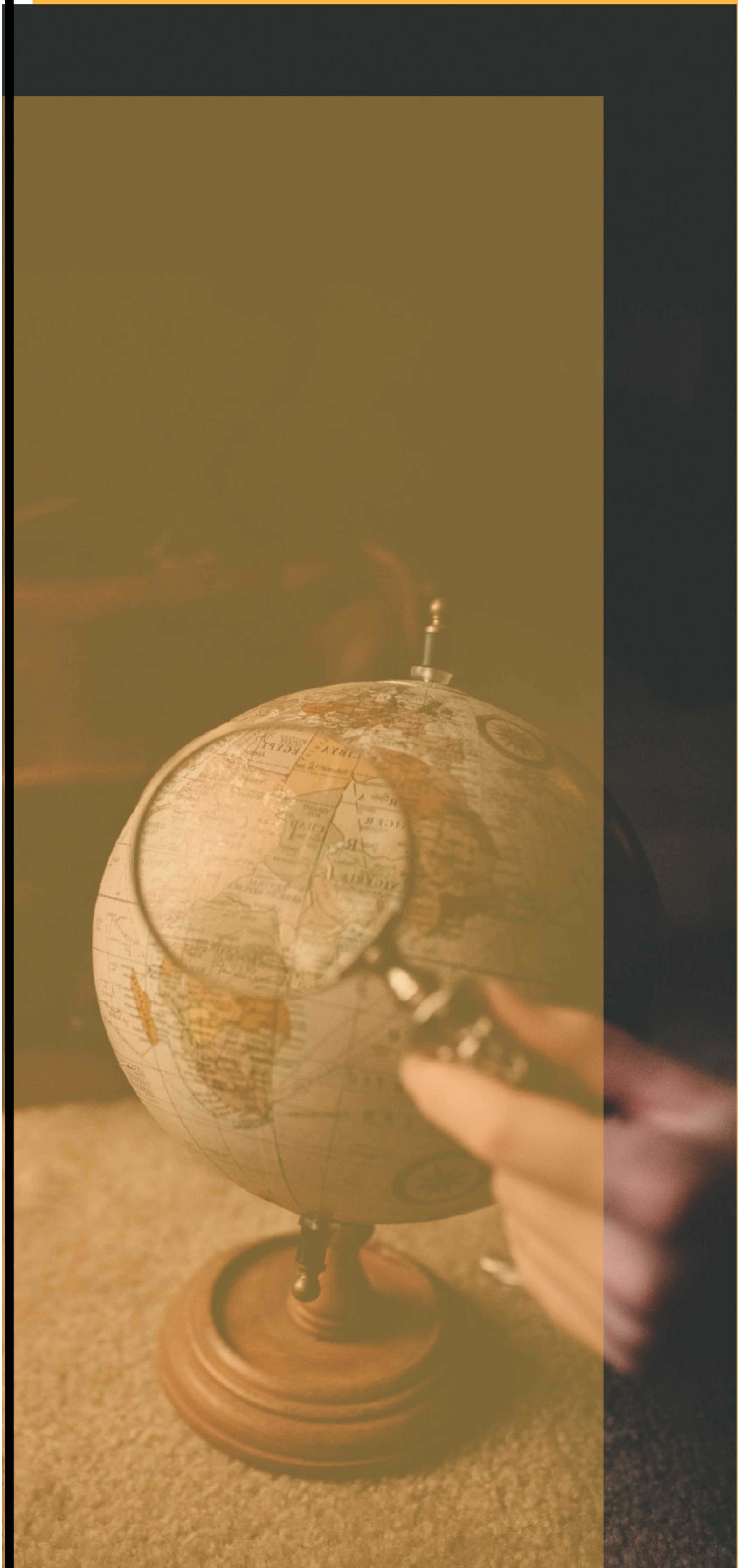

EDEN IAS

GEOGRAPHY

UPSC PREP

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UNIT-I

[INTRODUCTION]

GEOGRAPHY AS A DISCIPLINE

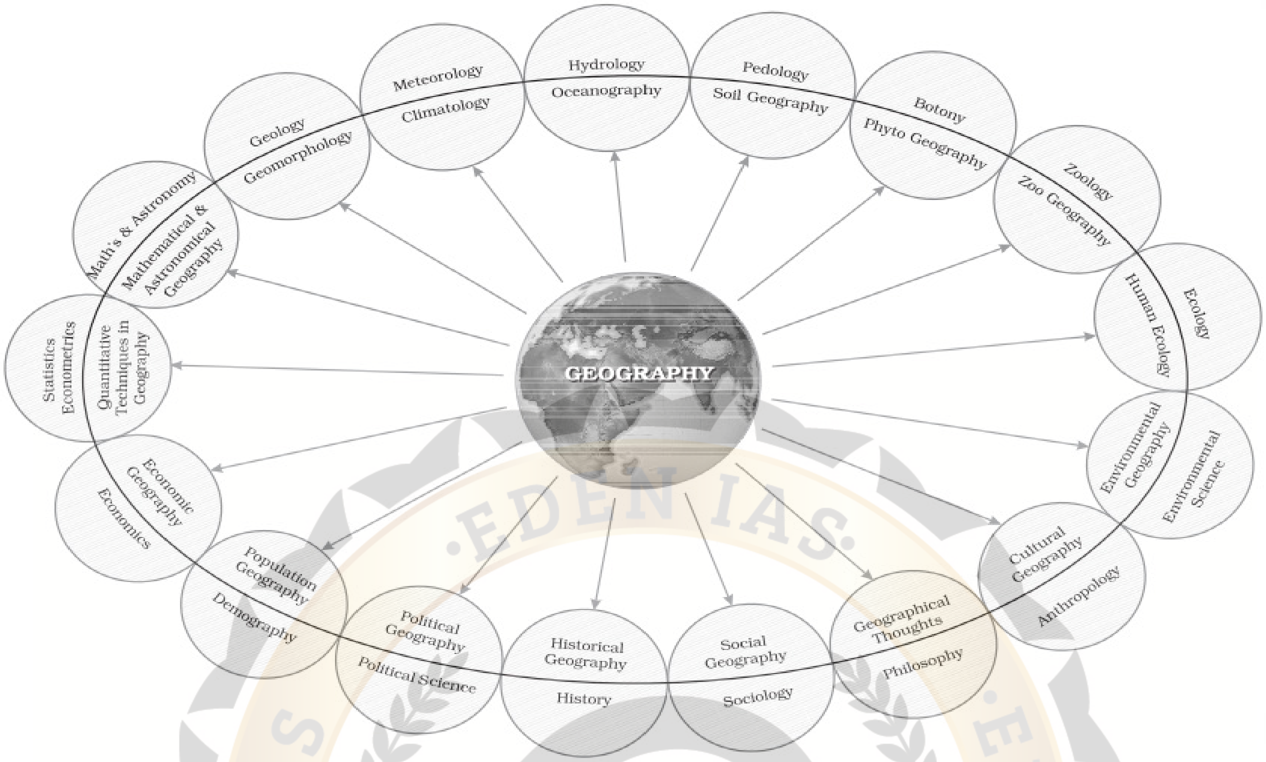
The word 'Geography' is derived from two Greek words viz. "Geo" meaning "earth" and "graphy" meaning "to describe." Therefore, Geography is the science that deals with the description of the Earth's surface**. The first person to use the word geography was Eratosthenes (276–194 BC).**Geography as a discipline is concerned with three sets of questions:

1) Questions that are related to the identification of the patterns of natural and cultural features as found over the surface of the earth. These are the questions about **what?**
2) Questions that are related to the distribution of the natural and human/ cultural features over the surface of the earth. These are the questions about **where?**
3) The third question is related to the explanation or the causal relationships between features and the processes and phenomena. This aspect of geography is related to the question, **why?**

Taken together, the first two questions take care of distributional and locational aspects of the natural and cultural features. These questions provided inventorised information of what features and where located. It was a very popular approach during the colonial period. These two questions did not make geography a scientific discipline till the third question was added.

GEOGRAPHY AS AN INTEGRATING DISCIPLINE

- Geography is a discipline of synthesis. It attempts spatial synthesis, as history attempts temporal synthesis. Its approach is holistic in nature.
- It recognises the fact that the world is a system of interdependencies.
- Geography as an integrating discipline has interface with numerous natural and social sciences.
- Every discipline, concerned with scientific knowledge is linked with geography as many of their elements vary over space.
- Geography helps in understanding the reality in totality in its spatial perspective. Geography, thus, not only takes note of the differences in the phenomena from place to place but integrates them holistically which may be different at other places.
- Every geographical phenomenon undergoes change through time and can be explained temporally. The changes in landforms, climate, vegetation, economic activities, occupations and cultural developments have followed a definite historical course.
- It is for this reason; time is an integral part of geographical studies as the fourth dimension.



GEOGRAPHY AND ITS RELATION WITH OTHER SUBJECTS

MAJOR APPROACHES TO STUDY GEOGRAPHY

The study of every subject is done according to some approach. There are two major approaches to study geography viz. Systematic and Regional. **The systematic geography** approach, also known as general geography was introduced by **Alexander Von Humboldt**, a German geographer (1769-1859) while **regional geography** approach was developed by another German geographer and a contemporary of Humboldt, **Karl Ritter** (1779-1859).

Systematic Geography- In systematic approach a phenomenon is studied world over as a whole, and then the identification of typologies or spatial patterns is done. For example, if one is interested in studying temperature, the study will be done at the world level as a first step. The typologies such as hot areas or warm areas or cold areas, etc. will be identified, discussed and delimited.

Regional Geography- In the regional approach, the world is divided into regions at different hierarchical levels and then all the geographical phenomena in a particular region are studied. For example if one studies India with a regional approach then one must study the climate, vegetation, soil, economic activity, population, settlement etc of India. **Regions can be at any scale** –Macro, Meso and Micro. Regions can be natural or designated. Regions can be **formal** based on some kind of uniformity say agricultural pattern or they can be **functional** based on some interdependence say trade.

BRANCHES OF GEOGRAPHY

BRANCHES OF GEOGRAPHY (BASED ON SYSTEMATIC APPROACH)

1. Physical Geography

- **Geomorphology** is devoted to the study of landforms, their evolution and related processes.
- **Climatology** encompasses the study of structure of atmosphere and elements of weather and climates and climatic types and regions.

- **Hydrology** studies the realm of water over the surface of the earth including oceans, lakes, rivers and other water bodies and its effect on different life forms including human life and their activities.
- **Soil Geography** is devoted to study the processes of soil formation, soil types, their fertility status, distribution and use.

2. Human Geography

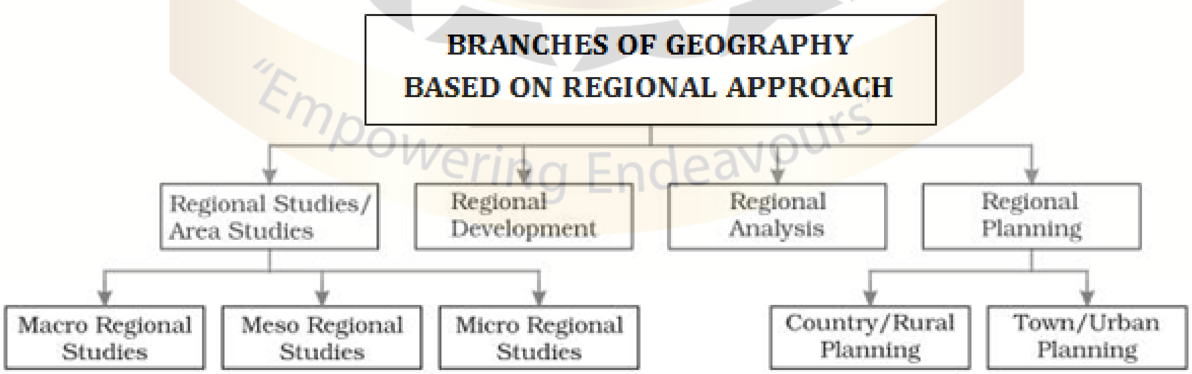
- **Social/Cultural Geography** encompasses the study of society and its spatial dynamics as well as the cultural elements contributed by the society.
- **Population Geography** studies population growth, distribution, density, sex ratio, migration and occupational structure etc.
- **Settlement Geography (Rural and Urban)** studies the characteristics of rural and urban settlements.
- **Economic Geography** studies economic activities of the people including agriculture, industry, tourism, trade, and transport, infrastructure and services, etc.
- **Historical Geography** studies the historical processes through which the space gets organised. Every region has undergone some historical experiences before attaining the present day status. The geographical features also experience temporal changes and these form the concerns of historical geography.

Note- The interface between physical geography and human geography has lead to the development of Biogeography which includes:

- **Plant Geography** which studies the spatial pattern of natural vegetation in their habitats.
- **Zoo Geography** which studies the spatial patterns and geographic characteristics of animals and their habitats.
- **Ecology /Ecosystem** deals with the scientific study of the habitats characteristic of species.
- **Environmental Geography** concerns world over leading to the realisation of environmental problems such as land gradation, pollution and concerns for conservation has resulted in the introduction of this new branch in geography.

BRANCHES OF GEOGRAPHY (BASED ON REGIONAL APPROACH)

- **Regional Studies/Area** Studies Comprising Macro, Meso and Micro Regional Studies
- **Regional Planning** Comprising Country/Rural and Town/Urban Planning
- **Regional Development**
- **Regional Analysis**



DETERMINISTIC AND POSSIBILISTIC PHILOSOPHY IN GEOGRAPHY

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, influence the psychological mind-set of individuals, which in turn define the behaviour and culture of the society that those individuals form. 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.

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. 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 example man can grow rice in arid regions but he has to take into consideration the input cost.

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" or "Stop and Go 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 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.

METHODS AND TECHNIQUES USED IN GEOGRAPHY

Major Methods and Techniques used in Geography include

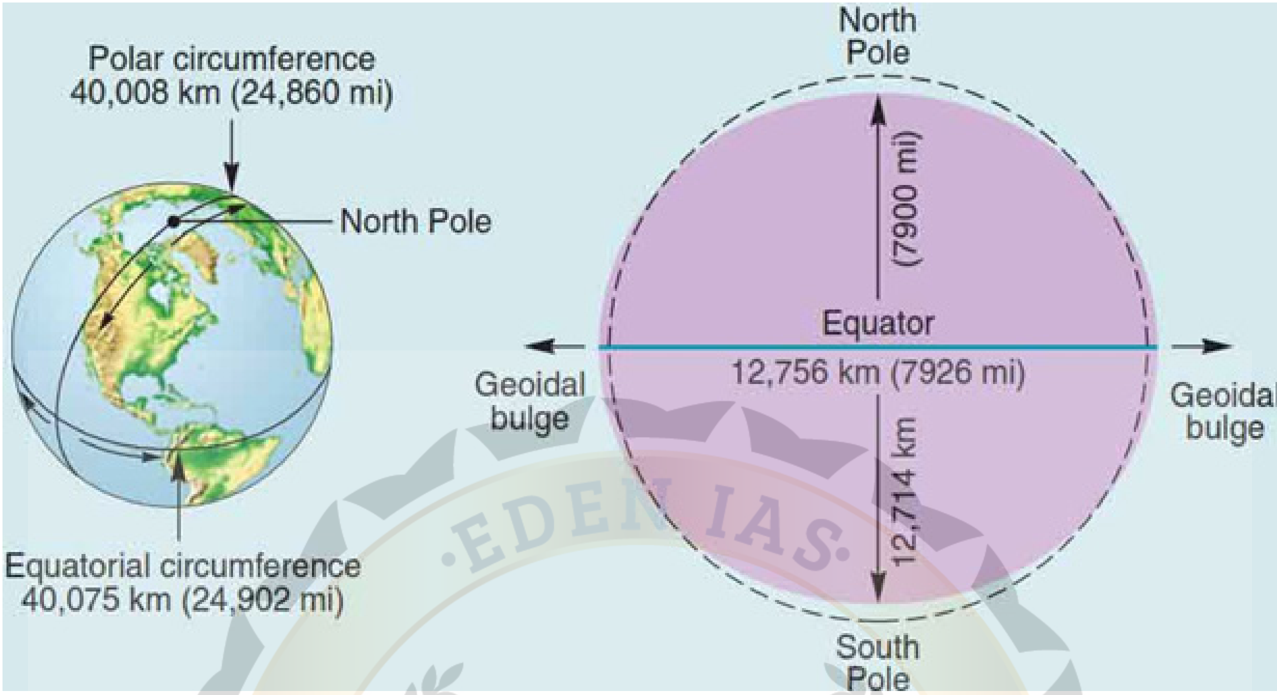
- Cartography including Computer Cartography
- Quantitative Techniques/Statistical Techniques
- Field Survey Methods
- Geo-informatics comprising techniques such as Remote Sensing, GIS, GPS, etc.

SHAPE AND SIZE OF THE EARTH

Earth, with an average distance of 92,955,820 miles (149,597,890 km) from the sun, is the third planet and one of the most unique planets in the solar system. It was formed around 4.5 to 4.6 billion years ago and is the only planet known to sustain life. This is because of factors like its atmospheric composition and physical properties such as the presence of water (70.8% of the planet) which allow life to thrive. **Earth is also the fifth largest planet in the entire solar system.**

As the largest of the terrestrial planets, Earth has an estimated mass of 5.9736×10^{24}kg. Its volume is largest of all terrestrial planets at **108.321×10^{10}km^3**.

In addition, **Earth is the densest of the terrestrial planets** as it is made up of a crust, mantle, and core. The Earth's crust is the thinnest of these layers while **the mantle comprises 84% of Earth's volume and extends 1,800 miles (2,900 km) below the surface**. What makes Earth the densest of these planets; however, is its core. It is the only terrestrial planet with a liquid outer core that surrounds a solid, dense inner core. **Earth's average density is 5515 × 10 kg/m^3. Mars, the smallest of the terrestrial planets by density, is only around 70% as dense as Earth.**



Earth is classified as the largest of the terrestrial planets based on its circumference and diameter as well. At the equator, **Earth's circumference is 24,901.55 miles (40,075.16 km).** It is slightly smaller between the North and South poles at **24,859.82 miles (40,008 km). Earth's diameter at the poles is 7,900 miles (12,713.5 km) while it is 7,926 miles (12,756.1 km) at the equator.** For comparison, the largest planet in Earth's solar system, Jupiter, has a diameter of 88,846 miles (142,984 km).

Earth's Shape

Earth's circumference and diameter differ because its shape is classified as an oblate spheroid or ellipsoid, instead of a true sphere. This means that instead of being of equal circumference in all areas, the poles are squished, resulting in a bulge at the equator, and thus a larger circumference and diameter there.

The equatorial bulge at Earth's equator is measured at 26.5 miles (42.72 km) and is caused by the planet's rotation and gravity. Gravity itself causes planets and other celestial bodies to contract and form a sphere. This is because it pulls all the mass of an object as close to the center of gravity (the Earth›s core in this case) as possible.

Because Earth rotates, this sphere is distorted by the centrifugal force. This is the force that causes objects to move outward away from the center of gravity. Therefore, as the Earth rotates, centrifugal force is greatest at the equator so it causes a slight outward bulge there, giving that region a larger circumference and diameter.

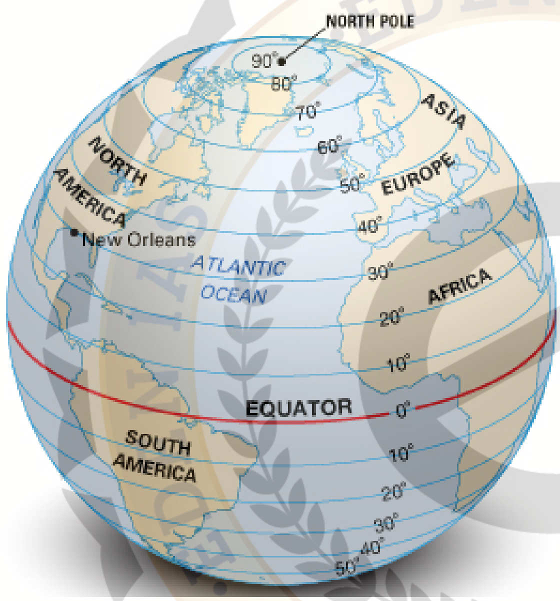
Local topography also plays a role in the Earth's shape, but on a global scale, its role is very small. The largest differences in local topography across the globe are **Mount Everest, the highest point** above sea level at 29,035 ft (8,8**48 m),** and the **Mariana Trench, the lowest point below sea level at 35,840 ft (10,924 m). This difference is only a matter of about 12 miles (19 km), which is quite minor overall.** If the equatorial bulge is considered, the world's highest point and the place that is farthest from the Earth's center is the peak of the Mount Chimborazo in Ecuador as it is the highest peak that is nearest to the equator. Its elevation is 20,561 ft (6,267 m).

GEODESY

Geodesy is a branch of science of accurately measuring and understanding Earth's geometric shape, orientation in space, and gravitational field. Geodesy also incorporates studies of how these properties change over time. Geodesy uses surveys and mathematical calculations to obtain results

PARALLELS OF LATITUDE

If you take a look at a map or globe of the world, you may notice lines running east-west and north-south. The lines that run east-west are known as Parallels of latitude. The lines running north-south are known as Meridians of longitude.



FACTS ABOUT LINES OF LATITUDE

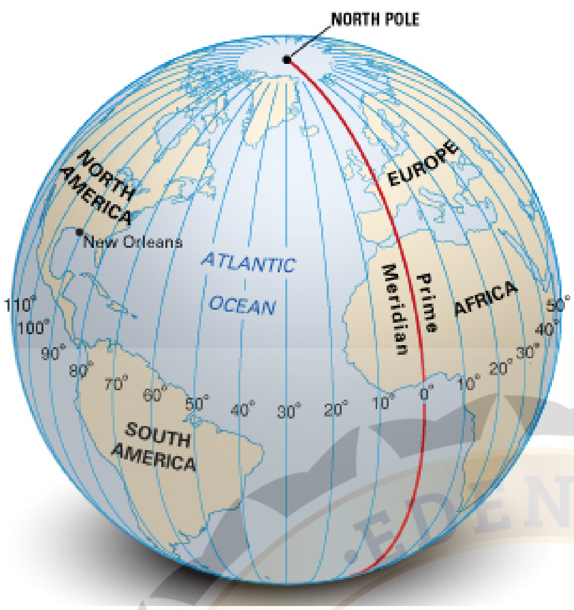
- Are known as parallels.
- Run in an east-west direction.
- Measure distance north or south from the Equator.
- Are parallel to one another and never meet.
- Cross the prime meridian at right angles.
- Lie in planes that cross the Earth's axis at right angles.
- Get shorter toward the poles, with only the Equator, the longest, a great circle.

While lines of latitude run across a map east-west, the point of latitude makes the north-south position of a point on earth. Lines of latitude start at 0 degrees at the equator and end at 90 degrees at the North and South Poles. Everything north of the equator is known as the Northern Hemisphere and everything south of the equator is known as the Southern Hemisphere.

Lines of latitude are called parallels and in total there are 180 degrees of latitude (90 degree north and south of the equator respectively). The distance between each degree of latitude is about 69 miles (110 kilometers). The five major parallels of latitudes from north to south are called: Arctic Circle, Tropic of Cancer, Equator, Tropic of Capricorn, and the Antarctic Circle. On a maps where the orientation of the map is either due north or due south, latitude appears as horizontal lines.

MERIDIANS OF LONGITUDE

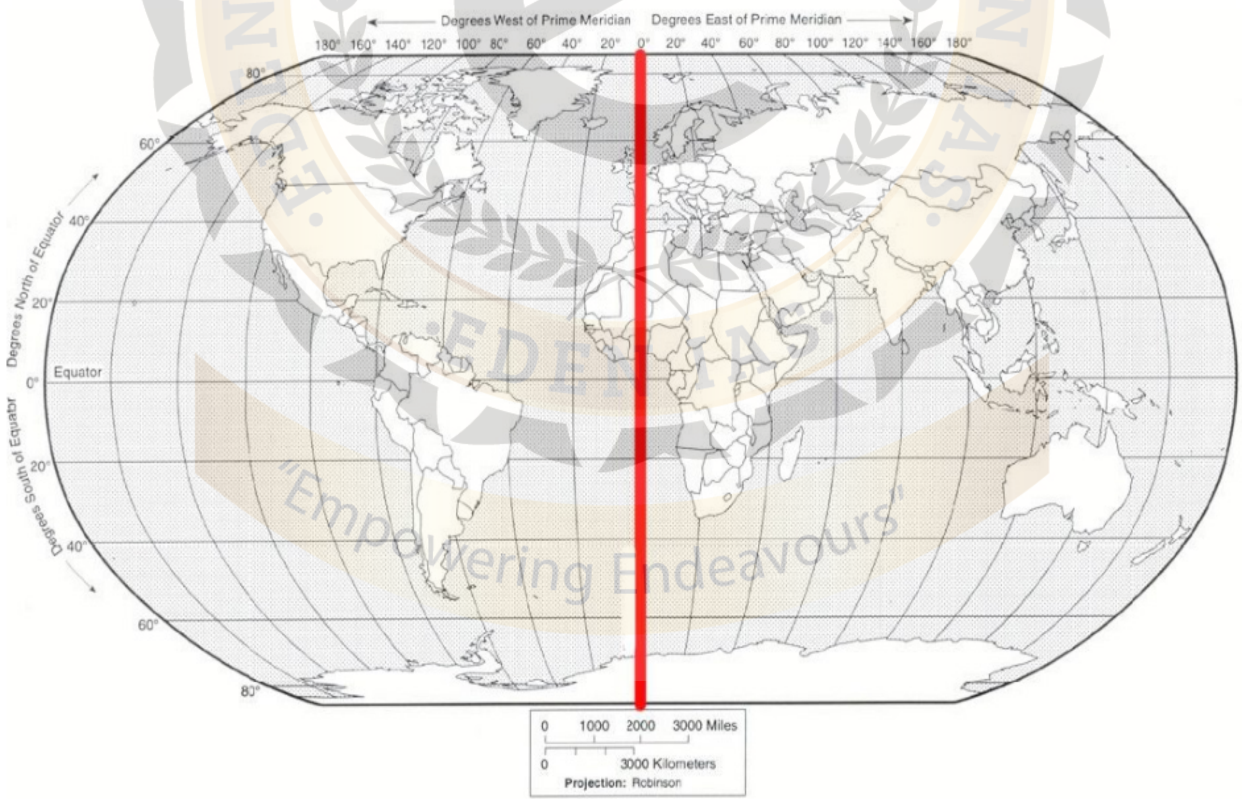
Longitude lines run north-south and mark the position east-west of a point**. Lines of longitude are known as meridians. These lines run from pole to pole, crossing the equator at right angles. There are 360 degrees of longitude and the longitude line of 0 degree is known as the Prime Meridian and it divides the world into the Eastern Hemisphere and the Western Hemisphere** (-180 degrees of longitude west and 180 degrees of longitude east).



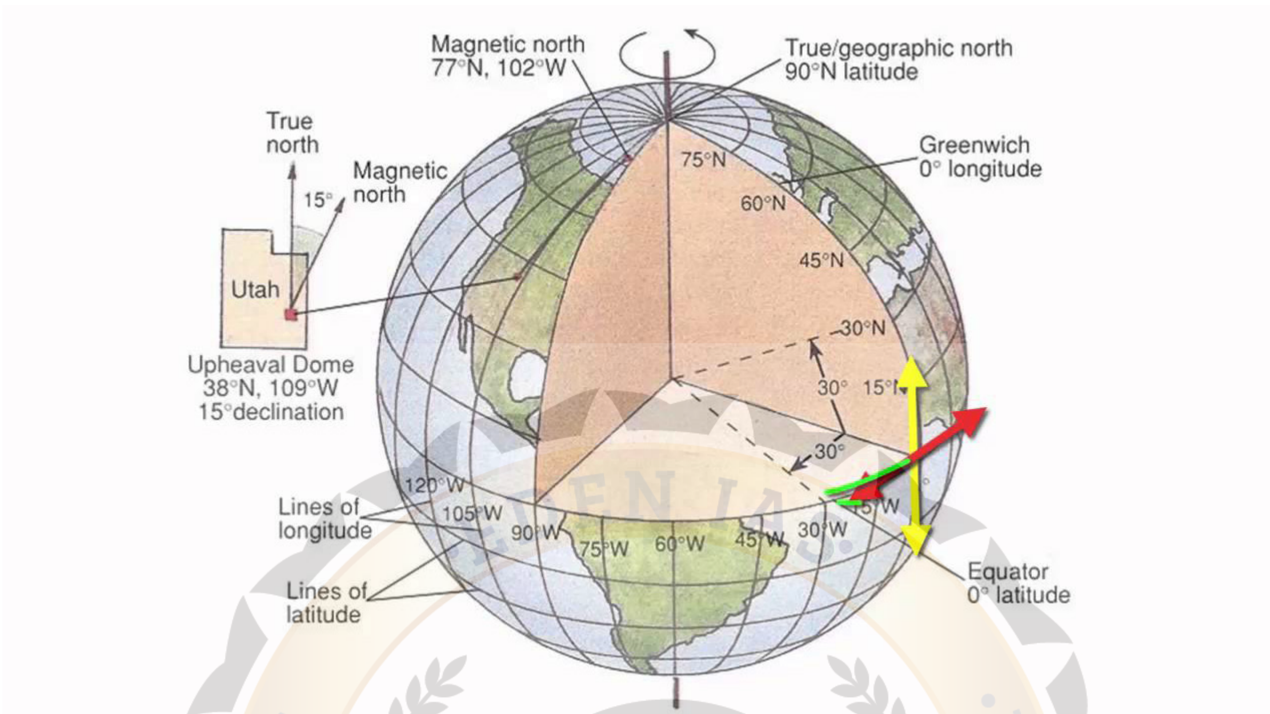
FACTS ABOUT LINES OF LONGITUDE

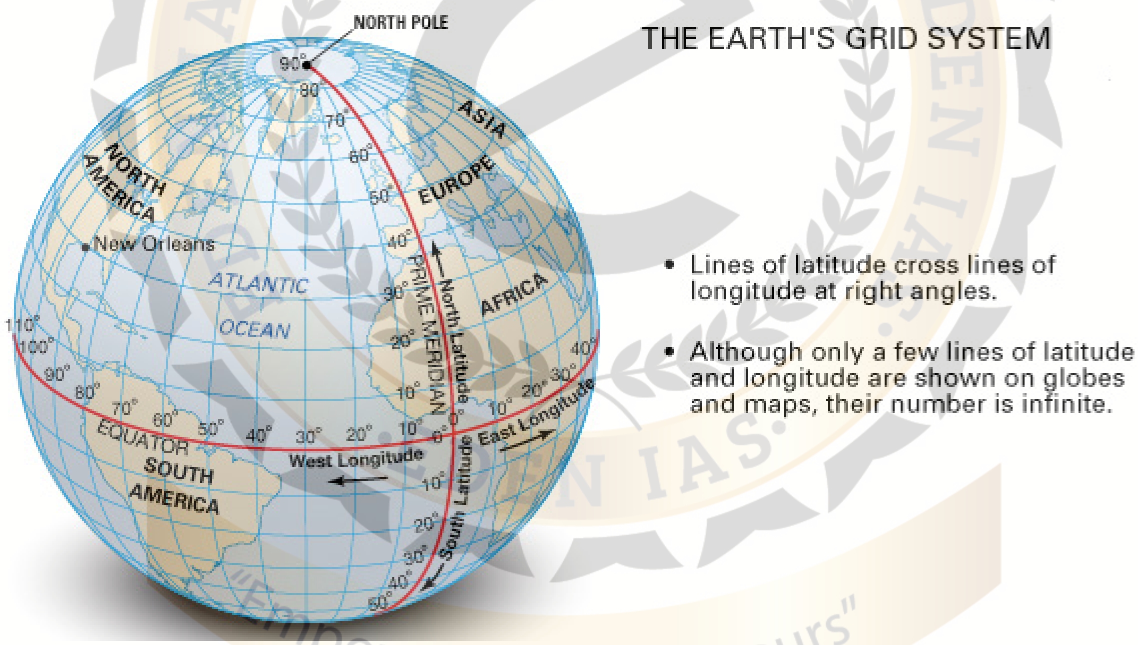
- Are known as meridians.
- Run in a north-south direction.
- Measure distance east or west of the prime meridian.
- Are farthest apart at the Equator and meet at the poles.
- Cross the Equator at right angles.
- Lie in planes that pass through the Earth's axis.
- Are equal in length.
- Are halves of great circles.

The distance between longitudes narrows away from the equator. The distance between longitudes at the equator is the same as latitude, roughly 69 miles. At 45 degrees north or south, the distance between is about 49 miles (79 km). The distance between longitudes reaches zero at the poles as all the lines of meridian converge at that point.



In the Northern Hemisphere, the **Prime Meridian** passes through the **UK, France** and **Spain in Europe**; **Algeria, Mali, Burkina, Faso, Tongo and Ghana in Africa. The only landmass crossed by the Meridian in the Southern Hemisphere is Antarctica**.





LOCAL TIME AND STANDARD TIME

Local time implies the time of a particular country, as regards the meridian running through it. On the contrary, **standard time** is referred as the official local time of a region ascertained by the distance from the Prime Meridian of the meridian running through the area.

Earth rotates on its axis, leading to sun rise and sun set in different parts of the world. The part of the earth which receives sunlight, experience day whereas the part in the darkness experience night. In other words, different parts of the earth receive daylight at different times.

Due to this, the earth is divided into sections called as time zones. **The earth completes one rotation of 360 degrees in 24 hours, i.e. it moves about 15 degrees in every hour. Therefore, the earth is**

parted into 24 time zones and each time zone is 15 degrees longitude wide, i.e. each time zone is one hour apart from the other. These time zones play a significant role in determining the standard time and local time of a place.

Definition of Local Time

Local time, as the name suggest is the time in a specific region, which is expressed in relation to the line of longitude passing through it. It is the time, reckoned on the basis of the meridian running through a particular place.

Local time is determined by the sun's position in the sky, i.e. the shadow cast by the sun, which is shortest in the middle of the day, i.e. noon and longest at the sunrise and sunset. When the sun is exactly over the head, it is noon at that place. Noon occurs at different times in different meridians. Hence local time varies from region to region.

Definition of Standard Time

Standard time indicates the reference time for a particular area. It is the local time of the standard meridian passing through the region or country.

Standard time is the official time, set up for the country by law, which is actually the time of a specific meridian running through the region. It is reckoned by the distance, east or west from the Prime Meridian at Greenwich.

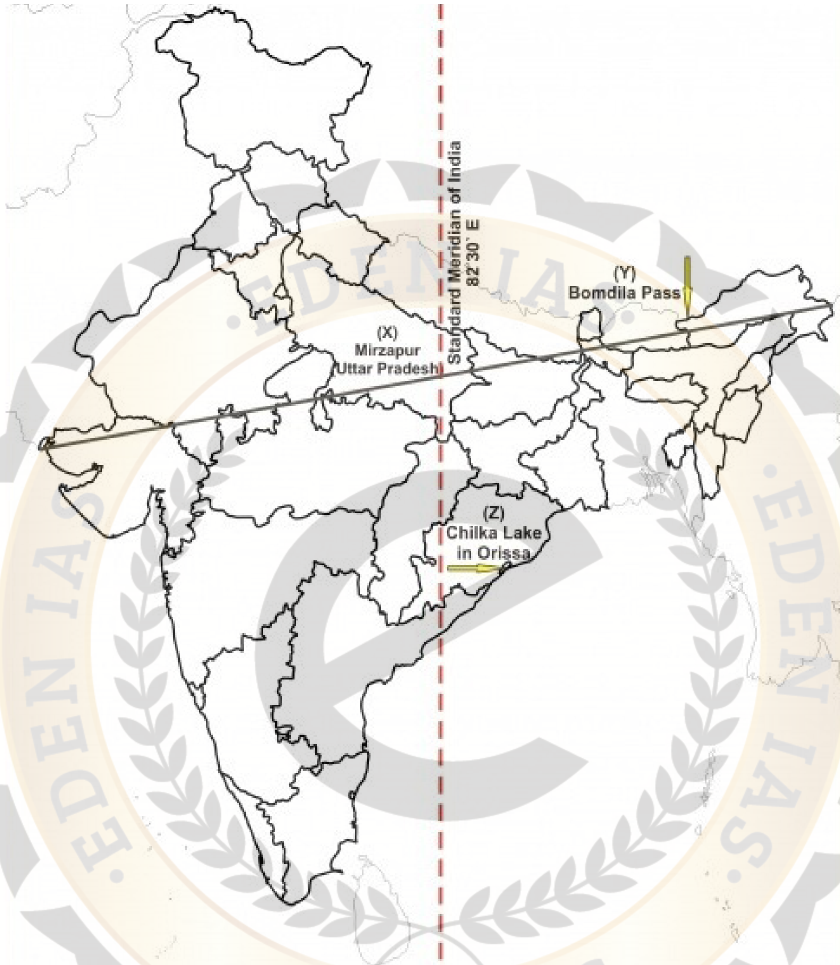
Key Differences Between Local Time and Standard Time

The points given below are substantial, so far as the difference between local time and standard time is concerned:

1. The time of a particular place that is measured on the basis of sun's transit over the meridian at that place is called local time. On the contrary, standard time is the time in any of the time zones, into which the earth is divided.
2. As midday occurs at different times at different meridians, so the local time is different in different meridians. As against this, standard time is same for a particular country, as it is established by the country as per law or custom.
3. The places that fall on the same line of longitude have same local time. However, their standard time may be different.
4. Local time is computed with reference to the shadow cast by the sun. Conversely, the standard time is determined on the basis of time zones.

INDIAN STANDARD TIME (IST)

Indian Standard Time (IST) represents the time observed throughout India, with a time offset of **GMT+5:30.** India opted out of observing daylight saving time, (DST) or other seasonal adjustments, although briefly using DST during the Sino–Indian War of 1962 and the Indo–Pakistani Wars of 1965 and 1971. **In military and aviation time, E* ("Echo-Star") designates IST**.



Indian Standard Time is calculated on the basis of **82.5° E longitude**, close to the town of Mirzapur, near Allahabad in the state of Uttar Pradesh. **The longitude difference between IST (Mirzapur) and the United Kingdom's Royal Observatory at Greenwich translate to an exact time difference of 5 hours 30 minutes**.

A clock tower at the Allahabad Observatory (25.15° N 82.5° E) calculates local time, though the National Physical Laboratory, in New Delhi has been entrusted with the official time-keeping devices.

DEMAND FOR MUTIPLE TIME ZONES

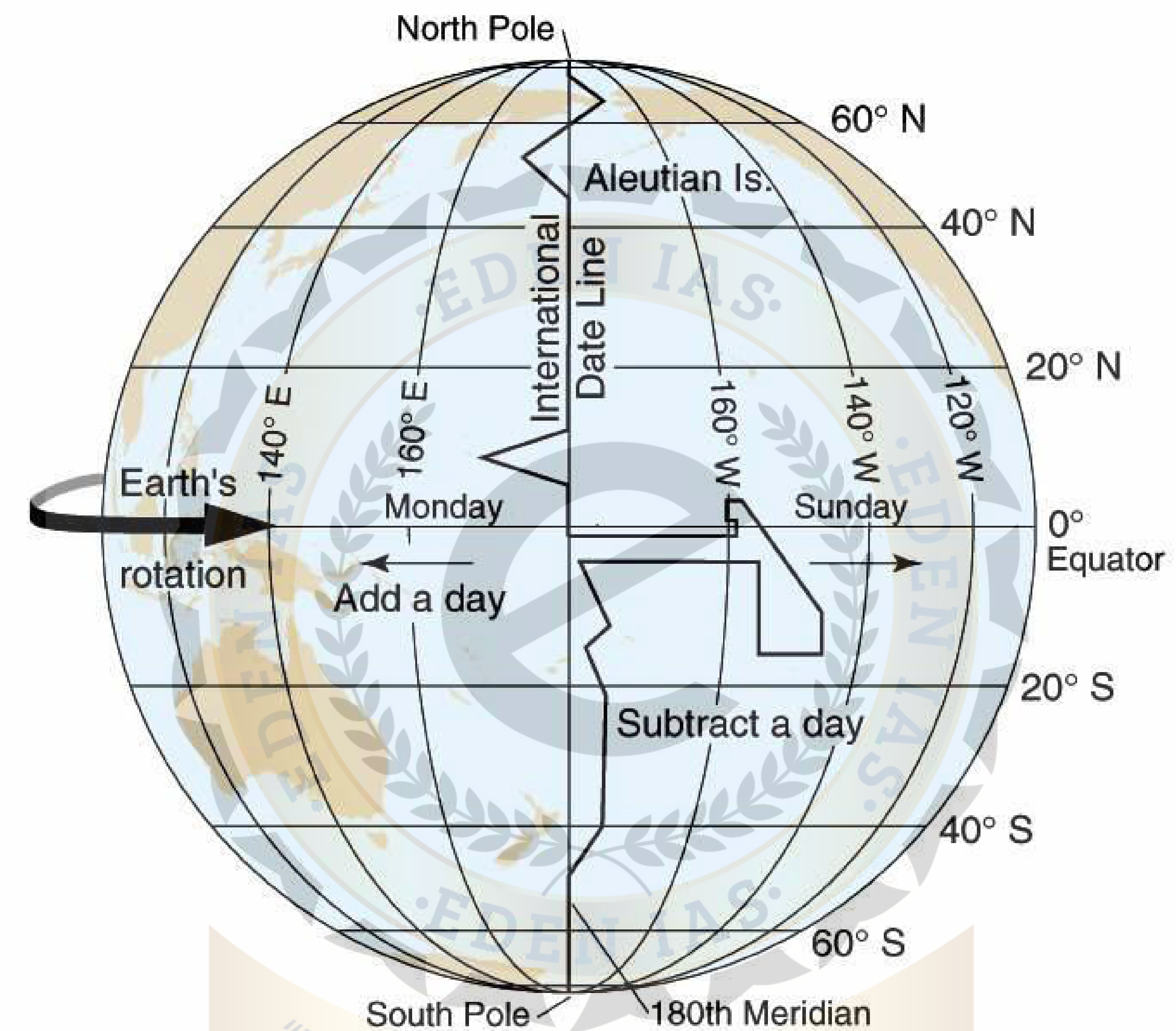
The country's east–west distance of more than 2,000 km (1,200 miles) covers over 28 degrees of longitude, resulting in the sun rising and setting almost two hours earlier in the north-eastern Seven Sister States than in the Rann of Kutch in the far west. In the late 1980s, a team of researchers proposed separating the country into two or three time zones to conserve energy. The binary system that they suggested involved a return to British–era time zones. The demand has picked momentum in recent years but is still to be acknowledged in government records

INTERNATIONAL DATE LINE

The International Date Line, established in 1884, passes through the mid-Pacific Ocean and roughly follows a 180 degrees longitude north-south line on the Earth. It is located halfway round the world from the prime meridian—the zero degrees longitude established in Greenwich, England, in 1852. **The IDL is not a straight Line.** The dateline runs from the North Pole to the South Pole and marks the divide between the Western and Eastern Hemisphere. It is not straight but zigzags to avoid political and country borders and to not cut some countries in half.

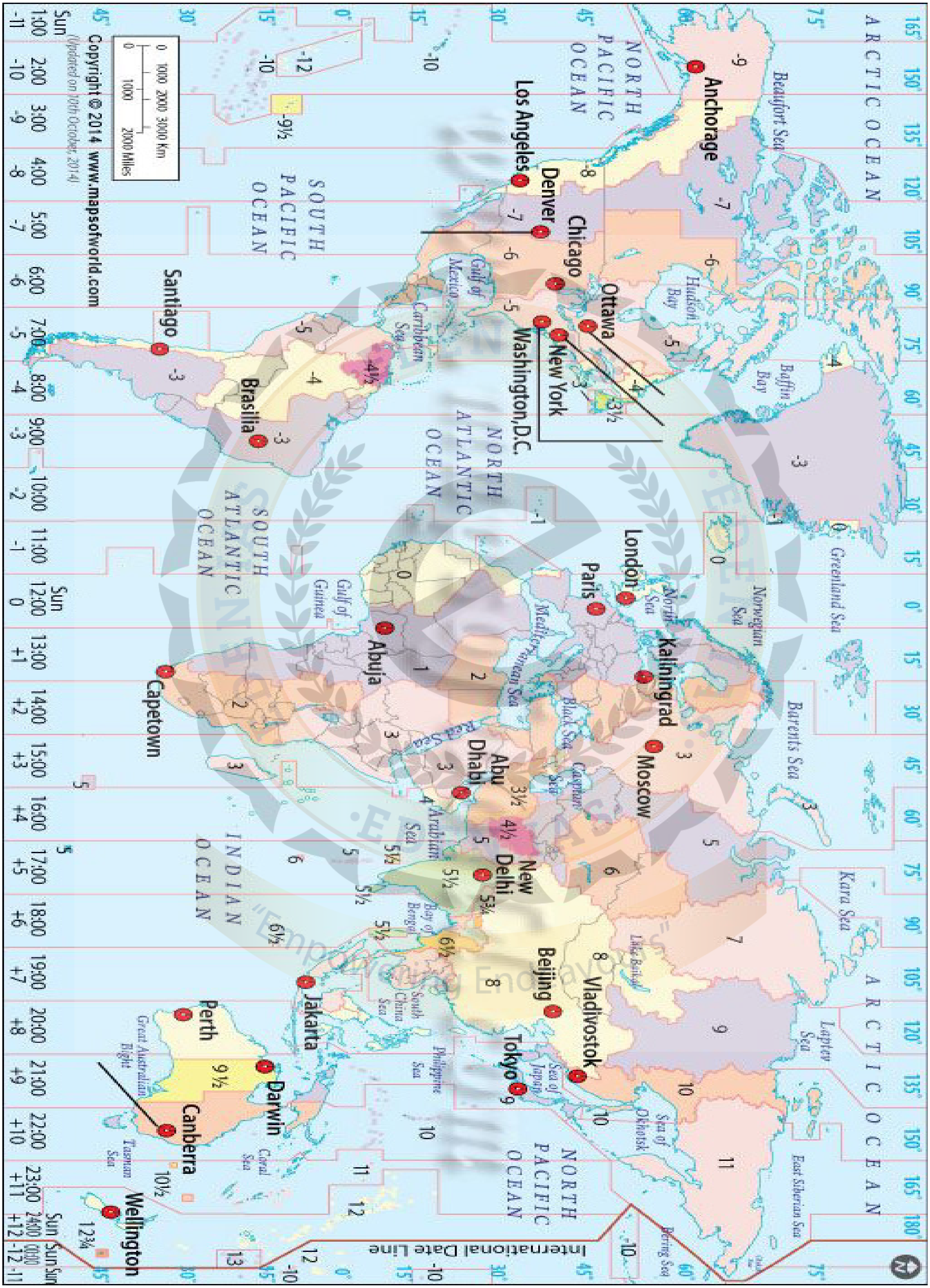
What happens when you cross the IDL?

When you cross the International Date Line from west to east, you subtract a day, and if you cross the line from east to west, you add a day. In other words a traveler crossing the **date line** from **east** to **west** loses a **day** and while crossing the **dateline** from **west to east** he **gains** a **day**.



- **Despite its name, the International Date Line has no legal international status and countries are free to choose the dates that they observe.**
- **The 180° meridian was selected as the International Date Line because it mostly runs through the sparsely populated Central Pacific Ocean**.
- It was decided at the International Meridian Conference in 1884 in Washington, D.C. where 26 countries attended.

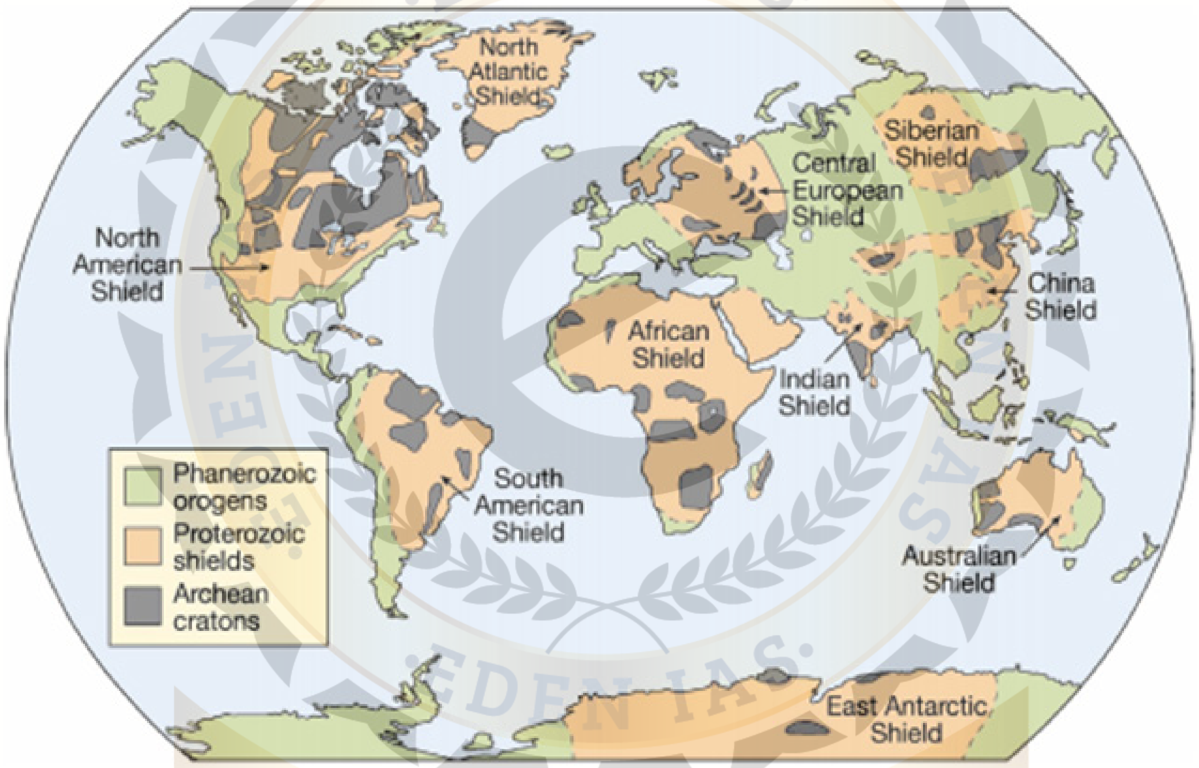
WORLD TIME ZONES



UNIT-II
[LITHOSPHERE]

DISTRIBUTION OF CONTINENTS AND OCEANS

When viewed from space, the predominance of Earth's oceans is readily apparent. The oceans and their marginal seas cover nearly 71 percent of Earth's surface, with an average depth of 3,688 metres (12,100 feet). The exposed land occupies the remaining 29 percent of the planetary surface and has a mean elevation of about 840 metres (approximately 2,755 feet). Actually, all the elevated land could be hidden under the oceans and Earth reduced to a smooth sphere that would be completely covered by a continuous layer of seawater more than 2,600 metres (8,530 feet) deep. This is known as the sphere depth of the oceans and serves to underscore the abundance of water on Earth's surface. The continents consist of two fundamental kinds of geological units: **Cratons/Shields/Platforms, and Unstable/ Mobile Belts/Orogen**.



A craton is an old and stable part of the continental lithosphere, where the lithosphere consists of the Earth's two topmost layers, the crust and the uppermost mantle. Having often survived cycles of merging and rifting of continents, cratons are generally found in the interiors of tectonic plates. They are characteristically composed of ancient crystalline basement rock, which may be covered by younger sedimentary rock. They have a thick crust and deep lithospheric roots that extend as much as several hundred kilometres into the Earth's mantle**. Cratons whose ancient rocks are widely exposed at the surface, often with relatively subdued relief, are known as shields. If the ancient rocks are largely overlain by a cover of younger rocks then the 'hidden' craton may be referred to as a platform.** The term craton is used to distinguish the stable portion of the continental crust from regions that are more geologically active and unstable**. The word craton was first proposed by the Austrian geologist Leopold Kober in 1921 as Kratogen, referring to stable continental platforms, and orogen as a term for mountain or orogenic belts**

A shield is generally a large area of exposed Precambrian crystalline igneous and high-grade metamorphic rocks that form tectonically stable areas. In all cases, the age of these rocks is greater

than 570 million years and sometimes dates back 2 to 3.5 billion years. They have been little affected by tectonic events following the end of the Precambrian, and are relatively flat regions where mountain building, faulting, and other tectonic processes are greatly diminished compared with the activity that occurs at the margins of the shields and the boundaries between tectonic plates. Major shields include Laurentian (Canadian) Shield, Brazilian Shield, Baltic Shield, African Shield, Arabian Shield, Siberian Shield, Deccan (Indian) Shield, China Shield, Antarctic Shield and Australian Shield.

Orogenic Belts are mobile and unstable zones that are mostly located at the margins of the continents and often experience subduction and deformation.

Relative Distribution of the Oceans

Earth possesses one "world ocean." However, those conducting oceanic research generally recognize the existence of five major oceans: the Pacific, Atlantic, Indian, Arctic, and Southern oceans. Arbitrary boundaries separate these bodies of water. The boundaries of each ocean are largely defined by the continents that frame them. In the Southern Hemisphere the southern portions of the Pacific, Atlantic, and Indian oceans and their tributary seas that surround Antarctica are often referred to as the Southern Ocean. Many subdivisions can be made to distinguish the limits of seas and gulfs that have historical, political, and sometimes ecological significance. However, water properties, ocean currents, and biological populations are not constrained by these boundaries. Indeed, many researchers do not recognize them either.

FACTORS AFFECTING EVOLUTION OF LANDFORMS

Landform, whether large or small result from the interaction of certain forces, they accomplish their work by various means of processes, which may be described as geologic, climatic and biologic and these processes bring about the changes in the Earth's surface which may be Classified as **(I) Long Period Changes (which man finds hard to appreciate during his life time) and (II) short period Changes (which happen in days, weeks, months or years; easily recognizable by man).** The forces which affect the crust of the earth are broadly classified in two types viz. Endogenetic and Exogenetic Forces

ENDOGENETIC FORCES (CREATORS)

The forces coming from within the earth are called as Endogenetic forces which causes two types of movement in the earth viz (I) Horizontal movements (II) Vertical movements. These forces derive their energy from changes such as radioactivity, chemical recombination, expansion or contraction or displacement of molten materials which occurs in the interior of the earth.

On the basis of intensity the endogenetic forces and movements are divided in to two major Categories viz. **DIASTROPHIC FORCES** and **SUDDEN FORCES. Diastrophism refers to deformation of the Earth's crust, and more especially to folding and faulting. Diastrophic forces are slow forces that bring change in the earth's crust over a very long period of time. They are further subdivided as radial (or epeirogenic) forces and tangential (or orogenic) forces. Sudden forces, also known as catastrophic forces, bring abrupt disruptions in relief which can be easily recognizable by an observer during his lifetime (e.g. Volcanism and Earthquakes)**

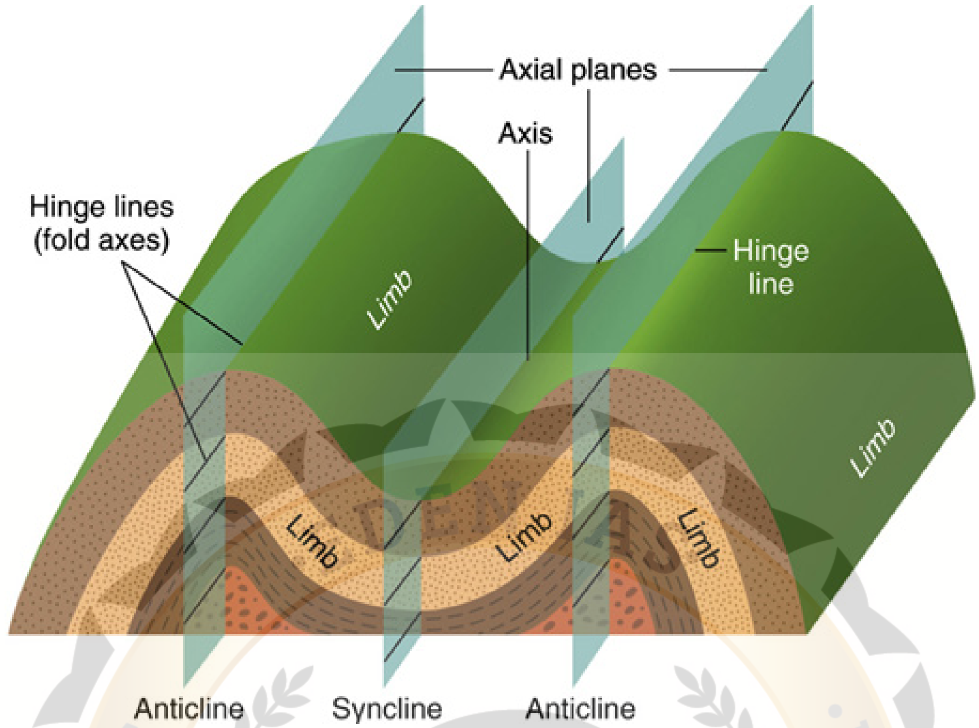
EXOGENETIC FORCES (DESTROYERS)

The exogenetic forces or processes, also called as denudational processes, or 'destructional forces or processes' originate from the atmosphere (The Sun being the ultimate source of energy). These forces are continuously engaged in the destruction of the relief features created by Endogenetic forces through their weathering, erosional and depositional activities.

Denudation includes both weathering and erosion where weathering being a static process includes the disintegration and decomposition of rocks in situ whereas erosion is a dynamic process which includes both, removal of materials and their transportation to different destinations. **The major exogenetic forces are Running Water, Glaciers, Sea Waves, Wind and Underground Water**. **The exogenetic forces are also known as geomorphic agents.**

FOLDS, WARPS, JOINTS AND FAULTS

Folds- Wave like bends are formed in crustal rocks due to the tangential compressive force resulting from horizontal movement caused by the Endogenetic force originating deep within the earth. Such bends are Called 'folds' wherein some parts are bent up and some parts are bent down.



Major Components of a Fold

The up folded rock strata in arch-like form are called **'anticlines'** while the down folded feature forming trough-like feature is called **'synclines'**. The two sides of the fold are called **limbs of the fold**. The limb which is shared between an anticline and its companion syncline is called **middle limb**. The Plane which bisects the angle between the two limbs of the anticline or middle limb of like syncline is called the **axis of fold or axial plane**. On the basis of anticline and syncline these axial planes are called as **axis of anticline** and **axis of syncline** respectively. The inclination of the rock beds with respect to the horizontal Plane is termed as **'dip'**. The line drawn perpendicular to dip is known as **'Strike'** of the fold.

Types of folds

The Nature of the folds depends on various factors such as the nature of rocks, the nature and the intensity of compressive forces, duration of the operation of the compressive forces etc. Based on the inclinations of the limbs the folds are classified in to the following types.

- **Symmetrical folds-** If both the limbs incline uniformly then they are called as symmetrical folds. These folds are an example of open folds and are formed when Compressive forces work regularly but with moderate intensity.
- **Asymmetrical folds-** These are characterized by unequal irregular limbs which incline at different angles. One limb is relatively larger and the inclination is moderate and regular while the other limb is relatively shorter with steep inclination.
- **Monoclinal folds-** These are the folds in which one limb inclines moderately with regular slope while the other limb inclines steeply at right angle and the slope is almost vertical.
- **Isoclinal folds-**These folds are formed when the compressive forces are so strong that both the limbs of the fold become parallel but not horizontal.
- **Recumbent folds-**These folds are formed when compressive forces are so strong that both the limbs of the folds become parallel as well as horizontal.

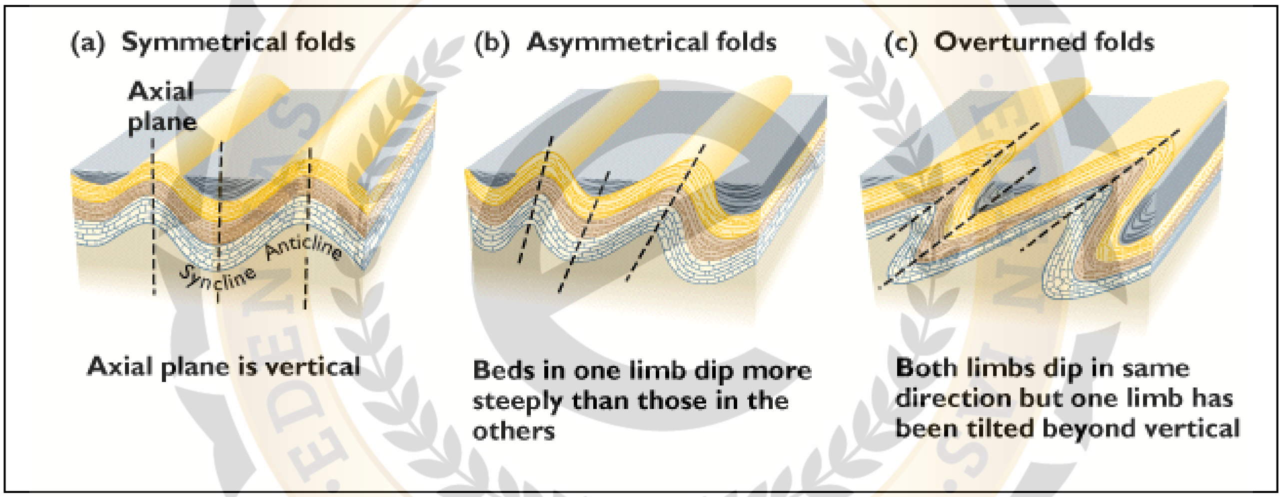
- **Overturned folds-**The fold in which one limb of the fold is thrust upon the other limb due to intense compressive forces.

- **Plunge folds-**When the axis of the fold instead of being parallel to the horizontal plane becomes tilted and forms plunge angle which is the angle between the axis and the horizontal plane.

- **Fan folds-** They represent an extensive broad fold consisting of several minor anticlines and synclines which resembles a fan. Such feature also called as **Anticlinorium** and **Synclinorium**.

- **Open folds-** The folds in which the angle between the two limbs of the fold is more than 90° but less than 180° (obtuse angle). These open folds are formed due to moderate nature compressive forces.

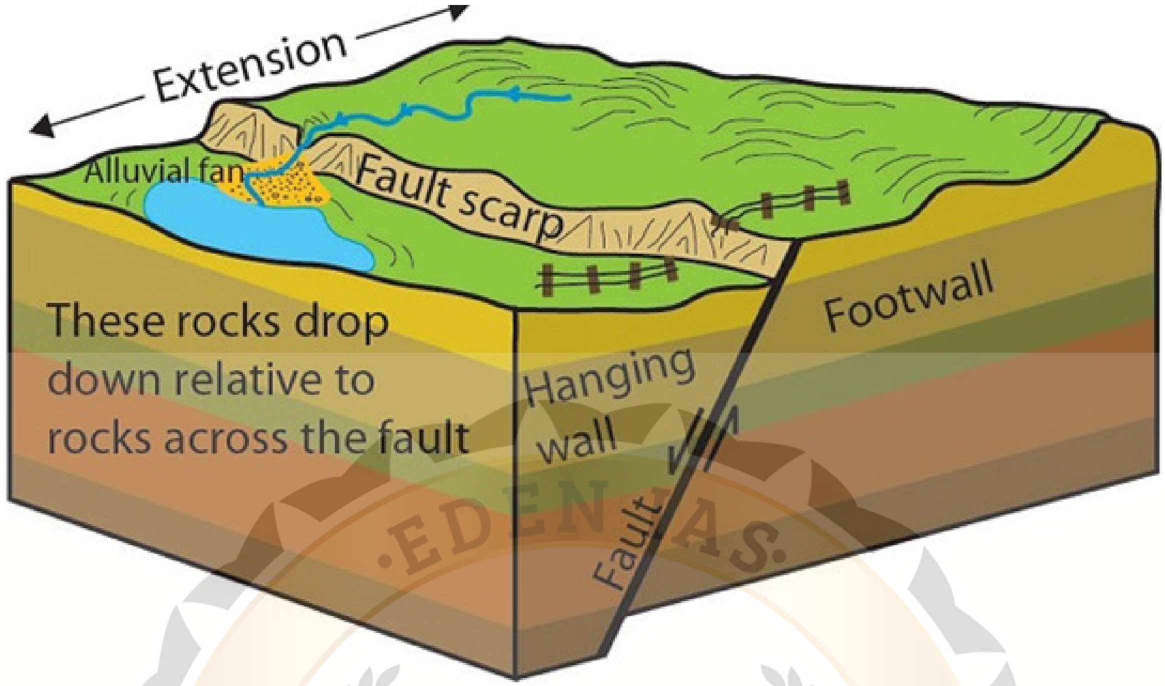
- **Closed folds-** The folds in which the angle between the limbs is acute are called as closed folds and are formed due to intense Compressive forces.



Warping- The process of crustal warping affects larger areas of the crust where in crustal parts are warped upward or downward. The upward rise of the crustal part due to the compressive force resulting in the Convergent horizontal movement is called **UPWARPING** while bending of the Crustal parts downward in the form of a basin or depression is called **DOWNWARPING**. When the process of up warping and down warping affects larger areas, the resultant mechanism is called **BROADWARPING**. In simple words warping is extensive or large scale folding. Though distinct both the words are often used interchangeably.

Joints- A joint is defined as a fracture in the crustal rocks wherein no appreciable movement of rocks takes place along the line or zone of fracture

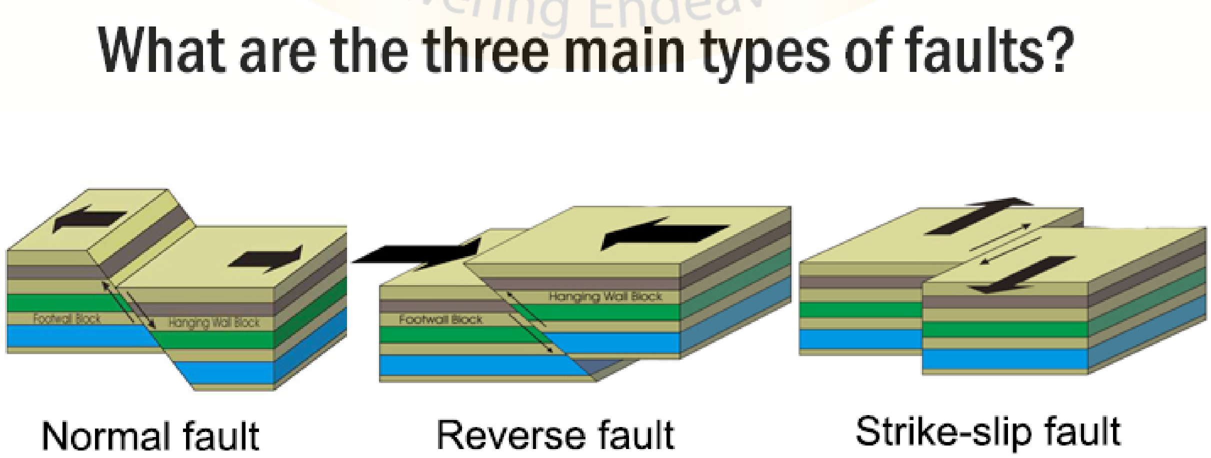
Faults- When the crustal rocks are displaced, due to tensional movement caused by the Endogenetic forces, along a plane, the resultant structure is called **fault**. The Plane along which the rock blocks are displaced is called **fault plane**. A fault Plane may be vertical, or inclined, or horizontal, or curved or of any type and form. The movement responsible for the formation of a fault may operate in vertical or horizontal or in any direction.



Major Components of a Fault

The major components of a fault include

- **Fault Plane-** The plane along which the rock blocks are displaced by tensional and Compressional forces acting vertically and horizontally to form a fault, fault plane may be vertical, inclined, horizontal, curved or of any other form.
- **Fault dip-** The angle between the fault plane and the horizontal plane
- **Up thrown side-**Represents the uppermost block of a fault
- **Downthrown Side-** Represents the lowermost block of a fault
- **Hanging Wall-** The upper wall of the fault
- **Foot wall-** The lower wall of the fault
- **Fault scrap-** The steep wall like slope caused by faulting of the crustal rocks, Sometimes the fault scarp is so steep that is resembles a cliff. Scarps are not formed by faulting alone and it may form



Normal Fault-If the displacement of the rock blocks is down to the direction of the dip then the resultant fault is called Normal fault. Normal faults are formed due to the displacement of both the rock blocks in opposite directions due to tensional force. The fault plane is usually between 45° and vertical. The Steep scrap resulting from the normal fault is called fault-scarp or fault-line scarps the height of which ranges between a few meters to hundreds of meters.

Reverse Fault-Reverse faults are formed due to the movement of both the fractured rock blocks towards each other. The fault Plane, in a reverse fault is usually inclined of an angle between 40° and horizontal 0° .The vertical Stress is minimum while the horizontal stress is maximum. In reverse faults the rock beds on the upper side are displaced up the fault plane relatively to the rock beds below **.It is apparent that reverse faults results in the shortening of the faulted area while normal faults cause extension of the faulted area**. It is thus, also obvious that some sort of compression is also involved in the formation of reverse faults. **Reverse faults are also called of thrust faults. Since reverse faults is formed due to compressive force resulting from horizontal movement and hence this is also called as Compressional fault**.

Lateral or Strike Strip Faults-This type of faults are formed When the rock beds are displaced horizontally along the fault plane due to horizontal movement These are called left-lateral or sinistral faults when the displacement of rocks occurs to the left on the far side of the fault and right lateral or dextral faults when the displacement of rock blocks takes place to the right on the far side of the fault.

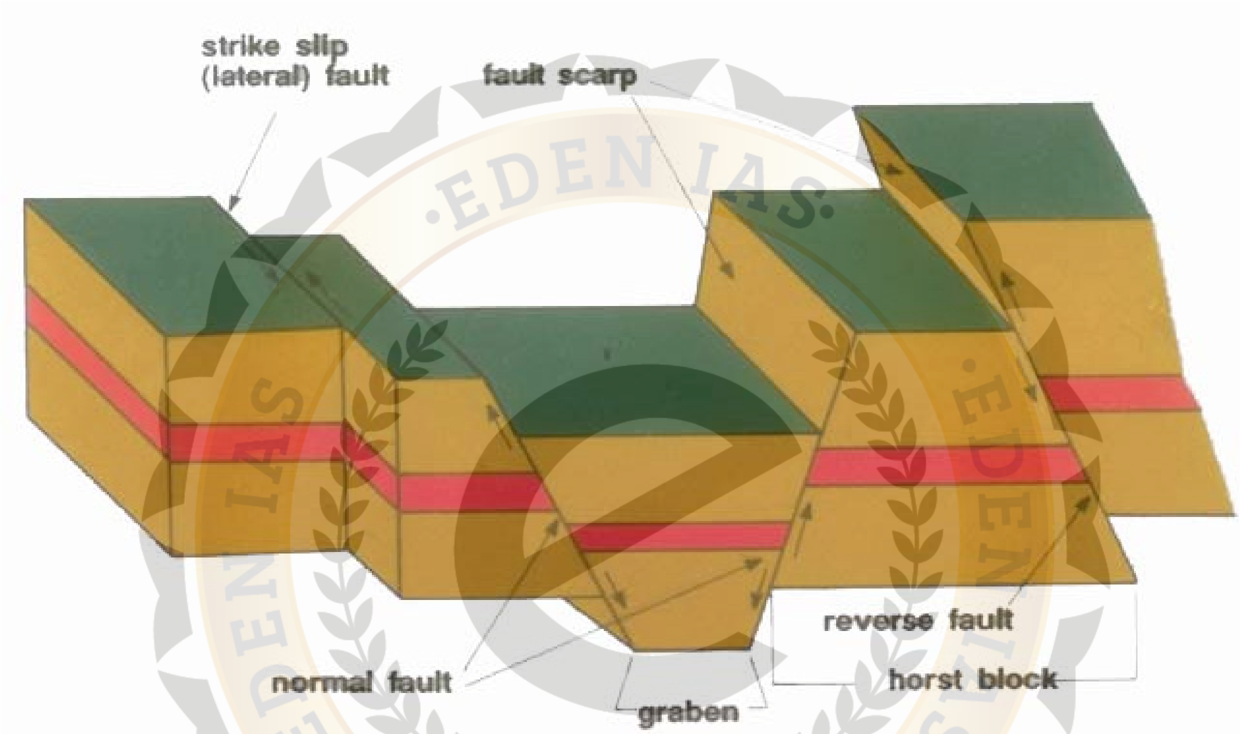
BLOCK MOUNTAINS AND RIFT VALLEY

A rift valley is a major relief feature resulting from faulting activities. It represents a trough, depression or basin between two crustal parts. Rift valleys are formed due to displacement of crustal Parts and subsidence of middle portion between two faults by horizontal and vertical movements motored by Endogenetic forces. Rift valleys are also called as **'Graben'** which is a German word which means trough-like depression. **The surrounding lithospheric blocks that are found on either side of a rift valley form Block Mountains** (Block Mountains are also known as horst)**.** A rift valley may be formed in two ways viz

- **When the middle portion of the crust between two normal faults is dropped downward while the two blocks on the either side of the down dropped block remain stable** (Tensional stress)

- **When the middle portion between two normal remains stable and the two side blocks on the either side of the middle position are raised upward** (Compressional stress)

Rhine rift valley is the best example rift valley. The one side of the rift valley is bounded by Vosges and Hardt mountains (block mountains-horst) while the other side is bordered by Black forest and odenwald mountains. Some of the other rift valleys are Jordan River valley, Death Valley of southern Californian, Narmada valley and Dead Sea in Asia. **The rift valleys are not only confined to continental crustal surfaces but they are also found on the sea floor.**



HORST (BLOCK MOUNTAIN) AND GRABEN (RIFT VALLEY)

CONTINENTAL DRIFT THEORY

It was not until **1912** that the idea of moving continents was seriously considered as a full-blown scientific theory - called Continental Drift - introduced in two articles published by a German meteorologist named **Alfred Lothar Wegener**.

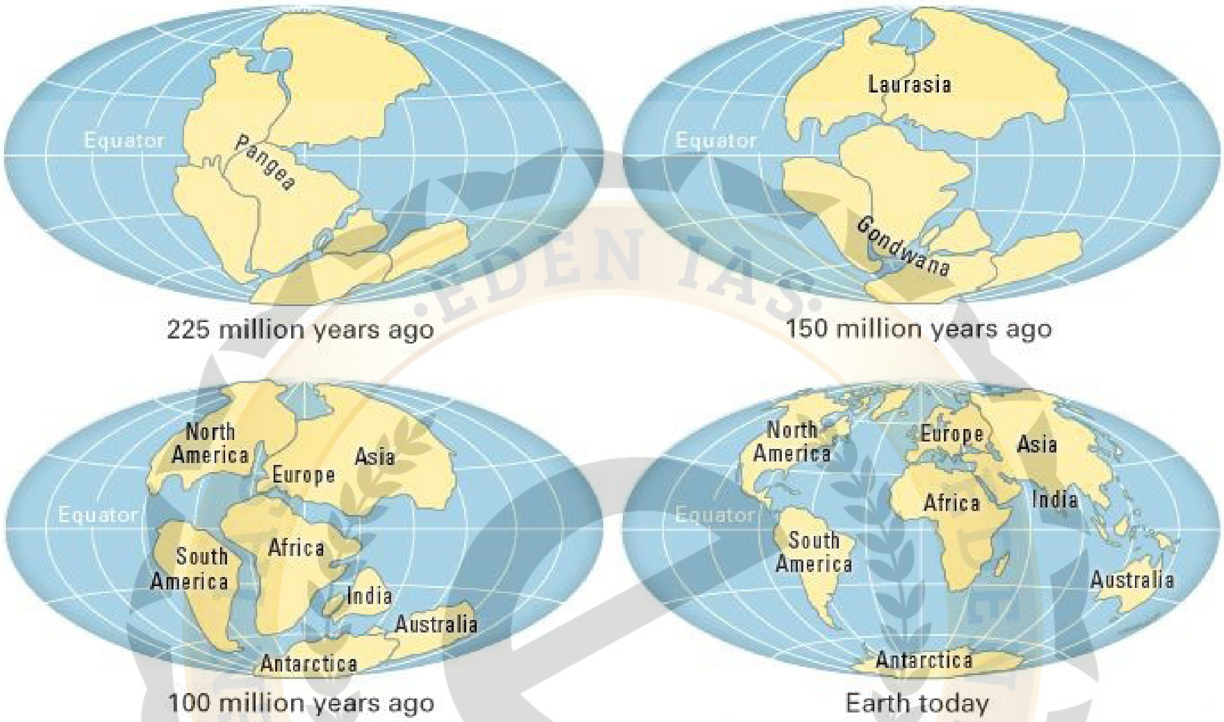
Professor **Alfred Wegener of Germany was primarily a meteorologist.** He propounded his concept on continental drift in the year 1912 but it could not come in light till 1922 when he elaborated his concept in a book entitled **'Die Entstechung der Kontinente and Ozeane'** and his book was translated in English in **1924**.

The main problem before Wegener, which needed explanation, was related to climatic changes. It may be pointed out that there are ample evidences which indicate widespread climatic changes throughout the past history of the earth. In fact, the continental drift theory of Wegener 'grew out of the need of explaining the major variations of climate in the past'. During his Paleomagnetic studies he discovered that the same region has experienced different climates at different times. **The climatic changes which have occurred on the globe may be explained in two ways**

(1) If the continents remained stationary at their places throughout geological history of the earth, the climatic zones might have shifted from one region to another region and thus a particular region might have experienced varying climatic conditions from time to time.

(2) If the climatic zones remained stationary the land masses might have been displaced and drifted.

Wegener opted for the second alternative as he rejected the view of the permanency of continents and ocean basins. Thus, the main objective of Wegener behind his **'displacement hypothesis'** was to explain the global climatic changes which are reported to have taken place during the past earth history.



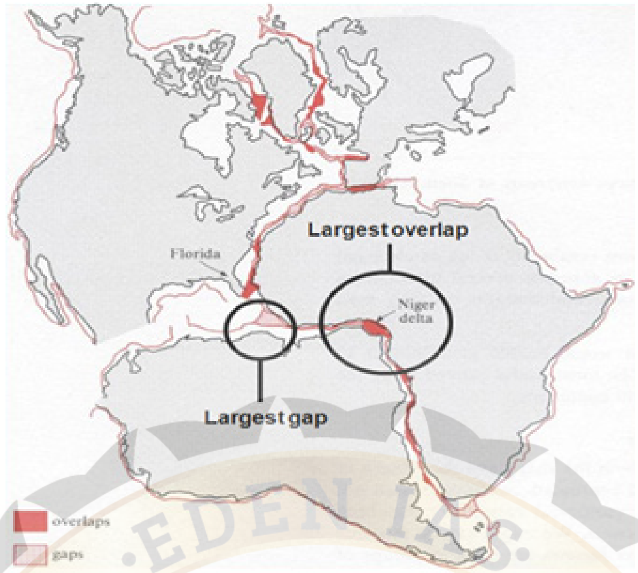
He assumed, on the basis of evidences of palaeo-climatology, paleontology, paleobotany, geology and geophysics, that all the landmasses were united together in the form of one landmass, which he named **Pangaea** (or the Super-continent). Pangaea was surrounded by a huge water body, which was named by Wegener as **'Panthalasa'** (or the Giant Ocean), representing primeval Pacific Ocean.

He argued that, around 200 million years ago, the super continent, Pangaea, began to split. Pangaea first broke into two large continental masses as Laurasia and Gondwanaland forming the northern and southern components respectively. This breaking up of Pangaea facilitated the intrusion of an arm of Panthalasa between the two landmasses (**Tethys Sea**). **Subsequently, Laurasia and Gondwanaland continued to break into various smaller continents that exist today**.

Evidences in Support of the Continental Drift Theory

Wegener has successfully attempted to prove the unification of all landmasses in the form of a single Iandmass, the Pangaea, during carboniferous period, on the basis of evidences gathered from geological, climatic and floral records. He claimed that all the present-day continents could be joined to form Pangaea. **The following evidences support the concept of the existence of Pangaea during carboniferous period**

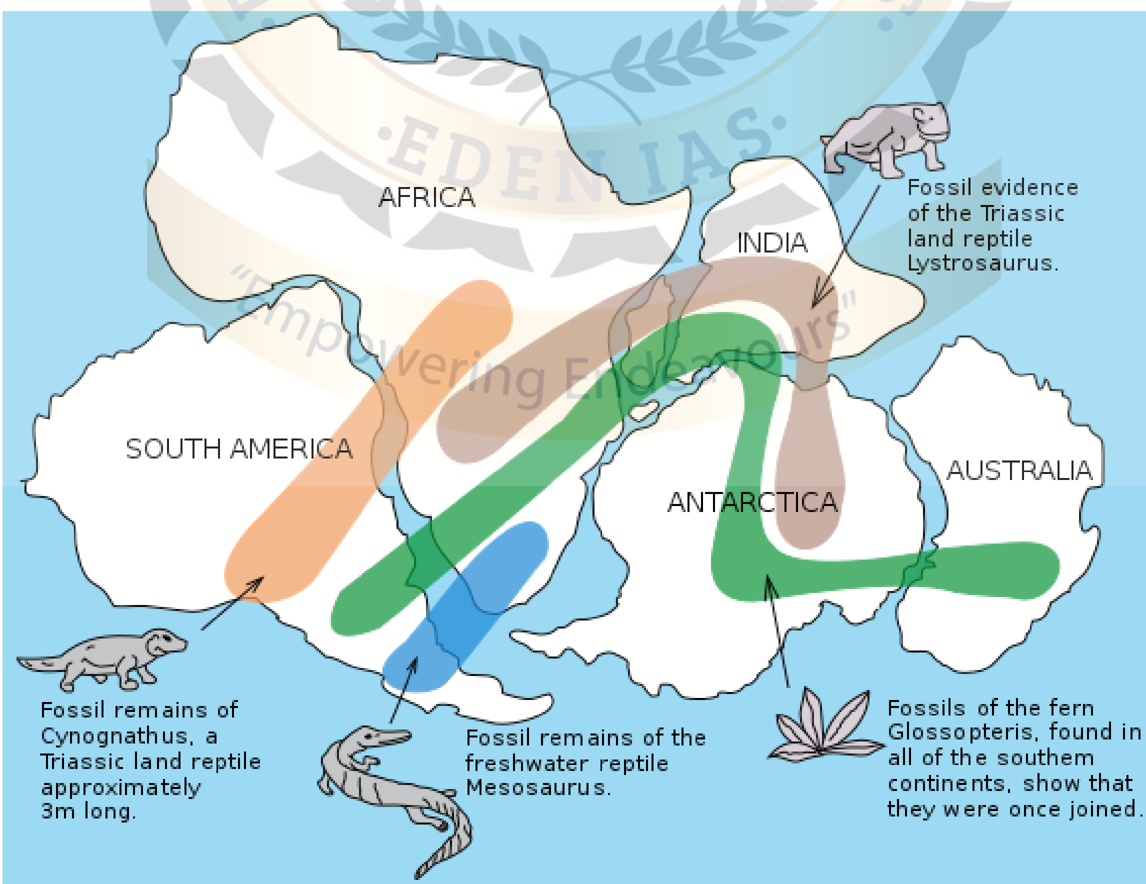
(1) According to Wegener there is geographical similarity along both the coasts of the Atlantic Ocean. Both the opposing coasts of the Atlantic can be fitted together in the same way as two cut off pieces of wood can be refitted.



(2) Geological evidences denote that the Caledonian and Hercynian mountain systems of the western and eastern coastal areas of the Atlantic are similar and identical. The Appalachians of the northeastern regions of North America are compatible with the mountain systems of Ireland, Wales and northwestern Europe.

(3) Geologically, both the coasts of the Atlantic are also identical. According to Du Toit both the landmasses (i.e., South America and Africa) cannot be actually brought together but near to each other because a gap of 400-800 km would separate them due to the existence of continental shelves and slopes of these two landmasses.

(4) There is marked similarity in the fossils and vegetation remains found on the eastern coast of South America and the western coast of Africa.



(5) It has been reported from geodetic evidences that Greenland is drifting westward at the rate of 20 cm per year. The evidences of seafloor spreading after 1960 have confirmed the movement of landmasses with respect to each other.

(6) The lemmings (small sized animals) of the northern part of Scandinavia have a tendency to run westward when their population is enormously increased but they are foundered in the sea water due to absence of any land beyond Norwegian coast. This behaviour of lemmings proves the fact that the landmasses were united in the ancient times and the animals used to migrate to far off places in the western direction.

(7) The distribution of glossopteris flora in India, South Africa, Australia, Antarctica, Falkland Islands etc. proves the fact that all the landmasses were previously united and contiguous in the form of Pangaea.

(8) The evidences of carboniferous glaciation of Brazil, Falkland, South Africa, Peninsular India, Australia and Antarctica further prove the unification of all landmasses in one landmass (Pangaea) during carboniferous period.

Evaluation of Continental Drift Theory

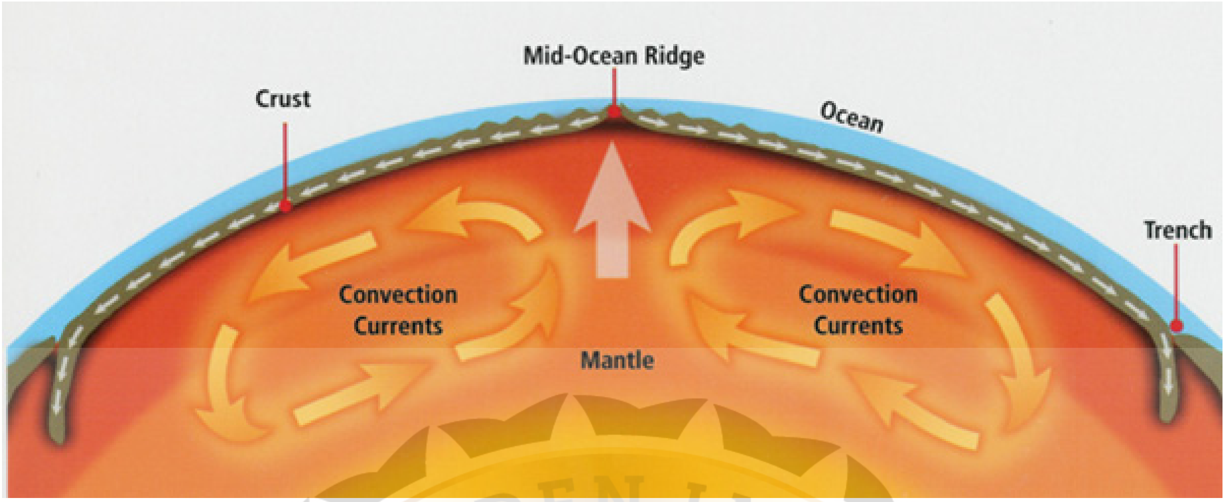
Force for Drifting -Wegener suggested that the movement responsible for the drifting of the continents was caused by pole-fleeing force and tidal force. The polar-fleeing force relates to the rotation of the earth. You are aware of the fact that the earth is not a perfect sphere; it has a bulge at the equator. This bulge is due to the rotation of the earth. The second force that was suggested by Wegener—the tidal force—is due to the attraction of the moon and the sun that develops tides in oceanic waters. Wegener believed that these forces would become effective when applied over many million years. However, most of scholars considered these forces to be totally inadequate

Conclusion

Though most point of Wegener's theory was rejected but its central theme of horizontal displacement was retained. In fact, the postulation of plate tectonic theory after 1960 is the result of this continental drift theory of Wegener. Wegener is, thus, given credit to have started thinking in this precarious field.

CONVECTIONAL CURRENT THEORY

Arthur Holmes in 1930s discussed the possibility of convection currents operating in the mantle portion. These currents are generated due to radioactive elements causing thermal differences in the mantle portion. Holmes argued that there exists a system of such currents in the entire mantle portion. This was an attempt to provide an explanation to the issue of force, on the basis of which contemporary scientists discarded the continental drift theory



SEA FLOOR SPREADING

The mapping of the ocean floor and Paleomagnetic studies of rocks from oceanic regions revealed the following facts:

i. It was realised that all along the midoceanic ridges, volcanic eruptions are common and they bring huge amounts of lava to the surface in this area.

ii. The rocks equidistant on either sides of the crest of mid-oceanic ridges show remarkable similarities in terms of period of formation, chemical compositions and magnetic properties. Rocks closer to the mid-oceanic ridges have normal polarity and are the youngest. The age of the rocks increases as one moves away from the crest.

iii. The ocean crustal rocks are much younger than the continental rocks. The age of rocks in the oceanic crust is nowhere more than 200 million years old. Some of the continental rock formations are as old as 3,200 million years.

iv. The sediments on the ocean floor are unexpectedly very thin. Scientists were expecting, if the ocean floors were as old as the continent, to have a complete sequence of sediments for a period of much longer duration. However, nowhere was the sediment column found to be older than 200 million years.

v. The deep trenches have deep-seated earthquake occurrences while in the midoceanic ridge areas; the quake foci have shallow depths.

These facts and a detailed analysis of magnetic properties of the rocks on either sides of the mid-oceanic ridge led **Harry Hess (1961)** to propose his hypothesis, known as the **"sea floor spreading".** Hess argued that constant eruptions at the crest of oceanic ridges cause the rupture of the oceanic crust and the new lava wedges into it, pushing the oceanic crust on either side. The ocean floor thus spreads. The younger age of the oceanic crust as well as the fact that the spreading of one ocean does not cause the shrinking of the other, made Hess think about the consumption of the oceanic crust. He further maintained that the ocean floor that gets pushed due to volcanic eruptions at the crest sinks down at the oceanic trenches and gets consumed

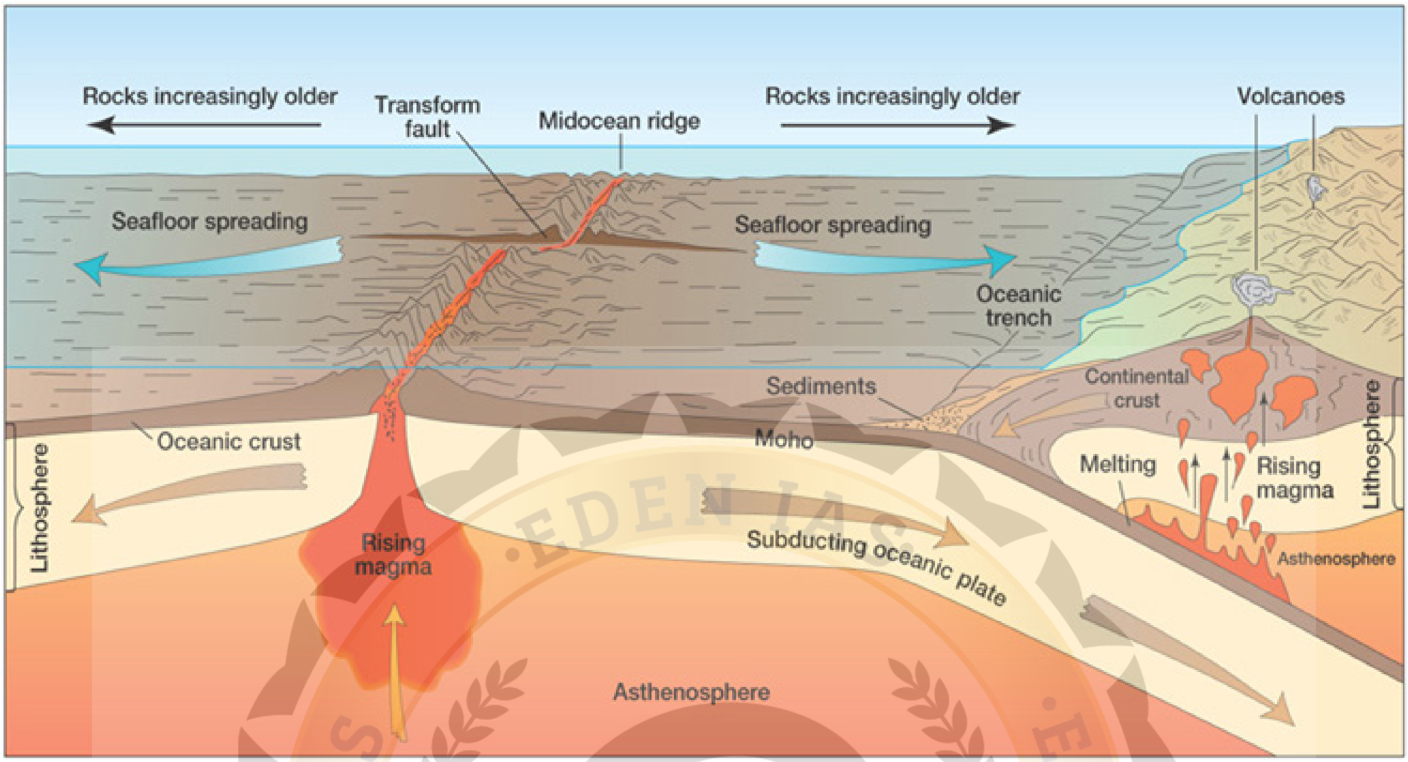


PLATE TECTONIC THEORY

Plate Tectonic Theory is a comprehensive theory which offers explanations for various relief features and tectonic events viz. mountain building, folding and faulting, continental drift, vulcanicity, seismic events (earthquakes) etc.

The rigid lithospheric slabs or rigid and solid landmasses having a thickness of about 100 km composed of Earth's crust and some portion of upper mantle are technically called 'Plates'. **The term 'plate' was first used by Canadian Geologist John Tuzo Wilson in 1965.** The whole mechanism of the evolution, nature and motion and resultant reactions of plates is called 'Plate Tectonics'.

A tectonic plate (also called lithospheric plate) is a massive, irregularly-shaped slab of solid rock, generally composed of both continental and oceanic lithosphere. Plates move horizontally over the asthenosphere as rigid units

A plate may be referred to as the continental plate or oceanic plate depending on which of the two occupy a larger portion of the plate. Pacific plate is largely an oceanic plate whereas the Eurasian plate may be called a continental plate.

The major plates are as follows:

1) **Antarctica and the surrounding oceanic plate**
2) **North American** (with western Atlantic floor separated from the South American plate along the Caribbean islands) **plate**
3) **South American** (with western Atlantic floor separated from the North American plate along the Caribbean islands) **plate**
4) **Pacific plate**
5) **India-Australia-New Zealand plate**
6) **Africa with the eastern Atlantic floor plate**
7) **Eurasia and the adjacent oceanic plate.**

Some important minor plates are listed below:

- **Cocos plate**: Between Central America and Pacific plate
- **Nazca plate**: Between South America and Pacific plate
- **Arabian plate**: Mostly the Saudi Arabian landmass
- **Philippine plate**: Between the Asiatic and Pacific plate
- **Caroline plate**: Between the Philippine and Indian plate (North of New Guinea)
- **Fuji plate**: North-east of Australia.

These plates have been constantly moving over the globe throughout the history of the earth. It is not the continent that moves as believed by Wegener. Continents are part of a plate and what moves is the plate. Moreover, it may be noted that all the plates, without exception, have moved in the geological past, and shall continue to move in the future as well. Wegener had thought of all the continents to have initially existed as a super continent in the form of Pangaea. However, later discoveries reveal that the continental masses, resting on the plates, have been wandering all through the geological period, and Pangaea was a result of converging of different continental masses that were parts of one or the other plates. There are three types of plate boundaries

i. **Constructive Plate Boundaries** are also called as **'divergent plate boundary'**, spreading boundary, or accreting plate boundary, represent zones of divergence along the mid oceanic ridges and are characterized by continuous addition (accretion) of materials as there is constant upwelling of motion materials (basaltic lava) from below the mid-oceanic ridges. These basalt lavas are cooled and solidified and are added to the trailing margins of the divergent plates and thus new oceanic crust is continuously formed. In fact, oceanic plates split apart along the mid-oceanic ridges and moves in opposite directions and thus transform faults are formed.

ii. **Destructive Plate Boundaries** are also known as 'Consuming Plate Boundaries' or **'Convergent Plate Boundary'** are those where two plates collide against each other and the leading edge of one plate having relatively lighter material overrides the other plate and the overridden plate boundary of relative denser material is sub ducted or thrust into the upper mantle and thus a part of the crust in lost in the mental. This is why convergent plate margins are called destructive margins, Collision zone, subduction zone and **'Benioff Zone'.**

iii. **Conservative Plate Boundaries** are also known as Sheer Plate Boundaries, and Transform Boundaries. Transform faults are those where two plates slip past each other without any collision along the transform fault and thus crust is neither created nor destroyed.

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

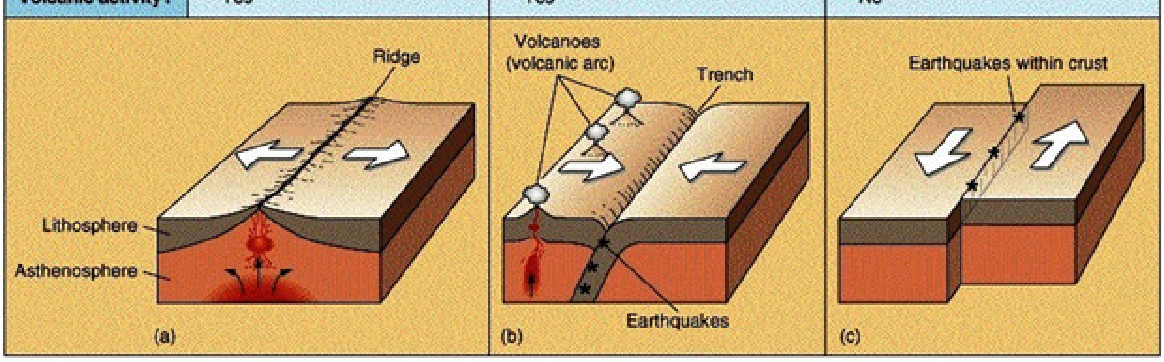
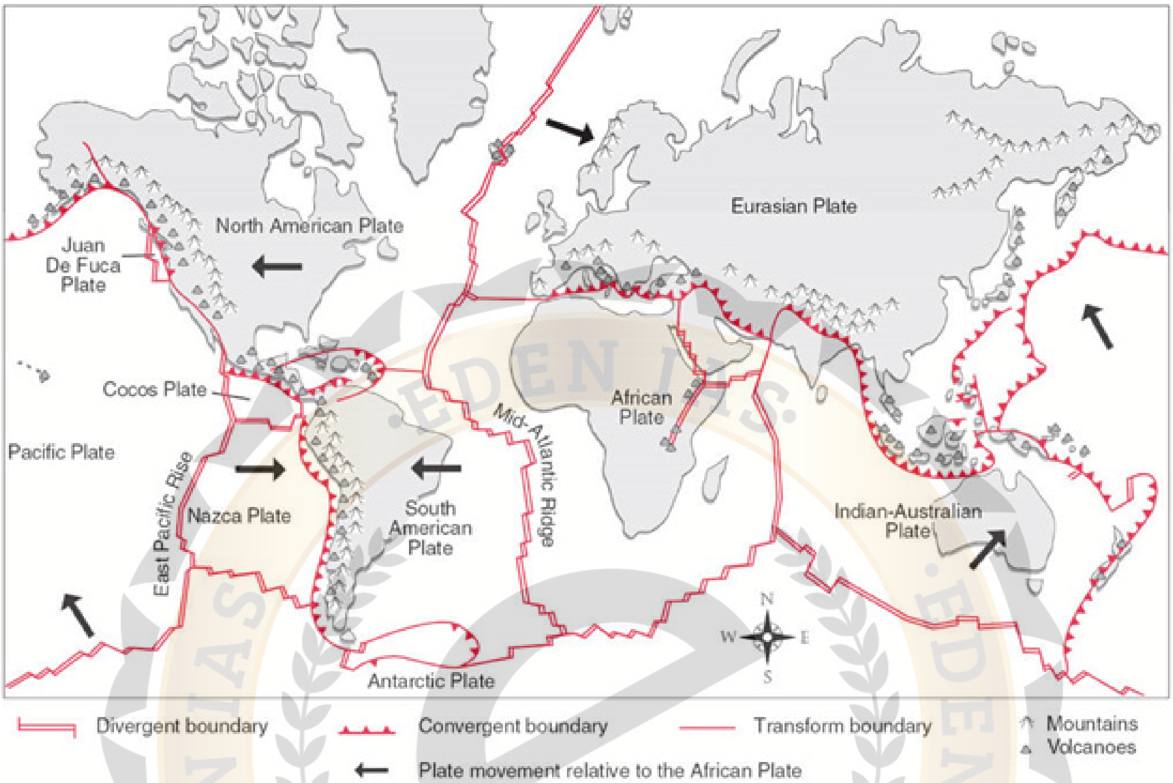


Plate tectonics helps in explaining all the major three tectonic events viz. earthquakes, volcanism and orogenesis by a single comprehensive approach. Till date it is accepted as the most authentic theory regarding the distribution of continents and ocean basins.

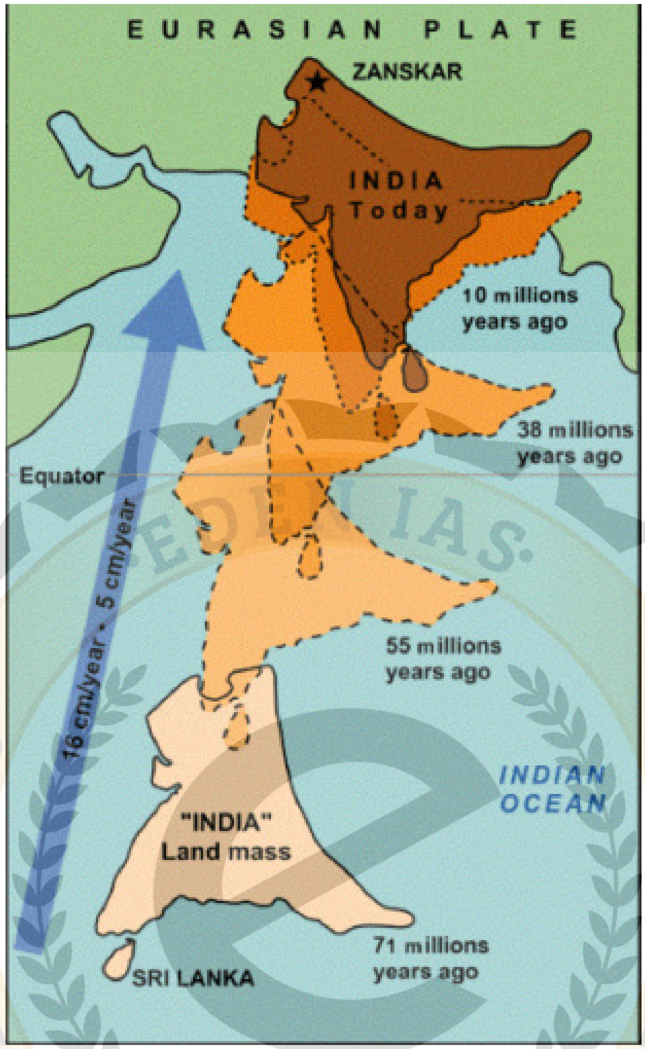


MOVEMENT OF THE INDIAN PLATE

The Indian plate includes Peninsular India and the Australian continental portions. The subduction zone along the Himalayas forms the northern plate boundary in the form of continent— continent convergence. In the east, it extends through Rakinyoma Mountains of Myanmar towards the island arc along the Java Trench. The eastern margin is a spreading site lying to the east of Australia in the form of an oceanic ridge in SW Pacific. The Western margin follows Kirthar Mountain of Pakistan. It further extends along the Makrana coast and joins the spreading site from the Red Sea rift southeastward along the Chagos Archipelago.

The boundary between India and the Antarctic plate is also marked by oceanic ridge (divergent boundary) running in roughly W-E direction and merging into the spreading site, a little south of New Zealand. India was a large island situated off the Australian coast, in a vast ocean.

The Tethys Sea separated it from the Asian continent till about 225 million years ago. India is supposed to have started her northward journey about 200 million years ago at the time when Pangaea broke. India collided with Asia about 40-50 million years ago causing rapid uplift of the Himalayas.



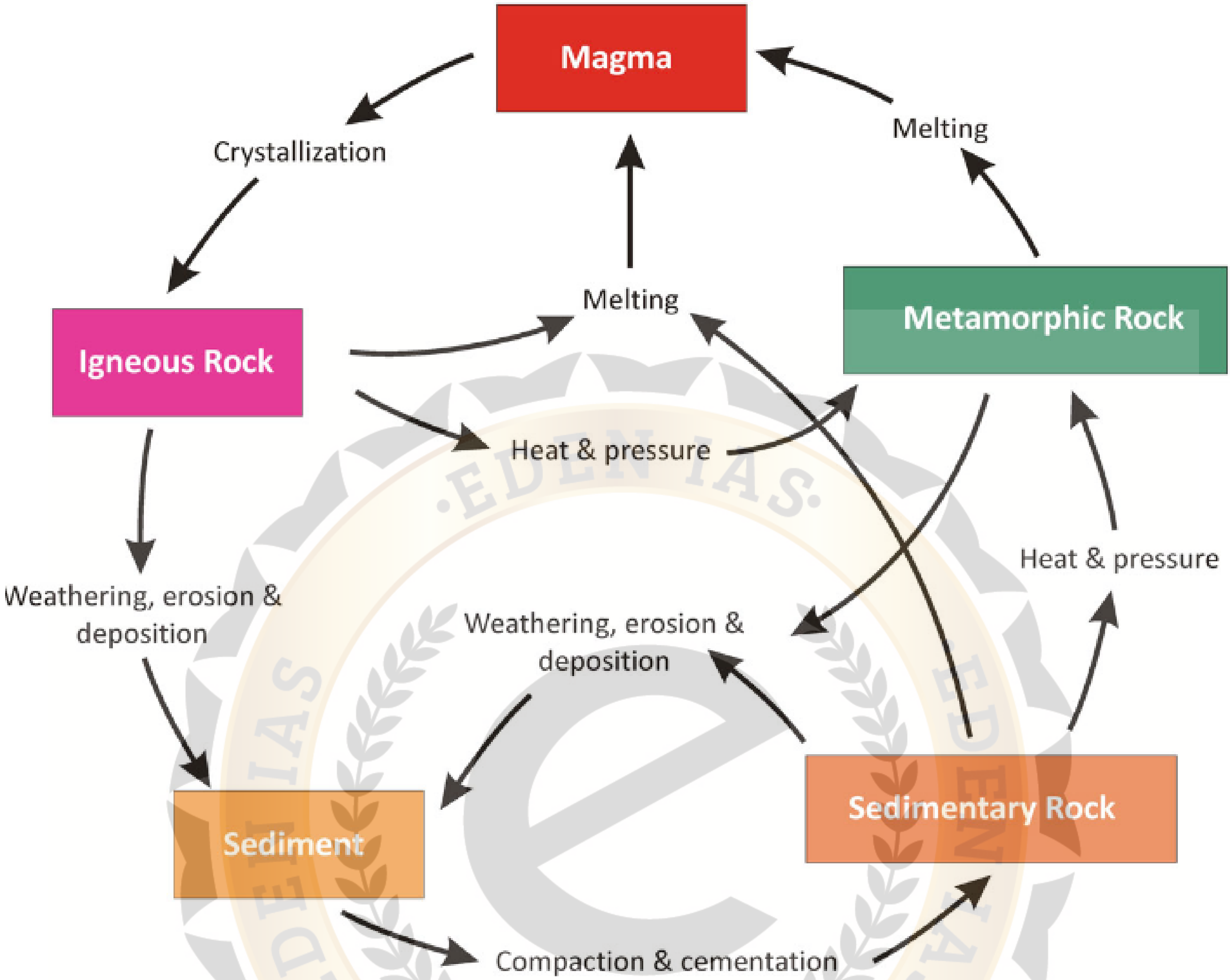
About 140 million years before the present, the subcontinent was located as south as 50 degree south latitude. The two major plates were separated by the Tethys.

During the movement of the Indian plate towards the Asiatic plate, a major event that occurred was the outpouring of lava and formation of the Deccan Traps. This started somewhere around 60 million years ago and continued for a long period of time. Note that the subcontinent was still close to the equator. From 40 million years ago and thereafter, the event of formation of the Himalayas took place. Scientists believe that the process is still continuing and the height of the Himalayas is rising even to this date.

MINERALS AND ROCKS

Like everything else in the universe, Earth is made up of varying proportions of the 90 naturally occurring elements — hydrogen, carbon, oxygen, magnesium, silicon, iron, and so on. In most geological materials, these combine in various ways to make minerals.

A mineral is a naturally occurring combination of specific elements that are arranged in a particular repeating three-dimensional structure or lattice. There are thousands of minerals. In nature, minerals are found in rocks, and the vast majority of rocks are composed of at least a few different minerals.



Rocks can form in a variety of ways. Igneous rocks form from **magma** (molten rock) that has either cooled slowly underground (e.g., to produce granite) or cooled quickly at the surface after a volcanic eruption (e.g., **basalt**). Sedimentary rocks, such as **sandstone**, form when the weathered products of other rocks accumulate at the surface and are then buried by other sediments. Metamorphic rocks form when either igneous or sedimentary rocks are heated and squeezed to the point where some of their minerals are unstable and new minerals form to create a different type of rock. An example is **schist**.

A key point to remember is the difference between a mineral and a rock. A mineral is a pure substance with a specific composition and structure, while a rock is typically a mixture of several different minerals (although a few types of rock may include only one type of mineral). Examples of minerals are feldspar, quartz, mica, halite, calcite, and amphibole. Examples of rocks are granite, basalt, sandstone, limestone, and schist.

EARTHQUAKES AND THE INTERIOR OF THE EARTH

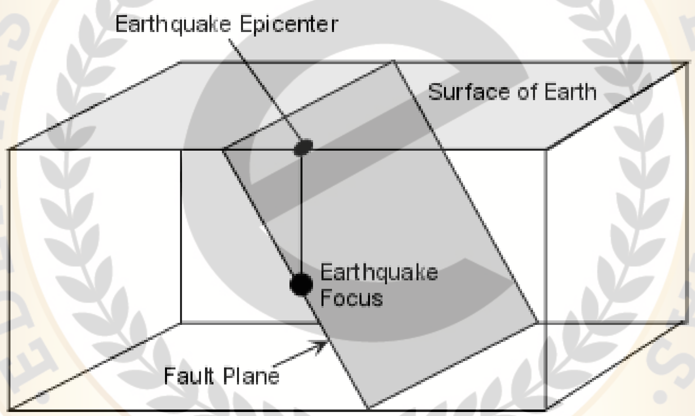
Earthquakes occur when energy stored in elastically strained rocks is suddenly released. This release of energy causes intense ground shaking in the area near the source of the earthquake and sends waves of elastic energy, called seismic waves, throughout the Earth. Earthquakes can be generated by bomb blasts, volcanic eruptions, sudden volume changes in minerals, and sudden slippage along faults. **Earthquakes are definitely a geologic hazard for those living in earthquake prone areas, but the seismic waves generated by earthquakes are invaluable for studying the interior of the Earth.**

Within the Earth rocks are constantly subjected to forces that tend to bend, twist, or fracture them. When rocks bend, twist or fracture they are said to deform. Strain is a change in shape, size, or volume. The forces that cause deformation are referred to as stresses. When stress is applied to rock, the rock passes through 3 successive stages of deformation.

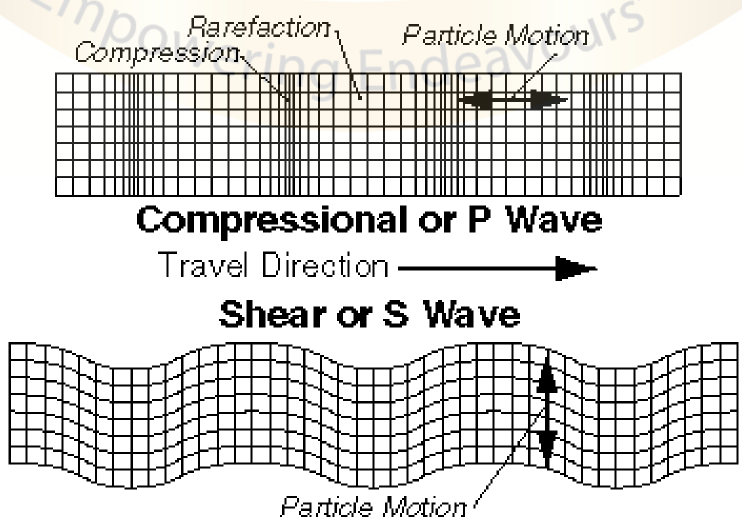
- **Elastic Deformation** -- wherein the strain is reversible.
- **Ductile Deformation** -- wherein the strain is irreversible.
- **Fracture** -- irreversible strain wherein the material breaks.

When an earthquake occurs, the elastic energy is released and sends out vibrations that travel in all directions throughout the Earth. These vibrations are called seismic waves. **The point within the earth where the fault rupture starts is called the focus or hypocenter.**

This is the exact location within the earth were seismic waves are generated by sudden release of stored elastic energy. The epicenter is the point on the surface of the earth directly above the focus. The study of how seismic waves behave in the Earth is called seismology.



Seismic waves emanating from the focus can be divided into two sets of waves viz. Body waves that travel throughout the body and surface waves that are generated due to the interaction between body waves and the surface rocks. **Body Waves** - emanate from the focus and travel in all directions through the body of the Earth. There are two types of body waves: **P-waves and S waves**.

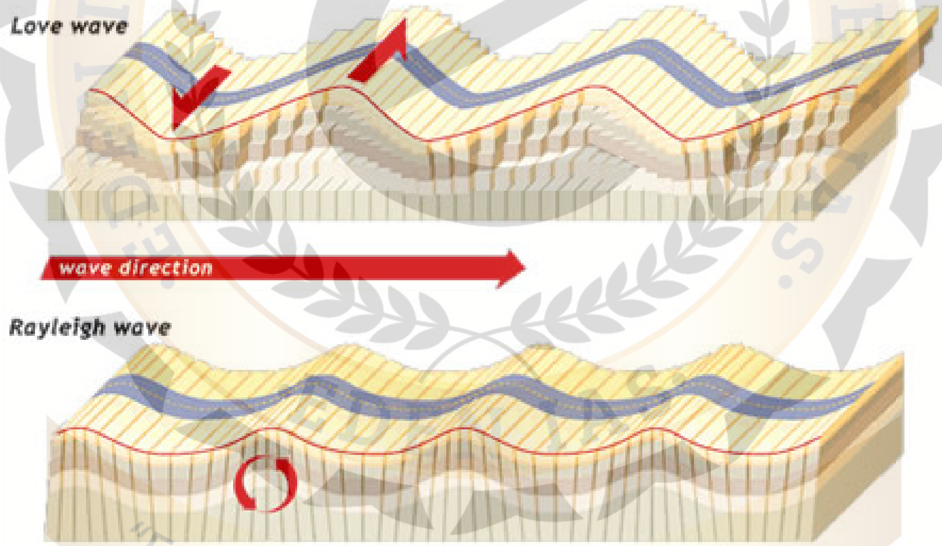


P - Waves - or Primary waves, are similar to sound waves. They move through the material by compressing it, but after it has been compressed it expands, so that the wave moves by compressing and expanding the material as it travels. Thus the velocity of the P-wave depends on how easily the material can be compressed (the incompressibility), how rigid the material is (the rigidity), and the density of the material. **P-waves have the highest velocity of all seismic waves and thus are the first to be recorded on seismographs. A seismograph, or seismometer, is an instrument used to detect and record earthquakes.**

S-Waves – or Secondary waves, are also known as shear waves. S-waves travel through material by shearing it or changing its shape in the direction perpendicular to the direction of travel. The resistance to shearing of a material is the property called the rigidity. **It is notable that liquids and gases have no rigidity, so that the velocity of an S-wave is zero in a liquid or gas**. In other words they cannot pass through liquid and gas.

Surface Waves - differ from body waves in that they do not travel through the earth, but instead travel along paths nearly parallel to the surface of the earth. Surface waves are responsible for much of the shaking that occurs during an earthquake. **Surface waves are of two types Rayleigh Waves or 'R' Waves and Love Waves or 'L' Waves**.

The Rayleigh waves follow a sea swell motion while the Love waves follow a whipping motion. The Love waves are the last to be recorded on a seismograph and most devastating of all earthquake waves.

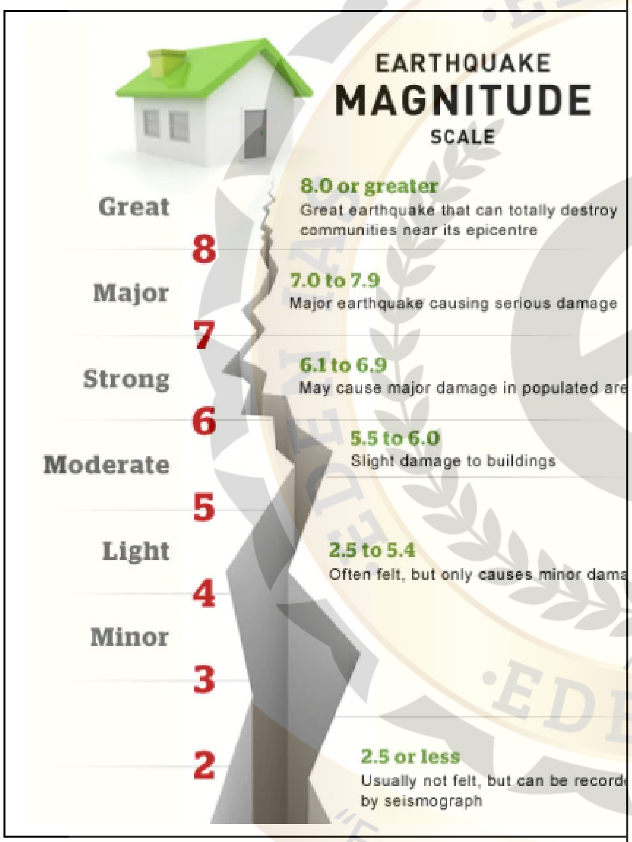


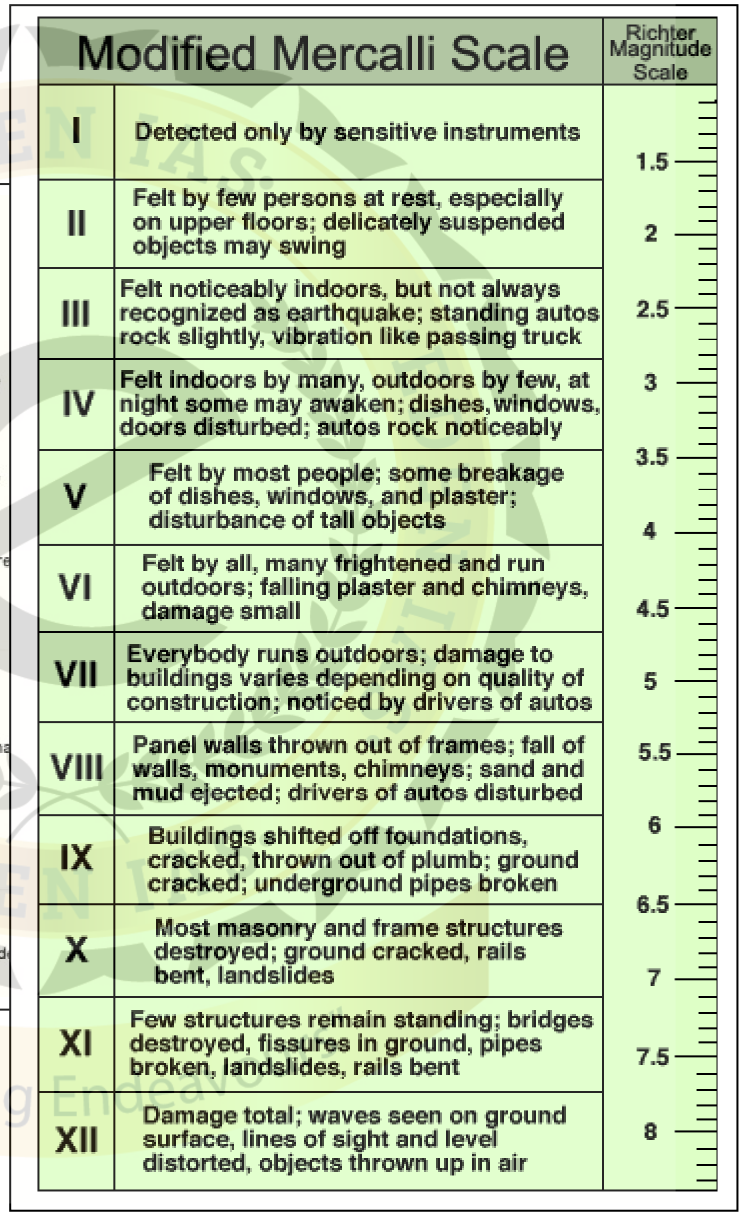
Measurement of earthquake

The size of an earthquake is usually given in terms of a scale called the Richter Magnitude. Richter Magnitude is a scale of earthquake size developed by a seismologist named Charles F. Richter. The Richter Magnitude involves measuring the amplitude (height) of the largest recorded wave at a specific distance from the earthquake. While it is correct to say that for each increase in 1 in the Richter Magnitude, there is a tenfold increase in amplitude of the wave, it is incorrect to say that each increase of 1 in Richter Magnitude represents a tenfold increase in the size of the Earthquake

Note that the Richter magnitude scale results in one number for the size of the earthquake. Maximum ground shaking will occur only in the area of the epicenter of the earthquake, but the earthquake may be felt over a much larger area. The **Modified Mercalli Scale was developed in the late 1800s to assess the intensity of ground shaking and building damage over large areas.**

The scale is applied after the earthquake by conducting surveys of people's response to the intensity of ground shaking and destruction.

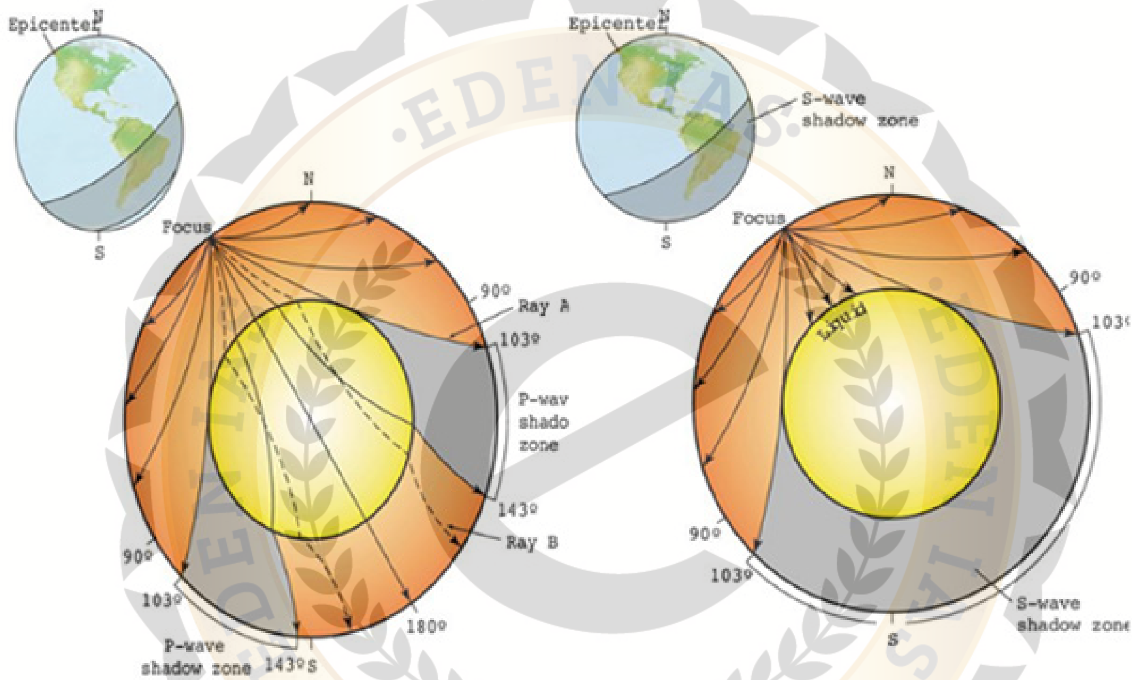




Modified Mercalli Scale		Richter Magnitude Scale
I	Detected only by sensitive instruments	1.5
II	Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing	2
III	Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibration like passing truck	2.5
IV	Felt indoors by many, outdoors by few, at night some may awaken; dishes, windows, doors disturbed; autos rock noticeably	3
V	Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects	3.5 4
VI	Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage small	4.5
VII	Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of autos	5
VIII	Panel walls thrown out of frames; fall of walls, monuments, chimneys; sand and mud ejected; drivers of autos disturbed	5.5
IX	Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken	6
X	Most masonry and frame structures destroyed; ground cracked, rails bent, landslides	6.5 7
XI	Few structures remain standing; bridges destroyed, fissures in ground, pipes broken, landslides, rails bent	7.5
XII	Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up in air	8

Seismic Waves and Earth's Interior

The structure of Earth's deep interior cannot be studied directly. But geologists use seismic (earthquake) waves to determine the depths of layers of molten and semi-molten material within Earth. Because different types of earthquake waves behave differently when they encounter material in different states (for example, molten, semi-molten, solid), seismic stations established around Earth detect and record the strengths of the different types of waves and the directions from which they came. Geologists use these records to establish the structure of Earth's interior.



P-Wave Shadow Zone S-Wave Shadow Zone

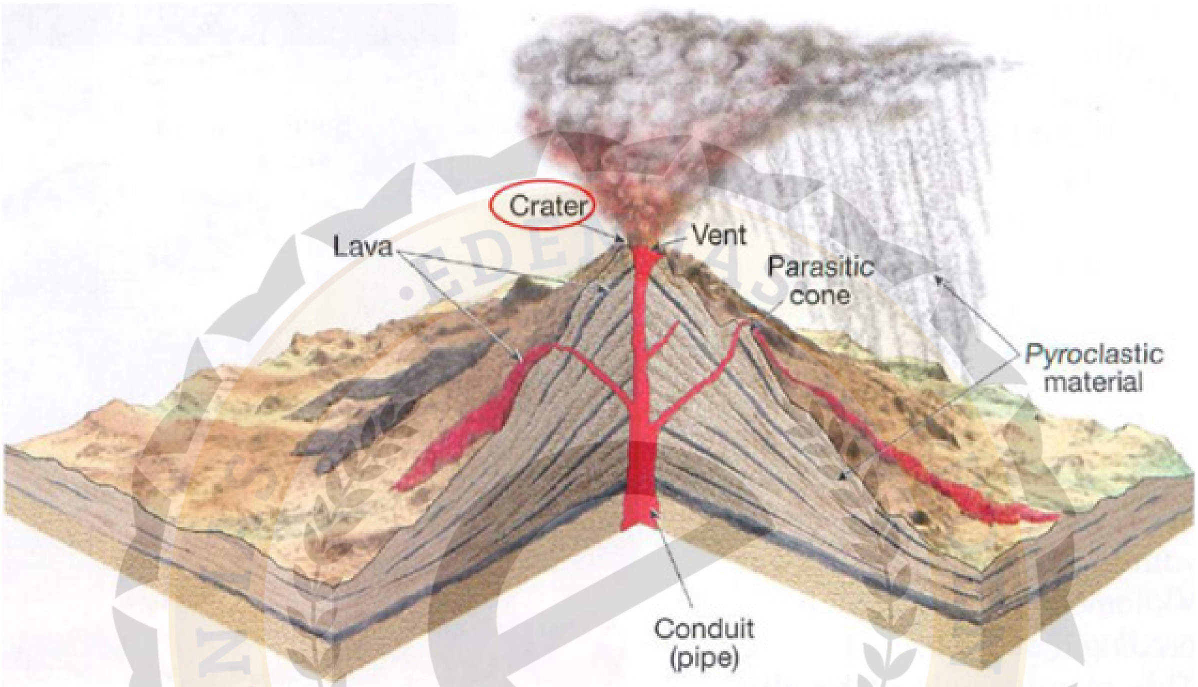
The two principal types of seismic waves are P-waves (pressure; goes through liquid and solid) and S-waves (shear or secondary; goes only through solid - not through liquid).

As we know from physics, all waves change direction when they pass through layers of different density (refraction). That is what makes light collect in a magnifying glass, and that is also what makes seismic waves travel in curved paths through the Earth (because of the increasing pressure, materials are more dense towards the core, travel velocity of seismic waves increases). Refraction of seismic waves causes them to curve away from a direct path. Reflection causes them to glance off certain surfaces (e.g. core mantle boundary) when they hit it at too shallow of an angle. The result of this behavior, in combination with the fact that S-waves cannot travel through liquids, is the appearance of seismic shadows, opposite of the actual earthquake site. **The shadow zones of S and P waves give us ample evidence in favour of a heterogeneous earth where atleast some part is liquid (the outer core).**

VOLCANOES

A volcano is an opening in Earth's crust that allows molten rock from beneath the crust to reach the surface. This molten rock is called magma when it is beneath the surface and lava when it erupts or flows from a volcano. Along with lava, volcanoes also release gases, ash, and rock. **It's a super hot mixture that can be both incredibly destructive and creative.**

Volcanoes form at the edges of Earth's tectonic plates. These huge slabs of Earth's crust travel atop the partly molten mantle, the layer beneath the crust. If you could see the plates, you might think they look like pieces of a puzzle because the edges fit together. But these puzzle pieces move, usually at the unnoticeable pace of only a few inches every year. Sometimes, though, plates collide with one another or pull apart, and it's at these active zones where volcanoes form. **Volcanoes may also erupt in areas called hot spots where the crust is thin**.



There is a wide range of variations in the mode of volcanic eruptions and their periodicity.

Volcanoes are classified on the basis of:

(i) The nature of volcanic eruption, and

(ii) The period of eruption.

(i) Classification on the Basis of the Nature of Volcanic Eruptions:

Thus, on the basis of the nature and intensity of eruptions volcanoes are divided into two types e.g.:

(1) Central eruption type or explosive eruption type.

(2) Fissure eruption type or quiet eruption type.

(1) Volcanoes of central eruption type:

Central eruption type or explosive eruption type of volcanoes occurs through a central pipe and small opening by breaking and blowing off crustal surface due to violent and explosive gases accumulated deep within the earth. The eruption is so rapid and violent that huge quantities of volcanic materials consisting of lavas, volcanic dusts and ashes, fragmental materials etc., are ejected upto thousands of meters in the sky. These materials after falling down accumulate around the volcanic vent and form volcanic cones of various sorts. Such volcanoes are very destructive and are disastrous natural hazards.

(2) Fissure eruption type of volcanoes

Such volcanoes occur along a long fracture, fault and fissure and there is slow upwelling of magma from below and the resultant lavas spread over the ground surface. The speed of lava movement depends on the nature of magma, volume of magma, slope of ground surface and temperature conditions.

(ii) Classification on the Basis of Periodicity of Eruptions:

Volcanoes are divided into three types on the basis of period of eruption viz. Active volcanoes, dormant volcanoes, and extinct volcanoes.

(i) Active Volcanoes:

Active volcanoes are those which constantly eject volcanic lavas, gases, ashes and fragmental materials. It is estimated that there are about more than 500 volcanoes in the world. Etna and Stromboli of the Mediterranean Sea are the most significant examples of this category.

(ii) Dormant Volcanoes:

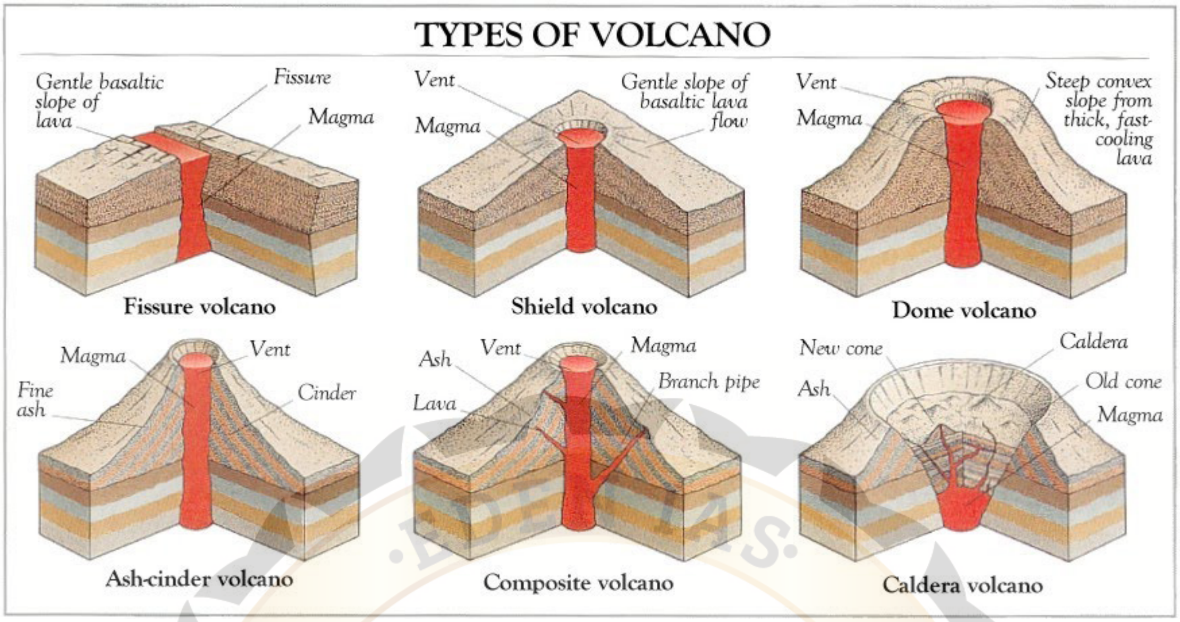
Dormant volcanoes are those which become quiet after their eruptions for some time and there are no indications for future eruptions but suddenly they erupt very violently and cause enormous damage to human health and wealth. Mt. Vesuvius is the best example of dormant volcano which erupted first in 79 A.D., then it kept quiet upto 1631 A.D., when it suddenly exploded with great force. The subsequent eruptions occurred in 1803, 1872, 1906, 1927, 1928, and 1929.

(iii) Extinct volcanoes:

The volcanoes are considered extinct when there are no indications of future eruption. The crater is filled up with water and lakes are formed. It may be pointed out that no volcano can be declared permanently dead as no one knows, what is happening below the ground surface.

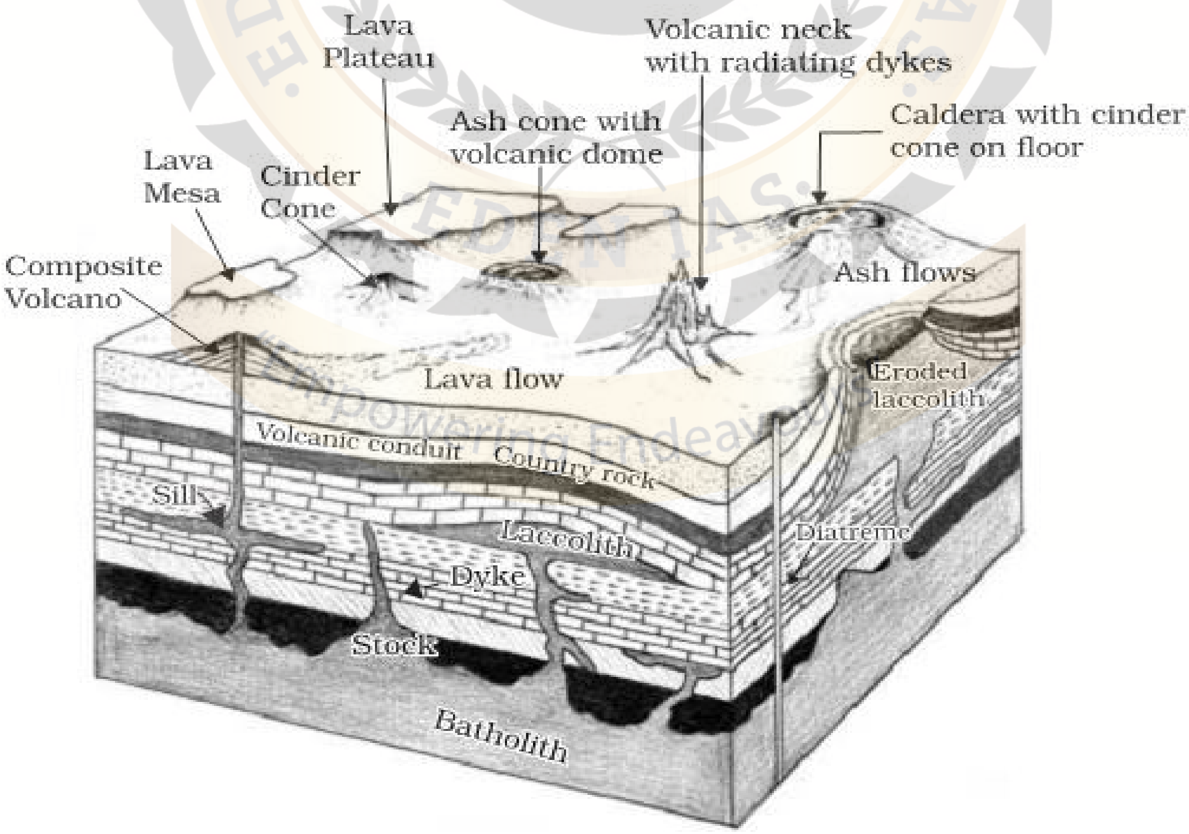
EXTRUSIVE AND INTRUSIVE VOLCANIC LANDFORMS

Volcanic landforms are divided into **extrusive and intrusive landforms** based on weather magma cools within the crust or above the crust. Rocks formed by cooling of magma within the crust are called **'Plutonic rocks'.** Rocks formed by cooling of lava above the surface are called **'Igneous rocks'.** In general, the term 'Igneous rocks' is used to refer all rocks of volcanic origin



When the lava cools and solidifies over the surface of the earth extrusive volcanic landforms are formed. Examples of the extrusive type include **Lava Cones, Lava Plains, Lava Plateaus, Composite cones, Cinder Cones, Parasitic Cones etc**.

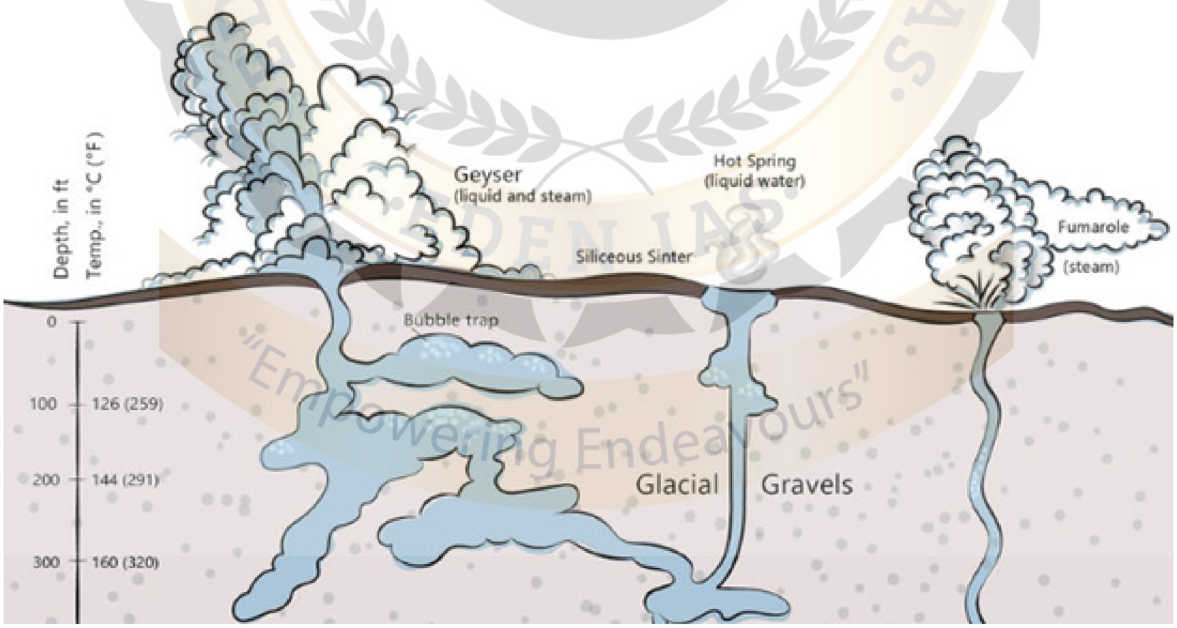
When the magma cools and solidifies beneath the surface of the earth intrusive volcanic landforms are formed. It includes landforms like Batholiths, Phacoliths, Laccolith, Lopoliths, Dykes and Sills. Intrusive volcanic landforms appear over the surface when they are exposed by forces of erosion.



- **Batholiths-**Batholiths are the cooled portion of magma chambers. It is a large body of magmatic material that cools in the deeper depth of the crust and form large domes. They appear on the surface only after the denudation processes eliminate the overlying materials.
- **Laccoliths-**These are large dome-shaped intrusive bodies with a level base and connected by a pipe-like channel from below. It bears a similarity to the surface volcanic domes of the composite volcano, only these are located at deeper depths.
- **Lopoliths-**When the lava moves upwards, a part of the same tends to move in a horizontal direction wherever it finds a weak plane. It can get rested in various forms. If it develops into a saucer shape, concave towards the surface of the earth, it is called lopoliths.
- **Phacoliths-**It is a wavy mass of intrusive rocks found at the base of synclines or at the top of anticline in folded igneous country. They are thin film like structures
- **Sills-**The near horizontal bodies of the intrusive igneous rocks are called sill. The thick horizontal deposits are called sills whereas the thinner ones are called sheets.
- **Dykes-**When the lava makes its channel through cracks and the fissures, and solidifies almost perpendicular to the ground they are known as dykes. In reality dykes are found inclined at some angle.

GEYSERS, HOTSPRINGS AND FUMAROLES

Geysers, fumaroles and hot springs are generally found in regions of young volcanic activity. Surface water percolates downward through the rocks below the Earth's surface to high-temperature regions surrounding a magma reservoir, either active or recently solidified but still hot. There the water is heated, becomes less dense, and rises back to the surface along fissures and cracks. Sometimes these features are called "dying volcanoes" because they seem to represent the last stage of volcanic activity as the magma, at depth, cools and hardens.



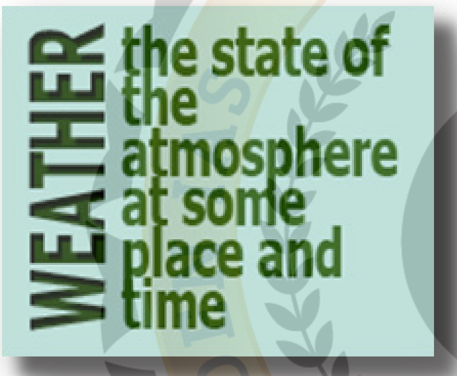
Geysers erupt intermittently and violently, whereas Hotsprings erupt more or less continuously and in relatively quieter fashion. This difference in the nature of eruption is due to the trapping of gases in Geysers, while gases mostly escape in hotsprings. Fumaroles are gas and smoke emitting vents often associated with areas of vulcanicity. Geysers are found in three major areas of the world viz. Iceland, New Zealand and USA (Yellowstone national park-old faithful)

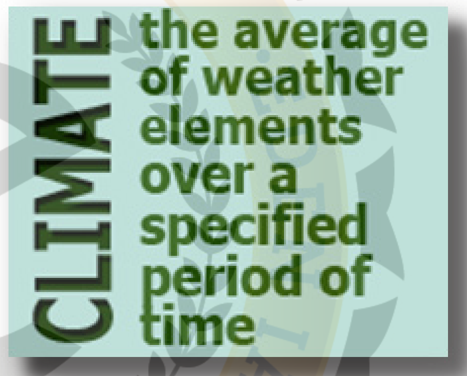
UNIT-III
[ATMOSPHERE]

WEATHER AND CLIMATE

The terms "weather" and "climate" are closely related but have subtly different meanings. Both refer to changes in atmospheric variables — such as air temperature, humidity, wind and clouds — but over different periods of time. According to the **American Meteorological Society (AMS), weather is defined as the state of the atmosphere at some place and time, usually expressed in terms of temperature, air pressure, humidity, wind speed, wind direction, precipitation, and cloudiness.**

Climate is defined in terms of the average (mean) of weather elements (such as temperature and precipitation) over a specified period of time. (The World Meteorological Organization defines the typical time period of time as 30 years.) Climate also encompasses weather extremes for a particular place.



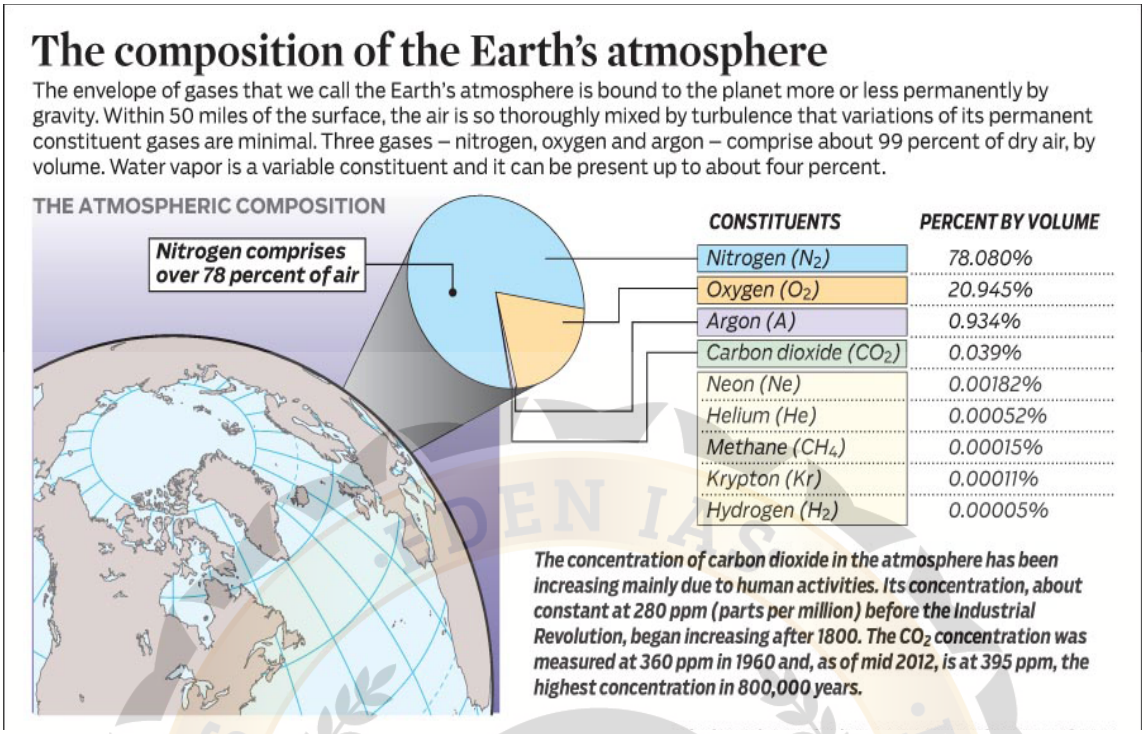


COMPOSITION OF THE ATMOSPHERE

The atmosphere of Earth is the layer of gases, commonly known as air that surrounds the planet Earth and is retained by Earth's gravity.

Pure dry air near sea level free from all impurities is a mechanical mixture of a number of gases. Two of them, **nitrogen (78 per cent)** and **oxygen (nearly 21 per cent),** together comprise 99 per cent of the total by volume. **The remaining 1 per cent is chiefly argon with much smaller amounts of ozone, carbon dioxide, and a number of other gases.** The above analysis is scarcely complete, however, for, in addition to those gases named, ordinary surface air contains variable amounts of **water vapor** (up to 5 per cent on very hot and humid days) and numerous organic and inorganic particles classed as **dust.**

Permanent Gases			Variable Gases	
Gas	**Symbol**	**Percent (by Volume) Dry Air**	**Gas (and Particles)**	**Symbol**
Nitrogen	N_2	78.08	Water vapor	H_2O
Oxygen	O_2	20.95	Carbon dioxide	CO_2
Argon	Ar	0.93	Methane	CH_2
Neon	Ne	0.0018	Nitrous oxide	N_2O
Helium	He	0.0005	Ozone	O_3
Hydrogen	H_2	0.0006	Particles (dust, soot, etc.)	
Xenon	X_2	0.000009	Chlorofluorocarbons	



CLIMATIC ELEMENTS

A **climatic element** is any one of the properties of the climate system. Combined with other elements, they describe the weather or climate at a given place for a given period of time. Every meteorological element that is observed may also be termed a climatic element. The most commonly used elements in climatology are air temperature (including maximum and minimum), precipitation (rainfall, snowfall, and all kinds of wet deposition such as hail, dew, rime, hoar frost, and precipitating fog), humidity, atmospheric motion (wind speed and direction), atmospheric pressure, evaporation, sunshine, and present weather (for example, fog, hail, and thunder).

STRUCTURE OF THE ATMOSPHERE

The atmosphere is conveniently classified using three criteria:

1. **Composition**
2. **Function**
3. **Temperature**

CHEMICAL COMPOSITION CRITERION

Based on chemical composition, the atmosphere is divided into two broad regions:

a) **The Heterosphere**

b) **The Homosphere**

a) HETEROSPHERE:

The outer atmosphere beginning from about 50 miles from the earth's surface and extending to space Gases are not evenly mixed but assorted by gravity according to their atomic weight and reaction of the gases with solar radiation. Less than **0.001%** of the mass of the earth's atmosphere is in the heterosphere.

b) HOMOSPHERE:

Extends from earth's surface to about 50 miles (80 kms). Density of air changes with altitude but the proportion of gases is nearly uniform. Exceptions are: **Ozone O3, Water vapor, Pollutants & Some trace chemicals.**

ATMOSPHERIC FUNCTION CRITERION

Based on function, the atmosphere has two zones that remove harmful solar radiation and charged particles:

a) **The Ionosphere**

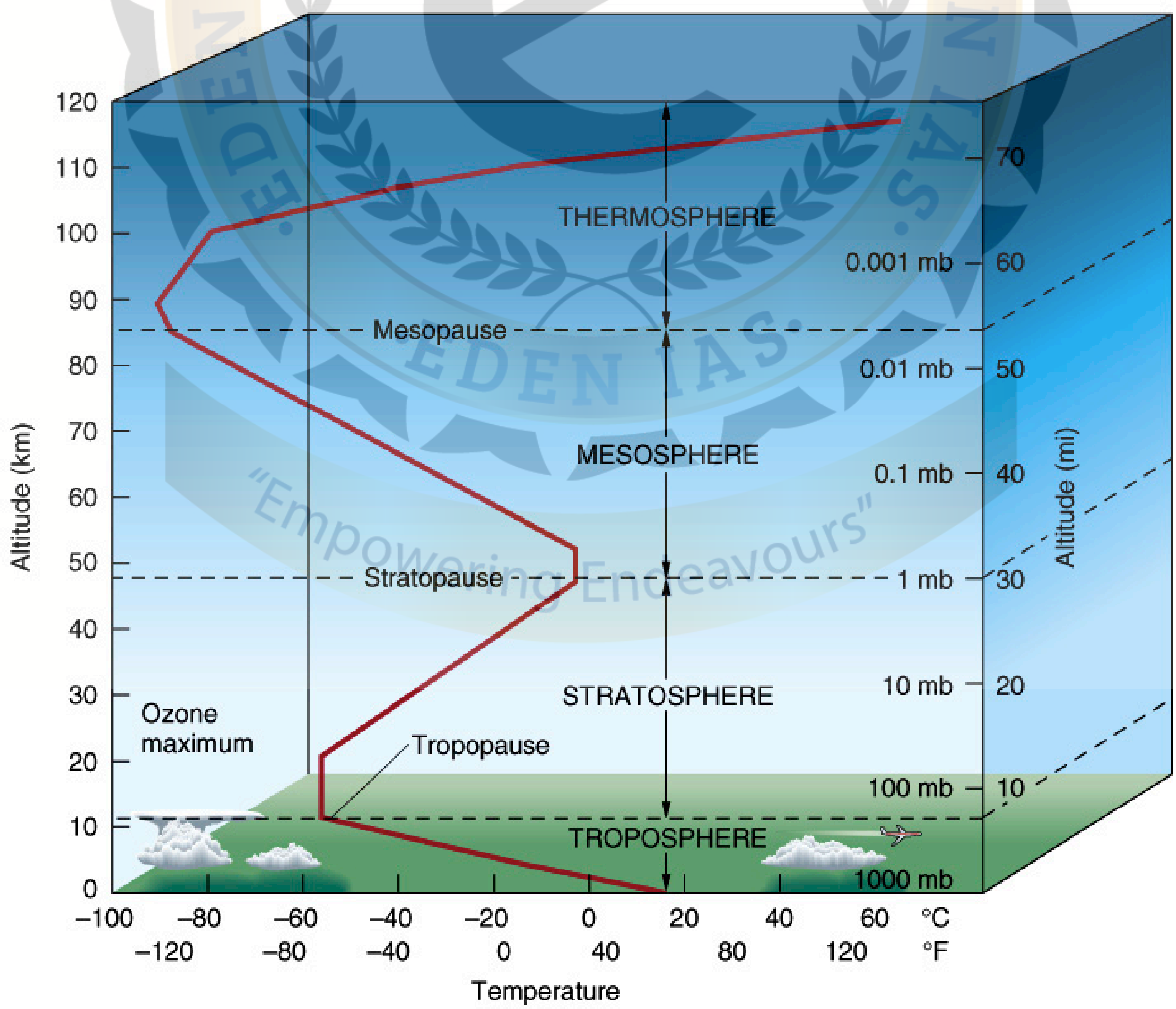
b) **The ozonosphere**

a) Ionosphere: extends throughout the thermosphere into the mesosphere. It absorbs Cosmic rays, gamma rays, X-rays and Ultraviolet radiation.

b) Ozonosphere: a layer of ozone gas (O3). Absorbs UV light and re-radiates it as long wave infrared radiation.

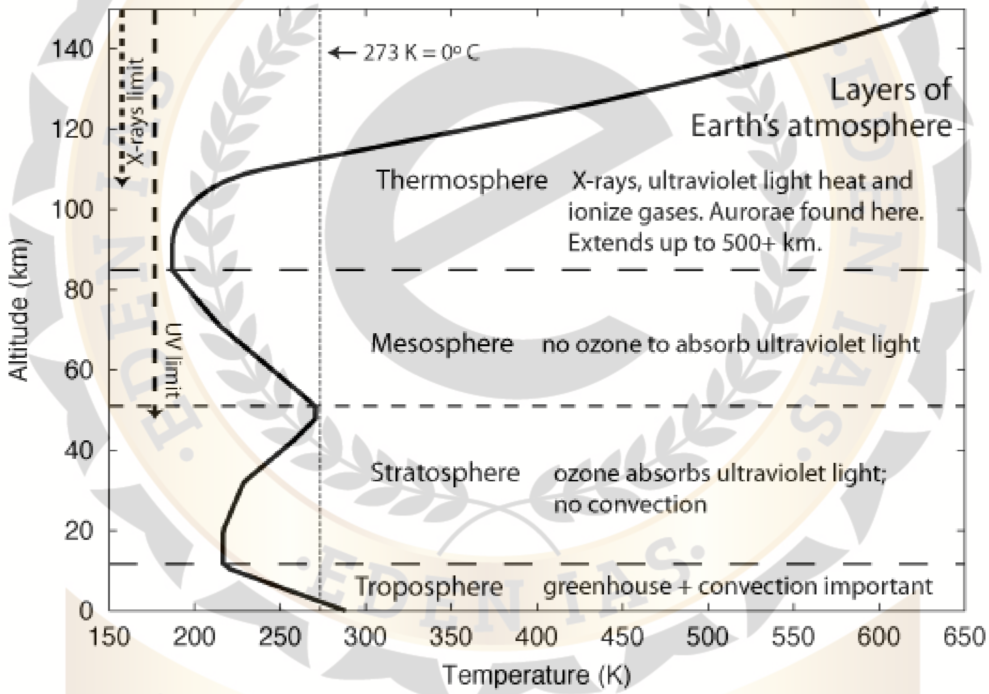
ATMOSPHERIC TEMPERATURE CRITERION

Using temperature, the atmosphere can be divided into **four distinct zones** viz. Troposphere, Stratosphere, Mesosphere and Thermosphere



The troposphere is the lowest layer of the atmosphere. This is the layer where we live and where all the weather and climatic events happen. Temperature in this layer generally decreases with height. This decrease in temperature with increase in height is known as the **normal lapse rate.** The rate of lapse is generally **6.5 degree Celsius per 1000 meters of ascent.** When in the troposphere there is increase in temperature with increase in height it is known as **temperature inversion**. The boundary between the stratosphere and the troposphere is called the tropopause. **The jet stream sits at this level and it marks the highest point that weather can occur.** The height of the troposphere varies with location, being higher over warmer areas and lower over colder areas.

Above the tropopause lies the stratosphere. In this layer the temperature increases with height. This is because the stratosphere houses the ozone layer. The ozone layer is warm because it absorbs ultraviolet (UV) rays from the sun. Some very high cirrus clouds are found in the stratosphere. **These cirrus clouds are responsible for the halo of the Sun**. The mesosphere is the layer above the stratosphere. The temperature decreases with height here just like it does in the troposphere. This layer also contains ratios of nitrogen and oxygen similar to the troposphere, except the concentrations are 1000 times less and there is little water vapour there, so the air is too thin for weather to occur. The mesosphere is separated from the thermosphere by Mesopause. **Mesopause is the coldest zone of the atmosphere with temperature about –130^{0}F (-90^{0}C).**



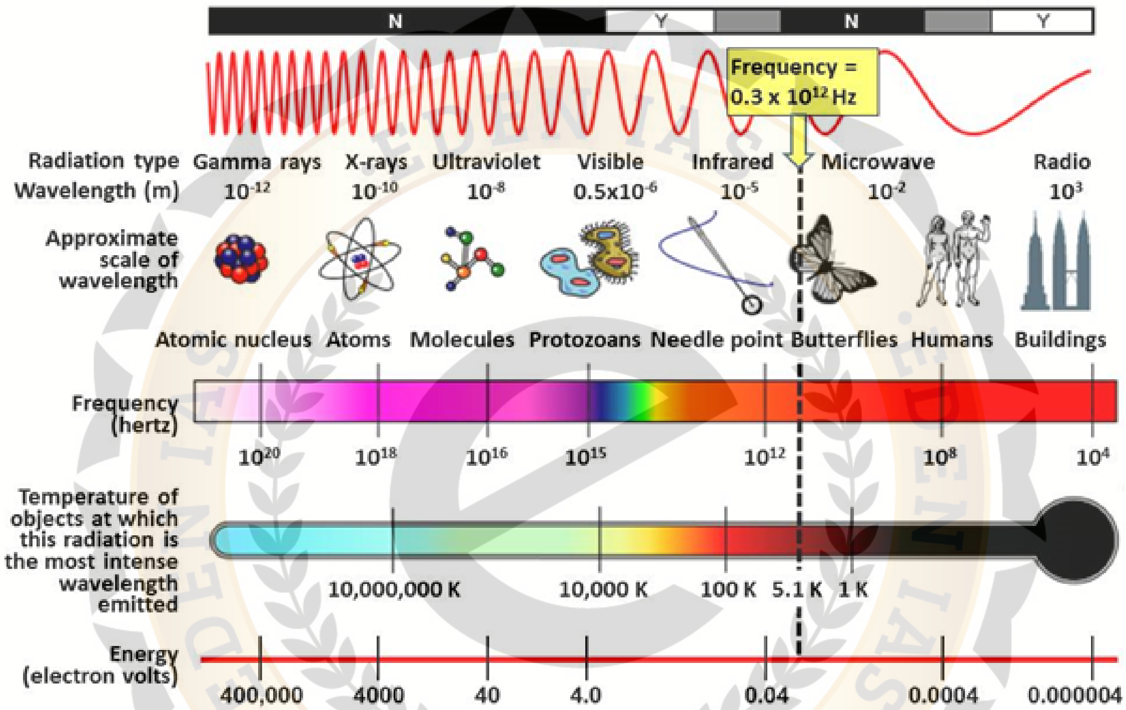
The thermosphere is the uppermost layer of the atmosphere. Thermosphere is divided into two sub-layers viz. Ionosphere and Exosphere. **In ionosphere the temperature increases with increase in height because of the presence of charged particles called-'ions'**. These ions reflect radio signals back to earth and facilitate radio-communication. **The Exosphere extends beyond the ionosphere till 29000 km (approx) it slowly merges with the outer space**. The exosphere is very hot due to its nearness to the sun but one rarely feels its temperature as the atmosphere at that height is extremely rarified.

DO YOU KNOW?

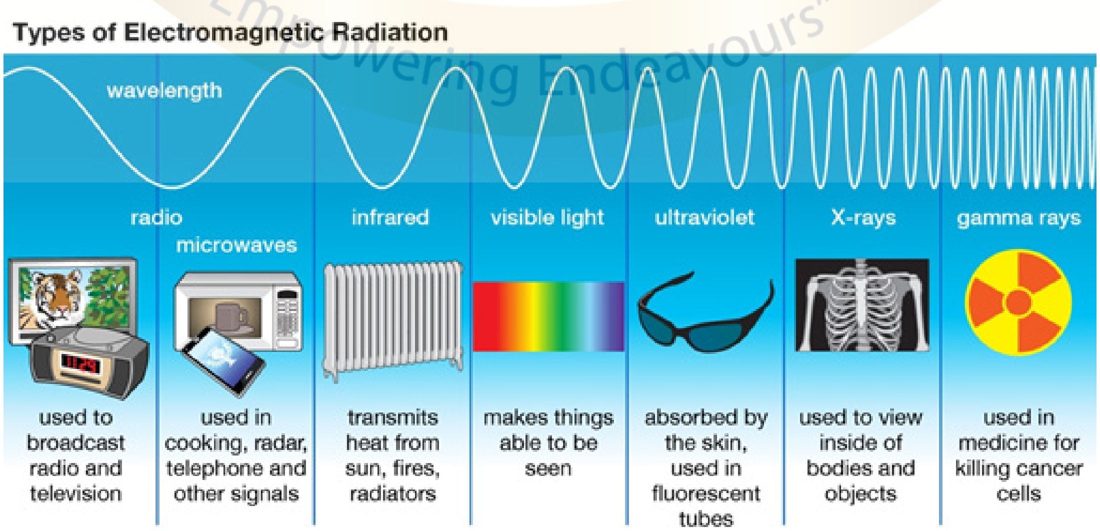
The sun is the great engine that drives the winds and the ocean currents, generates the weather, and makes the earth a livable place for human beings. The wood, coal, water power, and oil that heat our homes and power our engines are only transformed sunlight. Every locomotive, ship, auto-mobile, or plane moves, and every factory wheel turns, only by the delayed drive of solar energy.

SOLAR RADIATION AND ELECTROMAGNETIC SPECTRUM

All bodies, no matter what their temperature, give off radiation in the form of electromagnetic waves that travel at a speed of about 186,000 miles a second. The hotter the body the more intense its radiation and the shorter its wave lengths. Thus high-temperature radiation like the sun's is in the form of short waves, while low-temperature radiation, such as that from the earth, is in the form of longer waves. Only a comparatively narrow band of the total radiation spectrum is visible to the human eye in the form of light. All low-temperature radiation is invisible. **The radiant energy received from the sun, transmitted in a form analogous to short waves (1 /250 to 1 /6,700 mm. in length), and traveling at the rate of 186,000 miles a second, is called solar radiation, or insolation.**



Less than one-sixth of the solar radiation spectrum can be perceived as light. But there are other waves, some shorter (ultraviolet), and others longer (infrared), which cannot be seen. Since sun radiation is the single important source of atmospheric heat, its distribution over the earth is of outstanding significance in understanding weather and climatic phenomena, more especially those associated with temperature. **In solar energy is to be found the ultimate cause of all changes and motions of the atmosphere.** Certainly the sun, or insolation, is the single most important control of climate.



Although all electromagnetic waves travel at the speed of light in a vacuum, they do so at a wide range of frequencies, wavelengths, and photon energies. The electromagnetic spectrum comprises the span of all electromagnetic radiation and consists of many subranges, commonly referred to as portions, such as visible light or ultraviolet radiation. The various portions bear different names based on differences in behaviour in the emission, transmission, and absorption of the corresponding waves and also based on their different practical applications.

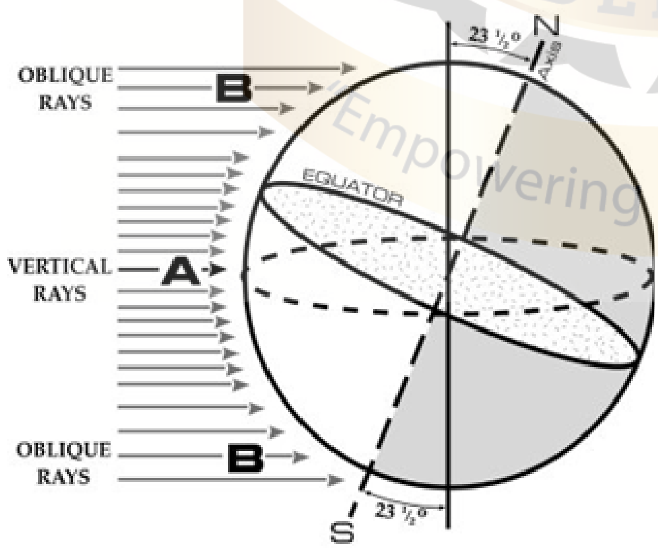
There are no precise accepted boundaries between any of these contiguous portions, so the ranges tend to overlap. The entire electromagnetic spectrum, from the lowest to the highest frequency (longest to shortest wavelength), includes all radio waves (e.g., commercial radio and television, microwaves, radar), infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays. **Nearly all frequencies and wavelengths of electromagnetic radiation can be used for spectroscopy**.

FACTORS AFFECTING DISTRIBUTION OF INSOLATION

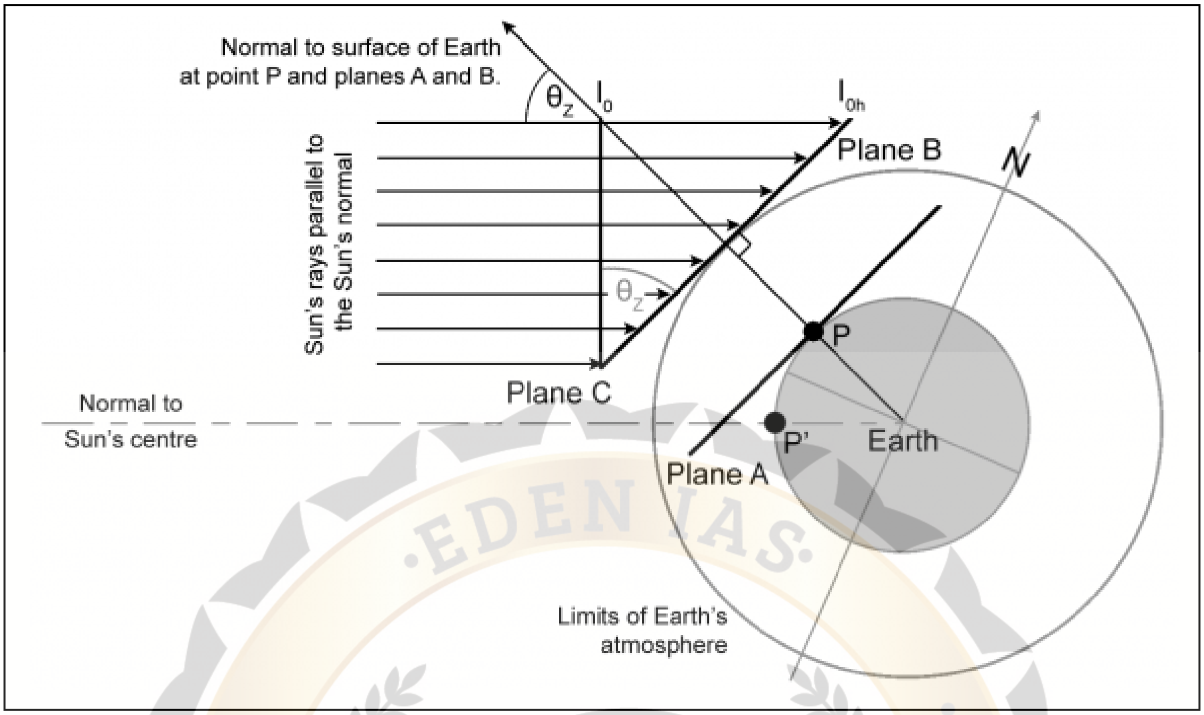
In order to simplify the problem of insolation distribution, imagine for the moment that the absorbing, scattering, and reflecting effects of the earth's atmospheric layers do not exist. Under that condition the amount of solar energy that any portion of the earth's surface receives would depend primarily upon two factors:

a) The angle at which the rays of sunlight reach the earth and
b) The duration of solar radiation, or length of day.

Because an oblique solar ray is spread out over a larger surface than a vertical one it delivers less energy per unit area. Moreover, although for the moment the effects of an atmosphere are being omitted, it may be added that an oblique ray also passes through a thicker layer of scattering, absorbing, and reflecting air. Winter sunlight, therefore, is much weaker than that of summer. As regards the second item, it would seem to require no further explanation of the fact that the longer the sun shines (length of day) the greater the amount of solar energy received, all other conditions being equal.



The oblique ray delivers less energy at the earth's surface than the vertical ray because it passes through a thicker layer of absorbing, scattering, and reflecting atmosphere, and likewise because its energy is spread over a greater area.

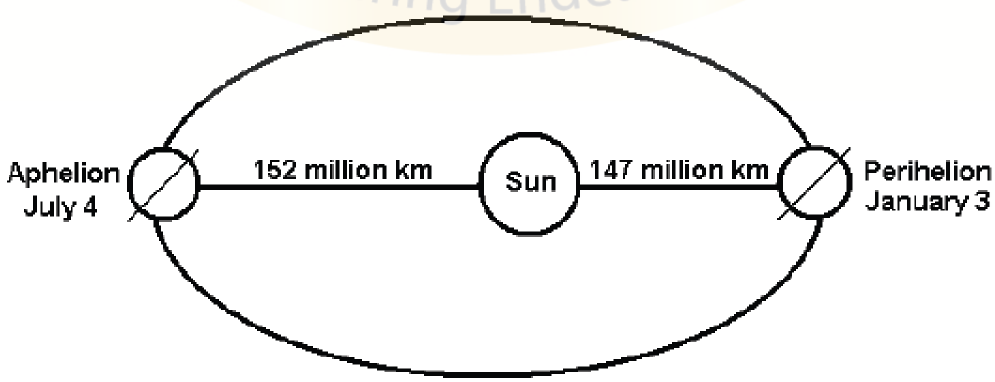


Since length of day and angle of the sun's rays are equal on all parts of the same parallel, it follows that **all places on a parallel (save for differences in the transparency of the atmosphere) receive the same amount of solar energy**. By the same reasoning, different parallels or latitudes receive varying amounts of insolation, there being a decrease from equator to poles for the year as a whole. If insolation were the only control of atmospheric phenomena, then all places in the same latitude should have identical climates. While certainly not identical throughout, the strong climatic resemblances within latitude belts testify to the dominant, although not exclusive, control of sun's rays.

MINOR FACTORS AFFECTING INSOLATION

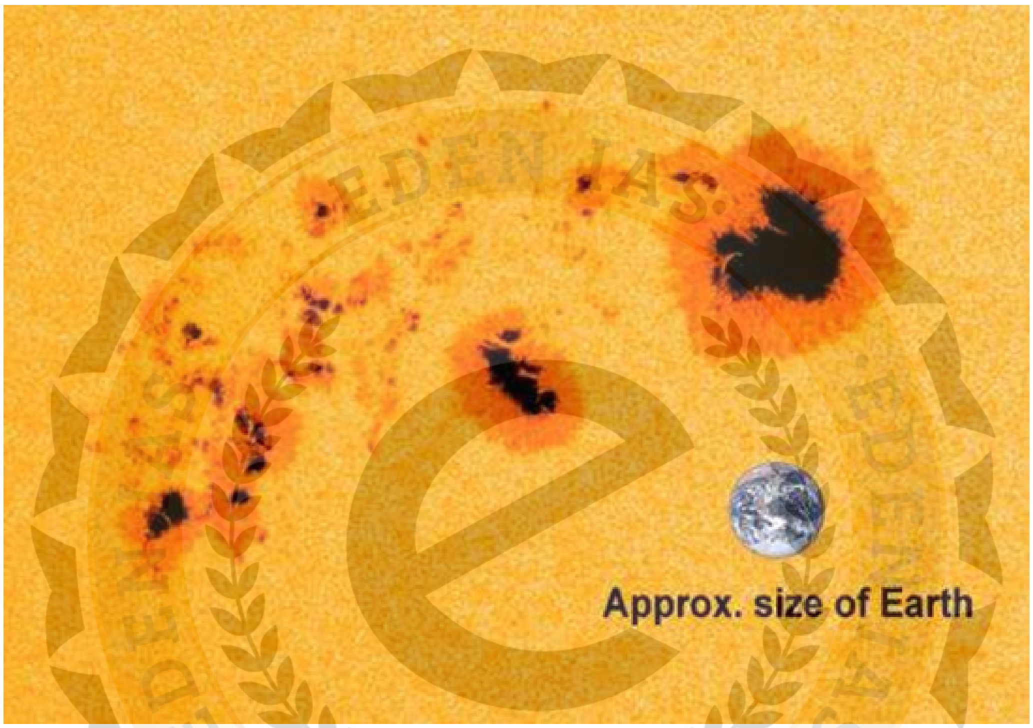
Other than length of day and angle of sun's rays, the more minor factors determining the amount and distribution of solar energy at the earth's surface are

- **The fluctuations in solar output of radiation, there being a 3 per cent variation from the average of 1.94 gram-calories per minute per square centimeter**, and
- **The varying distances of the earth from the sun at the several positions in its orbit**. Thus in January the earth is only 91.3 million miles from the sun, while in July they are 94.5 million miles apart.



That there is a cold season in the Northern Hemisphere at the time when the earth is nearest the sun, and a warm season when it is farthest from the sun, tends to emphasize the fact that this item of distance is minor compared with length of day and angle of sun's rays

The variations in solar output are, at least partly, cyclic in character. **A variation corresponding to the sunspot cycle of about 10.5 years, as well as others both shorter and longer, has been recognized.** Whether there is a definite relationship between variations in solar energy and world weather is still a disputed question. Some attempts at long-range forecasting, based upon insolation variations, have been made. Other factors enter in, however, to confuse and mask the effects of solar radiation.



COMPARISON OF SUNSPOTS WITH EARTH

ALBEDO

It is defined as the ratio of the reflected radiation to the total intercepted radiation. It is described in terms of percentage of reflected radiation. The albedo of the earth-atmosphere system is 0.30. The moon has an albedo of only about 0.07, indicating that it absorbs most of the solar radiation striking its surface.

Thus, viewed from space, the earth shines more brilliantly than the moon. The major reason for this is the presence of clouds. The moon has no atmosphere and no cloud.

Some typical albedo are :

Fresh snow	0.75 – 0.90
Cloud tops	0.60 – 0.90
Old snow	0.50 – 0.70
Sand	0.15 – 0.35
Seas (high sun angle)	0.05 – 0.10
Forests	0.03 – 0.10

THE SOLAR CONSTANT

The sun at a temperature of about 6000 K° is the source of nearly all of our energy. The earth intercepts an infinitesimally small part of the sun's output, 5×10^{-10} %. Only a portion of the sun's radiation reaches the earth's surface as direct radiation, the remainder being reflected, absorbed, or scattered by the atmosphere. The maximum emission of solar radiation occurs at relatively short wavelengths in the visible spectrum (between 0.4 µm and 0.7 µm).

The sun radiates approximately 56 $\times10^{26}$ cal of energy per minute. The energy per unit area incident on the earth is equal to

$$S = \frac{56\times10^{26}\,\text{cal}\,\text{min}^{-1}}{4\pi\times(1.5\times10^{13}\,\text{cm})^2} \approx 2.0\ \text{cal cm}^{-2}\ \text{min}^{-1}$$

S is called as the Solar Constant. {1.5×10^{13} cm is the mean distance of the earth from the sun }

The **Solar Constant** is defined as the flux of solar radiation at the outer boundary of the earth's atmosphere that is received on a surface held perpendicular to the sun's direction at the mean distance between the sun and the earth. The energy per unit area is expressed in Langleys (ly) and 1 ly = 1 cal cm^{-2}. Thus the solar constant for the earth is 2 Ly.

If the surface, oriented perpendicular to the sun's rays, is thought of as a circular non-rotating disc with a radius r equal to the radius of the earth, the sun facing side of the disc will intercept the same amount of solar radiation as does the spherically shaped rotating earth.

Since the area of a sphere is four times the area of one side of a disc (4πr2 versus πr2), as shown in Fig. the global average amount of energy received at the top of the atmosphere is 0.5 ly min-1, or one quarter of the solar constant.

EFFECTS OF ATMOSPHERE ON INSOLATION

Thus far the whole problem of insolation distribution has been greatly simplified by assuming that solar radiation is received at the earth's surface without passing through an atmosphere. When that gaseous envelope is considered, numerous modifications and complications result. Chief among these is a weakening of insolation at the earth's surface due to

a) **Selective scattering**, principally of the short wave lengths of blue light by very small obscuring particles (molecules of air, fine dust, etc.);
b) **Diffuse reflection** of all wave lengths by larger particles (dust, cloud droplets, ect.) and
c) **Absorption of selected wave lengths**, chiefly the longer ones, by water vapor and in a very minor degree by oxygen and ozone

When a beam of light or radiant energy passes through a transparent medium containing small obscuring particles or molecules, some of the light is deflected from the direct beam and sent in all directions from the particles. This phenomenon is known as scattering. True scattering occurs only when the diameters of the obscuring particles are smaller than the wave lengths of the radiation. The process is selective, the shorter wave lengths being affected most, so that various colors may result from the process.

Thus the blue colour of the sky is the consequence of a more complete scattering, chiefly by molecules of air, of the shorter wave lengths in the insolation beam. On the other hand, the sun appears red when seen through a smoke screen, because the blue light has been subtracted. The ruddy cloud colors of sunset and sunrise result from cloud illumination by beams of light from which the blue portion of the spectrum has been removed by scattering. The importance of scattering is evidenced by the small amount of ultraviolet light in cities as compared with the open country.

When the diameters of the obscuring particles are larger than the wave lengths of incident light, the effect is that of diffuse reflection, which is nonselective and therefore equally effective for all wave lengths. Thus the light reflected from a cloud when the sun is back of the observer is pure white, and the sun appears white when seen through a fog of water drops. It is worthy of emphasis that the scattered and reflected sunlight is still short-wave radiation and consequently is not readily absorbed by the atmosphere.

Absorption of solar energy by the earth's atmosphere is not very effective. To most of the wave lengths in the solar beam the atmospheric gases are transparent. Those gases that do absorb are selective in their action, absorbing more in some wave lengths than in others. Water vapor is the controlling agent in atmospheric absorption, although oxygen, ozone, and suspended particles, such as dust and cloud droplets, play a minor part.

A part of the solar energy which is scattered and reflected by the atmosphere and the earth's surface is sent back into space and is lost to the earth. This reflection from the earth is sufficient to cause the planet to shine with considerable brilliancy. It is this "earth shine" that illuminates the dark portion of the new moon so that one sees the earth-lit part as "the old moon in the new moon's arms."

Some of the solar energy scattered and reflected in the atmosphere, however, reaches the earth's surface in the form of diffuse blue light of the sky, called diffuse daylight, and is transformed into heat and other forms of energy. It is this diffuse daylight which prevents absolute darkness on cloudy days, indoors, or in the shade where direct sunlight is absent.

The energy transmitted to the earth in this form probably amounts to one-quarter of the energy of direct sunlight. The more oblique the ray of sunlight is, the thicker the layer of reflecting and scattering atmosphere through which it must pass. When the sun is only 4° above the horizon, the solar rays have to penetrate an atmosphere more than twelve times thicker than those coming from the sun at altitude 90°.

This explains why one can look at the sun at sunrise and sunset without being blinded. It is in the higher latitudes, where the sun is never very high above the horizon, and direct sunlight is consequently weak, that diffuse daylight becomes of greatest significance, for in such regions it is the source of a large part of the solar energy received at the earth's surface.

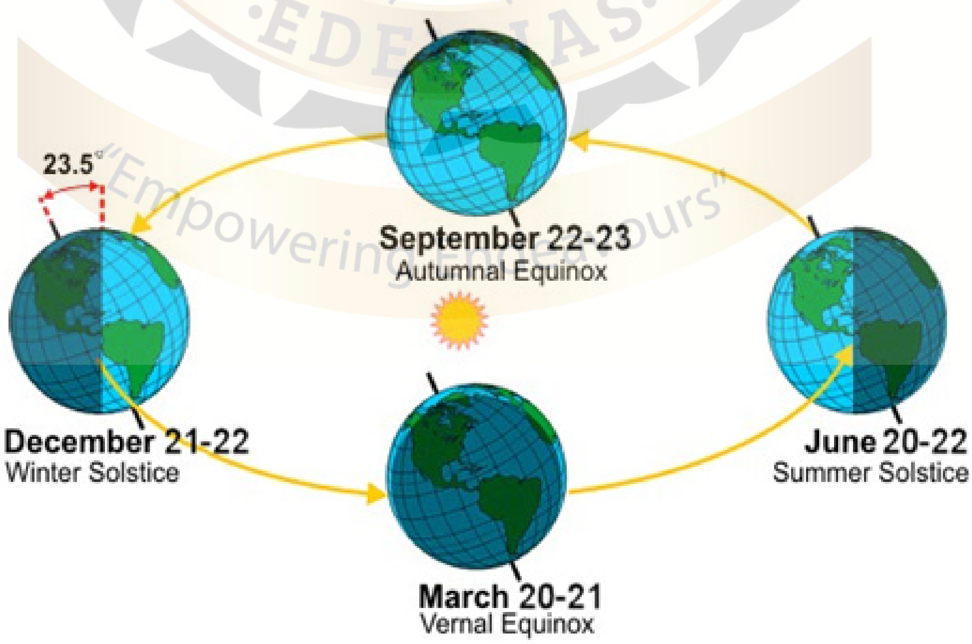
THE MARCH OF SEASONS

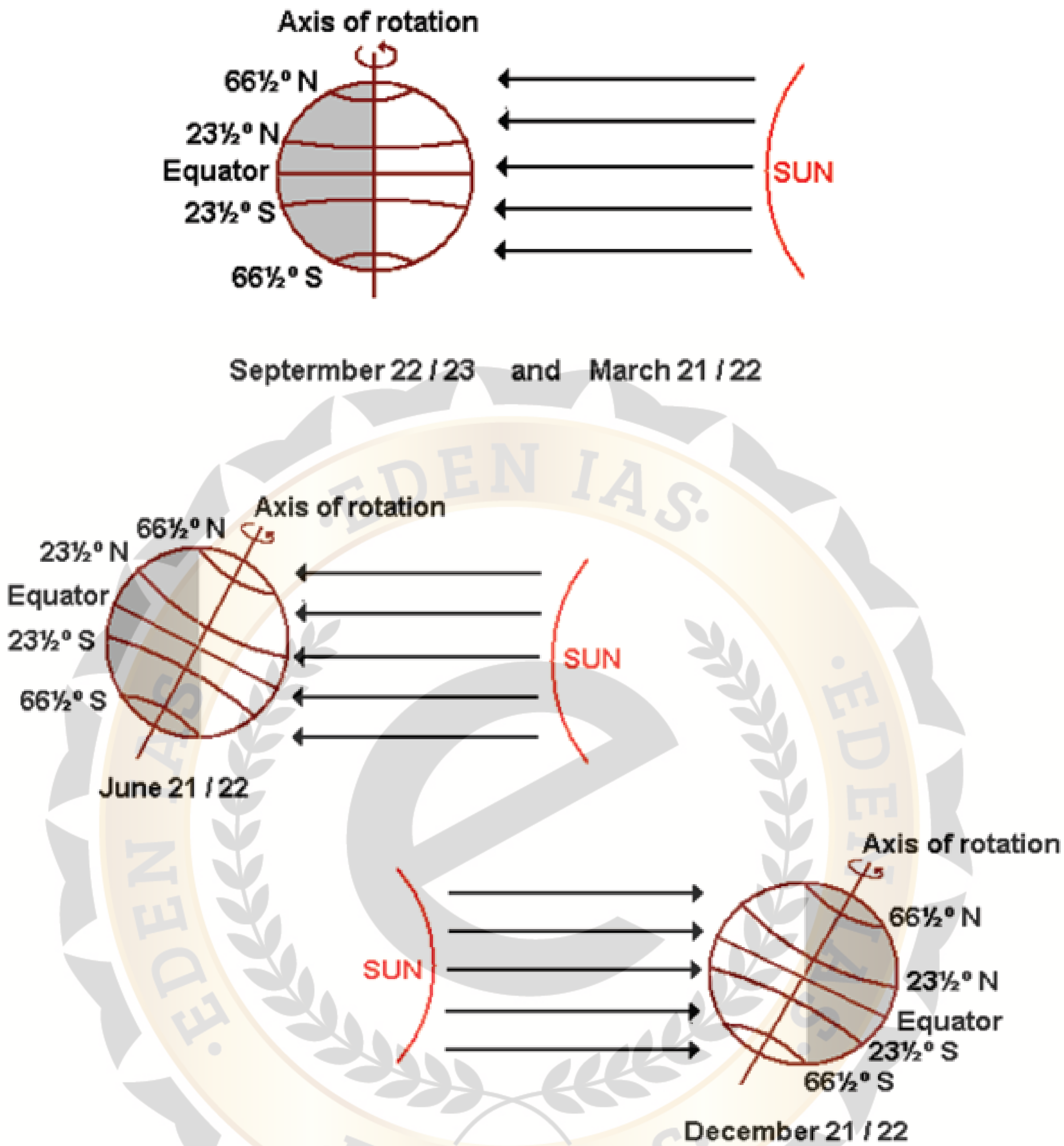
There are only two times of the year when the Earth's axis is tilted neither toward nor away from the sun, resulting in a "nearly" equal amount of daylight and darkness at all latitudes. These events are referred to as Equinoxes. The word equinox is derived from two Latin words - aequus (equal) and nox (night). At the equator, the sun is directly overhead at noon on these two equinoxes.

The summer solstice occurs at the moment the earth's tilt toward from the sun is at a maximum. The summer solstice occurs when the sun is directly over the Tropic of Cancer, which is located at 23.5° latitude north, and runs through Mexico, the Bahamas, Egypt, Saudi Arabia, India, and southern China. For every place north of the Tropic of Cancer, the sun is at its highest point in the sky and this is the longest day of the year.

The winter solstice marks the shortest day and longest night of the year. In the Northern Hemisphere, it occurs when the sun is directly over the Tropic of Capricorn, which is located at 23.5° south of the equator and runs through Australia, Chile, southern Brazil, and northern South Africa.

We all know that the Earth makes a complete revolution around the sun once every 365 days, following an orbit that is elliptical in shape. This means that the distance between the Earth and Sun, which is 93 million miles on average, varies throughout the year. During the first week in January, the Earth is about 1.6 million miles closer to the sun. This is referred to as the perihelion. The aphelion, or the point at which the Earth is about 1.6 million miles farther away from the sun, occurs during the first week in July. This fact may sound counter to what we know about seasons in the Northern Hemisphere, but actually the difference is not significant in terms of climate and is NOT a major reason why we have seasons. Seasons are caused by the fact that the Earth is tilted on its axis by 23.5°. The tilt's orientation with respect to space does not change during the year (Axial Parallelism) thus; the Northern Hemisphere is tilted toward the sun in June and away from the sun in December, as illustrated in the diagram below.



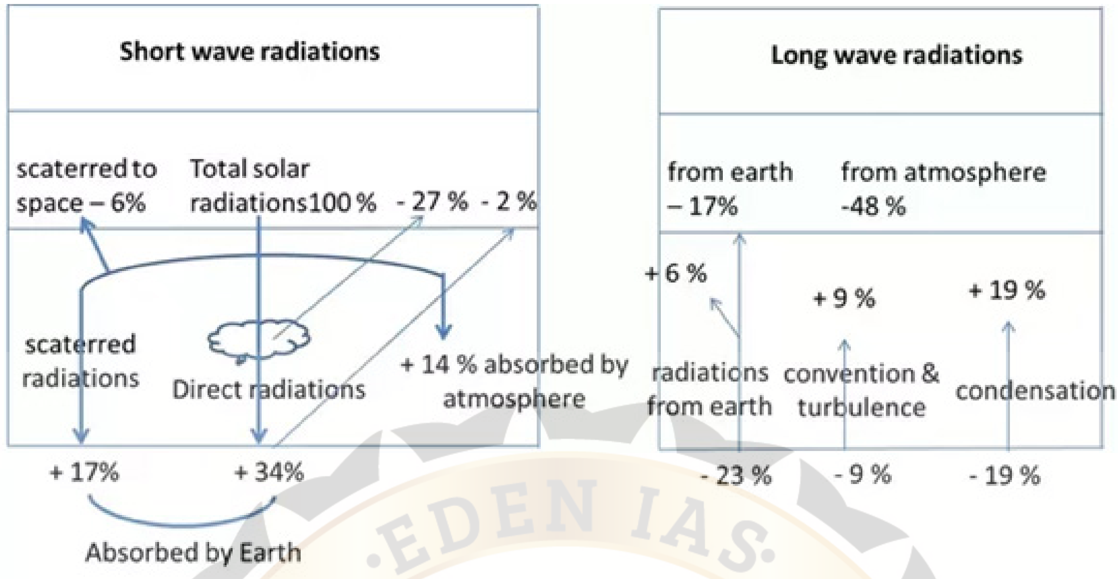


THE HEAT BUDGET

Incoming heat being absorbed by the Earth and outgoing heat escaping the Earth in the form of radiation are both perfectly balanced. If they were not balanced, then Earth would be getting either progressively warmer or progressively cooler with each passing year. This balance between incoming and outgoing heat is known as Earth's heat budget.

Out of the total incoming solar radiation entering the earth's atmosphere 35 per cent is sent back to space through scattering by dust particles (6%), reflection from the clouds (27%) and from the ground surface (2%), 51 per cent is received by the earth's surface (received as direct radiation), and 14 per cent is absorbed by the atmospheric gases (ozone, oxygen etc.) and water vapour in different vertical zones of the atmosphere.

The 51 per cent solar energy received by the earth comprises 34 per cent as direct solar radiation and 17 per cent as diffuse day light. The heat budget of the atmosphere comprises 48 per cent of solar radiation wherein 14 per cent is received through absorption of the shortwave incoming solar radiation and 34 per cent is received from the outgoing long-wave terrestrial radiation.



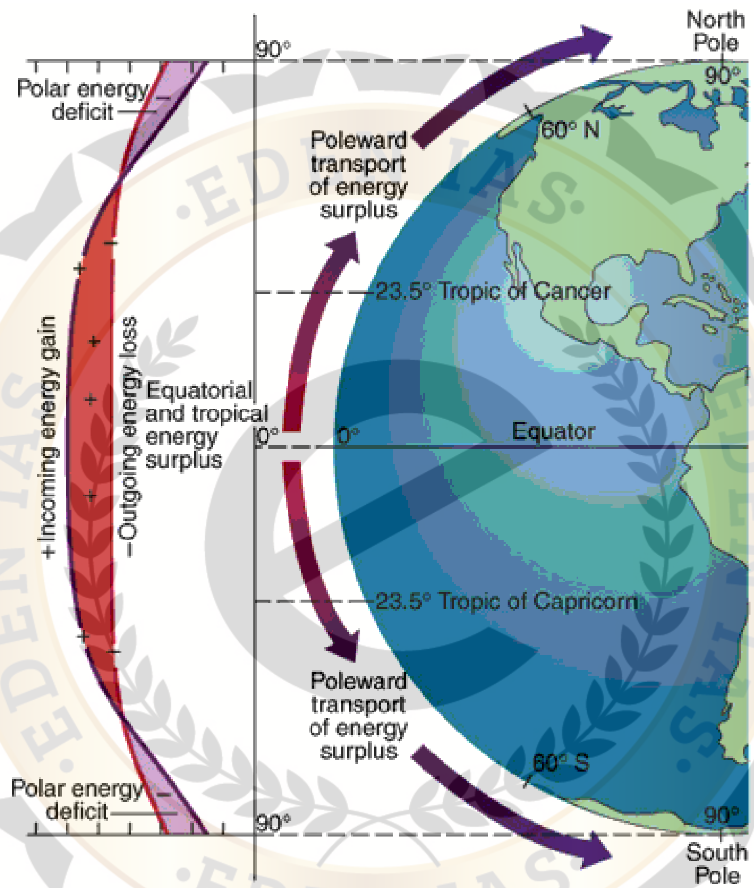
After receiving energy from the sun the earth also radiates energy out of its surface into the atmosphere through long-waves. **The terrestrial radiation is also called 'effective radiation' because it helps in heating the lower portion of the atmosphere.** Twenty three per cent energy (out of 51 % energy which the earth has gained from the sun) is lost through direct long-wave outgoing terrestrial radiation out of which 6 per cent is absorbed by the atmosphere and 17 per cent goes directly to the space.

About 9 per cent of the terrestrial energy is spent in convection and turbulence and 19 per cent is spent through evaporation which is added to the atmosphere as latent heat of condensation. Thus, the total energy received by the atmosphere from the sun (14%) and the earth (34%) becomes 48 per cent which is reradiated to the space in one way or the other.

Energy sent back to space = 35% + 17% (through radiation from the earth) + 48% (through radiation from the atmosphere) = 100%. It may be pointed out that the mechanism of solar and terrestrial radiation is not as simple as mentioned above, rather it is highly complex. For example, not all the energy received by the atmosphere from the sun and the earth is reradiated directly to the space rather a sizeable amount of energy received by the atmosphere is counter-radiated to the earth's surface which is again radiated to the space and the atmosphere.

LATITUDINAL HEAT BALANCE

The simplest observed global characteristic of the atmosphere is that the tropics are much warmer than the poles. This is a straightforward consequence of the geometry of the earth. The annually averaged incoming solar radiation per unit area of the earth's surface is much greater at the equator than at the poles. The difference arises because of the fact the Polar Regions are covered in ice and snow and therefore reflect much of the incoming radiation back to space. Another fact is that the tropical regions actually receive more energy from the sun than they emit back to space, while the converse is true in high latitudes.



Over the globe, the energy balance is nearly balanced when averaged over a year (incoming equals outgoing). Hence, there must be a process acting to transport excess energy from the tropics to make up the deficit in high latitudes. To compensate for the surplus and deficit of radiation in different regions of the globe, atmospheric and oceanic transport processes distribute the energy equally around the earth. This transport is accomplished by atmospheric winds and ocean currents.

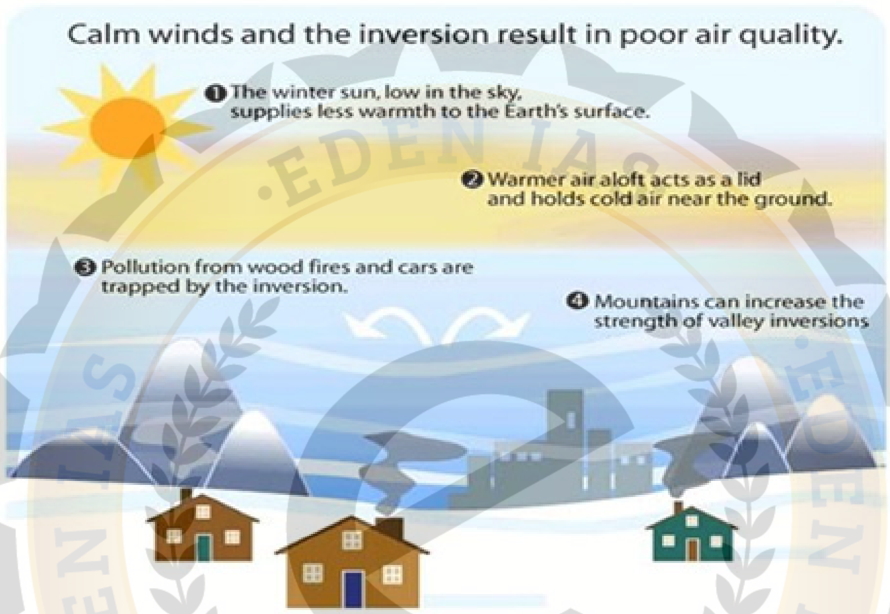
TEMPERATURE INVERSION

Temperature inversion, a reversal of the normal behaviour of temperature in the troposphere (the region of the atmosphere nearest the Earth's surface), in which a layer of cool air at the surface is overlain by a layer of warmer air. (Under normal conditions air temperature usually decreases with height.)

Inversions play an important role in determining cloud forms, precipitation, and visibility. An inversion acts as a cap on the upward movement of air from the layers below. As a result, convection produced by the heating of air from below is limited to levels below the inversion. **Diffusion of dust, smoke, and other air pollutants is likewise limited. In regions where a pronounced low-level inversion is present, convective clouds cannot grow high enough to produce showers**.

Temperature Inversion

Sometimes air doesn't mix in the troposphere. This happens when air is cooler close to the ground than it is above. The cool air is dense, so it stays near the ground. This is called a **temperature inversion**. An inversion can trap air pollution near the surface. Temperature inversions are more common in the winter. Can you explain why?



There are four kinds of inversions: ground, turbulence, subsidence, and frontal.

A ground inversion develops when air is cooled by contact with a colder surface until it becomes cooler than the overlying atmosphere; this occurs most often on clear nights, when the ground cools off rapidly by radiation. If the temperature of surface air drops below its dew point, fog may result. Topography greatly affects the magnitude of ground inversions. If the land is rolling or hilly, the cold air formed on the higher land surfaces tends to drain into the hollows, producing a larger and thicker inversion above low ground and little or none above higher elevations.

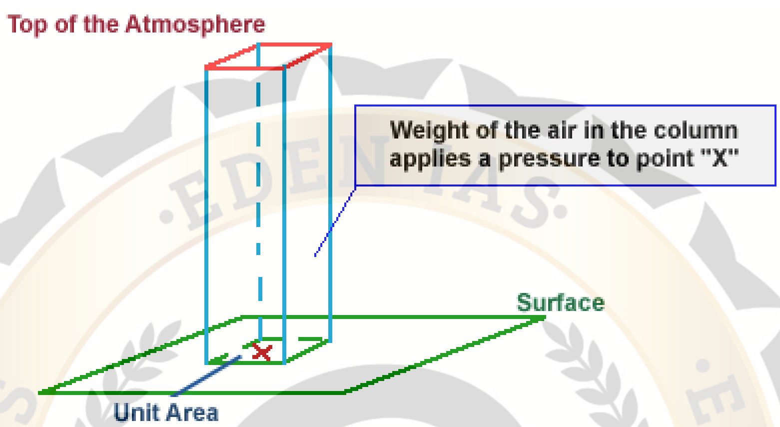
A turbulence inversion often forms when quiescent air overlies turbulent air. Within the turbulent layer, vertical mixing carries heat downward and cools the upper part of the layer. The unmixed air above is not cooled and eventually is warmer than the air below; an inversion then exists.

A subsidence inversion develops when a widespread layer of air descends. The layer is compressed and heated by the resulting increase in atmospheric pressure, and as a result the lapse rate of temperature is reduced. If the air mass sinks low enough, the air at higher altitudes becomes warmer than at lower altitudes, producing a temperature inversion. Subsidence inversions are common over the northern continents in winter and over the subtropical oceans; these regions generally have subsiding air because they are located under large high-pressure centres.

A frontal inversion occurs when a cold air mass undercuts a warm air mass and lifts it aloft; the front between the two air masses then has warm air above and cold air below. This kind of inversion has considerable slope, whereas other inversions are nearly horizontal. In addition, humidity may be high, and clouds may be present immediately above it.

ATMOSPHERIC PRESSURE AND CIRCULATION

Atmospheric pressure is defined as the force per unit area exerted against a surface by the weight of the air above that surface. In the diagram below, the pressure at point "X" increases as the weight of the air above it increases. The same can be said about decreasing pressure, where the pressure at point "X" decreases if the weight of the air above it also decreases.

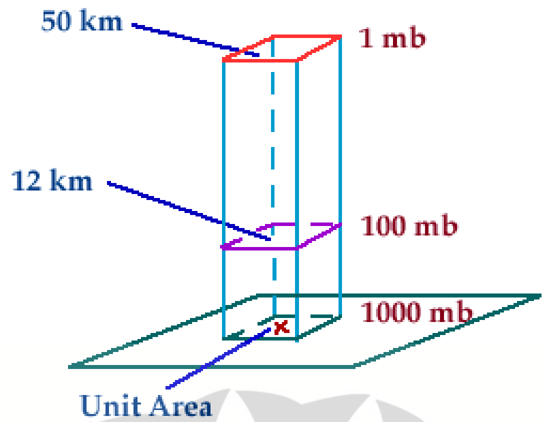


Thinking in terms of air molecules, if the number of air molecules above a surface increases, there are more molecules to exert a force on that surface and consequently, the pressure increases. The opposite is also true, where a reduction in the number of air molecules above a surface will result in a decrease in pressure. Atmospheric pressure is measured with an instrument called a "barometer", which is why atmospheric pressure is also referred to as barometric pressure.

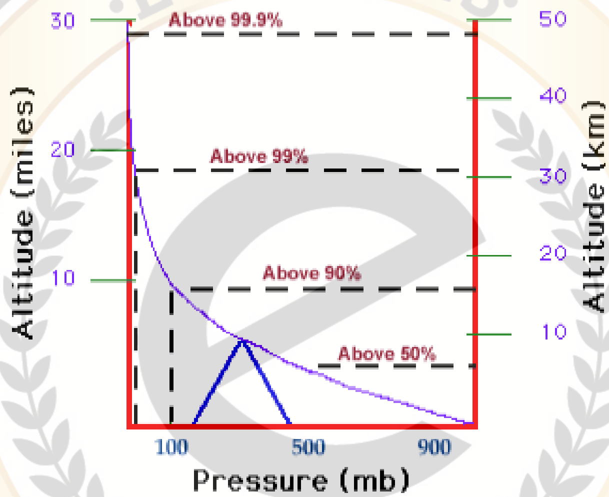
Inches of Mercury → ("Hg)	
Atmospheres → (atm)	**In aviation and television weather reports, pressure is given in inches of mercury ("Hg), while meteorologists use millibars (mb), the unit of pressure found on weather maps.**
Kilopascals → (kPa)	
Millibars → (mb)	
29.92 "Hg = 1.0 atm = 101.325 kPa = 1013.25 mb	

As an example, consider a "unit area" of 1 square inch. At sea level, the weight of the air above this unit area would (on average) weigh 14.7 pounds! That means pressure applied by this air on the unit area would be 14.7 pounds per square inch. Meteorologists use a metric unit for pressure called a millibar and the average pressure at sea level is 1013.25 millibars.

The number of air molecules above a surface changes as the height changes. For example, there are fewer air molecules above the 50 kilometer (km) surface than are found above the 12 km surface. **Since the number of air molecules above a surface decreases with height, pressure likewise decreases with height.**



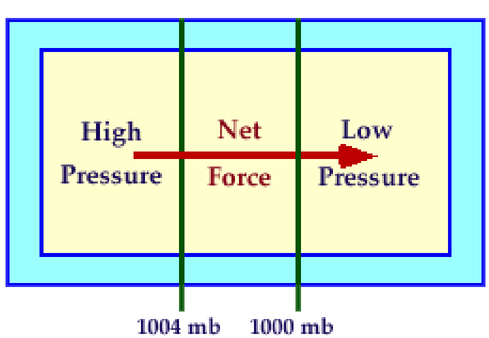
Most of the atmosphere's molecules are held close to the earth's surface by gravity. Because of this, air pressure decreases rapidly at first, then more slowly at higher levels.



Since more than half of the atmosphere's molecules are located below an altitude of 5.5 km, atmospheric pressure decreases roughly 50% (to around 500 mb) within the lowest 5.5 km. Above 5.5 km, the pressure continues to decrease, but at an increasingly slower rate (to about 1 mb at 50 km). **A line drawn on a weather map connecting points of equal pressure is called an "isobar". Isobars are generated from mean sea-level pressure reports and are given in millibars.**

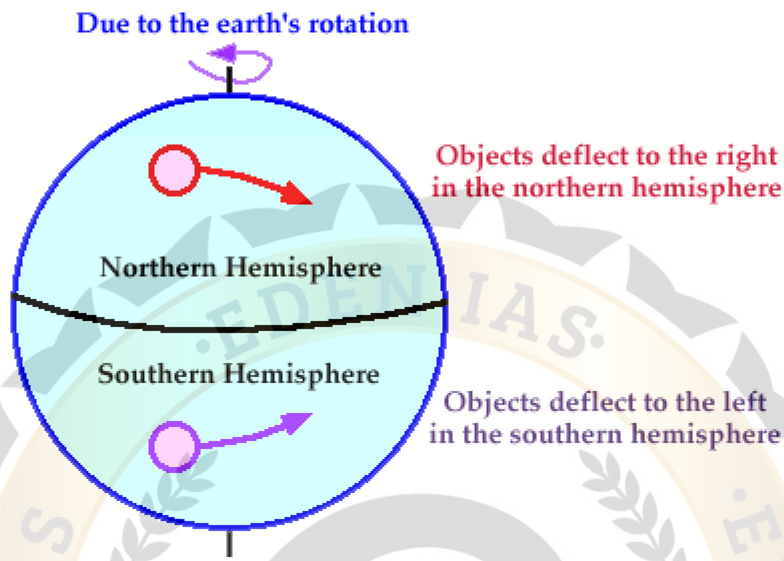
PRESSURE GRADIENT FORCE

The direction of air flow is from regions of greater to those of less density, i.e., from high to low pressure or down the barometric slope, which may be represented by a line drawn at right angles to the isobars. The rate of air flow, or velocity of the wind, is indicated by the steepness of the pressure gradient or the rate of pressure change. When the gradient is steep, air flow is rapid, and when it is weak, the wind is likewise weak. When isobars are far apart, gradients and winds are weak. The change in pressure measured across a given distance is called a "pressure gradient". The pressure gradient results in a net force that is directed from high to low pressure and this force is called the "pressure gradient force".



CORIOLIS FORCE

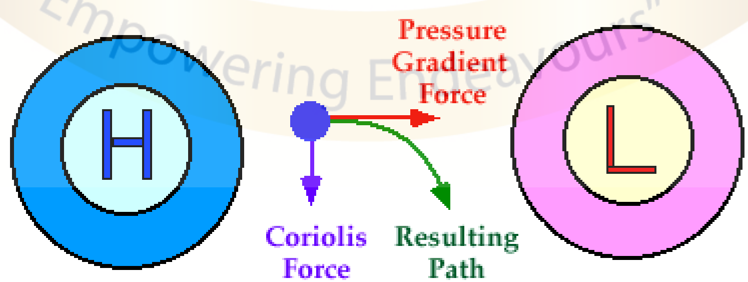
Once air has been set in motion by the pressure gradient force, it undergoes an apparent deflection from its path, as seen by an observer on the earth. This apparent deflection is called the "Coriolis force" and is a result of the earth's rotation.



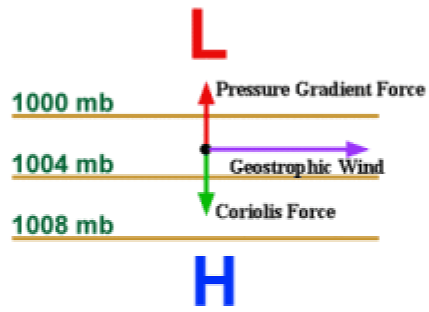
As air moves from high to low pressure in the northern hemisphere, it is deflected to the right by the Coriolis force. In the southern hemisphere, air moving from high to low pressure is deflected to the left by the Coriolis force. The amount of deflection the air makes is directly related to both the speed at which the air is moving and its latitude. Therefore, slowly blowing winds will be deflected only a small amount, while stronger winds will be deflected more. Likewise, winds blowing closer to the poles will be deflected more than winds at the same speed closer to the equator. The Coriolis force is zero right at the equator.

Geostrophic Wind

Winds balanced by the Coriolis and Pressure Gradient forces are known as geostrophic winds. An air parcel initially at rest will move from high pressure to low pressure because of the pressure gradient force (PGF). However, as that air parcel begins to move, it is deflected by the Coriolis force to the right in the northern hemisphere (to the left on the southern hemisphere). As the wind gains speed, the deflection increases until the Coriolis force equals the pressure gradient force. At this point, the wind will be blowing parallel to the isobars. When this happens, the wind is referred to as **geostrophic**.



Winds in nature are rarely exactly geostrophic, but to a good approximation, the winds in the upper troposphere can be close. This is because winds are only considered truly geostrophic when the isobars are straight and there are no other forces acting on it -- and these conditions just aren't found too often in nature.



FRICTIONAL FORCE

Geostrophic wind blows parallel to the isobars because the Coriolis force and pressure gradient force are in balance. However it should be realized that the actual wind is not always geostrophic -- especially near the surface. The surface of the Earth exerts a frictional drag on the air blowing just above it. This friction can act to change the wind's direction and slow it down -- keeping it from blowing as fast as the wind aloft. **Actually, the difference in terrain conditions directly affects how much friction is exerted.** For example, a calm ocean surface is pretty smooth, so the wind blowing over it does not move up, down, and around any features. By contrast, hills and forests force the wind to slow down and/or change direction much more.

As we move higher, surface features affect the wind less until the wind is indeed geostrophic. This level is considered the top of the boundary (or friction) layer. The height of the boundary layer can vary depending on the type of terrain, wind, and vertical temperature profile. The time of day and season of the year also affect the height of the boundary layer. However, usually the boundary layer exists from the surface to about 1-2 km above it. The frictional force affects both the direction and velocity of the wind

TRI-CELLULAR MERIDIONAL MODEL

This model envisages a three-cell model of meridional circulation of the atmosphere, popularly known as tri-cellular meridional circulation of the atmosphere, wherein it is believed that there is cellular circulation of air at each meridian (longitude). Surface winds blow from high pressure areas to low pressure areas but in the upper atmosphere the general direction of air circulation is opposite to the direction of surface winds. **Thus, each meridian has three cells of air circulation in the northern hemisphere:**

1. **Hadley cell**
2. **Ferrel cell**
3. **Polar cell**

(1) Hadley Cell

Tropical cell is also called as Hadley cell because G. Hadley first identified this thermally induced cell in both the hemispheres in the year 1735. The winds after being heated due to very high temperature at the equator ascend upward. These ascending warm and moist winds release latent heat after condensation which causes further ascent of the winds which after reaching the height of 8 to 12 kilometers in the troposphere over the equator diverge northward and southward or say poleward.

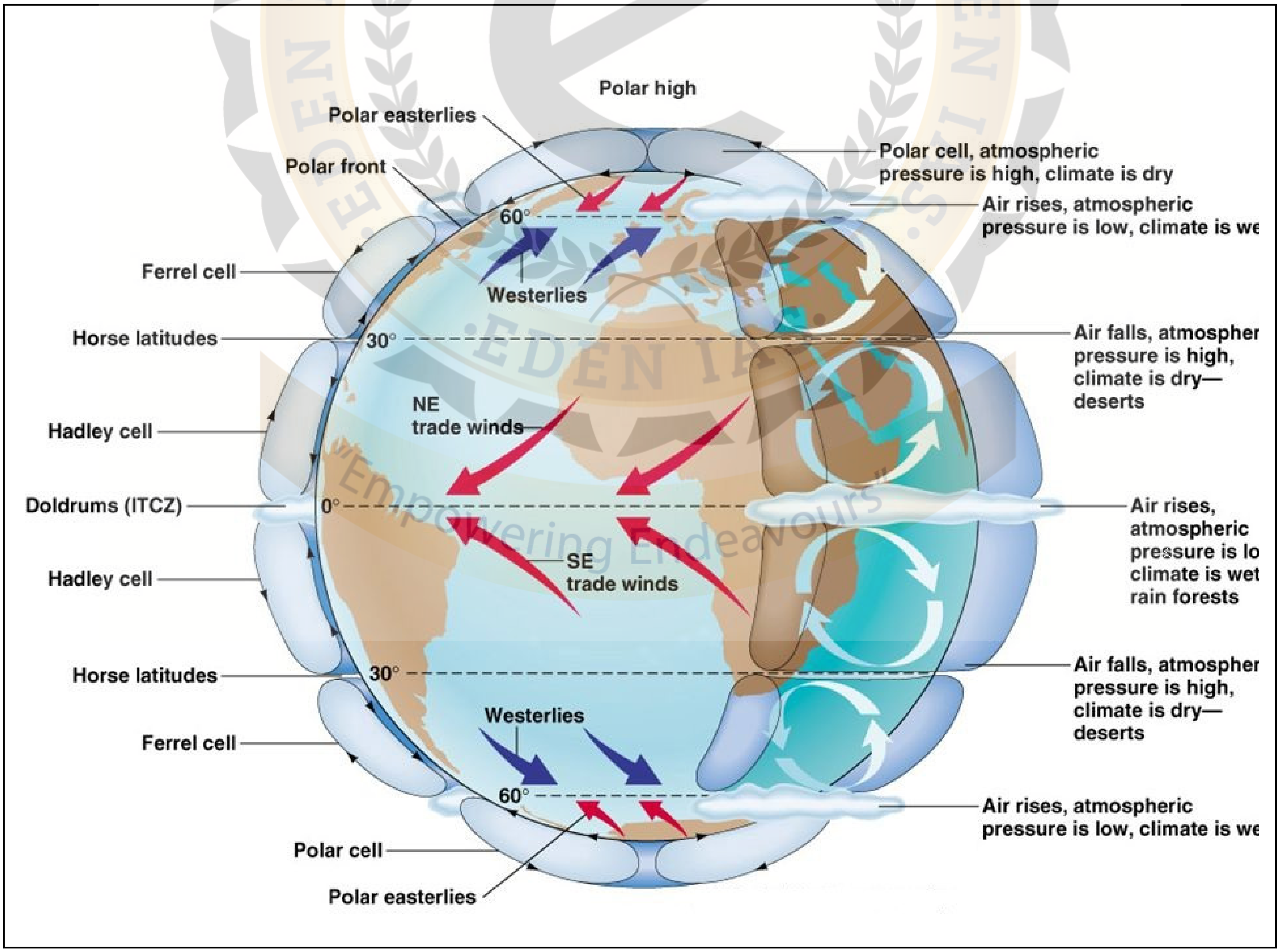
The surface winds in the name of trade winds blow from subtropical high pressure belts to equatorial low pressure belt in order to replace the ascending air at the equator. The upper air moving in opposite direction to surface winds (trade winds) is called antitrade. These upper air antitrades descend near 30°-35° latitudes to cause subtropical high pressure belt.

These antitrades after descending near 30°-35° latitudes again blow towards the equator where they are again heated and ascend. Thus, one complete meridional cell of air circulation is formed. This is called tropical meridional cell which is located between the equator and 30° latitudes.

(2) Ferrel Cell

Air circulation the pattern between 30°-60° latitudes consists of surface winds, known as westerlies, blow from the subtropical high pressure belt to subpolar low pressure belt (60°-65°). The winds ascend near 60°-65° latitudes and after reaching the upper troposphere diverge in opposite directions (poleward and equator-ward).

These winds (which diverge equator-ward) again descend near horse latitudes (30°-35° latitudes) to reinforce subtropical high pressure belt. After descending these winds again blow poleward as surface westerlies and thus a complete cell is formed. It may be mentioned that the regularity and continuity of westerlies are frequently disturbed by temperate cyclones, migratory extra-tropical cyclones and anticyclones.



(3) Polar Cell

Polar cell involves the atmospheric circulation prevailing between 60° and poles. Cold winds, known as polar easterlies, blow from polar high pressure areas to sub-polar or mid- latitude low pressure belt. The general direction of surface polar winds becomes easterly (east to west) due to Coriolis force. These polar cold winds converge with warm westerlies near 60°-65° latitudes and form polar front or mid- latitude front which becomes the centre for the origin of temperate cyclones. The winds ascend upward due to the rotation of the earth at the subpolar low pressure belt and after reaching middle troposphere they turn poleward and equator-ward. The poleward upper air descends at the poles and reinforces the polar high pressure. Thus, a complete polar cell is formed.

DOLDRUMS

The "doldrums" is a popular nautical term that refers to the belt around the Earth near the equator where sailing ships sometimes get stuck on windless waters. **Doldrums, also called equatorial calms, equatorial regions of light ocean currents and winds within the intertropical convergence zone (ITCZ), a belt of converging winds** and rising air encircling Earth near the Equator.

HORSE LATITUDES

The horse latitudes are located at about 30 degrees north and south of the equator. It is common in this region of the subtropics for winds to diverge and either flow toward the poles (known as the prevailing westerlies) or toward the equator (known as the trade winds). These diverging winds are the result of an area of high pressure, which is characterized by calm winds, sunny skies, and little or no precipitation.

According to legend, the term comes from ships sailing to the New World that would often become stalled for days or even weeks when they encountered areas of high pressure and calm winds. Many of these ships carried horses to the Americas as part of their cargo. Unable to sail and resupply due to lack of wind, crews often ran out of drinking water. To conserve scarce water, sailors on these ships would sometimes throw the horses they were transporting overboard. Thus, the phrase 'horse latitudes' was born.

ROARING 40s; FURIOUS 50s; SHRIEKING OR SCREAMING 60s

These nicknames, roaring forties, furious fifties and the screaming sixties, refer to the latitudes in the Southern Ocean. These areas are notorious for their strong westerly winds. The monotony of water with near absence of land has provided these winds such velocity. An old sailors saying is **'Below 40 degrees south there is no law and below 50 degrees south there is no God'**. This exemplifies the ferocious storms that sometimes rage over these areas. Waves can tower up to the size of a six-story building.

The roaring forties were a major plus for sailors on their way from Europe to the East. These winds could increase the SPEED immensely, which had great benefits in the Age of Sail. Now, we mainly sail here because it is extremely adventurous and exciting!

MOISTURE IN THE ATMOSPHERE

Although water vapor comprises only a very small part of the total atmosphere, averaging less than 2 per cent of the total mass, it is the single most important component of the air from the standpoint of weather and climate. The proportions of most of the gaseous constituents that compose the atmosphere near sea level are relatively constant from place to place at the surface of the earth. One in particular, water vapour is highly inconstant, varying from nearly zero up to a maximum of almost 5 per cent. This variability in the atmospheric content of water vapor, as to both place and time, is of outstanding importance for at least four reasons:

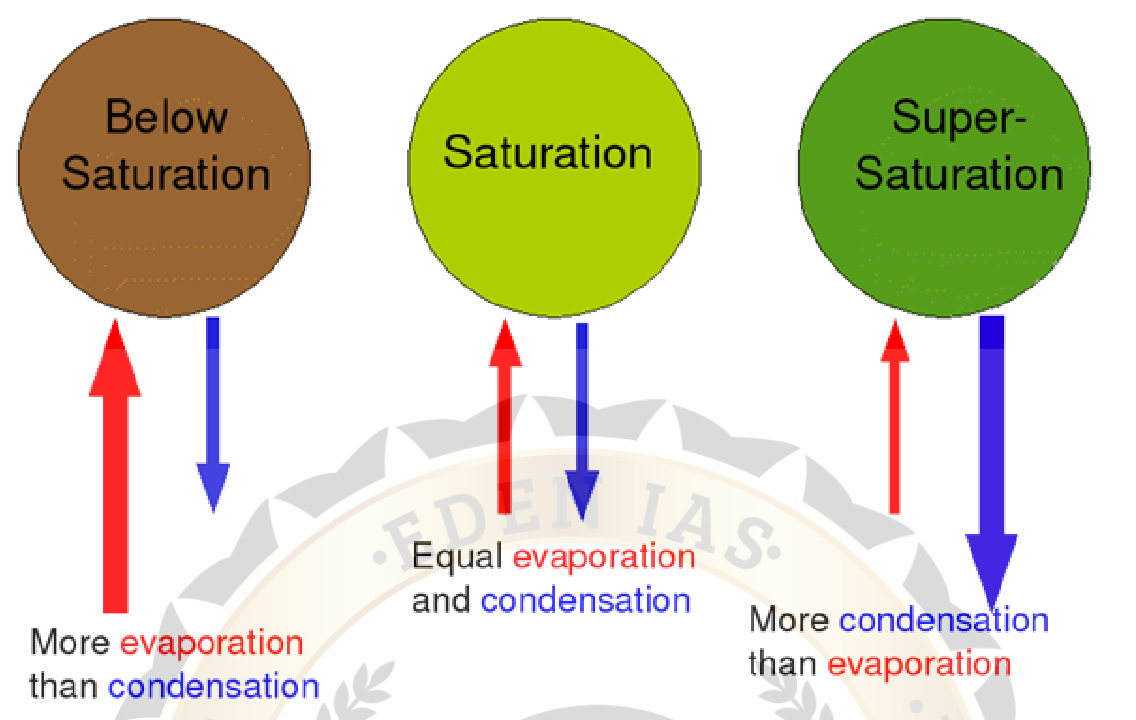
a) **The amount of that gas in a given mass of air is an indication of the atmosphere's potential capacity for precipitation, one of the two most important climatic elements.**
b) **Water vapor, through its absorptive effects on terrestrial radiation, is a regulator of rate of heat loss from the earth, and thereby significantly affects temperature phenomena,**
c) **The greater the amount of water vapor the larger the quantity of latent or potential energy stored up in the atmosphere for the origin and growth of storms; it frequently determines, therefore, whether an air mass will be stable or unstable,**
d) **The amount of water vapor is likewise an important factor affecting the human body's rate of cooling, i.e., the sensible temperature.**

ABSOLUTE HUMIDITY- The total amount of water vapour that a given volume of air contains, expressed in weight of the water vapor per unit volume is called its absolute humidity

SPECIFIC HUMIDITY- The total amount of water vapour measured in grams contained in per kilogram of air is called as specific humidity

RELATIVE HUMIDITY- Relative humidity is always expressed in the form of a ratio, fraction, or percentage. It represents the amount of water vapor actually present in the air (absolute humidity) compared with the maximum that could be contained under conditions of saturation at the given temperature and pressure (Humidity Capacity)

The temperature at which air becomes saturated is known as the Dew Point temperature. Saturated air has relative humidity of 100% (or is equal to 1). Condensation takes place only when the air is super saturated i.e. the Relative Humidity surpasses 100% (or is more than 1).



DIFFERENT FORMS OF CONDENSATION AND CLOUDS

Condensation is the change of the physical state of matter from the gas phase into the liquid phase, and is the reverse of vaporisation. The different forms of condensation are

Dew- Dew is water in the form of droplets that appears on thin, exposed objects in the morning or evening due to condensation. As the exposed surface cools by radiating its heat, atmospheric moisture condenses at a rate greater than that at which it can evaporate, resulting in the formation of water droplets

Frost- Frost is a thin layer of ice on a solid surface, which forms from water vapor in an above freezing atmosphere coming in contact with a solid surface whose temperature is below freezing, and resulting in a phase change from water vapor to ice as the water vapor reaches the freezing point. When the dew point temperature is above freezing point the result is dew, when it is below the freezing point it becomes frost.

Fog- Fog is a visible aerosol consisting of tiny water droplets or ice crystals suspended in the air at or near the Earth's surface. Fog can be considered a type of low-lying cloud, usually resembling stratus, and is heavily influenced by nearby bodies of water, topography, and wind conditions

Clouds- A cloud is made up of water droplets or ice crystals suspended in the air. Cloud is defined as a visible aggregation of minute water droplets and/or ice particles in the air, usually above the ground level. These particles have a diameter ranging from 20 to 50μ. Micrometre is one millionth of a meter. Each cloud particle is formed on a tiny centre of a solid particle, called a condensation nucleus. The diameter of this nucleus ranges from 0.1 to 1μ. Clouds very clearly reflect the physical processes taking place in the atmosphere. They are, therefore, indicators of weather conditions.

Clouds are the most important form of suspended water droplets caused by condensation. If these are brought down to the ground, these would exactly look like fog. Conversely, a fog raised above the ground would appear to be a cloud. The clouds are produced when the air above the ground is cooled below its dew point or extra moisture is added.

The cooling may come through many processes, but the rising air is usually involved in their formation. If the movement of the air is generally horizontal, the clouds will be formed in layers, and are called stratiform clouds. If the movement is vertical, then these are designated as cumuliform. As convectional currents are limited to the troposphere only, so this part of the atmosphere contains nearly all clouds. Although very high clouds can be found in the lower stratosphere

Classification of Clouds

Clouds are classified on the basis of their height, shape, colour and transmission or reflection of light. There are three basic cloud forms: **cirrus (feathery or fibrous), stratus (stratified or in layers) and cumulus (in heaps)**. Different forms of clouds are either pure forms or modifications and combinations of them at different elevations.

If a basic cloud form occurs above its normal height i.e. 1950m, the cloud will be thin and the word 'alto' is prefixed to its form. If any cloud is associated with rain, the word 'nimbus' meaning rain is prefixed or suffixed to its basic form. According to the 1956 International Cloud Atlas of **World Meteorological Organization**, clouds are classified into 10 characteristic forms.

Family	Height	Name	Abbreviation
High clouds	Top - 12,200m	Cirrus	Ci
	Base – 7,000m	Cirrostratus	Cs
		Cirrocumulus	Cc
Middle clouds	Top – 7,000m	Altostratus	As
	Base – 2,000m	Altocumulus	Ac
Low clouds	Top – 1,980m	Nimbostratus	Ns
	Base – 500m	Stratocumulus	Sc
		Stratus	St
Clouds with	Top – 12,200m	Cumulus	Cu
Vertical development	Base – 500m	Cumulonimbus	Cb

1. Cirrus:-These are highest, delicate, detached, fibrous, feather like clouds of silky appearance without shading. They appear as bright red or orange before sunrise or after sunset. They comprise of thin crystals or needles of ice and not droplets of water. The sun or moon shining through these clouds produces a halo. These clouds do not give precipitation.

2. Cirrostratus: - These clouds appear as a thin whitish veil of sheet, often covering all or a good portion of the sky. These are very thin, giving the sky a slight milky white appearance. These are formed of ice crystals. Cirrostratus clouds are responsible for the halos, often occurring but do not blur the outlines of sun or moon.

3. Cirrocumulus: - These appear in patches of small white flaky globular masses covering small or large portions of the sky and have no shading. They are often arranged into bands or fused into waves or ripples resembling those of sand on sea shore.

4. Altostratus: - These clouds are uniform bluish or greyish white cloud sheets covering all or large portion of the sky. Sometimes they may occur in uniform broad bands. The sun may be totally obscured or may shine through thin watery conditions. Altostratus do not show halo phenomena. Clouds of this type also consist of water droplets, often super-cooled to temperatures well below freezing. Precipitation may fall either as fine drizzle or snow.

5. Altocumulus: - These clouds form as elliptical, globular units occurring individually or in groups. Individual altocumulus clouds are frequently elongated elliptical units without vertical doming. Altocumulus clouds do not produce halos. They have dark shading on their under surfaces. These are often composed of supercooled liquid droplets. This type of cloud may occur at various levels simultaneously.

6. Stratus: - This is a uniform grey cloud sheet or layer which may give drizzle, ice prisms or snow grains. When the sun is visible through the cloud, its outline is clearly discernible. These do not produce halo phenomena. Stratus clouds have no particular form or structure and completely cover the sky. When stratus clouds are overlain by the higher altostratus, they become thicker and darker.

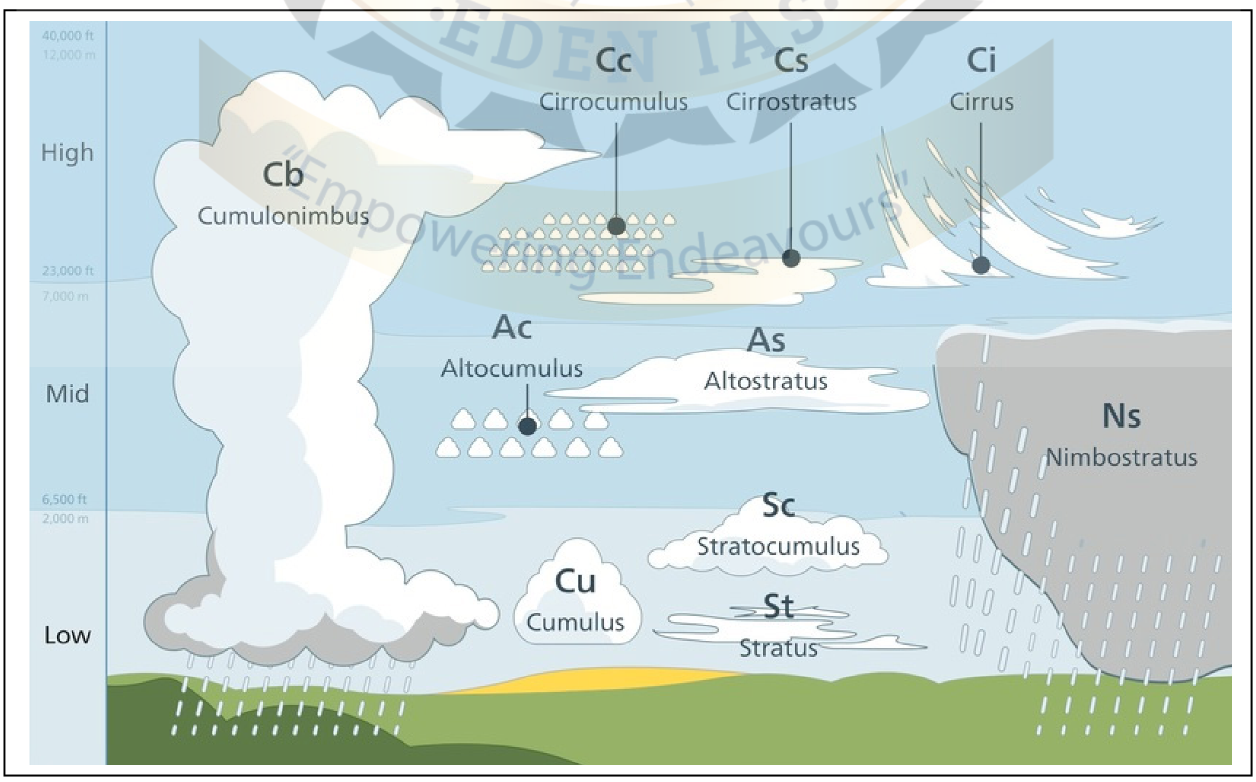
7. Nimbostratus: - These are thick, dark grey, shapeless cloud sheets with regular broken clouds beneath and surrounding them. It is a low cloud form and may be thousands of feet thick. It is a rain, snow or sleet cloud and is never accompanied by lightning, thunder or hail. It is distinguished from the stratus type in that it is darker.

8. Stratocumulus: - These form large, heavy rolls or elongated globular masses arranged in long grey parallel bands that usually cover all or most of the sky. They often form from the flattening of the cumulus clouds which may be arranged in bands or may develop as a continuation of altocumulus occurring at low altitudes. In the latter case, the strato-cumulus appear darker, lower and heavier than the related altocumulus.

9. Cumulus: - These are detached, white clouds, generally dense with sharp outlines, developing vertically in the form of domes or towers, of which the bulging upper parts often resemble a cauliflower. The sunlit parts of these clouds are mostly brilliant white; their base is relatively dark and horizontal. These clouds represent the tops of strong convective currents. They are prominent in summer time but may occur in any season. They are generally found in day time over land areas and dissipate at night. They produce only light precipitation. They often represent a transition to cumulonimbus, which is the heavier shower cloud.

10. Cumulonimbus: - These clouds develop from cumulus that have developed into tremendous towering clouds with a vertical range from base to top of 3 to 8 km. They may attain a height of 16 km in the tropical areas. When grown to this height, such clouds form the well known thunderstorms. Cumulonimbus is a towering cloud sometime spreading out on top to form an 'anvil head'.

This type of cloud is associated with heavy rainfall, thunder, lightning, hail and tornadoes. This cloud has a flat top (anvil head) and a flat base. It appears darker as condensation within it increases, and it obstructs the sun. It is the great thunderhead, which is the source of squally, gusty, short-lived thunderstorms. Such thunderstorms are very common in the summer afternoons in the middle and low latitudes. This type of cloud is easily recognised by the fall of a real shower and sudden darkening of the sky.



DIFFERENT FORMS OF PRECIPITATION

Precipitation is caused by condensation of water vapours of the air mass. The ascending air mass with sufficient amount of water vapours becomes saturated due to adiabatic cooling. Condensation of water vapours leads to the formation of clouds. Every cloud contains updraft and downdraft. The development and height of the clouds depend upon the updraft. Stronger the updraft, greater is the height of the cloud. When the liquid water increases, the strength of the updraft decreases and downdraft starts increasing. As a result, precipitation is produced.

Even though all clouds contain water, but some produce precipitation while others do not. In certain cases precipitated moisture falls from the clouds, but it gets evaporated from the atmosphere before reaching the earth surface.

Precipitation occurs only when the cloud droplets or ice crystals grow to such a size that it can overcome the updrafts in the atmosphere. It means that some special processes are working in a cloud from which precipitation falls.

The precipitation takes place in many different forms in the regions located in the middle latitudes. Typical characteristics of various forms of precipitation are explained below:

(i) Rain: - It consists of water drops mostly larger than 0.5 mm in diameter.

(ii) Drizzle: - They are tiny water droplets of size between 0.1 to 0.5 mm which fall with such slow settling rates that they occasionally appear to float.

(iii) Snow: - It is that type of precipitation which results from sublimation, i.e., water vapour directly changes into ice. It falls as white or translucent ice crystals often agglomerated into snowflakes. The specific gravity of snow is often taken to be 0.1.

(iv) Hail: - It is the precipitation in form of lumps of ice. The hail stones are produced in convective clouds mostly cumulonimbus. Their shape may be conical, spheroidal or irregular. The size of hail stones may be anything more than 5 mm. The specific gravity of hail stone is about 0.8.

(v) Snow Pallets: - Sometimes they are called soft hail also. Snow pallets are more crisp and are of size 2 to 5 mm. Due to their, crispness upon hitting the hard ground they often break up.

(vi) Sleet: - When the rain drops fall through the layer of sub-freezing air near the earth's surface the rain drops get frozen to ice stage. It is called sleet or grains of ice.

TYPES OF RAINFALL

There are three types of rainfall:

1. **Orographic Precipitation.**
2. **Convectional Precipitation.**
3. **Frontal Precipitation.**

Orographic Precipitation

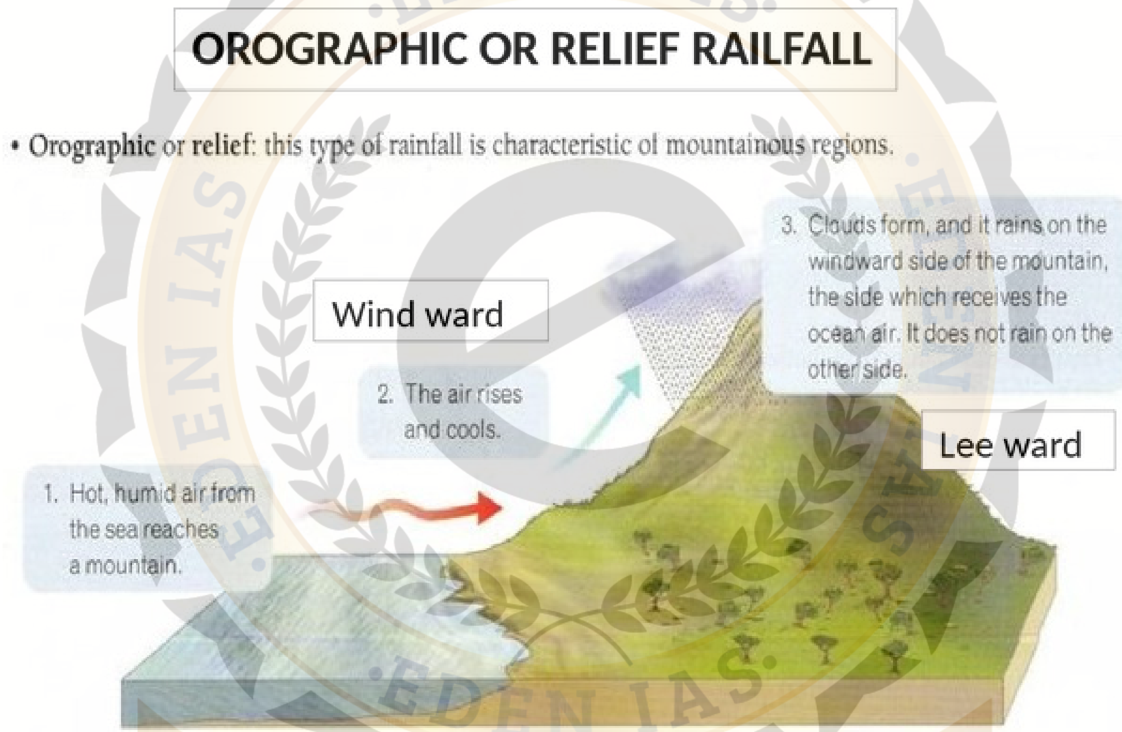
This type of precipitation occurs when the moist air mass rises on the windward side of the mountain. The moist air mass is lighter than the dry air mass; therefore, buoyancy forces push the air mass along the slope of the mountain and cools at the dry adiabatic rate. When cooling is sufficient, air mass becomes saturated and condensation starts. As a result, lifting condensation level is reached and clouds begin to form.

When the mountains act as barrier to the flow of air mass, the air cools adiabatically, as a result clouds and precipitation occur. This is called orographic precipitation. This type of precipitation occurs on the windward side of the mountains.

But on the leeward side, there is abrupt decrease in precipitation due to the descending air mass which gets heated at dry adiabatic lapse rate. The descending air mass becomes dry and hot.

As a result, the clouds on the leeward side disappear. Therefore, dry areas always exist on the leeward side of the mountains. These are known as rain shadow areas. This is due to the reason that moist air prevails on the windward side and warm dry air prevails on the leeward side.

In India, south-west monsoon causes heavy rain on the windward slope of Western Ghats, whereas on the leeward side there are extensive rain shadow areas. There is a continuous increase in precipitation on the windward side up to a certain height beyond which the rainfall starts decreasing. This is called the inversion of rainfall.



Convectional Precipitation

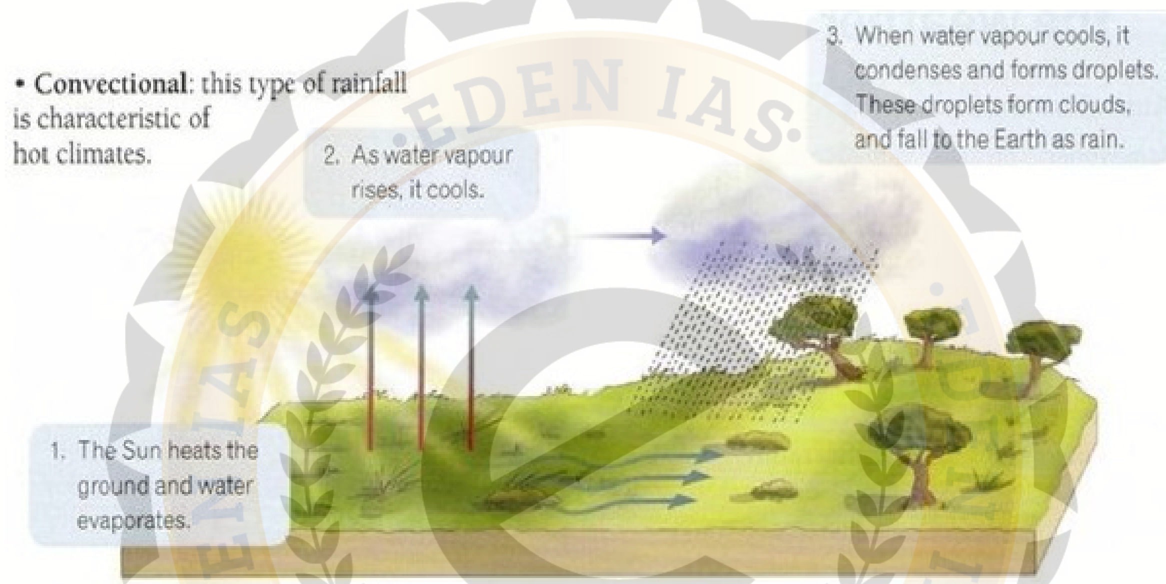
Two conditions are required to cause this type of precipitation:

a) **Intense heating of the ground surface.**
b) **ii. Abundant supply of moisture.**

Solar radiation is the main source of heat to produce convection currents in the air. This process starts, when surface is heated unequally. During day, the air above the bare soil will grow warmer than the air over the adjacent forest. Warm air is less dense as compared to cold air. Convection currents are set up forcing air to rise. The air is cooled adiabatically and its temperature will decrease as it rises. The air mass will continue to rise as long as it remains warmer than its surrounding air.

Rising air mass becomes saturated as it gets cooled adiabatically. Condensation starts and the rising air column becomes a puffy cumulus cloud. If the convection continues strongly, the cloud develops into a dense cumulonimbus cloud. Heavy rainfall is always associated with this type of cloud. Convective type precipitation is a warm weather phenomenon. It is generally associated with thunder, lightning and strong surface winds. Sometimes hails are also associated with it. This type of precipitation occurs in the low latitudes and in the temperate zones. It generally occurs in the summer months during evening time. On the mountains, this type of precipitation is of a very short duration and consists of heavy showers. Convective precipitation is less effective for the crop growth than the steady rain. In this case run off is maximum, therefore, little water is left for entering the soil. However, in the temperate region, it is most effective in promoting the growth of plants. The main reason is that in the mid latitudes it occurs only in warm season when the vegetation is very active.

CONVECTIONAL RAINFALL



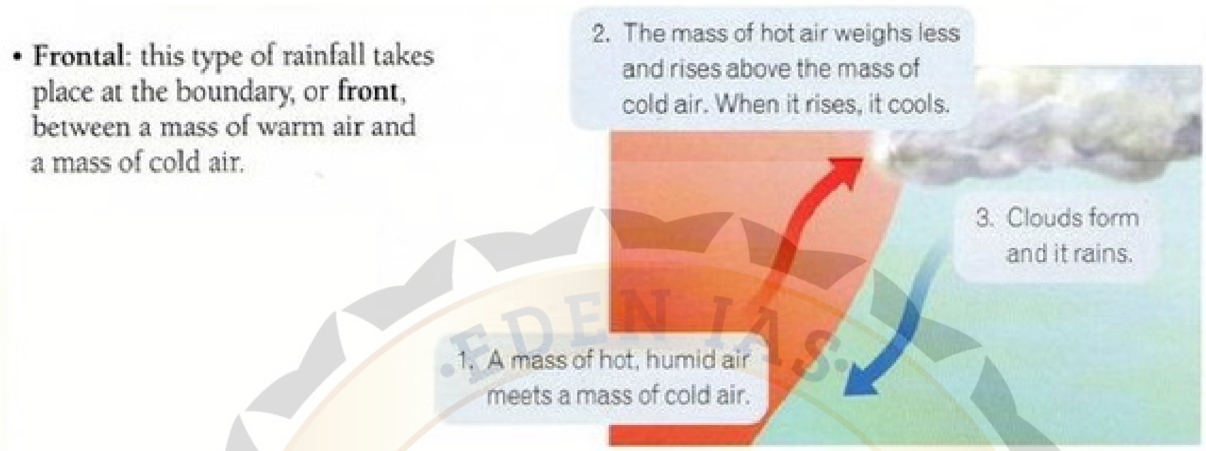
Frontal Precipitation

It occurs when deep and extensive air masses are made to converge and move upward so that their adiabatic cooling takes place. For this type of precipitation lifting of air mass is required. Cyclonic precipitation can be achieved in two ways:

a) **When two air masses with different temperature and moisture content meet at a certain angle, the warm and moist air is forced to rise over the heavier cold air mass.**
b) **When air masses from different directions converge to the centre, some of the air is forced up.**

In tropical region, there is little difference in the temperature and humidity of the converging air masses. The lifting is almost vertical and is accompanied by convection. In such a condition the convergence provides the initial upward movement of unstable air mass and causes large clouds and heavy showers. In temperate regions, a zone of contact between warm and cold air mass is called front. There may be warm or cold front. Frontal precipitation occurs when the warm and moist air gradually rises over the cold air mass. The main cause of this precipitation is the mixing of air along the front. Frontal precipitation along the warm front is in the form of drizzle. It is always widespread and of long duration. In case of cold front it is always in the form of intense thunder showers and is of very short duration. Frontal precipitation occurs in Europe and N. America. During winter season, cyclonic precipitation occurs in the northern parts of India.

CYCLONIC OR FRONTAL RAINFALL



AIR-MASSES AND TEMPERATE CYCLONES

"An air mass may be defined as a large body of air whose physical properties, especially temperature, moisture content, and lapse rate, are more or less uniform horizontally for hundreds of kilometres".

An air mass is an immense body of air moving over the earth's surface as a recognisable entity, having uniform physical properties at a given altitude. Air masses form an integral part of the global planetary wind system. Therefore, they are associated with one or other wind belt.

It may be pointed out that since a single air mass is so large that it may cover hundreds of thousands to millions of square kilometres of the earth's surface, and hence horizontal homogeneity of an air mass in terms of its physical properties may not be practically possible because the nature and degree of uniformity of air mass properties are determined by

(i) **The properties of the source area and the direction of its movement**
(ii) **Changes introduced in the air mass during its journey away from the source area, and**
(iii) **The age of the air mass.**

The vertical distribution of temperature in an air mass, and moisture content of the air are two basic properties of an air mass which control the weather conditions of the area affected by that air mass. An air mass is designated as cold air mass when its temperature is lower than the underlying surface while an air mass is termed warm air mass when its temperature is higher than the underlying surface. An airmass when gets formed over land is known as continental airmasses as opposed to those which are formed over oceans which are known as maritime airmasses. The airmasses formed within the tropics are known as tropical airmasses and those at higher latitudes are termed as polar airmasses.

The boundary between two contrasting air masses is called front. The physical properties of an air mass are determined on the basis of the characteristic features of the surface through which it travels. An air mass also affects and modifies temperature and moisture conditions of the areas visited by it and in turn it is also modified by the local conditions of the visited areas.

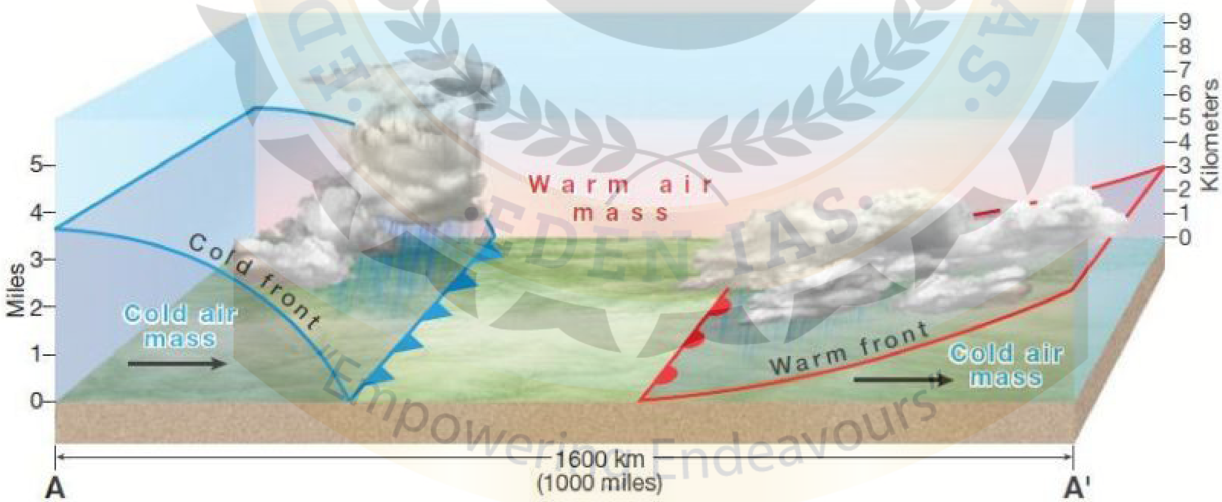
There are six major source regions of air masses on the earth's surface

1) **Polar oceanic areas** (North Atlantic Ocean between Canada and Northern Europe, and North Pacific Ocean between Siberia and Canada-during winter season),
2) **Polar and arctic continental areas** (snow-converted areas of Eurasia and North America, and Arctic region-during winter season),
3) **Tropical oceanic areas** (anticyclonic areas – throughout the year),
4) **Tropical continental areas** (North Africa-Sahara, Asia, Mississippi Valley zone of the USA – most developed in summers),
5) **Equatorial regions** (zone located between trade winds – active throughout the year), and
6) **Monsoon lands of S.E. Asia**.

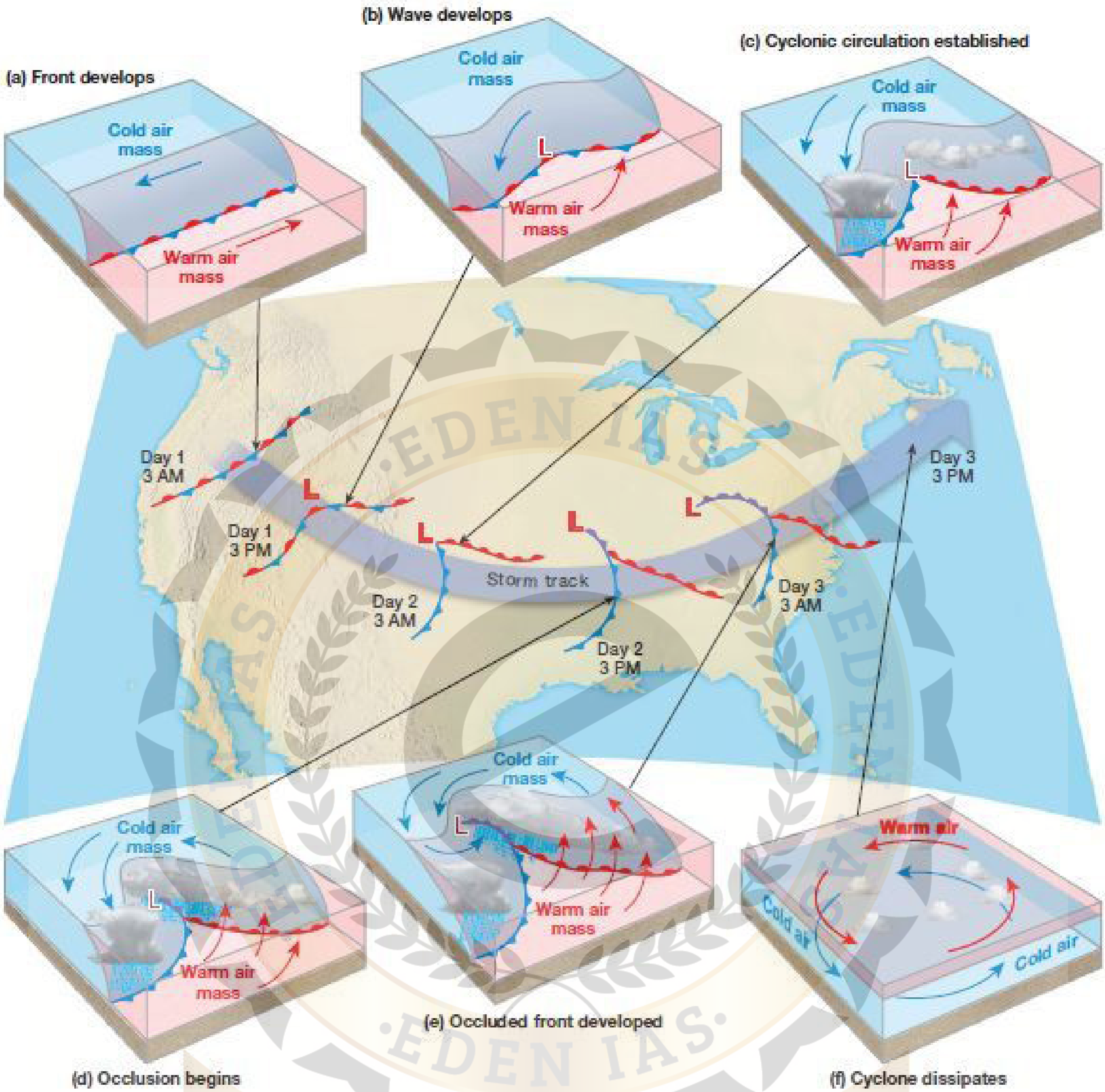
TEMPERATE CYCLONES

Temperate cyclones are active over mid-latitudinal region between 35° latitude and 65° latitude in both hemispheres. These cyclones are also called extra-tropical or mid-latitude or wave cyclones. Thus, they are found almost entirely within the band of westerly winds. **Their general path of movement is toward the east, which explains why weather forecasting in the mid-latitudes is essentially a west-facing vocation.**

Because each mid-latitude cyclone or temperate cyclones differs from all others in greater or lesser detail, any description must be a general one only. The discussions that follow, then, pertain to "typical" or idealized conditions.

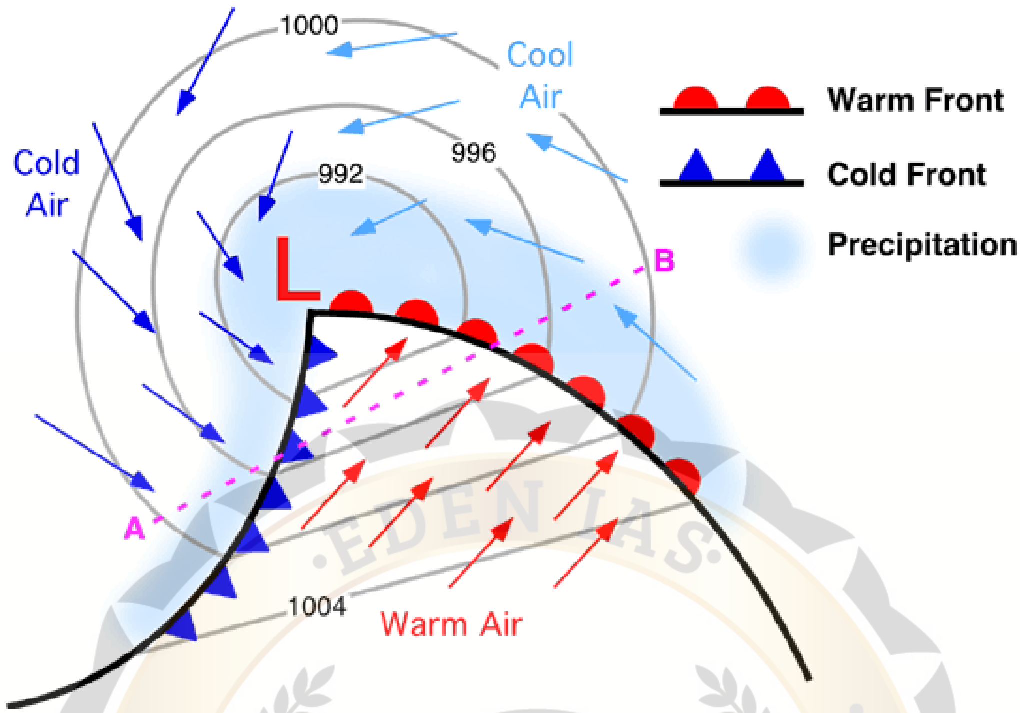


Mid-latitude cyclones or Temperate cyclones have a converging counterclockwise circulation pattern in the Northern Hemisphere and clockwise circulation in southern hemisphere. This wind flow pattern brings together cool air from the north and warm air from the south. The convergence of these unlike air masses characteristically creates two fronts: a cold front that extends to the southwest from the center of the cyclone and runs along the pressure trough extending from the center of the storm, and a warm front extending eastward from the center and running along another, usually weaker, pressure trough. The evolution of temperate cyclone occurs in different stages viz Frontogenesis (formation of front), Occlusion (One front overriding the other) and Frontolysis



Size and Shape: - The temperate cyclones are asymmetrical and shaped like an inverted 'V'. They stretch from 500 km to 600 km. They may go upto 2500 km over North America. They have a height of 8 to 11 km.

Structure: -The cold sector is one which is dominated by the cold airmass whereas the warm sector has dominance of warm airmass. At the cold front dark nimbus clouds and torrential downpour are common whereas at the warm front rainfall mostly occurs in the form of drizzle and is spread over a longer period of time. The cold sector is generally dominated by cumulonimbus clouds which cause heavy downpour, thunderstorm, lightning and hailstorm. In the warm sector, the extent of cloudiness and rainfall is limited.



The favourite breeding grounds of temperate cyclones are

- **Over USA and Canada, extending over Sierra Nevada, Colorado, Eastern Canadian Rockies and the Great Lakes region**
- **Mexican Gulf**
- **The belt extending from Iceland to Barents Sea and continuing over Russia and Siberia**
- **Winter storms over Baltic Sea.**
- **Mediterranean basin extending upto Russia and even upto India in winters (called western disturbances).**
- **The Antarctic frontal zone**

During summer, all the paths of temperate cyclones shift northwards and there is no temperate cyclone over sub-tropics and the warm temperate zone, although a high concentration of storms occurs over Bering Strait, USA and Russian Arctic and sub-Arctic zone.

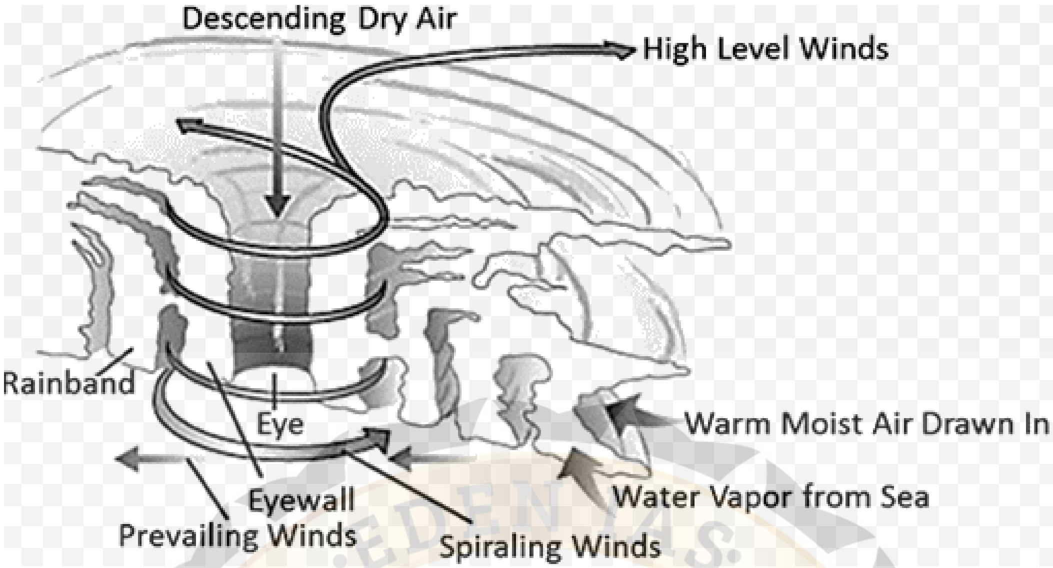
TROPICAL CYCLONES AND THUNDERSTORMS

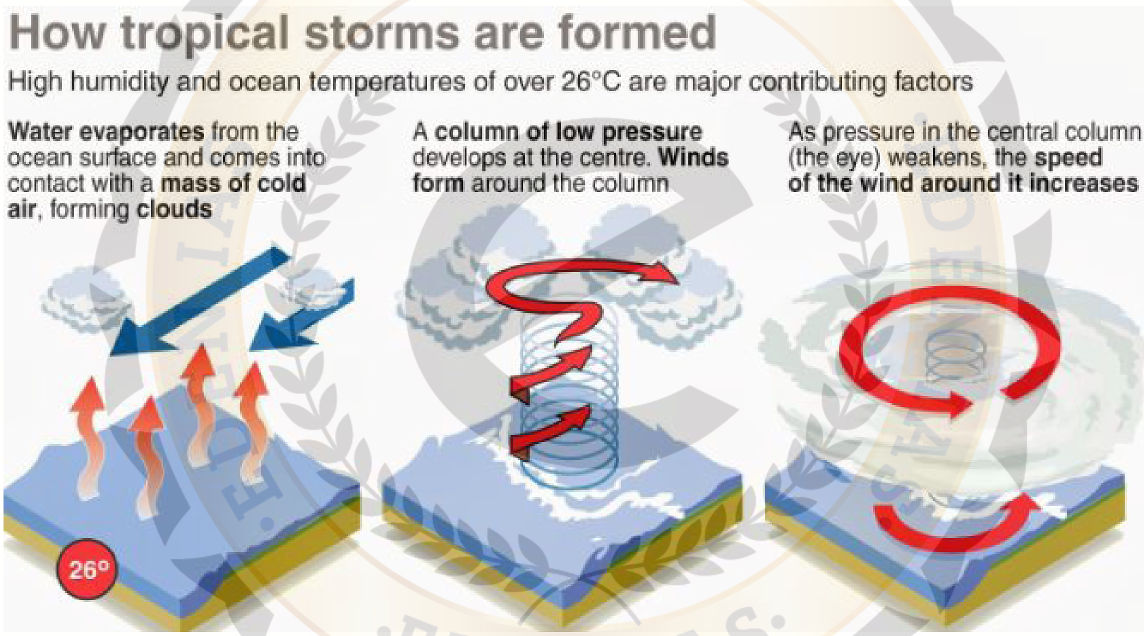
The tropical cyclones have a thermal origin, and they develop over tropical seas during certain seasons. At these locations, the local convectional currents acquire a whirling motion because of the Coriolis force generated by the earth's rotation. After developing, these cyclones advance till they find a weak spot in the trade wind belt. They originate due to local differences in the sea surface temperature.

The ideal conditions for the development of tropical cyclones are:

- **Quiet air**
- **High temperature**
- **Highly saturated atmospheric conditions.**

The source of energy for the development of tropical cyclones is latent heat of condensation. Coriolis force is necessary for their formation hence they are absent at the equator.





Favourite Breeding Grounds of tropical cyclones

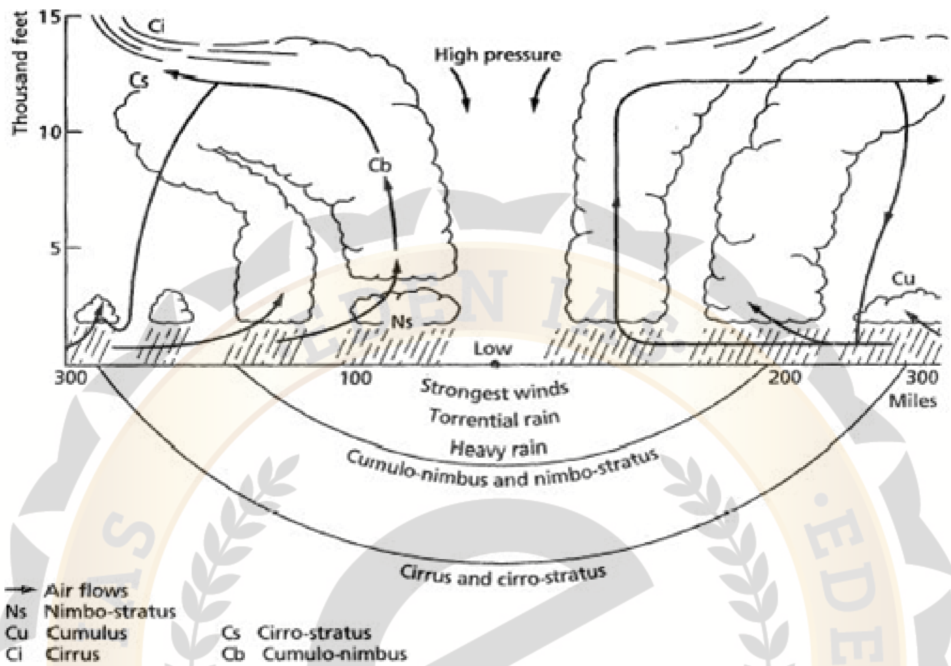
a) South-east Caribbean region where they are called hurricanes
b) Philippines islands, eastern China and Japan where they are called typhoons
c) Bay of Bengal and Arabian Sea where they are called cyclones
d) Around south-east African coast and Madagascar-Mauritius islands
e) North-west Australia where they are known as Willy-willies

The main features of tropical cyclones are as follows:

Size and Shape: - Tropical cyclones have symmetrical elliptical shapes (2:3 ratio of length and breadth) with steep pressure gradients. They have a compact size—80 km near centre, which may develop upto 300 km to 1500 km.

Wind Velocity and Strength: - Wind velocity, in a tropical cyclone, is more in poleward margins than at centre and is more over oceans than over landmasses, which are scattered with physical barriers. The wind velocity may range from nil to 1200 km per hour.

Orientation and Movement: - These cyclones start with a westward movement, but turn northwards around 20° latitude. They turn further north-eastwards around 25° latitude, and then eastwards around 80° latitude. They then lose energy and subside. Tropical cyclones follow a parabolic path, their axis being parallel to the isobars.

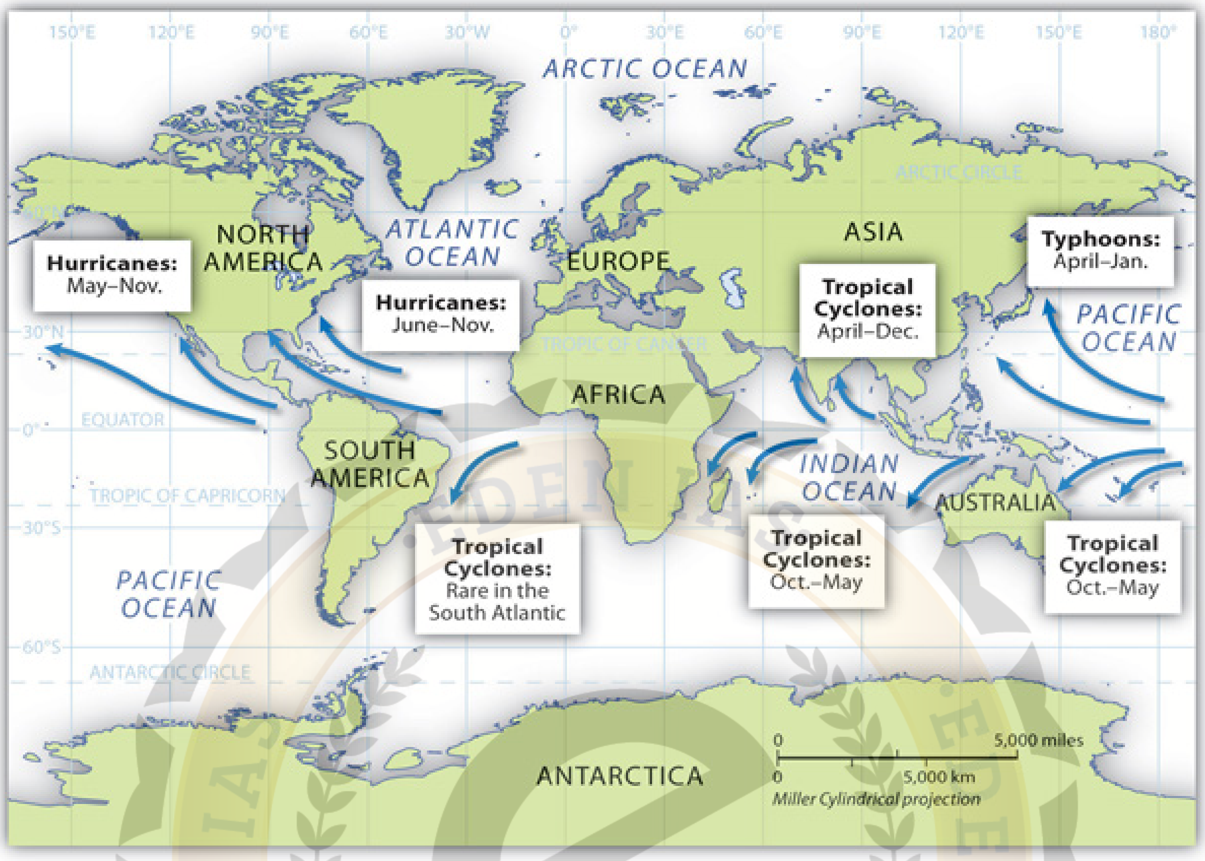


Structure of Tropical Cyclone: - The eye lies at the centre of the cyclone. The diameter of this core varies from 10 to 50 km. The wind speed is minimum and the sky remains generally clear in this region. Temperature is high due to the descending air currents which heat up by compression.

The eye wall, surrounding the eye, is made of cumulonimbus clouds, and it is characterised by winds of maximum velocities. A continuous ring of cumulonimbus clouds moves vertically. Therefore, the eye wall region witnesses the heaviest precipitation.

Two spiral bands are located outside the eye wall. A few km wide, they are also called rain bands or feeder bands. They rotate at speeds ranging from 20 km to 55 km. These regions are marked by high winds and precipitation.

The annular zone is characterised by suppressed cloudiness, fairly high temperature and low humidity conditions. The outer connective band, found at the edge of the cloud mass, has external fringe of deep convective clouds. These are produced due to the instability of air consequent upon converging air movement. A belt of limited cloud cover is found, away from the main cloud mass.



THUNDERSTORMS

Thunderstorms are local storms characterized by swift upward movement of air and heavy rainfall with cloud thunder and lightning. According to A.N. Strahler "**a thunderstorm is an intense local storm associated with large, dense cumulonimbus clouds in which there are very strong updrafts of air.**"

Because of heavy downpour associated with thunderstorms they are also called 'cloud bursts' but the rainfall is of very short duration. Thunderstorms differ from cyclones in that the latter are almost circular in shape wherein winds blow from outside towards the centre while the former is characterized by strong updraft of air. They are considered to be special case of convective mechanism.

Thunderstorms and Weather

(i) Rain Fall: - Rain fall in thunderstorms is in the form of heavy downpour with greatest intensity of all other forms of precipitation but is of short duration because of two factors viz.: (i) The air rises abruptly with great force due to which there is quick condensation and cloud formation, and (ii) there is abundant absolute humidity due to high rate of evaporation consequent upon very high temperature during summer season.

The rainfall of thunderstorm is closely related to its numerous cells. There is maximum rainfall in the centre and minimum at the periphery of each convective cell. Fully developed cell yields rainfall for about an hour whereas weak cell dies out within few minutes.

(ii) Hailstorms: - When condensation occurs below freezing point, ice particles are formed which range from the size of a pea to large ball. Hail is not associated with every thunderstorm. Not only this, hail is confined to only certain cells of a thunderstorm. Hails fall down on the ground surface when the rising convection currents become weak and feeble. The sudden fail of hails inflicts great damage to human health and wealth, birds and animals and standing agricultural crops.

(iii) Lightning: - Electrical discharge centres are developed in a mature thunderstorm. The centres of positive and negative electrical charges develop in the upper and lower portions of the clouds respectively with discharge values ranging between 20 to 30 coulombs. Lightning is produced when the electrical potential gradient between the electrical positive and negative charges becomes very steep.

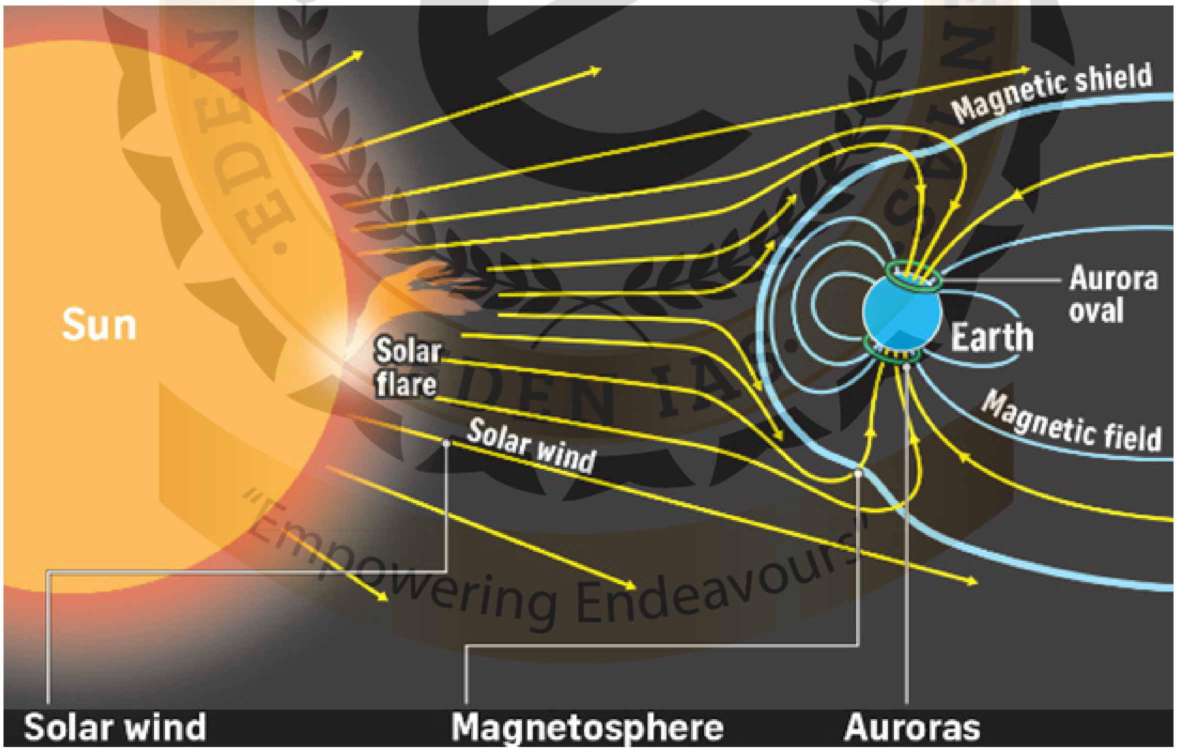
According to another view lightning is produced due to splitting of large water drops. Each water drop has positive and negative electrical charges which remain in neutral state when they are evenly balanced. This balance is disturbed due to splitting of these drops resulting into difference in positive and negative charges.

(iv) Thundering: - Sound is produced due to sudden and rapid expansion of air columns caused by intense heat (10,000°C) resulting from lightning strokes. This deafening noise produced by vibrating pressure wave due to rapid expansion of air column as mentioned above is called cloud thunder.

(v) Squall: - The downward movement and divergence of cold air at the ground surface is called squall. The velocity of squalls is equal to and some times greater than hurricane velocity and hence they inflict great damage to human structures and vegetation. Squall is produced after the thunderstorm becomes mature and heavy precipitation occurs.

AURORAS

An aurora sometimes referred to as polar lights, northern lights (aurora borealis), southern lights (aurora australis), is a natural light display in the Earth's sky, predominantly seen in the high-latitude regions (around the Arctic and Antarctic).



Auroras are produced when the magnetosphere is sufficiently disturbed by the solar wind that the trajectories of charged particles in both solar wind and magnetospheric plasma, mainly in the form of electrons and protons, precipitate them into the upper atmosphere (thermosphere/exosphere) due to Earth's magnetic field, where their energy is lost.

The resulting ionization and excitation of atmospheric constituents emits light of varying color and complexity. The form of the aurora, occurring within bands around both Polar Regions, is also dependent on the amount of acceleration imparted to the precipitating particles.

UNIT-IV
[HYDROSPHERE]

OCEAN BOTTOM TOPOGRAPHY

The use of modern technology and various expeditions now reveal that the **Ocean floor is not a monotonous plain as conceived by few rather it is a topographical complex that contain many diverse landform features which are as varied as those on land, if not more.** Four major divisions that can easily be identified on the ocean floor include

- **a) The Continental Shelf**
- **b) The Continental Slope**
- **c) The Continental Rise**
- **d) The Abyssal Plain**

Besides these major divisions, there are many associated and minor landform features viz. oceanic ridges, hills, seamounts, guyots, oceanic trenches, submarine canyons, oceanic plateau, Bank, Shoal, fracture zones, island arcs, coral reefs, submerged volcanoes and sea-scarps.

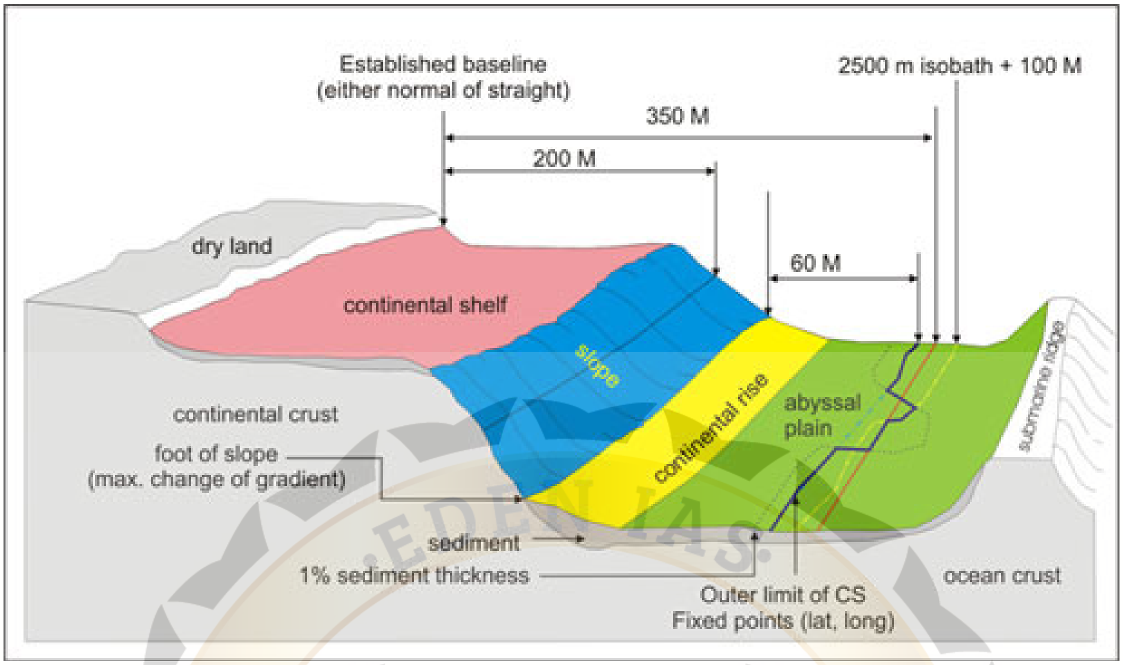
This great variety of relief is largely due to interaction of tectonic, volcanic, erosional and depositional processes. At greater depths, the tectonic and volcanic phenomena are more significant processes.

Continental Shelf

The continental shelf is the extended margin of each continent occupied by relatively shallow seas and gulfs. It is the shallowest part of the ocean showing an average gradient of1° or even less. The shelf typically ends at a very steep slope, called the shelf break.

The width of the continental shelves varies from one ocean to another. The average width of continental shelves is about80 km. The shelves are almost absent or very narrow along some of the margins like the coasts of Chile, the west coast of Sumatra, etc. On the contrary, the Siberian shelf in the Arctic Ocean, the largest in the world, stretches to 1,500 km in width. The depth of the shelves also varies; there average depth is nearly 200 meters from the mean sea level. However they may be as shallow as 30 m in some areas while in some areas it is as deep as 600 m.

The continental shelves are covered with variable thicknesses of sediments brought down by rivers, glaciers, wind, from the land and distributed by waves and currents. Massive sedimentary deposits received over a long time by the continental shelves, become the source of fossil fuels. There are various types of shelves—glaciated shelf, coral reef shelf, shelf of a large river, shelf with dendritic valleys and the shelf along young mountain ranges.



The shelves are of great use to man as marine food comes almost entirely from them; they provide the richest fishing grounds in the entire ocean, they are potential sites for economic minerals nearly twenty percent of world production of petroleum and natural gas comes from the continental shelves. They also supply raw materials for the construction sector for instance they are repositories of sand and gravel. **Under the United Nations Convention on the Law of the Sea, the name continental shelf was given a legal definition as the stretch of the seabed adjacent to the shores of a particular country to which it belongs**. Continental shelves teem with life, because of the sunlight available in shallow waters.

Continental Slope

The continental slope connects the continental shelf and the ocean basins. It begins where the bottom of the continental shelf sharply drops off into a steep slope. The gradient of the slope region varies between 2-5°. The depth of the slope region varies between 200 and 3,000 m. The slope boundary indicates the end of the continents. Canyons and trenches are observed in this region. The world's combined continental slope has a total length of approximately 300,000 km (200,000 miles) and descends at an average angle in excess of 4° from the shelf break at the edge of the continental shelf to the beginning of the ocean basins. The gradient of the slope is lowest off stable coasts without major rivers and highest off coasts with young mountain ranges and narrow continental shelves. Most Pacific slopes are steeper than Atlantic slopes. Gradients are flattest in the Indian Ocean.

Continental Rise

The continental slope gradually loses its steepness with depth. When the slope reaches a level of between 0.5° and 1°, it is referred to as the continental rise. With increasing depth the rise becomes virtually flat and merges with the abyssal plain.

Continental rises, form as a result of three sedimentary processes: mass wasting, the deposition from contour currents, and the vertical settling of biogenic particles. These sediments are composed of clay minerals and fine-grained particles (chiefly quartz, mica, and carbonate) swept off the continental shelf, wind-blown dust, organic detritus, and the tests of plankton.

Abyssal Plain

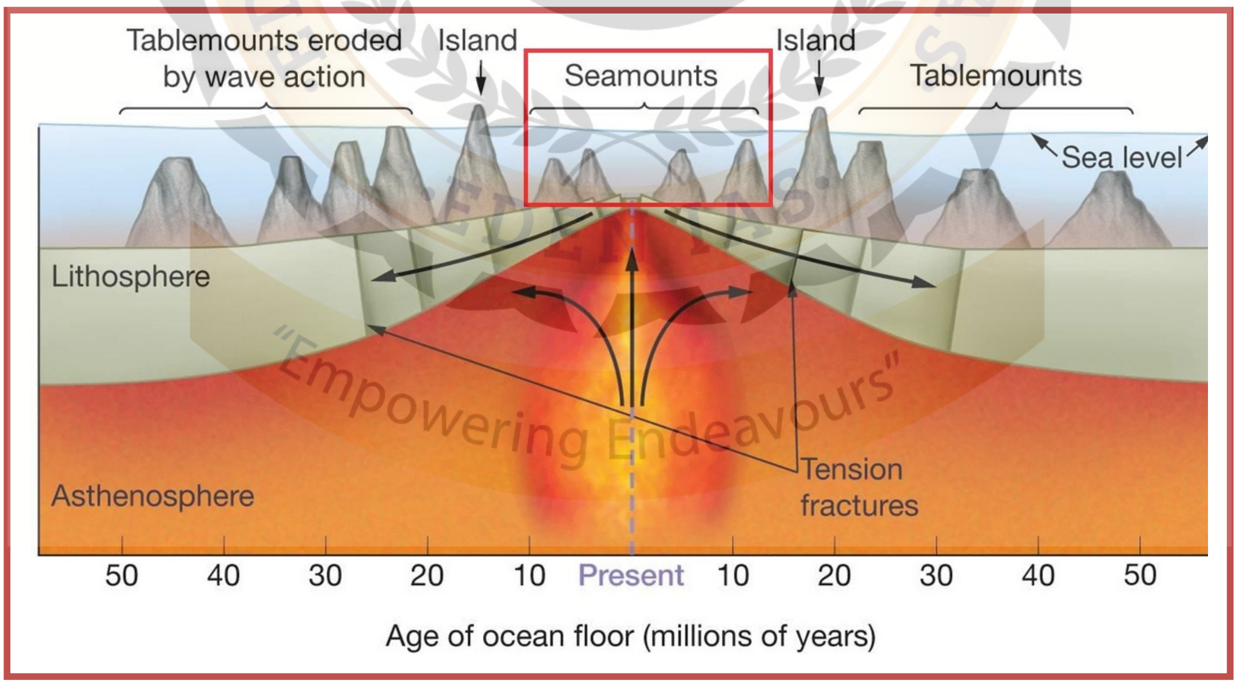
Abyssal plain sounds like a combination of two words 'abyss' and 'dismal.' And those two words might not be that far off when describing an abyssal plain. If you've ever thought the word 'abyss' reminded you of the depths of the ocean, you're on the right track. And the word 'plain' usually means a flat, wide area. Put those two things together and you have an abyssal plain, which refers to the huge, flat areas on the ocean floor. Flat is almost an understatement. The abyssal plains are some of the flattest features on the planet. Some drop in elevation less than a foot for every 1,000 feet in distance. Sometimes there are small hills called abyssal hills, but generally abyssal plains are as flat as a tabletop. The depths vary between 3,000 and 6,000m. These plains are covered with fine-grained sediments like clay and silt.

Abyssal plains are between the continental rise (the part of the underwater continental margin farthest from the shore) and the mid-ocean ridge (where under-ocean tectonic plates move away from each other, forming volcanoes that turn into underwater mountain ranges) or ocean trenches (where one tectonic plate slides beneath another, in a process called subduction).

MINOR OCEAN RELIEF FEATURES

OCEANIC RIDGES-The oceanic ridge system is a continuous underwater mountain range with parts found in every ocean of the world. The ridge system is created when magma rising between diverging plates of the lithosphere cools and forms a new layer of crust. The mountain ranges can have peaks as high as 2,500 m and some even reach above the ocean's surface. Iceland, a part of the mid-Atlantic Ridge, is an example.

ABYSSAL HILLS-SEA MOUNTS AND GUYOTS-These are elevated features of volcanic origin. A submarine mountain or peak rising more than 1,000 metres above the ocean floor is known as a seamount. Seamounts are volcanic in origin. These can be 3,000-4,500 m tall. The Emperor seamount, an extension of the Hawaiian Islands in the Pacific Ocean, is a good example. The flat topped mountains are known as guyots. Guyots show evidences of gradual subsidence through stages to become flat topped submerged mountains. Seamounts and guyots are very common in the Pacific Ocean where they are estimated to number around 10,000.



OCEANIC TRENCHES-Ocean trenches are steep depressions in the deepest parts of the ocean [where old ocean crust from one tectonic plate is pushed beneath another plate, raising mountains, causing earthquakes, and forming volcanoes on the seafloor and on land. With depths exceeding 6,000 meters (nearly 20,000 feet), trenches make up the world's "**Hadal Zone**," named for Hades, the Greek god of the underworld.

Trenches are formed by subduction, a geophysical process in which two or more of Earth's tectonic plates converge and the older, denser plate is pushed beneath the lighter plate and deep into the mantle, causing the seafloor and outermost crust (the lithosphere) to bend and form a steep, V-shaped depression. This process makes trenches dynamic geological features—they account for a significant part of Earth's seismic activity—and are frequently the site of large earthquakes, including some of the largest earthquakes on record. Subduction also generates an upwelling of molten crust that forms mountain ridges and volcanic islands parallel to the trench. Examples of these volcanic "arcs" can be seen in the Japanese Archipelago, the Aleutian Islands, and many other locations around this area called the Pacific "Ring of Fire."

The vast submarine slopes and steep walls of trenches make up much of the Hadal zone, where unique habitats extending across a range of depths are home to diverse number of species, many of which are new or still unknown to science.

Trenches are long, narrow and very deep and, while most are in the Pacific Ocean, can be found around the world. The deepest trench in the world, the Mariana Trench located near the Mariana Islands, is 1,580 miles long and averages just 43 miles wide. It is home to the Challenger Deep, which, at 10,911 meters (35,797 feet), is the deepest part of the ocean.

SUBMARINE FRACTURE ZONE-A Submarine fracture zone is a, long, narrow, and mountainous submarine lineation that generally separates ocean-floor ridges that differ in depth by as much as 1.5 km (0.9 mile).The largest fracture zones, in the eastern Pacific, are several thousand kilometres long, 100 to 200 km (60 to 125 miles) wide, and possess several kilometres of vertical relief.

OCEANIC PLATEAU-An oceanic plateau is a large, relatively flat submarine region that rises well above the level of the ambient seabed. While many oceanic plateaus are composed of continental crust, and often form a step interrupting the continental slope, some plateaus are undersea remnants of large igneous provinces.

SUBMERGED VOLCANOES-Submarine volcanoes are underwater vents or fissures in the Earth's surface from which magma can erupt. A large number of submarine volcanoes are located near areas of tectonic plate movement, known as mid-ocean ridges. The volcanoes at mid-ocean ridges alone are estimated to account for 75% of the magma output on Earth. Although most submarine volcanoes are located in the depths of seas and oceans, some also exist in shallow water, and these can discharge material into the atmosphere during an eruption. The total number of submarine volcanoes is estimated to be over 1 million, of which some 75 000 rise more than 1 km above the seabed

SEA SCARPS-An escarpment is an area of the Earth where elevation changes suddenly. Usually escarpment is used interchangeably with scarp. Some sources differentiate the two terms, however technically speaking there lies a difference, where escarpment refers to the margin between two landforms, while scarp is synonymous with a cliff or steep slope. Submarine escarpments formed due to faulting of the submarine bed is known as a sea scarp.

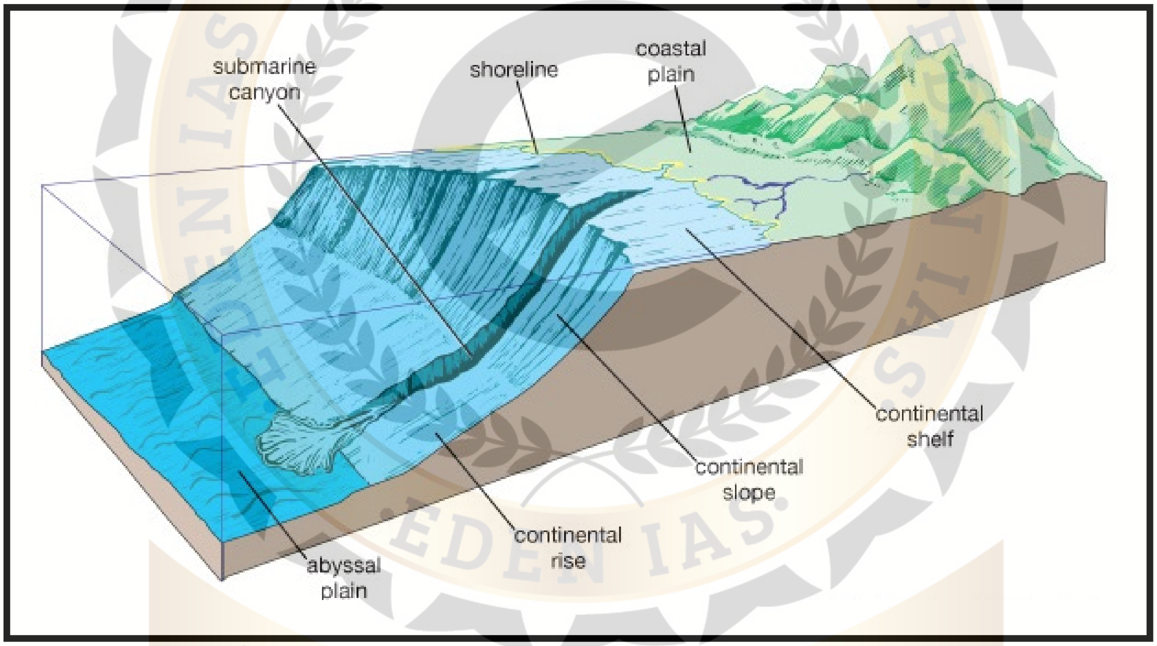
BANK, SHOAL AND REEF-These marine features are formed as a result of **erosional, depositional and biological activity.** These are produced upon features of **diastrophic** origin. Therefore, they are located on upper parts of elevations.

Bank-These marine features are formed as' a result of erosional and depositional activity. A bank is a flat topped elevation located in the continental margins. The depth of water here is shallow but enough for navigational purposes. The **Dogger Bank** in the North Sea and **Grand Bank** in the north-western Atlantic, Newfoundland are famous examples. The banks are sites of some of the most **productive fisheries of the world.**

Shoal-A shoal is a detached elevation with shallow depths. Since they project out of water with moderate heights, they are dangerous for navigation.

Reef-A reef is a predominantly organic deposit made by living or dead organisms that forms a mound or rocky elevation like a ridge. Coral reefs are a characteristic feature of the Pacific Ocean where they are associated with **seamounts and guyots.**

ISLAND ARCHS-As a lithospheric slab is being subducted, the slab melts when the edges reach a depth which is sufficiently hot. Hot, re-melted material from the subducting slab rises and leaks into the crust, forming a series of volcanoes. These volcanoes can make a chain of islands called an "island arc". Examples of island arcs are the Japanese islands, the Kuril Islands, and the Aleutian Islands of Alaska.



SUBMARINE CANYONS-Submarine Canyons are narrow steep sided valleys that cut into continental slopes and continental rises of the oceans. Submarine canyons originate either within continental slopes or on a continental shelf. They are rare on continental margins that have extremely steep continental slopes or escarpments. Submarine canyons are so called because they resemble canyons made by rivers on land. Unlike deep-sea trenches, which are found in areas where one tectonic plate slides beneath another, undersea canyons are found along the slopes of most continental margins.

OCEAN WATER TEMPERATURE

The temperature of the oceanic water is important for marine organisms including plants (phytoplanktons) and animals (zooplanktons). The temperature of sea water also affects the climate of coastal lands and plants and animals therein. The study of the temperature of the oceans is important for determining the movement of large volumes of water (vertical and horizontal ocean currents), type and distribution of marine organisms at various depths of oceans, climate of coastal lands, etc.

Three types of instruments are used for recording ocean temperatures, viz. Standard thermometers are used to measure the surface temperature; the reversing thermometers are used to measure sub-surface temperature, and the thermographs. Nowadays, the automatic self-recording instruments are also used instead of the above-mentioned thermometers.

SOURCES OF OCEANIC HEAT

The sun is the principal source of energy for oceans. Apart from that, the ocean is also heated by the inner heat of the ocean itself. The ocean water is heated by the following processes:

(1) Absorption of radiation from the sun is maximum over low latitude regions due to vertical insolation, whereas it decreases steadily towards poles. Even within the same latitude, the solar insolation received by the ocean varies due to factors such as currents and cloudiness.

(2)The convectional currents in the water body also heat up the oceanic water. Since the temperature of the earth increases with increasing depth, the ocean water at great depths is heated faster than the upper water layers in the ocean. So, a convectional oceanic circulation at the bottom layers of ocean water takes place causing circulation of heat in water.

(3)Kinetic energy is produced due to friction caused by the surface wind and the tidal currents which increase stress on the water body. Thus the ocean water is heated.

(4) Submarine Volcanism also releases some heat into ocean waters.

The ocean water is cooled in the following ways

1. Back radiation from the sea surface takes place as the solar energy once received is re- radiated as long wave radiation from the seawater.

2. Exchange of heat between the sea and the atmosphere takes place, but only if the sea water is colder or warmer than the atmosphere.

3. Evaporation takes place when sea water is warm and atmospheric stratification is unstable.

FACTORS AFFECTING DISTRIBUTION OF TEMPERATURE IN OCEANS

The following factors affect the distribution of temperature of ocean water:

(1) Latitudes:

The temperature of surface water decreases from equator towards the poles because the sun's rays become more and more slanting and thus the amount of insolation decreases poleward 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 40th latitude and the poles in both the hemispheres.

(2) 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 former and water in the latter. 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 former than the latter.

(3) Prevailing wind:

Wind direction largely affects the distribution of temperature of ocean water. The winds blowing from the land towards the oceans and seas (e.g., offshore winds) drive warm surface water away from the coast resulting into upwelling of cold bottom water from below. Thus, the replacement of warm water by cold water introduces longitudinal variation in temperature. Contrary to this, the onshore winds pile up warm water near the coast and thus raise the temperature. For example, trade winds cause low temperature (in the tropics along the eastern margins of the oceans or the western coastal regions of the continents) because they blow from the land towards the oceans whereas these trade winds raise the temperature in the western margins of the oceans or the eastern coastal areas of the continents because of their onshore position.

Similarly, the eastern margins of the oceans in the middle latitudes (western coasts of Europe and North America) have relatively higher temperature than the western margins of the oceans because of the onshore position of the westerlies.

(4) 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. For example, the Gulf Stream raises the temperature near the eastern coasts of N. America and the western coasts of Europe. Kuroshiyo drives warm water away from the eastern coast of Asia and raises the temperature near Alaska. Labrador cool current lowers down the temperature near north-east coast of N. America. Similarly, the temperature of the eastern coast of Siberia becomes low due to Kurile cool current. It may be mentioned that warm currents raise the temperature more in the northern hemisphere than in the southern hemisphere which is apparent from the fact that the 5°C isotherm reaches 70° latitude in the northern Atlantic Ocean whereas it is extended up to only 50° latitude in the southern Atlantic Ocean. This is because of more dominant effects of the warm Brazil current in the southern Atlantic Ocean.

(5) Minor Factors:

Minor factors include:

(i) Submarine ridges,

(ii) Local weather conditions like storms, cyclones, hurricanes, fog, cloudiness, evaporation and condensation, and

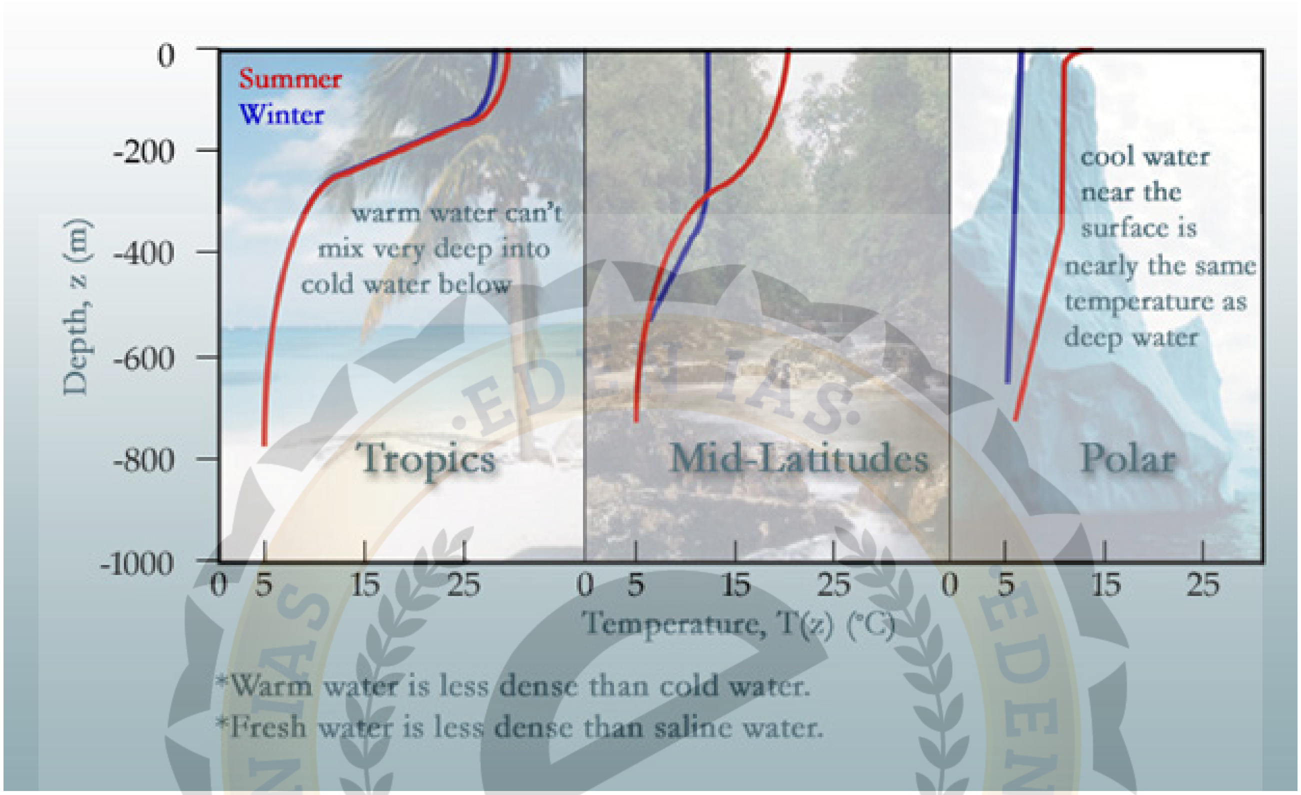
(iii) Location and shape of the sea.

VERTICAL DISTRIBUTION OF TEMPERATURE

Longitudinally more extensive seas in the low latitudes have higher temperature than the latitudinally more extensive seas as the Mediterranean Sea records higher temperature than the Gulf of California. 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 (Baltic Sea records 0°C (32°F) and open seas have 4.4°C or 40°F).

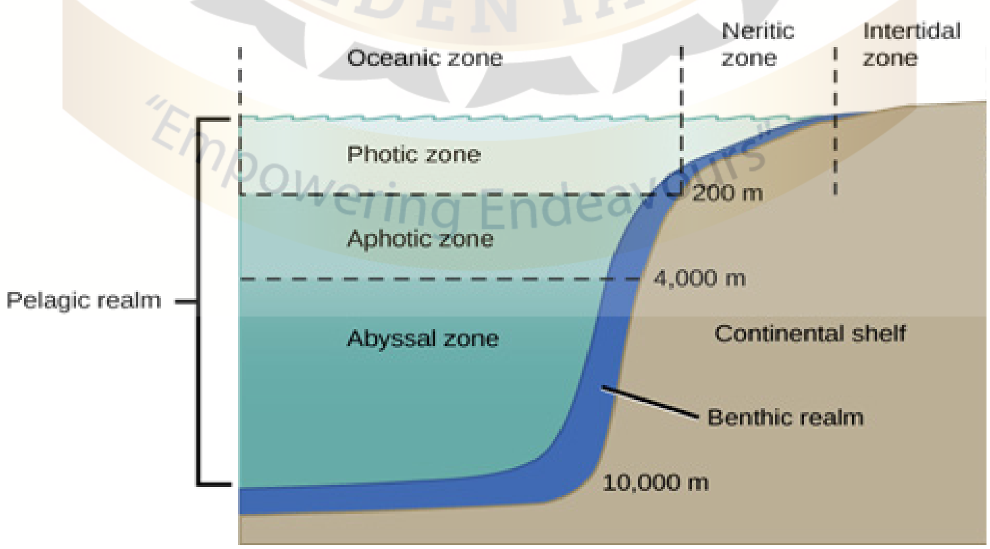
There is a gradual decrease of temperature with increasing descent. Normally, 90 per cent of the solar heat is absorbed in the topmost 15.6 m (60 feet) of water. The sea water temperature corresponds to the surface temperature only up to a depth of about 100 m, and, with further descent, temperature generally decreases.

In tropical oceans and seas, three layers can be recognised from surface to bottom. The first layer is about 500 m thick with temperature varying between 20° and 25°C. In mid-latitude regions this top layer is found only during summer. The thermocline layer is found just below the first layer. It is characterised by rapid decrease of temperature with increasing depth. The third layer is very cold and is extended up to the ocean floor.



In contrast to the tropical oceans, in Polar Regions only one layer of cold water is identified. It extends from the surface to the bottom.

As the temperature decreases in water with increasing depths, some scientists have divided the oceans into two broad zones: (i) photic or euphotic zone which extends from the upper surface to 200 m; the photic zone receives adequate solar insolation; and (ii) aphotic zone extending from 200 m to the ocean bottom; this zone does not receive adequate sunrays.



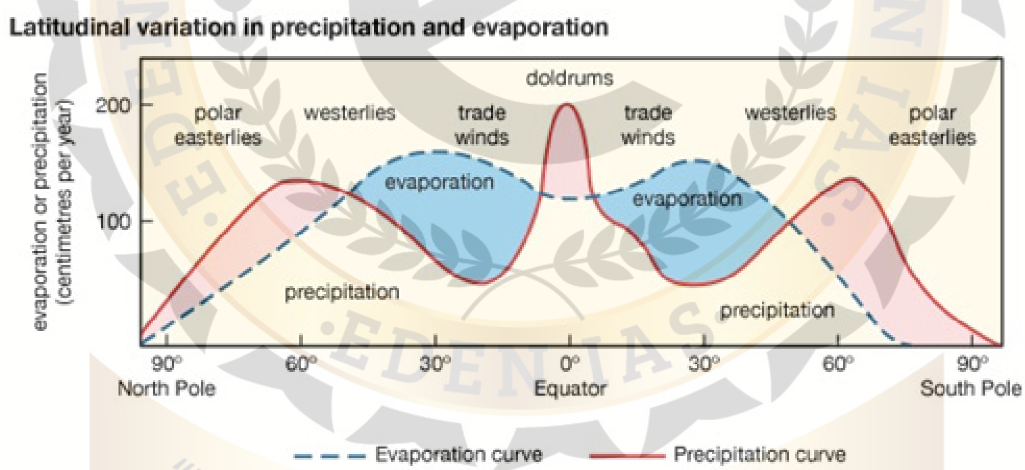
SALINITY OF THE OCEANS

Salinity means the amount of dissolved salts-per unit mass of water. Salinity is expressed as the number of grams of dissolved salts in 1,000 grams of sea water. The average salinity of the sea water is 35 per thousand. It means that in one kilogram of sea water, there are 35 grams of dissolved salts. Salinity is defined as the ratio between the weight of the dissolved materials and the weight of the sample sea water. Generally, salinity is defined as 'the total amount of solid material in grams contained in one kilogram of sea water and is expressed as part per thousand (%o) e.g., 30%o (Means 30 grams of salt in 1000 grams of sea water).Salinity of 24.7 (24.7 o/oo) has been considered as the upper limit to demarcate 'brackish water'.

The oceanic salinity not only affects the marine organisms and plant community but it also affects the physical properties of the oceans such as temperature, density, pressure, waves and currents etc. The freezing point of ocean water also depends on salinity e.g., more saline water freezes slowly in comparison to less saline water.

The boiling point of saline water is higher than the fresh water. Evaporation is also controlled by salinity as it is lower over more saline water than over less saline water. Salinity also increases the density of sea water. This is why man is seldom drowned in the sea water with very high salinity. Variation in salinity causes ocean currents.

On an average, salinity decreases from equator towards the poles. It may be mentioned that the highest salinity is seldom recorded near the equator though this zone records high temperature and evaporation but high rainfall reduces the relative proportion of salt. Thus, the equator accounts for only $\mathbf{35^0/_{00}}$ salinity.



The highest salinity is observed between **20^0-40^0N ($36^0/_{00}$)** because this zone is characterized by hi0gh temperature, high evaporation but significantly low rainfall. The average salinity of $\mathbf{35^0/_{00}}$ is recorded between **10^0-30^0** latitudes in the southern hemisphere. The zone between **40^0-60^0** latitudes in both the hemispheres records low salinity where it is $\mathbf{31^0/_{00}}$and $\mathbf{33^0/_{00}}$in the northern and the southern hemispheres respectively.

Salinity further decreases in the polar zones because of influx of melt-water. On an average, the northern and the southern hemispheres record average salinity of $\mathbf{34^0/_{00}}$ and $\mathbf{35^0/_{00}}$ respectively.

On the basis of latitudinal distribution of salinity four zones of oceanic salinity may be identified e.g.

(i) Equatorial zones of relatively low salinity (due to excessive rainfall),

(ii) Tropical zone (**20^0-30^0)** of maximum salinity (due to low rainfall and high evaporation),

(iii) Temperate zone of low salinity, and

(iv) Sub-polar and polar zone of minimum salinity.

Salinity is affected mainly by three factors viz.

- Salinity is reduced by precipitation,
- Salinity increases due to evaporation, and
- Salinity varies due to mixing of water of different character.

There is also temporal variation in oceanic salinity. The oceans in the northern hemisphere record maximum and minimum salinity during June (increased evaporation) and December (low evaporation) respectively.

VERTICAL DISTRIBUTION OF SALINITY

No definite trend of distribution of salinity with depth can be spelt out because both the trends of increase and decrease of salinity with increasing depths have been observed. For example, salinity at the southern boundary of the Atlantic is **$33^0/_{00}$** at the surface but it increases to **$34.5^0/_{00}$** at the depth of 200 fathoms (1200 feet).It further increases to **34.75%** at the depth of 600 fathoms. On the other hand, surface salinity is $37^0/_{00}$ at 20°S latitude but it decreases to **$35^0/_{00}$** at greater depth.

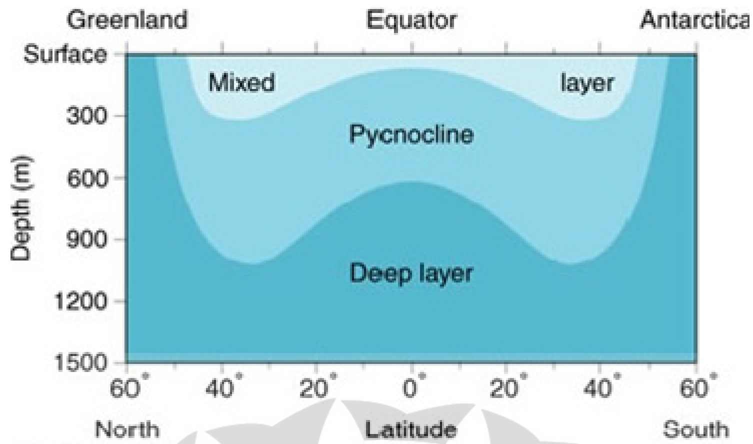
The following characteristics of vertical distribution of salinity may be stated:

1. Salinity increases with increasing depth in high latitudes i.e. there is positive relationship between the amount of salinity and depth because of denser water below.

2. The trend of increase of salinity with increasing depths is confined to 200 fathoms from the surface in middle latitudes beyond which it decreases with increasing depths. Salinity is low at the surface at the equator due to high rainfall and transfer of water through equatorial currents but higher salinity is noted below the water surface. It again becomes low at the bottom. More studies and data of salinity distribution at regular depths in different oceans and seas are required so that definite characteristic features of vertical distribution of salinity may be determined.

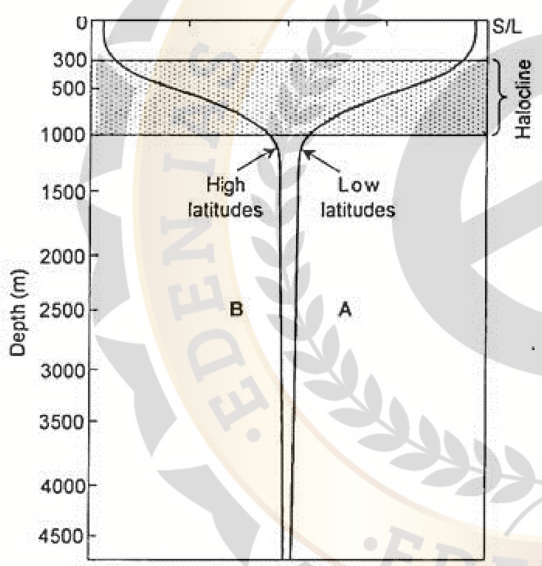
3. Maximum salinity is found in the upper layer of the oceanic water. Salinity decreases with increasing depth. Thus, the upper zone of maximum salinity and the lower zone of minimum salinity is separated by a transition zone which is called as thermocline zone, on an average above which high salinity is found while low salinity is found below this zone. It may be remembered that this should not be taken as a general rule because the vertical distribution of salinity is very complicated.

It may be mentioned that the depth zone of oceans between 300m and 1000m is characterized by varying trends of vertical distribution of temperature, density of seawater, and salinity of ocean water. This zone is characterized by rapid change of seawater density (increase in density with increasing depth in low latitudes, but constant high density in high latitudes) and is known as **Pycnocline**, while this zone represents rapid decrease of temperature with increasing depth upto 1000m in low latitudes and is called as **Thermocline**.

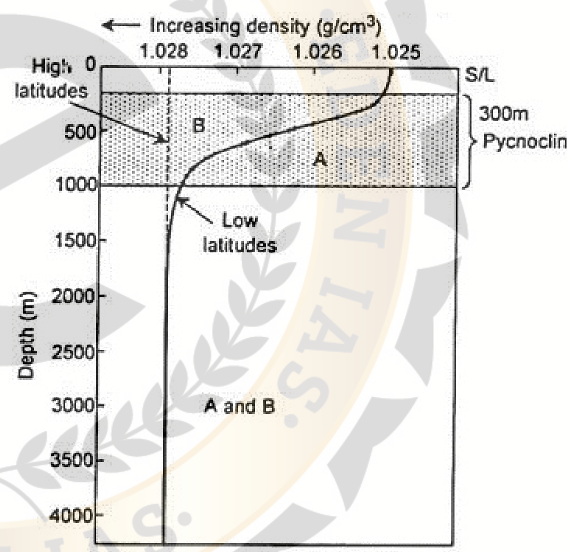


On the other hand, this zone, representing rapid change of salinity (decrease in sea water salinity with increasing depth in low latitudes, and increase in sea water salinity with increasing depth in high latitudes) is known as **Halocline.**

VERTICAL SALINITY CURVE



VERTICAL DENSITY CURVE



DENSITY OF THE OCEANS

The density of seawater plays a vital role in causing ocean currents and circulating heat because of the fact that dense water sinks below less dense. Salinity, temperature and depth all affect the density of seawater.

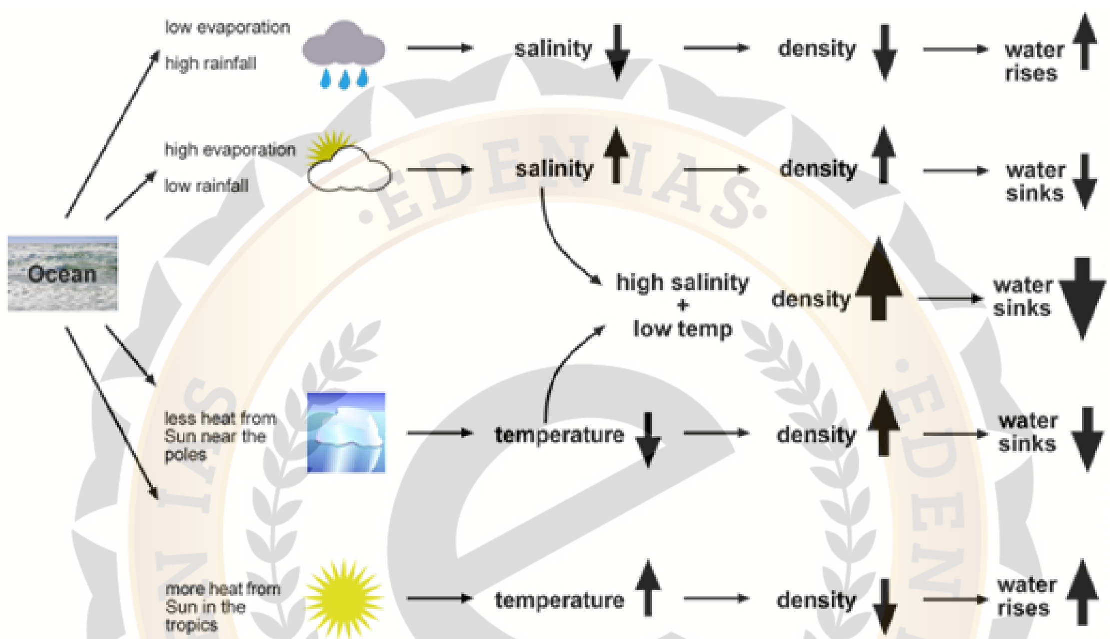
Density is a measure of how tightly a certain amount of matter is packed into a given volume. The more the stuff is packed in, the higher the density. Density can be calculated by dividing an object's mass by its volume. It is commonly measured in grams per millilitre or grams per cubic centimetre.

Seawater is not just water – it has lots of chemicals packed into it. This means it is denser than pure water. The higher the salinity, higher is the density.

Variation in density

Seawater density varies from place to place because it is affected by salinity and temperature. This means that ships float higher or lower in the water, depending on the density of the ocean.

High salinity makes water denser. This is because there is more salt packed into the water. High temperature makes water less dense. As water gets warmer, its molecules spread out, so it becomes less dense. As it gets colder, it becomes denser. Most chemicals get denser when they turn from a liquid to a solid, but water is different. When liquid water freezes into solid ice, it becomes less dense. When ice forms, water molecules arrange themselves into a rigid but open pattern. This structure is less dense than the liquid water, so ice floats. Deep water is denser than shallow water. The water molecules are packed together more tightly because of the weight of water above pushing down.



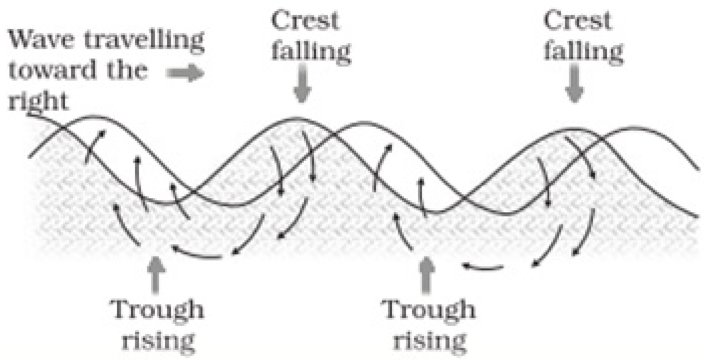
Dense water sinks below less dense water. This is the principle that drives the deep ocean currents that circulate around the world. A combination of high salinity and low temperature near the surface makes seawater dense enough to sink into the deep ocean and flow along the bottom of the basins.

OCEAN WATER CIRCULATION-WAVES

Waves are actually the energy, not the water as such, which moves across the ocean surface. Water particles only travel in a small circle as a wave passes. Wind provides energy to the waves. Wind causes waves to travel in the ocean and the energy is released on shorelines. The motion of the surface water seldom affects the stagnant deep bottom water of the oceans. As a wave approaches the beach, it slows down.

This is due to the friction occurring between the dynamic water and the sea floor. And, when the depth of water is less than half the wavelength of the wave, the wave breaks. The largest waves are found in the open oceans. Waves continue to grow larger as they move and absorb energy from the wind. Most of the waves are caused by the wind driving against water. When a breeze of two knots or less blows over calm water, small ripples form and grow as the wind speed increases until white caps appear in the breaking waves. Waves may travel thousands of km before rolling ashore, breaking and dissolving as surf.

A wave's size and shape reveal its origin. Steep waves are fairly young ones and are probably formed by local wind. Slow and steady waves originate from faraway places, possibly from another hemisphere. The maximum wave height is determined by the strength of the wind, i.e. how long it blows and the area over which it blows in a single direction. Waves travel because wind pushes the water body in its course while gravity pulls the crests of the waves downward. The falling water pushes the former troughs upward, and the wave moves to a new position.

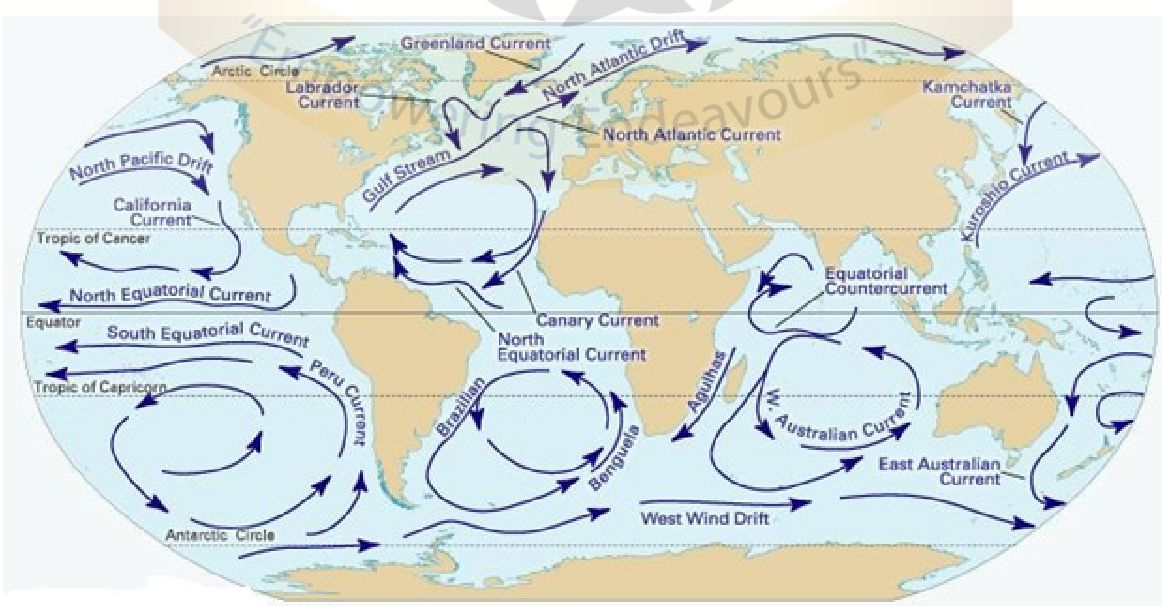


The actual motion of the water beneath the waves is circular. It indicates that things are carried up and forward as the wave approaches, and down and back as it passes.

- **Wave crest and trough**: The highest and lowest points of a wave are called the crest and trough respectively.
- **Wave height**: It is the vertical distance from the bottom of a trough to the top of a crest of a wave.
- **Wave amplitude**: It is one-half of the wave height.
- **Wave period**: It is merely the time interval between two successive wave crests or troughs as they pass a fixed point.
- **Wavelength**: It is the horizontal distance between two successive crests.
- **Wave speed**: It is the rate at which the wave moves through the water, and is measured in knots.
- **Wave frequency**: It is the number of waves passing a given point during a one second time interval

OCEAN CURRENTS

Ocean currents are like rivers flowing in the oceans. They represent a regular volume of water in a definite path and direction. An ocean current is a continuous, directed movement of seawater generated by forces acting upon it. Ocean currents flow for great distances, and together, create the global conveyor belt which plays a dominant role in determining the climate of many of the Earth's regions. More specifically, ocean currents influence the temperature of the regions through which they travel. For example, warm currents traveling along more temperate coasts increase the temperature of the area by warming the sea breezes that blow over them. Perhaps the most striking example is the Gulf Stream, which makes northwest Europe much more temperate than any other region at the same latitude. Another example is Lima, Peru where the climate is cooler (sub-tropical) than the tropical latitudes in which the area is located, due to the effect of the Humboldt Current.



Ocean currents are streams made up of horizontal and vertical components of the circulation system of the ocean waters that is produced by gravity, wind friction, and water density variation in different parts of the ocean. Ocean currents are similar to winds in the atmosphere in that they transfer significant amounts of heat from Earth's equatorial areas to the poles and thus play important roles in determining the climates of coastal regions. In addition, ocean currents and atmospheric circulation influence one another.

FACTORS RESPONSIBLE FOR THE CREATION AND MODIFICATION OF OCEAN CURRENTS

- **Factors related to the earth's rotation:-**Gravitational force and force of deflection.
- **Factors originating within the sea:-**Atmospheric pressure, winds, precipitation, evaporation and insolation.
- **Factors originating within the sea:-**Pressure gradient, temperature difference, salinity, density and melting of ice.
- **Factors modifying the ocean currents:-**Direction and shape of the coast, seasonal variations and ocean bottom topography.

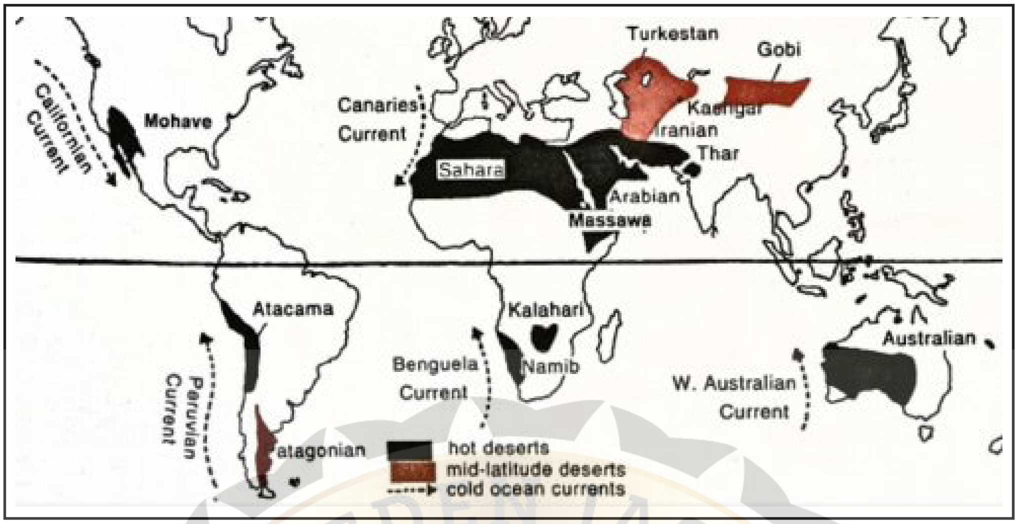
The general movement of the currents in the northern hemisphere is clockwise and in the southern hemisphere, anti-clockwise. This is due to the Coriolis force which is a deflective force and follows Ferrel's law. A notable exception to this trend is seen in the northern part of the Indian Ocean where the current movement changes its direction in response to the seasonal change in the direction of monsoon winds.

The warm currents move towards the cold seas and cool currents towards the warm seas. In the lower latitudes, the warm currents flow on the eastern shores and cold on the western shores. The situation is reversed in the higher latitudes—the warm currents move along the western shores and the cold currents along the eastern shores. Convergence along which the warm and cold currents meet and divergence from which they move out in different directions also control the currents.

The shape and position of coasts play an important role in guiding the direction of currents. The currents flow not only at the surface but also below the sea surface. Such currents are caused by the differences in salinity and temperature. For instance, heavy surface water of the Mediterranean Sea sinks and flows westward past Gibraltar as a sub-surface current.

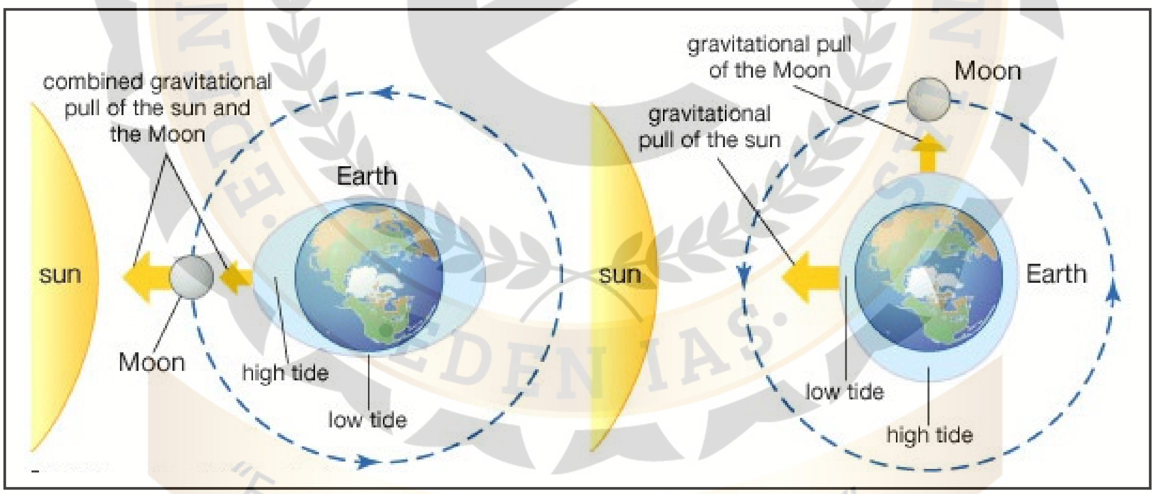
DESERT FORMATION AND OCEAN CURRENTS

The aridity of the hot deserts is mainly due to the effects of off-shore Trade Winds; hence they are also called **Trade Wind Deserts.** The major hot deserts of the world are located on the western coasts of continents between latitudes 15° and 30°N. and S .They include the biggest Sahara Desert (3.5 million square miles). The next biggest desert is the Great Australian Desert. The other hot deserts are the Arabian Desert, Iranian Desert, Thar Desert, Kalahari and Namib Deserts. The hot deserts lie along the Horse Latitudes or the Sub-Tropical High Pressure Belts where the air is descending, a condition least favorable for precipitation of any kind to take place. The rain-bearing Trade Winds blow **off-shore** and the Westerlies that are on-shore blow outside the desert limits. Whatever winds reach the deserts blow from cooler to warmer regions, and their relative humidity is lowered, making condensation almost impossible. There is scarcely any cloud in the continuous blue sky. The relative humidity is extremely low, decreasing from 60 per cent in coastal districts to less than 30 per cent in the desert interiors. Under such conditions, every bit of moisture is evaporated and the deserts are thus regions of permanent drought. Precipitation is both scarce and most unreliable. On the western coasts, the presence of cold currents gives rise to **mists and fogs** by chilling the on-coming air. This air is later warmed by contact with the hot land, and little rain falls. The **desiccating effect** of the cold Peruvian Current along the Chilean coast is so pronounced that the mean annual rainfall for the Atacama Desert is not more than 1.3 cm.



OCEAN TIDES

Tides are the cyclic deformations of one astronomical body caused by the gravitational forces exerted by others. The most familiar are the periodic variations in sea level on Earth that correspond to changes in the relative positions of the Moon and the Sun. The tides may be regarded as forced waves, partially running waves and partially standing waves. They are manifested by vertical movements of the sea surface (the height maximum and minimum are called high tide water [HTW] and low tide water [LTW];(HTW-LTW=Tidal Range)) and alternating horizontal movements of the water, the tidal currents. The words ebb and flow are used to designate the falling tide and the rising tide, respectively.



The moon's gravitational pull to a great extent and to a lesser extent the sun's gravitational pull, are the major causes for the occurrence of tides. Another factor is centrifugal force, which is the force that acts to counter balance the gravity. Together, the gravitational pull and the centrifugal force are responsible for creating the two major tidal bulges on the earth. On the side of the earth facing the moon, a tidal bulge occurs while on the opposite side though the gravitational attraction of the moon is less as it is farther away, the centrifugal force causes tidal bulge on the other side.

The 'tide-generating' force is the difference between these two forces; i.e. the gravitational attraction of the moon and the centrifugal force. On the surface of the earth, nearest the moon, pull or the attractive force of the moon is greater than the centrifugal force, and so there is a net force causing a bulge towards the moon. On the opposite side of the earth, the attractive force is less, as it is farther away from the moon, the centrifugal force is dominant. Hence, there is a net force away from the moon. It creates the second bulge away from the moon. On the surface of the earth, the horizontal tide generating forces are more important than the vertical forces in generating the tidal bulges

The tidal bulges on wide continental shelves have greater height. When tidal bulges hit the mid-oceanic islands they become low. The shape of bays and estuaries along a coastline can also magnify the intensity of tides. Funnel-shaped bays greatly change tidal magnitudes. When the tide is channelled between islands or into bays and estuaries they are called tidal currents.

Types of Tides

Tides vary in their frequency, direction and movement from place to place and also from time to time. Tides may be grouped into various types based on their frequency of occurrence in one day or 24 hours or based on their height. Tides based on Frequency

Semi-diurnal tide: The most common tidal pattern, featuring two high tides and two low tides each day. The successive high or low tides are approximately of the same height.

Diurnal tide: There is only one high tide and one low tide during each day. The successive high and low tides are approximately of the same height.

Mixed tide: Tides having variations in height are known as mixed tides. These tides generally occur along the west coast of North America and on many islands of the Pacific Ocean. Tides based on the Sun, Moon and the Earth Positions The height of rising water (high tide) varies appreciably depending upon the position of sun and moon with respect to the earth. Spring tides and neap tides come under this category.

Spring tides: The position of both the sun and the moon in relation to the earth has direct bearing on tide height. When the sun, the moon and the earth are in a straight line, the height of the tide will be higher. These are called spring tides and they occur twice a month, one on full moon period and another during new moon period.

Neap tides: Normally, there is a seven day interval between the spring tides and neap tides. At this time the sun and moon are at right angles to each other and the forces of the sun and moon tend to counteract one another. The Moon's attraction, though more than twice as strong as the sun's, is diminished by the counteracting force of the sun's gravitational pull.

Once in a month, when the moon's orbit is closest to the earth (perigee), unusually high and low tides occur. During this time the tidal range is greater than normal. Two weeks later, when the moon is farthest from earth (apogee), the moon's gravitational force is limited and the tidal ranges are less than their average heights.

When the earth is closest to the sun (perihelion), around 3rd January each year, tidal ranges are also much greater, with unusually high and unusually low tides. When the earth is farthest from the sun (aphelion), around 4th July each year, tidal ranges are much less than average. The time between the high tide and low tide, when the water level is falling, is called the ebb. The time between the low tide and high tide, when the tide is rising, is called the flow or flood

UNIT- V
[BIOGEOGRAPHY]

SOIL TYPES AND CHEMISTRY

The top most thin layer of the earth's surface consisting of rock and mineral particles mixed with decayed organic matter, which differs from the material below in morphology, physical makeup, chemical properties and biological composition is known as Soil. Soil is a natural body of organic and inorganic constituents. Soil is like the skin of the earth and it is indispensible for the existence of life on earth.

The look and feel of a soil is referred to as SOIL TEXTURE and is determined by the size and type of particles that make up the soil (including the organic but mostly referring to the inorganic material).The size of the ex-rock pieces (now the inorganic soil particles) varies substantially, from large bits of gravel to much smaller clay pieces. How you refer to the soil particles is actually based on their size:

- Gravel - particles greater than 2 mm in diameter
- Coarse sand - particles less than 2 mm and greater than 0.2 mm in diameter
- Fine sand - particles between 0.2 mm and 0.02 mm in diameter
- Silt - particles between 0.02 mm and 0.002 mm in diameter
- Clay - particles less than 0.002 mm in diameter

The soil texture directly affects:

- The soil water content
- Water flow
- Retention of nutrients
- Extent of aeration

Note-Rather than being one type or the other, most soils are a combination of sand, silt and clay. Generally speaking, good soils are a combination of clay and humus. The clay-humus complex is essential for a fertile soil as it provides it with a high water and nutrient holding capacity. Humus acts as cement binding the soil particles together and thus reducing the risk of erosion.

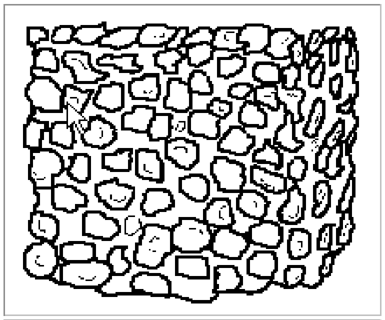
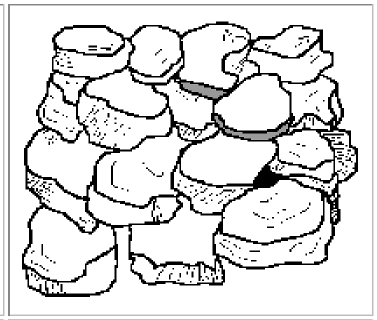
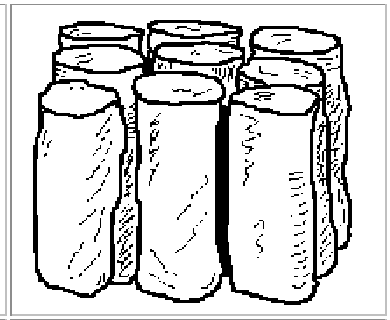
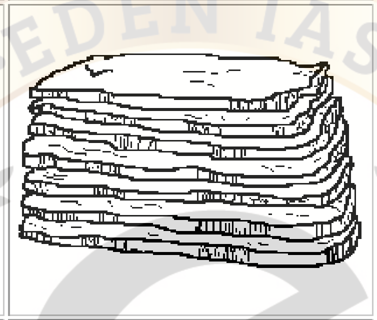
Soil Structure

Soil structure refers to the arrangement of soil separates into units called soil aggregates. An aggregate possesses solids and pore space. Aggregates are separated by planes of weakness and are dominated by clay particles. Silt and fine sand particles may also be part of an aggregate. The aggregate acts like a larger silt or sand particle depending upon its size.

Type	*Description*
Granular	Rounded surfaces
Crumb	Rounded surfaces but larger than granular
Subangular blocky	Cube-like with flattened surfaces and rounded corners
Blocky	Cube-like with flattened surfaces and sharp corners
Prismatic	Rectangular with a long vertical dimension and flattened top
Columnar	Rectangular with a long vertical dimension and rounded top
Platy	Rectangular with a long horizontal dimension
Single grain	No aggregation of coarse particles when dry
Structureless	No aggregation of fine particles when dry

The arrangement of soil aggregates into different forms gives a soil its structure. The natural processes that aid in forming aggregates are:

1) **Wetting and drying**
2) **Freezing and thawing**
3) **Microbial activity that aids in the decay of organic matter**
4) **Activity of roots and soil animals and**
5) **Adsorbed cations**

		
Granular: Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.	**Blocky**: Irregular blocks that are usually 1.5 - 5.0 cm in diameter.	**Prismatic**: Vertical columns of soil that might be a number of cm long. Usually found in lower horizons.
		
Columnar: Vertical columns of soil that have a salt "cap" at the top. Found in soils of arid climates.	**Platy**: Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.	**Single Grained**: Soil is broken into individual particles that do not stick together. Always accompanies a loose consistence. Commonly found in sandy soils.

Soil Types

Chalky Soil

Sometimes called basic soils, they are always very alkaline. Chalk is a solid, soft rock which breaks down easily. It is very free draining, and chalky soils hold little water and dry out easily. Chalky soils are fertile, but many of the nutrients are not available to plants because of the high alkalinity of the soil, which prevents the absorption of iron by plant roots.

Clayey Soil

The clay forms a heavy mass which makes it difficult for air, water and plant roots to move through the soil when wet. Once dry they form rock-hard clots. Blue or grey clays have poor aeration and must be loosened in order to support healthy growth. Red colour in clay soil indicates good aeration and a "loose" soil that drains well. Plants can take advantage of the high level of nutrients if drainage is adequate.

Loamy Soil

Considered to be the perfect soil, a mix of 40 % sand, 40% silt and 20% clay. Due to mix variations loam can range from easily workable fertile soils full of organic matter, to densely packed sod. Characteristically they drain well, yet retain moisture and are nutrient rich, making them ideal for cultivation.

Peat Soil

Peat soils are formed from partially decomposed plant material under anaerobic water saturated conditions. They are found in peatlands (also called bogs or mires). Peatlands cover about 3% of the earth's land mass; they are found in the temperate (Northern Europe and America) and tropical regions (South East Asia, South America, South Africa and the Caribbean) .Peat soils are classified as histosols. These are soils high in organic matter content. Peat formation is influenced by moisture and temperature. In highly saturated anaerobic soils, decomposition of plant material by micro organisms is slowed down, resulting in high carbon accumulation. In colder climates decomposition of plant material by micro organisms is slowed down leading to quicker peat formation. The carbon content of peat soils makes peatland a major storage of carbon on the earth surface. This is why its importance in fighting climate change can never be overemphasized. Provided they are not too acid and have effective sub drainage, these are rich in plant foods. Converting existing soil into a peat type soil is achieved by adding large amounts of organic matter.

Sandy Soils

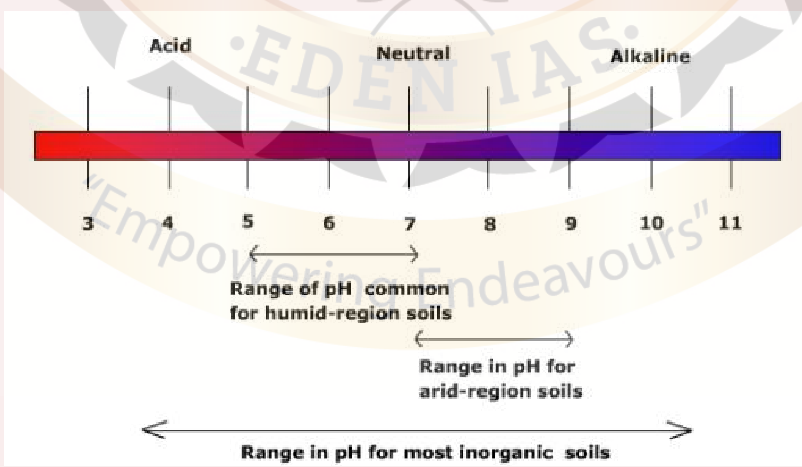
Sandy soils generally have a fine grained texture. They retain very little in the way of water, fertilizers or nutrients which means they are extremely poor. Prone to over-draining and summer dehydration, and in wet weather can have problems retaining moisture and nutrients and can only be revitalized by the addition of organic matter. Sandy soils are light and easy to dig, hoe and weed.

Silty Soil

Silty soil is considered to be one among the most fertile soils. Silt is often found in river estuaries, because the fine particles are washed downstream and deposited when the water flows more sluggishly. This soil is soft and smooth, with individual pieces close together. It too holds a lot of water, but the slightly larger particles make it a little better at draining than clay.

Soil Scale: Acidity or Alkalinity

An important aspect of soil chemistry is acidity, alkalinity (baseness) or neutrality.Low pH values indicate an acidic soil, and a high pH indicates alkaline conditions. Most complex plants grow only in the soils with levels between pH 4 and pH 10 but optimum pH varies with the plant species.



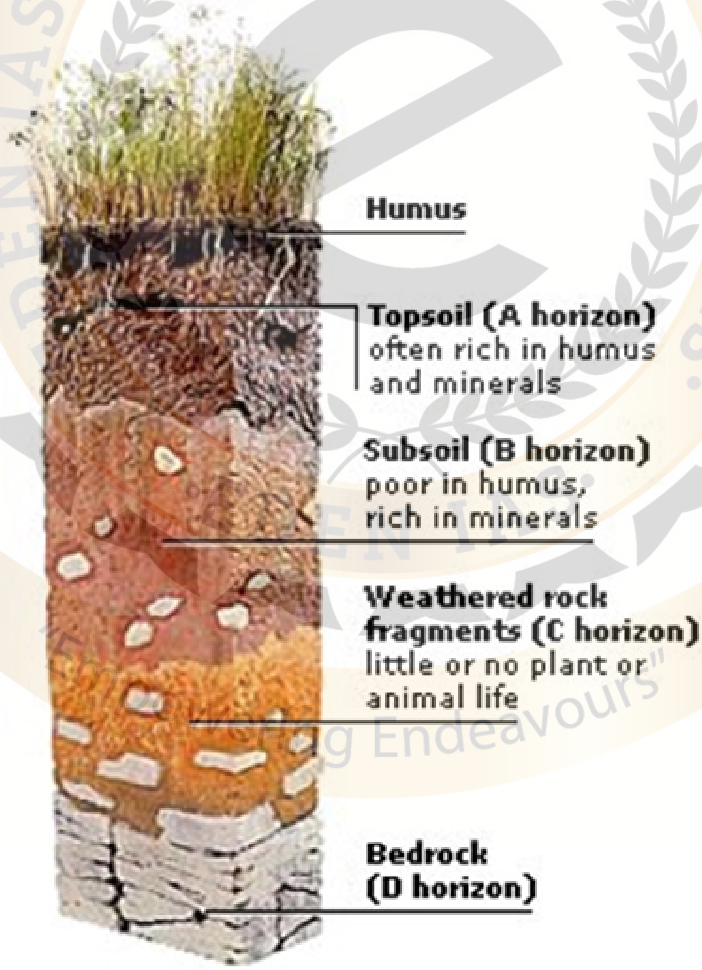
- In arid and semi-arid regions, soils tend to be alkaline and soils in humid regions tend to be acidic.
- To correct soil alkalinity and to make the soil more productive, the soil can be flushed with irrigation water.
- Strongly acidic soils are also detrimental to plant growth, but soil acidity can generally be corrected by adding lime to the soil.

SOIL PROFILE

The soil profile is an important tool in nutrient management. By examining a soil profile, we can gain valuable insight into soil fertility. As the soil weathers and/or organic matter decomposes, the profile of the soil changes. For instance, a highly weathered, infertile soil usually contains a light-colored layer in the subsurface soil from which nutrients have leached away. On the other hand, a highly fertile soil often has a deep surface layer that contains high amounts of organic matter. With clues provided by soil profile, we can begin to predict how a soil will perform under certain nutrient management conditions.

The world's soils are like blankets that cover most of the earth's land surfaces. We could not survive without it since most crops would not be able to grow in the dense rock that lies underneath. There is no uniform depth to our earth's soils. While it can be absent in places of exposed bedrock, soil may extend up to tens of meters into the earth's surface. Although this may not seem insignificant when compared to the depth to the core of the earth, the soil profile can be very intricate and diverse. In fact, the soil profile is made up of distinct layers, known as horizons. The five most common horizons are collectively known as the master horizons.

Various Soil Horizons



Components of the Soil Profile

A **soil horizon** makes up a distinct layer of soil. The horizon runs roughly parallel to the soil surface and has different properties and characteristics than the adjacent layers above and below. The **soil profile** is a vertical section of the soil that depicts all of its horizons. The soil profile extends from the soil surface to the parent rock material.

The **regolith** includes all of the weathered material within the profile. The regolith has two components: the **solum** and the **saprolite**. The solum includes the upper horizons with the most weathered portion of the profile. The saprolite is the least weathered portion that lies directly above the solid, consolidated bedrock but beneath the regolith.

Five Master Horizons-(O, A, E, B, C)

There are **five master horizons** in the soil profile. Not all soil profiles contain all 5 horizons; and so, soil profiles differ from one location to another. The 5 master horizons are represented by the letters: O, A, E, B, and C.

O: The O horizon is a surface horizon that is comprised of organic material at various stages of decomposition. It is most prominent in forested areas where there is the accumulation of debris fallen from trees.

A: The A horizon is a surface horizon that largely consists of minerals (sand, silt, and clay) and with appreciable amounts of organic matter. This horizon is predominantly the surface layer of many soils in grasslands and agricultural lands. The A horizon is often referred to as the **topsoil** and is the surface layer where organic matter accumulates. Over time, this layer loses clay, iron, and other materials because of leaching.

E: The E horizon is a subsurface horizon that has been heavily leached. Leaching is the process in which soluble nutrients are lost from the soil due to precipitation or irrigation. The horizon is typically light in color. It is generally found beneath the O horizon. The E horizon is thus the zone of greatest eluviation. Because the clay, chemicals, and organic matter are leached, the color of the E horizon is very light. This horizon usually occurs in sandy forest soils with high amounts of rainfall.

B: The B horizon is a subsurface horizon that has accumulated from the layer(s) above. It is a site of deposition of certain minerals that have leached from the layer(s) above. The B horizon is often referred to as the subsoil. It is often called the "zone of accumulation" because chemicals leached from the A and E horizons accumulate here. The accumulation of organic matter, chemical substances, and mineral particles in the lower horizons of soil from the upper horizons as a result of the downward movement of water is called illuviation. The B horizon has less organic matter and more clay than the A horizon. **Together, the A, E, and B horizons are known as the solum**. This is where most of the plant roots grow.

C: The C horizon is a subsurface horizon. It is the least weathered horizon. Also known as the saprolite, it is unconsolidated, loose parent material. The C horizon is called the substratum. It lacks the properties of the A and B horizons because it is influenced less by the soil-forming processes. It is usually the parent material of the soil.

The Bed Rock-"R" Horizon.

The R horizon is the underlying bedrock, such as limestone, sandstone, or granite. It is found beneath the C horizon.

FACTORS AFFECTING SOIL FORMATION

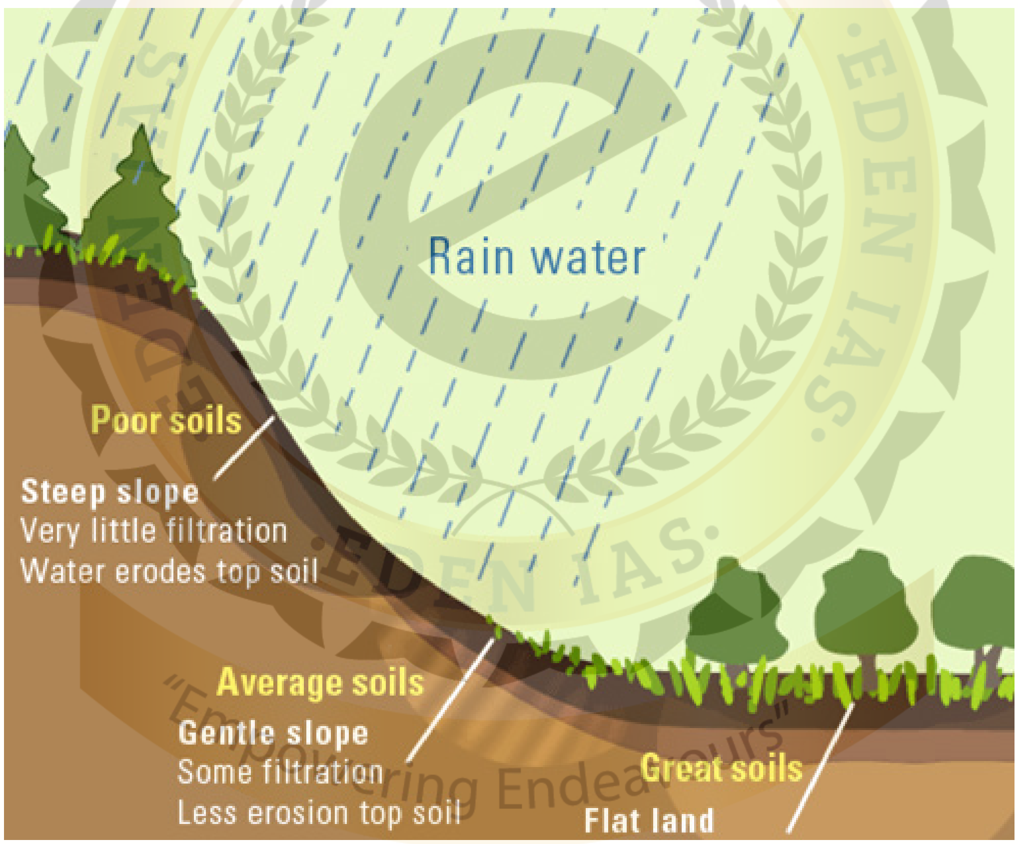
Soil research has shown that soil profiles are influenced by five separate, yet interacting, factors: parent material, climate, topography, organisms, and time. Soil scientists call these the factors of soil formation. These factors give soil profiles their distinctive character. Soils form from the interplay of five main factors namely Parent material, Time, Climate, Relief and Organisms.

Parent material: -This refers to the mineral material or organic material from which the soil is formed. Soils will carry the characteristics of its parent material such as color, texture, structure, mineral composition and so on. For example, if soils are formed from an area with large rocks (parent rocks) of red sandstone, the soils will also be red in color and have the same feel as its parent material.

Time: -Soils can take many years to form. Younger soils have some characteristics from their parent material, but as they age, the addition of organic matter, exposure to moisture and other environmental factors may change its features. With time, they settle and are buried deeper below the surface, taking time to transform. Eventually, they may change from one soil type to another.

Climate: -This is probably the most important factor that can shape the formation of soils. Two important climatic components, temperature and precipitation are key. They determine how quickly weathering will be, and what kind of organic materials may be available on and inside of the soils. Moisture determines the chemical and biological reactions that will occur as the soils are formed. A warmer climate with more rainfall means more vegetative cover and more animal action. It also means more runoff, more percolation and more water erosion. They all help to determine the kind of soils in an area.

Relief: -This refers to the landscape position and the slopes it has. Steep, long slopes mean water will run down faster and potentially erode the surfaces of slopes. The effect will be poor soils on the slopes, and richer deposits at the foot of the slopes. Also, slopes may be exposed to more direct sunlight, which may dry out soil moisture and render it less fertile.



Organisms: -The source and richness of organic matter are down to the living things (plants and animals) that live on and in the soils. Plants, in particular, provide lots of vegetative residues that are added to soils. Their roots also hold the soils and protect them from wind and water erosion. They shelter the soils from the sun and other environmental conditions, helping the soils to retain the needed moisture for chemical and biological reactions. Fungi, bacteria, insects, earthworms, and burrowing animals help with soil aeration. Worms help break down organic matter and aid decomposition. Animal droppings, dead insects and animals result in additional decaying organic matter. Microorganisms also help with mineral and nutrient cycling and chemical reactions.

SOIL EROSION

Soil erosion is a naturally occurring process that affects all landforms. In agriculture, soil erosion refers to the wearing away of a field's topsoil by the natural physical forces of water and wind or through forces associated with farming activities such as tillage.

Erosion, whether it is by water, wind or tillage, involves three distinct actions – soil detachment, movement and deposition. Topsoil, which is high in organic matter, fertility and soil life, is relocated elsewhere "on-site" where it builds up over time or is carried "off-site" where it fills in drainage channels. Soil erosion reduces cropland productivity and contributes to the pollution of adjacent watercourses, wetlands and lakes.

Soil erosion can be a slow process that continues relatively unnoticed or can occur at an alarming rate, causing serious loss of topsoil. Soil compaction, low organic matter, loss of soil structure, poor internal drainage, salinisation and soil acidity problems are other serious soil degradation conditions that can accelerate the soil erosion process.

Water Erosion

The rate and magnitude of soil erosion by water is controlled by the following factors:

Rainfall and Runoff

The greater the intensity and duration of a rainstorm, the higher the erosion potential. The impact of raindrops on the soil surface can break down soil aggregates and disperse the aggregate material. Lighter aggregate materials such as very fine sand, silt, clay and organic matter are easily removed by the raindrop splash and runoff water; greater raindrop energy or runoff amounts are required to move larger sand and gravel particles.

Soil movement by rainfall (raindrop splash) is usually greatest and most noticeable during short-duration, high-intensity thunderstorms. Although the erosion caused by long-lasting and less-intense storms is not usually as spectacular or noticeable as that produced during thunderstorms, the amount of soil loss can be significant, especially when compounded over time.

Surface water runoff occurs whenever there is excess water on a slope that cannot be absorbed into the soil or is trapped on the surface. Reduced infiltration due to soil compaction, crusting or freezing increases the runoff. Runoff from agricultural land is greatest during spring months when the soils are typically saturated, snow is melting and vegetative cover is minimal.

Soil Erodibility

Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Texture is the principal characteristic affecting erodibility, but structure, organic matter and permeability also contribute. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam-textured soils tend to be less erodible than silt, very fine sand and certain clay-textured soils.

Tillage and cropping practices that reduce soil organic matter levels, cause poor soil structure, or result in soil compaction, contribute to increases in soil erodibility. As an example, compacted subsurface soil layers can decrease infiltration and increase runoff. The formation of a soil crust, which tends to "seal" the surface, also decreases infiltration. On some sites, a soil crust might decrease the amount of soil loss from raindrop impact and splash; however, a corresponding increase in the amount of runoff water can contribute to more serious erosion problems.

Past erosion also has an effect on a soil's erodibility. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils were because of their poorer structure and lower organic matter. The lower nutrient levels often associated with subsoils contribute to lower crop yields and generally poorer crop cover, which in turn provides less crop protection for the soil.

Slope Gradient and Length

The steeper and longer the slope of a field, the higher the risk for erosion. Soil erosion by water increases as the slope length increases due to the greater accumulation of runoff. Consolidation of small fields into larger ones often results in longer slope lengths with increased erosion potential, due to increased velocity of water, which permits a greater degree of scouring (carrying capacity for sediment).

Cropping and Vegetation

The potential for soil erosion increases if the soil has no or very little vegetative cover of plants and/or crop residues. Plant and residue cover protects the soil from raindrop impact and splash, tends to slow down the movement of runoff water and allows excess surface water to infiltrate.

The erosion-reducing effectiveness of plant and/or crop residues depends on the type, extent and quantity of cover. Vegetation and residue combinations that completely cover the soil and intercept all falling raindrops at and close to the surface are the most efficient in controlling soil erosion (e.g., forests, permanent grasses). Partially incorporated residues and residual roots are also important as these provide channels that allow surface water to move into the soil.

The effectiveness of any protective cover also depends on how much protection is available at various periods during the year, relative to the amount of erosive rainfall that falls during these periods. Crops that provide a full protective cover for a major portion of the year (e.g., alfalfa or winter cover crops) can reduce erosion much more than can crops that leave the soil bare for a longer period of time (e.g., row crops), particularly during periods of highly erosive rainfall such as spring and summer. Crop management systems that favour contour farming and strip-cropping techniques can further reduce the amount of erosion. To reduce most of the erosion on annual row-crop land, leave a residue cover greater than 30% after harvest and over the winter months, or inter-seed a cover crop (e.g., red clover in wheat, oats after silage corn).

Tillage Practices

The potential for soil erosion by water is affected by tillage operations, depending on the depth, direction and timing of plowing, the type of tillage equipment and the number of passes. Generally, the less the disturbance of vegetation or residue cover at or near the surface, the more effective the tillage practice in reducing water erosion. Minimum till or no-till practices are effective in reducing soil erosion by water.

Tillage and other practices performed up and down field slopes creates pathways for surface water runoff and can accelerate the soil erosion process. Cross-slope cultivation and contour farming techniques discourage the concentration of surface water runoff and limit soil movement.

Forms of Water Erosion

Sheet Erosion

Sheet erosion is the movement of soil from raindrop splash and runoff water. It typically occurs evenly over a uniform slope and goes unnoticed until most of the productive topsoil has been lost. Deposition of the eroded soil occurs at the bottom of the slope or in low areas. Lighter-coloured soils on knolls, changes in soil horizon thickness and low crop yields on shoulder slopes and knolls are other indicators.

Rill Erosion

Rill erosion results when surface water runoff concentrates, forming small yet well-defined channels. These distinct channels where the soil has been washed away are called rills when they are small enough to not interfere with field machinery operations. In many cases, rills are filled in each year as part of tillage operations.

Gully Erosion

Gully erosion is an advanced stage of rill erosion where surface channels are eroded to the point where they become a nuisance factor in normal tillage operations. There are farms in central India that are losing large quantities of topsoil and subsoil each year due to gully erosion. Surface water runoff, causing gully formation or the enlarging of existing gullies, is usually the result of improper outlet design for local surface and subsurface drainage systems. The soil instability of gully banks, usually associated with seepage of groundwater, leads to sloughing and slumping (caving-in) of bank slopes. Such failures usually occur during spring months when the soil water conditions are most conducive to the problem.

Gully formations are difficult to control if corrective measures are not designed and properly constructed. Control measures must consider the cause of the increased flow of water across the landscape and be capable of directing the runoff to a proper outlet. Gully erosion results in significant amounts of land being taken out of production and creates hazardous conditions for the operators of farm machinery.

Bank Erosion

Natural streams and constructed drainage channels act as outlets for surface water runoff and subsurface drainage systems. Bank erosion is the progressive undercutting, scouring and slumping of these drainage ways. Poor construction practices, inadequate maintenance, uncontrolled livestock access and cropping too close can all lead to bank erosion problems.

Poorly constructed tile outlets also contribute to bank erosion. Some do not function properly because they have no rigid outlet pipe, have an inadequate splash pad or no splash pad at all, or have outlet pipes that have been damaged by erosion, machinery or bank cave-ins.The direct damages from bank erosion include loss of productive farmland, undermining of structures such as bridges, increased need to clean out and maintain drainage channels and washing out of lanes, roads and fence rows.

Effects of Water Erosion

On-Site

The implications of soil erosion by water extend beyond the removal of valuable topsoil. Crop emergence, growth and yield are directly affected by the loss of natural nutrients and applied fertilizers. Seeds and plants can be disturbed or completely removed by the erosion. Organic matter from the soil, residues and any applied manure, is relatively lightweight and can be readily transported off the field, particularly during spring thaw conditions. Pesticides may also be carried off the site with the eroded soil.

Soil quality, structure, stability and texture can be affected by the loss of soil. The breakdown of aggregates and the removal of smaller particles or entire layers of soil or organic matter can weaken the structure and even change the texture. Textural changes can in turn affect the water-holding capacity of the soil, making it more susceptible to extreme conditions such as drought.

Off-Site

The off-site impacts of soil erosion by water are not always as apparent as the on-site effects. Eroded soil, deposited down slope, inhibits or delays the emergence of seeds, buries small seedlings and necessitates replanting in the affected areas. Also, sediment can accumulate on down-slope properties and contribute to road damage.

Sediment that reaches streams or watercourses can accelerate bank erosion, obstruct stream and drainage channels, fill in reservoirs, damage fish habitat and degrade downstream water quality. Pesticides and fertilizers, frequently transported along with the eroding soil, contaminate or pollute downstream water sources, wetlands and lakes. Because of the potential seriousness of some of the off-site impacts, the control of "non-point" pollution from agricultural land is an important consideration.

Wind Erosion

Soil particles move in three ways, depending on soil particle size and wind strength – suspension, saltation and surface creep. The rate and magnitude of soil erosion by wind is controlled by the following factors:

Soil Erodibility

Very fine soil particles are carried high into the air by the wind and transported great distances (suspension). Fine-to-medium size soil particles are lifted a short distance into the air and drop back to the soil surface, damaging crops and dislodging more soil (saltation). Larger-sized soil particles that are too large to be lifted off the ground are dislodged by the wind and roll along the soil surface (surface creep). The abrasion that results from windblown particles breaks down stable surface aggregates and further increases the soil erodibility.

Soil Surface Roughness

Soil surfaces that are not rough offer little resistance to the wind. However, ridges left from tillage can dry out more quickly in a wind event, resulting in more loose, dry soil available to blow. Over time, soil surfaces become filled in, and the roughness is broken down by abrasion. This results in a smoother surface susceptible to the wind. Excess tillage can contribute to soil structure breakdown and increased erosion.

Climate

The speed and duration of the wind have a direct relationship to the extent of soil erosion. Soil moisture levels are very low at the surface of excessively drained soils or during periods of drought, thus releasing the particles for transport by wind. This effect also occurs in freeze-drying of the soil surface during winter months. Accumulation of soil on the leeward side of barriers such as fence rows, trees or buildings, or snow cover that has a brown colour during winter are indicators of wind erosion.

Unsheltered Distance

A lack of windbreaks (trees, shrubs, crop residue, etc.) allows the wind to put soil particles into motion for greater distances, thus increasing abrasion and soil erosion. Knolls and hilltops are usually exposed and suffer the most.

Vegetative Cover

The lack of permanent vegetative cover in certain locations results in extensive wind erosion. Loose, dry, bare soil is the most susceptible; however, crops that produce low levels of residue (e.g., soybeans and many vegetable crops) may not provide enough resistance. In severe cases, even crops that produce a lot of residue may not protect the soil.

The most effective protective vegetative cover consists of a cover crop with an adequate network of living windbreaks in combination with good tillage, residue management and crop selection.

Effects of Wind Erosion

Wind erosion damages crops through sandblasting of young seedlings or transplants, burial of plants or seed, and exposure of seed. Crops are ruined, resulting in costly delays and making reseeding necessary. Plants damaged by sandblasting are vulnerable to the entry of disease with a resulting decrease in yield, loss of quality and market value. Also, wind erosion can create adverse operating conditions, preventing timely field activities.

Soil drifting is a fertility-depleting process that can lead to poor crop growth and yield reductions in areas of fields where wind erosion is a recurring problem. Continual drifting of an area gradually causes a textural change in the soil. Loss of fine sand, silt, clay and organic particles from sandy soils serves to lower the moisture-holding capacity of the soil. This increases the erodibility of the soil and compounds the problem.

The removal of wind-blown soils from fence rows, constructed drainage channels and roads, and from around buildings is a costly process. Also, soil nutrients and surface-applied chemicals can be carried along with the soil particles, contributing to off-site impacts. In addition, blowing dust can affect human health and create public safety hazards.

Tillage Erosion

Tillage erosion is the redistribution of soil through the action of tillage and gravity. It results in the progressive down-slope movement of soil, causing severe soil loss on upper-slope positions and accumulation in lower-slope positions. This form of erosion is a major delivery mechanism for water erosion. Tillage action moves soil to convergent areas of a field where surface water runoff concentrates. Also, exposed subsoil is highly erodible to the forces of water and wind. Tillage erosion has the greatest potential for the “on-site” movement of soil and in many cases can cause more erosion than water or wind.

The rate and magnitude of soil erosion by tillage is controlled by the following factors:

Type of Tillage Equipment

Tillage equipment that lifts and carries will tend to move more soil. As an example, a chisel plow leaves far more crop residue on the soil surface than the conventional moldboard plow but it can move as much soil as the moldboard plow and move it to a greater distance. Using implements that do not move very much soil will help minimize the effects of tillage erosion.

Direction

Tillage implements like a plow or disc throw soil either up or down slope, depending on the direction of tillage. Typically, more soil is moved while tilling in the down-slope direction than while tilling in the up-slope direction.

Speed and Depth

The speed and depth of tillage operations will influence the amount of soil moved. Deep tillage disturbs more soil, while increased speed moves soil further.

Number of Passes

Reducing the number of passes of tillage equipment reduces the movement of soil. It also leaves more crop residue on the soil surface and reduces pulverization of the soil aggregates, both of which can help resist water and wind erosion.

Effects of Tillage Erosion

Tillage erosion impacts crop development and yield. Crop growth on shoulder slopes and knolls is slow and stunted due to poor soil structure and loss of organic matter and is more susceptible to stress under adverse conditions. Changes in soil structure and texture can increase the erodibility of the soil and expose the soil to further erosion by the forces of water and wind.

In extreme cases, tillage erosion includes the movement of subsurface soil. Subsoil that has been moved from upper-slope positions to lower-slope positions can bury the productive topsoil in the lower-slope areas, further impacting crop development and yield. Research related to tillage-eroded fields has shown soil loss of as much as 2 m of depth on upper-slope positions and yield declines of up to 40% in corn. Remediation for extreme cases involves the relocation of displaced soils to the upper-slope positions.

SOIL DEGRADATION

Soil degradation simply means the decline in soil quality which comes about due to aspects such as improper land use, agriculture, and pasture, urban or industrial purposes. It involves the decline of the soil's physical, biological and chemical state.

<u>Causes of Soil Degradation</u>

Physical Factors

There are several physical factors contributing to soil degradation distinguished by the manners in which they change the natural composition and structure of the soil. Rainfall, surface runoff, floods, wind erosion, tillage, and mass movements result in the loss of fertile top spoil thereby declining soil quality.

All these physical factors produces different types of soil erosion (mainly water and wind erosion) and soil detachment actions, and their resultant physical forces eventually changes the composition and structure of the soil by wearing away the soil's top layer as well as organic matter. In the long-term, the physical forces and weathering processes lead to the decline in soil fertility and adverse changes in the soil's composition/structure.

Biological Factors

Biological factors refer to the human and plant activities that tend to reduce the quality of soil. Some bacteria and fungi overgrowth in an area can highly impact the microbial activity of the soil through bio-chemical reactions, which reduces crop yield and the suitability of soil productivity capacity. Human activities such as poor farming practices may also deplete soil nutrients thus diminishing soil fertility. The biological factors affect mainly lessens the microbial activity of the soil.

Chemical Factors

The reduction of soil nutrients because of alkalinity or acidity or water logging are all categorized under the chemical components of soil degradation. In the broadest sense, it comprises alterations in the soil's chemical property that determine nutrient availability. It is mainly caused by salt buildup and leaching of nutrients which corrupt the quality of soil by creating undesirable changes in the essential soil chemical ingredients. These chemical factors normally bring forth irreversible loss of soil nutrients and productivity capacity such as the hardening of iron and aluminum rich clay soils into hardpans.

Deforestation

Deforestation causes soil degradation on the account of exposing soil minerals by removing trees and crop cover, which support the availability of humus and litter layers on the surface of the soil. Vegetation cover primarily promotes thee binding of the soil together and soil formation, hence when it is removed it considerably affects the capabilities of the soil such as aeration, water holding capacity, and biological activity.

When trees are removed by logging, infiltration rates become elevated and the soil remains bare and exposed to erosion and the buildup of toxicities. Some of the contributing activities include logging and slash and burn techniques used by individuals who invade forest areas for farming, rendering the soils unproductive and less fertile in the end.

Misuse or excess use of fertilizers

The excessive use and the misuse of pesticides and chemical fertilizers kill organisms that assist in binding the soil together. Most agricultural practices involving the use of fertilizers and pesticides often entail misuse or excessive application, thereby contributing to the killing of soil's beneficial bacteria and other micro-organisms that help in soil formation.

The complex forms of the fertilizer's chemicals are also responsible for denaturing essential soil minerals, giving rise to nutrient losses from the soil. Therefore, the misuse or excessive use of fertilizers increases the rate of soil degradation by destroying the soil's biological activity and builds up of toxicities through incorrect fertilizer use.

Industrial and Mining activities

Soil is chiefly polluted by industrial and mining activities. As an example, mining destroys crop cover and releases a myriad of toxic chemicals such as mercury into the soil thereby poisoning it and rendering it unproductive for any other purpose. Industrial activities, on the other hand, release toxic effluents and material wastes into the atmosphere, land, rivers, and ground water that eventually pollute the soil and as such, it impacts on soil quality. Altogether, industrial and mining activities degrade the soil's physical, chemical and biological properties.

Improper cultivation practices

There are certain agricultural practices that are environmentally unsustainable and at the same time, they are the single biggest contributor to the worldwide increase in soil quality decline. The tillage on agricultural lands is one of the main factors since it breaks up soil into finer particles, which increase erosion rates. The soil quality decline is exuberated more and more as a result of the mechanization of agriculture that gives room for deep plowing, reduction of plant cover, and the formation of the hardpan. Other improper cultivation activities such as farming on steep slope and mono-cropping, row-cropping and surface irrigation wear away the natural composition of the soil and its fertility, and prevent soil from regenerating.

Urbanization

Urbanization has major implications on the soil degradation process. Foremost of all, it denudates the soil's vegetation cover, compacts soil during construction, and alters the drainage pattern. Secondly, it covers the soil in an impermeable layer of concrete that amplifies the amount of surface runoff which results in more erosion of the top soil. Again, most of the runoff and sediments from urban areas are extremely polluted with oil, fuel, and other chemicals. Increased runoff from urban areas also causes a huge disturbance to adjacent water sheds by changing the rate and volume of water that flows through them, and impoverishing them with chemically polluted sediment deposits.

Overgrazing

The rates of soil erosion and the loss of soil nutrients as well as the top soil are highly contributed by overgrazing. Overgrazing destroys surface crop cover and breaks down soil particles, increasing the rates of soil erosion. As a result, soil quality and agricultural productivity is greatly affected.

Effects of Soil Degradation

Land degradation

Soil quality decline is one of the main causes of land degradation and is considered to be responsible for 84% of the ever diminishing acreage. Year after year, huge acres of land lost due to soil erosion, contamination and pollution. About 40% of the world's agricultural land is severely diminished in quality because of erosion and the use of chemical fertilizers, which prevent land from regenerating. The decline in soil quality as a result of agricultural chemical fertilizers also further leads to water and land pollution thereby lowering the land's worth on earth.

Drought and aridity

Drought and aridity are problems highly influenced and amplified by soil degradation. As much as it's a concern associated with natural environments in arid and semi-arid areas, the UN recognizes the fact that drought and aridity are anthropogenic induced factors especially as an outcome of soil degradation. Hence, the contributing factors to soil quality decline such as overgrazing, poor tillage methods, and deforestation are also the leading causes of desertification characterized by droughts and arid conditions. On the same context, soil degradation may also bring about loss of biodiversity.

Loss of arable land

Because soil degradation contributes to land degradation, it also means that it creates a significant loss of arable land. As stated earlier, about 40% of the world's agricultural land is lost on the account of soil quality depreciation caused by agro-chemicals and soil erosion. Most of the crop production practices result in the topsoil loss and the damage of soil's natural composition that make agriculture possible.

Increased flooding

Land is commonly altered from its natural landscape when it rids its physical composition from soil degradation. For this reason, the transformed land is unable to soak up water, making flooding more frequent. In other words, soil degradation takes away the soil's natural capability of holding water thus contributing to more and more cases of flooding.

Pollution and clogging of waterways

Most of the soil eroded from the land together with the chemical fertilizers and pesticides utilized in agricultural fields are discharged into waterways and streams. With time, the sedimentation process can clog waterways, resulting in water scarcity. The agricultural fertilizers and pesticides also damage marine and freshwater ecosystems and the limits the domestic uses of the water for the populations that depend on them for survival.

SOIL CONSERVATION

Soil Conservation is the name given to a number of techniques aimed at preserving the soil. Soil loss and loss of soil fertility can be traced back to a number of causes including over-use, erosion, salinisation and chemical contamination. Unsustainable subsistence farming and the slash and burn clearing methods used in some less developed regions, can often cause deforestation, loss of soil nutrients, erosion on a massive scale and sometimes even complete desertification.

Methods of Soil Conservation

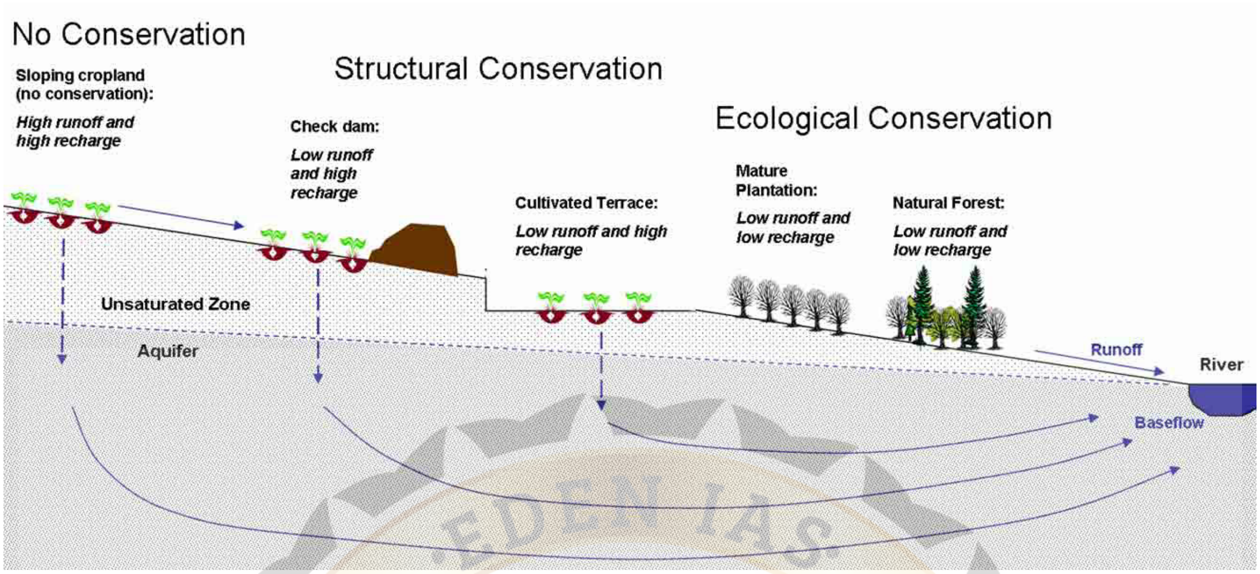
1. Contour Ploughing:

If ploughing is done at right angles to the hill slope, following the natural contour of the hill, the ridges and furrows break the flow of the water down the hill. This prevents excessive soil loss, as gullies are less likely to develop and also reduce run-off so that plants receive more water. Row crops and small grains are often planted in contour pattern so that the plants can absorb much of the rain, and erosion is minimized.

2. Terracing:

Slopes may be cut into a series of terraces with sufficient level ground on each terrace for cultivation, and an outer wall at the edge to retain the soil and to slow down the flow of rain-water down the slope.

Terracing is widely used in Monsoon Asia for wet paddy cultivation, as the excess water and silt can be retained at each terrace to form flooded paddy-fields. Many tree crops such as rubber are also planted on terraces to combat soil erosion. Terraces are also used in temperate and semi arid regions where slopes are steep. Terracing enables farmers in mountainous regions to utilize the steep ground on the favoured 'sunny slopes' of valleys for vines or other crops.



3. Strip Cropping:

Crops may be cultivated in alternate strips, parallel to one another. Some strips may be allowed to lie fallow while others are sown to different kinds of crops, e.g. grains, legumes, small tree crops. The various crops ripen at different times of the year and are harvested at intervals. This ensures that at no time will the entire area be left bare or exposed. The tall-growing crops act as windbreaks and the strips, which are often parallel to the contours, help to increase water absorption by the soil by slowing down run-off.

4. Fallowing:

Sometimes it is important to allow much used land to rest or lie fallow, so that the natural forces can act on the soil. The decayed natural vegetative matter helps to increase the plant nutrients in the soil. Fallowing also increases the sub-soil moisture and improves the general structure of the soil.

Winter fallow is commonly practised in temperate regions after the harvest, but cultivation is resumed in the spring after the snow and frost have weathered the top soil. Long periods of fallow cannot be allowed, however, in intensively run farms as farmers cannot afford it.

In semi-arid areas fields may be allowed to lie fallow for several years, though they are often ploughed or mulched, i.e. spread with straw or the stubble of the previous year's harvests. This enables them to build up a sufficient supply of moisture by reducing evaporation, and a crop can be grown every few years. This system of dry farming is practised in western U.S.A. and in parts of Mediterranean Europe.

5. Cover Cropping:

In some cases, as in plantations, where the gestation period of tree crops is long, cover crops may be inter-planted between the young trees. Creepers are preferred because they spread around and form a useful cover that protects the top soil from the full force of the tropical downpours.

Care must be taken that the cover crop does not compete with the young trees for the essential plant nutrients, and leguminous crops are often used because they add nitrogen to the soil. Cover crops may be grown simply to protect the soil or may consist of other valuable plants such as vegetables which provide an income while the plantation crop matures. Some such catch crops, e.g. cotton, maize or tobacco, should be avoided because they exhaust the soil or promote soil erosion instead of preventing it.

6. Crop Rotation:

It is not advisable to grow the same crop in the same field for more than two years in succession as the crop will tend to exhaust one particular kind of mineral nutrient. For example potatoes require much potash, but wheat requires nitrates.

Thus it is best to alternate crops in the fields. Legumes such as peas, beans, clover, vetch and many other plants, add nitrates to the soil by converting free nitrogen in the air into nitrogenous nodules on their roots. Thus if they are included in the crop rotation nitrogenous fertilizers can be dispensed with.

By rotating different types of crops in successive years, soil fertility can be naturally maintained. The best known crop rotation is the Norfolk Rotation which involves the growing of four crops in a given field over a period of four years.

These crops are wheat (cereal); clover or beans (legume); barley (another cereal); and turnips or sugar-beet (root crops). In fact on most temperate mixed farms all these crops will be grown on some of the fields each year but the fields in which they are grown will be different in each year so as to maintain the rotation for any particular field. The land can be much more profitably used by employing rotation systems than simply allowing it to lie fallow if moisture and other conditions allow this practice.

7. Crop Diversification:

This practice is often like crop rotation in that it helps to maintain soil fertility. Where annually-harvested crops are grown they can be alternated in the field. Where perennial crops like tree crops are grown, however, the chief importance of crop diversification to the farmer is economic. In particular it reduces the danger of depending on a single crop (monoculture) when world commodity prices are falling.

All the primary commodities, e.g. rubber, oil palm, cocoa, cotton, are subject to great fluctuation in prices, much depending on the demand of the western world. Over-dependence on one crop can be disastrous to the national economy as well as to the individual farmer, as in the case of Brazil's coffee, Ghana's cocoa, or Malaysia's rubber, when prevailing prices for the major money-earning crop are low.

Crop diversification overcomes this difficulty as when one crop is only fetching low prices another may be in good demand. Another great advantage of crop diversification is that all types of land can be used, e.g. rubber can be grown on hill slopes, oil palm on flat plains, coconuts on sandy soils. Thorough crop diversification on a national and local level can lead to the most economic use of land.

8. Water Management:

One of the major ways in which land can be improved for farming is by water management. By regulating the amount of water in the soil aeration can be improved, activity by useful bacteria can be stimulated and crop yields can be improved. In addition, by draining or irrigating land, areas which are marginal or useless in their natural state, such as deserts or swamps can be brought into agricultural production –

It should be emphasized that drainage and irrigation are interdependent. Where irrigation is used it is important also to provide drainage facilities, so that the irrigation water can be kept moving and not become stagnant. Similarly in drained areas, irrigation must be applied to prevent unwanted sea-water from seeping into the drained land. In other words a balance must be carefully maintained.

9. Contour Bunding:

Contour bunding is the construction of small bunds across the slopes of the land on a contour so that the long slope is cut into a series of small ones and earth contour bunds act as a barrier to the flow of water, thus, making it 'walk' rather than 'run' and at the same time impounding a greater part of water against the bund to increase the soil moisture.

10. Wind Break:

The principal method of reducing surface velocity of wind, upon which would depend the abrasive and transportation capacity, are vegetal measures. That is creating an array of trees that can act as a frictional drag and hindrance in the path of flow.

DEFORESTATION

Deforestation is the removal of a forest or stand of trees where the land is thereafter converted to a non-forest use. Examples of deforestation include conversion of forestland to farms, ranches, or urban use. The most concentrated deforestation occurs in tropical rainforests. About 30% of Earth's land surface is covered by forests.

Causes of deforestation and forest degradation

There are various reasons for deforestation, some of which are mentioned below:

Agricultural expansion

A combination of forces is responsible for deforestation and the biggest among them is agricultural expansion. Forests are being cleared on an alarming rate due to rising global demand of food grain and the commodities like soybeans and palm oil. Since the beginning of agriculture, there has been a mass reduction in the forests worldwide for agricultural expansion. As per an estimate, over 40% of the forests have already been cleaned worldwide to obtain land to meet the demands for agriculture and wood. Agricultural expansion has left the world much devoid of its original forests. Forest areas are eliminated for raising commercial crops such as plantation for palm oil. In simple terms, deforestation takes place because forest land is not financially viable.

Due to this trend, there has been widespread destruction of Savannah grasslands as the Savannah vegetation has been cleaned and the wide area has been converted into agricultural land. The grasslands and trees of temperate tropical regions (e.g. the prairies of North America, and the steppes of Russia) have been cleaned. Forests have been cleared on a large scale and converted into gardens, agricultural lands. Likewise, forest areas have been destroyed in a big way to expand the agricultural land to eradicate the hunger of the rapidly growing population in the monsoon areas of south and south-east Asia.

Increasing Urbanization and Industrialization

For the purpose of development work the cutting of trees has been going on for years. Increased urbanization is one of the major causes of deforestation. To meet residential and industrial requirements, such as for the development of housing on a mass scale besides, construction of roads, mineral exploitation and industrial expansion, forests are being cleared on a large scale.

The road expansions also leads to illegal logging, where the people take benefits of doubt and slash down trees without obtaining permission from authorities.

Growth in Population

Deforestation is taking place at a faster rate to cater to explosive growth in population. Due to rapid increase in human population in developing countries, it has become necessary that the vast areas of forests should be cleaned and farmed so that the needs of the growing population can be met. Demand for timber is increasing day by day. As a result, there is a steady increase in tree cutting. Equatorial mangrove forests are being eliminated by 20 million hectares annually.

More and more collection of wood for fodder and burning wood by the rural masses in developing and undeveloped countries also leads to depletion of forests.

Diverse Human Needs

Tree and forests have been burnt or cut for centuries to meet various human needs: to obtain wood for fuel, to build houses, boats, match boxes, furniture etc and the requirement of wood for use in many works.

Since the beginning of this century, deforestation has occurred at such a fast pace that many environmental problems have arisen. The greedy man has forgotten that the vast destruction of forests would endanger his own existence.

Livestock Ranching and Logging

Forests in major parts of the world have already been cleared for livestock ranching, or cattle farming. Cattle ranchers have burned huge tracts of rainforests converting them into pastures for the cattle. They clear vast swaths of forest lands for cattle grazing. Later when the land prices increase, they sell the land and make profit. This kind of deforestation is very common in developing countries.

Forests have decayed due to grazing of animals in the normal density forests of hot and subtropical and dry and semi-arid regions. It is known that in the developing and undeveloped countries of these areas, milch animals feed on bushes, and plants, scattered on the ground and in open forests. They also trample upon the land with their hooves so that plants do not bloom there. In most countries, large herds of sheep have completely wiped out the grass.

Logging is another major driver of deforestation. Some greedy people are indulging in activities leading to deforestation to earn money from wood. Illegal logging operations which are very common in developing countries also destroy the livelihood of the people who depend on forests.

Changes of Forests into Pastures

Forests have been converted into pastures for livestock for widespread expansion and development of dairy farming in temperate regions of the world, particularly in North and South America and Africa.

Multipurpose River-Valley Projects

During the implementation of multipurpose river valley projects, vast forest areas are lost, because in the large reservoirs built behind the dams, the extensive area covered with forest is submerged in water, due to which not only the natural forest wealth but the ecological balance of that area is also disturbed.

Jhum (Shifting) Cultivation

Jhum agriculture is one of the major reasons for the decay and destruction of forests in the mountainous areas of southern and south-eastern Asia. Under this practice of agriculture, the land is cleaned by burning forests on hillsides. When the productivity of that land decreases, farmers shift to another place, burning the jungle again.

Mining Operations

The people are cutting forests for oil and coal mining operations as well. Large-scale mining operations, result into major deforestation through clearing of forests. The construction of roads into the forests for such purposes is also responsible for deforestation.

Paper Production

Paper is made from pulp of trees. Rising consumption of paper and cutting down trees for manufacturing paper throughout the world has already attracted major attention of the environmentalists. In the past four decades, the use of paper has gone up by 400%. It takes twelve to seventeen full-grown trees to make one ton of good quality paper.

For Fuel

Extensive deforestation takes place due to requirement of wood for fuel.

Due to Corruption

Forest contractors and forest mafia resort to massive cutting of forests for their ulterior motives. To earn more money, they do large-scale cutting of trees and smuggle the wood.

Lack of Awareness

Deforestation takes place as people, by and large, lack adequate knowledge about the need to conserve forests.

Other causes

Natural Causes of Deforestation are global warming, landslides, earthquakes; hail, strong winds, hurricanes, lighting etc. also lead to loss of forest cover, apart from fires that erupt in the forests.

Various Effects of Deforestation

Floods and Droughts: Soil erosion increases the soil flows, due to which the specific cycle of flood and drought is started. Cutting forests on mountain slopes obstructs the flow of rivers towards the plains, which have an impact on their water efficiency, so that the water rapidly comes downwards. Deforestation leads to land erosion arises because the trees play an important role in maintaining the surface of the mountains and cause natural barriers to the rapidly rising rain water. Consequently the water level of the rivers increases suddenly, causing floods.

Loss of Soil Fertility: When the fuel becomes inadequate, the cow dung and the vegetable residue are used like fuels to make food. Because of this, every part of the plant is gradually used and nothing goes back in the soil. After some time the drift of this nutrition influences the productivity of the soil, it causes degradation of soil-fertility. With the elimination of forests, the fertile soil above the ground flows through rain water to those places where it is not used.

Air Pollution: There are grave consequences for forest destruction. Its biggest disadvantage is in the form of air pollution. The air where there is lack of trees gets polluted. And the problem of air pollution is the highest in the cities. There people suffer from many diseases, especially breathing problems such as asthma.

Extinction of species: Due to the destruction of forests, wildlife is disappearing. Many species have disappeared (such as Asiatic cheetah, Namdapha flying squirrel, Himalayan wolf, Elvira rat, Andaman shrew, Jenkins' shrew, Nicobar shrew, etc) and many are on the verge of extinction.

Global Warming: Deforestation has a direct impact on the natural climate change, thereby increasing the global temperature. With the decreasing area of forests, the rain is also becoming irregular. This contributes to 'global warming', which has direct impact on humans.

Spread of deserts: Due to continuous decrease in the area of forests, and the erosion of the land, the desert is spreading on a big scale.

Depletion in Water Resources: Today, the water of rivers is becoming shallow, less deep and polluted because of the indiscriminate harvest of trees and plants on their shores, exits and mountains. Due to this there is insufficient rainfall, the water source is getting contaminated, and the environment is also becoming polluted and fatal.

Ill-Effects of Industrialisation: Trees and plants prevent the environment from being polluted by preventing those toxic gases from dissolving in the atmosphere, and preventing the particles of ash and sand etc. from rising too. Nowadays, there is a flood of industries in the cities, even towns and villages. The smoke emanating from them fills the environment with different types of toxic gases.

Damage to ozone layer: The normal environment of the Earth as a result of deforestation has become polluted. It is posing grave danger to the ozone layer, which is necessary for the overall defence of the Earth. Imagine that bad day (may it never come), when the ozone layer disappears.

Endangering Tribals: Forest is essential for the survival of tribals or Adivasis. The thinking of modern society has made life an object of profit, but for the tribals, the jungle is a complete lifestyle. It is the means of their livelihood. Their approach is very important in forest conservation, which is neither being implemented nor is it being recognized. They have been protecting the forest from the time of their forefathers. Adivasis take as much as they need from the forest, and in exchange, they give something to them. They have deep respect towards the forest. The ways and the rules of the tribals in the use of the forest are inherently sustainable as forest conservation is in their blood.

It is noteworthy that the forest is not only the economic base of the tribals, but they also use wild herbs in the treatment of their diseases. 'Baiga tribals' of Mandla and Dindori districts are considered to have the best knowledge of herbs and herbal remedies throughout the country. *Baiga* tribals use barks of trees during maternity (delivery). Before removing the bark, they offer rice, pulses to the tree. Then they worship the tree with incense and chant mantras in the praise of the tree god. After that, they pluck out with their sickle only that much bark that is used as the medicine. According to these knowledgeable tribals, only a little bark is removed in this way. They believe that if bark is removed without any rules, then people will start using it arbitrarily.

Unavailability of herbal medicines: Today the mountains and forests have become deserted due to the loss of tree cover. With this, getting medicinal flora has become rare. Because of lack of tree plantation, this precious natural property is eroding fast. This is spoiling the balance of life and environment. Mountain cliffs are getting deserted by breaking of stones and the rainfall is decreasing in the nearby areas.

Homeless Animals: Due to endless deforestation, destitute animals are taking shelter in villages. As a result, incidents of wild animals entering villages and towns of the country are happening quite frequently, posing a grave danger to human life.

FOREST CONSERVATION

Some of the steps we can take to conserve our forest resources are as follows:

1. Regulated and Planned Cutting of Trees:

One of the main reasons of deforestation is commercial felling of trees. According to an estimate, about 1,600 million cubic metres of wood have been used for various purposes in the world. Although trees are considered as perennial resource, when exploited on a very large scale, their revival cannot be possible.

Therefore, cutting should be regulated by adopting methods like:

- **Clear cutting,**
- **Selective cutting, and**
- **Shelter wood cutting.**

The clear cutting method is useful for those areas where the same types of trees are available over a large area. In that case, trees of same age group can be cut down in a selected area and then marked for replantation. In selective cutting only mature trees are selected for cutting. This process is to be followed in rotation.

The time gap between these cuttings is helpful in re-growth of trees. In regulated cutting only one-tenth of the forest area is selected for use and rotational system is always followed for their protection. The forest can be managed in such a way that a timber crop may be harvested indefinitely year after year without being depleted. This technique is called the 'sustained yield' method adopted by many countries.

2. Control over Forest Fire:

Destruction or loss of forest by fire is fairly common; because trees are highly exposed to fire and once started it becomes difficult to control. Sometimes, the fire starts by natural process, i.e., by lightning or by friction between trees during speedy winds, while in most cases it is also by man either intentionally or unintentionally.

In order to save forests from fire, it is necessary to adopt latest techniques of fire fighting. Some of the fire suppression techniques are to develop three metre wide fire lanes around the periphery of the fire, back fires, arrangement of water spray, fire retardant chemicals should be sprayed from back tank and if possible by helicopters. There must be trained staff of fire fighters to control the fire.

3. Reforestation and Afforestation:

The sustained yield concept dictates that whenever timber is removed, either by block cutting or by selective cutting, the denuded area must be reforested. This may be done by natural or artificial methods. Similarly, any forested land, which has been destroyed by fire or mining activities, should be reforested. In rugged terrain aerial seeding is the method of choice.

Besides all this, fresh afforestation programmes should be started. New plantations will not only increase the forest cover but also help in making up the eco-balance. For afforestation, selection of trees should be done according to local geographical conditions and care must be taken during initial growth of the trees.

4. Check over Forest Clearance for Agricultural and Habitation Purposes:

Most of the present-day agricultural land was once forested and then cleared for the use of agriculture. But now it has reached the stage where further clearance will be dangerous for the entire ecosystem. There are tribals in some parts of Asia, Africa and South America, where shifting cultivation is still a part of their system of land procurement.

5. Protection of Forests:

The existing forests should be protected. Apart from commercial cutting, unorganised grazing is also one of the reasons. There are several forest diseases resulting from parasitic fungi, rusts, mistletoes, viruses and nematodes which cause the destruction of trees. The forests should be protected either by use of chemical spray, antibiotics or by development of disease resistant strains of trees.

6. Proper Utilisation of Forest and Forests Products:

Generally, trees are cut for logs and the rest, including stump, limbs, branches and foliage, etc., is left out as worthless debris. Further waste occurs at the saw mills. There is thus need to utilise this waste material. Today, several uses have been developed and products like waterproof glues, boar r etc., can be obtained.

Similarly, forests can be used or developed as tourist centres. By using them as tourist centres the country can earn substantial foreign exchange. This practice has been adopted by many countries, both developed and developing. The concepts of 'national park' and 'game sanctuary' have now become popular and every country has developed its unique forest area as a 'national park'.

7. Role of Government in Forest Conservation:

Although the government of every country is very particular about conservation of its forest resources and has several rules and laws for the protection of forests but, they are not implement in an effective manner.

Both national and provincial governments can take some steps in this direction, such as:

- Pass acts for the conservation of forests,
- Survey of the forest resources,
- Categorization of forest areas and proper delimitation of reserved forest areas,
- Find out the areas where reforestation can be done,
- Regulate the commercial use of forest products,
- Protect forest from fire, mining and other natural calamities,
- Develop national parks,
- Encourage forests developmental activities like social forestry, agro-forestry, etc., and
- Prepare master plans, both for long-term and short-term period, etc.

8. Forest Management:

Management of forest resources is the key to all conservation efforts. In forest management, the following aspects should be taken into consideration:

- Survey of forest,
- Categorisation of forest.
- Economic use of forest,
- Administrative setting for forest management,
- Training programmes for persons engaged in forest conservation activities,
- Use of forest land as tourist centers,
- Social and agro-forestry,
- Development of new techniques for the conservation of forests,
- Research for efficient use and conservation of forest, and
- Policy decisions and their proper implementation.

SOCIAL FORESTRY

Social forestry means the management and protection of forest and afforestation of barren and deforested lands with the purpose of helping environmental, social and rural development. The term, Social Forestry, was first used in India in 1977 by The National Commission on Agriculture, Government of India. It was then that India embarked upon a social forestry project with the aim of taking the pressure off currently existing forests by planting trees on all unused and fallow lands.

Objectives of Social Forestry

1. Increasing Forest Area and Restoring Ecological Balance

Moisture conservation—trees take water from the lower soil strata and bring it to the upper layers through long tap root system and, also, trees check evaporation of water; Soil conservation—trees help in checking erosion by wind and water; Natural habitat conservation—trees provide habitat to many birds and animals, some of which are agro-friendly.

2. Meeting Basic Rural Needs:

Social forestry satisfies the basic rural needs referred to as 'five Fs'—food, fuel, fodder, fertiliser (green manure) and fibre. The large-scale depletion of easily accessible forests has resulted in acute scarcity of fuel-wood and fodder. What is disturbing is that the deficit in fuel wood is met by using cow-dung cakes, thus wasting a rich and cheap source of manure. Trees also supply the raw material for various small and village industries through small timber and minor forest produce.

3. Ensuring Better Land Use:

Social forestry helps achieve a balanced and viable land use by checking soil erosion, facilitating reclamation of marginal lands, checking waterlogging and by bringing about monolithic integration of forestry, agriculture and animal husbandry.

4. Generation of Employment:

Social forestry operations have the potential of improving the employment situation in rural areas especially during the lean agricultural season. This helps in stabilising incomes of weaker sections of Society.

5. Controlling Pollution:

Trees are known to absorb harmful gases and release oxygen. This way they help reduce air pollution especially in urban areas.

AGRO-FORESTRY

Agroforestry is the management and integration of trees, crops and/or livestock on the same plot of land and can be an integral component of productive agriculture. It may include existing native forests and forests established by landholders. It is a flexible concept, involving both small and large-sized land holdings

Scientifically speaking, agroforestry is derived from ecology and is one of the three principal land-use sciences, the other two being agriculture and forestry. Agroforestry differs from the latter two principals by placing an emphasis on integration of and interactions among a combination of elements rather than just focusing on each element individually.

Agroforestry has a lot in common with intercropping (the practice of planting two or more crops on the same plot) with both practices placing an emphasis on interaction between different plant species. Generally speaking, both agroforestry and intercropping can result in higher overall yields and reduced operational costs.

According to the Agroforestry Research Trust, Agroforestry Systems can include the following benefits

1. They can control runoff and soil erosion, thereby reducing losses of water, soil material, organic matter and nutrients.
2. They can maintain soil organic matter and biological activity at levels satisfactory for soil fertility. This depends on an adequate proportion of trees in the system- normally at least 20% crown cover of trees to maintain organic matter over systems as a whole.
3. They can maintain more favourable soil physical properties than agriculture, through organic matter maintenance and the effects of tree roots.
4. They can lead to more closed nutrient cycling than agriculture and hence to more efficient use of nutrients. This is true to an impressive degree for forest garden/farming systems.
5. They can check the development of soil toxicities, or reduce exiting toxicities-both soil acidification and salinization can be checked and trees can be employed in the reclamation of polluted soils.
6. They utilize solar energy more efficiently than monocultural systems different height plants, leaf shapes and alignments all contribute.
7. They can lead to reduced insect pests and associated diseases.
8. They can be employed to reclaim eroded and degraded land.
9. Agro forestry can augment soil water availability to land use systems. In dry regions, though, competition between trees and crops is a major problem.
10. Nitrogen-fixing trees and shrubs can substantially increase nitrogen inputs to agro forestry systems.
11. Trees can probably increase nutrient inputs to agro forestry systems by retrieval from lower soil horizons and weathering rock.
12. The decomposition of tree and pruning can substantially contribute to maintenance of soil fertility. The addition of high-quality tree prunings leads to large increase in crop yields.
13. The release of nutrients from the decomposition of tree residues can be synchronized with the requirements for nutrient uptake of associated crops. While different trees and crops will all have different requirement, and there will always be some imbalance, the addition of high quality prunings to the soil at the time of crop planting usually leads to a good degree of synchrony between nutrient release and demand.
14. In the maintenance of soil fertility under agro forestry, the role of roots is at least as important as that of above-ground biomass.
15. Agro forestry can provide a more diverse farm economy and stimulate the whole rural economy, leading to more stable farms and communities. Economics risks are reduced when systems produce multiple products.

FACTORS INFLUENCING DISTRIBUTION OF PLANTS AND ANIMALS

Temperature - the ability to withstand extremes in temperature varies widely among plants & animals. Animals respond to variation in temperature both physiologically and behaviorally. Birds and mammals are Endotherms ('hot-blooded') & maintain relatively high body temperatures using the heat by their own metabolism. Other animals (such as reptiles, amphibians, fish, & insects) are called Ectotherms & their body temperatures are largely set by the ambient (surrounding) temperature.

Water-Precipitation determines, along with mean temperature, the world-wide distribution of biomes. Primary problem for plants in areas like deserts is a lack of water. Plants adapted for arid conditions include: Xerophytes, such as cacti and Joshua trees that usually have special means of storing and conserving water. They often have few or no leaves, which reduce transpiration. Phreatophytes - plants that grow extremely long roots, allowing them to acquire moisture at or near the water table.

Fire-Historically, humans have thought that all fires were detrimental because they blackened landscapes and burned trees. In fact, plants and animals evolved together with fire, making it a necessary element in the survival of many ecosystems. Tall grass prairie - Fires are important in the tall grass prairie because they eliminate woody vegetation & foreign plant species.

Many plants depend on fire to heat and scar their seeds as a process for germination. Decaying trees release nutrients into the soil and serve as a base for new plants to sprout. Much of the plant life in the United States has evolved to use fire directly as a catalyst for reproduction or benefited by the nourishment left in its path.

The specific effects of fire on animals depend on what kind of fire, the type of vegetation, and the individual animal. Larger animals generally survive more often than smaller ones; although a burrowed animal can escape burning, usually it suffocates in the meantime. Many birds also thrive after a fire when the seeds of many trees are dispersed.

Light-Light influences daily and seasonal activity patterns of plants and animals necessary for photosynthesis which, in turn, is the source of energy in almost all ecosystems.

Other factors include **Continental Drift, Soil pH; Salinity; and Mineral availability**.

UNIT- VI
[INDIA PHYSICAL]

PHYSIOGRAPHY OF INDIA

Physiographically India can be divided into the following six divisions

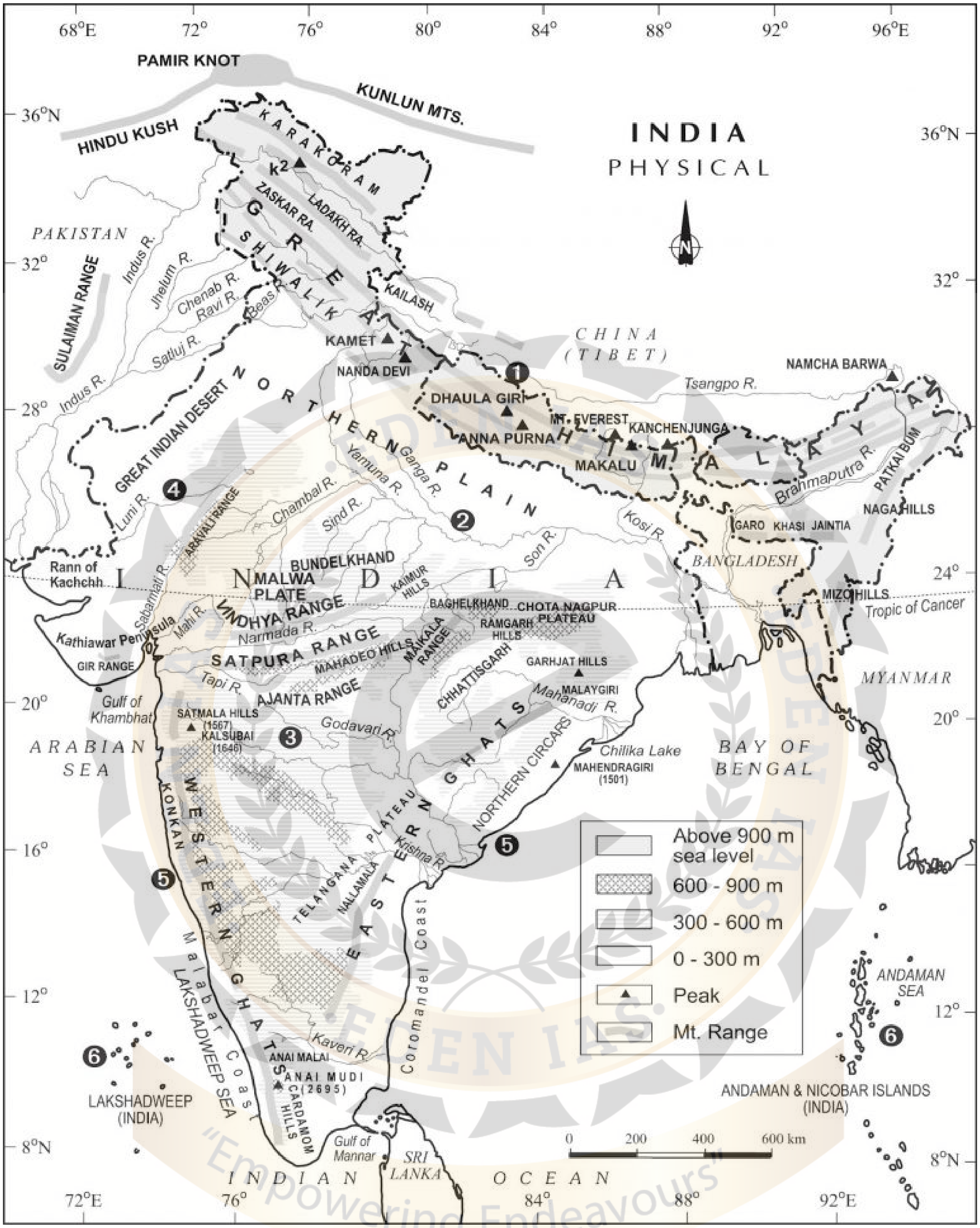
1) The Northern Mountains
2) The North Indian Plain
3) The Peninsular Plateau
4) Great Indian Desert
5) The Coastal Regions
6) The Island groups

The Northern Mountains

The Himalayas, geologically young and structurally fold mountains stretch over the northern borders of India. These mountain ranges run in a west-east direction from the Indus to the Brahmaputra. The Himalayas represent the loftiest and one of the most rugged mountain barriers of the world. They form an arc, which covers a distance of about 2,400 Km. Their width varies from 400 Km in Kashmir to 150 Km in Arunachal Pradesh. The altitudinal variations are greater in the eastern half than those in the western half. The Himalaya consists of three parallel ranges in its longitudinal extent. A number of valleys lie between these ranges. The northern most range is known as the Great or Inner Himalayas or the **'Himadri'**. It is the most continuous range consisting of the loftiest peaks with an average height of 6,000 metres. It contains all the prominent Himalayan peaks.

The folds of Great Himalayas are asymmetrical in nature. The core of this part of Himalayas is composed of granite. It is perennially snow bound, and a number of glaciers descend from this range. The range lying to the south of the Himadri forms the most rugged mountain system and is known as Himachal or lesser Himalaya. The ranges are mainly composed of highly compressed and altered rocks. The altitude varies between 3,700 and 4,500 metres and the average width is of 50 Km. While the Pir Panjal range forms the longest and the most important range, the Dhaula Dhar and the Mahabharata ranges are also prominent ones. This range consists of the famous valley of Kashmir, the Kangra and Kullu Valley in Himachal Pradesh. This region is well known for its hill stations

The outer most range of the Himalayas is called the Shiwaliks. They extend over a width of 10-50 Km and have an altitude varying between 900 and 1100 metres. These ranges are composed of unconsolidated sediments brought down by rivers from the main Himalayan ranges located farther north. These valleys are covered with thick gravel and alluvium. The longitudinal valley lying between lesser Himalaya and the Shiwaliks are known as Duns. Dehra Dun, Kotli Dun and Patli Dun are some of the well-known Duns.



Besides the longitudinal divisions, the Himalayas have been divided on the basis of regions from west to east. These divisions have been demarcated by river valleys. For example, the part of Himalayas lying between Indus and Satluj has been traditionally known as Punjab Himalaya but it is also known regionally as Kashmir and Himachal Himalaya from west to east respectively. The part of the Himalayas lying between Satluj and Kali rivers is known as Kumaon Himalayas. The Kali and Tista rivers demarcate the Nepal Himalayas and the part lying between Tista and Dihang rivers is known as Assam Himalayas. There are regional names also in these broad categories. The Brahmaputra marks the eastern most boundary of the Himalayas. Beyond the Dihang gorge, the Himalayas bend sharply to the south and spread along the eastern boundary of India. They are known as the Purvachal or the Eastern hills and mountains. These hills running through the north-eastern states are mostly composed of strong sandstones which are sedimentary rocks. Covered with dense forests, they mostly run as parallel ranges and valleys. The Purvachal comprises the Patkai hills, the Naga hills, Manipur hills and the Mizo hills.

The North Indian Plain

The northern plain has been formed by the interplay of the three major river systems, namely– the Indus, the Ganga and the Brahmaputra along with their tributaries. This plain is formed of alluvial soil. The deposition of alluvium in a vast basin lying at the foothills of the Himalaya over millions of years formed this fertile plain. It spreads over an area of 7 lakh sq. km. The plain being about 2400 Km long and 240 to 320 Km broad, is a densely populated physiographic division. With a rich soil cover combined with adequate water supply and favourable climate it is agriculturally a very productive part of India

The rivers coming from northern mountains are involved in depositional work. In the lower course, due to gentle slope, the velocity of the river decreases which results in the formation of riverine islands.

The rivers in their lower course split into numerous channels due to the deposition of silt. These channels are known as distributaries. The Northern Plain is broadly divided into three sections. The Western part of the Northern Plain is referred to as the Punjab Plains. Formed by the Indus and its tributaries, the larger part of this plain lies in Pakistan. The Indus and its tributaries–the Jhelum, the Chenab, the Ravi, the Beas and the Satluj originate in the Himalaya. This section of the plain is dominated by the doabs.

The Ganga plain extends between Ghaggar and Teesta rivers. It is spread over the states of North India, Haryana, Delhi, U.P., Bihar, partly Jharkhand and West Bengal to its East, particularly in Assam lies the Brahmaputra plain. The northern plains are generally deseribed as flat land with no variations in its relief. It is not true. These vast plains also have diverse relief features. According to the variations in relief features, the Northern plains can be divided into four regions. The rivers, after descending from the mountains deposit pebbles in a narrow belt of about 8 to 16 km in width lying parallel to the slopes of the Shiwaliks. It is known as **Bhabhar**. All the streams disappear in this Bhabhar belt. South of this belt, the streams and rivers re-emerge and create a wet, swampy and marshy region known as **terai**. This was a thickly forested region full of wildlife. The forests have been cleared to create agricultural land and to settle migrants from Pakistan after partition. Locate Dudhwa National Park in this region. The largest part of the northern plain is formed of older alluvium. They lie above the flood plains of the rivers and present a terrace like feature. This part is known as **bhangar**

The soil in this region contains calcareous deposits locally known as **kankar**. The newer, younger deposits of the flood plains are called **khadar**. They are renewed almost every year and so are fertile, thus, ideal for intensive agriculture.

The 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. This plateau consists of two broad divisions, namely, the Central Highlands and the Deccan Plateau. The part of the peninsular plateau lying to the north of the river Narmada covering a major area of the Malwa plateau is known as the Central Highlands. The Vindhyan range is bounded by the Central Highlands on the south and the Aravalis on the northwest. The further westward extension gradually merges with the sandy and rocky desert of Rajasthan. The flow of the rivers draining this region, namely the Chambal, the Sind, the Betwa and Ken is from southwest to northeast, thus indicating the slope. The Central Highlands are wider in the west but narrower in the east. The eastward extensions of this plateau are locally known as the Bundelkhand and Baghelkhand. The Chotanagpur plateau marks the further eastward extension, drained by the Damodar.

The Deccan Plateau is a triangular landmass that lies to the south of the river Narmada. The Satpura range flanks its broad base in the north while the Mahadev, the Kaimur hills and the Maikal range form its eastern extensions. Locate these hills and ranges in the physical map of India. The Deccan Plateau is higher in the west and slopes gently eastwards. An extension of the Plateau is also visible in the northeast– locally known as the Meghalaya, Karbi-Anglong Plateau and North Cachar Hills. It is separated by a fault from the Chotanagpur Plateau. Three Prominent hill ranges from the west to east are the Garo, the Khasi and the Jaintia Hills. The Western Ghats and the Eastern Ghats mark the western and the eastern edges of the Deccan Plateau respectively. Western Ghats lie parallel to the western coast. They are continuous and can be crossed through passes only. The Western Ghats are higher than the Eastern Ghats. Their average elevation is 900– 1600 metres as against 600 metres of the Eastern Ghats. The Eastern Ghats stretch from the Mahanadi Valley to the Nilgiris in the south. The Eastern Ghats are discontinuous and irregular and dissected by rivers draining into the Bay of Bengal. The Western Ghats cause orographic rain by facing the rain bearing moist winds to rise along the western slopes of the Ghats. The Western Ghats are known by different local names. The height of the Western Ghats progressively increases from north to south. The highest peaks include the Anai Mudi (2,695metres) and the Doda Betta (2,637 metres). Mahendragiri (1,501 metres) is the highest peak in the Eastern Ghats. Shevroy Hills and the Javadi Hills are located to the southeast of the Eastern Ghats. Locate the famous hill stations of Udagamandalam, popularly known as Ooty and the Kodaikanal. One of the distinct features of the peninsular plateau is the black soil area known as Decean Trap. This is of volcanic origin hence the rocks are igneous. Actually these rocks have denuded over time and are responsible for the formation of black soil. The Aravali Hills lie on the western and northwestern margins of the peninsular plateau. These are highly eroded hills and are found as broken hills. They extend from Gujarat to Delhi in a southwest-northeast direction.

Great Indian Desert

The Indian desert lies towards the western margins of the Aravali Hills. It is an undulating sandy plain covered with sand dunes. This region receives very low rainfall below 150 mm per year. It has arid climate with low vegetation cover. Streams appear during the rainy season. Soon after they disappear into the sand as they do not have enough water to reach the sea. Luni is the only large river in this region. Barchans (crescent shaped dunes) cover larger areas but longitudinal dunes become more prominent near the Indo-Pakistan boundary.

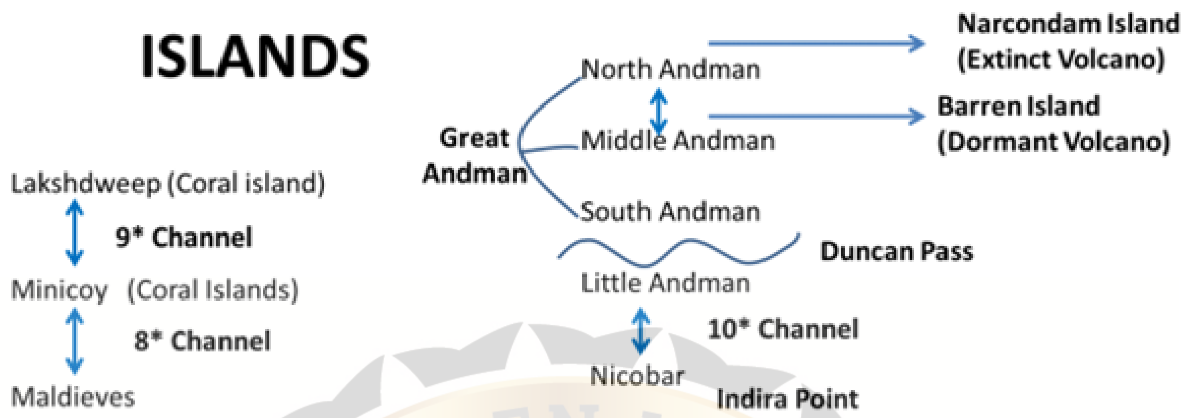
The Coastal Region

The Peninsular plateau is flanked by stretch of narrow coastal strips, running along the Arabian Sea on the west and the Bay of Bengal on the east. The western coast, sandwiched between the Western Ghats and the Arabian Sea, is a narrow plain. It consists of three sections. The northern part of the coast is called the Konkan (Mumbai – Goa), the central stretch is called the Kannad Plain while the southern stretch is referred to as the Malabar coast.

The plains along the Bay of Bengal are wide and level. In the northern part, it is referred to as the Northern Circar, while the southern part is known as the Coromandel Coast. Large rivers such as the Mahanadi, the Godavari, the Krishna and the Kaveri have formed extensive delta on this coast. Lake Chilika is an important feature along the eastern coast. The Chilika Lake is the largest salt water lake in India. It lies in the state of Orissa, to the south of the Mahanadi delta.

The Island groups

There are 247 islands in India → 204 islands in Bay of Bengal and 43 in the Arabian Sea. To this list must be added those islands that strech from the Gujarat coast to the Bengal coast. Andaman and Nicobar Islands in Bay of Bengal consist of hard volcanic rocks. The middle Andaman and Nicobar Islands are the largest islands of India. Lakshadweep islands in the Arabian Sea are formed of corals. The southern – most point of India is in Nicobar Island, known as Indira Point. Formerly Indira point was called Pygmalion Point; it is submerged now, after 2004 Tsunami



CLIMATE OF INDIA

India's climate closely resembles the climate that of a tropical country although it's northern part (north of tropic of cancer) is situated in the **temperate belt.** Indian subcontinent is separated from the rest of Asia by the **lofty Himalayan ranges** which block the **cold air masses** moving southwards from Central Asia. As a result, during winters, the northern half of India is warmer by **3°C to 8°C** than other areas located on same latitudes.

During summer, due to over the head position of the sun, the climate in the southern parts resemble equatorial dry climate. The north Indian plains are under the influence of hot dry wind called **'loo'** blowing from the **Thar, Baloch and Iranian Deserts**, increasing the temperatures to a level comparable to that of the southern parts of the country.

Thus the whole of India, south of the Himalayas can be climatically treated as a tropical country. The seasonal reversal of winds in Arabian Sea and Bay of Bengal give India a typical **tropical monsoon climate.** So Indian climate, to be precise, is **tropical monsoon type** rather than just a tropical or half temperate climate. India has high Regional Climatic Diversity because of its topographical diversity (location, altitude, distance from sea and relief).

Rainfall

The climate in most of the regions is characterized by **distinct wet and dry seasons**. Some places like Thar Desert, Ladakh have no wet season. Mean annual rainfall varies substantially from region to region. **Mawsynram and Cherrapunji** in Meghalaya receives around 1,000 cm of annual rainfall while at Jaisalmer the annual rainfall rarely exceeds 12 cm.

The Ganga delta and the coastal plains of Odisha see intense rainfall in July and August while the Coromandel Coast goes dry during these months. Places like Goa, Hyderabad and Patna receive south-west monsoon rains by the first quarter of June while the rains are awaited till early July at places in Northwest India.

Temperature

Diurnal and annual temperature ranges are substantial. **Highest diurnal temperature ranges occur in the Thar Desert and the highest annual temperature ranges are recorded in the Himalayan regions.** Both diurnal and mean annual temperature ranges are least in coastal regions.

In December, the temperature may dip to – 40°C at some places in J&K while in many coastal regions average temperature is 20-25°C. Winters are moderately cold in most of the regions while the summers are extremely hot. Himalayan regions experience brutal winters while the summers are moderate.

FACTORS AFFECTING INDIA's CLIMATE

Latitude

The Tropic of Cancer passes through the middle of the country from the Rann of Kachchh in the west to Mizoram in the east. Almost half of the country, lying south of the Tropic of Cancer, belongs to the tropical area. All the remaining area, north of the Tropic, lies in the sub-tropics. Therefore, India's climate has characteristics of tropical as well as subtropical climates.

Altitude

India has mountains to the north, which have an average height of about 6,000 metres. India also has a vast coastal area where the maximum elevation is about 30 metres. The Himalayas prevent the cold winds from Central Asia from entering the subcontinent. It is because of these mountains that this subcontinent experiences comparatively milder winters as compared to central Asia.

Pressure and Winds

The climate and associated weather conditions in India are governed by the following atmospheric conditions:

- Pressure and surface winds;
- Upper air circulation; and
- Western cyclonic disturbances and tropical cyclones.

India lies in the region of north easterly winds. These winds originate from the subtropical high-pressure belt of the northern hemisphere. They blow south, get deflected to the right due to the Coriolis force, and move on towards the equatorial low-pressure area. Generally, these winds carry very little moisture as they originate and blow over land. Therefore, they bring little or no rain. Hence, India should have been an arid land, but, it is not so.

The pressure and wind conditions over India are unique. During winter, there is a high-pressure area north of the Himalayas. Cold dry winds blow from this region to the low-pressure areas over the oceans to the south. In summer, a low-pressure area develops over interior Asia as well as over northwestern India. This causes a complete reversal of the direction of winds during summer. Air moves from the high-pressure area over the southern Indian Ocean, in a south-easterly direction, crosses the equator, and turns right towards the low-pressure areas over the Indian subcontinent. These are known as the Southwest Monsoon winds. These winds blow over the warm oceans, gather moisture and bring widespread rainfall over the mainland of India.

The upper air circulation in this region is dominated by a westerly flow. An important component of this flow is the jet stream. These jet streams are located approximately over 27°-30° north latitude, therefore, they are known as subtropical westerly jet streams. Over India, these jet streams blow south of the Himalayas, all through the year except in summer. The western cyclonic disturbances experienced in the north and north-western parts of the country are brought in by this westerly flow. In summer, the subtropical westerly jet stream moves north of the Himalayas with the apparent movement of the sun. An easterly jet stream, called the sub-tropical easterly jet stream blows over peninsular India, approximately over 14°N during the summer months.

JET-STREAMS

These are a narrow belt of high altitude (above 12,000 m) westerly winds in the troposphere. Their speed varies from about 110 km/h in summer to about 184 km/h in winter. A number of separate jet streams have been identified. The most constant are the mid-latitude and the sub tropical jet stream.

WESTERN DISTURBANCES

A Western Disturbance is an extratropical storm originating in the Mediterranean region that brings sudden winter rain to the northwestern parts of the Indian subcontinent. It is a non-monsoonal precipitation pattern driven by the westerlies. The moisture in these storms usually originates over the Mediterranean Sea and the Atlantic Ocean. Extratropical storms are a global phenomena with moisture usually carried in the upper atmosphere, unlike their tropical counterparts where the moisture is carried in the lower atmosphere. In the case of the Indian subcontinent, moisture is sometimes shed as rain when the storm system encounters the Himalayas. Western Disturbances are important for the development of the Rabi crop, which includes the locally important staple wheat.

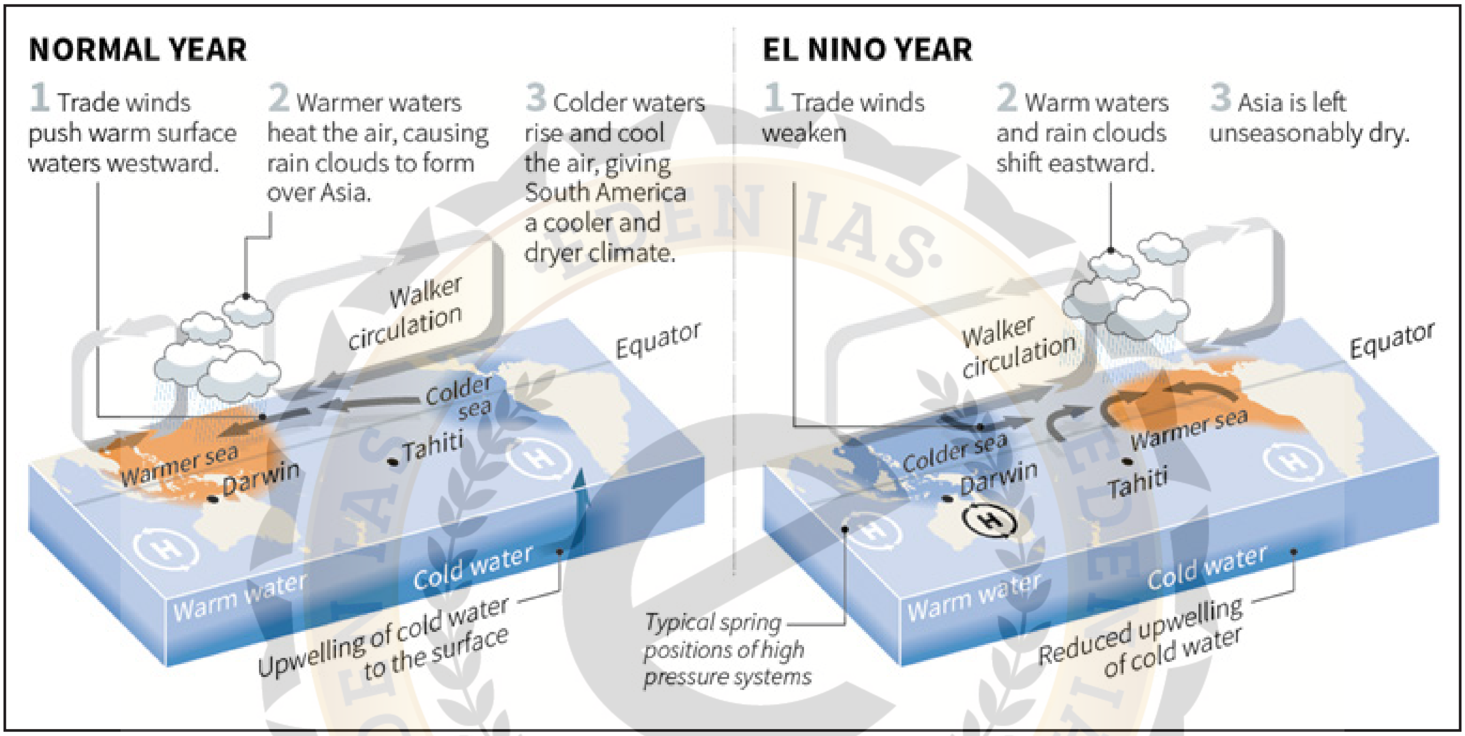
THE INDIAN MONSOONS

The word Monsoon is derived from the Arabic word '**Mausim'** meaning seasons. The climate of India is strongly influenced by monsoon winds. The sailors who came to India in historic times were one of the first to have noticed the phenomenon of the monsoon. They benefited from the reversal of the wind system as they came by sailing ships at the mercy of winds. The Arabs, who had also come to India as traders named this seasonal reversal of the wind system 'monsoon'. The monsoons are experienced in the tropical area roughly between 20° N and 20° S. To understand the mechanism of the monsoons, the following facts are important.

a) The differential heating and cooling of land and water creates low pressure on the landmass of India while the seas around experience comparatively high pressure.
b) The shift of the position of Inter Tropical Convergence Zone (ITCZ) in summer, over the Ganga plain (this is the equatorial trough normally positioned about 5°N of the equator. It is also known as the monsoon trough during the monsoon season).
c) The presence of the high-pressure area, east of Madagascar, approximately at 20°S over the Indian Ocean. The intensity and position of this high-pressure area affects the Indian Monsoon.
d) The Tibetan plateau gets intensely heated during summer, which results in strong vertical air currents and the formation of low pressure over the plateau at about 9 km above sea level.
e) The movement of the westerly jet stream to the north of the Himalayas and the presence of the tropical easterly jet stream over the Indian peninsula during summer.

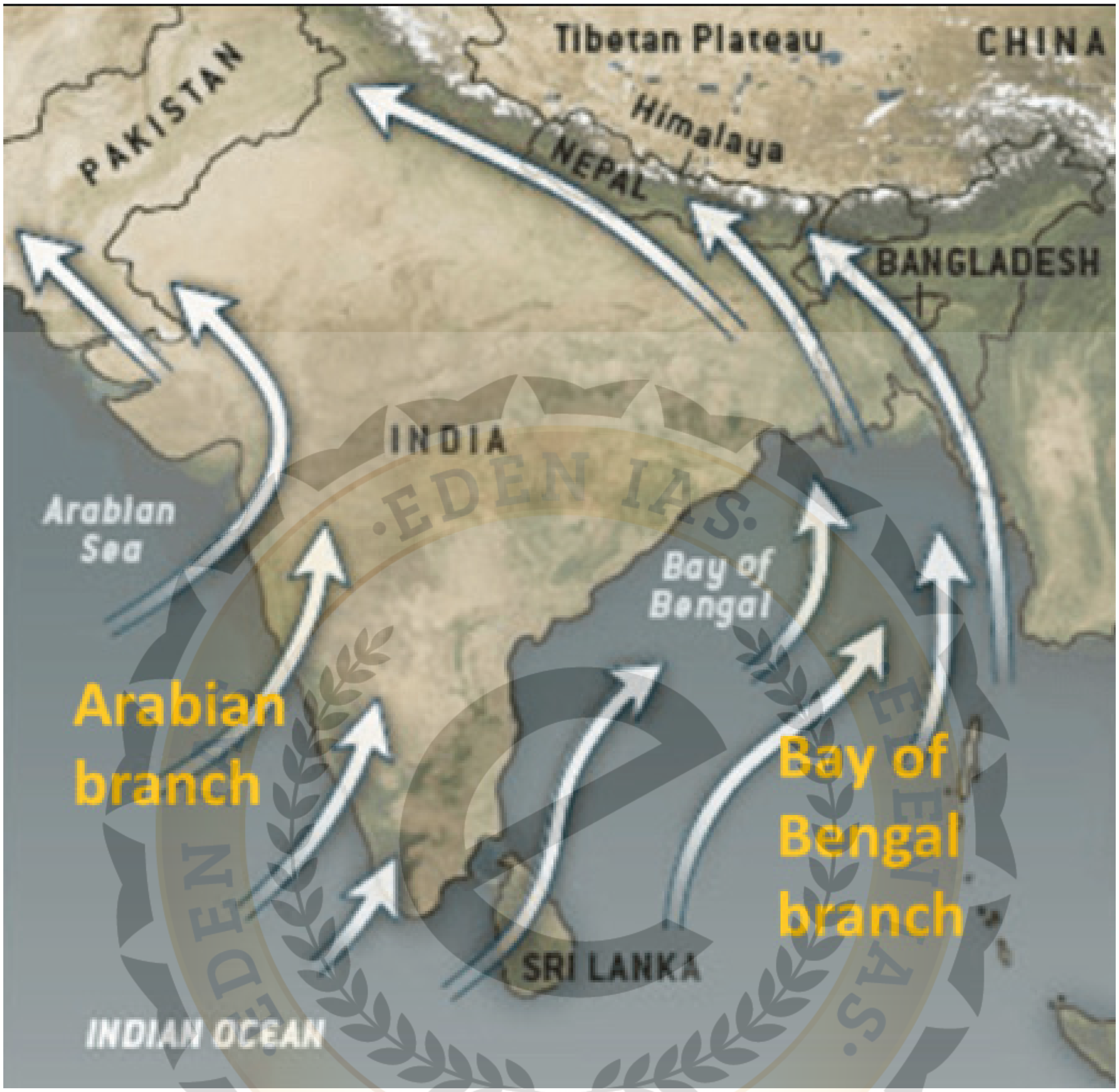
Apart from this, it has also been noticed that changes in the pressure conditions over the southern oceans also affect the monsoons. Normally when the tropical eastern South Pacific Ocean experiences high pressure, the tropical eastern Indian Ocean experiences low pressure. But in certain years, there is a reversal in the pressure conditions and the eastern Pacific has lower pressure in comparison to the eastern Indian Ocean. This periodic change in pressure conditions is known as the Southern Oscillation or SO. The difference in pressure over Tahiti (Pacific Ocean, 18°S/149°W) and Darwin in northern Australia (Indian

Ocean, 12°30'S/131°E) is computed to predict the intensity of the monsoons. If the pressure differences were negative, it would mean below average and late monsoons. A feature connected with the SO is the **El Nino** phenomenon in which a warm ocean current that flows past the Peruvian Coast, in place of the cold Peruvian current, every 2 to 5 years. The changes in pressure conditions are connected to the El Nino. Hence, the phenomenon is referred to as **ENSO (El Nino Southern Oscillations)**

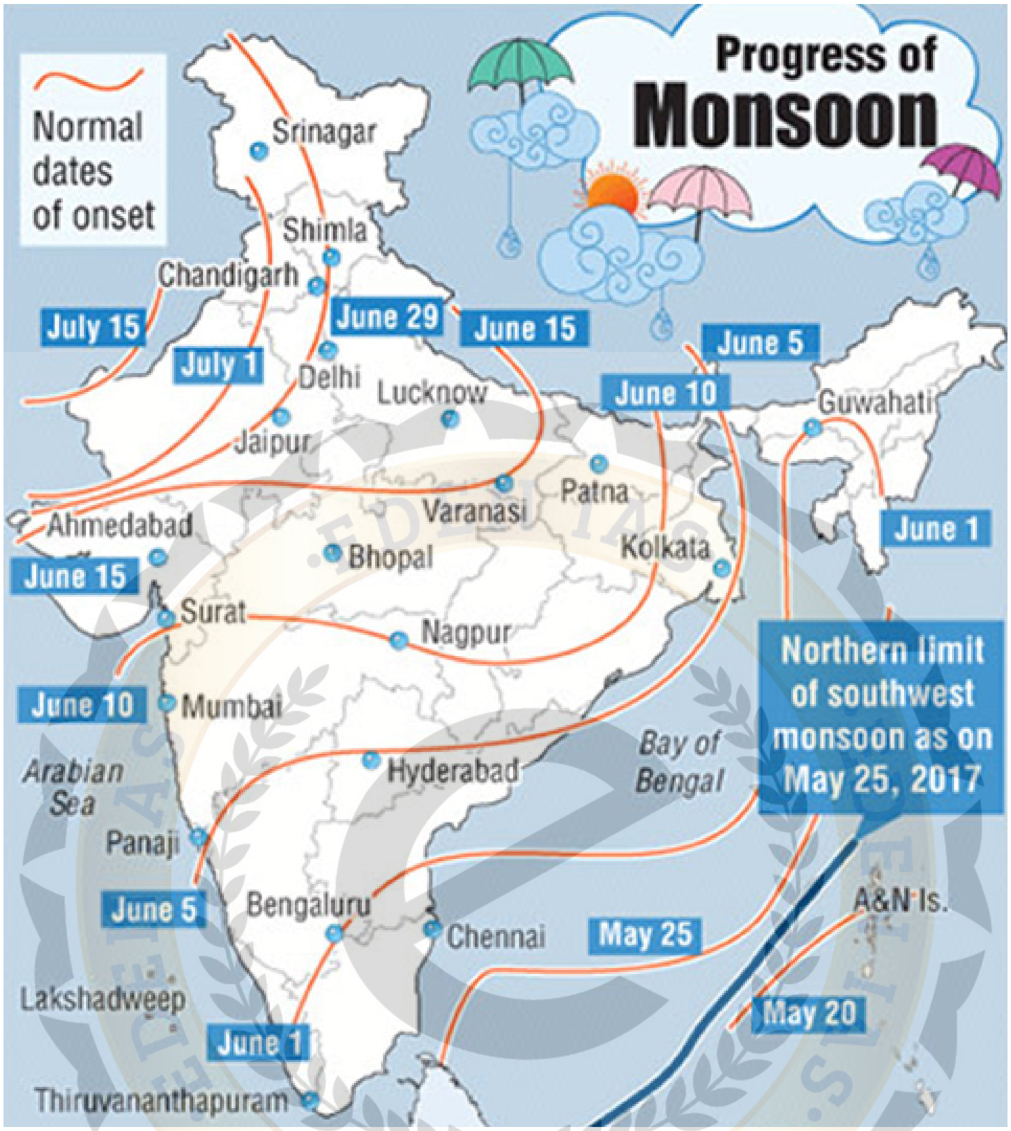


THE ONSET OF THE MONSOON AND WITHDRAWAL

The Monsoon, unlike the trades, are not steady winds but are pulsating in nature, affected by different atmospheric conditions encountered by it, on its way over the warm tropical seas. The duration of the monsoon is between 100- 120 days from early June to mid-September. Around the time of its arrival, the normal rainfall increases suddenly and continues constantly for several days. This is known as the 'burst' of the monsoon, and can be distinguished from the pre-monsoon showers. The monsoon arrives at the southern tip of the Indian peninsula generally by the first week of June. Subsequently, it proceeds into two – the Arabian Sea branch and the Bay of Bengal branch. The Arabian Sea branch reaches Mumbai about ten days later on approximately the 10th of June. This is a fairly rapid advance. The Bay of Bengal branch also advances rapidly and arrives in Assam in the first week of June. The lofty mountains causes the monsoon winds to deflect towards the west over the Ganga plains. By mid-June the Arabian Sea branch of the monsoon arrives over Saurashtra-Kachchh and the central part of the country.



The Arabian Sea and the Bay of Bengal branches of the monsoon merge over the northwestern part of the Ganga plains. Delhi generally receives the monsoon showers from the Bay of Bengal branch by the end of June (tentative date is 29th of June). By the first week of July, western Uttar Pradesh, Punjab, Haryana and eastern Rajasthan experience the monsoon. By mid-July, the monsoon reaches Himachal Pradesh and the rest of the country. Withdrawal or the retreat of the monsoon is a more gradual process. The withdrawal of the monsoon begins in northwestern states of India by early September. By mid-October, it withdraws completely from the northern half of the peninsula. The withdrawal from the southern half of the peninsula is fairly rapid. By early December, the monsoon has withdrawn from the rest of the country. The islands receive the very first monsoon showers, progressively from south to north, from the last week of April to the first week of May. The withdrawal, takes place progressively from north to south from the first week of December to the first week of January. By this time the rest of the country is already under the influence of the winter monsoon.



SEASONS OF INDIA

Four main seasons can be identified in India – the cold weather season, the hot weather season, the advancing monsoon and the retreating monsoon with some regional variations.

The Cold Weather Season (Winter)

The cold weather season begins from mid-November in northern India and stays till February. December and January are the coldest months in the northern part of India. The temperature decreases from south to the north. The average temperature of Chennai, on the eastern coast, is between 24° - 25° Celsius, while in the northern plains, it ranges between 10° - 15° Celsius. Days are warm and nights are cold. Frost is common in the north and the higher slopes of the Himalayas experience snowfall. During this season, the northeast trade winds prevail over the country. They blow from land to sea and hence, for most part of the country, it is a dry season.

Some amount of rainfall occurs on the Tamil Nadu coast from these winds as; here they blow from sea to land. In the northern part of the country, a feeble high-pressure region develops, with light winds moving outwards from this area. Influenced by the relief, these winds blow through the Ganga valley from the west and the northwest. The weather is normally marked by clear sky, low temperatures and low humidity and feeble, variable winds. A characteristic feature of the cold weather season over the northern plains is the inflow of cyclonic disturbances from the west and the northwest.

These low-pressure systems originate over the Mediterranean Sea and western Asia and move into India, along with the westerly flow. They cause the much-needed winter rains over the plains and snowfall in the mountains. Although the total amount of winter rainfall locally known as **'mahawat'** is small, they are of immense importance for the cultivation of 'rabi' crops. The peninsular region does not have a well defined cold season. There is hardly any noticeable seasonal change in temperature pattern during winters due to the moderating influence of the sea.

The Hot Weather Season (Summer)

Due to the apparent northward movement of the sun, the global heat belt shifts northward. As such, from March to May, it is hot weather season in India. The influence of the shifting of the heat belt can be seen clearly from temperature recordings taken during March-May at different latitudes. In March, the highest temperature is about 38° Celsius, recorded on the Deccan plateau. In April, temperatures in Gujarat and Madhya Pradesh are around 42° Celsius. In May, temperature of 45° Celsius is common in the northwestern parts of the country. In peninsular India, temperatures remain lower due to the moderating influence of the oceans.

The summer months experience rising temperature and falling air pressure in the northern part of the country. Towards the end of May, an elongated low-pressure area develops in the region extending from the Thar Desert in the northwest to Patna and Chotanagpur plateau in the east and southeast. Circulation of air begins to set in around this trough. A striking feature of the hot weather season is the **'loo'.** These are strong, gusty, hot, dry winds blowing during the day over the north and northwestern India. Sometimes they even continue until late in the evening. Direct exposure to these winds may even prove to be fatal. Dust storms are very common during the month of May in northern India. These storms bring temporary relief as they lower the temperature and may bring light rain and cool breeze. This is also the season for localised thunderstorms, associated with violent winds, torrential downpours, often accompanied by hail. In West Bengal, these storms are known as the **'Kaal Baisakhi'**. Towards the close of the summer season, pre-monsoon showers are common especially, in Kerala and Karnataka. They help in the early ripening of mangoes, and are often referred to as **'mango showers'.**

Advancing Monsoon (The Rainy Season)

By early June, the low-pressure condition over the northern plains intensifies. It attracts the trade winds of the southern hemisphere. These south-east trade winds originate over the warm subtropical areas of the southern oceans. They cross the equator and blow in a south westerly direction entering the Indian peninsula as the south-west monsoon. As these winds blow over warm oceans, they bring abundant moisture to the subcontinent. These winds are strong and blow at an average velocity of 30 km per hour. With the exception of the extreme north-west, the monsoon winds cover the country in about a month.

The inflow of the south-west monsoon into India brings about a total change in the weather. Early in the season, the windward side of the Western Ghats receives very heavy rainfall, more than 250 cm. The Deccan Plateau and parts of Madhya Pradesh also receive some amount of rain in spite of lying in the rain shadow area. The maximum rainfall of this season is received in the north-eastern part of the country. **Mawsynram in the southern ranges of the Khasi Hills receives the highest average rainfall in the world**. Rainfall in the Ganga valley decreases from the east to the west. Rajasthan and parts of Gujarat get scanty rainfall. Another phenomenon associated with the monsoon is its tendency to have 'breaks' in rainfall. Thus, it has wet and dry spells. In other words, the monsoon rains take place only for a few days at a time.

They are interspersed with rainless intervals. These breaks in monsoon are related to the movement of the monsoon trough. For various reasons, the trough and its axis keep on moving northward or southward, which determines the spatial distribution of rainfall. When the axis of the monsoon trough lies over the plains, rainfall is good in these parts. On the other hand, whenever the axis shifts closer to the Himalayas, there are longer dry spells in the plains and widespread rain occur in the mountainous catchment areas of the Himalayan rivers. These heavy rains bring in their wake, devastating floods causing damage to life and property in the plains. The frequency and intensity of tropical depressions too, determine the amount and duration of monsoon rains. These depressions form at the head of the Bay of Bengal and cross over to the mainland. The depressions follow the axis of the **"monsoon trough of low pressure".** The monsoon is known for its uncertainties. **The alternation of dry and wet spells vary in intensity, frequency and duration.** While it causes heavy floods in one part, it may be responsible for droughts in the other. It is often irregular in its arrival and its retreat. Hence, it sometimes disturbs the farming schedule of millions of farmers all over the country.

Retreating/Post Monsoons (The Transition Season)

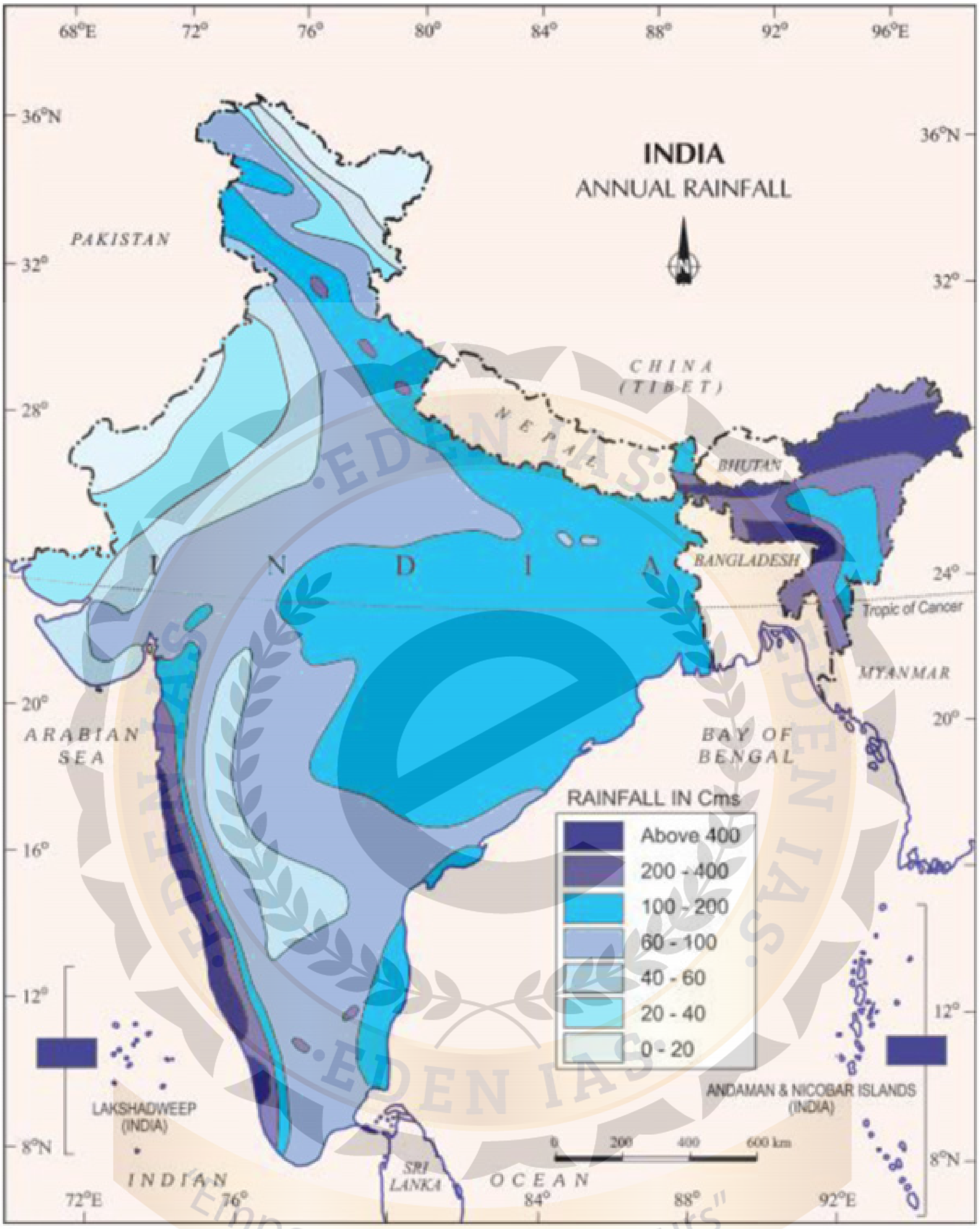
During October-November, with the apparent movement of the sun towards the south, the monsoon trough or the low-pressure trough over the northern plains becomes weaker. This is gradually replaced by a high-pressure system. The south-west monsoon winds weaken and start withdrawing gradually. By the beginning of October, the monsoon withdraws from the Northern Plains. The months of October-November form a period of transition from hot rainy season to dry winter conditions.

The retreat of the monsoon is marked by clear skies and rise in temperature. While day temperatures are high, nights are cool and pleasant. The land is still moist. Owing to the conditions of high temperature and humidity, the weather becomes rather oppressive during the day. This is commonly known as 'October heat'. In the second half of October, the mercury begins to fall rapidly in northern India. The low-pressure conditions, over northwestern India, get transferred to the Bay of Bengal by early November.

This shift is associated with the occurrence of cyclonic depressions, which originate over the Andaman Sea. These cyclones generally cross the eastern coasts of India cause heavy and widespread rain. These tropical cyclones are often very destructive. The thickly populated deltas of the Godavari, the Krishna and the Kaveri are frequently struck by cyclones, which cause great damage to life and property. Sometimes, these cyclones arrive at the coasts of Orissa, West Bengal and Bangladesh. The bulk of the rainfall of the Coromandel Coast is derived from depressions and cyclones.

DISTRIBUTION OF RAINFALL

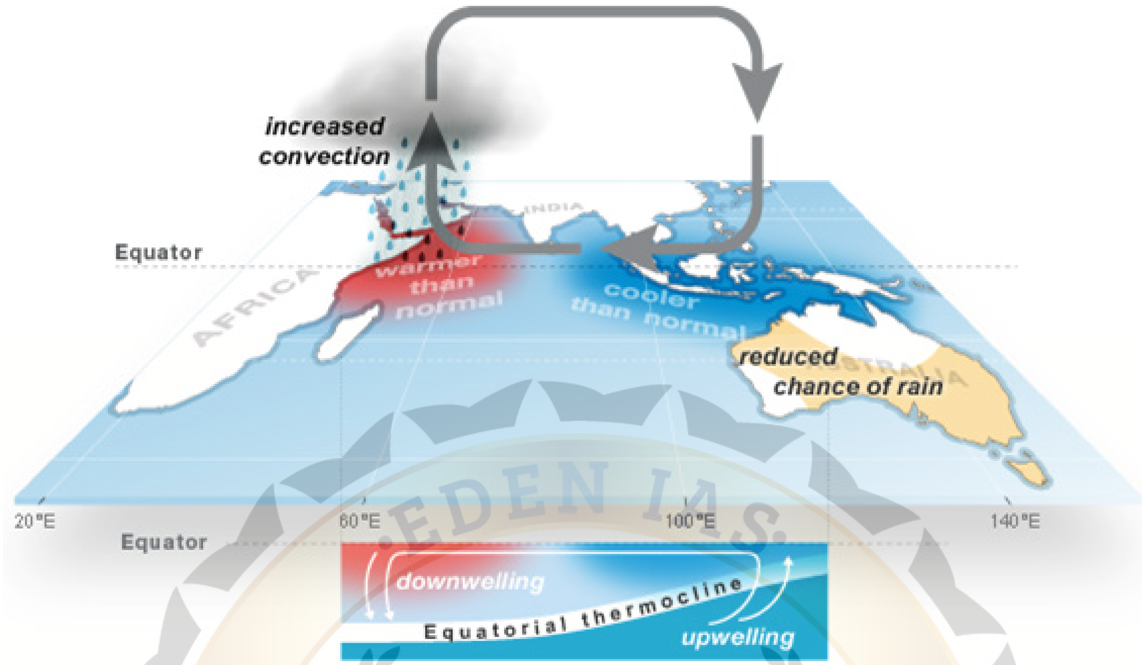
Parts of western coast and northeastern India receive over about 400 cm of rainfall annually. However, it is less than 60 cm in western Rajasthan and adjoining parts of Gujarat, Haryana and Punjab. Rainfall is equally low in the interior of the Deccan plateau, and east of the Sahyadris. Why do these regions receive low rainfall? A third area of low precipitation is around Leh in Jammu and Kashmir. The rest of the country receives moderate rainfall. Snowfall is restricted to the Himalayan region. Owing to the nature of monsoons, the annual rainfall is highly variable from year to year. Variability is high in the regions of low rainfall such as parts of Rajasthan, Gujarat and the leeward side of the Western Ghats. As such, while areas of high rainfall are liable to be affected by floods, areas of low rainfall are drought-prone



INDIAN OCEAN DIPOLE (IOD)

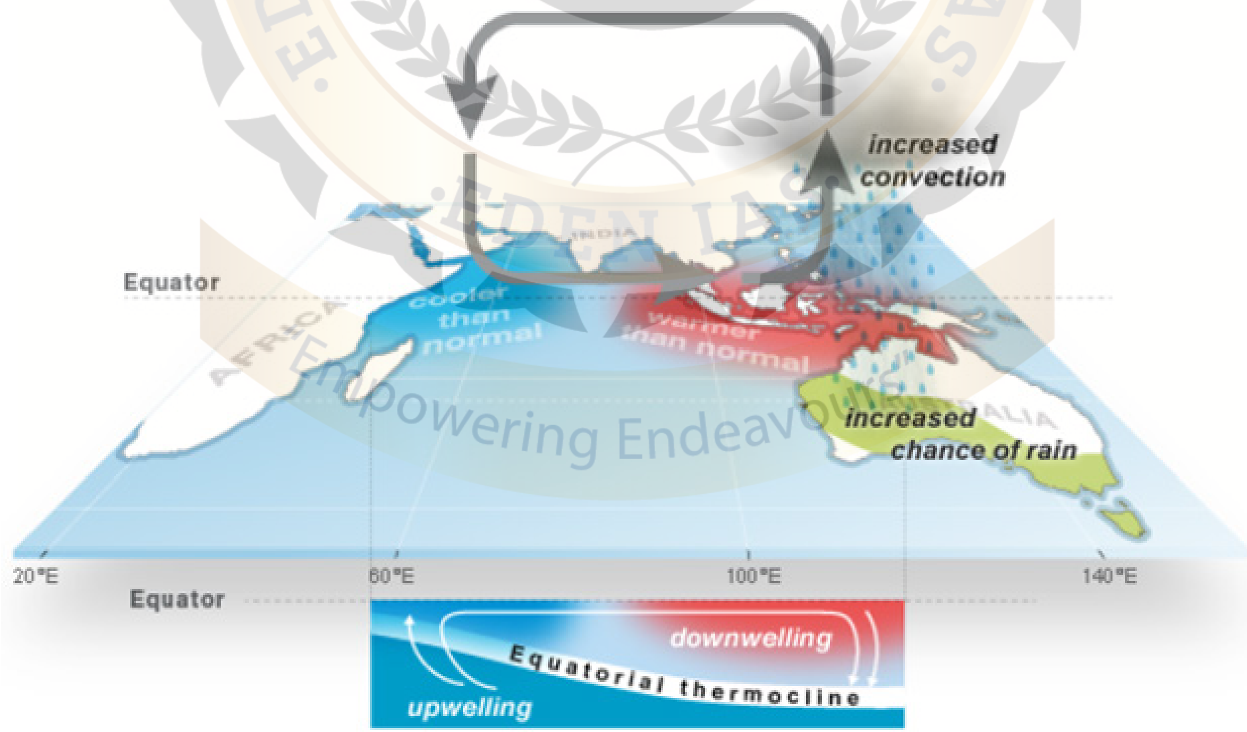
The Indian Ocean Dipole (IOD), also known as the **Indian Niño**, is an irregular oscillation of sea-surface temperatures in which the western Indian Ocean becomes alternately warmer and then colder than the eastern part of the ocean. Monsoon in India is generally affected by the temperature between Bay of Bengal in the east and The Arabian Sea in the west.

The IOD involves an aperiodic oscillation of sea-surface temperatures (SST), between "positive", "neutral" and "negative" phases. A positive phase sees greater-than-average sea-surface temperatures and greater precipitation in the western Indian Ocean region, with a corresponding cooling of waters in the eastern Indian Ocean—which tends to cause droughts in adjacent land areas of Indonesia and Australia. The negative phase of the IOD brings about the opposite conditions, with warmer water and greater precipitation in the eastern Indian Ocean, and cooler and drier conditions in the west.



Indian Ocean Dipole (IOD): **Positive phase**

The IOD also affects the strength of monsoons over the Indian subcontinent. A significant positive IOD occurred in 1997–98, with another in 2006. The IOD is one aspect of the general cycle of global climate, interacting with similar phenomena like the El Niño-Southern Oscillation (ENSO) in the Pacific Ocean.



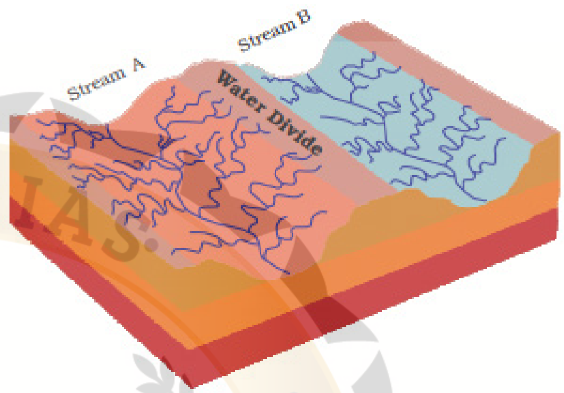
Indian Ocean Dipole (IOD): **Negative phase**

DRAINAGE OF INDIA

The term drainage describes the river system of an area. Look at the physical map. You will notice that small streams flowing from different directions come together to form the main river, which ultimately drains into a large water body such as a lake or a sea or an ocean. The area drained by a single river system is called a drainage basin. A closer observation on a map will indicate that any elevated area, such as a mountain or an upland, separates two drainage basins. Such an upland is known as a water divide.

The drainage systems of India are mainly controlled by the broad relief features of the subcontinent. Accordingly, the Indian rivers are divided into two major groups:

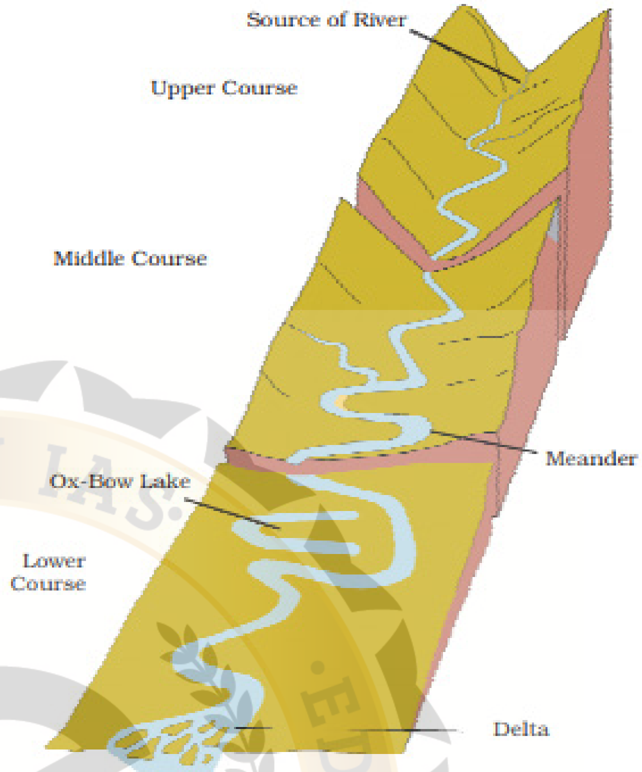
- **The Himalayan Rivers**
- **The Peninsular Rivers**

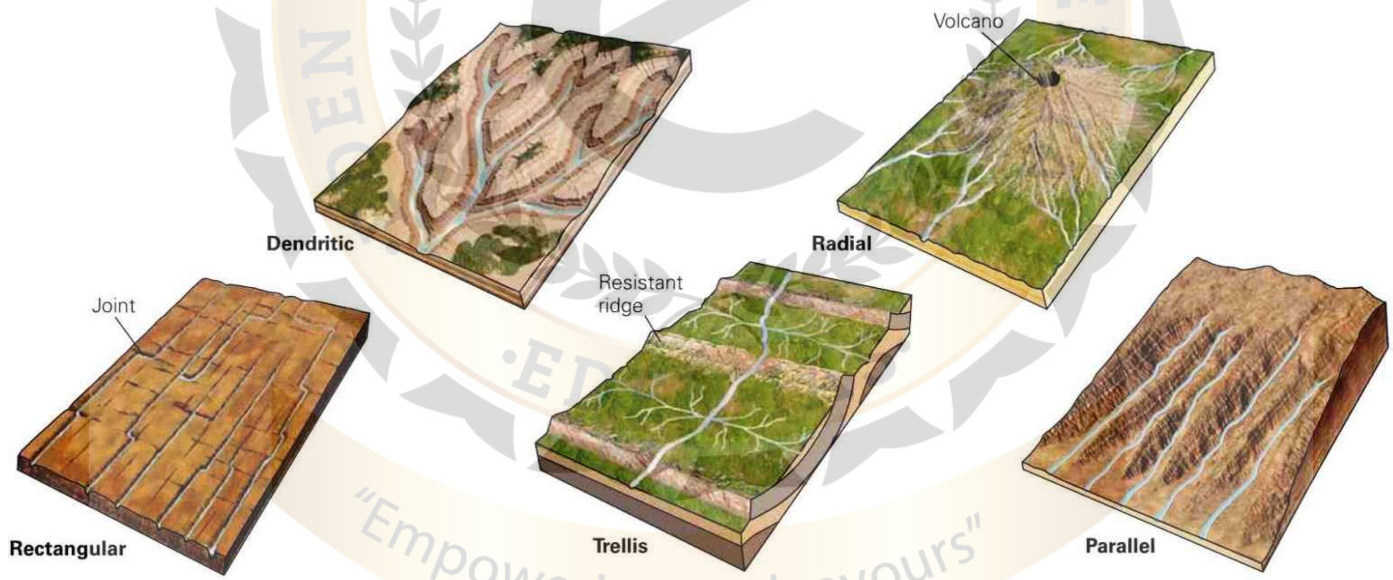


Apart from originating from the two major physiographic regions of India, the Himalayan and the peninsular rivers are different from each other in many ways. Most of the Himalayan rivers are perennial. It means that they have water throughout the year. These rivers receive water from rain as well as from melted snow from the lofty mountains. The two major Himalayan rivers, the Indus and the Brahmaputra originate from the north of the mountain ranges. They have cut through the mountains making gorges. The Himalayan rivers have long courses from their source to the sea. They perform intensive erosional activity in their upper courses and carry huge loads of silt and sand. In the middle and the lower courses, these rivers form meanders, oxbow lakes, and many other depositional features in their floodplains. They also have well-developed deltas.

Drainage Patterns

The streams within a drainage basin form certain patterns, depending on the slope of land, underlying rock structure as well as the climatic conditions of the area. These are dendritic, trellis, rectangular, and radial patterns. The dendritic pattern develops where the river channel follows the slope of the terrain. The stream with its tributaries resembles the branches of a tree, thus the name dendritic. A river joined by its tributaries, at approximately right angles, develops a trellis pattern. A trellis drainage pattern develops where hard and soft rocks exist parallel to each other. A rectangular drainage pattern develops on a strongly jointed rocky terrain. The radial pattern develops when streams flow in different directions from a central peak or dome like structure. A combination of several patterns may be found in the same drainage basin






INDIA
MAJOR RIVERS
68°E
72°
76°
80°
84°
88°
92°
96°E
36°N
32°
28°
24°
20°
16°
12°
8°N
PAKISTAN
CHINA (TIBET)
NEPAL
BHUTAN
BANGLADESH
MYANMAR
SRI LANKA
INDIA
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
Indus R.
Wular Lake
Jhelum R.
Chenab R.
Ravi R.
Beas R.
Satluj R.
Govind Sagar
Tsangpo R.
Dihang R.
Lohit R.
Brahmaputra R.
Ganga R.
Yamuna R.
Sarda R.
Ghaghara R.
Gandak R.
Kosi R.
Son R.
Chambal R.
Betwa R.
Sambhar Salt Lake
Rana Pratap Sagar
Gandhi Sagar
GovindBallabh Pant Sagar
Tropic of Cancer
Narmada R.
Tapi R.
Penganga R.
Godavari R.
Mahanadi R.
Chilika Lake
Nizam Sagar
Krishna R.
Nagarjuna Sagar
Kolleru Lake
Tungabhadra R.
Lingonamakki Reservoir
Krishnaraja Sagar Reservoir
Pulicat Lake
Kaveri R.
Vembanad Lake
LAKSHADWEEP (INDIA)
ANDAMAN & NICOBAR ISLANDS (INDIA)
0 200 400 600 km

A large number of the Peninsular Rivers are seasonal, as their flow is dependent on rainfall. During the dry season, even the large rivers have reduced flow of water in their channels. The Peninsular Rivers have shorter and shallower courses as compared to their Himalayan counterparts. However, some of them originate in the central highlands and flow towards the west. Most of the rivers of peninsular India originate in the Western Ghats and flow towards the Bay of Bengal.

HIMALAYAN RIVERS

1. INDUS RIVER SYSTEM

- **Indus** originates near Lake Mansarovar, Tibet.
    - **Jhelum** originates at Verinag (J&K).
    - **Chenab** originates near Kelong (H.P).
    - **Ravi** originates near Rohtang Pass (H.P),
    - **Beas** originates near Rohtang Pass (Beas Kund, H.P),
    - **Satluj** originates near Mansarovar Lake, Tibet.
- Indus flows through J&K in India & then through Pakistan into the Arabian Sea.
- Important Tributaries of Indus: Jhelum, Chenab, Beas, Ravi, Sutlej, Zanskar, Nubra, Shyok etc.
- **Indus Water Treaty**: According to the regulations of the Indus Water Treaty (1960), India can use only 20 percent of the total water carried by Indus river system. The usage rights of the 3 Northern Rivers (Indus, Jhelum & Chenab) have majorly been given to Pakistan whereas the usage rights of the 3 Southern Rivers (Beas, Ravi & Satluj have been given to India.

2. GANGA RIVER SYSTEM

- The headwaters of the Ganga called the '**Bhagirathi**' is originates at the **Gangotri Glacier** and joined by the Alaknanda at Devaprayag in Uttarakhand.
- Important **Tributaries** of Ganga: Yamuna, Ghaggara, Gandak, Kosi, Chambal, Betwa, Son etc.
- Enlarged with the waters from its right and left bank tributaries, the Ganga flows eastwards till Farakka in West Bengal.
- The Ganga bifurcates at Farakka Barrage; the Bhagirathi-Hooghly (a distributary) flows southwards through the deltaic plains to the Bay of Bengal. The mainstream flows southwards into Bangladesh and is joined by the Brahmaputra leading to the Sunderbans Delta.

3. BRAHMAPUTRA RIVER SYSTEM

- The Brahmaputra rises in Tibet east of Mansarovar lake very close to the sources of the Indus and the Satluj.
- It is slightly longer than the Indus, and most of its course lies outside India.
- It flows eastwards parallel to the Himalayas.

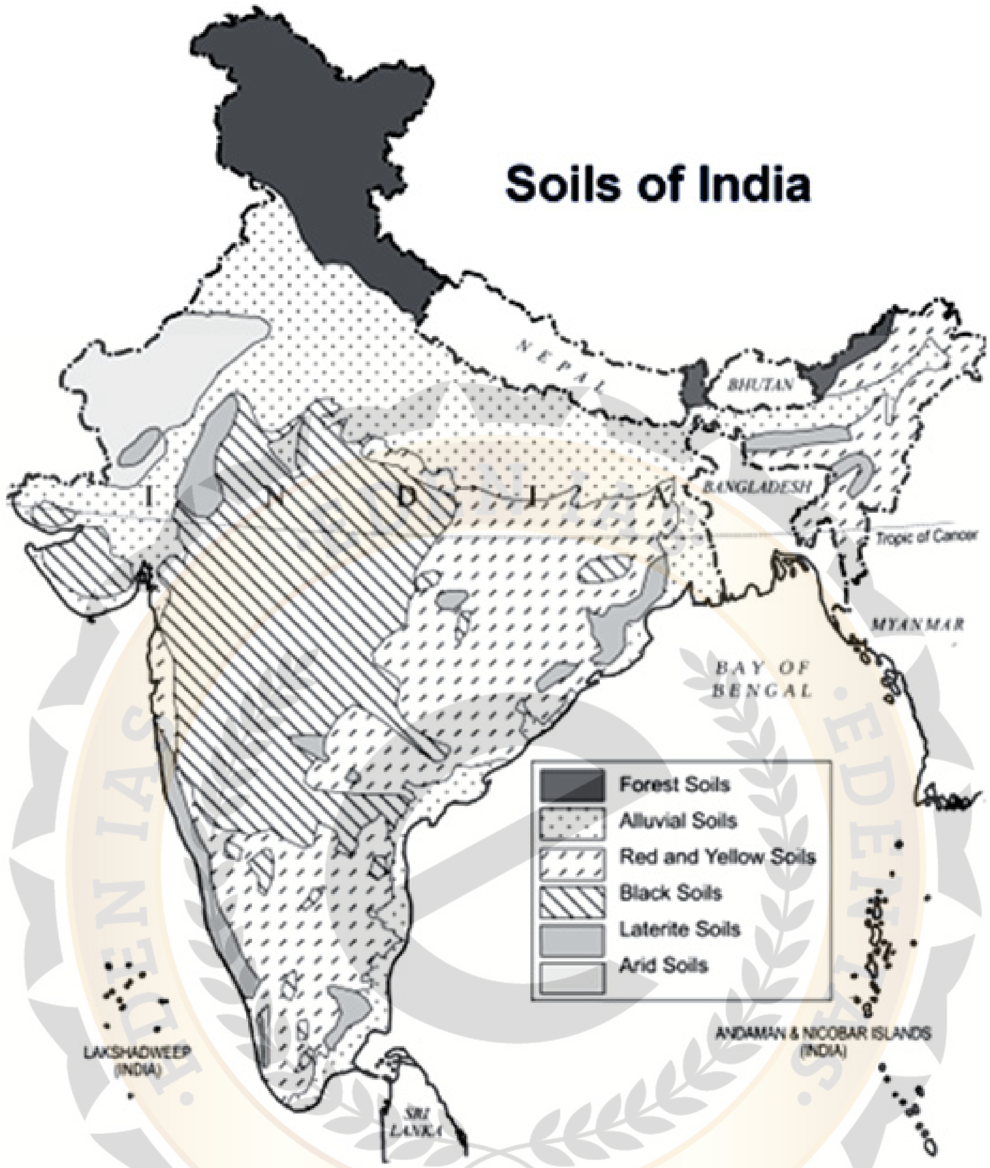
- On reaching the **Namcha Barwa**, it takes a 'U' turn and enters India in Arunachal Pradesh through a gorge.
- Tributaries: Dihang, Dibang, Kameng, Subansiri, Lohit, Manas, Teesta etc.

PENINSULAR RIVERS

- The main water divide for the Peninsular Rivers is the Western Ghats.
- East flowing Rivers (Bay of Bengal): Mahanadi, Krishna, Godavari & Kaveri.
- West flowing Rivers (Arabian Sea): Narmada, Tapi, Sabarmati, Mahi etc.
- **NARMADA BASIN**: The Narmada rises in the Amarkantak hills in Madhya Pradesh. It flows towards the west in a rift valley formed due to faulting.
- **TAPI BASIN**: The Tapi rises in the Satpura ranges, in the Betul district of Madhya Pradesh. It also flows in a rift valley parallel to the Narmada but it is much shorter in length.
- **GODAVARI BASIN**: The Godavari is the largest Peninsular river. It rises from the slopes of the Western Ghats in the Nasik district of Maharashtra. Its drainage basin is also the largest among the peninsular rivers. That is why it is also known as the **'Dakshin Ganga'**.
- **MAHANADI BASIN**: The Mahanadi rises in the highlands of Chhattisgarh and drains into the Bay of Bengal.
- **KRISHNA BASIN:** It rises near Mahabaleshwar and flows into the Bay of Bengal.
- **KAVERI BASIN**: The Kaveri rises in the Brahmagri range of the Western Ghats and it reaches the Bay of Bengal in south of Cuddalore, in Tamil Nadu.

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 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.

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. Bhangar soils contain calcareous concretions (Kankars).

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. Maharashtra 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 soils 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 Kachchh, 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.

Peaty Soils

Peaty soils are 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. 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.

VEGETATION OF INDIA

Natural vegetation refers to a plant community that has been left undisturbed over a long time, so as to allow its individual species to adjust themselves to climate and soil conditions as fully as possible. India is a land of great variety of natural vegetation. Himalayan heights are marked with temperate vegetation; the Western Ghats and the Andaman Nicobar Islands have tropical rain forests, the deltaic regions have tropical forests and mangroves; the desert and semi desert areas of Rajasthan are known for cactii, a wide variety of bushes and thorny vegetation. Depending upon the variations in the climate and the soil, the vegetation of India changes from one region to another. On the basis of certain common features such as predominant vegetation type and climatic regions, Indian forests can be divided into the following groups:

TYPES OF FORESTS

- **Tropical Evergreen and Semi Evergreen forests**
- **Tropical Deciduous forests**
- **Tropical Thorn forests**
- **Montane forests**
- **Littoral and Swamp forests.**

Tropical Evergreen and Semi Evergreen Forests

These forests are found in the western slope of the Western Ghats, hills of the northeastern region and the Andaman and Nicobar Islands. They are found in warm and humid areas with an annual precipitation of over 200 cm and mean annual temperature above 22oC. Tropical evergreen forests are well stratified, with layers closer to the ground and are covered with shrubs and creepers, with short structured trees followed by tall variety of trees. In these forests, trees reach great heights up to 60 m or above. There is no definite time for trees to shed their leaves, flowering and fruition. As such these forests appear green all the year round. Species found in these forests include rosewood, mahogany, aini, ebony, etc. The semi evergreen forests are found in the less rainy parts of these regions. Such forests have a mixture of evergreen and moist deciduous trees. The under growing climbers provide an evergreen character to these forests. Main species are white cedar, hollock and kail.

The British were aware of the economic value of the forests in India; hence, large scale exploitation of these forests was started. The structure of forests was also changed. The oak forests in Garhwal and Kumaon were replaced by pine (chirs) which was needed to lay railway lines. Forests were also cleared for introducing plantations of tea, rubber and coffee. The British also used timber for construction activities as it acts as an insulator of heat. The protectional use of forests was, thus, replaced by commercial use.

Tropical Deciduous Forests

These are the most widespread forests in India. They are also called the monsoon forests. They spread over regions which receive rainfall between 70-200 cm. On the basis of the availability of water, these forests are further divided into moist and dry deciduous.

The Moist deciduous forests are more pronounced in the regions which record rainfall between 100-200 cm. These forests are found in the northeastern states along the foothills of Himalayas, eastern slopes of the Western Ghats and Odisha. Teak, sal, shisham, hurra, mahua, amla, semul, kusum, and sandalwood etc. are the main species of these forests. Dry deciduous forest covers vast areas of the country, where rainfall ranges between 70 -100 cm. On the wetter margins, it has a transition to the moist deciduous, while on the drier margins to thorn forests. These forests are found in rainier areas of the Peninsula and the plains of Uttar Pradesh and Bihar. In the higher rainfall regions of the Peninsular plateau and the northern Indian plain, these forests have a parkland landscape with open stretches in which teak and other trees interspersed with patches of grass are common. As the dry season begins, the trees shed their leaves completely and the forest appears like a vast grassland with naked trees all around. Tendu, palas, amaltas, bel, khair, axlewood, etc. are the common trees of these forests. In the western and southern part of Rajasthan, vegetation cover is very scanty due to low rainfall and overgrazing.

Tropical Thorn Forests

Tropical thorn forests occur in the areas which receive rainfall less than 50 cm. These consist of a variety of grasses and shrubs. It includes semi-arid areas of south west Punjab, Haryana, Rajasthan, Gujarat, Madhya Pradesh and Uttar Pradesh. In these forests, plants remain leafless for most part of the year and give an expression of scrub vegetation. Important species found are babool, ber, and wild date palm, khair, neem, khejri, palas, etc. Tussocky grass grows upto a height of 2 m as the under growth.

Montane Forests

In mountainous areas, the decrease in temperature with increasing altitude leads to a corresponding change in natural vegetation. Mountain forests can be classified into two types, the northern mountain forests and the southern mountain forests. The Himalayan ranges show a succession of vegetation from the tropical to the tundra, which change in with the altitude. Deciduous forests are found in the foothills of the Himalayas. It is succeeded by the wet temperate type of forests between an altitude of 1,000-2,000 m. In the higher hill ranges of northeastern India, hilly areas of West Bengal and Uttaranchal, evergreen broad leaf trees such as oak and chestnut are predominant. Between 1,500-1,750 m, pine forests are also well-developed in this zone, with Chir Pine as a very useful commercial tree. Deodar, a highly valued endemic species grows mainly in the western part of the Himalayan range. Deodar is a durable wood mainly used in construction activity. Similarly, the chinar and the walnut, which sustain the famous Kashmir handicrafts, belong to this zone. Blue pine and spruce appear at altitudes of 2,225-3,048 m. At many places in this zone, temperate grasslands are also found. But in the higher reaches there is a transition to Alpine forests and pastures. Silver firs, junipers, pines, birch and rhododendrons, etc. occur between 3,000-4,000 m. However, these pastures are used extensively for transhumance by tribes like the Gujjars, the Bakarwals, the Bhotiyas and the Gaddis. The southern slopes of the Himalayas carry a thicker vegetation cover because of relatively higher precipitation than the drier north-facing slopes. At higher altitudes, mosses and lichens form part of the tundra vegetation.

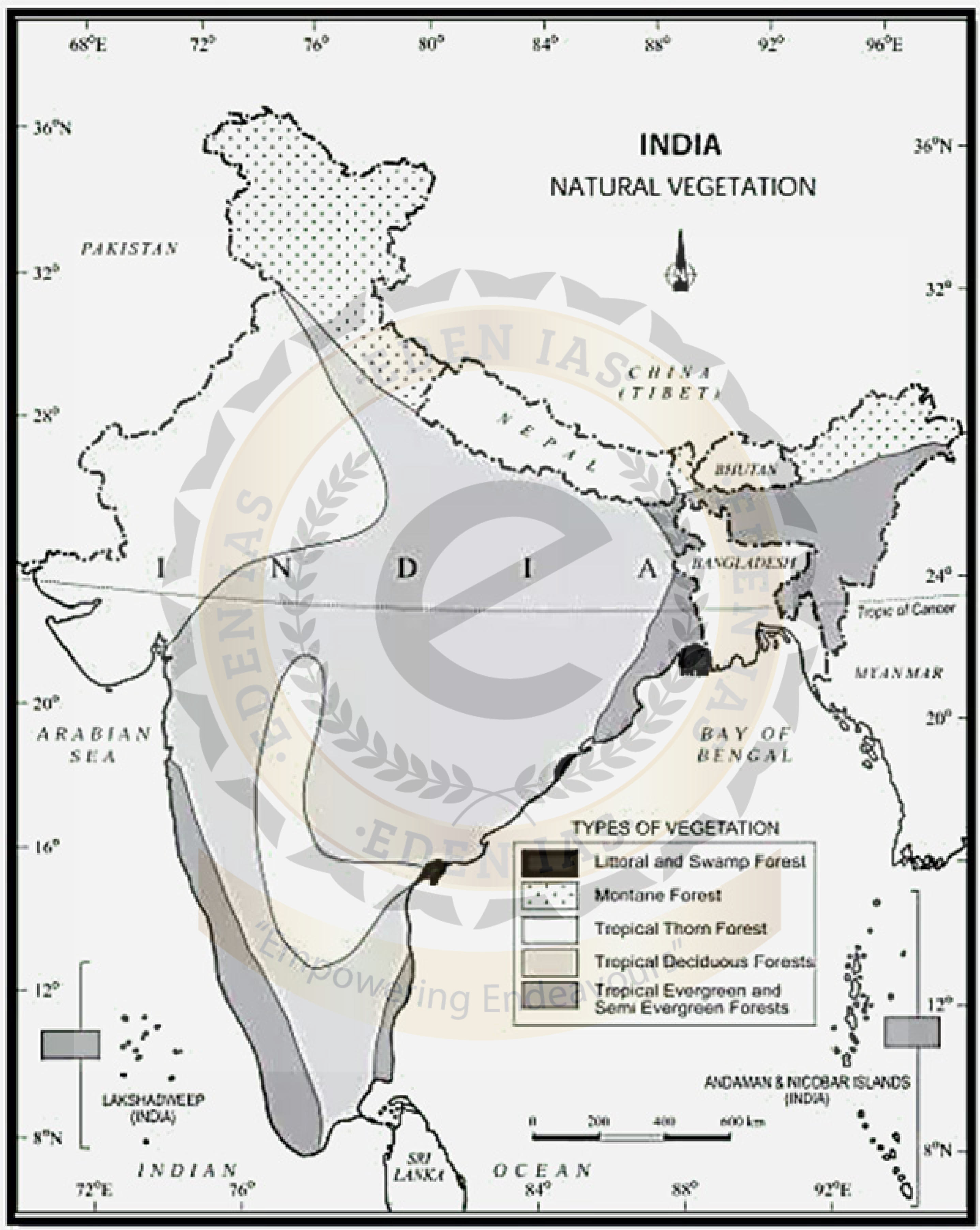
The southern mountain forests include the forests found in three distinct areas of Peninsular India viz; the Western Ghats, the Vindhyas and the Nilgiris. As they are closer to the tropics, and only 1,500 m above the sea level, vegetation is temperate in the higher regions and subtropical on the lower regions of the Western Ghats, especially in Kerala, Tamil Nadu and Karnataka. The temperate forests are called Sholas in the Nilgiris, Anaimalai and Palani hills. Some of the other trees of this forest of economic significance include magnolia, laurel, cinchona and wattle. Such forests are also found in the Satpura and the Maikal ranges.

Littoral and Swamp Forests

India has a rich variety of wetland habitats. About 70 per cent of this comprises areas under paddy cultivation. The total area of wet land is 3.9 million hectares. Two sites — Chilika Lake (Odisha) and Keoladeo National Park (Bharatpur) are protected as water-fowl habitats under the Convention of Wetlands of International Importance (Ramsar Convention).

The country's wetlands have been grouped into eight categories, viz. (i) the reservoirs of the Deccan Plateau in the south together with the lagoons and other wetlands of the southern west coast; (ii) the vast saline expanses of Rajasthan, Gujarat and the Gulf of Kachchh; (iii) freshwater lakes and reservoirs from Gujarat eastwards through Rajasthan (Keoladeo National Park) and Madhya Pradesh; (iv) the delta wetlands and lagoons of India's east coast (Chilika Lake); (v) the freshwater marshes of the Gangetic Plain; (vi) the floodplains of the Brahmaputra; the marshes and swamps in the hills of northeast India and the Himalayan foothills; (vii) the lakes and rivers of the montane region of Kashmir and Ladakh; and (viii) the mangrove forest and other wetlands of the island arcs of the Andaman and Nicobar Islands. Mangroves grow along the coasts in the salt marshes, tidal creeks, mud flats and estuaries.

They consist of a number of salt-tolerant species of plants. Crisscrossed by creeks of stagnant water and tidal flows, these forests give shelter to a wide variety of birds. In India, the mangrove forests spread over 6,740 sq. km which is 7 per cent of the world's mangrove forests. They are highly developed in the Andaman and Nicobar Islands and the Sunderbans of West Bengal. Other areas of significance are the Mahanadi, the Godavari and the Krishna deltas. These forests too, are being encroached upon, and hence, need conservation.


INDIA
NATURAL VEGETATION
PAKISTAN
CHINA (TIBET)
NEPAL
BHUTAN
BANGLADESH
MYANMAR
INDIA
Tropic of Cancer
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
SRI LANKA
LAKSHADWEEP (INDIA)
ANDAMAN & NICOBAR ISLANDS (INDIA)
TYPES OF VEGETATION
Littoral and Swamp Forest
Montane Forest
Tropical Thorn Forest
Tropical Deciduous Forests
Tropical Evergreen and Semi Evergreen Forests
0 200 400 600 km
68°E 72° 76° 80° 84° 88° 92° 96°E
36°N 32° 28° 24° 20° 16° 12° 8°N

INDIA MINERAL RESOURCES

- On the basis of chemical and physical properties, minerals are grouped as –
    - **Metallic** minerals and
    - **Non-metallic** minerals.
- Major examples of metallic minerals are iron ore, copper, gold, etc

Metallic minerals are further sub-divided as ferrous and non-ferrous metallic minerals. The minerals containing iron is known as ferrous and without iron is known as non-ferrous (copper, bauxite, etc.). Depending upon the origination, non-metallic minerals are either organic (such as fossil fuels also known as mineral fuels, which are derived from the buried animal and plant, e.g. such as coal and petroleum), or inorganic minerals, such as mica, limestone, graphite, etc.

Distribution of Minerals

Minerals are unevenly distributed on the earth's surface. All minerals are exhaustible in nature, i.e., will exhaust after a certain time. However, these minerals take long time to form, but they cannot be replenished immediately at the time of need. More than 97% of coal reserves occur in the valleys of Damodar, Son, Mahanadi, and Godavari rivers. Petroleum reserves in India are located in the sedimentary basins of Assam, Gujarat, and Mumbai High. Some new petroleum reserves are also found in the Krishna-Godavari and Kaveri basins (shown in the image given above).

Mineral Belts in India

- Further, there are **three major mineral belts** in India namely –
    - The North-Eastern Plateau Region,
    - The South-Western Plateau Region, and
    - The North-Western Region.

North-Eastern Plateau Region

- The major areas of north-eastern plateau region are Chotanagpur (Jharkhand), Odisha, West Bengal, and parts of Chhattisgarh. Iron ore, coal, manganese, bauxite, and mica are the major minerals of the north-eastern plateau region.

South-Western Plateau Region

- The south-western plateau region covers major parts of Karnataka, Goa, and contiguous Tamil Nadu uplands and Kerala. Major mineral resources of south-western plateau region are iron ore, manganese, and limestone.
- Kerala has deposits of monazite and thorium, and bauxite clay and Goa has deposits of iron ore.

North-Western Region

- The north-western region covers the areas of Aravalli in Rajasthan and parts of Gujarat. Major minerals of north-western regions are copper and zinc; other significant minerals include sandstone, granite, and marble, along with Gypsum and Fuller's earth deposits. In addition, Gujarat and Rajasthan, both have rich sources of salt.

- The **Himalayan belt** is also an important mineral belt, as it has rich deposits of copper, lead, zinc, cobalt, and tungsten.

Major Minerals

Following are the major minerals found in India –

Iron

- About 95% of total reserves of iron ore is found in the States of Odisha, Jharkhand, Chhattisgarh, Karnataka, Goa, Telangana, Andhra Pradesh, and Tamil Nadu.

- Sundergarh, Mayurbhanj, and Jhar are the major iron ore regions in Odisha and the important mines are Gurumahisani, Sulaipet, Badampahar (Mayurbhaj), Kiruburu (Kendujhar), and Bonai (Sundergarh).

- Noamundi (Poorbi Singhbhum) and Gua (Pashchimi Singhbhum) are important mines in Jharkhand.

- Dalli and Rajhara in Durg district are the important mines of Chhattisgarh.

- Sandur-Hospet area of Bellari district, Baba Budan hills, and Kudremukh in Chikkamagaluru district, and parts of Shivamogga are the important iron ore regions in Karnataka.

- The districts of Chandrapur, Bhandara, and Ratnagiri are the iron regions in Maharashtra.

- Other iron ore regions in India are Karimnagar and Warangal district of Telangana, Kurnool, Cuddapah, and Anantapur districts of Andhra Pradesh, and Salem and Nilgiris districts of Tamil Nadu.

Manganese

- Odisha is the leading producer of **Manganese**.

- Bonai, Kendujhar, Sundergarh, Gangpur, Koraput, Kalahandi, and Bolangir are the major manganese regions in Odisha.

- Dharwar, Ballari, Belagavi, North Canara, Shivamogga, Chitradurg, Tumkur, and Chikkmagaluru are major manganese regions in Karnataka.

- Nagpur, Bhandara, and Ratnagiri districts are the major regions of manganese in Maharashtra.

- Balaghat-Chhindwara-Nimar-Mandla and Jhabua districts are the important manganese regions of Madhya Pradesh.

Bauxite

- Odisha is the largest producer of Bauxite in India.
- Kalahandi, Sambalpur, Bolangir, and Koraput are the leading producers of bauxite in Odisha.
- Lohardaga (Jharkhand) is rich in bauxite deposits.
- Amarkantak plateau has rich deposits of bauxite in Chhattisgarh.
- Katni-Jabalpur area and Balaghat are the major regions of bauxite in Madhya Pradesh.
- Kolaba, Thane, Ratnagiri, Satara, Pune, and Kolhapur in Maharashtra are important bauxite producers.

Copper

- Copper deposits are largely concentrated in Singhbhum district of Jharkhand, Balaghat district of Madhya Pradesh, and Jhunjhunu and Alwar districts of Rajasthan.

Mica

- Hazaribagh plateau of Jharkhand and Nellore district of Andhra Pradesh have deposits of high grade mica.
- Jaipur to Bhilwara and areas around Udaipur are the major mica-bearing regions of Rajasthan.
- Other mica-bearing regions are Mysore and Hasan districts of Karnataka; Coimbatore, Tiruchirapalli, Madurai, and Kanniyakumari of Tamil Nadu; Alleppey of Kerala; Ratnagiri of Maharashtra; Purulia and Bankura of West Bengal.

Geography is the study of places and the relationships that exist between man and environment . This book is an effort by Team EDEN IAS to introduce the concepts and theories of Geography to young and enthusiastic minds who harbor the dream of becoming a Civil Servant

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