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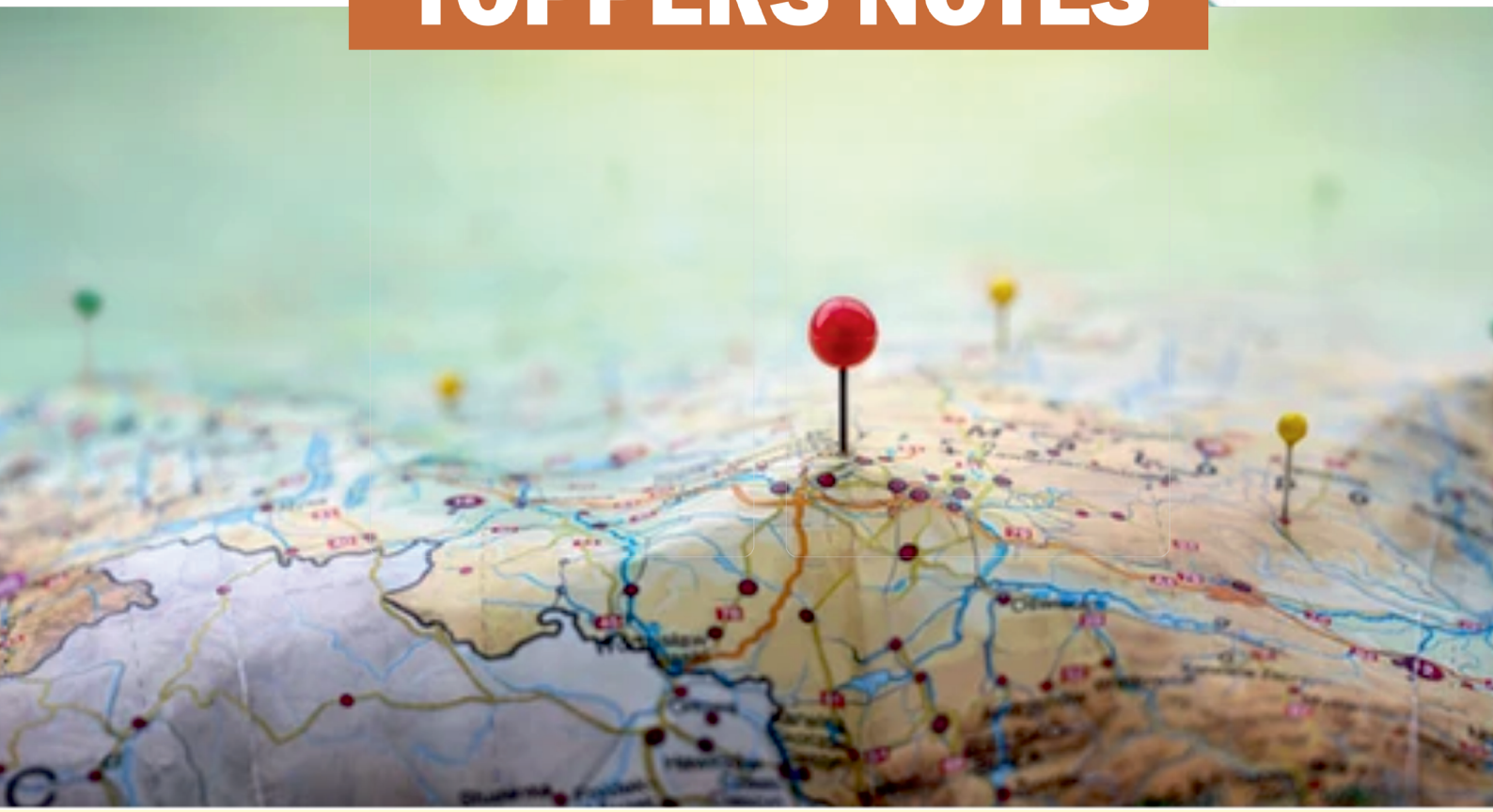
GEOGRAPHY

OF INDIA & WORLD

TOPPERS NOTES



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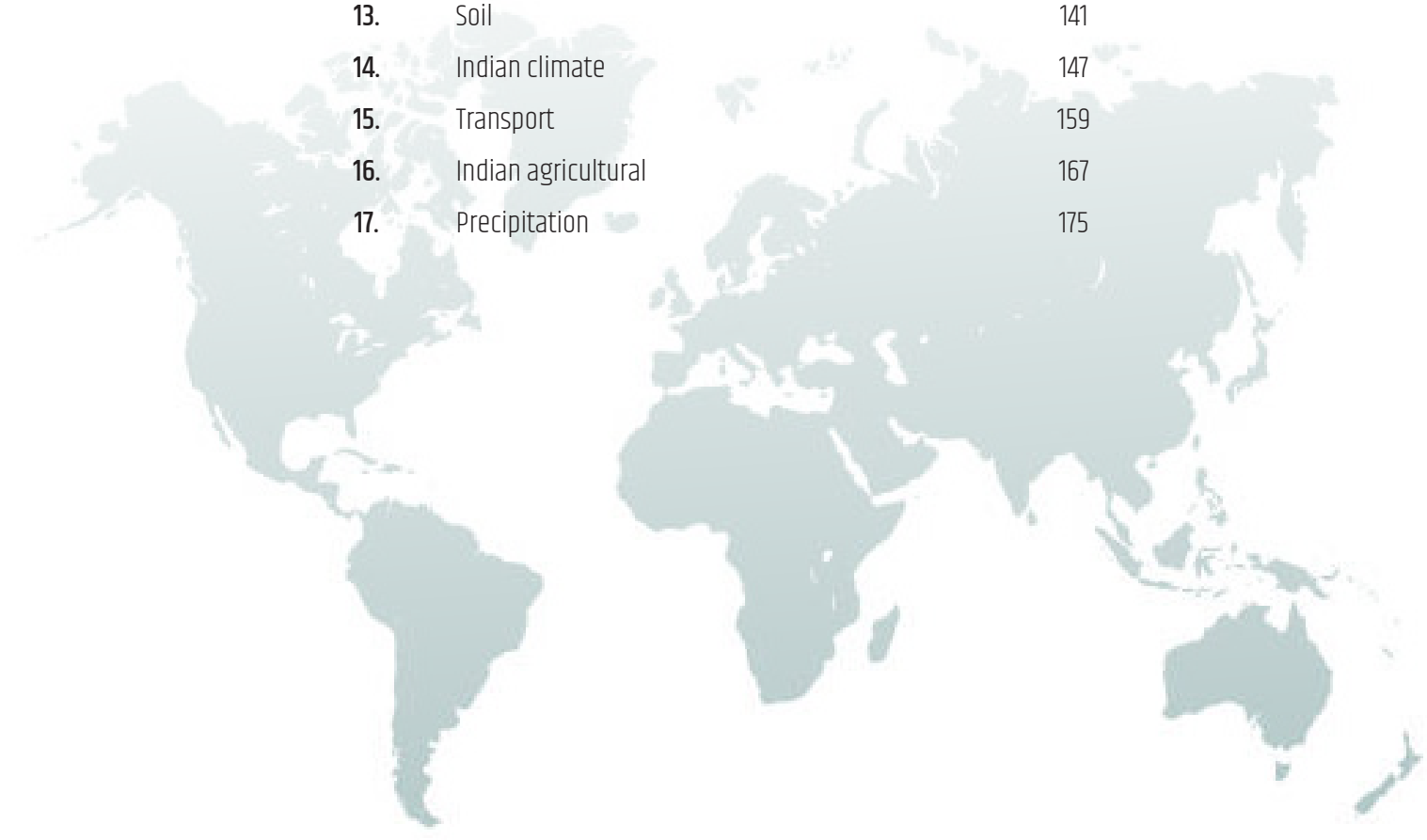


1 UNIVERSE AND SOLAR SYSTEM

- **Geomorphology,** is defined as the science of description (discourse) of various forms (morphe) of the earth's surface.
- **The Universe :** The vast space surrounding us is called universe. It is mostly empty space. The universe includes everything that exists : the most distant stars, planets, satellites, as well as our own earth and all the objects on it.

■ Origin Of The Universe :

A. Big Bang Theory Or Expanding Universe Hypothesis :

1. It was given by **Edwin Hubble.**
2. In the beginning, universe was a tiny ball (single atom) with unimaginably small volume and infinite temperature and density. **13.7 billion years** ago, this ball exploded leading to a huge expansion.
3. This expansion is continuing until now, at a smaller pace. First atom began to form within 3 minutes of Big Bang. Within 300,000 years of explosion, **temperature dropped to 4500 K** and gave rise to atomic matter.
4. Universe became transparent. The expansion in universe means increase in space between the galaxies.
5. An alternative theory is '**Hoyle's concept of steady state**' which considers universe to be roughly of same size at any point of time.

- **The Stars :** They are the heavenly bodies like the sun that are extremely hot and have light of their own. Stars are made up of vast clouds of hydrogen gas, some helium and dust.
- **Galaxies :** They are **building blocks of the universe**. Galaxy is a vast system of billions of stars, which also contains a large number of gas clouds mainly **of hydrogen gas** (where stars are born), and dust, isolated in space from similar system.

B. Nebular Hypothesis :

1. A galaxy starts to form by accumulation of Hydrogen gas in the form of a very large cloud called Nebula.
2. This growing Nebula starts developing localized clumps of gas.
3. These clumps continue to grow into even denser gaseous bodies, giving rise to formation of star. This event took place 5 to 6 billion years ago.

- **Units of Measuring Distances in the Universe -** expressed in terms Astronomical Unit (A.U), Light year, and Parsec.

1. **Astronomical unit** is defined as the mean distance from the earth to the sun. One AU is equal to 1.5×108 kilometres

2. **Light year** is the distance travelled by light in one year. It is equal to 9.46×10^{12} kilometres.

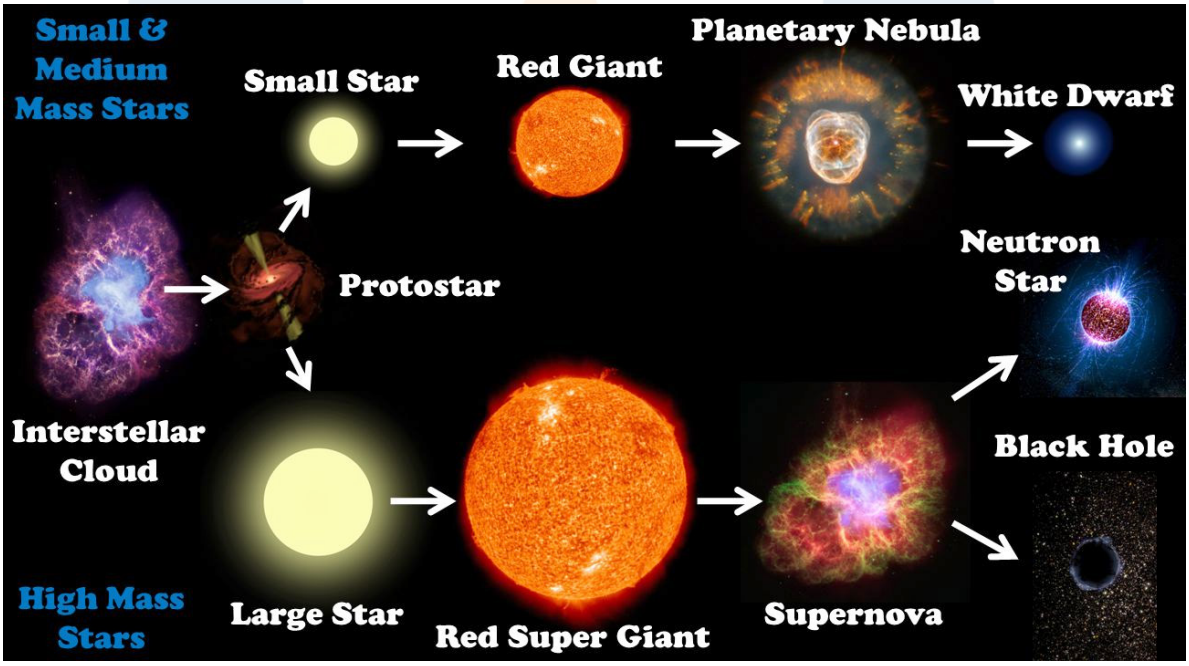
3. **Parsec :** It represents the distance at which the radius of Earth's orbit subtends an angle of one second of arc. One parsec equals about 3.26 light-years or 30.9 trillion kilometres.

Our Own Galaxy : The Milky Way

- It is a spiral type of galaxy.
- It is about 100000 light years in diameter and has disk-shaped structure.
- The Milky Way galaxy is rotating slowly about its centre in the counter-clockwise direction.
- All the stars (The sun too along with the solar system) rotate about the centre of the Milky Way galaxy.
- The disc of stars is quite thick at the centre representing a relatively high concentration of the stars at the centre of the galaxy.
- The sun is far away(~27000 LY) from the centre of the Milky Way galaxy.
- Since the Milky Way galaxy appears like a river of light in the night sky running from one corner of the sky to the other, it is called '**Akash Ganga**'

Stellar Evolution :

- Low And Medium-Mass Stars (Including The Sun)

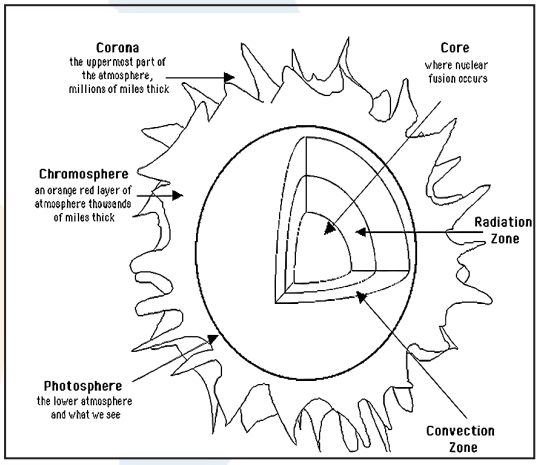


Birth and Evolution of a Star :

- **PROTOSTAR**-In the beginning, Galaxy had just very cold (-1730C), dense and large cloud of gases (Hydrogen and Helium). Very large gravitational pull led to the formation of a highly condensed body called Protostar. A protostar is a huge, dark, ball of gases. It does not emit light.
- **STAR**-Further contraction of Protostar leads to collision of Hydrogen gases and increases the temperature of the protostar. Hence, fusion reaction, where 4 Hydrogen nuclei fuse to form Helium and release tremendous amount of energy in the form of heat and light. It makes the star shine.

- **RED STAR**-Fusion reaction stops in the core when its Hydrogen gets exhausted. Pressure of the core diminishes and core starts shrinking. Fusion takes place as some Hydrogen remains in the envelope/ outer shell.
- It makes the star unstable. The star Expands and turns Red. Sun will enter its Red giant phase in 5000 million years from now. Its expanding outer shell at the time will engulf inner planets i.e. Mercury Venus and Earth.
- **DWARF STAR** When mass of star < 1.44 times the mass of Sun (Chandra Shekhar limit), it ends up as a white dwarf.
- The Red Giant Star looses its outer envelop and core shrinks into an extremely dense ball of matter due to gravitation. This leads to another set of fusion reaction where Helium fuses to form carbon. The fuel gets completely exhausted and the core shrinks under its own weight and becomes a white dwarf.
- **SUPERNOVA**-When mass of star > 1.44 times that of Sun, there remains enough Helium in the core for fusion reaction. The outer envelope explodes causing Supernova Explosion. When mass of the star is bigger than 3 times that of Sun, it becomes a Black hole
- When mass of the star is between 1.44 to 3 times that of Sun, it becomes a Neutron Star.

The Solar System :



SUN :

- Sun is a ball of hot gases, mainly **Hydrogen.**
- Shining surface of the Sun is called **Photosphere.**
- The outer layer of the sun's atmosphere is made up of thin hot gases is called **Corona.**
- Corona is visible only during full eclipse

GOLDILOCKS ZONE :

- A habitable zone, also called a Goldilocks zone, is the region around a star where orbiting planets similar to the Earth can support liquid water. It is neither too hot, nor too cold.

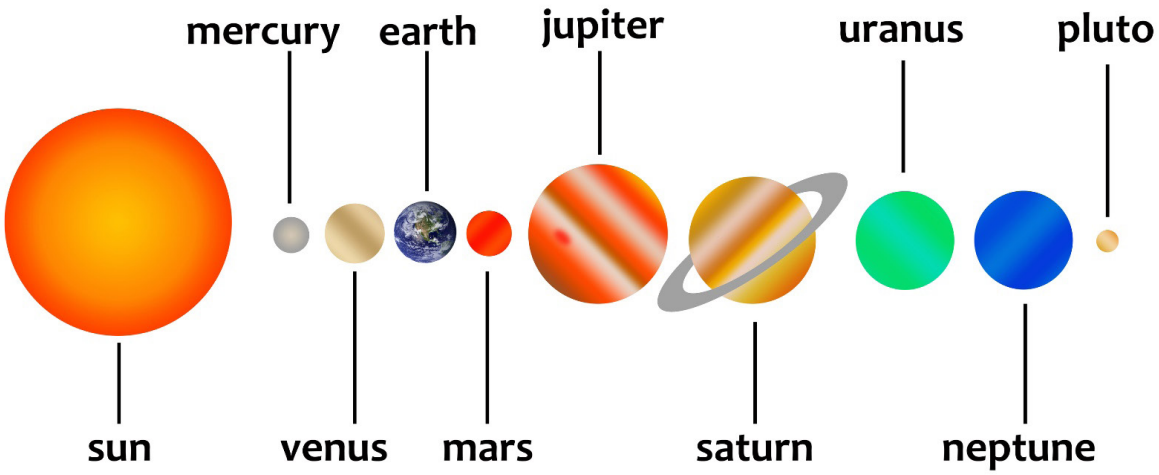
PLANETS :

- Planets are solid heavenly bodies which revolve round a star (e.g. the sun) in closed elliptical paths. A planet is made of rock and metal. It has no light of its own. A planet shines because it reflects the light of the sun. The planets move round the sun from west to east, so the relative positions of the planets keep changing day by day. There are 8 major planets including the earth.

IAU new definition of planet :

- The definition of planet set in 2006 by the International Astronomical Union (IAU) states that, in the Solar System, a planet is a celestial body which :
  1. is in orbit around the Sun,
  2. has sufficient mass to assume hydrostatic equilibrium (a nearly round shape), and

3. Has "cleared the neighbourhood" around its orbit. For this they become the dominant gravitational body in their orbit in the Solar System. Pluto lacks it



Planets of the solar system :

- **Mercury** is closest to the sun. It has a temperature range of 427^{0}C on its side facing the Sun and - 270^{0}C, on its dark side. It has no atmosphere.
- **Venus** is the closest neighbour of the earth. It is about 40 mk away. It is an extremely hot planet with a temperature of 480^{0}C. Its atmosphere has 96% carbon dioxide and poisonous gases like sulphur dioxide and carbon monoxide.
- **Earth** is the only planet known to sustain life.
- **Mars** is also close to earth. It is called the red planet. It has 95% carbon monoxide and reddish dust. It is relatively a very cold planet and as of now presence of life on it has not been conclusively established.
- **Jupiter** is the largest planet of the solar system. It is mainly a rapidly spinning ball of gas specially clouds of ammonia, and has no solid surface.
- **Saturn** consists mainly of hydrogen and helium. Its atmosphere has 90% nitrogen and a temperature of (-184^{0}C). It is also made up of hydrogen cyanide which is a highly poisonous gas. It is characterized by a ring that surrounds it.
- **Uranus** is also a very cold planet. Uranus is a distant planet of solar system and 7th in order from the sun. Uranus and Neptune are the outermost planets of the solar system. Uranus has a highly tilted rotational axis.
- **Neptune** is cold and dark with its surface coated with frozen methane.

■ ORIGIN OF LIFE :

- The universe is very old - almost **20 billion years** old. Huge clusters of galaxies comprise the universe. Galaxies contain stars and clouds of gas and dust. The Big Bang theory attempts to explain to us the origin of universe.
  1. It talks of a singular huge explosion unimaginable in physical terms. The universe expanded and hence, the temperature came down.
  2. Hydrogen and Helium formed sometime later. The gases condensed under gravitation and formed the galaxies of the present day universe.

3. In the solar system of the milky way galaxy, earth was supposed to have been formed about 4.5 billion years back.
4. There was no atmosphere on early earth. Primitive gases Water vapour, methane, carbondioxide and ammonia released from molten mass covered the surface.
5. The UV rays from the sun brokeup water into Hydrogen and Oxygen and the lighter H2 escaped.
6. Oxygen combined with ammonia and methane to form water, CO2 and others.
7. The ozone layer was formed. As it cooled, the water vapor fell as rain, to fill all the depressions and form oceans.
8. Life appeared 500 million years after the formation of earth, i.e., almost four billion years back.

Case of Pluto :

- **As** per International Astronomical Unit, three given characteristics are required to qualify as a planet :
  1. The celestial body has to be in orbit of the Sun
  2. It must have sufficient mass to assume hydrostatic equilibrium (i.e. a nearly round shape), and
  3. It must have 'cleared the neighbourhood' around its orbit i.e. it must become the dominant gravitational body in their orbit. Pluto lacks the third characteristic. That's why it is not a planet anymore and has been categorized as a Dwarf Planet.

	Terrestrial Planets (Earth Like)		Jovian Planets (Jupiter Like)
1.	Four innermost planets i.e. Mercury, Venus, Earth, and Mars They have a compact, rocky surface like Earth's terra firma	1.	Includes Jupiter, Saturn, Uranus, and Neptune (Jupiter like) planets, because they are all gigantic compared with Earth, and they have a gaseous nature like Jupiter's --mostly hydrogen, with some helium and trace gases and ices. Also referred to as the **"gas giants".**
2.	None of the terrestrial planets have rings, although Earth does have belts of trapped radiation.	2.	All of them have significant planetary magnetic fields, rings, and lots of satellites.
3.	Among the terrestrials, only Earth has a substantial planetary magnetic field. Mars and the Earth's moon have localized regional magnetic fields at different places across their surfaces, but no global field.	3.	Jupiter is more massive than all the other planets combined. It emits electromagnetic energy from charged atomic particles spiraling through its strong magnetic field.
4.	Of the terrestrial planets, Venus, Earth, and Mars have significant atmospheres.	4.	Saturn is the farthest planet easily visible to unaided eye is known for its extensive complex system of rings. its moon titan is the second largest moon after Ganymede
5.	Mercury lacks an atmosphere. Even though most of its surface is very hot ,there is strong evidence that water ice exists in locations near its north and south poles which are kept permanently shaded by crater walls.	5.	**Among four Galilean satellites of Jupiter :** • Lo is the most volcanically active body in the solar system, due to heat resulting from tidal forces.

6.	Venus' atmosphere of carbon dioxide is dense, hot, and permanently cloudy, making the planet's surface invisible.		• Europa is covered with an extremely smooth shell of water ice. There is probably an ocean of liquid water below the shell. • Ganymede has mountains, valleys, craters, and cooled lava flows. Its ancient surface resembles • Earth's moon, and it is also suspected of having a sub-surface ocean. • Callisto, the outermost Galilean moon, is pocked all over with impact craters, indicating that its • surface has changed little since the early days of its formation
7.	Mars' atmosphere, also carbon dioxide, is much thinner than Earth's. Mars has polar caps of carbon dioxide ice and water ice.		

■ SATELLITES :

- A satellite (or moon) is a solid heavenly body that revolves round a planet. Except Mercury and Venus all other planets of solar system have satellites. The satellites have no light of their own. They shine because they reflect the light of the sun.
- Jupiter has the largest number of Moons. It also has the biggest moon of the solar system, Ganymede. - Saturn's moon 'Titan' has its own atmosphere.

ABOUT EARTH'S MOON :

- It is a natural satellite of Earth. It revolves around the Earth in a definite regular path. Gravitational attraction of the earth holds the moon into its orbit. It is about 1/4th size of the Earth in diameter and 1/8th in weight.
- Moon does not have air or water. Its surface is covered with hard and loose dirt, craters and mountains. Days are extremely hot and nights are very cold on moon.

■ THEORIES OF FORMATION OF MOON :

DARWIN	MATERIAL FORMING	GIANT IMPACT OR THE BIG SPLAT
Both earth and moon formed a single rapidly rotating body.	The moon was separated from what we have at present the depression occupied by Pacific ocean.	A body of the size of one to three times that of Mars collided into the earth shortly after the earth was formed. It blasted a large part of earth into the space.
The whole mass became dumb-bell shaped and eventually broke.		The blasted portion started revolving around the earth and eventually formed into the present moon after 4.4 million years ago. Most accepted theory.

■ ASTEROIDS :

Asteroids are a belt of debris composed of rock and metals, which somehow failed to assemble into a planet and keep revolving between the orbits of Mars and Jupiter.

There are as many as 100,000 asteroids.

The biggest asteroid called **'Ceres'** has a diameter of about 800 km whereas the smallest asteroid is of size of a pebble. Asteroids can collide with earth.

It is believed that the extinction of dinosaur was due to such a collision.

The Lonar Lake in Maharashtra is a filled up crater formed after an asteroid collision

■ COMETS :

They are celestial objects formed of ice and dust.

They were formed very early from the same gas clouds from which other members of the solar system are formed. They orbit the Sun.

When their normal path gets disturbed, they start moving towards the sun.

As the comet approaches Sun, the ice sublimates into gas and form along with the entrained dust particle, a bright outflowing atmosphere around the comet nucleus called Coma.

The comet may also form two tails, one of ionized molecules and radicals and other of dust.

The tails of the comet always point away from the Sun. The study of the tails of the comet has shown presence of Carbon, Hydrogen, Nitrogen and Oxygen in it.

Comets do not last forever. Whenever they come close to sun, their gases get over and ultimately only dust particles remain.

■ METEORS :

They are small celestial bodies (may include dust particles of a comet, or a piece of broken asteroid) which enter into the earth's atmosphere and burns as a bright streak of light due to heat produced by the friction of its impact with the atmosphere.

They are also called shooting stars. If a Meteor is big enough and does not gets burnt up completely, and lands on earth (like stones from sky), it is called Meteorite.

It should be noted that the number of meteorites on moon's surface is much larger than that on earth because moon does not have an atmosphere to burn the meteor.

Study of meteorites can reveal the nature of materials of which the solar system is composed of.

Black Holes :

- A black **hole is an object with such a strong gravitational field** that even light cannot escape from its surface.
- A black hole may be **formed when a massive object (very big object) undergoes uncontrolled contraction (a collapse)** because of the inward pull of its own gravity.
- When a supernova explosion of a very massive star takes place, then the **gaseous matter present in the outer shell(or envelope) of the star is scattered into space but the core** of the star survives during supernova explosion. This heavy core of the **supernova star continues to contract** (shrink) and becomes a neutron star. The fate of this neutron star **depends on its mass.**
- black holes are invisible, they cannot be seen. The presence of a black hole can be felt only by the effect of its gravitational field on its neighbouring objects in the sky.

Dark matter :

- Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large **part of the mass** that appears to be missing from the universe.
- Dark matter cannot be seen directly with telescopes; evidently **it neither emits nor absorbs light** or other electromagnetic radiation at any significant level.
- Dark Matter **is not exactly balck hole**. The composition of the constituents of cold dark matter is currently unknown. It could be group of black holes, dwarfs or some new particle.

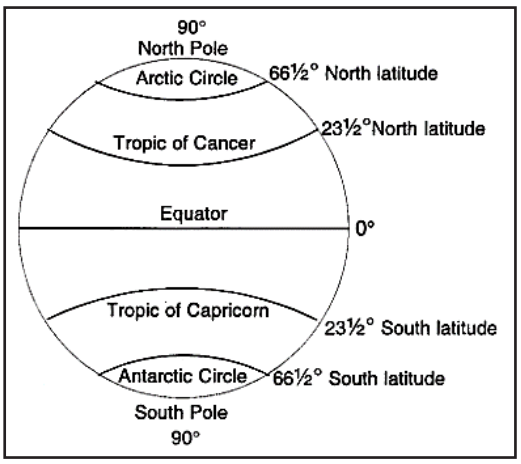
The Shape of the Earth :

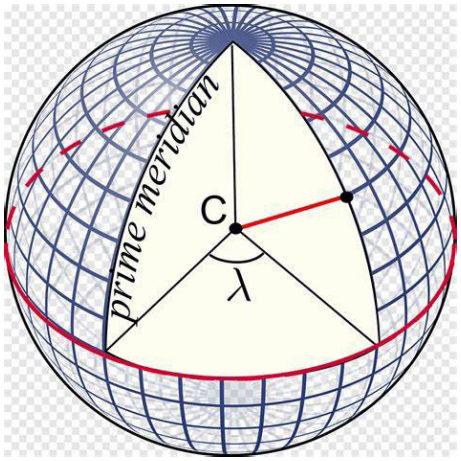
1. an oblate spheroid, bulging slightly at the equator and flattened slightly at the poles.
2. difference between the equatorial diameter and the polar diameter is less than 44 km.
3. The diameter of the Earth is 12,756 km at the equator, whereas it is 12,712 km between the poles
4. spherical in shape was first forwarded by the famous Greek philosopher, Phagoras

Geographical Grid- Latitude and Longitude :

A. Latitude- is the angular distance of a point on the earth's surface, measured in degrees from the centre of the earth. It is parallel to a line, the equator, which lies midway between the poles. These lines are therefore called **parallels of latitude**

B. Longitude is an **angular distance,** measured in degrees along the **equator east or west of the Prime** (or First) Meridian. On the globe longitude is shown as **a series of semi-circles** that run from pole to pole passing through the equator. Such lines are also **called meridians.** Unlike the equator which is centrally **placed between the poles,** any meridian could have been taken to begin the numbering of longitude. It was finally decided **in 1884,** by international agreement, to choose as **the zero meridian** the one which passes through the **Royal Astronomical Observatory at Greenwich**, near London. This is the **Prime Meridian (0°)** from which all other meridians radiate eastwards and westwards **up to 180°**.


90°
North Pole
Arctic Circle
66½° North latitude
Tropic of Cancer
23½°North latitude
Equator
0°
Tropic of Capricorn
23½° South latitude
Antarctic Circle
66½° South latitude
South Pole
90°


prime meridian
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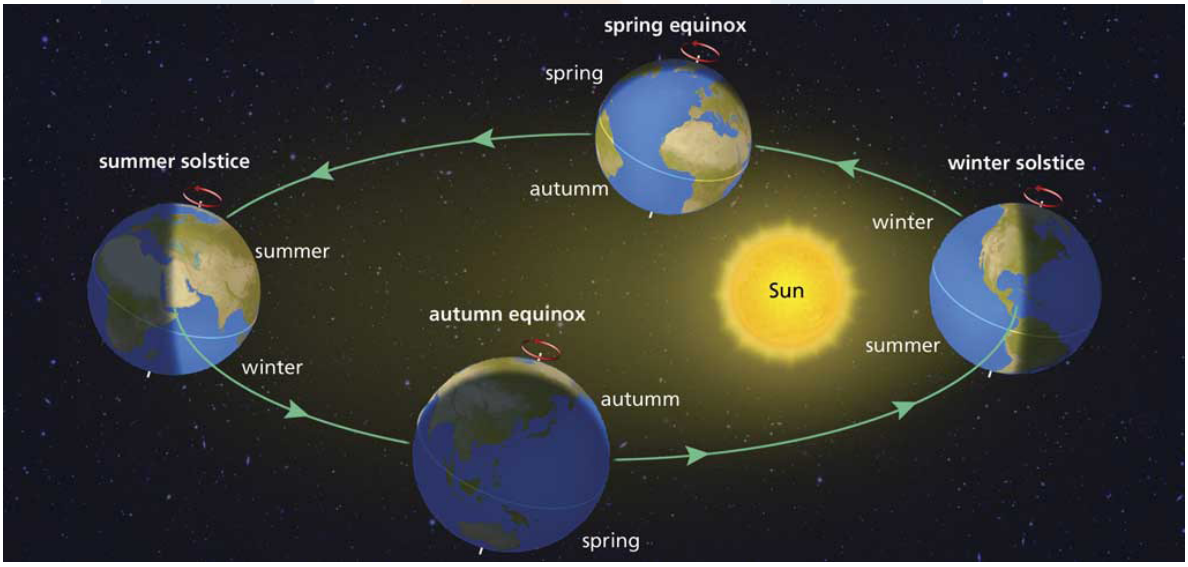
2 THE EARTH'S MOVEMENT

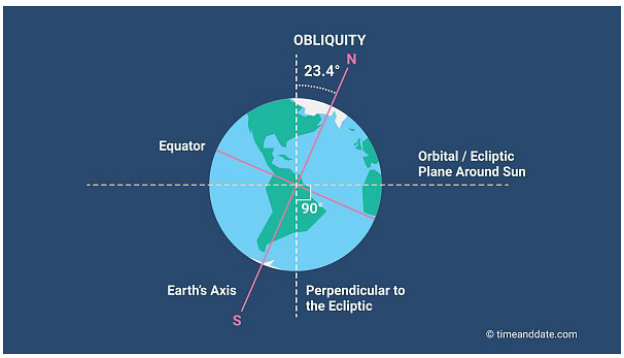
- The Earth, as the rest of the planets of the Solar System, rotates on its and (rotation movement) and **around the Sun (Orbit movement).** These two movements are responsible for phenomena such as day and night and the sequence of the seasons.
- **ORBIT** The Earth takes 365 days. 5 hours and 48 minutes to complete a burn around the Sun. As the Sun Varies its position relation as the Sun. The seasons appear and thee variation of the days and nights.
- **LEAP YEARS** -every four years February has 29 days instead of 28 they are the leap years
- **23^{0}5'** Is the angle between the Earth's axis and the Sun.

MARCH 21st	Spring equinox in the Northern hemisphere. Day and night hours are the same.
JUNE 21St	Summer solstice in the Northern hemisphere. It is the longest day of the year.
SEPTEMBER 21st	Autumnal equinox in the Northern Hemisphere. Day and night have the same amount of hours.
DECEMBER 21st	Winter solstice in the Northern hemisphere. It is the shortest day of the year.



- **TIME ZONES -** The Earth is divided in twenty four areas or time zones, each with a different time, with Greenwich Meridian as a central axis. As you areas a meridian to the East, an hour is added, and when you cross it to the West, an hour is substracted.
- **JET LAG -** Long distance trips on an airplane cause same well known disorders such as jet lag. Since they alter the habitual schedules of the body

ROTATION :



- Rotation is thee turn that the earth does on its axis every day. It is the responsible movement for the succession of days and nights, of the flattening of the poles, the marine currents and the different time zones.

HEMISPHERES :

- The Earth is divided into two halves; the northern hemisphere and southern hemisphere. Equator is the imaginary line between them. When it is summer is the north, south is winter and vice versa.

Longitude and Time :

- Since the Earth makes one complete revolution of 360° in one day or 24 hours, it passes through 15° in one hour or 1° in 4 minutes.
- The earth rotates from west to east, so every 15° we go eastward, local time is advanced by 1 hour. Conversely, if we go westwards, local time is retarded by 1 hour.
- We may thus conclude that places east of Greenwich see the dun earlier and gain time, whereas places west of Greenwich see the sun later and lose time.
- The Indian Government has accepted the meridian of 82.5° east for the standard time which is 5hrs. 30 minutes ahead of Greenwich Mean Time.
- Larger countries like U.S.A. (9), Canada (6) and Russia (9) which have a great east-west stretch have adopted 9, 6 and 9 time zones respectively for practical purposes.

Dawn and Twilight :

- The brief period between sunrise and full daylight is called **dawn** and that between sunset and complete darkness is termed twilight.
- This is caused by the fact that during the period the dawn and **twilight** the earth receives diffused or **refracted light** from the sun whilst it is still below the horizon.
- Since the sun rises and sets in a vertical path **at the equator** the period during which refracted light is received is short.
- But in temperate latitudes, the sun rises and sets in an oblique path and the period of refracted light is longer. It is much longer still **at the poles**, so that the winter darkness is really only twilight most of the time.

Eclipse :

- An eclipse occurs when the **Sun, the Earth and the Moon** are in a straight line in the plane of ecliptic.
- When the Earth obstructs the rays of the Sun from reaching the face of the Moon, the Moon gets eclipsed. When the Moon hides the face of the Sun, then it is an eclipse of the Sun.

A. Lunar Eclipse :

- only when the Sun, the Earth and the Moon are in a straight line, and the Earth lies between the Sun and

the Moon. This is possible on a Full Moon day. But a lunar eclipse does not occur on every Full Moon day, as these three bodies have to be in the plane of ecliptic.

(a) If the Moon is exactly in the plane of ecliptic, a total lunar eclipse will occur.

(b) If the Moon is close to the plane of ecliptic, a partial lunar eclipse will occur.

(c) If the Moon is far above or far below the plane of ecliptic, no eclipse will occur.

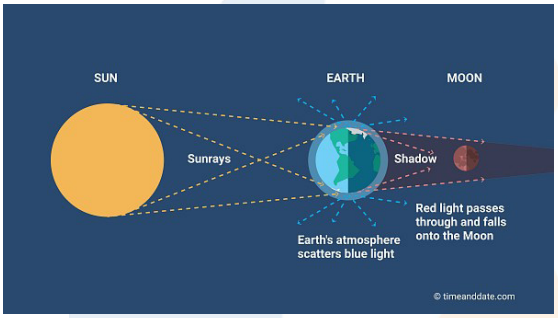
B. Solar Eclipse :

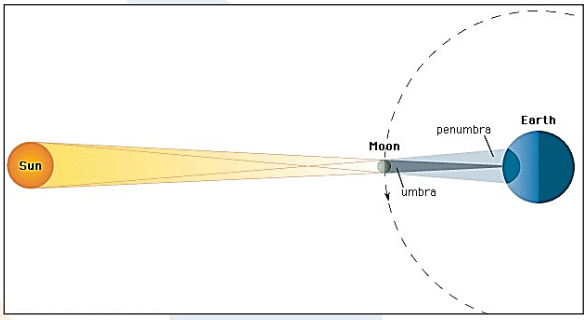
- A solar eclipse will occur only when the Sun, the Earth and the Moon are in a straight line, and the Moon lies between the Sun and the Earth. This is possible on a New Moon day.

(a) If the Moon is exactly in the plane of ecliptic, a total solar eclipse will occur.

(b) If the Moon is close to the plane of ecliptic, a partial solar eclipse will occur.

(c) If the Moon is far above or far below the plane of ecliptic, no eclipse will occur.





- The **Diamond Ring Effect** is a visual phenomenon that occurs during a total solar eclipse. It is seen from earth when standing in the umbra of the moon's shadow, and occurs as a part of Baily's Beads. Baily's Beads are glimmers of the sun's brilliant surface (the photosphere) which shine as dots of light around the disc of the lunar shadow.

Sources of Information :

A. Direct Sources :

(a) The deepest mine of the world is **Robinson Deep in South Africa**. Its depth is less than 4 kilometer

(b) The deepest depth of an oil well drilled so far is 8 kilometers.

(c) **"Deep Ocean Drilling Project"** and **"Integrated Ocean Drilling Project".** The deepest drill at **Kola, in Arctic Ocean**, has so far reached a depth of 12 km.

B. Indirect Sources :

(a) Artificial sources such as temperature, pressure and density.

(b) Evidences from the theories of origin of earth

(c) Natural Sources e.g. volcanic eruption, earthquakes, meteors and seismology.

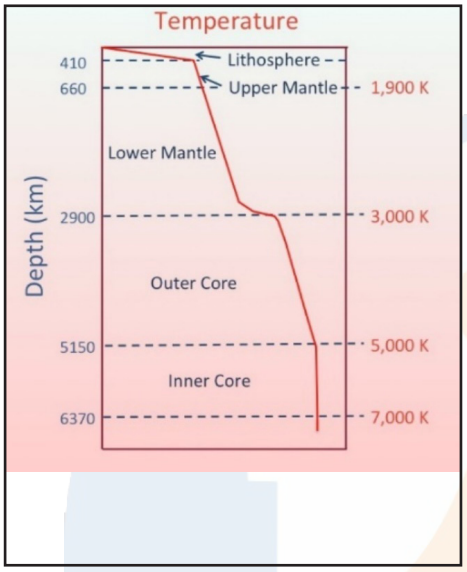
1. Temperature :

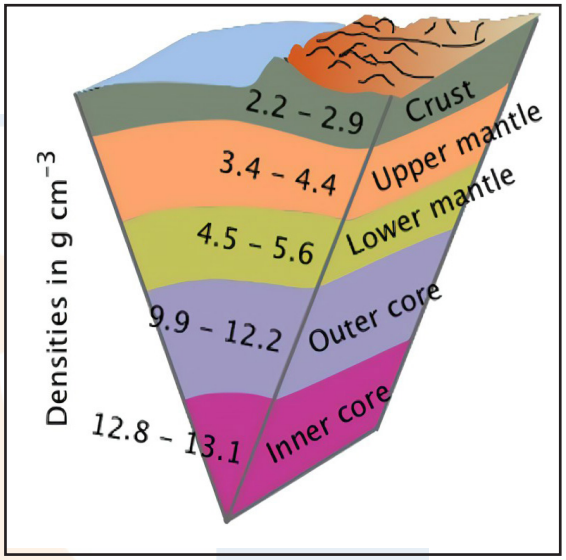
- Temperature goes on increasing with the increase in depth inside the earth.
- On an average, there is a rise of 1°C temperature for every 32 meters of depth.

- This rapid increase in temperature continues to great depth there after the temperature increases slowly.

The main reasons for the increase in heat and temperature in the interior of the earth are the following :

1. Radioactive disintegration within rocks which liberates heat
2. Internal and external forces (gravitational pull, weight of overlying rocks etc.)
3. Chemical reactions





2. **Density :**

- surface of the earth have an average density of 2.7 only (gms per cubic centimeter).
- **density too increases with the increase in depth.** The earth's internal part is composed of very dense rocks; their density must be in the range of 8-10 (gms per cubic centimeter). The density of the central part of the core is still more.
- Higher density could be due to heavy metals like Nichel and Iron at the centre as well as due to pressure of overlying layers

3. **Pressure :**

- Just like temperature and density and pressure too increase with increase in depth inside the earth.
- Some earth scientists believe that due to the weight of the overlying layers the pressure goes on increasing with depth and others think that materials of the interior of the earth are heavier since birth of the earth.

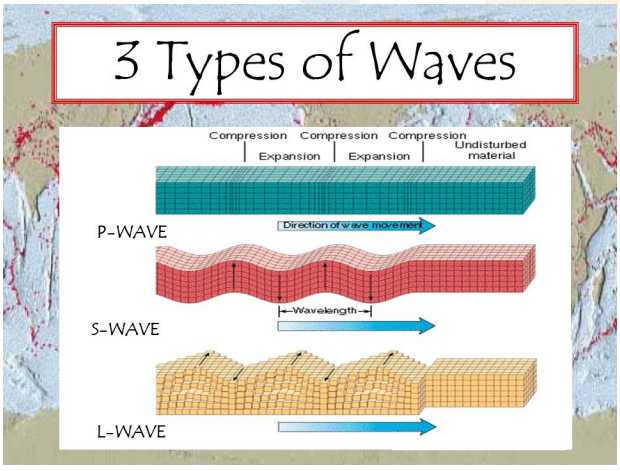
4. **Gravitation force :**

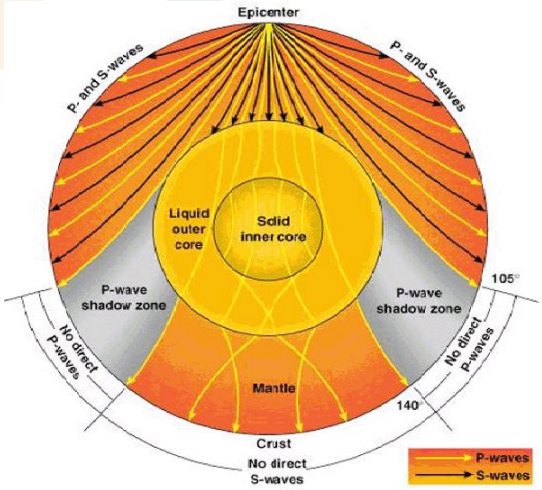
- The gravitation force (g) is not the same at different latitudes on the surface. It is greater near the poles and less at the equator.
- This is because of the distance from the centre at the equator being greater than that at the poles. The gravity values also differ according to the mass of material.
- These readings differ from the expected values. Such a difference is called **gravity anomaly.**

5. Earthquake Waves :

- Earthquake waves are basically of **two types** – body waves and surface waves.
- Body waves are generated due to the release of energy at the focus (origin of earthquake) and move in all directions travelling through the body of the earth.
- The body waves interact with the surface rocks and generate new set of waves **called surface waves**.
- The velocity of waves changes as they travel through materials with different densities. The denser the material, the higher is the velocity.
- **two types of body waves :** P-waves and S-waves
- Surface waves are Rayleigh waves and L-waves

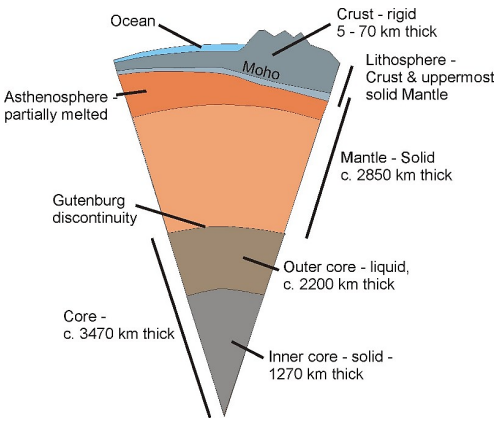
'P'- Waves' or Primary waves	'S'- Waves' or Secondary waves	L-waves
I. These are **Longitudinal** Waves	**I.** These are **transverse** waves.	**I.** These are **transverse** waves.
II. Under their influence particles are displaced in backward forward direction. (compression waves.)	**II.** Under their impact particles swing side by side (shear waves).	**II.** Their propagation is limited to the surface of the earth only.
III. Their velocity is the fastest.	**III.** Their velocity is lower than the primary waves.	**III.** Their velocity through solid particles or rocks is about 3.5 kilometers per second.
IV. Their average velocity is 6-15 kilometers per second.	**IV.** These waves cannot pass through liquids. They travel through solids only.	**IV.** They cause the greatest damage and destruction of property during the earthquake
V. Different densities of rocks have different velocities.		
VI. They can travel through all mediums - solids, liquids and gases.		

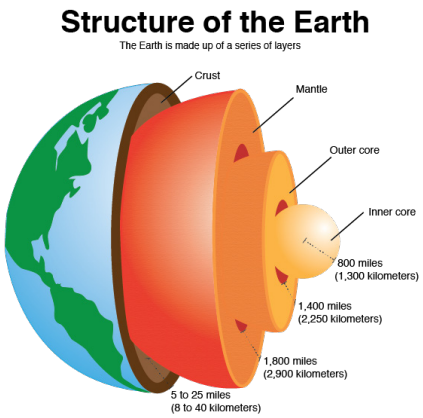




■ Structure of the Earth's Interior :

- Earth's Interior Has Three Main Layers. (i) Crust, (ii) Mantle and (iii) Core





Crust : :

- It is the outermost solid part of the earth, normally about **8-40** kms thick.
- It is brittle in nature.
- Nearly **1%** of the earth's volume and **5%** of earth's mass are made of the crust.
- The thickness of the crust under the oceanic and continental areas are different. **Oceanic crust** is thinner **(about 5kms)** as compared to the **continental crust (about 30kms).**
- **Major constituent elements** of crust are Silica (Si) and Aluminium (Al) and thus, it is often termed as SI**AL** (Sometimes SIAL is used to refer Lithosphere, which is the region comprising the crust and uppermost solid mantle, also).
- The mean density of the materials in the crust is 3g/cm^3.
- The discontinuity between the hydrosphere and crustis termed as the **Conrad Discontinuity.**

Mantle :

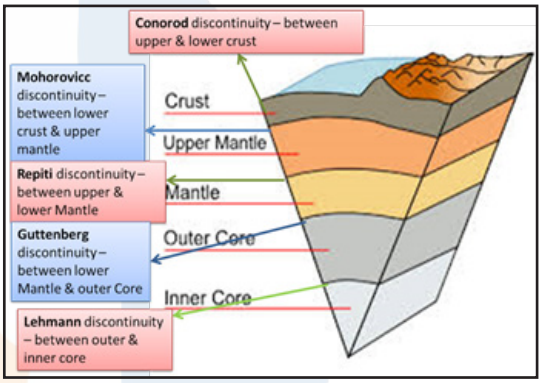
- The portion of the interior beyond the crust is called as the mantle.
- The discontinuity between the crust and mantleis called as the **Mohorovich Discontinuity or Moho discontinuity**.
- The mantle is about 2900kms in thickness.
- Nearly **84%** of the earth's volume and **67%** of the earth's mass is occupied by the mantle.
- The major constituent elements of the mantle are Silicon and Magnesium and hence it is also termed as **SIMA.**
- The density of the layer is higher than the crust and varies from 3.3 - 5.4g/cm^3.
- The uppermost solid part of the mantle and the entire crust constitute the **Lithosphere.**
- The **asthenosphere (in between 80-200km)** is a highly viscous, mechanically weak and ductile, deforming region of the upper mantle which lies just below the lithosphere.
- The asthenosphere is the main source of magma and it is the layer over which the lithospheric plates/ continental plates move (plate tectonics).
- The discontinuity between the upper mantle and the lower mantle is known as **Repetti Discontinuity**.
- The portion of the mantle which is just below the lithosphere and asthenosphere, but above the core is called as **Mesosphere.**

Core :

- It is the innermost layer surrounding the earth's centre.
- The core is separated from the mantle by **Guttenberg's Discontinuity**.
- It is composed mainly of iron (Fe) and nickel (Ni) and hence it is also called as **NIFE**.
- The core constitutes nearly **15%** of earth's volume and **32.5%** of earth's mass.
- The core is the densest layer of the earth with its density ranges between 9.5-14.5g/cm^3.
- The Core consists of **two sub-layers :** the inner core and the outer core.
- The inner core is in solid state and the outer core is in the liquid state (or semi-liquid).
- The discontinuity between the upper core and the lower core is called as **Lehmann Discontinuity.**
- **Barysphere** is sometimes used to refer the core of the earth or sometimes the whole interior.

■ Discontinuities Inside The Earth :

- Materials inside the earth are different from each other by their physical and chemical properties, such as temperature, density etc.
- Inside the earth, layers are arranged according to their characteristics. All those layers are separated from each other through a transition zones, called discontinuities. There are five discontinues inside the earth.



■ Temperature, Pressure and Density of the Earth's Interior :

Temperature :

- A rise in temperature with increase in depth is observed in mines and deep wells.
- These evidence along with molten lava erupted from the earth's interior supports that the temperature increases towards the centre of the earth.
- The different observations show that the rate of increase of temperature is not uniform from the surface towards the earth's centre. It is faster at some places and slower at other places.
- In the beginning, this rate of increase of temperature is at an average rate of 1°C for every 32m increase in depth.
- While in the upper 100kms, the increase in temperature is at the rate of 12°C per km and in the next 300kms, it is 20°C per km. But going further deep, this rate reduces to mere 10°C per km.
- Thus, it is assumed that the rate of increase of temperature beneath the surface is decreasing towards the centre (do not confuse rate of increase of temperature with increase of temperature. Temperature is always increasing from the earth's surface towards the centre).
- The temperature at the centre is estimated to lie somewhere between 3000°C and 5000°C, may be that much higher due to the chemical reactions under high-pressure conditions.
- Even in such a high temperature also, the materials at the centre of the earth are in solid state because of the heavy pressure of the overlying materials.

Pressure :

- Just like the temperature, the pressure is also increasing from the surface towards the centre of the earth.
- It is due to the huge weight of the overlying materials like rocks.
- It is estimated that in the deeper portions, the pressure is tremendously high which will be nearly 3 to 4 million times more than the pressure of the atmosphere at sea level.
- At high temperature, the materials beneath will melt towards the centre part of the earth but due to heavy pressure, these molten materials acquire the properties of a solid and are probably in a plastic state.

Density :

- Due to increase in pressure and presence of heavier materials like Nickel and Iron towards the centre, the density of earth's layers also gets on increasing towards the centre.
- The average density of the layers gets on increasing from crust to core and it is nearly 14.5g/cm3 at the very centre.

Composition Of Interior Of The Earth			
	Earth As Whole		Earths Crust
1.	Iron- highest	1.	Oxygen -Highest
2.	Oxygen	2.	Silicon
3.	Silicon	3.	Aluminium
4.	Magnesium	4.	Iron
5.	Sulphur	5.	Calcium
6.	Nickel	6.	Magnesium
7.	Calcium	7.	Sodium
8.	Aluminium-Lowest	8.	potassium

3 CONTINENTAL DRIFT AND PLATE TECTONICS

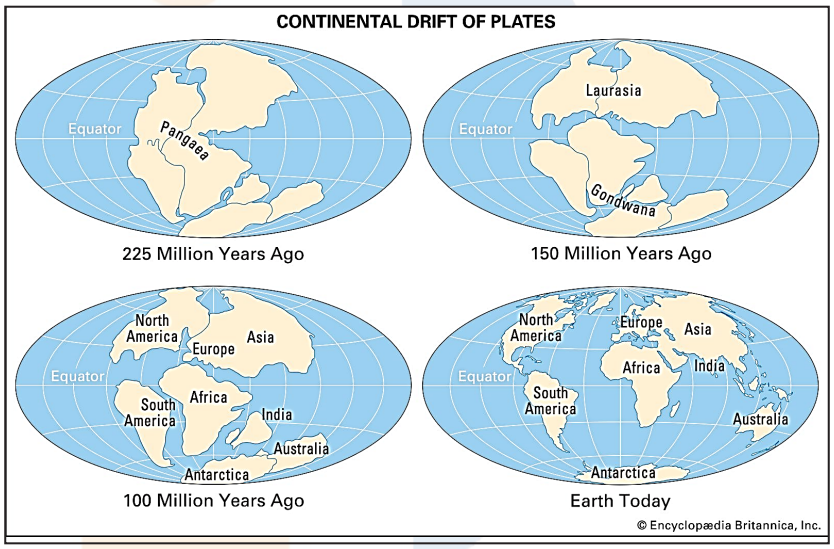
- **Supercontinent-** A supercontinent is the assembly of most or all the Earth's continental blocks to form a single large landmass. A supercontinent cycle is the breakup of one supercontinent and the development of another. Pangaea, last supercontinent.

■ Continental Drift Theory (Alfred Wegner In 1912) :

- All the continents formed a single continental mass (Pangaea), a mega ocean (Panthalassa) surrounded by the same. Around 200 million years ago, the Pangaea began to split. The initial two blocks - Gondwanaland and Laurasia - started drifting away and in between a shallow sea emerged by filling up the water from Panthalasa. It was known as Tethys Sea.

Evidence :

1. **Jig-Saw fit -** The shorelines of Africa and South America facing each other havea remarkable and unmistakable match.
2. **Rock of same age across ocean -** The belt of ancient rocks of 2,000 million years from Brazil coast matches with those from western Africa.



3. **Placer deposit -** The occurrence of rich placer deposits of gold in the Ghana coast and the gold bearing veins are in Brazil.
4. **Tillite -** Tillite indicating extensive and prolonged glaciation.
5. **Distribution of fossils -** The observations that Lemurs occur in India, Madagascar and Africa led some to consider a contiguous landmass "Lemuria" linking these three landmasses.

Forces For Drifting :

1. **The polar-fleeing force** relates to the rotation of the earth. This was, according to Wegener, the cause for movement of continents towards equatorward.
2. **Tidal force –** due to the attraction of the Moon and the Sun was the main reason given by Wegener for the westward movement of the Americas.

Major and Minor Plates :

(a) Antarctic plate - Antarctica and the surrounding ocean

(b) North American plate - North America continent along with Western Atlantic floor separated from the South American plate along the Caribbean islands

(c) South American plate - South America continent along with western Atlantic floor

(d) Pacific plate - covers almost entire pacific ocean

(e) India-Australia-New Zealand plate - Australian continent along with Indian subcontinent and Indian Ocean.

(f) African plate - Africa continent along with eastern Atlantic floor

(g) Eurasian plate - Eurasia along with eastern Atlantic floor

Major Plates :

(a) Cocos plate - Between Central America and Pacific plate

(b) Nazca plate - Between South America and Pacific plate

(c) Arabian plate - Mostly the Saudi Arabian landmass

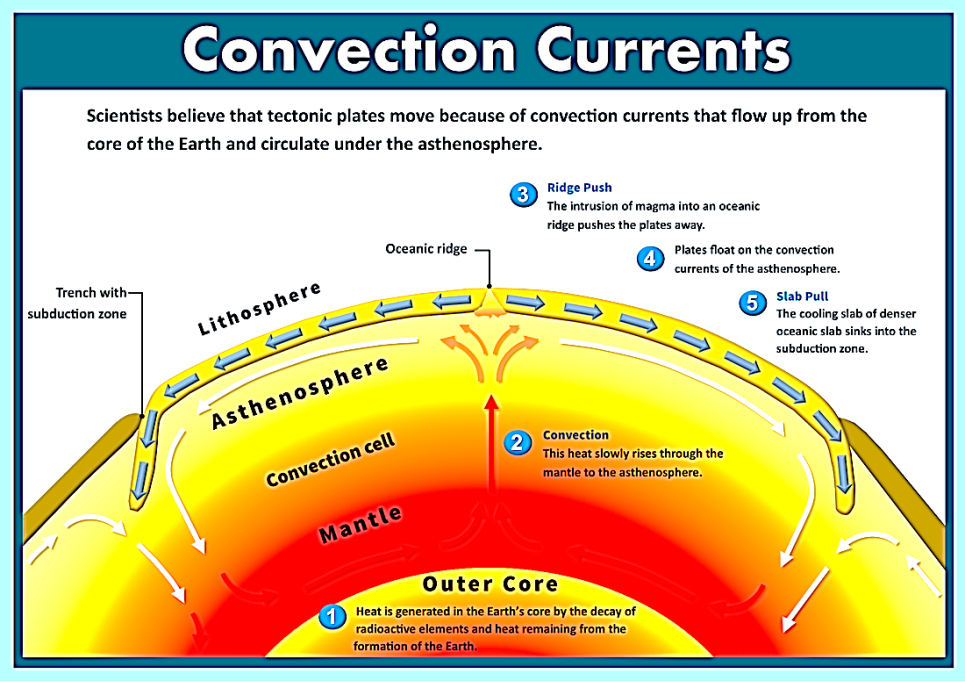
(d) Philippine plate - Between the Asiatic and Pacific plate

(e) Caroline plate - Between the Philippine and Indian plate (North of New Guinea)

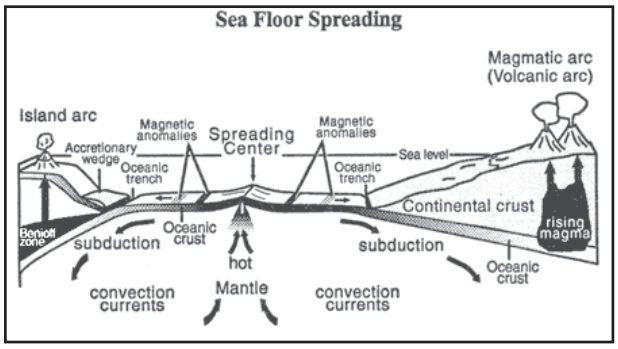
(f) Fuji plate- North-east of Australia.

CONVECTION CURRENT THEORY :

- Arthur Holmes put forward his Lithosphere theory of convection current in 1928-29. Cause of the origin of these currents is the presence of radioactive elements which causes thermal differences in the mantle portion.



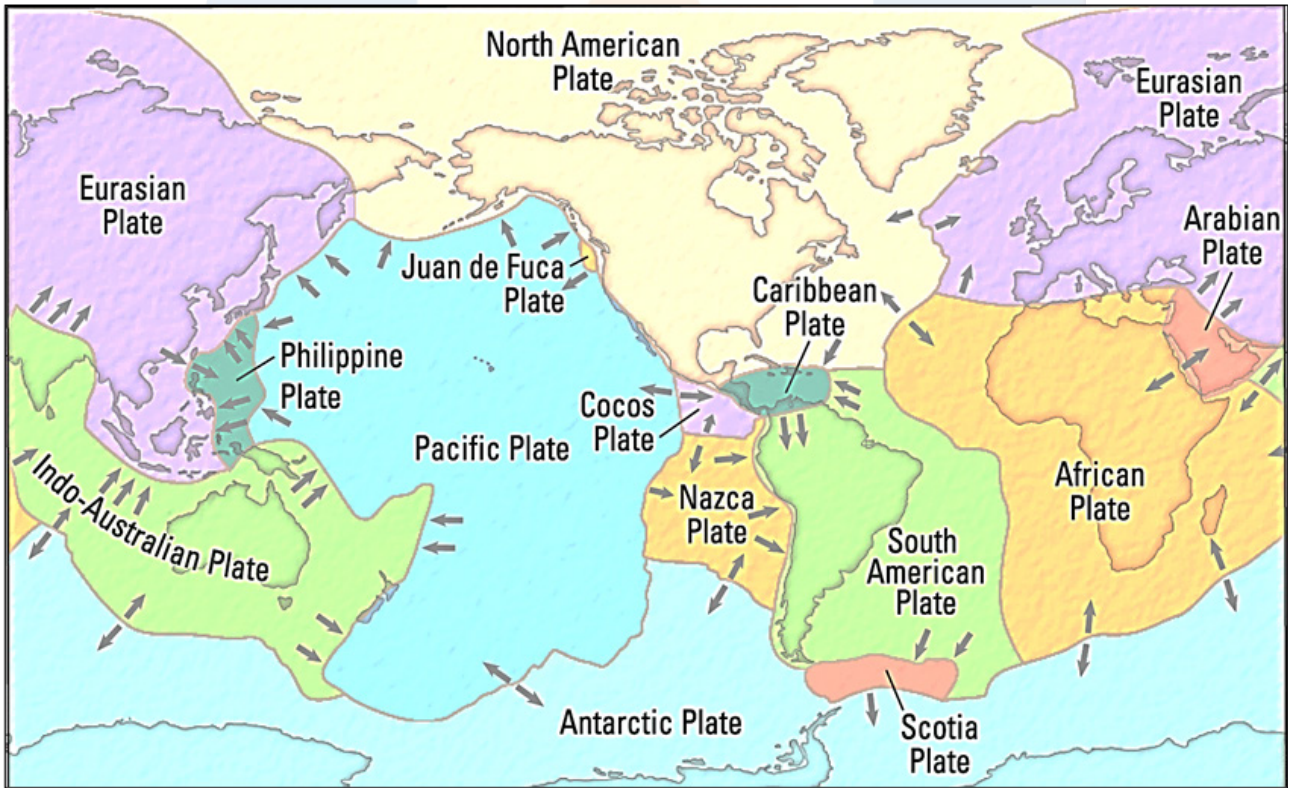
SEA FLOOR SPREADING THEORY :



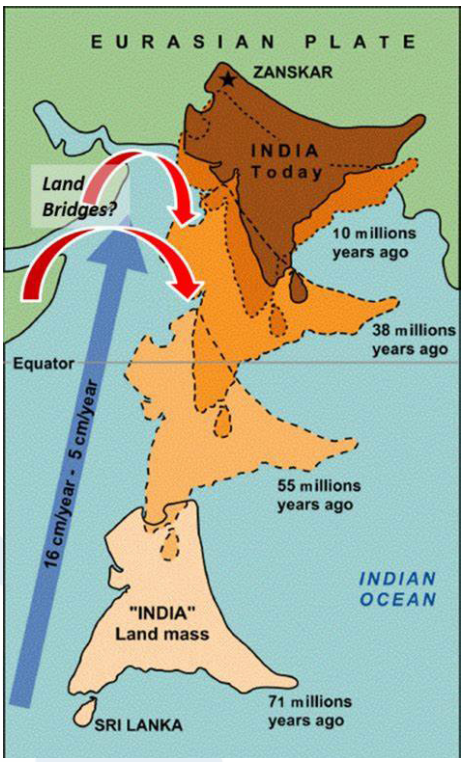
- **Harry Hess** in **1961** The ocean crust rocks are much younger than the continental rocks.
- The sediments on the ocean floor are unexpectedly very thin. Mid-oceanic ridge was not found only in Atlantic Ocean, but ridges were present in all the oceans.
- The rocks equidistant on either sides of the crest of mid-oceanic ridges show remarkable similarities in terms of period of formation, chemical compositions and magnetic properties.

PLATE TECTONICS :

- Term plate was first used by **Tuzo Wilson.**
- Hypothesis of plate tectonics was first outlined by **W.J. Morgan** in **1967**.
- There is spreading of sea floor and new oceanic crust is being continually created at the active mid-oceanic ridges and destroyed at trenches
- The amount of crust consumed almost equals the amount of new crust created



Movement of The Indian Plate :



- The Indian plate includes Peninsular India and the Australian continental portions. India was a large island situated off the Australian coast, in a vast ocean.
- The Tethys sea separated it from the Asian continent. India is believed to have started her northward journey about 200 million years ago. Student Notes : India collided with Asia about 40-50 million years ago causing formation of Himalayas.
- The subduction zone along the Himalayas forms the northern plate boundary in the form of continent–continent convergence.
- Scientists believe that the process is still continuing and the height of the Himalayas is rising even to this date.

Types Of Boundary :

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

1. Divergent Boundaries :

- Where new crust is generated as the plates pull away from each other. 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. At this, the American Plate(s) is/are separated from the Eurasian and African Plates at rate of around 2 cm per year

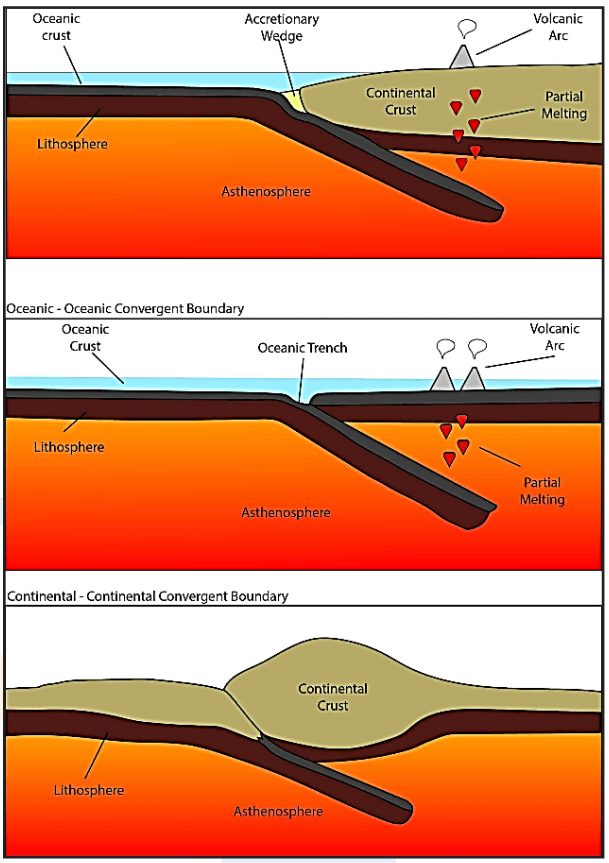
2. Convergent Boundaries :

- Where the crust is destroyed as one plate dived under another at an angle of approximately 450 . The location, where sinking of a plate occurs, is called a subduction zone. There are three ways in which convergence can occur

3. Transform Boundaries "

- Where the crust is neither produced nor destroyed as the plates slide horizontally past each other. Transform faults are the planes of separation generally perpendicular to the mid-oceanic ridges. As the eruptions do not take all along the entire crest at the same time, there is a differential movement of a portion of the plate away from the axis of the earth. Also, the rotation of the earth has its effect on the separated blocks of the plate portions.

Types Of Convergent Boundaries :



1. **Oceanic-Oceanic convergence :**
   - Cooler, denser oceanic lithosphere sinks beneath the warmer, less denseoceanic lithosphere.
   - water reduces the melting point of rocks in the asthenosphere and causes partial melting Formation of volcanic Arcs.
2. **Oceanic-Continent convergence**
   - Dense oceanic lithosphere subducts beneath the less dense continental lithosphere.
   - Volcanic arcs form on continental lithosphere.
   - Accretionary wedge forms on the continental crust
3. **Continent-Continent convergence**
   - Both of them have a density that is much lower than the mantle, which prevents subduction
   - The intense compression can also cause extensive folding and faulting of rocks within the two colliding plates

A. **Exogenic forces –** external forces caused by events occurring outside the earth

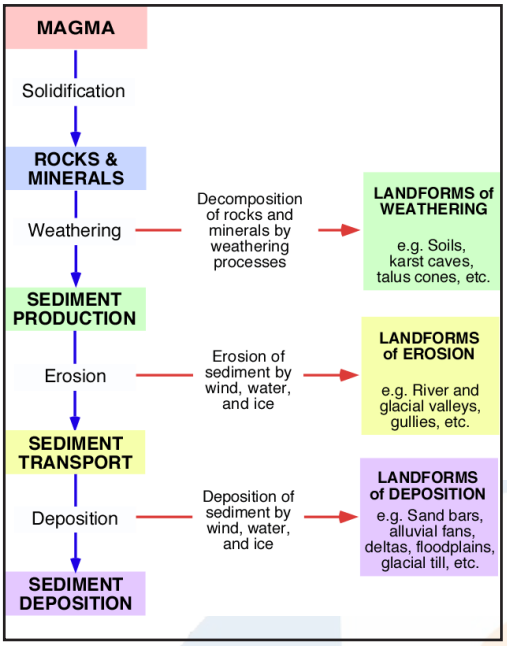
B. **Endogenic forces –** internal forces caused by events occurring inside the earth.

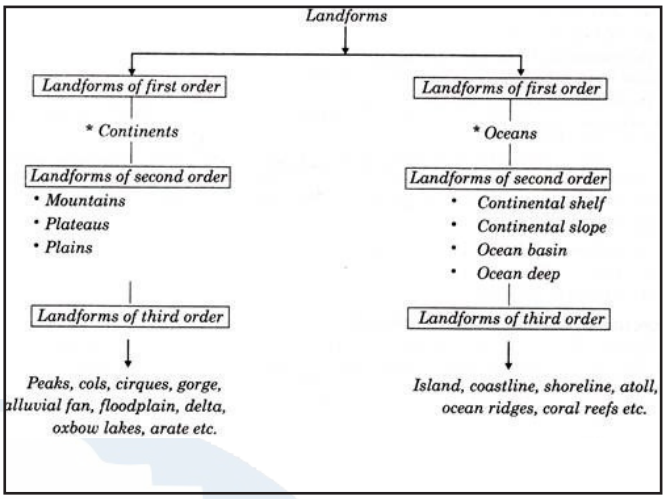
C. **Diastrophic forces -** Diastrophism refers to deformation of the Earth's crust. Diastrophic movements are gradual and might stretch for thousands of years.

D. **Epeirogenic or continent** forming movements are radial movements . They can cause upliftment or subsidence of continents.

E. **Orogenic or the mountain-**forming movements act tangentially to the earth surface. Folds are a result of ductile deformation of rocks in response to external forces. Faulting is a process under which rocks are forcefully broken with accompanying displacement.

F. **Weathering –** mechanical disintegration or chemical decomposition of rocks in situ by different geomorphic agents. Weathering is defined as mechanical disintegration and chemical decomposition of rocks through the actions of various elements of weather and climate.





Chemical Weathering :

- **Hydration -** process by which certain types of mineral expand as they take up water and expand, causing additional stresses in the rock due to increase in the volume of mineral itself.
- Oxidation and reduction - oxidation is the addition of oxygen to form oxides or hydroxides while reduction is the reverse of oxidation.
- **Solution -** few minerals such as rock salt are significant y soluble in water. Such rock-forming minerals are easily leached out without leaving any residue in rainy climates and accumulate in dry regions.
- **Carbonation -** many minerals are soluble in rainwater, which contains carbon dioxide and acts as a weak carbonic acid

Physical Weathering :

- **Expansion by unloading –** pressure release (unloading) mechanism causes disintegration of rock. Process is termed as exfoliation.
- **Thermal expansion of rock –** is the cause of rock cracking and Disintegration
- **Salt weathering –** On drying and crystallization the salts expand and set up a disruptive effect.
- **Frost action and crystal growth –** When water fills the pores, cracks and crevices in rocks and then freezes, it expands and exerts a bursting pressure.

Biological Weathering :

- Burrowing and wedging by organisms.
- Decaying plant and animal matter help in the production of humic, carbonic and other acids.
- Tree roots can occasionally be shown to have forced apart adjacent blocks of rock.
- Exfoliation This has already been explained under physical weathering processes of unloading, thermal contraction and expansion and salt weathering. Exfoliation is a result but not a process. Flaking off of more or less curved sheets of shells from over rocks or bedrock results in smooth and rounded surfaces

MASS MOVEMENT :

- Mass movement or mass wasting is the term used for the movement of material down a slope under the influence of gravity.
- **Factors favouring mass movement are :** (i) weathering; (ii) rock composition; (iii) texture and structure of material; (iv) slope gradient; (v) extent of lubrication

Types Of Mass Movement :

Slow movements –

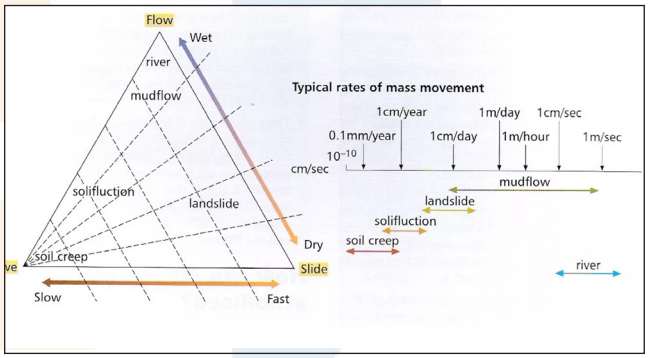
1. **Creep -** slow downhill movement of debris and soil on moderate slope.
2. **Solifluction**- slow downslope flowing soil mass or fine grained rock debris saturated or lubricated with water.

Rapid movement –

1. **Earthflow** - movement of water-saturated clayey or silty earth material down hillsides.
2. **Mudflow –** thick layers of weathered materials get saturated with water and either slowly or rapidly flows down along definite channels. Looks like a stream of mud.
3. **Avalanche –** Can be much faster than Mudflow

Landslides :

- Landslides occur when gravitational and other types of shear stresses within a slope exceed the shear strength (resistance to shearing of the materials that form the slope.

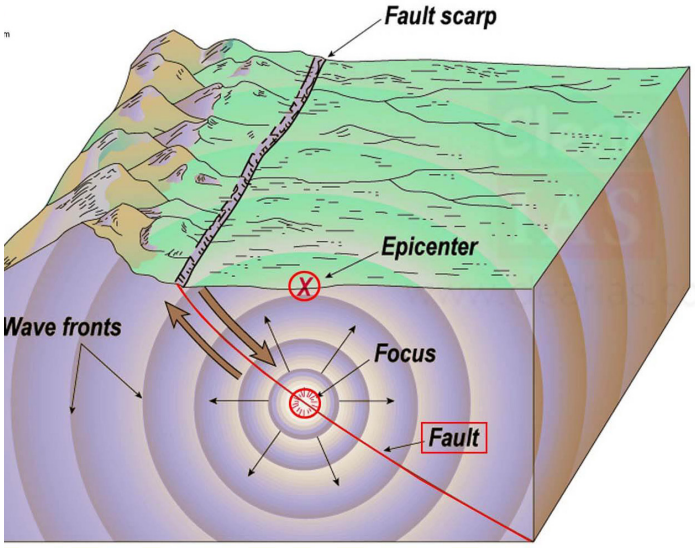


Erosion And Deposition :

- The erosion can be defined as **"application of the kinetic energy associated with the agent to the surface of the land along which it moves"**.
- Erosion is a term referring to those processes of Denudation which wear away the land surface by the mechanical action of the debris which is being acquired and transported by various agents of erosion.
- Deposition is a consequence of erosion. The erosional agents loose their velocity and hence energy on gentler slopes and the materials carried by them start to settle themselves.
- When massive rocks break into smaller fragments through weathering and any other process, erosional geomorphic agents like running water, groundwater, glaciers, wind and waves remove and transport it to other places depending upon the dynamics of each of these agents. Weathering aids erosion but it is not a pre-condition for erosion to take place
- Deposition is a consequence of erosion. The erosional agents loose their velocity and hence energy on gentler slopes and the materials carried by them start to settle themselves. The coarser materials get deposited first and finer ones later. Alluvial fans at the foothills, alluvial plains, delta etc. are few examples of deposition landforms.

4 EARTHQUAKES

- An earthquake in simple words is shaking of the earth. It is caused **due to release of energy,** which generates waves that travel in all directions.
- The release of energy occurs along a fault. A fault is a **sharp break** in the crustal rocks. Rocks along a fault tend to move in opposite directions.
- The point where the energy is released is called the focus of an earthquake, alternatively, it is called the **hypocentre.** The energy waves travelling in different directions reach the surface. The point on the surface, nearest to the focus, is called **epicentre.** It is the first one to experience the waves. It is a point directly above the focus.



Types of Earthquakes :

1) **Tectonic Earthquakes :** These are generated due to sliding of rocks along a fault plane. This movement causes imbalance in the crustal rocks which results in earthquakes of varying magnitude, depending upon the nature of dislocation in the rock strata.

2) **Volcanic Earthquakes :** Volcanic activity is considered to be one of the main causes of earthquakes. In fact, volcanic activity and seismic events are so intimately related to each other that they become cause and effect for each other.

3) **Collapse Earthquakes :** In areas of intense mining activity, sometimes the roofs of underground mines collapse causing minor tremors.

4) **Explosion Earthquakes :** Ground shaking may also occur due to the explosion of chemical or nuclear devices.

5) The earthquakes that occur in the areas of large reservoirs are referred to as reservoir induced earthquakes, anthropogenic

- **Seismic Waves-** waves generated by an earthquake are called the 'seismic waves' or **'earthquake waves'.** These are recorded by an instrument called the **seismograph** or the **seismometer**.

■ Measurement of Earthquakes :

Characteristic	Mercalli Scale	Richter Scale
Measures	The effects caused by earthquake	The energy released by the earthquake
Measuring Tool	Observation	Seismograph
Calculation	Quantified from observation of effect on earth's surface, human, objects and man-made structures	Base-10 logarithmic scale obtained by calculating logarithm of the amplitude of waves.
Scale	I (not felt) to XII (total destruction)	From 2.0 to 10.0+ (never recorded). A 3.0 earthquake is 10 times stronger than a 2.0 earthquake.
Consistency	Varies depending on distance from epicentre.	Varies at different distances from the epicentre, but one value is given for the earthquake as a whole

Classification of Earthquakes :

Category	Magnitude on Richter Scale
Slight	Upto 4.9
Moderate	5.0 to 6.9
Great	7.0 to 7.9
Very Great	8.0 and more

Distribution of Earthquakes :

Most earthquakes in the world are associated with the following :

- the zones of young fold mountains, the zones of faulting and fracturing, the zones representing the junctions of continental and oceanic margins, the zones of active volcanoes, and along the different plate boundaries.

1. **Circum-Pacific Belt :**

- The Belt includes the coastal margins of North America, South America and East Asia. These are as represent the eastern and western margins of the Pacific Ocean respectively, and account for about 65 per cent of the total earthquakes of the world. The western marginal zones are represented by the Rockies and the Andes mountain chains. The eastern marginal zones are represented by the island arcs of Kamchatka, Sakhalin, Japan and Philippines.

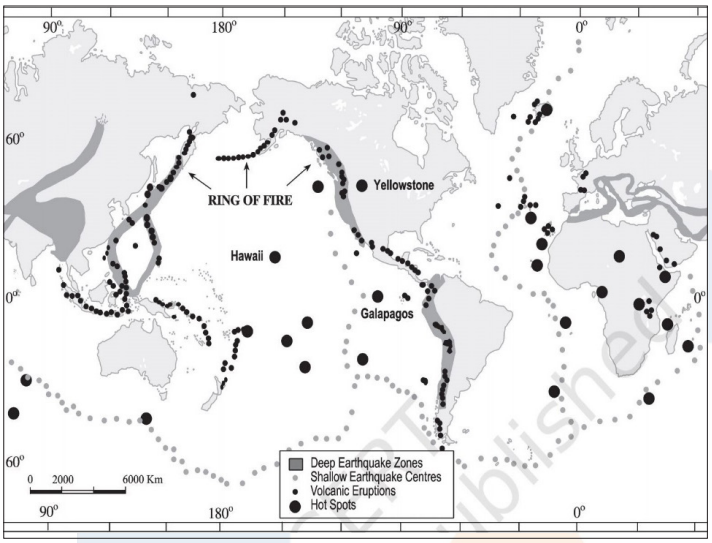
2. **Mid-Continental Belt :**

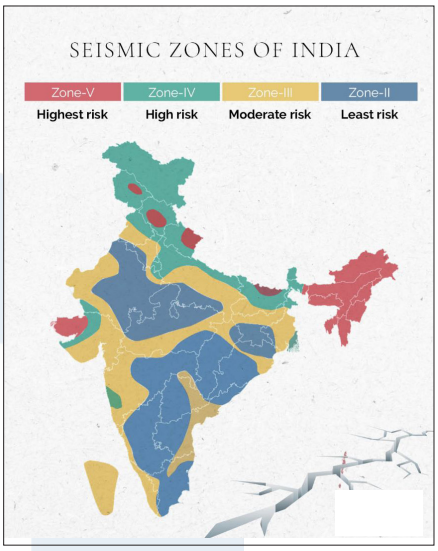
- The Mid-Continental Belt includes the Alpine mountains and their off shoots in Europe, Mediterranean Sea, northern Africa, eastern Africa and the Himalayas. The Mid-Continental Belt extends through Sulaiman

and Kirthar zones in the west, the Himalayas in the north and Myanmar in the east. This belt represents the weaker zone of Fold Mountains. About 21 per cent of the total seismic events are recorded in this belt

3. **Mid-Atlantic Ridge Belt :**

- The Mid-Atlantic Ridge Belt includes the Mid-Atlantic ridge and several islands near the ridge. It records moderate earthquakes which are caused due to the moving of plates in the opposite directions. Thus the seafloor spreading and the fissure type of volcanic eruptions cause earthquakes of moderate intensity in this region.





■ Seismic Zones of India :

- Earthquakes pose a real threat to India with 59% of its geographical area vulnerable to seismic disturbance of varying intensities including the capital city of the country.

Zone	Damage risk	Region
Zone V	Very high damage risk zone	The entire North-east, including the seven sister states, the Kutch district, parts of Himachal and Jammu & Kashmir, and the Andaman and Nicobar islands.
Zone IV	High damage risk zone	Parts of the Northern belt starting from Jammu and Kashmir to Himachal Pradesh. Also including Delhi and parts of Haryana. The Koyna region of Maharashtra is also in this zone.
Zone III	Moderate damage risk zone	A large part of the country stretching from the North including some parts of Rajasthan to the South through the Konkan coast, and also the Eastern parts of the country.
Zone II	Low damage risk zone	These two zones are contiguous, covering parts of Karnataka, Andhra Pradesh, Orissa, Madhya Pradesh, and Rajasthan, known as low risk earthquake zones.

EFFECTS OF EARTHQUAKES :

On ground	On manmade structures	On water
Fissures Settlements	Cracking, Slidings	Waves, Hydro-Dynamic Pressure
Landslides, Liquefaction	Overturning, Buckling, Collapse	Tsunami
Earth Pressure and Possible Chain-effects	Possible Chain-effects	Possible Chain-effects

Earthquake swarm :

- is a sequence of mostly small earthquakes with no identifiable mainshock. Swarms are usually short-lived, but they can continue for days, weeks, or sometimes even months. They often recur at the same locations. Swarms are observed in volcanic environments, hydrothermal systems, and other active geothermal areas.

Reasons for Earthquake proneness in india

1. The major reason for the high frequency and intensity of the earthquakes is that the Indian plate is driving into Eurasia at a rate of approximately 47 mm/year.
2. Himalayan belt : Collision between Indo-Austral plate with Eurasian plate and Burma Plate with Java Sumatra plate. This collision causes lots of strain in underlying rocks' energy of which is released in the form of earthquakes.
3. Andaman and Nicobar Islands : Seafloor displacement and underwater volcanoes which disturb the equilibrium of earth's surface.
4. Deccan Plateau : some earth scientists have come up with a theory of the emergence of a fault line and energy build-up along the fault line of the river Bhima (Krishna) near Latur and Osmanabad (Maharashtra).
5. Increasing population and unscientific land use for construction make India a high-risk land for earthquakes.

TSUNAMI :

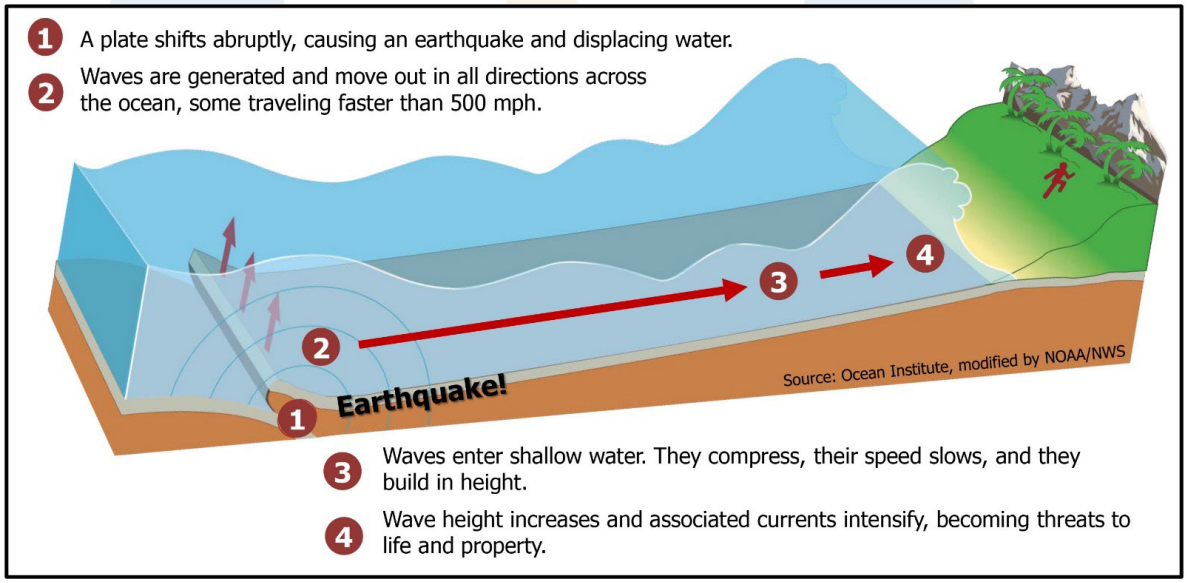
- Tsunami is a Japanese word which means **'harbour wave'.** It is a series of traveling ocean waves of extremely long length generated by disturbances associated primarily with earthquakes occurring below or near the ocean floor.
- Underwater volcanic eruptions and landslides can also generate tsunamis. Tsunamis are a threat to life and property to anyone living near the ocean
- Large tsunamis have been known to rise over **100 feet**, while tsunamis 10 to 20 feet high can be very destructive and cause many deaths and injuries.

Causes :

1. Tsunamis generally are caused by earthquakes.
2. Not all earthquakes generate tsunamis. To generate tsunamis, earthquakes must occur underneath or near the ocean, be large and create movements in the sea floor
3. All oceanic regions of the world can experience tsunamis, but in the Pacific Ocean there is a much more frequent occurrence of large, destructive tsunamis because of the many large earthquakes along the margins of the Pacific Ocean.

Early Warning and Mitigation :

1. **Pacific Tsunami Warning Center (PTWC) :** The Tsunami Warning System (TWS) in the Pacific, comprised of 26 participating international Member States, has the functions of monitoring seismological and tidal stations throughout the Pacific Basin to evaluate potentially tsunami genic earthquakes and disseminating tsunami warning information. The Pacific Tsunami Warning Center is the operational center of the Pacific TWS. Located near Honolulu, Hawaii, PTWC provides tsunami warning information to national authorities in the Pacific Basin.
2. **The Alaska Tsunami Warning Center (ATWC) :** in Palmer, Alaska, serves as the regional Tsunami Warning Center for Alaska, British Columbia, Washington, Oregon, and California.
3. **Indian Tsunami Early Warning System (ITEWS) :** The Indian Tsunami Early Warning System has the responsibility to provide tsunami advisories to Indian Mainland and the Island regions. Acting as one of the Regional Tsunami Advisory service Providers (RTSPs) for the Indian Ocean Region, ITEWS also provide tsunami advisories to the Indian Ocean Rim countries along with Australia and Indonesia.
   - In order to confirm whether the earthquake has actually triggered a tsunami, it is essential to measure the change in water level as near to the fault zone with high accuracy. There are two basic types of sea level gages : coastal tide gages and open ocean buoys.



■ Difference between 'tsunami' and 'tidal wave' :

1. Tsunamis are usually referred to as 'tidal waves' but they are not so. There are a lot of differences between a tsunami and a tidal wave based on various factors :
2. A tidal wave is the caused due to the gravitational forces of the sun and the moon whereas tsunamis are caused due to underlying causes like earthquakes, erupting submarine volcanoes or any gas bubble erupting in the sea or ocean.
3. Tidal waves are noticed mostly in coastal areas. On the contrary, tsunamis can take place in any large body of water if the underlying causes are present there.

4. Tidal waves take place at regular intervals whereas a tsunami has no specific time and can occur at any time if there are favourable conditions (seismic activity) for its occurrence. However, tsunamis are rare.
5. Tidal waves usually do not cause much damage if they are not very high and even if they are high, they can affect only coastal areas whereas a tsunami can travel a long distance and cause extensive damage.

VOLCANOES :

- The word volcano is derived from the name of **'Vulcano',** a volcanic island in the **Aeolian Islands of Italy whose** name in turn originates from 'Vulcan', **the name of a god of fire in Roman mythology.**
- Volcano is a vent or an opening through which heated materials consisting of water, gases, liquid lava and rock fragments are erupted from the highly heated interior to the surface of the Earth.
- The layer below the solid crust of earth is mantle. It has higher density than that of the crust. The mantle contains a weaker zone called asthenosphere.
- It is from this that the molten rock materials find their way to the surface. The material in the upper mantle portion is called magma. Once it starts moving towards the crust or it reaches the surface, it is referred to as lava.
- **'Volcanology' or 'vulcanology'** is the term given to the study of volcanoes, and the scientists who study them are called the 'volcanologists' or 'vulcanologists'.
- processes in which molten rock material or magma rises to the crust to solidify as crystalline or semi-crystalline rocks Vulcanicity has two components;
  - A. **endogenetic mechanism** includes the creation of hot and liquid magma and gases in the mantle and the crust, their expansion and upward ascent,
  - B. **exogenous mechanism** includes the process of the appearance of lava, volcanic dust and ashes, fragmental materials, mud, smoke, etc., in different forms on the earth's surface.

Causes of Vulcanism :

The mechanism of vulcanism and the volcanic activity are associated with several processes, such as :

1. A gradual increase of temperature with increasing depth at the rate of 1 degree Celsius for every 32 m.
2. Magma is formed due to the lowering of melting point, which in turn is caused by the reduction in pressure of the overlying material.
3. Gases and vapour are formed due to heating of water, which reaches underground through percolation.
4. The ascent of magma forced by vast volume of gases and water vapour.
5. The occurrence of volcanic eruption.

TYPES OF LAVA

Basic Lava	Acidic Lava
▲ Hottest & highly fluid	▲ Highly viscous & high melting paint
▲ Rich Iron, magnesium	▲ Rich in silica
▲ Poor in silica	▲ Forms steep sided volcanic domes
▲ Flow quietly, are not explosive	▲ Throws out volcanic bombs and pyroclasts with loud noise
▲ Forms flattened volcanoes	

ON THE BASIS OF MODE OF ERUPTION:	
Violent/Explosive Type	**Effusive / fissure type**
✆ Eruption is rapid	✆ Slow eruptions
✆ Destructive volcanoes	✆ Occurs along fracture, fault or fissure.
✆ Associated with acidic lavas.	✆ Associated with basic lava

Components of a Volcano :

- The volcanoes of explosive type have a **volcanic cone,** which is formed when the erupted material accumulates around the vent. The vent is an opening of circular or nearly circular shape at the centre of the cone. The vent is connected to the interior of the earth by a **narrow pipe**. The volcanic materials erupt through this **pipe.** A funnel-shaped hollow at the top of the cone is called the **crater.**

Types of lavas :

1. Basic Lavas :

- These are the hottest lavas and are highly fluid.
- They are dark coloured like basalt, rich in iron and magnesium but poor in silica.
- They flow quietly and are not very explosive. They affect extensive areas, spreading out as thin sheets over great distances before they solidify.
- The resultant volcano is gently sloping with a wide diameter and forms a flattened shield or dome.

2. Acid Lavas :

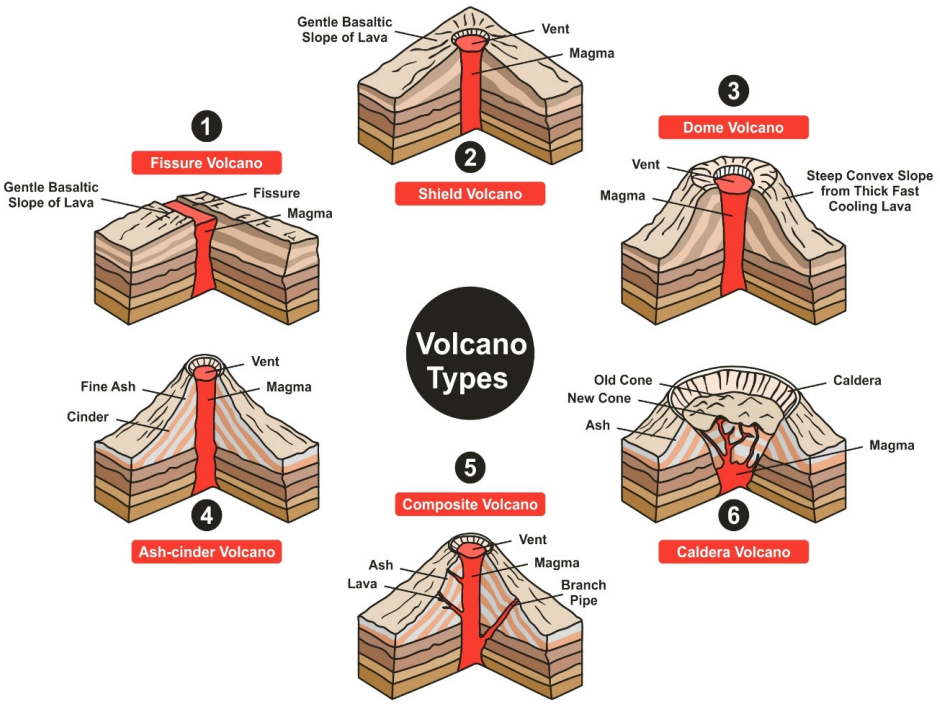
- These lavas are highly viscous with a high melting point.
- They are light coloured, of low density and have a high percentage of silica.
- They flow slowly and seldom travel far before solidifying.
- The resultant volcano is therefore steep-sided.
- The rapid cooling of lava in the vent obstructs the flow of the outpouring lava, resulting in loud explosions throwing out many volcanic bombs or pyroclasts.

Types of volcanoes :

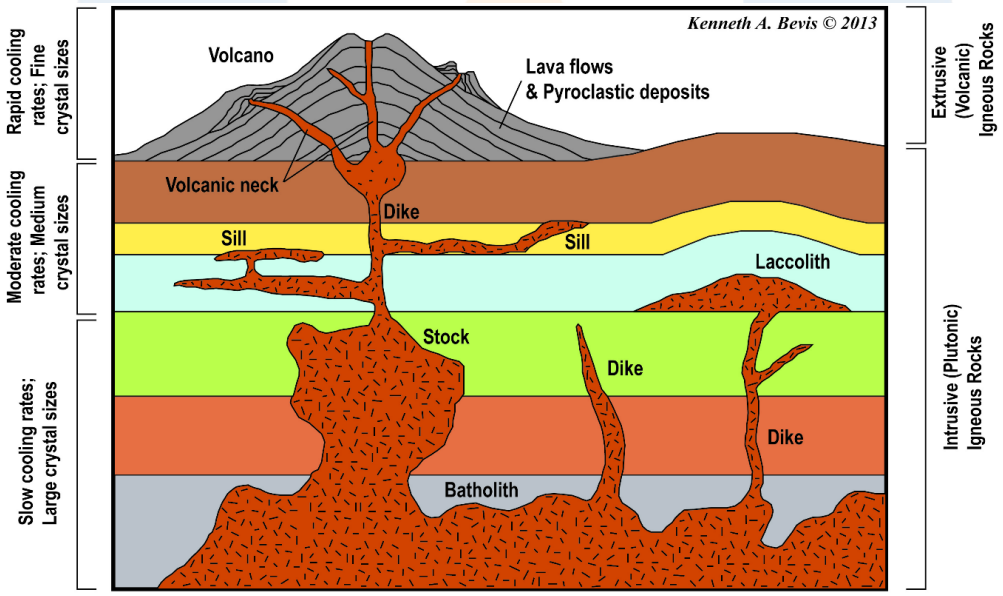
1. **Violent or Explosive type :** The eruption of violent or explosive type is so rapid that huge quantities of volcanic materials are ejected thousands of metres in the sky. On falling, these materials accumulate around the volcanic vent and form volcanic cones. Such volcanoes are very destructive. They are generally associated with acidic lavas.
2. **Effusive or Fissure type :** The eruption of the fissure type of volcanoes-occurs along a long fracture, fault or fissure. Magma ejects slowly and the resultant lava spreads on the surface.
3. **Active Volcanoes :** Volcanoes are said to be active when they frequently erupt or at least when they have erupted within recent time. Etna and Stromboli are typical examples.
4. **Dormant Volcanoes** : Volcanoes that have been known to erupt and show signs of possible eruption in future are described as dormant. Mt. Vesuvius is the best example.
5. **Extinct Volcanoes :** Volcanoes that have not erupted at all in historic times but retain the features of volcanoes are termed extinct. Ship rock in Netherlands is one such example.

Extrusive Landforms

- Extrusive landforms are determined by the nature and composition of the lava.
- **Cinder or ash cones -** are formed due to the accumulation of loose particles around the vent. Its size increases due to the continuous accumulation of volcanic material minus lava. The larger particles are arranged near the crater and the finer particles are deposited at the outer margins of the cone
- **Composite cones -** are the highest and are formed by the accumulation of various layers of volcanic material. They have alternate layers of lava and fragmented material, wherein lava acts as the cementing material. These are mainly associated with cooler and more viscous lava
- **Shield Volcanoes** - are built almost entirely of fluid lava flows. They are named for their large size and low profile, resembling a warrior's shield lying on the ground. Barring the basalt flows, the shield volcanoes are the largest of all the volcanoes on the earth.
- **Craters Flood -** are depressions formed at the mouth of the volcanic vent, which is usually funnel shaped. Some volcanoes may have greatly enlarged depressions called calderas. These are the result of violent eruptions accompanied by the subsidence of much of the volcano into the magma beneath.
- **Basalt Provinces-** are formed when volcanoes outpour highly fluid lava that flows for long distances. Some parts of the world are covered by thousands of sq. km of thick basalt lava flows. There can be a series of flows with some flows attaining thickness of more than 50 m.



Intrusive Landforms :



1. **Batholiths** are long, irregular, undulating and dome-shaped features. They are a large body of magmatic material that cools in the deeper depth of the crust and develops in the form of large domes.
2. **Laccoliths** are formed due to the intrusion of magma along the bedding planes of horizontal sedimentary rocks. They are usually mushroom or dome shaped.
3. **Phacoliths** are formed due to the intrusion of acidic magma along the anticlines and Student Notes : synclines in the region of fold mountains.
4. **Lapoliths** are formed when magma solidifies in shallow basins into a saucer shape.

5. **Sills and Sheets** are intrusive igneous rocks usually parallel to the bedding planes of sedimentary rocks. Depending on the thickness of deposits, thinner ones are called sheets while thick horizontal deposits are called sills

6. **Dykes** are wall-like formation of solidified magma. These are vertical to the bed of sedimentary rocks. The thickness ranges from a few centimetres to several hundred metres, but the length can be several kilometres.

Effects of volcanic eruptions :

- Large volumes of hot lava moving at a fast speed can bury man-made buildings, kill people and animals, destroy agricultural farms and pastures, burn and destroy forests.
- The fall out of large quantities of fragmented materials, dust, ash, smoke, etc., creates health hazards due to poisonous gases emitted during eruption. It also causes acid rain.
- If the explosive eruption has occurred suddenly, the human beings get no time to escape to safer places. Heavy rains mixed with volcanic dust and ash cause enormous mud-flow on the steep slopes of the cones.
- Earthquakes caused due to explosive eruptions can generate destructive tsunamis, seismic waves, etc. These can cause loss of life and property in the affected coastal regions.
- The volcanic eruptions can change the heat balance of the Earth and the atmosphere, causing climatic changes.

Geysers :

1. Geysers are fountains of hot water and superheated steam that may spout up to a height of 150 feet from the earth beneath.
2. The phenomena are associated with a thermal or volcanic region in which the water below is being heated beyond boiling point.
3. The jet of water is usually emitted with an explosion, and is often triggered by gases seeping out of the heated rocks.
4. Almost all the world's geysers are confined to three major areas : Iceland, New Zealand and Yellowstone park of U.S.A.

Hot Springs :

1. Hot springs or thermal springs are more common, and may be found in any part of the earth where water sinks deep enough beneath the surface to be heated by the interior forces.
2. The water rises to the surface without any explosion. Such springs contain dissolved minerals which have medical value.
3. Iceland has thousands of hot springs. Hot springs are common in many parts of India, especially in the hilly and mountainous parts.

4. Some of them are in Manikaran (Kulu), Tattapani (Shimla), Jwalamukhi (Kangra), Rajgir (Patna), Sitakund (Munger) and in Yamunotri and Gangotri.

Fumaroles :

1. A fumarole is a vent in the Earth's surface which emits gases and water vapour.
2. Sometimes the emission is continuous, but in majority of cases emission occurs after intervals.
3. It is widely believed that gases and water vapour are generated due to cooling and contraction of magma after the eruption.
4. Fumaroles are the last signs of the activeness of a volcano.

5 MOUNTAIN BUILDING, ISLAND FORMATIONS AND HOTSPOTS

- A landform is a feature on the Earth's surface that is part of the terrain.
- Mountains, hills, plateaus, and plains are the four major types of landforms. Minor landforms include buttes, canyons, valleys, and basins.
- Tectonic plate movement under the Earth can create landforms by pushing up mountains and hills. Erosion by water and wind can wear down land and create landforms like valleys and canyons. Both processes happen over a long period of time, sometimes millions of years.

Based on the order of relief development landforms can be classified into :

- **Landforms of First Order** : By the actions of internal forces anticlines and synclines were formed and in course of time these have been identified as continents and oceans. That is why, they are called as Landforms of First Order or Primary landforms. The continental landforms consist of Americas, Eurasia, Africa, Australia and Antarctica. The total area is nearly 148 million sq km, i.e., 28 per cent of the earth's surface and average height is 830 metres.
- **second order -** plateaus, mountains, plains and extensive deserts of the continents are the example of the landforms of second order on the continents.
- **Third Order-** Various features which are generally smaller parts of second order landforms or which form on the second order landforms are known as landforms of third order. Peaks, cols, cirques, gorge, morains, alluvial fans, floodplains, ox-bow lakes, levees, deltas, ocean islands, volcanoes and ridges are some of the many features of third order landforms.Since the dawn of geological time, no less than nine orogenic or mountain building movements have taken place, folding and fracturing the earth's crust.

Mountain Types :

On the basis of formation

1. **Circum-erosional or Relict Mountains :** Mountains of denudation. Examples, Vindhyachal ranges, Aravallis, Satpura, Eastern Ghats, Western Ghats etc.

2. **Tectonic Mountains :**

- Fold Mountains
- **Young Fold :** Himalayas, Rockies
- **Old Fold :** Appalachian, Urals
- Block/Horst Mountains Form Rift Valleys. Sierra Nevada, Satpura, Vindhyas
- Volcanic Mountains or Mountains of accumulation Vesuvius, Kilimanjaro, Fuji
- Dome Mountains Magmatic intrusion and Upwarping. Example : Batholithic domes, Salt domes

3. On the basis of Time Period

1. **Pre-Cambrian :** 4.6 billion years ago. E.g. Laurentian Mountain
2. **Caledonian :** 320 million year ago Mountains of Scotland, Satpura, Aravallis, MahadeoHills
3. **Hercynian :** 240 million year ago Urals, Pennines, Appalachians
4. **Alpine :** 30mya. Young fold mountains such as Alps, Himalayas, Andes, Rockies.

Fold Mountains :

- When such stresses are initiated, the rocks are subjected to compressive forces that produce wrinkling or folding along the lines of weakness. The upfolded waves are called anticlines and the troughs or downfolds are called **synclines.**
- Fold mountains are formed when sedimentary rock strata in **geosynclines** are subjected to compressive forces.
- They are the **loftiest** mountains, and they are generally concentrated along continental margins.
- Fold mountains belong to the group of **youngest mountains of the earth.**
- The presence of fossils suggests that the **sedimentary rocks** of these folded mountains were formed after accumulation and consolidation of silts and sediments in a marine environment.
- Fold mountains extend for great lengths whereas their width is considerably small.
- Generally, fold mountains have a concave slope on one side and a convex slope on the other.
- Fold mountains are mostly found along continental margins facing oceans (C-O Convergence).
- Fold mountains are characterized by **granite intrusions** (formed when magma crystallises and solidifies underground to form intrusions) on a massive scale.
- **Recurrent seismicity** is a common feature in folded mountain belts.
- High heat flow often finds expression in volcanic activity (Himalayas is an exception, because of C-C convergence).
- These mountains are by far the most widespread and also the most important.
- They also contain rich mineral resources such as **tin, copper, gold** etc.

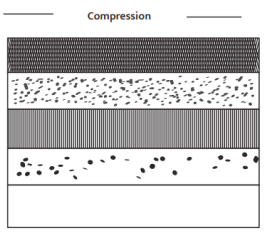


Fig.1 Earth's crush before folding

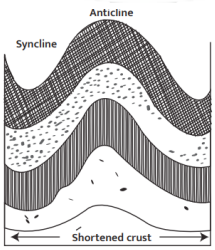


Fig.2 Earth's crush aftore folding

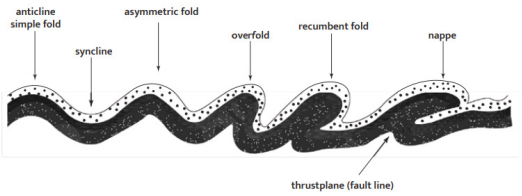


Fig.3 Type of Folding

Block Mountains :

1. Tension or compression leads to Faulting
2. When crust on both sides subside, the upstanding block becomes Horst or Block mountain. Example : Black Forest

3. When central portion between two adjacent fault blocks subside, it forms Graben or Rift Valley. Example : East African Rift Valley

4. Most block mountains are formed due to tension rather than compression.

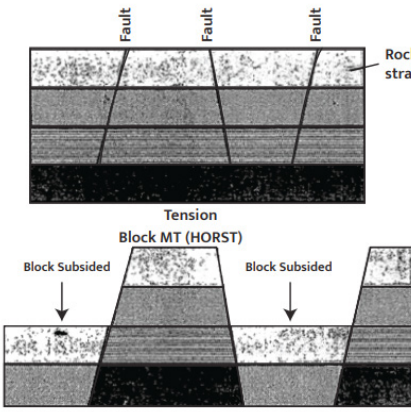


Fig. 4 Block mountains formed by tensional forces

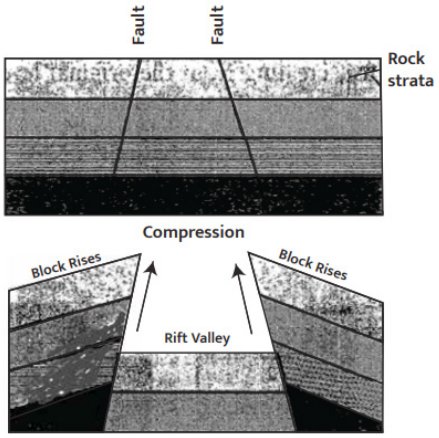


Fig. 5 Rift valleyformed by compressive forces

■ Types Of Island :

- **Continental Island-**Connected with main land through Strait, Channel or shallow Lagoon

1. **Individual Islands :** New Foundland, Madagascar
2. **Archipelagoes :** Island groups with varying shapes and sizes. British Isles
3. **Festoon or Island Arcs :** Forms loop around mainland. One tectonic plate subducts other one. Andaman & Nicobar Islands, East Indies

Oceanic Islands- No connection with the mainland, small and are located in the midst of oceans.

1. **Volcanic Islands** Topmost parts of the cones of extinct (mostly) volcanoes. **Example :** Mauna Loa, Galapagos, Mauritius, Reunion Island
2. **Coral Islands- Example :** Marshall Islands, Bermuda, Lakshadweep, Maldives.

■ Artificial Island :

- is a man-made island, created by expanding existing islets, building on existing reefs or making them from scratch, off the coastline. Man has been building such islands for hundreds of years. **The Flevopolder** in the Netherlands is the **largest artificial island** in the world.
- **The Palm Islands** are two artificial islands in Dubai, United Arab Emirates in the shape of palm trees. The islands are the Palm Jumeirah and the Palm Jebel Ali.

■ Isostasy :

- Isostasy is a fundamental concept in the Geology.
- It is the idea that the lighter crust must be floating on the denser underlying mantle.
- It is invoked to explain how different topographic heights can exists on the Earth's surface.
- Isostatic equilibrium is an ideal state where the crust and mantle would settle into in absence of disturbing forces.

- The waxing and waning of ice sheets, erosion, sedimentation, and extrusive volcanism are examples of processes that perturb isostasy.
- The physical properties of the lithosphere (the rocky shell that forms Earth's exterior) are affected by the way the mantle and crust respond to these perturbations.

Hotspots :

- It is a very hot region deep within the Earth, usually responsible for volcanic activity.
- They may be unanimously hot, and provide a great deal of molten magma. Hot spots do not always create volcanoes that spew rivers of lava.
- Sometimes magma heats up groundwater creating Geysers.
- 40 to 50 hot spots around the world, including near the Galapagos Islands and Iceland.
- Hot spots can create entire chains of islands, like the U.S. state of Hawaii. Hawaii is on the Pacific plate, an enormous section of the Earth in the Pacific Ocean that is constantly moving, but very, very slowly. Although the plate is always moving, the hot spot underneath it stays still.
- They can create entire chains of islands **e.g.** Hawaii. They are used to track movement of earth's plates.

6 ROCKS AND MINERALS

Minerals :

- Minerals are those substances which occur **naturally in rocks.** These are non-living solid substances which have a **definite chemical composition**.
- Minerals are often classified as **metallic and non metallic.** The surface of the metallic minerals is generally slippe and glossy. Gold, copper and lead are metallic minerals. They are melted to obtain metals. The surface of the non metallic minerals is dull. They cannot reflect the sun-rays. Gypsum, quartz and mica are non-metallic minerals. Metals cannot be obtained from these minerals.
- Rocks and minerals account for about **99 percent** of the materials found in the outer layer of the lithosphere. Some rocks have useful minerals, which provide us with metals and chemicals.
- Out of about **2000** different minerals, only **12 are known** as the rock-forming minerals. Oxygen and silicon account for about **75 percent** of the Earth's crust by weight. These elements are essential for plant and animal life on the Earth.

Some Major Minerals and Their Characteristics

Minerals	Composition	Importance	Other facts
Feldspar	Common fieldspar silicon and oxygen. Specific fieldspar sodium, potassium, calcium, aluminium .	Used in ceramics and glass making	Half of the earth's crust is composed of feldspar
Quartz	Consists of silica.	Prominent components of Sand and Granite and used in Radio and Radar	Hard mineral virtually insoluble in water
Pyroxene	Pyroxene consists of calcium, aluminum, magnesium, iron and silica.	commonly found in meteorites	Pyroxene forms 10 per cent of the earth's crust.
Amphibole	Aluminum, calcium, silica, iron, magnesium are the major elements of amphiboles.	used in asbestos industry Hornblende is another form of amphiboles	They form 7 per cent of the earth's crust
Mica	It comprises of potassium, aluminium, magnesium, iron, silica etc	used in electrical instruments	It forms 4 percent of the earth's crust. It is commonly found igneous and metamorphic rocks
Olivine	Magnesium, iron and silica are major elements of olivine.	Used in jewellery	Found in basaltic rocks

Rocks :

- Rocks are generally a mixture of two or more minerals and do not possess a definite chemical composition

Major Types of Rocks :

1. Igneous rocks

Characteristics of igneous rocks :

- They are compact and massive and do not possess rounded particles.
- They do not occur in distinct beds or stratas.
- They are generally granular and crystalline.
- They are hard and impermeable.
- They are less affected by chemical weathering.
- They do not contain any fossils or traces of animals or plants.
- Most of the igneous rocks consist of silicate minerals.
- The valuable minerals such as iron, gold, silver, aluminium, etc., are found in them.

2. Sedimentary rocks :

- The word sedimentary has been derived from the Latin word 'sedimentum', meaning settling down.
- Rain, wind, ice, running water, plants and animals constantly break the rocks into fragments of all sizes. These broken rock materials are carried away by wind, ice and running water, and deposited in the depressions. The deposited materials are called sediments, and they give rise to sedimentary rocks.
- The sedimentary rocks can be formed mechanically (sandstone), chemically (gypsum or salt) or organically (coal, limestone). The sedimentary rocks are most widespread and cover about 75 per cent of the total land area on the earth.

Characteristics of sedimentary rocks :

- They are comparatively softer than the igneous rocks.
- They are made up of minute particles of various shapes and sizes.
- They have layers horizontally arranged one above the other.
- They have been mostly formed under water.
- They have mud cracks and marks of ripples and waves.
- They have fossils between the layers.
- Most of them are permeable and porous.
- Of all the sedimentary deposits, coal and petroleum are the most important ones.
- Modern industries depend on the products from the sedimentary rocks.

3. Metamorphic rocks :

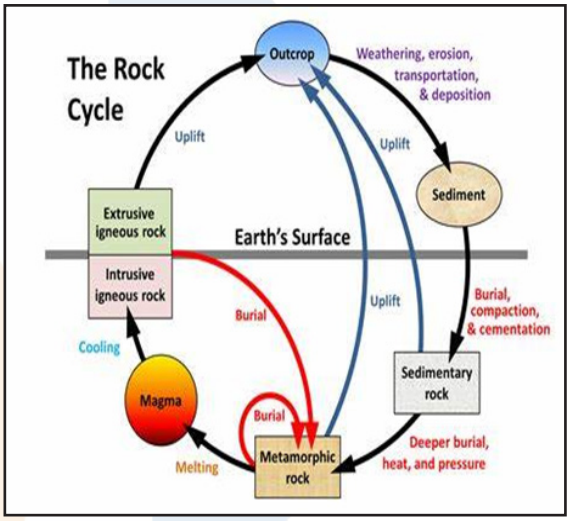
- The word metamorphic means 'changed form'. The rocks, originating at or near the surface of the Earth are sometimes subjected to tremendous heat and pressure. This can change the original properties of

rocks such as their colour, hardness, texture and mineral composition. Such changed rocks are called metamorphic rocks. Both igneous and sedimentary rocks can change into metamorphic rocks.

NAME OF THE ROCK	TYPE OF ROCK	NAME OF THE METAMORPHIC ROCK
Limestone	Sedimentary Rock	Marble
Dolomite	Sedimentary Rock	Marble
Sandstone	Sedimentary Rock	Quartzite
Shale	Sedimentary Rock	slate
Slate	Metamorphic Rock	Phylist / schist
Coal	Sedimentary Rock	Graphite / diamond
Granite	Igneous Rock	Gneiss
Phyllite	Metamorphic Rock	schist

Characteristics of metamorphic rocks :

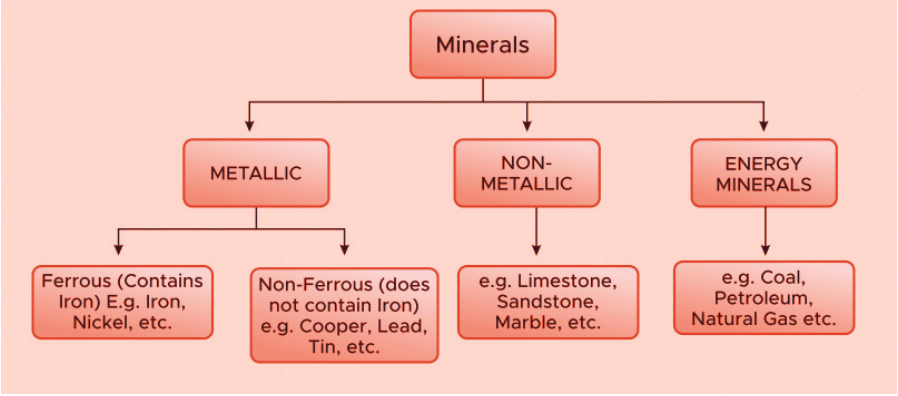
- They are usually hard.
- They have a high specific gravity.
- They may be banded.
- They do not have void spaces in them.



■ Rock Cycle :

- **Rock cycle** is the intimate relationship and mutual interdependence between the three types of rocks—igneous, sedimentary and metamorphic. The change of one type of rock into another type under different conditions is known as the rock cycle.
- In the cycle of rock change, the materials of the lithosphere are constantly being formed and transformed in both their physical and mineral composition. The rock cycle has neither a beginning nor an end. **There are two environments for the working of a rock cycle, such as :**
  (a) a surface environment of low temperature and pressure
  (b) a deep environment of high temperature and pressure.

■ MINERAL RESOURCES : Most of metallic mineral in India occur in the peninsular plateau region in old crystalline.



Distribution of mineral resources in India	
The North-Eastern Plateau Region	This belt covers Chota Nagpur (Jharkhand), Odisha Plateau, West Bengal and parts of Chhattisgarh.
	It has variety of minerals viz, iron ore, coal, manganese, bauxite. mica. The Chota Nagpur plateau is also known as mineral heart land of India
The Central Belt	This belt encompassing parts of Chhattisgarh, Madhya Pradesh, Andhra Pradesh and Maharashtra is the second largest mineral belt in the country.
	Large deposits of manganese, bauxite, limestone, marble, coal, mica, iron ore are available here.
The South-Western Plateau Region	This belt extends over Karnataka, Goa and contiguous Tamil Nadu uplands and Kerala.
	This belt is rich in ferrous metals and bauxite. It also contains high grade iron ore, manganese and limestone.
	This belt packs in coal deposits except Neyvell lignite.
	It does not have mica and copper deposits.
The North-Western Region	This belt extends along Aravali in Rajasthan and part of Gujarat and minerals are associated with Dharwar system of rocks.
	This belt recently developed holds great promise for mining of the non-terrous metals. Copper, zinc has been major minerals.
	Rajasthan is rich in building stones i.e. sandstone, granite, marble. Gypsum and Fuller's earth deposits are also extensive
	Dolomite and limestone provide raw materials for cement industry

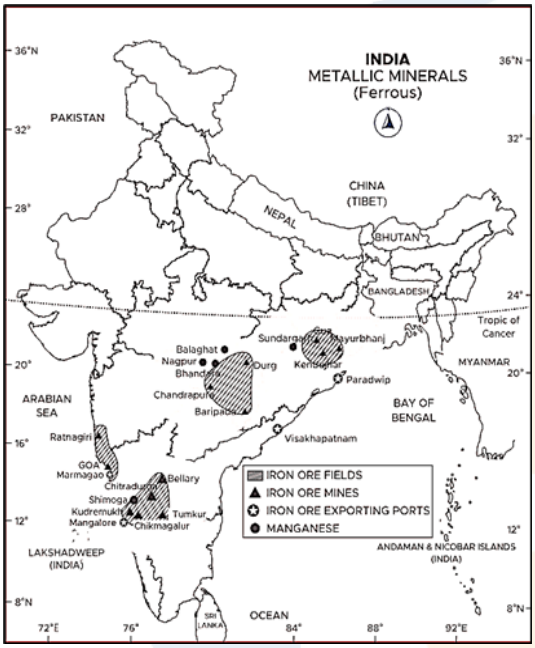
Ferrous Minerals :

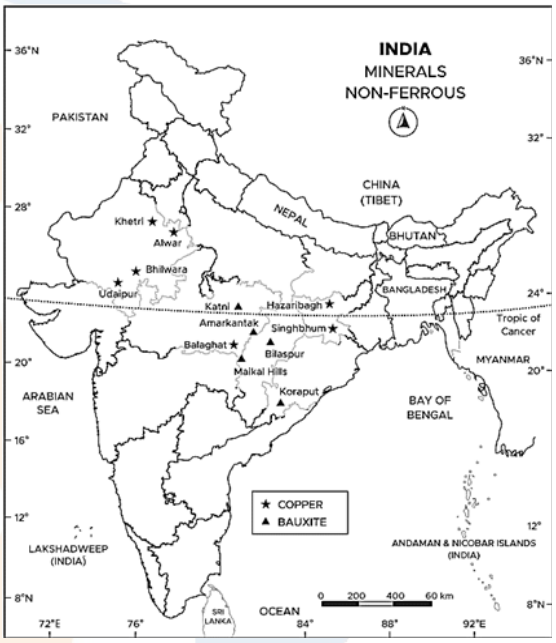
- Ferrous minerals such as iron ore, manganese, chromite, etc., provide a strong base for the development of metallurgical industries. Our country is well-placed in respect of ferrous minerals both in reserves and production.

■ Iron Ore :

1. India is endowed with fairly abundant resources of iron ore. It has the largest reserve of iron ore in Asia. The two main types of ore found in our country are haematite and magnetite.
2. It has great demand in international market due to its superior quality. The iron ore mines occur in close proximity to the coal fields in the north eastern plateau region of the country which adds to their advantage
3. About 95 per cent of total reserves of iron ore is located in the States of Odisha, Jharkhand, Chhattisgarh, Karnataka, Goa, Telangana, Andhra Pradesh and Tamil Nadu.
4. In Odisha, iron ore occurs in a series of hill ranges in Sundergarh, Mayurbhanj and Jhar. The important mines are Gurumahisani, Sulaipet, Badampahar (Mayurbhaj), Kiruburu (Kendujhar) and Bonai (Sundergarh).

5. Similar hill ranges, Jharkhand has some of the oldest iron ore mines and most of the iron and steel plants are located around them. Most of the important mines such as Noamundi and Gua are located in Poorbi and Pashchimi Singhbhum districts.
6. This belt further extends to Durg, Dantewara and Bailadila. Dalli, and Rajhara in Durg are the important mines of iron ore in the country.
7. In Karnataka, iron ore deposits occur in Sandur -Hospet area of Ballari district, Baba Budan hills and Kudremukh in Chikkamagaluru district and parts of Shivamogga, Chitradurg and Tumakuru districts.
8. The districts of Chandrapur, Bhandara and Ratnagiri in Maharashtra, Karimnagar and Warangal district of Telangana, Kurnool, Cuddapah and Anantapur districts of Andhra Pradesh, Salem and Nilgiris districts of Tamil Nadu are other iron mining regions. Goa has also emerged as an important producer of iron ore.





Types of iron Ores- :

A. Haematite :

1. It is also known as red-ochre, as it is reddish in colour.
2. The iron contents in this type ranges from about 60-70%.
3. Most of the iron ore reserves in India belong to this type.

B. Magnetite :

1. It is the best quality of iron ore and contains Iron > 70%.
2. The colour of the ore is dark brown to blackish and is known as black ore.
3. It has magnetic properties.

C. Limonite

1. It is yellow or light brown in colour and the iron contents ranges from about 40-60%.

2. It is called hydrated iron oxide, when the iron ore in mixed with oxygen and water.
3. Its mining is easier and cheaper.

D. **Siderite**

1. It is an Inferior variety of iron ore and has many Impurities.
2. The iron contents range from about 20-40%.
3. It is also called Iron carbonate.

■ Manganese :

1. Manganese is an important raw material for smelting of iron ore and also used for manufacturing ferro alloys. Manganese deposits are found in almost all geological formations, however, it is mainly associated with Dharwar system.
2. India is the worlds fifth largest producer of manganese ore and has second largest ore reserves in the world after Zimbabwe.
3. Odisha is the leading producer of Manganese. Major mines in Odisha are located in the central part of the iron ore belt of India, particularly in Bonai, Kendujhar, Sundergarh, Gangpur, Koraput, Kalahandi and Bolangir.
4. Karnataka is another major producer and here the mines are located in Dharwar, Ballari, Belagavi, North Canara, Chikkmagaluru, Shivamogga, Chitradurg and Tumakuru. Maharashtra is also an important producer of manganese
5. It is a black hard iron like metal and is an important raw material for smelting of iron ore. It is also used for manufacturing ferrous alloys.
6. It is also used for the manufacture of bleaching powder, insecticides, paints, glazed pottery, matches, batteries and china-clay.
7. It is mainly associated with Dharwar system.Odisha is the leading producer of Manganese.Major mines in Odisha : Located in the central part of the iron ore belt of India, particularly in Bonai, Kendujhar, Sundergarh, Gangpur, Koraput, Kalahandi and Bolangir.
8. Karnataka is another major producer and here the mines are located in Dharwar, Bellary. Belgaum, North Canara, Chikmagalur, Shimoga. Chitradurg and Tumkur.
9. Maharashtra, Madhya Pradesh, Andhra Pradesh, Goa and Jharkhand are minor producers of manganese.

■ Non Ferrous Minerals :

- India has limited reserves of non ferrous mineral except bauxite ,copper , bauxite, gold, silver, tungsten, nickel, cobalt are major non ferrous mineral.

Mineral	Uses	Distribution
BAUXITE	Properties like lightness, strength, malleability, ductility, heat and electrical conductivity and resistance to atmospheric corrosion makes Aluminium a very useful metal.	Kalahandi and Sambalpur in Odisha is the leading producers in the country.
		Jharkhand, Gujarat, Chhattisgarh, Madhya Pradesh and Maharashtra are other major producers.
		Bhavanagar, Jamnagar in Gujarat have the major deposits.
		Chhattisgarh has bauxite deposits in Amarkantak plateau while Katni-Jabalpur area and Balaghat in M.P. have important deposits of bauxite
COPPER	Used for making utensils and coins. Electrical industry for making wires, electric motors, transformers and generators.	Singhbhum district in Jharkhand, Balaghat district in Madhya Pradesh and Jhunjhunu and Alwar districts in Rajasthan.
LEAD	Occurs as a cubic sulphide known as Galena.	It occurs in India in the Himalayas, Tamil Nadu, Rajasthan. Andhra Pradesh and Jharkhand.
		Rajasthan is the leading producer of lead.
		About 75% of Indian requirements are met by Imports mainly from Australia, Canada and Myanmar
ZINC	The mixed ore containing lead and zinc and is mainly used for alloying and manufacturing galvanized sheets. It is also used for dry batteries, white pigments, electrodes, textiles etc.	More than 99% of zinc in India is produced in Zawar area in Udaipur district of Rajasthan.
		Most of the industrial needs are met via Imports from Zaire, Canada, Australia and Russia
GOLD	Used for making ornaments and usage as international currency.	Main gold fields in India namely, Kolar Gold Fleld (deepest in st in the world). Hutti Gold field in Raichur district of Kamataka and Ramgiri Gold field in Anantpur district of Andhra Pradesh.
		Alluvial gold is obtained from the sands of the Subarnarekha River in Jharkhand.
		Such deposits are called placer deposits and the process of recovering gold from these sources is called panning.
SILVER	Used in manufacture of chemicals, electroplating. photography, for colouring glasses etc.	Indiahas limited resources of silver ore.
		Majority of production comes from Zawar mines in Udaipur district of Rajasthan.

MICA	Mainly used in the electrical and electronic industries. Can be split into very thin sheets which are tough and flexible.	Rajasthan have the largest deposits of mica.
		Produced in Hazaribagh plateau of Jharkhand, Nellore district of Andhra Pradesh, Bhilwara and Udaipur in Rajasthan followed by Tamil Nadu Karnataka, West Bengal and Madhya Pradesh.
		India has near monopoly in the production of mica, producing about 60% of the world's total production
LIMESTONE	Used for large variety of purposes like cement industry. iron and steel industry. chemical industry etc.	Produced in the states of Madhya Pradesh, Rajasthan, Andhra Pradesh, Gujarat, Chhattisgarh and Tamil Nadu.
		Madhya Pradesh is the largest producer of limestone in India.
DOLOMITE	Limestone with more than 10% of magnesium is called dolomite, when percentage rises to about 45%, it is called true dolomite.	Odisha, Chhattisgarh, Andhra Pradesh. Jharkhand, Rajasthan and Karnataka are the major producers.
	Chiefly used in metallurgical activities; as refractories; as blast furnace flux; as a source of magnesium salts and in fertilizer and salt industry.	Odisha is the largest producer of dolomite.

Characteristic	Ferrous Minerals	Non-Ferrous Minerals
Iron Content	Contain a significant amount of iron.	Do not contain a substantial amount of iron.
Examples	Iron ore, magnetite, hematite, etc.	Copper, lead, zinc, gold, silver, etc.
Magnetic Properties	Often exhibit magnetic properties.	Typically do not exhibit significant magnetic properties.
Corrosion Resistance	Prone to rust and corrosion.	Generally more resistant to rust and corrosion.
Usage in Industries	Primarily used in the production of iron and steel.	Used in various industries such as electronics, construction, transportation, and jewelry.
Density	Tend to have higher density.	Density may vary depending on the specific mineral.
Color	Colors often range from black to brown.	Can display a wider range of colors.
Tarnishing	Susceptible to tarnishing and discoloration.	Generally have better resistance to tarnishing.

Atomic Minerals :

- Uranium and thorium are the main atomic minerals, beryllium ,lithium and zirconium are the other minerals. Two main sources of Uranium are **Pitchblende** (containing 50-80% Uranium) & **Uraninite** (containing 65-80% Uranium).
- India produces 2% of the total Uranium produced in the world. **Uranium Corporation of India Ltd**. (UCIL) is responsible for mining uranium ore for commercial purposes.
- Uranium mined by the UCIL is used for both weapons and civil nuclear programs. The imported Uranium is used for civil nuclear energy purposes only.

Uranium	Uranium deposits occur in Singhbhum and Hazaribagh districts of Jharkhand, Gaya district of Bihar, and in the sedimentary rocks in Saharanpur district of Uttar Pradesh.
	Largest source of uranium comprises the monazite sands, both beach and alluvial. The largest concentration of monazite sand is on the Kerala coast.
	Some uranium is found in the copper mines of Udaipur in Rajasthan. India produces about 2% of world's uranium reserves.
Thorium	Thorium is also derived from monazite which contains 10% thorium.
	Kerala, Bihar, Jharkhand, Tamil Nadu and Rajasthan are the main producers.

Isotope	Percentage	Nature of Radioactivity	
U238	99.3%	Fertile/Fissionable	It has to absorb a neutron to become fissile. Plutonium is formed in the process.
U235	0.7%	Fissile	- U235 can form a self-sustaining chain reaction.
			- But they need to be enriched to 3-4 % to sustain the chain reaction.
Distribution in India	• Jharkhand- Jadughoda , Bhatin, Narwapahar ,Turamdih • Meghalaya- Mahadek Basin , Andhra- Tumallapalle (largest mine in India), Karnataka- Bhima Basin, Rajasthan- Aravallis		

Rare Earth Elements :

- REE are a set of **seventeen** elements in the periodic table. These include the fifteen lanthanides on the periodic table plus scandium and yttrium.
- Samarium (Sm), scandium (Sc), terbium (Tb), thulium (Tm), ytterbium (Yb), yttrium (Y), cerium (Ce), dysprosium (Dy), erbium (Er), europium (Eu), gadolinium (Gd), holmium (Ho), lanthanum (La), lutetium (Lu), neodymium (Nd), praseodymium (Pr), promethium (Pm).
- REE are all metals, and the group is often referred to as the "rare earth metals.
- Although called "rare", they are actually found relatively abundantly in the Earth's crust.
- **Why they are called "rare"?** These metals are very difficult to mine because it is unusual to find them in concentrations high enough for economical extraction.
- These metals have many similar properties, and that often causes them to be found together in geologic deposits.

- They are also referred to as **"rare earth oxides"** because many of them are typically sold as oxide compounds.
- REE and alloys that contain them are used in many devices that people use every day such as computer memory, DVDs, rechargeable batteries, cell phones, catalytic converters, magnets, fluorescent lighting and much more.
- Rare earths are used as **catalysts, phosphors, and polishing compounds**.
- China has the highest reserves of rare earth minerals at 44 million MT. The country was also the world's leading rare earths producer in 2020 by a long shot, putting out 140,000 MT. It accounts for around 61% of global rare earths' production. Countries like the United States (second-largest), Myanmar, Australia, Thailand, Madagascar, India, Russia, Brazil, Vietnam and Burundi have also a significant share in rare earths' production.
- Data shows that thulium and lutetium are the two least abundant rare earth elements but each has an average crustal abundance that is nearly 200 times greater than the crustal abundance of gold.

■ ENERGY SOURCES :

<table>
<tr><th colspan="2">Conventional</th><th>Renewable energy</th></tr>
<tr><th>Non Renewable</th><th>Renewable</th><td>1. Solar energy</td></tr>
<tr><td>Mostly Fossil Fuels found under the ground.</td><td>Mostly non-fossil fuels seen above the ground.</td><td>2. Hydro power
3. Wind energy
4. Nuclear energy</td></tr>
<tr><td>Coal, oil, natural gas etc. are the examples.</td><td>Fire wood, cattle dung from vegetable wastes, wood charcoal etc. are the examples.</td><td>5. Hydrogen energy
6.Geothremal energy
7. Bio gas
8. Tidal energy
9. Bio-fuel</td></tr>
<tr><td colspan="3">Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes a critical importance in view of the everincreasing energy needs requiring huge investments to meet them.</td></tr>
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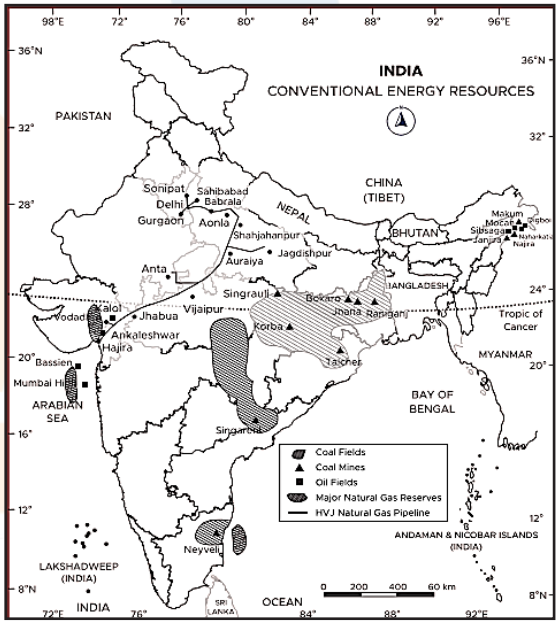


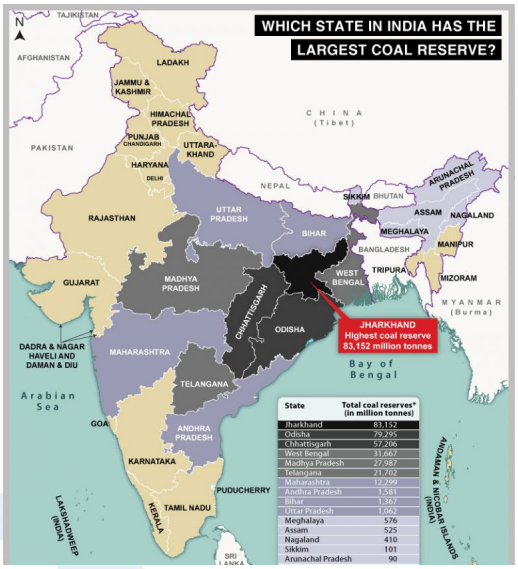
■ COAL :

- Coal is a one of the important minerals which is mainly used in the generation of thermal power and smelting of iron ore. It is the one of the most mined mineral from the earth. According to one estimate, proven coal reserves are **860, 938 million tonnes.**
- The largest proved reserves are found in the **United States, Russia, China, Australia and India**. A proved recoverable reserve is the tonnage of coal that has been proved by drilling etc. and is economically and technically extractable. Coal is found majorly in forms of Lignite and Anthracite.

- It accounts for **55% of the country's energy need**. Hard coal deposit spread over **27 major coalfields,** are mainly confined to eastern and south central parts of the country.
- The coal resources of India are available in **older Gondwana formations** of peninsular India and younger tertiary
- The Gondwana coal belongs to the **carboniferous period**. It is found in the Damodar, Mahanadi, Godavari, and Narmada valleys. Raniganj, Jharia, Bokaro, Ramgarh, Giridih, Chandrapur, Karanpura, Tatapani, Talcher, Himgiri, Korba, Penchgati, Sarguja, Kamthi, Wardha valley, Singreni (A.P.) and Singrauli are some of the important coal mines of the Gondwana formations.

Stage Of Coal	Characteristic
PEAT	First stage of coal formation.
	The carbon content < 40%.
	High percentage of moisture and volatile matter.
	Low heating capacity reduces its value as an industrial fuel.
LIGNITE	Regarded as the next stage of coal formation after peat.
	Also known as the brown coal.
	Lignite is soft, but more compact than peat.
	Carbon content : 40-60%.
	Large percentage of moisture and less amount of combustible matter
	In India, lignite is mostly found in Rajasthan, Tamil Nadu, Assam and Jammu and Kashmir states.
BITUMINOUS	Hard and compact variety of coal.
	The carbon content : 60-80%.
	Almost 80 per cent of the world's output : Bituminous
	Coke is mainly used in the iron and steel industry.
	Bituminous coal is found in Jharkhand, Orissa, West-Bengal, Madhya Pradesh and Chhattisgarh.
ANTHRACITE	It is the hardest and the best quality of coal.
	The carbon content : 80-90%.
	Anthracite, practically, has no volatile matter.
	Only about 5 per cent of the world's total coal is anthracite.
	In India this type of coal is found only in Jammu and Kashmir and that too in very small quantity.

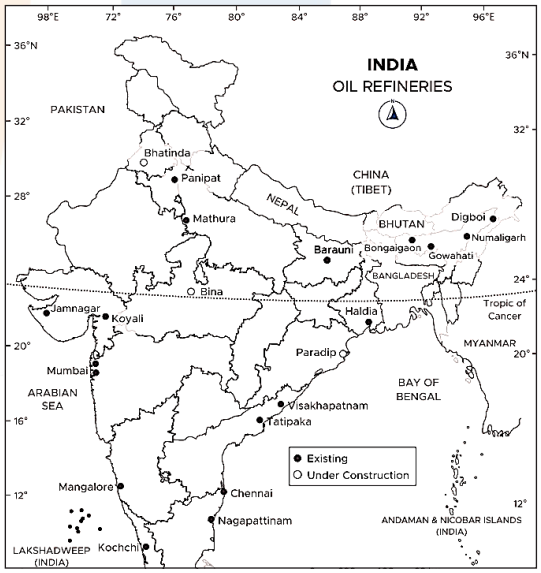
Important Coal Regions Of India :



- Gondwana coal fields of India are located in Damodar Valley.
- They lie in Jharkhand-Bengal coal belt and theimportant coal fields in this region are Raniganj, Jharia, Bokaro, Giridih, Karanpura.
- The other river valleys associated with coal are Godavari, Mahanadi and Son.
- The most important coal mining centres are Singrauli in Madhya Pradesh (part of Singrauli coal field lies in Uttar Pradesh), Korba in Chhattisgarh, Talcher and Rampur in Odisha, Chanda-Wardha, Kamptee and Bander in Maharashtra and Singareni and Pandur in Andhra Pradesh.

■ PETROLEUM :

- Petroleum is also called 'black gold' or 'liquid gold'. It is second to coal in terms of sources of energy. It is an essential source of energy for all internal combustion engines in automobiles, railways and aircraft. Crude petroleum occurs in sedimentary rocks of the tertiary period.
- It is formed when large quantities of dead organisms, usually zooplankton and algae, are buried underneath sedimentary rock and subjected to intense heat and pressure
- Petroleum (and natural gas) are born and accumulate in the sedimentary mantle of the Earth. Small amounts of these hydrocarbons are present throughout the mantle, but large accumulations are encountered less frequently. About 600 sedimentary basins, characterized by oil and gas occurrence, are found on the Earth.
- Crude petroleum consists of hydrocarbons of liquid and gaseous states. The crude petroleum deposits are found only in the sedimentary rock basins of marine origin. But all sedimentary rocks do not contain mineral oil.

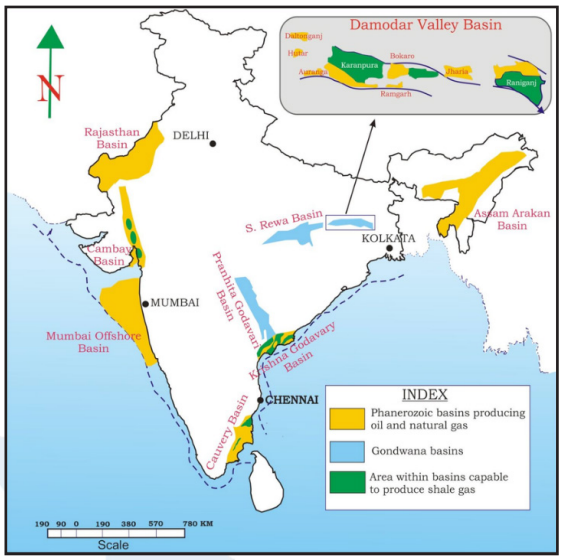


Major oil fields :

- **Ghawar field** - Saudi Arabia, **Burgan field** - Kuwait, **Azeri-Chirag-Guneshli** - Caspian Sea Azerbaijan, **Ku-Maloob-Zaap** - Mexico, **Zakum** - UAE, **Ferdows field** - Iran, **Sugar Loaf field** - Brazil, **Bolivar Coastal field** - Venezuela.

Pipelines :

1. Naharkatia-Nunmati - Barauni Pipeline
2. Mumbai High - Mumbai - Ankaleshwar - Kayoli Pipeline
3. Salaya-Koyali - Mathura Pipeline
4. Hajira - Bijapur - Jagdishpur (HBJ) Gas Pipeline
5. Jamnagar-Loni LPG Pipeline
6. Kandla - Bhatinda Pipeline



Natural Gas :

- Natural gas is often found dissolved in oil or as a gas cap above the oil.
- Sometimes, pressure of natural gas forces oils up to the surface. Such natural gas is known as associated gas or wet gas.
- Some reservoirs contain gas and no oil. This gas is termed non-associated gas or dry gas.
- Often natural gases contain substantial quantities of hydrogen sulphide or other organic sulphur compounds. The gas is known as **"sour gas."**
- Coalbed methane is called **'sweet gas'** because of its lack of hydrogen sulphide.
- Exclusive reserves have been located along the eastern coast TN, Odisha, Andhra Pradesh , As well as in Tripura Rajasthan off coast of Gujarat And MH.
- **top 10 natural gas producers-** Russia (20.0%) United States (19.2%) Canada (4.7%) Qatar (4.5%) Iran (4.4%) Norway (3.1%) China (3.0%) Saudi Arabia (2.7%) Indonesia (2.7%) Netherlands (2.4%)
- **Shale gas -** Shale gas is a natural gas produced from shale, a type of sedimentary rock. Due to constant announcements of shale gas recoverable reserves, as well as drilling in Central Asia, South America and Africa, deepwater drilling, estimates are undergoing frequent updates, mostly increasing. Since 2000, some countries, notably the US and Canada, have seen large increases in proved gas reserves due to development of shale gas, but shale gas deposits in most countries are yet to be added to reserve calculations. Some analysts expect that shale gas will greatly expand worldwide energy supply.
- **Coalbed Methane (CBM) -** CBM is generated by the conversion of plant material to coal through burial and heating. As "coalification" progresses, increasingly dense coal is formed. Coal serves as both the source rock and the reservoir rock. Coal is extremely porous but has low permeability (connected openings). Much of the methane generated by the coalification process escapes to the surface or migrates into adjacent reservoir or other rocks, but a significant volume remains trapped within the coal itself.

Solar Energy :

- India is endowed with vast solar energy potential. About 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day. National Institute of Solar Energy has assessed the country's solar potential of about 748 GW assuming 3% of the waste land area to be covered by Solar PV modules.

- India has achieved 5th global position in solar power deployment by surpassing Italy. Solar power capacity has increased by more than 11 times in the last five years from 2.6 GW in March, 2014 to 30 GW in July, 2019. Presently, solar tariff in India is very competitive and has achieved grid parity.

Two types of system :

1. Solar Thermal Power systems or Concentrating Solar Power systems
2. Solar Photovoltaic

Steps taken by India to promote Solar energy :

1. **National Solar Mission, 2010 :** Its objective is to establish India as a global leader in solar energy by creating the policy conditions for solar technology diffusion across the country as quickly as possible. The Mission targets installing 100 GW grid-connected solar power plants by the year 2022 in line with Paris agreement.
   a) Solar Park Scheme
   b) Scheme for setting up of Grid-Connected Solar PV Power Projects by the Central Public Sector Undertakings (CPSUs) and the Government of India organisations with Viability Gap Funding (VGF)
   c) VGF Scheme for setting up of 5000 MW of Grid Connected Solar PV Power Projects through SECI, which has a separate component of 1000 MW for N-E states.
   d) **Grid Connected Solar Rooftop Scheme :** For achieving cumulative capacity of 40,000 MW from Rooftop Solar (RTS) Projects by the year 2022.
   e) **Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan Yojana (PM-KUSUM) :** It is a scheme for farmers for installation of solar pumps and grid connected solar and other renewable power plants. The scheme aims to add solar and other renewable capacity of 25,750 MW by 2022 with financial support from centre.
2. **Development of Solar City Programme :** A total of 60 cities/towns are proposed to be supported for development as "Solar/ Green Cities". At least one city in each State to a maximum of five cities in a State may be supported by the Ministry of New and Renewable Energy.
3. A 25 percent capital subsidy for solar manufacturing units is available under the '**Modified Special Incentives Package Scheme' (M-SIPS)**.
4. **International Solar Alliance :**
   - It is an initiative jointly launched by India and France in 2015 on the sidelines of COP-21 of UNFCCC in Paris and officially established in 2017. It is a first treaty based international intergovernmental organization headquartered in India.

Wind Energy :

- **Five nations -** USA, China, Germany, India and Spain are the leading nations in terms of installed wind energy capacity.
- **Wind Energy in India :**
  - As on 31st March 2019, India has the fourth highest wind installed capacity in the world with total installed capacity of 35.6 GW.

- The Government through National Institute of Wind Energy (NIWE) has installed over 800 wind-monitoring stations all over country.
- The recent assessment indicates a gross wind power potential of 302 GW in the country at 100 meter above ground level.
- Out of the total estimated potential more than 95% of commercially exploitable wind resources are concentrated in seven states i.e. Gujarat, Rajasthan, Maharashtra, Tamil Nadu, Madhya Pradesh, Karnataka and Andhra Pradesh.

- **Offshore wind power vs the onshore wind power** Offshore wind power is the use of wind farms constructed in bodies of water, usually in the ocean on the continental shelf, to harvest wind energy to generate electricity. While, Onshore wind refers to turbines located on land.

Steps taken by India to promote wind energy :

- **National Offshore Wind Energy Policy, 2015 :** The objective of this policy is to explore and promote deployment of Offshore Wind Farms in the Exclusive Economic Zone (EEZ) of the country, including those under Public Private Partnership
- **National Wind Solar Hybrid Policy, 2018 :** This policy essentially aims at establishing a structure on the basis of which large-scale wind-solar hybrid power projects can be promoted.

Tidal Energy :

- The dam is then opened to run the turbines (which are reversible), electricity is produced as the water is let out of the reservoir. La Rance in France is the biggest commercial power station (240 MW) operating in the world.

India and Tidal Energy :

1. As per estimates, India has a potential of 8,000 MW of tidal energy. This includes about 7,000 MW in the Gulf of Cambay in Gujarat, 1,200 MW in the Gulf of Kutch and 100 MW in the Gangetic deltas in the Sunderbans region of West Bengal.
2. Despite the huge potential, India has no policy on tidal energy.
3. Tidal energy cannot be presently harnessed on commercial basis due to high capital cost ranging from Rs. 30 crores to 60 crores per MW.

Hydropower Energy :

- Generation of electricity by using the force of falling water (Kinetic Energy) is called hydroelectricity or hydel power. The basic principle behind hydropower energy is the damming of rivers to create artificial waterfalls, sometimes natural waterfalls are also used.

India and Hydropower Energy :

- India is blessed with a rich hydropower potential. In the exploitable potential terms, India ranks fifth in the world. India has 3 major rivers : the Indus, the Brahmaputra, and the Ganga. It also has three major river systems i.e. central Indian, west flowing rivers of south India, and east flowing rivers of south India

having a total of 48 river basins. The total potential from these river basins is 600TWh (Terawatt Hours) of electricity.

Large Hydro Energy :

- Hydro power plants of capacity more than 25 MW are classified as large hydro. It has four major advantages i.e. it is a source of green energy, has low variable cost, it is grid friendly and it can also can sub serve other purposes by irrigation, flood control, etc.

Small Hydro Energy In India :

- hydro power plants of 25MW or below capacity are classified as small hydro, which have further been classified into micro (100kW or below), mini (101kW-2MW) and small hydro (2- 25MW) segments. Their estimated potential is of 21000 MW. The hilly States of India mainly Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir and Uttarakhand constitute around half of this potential. Other potential States are Maharashtra, Chhattisgarh, Karnataka and Kerala.

Biomass Energy :

- Biomass is a renewable energy resource derived from plants and animal waste. The energy from biomass (biomass conversion) is released on burning or breaking the chemical bonds of organic molecules formed during photosynthesis.

INDIA and Biomass Energy :

- The current availability of biomass in India is estimated at about 500 million metric tonnes per year. India has estimated surplus biomass availability at about 120-150 million metric tonnes per annum covering agricultural and forestry residues corresponding to a potential of about 18,000 MW. This apart, about 7000 MW additional power could be generated through bagasse-based bio-energy obtained through sugar mills

1. **New National Biogas Student Notes : and Organic Manure Programme (NNBOMP) :** To provide clean cooking fuel for kitchens, lighting and meeting other thermal and small power needs of farmers/ dairy farmers /users including individual households and to improve organic manure system based on bio slurry from biogas plants in rural and semi urban areas by setting up of small size biogas plants of 1 to 25 Cubic Metre capacity.
2. **Biogas Power Generation (Off-grid) and Thermal energy application Programme (BPGTP) :** To promote biogas based Decentralized Renewable Energy Sources of power generation (Off-Grid), in the capacity range of 3 kW to 250 kW or thermal energy for heating/ cooling applications from the biogas generation produced from Biogas plants of 30 M3 to 2500 M3 size
3. **GOBAR (Galvanizing Organic Bio-Agro Resources) DHAN scheme, 2018 :** It focuses on managing and converting cattle dung and solid waste in farms to useful compost, biogas and bio-CNG, thus keeping villages clean and increasing the income of rural households. It was launched under Swachh Bharat Mission (Gramin).

- **Biomass Gasification :** It is the process through which solid biomass material is subjected to partial combustion in the presence of a limited supply of air.
- Solid fuel is converted by a series of thermo-chemical processes like drying, pyrolysis, oxidation and reduction to a gaseous fuel called Producer gas
- Producer gas consists mainly of carbon monoxide, hydrogen, and nitrogen

Biofuel :

Types of Biofuels : Depending upon sources of biomass, their limitations as a renewable source of energy, and their technological progress.

1. **First generation biofuels :** They are also known as conventional biofuels. They are made from sugar, starch, vegetable oil or animal fat. Processes such as fermentation, distillation and transesterification are used to produce primarily ethanol, and in smaller quantities, butanol and propanol.
2. **Second generation biofuels :** They include wood, organic waste, food waste, straw and farm residues and specific biomass crops which are non-edible. Thermochemical or biochemical reactions breakdown the lignin/glue in these plants to produce syngas (a mixture of carbon monoxide, hydrogen and other hydrocarbons). Hydrogen can be used as a fuel and the other hydrocarbons can be used as additives to gas oil. These biofuels don't compete between fuels and food crops and generate higher energy yields per acre than 1st generation fuels.
3. **Third generation biofuels :** They use specially engineered crops such as algae as the energy source. These algae are grown and harvested to extract oil within them. The oil can then be converted into biodiesel through a similar process as 1st generation biofuels, or it can be refined into other fuels.
4. **Fourth generation biofuels :** They are simply a step further from the third-generation biofuels as they use genetically modified algae and cyanobacteria to enhance biofuel production.
5. **Biodiesel :** It includes methyl or ethyl ester of fatty acids derived from non-edible vegetable oil, acid oil, used cooking oil, animal fat and bio-oil.
6. **Bioethanol :** Fuels produced from materials that have sugar such as sugar cane, sugar beet, sweet sorghum, etc.; materials that have starch such as corn, cassava, rotten potatoes, algae, etc.; cellulosic materials such as bagasse, waste wood, agricultural/forestry residues, etc. or other renewable industrial waste.
7. **Bio-CNG :** These fuels are purified form of biogas produced from agricultural residues, animal dung, food waste, MSW and sewage water but their composition and energy potential is comparable to fossil-based natural gas.

- **National Policy on Biofuels-2018 :** To achieve energy security of the country, the government is targeting to reduce import dependence i.e. usage of fossil fuels by 10% from 2014- 15 levels by the year 2022. To achieve this target a five-pronged strategy has been adopted, among which National Policy on Bio-fuels 2018 is also included.
- **Pradhan Mantri Ji-Van** (Jaiv Indhan- Vatavaran Anukool Fasal Awashesh Nivaran) **Yojana**

Details of the scheme :

- The scheme under the MoP&NG will provide financial support to Integrated Bioethanol Projects using lignocellulosic biomass and other renewable feedstocks.
- 12 commercial scale and 10 demonstration scale Second Generation (2G) ethanol projects will be provided viability gap funding support over the next six years in two phases : Phase-I (2018-19 to 2022- 23) and Phase-II (2020-21 to 2023-24).

- It also seeks to increase Research & Development in this area.
- The ethanol produced by the scheme beneficiaries will be mandatorily supplied to Oil Marketing Companies (OMCs) to further enhance the blending percentage under Ethanol Blended Petrol Programme.
- Centre for High Technology (CHT), a technical body under the aegis of MoP&NG, will be the implementation Agency for the scheme.

Geothermal Energy :

- Geothermal energy is the natural heat of the earth. Earth's interior heat originated from its fiery consolidation of dust and gas over 4 billion years ago. It is continually regenerated by the decay of radioactive elements, that occur in all rocks. Major geothermal fields are situated in circumpacific margins, rift zones of East Africa, North Africa, Mediterranean basin of Europe, and across Asia to Pacific.

There are four major types of Geothermal energy resources :

1. Hydrothermal :
2. Geo pressurized brines
3. Hot dry rocks
4. Magma

Geothermal Energy in India :

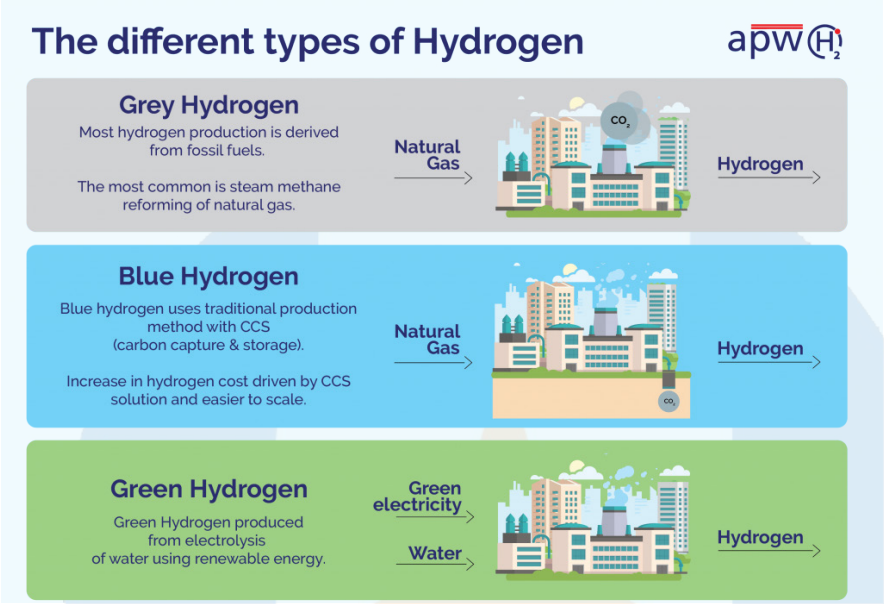
1. In India, North-western Himalayas and the western coast are considered geothermal areas.
2. Geological Survey of India has already identified more than 350 hot spring sites, which can be explored as areas to tap geothermal energy.
3. The estimated potential for geothermal energy in India is about 10000 MW.
4. There are seven geothermal provinces in India i.e. the Himalayas, Sohana, West coast, Cambay, SonNarmada-Tapi (SONATA), Godavari, and Mahanadi.
5. The Puga valley in the Ladakh region has the most promising geothermal field.
6. It is being used mainly for poultry farming, mushroom cultivation, and pashmina-wool processing, all of which need higher temperature.

Hydrogen Energy :

- When hydrogen gas burns in the air or in fuel cells, it combines with oxygen gas to produce non-polluting water vapour and fuel cells directly convert hydrogen into electricity. Widespread use of hydrogen as fuel would greatly reduce the problem of air pollution and danger of global warming because there will not be any CO2 emission. The current global demand of hydrogen is 70 million tons per year, most of which is being produced from fossil fuels – 76% from natural gas and around 23% from coal, with the remaining from electrolysis of water

Types of hydrogen depending upon process of extraction :

- **Green hydrogen :** It is derived by electrolysis of water, separating the hydrogen atom within it from oxygen using renewable energy (such as wind, solar or hydro) that eliminates emissions during process.
- **Grey hydrogen :** Hydrogen derived using fossil fuels is called as grey hydrogen.
- **Blue hydrogen :** It is derived from natural gas through the process of steam methane reforming SMR). SMR mixes natural gas with very hot steam, in the presence of a catalyst, where a chemical reaction creates hydrogen and carbon monoxide.



■ Manufacturing Industries :

- Manufacturing is the processing of primary products into more refined and more usable products. Many of the natural products cannot be used directly without processing. It is because of this reason that we manufacture cloth from cotton, sugar from sugarcane, paper from wood pulp etc. manufacturing means transformation of natural material endowments into commodities of utility by processing, assembling and repairing.

Types of Industries :

1. **On the basis of size, capital investment and labour force employed, industries are classified as :** large, medium, small scale, and cottage industries.
2. **On the basis of ownership, industries are categorised as :**
   (i) public sector, (ii) private sector, and (iii) joint and cooperative sector, Public sector enterprises are government/state controlled companies or corporations funded by governments. Industries of strategic and national importance are usually in the public sector.
3. **Industries are also classified on the basis of the use of their products such as** :
   (i) basic goods industries,
   (ii) capital goods industries
   (iii) intermediate goods industries, and
   (iv) consumer goods industries.

- **Another method of classifying industries is on the basis of raw materials used by them. Accordingly, these can be :**
  (i) agriculture based industries,
  (ii) forest-based industries,
  (iii) mineral-based industries, and
  (iv) industrially processed raw material based industries.

4. **Another common classification of industries is based on the nature of the manufactured products. Eight classes of industries, thus identified are :** (1) Metallurgical Industries, (2) Mechanical Engineering Industries, (3) Chemical and Allied Industries, (4) Textile Industries, (5) Food Processing Industries, (6) Electricity Generation, (7) Electronics and (8) Communication Industries.

■ Location of Industries :

A. geographical factors influencing the location of industries

1. Raw Materials :

a. Location of industries is influenced by the availability of raw materials.
b. Weight-losing raw material industries are situated near the source of raw materials.
c. Examples include sugar mills, pulp industry, copper smelting, and pig iron industries.

2. Power :

a. Regular power supply is essential for industrial locations.
b. Industries, like aluminum and synthetic nitrogen manufacturing, tend to be near power sources.
c. Power-intensive industries require a substantial amount of electricity.

3. Labour :

a. Industries, especially labor-intensive ones, depend on the availability of cheap and skilled labor.
b. Light consumer goods and agro-based industries require abundant labor.

4. Transport :

a. Efficient land or water transport is necessary for the movement of raw materials and finished goods.
b. Well-developed transport facilities contribute to proper industrial development.

5. Market :

a. Proximity to the market is crucial for the quick distribution of manufactured goods.
b. Reduces transport costs and ensures reasonable prices for consumers.
c. Industries like cotton textile and petroleum refineries are often located near markets.

6. Site :

a. Flat and well-served sites with adequate transport facilities are significant for industrial development.
b. Large areas are needed for building factories.

c. A tendency to set up industries in rural areas due to the rising cost of land in urban areas.

B. **Non-Geographical Factors Influencing Industrial Location :**

1. **Capital :**

- Modern industries demand significant capital investments.
- Urban centers attract industries due to the availability of substantial capital.

2. **Government Policies :**

- Government plays a pivotal role in planning industry distribution.
- Policies aim to reduce regional disparities, prevent pollution, and discourage clustering in major cities.
- Industries prefer locations with favorable and industry-friendly government policies.

3. **Industrial Inertia :**

- Industries often persist in their original locations despite changing circumstances.
- Geographical or industrial inertia leads to the continued development of industries in their initial establishment areas.

4. **Banking Facilities :**

- The establishment of industries involves substantial financial transactions.
- Areas with robust banking facilities are more suitable for industrial setups due to the ease of financial transactions.

■ **Major Industries :**

Industry	Description
Iron & Steel Industry	The iron and steel industry in India is a crucial driver of industrial development. It heavily influences various sectors. Raw materials include iron ore, coking coal, limestone, dolomite, manganese, and fire clay. Ideal locations for plants are near raw material sources. Major plants include Rashtriya Ispat Nigam Ltd., Jindal Steel & Power Ltd., Bhilai Steel Plant, Tata Steels Ltd., JSW Steel Ltd., and others. Key advantages of Tata Steel Ltd. include strategic raw material sources, water availability, and local labor.
Cotton Textile Industry	A traditional industry due to India's tropical climate and abundant cotton production. The first modern cotton mill was established in Mumbai in 1854. Two sectors : organized (large mills) and decentralized (handlooms, power looms). Cotton's weight stability allows for flexible location, but recent trends favor proximity to markets. Expansion occurred throughout the country, with leading states being Maharashtra, Gujarat, Tamil Nadu, West Bengal, Uttar Pradesh, Karnataka, and Punjab. Challenges include raw material scarcity, obsolete machinery, power supply issues, low labor productivity, and competition.

Sugar Industry	Second most important agro-based industry. Seasonal due to sugarcane seasonality. Maharashtra is the leading sugar producer, followed by Uttar Pradesh. Concentrated in Ganga-Yamuna doab and tarai region. Highly localized industry due to the weight-losing nature of sugarcane. Challenges include raw material scarcity, obsolete machinery, power supply issues, low labor productivity, and competition.
Petrochemical Industries	Rapidly growing industry with products derived from crude petroleum. Hub in Mumbai, with cracker units in various locations like Auraiya, Jamnagar, Gandhinagar, Hajira, Nagothane, Ratnagiri, Haldia, and Vishakhapatnam.
Machine Tools	Core industry providing machines to all sectors. Around 200 units manufacture various types of machine tools. Kirloskar Brothers Ltd. pioneered production in the 1930s. Hindustan Machine Tools (HMT), Bangalore, a key public sector unit, is the first large-scale modern machine tools factory. Produces a variety of machine tools, watches, tractors, and printing machinery.
Automobile Industry	Development started post-independence with Premier Automobiles (Mumbai) and Hindustan Motors Ltd. (Kolkata). Proximity to iron and steel production centers and port cities is preferred. Recent trend towards locating manufacturing units near the market.
Electronic Industry	Developed mainly after independence, covering a wide range of products. Indian Telephone Industry (ITI) at Bangalore boosted the industry. Bangalore is a major center for electronics goods production, earning the title 'Electronic Capital of India.' The IT revolution and software industry have significantly contributed to India's knowledge-based industries.
Knowledge-based Industries	The IT revolution has spurred knowledge-based industries in India. The Information Technology (IT) and IT-enabled Business Process Outsourcing (ITES BPO) services continue robust growth, contributing almost 2% to India's GDP.

7 LANDFORMS AND THEIR EVOLUTION

- **Causes-** Endogenic (tectonic forces) and Exogenic (gradational forces). Landforms and crustal order of relief.

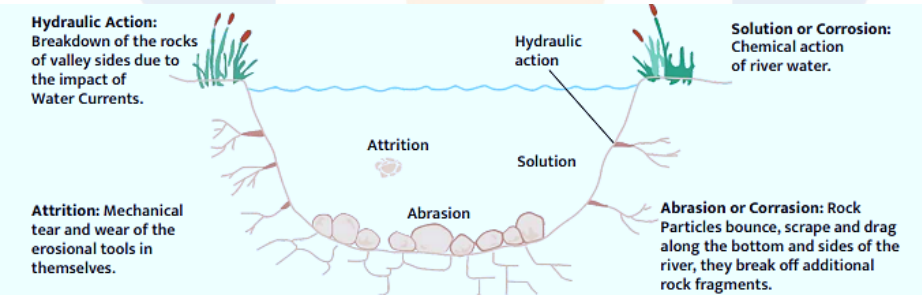
First order of relief	Continental platforms and the ocean basins.
Second order of relief	Mountains, plateaus, plains, continental shelves, continental slopes, abyssal plains, mid-oceanic ridges, submarine canyons and trenches
Third order of relief	Mountain peaks, cliffs, hills, spurs, sand dunes, valleys, etc.

1. Fluvial (River Based) Landforms :

- In humid regions, which receive heavy rainfall running water is considered the most important of the geomorphic agents in bringing about the degradation of the land. The landforms either carved out (due to erosion) or built up (due to deposition) by running water are called Fluvial Landforms (both erosional and depositional) and the running waters which shape them are called fluvial process

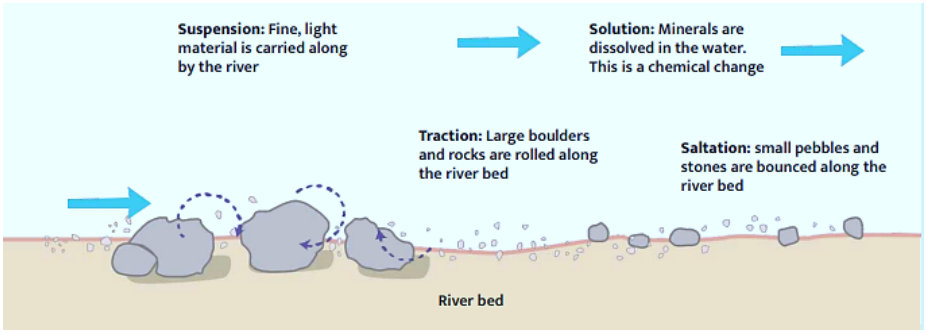
a) Erosion :

- **Solution or Corrosion-** This is the chemical action of river water. The acids in the water slowly dissolve the bed and the banks. This occurs in streams running through rocks such as chalk and limestone. Abrasion or Corrasion- As the rock particles bounce, scrape and drag along the bottom and sides of the river, they break off additional rock fragments. This form of erosion is called corrasion. This is the mechanical grinding of the rivers against the banks and bed of the river



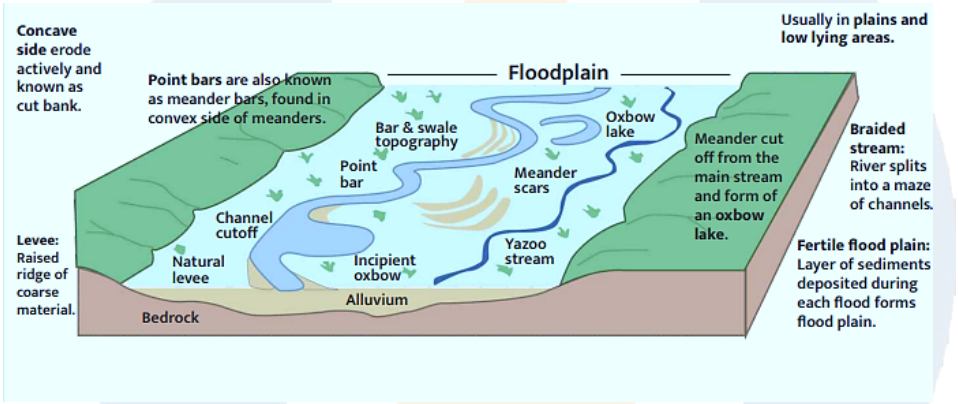
b) Transportation :

- **Traction -** The heavier and larger rock fragments like gravel, pebbles etc. are forced by the flow of river to roll along its bed. These fragments can be seen rolling, slipping, bumping and being dragged. This process is known as traction and the load is called traction load. Saltation-Some of the fragments of the rocks move along the bed of a stream by jumping or bouncing continuously. This process is called saltation. Suspension-The holding-up of small particles like sand, silt and mud by the water as the stream flows is called suspension. Solution-Some parts of rock fragments are dissolved in the river water and are thus transported.



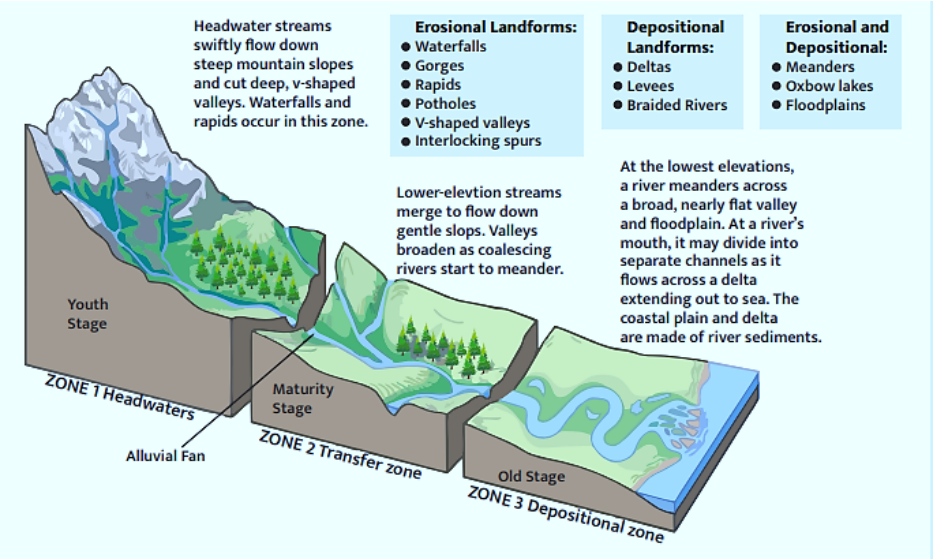
c) Deposition : Including the features formed due to deposition :

- When the stream comes down from hills to plain area, its slope becomes gentle. This reduces the energy of the stream. The decrease in energy hampers transportation; as a result part of its load starts settling down. This activity is known as deposition. The larger particles, such as boulders and pebbles, are deposited first and the finest particles of silt are the last to be deposited. Deposition takes place usually in plains and low lying areas. When the river joins a lake or sea, the whole of its load is deposited.



d) Development of the river valley :

- The erosional and depositional land features produced and modified by the action of running water may be better understood if we note the stages through which a stream passes from its source to its mouth. The source of a river may lie in a mountainous region and the mouth may meet the sea or lake. The whole path followed by a river is called its course or its valley.



Stages of a River's Course :

1. Upper Course (Stage of Youth) :

- Begins in hilly or mountainous areas.
- Rapid descent with maximum velocity and eroding power.
- Formation of 'V' shaped valleys, gorges, and deep canyons.
- Features include rapids, waterfalls, cascades, and plunge-pools.

2. Middle Course (Stage of Maturity) :

- Lateral corrasion replaces vertical corrasion.
- 'V' shaped valleys widen to 'U' shaped valleys.
- Development of meanders (loops) in river course.
- Alluvial fans formed by sediment deposits.
- Formation of piedmont alluvial plains.

3. Lower Course (Stage of Old Age) :

- Heavy with debris from upper and middle courses.
- Lateral corrasion continues, mainly deposition occurs.
- Formation of braided streams, levees, and point bars.
- Pronounced meanders, oxbow lakes, and deltas.
- Estuaries formed by rivers joining the sea without deltas.

Features Developed in Each Course :

Upper Course :

- Waterfalls, rapids, cataracts, potholes.
- 'I' shaped valleys and canyons.
- Interlocking spurs and deep gorges.

Middle Course :

- 'U' shaped valleys.
- Meanders and oxbow lakes.
- Alluvial fans and piedmont alluvial plains.

Lower Course :

- Braided streams, levees, and point bars.
- Oxbow lakes and deltas.
- Estuaries (in some cases).

■ **Formation Processes :**

Waterfalls, Rapids, and Cataracts :

- Develop where erosion-resistant rock intersects the stream's course.
- Result in steepened river beds, plunge pools, and erosion.

Meanders :

- Form due to deposition and erosion in the middle course.
- Loops formed as river swings around obstacles, meanders migrate downstream.

Deltas :

- Formed at river mouths due to sediment deposition.
- Triangular landforms, apex pointing upstream.
- Conditions favoring delta formation include active erosion, tideless coast, shallow sea.

Estuaries :

- Mouths widening without delta formation.
- Caused by subsidence of the earth's crust or scouring action of tides and currents.

e) **River rejuvenation, River Terrace and Incised or Entrenched Meanders :**

River Rejuvenation

1. **Rejuvenation Causes :**
   - Fall in sea level or rise of land relative to the sea.
   - Increased potential energy enhances the river's erosive capacity.
2. **Landforms Created :**

Knick Point :

- Sudden break or irregularity in the river's gradient.
- Can be sharply defined (e.g., waterfalls) or barely noticeable.
- Result of rejuvenation, where the river adjusts its long profile.

River Terrace :

- Remnant of a former floodplain left at a higher level post-rejuvenation.
- Old floodplain remains above the present river level.
- Formed in stages as the river widens its valley through lateral erosion.
- Provides shelter from floods and natural routes for roads and railways.

Incised or Entrenched Meanders :

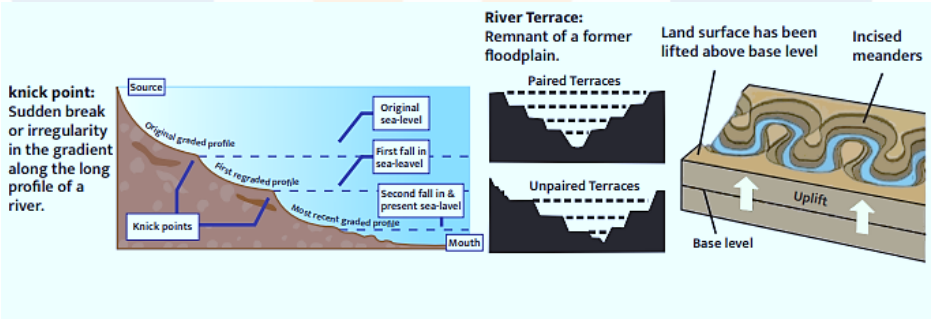
- Meanders deepened by a rejuvenated river.
- Rate of vertical erosion influences landform nature.
- Slow incision results in ingrown meanders with asymmetrical valleys.
- Rapid incision leads to symmetrical valleys resembling gorges.
- Also known as entrenched meanders.

3. **Terrace Types :**

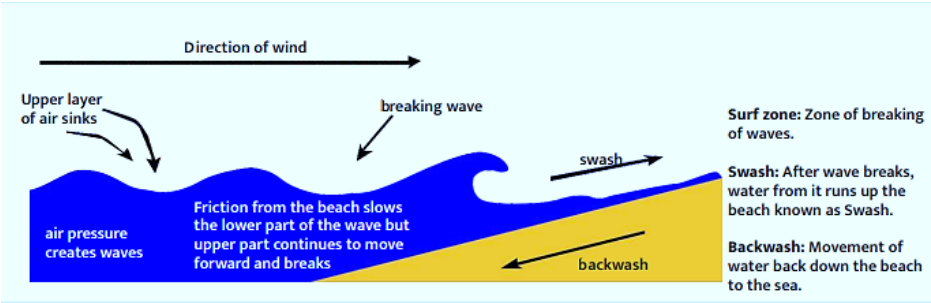
- **Paired Terraces :**
  - Terraces on both sides of the river at similar elevations.
  - Typical in areas with uniform changes along both banks.
- **Non-Paired Terraces :**
  - Terraces present only on one side or at different elevations on each side.
  - Found in areas of slow uplift or non-uniform water column changes.

4. **Examples :**

- The River Thames created terraces in its lower course through multiple stages of rejuvenation.
- Terraces along rivers like the Thames serve as strategic locations for built-up areas like Oxford and London.



■ **2. Coastal Landforms :** Process Included Tides, Current and Waves



a) **Coastal erosion :**

- Wearing away and breaking up of rock along the coast.
- Influenced by sea waves, rock nature, exposure, tides, currents, and human activities.

Erosional Features :

Cliffs and Wave-Cut Platforms :

- **Cliff :** Vertically rising rock above sea water with a steep slope., Formed due to maximum wave impact on lower coastal rocks.
- **Wave-Cut Platform :** Formed at the bottom of the retreating cliff, Gentle sloping rock-cut flat surface with ridges and grooves.

Capes and Bays :

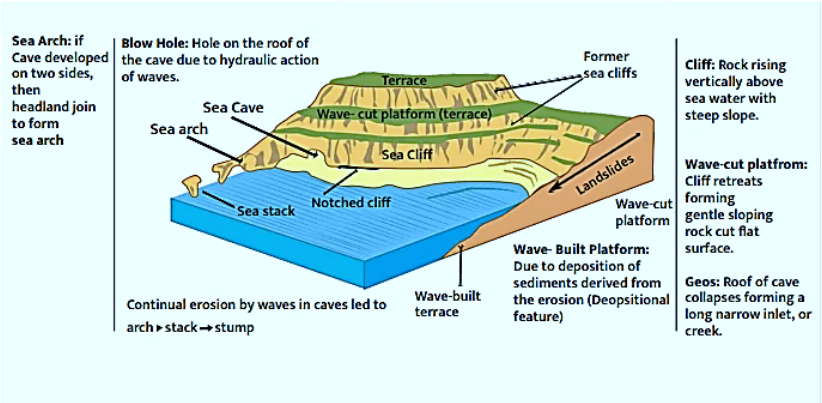
- Features of irregular coastlines, Formed where hard rocks (e.g., granite, limestone) alternate with softer rocks (e.g., sand, clay).
- Softer rocks erode into inlets, coves, and bays.
- Harder rocks resist erosion and persist as headlands or capes.

Cave, Arch, and Stack :

- **Cave Formation :** Erosion processes (hydraulic power, corrosion) turn vertical rock weaknesses into caves.
- Requires relatively hard or resistant rock to avoid collapse.
- **Arch and Stack :**
- If a headland erodes from two sides, caves join to form a natural sea arch.
- Continued erosion leads to arch collapse, leaving a vertical stack.
- Stack eventually erodes into a stump.

Blow Holes and Geos :

- **Blow Hole :** Hole on the cave roof formed by hydraulic action, Lines of weakness cause roof collapse, leading to a blow hole.
- **Geos :**Deep, long creeks formed when a cave roof collapses, Enlarged blow holes and continued wave action create geos.



b) Depositional Features :

Definition : Result from the transport and deposition of eroded materials by sea waves.

Landforms :

Wave-Built Platform or Terrace :

- Formed by the deposition of sediments from cliff erosion or abrasion by wave action.

Beaches :

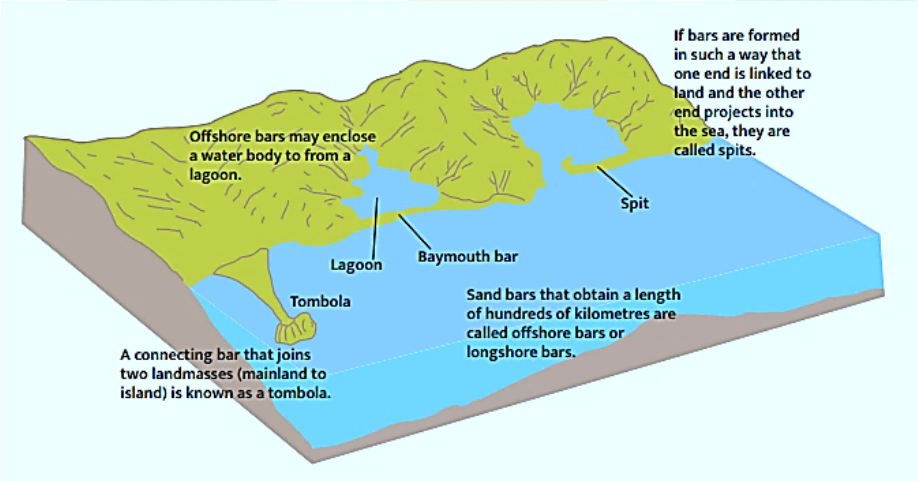
- Main deposition feature along the coast.
- Comprise materials (e.g., sand) between high and low tide marks.
- Sources include rivers, constructive waves, and cliff erosion.
- Temporary features; some beaches contain small pebbles and cobbles.
- **Examples :** Marina Beach in Chennai, Kovalam Beach in Thiruvananthapuram.

Bars, Spits, and Tombolo :

- **Bars :** Ridge joining two headlands across a bay. Offshore bars, extensive sandbars, may enclose lagoons **(e.g., Chilka Lake).**

Spits : Bars projecting into the sea, linked at one end to the land.

Tombolo : Connecting bar joining two landmasses (mainland to an island).



■ Types of Coasts :

- **Coastlines of submergence :** Become lowered below current sea level.

Type of Coast	Features	Examples
Ria Coasts	Formed when a non-glaciated highland coast becomes submerged & the valleys filled with sea water. Often "V" shaped	North-western Spain and south-western Ireland.
Fiord (Fjord) Coasts	Fjord is a narrow, highwalled, and very long submerged glacial valley. Formed when a descending glacier carves a U-shaped valley into the bedrock.	Fjord coasts of Norway

Dalmatian or Longitudinal Coasts	Formed when a mountain ridge running parallel to the sea coast is submerged. Alternating crests and troughs runs parallel to the sea coast.	Dalmatian coast of Yugoslavia.
Estuarine Coast	Coasts where lowland coast are submerged, flooding river. Their entrances are sand and silt free.	Thames of Britain.

- **Coastlines of Emergence :** The coast has been raised (due to fall in sea level or a rising of the crust) and the ocean waves now erode a lower level.

Type of Coast	Features	Examples
Emerged Upland Coasts	Formedwhen coastal plateau lands are raised above sea level. Raised beach or cliff-line.	Northern part of west coast of India
Emerged Lowland Coasts	Produced by the uplift of part of the neighbouring continental shelf. Main feature : spits lagoons, bars, marshes and beaches.	Coasts of Kerala and Tamil Nadu

■ 3. Glacial Landforms : Moving Mass Of Ice And Snow. Processes Involved Are Accumulation, Compaction And Re-Crystallization Of Snow :

Formation of Glaciers :

- Result from a net accumulation of snow over years.
- Snow layers accumulate, undergo pressure, compaction, and recrystallization.
- Solid mass of ice becomes mobile, forming a glacier.

a) **Action of Glacier :**

Glacial Movement : Very slow, ranging from centimeters to meters per day.

b) **Types of Glacial Erosion :**

a. **Plucking :** Meltwater freezes around rock, plucking it from the back wall as the glacier moves.

b. **Abrasion :** Rock frozen to the base and back of the glacier scrapes the bedrock.

c. **Freeze-Thaw :** Meltwater or rain in bedrock cracks freezes, expands, and causes crack enlargement, leading to eventual rock breakage.

c) **Erosional Work of Glacier :**

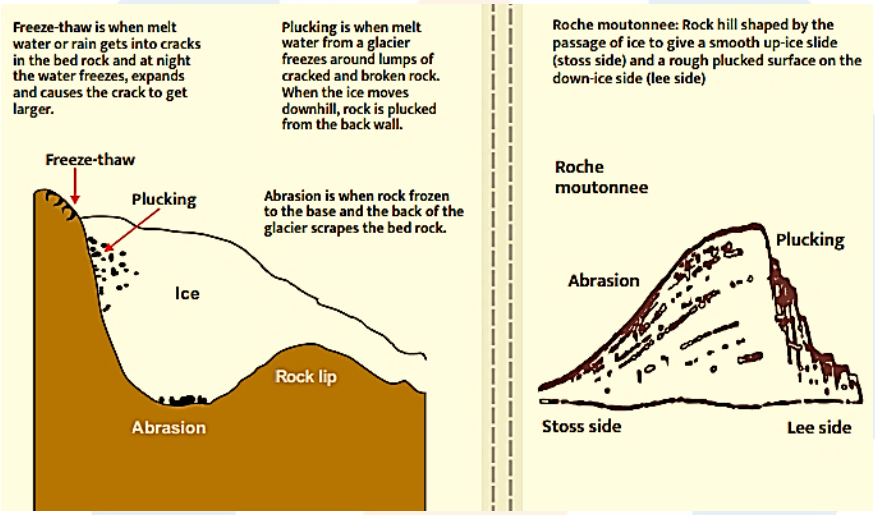
a. Tremendous erosion due to friction caused by the sheer weight of the ice.
b. Drags rock fragments, gravel, and sand, acting as efficient erosive tools.
c. Leaves behind scratches and grooves on rocks.
d. Can reduce high mountains into low hills and plains.

d) **Landforms Created by Glacial Erosion :**

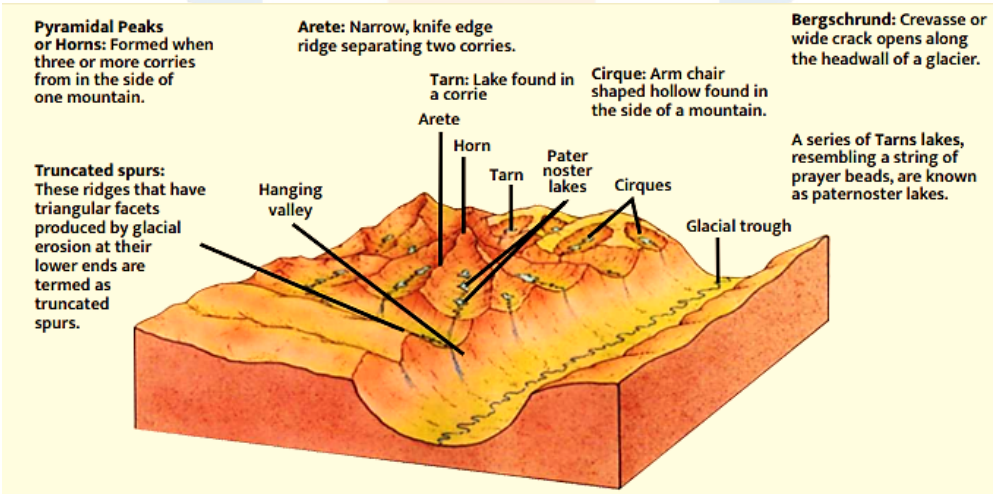
a. **Cirque (or Corrie) :** Armchair-shaped hollow on the side of a mountain.
b. **Arete :** Narrow, knife-edge ridge separating two cirques.
c. **Pyramidal Peaks :** Formed when three or more cirques form on the side of one mountain.
d. **Tarn :** Lake found in a cirque.
e. **Bergschrund :** Wide crack or crevasse along the headwall of a glacier.

e) Other Glacial Erosional Landforms :

a. **'U'-shaped Valley :** Glacier widens preexisting valleys, forming a 'U'-shaped valley.
b. **Hanging Valley :** Tributary glaciers create smaller valleys at higher levels, forming hanging valleys.
c. **Truncated Spurs :** Glacier erodes or truncates lower ends of ridges extending into the valley.
d. **Paternoster Lakes :** Series of tarns or lakes resembling a string of prayer beads.
e. **Roche Moutonnee :** Rock hill shaped by glacial passage with a smooth up-ice side and a rough, plucked surface on the down-ice side.



B) The Landforms created by glacial erosion :



C) Glacial landforms resulting from deposition :

1. Rock Fragments Transport : Glaciers carry rock fragments scraped and plucked from the underlying

bedrock.

2. **Glaciated Lowland Features :** Glacial deposition creates features in glaciated lowlands.

3. **Types of Glacial Deposits :**
   - **Boulder Clay or Glacial Till :** Unassorted coarse and fine debris dropped by melting glaciers.
   - **Outwash Deposits :** Rock debris small enough to be carried by meltwater streams; stratified and assorted.
   - **Erratics :** Large boulders deposited far from their origin by glaciers.
   - **Moraines :** Piles of rock deposits left by melting glaciers.

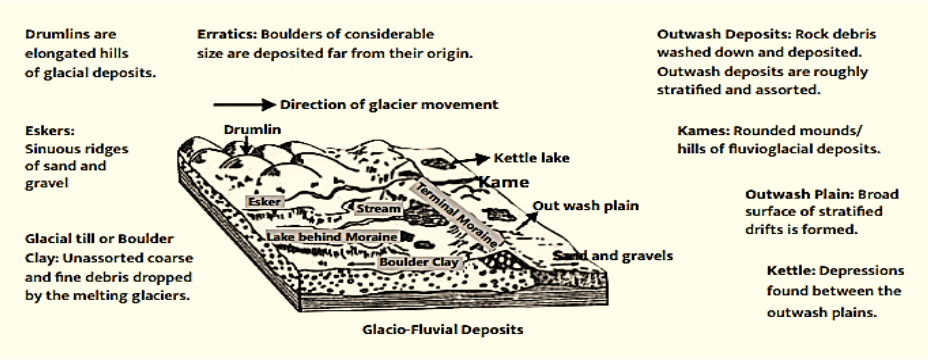
4. **Types of Moraines :**
   - **Terminal Moraines :** Found at the furthest point reached by a glacier.
   - **Lateral Moraines :** Deposited along the sides of the glacier.
   - **Medial Moraines :** Found at the junction between two glaciers.
   - **Ground Moraines :** Disorganized piles of rocks of various shapes, sizes, and differing rock types.

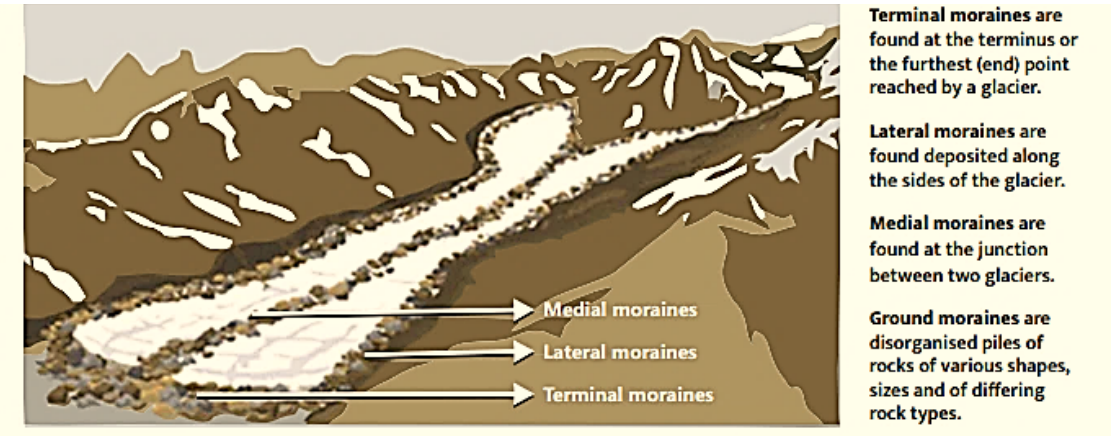
5. **Outwash Plain and Kettles :**
   - **Outwash Plain :** Broad surface of stratified drift formed by melting water.
   - **Kettles :** Basins or depressions found between outwash plains.

6. **Kames :** Rounded mounds or hills of fluvioglacial deposits.

7. **Eskers :** Sinuous ridges of sand and gravel marking former sub-glacial meltwater streams.

8. **Drumlins :**
   - Elongated hills of glacial deposits, often occurring in groups.
   - Drumlin swarm or basket of eggs indicates the direction of glacier movement.
   - Formation details are still debated among glaciologists.





■ **4. Landform By the Action Of Wind (Aeolian) :** Most Of The Deserts Are Confined Within The 15° To 30° North And South Latitudinal Belts. Factors Including : Mean Annual Rainfall, Cold Currents, Continetiality, Etc

- **Processes involved :** Attrition, Deflation, Abrasion or Corrosion, etc
- Surfaces formed in desert.

Surface	Features	Example
Erg (Sandy or True Desert)	Almost horizontal, sand sheets or of regular dune lines, or of an undulating sand sea	Erg in the Sahara and Saudi Arabia, koum in Turkmenistan.
Stony Desert	Stony desert, horizontal sheets of smoothly angular gravel cover the Surface.	Reg in Algeria and Serir in Libya and Egypt.
Badland	Characterised by deep dissection, ravines, gullies, and sharp- edged ridges	South Dakota, U.S.A.
Hamada or Rocky Desert	Large areas of sand and dust, with patches of barerock	Deserts in Sahara are known as Hamada.
Mountain Desert	In highlands, mountain ranges and the plateau areas	Ahaggar Mountain and Tibesti mountain of Sahara.

■ **a) Erosional Landforms-Wind :**

1. **Ventifacts or Dreikanter :**
   - Stones with highly polished, flattened facets due to windblown sand erosion.
   - Facets cut in sequence, correlating with dominant wind direction.
   - Dreikanter has three curved facets.
2. **Ventifact :** Features highly polished and flattened by windblown sand erosion.
3. **Rock Pedestals or Mushroom Rocks :**
   - Irregular pillars formed in rocks with alternate layers of soft and hard rock.
   - Sand-blasting by winds creates grooves and hollows, carving fantastic pillars.

4. **Yardangs :** Streamlined hills carved from bedrock or consolidated material by wind abrasion, dust, and sand.

5. **Zeugens :**

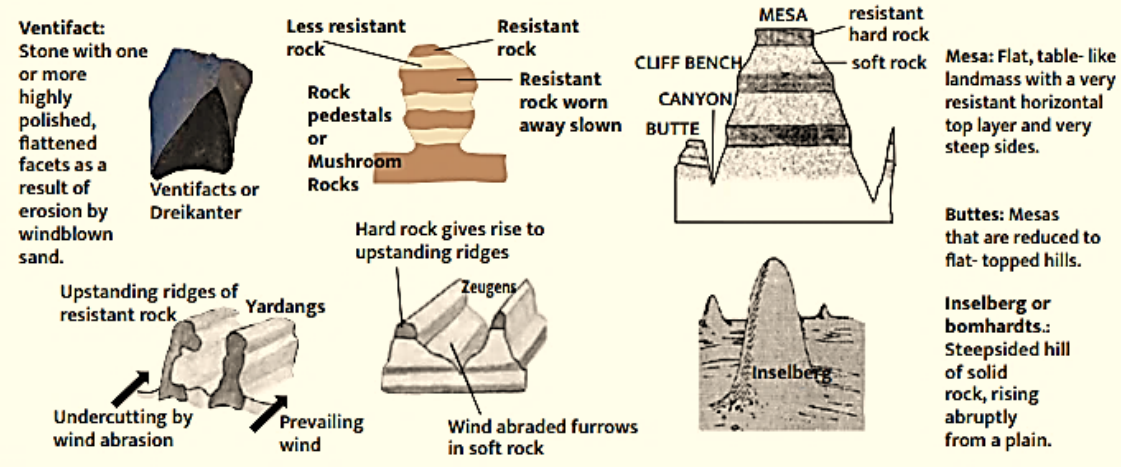
   - Ridge and furrow landscape formed by wind abrasion on a surface layer of hard rock over soft rock.
   - Zeugens are ridges, reaching heights up to 100 feet, undercut and gradually worn away.

6. **Mesas and Buttes :**

   - **Mesa :** Flat, table-like landmass with a resistant horizontal top layer and steep sides.
   - **Buttes :** Flat-topped hills formed as mesas undergo denudation through ages.

7. **Inselbergs :**

   - Steep-sided hills of solid rock rising abruptly from a plain.
   - Derived from the German word "Island Mountain."
   - Often made of granite; in arid regions, they are also called bomhardts.



b) Depositional Landforms-wind :

Wind Depositional Landforms :

1. **Ripple Marks :**

   - Small-scale depositional features of sand formed by wind in unconsolidated sediments.
   - Patterns may be longitudinal or transverse.

2. **Sand Dunes :**

   - Mounds or ridges of wind-blown sand, often mobile.
   - Height varies from a few meters to several hundred meters; common in erg deserts.

Barchans :

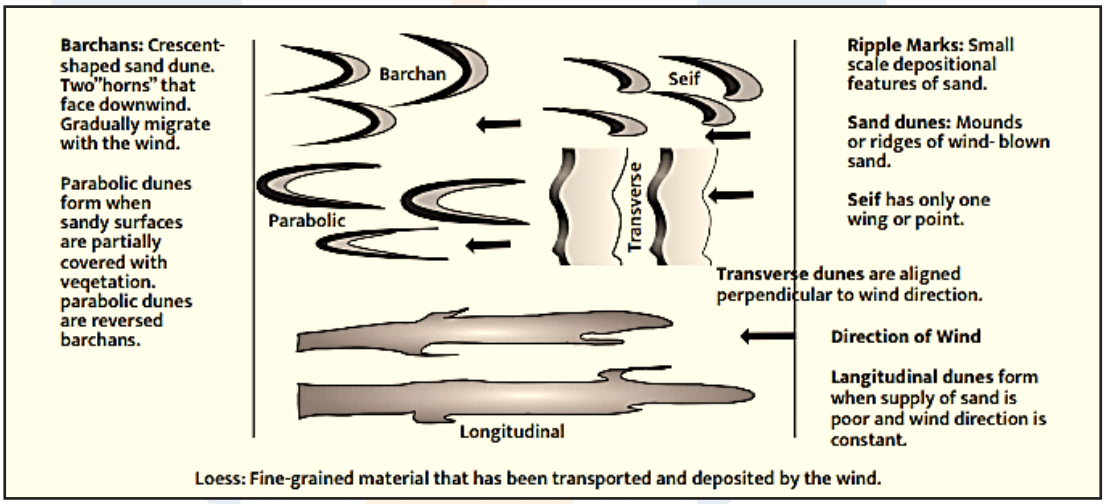
- Crescent-shaped dunes with two **"horns"** facing downwind.
- Steeper slope (slip face) faces away from the wind.
- Migrate with wind due to erosion on the windward side and deposition on the leeward side.

Longitudinal Dunes (Seif) :

- Long, straight dunes parallel to the wind direction.
- Formed in regions with wind from more than one direction and abundant sand supply.

3. **Loess :**

- Fine-grained material transported and deposited by the wind.
- Sediments originate from glacial outwash plains or desert areas with little vegetation.
- Prevailing winds can create thick deposits of loess downwind of source areas.
- In China, wind-borne dust from the Gobi Desert is known as Hwangtu or "yellow earth."



Loess: Fine-grained material that has been transported and deposited by the wind.

■ **c) Fluvial Desert Landforms :** Influenced by the action of running water :

Fluvial Desert Landforms :

1. **Flash Floods in Deserts :**

- Occasional intense rainfall in arid and semi-arid regions can lead to flash floods.
- Rapid runoff results in the sweeping of loose gravels, sand, and fine dust down hillsides.
- Formation of deep gullies and ravines, creating badland topography, with the Chambal River as an example.

2. **Wadis :**

- Wide channels formed during flash floods in deserts.
- Typically dry for most of the time.

3. **Pediments :**

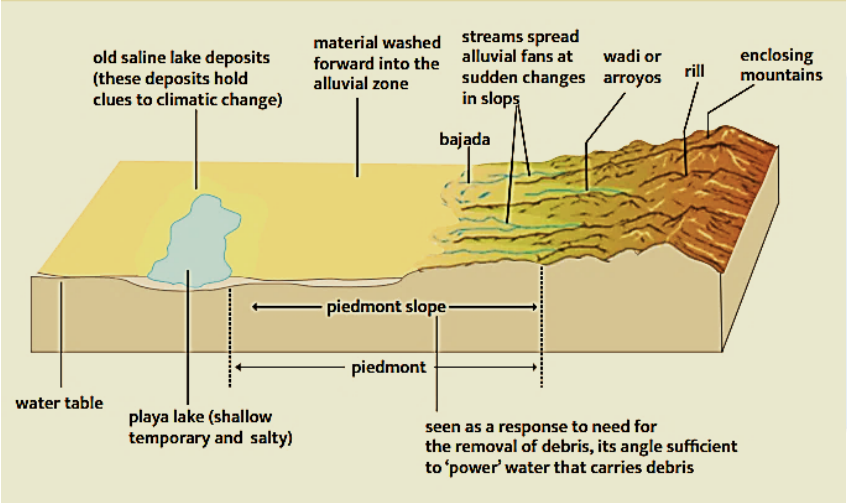
- Erosional plain at the base of surrounding mountain scraps.
- Formed through the action of water in deserts.

4. **Bajada (Bajada) :**

- Depositional feature composed of alluvial material deposited by seasonal streams.
- Also referred to as depositional plains of deserts.

5. **Playas :**

- Shallow lakes (playa lakes) may form in the central basin of a desert after abundant rainfall.
- These lakes are temporary and exist for only a few days or weeks.
- Evaporation and infiltration lead to the formation of a dry, flat lake bed known as a playa.



■ **5. Karst Topography :** Limestone Or Dolomitic Region Showing Typical Landform Produced By The Action Of Groundwater Through The Processes Of Solution And Deposition Is Called Karst Topography.

a) **Erosional landform :**

- Sinkholes, Swallow Holes, Dolines, Uvalas/Valley Sink

1. **Sinkhole :**

- A surface depression or hole in limestone terrain.
- Varies in size, from a few feet to over 100 meters deep.
- Can collapse through the roof of an underground cavern, forming a collapse sinkhole.

2. **Swallow Hole :**

- Enlargement of sinkholes due to continuous dissolution of limestone.
- Coalescence of closely spaced sinkholes into one large hole.

3. **Dolines in Karst Erosion :**

- Further enlargement of swallow holes.
- Continuous solution leads to the formation of larger depressions known as dolines in karst erosion.

4. **Uvalas/Valley Sink :**

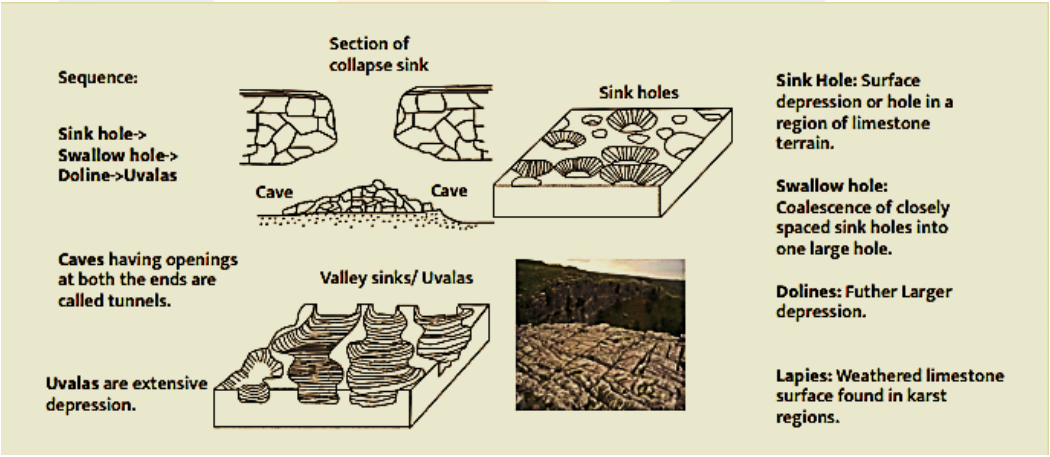
- Extensive depressions formed by the coalescence of several dolines.
- Larger uvalas can cover several square kilometers with depths of up to 200 meters.
- Formed due to continuous solution, enlargement of dolines, collapse of upper cave roofs, or coalescence of various sinkholes.

5. **Lapies :**

- Weathered limestone surface in karst regions.
- Consists of etched, fluted, and pitted rock pinnacles separated by deep grooves.
- Formed by the solution of rock along joints and areas of greater solubility by water containing carbonic and humic acids.

6. **Caves :**

- Prominent in areas with alternating beds of rocks, including limestones or dolomites.
- Formed by water percolation, dissolving limestone along bedding planes.
- Can have a maze of caves at different elevations, with openings for cave streams.
- Caves with openings at both ends are called tunnels.



b) **Depositional Landforms :**

1. **Stalactites and Stalagmites :**

- Major depositional features in limestone caverns.
- Water containing limestone in solution seeps through cavern roofs in the form of continuous drops.

2. **Stalactites :**

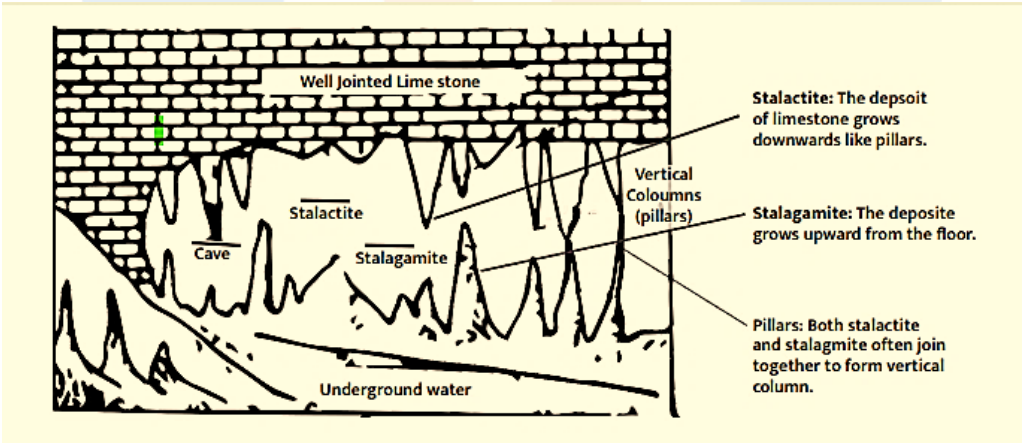
- Formed as a portion of water dropping from the cavern ceiling evaporates.
- Small deposits of limestone are left behind on the cavern roof.
- This process continues, and the limestone deposit grows downwards like pillars.
- Stalactites resemble icicles hanging from the cave ceiling.

3. **Stalagmites :**

- Formed when the remaining portion of water falling from the cavern roof reaches the floor.
- A part of it evaporates, leaving small deposits of limestone on the cavern floor.
- These deposits grow upward from the cavern floor.
- Stalagmites often join stalactites, forming vertical columns and pillars in the caverns.

4. **Column and Pillar Formation :**

- Over time, stalactites and stalagmites may join together, creating vertical structures known as columns or pillars.
- This fusion occurs as the continuous deposition from the ceiling and floor unites in the cavern environment.



8 INSOLATION

- The ultimate sole source of atmospheric energy is in fact heat and light received through space from the Sun. This energy is known as **solar insolation.**
- The Earth receives only a tiny fraction of the total amount of Sun's radiations. Only two billionths or two units of energy out of 1,00,00,00,000 units of energy radiated by the sun reaches the earth's surface due to its small size and great distance from the Sun. The unit of measurements of this energy is **Langley (Ly).**

Factors Influencing Insolation :

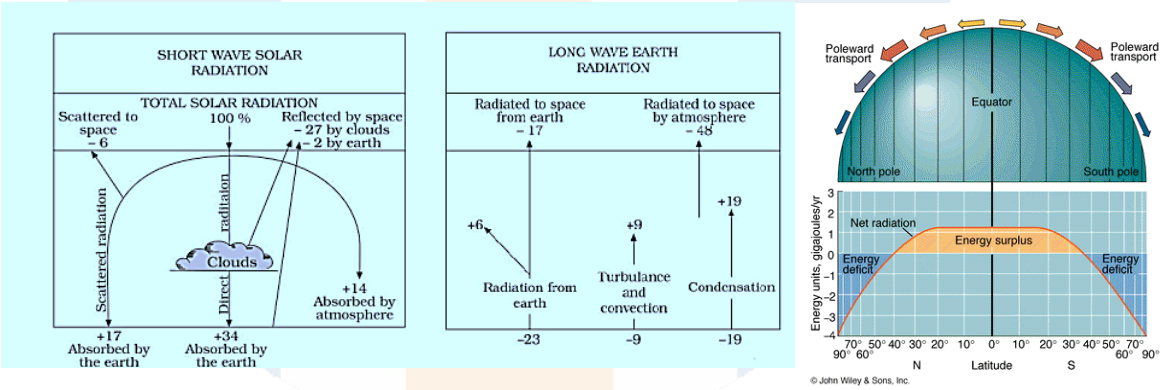
1. **Revolution of earth around sun-**annual insolation received by the earth at perihelion is slightly more than the amount received at aphelion.
2. **The rotation of earth on its axis-**earth rotates around its axis and makes an angle of 66½ with the plane of its orbit round the sun. This particular characteristic of earth has great amount of influence on the amount of insolation received at different latitudes.
3. **The angle of inclination of the sun's rays-**The angle formed by the sun's ray with the tangent of the earth's circle at a point is called angle of incidence.
   - When the sun is almost overhead, the rays of the sun are vertical. The angle of incidence is large.
   - The sun's rays with small angle traverse more of the atmosphere than rays striking at a large angle. Longer the path of sun's rays, greater is the amount of reflection and absorption of heat by atmosphere.
4. **The length of the day :** the duration of day is controlled partly by latitude and partly by the season of the year. The amount of insolation has close relationship with the length of the day. In summers, the days being longer the amount of insolation received is also more. As against this in winter the days are shorter the insolation received is also less.
5. **The transparency of the atmosphere :** The earth's atmosphere is more or less transparent to short wave solar radiation which has to pass through the atmosphere before striking the earth's surface.
6. **Solar variatio :** Sunspots are temporary phenomena on the photosphere of the Sun that appear visibly as dark spots compared to surrounding regions. When there is an increase in sun spots it leads to increase1 in the amount of solar radiation. But this change is almost negligible.
7. **Topographical variations :** Maximum insolation is received over the subtropical deserts. Equator receives comparatively less insolation than the tropics due to presence of clouds. Generally, at the same latitude the insolation is more over the continent than over the oceans because more clouds over the oceans reflect sun rays back into space. Isohels are lines connecting points on the earth surface that receive equal amounts of sunshine.

Heating and Cooling of the Atmosphere :

1. **Radiation :** it is the process where transference of heat is directly from space to atmosphere through electromagnetic radiations . The Earth, on the other hand, having a cool surface, re-radiates heat at much longer wavelengths. The reradiate heat from the earth is called Terrestrial radiation.
2. **Conduction :** When two objects of unequal temperature come in contact with each other, heat energy flow from the warmer object to the cooler object and this process of heat transfer is known as conduction.
3. **Convection :** In this process, energy is transferred through motion of molecules itself. The air in contact with the earth rises vertically on heating in the form of currents and further transmits the heat of the atmosphere.
4. **Advection :** The transfer of heat through horizontal movement of air is called advection. These winds take the characteristics of their source of origin with them. The temperature of a place will rise if it lies on the path of winds coming from warmer regions.

Heat Budget :

- The average temperature of the earth overall does not change in spite of continuous supply of sun rays. This is possible only when an equal amount of energy is sent back to space by the earth's system. In the way there is balance between incoming solar radiation and outgoing terrestrial radiations. This balance is known as the heat budget of the earth.

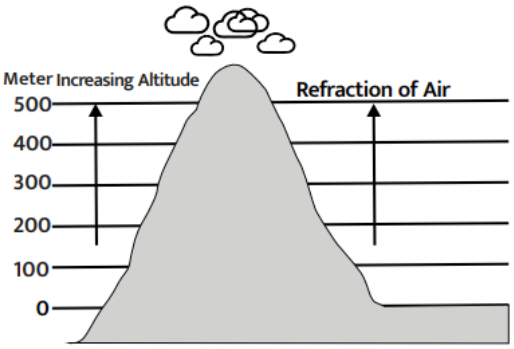


Temperature :

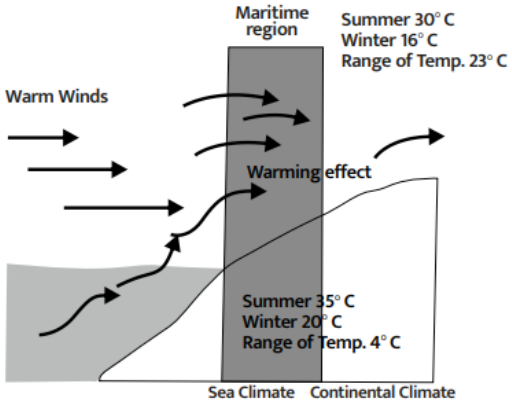
following factors determine the temperature of air at any place :

1. **The latitude of the place-**Moving from equator towards poles the inclination of the suns ray increase
2. **The altitude of the place-**lower layer of the atmosphere are comparatively warmer than the upper layer
3. **Distance from the Sea :** Moderating effect due to nearness to sea while interior areas have extreame of temperature
4. **Ocean Currents -**limited to the adjoining coastal areas
5. **Air-mass circulation-** masses in from of winds help in the redistribution of temperature
6. **Slope, Shelter and aspect-**slopes of a mountain facing the sun experiences high temperature than the slpoes on the leeward side .

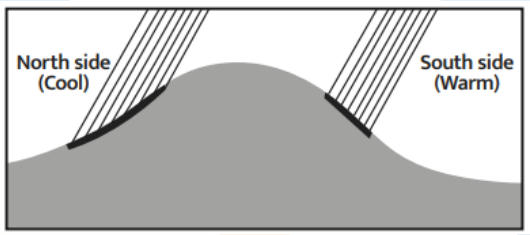
7. **Nature of ground surface**-snow has very high albedo, thus reflect much if the insolation. sandy surface record high temperature due to absorpation.



(a) -effect of altitude



(b) -maritime influence

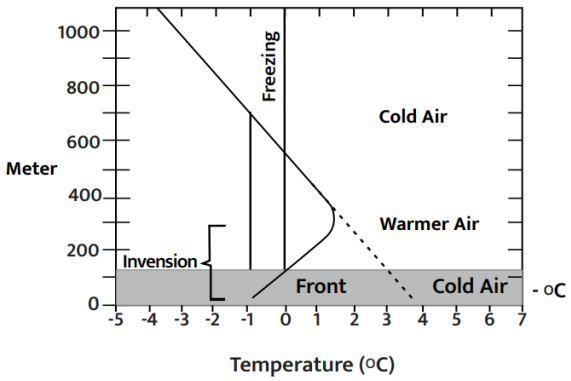


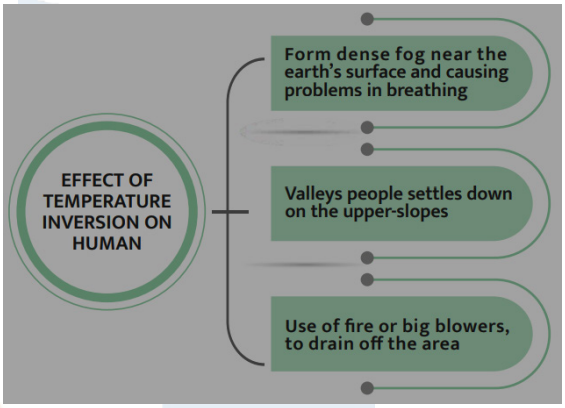
JANUARY	JULY	TERM	SIMILER ASPECT
Isotherms deviate to the north over the ocean and to the south over the continent.	Isotherms generally parallel to the latitude.	Isotherms	Line joining places having equal temperature.
		Isobars	Line joining places having equal pressures.
In southern hemisphere, more or less parallel to the latitudes due to less landmass and the variation in temperature.		Isohaline	Salinity (amount of salt) of sea water is same.
		Isohyte	Amount of precipitation is same.
		Isohel	Amount of sunshine is same.

Temperature Anomaly: Difference between the mean temperature of any place and the mean temperature of its parallels. Maximum temperature anomalies are found in the Northern hemisphere.

- Isotherms are generally parallel to equator .closely drawn isotherms indicate rapid change in temperature and vice -versa.
- **Temperature Inversion :** Generally , temperature decreases with normal lapse rate 6.5^{0}C per 1000m, the rise of temperature with height is known as temperature inversion.

CONDITIONS	REASON
Long winter nights	The bottom layer of atmosphere in contact with the ground is also cooled and the upper layer remains relatively warm.
Cloudless clear sky	No obstruction to the terrestrial radiation.
Dry air	No obstruction to the terrestrial radiation.
Calm atmosphere	Cold air stays put near the ground.
Ice covered surface	Air in contact with it is also cooled but the upper layer remains warm.





Temperature Ranges :

1. Diurnal range of Temperature- Daily pattern of temperature change .generally minimum is just before sunrise and maximum is about 2.00 PM
2. Annual average range of temperature - difference between the average temperature of hottest month and average temperature of the coldest month of the year .lower in low latitudes and higher in high latitudes.

■ Atmospheric Circulation :

1. Differential Heating :

- Varied insolation causes differential heating of Earth and its atmosphere.
- Temperature differences lead to air density variations.
- Air movement from high to low pressure results in three-dimensional global motion.

2. Atmospheric Pressure :

- Atmosphere held by Earth's gravitational pull.
- Atmospheric pressure is the weight of a column of air from sea level to the atmosphere's top.
- Measured in millibars or pascals, depicted by isobars on maps.
- Ranges from 950 to 1050 millibars.

- Barometric slope or pressure gradient shows gradual changes.

3. **Pressure Variations :**

- Lower atmosphere pressure decreases rapidly with height.
- Approximately 1 mb decrease for every 10 m elevation.
- High vertical pressure gradient doesn't lead to strong vertical air currents.
- Small horizontal pressure gradients crucial for wind direction and velocity.
- Pressure measured at a station reduced to sea level for comparison.

4. **Pressure Systems :**

- Low-pressure system enclosed by isobars, with the lowest pressure at the center.
- High-pressure system also enclosed by isobars, with the highest pressure at the center.
- Sea-level pressure conditions differ between hemispheres due to land-sea distribution.
- Northern hemisphere experiences greater seasonal pressure contrasts.

5. **Forces Governing Air Movement :**

Pressure Gradient :

- Primary force causing air movement from high to low pressure.
- Exerts force proportional to the steepness of the gradient.

Coriolis Force :

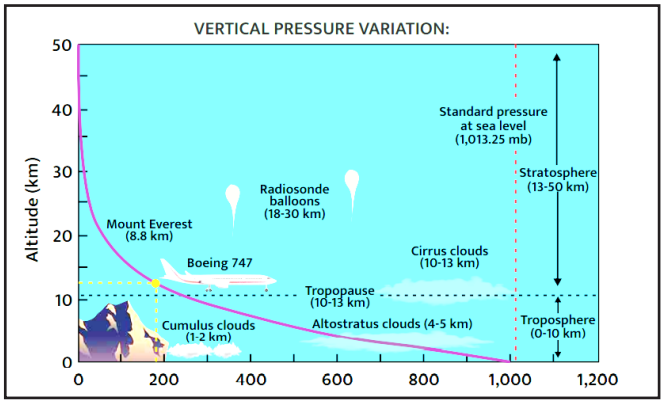
- Deflection of winds due to Earth's rotation.
- Deflection to the right in the northern hemisphere, to the left in the southern hemisphere.
- Increases with wind speed and distance from the Equator.

Centripetal Force :

- Applies when isobars are curved, as in cyclones.
- Acts centripetally, pulling air inwards.

Frictional Force :

- Reduces wind speed.
- Greatest at the surface, diminishes with height.
- Weakens Coriolis force, allowing the pressure gradient to dominate.



Geostrophic Wind :

Wind Dynamics :

- Wind velocity and direction result from wind-generating forces.
- Upper atmosphere winds (2-3 km above the surface) are influenced by pressure gradient and Coriolis force.
- Free from surface friction effects.

Geostrophic Wind :

- Winds at this height blow at right angles to the pressure gradient.
- Geostrophic wind occurs when pressure gradient force balances exactly with the Coriolis force.

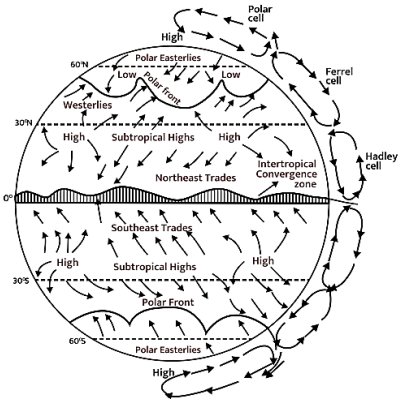
Balanced Forces :

- Geostrophic wind represents a state of equilibrium between pressure gradient and Coriolis forces.
- Forces act in diametrically opposite directions, resulting in a balanced air motion.

Dynamic Adjustments :

- Not all winds are perfectly geostrophic due to changing pressure patterns.
- When patterns change, winds strive to readjust, seeking a new geostrophic speed.
- Geostrophic wind represents a balanced and stable state in the upper atmosphere.

Distribution of Pressure Belts :



1. Equatorial Low Pressure Belt :

- Extends from the equator to 10°N and 10°S latitudes.
- Formed due to Sun's intense heating.
- Known as the Doldrums or Inter Tropical Convergence Zone (ITCZ).
- Characterized by vertical currents, lacking horizontal movement.

2. Sub-tropical High Pressure Belt :

- Extends roughly between 25° and 35° latitudes in both hemispheres.
- Result of equatorial air rising, deflecting towards poles, and descending in these regions.
- High pressure due to cold, descending air.
- Also known as Horse Latitudes, marked by calm conditions with feeble and variable winds.
- Discontinuous presence due to land masses; more prominent over oceans as discrete cells.

3. **Sub-polar Low Pressure Belt :**

- Extends along 60° latitudes (55°-65°) in both hemispheres.
- Convergence of winds from sub-tropics and polar regions.
- Rise of air creates a low-pressure belt.
- Great temperature contrast leads to cyclonic storms.
- More pronounced in the Southern Hemisphere (sub-antarctic low).

4. **Polar High Pressure Belt :**

- Results from low temperatures, air compression, and increased density.
- High pressure persists throughout the year.
- More prominent over the Antarctic continent than the North Pole.
- In the Northern Hemisphere, extends from Greenland to northern Canada islands.

5. **Geographical Factors :**

- Presence of land masses and ocean influences the continuity and characteristics of pressure belts.
- Land masses at certain latitudes can disrupt the typical pressure patterns observed over oceans.

■ Shifting Of Belts ;

The pressure belts swing around equator :

1. To the north of equator in July 2. To the south of equator in Dec

Reason-Due to the apparent annual migration of the sun :

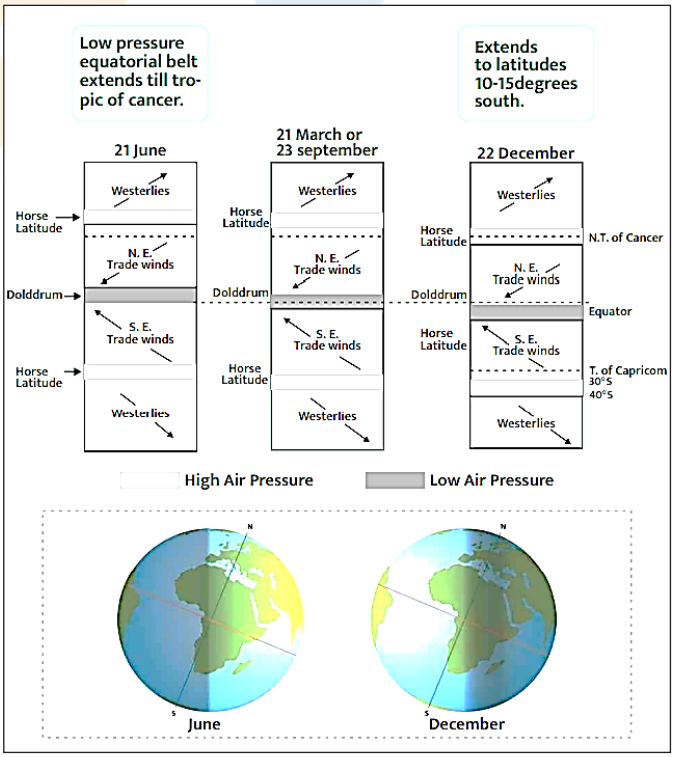
■ General Circulation of the Atmosphere :

1. **Wind Characteristics :**

- Result of pressure gradient due to differential heating of the Earth.
- Winds in the atmosphere exhibit varying directions and intensities within the same day.

2. **Classification of Wind Movement :**

- **Primary Circulation :**
- Planetary wind systems related to global pressure belt arrangement.
- Sets the framework for other circulation patterns.



- **Secondary Circulation :**
- Includes cyclones, anti-cyclones, and monsoons.
- **Tertiary Circulation :**
- Encompasses local winds generated by specific local causes (topography, sea influences).

3. **Planetary Winds :**

- Primary winds from high to low pressure belts.
- Comprise Trade winds, Westerlies, and Polar Easterlies.

Hadley Cell (Tropics) :

- Air rises at the ITCZ (Inter Tropical Convergence Zone) due to high insolation.
- Converging air moves towards the poles, sinking at about 30°N and S.
- Forms subtropical high, and flows back towards the equator as easterlies.

Ferrel Cell (Middle Latitudes) :

- Circulation of sinking cold air from poles and rising warm air from subtropical high.
- Deflected by Coriolis force, becomes westerlies.
- Meeting along sub-polar low, ascending in the troposphere.
- Descending above subtropical high and polar high, forming Ferrel cell and Polar cell.

Polar Easterlies :

- Wind moving away from polar high to sub-polar low, becoming easterlies due to Coriolis force.

Prevailing Westerlies :

- Variable in direction and intensity.
- Influenced by polar air masses, cyclones, and anti-cyclones.
- Stronger in colder conditions; referred to as 'roaring forties', 'furious fifties', and 'screaming sixties' in the southern hemisphere.

Polar Front :

- Zone of convergence where winds from sub-tropical and polar high belts meet, leading to cyclonic storms or low-pressure conditions.

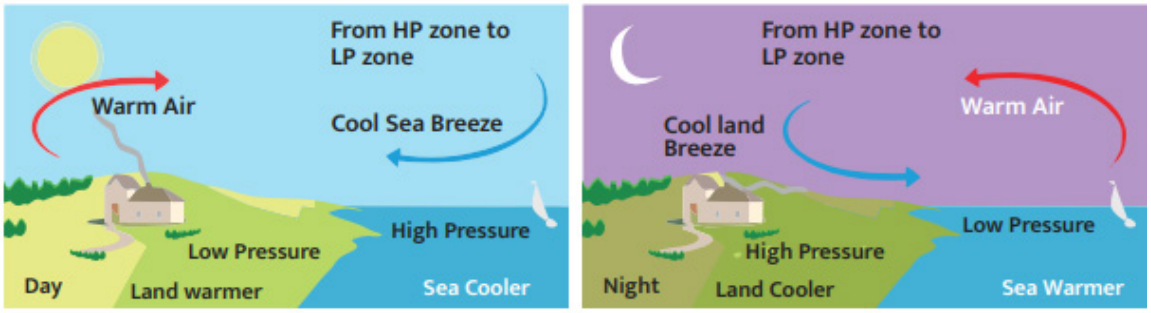
■ Local Winds :

Sea Breeze (Day) :

1. **Cause :**
   - Land heats up faster during the day, becoming warmer than the sea.
   - Heated air over the land rises, creating a low-pressure area.
   - Sea remains relatively cool, resulting in higher pressure over the sea.
2. **Pressure Gradient :** Pressure gradient created from sea to land.
3. **Wind Direction :** Wind blows from the sea to the land.
4. **Intensity :** Reaches maximum intensity in midafternoon.
5. **Significance :** Beneficial for fishermen returning from the sea after a successful catch.

Land Breeze (Night) :

1. **Cause :**
   - Land cools faster at night compared to the surrounding sea.
   - Results in relatively high pressure over the land.
2. **Pressure Gradient :** Pressure gradient created from land to sea.
3. **Wind Direction :** Wind blows from the land to the sea.
4. **Intensity :** Reaches its peak shortly before sunrise.
5. **Significance :** Facilitates fishermen entering the sea in the morning and staying until mid-afternoon.



■ The Mountain and Valley Breezes :

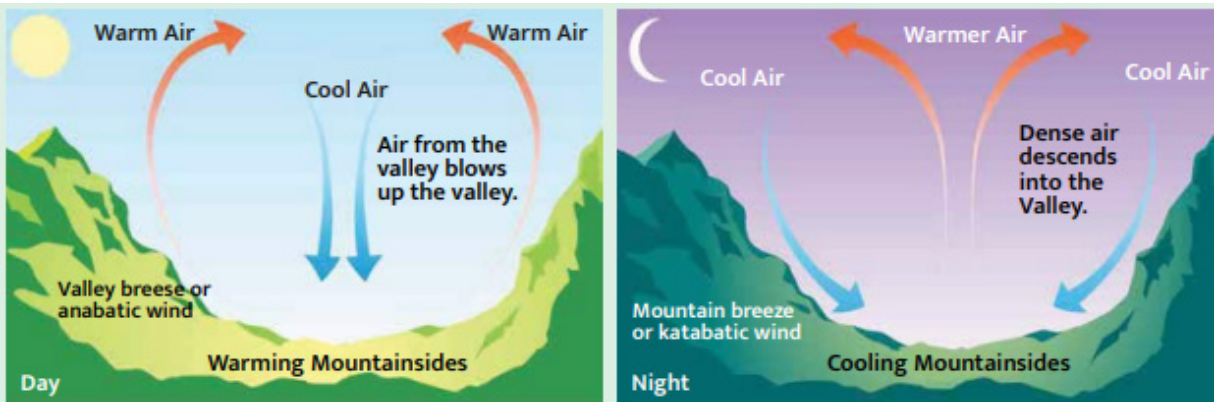
Valley Breeze (Day) :

1. **Daytime Heating :** Slopes heat up more than the valleys during the day.
2. **Pressure Conditions :**
   - Low pressure over the slopes.
   - Higher pressure in the valleys below.
3. **Wind Movement :** Air moves up from the slopes.
4. **Resulting Wind :** Known as the valley breeze or anabatic wind.
5. **Cloud Formation :**
   - Sometimes accompanied by cumulus cloud formation near mountain peaks.
   - Can lead to orographic rainfall.

Mountain Breeze (Night) :

1. **Nighttime Cooling :** Slopes cool down during the night.
2. **Pressure Conditions :** Dense air descends into the valley.
3. **Wind Movement :** Cool air from high plateaus and ice fields drains into the valley.
4. **Resulting Wind :** Known as the mountain breeze or katabatic wind.

- **Note :** This combination of local winds undergoes a daily reversal, influenced by the heating and cooling patterns of mountain slopes and valleys.



Other Local winds :

Hot Local Winds	Characteristics	Geographic Origin	Impact/Usage
Loo	Hot and dry wind Blows strongly over northern plains of India and Pakistan Occurs in May and June West to east direction	Northern plains of India and Pakistan	Afternoons experience Temperature varies : 45°C to 50°C
Foehn	Strong, dusty, dry, warm wind Develops on leeward side of Alps mountain ranges Ascends and crosses the mountain barrier	Leeward side of the Alps mountain ranges	Causes precipitation on windward side Descends as warm and dry wind on northern slopes Temperature varies : 15°C to 20°C
Chinook	Hot and dry wind Moves down eastern slopes of Rockies in U.S.A. and Canada Literally means 'snow eater'	Eastern slopes of the Rockies in U.S.A. and Canada	Melts snow earlier, clearing grasslands Beneficial to ranchers
Sirocco	Hot, dry, dusty wind Originates in Sahara desert Crosses the Mediterranean Sea	Sahara desert Crosses the Mediterranean Sea	Harmful to vegetation and cropsLocal names : Leveche, Khamsin, Gharbi Frequent in spring< Lasts a few days
Harmattan	Strong dry wind Blows over northwest Africa from the northeast	Blows directly from the Sahara desert	Hot, dry, and dusty wind Provides relief from moist heat Beneficial to health, known as 'the doctor' Contains fine desert dust, causing haziness and issues for caravan traders

Cold Local Winds	Characteristics	Geographic Origin	Impact/Usage
Mistral	• Originates on the Alps. • Moves over France towards the Mediterranean Sea through the Rhone valley. • Very cold, dry, high-velocity winds. • Brings temperature below freezing point.	Alps, Rhone valley, France, Mediterranean Sea	• Requires protective measures against extreme cold Houses and orchards in Rhone valley. • have trees and hedges as shields against Mistral

Bora	• Cold, dry north-easterly wind- Blows down from the mountains in the Adriatic Sea region. • Caused by pressure difference between continental Europe and the Mediterranean Sea. • Occurs in winter.	Mountains in the Adriatic Sea region, continental Europe, Mediterranean Sea	• Sometimes attains speeds of over 150 kmph. • Caused by pressure differenceOccurs in winter
Blizzard	• Violent and extremely cold wind. • Laden with dry snow. • Common occurrence in the Antarctic. • Wind velocity can reach 160 kmph, temperature as low as -7°C.	Antarctic region	• Extremely cold and violent. • Laden with dry snow. • High wind velocity and low temperatures. • Common in the Antarctic region.

■ Upper Air Circulation (Jet stream) :

Features of jet streams :

- **Narrow Belts at High Altitude :**
  - Located near the top of the troposphere.
  - Characterized by narrow belts.

Variable Speed : Speed ranges from about 110 km/h in summer to over 180 km/h in winter.

Circular Shape with Radial Speed Variation :

- Circular shape, and speed decreases radially outwards.
- Analogous to a river, where the current is strongest in the center and weaker toward the banks.

Dimensions :

- Several hundred kilometers wide.
- Depth ranges from about 2 km to 5 km.

Meandering Circulation :

- Flow is wavy and meandering.
- Meandering winds are known as Rossby waves.

Altitude and Latitude Changes :

- Dips and rises in altitude and latitude.
- May split, form eddies, and disappear, reappearing elsewhere.

Seasonal Shifts with Sun's Elevation :

- Follows the sun's elevation changes.
- Shifts poleward as the sun's elevation increases in spring.
- Moves toward the equator as the sun's elevation decreases in autumn.

Penetration into Lower Stratosphere :

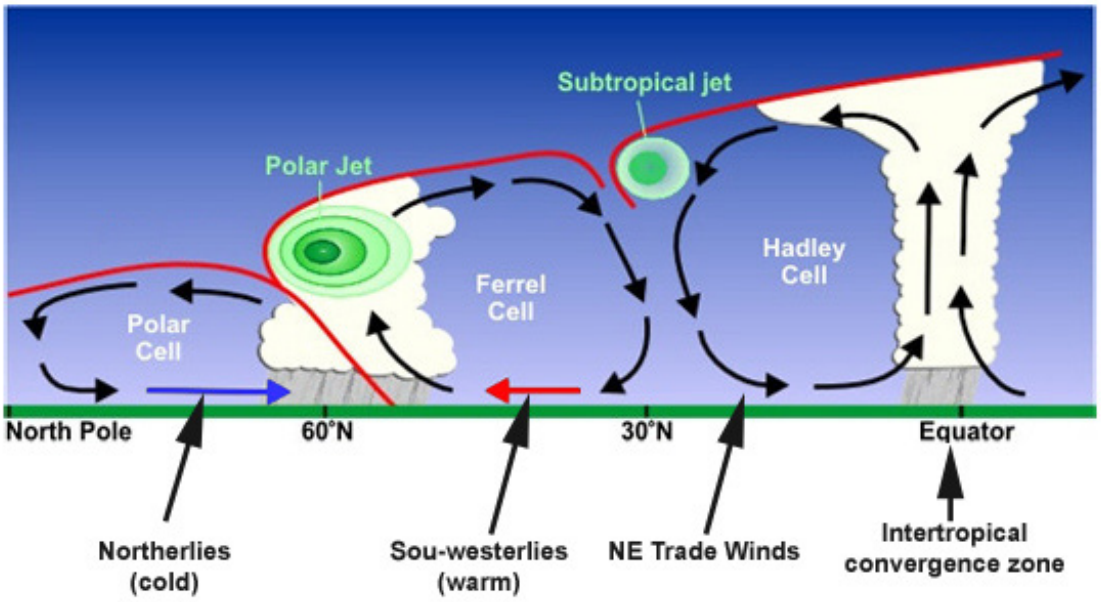
- On occasions, breaks through the tropopause into the lower stratosphere.
- Allows water vapor to reach the lower stratosphere, leading to occasional cirrus clouds.
- Effect may extend down to an altitude of about 3 km from the Earth's surface.

Longitudinal Variation in Strength :

- Well-marked longitudinal variation in strength.
- In winter, highest wind velocities near the east coast of Asia and weakest over the eastern Atlantic and Pacific Oceans.
- In summer, strongest jet is positioned along the Canadian border and Mediterranean region.

Two Permanent jet streams zones in each hemisphere -

1. Sub - tropical jet stream
2. Polar front jet stream



Type :

- Polar front jet stream (40-60 degree N-S in both hemisphere)
- Sub-tropical jet stream 25-30 degrees N-S in both the hemispheres.
- Eastern Tropical Jet Stream Between equator and 20-degrees north in south-east Asia, India and Africa.

Consequences of jet stream :

1. Affect weather conditions.
2. Contribute to originating cyclones, anticyclones, storms and depressions.
3. Bursting of monsoon in India : Related to Eastern Tropical Jet.
4. Speed and considerably save fuel to aeroplanes if flowing in same direction. Still various unknown aspects.

■ AIR MASS :

Air Mass Definition :

- Air mass is a large body of air with little horizontal variation in temperature and moisture.
- Acquires characteristics of the area it stays over for an extended time.

Source Regions :

- Homogenous surfaces where air masses form are called source regions.
- Five major source regions include warm tropical and subtropical oceans, subtropical hot deserts, relatively cold high-latitude oceans, very cold snow-covered continents in high latitudes, and permanently ice-covered continents in the Arctic and Antarctica.

Types of Air Masses :

- Classified based on source regions.
- **Primary air masses :**
  - Maritime tropical (mT)
  - Continental tropical (cT)
  - Maritime polar (mP)
  - Continental polar (cP)
  - Continental arctic (cA)

Attributes of Air Masses :

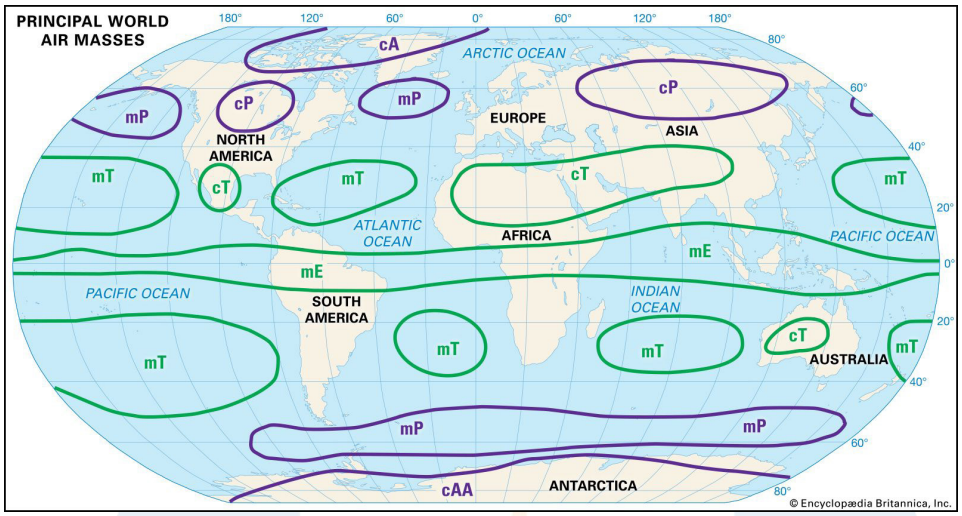
- As air masses move, they can acquire additional attributes.
- Example : Arctic air mass can become maritime polar by picking up warmth and moisture from the ocean.

Changes in Air Masses :

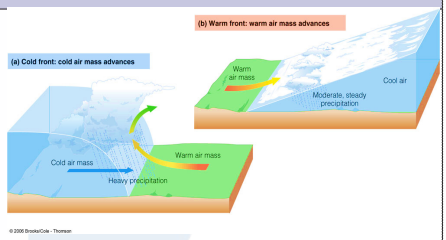
- Internal modifications can occur.
- Resultant air mass from changes is termed secondary air mass.

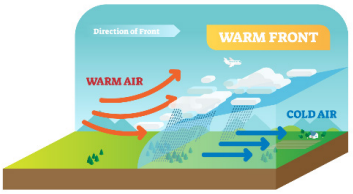
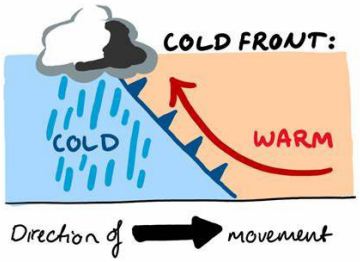
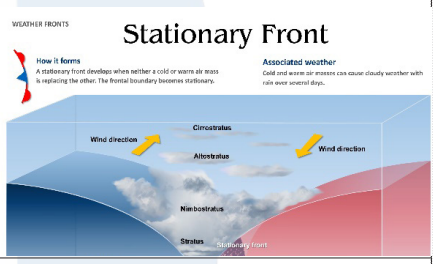
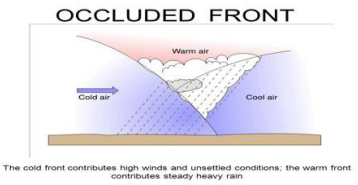
Weather Control :

- Air masses can control weather for extended periods (days to months).
- Weather often occurs along the boundaries of air masses, known as fronts.



FRONTS :

Front Types	Description	
Front Definition :	Boundary zone between two different air masses with distinct properties (temperature, moisture, density, pressure). Formed by converging movements in atmospheric circulation. Fronts do not mix readily; they come in contact along sloping boundaries.	
Frontogenesis Vs. Frontolysis	**Frontogenesis :** Creation of new fronts. Convergence of winds or contraction toward a line augments frontogenesis. Cyclonic wind shear contributes to frontogenesis. Only after the process of frontogenesis has been in operation for quite some time, fronts come into existence.	
	Frontolysis : Destruction or dying of a front. Divergence of winds from a point helps frontolysis. Anticyclonic wind shear prevents front formation or degenerates pre-existing fronts. Process of frontolysis must continue for some time to destroy an existing front. Likely to occur when the wind blows in such a way that the isotherms become packed along the leading edge of the intruding air mass. Likely to occur when fronts move into regions of divergent air flow. On crossing the sub-tropical high-pressure regions, fronts generally disappear.	

Identification of Fronts	Sharp temperature changes over a relatively short distance (sometimes change of 100 to 200°C). Change in moisture content. Rapid shifts in wind direction. Pressure changes. Clouds and precipitation patterns.	
■ **Front Types :**		
1. Warm Front	Warmer, lighter air mass moves against an existing cold and dense airmass. Gradual changes in temperature and wind direction. Cloudy condensation and precipitation occur. Changes are gradual compared to cold fronts.	
2. Cold Front	Cold, dense airmass forces its way under warm and lighter airmass. Friction retards air motion near the ground, causing the cold front to be steeper. Free air aloft has higher velocity.	
3. Stationary Front :	Forms when a cold or warm front stops moving. Results from opposing forces without enough power to move each other. Winds blow parallel to the front.	
4. Occluded Front	Cold front overtakes a warm front. Two types : cold front occlusion (colder overtaking air) and warm front occlusion (colder retreating air). Associated with abrupt temperature changes, cloud formation, and precipitation.	
Cold Front Occlusion Vs. Warm Front Occlusion :	Cold Front Occlusion : Occurs when the cold air overtaking the warm air is colder than the retreating cold air. In the initial stage, weather system of the warm front persists. At the later stages, weather conditions resemble those of the cold front. Overtaking cold airmass plows under both air masses. Warm Front Occlusion : Occurs when the retreating cold air mass is colder than the advancing cold air mass. Advancing cold air, being relatively less dense, overrides the retreating cold air mass.	

■ CYCLONES :

A. Extra-Tropical Cyclones :

Weather disturbances occurring in mid and high latitudes, beyond the tropics.

Formed in areas of convergence where contrasting air masses meet to create polar fronts.

Life Cycle Stages :

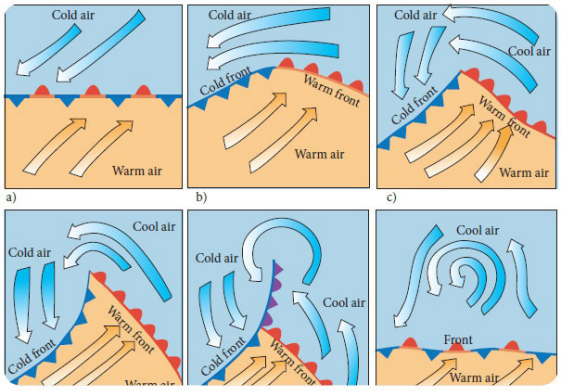


Figure 6.40 Development of Temperate cyclone

1. **Stationary Front :**

   Initial phase with a stationary front.

2. **Cyclonic Circulation Development :**

   (a) arm air from the south and cold air from the north converge.

   (b) Pressure drop triggers anticlockwise cyclonic circulation.

3. **Mature Extra-Tropical Cyclone :**

   Well-developed cyclone with a warm front and a cold front.

4. **Warm Front Cloud Formation :**

   (a) Warm air glides over cold air.

   (b) Sequence of clouds ahead of the warm front causes precipitation.

5. **Cold Front Interaction :**

   (a) Cold front approaches warm air, pushing it up.

   (b) Cumulus clouds develop along the cold front.

6. **Occlusion and Dissipation :**

   (a) Cold front overtakes the warm front.

   (b) Warm air lifted completely, front occluded, and cyclone dissipates.

Variability in Cyclone Shapes :

- Isobars are usually circular or elliptical.
- Some cyclones exhibit a V-shaped depression.
- Broad and shallow cyclones referred to as troughs of low pressure.

Paths and Movement :

- General movement from west to east.
- Frequent trends toward southeast to northeast.
- Aleutian and Icelandic lows are key areas for extra-tropical cyclones.
- Higher frequency and intensity during winter months.
- Average distance covered : about 1000 km per day.
- Invariably move toward higher latitudes.

Secondary Cyclones :

- Form during the late maturing stage of a primary cyclone.
- May follow the track of the primary cyclone or move along a new path.
- Rapid maturation through different life cycle stages.

Cyclone Families :

- Extra-tropical cyclones often appear in series, not alone.
- Primary cyclone gets occluded, and new ones originate on the trailing front.
- Polar air outbreak in the rear builds up an anti-cyclone.
- Primary cyclone in high latitudes; secondary cyclones follow progressively southerly paths.

Extra-Tropical Cyclones and Jet Stream :

- Close relationship between flow aloft and surface cyclonic storms.
- Rossby waves at the top of the troposphere transport polar and tropical air masses.
- Intensifies surface cyclonic activity.
- Instances of cyclones forming without a prior polar front, initiated by a trough in upper-air westerlies.
- Storms attract different air masses, leading to the generation of fronts.

B. TROPICAL CYCLONE

Tropical Cyclones Overview :

- Develops from a warm-core, extremely low-pressure area in tropical oceanic regions.
- Energized by condensation in towering cumulonimbus clouds surrounding the storm center.
- Circular arrangement of isobars, strengthened by continuous moisture supply from the sea.

Favorable Conditions for Formation :

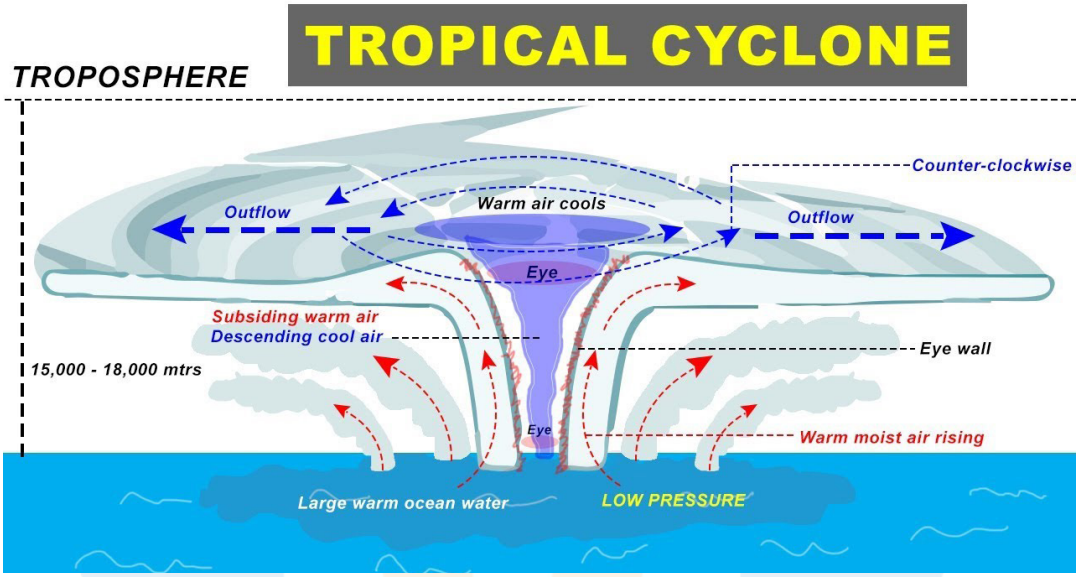
1. Large sea surface with temperature higher than 27°C.
2. Presence of the Coriolis force.
3. Small variations in vertical wind speed (wind shear).
4. Pre-existing weak low-pressure area or low-level-cyclonic circulation.
5. Upper divergence above the sea level system.

Tropical Cyclone Features :

- **Eye :** Center with calm, subsiding air; strong spirally winds circulate around it.
- **Eye Wall :** Spiraling ascent of air, reaching tropopause; maximum wind velocity (up to 250 km/h).
- **System diameter :** 150-250 km; over the Bay of Bengal, Arabian Sea, and Indian Ocean : 600-1200 km.
- System moves slowly (300-500 km per day).

Impact on Humans :

- Devastating natural calamity, causing large-scale destruction.
- Coastal areas experience violent winds, heavy rainfall, and storm surges.
- Recurving cyclones (crossing 20°N latitude) are more destructive.
- Uprooting of trees, destruction of objects, and opposing winds causing additional damage.
- Torrential rains lead to floods, landslides, and loss of life and property.
- Storm surges, with heights up to 20 meters, pose a hazard to shipping and combine disastrously with spring tides.



Naming of Tropical Cyclones :

- Initially named arbitrarily; later, feminine names were used.
- Meteorologists use an organized alphabetical list for identification.
- Names assigned regionally by Tropical Cyclone Regional Bodies.
- Criteria for suggesting names include shortness, clarity, cultural sensitivity, and avoidance of unintended meanings.
- Names are retired after causing significant damage.
- Naming serves to identify, increase public awareness, focus media attention, prevent confusion, and enhance warnings.

■ Difference Between Extra-Tropical and Tropical Cyclones :

Criteria	Extra-Tropical Cyclone	Tropical Cyclone
Energy Source	Horizontal temperature contrasts	Warm and moist air from the ocean
Frontal System	Clear frontal system present	No fronts present
Size	Large (1500-3000 km)	Relatively small
Origin	Can originate over land and sea	Originates only over the seas

Travel	Travels over both oceans and land	Dissipates upon reaching the land
Area Affected	Affects a much larger area	Smaller area, but more destructive
Wind Velocity	Lower wind velocity	Higher wind velocity
Movement Direction	Moves from west to east	Moves from east to west

Region	Local Name
Indian Ocean	Cyclone or Chakrvaat
Atlantic	Hurricanes
Western Pacific and South China Sea	Typhoons
Western Australia	Willy-willies

■ Thunderstorms and Tornadoes Overview :

- **Localization :** Highly localized and short-lived compared to tropical cyclones.
- **Prediction Challenge :** Difficult to predict due to their small size and short duration.

Thunderstorms :

- **Definition :** Storms with thunder and lightning, associated with cumulonimbus clouds.
- **Causes :** Intense convection on moist, hot days; may lead to hailstorms or dust storms.

Stages in Thunderstorm Development :

1. **Cumulus Stage :** Warm, moist air rises, forming cumulus clouds.
2. **Mature Stage :** Presence of updrafts and downdrafts; cumulonimbus cloud grows and flattens.
3. **Dissipating Stage :** Downdrafts throughout the cloud; collapse and glaciation occur.

Lightning and Thunder Causes :

- **Charging Mechanism :** Collisions between small ice crystals and larger snow and ice pellets.
- **Charge Polarity :** Small ice crystals become positively charged; pellets become negatively charged.
- **Lightning Formation :** Charge difference leads to lightning discharge; thunder results from the heating and cooling of the air near the lightning channel.

Concerns Associated with Thunderstorms :

- **Hazards :** Cloud-to-ground lightning, hail, tornadoes, flash floods, and downbursts.
- **Safety Measures :** No safe place outside during a thunderstorm; safe shelters in well-constructed buildings are advised.

■ Tornadoes :

Formation : Descending spiraling wind from severe thunderstorms with low pressure at the center.

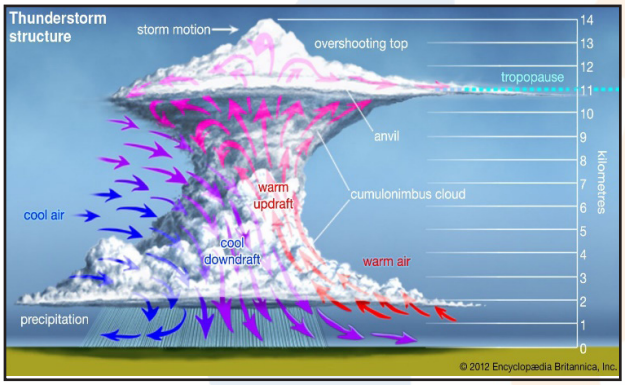
Prerequisites : Excessive instability and steep lapse rate in the atmosphere.

Characteristics :

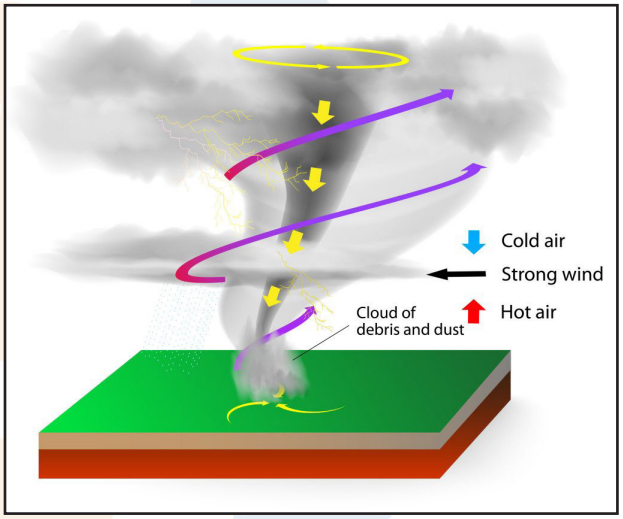
- **Funnel diameter :** 90-460m.
- **Velocity of winds :** More than 300 km/h.
- Violent storms with massive destruction, short duration, and small size.
- Dark appearance due to condensed moisture, dust, and debris.
- Occur singly or in families, moving in straight paths.

Violent Storm Manifestation :

- **Energy Conversion :** Atmosphere adjusts to varying energy distribution.
- **Energy Transformation :** Potential and heat energies converted into kinetic energy.
- **Outcome :** Restless atmosphere returns to a stable state.



Thunderstorm



Tornado

9 CLIMATE AND GLOBAL CLIMATE ZONES

Introduction :

- Climate is crucial in our daily lives and impacts economic activities like agriculture, industries, and commerce.
- Plays a significant role in physical geography, encompassing temperature, humidity, atmospheric pressure, wind, precipitation, and other meteorological variables.
- Climate is the average pattern of variation in these elements in a specific region over extended periods.

Climate & Weather :

Climate :

- Describes average conditions over a long period.
- Includes precipitation, temperature, humidity, sunshine, and wind velocity.
- Components involve phenomena such as fog, frost, and hail storms.
- Forecasted based on aggregates of weather statistics over 30 years.
- Studied in climatology.

Weather :

- Describes atmospheric conditions at a specific place and time.
- Includes sunshine, rain, cloud cover, winds, and various short-term phenomena.
- Forecasted through real-time measurements of atmospheric variables.
- Studied in meteorology.

Key Differences :

- **Definition :** Climate represents long-term average conditions, while weather denotes short-term atmospheric changes.
- **Components :** Climate encompasses various elements over extended periods, whereas weather focuses on real-time atmospheric conditions.
- **Forecast :** Climate forecast is based on 30-year aggregates, while weather forecast relies on real-time meteorological data.
- **Time Period :** Climate is measured over a long duration, contrasting with the short-term measurement of weather.
- **Study :** Climatology explores climate, while meteorology studies weather.

Factors Affecting Climate :

1. **Latitude :**
   - Sun's rays vary in intensity, affecting temperature.
   - Temperature diminishes from equator to poles.
2. **Altitude :**
   - Temperature decreases with increasing height.
   - Lapse rate is approximately 6.5°C per 1000 meters.
3. **Continentality (Distance from Sea) :**
   - Land heats and cools faster than water.
   - Inland areas experience temperature extremes.
4. **Ocean Currents :**
   - Warm or cold currents influence coastal climates.
   - Gulf Stream warms Western Europe, while cold currents freeze areas like Labrador.
5. **Local Winds :**
   - Warm winds raise temperatures; cold winds lower them.
   - Local winds like Fohn, Chinook, Sirocco, and Mistral bring temperature changes.
6. **Relief and Topography :**
   - Mountains influence rainfall; higher altitudes are colder.
   - Air forced over mountains cools, causing rainfall.
7. **Natural Vegetation and Soil :**
   - Dense vegetation affects temperature; areas with forests are cooler.
   - Soil types influence temperature variations.
8. **Slope, Shelter, and Aspect :**
   - Steep slopes experience rapid temperature changes.
   - South-facing slopes receive more sunlight, impacting vegetation and settlement.
9. **El Niño Effect :**
   - Irregular warming of Pacific surface water.
   - Alters global wind and rainfall patterns; causes extreme weather events.

10. **Human Influence :**

- Deforestation impacts carbon dioxide absorption.
- Human activities contribute to climate change.
- Increasing populations intensify climate impact.

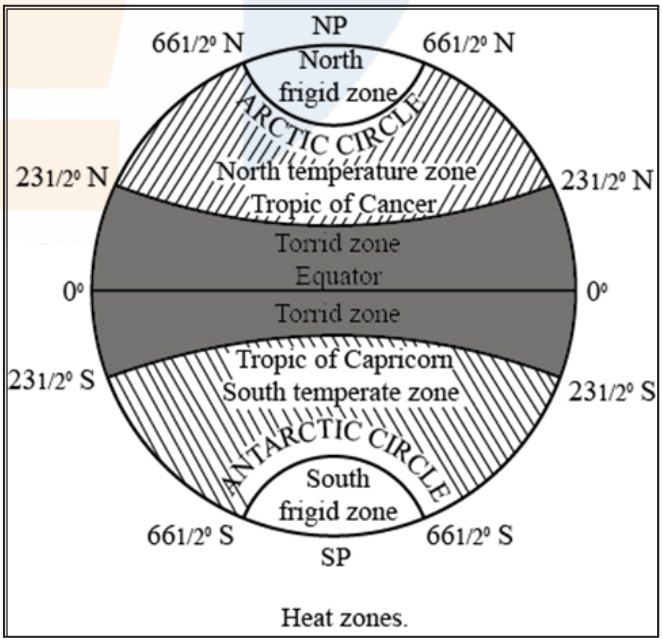
- Understanding these factors provides insights into the complex interplay of natural and human-induced influences on climate, contributing to the broader field of climatology.

■ Facts About Factors Affecting Climate :

1. A fall of 6.5°C occurs with an ascent of 1000 meters or 1.0°C per 165 meters.
2. It takes less energy to raise the temperature of a given volume of land by 1.0°C as compared to same volume of water body.
3. Mountains receive more rainfall than low lying areas because as air is forced over the higher ground it cools, causing moist air to condense and fall out as rainfall.
4. Dry soils like sands are very sensitive to temperature changes, whereas wet soils, like clay, retain much moisture and warm up or cool down more slowly.
5. Mountain ranges that have an east-west alignment like the Alps show a higher temperature on the south facing 'sunny slope' than the north facing 'sheltered slope'.
6. The warmer water pumps energy and moisture into the atmosphere, altering global wind and rainfall patterns

■ Heat Zones Classifications :

- **Tropical or Torrid Zone :** The sunrays are almost vertical throughout the year. The temperature always remains high. There is no winter season in this zone.
- **Temperate Zone :** There are two zones lying between the Tropic of Cancer - the Arctic Circle and the Tropic of Capricorn - the Antarctic Circle.
- **Frigid Zones :** The sunrays in these two zones in the Northern and Southern Hemisphere fall in slanting form throughout the year. Therefore these zones experience very low temperature and high degree of coldness.



Heat zones.

Classification Of Climate

- **Koeppen classification-** Based on annual averages of temperature and precipitation. 5 main climate types + Highland type climate

Table 2 : Climatic Types According to Koeppen

Group	*Type*	*Letter Code*	*Characteristics*
A-Tropical Humid Climate	Tropical wet	Af	No dry season
	Tropical monsoon	Am	Monsoonal, short dry season
	Tropical wet and dry	Aw	Winter dry season
B-Dry Climate	Subtropical steppe	BSh	Low-latitude semi arid or dry
	Subtropical desert	BWh	Low-latitude arid or dry
	Mid-latitude steppe	BSk	Mid-latitude semi arid or dry
	Mid-latitude desert	BWk	Mid-latitude arid or dry
C-Warm temperate (Mid-latitude) Climates	Humid subtropical	Cfa	No dry season, warm summer
	Mediterranean	Cs	Dry hot summer
	Marine west coast	Cfb	No dry season, warm and cool summer
D-Cold Snow-forest Climates	Humid continental	Df	No dry season, severe winter
	Subarctic	Dw	Winter dry and very severe
E-Cold Climates	Tundra	ET	No true summer
	Polar ice cap	EF	Perennial ice
H-Highland	Highland	H	Highland with snow cover

- **Thornthwaite Classification-** 5 humidity region based on Precipitation effectiveness and Temperature efficiency

Humidity Region	Special type of Vegetation
1. Very Humid	Rain Forest
2. Humid	Forest
3. Semi Humid	Grassland
4. Semi Dry	Steppe
5. Dry	Desert

- **On the basis of distribution of seasonal rainfall the above types of humidity regions were further divided into following subdivisions :**

1. Y = Heavy rainfall in all seasons
2. s = Scarcity of rainfall in summer season
3. w = Scarcity of rainfall in winter season
4. d = Scarcity of rainfall in all seasons

- After linking precipitation effectiveness and seasonal distribution of rainfall to temperature anomalies, the climates could be of 120 different types.

Global Climate Classification :

	Climatic Conditions	Vegetation	Location
1. The Hot, Wet Equatorial Climate	• 5-10 degrees North and South of the equator. • Great uniformity of temperature throughout the year (around 27°C). • No winter. Cloudiness and heavy precipitation moderates the daily temperature.	• Multitude of evergreen trees that yield tropical hardwood. • Lianas, epiphytic and parasitic plants are also found.	• Found in the lowlands of the Amazon, the Congo, Malaysia and the East Indies
2. The Tropical Monsoon and Tropical Marine Climates	• Found in the zones between 5° and 30° latitudes on either side of the equator. • The basic cause of monsoon climates is the difference in the rate of heating and cooling of land and sea. • **Tropical Monsoon Climate** : In regions like the Indian sub-continent which have a true Tropical Monsoon Climate, three distinct seasons are distinguishable. • The cool, dry season (October to February), the hot dry season (March to mid-June) and the rainy season (mid-June to September). • **Tropical Marine Climate** : This type of climate is experienced along the eastern coasts of tropical lands, receiving steady rainfall from the Trade Winds all the time	• Trees are normally deciduous because of the marked dry period, during which they shed their leaves to withstand the drought. • Where the rainfall is heavy, e.g. in Southern Burma, peninsular India, northern Australia and coastal regions with a tropical marine climate, the resultant vegetation is forest.	• **Tropical Monsoon Climate :** • They are best developed in the Indian sub-continent, Burma, Thailand, Laos, Cambodia, parts of Vietnam and south China and northern Australia • **Tropical Marine Climate :** • It is experienced in Central America. West Indies, north-eastern Australia, the Philippines, parts of East Africa, Madagascar, the Guinea Coast and eastern Brazil.

3. The Savannah or Sudan Climate	• It is characterized by distinct wet and dry seasons. • The extreme diurnal range of temperature is also a characteristic of Sudan type of climate. • The prevailing winds of the region are the Trade Winds which bring rain to the coastal districts. • The savannah, particularly in Africa, is the home of wild animals. It is known as the 'big game country'.	• Tall grass and short trees. The terms **'parkland' or 'bush-veld'** is also used. • The trees are deciduous and show adaptation to withstand drought.	• The Savannah or Sudan Climate is a transitional type of climate found between the equatorial forest and the trade wind hot deserts. • It is confined within the tropics and is best developed in the Sudan where the dry and wet seasons are most distinct, hence its name the Sudan Climate.
			• The belt includes West African Sudan, and then curves southwards into East Africa and southern Africa north of the Tropic of Capricorn. • In South America, there are two distinct regions of savannah north and south of the equator, namely the llanos of the Orinoco basin and the Campos of the Brazilian Highlands.
4. The Hot Desert and Mid-latitude Desert Climates	• The major hot deserts of the world are located on the western coasts of continents between latitudes 15 and 30 degrees N and S.	• Vegetation include grass, scrub, herbs, weeds, roots or bulbs.	• They include the Sahara Desert, the Great Australian Desert , the Arabian Desert, Iranian Desert, Thar Desert, Kalahari and Namib Deserts.

	• The hot deserts lie astride the Horse Latitudes or the Sub Tropical High Pressure Belts where the air is descending (least favourable for precipitation) • There is no cold season in the hot deserts and the average summer temperature is around 30°C.		• In North America, the desert extends from Mexico to USA and is called by different names at different places, • **e.g.** the Mohave Sonoran, Californian and Mexican Deserts. In South America, the Atacama or Peruvian Desert (driest). The Patagonian Desert is more due to its rain shadow position on the leeward side of the lofty Andes than to continentality.
5. The Warm Temperate Western Margin (Mediterranean) Climate	• They are entirely confined to the western portion of continental masses, between 30° and 45° north and south of the equator. • The Mediterranean type of climate is characterized by very distinctive climatic features - a warm summer with off-shore trades, a concentration of rainfall in winter with onshore westerlies, bright, sunny weather with hot dry summers and wet, mild winters and the prominence of local winds around the Mediterranean Sea (Sirocco, Mistral).	• The Mediterranean lands are also known as the **world's orchard lands.** • A wide range of citrus fruits such as oranges, lemons, limes, citrons and grapefruit are grown. Wine production is another specialty. • The absence of shade is a distinct feature of Mediterranean lands	• The basic cause of this type of climate is the shifting of the wind belts. • Though the area around the Mediterranean Sea has the greatest extent of this type of 'winter rain climate', and gives rise to the more popular name Mediterranean Climate. • Other Mediterranean regions include California (around San Francisco), the south-western tip of Africa (around Cape Town), southern Australia

	• Growth is slow in the cooler and wetter season, even though more rain comes in winter. The warm, bright summers and cool, moist winters enable a wide range of crops to be cultivated Some 85 per cent of grapes produced, go into wine. The long, sunny summer allows the grapes to ripen and then they are • **handpicked. Economy :** The area is important for fruit cultivation, cereal growing, wine-making and agricultural industries as well as engineering and mining.		• (in southern Victoria and around Adelaide, bordering the St. Vincent and Spencer Gulfs), and south-west Australia (Swanland).
6. The Temperate Continental (Steppe) Climate	• Summers are very warm and winters are very cold in the continental steppes of Eurasia because of the enormous distances from the nearest sea. • In contrast, the steppe type of climate in the southern hemisphere is never severe. The winters are mild. Temperatures below freezing point are exceptional. Temperate grasslands are found bordering the deserts, away from the Mediterranean regions and in the interiors continents.	• Trees are very scarce in the steppes, because of the scanty rainfall, long droughts and severe winters. • Tall, fresh and nutritious prairie grass are found. Granaries of the world.	• **In Eurasia :** Steppes. Stretch eastwards from the Black Sea to the Altai Mountains. • **In North America** : Prairies. They lie between the Rockies and the Great Lakes. • **In South America** : Pampas of Argentina and Uruguay. Extend right to the sea and enjoy much maritime influence. • **In South Africa :** Tropical Bushveld in North and High Veld in the South. They lie between the Drakensberg and the Kalahari Desert.

	• Their greatest difference from the tropical savannah is that they are practically treeless and the grasses are much shorter.		
7. The Warm Temperate Eastern Margin (China Type) Climate	• Warm moist summer and a cool, dry winter. • Fairly uniform distribution of rainfall throughout the year. • It has comparatively more rainfall than the Mediterranean climate. • The eastern margins of warm temperate latitudes have a much heavier rainfall than either the western margins or the continental interiors and thus have luxuriant vegetation.	• **Lowlands** : Evergreen broad-leaved forests and deciduous trees. • **Highlands** : Conifers such as pines and cypresses that are important softwood.	• **It can be sub-divided into three main types** : • **The China type** : Central and North China including southern Japan (temperate monsoonal). • **The Gulf type** : South-eastern United States bordering Gulf of Mexico (slight monsoonal). • **The Natal type** : The entire warm temperate eastern margin (non-monsoonal areas) of the southern • hemisphere including Natal, eastern Australia and southern Brazil-Paraguay-Uruguay and northern Argentina.
8. The Cool Temperate Western Margin (British Type) Climate	• Summers are never very warm. Adequate rainfall throughout the year with a tendency towards a slight winter or autumn maximum from cyclonic sources.	• Deciduous forests used for Lumbering Trees shed their leaves in winter as a protection mechanism.	• Permanent influence of Westerlies through out the year. • They are also regions of much cyclonic activity, typical of Britain.

	• The rain-bearing winds come from the west, the western margins have the heaviest rainfall.		• Climatic belt stretches from Britain to North-West Europe. • In the southern hemisphere, the climate is experienced in southern Chile, • Tasmania and most parts of New Zealand, particularly in South Island.
9. The Cool Temperate Continental (Siberian) Climate	• Characterized by a bitterly cold winter of long duration, and a cool brief summer. Spring and autumn are merely brief transitional periods. • The extremes of temperature are so great in Siberia that it is often referred to as the **'cold pole of the earth'.** • Some of the lowest temperatures in the world are recorded in Verkhoyansk.	• Coniferous forests (Softwood) • There are four major species in the coniferous forests - a) Pine, **e.g.** white pine, red pine b) Fir, **e.g.,** Douglas fir and balsam fir, c) Spruce and d) Larch.	• Experienced only in the northern hemisphere where the continents within the high latitudes have a broad east-west spread. • The Siberian Climate is conspicuously absent in the southern hemisphere because of the narrowness of the southern continents in the high latitudes.
10. The Cool, Temperate Eastern Margin Climate	• This climate has cold, dry winters and warm, wet summers. • It has features of both the maritime and the continental climates. • It is an intermediate type of climate between the British and the Siberian type of climate.	• The predominant vegetation of the Laurentian type of climate is cool temperate forest. • Oak, beech, maple and birch are the principal trees	• This climate is found only in two regions. • **North American Region** : north-eastern North America, including eastern Canada, north-east U.S.A. and Newfoundland.

			• **Asiatic Region :** The eastern coastlands of Asia, including eastern Siberia, North China, Manchuria, Korea and northern Japan. • In the southern hemisphere, this climatic type is absent because only a small section of the southern • continents extends south of the latitude of 40° S
11. The Polar Climate	• Exists poleward beyond 70° latitude. • Tundra-Climate [ET] is found in regions with permafrost. Short growing season i.e. summer with very long duration of day light. Drainage in the tundra is usually poor as the sub-soil is permanently frozen.	• Tundra vegetation i.e. Mosses, Lichens and flowering plants.	• **Two subtypes :** • Tundra Climate • Ice-Cap Climate
	• The ice cap climate (EF) occurs over interior Greenland and Antarctica. Even in summer, the temperature is below freezing point.		

The Global climatic conditions can be studied under the following twelve classifications :

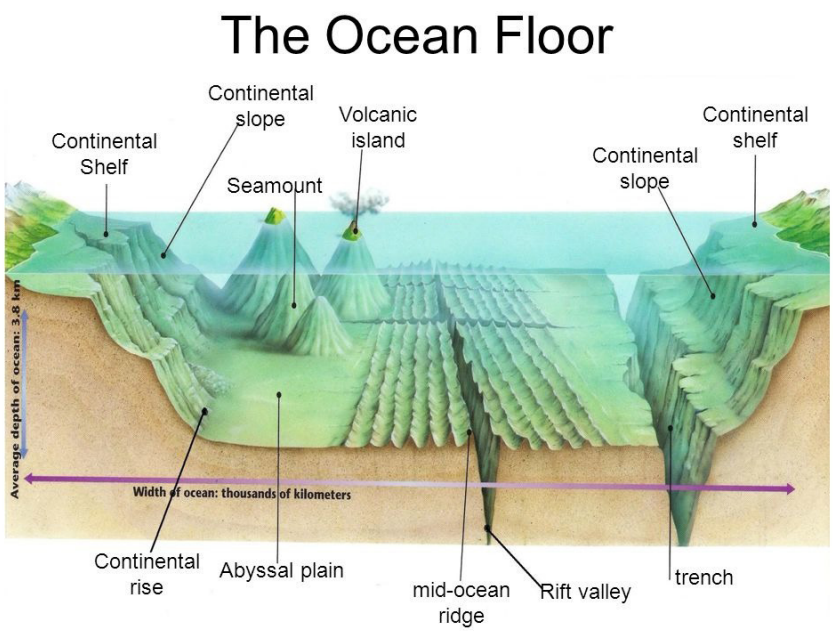
Climatic Zone	Latitude (Approachmate)	Climatic Type	Rainfall Regime (with approx. total)	Natural Vegetation
Equatorial Zone	0°-10°N and S	1. Hot wet equatorial	Rainfall all year round: 80 inches	Equatorial rain forests
Hot Zone	10°-30°N and S	2. a) Tropical Monsoon b) Tropical Marine	Heavy summer rain: 80 inches Much summer rain: 70 inches	Monsoon forests
		3. Sudan Type	Rain mainly in summer: 30 inches	Savanna (tropical grassland)
		4. Desert: a) Saharan type b) Mid-latitide type	Little rain: 5 inches	Desert vegetation and scrub
Warm Temperate Zone	10°-40°N and S	5. Western Margin (Mediterranean type)	Winter rain: 35 inches	Mediterranean forests and shrub
		6. Central Continental (Steppe type)	Light summer rain: 20 inches	Steppe or temperate grassland
		7. Eastern Margin: a) China type b) Gulf type c) Natal type	Light summer rain: 20 inches	Warm, wet forests and bamboo
Cool Temperate Zone	45°-65°N and S	8. Western Margin (British type)	More rain in autuma & winter: 30 inches	Deciduous forests
		9. Cental Continental (Siberian type)	Light summer rain: 25 inches	Evergreen coniferous forests
		10. Eastern Margin (Laurentian type)	Moderate summer rain: 40 inches	Mixed forests (coniferous and deciduous)
Cool Zone	65°-90°N and S	11. Arctic or Polar	Very light summer rain: 10 inches	Tundra, mosses, lichens
Alpine Zone	65°-90°N and S	12. Mountain climate	Heavy rainfall (variable)	Alpine pastures, conifers, fern, show

10 OCEAN BASICS AND OCEAN RESOURCES

- Water is an essential component of all life forms. The earth fortunately has an abundant supply of water on its surface. Hence, our planet is called the **Blue Planet.**
- About **97 percent** of the planetary water is found in the oceans. Oceans account for more than **70 percent** or **140 million** square miles of the earth's surface.
- The geographers have divided the oceanic part of the earth into four oceans, namely the Pacific, the Atlantic, the Indian and the Arctic.
- **The ocean floor** is a dynamic and varied landscape shaped by tectonic, volcanic, and depositional processes. It **consists of four major divisions :**

1. **Continental Shelf :** This is the shallowest part of the ocean, extending from the continents. It features a gradual slope (average gradient of 1° or less) that ends at a steep slope called the shelf break. Continental shelves vary in width, with an average of 80 km, and are covered with sediments that accumulate over time, becoming a source of fossil fuels.
2. **Continental Slope :** Connecting the continental shelf to the ocean basins, the continental slope begins where the shelf drops off sharply. The slope has a gradient of 2-5° and depths ranging from 200 to 3,000m. It marks the end of continents and exhibits features such as canyons and trenches.
3. **Continental Rise :** Beyond the continental slope, the gently sloping continental rise begins. It has a low relief and gradually merges with deep-sea plains. The continental rise is characterized by a flat terrain as depth increases.
4. **Deep Sea Plain (Abyssal Plain) :** These are gently sloping areas of ocean basins, covering two-thirds of the ocean floor. Depths range from 3,000 to 6,000m, and the plains are covered with fine-grained sediments like clay and silt. Deep sea plains contain features such as ridges, guyots, and oceanic islands, some of which rise above sea level.
5. **Oceanic Deeps or Trenches :** These are the deepest parts of the oceans, characterized by steep-sided, narrow basins. Trenches are located at the bases of continental slopes and along island arcs, associated with active volcanoes and strong earthquakes. The Mariana Trench near Guam Island is the deepest known trench, exceeding 36,000 feet in depth.

- The ocean floor's relief features provide valuable insights into plate movements, tectonic activity, and the distribution of resources. The exploration of these features contributes to a better understanding of the Earth's geology and environmental processes.



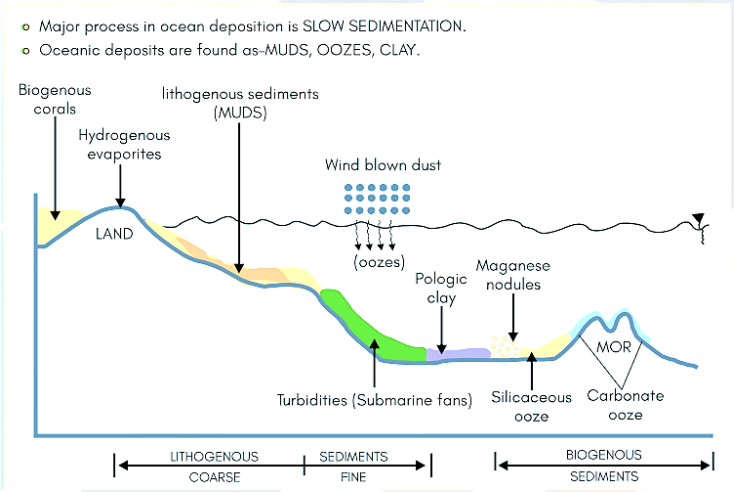
- **The minor relief features of the ocean floor** complement the major structures and play a significant role in understanding the dynamic nature of the oceanic environment :

1. **Mid-oceanic Ridges :** These are chains of mountains separated by large depressions, known as oceanic spreading centers. They result from seafloor spreading caused by convection currents in the mantle, leading to the emergence of magma as lava, creating new crust. Mid-ocean ridges, marking divergent plate boundaries, can have peaks reaching heights of up to 2,500 m, with some extending above the ocean's surface, such as Iceland along the mid-Atlantic Ridge.
2. **Seamounts :** These are underwater mountains with pointed summits that do not breach the ocean surface. Originating from volcanic activity, seamounts can reach heights of 3,000-4,500 m. An example is the Emperor seamount, an extension of the Hawaiian Islands in the Pacific Ocean.
3. **Submarine Canyons :** Deep valleys cut across continental shelves and slopes, extending from the mouths of large rivers. The Hudson Canyon is a well-known submarine canyon, showcasing the intricate underwater topography.
4. **Guyots :** These are flat-topped seamounts that exhibit evidence of gradual subsidence. More than 10,000 seamounts and guyots are estimated to exist in the Pacific Ocean alone, representing submerged mountains with flattened summits.
5. **Atolls :** Found in tropical oceans, atolls are low islands consisting of coral reefs surrounding a central depression. The central area may contain a lagoon or enclose a body of water with varying salinity levels.

- These minor relief features contribute to the overall complexity of the ocean floor, offering insights into geological processes, tectonic activity, and the diverse ecosystems that thrive in these underwater landscapes. The exploration and study of these features enhance our understanding of the Earth's geology and the interconnected nature of oceanic environments.

The Oceanic Deposits of the Ocean Floor :

1. **Muds :** These are terrigenous deposits because they are derived from land and are mainly deposited on the continental shelves. The muds are referred to as blue, green or red muds; their colouring depends upon their chemical content.
2. **Oozes :** These are pelagic deposits because they are derived from the oceans. They are made of the shelly and skeletal remains of marine microorganisms with calcareous or siliceous parts. Oozes have a very fine, flour-like texture and either occur as accumulated deposits or float about in suspension.
3. **Clays :** These occur mainly as red clays in the deeper parts of the ocean basins, and are particularly abundant in the Pacific Ocean. Red clay is believed to be an accumulation of volcanic dust blown out from volcanoes during volcanic eruptions



Factors Affecting Temperature Distribution

1. **Latitude :** The temperature of surface water decreases from the equator towards the poles because the amount of insolation decreases poleward.
2. **Unequal distribution of land and water :** The oceans in the northern hemisphere receive more heat due to their contact with larger extent of land than the oceans in the southern hemisphere.
3. **Prevailing winds :** The winds blowing from the land towards the oceans drive warm surface water away from the coast resulting in the upwelling of cold water from below.
4. **Ocean currents :** Warm ocean currents raise the temperature in cold areas while the cold currents decrease the temperature in warm ocean areas.

Vertical distribution of Temperature :

Vertical Temperature Distribution :

- Maximum temperature at the ocean surface due to direct sun exposure.
- Temperature decreases rapidly up to 200 meters depth.
- Rate of decrease slows after 200 meters.

- Thermocline, a boundary region with rapid temperature decrease, starts around 100-400 meters below the surface.
- About 90% of total water volume is below the thermocline, with temperatures approaching 0°C in the deep ocean.

Three-Layer System in Middle and Low Latitudes :

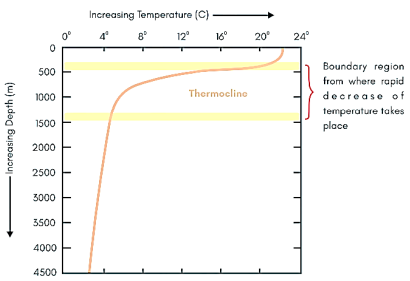
- **Surface layer :** Warm top layer, about 500 meters thick, with temperatures between 20° and 25°C.
  - Present year-round in tropical regions.
  - Develops mainly during summer in mid-latitudes.
- **Thermocline layer :** Rapid temperature decrease with increasing depth, 500-1,000 meters thick.
- **Third layer :** Extends to the deep ocean floor, very cold temperatures, close to 0°C.

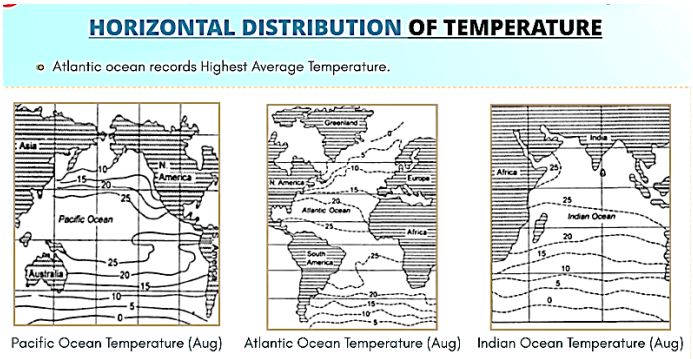
Arctic and Antarctic Circles :

- Surface water temperatures close to 0°C.
- Slight temperature change with depth.
- Only one layer of cold water exists, extending from the surface to the deep ocean floor.

Horizontal Temperature Distribution :

- Average surface water temperature about 27°C.
- Gradual decrease from equator to poles.
- Rate of temperature decrease with increasing latitude is generally 0.5°C per latitude.
- **Average temperatures :** 22°C at 20° latitudes, 14°C at 40° latitudes, and 0°C near poles.
- Northern hemisphere records higher temperatures than the southern hemisphere.
- Highest temperature slightly north of the equator.
- **Average annual temperatures :** around 19°C (northern hemisphere) and 16°C (southern hemisphere).
- Influenced by unequal distribution of land and water in the two hemispheres.





SALINITY :

Factors Affecting Ocean Salinity :

- The salinity of water in the surface layer of oceans depends mainly on evaporation and precipitation.

- Surface salinity is greatly influenced in coastal regions by the fresh water flow from rivers, and In polar-regions by the processes of freezing and thawing of ice.
- Wind also influences salinity of an area by transferring water to other areas.
- The ocean currents contribute to the salinity variations.

Distribution of Salinity

- There is a marked difference in the salinity between the surface zones and the deep zones of the oceans.
- The lower salinity water rests above the higher salinity dense water.
- Salinity, generally, increases with depth and there is a distinct zone called the **halocline**, where salinity increases sharply. 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.
- The salinity for normal open ocean ranges between 33 ppt and 37 ppt. In the land **locked Red sea,** it is as high as 41 ppt, while in the **estuaries and the Arctic,** the salinity fluctuates from 0 – 35 ppt, seasonally. In hot and dry regions, where evaporation is high, the salinity sometimes reaches to 70 ppt.
- The average salinity of the Indian Ocean is 35 ppt. The low salinity trend is observed in the **Bay of Bengal** due to large influx of river water. On the contrary, the Arabian Sea shows higher salinity due to high evaporation and low influx of fresh water.
- The average salinity of the **Atlantic Ocean is around 36 ppt**. The highest salinity is recorded between 15° and 20° latitudes. Maximum salinity (37 ppt) is observed between20° N and 30° N and 20° W - 60° W.
- It gradually decreases towards the north. **The North Sea,** in spite of its location in higher latitudes, records higher salinity due to more saline water brought by the **North Atlantic Drift**.
- **Baltic Sea** records low salinity due to influx of river waters in large quantity.
- The **Mediterranean Sea** records higher salinity due to high evaporation. Salinity is, however, very low in Black Sea due to enormous fresh water influx by rivers.

■ Movement Of Ocean Waters :

- Through oceanic waves- waves are ENERGY which moves through ocean surface.

Horizontal and Vertical Motion of Ocean Water :

- Horizontal motion includes ocean currents and waves.
- Vertical motion involves tides, upwelling of cold water, and sinking of surface water.

Waves :

- Waves are energy, not water, moving across the ocean surface.
- Wind imparts energy to waves, causing them to travel.
- Friction with the sea floor slows down waves near the shore, leading to wave breaking.
- Largest waves found in open oceans, growing as they absorb energy from the wind.
- Characteristics include wave crest, trough, height, amplitude, period, wavelength, speed, and frequency.

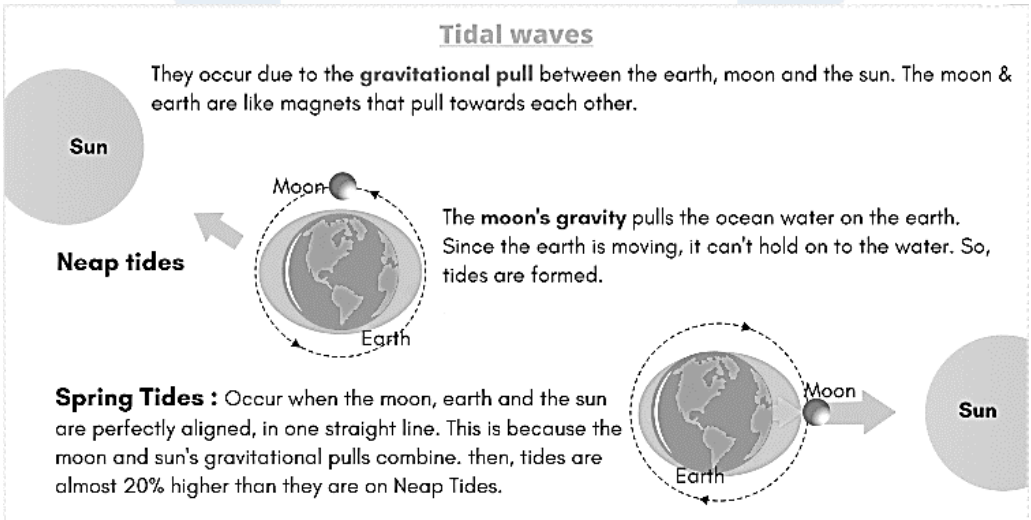
- Waves travel due to wind pushing water and gravity pulling wave crests downward.
- Circular motion of water beneath waves indicates upward and forward movement as waves approach and downward and backward as they pass.

Tides :

- Periodic rise and fall of sea level, influenced by the attraction of the sun and moon.
- Surges, caused by meteorological effects, are irregular and differ from tides.
- Causes of tides include gravitational pull of the moon and, to a lesser extent, the sun, along with centrifugal force.
- Tide-generating force results from the difference between moon's gravitational attraction and centrifugal force.
- Two major tidal bulges created on Earth due to gravitational pull and centrifugal force.
- Types of tides based on frequency : semi-diurnal, diurnal, mixed.
- Types of tides based on height : spring tides (higher, during full and new moons) and neap tides (lower, during first and last quarter phases).
- Characteristics of tides include tidal range (difference between high and low tide), ebb (falling water level), flow/flood (rising tide).

Additional Tidal Characteristics :

- Tidal range influenced by moon's orbit (perigee, apogee) and Earth's distance from the sun (perihelion, aphelion).
- Tidal currents result from the rise and fall of water levels due to tides.
- Tidal bore observed in estuaries, appearing as a vertical wall of water moving upstream.
- The Bay of Fundy in Nova Scotia, Canada, experiences the highest tides in the world (15-16 meters).



■ Significance of tidal waves :

Predictability and Planning :

- Tides, determined by the accurate positions of the Earth, moon, and sun, can be predicted in advance.

- Navigators and fishermen benefit from this predictability, enabling them to plan their activities efficiently.

Navigation :

- Tidal flows play a crucial role in navigation.
- Tidal heights are significant for harbors near rivers and estuaries with shallow bars at entrances.
- Ships and boats navigate harbors during high tide when water levels are suitable.
- London and Haldia (Hugli river mouth) are important ports due to tidal conditions.

Sedimentation Control :

- Tidal currents prevent sedimentation in river mouths and estuaries.
- Outgoing tide and river current carry silt away to the open sea, maintaining clear waterways for navigation.

Electricity Generation :

- Tidal force serves as a potential source for generating electricity.
- Tidal power projects, like the 3 MW project in Durgaduani, Sunderbans (West Bengal), are underway.

Preventing Freezing :

- Inflow of salty tidal water, particularly in cold countries, hinders freezing processes.
- Prevents harbors from becoming ice-bound, ensuring year-round accessibility.

Impact on Fishing Industry :

- High and low tides rhythmically influence the fishing industry.
- Fishermen sail to the open sea during low tides and return to the coast during high tides.
- The tidal cycle contributes to the planning and success of fishing activities.

Ocean current :

- Warm ocean currents raise the temperature in cold areas while the cold currents decrease the temperature in warm ocean areas
- Causes of Ocean Currents : Primary forces that initiate the movement of water. Secondary forces that influence the currents to flow

Forces Influencing Ocean Currents :

1. **Solar Heating :**

a. Solar energy causes water to expand, creating a slight gradient.

b. Near the equator, ocean water is about 8 cm higher than in middle latitudes.

c. Temperature differences between equator and poles drive slow movements of warm equatorial waters polewards and cold polar waters equatorwards.

2. **Wind :**

a. Surface wind pushes ocean water, with friction affecting water movement.

b. Prevailing winds determine the direction of most ocean currents globally.

3. **Coriolis Force :**

a. Coriolis force influences the direction of water movement.

b. In the northern hemisphere, water moves to the right; in the southern hemisphere, it moves to the left.

c. Gyres, large accumulations of water, result in circular currents in ocean basins.

4. **Salinity Variations :**

a. Salinity differences impact water density.

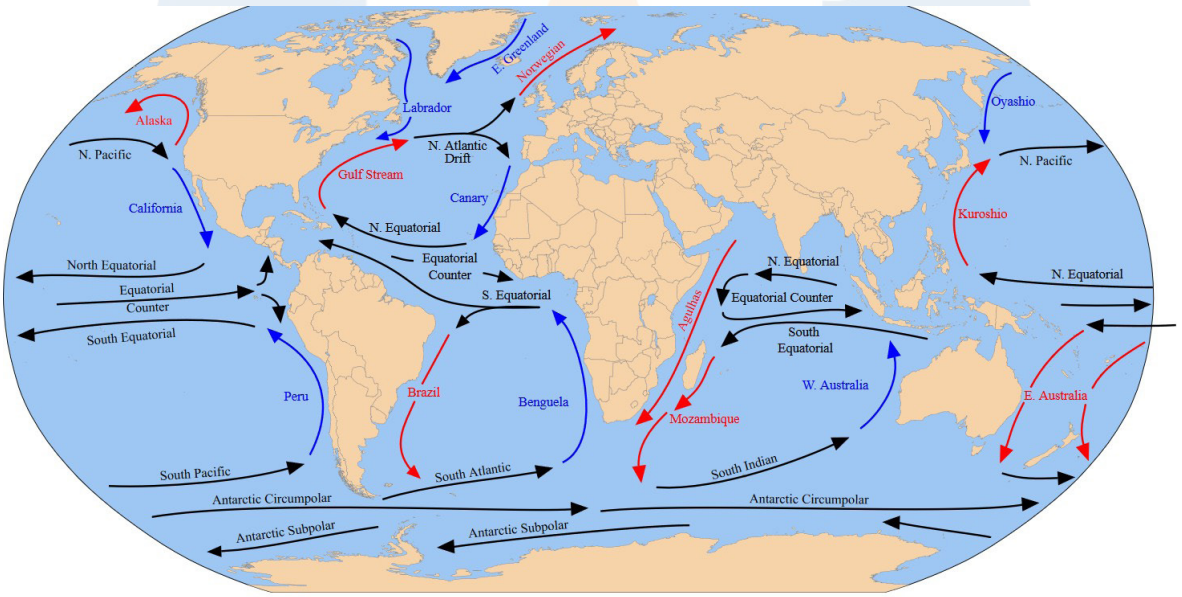
b. High salinity waters are denser and flow towards low salinity waters on the surface.

c. **At** the bottom, high salinity waters flow towards low salinity waters.

5. **Coastline Configuration :**

a. Coastline shapes act as obstacles to natural current flow, altering direction.

b. Notably observed in the equatorial region where landmasses deflect currents towards the north and south.



■ Types of Ocean Currents :

1. **Surface currents :** constitute about 10 per cent of all the water in the ocean, these waters are the upper 400 m of the ocean.

2. **Deep water currents :** make up the other 90 per cent of the ocean water. Deep waters sink into the deep ocean basins at high latitudes, where the temperatures are cold enough to cause the density to increase

3. **Cold currents :** bring coldwater into warm water areas. These currents are usually found on the west coast of the continents in the low and middle latitudes (true in both hemispheres) and on the east coast in the higher latitudes in the Northern Hemisphere

4. **Warm currents :** bring warm water into cold water areas and are usually observed on the east coast of continents in the low and middle latitudes (true in both hemispheres). In the northern hemisphere they are found on the west coasts of continents in high latitudes.

■ Major Fishing Grounds :

Geographical Distribution :

- Primary commercial fishing grounds are situated in the cool waters of the northern hemisphere, particularly in high latitudes.
- Fishing activity is less developed in tropical regions and the southern hemisphere.

Optimal Conditions :

- Best fishing grounds are located above continental shelves, not more than 200 meters below the water surface.
- Continental shelves with abundant plankton, crucial for marine life, are favored.

Key Locations :

- Extensive continental shelves are found in high or mid-latitudes in the northern hemisphere.
- Examples include the banks of Newfoundland, the North Sea, the continental shelf off north-western Europe, and the Sea of Japan.

Plankton Abundance :

- Plankton, essential for the marine food chain, is most abundant in polar waters, at the convergence of cold and warm ocean currents.
- Locations with upwelling, such as the Newfoundland "banks" and the Sea of Japan, offer rich plankton supply.
- Continental shelves in tropical regions have relatively less plankton due to warmer water conditions.

Dynamic Fish Availability :

- The quantity of fish in oceans undergoes continuous changes influenced by natural factors and human activities.
- Sustainable management of ocean fisheries is imperative to prevent depletion and ensure a persistent fish population.

■ Major Deep Sea Minerals :

1. **Manganese Nodules :**
    - Located at depths below 4000 meters.
    - Masses of up to 75 kilograms per square meter.
    - Composed primarily of manganese and iron.
    - Elements of economic interest include cobalt, copper, and nickel (around 3.0% by weight).

- Traces of significant elements like platinum and tellurium.
- Precipitated from seawater or originate in the pore waters of underlying sediments.
- Greatest densities off the west coast of Mexico, in the Peru Basin, and the Indian Ocean.

2. **Cobalt Crusts :**

- Accumulate on volcanic substrates at depths of 1000 to 3000 meters.
- Formed by deposition of manganese, iron, and trace metals (cobalt, copper, nickel, platinum) from dissolved water.
- Contain economically important resources.
- Of interest due to limited terrestrial sources, with some countries being politically unstable.
- Occur in regions with high volcanic activity, such as the territorial waters around the island states of the South Pacific.

3. **Massive Sulphides :**

- Sulphur deposits produced from underwater volcanic areas, known as black smokers.
- Form at submarine plate boundaries where heat and element exchange occur between rocks in the Earth's crust and the ocean.
- Cold seawater penetrates through cracks in the sea floor, reaching depths of several kilometers.
- Near heat sources like magma chambers, seawater is heated to temperatures exceeding 400 degrees Celsius.
- Hydrothermal solutions transport dissolved metals from rocks and magma, depositing them on the sea floor.
- Characteristic chimneys (black smokers) are produced.
- Economic interest in occurrences in the southwest Pacific containing copper, zinc, and gold.
- The Red Sea has the largest known sulphide occurrence, appearing as iron-rich ore muds.

11 India Physical Formation Physiographic and Relief

- **India is a vast country** lying entirely in the Northern hemisphere. The main land extends between **latitudes 8°4'N and 37°6'N** and **longitudes 68°7'E and 97°25'E**
- The Tropic of Cancer (23° 30'N) divides the country into almost two equal parts The southern part of the country lies within the tropics and the northern part lies in the sub-tropical zone or the warm temperate zone.
- Lakshadweep islands in Bay of Bengal and Arabian Sea respectively. Andaman and Nicobar islands make southern boundary of India Union at 6°45'E in Bay of Bengal.
- The southernmost point of the India Union **"Indira Point"** got submerged under the sea water in 2004 during the Tsunami.
- Indian standard meridian passes through 82° 30'E.Time along this **Standard Meridian of India** passing through **Mirzapur (in Uttar Pradesh)** is taken as the standard time for the whole country and known as IST with a time offset of UTC + 5 :30.
- India has a land boundary of about **15,200 km** and the total length of the coast line of the mainland including Andaman and Nicobar and Lakshadweep is **7,516.6 km.**
- India is part of Indian sub-continent and shares boundary with every country of this region. Land neighbours of India include **Pakistan, Afghanistan, China, Nepal, Bhutan, Myanmar and Bangladesh.**

Physical Formation of India :

1. The Peninsular Block
2. The Himalayas :
   - **Syntaxial Bends of the Himalayas-**The structures and trends of the Himalaya change sharply at both ends of the range, defining bends called **"syntaxes**.
3. Indo-Ganga-Brahmaputra Plain

Physiography :

A. Himalayan Mountains :

1. Kashmir or Northwestern Himalayas :

- This division is lying between Indus and Ravi rivers. With an average height of 3000m, it has the largest number of glaciers in India such as Baltoro, Siachen glaciers. Kashmir Himalayas comprise a series of ranges such as the Karakoram, Ladakh, Zaskar and Pir Panjal.
- The northeastern part of the Kashmir Himalayas, Ladakh, is a cold desert, which lies between the Greater Himalayas and the Karakoram ranges.

- A special feature of Kashmir valley is Karewas formation which is thick deposits of glacial clay and other materials embedded with moraines and useful for saffron cultivation.

2. **Himachal and Uttrakhand Himalayas :**

- Stretching over Himachal Pradesh, it occupies an area of about 83,000 sqkm. All the three ranges – the Greater, the Lesser (which is locally known as Dhaoladhar in Himachal Pradesh and Nagtibha in Uttaranchal) and the Shiwalik Himalayas – are well represented in this region.
- This division lies between Ravi and Kali rivers. It is drained by two major river systems of India, i.e. the Indus and the Ganga.
- Tributaries of the Indus include the river Ravi, the Beas and the Satluj, and the tributaries of Ganga flowing through this region include the Yamuna and the Ghaghara.
- The northernmost part of the Himachal Himalayas is an extension of the Ladakh cold desert. Gangotri, Milam and Pindar are the main glaciers of Uttarakhand.
- The places of pilgrimage such as the Gangotri, Yamunotri, Kedarnath, Badrinath and Hemkund Sahib are also situated in this part. The region is also known to have five famous Prayags - Vishnu Prayag, Nand Prayag, Karn prayag, Rudra Prayag and Dev Prayag, in the descending flow sequence of their occurrence.

3. **Darjiling and Sikkim Himalayas :**

- The Darjiling and Sikkim Himalayas are flanked by Nepal Himalayas in the west and Bhutan Himalayas in the east. It is relatively small but is a most significant part of the Himalayas.
- As compared to the other sections of the Himalayas, these along with the Arunachal Himalayas are conspicuous by the absence of the Shiwalik formations.
- The higher reaches of this region are inhabited by Lepcha tribes while the southern part, particularly the Darjiling Himalayas, has a mixed population of Nepalis, Bengalis and tribals from Central India.
- The passes of Nathu-La and Jelep-La connect Gangtok (Sikkim) with Lhasa, Tibet (China).

4. **Arunachal Himalayas :**

- Arunachal Himalayas extend from the east of the Bhutan Himalayas up to the Diphu pass in the east. The general direction of the mountain range is from southwest to northeast.
- In this part, the Himalayas rise very rapidly from the plains of Assam. Some of the important mountain peaks of the region are Kangtu and Namcha Barwa.
- Some of the important rivers are the Kameng, the Subansiri, the Dihang, the Dibang and the Lohit.

5. **Eastern Hills and Mountains or Purvanchal :**

- Eastern hills or Purvanchal are part of the Himalayan mountain system. On the southern border of Arunachal Pradesh, the Himalayas take a southerly turn and the ranges are arranged in a north-south direction.

- They are known by different local names. In the north, they are known as Patkai Bum (Arunachal Pradesh), Naga hills (Nagaland), the Manipur hills (Manipur) and in the south as Mizo or Lushai hills (Mizoram).
- The Barak is an important river in Manipur and Mizoram. The physiography of Manipur is unique by the presence of a large lake known as 'Loktak' lake at the centre, surrounded by mountains from all sides. Mizoram which is also known as the 'Molassis basin' is made up of soft unconsolidated deposits.

B . The Northern Plains :

1. The Bhabar Plain :

- Bhabar is a narrow belt ranging between 8-10 km parallel to the Shiwalik foothills at the breakup of the slope. Its width is, however, more in the western plains than in the eastern plains of Assam.
- The streams and rivers coming from the mountains deposit heavy materials of rocks and boulders, and at times, disappear in this zone due to high porosity.

2. The Tarai Tract :

- South of the Bhabar is the Tarai belt, with an approximate width of 10-20 km where most of the streams and rivers re-emerge without having any properly demarcated channel, thereby, creating marshy and swampy conditions known as the Tarai.
- Unlike Bhabar tracts, Tarai is wider in the eastern parts of the Great plains, especially in Brahmaputra valley due to heavy rainfall.

3. Bhangar Plains :

- The south of Tarai is a belt consisting of old and new alluvial deposits known as the Bhangar and Khadar respectively.
- The Bhangar represents the upland alluvial tracts formed by the older alluviums. The largest part of the northern plains is formed of this older alluvium.

4. Khadar Plains :

- New alluvial deposits along the courses of the rivers are known as the khadar lands. Himalayan rivers have more flood area in the eastern India and thus, Khadar plains are wider here as compared to western area.

5. The Delta Plains :

- The mouths of these mighty rivers also form some of the largest deltas of the world, for example, the famous Sunderbans delta. Otherwise, this is a featureless plain with a general elevation of 50-150 m above the mean sea level.
- The deltaic plains are extension of the Khadar land. It covers 1.9 lakh sqkm of area in lower reaches of the Ganga River. In fact, it is an area of deposition as the river flows in this tract sluggishly. The deltaic plain consists of old mud, new mud and marsh.

6. **The Plains of Rajasthan :**

- They lie to the west of Aravallis. These plains cover a total area of about 175,000 sqkm. A substantial part of this plain has been formed by the recession of the sea as is evidenced by the presence of salt water lakes such as Sambhar lake near Jaipur city.
- During the Permocarboniferous period, the greater part of the Rajasthan plain was under the sea. It has several dry beds of rivers like Saraswati which indicate that the area earlier was fertile.

7. **The Punjab Haryana Plains :**

- Stretching over an area of about 650km from northeast to southwest and 300km from west to east, the Punjab-Haryana plain is an aggradational plain, deposited by Satluj, Ravi and Beas rivers.
- Delhi ridge divides plains from the Gangetic plain.
- The height of the plains varies from 300 m in the north to 200 m in south east. The general direction of slope is from northeast to southwest and south. A plain between two rivers is called doab such as Bist doab between the Beas and Satluj

8. **The Ganga Plains :**

a) **The upper Ganga plain :**

- Includes the Ganga-Yamuna Doab, Rohilakhand division and parts of the Agra division. The catchment area of the Yamuna river makes its western boundary, Shiwalik in the north.
- Its height varies from 100m to 300m. Kali, Sharda are other rivers feeding these plains.

b) **The middle Ganga plain :**

- sprawling over an area of 150, 000 sqkm, it includes central and eastern Uttar Pradesh, Bihar up to Muzaffarpur and patna.
- It has thick alluvial deposits with less kankar. Being a low gradient plain, the rivers often change their courses in this region as described above about Kosi river. Son, Gandak are major tributaries of Ganga

c) **The lower ganga plain :**

- extends from Patna to the Bay of Bengal. It is bordered by Assam, Bangladesh in the east and Chotanagpur plateau in the west and Sundarban delta in the south.
- It is drained also by Tista, Sankosh, Mahananda, Damodar, Subarnarekha rivers. These plains have filled faults with sediment created during movement of Indian plate.

9. **The Brahmaputra Plain :**

- Stretching over an area of around 56,000sqkm, it is the eastern most part of plains. It is about 720 km long, 80 km wide and altitude varies from 30 m to 130 m.
- The region is surrounded by high mountains except in western side. Assam valley is characterized by a steep slope along northern margin.

- Majuli with area of around 930sqkm is the largest river island of India and the second largest of world.

C. The Peninsular Plateau :

1. The Deccan Plateau :

- This physiographic division is the largest region (about 7 lakh square km) of the Great Indian Plateau. The shape of this plateau is triangular and lies to the south of the river Narmada.
- This is bordered by the Western Ghats in the west, Eastern Ghats in the east and the Satpura, Maikal range and Mahadeo hills in the north.The Satpura range is formed by a series of scarped plateaus on the south, generally at an elevation varying between 600-900 m.
- It is a classic example of the relict mountains

2. The Central Highlands :

- It extends between Vindhayalchal range in South and Great Northern Plains in nroth. The Aravallis form the west-northwestern edge of the Central Highlands.
- **An** eastern extension of the Central Highland is formed by the Rajmahal hills.
- Malwa plateau forms the dominant part of the Central Highlands. The part of the Central Highlands which extends to the east of Malwa Plateau is known as Bundelkhand and is further followed by Baghelkhand and the well known Chhotanagpur Plateau with large mineral reserves.
- Chhotanagpur is drained by Damodar river. The Mahadeo Hills, Kaimur Hills and Maikal Range lie towards further east. The valley of Narmada has been formed due to the subsidence of the land mass between the Vindhyas and the Satpuras.

3. The North-Eastern Plateau :

- It is an extension of the main Peninsular plateau in the northeast- locally known as the Meghalaya and Karbi-Anglong Plateau. It is separated by Malda fault from the Chotanagpur Plateau.
- Later, this depression got filled up by the deposition activity of the numerous rivers. The Meghalaya plateau is further **sub-divided into three** : (i) The Garo Hills; (ii) The Khasi Hills; (iii) The Jaintia Hills, named after the tribal groups inhabiting this region

4. The Indian Desert :

- The Indian desert lies towards the western margins of the Aravali Hills. It is a land of undulating topography dotted with longitudinal dunes and barchans. This region receives low rainfall below 150 mm per year; hence, it has arid climate with low vegetation cover.

5. The Coastal Plains :

a. Western Coastal Plains :

- West Coastal Plain extends along the Arabian Sea from the Rann of Kutchch in the north to Kanyakumari in the south.

- These plains are an example of submerged coastal plain. Because of this submergence it is a narrow belt and provides natural conditions for the development of ports and harbours. Kandla, Mazagaon, JLN port Navha Sheva, Marmagao, Mangalore, Cochin, etc. are important natural ports

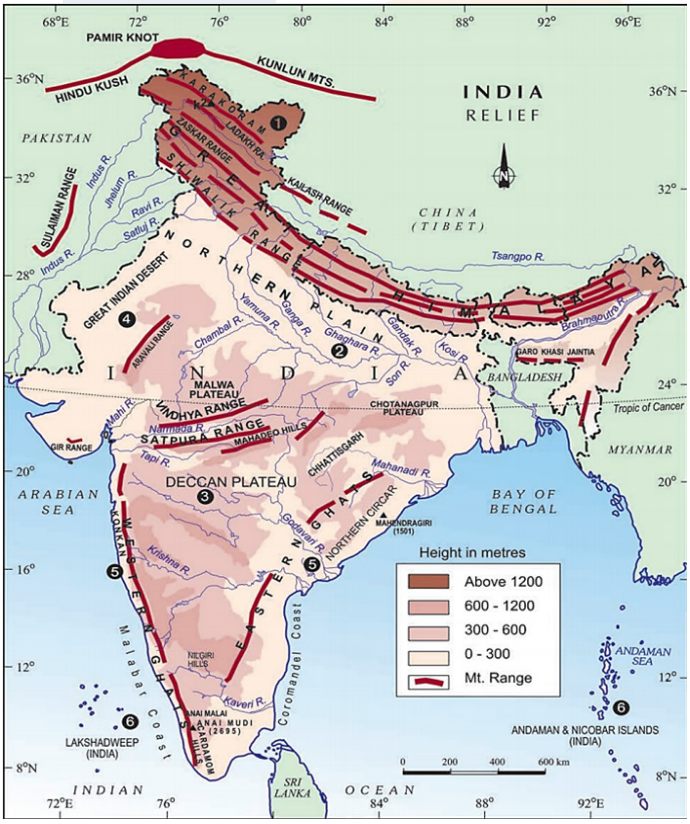
b. Eastern Coastal Plains :

- The eastern coastal plain is broader, leveled and is an example of an emergent coast. These plains are formed by the alluvial fillings.
- The monotony of plains is broken by the numerous hills. In the northern part, it is referred to as the Northern Circar, while the southern part is known as the Coromandal Coast.
- There are well developed deltas here, formed by rivers Mahanadi, Krishna, Godavari, Kaveri etc. Lakes such as Chilika, Pulicat, and Kolluru are the famous lagoons of this plain.
- Because of its emergent nature, it has less number of ports and harbours.

6. The Islands :

a. Andaman and Nicobar Islands-The Bay of Bengal island groups consist of about 572 islands/islets. These are situated roughly between 6°N-14°N and 92°E -94°E

b. Lakshadweep Island-Lakshadweep Islands are situated in the Arabian Sea, at a distance of 280-480km off the coast of Kerala. These are scattered between 8°N-12°N and 71°E -74°E . All these islands are of coral origin. They have been built up by corals. Only 11 out of 36 islands are inhabited.



12 DRAINAGE PATTERN AND TYPES

1. **Drainage System :**
   - The term 'drainage' refers to the river system of an area.
   - It is an integrated system of a river and its tributaries collecting and channeling surface water to the sea.
2. **Drainage Basin :**
   - The area drained by a single river system is called a drainage basin.
   - The boundary separating one drainage basin from another is known as the watershed.
3. **Watershed and Catchment Area :**
   - A watershed is the boundary line between drainage basins.
   - A river drains water collected from its specific area, known as its 'catchment area.'
4. **River Basins and Watersheds :**
   - Catchments of large rivers are called river basins.
   - Catchments of small rivulets and rills are referred to as watersheds.
   - Watersheds are small in area, while basins cover larger areas.

■ Drainage Pattern Overview :

- A drainage pattern refers to the geometric arrangement of streams in a region, influenced by various factors such as slope, rock resistance to weathering, climate, hydrologic variability, and structural controls.

Antecedent Rivers :

- Rivers like Indus, Satluj, and Ganga are considered antecedent rivers, which existed before the upheaval of the Himalayas. They cut their courses through mountains, forming gorges.

Consequent Rivers :

- Consequent rivers follow the general direction of the slope. **Examples** include Godavari and Krishna, which descend from the Western Ghats.

Dendritic Pattern :

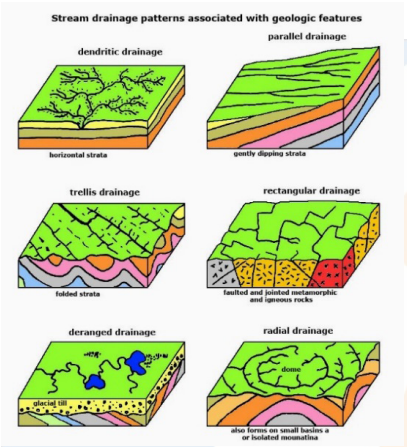
- This drainage pattern resembles the branches of a tree and is observed in rivers of the northern plain. It develops when the river channel follows the slope of the terrain.

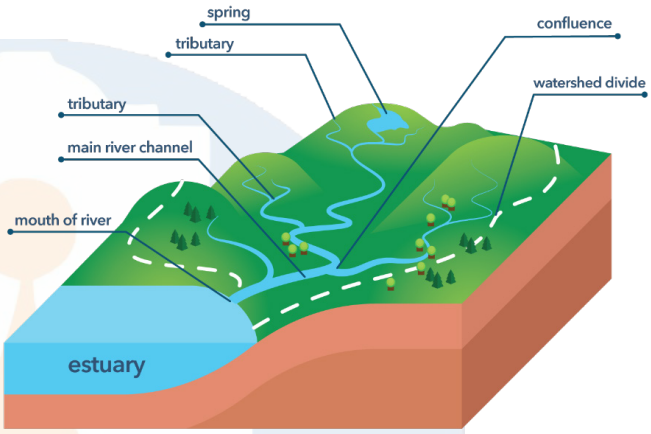
Radial Pattern :

- Radial drainage pattern occurs when rivers originate from a hill and flow in various directions. Rivers from the Amarkantak range exemplify this pattern.

Trellis Pattern :

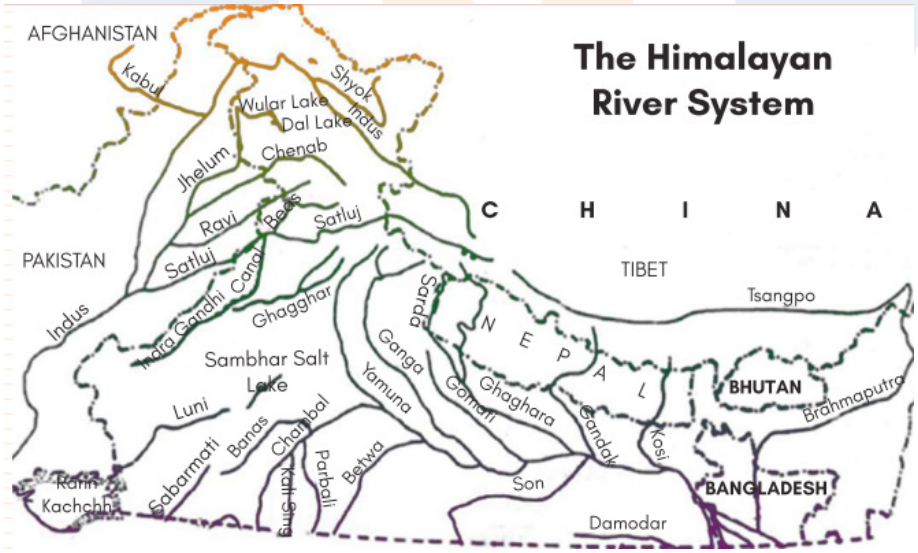
- In a trellis pattern, primary tributaries flow parallel to each other, and secondary tributaries join them at right angles. This pattern develops where hard and soft rocks exist parallel to each other.
- Right bank tributaries of Brahmaputra rivers exhibit a trellis pattern, while the left bank tributaries demonstrate a different pattern.





■ Types Of Drainage Patterns :

A. Himalayan Drainage System



- Himalayan rivers are in their youthful stage, resulting in the creation of various erosional landforms.
- Erosional activities occur simultaneously with the uplift of the Himalayas.
- Satluj and Indus form significant gorges near Gilgit and Sukkur, showcasing deep erosional features.
- V-shaped valleys, rapids, and waterfalls are characteristic features of these rivers in their mountainous course.

- Upon entering the plains, Himalayan rivers exhibit depositional features such as flat valleys, ox-bow lakes, floodplains, braided channels, and deltas near the river mouth.
- In the Himalayan region, the courses of these rivers are highly tortuous.
- Over the plains, Himalayan rivers display a strong meandering tendency and frequently shift their courses.

1. Indus System :

- The Indus drainage system is one of the largest in the world, covering 11,65,000 sq. km, with 1,114 km in India.
- The Indus originates from a glacier near Bokar Chu in the Kailash Mountain range in Tibet, known as 'Singi Khamban' or Lion's mouth.
- It flows through Ladakh, forming a spectacular gorge near Gilgit, and then enters Pakistan near Chillar.
- Tributaries in Jammu and Kashmir include Shyok, Gilgit, Hunza, Nubra, Shigar, Gasting, Dras, Khurram, and Tochi.
- In Pakistan, it receives the Panjnad (Satluj, Beas, Ravi, Chenab, Jhelum) before draining into the Arabian Sea.
- The Jhelum rises from Verinag Spring, enters Pakistan through a deep gorge, and joins the Chenab.
- The Chenab, the largest tributary, is formed by the Chandra and Bhaga streams, with major hydro power plants like Salal, Baghliar, and Dulhasti.
- The Ravi, originating near Rohtang Pass, flows through the Chamba valley and joins Chenab near Sarai Sidhu in Pakistan.
- The Beas originates from Beas Kund, flows through the Kullu and Kangra valleys, and meets the Satluj near Harike.
- The Satluj rises from Rakas Lake, flows parallel to the Indus, and cuts through various ranges before entering the Punjab plains.
- The Ghaggar (Saraswati) is an inland drainage rising near Ambala, disappearing and reappearing before vanishing near Hanumargarh in Bikaner.

Jhelum	Rises from a spring at Verinag Spring situated at the foot of the Pir Panjal.
	Flows through Srinagar and the Wular lake before entering Pakistan,
	Joins the Chenab in Pakistan.
Chenab	The Chenab (Asikni) flows in India for about 1180km draining around 26,755 sq km
	It is the largest tributary of the Indus.
	It is formed by two streams, the Chandra and the Bhaga Hence, it is also known as Chandrabhaga.
	Major hydro power plants installed in Chenab are Salal, Baghliar, and Dulhasti.
Ravi	The Ravi (Parushni) river flows for about 725 km and drains 6000 sqkm area in India.
	Rises near the Rohtang Pass in Kullu hills in Himachal Pradesh. Flows through the famous Chamba valley.
	Drains an area lying between Pir Panjal and Dhauladhar ranges.

Beas	The Beas (Vipasa) river originates from the Beas Kund near the Rohtang Pass.
	Flows through the Kullu valley & Kangra Valley.
	Enters the Punjab plains where it meets the Satluj near Harike in India's Punjab.
	Indira Gandhi Canal that feeds western Rajasthan has origin at Harike, confluence of Beas and Satluj.
Satluj	The Satluj (Satadru) river rises from the Rakas Lake near Mansarovar (4,555m) in Tibet.
	This is an antecedent river.
	Passes through the Shipki La (4300 m) on the Himalayan ranges at India-China border.
	It cuts the Zaskar ranges, Dhaula Dhar range, Shiwalik and finally enters the Punjab plains.
	Feeds the canal system of the Bhakra Nangal project.
Ghaggar	The Ghaggar (Saraswati) is an inland drainage which rises in the talus fan of the Shiwalik near Ambala, Haryana.
	After entering the plains, it disappears but reappears at Karnal. Further on, the stream disappears near Hanumargarh in Bikaner.
	It is believed that it is an old tributary of the Indus.

2. The Ganga System :

- The Ganga is the most significant river in India, covering a basin with about one-fourth of the country's area.
- It originates as Bhagirathi from the Gangotri glacier, meets Alaknanda at Devprayag, and further downstream splits into Bhagirathi and Hugli in Bengal.
- The Yamuna, the longest tributary, flows parallel to the Ganga and joins it at Allahabad, with major tributaries like Chambal, Sind, Betwa, Ken, Hindan, Rind, Sengar, and Varuna.

- The Gandak rises in Nepal Himalayas, enters Bihar, and joins Ganga at Sonpur near Patna, frequently changing its course.
- The Ghaghara originates in Nepal, joins the Ganga at Chhapra, and flows through Ayodhya.
- The Ramganga, originating in the Garhwal hills, joins the Ganga from the left near Kannauj.
- The Damodar drains the eastern parts of the Chotanagpur Plateau, joins the Hugli at Falta, and has been controlled by the Damodar Valley Corporation.
- The Chambal, rising near Mhow, flows through a gorge in Rajasthan, joining the Yamuna at Etawah, known for its badland topography and reclaimed ravines.
- The Son originates from the Amarkantak plateau, reaches Arrah, west of Patna, and joins the Ganga.
- The Sarda or Saryu, rising in the Nepal Himalayas, is known as Kali or Chauk along the Indo-Nepal border, joining the Ghaghara.
- The Mahananda, rising in the Darjeeling hills, joins the Ganga as its last left bank tributary in West Bengal.

Yamuna	Western most and the longest tributary of the Ganga, has its source in the Yamunotri glacier on the western slopes of Bander punch range (6,316 km).
	Meets Ganga at Allahabad (Prayag)
	The right bank tributaries Involve the Chambal, the Sind, the Betwa and the Ken which originates in the Peninsular plateau.
	Hindan, the Rind, the Sengar, the Varuna join it on its left bank.
	It flows through cities such as Karnal, Delhi, and Agra.
Gandak	The Gandak river comprises two streams, namely Kaligandak and Trishulganga.
	It rises in the Nepal Himalayas between Dhaulagiri and Mt. Everest.
	It enters the Ganga Plains of India in Champaran, Bihar and joins Ganga at Sonpur near Patna.

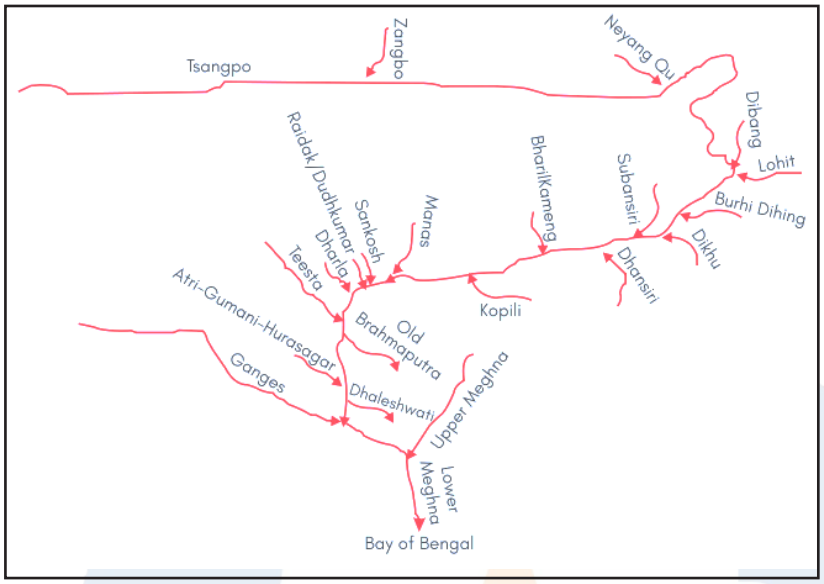
Ghaghara	The Ghaghara originates in the glaciers of Mapchachungo. It comes out of the mountain, cutting a deep gorge at Shishapani.
	The river Sarda joins it in the plain before it finally meets the Ganga at Chhapra. It flows through famous Ayodhya town.
Ramaganga	The Ramganga is the first major tributary to join the Ganga from its left near Kannauj.
	It rises in the Garhwal hills near Gairsain. A large dam has been built on this river near Kalagarh.
Damodar	The Damodar drains the eastern parts of the Chotanagpur Plateau where it flows through a rift valley and finally joins the Hugli at Falta.
	The Barakar is its main tributary. Once known as the 'Sorrow of Bengal' the Damodar has been now tamed by the Damodar Valley Corporation, a multipurpose project.
Chambal	The Chambal rises near Mhow in the Malwa plateau from Vindhyan. From Kota, it traverses down to Bundi, Sawai Madhopur and Dholpur, and finally joins the Yamuna at Etawah.
	The Chambal is famous for its badland topography called the Chambal ravines. Ravines are being reclaimed for agricultural and pastoral activities.
	Banas river is its main tributary. The main dams across the river are Gandhi Sagar (Kota), Rana Pratap Sagar and Jawahar Sagar.
Son	The Son originates from the Amarkantak plateau. It has length of 780km.
	After forming a series of waterfall at the edge of plateau, it reaches Arrah, west of Patna to join the Ganga. It is known for its frequent river shifting.
Sharda	The Sarda or Saryu river rises in the Milan glacier in the Nepal Himalayas where it is known as the Goriganga. Along the Indo-Nepal border, it is called Kali or Chauk, where it joins the Ghaghara.
Mahananda	The Mahananda is another important tributary of the Ganga rising in the Darjiling hills. It joins the Ganga as its last left bank tributary in West Bengal.

3. Brahmaputra River System :

- The Brahmaputra is one of the world's largest rivers, with a total length of 2900 km and a basin area of 5,80,000 sq km (916 km and 1,87,00 sq km in India).
- Originating in the Chemayungdung glacier of the Kailash range near Mansarovar lake, it flows parallel to the Greater Himalayas in Tibet, known as Tsangpo.
- Carving a deep gorge in the Central Himalayas near Namcha Barwa, it emerges as a dynamic river known as Siang or Dihang upon entering India west of Sadiya town in Arunachal Pradesh.
- Main left bank tributaries include Dibang or Sikang and Lohit, and in Assam, major left bank tributaries are Burhi Dihing, Dhansari (South), and Kalang, while right bank tributaries are Subansiri, Kameng, Manas, and Sankosh.
- Entering Bangladesh near Dhubri, it flows southward, with the Tista joining on its right bank, changing the river's name to Yamuna.

- Known for floods, channel shifting, and bank erosion due to the large size of its tributaries and the substantial sediment load from heavy rainfall in the region.

Left Bank Tributaries	Dibang or Sikang, Lohit, Burhi Dihing, Dhansari (South) and Kalang
Right Bank Tributaries	Subansiri, Kameng, Manas and Sankosh



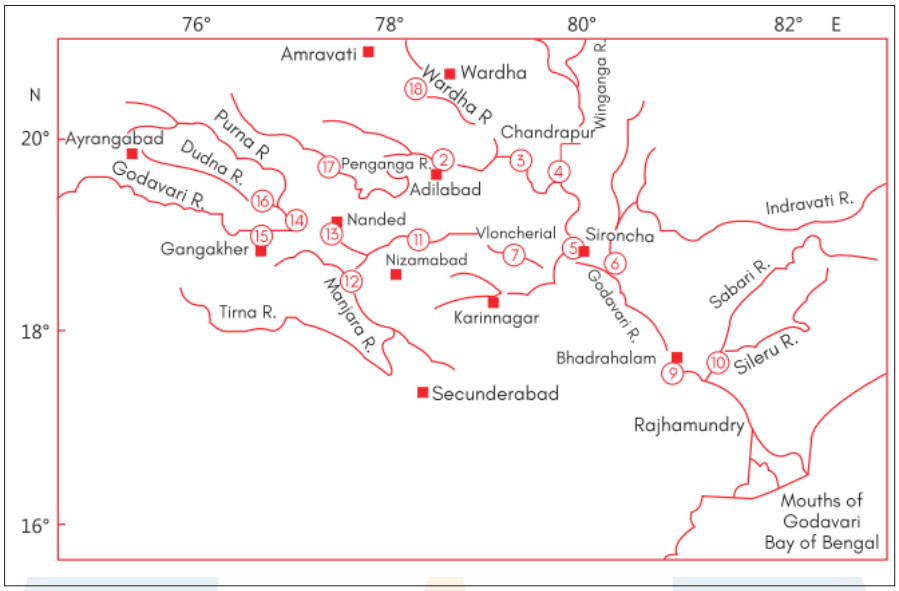
B. The Peninsular Drainage System :

- The Peninsular drainage system predates the Himalayan one, evident from its broad, largely-graded shallow valleys and mature rivers, following the plateau's relief pattern.
- **Three geological events shaped the Peninsular drainage :** subsidence of the western flank, upheaval of the Himalayas causing trough faulting, and a slight tilting of the Peninsular block towards the Bay of Bengal.
- **The Western Ghats** act as the major water divide, with rivers discharging into the Bay of Bengal and small rivulets joining the Arabian Sea. **East-flowing rivers** include the Mahanadi, Godavari, Krishna, and Kaveri, characterized by a fixed course, absence of meanders, and ephemeral water flow.
- **West-flowing rivers** like Narmada and Tapi flow through rift valleys and lack alluvial and deltaic deposits. The Narmada forms a picturesque gorge and meets the Arabian Sea, while the Tapi originates in Madhya Pradesh and discharges in Surat, Gujarat.
- **Luni,** originating near Pushkar, is the largest river system in Rajasthan. The Mahi rises in the Vindhyan mountains and drains into the Gulf of Khambhat. Numerous small west-flowing rivers rise in the Western Ghats, such as Shetrunji, Bhadra, Dhadhar, Vaitarna, Kalinadi, Sharavati, Mandovi, Juari, Bharathapuzha, and Periyar in Kerala.

1. The Godavari River System :

- The Godavari is the largest Peninsular river. It is 1,465 km long with 49 per cent of river course, lying in Maharashtra.
- The Godavari River is the second-longest course in India with brownish water.
- The river is often referred to as the Dakahin (South) Ganga or Vriddh (Old) Ganga.

- This river originates from Trimbakeshwar, near Nasik in Maharashtra.
- It flows southeast across south-central India through the states of Madhya Pradesh, Telangana, Andhra Pradesh, and Orissa, and drains into the Bay of Bengal.
- The river forms a fertile delta at Rajahmundry

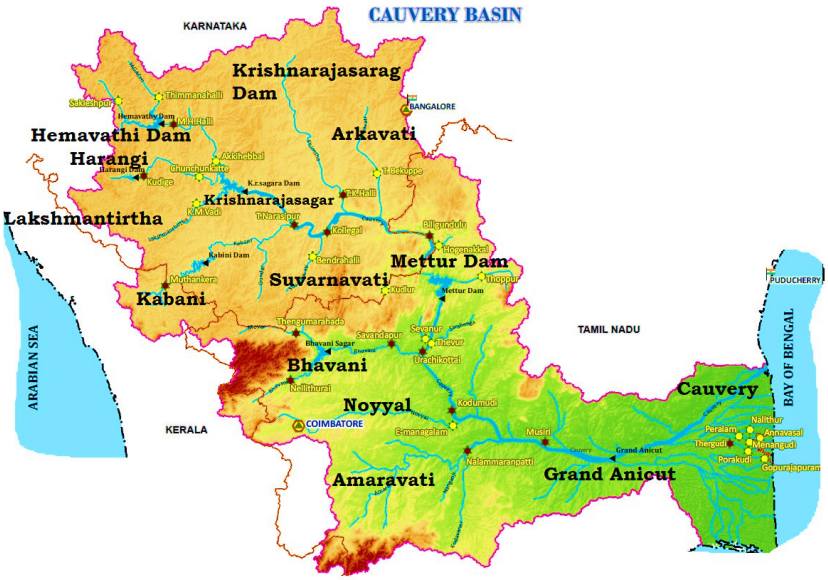


Left Bank	Purna, Pranhita (Penganga and Warda), Indravathi, Sabari
Right Bank	Dharna river, Pravara river, Sindphana river, Manjira river, Peddavagu river

2. Cauvery River System :

- The Kaveri rises in Brahmagiri hills (1,341m) of Kogadu district in Karnataka. Its length is 800 km.
- It flows into the Bay of Bengal at Kaveripatnam. It drains parts of Tamil Nadu, Karnataka and Kerala. Its important tributaries are the Kabini, the Bhavani and the Amravati.

Left Bank	the Harangi, the Hemavati, the Shimsha and the Arkavati.
Right Bank	Lakshmantirtha, the Kabbani, the Suvarnavati, the Bhavani, the Noyil and the Amaravati



3. Krishna River System :

- Krishna is one of the longest rivers of India, which originates from Mahabaleshwar in Maharashtra.
- The river flows through the states of Maharashtra, Karnataka, Telangana and Andhra Pradesh. Tungabhadra River is the main tributary which itself is formed by the Tunga and Bhadra rivers that
- originate in the Western Ghats.
- Dudhganga Rivers, Koyna, Bhima, Mallaprabha, Dindi, Ghataprabha, Warna, Yerla, and Musi are some of the other tributaries.

Left Bank	The Bhima,Koyna, the Musi and the Munneru.
Right Bank	The Ghatprabha, the Malprabha and the Tungabhadra

4. Mahanandi River System :

- The Mahanadi rises near Sihawa, Amarkantak hills in the highlands of Chhattisgarh and runs through Orissa to discharge its water into the Bay of Bengal. It is 851 km long.
- It flows east to the Bay of Bengal. The river drains of the state of Maharashtra, Chhattisgarh, Jharkhand, and Orissa.
- The largest dam, the Hirakud Dam is built on the river.

Left Bank	Sheonath, Mand, Ib, Hasdeo
Right Bank	Ong, Jonk, Tel

5. Narmada River System :

- The Narmada originates on the western flank of the Amarkantak plateau at a height of about 1,057 m. Flowing in a rift valley between the

Satpura in the south and the Vindhyan range in the north, it forms a picturesque gorge in marble rocks and Dhuandhar waterfall near Jabalpur.

- It meets the Arabian Sea south of Bharuch, forming a broad 27 km long estuary. Its length is 1512 km.
- All the tributaries are very short and make trellis pattern. The Sardar Sarovar Project has boon constructed on this river.

Left Bank	Burhner River, Banjar River, Shar River, Shakkar River, Dudhi River, Tawa River, Ganjal River, Chhota Tawa River, Karjan River
Right Bank	Hiran River, Tendoni River, Kolar River, Hatni River, Orsang River

6. **Other Notable Rivers :**

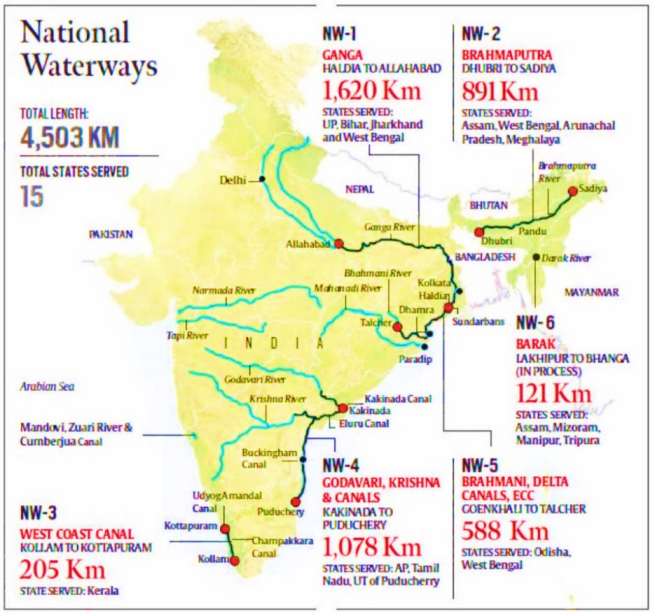
West Flowing Rivers	
Tapi	Originates from Multal in the Botul district of Madhya Pradesh and discharge in Surat district, Gujarat.
	The Purna, Gima and Panjhra are its important tributaries.
Luni	Luni is the largest river system of Rajasthan, west of the Aravallis
	Originates near Pushkar in two branches, ie. the Saraswati and the Sabarmati.
	Flows towards the west till Telwara and then takes a southwest direction to join the Rann of Kutch.
Mahi	The Mahi river rises in the Satmala hills of the Vindhyan mountains,
	After flowing for 533km, it drains into the Gulf of Khambhat.
	It is only river which cuts through Tropic of Cancer Twice along its course.
Sabarmati	Rises in the Aravalli hills
	Flows into Arabian Sea after flowing over a distance of 300km.
Bharathapuzha and Periyar	The longest river of kerala rises near Annamalai hills also known as ponnani.
	The Periyar is the second largest river of Kerala.
Zuari and Mandovi Rivers	The Mandovi and the Zuari are rivers in the state of Goa.
	Mahadayi/Mandovi River is described as the lifeline of the Indian state of Goa.
	Mandovi joins with the Zuari at a common creek at Cabo Aguada, forming the Mormugao harbour.
	Panaji, the state capital is situated on the left bank of the Mandovi.
Sharavati	Important river in Karnataka flowing towards the west.
	The Sharavati originates in Shimoga district of Karnataka..

S.N.	Aspects	Himalayan River	Peninsular River
1.	Place of Origin	Himalayan mountain covered with glaciers	Peninsular plateau and central highland
2.	Nature of Flow	Perennial	Ephemeral
3.	Type of Drainage	Antecedent and Consequent leading to dendritic pattern	Superimposed, rejuvenated resulting in trellis, radial, and rectangular patterns
4.	Nature of River	Long course, flowing through rugged mountains, experiencing headward erosion and river capturing; In plains, meandering and shifting of course	Smaller, fixed course with well-adjusted valleys; Flows over uneven plateau; Canals only in deltaic region
5.	Catchment Area	Very large basins	Relatively smaller basin
6.	Age of the River	Young, active, and deepening of valley	Old rivers with graded profile and lateral erosion
7.	Irrigation	Flows through plains and canal system	Flows over uneven plateau; Canals only in deltaic region
8.	Hydroelectricity	Eastern region has very high potential and large dams are being built	Natural waterfalls for generating electricity

■ National Waterways :

- The National Waterways (NW) of India play a crucial role in the country's transport sector, providing a fuel-efficient, environmentally friendly, and cost-effective mode of transportation. Currently, there are five national waterways, with a sixth under consideration. Here is an overview of the existing national waterways :

1. **NW1 :**
   - **Route :** Allahabad to Haldia
   - **Length :** 1620 km
   - **Usage :** Tourism vessels, ODC carriers, IWAI vessels
   - **Notable Features :** Many coal-based plants along the Ganga, serving as a potential revenue source for inland navigation.



   - **Usage :** Tourism vessels, Border security forces, Assam government, private vessels
   - **Notable Features :** Significant for tourism and security purposes.

3. **NW3 :**

- **Route :** Multiple canals on the western coast, including West coast canal (168 km), Udyogmandal canal (23 km), Champakara canal (14 km)
- **Usage :** Navigable and tourism potential, movement of raw materials for fertilizer plants.

4. **NW4 :**

- **Route :** Kakinada-Puducherry canal (767 km), Godavari river (171 km), Krishna river (157 km)
- **Usage :** Transportation of coal on Godavari river, cement on Krishna river, rice, and other food commodities.

5. **NW5 :**

- **Stretches :** Mahanadi Delta (101 km), Brahmani and others (265 km), Matai river (40 km), Geonkhali-Charbatia (217 km)
- **Usage :** Transportation of coal as a major commodity.

- The government is also considering the declaration of Barak river from Bhanga to Lakhipur (121 km) in the state of Assam as a National Waterway. The Budget 2013 emphasized waterway connectivity for Northeast India. However, challenges such as poor maintenance and insufficient government subsidies for transporting various commodities remain significant issues in the inland water navigation sector.

National River Linking Project

- aims to address the uneven distribution of water in India by linking water surplus Himalayan rivers with water-scarce regions in the west and peninsular parts of the country. While the project holds potential benefits, it faces significant challenges in implementation.

Key Points :

1. **Uneven Water Distribution :**
   - India's rivers carry varying volumes of water, with perennial rivers flowing throughout the year and non-perennial rivers experiencing water scarcity during dry seasons.
   - Water is often wasted during floods, and there is a lack of synchronization between water surplus and deficit regions.
2. **Benefits of River Linking :**
   - The project aims to provide irrigation, assured drinking water, flood and drought prevention, electricity generation, and inland navigation.
   - However, the massive undertaking involves substantial financial costs, raising questions about India's ability to afford such an ambitious project.
3. **Challenges and Concerns :**
   - The Peninsular plateau's higher altitude compared to the Ganges plains poses challenges in water transfer, requiring significant infrastructure and financial investment.

- Land acquisition on a large scale raises concerns about environmental impact, ecosystem disruption (submergence of forest land, deforestation), and the rehabilitation of displaced persons.
- The project's feasibility is questioned due to the difficulty of creating channels in the rocky Peninsular terrain and the need for substantial energy to pump water to higher altitudes.

4. **Climate Change Considerations :**

- Climate change effects on water availability in the Northern plains raise concerns about future water shortages.
- Shifting large quantities of water could impact the heat balance of the Indian subcontinent, potentially affecting monsoon patterns and intensities and influencing the temperature and salinity of Bay of Bengal water.

5. **Political and Public Opposition :**

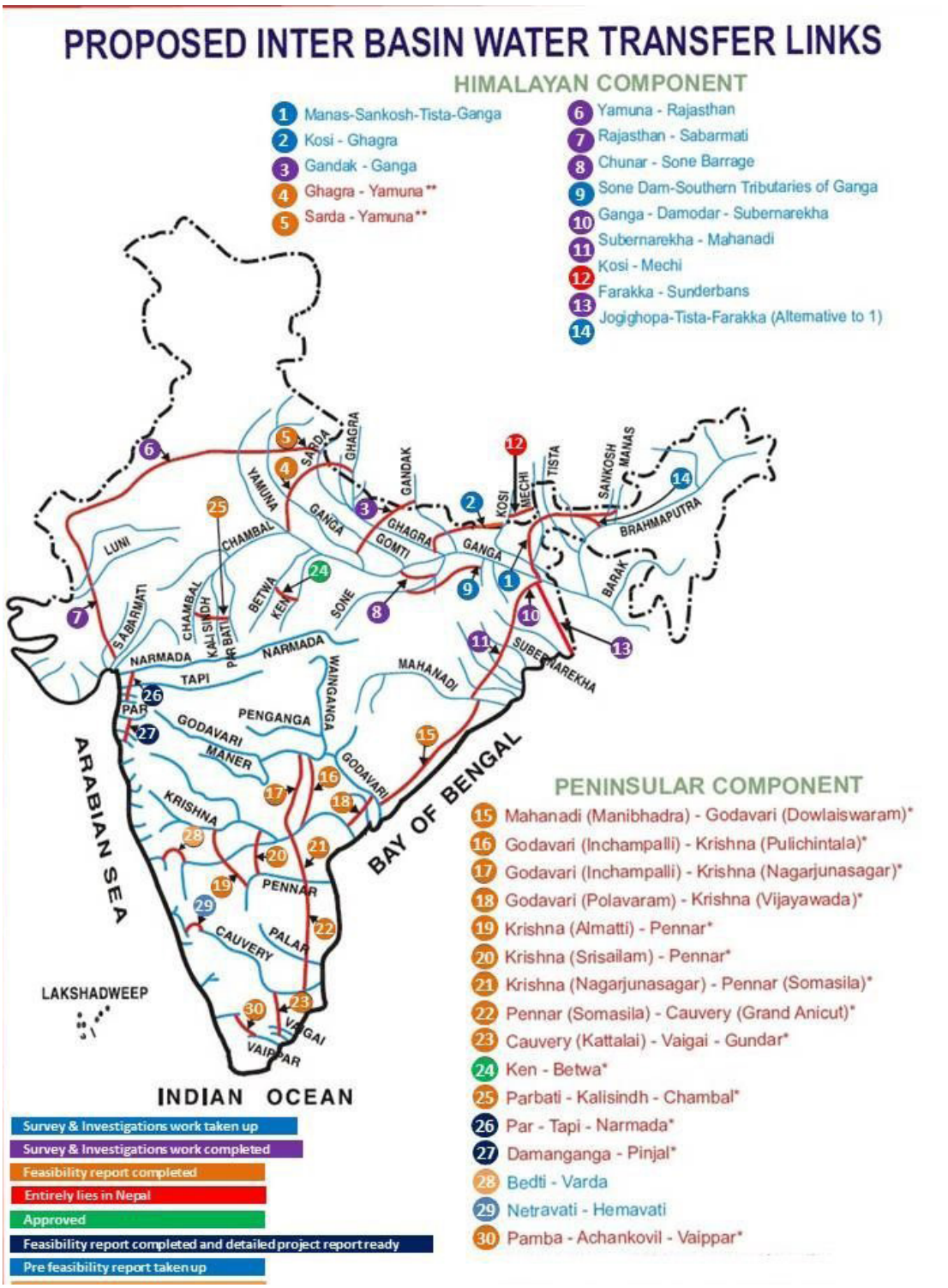
- The NDA government's proposal faced opposition, leading to a Supreme Court clearance but subsequent challenges and a review petition.
- Political and interstate consensus is a significant challenge, with the project crossing state boundaries.

6. **Feasibility and Implementation :**

- While small-scale river links are feasible, the comprehensive project faces hurdles.
- Some priority links, like Ken-Betwa, have undergone analysis, and the emphasis on water management at the local level is suggested as a solution in the 12th five-year plan.

Priority Peninsular Links :

- **The Ministry of Water Resources identified five priority Peninsular river links** :
  (i) Ken - Betwa
  (ii) Parbati - Kalisindh - Chambal
  (iii) Damanganga - Pinjal
  (iv) Par - Tapi - Narmada
  (v) Godavari (Polavaram) - Krishna (Vijayawada)


PROPOSED INTER BASIN WATER TRANSFER LINKS
HIMALAYAN COMPONENT
1 Manas-Sankosh-Tista-Ganga
2 Kosi - Ghagra
3 Gandak - Ganga
4 Ghagra - Yamuna**
5 Sarda - Yamuna**
6 Yamuna - Rajasthan
7 Rajasthan - Sabarmati
8 Chunar - Sone Barrage
9 Sone Dam-Southern Tributaries of Ganga
10 Ganga - Damodar - Subernarekha
11 Subernarekha - Mahanadi
12 Kosi - Mechi
13 Farakka - Sunderbans
14 Jogighopa-Tista-Farakka (Alternative to 1)
PENINSULAR COMPONENT
15 Mahanadi (Manibhadra) - Godavari (Dowlaiswaram)*
16 Godavari (Inchampalli) - Krishna (Pulichintala)*
17 Godavari (Inchampalli) - Krishna (Nagarjunasagar)*
18 Godavari (Polavaram) - Krishna (Vijayawada)*
19 Krishna (Almatti) - Pennar*
20 Krishna (Srisailam) - Pennar*
21 Krishna (Nagarjunasagar) - Pennar (Somasila)*
22 Pennar (Somasila) - Cauvery (Grand Anicut)*
23 Cauvery (Kattalai) - Vaigai - Gundar*
24 Ken - Betwa*
25 Parbati - Kalisindh - Chambal*
26 Par - Tapi - Narmada*
27 Damanganga - Pinjal*
28 Bedti - Varda
29 Netravati - Hemavati
30 Pamba - Achankovil - Vaippar*
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
LAKSHADWEEP
Survey & Investigations work taken up
Survey & Investigations work completed
Feasibility report completed
Entirely lies in Nepal
Approved
Feasibility report completed and detailed project report ready
Pre feasibility report taken up

13 SOIL

- Soil plays a crucial role in the natural environment, acting as a significant link between climate, vegetation, and human activities. As the most vital layer of the Earth's crust, soil is a valuable and dynamic resource, undergoing constant physical, chemical, and biological activities. The relative fertility of soil profoundly influences various aspects of human life and environmental processes.

Soil Properties :

1. Composition and States :

- Soil is a mixture of rock debris and organic materials found on the Earth's surface.
- It contains matter in solid, liquid, and gaseous states, with the solid portion being partly organic and partly inorganic.

2. Inorganic Composition :

- Inorganic part comprises particles derived from the parent material (rocks) that weather to form the soil.
- Organic portion consists of living and decayed plant and animal materials, such as roots and worms.

3. Soil Components :

- Soil contains water, which is a complex chemical solution derived from precipitation, run-off, and groundwater.
- Soil atmosphere occupies pore spaces when not filled with water, and their amounts vary based on soil type.

4. Texture :

- Soil texture refers to the sizes of solid particles, ranging from clay (less than 0.002mm) to gravel (more than 2mm).
- Texture influences water-retention properties, with loam texture considered best for plant growth.

5. Structure :

- Soil structure is the arrangement of particles, forming aggregates due to cementing action of ions.
- Structures include platy, prismatic, crumby, and granular; humus aids in crumb formation.
- Soil structure affects cultivation ease, with crumb structures being optimal for seed germination.

6. Soil Colloids :

- Colloids are tiny particles with unique chemical properties, either organic (humus) or mineral (clay minerals).

- Clay-humus complex includes negatively charged clay minerals with exchangeable cations like calcium, magnesium, potassium, and sodium.
- Cations are crucial for plant growth, exchanged with hydrogen ions, contributing to soil acidity.

7. **Soil Acidity :**

- Soil acidity is related to the proportion of exchangeable hydrogen ions, with a pH value around 6.5 considered favorable for cereal crops.
- Acidification occurs naturally through decomposition or artificially with fertilizers, affecting soil pH.

8. **Color :**

- Soil color varies, reflecting its formation and composition.
- Recently formed soils may reflect parent material color, but humus content influences color.
- Colors range from white to black, with high humus content in cool humid areas, light brown or grey in desert areas, and reddish hues indicating well-drained soil.

■ Soil Forming Factors :

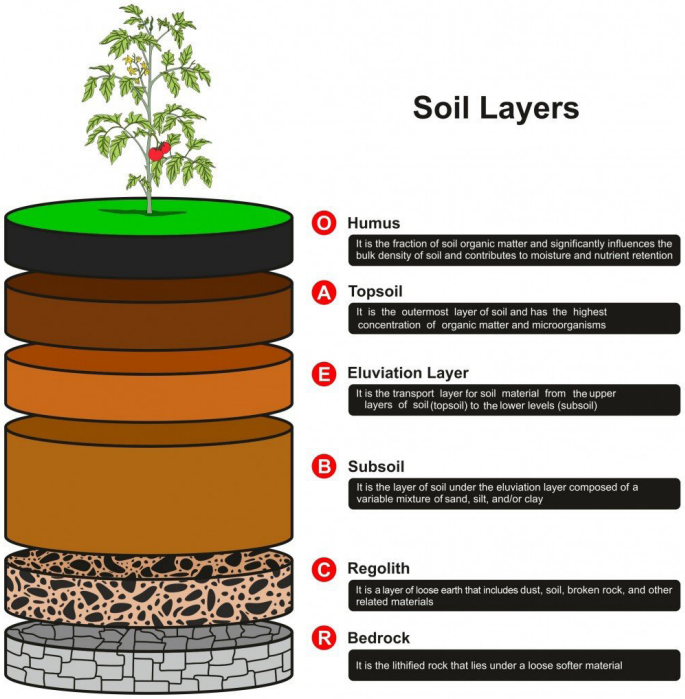
There are five main factors influencing soil formation, categorized into active and passive control factors :

1. **Active Control Factors :**

- **Climate :** Major influence on soil formation, affecting precipitation, temperature, and the rate of chemical and biological reactions. Precipitation, in terms of intensity and duration, plays a crucial role.
- **Biological Activity :** Vegetation and organisms contribute to soil development by adding organic matter, enhancing moisture retention, and influencing nitrogen fixation. Plants play a role in preventing erosion and maintaining soil fertility.

2. **Passive Control Factors :**

- **Parent Material :** Comprising in-situ weathered rock debris or transported deposits, influencing soil texture, structure, and mineral composition. Younger soils often resemble parent material, and fertility is observed through texture.
- **Topography :** Influences exposure to sunlight, drainage conditions, and slope angles. Hillsides tend to be well-drained, while valleys may experience gleying. Soil thickness varies with slope steepness, affecting susceptibility to erosion.
- **Time :** The duration of soil-forming processes determines soil maturation and profile development. Soil development rates vary based on factors such as material permeability. Climate and other changes can lead to renewed evolution and adjustments.



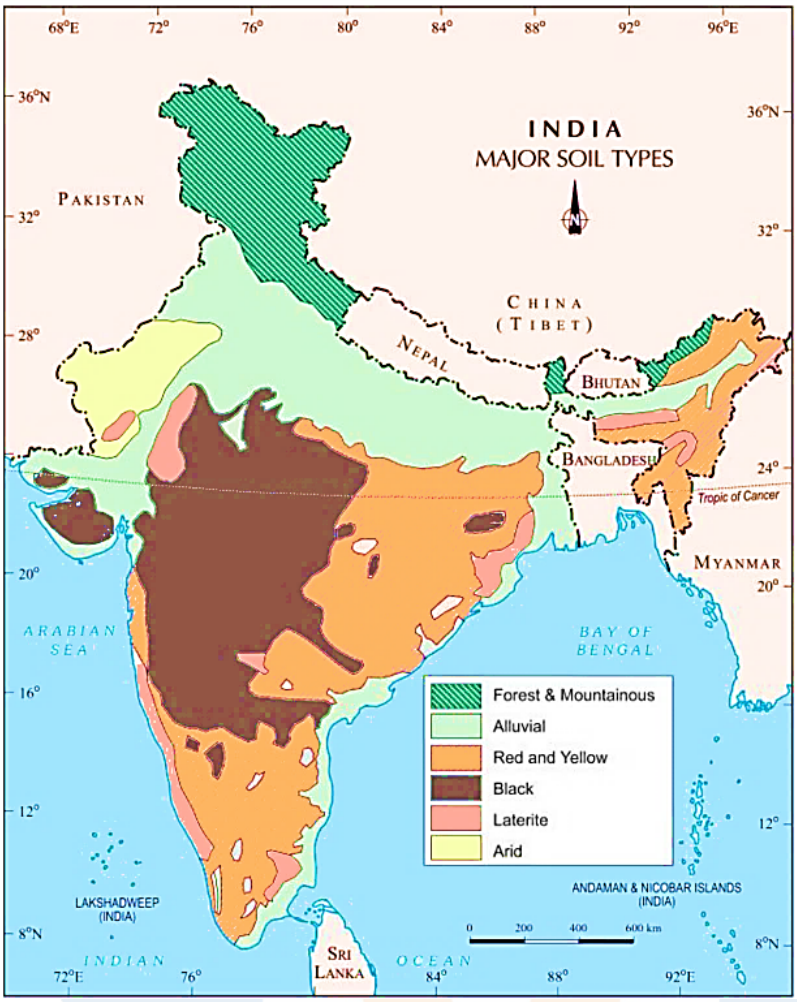
Three main classes of soil based on zonal system :

ZONAL	Well-developed soils which reflect the influence of climate as the major soil-forming factor.
	Can be subdivided into Podzol soils, Tundra soils, Brown earth, Fer- ralsol, Chernozem, Chestnut and Prairie soils.
INTRAZONAL	Well-developed soils formed where some local factors such as parent material, terrain or age is dominant.
	Can be subdivided into Podzol soils, Tundra soils, Brown earth, Fer- ralsol, Chernozem, Chestnut and Prairie soils.
	Can be subdivided into Calcimorphic soil (on calcareous parent material), Halomorphic soils(saline), and Hydromorphic soil (marsh es, swamps or poorly drained upland).
AZONAL	Immature or poorly developed soils lacking a B-horizon. A- hori zon lies immediately above the C-horizon of weathered parent material.
	This may happen because of characteristics of parent material or nature of terrain or simply the lack of time for development.
	Usually found on active flood plains, volcanic soils, newly deposited glacial drift, windblown sand, marine mud-flats.
	Can be subdivided into Lithosol (erosion removes soil almost as fast as it is formed on steep slopes), Regosol (dry and loose dune sands) and alluvial soils (regular supply of sediments).

Soil Classification in India

- The National Bureau of Soil Survey and the Land Use Planning an Institute under the control of the Indian Council of Agricultural Research (ICAR) did a lot of studies on Indian soils. ICAR has classified Indian soils into eight types on the basis of their formation, colour, composition and location.

Soil Type	Formation	Characteristics	Distribution	Use/Challenges
Alluvial Soil	River deposits, Khadar (fresh) and Bangar (older)	Loamy/clayey, rich in potash, poor in phosphorous	Northern plains, river valleys, deltas	Intensively cultivated, potential for agriculture
Black Soil	Volcanic lava, Regur soil	Clayey, deep, impermeable, high iron content	Deccan Plateau	'Self-ploughing,' moisture retention, suitable for rain-fed crops
Red and Yellow Soil	Weathering of granite and gneiss	Red (iron diffusion) or yellow (hydrated form), rich in iron, lime, potash	Eastern and southern Deccan plateau	Rich minerals, poor in nitrogen, phosphorous, and humus
Laterite Soil	Monsoon climate, accelerated leaching	Poor in organic matter, nitrogen, phosphate, calcium; rich in iron oxide and potash	Tamil Nadu, Andhra Pradesh, Kerala	Not suitable for cultivation, used in construction
Arid Soil	Desert weathering, mainly sand grains	High salt content, low moisture retention	Western Rajasthan, southern Punjab, Haryana	Limited fertility, challenges in cultivation
Forest Soil	Mountain ranges with sufficient rainfall	Loamy, silty (valley sides), coarse-grained (upper slopes)	Himalayas, Purvanchal, Sahyadri	Fertile in lower valleys, thin and less productive on steep slopes
Saline Soil (Usara)	High sodium, potassium, magnesium, poor drainage	Infertile, lack in nitrogen and calcium	Arid regions, western Gujarat, deltas, Sunderban	Salinity issues, gypsum addition recommended
Peaty and Marshy Soil	Heavy rainfall, high humidity	Rich humus, organic content (up to 40-50%), alkaline in some areas	Kerala, Odisha, Bengal, Coastal areas of Tamil Nadu	Dense vegetation growth, alkaline conditions, organic-rich.



Soil Erosion :

- Soil erosion is the process of soil removal at a rate higher than its natural replacement, influenced by both natural and human factors. When the balance between soil-forming and erosional processes is disrupted, net soil loss occurs. Human activities, such as agriculture, grazing, and land drainage schemes, often accelerate natural erosion.

Causes of Soil Erosion :

1. **Topography :** Rugged topography and steep slopes increase erosion rates.
2. **Climate :** Wind and rainfall are powerful agents of soil erosion. Wind erosion is significant in arid regions, while heavy rainfall dominates erosional processes in other areas.
3. **Vegetation Cover :** Removal of natural vegetation for agriculture or construction reduces soil stability. Living and dead plant biomass helps prevent erosion by intercepting raindrops and wind energy, binding soil particles, and increasing resistance to erosion.

Types of Soil Erosion :

1. **Splash Erosion :** Occurs when raindrops hit bare soil.
2. **Sheet Erosion :** Takes place on the level lands after heavy showers, removing finer topsoil.

3. **Rill Erosion :** Small channels are formed on the soil surface.
4. **Gullying Erosion :** Forms deep gullies, rendering land unfit for cultivation.

Impact of Human Activities :

1. **Land Use Practices :** Agricultural and pastoral activities contribute to erosion. Croplands, when repeatedly tilled without protective vegetation cover, become vulnerable.
2. **Deforestation :** Conversion of forest land to agriculture increases erosion rates due to vegetation removal.
3. **Over-grazing :** Excessive grazing reduces vegetation cover, enhancing soil erosion by wind and water.
4. **Over-irrigation :** Leads to the removal of topsoil with excess water, bringing salts to the surface and depleting fertility.

- Preventing soil erosion involves sustainable land management practices, maintaining vegetation cover, and addressing the impact of human activities on soil stability.

14 INDIAN CLIMATE

- Climate is a crucial element of the physical environment, encompassing atmospheric conditions like heat, moisture, and air movement. In India, a developing country, climatic characteristics significantly influence economic patterns, lifestyle, food preferences, clothing, and behavior. Despite scientific advancements, India heavily relies on monsoon rainfall for successful agriculture.
- India's climate is classified as 'tropical monsoon,' reflecting its location in the tropical belt and the impact of monsoon winds. While a significant portion of the country is in the northern temperate zone, the Himalayas and the Indian Ocean's presence contributes to India's unique climatic features. This distinctive climate has profound effects on various aspects of life and activities in the country.

Salient Features of Indian Climate :

1. **Reversal of Winds :**
   - **Winter :** Winds from north-east to south-west.
   - **Summer :** Winds from south-west to north-east.
2. **Formation of High and Low Pressure Areas :**
   - **Winter :** High-pressure areas over the northern part.
   - **Summer :** Low-pressure cell over the north-western part.
3. **Seasonal and Variable Rainfall :**
   - Over 80% of annual rainfall in the latter part of summer.
   - Duration ranges from 1-5 months.
   - Causes floods, soil erosion, and spatial variation in rainfall distribution.
4. **Plurality of Seasons :**
   - Three main seasons, broader consideration results in six seasons a year (winter, fall of winter, spring, summer, rainy, and autumn).
5. **Unity of Indian Climate :**
   - Himalayas prevent cold northerly winds from Central Asia.
   - Monsoon winds influenced by the Himalayas, causing rainfall across India.
   - Entire country experiences a monsoon type climate.

6. **Diversity of Indian Climate :**

- Regional differences in winds, temperature, rainfall, humidity, and aridity.
- Influenced by location, altitude, distance from the sea, distance from mountains, and general relief conditions.

7. **Characterized by Natural Calamities :**

- Peculiar weather conditions lead to floods, droughts, famines, and epidemics.
- The Indian climate exhibits a complex and varied nature with diverse characteristics and impacts on the country's geography, agriculture, and societal aspects.

■ Factors Determining the Climate of India :

- India's climate is influenced by various factors, categorized into two groups :

1. **Factors Related to Location and Relief :**

Latitude :

- Northern India (above Tropic of Cancer) experiences extreme climates with high temperature variations.
- Southern India (below Tropic of Cancer) lies in the tropical zone, closer to the equator, with high temperatures throughout the year and minimal temperature variations.

Himalayan Mountains :

- The Himalayas act as a climatic divide, blocking cold winds from the Arctic Circle and influencing India's climate.

Distribution of Land and Water :

- Surrounded by the Indian Ocean on three sides, creating different air pressure zones.
- Water heats up or cools down more slowly than land, affecting air pressure variations.

Distances from the Sea :

- Coastal areas have a more moderate climate due to the sea's moderating influence.
- Interior areas experience extreme climates with significant seasonal variations.

Altitude :

- Temperature decreases with height, resulting in cooler temperatures at higher altitudes.
- Places at higher altitudes, such as Darjeeling, exhibit lower temperatures compared to plains, e.g., Agra.

Relief :

- Physiography affects temperature, air pressure, wind direction and speed, and rainfall distribution.
- Windward sides of Western Ghats and Assam receive high rainfall, while the leeward side of the southern plateau remains dry.

2. **Factors Related to Air Pressure and Winds :**

- These factors include the reversal of winds, the formation of high and low-pressure areas, and the impact of monsoons.

3. **Weather Conditions in Water, Surface Pressure and Winds :**

Winter Monsoon :

- During the northern hemisphere's winter, high pressure builds up in Central and West Asia.
- Dry continental air mass flows from the north towards the Indian subcontinent, reaching south of the Himalayan mountain range.
- Continental winds meet trade winds over northwestern India, influencing the northwestern regions.
- The contact zone may shift, sometimes extending up to the middle Ganga valley, impacting northwestern India.

Jet Stream and Upper Air Circulation :

- At around 3 km above the surface, a different air circulation pattern is observed.
- Westerly winds influence Western and Central Asia at altitudes of 9-13 km from west to east.
- Jet Streams, flowing parallel to the Tibetan highlands, bifurcate north and south of the Himalayas.
- Jet Streams bring western disturbances from the Mediterranean, causing winter rain, hail storms, and snowfall in northwestern plains.

■ Western Cyclonic Disturbance and Tropical Cyclones :

Western Cyclonic Disturbance :

- Originates over the Mediterranean Sea and enters India through the westerly jet stream during winter.
- Brings little rain in winter, considered beneficial for wheat crops in the northern plains.

Tropical Cyclones :

- Originate over the Bay of Bengal and the Indian Ocean.
- Have high wind velocity and heavy rainfall, hitting the coasts of Tamil Nadu, Andhra Pradesh, and Orissa.
- Often destructive due to high wind velocity and torrential rain.

- India's water-related weather conditions are influenced by the intricate interplay of surface pressure, winds, jet streams, and cyclonic disturbances, impacting different regions during specific seasons.

Role of Jet Stream :

- As discussed earlier, the sub-tropical westerly jet stream bifurcates due to the high-land Tibet in winters. The northward branch extends up to 20°N-35°N, while the Tropical Easterly Jet Stream (TEJ) branches off from an anticyclone developed over Tibet, sometimes reaching the tip of Peninsular India. These jet speed winds descend over the Indian Ocean, intensifying the high-pressure cell known as Mascarene High. The onshore winds from this high-pressure cell become the south-westerly summer monsoon after crossing the equator.

Role of ENSO (El Niño-Southern Oscillation) :

El Nino Influence :

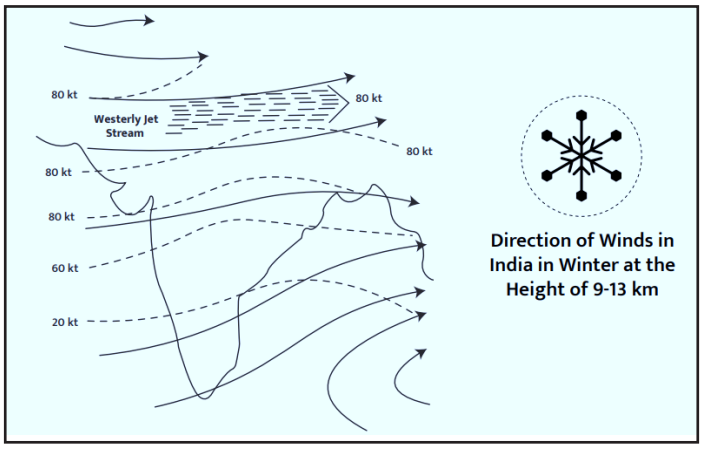
- El Nino, a reversal of normal conditions in the Pacific Ocean's sea surface temperature, influences the Indian monsoon.
- While there's no direct correlation between bad monsoon and El Nino, they are generally associated.
- Severe droughts and El Nino years may or may not coincide.

Southern Oscillation :

- Southern Oscillation is a see-saw pattern of atmospheric pressure between the eastern and western Pacific Ocean.
- Measured by the Southern Oscillation Index (SOI), a negative value indicates high pressure over the north Indian Ocean during winter, leading to a poor monsoon.

Somalian Current :

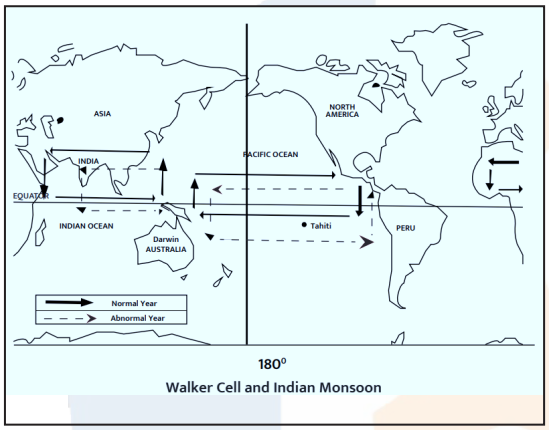
- The Somalian current changes direction every six months.
- During the North-East Monsoon, it flows southwest, and during the South-West Monsoon, it becomes a major western boundary current.
- In exceptional years, when the low-pressure area in the western Arabian Sea turns into a high-pressure area, a weaker monsoon in India results.



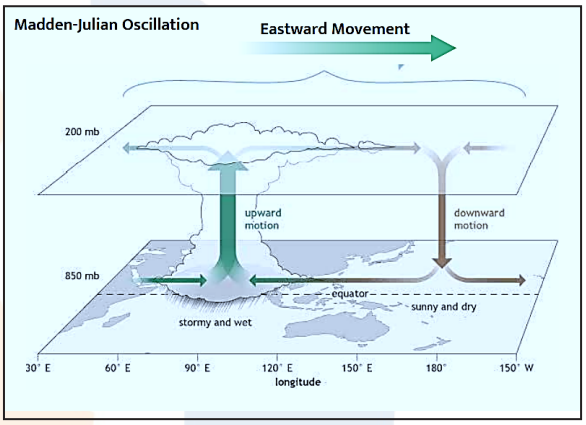
Walker Cell :

East-West Atmospheric Circulation :

- Walker cell is an east-west atmospheric circulation observed over tropical oceanic regions, particularly in the Pacific Ocean.
- Associated with Southern Oscillation, its strength fluctuates with the Southern Oscillation Index (SOI).
- A high positive SOI leads to a zone of low atmospheric pressure over Australia and the Indonesian archipelago.
- The rising air from this region deflects in the upper atmosphere towards Africa and South America.
- In the Indian Ocean, the descending air at the high-pressure zone causes surface winds as the Southwest monsoon in summers.



Walker Cell and Indian Monsoon



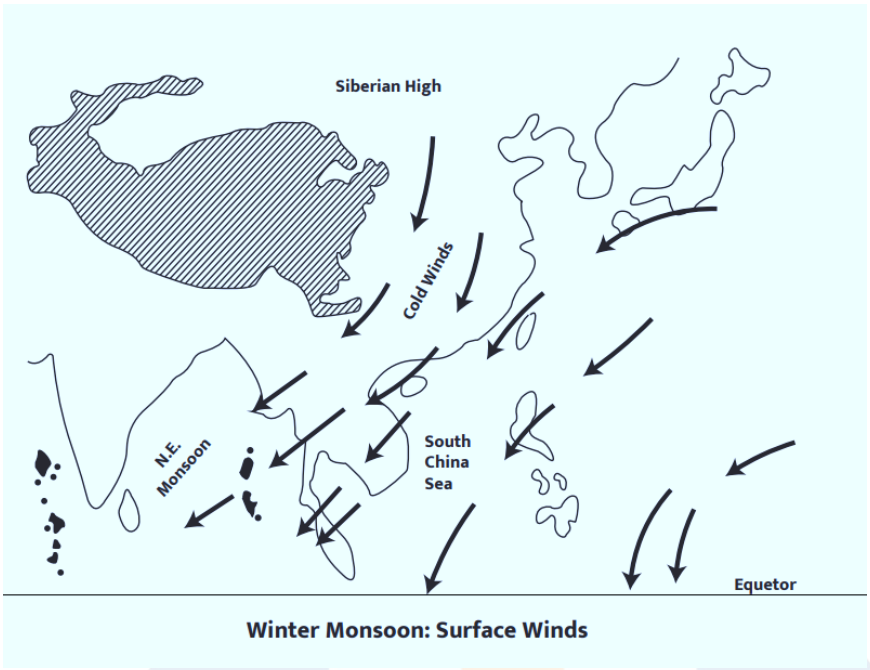
Indian Ocean Dipole (IOD) :

IOD Phases :

- The IOD involves a periodic oscillation of sea surface temperatures between positive, neutral, and negative phases.
- A positive phase has greater-than-average sea surface temperatures and precipitation in the western Indian Ocean, causing droughts in adjacent land areas of Indonesia and Australia.
- A negative phase brings about the opposite conditions, affecting monsoons and precipitation.

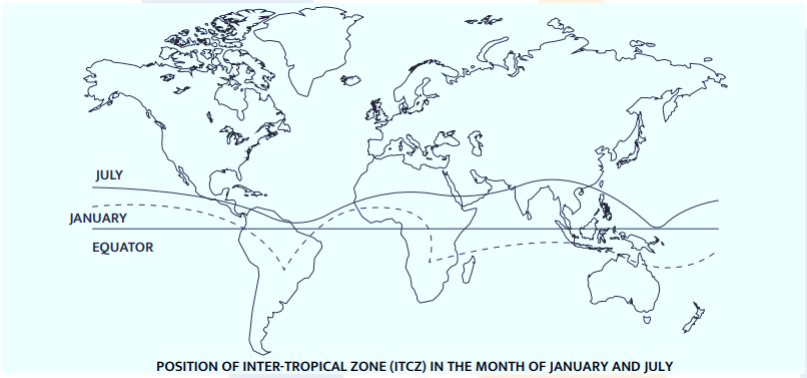
IOD and Monsoons :

- The IOD affects the strength of monsoons over the Indian subcontinent.
- Positive IO**D,** associated with warm sea surface temperatures in the western Indian Ocean, is favorable for monsoons in the Indian subcontinent.
- The interplay of these atmospheric and oceanic phenomena significantly influences the monsoon patterns and weather conditions in the Indian subcontinent.



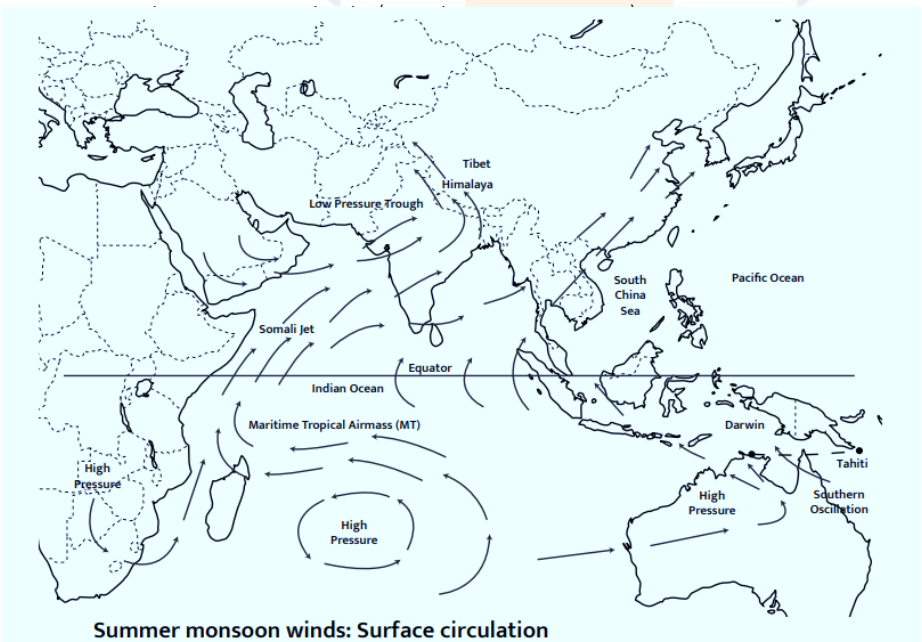
Winter Monsoon: Surface Winds

- **Summer-** Northward shift of ITCZ .(Low Pressure) .Maritime tropical mT airmass crosses Equator between 40 degrees E to 60 degrees E longitude (south -West Monsoon



POSITION OF INTER-TROPICAL ZONE (ITCZ) IN THE MONTH OF JANUARY AND JULY

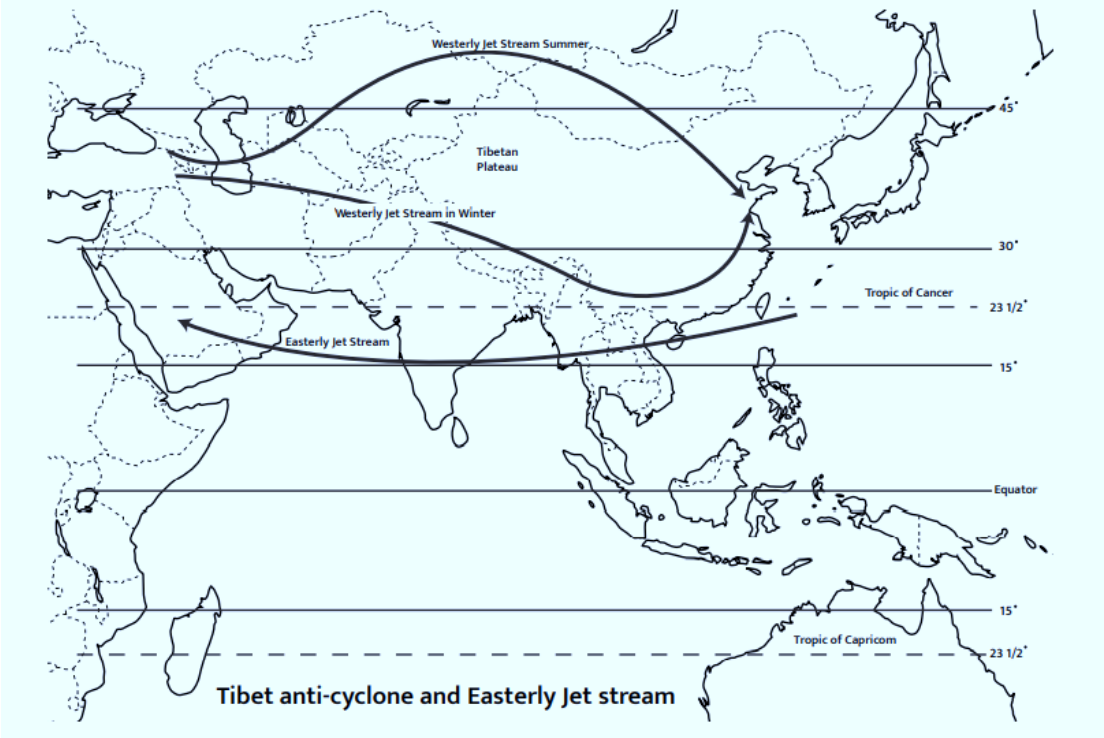
- Northward shift of ITCZ. Low pressure. Maritime Tropical mT airmass crosses equator between 40 degrees



Summer monsoon winds: Surface circulation

■ ORIGIN OF INDIAN MONSOON : FACTORS RESPONSIBLE

- **Role of Himalayas and Tibetan Plateau-** Due to its height, the area receives more insolation leading to clock wise circulation in the middle troposphere and emergence of two wind-streams i.e. Tropical Easterly Jet Stream and Westerly Jet Stream.



Tibet anti-cyclone and Easterly Jet stream

Nature Of Indian Monsoon :

Onset and Advance of Monsoon :

- Low pressure at **ITCZ (over north India)** becomes so intense in May that it pulls the trade winds of the southern hemisphere northwards. ITCZ shifts Northward and an Easterly Jet Stream develops.
- The southeast trade winds crosses equator (becomes S-W monsoon winds) takes moisture from the **equatorial warm currents** and enter the Bay of Bengal and the Arabian Sea.
- This sudden onset of the moisture-laden winds associated with violent thunder and lightning, is often termed as the **"break" or "burst" of the monsoons.**
- Southwest monsoon first of all reaches in Andaman-Nicobar Islands on 15th May. Kerala coast receives it on 1st June. It reaches Mumbai and Kolkata between 10th and 13th June. By 15th of July, Southwest monsoon covers whole of India
- Rain Bearing Systems and Distribution of Rainfall
- **Two branches :**
  - Arabian Sea branch (rainfall over West Coast) and
  - Bay of Bengal Branch (rainfall over plains of North India).
- Arabian sea branch is three times stronger than Bay of Bengal branch and extends till Thar desert.
- **Arabian Sea Branch :** Splits up into 3 more branches. First branch obstructed by Western Ghats gives Orographic rainfall in the windward side and causes rain shadow area in the Eastern side of Western

Ghats, Second branch hits Mumbai coast and along Narmada and Tapi covers Central India. They enter Ganga plain and mingles with Bay of Bengal Branch. A third branch strikes Saurashtra peninsula and Kutch.

- **Bay of Bengal branch :** Strikes the coast of Myanmar and gets deflected towards Indian subcontinent by Arakan Hills. Hence it enters West Bengal and Bangladesh from south and south-easterly direction and not South-West. The branch splits into two.
  - One branch moves westward towards Ganga plains.
  - Second branch moves towards Brahmaputra valley in the North and North-East
- The Tamil Nadu coast lies in rain shadow area of Arabian Sea branch of the south-west monsoon and lies parallel to the Bay of Bengal branch of south-west monsoon. Therefore, it is dry during monsoon.

Break in the Monsoon : Dry spells during south-west monsoon period :

- In northern India rains are likely to fail if the rain-bearing storms are not very frequent along the monsoon trough or the ITCZ over this region.
- Over the west coast the dry spells are associated with days when winds blow parallel to the coast.

Retreat of Monsoon :

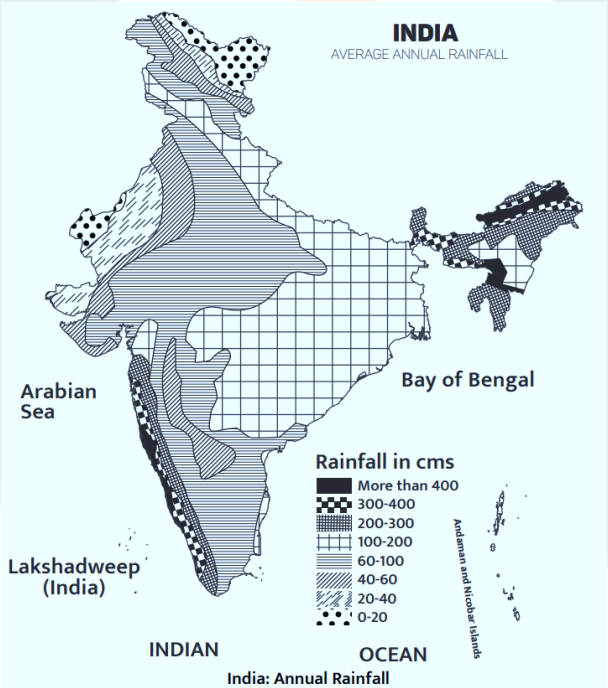
- Monsoon starts retreating in September. On the first of September it starts retreating from north-western part of India. This day is the last day of rainy season in Jaisalmer and Barmer in Rajasthan. By 15th September, monsoon leaves Punjab, Haryana, Rajasthan and Gujarat.
- The area under the monsoon influence shrinks slowly and the monsoon retreats from all parts of India except the southern peninsular region.
- Monsoon winds in most parts of the country are replaced by the north-easterly trade winds. These winds blowing over the Bay of Bengal pick up moisture from there and cause rainfall in Tamil Nadu.

■ Features Of Monsoon Rain :

1. Seasonal in character, occurs between June and September.
2. Spatial distribution of rainfall is largely governed by relief or topography
3. The monsoon rainfall has a declining trend with increasing distance from the sea. Rainfall decreases from east to west in plains as one branch of monsoon enters from eastern side
4. The rain displays a declining trend from west to east over the west coast, and from the southeast towards the northwest over the North Indian Plain and the northern part of the Peninsula.
5. Rajasthan desert receives low rainfall because Arabian Sea branch blows parallel to Aravalis mountain chain without obstruction and thus, does not release moisture here.
6. Breaks in rainfall are related to the cyclonic depressions mainly formed at the head of the Bay of Bengal, and their crossing into the mainland. Besides the frequency and intensity of these depressions, the passage followed by them determines the spatial distribution of rainfall.

Distribution & Variability of Rainfall In India :

Category	Rainfall (in cms)	Regions
Heavy Rainfall	More than 200	Western coast, Western Ghats, Sub-Himalayan region of Northeast, Garo, Khasi and Jaintia hills of Meghalaya. In some parts, rain exceeds 1000 cm.
Moderate Rainfall	Between 100 to 200	100 cm isohyet extends from Gujarat to south up to Kanyakumari parallel to Western Ghats. Northern Andhra Pradesh, eastern part of Maharashtra, Madhya Pradesh, Odisha, some parts of Jammu and Kashmir.
Low Rainfall	Between 60 to 100	Most parts of Tamil Nadu, Karnataka, Andhra Pradesh, eastern Rajasthan, southwestern Uttar Pradesh.
Inadequate Rainfall	Less than 60	Punjab, Haryana, northwestern Rajasthan, Kachchh, Kathiawar.

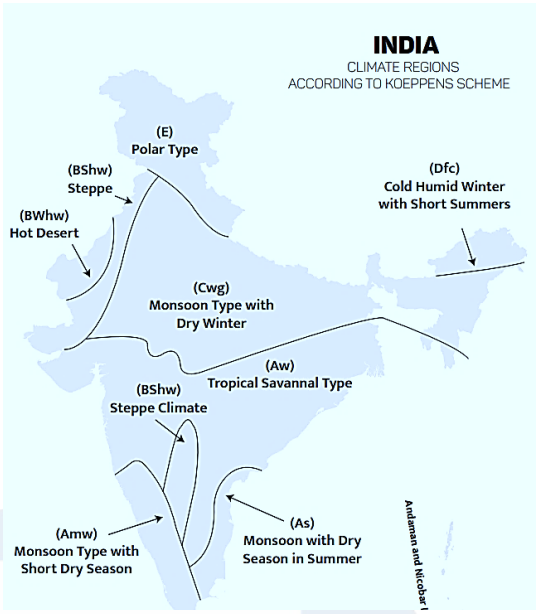


India: Annual Rainfall

Season	Indian Calendar Months	English Calendar Months
Vasanta	Chaitra-Vaisakha	March-April
Grishma	Jyaistha-Asadha	May-June
Varsha	Sravana-Bhadra	July-August
Sharada	Asvina-Kartika	September-October
Hemanta	Margashirsa-Pausa	November-December
Shishira	Magha-Phalguna	January-February

Agro Climatic Zones Of India :

Region	States/Union Territories Included	Characteristics and Features
Western Himalayan Region	Ladakh, Kashmir, Punjab, Jammu, etc.	Brown soils & silty loam, steep slopes.
Eastern Himalayan Region	Arunachal Pradesh, Sikkim, Darjeeling, Manipur, etc.	High rainfall and high forest covers, heavy soil erosion, floods.
Lower Gangetic Plains Region	West Bengal	Soils mostly alluvial & are prone to floods.
Middle Gangetic Plains Region	Bihar, Uttar Pradesh	High rainfall, 39% irrigation, cropping intensity 142%.
Upper Gangetic Plains Region	North region of U.P. (32 dists)	Irrigated by canal & tube wells, good groundwater.
Trans Gangetic Plains Region	Punjab, Haryana, Union Territory of Delhi	Highest sown area irrigated high.
Eastern Plateaus & Hills Region	Chota Nagpur, Garhjat hills, M.P, W. Banghelkhand plateau, Orissa	Soils shallow to medium sloppy, undulating. Irrigation tank & tube wells.
Central Plateau & Hills Region	Madhya Pradesh	
Western Plateau & Hills Region	Sahyadri, Maharashtra, Madhya Pradesh	Rainfall 904 mm, Sown area 65%, forest 11%, irrigation 12.4%.
Southern Plateau & Hills Region	Tamil Nadu, Andhra Pradesh, Karnataka	Typically semi and zone, dryland farming 81%, cropping intensity 11%.
East Coast Plains & Hills Region	Tamil Nadu, Andhra Pradesh, Orissa	Soils - alluvial, coastal sand, irrigation.
West Coast Plains & Hills Region	Saurashtra, Maharashtra, Goa, Karnataka, Tamil Nadu	Variety of cropping pattern, rainfall & soil types.
Gujarat Plains & Hills Region	Gujarat (19 districts)	Low rainfall arid zone, irrigation 32%, well and tube wells.
Western Dry Region	Rajasthan (9 districts)	Hot, sandy desert, rainfall erratic, high evaporation, scanty vegetation, famine droughts.
The Island Region	Eastern Andaman, Nicobar, Western Lakshadweep	Typical equatorial, rainfall 3000 mm (9 months), forest zone undulating.



■ Different Seasons Of India With Their Characteristics :

SUMMER	
DURATION	April, May, June
GENERAL CHARACTERISTICS	Excessive heat, hot loo, dust storms and dryness
TEMPERATURE	Temperature rises up to 45°C in north India.. Temperature has increased to 50°C in Ganganagar earlier. Summer in south India is not so extreme.
WIND DISTURBANCES	a Low pressure over north-western part of India and high pressure over southern parts of Bay of Bangal. ITCZ shifts to Ganges plain. Wind direction Varies from one part of India to the other. Dust storms are frequency experienced in the aftermoon in nothern plains.
RAINFALL	a Completely dry season. Dust storms and thunder storms provide some rainfall. Eastern regions recevies more rainfall comparatively.
WINTER	
DURATION	Mid-November to Febuary
GENERAL CHARACTERISTICS	Clear skies, fine weather, low humidity
TEMPERATURE	Mean daily temperature below 21°C in North India. Some part experience Temperature below freezing point. Temperature increases from north to south.
WIND DISTURBANCES	High pressure over north-western India. Winds blow from north west to south -east. Around four or five westerly disturbances are carried by westerly jet stream.
RAINFALL	Westerly disturbances cause rainfall in northern plains. Rainfall decreases from west to east in plains but increases in north-east again as it catch water from Bay of Bangal. North-eastmonsoon causes winter rainfall in southern Andhra Pradesh, Tamil Nadu etc.

SOUTH-WEST MONSOON	
DURATION	June- September
GENERAL CHARACTERISTICS	Whole of India under south-west monsoon. India faces severe cyclone thunderstorms etc.
TEMPERATURE	June is the hottest month. Temperature remains low during July and August which rises high in September with decreasing amount of precipitation.
WIND DISTURBANCES	Winds are south-westerly over mainland India.
RAINFALL	India receives its 80% precipitation in this season. There is decline of rainfall From east to west in plains. Details are disussed under 'Monsoon' Above.

15 TRANSPORT

Land Transport :

- Man has been using footpaths for transport since prehistorical times. After the invention of the wheel, manmade carts, driven by oxen, horse, and camel were used on unsurfaced roads. With the invention of the steam engine, the need for providing rail lines arose. The first public railway system, from Stockton and Darlington in northern England, opened in 1825. The road and rail transport networks opened up remote interior parts of continents to human settlements, grain farming, and industrialization.

Road Transport :

- **Pt. Jawaharlal Nehru said, "The path of development goes to villages through roads."** Roads are harbingers of economic development. Road networks are found in high density in areas with higher population density worldwide.

Advantages of Roads :

1. Cheaper than rail transport in terms of construction, repair, and maintenance.
2. Reach directly to the consumer's house, eliminating the need for loading and unloading.
3. Best for short and medium distances, providing faster travel.
4. Suitable for transporting ephemeral goods like green vegetables, fruits, and milk.
5. No time and travel constraints, available anytime, anywhere.
6. Regular expenditure on roads is lower than rail transport.
7. Construction and usage possible in hilly and forested areas.
8. Packing of goods is not always necessary.
9. Can negotiate steep slopes and sharp turns.

Distribution of Roads in the World :

- The road network is not evenly spread globally.
- The North American continent alone has 35% of the world's good roads.
- Developed countries generally have a good road network, while developing and poor countries struggle with traffic demands.

Distribution of Roads in India :

- India has one of the largest road networks globally, totaling 46.9 lakh km (2013).
- About 65% of freight and 80% of passenger traffic is carried by roads.

- National Highways constitute about 1.7% of the road network but carry about 40% of total road traffic.
- The Indian road network consists of National Highways, State Highways, District roads, Village roads, International highways, and Expressways.

- India's road network has a rich historical background, and efforts continue to improve road conditions, particularly in rural and remote areas.

National Highways :

- National Highways (NH) in India are the main roads constructed and maintained by the Central Government through the National Highway Authority of India (NHAI), established in 1995.
- These roads are meant for interstate movement, connecting state capitals, important ports, major cities, and railway junctions.
- The NHs constitute only 2% of the total road length in India but carry about 40% of the total road traffic.
- As of now, approximately 26% (18,350 km) of the total length of National Highways is single lane/ intermediate lane, 51% (36,031 km) is two-lane standard, and the remaining 23% (16,553 km) is four-lane standard or more.

NHDP Phases :

1. Phase I (Golden Quadrilateral) : Connects the four major cities of Delhi, Mumbai, Chennai, and Kolkata, covering 5,846 km. Completed in January 2012.
2. Phase II (North-South and East-West Corridors) : Connects Srinagar in the north to Kanyakumari in the south (7,300 km). Links the Golden Quadrilateral and corridors to 10 major ports.
3. Phase III : Upgrades 12,109 km of national highways on a Build, Operate and Transfer (BOT) basis, focusing on high-density traffic, state capitals connectivity, and economic centers.
4. Phase IV : Considers widening 20,000 km of highways not part of Phases I, II, or III, converting single-lane roads into two lanes with paved shoulders.
5. Phase V : Plans to upgrade about 5,000 km of four-lane roads as road traffic increases over time.
6. Phase VI : Involves constructing expressways connecting major commercial and industrial townships. Identified projects include Vadodara-Mumbai, Chennai-Bangalore, and Kolkata-Dhanbad.
7. Phase VII : Focuses on improving city road networks by adding ring roads for easier connectivity with national highways and upgrading stretches with additional flyovers and bypasses.

State Highways :

- Constructed and maintained by State Governments through their Public Works Departments (PWD).
- Provide linkages with National Highways, district headquarters, important towns, tourist centers, and minor ports.
- Total length is about 137,712 km, constituting 4% of the total road length in India.

District Roads :

- Constructed and maintained by Zila Parishads and Public Works Departments.
- Connect district headquarters with main towns and large villages within districts.
- Total length is about 4,70,000 km, accounting for 14% of the total road length in the country.

Village Roads :

- Constructed and maintained by Village Panchayats.
- Connect villages with neighboring towns and cities.
- Significant progress under the Pradhan Mantri Grameen Sadak Yojana (PMGSY).
- Total length in 2005 was 26,50,000 km, approximately 80% of all types of roads in India.

Border Roads :

- Border Roads Organisation (BRO) established in 1960 to plan and construct strategically important roads in northern and northeastern border areas.
- Construction in high-altitude mountainous areas, including snow clearance.

Expressways :

- Controlled-access highways, making up approximately 1,208 km (751 mi) of India's road network as of 2013.

- The development and maintenance of different categories of roads contribute significantly to India's transportation infrastructure.

Rail Transport

- The first train in the world started in 1825 A.D. between Stockholm and Darlington in northern England, marking the beginning of railways as a crucial means of land transport. Railroads are commonly referred to as tracks, with the distance between two parallel rails known as gauge. The standard gauge, prevalent in over sixty percent of the world's rail routes, is 1435 mm.
- Rail gauges can be broadly classified into standard gauge, broad gauge, and narrow gauge. Standard gauge is 1435 mm, broad gauge ranges between 1520 mm and 1676 mm (as in India), and narrow gauge typically falls between 914 mm and 1067 mm. Additionally, some countries use a 1000 mm gauge, known as meter gauge.

Advantages of Rail Transport :

1. **Cost-Effective for Long Distances :** Rail transport is cost-effective for long-distance journeys of both people and goods.
2. **High Speed :** Rail transport is known for its speed, and technological advancements have enabled trains to reach speeds exceeding 300 km per hour in countries like Japan, France, and Germany.
3. **Comfortable Travel :** Modern developments, including air-conditioned coaches and well-equipped sleeper coaches, have made train travel comfortable.
4. **Transport of Heavy Goods :** Trains are efficient for transporting heavy and bulky goods over long distances.
5. **Convenience for Agro-Products :** Trains provide a convenient mode of transport for sending agricultural products to consumers and raw materials to factories.
6. **Doorstep Delivery :** The introduction of containers has made it possible for trains and trucks to work together, ensuring goods reach the doorstep of consumers.

7. **Reduction in Expenses :** Container services have significantly reduced expenses on packing, loading, and unloading.
8. **Transport of Perishable Goods :** Refrigerated wagons enable the transportation of perishable goods under controlled conditions.
9. **Economic Development :** Railways play a crucial role in the economic development of a region, contributing to its overall growth.

■ Distribution of Railways in India :

- The Indian Railways network, the largest in Asia and fourth-largest in the world, serves as the lifeblood of the country, facilitating the movement of both passengers and freight on a massive scale. Initiated in 1853 with a 34 km line from Bombay to Thane, the Indian Railways has evolved into the largest government undertaking in the country, covering approximately 64,000 km.
- **Railway Zones :** To manage the vast railway network efficiently, India has been divided into sixteen zones. Each zone operates as a semi-autonomous entity, helping decentralize the management system.
- **Track Gauges :** The Indian Railways network consists of three main track gauges :
  1. **Broad Gauge :** The distance between the rails in broad gauge is 1.676 meters. It constitutes about 74% of the total length of rail routes in the country, covering approximately 46,800 km.
  2. **Metre Gauge :** With a rail distance of one meter, the metre gauge lines account for around 21% of the total length, covering about 13,300 km.
  3. **Narrow Gauge :** Narrow gauge, with a rail distance of 0.762 meters or 0.610 meters, is confined mainly to hilly areas. It constitutes about 5% of the total length, covering approximately 3,124 km.
- **Gauge Conversion :** The Indian government has nationalized railways and adopted a gauge conversion policy, primarily converting metre gauge to broad gauge. This unigauge system aims to enhance capacity, increase speed, and reduce transportation costs. However, the process is slow due to fund shortages.
- **Geographical and Economic Factors :** The distribution of the Indian Railway network is influenced by geographical, economic, and political factors. The Northern Plains, characterized by level terrain, high population density, fertile soils, and intense agricultural activities, favor railway development. In contrast, the Himalayas and plateaus pose challenges to large-scale railway expansion.

■ Problems of Railways in India :

- The Indian Railways, as the largest public sector undertaking, faces a multitude of challenges, reflecting the complexity of its operations. Some of the prominent issues include :

1. **Overburdened and Inadequate Network :**
   - The current railway network is overburdened and inadequate to meet the demands of a rapidly developing economy.
2. **Geographical Limitations :**
   - Certain regions remain inaccessible to railways due to unfavorable geographical conditions, contributing to regional economic disparities.

3. **Competition from Road Transport :**

- Railways face stiff competition from road transport, leading to a decline in their share of passenger and goods traffic.

4. **Surplus Staffing :**

- The railways grapple with an excess of surplus staff on regular payrolls, hindering further development.

5. **Political Pressures and Interference :**

- Uneconomic projects are sometimes undertaken by railways due to political pressures and interference, compromising efficiency.

6. **Outstanding Payments to Power Supply Companies :**

- Railways have substantial outstanding payments to diesel and electric power supply companies.

7. **Arbitrary Tariff Increases :**

- State Electricity Boards and NTPC can arbitrarily increase tariffs, adding to the financial burden of railways.

8. **Dependency on Diesel :**

- As the largest consumer of diesel, any increase in diesel rates adversely impacts the financial resources of the railways.

9. **Obsolete Equipment :**

- Much of the equipment used by the railways has become obsolete and requires immediate replacements for enhanced efficiency.

10. **Deficit and Political Decision-Making :**

- There is a growing deficit due to the government's reluctance to increase fares and tariffs for political reasons, affecting financial sustainability.

■ Oceanic Routes in India :

Port Connectivity Challenges in India

- India faces challenges in the efficient connectivity of its ports, affecting turnaround time and competitiveness. Some key issues include :

1. **Turnaround Time Discrepancy :**

- Despite having adequate capacity and handling facilities, major Indian ports experience a high average turnaround time of less than 4 days. This is significantly higher compared to global benchmarks, such as the 10-hour average turnaround time in Hong Kong.

2. **Competitiveness Impact :**

- The extended turnaround time undermines the competitiveness of Indian ports in the global market, making them less attractive to international shipping and logistics providers.

3. **Hinterland Linkages :**

- Inadequate linkage of ports to the hinterland contributes to slow cargo evacuation and congestion issues. Efficient connectivity is crucial for seamless transportation of goods from ports to their intended destinations.

4. **Traffic Distribution :**

- The concentration of around three-fourths of total traffic in major ports highlights the need for improved distribution and connectivity to non-major ports. Enhancing the efficiency of both major and non-major ports is vital for overall trade facilitation.

5. **Intermodal Connectivity :**

- The lack of efficient road-rail connectivity exacerbates the challenges in cargo evacuation. Coordinated efforts involving the National Highway Authority of India (NHAI), Railways, and State Governments are essential to address this issue.

6. **Comprehensive Planning :**

- To overcome connectivity challenges, port trusts have initiated collaborations with stakeholders, including NHAI, Railways, and State Governments. These collaborative efforts aim to develop comprehensive plans focused on enhancing road and rail connectivity to and from the ports.

7. **National Highways Development Project (NHDP) :**

- The NH**AI** has recognized the significance of port connectivity and has integrated it as a major component of the National Highways Development Project (NHDP). This strategic inclusion aims to improve the overall transportation infrastructure and facilitate smoother cargo movement.

■ Major Ports of India :

- India boasts **13 major ports** that play a crucial role in facilitating the country's foreign trade. These ports handle more than **95 percent** of foreign trade by volume and **70 percent** by value. Below are details of some of the major ports :

1. **Kandla :**

- Located at the eastern end of the Rann of Kachchh.
- Handles exports and imports for multiple states.
- Deals with crude oil, petroleum products, cotton, fertilizers, food grains, cement, sugar, etc.

2. **Mumbai :**

- Largest natural harbor on the west coast.

- Hub port serving Middle-East and European countries.
- Nhava Sheva, a new port near Mumbai, helps decongest traffic.

3. **Mormugao :**

- Important port of Goa.
- Handles iron ore export from India.
- Enhanced importance with the opening of Konkan Railway.

4. **New Mangalore :**

- Developed 9 km north of the old port.
- Well-linked with Mumbai and Kanyakumari.
- Handles iron ore, manganese ore, fertilizers, tiles, cement, coffee, cashew nuts, food grains, etc.

5. **Kochi :**

- Natural port in Kerala, known as the "Queen of the Arabian Sea."
- Main items of export/import include coir goods, copra, coconut oil, tea, rubber, spices, seafood, etc.
- Kochi Oil Refinery receives crude oil from this port.

6. **Tuticorin :**

- Recently developed along the south-eastern coast of Tamil Nadu.
- Artificial deep-sea harbor, well-connected by railways and roads.
- Handles tea, spices, cotton textiles, hides and skins, edible oils, sugar, petroleum products, etc.

7. **Chennai :**

- Oldest artificial harbor on the east coast.
- Handles petroleum products, fertilizers, iron ore, coal, machinery, cotton, metals, etc.
- Affected by cyclones in October and November.

8. **Vishakhapatnam :**

- Deepest, land-locked, and protected natural harbor.
- Outer harbor developed for iron ore and petroleum.
- Handles petroleum, fertilizers, chemicals, machinery, metals, iron ore, timber, leather goods, food grains.

9. **Paradip :**

- Deepwater, all-weather port located about 100 km east of Cuttack.
- Handles iron ore, coal, and some dry cargo.

- Well-connected by rail and road with different parts of Orissa.

10. **Kolkata-Haldia :**

- Located along the Hugli River, about 148 km from the sea shore.
- One of the leading ports, comprising Kidderpore Docks and Netaji Subhash docks.
- Haldia port, developed in 1978, handles bulk cargo to relieve pressure on the old port.

16 INDIAN AGRICULTURE

Salient Features of Indian Agriculture : Overview

- Indian agriculture exhibits diverse characteristics influenced by geography, technology, and socio-economic factors. Despite variations, certain features define the agricultural landscape :

1. **Subsistence Agriculture :**
   - Primarily subsistence-oriented.
   - Farmers typically cultivate small land areas, with surplus produce sold in the market.
2. **Population Pressure :**
   - Agriculture bears the burden of providing food and employment for a rapidly growing population.
   - Urbanization trends lead to the conversion of agricultural land for non-agricultural purposes.
3. **Role of Animals :**
   - Animals play a crucial role in various agricultural operations, including ploughing, irrigation, threshing, and transportation.
   - Complete mechanization remains a distant goal.
4. **Dependency on Monsoons :**
   - Heavy reliance on monsoons for irrigation; only about 35% of the cropped area is under perennial irrigation.
   - Uncertain and irregular monsoons make Indian agriculture vulnerable.
5. **Small Land Holdings :**
   - National average landholding size is only 1.7 hectares.
   - Small land size hinders economic viability and poses challenges to agricultural progress.
   - Many farmers are not landowners.
6. **Crop Diversity :**
   - Favorable environmental conditions allow cultivation of a wide variety of tropical and temperate crops.
   - Encompasses both food and commercial crops.

7. **Priority to Food Crops :**

- Farmers prioritize food crop production to meet the demands of the growing population.
- About two-thirds of total agricultural land is dedicated to food crops in India.

8. **Fodder Crops Neglect :**

- Despite having the world's largest livestock population, fodder crops receive limited attention.
- Poor emphasis on fodder crops contributes to the relatively low quality of domestic animals.

Cropping Season	Time Period	Major Crops (Northern States)	Major Crops (Southern States)
Kharif Season	June - September	Rice, Cotton, Bajra, Maize, Jowar, Tur	Rice, Maize, Ragi, Jowar, Groundnut
Rabi Season	October - November to March-April	Wheat, Gram, Rapeseeds, Mustard, Barley	Rice, Maize, Ragi, Groundnut, Jowar
Zaid Season	After Rabi harvest to summer	Watermelons, Cucumbers, Vegetables, Fodder Crops	Watermelons, Cucumbers, Vegetables, Fodder Crops

Type of Farming	Description	Examples/Regions
Shifting Agriculture	Also known as slash and burn cultivation. Practiced in backward forest areas with heavy rainfall. Farmers clear patches of ground by cutting and burning trees, cultivate for a few years, and then shift to another part of the forest.	Northeastern states, Orissa, Madhya Pradesh, Andhra Pradesh, parts of Kerala.
Subsistence Agriculture	Primarily for consumption and family maintenance. Small farms, low yield. Various manures used, including household waste, animal droppings, green manures, night soil, and some chemical fertilizers.	Tribal areas of Assam, Himalayan region.
Intensive Agriculture	Practiced in densely populated areas with limited cultivable land. Farmers aim for maximum output from a small piece of land, often cultivating more than one crop a year. Widely practiced in irrigated areas of northern and coastal plains.	Irrigated areas of northern plains, coastal plains.
Extensive Agriculture	Practiced in areas with low population density and abundant cultivable land. Farmers specialize in one or two commercial crops. Common in the Terai region of the Himalayas and northwestern states.	Terai region of the Himalayas, northwestern states.

Plantation Agriculture	Introduced by Europeans in tropical and subtropical regions. Large tracts of land, often owned by companies. Main crops include tea, coffee, spices, coconut, and rubber. Success depends on accessibility, labor availability, and transport.	Regions producing tea, coffee, spices, coconut, rubber.
Commercial Agriculture	Aims to produce crops for the market. Can be either intensive or extensive. Utilizes modern cultivation methods to keep production costs low. Not very common in India due to population pressure on land.	Punjab, Haryana, Gujarat, Maharashtra, Uttar Pradesh, West Bengal, Assam.
Mixed Farming	Involves rearing livestock along with crop farming. Cattle rearing and crop rotation are essential. Practiced in thickly populated areas. Yields are generally high. Relies on efficient cultivation methods, quick transport, and ready markets.	Areas with mixed farming practices in India.

Cereal	Description	Major Producing States
Rice	Most important cereal crop in India. Requires high temperature, ample rainfall, and is often grown in clayey alluvial soil. Labour-intensive cultivation. India ranks second in global production after China.	West Bengal, Punjab, Uttar Pradesh, Andhra Pradesh, Tamil Nadu.
Wheat	Second most important cereal crop. Grown during the winter (rabi season) in temperate zones. Requires moderate rainfall, loam soil, and lower temperatures during ripening. India ranks second in global production after China.	Uttar Pradesh, Punjab, Haryana, Rajasthan, Madhya Pradesh.
Jowar	Main food crop in semi-arid areas of central and southern India. Grown in both Kharif and Rabi seasons. Requires a mean monthly average temperature of 26°C to 33°C. Suitable for various soils.	Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh.
Bajra	Grown in hot and dry climatic conditions in north-western and western parts of the country. Resistant to dry spells and drought. Cultivated alone or as part of mixed cropping.	Maharashtra, Gujarat, Uttar Pradesh, Rajasthan, Haryana.
Maize	Grown under semi-arid climatic conditions and over inferior soils. Requires 50-100cm of rainfall and a temperature ranging from 21°C to 27°C. Widely sown across India, except in eastern and north-eastern regions.	Madhya Pradesh, Andhra Pradesh, Karnataka, Rajasthan, Uttar Pradesh.

Pulses	Rich source of protein in India. India is a leading producer, with cultivation concentrated in dryland areas. Gram and tur are the main pulses cultivated.	Central plateaus, Deccan, north-western parts of India.
Gram	Cultivated in subtropical areas, mostly rainfed during Rabi season. Preferred temperature range is 20°C - 25°C with rainfall in the range of 40-50cm. Major producers include Madhya Pradesh, Uttar Pradesh, Maharashtra.	Madhya Pradesh, Uttar Pradesh, Maharashtra, Andhra Pradesh, Rajasthan.
Tur (Red Gram/ Pigeon Pea)	Cultivated over marginal lands and under rainfed conditions in dry areas of central and southern states. Major producers include Maharashtra, Uttar Pradesh, Karnataka, Gujarat, Madhya Pradesh.	Maharashtra, Uttar Pradesh, Karnataka, Gujarat, Madhya Pradesh.

Oilseed	Description	Major Producing States
Groundnut	Mainly a rainfed Kharif crop grown in dryland areas. Leading producers include Gujarat, Tamil Nadu, Andhra Pradesh, Karnataka, and Maharashtra.	Gujarat, Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra.
Rapeseed & Mustard	Subtropical crops cultivated during Rabi season in north-western and central parts of India. Various types include rai, sarson, toria, and taramira. Rajasthan is a major contributor, along with Uttar Pradesh, Haryana, West Bengal, and Madhya Pradesh. Yields are higher in Haryana and Rajasthan.	Rajasthan, Uttar Pradesh, Haryana, West Bengal, Madhya Pradesh.
Soyabean	Primarily grown in Madhya Pradesh and Maharashtra.	Madhya Pradesh, Maharashtra.
Sunflower	Cultivated in Karnataka, Andhra Pradesh, and adjoining areas of Maharashtra. Minor crop in northern parts of the country, with higher yields due to irrigation.	Karnataka, Andhra Pradesh, Maharashtra.

Cash Crop	Description	Major Producing States
Cotton	Grown in Kharif season in semi-arid areas. Includes short staple (Indian) and long staple (American or 'narma') cotton. Three main regions : north-west, west, and south. **Leading producers :** Maharashtra, Gujarat, Andhra Pradesh, Punjab, Haryana.	Maharashtra, Gujarat, Andhra Pradesh, Punjab, Haryana.
Jute	A cash crop in West Bengal and adjoining eastern regions. West Bengal accounts for the majority of production, with additional cultivation in Bihar and Assam. **Ideal conditions :** temperature 24°C - 35°C, rainfall 120-150cm.	West Bengal, Bihar, Assam.

Sugarcane	A tropical crop cultivated in sub-humid and humid climates. Concentrated in Uttar Pradesh, with additional cultivation in Maharashtra, Gujarat, Karnataka, Tamil Nadu, and Andhra Pradesh. **Ideal conditions :** average temperature 21°C-27°C, rainfall 75-100cm.	Uttar Pradesh, Maharashtra, Gujarat, Karnataka, Tamil Nadu, Andhra Pradesh.
Tea	A plantation crop used as a beverage, grown in hilly areas with well-drained soils. Cultivated in Assam, West Bengal (Darjiling, Jalpaiguri, Cooch Bihar districts), Nilgiris, and Cardamom hills of Western Ghats. **Ideal conditions :** temperature 20°C-30°C, rainfall 150-300cm.	Assam, West Bengal, Nilgiris, Cardamom hills (Western Ghats).
Coffee	A tropical plantation crop with three varieties : arabica, robusta, and liberica. Grown in the highlands of Western Ghats in Karnataka, Kerala, and Tamil Nadu. **Ideal conditions :** temperature 15°C-28°C, rainfall 150-250cm.	Karnataka, Kerala, Tamil Nadu.

■ Major Schemes/Programmes for the Agricultural Sector :

National Mission on Agricultural Extension and Technology (NMAET) :

- **Aim :** Enhance farm mechanization and include small and marginal farmers in cost-effective mechanized farming.
- **Sub-Missions :** Agricultural Extension, Seed and Planting Material, Agricultural Mechanization, Plant Protection, and Plant Quarantine.

National Food Security Mission (NFSM) :

- **Objectives :** Enhance rice, wheat, and pulses production by 10, 8, and 2 million tonnes, respectively.
- **Special Plan for Pulses :** Launched to achieve 19+ million tonnes of pulses production during Kharif 2012.

Rashtriya Krishi Vikas Yojana (RKVY) :

- **Launched in 2007-08 to incentivize states for enhancing public investment in agriculture.**
- **Flexibility for states :** Allows taking up national priorities as sub-schemes, considering local requirements.

National Mission for Sustainable Agriculture (NMSA) :

- **Focus :** Transform Indian agriculture into a climate-resilient production system.
- **Key Dimensions :** Seed & culture water, pest, nutrient, farming practices, credit, insurance, market, information, and livelihood diversification.

Bringing Green Revolution to Eastern India (BGREI) :

- Initiated in 2010-11 to maximize productivity and production of crops in eastern India.

- Strategies include in situ water harvesting, soil reclamation, integrated nutrient management, soil & water conservation, and promotion of high-value crops.
- **Outcome :** Eastern region turned into a food surplus region, significant increase in rice production.

Integrated Scheme of Oilseeds, Pulses, Oilpalm & Maize (ISOPOM) :

National Mission on Oilseeds and Oil Palm (NMOOP) :

- **Objective :** Increase production of vegetable oils sourced from oilseeds, oil palm, and tree-borne oils (TBOs) from 7.06 million tonnes to 9.51 million tonnes by the end of Twelfth Plan (2016-17).

Implementation through Three Mini Missions :

1. **MM I on Oilseeds :**

- **Target :** Achieve production of 35.51 million tonnes and productivity of 1328 kg/ha of oilseeds.
- **Strategy :** Increase Seed Replacement Ratio (SRR), focus on Varietal Replacement, increase irrigation coverage, diversify low-yielding cereals to oilseeds, promote inter-cropping, utilize fallow land, and expand cultivation in watersheds and wastelands.

2. **MM II on Oil Palm :**

- **Target :** Bring an additional 1.25 lakh hectare area under oil palm cultivation.
- **Strategy :** Focus on area expansion, utilize wastelands, increase productivity of fresh fruit bunches (FFBs) from 4927 kg per ha to 15000 kg per ha.

3. **MM III on TBOs :**

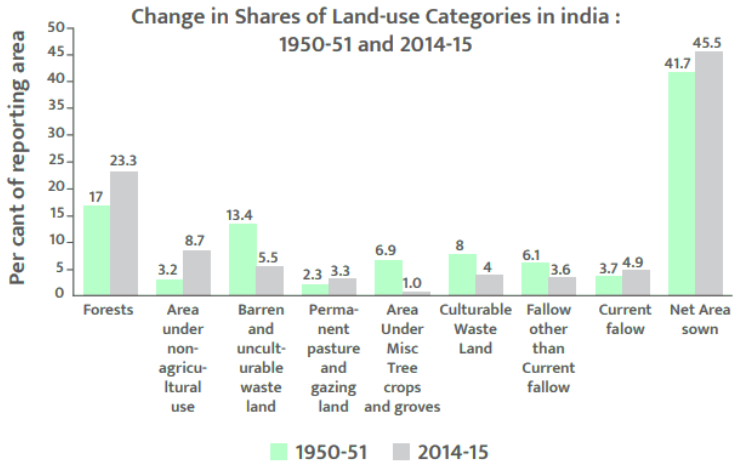
- **Target :** Enhance seed collection of TBOs from 9 lakh tonnes to 14 lakh tonnes.
- **Strategy :** Increase seed procurement, augment elite planting materials, and focus on area expansion under wasteland.

Land Use Categories :

- **Land-use categories as maintained in the Land Revenue Records are as follows –**

1. **Fallow other than Current Fallow-** uncultivated between 1 and 5 year
2. **Net sown area -** land on which crops are sown.
3. **Current Fallow -** Left without cultivation for one or less than one year
4. **Culturable Wasteland -** Fallow for more than 5 years
5. Area under Miscellaneous Tree Crops and Groves
6. Area under permanent pastures
7. Land under non-agricultural use
8. Barren and waste land - can not be brought under cultivation
9. Forest

Land Use Changes :



Observation :

- The rate of increase is the highest in case of area under non-agricultural uses. The area under non-agricultural uses is increasing at the expense of wastelands and agricultural land.
- Reason-Due to the changing structure of Indian economy, and expansion of area under both urban and rural settlements.
- The increase in the share under forest
- Reason -Can be accounted for by increase in the demarcated area under forest rather than an actual increase in the forest cover in the country.
- Trend of current fallow fluctuates a great deal over years
- Reason Depending on the variability of rainfall and cropping cycles.
- Increase in net area sown
- Reason- Due to use of culturable waste land for agricultural purpose

GREEN REVOLUTION :

- In **mid-1960s** and India introduced package technology comprising HYVs, along with chemical fertilizers in irrigated areas of **Punjab,Haryana, and Western Uttar Pradesh.**

Components of green revolution :

a. HYV seeds.

b. Irrigation

c. Use of fertilizer, insecticide and pesticide.

d. Command area development.

e. Consolidation of land holding.

f. Land reform.

g. Agriculture marketing, farm mechanisation and rural electrification.

Impact of Green revolution :

1. Increase in agriculture production - reduction in import of foodgrains.
2. Diffusion of rice and wheat technologies to new areas.
3. Prosperity of farmers.
4. Industrial growth and rural employment.
5. Change in attitude of farmers.

Demerits of green revolution :

a. Inter-crop imbalances - only cereals were benefitted from GR.
b. Regional disparities
c. Increase in inter-personal inequalities.
d. Some experts doubt about capability of HYV seeds.
e. Increase in unemployment due to farm mechanisation by green revolution.
b. Environmental pollution

ICAR
• Indian Council of Agricultural Research is an autonomous organisation under the Department of Agricultural Research and Education (DARE), Ministry of Agriculture, Government of India.

Mandates for the ICAR are to :

1. Plan, Undertake, Coordinate and Promote Research and Technology Development for Sustainable Agriculture.
2. Aid, Impart and Coordinate Agricultural Education to enable Quality Human Resource Development.
3. Frontline Extension for technology application, adoption, knowledge management and capacity development for agri-based rural development.
4. Policy, Cooperation and Consultancy in Agricultural Research, Education & Extension

17 PRECIPITATION

Water Vapour in the Atmosphere :

- Water exists in the atmosphere in gaseous, liquid, and solid forms.
- Water vapour comprises about 2% of the atmosphere, varying based on location and season.
- Atmospheric water vapour ranges from 0% in cold Arctic regions to 5% in warm equatorial regions.

Importance of Water Vapour :

- Influences weather conditions, precipitation, heat loss through radiation, surface temperature, latent heat, and air mass stability.
- Essential for storm development, providing latent heat energy for cyclones and hurricanes.

The Water Cycle :

- Continuous circulation of water from Earth's surface to the atmosphere and back.
- Includes processes like evaporation, transpiration, condensation, precipitation, runoff, and groundwater movement.
- Solar heat drives evaporation, forming clouds, and precipitation returns water to the land and seas.

Humidity :

- Refers to the amount of water vapour in the atmosphere at a specific time and place.

Types of Humidity :

- **Absolute Humidity :** Weight of water vapour in a unit volume of air, expressed in grams per cubic meter.
- **Specific Humidity :** Weight of water vapour in a unit weight of air, expressed in grams per kilogram.
- **Relative Humidity :** Ratio of actual water vapour to the air's capacity to hold water vapour at the same temperature, expressed in percentages.

Significance of Relative Humidity :

- Determines the possibility of precipitation.
- Indicates wet or dry conditions; influences evaporation.
- Associated with human health, with high relative humidity being unfavorable for health.
- Changes in relative humidity are influenced by temperature variations.

Horizontal Distribution of Relative Humidity :

- Equatorial regions exhibit the highest relative humidity.
- Relative humidity decreases towards the tropical high-pressure belts (25°–35° latitudes) and increases polewards.

- High and low relative humidity zones shift with the Sun's apparent migration during solstices.
- Maximum relative humidity occurs in the mornings, while minimum occurs in the evenings.

Evaporation :

- **Definition :** The transformation of liquid (water) into a gaseous form (water vapour).

Factors Affecting Evaporation :

- **Aridity (Vapour Pressure) :** Evaporation depends on the moisture content in the air.
- **Temperature :** Higher temperatures increase evaporation.
- **Air Movement :** Evaporation is faster in dry air and more from oceans than land.
- **Transpiration :** A specific form of evaporation involving water loss from plant leaves and stems.

Condensation :

- **Definition :** The process of transforming water vapour into liquid or solid forms (water or ice).

Ways of Condensation :

- Rising warm moist air expands.
- Warm moist air contacts a cold surface.
- Warm moist air mixes with air from colder regions.

- **Latent Heat :** Heat absorbed during evaporation and released during condensation; crucial for storm development.
- **Saturated Air :** Air at its maximum capacity to hold water vapour at a given temperature is saturated (100% humid air).
- **Hygroscopic Nuclei :** Particles like dust, smoke, oceanic salts, or carbon dioxide that facilitate condensation.
- **Dew Point :** Temperature at which air becomes saturated, leading to condensation.
- **Forms of Condensation :** Dew, frost, fog, mist, clouds, etc.

Dew :

- **Formation :** Occurs on solid objects (leaves, flowers, rocks) when the relative humidity is low, and the temperature drops.

Conditions for Dew Formation :

- Long nights (surface cooling).
- Cloudless clear sky (more daytime heating).
- Calm air (prolonged contact with the surface).
- High relative humidity (more condensation, prevalent in August-September in India).

Frost :

- **Nature :** Frozen dew formed when the dew point temperature falls below freezing point.
- **Conditions :** Similar to dew formation, but temperature must fall below freezing point.

- **Impact :** Harmful for plant growth.

Dew vs. Frost :

- **Dew :** Droplets of water on leaves or grass, forms above freezing point, useful for plants.
- **Frost :** Ice or snow crystals on solid surfaces, forms below freezing point, harmful for plant growth.

Fog :

1. **Definition :** Fog is a thin cloud near the Earth's surface, consisting of very small water droplets suspended in the air under specific conditions, such as low temperature and high relative humidity.
2. **Types of Fog :**

- **Radiation Fog :** Forms at night due to terrestrial radiation, resulting in the cooling of the surface. It's not very thick and typically ranges from 10 to 30 meters.
- **Advection Fog :** Forms when warm moist air moves horizontally over a cold surface, getting cooled by contact or mixing with cold air over cold surfaces.
- **Frontal or Precipitation Fog :** Forms at the boundaries of warm and cold air masses, leading to convergence and fog formation.

3. **Impact of Fog :**

- **Travel Disruption :** Hinders land, air, and sea travel.
- **Health Hazards :** Polluted fog can become poisonous and pose serious health risks.
- **Agricultural Impact :** Affects late-sowing crops negatively but can be beneficial for tea and coffee plants.

Mist :

1. **Definition :** Mist is a less dense type of fog with visibility ranging between 1 and 2 kilometers.
2. **Difference Between Mist and Fog :**

- **Density :** Fog is denser, reducing visibility to less than 1 km, while mist has visibility ranging from 1 to 2 km.
- **Formation :** Mists are frequent over mountains due to rising warm air meeting a cold surface, while fogs are prevalent where warm and cold air currents meet.

Smog :

1. **Definition :** Smog is a mixture of smoke and fog, resulting from the sun's impact on pollutants, particularly from automobile exhaust.
2. **Types of Smog :**

- **Photochemical Smog :** Contains primary pollutants (hydrocarbons, nitrogen oxides) from motor vehicles and forms harmful substances like ozone, aldehydes, and PAN.
- **Industrial Smog :** Composed of sulfur dioxide and various solid and liquid particles from stationary sources like furnaces and power plants.

Haze :

1. **Definition :** Haze is an atmospheric phenomenon where dust, smoke, and dry particles obscure the sky's clarity.
2. **Sources of Haze :**
   - Human Activities : Farming, traffic, industry, and wildfires contribute to haze particles.
   - Color Distinction : Natural haze is typically white, gray, or blue, while smog is yellowish or brownish.
3. **Visibility Classification :**

- **Fog :** Visibility less than 1 km.
- **Mist :** Visibility between 1 km and 2 km.
- **Haze :** Visibility between 2 km and 5 km.

Clouds :

- Clouds are droplets of water or tiny ice crystals which collect around the dust particles present in the atmosphere. All forms of precipitation occur from the clouds. It should be noted that not all clouds yield precipitation but no precipitation is possible without clouds

Types of Clouds :

- Clouds are classified based on various characteristics such as altitude, shape, density, and more. The three basic groups of clouds are Cirrus, Cumulus, and Stratus. These classifications were first introduced by Luke Howard in 1803.

1. **Cirrus Clouds (Curl of Hair) :**

- **Altitude :** Formed at high altitudes (8,000 - 12,000 meters).
- **Composition :** Composed of ice crystals, resulting in a white and thin appearance.
- **Characteristics :** Detached, fibrous, feathery, often with a silky sheen in direct sunlight.

2. **Cumulus Clouds (Heap) :**

- **Altitude :** Generally formed at a height of 4,000 - 7,000 meters.
- **Appearance :** Resemble cotton wool and exist in patches scattered in the sky.
- **Structure :** Have a flat base, and on rising, they appear like domes at the top.
- **Analogy :** Similar in appearance and structure to cauliflower.

3. **Stratus Clouds (Layer) :**

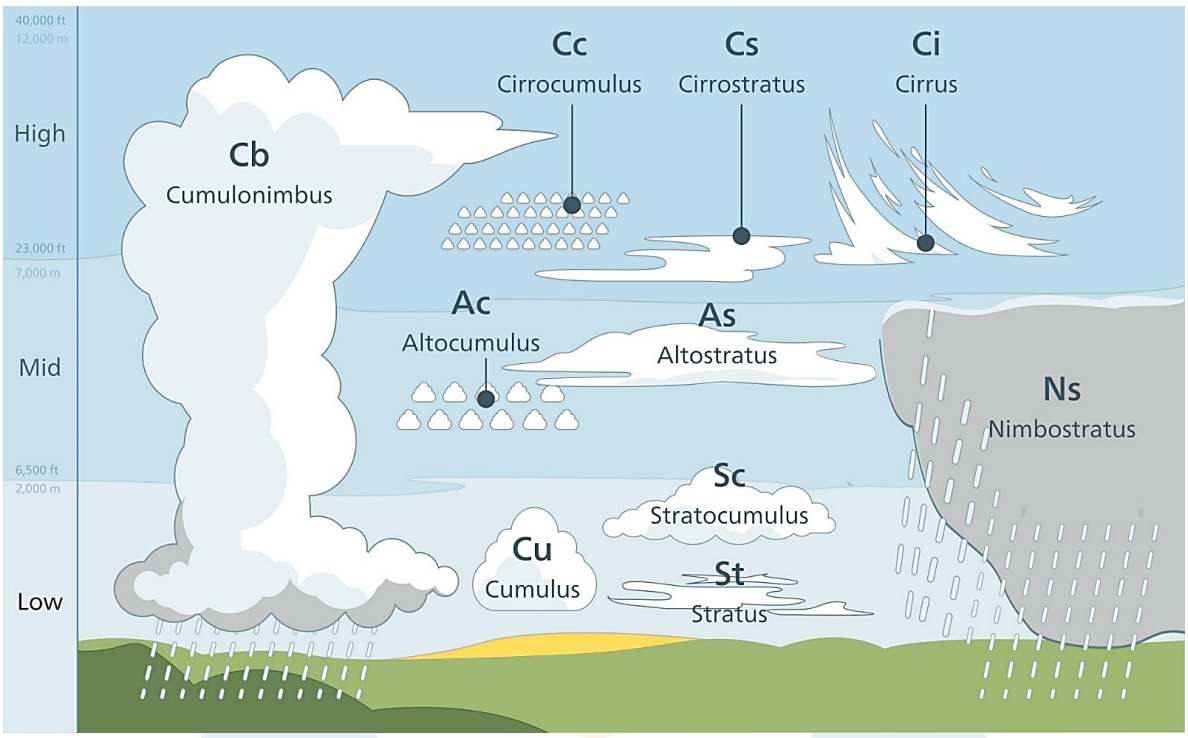
- **Altitude :** Form layered clouds covering large portions of the sky.
- **Formation :** Generally formed due to the loss of heat or the mixing of air masses with different temperatures.
- **Characteristics :** Can cover extensive areas of the sky, creating a layered appearance.

Rain-bearing Clouds :

- Clouds responsible for rainfall are generally low-level clouds. They are given the prefix or suffix "nimbus," a Latin word meaning a rainy cloud.

■ International Classification of Clouds :

Cloud Group	Height in meters	Types	Description
High Clouds = Cirrus	6000- 12000	1. Cirrus 2. Cirrostratus 3. Cirrocumulus	High-level clouds form above 6,000 meters and since the temperatures are so cold at such high elevations, these clouds are primarily composed of ice crystals.
			High level clouds are typically thin and white in appearance, but can appear in a magnificent array of colors when the sun is low on the horizon
Middle Clouds = Alto	2000- 6000	4. Altostratus 5. Altocumulus	The bases of mid-level clouds typically appear between 2,000 to 6,000 meters.
			Because of their lower altitudes, they are composed primarily of water droplets, however,
			they can also be composed of ice crystals when temperatures are cold enough
Low Clouds = Stratus	below 2000	6. Stratus 7. Stratocumulus 8. Nimbostratus	Low clouds are of mostly composed of water droplets since their bases generally lie below 2,000 meters.
			However, when temperatures are cold enough, these clouds may also contain ice particles and snow.
Clouds with Vertical Growth		9. Cumulus 10. Cumulonimbus	Probably the most familiar of the classified clouds is the cumulus cloud.
			Generated most commonly through either thermal convection or frontal lifting,
			these clouds can grow to heights in excess of 12,000 meters, releasing incredible amounts of energy through the condensation of water vapor within the cloud itself.



■ Necessary Conditions for Rainfall :

1. **Sufficient Evaporation :**

- There must be a significant amount of evaporation from water bodies (such as oceans, lakes, and rivers) to saturate the air mass with water vapor.

2. **Presence of Wind :**

- Wind is necessary to carry the saturated air mass, laden with water vapor, from one location to another. Wind helps in the horizontal movement of moist air.

3. **Decrease in Temperature :**

- There should be a mechanism to decrease the temperature of the moist air. This cooling can occur through various processes, including :
- **Adiabatic Cooling :** As air rises, it expands and cools.
- **Orographic Lifting :** Air is forced to rise over elevated terrain, leading to cooling and cloud formation.
- **Frontal Lifting :** When two air masses with different temperatures meet, the warmer air is forced to rise, resulting in cooling and potential rainfall.

4. **Formation of Raindrops :**

- Rainfall occurs when cloud droplets grow in size and become heavy enough to fall. This process involves the coalescence of smaller cloud droplets into larger raindrops.
- A raindrop typically has a diameter of about 5 mm, and it is formed by the aggregation of millions of smaller cloud droplets.

- In summary, the interplay of evaporation, wind movement, temperature changes, and the process of cloud droplet coalescence is crucial for the occurrence of rainfall.

Types of Rainfall :

- Rainfall is classified into three main types based on the way the cooling of the warm moist air mass takes place :

1. Convectional Rainfall :

- **Process :** As the warm moist air rises, it expands, loses heat, and undergoes condensation, forming cumulus clouds.

Characteristics :

- Heavy rainfall with thunder and lightning.
- Common in summer or the hotter part of the day.
- Frequently observed in equatorial regions and interior parts of continents, especially in the northern hemisphere.
- Equatorial regions experience daily afternoon convectional rainfall.

2. Orographic Rain :

- Also Known As Relief Rain.
- **Process :** When a saturated air mass encounters a mountain, it is forced to ascend. As it rises, it expands, cools, and undergoes condensation.

Characteristics :

- Windward slopes receive greater rainfall.
- Leeward slopes experience dry conditions and are known as rain-shadow areas.
- Windward slope has cumulus clouds during rainfall, while the leeward slope has stratus clouds.
- Orographic rainfall may occur in any season and is of longer duration.

Examples :

- Cherrapunji in the Meghalaya plateau.
- Western Ghats and the entire Himalayan region.

3. Cyclonic or Frontal Rainfall :

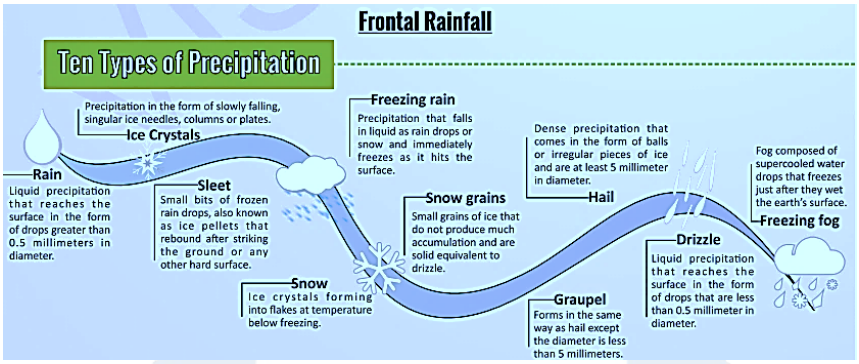
- **Process :** Associated with cyclones, which have low pressure at the center surrounded by high pressure. Different air masses meet, creating fronts. Warm air rises above cold air, undergoes cooling and condensation, leading to rainfall.

Characteristics :

- Commonly associated with temperate and tropical cyclones.
- Slow and gradual lifting of warm air results in slow and gradual condensation, leading to drizzle.
- Widespread and continues for a longer duration.

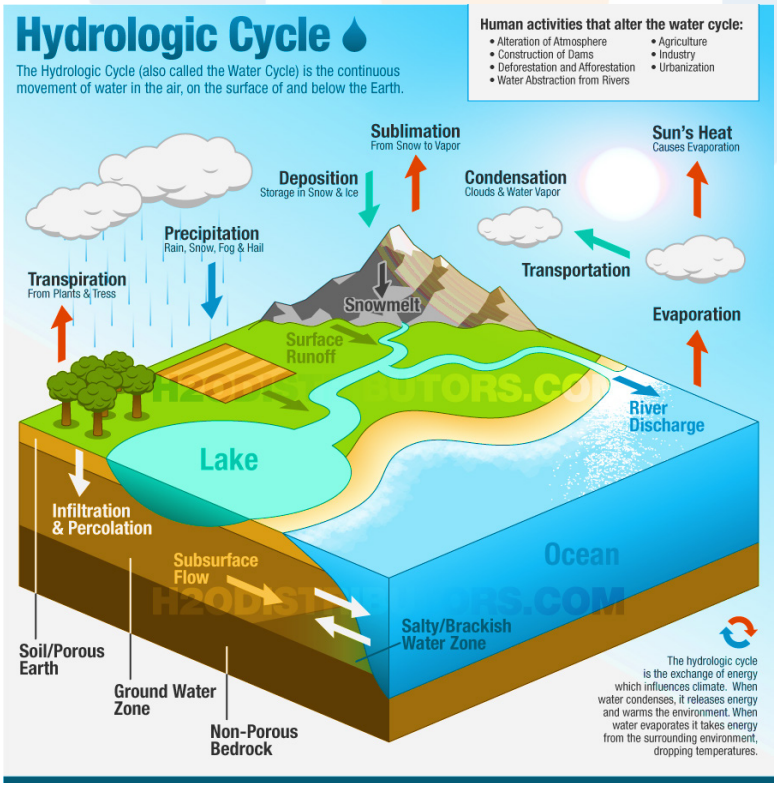
Examples :

- Temperate regions receive most of their rainfall through frontal or cyclonic rains.
- Tropical cyclones, known as typhoons, hurricanes, tornadoes, yield heavy downpours in various regions like China, Japan, Southeast Asia, India, and the USA.



■ Quick Concepts/Facts :

1. The absolute humidity decreases from the equator towards the poles. Generally, the absolute humi- dity changes as air temperature or pressure changes. However, if temperature increases but there is no excess water for evaporation then absolute humidity will not change.
2. The absolute humidity determines the amount of precipitation while the relative humidity tells us about the possibility of precipitation. The high and low relative humidity indicates the possibility of wet and dry conditions respectively. Evaporation decreases when there is high relative humidity &vice versa.



3. The equatorial region is characterized by the highest relative humidity. Relative humidity gradually decreases towards the Tropical high-pressure belts (between 25"-35" latitudes). After this, the relative humidity again increases poleward.

4. Relative humidity is maximum in the mornings and minimum in the evenings.

Changes in Relative Humidity can occur in the following three ways :

I. The temperature remaining the same and amount of water vapour in air increases. Its relative humidity will also increase.

II. When the temperature of air rises its humidity retentive capacity also rises correspondingly and the Relative Humidity decreases.

III. If the temperature of air decreases its humidity retentive capacity also decreases and Relative Humidity increases.

Condensation :

Condensation	The process of transforming of water vapour into water (liquid) and ice (solid) is called condensation. Condensation is level at which the air is not in a position to take up any more moisture
Latent Heat	At the time of evaporation, heat is absorbed and conserved in water vapour (This is why Evaporation leads to cooling). It is known as latent heat. Latent heat is essential for development of typhoons (storms, cyclones
Saturated Air	If at any given temperature the humidity retentive capacity of air equals its absolute humidity the air is said to be saturated. 100 percent humid air is called saturated air.
Saturated Air	If at any given temperature the humidity retentive capacity of air equals its absolute humidity the air is said to be saturated. 100 percent humid air is called saturated air.
Atmospheric Brown Cloud (ABC)/Asian Brown Cloud	The ABC originally referred to the enormous blanket of pollution spre- ading across Asia, distorting normal weather patterns in the region and threatening to devastate many countries' economies. It was called the 'Asian Brown Cloud' in 2002, when a UN report first warned of this layer of pollution comprising ash, acids and aerosols.
The dew point	It is the temperature at which air is saturated with water vapor, which is the gaseous state of water. Below the dew point, liquid water will begin to condense on solid surfaces (such as blades of grass) or around solid particles in the atmosphere (such as dust or salt), forming clouds or fog
	The relative humidity is 100 percent when the dew point and the temperature are the same.
HAZE	Haze is traditionally an atmospheric phenomenon where dust, smoke and other dry particles obscure the clarity of the sky.

	One way to distinguish between smog and naturally-occurring haze is by colour. Natural haze is typically white, Gray or even blue. Smog is almost always yellowish or brown in colour.
	The international definition of fog is a visibility of less than 1 kilometre; mist is a visibility of between 1 kilometre and 2 kilometres and haze from 2 kilometres to 5 kilometres.
	Fog and mist are generally assumed to be composed principally of water droplets, haze and smoke can be of smaller particle size.

Fog	Mist
Fog is a special type of thin cloud consisting of very small water droplets which remain suspended in air close to the surface of the Earth.	It is also a type of fog but is relatively less dense. The only difference between mist and fog is density and its effect on visibility.
A cloud that reduces visibility to less than 1 km is called fog, whereas	It is called mist if visibility range is between 1 and 2 km.
Fogs are drier than mist and they are prevalent where warm currents of air come in contact with cold currents	Mists are frequent over mountains as the rising warm air up the slopes meets a cold surface.
Fog is formed due to condensation of water drop- lets suspended in the atmosphere in the vicinity of the earth's surface under certain conditions, such as low temperature and high relative humidity	Mist can occur as part of natural weather or volcanic activity or could be created artificially.

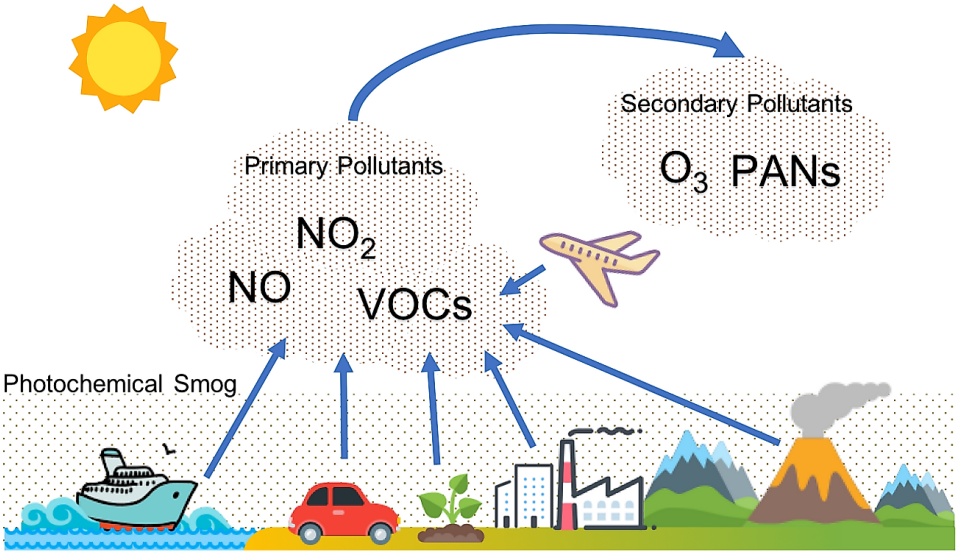
■ Smog :

- It refers to a mixture of smoke and fog. It also results from sun's effect on certain pollutants in the air, notably those from automobile exhaust.

two main types of smog— photochemical and industrial :

1. The photochemical smog :

- It is a mixture of primary and secondary pollutants.
- The primary pollutants are hydrocarbons and nitrogen oxides and their main source is the motor vehicles.
- The secondary pollutants are formed when sunlight acts upon motor vehicle exhaust gases to form harmful substances such as ozone (O_3), aldehydes and peroxyacetylnitrate (PAN).
- Photochemical smog formation requires (1) a still, sunny day and (2) temperature inversion (pollutants accumulate in the lower inversion layer).
- The photochemical smog directly affect lungs and eyes, causing irritation in these organs



2. **Industrial smog :**

- mixture of sulphur dioxide and a variety of solid and liquid particles suspended in air.
- It comes from the stationary sources, such as furnaces, power plants, etc., than from motor vehicles.
- Sulphur dioxide in combination with water and oxygen can turn into sulphuric acid in the atmosphere and falls on the earth as acid rain.
- It can dissolve marble and eat away iron and steel. In human it can affect the respiratory system.