Impact Hypothesis**
   - Earth struck by Theia (Mars size object) → Huge amount of debris → Debris coalesces during orbiting the Earth → Moon created



Geological Time Scale

Eons

- Broadest category of geological time.
- Earth's history is characterized by four eons; the Hadeon, Archean, Proterozoic, and hanerozoic (in order from oldest to youngest).
- Collectively, the Hadean, Archean, and Proterozoic are sometimes informally referred to as the "Precambrian"
- We live during the Phanerozoic, which means "visible life."

Eras

- Eons of geological time are subdivided into eras, which are the second-longest units of geological time.
- The Phanerozoic eon is divided into three eras: the Paleozoic, Mesozoic, and Cenozoic.

Periods

- Just as eons are subdivided into eras, eras are subdivided into units of time called periods.
- The most well-known of all geological periods is the Jurassic period of the Mesozoic era

Geological Time Scale

Epochs and Ages

- Periods of geological time are subdivided into epochs.
- In turn, epochs are divided into even narrower units of time called ages.

Decreasing order

- Supereon > Eon > Era > Period > Epoch

Eons

1. Hadeon Eon
    - Indicates the time before a reliable (fossil) evidence of life.
    - Extremely hot temperature.
        - Much of the Earth was molten (extreme volcanism) leading to formation of crust after cooling.
    - Volcanic outgassing probably created the primordial atmosphere (No oxygen) and then the ocean.
    - Heavy CO_2 atmosphere with water vapor and Hydrogen.

Geological Time Scale

2. **Archean Eon**
    - Beginning of life on Earth (Evidence of cyanobacteria date to 3500 mya).
    - Life was limited to Prokaryota (simple single-celled organisms lacking nuclei).
    - No oxygen in atmosphere.
    - Formation of continents due to the cooling of Earth's crust.
    - Higher volcanic activity than today with multiple lava eruptions.

3. **Proterozoic Eon**
    - Oxygen production started by Bacteria
    - Eukaryotes (have a nucleus) emerged.
    - The early and late phases of this eon may have undergone Snowball Earth periods (the planet gone through extensive glaciation resulting drop in sea levels).
    - Very tectonically active period.

4. **Phanerozoic Eon**
    - Complex multicellular life arose.

Geological Time Scale

- Plant life on land emerged in the early Phanerozoic eon.
- Pangaea forms and later disassociated into Laurasia and Gondwana.
- This Eon is divided into 3 eras:
    - Palaeozoic: An era of ancient life (arthropods,amphibians, fishes)
    - Mesozoic: Age of reptiles and gymnosperms (climatic extinction of the non-avian dinosaurs)
    - Cenozoic: Age of mammals and angiosperm

Latitude and Longitude

Latitudes

- Latitude is the angular distance of a place north or south of the earth's equator.
- Latitude tells you where you are between the North Pole and the South Pole.
- These are measured in degrees.
- Parallels or latitude lines
  - Lines that run across the Earth from east to west at a constant latitude.
  - Everywhere on a parallel must have the same latitude.
  - An example is the equator, which is at zero degrees of latitude.
- A circle of latitude is an imaginary ring linking all points sharing a parallel.

Longitudes

- Longitude is measured by imaginary lines that run around the Earth vertically (up and down) and meet at the North and South Poles.
- These lines are known as meridians.

Latitude and Longitude

- The line which runs through Greenwich in London is called the Greenwich Meridian or Prime Meridian. The Prime Meridian is 0° longitude.
- The Earth is then divided into 180° east and 180°west.
    - Longitude is the measurement east or west of the prime meridian.
    - Half of the world (the Eastern Hemisphere) is measured in degrees east of the prime meridian. The other half (the Western Hemisphere) in degrees west of the prime meridian.
- The anti-meridian is halfway around the world, at 180°. It is the basis for the International Date Line.
- Unlike parallels of latitude, all meridians are of equal length.

Latitude and Longitude

Important Parallels of Latitudes

Equator (0° latitude)

- Imaginary circular line running on the globe and divides it into two equal parts.
- These are measured in degrees.
    - Important reference point to locate places on the earth.
- All parallel circles from the equator up to the poles are called parallels of latitudes.
- All parallels north/south of the equator are called 'north latitudes'/'south latitudes'. It is indicated by the letter 'N' or 'S'.
- The size of the parallels of latitude decreases as we move away from the equator.

Tropic of Cancer ($23\frac{1}{2}$° N) in the Northern Hemisphere

- It is the farthest northern latitude at which the sun can appear directly overhead.
- It occurs on the Summer Solstice (marked between June 20 and June 22).
- North of this line is the subtropics and Northern Temperate Zone.

Latitude and Longitude

Tropic of Capricorn (23½° S) in the Southern Hemisphere

- It is the farthest southern latitude at which the sun can appear directly overhead.
- It occurs on the Winter-Solstice (marked between December 20 and December 23).
- South of this line is the subtropics and Southern Temperate Zone.

Arctic/Antarctic Circle at 66½° north/south of the equator

- Parallel of latitude around the Earth at approximately 66.5° N/S
- Because of the Earth's inclination of about 23½° to the vertical, It marks the southern/northern limit of the area within which, for one day or more each year, the Sun does not set (about June 21) or rise (about December 21).

North Pole (90°N) and South Pole (90° S)

- The North/South Pole is the northernmost or southernmost point on Earth.

Latitude and Longitude

- It is the precise point of the intersection of the Earth's rotational axis and the Earth's surface.
- Polaris (the current North Star) sits almost motionless in the sky above the North Pole, making it an excellent fixed point to use in celestial navigation in the Northern Hemisphere.
- All lines of longitude meet at the North and the South Pole.

Note:
India is a vast country and lying entirely in the Northern hemisphere.

Note:
The main land extends between latitudes 8°4'N and 37°6'N and longitudes 68°7'E and 97°25'E.

Note:
The Tropic of Cancer (23°30'N) divides the country into almost two equal parts.

Latitude and Longitude

Heat zones of the earth

Torrid Zone

- Areas lying between the Tropic of Cancer and the Tropic of Capricorn.
- This area receives the maximum heat and is called the Torrid Zone.
- The mid-day sun is exactly overhead at least once a year on all latitudes in between the Tropic of Cancer and the Tropic of Capricorn.
- The tropics are known for their lush green vegetation and moist climate.
- Average temperatures range from warm to hot year round.
- Many places in the tropics experience rainy seasons which range from one to several months of consistent rainfall.

Frigid Zone

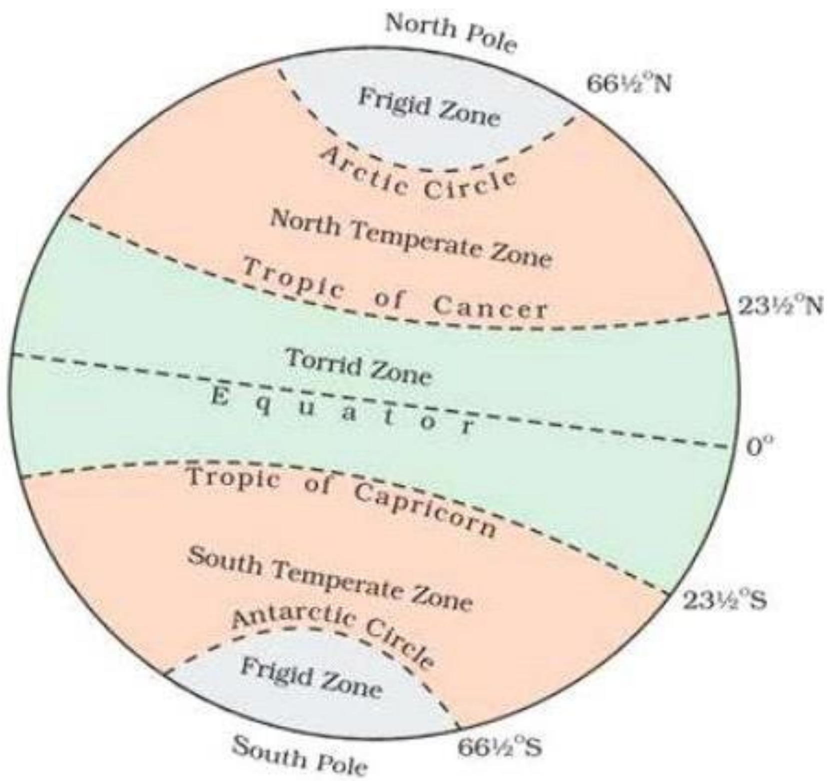
- Areas lying between the Arctic Circle and the North Pole in the Northern Hemisphere and the Antarctic Circle and the South Pole in the Southern Hemisphere called Frigid Zones.

Latitude and Longitude

- The mid-day sun never shines overhead on any latitude beyond the Tropic of Cancer and the Tropic of Capricorn.
- The angle of the sun's rays goes on decreasing towards the poles.
- Area is very cold because here the sun does not rise much above the horizon. Therefore, its rays are always slanting and provide less heat.

Temperate Zones

- The areas lying between the Torrid Zone and Frigid Zone and have moderate temperatures.



Latitude and Longitude

Greenwich Meridian Time (GMT)

Time Zone

- A time zone is a region of the Earth that has adopted the same standard time, usually referred to as the local time.
- Most adjacent time zones are exactly one hour apart, and by convention compute their local time as an offset from Greenwich Mean Time (GMT).

Latitude and Longitude

- Standard time zones can be defined by geometrically subdividing the Earth's spheroid into 24 lunes (wedge-shaped sections), bordered by meridians each 15° of longitude apart. The local time in neighboring zones is then exactly one hour different.

Note:

The earth rotates 360° in about 24 hours, which means 15° an hour or 1° in four minutes.

- The earth has been divided into 24 time zones of one hour each (24 hours x 15°rotation = 360° rotation in a day)

Indian Standard Time (IST)

- Time along the Standard Meridian of India (82° 30'E) passing through Mirzapur (in Uttar Pradesh) is taken as the standard time for the whole country.

Latitude and Longitude

- IST at 82°30'E is 5 hours and 30 minutes ahead of GMT.
- It goes through following states: Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Orissa, Andhra Pradesh

International Date Line

- It serves as the line of demarcation between two consecutive calendar dates.
- It passes through the mid-Pacific Ocean and roughly follows a 180° (located halfway round the world from the prime meridian).
- It bends and goes zig zag at the Bering Strait between Siberia and Alaska, Fiji, Tonga and in some other islands.
- It follows zig-zag pattern to avoid the confusion of having different dates in the same country.
- The date changes by exactly one day while crossing it.
- A traveller crossing the date line from east to west loses a day and while crossing the dateline from west to east gains a day.

Latitude and Longitude

Daylight saving time (DST)

- Daylight saving time (DST) or summer time is the practice of advancing clocks during summer months by one hour.
- It is done so that evening daylight lasts an hour longer i.e. fully utilizing the surplus sunlight in summers while compensating the short day length in winters.
- Typically, regions with summer time adjust clocks forward one hour close to the start of spring (terms "spring forward") and adjust them backward in the autumn to standard time (terms "fall back").
- Daylight saving time practice is prevalent in many temperate countries
    - To conserve energy by utilizing the day light and reduce evening use of incandescent lighting.
    - To compensate variation in day length experienced from season to season.

Motion of the Earth

Types of Motion

Rotation

- Movement of the earth on its axis.
- As the Earth rotates, each area of its surface gets a turn to face and be warmed by the sun. This is important to all life on Earth.
- If the Earth did not rotate, one half of the Earth would always be hot and bright, and the other part would be frozen and dark. Life would not have been possible in such extreme conditions.

Revolution

- Movement of the earth around the sun in a fixed path or orbit.
- It takes $365\frac{1}{4}$ days (one year) to revolve around the sun. Six hours saved every year are added to make one day (24 hours) over a span of four years.
    - This surplus day is added to the month of February. Such a year with 366 days is called a leap year.
- The earth is going around the sun in an elliptical orbit.

Motion of the Earth

Axial Tilt

- Axial tilt is the angle between the planet's rotational axis and its orbital axis.
- A planet's orbital axis is perpendicular to the ecliptic or orbital plane, the thin disk surrounding the sun and extending to the edge of the solar system.
- Earth's axis is not perpendicular. It has an axial tilt or obliquity.
    - The axis of the earth which is an imaginary line makes an angle of $66\frac{1}{2}°$ with its orbital plane.
- Some planets, such as Mercury, Venus, and Jupiter, have axes that are almost completely perpendicular, or straight up-and-down.
- Uranus has the largest axial tilt in the solar system. Its axis is tilted about 98 degrees, so its north pole is nearly on its equator.

Axial Precession

- Earth's axis appears stable but it actually wobbles very slowly like a spinning top.

Motion of the Earth

- This wobble is called axial precession.
- Earth's axis helps determine the North Star.
  - Currently, Earth's axis points toward a star called Polaris (current North Star due to its position almost directly above the North Pole).
- Polaris will not always be the North Star, however. The Earth's axis is slowly wobbling away from Polaris. In another 13,000 years, it will point toward the new North Star, a star called Vega.

Solstices

- Solstice means that either the Northern or Southern Hemisphere is tilted toward the sun and receives the maximum intensity of the sun's rays throughout the year.
- Solstices and shifting solar declination are a result of Earth's 23.5° axial tilt as it orbits the sun.
- From the North Pole, the sun is always above the horizon in the summer and below the horizon in the winter.

Motion of the Earth

Equinox

- There are only two times of the year when the Earth's axis is tilted neither toward nor away from the sun.
- On 21st March and September 23rd, direct rays of the sun fall on the equator. This results in a "nearly" equal amount of daylight and darkness at all latitudes. It is known as equinox.
- 23rd September = Autumn season (season after summer and before the beginning of winter) in the northern hemisphere and spring season (season after winter and before the beginning of summer) in the southern hemisphere.
- Due to the spherical shape of the earth, only half of it gets light from the sun at a time and experiences day.
- The circle that divides the day from night on the globe is called the circle of illumination.
- This circle does not coincide with the axis
- 21st March = Spring in the northern hemisphere and autumn in the southern hemisphere.

Motion of the Earth

Perihelion

- It is the point when Earth is closest to Sun.
- It occurs around 3rd January.
- The distance is 147.5 million kms.

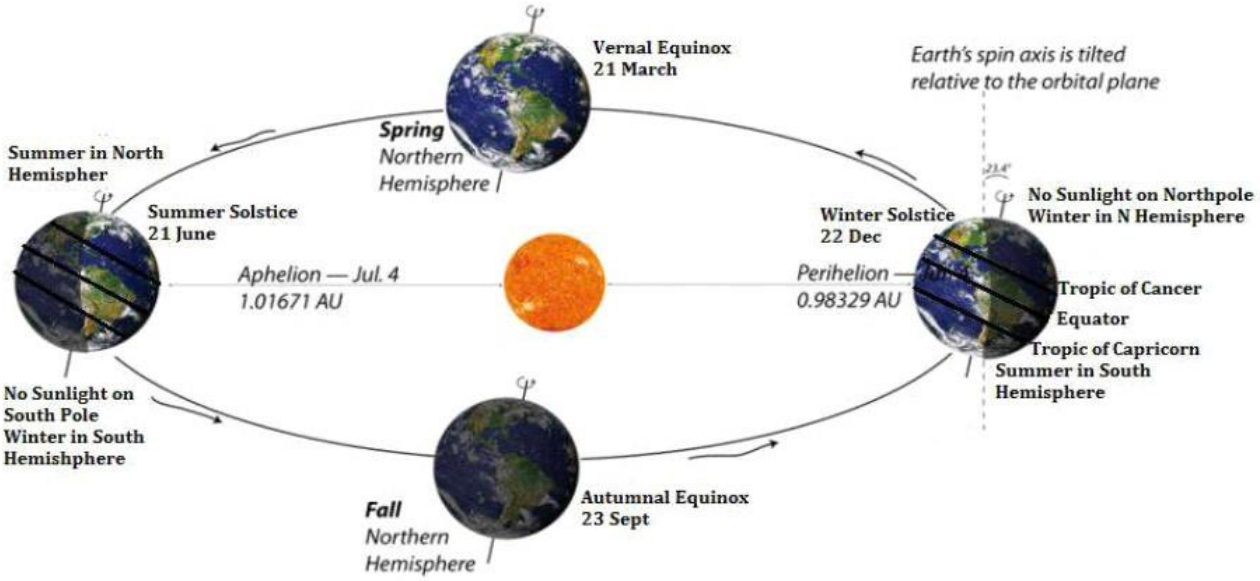
Aphelion

- It is the point when Earth is farthest from the Sun.
- It occurs on July 4.
- The distance is 152.5 million kms.
- Speed of Earth is fastest at Perihelion and slowest at Aphelion (Kepler's Second Law).

Effect of Earth Motion

- Reasons for day and night as well as seasons
  - Days and Nights → Rotation
  - Seasons → Revolution
- The schematic representation of seasonal variation is given below. The diagram depicts the four different seasons on the earth according to its position in the space at that time.

Motion of the Earth



Geomorphology

Interior of the Earth

1. Direct evidence
    - Samples drilled from deep inside Earth help in making inferences.
        - Deepest drill at Kola (in Arctic Ocean) has so
        - far reached a depth of 12 km
    - Volcanic eruptions

2. Indirect evidence
    - Seismic waves produced by earthquakes.
    - Meteors are likely to have a similar internal structure as of Earth (Both are solar objects and born from the same nebular cloud).
    - Gravity anomalies due to uneven distribution of mass of material within the earth (Provide information about the materials in the earth's interior).
    - Magnetic field study gives information about magnetic material distribution in crustal portion.

Geomorphology

Seismic Waves

- Seismic waves are the waves of energy caused by the sudden breaking of rock within the earth or an explosion. These are mechanical waves and requires medium to propagate.
  - These are the energy that travels through the earth and is recorded on seismographs.
- Seismology= Study of earthquakes and seismic waves that move through and around the earth.
- Seismologist= Scientist who studies earthquakes and seismic waves.

Types of Seismic Waves

- Two main types:
  - Body Waves
  - Surface Waves
- Body waves can travel through the earth's inner layers, but surface waves can only move along the surface of the planet like ripples on water.
- Earthquakes radiate seismic energy as both body and surface waves.

Geomorphology

Body waves

- Generated due to the release of energy at the focus. It moves in all directions travelling through the body of the earth.
- The velocity of waves changes as they travel through materials with different densities. The denser the material, the higher is the velocity.
- Their direction also changes as they reflect or refract when coming across materials with different densities.
- There are two types of body waves
  - P-Wave
  - S-Wave

P wave or Primary wave

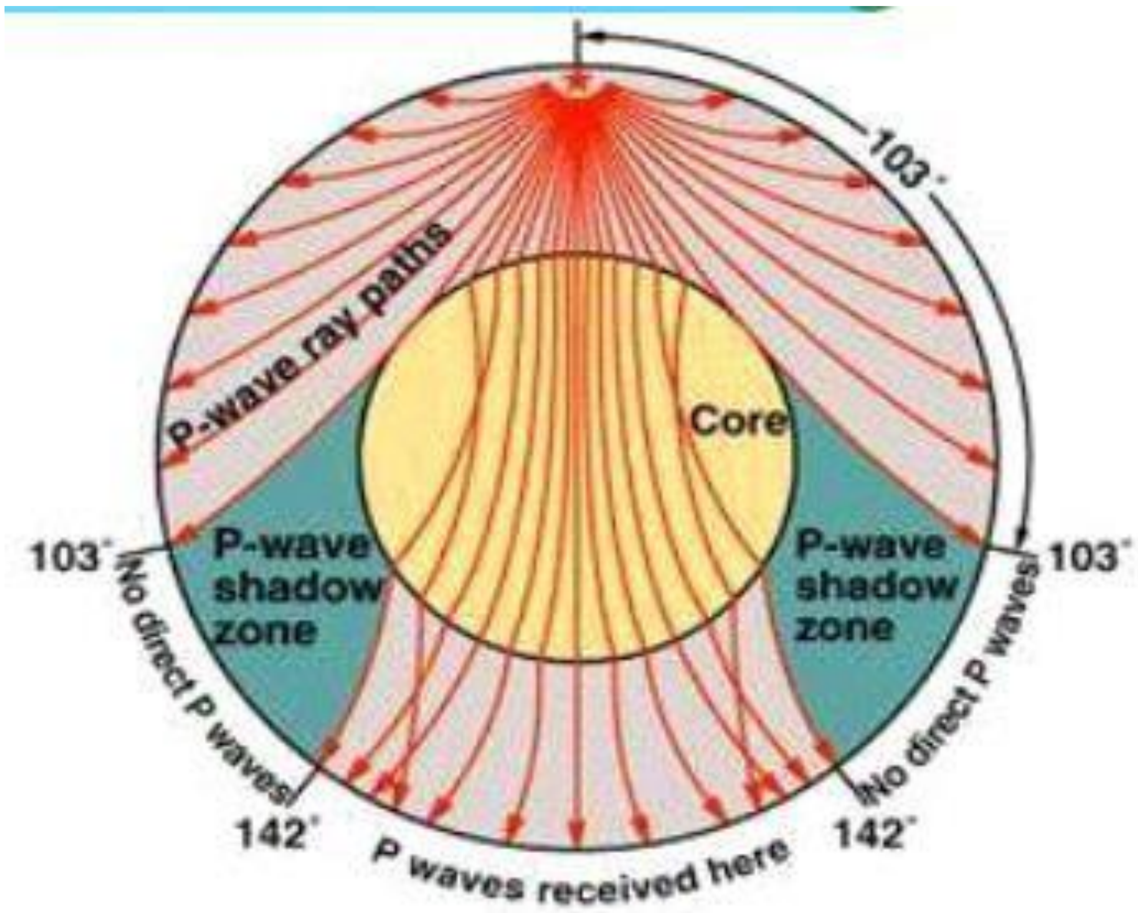
- Fastest kind of seismic wave.
- First to 'arrive' at a seismic station.
- Can move through solid rock and fluids.
- Velocity = Solids > Liquids > Gases
- It pushes and pulls the rock as it moves through, just like sound waves push and pull the air.
  - Hence, it is also known as compressional waves because of the pushing and pulling they do.

Geomorphology

S wave or Secondary wave

- Second wave felt in an earthquake.
- The S wave is slower than a P wave.
- It can only move through solid rock (not through any liquid medium).
    - Property helped seismologists to conclude that the Earth's outer core is a liquid.

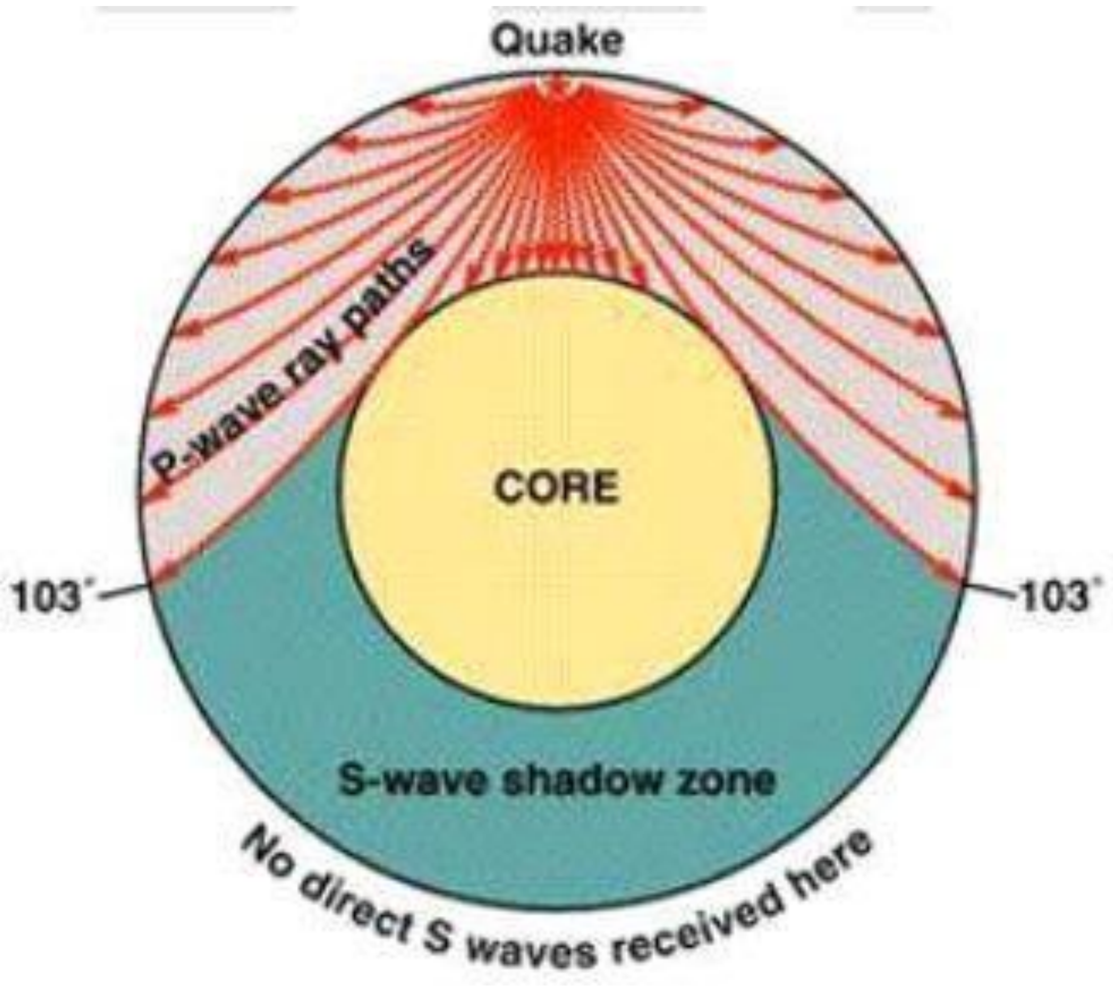
Note: S waves move rock particles up and down (or side-to side), perpendicular to the direction of wave propagation.



Geomorphology

Surface wave

- The body waves interact with the surface rocks and generate new set of waves called surface waves.
- It travels only through the crust and have lower frequency than body waves.
- Arrive after body waves.
- Also known as long period waves.
- Almost entirely responsible for the damage and destruction associated with earthquakes.



Geomorphology

How the properties of 'P' and 'S' waves help in determining the earth's interior?

- Change of density in different layers of the Earth greatly varies the wave velocity.
- The density of the earth as a whole can be estimated by observing the changes in velocity of waves.
- By the observing the changes in direction of the P and S waves (emergence of shadow zones), different layers can be estimated.

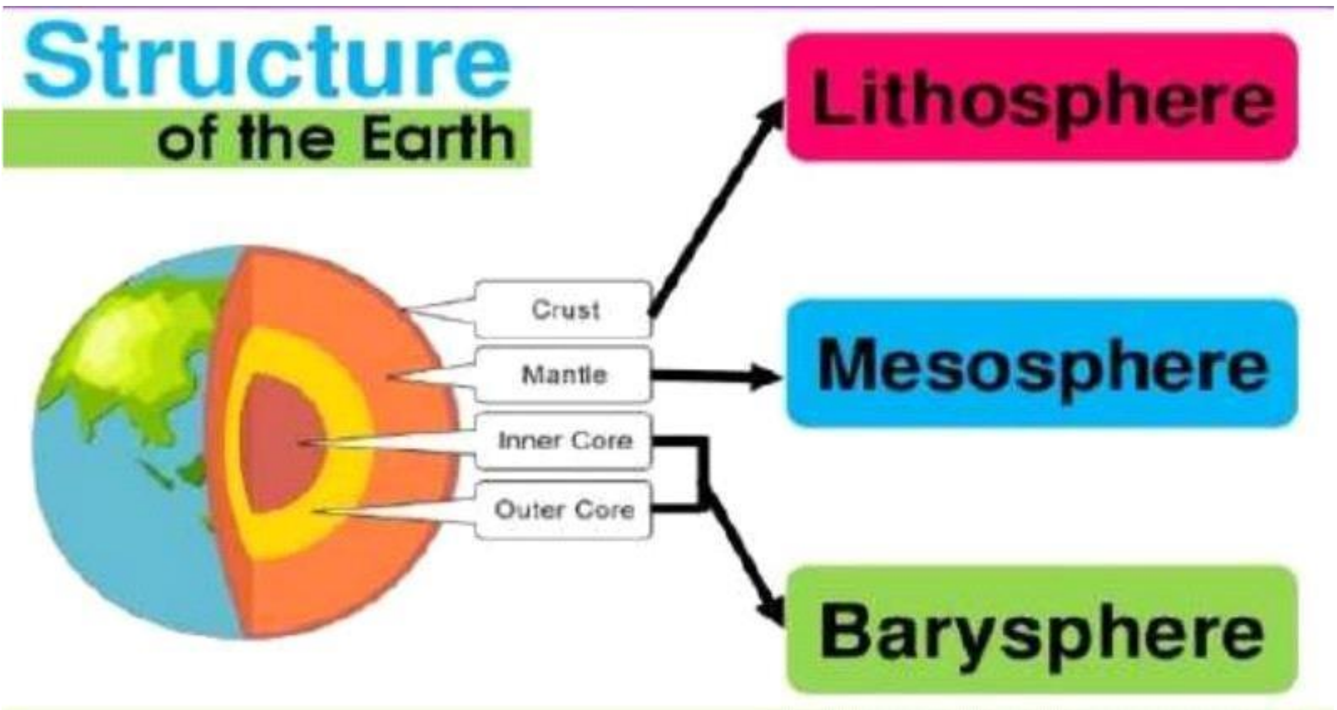
Emergence of Shadow Zone

- Shadow zone is the area of Earth's surface where seismographs cannot detect an earthquake after the waves have passed through the earth.
- P-waves are refracted by the liquid outer core and are not detected between 104° and 140°.
- S-waves cannot pass through the liquid outer core and are not detected beyond 104°.
- This information led scientists to deduce a liquid outer core.

Geomorphology

Concentric Layers of Earth's Interor

- Layers distinct in terms of temperature, composition, and density
- Heat radiation → Conduction mainly and convection in the magma chamber
- Temperature increases with depth = 1°C per 32 meters (at 48 km @ 1200-1300 °C)
- This rate is mainly due to presence of radioactive materials in the crust (up to 100kms)



Geomorphology

Crust

- Layer of solid rock that forms Earth's outer skin
- Above mohorovic discontinuity
- It includes both dry land (Continental) and ocean floor (Oceanic)
- Oceanic crust consists mostly of basalt
- Continental crust consists mainly of granite

Mantle

- Layer of solid, hot rock 40 kilometers beneath the surface- Largest layer
- Between Mohovoric and Gutenberg discontinuity
- Density = 3.3 g/cm3 at mohovoric and 5.7 g/cm3 at Gutenberg
- Divided into layers
  - Lithosphere – Uppermost part of mantle and the crust for a ridge layer about 100 kilometers thick
  - Asthenosphere – Softer part of mantle below the lithosphere which is hotter and under increased pressure
  - Lower Mantle – Solid material extending all the way to Earth's core

Geomorphology

Core

- Made mostly of the metals Iron and Nickel (NiFe)
- Consists of two parts
  - Outer core – Layer of molten metal that surrounds inner core (P waves slow down, while S waves stop)
  - Inner core - Dense ball of solid metal
- Movement of liquid outer core creates Earth's magnetic field

Minerals

- A mineral is a naturally occurring organic and inorganic substance, having an orderly atomic structure and a definite chemical composition and physical properties.
- A mineral is generally composed of two or more elements but sometimes single element minerals like sulphur, copper, silver, gold, graphite etc. are also found.
- The basic source of all minerals is the hot magma in the interior of the earth.
- Feldspar and quartz are the most common minerals found in rocks.

Geomorphology

- These are usually solid and inorganic, and have a crystal structure.
    - Exceptions: Minerals such as coal, petroleum, and natural gas are organic substances found in solid, liquid, and gaseous forms respectively.

Some major minerals and their characteristics

Feldspar

- Silicon and oxygen are common elements.
- Half of the earth's crust is composed of feldspar.
- It is used in ceramics and glass making.

Quartz

- It is one of the most important components of sand and granite.
- It consists of silica.
- It is a hard mineral virtually insoluble in water.
- It is white or colourless and used in radio and radar.

Bauxite

It is aluminium ore (hydrous oxide of aluminium).

- It is non-crystalline

Geomorphology

Rocks

- A rock is an aggregate of one or more minerals.
    - Do not have definite composition of mineral constituents.

Types of rocks

- Igneous Rocks: Solidified from magma and lava
- Sedimentary Rocks: Result of deposition of fragments of rocks
- Metamorphic Rocks: Formed out of existing rocks undergoing recrystallization

Igneous Rocks

- Formed out of magma and lava from the interior of the earth.
- They are known as primary rocks.
- Granite, gabbro, pegmatite, basalt, volcanic breccia and tuff are some of the examples of igneous rocks.
- Based on the presence of acid forming radical (silicon), igneous rocks are divided into Acid Rocks and Basic Rocks

Geomorphology

Sedimentary or Detrital Rocks

- Formed as a result of lithification of denuded rocks (Exogenic agents lead to weathering and erosion of rocks exposed to it).
    - Deposits through compaction turn into rocks.
    - They are layered or stratified of varying thickness.
- Sometimes, the deposits layers retain their characteristics even after lithification.
- It possesses 75% of the earth's crust but occupy only 5% on volume basis.
- Till/Tillite → Ice deposited sedimentary rocks
- Loess → Wind deposited sediments

Chief Characteristics of Sedimentary Rocks

- These rocks consist of a number of layers or strata.
- Marks of left behind water currents and waves etc.
- Have fossils of plants and animals.
- Generally porous (allow water to percolate through them)

Geomorphology

Metamorphic Rocks

- Metamorphic means 'change of form'
- Metamorphism is a process by which already consolidated materials within the original rocks undergo recrystallization and reorganization.
- These rocks form under the action of pressure, volume and temperature changes.

Rock cycle

- A continuous process through which old rocks are transformed into new ones
- Igneous rocks are primary rocks and other rocks form from these rocks.

Geomorphology

Oceans and Continents Distribution

To explain the present distribution of oceans and continents, various theories have been proposed.

Continental Drift Theory

- By Alfred Wegener
- According to the continental drift theory, the world was made up of a single continent called Pangaea surrounded by ocean called Panthalassa through most of geologic time.
- A sea called Tethys divided the Pangaea into two huge landmasses
    - Laurentia (Laurasia) to the north
    - Gondwanaland to the south
- Drift started around 200 million years ago (Mesozoic Era). The continents began to break up and drift away from one another.
- The continent eventually separated and drifted apart and the seven continents emerged that exist today

Geomorphology

Force for Continental Drift

- Pole-fleeing force (Rotation of the earth causes centrifugal effect)
- Buoyant force (Object floats in the fluid due to this property)
- Tidal force (Due to the attraction of the moon and the sun that develops tides in oceanic waters)
- Gravitational force

Wegener believed that these forces would become effective when applied over many million years and the drift is still continuing.

Geomorphology

The drift was in two directions

- Equator wards due to the interaction of forces of
  - Gravitational force
  - Pole-fleeing force
  - Buoyant force
- Westwards due to tidal currents caused by earth's rotation form west to east (Tidal currents act from east to west)

Evidence in support of Continental Drift

- Geomorphologic and geological similarities along the coasts of South America-Africa and Europe-North America.
  - Jig-Saw-Fit of Continents.
  - Placer Deposits of gold in the Ghana coast without any source rock in nearby region.
- Tillite
  - It is the sedimentary rock formed by glacier deposits.
  - The Gondawana systems of sediments from India have counter parts in six different landmasses of the Southern Hemisphere.
- Same Age of rocks across the Oceans. For example

Geomorphology

    - Ranges in Canada match Norway and Sweden.
    - Appalachian Mountains match UK Mountains.
- Fossil evidence for ancient climates
    - Plant and animal fossils on very different continents
        - Mesosaurus, which was a freshwater reptile.
        - Glossopteris, which was a tropical fern.
    - Same plants and animals on such different land masses indicates oneness of continents.

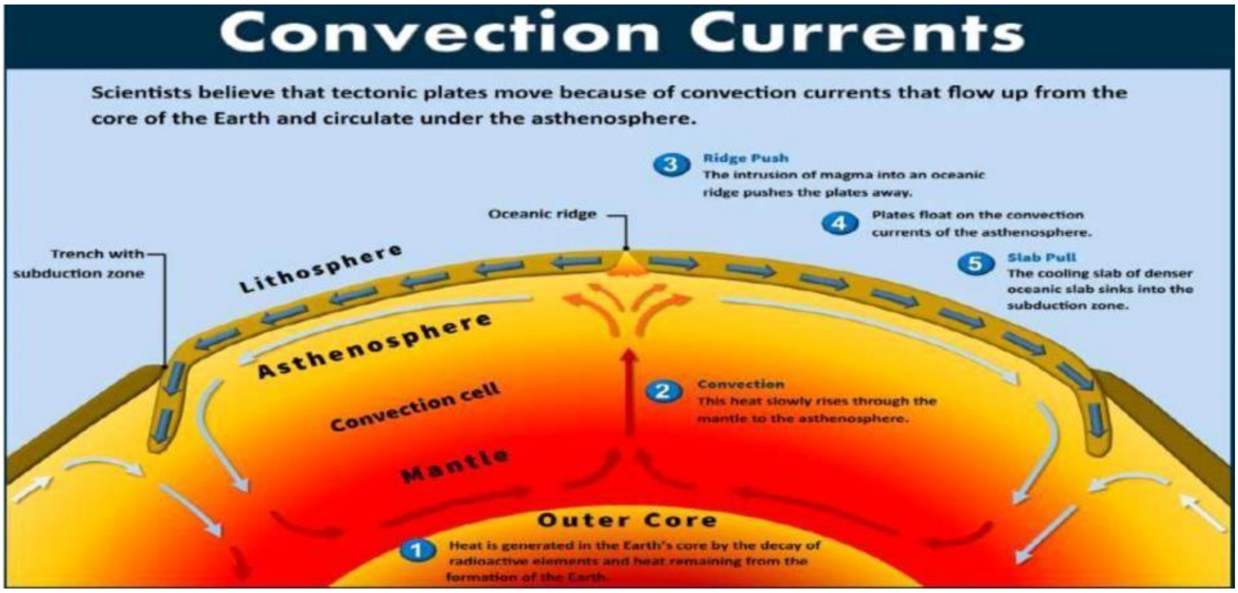
Drawbacks of Continental Drift Theory

- Too general with silly and sometimes illogical evidences.
    - Buoyancy and Gravity act in opposite directions
    - The Earth would have stopped rotation if the tidal force exerted by sun and moon is strong enough to rift the continents.
- It doesn't explain why drift initiated only in Mesozoic era and not before.
- The continental drift theory was unable to provide the strong reason for continent movement. This issue was eliminated by the later studies.

Geomorphology

Convectional Current Theory (By Arthur Holmes)

- Heat generated due to the decay of radioactive elements creates thermal differences in the mantle portion.
- To vent out, the thermal differences builds a convection current cycle in the mantle.
    - Rising (ascending) limbs of these currents = Oceanic ridges are formed (Due to the divergence of the lithospheric plate)
    - Falling (descending) limbs of these currents = Trenches are formed (Due to the convergence of the lithospheric plate)
- The movement of the lithospheric plate is driven by movement of magma in the mantle (Driven by convective process).



Geomorphology

Ocean Floor

Continental shelf

- Angle is 1°, depth is 120-150 meter, and it extends generally 70 km into the sea. But this varies a lot
  - The continental shelf is virtually absent in west coast of South America.
  - It is 120 km wide in east coast of North America. In Bay of Bengal, it is very wide as well.

Continental slope

- At the end of continental shelf slope steepens abruptly. Its end marks the end of continental blocks.

Continental rise

- At the end of continental slope, slope becomes gentle again to 0.5° to 1°. Its end marks the end of continental margin.

Geomorphology

Abyssal plains (Deep Sea Plain)

- Undulating plain lies 2-3 miles below sea level and cover 2/3rd of ocean floor. Lying generally between the foot of a continental rise and a mid-ocean ridge, abyssal plains cover more than 50% of the Earth's surface.

Oceanic Ridges

- The oceanic ridge system is a continuous underwater mountain range. It is created when magma rising between diverging plates of the lithosphere cools and forms a new layer of crust.

Abyssal hills

- Sea hills on abyssal plains rising less than 1000 meters from the floor are called Abyssal hills.

Sea mounts

- Sea hills on abyssal plains rising above 1000 meters from the floor are called sea mounts.

Guyots

- Guyots are seamounts which have flat tops. All of them are generally of volcanic origin.

Geomorphology

Submarine trenches/deeps

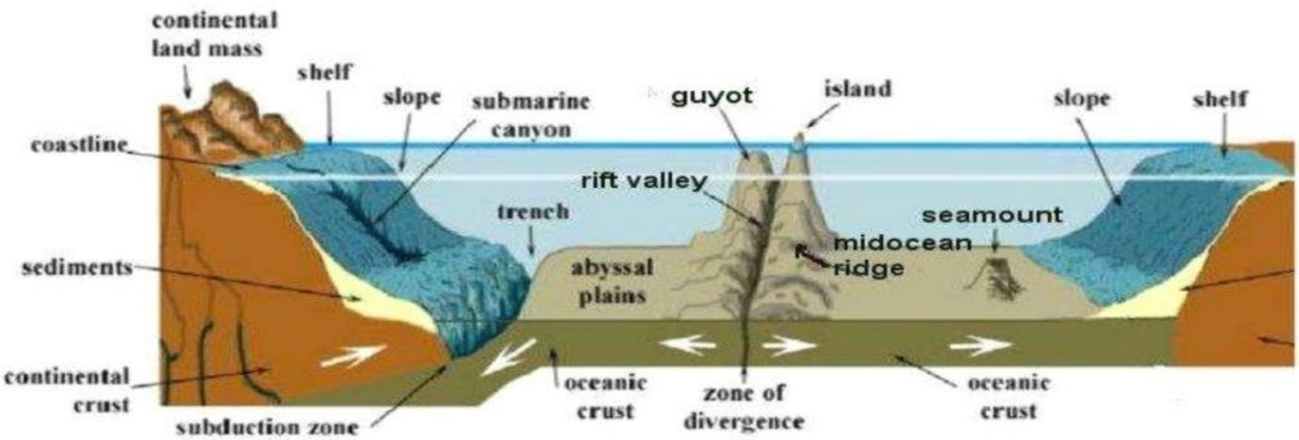
- Long narrow and steep depression on abyssal plain is called a trench. The deeper trenches (> 5500 meters) are called deeps. Ex- Mariana Trench

Canyons

- Canyons are deep concave gorges on continental shelf, slope or rise.

Strait, sound / channel

- Both straits and channels are narrow pieces of water connecting two larger bodies of water. Straits are narrower than a channel or sound.



Geomorphology

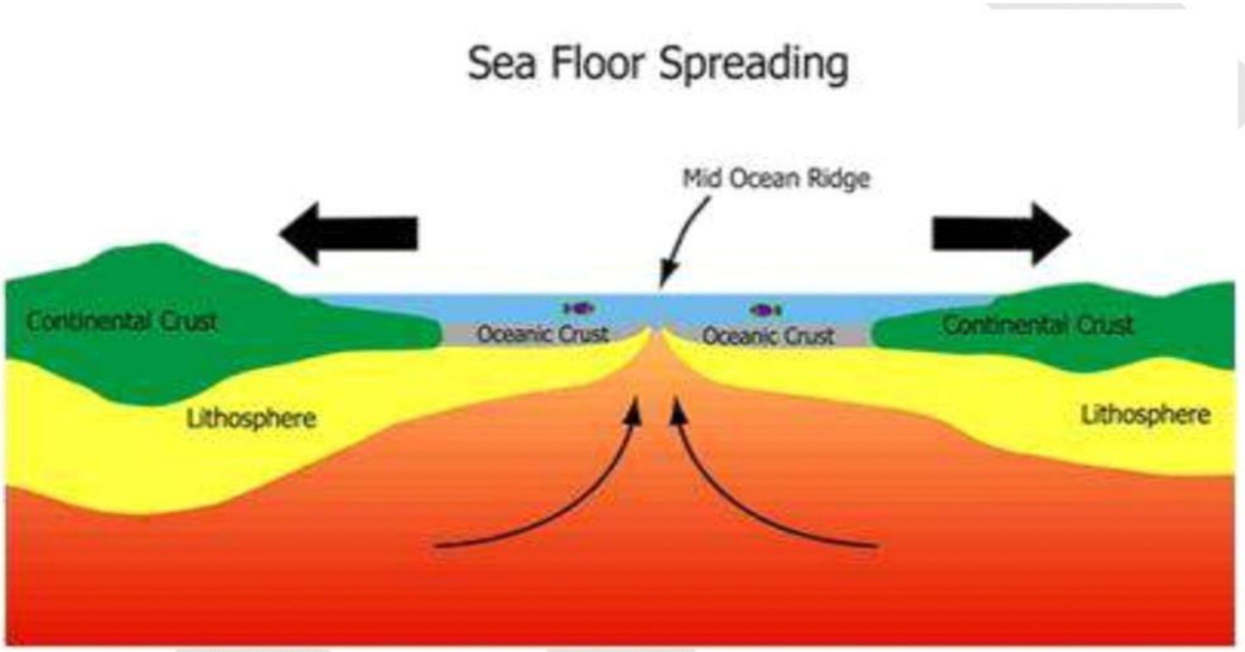
Sea Floor Spreading

- Harry Hess utilised the study of convection current and paleomganetism and proposed the theory of Sea Floor Spreading.
- The younger age of the oceanic crust and the fact that the spreading of one ocean does not cause the shrinking of the other indicates the consumption of the oceanic crust.
- Hot magma from Earth's mantle rises up through the mid-oceanic ridges and constantly produces new oceanic crust.
- Crust cools and flows sideways forming new seafloor. It is recycled millions of years later when it returns to the mantle by descending into the deep ocean trenches.
    - This indicates that the crust near the oceanic ridge would be youngest (due to its recent creation by outpour of basaltic lava from the interior of the earth) and near the trenches would be oldest.
    - Rate of sea floor spreading is decided by age and distance between two equal magnetic strips.

Geomorphology

Sea Floor Spreading

- This indicates the formation and consumption of the oceanic crust is a cyclical process driven by convection currents in the mantle.
- Seafloor spreading theory helps in providing explanation of continental drift in the theory of plate tectonics.



Geomorphology

Plate Tectonic Theory

- The sea floor spreading theory explained the oceanic crust movement effectively but it did not explain the reason of continental plate movement. To remove this drawback, plate tectonic theory is given by McKenzie and Parker.
- Tectonic plates are pieces of Earth's crust and uppermost mantle
- Lithospheric plates (or crustal plates or tectonic plates) can be differentiated as
  - Minor plates or major plates
  - Continental plates or oceanic plates
- Plate density (Denser plate goes for subduction)
  - Oceanic Plate > Continental Plate
  - Bigger Plate > Smaller Plate

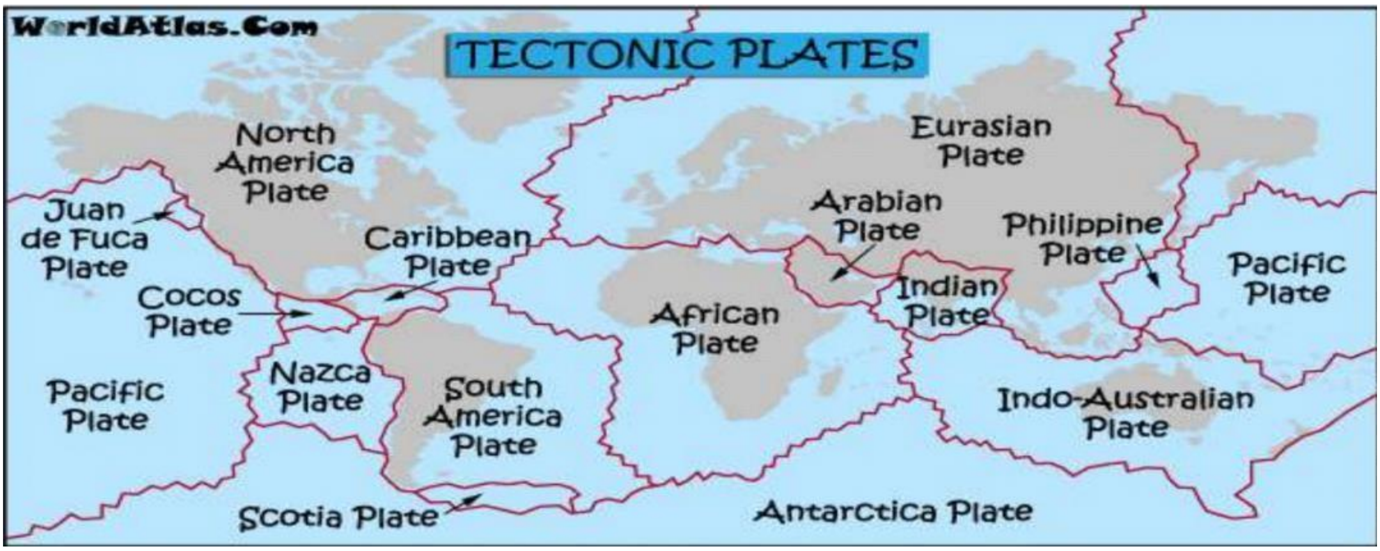
7 Major tectonic plates

- Antarctica and the surrounding oceanic plate
- North American plate
- South American plate
- Pacific plate
- India-Australia-New Zealand plate
- Africa with the eastern Atlantic floor plate
- Eurasia and the adjacent oceanic plate

Geomorphology

Minor tectonic plates

1. Cocos plate
    - Between Central America and Pacific plate
2. Nazca plate
    - Between South America and Pacific plate
3. Arabian plate
    - Mostly the Saudi Arabian landmass
4. Philippine plate
    - Between the Asiatic and Pacific plate
5. Caroline plate
    - Between the Philippine and Indian plate (North of New Guinea)
6. Fuji plate
    - North-east of Australia.



Geomorphology

Force for the Plate Movement

- Convection current cycle

Types of Plate boundaries interaction

- Divergence or Divergent Edge or the Constructive Edge
- Convergence or Convergent Edge or Destructive Edge
- Transcurrent Edge or Conservative Edge or Transform Fault.

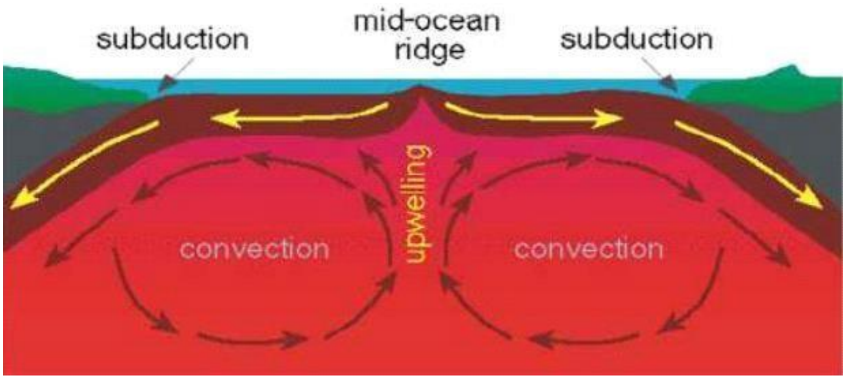
Divergence forming or Divergent Edge or the Constructive Edge

- Such edges are sites of earth crust formation (hence constructive) and volcanic earth forms are common along such edges.
- Earthquakes (shallow focus) are common along divergent edges.
- The sites where the plates move away from each other are called spreading sites.
- The best-known example of divergent boundaries is the Mid-Atlantic Ridge

Geomorphology

At Ocean

- Formation of Mid-oceanic ridges through which Basaltic magma erupts and moves apart (sea floor spreading).



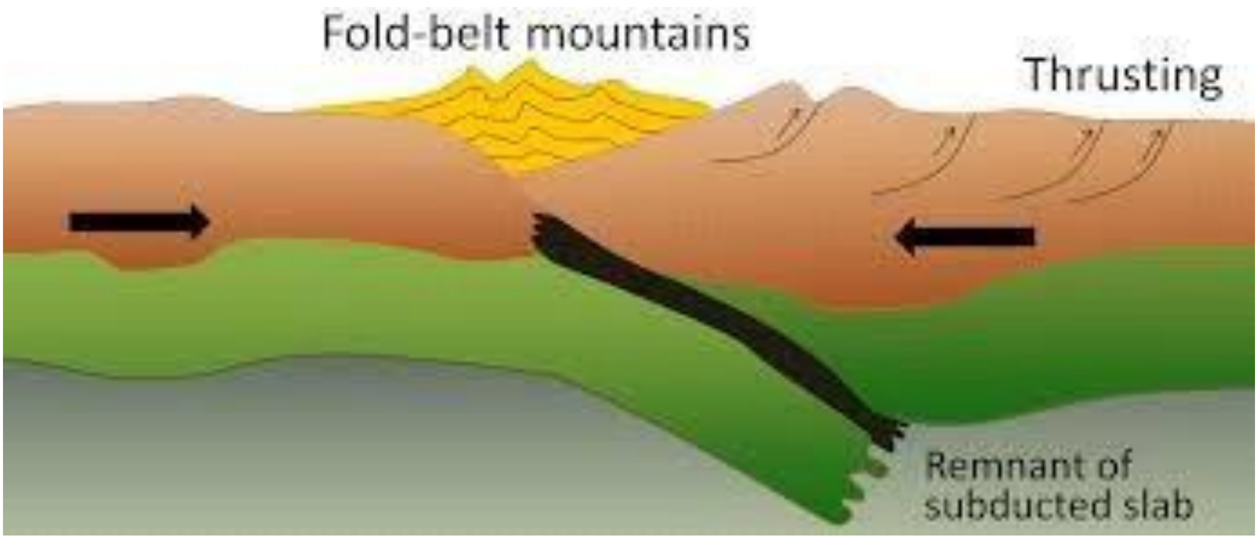
At Continents

- Formation of Rift Valley (East African Rift Valley on African and Somali plates).
- Rifts are the initial stage of a continental break-up.
- The continuous diverging force below the rifts can lead to the formation of a new ocean basin.

Geomorphology

Convergence or Convergent Edge or Destructive Edge

- When two oceanic plates collide, the denser plate sinks below the lighter plate.
    - Normally the older plate will subduct because of its higher density.
- It forms trench along the boundary.
- The rocks in the subduction zone become metamorphosed.
    - Low density and high pressure magma forms that rises upward due to the buoyant force.
- A continuous upward movement of magma creates volcanic islands on the ocean floor.
- Earthquake and Volcanism is common.



Geomorphology

Oceanic-Continental Boundaries

- When oceanic and continental plates collide, the oceanic plate undergoes subduction.
  - Oceanic plates are denser than continental plates, which mean they have a higher subduction potential.
  - They are constantly being pulled into the mantle, where they are melted and recycled into new magma.
  - It forms trench along the boundary. The trenches formed here are less deep than formed in ocean-ocean convergence.
- The rocks in the subduction zone become metamorphosed.
  - Low density and high pressure magma forms that rises upward due to the buoyant force.
- Earthquake and Volcanism is common.
- A continuous upward movement of magma creates constant volcanic eruptions at the surface of the continental plate along the margin.
- The Cascade Mountains of western North America and the Andes of western South America feature such active volcanoes.

Geomorphology

Continental-Continental Boundaries

- Continental-continental convergent boundaries pit large slabs of crust against each other.
- There is very little subduction as most of the rock is too light to be carried very far down into the dense mantle.
  - The zone of collision may undergo crumpling and folding and folded mountains may emerge.
- Magma cannot penetrate this thick crust; instead, it cools intrusively and forms granite. Highly metamorphosed rock, like gneiss, is also common.
  - Earthquake is frequent but no volcanic activity occurs.
- The ocean basin or a sedimentary basin (geosynclinal sediments found along the continental margins) is squeezed between the two converging plates.
  - Himalayan mountains have come out of a great geosyncline called the Tethys Sea.
- This is an orogenic collision. Himalayan Boundary Fault is one such example.

Geomorphology

Transform Boundaries

- Formed when two plates passes each other and grind against each other.
- There is only deformation of the existing landform (no creation or destruction)
  - Neither creation of crust (no basaltic lava eruption) nor destruction of crust (no subduction)
- Seismic activity occurs during grinding of passing plates.
- Example: San Andreas Fault @ western coast of USA

Ring of Fire

- The Ring of Fire is also known as the Circum-Pacific Belt.
- It is a path along the Pacific Ocean characterized by active volcanoes and frequent earthquakes.
- Along much of the Ring of Fire, plates overlap at convergent boundaries (falling limbs creating trenches) called subduction zones.
  - Plate that is underneath is pushed down (subducted) by the plate above, melts and becomes magma.

Geomorphology

- The abundance of magma so near to Earth's surface gives rise to conditions ripe for volcanic activity.

Importance of plate tectonic

- It helps in understanding of large-scale geological phenomena, such as earthquakes, volcanoes, and the existence of ocean basins and continents.
- It aids in the interpretation of landforms.
- The concept of plate tectonics explains mineralogy. New minerals pour up from the mantle and deposits on lithosphere. These rocks are the source of many minerals.
  - The famous Pacific Ring of fire known for its violent volcanic activity is also a ring of mineral deposits.

Geomorphology

Formation of Himalayas

- 225 million years ago (mya) India was a large island situated off the Australian coast and separated from Asia by the Tethys Ocean.
- The supercontinent Pangea began to break up and India started a northward drift towards Asia.
- India was 6,400 km south of the Asian continent but moving towards it at a rate of between 9 and 16 cm per year.
    - At this time Tethys Ocean floor would have been subducting northwards beneath Asia and the plate margin would have been a Convergent oceanic-continental one just like the Andes
- From about 50-40 Million years ago, the rate of northward drift of the Indian continental plate slowed to around 4-6 cm per year.
    - This slowdown is interpreted to mark the beginning of the collision between the Eurasian and Indian continental plates, the closing of the former Tethys Ocean, and the initiation of Himalayan uplift.

Geomorphology

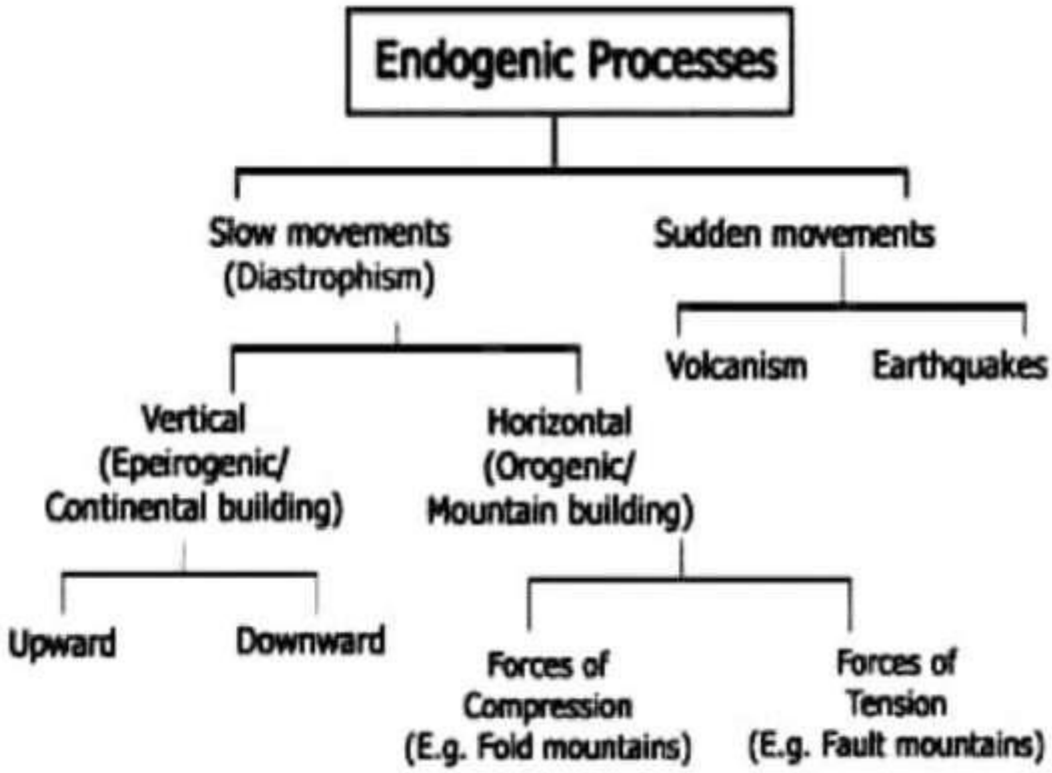
- The Eurasian plate was partly crumpled and buckled up above the Indian plate but due to their low density/high buoyancy neither continental plate could be subducted.
- This caused the continental crust to thicken due to folding and faulting by compressional forces pushing up the Himalaya and the Tibetan Plateau.
- The Himalayas are still rising by more than 1 cm per year as India continues to move northwards into Asia, which explains the occurrence of shallow focus earthquakes in the region today.

Geomorphic Processes

- After learning about the earth formation, the evolution of its crust and other inner layers, the rocks and minerals the crust is composed of, the crustal plates movement, it is time to know in detail about the surface of the earth on which we live.

Geomorphic Processes

- Force responsible for features on the earth surface comes from within (Endogenetic Forces) and above (Exogenetic Forces) the earth's surface.
- The endogenic and exogenic forces cause physical stresses and chemical actions on earth materials



and bring changes in the configuration of the surface of the earth are known as geomorphic processes.

- In general terms, the endogenic forces are mainly land building forces and the exogenic processes are mainly land wearing forces.
- The actions of exogenic forces result in wearing down (degradation) of relief/elevations and filling up (aggradation) of basins/ depressions, on the earth's surface.
- The phenomenon of wearing down of relief variations of the surface of the earth through erosion is known as gradation.
- The exogenic processes fail to even out the relief variations of the surface of the earth due to the endogenic forces that continuously elevate or build up parts of the earth's surface.
- The energy emanating from within the earth is the main force behind endogenic geomorphic processes.
- This energy is mostly generated by radioactivity, rotational and tidal friction and primordial heat from the origin of the earth.
- Due to variations in geothermal gradients and heat flow from within, the action of endogenic forces

Geomorphic Processes

are not uniform. Hence the tectonically controlled original crustal surface is uneven.

- Endogenetic forces are of 2 types based on direction
  a. Horizontal
  b. Vertical
- Endogenetic Forces are of 2 types based on intensity
  a. Sudden forces
  b. Diastrophic forces

Sudden Movements

- It is due to sudden forces from deep inside the earth.
- It can cause huge damage both at the surface and below the surface.

Endogenic Processes

- These are extreme events and become disaster when they occur in densely populated areas.
- It is a result of long period preparation deep within the earth; but the effects on the earth surface were quick and sudden.
- Geologically, they are known as 'Constructive forces' as they create relief features on the

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Geomorphic Processes

Earth's surface.

- The two main phenomenon for sudden movement are
- Volcanism
  - It includes the movement of molten rock (magma) onto or towards the earth's surface through narrow volcanic vents or fissures.
- Earthquake
  - It is a sudden motion or trembling in the earth caused by the abrupt release of slowly accumulated energy.

Diastrophic Movements

- All processes that move, lift or build up portions of the crust of Earth come under diastrophism.
- Very slow and effects become discernable after thousands and millions of years.
- Constructive forces- Affect larger areas of the globe and produce meso-level reliefs.
  - Example: mountains, plateaus and plains
- Diastrophic movements are further divided
  - Epeirogenic movements
  - Orogenic movements

Geomorphic Processes

Epeirogenic Movements

- Epeirogenic-or-continent forming movements are radial movements (act along the radius of the earth).
- It causes upliftment and subsidence of continental masses through upward and downward movements.
- Movements are vertical and they affect larger part.
- Vertical movements are mainly associated with the formation of continents and plateaus (continental building process).
- Upward movement can be of two types
  - Upward movement or upliftment
  - Downward movement or subsidence

Upward movement or upliftment

- Of whole continent or part there of
- Of coastal land of the continents called as emergence
- Coramandal coast (Tamil Nadu Coast)
- Malabar coast (Kerala Coast)
- Konkan coast (Maharashtra and Goa Coast)

Geomorphic Processes

Downward movement or subsidence

- Of whole continent or part there of
- Of coastal land near the coast called submergence
- Features = Ria, fjord, Dalmatian and drowned lowlands
- The Andamans and Nicobars is the visible part of the submerged Arakan range.
- A part of the Rann of Kachchh was submerged as a result of an earthquake in 1819.

Orogenetic Movements

- Horizontal movement or tangential force.
- Either move towards each other or away from each other.
- They move in opposite directions due to the 'tensional forces' or 'divergent forces' (create rupture, cracks, fracture and faults).
- They move towards each other due to the 'compressional forces or convergent force' (create crustal deformation leading to formation of folds or subsidence of crustal parts).

Crustal Deformation Processes

- The understanding of crustal deformation processes is very vital to effectively grasp the concept of fold and block mountains formation. These are basically of 3 types

- Compression- shortening (Fold mountain creation)
- Tension- Stretching (Block mountain creation)
- Shearing- stress when two pieces slide past each other (Transverse fault)

Folds

- A fold is an undulating structure (wave-like) that forms due to the application of compressional stress on rocks or a part of the earth's crust. The folds are made up of multiple strata (rock layers).Some important terminologies related to folds are
- Anticlines and synclines are the most common upand-down folds that result from compression.
- Anticline = ∩-shape with the oldest rocks in the center of the fold.
- Syncline = U-shape, with the youngest rocks in the center of the fold.
- OverturnedFold = A highly inclined axial plane such that the strata on one limb are overturned.
- RecumbentFold = has an essentially horizontal axial plane
- Nappe = A sheet of rock that has moved sideways

over neighbouring strata as a result of an overthrust or folding.

Faults

- A surface along which a rock body has broken and been displaced is known as a fault.
- Based on the elasticity of the rocks and the force, fractures are seen.
- Fault plane: The plane along which the rocks are displaced by tensional and compressional forces acting vertically and horizontally is known as a fault plane.
- Fault plane may be vertical, horizontal, inclined, curved or any other form

Normal Fault

- A dip-slip fault in which the block above the fault has moved downward relative to the block below.
- This type of faulting occurs in response to extension.
- Occurs when the "hanging wall" moves down relative to the "foot wall".

Reverse Fault

- A dip-slip fault in which the upper block, above

Geomorphic Processes

- the fault plane, moves up and over the lower block.
- This type of faulting is common in areas of compression.
- When the dip angle is shallow, a reverse fault is often described as a thrust fault.
- Occurs where the “hanging wall” moves up or is thrust over the “foot wall”.

Strike-slip fault

- A fault on which the two blocks slide past one another. The San Andreas Fault is an example of a right lateral fault.

Left-lateral strike-slip fault

- If you were to stand on the fault and look along its length, this is a type of strike-slip fault where the left block moves toward you and the right block moves away.

Right-lateral strike-slip fault

- If you were to stand on the fault and look along its length, this is a type of strike-slip fault where the right block moves toward you and the left block moves away.

Geomorphic Processes

Types of Mountains

Fold Mountains

- Fold Mountains are created at the converging site of two or more of Earth's tectonic plates.
- It is the result of Earth's crustal rocks folding by compressive forces due to the endogenic or internal forces.
- They are considered as the "true mountains".
- The term Orogenesis or mountain building is commonly used for Fold Mountains.
- These are extensive mountain chain with lofty Heights whereas their width is considerably small.
- These mountains formed along unstable part of the earth and hence have recurrent seismicity.
- They also contain rich mineral resources such as tin, copper, gold etc.
- Examples
  - Rockies (North America) – 4,830 km
  - Andes (South America)– 7,000 km
  - Alps (Europe)– 1,200 km
  - Atlas (Africa) – 2,500 km
  - Himalayas (Asia) – 2,400 km

Geomorphic Processes

Block Mountains

- Block Mountains are created where two or more of Earth's tectonic plates are drifted away.
- Result of rifting of the Earth's crustal rocks by tensile forces arising from the endogenic or internal forces.
- Also called fault-block Mountains since they are formed due to faulting as a result of tensile and compressive forces.
- The uplifted blocks are termed as horsts, and the lowered blocks are called graben.
- Examples
  - Great African Rift Valley
  - Rhine Valley

Volcanic Mountain

- A mountain formed due to volcanic activity is called Volcanic Mountain.
- As these are formed by the accumulation of volcanic material, they are also known as mountains of accumulation.
- Examples: Mt. Kilimanjaro (Tanzania), Mt. Fujiyama (Japan)

Geomorphic Processes

Residual Or Dissected Mountain

- These mountains are evolved by denudation.
- That is why they are also known as relict mountains or mountains of circumdenudation.
- They have been worn down from previously existing elevated regions.
- Examples
    - Nilgiri Hills
    - Parasnath
    - Girnar
    - Rajmahal.

Geomorphic Processes

The Andes

- Longest continental mountain range in the world.
- World's highest mountain range outside of Asia with an average height of 4000 meters.
- highest peak is Mount Aconcagua (6,962 m)
- volcanic origin, but now it's dormant
- World's highest volcanoes are in the Andes.
- Ojos del Salado (6,893 m),an active volcano, on the Chile-Argentina border is the highest volcano on earth.

The Rocky

- Mountain range forms a part of the American Cordillera.
- Formed due to Ocean-Continent collision.
- The rocks making up the mountains were formed before the mountains were raised.
- The Rocky Mountains took shape during an intense period of plate tectonic activity.

The Ural Mountains

- Their eastern side is usually considered the natural boundary between Europe and Asia.
- Since the 18th century, the mountains have been a major mineral base of Russia.

Geomorphic Processes

The Atlas Mountain

- Mountain range across the north-western stretch of Africa extending about 2,500 km through Algeria, Morocco and Tunisia.
- The highest peak is Toubkal (4,165 metres) in south-western Morocco.
- These mountains were formed when Africa and Europe collided.
- The Atlas ranges separate the Mediterranean and Atlantic coastlines from the Sahara Desert.
- It is home to the planet's highest peaks, including the highest, Mount Everest.
- The Himalayas are bordered on the northwest by the Karakoram and Hindu Kush ranges, on the north by the Tibetan Plateau, and on the south by the Indo-Gangetic Plain.

The Alps

- The mountains were formed as the African and Eurasian tectonic plates collided.
- Extreme folding caused by the event resulted in marine sedimentary rocks rising by thrusting and folding into high mountain peaks such as Mont Blanc (4,810 m) at French–Italian border.
- The Alpine region area contains about a hundred

Geomorphic Processes

- peaks higher than 4,000 meters, known as the fourthousanders.

Why world's highest mountains are at the equator

- Mountain height depends more on ice and glacier coverage than tectonic forces.
- In colder climates, the snowline on mountains starts lower down causing erosion at lower altitudes. At low latitudes, the atmosphere is warm and the snowline is high.
- At cold locations far from the equator, erosion by snow and ice easily matched any growth due to the Earth's plates crunching together.
- Hence, colder climates are better at eroding peaks.

Exogenic Processes

- Exogenic (Exogenetic) processes are a direct result of stress induced in earth materials due to various forces that come into existence due to sun's heat.
- Geomorphic Agent = Any exogenic element of nature (like water, ice, wind, etc.) capable of acquiring and transporting earth materials (mobile medium)

Geomorphic Processes

- The effects of most of the exogenic geomorphic processes are small and slow but it affect the rocks severely in the long run due to continued fatigue.

Denudation

- All the exogenic geomorphic processes (Weathering, mass wasting/movements, erosion and transportation) are included in denudation.
- 'Denude' means to strip off or to uncover.
- Internal resisting force applied per unit area is called stress. The basic reason that leads to weathering, erosion and deposition is development of stresses in the body of the earth materials.
- Forces acting along the faces of earth materials are shear stresses (separating forces). It is this stress that breaks rocks and other earth materials.
- Temperature and precipitation are the two important climatic elements that control various processes by inducing stress in earth materials.
- Earth materials become subjected to molecular stresses caused due to temperature changes.
- Loosening of bonds between grains caused due to chemical processes.

Volcanism

Volcanism

- Volcanism includes the movement of molten rock (magma) onto or toward the earth's surface.
- A volcano is a place where gases, ashes and/or molten rock material – lava – escape to the ground.
  - Pyroclastic: Denotes rock fragments or ash erupted by a volcano, especially as a hot, dense, destructive flow.

Why do they erupt?

- Volcanoes are just a natural way through which the Earth and other planets cool-off by releasing internal heat and pressure.

Factors that lead to volcanism

1. Plate Tectonics
   - Convergence of two lithospheric plates (due to the converging limbs of convection cell) causing downward movement of one into the mantle
2. Ocean floor spreading
   - The plates move apart on both sides of the ridge (due to the diverging limbs of convection cell) and magma wells up from the mantle.

Volcanism

3. Plate movement over a "hot spot"
   - Magmas can penetrate to the surface via relatively fixed "hotspot" (We will read about it in detail ahead).
4. Weak Earth Surface
   - Magma and gases find the opportunity to escape with great velocity through eruptions due to high internal pressure.
5. A decrease in External Pressure
   - This can trigger an eruption by minimizing the volcano's ability to hold back the increasing pressures inside the magma chamber.

Volcanism

Classification on The Basis Of External Landform

1. Conical Vent
   - Narrow vent through which magma comes out explosively.
   - Common in Andesitic volcanism (Stratovolcano)

2. Fissure vent
   - Narrow and linear volcanic vent through which lava comes out
   - Generally no explosive activity occurs.
   - Common in basaltic volcanism (shield type volcanoes)

3. Shield Volcanoes
   - Found at constructive plate margins
   - Mostly made-up of basalt
   - These volcanoes are not steep
   - Less explosive (But becomes explosive if water gets into the vent)
   - Example: Mauna Loa (Hawaii).

Volcanism

4. Composite Volcanoes (Stratovolcano)

- Found at destructive plate margins.
  Eruption of cooler and more viscous lava (Andesitic lava) than basalt.
- Violent eruption
- Pyroclastic material accumulates in the vicinity of the vent openings. This leads to formation of layers making the mounts appear as composite volcanoes.
- Examples Mount St. Helens, Mount Rainier, Mt. Stromboli 'Lighthouse of the Mediterranean', Mt. Vesuvius, Mt. Fuji etc.

Volcanism

Effects of Volcanoes

Positives Effects of Volcanoes

- Volcanism creates new landforms like islands, plateaus, volcanic mountains etc.
- The volcanic ash and dust are very fertile for farms and orchards.
- Volcanic rocks yield very fertile soil upon weathering and decomposition.
- Although steep volcano slopes prevent extensive agriculture, forestry operations on them provide valuable timber resources.
- Mineral resources, particularly metallic ores are brought to the surface by volcanoes.
- The Kimberlite rock (source of diamonds) of South Africa is the pipe of an ancient volcano.
- Waters in the depth are heated from contact with hot magma giving rise to springs and geysers.
- The geothermal heat energy resource from the earth's interior in areas of volcanic activity is used to generate Geothermal Electricity
- The Puga valley in Ladakh region and Manikaran (Himachal Pradesh) are promising spots in India for the generation of Geothermal Electricity.

Volcanism

- Geothermal potential can also be used for space heating.
- As scenic features of great beauty, attracting a heavy tourist trade, few landforms outrank volcanoes.

Destructive Effects of Volcanoes

- The damage is caused by advancing lava which engulfs whole cities.
- Showers of cinders and bombs can cause damage to life.
- Violent earthquakes associated with the volcanic activity and mudflows of volcanic ash saturated by heavy rain can bury nearby places.
- Sometimes ash can precipitate under the influence of rain and completely cover whole cities.
- In coastal areas, seismic sea waves (called tsunamis in Japan) are an additional danger which are generated by submarine earth faults where volcanism is active.

Volcanism

Volcanism - Acid Rain, Ozone Destruction

- The volcanic gases like sulfur dioxide, carbon dioxide, and hydrogen fluoride etc. pose the greatest potential hazard to people, animals, agriculture, and property.
- Locally, sulfur dioxide gas can lead to acid rain and air pollution.
- Globally, large explosive eruptions that inject high volume of sulfur aerosols into the stratosphere can lead to lower surface temperatures and promote depletion of the Earth's ozone layer.

Volcanos in India

- There are no volcanoes in the Himalayan region or in the Indian peninsula.
- Barren Island, lying 135 km north-east of Port Blair became active again in 1991 and 1995.
- The other volcanic island in Indian territory is Narcondam, about 150 km north-east of Barren Island; it is probably extinct. Its crater wall has been completely destroyed.

Volcanism

Some significant Volcanic Eruptions

- In the history of mankind perhaps the most disastrous eruptions were those of Mt. Vesuvius, Mt. Krakatau and Mt. Pelee.

Mt. Vesuviusis

- A Stratovolcano (composite volcano) in Italy.

Krakatau

- Krakatau is a small volcanic island in the Sunda Straits, between Java and Sumatra.

Mt. Pelee

- In West Indies

Tsunamis

Tsunamis

- Tsunamis are extremely high sea wave caused by an earthquake.
- It wreaks havoc on settlement of coastal areas.
- Tsunamis are waves generated by the tremors and not an earthquake in itself.

How Tsunami Waves Generated

- A tsunami is caused by a large and sudden displacement of the ocean. This displacement caused due to:
  - Earthquake
  - Undersea volcanoes
  - Anthropogenic factors like nuclear explosions
  - Landslides
  - Meteors, Asteroids

Properties of Tsunami Waves

- Tsunamis are a series of waves of very, very long wavelengths and period created in oceans by an impulsive disturbance.
- Tsunamis behave as shallow-water waves because of their long wavelengths.

Tsunamis

- It travels at different speeds in water: it travels slow in water that is shallow and fast in deep water.

2004 Indian Ocean Tsunami

- An earthquake under the Indian Ocean on 26th of December 2004 generated the Tsunami wave that had impacted the Indian Ocean Region very severely.
- Earthquake had its epicenter near the western boundary of Sumatra. The with magnitude of 9.0 on the Richter scale.
    - Reason: Indian plate went under the Burma plate due to the tectonic activity
- The gap that was being created by the displacement was filled by in-flow of surrounding water.
- This caused the withdrawal of the water mass from the coastlines of the landmasses in the south and Southeast Asia.
- The water mass rushed back towards the coastline as a tsunami after thrusting of the Indian plate below the Burma plate.

Oceanography

The oceans are the largest and most prominent feature on Earth. In fact, they are the single most defining feature of our planet. Water covers roughly around 70% of Earth's surface. The world ocean is a single inter-connected body of water, which is large in size and volume. It can be divided into five principal oceans- the Pacific, Atlantic, Indian, Southern or Antarctic Ocean, and Arctic Ocean.

Divisions of the Ocean Floor

The ocean floors can be divided into four major divisions

1. Continental-Oceanic margin
    a. Continental Shelf
    b. Continental Slope
    c. Continental Rise
2. Deep ocean plains
3. Oceanic Ridges

Oceanography

Continental Shelf

- Angle is 1°, depth is 120-150 meter and It extends generally 70 km into the sea. But this varies a lot
- Width: The continental shelf is virtually absent in west coast of South America. It is 120 km wide in east coast of North America. In Bay of Bengal too, it is very wide.
- Depth: It may be as shallow as 30 m in some areas while in some areas it is as deep as 600 m.
- The shelf typically ends at a very steep slope, called the shelf break.
- Continental Shelf of all oceans together covers 7.5% of the total area of the oceans.
- The continental shelves are covered with variable thicknesses of sediments brought down by rivers, glaciers etc.
- The shelf is formed mainly due to
    - Submergence of a part of continent
    - Relative rise in sea level
    - Sedimentary deposits brought down by rivers

Oceanography

Continental Slope

- At the end of continental shelf slope steepens abruptly.
- The continental slope connects the continental shelf and the ocean basins.
- The gradient of the slope region varies between 2°-5°.
- The depth of the slope region varies between 200 m and 3km.
- The seaward edge of the continental slope loses gradient at this depth and gives rise to continental rise.
- Canyons and trenches are observed in this region.

Continental Rise

- The continental rise is a sediment underwater feature found between the continental slope and the abyssal plain.
- Sediment, silt, and other material are picked-up by river when it travels over land, which is gradually carried out to sea. Some of these sediments settle on the continental shelf, but others drift down the continental slope to form the continental rise.

Oceanography

Deep Sea Plain (Abyssal Plain)

- At the end of continental slope, slope becomes gentle again to 0.5° to 1°.
- Its end marks the end of continental margin.
- Undulating plain lies 2-3 miles below sea level and cover 40% of ocean floor.
- Lying generally between the foot of a continental rise and a mid-ocean ridge.
- Abyssal plains cover more than 50% of the Earth's surface.
- These plains are covered with fine-grained sediments like clay and silt.

Oceanic Ridges

- A mid-oceanic ridge is composed of two chains of mountains separated by a large depression. [Divergent Boundary]
- The oceanic ridge system is a continuous underwater mountain range. It is created when magma rising between diverging plates of the lithosphere cools and forms a new layer of crust.

Oceanography

Minor Relief Features in the Ocean Floors

1. Submarine Canyons
    - Canyons are deep concave gorges on continental shelf, slope or rise, often extending from the mouths of large rivers.

2. Trenches
    - Long narrow and steep depression on abyssal plain is called a trench.
    - The trenches lie along the fringes of the deep sea plain at the bases of continental slopes and along island arcs.
    - They are of tectonic origin and are formed during Ocean-Ocean Convergence and Ocean-Continent Convergence.

3. Sea mounts
    - Sea hills on abyssal plains rising above 1000 meters from the floor are called sea mounts.

4. Hills
    - Sea hills on abyssal plains rising less than 1000 meters from the floor are called Abyssal hills.

Oceanography

5. Guyots
    - Guyots are seamounts which have flat tops. All of them are generally of volcanic origin.

Marginal Sea

- A marginal sea is a division of an ocean, partially enclosed by islands, archipelagos, or peninsulas, adjacent to or widely opens to the open ocean at the surface, and/or bounded by submarine ridges on the sea floor.
- Examples:
    - Arabian Sea
    - Persian Gulf
    - Red Sea
    - Gulf of Oman
    - Gulf of Aden
    - Gulf of Kutch
    - Gulf of Khambat
    - Bay of Bengal
    - Andaman Sea
    - Malacca Strait
    - Mozambique Channel
    - Great Australian Bight
    - Gulf of Mannar
    - Laccadive Sea

Oceanography

Bays

- Bay is a water body surrounded on three sides by land with the fourth side (mouth) wide open towards oceans (In Gulfs, the mouth is narrow).
- A bay is usually smaller and less enclosed than a gulf.
- Example: Hudson Bay (Canada), Bay of Bengal etc.
- An example of a bay at a river's mouth is New York Bay, at the mouth of the Hudson River

Gulfs

- A gulf is a large body of water, sometimes with a narrow mouth, that is almost completely surrounded by land.
- The world's largest gulf is the Gulf of Mexico.
- Other Examples:
    - Gulf of California
    - Gulf of Aden (between the Red Sea and the Arabian Sea)
    - Persian Gulf (between Saudi Arabia and Iran)
    - Gulf of Mannar

Oceanography

Straits

- A strait is a narrow passageway of water between the landmass (continents or islands).
- When a body of water such as a strait is capable of being blocked or even closed in order to control transportation routes, the body is called a choke point

Isthmus

- Isthmus is the land-equivalent of a strait i.e. a narrow strip of land connecting two larger land masses.
- Example: Isthmus of Panama and Isthmus of Suez

Oceanography

Ocean Temperature

- The study of the temperature of the oceans is important for determining:
  - movement of large volumes of water (Ocean Currents)
  - type and distribution of marine biodiversity
  - climate of coastal areas, etc.
- Main energy source for ocean temperature - Insolation (Incoming Solar Radiation)
- Oceans play an important role in energy and temperature regulation on earth (it warms slowly in comparison of land due to its specific heat of the water).
- Average temperature of ocean is 3-5 degree Celsius
- But average surface temperature of ocean water is 25 degree

Factors affecting temperature distribution

1. Latitude

- Surface water temperature decreases from the equator towards the pole.

Oceanography

- But highest temperature is not at the equator instead at the tropics

2. Hemispheric variation
   - Unequal distribution of land and water.
   - Northern hemisphere is warmer than southern because of large land mass in northern hemisphere

3. Prevailing winds
   - The offshore winds (winds blow towards the ocean from the land) drive warm surface water away from coast. This results in upwelling of cold water from below.
   - The onshore winds raise the temperature at coast by piling up warm water near it.

4. Ocean currents
   - Oceanic currents describe the movement of water from one location to another.
     - Warm ocean currents: Increases the temperature of cold areas (like Gulf stream)
     - Cold ocean currents: Lowers the temperature in cold areas (Like Canary current)

Oceanography

5. Enclosed and open sea
   - Temperature at Lower latitudes: Enclosed sea > Open sea
   - Temperature at Higher latitude: Open sea > Enclosed sea

6. Physical characteristics of the sea surface:
   - Boiling point of the sea water increases with increasing salinity and vice versa.
   - Salinity increased --> Boiling point increased --> Evaporation decreased

7. Diurnal range of temperature
   - Maximum temperature in day and minimum temperature in night time.
   - Tropical water has higher diurnal range (due to less cloud) than equatorial waters.
     - Because, heating and cooling of water rapid under clear sky.

8. Annual range of temperature
   - Bigger the size of ocean = Better mixing of water and heat + Slow heating

Oceanography

- Pacific ocean -> Lower annual range than Atlantic Ocean

Variation in ocean temperature

- Earth's surface at equator receives about four times more average incoming solar energy than at pole.
- Radiation penetrates some distance below the surface due to the transparency of water.
- Shorter wavelengths (high energy) penetrate deeper than longer wavelengths. Heat is carried further to the deeper levels by mixing.
- Diurnal and seasonal temperature variations are relatively small in water than on land due to the high specific heat of water.
- Most solar energy is absorbed within a few meters of the ocean surface by directly heating the surface water. This provides the energy for photosynthesis for marine plants and algae.

Vertical variation in oceanic temperature

- Vertical distribution of temperature in the deep ocean is controlled by density driven water movements

Oceanography

- The maximum temperature of oceans is always at their surface due to the direct incidence of solar energy.
- Heat conduction by itself is extremely slow, so only a small proportion of heat is transferred downwards by this process.
- The heat is transmitted to the lower sections of the oceans through the process of convection.

Thermal layer distribution in ocean

- 1st layer
  - Top layer consists of warm oceanic water.
  - It is about 500 meter thick with temperature range between 20-25°C.
  - This layer exists throughout the year in tropical region but develops only during summer in midlatitude.
- 2nd layer
  - Temperature decline rapidly between the depths of about 200 meters to 1000 meters.
  - This region of steep temperature gradient is known as the permanent thermocline.
  - About 90 per cent of the total volume of water is found below the thermocline in the deep ocean. In this zone, temperatures approach 0°

Oceanography

    - The thermocline is less steep (almost absent) in Polar Regions as the surface temperatures are close to 0°C which results in small variations in temperature with depth.
- 3rd layer
    - There is virtually no seasonal variation beyond 1000 meters (beneath permanent thermocline) and the temperatures are around 2°C.
    - This layer extends up to the deep ocean floor.
    - This narrow range is maintained throughout the deep oceans, both geographically and seasonally, because it is determined by the temperature of the cold, dense water that sinks at the polar-regions and flows towards the Equator.

Horizontal variation in oceanic temperature

- Average temperature of surface water of the ocean is about 27 °C.
- Average temperature gradually decreases from the equator towards the poles.
- The ocean temperature records, relativity lower temperature in southern hemisphere then the northern hemisphere.

Oceanography

- This anomaly is a result of unequal distribution of land and water in the northern and southern hemispheres.
- The highest temperature is recorded slightly away from equator in the northern direction.

Salinity

- Throughout Earth's history, certain processes have served to make the ocean salty. The weathering of rocks delivers minerals, including salt, into the ocean.
  - Salinity is a vital property of sea water. It is determined by the amount of salt (in gm) dissolved in 1,000 gm (1 kg) of seawater.
  - It is usually expressed as parts per thousand
  - Salinity of 24.7 o/oo has been considered as the upper limit to demarcate 'brackish water'.
- Even small variations in ocean surface salinity (i.e., concentration of dissolved salts) can have dramatic effects on the water cycle and ocean circulation.

Oceanography

Factors that increase salinity

- Evaporation from the ocean's surface waters removes water molecules, leaving the salt behind.
- Ice formation as freezing of ice leaves salt in the water.
- Advection of more saline water
- Mixing with more saline deep water(Due to the ocean currents)
- Solution of salt deposits

Factors that decrease salinity

- Precipitation on the ocean surface waters adds water molecules.
- Melting of ice which dilutes the concentration of salt in the water.
- Advection of less saline water
- Mixing with less saline deep water(Due to the ocean currents)
- Inflow of fresh water from land

Oceanography

Vertical Distribution of Salinity

- Salinity changes with depth, but the way it changes depend upon the location of the sea.
- Other factors being constant, increasing salinity of seawater causes its density to increase. High salinity seawater, generally, sinks below the lower salinity water. This leads to stratification by salinity.
- There is a distinct zone called the halocline (compare this with thermocline) where salinity increases sharply.

Horizontal Distribution of Salinity

- Highest salinity is found near tropics.
- It decreases towards equator and pole
    - Equator = Heavier rains causes incorporation of Freshwater
    - Poles = Less evaporation prevents removal of water molecule from the surface

Oceanography

Relationship Between Salinity, Temperature and Density

- Temperature and density share an inverse relationship. As temperature increases, the space between water molecules increases (hence volume increases) which therefore decreases the salinity.
- If the temperature of water decreases its density increases, but only to a point.
- At a temperature of 4°C pure water reaches its maximum or peak density, cooled further it expands and becomes less dense than the surrounding water which is why when water freezes at 0°C it floats.

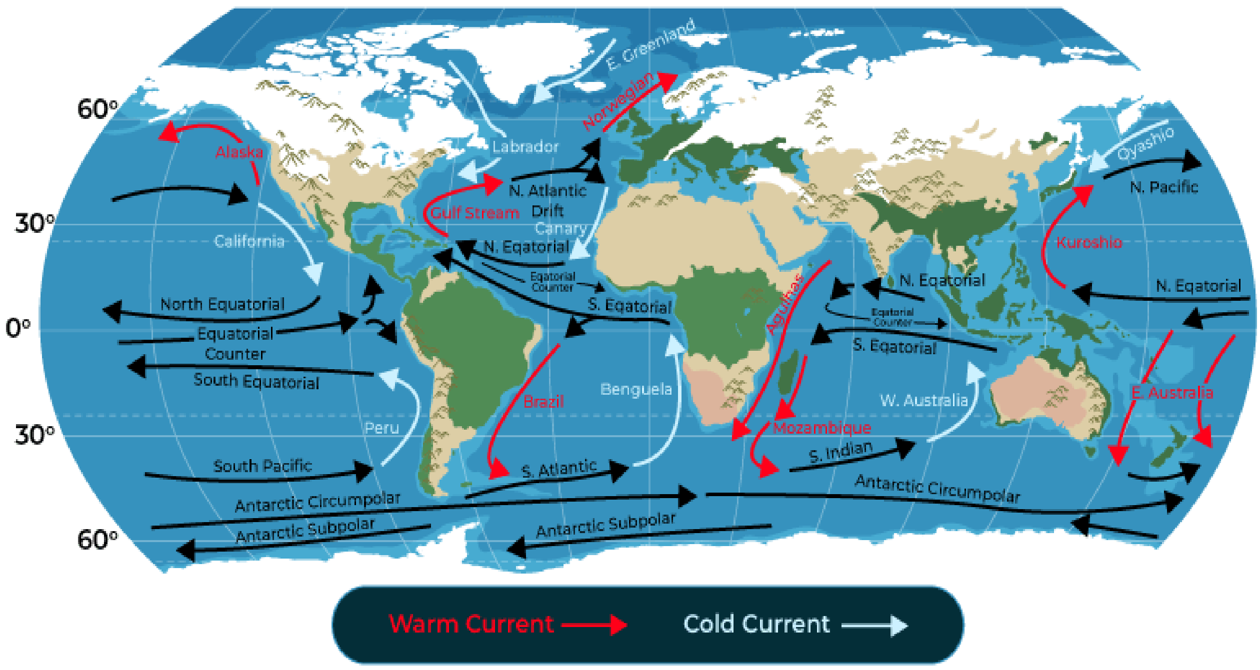
Salinity and density

- It share a positive relationship. As density increases, salinity increases.
- The ocean water is constantly churning underneath, bringing nutrients up to the top.
  - The difference in density of cold water versus density of warmer water is responsible for ocean currents and upwelling.
  - Warm seawater floats and cold dense seawater sinks

Oceanography

Ocean Current

- Ocean current is a continuous, directed movement of ocean water masses that flow from one place to another circumnavigating the earth.
- The forces that initiate the movement of water are:
    - Wind
    - Heating by Solar Energy
    - Salinity
    - Thermohaline Differences
- Ocean Currents can be classified as warm or cold currents



Oceanography

Equatorial Countercurrents

- Equatorial currents moves large volume of water westward. As a result water piles up along the western margin of an ocean basin, which raises sea level on the western side of the basin.
- The water on the western margins then flows downhill under the influence of gravity, creating narrow equatorial counter currents that flow to the east counter to and between the adjoining equatorial currents.

North Indian Ocean Currents

- Indian Ocean is half an ocean; hence the behavior of the North Indian Ocean Currents is different from that of Atlantic Ocean Currents or the Pacific Ocean Currents.
- Seasonal monsoon winds peculiar to the Northern Indian Ocean region directly influence the ocean surface water movement.
- Due to the seasonal change of ocean current circulation, North Indian Ocean Currents is important for sea-trade, cultural interaction.

Oceanography

- During summer, wind and current flow towards India from Arabia in influence of strong south-west monsoon winds.
  - Sea vessel moves from Arabia to India by utilizing wind and ocean current.
- During winter, wind and current flow towards Arabia from India in influence of prevailing trade winds (easterly trade winds)
  - Sea vessel moves from India to Arabia by utilizing wind and ocean current.

Effects of ocean currents

- Meeting of cold and warm currents creates excellent fishing zones.
  - Kurishio (warm) + Oyashio (cold)
  - Labrador (cold) + Gulf Stream(warm)
  - Falkland (cold) + Brazilian(warm)
  - Mixing of cold and warm water creates fog.
- Warming effect by warm current
  - This makes port operable near the adjacent areas in comparison of areas lying on the same latitude but at the locations where cold current flows.
  - Norway ports are operable in winter whereas ports in Russia freeze.

Oceanography

- Dessicating effect by cold currents (an element for desert formation)
  - Peru or Humboldt current = Atacama Desert
  - Benguela current = Namib Desert
  - Canary current = Sahara Desert
  - California current = Mojave Desert

Upwelling

- Upwelling occurs where water from the deeper parts of the ocean is allowed to travel upwards to the surface.

Downwelling

- Downwelling is the vertical movement of surface water to deeper parts of the ocean which occurs in the areas where waters converge and "pile up".

Oceanography

Coral Reefs

- Underwater structures made from calcium carbonate secreted by corals.
- It often called "rainforests of the sea" as they form some of the most diverse ecosystems on Earth.
- An individual coral is known as a polyp which has a symbiotic relationship with plant like cells called zooxanthellae.
  - Polyp ingests tiny organisms called plankton & other small creatures.
- Each polyp excretes a calcium carbonate exoskeleton beneath it. Over long periods of time, the skeletons of many coral colonies add up to build the structure of a coral reef.
- Many other species like fish, invertebrates, algae and microorganisms make their homes on and around this reef.
- Coral reefs over a period of time transform or evolve into coral Islands (Lakshadweep).
  - In India, they are present around A&N, Lakshadweep, Gulf of Kutch and the Gulf of Mannar.

Oceanography

Coral Reef Relief Features

- Fringing reef (Shore reefs), barrier reef and atoll (coral islands are formed on atolls) are the most important relief features.

Fringing Reef

- It is a coral platform attached to a continental coast or an island, sometimes separated by a narrow, shallow lagoon known as Boat Channel.
- They grow from the deep bottom of the sea and have their seaward side sloping steeply into the deep sea.
- Coral polyps do not extend outwards because of sudden and large increase in depth.
- Fringing Reefs are the most commonly found coral reefs among the three.
- Example: Sakau Island in New Hebrides, South Florida Reef

Barrier Reef

- Barrier Reefs develop off the coast and parallel to the shore as a broken and irregular ring.

Oceanography

- They are separated from their adjacent land mass by a lagoon of open, often deep water.
- They are considered as the largest, highest and widest reefs among the three coral reefs.
  - They run for 100 kilometres and is several kilometres wide
- Barrier reefs are far less common than fringing reefs or atolls, although examples can be found in the tropical Atlantic as well as the Pacific.
- Example: The Great Barrier Reef of Australia which is 1200 mile long.

Atoll

- An atoll can be defined as a reef that is roughly circular and surrounds a large central lagoon.
  - If a fringing reef forms around a volcanic island that subsides completely below sea level while the coral continues to grow upward, an atoll forms.
- This lagoon is mostly deep having a depth of 80-150 meters and may be joined with sea water through a number of channels cutting across the reef.
- Atolls are located at great distances from deep

sea platforms, where the submarine features may help in formation of atolls, such as a submerged island or a volcanic cone which may reach a level suitable for coral growth.

- **Example:** Fiji Atolls, Suvadivo in Maldives and Funafoothis Atoll of Ellice.

Conditions for survival

- Shallow Water upto 50 meters depth
- Clear Water
- Warm Water (20-32°C)
- Pollution Free Water
- Moderate Salinity

Oceanography

Prominent features of Coral Reefs

- Coral lives a symbiotic life. Inside the sac of each coral polyp lives zooxanthellae algae.
- Algae gives off oxygen and other nutrients (for food) that the coral polyp needs to live and in return the polyp provides the zooxanthellae with shelter and nutrients.
- That is why coral reefs grow so near the surface of the water where it is the sunniest–the algae need sunshine for photosynthesis.
- Corals also capture food. At night, they stretched out their stinging tentacles and catch the microscopic organisms that flow in the water and digest them in their stomachs.
- Hence, corals have two way of getting food - through zooxanthellae and capturing microscopic organisms.
- Despite occupying less than 1% of the world's ocean surface, they provide a home for 25% of all marine species.
- In addition to providing corals with essential nutrients, zooxanthellae are responsible for the unique and beautiful colors of many stony corals.

Oceanography

Distribution of Coral Reefs

- The majority of reef building corals are found within tropical and subtropical waters. These typically occur between 30° north and 30° south latitudes.
- The Indonesian/Philippines archipelago has the world's greatest concentration of reefs and the greatest coral diversity. Other area of reef concentration are the Great Barrier Reef of Australia, the Red Sea and the Caribbean, the latter having a much lower diversity than all major Indo- Pacific regions.

Coral Bleaching

- Coral bleaching occurs when the relationship between the coral host and marine algae, which give coral much of their colour, breaks down.
- Without the marine algae, the tissue of the coral animal appears transparent and the coral's bright white skeleton is revealed.

Oceanography

Causes of coral bleaching

- Rise in Sea Temperature due to extreme weather events and global warming
- Ocean Acidification
- Solar radiation and ultraviolet radiation
- Infectious Diseases
- Chemical Pollution
- Increased Sedimentation
- Human Induced Threats

Climatology

Evolution of the Atmosphere

- There are three stages in the evolution of the present atmosphere.

Loss of primordial atmosphere.

- The early atmosphere, with hydrogen and helium, is supposed to have been stripped off as a result of the solar winds.
  - Evolution of the atmosphere by hot interior of the earth.
- During early life of the earth, Nitrogen, Sulphur, Carbon Dioxide, Water Vapour, and Argon came out due to the extensive volcanism and degassing.
- Modification of atmospheric composition by the living world through the process of photosynthesis.
  - Water vapour condensed, that led to the formation of clouds andhence the rainfall washed out the bulk of Carbon Dioxide into the Oceans.
  - Oxygen was produced from anaerobic respiration of bacteria like, Cynobacteria (and not from degassing).
- The present composition of earth's atmosphere is chiefly contributed by nitrogen and oxygen.

Climatology

Properties of Gases

- Nitrogen, Oxygen, Hydrogen and Argon are permanent gases.
- Water vapour, Carbon Dioxide, Ozone are variable gases.
- Neon, Argon – inert gases
- Atmospheric gases
- No chemical interaction among them
- They don't lose their properties
- They act as a single unified gas

Composition of Atmosphere

- Atmosphere is a mixture of different odorless, tasteless and colorless gases, dust and vapour.
- It is a relatively thin layer enveloping the earth all round and held by the Earth's gravity. It extends several thousands of kilometers above earth surface.
- It is a protective boundary between outer space and the biosphere.

Air

- Air is mostly gas.
- Air in motion is called wind.
- Atmosphere is an envelope of air composed of numerous gases. These gases support life over the

earth's surface.

- The air in Earth's atmosphere is made up of approximately 78% nitrogen and 21% oxygen.
- Air also has small amounts of lots of other gases, too, such as carbon dioxide, neon, and hydrogen.

Dust Particles

- Small solid particles originate from different sources.
- It includes sea salts, fine soil, smoke-soot, ash, pollen, dust and disintegrated particles of meteors.
- They are generally concentrated in the lower layers of the atmosphere.
- They can be transported to great heights by convectional air currents.
- The higher concentration of dust particles is found in subtropical and temperate regions due to dry winds in comparison to equatorial and Polar Regions.

Hygroscopic nuclei

- They are the dust particles around which the water vapor condense to form clouds.

Climatology

Greenhouse Effect

- The greenhouse effect is a process that occurs when gases in Earth's atmosphere trap the Sun's heat.
- This process makes Earth much warmer than it would be without an atmosphere.
- The greenhouse effect is one of the things that make Earth a comfortable place to live.

Greenhouse Gases

- Greenhouse gases are gases in Earth's atmosphere that trap heat.
- They let sunlight pass through the atmosphere, but they prevent the heat that the sunlight brings from leaving the atmosphere.
- GHGs absorb long wave terrestrial radiation.
- Some of the main greenhouse gases are:
    - Water vapor
    - Carbon dioxide
    - Methane
    - Ozone

Each gas's effect on climate change depends on 3 main factors

How much is in the atmosphere?

- Concentration, or abundance, i.e. the amount of a particular gas in the air.

- Larger emissions of greenhouse gases lead to higher concentrations in the atmosphere.

How long do they stay in the atmosphere?

- Each of these gases can remain in the atmosphere for different amounts of time, ranging from a few years to thousands of years.

How strongly do they impact the atmosphere?

- Some gases are more effective than others at making the planet warmer and thickening the Earth's blanket.
- For each greenhouse gas, a Global Warming Potential (GWP) has been calculated to reflect how long it remains in the atmosphere, on average, and how strongly it absorbs energy. Gases with a higher GWP absorb more energy than gases with a lower GWP, and thus contribute more to warming Earth.

Water vapour

- A variable gas in the atmosphere that decreases with altitude and on moving from the equator towards the poles.
- Its concentration is higher in warm and wet

tropics in comparison of the dry and cold areas of desert and Polar Regions.

- It also absorbs parts of the incoming solar radiation and preserves the radiated heat from the earth (terrestrial radiation).
- Hence, it acts like a blanket allowing the earth neither to become too cold nor too hot.
- It also contributes to the stability and instability in the air.

Carbon Dioxide

- Meteorologically a very important gas because of its transparency to the incoming solar radiation but opaqueness to the outgoing terrestrial radiation.
- It absorbs a part of terrestrial radiation and reflects back some part of it towards the surface of earth.
- It is largely responsible for the greenhouse effect.

Methane

- One of the most important greenhouse gases.
- It is produced from decomposition of animal wastes and biological matter.

Climatology

Nitrous oxide

- Nitrous oxide is emitted during agricultural and industrial activities, combustion of fossil fuels and solid waste, as well as during treatment of wastewater.

Fluorinated gases

- These are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes.
- Fluorinated gases are sometimes used as substitutes for stratospheric ozone-depleting substances.
- These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases ("High GWP gases").

Ozone

- Important component of the atmosphere found between 10 and 50 km above the earth's surface.
- Prevents surface of the earth by absorbing the harmful ultra-violet radiations coming from the sun.

Climatology

Structure of Atmosphere

Thermal Zone Segregation

Troposphere

- Lowermost layer of the atmosphere.
- Also known as convective region (all convection occurs till the Tropopause).
- Tropopause Zone separating the troposphere from stratosphere. The temperature here is nearly constant.
    - Average height: 13 km
    - Highest at equator (18 km) because heat is transported to great heights by strong convectional currents
    - Lowest at poles (8 km)
- The temperature is also lowest at equator (-80°C) as compared to poles (-45°C). This is because convectional currents are strongest at equator.
- 90% of total mass.
- Contains dust particles and water vapor.
- Most cloud appear here as approx 99% of water vapor is found here.
- All changes in climate and weather take place in this layer.

Climatology

- Seasons and jet streams affect troposphere.
- Most important layer for all biological activity.
- Temperature reduces at 6.5°C/km or 1°C▼/165m (normal lapse rate) as we move up.

Stratosphere

- Extends from tropopause to 50 km.
- Important Feature = It contains the Ozone Layer (Shields life on the earth by absorbing intense, harmful ultra-violet radiation)
- Temperature inversion: Normal Lapse Rate ends here. This warming of the stratosphere with altitude is caused largely due to absorption of solar energy by ozone.
- The air movements are almost horizontal. This is because the effect of convection currents is almost negligible in comparison to troposphere. This in turn prevents vertical mixing of pollutants from troposphere to stratosphere.
- Ideal region for flying jets as clouds are almost absent (sometimes layer possess cirrus clouds in lower level).
- Winds blow from west to east.

Mesosphere

- Ranges 50-80 km (Stratopause and Mesopause)

Climatology

- Temperature again starts falling with elevation (because no GHGs exists here, i.e. no heat absorbing layer nor ozone layer).
  - Temperature decrease from 0 °C to -90 °C.
- Meteors burn in this layer.
  - Mesospheric or Noctilucent clouds visible at high latitude during summer season due to the condensation of moisture around the meteoric dust.
- **Mesopause:** Upper limit of mesosphere
- Very thin layer causes difficulty in breathing.

Thermosphere

- It extends from 80-400 km and contains electrically charged particles known as ions (Region is known as Ionosphere).
- Temperature rises with height again due to proximity to the sun (Ions absorbs heat).
  - Even though the temperature is high but because of rarified atmosphere the heat could not be felt.
- International Space Station & Satellites orbit in this layer.
- Auroras also form in this layer.

Climatology

Exosphere

- Uppermost layer of the atmosphere.
- Above the thermosphere.
- Highest layer and extremely rarefied.
- It gradually merges with the outer space.

Functional Zone Segregation

Ozonosphere

- It spans the stratosphere and lower mesosphere and lies at an altitude between 30 km and 60 km from the earth's surface.
- This layer reflects the harmful ultraviolet radiation due to the presence of ozone molecules.
- The ozonosphere is also known as chemosphere because of immense chemical activity goes on here.
- The temperature increases at a rate of 5°C/km.

Ionosphere

- Where electron density is very high (100-300 km).
- Ions useful for Radio communication(reflects radio waves).

Climatology

Heat

- It is a form of energy that is transferred between two substances at different temperatures. The effects of this energy transfer usually, but not always, is an increase in the temperature of the colder body and a decrease in the temperature of the hotter body.
- A substance may absorb heat without an increase in temperature by changing from one physical state (known as phase) to another. This absorbed heat is known as Latent Heat.

Heat versus Temperature

- While heat represents the molecular movement of particles comprising a substance, the temperature is the measurement in degrees of how hot (or cold) a thing (or a place) is. The interaction of incoming solar radiation with the atmosphere and the earth's surface creates heat which is measured in terms of temperature.

Climatology

- Plank's law states that hotter a body, the more energy it will radiate and shorter the wavelength of that radiation.
- Specific heat is the energy needed to raise the temperature of one gram of substance by one Celsius.

Heat Transfer mechanisms

- Conduction
  - Heat transfer by direct contact of particles of matter.
- Convection
  - Transfer of heat by the movement of a heated fluid (liquids and gases) molecules. Heat transfer by convection is caused by differences in temperature and density within a fluid.
- Advection
  - Heat transfer through horizontal movement of the air.
- Radiation
  - The transfer of energy through empty space. There is no direct contact between heat source and an object.

Climatology

Insolation & Terrestrial & Terrestrial Radiation

- Earth's surface receives most of its energy in the form of short wavelengths known as incoming solar radiation (Insolation).
- The earth absorbs short wave radiation (Short wavelength = High Energy) during daytime and reflects back the heat received into space as longwave radiation (mostly infrared radiation) during night. It makes the Earth a radiating body.
- The long wave energy radiated by the Earth known as Terrestrial Radiation.
- Terrestrial Radiation heats the atmosphere from below as it is absorbed by the atmospheric gases particularly the greenhouse gases.
- The atmosphere in turn radiates and transmits heat to the space.
- Finally, the amount of heat received from the sun is returned to space thereby maintaining constant temperature at the earth's surface and in the atmosphere.

Climatology

- This is why earth neither warms up nor does it get cooled over a period of time.
- The amount of heat received by different parts of the earth is not equal which causes pressure differences in the atmosphere.
- This leads to transfer of heat from one region to the other by winds.

Factors causing Variability Of Insolation

- Rotation of earth on its tilted axis (at 66.5 degree with the plane of its orbit round the sun).
- Angle of inclination of the sun's rays
  - Area under the insolation increases with increasing latitude as a result of slant sun rays.
- Length of the day
  - Duration of the day affects the amount of insolation received.
- Shorter the duration results in less received insolation.
- Transparency of the atmosphere
  - Affects reflection, absorption or transmission of insolation.

Climatology

- Depends upon the cloud cover and its thickness, dust particles, water vapor, etc
- Thick cloud hinders the solar radiation to reach the earth's surface.
- Water vapor absorbs solar radiation resulting in less amount of insolation reaching the surface.
- Slant rays are required to pass through greater depth of the atmosphere resulting in more absorption, scattering and diffusion.

- Configuration of land in terms of its topography
  - Sun facing slopes receive more vertical rays of sun.

Sub-solar point and Sun's declination

- The point on earth where the sun is directly overhead at a given point of time is called sub-solar point.
- The latitude of the sub-solar point is called Sun's declination.

Albedo

- This is the amount of insolation reflected by the body.
- It is defined as the ratio of the reflected

radiation to the total intercepted radiation.

- It is described in terms of percentage of reflected radiation.
- When sun is overhead, albedo is less.
- Albedo commonly refers to the "whiteness" of a surface, with 0 meaning black and 1 meaning white.
- A value of 0 means the surface is a "perfect absorber" that absorbs all incoming energy

Heat Budget

- The earth as a whole does not accumulate or loose heat. It maintains its temperature.
- This can happen only if the amount of heat received in the form of insolation equals the amount lost by the earth through terrestrial radiation (insolation=terrestrial radiation).
- 35% of insolation is radiated (27% from clouds, 2% from ice) and 14% of insolation is absorbed by atmosphere.
- Rest 51% of insolation reaching earth's surface get absorbed by it and later radiated back.
- 34% is absorbed by atmosphere again (19% via latent heat of condensation).

17% is radiated directly to space.

- Atmosphere together radiates back 48% to the space.

Latitudinal Heat Balance

- Latitudinal Heat Balance is the state of balance which exists between the latitudinal belts by maintaining net incoming solar radiation and the outgoing terrestrial radiation.
- The amount of insolation received by earth surface varies from latitude to latitude.
    - At latitudes below 40° = Insolation ≥ Outgoing Radiation (surplus of net radiation)
    - At latitudes above 40° = Insolation ≤ Outgoing Radiation (deficit of net radiation)
- Heat transfer takes from heat surplus zone to the heat deficit zone by ocean currents (20%) and atmosphere (80%).
- The temperature of the earth as a whole remains constant due to this equilibrium.
- If there is no latitudinal heat balance, the deficit heat belt will become extremely cold and the surplus heat belt will become extremely hot to live in.

Climatology

Temperature Distribution on the Earth

Factors controlling the distribution of Temperature

1. Latitudes

- Intensity of insolation decreases with the increase in latitude. Maximum temperature is not at equator but at 20°N.
    - Major portion is reflected by the clouds and sizeable amount is lost in evaporation.
    - At 45° latitude, insolation is about 75% of that at equator.
    - At 66.5° latitude, it is about 50% of that at equator.
    - At poles, it is about 40% of that at equator.

2. Altitude

- Temperature decreases with increasing height at an average rate of 6.5°C/km.
    - The layers of air are denser at the earth surface and become lighter with increasing altitude.
    - The lower layers contain water vapor and dust particles.

Climatology

3. Distance from the Coast

- Temperature is moderated by marine environment because of sea breeze and land breeze.

4. Terrestrial radiation

- Major source of atmospheric heat is the earth's surface from where heat is transferred to the atmosphere.

5. Ocean Currents

- Warm currents raise temperature where as cold current reduces.

6. Prevailing Winds

- Winds transfer heat from one latitude to another as well as between land and water bodies.
  - The oceanic winds bring moderating effect from the sea to coastal areas (cool summers and mild winters).
  - This effect is pronounced only on the windward side. The leeward side or the interiors experiences extreme temperature as it do not get moderating effect of the sea. (Grammer)

Climatology

7. Air mass

- Places having warm air mass experiences higher temperature than the places comes under influence of cold air mass. (We will read Air Mass in detail ahead)

8. Effect of continentality

- Daily Range of temperature is less in marine climate, while extremely high in continental climate.

Distribution of Temperature

- The global distribution of temperature can well be understood by studying the temperature distribution in January and July.
- The temperature distribution is generally shown on the map with the help of isotherms.

Isotherms

- Lines joining places having equal temperature at a given time or on average over a given period.
    - Effects of altitude is not considered while drawing an isotherm.

Temperature anomaly

Climatology

- The difference between mean temperature of a place and the mean temperature of its latitude is called temperature anomaly.
  - Positive Anomaly Local Temperature > Latitude Temperature
  - Negative Anomaly Local Temperature <Latitude Temperature

Isotherms and their general characteristics

- Generally, follow the latitude parallels (because all the points located on the same latitude receives same amount of insolation).
- Sudden bends at ocean-continent boundaries even on the same latitude (because of the differential heating of land and water).
- High thermal gradient (rapid change in temperature)indicated by narrow spacing between isotherms.
- Low thermal gradient (small or slow change in temperatures) indicated by wide spacing between isotherm.

Climatology

General Temperature Distribution

- Highest temperatures = Tropics and sub-tropics (high insolation)
- Lowest temperatures = Polar and Sub Polar Regions
- The interiors of continents have highest diurnal and annual temperature range because of continentality effect (No moderating effect of oceans).
- Temperature gradients are usually low over the eastern margins (because of warm ocean currents) and high over the western margins (because of cold ocean currents) of continents.
  - The isotherms show a poleward shift while passing through an area with warm ocean currents.
- An enhanced land-sea contrast makes isotherms irregular over the northern hemisphere.
  - Northern hemisphere is warmer than the southern
  - hemisphere due to the predominance of landmass.
- Temperature contrast between continents and oceans are greater during winters than in summers.

Climatology

- Maximum insolation is received over the subtropical Deserts due to less cloudiness.

January

- Summer in southern hemisphere and winter in the northern hemisphere.
- The thermal equator lies to the south of geographical equator (because ITCZ shifts southward with the apparent southward movement of the sun) and the high temperature belt runs somewhere along 30°S latitude.
- The western margins of continents are more warm the eastern margins due to the Westerlies that carry high temperature into the landmasses.
- The eastern margins of continents have close temperature gradient.
- The effect of the ocean makes isotherms almost parallel to the latitudes in southern hemisphere.
- Landmasses are cooler than the oceans in the northern hemisphere.
    - The isotherms bend towards the poles while crossing oceans and to the equator while crossing landmasses.

Climatology

- Oceans are cooler than the landmasses in the southern hemisphere.
    - Isotherms bend towards the equator while crossing oceans and towards the poles while crossing landmasses.

July

- Summer in northern hemisphere and winter in the southern hemisphere.
- The thermal equator lies to the north of geographical equator (due to the northward shift of ITCZ with the apparent northward movement of the sun).
- The southern hemisphere has regular gradient but shows a slight bend towards the equator at the continents edge.
- The deviation of isotherms is not that much pronounced in July as in January, especially in the northern hemisphere.
- Oceans are cooler than the landmasses in the northern hemisphere.
    - Isotherms bend towards the equator while crossing oceans and towards the poles while crossing landmasses.
- Landmasses are cooler than the oceans in the southern hemisphere.

Climatology

- Landmasses are cooler than the oceans in the southern hemisphere.
    - The isotherms bend towards the poles while crossing oceans and to the equator while crossing landmasses.

Air Moisture

Water or Hydrological cycle

- The water between the atmosphere, the oceans and the continents continuously exchanges through the processes of
    - Evaporation (Moisture driven from atmosphere by transforming liquid into gaseous state)
    - Transpiration (Moisture driven from plants)
    - Condensation (In the form of clouds)
    - Precipitation ((In the form of rain)
- The hydrological cycle maintains the balance between these processes so that the total amount of moisture in the entire system remain constant. Water vapor in air varies from zero to four percent by volume of the atmosphere and plays an important role in the weather phenomena.

Climatology

Humidity

Water vapor present in the air is known as humidity.

Absolute humidity

- It is the weight of water vapor per unit volume of moist air.
- It is an actual amount of water vapor present in atmosphere.
- It is expressed as grams of moisture per cubic meter of air (g/m3).
- Change in temperature or pressure may be impact volume hence affects absolute humidity.

Specific Humidity

- It is the weight of water vapor per unit weight of dry air.
- Since it is the weight of the air now, it is not impacted by change in temperature or pressure.

Relative humidity (RH)

- Proportion of actual water vapor present in the air to its water vapor carrying capacity at a constant temperature.
- Saturated Air parcel = 100% RH (The air is at full moisture carrying capacity and no further

moisture addition is possible)

- Relative humidity can be affected by two ways
  - By adding moisture through evaporation (by increase in absolute humidity)
  - RH = Over Ocean (greater availability of water for evaporation) > Over Continent
  - By changing temperature of air (Change in saturation point)
- Change in temperature can affect the moisture carrying capacity of the atmosphere.
- **Dew Point:** Temperature at which the sample of air becomes saturated and it cannot hold moisture any further.

Temperature Lapse Rate

- It is rate of change in temperature observed with rising altitude.
- Positive = Temperature decreases with altitude (Normal Lapse Rate)
- Zero = Temperature is constant with altitude
- Negative = Temperature increases with altitude (known as temperature inversion)

Climatology

Why does temperature fall with rising altitude

- The temperature falls with rising altitude is primarily due to two reasons.
- Atmospheric pressure falls (Pressure is directly proportional to Temperature and vice versa)
- Reduced greenhouse gases concentration (leading low heat absorption capacity of atmosphere).
- This fall in temperature with altitude is called Temperature Lapse and the rate at which it falls is known as Temperature Lapse Rate.

Rising and Falling Air Parcel

- The object sinks or rises in a fluid based on the its relative density with fluid.
- Air parcel density is more than the surrounding environment = It will fall
- Air parcel density is less than the surrounding environment = It will rise

Climatology

Rising Air Parcel

- Air parcel heated more than surrounding (Heat exchange hence non-adiabatic) = Temperature increase → Volume increase (due to expansion, Charles's law) → Density decrease
  - At constant Pressure, Change in Volume is directly proportional to Temperature change (i.e. Increase in Temperature →Increase in Volume)
  - Since there is only heat interaction take place with no addition of any mass in the air parcel, volume increases at constant mass.
  - As density is given by mass divided by volume, volume increment at constant mass causes decrease in density.
- Rising air parcel → Less pressure above (Atmospheric pressure decreases with altitude) → Volume increases (Removing pressure from object increases volume, Boyle's law) due to decreased pressure → Temperature falls (due to internal changes rather than heat exchange hence adiabatic)
- The increased volume causes further decrease in density. The air parcel keeps rising. As there is no interaction of heat, only expansion leads

Climatology

Falling Air Parcel

- Air parcel at upper level → Heat exchange between the air parcel and the surrounding environment (hence non-adiabatic process) → Temperature falls → Volume decreases (Charles's law) → Density increases
  - This can also occur if an air parcel comes in contact with cooler surfaces like mountain slopes.
- Air parcel start falling when its density become greater than surrounding.
- With fall, internal temperature of a falling air parcel increases adiabatically due to the increased atmospheric pressure (Gay-Lussac's law).
- The rate at which this temperature rise occurs is called Negative Adiabatic Lapse Rate.
- Fall in temperature of a rising air parcel without losing any internal heat.
- Air expands and cools adiabatically when it rises.
- Rate of cooling depends on the water vapor content of the air. Hence, ALR is usually differentiated as dry or wet (moist) air.
- Higher the water vapor = Lower the rate of cooling due to release of latent heat of condensation.

Climatology

- Dry adiabatic rate is about twice of the wet adiabatic rate.

Wet Adiabatic Lapse Rate (WALR)

- Saturated air parcel cools down slower than the unsaturated one due to the release of latent heat of condensation.
- The WALR varies considerably due to the high variability of water vapor amount in the air.
- High amount of vapor = Low ALR
  - More release of internal heat in the form of latent heat of condensation, hence less temperature reduction (Phase change occurs at constant temperature).
- Average WALR for the Earth's atmosphere = 4° C/km.
- WALR is mainly associated with unstable conditions (due to the high moisture content).

Dry Adiabatic Lapse Rate (DALR)

- Dry or unsaturated air parcel cools down early than the saturated as there is less release of latent heat of condensation.
- Low amount of vapor = High ALR

Climatology

  - Less internal heat release heat in the form of latent heat of condensation, hence more temperature reduction.
- Average DALR for the Earth's atmosphere = 8° C/km
- DALR is mainly associated with stable conditions (because it has less moisture).

Significance in meteorology

- The difference between the Normal Adiabatic Lapse Rate (NALR) in the atmosphere and the DALR & WALR determines the vertical stability of the atmosphere.

Weather conditions at different Adiabatic Lapse Rates (ALR)

- ALR = Adiabatic Lapse Rate of entire atmosphere = 6°C/km
- If ALR > 6°C/km = DALR
  - Less moisture than normal = more stable than normal
- If ALR < 6 °C/km = WALR
  - More moisture than normal = less stable than normal or instability.

Climatology

Atmospheric Stability

- Conditional stability WALR < NALR < DALR
  - Normal moisture conditions = It may or may not rain
- Absolute stability NALR < WALR < DALR
  - Little moisture in the air parcel = It won't rain
- Absolute instability WALR < DALR < NALR
  - Excess moisture in the air parcel = It will rain Violently.

Types of Condensation

Clouds

- A cloud is an aggregation of moisture droplets and ice crystals that are suspended in air.
- They are great enough in volume and density to be visible to the naked human eye.
- Each cloud particles diameter ranges from 20 to 50 mm. It is formed around a solid matter called condensation nucleus.
- They vary from sea level to 13,700 meters.

Based on altitude and shape they are given different name

Climatology

Shape division:

Cirrus

- Flat or layered
- clouds are developed horizontally

cumuliform

- Puffy and globular
- developed vertically

Cirroform

- Wispy- hair
- smoke- composed of ice crystals

Four altitudinal divisions:

Stratocumulus

- Large globular masses
- Bumpy looking
- Soft and grey in appearance
- Regular and sometimes wavy pattern

Nimbostratus

- Low clouds, dark grey with uniform base.

Climatology

- Continuous rain or snow
- Nimbus- any cloud from which rain is falling and dark grey in color

Cumulus

- Convection cloud
- Vertical development but lesser than cumulonimbus
- Appear like cotton balls

Cumulonimbus

- Dark grey from beneath and white from side
- Associated with thunderstorms
- Torrential rain, hail or snow falls

Stratus

- Uniform layer, resembling fog
- Dull grey and featureless
- Fractostratus when broken

Altocumulus

- Small, relatively thin, globular patches
- Sheep clouds or wool pack clouds

Climatology

Alto-stratus

- Continuous sheet, difficult to see sun or moon
- Associated with cyclone

Cirrus

- Fibrous or wispy, consisting of tiny particles of ice
- Indication of approaching depression
- Do not give precipitation

Cirrostratus

- Whitish in color
- Solar or lunar halo
- Thickening cirrostratus indicates approach of warm front

Cirro cumulus

- Made of ice crystals
- Mackerel sky- resembles fish

Dew

- It is the condensation of water vapor on a cold surface that causes formation of water droplets.

Climatology

- Condition => Clear Sky, calm air, high relative humidity temperature is above freezing point, long and cold nights.
- Dew point should be above of freezing point.

White Frost

- When under dew forming conditions, the dew point of the air is below or at 0° C, water vapor condenses as minute ice. This is called white frost.

Fog

- Fog is ground level cloud reducing horizontal visibility to less than 1km.
- It consists of very small water droplets in suspension in the lower layer of the atmosphere.
- Depending on the temperature, the water may be frozen which would result in freezing fog.
- Fog is a real danger for general aviation pilots.

There are several types of fog

Radiation fog

- When the ground cools rapidly due to radiation and the adjacent air becomes too cool, its water vapor condenses.

  - Such fog is not very thick.

Advection fog

- When moist warm air moves horizontally over a cold surface.
- Such fogs are thick and persistent.

Frontal fog

- Condensation and precipitation take place when warm air mass is forced to rise over the cold air mass and cools down.
- If the cold air below is near the dew point, its temperature falls further and excess moisture condenses as fog.
- It is formed at convergence zone.

Upslope Fog

- This fog forms adiabatically.
- Moist winds up glides while blowing toward a mountain and this causes the air to rise and cool.
- The cooling of the air from rising causes to meet up with the dew point temperature.
- Fog forms on top of the mountains.

Valley Fog

Climatology

- Valley fog forms in the valley when the soil is moist from previous rainfall.
- As the skies clear, solar energy exits earth and allow the temperature to cool near to dew point.
- This form deep and dense fog.

Ocean current

- At meeting point of cold current and warm current.

Mist

- Mist is a phenomenon consisting of a large amount of water droplets/ice crystals present in a layer of the atmosphere.
  - In mist, each nuceli contains a thicker layer of moisture.
  - Fogs are drier than mist and they are prevalent where warm currents of air come in contact with cold currents.
- Relative humidity is generally between 60% and 100%.
- It contains more moisture than fog.
- Mist does not represent a real danger for commercial aviation pilots (visibility is between 1 km and 5 km).

Climatology

- Mists are frequent over mountains as the rising warm air up the slopes meets a cold surface.

Haze

- Contrary to fog and mist, haze is a horizontal visibility reduction due to non-aqueous particles.
- Particles can be dust, sand grains, pollen grains, chemical pollution, etc.
- These particles are invisible to the naked eye, but sufficient to give the air an opalescent appearance.
- There is no condensation in haze. Smog is similar to haze but with condensation.

Gyanbazi (Extra Knowledge)

Primary Pollutants (PP) and Secondary Pollutants (SP)

Smog

- Smog is a kind of air pollution, originally named for the mixture of smoke and fog in the air.

Climatology

2 Types

Sulfurous smog or "London smog"

- Sulfurous smog is the result of a high concentration of sulfur oxides in the atmosphere.
- This is usually caused by the burning of fossil fuels like coal.
- It is intensified by dampness and a high concentration of suspended particulate matter in the air.

Photochemical smog or "Los Angeles smog" or "Summer smog"

- Photochemical smog is created when sunlight reacts with nitrogen oxides (PP) and at least one volatile organic compound (VOC, a PP) in the atmosphere.
- Nitrogen oxides are emitted in the atmosphere from automobiles, power plants, factory emissions.
- Volatile organic compounds are released in the atmosphere due to paints, gasoline and cleaning solvents.
- Occurs most prominently in urban areas or the places having large numbers of automobiles (Nitrogen oxides are the primary emissions).
- This kind of smog requires neither smoke nor fog.

Climatology

- This Ozone forms near the earth's surface and causes several ill effects in comparison of stratospheric Ozone
- Effect on Visibility = Mist > Haze > Fog > Smog

Temperature inversion

- It is a phenomenon in which the normal behavior of temperature in the troposphere get reversed. There is a cooler air mass near the ground and warmer air at higher altitudes. (Temperature usually decreases with altitude under the normal conditions).
- This happens when earth surface is able to radiate solar energy directly into space.
- Negative Lapse Rate = Increase in temperature with increasing altitude.

Types of Temperature Inversion

1. Non-advectional Inversion
    - Ground or surface inversion or radiation inversion.
    - Upper air inversion.
2. Advectional Inversion

Climatology

- Frontal inversion or cyclonic inversion.
- Valley inversion due to vertical air movement.
- Surface inversion due to horizontal air movement.

3. Mechanical Inversion
    - Subsidence inversion.
    - Turbulence and convective inversion.
4. Non-Advectional Inversion
    - Ground surface inversion or radiation inversion
    - Radiation inversion occurs near the earth's surface
      due to radiation mechanism.
    - It is non-advectional as there is no movement of air either vertical or horizontal.
    - It requires some necessary conditions like
        - Long cold winter nights.
        - Cloudless and clear sky.
        - Presence of dry air near the surface.
        - Slow movement of air to avoid mixing.
        - Snow covered ground surface.
    - Air coming in contact with the cool ground surface
      also becomes cold while the air layer lying above is relatively warm.

Climatology

Collision-Coalescence hypothesis of precipitation

- This explains precipitation in tropical areas where the temperature in clouds is too high for the formation of ice. So water droplets condense, positive charge attracts negative charge, they come together, become big and fall.

Precipitation Types:

Rain

- This is the wet stuff that nourishes plants and for which umbrellas were invented.
- It occurs when both the cloud temperature and ground temperature are above freezing.
- It can take three forms:
  - **Simple rain:** When the drops are about 0.5 mm (0.02 in) in diameter.
  - **Drizzle:** When the drops are smaller than Simple Rain.
  - **Virga:** When the drops are so small they don't reach the ground (Evaporated)

Sleet

- They are refrozen ice

Climatology

Hail

- Precipitation in form of hard round pellets.
- Strong ascending currents take water vapor to great heights where it condenses and precipitates as snow.
- As it comes down, it melts but strong currents push them up again increasing the size. Thus size keeps on increasing until it becomes very hard and big.

Rainfall Types

- Rainfall has been classified into three main types based on their origin
  - Convectional Rainfall
  - Orographic or Relief Rainfall
  - Cyclonic or Frontal Rainfall

Convectional Rainfall

- Occurs mostly in tropics where it is hot.
- Air naturally rises up in convection current when it heats up.
  - It cools and condenses due to the expansion while moving higher altitude leading cumulus clouds formation.

Climatology

- Heavy rainfall with lightning and thunder takes place which does not last long.
  - If the air is hot enough, it rises very quickly and can cause thunderstorms.
- Such rain is usual in the summer or in the hotter session of the day.
- This can happen over land or water as long as moisture is present.
- When it happens over tropical oceans (where the air is saturated with water), the combination of wind and moisture can create a tropical cyclone or hurricane.

Orographic or Relief Rainfall

- Relief rainfall occurs very frequently near mountains beside the sea.
- The moisture-laden air is forced to rise on encountering a mountain range. As it rises upwards, it is cooled and cloud is formed.

Climatology

- The cloud becomes saturated with water vapor and it begins to precipitate on the side of the mountain facing the sea (known as windward side)
  - The cloud precipitates the most on the windward side of the mountain.
- The cloud becomes almost exhausted by the time they reach another side (known as leeward side) so it rains very little there.
  - This makes leeward sides of a mountain very sheltered from rain and they hardly ever get much rain.

Cyclonic or Frontal Rainfall

- Frontal rainfall occurs when warm air is forced to rise over cold air.
- The moisture in the warm air condenses as it cools which causes clouds and rain.

Atmospheric Pressure

- The weight of a column of air contained in a unit area from the mean sea level to the top of the atmosphere is called the atmospheric pressure.
- It is expressed in units of milibar (mb).
- Due to gravity the air at the surface is denser

and hence has higher pressure.

- **Wind:** It is horizontal movement of air which flows from high pressure areas to low pressure areas.
- ***Air current:*** The vertical or nearly vertical movement of air is called air current.

Vertical Variation of Pressure

- The pressure decreases rapidly with height in the lower atmosphere.
    - It does not always decrease at the same rate due to the variations in the factors controlling air density (temperature, amount of water vapor and gravity).
- The vertical pressure gradient force is much larger than that of the horizontal pressure gradient.
- We do not experience these strong upward winds as they are generally balanced by a nearly equal but opposite gravitational force.
- A rising pressure indicates stable weather whereas a falling pressure indicates cloudy and unstable weather.

Climatology

Horizontal Distribution of Pressure

- It is studied by drawing isobars at constant levels.
  - Isobars are lines connecting places having equal pressure after being reduced to sea level.
- Low pressure system is enclosed by one or more isobars with the lowest pressure in the center.
- High pressure system is enclosed by one or more isobars with the highest pressure in the center.

Pressure and wind

Important Laws of atmospheric circulation

Buys Ballot Law

- If you stand with your back to the wind in the Northern Hemisphere, air pressure is lower on your left than on your right.
- Winds are strong where isobars are crowded and weak where they are spread.
- Pressure distribution affects wind speed in high and mid latitudes. Between 10 N and 10 S, it is difficult to relate winds to pressure distribution.
- Near Earth's surface, wind direction is influenced by surface features.

Climatology

- Maximum speed of wind at noon and minimum just before sunrise.
- Winds are named after the direction they come from.
- The wind circulation around a low pressure is called cyclonic circulation. Around a high pressure it is called anti cyclonic circulation.
- Generally, over low pressure area the air will converge and rise. Over high pressure area the air will subside from above and diverge at the surface.

Forces Affecting the Velocity And Direction of Wind

- Horizontal winds near the earth surface respond to the combined effect of three forces in addition with downward gravitational force
  - Frictional Force
  - Coriolis Force
  - Pressure Gradient Force (PGF)

Coriolis Force

- It is given by the formula 2vw sinX (v = Wind velocity; w = Earth's particular point angular speed, X = Angle of latitude)
- It is not a force, but an effect causes due to

rotation of the earth.

- It turns the object to right or clockwise in the Northern Hemisphere and to the left or anti-clockwise in the Southern Hemisphere.
- It affects wind direction and not the speed.
- Higher the wind speed greater is the coriolis effect.
- Maximum at poles as poles rotate slow and becomes zero at the equator.
- It always acts at right angle to the direction of the wind.

Frictional Force

- Friction is the resistance to motion of one object moving relative to another.
- The friction force drags the wind as it moves across surfaces.
- As the surface friction decrease wind speed, it reduces the effect of Coriolis force.

Pressure Gradient Force (PGF)

- The rate of change of pressure with respect to distance is the pressure gradient.
- Pressure Gradient is denoted by the spacing of isobars that expresses the rate and direction of pressure changes

Climatology

  - Close spacing = Steep or strong pressure gradient
  - Wide spacing = Weak gradient
- The higher the pressure gradient force, the more is the velocity of the wind and the larger is the deflection in the direction of wind.

Geostrophic Wind

- Geostrophic winds come about because pressure gradient force and Coriolis force come into balance after the air begins to move.
  - Under the influence of both the Pressure Gradient Force and Coriolis Force, air tends to move parallel to isobars in conditions where friction is low (1000 meters above the surface of the Earth) and isobars are straight.
- At the surface level wind blows at an angle, but above it becomes parallel to isobars.

Pressure Belts

- There are distinctly identifiable zones of homogeneous horizontal pressure regimes or 'pressure belts'.
- On the earth's surface, there are in all seven pressure belts.

Climatology

- equatorial low
- 2 sub-tropical highs
- 2 sub-polar lows
- 2 polar highs

Two Main Factors Controlling Pressure Systems

Thermal Factors

- Heating and cooling of air causes expansion (density decreases hence pressure reduces) and contraction (density increases hence pressure increases) respectively.

Dynamic Factors

- Arising out of Pressure Gradient Forces and rotation of the earth (Coriolis Force).

Equatorial Low Pressure Belt or 'Doldrums'

- These winds are roughly in between 5° N and S.
- The belt is generally known as doldrums (zone of calm and weak winds).
  - Doldrums = Characterized by convergence, rising air, and heavy rainfall
- This area is called the Inter Tropical Convergence Zone (ITCZ) or the thermal equator or the "equatorial belt of variable winds and calms".

Climatology

- The trade winds converge in the equatorial trough (or tropical low).

Weather

- A very moist air heated by the sun tends to expand and rise creating the area of low pressure.
- Due to the convergence of trade winds, only vertical current creates and the moisture laden air rises upward. This forms cumulonimbus clouds leading to thunderstorms.
- This region coincides with the world's latitudinal belt of heaviest precipitation and most persistent cloud cover.
- Old sailing ships often remained becalmed in the doldrums for days at a time.

Sub-Tropical Highs Pressure Belt or Horse Latitudes

- Areas of sinking and settling air from higher altitudes.
    - Winds blow poleward to become the westerlies and equator-ward as the trade winds.
- These areas located between latitudes 25° N and S.
- Often called the subtropical belts of variable winds, or the "horse latitudes."

Climatology

- The subtropical highs are areas like the doldrums in which there are no strong prevailing winds.

Weather

- Weather conditions are typically clear, sunny, and rainless, especially over the eastern portions of the oceans where the high pressure cells are strongest.
- As the subsiding air is warm and dry, most of the deserts are present along this belt.
- Tropical and extra-tropical disturbances are frequent in this belt.

Reasons for sub-tropical high belt

- The warm air rises from low pressure equator and starts cooling. It begins to move towards poles after reaching the upper layers. It further cools down, becomes dense and by 25-35° latitude it begins to subside.
- Due to Coriolis Effect, the movement of air becomes effectively west to east instead of going north in these latitudes. This produces a blocking effect and the dense air begins to subside heavily.
- Hence, sub-tropical high belt is dynamically produced Pressure Belt due to

Climatology

   - Coriolis Force (Produced by rotation of the earth on its axis).
   - Descent of air (due to the convergence of Trade winds and Westerlies).

Sub-Polar Low Pressure Belt

- Located between 45° N&S latitudes and the Arctic and the Antarctic circles (66.5° N and S latitudes)
- This is dynamically produced Pressure Belt due to
   - Coriolis Force (Produced by rotation of the earth on its axis).
   - Ascent of air (due to the convergence of Westerlies and polar easterlies).
- Polar Jet Streams are formed due to the contrasting areas between cold and warm air masses.

Weather

- Temperate cyclones are produced in this region due to a great contrast between the temperatures of the winds from sub-tropical and polar source regions.

Polar High Pressure Belt

- These are small area extends around the poles (lie around poles between 80°-90° North and South latitudes).

- The saturated dry air from the sub-polar low pressure belts becomes cold while moving towards poles through upper troposphere. This air subsides and diverge near pole creating high pressure belt at the surface of earth.
- The lowest temperatures are found over the poles.

Season shift of pressure belts

- The shift is less in Southern hemisphere due to abundant water.
- The shift of the pressure belts is also higher in lower latitudes than in higher ones.
- The ITCZ can shift about 20° N and only 10° S of equator.

World Distribution of Sea Level Pressure

- The continents and oceans distribution influence the distribution of pressure.
- In winter, the continents are cooler than the oceans causing development of high pressure (reverse with the oceans).
- In summer, continents are relatively warmer causing development of low pressure (reverse

with the oceans).

July

- The equatorial low pressure belt shifts towards the north (Apparent northward movement of the sun). This shift is maximum in Asia.
- The landmasses of the northern hemisphere become excessively hot and low pressure areas develop over them.
- The sub-tropical high pressure belt of the southern hemisphere extends continuously. In contrast, it is broken over the continents and remains confined to the North Atlantic and North Pacific Oceans in the northern hemisphere.
- Sub-polar low is deep and continuous in the southern hemisphere, while there is only a faint oceanic low in the northern hemisphere.

January

- The equatorial low pressure belt shifts a little south of its mean equatorial position (due to the apparent southward movement of the sun).
- The lowest pressure pockets occur on the land masses of Southern Hemisphere (because land masses become much hotter than the adjoining oceans).

Climatology

- Sub-tropical high pressure belt of the southern hemisphere is broken over the continents and remains confined to the oceans only.

General Circulation of The Atmosphere

Headley's Model

- His model assumed only one cell in each hemisphere.
- Low pressure at equator and high pressure at pole with air from pole flowing towards equator.
- It assumed a non-rotating earth and uniform earth surface.

Ferrel's Model

- The cell between equator low pressure belt and subtropical highs.
- The one between sub-tropical high and sub-polar low is called Ferrel cell and the one between sub-polar low and poles is called polar cell.
- It assumes a rotating earth, uniform surface (i.e. either land or water throughout) and sun being stationary overhead at equator.

Pressure Cells

Climatology

The Hadley cell

Occurs between ITCZ and 30° N&S

- Ground is intensely heated by the sun. This leads to the rise of air which creates a low pressure zone on the Earth's surface.
- The air separates and starts to moving towards pole in both north and south hemispheres.
- The air cools and sinks towards the ground after reaching about 30° north and south forming the subtropical high-pressure zone.
- The sinking air becomes warmer and drier. This creates the region of little cloud and low rainfall (where deserts are found).
- The air completes the cycle by flowing back to the equator as the trade winds.

The Ferrel cell

Occurs between 30° to 60° N and S

- Air on the surface is pulled towards the poles forming o warm south-westerly winds in the northern hemisphere
    - north-westerly winds in the southern hemisphere
- These winds gain moisture while travelling through the oceans.

Climatology

- They meet cold air (drifting from the poles) at around 60° N& S.
- Due to the relative light weight of warm air mass from the tropics in comparison of cold air mass, it rises as the two air masses meet. This air upliftment causes low pressure at the surface.
    - The unstable weather conditions are associated with this mid-latitude depressions.

The Polar cell

Occurs between 60° N and S to pole

- At the poles, air is cooled and sinks towards the ground forming high pressure known as the Polar high. It then flows towards the lower latitudes.
- At about 60° degrees N&S, the cold polar air mixes with warmer tropical air and rises upwards, creating a zone of low pressure called the sub-polar low.
- The boundary between the warm and cold air is called the polar front.
    - It accounts for a great deal of the unstable weather experienced in these latitudes.

Climatology

El-Nino Southern Oscillation (ENSO)

- The easterly trade winds move water and warmed air towards the west.
- The western side of the equatorial Pacific is characterized by low pressure weather with warm and wet air.
    - The Walker circulation leads movement of warm and wet air from western side of equatorial Pacific to Eastern side of Equatorial Pacific.
- The oceanic cycle develops below the water surface.
    - Warm water starts moving from Western side of Equatorial Pacific to Eastern side of Equatorial Pacific.
- Cold water upwelling brings nutrient to surface at Peru which helps in Plankton development and pisciculture.
- This is how water and air are returned to the east. Both are now much cooler, and the air is much drier.

Climatology

El-Nino

- El Nino is an Oceanic and Atmospheric phenomenon that leads to reversal of normal year conditions by unusual warming of water in the Peru coast.
- Prevailing conditions
    - Warm water as well as low pressure condition develops in the Eastern Pacific
- Due to the inverse relationship (increase of one causes decrease in another) between Pressure and amount of rainfall, El Nino creates drought situation in Australia and South East Asia.

La-Nina

- La Nina means The Little Girl in Spanish.
- It is a climate pattern that intensifies the normal year conditions.
- It creates cooling effect on surface ocean waters along the tropical west coast of South America.
- Effect of La Nina year on winter temperatures
    - Warmer than normal in the Southeast
    - Cooler than normal in the Northwest
- The El-Nino event is closely associated with the pressure variations in the Eastern and Western Pacific. This change in pressure condition over Pacific is known as the southern oscillation.

Climatology

- The combined phenomenon of southern oscillation and El Nino is known as ENSO.
  - Only El-Nino = Warm water in Eastern Pacific + Cold water in Western Pacific
  - Only SO = Low Pressure over Eastern Pacific + High Pressure over Western Pacific
- ENSO = Warm water and Low Pressure near Eastern Pacific + Cold water and High Pressure near Western Pacific
- El Nino and La Nina are opposite phases of what is known as the El Nino-Southern Oscillation (ENSO) cycle
  - La-Nina is sometimes referred to as the cold phase of ENSO and El-Nino as the warm phase of ENSO.
- This deviation from normal surface temperatures causes large-scale impacts not only on ocean processes, but also on global weather and climate.
- While their frequency can be quite irregular, El-Nino and La-Nina events occur on average every two to seven years. Typically, El-Nino occurs more frequently than La-Nina.

Climatology

Wind Types

Primary Winds or Prevailing Winds or Permanent Winds Or Planetary Winds

- Prevailing as they prevail throughout the year.
- Planetary because they are almost global in nature.

Trade Winds

- Occur is in the vicinity of the subtropical highs.
- Can be identified between latitudes 5° and 25° North and South latitudes.
- On Earth's surface, it blows out of the subtropical highs toward the equatorial trough in both the Northern and Southern Hemispheres
- Because of the Coriolis effect, the
    - Northern trades move in a clockwise direction out of the northeast.
    - Southern trades move in a counter-clockwise direction out of the southeast.
- Also known as the tropical easterlies (Because the trades tend to blow out of the east)
- It tends to be constant, steady winds, consistent in their direction. This is most true when they cross the eastern sides of the oceans (near the eastern portion of the subtropical high).

Climatology

- The area of the trades varies during the solar year. It moves north and south a few degrees of latitude with the sun.
- The weather of the trades is clear and dry near their source in the subtropical highs, but the trades have a high potential for stormy weather after crossing large expanses of ocean.
- Early Spanish sea captains depended on the northeast trade winds to drive their galleons to destinations in Central and South America in search of gold, spices, and new lands.
- Going eastward toward home, navigators usually tried to plot a course using the westerlies to the north.

Westerlies

- Occur between about 35° and 65° North and South latitudes.
- Winds flows poleward out of the subtropical high pressure cells deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.
    - Northern Hemisphere = Blow from the southwest
    - Southern Hemisphere = Blow out of the Northwest.

- Tend to be less consistent in direction than the trades.
- Usually stronger winds and may be associated with stormy weather.
- Westerlies of Southern hemisphere are stronger (known as Roaring forties, Furious fifties, and Screaming sixties) and more consistent in direction due to predominance of water.
- The westerlies attain their greatest consistency and strength in the Southern Hemisphere due to the less land than in the Northern Hemisphere.

Polar Easterlies

- Dry, cold prevailing winds that blow from the high pressure areas of the polar highs at the North and South Poles towards low-pressure areas.
- Cold air subsides at the poles creating the high pressure, forcing an equator-ward outflow of air that deflect westward by the Coriolis Effect.
- They are extremely cold winds as they blow from the Tundra and Icecap regions.
- More regular in the southern hemisphere than in the northern hemisphere.
- Unlike the westerlies in the middle latitudes, the polar easterlies are often weak and irregular.

Climatology

Local Winds

- Differences in the heating and cooling of earth surfaces creates local differences of temperature and pressure. This develops daily or annual cycles that can create several common, local or regional winds.

Periodic Winds

Sea and Land Breeze

- Due to differential heating of land surface and sea water

Sea Breeze

- Day time = Land gets heated → Warm air rises up → Low pressure develops
- Sea being less warm → High pressure develops at sea → Winds blow from sea to land causing sea breeze

Land Breeze

- Night time = Land cools faster than sea → High pressure over land (Low pressure over ocean)
- Winds blow from land towards sea.

Climatology

Diurnal Mountain Wind Systems (Valley and Mountain Breeze)

Katabatic Wind (Mountain Breeze)

- During the night, the slopes get cooled and the dense air descends into the valley as the mountain wind.
- This cool air of the high plateaus and ice fields draining into the valley is called Katabatic wind.
  Anabatic Wind (Valley Breeze)
- In mountainous regions, the slopes get heated up during the day and air moves upslope.
- The air from the valley blows up the valley to fill the resulting gap.
- This air flow travelling up on an orographic surface is known as anabatic wind.

Seasonal Winds

- The pattern of wind circulation is modified in different seasons due to the shifting of regions of maximum heating, pressure and wind belts.
- The most pronounced effect of such a shift is noticed in the monsoons, especially over Southeast Asia.

Climatology

Monsoon

- A seasonal prevailing wind in the region of South and South-East Asia.
- It arises due to a difference in temperatures between a land mass and the adjacent ocean.
- It blows from the south-west between May and September and bringing rain (the wet monsoon), or from the north-east between October and April (the dry monsoon).
- The rainy season in SE Asia accompanying the wet monsoon.
- The winds reverse again at the end of the monsoon season.

Air Masses

Air Mass

- It is a large mass of air that has similar characteristics of temperature and humidity within it along with little horizontal variations.
- It forms an integral part of the global planetary wind system.

Source Region

- The area (land or water) above which air mass lies and acquire its characteristics.

- Air mass picks up the distinct temperature and humidity characteristics of the region over which it sits for several days.
- Ideal Source Regions High pressure areas with little pressure difference (pressure gradient)
    - sub tropics (the source for tropical air masses)
    - poles (the source for polar air masses)
- Mid-latitudes have no major source regions due to the dominance of cyclonic and other disturbance.

Geographical Classification of Air Masses

- They are classified based on the source region and air mass modification.
- Types of air masses are recognized:

Maritime tropical (mT)

- Warm tropical and subtropical oceans
    - Warm, humid and unstable
    - Weather
    - Winter = Mild temperatures, overcast skies with fog
    - Summer = High temperatures and humidity, cumulous clouds, and convectional rainfall.

Continental tropical (cT)

- The subtropical hot deserts

Climatology

  - Dry, hot and stable
  - Do not extend beyond the source
  - Dry throughout the year

Maritime polar (mP)

- The relatively cold high latitude oceans
  - Cool, moist and unstable
  - These are the regions which cannot lie stagnant for long.
  - Weather
  - Winters = High humidity, overcast skies, and occasional fog and precipitation.
  - Summer = Clear and stable

Continental polar (cP)

- The very cold snow covered continents in high latitudes
  - Dry, cold and stable conditions
  - Weather
  - Winter = Frigid, clear, and stable
  - Summer = less stable

Continental arctic (cA)

- Permanently ice covered continents in the Arctic and Antarctica.

Climatology

- Tropical air masses are warm and polar air masses are cold.

Thermodynamic Modification in Air Mass

- When the air mass is heated or cooled from the surface below, it is a thermodynamic change.
- A warm air moves over a cold surface leads temperature inversion. It inhibits further vertical cooling.
- A cold air mass moving over a warm surface creates convectional currents. This leads to formation of vertical clouds (cumulus) and air turbulence.
- Addition or loss of latent heat also is an example of thermodynamic modification.

Dynamic Modification in Air Mass

- These modifications are independent of surface heating or cooling.
- Examples are subsidence caused by anti-cyclones or cyclones.
- Surface friction adds to the turbulence of air flow aiding the upward transfer of the effect of thermodynamic modifications.

Climatology

Fronts And Frontogensis

- Front is that slopping boundary which separates two opposing air masses having contrasting characteristics.
- The frontal activities are invariably associated with cloudiness and precipitation due to the ascent of warm air which cools down adiabatically, condenses and causes rainfall.
- Frontal zone is neither parallel nor vertical to ground surface, rather it is inclined at low angle.
- The intensity of precipitation depends on the slope of ascent and amount of water vapor present in ascending air.

Frontogenesis

- The process associated with creation of new fronts or the regeneration of decaying fronts already in existence.
  - Requires certain necessary conditions:

  a. Temperature Difference

  b. Opposite directions of Air Masses

Frontolysis

- The process of destruction or dying of existing fronts.

Climatology

Cold Front

- When the cold air moves towards the warm air mass, its contact zone is called the cold front.
- As the cold front nears your region, the barometer falls.
- The cold air behind the front wedges under the warm air and lifts it sharply off the ground.
- Large cumulonimbus clouds appear (often bring thunderstorms and rain showers).
- As the cold front passes, the wind changes direction.
- The weather becomes clear and colder and the barometer rises again.
- Cold front moves up at about double speed than warm fronts.

Warm front

- If the warm air mass moves towards the cold air mass, the contact zone is a warm front.
- The warm air behind the front rises up over the cold air.
- The barometer falls leading to a long, steady rain.
- The front passes gradually and the sky clears.

Climatology

- As the warm air moves up the slope, it condenses and causes precipitation.
- Unlike a cold front, the changes in temperature and wind direction are gradual.
- Such fronts bring moderate to gentle precipitation over a large area for several hours.
- Cirrostratus clouds ahead of the warm front create a halo around sun and moon.

Occluded Front

- It results when a cold air front overtakes a warm front and lifts the warm air mass completely off the ground.
- Steady rain falls at an occluded front.
- The occluded front causes complex weather - a mix of cold and warm front type weather. These fronts are common in west Europe.
- A combination of clouds formed at cold front and warm front.
- The formation Mid-latitude cyclones involve the formation of occluded front.

Stationary Front

- A stationary front forms when a cold front or warm front stops moving.

Climatology

- The surface position of a front does not change.
- This happens when two masses of air are pushing against each other but neither is powerful enough to move the other.
- Winds blowing parallel to the front instead of perpendicular can help it stay in place.

Jet Stream

- The Jet Stream is a geostrophic wind which meanders with high velocity in the upper layers of the troposphere and encircles the globe.
    - The meandering or the whirl movement of the Jet Stream is called 'Rossby Wave'. (We will read about Rossby wave ahead)
- Reason that causes high velocity
    - Low friction at upper troposphere due to less air density.
    - Higher air temperature difference enhances speed (The Jet stream have high velocity in winter in comparison of summer).
- These slim strips of strong winds are like rivers of wind high above in the atmosphere.
- Generally, blow from west to east near tropopause at very high speeds (120 kmph in winters and 50 kmph in summers). That is why it is also referred as westerlies or upper level westerlies.

Climatology

  - Polar jet streams flows 6-9 km above the ground
  - It flows from temperate region towards polar region and get deflected right in the northern hemisphere and left in the southern hemisphere due to the Coriolis Effect.
- Sub-tropical jet streams flows 10-16 km above the grounds.
  - It flows from sub-tropical region towards temperate region and get deflected right in the northern hemisphere and left in the southern hemisphere due to the Coriolis Effect.

Sub-Tropical Jet (STJ) Stream

- They prevail over the lower latitudes of westerlies.
- It is produced by the rotation of earth and its spherical shape (dynamically induced).
- The air over equator has the highest velocity.
- As it rises and moves towards north, it has a higher velocity than the air at lower altitude prevailing at same latitude. So it begins to flow from west to east around 30° latitude.
- It flows all-round the year.
- They flow to conserve the angular momentum in

upper atmosphere.

- The sub-tropical westerly jet does not seem to affect surface weather as much as the polar fronts jets do.

Mid-latitude or Polar Front Jet (PFJ) Stream

- It is more variable and is produced by a temperature difference (thermally induced).
- Its position shifts towards poles in summers and towards equator in winters.

Tropical Easterly Jet (TEJ)

- They are seasonal jet streams flowing east to west.
- These are in only found northern hemisphere and generates only in summer season.
- These are also thermally induced.
- The reason for the establishment and maintenance of the TEJ is still not clear.
    - It is believed that these jet may be developing due to uniquely high temperatures and heights over the Tibetan Plateau during summer.
- The TEJ is the upper-level venting system for the strong southwest monsoon.

Weather System of Mid Latitudes And High Latitude

Climatology

- The weather of mid and high latitude regions is more complex than the equatorial or tropical regions.
- The heat surplus areas of equatorial or tropical regions create thermally induced weather system.
- The higher latitudes weather systems are dynamically induced. They consist of localised and upper troposphere circulations known as Jet Streams.
  - Jet Stream have a huge influence on climate as it can push air masses around and affect weather patterns.
- These differences of thermally and dynamically induced weather system create convectional and frontal rainfall system respectively.

Extra-Tropical/Middle-Latitude/Temperate Cyclones

- The system develops in the mid and high latitude (beyond the tropics).
- The passage of front causes abrupt changes in the weather conditions over the area in the middle and high latitudes.

Stages of formation and disappearance

- Front is stationary initially.

Climatology

- Warm air blows northern hemisphere from the south.
- Cold air blows from the north of the front.

- Pressure drops along the front leads movement of the warm air northwards and the cold air southward. Results in counter-clockwise cyclonic circulation.
- The cyclonic circulation leads to a well-developed extra tropical cyclone (consisting of a warm front and a cold front).
- There are pockets of warm air or warm sector wedged between the forward and the rear cold air or cold sector.
  - The warm air glides over the cold air. A sequence of clouds appears over the sky ahead of the warm front and cause precipitation.
  - The cold front approaches the warm air from behind and pushes the warm air up. As a result, cumulus clouds develop along the cold front.
- The cold front moves faster than the warm front ultimately overtaking the warm front.
- The warm air is completely lifted up and the front is occluded. Ultimately the cyclone gets dissipates.

Climatology

Tropical Cyclone

- Violent storms that originate and intensify over warm tropical oceans.
- It moves towards the coastal areas and causes large scale destruction due to violent winds, very heavy rainfall and storm surges.
- This is one of the most devastating natural calamities.
- Favorable conditions for the formation and intensification tropical cyclone are:
  - Large sea surface with temperature higher than 27° C.
  - Presence of the Coriolis force.
  - Small variations in the vertical wind speed.
  - A pre-existing weak-low-pressure area or low-level-cyclonic circulation.
  - Upper divergence above the sea level system.
- The place where a tropical cyclone crosses the coast is called the landfall of the cyclone.
- Cyclones that cross 20° N latitude generally recurve and they are more destructive.
- A mature tropical cyclone is characterized by the strong spirally circulating wind around the centre. This center is called the eye.
- The diameter of the circulating system can vary

between 150 and 250 km.

Cyclone formation

- Warm, moist air over the ocean rises upward leaving less air near the surface. This causes low air pressure area below.
- Air from surrounding areas with higher air pressure pushes in to the low pressure area and undergoes deflection due to Coriolis force creating a cyclonic vortex (spiraling air column).
- The new "cool" air becomes warm and moist and rises too and the cycle continues.
- The condensation of the rising warmed, moist air leads to the formation of clouds.
- Heat is emitted during this process and a reaction between the moisture from the evaporation of water takes place that produces Thunderstorms.
- The whole system of clouds as well as wind spins and grows, fed by the ocean's heat and water evaporating from the ocean surface.

Eye and Eye-wall

- The air in the vortex is forced to form a region of calmness called an eye at the center of the cyclone due to the centripetal acceleration.
- Higher pressure air from above flows down into

the eye.

- The inner surface of the vortex forms the eye wall. It is the most violent region of the cyclone.

Regional names of Tropical Cyclone

Path of Tropical Cyclones

- Start with a westward movement because of
    - Earth rotation from west to east
    - Zone of cyclone formation is under the influence of easterlies
- Turn northwards around 20° latitude and further north-eastwards around 25° latitude (Deflection towards right due to the Coriolis force).
- Eastwards turn around 30° latitude because of westerly winds.
- Loss of energy and subsidence because of
    - Ocean water at 30° latitude is not warm enough to sustain a cyclone.
    - Increasing wind shear due to westerlies doesn't facilitate the formation of cyclonic vortex..

Thunderstorms

- It is a well-grown cumulonimbus cloud which produces thunder and lightning.

Climatology

- It is caused by intense convection on moist hot days.
- Since thunder comes from lightning, all thunderstorms have lightning.
- When the clouds extend to heights where sub-zero temperature prevails, hails are formed and they come down as hailstorm.
- If there is insufficient moisture, a thunderstorm can generate duststorms.

Three basic ingredients required to form a thunderstorm

- Moisture
- Rising unstable air (air that keeps rising when given a nudge)
- Lifting mechanism to provide the "nudge"

Formation of thunderstorm

- The sun heats the surface of the earth, which warms the air above it.
- This warm surface air is forced to rise—
  - Hills or mountains (Orographic thunderstorm)
  - Areas where warm/cold or wet/dry air bump together can cause rising motion (Frontal thunderstorm)

Climatology

- It will continue to rise as long as it weighs less and stays warmer than the air around it.
- The rising air transfers heat from the surface of the earth to the upper levels of the atmosphere (the process of convection).
- The water vapor it contains begins to cool, releases the heat, condenses and forms a cloud.
- The cloud eventually grows upward into areas where the temperature is below freezing.
- As a storm rises into freezing air, different types of ice particles can be created from freezing liquid drops.
- The ice particles can grow by condensing vapor (like frost) and by collecting smaller liquid drops that haven't frozen yet (a state called supercooled").
- When two ice particles collide, they usually bounce off each other. During this the particle can rip off a little bit of ice from each other and grab some electric charge.
- Lots of these collisions build up big regions of electric charges to cause a bolt of lightning, which creates the sound waves we hear as thunder.

Climatology

Three Stages of Thunderstorm Life Cycle

Developing stage

- Marked by a cumulus cloud that is being pushed upward by a rising column of air (updraft).
- The cumulus cloud soon looks like a tower (called towering cumulus) as the updraft continues to develop.
- There is little to no rain during this stage but occasional lightning.

Mature stage

- The updraft continues to feed the storm, but precipitation begins to fall out of the storm, creating a downdraft (a column of air pushing downward).
- The downdraft and rain-cooled air spreads out along the ground and forms a gust front, or a line of gusty winds.
- The mature stage is the most likely time for hail, heavy rain, frequent lightning, strong winds, and tornadoes.

Dissipating stage

- Eventually, a large amount of precipitation is produced and the updraft is overcome by the downdraft beginning the dissipating stage.

- At the ground, the gust front moves out a long distance from the storm and cuts off the warm moist air that was feeding the thunderstorm.
- Rainfall decreases in intensity, but lightning remains a danger.

Types of thunderstorm

Single Cell Storms

- Typically last 20-30 minutes.
- Pulse storms can produce severe weather elements such as downbursts, hail, some heavy rainfall and occasionally weak tornadoes.

Multicell Cluster Storms

- A group of cells moving as a single unit, with each cell in a different stage of the thunderstorm life cycle.
- Multicell storms can produce moderate size hail, flash floods and weak tornadoes.

Multicell Line Storms

- Multicell line storms consist of a line of storms with a continuous, well developed gust front at the leading edge of the line.

Climatology

- Also known as squall lines.
- These storms can produce small to moderate size hail, occasional flash floods and weak tornadoes.

Supercells

- Defined as a thunderstorm with a rotating updraft.
- These storms can produce strong downbursts, large hail, occasional flash floods and weak to violent tornadoes.

Tornadoes/Twisters

- Much about tornadoes remains a mystery. They are rare, unpredictable and deadly.
- Tornado is a narrow, violently rotating column of air that extends from a thunderstorm to the ground.
- Because wind is invisible, it is hard to see a tornado unless it forms a condensation funnel made up of water droplets, dust and debris.
- Tornadoes can be among the most violent phenomena of all atmospheric storms we experience.
- The U.S. typically has more tornadoes than anywhere else in the world, though they can occur

almost anywhere.

- Most tornadoes come from rotating thunderstorms, called supercells.
- Tornadoes generally occur in middle latitudes.
- The tornado over the sea is called Water Sprouts.

Rossby Waves

- Rossby waves are naturally occurring planetary waves in rotating fluids.
- They are of two types – Oceanic and Atmospheric Rossby waves
- These waves affect the planet's weather and climate.

Atmospheric Rossby waves

- It forms primarily as a result of the Earth's geography.
- Rossby waves help transfer heat from the tropics toward the poles and cold air toward the tropics in an attempt to return atmosphere to balance.
- They also help locate the jet stream and mark out the track of surface low pressure systems.
- The slow motion of these waves often results in fairly long, persistent weather patterns.

Climatology

Polar Vortex

- The term "vortex" refers to the counter-clockwise flow of air that helps keep the colder air near the Poles.
- The polar vortex is a large area of low pressure and cold air surrounding both of the Earth's poles.
- It develops at upper troposphere or stratosphere.
- It always exists near the poles, but weakens in summer and strengthens in winter.

Disruption of Polar Vortex

- Rossby Waves can disrupt the circulation around the polar vortex.
- It originated during winters due to sharp temperature differential created between poles and equator.
- Many times during winter in the northern hemisphere, the polar vortex will expand, sending cold air southward with the jet stream.
- This occurs fairly regularly during wintertime and is often associated with large outbreaks of Arctic air in the United States.

Ozone Hole

- It is an area of depleted layers of ozone above the Antarctic region.

Climatology

- Manufactured chemicals deplete the ozone layer.
- Atmospheric ozone is destroyed by chemical processes in each spring over Antarctica.
- This creates the ozone hole, which occurs because of special meteorological and chemical conditions that exist in that region.

Factors responsible for the depletion of ozone

- Depletion of ozone is due to many factors. The most dominant of which is the release of chlorine from CFCs (Chlorofluorocarbons) which destroys the ozone.
- CFCs are released by products such as hairsprays, old refrigerators etc.

Vienna Convention

- A Multilateral Environmental Agreement.
- It was agreed upon at the 1985 Vienna Conference and entered into force in 1988.
- It is one of the most successful treaties of all time.
- It has been ratified by 197 states.
- It acts as a framework for the international efforts to protect the ozone layer.
- These are laid out in the accompanying Montreal Protocol.

- It is not legally binding.

Montreal Protocol on Ozone Depleting Substances

- It is a protocol to Vienna Convention for the Protection of Ozone Layer.
- It was the first treaty in history to achieve universal ratification (i.e. ratified by every member state of the United Nations).
- It is an international treaty and aims to protect the ozone layer by phasing out ozone depleting gases.

Kigali Agreement

- The Kigali Agreement amends 1987 Montreal Protocol to phase out Hydrofluorocarbons (HFCs), a family of potent greenhouse gases by the late 2040s.
    - Montreal Protocol conceived only to phasing out gases that were destroying the ozone layer.
    - This move will help to prevent a potential 0.5 degree Celsius rise in global temperature by the end of the century.

Polar Stratospheric Clouds (PSCS)

- Polar stratospheric clouds are clouds that form in the polar regions during the winter.

Climatology

- Type-I PSCs
  - Form when the stratospheric temperature drops below -78°C.
  - They are primarily composed of nitric acid, water, and sulfuric acid.
- Type-II PSCs
  - Form when the stratospheric temperature drops below -83°C.
  - They are composed of crystals of water ice.
- They are referred as nacre clouds or mother-of-pearl clouds due to their iridescence.
  - Only Type-II clouds are necessarily nacreous whereas Type-I clouds can be iridescent under certain conditions, just as any other cloud.
- PSCs play a critical role in facilitating ozone depletion during the polar spring and summer.
  - Type I clouds are now known as sites of harmful destruction of stratospheric ozone over the Antarctic and Arctic.
  - Their surfaces act as catalysts that convert human-made chlorine into active free radicals (for example ClO, chlorine monoxide).
  - These radicals destroy many ozone molecules in a series of chain reactions during the return of spring sunlight.

- Cloud formation is doubly harmful because it also removes gaseous nitric acid from the stratosphere that can combine with ClO to form less reactive forms of chlorine.

Aurora

- An Aurora is a display of light in the sky which predominantly seen in the higher latitude of northern and southern regions (Arctic and Antarctic). Due to this, it is also known as a Polar Light.
- It is less frequent at mid-latitudes and seldom seen near the equator.
- 2 Types
  - Aurora Borealis (Northern Lights)
  - Aurora Australis (Southern Lights)
- It is usually milky greenish in color but can also be seen in red, blue, violet, pink, and white colors.
- Auroras affect communication lines, radio lines and power lines.
- These light shows are the result of interaction between sun energy (in the form of solar wind) and electrically charged particles trapped in Earth's magnetic field.

Climatology

- It is an outcome of collisions between the oxygen and nitrogen in Earth's upper atmosphere with the fastmoving electrons from space.
    - The electrons coming from the Earth's magnetosphere (region of space controlled by Earth's magnetic field) enhances the energy of oxygen and nitrogen atoms and makes them "excited".
- During returning to their normal state, these gases emit photons and small bursts of energy in the form of light.
- The color of the aurora depends on
    - Which gas - oxygen or nitrogen - is being excited by the electrons, and on how excited it becomes and by what extent.
    - How fast the electrons are moving, or how much energy they possess at the time of their collisions.

Climatic Regions

Equatorial Climate

Distribution

- Main regions are Amazon belt, Congo-Zaire basin, South-East Asia between 10° N-S.
- Further away from equator, the influence of trade winds leads to monsoonal influences.

Temperature

- Consistently high and uniform throughout the year with annual range of less than 2 °C.
    - Even on highlands the annual range of temperature < 2°C
- Due to great heat in equatorial belts, mornings are brighter and sunny.

Rainfall

- This region experiences convectional rainfall (4 pm rainfall) through cumulonimbus clouds which comes with a thunderstorm.
- No month is without rain.
- Rainfall has twin monthly peaks (equinoxes) - in March and September
    - Because the sun is directly overhead during these times and rainfall is convectional.

Climatic Regions

- Rainfall is least on solstices.
- As one goes north from the equatorial regions, the rainfall pattern starts to get disturbed by monsoon winds.
- Not good for habitation due to hot and moist climate (High incidents of malaria and other tropical diseases).

Vegetation

- Dense tropical rain forests (called selvas in Amazon) are found.
    - Trees compete for the sunlight because of the huge density and closeness.
    - Epiphytes development.
    - Forest is arranged in 3 canopy layers vertically.
    - Growing season is entire year.
    - No distinct season of seeding, flowering, shedding of leaves.
- Many species of trees are intermixed, and hardwood logs sink in water so that commercial logging is not feasible. e.g. mahogany, ebony, dyewoods etc.
    - Cutting and transportation of the hardwood is a difficult task.

- Many parts of the tropical rain forests have been cleared either for lumbering or shifting cultivation.

Epiphytes

- They are plants that grow upon other plants non-parasitically. They usually derive only physical support and not nutrition from their host.
- They use photosynthesis for energy obtain moisture from the air or from dampness on the surface of their hosts.

Economic activities

- Main crops are plantation crops like rubber (SE Asia), cocoa (W Africa - Ghana & Nigeria), coconuts, sugar, coffee, tobacco, spices, banana.
- Belukar is the secondary forest growing as a result of shifting cultivation activities in Malaysia.
- Agriculture and developmental activities are difficult because thick grass and undergrowth grows as soon as the forest is cut.

Tropical Monsoon Climate

Distribution

Climatic Regions

- South and South-East Asia and North Australia.
  - Outside this zone the climate is modified by the onshore trade winds and rainfall is distributed more evenly throughout the year (tropical marine climate).

Temperature

- It experiences warm to hot summers due to the region's proximity to the tropics.
- Average monthly temperature is above 18 °C, but in summers the maximum temperature can reach as high as 45 °C.
- The average temperature in the summer is around 30 °C, with an overall temperature range of 30-45 °C.
- Mean temperature during winters is around 25 °C with temperature range of 15-30 °C.

Seasons

- Seasons are chief characteristics of monsoon climate.
  - Cool, dry winters (October - February).
  - Hot, dry summers (March - June).
  - Rainy season (June-September).
    - Orographic rainfall

Climatic Regions

The cool, dry season (October to February)

- The North-East Monsoon (Out blowing dry winds) bring little or no rain to the Indian sub-continent.
  - However, a small amount of rain falls in Punjab from cyclonic sources (Western Disturbances)

- North-East Monsoons blowing over the Bay of Bengal acquires moisture and bring rains to the south-eastern regions of Indian peninsula during Nov-Dec of the year.

The hot dry season (March to mid-June)

- The sun's northward shift to the Tropic of Cancer causes sharp rise in temperature.
- Coastal districts are a little relieved by sea breezes and little rain.

The rainy season (mid-June to September)

- Torrential downpours sweep across the country with the 'burst' of the South-West
- Almost all the rain for the year falls within this rainy season (this concentrated heavy rainfall in summer is a chief characteristic of the Tropical Monsoon Climate).

Vegetation

- Deciduous due to marked dry season during which leaves are shed.

- Forests are generally logged but the vegetation differs with the rainfall.
- Broad-leaved hardwood trees.
- The forests are more open and less luxuriant than the equatorial region forest and there are far fewer species.

Economic activities

- The region supports high population density.
- Subsistence farming is the main occupation (crops grown with an intention to secure food for the season and not sold as the production is very low).
- Intensive cultivation is common in regions with irrigational facilities.
- Shifting cultivation is prevalent in North-East India and South-East countries.
- Main crops are rice, sugar, jute (hemp in Manilla), cotton. Coffee is grown in Brazil. Tea requires modest temperatures (15 - 20°C), heavy rainfall (150 cm) and well drained slopes.
- Cattle and sheep rearing are carried out for domestic and commercial purposes, but livestock industry is not as profitable as in temperate regions.

Climatic Regions

Tropical Marine Climate

Distribution

- Occurs on the eastern coasts in tropics under the influence of trade winds. Philippines, Central America, NE Australia, Madagascar, East Africa and East Brazil.

Rainfall

- It is both orographic and convectional. It is maximum in summer season but without any distinct dry season.
- It is prone to severe tropical storms and typhoons.

Desert Climate

Distribution

- Areas having less than 25 cm of annual precipitation known as deserts (whether hot or cold).
- Major hot deserts are located on the western side of tropics (i.e. on 15°-30° latitude range of continent).

Hot desert

- Aridity of hot deserts is mainly due to offshore trade winds.

- Lie in the horse latitude belt where the air is subsiding - a condition least favorable to precipitation. Further winds blow from cooler to hotter regions, hence the lack of water content.

Cold deserts

- Aridity of cold deserts is because of offshore westerlies or leeward side effects.
- Cold deserts are also generally located on high plateaus.
- Atacama/Peruvian desert (driest place on earth) is the driest of all deserts (<1.25 cm p.a.).
- Cold currents have the effect of cooling the air. When this comes in contact with the hot air on the land mass, relative humidity drops further.

Rainfall

- Whatever occurs, occurs mostly because of convectional rainfall and with thunderstorms.
- In cold deserts in Asia, whatever rainfall happens occurs because of occasional western disturbances and in form of snow.

Temperature

Climatic Regions

- Temperature is high throughout the year (due to clear cloudless sky, intense insolation, high rate of evaporation). No winter.
- Average temperature is around 30-35°C.
- Diurnal and annual range is high.
- Coastal deserts generally have less temperature than interiors due to cold currents. Ranges are also high in interiors.
- Annual range of temperature is higher in cold deserts compared to hot deserts (because they are mostly located in mid-latitudes where variation in insolation is highest and because they are located deep inside continents).

Vegetation

- Vegetation is xerophytes / drought resistant scrubs (like cactus)
- Shrubs remain dormant for years waiting for rainfall. They also have long roots, modified leaves and stems. Seeds have thick tough skins and lie dormant until it rains.
- High evaporation means salts are brought upwards and they accumulate on the surface forming hard pans. Soil is also deficient in humus.

Climatic Regions

Minerals

- Gold is mined in Australia, diamonds and copper in Kalahari Desert, copper and nitrates in Atacama Desert.

Tropical Savanna / Sudan Climate

Distribution

- It is found between equatorial forests and the trade wind hot deserts.
- The grasses are called llanos in Orinoco basin and campos in Brazil.

Seasons

- Distinct wet and dry season with extreme diurnal range of temperature.
    - Hot, rainy season (May-September in Northern hemisphere, October-March in Southern hemisphere).
    - The amount of rainfall and the length of the rainy season decreases from equator to pole wards towards the desert fringes.
    - Trade winds bring rains to the eastern coasts but become dry by the time they reach interiors of the continents.
- Cool, dry season.

Climatic Regions

- Annual range of temperature is about 10°C and the range increases as we move pole wards.
  - Highest temperatures don't coincide with period of highest sun but fall just below the onset of rains.
- These conditions are best developed in Sudan hence it is called Sudan type of climate.

Local Winds

- Harmattan (the doctor) are the north east trades whichblow from interior Africa to the Atlantic coast in Guinea. They come from deserts and humidity rarely exceeds 30%. It is called the doctor because it gives relief from moist sea winds.

Vegetation

- Tall savanna grasses (elephant grass). Grasses have deep roots. It lays dormant during cool, dry season.
- Trees decrease in height and density polewards.
- Some trees are deciduous shedding their leaves in cool, dry season to prevent water loss.
- Some trees have broad trunks with water storing devices (like Acacia tree).

Climatic Regions

- Many trees are umbrella shaped exposing only a narrow edge to the winds.
- Heavy rainfall in hot, wet season lead to intense leaching of the soil and all the nutrients are washed away.
- Domestication of animals is popular in Australia.
- Grass fire occurs during dry season that also burn the seeds of trees which are ready to germinate.

Animal Life of the Savanna

- The savanna is the home large variety of animals and known as the 'big game country' due to the prevalence of hunting.
- There are mainly two groups of animals in the savanna, one is the grass-eating herbivorous animals and second is the fleshing-eating carnivorous animals.
  - Herbivorous zebra, antelope, giraffe, deer, gazelle, elephant etc.
  - Carnivorous lion, tiger, leopard, hyena, panther, jaguar, jackal etc.

Warm Temperate / Mediterranean Climate

Distribution

- It is confined between 30 - 45° latitudes on the western margins of the continents.

Climatic Regions

- It is caused by shifting of pressure belts and comes under the effect of trade winds during summers (continental trades and hence dry) and westerlies during winters (onshore winds and hence wet).

Temperature

- Highest temperatures are experienced as we move inland away from maritime influence.
- Climate is not extreme because of cooling effect by water bodies.

Rainfall

- Cyclonic rainfall is prevalent from westerlies. The rain comes as heavy showers and only on few days with bright sunny intervening days.
- The region experiences dry warm summers and wet cold winter.

Dry, warm summers with offshore Tradewinds

- The sun is overhead the Tropic of Cancer and Tropic of Capricorn during the summer months.
- The belt of influence of the Westerlies is shifted a little polewards. Rain bearing winds are therefore not likely to reach the Mediterranean lands.

Climatic Regions

- Hence the regions are practically rainless in summers and remain dry.
- The heat is intense, and the days are excessively warm.
- In the interiors, prolonged droughts are common. The relative humidity is generally low.

Wet, cold winters with on-shore Westerlies

- The Westerlies belt shifts equator ward in the winter and the Mediterranean regions are under the influence of on-shore Westerlies.
- Hence, these lands receive almost all of their precipitation during the winter months.
- The rain comes in heavy downpours and causes floods in the months of September and October in Mediterranean Europe.

Local Winds

Sirocco

- They are the south-westerlies blowing from Sahara Desert into the mediterranean climate. They are hot and dry and remain dry even after passing above Mediterranean Sea. It is most frequent during spring and is bad for crops.

Climatic Regions

Mistral

- It is a cold wind from north in Alps region which rushes down in winter into the valleys to fill the low pressure towards the sea.It is fast and may take the temperature below the freezing point.

Bora

- In the Adriatic coast, the cold winds blowing from the continent to the sea in winters are called Bora. They are very fast.

Vegetation

- Mediterranean evergreen forests
  - They are found in regions of high rainfall. Cork oak trees are common in Europe while eucalyptus are grown in Australia.
- Evergreen coniferous forests
  - They are found in highlands.
- Mediterranean shrubs
  - They are the dominant vegetation.
- Orchard farming
  - Fruit trees have long roots enabling them to fetch water in hot summer season as well. The thick leathery skin of the fruits also prevents transpiration.

Climatic Regions

Agriculture

- Summer is dry hence monsoon crops are not grown.
- This region is not suitable for agriculture, but some regions do cultivate using irrigation methods.
- Citrus fruits are mostly grown and viticulture (wine making) is mostly done here.

Temperate Continental Grasslands Steppe Climate

Distribution (30° - 45°)

- They border the deserts and lie in the interiors of the continents in Northern hemisphere and near the oceans in Southern hemisphere. Though they lie in the westerly belt, they are far removed from the maritime influence.
- Mostly they are grassland / treeless because of absence of maritime influence. They are extensive in northern hemisphere.
- Grasslands in Southern hemisphere are less continental due to proximity to oceans. They have less extreme temperatures (milder winters and less annual range) and rainfall is higher as well.

Temperature (Continental Climate)

- Warm summers and cold winters. Extreme variation of temperature.

Climatic Regions

- Wetter and cooler than Savannah.
- Annual range is very high in northern hemisphere.
- Southern hemisphere climate is never severe (effect of ocean).

Rainfall

- Annual precipitation (conventional sources) is light with maximum rainfall in summers. Winters get occasional rains from western disturbances and in the form of snow.
- Annual precipitation is higher in Southern hemisphere due to proximity to ocean and warm ocean currents.

Chinooks

- They are south-westerly winds pulled over from the Rockies. They are hot winds and can raise the temperatures by 20° C in 20 minutes.

Vegetation

- Nutritious grasses (No trees).
- Complete grasslands are converted into agricultural lands.
    - Truck farming is done (mostly in prairies).
    - Heavily mechanised farming (Aeroplane

used for dropping fertilizers).

- Per person productivity is high, per acre productivity is low (because of absence of intense farming).
- The grasses lie dormant in the winters and become active in the spring when the temperature is hot enough. In summers they get scorched but in autumn they grow again.
- Polewards, an increase in precipitation gives way to coniferous trees while equatorward they merge with desert shrubs.

Economic Development

- Prairies would have wheat, cotton, maize cultivation
- Steppes are one of the major producers of wheat
- Pampas region would have wheat cultivation, animal husbandry livestock ranching (alfa-alfa a nutritious grass is found here).
- Downs of Australia would have sheep rearing (Marino sheep famous for wool).
- Veldts are famous for sheep rearing (agora goat is famous for wool production).

Warm Temperate/ China Climate / Natal Type / Gulf Type

Climatic Regions

Distribution

- Eastern margin in warm temperate zone (30°-45°)
- China type
  - East and central China.
  - Rainfall throughout the year.
  - Trade winds take the warm current moist air inside and causes rain in summers. Typhoons are carried in by the trades in late summers.
  - In winters, however there is a reversal of wind direction due to cooling of Asian land mass and temperatures plummet (rain through moisture gain by Siberian plateau wind while passing yellow). So annual range of temperature is high.

Gulf type

- SE USA, Gulf of Maxico.
- The monsoonal characteristics are less here as the pressure gradient between continental North America and the Atlantic Ocean is never high enough to reverse the wind direction completely.
  - Rainfall in summer is maximum.
  - In winter season this type will experience temperate cyclone while in late summers they experience tropical cyclones (hurricane).

Climatic Regions

Natal type

- In southern hemisphere like South Africa (Natal province), Eastern Australia, Southern Brazil.
- These lands have no monsoonal climate due to thinness of the land masses which is not sufficient to cause any wind change.
- More dominance of maritime climate. So annual range of temperature is less, rainfall is more and distributed throughout the year.

Rainfall & Temperature

- It has more rainfall than Mediterranean climates for same latitude because of influence of warm currents. They are under the influence of trade winds.
- Summers are warm and winters are cool. Rainfall varies from 60-150 cm.

Natural Vegetation

- The region supports luxurious vegetation due to heavier rainfall.
- There are perennial plants, a well-suited condition for the rich variety of plant life.
- The lowlands carry both evergreen broad-leaved forests and deciduous trees, like tropical monsoon forests.

Climatic Regions

- The highlands carry various important softwoods species of conifers such as pines and cypresses.
- Eastern Australia = Eucalyptus
- South-Eastern Brazil, eastern Paraguay, north-eastern Argentina = Parana pine, the quebracho, wild yerba mate trees.
- Natal = palm trees

Economic Development

- These regions are the most productive part of the middle latitudes due to the adequate rainfall; no prolonged drought and the cold season is warm.
- This shows almost continuous growing season.
- The temperate monsoon regions are the most intensively tilled parts of the world.

Cool Temperate Western Margin/British Climate

Distribution

- Located to the western margin in cool temperate zone (45°-65°) North and South.
- They are under the influence of westerlies all through the year, but westerly influence is blocked by Rockies and Andes in N and S

America, respectively.

- Britain, Northern France, Northern Germany, Norway, Western Canada (Vancouver provinces) Tasmania and New Zealand, Southern Chile.
- British type will experience four seasons.

Temperature & Precipitation

- Cool moderate climate.
- Low annual range of temperature. Moderate temperature best suited for human habitation. Summers are never very warm.
- Rainfall is throughout the year with winter or autumn maximum because of cyclonic conditions.
  - Rainfall from westerlies in summer.
  - Western coast receives most rainfall and rain decreases towards interior.
- Temperature have much oceanic influence, mostly warm ocean currents influence.

Natural Vegetation

- Deciduous forests are found, and they shed their leaves in autumn to prepare for the cold season.
- Tall trees with good canopy cover, mostly give softwood.
- Trees are social species and are in pure stand, multiple species are not found (hence commercially

viable).

- Example Oak, Birch, Beech, Elm

Economic activities

- Lumbering (cutting of trees for commercial purpose) in systematic way. Winter cutting is done where they would make wood logs float on frozen river.
- Market gardening is a type of agricultural practice.

Cool Temperate Eastern / Laurentian Climate

Distribution

- It is the intermediate types and has both maritime and continental traits.
- It is extended in cool temperate eastern margin (45°- 65°) of northern hemisphere.
- It extends in eastern Canada (Newfoundland), North East USA (new England states) regions, Korea, Northern Japan present beyond 40° latitude).
- It also extends in Eastern Siberia, North china, Manchurian regions.
- In southern hemisphere this climatic type is absent (land is not present beyond 40°latitude).

Climatic Regions

Rainfall and Temperature

- Winters are cold and dry while summers are warm and wet. Summers would be warmer but for the cold continental winds.
- Rainfall throughout the year.
    - In summer, westerlies bring rain fall in North America region because they catch moisture from great lakes. In winter, gulf stream increases moisture content which results in rainfall from polar easterly wind.
    - In china, we have summer maximum rainfall because of intense heating of land leading winds penetration come from pacific (southeast monsoon). In winter, anti cyclonic conditions in central Asia exists hence cold wind blows out and create some rainfall (Borrowing moisture from Yellow Sea).

Natural Vegetation

- Mixed forestry (coniferous and deciduous).
    - Deciduous would spread below 50° latitude, Coniferous would spread above 50° latitude.
- Oak, birch beech maple are principle trees.

Climatic Regions

Economic activities

- Lumbering and its associated timber, paper and pulp industries are the most important economic activity.
- Fishing is also an important economic activity.
- Agriculture is less important because of long and severe winters.
- Farmers are engaged in dairy farming in the North American region.

Boreal Climate / Taiga Climate / Siberian Climate / Cool Temperate / Continental Climate / Continental Sub-Polar Climate

Distribution

- It has tundra towards the north and steppes towards the south. Taiga is the Russian name.
- It stretches along a continuous belt across central Canada, some parts of Scandinavian Europe and most of central and southern Russian (50° to 70° N).
- Found only in the northern hemisphere (due to great east-west extent).

Climatic Regions

- Absent in the southern hemisphere (Because of the narrowness in the high latitudes. Also, the strong oceanic influence reduces the severity of the winter).

Temperature

- Summers are brief and warm reaching whereas winters are long and brutally cold.
- Annual temperature range of the Siberian Climate is the greatest (Almost 50-60 °C in Siberia).
- In North America, the extremes are less severe, because of the continent's lesser east-west stretch.
- Occasionally cold, northerly polar local winds such as the Blizzards of Canada and Buran of Eurasia blow violently.
- Permafrosts (a thick subsurface layer of soil that remains below freezing point throughout the year) are generally absent as snow is a poor conductor of heat and protects the ground from the severe cold above.

Precipitation

- Rainfall annually is not high as maritime influence in the interiors is absent.
- Frontal disturbances might occur in winter.

Climatic Regions

- It is quite well distributed throughout the year, with a summer maximum (convectional rain in mid-summer - 15 °C to 24 °C).
- In winter, the precipitation is in the form of snow as mean temperatures are well below freezing all the time.

Natural Vegetation

- The predominant type of vegetation is evergreen coniferous forest.
- The conifers are best suited to this type of sub-Arctic climate as they require little moisture
  - Juniper, spruce, fir, pine are example species of coniferous
- The greatest single band of the coniferous forest is the taiga (a Russian word for coniferous forest) in Siberia.
- These coniferous belts are rich source of softwood (used in furniture, construction, paper making industries).

Tundra Climate / Polar Climate / Arctic Climate

Distribution

- Found in regions north of the Arctic Circle and south of Antarctic Circle.

Climatic Regions

- The icecaps are confined to highlands and high latitude regions of Greenland and Antarctica.
- In the southern hemisphere, Antarctica is the greatest single stretch of ice-cap.
- The lowlands – coastal strip of Greenland, the barren grounds of northern Canada and Alaska and the Arctic seaboard of Eurasia, have tundra climate.

Temperature

- The tundra climate is characterized by a very low mean annual temperature (most of the year below freezing point).
    - Temperatures are as low as 40-50 °C below freezing in mid-winter whereas summers are relatively warmer.

Precipitation

- Precipitation is mainly in the form of snow and sleet.
- Frequent blizzards reaching a velocity of 130 miles an hour.
- Convectional rainfall is generally absent.

Natural Vegetation

- There are no trees in the tundra.

Climatic Regions

- Lowest form of vegetation like mosses, lichens etc. are found in patches.
- Climatic conditions along the coastal lowlands are a little favorable.
- Coastal lowlands support hardy grasses and the reindeer moss which provide the only pasturage for reindeers.
- Berry-bearing bushes and Arctic flowers bloom in the brief summer.
- In the summer, Birds migrate north to prey on the numerous insects which emerge when the snow thaws.
- Residing Mammals = Wolves, foxes, muskox, Arctic hare and lemmings.
- Penguins live only in Antarctic regions.

Human Activities

- People live a semi-nomadic life and largely confined to the coast.
- In Greenland, northern Canada and Alaska live the Eskimos.
- During winter they live in igloos.
- Fish, seals, walruses, and polar bears are their major food.