General Knowledge Today

Prelims Geography-1: Astronomy

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Contents

Model Questions

Kindly Check the 20 Model Questions in the end of this module for Prelims Examinations.

Basic Facts about Universe

The universe is all of *space, time, matter, and energy* that exist. Universe is not just space, but space is just the framework or the scaffolding in which the universe exists. As Space and time are intimately connected in a four-dimensional fabric called space-time.

Age of Universe

The universe is *not infinitely old*. According to modern astronomical measurements, the universe began to exist about 13.7 billion years ago.

Size of Universe

It has not yet been scientifically determined exactly how large the universe is. It may indeed be infinitely large, but we have no way yet to confirm this possibility scientifically.

Cosmic Horizon

The *farthest limit to our viewing is called the cosmic horizon*, which is about 13.7 billion light-years away in every direction. Everything within that cosmic horizon is called the observable universe.

Structure of Universe

The structure of the universe—as opposed to the structure of matter in the universe— is determined by the shape of space. The shape of space is, surprisingly, curved.

On a very large scale—millions or even billions of light-years across—space has a three-dimensional "saddle shape" that mathematicians refer to as "negative curvature".

Big Bang Theory

According to the Big Bang theory, the universe began to exist as a single point of space-time, and it has been expanding ever since. As that expansion has occurred, the conditions in the universe have changed—from small to big, from hot to cold, and from young to old—resulting in the universe we observe today.

Big Bang theory developed as independent works on Einstein's General Theory of relativity by Willem de Sitter (1917), Alexander Friedmann (1922), Georges Lemaître (1927), Robertson, and Walker.

In 1929, Edwin Hubble analyzed and concluded that the galaxies are drifting apart. This became one of the cornerstone of the Big Bang theory.

Big Bang theory remains a theory as of now. The key evidences to Big Bang theory include *expansion of universe* and the *cosmic microwave background radiation*.

Expansion of the Universe

Universe is expanding but the scientists say that this expansion has not been at same rate all the times. Scientists say that for a very small fraction of second (Planck Time or 10 Scientists say that for a very small fraction of second (Planck Time or 10^{-43} seconds), universe underwent hyperinflationary expansion, which suddenly expanded the diameter of universe by at least a factor of ten billion billion. This is the so called Hyperinflationary model of expansion of universe.

Long after the hyperinflation ended, the expansion returned to an almost-constant rate, slowed down very slightly, and then billions of years ago started speeding up. Right now, the expansion rate of the universe is slowly but surely increasing. *We live in an accelerating universe.*

Cosmic Microwave Background

In the 1960s, astronomers at Bell Telephone Laboratories in USA were testing some of their instruments when the detected an ubiquitous microwave static that came from all directions in the sky. This discovery was later used as a proof to big bang theory.

Cosmic Microwave Background refers to the leftover energy from the hot, early universe that still fills space and permeates the cosmos in every direction.

Hubble Constant

The expansion rate of the universe is called the Hubble Constant in honor of Edwin Hubble (1889–1953). Currently the best measured value of the Hubble Constant is about73 kilometers per second per megaparsec.

This implies that if a location in space is one million parsecs from another location, then in the absence of any other forces or effects the two locations will be moving apart from one another at the speed of 263,000 kilometers per hour!

Hubble measured the galaxies' Doppler effect—the shift in the observed color of objects moving toward or away from an observer—by mounting a machine called a spectrograph on a telescope. He split the light from distant galaxies into its component parts and measured how far the wavelengths of emitted light shifted toward longer wavelengths.

Doppler Effect Definition

Doppler Effect is named after Christian Johann Doppler (1803–1853). It occurs when a source of sound (or any other wave) is moving toward or away from a listener. If the source is moving toward the listener, the sound wave's wavelength decreases, and the frequency increases, making the sound higher-pitched.

Conversely, if the source is moving away from the listener, the sound wave's wavelength increases, and the frequency decreases, making the sound lower-pitched. The next time a car or train passes by you on the street, listen to the sound it is making as it approaches and then moves away.

Doppler effect for light: Blue shift and Red Shift

When an object emitting light—or any kind of electromagnetic radiation, for that matter— moves toward someone, the wavelength of its emitted light is decreased.

Conversely, when the object moves away, the wavelength of its emitted light is increased.

For visible light, the bluer part of the spectrum has shorter wavelengths, and the redder part of the spectrum has longer wavelengths. Thus, the Doppler effect for light is called a "blue shift" if the light source is coming toward an observer, and a "red shift" if it is moving away. The faster the object moves, the greater the blue shift or red shift.

Black Holes

Each object has its own gravity which depends on its size and mass. The objects which have *highest mass in smallest size* would exert most gravity. The ultimate combination of large mass and small size is called a black hole. A black hole exerts such massive gravitational force that its escape velocity is equal or more than speed of light. The idea came in 18th century that such objects were so small and massive that particles of light could not escape from them and this would be black. When the general theory of relativity was confirmed, scientists started to explore the implications of gravity as the curvature of space by matter. Scientists realized that there could be locations in the universe where space was so severely curved that it would actually be "ripped" or "pinched off." Anything that fell into that location would not be able to leave. This idea of an inescapable spot in space—a hole where not even light could leave—led physicists to coin the term "black hole."

How Black Holes are detected?

One way of finding black holes is to observe the matter moving around in a orbit at much higher speed than expected. By carefully mapping this motion, the third law of Kepler and Newton's law of gravitation can be applied without seeing the actual object at the centre of the orbit.

Another way of finding black holes is to look at them as sources of X-ray radiation. The tremendous gravitational field of the black hole can produce huge amount of light nearby and around itself even if it itself is black. Just as a meteorite or spacecraft gets hot as it enters Earth's atmosphere, the in falling matter gets hot from the frictional drag too, sometimes reaching temperatures of millions of degrees. That hot material glows brightly and emits far more X-ray radiation and radio waves than would normally be expected from such a small volume of space. The scientists search for such small spaces with abonormally high X-Ray radiation to look for black holes.

Types of Black Holes

There are two categories of black holes viz. *low mass* and *super massive* are known to exist, and a third kind (*primordial blank hole*) has been hypothesized but not yet detected.

Low mass / Stellar Black Hole

Stellar black hole or low-mass black hole is found wherever the core of a very massive star (usually 20 or more times the mass of the Sun) has collapsed.

Super massive Black Hole

Super massive black hole is found at the centres of galaxies and is millions or even billions of times more massive than the Sun. Our Galaxy also has a black hole at its centre.

Promordial Black Hole

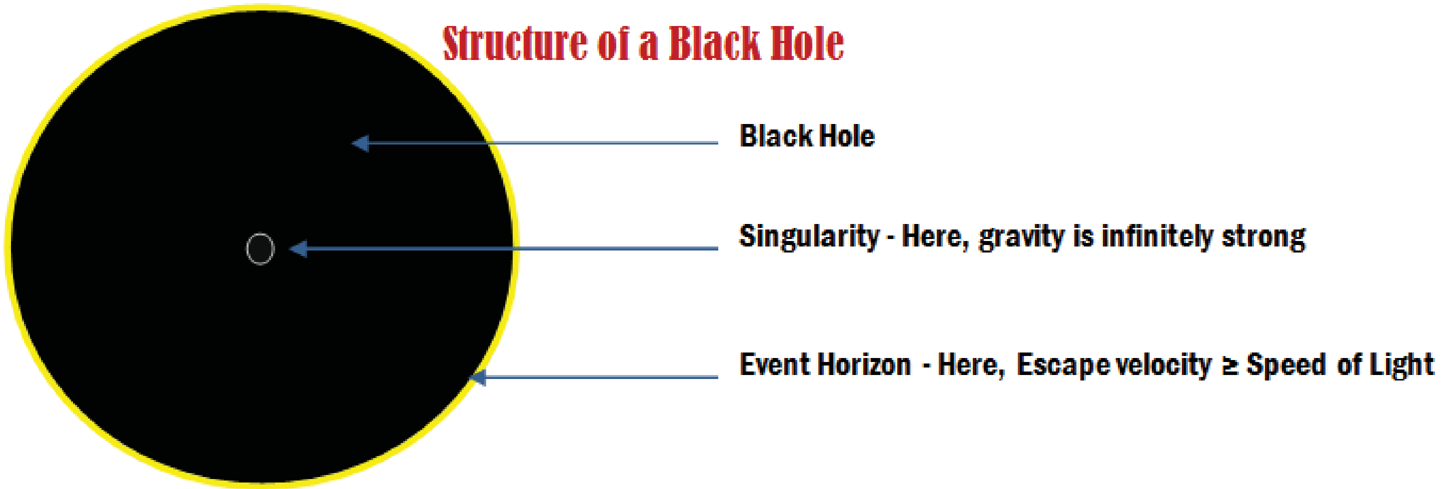
The third kind of black hole called a *primordial black hole* is found at random locations in space. It is hypothesized that these black holes were created at the beginning of cosmic expansion as little "imperfections" in the fabric of space-time. However, no such black hole has yet been confirmed to exist.

How many black holes are known today?

Today, thousands of black holes are known to exist, and the total population of black holes may number in the many billions.

Structure of a Black hole?

The centre of the black hole is called the**singularity**. It is a single point thathas no volume but infinite density. The laws of physics as we understand them simply do not work at the singularity of a black hole the way they do in the rest of the universe. Surrounding the singularity is a boundary called the *event horizon.* This is the place of no return, where the escape velocity for the black hole is the speed of light. The more massive the black hole is, the farther the event horizon is from the singularity, and the larger the black hole is in size.



The singularity at the centre of any black hole has no volume. The size of the event horizon however, varies depending on the black hole's mass. The mathematical relationship between the mass of a black hole and the size of its event horizon was derived by the German astrophysicist Karl Schwarzschild (1873–1916), and in his honour, the radius of a black hole's event horizon is called **Schwarzschild radius**.

The Radius of a stellar black holes is few hundred miles while that of super massive black holes is few million to billion miles. Further, if Sun is squeezed small enough to become a black hole; its radius would be around three miles only. If earth is squeezed into a black hole, its radius would be about three-quarters of an inch.

Properties of Black holes

Black holes have huge densities and the key properties they have include mass (weight), rotation (spin) and electric charge.

Wormholes and Cosmic Strings

Wormholes and cosmic strings are theoretical imperfections in space-time. While a Black hole has one point of singularity, the wormhole may have two points – one where matter can only enter and another where matter can only exit. No worm hole has been detected so far, so they are only in theory and science fiction.

A cosmic string is a theoretical, vibrating stand that is like a black hole but instead of being a point or sphere, it is a long but very think crease left in otherwise smooth universe. Cosmic string is also theoretical and no such string has been detected so far.

Dark Matter and Dark Energy

In 1930s, astronomers noticed that in some galaxy clusters, some of the galaxies were moving extra fast than possible with available matter (and its gravitational force). The question was – Is there any matter which is not visible to us but exerts its gravitation responsible for keeping the galaxies put together? Again in 1970s researchers proposed that stars of Andromeda galaxy were moving so fast that there needs to be present some tremendous amount of matter which does not emit any electromagnetic radiation but exerts gravity. Since it does not emit any EM radiation, it's not visible to telescopes and thus is called dark matter. Later, the scientists confirmed that dark matter does exist and is an important constituents of the galaxies and clusters of galaxies and puts them together. Further, it is now estimated that 80% of the matter in universe is dark matter.

The direct observational evidence of the dark matter comes from careful observations of the rotation rate of the galaxies. To scientists, the galaxies appear to be surrounded by *giant or galactic halo* containing matter capable of exerting gravitational influence but not emitting any observable radiation. Further, it was also indicated that majority of a galaxy's mass lays in this very large halo, which is around 10 times the diameter of the visible galaxy. For example, our own Milky Way galaxy contains about 100 billion stars and it is thought to have been surrounded by a dark matter halo that probably extends out to about 750,000 light-years. The mass of this dark matter halo appears to be about 10 times greater than the estimated mass of all the visible stars in our galaxy.

Dark Energy

Albert Einstein had introduced a mathematical term into his equations to keep a balance between cosmic expansion and gravitational attraction. This term became known as the "*cosmological constant*," and seemed to represent an unseen energy that emanated from space itself.

After Edwin Hubble and other astronomers showed that the universe was indeed expanding, the cosmological constant no longer appeared to be necessary, and so it was not seriously considered again for decades.

Then, starting in the 1990s, a series of discoveries suggested that the "dark energy" represented by the cosmological constant does indeed exist.

Current measurements indicate that the *density of this dark energy throughout the universe is much greater than the density of matter*—both luminous matter and dark matter combined.

Though astronomers have measured the presence of this dark energy, scientists still have no idea what causes this energy, nor they have a clue what this energy is made of.

The quest to understand the cosmological constant in general, and dark energy in particular, is one of the great unsolved questions in astronomy.

Composition of Dark Matter

But nobody has a real idea of what dark matter is and what these galactic halos are made of. However, there are some educated guess works divided into two schools of thoughts. One schools supports MACHOS or **Massive Compact Halo Objects** and another school advocates WIMPs or **Weekly Interacting Massive Particles.** However, no dark matter particle has ever been detected.

Implication of dark matter on shape of universe

- Dark matter in the universe exerts a gravitational pull in the expanding universe. The more dark matter there is in the universe, the more likely it would be that the universe would have a closed geometry, and that the universe would end in a Big Crunch.
- Continued expansion of the universe means that the total amount of dark energy keeps increasing.
- Since the total amount of mass in the universe is not increasing, that means that the expansive effect of dark energy will ultimately overcome the contractive effect of dark matter.
- The more dark energy there is, the more open the geometry of the universe will tend to be, and the faster the expansion rate of the universe will increase over time.

Galaxies

A galaxy is a vast collection of *stars, gas, dust, and dark matter* that forms a cohesive gravitational unit in the universe. In a way, galaxies are to the universe what cells are to the human body: each galaxy has its own identity, and it ages and evolves on its own, but it also interacts with other galaxies in the cosmos.

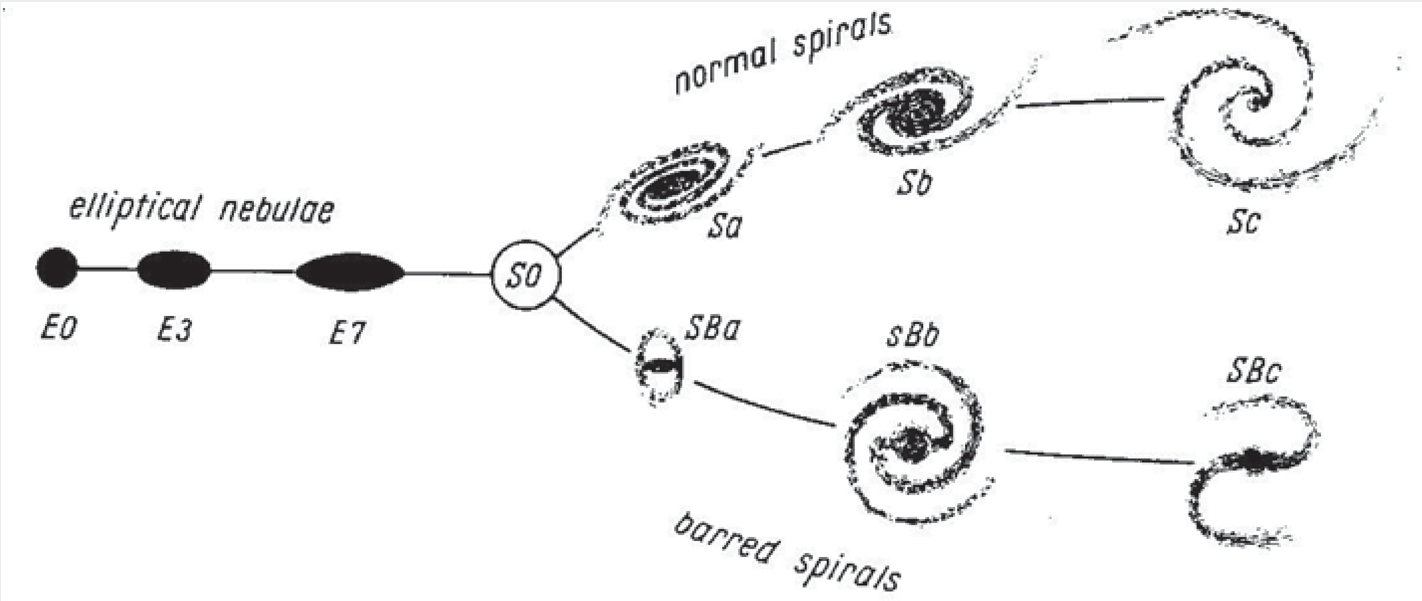
Within the observable universe alone, there exist an estimated 50 to 100 billion galaxies.

Types of Galaxies

Galaxies are of various kinds mainly divided into four types viz. elliptical, normal spirals, barred spirals and irregular.

Hubble Sequence and Tuning Fork Diagram

Hubble had proposed a way to classify galaxies based on their shapes. He proposed a "sequence" of galaxy types: from E0 (sphere-shaped elliptical galaxies) to E7 (cigar-shaped ellipticals), S0 (lenticular galaxies) to Sa and SBa (spiral galaxies with large bulges and bars), Sb and SBb (spirals with medium-sized bulges and bars), and Sc and SBc (spirals with small bulges and bars). The sequence is known as the Hubble sequence, and it is often shown visually as a Hubble "tuning fork diagram."



Further, an irregular galaxy is a galaxy that does not fit well into the standard categories of elliptical, spiral, or barred spiral galaxies. Two examples of irregular galaxies are the **Large Magellanic Cloud** and **Small Magellanic Cloud**, *which are visible from Earth's southern hemisphere.*

Size of Galaxies

Galaxies range greatly in size and mass. The smallest galaxies contain perhaps 10 to 100 million stars, whereas the largest galaxies contain trillions of stars. There are many more small galaxies than large ones. Our galaxy Milky Way has at least 100 billion stars and is a large galaxy. Its disk spreads around 100,000 light-years across.

Dwarf Galaxy

Dwarf galaxies have the least mass and fewest stars. The *Large Magellanic Cloud*, a *galaxy that orbits the Milky Way*, is considered a large dwarf galaxy; it contains, at most, about one billion stars.

Distribution of Galaxies

Galaxies are distributed unevenly throughout the universe. Majority of galaxies are collected along vast filamentary and sheet like structures many millions of light years long.

These filaments and sheets connect at dense nodes—clusters and super clusters— of galaxies, and the net result is a three-dimensional weblike distribution of matter in the universe. This is known as *Cosmic Web*.

Between the filaments and sheets are large pockets of space with relatively few galaxies; these sparse regions are called *voids*.

Group of Galaxies

Group of Galaxies contains two or more galaxies of bigger size and a dozen or more smaller galaxies. The *Milky Way and Andromeda galaxies are the two large galaxies in the* ***Local Group***. There are a few dozen smaller galaxies in the group, including the **Magellanic Clouds**, the dwarf elliptical **Messier 32,** the small spiral galaxy **Messier 33,** and many small dwarf galaxies. The Local Group of galaxies is a few million light-years across.

Cluster of Galaxies

A cluster of galaxies is a large collection of galaxies in a single gravitational field. Rich clusters of galaxies usually contain at least a dozen large galaxies as massive as the Milky Way, along with hundreds of smaller galaxies. At the center of large clusters of galaxies there is usually a group of elliptical galaxies called "cD" galaxies. Clusters of galaxies are usually about ten million light-years across. The Milky Way galaxy is *near, but not in*, the Virgo cluster, which itself is near the center of the Virgo supercluster.

Supercluster of Galaxies

Superclusters are the largest collections of massive structures. There are usually many clusters of galaxies in a supercluster, or a single very large cluster at its center, along with many other groups and collections of galaxies that are collected in the supercluster's central gravitational field. Superclusters contain many thousands—and sometimes millions—of galaxies. The Milky Way galaxy is located on the outskirts of the Virgo supercluster.

Milky Way Galaxy

The Milky Way is the galaxy we live in. It contains the Sun and 100 to 500 billion other stars. It is a barred spiral galaxy as grouped in the Hubble tuning fork diagram. It is located at the outskirts of the Virgo supercluster. The centre of the Virgo cluster is about 50 million light-years away from Milky Way.

Basic Features of Milkyway

Location of Earth in Milky Way

Earth orbits the Sun, which is situated in the Orion Arm, *one of the Milky Way's spiral arms* Earth and the Sun are about 25,000 light-years away from the galactic center.

Size of Milky Way

The Stellar disk of the Milky Way is about 100,000 light-years across and 1,000 light-years thick. Based on current measurements, at least 90 percent of the mass in the Milky Way's gravitational field is made up of dark matter, so the luminous stars, gas, and dust of the galaxy are embedded at the center of a huge, roughly spherical dark matter halo more than a million light-years across.

Blackhole at centre of milky way

There is an object at the center of the Milky Way called Sag-A* (Sagittarius A-star) which emits much more X-rays and radio waves than expected for a star-sized body.

After mapping the motions of stars near Sag A* for more than a decade, astronomers concluded that Sag A* is an invisible object that is more than three million times the mass of the Sun. This is a super massive black hole.

Movement of Earth within the Milky Way Galaxy

Earth (and the solar system) is moving through the Milky Way's disk in a stable, *roughly circular orbit* around the galactic center. Our orbital velocity around the center of the Milky Way is about 200 kilometers per second. Even so, the Milky Way is so huge that one complete orbit takes about 250 million years.

Can we see the whole Milky Way?

Much of the galaxy is blocked from our view on Earth due to the barriers created by dusty gas clouds blocking much of the light. Using infrared, microwave, and radio astronomy techniques, it is possible to penetrate much of this dusty fog. However, that too allows us only detect only half of stars and gas.

Neighbours of Milky Way

Milky way galaxy is one of the 54 galaxies in the "Local Group" of galaxies. The Local group itself is a part of a larger group called *Virgo Supercluster*. Virgo super cluster itself is a part of *Laniakea Supercluster*.

Within the local group, three largest galaxies viz. Milky Way, Andromeda and Triangulum have their own system of satellite small galaxies and clouds. For example, the satellite galaxies of Milky way include Sagittarius Dwarf Galaxy, Large Magellanic Cloud, Small Magellanic Cloud, Canis Major Dwarf, Ursa Minor Dwarf etc. Some of those galaxies, such as the Sagittarius dwarf galaxy, are almost in physical contact with the Milky Way's outskirts.

The Andromeda Galaxy (aka. M31) is the closest large galaxy to the Milky Way. It can be seen from earth with naked eyes. This galaxy is considered to be slightly larger than Milky way and *largest galaxy of the local group*.

Important Facts About Andromeda

- In the local cluster, the Andromeda is largest galaxy but may not be most massive. It is thought that Milky way has indeed more dark matter which makes is more massive.
- Andromeda is nearest spiral galaxy from milky way. Both Andromeda and Milky way are approaching each other and it is thought that 4.5 billion years from this time, the Andromeda Galaxy and the Milky Way would collide and would form a giant elliptical galaxy.

Similarities between Andromeda and Milky Way

Both milkyway and Andromeda are *spiral galaxies*, both appear to be of *same age* and both have *similar objects including a massive blackhole at the center* However, Andromeda is known to have a crowded double nucleus and its spiral arms are getting distorted by gravitational interactions with two satellite galaxies viz. M32 and M110.

Radio Galaxies

Radio galaxies are those ordinary-looking elliptical galaxies in which the radio wave emission far exceeds that of the galaxy's visible light emission.

Large / Small Magellanic Clouds

The Large Magellanic Cloud (LMC) and Small Magellanic Cloud (SMC) are two dwarf galaxies that are satellite galaxies of Milky way and orbit around Milkyway. Both of them are irregular galaxies. Both of them have forming stars at much faster rates than milkyway and so are important for the astronomers studying the formation and aging of stars and galaxies.

Interstellar medium

The interstellar medium is the matter that exists within, between and among the galaxies. Almost all of the interstellar medium is comprised of gas and microscopic dust particles.

Its density is very less, for example, interstellar medium in our region of the Milky Way galaxy has a density of about one atom of gas per cubic centimetre. By contrast, Earth's atmosphere at sea level contains about 1019 gas molecules per cubic centimeter.

Nebula

A nebula is a cloud or collection of interstellar medium in one location in space. Nebulae are produced in different ways. For instance, they can be gathered together by gravity, dispersed by stars, or lit up by a powerful radiation source nearby. Most of these beautiful nebulae contain only a few thousand atoms or molecules per cubic centimetre. This is many times sparser than even the best laboratory vacuum chambers on Earth can achieve.

Types of nebulae

There are different kinds of nebulae based on their appearance {such as dark nebulae, reflection nebulae and planetary nebulae} or the physical processes that create them {such as protostellar nebulae, protoplanetary nebulae, or supernova remnants}.

Dark nebulae

Dark nebulae look like black blobs in the sky. They are generally dark because they contain mainly cold, high-density, opaque gas, as well as enough dust to quench the light from stars behind them. One example of a dark nebula is the **Coal Sack Nebula**.

Reflection nebulae

Reflection nebula **is lit by bright, nearby light sources** because the dust particles in them act like countless microscopic mirrors, which reflect light from stars or other energetic objects toward Earth. To the human eye, reflection nebulae usually look bluish. This is because blue light is more effectively reflected in this way than red light.

Emission nebulae

An emission nebula is a glowing gas cloud *with a strong source of radiation—usually a bright star*—within or behind it. If the source gives off enough high-energy ultraviolet radiation, some of the gas is ionized, which means the electrons and nuclei of the gas molecules become separated and fly freely through the cloud.

When the free electrons recombine with the free nuclei to become atoms again, the gas gives off light of specific colors. What colors they emit depends on the temperature, density, and composition of the gas. For example the Orion Nebula glows mostly green and red.

Quasar

Quasar refers to quasi-stellar radio source. They were thought to be stars earlier but they are not stars at all, but rather active galactic nuclei. Nowadays, the word “quasar” is often used to mean any Quasi-Stellar Object (QSO), whether or not it emits radio waves.

Stars

A star is a mass of incandescent *gas that produces energy at its core by nuclear fusion.* Most of the visible light in the universe is produced by stars. The Sun is also a star. Stars shine because nuclear fusion occurs in their core. Nuclear fusion changes lighter elements into heavier ones and can release tremendous amounts of energy in the process. Stars are mostly comprised plasma {gas that is electrically charged}. A person with good eyesight can see about 2,000 stars on any given night with naked eye.

Basic Facts About Stars

Asterism and Constellations

A group of stars that make some recognizable shape or pattern is called**Asterism**. Two famous asterism include the Big Dipper {used to locate north star} and Summer Triangle {three of the most prominent stars in the Northern Hemisphere's summer night sky}. A**constellation** is much more complicated asterism, containing more stars or larger areas of the sky. Constellations are mostly named after mythological gods, legendary heroes, creatures, or structures. The constellations encompass the entire celestial sphere and provide a visual reference frame.

Structure in Stars

All **stars** have layers like a **core, radiative zone, convective zone, photosphere, chromosphere,** and **corona**, but in different ratios of thickness depending on the star's temperature, mass, and age. Very hot, young stars can even be completely radiative and have no convective zone; very cool stars, on the other hand, can be completely convective and have no radiative zone.

The coronae around stars can also vary tremendously, depending on the strengths of the magnetic fields around the stars.

Closest stars to Earth

The Sun is the closest star to Earth. It is average 93 million miles / 149.6 million km away from Earth. The *closest star system* to Earth is Alpha Centauri. Nearest start in this system isProxima Centauri, has been measured to be 4.3 light-years away from Earth. The main star in Alpha Centauri is about 4.4 lightyears away.

Proxima centaury is although closest star to Earth after sun, yet it is very faint. The brightest star as seen from Earth is Sirius or Dog Star, which is in a different constellation called Canis Major. It is 8.58 light years away from Earth.

North Star

The North Star is any star near the spot in the sky called the north celestial pole: the place that Earth's rotational axis is pointing toward.

Right now, and for the past several centuries, Polaris has been very close to the pole, and thus has served as a good north star. Earth's rotational axis changes its pointing location across the sky over the millennia.

Thousands of years ago, while ancient Egyptian culture thrived, the **North Star was a dimmer star called Thuban**. Between then and now, there have been stretches of many centuries when there was no useful North Star at all.

South Star

At present , there is no easily visible star near the south celestial pole. There are many asterisms and celestial objects relatively near the pole, so it is possible to triangulate between them and roughly find the location of the south celestial pole.

Stellar Evolution

Stellar evolution is a complicated process. All stars go through the continuous change and their life cycle is made of immature stage, mature stage and final changes towards end of their lives.

Stars pass through a definite evolutionary sequence, which can be broadly divided into three parts viz. Pre-main sequence, Main sequence and Post-main sequence stages. A star which is currently in its main mature period of its life cycle is called *Main Sequence Star*. Main sequence stars convert hydrogen into helium and are in an equilibrium state The stars which are not yet in the main sequence are called *pre-main sequence or infant* stars. The stars which have already lived their main sequence life are called *post-main sequence or elderly* stars.

Pre-main sequence phases

Protostar

Birth of any star begins with the gravitational collapse of a giant molecular cloud (nebula) spread across hundreds of light years. When it collapses, the molecular cloud breaks into smaller fragments releasing gravitational potential energy as heat. Its temperature and pressure increases and one of the fragments condenses into a rotating sphere of superhot gas to be known as Protostar. A Protostar is a highly condensed cloud of gases, mainly hydrogen and helium. It continues to grow by accretion of gas and dust from the molecular cloud. However, its further development depends upon its mass. If it is of low mass, it would turn into a **brown dwarf**, while if it is high mass, it would further evolve into **main sequence star**.

Brown Dwarf

A brown dwarf develops from a low mass protostar in which absence of required temperature and pressure leads to no nuclear fusion chain reaction. However, they still have more mass than any of the planets in solar system. They are dim, emit very less visible light and can be found only by using infrared telecopy. Brown dwarfs have been identified lately only after development of infrared telecopy. Now it is assumed that there are so many brown dwarfs out there that they can outnumber all other different types of stars in galaxy. However, still, red dwarfs are considered to be te largest number of stars in galaxy.

Main sequence star

If the protostar is massive and its core temperature is worth starting a proton-proton chain reaction; it would onset its journey to become a main sequence star. Its mass decides which path it would further take. If it is of low mass, it would turn into a red dwarf; if it is intermediate mass, it would turn into a red giant. Both of them would burn for 6-12 trillion years and would end their life as post mains sequence **white dwarf.** However, if it is a higher mass, it would turn into a red giant or blue giant.

Red Dwarf

A red dwarf as discussed above, is a low-mass, main-sequence star, which is hot and massive than brown dwarfs and is capable to sustain proton-proton chain reaction; but is cool and less massive then other stars such as red giants, blue giants etc. The temperature of their photosphere is around 3,000°K. They are small and faint than other stars and have no radiative zone between their core and the convection zone. It is thought that red dwarf stars are in largest population in galaxy among all kinds of stars.

Red Giant

A red giant is also a main sequence star but has ahigher mass than red dwarfs. The red dwarfs convert hydrogen into helium via nuclear fusion and over its life, the outward pressure of fusion is balanced against the inward pressure of gravity. However, once the hydrogen is finished off, the fusion would stop and gravity would take lead. This would upset the overall equilibrium of the star and to re-adjust it. During this readjustment, the star's outer region expands while the core shrinks. Due to the large expansion of the outer shell, the star becomes very big, and its colour changes- to red. However, its core would compress and get tighter and smaller. This contraction increases the temperature at core and reaches at levels where Helium fuses with Carbon and turns into a white dwarf in post main sequence life.

We note that since energy in red giants is spread across large area, they have surface temperature cooler (around 2200-3200°C) and thus are little over half as hot as Sun. They shine in the red part of the spectrum and thus are called red giants.

Similarities and differences between Red Dwarfs and Red Giants

Similarities

- Both are main sequence stars
- Both end their lives as white dwarfs

Differences

- While red dwarf is of low mass, red giant is of intermediate mass
- While red dwarfs sustain hydrogen fusion, red giants go further and result in helium fusion reaction
- While red dwarf has little light emanating from it, red giants are little more radiative.

Yellow Dwarf

A yellow or G-dwarf star has a surface temperature of 5300-6000K and converts hydrogen to helium in its core by nuclear fusion. Sun, Alpha Centauri A etc. are some of the yellow dwarfs. The term yellow is a misnomer because yellow is white {for example Sun would appear white if there was no atmosphere}.

Sun's future as a red giant

Scientists believe that sun, currently a yellow / white dwarf, would deplete its hydrogen in next 5-6 billion years and once that happens – it will start to expand. At its largest size, its photosphere would engulf Venus, mercury and possibly earth. However, this is only a hypothesis. It is argued that when sun loses its hydrogen, it would cause earth and other planets to farther away due to lesser gravity.

Blue Giant

A blue giant big and blue. Such stars are usually**high-mass stars on the main sequence** Blue giants live for only a million years or so, glowing a million times brighter than the Sun before they blow apart in titanic supernova explosions.

Post-main sequence stars

A giant star phase ends in white dwarfs, nova or super nova depending upon mass and some other factors. S. Chandrasekhar had proposed that only stars that have a certain mass limit would end their life as white dwarfs. He proposed that a star with mass above about 1.4 solar masses would collapse beyond the white dwarf stage and turn into something far denser and more compact. This upper mass limit is today called the Chandrasekhar limit.

Nova and Supernova

These are stars whose brightness increase suddenly by ten to twenty times or more due to a partial or outright explosion in the star. When brightness increases to 20 magnitudes or more, it is called a Supernova.

If the mass of the star is above Chandrasekhar limit, a tremendous explosion occurs at its core giving rise to a supernova. When that happens, it takes only a fraction of a second for the stellar core to collapse into a dense ball about ten miles across. The temperature and pressure becomes almost immeasurably hot and high.

There are two general types of supernovae.

- A Type I supernova is the result of an existing, older white dwarf that gains enough mass to exceed the Chandrasekhar limit, causing a runaway collapse.
- A Type II supernova is produced by a single highmass star whose gravity is so strong that its own weight causes the stellar core to reach a mass beyond the Chandrasekhar limit.

Neutron Star

A supernovae explosion in a star bigger than Sun but not more than twice as big, may leave behind an extremely dense, residual 'core of that star, reaching a density of 10^{14}gms/cm^{3}, known as Neutron Star. This serves as matter's last line of defense against gravity. In order to stay internally supported as an object and not be crushed into a singularity, the neutrons in the object press up against one another in a state known as *neutron degeneracy*. This state, which resembles the conditions within an atomic nucleus, is the densest known form of matter in the universe.

A neutron star is about as dense as a neutron itself. In other words, it has the density of an object more massive than the Sun, yet it is only about ten miles across. Its density is such that a single teaspoon of neutron star material would weigh about five billion tons!

Pulsar

When a neutron star spins incredibly fast, it forms magnetic field billions of times stronger than Earth's field. This magnetic field interacts with nearby electrically charged matter and can result in a great deal of energy being radiated into space, a process called *synchrotron radiation.*

The slightest unevenness or surface feature on the neutron star can cause a significant "blip" or "pulse" in the radiation being emitted. Each time the neutron star spins around once, a pulse of radiation comes out. Such an object is called a pulsar.

As of now, more than 1,000 pulsars have been found throughout our galaxy. Perhaps the best known one is the *Crab Nebula pulsar*. It is at the center of the Crab Nebula and is a remnant from a supernova that was first observed in 1054 AD.

It pulses once every 33 milliseconds, which shows that the body with the mass of the Sun is spinning more than 30 times per second!

X-Ray Star

An X-ray star emits a great deal of X-ray radiation. X-ray stars may emit thousands of times more X rays than visible light radiation. X-ray stars are almost always binary star systems or multiple star systems. The interaction between the two or more stars in the systems—one of which is usually a compact object like a white dwarf, neutron star, or black hole—is what causes the strong X-ray emission.

Binary Star

A binary star is a pair of stars that are so close together in the sky that they appear to be closely associated with one another.

Some binary stars, called apparent binaries, are merely close together because of our point of view from Earth; they have nothing to do with one another physically.

Black Holes

A black hole is an object With such strong gravitational field that even light cannot escape from its surface. Black holes are formed from neutron stars after the Supernova explosions of big stars.

Factors that influence, how stars will evolve

The most important factor that affects evolution of star is its **initial mass.** On this basis, the stars can be of very low mass (0.01 solar mass), low mass (0.1 solar mass),
intermediate mass (about 1 solar mass), high mass (about 10 solar masses), and very high mass (up to

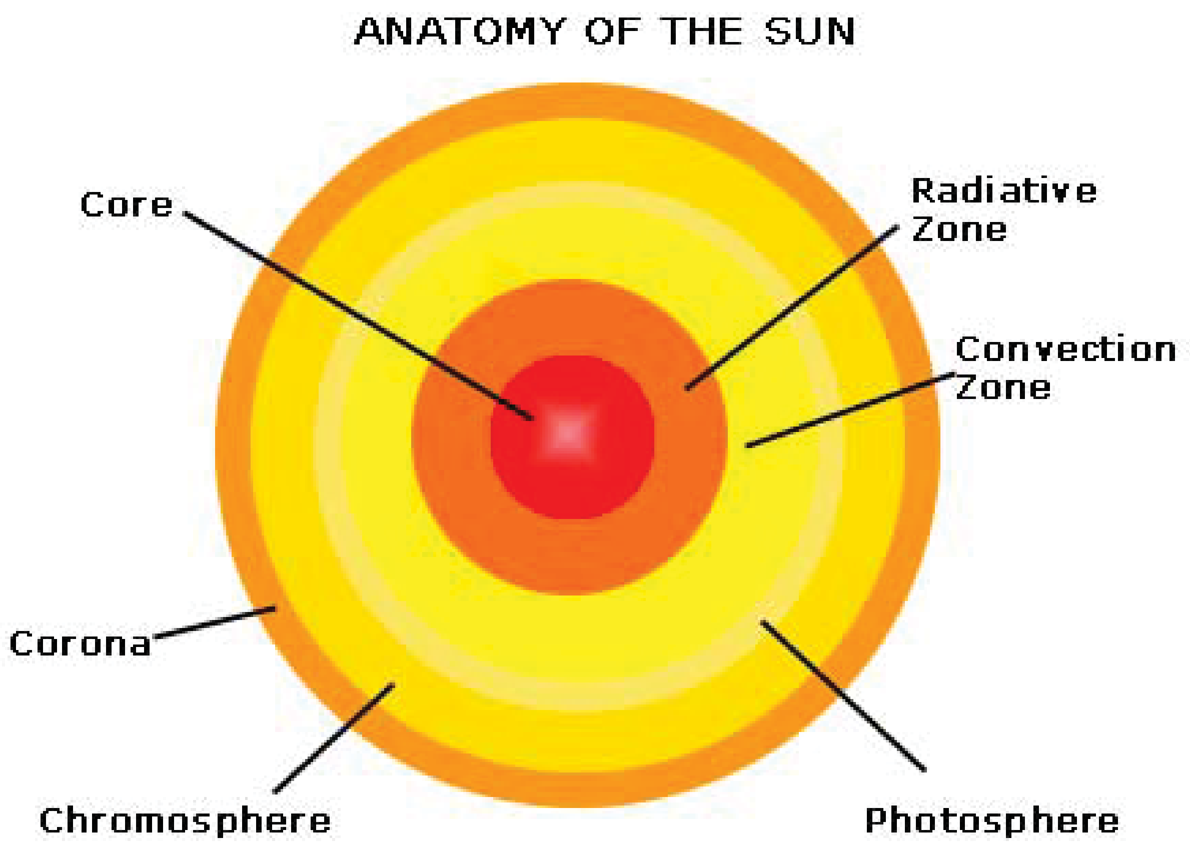
about 100 solar masses). By this definition, Sun is intermediate mass star. *The more is the mass of the sun, more it spends time in its main sequence and* the hotter it is during its main sequence.

Sun & Solar System

Sun is a star with a diameter of 109 times of earth and a mass of 3.30 lakh times of Earth, roughly accounting for 99.9% of total mass of the Solar system. Sun is mostly made of Hydrogen and Helium and is a *main sequence yellow dwarf*. It was formed some 4.6 billion years ago and is expected to deplete its hydrogen in next 5-6 billion years to turn into a red giant at the end of its life.

Structure of Sun

The Sun has a core at its center; a radiative zone surrounding the core; a convective zone surrounding the radiative zone; a thin photosphere at its surface; and a chromosphere and corona that extends beyond the photospheric surface.



Each of these zones are briefly discussed here:

Core

Solar energy is produced at the core of the sun where temperatures reach 15 million °C by nuclear fusion. This enormous energy makes the sun shine.

Radiative Zone

Energy produced in core slowly rises in the radiative zone outside the core. It takes around one million years for energy to travel out of the radiative zone.

Convection Zone

Convection zone is just beneath the Sun's surface.

Photosphere

Photosphere is the visible surface of Sun where temperature is around 5500°C. This part gives us light, which takes around 8 minutes to reach from sun to earth.

Chromosphere

Chromosphere is a thin layer of gas above the photosphere. Along with Corona, it makes the atmosphere of Sun.

Corona

Corona is a thick layer of gas above chromosphere. It extends millions of kilometers around the sun. Corona and Chromosphere are visible during a total solar eclipse when the sun's surface is completely hidden behind moon.

We note here that Corona is much dimmer than the rest of the Sun, and can only be seen when the Sun is blocked from view—either by a scientific instrument called a coronagraph, or naturally during a solar eclipse. Even though it is thinner than the best laboratory vacuums on Earth and so far away from the Sun's core, the corona is very energetic and very hot, with its plasma reaching temperatures of millions of degrees. The scientists still have not been able to figure out how the corona gets so hot. Current research suggests that the strong electrical currents and magnetic fields in and around the Sun transfer tremendous amounts of energy to the corona, either generally or by special "hotspots" that form for short periods of time and then disappear again.

Composition of Sun

The Sun's mass is composed of 71 percent hydrogen, 27 percent helium, and 2 percent other elements.

In terms of the number of atoms in the Sun, 91 percent are hydrogen atoms, 9 percent are helium atoms, and less than 0.1 percent are atoms of other elements. Most of the stars in the universe have a similar chemical composition.

Mass of Sun

The Sun has a mass of 1.99 million trillion trillion kilograms. The most massive supergiant stars have about one hundred times more mass than the Sun. The least massive dwarf stars and brown dwarfs contain about one-hundredth the mass of the Sun.

Rotation of Sun

Sun rotates about its axis from *west to east*. Since the Sun is not a solid object but rather a big ball of electrically charged gas, it spins at different speeds depending on the latitude.

The Sun spins once around its axis near its equator in about 25 days, and in about 35 days near its north and south poles. This kind of spinning, in which different parts move at different speeds, is called **differential rotation**.

Implications of Sun's Spin

- Magnetic fields in the Sun, created by strong electric currents, are produced because of the Sun's spin.
- Since Sun has differential rotation, and its interior roils with tremendous heat and energy, the magnetic field lines in the Sun get bent, twisted, knotted, and even broken; sunspots, prominences, solar flares, and coronal mass ejections are the result.

Formation of Solar System

The solar system is thought to have developed by the so called nebular hypothesis {given by Simon de Laplace}. About 4.6 billion years ago, the Sun formed from a large cloud of gas and dust that collapsed upon itself because of gravitational instability. When the Sun was born, not the entire nebula of gas and dust that had been gravitationally gathered was incorporated into the Sun itself.

Some of it settled into a disk of orbiting material. As this material orbited in a protoplanetary disk, numerous collisions between the tiny grains led to some of the grains sticking together, making larger bodies. After millions of years, the largest bodies—planetesimals—had sufficient mass (and hence gravity) to start attracting other objects in the disk to them.

Growing larger and larger, these planetesimals became protoplanets; the largest protoplanets grew larger still, until at last the planets were formed.

Although the solar wind has removed much of the remaining, unprocessed gas and dust, numerous smaller objects (and some of the gas and dust, as well) still remain today, providing the rich variety of objects and phenomena in a solar system more than four and a half billion years later.

Size of Solar System

Solar system reaches out to the orbit of the most distant planet, Neptune, or about five billion kilometers away from the Sun. Beyond Neptune is the Kuiper Belt, a thick, doughnut-shaped cloud of small icy bodies that extends to about eight billion miles (12 billion kilometers). Beyond Kuiper belt is the Oort Cloud, which is a huge, thick, spherical shell thought to contain trillions of comets and comet-like bodies. The Oort Cloud may extend as far as a light-year out from the Sun.

Thus, Solar system is generally divided into five major zones:

1. the inner (or terrestrial) planet zone,
2. the asteroid belt,
3. the outer (or gas giant) planet zone,
4. the Kuiper Belt, and the
5. Oort Cloud.

There is no exact boundary for these zones, however, and their sizes are not well determined; there is also overlap, in the sense that objects from one zone often appear in another zone.

Planets

A planet is an object which is not a star {i.e. no nuclear fusion takes place in it} and that orbits around a star and is mostly round because its own gravitational pull has shaped it into more or less a sphere.
As per current scientific classification, the planets must satisfy three basic criteria as follows:

- A planet must be in *hydrostatic equilibrium* which implies a balance between the inward pull of gravity and the outward push of the supporting structure. Objects in this kind of equilibrium are almost always spherical or very close to it.
- A *planet's primary orbit must be around the Sun* That means objects like the Moon, Titan, or Ganymede, are not planets, even though they are round due to hydrostatic equilibrium, because their primary orbit is around a planet.
- A planet *must have cleared out other, smaller objects in its orbital path*, and thus must be by far the largest object in its orbital neighbourhood. Due to this condition, Pluto is not considered a planet {but a dwarf planet}, even though it meets the other two criteria; there are thousands of Plutinos in the orbital path of Pluto, and it crosses the orbit of Neptune, which is a much larger and more massive object.

As per the current system, there are eight planets in the solar system—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune—and a number of dwarf planets, including *Pluto, Charon, Ceres, Eris* etc.

Planetary Rings

A planetary ring is a system of huge numbers of small bodies—ranging in size from grains of sand to house-sized boulders—that orbit in a coherent ring-shaped pattern around a planet.
The most spectacular planetary rings in the solar system orbit around Saturn; they are more than 170,000 miles across, and are less than one mile thick.

Inner Planets/ Terrestrial Planets

The planets that are collectively thought of as belonging to the inner solar system are **Mercury, Venus, Earth, and Mars**. These four objects are called the terrestrial planets because they resemble one another (specifically, Earth) in their structure: a metallic core, surrounded by a rocky mantle and thin crust.
There are three moons in the terrestrial zone as well: Earth's moon, and the two moons of Mars: Phobos and Deimos.

Outer Planets / Gas Giants

Gas giant planets are so named because they are much larger than the terrestrial planets and they have atmospheres so thick that the gas is a dominant part of the planets' structure. Jupiter, Saturn, Uranus, and Neptune are all categorized as gas giants.

The gas giant zone is the part of the solar system roughly between the orbit of Jupiter and the orbit of Pluto. It contains the outer (gas giant) planets Jupiter, Saturn, Uranus, and Neptune. Each of the gas giant planets has a host of moons and rings or ringlets.

Important Facts About Planets

Mercury

At 58 million kilometers distance, Mercury is closest planet to Sun. Due this much proximity, mercury's orbit is very much stretched into a *long elliptical shape*. Other important facts about mercury are as follows:

- Mercury takes 88 Earth days to complete one revolution around sun, however, it takes 59 Earth days to complete one rotation.
- It's surface is covered with deep craters, separated by plains and huge banks of cliffs.
- Mercury's most notable surface feature is an ancient crater called the **Caloris Basin**, which is a huge pit for such a small planet.
- Mercury's very thin atmosphere is made primarily of *sodium, potassium, helium, and hydrogen*.
- On its day side (the side facing the Sun), temperatures reach 430°C ; on its night side, the heat escapes through the negligible atmosphere, and temperatures plunge to -170°C.
- Mercury is so close to the Sun, the glare of the Sun makes it difficult to observe Mercury from Earth. Mercury is therefore visible only periodically, when it is just above the horizon, for at most an hour or so before sunrise and after sunset.
- It also moves more quickly across the sky than the other planets. Even when Mercury is visible, the sky is often so bright that it is hard to distinguish it from the background sky. **TH**
- NASA's Mercury-orbiting probe, **Messenger,** has confirmed a vast amount of ice at the north pole on Mercury, the closest planet to the Sun. Mercury's north pole is always in shadows. The South pole is also believed to harbor ice but there is little data to support it.
- Messenger which was launched in 2004 orbits much closer to the north pole than the south.

Venus

Venus is similar to Earth in many ways and is closer in distance to Earth than any other planet, and it has a similar size and composition. Key facts about Venus are as follows:

- A Venus year is equal to 225 days while a Venus day is equal to 243 days. Thus, a day on Venus is longer than a year.
- Venus rotates on its polar axis backwards compared to Earth, so a Venus sunrise occurs in the west and sunset in the east.
- Venus is blanketed by a thick atmosphere nearly 100 times denser than Earth; it is made mostly of carbon dioxide, along with some nitrogen and trace amounts of water vapor, acids,

and heavy metals. No terrestrial life is possible on Venus.

- Venus's clouds are laced with poisonous sulphur dioxide, and its surface temperature is 500°C. *Interestingly, this is even hotter than Mercury, which is much closer to the Sun*These hostile conditions are because of a runaway greenhouse effect on Venus.
- Since Venus is closer to the Sun than Earth,it is never up in the sky at midnight Rather, Venus is visible in the sky either just after dark or just before sunrise, depending on the season, so it is called Morning or Evening Star.
- Further, due to highly reflective clouds on Venus, its albedo is much higher and it looks as third brightest object in the sky, after the Sun and the Moon.
- Through a small telescope, it is possible to see Venus undergo phases, just like the Moon. This occurs because, from our point of view on Earth, we see only the parts of Venus that are illuminated by sunlight at any given time. However, unlike the Moon, though, Venus is usually brighter to our view in its crescent phase than in its full phase.
- The magnetic field of Venus is *far* weaker than that of Earth because it is assumed that the core of Venus is less convective and may have already solidified.

Mars

Mars is known as the red planet because it looks red from Earth. The reddish color comes from the *high concentration of iron oxide compounds*—that is, rust—in the rocks of the Martian surface. Some key facts about Mars are as follows:

- Martian year is of 687 days and Martian day is 24h 37m.
- Martian atmosphere is very thin—only about 7000th the density of Earth's atmosphere. The atmosphere is mostly carbon dioxide, with tiny fractions of oxygen, nitrogen, and other gases.
- At the equator, during the warmest times of the Martian summer, the temperature can reach nearly –18°C at the poles, during the coldest times of the Martian winter, temperatures drop to -85°C and beyond.
- Mars is known for fascinating geologic features on its surface; it is covered with all sorts of mountains, craters, channels, canyons, highlands, lowlands, and **even polar ice caps.**
- Scientific evidence strongly suggests that once, billions of years ago, Mars was much warmer than it is now, and was an active, dynamic planet.

Polar Ice Caps on Mars

- Polar Ice Caps were first observed by Italian astronomer Gian Domenico Cassini, who is known for many important discoveries, including a gap in Saturn's rings (This is called Cassini division).
- He made detailed observations of Mars, and discovered light-colored patches at the Martian

north and south poles. These polar caps showed seasonal variations, spreading during the Martian winter and shrinking during the summer.

- Martian polar ice caps are made up mostly of frozen carbon dioxide {dry ice.}. Some frozen water, or just plain ice, may also be embedded within the polar caps.
- Due to the atmospheric conditions on the surface of Mars, however, neither the ice nor the dry ice would melt to make water or liquid carbon dioxide when the temperatures go up; rather, they would sublimate, or turn directly into gas. Thus, polar ice caps on Mars are not a source of liquid water.

Geological features of Mars

- Mars has a rich variety of geological features: huge craters, broad plains, tall mountains, deep canyons, and much more, all with colorful names.
- The tallest mountain in the solar system, the extinct volcano Olympus Mons, rises 24 kilometers above the Martian surface.
- A massive canyon called the ***Vallis Marineris*** (Mariner Valley) cuts across the northern hemisphere of Mars for more than 3,200 kilometers; it is three times deeper than the Grand Canyon, here on Earth.
- On the southern hemisphere of Mars is **Hellas,** an ancient canyon that was probably filled with lava long ago and is now a large, light area covered with dust.

Martian meteorite ALH84001

- **A**LH84001 was so named because it was found in the *Allan Hills region of Antarctica in 1984* . It is the most famous of a number of meteorites that are thought to have been pieces of the Martian surface millions of years ago.
- They were probably knocked loose by a powerful collision from a comet or asteroid, which sent pieces of rock into orbit around the Sun that later landed on Earth.
- Mars Exploration Rovers, *Spirit* and *Opportunity,* are geological robots that have explored several areas of Mars. Among the many discoveries made with them are minerals that form only in the long term presence of water; microscopic *mineral structures nicknamed "blueberries" that only form when moisture is present,* along with chemical and isotopic ratios in Martian rocks that would have formed only if liquid water were in the environment.
- The strong scientific conclusion is that Mars is currently dry on its surface, but that this was not always the case. It may even have been awash with liquid water billions of years ago.

Moons of Mars – Phobos and Deimos

Phobos and Deimos are irregularly shaped rocky objects. They look very much like asteroids. Phobos is about 10 miles across, and Deimos is about half that size.

Phobos and Deimos look like small asteroids. The proximity of Mars to the asteroid main belt, suggests that they were indeed once asteroids whose orbits took them close to Mars. The orbital conditions were just right for Mars to capture them with its gravity, causing them to enter into stable orbits around Mars.

Jupiter

Jupiter is the largest planet in solar system, twice as massive as all the other planets, moons and asteroids in solar system put together. More than 90 percent of Jupiter's mass consists of swirling gases, mostly hydrogen and helium; in this incredibly thick, dense atmosphere, *storms of incredible magnitude rage and swirl.* The largest of these storms is the **Great Red Spot**, which is often visible from Earth through even a small telescope.

Other notable facts about Jupiter are as follows:

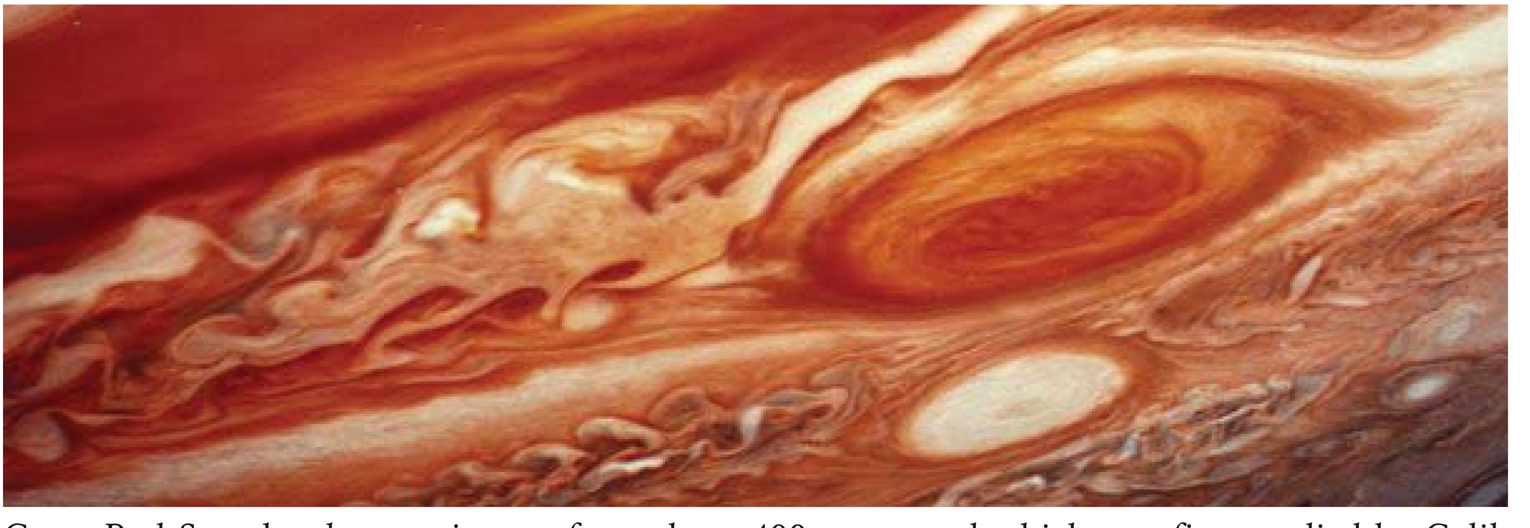
- A day on Jupiter is only 9 hours 56 minutes which makes it fastest rotating planet / body in solar system.
- Jupiter is 1,300 times Earth's volume and 320 times Earth's mass.
- Jupiter has a rocky core made of material thought to be similar to Earth's crust and mantle. Around this core, in these extreme conditions, it is likely that a thick layer of compressed hydrogen is present; the hydrogen in this layer probably acts like metal, and may be the cause of Jupiter's intense magnetic field, which is five times greater than even that of the Sun.
- As of now , there are 67 known moons of Jupiter; may of which are only a few miles across. However, four of them—*Io, Europa, Ganymede, and Callisto*—are about the size of Earth's Moon or larger.

Atmosphere of Jupiter

- Jupiter's upper atmosphere is composed of about 88–92% hydrogen and 8–12% helium by percent volume or fraction of gas molecules.
- There are also traces of carbon, ethane, hydrogen sulfide, neon, oxygen and sulphur. The outermost layer of the atmosphere contains crystals of frozen ammonia.

The Great Red Spot at Jupiter

The Great Red Spot on Jupiter is a huge windstorm more than 14,000 kilometers wide and 26,000 kilometers long. The storm that perpetuates the Spot is apparently powered by the upwelling of hot, energetic gases from deep inside Jupiter's atmosphere which produce winds that blow counter clockwise around the Spot at 400 kilometers per hour. Its red colour may be because of Sulphur or Phosphorus. Beneath it are three white, oval areas; each is a storm about the size of the planet Mars. There are thousands of huge and powerful storms on Jupiter, and many of them can last for a very long time.



Great Red Spot has been going on for at least 400 years, and which was first studied by Galileo Galilei, remains the biggest and most visible Jovian storm yet recorded.

Jupiter is the archetypal gas giant planet—so much so that gas giants are often called Jovian planets.

Rings of Jupiter

Jupiter has several very faint rings. They are nothing like Saturn's enormously developed and beautiful rings, but they can be detected through careful observations with instruments like the Hubble Space Telescope.

Possible Impacts of Jupiter on life on Earth?

Some astronomers believe that Jupiter helps Earth to remain habitable because it protects Earth from some comets, which in absence of Jupiter would have collided with Earth. The gravity of Jupiter slings these fast moving ice balls out of solar system before they can get closer to Earth. The scientists observed in 1994 a comet Shoemaker-Levy 9 breaking into several fragments and crashing on to Jupiter's atmosphere.

However, this theory has a negative side also. Sometimes, Jupiter can also divert a comet more towards earth. For example, in 18th century, a Comet Lexell had streaked past Earth at a distance of only one million miles. It had passed close to Jupiter which diverted it straight towards Earth, but somehow it missed earth.

Important Moons of Jupiter

Io – the most geologically active body in solar system

Io, the closest of the Galilean moons to Jupiter, is affected so strongly by the gravitational tides exerted on it by Jupiter and the other moons that it is the most geologically active body in our solar system. The *Voyager* spacecraft first detected huge volcanoes spewing lava and ash into space, and the surface is completely recoated with fresh lava every few decades.

Impact of Jupiter on its Io – Io Torus

- Jupiter's tremendous gravitational influence on its surroundings causes tidal activity on the Galilean moons.
- The tides alternately stretch and compress the cores of these moons.
- Another important influence exerted by Jupiter on its moons comes from the giant planet's magnetic field.
- Jupiter spins so fast, and contains so much mass, that the magnetic field generated by it engulfs the nearby moons and bathes them with ionization and charged particles.
- Meanwhile, powerful volcanoes that erupt on the surface of Io eject large amounts of small particles into space; many of them are swept up into Jupiter's magnetosphere, forming a doughnut-shaped torus of volcanic particles that form an ethereal envelope around the Jovian environment. This is called Io torus.

Europa

- Europa is the second closest to Jupiter of the four Galilean moons. Its surface is covered with frozen water ice.
- Studies by the *Galileo* spacecraft show that the ice has been moving and shifting much the same way that densely packed ice behaves on Earth's polar oceans.

Ganymede

Ganymede is the largest moon in the solar system, about one-and-a-half times as wide as Earth's Moon. It has a very thin atmosphere and its own magnetic field.

Calisto

Callisto, the furthest away from Jupiter of the four Galilean moons, is scarred and pitted by ancient craters. Its surface may be the oldest of all the solid bodies in the solar system.

Saturn

Saturn is similar to Jupiter, although about one-third the mass. A day on Saturn is only 10 hours and 39 minutes long; it spins so fast that its diameter at the equator is 10 percent larger than its diameter from pole to pole. However, its day is longer than that of Jupiter.

Saturn has a solid core likely made of rock and ice, which is thought to be many times the mass of Earth. Covering this core is a layer of liquid metallic hydrogen, and on top of that are layers of liquid hydrogen and helium. These layers conduct strong electric currents that, in turn *generate Saturn's* *powerful magnetic field.*

Saturn's Moons

Saturn has 62 confirmed moons, and its largest moon is Titan, which is larger than Earth's own moon and has a thick, opaque atmosphere.

Saturn's Ring System

The most spectacular part of Saturn is its magnificent system of planetary rings, which stretch some 300,000 kilometers across. The ring system is divided into three main parts: the bright A and B rings and the dimmer C ring. There are many other fainter rings as well.

- The A and B rings are divided by a large gap called the Cassini Division, named after Gian Domenico Cassini.
- Within the A ring itself is another division, called the **Encke Gap** after Johann Encke, who first found it in 1837.
- Although these gaps appear to be completely empty, they are nonetheless filled with tiny particles, and, in the case of the Cassini Division, dozens of tiny ringlets.
- Although Saturn's rings measure more than 100,000 miles across, they are only about a mile or so (one or two kilometers) thick. That is why they sometimes seem to disappear from view on Earth. When the orbit of Saturn is such that we see the rings edge-on, the rings look like a thin line and can be nearly invisible.

One idea about formation of Rings is that the rings were once larger moons that were destroyed, either by collisions, or by tidal interactions with Saturn's gravity tearing them apart. The bits of moons then settled into orbit around Saturn.

Moons of Saturn

Saturn has 62 confirmed moons. Also like Jupiter, many of these are small moons that are likely to be asteroids captured in Saturn's gravitational field.

Mimas

- Mimas, the victim of a huge cratering collision long ago, looks almost exactly like the fictional "Death Star" space station from the movies.
- Mimas has a diameter of 396 kilometers. It is the smallest known body in the solar system that became round because of its own gravitation.

Enceladus

- Enceladus was recently (2005) detected as having geysers of water shooting out from its surface, suggesting the presence of liquid water deep in its core.
- Enceladus is one of only three outer Solar System bodies (along with Jupiter's moon Io and Neptune's moon Triton) where active eruptions have been observed.
- The craters of Enceladus have been named Alibaba and Alladin.

Titan

- Titan is largest moon of Saturn and perhaps the most complex moon in the entire solar system. This is the only moon in solar system with a dense atmosphere.

Uranus

Uranus is the seventh major planet in our solar system, and the third of four gas giant planets. It is 51,200 kilometers in diameter, just under four times the diameter of Earth.

- Like the other gas giant planets, Uranus consists mostly of gas. Its pale blue-green, cloudy atmosphere is made of 83 percent hydrogen, 15 percent helium, and small amounts of methane and other gases.
- *Uranus gets its color because the methane in the atmosphere absorbs reddish light and reflects bluish-greenish light*. Deep down below its atmosphere, a slushy mixture of ice, ammonia, and methane is thought to surround a rocky core.
- Although it orbits the Sun in a perfectly ordinary, near-circular ellipse every 84 Earth years, Uranus has an extremely odd rotation compared to the other major planets.It rotates on its side, almost like a bowling ball rolling down its lane, and its polar axis is parallel rather than perpendicular to its orbital plane.

This means that one end of Uranus faces the Sun for an entire half of its orbit, while the other end faces away during that time. So one "day" on Uranus is equal to 42 Earth years. Uranus is orbited by some 27 known moons and several thin rings.

Neptune

Neptune is the eighth major planet in our solar system, 17 times more massive than Earth and about four times its diameter.

- The most remote of the four gas giant planets in our solar system, Neptune takes 165 Earth years to orbit the Sun once.
- A "day" on Neptune, however, is only 16 Earth hours.
- Similar to Uranus, Neptune's cloud-top temperature is a frosty –210°C

Neptune is bluish-green in color, which might seem fitting for a planet named after the Roman god of the sea. However, the color does not come from water; it is due to the gases in Neptune's atmosphere reflecting sunlight back into space. Neptune's atmosphere consists mostly of hydrogen, helium, and methane. Below the atmosphere, scientists think there is a thick layer of ionized water, ammonia, and methane ice, and deeper yet is a rocky core many times the mass of Earth.

Kuiper Belt

Kuiper Belt or the **Kuiper-Edgeworth Belt** is a doughnut-shaped region that extends between about three to eight billion miles (5 to 12 billion kilometers) out from the Sun (its inner edge is about at the orbit of Neptune, while its outer edge is about twice that diameter).

Kuiper Belt Objects

Kuiper Belt Objects (KBOs) are objects that originate from or orbit in the Kuiper Belt.

Only one KBO was known for more than 60 years: Pluto.

Largest KBOs in solar system: (Diameter: km)
Eris 2300-2400
Pluto 2,306
Sedna 1,500
Quaoar 1,260
Charon 1,210
Orcus 940
Varuna 890
Ixion 820
Chaos 560
Huya 500

Many KBOs have been discovered since 1990s, however, and the current estimate is that there are millions of KBOs.

KBOs are basically comets without tails, i.e. icy dirtballs that have collected together over billions of years. If they get large enough—such as Pluto did—they evolve as other massive planet like bodies do, forming dense cores that have a different physical composition than the mantle or crust above it. Most short-period comets— those with relatively short orbital times of a few years to a few centuries—are thought to originate from the Kuiper Belt.

Plutinos

Plutinos are Kuiper Belt Objects that are smaller than Pluto, have many physical characteristics similar to Pluto, and orbit around the Sun in much the same way that Pluto does.

The discovery of Plutinos led to the recognition that the Kuiper Belt is heavily populated, and that Pluto itself is a Kuiper Belt Object.

Asteroids

Asteroids are relatively small, primarily rocky or metallic chunks of matter that orbit the Sun. They are like planets, but much smaller; the largest asteroid, Ceres, is only about 930 kilometers across, and only ten asteroids larger than 250 kilometers across are known to exist in the solar system. While most asteroids are made mostly of carbon-rich rock, some are made at least partially of iron and nickel.

Aside from the largest ones, asteroids tend to be irregular in shape, rotating and tumbling as they

move through the solar system.
The four largest asteroids are the dwarf planet Ceres, Pallas, Vesta, and Hygiea. Other well-known asteroids include Eros, Gaspra, Ida, and Dactyl.

Asteroid belt

The asteroid belt (or the "main belt") is the region between the**orbit of Mars and the orbit of Jupiter**—about 240 to 800 million kilometers away from the Sun.
The vast majority of known asteroids orbit in this belt. The main belt itself is divided into thinner belts, separated by **object-free zones called Kirkwood Gaps** The gaps are named after the American astronomer Daniel Kirkwood, who first discovered them.
Even though there are at least a million or more asteroids in the main belt, the typical distance between asteroids is huge—thousands or even millions of miles.

Asteroids located other than Asteroid Belt

There are many asteroids in other regions of the solar system. Chiron, for example, which was discovered in 1977, orbits between Saturn and Uranus.
Another example is the **Trojan asteroids** that follow the orbit of Jupiter near Lagrange points—one group preceding the planet, the other following it—and can thus orbit safely without crashing into Jupiter itself.

2010TK7 : Earth's Trojan Satellite

It was discovered in 2010 that Earth is not alone in its orbit around the Sun. There is a small 'Trojan' asteroid 2010TK7 that sits in front of earth and leads it. This is the 1st Trojan Asteroid of Earth discovered using the WISE Telescope. It has now become the First known Trojan Asteroid in Earth's Orbit.
A Trojan asteroid shares an orbit with a larger planet or moon, but does not collide. So a Trojan has a particular position in a stable spot – either in front of a planet or behind it called Lagrangian points. Because the asteroid and planet are constantly on the same orbit, they can never collide. Trojan asteroids were anticipated in earth's orbit but never discovered yet. Nasa discovered the asteroid, which lies 80 million km from Earth, using its Widefield Infrared Survey Explorer (WISE) telescope. Astronomers have long thought that Earth did have Trojans but their discovery has proved elusive because they can't be seen in daylight.

Origin of Asteroids

The origin of asteroids remains the subject of scientific study. Astronomers today think that most asteroids are planetesimals that never quite combined with other bodies to form planets.
Some asteroids, on the other hand, may be the shattered remains of planets or protoplanets that suffered huge collisions and broke into pieces.

Number of Asteroids

Many thousands of asteroids are being tracked regularly, and tens of thousands have been identified and catalogued. At least one million asteroids are estimated to exist; of those, astronomers estimate that about one in ten can be observed from Earth.

Comets

Comets are basically "**snowy dirtballs" or "dirty snowballs**"—collections of rocky material, dust, and frozen water, methane, and ammonia that move through the solar system in long, **highly elliptical orbits** around the Sun.

When they are far away from the Sun, comets are simple, solid bodies; but when they get closer to the Sun, they warm up, causing the ice in the comets' outer surface to vaporize. This creates a cloudy "coma" that forms around the solid part of the comet, called the "nucleus."

The loosened comet vapor forms long "tails" that can grow to millions of miles in length.

The English astronomer Edmund Halley (1656–1742) calculated the paths travelled by 24 comets recorded by astronomers over the years. Among these, he found that three—one visible in 1531, one in 1607, and one that Halley himself had observed in 1682—had nearly identical flight paths across the sky. This discovery led him to the conclusion that comets follow in an orbit around the sun, and thus can reappear periodically.

In 1695 Halley had predicted that a comet which has been seen thrice would return 76 years after its last sighting, in the year 1758. Unfortunately, Halley died before he could see that he was, indeed, correct. The comet was named in his honor, and to this day Halley 's Comet remains the best-known comet in the world. It last passed by Earth in 1986, and will return again in 2062.

Origin of Comets

Most of the comets that orbit the Sun originate in the *Kuiper Belt or the Oort Cloud*, two major zones in our solar system beyond the orbit of Neptune.

"Shortperiod comets" usually originate in the Kuiper Belt.

Some comets and comet-like objects, however, have even smaller orbits; they may have once come from the Kuiper Belt and Oort Cloud, but have had their orbital paths altered by gravitational interactions with Jupiter and the other planets.

Comet Shoemaker-Levy 9

The encounter between Comet Shoemaker-Levy 9 and the planet Jupiter was the first collision between solar system bodies ever directly observed by humans.

As the comet approached Jupiter in 1994, it broke up into a long chain of fragments. Astronomers observed with amazement in July 1994 as these fragments crashed, one by one, into the gas giant's thick atmosphere.

Meteorite and meteors

A meteorite is a large particle from outer space **that lands on Earth.** They range in size from a grain of sand on up. Around 30 thousand meteorites have been recovered in recorded history; about 600 of them are made primarily of metal, and the rest are made primarily of rock. A meteor is an object from outer space that enters Earth's atmosphere, **but does not land on Earth**. Instead, the particle burns up in the atmosphere, leaving a short-lived, glowing trail that traces part of its path through the sky. If a meteor is large enough to reach Earth, we call it a meteorite.

Sources of Meteors and Meteorites

Most meteors, especially those that fall during meteor showers, are *the tiny remnants of comets left in Earth's orbital path over many, many years*. Most meteorites, which are generally larger than meteors, *are pieces of asteroids and comets that somehow came apart from their parent bodies*—perhaps from a collision with another body—and orbited in the solar system until they collided with Earth.

Meteor Showers

Every Year the **Perseid meteor shower** happens in August, as Earth travels through the remnant tail of Comet 109P/Swift-Tuttle. In November, when earth moves through the remnants of Comet 55P/Tempel-Tuttle, it causes **Leonid meteor shower**.

Types of Meteorites

There are two main categories of meteorites: **stony and metallic**.

- Each category is further subdivided into more detailed groups with similar characteristics.
- **Vestoids**, for example, are all thought to have come from the asteroid Vesta, where, long ago, a powerful collision created shattered bits of Vesta that have been orbiting the solar system ever since.
- **Chondrites** are one kind of stony meteorite; they are often the oldest meteorites.
- Another category, the **pallasites**, have fascinating mixtures of stony and metallic material. Pallasites probably originated from boundary areas in larger asteroids, where rocky mantles were in physical contact with metallic cores.

Cosmic Rays

Cosmic rays are invisible, high-energy particles that constantly bombard Earth from all directions. Most cosmic rays are protons moving at extremely high speeds, but they can be atomic nuclei of any known element. They enter Earth's atmosphere at velocities of 90 percent the speed of light or more. The cosmic rays were discovered by Victor Franz Hess , who got interested in a mysterious radiation that scientists had found in the ground and in Earth's atmosphere. This radiation could change the electric charge on an electroscope even when placed in a sealed container. In 1912 Hess took a series of high-altitude, hot-air balloon flights with an electroscope aboard. He made ten trips at night, and one during a solar eclipse, just to be sure the Sun was not the source of the radiation. Hess found that the higher he went, the stronger the radiation became. This discovery led Hess to conclude that this radiation was coming from outer space. For his work on understanding cosmic rays, Hess received the Nobel Prize in physics in 1936.

Source of Cosmic Rays

A continuous stream of electrically charged particles flows from the Sun; this flow is called the solar wind. So, a fraction of cosmic rays originate **from** the Sun, but the Sun alone cannot account for the total flux of cosmic rays onto Earth's surface.

The source for the rest of these cosmic rays remains mysterious. Distant supernova explosions could account for some of them; another possibility is that many cosmic rays are charged particles that have been accelerated to enormous speeds by interstellar magnetic fields.

All of us are being struck by cosmic rays all the time, however, at Earth ordinarily, they have no deleterious effect on our health. If we go beyond Earth's magnetosphere, cosmic rays can cause potentially more damage to your body's cells and systems.

Model Question Answers for Prelims

Astronomy Model Questions for Prelims

1. Which among the following are the sources of Cosmic microwave background radiation?

1. Stars
2. Galaxies
3. Pulsars

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 3

[C] Only 2 & 3

[D] None of the 1, 2 or 3

Answer: [D] None of the 1, 2 or 3

Just after the birth of the universe, the atmosphere was extremely dense and glowing white hot. Through the ages, the universe has been cooling — a process that is still going on. Light waves from a very distant part of the early universe reached the earth, making it possible to see the glow. However, since the universe is still expanding, the frequency of the waves of visible light changes to microwave frequency. This occurs due to the relative motion of either the source or receiver of the waves or both, with respect to each other. These waves, originating in the early stage of the cosmos, are cosmic microwaves. Cosmic microwave background radiation is not associated with any star, galaxy, or other object. This glow is strongest in the microwave region of the radio spectrum. The CMB's serendipitous discovery in 1964 by American radio astronomers Arno Penzias and Robert Wilson was the culmination of work initiated in the 1940s, and earned them the 1978 Nobel Prize.

2. With reference to the birth and death of stars, consider the following general observations:

1. The fate of a star after its nuclear fuel burns out, depends on the mass it was born with
2. When the star exhausts its nuclear fuel, gravity causes it to collapse & shrink
3. White dwarfs are one of the densest forms of matter in the universe, next only to black holes

Which among the above observations is / are correct?

[A] Only 1

[B] 1 & 2

[C] 1, 2 & 3

[D] 2 & 3

Answer: [C] 1, 2 & 3

The fate of a star after its nuclear fuel burns out depends on the mass it was born with. Stars with a lot of mass become neutron stars or black holes. A low- or medium-mass star (less than about five times the solar mass, Ms) will become a white dwarf. When such sun-like medium-mass stars are generating energy by nuclear fusion of hydrogen in their cores, there is a delicate balance between gravity that pulls the star matter inward and the pressure of hot gas in the core that pushes outward. When the star exhausts its fuel, gravity wins and the star begins to collapse, resulting in a dense object called white dwarf, which is about as massive as the sun but only slightly bigger then the earth. Its density is about 200,000 times that of the earth. White dwarfs are one of the densest forms of matter in the universe, next only to black holes. (Frontline)

3. With reference to the recent developments in Astronomy, the Kepler Object of Interest (KOI) refers to ____:

[A] Earth Like Planets

[B] Dwarf Planets

[C] Stars located in Goldilocks Zones

[D] Potentially Hazardous Objects

Answer: [A] Earth Like Planets

4. With reference to the Milky way galaxy, which among the following statements is / are correct?

1.The Milky Way is a member of the Virgo super cluster

2.The two most massive members of the Virgo super cluster are the Milky Way and the Andromeda Galaxy

Choose the correct option from the codes given below:

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [A] Only 1

A galaxy is a group of large number of stars in the sky which have generally the same origin of evolution, such as our Milky Way. A galaxy may contain billions of stars. A cluster of galaxies, which may have up to 10 or even more galaxies is called a local group. Clusters of galaxies are known as a super galaxy, or a super cluster. This may have up to 50 or even 1,000 galaxies. The Milky Way is a member of the Virgo super cluster. However, before that its is a part of smaller "Local group". Local Group is the group of galaxies that includes Earth's galaxy, the Milky Way. The group comprises more than 54 galaxies (including dwarf galaxies), with its gravitational center located somewhere between the Milky Way and the Andromeda Galaxy. The galaxies of the Local Group cover a 10 million light-year diameter and have a binary (dumbbell) shape. This group itself is part of the Virgo Supercluster. Thus second statement is not correct. Virgo Supercluster contains the Virgo Cluster in addition to the Local Group, which in turn contains the Milky Way and Andromeda galaxies. At least 100 galaxy groups and clusters are located within its diameter of 33 megaparsecs. It is one of millions of superclusters in the observable Universe.

5. Several reasons have been cited with reference to the inability of the Mars to sustain life. What is / are those reasons?

1.Mars has no magnetosphere

2.The atmosphere of Mars is very thin

3.Mars is well beyond habitable zone of solar system

4.Mars has no water, water ice and oxygen

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 1, 2 & 3

[C] Only 2, 3 & 4

[D] Only 1 & 3

Answer: [A] Only 1 & 2

The first two statements are correct. The lack of a magnetosphere and extremely thin atmosphere of Mars are a challenge: the planet has little heat transfer across its surface, poor insulation against bombardment of the solar wind and insufficient atmospheric pressure to retain water in a liquid form (water instead sublimates to a gaseous state). Mars is also nearly, or perhaps totally, geologically dead; the end of volcanic activity has apparently stopped the recycling of chemicals and minerals between the surface and interior of the planet. The current understanding of planetary habitability—the ability of a world to develop and sustain life—favors planets that have liquid water on their surface. This most often requires that the orbit of a planet lie within the habitable zone, which for the Sun currently extends from just beyond Venus to about the semi-major axis of Mars. During perihelion Mars dips inside this region, but the planet's thin (low-pressure) atmosphere prevents liquid water from existing over large regions for extended periods. The past flow of liquid water demonstrates the planet's potential for habitability. Some recent evidence has suggested that any water on the Martian surface may have been too salty and acidic to support regular terrestrial life. The 4th statement is not correct because presence of water ice as well as traces of oxygen have been reported at Mars.

6. With reference to the Kuiper Belt, consider the following statements:

1. No planet of solar system is located in Kuiper Belt
2. In comparison to asteroid belt, the bodies found in Kuiper Belt are generally large
3. Haumea and Makemake are dwarf planets located in Kuiper Belt

Which among the above statements is / are correct?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [C] Only 1 & 3

The Kuiper belt is a region of the solar system beyond the planets, extending from the orbit of Neptune. It is similar to the asteroid belt, although it is far larger — 20 times as wide and 200 times as massive. Like the asteroid belt, it consists mainly small bodies or remnants from the solar system's formation. The Kuiper belt objects are composed largely of frozen volatiles (termed 'ices'), such as methane, ammonia and water. It is home to at least three dwarf planets — Pluto, Haumea and Makemake. Pluto, discovered in 1930, is considered its largest member.

7. Which among the following is / are Jovian Planets?

1. Jupiter

2. Mars
3. Saturn
4. Venus

Choose the correct option from the codes given below:

[A] Only 1 & 3

[B] Only 1 & 2

[C] Only 1, 3 & 4

[D] 1, 2, 3 & 4

Answer: [A] Only 1 & 3

Jovian planets, also known as gas giants, is a collective term for Jupiter, Saturn, Uranus and Neptune. The term Jovian came from planet Jupiter, which describes the other gas giants in our solar system which are like Jupiter. These planets are surrounded by a number of moons and rings and their rotation is faster than terrestrial planets. Jovian planets have a dense core surrounded by a huge layer of gas which is made up of hydrogen and helium.

8. Pluto is considered to be a dwarf planet and not a planet. What could be the possible explanation to this?

[A] It is not in an orbit around the Sun

[B] It is not massive enough to be sphere by its own gravitation

[C] It makes a two system body with Neptune

[D] It has not cleared its neighbouring region of small bodies

Answer: [D] It has not cleared its neighbouring region of small bodies

According to current definitions, objects in orbit around the Sun are classed dynamically and physically into three categories: planets, dwarf planets and small Solar System bodies. A planet is any body in orbit around the Sun that has enough mass to form itself into a spherical shape and has cleared its immediate neighborhood of all smaller objects. By this definition, the Solar System has eight known planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. Pluto does not fit this definition, as it has not cleared its orbit of surrounding Kuiper belt objects. A dwarf planet is a celestial body orbiting the Sun that is massive enough to be rounded by its own gravity but has not cleared its neighbouring region of planetesimals and is not a satellite. By this definition, the Solar System has five known dwarf planets: Ceres, Pluto, Haumea, Makemake, and Eris.Other objects may be classified in the future as dwarf planets, such as Sedna, Orcus, and Quaoar. Dwarf planets that orbit in the trans-Neptunian region are called “plutoids”.The remainder of the objects in orbit around the Sun are small Solar System bodies.

9. As per the current theory, whether a collapsing star would become a white dwarf or a black hole, is decided by __:

1.Mass of star

2.Temperature of star

3.Position of the star in a galaxy

Choose the correct option from the codes given below:

[A] Only 1

[B] 1 & 2

[C] 1 & 3

[D] 1, 2 & 3

Answer: [A] Only 1

The collapse of a star is a natural process that occurs when all stellar energy sources are exhausted. If the mass of the collapsing part of the star is below a certain critical value, the end product is a compact star, either a white dwarf or a neutron star. But if the collapsing star has a mass exceeding this limit, the collapse will continue forever and form a black hole and astronomers believe that any collapsing star with solar mass above 0.7 will form a black hole.

10. With reference to the Cosmic rays, which among the following statements is / are correct?

1.They are made up of only positively charged particles

2.The major source of Cosmic Rays in universe is Sun

3.They cause Ozone Depletion

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 3

[D] 1, 2 & 3

Answer: [C] Only 3

The first statement is incorrect. Almost 90% of cosmic rays are protons, about 9% are helium nuclei (alpha particles) and nearly 1% are electrons. This means that Cosmic Rays are not made up of only positively charged particles. The second statement is also incorrect. Cosmic rays may broadly be divided into two categories: primary and secondary. The cosmic rays that originate from astrophysical sources are primary cosmic rays; these primary cosmic rays interact with interstellar matter creating secondary cosmic rays. Sun is not the major source but exactly is a minor source. The Sun also emits low energy cosmic rays associated with solar flares. The third statement is correct. The chain of reactions in the upper atmosphere due to the cosmic rays causes depletion of the ozone but this depletion is small in comparison to the depletion caused by CFCs.

11. With reference to the astronomical bodies, what is the difference between Blue Galaxies and Red Galaxies?

[A] Blue Galaxies are those which are moving towards earth, while Red Galaxies are those which are moving away from earth

[B] Blue Galaxies are those which are still actively making new stars, while Red Galaxies are those which have stopped making new stars

[C] Blue Galaxies are those which rotate clockwise as seen from earth, while Red Galaxies are those which rotate anti-clockwise as seen from earth

[D] Blue Galaxies are those which have a black hole at their center, while Red Galaxies are those which have no black hole at their centre

Answer: [B] Blue Galaxies are those which are still actively making new stars, while Red Galaxies are those which have stopped making new stars

12. Which among the following planets are called "Superior Planets"?

1. Venus
2. Mars
3. Jupiter
4. Saturn

Select the correct option from the codes given below:

[A] Only 1, 2 & 3

[B] Only 2, 3 & 4

[C] Only 2 & 3

[D] Only 3 & 4

Answer: [B] Only 2, 3 & 4

The planets closer to the sun than the earth, namely Mercury and Venus, are called the inferior planets. The planets located at a distance greater than the distance of the earth from the sun are called the superior planets. Mars, Jupiter, Saturn, Uranus and Neptune are superior planets.

13. With reference to the solar system, consider the following statements:

1. All planets except Venus revolve around the sun in the same direction i.e. from west to east
2. The direction of rotation of planets on their axis is also the same as the direction of their revolution around the sun

Which among the above is / are correct statements?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [D] Neither 1 nor 2

All of the planets move around the Sun in a direct (eastward) direction, but three of them (Venus, Uranus and Pluto) rotate in a retrograde (westward) direction, and are said to have a retrograde rotation. Do not confuse revolution, or motion around an orbit, with rotation, or turning about an axis.

14. The scientists use Red shift of distant galaxies as an evidence for which of the following?

1. Expansion of the universe
2. Existence of Black holes
3. Existence of Dark Energy

Select the correct option from the codes given below:

[A] Only 1

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [C] Only 1 & 3

Redshift occurs when light sources move away from the observer. If all the galaxies in the universe are moving away from us, that's evidence that the universe is expanding.

The evidence that black holes exist is their gravitational effects on visible objects near them, not redshift.

Redshift—specifically, increasing redshift, has been used as an evidence for **dark energy.**

On the other hand, anomalous rotation curves in galaxies, not redshift is linked to dark matter.

15. Stars pass through a definite evolutionary sequence. With this reference, which among the following is a correct order?

[A] Red giant, Nova, Supernova, White Dwarf

[B] White dwarf, Nova, Super Nova, Neutron Star

[C] Neutron star, Pulsar, Red Giant, White dwarf

[D] Nova, Supernova, White Dwarf, Red Giant

Answer: [A] Red giant, Nova, Supernova, White Dwarf

Stars pass through a definite evolutionary sequence.

Protostar

The first step in the formation of a star from gases is the Protostar. Protostar is formed by the gravitational contraction of gases present in the Galaxy. A Protostar is a highly condensed cloud of gases, mainly hydrogen and helium.

Red Giants

Second stage is Red Giants. The continued Nuclear fusion upset the overall equilibrium of the star and to readjust it star's outer region expands while the core shrinks. Due to the large expansion of the outer shell, the star becomes very big, and its colour changes- to red.

Third Novae and Supernovae

A giant star phase may end in a Novae/
Supernovae stage. These are stars whose brightness increase suddenly by ten to twenty magnitudes or more due to a partial or outright explosion in the star. When brightness increases to 20 magnitudes or more, it is called a Supernovae.

White dwarfs

A Novae/Supernovae explosion in a small star like our Sun (stars lighter than 1 .2 solar mass) may leave behind a very dense core of that state. A star of this size cools and contracts to become a White Dwarf.

Neutron star

A supernovae explosion in a star bigger than Sun but not more than twice as big, may leave behind an extremely dense, residual 'core of that star, reaching a density of 10^{14} gms/cm^3, known as Neutron Star.

Pulsar

A spinning neutron star emits radio waves and is called a Pulsar

Black Holes

A black hole is an object With such strong gravitational field that even light cannot escape from its surface. Black holes are formed from neutron stars after the Supernova explosions of big stars.

16. Consider the following:

1. Asteroid Belt
2. Kuiper Belt
3. Oort Cloud

Which among the following is the correct sequence of their increasing distance from Sun?

[A] 1, 2, 3

[B] 1, 3, 2

[C] 2, 1, 3

[D] 3, 1, 2

Answer: [A] 1, 2, 3

The Kuiper Belt is a doughnut-shaped ring, extending just beyond the orbit of Neptune from about 30 to 55 AU. The Oort Cloud is a spherical shell, occupying space at a distance between five thousand and 100 thousand AU. Thus, both of them are beyond the orbit of Neptune. The first mission to the Kuiper Belt is New Horizons of NASA. We note here that New Horizons is expected to reach Pluto in July 2015 before possibly heading farther into the Kuiper Belt.

17. Consider the following objects of the solar system:

1. Planets
2. Comets
3. Asteroids

Which among the above have elliptical orbits?

[A] Only 1

[B] Only 1 & 2

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

All planets, comets and asteroids in our solar system have elliptical orbits. Thus, they all have a closest and a farthest point from the Sun- a perihelion and an aphelion.

18. Which among the following decide decides whether a collapsing star would become a white dwarf or a black hole?

1. Mass
2. Temperature
3. Position in a galaxy

Select the correct option from the codes given below:

[A] Only 1

[B] 1 & 2

[C] 2 & 3

[D] 1, 2 & 3

Answer: [A] Only 1

The collapse of a star is a natural process that occurs when all stellar energy sources are exhausted.

If the mass of the collapsing part of the star is below a certain critical value, the end product is a compact star, either a white dwarf or a neutron star. But if the collapsing star has a mass exceeding this limit, the collapse will continue forever and form a black hole and astronomers believe that any collapsing star with solar mass above 0.7 will form a black hole.

19. Studying the ultraviolet images of galaxies is not possible from a telescope on earth. Why?

[A] Human eye cannot see ultraviolet waves

[B] Earth's atmosphere filters out most ultraviolet light

[C] A telescope on earth cannot see that far in space

[D] Cosmic background radiation interferes with ultraviolet signals on earth

Answer: [B] Earth's atmosphere filters out most ultraviolet light

Earth's atmosphere filters most ultraviolet light so NASA's Hubble Space Telescope is helping create the first ultraviolet image of the universe."

20. Kuiper Belt is:

[A] an asteroid belt located between Mars and Jupiter

[B] an elliptical plane located around the sun in the solar system

[C] a region filled with icy bodies located beyond the planet Neptune

[D] a collection of charged particles, gathered in place by Earth's magnetic field

Answer: [C] a region filled with icy bodies located beyond the planet Neptune

Third option is correct.

General Knowledge Today

Prelims Geography-2: Earth Basics

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Contents

Model Questions

Please check Prelims model questions and answers at the end of this module.

Motions of Earth , Seasons and Eclipse

There are four kinds of Earth's motions as follows:

1. Earth's rotation on its axis
2. Earth's precession movement which is very much similar to a spinning top.
3. Earth revolution around the Sun
4. Earth along with the entire solar system moves around the center of the Milky way Galaxy.

Earth's Rotation and Precession Movements

Earth rotates around its own axis from west to east. When seen from the North Star Polaris {Alpha Ursae Minoris}, Earth turns counter-clockwise. Rotation of Earth results in days and nights. Earth's rotation is mostly the *result of angular momentum left over during the formation process of Earth* There are three distinct motions, the most noticeable being Earth's rotation. Earth rotates once every 23 hours, 56 minutes, causing our cycles of day and night. Earth also has precession (a wobble of the rotational axis) and nutation (a back-and-forth wiggle of Earth's axis), caused primarily by the gravitational pull of the Moon as it orbits Earth. Precession and nutation, over long periods of time, cause Earth's north and south poles to point toward different stars.

Solar Day

A Solar day refers to one complete rotation of Earth on its own axis relative to Sun. However, since Earth also revolves around the sun, there are three kinds of days recognized by astronomers viz. Apparent or True solar day; Mean solar day and sidereal day. These are discussed as follows:

Apparent {True} Solar Day

Apparent solar day is the interval between two successive returns of the Sun to the local meridian. A sundial can measure the apparent solar day with limited precision. The length of true solar day keeps changing throughout the year. There are two reasons for this. Firstly, Earth's orbit around sun is an ellipse. The second law of Kepler says that in elliptical orbits, the line joining the planet and sun sweeps out equal areas during equal intervals of time. Thus, earth moves faster when its is nearest to Sun (perihelion) and moves slower when it is farthest from Sun (Aphelion). Secondly, Earth currently has an axial tilt of about 23.5° and remains tilted in the same direction towards the stars throughout a year. This implies that when a hemisphere is pointing away from the Sun at one point in the orbit then half an orbit later (half a year later) this hemisphere will be pointing towards the Sun. This effect is the main cause of the seasons.

What is obliquity of the ecliptic?

Earth's orbital plane is known as the ecliptic plane, and so the Earth's axial tilt is called the obliquity of the ecliptic.

Due to Earth's tilt, Sun moves along a great circle (the ecliptic) that is tilted to Earth's celestial equator. When the Sun crosses the equator at both equinoxes, the Sun is moving at an angle to the equator, so the projection of this tilted motion onto the equator is slower than its mean motion; when the Sun is farthest from the equator at both solstices, the Sun moves parallel to the equator, so the projection of this parallel motion onto the equator is faster than its mean motion. The result is that apparent solar days are shorter in March (26–27) and September (12–13) than they are in June (18–19) or December (20–21).

The true solar day tends to be longer near perihelion taking about 10 seconds longer and is about 10 seconds shorter near aphelion. It is about 20 seconds longer near a solstice and shorter by 20 seconds near equinox.

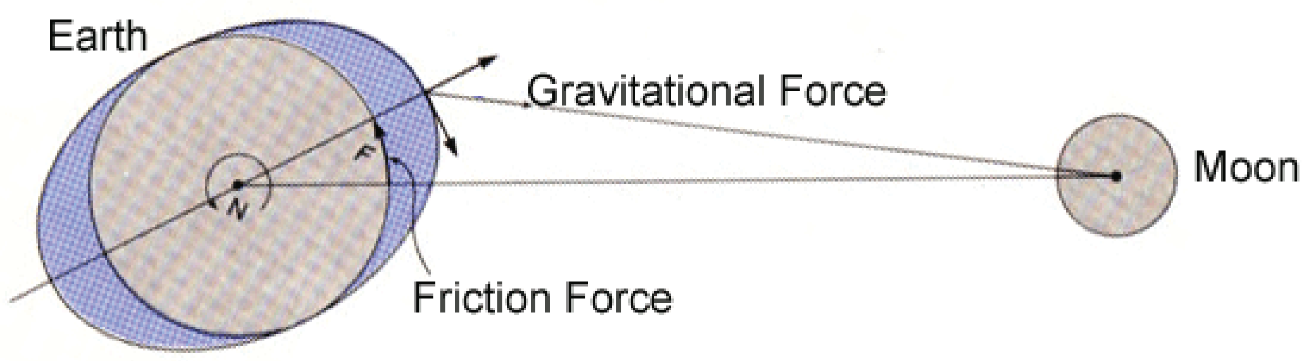
Mean Solar Day

The average of the true or apparent solar day over an entire year is called the mean solar day. It has 86400 seconds. Albeit, the amount of daylight varies significantly, the length of a mean solar day does not change on a seasonal basis. However, the length of the Mean Solar Day increases by 1.4 milliseconds per century. The astronomers have calculated that Mean Solar Day was exactly 86,400 (24 hours × 60 minutes × 60 seconds) SI seconds in approximately 1820 AD and now it is **86400.002** SI seconds. The reason behind this slow down is the net effect of **tidal acceleration** and global glacial rebound.

Tidal Acceleration

Tidal acceleration refers to the effect of the tidal forces between an orbiting natural satellite and the primary planet that it orbits.

We know that Moon's mass is a considerable fraction of that of the Earth. The Ratio of masses of moon and Earth is about 1:81. So these two bodies can be regarded as a double planet system, rather than as a planet with a satellite. The large mass of moon is sufficient to raise tides in the matter of earth. The water of the oceans bulges out along both ends of the axis, passing through the centers of Moon as well as Earth. This tidal bulge is shown below.



The average tidal bulge shown in above figure closely follows the Moon in its orbit. However, since earth also rotates, the rotation drags this bulge ahead of the position directly under the Moon The arrow shown in the earth shows the direction of this drag. Due to the simultaneously forces of moon's gravitational force giving rise to the bulges in ocean water and substantial amount of mass in these bulges of water dragged by earth's rotation, this bulge is deviated from the line through the centers of Earth and Moon. This gives rise to a Torque which is perpendicular to the earth moon line. This torque boosts moon in its orbit and decelerates earth's rotation. The above phenomenon is responsible for the slowing Earth's rotation. Due to the tidal acceleration, Earth's mean solar day extends by 2.3 milliseconds every century. However, due to**glacial rebound**, this extension gets reduced by 0.6 seconds per century. So the net effect on mean solar day every century is 1.7 milliseconds.

Global Glacial Rebound

The average position of water is always nearer the equator. During glaciations water is taken from the oceans and deposited as ice over the higher latitudes closer to the poles. These poles are close to the polar axis or rotational axis of the Earth. The moment of inertia of Earth-water-ice system gets reduced which is very much similar to a rotating figure skater bringing her arms closer to her body, the earth should spin faster. This process leads to an increase in the rotation speed of the Earth and therefore to a decrease of the length of day.

Sidereal Day

The spinning of the earth on its polar axis is in fact takes 23 hours, 56 minutes and 4.09 seconds for rotation through the 360 degree. This is called sidereal day. During the time needed by the Earth to complete a rotation around its axis (a sidereal day), the Earth moves a short distance (approximately 1°) along its orbit around the sun. So, after a sidereal day, the Earth still needs to rotate a small additional angular distance before the sun reaches its highest point. A solar day is, therefore, nearly 4 minutes longer than a sidereal day.

Precession Movement of earth

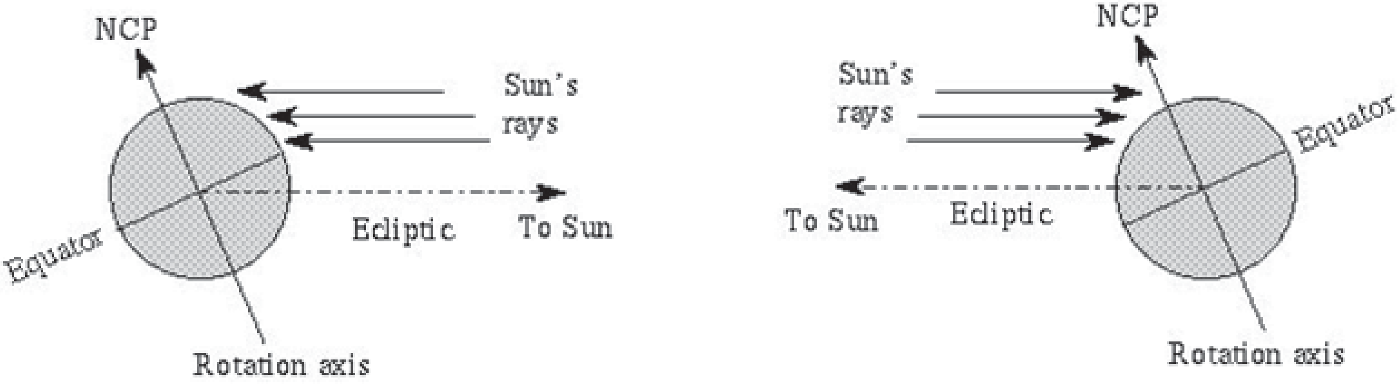
The Precession movement of Earth is very slow and proceeds in the direction of the opposite of Earth's Rotation. The one cycle completes in 28000 years. The reason of precession movement is gravitational attraction of Moon as well as Sun. The slightly irregular movement of earth's axis due to precession is called Nutation.

Earth's Revolution

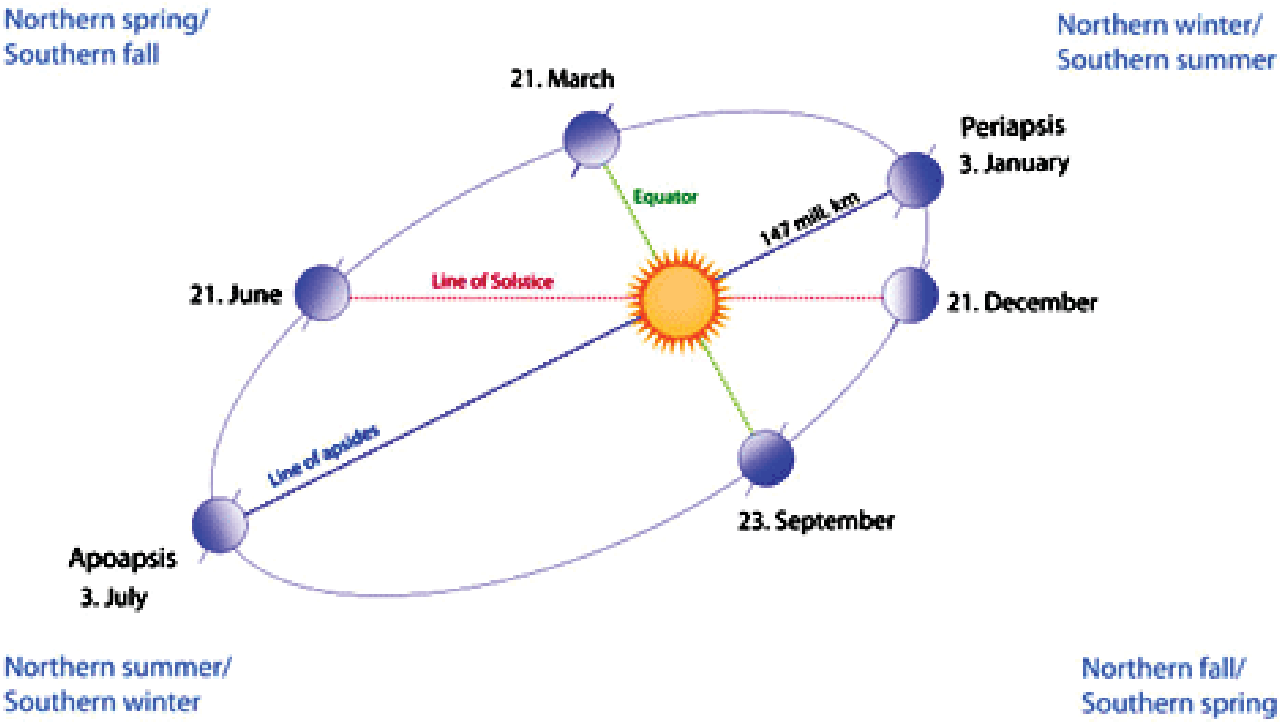
The orbit of the Earth is the motion of the Earth around the Sun every 365.242199 mean solar days. The orbital speed of Earth around the Sun averages about 30 kilometre per second or 108,000 kilometers per hour. This speed is equivalent to cover earth's orbit in 7 minutes and distance from moon to Sun in 4 hours.

Occurring of Seasons

The path of the Earth around the Sun is elliptical and slightly irregular due to gravitational attraction of moon and other celestial bodies. A constant angle is maintained between the earth's axis and its plane of elliptic, which is called *angle of inclination.* As we know that Earth's rotation axis is tilted by 23.44° with respect to the elliptic, and is always pointed towards the celestial poles when the earth moves around the Sun.



The above phenomenon gives rise to 4 seasons.



Solstice

The solstice refers to the events when the Sun's apparent position in sky reaches its northernmost or southernmost extremes. Solstice happens twice a year, and twice a year happen the equinoxes. Altogether, the four are considered to start 4 seasons.

- At the time of northern solstice, sun is perceived to be directly overhead the 23.44° north known as Tropic of Cancer.
- Likewise, at the southern solstice the same thing happens for latitude 23.44° south, known as the Tropic of Capricorn.
- The sub-solar point will cross every latitude between these two extremes exactly twice per year. The point where sun is perceived to be directly overhead is called subsolar point.
- The Northern solstice happens at 20-21 June and Southern solstice happens at 20-22 December.
- In 2010, Northern solstice happened at 21 June and Southern solstice will happen on 21 December.
- At Northern solstice, the places which are located at Arctic circle, posited at latitude 66.56° north will see the Sun just on the horizon during midnight. And all the places north of Arctic Circle will see Sun above horizon for 24 hours. This is called Midnight Sun or a Polar Day.
- At Northern solstice which are located at Antarctic circle, posited at latitude 66.56° south will see the Sun just on the horizon during midday. And all the places south of Antarctic Circle will NOT see at anytime of the day. This is called Polar Night.

- At Southern solstice, Polar day occurs at Southern Pole and Polar Night occurs at Northern Pole.

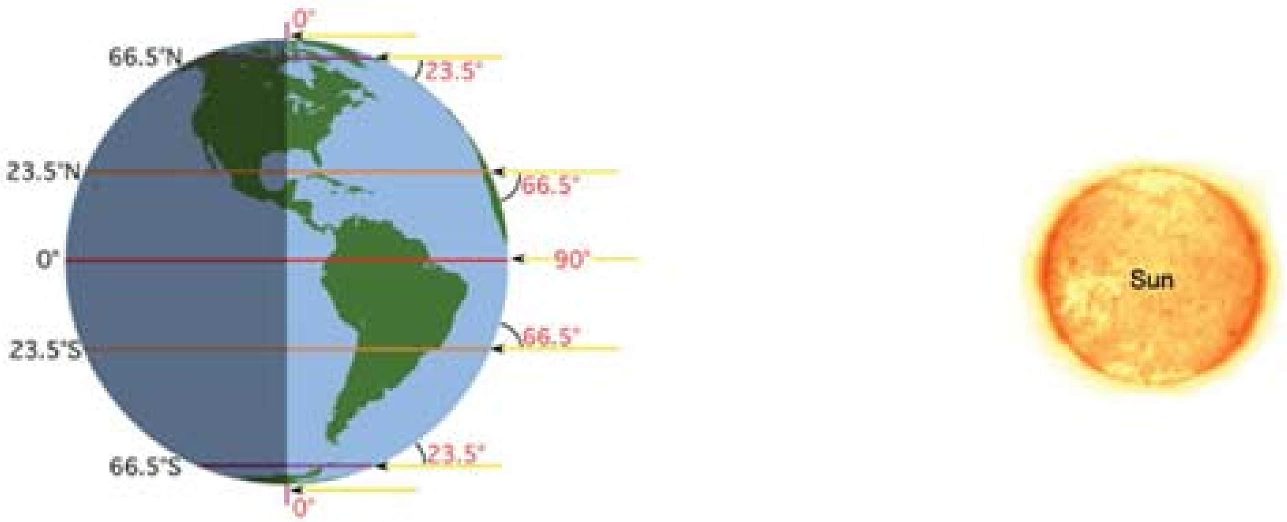
Uttarayan & Dakshinayan

For 6 months of the year, the Sun appears to be moving north. This Northward migration of Sun appears to begin after December 22 and is completed on June 21, when the Sun is directly overhead 23.44° North. Dute to this, In India we call this Uttarayan.

After June 21, for the next 6 months, Sun appears to be moving South and this southward migration appears to get finished , when Sun is directly overhead the 23.44° South. In India we call this apparent migration Dakshinayan.

Equinox

At equinox, Sun is at one of two opposite points where the celestial equator and ecliptic intersect. Sun can be observed to be vertically overhead the Equator. Equinox happens around March 20/21 and September 22/23 each year.



Longest Days & Nights

When Sun is direct overhead on 23.44° north, it is called Longest Day in Northern hemisphere. So Northern Solstice represents the longest day of the Northern hemisphere and smallest night of the Southern Hemisphere.

When Sun is direct overhead on 23.44° south, it is called Longest Day in Southern hemisphere. So Southern Solstice represents the longest day of the Southern hemisphere and smallest night of the Northern Hemisphere.

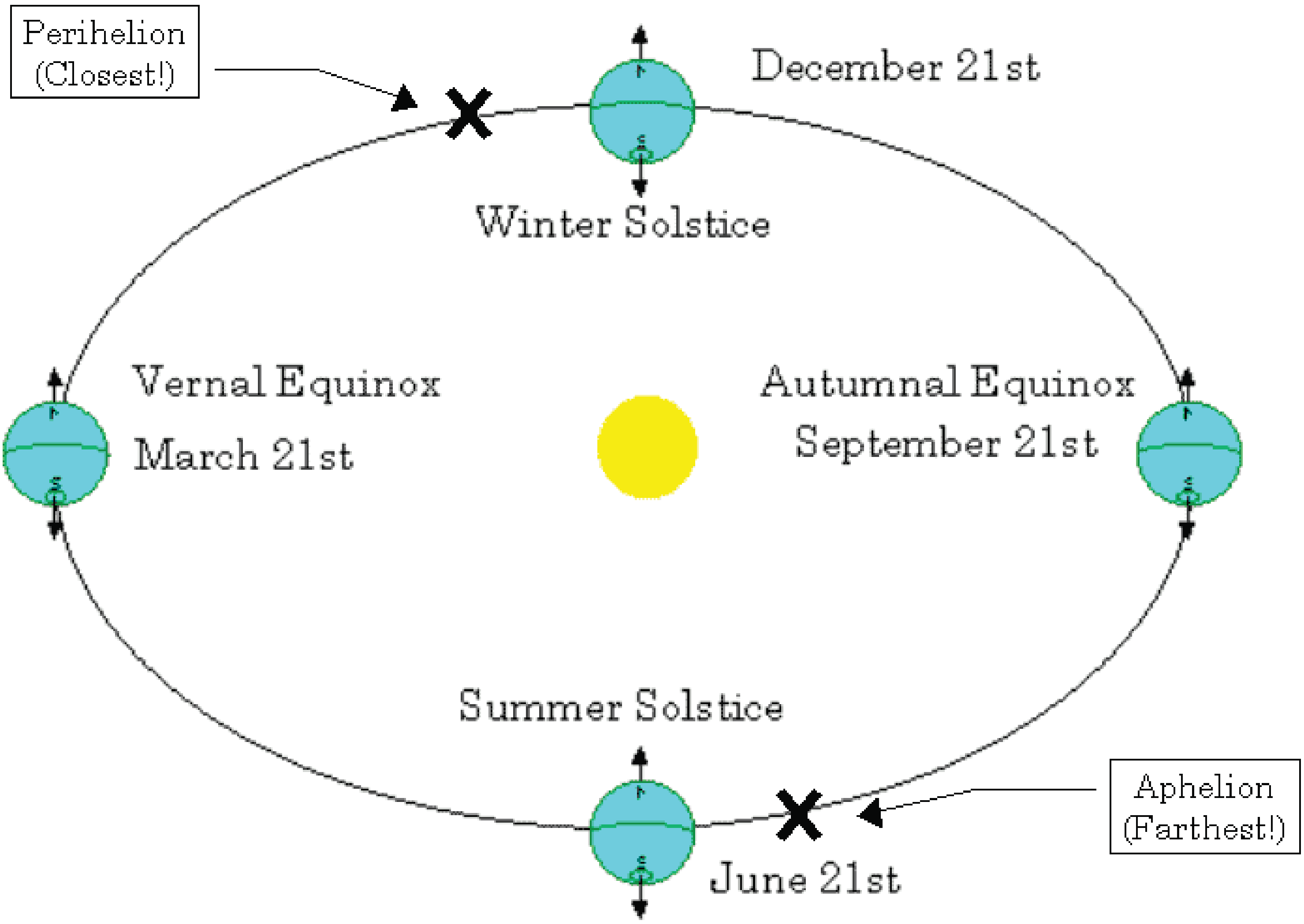
Perihelion and Aphelion

Earth travels 939,886,400 kms along its elliptical orbit in a single revolution. The average distance is 150 million kms, but the orbit is elliptical and there is the difference if 2.5 million kms. Perihelion is the point when Earth is closest to Sun and it occurs around 3rd January. The distance is 147.5 million kms.

Aphelion is the point when Earth is farthest from the Sun and it occurs on July 4. The distance is 152.5 million Kms,

- **Perihelion:** On around January 3rd, Earth is closest to sun and distance is around 147.5 million Kilometers. This is called Perihelion.
- **Aphelion:** On about July 4th earth is Farthest from Sun and this is called Aphelion.

Speed of Earth is fastest at Perihelion and slowest at Aphelion (Kepler's Second Law). The following Graphic shows the Solstice, Equinoxes and Helions altogether:



Eclipses

An eclipse is the partial or total blocking of the light of one object by another. In the solar system, relative positions of the Sun, Moon, and Earth create solar eclipses and lunar eclipses.

Frequency of Eclipses

Perfect alignments of the Sun, Moon, and Earth are relatively uncommon, because the plane of Earth's orbit around the Sun (ecliptic plane) is not the same as the plane of the Moon's orbit around Earth. Thus, during the new moon or full moon phases when an eclipse might be possible, the Moon is usually located just above or below the straight line that runs between Earth and the Sun, so no eclipse occurs. All three bodies viz. Earth, Moon, and Sun line up just right about twice a year.

Lunar Eclipse

A lunar eclipse occurs when Earth passes between the Sun and the Moon in such a way that the Moon moves into Earth's shadow. When a partial lunar eclipse is going on, the curved shadow of our planet is apparent on the Moon's face; the Moon looks kind of like it is in a crescent phase, but the terminator line (the line between light and dark) is not curved the same way. When a total lunar eclipse is happening, the entire Moon is in Earth's shadow, and the Moon looks full, but glows only faintly red. Why?

The reason is as follows: Earth's atmosphere is dense enough to act a little bit like a lens, so it refracts a small amount of sunlight shining through it toward the Moon. This small fraction of light, which is mostly red because that is the color of light that refracts best, bounces off the Moon's surface and comes back to Earth. Before and after totality, the direct sunlight reflected off the Moon is so strong by comparison that it drowns out this refracted light, so we normally cannot see it with our unaided eyes. During totality, however, the Earth-atmosphere-refracted light is quite visible as a soft reddish glow.

Solar Eclipse

A solar eclipse happens when the Moon is directly in line between Earth and the Sun. The Moon's shadow sweeps across Earth's surface; at those places where the shadow lands, an eclipse is seen.

Like Earth's shadow, the Moon's shadow consists of two parts: a dark,**central region called the umbra**, and a lighter region called the penumbra that surrounds the umbra. *Under the penumbra, a partial solar eclipse occurs. Under the umbra, a total eclipse or an annular eclipse is seen.*

Since the Moon travels in a slightly elliptical orbit around Earth, rather than in a perfectly circular path, its distance from Earth is not always the same. If the Moon's umbra falls on Earth's surface when the two bodies are at a closer point in the Moon's orbit, there is total solar eclipse. But if the Moon happens to be too far away from Earth at that time, the Moon does not cover enough of the sky to block the Sun's rays entirely. In that case, the Sun is seen as a ring, or annulus, of light glowing around the silhouette of the Moon.

During totality of a solar eclipse, the Sun looks like a perfectly black disk surrounded by glowing light. This light is actually the Sun's corona, which is invisible under normal circumstances because the Sun is so bright. Away from the corona, the sky is dark, so planets and stars that ordinarily could be seen only at night become visible.

Frequency of Solar Eclipse at a particular location on earth

The entire process of a solar eclipse, from the beginning of partial coverage until the end, usually takes about an hour. However, the totality of solar eclipse lasts at most only a few minutes. Most total solar eclipses last between 100 and 200 seconds— just about two to three minutes. Furthermore, total solar eclipses can be observed only from narrow bands on Earth's surface, and these bands change with each eclipse. In any given location on Earth, therefore, a total solar eclipse may appear only once every few centuries.

Why Moon blocks Sun so perfectly during solar eclipse?

The Moon's diameter is just under 400 times smaller than the diameter of the Sun. Coincidentally, the Moon's distance from Earth is also just under 400 times smaller than the Sun's distance from Earth. That is why the Moon covers almost exactly the same amount of sky, when viewed from Earth's surface, as the Sun. We are able to see only Corona during Total solar eclipse.

Geodesy: Latitudes and Longitudes

Eratosthenes was the first person to calculate the size of the earth. He realized that Earth could be located with a basic grid of lines called Longitudes and Latitudes.

Great Circle

When a sphere is divided exactly in half through its center, the circumference represents the largest circle that can be drawn on that sphere. The shortest distance between two points on a sphere is a great circle, or a circle whose plane passes through the centre of sphere. *In case of Earth, only equator is a great circle among latitudes and all longitudes are half great circles.*

Latitudes

Latitude is the angle between the equatorial plane and the axis. Lines joining points of the same latitude are called parallels. Equator {0° parallel} itself is largest parallel and only circle of latitude which also is a great circle. Equator is also used as fundamental plane of all geographic coordinate systems. It's worth note that geostationary satellites are over the equator at a specific point on Earth, so their position related to Earth is expressed in longitude degrees only. Their latitude is always zero. There are 180° of latitudes and *each degree of latitude spans around 111 kilometers or 69 miles or 60 Nautical miles*. But this distance varies because Earth is not a perfect sphere. From Equator to 40° towards both poles it is slightly less than 111 kilometers and from 41° towards both poles it is slightly more than 111 kilometers. The 90° North and 90° South are not circles but only reference points. Latitudes tell us the temperature and climatic position of a particular place.

Longitudes

Longitude is the angle east or west of a reference meridian between the two geographical poles to another meridian that passes through an arbitrary point. All meridians are halves of great circles, and are not parallel to each other. They converge only at the north and south poles. A line passing to the rear of the Royal Observatory, Greenwich (near London in the UK) has been chosen as the international zero-longitude reference line and is known as the Prime Meridian. Places to the east are in the eastern hemisphere, and places to the west are in the western hemisphere. The antipodal meridian of Greenwich serves as both 180°W and 180°E. There are 360° of the meridians and the longitude of prime meridian is 0°. Length of all meridians is equal. The distance between two meridians is farthest at the equator and it decreases as we move towards poles and becomes zero at poles.

Earth Structure

Earth Basic Information

Earth is located in the **Solar System**, which is located in the **Orion** (or local) **arm of Milky Way Galaxy**, which is a part of **Virgo Super cluster**. As a part of the Milky Way Galaxy, the Earth is accelerating outward toward the outer regions of the universe. The Earth and the other members of the solar system are orbiting the galaxy at about 225 kilometers per hour. Earth is third planet from the Sun and Fifth largest planet. It is largest among the Solar System's four terrestrial planets (Mercury, Venus, Earth, and Mars). Earth is also the *densest planet of the solar system*.

Radius and Circumference of Earth

The Mean radius of Earth is 6,371.0 km. Equatorial radius is 6,378.1 km, while polar radius is 6356.8 kilometers. This means that Earth is not perfectly spherical; no single value serves as its natural radius. Even calling it Radius is factually incorrect because "radius" normally is a characteristic of perfect spheres. Earth's rotation causes it to be like an oblate spheroid with a bulge at the equator and flattening at the North and South Poles. So the equatorial radius is larger than the polar radius.

The ***farthest point from Earth's centre is Chimborazo*** , an inactive volcano in the Andes mountains in Ecuador, in South America. Chimborazo is not the highest mountain by elevation above sea level, but its location along the **equatorial bulge** makes its summit the farthest point on the Earth's surface from the Earth's center.

The **Equatorial Circumference** of Earth is 40,075.16 km, while the **Meridional Circumference** is 40,008.00 km.

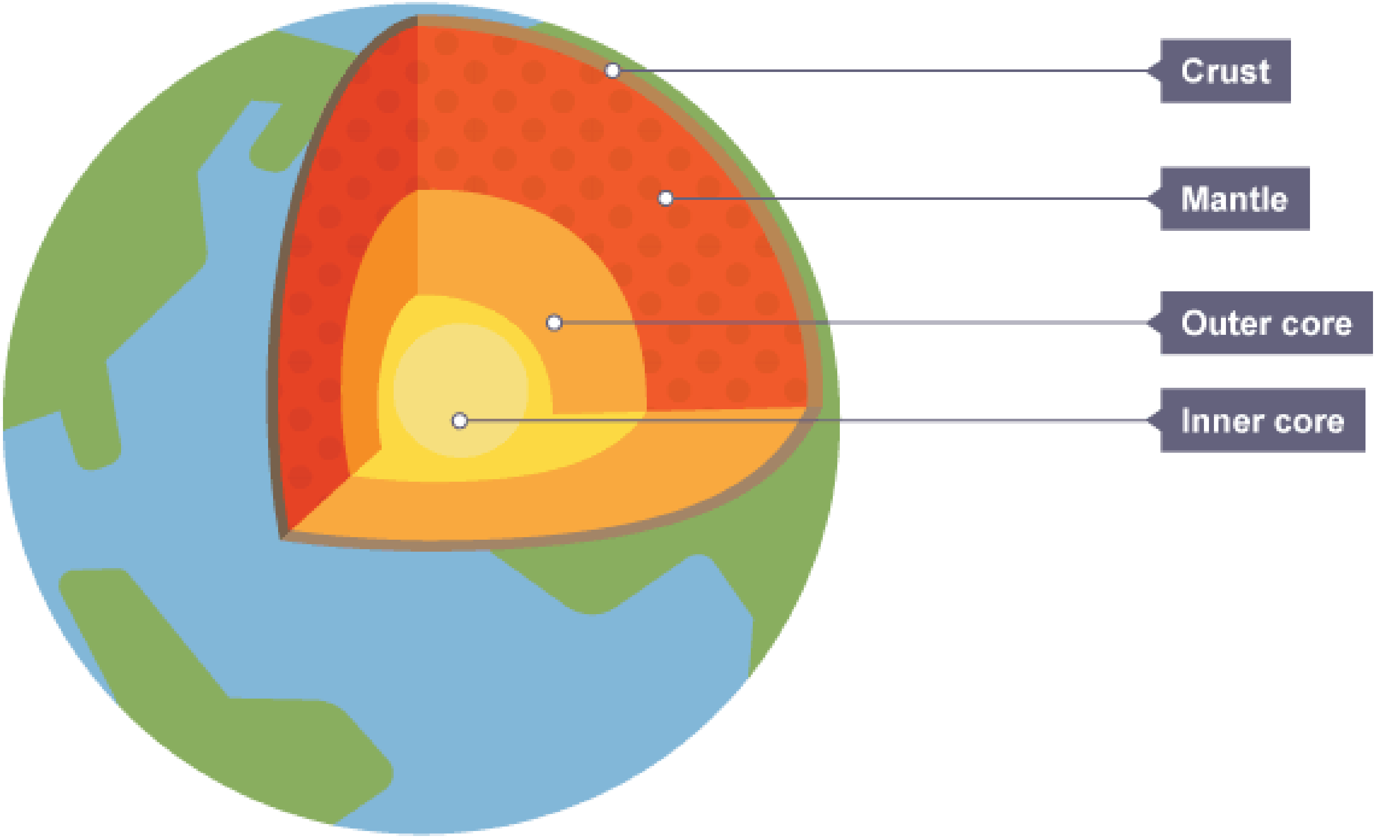
Other Basic Data

Variable	Information
Surface area	510,072,000 km^2
Land Area	148,940,000 km^2 (29.2 %)
Water Area	361,132,000 km^2 (70.8 %)
Volume	1.08321 × 10^{12} km3

Variable	Information
Mass	5.9736×10^{24} kg
Mean density	5.515 g/cm^3
Equatorial surface gravity	9.780327 m/s^2
Escape velocity	11.186 km/s
Sidereal rotation period	23h 56m 4.100s
Equatorial rotation velocity	1,674.4 km/h
Axial tilt	23°26’21”.4119
Albedo	0.36
Surface temp	Minimum −89.4 °C Median=14 °C Maximum =58 °C
Surface pressure	101.325 kPa
Composition	78.08% nitrogen, 20.95% oxygen, 0.93% argon, 0.038% carbon dioxide, approx. 1% water vapour

Structure of Earth

The internal structure of earth is layered. The Earth is generally divided into four major layers: the crust, mantle, inner core, and outer core.



The following defines each division.

Crust

The Earth's crust is the outermost layer and is the most familiar, since people live on the outer skin of the crust. It is rigid, brittle, and thin compared to the mantle, inner core, and outer core. Because of its varying characteristics, this outer layer is divided into the continental and oceanic crusts.

Mantle

Earth's mantle lies beneath the crust and above the outer core, averaging about 1,802 miles (2,900 kilometers) thick and representing ***68.3 percent of the Earth's mass*** and 84% of Earth's volume. A transition zone divides this layer into the upper and lower mantles.

Outer core

The **liquid outer core** is a layer between 2,885 and 5,155 kilometers deep in the Earth's interior. It is thought to move by convection (the transfer of heat through the circulating motion of materials), with the movement possibly contributing to the Earth's magnetic field. The outer core represents about 29.3 percent of the Earth's total mass.

Inner core

The inner core is thought to be roughly the size of the Earth's Moon. It lies at a depth 5,150 to 6,370 kilometers beneath the Earth's surface and generates heat close to temperatures on the sun's surface. It represents about 1.7 percent of the Earth's mass and is thought to be composed of a solid iron-nickel alloy suspended within the molten outer core.

Density of Various Earth Layers

The average density of Earth is 5,515 kg/m^3. Since the average density of surface material is only around 3,000 kg/m^3, it can be concluded that denser materials exist within Earth's core. When we move from earth's Crust to Core, the density increases. The following table shows the depth as well as the average density of various layers:

Depth (Sq. Kms)	Layer	Density gm per cubic cm.
0-60	Lithosphere	1.2-2.9
0-35	Crust	2.2-2.9
35-60	Upper mantle	3.4-4.4
35-2890	Mantle	3.4-5.6
100-700	Asthenosphere	NA
2890-5100	Outer core	9.9-12.2
5100-6378	Inner core	12.8-13.1

Earth's Crust

Earth's crust is the outermost layer composed of various types of rocks. *The boundary between the crust and mantle is generally called the Mohorovičić discontinuity*.

Thickness of Continental and Oceanic Crust

It varies in thickness from around 5 to 100 kilometers. The continental crust is thicker in comparison to oceanic crust. The oceanic crust ranges from 5 to 10 kilometers {average 7 km} while continental crust ranges from 25 to 100 kilometers {average 30-35 km}.*Thickest continental crust regions are under large mountain ranges.*

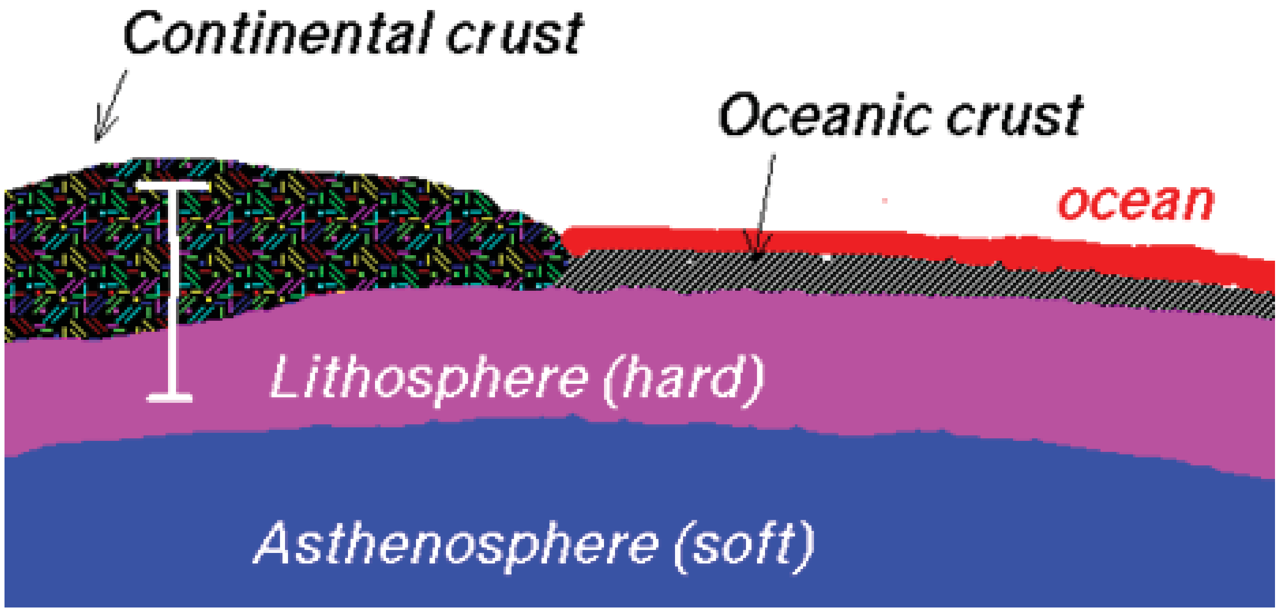
Difference in composition and density

Oceanic crust is made of dark rocks having more of Iron and Magnesium and are more basaltic. Continental crust is made of lighter rocks, having more of Silica and are more felsic. The below table shows the key differences between Oceanic and continental rocks.

Oceanic Crust	Continental Crust
Thinner (average 7 Km)	Thicker (Thickest where there are mountains) Average 30 Km.
Dark colored	Light colored
High in Silica and Magnesium (SIMA)	High in Silica and Aluminium (SIAL)
More Basaltic / Mafic	More Felsic
More Feldspar	More quartz
More dense (3000Kg/m^3)	Less dense (2500 Kg/m^3) due to increased amount of aluminium

Lithosphere, Asthenosphere and Pedosphere

Lithos means rock. Lithium is an alkali metal and its name is also derived from*Lithos. Lithosphere* is the upper 80 Kilometers layer composed of *both the crust and part of the upper mantle*. However, overall, it is cool enough to be tough and elastic than the molten mantle. The Oceanic lithosphere is associated with Oceanic crust and exists in the ocean basins, while the Continental lithosphere is associated with Continental crust. The Oceanic lithosphere is denser than the continental lithosphere.



Lithosphere is obviously thinner under the oceans and volcanically active continental regions than the other landmasses. The entire lithosphere is physically broken up into the brittle, moving plates containing the world's continents and oceans. These lithospheric plates appear to "float" and move around on the more ductile **asthenosphere**. The asthenosphere is the relatively **narrow, moving zone in the upper mantle** located between 72 to 250 kilometers beneath the Earth's surface. It is composed of a hot, semi-solid material that is soft and flowing after being subjected to high temperatures and pressures. The asthenosphere boundary is closer to the surface-within a few kilometers under oceans and near mid-ocean ridges than it is below the landmasses. The upper section of the asthenosphere is thought to be the area in which the lithospheric plates move, "carrying" the continental and oceanic plates also known as **Tectonic Plates**.

Further, the uppermost part of the Lithosphere that reacts with the atmosphere, biosphere and Hydrosphere is called as pedospehere. *Pedos* means soil. Pedospehere is composed of soil and it is the cradle of all the chemical and biogeochemical reactions which leads to soil development.

Composition of Earth Crust

Almost half of Earth's crust is made of oxygen, while a quarter of it is made of silicon. Since silicon and Oxygen react to make silica, around 48.6% of Earth's crust is made of silica.

Major elements in Earth's crust are Oxygen (47%), Silicon (28%), Aluminum (8%), Iron (5%), Calcium (3.5%), Sodium (2.5%), Potassium (2.5%), Magnesium (2.2%) and other elements such as

Hydrogen, Carbon, Phosphorus, Sulphur etc.
Major compounds in Earth's crust are shown in below table.

Compound	Formula	Continental	Oceanic
Silica	SiO_2	60.2%	48.6%
Alumina	Al_2O_3	15.2%	16.5%
Lime	CaO	5.5%	12.3%
Magnesia	MgO	3.1%	6.8%
Iron(II) Oxide	FeO	3.8%	6.2%
Sodium Oxide	Na_2O	3.0%	2.6%
Potassium Oxide	K_2O	2.8%	0.4%
Iron(III) Oxide	Fe_2O_3	2.5%	2.3%
Water	H_2O	1.4%	1.1%
Carbon Dioxide	CO_2	1.2%	1.4%
Titanium Dioxide	TiO_2	0.7%	1.4%
Phosphorus Pentoxide	P_2O_5	0.2%	0.3%
Total		99.6%	99.9%

Thus, most of the rocks in Earth's crust are all oxides. The principal oxides are silica, alumina, iron oxides, lime, magnesia & potash. There are not many iron loving compounds in Earth Crust because they were depleted and relocated deeper. Further, more meteoritic content is found in Earth's Crust.

Conrad Discontinuity

Conrad discontinuity (named after the seismologist Victor Conrad) is considered to be the border between the *upper continental crust and the lower one* It is not as pronounced as the Mohorovičić discontinuity, and absent in some continental regions.

Earth's Mantle

The mantle is a **highly viscous** layer between the crust and the outer core. The boundary between crust and mantle is called Mohorovičić discontinuity after the name of Croatian geologist**Andrija Mohorovičić** who proposed this. No one has been able to physically drill into the mantle and there are no samples of the mantle with human beings as of now. Whatever information we have is based on indirect study, particularly of seismic waves.

Composition of the Earth's Mantle

Similar to earth's crust, Oxygen is most abundant element in Earth's Mantle. The following table shows the composition of earth's mantle.

Element	Amount	Compound	Amount
O	44.8		
Si	21.5	SiO_2	46
Mg	22.8	MgO	37.8
Fe	5.8	FeO	7.5
Al	2.2	Al_2O_3	4.2
Ca	2.3	CaO	3.2
Na	0.3	Na_2O	0.4
K	0.03	K_2O	0.04
Total	99.7	Total	99.1

Salient Features of Mantle

Earth's mantle is a rocky shell about 2,890 Kms thick that constitutes about 84 percent of Earth's volume. It is predominantly solid and encloses the iron-rich hot core, which occupies about 15 percent of Earth's volume. The mantle is divided into sections viz.

- The **Upper Mantle**, which starts from the Mohorovičić discontinuity around 7 to 35 km, downward to 410 km),
- The **transition zone** (410–660 km)
- The **Lower Mantle** (660–2891 km).

The upper and lower mantle differentiate on the basis of seismic and chemical changes in the layer. These changes create different kinds of *discontinuities* in the mantle. For example:

- Hales Discontinuity is found in the upper mantle at depths of about 60 to 90 kilometers, a region in which seismic velocities change.
- Gutenberg Discontinuity or the core–mantle boundary (CMB) lies between the Earth's silicate mantle and its *liquid iron-nickel outer core*. This boundary is located at approximately

2900 km depth beneath the Earth's surface. The boundary is observed via the discontinuity in seismic wave velocities at that depth.

Convective Material Circulation in Mantle

Due to the temperature difference between the Earth's surface and outer core and the ability of the crystalline rocks at high pressure and temperature to undergo slow, creeping, viscous-like deformation over millions of years, there is a convective material circulation in the mantle. Hot material upwells, while cooler (and heavier) material sinks downward. Downward motion of material occurs at convergent plate boundaries called subduction zones. The convection of the Earth's mantle is a chaotic process, which is thought to be an integral part of the motion of plates. Here, we have to note that the Plate motion is different from the continental drift which applies purely to the movement of the crustal components of the continents.

Earth's Core

Using the seismic data, the scientists had first postulated the existence of a fluid core. In 1915, Gutenberg published a measurement of the core's radius. In 1936, Danish seismologist **Inge Lehmann** (1888-1993) presented a paper titled, "P'" (or P -Prime, after the seismic waves) ***which announced the discovery of Earth's inner core.*** The division between the inner and outer core is now called the **Lehmann discontinuity.**

The size of this core was calculated later in 1960s when an underground nuclear test was conducted in Nevada. Because the precise location and time of the explosion was known, echoes from seismic waves bounced off the inner core provided an accurate means of determining its size. These data revealed a radius of Earth's Inner solid Core about 1,216 kilometers. *The seismic P-waves passing though the inner core move faster than those going through the outer core-good evidence that the inner core is solid*. The presence of high-density iron thought to make up the inner core also explains the high density of the Earth's interior, which is about 13.5 times that of water.

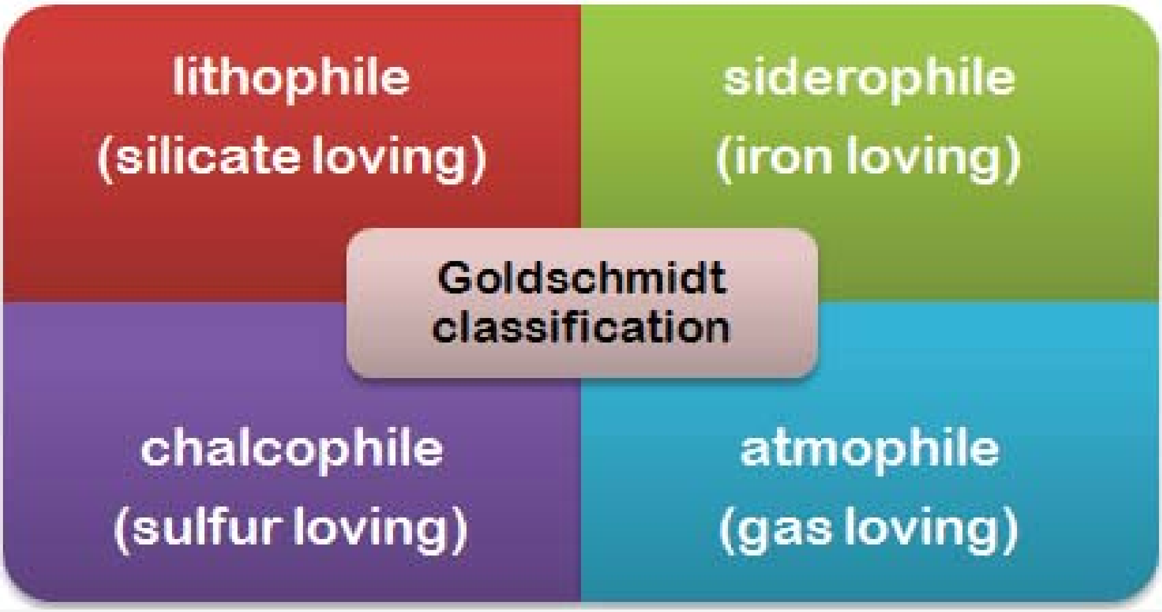
Outer Core versus Inner Core

Earth's core is divided into two parts viz. a solid inner core with a radius of =1,216 km and a liquid outer core extending beyond it to a radius of ~3,400 km. The solid inner core is generally believed to be composed primarily of iron and some nickel.

How it was formed?

The major event which led to the formation of core was **iron catastrophe**. Earth was formed approximately 4500 million years ago. After accumulation of the Earth's material into a spherical mass, the material was mostly uniform in composition. The collision of the material which formed the Earth was significant; heating from radioactive materials in this mass further increased the temperature until a critical condition was reached, when the material was molten enough to allow movement. At this point, the denser iron and nickel evenly distributed throughout the mass sank to the centre of the planet to form the core – an important process of planetary differentiation. The gravitational potential energy released by the sinking of the dense Ni-Fe globules increased the temperature of the protoplanet above the melting point resulting in a global silicate magma which accelerated the process. This event occurred at about500 million years into the formation of the planet and is known as Iron catastrophe.

Recent researches show that the innermost part of the core is enriched in gold, platinum and other **Siderophile** elements (Siderophile elements are those 'Iron Loving" elements that tend to bond with metallic iron as per **Goldschmidt classification**).



Earth's Magnetic Field and Magnetosphere

Earth's Magnetic Field

The Magnetic Field of the Earth is generated by the *motion of molten iron alloys in the Earth's outer core*.

The solid inner core is too hot to hold a permanent magnetic field, but the outer core gives rise to Earth's magnetic field. The geomagnetic field extends from outer core to where it meets the solar wind. At the surface of Earth, the magnitude of Earth's magnetic field ranges from 25 to 65 microteslas (0.25 to 0.65 gauss).

How magnetic field protects life on Earth?

The magnetic field deflects most of the charged particles emanating from the Sun in the form of solar winds. If there were no magnetic field, the particles of the solar wind would strip away the ozone layer, which protects the Earth from harmful ultraviolet rays. One of the reasons that there is no atmosphere at Mars is that its magnetic field is turned off which led to the loss of carbon dioxide due to scavenging of ions by the solar wind.

How it is formed?

The Earth's magnetic field is believed to be caused by electric currents in the liquid outer core, which is composed of highly conductive molten iron. The motion of the fluid is sustained by convection, motion driven by buoyancy. At the core, the pressure is so great that the super hot iron crystallizes into a solid. The higher temperature of the fluid lower down makes it buoyant. This buoyancy is enhanced by chemical separation: As the core cools, some of the molten iron solidifies and is plated to the inner core. In the process, lighter elements are left behind in the fluid, making it lighter. This is called compositional convection.

> The mechanism of formation of Earth's Magnetic field has not yet been understood fully. The basic physics of electromagnetism can be used to somewhat explain the phenomena. Iron, whether liquid or solid, conducts electricity; when we move a flowing electric current, we generate a magnetic field at a right angle to the electric current direction (Ampère's law) . *The molten outer core of our planet releases heat by convection, which then displaces the flowing electrical currents. This generates the magnetic field that is oriented around the axis of rotation of the Earth, mainly due to the rotational effects on the moving fluid.* However, it has not been explained how the charges, necessary for creation of electric field originate, which in turn give rise to the magnetic field.

This convection caused by heat radiating from the core, along with the rotation of the Earth (Coriolis force), causes the liquid iron to move in a rotational pattern. It is believed that these rotational forces in the liquid iron layer lead to weak magnetic forces around the axis of spin. The role of the Coriolis Effect is that it causes overall planetary rotation, and tends to organize the flow into rolls aligned along the north-south polar axis.

Reversal of the fields

Based on data from ancient and new rocks, it has been observed that Earth's north and south magnetic fields have reversed polarity many times. *This is because the polarity of the Earth's magnetic field is recorded in sedimentary rocks.* The switching from north to south (an individual reversal event) seems to take around a couple thousand years to complete; once the reversal takes place, periods of stability seem to average about 200,000 years. No body has been able to explain why the poles reverse, but theories range from the changes in lower mantle temperatures to the imbalance of landmasses on our world (most of the continental landmass is in the Northern Hemisphere). The last magnetic reversal was 780,000 years ago, which gives us current northern and southern magnetic poles. It is believed that geomagnetic field is slowing weakening, so Earth might be heading for a long-overdue magnetic reversal. Reversals tend to occur when there is a wide divergence between the magnetic poles and their geographic equivalent (as it is now).

Intensity gradient of the Geomagnetic Field

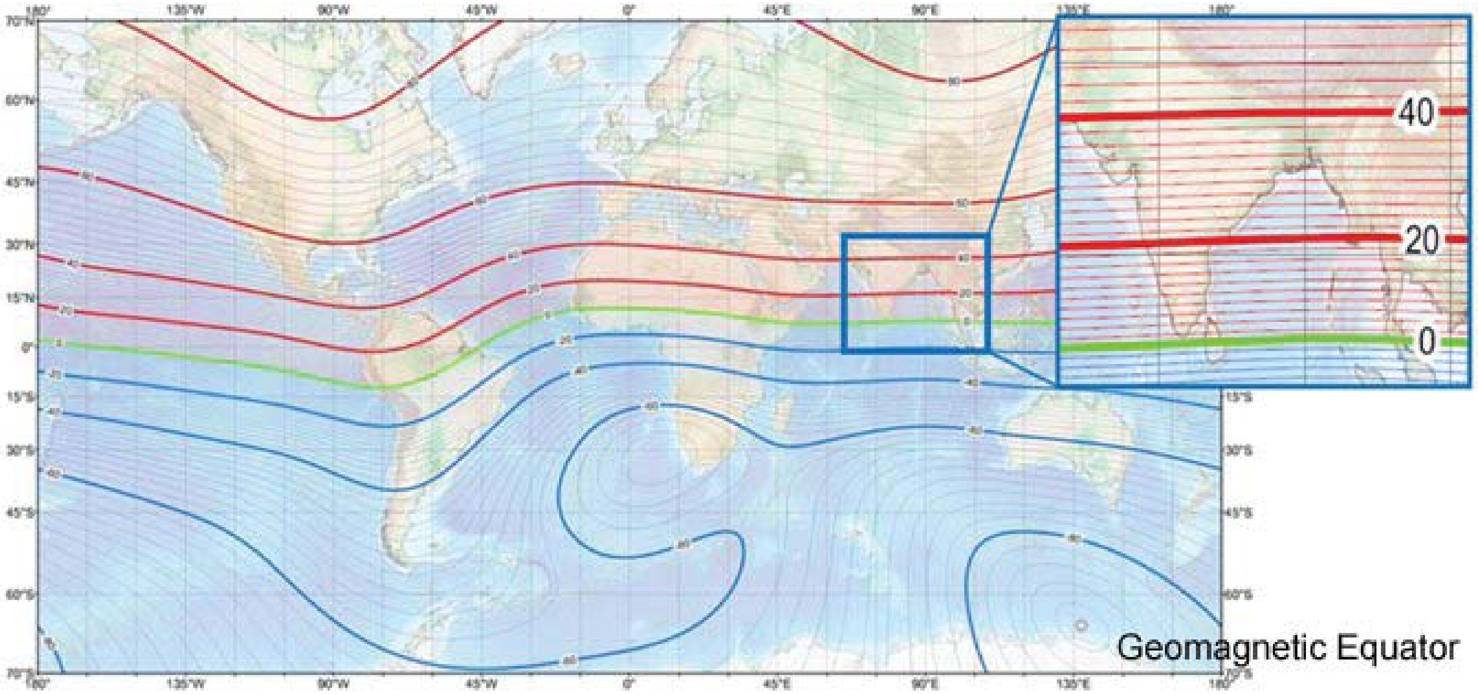
The intensity of the geomagnetic field is **greatest near the poles and weaker near the Equator**. A map of intensity contours of the geomagnetic field is called an isodynamic chart. Isodynamic chart for the Earth's magnetic field shows that *minimum intensity of the magnetic field is over South America* while maximum is over northern Canada, Siberia, and the coast of Antarctica south of Australia.

Magnetic Dip

Magnetic dip or magnetic inclination is the angle made with the horizontal by the compass needle of a vertically held compass. This angle varies at different points on the Earth's surface. ***In the northern hemisphere, the field points downwards.*** It is straight down at the North Magnetic Pole and rotates upwards as the latitude decreases until it is **horizontal (0°) at the magnetic equator.** It continues to rotate upwards until it is straight up at the South Magnetic Pole. North Magnetic Pole on the surface of Earth's Northern Hemisphere at which the planet's magnetic field points vertically downwards. In 2001, it was in Canada, but now, it has moved out of Canada's territory towards Russia. The south magnetic pole was off the coast of Wilkes Land — a part of Antarctica — about 2750 km from South Pole.

Geomagnetic Equator & Equatorial Electrojet

Contour lines along which the dip measured at the Earth's surface is equal are referred to as isoclinic lines. The locus of the points having zero dip is called the **magnetic equator or aclinic line**. In the following graphics, the green line shows the ***magnetic equator, which runs very close the southern tip of our country***. This is the important reason for the establishment of the Vikram Sarabhai Space Centre at Thumba, which is close to Geomagnetic Equator. The reason is that the magnetic equator differs significantly from the geographic equator. Directly above the magnetic equator, at altitudes of around 110 km in the atmosphere, a system of electric currents exists that flows from west to east along the magnetic equator. It is known as **Equatorial Electrojet.**



The closer we are to the magnetic equator, the better we are placed to study the Equatorial electrojet. In the early 1960s, there were very few places in the world close to the magnetic equator with adequate infrastructure to support research in this field. That is the reason that Thumba was chosen.

Thumba is located in the outskirts of Thiruvananthapuram. Here, Thumba Equatorial Rocket Launching Station (TERLS) was launched in 1963. Eventually, TERLS have given birth to the Vikram Sarabhai Space Centre (VSSC) and to the Indian Space Research Organisation (ISRO).

Earth's Magnetosphere

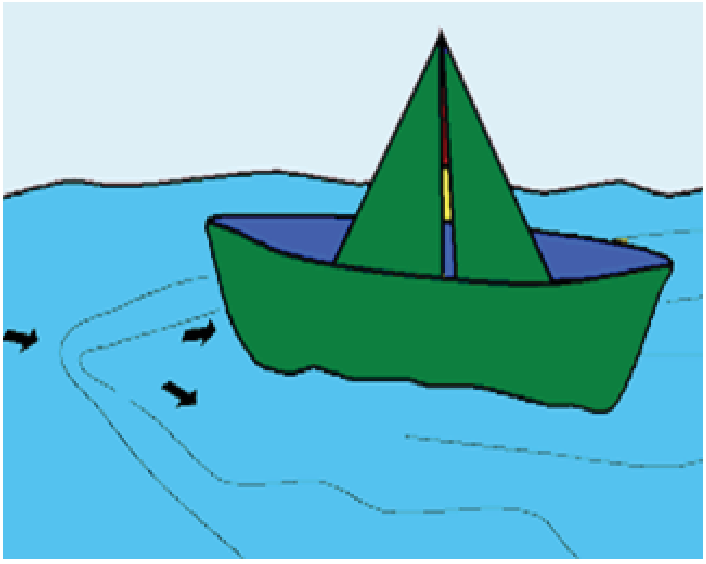
Earth is surrounded by a magnetosphere. The invisible geomagnetic lines stretch from one pole, curve far out into space, then go back to the opposite pole. The curved lines are further shaped by the electrically charged particles of the solar wind into a teardrop shape called the magnetosphere. The Magnetosphere is thus the magnetic field that prevents the solar winds, or highly energetic particles to reach Earth. Please note that the *shape of magnetosphere of Earth is determined by the Earth's internal magnetic field, the solar wind plasma, and the interplanetary magnetic field (IMF).*This shape is not static but is dynamic.

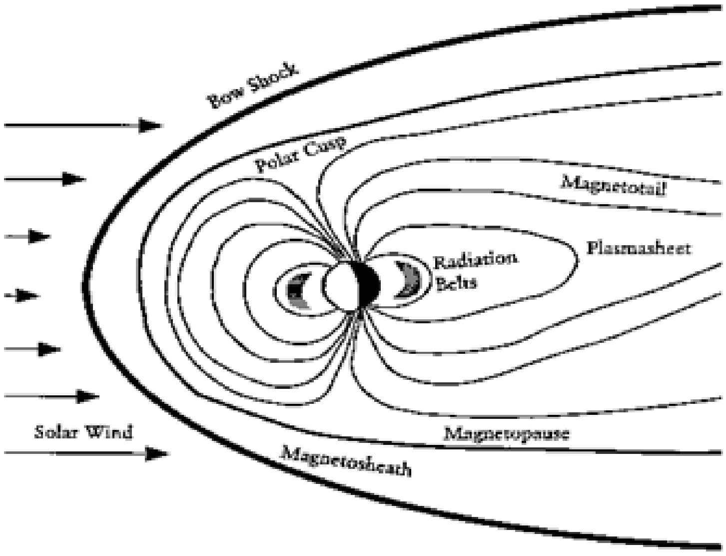
Structure of the Magnetosphere

The complex structure of Earth's magnetosphere is the result of the interplay between the charged particles originating in the upper layers of the terrestrial atmosphere, whose motion is guided by the Earth's magnetic field, and the solar wind particles carrying the interplanetary magnetic field. The magnetosphere is basically a space filled primarily with particles **from terrestrial origin**.

The shape of magnetosphere keeps changing throughout the day and night, with Earth's rotation, revolution and during solar storms and other such events which can affect it.

To understand its boundary, we take an example of a boat that moves through the sea. In front of the boat a bow wave is formed: that bow wave demarcates the region in which the boat disturbs the flow of the water. The water behind the bow wave is forced to flow smoothly around the boat's hull. Behind the boat a wake is formed. The similar kind of interaction is the solar wind -magnetosphere interaction. The solar wind consists of particles that are mainly of solar origin. It is pervaded by the interplanetary magnetic field. A bow shock is formed in front of the Earth's magnetosphere, which demarcates the region where the solar wind flow is impeded by the presence of the Earth. The solar wind in the magneto sheath, the region between the bow shock and the Earth's magnetosphere, is forced to flow around the Earth's magnetosphere and is compressed.





The impermeable outer surface of the magnetosphere, where the total pressure of the compressed solar wind precisely balances the total pressure inside the magnetosphere, is called the **magnetopause**. As shown in the accompanying figure, the magnetopause has a shape that is elongated and stretched out in the anti-solar direction, forming a long**magnetotail**, which is in a sense similar to the wake behind the boat.

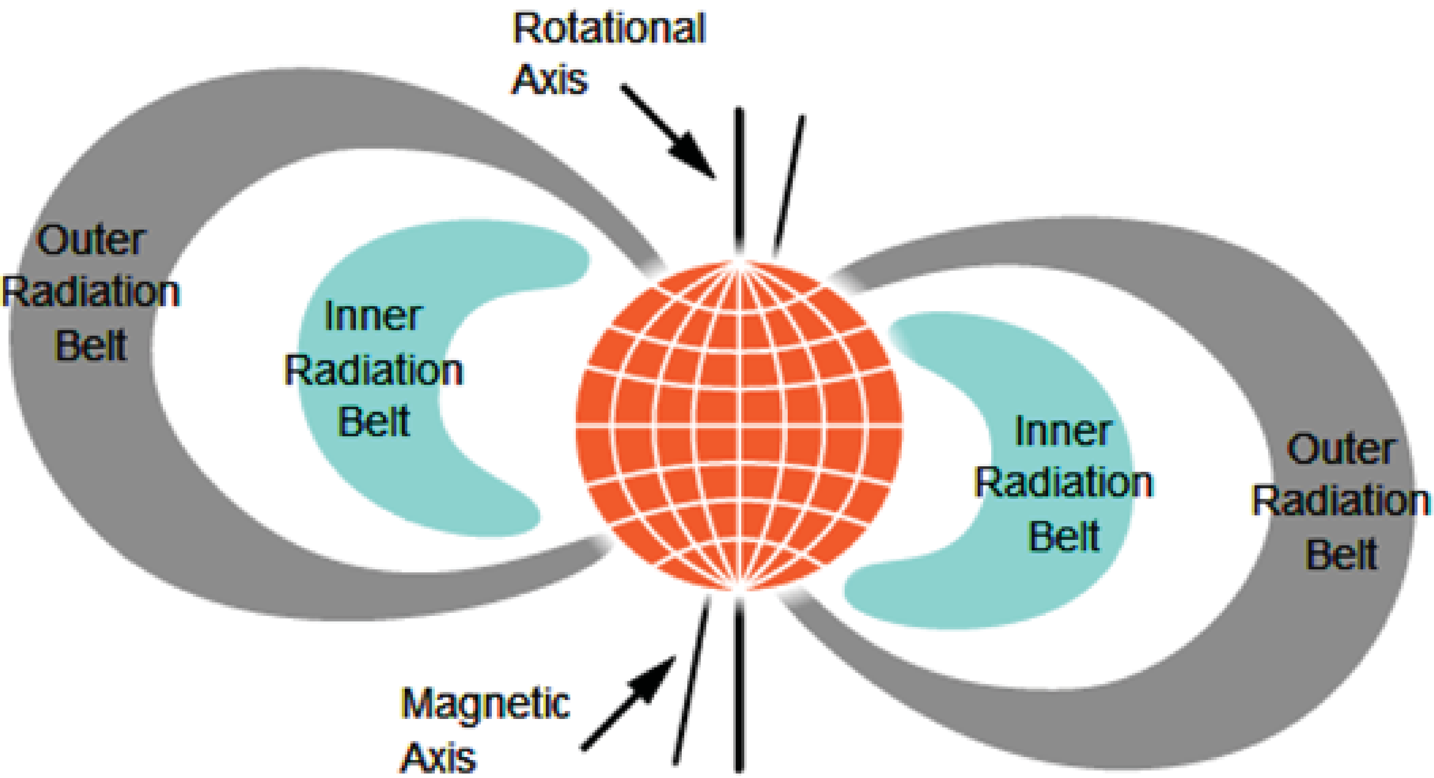
Due the complex interplay, the magnetosphere becomes roughly bullet shaped and extends on the **night side** in the "magnetotail" or "geotail" approaching a cylinder with a radius that is around 20-25 times of the Radius of Earth. The tail stretches to around 200 times the Radius of Earth. The day side tip or sub-solar point of the magnetopause is called "nose' of the magnetopause. It is normally located at 10 RE (Earth radii) towards the Sun.

There are two polar cusp regions above the "**Geomagnetic Poles**". These are regions where solar wind can enter relatively easily into the magnetosphere. The inner magnetosphere is strongly connected to the Earth's ionosphere. The inner region, called the plasmasphere, which consists of dense cold plasma largely of ionospheric origin, rotes more or less, along with the Earth.

Van Allen belts

In the inner region of the Earth's magnetosphere, there are **two distinct rings** of **electrically**

charged particles that encircle our planet. These are called Van Allen belts after their discover. *The particles in these belts originate from different sources; some come from the solar wind, some from the Earth's upper atmosphere, some from cosmic rays originating in the distant Universe*. The belts are shaped like fat doughnuts, ***widest above Earth's equator and curving downward toward Earth's surface near the Polar Regions.***



Van Allen Belts

These charged particles usually come toward Earth from outer space—often from the Sun—and are trapped within these two regions of Earth's magnetosphere. Since the particles are charged, they spiral around and along the magnetosphere's magnetic field lines. The lines lead away from Earth's equator, and the particles shuffle back and forth between the **two magnetic poles**. The closer ring is about 3,000 kilometers from Earth's surface, and the farther belt is about 15,000 kilometers away. The highly charged particles of the Van Allen belts pose a hazard to satellites, which must protect their sensitive components with adequate shielding if their orbit spends significant time in the radiation belts.

Van Allen Belts and Impact on Apollo Mission

There are several (conspiracy) theories on impact of the Van Allen Belts on its impact on astronauts who pass through them. It is said that there is deadly radiation in the Van Allen belts, which could have killed the Apollo astronauts (Thus, claiming that actually Apollo 11 was a fake mission). The NASA claims that the nature of that radiation was

known to the Apollo engineers and they were able to make suitable preparations. The principle danger of the Van Allen belts is high-energy protons, which are not that difficult to shield against. And the Apollo navigators plotted a course through the thinnest parts of the belts and arranged for the spacecraft to pass through them quickly, limiting the exposure. The Van Allen belts span only about forty degrees of earth's latitude — twenty degrees above and below the magnetic equator. Further, The region between two to four earth radii lies between the two radiation belts and is sometimes referred to as the "safe zone".
The diagrams of Apollo's translunar trajectory printed in various press releases are not entirely accurate. They tend to show only a two-dimensional version of the actual trajectory. The actual trajectory was three-dimensional. The highly technical reports of Apollo, accessible to but not generally understood by the public, give the three-dimensional details of the translunar trajectory. {Source: http://www.clavius.org}

Please note that the inner belt consists mainly of**energetic protons**, while the outer belt consists mainly of **electrons.** As far as protective effects of Van Allen Belts are concerned,***they have not much to credit for***. Van Allen belts *protect against charged particle radiation* but at the same time *don't not protect against electromagnetic radiation*. ***This protection is done by the atmosphere (Ionosphere).*** Thus, the statement that these belts protect earth is true in terms of particle radiation, false in terms of EM radiation. Van Allen Belts are regions of high concentrations of particle radiation. It is the Earth's magnetic field that does the protecting, forming the belts in the process.

Chapman Ferraro Cavity

On the sunward side, the Earth's Magnetosphere is compressed because of the solar wind, while on the other side it is elongated to around three earth radii. This creates a cavity called the Chapman Ferraro Cavity, in which the Van Allen radiation belt resides.

Magnetospheric storms

We have read above that the magnetosphere is not a static structure. Rather, it is constantly in motion, as the orientation of the Earth's magnetic dipole varies with the Earth's daily rotation and with its yearly revolution around the Sun, and as the solar wind is characterized by a strong time-variability on time scales ranging from seconds to years. As a consequence of this time-variability, the sizes and shapes of the regions may change with time. When material from a solar Coronal Mass Ejection travels through the interplanetary medium and hits the Earth, the dynamic pressure of the solar wind is strongly enhanced so that the***bow shock and the magnetopause are pushed inward, producing a Magnetospheric storm***.

Geocorona

The magnetosphere is an almost completely ionized collision less plasma. Nevertheless, a large cloud of **neutral hydrogen** surrounds the Earth, which is called the Geocorona. Since collisions are so rare, this neutral cloud can co-exist with the plasma in the inner regions of the magnetosphere with relatively little interference.

Other plants with magnetosphere

Other planets with intrinsic magnetic fields viz. *Mercury, Jupiter, Saturn, Uranus, and Neptune. Jupiter's moon Ganymede also has a small magnetosphere, but it is situated entirely within the magnetosphere of Jupiter, leading to complex interactions.*

Model Questions and Answers for Prelims

Earth Basics Prelims Model Questions

1. In comparison to the Oceanic Crust, the Continental crust __:

1. is thicker
2. has more density
3. has more of quartz
4. called SIMA

Choose the correct option from the codes give below:

[A] 1 & 2

[B] 1, 2 & 3

[C] 1 & 3

[D] 1, 3 & 4

Answer: [C] 1 & 3

Oceanic Crust	Continental Crust
Thinner (average 7 Km)	Thicker (Thickest where there are mountains) Average 30 Km.
Dark colored	Light colored
High in Silica and Magnesium (SIMA)	High in Silica and Aluminium (SIAL)
More Basaltic / Mafic	More Felsic
More Feldspar	More quartz
More dense (3000Kg/m³)	Less dense (2500 Kg/m³) due to increased amount of aluminium

2. The shape of the Earth's Magnetosphere is defined by___?

1. Earth's internal magnetic field
2. Solar winds
3. Interplanetary magnetic field
4. Rotation of earth

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2

[C] Only 2, 3 & 4

[D] 1, 2, 3 & 4

Answer: [D] 1, 2, 3 & 4

3. Which among the following cause(s) the generation of the Van Allen belts?

1. Refraction of sunlight

2. Charged particles trapped in the earth's magnetic field.

3. Reflection of polar snow.

4. Precession of earth

Choose the correct option from the codes given below:

[A] Only 2 & 4

[B] Only 2

[C] Only 1 & 2

[D] 1, 2 & 4

Answer: [B] Only 2

4. Consider the following statements with respect to Earth's Lithosphere:

1. Lithosphere is a part of Earth&#146s Crust only

2. The Oceanic lithosphere is denser than the continental lithosphere

Which among the above statements is / are correct?

[A] Only 1 is correct

[B] Only 2 is correct

[C] Both 1 & 2 are correct

[D] Neither 1 nor 2 is correct

Answer: [B] Only 2 is correct

5. What benefits are provided by the Van Allen Belts ?

1. They protect the communication satellites

2. They protect life on earth against charged particle radiation

3. They protect life on earth from Electromagnetic radiation

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2

[C] Only 2 & 3

[D] 1 & 3

Answer: [B] Only 2

6. If the earth's axis changed from a 23.5 degree tilt to a 45 degree tilt, there would have been:
1. hotter summers and colder winters
2. longer days in summer and shorter days in winter
3. Shifting of equator towards north pole
Select the correct statements from the codes given below:
[A] Only 1
[B] Only 2 & 3
[C] Only 1 & 2
[D] 1, 2 & 3
Answer: [C] Only 1 & 2

Perhaps one of the most apparent factors contributing to Earth climate change is the angle at which the earth is tilted. This is the angle at which Earth's axis of rotation is from the vertical, also known as Earth's obliquity.

Earth's current tilt angle is approximately 23.5 degrees. The axial tilt angle affects climate largely by determining which parts of the earth get more sunlight during different stages of the year. This is the primary cause for the different seasons Earth experiences throughout the year, as well as the intensity of the seasons for higher latitudes. For example, in the Northern Hemisphere, if there were no axial tilt, i.e. Earth's obliquity would be zero degrees, then there would be no change in the seasons from year to year. This would be because there would be no difference in the amount of solar irradiation received, year-round, anywhere on Earth.

On the other hand, if Earth's axial tilt angle was great (45+ degrees), the seasonality of each hemisphere, individually, would be highly exaggerated. Summers would be extremely hot, with substantially more hours of daylight than night each day. Winters would be extremely cold, with substantially more hours of night than daylight each day. This is because, during summer for the northern hemisphere, if the earth is tilted more (pointed towards the sun more), there would be more available hours in which the suns rays can strike any certain place, thereby increasing the number of daylight hours at any given place, with more and more daylight hours at higher latitudes.

Also, because the northern hemisphere would be tilted much more towards the sun, it would be physically closer to the sun, thereby increasing the intensity of the sun's rays hitting the northern hemisphere, thereby causing the northern hemisphere to become hotter. Likewise, during winter for the northern hemisphere, there would be fewer hours of daylight because the northern hemisphere would essentially be pointed away from the sun. Fewer daylight hours means less solar radiation hitting the northern hemisphere, especially at higher latitudes, and therefore causing the

northern hemisphere to become colder.
The same things can also be said about the southern hemisphere, particularly at high latitudes. In either case, the climate around the equator is not affected nearly as much as the higher latitudes, thereby creating a sizable difference in how obliquity affects different latitudes. This is all, of course, dependent on what the actual tilt angle is at any given point in time.
The thing is, though, that Earth does in fact change obliquity over time in a cyclic pattern. Earth's obliquity does not change much, though, as obliquity has been determined to cycle between the small range of 22.2 degrees to 24.5 degrees, in a cycle that lasts approximately 41,000 years. Therefore with the small tilt variation over time, the Earth has always been thought to have had a seasonal climate, at least in the high latitudes due to the solar affect of changing Earth obliquity.

7. What do you call the phenomenon when Moon blocks the light coming from a star?

[A] Eclipse

[B] Occultation

[C] Transit

[D] Blockage

Answer: [B] Occultation

When two heavenly bodies apparently cross each other's path as seen from the Earth, there are 3 possibilities:
1.Eclipse: It occurs when two heavenly objects having apparently the same size cross each other. Eg: During the eclipse of sun, even though the Moon is much smaller, it appears to be of the same size as the Sun, because it is nearer to us. Therefore, it can completely hide the Sun behind it.
2.Occultation: It occurs when an apparently larger heavenly object covers an apparently smaller one. Eg: When Moon blocks the light coming from a star.
3.Transit: It occurs when an apparently smaller object traverses in front of an apparently larger one. Eg: Inferior planets Mercury and Venus can occasionally cross the Sun's disc when viewed from the Earth.

8. Consider the following differences between the Oceanic Crust and Continental Crust:

1.The Continental crust is denser in comparison to the Oceanic Crust

2.The Continental crust has more of quartz , while the Oceanic Crust has more of Feldspar

3.The Continental Crust is otherwise called SIMA, while the Oceanic Crust is otherwise called SIAL

4.The rocks that make the continental crust are little denser than those making Oceanic crust.

Which among the above statements is / are correct?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] Only 3 & 4

Answer: [A] Only 1 & 2

The oceanic crust is thinner than the Continental Crust. Oceanic Crust measures from 5 to 10 kilometers, averaging about 7 kilometers in thickness; the continental crust measures between 25 to 100 kilometers, averaging about 30 kilometers thick. Obviously, the thickest continental crust regions are under large mountain ranges.

Apart from the thickness, the oceanic and continental crusts also differ in composition and density. The oceanic crust is composed of dark, iron-rich rock similar to basalt. It is high in silica and magnesium, that is why called SIMA. It is often distinguished from the mantle by having more silica. This implies that Oceanic crust is more basaltic. Since Magnesium is denoted by Mg and Iron is denoted by Fe, these rocks have also been named Mafic Rocks. Most common rock-forming Mafic minerals in the oceanic crust are olivine, pyroxene, amphibole, and biotite.

The continental crust's composition is more complex. In general, continental rocks are light-colored, with an average composition between diorite (generally hornblende and plagioclase feldspar with a little quartz) and granodiorite (the same composition as diorite, but with more quartz present). These are rocks high in silica and aluminium and are often referred to as SIAL. This implies that Continental crust is more
felsic.

Then, there is a difference in density also. The oceanic crust has a density of 3,000 kilograms/m^3 while the continental crust has a lower density of 2,500 kilograms/m^3. This also implies that the rocks which make continental crust are slightly less dense than those making the Oceanic Crust. The less dense rocks such as granite is more common in continental crust than in oceanic crust. Density of Sial is lower than Sima primarily because of the increased amount of aluminium.

Please note that at a certain depth, the SIAL of the Continental Crest becomes close in its physical properties to SIMA. The temperature of the crust increases with depth, reaching values typically in th range from about 200-400°C at the boundary with the

9. Earth is at the closest distance from the Sun in January and farthest in July. Why the temperature of earth does not rise in January?

1. Distance of earth in its orbit from Sun does not affect the seasons
2. Earth is tilted on its axis which causes rise and fall in seasonal temperatures
3. At perihelion, southern hemisphere is more hot in comparison to northern hemisphere at

Aphelion

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [A] Only 1 & 2

There are many reasons for it. Blame it on the tilt of the Earth's axis. Actually, our seasons are determined by the tilt of the Earth and not by how close the Earth is to the Sun. Sunlight raises the temperature of continents more than it does of the oceans.

10. The pointer or arrow of the magnetized needle of a compass indicates which among the following?

[A] Geographic North Pole

[B] Magnetic North Pole

[C] Geo-magnetic North Pole

[D] Magnetic South Pole

Answer: [D] Magnetic South Pole

The north pole of a magnet in a compass points north because it is attracted to the Earth's magnetic south pole, which is located near Earth's geographic north pole. The geographic north pole of earth corresponds to magnetic south pole and geographic south pole of earth corresponds to magnetic north pole. The direction in which a compass needle points is known as magnetic north. This is not exactly the direction of the North Magnetic Pole.

Instead, the compass aligns itself to the local geomagnetic field, which varies in a complex manner over the Earth's surface. The angular difference between magnetic north and true north (defined in reference to the Geographic North Pole), at any particular location on the Earth's surface, is called the magnetic declination. Most map coordinate systems are based on true north, and magnetic declination is often shown on map legends so that the direction of true north can be determined from north as indicated by a compass.

11. With reference to the structure of Earth, despite the hottest temperature at Inner Core, why the Earth has a solid inner core but liquid outer core?

1. Because the inner core is made of heavy metals
2. Because the inner core is under huge pressure
3. Because the inner core is actually getting cooled from inside

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 2

[D] Only 1 & 3

Answer: [C] Only 2

The high pressures deep inside the Earth do have other interesting effects; for example, in the crust and mantle (which make up the outer 2900 km (1800 miles) of the Earth), you see different sorts of minerals at different depths because each is only stable over a certain range of pressures. Also, while the outer core of the Earth is made of liquid iron, the inner core is solid due to the high pressures at the center of the Earth.

12. Consider the following statements

1. A solar day is nearly 4 minutes smaller than a sidereal day
2. Approximately 1° is the distance covered by earth in its orbit everyday
3. The mean solar day at present is 86400 seconds

Which among the above statements is / are correct?

[A] 1 & 2 only

[B] 1 & 3 only

[C] 2 only

[D] 2 & 3 only

Answer: [C] 2 only

A solar day is nearly 4 minutes longer than a sidereal day. The mean solar day at present is 86400.002 seconds, It was 86400 in 1820

General Knowledge Today

Prelims Geography-3: Plate Tectonics, Earthquake, Volcano, Tides

Target 2016: Integrated IAS General Studies
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Contents

Model Questions

Please check Prelims Model Questions in the end of this Module.

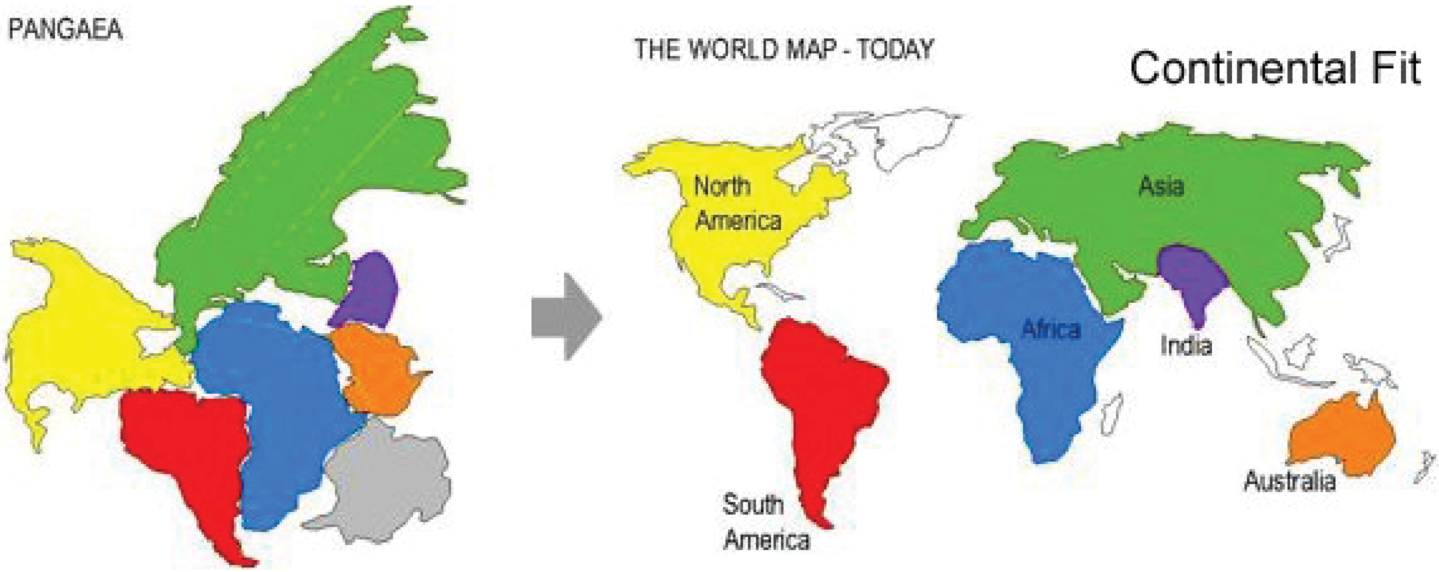
Plate Tectonics

Evidence of Continental Drift: Wegener's Continental Drift Hypothesis

The Lithosphere is always in a state of work in progress. In 1912, a German geologist named **Alfred Wegener** came up with an outlandish theory known as**continental drift.** His theory was based upon the following clues.

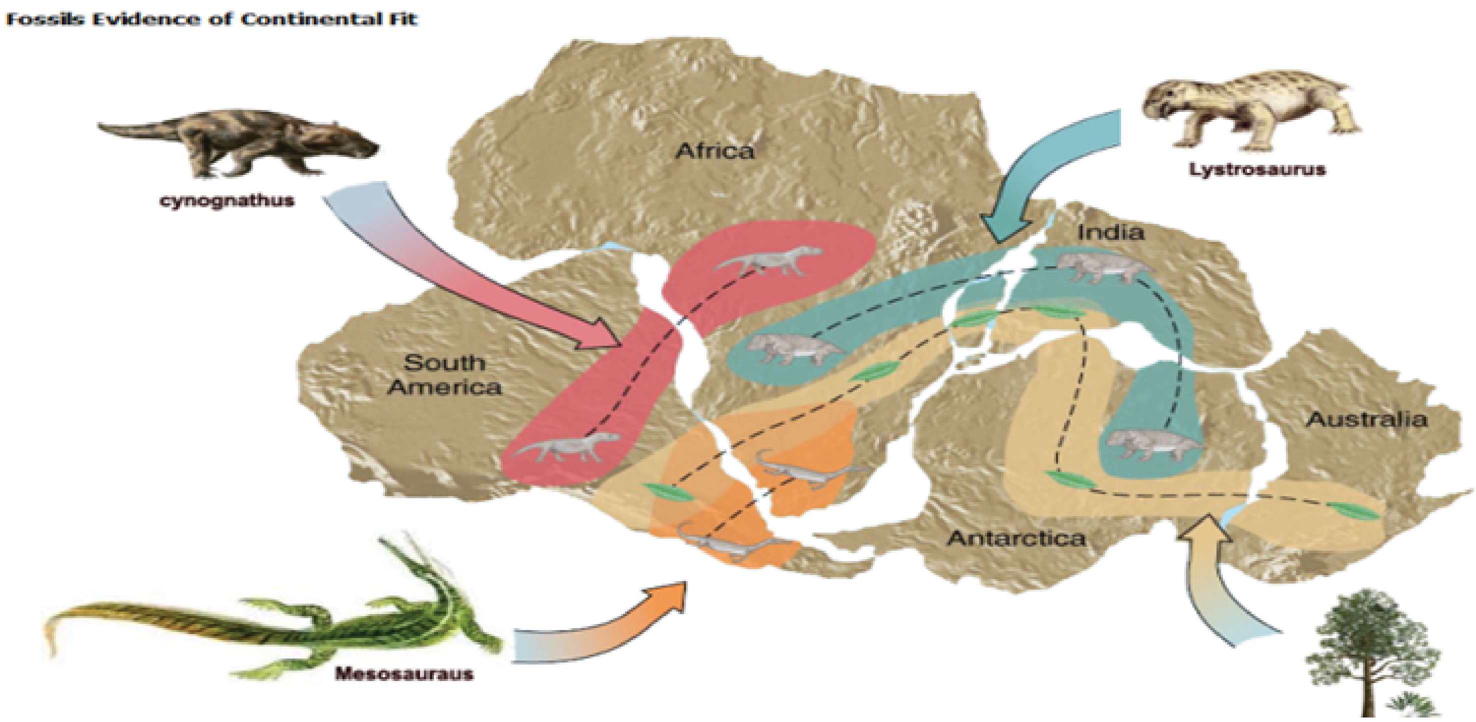
Continental Fit

One of the first clues he had was that the continents were once joined once, by noting the jigsaw puzzle–like geometry of Africa's west coast and South America's east coast. This was called "**Continental Fit**".



Fossils

Fossils of Mesosaurus, a freshwater reptile, have only been found in Africa and South America. The fossil remains of Cynognathus, a land reptile, are found in South America and Africa. A **fern called Glossopteris** was found fossilized on all of the southern continents. Since these continents all have different climates now, Wegener proposed that they once all shared a similar climate as one landmass. The evidence of another land reptile, Lystrosaurus, was found in Africa, India, and Australia.

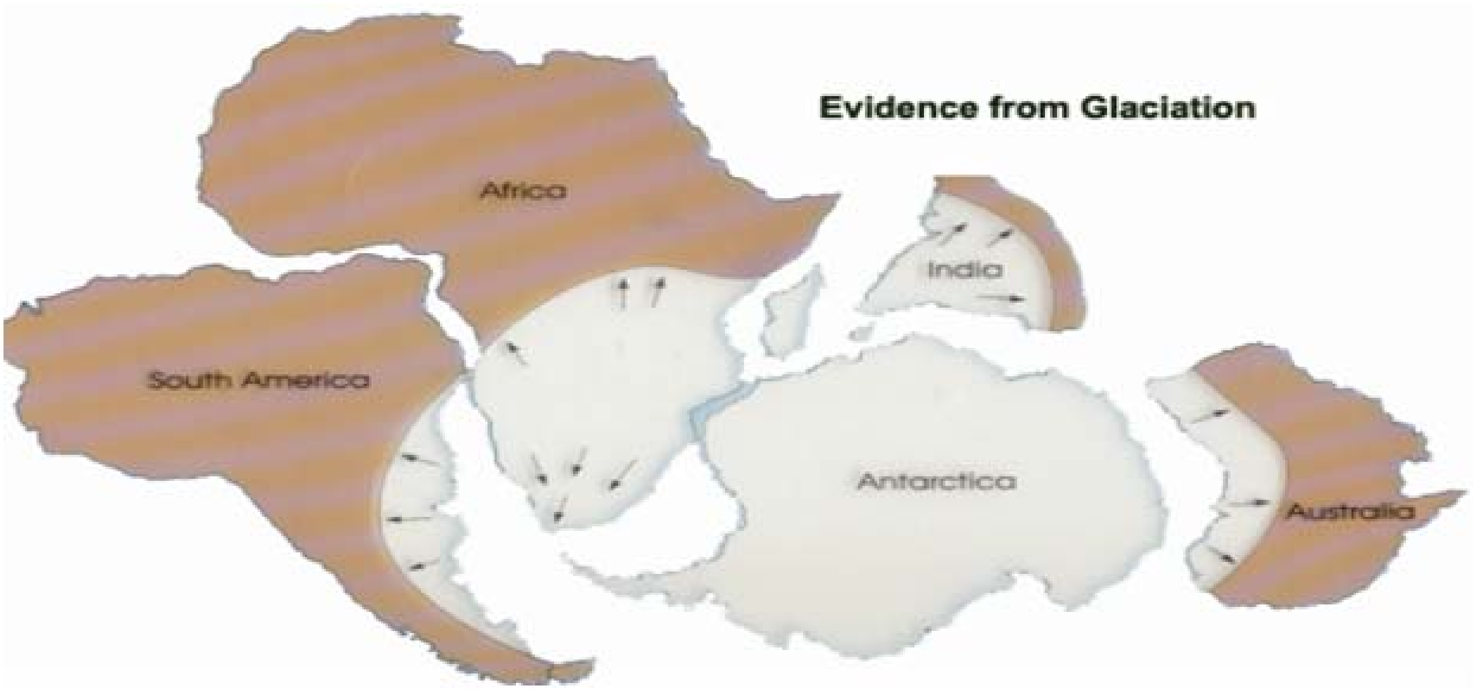


Coal Fields

He noticed the presence of coal fields in the temperate regions, while they could only be formed in the Tropical regions.

Glacial Flow

Wegener noticed that all over the southern hemisphere there are glacier deposits left over from millions of years ago. India, which is now located above the equator, shows signs of glaciers moving across it from the south. Since, it can not be explained without continental drift why would glaciers move toward India from the equator? The clue Wegener had was of a single giant ice sheet that moved outward from Antarctica.



Similarity in Rocks

The similarity in the rock structure on opposite sides of the Atlantic was another clue.

So, **Wegener** proposed that the present continents were once joined in a super continent named **Pangaea** and later the drifted apart. Wegener proposed that the **Pangaea** broke into continents and the new continents drove away themselves in two directions viz. Equatorward and Westward movements. He said that the movements towards the equators were because of the gravitational differential forces and force of buoyancy. The Westward movement occurred because of the tidal force of sun and moon.

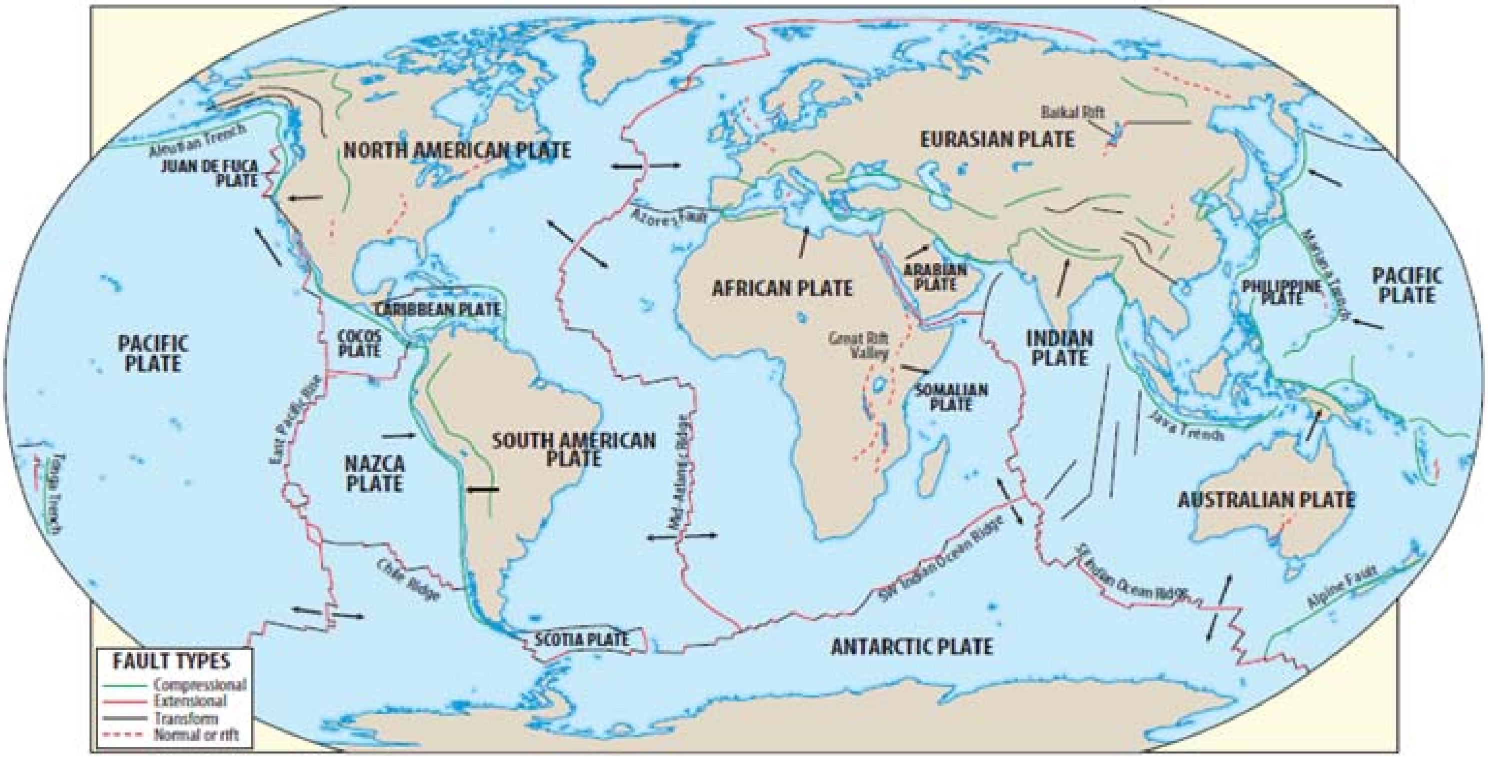
He proposed that the Pangaea began to separate into the**Gondwanaland** and **Angaraland** in the Carboniferous period and the space between the two was filled with water that was called**Tethys Sea**. Later the Gondwanaland disrupted during the Cretaceous period and with this, the Indian subcontinent (peninsula) , Madagaskar, Australia and Antarctica broke away from the Gondwanaland. Similarly the North America broke away from th**Angaraland** and drifted westward due to Tidal forces. He went on further proposing that South America broke way from Africa and moved westwards due to Tidal forces. This theory was interesting and thrilling but Wegener was unable to explain what the forces behind this drift were. So, the result was that **Alfred Wegener** was derided by the scientific community; his proposal was called "geopoetry". However, the later discoveries in deep-sea science led Wegener's basic proposition to be accepted as fact, and today a good deal is known about how the continental drift occurs.

Paleomagnetism

Earth has a magnetic field that causes a compass needle to always point toward the North magnetic pole. When the magnetic minerals cool down, the domains within the magnetic mineral take on an orientation parallel to any external magnetic field present at the time they cooled below this temperature. Using this, it can be determined what was the orientation of the magnetic field present at the time the rock containing the mineral cooled, and thus be able to determine the position of the magnetic pole at that time. Magnetite is the most common magnetic mineral in the Earth's crust. The studies showed that the magnetic pole had apparently moved through time. When similar measurements were made on rocks of various ages in North America, however, a different path of the magnetic pole was found. This would first imply that either the Earth has had more than one magnetic pole at various times in the past, which can not happen. The second implication is that the different continents have moved relative to each other over time. This led to the confirmation of the theory of continental drift.

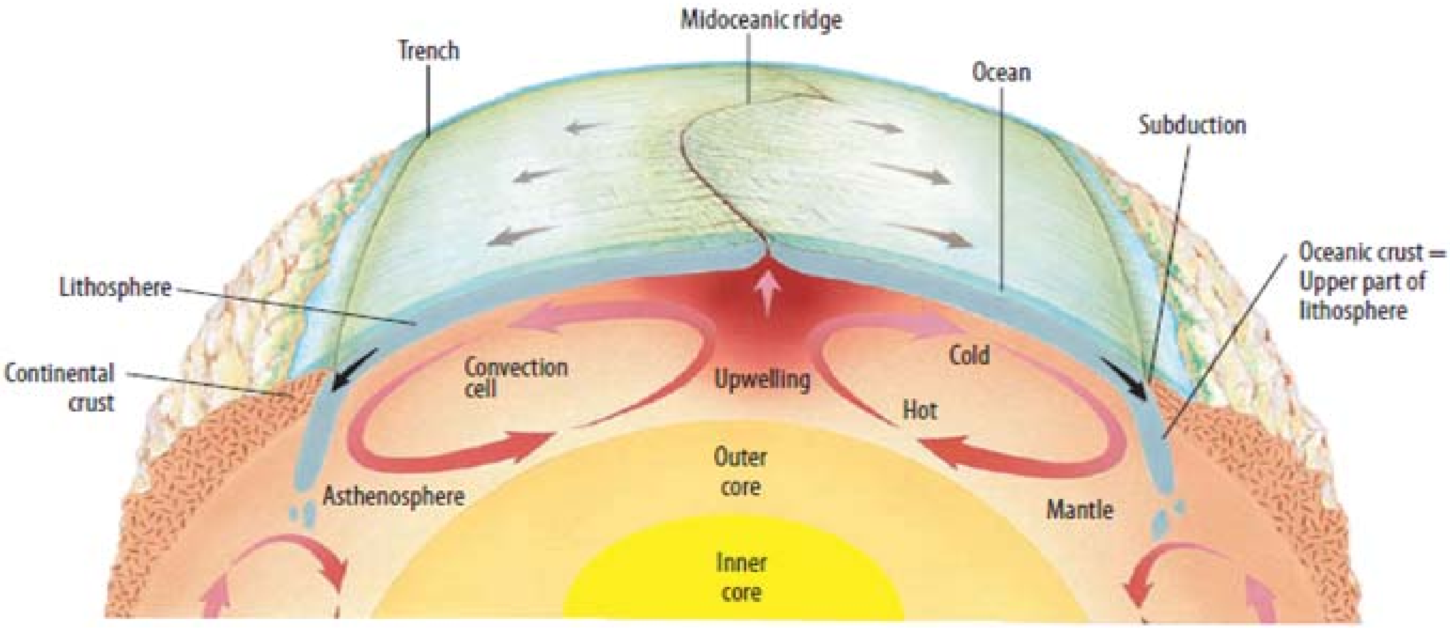
Plate Tectonics and Seafloor Spreading

Lithosphere is made up of about a dozen giant and several smaller sections called plates, and these move in various directions in processes known collectively as plate tectonics. The below graphics shows the plates and their general direction of Movement.



Earthquakes, volcanoes, and other geologic events are concentrated where plates *separate, collide, or slide past one another.* Where they separate, rifting produces **very low land elevations** (e.g. well below sea level at the Dead Sea of Israel and Jordan) or the emergence of new crust on the ocean floor (e.g. in the middle of the Atlantic Ocean).

The central item in the Plate Tectonics is the **Mid-Oceanic Ridge**. *The mid-ocean ridges of the world are connected and form a single global mid-oceanic ridge system that is part of every ocean, making the mid-oceanic ridge system the longest mountain range in the world.* The continuous mountain range is 65,000 km (40,400 mi) long and the total length of the oceanic ridge system is 80,000 km (49,700 mi) long.



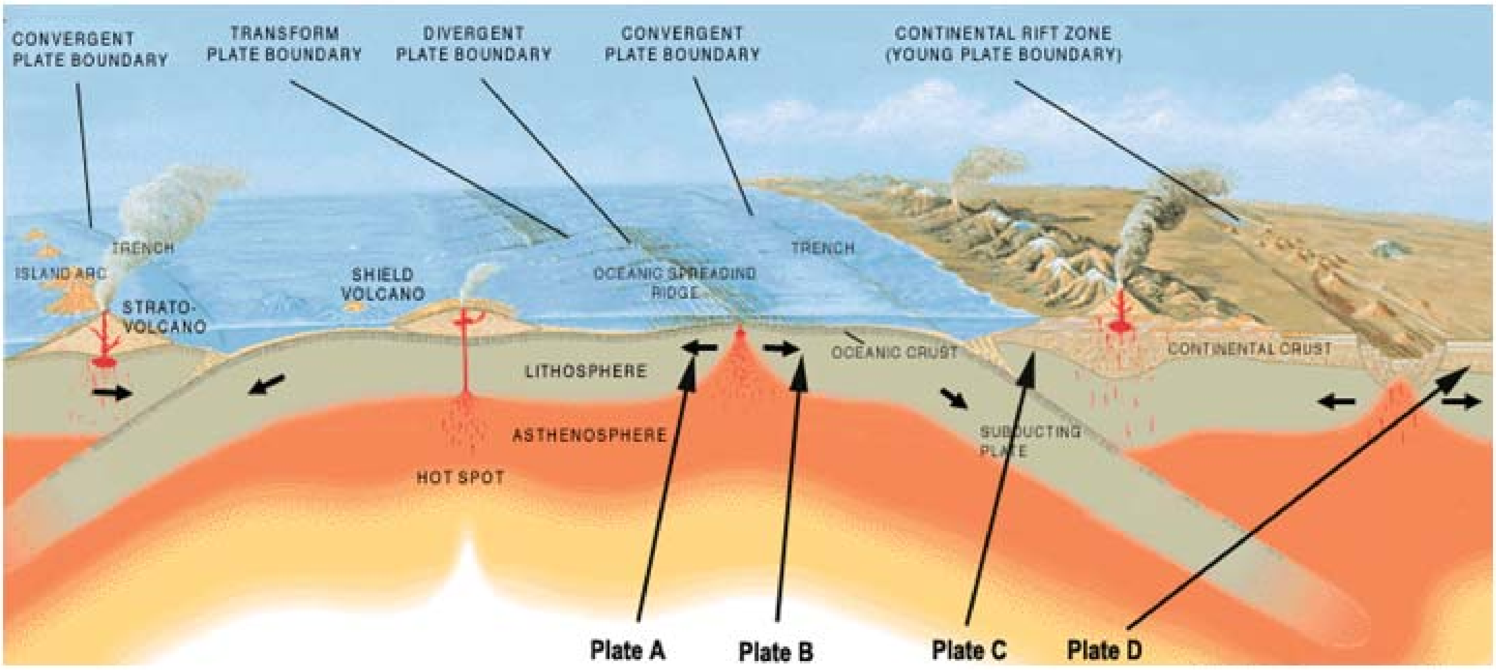
When the ocean floors such as Mid-Atlantic Ridge and the East Pacific Rise, new lithosphere is "born" as molten material rises from the earth's mantle and cools into solid rock. Plate tectonics are often explained by the useful analogy of a "conveyor belt" in constant motion. On either side of the long, roughly continuous ridges, the two young plates move away from one another, carrying islands with them; this process is called **seafloor spreading.**

Seafloor spreading has few impacts on us, but when the earth's plates collide, there is cause for great concern: tectonic forces are among the planet's greatest natural hazards. The seismic activity (seismic refers to earth vibrations, mainly earthquakes) that causes earthquakes and tsunamis (tidal waves) and the volcanism (movement of molten earth material) of volcanoes and related features are the most dangerous tectonic forces.

Subduction

We have already studied that the *Oceanic lithosphere is thinner and denser*, whereas *continental lithosphere is thicker and lighter.* Both of these crustal plates float on the plastic asthenosphere. We can visualize this as two blocks of wood floating in water, where a thicker block rides higher above the water surface than a thinner block. This implies that the *thicker continental surfaces rise higher above the ocean floors.*

In the below graphics, there are four plates viz. A, B, C and D. Plate A and B are pulling apart along their common boundary, which lies along the axis of a midoceanic ridge. When they pull apart, it creates a gap in the crust that is filled by magma rising from the mantle beneath. At greater depth under the rift, magma solidifies into plutonic rocks. The boundary between the plates A and B is called a **spreading boundary**.



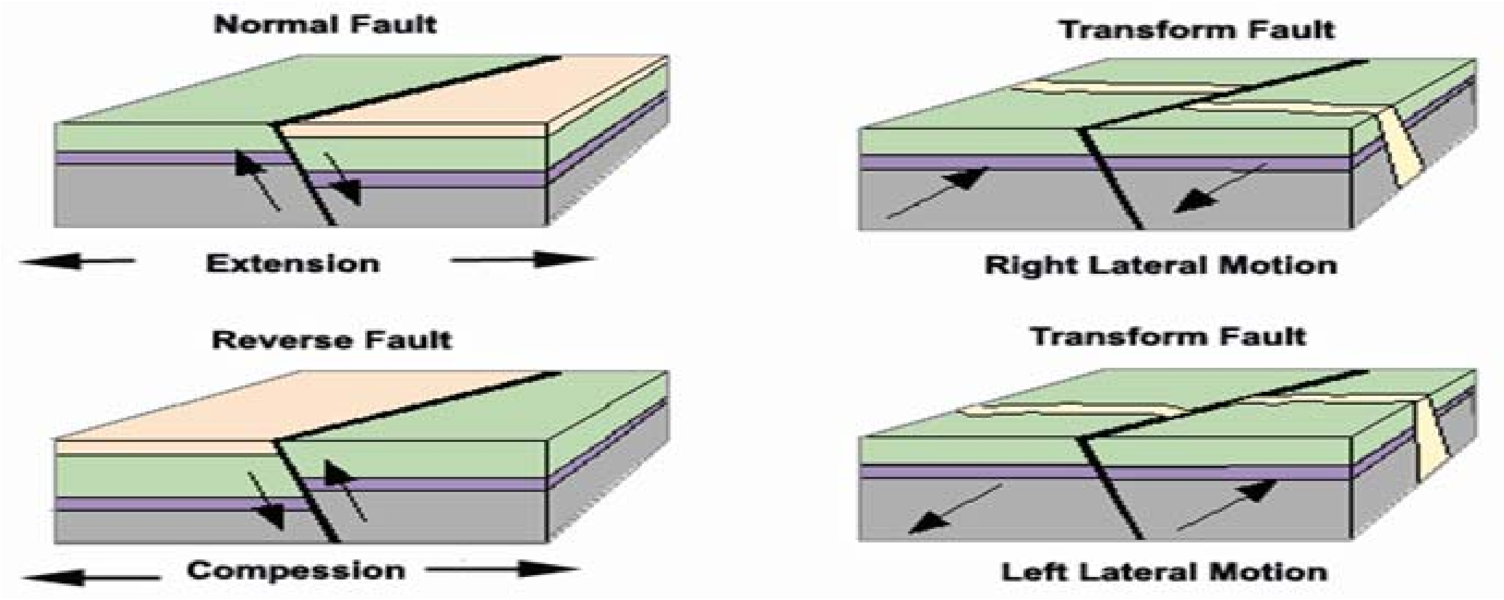
In the right, we see that the oceanic lithosphere of plate B is moving toward the continental lithosphere of plate C. Where these two plates collide, they form a**converging boundary**. Here, since the oceanic plate is comparatively thin and dense, in contrast to the thick, buoyant continental plate, the oceanic lithosphere bends down and plunges into the asthenosphere.*The process in which one plate is carried beneath another is called subduction*. The descending lithosphere is melted again as it dives into the earth's mantle along a deep linear feature called trench (such as the Mariana Trench off Japan). Subduction is another stage along the "conveyor belt" process that will eventually see this material recycled as newborn lithospheric crust. This subduction process releases enormous amounts of energy. The great stress of one plate pushing beneath another is released in the form of an earthquake. The world's largest recorded earthquakes—registering 9.5 (Chile, 1960), 9.2 (United States, 1964), and 9.1 (Indonesia, 2004), respectively, on the Richter scale, which measures the strength of the earthquake at its source—*struck along these subduction zones*. This sudden displacement of a section of oceanic lithosphere is also what triggers a tsunami and the attendant loss of life and property such a powerful wave can cause. Further, the Volcanism generally occurs at places near the subduction zones.

Movement of Plates – Faulting

In some other places, the lithospheric plates **grind and slide along one another.** The processes of rock crowding together or pulling apart along these**fracture lines** is known as **faulting. The** movement along various kinds of faults causes earthquakes, the emergence of new landforms, and other consequences. They are of the following types:

- Normal – tension in the crust (a 'pulling apart")
- Reverse – Compression in crust (a 'pushing in')

- Reverse Thrust Fault
- Transform



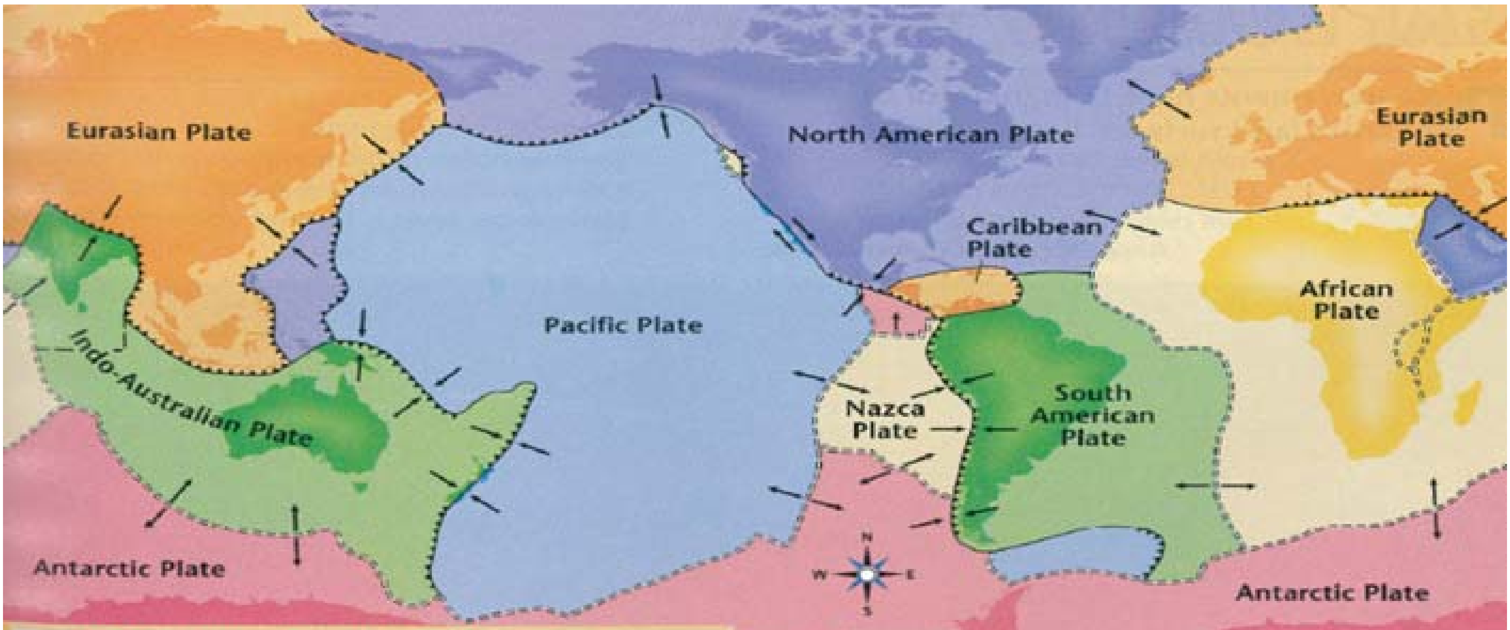
Subduction is responsible for high rates of volcanism, earthquakes, and mountain building. When the large pieces of material on the subducting plate are pressed into the overriding plate, it results in the Orogeny or Mountain formation. These areas are subject to many earthquakes.

Faulting Versus Folding

Please note that *both faulting of the Rocks and folding of the Rocks* play role in creation of the Earthquake, however, the role of later is also dependent upon the former. Earthquakes usually occur where Earth's crust has cracks and is weak. The cracks through which these vibrations pass are called Faults. The movement of rocks along these faults cause earthquakes. As a result of the earthquake, the rocks on the surface of earth change from their earlier position. Their up and down bending into elevations and hollows is called folding of rocks. When the folding continues for a long time, the beds of the rocks can no longer bear the pressure of the force. They break and the rocks may be thrown up on one side and down on the other, thus resulting in Faulting.

The Lithospheric Plates System and Plate Boundaries

The Earth's surface is composed of six major lithospheric plates' viz. Pacific, American, Eurasian, African, Austral-Indian, and Antarctic. Apart from those, there are some lesser plates and sub plates also. The below graphics shows these Lithospheric Plates.



Global System of Lithospheric Plates

<u>*Some important notable observations about these plates are as follows:*</u>

- American plate includes most of the continental lithosphere of North and South America.
- Most part of the Eurasian plate is continental lithosphere, but it is fringed on the west and north by a belt of oceanic lithosphere.
- <u>*African Plate is also known as the Nubia Plate*</u>. It is a mix of continental and oceanic lithosphere.
- The great Pacific plate occupies much of the Pacific Ocean basin and consists *almost entirely of oceanic lithosphere.*
- The Antarctic plate is almost completely enclosed by a spreading plate boundary. This means that the other plates are moving away from the pole. The continent of Antarctica forms a central core of continental lithosphere completely surrounded by oceanic lithosphere.
- The *Austral-Indian plate is mostly oceanic lithosphere but contains two cores of continental lithosphere– Australia and peninsular India.* The recent studies show that they may be different parts of two different plates.

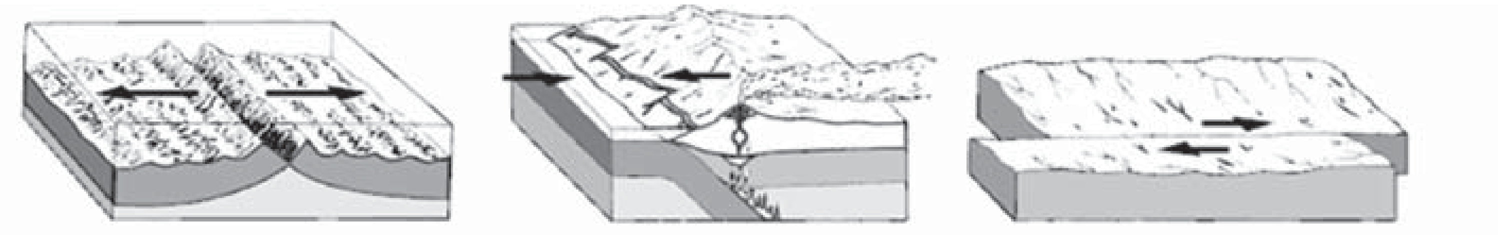
Plate Boundaries

The above discussed Lithospheric Plates are composed of lithosphere, about 100 km thick, that "float" on the plastic asthenosphere. While the continents do indeed appear to drift, they do so only because they are part of larger plates that float and move horizontally on the upper mantle asthenosphere. The plate boundaries can be identified <u>***because they are zones along which maximum earthquakes occur***</u>. Plate interiors have much fewer earthquakes.

There are three types of plate boundaries:

- Convergent Plate Boundaries: where plates move toward each other.
- Divergent Plate boundaries: where plates move away from each other.

- Transform Plate Boundaries: where plates slide past one another.

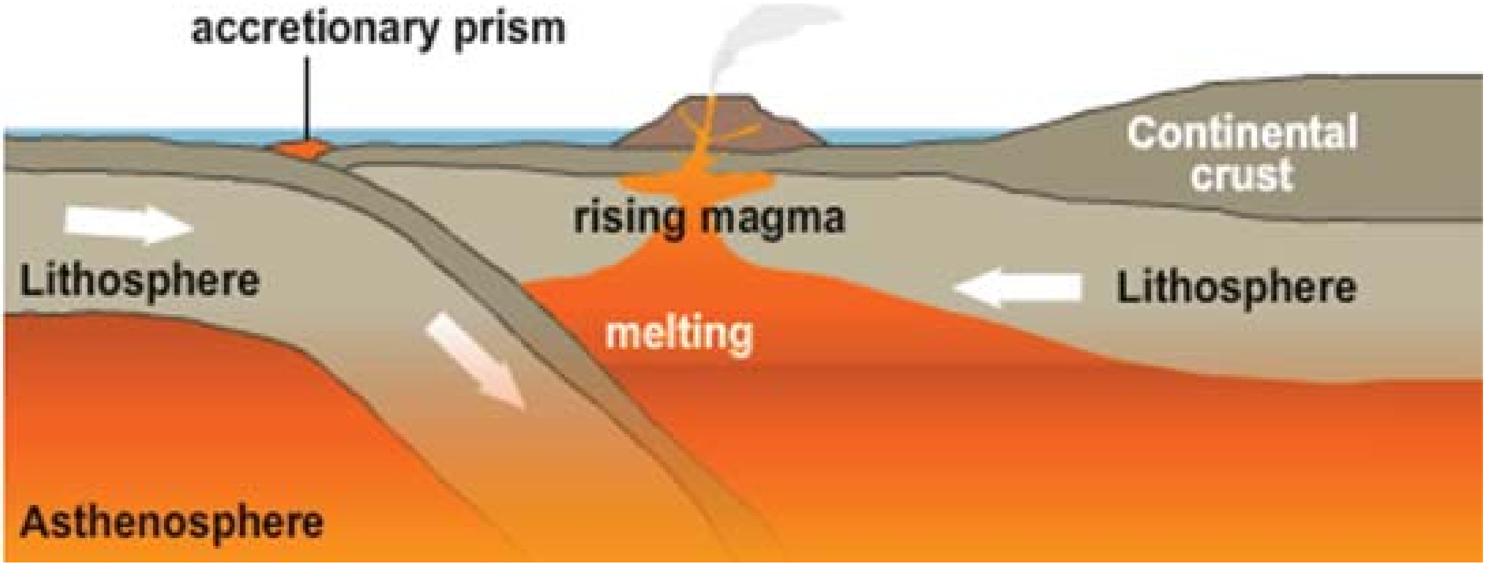


Convergent Plate Boundaries

The convergent plate boundaries are also responsible for nearly ***75% of Earth's volcanoes.*** There are following types of Convergent Boundaries:

Ocean-Ocean Convergent Plate Boundary

When two oceanic plates meet and collide against each other, the denser of the two plates is pulled under the other and is subducted. It descends into the asthenosphere, or upper mantle, where it will lead to the generation of new magma. Such boundary would be called an Ocean-ocean convergent plate boundary.



Please note that when one oceanic plate is subducted under the other, the resulting new magma is less dense than the surrounding rock. Therefore it easily rises and erupts on the seafloor, ultimately building a volcano or a volcanic island in the sea. Areas of ocean-ocean convergence are characterized by ocean trenches, seafloor volcanoes, and volcanic islands.

Island Volcanic Arc

At ocean-ocean convergent boundaries, the resulting body of many volcanoes is called an island volcanic arc. An island volcanic arc may include islands that develop in the sea from the build-up of volcanic rocks. Thus, Island volcanic arcs are a chain of islands and mountains that form on the overriding or non-subducting oceanic plate. *Examples of such arcs are Japan, the Philippines, the Tonga Islands, the Aleutian Islands, and the West Indies Islands etc. All of them have developed parallel to the direction of subduction.*

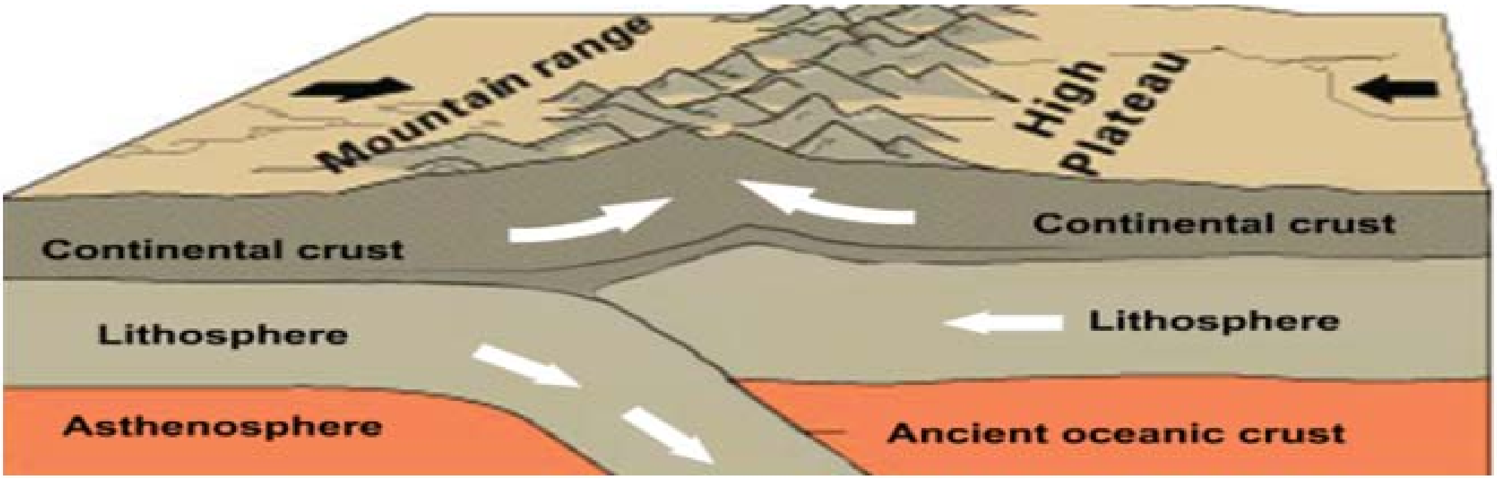
Ocean-Continental Convergent Boundary

Convergence of an oceanic plate with a continental plate is similar to ocean-ocean convergence and often results in the volcanic. *When an oceanic plate collides with a continental plate, the oceanic plate is always pulled under and subducted because it is denser than the continental plate.* When the oceanic plate is subducted under the continental plate, it leads to the generation of new magma, which upwells and forms volcanoes on the non-subducting plate, or the continental plate. Thus Volcanoes are common on Ocean-Continent Boundary also. At ocean-continent boundaries, the resulting body of volcanoes is called a continental volcanic arc. Continental volcanic arcs are chains of volcanoes found on the margin of the continent above a subduction zone at ocean-continent boundaries.*The most visible example is Andes Mountains off the west coast of the U.S.*

Here we should also note that Pacific Ring of Fire, where subduction is taking place at numerous trenches that border the continental shores, has 450 volcanoes, more than 75% of all the volcanoes on Earth. This makes plate convergence responsible for nearly all volcanic activity on Earth.

Continent-Continent Boundary

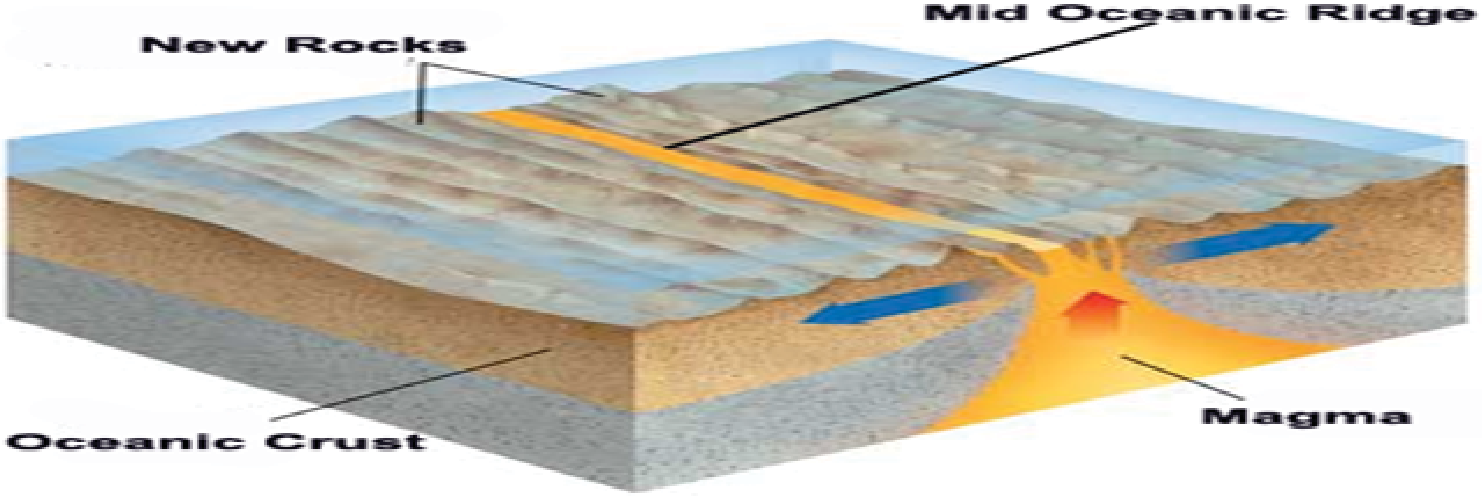
When the continent and continent converge, the crust at both the sides is too light and buoyant to be subducted, so neither plate is subducted in continent-continent convergent boundary. Both continental masses press against the other, and both become compressed and ultimately fused into a single block with a **folded mountain belt forming between them**.



- This is the type of activity is responsible for forming the Himalayas, and is still going on. The Himalayas are still growing, as we all know.
- Please note that due to intense pressure between the colliding plates, metamorphic rocks formation is common at such boundaries.
- Please also note that Volcanoes are not common at Continent-continent convergent boundaries because there is no subduction of plates. Subduction is prerequisite for formation of the new magma.

Divergent Plate Boundaries

The Continental Drift Theory says that all the continents were once joined together in one giant supercontinent called Pangaea. Because of plate tectonics, Pangaea broke apart and the continents began their slow migration to their present locations. The Atlantic Ocean opened up in between North America and the west coasts of Europe and Africa. The agent for causing this is the Mid-Atlantic Ridge, a divergent plate boundary, where two plates are rifting and moving away from each other. Thus, divergent plate boundaries are places of extension stress, where the crust is being extended, thinned, and rifted.



In the convergent plate boundaries are the**destructive plate boundaries** where the crustal material is consumed at the subduction zones. However, the divergent plate boundaries are ***constructive boundaries because it leads to formation of new Lithosphere*** The creation of the new crustal material takes place at mid-ocean ridges, where the oceanic crust is rifted open and magma wells up to fill the opening. The magma then hardens to form the igneous rocks that make up the oceanic crust. This is the mechanism which forms maximum amount of rock material on earth.

Comparison: Divergent and Convergent Plate Boundaries

Kindly note & remember the following points:

Convergent Boundaries	Divergent Boundaries
Explosive Volcanoes	Quite, Non explosive volcanoes
High Silicic Magma: The magma comes from the subduction of lithospheric crust so it has more of silicate.	High Basaltic Magma: Oceanic crust is created at the mid-oceanic ridges; it forms from up welling magma that cools and solidifies to igneous rock. Most of this is Basaltic.
Stratovolcanoes	Shield Volcanoes
Consumption of the Ocean Floor	Creation of Ocean Floor

Convergent Boundaries	Divergent Boundaries
Shallow, Intermediate as well as Deep Focus Earthquakes	Shallow Focus earthquakes only

Continental Rift Zones

Please note that the divergent plate boundaries can also develop on the continents, and here, we name them as Continental Rift Zones. Most of the features of Oceanic Divergent boundaries are valid for them also such as *thinned crust; normal faults; shallow earthquakes; basaltic volcanoes etc.*

While the Continental Rift Zones develop, the earth is stretched and thinned, leading to development of a small body of water. When the rifting keeps continuing, the body of water grows bigger to form a juvenile ocean. After millions of years of rifting, the body of water becomes a mature ocean with two separate continents on each side. Red Sea and Gulf of Aden is the best example of this phenomenon.

Transform Plate Boundary

Transform plate boundaries are places where two plates are sliding past each other. At these boundaries, the plates are neither compression nor extension stress, but are under shear stress. Then there is neither creation nor consumption of the lithospheric material. So, the transform plate boundaries are basically faults and nothing else.

The transform plate boundaries can cause horizontal displacement of hundreds of kilometers of land on the continents which results in several types of landscapes such as ridges and troughs. In oceans, transform plate boundaries are part of fracture zones. *Earthquakes are most common at transform plate boundaries. Volcanoes rarely develop at transform plate boundaries because transform boundaries do not allow for the upwelling or new creation of magma.*

Earthquakes & Seismic Waves

In Earthquake, there is a sudden release of energy in the**Earth's crust**, which leads to a series of motions because of the waves created due to this energy (called seismic waves) released. These seismic waves originate in a limited region and spread in all directions.

Types of Earthquakes

Earthquakes can be generated by a number of sources, most of which are result of natural tectonic processes, usually caused by the interaction between two lithospheric plates. Other quakes can be generated by volcanoes as magma is injected into the Earth's crust. For example, earthquakes in the island of Hawaii are generally volcanic earthquakes. Rest of the Earthquakes are artificially generated by nuclear test explosions. Thus, there are several types of Earthquakes such as:

- **Tectonic Earthquakes:** Tectonic Earthquakes are most commonand generated due to folding, faulting plate movement.

- **Volcanic Earthquakes:** Earthquake associated with volcanic activity are called volcanic earthquake. These are confined to areas of volcanoes and pacific ring of fire is best example of these types of earthquakes.
- **Collapse Earthquakes:** They are evident in the areas of intense mining activity, sometimes as the roofs of underground mines collapse causing minor tremors.
- **Explosion earthquakes:** This is a minor shock due to the explosion of the nuclear devices.
- **Reservoir Induced Earthquakes:** Large reservoirs may induce the seismic activity because of large mass of the water. They are called reservoir induced earthquakes

Foreshocks, Mainshocks and Aftershocks

The Earthquakes come in three forms of clusters called foreshocks, mainshocks, and aftershocks. Foreshocks are quakes that occur before a larger one in the same location; around a quarter of all mainshocks happen within an hour of their foreshock. Mainshocks and aftershocks are better known. Mainshocks are of the highest magnitude. Aftershocks are smaller quakes that occur in the same general geographic area for days-and even years-after the larger, mainshock event.

Hypocentre and Epicentre

The point, where earthquakes are generated first, is called focus or hypocenter. A hypocenter is below the surface, where the first rock displaces and creates the fault. Epicentre is the point on the Earth's surface that is directly above the hypocenter or focus. This is the point where the shock waves reach the surface. Earthquakes originate at depths ranging from about 5 to 700 kilometers. Nearly *90 percent of all earthquakes occur at depths of less than 100 km. Shallower is the depth, more destructive an earthquake is.*

Mechanism of Tectonic Earthquakes

Theory of plate tectonics explains that earth's crust is formed by a number of large plates that move very slowly in various directions on the earth's surface. These plates are 60-200 km thick and float on top of a more fluid zone, much in the way that icebergs float on top of the ocean. Most earthquakes occur near a boundary between two plates. As one plate pushes past or moves over another, great stresses build up in the rock along the edges of the plates because friction prevents them from sliding past each other. Subsequently, the stresses become great enough so that the rocks can rupture. The edges of the plates slip a short distance in different directions, causing an earthquake. Greater the stresses, greater is the resulting earthquake. The movements are of three kinds

Divergent:

In divergent movements the plates move apart from each other. This is most common type of movement in mid-oceanic zones.

Convergent

In convergent movements the plates move towards each other and the border overlap. This is most common type of movement in subduction zones where the dense oceanic plates collide and slide beneath the continental plates.

Transformational

In this type of movement the plates move in opposite side, on parallel. Some earthquakes are caused by the movement of lave beneath the surface of the earth during volcanic activity.

Earthquake Belts

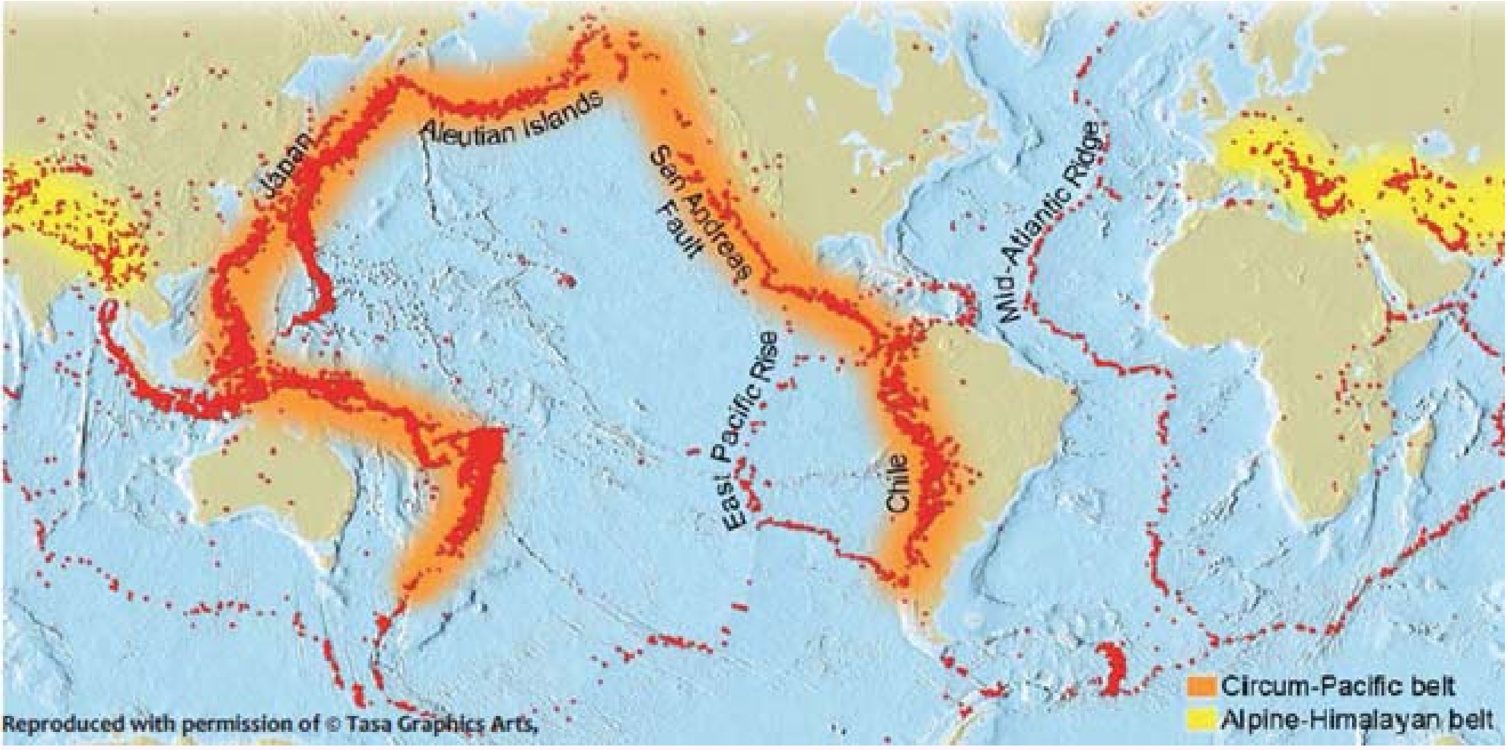
There are two major belts of earthquakes in the world. They are as follows:

Circum-Pacific Belt

This belt is along a path surrounding the Pacific Ocean This zone included the regions of great seismic activity such as Japan, the Philippines, and Chile. This path coincides with the “Pacific Ring of Fire”.

Alpine-Himalayan Belt

Another major concentration of strong seismic activity runs through the mountainous regions that flank the Mediterranean Sea and extends through Iran and on past the Himalayan Mountains. This zone of frequent and destructive earthquakes is referred to as the Alpine-Himalayan belt.



Earthquake Magnitude and Earthquake Intensity

Earthquake Magnitude and **Earthquake Intensity** are two terms often misunderstood. Earthquake magnitude is a measure of the size of the earthquake reflecting the elastic energy released by the earthquake. It is referred by a certain real number on the Richter scale (such as magnitude 6.5 earthquake).

On the other hand, earthquake intensity indicates the**extent of shaking** experienced at a given location due to a particular earthquake. It is referred by a Roman numeral (such as VIII on MSK scale). Intensity of shaking at a location depends not only on the magnitude of the earthquake, but also *on the distance of the site from the earthquake source and the geology / geography of the area*. We note here that the ***Isoseismals** are the contours of equal earthquake intensity*. The area that suffers strong shaking and significant damage during an earthquake is termed as ***meizoseismal region.***

Richter Magnitude Scale

The concept of **earthquake magnitude** was first developed by Richter and hence the term "Richter scale". The value of magnitude is obtained on the basis of recordings of earthquake ground motion on seismographs.

Richter magnitude scale is a base-10 logarithmic scale obtained by calculating the logarithm of the shaking amplitude of the largest displacement from zero on **Wood-Anderson torsion** seismometer. It was developed in 1935 by Charles Richter in partnership with Beno Gutenberg, both of the California Institute of Technology.

Since in this scale, Earthquake magnitude is measured on a log scale, a small difference in earthquake recording on the instruments leads to a much smaller error in the magnitude. An increase of 1 in the

Richter magnitude, there is a tenfold **increase in the size of the waves also known as shaking amplitude**. The Richter scale 5.0 is 10 times more shaking amplitude of 4.0. But there is a huge difference in energy. The energy release of an earthquake denotes the destructive power. It scales with $^3/_2$ power of the shaking amplitude. A difference in magnitude of 1.0 is equivalent to a factor of 31.6. This is shown by the following equation:

$$(10^{1.0})^{\frac{3}{2}} = 31.6$$

A difference in magnitude of 2.0 is equivalent to a Factor of 1000. It is shown below:

$$(10^{2.0})^{\frac{3}{2}} = \frac{100^3}{100^2} = \frac{1000000}{10000} = 1000$$

With increase in magnitude by 1.0, the energy released by the earthquake goes up by a factor of about 31.6. Thus, a magnitude 8.0 earthquake releases about 31 times the energy released by a magnitude 7.0 earthquake, or about 1000 times the energy released by a magnitude 6.0 earthquake. There are no upper or lower bounds on earthquake magnitude. In fact, magnitude of a very small earthquake can be a negative number also. Usually, earthquakes of magnitude greater than 5.0 cause strong enough ground motion to be potentially damaging to structures. Earthquakes of magnitude greater than 8.0 are often termed as great earthquakes

Following table shows the exponential increase in earthquake energy on Richter scale:

Richter Approximate Magnitude	Approximate TNT for Seismic Energy Yield
1.0	474 g (1.05 lb)
2.0	15.0 kg (33.1 lb)
3.0	474 kg (1050 lb)
4.0	15.0 metric tons
5.0	474 metric tons
6.0	15.0 kilotons
7.0	474 kilotons
8.0	15.0 megatons
9.0	474 megatons
10.0	15.0 gigatons

Examples of the most devastating Earthquake recorded are Indian Ocean Earthquake 2004, which caused the 2004 Indian Ocean Tsunami and the **Valdivia earthquake** (Chile), 1960. The Indian

Ocean Earthquake was of 9.3 intensity in Richter scale while the**Valdivia earthquake of Chile was 9.5**. An earthquake of 10.0 on Richter scale has never been recorded by Humankind. The 2010, Haiti Earthquake was 7.0 on the Richter scale. The undersea megathrust earthquake off the coast of Japan that occurred on 11 March 2011 was **9.0** on Moment Magnitude Scale.

Moment Magnitude Scale

The Richter scale is denoted by $\mathbf{M_L}$. This scale was replaced in 1970s by the new Moment magnitude scale which is denoted as $\mathbf{M_w}$. The scale is almost same and media uses the same term "Richter Scale" for the new MMS also. This is because medium earthquakes such as 5.0 are equal on both the scales. The Richter scale was based on the ground motion measured by a particular type of seismometer at a distance of 100 kilometers from the earthquake, and Richter scale has a highest measurable magnitude. The large earthquakes have a similar magnitude of around 7.0 on Richter scale. The Richter scale measurement is also unreliable for measurements taken at a distance of more than about 600 kilometers from the earthquake's epicenter. This problem is solved by the MMS (Moment magnitude scale). The Moment magnitude scale does not uses the ground motion, but used the physical properties of the Earthquake such as seismic moment. The scale was introduced by Thomas C. Hanks and Hiroo Kanamori in 1979. The US Geological survey uses the Moment magnitude scale for all large earthquakes. Drawback: Moment magnitude scale deviates at the low scale Earthquakes.

Shindo Scale

Shindo scale is also known as Japan Meteorological Agency (JMA) seismic intensity scale. It is used in Japan and Taiwan to measure the intensity of earthquakes. It is measured in units of Shindo which literally means degree of shaking. Unlike the moment magnitude scale, which measures the energy released by the earthquake, the JMA scale describes the degree of shaking at a point on the Earth's surface. Thus it is similar to Mercalli intensity scale. The Shindo Scale ranges between Shindo-0 to Shindo-7. Shindo-0 quake is not felt by most people, while Shindo-7 is most devastating earthquake. However, note that same earthquake has different Shindo numbers at different places. For example, 2011 Great Earthquake of Japan registered Shindo-7 at Kurihara, Miyagi Prefecture, while Shindo-6 at Fukushima, Ibaraki and Tochigi and Shindo-7 in Tokyo.

Medvedev-Sponheuer-Karnik scale (MSK-64)

Prior to the development of ground motion recording instruments, earthquakes were studied by recording the description of shaking intensity. This lead to the development of intensity scales which describe the effects of earthquake motion in qualitative terms. An intensity scale usually provides ten or **twelve grades of intensity** starting with most feeble vibrations and going upto most violent (i.e., total destruction). The most commonly used intensity scales are: Modified Mercalli (MM) Intensity Scale and the Medvedev-Sponhener-Karnik (MSK) Intensity Scale. Both these scales are quite similar except that the MSK scale is more specific in its description of the earthquake effects. Medvedev-Sponheuer-Karnik scale denoted by MSK or MSK-64, is a macro seismic intensity scale which is used to evaluate the severity of ground shaking on the basis of observed effects in an area of the earthquake occurrence. It was proposed by Sergei Medvedev (USSR), Wilhelm Sponheuer (East Germany), and Vft Karnfk (Czechoslovakia) in 1964.

*MSK-64 is used in India, Israel, Russia, and throughout the Commonwealth of Independent States.*In India the *seismic zoning has been done on the basis of this scale*. This scale has 12 intensity degrees expressed in Roman numerals, which are shown in the below graphics.

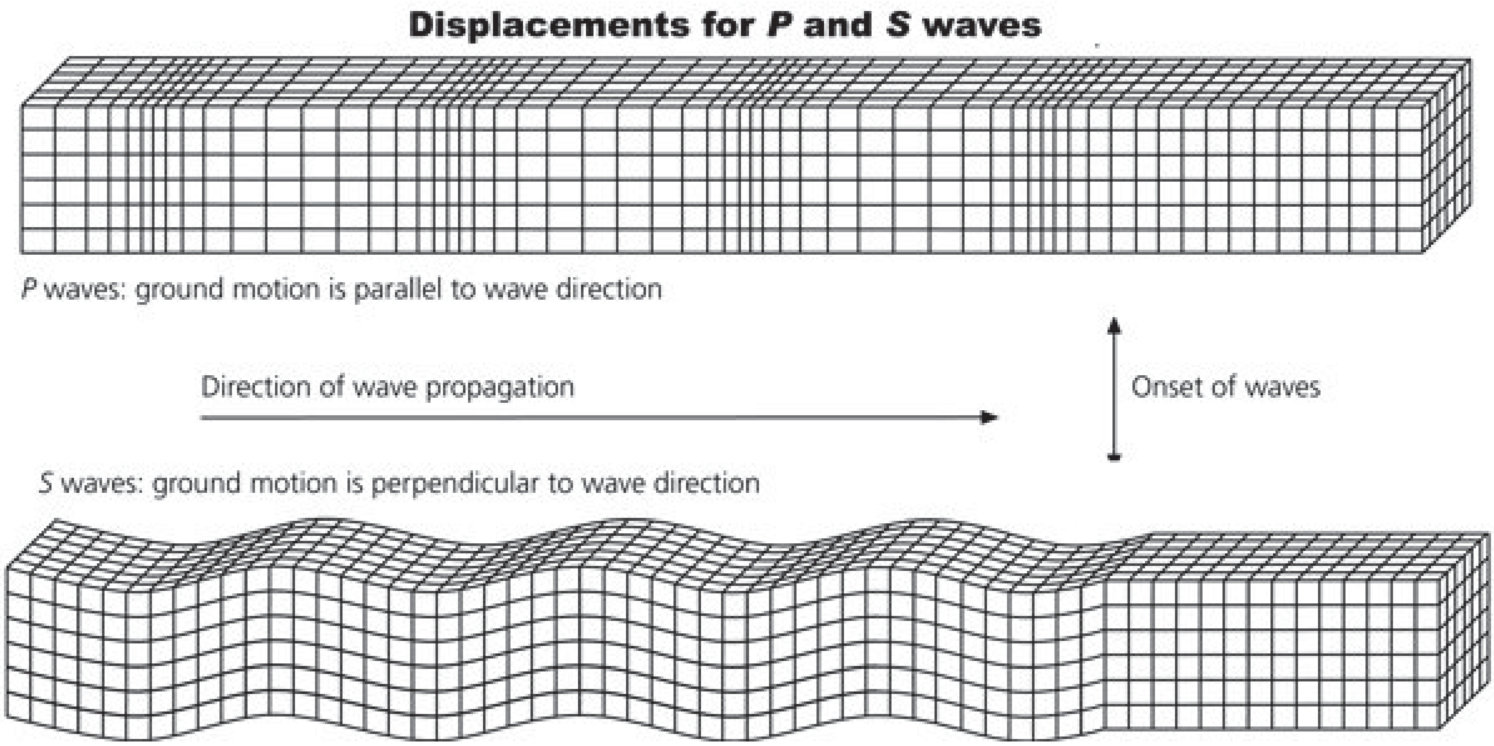
	MSK 64 Scale
	Not perceivable
II	Hardly perceivable
III	Weak
IV	Largely Observed
V	Fairly Strong
VI	Strong
VII	Very Strong
VIII	Damaging
IX	Destructive
X	Devastating
XI	Catastrophic

Seismic Waves

The waves generated by the earthquake are called Seismic waves. The study of earthquake and seismic waves is called Seismology and the researchers are called Seismologists. Seismic waves are divided into two broad categories viz. Body Waves and Surface Waves.

Body waves

In Body waves the speed decreases with increasing density of rock and increases with increasing rock elasticity. Rock elasticity increases faster than density with depth. There are two kinds of body waves viz. P-waves and S-waves.



Primary Waves or P-waves

The **Primary waves** or **Push waves** are *longitudinal / compression* waves that vibrate parallel to the direction of wave movement. They have shortest wavelength, fastest speed {5-7 km/s} and can travel through *solid, liquid and gas. They travel fast in denser, solid materials.*

Secondary waves or S-waves

Secondary waves or **Sheer waves** or **shock waves** are *transverse waves* which create vibrations perpendicular to the direction of wave movement. The S waves only travel through solids because liquids and gases have no sheer strength.

They have a medium wavelength and cause vibrations at right angles to the direction of propagation of waves. Their velocity is 3 to 4 km per second.

Surface Waves

Surface waves are of two types viz. Rayleigh Waves and Love waves

Rayleigh Waves or L-waves

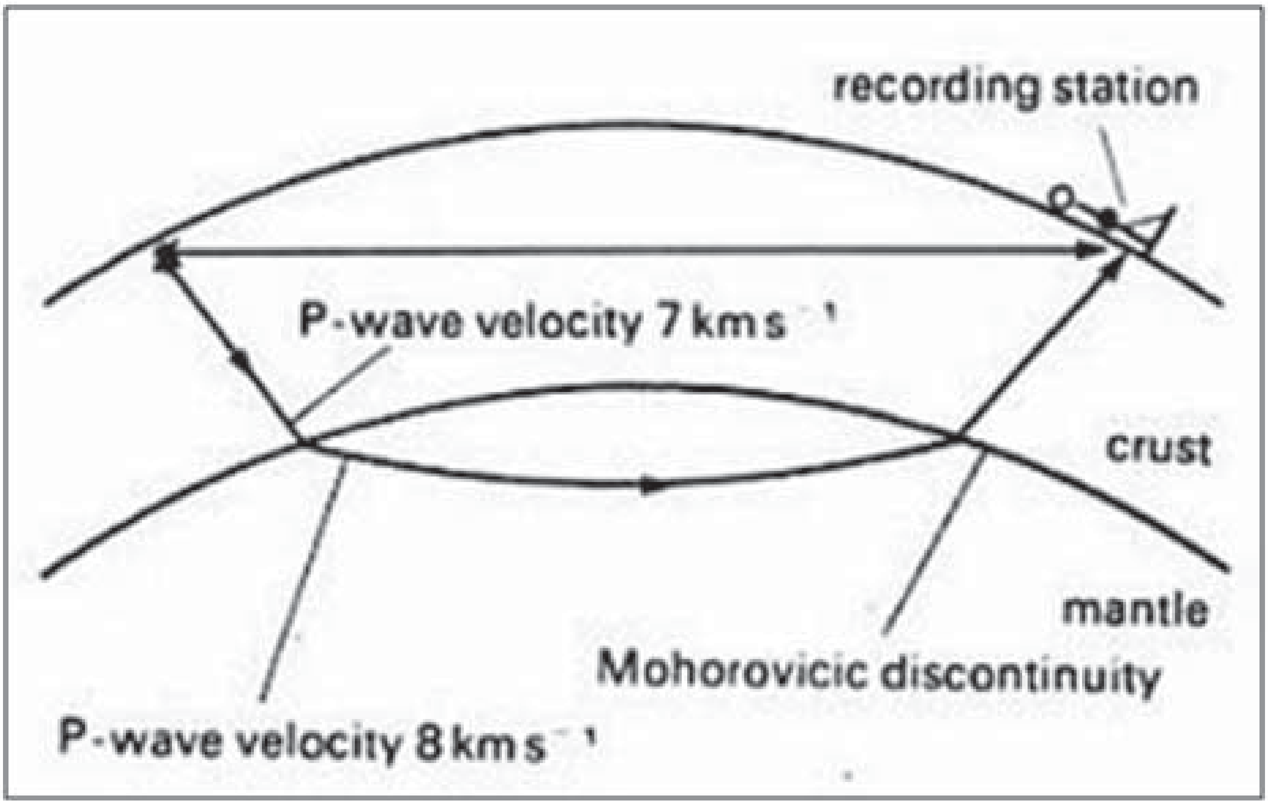
L Waves or Surface Waves travel near the earth's surface and within a depth of 30-32 kilometers from the surface. These are also called Rayleigh waves after Lord Rayleigh who first described these waves. Behave like water waves with elliptical motion of material in wave. Generally slower than Love waves.

Love waves

Love waves make the ground vibrate at right angles to the direction of waves . They are a variety of S-waves where the particles of an elastic medium vibrate transversely to the direction of wave propagation, with no vertical components. Involve shear motion in a horizontal plane. Most destructive kind of seismic wave.

How Seismic waves help in defining Earth's interior?

The speed of the **seismic waves varies with the composition of the medium** In earth crust their speed is around 2-8 kilometers per second, while in mantle the speed is up to 13 kilometer per second, because mantle is denser. In his observations, Mohorovičić found that when the focus of the Earthquake is not too deep, some waves are propagated along the surface and remains in the crust, while other *set enters the mantle, speeds up and reaches the seismometer first*.This means that for a seismograph stations located at about 150 Kilometers from a shallow focus earthquake epicentre received those waves first which came from beneath the ground via mantle. This was enough to conclude that there is something below earth crust which has a greater density and varied composition. It was later called Mohorovičić discontinuity or simply Moho.



The above finding led to determine that mantle is denser than crust and is viscous, semi-molten material. P-wave velocities are much slower in the outer core than in the deep mantle while S-waves do not travel at all in the liquid portion of the outer core.

Role of Seismic waves in determination of Epicentre

To determine the location of an earthquake, the following two things of info are required:

- Recorded seismograph of the earthquake from**at least three seismographic** stations at different distances from the epicentre of the quake.
- Time it takes for P-waves and S-waves to travel through the Earth and arrive at a seismographic station.

As we know that the P waves reach the to the seismographs first at a station, the difference between the time of P waves and S waves is called S-P Interval. **The S-P interval increases with increasing distance from the epicentre**. At each station a circle on a map can be drawn which has a radius equal to the distance from the epicenter.

Earthquake Shadow Zone

Seismic waves recorded at increasing distances from an earthquake indicate that seismic velocities gradually increase with depth in the mantle. However, at arc distances of between about 105° and 140° no P waves are recorded. Furthermore, no S waves are record beyond about 105°. This is called Shadow zone.

Earthquakes in India

India has a very ***high frequency of great earthquakes*** (magnitude greater than 8.0) ***in comparison to the moderate earthquakes*** (magnitude 6.0 to 7.0). For example, during 1897 to 1950, India was hit by four great earthquakes. However, since 1950, only moderate size earthquakes have occurred in India which should be no reason to assume that the truly great earthquakes are a thing of the past.

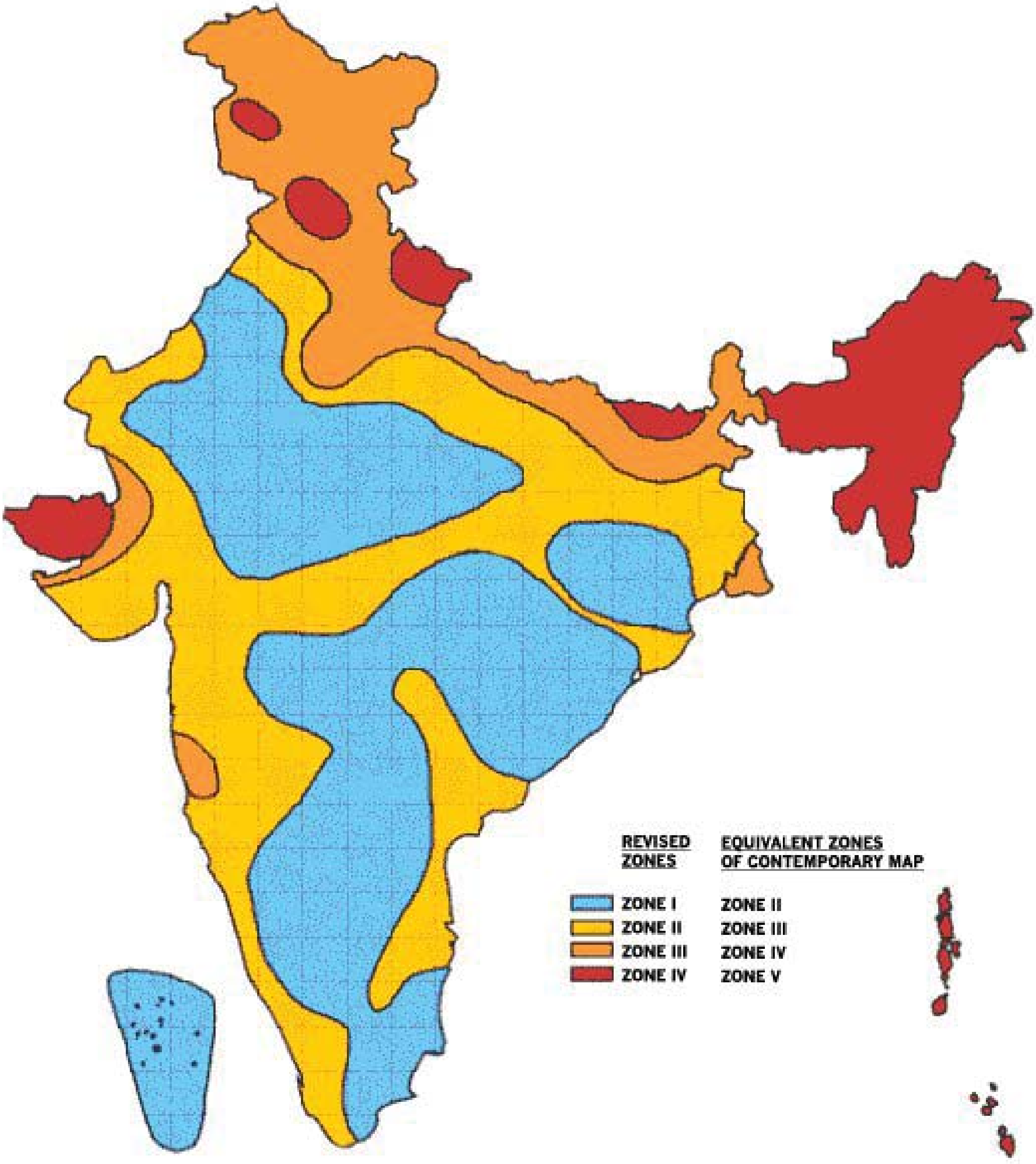
The reasons of high magnitude earthquakes in India are hidden in the tectonic setting of India. India is currently penetrating into Asia at a rate of approximately 45 mm/year and ***rotating slowly anticlockwise***. This rotation and translation results in left-lateral transform slip in Baluchistan at approximately 42 mm/year and right-lateral slip relative to Asia in the Indo-Burman ranges at 55 mm/year. At the same time, deformation within Asia reduces India's convergence with Tibet to approximately 18 mm/year. Since Tibet is extending east-west, there Is a convergence across the Himalaya that results in the development of potential slip available to drive large thrust earthquakes beneath the Himalaya at roughly 1.8 m/century.

Seismic Zoning of India

Indian subcontinent has a long history of devastating earthquakes, partially due to the fact that India is driving into Asia at a rate of approximately 47 mm/year. More than 50% area of Indian Subcontinent is vulnerable to earthquakes. According to the IS 1893:2002 (It is the latest code of Bureau of Indian Standards (BIS) which lays down the criteria of for earthquake resistant design of structures), India has been divided into four seismic zones viz. Zone-II, -III, -IV and -V unlike its previous version which consisted of five zones for the country. After some revisions in the previous zoning, Zone I was altogether removed.

This zoning has been done on the basis of MSK-64 scale and a IS code Zone factor has been assigned by the BIS to each of them. The zone factor of 0.36 is indicative of effective (zero period) peak horizontal ground acceleration of 0.36 g (36% of gravity) that may be generated during MCE level earthquake in this zone. They are presented in the following table with IS code.

Seismic Zoning of India		
MSK-64	Seismic Zone	Zone Factor
VI. Strong	Zone II This region is liable to MSK VI or less and is classified as the Low Damage Risk Zone	0.10
VII. Very Strong	Zone III The Andaman and Nicobar Islands, parts of Kashmir, Western Himalayas fall under this zone. This zone is classified as Moderate Damage Risk Zone which is liable to MSK VII.	0.16
VIII. Damaging	Zone IV This zone is called High Damage Risk Zone anc covers Indogangetic Basin, Delhi, Jammu and Bihar	0.24
IX. Destructive	Zone V Zone 5 covers areas with the highest risk zone that suffers earthquakes with intensity of IX and greater. It includes Kashmir, Punjab, Western and central Himalayas, North East India and Rann of Katch	0.36



Some Great Indian Earthquakes

India has suffered some of the greatest earthquakes in the world with magnitude exceeding 8.0. For instance, in a short span of about 50 years, four such earthquakes occurred: Assam earthquake of 1897 (magnitude 8.7), Kangra earthquake of 1905 (magnitude 8.6), Bihar-Nepal earthquake of 1934 (magnitude 8.4) and the Assam-Tibet earthquake of 1950 (magnitude 8.7).

Katch Earthquake of 1819

This 8.3 magnitude earthquake took place on the west coast of India and caused ground motion which was perceptible as far as Calcutta. It created a fault scarp of about 16 mile long and about 10 foot high which was later named as "Allah Bund".

Assam earthquake of 1897

This 8.7 magnitude earthquake caused severe damage in an area of about 500 km radius and caused extensive surface distortions in the area. The earthquake caused extensive liquefaction in the alluviated plains of Brahmaputra.

Bihar – Nepal Earthquake Of 1934

This 8.4 magnitude earthquake caused wide-spread damage in the northern Bihar and in Nepal. Due to extensive liquefaction, most buildings tilted and slumped bodily into the ground in an area of about 300 km long and of irregular width. This area was termed as the "slump belt".

Koyna Earthquake Of 1967

This 6.5 magnitude earthquake occurred close to 103 metre concrete gravity dam at Koyna. Prior to this earthquake, the area used to be considered aseismic. However, after the construction of dam and filling up of reservoir in 1962, the seismic activity increased significantly.

The main shock of December 10, 1967 caused widespread damage, killing about 200 persons and injuring more than 1500 persons. This was an example of the reservoir-induced seismicity in India. The dam, designed keeping in mind the possible seismic activity, performed quite well with only nominal damage to the dam. This earthquake lead to the revision of Indian seismic zone map wherein the area around Koyna was brought in zone IV from zone I, and seismic zone for Bombay was upgraded from zone I to zone III.

Uttarkashi Earthquake Of 1991

This 6.6 magnitude earthquake shook the districts of Uttarkashi, Tehri, and Chamoli of current Uttarakhand.

Killari (Latur) earthquake of 1993

This was a magnitude 6.4 earthquake that shook the area near village Killari in Latur district killing about 8,000 persons. Until this earthquake the area was considered non-seismic and placed in the lowest seismic zone (zone I) by the Indian code (IS:1893-1984).

The affected area did not have any modern towns, modern buildings or major industries. In some of the villages more than 30% of the population was killed. This earthquake will be known for outstanding rescue, relief and rehabilitation.

Jabalpur Earthquake Of 1997

This magnitude 6.0 earthquake is only example of such earthquakes which occurred close to a major Indian city in recent times.

2004 Indian Ocean earthquake and tsunami

The 2004 Indian Ocean earthquake was an undersea megathrust earthquake with an epicentre off the west coast of Sumatra, Indonesia, and it is known as Sumatra–Andaman earthquake or 2004 Indian Ocean tsunami or South Asian tsunami, Indonesian tsunami, and the Boxing Day tsunami. It killed 230,000 people in fourteen countries, and inundating coastal communities with waves up to 30 meters.

Impact of Earthquakes – Liquefaction

Earthquakes can cause soil liquefaction where loosely packed, water-logged sediments come loose from the intense shaking of the earthquake. The liquefaction is more prominent in areas such as river valleys, river plains and deltas. The randomly bunched together soil particles have spaces have formed between them. These spaces, called pores, can be filled with water or air. The pressure of the material in the spaces holds the particles apart and stabilizing the soil in its present configuration.
The effect of a seismic wave on granular soil and pore pressure is that it increases the water pressure and forces the particles apart as well as disrupts the contact point of the particles themselves. At this point in time the soil will flow like a liquid. The end product is the collapse of the particles so that there is less space between them. The water that was in that space is then forced upward. Liquefaction should have the following conditions for it to take place:

- Water table is less deep
- The soil has pore spaces
- The intensity of shaking in that area is viii or greater

The impacts of the Liquefaction are as follows:
The underlying layer of water rich sand compacts and sends a column of water and fine sand up and out onto the surface. This phenomenon is called Differential Compaction. At the same time, **depth of lakes, ponds, borrow areas, and other depressions becomes lower** because the sand is pushed through the ground. The buildings sink into the ground after the earthquake.

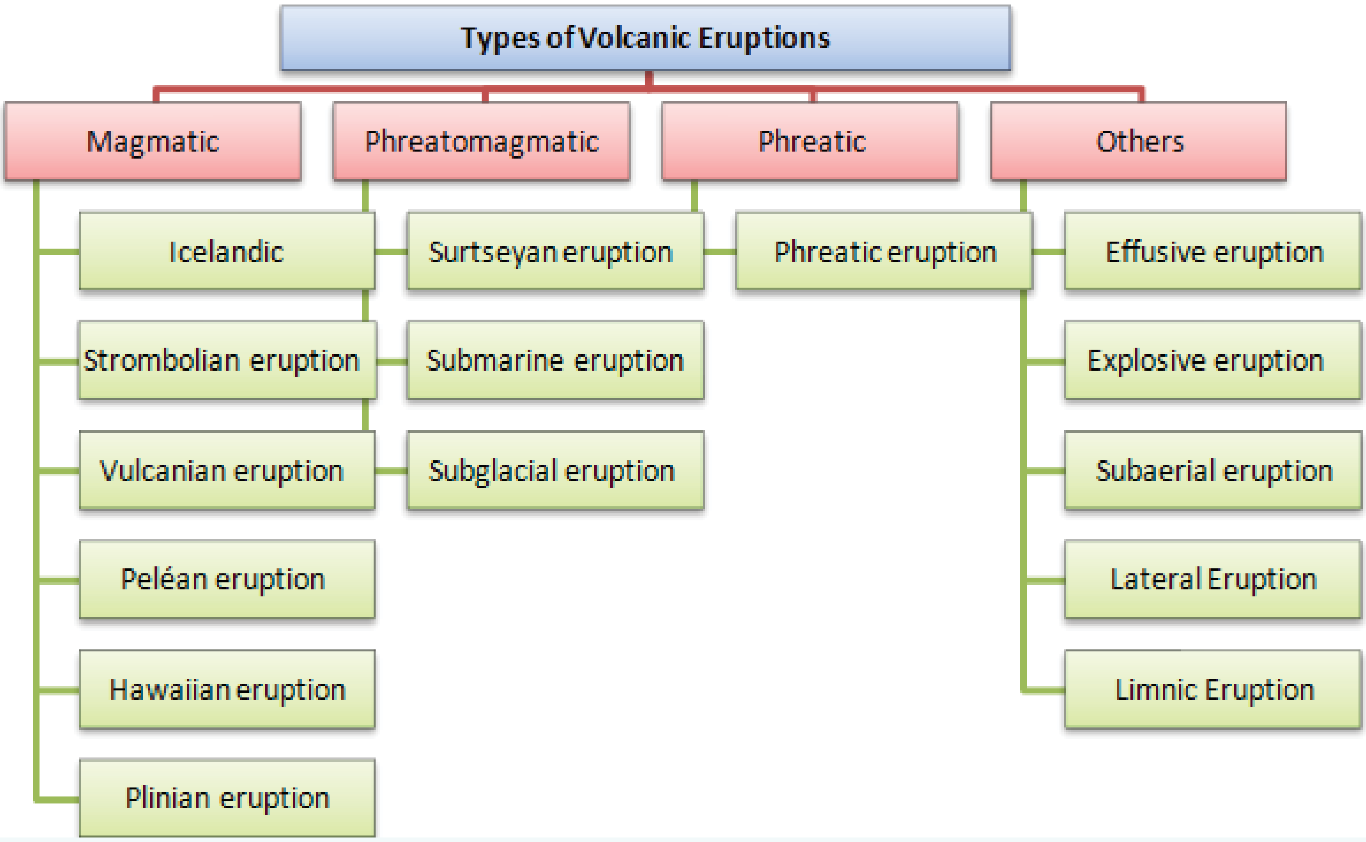
Volcanoes & Volcanism

Introduction to Volcanoes

A volcano is simply an opening in the Earth's surface in which eruptions of dust, gas, and magma occur; they form on land and on the ocean floor. The driving force behind eruptions is pressure from deep beneath the Earth's surface as hot, molten rock up wells from the mantle. The results of this activity are a number of geological features, including the build-up of debris that forms a mound or cone, which we commonly imagine when talking about a volcano.

Vulcan is Greek God of beneficial and hindering fire. Vulcanization is another term derived from the name of Vulcan God. Vulcanization is adding sulfur or other curatives to rubber or other polymers to make them more durable. The rubber so produced is called Vulcanite or ebonite. Vulcano is the name of an island near Sicily, the largest island in the Mediterranean Sea and an autonomous region of Italy.

An opening or vent through which the magma, molten rocks, ashes, gases and other volatiles erupt on the surface of Earth is called a Volcano. The most known types of Volcanoes are conical mountains which spit law and poisonous gases. But there are other types of Volcanoes. The Volcanoes can be divided in the basis of**Type of Eruption**, **Material erupted** & **Periodicity of eruption**.



Types of Volcanoes by Volcanic Eruption

There are three major categories of the volcanic eruptions. The**magmatic eruptions** involve the decompression of gas within the magma. This decompression of the gas propels it outward. In **Phretomagmatic** eruptions involves compression of the gas within the magma. Another is **Phreatic eruption** which involves superheating of steam via contact with Magma. In Phreatic eruption, there is no magmatic release and they cause the granulation of the rocks. Apart from this there are other types of eruptions which sometimes don't seem to be Volcanic Eruptions. The following graphic shows this classification.

Magmatic Eruptions

When Magma, the mixture of rocks, volatiles and solids erupts in a fissure, it is called magmatic eruption.

Pheratic Eruptions

These eruptions usually occur with extremely loud explosions. The explosions are mostly accompanied by carbon dioxide or hydrogen sulfide gas emissions which prove fatal to the organisms around. This eruption is also known as steam-blast eruption and most common example is 1979 explosion in the Java Island, which killed more than 100 people.

Other Types of Eruptions

Effusive eruption causes the lava to flow on ground slowly, and it travels slowly away from the site of eruption. Sub aerial eruptions occur on the surface in contrast with the submarine or subglacial eruption. Limnic Eruptions occur below the bed of lakes and is called Lake Overturn. The gases (mostly CO2) suddenly erupt from the bed of the lake making the water and environment poisonous killing animals. The lake tsunamis are caused by Limnic disruptions sometimes.**Lake Monoun & Lake Nyos in Cameroon** have suffered this kind of eruptions in near past.

Types of Volcanoes by Periodicity of Eruption

There are three kinds of Volcanoes on the basis of frequency of eruption viz. Active, Dormant and Extinct.

Active volcanoes

Active Volcanoes erupt frequently and mostly located around Ring of Fire. The Mount Stromboli is an active volcano and it produces so much of Gas clouds that it is called Light house of Mediterranean. Other examples are Eyjafjallajökull in island, which erupted in 2010, Mount St. Helens located in Washington USA, Mt. Etna located in Sicily.

Dormant Volcano

Dormant Volcanoes are those who are not extinct but not erupted in recent history. Mount Kilimanjaro, located in Tanzania which is also the highest mountain in Africa is known to be a dormant Volcano. **The dormant volcanoes may erupt in future.**

Extinct Volcano

Extinct or inactive volcanoes have not worked in distant geological past. In most cases the crater of the Volcano is filled with water making it a lake.

Some Notable Terms Related to Volcanoes

Tephra

Materials of all types and sizes that are erupted from a crater or volcanic vent and deposited from the air. The Tephra is all the volcanic material such as Ash, Plumes, Volcanic Bombs, Volcanic Blocks, lapilli etc.

Volcanic Bomb

Pieces of Viscous lava often 2.5 inch size are ejected from the volcanoes. They are viscous rounded shaped half semisolid pieces called Volcanic Bombs. They are either round or spindle shaped or ribbon shaped. Sometimes referred to as Volcanic Blocks, however, Volcanic blocks are thought almost same size, are solid. The smaller particles less than 2.5 inch are called**Lapilli.** The pieces of rocks that erupt violently are also called ballistic fragments.

Lapilli

Lapilli mean "little stones." These are round to angular rock fragments, measuring $^{1/10}$ inch to 2 $^{1/2}$ inches in diameter, which may be ejected in either a solid or molten state.

Volcanic Ash

The Ash from the Volcanoes is hard and abrasive type which is made up of rock particles, minetals and Volcanic glass fragments. The cloud made by the Volcanic Ash is called Ash Cloud. When this ash falls on the ground, it is called Volcanic Ash Fall. The clouds are called Avalanches sometimes.

Pillow lava

Interconnected, sack-like bodies of lava formed underwater.

Pyroclastic Rocks

It is the fragmented (clastic) rock material formed by a volcanic explosion or ejection from a volcanic vent.

Cinder Cone

A cone shape hill of volcanic fragments that accumulate around and downwind from a volcanic vent is a cinder cone. There is usually a bowl-shaped crater at the top. As the gas-filled lava erupts into the air, the lava fragments and forms cinders.

Repose

The time lag between the volcanic eruptions is called repose.

Volcanic Explosivity Index

Volcanic Explosivity Index is a scale that measures the Volume of Volcanic Products, Height of Plume and other observations to decide which volcano is more explosive. Highest Magnitude is 8.

Other Important Trivia

- There are more than 1500 active Volcanoes in the word.
- The Crater Lake in Oregaon USA was formed when a Volcano lost its top in eruption thousands of years ago.
- *The Volcanic Ash is mostly acidic.*
- The Olympus Mons is the tallest known Volcano on Planet Mars.
- Italy's Stromboli Volcano is erupting for more than 2500 years.
- The Mount St. Helense had erupted in 1980, which caused the ash travel across entire US.
- The 1883 eruption of Indonesia's Krakota eruption was so loud that blasts were heared 3000 miles away.
- Mauna Kea in Hawaii is the tallest Volcano on earth. The meaning of its name is White Mountain as it is snow capped. Its height is 4205 meter from Sea Level; however, if it measured from its oceanic base, it is the higher than mount Everest (over 10000 meters).

Pacific Ring of Fire

Pacific Ring of Fire is a horse-shoe shaped 40,000 kilometer area with 75% of Earth's active and dormant volcanoes. It is the area with large number of Volcanic Eruptions and Earth quakes. The most active Volcanoes are located in Chile, Mexico, United States, Canada, Russian Far East, Japan, Philippines, Indonesia, New Zealand, & Antarctica.

Basics of Magma

Magma is a mixture of molten or semi-molten rock, volatiles and solids. Besides molten rock it may contain suspended crystals and dissolved gases. The two most abundant elements in earth's crust and mantle are oxygen and silicon which combine to make Silica i.e SiO_2.

Types of Magma

The classification of the Magmas is done primarily on the basis **of Silica content**. On this basis there are four types of Magmas as mentioned below:

Magma Type	Silica Content	Fe-Mg Content	Temperature	Eruption	Viscosity
Ultramafic or Picritic	Less than 45%	8-32%	High up to 1500°C	Gentle	Low
Mafic or Basaltic	Around 50%	Less than 10%	Up to 1300°C	Gentle	Low

Magma Type	Silica Content	Fe-Mg Content	Temperature	Eruption	Viscosity
Andesitic	Around 60%	Around 3%	Up to 1000°C	Explosive	Medium
Felsic / Rhyolitic	Around 70%	Around 2%	Below 900°C	Explosive	High

From the above table we may note down the following observations:

- Increasing silica content is the basis of classifying the Magma from Picritic to Felsic.
- Increasing Silica content implies a lower temperature of the Magma.
- Increasing silica content implies an explosive eruption behaviour of Magma
- Increasing silica content implies an increasing viscosity of Magma.

Magma often collects in magma chambers that may feed a volcano or turn into a pluton. Magma is capable of intrusion into adjacent rocks, giving rise to **Sills and Dikes,** and extrusion onto the surface as lava, and explosive ejection as Tephra to form **pyroclastic rocks**. The Tephra is all the volcanic material such as Ash, Plumes, Volcanic Bombs, Volcanic Blocks, lapilli etc.

Gases in Magma

The gases are dissolved in magma at high pressure beneath the layers. The gas forms a separate vapor phase when pressure is decreased as magma rises toward the surface of the Earth; very much similar to the carbonated beverages which are bottled at high pressure. Gas gives magmas their explosive character, because volume of gas expands as pressure is reduced. The composition of the gases in magma is:

- Mostly H_2O (water vapour) & some CO_2 (carbon dioxide)
- Minor amounts of Sulphur, Chlorine, and Fluorine gases

The amount of gas in magma is also related to the chemical composition of the magma. Rhyolitic magmas usually have higher gas contents than basaltic magmas. That is also the reason that the Rhyolitic Magma is more explosive than the Basaltic Magma.

Formation of Magma

Outer core is the ONLY part of earth which is liquid, but ***outer core is NOT the source of Magma****, because it does not have the right chemical composition*. For instance, *the outer core is mostly Iron, but magmas are silicate liquids*. Magma originates in the lower part of the Earth's crust and in the **upper portion of the mantle**. There, high temperatures and pressure cause some rocks to melt and form magma.

Since the rest of the earth is solid, in order for magmas to form, some part of the earth must get hot enough to melt the rocks present. Then, magma does not occur everywhere below us. There are only some specific places where volcanoes exist. This means that Magma is formed under some special conditions, which exist in some limited area.

Another point is that in the ocean basins, magmas are not likely to come from melting of the oceanic crust, since ***most magmas erupted in the ocean basins are basaltic.*** To produce basaltic magmas by melting of the basaltic oceanic crust would require nearly 100% melting, which can not happen. In the continents, both basaltic and rhyolitic magmas are erupted and intruded. Basaltic magmas are not likely to have come from the continental crust, since the average composition is more siliceous, but more siliceous magmas (andesitic – rhyolitic) could come from melting of the continental crust. Basaltic magmas must come from the underlying mantle. Thus, with the exception of the continents, ***magmas*** *are most likely to originate in the mantle from* ***melting of mantle peridotite, (a rock made up of olivine, pyroxene, and garnet)*** *— evidence comes from pieces brought up by erupting volcanoes.*

Does Geothermal Gradient causes melting of Rocks?

Temperature increases with depth or pressure in the Earth along the geothermal gradient. The normal geothermal gradient is somewhat higher beneath the oceans than beneath the continents, at least at shallow levels. But when we observe the normal geothermal gradients, we find that under the normal conditions, the *geothermal gradient is not high enough to melt rocks*, that is why that with the exception of the outer core, most of the Earth is solid. Thus, the **geothermal gradient is not a very substantial factor** contributing in the formation of the Magma.

Does Radioactive Heat Cause Melting of Rocks?

The radioactive elements such as Uranium, Thorium etc, keep decaying below. During radioactive decay, sub-atomic particles are released by the decaying isotope and move outward until they collide with other atomic particles. Upon collision, the kinetic energy of the moving particles is converted to heat. If this heat cannot be conducted away, then the temperature will rise. Most of the heat within the Earth is generated by radioactive decay, and this is the general reason why temperature increases with depth in the Earth. But again *this is not enough to prove the melting of the rocks* We should know that ***most the radioactive isotopes are concentrated in the crust.*** Although there are areas in the continental crust where high concentrations of radioactive elements have locally raised the temperature, at least high enough to cause metamorphism, but it is more unlikely that areas of high concentration *develop within the mantle. Thus, concentrations of radioactive elements are not likely to cause melting.*

Does decrease in Pressure cause rock melt?

There are two things. First is that very high pressures in mantle rocks prevent atoms within minerals from breaking chemical bonds and moving freely from one another to form magma. Therefore, most rocks within the mantle do not melt even though their temperature may be greater than that necessary to melt the same rocks at the lower pressures of the Earth's surface. However, if something occurs that the pressure on mantle rock is decreased; the atoms may move freely from one another.

This would result in the partial melting of the already very hot solid rock. This process is called pressure-release melting. It is a scientifically proved theory and is found to be *common along divergent plate margins*, and within mantle plumes.

Does addition of Water causes melting?

The addition of small amounts water to peridotite will result in a decrease in its melting temperature. This is largely due to the electrically polarized nature of a water molecule, as there is an unequal distribution of electrons around the water molecule. The electrical polarization causes a decrease in cation-anion bond strengths within minerals, and so at very high temperatures the bonds may be broken so that atoms may move freely from one another to form a magma. This process also results in partial melting of the mantle rock. This type of melting occurs within subduction zones as water is 'squeezed' from the subducted oceanic lithosphere into the overlying ultramafic mantle wedge.

How Magma is finally formed?

The initial composition of the magma depends upon the composition of the source rock and the degree of partial melting. In general, melting of a mantle source (garnet peridotite) results in mafic/basaltic magmas, while melting of crustal sources yields more siliceous magmas. In general more siliceous magmas form by low degrees of partial melting. As the degree of partial melting increases, less siliceous compositions can be generated. So, melting a mafic source thus yields a felsic or intermediate magma. Melting of ultramafic (peridotite source) yields a basaltic magma. Then, the transportation toward the surface or during storage in the crust can alter the chemical composition of the magma. This is called magmatic differentiation and includes some processes such as assimilation, mixing, and fractional crystallization.

Tides

Tides are a result of gravitational pull by**both Sun and Moon**, but the pull exerted by Sun is apparently weak. This is because of the larger distance as the gravitational force is inversely proportional to the square of the distance. The alignment of Sun and moon affects the size of the tides.

Tides are known to Indians since ancient times. In Rig-Veda there was no record about Tides, but in Samveda Chapter 10, Part II, 20, mentions *Soma….samudravardhanam,* links moon to tides. In the Indus Valley Civilization, a dockyard was found in Lothal in Gujarat.The 4 walls of this dock towards the estuary are made up of kiln burnt bricks, which prove that these people not only observed but also understood and created structures as per the phenomena & impact of tides.

Earliest geographer to state that the tides are caused by moon was Pytheas, an early Greek geographer around 300 BC. But he could not understand what the reason was. Newton's analysis of gravitation explained the phenomenon.

Stages of Tides

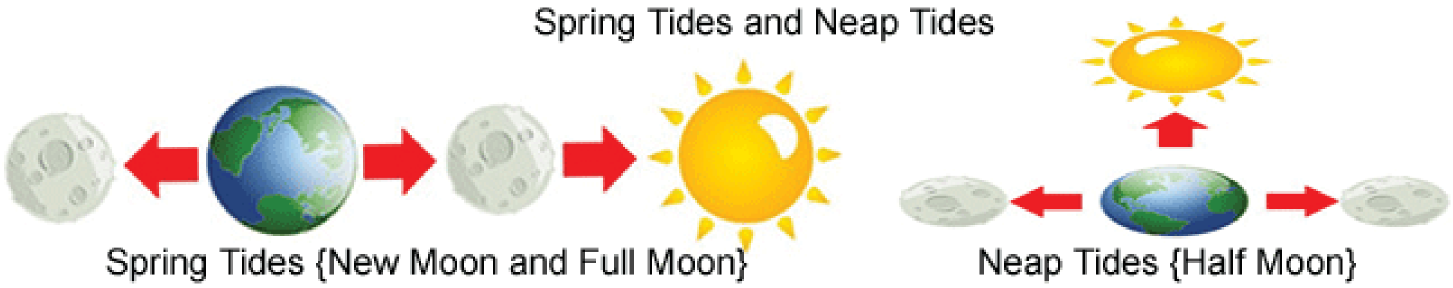
There are 4 distinct stages of tides:

- Stage I: Sea level rises over several hours, covering the intertidal zone and this is called **flood tide**.
- Stage II: The water rises to its highest level, known as **high tide**.
- Stage III: Sea level falls over several hours, revealing the intertidal zone. This is called **ebb tide**.
- Stage IV: The water stops falling, this is called **low tide**.

In general the rising tides are called *flood tides* and falling tides are called *ebb tides* and they are known as Jwar & Bhata in Hindi respectively. In astronomy, the alignment of three or more celestial bodies in the same gravitational system along a line is called **Syzygy** and eclipses occur at the time of Syzygy. Syzygy also affects tides in the form of variations between the High tides and Low Tides.

Spring Tides and Neap Tides

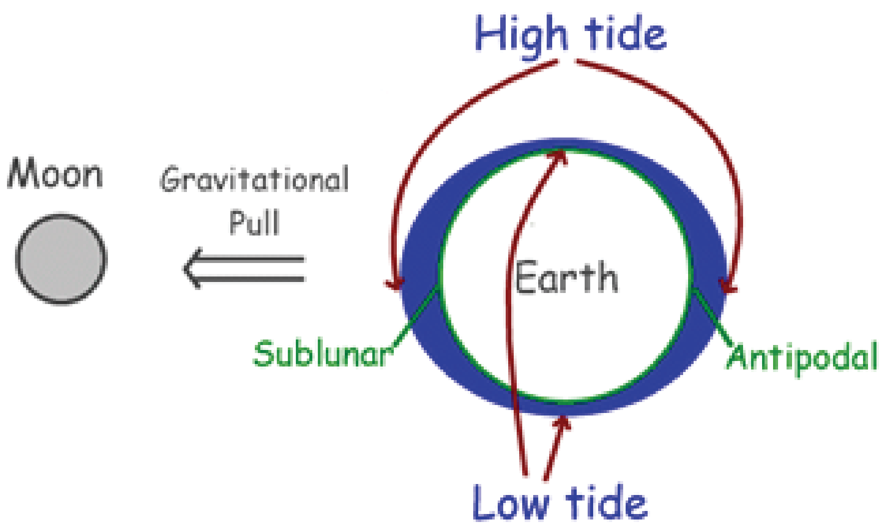
When there is greatest variation between the high tides and low tides, it is called Spring Tides. **Gulf of Fundy** is known for highest tides in the world (approximately 50 meters). At spring tide, Sun, Moon and Earth are in a line. When there is smallest difference between high and low a tide, it is called Neap tide. It occurs when Sun, moon and Earth are at right angles.



- Neap Tides occur when Moon is a quarter phase
- Spring tides occur on Full Moon as well as New Moon.
- *Spring tide has **higher than normal high tides** and lower than normal low tides.*
- During the Neap Tides, the high tide is lower and the low tide is higher than usual.

Daily Frequency of Tides

Earth rotates around its own axis and it takes 24 hours to finish its rotation. The direction of Earth rotation is the same in which Moon revolves around earth. The gravitational attraction moon raises the water on two opposite sides of Earth; these points are called Sub-lunar and antipodal points.



The tidal bulge shown in the above graphics follows the revolution of the moon, and the earth rotates eastward through the bulge once every **24 hours and 50 minutes**. (This is because, of the relative distance covered by moon in its orbit). This tidal bulge shows that the water of the entire world ocean is pulled by the moon's gravity.

On **both the opposite side of the earth simultaneously there is a high tide.** This high tide is on both sides due to inertia of the ocean water and because the earth is being pulled toward the moon by its gravitational field and the ocean water remains left behind. This means that Earth is pulled little away from the water. This creates a high tide on the side of the earth opposite the high tide caused by the direct pull of the moon.

Duration and Frequencies of Daily Tides

Most coastal areas experience **two high and two low tides per day**. One of these high tides is at the point on the earth which is closest to the moon (sub lunar) and other high tide is at the opposite point on the earth (antipodal).

One tidal cycle comprises two high tides and two low tides. One tidal cycle completes in 24 hours and 50.4 minutes. This is because of the revolution of Moon around the earth and both earth's rotation and moon revolution are in same direction. (Moon is not stationary, so there is a difference, if moon were stationary the high tides would have occurred exactly in 12 hours). The high tides occur at an interval of 12 hours and 25.2 minutes. This means that if there is a high tide is at 7.00 am, next high tide would be at 7.25 pm and next would be at 7.50 am, and so on. The time difference between two high tides is called "Tidal Interval". The tidal cycle in this pattern is called **semidiurnal.** However, most of the enclosed water bodies or away from the open ocean such as Caribbean sea or Caspian Sea, there are only one high tide and one low tide. This pattern is called Diurnal tides. At the coast of the oceans, there may be two high tides, of unequal length. This is called Mixed Tides.

Apogean Tides and perigean tides

When moon is at closest point to Earth during its revolution around earth it is called Perigee. The high tides are higher than usual and low tides are lower than usual at this point. When moon is farthest, it is called apogee and the high tides are lower than usual and low tides are higher than usual at this point of time. The highest Spring tides occur when the Moon is at its closest to the Earth…the so-called Perigee Tide.

Impact on tides if there was no moon?

If there is no moon, lunar water tides on the Earth go away, but the solar water tides still occur. At the same time, there would be no 'Spring' or 'Neap' tides.

The Tides Which Are Not Tides

The tide suffix has been used for various phenomena. Some of them are not at all related to the tides. The following are a few:

Storm Tides

Storm tides is the name given to the offshore rise of water associated with a low pressure weather system. Wind causes the water to pile up higher than the ordinary sea level and they are nowhere related to the tides.

Rip Tides

Rip tides are strong channel of water flowing seaward from near the shore, typically through the surf line. They are again caused by the winds and not related to Tides.

Tsunami

Tsunamis are called 'harbour wave', and they are result of displacement of a large volume of a body of water, usually an ocean due to Earthquakes, volcanic eruptions and other underwater explosions.

Other Terms Related to Tides

Tidal datum

A chart obtained from the long period of a tidal record is called tidal datum.

Tidal Flat

The sands uncovered by the low tides is called tidal flat

Tidal Range

Tidal range is the difference between the *height of water at low and high tides.*

Tidal Bore

Tidal bore is a Tidal phenomenon in which the leading edge of the incoming tide forms a wave (or waves) of water that travel up a river or narrow bay against the direction of the river or bay's current.

Earth's Tides

Earth's tides, also known as terrestrial tides affect the entire Earth's mass. This involves the movement of Earth's crust in all directions, due to solar and lunar gravitation.

Intertidal zone

Intertidal zone is sometimes known as littoral zone and it is that area of the sea shore or shore of water body such as Open Ocean, which is exposed to air at low tides and water at high tides. The examples are rocky cliffs, sandy beaches, or wetlands.**Bay of Fundy is an excellent Intertidal Zone Ecosystem.**

Do tides affect Earth's Magnetic Field?

Yes. The tidal forces generate currents in conducting fluids in the Earth's interior and they affect the Earth's magnetic field.

Tidal Ports

During high tides, water rushes into harbours (Tidal Bore). This helps ships enter and exit harbours safely. High tides make ocean/sea water rush into the mouths of rivers. This helps ships to enter port towns like New York, London, Rotterdam, and Hamburg. This is perfectly advantageous for some ports in India such as *Kandla, Mangalore and Kolkata's diamond harbour.*

Tides and prevention of siltation

Tides take away the terrigenous material brought by the rivers at the rivine harbours and thus help in the prevention of siltation.

Tides and prevention of Rivers Freezing

The temperature at which sea water freezes is much lower than that of river water. In cities like London, due to the high tide, the sea water enters the river and prevents it from freezing.

Tidal power

Power can be generated exploiting the huge energy of the tides. This can be done by making dams and the tidal zones where best tides occur and allowing the water to enter and exit through a turbine. However, this is a complicated work and not much success has been achieved as of now. The water accumulation during high tides can also be stored behind specially made dams, which can be then used for hydel power. World first tidal power station is Rance Tidal Power Station, located on the estuary of the Rance River, in Brittany, France. It is also world's largest tidal power station which started working in 1966. Its annual output is 600 GWh.

Some Questions Related to Tides

Why there are no high low tides at Equator?

For any particular location, their height and fluctuation in time depends to varying degrees on the location of the Sun and the Moon, and to the details of the shape of the beach, coastline, coastline depth and prevailing ocean currents. The tidal bulge of the Moon follows along the path on the earth's surface which intersects with the orbital plane of the Moon. This plane is tilted about 23 degrees with respect to the equatorial plane of the earth. The result is that near the equator, the difference between high tide and low tide is actually rather small, compared to other latitudes. Further also note that the Atlantic and Pacific coast tides are not the same. This is because of the fact that the nature of tides on the Earth's oceans is very complex. Every coastal location has its own unique tidal signature depending on its latitude, longitude, water depth and salinity.

What is use of Tides in Navigation?

Tidal flows as well as Tidal heights are of profound importance in navigation and very significant errors in position will occur if they are not taken into account. Many rivers and harbours have a shallow " bar" at the entrance which will prevent some boats with significant draught from entering at certain states of the tide. The timings and velocities of tidal flow can be found by looking at a tidal chart or tidal stream atlas for the particular local area.

How tides are useful in Fishing?

Tides move water, bringing water in and taking water out. Understanding the cycles and effects of tides on fish helps in better fishing. The full and new moons normally create better fishing conditions because of the spring tides. The reason behind this is that fish are easier to catch when they are feeding and it's the tide and currents that dictate this. When the water begins to move, smaller fishes are at the mercy of the current and get confused in the turbulent water. Larger fishes have an advantage because they are equipped to feed in this turbulent water. These larger fishes get more easily trapped when there are tides.

Prelims Model Questions

Earthquake Model Questions

1. Which among the following is are characteristic features of the boundaries of the Indian Plate?

1. Young fold mountains
2. Island arcs
3. Mid-Oceanic Ridges
4. Trenches

Choose the correct option from the codes given below:

[A] Only 1

[B] Only 1 & 2

[C] Only 1, 2 & 3

[D] 1, 2, 3 & 4

Answer: [D] 1, 2, 3 & 4

Salient features of the Indian Plate

The countries that lie within the Indian Plate are India, Sri Lanka, Bangladesh, Bhutan and parts of Pakistan, Nepal, and Afghanistan. Australia and Tasmania are also part of the Indian plate but are located on a separate continental crust. Some countries contiguous with the Indian plate are Iran, Afghanistan, China, Tibet, Tajikistan, Kyrgyzstan, Myanmar, and New Zealand. Diverse topographic features that characterize boundaries of the Indian plate include young mountain chains, trenches, island arcs, and mid-oceanic ridges. A large portion of the Indian plate is submerged below the Indian Ocean and the Pacific Ocean and consists of oceanic crust. The northern boundary of the Indian plate is defined by the Himalayan Mountains, which are part of the Alpine Himalayan seismic belt.

The Himalayas stretch from Kashmir in the west to Arunachal Pradesh in the east and straddle Nepal and Bhutan in between. From Arunachal Pradesh, the boundary of the Indian plate swings sharply southward, from where it extends as the Arakan Yoma range of mountains. From there, it extends eastward toward the Andaman, Nicobar, and Indonesian Islands as a long continuous chain of Andaman, Sumatra, Java, Sunda Trenches. This intersects the Circum Pacific Belt near Philippines and enters the Pacific Ocean. Beyond this, it again turns southward, toward and through New Zealand, via the Kermadec-Tonga Trench, New Hebrides Trench, and Macquarie Ridge. Beyond this, it re-enters the Indian Ocean as South East Indian Ocean Ridge and swings toward the Arabian Sea as the South West Indian Ocean Ridge, Central Indian Ocean Ridge, and the Carlsberg Ridge. There it joins the Sulaiman and Kirthar ranges of Pakistan. Several major fracture zones are associated with the oceanic ridges.

The Indian plate is bound by all three kinds of plate boundaries, i.e., destructive, constructive and conservative. A destructive boundary indicates the presence of a subduction zone, which manifests as shortening of the crust, and its topographic manifestation is the trench and island arc system. The Andaman Sumatra Java Sunda trench represents the convergent boundary between the Indian plate and the Eurasian plate in the Bay of Bengal and likewise further east, in the Pacific Ocean, the New Hebrides trench, Tonga trench and the Kennadec trench represent the boundary between the Indian and the Pacific plate. A divergent, i.e., a creative plate boundary indicates sea floor spreading and is indicated by mid-oceanic ridges. A long chain of midoceanic ridges exists in the Indian Ocean. A conservative boundary indicates that the Indian plate is sliding past the adjacent plate in that region.

(source: Understanding Earthquake Disasters By Amita Sinvhal, PP 52)

2. Which one of the following terms are related to volcanoes?

1. Caldera
2. Erg
3. Pumice
4. Dykes

Choose the correct option from the codes given below:

[A] 1, 2 & 3

[B] 1, 2, 3 & 4

[C] 1, 3 & 4

[D] 1 & 4

Answer: [C] 1, 3 & 4

Calderas are large volcanic craters that form by two different methods: 1) an explosive volcanic eruption; or, 2) collapse of surface rock into an empty magma chamber. Pumice is a is a volcanic rock that consists of highly vesicular rough textured volcanic glass, which may or may not contain crystals. It is typically light coloured.

3. Consider the following statements with reference to the spring tides and neap tides:
1. Neap Tides occur when Moon is a quarter phase
2. Spring tides occur on Full Moon as well as New Moon
3. Spring tide has higher than normal high tides and lower than normal low tides
4. During the Neap Tides, the high tide is lower and the low tide is higher than usual

Which among the above statements is / are correct?

[A] Only 1 & 2

[B] Only 1, 2 & 3

[C] Only 2, 3 & 4

[D] 1, 2, 3 & 4

Answer: [D] 1, 2, 3 & 4

Kindly note the above four differences between spring tides and neap tides.

4. A tourist in Mumbai observes high tide near Gateway of India at 7.00 AM. At what time, he should expect another high tide on the same day?

[A] 7.00 PM

[B] 7.25 PM

[C] 7.40 PM

[D] 8.50 PM

Answer: [B] 7.25 PM

Most coastal areas experience two high and two low tides per day. One of these high tides is at the point on the earth which is closest to the moon (sub lunar) and other high tide is at the opposite point on the earth (antipodal). One tidal cycle comprises two high tides and two low tides. One tidal cycle completes in 24 hours and 50.4 minutes. This is because of the revolution of Moon around the earth and both earth's rotation and moon revolution are in same direction. (Moon is not stationary, so there is a difference, if moon were stationary the high tides would have occurred exactly in 12 hours). The high tides occur at an interval of 12 hours and 25.2 minutes. This means that if there is a high tide is at 7.00 am, next high tide would be at 7.25 pm and next would be at 7.50 am, and so on. The time difference between two high tides is called "Tidal Interval". The tidal cycle in this pattern is called semidiurnal. However, most of the enclosed water bodies or away from the open ocean such as Caribbean Sea or Caspian Sea, there are only one high tide and one low tide. This pattern is called Diurnal tides. At the coast of the oceans, there may be two high tides, of unequal length. This is called Mixed Tides.

5. Which among the following is the outcome when tide enters the narrow and shallow estuary of a river?

[A] Tidal Bore

[B] Ocean Gyre

[C] Flood Tide

[D] Rotary current

Answer: [A] Tidal Bore

Tidal bore is a Tidal phenomenon in which the leading edge of the incoming tide forms a wave (or waves) of water that travel up a river or narrow bay against the direction of the river or bay's current.

6. Subduction is responsible for__:

1. Volcanoes
2. Earthquakes
3. Orogeny

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

Subduction is responsible for high rates of volcanism, earthquakes, and mountain building. When the large pieces of material on the subducting plate are pressed into the overriding plate, it results in the Orogeny or Mountain formation. These areas are subject to many earthquakes.

7. With reference to the subduction, consider the following statements:

1. Subduction occurs when denser ocean crusts slide beneath lighter continental crusts
2. Subduction causes the formation of deep ocean trenches

3. Subduction is responsible for high occurrences of volcanoes and earthquakes in some areas

Which among the above statements is / are correct?

[A] 1 & 2

[B] 2 & 3

[C] 1 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

Subduction is the process that takes place at convergent boundaries by which one tectonic plate moves under another tectonic plate and sinks into the mantle as the plates converge. Plates include both oceanic crust and continental crust. Stable subduction zones involve the oceanic crust of one plate sliding beneath the continental crust or oceanic crust of another plate. That is, the subducted crust is always oceanic while the overriding crust may or may not be oceanic. Subduction zones are often noted for their high rates of volcanism, earthquakes, and mountain building. Formation of Trench: Trenches are centerpieces of the distinctive physiography of a convergent plate margin. As the subducting plate approaches the trench, it is first bent upwards to form the outer trench swell, then descends to form the outer trench slope. The outer trench slope is disrupted by a set of subparallel normal faults which staircase the seafloor down to the trench. The plate boundary is defined by the trench axis itself. Beneath the inner trench wall, the two plates slide past each other along the subduction decollement, the seafloor intersection of which defines the trench location. The overriding plate contains volcanic arc (generally) and a forearc. The volcanic arc is caused by physical and chemical interactions between the subducted plate at depth and asthenospheric mantle associated with the overriding plate. The forearc lies between the trench and the volcanic arc. Forearcs have the lowest heatflow from the interior Earth because there is no asthenosphere (convecting mantle) between the forearc lithosphere and the cold subducting plate.

8. Consider the following statements:

1. Convergent plate boundaries produce more explosive volcanoes in comparison to divergent plate boundaries

2. Convergent plate boundaries produce more dangerous earthquakes in comparison to divergent plate boundaries

Which among the above statements is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [A] Only 1

Convergent Boundaries

- Explosive Volcanoes
- High Silicic Magma: The magma comes from the subduction of lithospheric crust so it has more of silicate.
- Stratovolcanoes
- Consumption of the Ocean Floor
- Shallow, Intermediate as well as Deep Focus Earthquakes

Divergent Boundaries

- Quite, Non explosive volcanoes
- High Basaltic Magma: Oceanic crust is created at the mid-oceanic ridges; it forms from up welling magma that cools and solidifies to igneous rock.
- Most of this is Basaltic.
- Shield Volcanoes
- Creation of Ocean Floor
- Shallow Focus earthquakes only

In the above question, the second statement is not correct, because any of them can produce dangerous earthquakes

9. What is / are the implications of the liquid outer core on the Earthquake waves?

1.The P waves can not pass through the liquid outer core

2.The S waves can not pass through the liquid outer core

3.The P-waves are deviated

4.The S-waves are deviated

Choose the correct option:

[A] 1 & 2

[B] 2 & 3

[C] 3 & 4

[D] 1 & 4

Answer: [B] 2 & 3

10. Consider the following general observations:

1. Roughly half of India's total area is earthquake prone

2. When we travel from north to south, the seismicity roughly decreases
3. Most epicentres are located near eastern and western syntaxes of Himalaya

Which among the above statements is / are correct?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

11. If the earth had no satellite of its own i.e., the moon, which of the following phenomena will not occur ?

[A] Neap tides

[B] Ocean currents

[C] Spring tides

[D] Tides

Answer: [C] Spring tides

The moon has a significant impact on tides, due to the gravitational attraction of the moon on the Earth's water. This effect is magnified when the moon's gravitational attraction aligns with the gravitational pull of the sun. This produces the highest high tides and lowest low tides, known as spring tides. When the pull of the moon and the sun are perpendicular to each other, the lowest high tides and highest low tides, collectively termed neap tides, are produced. While ocean currents are primarily affected by winds and the Coriolis force, tides can have a large impact on currents near the coasts.

12. Consider the following:
1. Southeast Asia
2. Andes Mountains
3. Mid-Atlantic Ridge
4. Caribbean Plate

Which among the above is / are subduction zones?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 2, 3 & 4

[D] Only 1, 2 & 4

Answer: [D] Only 1, 2 & 4

Mid Atlantic Ridge is where the two plates are diverging, which creates more oceanic floor. Thus, it is not subduction zone. Rest all are subduction zones.

13. With reference to the Earthquakes, consider the following statements:

1. Majority of earthquake devastation is caused by Love (L) and Rayleigh waves

2. The S waves can not pass through the liquid outer core

Which among the above is / are correct statements?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [C] Both 1 & 2

14. Consider the following statements:

1. The rotation of the earth on its axis generates centrifugal force on water.

2. Effect of centrifugal force in creating tides is of great use in determining the location of the high tides and low tides

Which among the above is / are correct statements?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [A] Only 1

The rotation of the earth on its axis generates centrifugal force on water. As a result there is a tendency for the water to be thrown away from the earth. The centrifugal force is directly proportional to the radius of the circle of rotation. Therefore the centrifugal force will be the maximum at the equator and minimum near the poles. However, the effect of the centrifugal force along parallels of latitude will be uniform irrespective of the longitude. Therefore, the effect of centrifugal force in creating tides is of no concern while determining the location of the high tides and low tides.

15. Which of the following phenomena pertain to the plate tectonics?

1. Polar Wandering

2. Continental drift

3. Sea floor spreading
4. Glaciation

Select the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1, 2 & 3

[D] 1, 2, 3 & 4

Answer: [C] Only 1, 2 & 3

Plate motion/movement takes place primarily due to three factors-Polar Wandering, Continental drift and Sea floor spreading.

Polar wandering is the relative movement of the earth's crust and upper mantle with respect to the rotational poles of the earth. Continental drift refers to the movement of the continents relative to each other.

Sea floor spreading describes the movement of oceanic plates relative to one another.

A glacial period (alternatively glacial or glaciation) is an interval of time (thousands of years) within an ice age that is marked by colder temperatures and glacier advances. Interglacials, on the other hand, are periods of warmer climate between glacial periods. The last glacial period ended about 15,000 years ago. The Holocene epoch is the current interglacial. A time when there are no glaciers on Earth is considered a greenhouse climate state.

General Knowledge Today

Prelims Geography-4: Oceanography

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Contents

Model Questions

Please Check Model Questions for Prelims at end of this module.

Ocean Relief

Mega relief Basics

There are various structures on the surface of the earth that give rise to various kinds of Landscapes. On a large scale, the landscapes of can be divided into three orders of relief called**Megarelief**. The Megareliefs include the largest landscapes by scale, from enormous ocean basins and continents down to local hills, spurs, cliffs, valleys, gorges and river terraces. Accordingly, there are three orders of relief as follows:

First Order of Relief

The broadest category of land forms includes huge**continental platforms** and **ocean basins**. Continental platforms are the masses of crust that exist above or near sea level, including the undersea continental shelves along the coastline. The ocean basins are entirely below the sea level. Approximately 71 percent of the earth is covered by water, with only about 29 percent of its surface appearing as continents and islands. The distribution of land and water in evidence today demonstrates a distinct water hemisphere and continental hemisphere.

Second Order of Relief

In the ocean basins, the second order of relief includes continental rises, slopes, abyssal plains, mid-ocean ridges, submarine canyons, and subduction trenches.

Continental features that are classified in the second order of relief include continental masses, mountain masses, plateaus, plains and lowlands. A few examples are the Himalayas, Alps, Rocky Mountains, Andes, Tibetan plateau, plateau of Anatolia (Turkey), Indo-Gangetic plains, Siberian lowlands and the plains of Mississippi. The great rock cores (shields) that form the heart of each continental mass arc of this order.

Third Order of Relief

The third order of relief includes individual peaks, cliffs, valleys, hills, spurs, gorges, sand dunes, caves, moraines, cirques, ripples, beaches, etc. These features are identified as local landscapes.

Ocean Relief Features

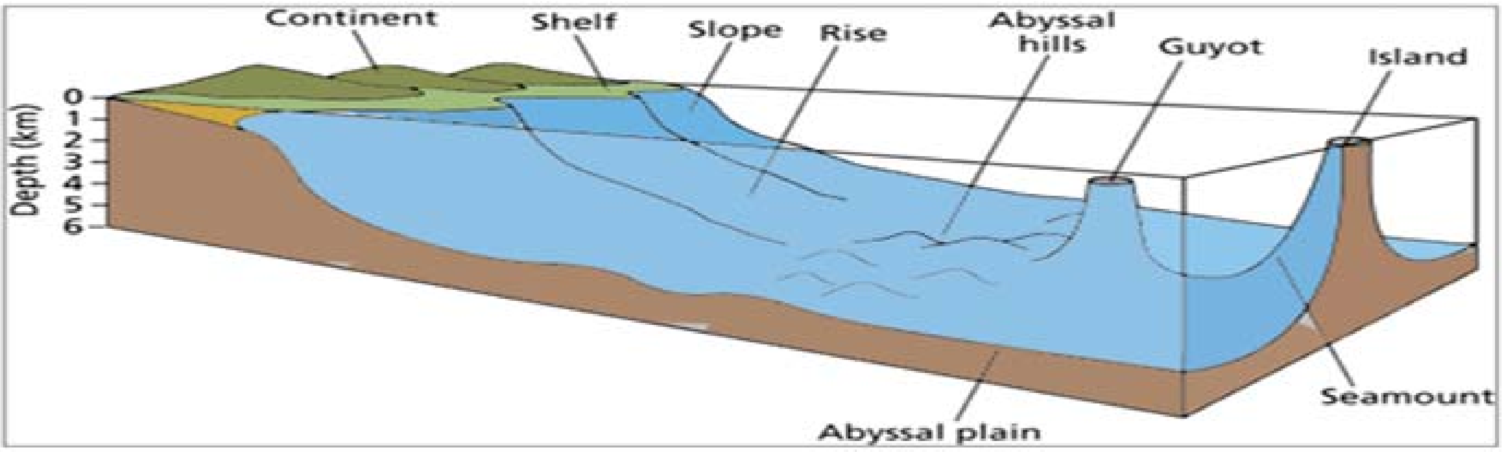
Surface area of earth is 510,072,000 km². It comprises of 148,940,000 km² land (29.2 %) & 361,132,000 km² water (70.8 %). Relief features of oceans are quite different from those of the continents. Please note that much of the oceanic crust is less than 60 million years old, while the great bulk of the continental crust is of Proterozoic age—mostly over 1 billion years old. Thus, the young age of the oceanic crust is quite remarkable.

Ocean is blue because water shows slightly blue color and that is because of the fact that it absorbs the Red photons of the light. Because the absorption which gives water its color is in the red end of the visible spectrum, one sees blue, the complementary color of red, when observing light that has passed through several meters of water.

Some Extreme Points in Oceans

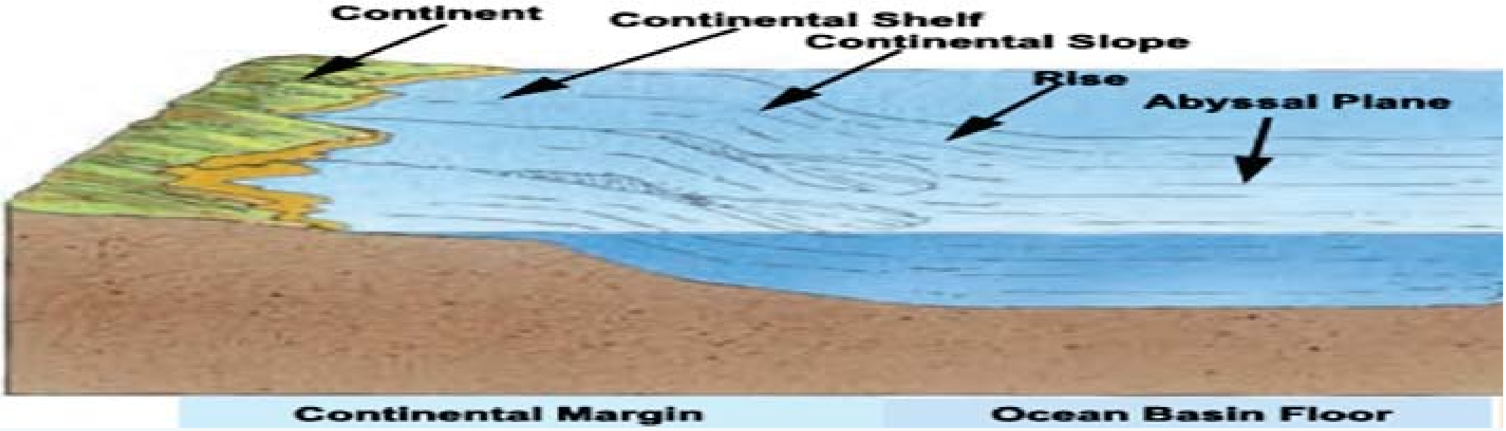
- The deepest point in the ocean is the Mariana Trench, located in the Pacific Ocean near the Northern Mariana Islands.
- Its maximum depth has been estimated to be 10,971 meters (plus or minus 11 meters).
- British naval vessel, Challenger II surveyed the trench in 1951 and named the deepest part of the trench, the "Challenger Deep".
- In 1960, the Trieste successfully reached the bottom of the trench, manned by a crew of two men.

The ocean relief can be divided into various parts such as Continental Shelf, Continental Slope, Continental Rise or Foot, Deep Ocean basins, Abyssal plains & Abyssal Hills, Oceanic Trenches, Seamounts and Guyots.



Continental Shelf

Continental Shelf is the submerged edge of a continent. It is a gently sloping plain that extends into the Ocean. The typical gradient is less than 1°. Taken together, total area of the continental shelves is 18% of earth's dry land area. The width of the continental shelf varies considerably;*there are many places on earth where there is virtually no shelf at all* The **largest continental shelf is the Siberian Shelf in the Arctic Ocean**, which stretches to 1,500 kilometers in width. The average width of continental shelves is about 80 km. The depth of the shelf also varies, but is generally limited to water shallower than 150 m. Continental shelf is made up of Granite rock overlain by the sediments. Because of the gentle slope, the continental shelf is influenced by the changes in the sea level.



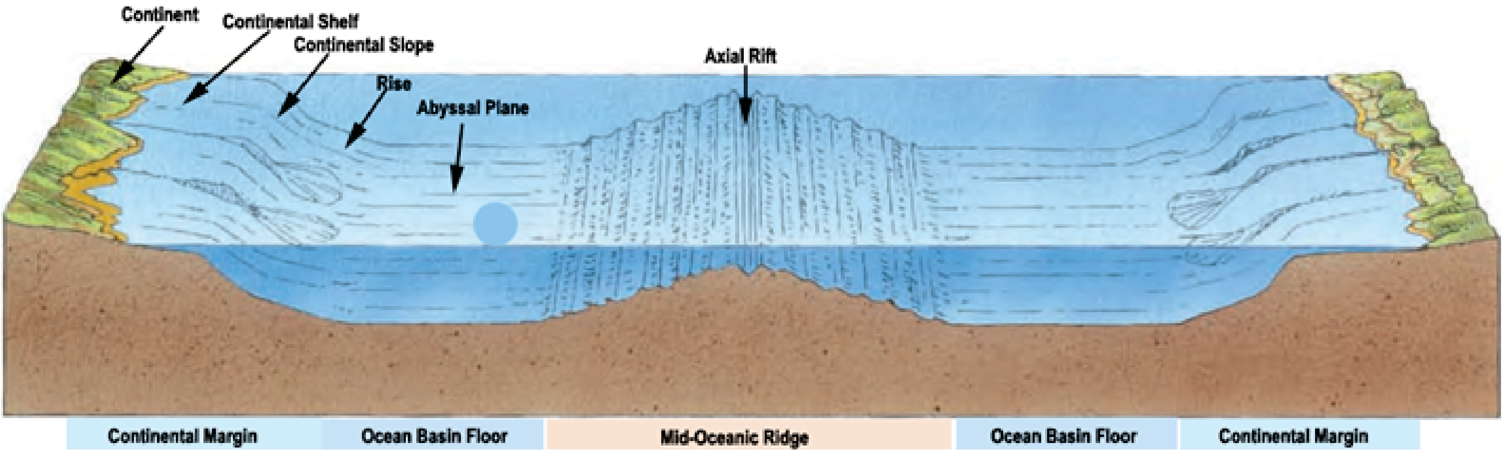
Continental Slope & Continental Rise

Continental slope is relatively steep descent from the shelf break to the deep sea floor. Inclination of the typical continental slope is around 4° and usually between 2° to 5°. Shelf break is almost constant all over the globe and is around 150 meters, except the Antarctica and Greenland continental slopes. The slope plunges down at least 1 kilometer and usually 2-3 kilometers.

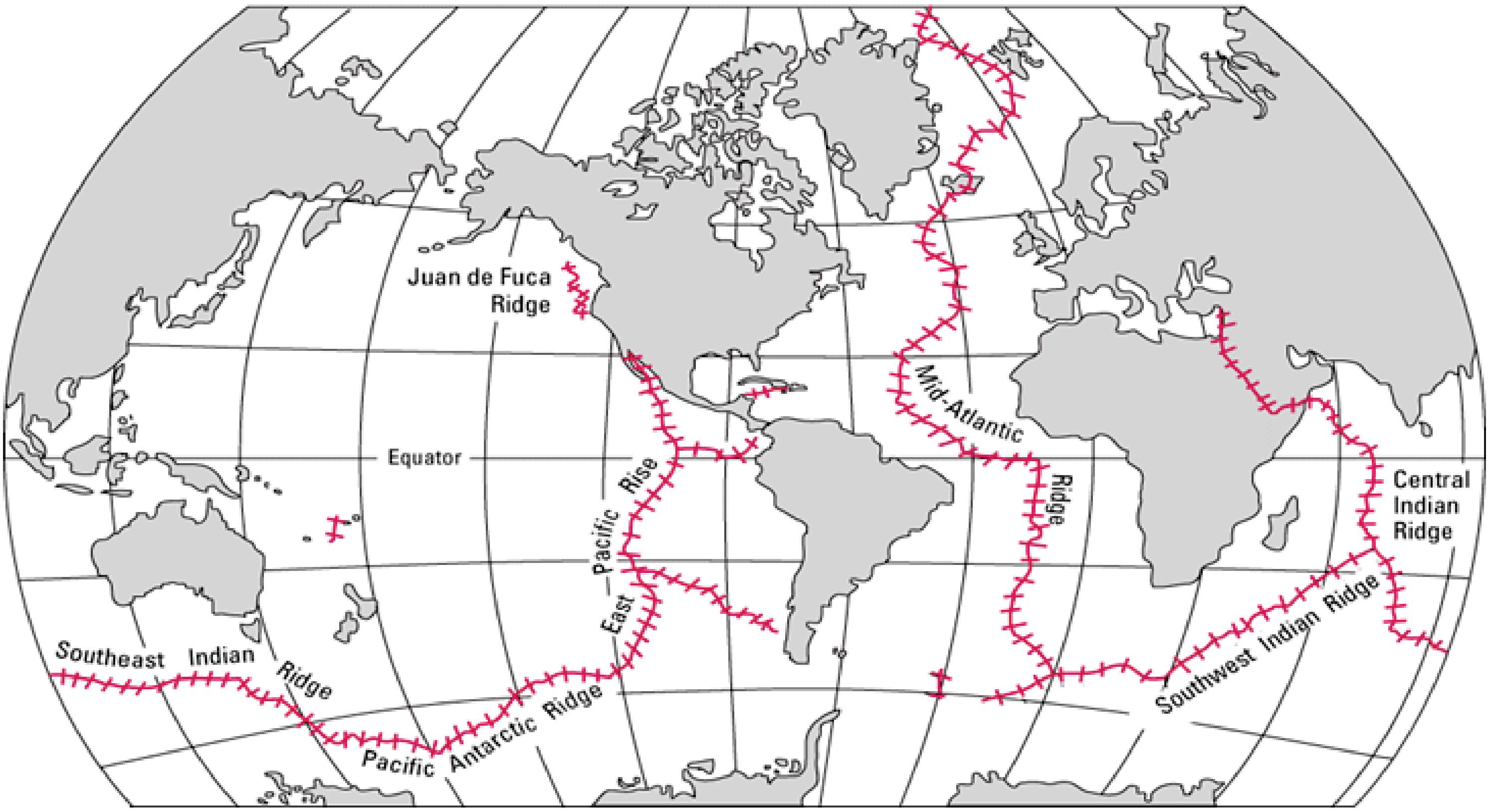
The Continental Rise connects the Continental slope to the deep sea or abyssal plain. Its width is around 100-1000 kilometers. Slope is gradual and around 1/8th of the continental slope. *The transition from continental to oceanic crust commonly occurs within the continental rise.*

Deep Ocean basin & Oceanic Ridges

Deep Ocean Basin is the lowest layer in the ocean. The sea floor is like a covering of sediments over a basalt rock which may be up to 5 kilometers thick. **Oceanic ridges** or **Mid-oceanic Ridges** refer to the boundary between the diverging plates. A mid-ocean ridge (MOR) refers to an underwater mountain system that consists of various mountain ranges (chains), typically having a valley known as a rift that runs along its spine, formed by plate tectonics. The midoceanic ridge of submarine hills divides the basin in about half. Precisely in the center of the ridge, at its highest point, is a narrow trenchlike feature called the **axial rift.** The location and form of this rift suggest that the crust is being pulled apart along the line of the rift.



The oceanic ridges present a mountainous chain of **young rocks** which stretch around 65000 kilometers, i.e. 1.5 times of the earth's circumference. *Oceanic ridges are made up of basalt rocks*, are geologically active as the new magma constantly emerging onto the ocean floor accumulates in the crust at and near rifts along the ridge axes. The adjacent graphic shows distribution of some Oceanic Ridges around the world.



Location of the important ridges are as follows:

- **Aden Ridge:** Gulf of Aden and Indian Ocean along the south-eastern coastline of the Arabian Peninsula.
- **Explorer Ridge:** Located 240 km west of Vancouver Island, British Columbia, Canada.
- **Gorda Ridge:** off the coast of Oregon and northern California north of Cape Mendocino
- **Juan de Fuca Ridge:** off the coasts of the state of Washington in the United States

- **Cocos Ridge:** Its is a Volcanic hotspot. Also known as**Galapagos hotspot** located in East Pacific Ocean *responsible for the creation of the Galapagos Islands as well as three major seismic ridge systems. Carnegie, Cocos and Malpelso.*
- **Gakkel Ridge:** located in the Arctic Ocean between Greenland and Siberia, and has a length of about 1,800 kilometers. It is **slowest known spreading ridge** on the earth.
- **Pacific-Antarctic Ridge:** located in South Pacific Ocean
- **Southeast Indian Ridge:** It is located in the Indian Ocean and separates the Indo Ocean plate from the Antarctic plate.
- **Carlsberg Ridge:** Located in the Indian Ocean.

Abyssal Plain

Abyssal plain is flat, cold and sediment covered ocean floor. Abyssal plains are more extensive in Atlantic and Indian Oceans and less extensive in Pacific Ocean. Abyssal plain is found at an average depth between 3000 and 6000 meters. They are among the flattest, smoothest and least explored regions on earth.

Oceanic Trench

An elongated through or deep in the ocean floor is called ocean trench. It is more or less a U shaped valley. Most of world's trenches are in Pacific Ocean. Trenches are ***most active geological features*** on earth where great earthquakes are Tsunamis are born. Here is a brief info about important trenches:

Mariana Trench

Mariana Trench is the deepest part of the world's oceans. It is located in the western Pacific Ocean, east of the Mariana Islands. The trench is about 2,550 kilometers long but has a mean width of only 69 kilometers. The maximum known depth is 11.03 kilometers at the Vityaz-l Deep and about 10 91 kilometers at the Challenger Deep.

Tonga Trench

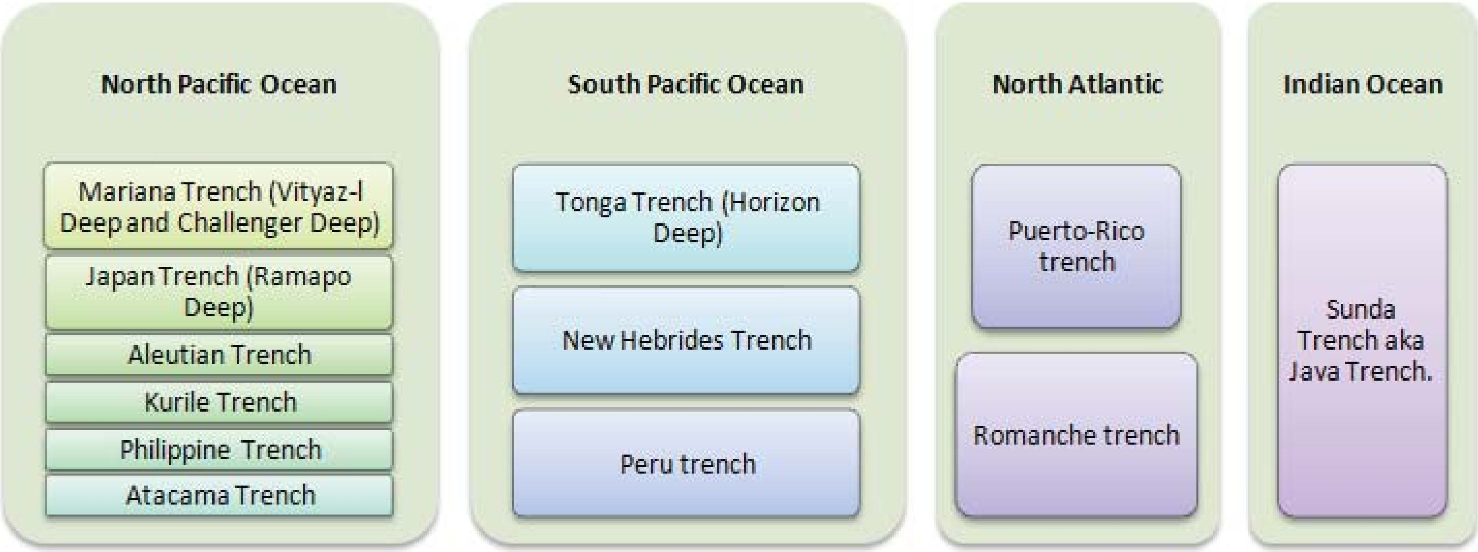
Tonga Trench us located in South Pacific Ocean and is second deepest trench. Its deepest point is called Horizon Deep. It is Steepest Trench of the World.

Factbox: Tonga Trench and Apollo 13

Apollo 13 was the third Apollo mission which was launched to land on the Moon. It was successfully launched toward the Moon, but the landing had to be aborted after an oxygen tank ruptured. It was launched on April 11, 1970 and subsequently failed. Its lunar module re-entered earth's surface on April 17. 1970 and was targeted over the pacific Ocean to reduce the contamination from the Radioisotope Thermoelectric Generator (RTG) on board, which would have provided energy to the mission. This RTG was landed in the Tonga Trench. The RTG will remain active for next 2000 years. It has 3.9 kilogram of radioactive plutonium.

Puerto Rico Trench

Puerto Rico Trench is located on the boundary between the Caribbean Sea and the Atlantic Ocean. The trench is 800 kilometers long and has a maximum depth of 8,605 meters at Milwaukee Deep. which is the deepest point in the Atlantic Ocean.



Seamounts & Guyots

Seamounts are elliptical projections from the sea floor which look like mountains and have a steep slope of around 22° to 24°.Half of the world's total seamounts arc in Pacific Ocean. Guyots are basically inactive volcanoes which are flat topped. Some of them are tall enough to approach or even penetrate the sea surface. Guyots are confined to Central Pacific Ocean.

Rift valleys

A rift valley is linear-shaped lowland between highlands or mountain ranges created by the action of a geologic rift or fault in opposite or parallel. The result is the formation of a long steep sided, flat floored valley. **World's largest Fresh water lakes are typical rift valleys.**Examples are Lake Baikal in Siberia, Lake Tanganyika, Lake Superior, Lake Vostok, Lake Nipissing and Lake Timiskaming. **Jordan Rift Valley**, which is lowest land elevation on earth is located in the Dead Sea and is 760 meters below the surface of the Mediterranean Sea. **Gulf of Aqaba** in the Red Sea is also a rift valley.

Factbox: Important Lakes in Rift Valleys

Lake Baikal

Lake Baikal, also known as "Pearl of Siberia" is located in Siberia and is second most voluminous lake in the world after the Caspian Sea. It is also world's oldest and deepest lake. It's a Rift valley, created by the Baikal Rift Zone, and a World Heritage site declared in 1996. Lake Baikal is home to Buryats , the largest ethnic minority group and a tribe in Siberia. It was referred as North Sea by ancient Chinese writers.

Lake Tanganyika

After lake Baikal, Lake Tanganyika is second deepest lake in the world. It is world's longest Lake spanning in 4 countries of Africa viz. Burundi, Tanzania, Congo and Zambia. This lake is a Rift Valley and largest rift lake in Africa.

Lake Superior

Lake Superior is largest lake of North America, shared by Canada as well as USA. It is largest freshwater lake in the world by surface area if lake Michigan and lake Huron are NOT considered one.

Lake Vostok

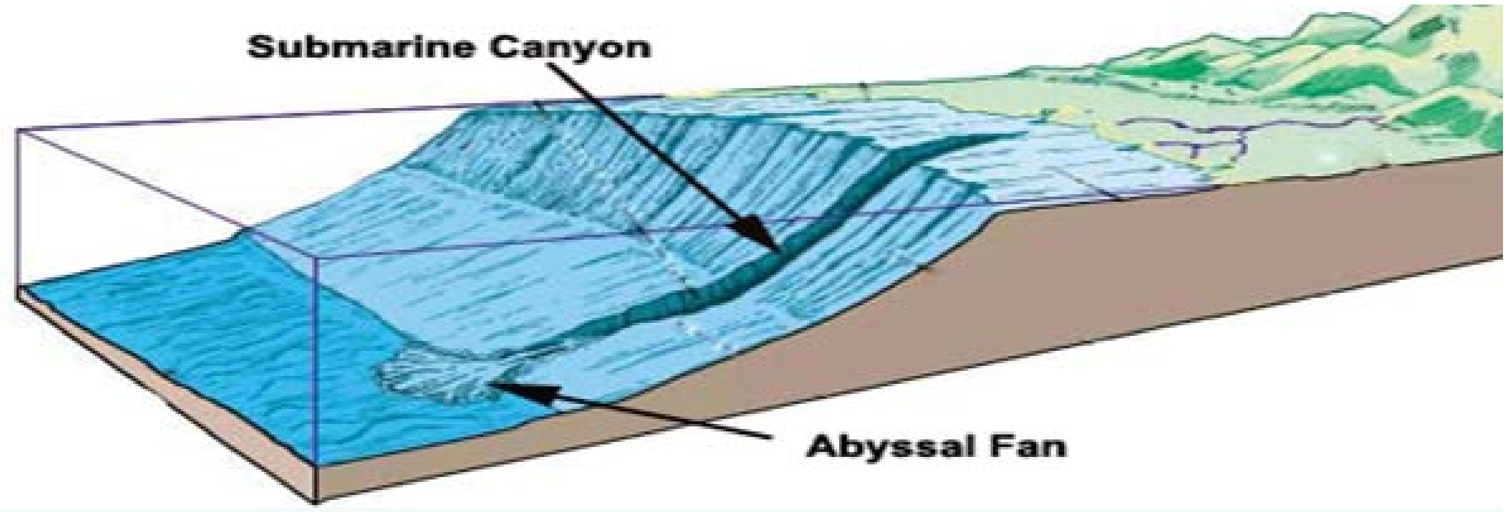
Lake Vostok is in Antarctica and is a Sub Glacial lake. It is located below the Vostok Station of Russia in Antarctica.

Lake Nipissing

Lake Nipissing is located in Canada. It's one of the shallowest lakes of Canada

Abyssal Fans

Abyssal fans are also known as **deep-sea fans**, **underwater deltas,** and **submarine fans**. They are delta like structures formed at the deep sea surfaces. Abyssal plain is found at the depths between 3000 and 6000 meters. Abyssal plains cover more than 50% of Earth's total surface. They are considered to be major reservoir of biodiversity.



Archipelago

Archipelago refers to a cluster of islands which are formed tectonically. This term was initially used for Aegean Islands located in the Aegean Sea between Greece and Turkey. Indonesia is often referred to as the world's largest archipelago; however, this means that it is largest by area and not by number of islands. Indonesia has 17,500 islands which span more than 5000 km². World's largest archipelago by number of Islands is Archipelago Sea which is located Baltic Sea between the Gulf of Bothnia and the Gulf of Finland. It has 50,000 Islands. Top 5 archipelagos in the world by number of Islands are as follows:

- Archipelago Sea (Finland) 50,000

- Canadian Arctic Archipelago 36.563
- Stockholm Archipelago 24,000
- Indonesian Archipelago 17.508
- Philippine Archipelago 7.107

Lagoon

Lagoon is a shallow body of sea water or brackish water **separated from the sea by some form of barrier**. The biggest lagoon in the world is located in New Caledonia, in southwest pacific. In India, **Chilika Lake** in Orissa and the **Vembanad Lake** in Kerala are both connected to the Bay of Bengal and the Arabian Sea respectively through a narrow channel and they are **typical lagoons**.

Coral Reefs

Coral reefs, which are also called as "rainforests of the sea", are underwater reefs made by calcium carbonate secreted by Corals. Coral is the hard exoskeleton of the polyps. Coral Reefs grow best in **warm, shallow, clear, sunny and agitated** waters.

Coral reefs are some of the most diverse ecosystems on earth which despite of covering less than 10% of world ocean surface (284,300 km²) provide home to 25% of marine species including fishes, molluscs etc. Coral Reefs are very fragile ecosystem and are **susceptible to "Surface Temperature"** of the oceans. They are threatened by the climate change, ocean acidification, **blast fishing**, **cyanide fishing** for aquarium fish, overuse of reef resources, and harmful land-use practices.

Some Observations on Coral Reliefs

- The Indian Ocean and Pacific Ocean region including the **Red Sea, Indian Ocean, Southeast Asia and the Pacific** account for 91.9% or total Coral reefs in the world.
- Southeast Asia accounts for 32.3%, while the Pacific including Australia accounts for 40.8%. **Atlantic and Caribbean coral reefs only account for** 7.6%.
- **Largest Coral reef in the world is Great Barrier Reef.** It is located in the Coral Sea, off the coast of Queensland in north-east Australia. It is composed of over 2,900 individual reefs and 900 islands stretching for over 2,600 kilometers. This reef can be seen from outer space and is the world's biggest single structure made by living organisms. It is a World Heritage Site (1981). It is also a state icon of Queensland, made by Queensland National Trust. A large part is protected by the Great Barrier Reef Marine Park, established by Government of Australia through Great Barrier Reef Marine Park Act 1975.
- **Belize Barrier Reef is world's second largest Coral Reef** which is a part of 900 kilometer Mesoamerican Barrier Reef System. It was described by Charles Darwin in 1842 as "the most remarkable reef in the West Indies".
- ***Pulley Ridge is*** *located off the coast of Florida, United States. It is deepest photosynthetic coral reef*

known so far.

- Raja Ampat Islands, largest marine national park in Indonesia are located in Indonesia and New Guinea and comprise 1,500 small islands ***It is known for highest recorded marine biodiversity on Earth***. It makes the Coral Triangle which is a triangular shaped area of the tropical marine waters of Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands and Timor-Leste. These waters contain at least 500 species of reef-building corals in each ecoregion. Coral Triangle as well as Raja Ampat Islands is considered to be the global epicenters of marine biodiversity. INWF considers the region as a top priority for marine conservation and has launched the Coral Triangle Program in 2007

Beach

Beach is the shoreline of an ocean, sea or lake which consists of loose particles such as sand, gravel. pebbles etc. They are formed as a result of wave action by which waves or currents move sand or other loose sediments.

Cox's Bazaar

Cox's Bazaar sandy beach in Bangladesh's Chittagong is considered to be world's longest natural sandy beach. It has an unbroken length of 120 kilometers.

Marina Beach

Marina Beach is located in India's Chennai and is one of the largest beaches of India.

Ocean Sediment

Ocean sediments are particles and fragments of dirt, dust, and other debris that have settled out of the water and accumulated on the ocean floor. *The crucial importance of marine sediments is that they reveal much about Earth's history.* Marine sediments provide clues to past climates, movements of the ocean floor, ocean circulation patterns, and nutrient supplies for marine organisms.

Marine sediments can also be helpful in ascertaining the timing of major extinctions, global climate change, and the movement of plates.

> More than half of the rocks exposed on the continents are sedimentary rocks deposited in ancient ocean environments and uplifted onto land by plate tectonic processes. Even the tallest mountains on the continents far from any ocean contain marine fossils, which indicate that these rocks originated on the ocean floor in the geologic past. Mount Everest consists of limestone, which is a type of rock that originated as sea floor deposits.

Over time, sediments can become lithified and turned to rock and form **sedimentary rock**. Particles of sediment come from worn pieces of rocks, as well as living organisms, minerals dissolved in water, and outer space.

There are several types of marine sediments such as:

- Lithogenous sediment
- Biogenous Sediment
- Hydrogenous sediment

Lithogenous Sediment

This type of sediment is derived from pre-existing rock material that originates on the continents or islands from erosion, volcanic eruptions, or blown dust. The another term used for lithogenous sediment is **terrigenous** sediment. Obviously, the origin of Lithogenous Sediment begins as rocks on continents or islands. Over time, weathering agents such as water, temperature extremes, and chemical effects break rocks into smaller pieces.

Neritic Deposits versus Pelagic Deposits

Marine sedimentary deposits can also be categorized as either neritic or pelagic. Neritic deposits are found on continental shelves and in shallow water near islands; these deposits are generally coarse grained. Alternatively, pelagic deposits are found in the deep ocean basins and are typically fine grained.

When rocks are in smaller pieces, they can be more easily eroded and transported. This eroded material is the basic component of which all lithogenous sediment is composed. Eroded material from the continents is carried to the oceans by streams, wind, glaciers, and gravity. The transported sediment can be deposited in many environments, including bays or lagoons near the ocean, as deltas at the mouths of rivers, along beaches at the shoreline, or further offshore across the continental margin. It can also be carried beyond the continental margin to the deep-ocean basin by turbidity currents. The greatest quantity of lithogenous material is found around the margins of the continents, where it is constantly moved by high-energy currents along the shoreline and in deeper turbidity currents

The majority of lithogenous deposits such as beach sands are composed primarily of quartz.

Biogenous Sediment / Ooze

Biogenous sediment is derived from the remains of hard parts of once living organisms. Origin of Biogenous Sediment Biogenous sediment begins as the hard parts (shells, bones, and teeth) of living organisms ranging from minute algae and protozoans to fish and whales. When organisms that produce hard parts die, their remains settle onto the ocean floor and can accumulate as biogenous sediment. Biogenous sediment can be classified as either macroscopic or microscopic. Macroscopic biogenous sediment is large enough to be seen without the aid of a microscope and includes shells, bones, and teeth of large organisms.

Ooze

The microscopic organisms produce tiny shells called **tests** that begin to sink after the organisms die and continually rain down in great numbers onto the ocean floor. These microscopic tests can accumulate on the deep ocean floor and form deposits called ooze. Ooze resembles very fine grained, mushy material like mud. The organisms that contribute to biogenous sediment are chiefly algae and protozoans. Algae are primarily aquatic, eukaryotic, photosynthetic organisms, ranging in size from microscopic single cells to large organisms like giant kelp. Protozoans are any of a large group of single-celled, eukaryotic, usually microscopic organisms that are generally not photosynthetic.

Opal

The two most common chemical compounds in biogenous sediment are calcium carbonate (which forms the mineral calcite) and silica. Silica is often chemically combined with water to produce the hydrated form of silica, which is called **opal**.

Diatoms and Diatomaceous Earth

Most of the silica in biogenous ooze comes from microscopic algae called diatoms and protozoans called radiolarians. Because diatoms photosynthesize, they need strong sunlight and are found only within the upper, sunlit surface waters of the ocean. Most diatoms are free floating, or planktonic. The living organism builds a glass greenhouse out of silica as a protective covering and lives inside. Where diatoms are abundant at the ocean surface, thick deposits of diatom rich ooze can accumulate below on the ocean floor. When this ooze lithified, it becomes**diatomaceous earth**, which is a lightweight white rock composed of diatom tests and clay.

Hydrogenous Sediment

Hydrogenous sediment is derived from the dissolved material in water. Chemical reactions within seawater cause certain minerals to precipitate.*Precipitation usually occurs when there is a change in conditions, such as a change in temperature or pressure or the addition of chemically active fluids.*

Manganese Nodules

Manganese nodules are rounded, hard lumps of manganese plus iron plus other metals typically 5 cms to 20 cms in diameter. When cut in half, they often reveal a layered structure formed by precipitation around a central nucleation object, which might be a piece of lithogenous sediment, coral, volcanic rock, a fish bone, or a shark s tooth.

Manganese nodules are found on the deep-ocean floor. The major components of these nodules are **manganese dioxide** (around 30% by weight) and **iron oxide** (around 20%). Other accessory metals present in manganese nodules include copper, nickel and cobalt. Although the concentration of these accessory metals is usually less than 1%, they can exceed 2% by weight, which may make them attractive exploration targets in the future.

Phosphates

Phosphates occur abundantly as coatings on rocks and as nodules on the continental shelf and on banks at shallow depths. Concentrations of phosphates in such deposits indicate abundant biological activity in surface water above where they accumulate. Because phosphates are valuable as fertilizers, ancient marine phosphate deposits that have been uplifted onto land are extensively mined to supply agricultural needs.

Carbonates

The two most important carbonate minerals in marine sediment are**aragonite and calcite**. Both are composed of calcium carbonate but aragonite has a different crystalline structure that is less stable and changes into calcite over time. Most carbonate deposits are biogenous in origin. However, hydrogenous carbonate deposits can precipitate directly from seawater in tropical climates to form aragonite crystals

Metal Sulfides

Deposits of *metal Sulfides are associated with hydrothermal vents and black smokers along the mid-ocean ridge*. These deposits contain iron, nickel, copper, zinc, silver, and other metals in varying proportions. Transported away from the mid-ocean ridge by sea floor spreading, these deposits can be found **throughout the ocean floor** and can even be uplifted onto continents.

FactBox: Some important Facts on Diatoms

Diatoms are microscopic single-celled **photosynthetic** organisms. Each one lives inside a protective silica test, most of which contain two halves that fit together very much similar to a shoebox and its lid. The fossil record indicates that diatoms have been on Earth since the Jurassic Period (180 million years ago), and at least 70,000 species of diatoms have been identified.

The tests of diatoms are exquisitely ornamented with holes, ribs, and radiating spines**unique to individual species**.

Diatoms live for a few days to as much as a week, can reproduce sexually or asexually, and occur individually or linked together into long communities. They are found in great abundance floating in the ocean and in certain freshwater lakes but can also be found in many diverse environments, such as on the undersides of polar ice, on the skins of whales, in soil, in thermal springs, and even on brick walls.

When marine diatoms die, their tests rain down and accumulate on the sea floor as**siliceous ooze**. Hardened deposits of siliceous ooze, called diatomaceous earth, can be as much as 900 meters thick. Diatomaceous earth consists of billions of minute silica tests and *has many unusual properties* such as :

- It is lightweight and has an **inert chemical composition**.
- It is **resistant to high temperatures**, and

- It has excellent **filtering properties**.

Due these properties, diatomaceous earth is used to produce a variety of common products such as **filters**, **mild abrasives** (in toothpaste, facial scrubs, matches, and household cleaning and polishing compounds) **absorbents** (for chemical spills, in cat litter, and as a soil conditioner) **chemical carriers** (in pharmaceuticals, paint, and even dynamite) Other products from diatomaceous earth include **optical-quality glass** (because of the pure silica content of diatoms) and **space shuttle tiles** (because they are lightweight and provide good insulation). Diatomaceous earth is also used as an **additive in concrete**, a **filler in tires**, an **anticaking agent**, a **natural pesticide**, and as building stone in the construction of houses.

Apart from this, each living diatom contains a tiny droplet of oil. When diatoms die, their tests containing droplets of oil accumulate on the sea floor and thus they are the **beginnings of petroleum deposits**.

Resources from Ocean Sediments

Ocean beds are rich in potential mineral and organic resources. Much of these resources, however, are not easily accessible, so their recovery involves technological challenges and high cost.

Energy

The main energy resources associated with marine sediments are petroleum and gas hydrates. The ancient remains of microscopic organisms, buried within marine sediments before they could decompose, are the source of today s petroleum (oil and natural gas) deposits. Petroleum products account for 95% of the economic value of the ocean beds. This mainly includes the oil produced from offshore regions. Today major offshore reserves exist in the Persian Gulf, in the Gulf of Mexico, off Southern California and in the North Sea.

Gas hydrates are unusually compact chemical structures made of water and natural gas. They form only when high pressures squeeze chilled water and gas molecules into an icelike solid. Although hydrates can contain a variety of gases including carbon dioxide, hydrogen sulfide, and larger hydrocarbons such as ethane and propane; methane hydrates are by far the most common hydrates in nature.

Gas hydrates occur beneath ***Arctic permafrost areas on land and under the ocean floor***, where they were discovered in 1976. In deep-ocean sediments, where pressures are high and temperatures are low, water and natural gas combine in such a way that the gas is trapped inside a lattice like cage of water molecules.

Sand and Gravel

The offshore sand and gravel industry is second in economic value only to the petroleum industry. These include the rock fragments that are washed out to sea and shells of marine organisms, is mined by offshore barges using a suction dredge. This material is primarily used as aggregate in concrete, as a fill material in grading projects, and on recreational beaches.

Evaporative Salts

When seawater evaporates, the salts increase in concentration until they can no longer remain dissolved, so they precipitate out of solution and form salt deposits. The most economically useful salts are gypsum and halite i.e, common salt.

Manganese Nodules and Crusts

Manganese nodules are rounded, hard, golf- to tennis-ball-sized lumps of metals that contain significant concentrations of manganese, iron, and smaller concentrations of copper, nickel, and cobalt, all of which have a variety of economic uses.

Ocean Temperature

Trends in Ocean Temperature

The temperature of the oceanic water is important for **phytoplanktons as well as zooplanktons**. The temperature of sea water also affects the *climate of coastal lands and plants and animals*. The study of both, surface and subsurface temperature of sea water is thus significant.

Measurement of Temperature

Standard type of thermometer is used to measure the surface temperature while reversing thermometers and **thermograph**s are used to measure the subsurface temperature. These thermometers record the temperature up to the accuracy of ±O.02° centigrade.

Layers of Temperature in tropics

Oceans absorb more than 80% of the solar radiation and water which has highest specific heat is the remarkable capacity of storing the heat. The *uppermost 10% of the oceans has more heat* than the entire atmosphere of earth!

With respect to temperature, there are three layers in the oceans from surface to the bottom in the tropics as follows:

- The first layer represents the top-layer of warm, oceanic water and is 500m thick with temperature ranging between 20° and 25°C. This layer is present within the tropics throughout the year but it develops in mid· latitudes only during summer.
- The **thermocline layer** represents vertical zone of oceanic water below the first layer and is characterized ***by rapid rate of decrease of temperature with increasing depth***,
- The third layer is very cold and extends upto the deep ocean floor. The *polar areas have only one layer of cold water from surface (sea level) to the deep ocean floor*.

The radiant energy transmitted from the photosphere of the sun in the form of electromagnetic short waves and received at the ocean surface is called **insolation**. Besides, some energy, though insignificant, is also received from **below the bottom and through the compression of sea water**. The amount of insolation to be received at the sea surface depends on the angle of sun's rays, length of day, distance of the earth from the sun and effects of the atmosphere. The mechanism of the heating and cooling of ocean water differs from the mechanism on land because besides *horizontal and vertical movements of water, the evaporation is most active over the oceans.*

Daily Range of Temperature

The difference of maximum and minimum temperature of a day (24 hours) is known as daily range of temperature. The daily range of temperature of surface water of the oceans is **almost insignificant** as it is around 1°C only. The daily range of temperature is usually 0.3°C in the low latitudes and 0.2° to 0.3°C in high latitudes.

The diurnal range depends on the

- Conditions of sky (cloudy or clear sky),
- Stability or instability of air and
- Stratification of seawater.

The heating and cooling of ocean water is rapid under clear sky (cloudless) and hence the diurnal range of temperature becomes a bit higher than under overcast sky and strong air circulation. The high density of water below surface water causes very little transfer of heat through conduction and hence the diurnal range of temperature becomes low.

Annual Range of Temperature

The maximum and minimum annual temperatures of ocean water are recorded in August and February respectively in the northern hemisphere. Usually, the average annual range of temperature of ocean water is -12°C but there is a lot of regional variation which is due to regional variation in insolation, nature of seas, prevailing winds, location of seas etc.

Annual range of temperature is higher in the enclosed seas than in the open sea (Baltic Sea records annual range of temperature of 4.4°C or 40°F). The size of the oceans and the seas also affects annual range of temperature e.g., *bigger the size, lower the annual range and vice versa* The Atlantic Ocean records relatively higher annual range of temperature than the Pacific Ocean.

Distribution Pattern of Temperature

The distributional pattern of temperature of ocean water is studied in two ways viz.

- Horizontal distribution (temperature of surface water) and
- Vertical distribution (from surface water to the bottom).

Since the ocean has three dimensional shape, the **depth of oceans, besides latitudes,** is also taken into account in the study of temperature distribution. The following factors affect the distribution of temperature of ocean water.

Latitudes

The temperature of surface water decreases from **equator toward the poles** because the sun's rays become more and more slanting and thus the **amount of insolation decreases pole ward** accordingly. The temperature of surface water between 40°N and 40°S is lower than air temperature but it becomes higher than air temperature between 40°Latitude and the poles in both the hemispheres.

Unequal distribution of land and water

The temperature of ocean water varies in the northern and the southern hemispheres because of dominance of land in the northern hemisphere and water in the southern hemisphere. As far as surface temperature is concerned, it has the following implications:

- *The oceans in the northern hemisphere receive more heat due to their contact with larger extent of land* than their counterparts in the southern hemisphere and thus the temperature of surface water is comparatively higher in the northern hemisphere than the southern hemisphere.
- The isotherms are not regular and do not follow latitudes in the northern hemisphere because of the existence of both warm and cold landmasses whereas they (isotherms) are regular and follow latitudes in the southern hemisphere because of the dominance of water.

The temperature in the enclosed seas in low latitudes becomes higher because of the influence of surrounding land areas than the open seas e.g., the average annual temperature of surface water at the equator is 26.7°C whereas it is 37.8°C in the Red Sea and 34.4°C (94°F) in the Persian Gulf.

Prevailing wind

Wind direction largely affects the distribution of temperature of ocean water. The winds blowing from the land towards the oceans and seas (i.e. offshore winds) drive warm surface water away from the coast resulting into upwelling of cold bottom water from below. Thus, the <u>replacement of warm water by cold water introduces longitudinal variation in temperature</u>. Contrary to this, the onshore winds pile up warm water near the coast and thus raise the temperature.

Ocean currents

Surface temperatures of the oceans are controlled by warm and cold currents. Warm currents raise the temperature of the affected areas whereas cool currents lower down the temperature.

Other factors

Other factors include the following:

- Submarine ridges
- Local weather conditions such as storms, cyclones, hurricanes, fog, cloudiness, evaporation and condensation
- **Location and Shape of area:** The enclosed seas in the low latitudes record relatively higher temperature than the open seas whereas the enclosed seas have lower temperature than the

open seas in the high latitudes.

Horizontal Distribution of Temperature

Average temperature of surface water of the oceans is 26.7°C and the temperature gradually decreases from equator towards the poles. The rate of decrease of temperature with increasing latitudes is generally 0.5°C per latitude. The average temperatures become 22°C at 20° N and S latitudes, 14°C at 40° N and S latitude, and 0°C near the poles. I have already mentioned above that the oceans in the northern hemisphere record relatively higher average temperature than in the southern hemisphere. Please note that the *highest temperature is not recorded at the equator rather it is a bit north of it.*

Also we should note that the average annual temperature of all the oceans is 17.2°C. The average annual temperatures for the northern and southern hemispheres are 19.4°C and 16.1°C respectively. The variation of temperatures in the northern and southern hemispheres is because of unequal distribution of land and water as Northern hemisphere is made up of more land, while the southern hemisphere is made up of more oceans.

In Northern Atlantic, there is a**very low decrease of temperature**with increasing latitudes towards north. This is because of the Gulf Stream currents which are warm currents. However, in southern Atlantic, the decrease of temperature with increasing latitude is more pronounced. The table shows the variations of three major oceans:

Latitudes	Pacific Ocean	Atlantic Ocean	Indian Ocean
00-10°	26	25.2	27
10-20°	25	23.2	26.9
20-30°	21.5	21.2	22.5
30-40°	17	17	17
40-50°	11.1	9	8.7
50-60°	5	1.8	1.6
60-70°	-1.3	-1.3	-1.5

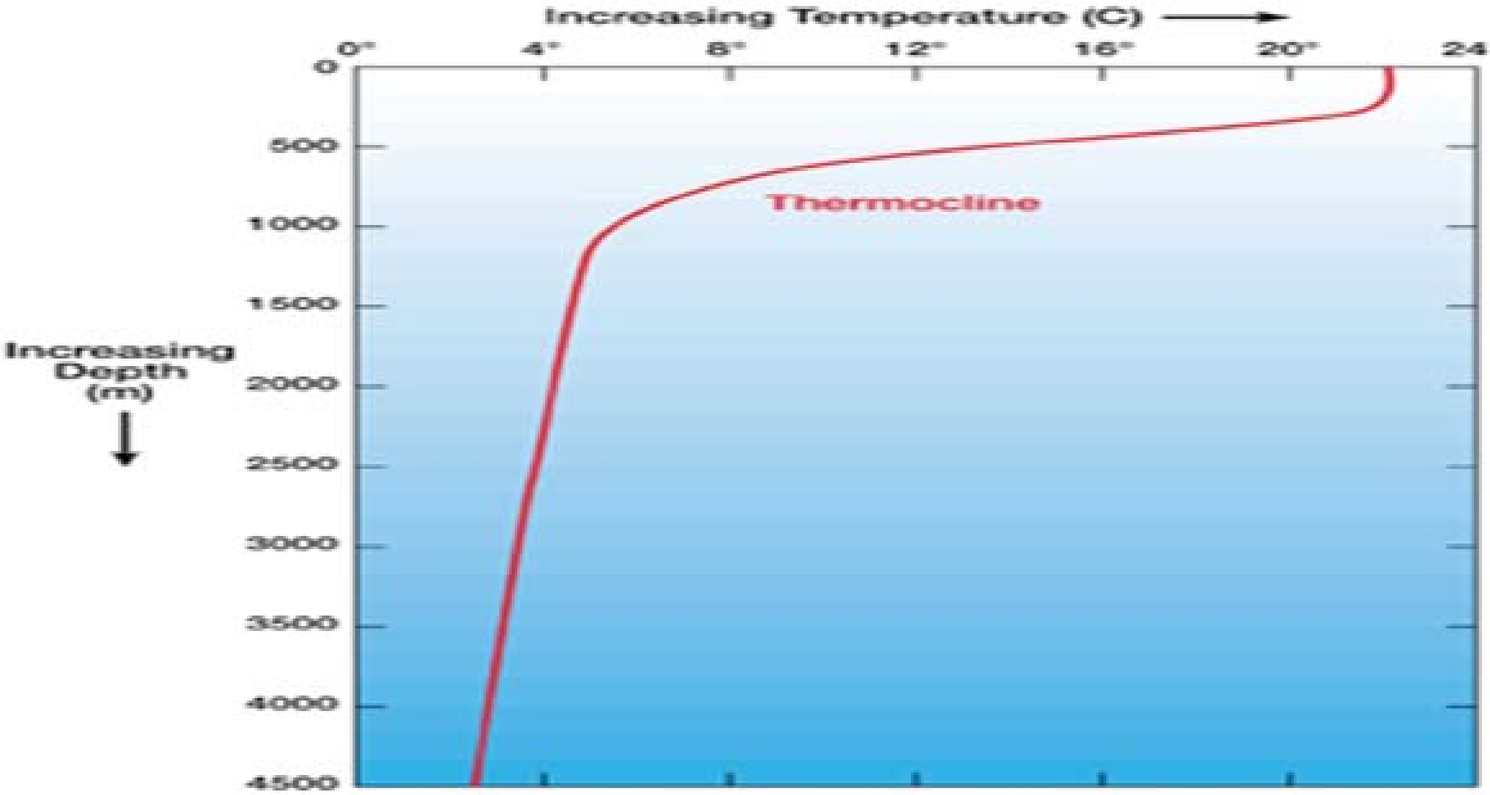
Vertical Distribution of Temperature

The maximum temperature of the oceans is always on the surface because it directly receives the insolation. The heat is transmitted to the lower sections of the oceans through the mechanism of **conduction**.

Solar rays very effectively penetrate up to 20m depth and they seldom go beyond 200m depth.

Consequently, the temperature decreases from the ocean surface with increasing depth but the***rate of decrease of temperature with increasing depth is not uniform everywhere***. The temperature falls very rapidly up to the depth of 200m and thereafter the rate of decrease of temperature is slowed down.

On this basis, oceans are vertically divided into three zones as follows:



Photic Zone or Euphotic Zone

This is the upper layer of the ocean. The temperature is relatively constant and is 100 meters deep.

Thermocline

Thermocline lies between 100-1000 meters. There is a steep fall in the temperature. The following graph shows the thermocline.

Deep Zone

Below 1000 meters is the deep zone. Here, the temperature is near zero °C. Please note that near bottom, the temperature of water never goes to 0°C. It is always 2-3°C.

Important Observations

- Sea temperature decreases with increasing depth but the rate of decrease of temperature is not uniform.
- The change in sea temperature below the depth of 1000m is negligible. The maximum change in temperature is between 100-1000 meters which is called Thermocline or Pycnocline.
- Diurnal and annual ranges of temperature cease after a depth of 30 feet and 600 feet respectively.
- The rate of decrease of temperature with increasing depth from equator towards the poles is not uniform.

Though, the surface temperature of the oceans decreases from equator to the poles, the **temperature at the ocean bottom is uniform at all latitudes**However, some studies have shown that the ***coldest bottom temperatures, just below — 0.25℃, occur at 60-70°S, near the Antarctic continent***.

Salinity of Ocean Water

Salinity of the ocean water is between 3.3-3.7 percent. The maximum amount of salt is common salt i.e. Sodium Chloride, which is *followed by Magnesium Chloride*. The major salts are as follows:

Salt	‰ (parts per thousand)
Sodium Chloride	2.6
Magnesium Chloride	0.3
Magnesium Sulphate	0.2
Calcium Sulphate	0.1
Potassium Chloride	0.1
Potassium Bromide	0.001
Others	0.001

Most of the salinity of the sea comes from the dissolved material that originates from land and was carried by the rain, running water, ground water, wind, sea waves, glaciers etc. Some of the salts come from the deeper layers of earth. Volcanic lava, dead organic matters also contribute in the Ocean salinity. The salinity of the ocean water depends upon the following:

Evaporation

Higher the rate of evaporation, higher is salinity. The Highest evaporation has been recorded along the tropic of Cancer and that is one of the reasons that region of Red Sea and Persian Gulf has one of the highest salinity. Another reason is that enclosed seas tend to have more salinity in their water.

Temperature

There is a direct relationship between ocean temperature and salinity. So the warmer parts are more saline and frigid parts are less saline.

Precipitation

Precipitation is inversely related to salinity. Higher is the precipitation, lower is the proportion of salinity. The equatorial region records highest rainfall and that is why it has low salinity in comparison to those which are near to tropics.

Influx of Freshwater

Low salinity will be found at the mouth of rivers. This salinity is minimum in the raining season.

Atmospheric Pressure

High pressure areas have high salinity and vice versa.

Circulation of Ocean water

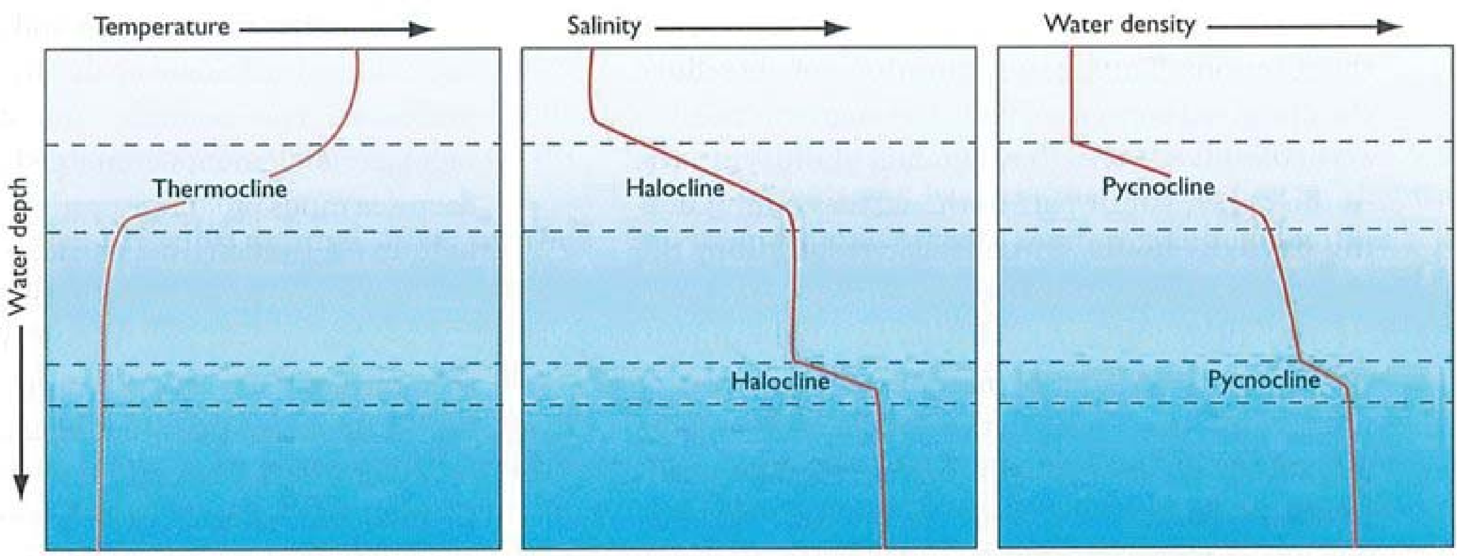
Ocean currents play a major role in distribution of salinity.

Horizontal Distribution of Salinity of Ocean Water

As a general rule, the salinity of the oceans decreases on both sides from the tropic of Cancer. This is attributed to the high occurrence of precipitation on equator. Highest salinity of the seawater has been recorded between 20°N to 40°N. The average salinity of the Northern and Southern hemisphere is 3.5 and 3.4 % respectively. This also because of the fact that the Northern Hemisphere is land dominated.

Vertical Distribution of Salinity of Ocean Water

There is no definite trend in the vertical distribution of salinity in the oceans, so there are no generalizations. However, it has been noted that**the salinity of the ocean increases with increasing depth in the higher latitudes and polar areas**. In the middle latitudes also, the same trends is seen but ONLY up to a depth of 370 meters after that it decreases with increasing depth.



Ocean Currents

Ocean current is the general movement of a mass of oceanic water in a definite direction, which is more or less similar to water streams flowing on the land surface of the earth. Ocean currents are most powerful of all the dynamics of oceanic waters because these drive oceanic waters for thousands of kilometers away.

Origin of Ocean Currents

The currents in the oceans are originated due to combined effects of several internal as well as external factors, which control the origin and other characteristics of ocean current. They are related to different characteristics of ocean waters, rotational mechanism of the earth, external factors or atmospheric factors, topographic characteristics of the coasts and ocean basins.

	Factors that cause Ocean Currents
1	Rotation of Earth
2	Coriolis Force
3	Pressure Gradient
4	Temperature Variations
5	Salinity Differences
6	Atmopsheric Pressure
7	Winds
8	Evaporation
9	Precipitation
10	Tides

Each of the above factors can also significantly affect / modify the ocean currents.

Difference between Drifts, Current and Streams

On the basis of velocity, dimension and direction, they can be divided into drifts, currents and streams. *The forward movement of surface water of the oceans under the influence of prevailing winds is called drift whereas the ocean current involves the movement of Oceanic water in a definite direction with greater velocity.* Ocean stream involves movement of larger mass of ocean water like big rivers of the continent in a definite direction with greater velocity than the drifts and currents such as in Gulf Stream.

Difference between Warm Currents and Cold Currents

Ocean currents are divided on the basis of temperature into *warm currents* and *cold currents.* Those currents that flow from the Equator towards the poles are warmer than the surrounding water and so *they are called warm currents*. The ocean currents that flow from the *polar areas towards the Equator are cooler compared to the surrounding water, so they are called cold currents*The actual difference in temperature of warm and cold currents is only a few degrees.

- *The cold currents are usually found on the west coast of the continents in the low and middle latitudes in both the hemispheres and on the east coast in the middle latitudes in the Northern Hemisphere.*
- *The warm currents are usually observed on the east coast of the continents in the low and middle latitudes in both the hemispheres. In the Northern Hemisphere they are found on the west coasts of the continents in the high latitudes.*

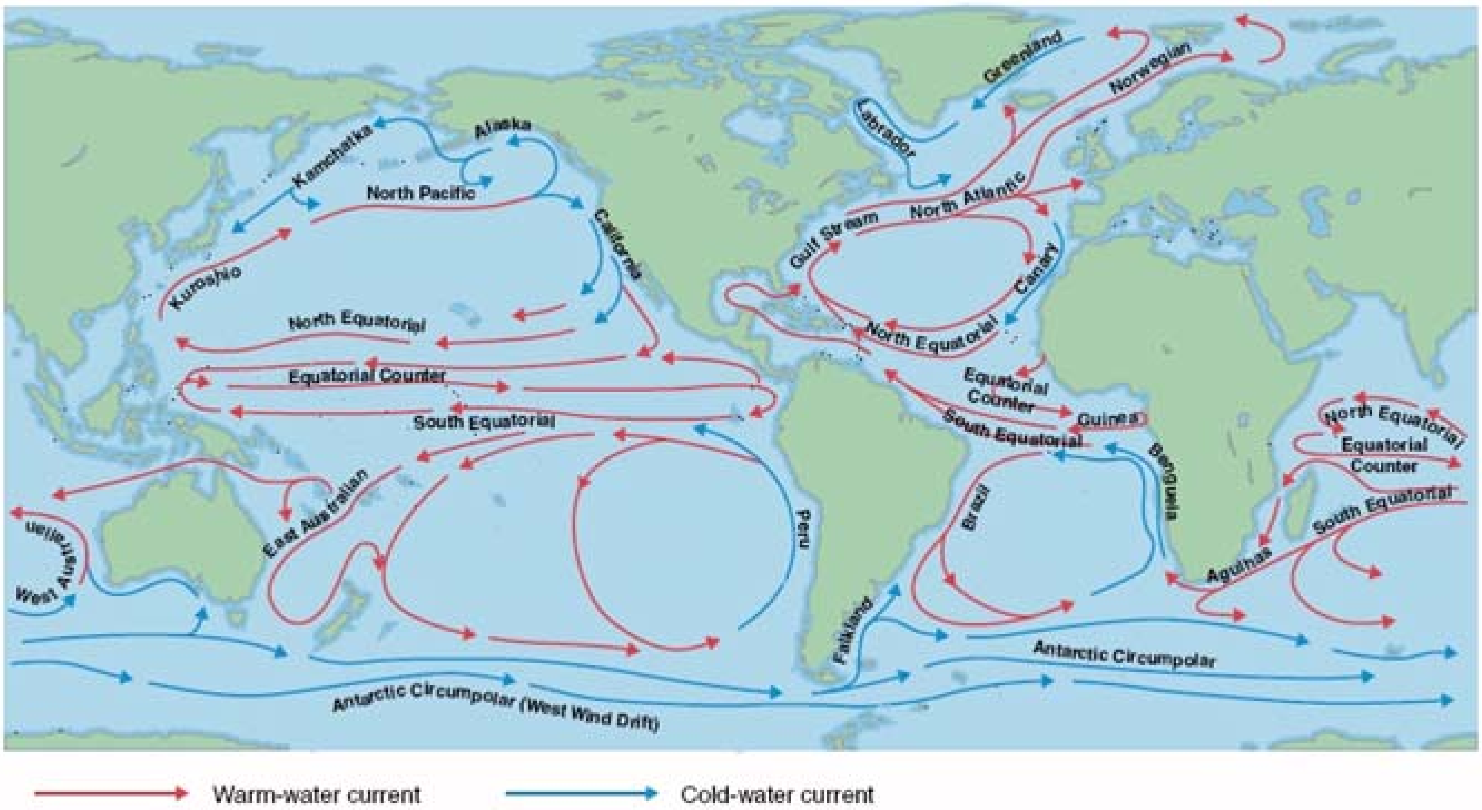
Difference between Surface Currents and Deep Currents

Ocean currents can also be divided into **Surface Currents** and **Deep Currents**. Surface currents affect surface water above the **pycnocline** (<10% of ocean water). These currents are primarily driven by major wind belts. The Deep currents affect deep water below pycnocline (90% of ocean water) and are primarily driven by **density differences**. The deep currents are larger and slower than surface currents.

Ekman Transport

The stress of wind blowing across the sea causes a surface layer of water to move. Due to the low viscosity of water, this stress is not directly communicated to the ocean interior, but is balanced by the Coriolis force within a relatively thin surface layer, 10-200m thick. **This layer is called the Ekman layer and the motion of this layer is called the Ekman transport**. Because of the deflection by the Coriolis force, the Ekman transport is not in the direction of the wind, but is 90° to the right in the Northern Hemisphere and 90° toward the left in the Southern Hemisphere. The amount of water flowing in this layer depends only upon the wind and the Coriolis force and is independent of the depth of the Ekman layer and the viscosity of the water.

The major surface currents are shown below:



Currents of Atlantic Ocean

Important Currents of the Atlantic Ocean are as follows:

North Equatorial Current (warm)

North equatorial current is a significant Pacific and Atlantic Ocean current that flows east-to-west between about 10° north and 20° north. This current is generated because of upwelling of cold-water near the west coast of Africa. This warm current is also pushed westward by the cold Canary current.

On an average, the north equatorial warm current flows from east to west but this saline current is deflected northward when it crosses the mid-Atlantic Ridge near 15°N latitude. It again turns southward after crossing over the ridge. This current, after being obstructed by the land barrier of the east coast of Brazil, is bifurcated into two branches viz. Antilles current and Caribbean current. The Antilles current is diverted northward and flows to the east of West Indies islands, and helps in the formation of Sargass Sea eddy while the second branch known as the Caribbean current enters the Gulf of Mexico and becomes Gulf Stream.

South Equatorial Current (warm)

The South Equatorial Current is a significant Pacific, Atlantic, and Indian Ocean current that flows east-to-west between the equator and about 20 degrees south. In the Pacific and Atlantic Oceans, it extends across the equator to about 5 degrees north. South equatorial current flows from the western coast of Africa to the eastern coast of South America between the equator and 20°S latitude. This current is more constant, stronger and of greater extent than the north equatorial current. In fact, this current is the continuation of the cold **Benguela current.** This warm current is bifurcated into two branches due to obstruction of land barrier in the form of the east coast of Brazil.

The northward branch after taking north-westerly course merges with the north equatorial current near Trinidad while the second branch turns southward and continues as Brazil warm current parallel to the east coast of South America. This current is basically originated under the stress**of trade winds.**

Equatorial Counter Current

Equatorial Counter Current is a significant ocean current in the Pacific and Indian oceans that flows west-to-east at approximately five degrees north. The Counter Currents result from balancing the westward flow of water in each ocean by the North and South Equatorial currents.
In El Niño years, Equatorial Counter current intensifies in the Pacific Ocean.

The Equatorial Counter current flows from west to east in between the westward flowing strong north and south equatorial currents. This currents is less developed in the west due to stress of trade winds. In fact, the counter current mixes with the equatorial currents in the west but it is more developed in the east where it is known as the**Guinea Stream**. The Equatorial Counter current carries relatively higher temperature and lower density than the two equatorial currents. Several ideas have been put forth to explain the origin of the Equatorial Counter current. According to some scientists this current is originated because of the *influence of the westerlies which blow from west to east in the calm zone of the doldrums or in the convergence zone of the north east and south east trade winds.*

Gulf Stream

The Gulf Stream is a system of several currents moving in north-easterly direction. This current system originates in the Gulf of Mexico around 20°N latitude and moves in north easterly direction along the eastern coast of North America and reaches the western coasts of Europe near 70°N latitude. This system, named Gulf Stream because of its origin in the Mexican Gulf, consists of

- Florida current from the strait of Florida to Cape Hatteras,
- Gulf Stream from Cape Hatteras to the Grand Bank, and
- North Atlantic Drift (current) from Grand Bank to the Western European coast.

North Equatorial Current flows westward off the coast of northern Africa. When this current interacts with the northeastern coast of South America, the current forks into two branches. One passes into the Caribbean Sea, while a second, the Antilles Current, flows north and east of the West Indies. These two branches rejoin north of the Straits of Florida. Thus, Florida current is in fact, the northward extension of the north equatorial current. This current flows through Yucatan channel into the Gulf of Mexico, thereafter the current moves forward through Florida Strait and reaches 30°N latitude. Thus, the Florida warm current contains most of the characteristics of the equatorial water mass.

The trade winds blow westward in the tropics, and the westerlies blow eastward at mid-latitudes. This wind pattern applies a stress to the subtropical ocean surface with negative curl across the North Atlantic Ocean. The resulting Sverdrup transport is Equatorward. Because of conservation of potential vorticity caused by the northward-moving winds on the subtropical ridge's western periphery and the increased relative vorticity of northward moving water, transport is balanced by a narrow, accelerating poleward current, which flows along the western boundary of the ocean basin, outweighing the effects of friction with the western boundary current known as the Labrador Current. The conservation of potential vorticity also causes bends along the Gulf Stream, which occasionally break off due to a shift in the Gulf Stream's position, forming separate warm and cold eddies. This overall process, known as western intensification, causes currents on the western boundary of an ocean basin, such as the Gulf Stream, to be stronger than those on the eastern boundary.

As a consequence, the resulting Gulf Stream is a strong ocean current. It transports water at a rate of 30 million cubic meters per second through the Florida Straits. As it passes south of Newfoundland, this rate increases to 150 million cubic meters per second.

The average temperature of water at the surface is 24°C while the salinity is 3.6%. The temperature never falls below 6.5°C . The current becomes narrow while passing through the Florida strait but thereafter its width increases and current flows close to coast.

Canary Current (Cold)

The Canary current, a cold current, flows along the western coast of north Africa between Maderia and Cape Verde. In fact, this current is the continuation of North Atlantic Drift which turns sout.hward near the Spanish coast and flows to the south along the coast of Canaries Island. The average velocity of this current is 8 to 30 nautical miles per day. This current brings cold water of the high latitudes to the warm water of the low latitudes and finally merges with the north equatorial current. The Canary cold current ameliorates the otherwise hot weather conditions of the western coasts of North Africa.'

Labrador Current (Cold)

The Labrador Current, an example of cold current, originates in the Baffin Bay and Davis Strait and after flowing through the coastal waters of Newfoundland and Grand Bank merges with the Gulf Stream around 50°W longitude. The flow discharge rate of the current is 7.5 million ml of water per second. This current brings with it a large number of big icebergs as far south as Newfoundland and Grand Bank. These icebergs present effective hindrances in the oceanic navigation. Dense fogs are also produced due to the convergence of the Labrador cold current and the Gulf Stream near Newfoundland.

Brazil Current (Warm)

The Brazil current is characterized by high temperature and high salinity. This current is generated because of the bifurcation of the south equatorial current because of obstruction of the Brazilian coast near Sun Rock. The northern branch flows northward and merges with the north equatorial current while the southern branch known as the Brazil current flows southward along the east coast of South America up to 40°S latitude. Thereafter it is deflected eastward due to the deflective force of the rotation of the earth and flows in easterly direction under the influence of westerlies. The Falkland cold current coming from south merges with Brazil current at 40° S.

Falkland Current (Cold)

The cold waters of the Antarctic Sea flows in the form of Falkland cold current from south to north along the eastern coast of South America up to Argentina. This current becomes most extensive and developed near 30°S latitude. This current also brings numerous icebergs from the Antarctic area to the South American coast.

South Atlantic Drift (Cold)

The eastward continuation of the Brazil current is called South Atlantic Drift. This current is originated because of the deflection of the Brazil warm current eastward at 40°8 latitude due to the deflective force of the rotation of the earth. The South Atlantic Drift, thus, flows eastward under the influence of the westerlies. This current is also known as the Westerlies Drift or the Antarctic Drift.

Benguela Current (Cold)

The Benguela current, a cold current, flows from south to north along the western coast of south Africa. In fact, the South Atlantic Drift turns northward due to obstruction caused by the southern tip of Africa. Further northward, this current merges with the South Equatorial Current.

Currents of Pacific Ocean

Important currents of the Pacific Ocean are as follows:

North Equatorial Current (Warm)

The north equatorial current originates off the western coast of Mexico and flows in westerly direction and reaches the Philippines coast after covering a distance of 7500 nautical miles. This current is originated because of the Californian current and north-east monsoon. The volume of water continuously increases westward because numerous minor branches join this current from the north. A few branches also come out of the main current and turn towards -north and south. One branch emerges from the north equatorial current near Taiwan and flows northward to join **Kuroshio current** while the southern branch turns eastward to form counter equatorial current. It is significant to note that north equatorial current flows as a continuous current i n the north Pacific Ocean but there are seasonal variations in its northern and southern marginal areas. The velocity of the current ranges between 12 and 18 nautical miles per day. With the northward (northern summer) and southward (south northward and southward but it always remains to the north of equator.

South Equatorial Current (Warm)

The south equatorial current is originated due to the influence of south-east trade winds and flows from east to west. This current is stronger than the north equatorial current. The average velocity is 20 nautical miles per day while the maximum velocity becomes 100 nautical miles a day. Numerous minor currents join this current. from the left and thus. the volume of water continuously increases west-ward, The current is bifurcated into northern and southern branches near New Guinea. The northern branch turns eastward and flows as counter equatorial current w rule the southern branch –moves towards the northern and north-eastern coasts of Australia.

Counter Equatorial Current (Warm)

The current flowing west to east between the north and south equatorial currents is termed counter equatorial current. Because of trade winds immense volume of water is piled up in the western marginal parts of the ocean, with the result there is general slope gradient of water surface from west to east. This higher water level in the west and descending slope gradient of water surface from west to east make the oceanic water flow in easterly direction in the name of counter equatorial current which is the most developed counter current in the Pacific Ocean. This counter equatorial current is extended up to the Panama Bay.

Kuroshio System (Warm)

The Kuroshio System consists of several currents and drifts is similar to the Gulf Stream system of the Atlantic Ocean. This system runs from Taiwan to the Bering Strait and consists of the Kuroshio current, the Kuroshio extension, the north Pacific drift, the Tsushima current and the counter Kuroshio current.

Oyashio Current (Cold)

The Oyashio cold current is also known as Kurile cold current. This cold current flows through the Bering Strait in southerly direction and thus transports cold water of the Arctic Sea into the Pacific Ocean. Near 50°N latitude this current is bifurcated into two branches. One branch turns east-ward and merges with the Aleutian and Kuroshio currents. The second branch moves upto the Japanese coasts. This current is comparable to the cold **Labrador Current** of the North Atlantic Ocean. The convergence of cold Oyashio (Kurile) and warm Kuroshio Current causes dense fogs which become potential hazards for navigation.

California Current (Cold)

The California current, an example of cold current, is similar to the Canary cold current of the Atlantic Ocean in most of its characteristics. In fact, this current is the eastward extended portion of the North Pacific drift. The cold California current is generated because of the movement of oceanic water along the Californian coast from north to south in order to compensate the loss of water which is caused due to large-scale transport of water off the coast of Mexico under the influence of trade winds in the form of the north equatorial current. This current after reaching the Mexican coast turns west-ward and merges with the north equatorial current.

Peru Current (Cold)

The cold current flowing along the western coast of South America from south to north is called Peru current or Humboldt current. This current is known as Peru coastal current near the coast w bile it is called Peru oceanic current off the coast. Mean annual temperature ranges between 14°C and 17°C and the average velocity of moving water is 15 nautical miles (27km) per day. The temperature of sea water increases from the coast towards the ocean.

East Australia Current (Warm)

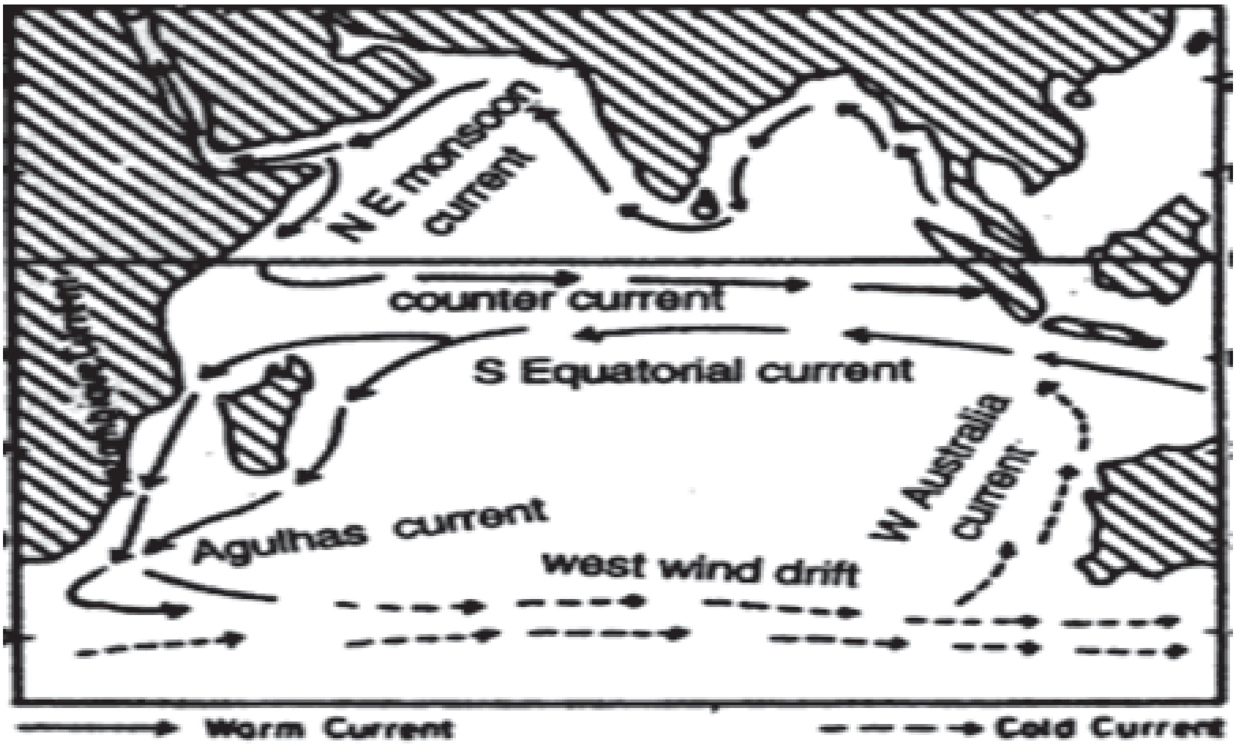
South equatorial current is bifurcated near the Australian coast into northern and southern branches. The southern branch flows as east Australia current from north to south along the eastern coasts of Australia. New Zealand is surrounded by this current. It is deflected eastward near 40°S latitude due to deflective force of the earth and flows in easterly direction under the influence of the westerlies. This is a warm and more consistent current. It raises the temperature of east Australian coast for considerable distance southward.

Currents of the Indian Ocean

The current systems of the Indian Ocean are largely controlled and **modified by landmasses and monsoon winds**. Indian Ocean being surrounded by the Indian subcontinent, Africa and Australia does not present most favourable conditions for the development of consistent system of ocean currents. *The currents in the northern Indian Ocean change their flow direction twice a year due to north-east* *and south-west monsoon winds.*

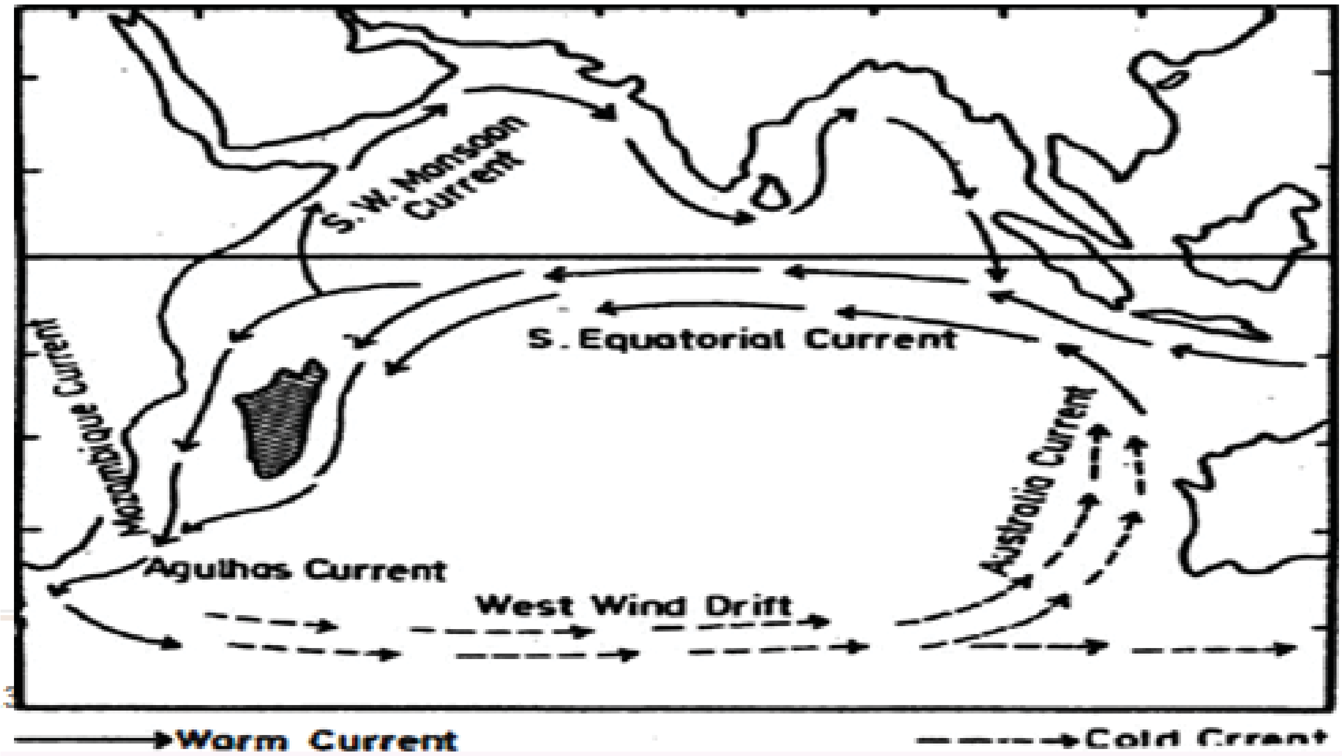
North-East Monsoon Current (Warm)

North-east monsoon winds blow from land to the ocean during winter season in the northern hemisphere and thus westward blowing north-east monsoon currents are produced in Indian Ocean. This current flows to the south of 5°N latitude. Besides, some independent currents originate in the Bay of Bengal and Arabian sea and flow in south-westerly direction.



S.W. Monsoon Current (Warm)

There is complete reversal in the direction of monsoon winds during summer season. The north-easterly direction of winter monsoon winds becomes south-westerly during summer season in the northern hemisphere. This reversal of direction of monsoon winds also reverses the direction of ocean currents of Indian Ocean during summer season. North-east monsoon ocean currents disappear and south-west monsoon ocean currents are developed. The general direction of monsoon currents is from south-west to north-east but several minor branches emerge from the main branch and move in the Bay of Bengal and Arabian Sea. The Indian counter current developed during winter season disappears due to this current.



Origin and Factors Affecting Ocean Currents

The main effect of temperature differences on the earth occurs in a north-south direction i.e. from equator to poles. Warm equatorial waters therefore move slowly along the surface towards the poles while heavier cold waters of the polar areas creep slowly towards the Equator along the bottom of the sea. Thus, the difference in the temperature of the ocean waters causes ocean currents. They are convectional currents giving rise to a transfer of heat energy in the ocean waters from the areas of excess to the areas of deficit heat energy.

- The factors relating to the earth's nature and its rotation include the gravitational force and deflective force by earth's rotation also known as Coriolis force.
- Oceanic factors include the pressure gradient, temperature variations and salinity differences. Ex-oceanic factors are atmospheric pressure and winds, evaporation and precipitation.
- Tides caused by the gravitational pull of the Moon and the Sun also play role in the forming of oceanic currents.
- The factors that can modify the currents are direction and shape of coastlines, bottom reliefs of the ocean basins, seasonal variations and *rotation of the earth*.
- Ocean circulation is driven by winds and by differences in water density. Along with the winds, ocean currents distribute the tropical heat worldwide, thus they play a very important role in maintaining Earth's heat balance.
- Please note that water at the poles travels in slow creeps below the surface water towards equator, which is called Ocean Creep. Ocean Creep is not a surface movement of water. It is

an undercurrent flow occasioned by the sinking of cold and heavy water. The water, on becoming cold, contracts and its density increases.

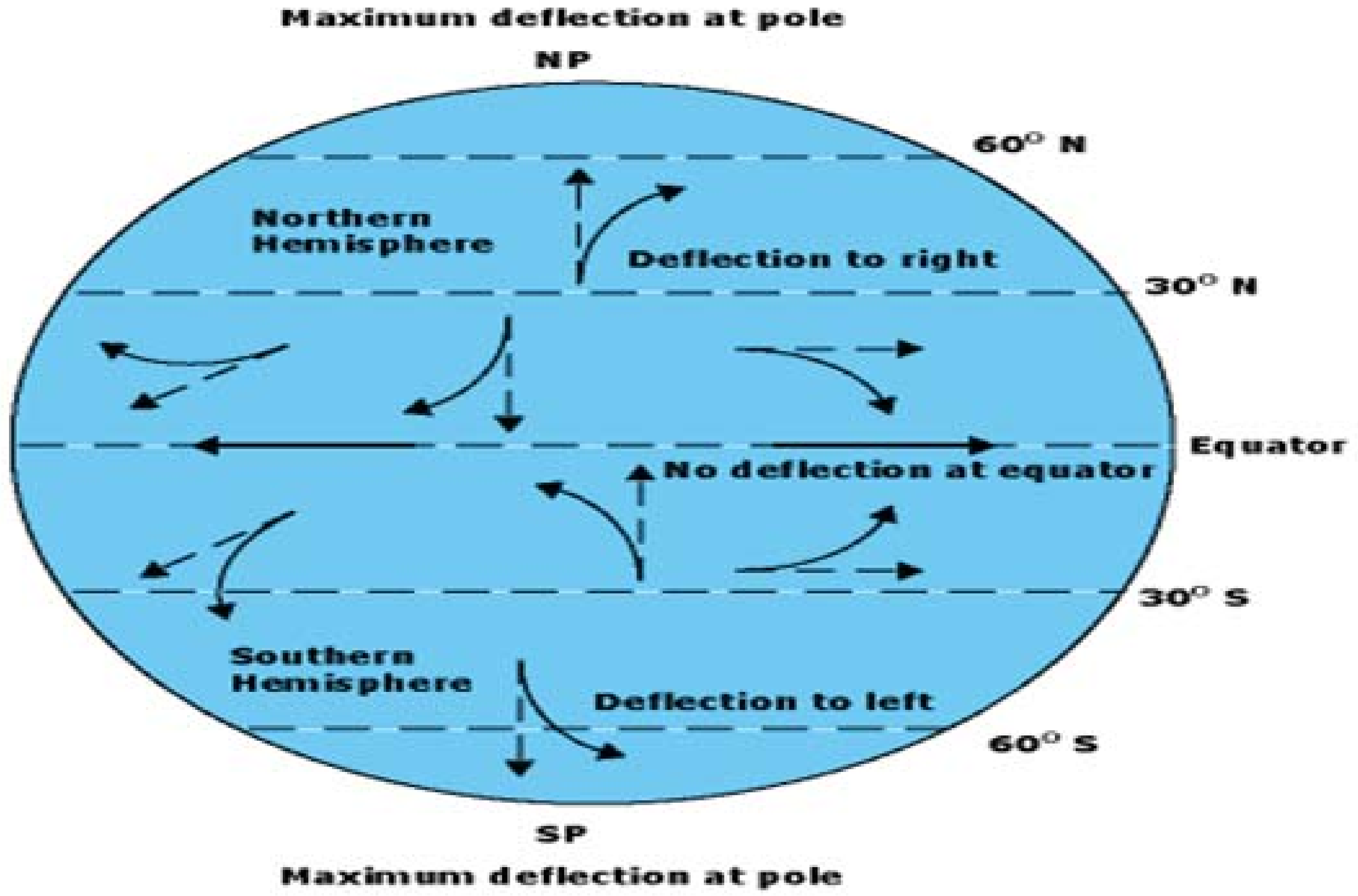
- The density of the ocean water varies from place to place, a movement in the ocean waters occurs due to this.
- A gyre is any large system of rotating surface ocean currents, particularly those involved with large wind movements. Gyres are caused by the Coriolis Effect; planetary vorticity along with horizontal and vertical friction, which determine the circulation patterns from the wind curl (torque).

Impacts of Coriolis Force

Coriolis Effect is a deflection of moving objects when they are viewed in a rotating reference frame. In a reference frame with clockwise rotation, the *deflection is to the left of the motion of the object*; in one with counter-clockwise rotation, the *deflection is to the right* Coriolis Effect is causes ONLY in a rotating reference frame. The deflective force causes by the Coriolis Effect is caused Coriolis force. It has its own say in many geographical phenomena, most important being the deflection of the general direction of ocean currents.

Important Observations about Coriolis Force:

The currents flowing from equator towards the North Pole and from North Pole towards the equator are deflected to their right while the currents flowing north-south and south-north in the southern hemisphere are deflected towards their left.



The rotational force of the earth causes movement of ocean water near the equator in opposite direction to '**the west to east rotation of the earth**and thus equatorial currents are generated. These currents flow from **east to west**. Some ocean water moves in the direction of the rotation of the earth i.e. from west to east and thus counter equatorial currents are also formed.

Please note that the magnitude of the deflection, or "Coriolis effect," varies significantly with latitude. The **Coriolis Effect is zero at the equator**and **increases to a maximum at the poles** The deflection is *proportional to wind speed; that is, deflection increases as wind strengthens*The resultant balance between the pressure force and the Coriolis force is such that, in the absence of surface friction, air moves parallel *to isobars (lines of equal pressure).* This is called the geotropic wind.

The Coriolis force explains why winds circulate around high and low pressure systems as opposed to blowing in the direction of the pressure gradient.

Impact of Physical Properties of Ocean on Ocean Currents

Local variations in the physical properties of the ocean such as pressure gradient, temperature differences, salinity differences, density variations etc. generate ocean currents.

Temperature

The amount of insolation received at the earth's surface and consequent temperature decreases from equator towards the poles. Due to high temperature in the equatorial region the water density decreases because of greater expansion of water molecules whereas the density of sea water becomes comparatively greater in the polar areas. Consequently water moves due to expansion of volume from equatorial region (of higher temperature) to polar areas (colder areas) of relatively very low temperature.

There is movement of ocean water below the water surface in the form of subsurface current from colder polar areas to warmer equatorial areas in order to balance the loss of water in the equatorial areas. Thus, the poleward surface current and Equatorward subsurface currents form a complete circulatory system of ocean water. The Gulf Stream and Kuroshio warm currents moving from equator towards north are examples of such currents.

Salinity

Oceanic salinity affects the density of ocean water and density variation causes ocean currents. Salinity increases the density of ocean water. If two areas having equal temperature are characterized by varying salinity, the area of high salinity will have greater density than the area of low salinity. The denser water sinks and moves as subsurface current whereas less saline water moves towards greater saline water as surface current. In other words, *ocean currents on the water surface are generated from the areas of less salinity to the areas of greater salinity. Such system of surface and subsurface currents caused by salinity variation is originated in open and enclosed seas.* For example, the current flowing from the Atlantic Ocean to the Mediterranean Sea via Gibraltar Strait is caused because of the difference in salinity.

The salinity of the Mediterranean Sea is much higher than the adjoining Atlantic Ocean. Consequently, water sinks in the Mediterranean Sea. In order to compensate the loss of water Atlantic water flows as surface current into the Mediterranean Sea. The sinking water in the Mediterranean Sea moves as subsurface current towards the Atlantic Ocean. Similarly, such system of surface and subsurface currents is generated between the Red Sea and the Arabian Sea via Bab-el-Mandeb Strait.

The salinity of the Baltic Sea is lowered due to the flow of fresh water by the rivers but the level of water is raised. With the result water moves northward as a surface current into the North Sea and subsurface current moves from the North Sea to the Baltic Sea.

Impact of Air Pressure and Winds on Ocean Currents

Air pressure on the oceanic water causes ocean currents through density variations. The areas of high atmospheric pressure are characterized by low volume of water and thus lowering of water level. Contrary to this the areas of low atmospheric pressure record higher volume of water and higher water level. Thus, water moves as surface current from the areas of higher water level (Low pressure areas) to low water level areas (high pressure areas).

Prevailing or planetary winds (e.g., trade winds, westerlies and polar winds) play major roles in the origin of ocean currents. The wind blowing on the water surface also moves water in its direction due to its friction with the water. Most of the ocean currents of the world follow the direction of prevailing winds. For example, equatorial currents flow westward under the influence of N.E. and S.B. trade winds. The Gulf Stream in the Atlantic and the Kuroshio in the Pacific move in northeastern direction under the influence of the westerlies. There is seasonal change in the direction of currents in the Indian Ocean twice a year (after every 6 months) due to seasonal change in the direction of monsoon winds. Friction caused by the wind sets the sea water in motion.

Prelims Model Questions

Oceanography Model Questions

1. With reference to the Ocean Currents, which among the following observations is / are correct?

1. They are slow surface movements of water
2. They generally comprise warm water
3. Configuration of Oceans affects them

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [B] Only 3

First statement is not correct. Ocean currents are not always slow; in fact most of them are swift, deep and narrow. The slow and shallow currents are called Drifts. Then, this statement is also incorrect in the sense that when we talk only about the surface currents, we miss the more important Global Thermohaline circulation. Surface Currents are generally wind driven movements of water at or near the ocean's surface. Thermohaline currents (which are caused by variation of temperature and salinity and density) are slow deep currents that affect bulk of the seawater beneath the Pycnocline.

2. With reference to the general features of Ocean bottom relief, which among the following statements is / are correct?

1.Continental Slope connects the continental shelf and the ocean basins

2.Deep sea plains are the flattest and smoothest regions of the world

3.Guyot is a volcanic mountain on seabed with its flat tip over the surface of sea

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [A] Only 1 & 2

The ocean floors can be divided into four major divisions:

1. The Continental Shelf;
2. The Continental Slope;
3. The Deep Sea Plain;
4. The Oceanic Deeps.

Besides, these divisions there are also major and minor relief features in the ocean floors like ridges, hills, sea mounts, guyots, trenches, canyons, etc. Continental Shelf is the extended margin of each continent occupied by relatively shallow seas and gulfs. Continental Slope connects the continental shelf and the ocean basins. It begins where the continental shelf sharply drops off into a steep slope. Deep sea plains are gently sloping areas of the ocean basins. These are the flattest and smoothest regions of the world. Oceanic Deeps or Trenches are the deepest parts of the oceans. They are relatively steep sided, narrow basins.

A guyot also known as a table mount is an isolated underwater volcanic mountain (seamount), with a flat top over 200 meters (660 feet) below the surface of the sea. The diameters of these flat summits can exceed 10 km.

3. Which among the following play role on formation of Ocean currents?

1.Rotation of Earth

2.Revolution of Earth

3.Gravitational Pull by Sun and Moon

4.Prevailing Winds

Choose the correct option from the codes given below:

[A] 1 & 4

[B] 1, 3 & 4

[C] 1, 2, 3 & 4

[D] 1, 2 & 3

Answer: [C] 1, 2, 3 & 4

The currents in the oceans are originated due to combined effects of several internal as well as external factors, which control the origin and other characteristics of ocean current. Regarding Revolution, we know that Earth is tilted and due to revolution of earth, various regions are tipped away or toward the sun during round the year journey around Sun. This creates opposite seasons in northern and southern hemispheres. This affects global air circulation and global air circulation would affect the ocean currents.

4. Consider the following comparisons of the Surface Oceanic Currents and Deep Oceanic Currents?

1. While surface currents are primarily driven by winds, deep currents are primarily driven by density differences
2. While surface currents are swift, deep currents are relatively slower

Which among the above observations is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [C] Both 1 & 2

Ocean currents are of two type's viz. Surface Currents and Deep Currents. Surface currents affect surface water above the pycnocline (<10% of ocean water). These currents are primarily driven by major wind belts. The Deep currents affect deep water below pycnocline (90% of ocean water) and are primarily driven by density differences. The deep currents are larger and slower than surface currents.

5. With reference to the Ocean Currents in Indian Ocean, consider the following statements:

1. Indian Ocean is known for one of the most consistent system of Ocean Currents
2. The currents in the northern Indian Ocean change their flow direction twice a year

Which among the above statements is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [B] Only 2

The current systems of the Indian Ocean are largely controlled and modified by landmasses and monsoon winds. Indian Ocean being surrounded by the Indian subcontinent, Africa and Australia does not present most favourable conditions for the development of consistent system of ocean currents. The currents in the northern Indian Ocean change their flow direction twice a year due to north-east and south-west monsoon winds.

6. Consider the following observations:
1. Abyssal plains are more extensive in Atlantic / Indian Oceans in comparison to pacific ocean
2. Oceanic trenches are more extensive in Pacific Ocean in comparison to Atlantic / Indian Oceans
3. Seamounts are more common in Pacific Ocean in comparison to Atlantic / Indian Oceans

Which among the above statements is / are correct?

[A] Only 1 & 2

[B] Only 1 & 3

[C] Only 2 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

Abyssal Plain

Abyssal plain is flat, cold and sediment covered ocean floor. Abyssal plains are more extensive in Atlantic and Indian Oceans and less extensive in Pacific Ocean. Abyssal plain is found at an average depth between 3000 and 6000 meters. They are among the flattest, smoothest and least explored regions on earth.

Oceanic Trench

An elongated through or deep in the ocean floor is called ocean trench. It is more or less a U shaped valley. Most of world's trenches are in Pacific Ocean. Trenches are most active geological features on earth where great earthquakes are Tsunamis are born.

Seamounts

Seamounts are elliptical projections from the sea floor which look like mountains and have a steep slope of around 22° to 24°. Half of the world's total seamounts arc in Pacific Ocean.

Guyots

Guyots are basically inactive volcanoes which are flat topped. Some of them are tall enough to approach or even penetrate the sea surface. Guyots are confined to Central Pacific Ocean.

7. With reference to the temperature of the surface of Ocean, consider the following statements:
1. Temperature of the surface of the Oceans is higher in Northern Hemisphere in comparison to Southern Hemisphere
2. Isotherms drawn in the Northern Hemisphere are more regular in comparison to southern hemisphere

Which among the above statements is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [A] Only 1

The oceans in the northern hemisphere receive more heat due to their contact with larger extent of land than their counterparts in the southern hemisphere and thus the temperature of surface water is comparatively higher in the northern hemisphere than the southern hemisphere warm and cold landmasses whereas they (isotherms) are regular and follow latitudes in the southern hemisphere because of the dominance of water.

8. Which two hot and cold ocean currents meet at the Grand Banks of Newfoundland in the North American continental shelf, making it one of the richest fishing grounds in the world?

[A] Agulhas Current and Labrador Current

[B] Gulf Stream and Labrador Current

[C] Falkland current and Norwegian current

[D] Labrador Current and Norwegian current

Answer: [B] Gulf Stream and Labrador Current

The Grand Banks of Newfoundland are a group of underwater plateaus southeast of Newfoundland on the North American continental shelf. These areas are relatively shallow, ranging from 80 to 330 feet (24–101 m) in depth. The cold Labrador Current mixes with the warm waters of the Gulf Stream here. The mixing of these waters and the shape of the ocean bottom lifts nutrients to the surface. These conditions helped to create one of the richest fishing grounds in the world.

9. With reference to the relief features of Indian Ocean, consider the following statements:

1. The average depth of the Indian Ocean is more in eastern side in comparison to western side
2. The deeps and trenches are almost absent in Indian Ocean

Which among the above is / are correct statements?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [A] Only 1

The Indian ocean is smaller than Pacific and Atlantic ocean. It is bounded by Asia in North, Africa in West, Asia in East, Australia in South East and Antarctica in the South. It has got connected with Pacitic and Atlantic oc.ean near Antarctica. The average depth of the ocean is 4000 m. Majority of this ocean is formed by the block mountains of Gondwanaland. Here some prominent marginal seas are Mozambique channal, Red sea, Persian gulf, Andaman sea, Arabian sea, Bay of Bengal etc. The Indian subcontinent in the North divides the Indian ocean into Arabian sea and Bay of Bengal.

Johnson has divided the Indian ocean into three zones.

1. The Western zone : It is between the African coast and the mid Indian oceanic ridge, and average depth is around 400 m. or 2000 fathoms in this zone.
2. The Eastern zone : It is deepest with a depth of around 550 m or 3000 fathoms.
3. The Central zone : It represents the mid oceanic ridge where many tiny island are located

Deeps and Trenches : Important deep-Sea trenches are Sunda trench (7450 m deep), o b trench (687.5 m deep). Mauritius trench, Amirante trench etc. The deeps are almost absent.

10. Consider the following ocean currents:

1. Kamchatka Current
2. Humboldt Current
3. Leeuwin Current
4. Agulhas Current

Which of the above is/are cold water currents?

[A] Only 1 & 2

[B] Only 1, 2 & 3

[C] Only 2, 3 & 4

[D] 1, 2, 3 & 4

Answer: [A] Only 1 & 2

Agulhas Current is warm water current along the east coast of South Africa. Leeuwin Current is a warm ocean current.

General Knowledge Today

Prelims Geography-5: Land Relief, Land Forms, Rock & Minerals

Target 2016: Integrated IAS General Studies

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Contents

Model Questions

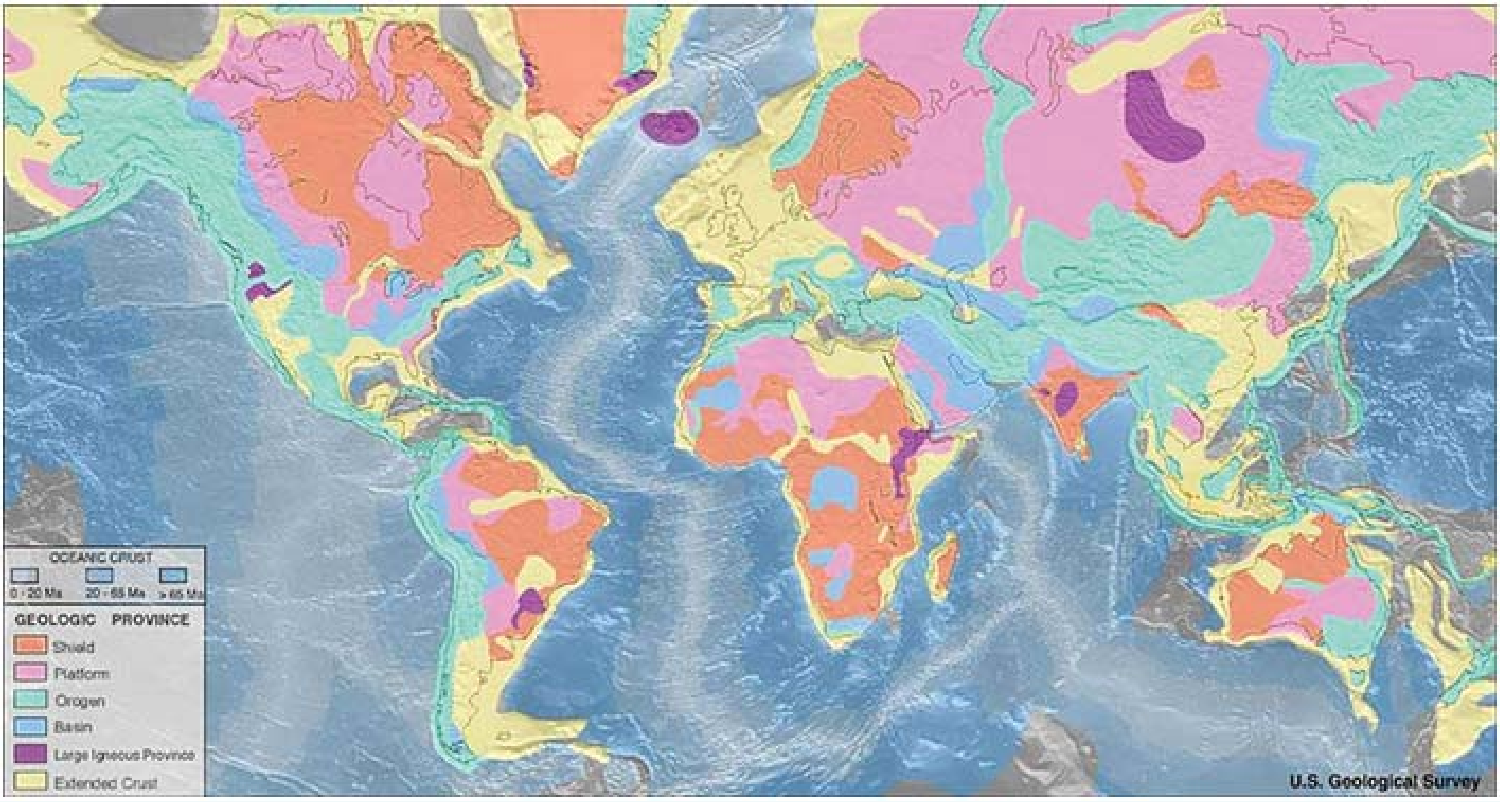
Please check Prelims Model Questions in the end of this module.

Relief Features of the Land and Landforms

Geological Provinces

The entire Earth has been divided into several Geological Provinces on the basis of their origin. A geologic or geomorphic province is an entity with common geologic or geomorphic attributes. The six Geological provinces include:

- **Continental Shield**
- **Platform**-which is a shield covered with sediment
- **Orogen**-which leads to development of mountains
- **Structural Basins**-which are geological depressions, and are the inverse of domes
- **Large igneous provinces**-which are extremely large (More than 100,000 Km²) accumulation of igneous rocks—intrusive, extrusive, or both—in the earth's crust. One example of large igneous province is India's Deccan trap.
- Extended Crust.



Continental Shields

The first order of relief contains Earth's continents and ocean basin, which were created by the movements of plates on the surface of the Earth. The lithospheric shell of the Earth is divided into large pieces called **lithospheric plates**. A single plate can be as large as a continent and can move independently of the plates that surround it. This is very much similar to a great slab of ice floating on the polar sea. The continents can be geologically derived into two types of regions viz.

- Active mountain-making belts and
- Inactive regions of old, stable rock.

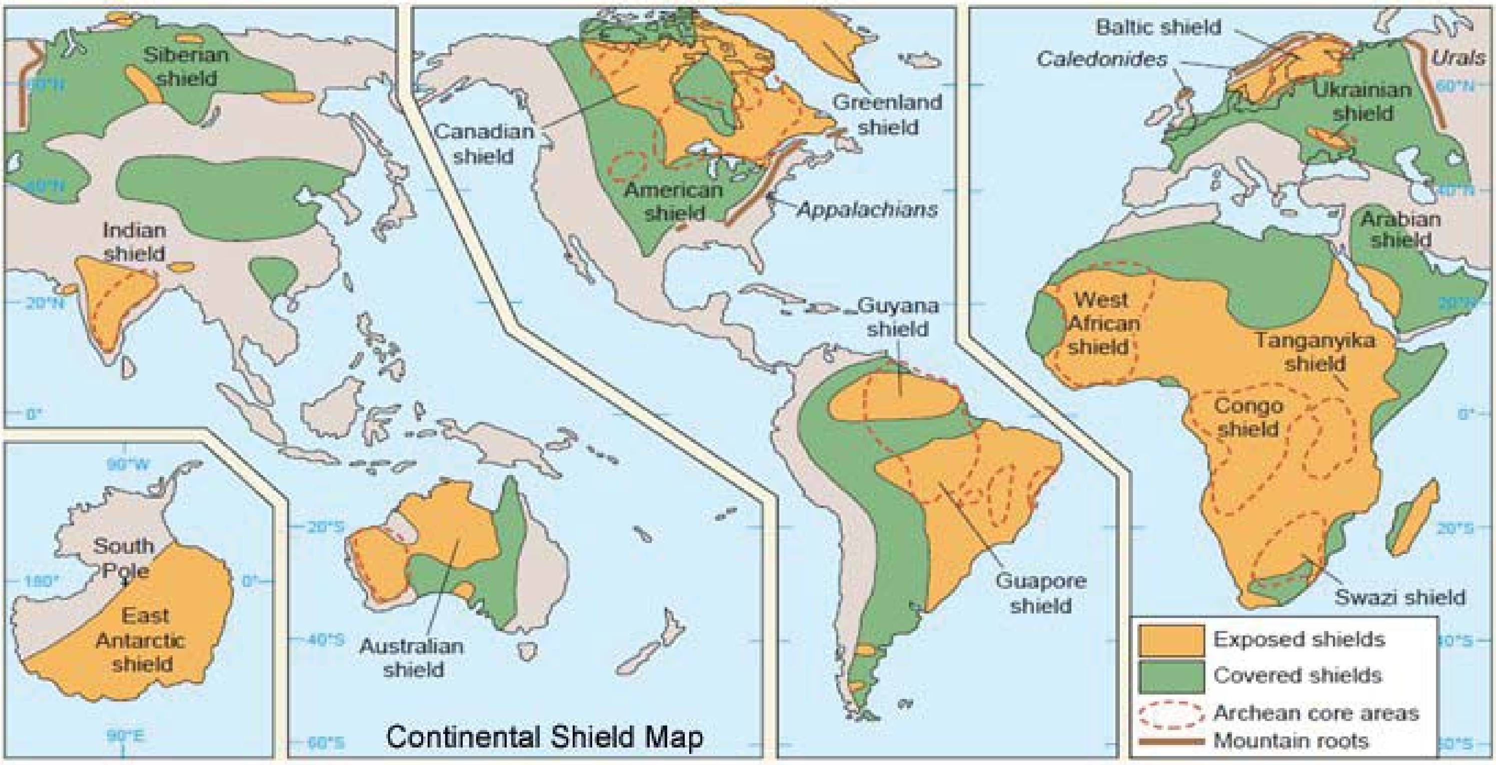
The mountain ranges in the active belts grow through **two major complex geologic processes**.

- First of them is **volcanism,** in which massive accumulations of volcanic rock are formed by extrusion of magma.
- Second process is the **tectonic activity**e. the breaking and bending of the Earth's crust *under internal Earth forces.* This tectonic activity usually occurs when great lithospheric plates come together in collision. Crustal masses that are raised by tectonic activity create mountains and plateaus. At some places, both volcanism and tectonic activity combine to produce a mountain range. ***Tectonic activity can not only form mountains but also lower crustal masses to form depressions***.

Please note that the active mountain-making belts are narrow zones that are usually found along the margins of lithospheric plates. The rest of the Lithospheric plates are much older, comparatively inactive rocks. There are two types of stable structures— **continental shields** and **mountain roots**.

The **continental shields** are regions of low-lying **igneous and metamorphic rocks**. The shields may be exposed or covered by layers of sedimentary rock. The core areas of some shields are made of rock dating back to the Archean eon, 2.5 to 3.5 billion years ago. Thus, continental shields are formed on ancient metamorphic rocks such as granitic, batholiths, and dikes. The oldest rocks on Earth are found in the shields.

Mountain roots are mostly formed of Paleozoic and early Mesozoic sedimentary rocks that have been intensely bent and folded, and in some locations changed into metamorphic rocks. Thousands of meters of overlying rocks have been removed from these old tectonic belts, so that only the lowermost structures remain. Roots appear as chains of long, narrow ridges, rarely rising over a thousand meters above sea level.



Mountain Formation: Orogeny

Orogeny is primarily the mechanism by which mountains are built on continents due to the large structural deformation of the Earth's lithosphere caused by Plate Tectonics. Orogenesis involves the following:

- Structural deformation of the rocks
- Faulting of rocks
- Folding of rocks
- Igneous Processes
- Metamorphism
- Glaciation
- Erosion
- Sedimentation

Mountains are born and have a finite life span. Young mountains are high, steep, and growing upward. Middle-aged mountains are cut by erosion. Old mountains are deeply eroded and often buried.

We have to note here that the constructive processes, like deformation, folding, faulting, igneous processes and sedimentation build mountains up. On the contrary, the destructive processes like erosion and glaciation, tear them back down again.

Causes of Mountain Building

There are three primary causes of mountain building as follows, which have already studied:

- Convergence at convergent plate boundaries.

- Continental Collisions
- Continent Rifting

Forms of Mountains

A mountain may have several forms. Important among them are: i) mountain ridge, ii) mountain range, iii) mountain chain, iv) mountain system, v) mountain group, and vi) cordillera.

Mountain Ridge

It is a linear, steep-sided high hill, or spur. The slope of one side of a ridge is steep, while the other side is of moderate slope. A ridge, however, may have symmetrical slopes on both sides. The Shimla Ridge is a good example of mountain ridge.

Mountain Range

A mountain range is a linear system of mountains and hills having several ridges, peaks, summits and valleys.

Mountain Chain

A mountain chain consists of several parallel long and narrow mountains of different periods.

Mountain System

A mountain system consists of different mountain ranges of the same period. In a mountain system, different mountain ranges are separated by valleys.

Mountain Group

A mountain group consists of several unsystematic patterns of different mountain systems

Cordillera

It is a Spanish term referring to a system or major group of mountains. A cordillera consists of several mountain groups and systems. In other words, cordillera is a community of mountains having different ridges, ranges, mountain chains and mountain systems. It usually refers to an orogenic belt at a continental scale, e.g., the Western Cordillera of the U.S.A., which includes all the ranges between the Pacific and the Great Plains.

Types of the Mountains

No two mountains are the same. They, however, can be classified on the basis of their most dominant characteristics into: i) folded mountains, ii) volcanic mountains, iii) fault-block mountains, and iv) upwarped (dome) mountains.

Folded Mountains

Folded mountains comprise the largest and most complex mountain systems. Although folding is the dominant characteristic, faulting and igneous activity are always present in varying degrees in folded mountains. The Alps, Himalayas, Rockies, Andes, Appalachians, Tien Shan, Caucasus, Elburz, Hindukush, etc., are all of this type. The folded mountains present the world's major mountain systems. They are the youngest mountains in the world.

Volcanic Mountains

Volcanic mountains are formed from the extrusion of Java and pyroclastic materials, which if continued long enough, produces gigantic volcanic piles. The Kilimanjaro (Africa), Cotopaxi (Andes), Mt. Rainier, Hood and Shasta (U.S.A.), are some of the examples of volcanic mountains.

Fault Block Mountains

Fault-block Mountains are bounded by high angle normal faults. Some of them are associated with rift valleys such as those in East Africa, while others appear to be formed by vertical uplifting. A notable example of fault-block mountain is found in the Basin and Range Province of the southwestern USA. The Salt Range of Pakistan, and Siena-Nevada of California (U.S.A.) are also the typical examples of fault-block mountains.

Upwarped (Domed) Mountains

Upwarped or domed mountains are formed by magmatic intrusions and upwarping of the crystal surface. The lava domes, batholithic domes, laccolithic domes, salt domes, etc., are the examples of Dome Mountains. The Black Hills of South Dakota, and the Adirondack mountains of New York may be cited as the examples of upwarped (domes) mountains.

Different Stages of Orogeny

Mountains can also be divided on the basis of their making i.e. Orogeny during different geological periods.

Pre-Cambrian Orogeny

This was the first ever Orogeny on earth and represents the oldest mountains of the earth. The examples are Laurasian of North America, Elogoman etc.

Caledonian or Mid Paleozoic Orogeny

It occurred during Silurian and Devonian periods. The example are Aravallis of India, Brazilian Highlands in America, Scotland of Europe etc.

Harcynian or Late Paleozoic Orogeny

This occurred in the Permian period. Example are Appalachian of North America, Black Forest of Europe etc.

Alpine Orogeny

This took place in Tertiary period and represents the youngest and newest mountain ranges of Earth. The examples are Himalaya, Rocky, Andes, Apennines, Alps etc.

Plateaus

Plateau is an elevated tract of relatively flat land, usually limited on at least one side by a steep slope falling abruptly to lower land. It may also be delimited in places by abrupt slopes rising to residual mountains or mountain ranges, as in the Tibetan plateau, where it occurs as an intermontane plateau. The term is also used to refer to a structural surface such as Meseta of Spain, in which case it is a tectonic plateau. It is also used to describe extensive lava flows (lava plateau). The surfaces of plateaus may be plain-like in quality, very flat, rolling or hilly, or they may be so dissected by streams and glaciers that it is difficult to recognize their original plateau characteristics.

Diastrophic Plateaus

Diastrophism is the large-scale deformation of the earth's crust which produces continents, ocean basins and mountain ranges, etc. All the highest plateaus of the earth are the direct products of diastrophism. Since their uplifts they have been modified by various agents of erosion and in many cases by volcanism and minor earth movements. For convenience they may be classified as:

- Intermontane plateaus
- Mountain border plateaus
- Domed plateaus,
- Volcanic plateaus
- Erosional plateaus.

Intermontane Plateau

Intermontane Plateaus include the highest, largest and in many respects most complex plateaus of the world. Their surfaces show an extraordinary variety of topographic features.

- The best example is the Tibetan Plateau. It stretches approximately 1,000 kilometers north to south and 2,500 kilometers east to west. The average elevation is over 4,500 meters (14,800 ft), and all 14 of the world's 8,000 metres (26,000 ft) and higher peaks are found in the region. Sometimes called "the roof of the world," it is the highest and biggest plateau, with an area of 2.5 million sq. km or about four times the size of France. The Tibetan Plateau is bounded on the north by the Kunlun mountains, and in the south by the mighty Himalayas. These two systems meet to make the western boundary of the plateau, while on the east is the less sharp demarcation between the plateau proper and the lower mountains of western China.The Qinghai-Tibet Plateau not only gives rise to most of Asia's major rivers, it also holds a constellation of salt- and freshwater lakes.
- Another example of Intermontane Plateau is Plateau of Bolivia and Peru. It lies largely in Bolivia at an average elevation of more than 3,692 metres (12,000 ft) above the sea level.
- One more example is Mexican Plateau which extends from the United States border in the north to the Cordillera Neovolcánica in the south, and is bounded by the Sierra Madre Occidental and Sierra Madre Oriental to the west and east, respectively.

Border Plateaus

Many plateaus border mountain ranges and owe their present position to the same uplifts that raised the mountains. Piedmont plateau is an excellent example of border plateaus. This plateau is a strip of land that stands between tile Atlantic coastal plains and the Appalachian Mountains. Its eastern side is marked by a more or less definite fall-line where the gradient of the rivers is steepest. On the west it terminates against the mountains of the Blue Ridge. Plateau of Colorado is also an example of the border plateau. It is bounded on the northeast by the Rocky Mountains and on the southwest by the

Basin and Range Province.

Domed Plateaus

The plateau of Ozark (U.S.A.) is a good example of domed plateau. Ozark plateau was uplifted by folding and faulting into a broad dome some 65,000 sq km (40,000 square miles) in area during the Appalachian Revolution which occurred at the close of the Paleozoic Era.

Volcanic Plateaus

Volcanoes also form several varieties of plateaus. The largest are built by the lava flow. Smaller, degraded plateaus are formed by the resistant lava caps that protect the land from erosion and maintain its high elevation after the surrounding land has been worn away.

Erosional Plateaus

Such plateaus are formed particularly in semiarid regions where streams have cut away portions of high lands.

Land Forms

Landforms are defined as the geomorphologic units defined by its surface form and location in the landscape. Landforms are typical elements of the topography. The water body interfaces also called landforms. They are categorized on the basis of elevation, slope, orientation, stratification, rock exposure, and soil types as follows:

- Aeolian landforms
- Coastal and oceanic landforms
- Erosion landforms
- Fluvial landforms
- Mountain and glacial landforms
- Slope landforms
- Volcanic landforms

Aeolian landforms

Aeolian landforms refer to the Landforms that are formed by the winds. There are two types of the Aeolian Landforms viz. Erosional and Depositional.

Aeolian Landforms: Erosional

Zeugen or Rock Mushrooms

They are also known as rock pedestal or a pedestal rock or Zeugen. Usually Found in Desert Areas.

Yardangs

Yardangs form in environments where water is scarce and the prevailing winds are strong, unidirectional and carry an abrasive sediment load. They consist of an elongated ridge carved by the unidirections erosion.

Dreikanter

Dreikanter exhibits a 3 faced Pyramidal Shape. They typically form in Deserts due to wind erosion.

Blow Outs

Blowouts refer to sandy depressions in a sand dune ecosystem, which are caused by the removal of sediments by wind.

Inselbergs

Inselbergs refer to the prominent steep sided hill of solid rock rising abruptly from a plain of low relief. Inselbergs are generally composed of resistant rocks such as Granites.

Desert pavement

Desert pavement refers to mountain wash containing pebbles, gravels and sand particles exposed to wind and surface appears as a pavement with closely packed, interlocking angular or rounded rock fragments of pebble and cobble size

Aeolian Landforms: Depositional

Erg or Sand Sea

Erg is a sand sea or a dune sea. They are flat area of desert covered with wind-swept sand with little or no vegetative cover. The area is generally more than 100 square miles and is deposited by windblown sand. Largest Hot Desert in the World viz. Sahara has several sand Seas. The Ergs have 85% of Earth's mobile sand.

Ripples

Ripples are well marked small waves produced on the surface of sand, mud and even rock by the drag of the wind / water moving over it. They are most common in deserts.

Barchan

Barchan refers to crescent shaped dunes, which have tips or horns pointing downwards. Barchans are found in desert areas which have low sand quantity.

Longitudinal dunes

Longitudinal dunes are also known as Seif dunes. Seif is a arabic word for Sword. These are long, slightly sinuous, ridge shapped dunes which are parellel to the wind direction, elongate parallel to the prevailing wind, possibly caused by a larger dune having its smaller sides blown away. Seif dunes are sharp-crested and are common in the Sahara.

Transverse Dunes

Transverse Dunes are asymmatrical sands in deserts which are at right angle to the wind direction. They are most probably caused by a steady build-up of sand on an already existing minuscule mound.

Star Dunes

Star Dunes are giant star shapped dunes with 3 or more sinuous arms extending outwards from the center. These shapes can alter due to windspeeds.

Fluvial Landscapes

The landforms which develop as a result of the water action are known as Fluvial Landforms.

Running water such as rivers are the most important agent of erosion. Other agents such as Glaciers, Groundwater, wind and sea water are locally dominant agents of erosion. *The Fluvial processes are most important of all the exogeneric processes as landforms associated with them have overall dominance in the environment of terrestrial life.* These fluvial processes can be divided into three phases viz. erosion, transportation and deposition.

Erosional Landforms

The **Erosion** can be **normal erosion** which takes place by the natural physical processes or the **Accelerated Erosion**, which is produced by human interference. The**Sheet Erosion** refers to the **s**urface flow removing soil in thin layers. It can be accelerated in the Steep slopes, where innumerable closely spaced channels are formed, which grows larger form in gullies (steep-walled canyon like trench). The Erosion can be of following types:

- Chemical erosion: Corrosion (Or solution) and carbonation.
- Mechanical erosion.
- Impaction (effect of blow upon the river bed or banks by large boulders).
- Cavitations (shattering and breaking up of the stream load through collisions and mutual abrasion).
- Hydraulic action (lifting and quarrying effect of rushing water).
- Corrosion or abrasion (stream uses its load to scrape away its bed, particularly in steep confined sections of stream channels).

Landforms made by River Erosion

Landforms made by River Erosion


V shaped Valley


Gorge


Meander


River Terrace


Peneplain


Canyon

V-shaped Valley

Valley starts as small and narrow rills which gradually develop into long and wide gullies. The gullies will further deeper widen and lengthen to give rise to valleys which is V-shaped. The **River valley** is an important erosional landform. They are formed in the youthful stage of fluvial cycle of erosion. The vertical erosion or valley deepening causes the V-shaped valleys.

Gorge & Canyons

The V-shaped valley can be a **Gorge**, where steep precipitous wall within which a narrow river is confined (e.g. – Indus, Sutlej, Brahmaputra, Rhine, Zambezi). Thus, we can say that Gorge is a V-shaped valley but its sides becomes so steep that they look almost vertical. Or it can be a **Canyon**, which is basically a very deep and extended gorge. The Grand Canyon in Arizona, United States of America is the largest Canyon in the world.

Meander

The meanders or meandering rivers are the low slope rivers which are not choked with the sediment and move back and forth in a zig-zag order of loops. The meander has thus a serpentine path and it helps in accommodating in extra volume of water.

River Terraces

River terraces are abandoned floodplains that formed when a river flowed at a higher level than it does today. Thus, these are the surfaces that mark an old valley floor or floodplain levels.

Peneplain

When an extensive area has been eroded sufficiently to give the look of almost a plain, it is called a

Peneplain.

Landforms made by River Deposition

Alluvial Fans

When the velocity of the running water, as it comes out of hills and meets the plain, decreases, it dumps the transported material at the foothills. The structure made are called alluvial fans. The alluvial fans are formed due to accumulation of materials in the form of fan and cones respectively at the base of foot hills Alluvial cones are made of coarse materials than the alluvial fans.

Natural leaves

Narrow belt of ridges of low height built by the deposition of sediments by the spill water of the stream on its either bank.

Food plain

Surfaces on either side of a stream that is frequently inundated.

Crevasse splays

Formed by breaching of leaves when water escapes through a series of distributaries channels.

Back swamps

Plain area adjoining a levee may contain marshes called back swamps.

Yazoo streams

Distributions of rivers occupying lateral positions.

Delta

Delta is the triangular deposition at the mouth of a river debouching in a lake or a sea. The Factors that help in delta formation are as follows:

- Long courses of rivers.
- Medium size sediments.
- Calm or sheltered sea.
- Suitable place (shallow sea and lake shores).
- Large amount of sediments.
- Accelerated
- Stable condition of sea coast.

On the basis of shape delta can be divided into following categories such as arcuate, bird-foot, Estuarine, Cuspate, Truncated etc.

Arcuate (lobate form) Delta

The Arcuate delta resembles the fan and is convex towards the Sea. It is semicircular in shape and is commonly found in semi-arid region; growing delta such as Nile, Niger, Ganga, Indus, Mekong, Irrawaddy, Rhine, Volga, Danube, Rhone, Lena rivers.

Bird-foot Delta

Birdfoot Delta is also known as a finger delta. In these deltas, the sediments deposited are composed of those fine particles which are received from the limestone rocks. The rivers with high velocity carry suspended finer load to greater distance inside the oceanic water (such as Mississippi).

Estuarine delta

When a river enters the sea through the single mouth or estuary, then the Estuarine Delta is formed which is submerged under marine water. Examples are Narmada River, Congo River, Amazon River and Hudson River.

Cuspate Delta

Cuspate delta are pointed. They are shaped by regular, opposing, gentle water movement as seen at the Tiber river.

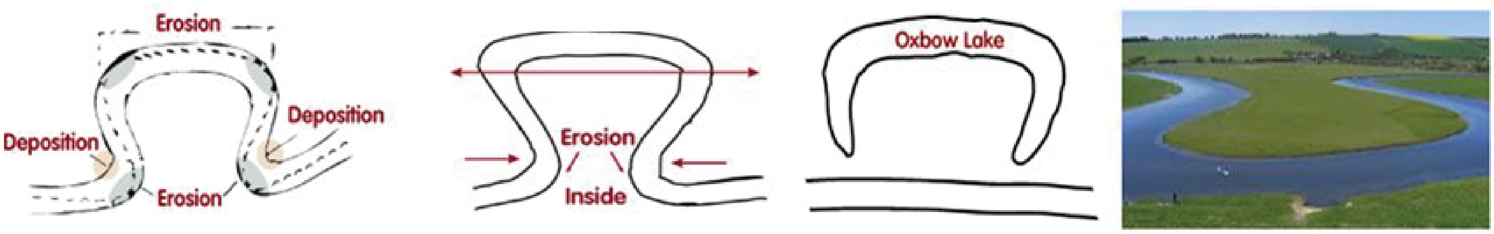
Oxbow lakes

The Oxbow lakes are formed by the depositional and erosional actions taking place simultaneously. Please note that excessive meandering would result in Oxbow lakes.

How Oxbow lakes are formed?

On the inside of the loop, the river travels more slowly leading to deposition of silt. Meanwhile water on the outside edges tends to flow faster, which erodes the banks making the meander even wider. Over time the loop of the meander widens until the neck vanishes altogether. Then the meander is removed from the river's current and the horseshoe shaped oxbow lake is formed.

Formation of Oxbow Lakes



Black Swamps

When the water spills out onto the flood plains, the heaviest material drops out first and finest material is carried over a greater distance. This fine grained alluvium would hold much water and would give rise to a wetland which is called Black swamps or simply swamps.

Landforms made by River Transportations

The dissolved solids in the rivers travel downstream and become a part of Ocean. The particles of clay, silt and fine grains are carried in suspension. Whenever a soft rock obstructs the course of stream and is eroded and sediments are scattered all around, it would be called **Eddies.** These **Eddies** sometimes look like discs and so are called **potholes**. The large potholes are called Plungepools.

Rocks & Minerals

Types of Rocks

Minerals are naturally occurring inorganic substances, often with a crystalline structure. They are composed largely of the most abundant elements in the Earth's crust oxygen & silicon, coupled with metals or the metallic elements of iron, calcium, sodium, potassium, and magnesium.

Rocks are usually composed of two or more minerals. Often, many different minerals are present, but a few rock varieties are made almost entirely of one mineral. Most rock in the Earth's crust is extremely old, dating back many millions of years, but rock is also being formed at this very hour as active volcanoes emit lava that solidifies on contact with the atmosphere or ocean.

The **Great Oxygenation Event** or oxygen catastrophe which happened 2400 million years ago in the Proterozoic eon triggered an explosive growth in the diversity of minerals on Earth.

The three types of Rocks are Sedimentary, Igneous and Metamorphic.

Igneous rocks

These rocks have crystallized from **magma** which is made up of various components of pre-existing rocks and has been subjected to melting either at subduction zones or within the Earth's mantle.

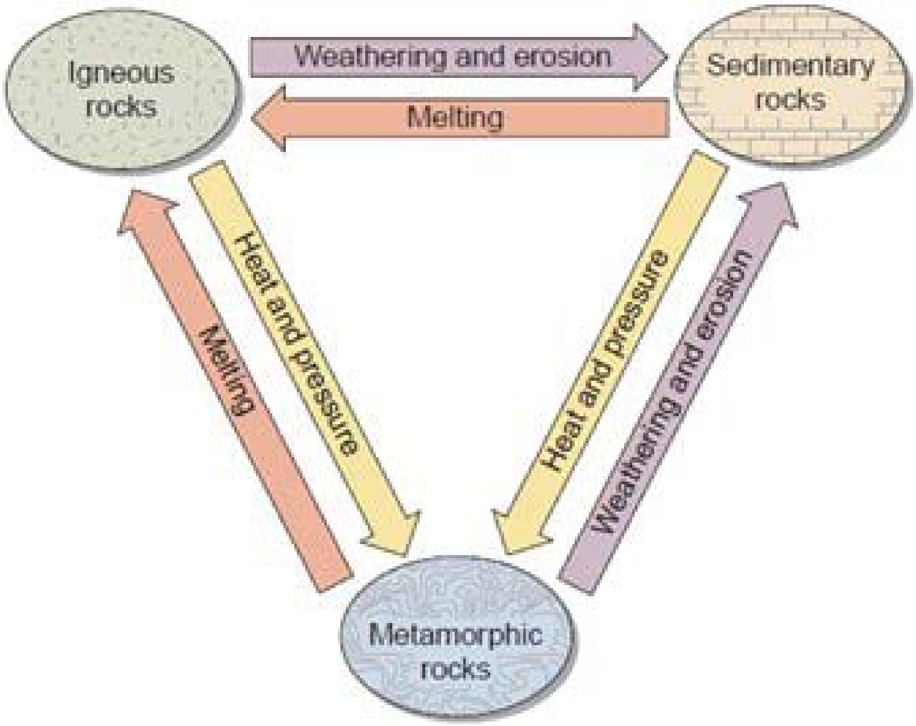
Sedimentary rocks

These rocks are formed through the gradual accumulation of sediment, such as sand on a beach or mud on a river bed. The sediment is buried and then it is compacted as more and more material is deposited on top. In several thousand to Lakhs of years, the sediment becomes so dense that it becomes a rock. This process is known as lithification.

Metamorphic rocks

These rocks once existed as igneous or sedimentary rocks but have been subjected to varying degrees of pressure and heat within the Earth's crust. The processes involved changes the composition and fabric of the rock and their original nature is often hard to distinguish. Metamorphic rocks are typically found in areas of mountain building.

The above three classes of rocks are constantly being transformed from one to another in a continuous process through which the crustal minerals have been recycled during many millions of years of geologic time. The following diagram shows these transformations.



Igneous Rocks

The upper 16 kilometers of the Earth's crust is made up of 95% Igneous rock, with a thin covering of sedimentary and metamorphic rocks. Igneous rocks are formed when molten rock cools, forming silicate mineral crystals. Felsic minerals are light colored and less dense, and mafic minerals are dark colored and more dense. The igneous rocks are generally hard and water percolates in them not so easily.

The most important characteristics of Igneous rocks are as follows:

- They usually do not occur in distinct beds or strata like sedimentary rocks.
- Igneous rocks are generally not having any fossils
- They are generally granular and crystalline.
- They are less affected by chemical weathering as the water does not percolate in them easily.

Magma as source of Igneous Rocks

The mixture of the Molten Rocks which makes the Igneous rocks is called Magma. Magma in fact is a mixture of molten rocks, volatiles (gas) and other solids. It originated from the partial melting of the lower crust and the upper mantle, mainly at depths of 15-200 kilometers. Most magma is as hot as 700 °C to 1300 °C and is silicate mixtures mostly.

> *Most igneous rock consists of silicate minerals.* These rocks also *contain mostly metallic elements*. The mineral grains in igneous rocks are very tightly interlocked, and so the rock is normally very strong. Quartz, which is made of silicon dioxide (SiO_2), is the most common mineral of all rock classes. It is quite hard and resists chemical breakdown.

The chambers under a volcano where Magma collects are called magma chambers. The magma chambers feed a volcano. Bulks of the igneous rocks are result of the cooling and solidifying of Magma. There are two processes by which Magma cools and solidifies. These are called "plutonic" and "Volcanic Eruption". When the Molten Magma goes down deep within the earth and gets solidified, it is called **Plutonism**. On the contrary, the molten Magma can also come out on the surface of earth via a **volcanic eruption**.

Intrusive and Extrusive Igneous Rocks

Magma that solidifies below the Earth's surface and remains surrounded by older, pre-existing rock is called **intrusive igneous rock**. Because intrusive rocks cool slowly, they develop large mineral crystals that are visible to the eye. They are further classified into Plutonic, Hypabyssal, Batholiths and Laccoliths as follows:

- **Plutonic:** Generally very large crystal and they were formed due to cooling of magma very deep inside the Earth
- **Hypbyssal / subvolcanic :** Consolidated in a zone above the base of Earth's crust and hence has distinct structural characteristics.
- **Batholiths:** They extend to greater depths and larger areas
- **Laccoliths:** A sheet intrusion that has been injected between two layers of sedimentary rock

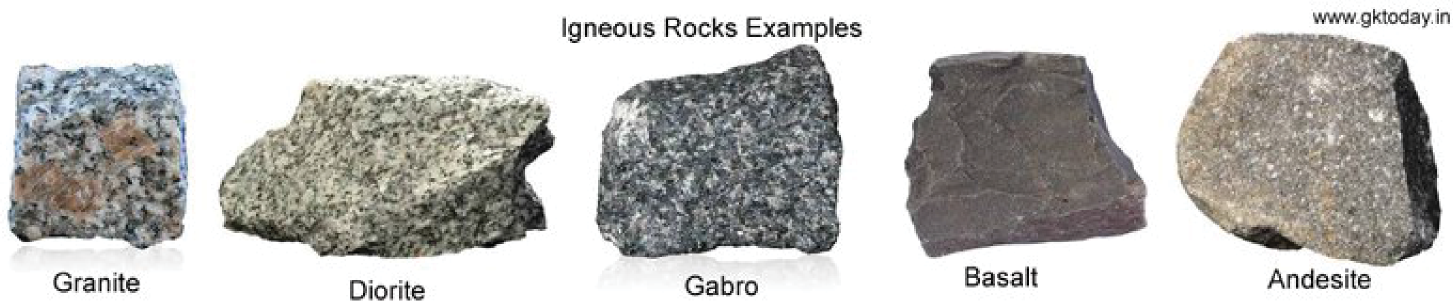
If the magma reaches the surface and emerges as lava, it forms**extrusive igneous rock**. Extrusive igneous rocks cool very rapidly on the land surface or ocean bottom and thus show crystals of only microscopic size.

We note here that **Granite** typically accumulates in batholiths. A single batholith sometimes extends down several kilometers and may occupy an area of several thousand square kilometers.

Felsic Rocks and Mafic Rocks

Whatever may be the process of cooling and solidifying, the magma while converting into a rock, undergoes numerous chemical and physical changes. Accordingly, there are two major types of Igneous rocks are produced viz. **Felsic Rocks** and **Mafic Rocks**. *Felsic rocks are rich in silicon, oxygen, aluminium, sodium, and potassium, while the mafic rocks are rich in magnesium and iron. If the rock is highly dominated by Magnesium and Iron, it is called Ultramafic.*

Examples of Igneous Rocks



- Granite: Intrusive (batholith generally), Felsic, igneous rock. Worldwide average chemical composition of Igneous Rocks has SiO_2 — 72.04% & Al_2O_3 — 14.42%
- Diorite: intermediate intrusive igneous rock
- Gabbro: Mafic igneous rocks equivalent to basalt.
- Peridotite, Rhyolite, Andesite, Basalt, Komatiite, Diabase etc.

Sedimentary Rocks

Sedimentary rocks are made from layers, or strata, of mineral particles found in other rocks that have been weathered and from newly formed organic matter. Sedimentary rocks are important because they preserve a record of ancient landscapes, climates, and mountain ranges, as well as the history of the erosion of Earth. In addition, fossils are found in abundance in sedimentary rocks younger than 600 million years and provide evidence of the evolution of life through time. Earth's geologic time scale was worked out using this record of sedimentary rocks and fossils.

Salient Features of Sedimentary Rocks

Sedimentary rocks **form at Earth's surface by the hydrologic system**. Their origin involves the **weathering of pre-existing rock**, transportation of the material away from the original site, deposition of the eroded material in the sea or in some other sedimentary environment, followed by compaction and cementation. Some common features are:

- They contain strata or layers. The layers are**rarely horizontal** and ***generally tilted*** due to lateral compressive and tensile forces. They are formed of sediments derived from the older rocks, plants and animals remain.
- Most part (around 75 percent) of the surface area of the globe is covered by Sedimentary Rocks.
- Most of the sedimentary rocks are permeable and porous.
- Sedimentary rocks are generally characterized by different sizes of joints, generally perpendicular to the bedding plains.

Types of Sedimentary Rocks

When rock minerals are weathered, their chemical composition is changed, weakening the solid rock. The rock breaks up into particles of many sizes. When these particles are transported in a fluid such as air, water, or glacial ice, we call them **sediment**. There are three major classes of sediment: **clastic sediment**, chemically precipitated sediment, and organic sediment. On this basis, three main types of sedimentary rocks are recognized viz.**clastic rocks, organic rocks** and **chemically precipitated** rocks.

- **Clastic:** Made up of discrete fragments or clasts of materials derived from other minerals, largely of quartz and others such as feldspar, amphiboles, clay minerals

- **Organic :** They contain the materials which are generated by living organisms such as corals, mollusks, and foraminifera, which cover the ocean floor with layers of calcium carbonate, which can later form limestone.
- **Chemical:** Formed by the Chemical & Biological Processes like limestone, rock salt, gypsum and dolostone

Clastic Sedimentary Rocks

Clastic sediment is made up of inorganic rock and mineral fragments, called clasts. These can come from igneous, sedimentary, or metamorphic rocks, and so they can include a very wide range of minerals. Quartz and feldspar usually dominate clastic sediment. When layers of clastic sediment build up, the lower strata are pushed down by the weight of the sediments above them.

This pressure compacts the sediments, squeezing out excess water. Dissolved minerals recrystallize in the spaces between mineral particles in a process called cementation, thus giving rise to the**Clastic Sedimentary Rocks**. Due to the mechanical process, the clastic sedimentary rocks are also sometimes called ***mechanically formed*** *Sedimentary Rocks.*

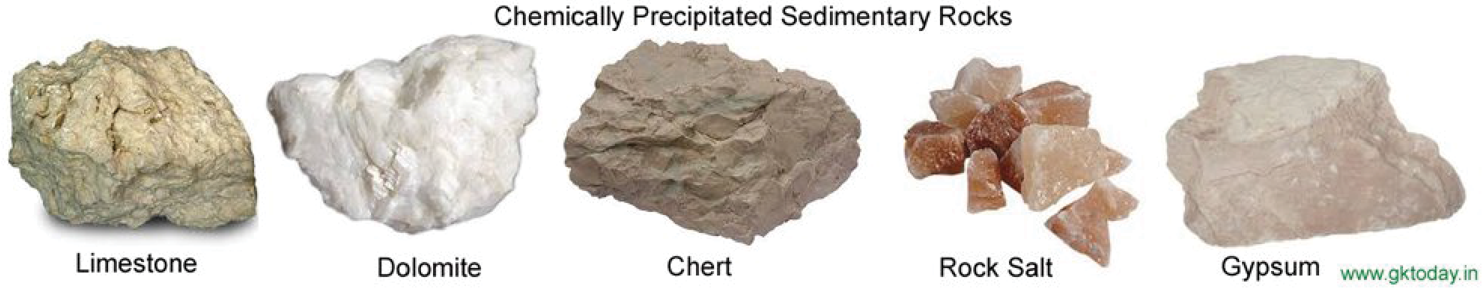
Common examples of clastic / mechanically formed sedimentary rocks include Sandstone {cemented sand grains}, Siltstone {Cemented silt particles}, Congomerate {sandstone containing pebbles of hard rocks}, Mudstone {mainly silt and clay}, Claystone {mainly clay} and shale {clay and mud rock which breaks easily into flat flakes and plates}.

Chemically Precipitated and Organic Sedimentary Rocks

Chemically precipitated sediment is made of solid inorganic mineral compounds that precipitate from water solutions or are formed by organisms living in water. One of the most common sedimentary rocks formed by chemical precipitation is limestone.

The third class of sediment is**organic sediment**. This is made up of the tissues of plants and animals. Peat is an example of organic sediment. This soft, fibrous, brown or black substance accumulates in bogs and marshes where the water stops the plant or animal remains from decaying.

Examples of Chemically precipitated rocks are Limestone {Calcium Carbonate, formed by precipitation on sea or lake floors}, Dolomite {Magnesium and Calcium Carbontes}, Chert {a microcrystalline form of silica} and Evaporites {minerals formed by evaporation of salty solutions in shallow inland lakes or coastal lagoons}.



Limestone

Limestone is by far the **most abundant chemically precipitated rock**. It is composed principally of calcium carbonate (CaCO3 or calcite) and originates by both inorganic chemical and biochemical processes. Limestone has a great variety of rock textures such as skeletal limestone, oolitic limestone, and microcrystalline limestone. Marine sediments form largely by biochemical precipitation. *Carbonate sediments dominate at shallow depths and in warm near-shore waters. Elsewhere, siliceous sediment, which eventually forms chert, is typical in deeper water.*

Skeletal Limestone

Some marine invertebrate animals construct their shells or hard parts by extracting calcium and carbonate ions from seawater. Corals, clams, algae, snails, and many other marine organisms construct their skeletons of calcium carbonate. After the organisms die, the shells accumulate on the seafloor. Over a long period of time, they build up a deposit of limestone with a texture consisting of shells and shell fragments. These particles may then be cemented together as more calcite precipitates between the grains. This type of limestone, composed mostly of skeletal debris, can be several hundred meters thick and can extend over thousands of square kilometers.

- **Chalk** is a skeletal limestone in which the skeletal fragments are remains of microscopic plants and animals.

Oolitic Limestone

Other limestones are composed of small semi spherical grains of calcium carbonate known as oolites. Oolites form where small fragments of shells or other tiny grains become coated with successive thin layers of CaCO3 as they are rolled along the seafloor by waves and currents.

Microcrystalline limestone

A third important type of limestone forms in quiet waters where calcium carbonate is precipitated by algae as tiny, needle like crystals that accumulate on the seafloor as limy mud. Soon after deposition, the grains commonly are modified by compaction and recrystallization.

- Some kinds of algae produce calcium carbonate particles that accumulate to form limestone.These are found near the Kuril Islands of the north Pacific.
- Diatoms are the shells of tiny single-celled algae that are made of silica. Some deepmarine sediments are dominated by diatoms. Some accumulations convert to chert.

Dolostone / Dolomite

Dolostone or dolomite rock is a sedimentary carbonate rock that contains a high percentage of the mineral dolomite. Dolomite is a carbonate mineral composed of calcium magnesium carbonate CaMg(CO3)2. ***It is similar to limestone in general appearance, but reacts with acid only when powdered***

Dolostone is commonly dull brownish yellow or light gray.

Chert

Chert is a common rock composed of microcrystalline quartz. In a hand specimen, it is hard, dense, and typically breaks like glass, but under a high-power microscope, it has a fibrous or granular texture. A distinctive type of deep-marine chert develops from deposits of siliceous shells of microscopic organisms, such as radiolaria and diatoms.

Rock salt

Rock salt is made of the mineral halite (NaCl). It crystallizes when evaporation concentrates sodium and chlorine ions to the point that salt is stable in the residual brine. Strong evaporation creates saline lakes in closed desert basins (for example, the Great Salt Lake and the Dead Sea). Enhanced evaporation also occurs in restricted bays along the shore of the ocean.

Gypsum

Gypsum, $CaSO_4 \cdot 2H_2O$ too originates from evaporation. It collects in layers as calcium sulphate is precipitated from water.

Hydrocarbons

Coal is an important biochemical precipitate. It forms by the decomposition of organic material buried within sedimentary rocks. Lush vegetation may form in an ancient swamp and then be converted by burial into coal. The coal beds on the left are interlayered with sandstone.

The accumulation of partially decayed vegetation is called Peat. Peat is a compound of hydrogen, carbon, and oxygen. They formed from plant remains that built up over millions of years and were compacted under thick layers of inorganic clastic sediment. Hydrocarbons can be solid (peat and coal), liquid (petroleum), or gas (natural gas). Coal is the only hydrocarbon that is a rock. We often find natural gas and petroleum in open interconnected pores in a thick sedimentary rock layer, such as in porous sandstone.

Metamorphic Rocks

The mountain-building processes of the Earth's crust involve tremendous pressures and high temperatures. These extreme conditions alter igneous or sedimentary rocks, transforming them into metamorphic rock. Thus, metamorphic rocks are formed from the pre-existing rocks within the Earth's crust by changes in temperature and pressure and by chemical action of fluid. This means that Both the Igneous and Sedimentary socks undergo profound physical and chemical changes under the increased pressure and temperature. The process is called "metamorphism". Some metamorphic Rocks are Schist, Gneiss, Slate, Quartzite, Marble and Granite.

There are two basic types of metamorphic rocks:

- Foliated metamorphic rocks such as gneiss, phyllite, schist and slate which have a layered or banded *appearance that is produced by exposure to heat and directed pressure. This is called Foliation.*
- Non-foliated metamorphic rocks such as marble and quartzite which do not have a layered or banded appearance.

In the surface environment, rocks weather into sediment. In the deep environment, heat and pressure transform sediment into rock that is eventually exposed at the surface.

Weathering & Mass Wasting

Weathering

There are two types of the processes that affect the landforms viz. **Exogenic** and **Endogenic**.

- Endogenic are the processes that **occur within the earth's surface** such as Plate tectonics, earthquakes, volcanoes etc.
- Exogenic are the processes that occur on or near the earth's surface. The tidal force is Exogenic. The radiation from Sun is also Exogenic.

Further, there are 3 Exogenic geological processes which refer to the process of disaggregation which lead to the reduction in the elevation & relief of the landforms and landscapes such as rocks and mountains. These 3 important phenomena are **weathering, mass wasting and erosion**. These all together are called "**Degradation**" or "**Denudation**". Endogenic processes uplift and expose continental crust to the Exogenic denudation. Exogenic denudation works in opposition and reduces landscapes to sea level.

Weathering is the breaking down of Rocks, soils and minerals through "direct Contact" with the atmosphere of the earth. It occurs *in situ*, means there is **no movement** involved.

Erosion

This is distinct from **erosion** which involves the movement of rocks and minerals such as water, ice, wind and gravity.

Mass wasting

Mass wasting involves the movement of the rocks and particles across a slope **due to gravity.**

Weathering

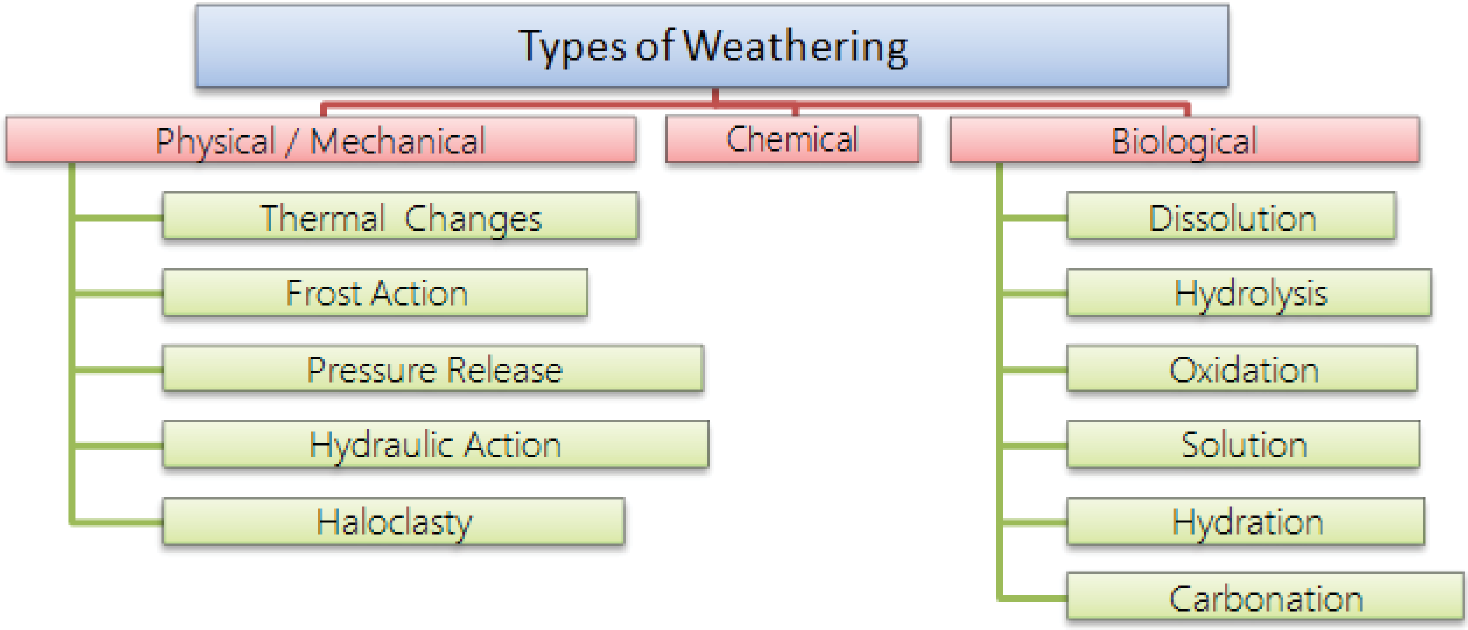
Weathering refers to the combined action of all processes that cause rock to disintegrate physically and decompose chemically because of exposure **near the Earth's surface**. Weathering produces **regolith.** Weathering also creates a number of distinctive landforms.

- **Regolith** is a surface layer of weathered rock particles that lies above solid, unaltered rock.

Weathering is the *in situ* disintegration and breakdown of rocks, soils and minerals.

Types of Weathering

There are three types of weathering viz. Mechanical or Physical Weathering, Chemical Weathering & Biological Weathering.



Physical Weathering

Physical Weathering can be caused by thermal changes, Frost Action, Pressure Release, Hydraulic action and Haloclasty. These terms have been discussed below:

Thermal Changes

Repeated changes in the temperature (heating and cooling) exert the stress on the outer layers of the rocks which is called as **Thermal Stress**. The rocks expand when there is a rise in the temperature and contract when there is a fall in the temperature. *In deserts, the phenomena are more common as there is large diurnal temperature range. The Forest fires can raise the temperature suddenly and this leads to **thermal shock**.*

Thermal Expansion versus Thermal Contraction

Please note that all materials respond by changing volumes because of temperature. Most materials expand when there is a rise in temperature. But there are some rare example which contract when temperature increases and expand when temperature decreases. This is called Thermal contraction.

The coefficient of thermal expansion is positive for the material which expand when there is a rise in temperature. If the coefficient of thermal expansion becomes zero, there is no expansion or contraction. At negative coefficient, the material contracts when there is a rise in temperature. Best example is water. Water when cooled till 4°C, the coefficient of thermal expansion decreases and become zero at 4°C. After that, when temperature is further reduced, it expands. So, at 4°C, water has maximum density. After that, density is reduced and this is the reason why ice floats and the water bodies are able to retain a temperature of 4°C at sub zero weathers. Similarly, Pure Silicon has a negative coefficient of thermal expansion between -255°C to -153°C.

Frost Action

One of the most important physical weathering processes in cold climates is frost action. As water in the pore spaces of rocks freezes and thaws repeatedly, expansion can break even extremely hard rocks into smaller fragments. Water penetrates fractures in bedrock. These fractures, called joints, are created when rocks are exposed to heat and pressure, then cool and contract. Joints typically occur in parallel and intersecting planes, creating natural surfaces of weakness in the rock. Frost action then causes joint-block separation. Water invades sedimentary rocks along their stratification planes, or bedding planes.

Pressure Release or exfoliation

This refers to the release of the pressure from unloading of existing rock on the rocks that lie beneath it due to other processes such as erosion. The igneous rocks are formed deep in earth and when the rocks above them get removed, the igneous rocks expose and the pressure is released. This causes their outermost surfaces to expand. This expansion leads to weathering.

Hydraulic Action

This phenomenon takes place due to very high powered water waves. When water rushes into cracks in the rocks with a very fast speed, the trap of air in the cracks get compressed and thus weakens the rocks. When water retreats, the trapped air is suddenly released with explosive force.

Salt Crystallization or Haloclasty

This refers to the process in which the rocks are denudated due to salt formation. This is a two step process. The first step is started when saline water seeps into cracks and evaporates depositing salt crystals. In the second step, when the rocks are heated up, the crystals expand putting pressure on the surrounding rock. Over the period of time, it splinters the stone into fragments.

Biological Weathering

Biological Weathering refers to the contribution made by the organisms such as **Lichens and mosses**, which grow on essentially bare rock surfaces and create a more humid chemical microenvironment. Biological weathering is both physical as well as chemical breakdown of the surface micro layer of the rock. The animals such as earthworms and other annelids, moles, rabbits all contribute to the biological weathering.

Chemical Weathering

Chemical weathering refers to the changes in the chemical composition of the rocks and generally refers to the chemical reactions of water with minerals.

Hydration

Hydration means absorption of water by some kinds of rock, leading to expansions and disintegrations. When water molecules bind with the mineral molecules, it is called Mineral

Hydration.

Hydrolysis

The chemical breakdown of the rocks caused by rainwater is called Hydrolysis. The result may be secondary minerals with different chemical structure.

Oxidation

Oxidation or rusting occurs when atmospheric oxygen reacts with the minerals such as Iron Ores. This leads to decomposition of the rocks.

Solutions

This refers to dissolving of the minerals in water.

Carbonation

Carbonation refers to the chemical weathering in which Carbon dioxide attacks the rocks after it makes weak acid reacting the water. The rocks are generally made up of calcium carbonate such as Limestone and Chalk.

Mass wasting

In Mass Wasting, the gravitational force of the earth acts directly on the loose material and the unstable slopes result the slide of the rocks and rock debris. This is known as Mass movement. This movement may be slow or fast depending upon the slope angle. The steepest angle that cohesion less slope can maintain without losing its stability is known as its **Critical angle of repose.**

Thus, mass wasting is spontaneous movement of soil, regolith, and rock under the influence of gravity. There are many forms of mass wasting, depending on the speed of the motion and the amount of water involved.

Mass wasting is of following types:

Creeps

It is a long term process which refers to the small movements of soil or rock in different directions over time, directed by gravity. The speed is so slow that naked eye is not able to show the movement.

Landslides

It includes the rock slides, slumps (short distance moving of rocks) & sturzstroms (more horizontal movement when compared to its initial vertical drop*). Landslides are most common type of mass wasting.*

Flows

Flows refer to the movement of the soil, dust, rock particles and bigger pabbles resembling the fluid behavior. Examples of the flows are avalanches, mudflows, debris flows, earth flow, lahars and sturzstroms. The water and air may contribute to the fluid like behaviour.

Topples

When rocks break away and fall from a slope , it is called Topples.

Slump

Slump refers to slipping of the rock material.

Falls

Rocks fell from the steep slopes such as a cliff face, and the movement may be contributed by the earthquakes, rain, plant-root wedging, expanding ice, among other things.

Induced Mass wasting

Human activities can induce mass wasting processes by creating unstable piles of waste soil and rock and by removing the underlying support of natural masses of soil, regolith, and bedrock. Mass movements produced by human activities are called induced mass wasting.

Erosion

Erosions refer to the earth-sculpting processes in which the debris produced by weathering is "transported". So it's a kind of weathering in which the soils break up and get carried away. The agents of erosion are Rainwater, River water, ice, wind, sea waves, and underground water.

Erosion is a very important topic physical and well as human geography. Apart from the transport by wind, water, or ice; erosion also involves the down-slope creep of soil and erosion by the living organisms, such as burrowing animals, in the case of bioerosion, and human land use.

Soil Basics

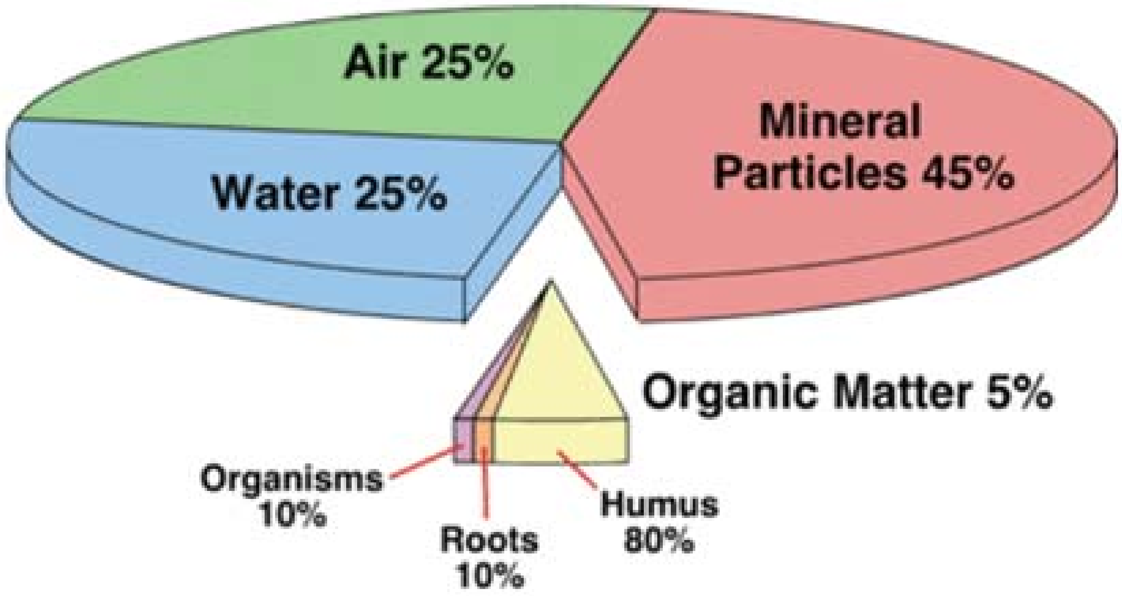
Soil Basics

The fine particles of the solid rocks along with the organic / inorganic matter are called soil. The naturally occurring soil is influenced by parent material, climate, relief and the physical, chemical and biological agents such as microorganisms living in it. The naturally occurring soil is influenced by Parent rocks, Climate, Organic content, Topography, Land use practices/ Human interference, Time etc.

Soil contains mineral particles, decayed organic material, soil water, soil atmosphere, and living organisms, which exist in a complicated and dynamic relationship with one another. Soil is a dynamic natural body made up of the materials covering the earth's surface in which plants grow. It is composed of both mineral and organic matter.

Complex Nature of Soil

The above mentioned factors do not work on soil independently or in isolation, but in close association with each other, leading to a whole network of inter-relationships of quite a complex nature. The material of the soil or the parent material is derived from the rocks ex-posed on the surface. The relief and slope along with the work of various materials. Soils weathering determine conditions for the disintegration of the rock materials. Soils may be transported by the running water, wind or other agents of the rock materials. Soils remain in the original position.



When the soil remains in its original position, it is said to be in situ, and in that state it is further modified by the climate, particularly moisture supply, plant growth ,and bacterial activity dependent on these factors . A brief supply, plant growth ,and bacterial activity dependent on these factors.

A soil is made up of four elements:**inorganic or mineral fraction** (derived from the parent material), **organic material, air and water.** The abundance of each component and its importance in the functioning of the soil system vary from horizon to horizon and from one soil to another.

Humus

The end-product of the breakdown of dead organic material is known as Humus. Humus is a structure-less, dark-brown or black jelly found beneath the soil surface. In uncultivated land, the humus is derived from the natural decay of previous generations of plants, while in the ploughed and cultivated land it is supplied as some kind of manure. The humus of ordinary soil is black, and is thus responsible for making the soil darker than the subsoil. It plays an important but very complicated part in maintaining the fertility of soil. The amount of humus in different soils varies considerably; some, like the peat soil, consist largely of slightly decomposed organic matter which has not yet become humus.

Soil Texture

A soil is generally characterized by the size of its particles. A clayey soil may thus be described as fine, a sandy soil as coarse, while a silly soil is intermediate. If one handles a moist soil sample of each of these he feels gritty, sticky and silky, respectively. The standard unit for the measurement of soil particles is the millimeter, but a smaller unit is the micron (1 micron= 0.001 mm), which is applicable, for instance, to the measurement of soil colloids.

Sandy Soil

Sandy soil is a light soil that consists mainly of sand, i.e., grains of quartz with considerable air spaces between them. The sand may either be 'coarse' where the particles are between 0.2 and 2 mm in diameter, or 'fine' where the grains between 0.05 and 0.2 mm are just visible to the naked eye. These light soils allow water to drain through rapidly, taking soluble plant foods with it. Sandy Soils are known as 'hungry' soils, which not only **need constant manuring** but **may dry out completely during a period of drought** so that shallow-rooted crops fail and pastures 'burn'. They are good for horticulture (vegetables and fruits), legumes (such as moth and pulses), ground nut and bajra.

Clayey Soil

Clayey soil is an exceptionally fine grained soil, very retentive of moisture. It often becomes plastic when mixed with water. The individual grains of clayey soil are 0.002 mm in diameter. These particles consist mainly of **hydrated aluminium silicates**.

Clay **contains little air and can hold more water, so forming a sticky mass,** but when it dries out completely, it forms a hard, concrete like surface, seamed with numerous cracks. Sometimes, a compacted solid layer of clay in the subsoil is formed, which is known as **claypan**, and is often hard and difficult to dig or plough. Clayey soils are often rich in plant food and give much better yields than that of sandy soils. They are devoted to rice, perennial grasses other crops such as clover. Efficient drainage methods, modern machinery and careful liming enable clayey soils to grow roots, green crops and cereals.

Silty Soil

Silty soil is finer than sand but coarser than clay. Its particles are assumed to have a diameter between 0.02 and 0.002 mm. These soils are rich in humus contents and are devoted to numerous cereal and non-cereal crops.

Loamy Soil

It is highly fertile soil consisting mainly of a mixture of sand and day, together with silt and humus. It has the good qualities of both sand and clay, but not their bad qualities. It comprises an almost equal mix of sand and silt with less than 30 per cent clay. It can retain some moisture and plant food even under the adverse weather and climatic conditions. It is well· aerated and drained, and can be readily worked. It is generally devoted to wheat, barley, legumes, sugarcane, sugar beet, maize, millets, rice, grasses, vegetables and orchards.

Soil pH

Soil pH is a measure of the acidity or basicity in soils. As we know, the pH below 7 is acidic and above 7 is basic. Soil pH is considered a master variable in soils as it controls many chemical processes that take place. It specifically affects plant nutrient availability by controlling the chemical forms of the nutrient. The **optimum pH range for most plants is between 6 and 7.5,** however many plants have adapted to thrive at pH values outside this range.

The first thing we should note that in cool and moist areas, percolating groundwater leaches out the soluble bases (such as calcium). As a result, the soils gradually become lime-deficient which increases the acidity of the *soil.*

Both the highly acidic and alkaline soils are injurious to crops. If the soil becomes unduly acidic, the farmers **apply lime** in various forms to meet the requirements of the soil. In practice, a pH value between 6 and 6.5, i.e., very slightly acidic, is desired. Lime not only helps to neutralize the excess adds and so 'sweeten' the soil, but it also **encourages bacteria** and helps to improve the physical , texture of heavy soils. **High soil acidity is typical of cold, humid climates. In arid climates, soils are typically alkaline.**

How to Increase soil pH?

Acidity can be corrected by the application of lime, a compound of calcium, carbon and oxygen ($CaCO_3$), which removes add ions and replaces them with the base calcium.

How to Decrease soil pH?

To decrease the pH of the soil, the Iron sulphates or aluminium sulphate as well as elemental sulfur (S) are used through the formation of sulphuric acid. Further, Urea, urea phosphate, ammonium nitrate, ammonium phosphates, ammonium sulphate and monopotassium phosphate fertilizers have a organic matter in the form of plant litter, compost, and manure will decrease soil pH through the decomposition process.

Certain acid organic matter such as pine needles, pine sawdust and acid peat are effective at reducing pH.

The problem of Alkaline Soils

Alkali or alkaline soils are the soils with high pH (> 9). The fist visible impact of Alkaline soil is that it has a **poor soil structure and a low infiltration capacity.** The Alkali soil is generally having **a hard calcareous layer at 0.5 to 1 metre depth**. Alkali soils have dominated presence of minerals such as Sodium Carbonate which causes the soil to swell. Please note that **all alkaline soils are basic, but NOT all basic soils are alkaline.** This is because even presence of basic salts, the soil may not become alkaline due to other chemical reactions. For example, pH of a solution can be lowered by the addition of CO_2. This will reduce the basicity; however, the alkalinity will remain unchanged.

The reason is that net reaction produces the same number of equivalents of positively contributing species (H+) as negative contributing species (HCO^{3-} and/or CO_3^{2-}).

How Gypsum helps in Treatment of Alkali soils?

Gypsum (calcium sulphate, $CaSO_4 \cdot 2H_2O$) can be applied as a source of Ca++ ions to replace the sodium at the exchange complex in the soil. However, there must be enough natural drainage to the underground, or else an artificial subsurface drainage system must be present, to permit leaching of the excess sodium by percolation of rain and/or irrigation water through the soil profile, while using Gypsum.

Soil Air

Soil air is vital both to soil itself and to organic life within it. A certain amount of air is contained between the individual particles except for the waterlogged soils. The air in the soil helps in the process of oxidation which converts part of the organic material into nitrogen in a form readily available to the plants.

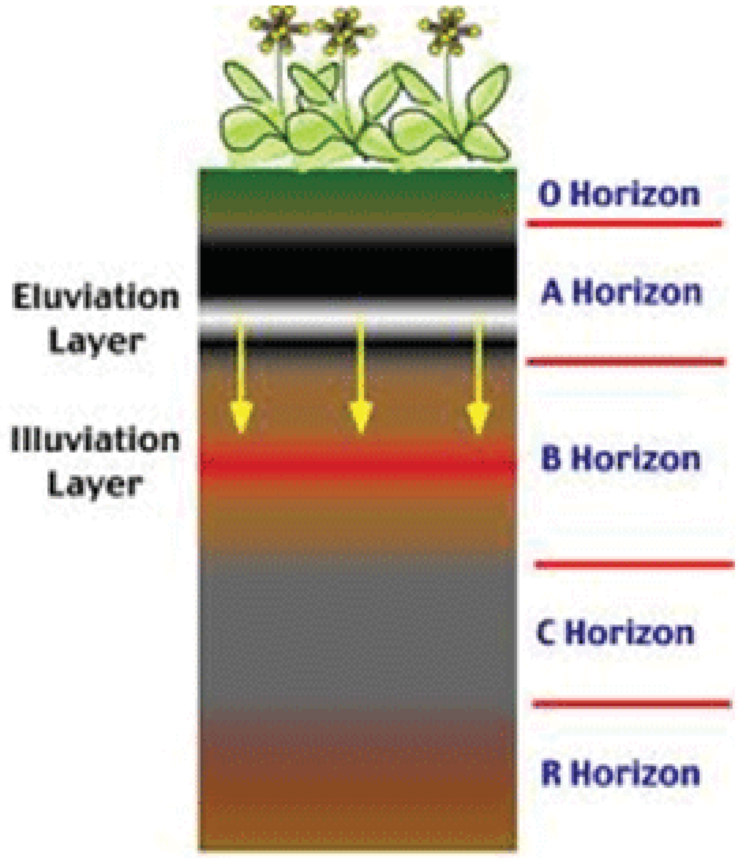
On the other hand, too high degree of oxidation may consume so much organic material that the soil becomes increasingly sterile.

Soil fertility

Soil fertility is the ability of soil to sustain plants. Soil has fertility when it contains organic substances and clay minerals that absorb water and certain elements needed by plants. The boundary between horizons is usually visible in the field, using the properties of colour, texture consistency, porosity, the presence or absence of certain minerals, moisture, and chemical processes.

Soil horizons

Soil horizons are the building blocks of soil classification. The various layers exposed in a pedon; roughly parallel to the surface and identified as O,A,E,B, and C are known as soil horizon.



- The **O horizon** is the topmost layer of most soils. It is composed mainly of plant litter at various levels of decomposition and humus.
- **A horizon** is found below the O layer. This layer is composed primarily of mineral particles and has two characteristics: it is the layer in which humus and other organic materials are

mixed with mineral particles, and it is a zone of translocation from which eluviation has removed finer particles and soluble substances, both of which may be deposited at a lower layer. Thus the A horizon is dark in color and usually light in texture and porous. The A horizon is commonly differentiated into a darker upper horizon or organic accumulation, and a lower horizon showing loss of material by eluviation.

- The **B horizon** is a mineral soil layer which is strongly influenced by illuviation. Consequently, this layer receives material eluviated from the A horizon. The B horizon also has a higher bulk density than the A horizon due to its enrichment of clay particles. The B horizon may be colored by oxides of iron and aluminium or by calcium carbonate illuviated from the A horizon.
- The **C horizon** is composed of weathered parent material. The texture of this material can be quite variable with particles ranging in size from clay to boulders. The C horizon has also not been significantly influenced by the pedogenic processes, translocation, and/or organic modification.

The final layer in a typical soil profile is called the**R horizon**. This soil layer simply consists of unweathered bedrock.

Soil Taxonomy

Soil classification based on observable soil properties actually seen in the field is known as soil taxonomy. There are a number of soil classifications presented by the experts of soil science. The major types of the soils have been discussed here:

Oxisols

These soils develop in the hot and humid climates of the equatorial region. These soils are called oxisols because they have distinctive horizon with a mixture of iron and aluminium oxides. Related vegetation is the luxuriant and diverse tropical and equatorial rain forest. Typical are red-dish and yellowish from the iron and aluminium oxides left behind, with a weathered clay-like texture. In fact, these are the lateritic soils in which the leaching process is very strong. The Laterite can be quarried in blocks and used as building material. They are traditionally being used for shifting cultivation. When oxisols are disturbed, soil loss can exceed a thousand tones per sq km per year.

The regions dominated by oxisols by oxisols and rain forests are attracting the much worldwide environmental attention.

Aridisols (desert soils)

The largest single soil order occurs in dry regions of the world. These soils occupy nearly 19 per cent of the earth's land surface. Pale and light near the surface, deficit in moisture. Lack in organic matter. Salinisation is the main problem of these soils. Salinisation complicates farming in Aridisols.

Mollisols (grassland soils)

- They are most productive soils of the earth. They are rich in humus content. They have dark –colored surface.
- Mollisols are soft, even when dry, with granular pads, loosely arranged when dry. These humus rich organic soils are high in basic cations and have high fertility.
- **Soils of the steppes and prairies of the world belong to this group.** These soils are being utilized for large-scale commercial grain farming and grazing.
- The process of calcification is very strong in these soils. When cemented or hardened, these deposits are called ***calche or kankar.***

Alfisols (moderately weathered forest soils)

- These are the most widespread of the soils orders, extending form near the equator to high latitudes. Pale, grayish brown to reddish in colour and are considered moist versions of Mollisols soil group.
- Alfisols have moderate-to-high reserves of basic cations and are fertile. How-ever, their productivity depends on moisture and temperature. They are supplemented by the moderate application of lime and other chemical fertilizers. Some of the best agricultural farms of usa have this type of soil.

Ultiosols

- These highly weathered forest soil are found in the temperature climates. These soils tend to be reddish in colour because of residual iron and aluminium oxides in the a horizon.
- The increased precipitation in ultisol regions means greater mineral alteration, more leaching, and therefore, a lower level of fertility.
- Fertility is further reduced by certain agricultural practices and the effect of soil damaging crops such as cotton and tobacco. These soils need substantial management.

Spodosols (coniferous forest soils)

- Found in the humid continental mild summer climates. Their distribution is found in North America and Eurasia.
- They are not found in the southern hemisphere.
- Spodosols lack in humus and clay in the horizons.
- The leaves of the conifers add acidity in soil. Their colour is ash gray and they are also known as podozal soils. These are not very fertile soils.
- To enhance the fertility, the application of lime required.

Entisols (recent, underdeveloped soils)

- Usually young or underdeveloped.
- Lack vertical development of horizons.

- These are less fertile soils. The sand dunes ergs outwash glacial plains, and the poorly drained tundra, tidal mud flats, etc. are the examples of Entisols.

Inceptisols (weakly developed soils)

- These soils are inherently infertile.
- They are usually the weakly developed young soil though they are more developed than entisols.
- They include the soils of most of the arctic tundra and outwash moraines.

Andisols (volcanic parent materials)

- The term andisols has been derived from **volcanic ash and glass.**
- Highly fertile and have a high water holding capacity.
- These soils occupy relatively smaller area, especially around the volcanic ring of fire in the pacific rim. Examples are the fertile soils of Hawaii that produce sugarcane and pineapple as important cash crops.

Vertisols (expandable clay soils)

- Composed of more than 30 per cent clays.
- Vertisol clays are black when wet and become iron hard when dry.
- When drying, Vertisols crack and the cracks widen and deepen as the soil dries ; this produces cracks 2-3 cm wide. These are productive soils .
- The **regur** soils of India are an example of vertisols.

Histosols (organic soils)

- Formed from accumulation of thick organic matter.
- Bog marsh are the examples of Histosols. Dried Histosols are used as low-grade fuel.

Prelims Model Questions

Rocks and Landforms Model Questions

1. With reference to the Felsic and Mafic rocks, consider the following statements:

1. While the Felsic rocks are rich in silicon, Mafic rocks are rich in Magnesium

2. Quartz is an example of Felsic Rock, while Granite is an example of Mafic Rock

3. Mafic Rocks are produced by Volcanic Eruption

Which among the above statements is / are correct?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [C] Only 1 & 3

The first statement is correct. Felsic rocks are rich in silicon, oxygen, aluminium, sodium, and potassium, while the Mafic rocks are rich in magnesium and iron. If the rock is highly dominated by Magnesium and Iron, it is called Ultramafic. Second statement is not correct because Granite is a Felsic rock. Third statement is correct.

2. With reference to metamorphic rocks, consider the following statements:
1. Metamorphic rocks may develop from igneous as well as sedimentary rocks
2. Metamorphic rocks are typically found in regions of orogeny
Which among the above statements is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [C] Both 1 & 2

Metamorphic rocks once existed as igneous or sedimentary rocks but have been subjected to varying degrees of pressure and heat within the Earth's crust. The processes involved changes the composition and fabric of the rock and their original nature is often hard to distinguish. Metamorphic rocks are typically found in areas of mountain building. Thus, both statements are correct.

3. Consider the following differences about Intrusive and extrusive igneous rocks:
1. While Intrusive rocks have larger crystals, extrusive rocks have smaller crystals
2. While Intrusive rocks are result of fast cooling of magma, extrusive rocks are result of slow cooling of magma
Which of the above statements is/are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [A] Only 1

Magma that solidifies below the Earth's surface and remains surrounded by older, pre-existing rock is called intrusive igneous rock. Because intrusive rocks cool slowly, they develop large mineral crystals that are visible to the eye. If the magma reaches the surface and emerges as lava, it forms extrusive igneous rock. Extrusive igneous rocks cool very rapidly on the land surface or ocean bottom and thus show crystals of only microscopic size.

4. Sedimentary rocks are important because __:

1. They keep a record of early thermal history of earth

2. They keep a record of history of the erosion of Earth

3. They provide us information about paleoclimate

4. They provide us information about evolution

Choose the correct options from the codes given below:

[A] Only 1, 2 & 3

[B] Only 2, 3 & 4

[C] Only 2 & 3

[D] Only 2

Answer: [B] Only 2, 3 & 4

Thermal history is something which is more commonly related to Igneous rocks. Sedimentary rocks are important because they preserve a record of ancient landscapes, climates, and mountain ranges, as well as the history of the erosion of Earth. In addition, fossils are found in abundance in sedimentary rocks younger than 600 million years and provide evidence of the evolution of life through time. Earth's geologic time scale was worked out using this record of sedimentary rocks and fossils.

5. Which among the following is not a rock that is similar to other three?

[A] Sandstone

[B] Limestone

[C] Dolomite

[D] Chert

Answer: [A] Sandstone

Sandstone, a rock made of sand, is an example of Clastic Sedimentary Rocks. Rest three are Chemically Precipitated sedimentary rocks.

6. Consider the following statements:

1. Exposure of rock to the changes in temperature causes chemical weathering

2. Lichens and mosses are agents of physical as well as chemical weathering

Which among the above statements is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [B] Only 2

Physical Weathering can be caused by thermal changes, Frost Action, Pressure Release, Hydraulic action and Haloclasty. Biological Weathering refers to the contribution made by the organisms such as Lichens and mosses, which grow on essentially bare rock surfaces and create a more humid chemical microenvironment. Biological weathering is both physical as well as chemical breakdown of the surface micro layer of the rock. The animals such as earthworms and other annelids, moles, rabbits all contribute to the biological weathering.

7. With reference to the metamorphic rocks, which among the following is NOT a correct sequence?

[A] Limestone → Marble

[B] Sandstone → Quartzite

[C] Talc → Soapstone

[D] Graphite → Slate

Answer: [D] Graphite → Slate

Slate is a fine-grained, foliated, homogeneous metamorphic rock derived from an original shale-type sedimentary rock composed of clay or volcanic ash through low-grade regional metamorphism.

8. An Igneous rock can be converted into a sedimentary rock by __:

1. Weathering and Erosion
2. Melting
3. Heating and Pressure

Choose the correct option from the codes given below:

[A] Only 1

[B] 1 & 2

[C] 1, 2 & 3

[D] 1 & 3

Answer: [A] Only 1

9. Which among the following processes play role in formation of sedimentary rocks:

1. Weathering and Erosion
2. Hydrological Processes
3. Compaction and Cementation

4. Lithification

5. Upwelling

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 1, 2 & 3

[C] Only 1, 2, 3 & 4

[D] 1, 2, 3, 4 & 5

Answer: [C] Only 1, 2, 3 & 4

Sedimentary rocks are made from layers, or strata, of mineral particles found in other rocks that have been weathered and from newly formed organic matter. Sedimentary rocks form at Earth's surface by the hydrologic system. Their origin involves the weathering of pre-existing rock, transportation of the material away from the original site, deposition of the eroded material in the sea or in some other sedimentary environment, followed by compaction and cementation. In the above question, term Upwelling is not related to formation of sedimentary rocks.

10. Which among the following generally occur in-situ?

1.Weathering

2.Erosion

3.Mass Wasting

Choose the correct option from the codes given below:

[A] Only 1

[B] 1 & 2

[C] 1, 2 & 3

[D] 2 & 3

Answer: [A] Only 1

Weathering is the breaking down of Rocks, soils and minerals through "direct Contact" with the atmosphere of the earth. It occurs in situ, means there is no movement involved. Erosion is is distinct from erosion which involves the movement of rocks and minerals such as water, ice, wind and gravity. Mass wasting involves the movement of the rocks and particles across a slope due to gravity.

General Knowledge Today

Prelims Geography-6: Atmosphere and Climatology

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Contents

Model Questions

Please check Prelims Model Questions at the end of this module.

Composition and Layers of Atmosphere

Earth's atmosphere is mainly consisted of nitrogen, oxygen, and argon, which together constitute the major gases of the atmosphere. The remaining gases are often referred to as trace gases. The below table shows the composition of Dry atmosphere.

Composition of Earth's Atmosphere	
Gas	Volume
Nitrogen (N_2)	78.08%
Oxygen (O_2)	20.95%
Argon (Ar)	0.93%
Carbon dioxide (CO_2)	0.04%
Neon (Ne)	0.00%
Helium (He)	0.00%
Methane (CH_4)	0.00%
Krypton (Kr)	0.00%
Hydrogen (H_2)	0.00%
Nitrous oxide (N_2O)	0.00%
Carbon monoxide (CO)	0.00%
Xenon (Xe)	0.00%
Ozone (O_3)	0 to 7×10−6%
Nitrogen dioxide (NO_2)	0.00%
Iodine (I_2)	0.00%
Ammonia (NH_3)	trace

The upper boundary of the atmosphere is not clearly defined. For differentiation of aeronautics and astronautics, the Kármán line at 100 kilometers from sea level is used. Below around 100 kilometers or so, the atmosphere behaves like a fluid. The ***outermost layer of Earth's atmosphere is mainly composed of hydrogen and helium***. The particles are so far apart that they can travel hundreds of kilometers without colliding with one another. Since the particles rarely collide, the atmosphere no longer behaves like a fluid. These free-moving particles follow ballistic trajectories and may migrate into and out of the magnetosphere of the Earth.

The atmosphere has been divided into several layers on the basis of change in height and some other factors such as change in climate etc. These include the Troposphere (the lowermost), Stratosphere (stratified), Mesosphere, Thermosphere, Exosphere (outer space). Between individual spheres there are usually distinguished transitory layers, called 'PAUSES' where temperature varies but little with height The character and composition of the atmosphere changes as we go higher and higher. Thus, there are 4 important spheres, with 3 pauses as follows:

- Troposphere with tropopause
- Stratosphere with stratopause
- Mesosphere with mesopause, and
- Ionosphere or thermosphere.

Troposphere

Troposphere is the lowest portion of Earth's atmosphere and contains approximately 80% of the atmosphere's mass and 99% of its water vapour and aerosols. The average depth of the troposphere is approximately 17 km in the middle latitudes. The characteristic features of the Troposphere are its great density. In addition to nitrogen and oxygen, carbon dioxide, and water vapour (nearly all of the water vapour contained in the atmosphere is concentrated in the troposphere) and of numerous particles of various origin.

Thickness of Troposphere

It thickness of the Troposphere is maximum at equator, deeper in the tropics, up to 20 km , and shallower near the polar regions, at 7 km in summer, and indistinct in winter. In India, it is taken to be around 16 Kilometers. The thickness of the troposphere and consequently the atmosphere is maximum at the equator due to the reasons discussed below:

High insolation and strong convection currents occur over the Equator

One of the laws of Ideal gases called Charles' law says that in an ideal gas, **density decreases with increasing temperature**, when pressure is constant. The hot air rises and the Earth is not equally heated everywhere. The troposphere is thicker over the equator than the poles **because the equator is warmer**. Heat differential on the planet's surface causes convection currents to flow from the equator to the poles. This implies that the warmer the weather, the thicker is the troposphere. Thus the simple reason is thermal expansion of the atmosphere at the equator and thermal contraction near the poles.

Air is less dense at Equator

Over equatorial regions, where the surface is being heated strongly throughout the year and air warmed by contact with it is expanding and rising, the air all the way up to the tropopause is less dense than air to the north and south. Thus, density of the air is maximum at the equator. But here, you must note that almost same amount of atmospheric **mass** exists at both equator and poles but only the density of the air is less at equator and greater at poles

Poles Exert more gravitational pull on atmospheric gases

Gravity increases from equator to poles as the earth is not a perfect sphere. That means the gravitational force is **more over poles**. Hence the atmosphere is pulled with more force near the poles and leads to contraction of the atmosphere.

The centrifugal force due to Earth's rotation is maximum at Equator

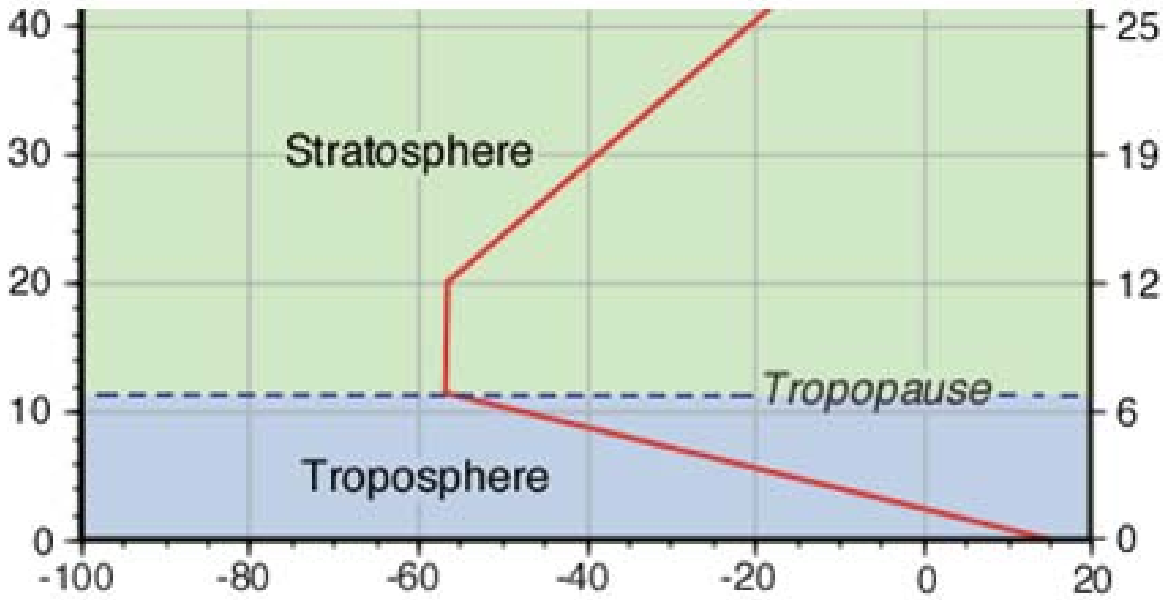
Because the speed of the rotating earth is greatest at the equator the atmosphere tends to bulge out due to friction and Coriolis force.

Chemical Composition of Troposphere

The chemical composition of the troposphere is essentially uniform, with the notable exception of water vapour. The amount of water vapour decreases strongly with altitude. Thus the proportion of water vapour is normally *greatest near the surface* and decreases with height.

Temperature of Troposphere

Temperature of the troposphere **decreases with height**. The rate at which the temperature decreases is called the **Environmental Lapse Rate** (ELR). The environmental lapse-rate (ELR) is about 0.6°C per every 100 meters. Temperature decreases at a *nearly uniform rate* with increased altitude.



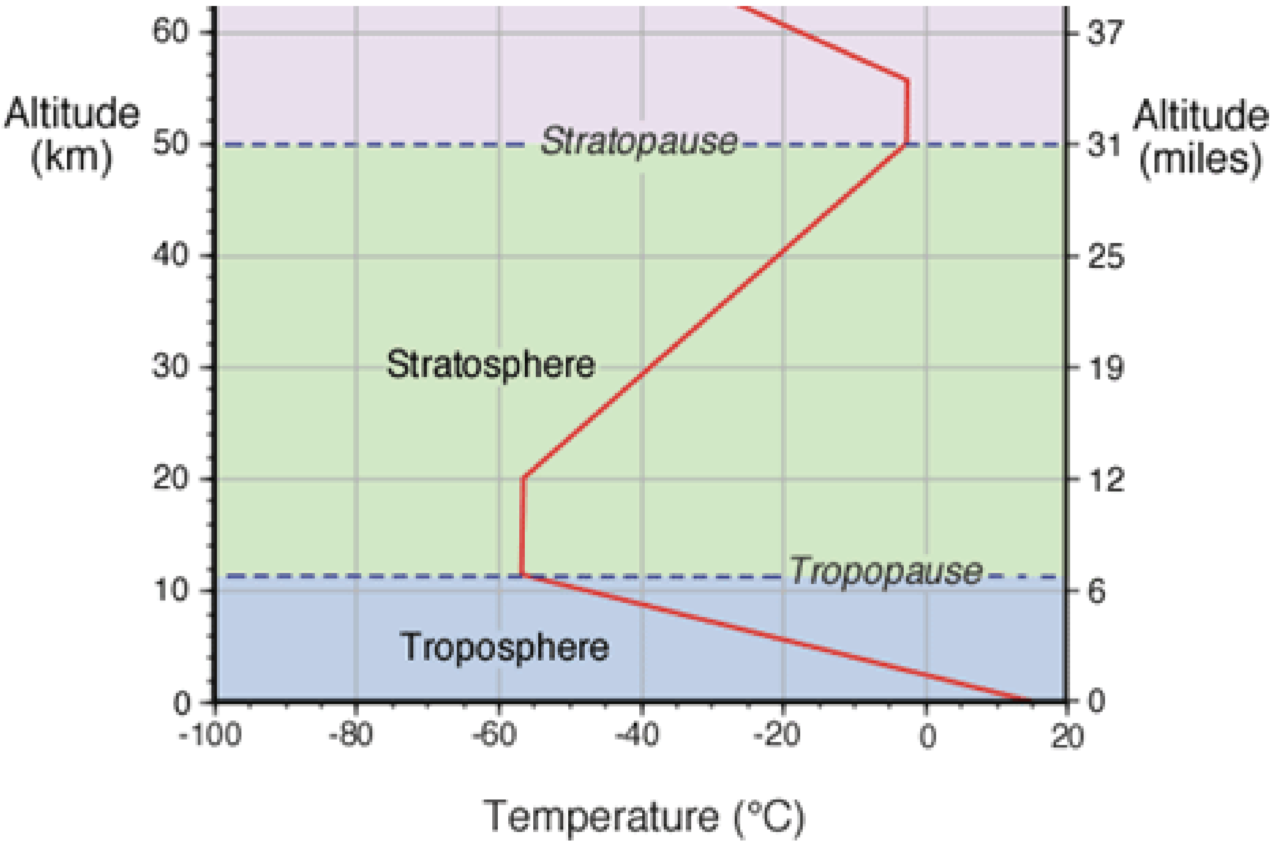
The reason for lapse is that *maximum absorption of the sun's energy occurs at the ground* which heats the lower levels of the atmosphere, and the radiation of heat occurs at the top of the atmosphere cooling the earth, this process maintaining the overall heat balance of the earth.

Tropopause

The boundary between troposphere and stratosphere, called the tropopause, is a temperature inversion. Tropopause refers to the altitude at which the fall in the temperature is stalled. This layer separates the troposphere from the stratosphere (the second layer of the atmosphere). This layer is usually quiet and no major movement of air takes place in it. Its height at Tropic of Cancer and Tropic of Capricorn is roughly 10 to 15 km, highest at the equator 18 km and at the poles it is about 8 km above the earth. In India, the tropopause is generally at a height of around 16 km. The altitude of the tropopause varies with the variations of sea — surface temperature, season, latitude, and weather systems, such as the passage of cyclones and anti-cyclones. So, Tropopause is not a hard lined boundary. The *higher is the temperature of the lower layers, the higher is the height of this layer*, the *layer is lower where there is a cyclone below it.* Also note that the tops of cumulus-nimbus clouds often float in his region.

Stratosphere

The stratosphere is the second major layer of Earth's atmosphere, just above the troposphere, and below the mesosphere. It is called stratosphere because **it is stratified in temperature**, with **warmer layers higher up** and **cooler layers farther down**. Top of the stratosphere has a temperature of about −3°C, just slightly below the freezing point of water. This is in contrast to the troposphere near the Earth's surface, which is cooler higher up and warmer farther down. This **inversion begins in tropopause.**



The stratosphere is situated between about 10 km and 50 km altitude above the surface at moderate latitudes, while at the poles it starts at about 8 km (5 mi) altitude. Thus, stratosphere is nearest to poles altitudinally.

Why there are no Vertical Winds in Stratosphere?

The increase in the temperature with height in the stratosphere makes this region very stable place where the air tends not to overturn vertically. Thus vertical winds are almost absent in Stratosphere. In contrast with the atmosphere, where the vertical wind speeds are often several meters per second, in the stratosphere, they are seldom more than a few centimetres per second. The result is that it takes air a very long time to be transferred from the bottom of the stratosphere, unless there is a thrust of gases such as that during the highly explosive volcanic eruptions. The inability of the air to mix in vertical direction is also the principal reason *why the Ozone depleting Chloro-Fluoro Carbons take so long to reach the altitudes where the Sun's energy is sufficient enough to break them apart*. This also implies that some of the ozone depleting substances will still be there a centuries later from now.

Water vapor Methane Interaction in Stratosphere

The source of methane in Earth's atmosphere can be traced to its release at the surface through a variety of sources such as wood combustion, coal mining, oil and gas drilling and refining, landfills, **wetland rice cultivation**, crop residue burning, industrial activities and the digestive action by grazing animals (such as cow flatulence) and to some extent human flatulence because *around half of us* produce methane in farts!

The tropopause is the very cold boundary between the troposphere and the stratosphere. Due to this, the water vapour is frozen out when moist air is lofted upward through the tropopause. *This means that the air that enters stratosphere is almost dry*. On the other hand, methane remains unaffected by the cold temperatures as it passes through this boundary. Only when methane reaches the upper stratosphere, it is depleted via oxidation reactions with OH. These reactions lead to the production of water vapour molecules. Indeed, each methane molecule eventually is converted in to two molecules of water vapour in the middle to upper stratosphere via the following reaction in which methane is converted into water vapour by a reaction with the hydroxyl radical OH.

$CH_4 + OH \rightarrow CH_3 + H_2O$

The second reaction involves a series of steps that begins with the methane reacting with the free oxygen form a hydroxyl radical (OH). This hydroxyl radical is then able to interact with non-soluble compounds like chlorofluorocarbons, and UV light breaks off chlorine radicals (Cl). These chlorine radicals break off an oxygen atom from the ozone molecule, creating an oxygen molecule (O2) and a hypochlorite radical (ClO). The hypochlorite radical then reacts with atomic oxygen creating another oxygen molecule and another chlorine radical, thereby preventing the reaction of monatomic oxygen with O2 to create natural ozone. This way, methane plays a role in hindering the formation of the Ozone layer. Above about 65 km, photodissociation of methane becomes an important mechanism for **Ozone loss**.

The temperature stratification in Stratosphere

In the stratosphere, temperature has a tendency to rise. This is due to the presence of Ozone. The first thing we have to note is that the air is highly rarefied and there are only eight ozone molecules to a million. The ozone (O3) here absorbs high energy Ultraviolet energy waves from the Sun and is broken down into atomic oxygen (O) and diatomic oxygen (O2). Atomic oxygen is found prevalent in the upper stratosphere due to the bombardment of UV light and the destruction of both ozone and diatomic oxygen. The mid stratosphere has less UV light passing through it, O and O2 are able to combine, and is where the majority of natural ozone is produced. It is when these two forms of oxygen recombine to form ozone that they release the heat found in the stratosphere. The lower stratosphere receives very low amounts of UV, thus atomic oxygen is not found here and ozone is not formed (with heat as the byproduct). This vertical stratification, with warmer layers above and cooler layers below, makes the stratosphere dynamically stable: there is ***no regular convection and associated turbulence in this part of the atmosphere***. The top of the stratosphere is called the stratopause, above which the temperature decreases with height.

Aviation & Jet Streams in Stratosphere

Stratosphere is free from the violent weather changes which occur below in the Troposphere. So, it is preferred by commercial airliners. The commercial airliners typically cruise at altitudes of 9–12 km in the lower reaches of the stratosphere. They do this to**optimize fuel burn**. Jet liners, however, face another menace in stratosphere, namely jet streams. Jet streams are high velocity **horizontal** air currents. The main jet streams are located near the tropopause, the transition between the troposphere (where temperature decreases with altitude) and the stratosphere (where temperature increases with altitude). The location of the jet stream is extremely important for aviation. Jet streams are NOT always harmful for aviation. They are beneficial and used commercially as it reduced the trip time and fuel consumption. Commercial use of the jet stream began in 1950s when an aeroplane flew from Tokyo to Honolulu at an altitude of 7,600 meters cutting the trip time by over one-third. It also nets fuel savings for the airline industry.

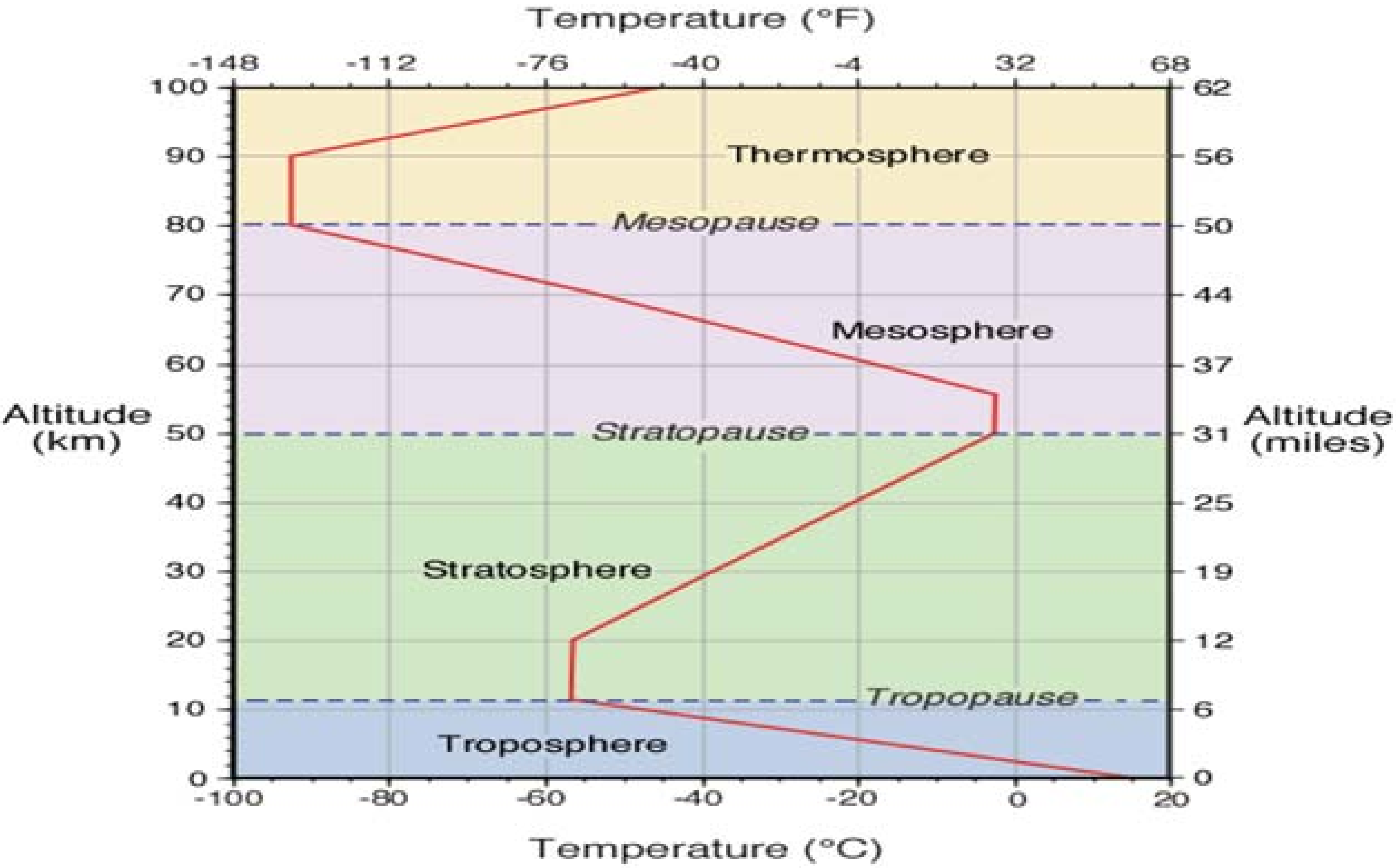
Ozone Layer in stratosphere

As discussed above, the **Ozone layer is contained within the stratosphere.** In this layer ozone concentrations are about 2 to 8 parts per million, which is much higher than in the lower atmosphere but still very small compared to the main components of the atmosphere. It is mainly located in the lower portion of the stratosphere from about 15–35 km, though the thickness varies seasonally and geographically. About 90% of the ozone in our atmosphere is contained in the stratosphere.

The Ozone layer absorbs ultraviolet radiation from the sun andconverts it into heat and chemical energy. It is this activity that is responsible for the rise in temperature. The layer is NOT of uniform thickness. ***Height at the equator is maximum and lowest at the poles.***

Mesosphere

The mesosphere extends from the stratopause to 80–85 km. Most meteoroids get burnt in this layer.



Temperature **decreases with height in the mesosphere** The **mesopause**, the temperature minimum that marks the top of the mesosphere, is the coldest place around Earth and has an average temperature around −85 °C. At the mesopause, temperatures may drop to −100 °C. Due to the cold temperature of the mesosphere, water vapour is frozen, forming ice clouds. These clouds are called **noctilucent clouds**. This implies that the **noctilucent clouds are** the highest clouds in the Earth's atmosphere, located in the mesosphere at altitudes of around 76 to 85 kilometers (47 to 53 mi). They are normally too faint to be seen, and are visible only when illuminated by sunlight from below the horizon while the lower layers of the atmosphere are in the Earth's shadow. Noctilucent clouds are not fully understood and are a recently discovered meteorological phenomenon.

Mesopause, a thin layer of extremely cold atmosphere, separates the mesosphere from the Ionosphere above.

Ionosphere

Ionosphere is called so because it is ionized by solar radiation. It plays an important part in **atmospheric electricity** and forms the inner edge of the magnetosphere. Ionosphere stretches from 50 to 1,000 km and typically overlaps both the exosphere and the thermosphere. It has practical importance because it influences, for example, radio propagation on the Earth. It is also *responsible for auroras.*

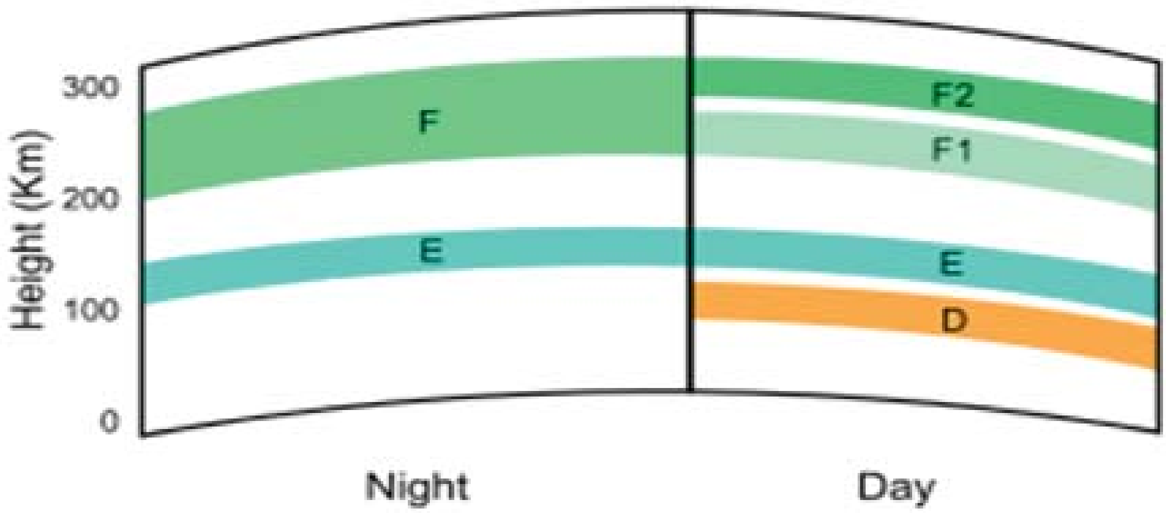
Temperature in Ionosphere

Ionosphere is also known as THERMOSPHERE because of the high temperatures because of the high temperatures prevailing there as much as **870°C over the equator** and **1427°C over the north pole**, the temperature near the upper boundary of the thermosphere may become higher than 1000-1500°C. Along with temperature rise sharp changes caused by the corpuscular and ultraviolet solar radiation are observed in it.

Various Layers in Ionosphere

We note that the ionization depends primarily on the Sun and its activity. This means that the amount of ionization in the ionosphere varies greatly with the amount of radiation received from the Sun. This is the reason that there are changes in the Ionosphere and there are diurnal effect and seasonal effects. The activity of the Sun is associated with the position of earth in the revolutionary orbit, sunspot cycle, with more radiation occurring with more sunspots. Radiation received also varies with geographical location (polar, auroral zones, mid-latitudes, and equatorial regions). There are also mechanisms that disturb the ionosphere and decrease the ionization. There are disturbances such as solar flares and the associated release of charged particles into the solar wind which reaches the Earth and interacts with its geomagnetic field.

Accordingly, Ionosphere has been divided into *different sets of layers* during day and night which are shown in this graphic:



D Layer

The D layer explains **why the AM Radio gets disturbed during day time**, but quite smooth in night time. We see in the above graphics that the D layer is the innermost layer, 60 km to 90 km above the surface of the Earth. At this layer, the net ionization effect is low, but loss of wave energy is great due to frequent collisions of the electrons. This is the reason that the high-frequency (HF) radio waves are not reflected by the D layer but suffer loss of energy therein. The absorption is small at night and greatest about midday. This causes the disappearance of distant AM broadcast band stations in the daytime.

E-Layer

The E layer is the middle layer, 90 km to 120 km above the surface of the Earth, with primary source of ionization being soft X-ray (1-10 nm) and far ultraviolet (UV) solar radiation ionization of molecular oxygen (O2). This layer disappears in the night because primary source of ionization is no longer present. The practical value of this layer is that it reflects long radio-waves back to earth, which enables them to be received at a distance, rather than disappear into space. It is also known as HEAVYSIDE-KENNELY LAYER.

Importance of E-Layer

The E layer is a region of the ionosphere which influences long-distance communications by strongly reflecting radio waves in the 1-3 megahertz. It is also called E region, Heaviside layer, or Kennelly-Heaviside layer. This region reflects radio waves of medium wavelength and allows their reception around the surface of the Earth. The layer approaches the Earth by day and recedes from it at night. In technical terms, it is a cylinder of relativistic electrons gyrating in the magnetic field, which produces a self field strong enough to dominate the externally applied field and produces half reversal in the system. Since the mid '20s, another connection regarding the ionosphere has been hypothesized that lightning can interact with the lower ionosphere. According to this theory, thunderstorms could modulate the transient, localized patches of relatively high-electron density in the mid-ionosphere E layer, which significantly affects radio wave propagation.

F-Layer

The **F LAYER** extends from about 200 km to more than 500 km above the surface of Earth. The E-layer allows the penetration of short-radio waves, which continue until they reach the APPLETON LAYER. . Appleton layer reflects short-radio waves (which have penetrated the HEAVYSIDE-KENNELY LAYER) back to earth. This is also supposed to be the region where polar AURORAS occur and where most of the meteors burn themselves out.

Concept of Aurora

The luminous effect of electro-magnetic phenomena in the ionosphere is known as **Aurora**, visible *in high latitudes* as red, green and white arcs, draperies, streamers, rays and sheets in the night sky, best developed at a height of about 90 km. Probably, aurora is the result of magnetic storms and of electrical discharges from the sun during periods of sun-spot activity, causing ionization of gases, though this is still a matter of research. It is called the ***Aurora Borealis*** (or northern lights) in the northern hemisphere and the **Aurora Australis** in the southern hemisphere. Occasionally the Aurora borealis is seen in England, but it is more common in northern Scotland, presents a magnificent spectacle in northern Scandinavia and northern Canada.

Exosphere

The exosphere lies above the altitude of 800 kilometer and it needs further studies. Characteristic of exosphere is an extreme rarefaction of the air; gas particles, moving with tremendous velocities, nearly fail to meet one another and there takes place an outflow of gas particles into the interpreter space.

Insolation Energy Budget

Atmosphere and Insolation

Sun is the major source of energy for the entire earth system. The earth does receive very small proportions of energy from other stars and from the interior of the earth itself (volcanoes and geysers provide certain amount of heat energy). However, when compared with the amount received from the sun, these other sources seem insignificant.

The energy emitted by the sun which reaches the surface of the earth is called **Insolation**. The sun, a mass of intensely hot gases, with a temperature at the surface be 6000°C emits radiant energy in the form of waves, which consists of very short wave-length x-rays, gamma rays, and ultraviolet rays; the visible light rays and the longer infrared rays. The earth receives only about one **two-thousand-millionth** of the total insolation poured out by the sun, but this is vital to it; the amount received at the outer limit of the atmosphere is called **Solar Constant**. Thus **Solar Constant** is the rate per unit area at which solar radiation is received at the outer limit of the atmosphere.

Effects of the Atmosphere on Solar Radiation

When the sun's energy passes through the atmosphere several things happen to it. Around one fourth of this energy is directly reflected back to clouds and the ground. Around 8 percent is scattered by minute atmospheric particles and returned to space as diffuse radiation. Some 20 percent reaches the earth's surface as diffuse radiation after being scattered. Approximately 27 percent reaches the earth's surface as direct radiation and 19 percent is absorbed by the ozone layer and by water vapour in the clouds of the atmosphere.

On an average, 47 percent of the solar energy arriving at the outer limits of the atmosphere eventually reaches the surface, and 19 percent is retained in the atmosphere. This 19 percent of direct solar radiation that is retained by the atmosphere is locked up in the clouds and the ozone layer and is thus not available to heat the troposphere. The warmth of the atmosphere is due to the 47 percent of incoming solar energy reaching the earth's surface (that is, both land and bodies of water) and in the transfer of heat energy from the earth back to the atmosphere through such physical processes such as **Long-Wave Radiation, Conduction and Conve**ction. Some related phenomena such as **advection** and **Latent Heat of Condensation** also contribute to the warmth of the atmosphere.

Radiation as method of Heat Energy Transfer

Radiation is the process by which most energy is transferred through space from the sun to the earth. Radiation is given off by all bodies including earth and human being. The***hotter is the body, shorter are the waves***.

We can simply say that the radiation from Sun comes to earth in the form of smaller waves and earth being cooler body, gives off energy in the form of long-wave. These are then radiated back to the atmosphere. This Long-Wave Radiation from the earth's surfaces heats the lower layers of the atmosphere. It is evident that the atmosphere is primarily heated from below by radiation from the heated Earth surface.

As we discussed above, the most important cause of atmospheric temperature is the energy received from the sun. The ***atmosphere of the earth does not heat up directly as solar radiation is in the form of short waves and air cannot absorb the short waves.*** The earth absorbs the short wave energy and then radiates in the form of long wave terrestrial radiation that can be absorbed by the air. So, air heats up when comes in contact with the surface of the earth.

Conduction as Method of Heat Transfer

Conduction is the means by which heat is transferred from one part of a body to another or between two touching objects. Heat flows from the warmer to the cooler (part of a) body in order to equalize temperature. Conduction actually occurs through molecular movement, with one molecule bumping into another. The Atmospheric conduction occurs at the interface of (zone of contact between) the atmosphere and the earth's surface. However, it is actually a insignificant method of heat transfer in terms of warming the atmosphere since it affects only the layers of air closest to the earth's surface. This is because air is a very poor conductor of heat.

Convection as Source of Heat Transfer

When the pockets of air near the surface are heated, they expand in volume, become less dense than the surrounding air, and therefore rise. This vertical transfer of heat through the atmosphere is called convection, and is the same type of process by which heated water circulates in a pan while heating. The currents set into motion by the heating of a fluid (liquid or gas) make up a convectional system. Most vertical transfer of heat within the atmosphere & Oceans occurs via Convection and is a major cause of clouds and precipitation.

Advection as Source of Heat Transfer

Advection is the horizontal heat transfer within the atmosphere. Obviously the wind is the transfer agent of advection. Wind brings about the horizontal movement of large portions of lower atmosphere. This advection transports warmer or accounts for a major proportion of the lateral heat transfer that takes place within the atmospheric system.

Latent Heat of Condensation

A proportion of the solar energy is used to change liquid water from rivers, lakes, and oceans to water-vapour. The solar energy used to do this is then stored in the water-vapour as latent or potential energy. Later the water-vapour in the atmosphere may change to form liquid water again through a process called CONDENSATION. The energy released through this process is known as the **Latent Heat of Condensation**. Like other means of heat transfer in the earth system, latent heat of condensation plays a major role in warming of the atmosphere and in addition, is a **source of energy for STORMS**.

Earth's Albedo

The ratio between the total solar radiation falling (incident) upon a surface and the amount reflected without heating the earth, is called ALBEDO (expressed as a decimal or as a percentage). The earth's average albedo is about 0.4 (40 percent) ; that is , 4/10 of the solar radiation is reflected back into space. It varies from 0.03 for dark soil to 0.85 for a snow-failed. Water has a low albedo (0.02) with near-vertical rays, but a high albedo for low-angle slanting rays. The figure for grass is about 0.25. Over-pastured land and bare soil are more reflective of solar radiation than are crops and vegetation. A desert is much more reflective than a savanna or forest. If economic pressure on soil and vegetation increases, and drought then occurs, the effect overall is to increase the albedo of the surface.

Earth's Energy Budget

Earth's Energy Budget can be discussed in terms of incoming heat energy and outgoing heat energy. These are as follows:

Incoming Heat Energy

This is made of :

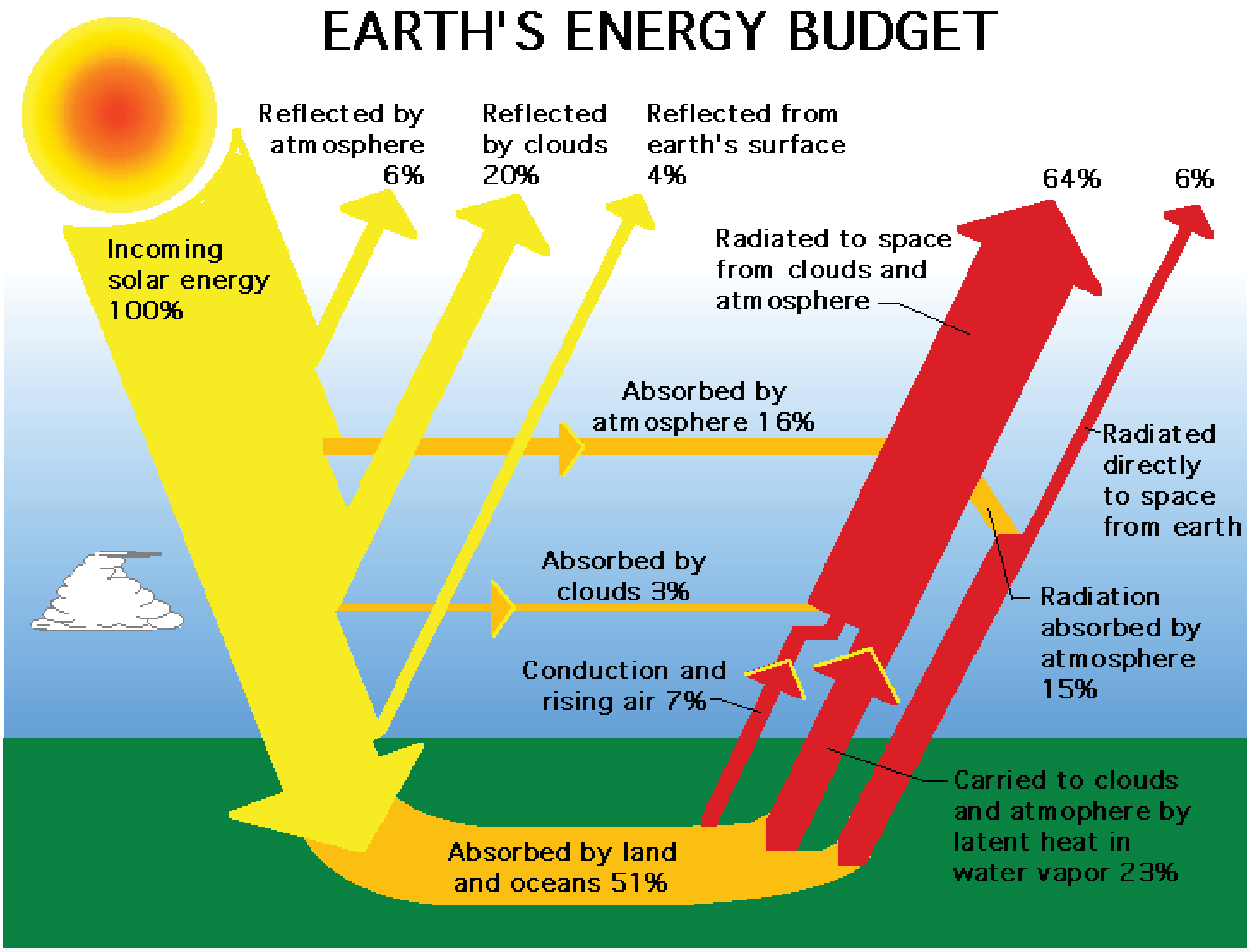
- Solar radiation (99.97%)
- Geothermal energy (0.025%)
- Tidal energy (0.002%)
- Fossil fuel consumption (about 0.007%)
- Minor Sources: remains part

Outgoing Heat Energy

- The average albedo (reflectivity) of the Earth is about 0.3, which means that 30% of the incident solar energy is reflected into space, while 70% is absorbed by the Earth and reradiated as infrared. This 30% of the incident energy is reflected, consisting of 6% reflected from the atmosphere, 20% reflected from clouds and 4% reflected from the ground (including land, water and ice). The remaining 70% of the incident energy is absorbed, out of 51% is absorbed by land and water, and then emerges in the following ways:

- 23% is transferred back into the atmosphere as latent heat by the evaporation of water, called latent heat flux
- 7% is transferred back into the atmosphere by heated rising air, called Sensible heat flux
- 6% is radiated directly into space
- 15% is transferred into the atmosphere by radiation, then reradiated into space
- 19% is absorbed by the atmosphere and clouds, including:
- 16% reradiated into space
- 3% transferred to clouds, from where it is radiated back into space.

The above figures are the averages for the whole earth over a year's time.



Balance in Earth's Heat Budget

For any particular location, the factors discussed may not be balanced, and adjustments must be made within the entire earth system. Some places have a surplus of incoming solar energy over outgoing energy loss in their budget, while others have a deficit. The main cause of these variations is the differences in latitude, and the seasonal fluctuations.

We know that the amount of insolation received is directly related to the latitude. The tropical zone where insolation in high throughout the year; more solar energy is received at the earth's surface and in the atmosphere than can be emitted back into space. In the arctic and Antarctic zones there is so little insolation during the winter, when the earth is still emitting long-wave radiation, that there is a large deficit for the year. Places in the midlatitude zone have lower deficits or surpluses, but only at about **latitude 38° is the budget balanced**. It is the *heat energy transfer within the atmosphere that prevents a situation whereby the tropical zones get hotter and hotter and the arctic and Antarctic zone get colder and colder.*

Atmospheric Temperature and Pressure

Distribution of Temperature

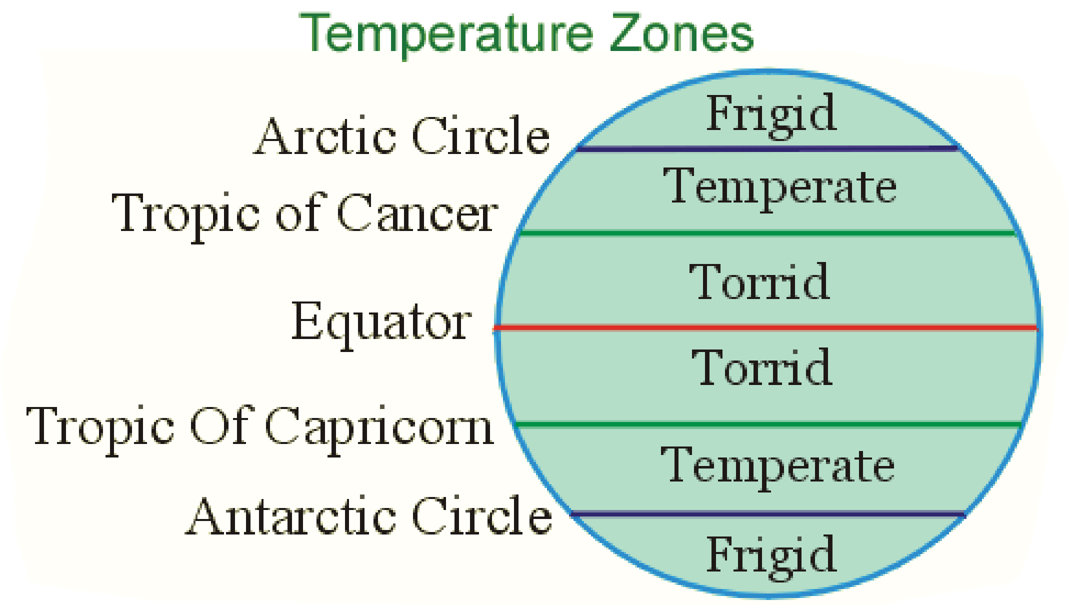
Temperature differs from one part of the world to the other. Since Insolation is the basic source of energy for the atmosphere, the distribution of insolation would determine the temperature of the earth. Thus **latitude, altitude, distance from sea, features of the surface, nature of the landscape** are some important factors that affect the distribution of temperature.

Since, the insolation is highest at equator; temperature should be highest at the equator and lowest near the poles, however actually it is not. *Highest temperature on earth is recorded at a few degrees north of equator*. Altitude is the second major control of temperature of a place. The temperature depends upon albedo of the surface also.

One major factor affecting the distribution of the temperature of Earth is distribution of Land and Oceans. Since there is more land in Northern Hemisphere and more waters in Southern hemisphere and *there is a big difference between the specific heat of land and water*, the **loss of heat from the continents is bigger than the oceans**. The continents get heated faster and get cooled faster in comparison to the Oceans. This is the reason that the *temperatures of the Oceans are moderate while that of continents is extreme*. The moderating effect on temperature of the land due to proximity of the seas is called **Maritime influence**. The increasing effect on temperature of the land at interior of the continents is called **Continental Influence**.

Three Broad Temperature Zones

The earth can be generally divided into three broad temperature zones viz. Torrid Zone, Temperate Zone and Frigid zone.



Torrid Zone

Torrid Zone is the tropical region. The temperature remains high. Sun is directly overhead at least once during the year. In the Northern Hemisphere, the overhead Sun moves north from the equator until it reaches 23.5 °North (Tropic of Cancer) for the June solstice after which it moves back south to the equator. The year is consequently divided nearly into four equal parts by the two times at which the sun crosses the equator (Equinoxes) and those two at which it attains greatest declinations (Solstices). The Torrid Zone forms the hottest region of the world with ***two annual seasons namely a dry and a wet season*** This zone includes most of Africa, southern Asia, Indonesia, New Guinea, northern Australia, southern Mexico, Central America and northern South America.

Temperate Zones

Temperate zones are the mid latitudinal areas, where the temperature is moderate. There are two temperate areas viz. North and South. In the two Temperate Zones, consisting of the tepid latitudes, the **Sun is never directly overhead**, and the climate is mild, generally ranging from warm to cool. The **four annual seasons, Spring, Summer, Autumn and Winter occur in these areas.**The North Temperate Zone includes Great Britain, Europe, northern Asia, North America and northern Mexico. The South Temperate Zone includes southern Australia, New Zealand, southern South America and South Africa.

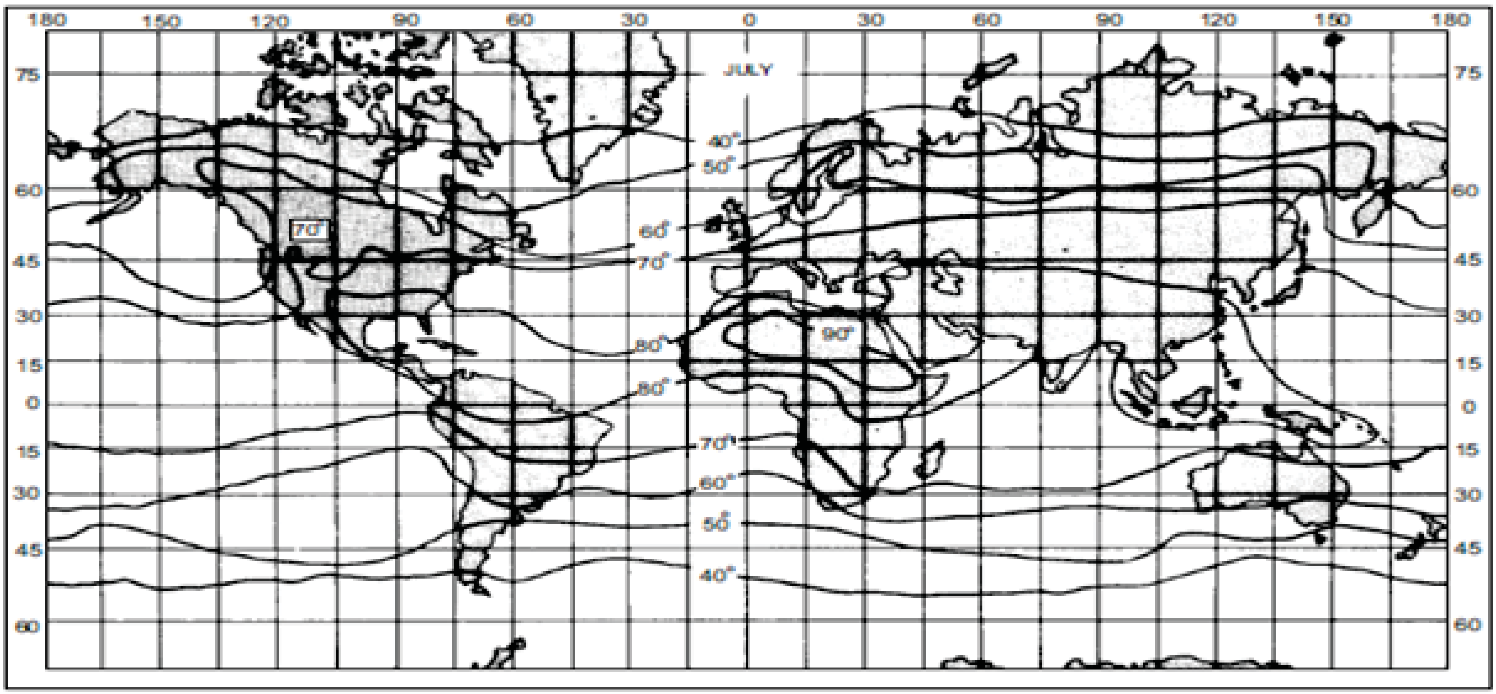
Frigid Zones

The two Frigid Zones, or polar regions, experience the midnight sun and the polar night for part of the year – the cliff of the zone experiences one day at the solstice when the Sun doesn't rise or set for 24 hours, while in the centre of the zone (the pole), the day is literally one year long, with six months of daylight and six months of night. Please note that the Frigid Zones are not the coldest parts of the earth, and are covered with ice and snow. The*coldest temperature on earth has been recorded a few degrees below the 90°N.*

Patterns of Global Isotherms

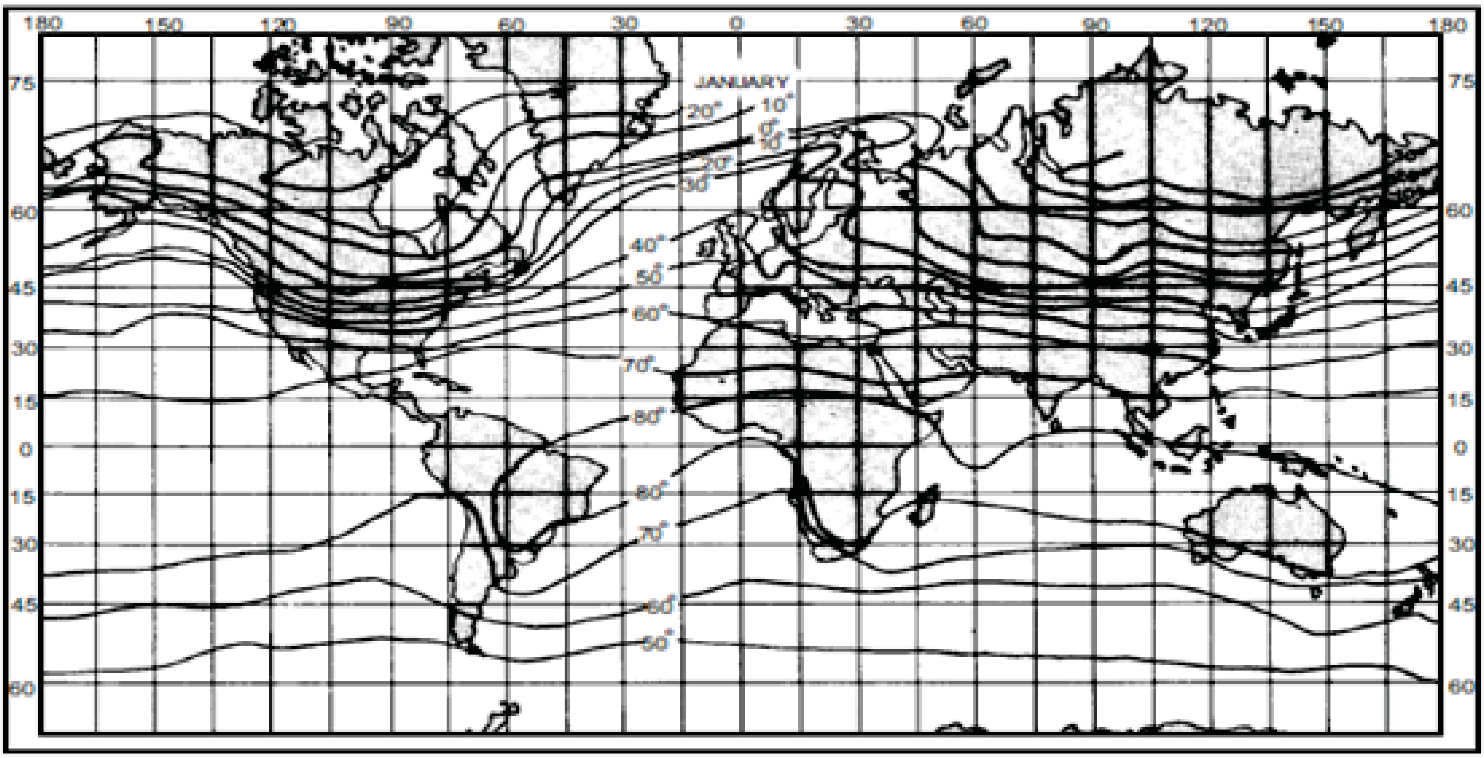
The global distribution of temperature can be represented with the help of isotherms. Isotherms are the lines that join the places with the identical temperatures. Please note that isotherms are drawn after correcting the temperature of a *place to the sea level so that the differences due to altitude can be minimized.* The *Isotherms on the earth run parallel to the latitudes*.

Due to the difference between the specific heat between water and land, at any latitude, the temperature over the landmass is higher in summer and lower in winter in comparison to the seas. Here we discuss about the global isotherms drawn in the month of January and July. As shown in the picture, Isotherms for the month of July bend towards Northward while moving from Sea to Land.



JULY

For the Month of January, the isotherms bend towards south while moving from sea to land. The only thing you have to note about Isotherms is that water in the South Atlantic and Pacific is absorbing greater amounts of energy during January and the land is rapidly heating and reradiating energy. Please also note that due to difference in the specific heat, both highest and lowest temperatures are observed in the interiors of the continents.



JANUARY

Vertical Distribution of Temperature

The vertical distribution of temperature on earth is also unequal. As we studied above in detail that in troposphere, the temperature falls uniformly with height as per the Environmental Lapse Rate. The normal value of this Lapse Rate is 6.4°C per kilometers. When a parcel of air rises upwards and cools this is known as adiabatic cooling. This adiabatic cooling is the result of the expansion of air as it is lifted upwards. When the air descends, it gets warmed and this is called adiabatic warming.

Inversion of the Temperature

In the mountain valleys, the temperature of the air is **found increasing with increasing altitude**. Thus there is an inversion of the temperature. This is because during the night, the quick radiation from the upper exposed slopes of the mountains causes the surface and air over it to cool rapidly. This cooler air is denser and gets drained by the valley slopes and displaces the warmer air toward up. So, when we go up in a valley, the temperature seems to getting increased. This phenomenon is also called **drainage inversion**.

Mean Thermal Equator

Thermal equator is a global isotherm having the highest mean annual temperature at each longitude around the globe. Thermal equator does not coincide with the geographical equator. The *highest absolute temperatures are recorded in the Tropics* but the *highest mean annual temperatures are recorded at equator*. But because local temperatures are sensitive to the geography of a region, and mountain ranges and ocean currents ensure that smooth temperature gradients (such as might be found if the Earth were uniform in composition and devoid of surface irregularities) are impossible, the location of the thermal equator is not identical to that of the geographic Equator.

Further, we know that the Earth reaches perihelion (the minimum distance from the Sun in its orbit) in early January and is at aphelion (maximum distance) in early July. During winter season of the respective hemispheres, the angle of incidence of the sun's rays is low in tropics. The average annual temperature of the tropical regions is therefore lower than the observed near the equator, as the change in the angle of incidence is minimum at equator.

The thermal equator shifts towards north and south with north south shift in the position of vertical rays of the sun. *However, annual average position of the Thermal equator is 5° N latitude* The reason is that highest mean annual temperature shifts towards northwards during the summer solstice to a much greater extent than it does towards south at the time of winter solstice.

Daily variation of Temperature

Sun is at the highest point at noon but the highest temperature does not occur at 1200 hours because the ***atmosphere does not get the heat directly from the Sun*** It receives heat from the earth's surface slowly and that is why maximum temperature is generally attained by 1400 hours (2.00p.m.). The daily minimum temperature at a place does not occur at about 0400 hours (4.00 p.m.) in the morning because radiation of heat continues upto the sun rise.

Here are some notable observations on daily temperature ranges:

- Daily temperature range is **low in clouded areas** because the clouds obstruct the receipt and loss of insolation.
- The sky is clear in hot desert's areas. Insolation is received without obstruction in the day and lost without obstruction in the night. This causes **high temperature range in deserts.**
- Ice or snow absorbs less and reflects the insolation more. Hence, the daily temperature range is low is snow bound areas.
- The air is thin in areas of high altitude. There is great loss of insolation in the night. There is no obstruction in the receipt of insolation in the day. Such places have a high temperature range.
- There is a higher temperature range in than interior areas of continents than at seas because the sea heats and cools slowly but the land heats and cools rapidly.
- Warm and cool winds also disturb the temperature range.

Annual temperature range

On Equator

The duration of the day or night is the same in equatorial countries. The sun's rays are vertical all through the year. Hence, there is no worthwhile difference between the summer and winter seasons. This is the reason that the ***lowest annual temperature range is found in equatorial areas.***

On Poles

Towards the poles, the duration of the day and the inclination of the sun rays go on increasing. It causes a lot of difference between the temperatures of the two seasons. Hence, towards the poles, the annual temperature range goes on increasing.

Near Oceans

Near the seas and oceans, the equalizing effect of sea water makes the winter less cold and the summer less hot. This reduces the annual range of temperature near the seas. The equalizing effect of the sea water cannot reach land areas, away from the seas. The countries like Mongolia and Tibet which are situated far into the interior of the continent have a high annual range of temperature. The ocean currents near the coasts also affected the temperature range. Due to the warm gulf stream, the winter of western Europe is less cold than what it Europe is less cold than what it should have been without the gulf stream. This reduces the annual temperature range.

The shifting attitude of ocean currents has a lot of effect on the annual temperature range. For example, the weather and seasons have to undergo greater changes on the eastern coasts of Indian and Australia due to the shifting of ocean currents. It increases the annual temperature range on these coasts as compared to that on the opposite side coasts.

Impact of Winds

The prevailing winds also have a greater effect on the annual temperature range. Winds from the land blow in Arabian countries and therefore increase the annual range of temperature. Winds from the oceans and seas blow into Western Europe and reduce the annual temperature range. The variation in the annual temperature range in west and east European countries is due to land and sea winds. The effect of winds from the ocean has a far smaller effect in Eastern Europe than in Western Europe. It is why the annual temperature range is higher in eastern than in Western Europe.

Atmospheric Pressure and Pressure Belts

Air has weight and a column of air extending vertically over a given area on earth's surface exerts pressure. The atmospheric pressure is measured as a force per unit of area and most common unit of measuring the air pressure is millibar. The instrument used for measuring pressure is Barometer. Some barometers are calibrated to show pressure in mercury inches. At constant temperature of 0°C and latitude of 45°, 1049 millibar is equal to 31 inches of mercury. Barograph is used to take continuous readings of air pressure.

Measuring Atmospheric Pressure

Bar is a unit of pressure equal to 100 kilopascals and roughly equal to the atmospheric pressure on Earth at sea level. Other units derived from the bar are the megabar (symbol: Mbar), kilobar (symbol: kbar), decibar (symbol: dbar), centibar (symbol: cbar), and millibar (symbol: mbar or mb). Bar is neither an SI unit nor a CGS unit. 1

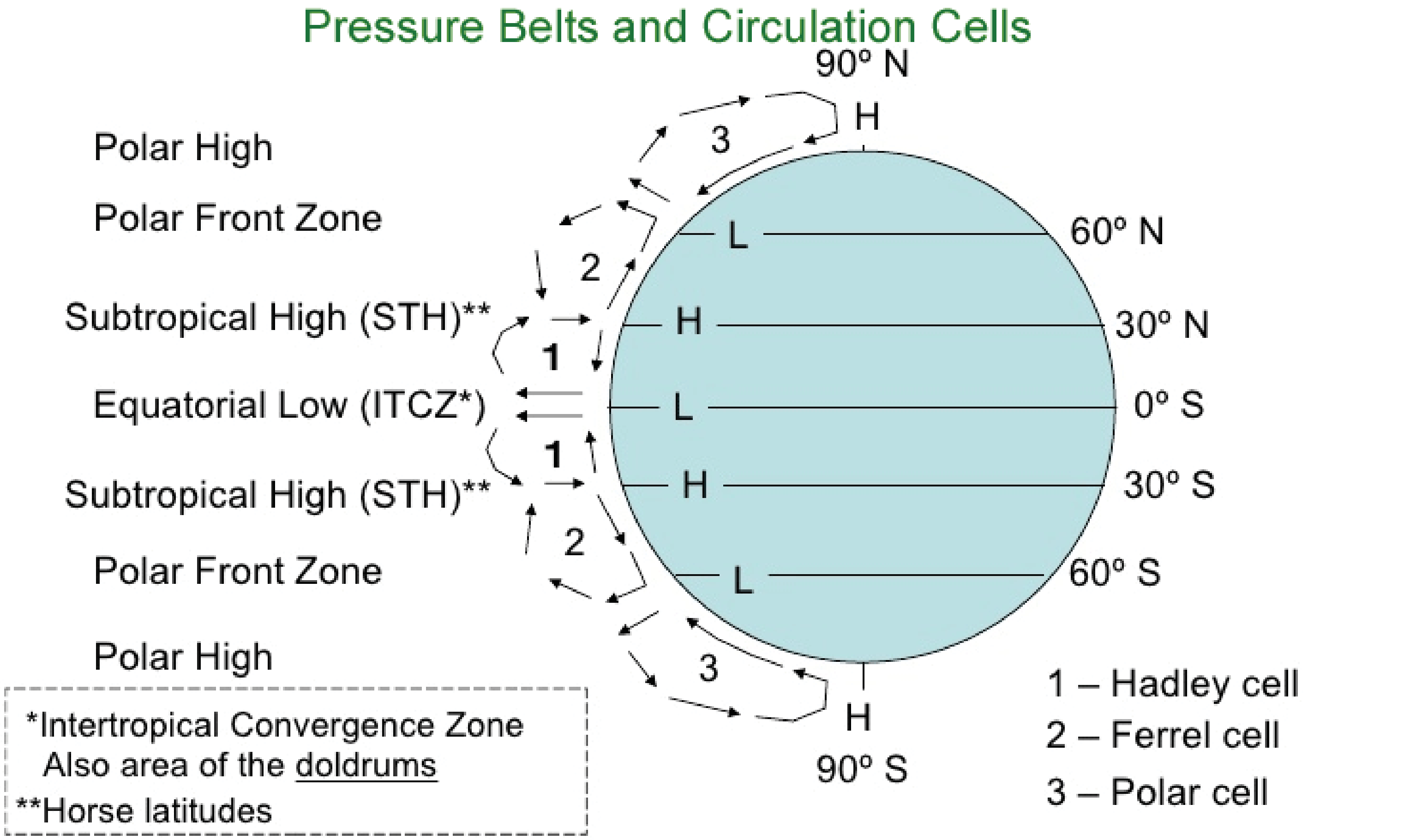
bar is 1% smaller than the atmosphere (symbol: atm), which now is defined to be 1.01325 bar exactly. One millibar is also equal to 1000 dynes per cm².

Pressure Belts of Earth

The distribution of pressure **on earth is uneven** Usually pressure is inversely related to the temperature and pressure reduced with altitude. The major factors are earth's rotation and ascent and descent of air to affect distribution of pressure.

Creation of the Pressure Belts

Due to high amount of insolation over the equator, the air ascends and this air rising in the equatorial region descends at around 30° north and south latitudes. This means that the air at the equatorial region is thrown away from the earth and air at the Polar Regions is pulled towards earth. *This implies that there is a low pressure is on equator and there is a high pressure area on poles* This gives rise to two belts of high pressure on Polar Regions each and one belt of low pressure on equator. The air that descends at 30°N and 30°S also created two belts of high pressures in the subtropical regions of both the hemispheres. Further, the rotation of the earth pulls the air at Polar Regions causes a rarification of air pressure at sub-polar regions. This also produces two belts of low pressure around 60°N and S latitude. This means that there are 7 belts of pressure as shown in the below graphics.



The planetary distribution of pressure, in the 7 belts is determined by two major factors viz. **thermal factor and dynamic factor**. Please note that equatorial belt of low pressure and polar belts of high pressures are due to the thermal factor while, the subtropical belts of high pressure and subpolar belts of low pressure are primarily due to **earth's rotation or dynamic factors**.

Intertropical Convergence Zone / Doldrums

The pressure belt between the 0° to 5°N and S is called**Equatorial Low Pressure Belt**. This belt is characterized by intense heating, with expanding air and ascending convectional currents. Because the air is largely moving upward, surface winds are light and variable. This region is known as the **doldrums.**

The term doldrums has been used by the sailors as it has been marked by erratic weather patterns with stagnant calms and violent thunderstorms.

Doldrums are ***belt of calms and variable winds***occurring at times along the equatorial trough. Doldrums are characterised by:

- Low atmospheric Pressure
- High Humidity
- Thunderstorms

The same area is also called the Intertropical Convergence Zone (ITCZ) or Doldrums. This is the area encircling the earth near the equator where winds originating in the northern and southern hemispheres come together. Please note that the location is not precisely defined as location of the Intertropical convergence zone varies over time. Over land, it moves back and forth across the equator following the sun's zenith point. Over the oceans, where the convergence zone is better defined, the seasonal cycle is more subtle, as the convection is constrained by the distribution of ocean temperatures. Sometimes, a double ITCZ forms, with one located north and another south of the equator. When this occurs, a narrow ridge of high pressure forms between the two convergence zones, one of which is usually stronger than the other. Between 10° and 15° North and South, there are high pressure belts, where air is comparatively dry, light and calm. This region is beneficial to the maritime trade.

Subtropical High / Horse Latitudes

Horse Latitudes or Subtropical High are subtropical latitudes between 30 and 35 degrees both north and south. This region, under a ridge of high pressure receives little precipitation and has variable winds mixed with calm. The air is**comparatively dry and calm**. This is also the region of descending air current and is marked by some cyclonic activities. The consistently *warm, dry conditions of the horse latitudes also contribute to the existence of temperate deserts, such as the Sahara Desert in Africa, the southwestern United States and northern Mexico, and parts of the Middle East in the Northern Hemisphere; and the Atacama Desert, the Kalahari Desert, and the Australian Desert in the Southern Hemisphere.*

Other Belts

30°-60°North and South Belt region is of temperate low pressure belt or anti-trade wind area. It is marked by cyclones and anticyclones. 60°North and South are the two Temperate Low Pressure belts which are also called zones of convergence with Cyclonic activity. The 90° North and South are called Polar High belts.

Winds

Global Winds

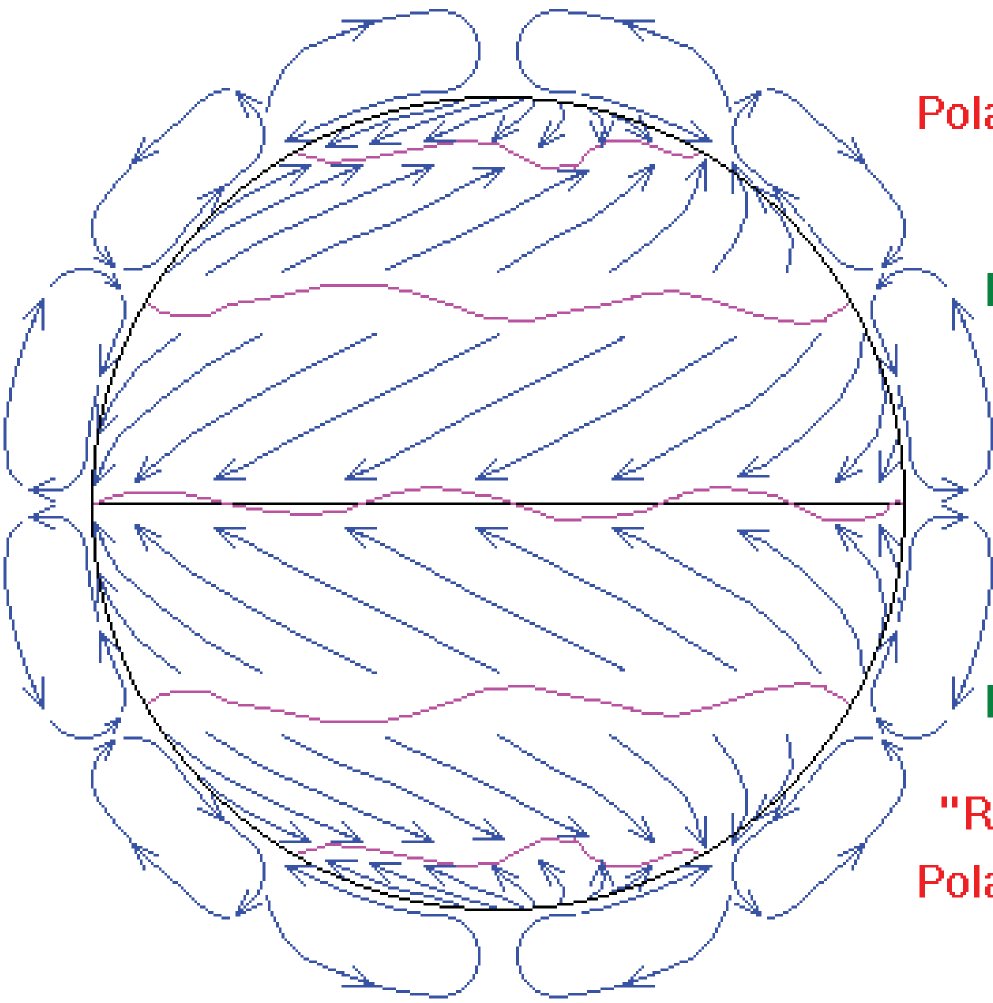
When air moves in a definite direction, it is called wind. If the winds move **from west** to east, they are called westerlies. If they move **from east** to west, they are called easterlies.

There are winds because there are differences in pressures. The direction of wind is also affected by coriolis affect. Due to Coriolis Force, the wind flowing from equator towards the North Pole and from North Pole towards the equator are deflected to their right while the winds flowing north-south and south-north in the southern hemisphere are deflected towards their left. The magnitude of the deflection, or "Coriolis effect," varies significantly with latitude. *The Coriolis Effect is zero at the equator and increases to a maximum at the poles.* The effect is proportional to wind speed; that is, deflection increases as wind strengthens. The resultant balance between the pressure force and the Coriolis force is such that, in the absence of surface friction, air moves parallel to isobars (lines of equal pressure). This is called the geotropic wind. The Coriolis force explains why winds circulate around high and low pressure systems as opposed to blowing in the direction of the pressure gradient. Central idea behind the Coriolis force is that when the earth rotates from west to east, it produces the centrifugal force and due to this force, there is a change in the direction of the wind. There is Ferrel's law derived from Coriolis Effect, which says that in northern hemispheres, wind deflects towards the right and in southern hemisphere wind deflects towards left. This means that in northern hemisphere, wind deflects clockwise, while in southern hemisphere, wind deflects anti-clockwise.

Trade winds

Trades wind blow out from the Subtropical High Pressure belts. In the northern hemisphere, they blow towards the equatorial low and called **North East Trade Winds.** In the Southern hemisphere they blow towards the equatorial low and become the **South East Trade winds**. This implies that Trade winds blow from North east towards equator in Northern hemisphere and South East Towards equator in southern hemisphere. It has been shown in the following graphics.

The trade winds are **most regular winds of all kinds on earth**. They blow with great force and in constant direction that is why they are preferred by the sailors. The trade winds bring heavy rain falls and sometimes contain intense depressions.



Trade winds and Hadley cells

There are three primary circulation cells on earth known as the Hadley cell, Ferrel cell, and Polar cell. The Hadley cell mechanism provides an explanation for the trade winds. Hadley cell is a closed circulation loop, which begins at the equator with warm, moist air lifted aloft in equatorial low pressure areas (the Intertropical Convergence Zone, ITCZ) to the tropopause and carried pole ward. At about 30°N/S latitude, it descends in a high pressure area. Some of the descending air travels equatorially along the surface, closing the loop of the Hadley cell and creating the Trade Winds. Hadley Cells is described to be lying on equator but it follows sun's zenith point, or what is termed the "thermal equator".

Origin of Trade Winds

Trade winds are part of the Hadley cell circulation. At the equator, a low-pressure area of calm, light variable winds is known Intertropical Convergence Zone as we discussed above. The air lifts from here and at around 30° North and South, the air begins to descend toward the surface in subtropical high-pressure belts known as subtropical ridges. At the surface, the air flows from these subtropical high-pressure belts toward the Equator but is deflected toward the west in both hemispheres by the

Coriolis Effect. Thus, these winds blow predominantly from the northeast in the Northern Hemisphere and from the southeast in the Southern Hemisphere. Because winds are named for the direction from which the wind is blowing, these winds are called the northeast trade winds in the Northern Hemisphere and the southeast trade winds in the Southern Hemisphere. **The trade winds meet at the doldrums.**

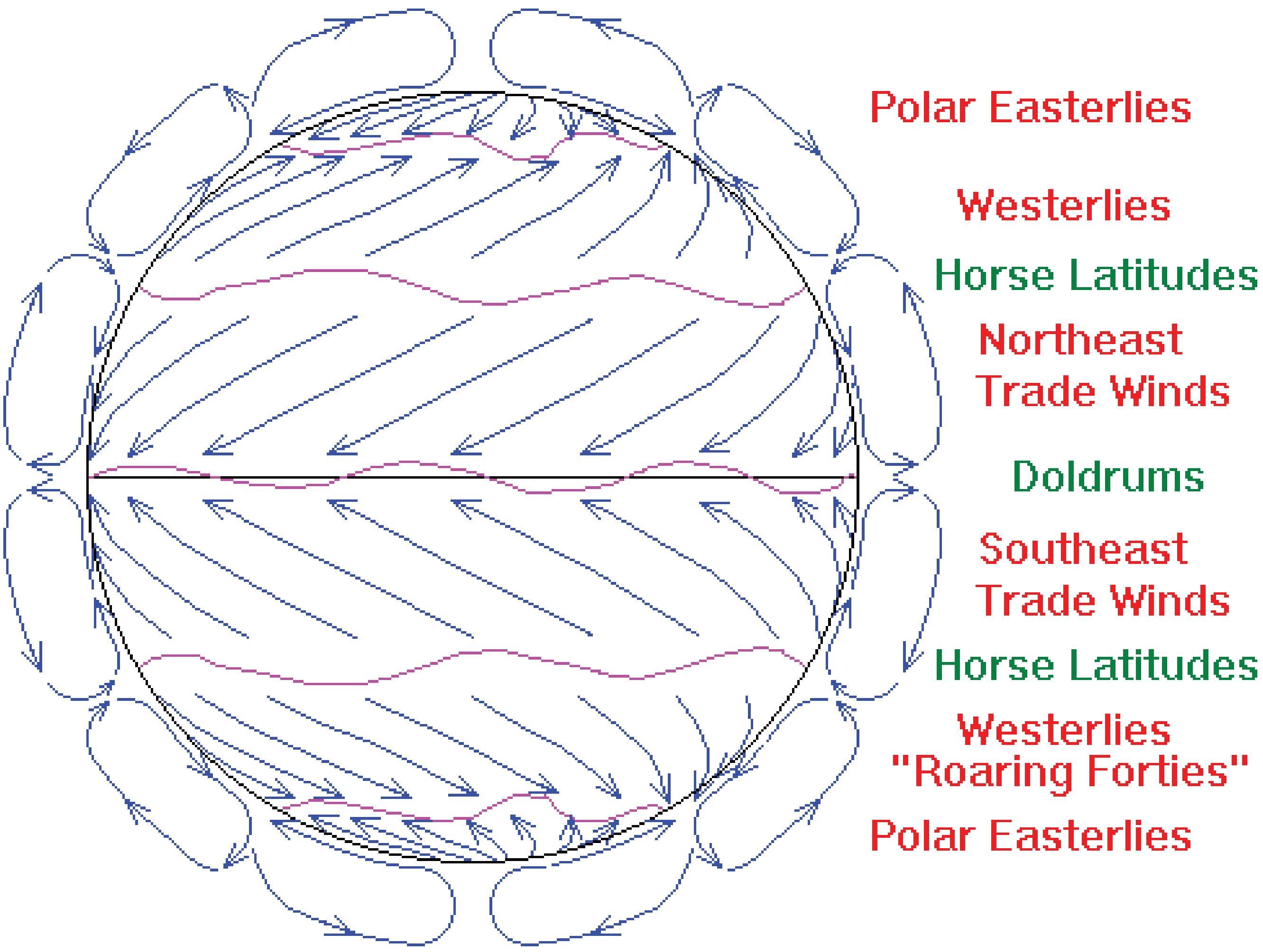
You can visualize more about trade winds & Hadley Cells in this animation: http://bit.ly/UfHnbt

Implications of Trade winds

- Trade winds are the surface winds in low latitudes, representing the low-level airflow. Back in history, two large belts of winds were discovered blowing toward the equator called North East and South East trade winds. The word trade in those days referred to advance steadily and was synonymous with efficient sailing. The trade winds allowed the sailing vessels to advance steadily—and, of course, to set up patterns of international trade. However, you must note that trade winds are not totally steady in force or direction, but they do trend in the general direction of southwest and northwest.
- Hawaii is located south of Tropic of Cancer, yet, the temperatures are pleasant, temperatures and humidity tends to be a bit less extreme. This makes it one of the most famous tourist destinations of the world. What make such a climate are Trade Winds.

Westerlies

The directions of the Westerlies are opposite to trade winds and that is why they are also called **antitrade winds**. Westerlies blow in the middle latitudes between 30 and 60 degrees latitude, and originate from the high pressure area in the horse latitudes towards the poles. Under the effect of the Coriolis force, they become the south westerlies in the northern hemisphere and Northern westerlies in the southern hemisphere. Please note that in the southern hemisphere, there is more of ocean and less of land in comparison to the northern hemisphere. Due to this reason, the westerlies blow with much greater force in southern hemisphere in comparison to northern hemisphere.



This also has implications in the Ocean currents. The currents in the Northern Hemisphere are weaker than those in the Southern Hemisphere due to the differences in strength between the Westerlies of each hemisphere.

Generally, **Westerlies are strongest in the winter hemisphere** and at times when the pressure is lower over the poles, while they are weakest in the summer hemisphere and when pressures are higher over the poles. Please note the westerlies are also associated with the "**extra tropical**" cyclones which refer to the fact that this type of cyclone generally occurs outside of the tropics, in the middle latitudes of the planet, where the Westerlies steer the system generally from west to east. Whenever there is a convergence of the cold and denser polar winds and warm and light westerlies, there are much variation in the weather. The velocity of the westerlies increases southward and they become stormy. When we move towards poles, the velocity of the westerlies is given different terms as follows:

- Roaring Forties between the 40-50°S
- Furious Fifties at the 50°S and Shrieking Sixties at 60°S.

Polar Easterlies

Polar easterlies blow from the polar high pressure belts towards the temperate low pressure belts. These are extremely cold winds that come from the Tundra and Icecap regions of the poles. The Polar Easterlies ***are more regular in the southern hemisphere in comparison to the northern hemisphere***. These polar cold winds converge with the warm easterlies near 60° latitudes and form the Polar front or Mid Latitude front. This mid-latitude front becomes the centre of the origin of the Temperate Cyclones.

Local Winds

The Local winds around the world are formed through the *heating of land*. In coastal regions, the sea breezes and land breezes are important factors in a location's prevailing winds. The sea is warmed by the sun more slowly because of water's greater specific heat compared to land. As the temperature of the surface of the land rises, the land heats the air above it by conduction. The warm air is less dense than the surrounding environment and so it rises. This causes a pressure gradient of about 2 millibar from the ocean to the land. The cooler air above the sea, now with higher sea level pressure, flows inland into the lower pressure, creating a cooler breeze near the coast. At night, the land cools off more quickly than the ocean because of differences in their specific heat values. This temperature change causes the daytime sea breeze to dissipate. When the temperature onshore cools below the temperature offshore, the pressure over the water will be lower than that of the land, establishing a land breeze, as long as an onshore wind is not strong enough to oppose it.

Local winds near Mountains

There is a different explanation for local winds near mountains. Over elevated surfaces, heating of the ground exceeds the heating of the surrounding air at the same altitude above sea level, creating an associated thermal low over the terrain and enhancing any thermal lows that would have otherwise existed, and changing the wind circulation of the region. In areas where there is rugged topography that significantly interrupts the environmental wind flow, the wind circulation between mountains and valleys is the most important contributor to the prevailing winds.

Barrier Jet

The mountains and valleys are capable to distort the airflow by increasing friction between the atmosphere and landmass by acting as a physical block to the flow, deflecting the wind parallel to the range just upstream of the topography, which is known as a **barrier jet**. This barrier jet can increase the low level wind. Wind direction also changes because of the contour of the land. If there is a pass in the mountain range, winds will rush through the pass with considerable speed because of the Bernoulli principle that describes an inverse relationship between speed and pressure. The airflow can remain turbulent and erratic for some distance downwind into the flatter countryside. These conditions are dangerous to ascending and descending airplanes.

List of major Local Winds

- Abroholos: squall frequent wind that occurs from May through August between Cabo de Sao Tome and Cabo Frio on the coast of Brazil
- Amihan : northeasterly wind across the Philippines
- Bayamo : violent wind on Cuba's southern coast
- Bora : northeasterly from eastern Europe to northeastern Italy
- Calima : dust-laden south to southeasterly wind blowing in the Saharan Air Layer across the Canary Islands
- Cape Doctor : dry south-easterly wind that blows on the South African coast in summer
- Chinook : warm dry westerly off the Rocky Mountains
- Elephanta : strong southerly or southeasterly wind on the Malabar coast of India
- Föhn : warm dry southerly off the northern side of the Alps and the North Italy, the name gave rise to the fén-fēng or 'burning wind' of Taiwan
- Fremantle Doctor : afternoon sea breeze from the Indian Ocean which cools Perth, Western Australia during summer
- Gregale : northeasterly from Greece
- Habagat : southwesterly wind across the Philippines
- Harmattan : dry northerly wind across central Africa
- Karaburan : "black storm", a Spring and Summer Katabatic wind of central Asia
- Khamsin : southeasterly from north Africa to the eastern Mediterranean
- Khazri : cold north wind in the Absheron Peninsula of the Azerbaijan Republic
- Kona : southeast wind in Hawaii, replacing trade winds, bringing high humidity and often rain
- Košava : strong and cold southeasterly season wind in Serbia
- Lodos : southwesterly towards Turkey. Strong "Lodos" events occur 6 – 7 times a year bringing 35 kt winds into Marmara Sea. The winds are funneled SE from the Mediterranean and through the Dardanelles Strait.
- Loo : hot and dry wind which blows over plains of India and pakistan.
- Mistral : cold northerly from central France and the Alps to Mediterranean
- Monsoon : mainly south-westerly winds combined with heavy rain in various areas close to the equator
- North wind : northern cold winds blowing from the Gulf of Mexico to the Isthmus of Tehuantepec

- Nor'easter : strong storm with winds from the northeast in the eastern United States, especially New England
- Nor'wester : wind that brings rain to the West Coast, and warm dry winds to the East Coast of New Zealand's South Island, caused by the moist prevailing winds being uplifted over the Southern Alps, often accompanied by a distinctive arched cloud pattern
- Pampero : Argentina, very strong wind which blows in the Pampa
- Simoom : strong, dry, desert wind that blows in the Sahara, Israel, Jordan, Syria, and the desert of Arabia
- Sirocco : southerly from north Africa to southern Europe
- Sundowner : strong offshore wind off the California coast
- Zonda wind : on the eastern slope of the Andes in Argentina

Climate Related Topics

Monsoon Mechanism

The word monsoon derived from the Arabic word *mausim* means seasonal winds. In this system, the direction of the winds reverses seasonally. The first thing we note is that Monsoon is typically considered a phenomenon of tropical south Asia, but it is also experienced over parts of North America and Africa.

Mechanism of Monsoon: Traditional View

Traditionally, monsoon has been considered a result of the differential heating of land and sea.

- In summer, southern Asia develops a low pressure while the pressure over the sea is relatively higher. As a result the air starts flowing towards land from the Indian oceans. The winds coming from ocean carry moisture and thus cause rainfall in summer reason. This is known as the southwest monsoon or summer monsoon.
- In winter, the pressure over land is higher than over the sea and consequently the air starts flowing from land to sea. The air coming from land being dry, these winds do not cause rainfall.

The above explanation is known as the thermal theory of monsoon. This theory explains monsoon as a regional phenomenon but fails to explain the total amount of energy / processes involved in the global monsoon circulation.

Mechanism of Monsoon: Modern View

The modern meteorologists seek explanation for the phenomenon of monsoon on the basis of *seasonal shift in the position of the global belts of pressure and winds* This is also known as **Dynamic Theory**.

According to the dynamic theory, monsoons are a result of the *shift of the inter-tropical convergence* zone (ITCZ) under the influence of the vertical sun. Though the average position of the ITCZ is taken as the equator, it keeps shifting vertical sun towards with the migration of the vertical sun towards the tropics during the summer of the respective hemisphere.

- During summer in the northern hemisphere in the months of May and June, the sun shines vertically over the tropic of cancer. Due to the northward shift of the zone of maximum heating and low pressure at this time the ITCZ also shifts northwards and approaches, the tropic of cancer. The ITCZ being the zone of the lowest pressure in the tropical region is the destination of the trade winds blowing from both the hemispheres.
- With ITCZ situated close to the tropic of cancer the northeast trade winds are confined to an area extending to its north while the southeast trade winds blowing from the southern hemisphere have to cross the equator to reach this area of low pressure. However as the winds blowing from the southern hemisphere cross the equator their direction is altered due to Coriolis effect, i.e. they are direction is their right and thus it give rise to the formation of a belt of equatorial westerlies in the months of many of June northeast and they are called the southwest monsoon.
- As the ITCZ again moves southwards at the end of the summer of the northern hemisphere the areas north of the equator which experienced the equatorial westerlies during the summer season come under the influence of the northeast trade winds. These northeasterly winds are called the northeast The onset of winter season the ITCZ shifts south of the equator and reaches as far south at this time. in this season the northeast trades blowing towards the ITCZ have to cross the equator towards south and as a result they get deflected giving rise to the equatorial westerlies in the southern hemisphere. these westerlies blow form the northwest to the southwest, replacing the trade winds of the southern hemisphere between the ITCZ and the equator. They form the summer monsoon of the southern hemisphere.

We can say that due to the seasonal shift of the wind belts under the influence of the north-south migration of the vertical sun the areas situated in the tropical zone in the both the hemisphere come under the influence of the trade winds during the respective winter and the equatorial westerlies during the respective summer season. The direction of the winds is thus reversed seasonally and it makes up the monsoon system of these regions.

Please note that though, dynamic theory provides a much better explanation of the system of monsoon as a global phenomenon, it does not negate the influence of differential heating of land and sea.

Differential heating still plays an important role in making monsoon much stronger in certain of the south-west monsoon factor that explains the extension of the southwest monsoon even to the north of the tropic of cancer in northern India.

Rainfall

The amount of moisture in air is commonly recorded as **relative humidity**; which is the percentage of the total water vapour air can hold at a particular air temperature. The presence of warm, moist and unstable air and sufficient amount of the hygroscopic nuclei is a prerequisite condition for rainfall. The warm and moist air after being lifted upwards becomes saturated and clouds are formed after condensation of water vapour around the hygroscopic nuclei such as dust particles.

How much water vapour a parcel of air can contain before it becomes saturated (100% relative humidity) and forms into a cloud (a group of visible and tiny water and ice particles suspended above the Earth's surface) depends on its temperature. Warmer air can contain more water vapour than cooler air before becoming saturated.

Cooling

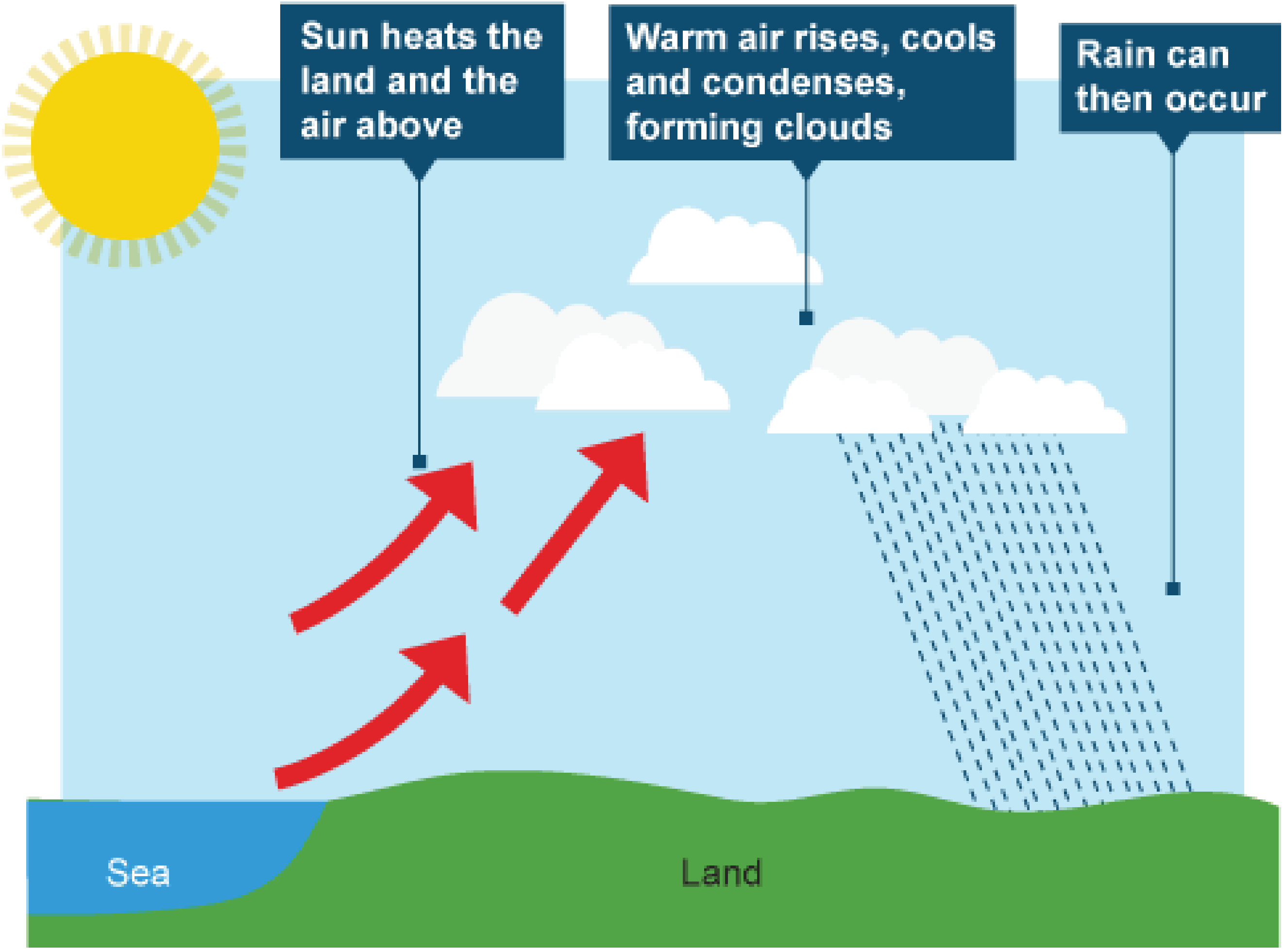
The process of condensation begins only when the relative humidity of the ascending air becomes 100% and air is cooled through four main mechanisms to its dew point: adiabatic cooling, conductive cooling, radiational cooling, and evaporative cooling.

- **Adiabatic cooling** occurs when air rises and expands. The air can rise due to convection, large-scale atmospheric motions, or a physical barrier such as a mountain (orographic lift).
- **Conductive cooling** occurs when the air comes into contact with a colder surface, usually by being blown from one surface to another, for example from a liquid water surface to colder land.
- **Radiational cooling** occurs due to the emission of infrared radiation, either by the air or by the surface underneath.
- **Evaporative cooling** occurs when moisture is added to the air through evaporation, which forces the air temperature to cool to its wet-bulb temperature, or until it reaches saturation.

Further, we note that the very small rain drops are almost spherical in shape. As drops become larger, they become flattened on the bottom, like a hamburger bun. Very large rain drops are split into smaller ones by air resistance which makes them increasingly unstable. When water droplets fuse to create larger water droplets, it is called Coalescence. When water droplets freeze onto an ice crystal, which is known as the **Bergeron process**. Air resistance typically causes the water droplets in a cloud to remain stationary. When air turbulence occurs, water droplets collide, producing larger droplets. As these larger water droplets descend, coalescence continues, so that drops become heavy enough to overcome air resistance and fall as rain. Coalescence generally happens most often in clouds above freezing, and is also known as the warm rain process.

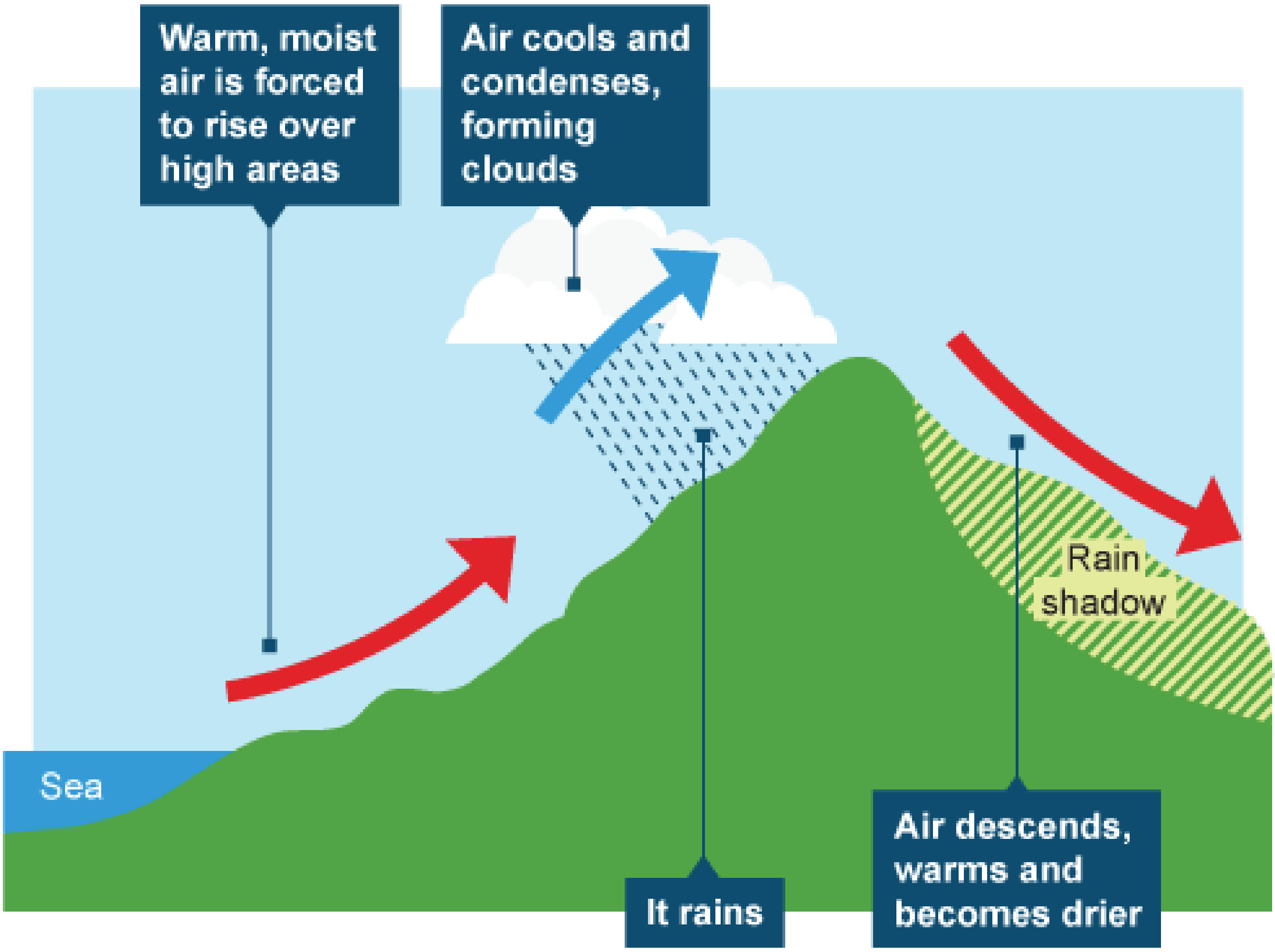
Convectional Rainfall

The convectional rainfall occurs due to the thermal convection currents caused due to the heating of ground due to insolation. The convectional rainfall is prevalent in equatorial regions. In these, the warm air rises up and expands then, reaches at a cooler layer and saturates, then condenses mainly in the form of **cumulus or cumulonimbus clouds**. In the equatorial regions, the precipitation due to convectional rainfall occurs in the afternoon. The rainfall is of very short duration but in the form of heavy showers.



Cyclonic / Frontal Rainfall

Frontal rainfall occurs due to the upward movement of the air caused by the convergence of different air masses with different temperatures. The warm air rises over the cold air and cyclonic rain occurs. The cold air pushes up the warm air and sky gets clear again.



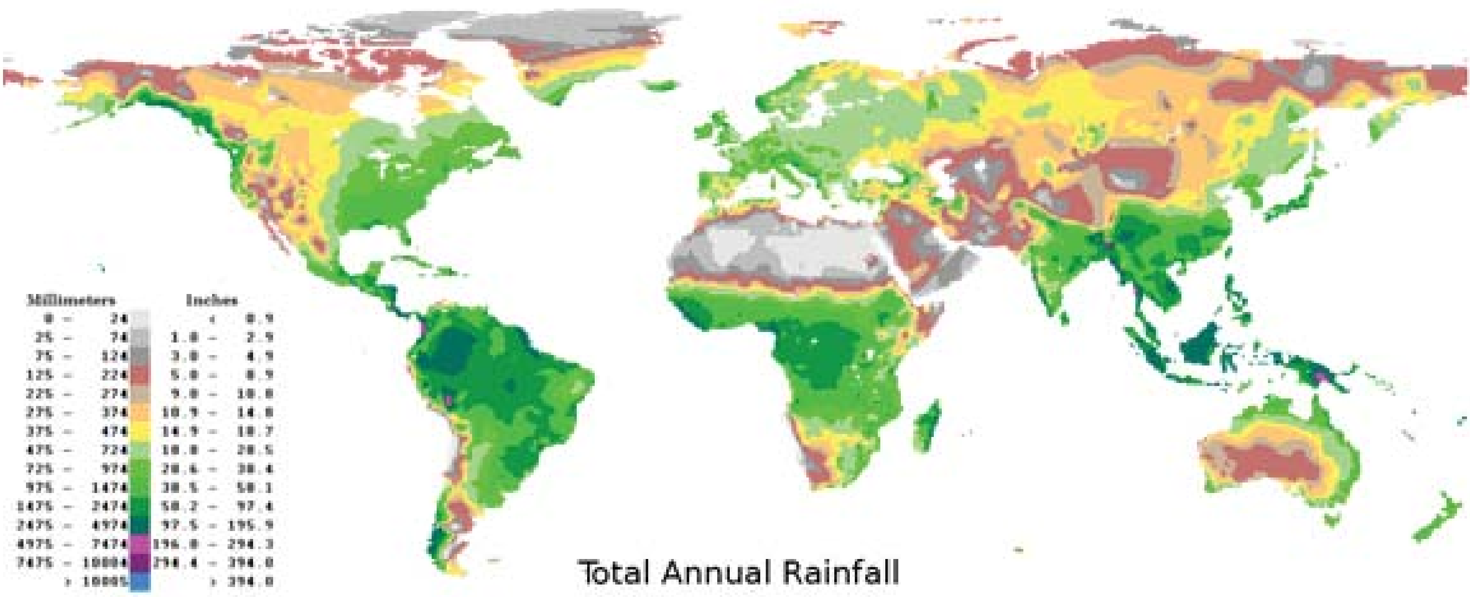
Orographic Rainfall

The orographic rainfall occurs due to the ascent of air forced by the mountain barrier. The mountain barrier should be across the wind direction. So that the moist air is forced in obstruction to move upward and get cooled. In Rajasthan, the Aravalli is not an obstructing barrier to the highly moist air coming from Arabian Sea and that is why they don't play very important role in rainfalls. Thus they produce a Rain shadow area. A rain shadow is a dry area on the lee side of a mountainous area. The mountains block the passage of rain-producing weather systems, casting a "shadow" of dryness behind them. In south India, the Mangalore is located on the western windward slope and gets 2000 mm of rainfall. But Bangalore is in rain shadow area and that is why receives less than 500 mm of rainfall.

Please note that the amount of the rainfall increases with increasing height of the barrier such as mountain, but this is up to a certain limit. After that there is a marked decrease due to lesser moisture content of the air and this phenomenon is called "**Inversion of Rainfall**"

Distribution of Rainfall

The regions having high temperature and abundance of water receive higher amount of rainfall, such as equatorial regions. In the subtropical regions, the western parts receive lesser rainfalls. This is due to anticyclone activities.



Mean annual rainfall for earth is 970mm. The equatorial regions receive rainfall through out the year while the other regions receive rainfall seasonally. The Mediterranean region receives rainfall during the winter generally.

Air Mass & Fronts

Air mass is a volume of air defined by its temperature and water vapour content. An air mass may be of many hundreds or thousands of square miles, and adopt the characteristics of the surface below them. An air mass can be so extensive that it may cover the large portion of a continent below it and may be vertically so thick that may cover the troposphere. The vertical distribution of the temperature in an air mass and moisture content of the air are the two properties of air air mass which control the weather conditions of an area under that particular air mass. The air mass is considered to be cold air mass if its temperature is lower than the underlying surface, while an air mass is terms warm air mass when its temperature is higher than the underlying surface. The boundary between the two air masses is called the **front.**

Air masses are classified according to latitude and their continental or maritime source regions. Colder air masses are termed polar or arctic, while warmer air masses are deemed tropical. Continental and superior air masses are dry while maritime and monsoon air masses are moist. Weather fronts separate air masses with different density (temperature and/or moisture) characteristics. Once an air mass moves away from its source region, underlying vegetation and water bodies can quickly modify its character.

Frontogenesis and Frontolysis

The boundary between the two air masses is called the **front.** A temperature difference is essential in the definition of a front because it implies a density differenceThe air masses of different densities don't mix readily and tend to retain their identity as far as we care for the moisture. The front represents a transition zone between two air masses of different density. Generally, an air mass from one region moves to the other region which is occupied by some other air mass. When a warmer and lighter air mass moved against a cold and denser air mass, the former rides over the other and it is called **warm front.** If the cold air mass forces its way under a warm air mass, it is called **cold front.** When new fronts are created or old fronts are regenerated, it is called Frontogenesis. Please note that fronts don't appear all of a sudden. They appear only after a process of Frontogenesis which is there in place for quite some time. When winds converge towards a point it would lead to **Frontogenesis**.

Frontogenesis takes place only when two conditions are met. First, two air masses of different densities must exist adjacent to one another; and second, a prevailing wind field must exist to bring them together. There are three basic situations, which are conducive to Frontogenesis and satisfy the two basic requirements. The wind flow is cross isothermal and flowing from cold air to warmer air. The flow must be cross isothermal, resulting in a concentration of isotherms (increased temperature gradient). The flow does not have to be perpendicular; however, the more perpendicular the cross isothermal flow, the greater the intensity of Frontogenesis.

On the other hand, the dying of a front is called **Frontolysis.** Frontolysis also does not happen all of a sudden. The process of Frontolysis must happen for quite some time to destroy the existing front.

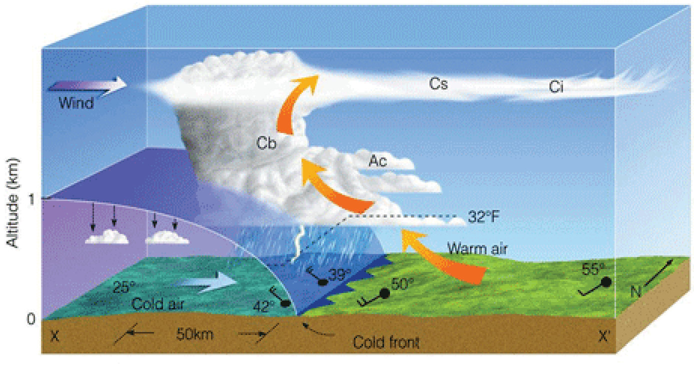
Types of Fronts

Cold Front

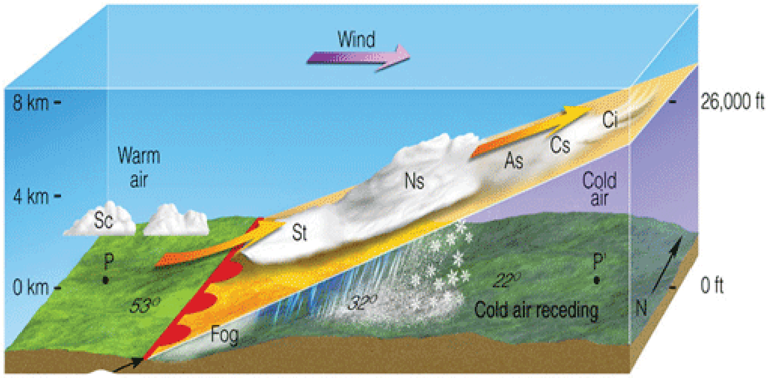
When a cold air invades the warm air, it remains at the ground and forcibly**uplifts the warmer and lighter air mass.** This is known as **Cold front.** This upward motion causes lowered pressure along the cold front and can cause the formation of a narrow line of showers and thunderstorms when enough moisture is present. Cold fronts can move up to twice as fast as warm fronts and can produce sharper changes in weather. Since cold air is denser than warm air, it rapidly replaces the warm air preceding the boundary. Cold fronts are usually associated with low-pressure areas. Cold front usually causes a shift of wind from southeast to northwest, and in the southern hemisphere a shift from northeast to southwest.

Warm front

When a warmer and lighter air mass moved against a cold and denser air mass, the former rides over the other and it is called **warm front.** Being lighter, the warm air mass is unable to displace the cooler air mass and instead is forced upward along the upper boundary of the colder air in a process known as overrunning. The boundary between the two air masses has a gradual slope of 130 and lifting is slow but persistent. As the air mass rises into regions of lower pressure, it expands and cools. As it cools, water vapour condenses and forms extensive cloud coverage. The first clouds to form along the sloping surface of the cold air are high cirrus, which thicken to cirrostratus and altostratus.



Cold Front



Warm Front

Image Curtsey: © Thomson Higher Education

Occluded front

An occluded front is a front that is formed when a cold front overtakes a warm front. The cold front moves rapidly than the warm front. Ultimately, the cold front overtakes the warm front and completely displaces the warm air at the ground.

Cyclones

Cyclone is a *system of low atmospheric pressure in which the barometric gradient is steep* Cyclones represent circular fluid motion **rotating in the same direction as the Earth.** This means that the inward spiralling winds in a cyclone rotate anticlockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere of the Earth. Most large-scale cyclonic circulations are centred on areas of low atmospheric pressure. The cyclones can be tropical cyclones or temperate cyclones (extra-tropical cyclones).

Basic difference between Tropical Cyclone and Extra-tropical Cyclone

The term "tropical cyclone" is used to refer to **warm-core**, low-pressure systems that develop over tropical or subtropical oceans. This definition differentiates tropical cyclones from extra tropical (midlatitude) cyclones that exhibit a **cold-core** in the upper troposphere and often form along **fronts in higher latitudes** Subtropical cyclones are hybrid systems that exhibit some characteristics of tropical cyclones and some characteristics of extra-tropical cyclones.

Tropical cyclones extract much of their energy from the upper layer of the ocean, while extratropical cyclones derive much of their energy from the *baroclinic temperature gradients in which they form*.

Tropical Cyclones

The tropical cyclone is a system of low pressure occurring in tropical latitudes characterized by very strong winds. Here are the important notes which you must note about the Tropical Cyclones:

Distribution

The tropical cyclones are found over the North Atlantic Ocean, Southern Atlantic Ocean, the eastern, central and western North Pacific Ocean, the central and western South Pacific Ocean and the northern and southern Indian Ocean.

Formation in Low Pressure areas

All tropical cyclones are formed in areas of low atmospheric pressure in the Earth's atmosphere.

Minimum Pressure is at centre

The pressures recorded at the centers of tropical cyclones are among the lowest that occur on Earth's surface at sea level.

Driver is the Large Heat of Condensation

Tropical cyclones are driven by the release of large amounts of latent heat of condensation, which occurs when moist air is carried upwards and its water vapour condenses. This heat is distributed vertically around the center of the storm. Thus, at any given altitude, environment inside the cyclone is warmer than its outer surroundings.

Eye is the sinking air

There is an area of sinking air at the center of circulation, which is known as Eye. Weather in the eye is normally calm and free of clouds, although the sea below it may be extremely violent. Eye is normally circular in shape, and is typically 30–65 km in diameter.

Stadium Effect

The mature tropical cyclones sometimes exhibit an outward curving of the eye wall's top, making it resemble an arena football stadium. It is called Stadium Effect.

Greatest Wind speeds are at eye walls

Greatest wind speeds in a tropical cyclone is found at the eye wall, which is a circle of strong thunderstorms that surrounds the eye. Here, the clouds reach the highest, and precipitation is the heaviest. The heaviest wind damage occurs where a tropical cyclones eye wall passes over land.

Source of the huge Energy

Primary energy source is the release of the heat of condensation from water vapour condensing, with solar heating being the initial source for evaporation. So a tropical cyclone can be visualized as a giant vertical heat engine supported by mechanics driven by physical forces such as the rotation (Coriolis force) and gravity of the Earth. Inflow of warmth and moisture from the underlying ocean surface is critical for tropical cyclone strengthening.

Impact of Earth's Rotation

The rotation of the Earth causes the system to spin (Coriolis Effect) giving it a cyclonic characteristic and affecting the trajectory of the storm. In Northern Hemisphere, where the cyclone's wind flow is counterclockwise, the fastest winds relative to the surface of the Earth occur on the eastern side of a northward-moving storm and on the northern side of a westward-moving one; the opposite occurs in the Southern Hemisphere, where the wind flow is clockwise.

Movement of Clouds

In Lower troposphere, motion of clouds is toward the center. At upper-level, there is outward flow of clouds.

Formation in Northern Atlantic Ocean

Northern Atlantic cyclone season occurs from June 1 to November 30, sharply peaking from late August through September. The statistical peak of the Atlantic hurricane season is 10 September.

Formation in North East Pacific

The Northeast Pacific Ocean has a broader period of activity, but in a similar time frame to the Atlantic.

Formation in North West Pacific

The Northwest Pacific sees tropical cyclones year-round, with a minimum in February and March and a peak in early September.

Formation in North Indian basin

Storms are most common from April to December, with peaks in May and November.

Formation in Southern Hemisphere

Tropical cyclone year begins on July 1 and runs all year-round and encompasses the tropical cyclone seasons, which run from November 1 until the end of April, with peaks in mid-February to early March.

Requirements for formation

- Water temperatures of at least 26.5 °C down to a depth of at least 50 m, so that it may cause the overlying atmosphere to be *unstable enough to sustain convection and thunderstorms*.
- Rapid cooling with height, so that it may cause release of the heat of condensation that powers a tropical cyclone.
- High humidity
- Low amounts of wind shear as high shear is disruptive to the storm's circulation.
- A **distance from the Equator is necessary,** which should be at least 555 km or 5° of latitude, so that it *allows the Coriolis effect to deflect winds blowing towards* the low pressure center and creating a circulation. Because the Coriolis effect initiates and maintains tropical cyclone rotation, tropical cyclones rarely form or move within about 5° of the equator, where the Coriolis effect is weakest.
- A pre-existing system of disturbed weather.

Movement

Coriolis Effect causes cyclonic systems to turn towards the poles in the absence of strong steering currents. The pole ward portion of a tropical cyclone contains easterly winds, and the Coriolis effect pulls them slightly more pole ward. The westerly winds on the Equatorward portion of the cyclone pull slightly towards the equator, but, because the Coriolis effect weakens toward the equator, the net drag on the cyclone is pole ward. Thus, tropical cyclones in the Northern Hemisphere usually turn north (before being blown east), and tropical cyclones in the Southern Hemisphere usually turn south (before being blown east) when no other effects counteract the Coriolis Effect.

High speed of rotation

It is caused by Coriolis effect as well as energy released by heat of condensation.

Fujiwhara effect

When two cyclones approach one another, their centers will begin orbiting cyclonically about a point between the two systems. The two vortices will be attracted to each other, and eventually spiral into the center point and merge. *When the two vortices are of unequal size, the larger vortex will tend to dominate the interaction, and the smaller vortex will orbit around it. This phenomenon is called the Fujiwhara effect.*

Impact on passing over land

We should note that the ***deep convection is a driving force for tropical cyclones*** The convection is strongest in a tropical climate; it defines the initial domain of the tropical cyclone. This is a major difference between the Tropical cyclones with other mid-latitude cyclones as the later derive their energy mostly from pre-existing horizontal temperature gradients in the atmosphere. To continue to drive its heat engine, a *tropical cyclone must remain over warm water*,which provides the needed atmospheric moisture to keep the positive feedback loop running. When a tropical cyclone passes over land, it is cut off from its heat source and its strength diminishes rapidly. The moving over land deprives it of the warm water it needs to power itself, quickly losing strength. Thus, most strong storms lose their strength when the pass on to land, but if it manages to move back to ocean, it will regenerate.

Impact of passing over cold water

When a tropical storm moves over waters significantly below 26.5 °C, it will lose its strength. This is because of losing its tropical characteristic of the warm core.

Project Stormfury

The United States Government attempted in 1960s and 1970s to artificially weaken the Cyclones. During this project, Cyclones were seeded with silver iodide. It was thought that the seeding would cause supercooled water in the outer rainbands to freeze, causing the inner eye wall to collapse and thus reducing the winds. The ***Hurricane Debbie*** lost as much as 31% of its strength, when seeded with Silver Iodide in this project but Debbie regained its strength after each of two seeding forays. So, it was not a good idea. There were some more ideas applied which were as follows:

- Cooling the water under a tropical cyclone by towing icebergs into the tropical oceans and covering the ocean in a substance that inhibits evaporation
- Dropping large quantities of ice into the eye at very early stages of development (so that the latent heat is absorbed by the ice, instead of being converted to kinetic energy that would feed the positive feedback loop)

- Blasting the cyclone apart with nuclear weapons.
- A Project called Project Cirrus involved throwing dry ice on a cyclone.
- None of the idea was very much practical because the tropical storms are too large and too momentary.

Naming of Cyclones

Tropical cyclones are classified into three main groups, based on intensity: tropical depressions, tropical storms, and a third group of more intense storms, whose name depends on the region. If a tropical storm in the North-western Pacific reaches hurricane-strength winds on the Beaufort scale, it is referred to as a typhoon. If a tropical storm passes the same benchmark in the Northeast Pacific Basin, or in the Atlantic, it is called a hurricane. Neither "hurricane" nor "typhoon" is used in either the Southern Hemisphere or the Indian Ocean. In these basins, storms of tropical nature are referred to simply as "cyclones".

Types of the Tropical Cyclones

There are three kinds of Tropical cyclones:

- **Tropical Depression:** A tropical depression is a system with low pressure enclosed within few isobars and with the wind speed of 60 kmph. It lacks marked circulation
- **Tropical Storm:** It is a system with several closed isobars and a wind circulation of 115 kmph.
- **Tropical Cyclone:** It is a warm core vortex circulation of tropical origin with small diameter , circular shape and occurs in oceanic areas.

Anticyclones

An 'anticyclone' is opposite to a cyclone, in which<u>winds move into a low-pressure area</u> In an anticyclone, winds move out from a high-pressure area with wind direction clockwise in the northern hemisphere, anti-clockwise in the southern hemisphere. Such a high pressure area is usually spread over a large area, created by descending warm air devoid of moisture. The absence of moisture makes the dry air denser than an equal quantity of air with moisture. When it displaces the heavier nitrogen and oxygen, it causes an anti-cyclone.

Temperate Cyclones

Temperate cyclones are generally called depressions. They have low pressure at the centre and increasing pressure outwardly. They are of varying shapes such as circular, elliptical. The formation of tropical storms as we read above are confined to oceans, the temperate cyclones are***<u>formed over land and sea alike.</u>*** Temperate Cyclones are formed in 35-65° North as well as South Latitudes. While the tropical cyclones are largely formed in summer and autumn, the temperate cyclones are formed in generally winter. Rainfall in these cyclones is low and continuous not as furious as in case of tropical cyclones.

Tornado

Basically, hurricanes and typhoons form over water and are huge, while tornados form over land and are much smaller in size. A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud. In the United States, twister is used as a colloquial term for tornado.

What is it?

Technically, a tornado is a rotating column of air that is in contact with both the surface of the earth and a cloud, which is generally cumulonimbus and occasionally cumulus. Most tornadoes have wind speeds less than 110 miles per hour and travel several kilometers before dissipating.

How it is formed?

First the rotating cloud base lowers. This lowering becomes a funnel, which continues descending while winds build near the surface, kicking up dust and other debris. Finally, the visible funnel extends to the ground, and the tornado begins causing major damage.

Where they are seen?

Tornadoes have been observed on every continent except Antarctica.

How they are detected?

Tornadoes can be detected before or as they occur through the use of Pulse-Doppler radar by recognizing patterns in velocity and reflectivity data.

What is Fujitsa Scale?

Fujita scale rates tornadoes by damage caused, and has been replaced in some countries by the updated Enhanced Fujita Scale. An F0 or EF0 is the weakest tornado, while F5 or EF5 is the strongest tornado.

What is Torro Scale?

TORRO scale ranges from a T0 for extremely weak tornadoes to T11 for the most powerful known tornadoes.

Funnel Cloud as predecessor

Tornadoes often begin as funnel clouds with no associated strong winds at the surface, although not all evolve into a tornado. However, many tornadoes are preceded by a funnel cloud. Most tornadoes produce strong winds at the surface while the visible funnel is still above the ground, so it is difficult to discern the difference between a funnel cloud and a tornado from a distance.

Infrasonic signature

Tornadoes produce identifiable inaudible infrasonic signatures. Due to the long distance propagation of low-frequency sound, efforts are ongoing to develop tornado prediction and detection devices with additional value in understanding tornado morphology, dynamics, and creation.

Electromagnetic Spectrum

Tornadoes emit on the electromagnetic spectrum. There are observed correlations between tornadoes and patterns of lightning.

When they occur?

Tornadoes are most common in spring and least common in winter. Spring and fall experience peaks of activity as those are the seasons when stronger winds, wind shear, and atmospheric instability are present. Tornado occurrence is highly dependent on the time of day, because of solar heating. Worldwide, most tornadoes occur in the late afternoon, between 3 pm and 7 pm local time, with a peak near 5 pm.

Prelims Model Questions

Atmosphere and Climatology Model Questions

1. Why the thickness of the atmosphere is maximum at equator ?

1.High insolation and strong convection currents occur in troposphere over the Equator

2.Air is less dense at Equator

3.Equator exerts more gravitational pull on atmospheric gases

4.The centrifugal force due to Earth's rotation is maximum at Equator

Which among the above is / are correct?

[A] Only 1, 2 & 3

[B] Only 2, 3 & 4

[C] Only 1, 2 & 4

[D] 1, 2, 3 & 4

Answer: [C] Only 1, 2 & 4

One of the laws of Ideal gases called Charles' law says that in an ideal gas, density decreases with increasing temperature, when pressure is constant. The hot air rises and the Earth is not equally heated everywhere. The troposphere is thicker over the equator than the poles because the equator is warmer. Heat differential on the planet's surface causes convection currents to flow from the equator to the poles. This implies that the warmer the weather, the thicker is the troposphere. Thus the simple reason is thermal expansion of the atmosphere at the equator and thermal contraction near the poles.

Air is less dense at Equator

Over equatorial regions, where the surface is being heated strongly throughout the year and air warmed by contact with it is expanding and rising, the air all the way up to the tropopause is less dense than air to the north and south. Thus, density of the air is maximum at the equator. But here, you must note that almost same amount of atmospheric mass exists at both equator and poles but only the density of the air is less at equator and greater at poles.

Third statement is incorrect because it will result in reducing the thickness at equator.

2. The atmosphere of the Earth primarily get heated due to ___:

[A] Conduction of Heat Energy by Atmosphere

[B] Convection of Heat Energy

[C] Radiation from Earth

[D] Absorption of Solar light

Answer: [C] Radiation from Earth

Radiation is the process by which most energy is transferred through space from the sun to the earth. Radiation is given off by all bodies including earth and human being. The hotter is the body, shorter are the waves. We can simply say that the radiation from Sun comes to earth in the form of smaller waves and earth being cooler body, gives off energy in the form of long-wave. These are then radiated back to the atmosphere. This Long-Wave Radiation from the earth's surfaces heats the lower layers of the atmosphere. It is evident that the atmosphere is primarily heated from below by radiation from the heated Earth surface.

3. Consider the following statements:

1.Strongest westerlies blow in the winter hemisphere

2.Westerlies play major role in the formation of tropical cyclones

3.Roaring Forties are a kind of westerlies

Which among the above statements is / are correct?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [C] Only 1 & 3

Second statement is incorrect because westerlies are higher latitude winds and are not responsible for tropical cyclones.

4. With reference to Geographical terminology, the term "Roaring Forties" is used for ___:

[A] Westerlies

[B] Easterlies

[C] Doldrums

[D] None of the options A, B and C is correct

Answer: [A] Westerlies

Roaring Forties is the name given to strong westerly winds found in the

Southern Hemisphere, generally between the latitudes of 40 and 49 degrees

5. With reference to the Tropical Cyclones, which among the following is / are correct observation(s)?

1. All Tropical Cyclones are formed in low atmospheric pressure areas
2. The highest atmospheric pressures are generally recorded at their centres
3. At any given altitude, environment inside the cyclone is warmer than its outer surroundings

Choose the correct option from the codes given below:

[A] Only 1

[B] Only 1 & 2

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [C] Only 1 & 3

All tropical cyclones are formed in areas of low atmospheric pressure in the Earth's atmosphere. The pressures recorded at the centers of tropical cyclones are among the lowest that occur on Earth's surface at sea level. Tropical cyclones are driven by the release of large amounts of latent heat of condensation, which occurs when moist air is carried upwards and its water vapour condenses. This heat is distributed vertically around the center of the storm. Thus, at any given altitude, environment inside the cyclone is warmer than its outer surroundings.

6. Why the strong tropical cyclones lose their strength when they pass on to land?

1. Land terrain impedes the movement of Cyclone
2. Land absorbs the heat energy of Cyclone quickly
3. Cyclone is cut from its heat source

Choose the correct option from the codes given below:

[A] Only 1

[B] Only 1 & 2

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [C] Only 1 & 3

The first statement is correct. The Friction over land increases considerably from that over water, and this acts to weaken the storm's structure. This is especially true over rugged terrains and mountains in particular. But the real reason is something very important. We know that the deep convection is a driving force for tropical cyclones. The convection is strongest in a tropical climate, it defines the initial domain of the tropical cyclone. This is a major difference between the

Tropical cyclones with other mid-latitude cyclones as the later derive their energy mostly from pre-existing horizontal temperature gradients in the atmosphere. To continue to drive its heat engine, a tropical cyclone must remain over warm water, which provides the needed atmospheric moisture to keep the positive feedback loop running. When a tropical cyclone passes over land, it is cut off from its heat source and its strength diminishes rapidly. The moving over land deprives it of the warm water it needs to power itself, quickly losing strength. Thus, most strong storms lose their strength when the pass on to land, but if it manages to move back to ocean, it will regenerate. Please also note that when a tropical storm moves over waters significantly below 26.5 °C , it will lose its strength. This is because of losing its tropical characteristic of the warm core.

7. The atmospheric temperature of a place is governed by __:

1. Its latitudinal distance from the equator
2. Its elevation from the sea level
3. Prevailing winds and influence of ocean currents, if any

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

The atmospheric temperature governs the type of biodiversity, fertility of soil, the hydrological cycle and many other abiotic and biotic parameters of our planet. It acts as a resource – in the sense that optimum temperature promotes the production and productivity of many natural resources, such as plants, animals and microbes. Adverse temperature may also act as deterrent to production and propagation of these natural resources.

8. In context with the Monsoon winds, consider the following statements:

1.They are generally regular and equally distributed winds

2.They show a complete reversal of direction during a year

3.They are generally orographic in nature

Which among the above statements is / are correct?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [B] Only 2 & 3

First statement is incorrect because monsoon winds are not equally distributed winds. The rainfall due to monsoon winds is mainly orographic (relief) in nature.

9. The Coastal deserts are usually consequences of ___?

[A] warm ocean currents

[B] orographic precipitation

[C] cold ocean currents

[D] subtropical high pressure

Answer: [C] cold ocean currents

Cold ocean currents contribute to the formation of coastal deserts. Cold ocean currents contribute to the formation of coastal deserts. Air blowing toward shore, chilled by contact with cold water, produces a layer of fog. This heavy fog drifts onto land. Although humidity is high, the atmospheric changes that normally cause rainfall are not present. A coastal desert may be almost totally rainless, yet damp with fog.

The Atacama Desert, on the Pacific shores of Chile, is a coastal desert. Some areas of the Atacama are often covered by fog. But the region can go decades without rainfall. In fact, the Atacama Desert is the driest place on Earth. Some weather stations in the Atacama have never recorded a drop of rain. (National Geographic)

10. The propagation of the Radio Waves in the atmosphere of earth is affected by ___:

1. Reflection
2. Refraction
3. Diffraction
4. Absorption

Choose the correct option from the codes given below:

[A] Only 1, 2 & 3

[B] Only 1, 3 & 4

[C] Only 1, 2 & 4

[D] 1, 2, 3 & 4

Answer: [D] 1, 2, 3 & 4

11. The southern hemisphere of the earth has more water than land. What is / are the implications of this?

1. The atmospheric pressure is generally high at south pole
2. More doldrums are produced near south pole
3. Less westerlies blow in southern hemisphere

Choose the correct option from the codes given below:

[A] Only 1 is correct

[B] Only 1 & 2 are correct

[C] Only 2 & 3 are correct

[D] 1, 2 & 3 are correct

Answer: [A] Only 1 is correct

12. Consider the following statements:

1. If there were no atmosphere, Sun would have looked white and sky have looked black
2. If earth stops rotating on its axis, the oceans would migrate toward the poles

Which among the above is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [C] Both 1 & 2

The blue color of the sky is due to Rayleigh scattering. As light moves through the atmosphere, most of the longer wavelengths pass straight through. Little of the red, orange and yellow light is affected by the air. However, much of the shorter wavelength light is absorbed by the gas molecules. The absorbed blue light is then radiated in different directions. It gets scattered all around the sky. Whichever direction you look, some of this scattered blue light reaches you. Since you see the blue light from everywhere overhead, the sky looks blue. If there was no atmosphere, sky would look black and sun would look white.

The second statement is also correct. Please refer to this page for understanding.

http://www.esri.com/news/arcuser/0610/nospin.html

13. Consider the following statements:

1. Most of the meteoroids that enter into Earth's Atmosphere, get burnt into mesosphere
2. The lowest temperatures in the entire atmosphere of the earth are found in mesosphere

Which among the above is / are correct statements?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [C] Both 1 & 2

The mesosphere extends from the stratopause to 80–85 km. Please note that most meteoroids get burnt in this layer. Temperature decreases with height in the mesosphere. The mesopause, the temperature minimum that marks the top of the mesosphere, is the coldest place around Earth and has an average temperature around -85 °C . At the mesopause, temperatures may drop to -100 °C. These are the lowest temperatures anywhere in Earth's atmosphere.

14. Which among the following is the source of light in aurora in sky near the earth's poles?

[A] Photon emissions in the earthâ s upper atmosphere

[B] Cosmic Rays

[C] Sunlight

[D] None of them

Answer: [A] Photon emissions in the earthâ s upper atmosphere

The aurora borealis is a display of natural light in the sky near the North Pole. It was named after the Roman goddess of the dawn, Aurora, and the Greek name for the north wind, Boreas, by Pierre Gassendi in 1621. It is a result of photon emissions in the earth's upper atmosphere from ionized nitrogen atoms regaining an electron, and oxygen and nitrogen atoms returning from an excited state to a low-energy state.

15. Which among the following methods of heat transfer is maximum responsible for heating of the lower layers of the atmosphere near earth's surface?

[A] Radiation from Sun

[B] Radiation from Earth

[C] Conduction

[D] Convection

Answer: [B] Radiation from Earth

Radiation from Sun comes to earth in the form of smaller waves and earth being cooler body, gives off energy in the form of long-wave. These are then radiated back to the atmosphere. This Long-Wave Radiation from the earth's surfaces heats the lower layers of the atmosphere.

The Atmospheric conduction occurs at the interface of (zone of contact between) the atmosphere and the earth's surface. However, it is actually a minor method of heat transfer in terms of warming the atmosphere since it affects only the layers of air closest to the earth's surface. This is because air is a very poor conductor of heat. When the pockets of air near the surface are heated, they expand in volume, become less dense than the surrounding air, and therefore rise. This vertical transfer of heat through the atmosphere is called convection, and is the same type of process by which heated water circulates in a pan while heating. The currents set into motion by the heating of a fluid (liquid or gas) make up a convectional system. Most vertical transfer of heat within the atmosphere & Oceans occurs via Convection and is a major cause of clouds and precipitation.

General Knowledge Today

Prelims Geography-7: India's Geology and Climatology

Target 2016: Integrated IAS General Studies
Last Updated: April 3, 2016
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Contents

Model Questions

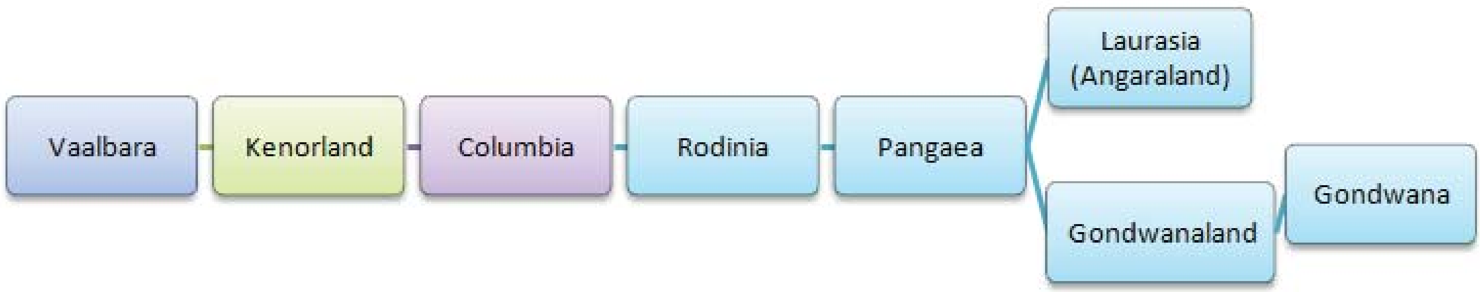
Please check Prelims Model Questions at the end of this Module.

Geology of India

Geological History of India

India is mostly located on the **Indian Plate**, which is generally called the northern portion of the Indo-Australian Plate. Indian subcontinent, Australia, New Guinea, and Tasmania, New Zealand etc. have a common geological history by virtue of being an integral part of the Mesozoic **Gondwana super-continent** until 160 million years ago.

The earth is 4700 million years old and the earliest supercontinent **Vaalbara** started forming around 3600 million years ago. It took nearly 400 million years to get completed and was ready by 3100 million years ago. Then, around 2500 years ago, Vaalbara started breaking. The result of this breaking was that another supercontinent **Kenorland** formed around 2700-2500 million years ago. The breaking kept on and then Supercontinent **Columbia** formed around 1800-1500 million years ago. Around 750 million years ago, a new supercontinent was formed that was called **Rodinia**. In the late Paleozoic period (542 – 250 million years ago) super continent **Pangaea** was formed that existed during the Paleozoic and Mesozoic eras. Pangaea started beginning to break up approximately 200 million years ago, before the component continents were separated into their current configuration. It first broke into Northern **Laurasia** (**Angaraland**) and Southern **Gondwanaland**.



Later, the Laurasia and Gondwana drifted apart. Gondwana included Antarctica, South America, Africa, Madagascar, Australia-New Guinea, and New Zealand, as well as Arabia and the Indian subcontinent, which have now moved entirely into the Northern Hemisphere.

Thus, from geological history two main structural divisions of India are:

- **Himalayan Mountain Chain**, **which is a part of Laurasia or Angaraland**
- southern pan called Gondwanaland of which Peninsular India formed one of the blocks.

The intervening space between the two giant continental blocks was filled with water. It was a shallow sea called **Tethy's Sea**. During the subsequent geological periods, the Indian Peninsular block began drifting northward leaving a huge gap filled with water which truly came to be called the Indian Ocean. As the peninsular block continued its drift northward, the Indian Ocean continued to advance and filled up the depressions on either side of the landmass when it compressed the Tethy's Sea. Thus, the Arabian Sea and Bay of Bengal were formed. What was once the Tethy's Sea ***has become the Mediterranean Sea***. Other remnants are the Black, Caspian, and Aral Seas (via a former inland branch known as the Paratethys).

The similarity in the geological formation produced more or less similar type of mineral wealth in both India and Australia. Despite the variance in the biotic life between India and Australia, there are certain endemic plant and animal species, pointing to the super continent connection.

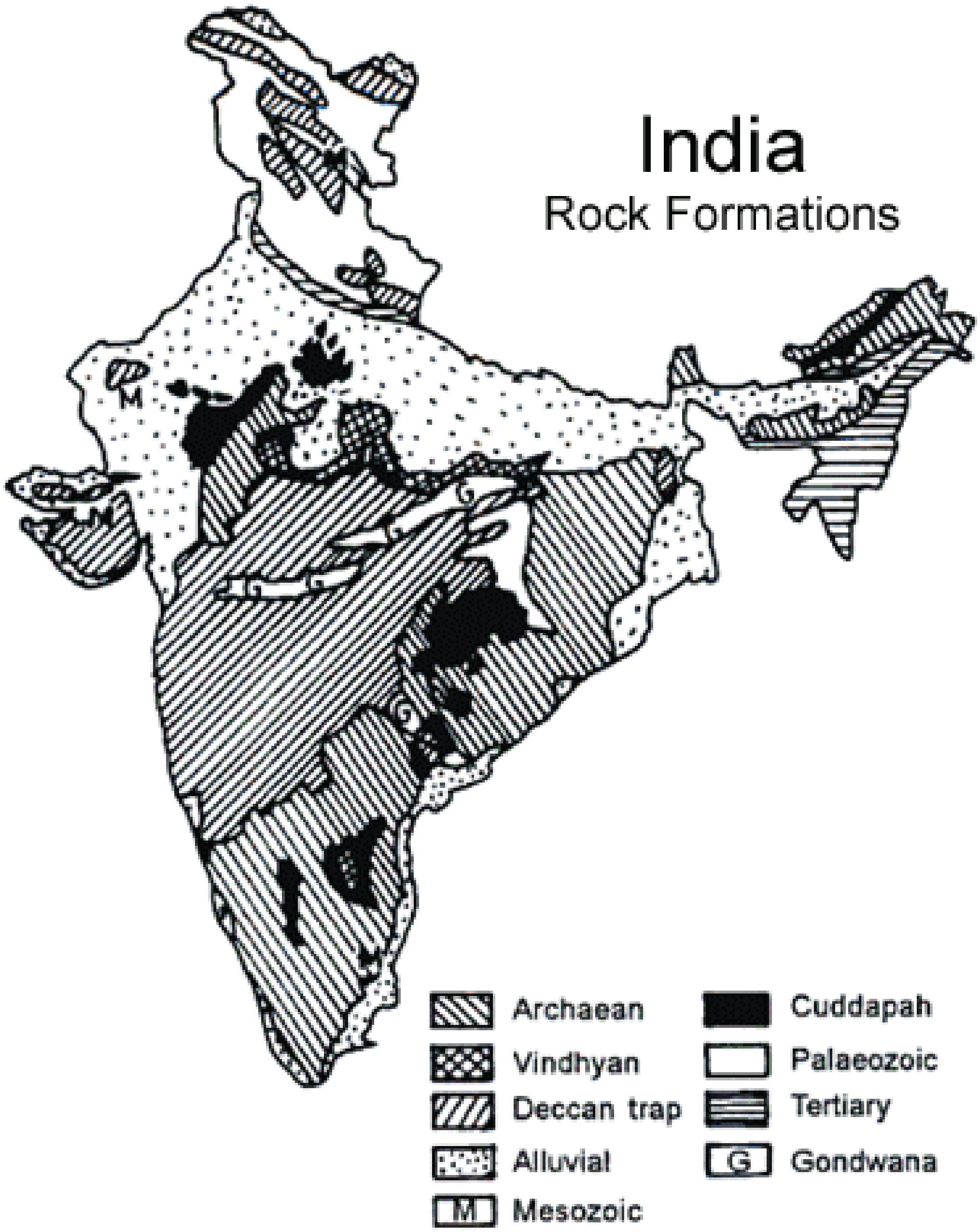
Please note that **Strait of Lombok** is part of the biogeographical boundary between the fauna of Indomalaya ecozone and the distinctly different fauna of Australasia. The boundary is known as the **Wallace Line**, for Alfred Russel Wallace, who first remarked upon the striking difference between animals of Indo-Malaysia from those of Australasia and how abrupt the boundary was between the two biomes.

India's Rock Formations (Stratigraphy)

India, being a large country, has diverse geology. Different regions in India contain rocks of all types belonging to different geologic periods. Some of the rocks are badly deformed and transmuted while others are recently deposited alluvium that has yet to undergo diagenesis. Mineral deposits of great variety are found in the subcontinent in huge quantity. Structurally the Indian landmass is divided into three main divisions consisting of

- The Himalayan Mountain Chain
- The North Indian Plain; and
- The Peninsular Plateau.

However, stratigraphically, India can be divided into several divisions such as Archean System, Dharwar System, Cudappah system, Vindhyan system, Paleozoic,Mesozoic, Gondwana, Deccan Trap, Tertiary and Alluvial.



Archean formations

Archean rocks, also known as **Pre-Cambrian rocks** are the oldest rocks of the earth's crust. The Archean period covers 86.7% of Total geological history time of earth and therefore is very significant. This period marks the development of first photosynthesis, the life support atmosphere.
The major characteristic of the Archean rocks is that **they are azoid,** means that are *devoid of any form of remnants of life in them.* They serve as the basement complex or fundamental gneisses.
The Archean rocks in India are called **Purana Rocks** *means the oldest rocks*. The Archean or Purana rock system in India is found in Aravallis mountains, 2/3rd of the Deccan peninsula and some parts of north east. These rocks have abundant metallic and non-metallic minerals such as iron, copper, manganese, bauxite, lead, zinc, gold, silver, tin, tungsten, mica, asbestos, graphite, etc.

Dharwar system

Dharwar system is later than the Archean system but older than the other systems. The Dharwar period of rock formation has been largely fixed from 2500 million years ago to 1800 million years ago. Dharwar Rock System is special because it is the ***first metamorphic sedimentary rocks*** in India.

They are named Dharwar system because they were first studied in Dharwar region of Karnataka. But they are also found in Aravallis, Tamil Nadu, Chotanagpur plateau, Meghalaya, Delhi, and the Himalayas region.

The Dharwar rocks are rich in iron ore, manganese, lead, zinc, gold, silver etc.

The **Champions series** containing gold mines lie within this system. This Champion system is named after the Champion reef in the Kolar Gold Fields. The Kolar Gold Fields contain one of the deepest gold mines of world.

The other series of Dharwar system are as follows:

- Champaner series that is found near Baroda. This is source of a lush green variety of marble.
- Closepet series that is found in Balaghat and Chhindwara of Madhya Pradesh. It is rich in Copper ores.
- Chilpi Series that is found in and around the Closepet series in Balaghat and Chhindwara
- Iron-Ore series that is located in Singhbhum, Mayurbnhanj and Keonjhar rangaes.

Cudappah System

Cudappah System rocks are rich in metamorphic rocks such as sandstone, shale, limestone, quartzite, and slate. They contain iron and other inferior quality of ores and minerals. They are mainly found in Cudappah district of Andhra Pradesh along with other places such as Chhattisgarh, Rajasthan, Delhi, and the lesser Himalayas. One of the important series of Cudappah System is Papaghani series, named after the river of same name in Andhra Pradesh.

Vindhyan System

The Vindhyan Mountains form a dividing line between the Ganges plain and Deccan Plateau. The Vindyan system is named after Vidhyan Mountains. This system rocks are extensively distributed in India from Chittorgarh (Rajasthan) to Sasaram (Bihar). The Vindhyan System is separated from Aravallis by the Great Boundary Fault. They are famous sources of Red Sandstone and other building material. The well known Panna and Golconda diamonds are found in this formation. The important series of this system are Bhander series, Bijwar series and Kaimur series. All are rich sources of Building material.

Archean (Purana System) Dharwar System Cudappah & Vidhyan System

Gondwana System or Carboniferous period System or Dravidian System

As the name suggests, these are the **major coal deposits of India.** This system contains famous **Damuda and Panchet series** which are *famous for coal deposits (discussed below).* The important coal bearing areas of this series are Raniganj, Jharia, Karanpur, and Bokaro of the Damodar basin in Odisha, and the Pench valley in Chhattisgarh and Madhya Pradesh, the jhingurda coal seam (Chhattisgarh). The Gondwana Supergroup forms a unique sequence of fluviatile rocks deposited in Permo-Carboniferous time. Damodar and Sone river valley and Rajmahal hills in the eastern India is depository of the Gondwana rocks.

The Cretaceous system or the Deccan Trap

Some people broadly divide the geographical land area of India into three parts viz. Deccan trap, Gondwana and Vindhyan. The Deccan Trap covers almost all of Maharashtra, some parts of Gujarat, Karnataka, Madhya Pradesh and marginally Andhra Pradesh. Deccan Trap is thought to have formed as result of sub-aerial volcanic activity associated with the continental deviation in this part of the Earth during the Mesozoic era. This implies that generally, the **rocks of Deccan Trap are igneous**.

The Deccan system is marked by a transgression of the sea at Coromandal coast and Narmada valley and the upwelling of huge quantity of Lava/ basalt , so the Cretaceous system or Deccan Trap is made up of Basalt rocks. This system is also called lava trap and is 3000 meters deep. The rocks of this system are found in Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh, Jharkhand, Orissa, and Karnataka.

Deccan Trap and Paleontological Murder Mystery

Some scientists believe that a series of monumental volcanic eruptions in India may have killed the dinosaurs 65 million years ago, not a meteor impact in the Gulf of Mexico. The eruptions, which created the gigantic Deccan Traps lava beds of India, are now the prime suspect in the most famous and persistent paleontological murder mystery, say scientists who have conducted a slew of new investigations honing down eruption timing. The main phase of the Deccan eruptions spewed 80 percent of the lava which spread out for hundreds of miles. It is calculated to have released ten times more climate altering gases into the atmosphere than the nearly concurrent Chicxulub meteor impact, according to volcanologist Vincent Courtillot.

How it was formed?

When the Indian Plate mobbed northward after breaking off from the rest of Gondwana, it passed over a geologic hotspot, the Réunion hotspot, which caused extensive melting underneath the Indian craton. The melting broke through the surface of the craton in a massive flood basalt event, creating what is known as the Deccan Traps. It is also thought that the Reunion hotspot caused the separation of Madagascar and India.

The Tertiary System

The Tertiary rock system belongs to Cenozoic era. The Cenozoic era has two periods' viz. tertiary and quaternary. The beginning of the tertiary period is about 66 million years back. The final break-up of the Gondwana land occurred in this era and the Tethys sea got lifted in the Himalayas. The most important rocks of this system are in northern plains of India, karewas of Kashmir and bhadarwah, **Bhangar,** and **Khadar** of the Great Plains. The terraces of Jeelum Narmada, Taptii, Godavari, Krishna, Kaveri, etc. are of this period. The rocks of this system are also found in coast of Kachchh, Katiawar, Konkan, Malabar, Nilgiri, and the Eastern Ghats.

Gondwana and Tertiary Coal Deposits of India

Most of the coal mined in India comes from the rock formations of two geological ages viz.Lower Gondwana and Tertiary. About 80 per cent of the coal deposits in India is of bituminous type and is of non-coking grade. This is one of the reasons that India has to rely upon imports of coking coal.

Gondwana Coal

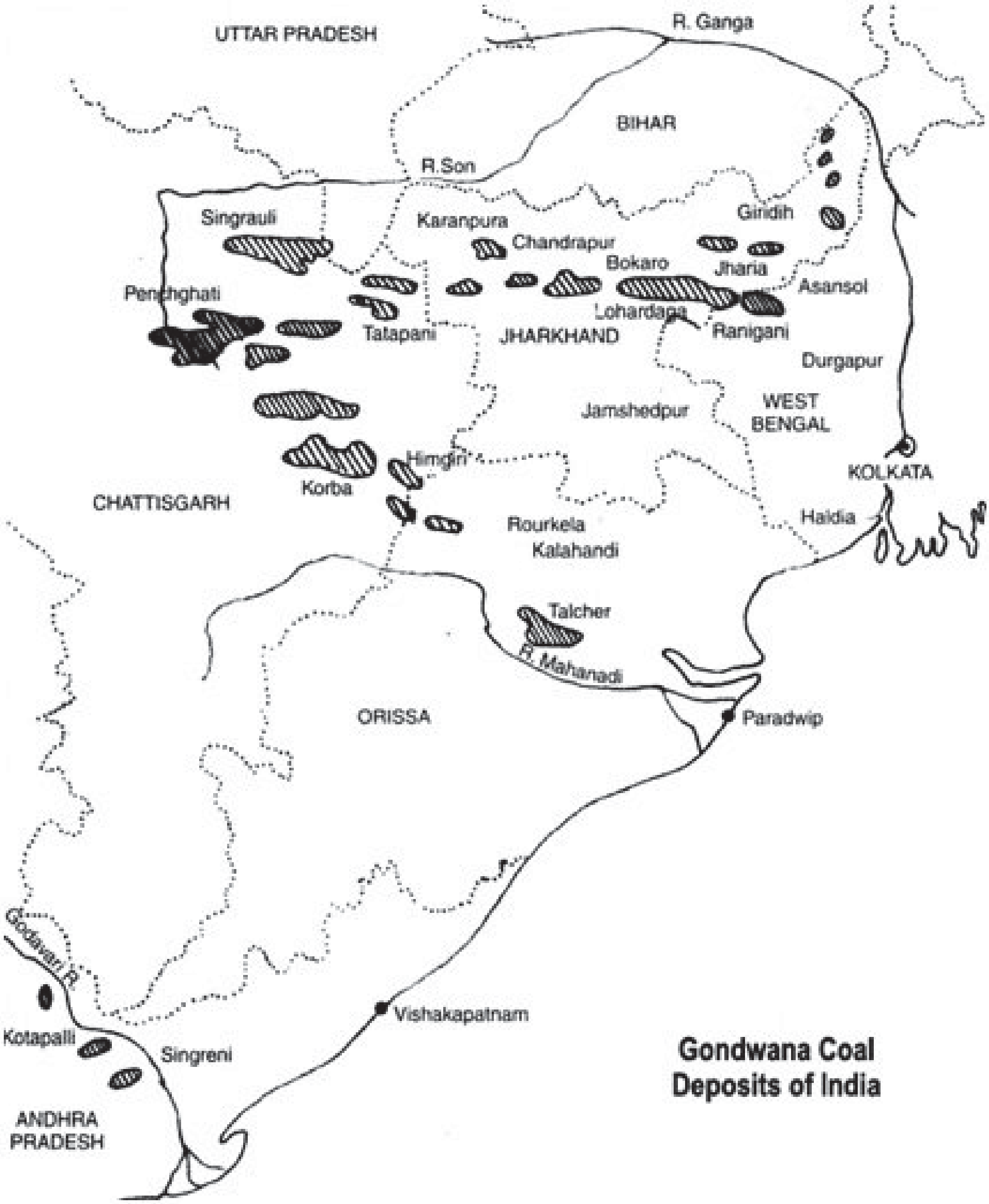
Gondwana coal has overwhelmingly higher share (99%) in India's coal resources and the entire coal mined in the peninsular plateau part belongs to this category. This coal was formed in carboniferous period between 600 to 300 million years ago. The coal obtained from the Gondwana formations is mainly bituminous and needs to be converted into Coke before it can be used in the iron and steel industry.

Distribution of Gondwana Coal

The Gondwana coal mines are located in river valleys of Damodar, Mahanadi, Godavari, Son and Narmada. Damodar valley is home to largest coal mines in Jharkhand-West Bengal coal belt located in Jharia (largest coal field of India), Raniganhj (second largest coal field of India), Bokaro, Giridih, Karanpura , Chandrapur, Tatapani, Talcher, Himgiri, Korba, Singrauli etc.

On the basis of geological units, there are three different Gondwana formations viz. Raniganj

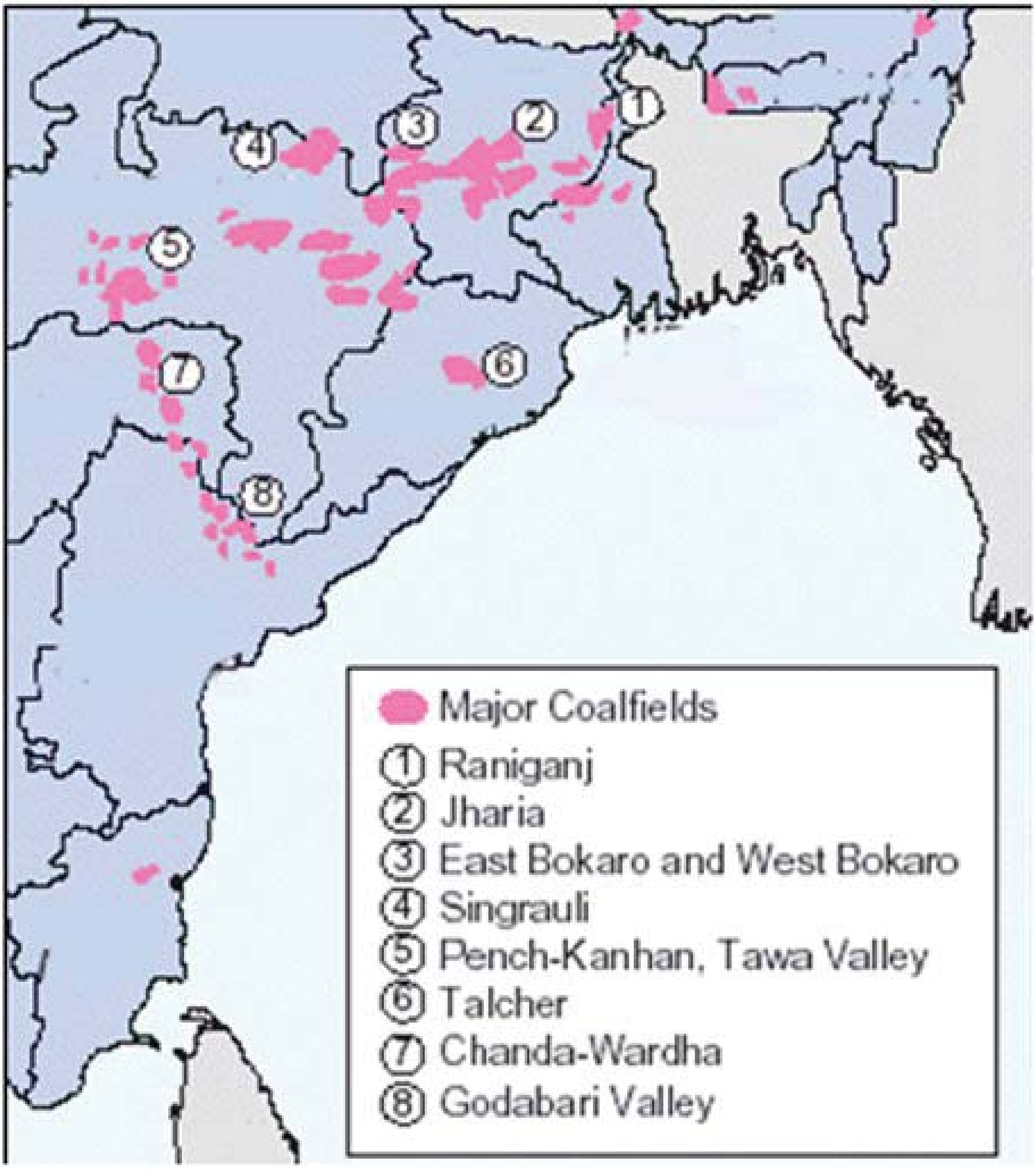
Formation, Barkar Formation and Karharbari Formation. **Karharbari Formation** is the oldest coal formation in India.



The states in which Gondwana coal fields are found include Jharkhand, Orissa, Chhattisgarh, West Bengal, Madhya Pradesh, Andhra Pradesh, Maharashtra, Uttar Pradesh, Bihar, Sikkim, Assam, with the quantity of reserves in the same order.

Tertiary coals

Tertiary coal fields share only 1% of coal production of India. Such fields occur in Assam, Arunachal Pradesh, Meghalaya and Nagaland and also in small quantities in Jammu & Kashmir. It is extracted from Darangiri, Cherrapunji, Mewlong and Langrin (Meghalaya); Makum, Jaipur and Nazira in upper Assam, Namchik – Namphuk (Arunachal Pradesh) and Kalakot (Jammu and Kashmir).



Tertiary coal is the lignite coal . Lignite also occurs in the coastal areas of Tamil Nadu, Pondicherry, Gujarat and Jammu and Kashmir. The coal is of inferior quality with around 30 to 50% carbon. India's largest ignite deposits are at Neyveli in Tamil Nadu.

Coal Mines

81% of the coal production in India comes from open pit mines while underground mining currently accounts for around 19% of national output.

List of Gondwana Coalfields

West Bengal

- Damodar Valley: Raniganj (Trans Barakar),Bankura

- Darjeeling District: Bagrakote, Tindharia

Bihar

- Damodar Valley: Ranigunj (Cis Barakar), Jharia, Bokaro, Chandrapura, South Karampura, North Karampura, Ramgarh
- Rajmahal Area: Hura, Gilhuria and Jilbari, Chuparbhita, Pachwara, Brahmini
- Deogarh Area: Kundit Kuria, Sahajuri, Jainti
- Hazaribagh District: Giridhi, Chope, Itkhori.
- Palamu Region: Anuranga, Daltongunj, Hutar

Madhya Pradesh

- South Rawa Region: Singrauli, Korar, Johilla river, Umaria, Sohagpur
- North Chattishgarh Region: Jhilmili, Tatapani-Ramkola, Sanhat, Jharkhand, Chirimiri-Kurasia, Koreagarh, Bassar, Bisrampur, Lakhanpur, Panchbhaini, Dambhamunda, Sendargarh
- South Chattishgarh Region: Hasdo -Rampur, Korba, Raigarh, Mand River, Kankani.
- Satpura Region: Mohpani, Sonada, Sahpur (Tawa), Dulhara (Tawa), Pathakera, Bamhanwara, Upper Tawa Valley, Kanhan Valley, Pench Valley.

Maharashtra

- Wardha Valley: Kamptee, Bandar, Warora, Rajur (Wun), Ghugus – Telwasa, Chanda, Ballarpur, Wamanapalli, Antargaon – Aksapur, Sasti – Rajpura.

Odisha

- Mahanadi Valley: Talcher, Ib river (Rampur – Hingir).

Andhra Pradesh / Telangana

- Pranhita – Godavari Valley
- Tandur Kanala, North Godavari, South Godavari, Jangam, Chinur-Sendrapalli, Kamavaram, Bandala – Alapalli, Singareni (yellendu), Lingala, Kothagudium, Damar-cherla, Kannergiri, Beddadanuru.

Uttar Pradesh

- Kota (in Mirzapur District)

Assam

- Abor, Aka and Daphla Hills

Sikkim

- Ranjit Valley

List of Tertiary Coal Fields

- **Assam:** Makum coalfield in Dibrugarh district is the main coalfield. Other include Nahorkatiya, Doigrung, Nambor and Longoi.
- **Meghalaya:** Khasi Jaintia and Mikir hills, Balyong, Doigring and Waimong coal-fields

- **Arunachal Pradesh:** Namchick- Namphuk (Tirap) Abor hills, Miri, Daphla, Aka hills and Miao Bum
- **Nagaland:** Nazira, Janji, Disai and Barjan are important coalfields of Nagaland.
- **Jammu and Kashmir:** Kalakot, Mohogala, Metka, Ladda and Saugar Marg

India's Climatology

Climate of India and Factors Affecting it

India is home to an extraordinary variety of climatic regions, ranging from tropical in the south to temperate and alpine in the Himalayan north, where elevated regions receive sustained winter snowfall. India's climate is strongly influenced by the Oceans, Himalayas and the Thar Desert. The Himalayas act as a barrier to the frigid katabatic winds flowing down from Central Asia keeping the bulk of the Indian subcontinent warmer than most locations at similar latitudes.

The climate of India may be broadly described as **tropical monsoon type**. India's climate is affected by **two seasonal winds** viz. the north-east monsoon and the south-west monsoon.

- The north-east monsoon commonly known as winter monsoon **blows from land to sea** whereas south-west monsoon known as summer monsoon **blows from sea to land** after crossing the Indian Ocean, the Arabian Sea and the Bay of Bengal.
- The south-west monsoon brings most of the rainfall during the year in the country.

As such, land areas in the north of the country have a continental climate with severe summer conditions that alternates with cold winters when temperatures plunge to freezing point. In contrast are the coastal regions of the country, where the warmth is unvarying and the rains are frequent. India, not only its physiographic divisions are diverse but also far more contrasting in nature. Each one of these factors (Size, Shape, location extent etc.,) has an impact on climatic conditions of India, be it temperatures, atmospheric pressure, wind system or precipitation.

Factors influencing the Indian climate

Location and Latitudinal Extent

- The Tropic of Cancer passes through the middle of the country. The southern parts being closer to the Equator, experience high temperatures throughout the The northern parts on the other hand lie in the warm temperate zone. Hence they experience low temperatures particularly, in winter.
- For example, Bangalore would be hotter than Faridabad. Broadly speaking parts lying south of the Tropic of Cancer receive more solar heat than those lying north of it.

Distance from the Sea

- Southern or peninsular India is surrounded by the Arabian Sea, the Indian Ocean and the Bay of Bengal, hence the climate of coastal regions of India is equable or maritime.

- Contrary to this, the climates of the regions located in the interior of the country are cut off from the oceanic influence. As a result, they have an extreme or continental type of climate.

Altitude

- The atmosphere becomes less dense and temperature also decreases with the height. For example, the cities located on the hills are cooler like Shimla whereas the cities lying in the plains will have hot climate like Ludhiana.

Mountain Ranges

- These ranges protect India from the bitterly cold and dry winds of Central Asia during winter. Further more, they act as an effective physical barrier for the rain bearing southwest monsoons winds to cross the northern frontiers of India.
- On the other hand, they check rain bearing South-West Monsoon winds and compel them to shed their moisture in India.
- Similarly, Western Ghats force rain bearing winds to cause heavy rain fall on the Western slopes of the Western Ghats.

Direction of Surface Winds

- The wind system also affects the Indian climate. This system consists of monsoon winds, land and sea breeze, and local winds. In winter the winds blow from land to sea so they are cold and dry.
- On the other hand, in summer wind blow from sea to land bringing the moisture along with them from the sea and they cause wide spread rain in most part of the country.

Upper air Currents

Besides surface winds, there are strong air currents called Jet streams which also influence the climate of India. These jet streams are a narrow belt of fast blowing winds located generally at 12,000 metre height above the sea level. They bring western cyclonic disturbances along with them. These cyclonic winds originate near the Mediterranean Sea and move eastwards. On their way, they collect moisture from Persian Gulf and shed it in the North western part of India during winter seasons. These Jet streams shift northwards during summer season and blow in Central Asia. Thus helps in the onset of monsoons.

Physiography

The physical features influence the air temperature, atmospheric pressure, direction of winds and the amount of rainfall in different parts of the country.

El-Nino & La Nina

- Weather conditions in India are also influenced by El-Nino which causes wide spread floods and droughts in tropical regions of the world. This warming of tropical Pacific waters affects the global pattern of pressure and wind systems including the monsoon winds in the Indian Ocean. It is believed that the severest droughts in India have been caused by El-Nino.

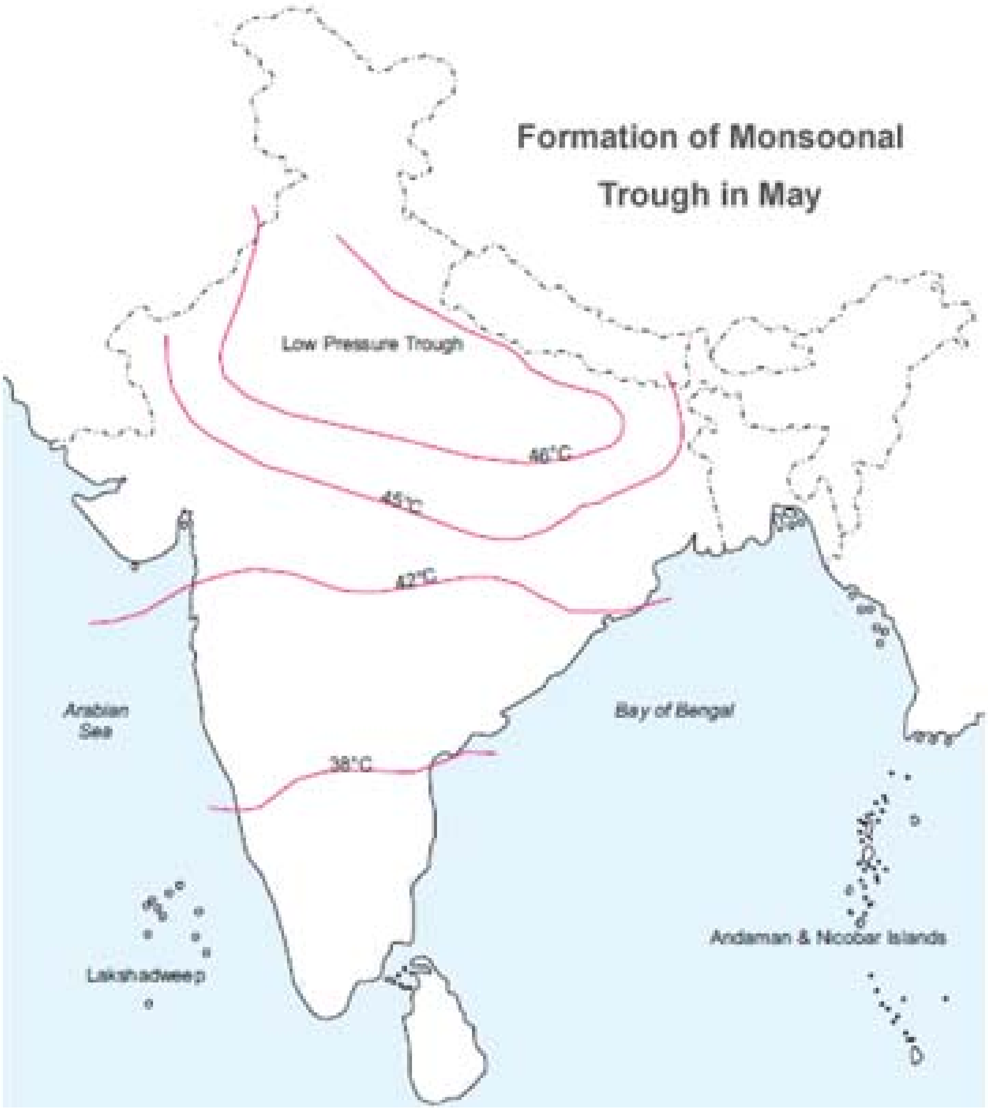
- La Nina is thought to be favourable to India as it brings rains.

Monsoon and Seasons in India

The word monsoon is derived from the Arabic word 'Mausim' which means season. Monsoon refers to the ***seasonal reversal in the wind direction*** during a year. During summer, the interior parts of North Indian Plains covering Rajasthan, Punjab, Haryana, and Western Uttar Pradesh are intensely hot. The daily maximum temperature in some of these parts is as high as 45° to 47° C.

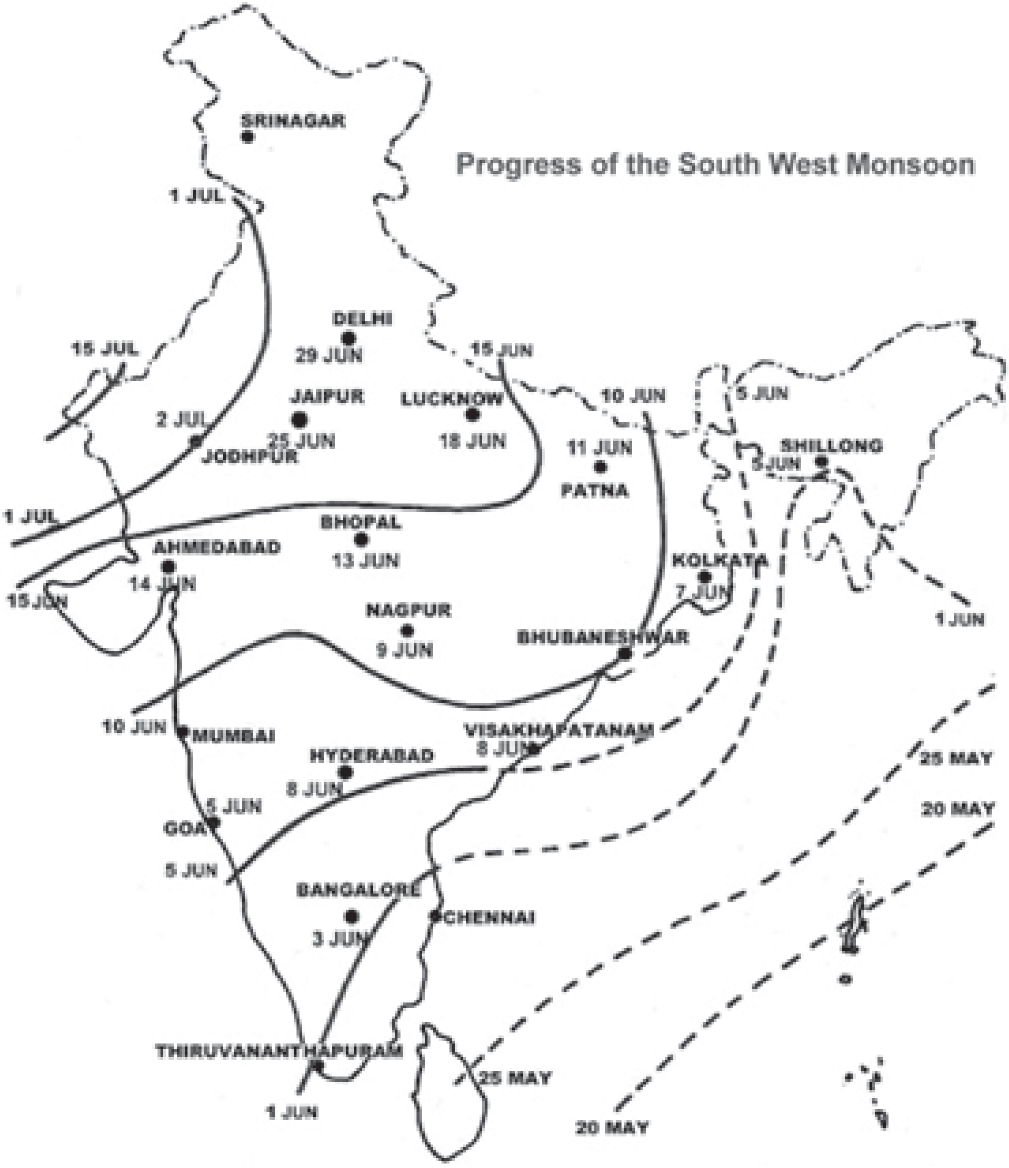
Summer Monsoon

The average maximum temperature is above 33°C in the month of May at Delhi, Jodhpur and Jaisalmer. Such high temperature heats up the air of that region. Hot air rises and due to this a low pressure area is created under it. This low pressure is also known as **monsoonal trough**. It lies between western Rajasthan to Odisha.



On the other hand temperature over Indian Ocean is relatively low. So a relatively high pressure region is created over the sea.

The pressure difference between Indian Ocean and North Central Indian Plains causes the air from high pressure region of the sea move towards the low pressure region of North India. This implies that the general movement of air is in June is from equatorial region of Indian Ocean to the Indian subcontinent in the South-West to North-East direction. This direction is exactly opposite to that of the trade winds (North – East to South-West) prevailing during winter in India. This complete reversal of wind direction from North-East to South West and vice-versa is known as monsoons. The winds contain a lot of moisture. When these moisture laden winds move over the Indian sub-continent they cause wide spread rain throughout India and from June to September. Thus, most of the total rainfall in India is confined to these four months only.



Winter Monsoon

During the winter season, **North-East trade winds** prevail over India. They blow from land to sea and that is why that for most part of the country, it is a dry season. A part of North-East trade winds blow over Bay of Bengal. They gather moisture which causes rainfall in the Coromandal coast while the rest of the country remains dry. Strictly speaking these winds are planetary winds known as

Northeast Trades. In India they are essentially land bearing winds.

Irregularity of Monsoon

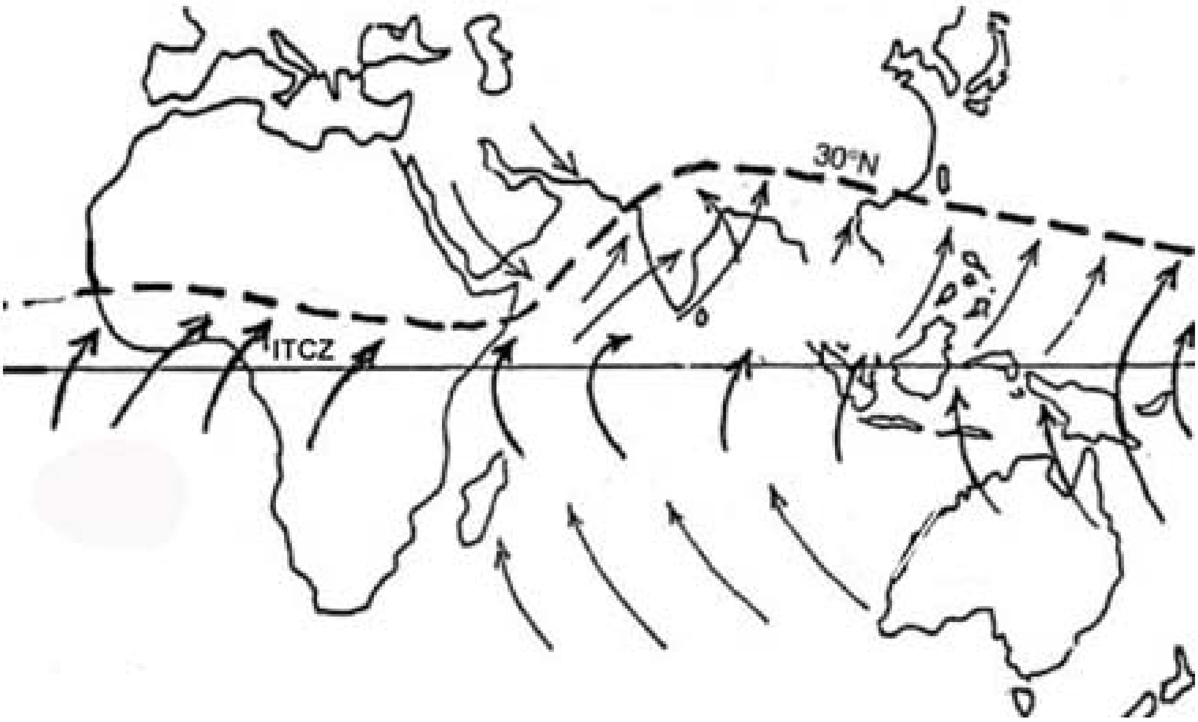
Monsoons winds are irregular in nature affected by different atmospheric conditions. They are also not equally distributed. Coastal areas like Kerala West Bengal and Odisha receive heavy rain fall, whereas interior regions like Haryana, Madhya Pradesh, receive less rainfall. When monsoon arrives, it gives heavy rainfall which continues for several days. This is known as 'burst of monsoon', which generally occurs at the Kerala coast. The monsoon tends to have 'breaks' in its rainfall which causes wet and dry spells. This means that monsoon rains occur only a few days at a time. Rainless dry spells occur in between.

The above simple story is based upon a mechanism proposed by **Halley and is also known as Thermal Concept**. However, it fails to answer the following questions:

- Why the low pressure areas on land are not stationary and why they suddenly change their location?
- Why there is no antimonsoon circulation in the upper troposphere, which must be there if the monsoon winds are thermally induced?
- Low Pressure are in northern India is in April and May, but rains start in the end of June or beginning of July.
- Monsoon rains are an amalgamation of convectional, orographic and cyclonic rainfall, the thermal concept is unsatisfactory to explain in details.

Another gentleman **Fohn** tried to link the Monsoon with the ITCZ or Intertropical Convergence Zone, which is called **Dynamic Concept**.

This concept says that monsoon is the result of seasonal migration of planetary winds and pressure belts around Equator. The Inter-Tropical Convergence Zone (ITCZ) is formed due to the convergence of north-east and south-east trade winds near the equator. In summer when the rays of Sun are directly above the Tropic of Cancer, the Northern Intertropical Zone gets extended up to 30° N latitude, thus covers the South Asia as well as South East Asia, where a low pressure area develops.



When this happens, the trade winds of the Southern Hemisphere need to cross the equator in order to reach the ITCZ. Thus, the trade winds of the Southern Hemisphere cross the equator but are deflected towards right under the Coriolis Effect. In this manner a new belt of "*equatorial westerlies*" is developed and Indian landmass receives the south west monsoon due to these winds.

This theory further explains that in winter, the ITCZ shifts towards south of Equator and the North East Trade winds have to cross the equator to reach the ITCZ. These winds blowing from the northern hemisphere to southern hemisphere deflected left due to Coriolis Effect and blow as North westerly Monsoon there. Since the winds blowing over the Indian subcontinent at this time are usual trade winds of these latitudes, they blow from North East to South West and so become the North East Monsoon.

Seasons in India

There are four seasons in India viz. Winter (December-February), Hot weather summer (March-May), Rainy south-western monsoon (June-September) and Post-monsoon, also known as north-east monsoon in the southern Peninsula (October-November).

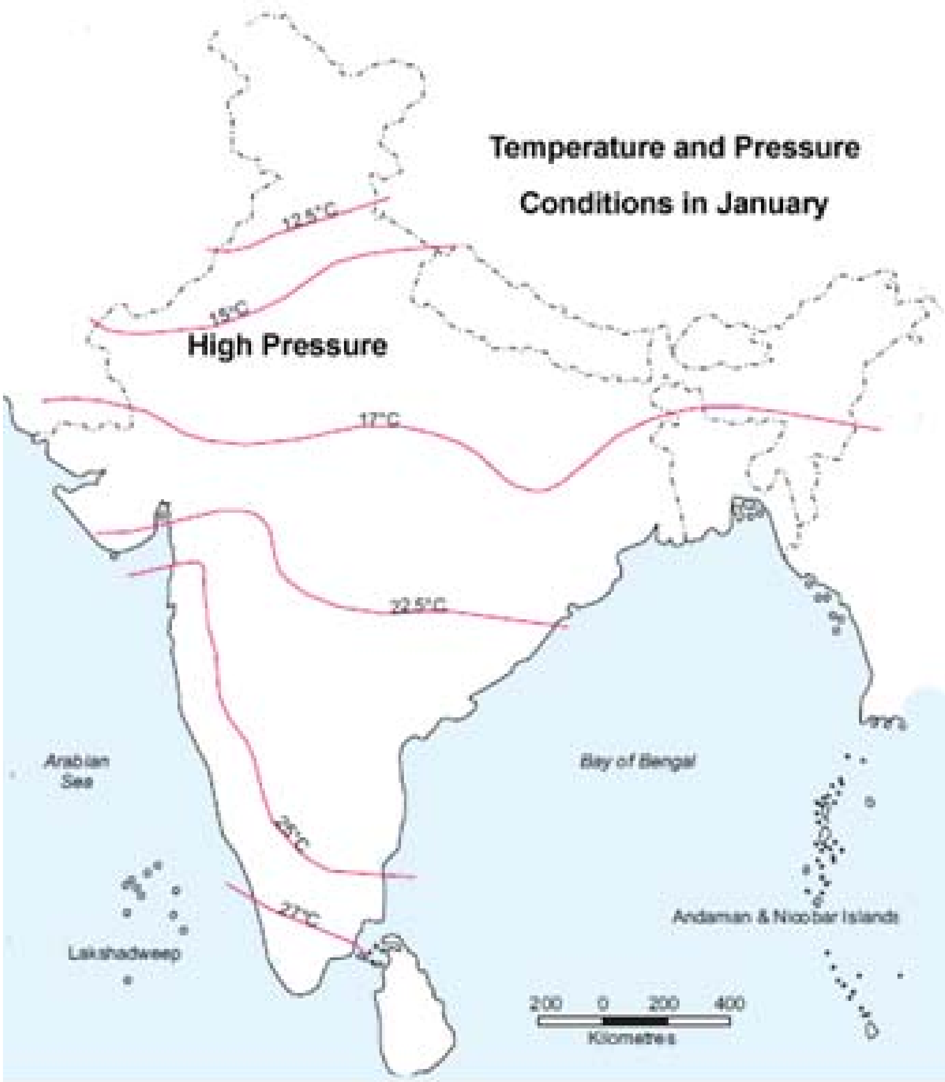
Winter Season

During the winter season, the temperature decreases with increasing latitude in India from 25°C in South to near zero temperature on north. This season is characterised by Fog and Frost in North and North-West India. There is light rainfall in this region due to Western disturbances. There is a sustained snowfall on the higher slopes of the Himalayas.

North East Monsoon

In India, rains occur in winter due to the North East Monsoon. During the winter season,**North-**

East trade winds prevail over India. They blow from land to sea and that is why that for most part of the country, it is a dry season. A part of North-East trade winds blow over Bay of Bengal. They gather moisture which causes rainfall in the Coromandal coast while the rest of the country remains dry. In the northern part of the country the weather is marked by clear sky, low temperatures and low humidity. The winter rainfall is very important for the cultivation of 'Rabi' crops.



Impact of Jet streams in Winter

Jet streams are **fast flowing**, **narrow** air currents located ***near the Tropopause***, the transition between the troposphere and the stratosphere. The **major jet streams on Earth are westerly winds** (flowing west to east). Their paths typically have a **meandering shape**; jet streams may start, stop, split into two or more parts, combine into one stream, or flow in various directions including the opposite direction of most of the jet.

The **strongest jet streams are the polar jets**, at around 7–12 km above sea level, and the higher and somewhat weaker subtropical jets at around 10–16 km. The Northern Hemisphere and the Southern Hemisphere each have both a polar jet and a subtropical jet. The northern hemisphere polar jet flows over the middle to northern latitudes of North America, Europe, and Asia and their intervening oceans, while the southern hemisphere polar jet mostly circles Antarctica all year round. The Jet streams are upper level, irregular, concentrated, meandering bands of westerly winds that travel at speeds of 300 to 400 kmph and come to India from the Mediterranean side in winter. This jet stream is bifurcated due to the physical obstruction of the Himalayas and Tibetan Plateau. One branch is located to the south of the Himalayas, while the second branch is positioned to the north of the Tibetan Plateau. The southern branch blows eastwards south of the Himalayan ranges along 25° N latitude (Rajasthan., MP, Chhattisgarh etc.) . These winds tend to descend over the north-western parts of India, resulting into the development of atmospheric stability and **dry conditions**. It is believed that this branch of jet stream exercises a significant influence on the winter weather conditions in India. *This jet stream is responsible for bringing western disturbances from the Mediterranean region into Indian sub-continent.* Winter rain and hail storms in north western plains and occasional heavy snowfall in hilly regions are caused by these disturbances. These are generally followed by cold waves in whole of northern plains.

Western Disturbances

Western Disturbances are basically the **temperate cyclones** that originate in the Mediterranean Sea and west Asia and happen to reach Afghanistan and Pakistan. In winters, they cross the North West borders of India and reach up to Central India. These disturbances bring small winter rains in India which are locally called *Mahavat* (Rajasthan, Haryana, Punjab) and are beneficial for the Rabi Crops. They also bring cold waves and snowfall in the higher altitudes of the Jammu and Kashmir and Himachal Pradesh.

Summer Season

By the end of February the temperature starts rising and there is a hot weather season in India from March to May. During these months the central part of peninsular India expiries extreme hot weather and an elongated low pressure belt which is called monsoonal trough created, which extends from Jaisalmer in western Rajasthan to Jharkhand and parts of Odisha to the East.

However, over Indian Ocean south of the equator high pressure belt begins to develop in this season. In North-West India, afternoon dust storms are common. During summer, very hot and dry winds blow over North Indian plains. They are locally called 'Loo'. At the same time, localized thunderstorms, associated with violent winds, torrential downpours, often accompanied by hail occur in many parts of India.

- In West Bengal, these storms are known as the **Kaal Baisakhi**' (calamity for the month of Baisakh).
- Towards the close of the summer season, pre-monsoon showers are common, especially in Kerala and Karnataka, which help in the early ripening of mangoes, and are often referred to

as '**mango showers**'.

- The thunderstorms which occur during summer to bring some rainfall in Karnataka are also known as **Cherry Blossom Showers**.

Rainy south-western monsoon (June-September)

June to September are the months of advancing South-West monsoon season. By the end of May, the monsoon trough further intensifies over north India due to high temperature. The General direction of the wind during this season is from South-West to north-east. These winds are strong and blow at an average velocity of 30 km per hour. These moisture laden winds first hit at Andaman and Nicobar Islands in the last week of May and Kerala coast in the first week of June with violent thunder and lightning. This South-West monsoon that flows in to India brings about a major change in its weather. Two branches of south-west monsoon originate from:

- Arabian Sea
- Bay of Bengal.

The Arabian Sea Branch obstructed by Western Ghats gives heavy rainfall on the Western side of Western Ghats. It reaches Mumbai by 10th June. When this branch crosses the Western Ghats and reaches the Deccan Plateau and parts of Madhya Pradesh, it gives less rainfall as it is a rain shadow region. Further, this branch reaches in Northern Plain by 20th June.

Rains in Bangalore versus Mangalore

Bangalore receives less rainfall in comparison to Mangalore because Bangalore is located in the rain shadow (Leeward Side) of Western Ghats and when the wind blows from the west, it gets obstructed by the hills. Thus the moisture laden wind blows to the windward side of the ghats, causing heavy rainfall in the coastal region and ghat areas and the rainfall in Bangalore is limited. However, you must note here that during weak monsoon condition when there is ample sunshine, the lower levels of the atmosphere are warm which gives rise to convection current. The air goes up leading to the formation of clouds, resulting in rainfall in the city.

Similarly, Pune receives less rainfall because it is also located on lewardside of western Ghats. Other examples are Shillong and Hyderabad. Shillong lies on the northern leeward slopes of the Khasi Hills and therefore receives less rain.

The monsoon winds that move from Bay of Bengal strike Andaman and Nicobar Islands North-Eastern states and coastal areas of West Bengal and cover the whole of India by the 15th of July. They cause heavy rainfall in the region. However, quantity of rainfall decreases as they move towards West over the Northern plains. For examples rainfall at Kolkata is 120 cm, Allahabad 91 cm and Delhi 56cm.

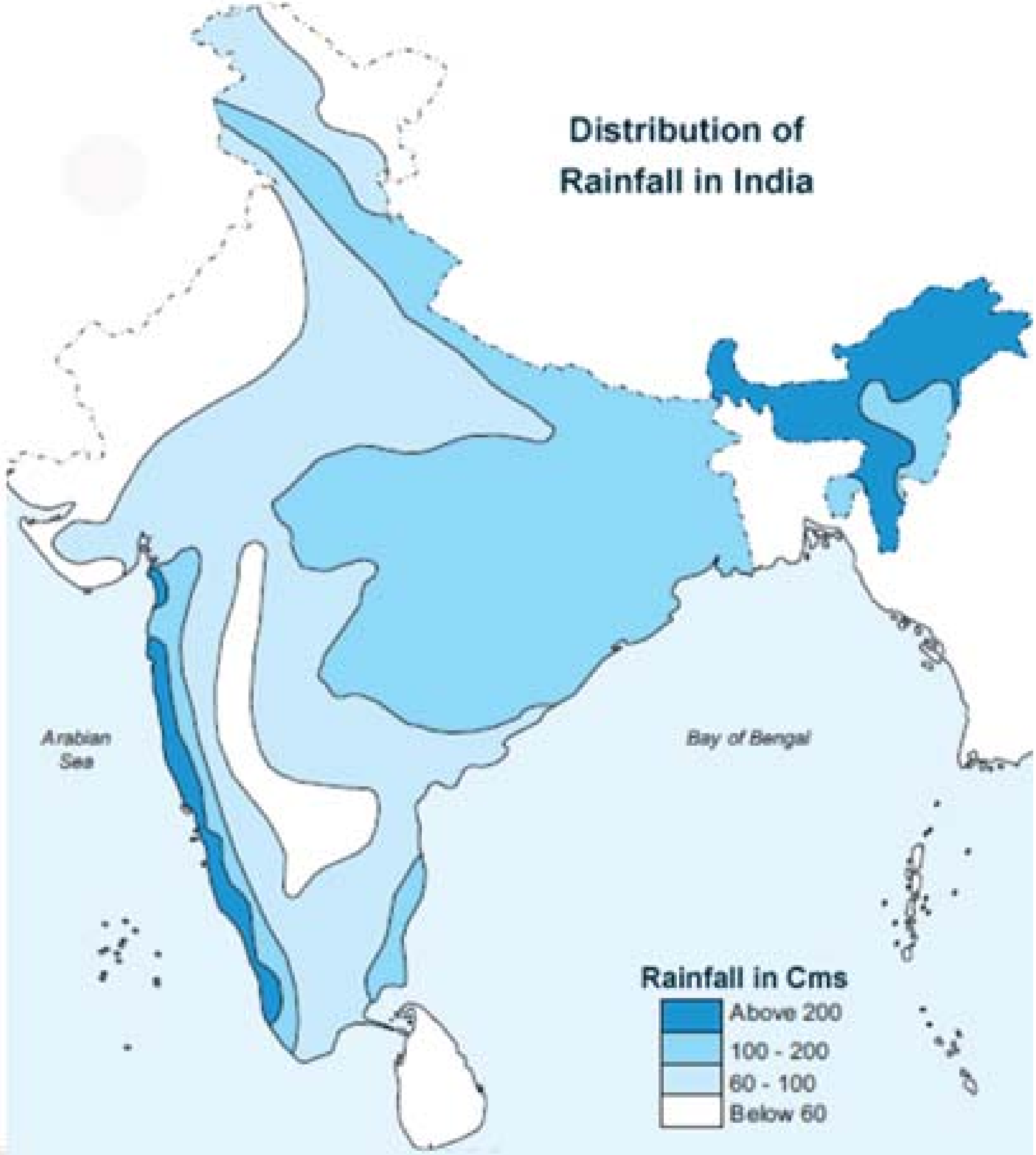
Post Monsoon Season

October and November are the months of post (or retreating) monsoon season. The temperatures during September-October start decreasing in north India. Monsoonal trough also becomes weak over North-West India. This is ***gradually replaced by a high pressure system***. The South-West monsoon winds weaken and start withdrawing gradually from North Indian Plains by November. In October the weather remains humid and warm due to continuing high temperature and moist land in month of October. *In Northern plains hot and humid weather becomes oppressive at this time. It is commonly called 'October Heat'. However, towards the end of October, temperature starts decreasing, making nights pleasant.*

By the month of November, the low pressure of North India shifts to Bay of Bengal and this is the time of cyclonic storms which develop in the Bay of Bengal. These storms create havoc in coastal areas of Odisha, Andhra Pradesh and Tamil Nadu, especially in the deltas of Mahanadi, Godavari and Krishna rivers.

Distribution of Rainfall in India

Rainfall in India is highly uneven over a period of time in a year. The western coasts and North East India receive rainfall of over 400 cm. It is less than 60 cms in western Rajasthan and adjoining parts of Gujarat, Haryana and Punjab. Similarly, rainfall is *low in the interiors of the Deccan Plateau and east of Western Ghats*. Then, Leh in Jammu and Kashmir is also an area of low precipitation.



Here are some more observations about distribution of rainfall in India

- As we move from Meghalaya to Haryana or Punjab in Northern plains, we observe that the rainfall decreases.
- In peninsular India, rainfall decreases from coast to interior parts.
- In North-East India, the *rainfall increases with altitude.*
- Maximum rainfall (above 200 cms) in India occurs in the western coast, sub Himalayan regions of north-east and Garo, Khasi and Jaintia hills of Meghalaya.
- Moderate rainfall (100-200cm) occurs in some parts of the Western Ghats, West Bengal, Odisha and Bihar and many states.
- Low rainfall (60 to 100cm) occurs in parts of Uttar Pradesh, Rajasthan, and interior Deccan plateau.
- Inadequate rainfall (Less than 60cm) occurs in western part of Rajasthan and Gujarat, Ladakh

and south central part receives a rainfall of less than 20cm.

Impact of El Niño/La Niña–Southern Oscillation

A recurring characteristic of the climate is called Climatic Pattern. The gap between two recurrences may be from one year to as long as tens of thousands of years. Some of the events are in regular cycle, while some are not. When they recur in the form of regular cycles of fluctuations in climate parameters, they are called **climate oscillations**. The term **oscillation** is used because such fluctuations are *not perfectly periodic*. For example, we say that El Nino returns every four and half years. But actually it may or may not return. Or it may return too early or too late. So, El Nino is quasi periodic.

El Niño

El Niño was originally recognized by fisherman off the coast of **Peru** in South America. The ocean off the coast of Peru is one of the world's richest fisheries regions. In most years trade winds flow from the southeast push warm surface water **away** from the coast. In its place, the cold water comes up on the surface *due to upwelling*. This cold water is full of nutrients and provides nourishments to planktons. These planktons serve as food for fishes. Fishes in turn provide food to the sea birds. Due to all this, not only there is a good catch of fishes but also good collection of the **Guano**, the bird excreta, used as a valuable fertilizer. This is what that made Peru number one fishing nation in the world by the early 1970s.

Pattern of flow of warm winds off the coast of Peru

However, every few years, there is a change in the pattern of air circulation. It changes in such a way that the trade winds reverse direction, blowing from west to east. Due to this reversal, the upwelling of the cold water gets weakened. The surface water is warm. This lowers the nutrients available to fish and thus poses problems to the economics of fisheries. The problems don't end here. The accumulation of large mass of warm water allows formation of more and more clouds and this would bring destructive rains that occur in normally dry areas of Peru and Chile. The same is also responsible for bring outbreaks of Malaria and Cholera in some parts of South America. Peru , as you may know is a **Hispanophone** country as many people speak Spanish out there. The above mentioned reversal of the winds occurred during Christmas times (Please note that we have Christmas in winter, but Peruvians have in summer, because they are in southern hemisphere), so they named it El Niño or "Christ Child" or "The Little Boy" in their own language. Before, you read further, please understand the location of Eastern, Central and Western Pacific on the map, otherwise it would be too confusing (earth is round…after all)

Now, here is how it affects the entire tropical region.

- Off the coast of Peru (read in Eastern Pacific and Central Pacific), there is normally cool surface water. But El Niño makes it go warm. When the water becomes warm, the tread winds, which otherwise flow from East to west, either reverse their direction or get lost. The warm water causes lots of clouds getting formed in that area, causing heavy rains in Peruvian desert during El Niño years.
- Due to this warm water, the air gets up and surface air pressure above Eastern Pacific gets down. On the other hand, the waters cool off in western pacific and off Asia. This leads to rise in surface pressure over the Indian Ocean, Indonesia, and Australia
- So, while there is raining (read flooding) in Eastern Pacific; the drought sets in over Asia as high pressure builds over the cooler ocean waters.
- The net result is:
- Normal or high rainfall in eastern / central pacific.
- Drought or scant rainfall in western pacific / Asia.

Although El Niño originally referred to local conditions off the coast of Peru and Ecuador, the use of the term has been broadened by many scientists to represent all surface temperature warming in the eastern and central Pacific. The impacts of El Niño , which have been well documented include the following:

- Heavy rains in Ecuador and Peru.
- Heavy rains in southern Brazil but drought in north East Brazil
- Drought in Zimbabwe, Mozambique, South Africa, Ethiopia
- Warm winter in the northern half of the United States and southern Canada
- Drought, Scant rains off Asia including India, Indonesia, and Philippines etc.
- Coral bleaching worldwide
- Drought in eastern Australia

La Niña

La Niña, which means "The Little Girl" or "El Viejo" or "anti-El Niño" or simply "a cold event" or "a cold episode is the cooling of water in the Eastern Pacific Ocean. Here is what happens in La Niña.

- The water in Eastern Pacific, which is otherwise cool; gets colder than normal. There is no reversal of the trade winds but it causes strong high pressure over the eastern equatorial Pacific.
- On the other hand, low pressure is caused over Western Pacific and Off Asia.
- This has so far caused the following major effects:
    - Drought in Ecuador and Peru. Low temperature, High Pressure in Eastern Pacific
    - Heavy floods in Australia; High Temperature in Western Pacific, Indian Ocean, Off coast Somalia and good rains in India.
    - Drought in East Africa (Somalia Drought of 2011 was linked to it)

ENSO

Both **El Nino** and **La Nina** are part of a larger cycle called ENSO, or**El Niño–Southern Oscillation**. The El Niño (warm event) and La Nina (Cold event) both have now established themselves as the integral part of the global climate system. It is a recurrent phenomenon with an average return period of $4^{1/2}$ years, but can recur as little as 2 or as much as 10 years apart. Such events have occurred for millennia, and can be expected to continue to occur in the future.

Impact of El Niño and La Nina on Indian Weather

- El Nino and La Nina are among the most powerful phenomenon on the Earth. These are known to alter climate across more than half the planet and dramatically impact weather patterns.
- Over Indian subcontinent, El Nino during winter results in development of warm conditions. During summer, it leads to dry conditions and deficient monsoon. It also leads to drought in Australia. On the other hand, La Nina results in better than normal monsoon in India. At the same time, in Australia it has caused floods.
- In the recent past, India experienced deficient rainfall during El Nino years 2002 and 2009

whereas monsoon was normal during El Nino years 1994 and 1997. *This so far implies that in about 50 per cent of the years with El Nino during summer, India experienced droughts during monsoon.*

- This implies that *El Nino is not the only factor that affects monsoon in India* There are other factors that affect India's rainfall pattern. These include North Atlantic SST, Equatorial SE Indian Ocean SST, East Asia Mean Sea Level Pressure, North Atlantic Mean Sea Level Pressure and North Central Pacific wind at 1.5 km above sea level.

Difference between El Nino and La Nina

Feature	El-Nino	La-Nina
Meaning	El Nino is a Spanish term which represents "little boy"	La Nina is a Spanish term which represents 'little girl'.
Temperature at Sea Surface	Temperature at sea surface is warmer than normal sea-surface temperatures. El Nino is a warming of the Pacific Ocean between South America and the Date Line, centred directly on the Equator, and typically extending several degrees of latitude to either side of the equator.	Temperature at sea surface is cooler than normal sea-surface temperatures. La Nina exists when cooler than usual ocean temperatures occur on the equator between South America and the Date Line.
Pressure	It accompanies high air surface pressure in the western Pacific	accompanies low air surface pressure in the eastern Pacific
Trade winds	El Niño occurs when tropical Pacific Ocean trade winds die out and ocean temperatures become unusually warm	La Nina, which occurs when the trade winds blow unusually hard and the sea temperature become colder than normal
Seasons	Winters are warmer and drier than average in the Northwest of pacific, and wetter in Southwest of pacific and experience reduced snowfalls.	Winters are wetter and cause above-average precipitation across the Northwest of pacific and drier and below average precipitation in South west of pacific.
Coriolis force	El Nino results in a decrease in the earth's rotation rate (very minimal) , an increase in the length of day, and therefore a decrease in the strength of the Coriolis force	La Nino results in increase in the earth's rotation rate, decrease in the length of day, and therefore a increase in the strength of the Coriolis force.
Ocean waters in Pacific	Warm water approaches the coasts of South America which results in reduced upwelling of nutrient-rich deep water impacting impacts on the fish populations.	Cold water causes increased upwelling of deep cold ocean waters numbers of drought occurrence, with more nutrient-filled eastern Pacific waters.

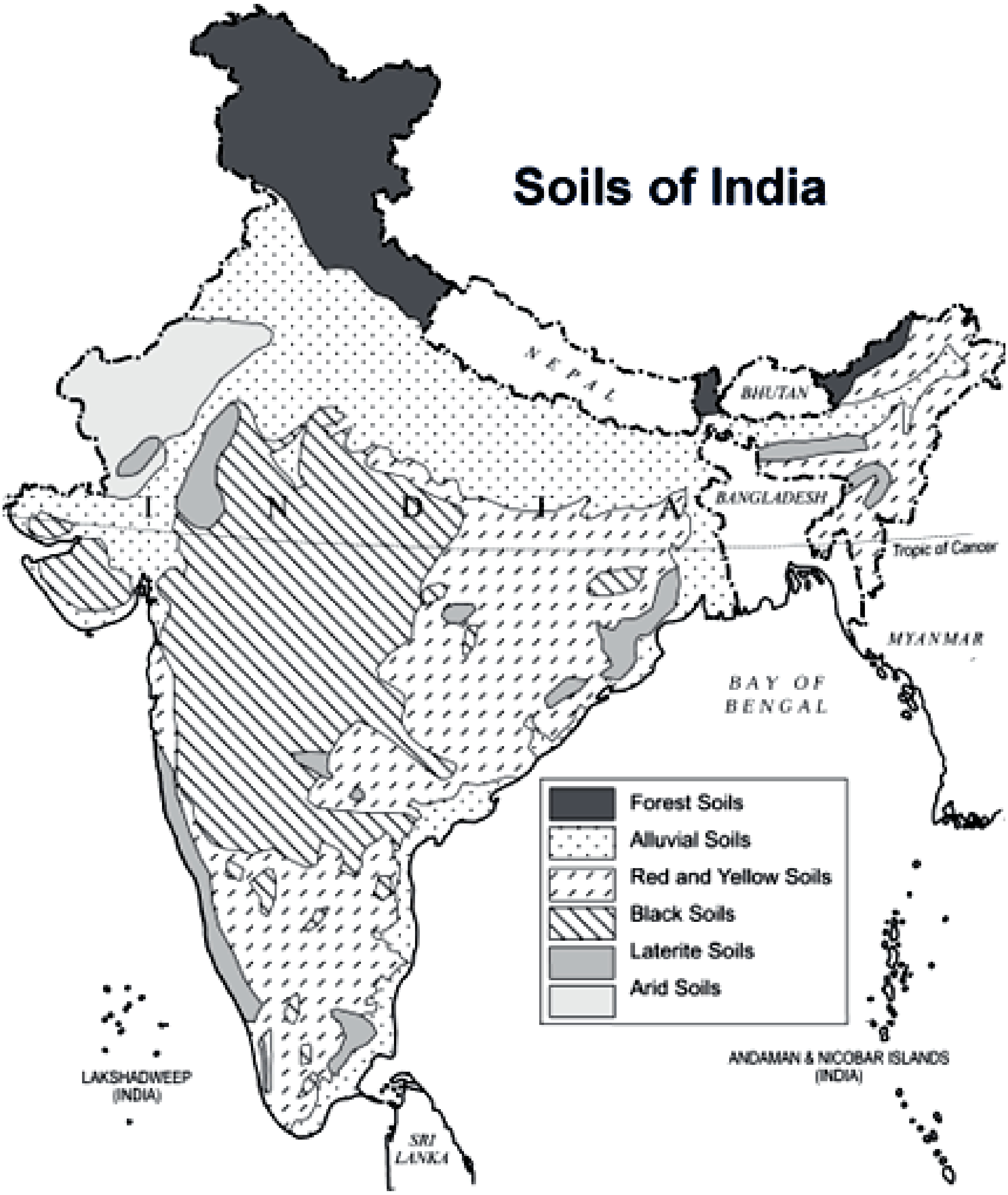
Feature	El-Nino	La-Nina
Cyclones	Comparatively less compared to La Niña as wind speed is low	La Nina had a greater tendency to trigger intense tropical cyclones as wind direction changes pilling up water between Indonesia and nearby areas as winds from Africa onwards gets blocked.

Do El Nino and La Nina explain most of the unusual climatic happenings?

It is undeniable that the El Nino has been used to explain unusual climatic changes across the globe. But, modern climatology taken into account various other phenomena also. However, El-Nino has far-reaching and varied effect on climate across the world. The major reason for these unusual climatic happenings is the shifting in tropical rainfall, which in turn affect the wind patterns across the world. When the El-Nino effect causes the rainy areas centered around Indonesia and the Pacific region to move eastward, the subsequent changes result in unseasonable weather in many regions of the world. The El Nino is typically characterized by warm ocean currents and heavy rains, however, it also plays havoc with the normal weather conditions in different areas of the world. Also, the increase in temperatures affects fishing adversely, disrupts local weather and indigenous marine life in the areas concerned, other than having an effect on climatic conditions worldwide. When the linkage between El Nino and climate effects were initially suggested by the British scientist, Gilbert Walker, it was deemed ridiculous that one phenomenon could have an effect on regions as far off as Australia, India etc and Canada. However, the occurrence of El Nino in the past few decades has proved without a doubt, their far-reaching consequences. Some of the effects of El Nino in the past have been causing of droughts and forest fires in South Asia (Indonesia and Philippines) and Australia, floods in the South American countries in the eastern Pacific region, increased rain in certain other areas of the world etc.

Soils of India

Soil is the mixture of rock debris and organic materials which develop on the earth's surface. The major *factors affecting the* ***formation of soil are relief, parent material, climate, time, and biodiversity*** including the human activities. India is a diverse country with variety of relief features, landforms, climatic realms and vegetation types. These have contributed in the development of various types of soils in India.



In ancient times, soils used to be classified into two main groups –**Urvara and Usara**, which were fertile and sterile, respectively. In medieval times, the soils were classified on the basis of the external features such as texture, colour, slope of land and moisture content in the soil. So, the soils were identified as sandy, clayey, silty and loamy, etc. Then, they were also classified on the basis of colour such as red soil, yellow soil, black soil, etc.
The Indian soils have been classified by ICAR on the basis of characters as per the United States Department of Agriculture (USDA) Soil Taxonomy. These types are as follows:

Types of Soils in India			
Soil Type	General Characters / Position in entire world soil classification	Area	% of Total area of India
Inceptisols	These are usually the weakly developed young soil though they are more developed than entisols.	130372.9	39.74
Entisols	Usually young or underdeveloped. Lack vertical development of horizons. These are less fertile soils.	92131.71	28.08
Alfisols	Pale, grayish brown to reddish in colour with moderate-to-high reserves of basic cations and are fertile. However, their productivity depends on moisture and temperature. They are supplemented by the moderate application of lime and other chemical fertilizers.	44448.68	13.55
Vertisols	These are expandable clay soils , composed of more than 30 per cent clays. Vertisol clays are black when wet and become iron hard when dry. When drying, Vertisols crack and the cracks widen and deepen as the soil dries ; this produces cracks 2-3 cm wide. These are productive soils. The regur soils of India are an example of vertisols.	27960	8.52
Aridisols	Ardisoil is the largest single soil order occurs in dry regions of the world. These soils occupy nearly 19 per cent of the earth's land surface. These are pale and light near the surface, deficit in moisture. Lack in organic matter. Salinisation is the main problem of these soils. Salinisation complicates farming in Aridisols.	14069	4.28
Ultisols	Highly weathered forest soil, which tend to be reddish in colour because of residual iron and aluminum oxides in the a horizon. The increased precipitation in ultisol regions means greater mineral alteration, more leaching, and therefore,a lower level of fertility. Fertility is further reduced by certain agricultural practices and the effect of soil damaging crops such as cotton and tobacco. These soils need substantial management.	8250	2.51
Mollisols	Most productive soils of the earth. They are rich in humus content. They have dark –colored surface. Mollisols are soft, even when dry, with granular pads, loosely arranged when dry. These humus rich organic soils are high in basic cations and have high fertility. Soils of the steppes and prairies of the world belong to this group	1320	0.4
Others		9503.1	2.92

The Indian Classification of Soils

On the basis of genesis, colour, composition and location, the soils of India have been classified into various soils such as Alluvial soils, Black soils, Red and Yellow soils, Laterite soils, Arid soils, Saline soils, Peaty soils, Forest soils etc.

Important Observations have been written down in the below descriptions:

Alluvial Soils

Alluvial soils, the depositional soils transported by rivers, are the predominant type of soil in the northern plains of the country, widespread in the **Ganga plains and the river valleys**. These soils cover about **40 per cent** of the total area of the country.

Apart from the northern Gangetic plains, via a narrow corridor in Rajasthan, they extend into the plains of Gujarat.

In the Peninsular region, they are found in deltas of the east coast such as Mahanadi , Godavari and Krishna.

The alluvial soils are generally **rich in potash** but **poor in phosphorous**.

In the Upper and Middle Ganga plain, two different types of alluvial soils have developed, viz. Khadar and Bhangar.

- Khadar is the new alluvium and is deposited by floods annually, which enriches the soil by depositing fine silts.
    - Bhangar represents a system of older alluvium, deposited away from the flood plains.
        - Both the Khadar and Bhangar soils contain calcareous concretions (Kankars). These soils are more loamy and clayey in the lower and middle Ganga plain and the Brahamaputra valley. The sand content decreases from the west to east.

The colour of the alluvial soils varies from the light grey to ash grey. Its shades depend on the depth of the deposition, the texture of the materials, and the time taken for attaining maturity. Alluvial soils are intensively cultivated.

Coastal Alluvium: Please note that the alluviums of the peninsular coastal strip are darker in colour than the alluvium of the northern plains because the rivers of the peninsula flow over the Deccan Plateau composed of basalt, and over black soil are only to deposit It in coastal areas . Maharastra has no alluvial soils but coastal alluvium is found in that state.

Black Soil

Most of the Deccan plateau, including Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh and some parts of Tamil Nadu has black soils .

In the upper reaches of the Godavari and the Krishna, and the north western part of the Deccan Plateau, such as parts of Gujarat, the black soil is very deep. These soils are also known as the 'Regur

Soil' or the 'Black Cotton Soil'. This soil is of volcanic origin.

The black soils are generally clayey, deep and impermeable. They swell and become sticky when wet and shrink when dried. So, during the dry season, these soil develop wide cracks. Thus, there occurs a kind of '**self ploughing**'. Because of this character of slow absorption and loss of moisture, the black soil retains the moisture for a very long time, which helps the crops**, especially, the rain fed crops**, to sustain even during the dry season.

Chemically, the **black soils are rich in lime, iron, magnesia and alumina.**They also contain potash. But they lack in phosphorous, nitrogen and organic matter. The colour of the soil ranges from deep black to grey.

Red and Yellow Soil

On the eastern and southern parts of the Deccan Plateau, the Red soil develops on crystalline igneous rocks.

These soils are abundant along the eastern slopes of Western Ghats, Odisha and Chhattisgarh and in the southern parts of the middle Ganga plain.

The soil develops a reddish colour due to a **wide diffusion of iron in crystalline and metamorphic rocks**. It looks yellow when it occurs in a hydrated form (Iron Hydroxides).

The fine-grained red and yellow soils are normally fertile, whereas coarse-grained soils found in dry upland areas are **poor in fertility due to leaching of the nutrients.**They are generally poor in nitrogen, phosphorous and humus but respond well to fertilizers.

Laterite Soil

The Laterite soils develop in areas with high temperature and high rainfall and are common in the high altitude areas of Peninsular plateau.

Laterite soil and is mainly found on the summits of the Western Ghats, Eastern Ghats, Rajmahal Hills, Vindhyas, Satpuras and Malwa plateau, thus abundant in Karnataka, Kerala, Tamil Nadu, Madhya Pradesh and the hilly areas of Odisha and Assam.

Laterite soil represents intense leaching due to heavy rains, due to which the lime and silica are leached away, and soils rich in iron oxide and aluminium compound are left behind. Then, the Humus content of the soil is removed fast by bacteria that thrives well in high temperature.

This implies that the Laterite soil is poor in organic matter, nitrogen, phosphate and calcium, while **iron oxide and potash are in excess**. **Due to excess of Iron**, laterites are not suitable for cultivation; *however, application of manures and fertilisers are required for making the soils fertile for cultivation.*

Red Laterite soils in Tamil Nadu, Andhra Pradesh and Kerala are more suitable for tree crops like cashewnut.

Laterite soils are widely cut as bricks for use in house construction.

Arid Soils

Arid soils, which is sandy and saline soil is abundant in arid regions of western Rajasthan. These soils are poor and contain little humus and organic matter. The color appears from red to brown.

In some areas, the salt content is so high that common salt is obtained by evaporating the saline water. Due to the dry climate, high temperature and accelerated evaporation, they lack moisture and humus. Nitrogen is insufficient and the phosphate content is normal.

Lower horizons of the soil are occupied by 'kankar' layers because of the increasing calcium content downwards. The 'Kankar' layer formation in the bottom horizons restricts the infiltration of water, and as such when irrigation is made available, the soil moisture is readily available for a sustainable plant growth.

Saline Soils

Saline soils or **Usara soils** contain a larger proportion of sodium, potassium and magnesium, and thus, they are infertile, and do not support any vegetative growth.

They have more salts, largely because of dry climate and poor drainage. They occur in arid and semi-arid regions, and in waterlogged and swampy areas.

Their structure ranges from sandy to loamy. They lack in nitrogen and calcium.

- Saline soils are more widespread in western Gujarat, deltas of the eastern coast and in Sunderban areas of West Bengal.
- In the Rann of Kuchchh, the Southwest Monsoon brings salt particles and deposits there as a crust. Seawater intrusions in the deltas promote the occurrence of saline soils. In the areas of intensive cultivation with excessive use of irrigation, especially in areas of green revolution, the fertile alluvial soils are becoming saline.
- Excessive irrigation with dry climatic conditions promotes capillary action, which results in the deposition of salt on the top layer of the soil. In such areas, especially in Punjab and Haryana, farmers are advised to add gypsum to solve the problem of salinity in the soil.

Peaty Soils

- Peaty soils arte found in the areas of heavy rainfall and high humidity, where there is a good growth of vegetation. Thus, large quantity of dead organic matter accumulates in these areas, and this gives a rich humus and organic content to the soil.
- Organic matter in these soils may go even up to 40-50 per cent.
- These soils are normally heavy and black in colour. At many places, they are alkaline also.
- These soils occur widely in the northern part of Bihar, southern part of Uttaranchal and the coastal areas of West Bengal, Orissa and Tamil Nadu.

Forest Soils

Forest soils are formed in the forest areas where sufficient rainfall is available. The soils vary in structure and texture depending on the mountain environment where they are formed.

They are loamy and silty on valley sides and coarse-grained in the upper slopes.

In the snow-bound areas of the Himalayas, they experience denudation, and are acidic with low humus content. The soils found in the lower valleys are fertile.

Major Soils abd Crops Grown in them

Alluvial Soils

Rice, wheat, sugarcane, cotton and jute all grow well in these soils.

Black Soils

Rice, wheat, sugarcane and cotton apart from groundnut, millet and oilseeds.

Arid Soils

Only drought-resistant crops such as barley and millet can grow in this type of soil.

Laterite Soils

It is an acidic soil and is rich in iron, which gives the soil a somewhat red appearance. Cash crops such as cashew, rubber, coconut, tea and coffee.

Red and Yellow Soils

Derive names from the very large amounts of iron oxide & Hydroxides present in them. They are sandy and somewhat acidic, and are also low in nitrogen and phosphorous. Despite this, red and yellow soils are used to grow rice, wheat, sugarcane, millet, groundnut, ragi and potato.

Soil Degradation & Soil Erosion

The decline in soil fertility, when the nutritional status declines and depth of the soil goes down due to erosion and misuse is called Soil degradation. Soil degradation is the main factor leading to the depleting soil resource base in India. The degree of soil degradation varies from place to place according to the topography, wind velocity and amount of the rainfall.

Soil Erosion

The soil forming processes and the erosion processes of running water and wind go on simultaneously. However, generally, there is a balance between these two processes. Sometimes, such a balance is disturbed by natural or man made factors, leading to a greater rate of removal of soil.

- With increasing population, the pressure on the land increases and forests are removed for human settlement, for cultivation, for grazing animals and for various other needs.

The two most important agents of soil erosion are wind and water. Wind erosion is significant in arid and semi-arid regions. Water erosion is significant in regions with heavy rainfall and steep slopes. Water erosion which is more serious and occurs extensively in different parts of India, takes place mainly in the form of sheet and gully erosion.

There are four kinds of soil erosion which can be arranged in an order of Splash erosion, Sheet erosion, Rill erosion, Gully erosion.

Splash Erosion

Raindrop splash erosion is a result of the energy of falling raindrops causing detachment of soil particles and and down-slope movement of sediment. Maintenance of ground cover, such as in reduced- or no-till operations, use of cover crops, and enhancement of the stability of soil aggregates can be important in reducing detachment of soil particles. The effect of manure application in enhancing soil aggregation also leads to reducing soil erodibility due to the raindrop splash effect.

Sheet Erosion

Sheet erosion, although less noticeable than other types of erosion, typically is the main erosive force. Sheet erosion is less noticeable, as it does not leave obvious cuts in the soil surface as with gully erosion. Sheet erosion is the removal of a relatively uniform, although thin, layer of soil from the land surface by unchanneled runoff, or sheet flow.

Sheet erosion takes place on level lands after a heavy shower and the soil removal is not easily noticeable. But it is harmful since it removes the finer and more fertile top soil.

Rill Erosion

Rill erosion is the process by which numerous small channels–less than three inches in depth–are formed. This type of erosion results from concentration of overland water flow associated with sheet erosion. Rill erosion can be especially serious on recently cultivated land. Rill erosion is best minimized by minimizing sheet flow, such as by maintaining crop residues and utilizing cover crops. Physical barriers, such as terraces, and vegetative barriers can be effective in stopping or reducing rill erosion.

Gully Erosion

Gully erosion refers to the cutting of narrow channels called gullies. The gullies can be caused by small channels of approximately 3 to 12 inches deep. Gullies may be one to several feet deep. Gully erosion cuts deep and removes the **surface soil as well as deeper soil** that may still have substantial amounts of total nutrients but less compared to the surface soil.

Gully erosion needs to be prevented, as it is difficult to check once started Gully erosion is common on steep slopes. Gullies deepen with rainfall, cut the agricultural lands into small fragments and make them unfit for cultivation.

- A region with a large number of deep gullies or **ravines** is called **badland topography**. Ravines are widespread, in the Chambal basin, which have been caused due to gully erosion. Apart from Chambal valley, the ravines are also found in Tamil Nadu and West Bengal.

Some more observations

- The Indian soils have been formed under varied geographical conditions and differ widely in their physical properties, chemical composition and fertility level. *Most soils are old and mature*.

- Soils of the peninsular plateau are much older then the soils of the great northern plain.
- Indian soils are largely deficient in nitrogen, minerals salts, humus and other organic materials.
- Plains and valleys have thick layers of soils while hilly and plateau areas depict thin soil cover.
- Some soils like alluvial and black soils are fertile while some other soils such as Laterite, desert and alkaline soils lack in fertility and do not yield good harvest.
- Indian soils have been used for cultivation for hundreds of years and have lost much of their fertility. As such there is urgent need of giving scientific treatment to our soils.
- Indian climate is characterized by seasonal rainfall and our soils need irrigation during the dry period.
- Indian soils suffer from soil erosion and other allied problems.

Prelims Model Questions

India Geology and Climate Model Questions

1. Consider the following statements:

1.The distribution of coal in India is more abundant on the eastern side of the country

2.Most coal produced in India is from Gondwana Coal Fields

Which among the above statements is / are correct?

[A] Only 1 is correct

[B] Only 2 is correct

[C] Both 1 & 2 are correct

[D] Neither 1 nor 2 is correct

Answer: [C] Both 1 & 2 are correct

The India coal fields have been classified in two parts viz. Gondwana coal fields and Tertiary coal fields. The Gondwana Fields account for 98% of the total reserve and 99% of the total coal production in India. Rest 2% is the tertiary coal. Please note that distribution of coal in India is more abundant on the eastern side of the country. While Gondwana coal is about 200 million years old, tertiary deposits are approximately 55 million years old.

Gondwana Coal

The Gondwana coal fields occur mostly in the river valleys such as Damodar, Mahanadi, Godavari, and Narmada. The Gondwana coal is a laminated bituminous coal within which dull and bright layers alternate. This coal is almost free from moisture but it contains variable quantities of sulphur and phosphorous. In general, Gondwana coal is good steam or gas coal. This is also known as metallurgical coal. The largest resources of Gondwana coal are located in the Damodar valley (West Bengal, Jharkhand), Jharia, Raniganj and Bokaro. The Godavari, Mahanadi, Son and

Wardha valleys also contain coal deposits.

2. With reference to the rock formation in India, the Deccan Trap is exposed in__:

1. Maharashtra
2. Gujarat
3. Uttar Pradesh
4. Tamil Nadu

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 1

[C] Only 1, 2 & 3

[D] 1, 2, 3 & 4

Answer: [C] Only 1, 2 & 3

In Western and Central India, DVP is exposed mainly in the states of Maharashtra, Madhya Pradesh, Karnataka, Gujarat, and Andhra Pradesh and also has its nominal presence in southern parts of Uttar Pradesh and eastern parts of Rajasthan.
Based on the area of occurrence, the Deccan Lavas have been further classified into four classes viz. Malwa Trap: occurring in Malwa region of Madhya Pradesh, Mandla Traps: occurring in Mandla region of Madhya Pradesh, Saurashtra Trap: occurring in Saurashtra region of Gujarat and Main Deccan plateau: occurring in States of Maharashtra, Karnataka and Andhra Pradesh.

3. Consider the following caves of historical importance in India?

1. Ajanta Caves
2. Elephanta Caves
3. Barabar Caves

Which among the above is / are Deccan Trap caves?

[A] Only 1

[B] Only 1 & 2

[C] Only 2 & 3

[D] 1, 2 & 3

Answer: [B] Only 1 & 2

Some of the best known Deccan Trap caves are close to Mumbai (Bombay), including Ajanta (perhaps the oldest one dating back to 200 B.C.), Mandapesvara Caves, Kanheri Caves, Jogeshwari Caves, Mahakali Caves, and Elephanta Caves.

4. Consider the following:
1. Kashmir Valley
2. Tamil Nadu
3. Arunachal Pradesh
4. Rajasthan

One can fine tertiary coal in which among the above regions / states?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 2 & 4

[D] 1, 2, 3 & 4

Answer: [D] 1, 2, 3 & 4

Kashmir Valley-Nichahom lignite, Former South Arcot (Now Cuddalore and surrounding area) of Tamilnadu and of Kerala, Jaipur, Nazira and Makum coalfields of Assam ; Namchick and Namphuk coalfields of Arunachal Pradesh. Palana of Rajasthan; Katch of Gujarat, Darranggiri, Rongrenggiri in the Garo Hills; Cherapunji, Mawlong and Shilong in Meghalaya, Mikir Hills in Upper Assam, and Coals of Jammu coalfields– Kalkot, Metka, Mahogala, Chakar Dhanwal Sawalkot-Lodhra, Kura and Chinkah. All of them are sources of tertiary coal.

5. With reference to the Jet streams, which among the following statements is / are correct?
1. Most Jet streams on earth flow westwards
2. They help in bringing western disturbances from the Mediterranean region into Indian sub-continent
3. Withdrawal of subtropical jet stream from India is critical for the onset of the southwest monsoon over India

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] Only 2

Answer: [B] Only 2 & 3

First statement is incorrect because jet streams blow from west to east.

6. Which among the following affect the behaviour of the monsoon over India?
1. Subtropical westerly jetstream
2. Tropical easterly jet stream

3. El Nino and La Nina
4. Indian Ocean Dipole
5. Anthropogenic aerosols

Choose the correct option from the codes given below:

[A] 1, 3, 4 & 5

[B] 1, 2, 3, 4, 5

[C] 1, 3, 4

[D] 1 & 3

Answer: [B] 1, 2, 3, 4, 5

7. Consider the following statements in context with the Jet streams:

1.Jet stream are fast moving moisture laden winds blowing only in the stratosphere
2.They help to bring the Western Disturbances Into India In winter
3.They generally blow from West to East
4.They generally blow in a wavy pattern

Which among the above statements is / are correct?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 2, 3 & 4

[D] 1, 2, 3 & 4

Answer: [C] Only 2, 3 & 4

First statement is incorrect because Jet Streams are fast moving winds which blow over an altitude of 8-15 km, which includes both troposphere as well as stratosphere.

8. The Deccan Trap:

1. is spread in all states of Peninsular India
2. is made of predominantly Igneous Rocks
3. formed as result of sub-aerial volcanic activity

Which among the above statements is / are correct?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [B] Only 2 & 3

Some people broadly divide the geographical land area of India into three parts viz. Deccan trap, Gondwana and Vindhyan. The Deccan Trap covers almost all of Maharashtra, some parts of Gujarat, Karnataka, Madhya Pradesh and marginally Andhra Pradesh. Deccan Trap is thought to have formed as result of sub-aerial volcanic activity associated with the continental deviation in this part of the Earth during the Mesozoic era. This implies that generally, the rocks of Deccan Trap are igneous.

9. The Indian monsoon is characterised by great variability. Consider the following statements with this reference:

1. The single most important characteristic of monsoon is seasonal reversal of winds.
2. A delay in onset of monsoon usually results in an early retreat

Which among the above is / are correct statements?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [C] Both 1 & 2

10. The north-east monsoon:

1. Blows from land to sea
2. Comes between October to December
3. Brings 60% of the annual rainfall in coastal Tamil Nadu

Which of the above is / are correct statements?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

India's climate is affected by two seasonal winds—the north-east monsoon and the south-west monsoon. The north-east monsoon commonly known as winter monsoon blows from land to sea whereas south-west monsoon known as summer monsoon blows from sea to land after crossing the Indian ocean, the Arabian sea and the Bay of Bengal. The south-west monsoon brings most of the rainfall during the year in the country.

http://www.imdchennai.gov.in/northeast_monsoon.htm

General Knowledge Today

Prelims Geography-8: Physiography of India-1

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Model Questions

Please check prelims model questions at the end of this module.

India can be divided into six physiographic regions viz. Himalayan Mountains, Northern Plains, Great Indian Desert, Peninsular Plateau, Coastal Plains and Islands

The Himalayan Mountains

The Himalayan mountain system is the world's highest, and home to the world's highest peaks including Mount Everest and K2. This system also includes Karakoram, Hindu Kush and other ranges extending out from the Pamir knot. There are over 100 mountains in Himalaya system whose height exceeds 7,200m. *After Himalayan peaks, it is Aconcagua, in the Andes, at 6,962 metres, known to be the highest peak outside Asia.*

Himalaya system gives rise to some of world's major river systems. The combined drainage basin is home to slightly less than half of world's population. The highest peak Everest is located in Nepal. Another peak K2 is on the border of Pakistan and China. Kanchenjunga is located on the border of Nepal and India. Nanda Devi is the highest peak within India.

Extent of Himalayas

The main Himalayan ranges run from Indus river valley in the west to the Brahmaputra river valley in east forming a 2,400 km long arc. The width of this arc is around 400 kilometer in Western Kashmir while 150 kilometers in Arunachal Pradesh-Tibet region.

Himalayan Orogeny

Geologically, the origin of the Himalayas is the impact of the Indian tectonic plate travelling northward at 15 cm per year to impact the Eurasian continent, about 40-50 million years ago. The formation of the Himalayan arc resulted since the lighter rock of the seabeds of that time was easily uplifted into mountains. The evidence for this is that the *summit of Mount Everest is made of* ***marine limestone***. Due to recent origin on geological time scale, Himalayan mountains are called *Young Fold Mountains*. These young fold mountains consist of a series of parallel ranges with deep valleys between them and have variety of rock structures, deep gorges and high pyramidal peaks. In High Himalayas the rivers have steep gradients, which result from the differential uplift of the High Himalayas. It has been suggested that a long and narrow arc of High Himalayas has been uplifted during quaternary.

Important Mountain passes in Himalayas

The rugged terrain makes few routes through the mountains possible. Some of these routes include:

- **Banihal** is an important pass connecting the hill areas of Jammu to the Kashmir Valley. The

Jawahar Tunnel (named after Pandit Jawaharlal Nehru), inaugurated in December 1956, was constructed for round-the-year surface transport

- **Zoji La** lies between the valley of Kashmir and the Kargil district, and is theonly Western entrance to the highlands of Ladakh.
- Rohtang Pass in Himachal Pradesh, India.
- Mohan Pass is the principal pass in the Shiwalik Hills, the southernmost and geologically youngest foothills running parallel to the main Himalayas in Sikkim.
- **Kora La** at 4,594 meters elevation on the Nepal-Tibet border at the upper end of Mustang. The Kali Gandaki Gorge transects the main Himalaya and Transhimalayan ranges. Kora La is the lowest pass through both ranges between K2 and Everest, but some 300 metres higher than Nathula and Jelepla passes further east between Sikkim and Tibet.
- **Aghill Pass:** Situated to the north of K2 in the Karakoram at an elevation of 5000 meters, joins Ladakh with the Xinjiang Province of China.
- **Bara-Lacha:** Bara-lacha la also known as Bara-lacha Pass is located in the Zanskar range connecting Lahaul district in Himachal Pradesh to Ladakh in Jammu and Kashmir, situated along the Leh-Manali highway.
- **Bomdi-La:** It connects Arunachal Pradesh with Lhasa, the capital of Tibet.
- **Chang-La:** The Changla Pass or Chang La Pass (el. 5,360 m is located in Ladakh, India. It is the third highest motorable road in the world.
- **Debsa Pass:** Debsa Pass is a 5,360-metre (17,590 ft) high mountain pass in the Himalaya mountains between the Kullu and Spiti Districts of Himachal Pradesh.
- **Dihang-Debang:** Situated in the state of Arunachal Pradesh at an elevation of about 4000 feet this pass connects Arunachal Pradesh with Mandalay (Myanmar). The Dihang-Debang Biosphere reserve is located around this area.

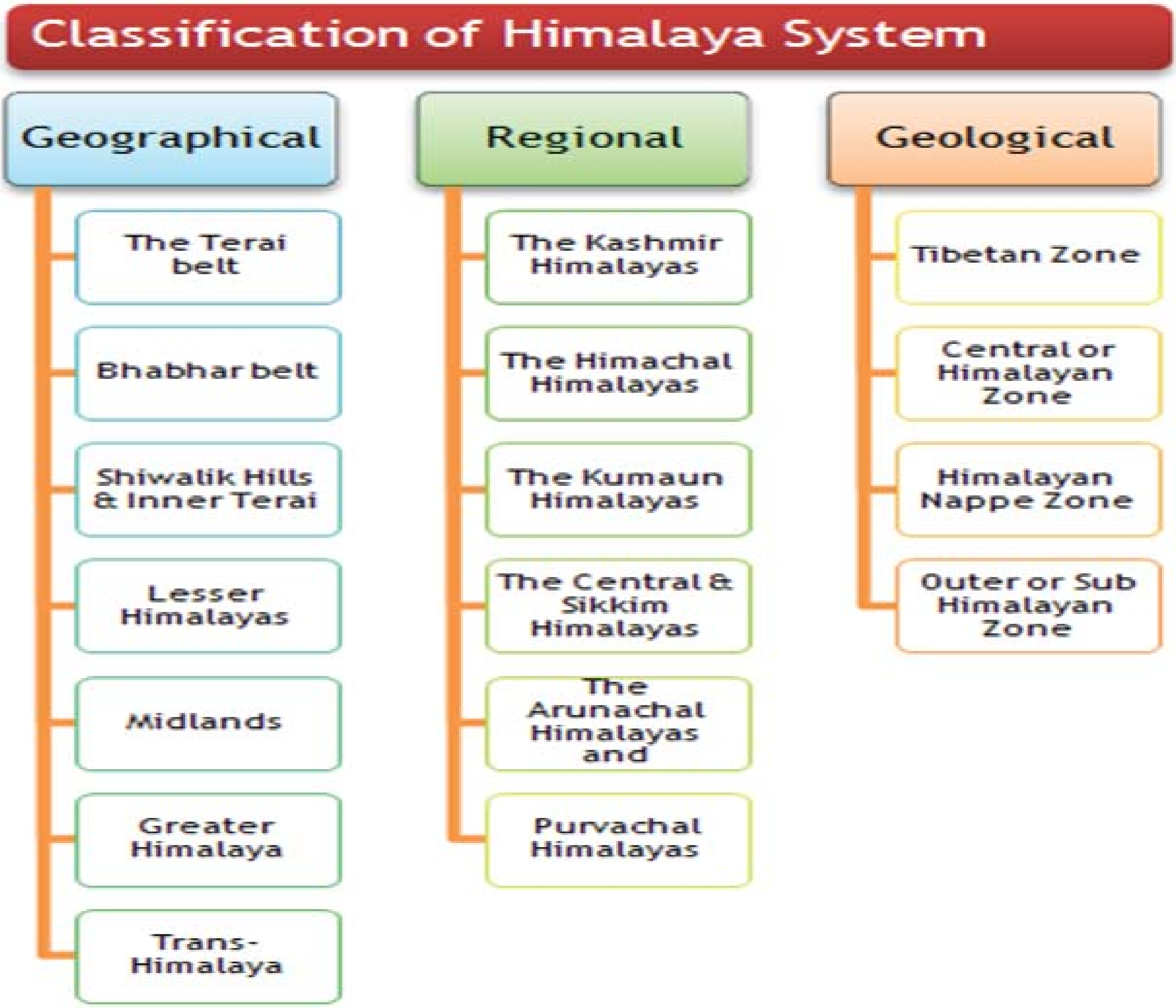
Important Peaks of Himalayas

Peak Name	Other names and meaning	Elevation
Everest	Sagarmatha (Nepali), “Head of the World”,	8,848
K2	Chogo Gangri, Qogir Feng, Mount Godwin Austen, Dapsang	8,611
Kangchenjunga	Kangchen Dzö-nga, “Five Treasures of the Great Snow”	8,586
Lhotse	South Peak	8,516
Makalu	The Great Black	8,462

Peak Name	Other names and meaning	Elevation
Cho Oyu	Qowowuyag, "Turquoise Goddess"	8,201
Dhaulagiri	White Mountain	8,167
Manaslu	Kutang, "Mountain of the Spirit"	8,156
Nanga Parbat	Diamir, "Naked Mountain"	8,126
Annapurna	Goddess of the Harvests	8,091
Gasherbrum I	Beautiful Mountain	8,080
Broad Peak	Faichan Kangri	8,047
Gasherbrum II	–	8,035
Shishapangma	Xixiabangma, "Crest Above The Grassy Plains", Gosainthan	8,013
Gyachung Kang	unknown	7,952
Gasherbrum IV	–	7,925
Masherbrum	unknown	7,821
Nanda Devi	Bliss-giving Goddess	7,817
Rakaposhi	Shining Wall	7,788
Tirich Mir	King of Shadows or "King of Tirich Valley"	7,708
Gangkhar Puensum	Gankar Punzum, "Three Mountain Siblings"	7,570
Ismoil Somoni Peak	Stalin Peak 1933–1962	7,495
Machapuchare	Fish Tail	6,993
Ama Dablam	Mother And Her Necklace	6,848
Kailash	Sanskrit: Kailāsa Parvata, Tibetan: Kang Rinpoche (Precious Snow Peak), Mandarin Chinese: Gāngrénbōqí fēng	6,638
(Don't Cram) **source wikipedia**		

Classification of the Himalaya System

The classification of the Himalayan Ranges is done on three bases viz. **Geographical**, **Regional** and **Geological.**



Geographical Regions of Himalaya

Himalayas can be divided into several geographical regions, which are distinct in flora and fauna also. These different regions, demarcated at various thrust and faults, make the climate of Himalayas diverse. The climate ranges from **tropical at the base of the mountains** to **permanent ice and snow at the highest elevations**. The *amount of yearly rainfall increases generally from west to east along the front of the range.* This diversity of climate, altitude, rainfall and soil conditions generates enormous biodiversity region making it one of the Biodiversity Hotspots of the world.

The main geographical regions of Himalaya include Terai belt, Bhabhar belt, Shiwalik Hills & Inner Terai, Lesser Himalayas, Midlands, Greater Himalaya and Trans-Himalaya.

Terai belt

Terai belt is the zone of sand and clay soils at the junction of northern plains and Himalayas. As the name suggests, Terai region gets higher rainfall than the plains. The speed of the Himalayan Rivers is slowed down in the Terai region and these *rivers deposit fertile silt during the monsoons* The water table in this region is high and vegetation is largely savannah in a mosaic of deciduous and evergreen forests called **Terai-Duar forests**.

Bhabhar belt

Bhabar belt is located above the Terai belt, also sometimes known as **Himalayan foothills**. It is made up of porous and rocky soils that get made of the debris washed down from the higher ranges. The climate here is subtropical and vegetation is *Himalayan subtropical pine forests* and *Himalayan subtropical broadleaf forests*. The *Himalayan subtropical pine forests* are dominated by **Chir trees** and *Himalayan subtropical broadleaf forests* are dominated by the sal tree *(Shorea robusta)*.

Shivalik Hills & Inner Terai

Shivaliks or Churia or Margalla Hills are the outermost range of foothills extending across the Himalayan region through Pakistan, India, Nepal and Bhutan. This is mainly located along a Himalayan Frontal Thrust (HFT).

The vegetation here is dominated by Himalayan subtropical pine and broadleaf forests. The Inner Terai valleys are open valleys north of Shiwalik Hills or nestled between Shiwalik sub ranges. Examples include Dehra Dun in India and Chitwan in Nepal.

Lesser Himalaya

Lesser Himalaya is also known as Mahabharat Zone. The hills here range 2000 to 3000 meters and are located along the Main Boundary Thrust (MBT) fault zone. This zone is home to ***some of the deepest canyons in the world***. The vegetation here is Himalayan subtropical forests.

Midlands

This region is located north of the Mahabharata range or Lesser Himalaya. It is located along the Main Central Thrust fault zone, where the Greater Himalaya begin. Here the vegetation is along with coniferous forests along with broadleaf forests.

Greater Himalaya

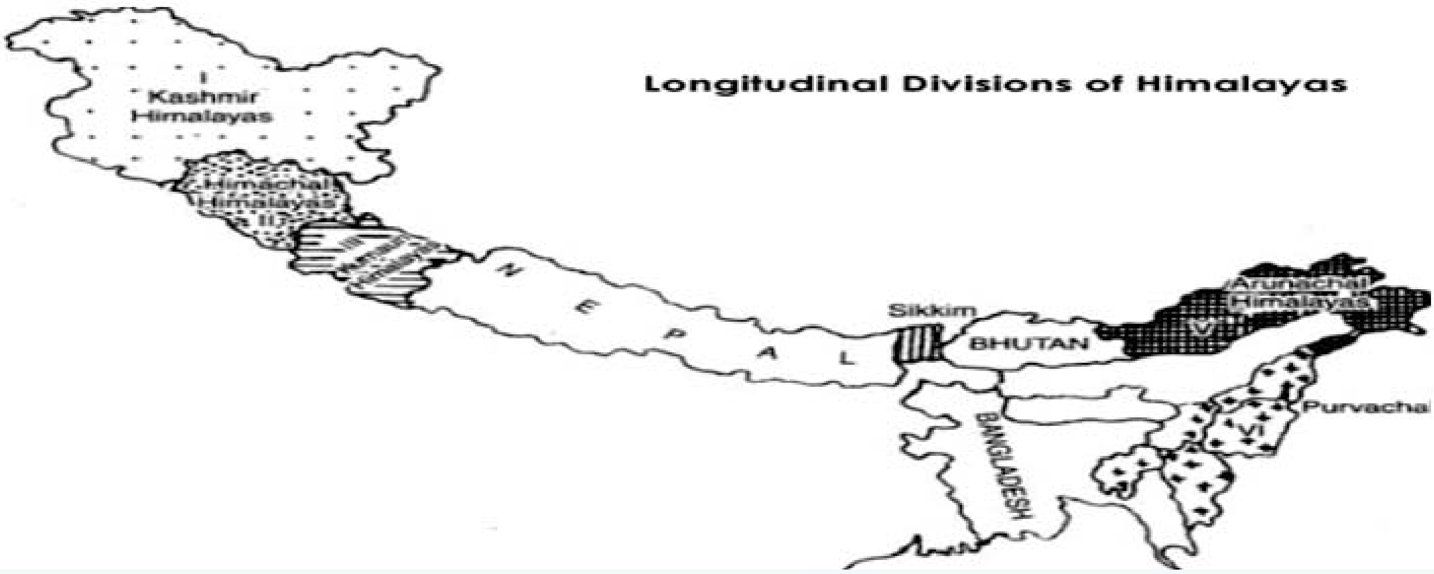
The Great Himalayas which is a **single range and the oldest** of the three ranges with a height above 6,000 m including Mount Everest, K2 and Kanchendzonga and nine of the 14 highest peaks in the world. Greater Himalayas is located north of the Main Central Thrust. Here the highest ranges rise abruptly into the realm of perpetual snow and ice. The vegetation here is Himalayan alpine shrub and meadows. The shrublands are composed of junipers as well as a wide variety of rhododendrons. They also possess a remarkable variety of wildflowers **Valley of Flowers National Park** in the western Himalayan alpine shrub and meadows contains hundreds of species. The upper limit of the grasslands increases from west to east, rising from 3,500 meters to 5,500 meters.

Trans-Himalayas

The trans-Himalaya is the rain-shadow region just behind the main peaks of the towering Himalayan Mountains. Notable places of the trans-Himalayas include the Tibetan Plateau, the Ladakh area of the Northern Indian Himalayas (Indus Valley) along with the Lahaul-Kinnaur-Spiti region and in north-western Nepal the Dolpo/Dolpa, Mustang, Manang, Humla and Mugu areas. The Trans-Himalayas, mainly composed of granites and volcanic rocks of Neogene and Paleogene age are bounded by the Kailas (southwest), Nganglong Kangri (north), and Nyainqêntanglha (southeast) mountain ranges and by the Brahmaputra River.

Regional Divisions of Himalayas

From west to East, Himalayas have been divided into six regions viz. Kashmir Himalayas, Himachal Himalayas, Kumaun Himalayas, Central & Sikkim Himalayas, Arunachal Himalayas and Purvachal Himalayas.



The Kashmir Himalayas

- The Kashmir Himalayas have the *largest number of Glaciers in India*. The Ladakh region of the Kashmir Himalayas is India's Cold Desert Biosphere reserve.
- A special feature of the valleys of Kashmir Himalayas is the Karewa deposits which are made up of silt, clay and sand.
- The Karewas are known for saffron cultivation and have orchards of fruits and dry fruits such as apple, peach, almond, and walnut.
- The major characters of Kashmir Himalayas are Glaciers, snow peaks, deep valleys and High Mountain passes.
- The important passes are Pir-Panjal, Banihal, Zoji-La, Saser-La, Chang-La, Jara-La etc.

The Himachal Himalayas

- Himachal Himalayas are spread in Himachal Pradesh. The Rohtang, Bara-Lacha, Shipki-La are important passes joining India and China.

- The valleys of Kullu, Kangra, Manali, Lahaul, Spiti are known for orchards and tourist spots.

The Kumaun Himalayas / Central Himalayas / Garhwal Himalayas

- Kumaun Himalayas are located between the Sutlej and Kali rivers. They are home to**India's highest peak Nanda Devi**.
- Other peaks located in Kumaun Himalayas are Kamet, Trishul, Badrinath, Kedarnath, Dunagiri, Gangotri etc. Gangotri and Pindar are important glaciers.

Garhwal Himalaya versus Kumaon Himalaya

- The western part of Kumaon Himalaya is known as Garhwal Himalayan while East as Kumaon. Geographically, Garhwal Himalaya lies between the lat. 29°31′ 9” N and 31°26′ 5″N and long. 77°33′ 5″E and 80°6′ 0″E with a total geographical area of 29,089 km.

The Sikkim (Central) Himalayas

- Sikkim Himalayas are located beyond the Kali River up to the Teesta River. Most of them are located in Nepal and known as Central Himalayas. These Himalayas are home to *highest peaks of Himalayas such as Everest, Kanchenjunga, Makalu, Dhaulagiri, Annapurna*
- ***It is characterized by very few passes***. Two passes viz. Nathu La and Jelep-La are important as they connect India's Sikkim to Tibet of China.

Eastern Himalayas & Purvanchal Hills

- The Eastern Himalayas occupy the Arunachal Pradesh and Bhutan. The important hills in this region are *Aka Hills, Daphla Hills, Miri Hills, Mishmi Hills, Namcha Barwa*The *Dihang and Debang passes of Arunachal Pradesh are its parts.*
- Passing from Arunachal Pradesh, there is an eastward extension of the Himalayas in the north-eastern region of India. This is known as Purvanchal Hills. Purvanchal Hills comprises the *Patkai hills, the Manipur hills, Bairal range, the Mizo hills and the Naga hills* It is a densely forested area, mainly composed of strong sandstones.

Syntaxial bends in Himalayas

Himalaya is marked at the both the western and eastern ends by geological Syntaxial bends in rock structure wherein the tight, fault bounded, trapdoor or pop-up uplifts of Naga Parbat on the west and Namche Barwa at the east have occurred in past few million years. These mark the end of Himalayas at both end, more prominently at the western end.

Geological Divisions of Himalayas

From a geological point of view, Himalayas can be divided into four zones. These zones are identified on the basis of age and composition of the rocks.

Tibetan Region

This region lies north of the Greater Himalayas. Rocks in this region date back from the Palaeozoic Era to Pleistocene Epoch.

Central or Himalayan Zone

This zone has **Isoclinal folds** and it includes the Greater Himalayas and some parts of Lesser Himalayas. *The Isoclinal folds are essentially parallel to each other* and thus approximately parallel to the axial plane. This region has abundant rocks such as granite as well as metamorphic rocks like schists and gneiss. This region also has sedimentary rocks.

Himalayan Nappe Zone

A nappe (literally means tablecloth) is a large sheetlike body of rock that has been moved some kilometers away from its original position. Nappes form during continental plate collisions, when folds are sheared so much that they fold back over on themselves and break apart. The resulting structure is a large-scale recumbent fold. The nappes are most common in Kashmir and Kumaun Himalayas.

Outer or Sub-Himalayan Zone

This zone includes the Siwalik range which is mainly composed of sedimentary deposits of upper tertiary period. This implies that the Shivalik hills are mainly derived from the eroded material of the main Himalayan ranges.

Eastern Himalayas versus Western Himalayas

Himalayas are also divided in terms of Eastern and Western Himalayas, the two parts which are different from each other in many ways. The following table makes these important distinctions:

Western Himalayas	Eastern Himalayas
1. Extends till west of River Kali (around 80°E Longitude). 2. Height of the mountains from the plains in this part rises in a number of stages. The high mountain ranges are at a long distance from the plains 3. Amount of rainfall here is less and is 1/4th of that of Eastern Himalayas. 4. *The dominant vegetation in the western Himalayas is Coniferous forests and alpine vegetations.* The Natural vegetation reflects the impact of lower rainfall. 5. The altitude of the Western Himalayas is higher than the Eastern Himalayas 6. Snowline is HIGHER than Eastern Himalayas 7. Western Himalayas receive more precipitation from northwest in the winters 8. Less biodiversity in comparison to eastern Himalayas	1. This is considered to be ranging from east of the Singalila ranges in Sikkim (88°E Longitudes) to eastern boundaries of Himalayas. 2. This part rises abruptly from the plains, thus peaks are not faraway from the plains (Example: Kanchenjunga) 3. This region received 4 times more rainfall than western Himalayas. Due to high rainfalls, it is covered with dense forests. 4. Snowline is LOWER than Western Himalayas 5. Eastern Himalayas receive more precipitation from south-eastern monsoon in the summers. 6. Much ahead from western Himalayas in terms of Biodiversity and is one of the Biodiversity hotspots

Some more observations

- Western Himalayas are above 36°N Lat. (Mt. Godwin-Austin), and eastern Himalayas are below 28°N Lat. (Kanchenjunga). Thus the 8° difference in the latitude between the two ends of the Himalayas has affected the altitude of the regional snowline so that it is lower in western Himalayas and higher in the east. .
- The difference in the observed level of the snowline in western and eastern Himalayas is also due to yearly changes in the climatic conditions of the region. In the Himalayas, volume of precipitation changes from year to year, and with that the altitude at which snow falls also changes. In the years of high precipitation, often snow falls at lower altitude than the years of low precipitation.

Northern Slopes and Southern Slopes of Himalayas

The Southern slopes in Himalayan region are covered with thick vegetation, while the northern slopes are generally barren. The reasons are many. The first is that Southern slopes receive more precipitation, as we all know and northern slopes in a rain shadow area. Further, the northern slopes usually receive sun rays only for a few hours during the day at a low angle. The southern slopes receive comparatively vertical rays during the middle of the day. As a result, southern slopes being warmer fall in the area of greater evapotranspiration, and that is why the vegetation is up to a higher altitude in southern slopes. Longer periods of sunshine also have an effect on the volume of snow accumulation on the southern slopes. Due to longer period of sunshine, less snow accumulates on the southern slopes than on the northern slopes. That is why; the snowline on southern slopes is lower in comparison to the northern slopes.

- Himalayas are oriented east-west and their southern slopes are in direct sunshine for a larger part of the year so the snowline on the southern slopes of the ridges is higher than the northern slopes.
- Volume of precipitation decreases from the south towards the north, therefore southern ranges in eastern Himalayas have lower snowline than the northern ranges.
- Volume of precipitation *increases with altitude.*

The Great Plains

The Indo-Gangetic plains or the Great Plains are large alluvial plains dominated by three main rivers, the Indus, Ganges, and Brahmaputra. The great plains of India run parallel to the Himalayas, from Jammu and Kashmir in the west to Assam in the east, and drain most of northern and eastern India. The plains stretch 2400 kilometers from west to east and encompass an area of 700,000 km².

The major rivers in this region are the Ganges, Indus, and Brahmaputra along with their main tributaries–Yamuna, Chambal, Gomti, Ghaghara, Kosi, Sutlej, Ravi, Beas, Chenab, and Teesta—as well as the rivers of the Ganges Delta, such as the Meghna. The Great plain is home to nearly 1/7 of the world's population. It is bound on the north by the abruptly rising Himalayas, which feed its numerous rivers and are the source of the fertile alluvium deposited across the region by the two river systems. The southern edge of the plain is marked by the Vindhya- and Satpura Range, and the Chhota Nagpur Plateau. On the west rises the Iranian Plateau.The Great Plains of India consists largely of **alluvial deposits** brought down by the rivers originating in the Himalayan and the peninsular region. The exact depth of alluvium has not yet been fully determined. As per recent estimates the average depth of alluvium in the southern side of the plain (north of Bundelkhand) varies between 1300 to 1400 meters, while towards the Shivaliks, the depth of alluvium increases. The maximum depth of alluvium has been recorded in Haryana near Ambala and Yamunanagar.

Divisions of Great Plain

Great plains are generally classified into four divisions:

Bhabar belt

Bhabar belt is adjacent to the foothills of the Himalayas and consists of **boulders and pebbles** which have been carried down by the river streams. As the porosity of this belt is very high, the streams flow underground. The Bhabar is generally narrow about 7–15 km wide. *Babar is wider in the western plains in comparison to the eastern plans of Assam.* The porosity of Bhabar is so high that most of the narrow streams get disappeared in this belt only and some of them go underground. This is also one reason that it is not suitable for crops and only big trees are able to survive.

Thus, Bhabar belt is a **narrow belt** that is located above the Terai belt, also sometimes known as **Himalayan foothills.** It is made up of porous and rocky soils that get made of the debris washed down from the higher ranges. *Streams disappear in this belt.*

Terai belt

The Terai belt lies next to the Bhabar region and is composed of newer alluvium. The underground streams reappear in this region. The region is excessively moist and thickly forested. It also receives heavy rainfall throughout the year and is populated with a variety of wildlife. The Terai tract lies south of the Bhabar belt. The tract is *marshy and lots of mosquitoes thrive there*. The *Terai belt is wider in eastern side especially in the Brahmaputra valley.* The high rainfall, newer alluvium makes it excessive damp and lots of forests are found here. This implies that Terai belt is rich in biodiversity. Over the period of time, the forests have been cleared in various states such as Uttarakhand, Uttar Pradesh, Haryana, Punjab, and Jammu Divisions for cultivation of crops. Terai belt is known for the good cultivation of sugar-cane, rice, wheat, maize, oilseeds, pulses, and fodder.

Bhangar belt

This is the largest part of the Northern Plains made up of **old alluvium** and forms the alluvial terrace of the flood plains. The soil in this region consists of **calcareous deposits called kankar**. The Bangar or Bhangar belt consists of **older alluvium**. In the Gangetic plains, it has a low upland covered by Laterite deposits. The Bhangar formations were deposited during the middle Pleistocene Period. The Bhangar land lies above the flood limits of the rivers. The older alluvium soil is dark in colour, rich in humus content and productive. Bhangar is generally a well drained and the **most productive land of the Great Plains of India**.

Khadar belt

The Khadar belt lies in lowland areas after the Bhangar belt. It is made up of fresh newer alluvium which is deposited by the rivers flowing down the plain. The Khadar tracts are enriched by fresh deposits of silt every year during the rainy season. The Khadar land consists of sand, silt, clay and mud. After Independence, most of the Khadar land has been brought under cultivation and devoted to sugarcane, rice, wheat, maize, oilseeds. legumes, and fodder crops.

Delta Plains

The deltaic plain is an extension of the Khadar land. It covers about 1.9 lakh sq km of area in the lower reaches of the Ganga River. It is an area of deposition as the river flows in this tract sluggishly. The deltaic plain consists mainly of old mud, new mud and marsh. *In the delta region, the uplands are called 'Char' while marshy areas are known as 'Bili.* The delta of Ganga being an active one, is extending towards the Bay of Bengal.

Importance of Great Plains

The Indo-Gangetic belt is the world's most extensive expanse of uninterrupted alluvium formed by the deposition of silt by the numerous rivers. The plains are flat and mostly treeless, making it conducive for irrigation through canals. The area is also rich in ground water sources. The plains are the world's most intensely farmed areas. The main crops grown are rice and wheat, which are grown in rotation. Others include maize, sugarcane and cotton.

The Indo-Gangetic plains rank among the world's most densely populated areas. The Great Plains of India are covered with one of the most productive soils of the world. Its soils have the capacity to grow any crop of the tropical and temperate regions. The plains are often termed as the 'Granary of India'. Most of the rivers traversing the Northern Plains of India are perennial in nature. A number of canals have been carved out of these rivers which make agriculture more remunerative and sustainable. The water table is high and suitable for tube well irrigation. The gentle gradient makes it navigable over long distances.

Thar Desert

Thar Desert or Great Indian Desert is the **world's ninth largest desert**. It forms a significant portion of western India and covers an area of about 200,000 km² to about 238,700 km². In Pakistan is continues as **Cholistan Desert**. Most of the Thar Desert is situated in Rajasthan, covering 61% of geographic area of Rajasthan. About 10 percent of this region comprises sand dunes, and the remaining 90 percent consist of craggy rock forms, compacted salt-lake bottoms, and interdunal and fixed dune areas. Annual temperatures can range from 0°C in the winter to over 50°C during the summer. Most of the rainfall received in this region is associated with the short July–September southwest monsoon that brings around 100–500 mm of precipitation. Water is scarce and occurs at great depths, ranging from 30 to 120 m below the ground level. Rainfall is precarious and erratic, ranging from below 120 mm in the extreme west to 375 mm eastward. The soils of the arid region are generally sandy to sandy-loam in texture. The consistency and depth vary as per the topographical features. The low-lying loams are heavier and may have a hard pan of clay, calcium carbonate or gypsum.

Origin of Thar Desert

The origin of the Thar Desert is a controversial subject. Some consider it to be 4000 to 10,000 years old, whereas others state that aridity started in this region much earlier. Another theory states that area turned to desert relatively recently: perhaps around 2000 – 1500 BC. Around this time the Ghaggar-Hakra ceased to be a major river. It now terminates in the desert but at one time was a water source for the Indus Valley Civilization centre of Mohenjodaro.

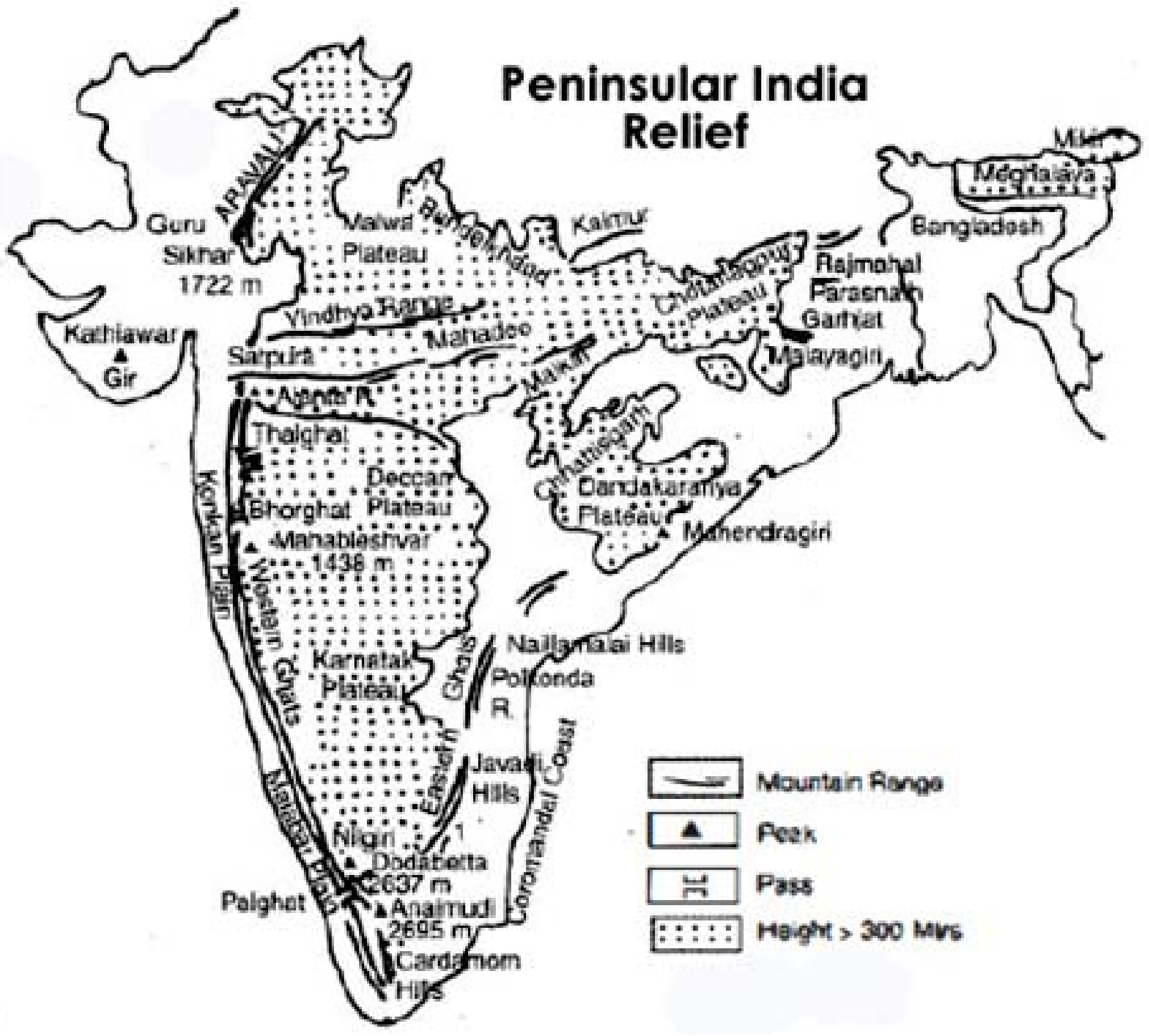
It has been observed through remote sensing techniques that*Late Quaternary climatic changes and neotectonics have played a significant role in modifying the drainage courses in this part and a large number of palaeochannels exist.* Most studies did not share the opinion that the palaeochannels of the Sarasvati River coincide with the bed of the present-day Ghaggar and believe that the Sutlej along with the Yamuna once flowed into the present riverbed. It has been postulated that the Sutlej was the main tributary of the Ghaggar and that subsequently the tectonic movements might have forced the Sutlej westwards, the Yamuna eastwards and thus dried up the Ghaggar-Hakra.

Studies on Kalibangan in the desert region by Robert Raikes indicate that it was abandoned because the river dried up. Prof. B. B. Lal (retd. Director General of Archaeological Survey of India) supports this view by asserting: *"Radiocarbon dating indicates that the Mature Harappan settlement at Kalibangan had to be abandoned around 2000-1900 BCE.*

And, as the hydrological evidence indicates, this abandonment took place on account of the drying up of the Ghaggar-Hakra. This latter part is duly established by the work of Raikes, an Italian hydrologist, and of his Indian collaborators".

Peninsular India

The Peninsular India comprises the diverse topological and climatic patterns of South India. The Peninsula is in shape of a vast inverted triangle, bounded on the west by the Arabian Sea, on the east by the Bay of Bengal and on the north by the Vindhya and Satpura ranges. The line created by the Narmada River and Mahanadi river is the traditional boundary between northern and southern India. Covering an area of about 16 Lakh km², the peninsular upland forms the largest physiographic division of India. It is bounded by the Aravallis in the North West, Hazaribagh and Rajmahal Hills in the northeast, the Western Ghats (Sahayadri Mountains) in the west and the Eastern Ghats in the east. The **highest peak of Peninsular India is Anamudi** that is 2695 metres above sea level.



The narrow strip of verdant land between the Western Ghats and the Arabian Sea is the Konkan region; the term encompasses the area south of the Narmada as far as Goa. The Western Ghats continue south, forming the Malnad (Canara) region along the Karnataka coast, and terminate at the Nilgiri mountains, an inward (easterly) extension of the Western Ghats. The Nilgiris run in a crescent approximately along the borders of Tamil Nadu with northern Kerala and Karnataka, encompassing the Palakkad and Wayanad hills, and the Satyamangalam ranges, and extending on to the relatively low-lying hills of the Eastern Ghats, on the western portion of the Tamil Nadu–Andhra Pradesh border. The Tirupati and Anaimalai hills form part of this range.

The Deccan plateau, covering the major portion of the states of Maharashtra, Karnataka and Tamil Nadu, is the vast elevated region bound by the C-shape defined by all these mountain ranges. No major elevations border the plateau to the east, and it slopes gently from the Western Ghats to the eastern coast.

The Peninsular India can be divided into four regions viz. Central Highlands, Deccan Plateau, Western Ghats or Sahayadri and Eastern Ghats

Central Highlands

The northern central highlands of peninsular India include the Aravallis, the Malwa Plateau, and some parts of Vindhyan Range.

Aravallis

Aravallis Range literally meaning 'line of peaks' running approximately 800 km from northeast to southwest across states of Rajasthan, Haryana, and Gujarat and Pakistan's provinces of Punjab and Sindh. The northern end of the range continues as isolated hills and rocky ridges into Haryana state, ending in Delhi. The famous **Delhi Ridge** is the last leg of the Aravalli Range, which traverses through South Delhi and terminates into Central Delhi. The southern end is at **Palanpur near Ahmadabad**, Gujarat. The highest peak is Guru Shikhar in Mount Abu. Rising to 1722 meters, it lies near the southwestern extremity of the range, close to the border with the Gujarat. The city of Udaipur with its lakes lies on the south slope of the range in Rajasthan. Numerous rivers arises amidst the ranges including, Banas River, Luni River, Sakhi, Sabarmati River. The Great Boundary Fault (GBF) separates the Aravallis from the Vindhyan Mountains.

Origin of Aravallis

The Aravallis Range is the eroded stub of a range of ancient folded mountains that rose in a Precambrian event called the **Aravalli-Delhi Orogeny**. The range joins two of the ancient segments that make up the Indian craton, the Marwar segment to the northwest of the range, and the Bundelkhand segment to the southeast. It has been postulated that the Aravalli peaks were extremely high once but since have worn down almost completely by millions of years of weathering. In stark contrast Himalayas are continuously rising young fold mountains of today. Aravallis is rich in mineral resources. The erosion of Aravalli has a great concern for the environment because the ranges from a natural barrier against the spread of the Thar desert northwards into the Gangetic plains in the Gangetic basin and Gujarat.

Malwa Plateau

The Malwa region occupies a plateau in western **Madhya Pradesh** and south-eastern **Rajasthan with Gujarat** in the west.

- The region includes the Madhya Pradesh districts of Dewas, Dhar, Indore, Jhabua, Mandsaur, Neemuch, Rajgarh, Ratlam, Shajapur, Ujjain, and parts of Guna and Sehore, and

- Rajasthan districts of Jhalawar and parts of Banswara and Chittorgarh.
- The plateau is bound in north-east by the Hadoti region, in the north-west by the Mewar region, in the west by the Vagad region and Gujarat. To the south and east is the Vindhya Range and to the north is the Bundelkhand upland. The average elevation of the plateau is 450-500 m.

The western part of the Malwa Plateau is drained by the Mahi River, while the Chambal River drains the central part, and the Betwa River and the headwaters of the Dhasan and Ken rivers drain the east. The Shipra River is of historical importance because of the Simhasth mela, held every 12 years. Other notable rivers are Parbati, Gambhir and Choti Kali Sindh.

- The Vindhya Range marks the southern boundary of the plateau, and is the source of many rivers of the region.

Vegetation in the Malwa Plateau is tropical dry forest, with scattered teak (*Tectona grandis*) forests. The other main trees are Butea, Bombax, Anogeissus, Acacia, Buchanania and Boswellia. The shrubs or small trees include species of *Grewia, Ziziphus mauritiana, Casearia, Prosopis, Capparis, Woodfordia, Phyllanthus,* and *Carissa.*

The Malwa plateau is considered to be an extension of the Deccan Traps and was formed at the end of Cretaceous period. Black, Brown and Bhtatori or stony soil is abundantin the Malwa Plateau. The black soil requires less irrigation because of its high capacity for moisture retention. The other two soil types are lighter and have a higher proportion of sand.

Vindhyan Range

The Vindhyan range is bounded by the Central Highlands on the south and the Aravalis on the northwest. It extends from Jobat (Gujarat) and Chittorgarh (Rajasthan) to Sasaram in Bihar for about 1050 km with general elevation between 450 to 600 metres. The western end of the Vindhyan range is in Gujarat at the eastern side of the Gujarat peninsula, near the border with Rajasthan and Madhya Pradesh. Reaching the sub-continent proper, the range runs east and north nearly to the Ganges River at Mirzapur. The area to the north and west of the range are arid and inhospitable, located in the shadow of both the Vindhya and the higher Aravalli range to the south blocking the prevailing winds.

The southern slopes of the Vindhyan Range are drained by the Narmada River, which proceeds westward to the Arabian Sea in the wide valley between the Vindhya Range and the parallel Satpura Range farther to the south. The northern slopes of the range are drained by tributaries of the Ganges, including the Kali Sindh, Parbati, Betwa, & Ken (both are tributary of the Yamuna,), Son & Tamsa or Tons both are tributary of the Ganges, drains the southern slopes of the range at its eastern end.

Vindhyachal Plateau

The Vindhyachal plateau lies to the north of the central part of the range. The cities of Bhopal, the capital of Madhya Pradesh, and Indore lie on this plateau, which rises higher than the Indo-Gangetic plain to its north.

Satpura Range

The Satpura range parallels the Vindhya Range to the north, and these two east-west ranges divide Indian Subcontinent into the Indo-Gangetic plain of northern India and the Deccan Plateau of the south. Satpura range rises in eastern Gujarat state near the Arabian Sea coast, running east through the border of Maharashtra and Madhya Pradesh to the east till Chhattisgarh.

- The Narmada River originates from north-eastern end of Satpura & runs in the depression between the Satpura and Vindhya ranges, draining the northern slope of the Satpura range and southern slopes of Vindhyan range, running west towards the Arabian Sea.
- The Tapti River originates from eastern-central part of Satpura, crosses the range in the center & further runs at the southern slopes of Satpura towards west meeting the Arabian Sea at Surat, draining central & the southern slopes of the Satpura Range.
- Please note that Mount Dhupgarh or Dhoopgarh is the highest point in the Satpura Range and in Madhya Pradesh, India. Located near Pachmarhi, it has an elevation of 1,350 metres.

The Chhotanagpur Plateau

Chhotanagpur Plateau covers much of Jharkhand state. It also covers the adjacent parts of Odisha, West Bengal, Bihar and Chhattisgarh. The Indo-Gangetic plain lies to the north and east of the plateau, and the basin of the Mahanadi River lies to the south. The total area of the Chhotanagpur Plateau is approximately 65,000 square kilometres. This Plateau consists of three steps. The highest step is in the western part of the plateau, ranging from 3,000 -3500 feet. The next part contains larger portions of the old Ranchi and Hazaribagh districts and some parts of old Palamu district, before these were broken up into smaller administrative units. The general height is 2,000 feet. The lowest step of the plateau is at an average level of around 1,000 feet, covering the old Manbhum and Singhbhum districts.

The Chhotanagpur Plateau is composed of *Archaean granite and gneiss rocks with patches of Dharwar* and Damuda series of the Gondwana Period, and the lava flow of the Cretaceous Period. The western higher plateau of the Chhotanagpur Plateau is called Pat region. It is believed to be composed of Deccan lava. The largest part of the Chhotanagpur Plateau is called**Ranchi Plateau**. Damodar River originates here and flows through a rift valleyDamodar basin forms a trough between the Ranchi and Hazaribagh plateaus resulting from enormous fractures at their present edges, which caused the land between to sink to a great depth and incidentally preserved from denudation the Karanpura, Ramgarh and Bokaro coalfields. The plateau is covered with a variety tropical and subtropical dry broadleaf forests of which Sal forest is predominant. The plateau is home to the Palamau Tiger Reserve. Chhotanagpur plateau is a store house of minerals like mica, bauxite, copper, limestone, iron ore and coal. The Damodar valley is rich in coal and it is considered as the prime centre of coking coal in the country. Massive coal deposits are found in the central basin spreading over 2,883 km2. The important coalfields in the basin are Jharia, Raniganj, West Bokaro, East Bokaro, Ramgarh, South Karanpura and North Karanpura.

Karbi-Meghalya plateau

Karbi-Meghalya plateau is in fact an extension of the main Indian peninsular plateau and are originally two different plateaus – Karbi Anglong plateau and Meghalya plateau. It is believed that due to the force exerted by the north-eastwardly movement of the Indian plate at the time of the Himalayan origin, a huge fault was created between the Rajmahal hills and the Karbi-Meghalaya plateau. Later, this depression was filled up by the depositional activity of numerous rivers. Today the Maghalaya and Karbi Anglong plateau remains detached from the main Peninsular block. This area receives maximum rainfall from the South-West monsoon.

Deccan Plateau

The Deccan Plateau covers the majority of the southern part of the country. It is located between three mountain ranges and extends over **eight Indian states**. The plateau covers 4,22,000 sq. km., *43 percent of India's landmass*. On the west of the plateau are the Western Ghats and in the east are the Eastern Ghats. These mountain ranges rise from their respective nearby coastal plains and nearly meet at the southern tip of India. The mountains make the southward-pointing vertex of a triangle. The northern boundary of the triangle is made up by the Satpura Range and Vindhyan Range. These northern ranges separate the plateau from the heavily populated riverine plains of northern India.

Important Notes on Deccan Plateau

- This Plateau makes up a triangle nested within the familiar downward-pointing triangle of the Indian sub-continent's coastline.
- In the south, the plateau is mostly over 1,000 metres above sea level. In the north it is mostly about 500 m above sea level. The Deccan Plateau is **higher in the west and slopes gently eastwards**. This would imply that *most Deccan plateau rivers flow from west to east*. The rivers flowing through the Deccan plateau have cut deep valleys and divided the plateau into several smaller plateus such as the Maharastra Plateau, Andhra Plateau and Karnataka Plateau.
- The plateau is very big and there are many habitats: different Ecosystems with different sorts of vegetation, climate, geology and animals. The *forests on the plateau are older than the Himalayan mountains*.

- The Western Ghats mountain range is tall and blocks the moisture from the southwest monsoon from reaching the Deccan Plateau, this is the reason that the Deccan Plateau region receives very little rainfall.
- The Godavari River and its tributaries, including the Indravati River, drain most of the northern portion of the plateau, rising in the Western Ghats and flowing **east towards the Bay of Bengal**. The Tungabhadra River, Krishna River and its tributaries, including the Bhima River, which also run from west to east, drain the central portion of the plateau.
- The southernmost portion of the plateau is drained by the Kaveri River, which rises in the Western Ghats of Karnataka and bends south to break through the Nilgiri Hills at Hogenakal Falls into Tamil Nadu, then forming the *Sivasamudram Falls* at the island town of Shivanasamudra, the second-biggest waterfall in India and the sixteenth-largest in the world, before flowing into the Stanley Reservoir and the Mettur Dam that created the reservoir and finally emptying into the Bay of Bengal.
- The two main rivers which do not flow into the Bay Of Bengal are the Narmada and Tapti. They start in the Eastern Ghats and flow into the Arabian Sea.
- *All Deccan plateau rivers depend on the rains and dry up in the summers.*

Western Ghats

The Western Ghats or Sahyādri runs north to south along the western edge of the Deccan Plateau, and separates the plateau from a narrow coastal plain along the Arabian Sea. The range starts near the border of Gujarat and Maharashtra, south of the Tapti River, and runs approximately 1600 km through the states of Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala ending at Kanyakumari. These hills cover 160,000 km² (roughly 6% of India's total geographical area) and form the catchment area for complex riverine drainage systems that drain almost 40% of India. The average elevation is around 1,200-1300 metres. Western Ghats are home to 30% of flora and fauna species found in India.

States and Union Territories under Western Ghats

Western Ghats are spread in six states viz. Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu, Kerala and two Union Territories viz. Dadra & Nagar Haveli and Pondicherry. The range starts near the border of Gujarat south of Tapti river where foothills of the ranges are occupying the eastern portion of Dadra and Silvassa in D&N. Running around 1600 kilometers down south, it ends at its **southern part** at Anamudi peak in Kerala. **Mahe** in Pondicherry is situated on the Malabar coast on the **Western Ghats** surrounded by Kerala

Mountains

Western Ghats are known as Sahyadri in northern Maharashtra, *Sahya Parvatam* in Kerala and

Nilagiri Malai in Tamil Nadu. Western Ghats are home to many hill stations like Matheran, Lonavala-Khandala, Mahabaleshwar, Panchgani, Amboli Ghat, Kudremukh and Kodagu.
The extreme northern parts of Western Ghats falls in the Dangs district of Gujarat, known for Dang (Bamboo) forests. The confluence of the Eastern and the Western Ghats is atBiligirirangan Hills in Karnataka. Anamudi 2,695 metres in Kerala the highest peak in Western Ghats. Mullayanagiri is the highest peak in Karnataka 1,950 meters. The smaller ranges of the Western Ghats include the Cardamom Hills and the Nilgiri Hills. Cardamom hills are located in southeast Kerala and southwest Tamil Nadu. They conjoin the Anaimalai Hills to the northwest, the Palni Hills to the northeast and the Agasthyamalai Hills to the south as far as the Ariankavu pass. The crest of the hills forms the boundary between Kerala and Tamil Nadu. Anamudi is also located in Cardamom Hills. The Nilgiri Hills are home to the hill station Ooty.
There are many important passes in Western Ghats such as Tamhini Ghat, Palakkad Gap, Naneghat, Kasara ghat etc.
The northern portion of the narrow coastal plain between the Western Ghats and the Arabian Sea is known as the Konkan Coast, the central portion is called Kanara and the southern portion is called Malabar region or the Malabar Coast. The foothill region east of the Ghats in Maharashtra is known as Desh, while the eastern foothills of the central Karnataka state is known as Malenadu.

Geology

There are two views regarding the Geology of the Western Ghats. One view says the mountains of the Western Ghats are Block Mountains formed due to the down warping of a part of land into the Arabian Sea. Other view says that the mountains of the Western Ghats are *not true mountains*, but are the faulted edge of the Deccan Plateau. Major rocks found in the region include Basalt, charnockites, granite gneiss, khondalites, leptynites, metamorphic gneisses with detached occurrences of crystalline limestone, iron ore, dolerites and anorthosites.

Rivers

The rivers that originate in Western Ghats and flow towards west are Periyar, Bharathappuzha, Netravati, Sharavathi, Mandovi etc. The west flowing rivers of Western Ghats are fast-moving, owing to the short distance travelled and steeper gradient. This makes Western Ghats more useful than Eastern Ghats in terms of production of hydroelectricity. The steep gradient makes the Jog Falls on Shravasthi River in Karnataka as one of the most spectacular waterfalls in India. Narmada and Tapti although don't rise from Western Ghats but flow westwards.
The rivers that originate in Western Ghats and flow towards east include three major rivers viz. Godavari, Krishna and Kaveri, and many smaller / tributary rivers such as Tunga, Bhadra, Bhima, Malaprabha, Ghataprabha, Hemavathi, Kabini. These east flowing rivers are comparatively slower moving and eventually merge into larger rivers such as the Kaveri and Krishna.

Climate

In comparison to the eastern side, the western side of the Western Ghats is area of high rainfall because the mountains intercept the rain-bearing westerly monsoon winds. The dense forests also contribute to high orographic precipitation. The climate is humid and tropical in the lower reaches tempered by the proximity to the sea. Elevations of 1,500 m and above in the north and 2,000 m and above in the south have a more temperate climate. Average annual temperature here is around 15 °C. In some parts frost is common, and temperatures touch the freezing point during the winter months. Mean temperature range from 20 °C in the south to 24 °C in the north. It has also been observed that the *coldest periods in the south Western Ghats coincide with the wettest.*

During the monsoon season between June and September, the unbroken Western Ghats chain acts as a barrier to the moisture laden clouds. The heavy, eastward-moving rain-bearing clouds are forced to rise and in the process deposit most of their rain on the windward side. Rainfall in this region averages 3,000–4,000 mm. The eastern region of the Western Ghats which lie in the rain shadow, receive far less rainfall averaging about 1,000 mm bringing the average rainfall figure to 2,500 mm.

Vegetation

Due to a sharp contrast in precipitation between western and eastern slopes of the Western Ghats, there is a clear difference between the vegetation of the two sides. Similarly, there is also a clear contrast between the northern and southern Western Ghats. Moreover, the vegetation found on the high hills is also different from the low hills. Thus, there are various different kinds of vegetations found in Western Ghats as follows:

- The western slopes havetropical and subtropical moist broadleaf forestsmarked predominantly by Rosewood, Mahogany, Cedar etc. These slopes appear green in almost all parts of the year. No time is fixed when these trees would shade their leaves.
- The eastern slopes of the Western Ghats have dry as well as moist deciduous forests marked predominantly by Teak, Sal, Shisham, Sandalwood etc. trees.
- Further, on the northern side of the Wayanad forests; we find *dry deciduous forests* while on the southern side there are wet deciduous forests. The evergreen Wayanad forests of Kerala mark the transition zone between the northern and southern ecoregions of the Western Ghats. The southern ecoregions are generally wetter and more species-rich. South Western Ghats Montane rain forests are the most species-rich ecoregions in peninsular India. Eighty percent of the flowering plant species of the entire Western Ghats range are found in this ecoregion.
- The areas which are high in elevation are cooler and wetter in the north and so the forests there are called North Western Ghats Montane rain forests. The vegetation here is evergreen characterized by trees of family Lauraceae. Such plants include *Litsea glutinosa* or ***Maida lakri***

in Hindi (a plant of medicinal value), Cinnamomum (Tejpatta) etc.

- There are montane grasslands as well as stunted forests also in the Western Ghats.
- The forest in the Western Ghats has been severely affected due to human activities, especially clear felling for tea, coffee, and teak plantations during 1860 to 1950. Species that are rare, endemic and habitat specialists are more adversely affected and tend to be lost faster than other species. Complex and species rich habitats like the tropical rainforest are much more adversely affected than other habitats. The area is ecologically sensitive to development. Though this area covers barely five percent of India's land, 27% of all species of higher plants in India (4,000 of 15,000 species) are found here. Almost 1,800 of these are endemic to the region.

Protected Areas

Western Ghats is home to India's two biosphere reserves, 13 National parks, several wildlife sanctuaries and many Reserve Forests. The Nilgiri Biosphere Reserve comprising 5500 km² of the evergreen forests of Nagarahole, deciduous forests of Bandipur National Park and Nugu in Karnataka and adjoining regions of Wayanad and Mudumalai National Park in the states of Kerala and Tamil Nadu forms the largest contiguous protected area in the Western Ghats. The Silent Valley National Park in Kerala is among the last tracts of virgin tropical evergreen forest in India.

Fauna

There are two biodiversity hotspots in our country viz. Eastern Himalayas and Western Ghats. Western Ghats are home to over 5000 species of flowering plants, 139 mammal species, 508 bird species and 179 amphibian species, many undiscovered species lives.

Following four species are endemic to Western Ghats.

- Malabar Large-spotted Civet
- Lion-tailed Macaque
- Brown Palm Civet
- Nilgiri Tahr

Malabar Large-spotted Civet is a critically endangered nocturnal mammal. The Lion-tailed Macaque is endangered and is arboreal (lives on trees). Only 2500 members of this species are remaining. The largest population of Lion Tailed Macaque is in Silent Valley National Park Kudremukh National Park also protects a viable population. Nilgiri tahr is a goat antelope found high up in the mountains of southern India, it is known locally as the 'Nilgiri ibex'. Its largest population is found within the Eravikulam National Park. Outside breeding seasons, males are found lower down in the best grazing fields, whilst female herds are found on the exposed cliff ledges. It has been classified as Endangered (EN) on the IUCN Red List. The brown palm civet's distribution extends from the southern tip of Western Ghats in Kalakkad Mundanthurai Tiger Reserve to Castle Rock in Goa to the north. They are nocturnal, and not as rare as previously thought and come under Least Concerned Category. These hill ranges serve as important wildlife corridors, allowing seasonal migration of endangered Asian Elephants. The *Nilgiri Bio-sphere is home to the largest population of Asian Elephants* and forms an important Project Elephant and Project Tiger reserve. Brahmagiri and Pushpagiri wildlife sanctuaries are important elephant habitats. Karnataka's Ghat areas hold over six thousand elephants (as of 2004) and ten percent of India's critically endangered tiger population.

Eastern Ghats

Eastern Ghats or Pūrbaghāṭa are a **discontinuous range** of mountains along India's eastern coast. They run from West Bengal through Orissa and Andhra Pradesh to Tamil Nadu in the south passing some parts of Karnataka. They are eroded and cut through by the four major rivers of southern India, the Godavari, Mahanadi, Krishna, and Kaveri. The mountain ranges run parallel to the Bay of Bengal. The Deccan Plateau lies to the west of the range, between the Eastern Ghats and Western Ghats.

The *Eastern Ghats are not as high as the Western Ghats.* The climate of the higher hill ranges is generally cooler and wetter than the surrounding plains and the hills are home to coffee plantations and enclaves of dry forest. The Bilgiri Hills, which run east from the Western Ghats to the River Kaveri, forms a forested ecological corridor that connects the Eastern and Western Ghats, and allows the second-largest wild elephant population in India to range between the South Eastern Ghats, the Biligiri and Nilgiri Hills, and the South Western Ghats. The famous temple Malai Mahadeshwara Hills Temple is situauted in Chamarajanagar District in the Karnataka state on the Eastern Ghat.

Important Facts on Eastern Ghats

- Jindhagada is the highest mountain in the Eastern Ghats situated in Araku, district Vishakapatnam in Andhra Pradesh.
- The region boasts of fertile soil but hydropower generation here is not as profitable as it is in the Western Ghats.
- Eastern Ghats are older than the Western Ghats, and have a complex geologic history, related to the assembly and break-up of the ancient supercontinent of Rodinia and the assembly of the Gondwana supercontinent.
- The Eastern Ghats is the homeland for many Buddhist ruins from Orissa to south andhra.
- The Eastern Ghats harbour primarily tropical moist deciduous vegetation, which represents species of high economic, timber, medicinal Eastern Ghats are highly significant in terms of its biodiversity. Of the estimated 3,200 flowering plant taxa, there are about
- 528 tree taxa under 271 genera belonging to 80 families distributed in different regions of Eastern Ghats. In total 454 species under 243 genera and 78 families are endemic to Eastern

Ghats.

- Based on geological and tectonic considerations, the Eastern Ghats in Orissa starts from North of Similipal in Mayurbhanj district and runs through Malkangiri.
- Seventeen districts of Orissa come under the Eastern Ghats including 14 protected areas (13 wild life sanctuaries, one Biosphere reserve, one National Park, two tiger reserve and one Ramser Wetland).

Other Mountains, Hills and Hill Ranges

Mount Abu

- Highest peak in the Aravalli Range
- Located in Sirohi district, Rajasthan.
- Highest peak on the mountain is Guru Shikhar, at 1,722 metres
- Ancient name of Mount Abu is "Arbudaanchal"
- Only hill station in Rajasthan
- Mount Abu Wildlife Sanctuary was established in 1960 and covers 290 km² of the mountain.
- Mount Abu is home to a number of Jain temples. The Dilwara Temples are a complex of temples, carved of white marble, that were built between the 11th and 13th centuries AD. The oldest of these is the Vimal Vasahi temple, built in 1021 AD by Vimal Shah and dedicated to the first of the Jain Tirthankaras.
- Home to famous Nakki Lake.
- The Achalgarh fort, built in the 14th century by Rana Kumbha of Mewar, stands nearby. It encloses several Jain temples
- Location of Madhuban which is the headquarters of the Brahma Kumaris World Spiritual University.

Cardamom Hills

- Part of the southern Western Ghats located in southeast Kerala and southwest Tamil Nadu.
- Name comes from the cardamom spice grown in much of the hill's cool elevation, which also grows pepper and coffee.
- Home to drainages of the west flowing Periyar, Mullakudy and Pamba rivers. It includes Idukki Dam and Mullaperiyar Dam.
- They conjoin the Anaimalai Hills to the northwest, the Palni Hills to the northeast and the Agasthyamalai Hills to the south as far as the Ariankavu pass. The highest peak in the range is Anamudi, with a height of 2,695 metres.
- The central part of the hills comprises the Periyar Wildlife Sanctuary covering an area of 777 km². The 350 km² core zone of the sanctuary is the Periyar National Park and Tiger Reserve.

Periyar is a major ecotourism destination.

Anamudi

- Located in Kerala, Highest peak of western Ghats and also in south India.
- Elevation 2695 meters.
- Anamudi literally translates to "elephants forehead," a reference to the resemblance of the mountain to an elephant's head.
- Highest point in India outside the Himalaya-Karakoram mountain range.

Anginda peak

- Anginda peak is in the Nilgiri Hills of the Western Ghats in Kerala.
- Highest peak in Silent Valley National Park.

Phawngpui

- Phawngpui or the Blue Mountain of Mizoram is a highly revered peak, considered to be the abode of the Gods.
- Phawngpui Peak is the highest mountain peak in Mizoram (2165 metres).
- Famous for orchids and rhododendrons.

Doddabetta

- Doddabetta is highest mountain in the Nilgiri Hills, at 2637 metre.

Kangchenjunga

- Kangchenjunga is the third highest mountain of the world with an elevation of 8,586 m.
- Located along the India-Nepal border in the Himalayas.
- Kangchenjunga is also the name of the section of the Himalayas and means "The Five Treasures of Snows", as it contains five peaks, four of them over 8,450 m
- The treasures represent the five repositories of God, which are gold, silver, gems, grain, and holy books.
- Until 1852, Kangchenjunga was assumed to be the highest mountain in the world, but calculations made by the Great Trigonometric Survey of India in 1849 came to the conclusion that Mount Everest (known as Peak XV at the time) was the highest and Kangchenjunga the third-highest

Nanda Devi

- Second highest mountain in India and highest entirely within the country.
- Part of the Garhwal Himalayas, and is located in the state of Uttarakhand, between the Rishiganga valley on the west and the Goriganga valley on the east.
- Peak is regarded as the patron-goddess of the Uttarakhand Himalaya.

Garo Hills

- Part of the Garo-Khasi range in Meghalaya, India.It is one of the wettest places in the world. The range is part of the Meghalaya subtropical forests ecoregion.

- Two mountain ranges – the Arabella range and the Tura range, pass through the Garo Hills, forming the great Balpakram valley in between.
- Largest town Tura.
- Shillong also located in Garo Hills.

Khasi Hills

- Khasi Hills are part of the Garo-Khasi range in the Indian state of Meghalaya, and is part of the Patkai range and of the Meghalaya subtropical forests ecoregion.

Jaintia Hills

- Tribal region located in HImalaya.
- Home to Monolith in Nartiang which is touted as one of the tallest monolith in the world.

Mizo Hills

- Lushai Hills (or Mizo Hills) are part of the Patkai range in Mizoram and partially in Tripura, India.

Naga Hills

- Located on India Myanmar border,
- Naga hills, reaching a height of around 3825 metres, lie on the border of India and Burma (Myanmar). These hills are part of a complex mountain system, and the parts of the mountain ranges inside the Indian state of Nagaland and the Burmese region of Sagaing are called the Naga Hills.
- In British India, the major part of the hills came under the Naga Hills district.
- The hills, due to their complexity and position form a barrier between the two countries. The Naga Hills are part of the Arakan Range (Rahkine Range) which to the north rise to 12,552 feet.

Palni Hills

- Palni Hills or Palani Hills are in Tamil Nadu.
- They are eastward extension of the Western Ghats ranges, which run parallel to the west coast of India.
- Home to one of the shrines of Lord Karthikeyan or Murugan.

Patkai Hills

- Located on India's North Eastern border with Burma.
- Mawsynram and Cherrapunji, on the windward side of these hills are the world's wettest places, having the highest annual rainfall.
- Climate ranges from temperate to alpine due to altitude.

Shivalik Hills

- Was known as Manak Parbat in ancient times.
- Also known as Churia and Margalla hills.

- Southernmost and geologically youngest east-west mountain chain of the Himalayas ranging from Indus to Brahamputra.
- Chiefly composed of sandstone and conglomerate rock formations, which are the solidified detritus of the great range in their rear, but often poorly consolidated.
- Bounded on the south by a fault system called the Main Frontal Thrust, with steeper slopes on that side.
- Sivapithecus or Ramapithecus is among many fossil finds in the Siwalik region.
- The Siwalik Hills are also among the richest fossil sites for large animals anywhere in Asia.

Zanskar Range

- Located in Jammu & Kashmir of India , seperates Zanskar from Ladakh.
- Geologically, the Zanskar Range is part of the Tethys Himalaya, an approximately 100-km-wide synclinorium formed by strongly folded and imbricated, weakly metamorphosed sedimentary series.
- The average height of the Zanskar Range is about 6,000 m (19,700 ft).
- Its eastern part is known as Rupshu.

Prelims Model Questions

India's Physiography-1 Model Questions

1. Consider the following statements:

1. The altitude of the Western Himalayas is higher than the Eastern Himalayas

2. Snowline in Eastern Himalayas is lower than Western Himalayas

3. Eastern Himalayas are much ahead from western Himalayas in terms of Biodiversity

Which among the above statements is / are correct?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

Western Himalayas	Eastern Himalayas
Extends till west of River Kali (around 80°E Longitude).	This is considered to be ranging from east of the Singalila ranges in Sikkim (88°E Longitudes) to eastern boundaries of Himalayas.
Height of the mountains from the plains in this part rises in a number of stages. The high mountain ranges are at a long distance from the plains	This part rises abruptly from the plains, thus peaks are not faraway from the plains (Example: Kanchenjunga)

Western Himalayas	Eastern Himalayas
Amount of rainfall here is less and is 1/4th of that of Eastern Himalayas.	This region received 4 times more rainfall than western Himalayas. Due to high rainfalls, it is covered with dense forests.
The dominant vegetation in the western Himalayas is Coniferous forests and alpine vegetations. The Natural vegetation reflects the impact of lower rainfall.	Snowline is LOWER than Western Himalayas
The altitude of the Western Himalayas is higher than the Eastern Himalayas	Eastern Himalayas receive more precipitation from south-eastern monsoon in the summers.
Snowline is HIGHER than Eastern Himalayas	Much ahead from western Himalayas in terms of Biodiversity and is one of the Biodiversity hotspots
Western Himalayas receive more precipitation from northwest in the winters	
Less biodiversity in comparison to eastern Himalayas	

2. With reference to the Geographical features of Himalayas, consider the following observations:

1. The Margalla Hills are the outermost range of foothills

2. The Mahabharat Zone is home to some of the deepest canyons in the world

Which among the above statements is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [C] Both 1 & 2

Shivaliks or Churia or Margalla Hills are the outermost range of foothills extending across the Himalayan region through Pakistan, India, Nepal and Bhutan. This is mainly located along a Himalayan Frontal Thrust (HFT). The vegetation here is dominated by Himalayan subtropical pine and broadleaf forests. The Inner Terai valleys are open valleys north of Shiwalik Hills or nestled between Shiwalik sub ranges. Examples include Dehra Dun in India and Chitwan in Nepal. Lesser Himalaya: Lesser Himalaya is also known as Mahabharat Zone. The hills here range 2000 to 3000 meters and are located along the Main Boundary Thrust (MBT) fault zone. This zone is home to some of the deepest canyons in the world. The vegetation here is Himalayan subtropical forests.

3. Which among the following is / are present in Himalayas:
1. Deep gorges
2. U-turn river courses
3. Parallel mountain ranges
4. Remnants of the lava Channels

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 1, 2 & 3

[C] 1, 2, 3 & 4

[D] Only 2 and 3

Answer: [B] Only 1, 2 & 3

The Himalaya extends like a curve of parallel ranges for nearly 2500 kilometres across southern Asia. The young fold mountains consist of a series of parallel ranges with deep valleys between them. Being young fold mountains, Himalaya has variety of rock structures, deep gorges and high pyramidal peaks. In High Himalayas the rivers have steep gradients, which result from the differential uplift of the High Himalayas. It has been suggested that a long and narrow arc of High Himalayas has been uplifted during quaternary. The classification of the Himalayan Ranges is done on three bases viz. Geographical, Regional and Geological.

4. Which among the following types of Landforms can be seen in Himalayas?
1. Cirque
2. Moraine
3. U-shaped Valleys

Choose the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

The given landforms are Glacial landforms and all of them are found in Himalayas. A cirque is an erosional form caused by mountain glaciers. As glaciers retreat, they leave behind large hills of debris known as Moraines. A U-shaped valley or glacial trough is formed by the process of glaciation. Examples of U-valleys are found in mountainous region like the Alps, Himalaya, Rocky mountains, Scottish Highlands, Scandinavia, New Zealand and Canada. A classic glacial trough in Glacier National Park in Montana, USA in which the St. Mary River runs.

5. Which among the following hill ranges of South India are not spread in both Kerala and Tamil Nadu?

[A] Anaimalai Hills

[B] Cardamom Hills

[C] Agasthyamalai Hills

[D] Palani Hills

Answer: [D] Palani Hills

Anaimalai

- The hills straddle both sides of the state border Kollam District and Thiruvananthapuram District in Kerala and Tirunelveli District and Kanyakumari District in Tamil Nadu.

Cardamom

- The Cardamom Hills are southern hills of India and part of the southern Western Ghats located in southeast Kerala and southwest Tamil Nadu.

Palani Hills

- The Palani Hills are a mountain range in Tamil Nadu. The Palani Hills are an eastward extension of the Western Ghats ranges, which run parallel to the west coast of India

Agastyamalai

- Agastyamalai or Agasthyarkoodam is within Neyyar Wildlife Sanctuary in the Western Ghats of South India. The mountain lies in Thiruvananthapuram district of Kerala and Kanyakumari and Tirunelveli districts of Tamil Nadu.

6. Which among the following Himalayan passes can be used for cross border trade between China and India? 1. Nathu La 2. Lipulekh Pass 3. Shipki La Select the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 1

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

7. Which among the following you will find while visiting the peninsular plateau of India?

1. Deep and narrow valleys

2. Rounded hills

3. Old crystalline, igneous and metamorphic rocks

Select the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2 & 3

[C] 1, 2 & 3

[D] Only 3

Answer: [B] Only 2 & 3

Deep and narrow valleys are found in Himalayas not in peninsular plateau. The Peninsular plateau is a tableland composed of the old crystalline, igneous and metamorphic rocks. It was formed due to the breaking and drifting of the Gondwana land and thus, making it a part of the oldest landmass. The plateau has broad and shallow valleys and rounded hills. The hills are rounded because of millions of years of erosion.

8. Which among the following natural phenomena you will find common in Himalayan region?

1. Glacial Lake Outburst Floods (GLOFs)

2. Geysers and Hotsprings

3. Moraines

4. Hanging Valleys

Select the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 1, 2 & 4

[C] Only 2 & 3

[D] 1, 2, 3 & 4

Answer: [D] 1, 2, 3 & 4

Kindly note that Glacial Lake Outburst Flood (GLOF) refers to the glacier floods caused by the drainage of naturally dammed lakes in the glacier, on or at the margin of glaciers. GLOFs are common in Himalayan region. Many big glaciers melted rapidly, forming a large number of glacial lakes. Such lakes are inherently unstable and can be subject to catastrophic drainage, which is a potential source of danger to people and property in the valleys below them. These result in serious death tolls and destruction of valuable natural resources, such as forests, farms, and costly mountain infrastructures. This term was making news because of rumours that the Kedarnath tragedy of last year was caused by a GLOF. However, it was confirmed later that this tragedy was not caused due to GLOF but due to a combination of several factors viz. early rainfall, movement of southwest monsoon winds, and the formation of a temporary lake.

9. The river valleys of the western, central and eastern regions of the Himalayan ranges show a great variation among themselves. With this reference, consider the following statements:
1. The valleys in the western Himalayas are deep, longitudinal & well drained; while the valleys of the eastern Himalayas are broad & relatively shallow
2. The valleys in western Himalayas are called doons, while in eastern Himalayas are called duars
Which among the above is / are correct statements?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [C] Both 1 & 2

Himalayan rivers form part of the Antecedent Drainage system wherein the rivers flow in their original direction even after the upliftment of land across their course and result in deep valleys across the uplifted landmass. Most of them have their origins in Tibetan Highlands and flow across the Himalayas for considerable distance.

Western Himalayas:

Valleys are deep. They are longitudinal and are well-drained. e.g. Kashmir and Kathmandu etc.

Eastern Himalayas

Valleys are large, broad and relatively shallow due to erosion caused by rivers, raised water levels from monsoonal rains and a less resistant sedimentary rock bed lying underneath.

Central Himalayas: Broad, flat and structural valleys better known as 'duns' in west and 'duars' in eastern ranges. E.g. Dehradun, Kothari Dun and Patli Dun etc.

10. Which of the following states is/are part of Western Ghats?
1. Gujarat
2. Tamil Nadu
3. Andhra Pradesh
Select the correct option from the codes given below:

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [A] Only 1 & 2

Refrence

General Knowledge Today

Prelims Geography-9: Physiography of India-2

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Contents

Model Questions

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India's Drainage System

Open and Closed Basins

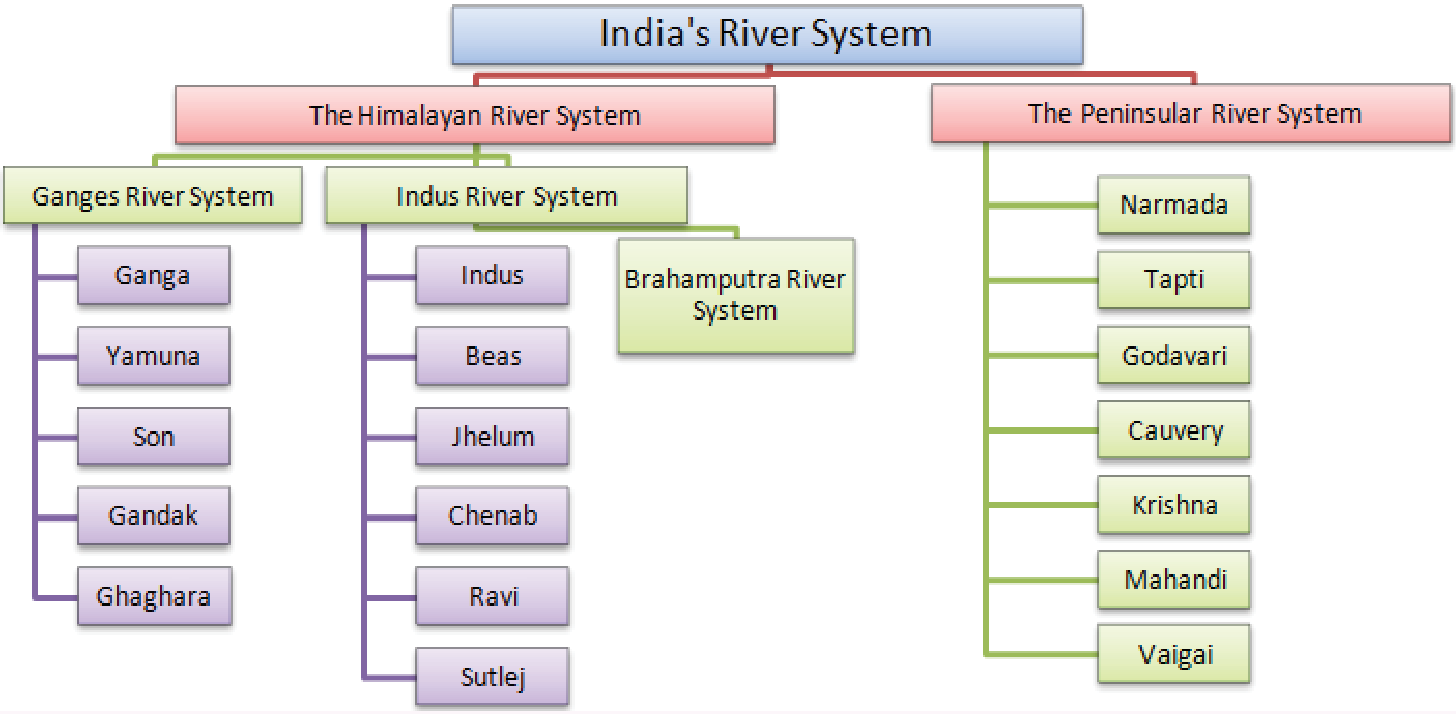
A drainage system is the pattern formed by the streams, rivers, and lakes in a particular **drainage basin**. A drainage basin is an extent or an area of land where surface water from rain and melting snow or ice converges to a single point or where the waters join another water body, such as a river, lake, reservoir, estuary, wetland, sea, or ocean.

The basin can be closed basin or open Basin. In open basin, the water body is hydro-logically toward the sea. The rivers which drain to oceans and seas have open basins.

In closed drainage basins the water converges to a single point inside the basin, known as a sink, which may be a permanent lake, dry lake, or a point where surface water is lost underground.

The drainage basin includes both the streams and rivers that convey the water as well as the land surfaces from which water drains into those channels, and is separated from adjacent basins by a drainage divide. The other words used for basin are catchment, catchment area, catchment basin, drainage area, river basin, water basin and watershed.

The river basins are controlled by the topography of the land such as rock types, gradient, soil type etc. The stream in a basin can be runoff, through flow or underground flow. The topographic barriers make watersheds. A watershed would represent all the stream tributaries that flow to some distance along the main stream. *Almost all of India's rivers are of open basin as more than 90% of total surface water runoff would go to Bay of Bengal*. Rest goes to Arabian Sea. There is just a small area in parts of Ladakh, northern parts of the Aravalli range and the arid parts of the Thar Desert, that have inland drainage.



Indus River System

Indus River System is made of Indus River and its tributaries viz. Ravi, Beas, Satluj, Jhelam, Kishenganga (Neelum) and Chenab.

The important facts about the rivers are as follows:

Indus River

- Indus River originates in Tibet in northern slopes of Mount Kailash near lake Mansarovar. Running via Ladakh, it enters into Pakistan through Gilgit-Baltistan and ends in Arabian Sea near Karachi.
- The total length of the river is 3,180 kilometers, making it Pakistan's longest river and world's

21st largest river in terms of annual flow. The river basin is 11,165,000 square kilometers.

- Several tributaries of Indus River in Pakistan side are Nagar River, Astor River, Balram River, Dras River, Gar River, Ghizar River, Gilgit River, Gumal River Kabul River, Kurram River, Panjnad River, Shigar River, Shyok River, Sohan River, Tanubal River, Zanskar River etc.
- On the eastern side, portion of it does run through Indian territory, as do parts of the courses of its five major tributaries viz. Beas, Chenab, Jhelum, Ravi and Sutlej. These tributaries are the source of the name of the Punjab region.

Beas River

- Originates in the southern slopes of Pir Panjal ranges near Rohtang Pass in Himachal Pradesh.
- It flows south past Manali and through the Kullu Valley before entering the Punjab plains. It meets the Sutlej River near the **Harike Wetland** south of Amritsar. The Sutlej continues into Pakistani Punjab and joins the Chenab River at Uch near Bahawalpur to form the Panjnad River; the latter in turn joins the Indus River at Mithankot. So, originating in India and running for 470 kilometers, the river meets Sutlej in Punjab of India.
- The river is of Historic, known as *Arjikuja* and *Vipasa* in ancient times and **Hyphasis to ancient Greeks.**
- Some of the tributaries of the river Beas are as
    - **Parbati** which rises in the snowy wastes above Manikaran. It joins the river Beas near Shamshi in the Kulu valley;
    - **Haria** which joins the river Beas near Bhuntar;
    - **Sainj** which rises in the snows of an off-shoot of the Pir Panjal range that marks the watershed of the Seas and Satluj rivers. It joins the river Beas near Larji;
    - **Tirthan** which rises in the snows of an off-shoot of the Pir Panjal range. It joins the river Beas near Larji.

Jhelum River

- Jhelum rises from **northern slopes of Pir Panjal ranges at Verinag spring** **(which is main source)** which girdles the valley of Kashmir. It flows through Srinagar and the Wular Lake before entering Pakistan through a deep narrow gorge.
- **The Kishenganga (Neelum) River, the largest tributary of the Jhelum**, joins it, at Domel Muzaffarabad. The Jhelum enters the Punjab in the Jhelum District. From there, it flows through the plains of Pakistan's Punjab, forming the boundary between the Chaj and Sindh Sagar Doabs.

- It ends in a confluence with the Chenab at Trimmu in District Jhang. The Chenab merges with the Sutlej to form the **Panjnad River** which joins the Indus River at Mithankot. Thus, In India it flows on in Jammu & Kashmir State.
- *Jhelam is the largest and most western of the five rivers of Punjab*.Chenab is its tributary. It was called **Vitasta in Rigveda** and **Hydaspes by the ancient Greeks.** Alexander the Great and his army crossed the Jhelum in BC 326 at the Battle of the Hydaspes River where it is believed that he defeated the Indian king, Porus.
- Verinag is situated at a distance of approximately 80 km from Srinagar. Considered to be the source of the River Jhelum, often termed as the lifeline of the province of Jammu and Kashmir, the beautiful region of Verinag a weekend getaway from Srinagar. The important dams and barrages on Jhelam river are **Mangla Dam, Rasul Barrage, Trimmu Barrage.**
- Its major tributaries are –
    - Liddar which originates in the snowy wastes at Chandanwari. It joins the river Jhelum in the central pan of the Kashmir valley;
    - Sind River which originates in the southern slopes of the great Himalayan range which hems the Kashmir valley;
    - Kishenganga which also originates on the southern slopes of the great Himalayan range.

Chenab River

- Chenab River was called **Ashkini in Vedic times.** It originates at snow melt from the **Bara Lacha Pass in the Himachal Pradesh**. The waters flowing south from the pass are known as the **Chandra River** and those that flow north are called the **Bhaga River.** Eventually the Bhaga flows around to the south joining the Chandra at the village of Tandi, forming the **Chandrbhaga River at Tandi.**
- It becomes the Chenab when it joins the Marau River at Bhandera Kot, 12 km from Kishtwar Town in Jammu and Kashmir. It flows in the Indian state of Jammu & Kashmir, then Pakistan Province of Punjab and merges with Jhelum River at Trimmu, Ravi River Ahmedpur Sialand Sutlej River near Uch Sharif, Pakistan to form the Panjnad or the 'Five Rivers', the fifth being the Beas River which joins the Satluj near Ferozepur, India. The Chenab then joins the Indus at Mithankot, Pakistan.
- The total length of the Chenab is approximately 960 kilometres.The waters of the Chenab are allocated to Pakistan under the terms of the Indus Waters Treaty**It was known as Acesines to the Ancient Greeks.**

Ravi River

- The Ravi or **Iravati or Purushni of ancient India** is smallest of Five Punjab Rivers. It originates in Bara Bhangal, District Kangra in Himachal Pradesh and gets hemmed by Dhauladhar range in the south and the Pir Panjal in the north. It originates in Bara Bangahal as a joint stream formed by:
    - The Bhadal. which is fed by glaciers.
    - The Tant Gari, which is also fed by glaciers.
- The river Ravi flows in more or less westerly direction before it cuts across the Dhauladhar range to enter the plains of Punjab. Its main northern bank tributaries are the snow fed Siul and Baira streams. It follows a north-westerly course, flows through Barabhangal, Bara Bansu and Chamba districts. It flows in rapids in its initial reaches with boulders seen scattered in the bed of the river. The Budhil River, in Himachal Pradesh is a major tributary of the Ravi River. Another major tributary that joins the Ravi River, just below Bharmour, the old capital of Chamba, is the Seul River from the northern direction.
- The valley formed by the river was also exploited for its rich timber trees. However, the valley has large terraces, which are very fertile and known as "the garden of Chamba". crops grown here supply grains to the capital region and to Dalhousie town and its surrounding areas. One more major tributary that joins the Ravi River near Bissoli is the Siawa. It enters the Punjab plain near Madhopur and Pathankot. It then flows along the Indo–Pak border for80 kilometres (50 mi) before entering Pakistan and joining the Chenab River. The total length of the river is about 725 kilometres.
- Since this river flows at the boundary of India and Pakistan, studies have shown that the river is changing its course towards India due to heavy constructions in its way by Pakistan.

Sutlej River

- Sutlej River was known as Śutudri in ancient India and is longest of the five rivers of Punjab. It originates near Lake Rakshastal in Tibet. It flows for a considerable distance before entering Indian Territory near Shipki La. Thereafter, it drains past the trans-Himalayan zone of Spiti. The major tributary which joins the river Satluj in this tract is the river Spiti. This tributary rises on the northern slopes of the great Himalayan range which hems the Lahaul and Spiti valleys. It drains the latter valley and flows in a eastern and south westerly direction before joining the river Satluj. The river Satluj has cut across the great Himalayan range through a deep gorge.
- Just upstream of this gorge, it is joined by the river Baspa which drains the north eastern part of Himachal Pradesh. After crossing the great Himalayan range, the river Satluj flows in a

more or less S W direction before emerging into the plains near Bhakra. In Pakistan, it waters the ancient and historical former Bahawalpur state. The region to its south and east is arid, and is known as Cholistan, is a part of Bahawalpur Division.

- The Sutlej is joined by the Beas River in Hari-Ke-Patan, Amritsar, Punjāb, India, and continues southwest into Pakistan to unite with the Chenab River, forming the Panjnad River near Bahawalpur. The Panjnad joins the Indus River at Mithankot. Indus then flows through a gorge near Sukkur, flows through the fertile plains region of Sindh, and terminates in the Arabian Sea near the port city of Karachi in Pakistan.The waters of the Sutlej are allocated to India under the Indus Waters Treaty between India and Pakistan, and are mostly diverted to irrigation canals in India.

Ganges River System

The major river Ganga and its tributaries like Yamuna, Son, and Gandak make the biggest cultivable plains of north and eastern India, known as the Indo-Gangetic plains. The main river, Ganga forms by the joining of the Alaknanda River and Bhagirathi River at Devprayag. The Bhagirathi, which is considered the Ganga' true source starts from Gomukh.

Course of Ganga

Gangotri is called the origin of the River Ganga and seat of the goddess Ganga. However, it is actually the source of one of the Ganga's **6 headstreams** known as **Bhagirathi. Bhagirathi itself is joined by two headstreams calledBhilangna River and Jahnavi River.**Another mighty headstream is river **Alaknanda**. Bhagirathi and Alaknanda are the two major rivers of the Garhwal Himalaya, both originating from the mighty**Chaukhamba range of glaciers**. Chaukhamba is a mountain massif in the Gangotri Group of the Garhwal Himalaya. Its main summit,**Chaukhamba I,** is the highest peak in the group. It lies at the head of the Gangotri Glacier and forms the eastern anchor of the group. Other peaks are Chaukhamba II, Chaukhamba III and Chaukhamba IV.

Bhagirathi has its origin at Gangotri (which is called Gangotri Glacier) on the north-western face of Chaukhamba.

Alaknanda rises at the confluence and feet of the**Satopanth and Bhagirath Kharak glaciers,** on the south-eastern slopes of glacier fields of Chaukhamba.

Gangotri & Gaumukh

Gangotri is one of the four sites in the Char Dham pilgrimage circuit, other being Yamunotri, Kedarnath and Badrinath. The Gangotri Glacier is located in Uttarkashi District, Uttarakhand. The terminus of the Gangotri Glacier is said to resemble a cow's mouth, and the place is called Gomukh. Gaumukh is the source of Bhagirathi river. Gomukh is situated near the base of Shivling; in between lies the Tapovan meadow. The river Bhagirathi flows from Gangotri and at Devprayag, it meets another headstream of Ganga called Alaknanda.

Alaknanda

As written above, Alaknanda rises at the confluence and feet of the Satopanth and Bhagirath Kharak glaciers, on the south-eastern slopes of glacier fields of Chaukhamba. It meets the Bhagirathi river at Devprayag after flowing for approximately 190 km through the Alaknanda valley. After originating, it first meets the Saraswathi River and then flows in front of the Badrinath temple. After this, it meets its tributary and another headstream of Ganga called Dhauliganga. When Alaknanda meets Dhauliganga, it is called Vishnu Prayag. The two streams now become one and go ahead. Next headstream is Nandakini, which meets Alaknanda at Nandaprayag.

- From here, the Alaknanda river becomes mighty and now meets Pindar River at Karnaprayag.
- After Karnaprayag, the Mandakini river meets this stream and it is called Rudraprayag.
- Finally, the Alaknanda meets Bhagirathi at Devprayag and from here, it is called Ganga.

- These five Prayags or confluences are collectively called **Panchaprayag**. The Alaknanda contributes a significantly larger portion to the flow of the Ganga than the Bhagirathi.

Thus in all there are 6 headstreams that contribute in the making of Ganga. These are Alaknanda, Dhauliganga, Nandakini, Pindar, Mandakini, and Bhagirathi rivers.

Further Course of Ganga Till Kanpur

After flowing 250 kilometers, Ganga emerges from the mountains at Rishikesh, and then debouches onto the Gangetic Plain at Haridwar.

Some of the Ganga water at Haridwar is diverted into the Ganga Canal, which irrigates the Doab region of Uttar Pradesh. Till Haridwar, the route of Ganga is little southwest, from here it begins to flow southeast through the plains of northern India. It flows 800 kilometers passing via Kannauj, Farukhabad, and reaches Kanpur. Before Ganga reaches Kanpur, two important rivers join it. One is **Kali River** and another is Ramganga. Kali River is also known with this name in Nepal but is known as **Sharda River in India**. It originates at Kalapaani in Pithoragarh district of Uttarakhand. Kali River makes India's eastern boundary with Nepal at some places and when it reaches the plains of Uttarakhand and Uttar Pradesh, it would be called as Sharda.

Next is Ramganga. Please note that there are two Ramganga rivers. One of them starts from Doodhatoli ranges in Pauri Garhwal and another from Namik Glacier of Pithoragarh. The Bareilly of Uttar Pradesh is located on the banks of the first. After Bareilly , it meets Kali River. The Kali river keeps flowing till Bahraich, by then it is known as **Saryu River.** Saryu River meets Ganga in the Bahraich of Uttar Pradesh.

After Kanpur

After Kanpur, Ganga joins the Yamuna at the **Triveni Sangam** at Allahabad, a holy confluence in Hinduism. At their confluence the Yamuna is larger than the Ganga. After this, several stream such as Tamsa River, Ghaghara river, Gandaki River, Kosi River join it at various places which shall be discussed in this module. Ganga remains one stream flowing southeast till Bhagalpur. From Pakur in Jharkhand, Ganga starts dividing into various distributaries. In the Murshidabad District of West Bengal at the Farakka Barrage, Ganga's first distributor **Bhāgirathi-Hooghly** gets branched out. This Bhāgirathi-Hooghly river later becomes Hooghly river and then enters the twin cities of Kolkata and Howrah. At Nurpur it enters an old channel of the Ganga and turns south to empty into the Bay of Bengal.

The Farakka Barrage controls the flow of the Ganga, diverting some of the water into a feeder canal linked to the Hooghly for the purpose of keeping it relatively silt-free. Before the Hooghly river empties into Bay of Bengal, it meets Damodar River. But, the main branch of Ganga has to go a long way still. It enters Bangladesh from India near Chapai Nababganj and now its name is **Padma River**.

Here Padma meets one of the distributaries of Brahmaputra called **Jamuna or Jomuna**.

This combined stream meets Meghna river, that is another distributary of Brahmaputra at Chandpur in Bangladesh. The Meghna River finally flows into the Bay of Bengal.

The above discussion makes it clear that various distributaries of Ganga and Brahmaputra meet along the Bay of Bengal and these make one of the**largest delta in the world called Gangaes Delta** or **Ganges-Brahmaputra** delta.

They also create underwater Bengal Fan, which is one of the largest submarine fans on Earth. The fan is about 3000 km long, 1000 km wide with a maximum thickness of 16.5 km. Most of the sediment is supplied by the confluent Ganga and Brahmaputra Rivers through the Ganga Delta in Bangladesh and West Bengal, India, with several other large rivers in Bangladesh and India providing smaller contributions.

Tributaries of Ganga

The main tributaries of Ganga River are as follows:

Son River

Son River is largest of **<u>southern tributaries of Ganga</u>** that originates near Amarkantak in Madhya Pradesh near the source of Narmada River, and flows north-northwest through Madhya Pradesh before turning sharply eastward where it encounters the southwest-northeast-running Kaimur Range.

- The Son parallels the Kaimur hills, flowing east-northeast through Uttar Pradesh, Jharkhand

and Bihar states to join the Ganga just above Patna. Geologically, the lower valley of the Son is an extension of the Narmada Valley, and the Kaimur Range an extension of the Vindhya Range.

- Chief tributaries of Son river are **Rihand and the North Koel.** The Son has a steep gradient (35–55 cm per km) with quick run-off and ephemeral regimes, becoming a roaring river with the rain-waters in the catchment area but turning quickly into a fordable stream.
- The Rihand River is a tributary of the Son River and flows through the Indian states of Chhattisgarh and Uttar Pradesh. It rises in Chhattisgarh at Matiranga hills and there is a Rihand Dam that was constructed at Pipri in Sonbhadra district of Mirzapur division in 1962 for hydropower generation. The reservoir of this dam is called Govind Ballabh Pant Sagar. Rihand meets Son at Sonbhadra of Uttar Pradesh.

Ghaghara River

Karnali or Ghaghara originates in glaciers of Mapchachungo on the Tibetan Plateau near Lake Mansarovar, cuts through the Himalayas in Nepal and joins the Sarda River at Brahmaghat in India. With a length of 507 kilometers it is the largest river in Nepal. The total length of Ghaghara River up to its confluence with the Ganga at Doriganj in Bihar is 1,080 kilometers.

It is the largest tributary of the Ganga by volume and the second longest tributary of the Ganga by length after Yamuna.

In Chinese it is called ***K'ung-ch'iao Ho***, in Nepali it is called Kauriala and Karnali.

- Before Ghaghara joins the Ganga, river **West Rapti** joins it as an important tributary.
    - West Rapti is known as "Gorakhpur's Sorrow".
        - West Rapti is itself tributed by Rohni River in Gorakhpur.

Gomti River

The Gomti originates from Gomat Taal which formally known as Fulhaar jheel, near Madho Tanda, Pilibhit, India.

It extends 900 km through Uttar Pradesh and meets the Ganga River near Saidpur, Kaithi in Ghazipur.

Yamuna River

India's Yamuna River is largest tributary of Ganga River, while Bangladesh's Jamuna River is largest distributary channel of the Brahmaputra River. Origin of Yamuna is at Yamunotri Glacier on the south western slopes of **Banderpooch peak** in the Lower Himalayas in Uttarakhand. From there it travels a total length of 1,376 kilometers before merging with the Ganga at Triveni Sangam or Prayag at Allahabad.

Yamuna River

Yamuna River is largest tributary of Ganga River, while Bangladesh's Jamuna River is largest distributary channel of the Brahmaputra River. Yamuna is another sacred river of India that origins from Yamunotri Glacier at height 6,387 metres, on the south western slopes of **Banderpooch peak**, in the Lower Himalayas in Uttarakhand. From there it travels a total length of 1,376 kilometers and has a drainage system of 366,223 km², 40.2% of the entire Ganga Basin, before merging with the Ganga at Triveni Sangam or Prayag at Allahabad.

- From Uttarakhand, Yamuna river flows for some 200 kilometers in Lower Himalayas and Shivalik Ranges.
- Its largest tributary **Tons River** flows through Garhwal region in Uttarakhand, and meets Yamuna near Dehradun.
- The other rivers such as Giri, Rishi Ganga, Kunta, Hanuman Ganga and Bata tributaries meet Yamuna, before it descends on to the plains of Doon Valley, at Dak Pathar near Dehradun.
- Further down, Yamuna is met by the Assan River, lies the Assan barrage, which hosts a Bird Sanctuary as well.
- After passing Paonta Sahib, it reaches Tajewala in Yamuna Nagar district, of Haryana, where a dam built in 1873, is the originating place of two important canals, the Western Yamuna Canal and Eastern Yamuna Canal, which irrigate the states of Haryana and Uttar Pradesh.
- The Western Yamuna Canal (WYC) crosses Yamuna Nagar, Karnal and Panipat before reaching the Haiderpur treatment plant, which supplies part of municipal water supply to Delhi, further it also receives waste water from Yamuna Nagar and Panipat cities.
- Yamuna is replenished again after this by seasonal streams and groundwater accrual, in fact during the dry season, it remains dry in many stretches from Tajewala till Delhi, where it enters near Palla village after traversing 224 km.

Along with Ganga to which run almost parallel after it touches the Indo-Gangetic plain and creates the Ganga-Yamuna Doab region. From Delhi onwards Yamuna gets polluted due to discharge of waste water through 15 drains between Wazirabad barrage and Okhla barrage renders the river severely polluted after Wazirabad in Delhi

Tributaries of Yamuna

Betwa River

- Betwa or Vetravati originates in Vindhya Range just north of Hoshangabad in Madhya Pradesh and flows north-east through Madhya Pradesh and flow through Orchha to Uttar Pradesh. It meets Yamuna at Hamirpur town in Uttar Pradesh.

Sindh River

- Sindh River originates on the Malwa Plateau in Vidisha district, and flows north-northeast through the districts of Guna, Ashoknagar, Shivpuri, Datia, Gwalior and Bhind in Madhya Pradesh to join the Yamuna River in Etawah district, Uttar Pradesh.

- Manikheda Dam has been constructed across the Sindh River in Shivpuri district, Madhya Pradesh.

Hindon River

- Hindo River is a rainfed river that originates in the Saharanpur District. It flows between Ganges and Yamuna rivers and joins Yamuna river just outside Delhi.

Chambal River

- Chambal River is one of the most pollution free rivers of India.
- It's a 960 Kilometer long river that originates at the Singar Chouri peak in the northern slopes of the Vindhyan mountains, 15 km West-South-West of Mhow in Indore District in Madhya Pradesh.
- From there, it flows in a northerly direction in Madhya Pradesh(M.P.) for a length of about 346 km and then in a generally north-easterly direction for a length of 225 km through Rajasthan.
- It enters U.P. and flows for about 32 km before joining the Yamuna River in Etawah District at an elevation of 122 m, to form a part of the greater Gangetic drainage system. Chambal is a rainfed river and its basin is bounded by the Vindhyan mountain ranges and on the north-west by the Aravallis.

Tributaries of Chambal:

- **Banas River:** Banas river is a rainfed river that flows in Rajasthan. Banas means hope of forests. It originates in Khamnor Hills of the Aravalli Range, about 5 km from Kumbhalgarh in Rajsamand and flows northeast through Mewar region of Rajasthan, meets the Chambal near the village of Rameshwar in Sawai Madhopur District. The cities of Nathdwara, Jahanpur, and Tonk lie on the river.
- **Kali Sindh River:** The Kali Sindh is a river in the Malwa region of Madhya Pradesh, that joins the Chambal River at downstream of Sawai Madhopur in Rajasthan
- **Parbati River:** Parbati River is a river in Madhya Pradesh, India that flows into the Chambal River. It is one of the Chambal River's three main tributaries, along with the Banas River and the Kali Sindh River.

Brahmaputra River System

Brahmaputra originates on the Angsi Glacier located on the northern side of the Himalayas in Burang County of Tibet as the Yarlung Tsangpo River and flows southern Tibet to break through the Himalayas in great gorges. Tsangpo enters India after taking a **U turn at Namcha Barwa** and flows in Arunachal Pradesh and here we call it **Dihang River or Siang River**. This U turn marks the starting point of the Grand Canyon, known as **Yarlung Zangbo Grand Canyon**, which has been confirmed as the largest in the world. It is 496.3 kilometers long, 56.3 kilometers longer than the Colorado Grand Canyon, previously considered the world's longest. It is 5,382 meters deep, much deeper than the 3,200 meters of Peru's Colca Canyon, previously known as the world's deepest canyon.

After taking this U -turn, Dihang meets Dibang River and the Lohit River at the head of the Assam Valley and then flows southwest through the Assam Valley, where it is known as Brahmaputra. In Assam it becomes a wide stream. Then its enters Bangladesh. In Bangladesh, the Brahmaputra is joined by the Teesta River, one of its largest tributaries. Below the Teesta, the Brahmaputra splits into two distributary branches. The western branch, which contains the majority of the river's flow, continues due south as the Jamuna to merge with the lower Ganges, called the Padma River. The eastern branch is called the lower or old Brahmaputra . It curves southeast to join the Meghna River near Dhaka. The Padma and Meghna converge near Chandpur and flow out into the Bay of Bengal.

Brahmaputra is 3,848 km long, and its drainage area is 712,035 km^2.

The waters of the River Brahmaputra are shared by China, India, and Bangladesh. In the 1990s and 2000s, there was repeated speculation about China building a dam at the Great Bend, with a view to divert the waters to the north of the country. This was denied by the Chinese government, later on.

Important Tributaries of Brahmaputra

Teesta River

- Teesta River is lifeline of Sikkim and makes a border between Sikkim and West Bengal before joining the Brahmaputra as a tributary in Bangladesh. The total length of the river is 315 kilometres .
- It originates at Tso Lhamo Lake in North Sikkim and is formed by the melting of the Tista Khantse glacier.
- Just before the Teesta Bridge, which joins Kalimpong with Darjeeling, the river is met by its main tributary, the Rangeet River.
- At this point, it changes course southwards flowing into West Bengal. The river hits the plains at Sevoke, at a distance of 22 Km from Siliguri, where it is spanned by the Coronation Bridge which links the north-east states to the rest of India.
- The river then courses its way to Jalpaiguri and then to Rangpur District of Bangladesh, before finally merging with the mighty Brahmaputra at Fulchori.

Manas River

- Manas River folows in India and Bhutan and is the largest river system of Bhutan. Three other river systems of Bhutan are Amo Chu or Torsa, Wong Chu or Raidak, Mo Chu or Sankosh. It is met by three other major streams before it again debouches into India in western Assam.

- After flowing a total of 376 kilometers, it meets Brahmaputra River at Jogighopa. Its river valley is home to Royal Manas National Park in Bhutan and the contiguous Manas Wildlife Sanctuary of India which is a Project Tiger Reserve, an Elephant Reserve and a Biosphere Reserve as well as a UNESCO World Heritage Site.

Rivers of Peninsular India

As a general observation, the Rivers of Peninsular India are rainfed and they shrink during the dry season. The line created by the Narmada River and Mahanadi River is the traditional boundary between northern and southern India. The Narmada flows westwards in the depression between the Vindhya and Satpura ranges. The plateau is watered by the east flowing Godavari and Krishna rivers. The other major rivers of the Deccan plateau are the Pennar and the Tungabhadra, a major tributary of the Krishna. There are numerous very small rivers on the Deccan plateau which flow mostly north to south and also south to north mixing with any of the west or east flowing major rivers.

Mahanadi River Basin

The 858 Kilometers long Mahanadi river flows through the states of Chhattisgarh and Odisha. It gets formed by numerous mountain streams and the farthest headstream is located in hills of the Dhamtari district of Chhattisgarh. These hills are extensions of the Eastern Ghats and are a source of many other streams which then go on to join the Mahanadi. The river first flows in north and drains Raipur. After Bilaspur, it is joined by its major tributary river Seonath.

After that the river flows eastward and joined by Jonk, Hasdeo rivers and reaches Odisha. Near Sambalpur of Odisha, the largest dam of the world Hirakud Dam blocks its water, spread between Lamdungri and Chandili Dunguri hills. After reaching Dholpur in Odisha, the rivers rolls towards the Eastern Ghats and passes the Satkosia Gorge. After crossing the Gorge, it meets the plains of Odisha and reaches Cuttak. Before entering Cuttack city, it gives off a large distributary called the Kathjori. Cuttack is located between these two channels. The Kathjori then throws off many streams like the Kuakhai, Devi and Surua and becomes Jotdar River, which fall into the Bay of Bengal after entering Puri district. The main stream of Mahandi gets divided into several distributaries such as Paika, Birupa, Chitartala, Genguti and Nun. These all distributares form the Mahandi Delta which is one of the largest deltas in India. The Mahandi river empties into Bay of Bengal via several channels near Paradeep at False Point, Jagatsinghpur.

Importance of Mahanadi River

- Mahanadi valley is best known for its fertile soil and flourishing agriculture. Before the Hirakud dam was built, the river carried a huge amount of silt and its delta had one of the highest yield per acre in the whole of India. At present, agriculture primarily depends on a network of canals that arise from the river. Rice, oilseeds and sugarcane are the principal crops here.

- The river was notorious for devastating floods, but the construction of Hirakud Dam has altered the situation.

Tributaries of Mahanadi

The following flowchart shows the flow of Mahanadi from Source to Sea.

The major tributaries of Mahanadi are Seonath, Jonk, Hasdo, Mand, Ib, Ong, Tel etc.

- **Seonath River:** The Seonath River is the longest tributary of Mahanadi. It rises in an undulating region with numerous small groups of hills at Kotgal and flows 383 kilometers to join Mahanadi at its left bank at Khargand.
- **Tributaries of Seonath** are Kharahara, Tandula, Kharun, Surhi, Agar, Arpa rivers. The total drainage area of Seonath is 22% of the total drainage area of Mahanadi Basin.
    - **Jonk River:** Jonk River originates from the Khariar Hills of Kalahandi district of Odisha at an elevation of 762 meters. It flows 196 kilometers to join the Mahanadi on ints right at Sheorinarayan.
- **Hasdo River:** It rises in the Sarguja district of Chhattisgarh and traverses 333 kilometers to meet Mahanadi at Mahuadih.
- Gej River is a principle tributary of Hasdo River
- **Mand River:** Mand River originates at an elevation of 686 meters in Sarguja district of Odisha and flows 241 kilometers to meet Mahanadi at Chandarpur.
- **Ib River :** Ib originates in Pandrapat of the Raigarh distriuct of Chhattishgarh and flows 251 kilometers to fall into Hirakud Dam. Its a rainfed river.
- **Ong River:** It rises at an elevation of 457 meters on a hill in the northern outskirts of hills located on the course of Jonk River and flows 204 kilometers to meet Mahandi at Sonepur.
- **Tel River:** Tel river originates in plain in the Koraput of Odisha. It traverses 296 kilometers to meet Mahanadi at Sonepur.

Hirakud Dam on Mahanadi River

- Built across Mahanadi River, about 15 km from Sambalpur in Odisha.
- Built in 1957, the dam is one of the world's longest earthen dam.
- Behind the dam extends a lake, Hirakud Reservoir, 55 km long.
- Initially proposed Sir M. Visveswararya in 1937, Central Waterways, Irrigation and Navigation Commission took up the work, and in 1946, Sir Howthrone Lewis, then the Governor of Orissa, laid the foundation stone of the Hirakud Dam.
- There are two observation towers on the dam one at each side. One is "Gandhi Minar" and the other one is "Nehru Minar". Both the observation towers present breathtaking views of

the lake.

- Helps control floods in the Mahanadi delta and irrigates 75,000 square kilometres of land. Hydroelectricity is also generated.
- Cattle Island is located in one of the extreme points of Hirakud Reservoir, a natural wonder. Completely inhabited by wild cattle, with out any trace of humans.
- Debrigarh wildlife sanctuary is located here.

Brahmani River

Brahmani River is NOT a tributary of Mahanadi. It's a seasonal river that flows in Odisha. It is formed by the confluence of the Sankh and South Koel rivers near Raurkela, and flows through the districts of Sundargarh, Kendujhar, Dhenkanal, Cuttack and Jajapur. Together with the rivers Mahanadi and Baitarani, it forms a large delta before entering into the Bay of Bengal at Dhamra. Both headstreams of Brahmani river viz. Sankh and South Koel originate in Choota Nagpur Plateau.

- Sankh has its origins near the Jharkhand-Chhatisgarh border, near Netarhat Plateau.
- South Koel too arises in Jharkhand, near Lohardaga, on the other side of a watershed that also gives rise to the Damodar River.

Brahmani river is 480 kilometers long and is the second longest river in Orissa after the Mahanadi.

Tributaries of Brahmani River

- **Baitarni River:** Baitarani River is another one of six major rivers of Odisha, which earn the name of coastal plains of Odisha as "Hexadeltaic region". The river originates in Guptaganga hills in Gonasika of Keonjhar district in Odisha and flows to make a natural boundary between Odisha and Jharkhand. It travels a distance of 360 km to drain into the Bay of Bengal after joining of the Brahmani at Dhamra mouth near Chandabali.

Krishna River

The 1300 Kilometers long Krishna River or Krishnaveni is one of the longest rivers in Peninsular India. It is the fourth largest river in India after the Ganga, Godavari and the Narmada.

Origin & Course

Krishna River rises at Mahabaleswar in district Satara, Maharashtra in the west and meets the Bay of Bengal at Hamasaladeevi in Andhra Pradesh, on the east coast. It flows throug**Maharastra, Andhra Pradesh and Karnataka**. The delta of this river is one of the most fertile regions in India and was the home to ancient Satavahana and Ikshvaku Dynasty kings. Vijayawada is the largest city on the River Krishna.

The river flows quickly, causing much erosion in June and August. During this time, Krishna takes fertile soil from Maharashtra, Karnataka and western Andhra Pradesh towards the delta region.
The river has a number of tributaries but Tungabhadra is the principal tributary. Other tributaries include the Mallaprabha, Koyna, Bhima, Ghataprabha, Yerla, Warna, Dindi, Musi and Dudhganga.
Leaving Mahabaleswar behind, the Krishna takes the form of the Dhom lake in Panchgani, a popular hill station just 17 km from Mahabaleswar. Crisscrossing its way through Wai, Narsobachi and Wadi (near Kolhapur) in Maharashtra, the river enters Karnataka at Kurundwad, 60 km from Kolhapur. In Karnataka, the river passes through the Belgaum, Bijapur and Gulbarga districts, covering a total distance of 220 km. The Krishna enters Andhra Pradesh near Deosugur in Raichur district and meanders through Mehbubnagar, Kurnool, Guntur and Krishna districts. The river merges into the Bay of Bengal at Hamasaladeevi. Two dams, Srisailam and Nagarjuna Sagar are constructed across the Krishna River. Nagarjuna Sagar Dam is world's tallest masonry dam (124 meters).

Krishna River Basin

Krishna Basin extends over an area of 258,948 square kilometers which is nearly 8% of total geographical area of the country. The basin lies in the states of Andhra Pradesh (113,271 km2), Karnataka (76,252 km2) and Maharashtra (69,425 km2). Most part of this basin comprises rolling and undulating country except the western border which is formed by an unbroken line of ranges of the Western Ghats. The important soil types found in the basin are black soils, red soils, Laterite and lateritic soils, alluvium, mixed soils, red and black soils and saline and alkaline soils. An average annual surface water potential of 78.1 km^3 has been assessed in this basin. Out of this, 58.0 km^3 is utilizable water. Culturable area in the basin is about 203,000 km2, which is 10.4% of the total culturable area of the country. In 2009 October heavy floods occurred, isolating 350 villages and leaving millions homeless, which is believed to be first occurrence in 1000 years. The flood resulted in heavy damage to Kurnool, Mahabubnagar, Guntur, Krishna and Nalagonda Districts.

Tributaries of Krishna

Major Tributaries of Krishna River are as follows:

- **Left: B**hima, Dindi, Peddavagu, Halia, Musi, Paleru, Munneru
- **Right:** Venna, Koyna, Panchganga, Dudhganga, Ghataprabha, Malaprabha, Tungabhadra

Tungabhadra River

Most important tributary of Krishna River is the Tungabhadra River, which is formed by the Tunga River and Bhadra River that originate in the Western Ghats. Tungbhadra flows in Karnataka and Andhra Pradesh. It was known as Pampa during the epic period. The name of famous tourist spot Hampi is derived from Pampa, which is the old name of the Tungabhadra River on whose banks the city is built.

The Tunga and Bhadra Rivers rise at Gangamoola, in Varaha Parvatha in the Western Ghats forming parts of the Kuduremukh Iron Ore Project, at an elevation of 1198 metres. Bhadra flows through Bhadravati city and is joined by numerous streams. At Koodli, a small town near Shimoga City, Karnataka, the two rivers meet and called with the common name Tungabhadra. From here, Thungabhadra meanders through the plains to a distance of 531 km (330 mi) and mingles with the Krishna at Gondimalla, near Mahaboobnagar in Andhra Pradesh.

Importance of Tungabhadra River

There are a number of ancient and holy sites on the banks of the Tungabhadra River.

- At Harihara there is a temple dedicated to Harihareshwara.
- The river surrounds the modern town of Hampi, where are the ruins of Vijayanagara, the site of the powerful Vijayanagara Empire's capital city and now a World Heritage Site. The site, including the Vijayanagara temple complex ruins, is being restored.
- Alampur, on the left – northern bank of the river, known as Dakshina Kashi in Mahabubnagar Dist. The Nava Brahma Temples complex is one of the earliest models of temple architecture in India.
- Bhadravthi, Hospet, Hampi, Mantralayam, Kurnool are located on its bank.

Tributaries of Tungabhadra:

- Tunga River, Kumudvati River, Varada River, Bhadra River, Vedavathi River, Handri River

Bhima River

Bhima River originates in Bhimashankar hills near Karjat in Maharashtra and flows southeast for 861 km through Maharashtra, Karnataka, Andhra Pradesh states. Bhima is a major tributary of the

Krishna River. Its banks are densely populated and form a fertile agricultural area. During its 861 kilometer journey, many smaller rivers flow into it. Kundali River, Kumandala River, Ghod river, Bhama, Indrayani River, Mula River, Mutha River and Pavna River are the major tributories of this river around Pune. Of these Indrayani, Mula, Mutha and Pawana flow through Pune and Pimpri Chinchwad city limits. Chandani, Kamini, Moshi, Bori, Sina, Man, Bhogwati and Nira are the major tributaries of the river in Solapur. Of these Nira river meets with the Bhima in Narsingpur, in Malshiras taluka in Solapur district.

- The holy city of Pandharpur is on the bank of Bhima River.
- Bhimashankar is one of the twelve esteemed Jyotirlinga shrines.Other temples are Siddhatek, Siddhivinayak Temple of Ashtavinayak Ganesh Pandharpur Vithoba Temple in Solapur district., Sri Dattatreya Temple, Ganagapura, Gulbarga district, Karnataka, Sri Kshetra Rasangi Balabheemasena Temple in Rasanagi, Jevargi Taluq, Gulbarga district, Karnataka
- Tributaries of Bhima are:
    - Ghod, Sina, Kagini, Bhama, Indrayani, Mula-Mutha, Nira

Malaprabha River

Malaprabha River is another important tributary of Krishna River, which flows in Karnataka.It rises at Kanakumbi in the Belgaum district and joins Krishna River at Kudalasangama in Bagalkot district. It also flows through Dharwar District. Hubli city gets its drinking water from this reservoir.

- Tributaries of Malprabha: Bennihalla, Hirehalla and Tuparihalla are the major tributaries to Malaprabha.

Ghataprabha River

Ghataprabha is a tributary of Krishna that flows in Karnataka. The Ghataprabha Project at Hidkal is a hydroelectric and irrigational dam across the river.

Tributaries of Ghataprabha:

- Hiranyakeshi and Markandeya rivers are tributaries of Ghataprabha

Other Tributaries of Krishna

Other tributaries include the Kudali river, Venna River, Koyna River, Yerla River, Warna River, Dindi River, Paleru River, Musi River, Urmodi River, Tarli River and Dudhganga River. The rivers Venna, Koyna, Vasna, Panchganga, Dudhganga, Ghataprabha, Malaprabha and Tungabhadra join Krishna from the right bank; while the Yerla River, Musi River, Maneru and Bhima rivers join the Krishna from the left bank.

Important places on banks of River Krishna

Mahabaleshwar

- Mahabaleshwar besides being a popular hill station and a weekend getaway from Mumbai is also the source of the Krishna River

- Mahabaleshwar is located at an altitude of 1,372 meters in the Western Ghats.
- Mahabaleshwar can also be called the 'land of five rivers', since the holy streams Krishna, Koyna, Venna, Gayatri and Savitri emerge from here.
- There are many places of tourist interest in Mahabaleshwar. Lodwick Point is an important landmark in Mahabaleshwar. It is considered one of the finest locations in Mahabaleshwar from where one can enjoy the beauty of the surrounding area. This point was earlier known as Sydney Point. Arther Point is the queen of all points. It is fascinating to see the barren deep valley Savitri on the left and shallow green valley on the right.
- Other places of tourist interest in Mahabaleshwar include Elphinstone Point, Tiger's Spring, Kate's Point, Bombay Point, Wilson Point, Venna Lake and Kate's Point. Lingmala, Chinaman and Dhobi Waterfalls are also worth visiting in Mahabaleshwar. Kate's Point (also known as sunrise point) in particular offers fabulous view of the Krishna River.

Srisailam

- Leaving Mahabaleshwar behind, the Krishna river takes the form of Dhom in Panchgani, a beautiful hill station close (17 km) to Mahabaleshwar.
- It meanders through Narsobachi, Wadi in Maharashtra and crisscrosses its way through Karnataka before entering Andhra Pradesh.
- Srisailam (in Andhra Pradesh) is a holy town located on the banks of the Krishna. Srisailam is surrounded by lush greenery and has beautiful locations around.
- It is a wonderful weekend getaway from Hyderabad. Srisailam Sanctuary is the main attraction that covers an area of 3568 sq kms. The down waters Srisailam dam is home to a variety of crocodiles.

Nagarjuna Sagar

- Popularly known for the Nagarjuna Sagar Dam, Nagarjuna Sagar is approximately 170 km from Hyderabad. The dam is an engineering marvel. Stretching across the mighty river Krishna, the barrage also has another distinction to its credit – it has created one of the world's largest man-made lake.
- The dam has played an important role in agricultural sector of the state.
- Nagarjunakonda was the largest and most important Buddhist centres in South India . The place derives its name from Acharya Nagarjuna, a renowned Buddhist scholar and philosopher, who had migrated here from Amaravati to propagate and spread the Buddha's message of universal peace and brotherhood.
- Not too far from Nagarjunakonda is Anupa, where a Buddhist University and Stadium were excavated.

Amaravati

- Situated on the banks of the Krishna, Amaravati is a small town in Guntur district of Andhra Pradesh. Amaravati is an excavation site and was once the capital of Satavahanas. It is one of the important Buddhist sites in India. Amaravati is located about 60 km from Vijayawada.
- Amareswara Temple is the major tourist attraction in Amaravati. The temple is dedicated to Lord Shiva. It is believed that Lord Shiva is present here in the form of five lingams - Pranaveswara, Agasteswara, Kosaleswara, Someswara and Parthiveswara. The temple is built in the Dravidian style of architecture and has many legends associated with it.
- The remains of a 2000-year-old Buddhist settlement along with the great Buddhist stupa are among the main attractions in Amaravati. Mahachaitya or the Great Stupa was constructed approximately 2000 years ago. The stupa is made of brick with a circular vedika and depicts Lord Buddha in a human form, subduing an elephant.

Vijayawada

- Vijayawada being a popular trade and commerce centre is also referred to as 'the business capital of Andhra Pradesh'. Vijayawada is the 3rd largest city in Andhra Pradesh and is the largest city on the banks of Krishna River.

Kaveri River Basin

Kaveri or Cauvery flows in Karnataka and Tamil Nadu. The river covers a distance of about 765 km and flows through the state of Karnataka and Tamil Nadu. On its journey to the Bay of Bengal, the river is joined by its tributaries, which include Shimsa, Hemavathi, Honnuhole, Arkavathi, Kapila, Lakshmana Theertha, Kabini, Lokapavani, Bhavani, Noyil and Amaravathy.

Talacauvery (also Talakaveri) located about 5000 ft above sea level is considered the source of the Cauvery.

Talacauvery is located in Coorg district of Karnataka and is 47 km from Maidekri.

Talacauvery is considered a famous pilgrimage site in Karnataka. At the source of the Cauvery there is a temple where every year on Tula sankramana thousands of pilgrims gather to pay their respects to the Cauvery.

The river then flows through Mysore district where two islands Srirangapatnam and Shivanasamudram are formed. At Sivasamudram the river drops 98 meters forming famous falls known as Gagan Chukki and Bara Chukki. After meandering through Karnataka, the river then enters Tamil Nadu and forms the boundary between the Erode and Salem districts. The Cauvery is joined by the Bhavani River at Bhavani. Hogenakkal is a major landmark on the course of the Cauvery in Tamil Nadu. Trichy and Thanjavur are other important towns on the banks of the Cauvery.

The river after covering a distance of 765 km merges into the Bay of Bengal through two principal mouths. One of the important distributory is Kollidam , which is is the northern distributary of the Kaveri River as it flows through the delta of Thanjavur. It splits from the main branch of the Kaveri River at the island of Srirangam and flows eastward into the Bay of Bengal.

Tributaries

Amaravati, Arkavathy, Bhavani, Chinnar, Hemavati, Honnuhole, Kabini, Kannika, Kollidam, Lakshmana Tirtha, Lokapavani, Noyyal, Pambar, Shimsha, Sujyothi

Riparian States and UTs

Karnataka, Kerala, Pondicherry, Tamil Nadu

Cauvery River Basin

The Kaveri basin is estimated to 72,000 km2 with many tributaries including the Shimsha, the Hemavati, the Arkavati, Honnuhole, Lakshmana Tirtha, Kabini, Bhavani River, the Lokapavani, the Noyyal and the Amaravati River.

Tributaries of Cauvery

Amaravathi River: Amaravati River is a tributary of Kaveri River in Coimbatore. It is continuation of the Pambar and Chinnar rivers in Kerala. It begins at Manjampatti Valley between the Annamalai Hills and the Palni Hills in Indira Gandhi Wildlife Sanctuary and National Park. It descends in a northerly direction through Amaravathi Reservoir and Amaravathi Dam at Amaravathinagar. It is joined by the Kallapuram River at the mouth of the Ajanda valley in Udumalaipettai. It joins with the Kaveri at Thirumukkudal, about 10km from Karur.

Arkavati River: It originates in Nandi Hills of Karnataka and joins Cauvery at Kanakapura, called Sangama in Kannada, after flowing through Kolar District and Bangalore Rural district. The river is used by the Bangalore Water Supply and Sewerage Board to provide 135 million liters of drinking water per day to the city of Bangalore, or about 20% of all the city's water. The river drains into the Chikkarayappanahalli Lake near Kanivenarayanapura.

Tributaries of Akravati

Kumudavathi and Vrishabhavathi rivers are tributaries to this river.

- **Bhavni River:** Its is a major tributary of Cauvery River. It originates in Nilgiri Hills, where 12 major rivulets join Bhavani. The west and East Varagar tributaries coming from the Nilgiris are the largest and each have dams in Tamil Nadu. The Bhavani is a 217 km. long perennial river fed mostly by the southwest monsoon and supplemented by the northeast monsoon. Its watershed drains an area of 6,200 km² spread over Tamil Nadu (87%), Kerala (9%) and Karnataka (4%).
- **Hemavati River:** It starts in the Western Ghats at an elevation of about 1,219 meters near Ballala rayana durga in the Chikmagalur District of the state of Karnataka, in southern India, and flows through Chikkamagaluru, Hassan District and Mysore district before joining the Kaveri near Krishnarajasagara.

Godavari River Basin

With a length of 1465 Kilometers, Godavari is India's second largest river that runs within the country and also the longest river in South India. It originates near Trimbak in Nashik District of Maharashtra state and flows east across the Deccan Plateau into the Bay of Bengal near Narasapuram in West Godavari district of Andhra Pradesh.

The river is also known as Dakshin Ganga and Gautami. The Manjra and Indravati rivers are its major tributaries.

The Godavari is sacred river and there are several places of pilgrimage on its banks. Trimbakeshwar and Nasik are major pilgrimage sites where one of the four Sinhastha Kumbh Mela takes place.

Every twelve years, Pushkaram, a major bathing festival, is held on the banks of the Godavari. The next Pushkaram festival is scheduled to be held in 2015.

Course of Godavari River

The river originates from Trimbak and then flows in the east across the Deccan Plateau traversing through the Trimbakeshwar, Nashik, Kopargaon, Paithan, Nanded, Rajahmundry, Adilabad and Bhadrachalam.

Just after Rajahmundry, the river splits into two streams that widen into a large river delta, which provides an extensive navigable irrigation. In Nizamabad district of Andhra Pradesh, there is a multipurpose project on the Godavari, which is called the Sriramsagar Project. Godavari empties into the Bay of Bengal near Narasapuram in West Godavari district of Andhra Pradesh.

- A barrage was built on the river at Dowleswaram by Sir Arthur Cotton in 1852. As it was damaged in 1987 floods, it was rebuilt as a barrage and roadway during 1987 and named after him. The roadway connects Dowleswaram in East Godavari and Vijjeswaram in West Godavari.
- There is also a big dam built just after the source of the river at Trimbakeshwar. The dam is in the town of Gangapur, which literally means a town on a river. The dam provides drinking water to the residents of Nashik and also supplies water to the thermal power station situated downstream at Eklahara, which provides power to the town.
- There is another multipurpose project on the Godavari River named Sriram Sagar Project on the borders of Adilabad and Nizamabad District. It is in the town of Pochampad, 60 km away from Nizamabad. It irrigates 4 districts of Northern Telangana Region of Andhra Pradesh and supplies power.
- The Jayakwadi dam near Paithan is one of the largest earthen dam in India. This dam was built to address the problem of drought in Marathwada region and problem of flood along the bank of river. Two 'left' and 'right' canals provide the irrigation to fertile land up to Nanded district. This dam has major contribution in industrial development of Aurangabad Maharashtra.

- **Havelock bridge is on Godavari River.** It was constructed under the supervision of F.T. Granville Walton who had constructed the Dufferin Bridge over the Ganges, and Granville Mills, British engineers. Spanning over 3 km in length, it linked the East Godavari and West Godavari districts. The brige has been a vital link enabling trains to run between Chennai and Howrah. Trains continued to ply over the bridge for a century until 1997, when train services over the bridge were suspended after the construction of 2 additional bridges.
- The **Coringa mangrove forests in the Godavari delta** are the second largest mangrove formation in the country. Part of this has been declared as the Coringa Wildlife Sanctuary, renowned for its reptiles. They also provide an important habitat to a wide variety of fish and crustaceans. These forests also act as barriers against cyclones, tropical storms and tidal waves thus protecting the nearby villages.
- The Krishna Godavari basin is one of the main nesting sites of the endangered Olive Ridley turtle.

Important Places on the Bank of River Godavari

- **Trimbakeshwar:** The source of the Godavari – Trimbakeshwar is one of the holy places in the country. It is located about 40 km from Nashik. Trimbakeshwar is one of the twelve Jyotirlingas of Lord Shiva. It is believed that there is no sacred place like Trimbakeshwar, no river like Godavari and no mountain like Bhrahmagiri.
- **Nashik:** Nashik is the first major city on the banks of the Godavari after Trimbakeshwar. Nashik is located about 185 km from Mumbai. It is an important religious center and attracts thousands of pilgrims every year from different parts of the country.
- **Paithan:** Famous for its Paithani sarees, Paithan is located on the banks of the Godavari in Aurangabad district of Maharashtra. It is 56 km south of Aurangabad, the ancient capital city of the Satvahanas. Paithan is associated with great saint Eknath. His 'samadhi' is located here. The Eknath Shrine comes alive during 'Paithan Yatra', also known as Nath Shashti, when devotees from Maharashtra and neighbouring states come to pay their respects to the saint.
- **Nanded:** Nanded is famous for the Sikh gurudwara – Takhat Sachkhand Shri Hazur Abchalnagar Sahib. A town of great antiquity, Naded was earlier known as 'Nandigram'. Gurudwara Shri Hazur Sahib is the main landmark in Nanded. It is one of the four high seats of authority of the Sikhs. This is the place where Shri Guru Gobind Singhji breathed his last. The gurudwara was built by Maharaja Ranjit Singh.
- **Bhadrachalam:** Bhadrachalam is situated on the banks of the Godavari and is 161 km from Rajahmundry and 200 km from Vijayawada. Bhadrachalam is regarded to be one of the holiest shrines in South India.

Tributaries of Godavari

- **Indravati River:** Indravati River rises in the Eastern Ghats in Kalahandi Orissa, and flows west to join the Godavari, forming the boundary between Maharashtra and Chhattisgarh states at places. The river flows for a length of 535 km with a drainage area of 41,665 sq.km.The Indravati is sometimes known as the "lifeline" of the Bastar District, one of the most green districts in India.
- **Pranahita River:** Pranhita River flows on the border of Gadchiroli district in Maharashtra and Adilabad district in Andhra Pradesh. It forms with the confluence of two rivers called Wardha and Wainganga.The Painganga River joins Vainganga near Aheri. The river then flows up to Sironcha before it empties into the Godavari River,near Sironcha in Maharashtra. The River course is mainly through the dense forests which are rich in Sagwan (timber).

Narmada River

Narmada or Rewa River is the third largest river that completely flows within India after Ganga & Godavari. It forms the traditional boundary between North India and South India. Narmada flows in a rift valley between the Satpura and Vindhya Ranges. It has been mentioned as Nammadus in the Periplus of Erythrean Sea.

Source and Course

Narmada origins in a small tank called Narmada Kund located on the Amarkantak hill in the Anuppur District of eastern Madhya Pradesh. The river descends from the Amarkantak hill range at the Kapildhara falls over a cliff and meanders in the hills flowing through a tortuous course crossing the rocks and islands up to the ruined palace of Ramnagar. Between Ramnagar and Mandla, (25 km (15.5 mi)), further southeast, the course is comparatively straight with deep water devoid of rocky obstacles. The Banger joins from the left. The river then runs north–east in a narrow loop towards Jabalpur. Close to this city, after the Dhuandhara falls, Narmada enters three narrow valleys between the Vindhya scarps in the north and the Satpura range in the South. The southern extension of the valley is wider at most places. These three valley sections are separated by the closely approaching line of the scarps and the Satpura hills. It forms the traditional boundary between North India and South India and flows westwards over a length of 1,312 km before draining through the Gulf of Cambey into the Arabian Sea, 30 km (18.6 mi) west of Bharuch of Gujarat

Basin

Between Vindya and Satpura ranges, Narmada extends over an area of 98,796 km² . The basin covers large areas in the states of Madhya Pradesh (86%), Gujarat (14%) and a comparatively smaller area (2%) in Maharashtra. In the river course of 1,312 km, there are 41 tributaries, out of which 22 are from the Satpuda range and the rest on the right bank are from the Vindhya range.

Importance

Narmada is one of the most sacred rivers of India. *Geologically, Narmada River is older than the river Ganges*. The river has been mentioned by Ptolemy in the Second century AD as Namade. In Puranas, it has been mentioned as Rewa. In Indian history, Kannada emperor from Chalukya dynasty Pulakeshin II is said to have defeated emperor Harshavardhana of Kannauj on the banks of Narmada. The valley is famous for the gorgeous Maheshwari saris, which are handwoven; comfortable in warm and cold weather, dressy and yet light; these saris have a dedicated, select following among Indian women. The Bhimbetka caves are located in a dyke of the Narmada valley at about 45 km northeast of Bhopal.

Mahi River

Mahi rises in Minda Village, in sardarpur district Madhaya Pradesh and, after flowing through the Vagad region of Rajasthan, enters Gujarat and falls into the sea by a wide estuary near Khambhat. Mahi encircles entire Banswara District in Rajasthan and first dam known as Mahi dam is at right side in Rajasthan. Kadana Dam is on Mahi in Gujarat. It is one of only three major rivers in peninsular India that runs from east to west along with the Tapti River and the Narmada River.

Tapti River

Tapi River, with length of 724 km, is one of only three rivers in peninsular India that run from east to west – the others being the Narmada River and the Mahi River. The river rises in the eastern Satpura Range of southern Madhya Pradesh state, and flows westward, draining Madhya Pradesh's Nimar region, Maharashtra's Kandesh and east Vidarbha regions in the northwest corner of the Deccan Plateau and south Gujarat, before emptying into the Gulf of Cambay of the Arabian Sea, in the Surat District of Gujarat. The river, along with the northern parallel Narmada river, form the boundaries between North and South India. The Western Ghats or Sahyadri range starts south of the Tapti River near the border of Gujarat and Maharashtra. The Tapti (Tapi) River empties into the Gulf of Khambhat near the city of Surat in Gujarat. Tapti Basin lies in the states of Maharashtra (51,504 km^2), Madhya Pradesh (9,804 km^2) and Gujarat (3,837 km^2).

Ghaggar-Hakra River

Ghaggar-Hakra River flows in monsoon season only. It is known as Ghaggar before the Ottu barrage and as the Hakra downstream of the barrage. It originates in the Shivalik Hills of Himachal Pradesh and flows through Punjab and Haryana states into Rajasthan; just southwest of Sirsa, Haryana and by the side of talwara jheel in Rajasthan, this seasonal river feeds two irrigation canals that extend into Rajasthan. The downstream Hakra is a dried up stream that possibly end in Rann of Katch.

Coastal Environment

Basics of Indian Coasts

The total coastline of India measures about 7,517 km, which is distributed among *nine coastal states* and *four Union Territories; and entire coast of India falls within tropics.* The **nine coastal states** are Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha and West Bengal. The **Four coastal Union Territories** are Puducherry, Lakshadweep, Daman & Diu and Andaman & Nicobar Islands. The coasts of India include West coast, East coast and Coast of Lakshadweep and Andaman and Nicobar islands.

Largest states by Coastline

Gujarat is strategically located with **largest share in India's coastline,** followed by Andhra Pradesh and Tamil Nadu.

State	Coastline
Gujarat	1915.29
Andhra Pradesh	1037
Tamil Nadu	864.73
Kerala	560
Maharashtra	510.31
Orissa	457.2
West Bengal	374
Karnataka	258.15
Goa	113.03
Daman & Diu	—
Total	6089.71

Over 22.6% of total coasts of India are of islands (Andaman and Nicobar, Lakshadweep and Diu islands). The Exclusive Economic Zones (EEZs) of India cover an area of about 2,305,143 km², enclosed within 200 nautical miles (that is : 370.4 km) from the land. Out of this, 1,641,514 km² is shared by India's coasts of mainland while 663,629 km² is of Andaman and Nicobar Islands. This implies that all the areas on the continental shelves (Indian Continental Shelf- 468,000 km2) are under national sovereignty.

From various points of view, Indian coasts are very much important. India has *large **coastal wetlands** which cover an area of over 41,401 km²*. This is 27.13% of the Total area covered by wetlands in India. *In contrast with the Inland wetlands, coastal wetlands are much less however*.The inland wetlands of India cover 105649 Km², which accounts Inland wetlands of India share around 69.22% of Total wetland area. (a question was asked in Prelims 2012 on this)

Origin of the western and eastern coasts of India is generally attributed to the faulting and subsidence of the Arabian Sea and the Bay of Bengal towards the close of the Eocene Period. This implies that the alluvial deposits along these coasts are of very recent origin, ranging from Pliocene to recent times.

West Coast of India

The Western Coastal plain lies between Kerala and Gujarat and stretches from the Arabian Sea to the Western Ghats. The total length of the western coasts is 1400 kilometers and its width varies from 10 kilometers to 80 kilometers. The elevation of the land ranges from 150m to 300m above sea level. The most important characteristics of the Western Coastal Plain are *sandy beaches, coastal sand-dunes, mud-flats, lagoons, alluvial tracts, estuaries, lateritic -platforms and residual hills.*

On the west coast, we have coastal plains of Gujarat and the coasts of the Peninsular India between Western Ghats and Arabian Sea. We divide the west coast into these three parts Coasts and Coastal Plains of Gujarat, Konkan Coast and Malabar Coast

Coastal Plains of Gujarat

Physiographically, Gujarat is divided into three regions viz. Mainland Gujarat, Saurashtra Peninsula and Katch. Out of them, the **Mainland Gujarat** consists of eastern rocky highlands, the extensions of mountains of western India and the western Alluvial Plains including the coastal plains.

The **Saurashtra Peninsula** forms a rocky table land fringed by the coastal plains with the central part made up of the undulating plain broken by hills and dissected by various rivers flowing in all directions.

The eastern fringe is a low land which marks the site of the former sea connection between the Gulfs of Katch and Gulf of Cambay.

Then, the **Katch region** is made up of Ranns which is basically a salt encrusted wasteland just a few meters above sea level. It gets denudated in the monsoon. It is divided into Great Rann in the north and Little Rann in the east. Between Great Rann and Rocky mainland lies the **Banni Plains**.

The above discussion makes it clear that plains of Gujarat cover almost the entire state of Gujarat, except two districts viz. Banaskantha and Sabarkantha. These plains have become mainly due to the alluvial deposits of Sabarmati, Mahi, Luni and other rivers and also the depositional activity of winds.

Luni and Banas rivers discharge into Rann forming inland drainage during rainy season, both of them are inland rivers.

Konkan Coast

From South of Gujarat plain, Konkan coastal plain extends from Daman to Goa. Its last boundary down south is Gangavalli River.

The Konkan coast is generally narrow, not exceeding 65 km. It is widest near Mumbai. It is rocky and uneven, a few hills protrude up to the sea and that is why we find numerous light houses across the costs to warn the ships remain away from the rocky area. The coast is rich in oil resources such as Bombay High. The northern part is sandy while the southern part is rugged.

Malabar Coast

The Malabar Coast starts from south of Goa to Kanyakumari or Cape Comorin on India's southern tip extends. This is known for numerous**lagoons** aka. Kayals, which run parallel to the coast in southern part of Kerala. A chain of brackish lagoons and lakes lying parallel to the Malabar Coast in Kerala are called Backwaters. The network of Kerala Backwaters includes five large lakes linked by canals, both manmade and natural, fed by 38 rivers, and extending virtually half the length of Kerala state. *The backwaters were formed by the action of waves and shore currents creating low barrier islands* *across the mouths of the many rivers flowing down from the Western Ghats range.*

Some important landmarks of this coast are the Vembanad lake, the longest lake of India and the **National Water Way-3**, that stretches Kottapuram to Kollam.

Importance of Kerala Coasts

Kerala coastal zone is famous for its beautiful beaches, backwaters and lagoons. The coastal belt, a narrow strip of lowland, is the most picturesque region of Kerala, interspersed with extensive backwaters, lagoons and canals and flanked by luxuriant coconut groves and green rice fields. The lagoons and backwaters are never far from the sea and at several places they have established a permanent connection with it. The backwaters, rivers and the canal system form a navigable waterway of about 1,920 km.

This offers an unique ecological niche with great potential for brackish water fish farming in the state.

The sea off Kerala is one of the most productive zones for marine fish in India. Kochi is the major port located along the coast. The entitre coastline is of natural beauty with vast beaches.*The tidal implications are felt deep into inland areas through the network of backwaters*. These tides have high utility for fishing, navigation and boating.

Eastern Coast of India

The eastern coasts cut through the **three states** viz. Tamil Nadu, Andhra Pradesh and Odisha. The **Cauvery delta** is most important sub region in Tamil Nadu, the **Krishna Godavari Delta** is most important landmark in Andhra Pradesh while the **Mahanadi Delta** is most important landmark in Odisha.

Eastern Coastal plain lies between the Eastern Ghats and the Bay of Bengal and is more extensive and wide than its western counterpart. They represent an **emergent coast** while it's western counterpart is an example of **submerging coast**. The region receives both the Northeast and Southwest monsoon rains with its annual rainfall averaging between 1,000 mm and 3,000 mm. The width of the plains varies between 100 to 130 kilometers. The region is *wider, gets more rainfall, more hot and humid, more discontinuous and more fertile & irrigated in comparison to the western plains.* At places the plains are bordered with dunes. Mangrove forests also grow in this region. Lagoons are also found here.

This plain is broadly divided into

- **Coromandal Coast:** Ranges from Kanyakumari in Tamil Nadu to **False Divi Point** in Andhra Pradesh, which is just at the apex of the Krishna River delta.
- The region between the Krishna and Mahanadi for which an old tem Northern Circars is sometimes used. Some classify it as Andhra Pradesh coastal plains.

- Mahanadi Delta. Another broader term used is Utkal Coast, which also includes the **Chilika Lake.**

Comparison of the East Coast and West Coast

West Coast	East Coast
Stretching from Rann of Katch to Kanyakumari as a narrow strip between Arabian Sea and Western Ghats Divided into costal plains of Gujarat, Konkan Coast and Malabar Coast Highly influenced by *south west monsoon* *Lagoons and Estuaries are common* *Submerging Coast* *Less attacked by Cyclones*	Stretching from Kanyakumari to Sunderbans as a relatively *broader (than western coast)* between Eastern Ghats and Bay of Bengal. Divided into Coromandal Coast and North Sircar coastal plains Influenced by *North East Monsoon. Also receives rains from South West Monsoon.* *Deltas are common* *Emergent Coast* *More attacked by Cyclones*

Important Observations about the Coastal Landmarks of India

Gulf of Katch

Gulf of Kutch is the largest coastal habitat in the West coast of India. It is a shallow water body with depth extending from 60 m at the mouth to less than 20 m at the head of the Gulf. Average depth is 30 meters. Around the **Lushington Island**, the depth is just 5 meters.

- Bordered by Katch in the north and Saurashtra in the south.
- Home to a **Marine National Park and Marine Sanctuary** at the southern shore, which includes 42 islands and a complex of fringing reefs backed by mudflats and sand flats, coastal salt marsh and mangrove forests, sand and rocky beaches which support a great diversity of fauna and flora.
- Many islands are **fringed with corals and mangroves** which provide disturbance free

habitats for many species of nesting birds.

- Apart from the islands, there are a large number of **wavecut**s (eroded shallow banks) such as Pirothan, Deda, Donna, Sankhodhar Beyt, Paga, Adatra and Boria, many of them have corals within.
- Gulf of Katch is the home for more than 800 species of organisms; 32 hard corals (Scleractinia) and 12 soft corals (Alcyonaria), 150-200 species of fishes, more than 100 species of algae, great diversity of sponges and worms, brittlestars, marine turtles and other reptiles, over 200 species of migratory and resident bird species.
- Gulf of Katch is home to the rare and endangered marine mammal, the **dugong (Sea Cow).**
- Gulf of Kutch produces **95% of the salt requirements of the country.** Salt pans are located close to inter-tidal area and deep into the land.
- Gulf of Katch area is home for intermediate and major ports like **Kandla, Adani, Okha and Salaya**. Kandla is one of the major ports of India.
- The Asia's largest oil refinery is located at Jamnagar in the Gulf of Kutch.

Gulf of Cambay

Gulf of Cambay or Gulf of Khambat is a 80 miles long gulf that divides the Kathiawar peninsula to the west from the eastern part of Gujarat state on the east. Two major rivers of Gujarat viz. **Narmada and Tapti** empty here.

- The Gulf of Cambay is known for its extreme tides.
- The Gulf of Cambay is home to Alang shipyard, which is known for marine salvage industry,

half of all ships salvaged around the world are recycled here. The state government wants to make it largest International Maritime Organization-compliant ship recycling yard in the world and for that Gujarat has joined hands with Japan. The industry is benefited a lot by the tides here. Large ships are beached during the twice-monthly highest tides, and are dismantled when the tide recedes.

- The Gulf is encircled by a string of historical port towns such as Bharuch, Surat, Khambhat, Bhavnagar, and Daman.
- The Gulf is shallow and abounds in shoals and sandbanks. Mangroves are also found here, mainly in the Piram island.

Gulf of Mannar

The Gulf of Mannar is a shallow bay, part of the Laccadive Sea in the Indian Ocean. A chain of low islands and reefs known as Adam's Bridge, also called Ramsethu, which includes Mannar Island, separates the Gulf of Mannar from Palk Strait, which lies to the north between India and Sri Lanka.

- The Thamirabarani River of south India and the Aruvi Aru of Sri Lanka drain into the Gulf of Mannar.
- The gulf of Mannar is home to thousands of species of flora and fauna and is known as one of the richest coastal regions in India. The corals, sharks, dugongs, dolphins and sea cucumber.
- The Gulf of Mannar Marine National Park was declared in 1986. The national park and its 10km buffer zone were declared Biosphere Reserve in 1989. The Gulf of Mannar is famous for its pearl banks of Pinctada radiata and Pinctada fucata for at least two thousand years.

Palk Strait

Palk Strait connects the Bay of Bengal in the northeast with the Palk Bay anc connects the Palk bay to Gulf of Mannar in the southwest. It is 53-80 kilometers wide, studded with a chain of low islands and reef shoals that are collectively called Adam's Bridge. This chain extends between Dhanushkodi on Pamban (Rameswaram) Island in Tamil Nadu and Mannar Island in Sri Lanka.

The shallow waters and reefs of the strait make it difficult for large ships to pass through, although fishing boats and small craft carrying coastal trade have navigated the strait for centuries. Large ships must travel around Sri Lanka. Construction of a shipping canal through the strait was first proposed to the British government of India in 1860, and a number of commissions have studied the proposal up to the present day. It is curently in news because of the Sethusamudram Shipping Canal Project.

Islands of India

The islands of India constitute Andaman and Nicobar group of islands (Bay of Bengal), Lakshadweep Islands (Arabian Sea), riverine and off shore islands. The Lakshadweep and the Andaman & Nicobar Islands are India's two major island formations. Other significant islands in India include Diu Daman, a former Portuguese enclave; Majuli, a river island of the Brahmaputra; Elephanta in Bombay Harbour; and Sriharikota, a barrier island in Andhra Pradesh. Salsette Island is India's most populous island on which the city of Mumbai (Bombay) is located. 42 islands in the Gulf of Kutch constitute the Marine National Park. The number of islands of India in Bay of Bengal is approximately 5 times the islands in the Arabian Sea.

Andaman and Nicobar Islands which are largely tectonic and volcanic in origin, while the islands of the Arabian Sea are mainly coral formations.

Andaman & Nicobar Islands (ANI)

The Andaman and Nicobar Archipelago consists of over 345 islands, islets and rocky outcrops, with land area extending up to 8,249 km^2 and a coastline stretch of 1,962 km; the Andaman Islands constitute 6408 km^2 and the Nicobars 1841 km^2.

The Andaman Islands are the extension of the submerged **Arakan Yoma Tertiary Mountain range of Myanmar** and the Nicobars are the continuation of the **Mentawai Islands to the south and southeast of Sumatra**. The main rocks of these islands are sandstone, limestone and shale. These two island groups situated in the Bay of Bengal span 6°45′ N to 13°41′ N (740 km) and 92°12′ E to 93°57′ E (190 km).

The *nearest land mass to Great Nicobar Island is Sumatra*, 145 km southeast; and the Myanmar coast is roughly 280 km north of Landfall Island, the northern- most island in the Great Andaman group.

The topography of the Andaman and Nicobar Islands is hilly and undulating, the elevation in the Andamans is from 0 to 732 m, *Saddle Peak being the highest in North Andaman Island*. In the Nicobars the elevation rises from 0 to 568 m, *Mt Thuillier being the highest peak on Great Nicobar Island*.

The Andaman Islands support one of the world's most extensive mangrove ecosystems. Due to their long isolation, these islands have evolved significant diversity of flora and fauna with a **high level of endemism**.

The land area of 6408 km² in the Andamans constitutes ***90% as reserves*** and protected areas of which 36% is tribal reserves. The *entire Nicobar group is a tribal reserve* and has four wildlife sanctuaries, two national parks and one biosphere reserve.

Important Observations about the Ecological Profile of Andaman and Nicobar Islands

- The ANI consists of very fragile island ecosystems and some of the most pristine in the world, which supports very unique flora and fauna. The landscape for large islands emerges from **sea grass beds, coral reef or rocky outcrops, to beaches, littoral forest, Andaman slope forests, hilltops, into valleys and streams** Some of the dominant tree species in these luxuriant forests reach heights of 40- 60 m.
- In some areas in the Andamans along the west and the east coast, the landscape starts from reefs or rocky outcrops to steep rock faces with wind blown vegetation.
- The topography of all large islands in the Andamans, Little Andaman, Little Nicobar and Great Nicobar Islands, is mostly interlaced with perennial and seasonal freshwater streams and in some areas a matrix of mangrove creeks extending into marshes.
- Little Andaman Island has ecosystems that do not occur anywhere else in the Andamans or the Nicobars, mainly extensive fresh and saline water marshes and peat
- 9% Dense Forests, 1.7% Open Forests, 12% Mangroves. Mangroves cover an area of 929 km^2 and in the Nicobar the extent is 37 km^2 (Balakrishnan, 1989; Andrews & Sankaran, 2002).
- ANI are fringed by one of the most spectacular **coral reefs** in the world.
- The **only primate,** the Nicobar crab eating macaque (Macaca fascicularis umbrasa) occurs in the southern group of the Nicobar Islands. The islands are a birdwatcher's paradise with as many as 250 species recorded.
- The complex geological history of these islands and the submergence of land bridges leading to isolation have left the islands with high levels of endemism. The widespread distribution of certain species indicates that there was an early evolution and dispersal throughout the archipelago. Endemism in reptiles and amphibians appears relative to species richness, islands with larger diversity have greater number of endemics.
- Protected areas in the islands are tribal reserves, national parks, wildlife sanctuaries, reserve, protected and preserved forest; and a biosphere reserve.
- An area of 513.70km^2 along the **west coast of South Andaman Island** is notified as a tribal reserve for the Jarawa people. This reserve extends north along the same coast into **Middle Andaman Island**, extending the reserve for another 338. 69 km^2. A 5 km distance into the sea from the high tide line right along the entire stretch of the Jarawa Reserve is also notified as part of the reserve.
- **Strait Island**, 6.01 km^2 in area, on the east coast of Middle Andaman Island supports a population of 45-50 of the last remaining Great Andamanese people.

- To the south west of South Andaman Island is North Sentinel Island with an area of 59. 67 km² and is inhabited by the Sentinalese people.
- The southern most island Little Andaman Island with a geographical area of 731. 57 km² and of this, 706. 49 km² with a distance of 3 km from the high tide line and into the sea along the coast has been notified as a tribal reserve for the Onge people.
- The entire group of 24 Nicobar Islands is notified as tribal areas; only 1,499.65 ha along the east coast from Campbell bay and up to 35 km is outside the Tribal Area and is inhabited by ex-servicemen, traders, government departments and the residents. Great Nicobar has a total area of 1044. 54 km² and of which 853. 19 km² is the tribal reserve, for both, the 380 Shompen people and the Nicobarese people.
- There are four national parks in the Andamans, Mahatma Gandhi Marine, Mount Harriet, Rani Jhansi Marine and Saddle Peak National Parks. The Nicobars have two areas notified as national parks and an area in Great Nicobar designated as the **Great Nicobar Biosphere Reserve.** Within the area of 960.40 km² in Great Nicobar Island, 110 km² is the **Galathea National Park**, situated on the south east of the island. On the east coast an area of 476. 73 km² is notified as the **Campbell Bay National Park**. An area of 885 km² includes the Nicobar Biosphere Reserve and all these parks are within the tribal area.
- The Barren Island in the Andamans has an active volcano. In the Bay of Bengal, there are two volcanic islands (Barren and Narcondam) situated within 80 km east of the Andaman Islands.
- Rice is the main crop in Andaman and Nicobar Islands. Coconut and Arecanut are the main cash crops of Nicobar.

Some other notes on Andaman and Nicobar Islands

Kalapani

Andaman & Nicobar were known as 'Kalapani' because of their having been a penal settlement under the British Rule. First establishment of East India Company was in 1789 which was abandoned in 1796. Following the first war of Indian Independence in 1857, the British India Government founded the penal settlement in these islands in 1858, primarily known as Kalapani, for the deportation of freedom fighters from the mainland India, which continued till the Second World War During the Second World War, the Japanese forces occupied the Andaman and Nicobar Islands in 1942. Further following the surrender of the Japanese forces in the Second World War, the British India Government reoccupied these islands in 1945 and continued their administration till the Independence of the country in 1947.

10 Degree Channel

It is a channel that separates the Andaman Islands from the Nicobar Islands in the Bay of Bengal. The channel is approximately 150 km wide, 400 fathoms deep running essentially along an east-west orientation. It is so named because it lies on the 10-degree line of latitude, north of the equator.

Landfall Islands

The northern most point is Landfall Island which is 901kms away from the mouth of Hoogly River and about 190kms from Burma.

Indira Point

The southern-most island is Great Nicobar, the southern-most tip of which Pygmalian Point now Indira Point is about 150kms away from Sumatra (Indonesia).

Saddle Peak

Saddle Peak in North Andaman at a height of 732 meters above sea level is the highest point in these islands.

Tribes

The original inhabitants of Andaman & Nicobar Islands lived in the forests on hunting and fishing. There are four Negrito tribes; viz., the Great Andamanese, Onge, Jarawa and Sentinalese in the Andaman group of islands and and the Nicobarese and Shompens in the Nicobar group.

Around 50 percent of the population is made up of settlers from the mainland India, some people call Andamans as a Little India or a mini-India. The settlers or ancestors of these settlers came either prior to 1947 or after 1947.

Chatam Island

The centre of activity of the Forest Department is Chatham Island. It has perhaps the biggest Saw Mill of its kind in Asia. Here logs are extracted with the help of elephants.

Mount Harriet

It is the highest hill around South Andaman and is about 365m . Formerly it was the headquarters of the Chief Commissioner.

Ross Islands

Seat of British Administration. The place came into decay with the shifting of the Chief Commissioner's Office in 1942 as areas close to the shore had developed serious cracks and it was felt that the building was not safe. Ross Island was occupied by Japanese in March 1942. In October 1945 the Islands were re-occupied by the British. Today the Island is deserted.

Madhuban

A training ground for elephants.

Ritchie's Archipelago

Ritchie's Archipelago is a cluster of smaller islands which lie some 25–30 km (16–19 mi) east of Great Andaman. The archipelago comprises some 4 larger islands, 7 smaller islands and several islets. The 4 large islands are Havelock Island, Henry Lawrence Island, John Lawrence Island and Sir William Peel Island.

Havelock Island

Known for Coral Reefs

Neil Island

Known for timbering operations.

Chiriya Tapu

Also known as Bird Island

The Viper Island

There was a jail prior to commissioning of Cellular jail.

Car Nicobar

Most of the Nicobarese people are Christians.

Cellular Jail

Regarded by the freedom fighters all over the country as a place of pilgrimage and meant for "dangerous prisoners". The construction of the Cellular Jail was taken up in 1898 and completed by about 1906. Whole jail consists of cells and each cell was meant for one inmate only. Cellular Jail originally had seven, three storied wings with a total of 698 cells, radiating from a central tower which had an additional storey to facilitate watch and ward.

"Tyranny of our Freedom Fighters"

Convicts who were sentenced to transportation for life were sent to these islands and interned in the Cellular Jail. Many political prisoners and revolutionaries were incarcerated here during the freedom struggle. Against the tyranny of the Jail management political prisoners were not allowed to communicate with their friends and relatives on the mainland except once in a year. Even the letters coming from mainland and newspapers subscribed by the prisoners were censored before being given to them. While fighting against this tyranny some political leaders had to lay down their lives. Many prisoners had gone insane in the Jail and ended their live by *committing suicide rather than subjecting themselves to the indignities heaped on them.*

Damage to Building:

In 1941 earthquake caused considerable damage to the Jail building. During the Japanese occupation from March 1942 to October 1954 further damage was caused to the building. All this finally resulted in the demolition of four out of the seven wings of the Jail. At present there are only three wings and these stand as silent monument to the great patriot's and martyrs who were interned in this Jail, who had to sacrifice their lives at the altar of their country's freedom.

Lakshadweep Islands

Lakshadweep is an archipelago consisting of 12 attols, 3 reefs and 6 newly formed/ submerged sand banks. It is comprised of – 11 inhabited islands, 16 uninhabited islands; six newly formed/ submerged sand banks and 3 reefs. The Inhabited islands are Kavaratti, Agatti, Bangaram, Amini, Kadmat, Kiltan, Chetlat, Bitra, Andrott, Kalpeni and Minicoy.

Aminidivi group (All Inhabited)
- Amini . Kadmat . Kiltan . Chetlat. Bitra

Laccadive group (First four Inhabited)
- Andrott. Kavaratti. Agatti. Kalpeni . Kalpitti . Bangaram. Tinnakkara . Parali . Tilakkam . Pitti . Cheriyam . Suheli . Valiyakara . Pakshi Pitti . Kodithala

Minicoy group (Minicoy Inhabited)
- Minicoy. Veiningili

Submerged Reefs
- Beliapani. Cheriapani. Perumul Par

Submerged Banks
- Bassas de Pedro . Sesostris Bank . Cora Divh. Amini Pitti . Kalpeni Bank

- Bitra is the smallest of all having only a population of 267 (Census 2001).
- Though, the land area of this Coral paradise is only 32 Sq.kms. the inclusion of about 4200 Sq.Kms. of its lagoon area, 20,000 Sq.km. of its territorial waters and almost 4, 00,000 Sq.kms of Exclusive Economic Zone makes it one of the largest territories of the country. Kavaratti is its capital (Headquarters). The total population of these islands is 60650 (as per 2001 census). Malayalam is traditional vernacular spoken in all the islands, *except Minicoy; where people speak*

Mahl, which is written in Divehi script and is the language of Maldives.

- The entire indigenous population because of their economic and social backwardness and geographical isolation is classified as Scheduled Tribes.
  The tribes have, however not been named. The islanders are Muslims by religion. These islands lie about 220 to 440 kilometers away from the coastal city of Kochi in Kerala between 8o and 12° 13" North Latitude and 71° and 74° East Longitude.

Important Observations about Lakshadweep

- Each island of Lakshadweep is fringed by coral sands. A common feature of these islands is that **a shallow lagoon exists invariably in their western side**separating the outer reef rim from low-lying coral islands composed essentially of calcareous sand and soil.
- Elevation of the Lakshadweep islands range from 0.5-7.0m above mean sea level. This implies that the danger from storm tides is tremendous over here.
- The origin of Lakshdweep Islands is attributed to theory of Sir Charles Darwin, according to whom the origin of these Islands can be traced to gradual submergence of some of the volcanic ridge into the Indian Ocean followed by accumulation of coralline deposits on the peaks and craters of these mountains. These deposits grew into coral islands resting on submerged mountaintops over a period of time.
- The islands are mostly coralline and their alignment appears to be in continuation of the Aravalli Strike of Rajasthan.
- Lakshadweep Islands are rich in marine wealth and an abode of plethora of coastal and marine bio-diversity with pristine Coral Reef Ecosystem which support variety of ornamental and food fishes belonging to various species besides the sedentary and slow moving creature such as Sea Cucumbers, shelled animals (Molluscs) and Hermit Crabs, Lobsters and Shrimps.
- The common farm species which are tend by the people are Cows, Goats, Ducks and Hens. Cats are common, but **dogs are almost wholly absent.** **There are no poisonous snakes on the islands**, and the islands are infested with rats and mosquitoes. The rats bring about a great deal of damage to coconut trees.
- The flora of Lakshadweep mainly consists of palm trees with coconut as the only commercial crop.
- Coastal bleaching and Coral erosion is one of the serious problems being faced by the Lakshadweep group of islands. During 1998 the strongest El Nino was recorded in Lakshadweep islands leading to rise in temperature in a range of 3-5° C above normal which resulted into severe coral bleaching, with mortality rates as high as 90% in some parts of these Islands. Rising sea levels may also lead to potentially acute erosion

Other Islands

Diu Island

Diu is an off – shore island on the western coast, off the Gulf of Cambay, bordering Junagarh district. It is separated from the Gujarat Coast by a **tidal creek**. The coast has limestone cliffs, rocky coves and sandy beaches, the best of which are at Nagoa. A massive fort built by the Portuguese dominates the skyline. Nagoa beach is the most famous in Diu. Another beautiful beach is Ghoghla beach. The Diu fort was constructed between 1535 and 1541 AD after the defence alliance concluded between the Sultan of Gujarat and the Portuguese. The fort commands a magnificent view of sea.

Mājuli Island

Mājuli is a large river island in the Brahmaputra river, in Assam with an area of 1,250 Kms² once upon a time but but having lost significantly to erosion it has left with only a third of it. It was formed due to course changes by the river Brahmaputra and its tributaries, mainly the Lohit. It was originally a piece of land between Brahamputra River (north) and Burhidihing river (south). Due to earthquakes back in mediveal times, the change of Brahamputra river course caused the formation of the Majuli Island. Mājuli is also the abode of the Assamese neo-Vaisnavite culture. A wetland, Mājuli is rich biodiversity spot and is home to many rare and endangered avifauna species including migratory birds that arrive in the winter season. Among the birds seen here are: the Greater Adjutant Stork, Pelican, Siberian Crane and the Whistling Teal. After dark wild geese and ducks fly in flocks to distant destinations. The island is almost pollution free owing to the lack of polluting industries and factories and also the chronic rainfall.

Islands Off Mumbai

Butcher Island

Butcher Island (Jawahar Dweep) is an island off the coast of Mumbai. It has an oil terminal used by the port authorities to offload it from oil tankers. The crude oil is stored in oil containers on the island. From there they are piped to Wadala, in Mumbai where they are refined. This keeps the city relatively safe from a mishap. It is a restricted area and most of the island is covered with dense vegetation. A hillock rises from the centre of the island. It is located 8.25 kilometres (5.13 mi) from the Gateway of India.

Elephanta Island

Elephanta Island or Gharapuri Island is in Mumbai Harbour. It is home to the Elephanta Caves that have been carved out of rock.

Oyster Rock

Oyster Rock is an island in the Mumbai harbour, Mumbai, India. It is fortified, and owned by the Indian Navy.

Pamban Island

Pamban Island or Rameswaram Island is in Tamil Nadu. The chain formed by Pamban Island, the shoals of Adam's Bridge, and Mannar Island of Sri Lanka separate Palk Bay and the Palk Strait in the northeast from the Gulf of Mannar in the southwest. Pamban Island extends for around 30 kilometres in width from the township of Pamban in the west to the remains of Dhanushkodi towards the south-east.

Sri Harikota

Sriharikota is a barrier island off the coast of Andhra Pradesh. It houses India's only satellite launch centre in the Satish Dhawan Space Centre (also known as SHAR) and is used by the Indian Space Research Organisation to launch satellites using multi-stage rockets such as the Polar Satellite Launch Vehicle and the Geosynchronous Satellite Launch Vehicle. Sriharikota separates the Pulicat Lake from the Bay of Bengal, and is home to the town of Pulicat.

Prelims Model Questions

India's Physiography-2 Model Questions

1. Consider the following river of India:

1. Krishna River

2. Cauvery River

3. Godavari River

Which among the above originate in Western Ghats?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

http://ces.iisc.ernet.in/biodiversity/documents/rivers.htm

2. Which one of the following rivers originates from Amarkantak ?

1. Narmada

2. Son

3. Damodar

4. Tapti

Choose the correct option from the following codes:

[A] Only 1 & 2

[B] Only 1, 2 & 4

[C] Only 2 & 4

[D] Only 1

Answer: [A] Only 1 & 2

River Narmada emerges from Amarkantak Hill of Maikal Range. Son river is largest of southern tributaries of Ganga that originates near Amarkantak in Madhya Pradesh near the source of Narmada River. Damodar originates in Chandwa on the Chota Nagpur Plateau. The Tapi River originates in the Betul district.

3. Indus river and Sutlej river have made magnificent gorges in Himalayas. Consider the following statements in this context:

1. Both Indus and Sutluj rivers originated before the Himalayan range was uplifted
2. Both Indus and Sutluj rivers emerge from the Tibetan side of Himalayas

Which among the above statements is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [C] Both 1 & 2

River Indus is an antecedent river as it is considered as older than the Himalayas. It has cut a magnificent gorge through the Himalayan mountain ranges that is more than 3 kilometres deep. Another major river of this system that is considered an antecedent river is the Sutlej. Satluj has also cut a gorge through the Central Himalayan Range. These rivers originated well before the Himalayan region was uplifted. The rivers Indus, Brahmaputra and Sutlej originated on Tibetan side and now traverse the existing mountain ranges, cutting deep gorges.

4. Most of the peninsular rivers in India are seasonal in nature. Which among the following is the least seasonal among all the rivers of the peninsula?

[A] Godavari

[B] Krishna

[C] Kaveri

[D] Tungbhadra

Answer: [C] Kaveri

Because of a long rainy season in its basin, the Cauvery is the least seasonal among all the rivers of the peninsular region

5. Consider the following statements:

1. Majority of the islands in Lakshadweep are unhabited

2. There are almost no snakes in Lakshadweep

Which among the above statements is / are correct?

[A] Only 1

[B] Only 2

[C] Both 1 & 2

[D] Neither 1 nor 2

Answer: [C] Both 1 & 2

6. What is the approximate ratio of parts of Indian Coast belonging to Peninsular India to that belonging to Andaman, Nicobar, and Lakshadweep Islands?

[A] 2:1

[B] 2.5:1

[C] 3:1

[D] 3.5:1

Answer: [B] 2.5:1

7. The origin of which among the following rivers is in Tibet?

1. Sutlej River

2. Indus River

3. Ghaghara River

Select the correct option from the codes given below:

[A] 1 & 2

[B] 2 & 3

[C] 1 & 3

[D] 1, 2 & 3

Answer: [D] 1, 2 & 3

8. Consider the following comparisons of the Himalayan Rivers and Peninsular rivers:

1. Most of the Himalayan rivers are perennial, while most of the peninsular rivers are rainfed

2. The gradient of the Himalayan rivers is steeper than peninsular rivers

3. The peninsular rivers cause more erosion on their way in comparison to the Himalayan rivers

Which among the above is / are correct?

[A] Only 1 & 2

[B] Only 2 & 3

[C] Only 1 & 3

[D] 1, 2 & 3

Answer: [A] Only 1 & 2

The rivers of the Himalayan region rise in the glaciers and they are perennial. In summer their volume tends to increase because snow melt in the upper reaches.

The peninsular rivers do not have their sources in glaciers and most of them are rainfed.

The Himalayan rivers not only carry a larger volume of water in comparison to their peninsular counterparts but also carry a larger amount of silt. On the other hand the peninsular region rivers carry a very limited amount of sediment.

The slopes of the Himalayan rivers is very steep on the upper reaches. That is one reason that they erode and transport huge amounts of sediments. Further, the landforms over these rivers flow is also young.

On the other hand, the peninsular rivers have not very steep gradient and they flow on already eroded old topography. Further, the hard rocks of the peninsular region are not as susceptible to erosion as those of the Himalayan region.

9. The correct location of the Duncan pass is between__:

[A] South and little Andaman

[B] North Andaman and south Andaman

[C] North and east Andaman

[D] North and Middle Andaman

Answer: [A] South and little Andaman

Duncan pass is located between South and little Andaman. Duncan Passage is a strait in the Indian Ocean. It is about 48 km (30 mi) wide; it separates Rutland Island (part of Great Andaman) to the north, and Little Andaman to the south. West of Duncan Passage is the Bay of Bengal; east is the Andaman Sea.

10. With reference to the rivers in India, the "Upper Yamuna" refers to the Yamuna river from its origin at Yamunotri to_:

[A] Tajewala in Yamuna Nagar district

[B] Dak Pathar near Dehradun

[C] Okhla Barrage in Delhi

[D] Paonta Sahib in Himachal Pradesh

Answer: [C] Okhla Barrage in Delhi

"Upper Yamuna" refers to the reach of Yamuna from its origin at Yamunotri to Okhla Barrage in Delhi. A Memorandum of Understanding (MoU) was signed on 12th May, 1994 amongst the basin states of Himachal Pradesh, Uttar Pradesh, Haryana, Rajasthan and Delhi, for sharing the utilizable surface flows of river Yamuna up to Okhla. The MoU also provided for creation of "Upper Yamuna River Board" to implement the said agreement. Accordingly, the Central Government constituted the Upper Yamuna River Board in 1995 as a subordinate office under the Ministry of Water Resources. After the creation of Uttaranchal State in 2000, the resolution was modified to include Uttaranchal (now Uttarakhand) also in the Board. The resolution also provided for constitution of a Review Committee, to be known as the Upper Yamuna Review Committee (UYRC), comprising the Chief Ministers (Governor in case of President's rule) of the co-basin states as members and Union Minister/Minister of State for Water Resources as Chairman, to supervise the working of the Upper Yamuna River Board (UYRB).

General Knowledge Today

Prelims Geography-10: Human & Economic Geography Basics

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Human Geography Concepts

Human geography studies the inter-relationship between the physical environment and socio-cultural environment created by human beings through mutual interaction with each other.

Determinism and Possibilism

Determinism and possibilism are two philosophical approaches in human geography.

Determinism

Philosophy of Determinism is based upon the interaction between primitive human society and strong forces of nature. This is an older philosophy which persisted till World War II. It says that the strong forces of environment control the course of human action. This implies that the history, culture, mode of life, and the level of development of the societal groups and countries are exclusively or largely controlled by the physical environment.

- According to Determinism, man is a passive agent, and nature is active agent, which controls and determines the action and decision-making processes of man.
- As per determinism, the human actions can be explained as a response to the natural environment.

Environmental determinism

This philosophy says that aspects of physical geography, particularly climate, influenced the psychological mind-set of individuals, which in turn defined the behaviour and culture of the society that those individuals formed. For example, tropical climates were said to cause laziness, relaxed attitudes and promiscuity, while the frequent variability in the weather of the middle latitudes led to more determined and driven work ethics.

- The core philosophy is that the supreme achievements of civilisation in any region were always bound up with a particular type of climate and variation in climate led to pulsations in the history and culture of the people.

These geographers who propound this theory say that the civilisations of Egyptians, Mesopotamians, Indus-valley, disappeared because of the climatic changes. The attacks of the central Asian nomads in different directions in the 13th century were also attributed to the drying up of their pastures directions of climatic change.

Possibilism

Possibilism is reaction to determinism and environmental determinism. It is based upon the assumption that environment sets certain constraints or limitations, but culture is otherwise determined by social conditions. This theory says that the true and only geographical problem is that to **utilisation of possibilities**.

Essence of Possibilism is that:

- Nature provides possibilities and man utilises them according to his culture, traditions, and levels of socioeconomic development.
- People are not just the products of their environment or just pawn of natural environment.
- *Nature is never more than an adviser.*
- There are not necessities but everywhere possibilities.
- The range of possibilities in every region is limited more by the price man is willing to pay of what he wants than by the dictates of environment. For instance, man through his technical skill can grow banana, rice and rubber plants in tundra, Greenland, and Antarctica, but he has to take into consideration the input cost.
- The prohibitive cost of production of these crops in the extremely cold conditions of these areas will compel man not to grow them in the tundra climate.

This approach has been criticised on several accounts. For example, despite numerous possibilities, man, has not been able to get rid of the obstacles set by the physical forces. The possibilities may be many in the temperate regions but they are very limited in the deserts, equatorial, tundra, and high mountainous regions.

Neo-determinism

Australian geographer Griffith Taylor, in 1920 argued that the limit of agricultural settlements in Australia has been set by factors of the physical environment such a distribution of rainfall. He further said that the best economic programme for a country to follow has in large part been determined by nature ,and it is the geographer's duty to interpret this programme. Man is able to accelerate, slow, or stop the progress of a country's regions development. But he should not, if he is wise, *depart from directions as indicated by natural environment.* He is like the traffic controller in a large city who alters the rate but not the direction of progress.

- This theory is also called ''stop and go determinism".
- It says that man follows nature's plan only if he is wise, presuming he can act foolishly ,which admits the possible contention that within broad limits set by environment, man can choose at the very least. But wisdom and folly are human concepts. The nature knows nothing of them.
- This theory says that in no environment are the possibilities limitless and for every choice a price must be paid. Man makes his choice and man himself judges its relative wisdom or folly by reference to goals he himself has established.

Migration

Migration, fertility and mortality are the basic fundamental elements determining population growth and demographic structure of a country. Migration may be international, intra-national, interregional, intra-urban, rural-to-urban, , and urban-to-rural.

Migration is permanent or semi-permanent change of residence of an individual or group of people over a significant distance. On the basis of distance, it may be long or short distance. On the basis of number, migration may be individual or mass; it may be politically sponsored or voluntary. On the basis of social organisation, migration may be that of family, community, clan, or individual. On the basis of causes, migration may be economic, social, cultural, religious or political. Migration may be stepwise or direct from the place of origin to the destination.

There can be various causes of migration such as over population, economic causes, Technology, Political causes, socio-religious causes, demographic causes and wars.

People migrate for a better economic and social life. There are two sets of factors that influence migration.

- The **Push factors** make the place of origin seem less attractive for reasons like unemployment, poor living conditions, political turmoil, unpleasant climate, natural disasters, epidemics and socio-economic backwardness.
- The **Pull factors** make the place of destination seem more attractive than the place of origin for reasons like better job opportunities and living conditions, peace and stability, security of life and property and pleasant climate

Migration has a direct and indirect consequence on society, demography, economy, and environment. Some of the main consequences of migration are:

Reallocation of resources

Generally, people from the crowded and overpopulated areas emigrate to the areas of sparse population with better re-source base, which helps in maintaining a balance between population and physical resources.

Change in demographic characteristics

Migration brings tangible change in demographic characteristics of place of origin and place of destination. The absolute number of population, the density of population, age composition, and literacy rates are either favourably or adversely affected.

Change in sex ratio

The sex ratio at the place of destination drops as the male members have been added while the sex ratio at the place of origin increases.

Economic gains

There is more intensive and judicious utilisation of physical resources at the place of destination, leading to higher agricultural and industrial production. The migrants send money back to home to their families which brings prosperity to the place of origin of migration also.

Transformation of ethnic characteristics

The physical and marital contacts of people belonging to different ethnic groups may change the biological characteristic of the migrants and that of the host population.

Transformation of cultural values

When large scale migration takes place, the cultural values of the people undergo radical transformation. The dietary habits of the people are also significantly transformed.

Theory of Demographic Transition

The demographic transition theory studies the relationship between economic development and population growth. It discusses about changes in birth rate and death rate and consequently growth rate of population in assonance with the process of growth and development. It is also used to describe and predict the future population of any area. The theory tells us that population of any region changes from high births and high deaths to low births and low deaths as society progresses from rural agrarian and illiterate to urban industrial and literate society. These changes occu**in stages** which are collectively known as the demographic cycle. There are four stages of demographic transition related to the state of economic development.

First Stage or Stage of High Birth Rate and High Death Rate

In first stage, the country is at low level of economic development. Agriculture is the main occupation of the people. Standard of living of the people is low. Death rate is high because of lack of medical facilities, epidemics, famines and illiteracy. Birth rate is high because of social and economic reasons. The key notable features of this stage are as follows:

- *Population Pyramid in the first stage is Expanding at the bottom*
- Stable population
- High birth rate, High infant mortality and High death rate = low life expectancy
- Many young people, very few older people
- High fertility rate (8+)

The first stage has high fertility and high mortality because people reproduce more to compensate for the deaths due to epidemics and variable food supply. The population growth is slow and most of the people are engaged in agriculture where large families are an asset. Life expectancy is low, people are mostly illiterate and have low levels of technology. Two hundred years ago all the countries of the world were in this stage.

Second Stage or Stage of High Birth Rate and Low Death Rate or Stage of Population Explosion

In this stage, birth-rate is high but death rate is low. It results in high growth rate of population. In this stage, income begins to rise and economic activities expand. On account of better health facilities and nourishing diet, death rate falls rapidly. Birth rate remains high due to social backwardness and limited access to contraceptives. The key notable features of this stage are as follows:

- Population Pyramid in this stage is Rapidly Expanding
- Very rapid increase in population (population explosion)
- Rapid decline in death rate but death rate remains below the birth rate
- Fertility rate remains high
- High birth rate
- High rate of natural increase
- Decline in infant mortality
- Many young people

Fertility remains high in the beginning of second stage but it declines with time. This is accompanied by **reduced mortality rate**. Improvements in sanitation and health conditions lead to decline in mortality. Because of this gap the net addition to population is high.

Third Stage or Stage of Declining Birth Rate and Low Death Rate

In the third stage, a declining birth rate and low death rate lead to low population growth. Along with economic development of the country, structural changes in the economy begin to take place. Large population begins to reside in urban areas. People start considering large families as liability. Consequently, birth rate begins to fall. Death rate continues to be low. Growth rate of population declines. India is passing through this stage of demographic transition. The key notable features of this stage are as follows:

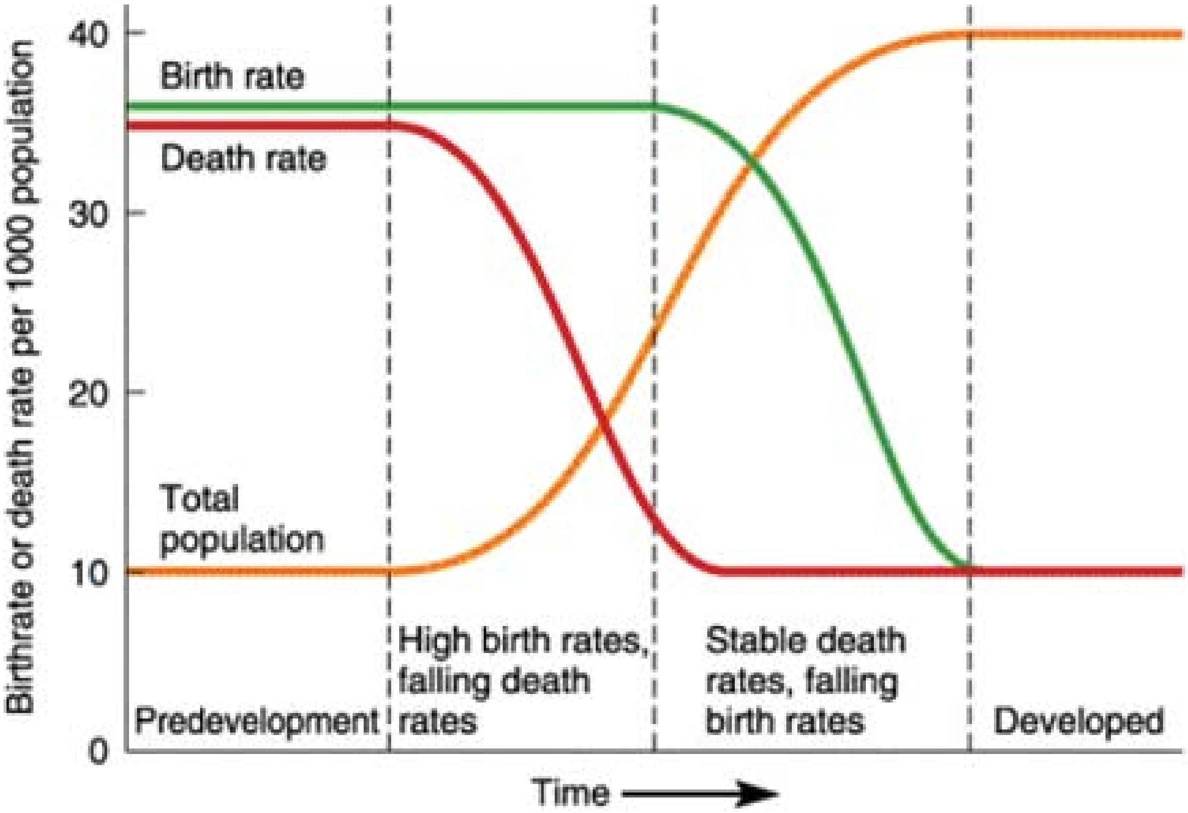
- The Population Pyramid in third stage is Stationary
- Population growth slows down
- Birth rate declining rapidly
- Decline in fertility rate
- Death rate declining slowly
- Birth rate approaching death rate
- High life expectancy
- Increasing number of older people

Fourth Stage or Stage of Low Birth Rate and Low Death Rate

In the fourth stage, low birth rate and low death rate lead to Population stabilisation. In this stage, because of rapid economic development, standard of living of the people becomes very high. Quality of life is given a priority to the size of the family. The key notable features of this stage are as follows:

- Population Pyramid is Contracting
- Stable or slow population increase
- Low birth rate
- Low death rate

- High life expectancy
- Birth rate is approximately the same as the death rate
- Fertility rate is close to or below 2.1
- Many older people



In the last stage, both fertility and mortality decline considerably. The population is either stable or grows slowly. The population becomes urbanised, literate and has high technical knowhow and deliberately controls the family size. This shows that human beings are extremely flexible and are able to adjust their fertility. In the present day, different countries are at different stages of demographic transition.

Demographic Dividend

India is a nation of young people – out of a population of above 1.1 billion, 672 million people are in the age-group 15 to 59 years, – which is usually treated as the "working age population".

A few years back, it was proposed that India in near future (30 years) will see a sharp **decline in the dependency ratio** over, which will constitute a major 'demographic dividend' for India. In 2001, 11% of population of the country was in age group of 18-24 years which is expected to rise to 12% by the end of XI Five Year Plan.

However, recent data says that India's old age dependency ratio is increasing consistently:

Longevity Dividend

When people live longer, it offers society a chance to reap a 'longevity' dividend. This implies that the elderly continue to contribute significantly for an unprecedented period of time. However, in order to reap that benefit, it is necessary that the challenges of an ageing population and understood and effective policy are made in time.

Zero Population Growth

Zero population growth is an ideal condition when the birth rate equals death rate and the replacement level is 2. Zero population growth is often a goal of demographic planners and environmentalists who believe that reducing population growth is essential for the health of the ecosystem. Preserving cultural traditions and ethnic diversity is a factor for not allowing human populations levels or rates to fall too low. Zero population growth is seen with increase in elderly population which is opposite to demographic dividend.

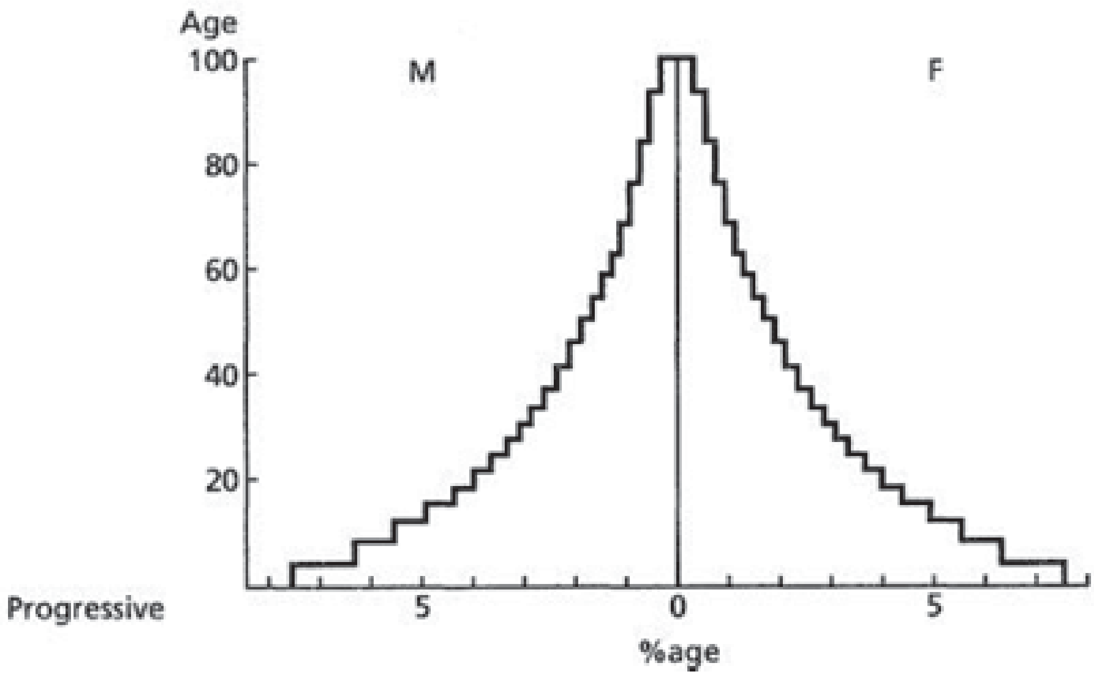
Age Sex Pyramid

The age-sex structure of a population refers to the number of females and males in different age groups. An age sex pyramid or population pyramid is used to show the age-sex structure of the population. The shape of the population pyramid reflects the characteristics of the population and also indicates whether the population is experiencing growth or decline or stability.

In an age sex pyramid, the left side shows the percentage of males while the right side shows the percentage of women in each age group. By convention, the younger ages are at the bottom.

Triangle Shaped Pyramid

A Triangle shaped pyramid with a wide base reflects that the number of people with lower age groups is larger and thus there would be high birth rates.



This kind of age sex pyramid is typical for Nigeria, Bangladesh or Mexico or such less developed countries. These have larger populations in lower age groups due to high birth rates.

Bell shaped Pyramid tapered at top

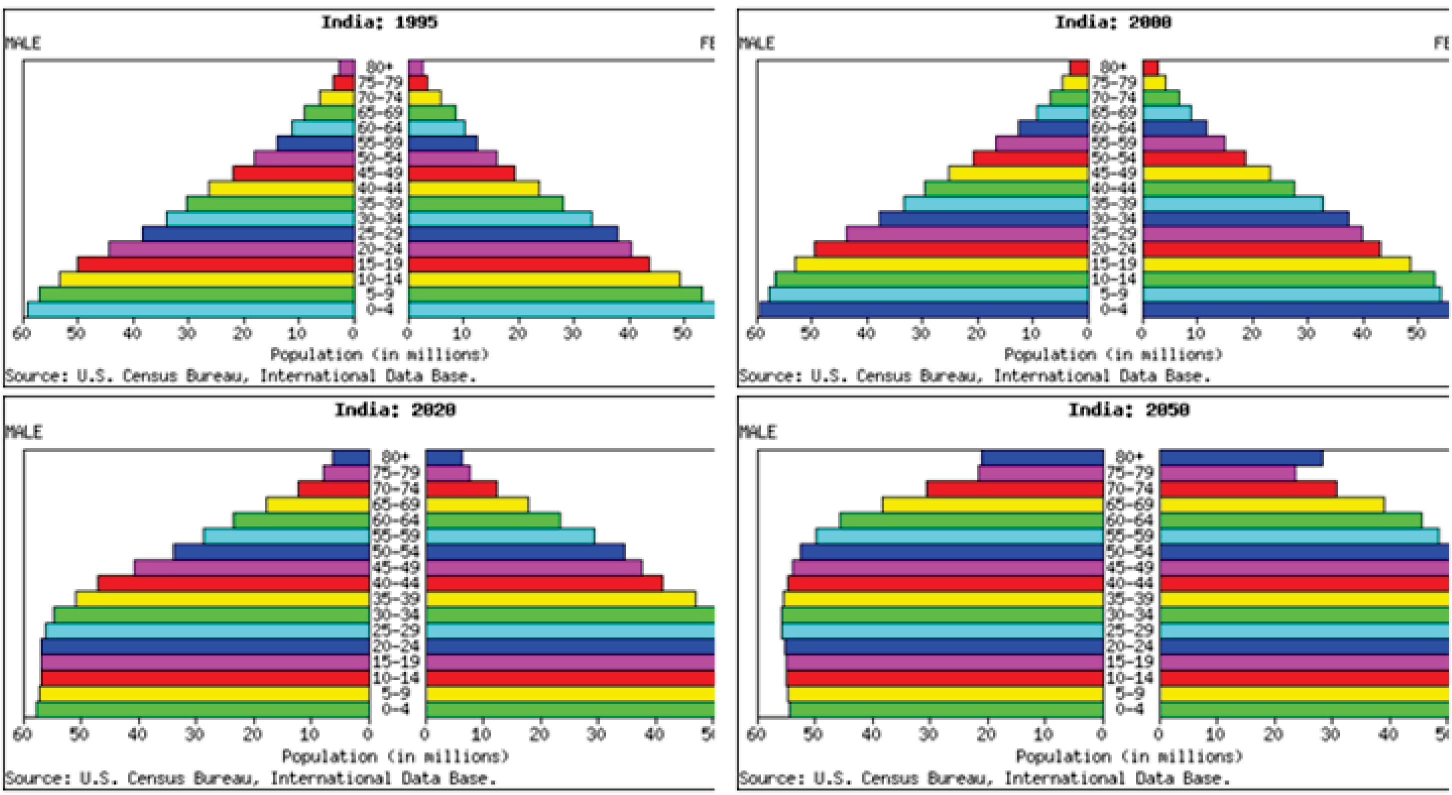
Australia's age-sex pyramid is bell shaped and tapered towards the top. This shows birth and death rates are almost equal leading to a near constant population.

Bell shaped Pyramid tapered at top and bottom

The Japan pyramid has a narrow base and a tapered top showing low birth and death rates. The population growth in developed countries is usually zero or negative.

India's Age Sex Pyramid

India's population is to grow by just over 57% between 2000 and 2050. This overall growth will, in part, be due to increased life expectancy and, therefore, a larger elderly population – around 10 million aged 80 years and over in 2005 to grow to around 50 million in 2050. However, the population is expected to begin to decline beyond 2050, with the 0-4 year old group falling from over 110 million in 2005 to just over 105 million. This means that India's Age Sex Pyramid was on stage 1 in past and expected to be at stage 4 in 2050. Since 1981, India has been passing through the**Third Stage** of demographic transition. Few states and union territories of India already reached the fourth stage.



Human Races

Human race refers to a group of people with certain features in common that distinguish them from other groups of people. There are various systems of classifications of human races. A 20th century classification given by American anthropologist Carleton S. Coon has divided the humans into five races as follows:

- Caucasoid (White) race
- Negroid (Black) race
- Capoid (Bushmen/Hottentots) race
- Mongoloid (Oriental/ Amerindian) race
- Australoid (Australian Aborigine and Papuan) race

We note here that technically, there are only three races viz. Caucasoid, mongoloid and negroid. Australoids as well as the Capoids (Hottentots and Bushmen) are considered to be sub-groups of Negroid people. In terms of population, the largest group is of Caucasoid (55%) followed by Mongoloid (33%), Negroid (8%) and Australoid (4%).

Caucasoid

Caucasoid includes people from Europe, North Africa, the Horn of Africa, Western Asia (the Middle East), parts of Central Asia and South Asia. The term Caucasian was initially a geographical term denoting the Caucasus region (Caucasia) of central Eurasia. However, later the word got many meanings including one of the races of humans.

The Caucasoids are further classified into various sub-races such as Aryans (including some Indo-Europeans), Semitic (Arabs and Israelis) Hamitic (Berber-Cushitic-Egyptian races), Nordic, Mediterranean, Dinaric, Alpine, Arabid, East Baltic, Turanid, Iranid, Armenoid and so on. Each of these sub-races is based on some geographic location.

Key Features Caucasian people

- The people of Caucasian and its sub-races have white skin color ranging from white to dark wheatish.
- They posses all kinds of hair including straight, blonde, wavy etc.
- They have prominent eyes, pronounced and well-shaped nose and sharp features, medium built and average to stocky musculature.

The Caucasian people have sparse skin pigmentation and due to this reason, they are not suited to live in hot equatorial climates.

Negroid

The Negroid are represented by the African people. They are also called woollen haired people. There are several sub-races of Negroids also including Aborigines, Melanesians, Negritos, Papuans, Dravidians etc. They also include a number of tribes such as Nilotic, Bantu, Sudanic, Pygmy, Khosian etc.

Salient Features

- Most striking feature of Negroids dark skin due to dense pigmentation, coarse black and wavy hair.
- They have wide noses and foreheads, broad, often thick lips, large built and broad skeletal

structure.

- These people have stamina and ability to survive in very adverse environmental conditions including sever heat. The dense pigmentation adapts them to strong heat and sun of equatorial regions in which this race originated.

Hottentots and Bushmen of the Kalahari. Hottentots and Bushmen are two major groups of Negroid people.

Mongoloid

Chinese and Japanese key representatives of the Mongoloid people. They are also called straight haired people. The Amerinds (Native American Indians) are supposed to be an early offshoot while the Polynesians are a sub-group of the Mongoloids with a great deal of racial intermixture.

Thus Mongoloid group has vast and diverse geographical distribution and so "Asian" seems to be more suitable term for them. The sub-races of Mongoloids include East Asian, North Asian and Native American.

Salient Features

- The striking feature of Mongoloids is yellowish or light wheatish skin, extremely straight and black hair, very less hair growth upon their bodies, small, almond-shaped eyes, slight built, very lean musculature and small but clear facial features.

Mongoloids can also be divided into **Neo-Mongoloids** and Paleo-**Mongoloids** also. Neo-Mongoloids include ethnic groups such as Eskimos, Buryats, Chinese, Chukchis etc. They have extremely mongoloid features. The Paleo-Mongoloids include ethnic groups such as Polynesians, Filipinos, Burmese, some Native American people etc.

Australoid

The Aborigines, Melanesians, Papuans, and Negritos i.e. original natives of the Australia sub-continent come under the Australoid race.

Salient Notes on Various Tribes of world

Aborigines

The term Aborigines is used to refer native people of a particular region but specifically this term denotes the original natives of Australia. They are negroid people mostly found in Queensland, Northern Territory and Western Australia.

Afrikaner

Africaner is a racial group of South Africa. These people have descended from the Dutch settlers who dominated the region in 17th and 18th century.

Amerinds

The term Amerinds is used for pre-Columbian inhabitants of North and South America. These are people of mixed original and European blood.

Bantus

Bantus are the Negroes of central and southern Africa who speak Bantu language.

Bedouins

Bedouins {literally desert dwellers} is a semi-nomadic tribe of Arab stock in Africa and Southwest Asia. Their ancestors used to inhabit the Arabian and Syrian deserts. Most of them herd camels and goats.

Berbers

Berbers are the Tribals of northern African countries of Morocco, Algeria and Tunisia.

Bushmen

Bushmen are the hunting gathering aborigines of Kalahari desert of Africa including countries Botswana, Namibia, Angola, Zambia, Zimbabwe, Lesotho and South Africa. They are excellent stalkers and hunters.

Eskimos

Eskimoes are the natives of tundra region (very cold high latitude areas) in Siberia (Russia), Alaska, Canada and Greenland. They used to live in igloos in winter and today, the 21st century Eskimoes do that snow house building only for fun.

Gaucho

Gauchos are nomads of Pampas in Uruguay and Argentina.

Hamites

Hamites are the dark-skinned Muslims in North-West Africa,

Hottentots

They are one of the original races inhabiting tropical Africa.

Kaffris

Kaffirs is a group of martial people inhabiting South Africa.

Kirghiz

Kirghiz are the people of the steppe-type region in Asia,

Magyars

Hungarians, also known as Magyars, are a nation and ethnic group who speak Hungarian and are primarily associated with Hungary.

Maoris

Maoris are the original inhabitants of New Zealand.

Masai

Masai is a negro tribe of East Africa and they are mostly cattle rearing tribes.

Masuds

Masuds is a tribal group inhabiting Waziristan region of Pakistan.

Moors

Moors refers to a mixed tribe of Arabs and Berber people of Morocco.

Moros

The Moro people are the indigenous Muslims in the Philippines, forming the largest non-Christian group there, and comprising about 5% of the total Philippine population. The Moro people mostly live in Mindanao and other parts of the southern Philippines. The area where settlements of Moro people (Muslim Filipinos) existed is called the Bangsamoro region.

They have been subject to continous migration and that is why they are found in all cities of Philippines such as Manila, Cebu and Davao City. In the last half of the 20th century, many Moros have emigrated to Malaysia, Indonesia and Brunei.

Pygmies

Pygmies are the extremely short-statured people of Zaire Basin in Africa.

Red Indians

Red Indians are aborigines of North America.

Swahili

Swahili is a group of aborigines in Kenya and Tanzania

Tartar

Tartar refers to a mixed group of people in Siberia.

Tenharim

The Tenharim are an indigenous people of Brazil, living in the state of Amazonas.

Yakuts

Yakuts are the people in the tundra region in Russia.

Zulus

The Zulu are the largest South African ethnic group, with an estimated 10–11 million people living mainly in the province of KwaZulu-Natal. Small numbers also live in Zimbabwe, Zambia and Mozambique. Their language, Zulu, is a Bantu language; more specifically, part of the Nguni subgroup. The Zulu Kingdom played a major role in South African history during the 19th and 20th centuries. Under apartheid, Zulu people were classed as third-class citizens and suffered from state-sanctioned discrimination. They remain today the most numerous ethnic group in South Africa, and now have equal rights along with all other citizens. They are considered warriors.

Economic Geography Basics

Economic geography deals with the spatial variations on the surface of the earth of activities related to production, exchange and consumption of goods and services. All the economic activities can be divided into four categories as follows:

Primary activities

Primary activities pertain to obtaining of natural resources from nature directly. Hunting, gathering, farming, animal husbandry, fishing, forestry, obtaining minerals from earth crust etc. are primary activities. Since these activities are outdoor in nature, the people engaged in them are called red-collar workers.

Secondary Activities

Secondary activities pertain to *adding value to already existing products by changing their form* via processing etc. Manufacturing industries are included in the secondary activities. We note here that sometimes, *commercial farming* is also included in secondary activities because of use of hybrid seeds and modern technology in cultivation. The workers engaged in secondary activities are called blue-collar workers.

Tertiary activities

Tertiary activities are concerned with providing service. The personal and business services such as clerks, barbers etc. are tertiary services. People engaged in these activities are called pink-collar workers.

Quaternary services

The services which are provided in special environments are called quaternary services. For example, health services are provided into hospitals, hospitality services are provided in hotels, teaching service is provided into school and institutors, entertainment services are provided into theatres, software services are provided over internet or computers. The workers engaged in such services are called white-collar workers. Researchers, legal consultants, financial advisors, professional consultants, software personnel etc. are white-collar workers. In summary, Quaternary activities are developed from of services with specific knowledge, technical skills, and competence of communication or administration.

Primary Activities

Human activities which generate income are known as economic activities. Economic activities are broadly grouped into primary, secondary, tertiary and quaternary activities.
Primary activities are directly dependent on environment as these refer to utilisation of earth's resources such as land, water, vegetation, building materials and minerals. It, thus includes, hunting and gathering, pastoral activities, fishing, forestry, agriculture, and mining and quarrying. We have already studied the primary sector of India economy, this section focuses on some core concepts.

Red Collar workers

People engaged in primary activities are called red collar workers due to the outdoor nature of their work.

Gathering

Gathering and hunting are the oldest economic activity known. Gathering is practised in regions with harsh climatic conditions. It often involves primitive societies, who extract both plants and animals to satisfy their needs for food, shelter and clothing. The main features of Gathering and Hunting activities are:

- Low Capital / Skill Investment

- Low Yield Per Person
- No Surplus in production

Gathering is practised in the following areas of the world:

- Northern Canada, northern Eurasia and southern Chile (High Altitude Areas)
- Low latitude zones such as the Amazon Basin, tropical Africa, Northern fringe of Australia and the interior parts of Southeast Asia.

Areas with Subsistence Gathering Around the world

Nomadic Herding Or Pastoral Nomadism

Nomadic herding or pastoral nomadism is a primitive subsistence activity, in which the herders rely on animals for food, clothing, shelter, tools and transport. They move from one place to another along with their livestock, depending on the amount and quality of pastures and water, **thus there is an irregular pattern of movement**. It is different from **Transhumance** *in which there is a fixed seasonal pattern of movement*.

Nomadic pastoralism is commonly practised in regions with little arable land, typically in the developing world. Of the estimated 30–40 million nomadic pastoralists worldwide, most are found in **central Asia and Northern and western region of Africa**, some parts of southern Africa and Tundra regions.

Areas of Nomadic Herding around the World

Transhumance

Transhumance is the **seasonal movement** of people with their livestock between fixed summer and winter pastures. In montane regions (vertical transhumance) it implies movement between higher pastures in summer and lower valleys in winter. Herders have a permanent home, typically in valleys. Only the herds travel, with the people necessary to tend them. In contrast, horizontal transhumance is more susceptible to being disrupted by climatic, economic or political change.

Transhumance in India & World

In mountain regions, such as Himalayas, Gujjars, Bakarwals, Gaddis and Bhotiyas migrate from plains to the mountains in summers and to the plains from the high altitude pastures in winters. In Rajasthan also the herders from desert regions move towards central India during summer season. Similarly, in the tundra regions, the nomadic herders move from south to north in summers and from north to south in winters. The number of pastoral nomads has been decreasing and the areas operated by them shrinking. This is due to imposition of political boundaries and new settlement plans by different countries.

Commercial Livestock Rearing

Commercial livestock rearing is more organised and capital intensive activity in comparison to the Nomadic pastoralism. It is generally practised in permanent ranches.

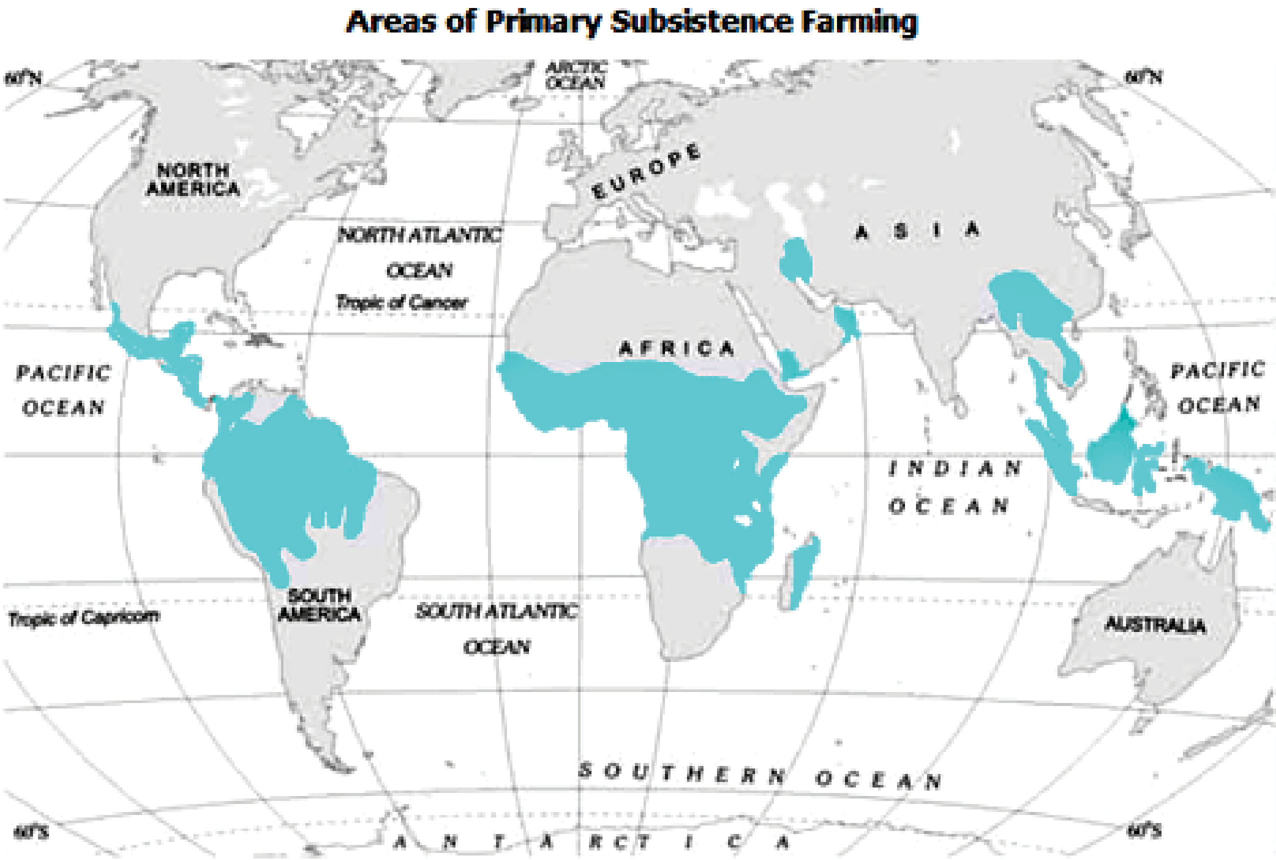
Ranches
Ranches refers to the large stock farms, usually fenced in, where animals are bred and reared on a commercial scale. They are found especially in the United States.

Products such as meat, wool, hides and skin are processed and packed scientifically and exported to different world markets emphasis is on breeding, genetic improvement, disease control and health care of the animals. New Zealand, Australia, Argentina, Uruguay and United States of America are important countries where commercial livestock rearing is practised.

Areas of Commercial Livestock Rearing

Primary Subsistence Agriculture

Subsistence agriculture is one in which the farming areas **consume all, or nearly so, of the products locally grown**. It is of two types viz **Primitive Subsistence Agriculture** and **Intensive Subsistence Agriculture**. Primitive subsistence agriculture is also known as **Shifting Cultivation.** It is widely practised by many tribes in the tropics, especially in Africa, south and Central America and south East Asia.



When the vegetation is cleared by fire, and the ashes add to the fertility of the soil, it is called slash and burn agriculture. After sometime (3 to 5 years) the soil looses its fertility and the farmer shifts to another parts and clears other patch of the forest for cultivation.

The farmer may return to the earlier patch after sometime. Major problem of shifting cultivation is that the cycle of jhum becomes less and less due to loss of fertility in different parcels. It is prevalent in tropical region in different names, e.g.

- *Jhuming in North eastern states of India*
- *Milpa in central America and Mexico*
- *Ladang in Indonesia and Malaysia,*
- *Caingin in Philippines,*
- *Ray in Vietnam,*
- *Taungya In Myanmar*
- *Tamrai in Thailand,*
- *Chena in Sri Lanka,*
- *Conuco in Venezuela,*
- *Roca in Brazil,*
- *Masole in central Africa.*

Intensive subsistence agriculture

Intensive subsistence agriculture is predominant in the densely populated regions of monsoon Asia. There are two types as follows:

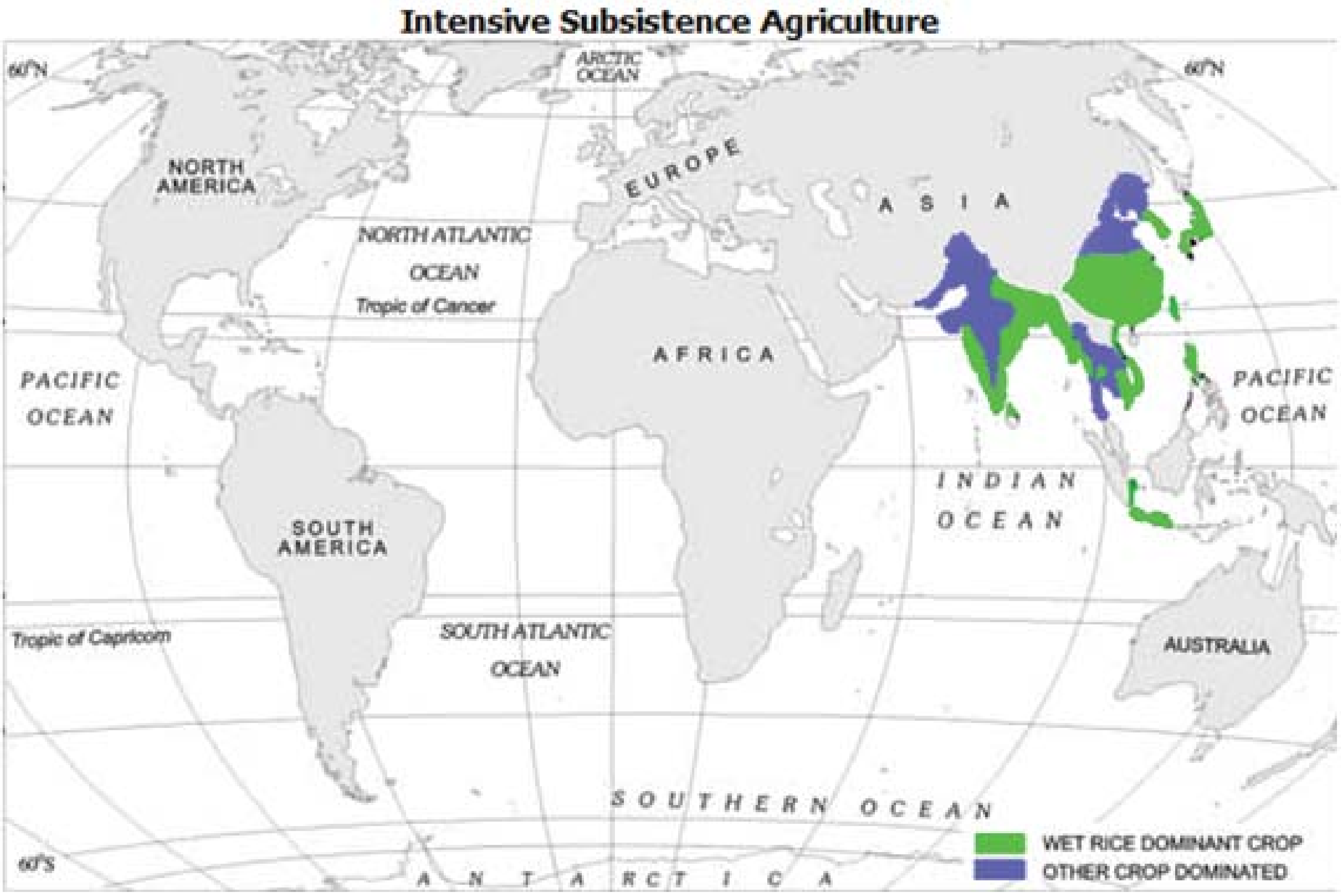
Intensive subsistence agriculture dominated by wet paddy cultivation

This is dominated by the paddy crop and is prevalent in the Eastern India. The Land holdings are very small due to the high density of population. Farmers work with the help of family labour leading to intensive use of land. Use of machinery is limited and most of the agricultural operations are done by manual labour. Farm yard manure is used to maintain the fertility of the soil. In this type of agriculture,

- *The yield per unit area is high*
- *Per labour productivity is low.*

Intensive subsidence agriculture dominated by crops other than paddy:

Wheat, soyabean, barley and sorghum are grown in northern China, Manchuria, North Korea and North Japan. In India wheat is grown in western parts of the Indo-Gangetic plains and millets are grown in dry parts of western and southern India. Most of the characteristics of this type of agriculture are similar to those dominated by wet paddy except that irrigation is often used.



Plantation Agriculture

Plantation agriculture was introduced by Europeans in their tropical colonies. Some of the important plantation crops are tea, coffee, cocoa, rubber, cotton, oil palm, sugarcane, bananas and pineapples.

The characteristic features of this type of farming are

- Large estates or plantations,
- Large capital investment,
- Managerial and technical support
- Scientific methods of cultivation
- Single crop specialisation
- Cheap labour,
- Good system of transportation which links the estates to the factories and markets for the export of the products.

Europeans in Plantation Crops

- The French established cocoa and coffee plantations in West Africa.
- The British set up large tea gardens in India and Sri Lanka, rubber plantations in Malaysia and sugarcane and banana plantations in West Indies.
- Spanish and Americans invested heavily in coconut and sugarcane plantations in the Philippines.
- The Dutch once had monopoly over sugarcane plantation in Indonesia.
- Some coffee fazendas (large plantations) in Brazil are still managed by Europeans.

Extensive Commercial Grain Cultivation

Commercial grain cultivation is practised in the interior parts of semi-arid lands of the midlatitudes. Wheat is the principal crop, other crops being corn, barley, oats and rye . This is characterised by very large farms and entire operation mechanised. Predominant in Eurasian steppes, the Canadian and American Prairies, the Pampas of Argentina, the Velds of South Africa, the Australian Downs and the Canterbury Plains of New Zealand.

Mixed Farming

Mixed Farming is a type of farming in which**cultivation of crops and raising of livestock go hand in hand**. Both these activities play an important part in the economy.

Mixed Farming is predominant in highly developed parts of the world, e.g. North-western Europe, Eastern North America, parts of Eurasia and the temperate latitudes of Southern continents. The important features of Mixed Farming are:

- Medium to large size farms
- **Crop rotation and intercropping for maintaining soil fertility.**
- **Crop cultivation and equal importance on animal husbandry**.

Animals like cattle, sheep, pigs and poultry provide the main income along with crops. Mixed farming is characterised by high capital expenditure on farm machinery and building, extensive use of chemical fertilisers and green manures and also by the skill and expertise of the farmers.

Dairy is the most advanced and efficient type of rearing of milch animals. It is highly capital intensive.

Some Other terms

Rotation of Crops

A systematic succession of different crops on a given piece of land carried out in order to avoid exhaustion of the soil.

Sedentary Agriculture

Farming practised more or less permanently on the same piece of land, the same as settled agriculture.

Truck Farming

Growing of vegetables around the urban centres to meet the daily demand of the people is known as truck farming. It is governed by the distance a truck can cover overnight between the farm and the market.

Secondary Activities

The secondary sector of the economy is involved in the production of finished goods. All manufacturing, processing and construction activities lie in this sector. Some of the activities in this sector are metal working, automobile manufacturing, textile, production, ship building, etc. Most economies in their process of development go through the middle phase, where the secondary sector becomes the largest sector of the economy in terms of production and employment with the reduction in importance of the primary sector. However, India is an exception, where we have directly moved to services sector development without first improving the manufacturing capabilities.

Manufacturing refers to production of goods from raw material. The literal meaning of manufacturing is to "make by hand", however, this term today includes the manufacturing by machines also.

The key features of modern large scale manufacturing include specialization of skills and methods of production, mechanization, technological innovation, organizational structure, uneven geographical distribution whereby most concentrations of manufacturing units is in few places.

Factors affecting Industrial Locations

The major concentrations of modern manufacturing have flourished in a few numbers of places and cover less than 10% of global geographical area. Since the objectives of firms are to maximize the profits, the industry locations tend to be chosen in such a way that production costs are minimized.

The factors that influence the industrial location are as follows:

Access to Market

The existence of a market for manufactured goods is the most important factor in the location of industries. 'Market' means people who have a demand for these goods and also have the purchasing power (ability to purchase) to be able to purchase from the sellers at a place. Remote areas inhabited by a few people offer small markets. The developed regions of Europe, North America, Japan and Australia provide large global markets as the purchasing power of the people is very high. The densely populated regions of South and South-east Asia also provide large markets. Some industries, such as aircraft manufacturing, have a global market. The arms industry also has global markets.

Access to Raw Material

Raw material used by industries should be cheap and easy to transport. Industries based on cheap, bulky and weight-losing material (ores) are located close to the sources of raw material such as steel, sugar, and cement industries. Perishability is a vital factor for the industry to be located closer to the source of the raw material. Agro-processing and dairy products are processed close to the sources of farm produce or milk supply respectively.

Access to Labour Supply

Labour supply is an important factor in the location of industries. Some types of manufacturing still require skilled labour. Increasing mechanisation, automation and flexibility of industrial processes have reduced

the dependence of industry upon the labours.

Access to Sources of Energy

Industries which use more power are located close to the source of the energy supply such as the aluminium industry. Earlier coal was the main source of energy, today hydroelectricity and petroleum are also important sources of energy for many industries.

Access to Transportation and Communication Facilities

Speedy and efficient transport facilities to carry raw materials to the factory and to move finished goods to the market are essential for the development of industries. The cost of transport plays an important role in the location of industrial units. Western Europe and eastern North America have a highly developed transport system which has always induced the concentration of industries in these areas. Modern industry is inseparably tied to transportation systems. Improvements in transportation led to integrated economic development and regional specialisation of manufacturing. Communication is also an important need for industries for the exchange and management of information.

Government Policy

Governments adopt 'regional policies' to promote 'balanced' economic development and hence set up industries in particular areas.

Access to Agglomeration Economies/ Links between Industries

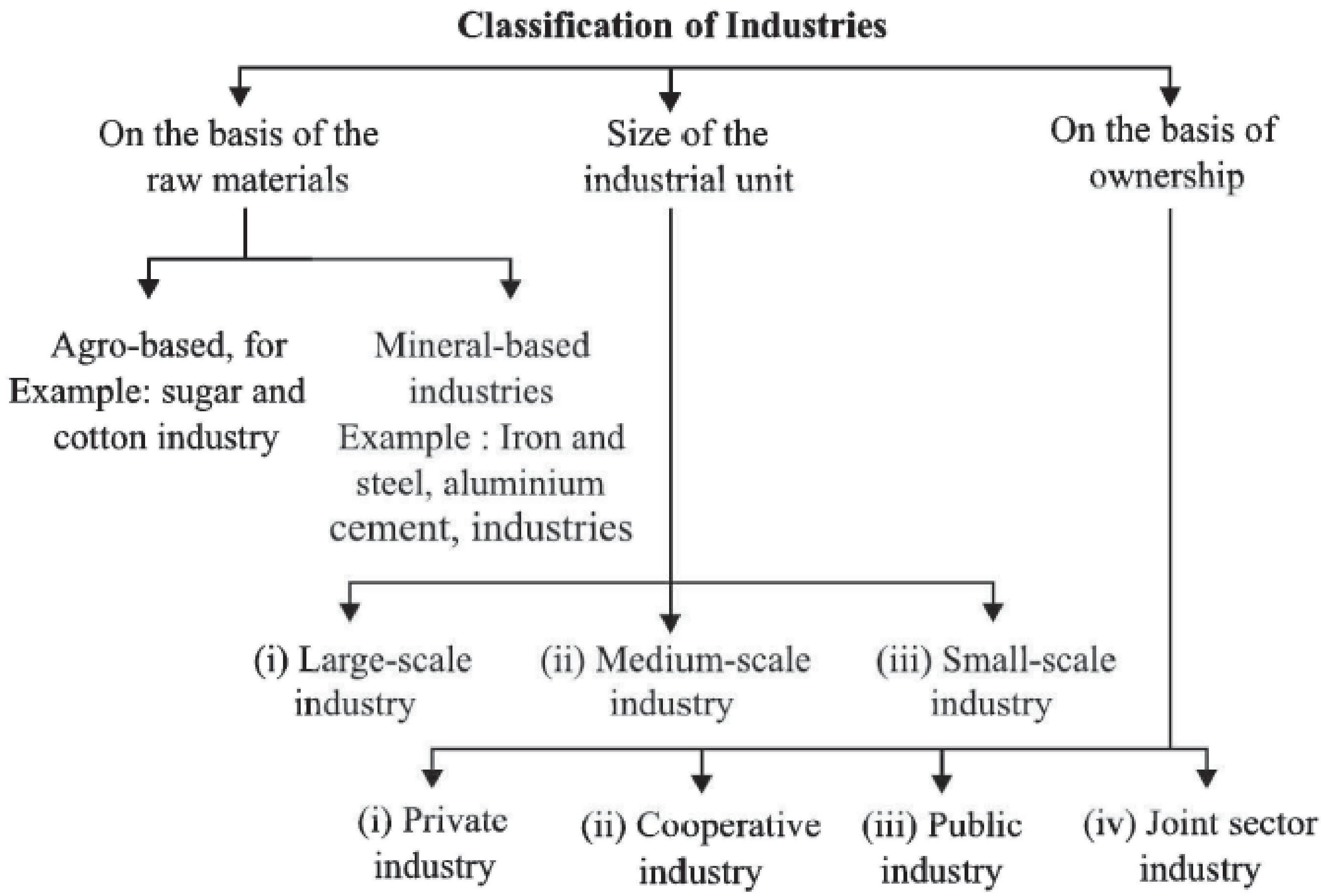
Many industries benefit from nearness to a leader-industry and other industries. These benefits are termed as agglomeration economies. Savings are derived from the linkages which exist between different industries.

Footloose Industries

Footloose industries are those industries which nearly remain indifferent with locational aspects of plant. Their products are having very high value addition and smaller in size and so transportation cost is only a small fraction of total cost. These industries usually requires a very small production space, are usually less polluting and but requires highly skilled workers. Examples are: watch, camera, diamond cutting, precision electronics, etc. Kindly note that Material Index in footloose industries is 1.0.

Classification of Manufacturing Industries

Manufacturing industries are classified on the basis of their size, inputs/raw materials, output/products and ownership.



Industries based on Size

The amount of capital invested, number of workers employed and volume of production determine the size of industry. Accordingly, industries may be classified into household or cottage, small-scale and large-scale.

Household Industries or Cottage Manufacturing

It is the smallest manufacturing unit. The artisans use local raw materials and simple tools to produce everyday goods in their homes with the help of their family members or part-time labour. Finished products may be for consumption in the same household or, for sale in local (village) markets, or, for barter. Capital and transportation do not wield much influence as this type of manufacturing has low commercial significance and most of the tools are devised locally.

Some common everyday products produced in this sector of manufacturing include foodstuffs, fabrics, mats, containers, tools, furniture, shoes, and figurines from wood lot and forest, shoes, thongs and other articles from leather; pottery and bricks from clays and stones. Goldsmiths make jewellery of gold, silver and bronze. Some artefacts and crafts are made out of bamboo, wood obtained locally from the forests.

Small Scale Manufacturing

Small scale manufacturing is distinguished from household industries by its production techniques and place of manufacture (a workshop outside the home/cottage of the producer). This type of manufacturing uses local raw material, simple power-driven machines and semi-skilled labour. It provides employment and raises local purchasing power. Therefore, countries like India, China, Indonesia and Brazil, etc. have developed labour-intensive small scale manufacturing in order to provide employment to their population.

Large Scale Manufacturing

Large scale manufacturing involves a large market, various raw materials, enormous energy, specialised workers, advanced technology, assembly-line mass production and large capital. This kind of manufacturing developed in the last 200 years, in the United Kingdom, north-eastern U.S.A. and Europe. Now it has diffused to almost all over the world. On the basis of the system of large scale manufacturing, the world's major industrial regions may be grouped under two broad types viz.

1. Traditional large-scale industrial regions which are thickly clustered in a few more developed countries.
2. High-technology large scale industrial regions which have diffused to less developed countries.

Industries based on Inputs/Raw Materials

On the basis of the raw materials used, the industries are classified as: (a) agro-based; (b) mineral based; (c) chemical based; (d) forest based: and (e) animal based.

Agro based Industries

Agro processing involves the processing of raw materials from the field and the farm into finished products for rural and urban markets. Major agro-processing industries are food processing, sugar, pickles, fruits juices, beverages (tea, coffee and cocoa), spices and oils fats and textiles (cotton, jute, silk), rubber, etc.

Agri-business is commercial farming on an industrial scale often financed by business whose main interests lie outside agriculture, for example, large corporations in tea plantation business. Agri-business farms are mechanised, large in size, highly structured, reliant on chemicals, and may be described as 'agro-factories'.

Mineral based Industries

These industries use minerals as a raw material. Some industries use ferrous metallic minerals which contain ferrous (iron), such as iron and steel industries but some use non-ferrous metallic minerals, such as aluminium, copper and jewellery industries. Many industries use non-metallic minerals such as cement and pottery industries.

Chemical based Industries

Such industries use natural chemical minerals, e.g. mineral-oil (petroleum) is used in petrochemical industry. Salts, sulphur and potash industries also use natural minerals. Chemical industries are also based on raw materials obtained from wood and coal. Synthetic fibre, plastic, etc. are other examples of chemical based industries.

Forest based Raw Material using Industries

The forests provide many major and minor products which are used as raw material. Timber for furniture industry, wood, bamboo and grass for paper industry, lac for lac industries come from forests.

Animal based Industries

Leather for leather industry and wool for woollen textiles are obtained from animals. Besides, ivory is also obtained from elephant's tusks.

Industries Based On Ownership

- Public Sector Industries are owned and managed by governments. In India, there were a number of Public Sector Undertakings (PSUs). Socialist countries have many state owned industries. Mixed economies have both Public and Private sector enterprises.
- Private Sector Industries are owned by individual investors. These are managed by private organisations. In capitalist countries, industries are generally owned privately.
- Joint Sector Industries are managed by joint stock companies or sometimes the private and public sectors together establish and manage the industries.

General Knowledge Today

Prelims Geography-11:Places in News

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Akodara Village of Gujarat

Industrial Credit and Investment Corporation of India (ICICI) Bank had launched its own version of Digital Village Project by adopting entire Akodara Village in Sabarkantha district of Gujarat in January 2015.

Idukki district, Kerala

Idukki district of Kerala became first district in India to have high speed Rural Broadband Network i.e. National Optical Fibre Network (NOFN) Internet connectivity in January 2015.

Sun Temple, Konark

In January 2015, the Sun Temple at Konark, Odhisa has been the coveted with Adarsh Monument tag by the Archaeological Survey of India (ASI).

Nelapattu Bird Sanctuary

The Nelapattu Bird Sanctuary, considered one of the biggest habitats for some hundreds of pelicans and other birds. It is located about 20 km north of the Pulicat Lake on the Andhra Pradesh-Tamil Nadu border. It is venue of Flamingo Festival in January every year.

Bannerghata Biological Park

The Bannerghata Biological Park in Karnataka is to be developed as India's 1st solar fenced elephant sanctuary. The park has joined hand with PETA for this in February 2015.

Sikandara

Located in Uttar Pradesh, near Agra and site for tomb of Mughal emperor Akbar. Lots of blackbucks (Antilope cervicapra) found here but now they are threatened by increasing number of Jackals. The Uttar Pradesh Government is now taking up a Jackal Research & Translocation Project to relocate the Jackals somewhere else to save the antelopes.

Ganjam

Ganjam district in Odisha is known for its Ganjam coast, rich in mineral resources. In February 2015, the Industrial Infrastructure Development Corporation (IDCO) had signed a MoU with public sector Indian Rare Earth Ltd (IRE) to set up a mineral separation plant here.

Jamaica

Jamaica is a Caribbean country which in 2015 passed a law to decriminalize the possession of small amounts of marijuana up to 57 grams for personal use. Marijuana is a greenish-gray mixture of the dried, shredded leaves, stems, seeds and flowers of Cannabis sativa – the hemp plant. Medicinal values of marijuana is used as a drug for controlling pain for medical issues, like cancer, nervous system diseases, glaucoma, migraines, etc. It also can be used to treat nausea and improve appetites for people with HIV or other chronic illnesses.

Ancient Hatra site, Iraq

In March 2015, Islamic State (IS) militants destroyed the ruins at the ancient city of Hatra located in south-west of Mosul in Northern Iraq. City of Hatra is a UNESCO World Heritage Site founded 2,000 years ago, in the days of the Parthian Empire.

Shree Singaji Thermal Power Project , Khandwa

In March 2015, Prime Minister Narendra Modi inaugurated two units each of 600 Mega Watt (MW) capacity in Shree Singaji Thermal Power Project in Khandwa district of Madhya Pradesh. Shree Singaji Thermal Power Plant is a coal-fired project. It is owned and developed by Madhya Pradesh Power Generation Company Limited (MPPGCL).

Agartala

North East India's first Kisan Call Centre (KCC) was opened in Agartala, Tripura in March 2015.

Vanuatu

Powerful cyclone Pam had slammed the south Pacific archipelago of Vanuatu in March 2015.

Amaravathi

Andhra Pradesh government has approved Amaravathi as name of the new capital city of the state coming up in the Vijayawada-Guntur region. The name Amaravathi was chosen in view of the historical and spiritual significance as it was ancient seat of Satavahana ruler's kingdom.

Calbuco volcano

Calbuco volcano in southern Chile erupted on 23 April 2015 for the first time after more than 42 years. It had erupted twice in the space of a few hours which led to billowing of huge ash cloud over a sparsely populated, mountainous area in southern Chile.

Lamjung, Nepal

A high-intensity earthquake of magnitude 7.8 on the Richter scale had struck central Nepal in April 2015. Earthquake's epicenter was in Lamjung district. It had a depth of only 11 kilometers (7 miles) i.e. in geological terms it was a shallow depth, causing huge devastation.

Swayambhunath Stupa

Nepal's devastating 7.9-magnitude earthquake on April 25 has partially damaged Swayambhunath Stupa located in Kathmandu which is believed to be the world's oldest Buddhist shrine.

Nadia District

Nadia district in West Bengal has won the 2015 United Nations Public Service Award in the category of improving delivery of public services for the initiative 'Sabar Shouchagar'. Nadia district is the first open defecation free district in country.

Maria Elena South

Researchers have discovered the driest location on Earth in the Atacama Desert in Chile. The site discovered is called as Maria Elena South (MES). It was discovered by team of research scientist at the Blue Marble Space Institute of Science in Seattle, United States. {May 2015}

Ancient city of Palmyra

In May 20105, the Islamic State of Iraq and Syria (ISIS) militants had taken complete control of the ancient Syrian city of Palmyra. The city is a UNESCO designated World Heritage site and home to some of the world's most magnificent ancient ruins.

Kamalasagar border haat

The second border haat (rural market) was opened for common people at Kamalasagar in Sipahijala district of Tripura bordering Brahmanbaria district of Bangladesh. This market is set up at the zero line of the international border with one part on the Indian side and the other in Bangladesh. (June 2015)

Kunming: first India-China Yoga College

First India-China Yoga College was inaugurated at Yunnan Minzu University in Kunming, China. It is a first Indian government institution related Indian spiritual art form i.e. Yoga in China inaugurated. {June 2015}

Sri Anandpur Sahib City

In Punjab state, 350th years of foundation of holy city Sri Anandpur Sahib was observed which was founded in 1665 by the Sri Guru Tegh Bahadur, ninth Guru of Sikhs. Later in 1699, Khalsa Panth was created here by the Tenth Guru Sri Guru Gobind Singh.

Nathu La border crossing

China has opened 2nd land border crossing in Tibet via Nathu La, Sikkim to allow the Indian pilgrims for Kailash-Mansarovaryatra. The new route is in addition and alternative to the existing Lipulekh Pass route located in Uttarakhand which was only route earlier.

Meiji industrial revolution sites

Japan's Meiji-era (1868-1912) industrial revolution sites have received World Cultural Heritage status from United Nations Educational, Scientific and Cultural Organization (UNESCO). {July 2015}

Pune's Fergusson College

Pune's prestigious Fergusson College, has been accorded the special heritage status by the University Grants Commission (UGC). It is among the 19 institutions in the country to get the heritage status.

Communication Super-expressway

Maharashtra Government has announced construction of 800 kms long Nagpur-Mumbai expressway. This expressway will be called as Communication Super-expressway or Nagpur-Amravati-Aurangabad-Ghoti-Mumbai expressway.

Suez Canal Expansion Project

Egypt has launched a major expansion of the Suez Canal. It was inaugurated by Egyptian President Abdel Fattah al-Sisi in a lavish ceremony held at port city of Ismailiya (located on west bank of canal).

Temple of Bel

Islamic State (IS) militant group has destroyed part of historical Temple of Bel in the ancient site of Palmyra in Syria. The ancient temple was dedicated to the Palmyrene gods and was one of the best preserved parts of the historical sites of Palmyra. (July 2015)

Mount McKinley renamed as MountDenali

United States has changed the name of tallest mountain in North America Mount McKinley to its original native name Denali. It was announced by US President Barack Obama ahead of his three-day visit to Alaska to highlight the issue of climate change.

Bodhgaya: Spiritual Capital of India

Union Government is going to develop Bodhgaya in Gaya district of Bihar as Spiritual Capital of the country in order to serve the civilizational bond between India and the Buddhist world. It was announced by Prime Minister NarendraModi while addressing delegates from 90 countries on the concluding day of the International Buddhist Conclave held at Bodh Gaya.

Hangzhou: host of 2022 Asian Games

Capital city of Zhejiang Province Hangzhou in East China has been chosen by the Olympic Council of Asia (OCA) to host the 2022 Asian Games. Hangzhou was the only candidate city for the 2022 Asian Games i.e. XIX edition of games.

Ibrahimpatnam

Godavari River was formally interlinked with the Krishna River at Ibrahimpatnam near Vijayawada in Andhra Pradesh. State government has named this historic occasion as 'Krishna-Godavari Pavitra Sangamam' meaning holy confluence in Telugu.

Changla in Ladakh: World's Highest Terrestrial Research Centre

DRDO has established the world's Highest Terrestrial Research Centre near Pengong Lake at Changla in Ladakh. The centre dubbed as Extreme Altitude Research Centre is located at 17,600 feet above mean sea level.

Arch of Triumph, Palmyra

Islamic State (IS) militants blown up the iconic Arch of Triumph in the ancient Syrian city of Palmyra. It was a centrepiece of the UNESCO world heritage site of ancient ruins of Palmyra and dated between 193 and 211 AD.

Sierra Leone

In November 2015, World Health Organization (WHO), a UN health agency has officially declared Sierra Leone Ebola-free. It is considered as a major milestone in UN-backed efforts to wipe out Ebola from the three western African countries viz. Liberia, Sierra Leone and Guinea.

Genome Valley, Hyderabad

In November 2015, Union Cabinet approved setting up of a National Resource Facility for Bio-medical Research (NARF) at Genome Valley in Hyderabad, Telangana. NARF will be set up by the Indian Council for Medical Research (ICMR).

UNESCO's Creative Cities Network (UCCN)

Two Indian cities for first time have been designated as members of UNESCO's Creative Cities Network (UCCN). Two cities are Varanasi City (Uttar Pradesh): It has been added in the City of Music category of network. Jaipur City (Rajasthan): It has been added in the City of Crafts and Folk Art category of network

Inle Lake

Myanmar has launched the country's first United Nation Educational, Scientific and Cultural Organisation (UNESCO) Biosphere Reserve at Inle Lake in Shan state. {December 2015}

Salma Dam Project, Afghanistan

The Union Cabinet has approved the reconstruction and completion of Salma Dam Project in Afghanistan at the Revised Cost Estimates (RCE) of 1775.69 crore rupees in December 2015.

Atal Setu

North India's first cable-stayed bridge named Atal Setu was inaugurated on Dunera-Basohli-Bhadharwah road in Basohali town in Kathua district of Jammu and Kashmir.

Kakatiya Thermal Plant

In January 2016, the 600-MW Kakatiya thermal power plant Stage-II has been commissioned at Bhoopalapally in Warangal, Telangana. This is the first major power plant to be commissioned after the formation of the new State of Telangana in June 2014. The power plant is one of the coal based power plants of Telangana Power Generation Corporation Limited (TSGENCO)

Machia Biological Park

In January 2016, Rajasthan government has inaugurated the state's second biological park 'Machia Biological Park' in Jodhpur. The new park will have a food store, cafeteria, interpretation centre, ticket window, visitors and service roads and will be opened for public in March 2016. The park is spread over 41 hectare and is the house of lions, tigers, jackals, hyenas, desert cats and desert foxes etc.

Bogodara Village, Gujarat : India's First Aviation Park

Gujarat state government has decided to set up India's first aviation park near Bagodara village in Ahmedabad district to strengthen the aviation sector.

Souss-Massa-Drâa : World's largest concentrated solar power plant

The first phase of the world's largest concentrated solar power (CSP) plant was launched in the Souss-Massa-Drâa area in Morocco. It is part of Noor Ouarzazate Solar Complex.

Kozhikode, India's first Gender Park

President Pranab Mukherjee inaugurated India's first Gender Park at Kozhikode district of Kerala. It is also the first of its kind gender equality convergence centre in Asia.

Nagepur village, Varanasi

In March 2016, Prime Minister Narendra Modi has selected Nagepur village in his Varanasi Constituency of Lok Sabha in Uttar Pradesh under the Saansad Adarsh Gram Yojana (SAGY).

Ivory Coast

Ivory Coast is world's biggest producer of Cocoa. It is usually in news because about 89 per cent of children in this country are involved in growing cocoa, violating Child Labour Norms.

Maghreb

Maghreb or Barbary Coast refers to Northwest African region including Atlas Mountains and the coastal plains of Morocco, Algeria, Tunisia, and Libya. The inhabitants of Meghrib are also known as Moors.

Cho-Lhamu Lake

'Cho-Lhamu' lake in Sikkim located over 18,000 feet above sea level is India's highest lake as declared in wetland atlas of MOEFCC few years ago. The Teesta river, has its origin in Cho-Lhamu lake.

Heera Oil Fields

Off Mumbai Coast. Were discovered by chance in 2012, and are thought to be third largest field in western offshore after the prolific Mumbai High and Heera.

Malankhand mine

Malanjkhand mine {contains more than 70 per cent of India's known copper reserves}: Madhya Pradesh

Tipaimukh Dam

A proposed embankment dam on the river Barak – Manipur

Azeri, Chirag and Guneshli (ACG) oil and gas fields

Located in the South Caspian Sea about 95 km off the coast of Azerbaijan, is the largest oil and gas field complex in Azerbaijan and is one of the largest producing oil fields in the world. India's ONGC has interests in it.

Sambhar Lake

Known to be a salt lake. It is a key wintering area for tens of thousands of flamingos and other birds that migrate from northern Asia: Rajasthan

Chutka Nuclear power plant: Madhya Pradesh

Chutka Nuclear power plant has been planned in a 497.73 hectare area in Narayanganj tehsil, on the bank of Narmada in Madhya Pradesh. Villagers of Chutka, Tatighat, Kunda and Manegaon, predominantly of the Gond Scheduled Tribe, have been protesting against the project since it was cleared by the Union

Inga Dam, DRC

Inga dam is the world's largest proposed hydropower project. It is located in western Democratic Republic of the Congo, 50 km upstream of the mouth of the Congo River.

Rollapadu Great Indian Bustard Bird sanctuary

Rollapadu Great Indian Bustard Bird sanctuary was set up in 1987 in an area of 6.14 square km near Nandikotkur in Kurnool district of Andhra Pradesh. The rare giant bird, Great Indian Bustard, is currently facing deep trouble due to ecological changes and their populations have also dwindled. As the alarm bells are ringing, the Union Ministry of Environment and Forest, Bombay Natural History Society, World Wide Fund for nature and State forest department have launched a unique Species Recovery Programme to save the Great Indian Bustard, which will continue for decade.

Eaglenest Wildlife Sanctuary

Eaglenest is a protected area in the foothills of West Kameng district, Arunachal Pradesh. Eaglenest is notable as a prime birding site due to extraordinary variety, numbers and accessibility of bird species there.

Tummalapalli

The Tummalapalli mine is a uranium mine in Tummalapalli village located in Kadapa district of Andhra Pradesh. Atomic Energy Commission of India confirmed on reserves of 49,000 tonnes and suggested that they could be even three times larger which could make it world largest uranium deposit.

Diego Garcia

Diego Garcia is a tropical, footprint-shaped coral atoll located south of the equator in the central Indian Ocean. It is part of the British Indian Ocean Territory.

Death Valley

Death Valley is a desert valley located in Eastern California. Situated within the Mojave Desert, it is the lowest, hottest and driest area in North America.

Mount Augustus

It is an inselberg and world largest monolith located in Western Australia.

Arakan Mountains

The Arakan Mountains is a mountain range in western Burma (Myanmar), between the coast of Rakhine State and the Central Burma basin. The Arakan mountains run from Cape Negrais in the South in to the Manipur State of India in north. Arakan Mountains divide the Rakhine coast from the rest of Burma, and thus have acted as a barrier between the peoples of central Burma and those of the Indian subcontinent. This played a role in fostering the separate development of the Rakhine people, both linguistically and culturally, from the Burmese. (wikipedia)

Yellowknife Bay

Yellowknife Bay is located on Mars. It's one of the lowest spots topographically on the crate floor. NASA's curiosity rover analysis of clays drilled out from two rock samples in the area of Yellowknife Bay show the freshwater lake existed at a time when other parts of Mars were dried up or dotted with shallow, acidic, salty pool ill suited for life.

Bhimgarh Sanctuary

Bhimgad Wildlife Sanctuary is a protected area in the Western Ghats, in Belgaum district of Karnataka. The Bhimgad forests are notable for the Barapede Caves, the only known breeding area of the Wroughton's free-tailed bat, a threatened species on the verge of extinction.

Aconcagua

Aconcagua is the highest mountain in the Americas at 6,960.8 metres. It is located in the Andes Mountain range, in the provenance of Mendoza, Argentina. Recently, United States Tyler Armstrong became the youngest person to reach Aconcagua.

Araku Valley

Araku Valley is a hill station in Visakapatnam district of Andhra Pradesh. It is a valley in the Eastern

Ghats inhabited by different tribes. The Anantagiri and Sunkarimetta Reserved forest which are part of Araku valley are rich in biodiversity.

Reunion Island

Reunion Island is a small French island in the Indian Ocean, near Mauritius. The Indian-origin population comprises 45 percent of the people on the island that has a population of over 837,000 inhabitants.

Registan Desert

Registan Desert is an extremely arid plateau region located between Helmand and Kandahar provenances in south-western Afghanistan.

Tungurahua Volcano

Tungurahua is 16,480 feet high active volcano located in Ecuador. The Tungurahua is active since 1999.

Lombok Strait

Lombok Strait, is a strait connecting the Java Sea to the Indian Ocean, and is located between the islands of Bali and Lombok in Indonesia.

Dehing Patkai

Dehing Patkai, is the only rainforest in Assam. It is located in the Dibrugarh and Tinsukia districts of Assam.

Rani-ki-Vav

UNESCO's World Heritage Site in Gujarat. Rani-ki-Vav, one of the finest examples of step wells in Gujarat, was constructed by Queen Udayamati of Solanki Dynasty.

Kalisindh Super Thermal Power Plant

Kalisindh Super Thermal Power Plant is located at Jhalawar district of Rajasthan. The coal based power plant has a designed capacity of 1200 Mwe.

Duisburger-Ruhroter harbours

Duisburger-Ruhroter harbours are located in the Germany city of Duisburg at the embouchure of Rhein and Ruhr. They are regarded as the biggest inland harbours of Europe and in sum of all harberbuildings it is the biggest inland harbour of the world.

Protected Areas in Terai Arc Landscape

There are 11 protected areas in Terai Arc Landscape. 7 located in India and 4 in Nepal.

Indian National Parks

1. Valmikinagar Wildlife Sanctuary
2. Sohelwa Wildlife Sanctuary
3. Katarniaghat Wildlife Sanctuary
4. Dudhwa National Park
5. Kishanpur Wildlife Sanctuary
6. Corbett National Park

7. Rajaji National Park

Nepalese National Parks

1. Parsa Wildlife Reserve
2. Royal Chitwan National Park
3. Royal Bardia National Park
4. Sukla Phanta Wildlife Reserve

Benuban Vihar monastery

Benuban Vihar monastery is in Agartala, Tripura. It is considered one of the important pilgrim centres for Buddhism in northeast India.

Bab-el-Mandeb

Bab-el-Mandeb is a strait located between Yemen on the Arabian Peninsula, and Djibouti and Eritrea in the Horn of Africa. It connects the Red Sea to the Gulf of Aden.

Carajas Iron ore mine

Carajas Iron ore mine, world's largest iron ore mine, is located in the state of Para in Northern Brazil.

Daroji Sloth bear sanctuary

Daroji Sloth bear sanctuary is located in Bellary district in Karnataka. The sanctuary was exclusively created for the preservation of Indian Sloth bears

Arsia Mons

Arsia Mons is the southernmost of three volcanoes on the Tharsis bulge near the equator of the planet Mars.

Bakken Formation

The Bakken Formation is one of the largest contiguous deposits of oil and natural gas in the United States. It is an interbedded sequence of black shale, siltstone and sandstone that underlies large areas of north-western North Dakota, north-eastern Montana, southern Saskatchewan and south-western Manitoba.

Mount Vinson

Mount Vinson is the highest peak in Antarctica, with an elevation of 16,066 feet (4,897 meters). It is located on the southern part of the main ridge of the Sentinel Range of the Ellsworth Mountains.

Bhamala Stupa

Bhamala Stupa is an ancient Gandhara stupa located in Pakistan near Haripur and is a part of so called Bhamala Buddhist Complex. It is a national heritage site of Pakistan and dates back to 4th century AD. This stupa is different from other Gandhara stupas as it looks cross shaped like an Aztec Pyramid.

Sukinda Chromite mine

Sukinda Chromite mine is located in Odisha state. The chromite mines in Sukinda possesses one of the largest chrome ore reserves in Odisha.

Yamal Peninsula

The Yamal Peninsula stretches some seven hundred kilometres into the Arctic Ocean from the Russian mainland below the Arctic Circle. It is believed that his region has one of the largest oil and gas reserves in the world.

Silesia

Silesia is a region of Central Europe now located mostly in Poland, with small parts in the Czech Republic and Germany. Silesia is a resource-rich and populous region. This region is best known for coal mining.

Great Rift Valley

Great Rift Valley is a part of an intra-continental ridge system running north to south for around 4,000 miles (6,400 kilometres), from northern Syria to central Mozambique in East Africa.

Cumbum Valley

The Cumbum Valley or Kambam Valley is a valley in the Theni district of Tamil Nadu. This is the most fertile valley in south India. It is one of the few places in Tamil Nadu producing grapes and the valley produces about 90,000 tonnes of Muscat grapes and 10,000 tonnes of Thomson seedless grapes every year.

Mt. Stromboli

Mt Stromboli is an active volcano located in Tyrrhenian Sea, Italy. It is known as the "Lighthouse of the Mediterranean".

Vembanad Kol Lake

Vembanad Kol Lake is in Kerala. It is one of the longest and largest body of wetland in the country. It is home to more than 20,000 waterfowl, and a variety of fin and shell fish. Vembanad is a hotbed for livelihood activities including fishing, agriculture, tourism, and lime shell collection among others.

Great Artesian Basin

Great Artesian Basin is one of the largest underground water reservoirs in the world. It underlies approximately 22 per cent of Australia, occupying an area of over 1.7 million square kilometres beneath the arid and semi-arid parts of Queensland, New South Wales, South Australia and the Northern Territory.

Puerto Toro

Puerto Toro, the southernmost permanently inhabited community on the globe, is in Chile. It is the only such community on Earth that is situated below the 55th parallel south. Puerto Toro is inhabited by 36 people according 2002 census, including fishermen and their families.

Hajong Lake

Hajong lake a unique tortoise habitat situated in the Langting-Mupa reserve forest in North Cachar Hills district of Assam. It is the only natural tortoise habitat in Assam. On bank of the Hajong lake Tortoise Festival was organised every year. This festival aims to create awareness among the villagers surrounding villages of Hajong Lake about the safety of the endangered tortoise species available in the area

Kanhar Dam Project

Kanhar dam project is located downstream of the confluence of River Pagan with Kanhar near village Sugawan in Tehsil Dudhi of District Sonebhadra, Uttar Pradesh. It was originally approved by the Central Water Commission in September, 1976 and has been in abeyance since last 25 years. The inauguration of construction of the dam was held on 5th December, 2014, however the National Green Tribunal (NGT) had stayed any further construction on the dam site after a petition was filed, stating that the environment clearance granted to the project was not valid anymore.

Villarrica volcano

Villarrica volcano is one of Chile's most active volcanoes. It is also known as House of the Spirit. Chile has more than 2,000 volcanoes and about 90 of them remain active. Villarrica is considered among the country's most dangerous.

Mozambique Channel

The Mozambique Channel is located between Madagascar and Mozambique. It is 460 kilometres at its narrowest point.