Contents

Some theories and doctrines of Geology

Geology is the study of the Earth. There are *no real laws in geology* because most of the processes, events, and sundry items attached to geology don't work in all situations at all times. For example, the "**Law of Superimposition**" in Geology says that rock layers on the bottom are the oldest, while those on the top were formed more recently. But this law is *not true in case of the mountain formation* in which the rock layers fold over, resulting in older layers lying on top of younger layers.

One of the key principles in Geology is **Uniformitarianism**. This doctrine is based upon the assumption that the same natural laws and processes that operate in the universe now, have always operated in the universe in the past and apply everywhere in the universe. It has included the gradualistic concept that "***the present is the key to the past***" and is functioning at the same rates. Uniformitarianism has been a key principle of not only geology but virtually all fields of science, but in case of the Geology, the modern scientists don't hold it correct any more. They say that the Geologic processes may have been active at different rates in the past that humans have not observed. The most basic query of the Geology has been on how the earth was formed and how the surface features on earth have developed. It will not be out of the context to discuss about the three camps which have three different theories in Geology, which are now obsolete.

❖ Neptunism

Neptunism was given by German scientist Abraham Werner. It held that the world was once all oceans, and that the rocks of the Earth's crust, including basalt and granite, seen today were precipitated out of the ocean. The theory was rebutted.

❖ Catastrophism

This doctrine says that most geologic formations were created by sudden, violent, catastrophic events, such as earthquakes, floods, asteroids strikes, and volcanoes. It has been discarded because now it has been accepted that Earth's *features are formed by slow natural processes* that, at times, are punctuated by certain catastrophic events.

❖ Plutonism / Vulcanism

Theory was put forward by Scottish geologist James Hutton. It says that the rocks forming the Earth were formed in fire by volcanic activity, with a continuing gradual process of weathering and erosion wearing away rocks,

which were then deposited on the sea bed, re-formed into layers of sedimentary rock by heat and pressure, and raised again. It proposed that basalt was solidified molten magma. They theory was named after Pluto, the classical ruler of the underworld, or alternatively after Vulcan, the ancient Roman god of fire and volcanoes.

Earth: Observations of the Early Philosophers

In the beginning of the civilization, Earth was believed to be the center of the universe, which consisted only of those planets visible with the naked eye and an outlying sphere of fixed stars. This was called the **Geocentric Model**. In those times, we even did not know that Earth was round. For example, ***Thales,*** *who is considered to be the Earliest Geographer, proposed that world was a flat disc based on water, and that all things grew out of it*. His disciple **Anaximander,** who is known to have first attempted to create a scale map of the known world said that *Earth has shape is that of a cylinder with a height one-third of its diameter and flat top forms the inhabited world, which is surrounded by a circular oceanic mass.* Such was the knowledge about Earth to the early geographers.

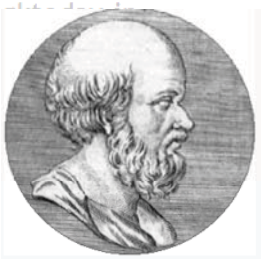
Thales


Thales Circa. 624-547 BC

Thales is regarded as first philosopher in the Greek tradition. According to Bertrand Russell, "*Western philosophy begins with Thales*." He dared to explain natural phenomena without reference to mythology and was tremendously influential in this respect. He is called father of science.

Around five centuries before Christ, it was probably **Pythagoras**, who proposed a spherical world. Pythagoras was so much convinced with the goodness of "being round" that argued that a sphere is a most perfect form. The idea of a spherical earth was embraced by Plato and Aristotle too. Earth's shadow during an eclipse is curved, and also that stars increase in height as one moves north, these were some of the observations of Pythagoras, which helped the human beings know about the round shape of earth. *Pythagoras had also probably proposed that the Earth rotates.*

The next important query of the Greeks was about the size of the Earth. **Eratosthenes** attempted to calculate its circumference by measuring the angle of the sun at two different locations. *Eratosthenes is known to be the first person to use the word "geography" and invented the discipline of geography as we understand it as Today. A system called "latitude and longitude" was also invented by Eratosthenes.* These were some of the reason why the westerners call Eratosthenes as "father of geography". Indeed, he was the first person to use the term "geography" itself.


Portrait of Eratosthenes

Apart from the observations of the Greek Philosophers, it would be important here to discuss what Indians knew and observed about the Earth and universe. Astronomy is as old as Veda themselves are. The ***Atharva Samhita*** *has a list of 27 nakshatras*. Nakshtra Vidya was mentioned on Chadogyapnishad at several places. *The earliest well defined Indian astronomical work is* ***Vedanga Jyotisha of Lagadha***, which has not yet been conclusively dated. Post Jyotisha Vedanga, all Indian astronomical texts are dated to the sixth century AD or later with a high degree of certainty. The modern scientists are in favour of as well as against the originality and independent development of Indian astronomy. We have lost many of the important primary sources on which we can prove the superiority of our knowledge.

The most important observations about Earth are of **Aryabhatta**.

Model Question - 1.
Among various scientifically proved conclusions in Astronomy, which among the following was / were given by Aryabhatta?
1. Earth's Rotation on its own axis
2. A Heliocentric Model of Universe
3. Explanation of Eclipses
4. Almost correct calculation of sidereal rotation of Earth

Choose the correct option:
Answer: **1**

The first observation of Aryabhatta was that "earth rotates about its axis daily". He also writes that it is the apparent (probably) movement of the starts is due to the motion of Earth. This was in contrast with what was generally believed that the sky itself rotates. However, still, there was a Geocentric Model of Universe. The model of the universe given by Aryabhatta was more clearly a Geocentric Model and less clearly, it has been claimed to be heliocentric model. In the *Paitāmahasiddhānta,* it has been documented by Aryabhatta that the motions of the planets are each governed by two epicycles, a smaller *manda* (slow) and a larger *shighra* (Fast). The order of the planets in terms of distance from earth, as in Aryabhata's model is Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn, and the asterisms. Aryabhatta is known to have calculated the sidereal rotation and sidereal year at almost correct value. Solar and lunar eclipses were scientifically explained by Aryabhatta. He writes in Golapada that the lunar eclipse occurs when the moon enters into the Earth's shadow. Not only this, he calculated the size of earth's shadow and correlated it correctly with the duration of the eclipse.

Fact Box: Aryabhatta

Aryabhatta was a great mathematician-astronomer from the classical age of Indian mathematics and Indian astronomy. He wrote Aryabhatiya in 499 AD when he was 23 years old. Arya-siddhanta was another work.

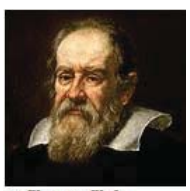
He describes the shanku-yantra or Chhyayantra which was a series of development of what was basically the Gnomon, the angle-measuring device. Aryabhatta describes Dhanuryantra (semicircular device), Chakrayantra (Circular device), Yasti-Yantra (Cylindrical device), Chhatra Yantra (the umbrella device) and water clocks of two types, bow-shaped and cylindrical. In the Golapada of the Aryabhatia, he writes about Geometric/trigonometric aspects of the celestial sphere, features of the ecliptic, celestial equator, node, shape of the earth, cause of day and night, rising of zodiacal signs on horizon, etc.

In addition, some versions cite a few colophons added at the end, extolling the virtues of the work, etc.

The heliocentric model of Earth was accepted in the 17th century. Nicolaus Copernicus was the first to develop a mathematically predictive heliocentric system, thus he is generally known **to have discovered the solar system**. (But it is incorrect to credit one person for discovery of solar system). He said that Earth was a planet orbiting the Sun, and that all planets moved in circles, one inside the other. Mercury and Venus had the smallest circles, smaller than that of the Earth, and *that is the reason is that their position in the sky was always near the Sun's.* Indeed it was a daring voice in those times. It denied century's old belief that Earth was the center of the universe. However, Copernicus was not even able to fully describe the motion of the planets. Some corrections were still needed.


Nicolaus Copernicus

His successor Galileo Galilei, the Italian scholar was the ***first to observe the planets through a telescope***, and what he saw convinced him that Copernicus was right. However, his aggressive defense of the Copernican theory turned the Catholic Church against him and cost him his freedom. The Catholic Church issued a decree against him for declaring that Sun stood still and that the Earth moved was "false" and "altogether contrary to Holy Scripture". They forced him to "correct" his theory. He was put under house arrest and made to face a lot of problems. Out of pressure, he is said to have agreed to what pleased the Catholic Church but is also believed to rebelliously have muttered "*Eppur si muove*" means "**And Yes it moves**".


Galileo Galilei

Some more 17th century physicists such as **Johannes Kepler** and **Isaac Newton** developed an understanding of physics that led to the gradual acceptance of the idea that the Earth moves around the Sun and that the planets are governed by the same physical laws that governed the Earth. Then, the invention of the telescope led to the

1 Correct Answer 1, 3 & 4

discovery of further planets and moons. Improvements in the telescope and the use of unmanned spacecraft have enabled the investigation of geological phenomena such as mountains and craters, and seasonal meteorological phenomena such as clouds, dust storms and ice caps on the other planets.

Earth: Basic Data

The first thing is that there is no "center" or "edge" of the universe, and so there is no particular reference point with which to plot the overall location of the Earth in the universe. The Earth is at the center of the **observable universe** because its observability is determined by its distance from Earth.

Location

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

Radius

The Mean radius of Earth is 6,371.0 km. Equatorial radius is 6,378.1 km, while polar radius is 6356.8 kilometers. This means that Earth is not perfectly spherical; no single value serves as its natural radius. Even calling it Radius is factually incorrect because "radius" normally is a characteristic of perfect spheres. By Earth's radius we refer to the distance from some "center" of the Earth to a point on the surface or on an idealized surface that models the Earth.

Why Earth is an oblate spheroid?
Rotation of a planet causes it to approximate an oblate spheroid with a bulge at the equator and flattening at the North and South Poles. So the equatorial radius is larger than the polar radius.

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

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

Other Data:

Variable	Information
Surface area	510,072,000 km^2
Land Area	148,940,000 km^2 (29.2 %)
Water Area	361,132,000 km^2 (70.8 %)
Volume	1.08321 × 10^{12} km3
Mass	5.9736 × 10^{24} kg
Mean density	5.515 g/cm^3
Equatorial surface gravity	9.780327 m/s^2
Escape velocity	11.186 km/s
Sidereal rotation period	23h 56m 4.100s
Equatorial rotation velocity	1,674.4 km/h
Axial tilt	23°26'21".4119
Albedo	0.36
Surface temp	Minimum −89.4 °C Median=14 °C Maximum =58 °C
Surface pressure	101.325 kPa
Composition	78.08% nitrogen, 20.95% oxygen, 0.93% argon, 0.038% carbon dioxide, approx. 1% water vapour

Structure of Earth

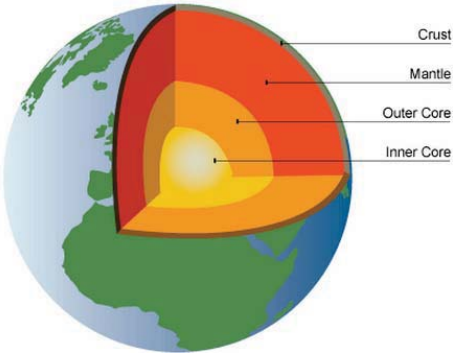
The internal structure of earth is layered. The Earth is generally divided into four major layers: the crust, mantle, inner core, and outer core. The following defines each division.

Model Question - 2.
Consider the following statements in context with the Crust, Mantle, Inner Core and Outer Core of Earth:
1. Maximum Share in Earth's mass and volume is shared by Mantle
2. When we move from earth's crust to core, density increases

Which among the above statements is / are correct?
Answer: **2**

2 Both are correct statements. Although the core and mantle are about equal in thickness, the core actually forms only 15 percent of the Earth's volume, while the mantle comprises 84 percent. The crust makes up the remaining 1 percent.

❖ **Crust**



The Earth's crust is the outermost layer and is the most familiar, since people live on the outer skin of the crust. It is rigid, brittle, and thin compared to the mantle, inner core, and outer core. Because of its varying characteristics, this outer layer is divided into the continental and oceanic crusts. Earth's crust varies in thickness from as little as 2km thick to over 70 km thick with an average value of approximately 35 km for the continental crust and 4.5 km for the oceanic crust.

❖ **Mantle**

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

Density of Various Layers

The average density of Earth is 5,515 kg/m3. Since the average density of surface material is only around 3,000 kg/m3, it can be concluded that denser materials exist within Earth's core. **When we move from earth's Crust to Core, the density increases.** The following table shows the depth as well as the average density of various layers:

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

❖ **Outer core**

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

❖ **Inner core**

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

Earth's Crust

Earth's crust is the outermost layer composed of various types of rocks. *The boundary between the crust and mantle is generally called the Mohorovičić discontinuity*. The crust occupies less than 1% of Earth's volume. Crust varies in thickness and composition beneath the oceans and continents.

Model Question - 3.

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

1. The Continental crust is denser in comparison to the Oceanic Crust
2. The Continental crust has more of quartz , while the Oceanic Crust has more of Feldspar
3. The Continental Crust is otherwise called SIMA, while the Oceanic Crust is otherwise called SIAL
4. The rocks that make the continental crust are little denser than those making Oceanic crust.

Which among the above statements is / are correct?

Answer: 3

Please mug the following observations:

- ✓ The ***oceanic crust is thinner than the Continental Crust***. Oceanic Crust measures from 5 to 10 kilometers, averaging about 7 kilometers in thickness; the continental crust measures between 25 to 100 kilometers, averaging about 30 kilometers thick. *Obviously, the thickest continental crust regions are under large mountain ranges.*
- ✓ Apart from the thickness, the oceanic and continental crusts also differ in **composition and density**. The oceanic crust is composed of dark, **iron-rich rock similar to basalt**. *It is high in silica and magnesium,*

3 1 & 2 are correct statements.

that is why called SIMA. It is often distinguished from the mantle by having more silica. ***This implies that Oceanic crust is more basaltic.*** Since Magnesium is denoted by Mg and Iron is denoted by Fe, these rocks have also been named **Mafic Rocks**. Most common rock-forming Mafic minerals in the oceanic crust are *olivine, pyroxene, amphibole, and biotite*.

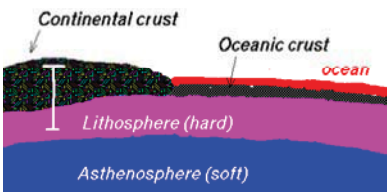
- ✓ The continental crust's composition is more complex. In general, continental rocks are light-colored, with an average composition between diorite (generally hornblende and plagioclase feldspar with a little quartz) and granodiorite (the same composition as diorite, but with more quartz present). These are rocks high in silica and aluminium and are often referred to as **SIAL.** ***This implies that Continental crust is more felsic.***
- ✓ Then, there is a difference in density also. The oceanic crust has a density of 3,000 kilograms/m^3 while the continental crust has a lower density of 2,500 kilograms/m^3. This also implies that the ***rocks which make continental crust are slightly less dense than those making the Oceanic Crust***. The less dense rocks such as granite is more common in continental crust than in oceanic crust. *Density of Sial is lower than Sima primarily because of the increased amount of aluminium.*
- ✓ Please note that at a certain depth, the SIAL of the **Continental Crest** becomes close in its physical properties to SIMA.
- ✓ The temperature of the crust increases with depth, reaching values typically in the range from about 200-400°C at the boundary with the underlying mantle.

Lithosphere versus Asthenosphere verses Earth's Crust

Model Question - 4.
Consider the following statements:
1. Lithosphere is a part of Earth's Crust
2. Asthenosphere is a part of Earth's Mantle

Which among the above statements is / are correct?
Answer: 4

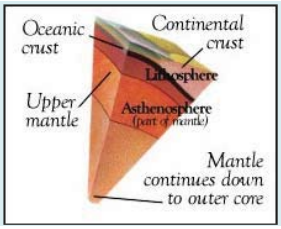
The geologists also have another way of looking at the Earth's interior layers. According to this view, the **lithosphere** is the upper 80 Kilometers layer composed of **both the crust and part of the upper mantle**. However, overall, it is cool enough to be tough and elastic than the molten mantle.



Lithosphere is obviously thinner under the oceans and volcanically active continental regions than the other landmasses. The entire lithosphere is physically broken up into the brittle, moving plates containing the world's continents and oceans. These lithospheric plates appear to "float" and move around on the more ductile **asthenosphere**.

The asthenosphere is the relatively **narrow, moving zone in the upper mantle** located between 72 to 250 kilometers beneath the Earth's surface. It is composed of a hot, semi-solid material that is soft and flowing after being subjected to high temperatures and pressures. The asthenosphere boundary is closer to the surface-within a few kilometers under oceans and near mid-ocean ridges than it is below the landmasses. The upper section of the asthenosphere is thought to be the area in which the lithospheric plates move, "carrying" the continental and oceanic plates also known as **Tectonic Plates**.

Lithosphere versus Pedosphere



Lithos means rock. Lithium is an alkali metal and its name is also derived from *Lithos.* The uppermost part of the Lithosphere that reacts with the atmosphere, biosphere and Hydrosphere is called as pedosphere. *Pedos* means soil. Pedosphere is composed of soil and it is the cradle of all the chemical and biogeochemical reactions which leads to soil development.

Lithosphere is of two types
- ✓ Oceanic lithosphere, which is associated with Oceanic crust and exists in the ocean basins
- ✓ Continental lithosphere, which is associated with Continental crust

The Oceanic lithosphere is denser than the continental lithosphere.

4 Only 2 is a correct statement

Composition of Earth Crust

By Chemical Elements

Observations:

- ✓ 47% of the Earth's crust consists of oxygen. Most of the rocks in Earth's crust are all oxides. The principal oxides are silica, alumina, iron oxides, lime, magnesia & potash.
- ✓ Highest compound in Earth's Crust: **Silica**
- ✓ Top 5 Elements in Earth's Crust: **OSAIC**
- ✓ Not many iron loving compounds in Earth Crust because they were depleted and relocated deeper.
- ✓ More meteoritic content is found in Earth's Crust.

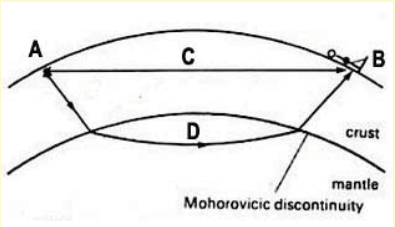
Element	Percent
Oxygen	47
Silicon	28
Aluminium	8
Iron	5
Calcium	3.5
Sodium	2.5
Potassium	2.5
Magnesium	2.2
Titanium	0.5
Hydrogen	0.2
Carbon	0.2
Phosphorus	0.1
Sulphur	0.1

By Oxides

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

Mohorovi?i? discontinuity

Model Question - 5.



The adjacent graphics shows the waves travelling from a focus A of the Earthquake to a seismometer located at "B". Which among the following is a correct conclusion in this context:

1. The waves via path ACB reach first to seismometer at point B
2. The waves via path ADB reach first to the seismometer at point B
3. Both waves reach simultaneously
4. Either A or B reaches first to seismometer at point B

Answer: **5**

The boundary between the crust and mantle is named in honour of the man who first proposed its existence, Croatian geologist **Andrija Mohorovičić.** In 1909, Mohorovičić analysed data from a Croatian earthquake, calculating a jump in seismic wave velocity at a depth of about 54 kilometers. This was concluded to be the mantle boundary underneath the continental crust, a division now called the Moho or the Mohorovičić discontinuity.

Fact box: Seismic Waves

The waves generated by the earthquake are called Seismic waves. They are divided into two broad categories viz. **Body Waves** and **Surface Waves.**

A. Body waves

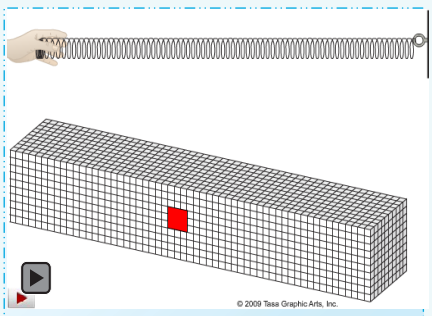
In Body waves the speed decreases with increasing density of rock and increases with increasing rock elasticity. Rock elasticity increases faster than density with depth. There are two kinds of body waves viz. P-waves and S-waves.

Primary Waves or P-waves:

The Primary waves are **Compression waves** that ***vibrate parallel to the direction of wave movement and travel through solid, liquid and gas***.

- These are the **fastest seismic waves.**
- **They are also called push waves or longitudinal waves are similar to sound waves in nature. *They have the shortest wavelength among the four* .**
- **The velocity of P waves is 5 to 7 km per second .**
- **They can travel through liquids and solids but travel faster in denser solid materials.**

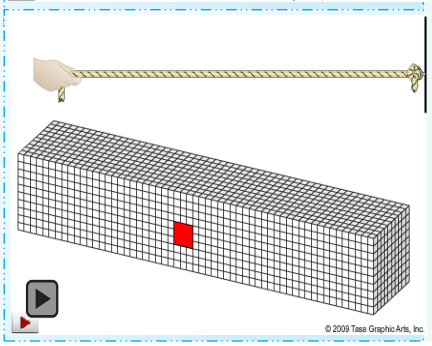
Click to Play



Secondary waves or S-waves:

These waves create **vibrations perpendicular to the direction of wave movement.**

- The S waves only **travel through solids as liquids** I gases have no shear strength (because when these phases of the matter are deformed, they don't return to the original shape).
- The S waves or secondary waves or Transverse Waves are in nature it is **similar to light wave**. Also known as Shock waves or Shear Waves.
- They have a medium wavelength and are also called shake or shear waves. The vibrations are transverse or at right angles to the direction of propagation of waves and can travel only through solid and not through liquids.
- S waves is the main evidence to assume that the earth's core liquid. Their velocity is 3 to 4 km per second.



5 Correct answer is 2.

B. Surface Waves:

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

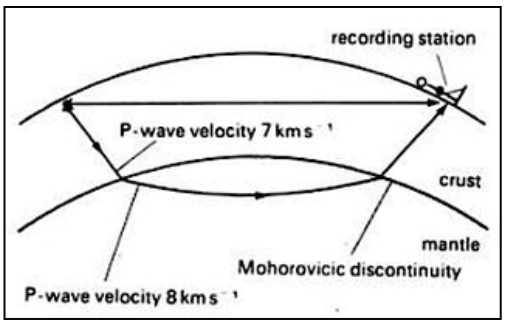
Rayleigh Waves or L-waves

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

Love waves

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

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



Please note that Moho mostly lies entirely within the lithosphere, but only beneath mid-ocean ridges it defines the lithosphere – asthenosphere boundary. The Mohorovičić discontinuity is 5 to 10 kilometres below the ocean floor and 20 to 90 kilometres beneath continents.

Fact Boxes

What is Conrad discontinuity?

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

What is Chikyū Project?

Please note that no one has been able to physically drill into the mantle and there are no samples of the Mantle with human beings as of now. Today's drilling technology is not capable to bring out samples from such a depth. In 1956, the Moho Project was developed to drill through the Earth's crust to the Mohorovicic discontinuity. But the project was closed due to lack of funding and other problems. At present, the Japanese project Chikyū or Chikyu Hakken is trying to drill down to Moho.

Earth's Mantle

The mantle is a **highly viscous** layer between the crust and the outer core. Earth's mantle is a rocky shell about 2,890 Kms thick that constitutes about 84 percent of Earth's volume. It is predominantly solid and encloses the iron-rich hot core, which occupies about 15 percent of Earth's volume.

The mantle is divided into sections viz.

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

Similar to earth's crust, **Oxygen is most abundant element in Earth's Mantle**.

The mantle is divided into the upper and lower mantle, represented by seismic and chemical changes in the layer. The ***Mantle of Earth is characterised by many boundaries or discontinuities*** created by seismic or chemical changes.

For example, the **Hales discontinuity** is found in the upper mantle at depths of about 60 to 90 kilometers, a region in which seismic velocities change. Other seismic discontinuities include the **Gutenberg** and **Lehmann** discontinuities. Other discontinuities occur in the mantle at about 410,520, and 670 kilometers. Each is either a

chemical or seismic change, the entire range representing the gradual transition between the upper and lower mantles.

Gutenberg Discontinuity

Model Question - 6.

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

1. The P waves can not pass through the liquid outer core
2. The S waves can not pass through the liquid outer core
3. The P-waves are deviated
4. The S-waves are deviated

Choose the correct option:

6

Model Question - 7.

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

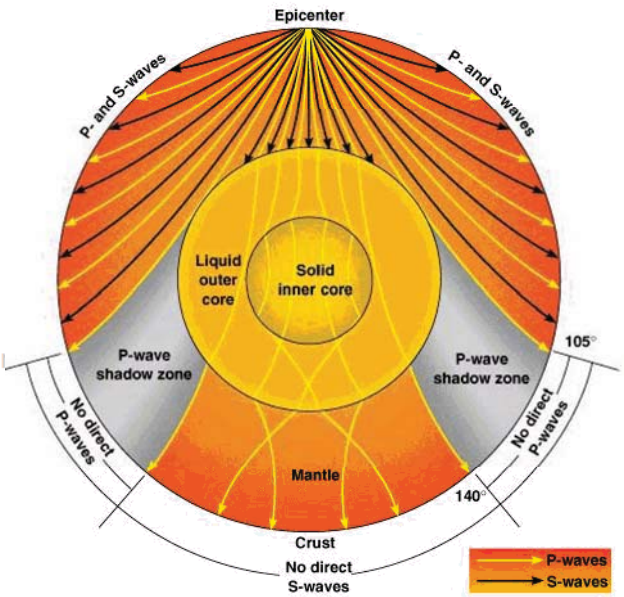
1. Absorption of the S-waves
2. Refraction in the S-waves
3. Refraction in the P-waves
4. Absorption of the P-waves

Choose the correct options:

7

Gutenberg Discontinuity is also known as the core–mantle boundary (CMB). It lies between the Earth's silicate mantle and its **liquid iron-nickel outer core**. This boundary is located at approximately 2900 km depth beneath the Earth's surface. The boundary is observed via the discontinuity in seismic wave velocities at that depth.

This discontinuity is due to the differences between the acoustic impedances of the solid mantle and the molten outer core***. P-wave velocities are much slower in the outer core than in the deep mantle while S-waves do not exist at all in the liquid portion of the core***. Seismic waves recorded at increasing distances from an earthquake indicate that seismic velocities gradually increase with depth in the mantle. **However, at arc distances of between about 105° and 140° no P waves are recorded. Furthermore, no S waves are record beyond about 105°.**



*Please note that the S waves are **transverse waves that twist rock back and forth, deforming its shape in the direction of the perpendicular to that of wave travel**. S-waves can be transmitted only through the solids. They can not travel through the liquids and gases because when these phases of the matter are deformed, they don't return to the original shape. That is why the S-waves from the earthquake that travels towards earth's centre **will be "absorbed" by the liquid outer core.***

This was explained by Gutenberg that this as the result of a molten core beginning at a depth of around 2900 km. Shear waves could not penetrate this molten layer and P waves would be severely slowed and refracted (bent).

---

6 Correct statements are 2 and 3. Statement 3 is correct because the change in the speed of the waves also changes its direction.

7 Correct Statements are 1 & 3

Composition of the Earth's Mantle

The following table shows the composition of earth's mantle.

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

Convective Material Circulation in Mantle

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

Earth's Core

Using the seismic data, the scientists first postulated the existence of a fluid core. In 1915, Gutenberg published a measurement of the core's radius. In 1936, Danish seismologist **Inge Lehmann** (l888-1993) presented a paper titled, "P'" (or P -Prime, after the seismic waves), ***which announced the discovery of Earth's inner core.*** The division between the inner and outer core is now called the **Lehmann discontinuity.**

Model Question - 8.

Arrange the following in the correct order of their existence from Earth's Crust to Inner Core:

1. Lehmann discontinuity
2. Gutenberg discontinuity
3. Mohorovičić discontinuity
4. Conrad discontinuity

Answer: 8

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

Outer Core versus Inner Core

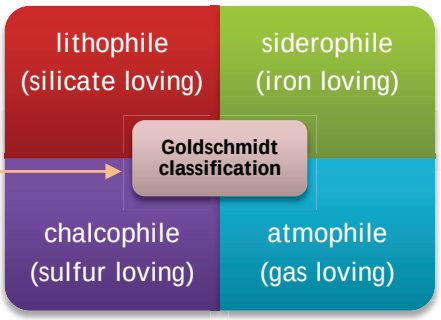
Earth's core is divided into two parts viz. a solid inner core with a radius of =1,216 km and a liquid outer core extending beyond it to a radius of ~3,400 km. The solid inner core is generally believed to be composed primarily of iron and some nickel.

How it was formed?

The major event which led to the formation of core was **iron catastrophe**. Earth as we all know was formed approximately 4500 million years ago. After accumulation of the Earth's material into a spherical mass, the material was mostly uniform in composition. The collision of the material which formed the Earth was significant;

8 Correct order is 4, 3, 2, 1

heating from radioactive materials in this mass further increased the temperature until a critical condition was reached, when the material was molten enough to allow movement. At this point, the denser iron and nickel evenly distributed throughout the mass sank to the centre of the planet to form the core - an important process of planetary differentiation. The gravitational potential energy released by the sinking of the dense Ni-Fe globules increased the temperature of the protoplanet above the melting point resulting in a global silicate magma which accelerated the process. This event occurred at about 500 million years into the formation of the planet and is known as Iron catastrophe.



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

Earth's Magnetic Field

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

How it is generated?

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

How it protects life on Earth?

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

How it is formed?

Model Question - 9.

Consider the following:

1. Electric Currents in the Inner Core of Earth
2. Electric Currents in the Outer Core of Earth
3. Coriolis Force

Which among the above play role in creation of Earth's Magnetic Field?

Answer: 9

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

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

This convection caused by heat radiating from the core, along with the rotation of the Earth (Coriolis force), causes the liquid iron to move in a rotational pattern. It is believed that these rotational forces in the liquid iron layer lead to weak magnetic forces around the axis of spin. The role of the Coriolis Effect is that it causes

9 Correct Answer is 2 & 3.

overall planetary rotation, and tends to organize the flow into rolls aligned along the north-south polar axis.

Reversal of the fields:

Model Question - 10.

Consider the following statements:
1. Geomagnetic north pole is located near the Geographic South Pole
2. Intensity of the Earth's Geomagnetic Field is greatest at Equator
3. The compass needle of a vertically held compass at Equator points downwards

Which among the above statements is / are correct?
Answer: **10**

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

Intensity gradient of the Geomagnetic Field

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

Magnetic Dip

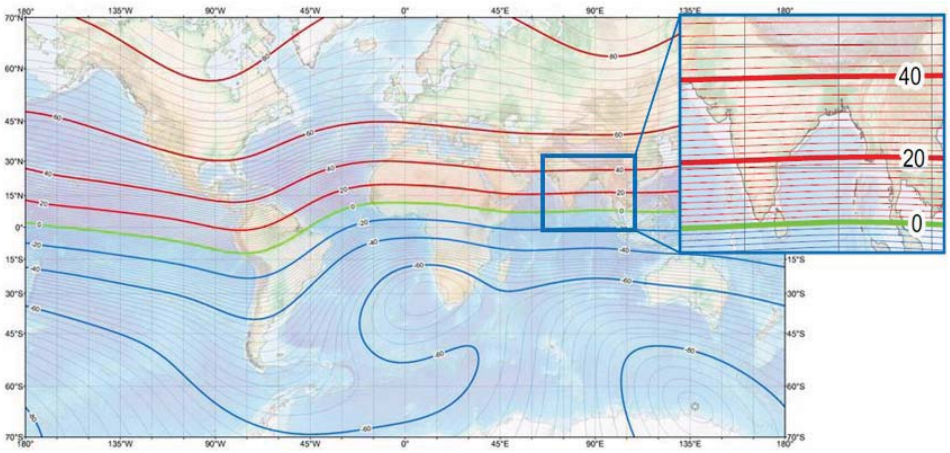
Magnetic dip or magnetic inclination is the angle made with the horizontal by the compass needle of a vertically held compass. This angle varies at different points on the Earth's surface. ***In the northern hemisphere, the field points downwards.*** It is straight down at the North Magnetic Pole and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

Geomagnetic Equator & Equatorial Electrojet

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

10 All are incorrect statements and myths.

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



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

Earth's Magnetosphere

Model Question - 11.

Consider the following statements:

1. Magnetosphere is found around only terrestrial planets of the Solar System
2. The shape of Earth's Magnetosphere is defined by Solar winds

Which among the above statements is/ are correct?

Answer: 11

The invisible geomagnetic lines stretch from one pole, curve far out into space, then go back to the opposite pole. The curved lines are ***further shaped by the electrically charged particles of the solar wind*** into a **teardrop shape called the magnetosphere.** The Magnetosphere is thus the magnetic field that prevents the solar winds, or highly energetic particles to reach Earth.

Planets with Magnetosphere

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

Model Question - 12.

The shape of the magnetosphere of Earth keeps changing. Which among the following factors play role in the ever-changing shape of Earth's Magnetosphere?

1. Earth's internal magnetic field
2. Solar winds
3. Interplanetary magnetic field

Choose the correct options:

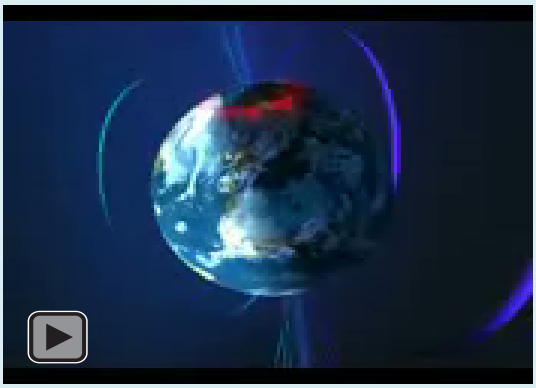
Answer: 12

Please note that the shape of magnetosphere of Earth is determined by the Earth's internal magnetic field, the solar wind plasma, and the interplanetary magnetic field (IMF).

Structure of the Magnetosphere

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

Video: Earth's Magnetosphere



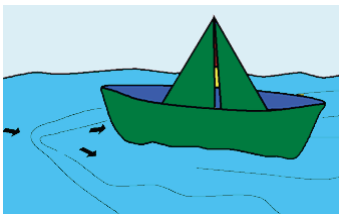
Video Source © NASA

11 Only 2 is a correct statement.

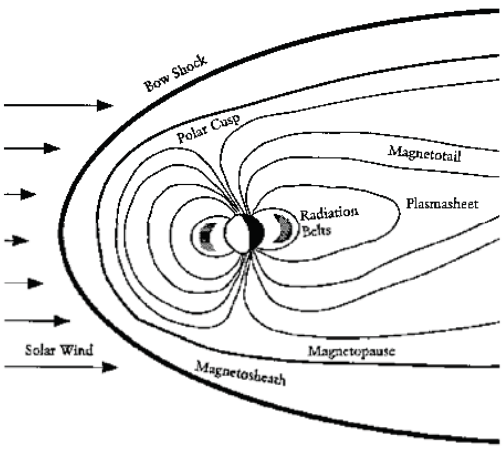
12 Correct Answer is 1, 2 & 3

The first thing you have to note is that the **shape of magnetosphere is not a static shape** but is very dynamic and keeps changing through out the day and night, with Earth's rotation, revolution and during solar storms and other such events which can affect it.

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



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



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

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

Van Allen belts

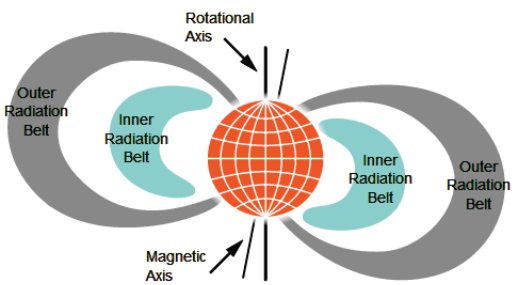
Model Question - 13.

The Van Allen belts are:

A. Caused by the refraction of sunlight like rainbows.
B. Charged particles trapped in the earth's magnetic field.
C. Caused by the reflection of polar snow.
D. Caused by precession

Answer: 13

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



Van Allen Belts

13 Correct Answer is option B

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

Model Question - 14.

In context with the Van Allen Belts, consider the following statements:

1. They are prominently made up of Protons
2. They protect the earth from Electromagnetic Radiation

Which among the above statements is / are correct?

Answer: 14

www.gktoday.in

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

Chapman Ferraro Cavity

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

Van Allen Belts and Impact on Apollo Mission

There are several (conspiracy) theories on impact of the Van Allen Belts on its impact on astronauts who pass through them. It is said that there is deadly radiation in the Van Allen belts, which could have killed the Apollo astronauts (Thus, claiming that actually Apollo 11 was a fake mission). The NASA claims that the nature of that radiation was known to the Apollo engineers and they were able to make suitable preparations. The principle danger of the Van Allen belts is high-energy protons, which are not that difficult to shield against. And the Apollo navigators plotted a course through the thinnest parts of the belts and arranged for the spacecraft to pass through them quickly, limiting the exposure. The Van Allen belts span only about forty degrees of earth's latitude -- twenty degrees above and below the magnetic equator. Further, The region between two to four earth radii lies between the two radiation belts and is sometimes referred to as the "safe zone".

The diagrams of Apollo's translunar trajectory printed in various press releases are not entirely accurate. They tend to show only a two-dimensional version of the actual trajectory. The actual trajectory was three-dimensional. The highly technical reports of Apollo, accessible to but not generally understood by the public, give the three-dimensional details of the translunar trajectory.

Source: http://www.clavius.org

Magnetospheric storms

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

14 Both statements are incorrect.

Geocorona

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

Earthquakes

In Earthquake, there is a sudden release of energy in the **Earth's crust**, which leads to a series of motions because of the waves created due to this energy released. The waves are called **Seismic Waves**. We have studied the types of seismic waves already. These seismic waves originate in a limited region and spread in all directions.

We have also studied that all that we know about what happens in the mantle and cores of the Earth has been derived from circumstantial evidence-mostly the analysis of seismic data. Scientists use earthquake waves to better understand the Earth's interior. As speculated by the scientists, the first earthquake probably occurred sometime after the Earth's crust had cooled enough to become solid some 4.55 billion years ago. Ancient records of earthquakes are scarce, despite the fact that writing had started as back as 8000BC. Earliest record of Earthquakes is from China dating back to 1177 BC.

The start of modern earthquake study occurred toward the mid-1700s. Much of the work was precipitated by studies of the devastating quake and tsunami that struck Lisbon, Portugal, in 1755. In 1760, John Mitchell was the first to theorize that earthquakes were generated when water met subterranean fires, a force that generated waves in the Earth's crust. British geologist and astronomer **John Milne**, also known as "**Earthquake Milne"** was the inventor of the horizontal pendulum seismograph (1880), a device for measuring ground shaking during an earthquake. He also worked for two decades in Japan, along with British scientists Sir James Alfred Ewing (1855-1935) and Thomas Gray, establishing the world's first earthquake laboratory. He is known as father of Modern Seismology.

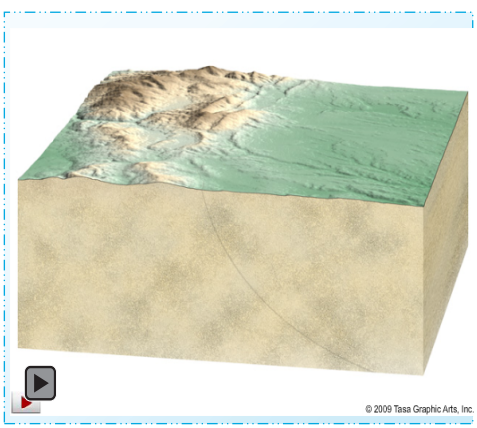
John Milne

Earthquakes can be generated by a number of sources. Most are the result of natural tectonic processes, usually caused by the interaction between two lithospheric plates. Other quakes can be generated by volcanoes as magma is injected into the Earth's crust. For example, earthquakes in the island of Hawaii are generally volcanic earthquakes. Rest of the Earthquakes are artificially generated by nuclear test explosions. The Earthquakes come in three forms of clusters called foreshocks, mainshocks, and aftershocks. Foreshocks are quakes that occur before a larger one in the same location; around a quarter of all mainshocks happen within an hour of their foreshock. Mainshocks and aftershocks are better known. Mainshocks are of the highest magnitude. Aftershocks are smaller quakes that occur in the same general geographic area for days-and even years-after the larger, mainshock event.

Understanding Earthquake

Focus / Hypocenter:

The point, where earthquakes are generated first, is called focus or hypocenter. A hypocenter is below the surface, where the first rock displaces and creates the fault.



Epicenter:

It is the point on the Earth's surface that is directly above the hypocenter or focus**.** This is the point where the shock waves reach the surface. Earthquakes originate at depths ranging from about 5 to 700 kilometers. Nearly **9o percent of all earthquakes occur at depths of less than 100 km**. Most destructive earthquakes originate at even shallower depths.

Seismic Waves

The waves generated by the earthquake are called Seismic waves. The study of earthquake and seismic waves is called Seismology and the researchers are called Seismologists. The speed of the seismic waves varies. In earth crust their speed is around 2-8 kilometers per second, while in mantle the speed is up to 13 kilometer per second. The instruments to measure the seismic wave fields are **seismograph, geophone, hydrophone and accelerometer.**

How The Earthquakes Occur?

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

Types of earthquakes

There are several types of earthquakes as follows:

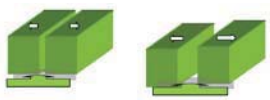
- **Tectonic Earthquakes:** **Tectonic Earthquakes are most common** and generated due to folding, faulting plate movement.
- **Volcanic Earthquakes:** Earthquake associated with volcanic activity are called volcanic earthquake. These are confined to areas of volcanoes and pacific ring of fire is best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

Types of Plate Movements

The movements are of three kinds:

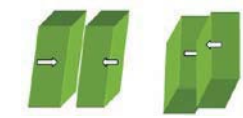
❖ **Divergent:**

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



❖ **Convergent**

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



❖ **Transformational**

In this type of movement the plates move in opposite side, on parallel.

Determination of Epicentre

Model Question - 15.

To determine the correct location of the epicentre of the Earthquake, it is necessary to get recorded seismograph data of at least how many station/s?

A. One
B. Two
C. Three
D. Four

Answer: 15

15 Three Stations

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

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

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

Earthquake Magnitude and Earthquake Intensity

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

On the other hand, earthquake intensity indicates the **extent of shaking** experienced at a given location due to a particular earthquake. It is referred by a Roman numeral (such as VIII on MSK scale). Intensity of shaking at a location depends not only on the magnitude of the earthquake, but also *on the distance of the site from the earthquake source and the geology / geography of the area*.

Please note that ***Isoseismals*** *are the contours of equal earthquake intensity*. The area that suffers strong shaking and significant damage during an earthquake is termed as ***meizoseismal region.***

Richter Magnitude Scale

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

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

Model Question - 16.

A difference between Richter scale 4.0 and Richter scale 5.0 denotes that:

A. There is a 10 fold increase in energy
B. There is a 10 fold increase in the area affected
C. There is a 10 fold increase in the waves sizes
D. There energy of Earth quake doubles.

Answer: 16

Since in this scale, Earthquake magnitude is measured on a log scale, a small difference in earthquake recording on the instruments leads to a much smaller error in the magnitude. An increase of 1 in the Richter magnitude, there is a tenfold **increase in the size of the waves also known as shaking amplitude**. The Richter scale 5.0 is 10 times more shaking amplitude of 4.0. But there is a huge difference in energy. The energy release of an earthquake denotes the destructive power. It scales with $\frac{3}{2}$ power of the shaking amplitude. A difference in magnitude of 1.0 is equivalent to a factor of 31.6. This is shown by the following equation:

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

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

16 Correct Answer is C. There is a 10 fold increase in the waves sizes

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

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

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

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

Examples of the most devastating Earthquake recorded are Indian Ocean Earthquake 2004, which caused the 2004 Indian Ocean Tsunami and the **Valdivia earthquake** (Chile), 1960. The Indian Ocean Earthquake was of 9.3 intensity in Richter scale while the **Valdivia earthquake of Chile was 9.5**. An earthquake of 10.0 on Richter scale has never been recorded by Humankind. The 2010, Haiti Earthquake was 7.0 on the Richter scale. The undersea megathrust earthquake off the coast of Japan that occurred on 11 March 2011 was **9.0** on Moment Magnitude Scale.

Moment magnitude scale

The Richter scale is denoted by $\mathbf{M_L}$. This scale was replaced in 1970s by the new Moment magnitude scale which is denoted as $\mathbf{M_w}$. The scale is almost same and media uses the same term "Richter Scale" for the new MMS also. This is because medium earthquakes such as 5.0 are equal on both the scales.

Model Question - 17.

A new type of scale called Moment magnitude scale is nowadays being used to measure the magnitude of the Earthquakes. In this context, consider the following statements:

1. The Moment magnitude scale is used for larger magnitude earthquakes while Richter scale is used for smaller magnitude earthquakes.
2. The Moment magnitude scale has no upper limit while the Richter scale has an upper limit.

Which among the above statements is / are correct?

Answer: 17

The Richter scale was based on the ground motion measured by a particular type of seismometer at a distance of 100 kilometers from the earthquake, and Richter scale has a highest measurable magnitude. The large earthquakes have a similar magnitude of around 7.0 on Richter scale. The Richter scale measurement is also unreliable for measurements taken at a distance of more than about 600 kilometers from the earthquake's epicenter. This problem is solved by the MMS (Moment magnitude scale). The Moment magnitude scale does not uses the ground motion, but used the physical properties of the Earthquake such as seismic moment. The scale was introduced by Thomas C. Hanks and Hiroo Kanamori in 1979. The US Geological survey uses the Moment magnitude scale for all large earthquakes. Drawback: Moment magnitude scale deviates at the low scale Earthquakes.

Shindo Scale

Shindo scale is also known as Japan Meteorological Agency (JMA) seismic intensity scale. It is used in Japan and Taiwan to measure the intensity of earthquakes. It is measured in units of Shindo which literally means degree of shaking. Unlike the moment magnitude scale, which measures the energy released by the earthquake, the JMA scale describes the degree of shaking at a point on the Earth's surface. Thus it is similar to Mercalli intensity scale. The Shindo Scale ranges between Shindo-0 to Shindo-7. Shindo-0 quake is not felt by most people, while Shindo-7

17 Both are correct statements

is most devastating earthquake. However, note that same earthquake has different Shindo numbers at different places. For example, 2011 Great Earthquake of Japan registered Shindo-7 at Kurihara, Miyagi Prefecture, while Shindo-6 at Fukushima, Ibaraki and Tochigi and Shindo-7 in Tokyo.

Medvedev-Sponheuer-Karnik scale (MSK-64)

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

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

MSK-64 is used in India, Israel, Russia, and throughout the Commonwealth of Independent States. In India the seismic zoning has been done on the basis of this scale.

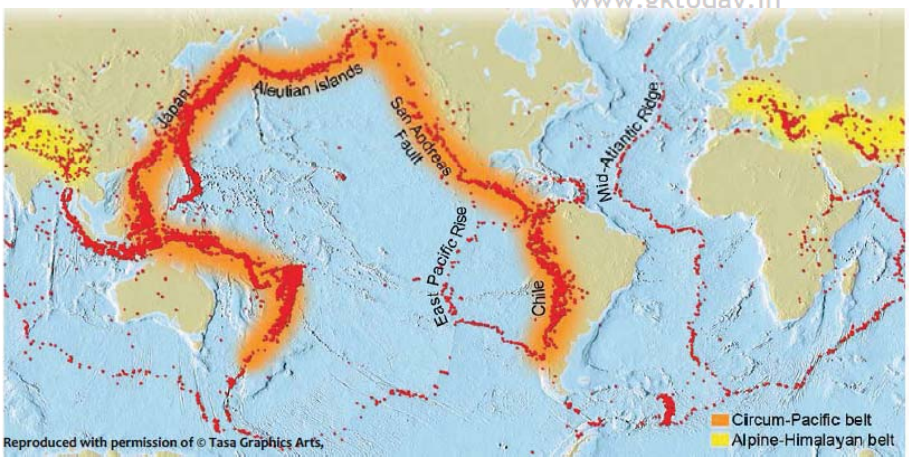
This scale has 12 intensity degrees expressed in Roman numerals, which are shown in the table shown in the right.

Earthquake Belts

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

A. Circum-Pacific Belt:

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



B. Alpine-Himalayan Belt

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

Earthquakes in India

Model Question - 18.

India has a very high frequency of great earthquakes. What could be the geological reasons / reasons for this?

1. India is currently penetrating in Asia
2. India is rotating clockwise
3. The molten magma under the earth's crust beneath India is under enormous pressure

Choose the correct statements

Answer: 18

The first observation is that India has a very ***high frequency of great earthquakes*** (magnitude greater than 8.0) ***in comparison to the moderate earthquakes*** (magnitude 6.0 to 7.0). For example, during 1897 to 1950, India

18 Only 1 is correct statement.

was hit by four great earthquakes. However, note that since 1950, only moderate size earthquakes have occurred in India which should be no reason to assume that the truly great earthquakes are a thing of the past.

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

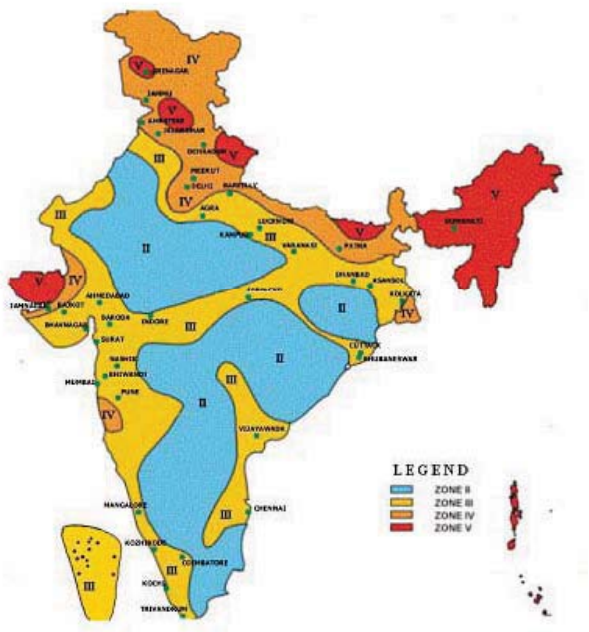
Seismic Zoning of India

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

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

Seismic Zoning of India

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



Some Great Indian Earthquakes

Model Question - 19.

Which among the following earthquakes of India is an example of Induced seismicity?

A. Katch Earthquake of 1819
B. Assam earthquake of 1897
C. Koyna Earthquake Of 1967
D. Uttarkashi Earthquake Of 1991

Answer: 19

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India has suffered some of the greatest earthquakes in the world with magnitude exceeding 8.0. For instance, in a short span of about 50 years, four such earthquakes occurred: Assam earthquake of 1897 (magnitude 8.7), Kangra

19 Correct Answer is option C Koyna

earthquake of 1905 (magnitude 8.6), Bihar-Nepal earthquake of 1934 (magnitude 8.4) and the Assam-Tibet earthquake of 1950 (magnitude 8.7).

Here are some important notes:

- **Katch Earthquake of 1819**
  - ✓ This 8.3 magnitude earthquake took place on the west coast of India and caused ground motion which was perceptible as far as Calcutta.
  - ✓ It created a fault scarp of about 16 mile long and about 10 foot high which was later named as "Allah Bund".
- **Assam earthquake of 1897**
  - ✓ This 8.7 magnitude earthquake caused severe damage in an area of about 500 km radius and caused extensive surface distortions in the area. The earthquake caused extensive liquefaction in the alluviated plains of Brahmaputra.
- **Bihar - Nepal Earthquake Of 1934**
  - ✓ This 8.4 magnitude earthquake caused wide-spread damage in the northern Bihar and in Nepal. Due to extensive liquefaction, most buildings tilted and slumped bodily into the ground in an area of about 300 km long and of irregular width. This area was termed as the "slump belt".
- **Koyna Earthquake Of 1967**
  - ✓ This 6.5 magnitude earthquake occurred close to 103 metre concrete gravity dam at Koyna. Prior to this earthquake, the area used to be considered aseismic. However, after the construction of dam and filling up of reservoir in 1962, the seismic activity increased significantly.
  - ✓ The main shock of December 10, 1967 caused widespread damage, killing about 200 persons and injuring more than 1500 persons. This was an example of the reservoir-induced seismicity in India.
  - ✓ The dam, designed keeping in mind the possible seismic activity, performed quite well with only nominal damage to the dam. This earthquake lead to the revision of Indian seismic zone map wherein the area around Koyna was brought in zone IV from zone I, and seismic zone for Bombay was upgraded from zone I to zone III.
- **Uttarkashi Earthquake Of 1991**
  - ✓ This 6.6 magnitude earthquake shook the districts of Uttarkashi, Tehri, and Chamoli of current Uttarakhand.
- **Killari (Latur) earthquake of 1993**
  - ✓ This was a magnitude 6.4 earthquake that shook the area near village Killari in Latur district killing about 8,000 persons. Until this earthquake the area was considered non-seismic and placed in the lowest seismic zone (zone I) by the Indian code (IS:1893-1984).
  - ✓ The affected area did not have any modern towns, modern buildings or major industries. In some of the villages more than 30% of the population was killed. This earthquake will be known for outstanding rescue, relief and rehabilitation.
- **Jabalpur Earthquake Of 1997**
  - ✓ This magnitude 6.0 earthquake is only example of such earthquakes which occurred close to a major Indian city in recent times.
- **2004 Indian Ocean earthquake and tsunami**
  - ✓ The 2004 Indian Ocean earthquake was an undersea megathrust earthquake with an epicentre off the west coast of Sumatra, Indonesia, and it is known as Sumatra–Andaman earthquake or 2004 Indian Ocean tsunami or South Asian tsunami, Indonesian tsunami, and the Boxing Day tsunami. It killed 230,000 people in fourteen countries, and inundating coastal communities with waves up to 30 meters.

Model Question - 20.

One of the impacts of Earthquakes is liquefaction. What is / are the outcome / outcomes of liquefaction?

1. Buildings and slumped and tilted
2. Ground water is forced upward
3. Depth of lakes, ponds and other depressions increases

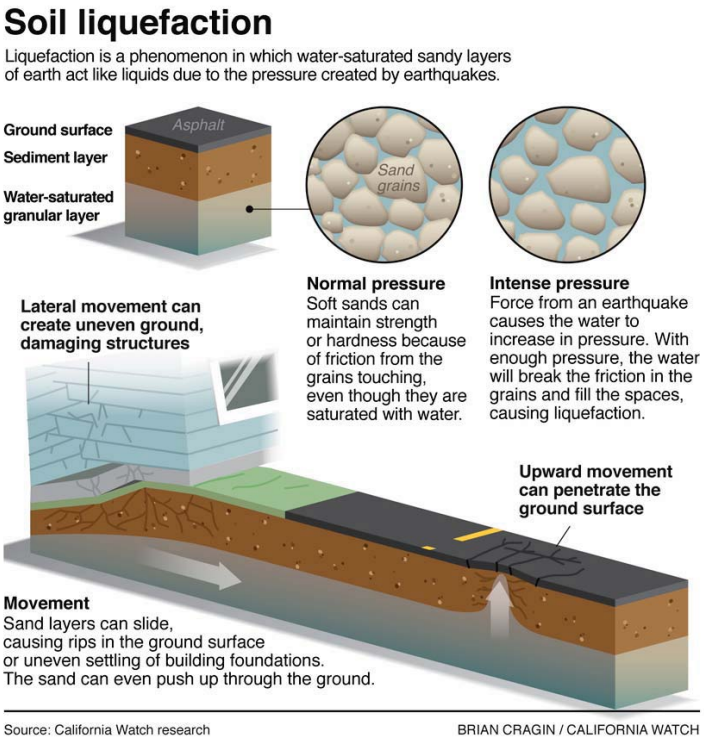
Choose the correct statements:

Answer: 20

Earthquakes can cause soil liquefaction where loosely packed, water-logged sediments come loose from the intense shaking of the earthquake. The liquefaction is more prominent in areas such as river valleys, river plains and deltas.

The randomly bunched together soil particles have spaces have formed between them. These spaces, called pores, can be filled with water or air. The pressure of the material in the spaces holds the particles apart and stabilizing the soil in its present configuration.

The effect of a seismic wave on granular soil and pore pressure is that it increases the water pressure and forces the particles apart as well as disrupts the contact point of the particles themselves. At this point in time the soil will flow like a liquid. The end product is the collapse of the particles so that there is less space between them. The water that was in that space is then forced upward.



Liquefaction should have the following conditions for it to take place:

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

The impacts of the Liquefaction are as follows:

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

20 Correct statements are only 1 & 2

Contents

Types of Rocks

Minerals are naturally occurring inorganic substances, often with a crystalline structure. They are composed largely of the most abundant elements in the Earth's crust oxygen & silicon, coupled with metals or the metallic elements of iron, calcium, sodium, potassium, and magnesium.

Rocks are usually composed of two or more minerals. Often, many different minerals are present, but a few rock varieties are made almost entirely of one mineral. Most rock in the Earth's crust is extremely old, dating back many millions of years, but rock is also being formed at this very hour as active volcanoes emit lava that solidifies on contact with the atmosphere or ocean.

The **Great Oxygenation Event** or oxygen catastrophe which happened 2400 million years ago in the Proterozoic eon triggered an explosive growth in the diversity of minerals on Earth.

The three types of Rocks are Sedimentary, Igneous and Metamorphic.

❖ Igneous rocks

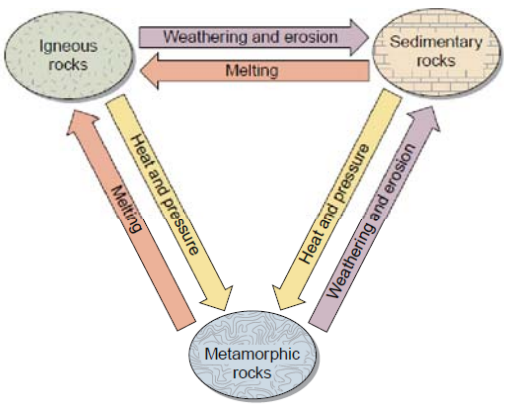
These rocks have crystallized from **magma** which is made up of various components of pre-existing rocks and has been subjected to melting either at subduction zones or within the Earth's mantle.

❖ Sedimentary rocks

These rocks are formed through the gradual accumulation of sediment, such as sand on a beach or mud on a river bed. The sediment is buried and then it is compacted as more and more material is deposited on top. In several thousand to Lakhs of years , the sediment becomes so dense that it becomes a rock. This process is known as lithification.

❖ Metamorphic rocks

These rocks once existed as igneous or sedimentary rocks but have been subjected to varying degrees of pressure and heat within the Earth's crust. The processes involved changes the composition and fabric of the rock and their original nature is often hard to distinguish. Metamorphic rocks are typically found in areas of mountain building.



The above three classes of rocks are constantly being transformed from one to another in a continuous process through which the crustal minerals have been recycled during many millions of years of geologic time. The adjacent diagram shows these transformations.

Igneous Rocks

The upper 16 kilometers of the Earth's crust is made up of 95% Igneous rock, with a thin covering of sedimentary and metamorphic rocks. Igneous rocks are formed when molten rock cools, forming silicate mineral crystals. Felsic minerals are light colored and less dense, and mafic minerals are dark colored and more dense. The igneous rocks are generally hard and water percolates in them not so easily.

Model Question - 1.

Consider the following statements:

1. Felsic rocks are rich in silicon
2. Quartz is a Felsic Rock
3. Mafic Rocks are produced by volcanic Eruption

Which among the above statements is / are correct?

Answer: 1

1 Correct statements are 1, 2 & 3

The most important characteristics of Igneous rocks are as follows:

- ✓ They usually do not occur in distinct beds or strata like sedimentary rocks.
- ✓ Igneous rocks are generally not having any fossils
- ✓ They are generally granular and crystalline.
- ✓ They are less affected by chemical weathering as the water does not percolate in them easily.

Magma as source of Igneous Rocks

The mixture of the Molten Rocks which makes the Igneous rocks is called Magma. Magma in fact is a mixture of molten rocks, volatiles (gas) and other solids. It originated from the partial melting of the lower crust and the upper mantle, mainly at depths of 15-200 kilometers. Most magma is as hot as 700 °C to 1300 °C and is silicate mixtures mostly. The chambers under a volcano where Magma collects are called magma chambers. The magma chambers feed a volcano. Bulks of the igneous rocks are result of the cooling and solidifying of Magma. There are two processes by which Magma cools and solidifies. These are called "plutonic" and "Volcanic Eruption". When the Molten Magma goes down deep within the earth and gets solidified, it is called **Plutonism**. On the contrary, the molten Magma can also come out on the surface of earth via a **volcanic eruption**.

Most igneous rock consists of silicate minerals. These rocks also *contain mostly metallic elements*. The mineral grains in igneous rocks are very tightly interlocked, and so the rock is normally very strong. Quartz, which is made of silicon dioxide (SiO_2), is the most common mineral of all rock classes. It is quite hard and resists chemical breakdown.

Intrusive and Extrusive Igneous Rocks

Magma that solidifies below the Earth's surface and remains surrounded by older, pre-existing rock is called **intrusive igneous rock**. Because intrusive rocks cool slowly, they develop large mineral crystals that are visible to the eye. They are further classified into **Plutonic, Hypabyssal, Batholiths and Laccoliths as follows:**

Types of Igneous Rocks		
Intrusive	**Plutonic**	Generally very large crystal and they were formed due to cooling of magma very deep inside the Earth
	Hypabyssal	Consolidated in a zone above the base of Earth's crust and hence has distinct structural characteristics.
	Batholiths	They extend to greater depths and larger areas
	Laccoliths	A sheet intrusion that has been injected between two layers of sedimentary rock
Extrusive		Formed at the crust's surface as a result of the partial melting of rocks within the mantle and crust

If the magma reaches the surface and emerges as lava, it forms **extrusive igneous rock**. Extrusive igneous rocks cool very rapidly on the land surface or ocean bottom and thus show crystals of only microscopic size.

Please note that **Granite** typically accumulates in batholiths. A single batholith sometimes extends down several kilometers and may occupy an area of several thousand square kilometers.

Felsic Rocks and Mafic Rocks

Whatever may be the process of cooling and solidifying, the magma while converting into a rock, undergoes numerous chemical and physical changes. Accordingly, there are two major types of Igneous rocks are produced viz. **Felsic Rocks** and **Mafic Rocks**. *Felsic rocks are rich in silicon, oxygen, aluminium, sodium, and potassium, while the mafic rocks are rich in magnesium and iron. If the rock is highly dominated by Magnesium and Iron, it is called Ultramafic.*

Examples of Igneous Rocks

- ✓ *Granite: Intrusive (batholith generally), Felsic, igneous rock. Worldwide average chemical composition of Igneous Rocks has SiO_2 — 72.04% & Al_2O_3 — 14.42%*
- ✓ *Diorite: intermediate intrusive igneous rock*
- ✓ *Gabbro: Mafic igneous rocks equivalent to basalt.*
- ✓ *Peridotite*
- ✓ *Rhyolite*
- ✓ *Andesite*
- ✓ *Basalt*
- ✓ *Komatiite*
- ✓ *Diabase*

Sedimentary rocks are made from layers, or strata, of mineral particles found in other rocks that have been weathered and from newly formed organic matter.

Model Question - 2. (IAS 2001)

Consider the following statements made about the sedimentary rocks:

1. Sedimentary rocks are formed at earth's surface by the hydrological system
2. The formation of sedimentary rocks involves the weathering of pre-existing rocks.
3. Sedimentary rocks contain fossils
4. Sedimentary rocks typically occur in layers

Which of these statements are correct?

Answer: 2

Sedimentary rocks **form at Earth's surface by the hydrologic system**. Their origin involves the **weathering of pre-existing rock**, transportation of the material away from the original site, deposition of the eroded material in the sea or in some other sedimentary environment, followed by compaction and cementation. Some common features are:

Importance of Sedimentary Rocks

Sedimentary rocks are important because they preserve a record of ancient landscapes, climates, and mountain ranges, as well as the history of the erosion of Earth. In addition, fossils are found in abundance in sedimentary rocks younger than 600 million years and provide evidence of the evolution of life through time. Earth's geologic time scale was worked out using this record of sedimentary rocks and fossils.

- They contain strata or layers. The layers are **rarely horizontal** and ***generally tilted*** due to lateral compressive and tensile forces. They are formed of sediments derived from the older rocks, plants and animals remain.
- Most part (around 75 percent) of the surface area of the globe is covered by Sedimentary Rocks.
- Most of the sedimentary rocks are permeable and porous.
- Sedimentary rocks are generally characterized by different sizes of joints, generally perpendicular to the bedding plains.

When rock minerals are weathered, their chemical composition is changed, weakening the solid rock. The rock breaks up into particles of many sizes. When these particles are transported in a fluid such as air, water, or glacial ice, we call them **sediment**. There are three major classes of sediment: **clastic sediment**, chemically precipitated sediment, and organic sediment. On this basis, three main types of sedimentary rocks are recognized viz. **clastic rocks, organic rocks** and **chemically precipitated** rocks.

Types of Sedimentary Rocks	
Clastic	Made up of discrete fragments or clasts of materials derived from other minerals, largely of quartz and others such as feldspar, amphiboles, clay minerals
Organic	They contain the materials which are generated by living organisms such as corals, mollusks, and foraminifera, which cover the ocean floor with layers of calcium carbonate, which can later form limestone.
Chemical	Formed by the Chemical & Biological Processes like limestone, rock salt, gypsum and dolostone

2 All are correct statements.

Clastic Sedimentary Rocks

Model Question - 3.

Which one among the following is a mechanically formed sedimentary rock?

A. Salt rock
B. Limestone
C. Sandstone
D. Gypsum

Answer: 3

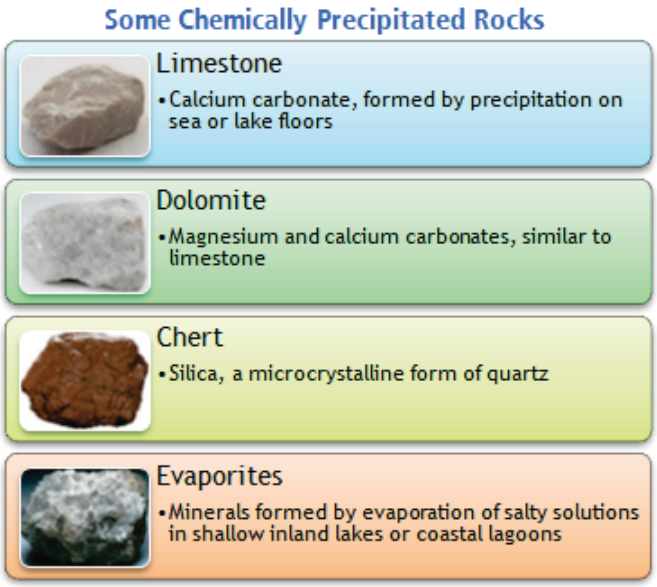
Clastic sediment is made up of inorganic rock and mineral fragments, called clasts. These can come from igneous, sedimentary, or metamorphic rocks, and so they can include a very wide range of minerals. Quartz and feldspar usually dominate clastic sediment.


Sandstone

When layers of clastic sediment build up, the lower strata are pushed down by the weight of the sediments above them. This pressure compacts the sediments, squeezing out excess water. Dissolved minerals recrystallize in the spaces between mineral particles in a process called cementation, thus giving rise to the **Clastic Sedimentary Rocks**. Due to the mechanical process, the clastic sedimentary rocks are also sometimes called ***mechanically formed*** *Sedimentary Rocks*. **Sandstone**, a rock made of sand, and **shale,** a rock made of clay particles, are typical examples of Clastic Sedimentary Rocks. Shale is a clastic sedimentary rock composed of very fine grains of clay or mud.

Chemically Precipitated and Organic Sedimentary Rocks

Chemically precipitated sediment is made of solid inorganic mineral compounds that precipitate from water solutions or are formed by organisms living in water. One of the most common sedimentary rocks formed by chemical precipitation is limestone.



The third class of sediment is **organic sediment**. This is made up of the tissues of plants and animals. Peat is an example of organic sediment. This soft, fibrous, brown or black substance accumulates in bogs and marshes where the water stops the plant or animal remains from decaying.

Limestone

Limestone is by far the **most abundant chemically precipitated rock**. It is composed principally of calcium carbonate ($CaCO_3$ or calcite) and originates by both inorganic chemical and biochemical processes. Limestones have a great variety of rock textures such as skeletal limestone, oolitic limestone, and microcrystalline limestone.

3 Correct Answer is C, Sandstone

Marine sediments form largely by biochemical precipitation. *Carbonate sediments dominate at shallow depths and in warm near-shore waters. Elsewhere, siliceous sediment, which eventually forms chert, is typical in deeper water.*

Skeletal Limestone

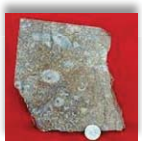
Some marine invertebrate animals construct their shells or hard parts by extracting calcium and carbonate ions from seawater. Corals, clams, algae, snails, and many other marine organisms construct their skeletons of calcium carbonate. After the organisms die, the shells accumulate on the seafloor. Over a long period of time, they build up a deposit of limestone with a texture consisting of shells and shell fragments. These particles may then be cemented together as more calcite precipitates between the grains. This type of limestone, composed mostly of skeletal debris, can be several hundred meters thick and can extend over thousands of square kilometers.

- ***Chalk*** *is a skeletal limestone in which the skeletal fragments are remains of microscopic plants and animals.*

Oolitic Limestone

Other limestones are composed of small semi spherical grains of calcium carbonate known as oolites. Oolites form where small fragments of shells or other tiny grains become coated with successive thin layers of $CaCO_3$ as they are rolled along the seafloor by waves and currents.

Microcrystalline limestone



A third important type of limestone forms in quiet waters where calcium carbonate is precipitated by algae as tiny, needle like crystals that accumulate on the seafloor as limy mud. Soon after deposition, the grains commonly are modified by compaction and recrystallization.

- *Some kinds of algae produce calcium carbonate particles that accumulate to form limestone.These are found near the Kuril Islands of the north Pacific.*
- *Diatoms are the shells of tiny single-celled algae that are made of silica. Some deepmarine sediments are dominated by diatoms. Some accumulations convert to chert.*

Dolostone / Dolomite

Dolostone or dolomite rock is a sedimentary carbonate rock that contains a high percentage of the mineral dolomite. Dolomite is a carbonate mineral composed of calcium magnesium carbonate $CaMg(CO_3)_2$. ***It is similar to limestone in general appearance, but reacts with acid only when powdered***. Dolostone is commonly dull brownish yellow or light gray.

Chert

Chert is a common rock composed of microcrystalline quartz. In a hand specimen, it is hard, dense, and typically breaks like glass, but under a high-power microscope, it has a fibrous or granular texture. A distinctive type of deep-marine chert develops from deposits of siliceous shells of microscopic organisms, such as radiolaria and diatoms.

Rock salt

Rock salt is made of the mineral halite (NaCl). It crystallizes when evaporation concentrates sodium and chlorine ions to the point that salt is stable in the residual brine. Strong evaporation creates saline lakes in closed desert basins (for example, the Great Salt Lake and the Dead Sea). Enhanced evaporation also occurs in restricted bays along the shore of the ocean.

Gypsum

Gypsum, $CaSO_4 \cdot 2H_2O$ too originates from evaporation. It collects in layers as calcium sulphate is precipitated from water.

Hydrocarbons

Coal is an important biochemical precipitate. It forms by the decomposition of organic material buried within sedimentary rocks. Lush vegetation may form in an ancient swamp and then be converted by burial into coal. The coal beds on the left are interlayered with sandstone.

The accumulation of partially decayed vegetation is called Peat. Peat is a compound of hydrogen, carbon, and oxygen. They formed from plant remains that built up over millions of years and were compacted under thick layers of inorganic clastic sediment. Hydrocarbons can be solid (peat and coal), liquid (petroleum), or gas (natural gas). Coal is the only hydrocarbon that is a rock. We often find natural gas and petroleum in open interconnected pores in a thick sedimentary rock layer, such as in porous sandstone.

Metamorphic Rocks

The mountain-building processes of the Earth's crust involve tremendous pressures and high temperatures. These extreme conditions alter igneous or sedimentary rocks, transforming them into metamorphic rock. Thus, metamorphic rocks are formed from the pre-existing rocks within the Earth's crust by changes in temperature and pressure and by chemical action of fluid. This means that Both the Igneous and Sedimentary socks undergo profound physical and chemical changes under the increased pressure and temperature. The process is called "metamorphism". Some metamorphic Rocks are Schist, Gneiss, Slate, Quartzite, Marble and Granite.

There are two basic types of metamorphic rocks:

1. Foliated metamorphic rocks such as gneiss, phyllite, schist and slate which have a layered or banded *appearance that is produced by exposure to heat and directed pressure. This is called Foliation.*
2. Non-foliated metamorphic rocks such as marble and quartzite which do not have a layered or banded appearance.

In the surface environment, rocks weather into sediment. In the deep environment, heat and pressure transform sediment into rock that is eventually exposed at the surface.

Part II. Volcanoes & Volcanism

Introduction to Volcanoes

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

Factbox: Vulcan

Vulcan is Greek God of beneficial and hindering fire. A festival was celebrated in Athens devoted to *Vulcan* on August 23, and the name of the festival was **Volcanalia**. Vulcanization is another term derived from the name of Vulcan God. Vulcanization is adding sulfur or other curatives to rubber or other polymers to make them more durable. The rubber so produced is called Vulcanite or ebonite. Vulcano is the name of an island near Sicily, the largest island in the Mediterranean Sea and an autonomous region of Italy.

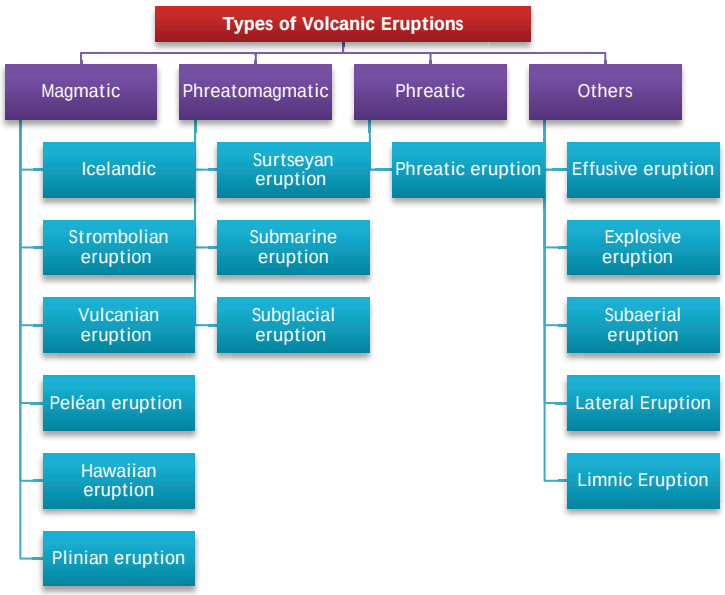
An opening or vent through which the magma, molten rocks, ashes, gases and other volatiles erupt on the surface of Earth is called a Volcano. The most known types of Volcanoes are conical mountains which spit law and poisonous gases. But there are other types of Volcanoes.

The Volcanoes can be divided in the basis of **Type of Eruption**, **Material erupted** & **Periodicity of eruption**.

Types of Volcanoes by Volcanic Eruption

There are three major categories of the volcanic eruptions. The **magmatic eruptions** involve the decompression of gas within the magma. This decompression of the gas propels it outward.

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

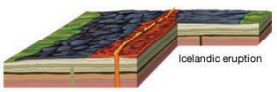


Magmatic Eruptions

When Magma, the mixture of rocks, volatiles and solids erupts in a fissure, it is called magmatic eruption. Here are some subtypes of eruptions, which you don't need to remember.

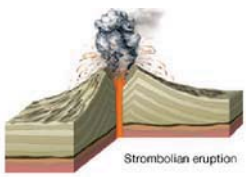
Icelandic Eruption

The free flowing basaltic lava is released is a large quantity. The eruption is poor in gas and issues a great volume of lava. The lava flows as sheets over a large area to build up plateaus.



Strombolian Eruption:

The term is derived from Italian Volcano **Mount Stromboli** and such kind of volcanoes is also known as summit craters. They are moderate and exhibit continuous explosions. Mostly light colored clouds are seen as in the picture. *Mount Stromboli is located in the Stromboli Island, and is best known as "Light House of the Mediterranean".*

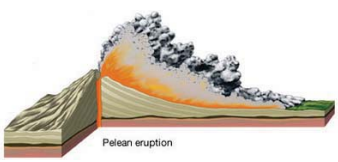


Vulcanian Eruption:

These types of volcanoes allow the gas to compress beneath the magma and this result in violent eruption over quite periods. The volcano ejects bombs, and the lava flows after the main explosion giving rise to a layer of lava and ash. The clouds formed are cauliflower shaped and grows vertically and often result in acid rains. *Strombolian Eruption and Vulcanian eruptions are sometimes used synonymously.* The only major difference is that Vulcanian Eruption is more violent than the Stombolian eruption and eruption occurs over long periods.

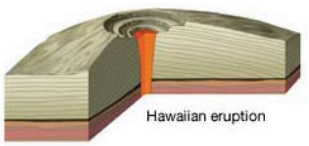
Peléan eruption

The Peléan eruption results from the highly viscous lava and the main characteristics are **formation of lava domes**. There is a presence of **glowing cloud of hot volcanic ash**. This term is derived for 1902 explosion of Mount Pelée, also known as Bald Mountain located in the Caribbean. The Volcanic cones of such Volcanoes are composed of layers of volcanic ash and hardened lava.



Hawaiian eruption

Hawaiian eruption is the main characteristic of Hawaiian Volcanoes. This is the most common type of eruption in most hotspot volcanoes. These volcanoes have lower water content and that is why they are more peaceful in eruptions. The lava is basalt in composition. These eruptions produce Fire Mountains and the amount of as is minor.



Plinian Eruption:

Plinian Eruptions are synonymous with **Vesuvian Eruption**. The term derived after the name of Pliny. **Pliny, the younger** was a lawyer, writer and magistrate of ancient Rome. His uncle was **Pliny, the elder**. **Pliny, the elder** was the same writer who had written about Indian Emperor Chandragupta Maurya. Seleucus, the successor of Alexander the Great was in good terms with Chandragupta Maurya and the details are provided by **Pliny, the elder**. **Pliny the elder** was killed in the great eruption of the Mount Vesuvius in Italy on August 24, 79AD. The account of his death was provided by Pliny the Younger. The plumes are very high range varying from 20-25 kilometers.

Phreatomagmatic eruptions

They are juvenile eruptions mostly occur due to interaction of water and magma. The thermal contraction of the particles when come in touch with water the rapid cooling follows which results in this type of explosion. These may occur under the sea when basalt erupts and comes in touch with the water to give rise to the Pillow basalts, rocks in the pillow shape.

Surtseyan eruption

Surtseyan eruption takes place in **shallow seas and lakes**. They are named after the Surtsey, a volcanic island off the coast of Iceland.

Submarine eruption

Submarine eruption occurs under an ocean. These are the most common eruptions on earth. However, they are not documented because of the difficult monitoring.

Subglacial eruption

Subglacial eruptions occur under the ice. **They are also known as Tuya**. The examples of these types of eruptions are Eruption of a Volcano under the Antarctica ice sheet and Hudson Mountains. The former occurred 2200 years ago. **2010, Eyjafjallajökull eruption in Island was a Subglacial eruption.**

Pheratic Eruptions:

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

Other Types of Eruptions:

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

Types of Volcanoes by Periodicity of Eruption

There are 3 kinds of Volcanoes on the basis of frequency of eruption viz. Active, Dormant and Extinct.

Active volcanoes

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

Dormant Volcano

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

Extinct Volcano

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

Some definitions

Tephra

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

Volcanic Bomb

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

Lapilli

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

Volcanic Ash:

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

Pillow lava

Interconnected, sack-like bodies of lava formed underwater.

Pyroclastic Rocks

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

Cinder Cone:

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

Repose.

The time lag between the volcanic eruptions is called repose.

Volcanic Explosivity Index

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

Pacific Ring of Fire

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

Some other Notes

- There are more than 1500 active Volcanoes in the word.
- Crater Lake in Oregaon USA was formed when a Volcano lost its top in eruption thousands of years ago.
- *The Volcanic Ash is mostly acidic.*
- The Olympus Mons is the tallest known Volcano on Planet Mars.
- Italy's Stromboli Volcano is erupting for more than 2500 years.
- The Mount St. Helense had erupted in 1980, which caused the ash travel across entire US.
- The 1883 eruption of Indonesia's Krakota eruption was so loud that blasts were heared 3000 miles away.

- Mauna Kea in Hawaii is the tallest Volcano on earth. The meaning of its name is White Mountain as it is snow capped. Its height is 4205 meter from Sea Level; however, if it measured from its oceanic base, it is the higher than mount Everest (over 10000 meters).

Basics of Magma

Model Question - 4. (IAS 2001)

Consider the following statements:

1. Most magma are a combination of liquid, solid and gas.
2. Water vapour and carbon dioxide are the principal gases dissolved in magma.
3. Basaltic magma is hotter than the silicic magma.
4. The magma solidified between sedimentary rocks in a horizontal position is known as dike.

Which of these statements are correct?

Answer: **4**

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

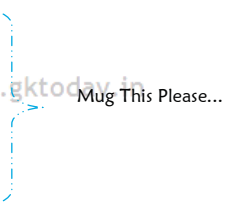
Types of Magma

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

Magma Type	Silica Content	Fe-Mg Content	Temperature	Eruption	Viscosity
Ultramafic or Picritic	Less than 45%	8-32%	High up to 1500°C	Gentle	Low
Mafic or Basaltic	Around 50%	Less than 10%	Up to 1300°C	Gentle	Low
Andesitic	Around 60%	Around 3%	Up to 1000°C	Explosive	Medium
Felsic / Rhyolitic	Around 70%	Around 2%	Below 900°C	Explosive	High

From the above table please note down the following observations:

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



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

Gases in Magma

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

- Mostly H2O (water vapour) & some CO2 (carbon dioxide)
- Minor amounts of Sulfur, Chlorine, and Fluorine gases

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

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4 In this question, first three statements are correct. The fourth definition is of a sill. A **sill is a horizontal sheet intrusion** that has intruded between older layers of sedimentary rock, beds of volcanic lava or tuff, or even along the direction of foliation in metamorphic rock. **If it vertical, it is called Dike.**

Model Question - 5.

Which among the following is/ are the sources of Magma:

1. Molten Outer Core of the Earth
2. Solid Rocks of Earth's Crust
3. Solid Rocks of Mantle

Choose the correct options:

Answer: 5

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

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

Model Question - 6.

Consider the following statements:

1. Most Magmas erupted in the ocean basins are basaltic
2. The melting of rocks of Earth's mantle generated Basaltic Magma

Which among the above statements is / are correct?

Answer: 6

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

Does Geothermal Gradient causes melting of Rocks?

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

Does Radioactive Heat Cause Melting of Rocks?

The radioactive elements such as Uranium, Thorium etc, keep decaying below. During radioactive decay, sub-atomic particles are released by the decaying isotope and move outward until they collide with other atomic particles. Upon collision, the kinetic energy of the moving particles is converted to heat. If this heat cannot be conducted away, then the temperature will rise. Most of the heat within the Earth is generated by radioactive decay, and this is the general reason why temperature increases with depth in the Earth. But again *this is not*

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5 Only 2 & 3.

6 Both 1 & 2 are correct statements.

enough to prove the melting of the rocks. We should know that ***most the radioactive isotopes are concentrated in the crust.*** Although there are areas in the continental crust where high concentrations of radioactive elements have locally raised the temperature, at least high enough to cause metamorphism, but it is more unlikely that areas of high concentration *develop within the mantle*. *Thus, concentrations of radioactive elements are not likely to cause melting.*

Does decrease in Pressure cause rock melt?

There are two things. First is that very high pressures in mantle rocks prevent atoms within minerals from breaking chemical bonds and moving freely from one another to form magma. Therefore, most rocks within the mantle do not melt even though their temperature may be greater than that necessary to melt the same rocks at the lower pressures of the Earth's surface. However, if something occurs that the pressure on mantle rock is decreased; the atoms may move freely from one another. This would result in the partial melting of the already very hot solid rock. This process is called pressure-release melting. It is a scientifically proved theory and is found to be *common along divergent plate margins*, and within mantle plumes.

Does addition of Water causes melting?

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

How Magma is finally formed?

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

Part III. Megarelief

Mega-Relief Basics

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

First Order of Relief:

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

Second Order of Relief:

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

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

Third Order of Relief:

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

Relief Features of the Oceans

Oceans make up 71 percent of the Earth's surface. Relief features of oceans are quite different from those of the continents. Please note that much of the oceanic crust is less than 60 million years old, while the great bulk of the continental crust is of Proterozoic age—mostly over 1 billion years old. Thus, the young age of the oceanic crust is quite remarkable.

Oceans: Quick Facts

- Surface area of earth is 510,072,000 km². It comprises of 148,940,000 km² land (29.2 %) & 361,132,000 km² water (70.8 %).
- Half of this more than 36 Crore Square Kilometers of total area under oceans is deeper than 3000 meters.
- The Average salinity of the oceans is 3.5% or 35ppt i.e. parts per thousand. The volume of all oceans is around 1.3 billion Km^3.
- Average depth is 3790 meters. Maximum Depth is 10923 meters.
- Total mass of ocean water is 1.4×10^{21} kilograms. It is 0.023% of Earth's total mass.
- Less than 3% of water available on earth is Fresh water, rest is saline water.

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

Some Extreme Points

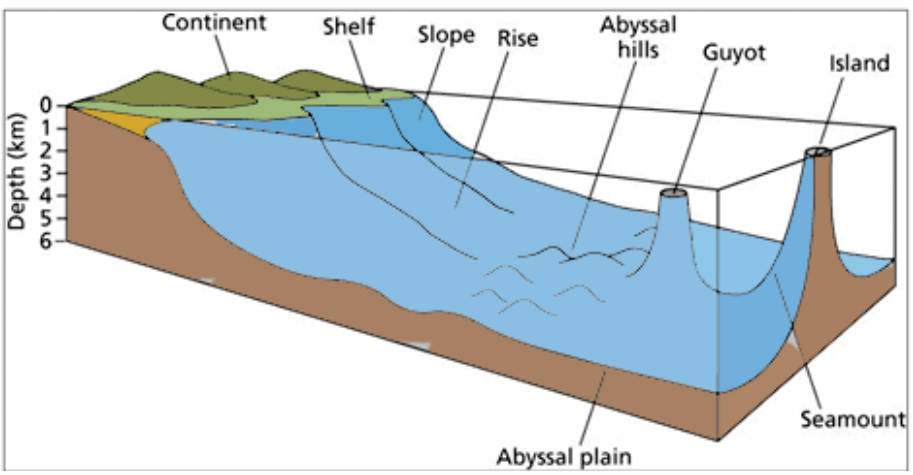
- The deepest point in the ocean is the Mariana Trench, located in the Pacific Ocean near the Northern Mariana Islands.
- Its maximum depth has been estimated to be 10,971 meters (plus or minus 11 meters).
- British naval vessel, Challenger II surveyed the trench in 1951 and named the deepest part of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

The ocean relief can be divided into the following parts as shown in the graphics:

- Continental Shelf
- Continental Slope
- Continental Rise or Foot

Continental margin.

- Deep Ocean basins
- Abyssal plains & Abyssal Hills
- Oceanic Trenches
- Seamounts
- Guyots.



Model Question - 7.

Consider the following statements:

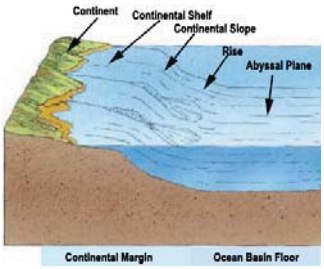
1. Largest Continental Shelf is in Atlantic Ocean
2. While going down along continental slope, the transition of Continental Crust to Oceanic Crust generally occurs at Continental Rise

Which among the above statements is / are correct?

Answer: 7

Continental Shelf

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



Continental Slope & Continental Rise

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

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

Deep Ocean basin & Oceanic Ridges

Model Question - 8.

Consider the following statements in context with the Mid-Oceanic Ridges:

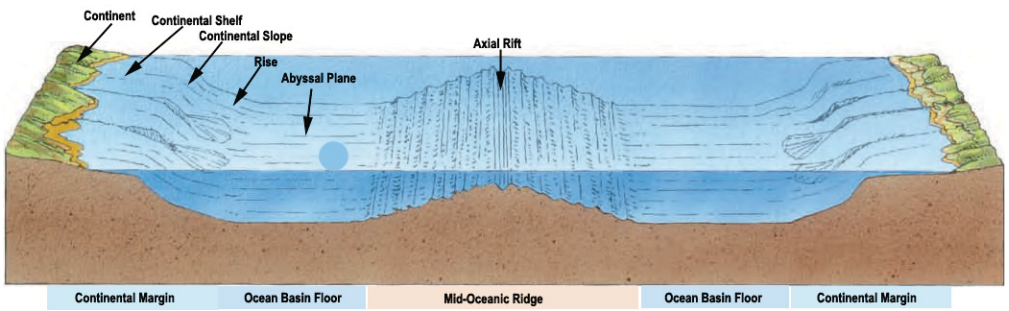
1. They represent geologically young rocks
2. They are found in every ocean
3. Many of them are near Volcanic Hotspots

Which among the above statements is/ are correct?

Answer: 8

Deep Ocean Basin is the lowest layer in the ocean. The sea floor is like a covering of sediments over a basalt rock which may be up to 5 kilometers thick. **Oceanic ridges** or **Mid-oceanic Ridges** refer to the boundary between the diverging plates. A midoceanic ridge of submarine hills divides the basin in about half. Precisely in the center of the ridge, at its highest point, is a narrow trenchlike feature called the **axial rift.** The location and form of this rift suggest that the crust is being pulled apart along the line of the rift.

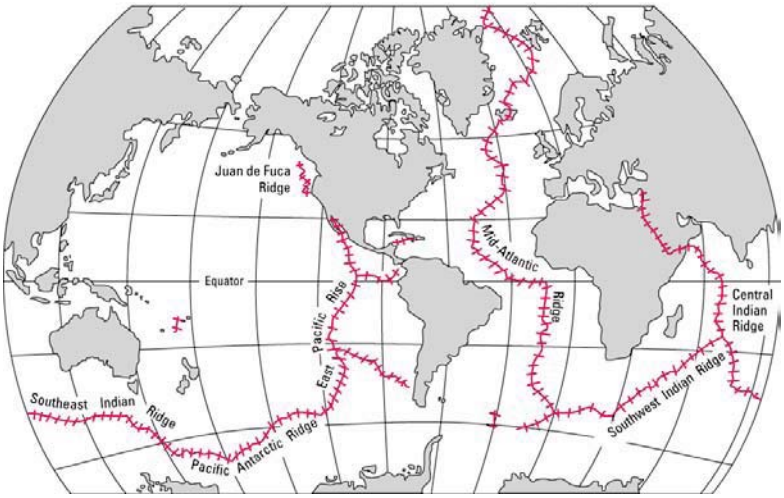
A mid-ocean ridge (MOR) refers to an underwater mountain system that consists of various mountain ranges (chains), typically having a valley known as a rift that runs along its spine, formed by plate tectonics.



7 Only 2 is a correct statement.

8 All are correct statements

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



Location of the important ridges are as follows:

- **Aden Ridge:** Gulf of Aden and Indian Ocean along the south-eastern coastline of the Arabian Peninsula.
- **Explorer Ridge:** Located 240 km west of Vancouver Island, British Columbia, Canada.
- **Gorda Ridge:** off the coast of Oregon and northern California north of Cape Mendocino
- **Juan de Fuca Ridge:** off the coasts of the state of Washington in the United States
- **Cocos Ridge:** Its is a Volcanic hotspot. Also known as **Galapagos hotspot** located in East Pacific Ocean *responsible for the creation of the Galapagos Islands as well as three major seismic ridge systems. Carnegie, Cocos and Malpelso*.
- **Gakkel Ridge:** located in the Arctic Ocean between Greenland and Siberia, and has a length of about 1,800 kilometers. It is **slowest known spreading ridge** on the earth.
- **Pacific-Antarctic Ridge:** located in South Pacific Ocean
- **Southeast Indian Ridge:** It is located in the Indian Ocean and separates the Indo Ocean plate from the Antarctic plate.
- **Carlsberg Ridge:** Located in the Indian Ocean.

Abyssal Plain

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

Oceanic Trench

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

Mariana Trench

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

Tonga Trench

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

Factbox: Tonga Trench and Apollo 13

Apollo 13 was the third Apollo mission which was launched to land on the Moon. It was successfully launched toward the Moon, but the landing had to be aborted after an oxygen tank ruptured. It was launched on April 11, 1970 and subsequently failed. Its lunar module re-entered earth's surface on April 17. 1970 and was targeted over the pacific Ocean to reduce the contamination from the Radioisotope Thermoelectric Generator (RTG) on board, which would have provided energy to the

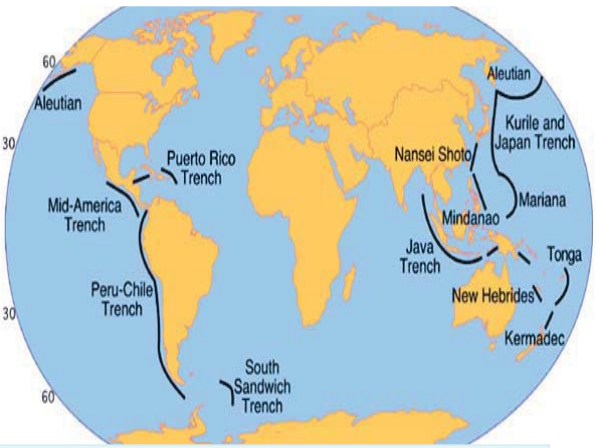
mission. This RTG was landed in the Tonga Trench. The RTG will remain active for next 2000 years. It has 3.9 kilogram of radioactive plutonium.

Puerto Rico Trench

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

Location of some Mid-Oceanic Trenches in Oceans

North Pacific Ocean	South Pacific Ocean	North Atlantic	Indian Ocean
Mariana Trench (Vityaz-I Deep and Challenger Deep)	Tonga Trench (Horizon Deep)	Puerto-Rico trench	Sunda Trench also known as Java Trench.
Japan Trench (Ramapo Deep)	New Hebrides Trench	Romanche trench	
Aleutian Trench	Peru trench		
Kurile Trench	Plate Tectonics		
Philippine Trench			
Atacama Trench			



Seamounts & Guyots

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

Rift valleys

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

Lake Baikal

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

Lake Tanganyika

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

Lake Superior

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

Lake Vostok

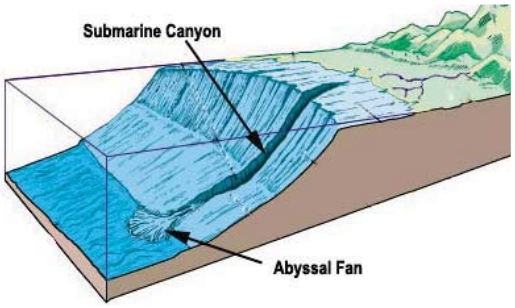
- Lake Vostok is in Antarctica and is a Sub Glacial lake. It is located below the Vostok Station of Russia in Antarctica.

Lake Nipissing

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

Abyssal Fans

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



Archipelago

Archipelago refers to a cluster of islands which are formed tectonically. This term was initially used for Aegean Islands located in the Aegean Sea between Greece and Turkey. Indonesia is often referred to as the world's largest archipelago; however, this means that it is largest by area and not by number of islands. Indonesia has 17,500 islands which span more than 5000 km^2. World's largest archipelago by number of Islands is Archipelago Sea which is located Baltic Sea between the Gulf of Bothnia and the Gulf of Finland. It has 50,000 Islands. Top 5 archipelagos in the world by number of Islands are as follows:

- Archipelago Sea (Finland) 50,000
- Canadian Arctic Archipelago 36.563
- Stockholm Archipelago 24,000
- Indonesian Archipelago 17.508
- Philippine Archipelago 7.107

Lagoon

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

Chilika lake

- Chilika Lake is a Brackish water lagoon spanning in 3 districts of **Puri, Khurda and Ganjam** of Odisha. It is largest Coastal lagoon in India. The lake is an ecosystem with large fishery resources and supports 1.5 Lkh fishermen. Chilka lake has the distinction of being India's First Wetland of International Importance under the Ramsar Convention. Chilika Development Authority (CDAI is monitoring the water quality of the lagoon every month from 30 different Stations for various physico-chemical parameters, which are said to be within the permissible limits.

Vembanad Lake

- Vembanad Lake located in Kerata is India's longest lake, bordered by 3 districts of Kerala viz. Alappuzha, Kottayam, and Ernakulam. Its length is 96.5 kilometers and widest width is 14 kilometers.

Coral Reefs

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

Model Question - 9. (IAS 2007)

The Largest coral reef in the world is found near the coast of which one of the following countries?

A. Australia
B. Cuba
C. Ghana
D. Philippines

Answer: 9

9 Australia

Coral reefs are some of the most diverse ecosystems on earth which despite of covering less than 10% of world ocean surface (284,300 km^2) provide home to 25% of marine species including fishes, molluscs etc. Coral Reefs are very fragile ecosystem and are **susceptible to "Surface Temperature"** of the oceans. They are threatened by the climate change, ocean acidification, **blast fishing**, **cyanide fishing** for aquarium fish, overuse of reef resources, and harmful land-use practices.

Blast Fishing & Cyanide Fishing

- Blast fishing refers to using the explosives to kill schools of Fishes for easily collection. The underwater shockwaves produced by the blast made by dynamite or a bomb causes the swim bladder of the fish rupture and leave them dead. The practice is Illegal. It is most common in Tanzania and Indonesia.
- Cyanide fishing refers to capturing the fishes using Sodium Cyanide to kill the schools of the fishes. The fish killed are put in fresh water for 10 days and then supplied to the markets for consumption.

Some Notes

- The Indian Ocean and Pacific Ocean region including the **Red Sea, Indian Ocean, Southeast Asia and the Pacific** account for 91.9% or total Coral reefs in the world.
- Southeast Asia accounts for 32.3%, while the Pacific including Australia accounts for 40.8%. **Atlantic and Caribbean coral reefs only account for 7.6%**.
- **Largest Coral reef in the world is Great Barrier Reef.** It is located in the Coral Sea, off the coast of Queensland in north-east Australia. It is composed of over 2,900 individual reefs and 900 islands stretching for over 2,600 kilometers. This reef can be seen from outer space and is the world's biggest single structure made by living organisms. It is a World Heritage Site (1981). It is also a state icon of Queensland, made by Queensland National Trust. A large part is protected by the Great Barrier Reef Marine Park, established by Government of Australia through Great Barrier Reef Marine Park Act 1975.
- **Belize Barrier Reef is world's second largest Coral Reef** which is a part of 900 kilometer Mesoamerican Barrier Reef System. It was described by Charles Darwin in 1842 as "the most remarkable reef in the West Indies".
- ***Pulley Ridge is*** *located off the coast of Florida, United States. It is deepest photosynthetic coral reef known so far.*
- Raja Ampat Islands, largest marine national park in Indonesia are located in Indonesia and New Guinea and comprise 1,500 small islands .***It is known for highest recorded marine biodiversity on Earth***. It makes the Coral Triangle which is a triangular shaped area of the tropical marine waters of Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands and Timor-Leste. These waters contain at least 500 species of reef-building corals in each ecoregion. Coral Triangle as well as Raja Ampat Islands is considered to be the global epicenters of marine biodiversity. INWF considers the region as a top priority for marine conservation and has launched the Coral Triangle Program in 2007

Beach

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

Cox's Bazaar

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

Marina Beach

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

Evidence of Continental Drift: Wegener's Continental Drift Hypothesis

Model Question - 10.

Consider the following statements:

1. Glacial evidence shows that areas now north of the equator were once covered by glaciers moving from the south
2. Fossils show that similar species of land animals once lived in Brazil and Africa, indicating that these land masses were once connected
3. Glossopteris was a marine organism whose fossils are found only in the northern hemisphere.

Which among the above statements is / are correct?

Answer: 10

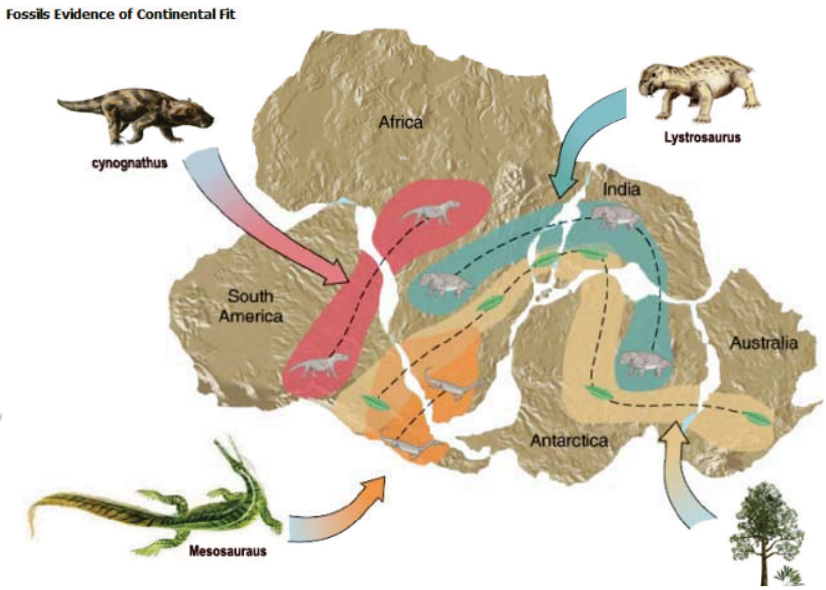
The Lithosphere is always in a state of work in progress. In 1912, a German geologist named **Alfred Wegener** came up with an outlandish theory known as **continental drift.** His theory was based upon the following clues.

Continental Fit

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

Fossils

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

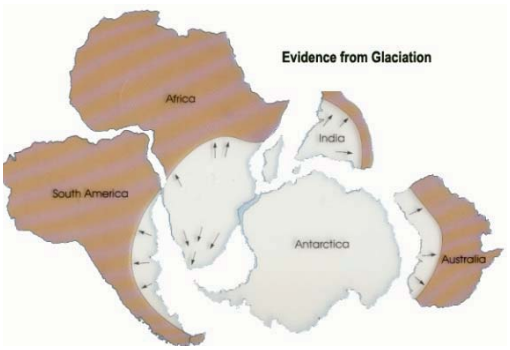


Coal Fields

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

Glacial Flow:

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



Similarity in Rocks

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

So, **Wegener** proposed that the present continents were once joined in a super continent named **Pangaea** and later the drifted apart. Wegener proposed that the **Pangaea** broke into continents and the new continents drove

10 Only 1 & 2 are correct statements.

away themselves in two directions viz. Equatorward and Westward movements. He said that the movements towards the equators were because of the gravitational differential forces and force of buoyancy. The Westward movement occurred because of the tidal force of sun and moon.

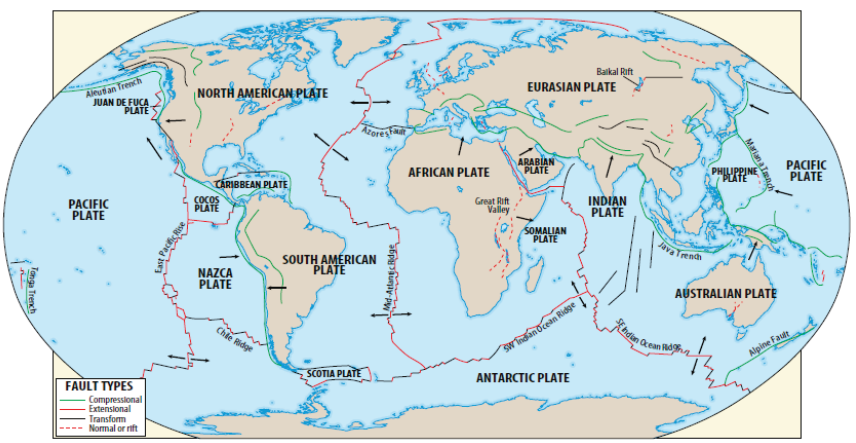
He proposed that the Pangaea began to separate into the **Gondwanaland** and **Angaraland** in the Carboniferous period and the space between the two was filled with water that was called **Tethys Sea**. Later the Gondwanaland disrupted during the Cretaceous period and with this, the Indian subcontinent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

Paleomagnetism

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

Plate Tectonics and Seafloor Spreading

Lithosphere is made up of about a dozen giant and several smaller sections called plates, and these move in various directions in processes known collectively as plate tectonics. The adjacent graphics shows the plates and their general direction of Movement. Earthquakes, volcanoes, and other geologic events are concentrated where plates *separate, collide, or slide past one another.* Where they separate, rifting produces **very low land elevations** (e.g. well below sea level at the Dead Sea of Israel and Jordan) or the emergence of new crust on the ocean floor (e.g. in the middle of the Atlantic Ocean).

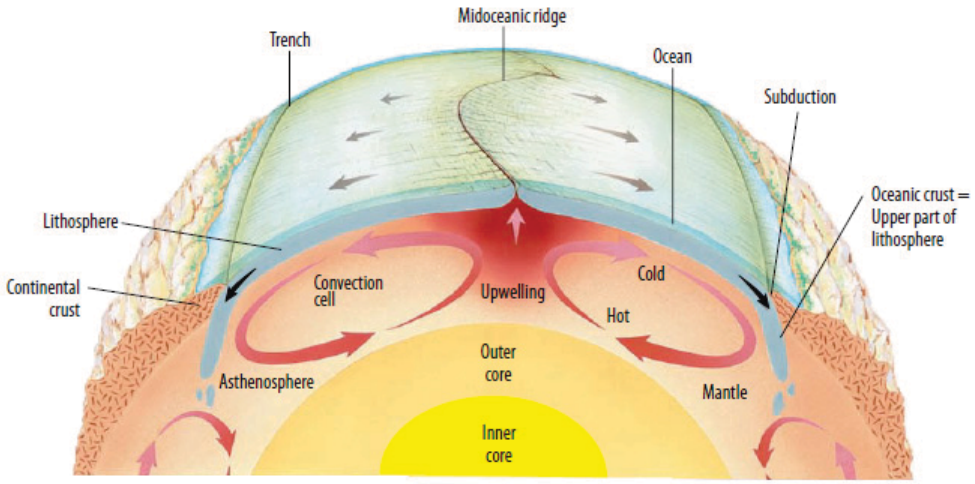


The central item in the Plate Tectonics is the **Mid-Oceanic Ridge**. *The mid-ocean ridges of the world are connected and form a single global mid-oceanic ridge system that is part of every ocean, making the mid-oceanic ridge system the longest mountain range in the world.* The continuous mountain range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

When the ocean floors such as Mid-Atlantic Ridge and the East Pacific Rise, new lithosphere is "born" as molten material rises from the earth's mantle and cools into solid rock. Plate tectonics are often explained by the useful

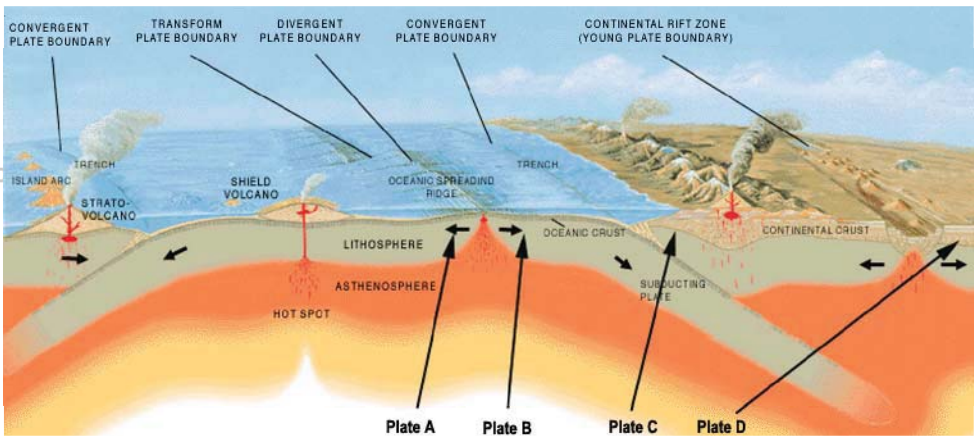
analogy of a "conveyor belt" in constant motion. On either side of the long, roughly continuous ridges, the two young plates move away from one another, carrying islands with them; this process is called **seafloor spreading.**

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



Subduction

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



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

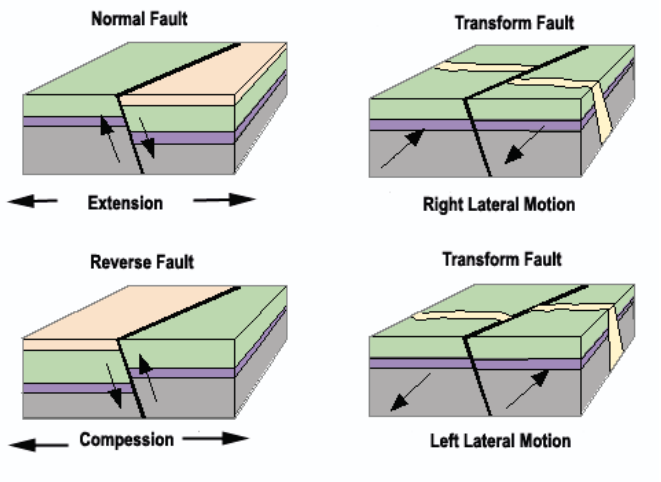
In the right, we see that the oceanic lithosphere of plate B is moving toward the continental lithosphere of plate C. Where these two plates collide, they form a **converging boundary**. Here, since the oceanic plate is comparatively thin and dense, in contrast to the thick, buoyant continental plate,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

what triggers a tsunami and the attendant loss of life and property such a powerful wave can cause. Further, the Volcanism generally occurs at places near the subduction zones.

Movement of Plates – Faulting

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

A. Normal – tension in the crust (a 'pulling apart")
B. Reverse – Compression in crust (a 'pushing in')
C. Reverse Thrust Fault
D. Transform



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

Faulting Versus Folding

Model Question - 11.

Consider the following:
1. Folding of the Rocks
2. Faulting of the Rocks
3. Subduction

Which among the above lead to Earthquake?

Answer: 11

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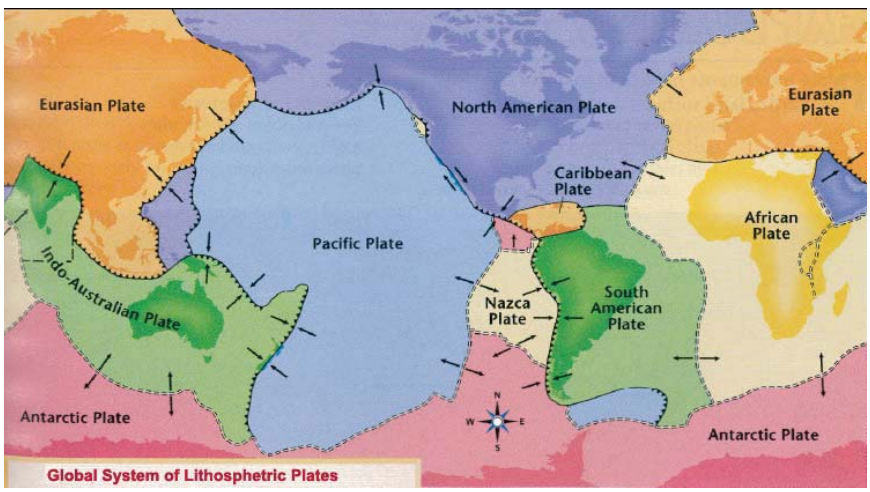
Please note that *both faulting of the Rocks and folding of the Rocks* play role in creation of the Earthquake, however, the role of later is also dependent upon the former. Earthquakes usually occur where Earth's crust has cracks and is weak. The cracks through which these vibrations pass are called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

The Lithospheric Plates System

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



Some important notable observations about these plates are as follows:

- American plate includes most of the continental lithosphere of North and South America.

11 Correct Answer 1, 2 & 3

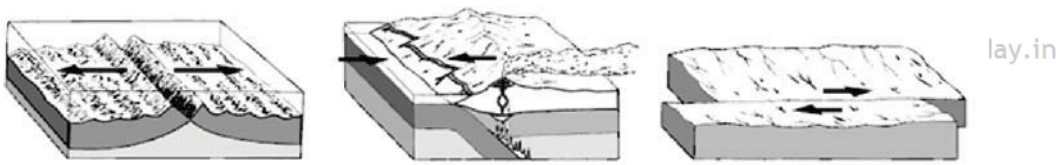
- Most part of the Eurasian plate is continental lithosphere, but it is fringed on the west and north by a belt of oceanic lithosphere.
- *African Plate is also known as the Nubia Plate*. It is a mix of continental and oceanic lithosphere.
- The great Pacific plate occupies much of the Pacific Ocean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

Plate Boundaries

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

There are three types of plate boundaries:

- Convergent Plate Boundaries: where plates move toward each other.
- Divergent Plate boundaries: where plates move away from each other.
- Transform Plate Boundaries: where plates slide past one another.



Convergent Plate Boundaries

Model Question - 12.

Kindly check the validity of the following statements as true or false:

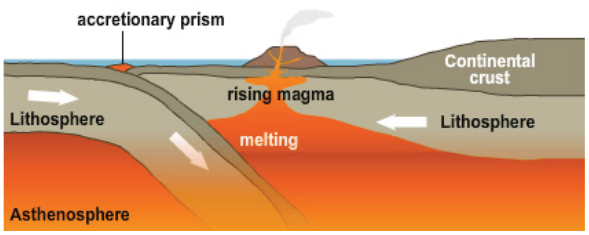
1. Most volcanoes are found near **all** convergent plate boundaries
2. Formation of Himalaya is a result of subduction of lithospheric plates
3. Japan is an example of Island Volcanic Arc
4. Subduction is a common activity around pacific ring of fire
5. Subduction is a prerequisite for volcanoes to occur at a plate boundary
6. Metamorphic rocks are common in Himalaya

Answer: 12

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

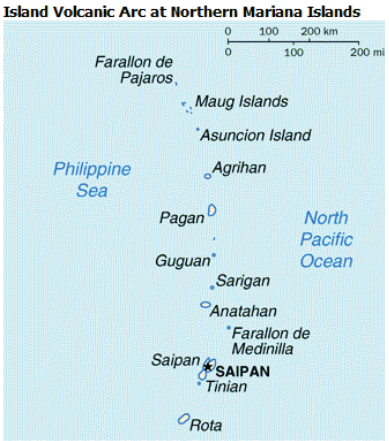
Ocean-Ocean Convergent Plate Boundary:

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



12 1. False | 2. False | 3. True | 4. True | 5. True | 6. True

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



Island Volcanic Arc:

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

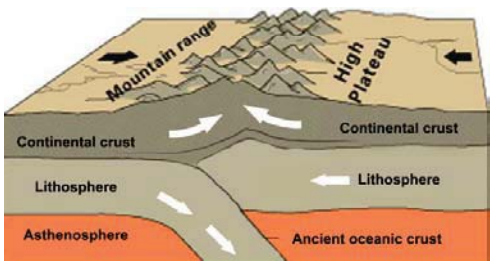
Ocean-Continental Convergent Boundary

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

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

Continent-Continent Boundary

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



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

Divergent Plate Boundaries

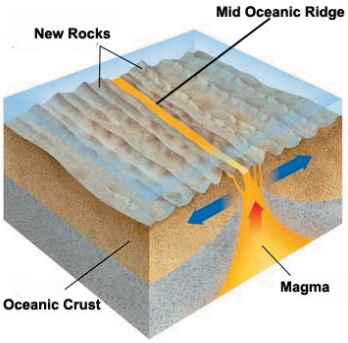
Model Question - 13.

Kindly check the validity of the following statements as true or false:

1. Mid-Atlantic Ridge is a divergent plate boundary
2. New Crust is formed at the Mid-oceanic Ridge
3. Maximum Rock Material is formed at the Convergent Plate Boundaries
4. Explosive Volcanoes are common at Convergent Boundaries
5. Divergent Plate Boundaries are generally home to shallow focus earthquakes only.

Answer: 13

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



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

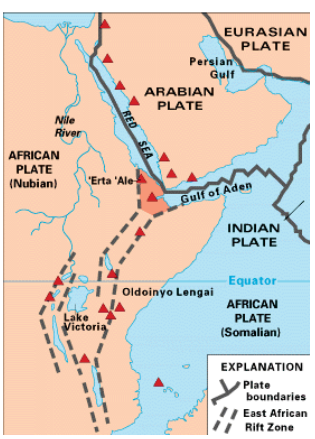
Comparison: Divergent and Convergent Plate Boundaries

Kindly note & remember the following points:

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

Continental Rift Zones

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



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

Transform Plate Boundary

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

13 1-True, 2-True, 3-False, 4-True, 5-True

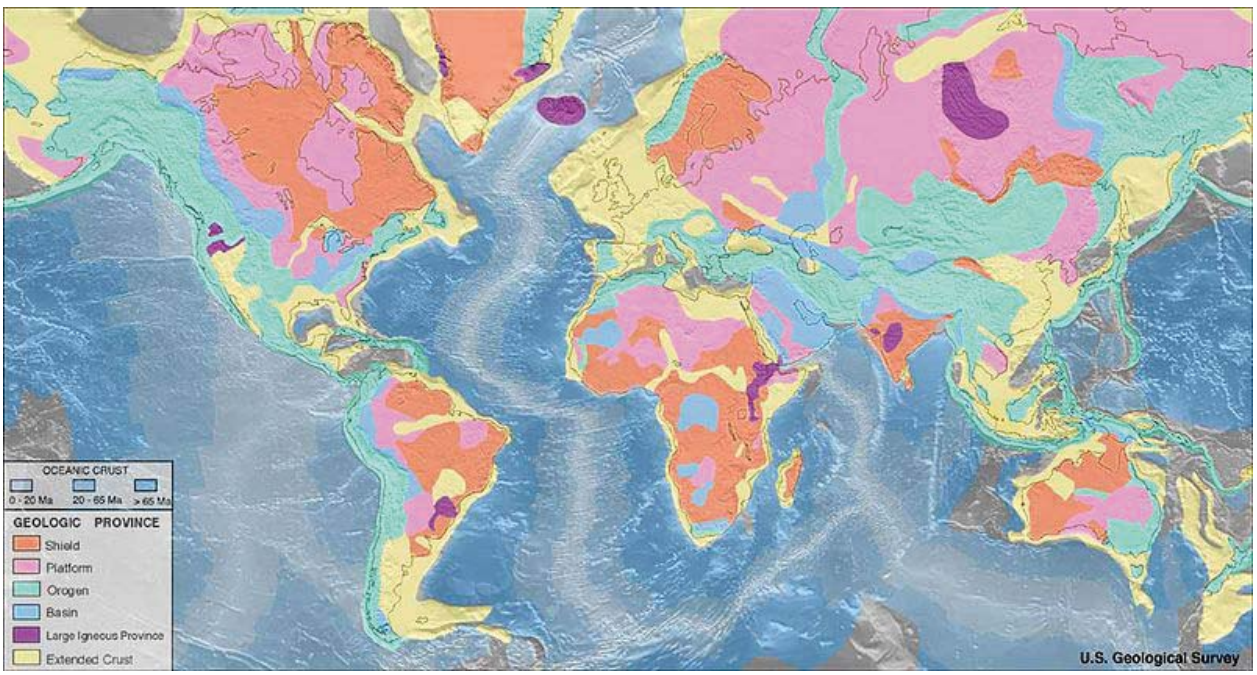
The transform plate boundaries can cause horizontal displacement of hundreds of kilometers of land on the continents which results in several types of landscapes such as ridges and troughs. In oceans, transform plate boundaries are part of fracture zones. *Earthquakes are most common at transform plate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

Part V. Relief Features of the Land

Geological Provinces

The entire Earth has been divided into several Geological Provinces on the basis of their origin. A geologic or geomorphic province is an entity with common geologic or geomorphic attributes. The Geological provinces include **Continental Shield**, **Platform-**which is a shield covered with sediment, **Orogen**-which leads to development of mountains, **Structural Basins**-which are geological depressions, and are the inverse of domes, **Large igneous provinces**-which are extremely large (More than 100,000 Km^2) accumulation of igneous rocks—intrusive, extrusive, or both—in the earth's crust. One example of large igneous province is India's Deccan trap. The last such geological province is **extended crust**.

Major geological provinces are:
- ✓ *Continental Shield*
- ✓ *Platform*
- ✓ *Orogen*
- ✓ *Structural Basins*
- ✓ *Large Igneous province*
- ✓ *Extended Crust.*



Continental Shields

The first order of relief contains Earth's continents and ocean basin, which were created by the movements of plates on the surface of the Earth. The lithospheric shell of the Earth is divided into large pieces called **lithospheric plates**. A single plate can be as large as a continent and can move independently of the plates that surround it. This is very much similar to a great slab of ice floating on the polar sea. The continents can be geologically derived into two types of regions viz.

1. *Active mountain-making belts* and
2. *Inactive regions of old*, stable rock.

The mountain ranges in the active belts grow through **two major complex geologic processes**.

- First of them is **volcanism,** in which massive accumulations of volcanic rock are formed by extrusion of magma.
- Second process is the **tectonic activity** i.e. the breaking and bending of the Earth's crust *under internal Earth forces.* This tectonic activity usually occurs when great lithospheric plates come together in collision. Crustal masses that are raised by tectonic activity create mountains and plateaus. At some

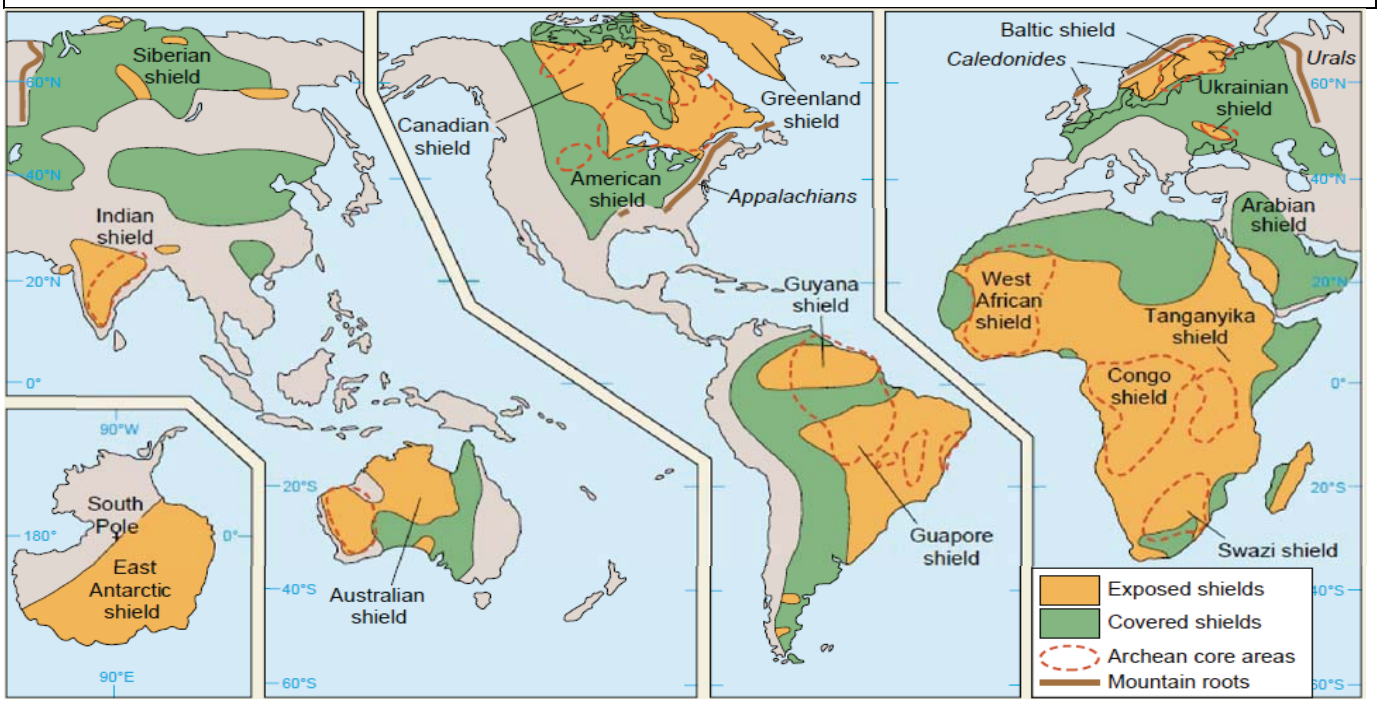
places, both volcanism and tectonic activity combine to produce a mountain range. ***Tectonic activity can not only form mountains but also lower crustal masses to form depressions***.

Please note that the active mountain-making belts are narrow zones that are usually found along the margins of lithospheric plates. The rest of the Lithospheric plates are much older, comparatively inactive rocks. There are two types of stable structures— **continental shields** and **mountain roots**.

The **continental shields** are regions of low-lying **igneous and metamorphic rocks**. The shields may be exposed or covered by layers of sedimentary rock. The core areas of some shields are made of rock dating back to the Archean eon, 2.5 to 3.5 billion years ago. Thus, continental shields are formed on ancient metamorphic rocks such as granitic, batholiths, and dikes. The oldest rocks on Earth are found in the shields.

Mountain roots are mostly formed of Paleozoic and early Mesozoic sedimentary rocks that have been intensely bent and folded, and in some locations changed into metamorphic rocks. Thousands of meters of overlying rocks have been removed from these old tectonic belts, so that only the lowermost structures remain. Roots appear as chains of long, narrow ridges, rarely rising over a thousand meters above sea level.

Continental Shied Map



Mountain Formation: Orogeny

Model Question - 14.

Consider the following:

1. Erosion
2. Sedimentation
3. Faulting of Rocks
4. Folding of Rocks

Which among the above play role in Orogenesis?

Answer: 14

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Orogeny is primarily the mechanism by which mountains are built on continents due to the large structural deformation of the Earth's lithosphere caused by Plate Tectonics. Orogenesis involves the following:

- ✓ *Structural deformation of the rocks*
- ✓ *Faulting of rocks*
- ✓ *Folding of rocks*
- ✓ *Igneous Processes*
- ✓ *Metamorphism*
- ✓ *Glaciation*
- ✓ *Erosion*

Mountains are born and have a finite life span. Young mountains are high, steep, and growing upward. Middle-aged mountains are cut by erosion. Old mountains are deeply eroded and often buried.

14 1, 2, 3 & 4

- ✓ *Sedimentation*

We have to note here that the constructive processes, like deformation, folding, faulting, igneous processes and sedimentation build mountains up. On the contrary, the destructive processes like erosion and glaciation, tear them back down again.

Causes of Mountain Building

There are three primary causes of mountain building as follows, which have already studied:

- ✓ *Convergence at convergent plate boundaries.*
- ✓ *Continental Collisions*
- ✓ *Continent Rifting*

Forms of Mountains

A mountain may have several forms. Important among them are: i) mountain ridge, ii) mountain range, iii) mountain chain, iv) mountain system, v) mountain group, and vi) cordillera.

Mountain Ridge

- It is a linear, steep-sided high hill, or spur. The slope of one side of a ridge is steep, while the other side is of moderate slope. A ridge, however, may have symmetrical slopes on both sides. The Shimla Ridge is a good example of mountain ridge.

Mountain Range

- A mountain range is a linear system of mountains and hills having several ridges, peaks, summits and valleys.

Mountain Chain

- A mountain chain consists of several parallel long and narrow mountains of different periods

Mountain System

- A mountain system consists of different mountain ranges of the same period. In a mountain system, different mountain ranges are separated by valleys.

Mountain Group

- A mountain group consists of several unsystematic patterns of different mountain systems

Cordillera

- It is a Spanish term referring to a system or major group of mountains. A cordillera consists of several mountain groups and systems. In other words, cordillera is a community of mountains having different ridges, ranges, mountain chains and mountain systems. It usually refers to an orogenic belt at a continental scale, e.g., the Western Cordillera of the U.S.A., which includes all the ranges between the Pacific and the Great Plains.

Types of the Mountains

No two mountains are the same. They, however, can be classified on the basis of their most dominant characteristics into: i) folded mountains, ii) volcanic mountains, iii) fault-block mountains, and iv) upwarped (dome) mountains.

Folded Mountains

Folded mountains comprise the largest and most complex mountain systems. Although folding is the dominant characteristic, faulting and igneous activity are always present in varying degrees in folded mountains. The Alps, Himalayas, Rockies, Andes, Appalachians, Tien Shan, Caucasus, Elburz, Hindukush, etc., are all of this type. The folded mountains present the world's major mountain systems. They are the youngest mountains in the world.

Volcanic Mountains:

Volcanic mountains are formed from the extrusion of Java and pyroclastic materials, which if continued long enough, produces gigantic volcanic piles. The Kilimanjaro (Africa), Cotopaxi (Andes), Mt. Rainier, Hood and Shasta (U.S.A.), are some of the examples of volcanic mountains

Fault Block Mountains:

Fault-block Mountains are bounded by high angle normal faults. Some of them are associated with rift valleys such as those in East Africa, while others appear to be formed by vertical uplifting. A notable example of fault-block mountain is found in the Basin and Range Province of the southwestern USA. The Salt Range of Pakistan, and Siena-Nevada of California (U.S.A.) are also the typical examples of fault-block mountains.

Upwarped (Domed) Mountains

Upwarped or domed mountains are formed by magmatic intrusions and upwarping of the crystal surface. The lava domes, batholithic domes, laccolithic domes, salt domes, etc., are the examples of Dome Mountains. The Black Hills of South Dakota, and the Adirondack mountains of New York may be cited as the examples of upwarped (domes) mountains.

Different Stages of Orogeny

Mountains can also be divided on the basis of their making i.e. Orogeny during different geological periods.

Pre-Cambrian Orogeny

This was the first ever Orogeny on earth and represents the oldest mountains of the earth. The examples are Laurasian of North America, Elogoman etc.

Caledonian or Mid Paleozoic Orogeny

It occurred during Silurian and Devonian periods. The example are Aravallis of India, Brazilian Highlands in America, Scotland of Europe etc.

Harcynian or Late Paleozoic Orogeny

This occurred in the Permian period. Example are Appalachian of North America, Black Forest of Europe etc.

Alpine Orogeny

This took place in Tertiary period and represents the youngest and newest mountain ranges of Earth. The examples are Himalaya, Rocky, Andes, Apennines, Alps etc.

Plateaus

Plateau is an elevated tract of relatively flat land, usually limited on at least one side by a steep slope falling abruptly to lower land. It may also be delimited in places by abrupt slopes rising to residual mountains or mountain ranges, as in the Tibetan plateau, where it occurs as an intermontane plateau. The term is also used to refer to a structural surface such as Meseta of Spain, in which case it is a tectonic plateau. It is also used to describe extensive lava flows (lava plateau). The surfaces of plateaus may be plain-like in quality, very flat, rolling or hilly, or they may be so dissected by streams and glaciers that it is difficult to recognize their original plateau characteristics.

Diastrophic Plateaus:

Diastrophism is the large-scale deformation of the earth's crust which produces continents, ocean basins and mountain ranges, etc. All the highest plateaus of the earth are the direct products of diastrophism. Since their uplifts they have been modified by various agents of erosion and in many cases by volcanism and minor earth movements. For convenience they may be classified as:

- ✓ *Intermontane plateaus*
- ✓ *Mountain border plateaus*
- ✓ *Domed plateaus,*
- ✓ *Volcanic plateaus*
- ✓ *Erosional plateaus.*

Intermontane Plateau:

Intermontane Plateaus include the highest, largest and in many respects most complex plateaus of the world. Their surfaces show an extraordinary variety of topographic features.

- ✓ *The best example is the Tibetan Plateau. It stretches approximately 1,000 kilometers north to south and 2,500 kilometers east to west. The average elevation is over 4,500 meters (14,800 ft), and all 14 of the world's 8,000 metres (26,000 ft) and higher peaks are found in the region. Sometimes called "the roof of the world," it is the highest and biggest plateau, with an area of 2.5 million sq. km or about four times the size of France. The Tibetan Plateau is bounded on the north by the Kunlun mountains, and in the south by the mighty Himalayas.*

These two systems meet to make the western boundary of the plateau, while on the east is the less sharp demarcation between the plateau proper and the lower mountains of western China.The Qinghai-Tibet Plateau not only gives rise to most of Asia's major rivers, it also holds a constellation of salt- and freshwater lakes.

- ✓ *Another example of Intermontane Plateau is Plateau of Bolivia and Peru. It lies largely in Bolivia at an average elevation of more than 3,692 metres (12,000 ft) above the sea level.*
- ✓ *One more example is Mexican Plateau which extends from the United States border in the north to the Cordillera Neovolcánica in the south, and is bounded by the Sierra Madre Occidental and Sierra Madre Oriental to the west and east, respectively.*

Border Plateaus

Many plateaus border mountain ranges and owe their present position to the same uplifts that raised the mountains. Piedmont plateau is an excellent example of border plateaus. This plateau is a strip of land that stands between tile Atlantic coastal plains and the Appalachian Mountains. Its eastern side is marked by a more or less definite fall-line where the gradient of the rivers is steepest. On the west it terminates against the mountains of the Blue Ridge. Plateau of Colorado is also an example of the border plateau. It is bounded on the northeast by the Rocky Mountains and on the southwest by the Basin and Range Province.

Domed Plateaus:

The plateau of Ozark (U.S.A.) is a good example of domed plateau. Ozark plateau was uplifted by folding and faulting into a broad dome some 65,000 sq km (40,000 square miles) in area during the Appalachian Revolution which occurred at the close of the Paleozoic Era.

Volcanic Plateaus

Volcanoes also form several varieties of plateaus. The largest are built by the lava flow. Smaller, degraded plateaus are formed by the resistant lava caps that protect the land from erosion and maintain its high elevation after the surrounding land has been worn away.

Erosional Plateaus

Such plateaus are formed particularly in semiarid regions where streams have cut away portions of high lands.

Part VI. Weathering, Mass Wasting and Erosion

There are two types of the processes that affect the landforms viz. **Exogenic** and **Endogenic**.

- Endogenic are the processes that **occur within the earth's surface** such as Plate tectonics, earthquakes, volcanoes etc.
- Exogenic are the processes that occur on or near the earth's surface. The tidal force is Exogenic. The radiation from Sun is also Exogenic.

Further, there are 3 Exogenic geological processes which refer to the process of disaggregation which lead to the reduction in the elevation & relief of the landforms and landscapes such as rocks and mountains. These 3 important phenomena are **weathering, mass wasting and erosion**. These all together are called "**Degradation**" or "**Denudation**". Endogenic processes uplift and expose continental crust to the Exogenic denudation. Exogenic denudation works in opposition and reduces landscapes to sea level.

Model Question - 15.

Consider the following:

1. Weathering
2. Erosion
3. Mass Wasting

Which among the above generally occur in-situ?

Answer:[15]

❖ Weathering

Weathering is the breaking down of Rocks, soils and minerals through "direct Contact" with the atmosphere of the earth. It occurs *in situ*, means there is **no movement** involved.

❖ Erosion

[15] Correct Answer is Only 1.

This is distinct from **erosion** which involves the movement of rocks and minerals such as water, ice, wind and gravity.

❖ Mass wasting

Mass wasting involves the movement of the rocks and particles across a slope **due to gravity.**

Weathering

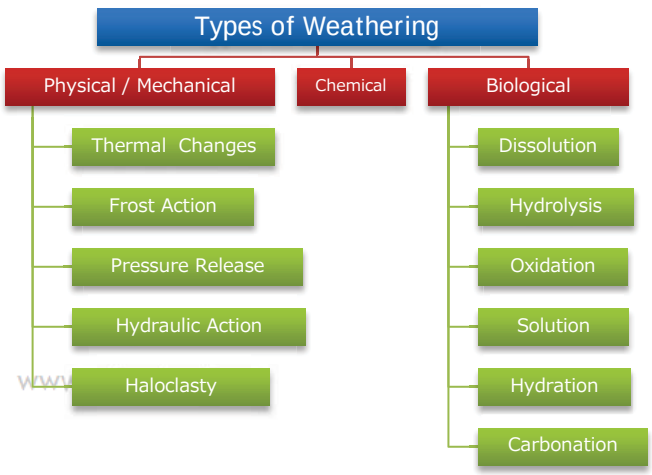
Weathering refers to the combined action of all processes that cause rock to disintegrate physically and decompose chemically because of exposure **near the Earth's surface**. Weathering produces **regolith.** Weathering also creates a number of distinctive landforms.

- **Regolith** is a surface layer of weathered rock particles that lies above solid, unaltered rock.

Weathering is the *in situ* disintegration and breakdown of rocks, soils and minerals. There are three types of weathering viz. Mechanical or Physical Weathering, Chemical Weathering & Biological Weathering.

Physical Weathering:

Physical Weathering can be caused by thermal changes, Frost Action, Pressure Release, Hydraulic action and Haloclasty. These terms have been discussed below:



Thermal Changes

Repeated changes in the temperature (heating and cooling) exert the stress on the outer layers of the rocks which is called as **Thermal Stress**. The rocks expand when there is a rise in the temperature and contract when there is a fall in the temperature. *In deserts, the phenomena are more common as there is large diurnal temperature range. The Forest fires can raise the temperature suddenly and this leads to* ***thermal shock****.*

Thermal Expansion versus Thermal Contraction

Please note that all materials respond by changing volumes because of temperature. Most materials expand when there is a rise in temperature. But there are some rare example which contract when temperature increases and expand when temperature decreases. This is called **Thermal contraction**.

The coefficient of thermal expansion is positive for the material which expand when there is a rise in temperature. If the coefficient of thermal expansion becomes zero, there is no expansion or contraction. At negative coefficient, the material contracts when there is a rise in temperature. Best example is water. Water when cooled till 4°C, the coefficient of thermal expansion decreases and become zero at 4°C. After that, when temperature is further reduced, it expands. So, at 4°C, water has maximum density. After that, density is reduced and this is the reason why ice floats and the water bodies are able to retain a temperature of 4°C at sub zero weathers. Similarly, **Pure Silicon** has a negative coefficient of thermal expansion between -255°C to -153°C.

Frost Action

One of the most important physical weathering processes in cold climates is frost action. As water in the pore spaces of rocks freezes and thaws repeatedly, expansion can break even extremely hard rocks into smaller fragments. Water penetrates fractures in bedrock. These fractures, called joints, are created when rocks are exposed to heat and pressure, then cool and contract. Joints typically occur in parallel and intersecting planes, creating natural surfaces of weakness in the rock. Frost action then causes joint-block separation. Water invades sedimentary rocks along their stratification planes, or bedding planes.

Pressure Release or exfoliation

This refers to the release of the pressure from unloading of existing rock on the rocks that lie beneath it due to other processes such as erosion. The igneous rocks are formed deep in earth and when the rocks above them get removed, the igneous rocks expose and the pressure is released. This causes their outermost surfaces to expand. This expansion leads to weathering.

Hydraulic Action

This phenomenon takes place due to very high powered water waves. When water rushes into cracks in the rocks with a very fast speed, the trap of air in the cracks get compressed and thus weakens the rocks. When water retreats, the trapped air is suddenly released with explosive force.

Salt Crystallization or Haloclasty

This refers to the process in which the rocks are denudated due to salt formation. This is a two step process. The first step is started when saline water seeps into cracks and evaporates depositing salt crystals. In the second step, when the rocks are heated up, the crystals expand putting pressure on the surrounding rock. Over the period of time, it splinters the stone into fragments.

Biological Weathering:

Biological Weathering refers to the contribution made by the organisms such as **Lichens and mosses**, which grow on essentially bare rock surfaces and create a more humid chemical microenvironment. Biological weathering is both physical as well as chemical breakdown of the surface micro layer of the rock. The animals such as earthworms and other annelids, moles, rabbits all contribute to the biological weathering.

Chemical Weathering:

Chemical weathering refers to the changes in the chemical composition of the rocks and generally refers to the chemical reactions of water with minerals.

Hydration

Hydration means absorption of water by some kinds of rock, leading to expansions and disintegrations. When water molecules bind with the mineral molecules, it is called Mineral Hydration.

Hydrolysis

The chemical breakdown of the rocks caused by rainwater is called Hydrolysis. The result may be secondary minerals with different chemical structure.

Oxidation

Oxidation or rusting occurs when atmospheric oxygen reacts with the minerals such as Iron Ores. This leads to decomposition of the rocks.

Solutions

This refers to dissolving of the minerals in water.

Carbonation

Carbonation refers to the chemical weathering in which Carbon dioxide attacks the rocks after it makes weak acid reacting the water. The rocks are generally made up of calcium carbonate such as Limestone and Chalk. The degradation

Mass wasting:

In Mass Wasting, the gravitational force of the earth acts directly on the loose material and the unstable slopes result the slide of the rocks and rock debris. This is known as Mass movement. This movement may be slow or fast depending upon the slope angle. The steepest angle that cohesion less slope can maintain without losing its stability is known as its **Critical angle of repose.**

Thus, mass wasting is spontaneous movement of soil, regolith, and rock under the influence of gravity. There are many forms of mass wasting, depending on the speed of the motion and the amount of water involved.

Mass wasting is of following types:

Creeps

It is a long term process which refers to the small movements of soil or rock in different directions over time, directed by gravity. The speed is so slow that naked eye is not able to show the movement.

Landslides

It includes the rock slides, slumps (short distance moving of rocks) & sturzstroms (more horizontal movement when compared to its initial vertical drop*). Landslides are most common type of mass wasting.*

Flows

Flows refer to the movement of the soil, dust, rock particles and bigger pabbles resembling the fluid behavior. Examples of the flows are avalanches, mudflows, debris flows, earth flow, lahars and sturzstroms. The water and air may contribute to the fluid like behaviour.

Topples

When rocks break away and fall from a slope , it is called Topples.

Slump
Slump refers to slipping of the rock material.

Falls
Rocks fell from the steep slopes such as a cliff face, and the movement may be contributed by the earthquakes, rain, plant-root wedging, expanding ice, among other things.

Induced Mass wasting
Human activities can induce mass wasting processes by creating unstable piles of waste soil and rock and by removing the underlying support of natural masses of soil, regolith, and bedrock. Mass movements produced by human activities are called induced mass wasting.

Erosion:
Erosions refer to the earth-sculpting processes in which the debris produced by weathering is "transported". So it's a kind of weathering in which the soils break up and get carried away. The agents of erosion are Rainwater, River water, ice, wind, sea waves, and underground water.

Erosion is a very important topic physical and well as human geography. Apart from the transport by wind, water, or ice; erosion also involves the down-slope creep of soil and erosion by the living organisms, such as burrowing animals, in the case of bioerosion, and human land use.

Part VII. Land Forms

Landforms are defined as the geomorphologic units defined by its surface form and location in the landscape. Landforms are typical elements of the topography. The water body interfaces also called landforms. They are categorized on the basis of elevation, slope, orientation, stratification, rock exposure, and soil types as follows:

- Aeolian landforms
- Coastal and oceanic landforms
- Erosion landforms
- Fluvial landforms
- Mountain and glacial landforms
- Slope landforms
- Volcanic landforms

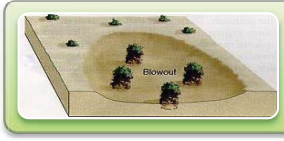
Aeolian landforms
Aeolian landforms refer to the Landforms that are formed by the winds. There are two types of the Aeolian Landforms viz. Erosional and Depositional.

Aeolian Landforms: Erosional

Zeugen or Rock Mushrooms :
They are also known as rock pedestal or a pedestal rock or Zeugen. Usually Found in Desert Areas.

Yardangs
Yardangs form in environments where water is scarce and the prevailing winds are strong, unidirectional and carry an abrasive sediment load. They consist of an elongated ridge carved by the unidirections erosion.

Dreikanter
Dreikanter exhibits a 3 faced Pyramidal Shape. They typically form in Deserts due to wind erosion.



Blow Outs
Blowouts refer to sandy depressions in a sand dune ecosystem, which are caused by the removal of sediments by wind.

Inselbergs
Inselbergs refer to the prominent steep sided hill of solid rock rising abruptly from a plain of low relief. Inselbergs are generally composed of resistant rocks such as Granites.

Desert pavement
Desert pavement refers to mountain wash containing pebbles, gravels and sand particles exposed to wind and surface appears as a pavement with closely packed, interlocking angular or rounded rock fragments of pebble and cobble size

Aeolian Landforms: Depositional

Erg or Sand Sea :
Erg is a sand sea or a dune sea. They are flat area of desert covered with wind-swept sand with little or no vegetative cover. The area is generally more than 100 square miles and is deposited by windblown sand. Largest Hot Desert in the World viz. Sahara has several sand Seas. The Ergs have 85% of Earth's mobile sand.

Ripples:
Ripples are well marked small waves produced on the surface of sand, mud and even rock by the drag of the wind / water moving over it. They are most common in deserts.

Barchan:
Barchan refers to crescent shaped dunes, which have tips or horns pointing downwards. Barchans are found in desert areas which have low sand quantity.

Longitudinal dunes
Longitudinal dunes are also known as Seif dunes. Seif is a arabic word for Sword. These are long, slightly sinuous, ridge shapped dunes which are parellel to the wind direction, elongate parallel to the prevailing wind, possibly caused by a larger dune having its smaller sides blown away. Seif dunes are sharp-crested and are common in the Sahara.

Transverse Dunes:
Transverse Dunes are asymmatrical sands in deserts which are at right angle to the wind direction. They are most probably caused by a steady build-up of sand on an already existing minuscule mound.

Star Dunes:
Star Dunes are giant star shapped dunes with 3 or more sinuous arms extending outwards from the center. These shapes can alter due to windspeeds.

Fluvial Landscapes

The landforms which develop as a result of the water action are known as Fluvial Landforms. Running water such as rivers are the most important agent of erosion. Other agents such as Glaciers, Groundwater, wind and sea water are locally dominant agents of erosion. *The Fluvial processes are most important of all the exogeneric processes as landforms associated with them have overall dominance in the environment of terrestrial life.* These fluvial processes can be divided into three phases viz. erosion, transportation and deposition.

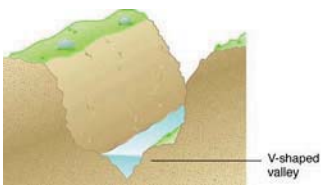
Erosion

The **Erosion** can be **normal erosion** which takes place by the natural physical processes or the **Accelerated Erosion**, which is produced by human interference. The **Sheet Erosion** refers to the **s**urface flow removing soil in thin layers. It can be accelerated in the Steep slopes, where innumerable closely spaced channels are formed, which grows larger form in gullies (steep-walled canyon like trench). The Erosion can be of following types:

- ✓ *Chemical erosion: Corrosion (Or solution) and carbonation.*
- ✓ *Mechanical erosion.*
- ✓ *Impaction (effect of blow upon the river bed or banks by large boulders).*
- ✓ *Cavitations (shattering and breaking up of the stream load through collisions and mutual abrasion).*
- ✓ *Hydraulic action (lifting and quarrying effect of rushing water).*
- ✓ *Corrosion or abrasion (stream uses its load to scrape away its bed, particularly in steep confined sections of stream channels).*

Landforms made by River Erosion

V-shaped Valley



Valley starts as small and narrow rills which gradually develop into long and wide gullies. The gullies will further deeper widen and lengthen to give rise to valleys which is V-shaped. The **River valley** is an important erosional landform. They are formed in the youthful stage of fluvial cycle of erosion. The vertical erosion or valley deepening

causes the V-shaped valleys.

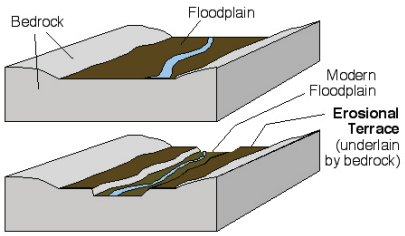
Gorge & Canyons:

The V-shaped valley can be a **Gorge**, where steep precipitous wall within which a narrow river is confined (e.g. – Indus, Sutlej, Brahmaputra, Rhine, Zambezi). Thus, we can say that Gorge is a V-shaped valley but its sides becomes so steep that they look almost vertical. Or it can be a **Canyon**, which is basically a very deep and extended gorge. The Grand Canyon in Arizona, United States of America is the largest Canyon in the world.

Meander:

The meanders or meandering rivers are the low slope rivers which are not choked with the sediment and move back and forth in a zig-zag order of loops. The meander has thus a serpentine path and it helps in accommodating in extra volume of water.

River Terraces



River terraces are abandoned floodplains that formed when a river flowed at a higher level than it does today. Thus, these are the surfaces that mark an old valley floor or floodplain levels.

Peneplain

When an extensive area has been eroded sufficiently to give the look of almost a plain, it is called a Peneplain.

Landforms made by River Deposition

Alluvial Fans

When the velocity of the running water, as it comes out of hills and meets the plain, decreases, it dumps the transported material at the foothills. The structure made are called alluvial fans. The alluvial fans are formed due to accumulation of materials in the form of fan and cones respectively at the base of foot hills Alluvial cones are made of coarse materials than the alluvial fans.

Natural leaves

Narrow belt of ridges of low height built by the deposition of sediments by the spill water of the stream on its either bank.

Food plain

Surfaces on either side of a stream that is frequently inundated.

Crevasse splays

Formed by breaching of leaves when water escapes through a series of distributaries channels.

Back swamps

Plain area adjoining a levee may contain marshes called back swamps.

Yazoo streams

Distributions of rivers occupying lateral positions.

Delta

Delta is the triangular deposition at the mouth of a river debouching in a lake or a sea. The Factors that help in delta formation are as follows:

- ✓ *Long courses of rivers.*
- ✓ *Medium size sediments.*
- ✓ *Calm or sheltered sea.*
- ✓ *Suitable place (shallow sea and lake shores).*
- ✓ *Large amount of sediments.*
- ✓ *Accelerated erosion.*
- ✓ *Stable condition of sea coast.*

On the basis of shape delta can be divided into following categories :

- ✓ *Arcuate*
- ✓ *Bird-foot*
- ✓ *Estuarine*

- ✓ *Truncated*

Arcuate (lobate form) Delta:

The Arcuate delta resembles the fan and is convex towards the Sea. It is semicircular in shape and is commonly found in semi-arid region; growing delta such as Nile, Niger, Ganga, Indus, Mekong, Irrawaddy, Rhine, Volga, Danube, Rhone, Lena rivers.

Bird-foot Delta

Birdfoot Delta is also known as a finger delta. In these deltas, the sediments deposited are composed of those fine particles which are received from the limestone rocks. The rivers with high velocity carry suspended finer load to greater distance inside the oceanic water (such as Mississippi).

Estuarine delta

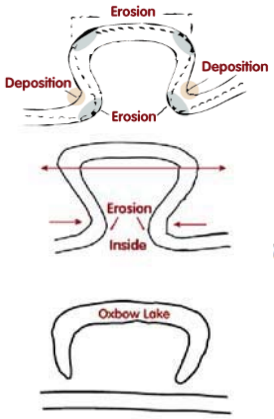
When a river enters the sea through the single mouth or estuary, then the Estuarine Delta is formed which is submerged under marine water. Examples are Narmada River, Congo River, Amazon River and Hudson River.

Cuspate Delta

Cuspate delta are pointed. They are shaped by regular, opposing, gentle water movement as seen at the Tiber river.

Oxbow lakes

The Oxbow lakes are formed by the depositional and erosional actions taking place simultaneously. Please note that excessive meandering would result in Oxbow lakes.



How Oxbow lakes are formed?

On the inside of the loop, the river travels more slowly leading to deposition of silt. Meanwhile water on the outside edges tends to flow faster, which erodes the banks making the meander even wider. Over time the loop of the meander widens until the neck vanishes altogether. Then the meander is removed from the river's current and the horseshoe shaped oxbow lake is formed.

Black Swamps

When the water spills out onto the flood plains, the heaviest material drops out first and finest material is carried over a greater distance. This fine grained alluvium would hold much water and would give rise to a wetland which is called Black swamps or simply swamps.

Landforms made by River Transportations

The dissolved solids in the rivers travel downstream and become a part of Ocean. The particles of clay, silt and fine grains are carried in suspension. Whenever a soft rock obstructs the course of stream and is eroded and sediments are scattered all around, it would be called **Eddies.** These **Eddies** sometimes look like discs and so are called **potholes**. The large potholes are called Plungepools.

Part VIII. Movements of Earth

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

- Earth moves with the Milky Way, because entire Milky Way galaxy moves through the universe.
- Earth follows Sun, while the Sun travels in the Milky Way.
- Earth's precession movement which is very much similar to a spinning top.
- Earth revolution around the Sun
- Earth's rotation on its axis

Earth's Rotation

Rotation is the rotation of the Earth around its own axis. The rotation is from west to east. The phenomenon gives rise to Day and Nights.

Model Question - 16.

To an observer in Jaipur, the North Star, Polaris, is always located above the northern horizon at an altitude of approximately___ (Consider latitude of Jaipur is 29.9°N)

A. 23½°
B. 29.9°
C. 60.1°
D. 90°

Answer: **16**

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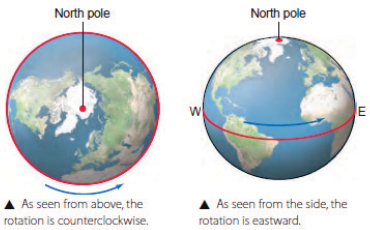
When seen from the North Star **Polaris** scientifically known as **Alpha Ursae Minoris** *Earth turns **counter-clockwise**.*

North Star Polaris stands almost motionless in the sky, and all the stars of the Northern sky appear to rotate around it. Therefore, it makes an excellent fixed point from which to draw measurements for celestial navigation and for astrometry. The movement of Polaris towards, and in the future away from, the celestial pole, is due to the **precession of the equinoxes**. Please note that for an observer in the Northern hemisphere, the **North Star (Polaris) is always equal to the observer's latitude**. This is due to Polaris' position in space which is over the Northern tilt of axis in relation to the Earth.



▲ As seen from above, the rotation is counterclockwise.
▲ As seen from the side, the rotation is eastward.

Concept of Day & Night

There are 3 kinds of the days recognized and measured viz. **Apparent** or **true solar day**, **mean solar day** and **sidereal day.**

Apparent Solar Day:

Apparent solar day is the interval between two successive returns of the Sun to the local meridian; it can be measured by a sundial to a very limited precision. It is called true solar day because a Sundial would tell, where local noon is when Sun to the local meridian. The length of the solar day **varies throughout the year**. This is because of two reasons.

Model Question - 17.

Which among the following is / are the reasons for varying length of the Apparent Solar day?

1. Earth moves faster at aphelion in comparison to perihelion
2. Earth is tilted on its axis

Choose the correct option:

Answer: 17

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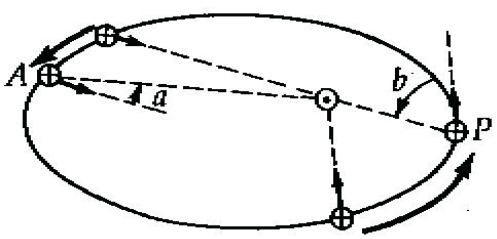
❖ Elliptical Orbit of Earth

Earth's orbit is an ellipse and not a circle. According to Kepler's First Law of planetary Motion, the orbit of every planet is an ellipse with the Sun at one of the two foci. The second Kepler's planetary motions say that a line joining a planet and the Sun sweeps out equal areas during equal intervals of time. This means that *Earth moves faster, when it is nearest to the Sun (perihelion) and moves smaller when it is farthest from Sun (Aphelion).*

In the adjacent diagram, P denotes when the Earth is at perihelion, the closest approach to the Sun, and A when it is furthest away at aphelion. When the Earth is closer to the Sun, such as at **perihelion;** it will travel faster in its orbit. In the diagram at perihelion, the Earth has travelled the arc of the arrow in the time it takes to rotate 360° around its axis and must still revolve through angle b to complete the apparent solar day. Thus the apparent solar



16 29.9°

17 Only 2 is correct statement. 1 is incorrect factually, otherwise hints to elliptical orbit of earth.

day is longer for this time of year. At aphelion the Earth still has the angle a to rotate through at the end of the arc, but since that angle is not as great the time will not be as much for that part of the year.

❖ **Earth's Axial Tilt**

Earth's orbital plane is known as the ecliptic plane, and so the Earth's axial tilt is called the obliquity of the ecliptic. Earth currently has an axial tilt of about 23.5°, and due to this the axis remains tilted in the same direction towards the stars throughout a year and this means that when a hemisphere is pointing away from the Sun at one point in the orbit then half an orbit later (half a year later) this hemisphere will be pointing towards the Sun. This effect is the main cause of the seasons.

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

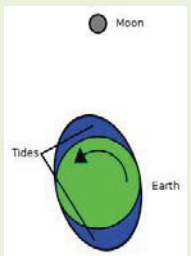
Mean Solar Day:

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

- The length of the mean solar day is increasing due to the **tidal acceleration** of the Moon by the Earth, and the corresponding deceleration of the Earth rotation rate by the Moon.
- The Earth-water-ice system also causes a decrease in the mean solar day.

Concept of Tidal Acceleration

Tidal acceleration refers to the effect of the tidal forces between an orbiting natural satellite and the primary planet that it orbits. We know that Moon's mass is a considerable fraction of that of the Earth. The Ratio of masses of moon and Earth is about 1:81. So these two bodies can be regarded as a double planet system, rather than as a planet with a satellite. The large mass of moon is sufficient to raise tides in the matter of earth. The water of the oceans bulges out along both ends of the axis, passing through the centers of Moon as well as Earth. This tidal bulge is shown in the adjacent graphics. The average tidal bulge shown in above figure closely follows the Moon in its orbit. However, since earth also rotates, the rotation drags this bulge ahead of the position directly under the Moon. The arrow shown in the earth shows the direction of this drag. Due to the simultaneously forces of moon's gravitational force giving rise to the bulges in ocean water and substantial amount of mass in these bulges of water dragged by earth's rotation, this bulge is deviated from the line through the centers of Earth and Moon. This gives rise to a Torque which is perpendicular to the earth moon line. This torque boosts moon in its orbit and decelerates earth's rotation. The above phenomenon is responsible for the slowing Earth's rotation. Due to the tidal acceleration, Earth's mean solar day extends by 2.3 milliseconds every century. However, due to glacial rebound, this extension gets reduced by 0.6 seconds per century. So the net effect on mean solar day every century is 1.7 milliseconds.



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

Sidereal Day:

The spinning of the earth on its polar is in fact takes 23 hours, 56 minutes and 4.09 seconds for rotation through the 360 degree. This is called **sidereal day**. The question remains, 360° relative to what?

Model Question - 18.

Consider the following statements:

1. Sidereal Day is little longer than the Solar Day
2. Sidereal Day is based upon the Earth's rate of rotation measured relative to the fixed stars.

Which among the above is / are correct statements:

Answer: 18

Please note that the Sidereal Time is based upon the Earth's rate of rotation measured relative to the fixed stars. From a given observation point, a star found at one location in the sky will be found at nearly the same location on another night at the same sidereal time. Both solar time and sidereal time make use of the regularity of the Earth's rotation about its polar axis, **solar time following the Sun while sidereal time roughly follows the stars**. Because stars are much farther away, *Earth's position with respect to them changes only to a miniscule degree*.

During the time needed by the Earth to complete a rotation around its axis (a sidereal day), the Earth moves a short distance (approximately 1°) along its orbit around the sun. So, after a sidereal day, the Earth still needs to rotate a small additional angular distance before the sun reaches its highest point. A solar day is, therefore, nearly 4 minutes longer than a sidereal day.

Grid System: Latitudes and Longitudes

The geographic grid consists of an orderly system of circles—meridians and parallels—that are used to locate position on the globe and define geographic directions. All of you know that when we walk directly north or south, we follow a meridian; when we walk east or west we follow a parallel. There are an infinite number of parallels and meridians that can be drawn on the Earth's surface. Every point on the Earth is associated with a unique combination of one parallel and one meridian. The position of the point is defined by their intersection.

Parallels of latitude divide the globe crosswise into rings.

Meridians of longitude divide the globe from pole to pole.

Both meridians and parallels are made up of two types of circles—**great and small**.

Model Question - 19.

Consider the following statements:
1. Each meridian is half of a great circle
2. All parallels are not great circles
3. All meridians are of equal length

Which among the above statements is / are correct?

Answer Footnote: 19

A great circle is created when a **plane passing through the center of the Earth** intersects the Earth's surface. It bisects the globe into two equal halves. A small circle is created when a plane passing through the Earth, but not through the Earth's center, intersects the Earth's surface.

So, each of the meridians is actually halve of a great circle, while all parallels except the Equator are small circles. We label parallels and meridians by their latitude and longitude. The Equator divides the globe into two equal portions—the northern hemisphere and the southern hemisphere. Parallels are identified by their angular distance from the Equator, which ranges from 0° to 90°. All parallels in the northern hemisphere are described by a north latitude (°N) , and all parallels south of the Equator are given as south latitude (°S).

Latitudes

Latitude (denoted by φ) is the angle between the *equatorial plane and the axis*. Lines joining points of the same latitude are called parallels, which trace concentric circles on the surface of the Earth, parallel to the equator. The largest parallel is Equator. The North Pole is 90° N; the South Pole is 90° S. Equator is the fundamental plane of all geographic coordinate systems. Latitudes tell us the temperature and climatic position of a particular place.

Length of a Degree of Geodetic Latitude

Latitude (°)	Miles	Kilometers
0	68.71	110.57
10	68.73	110.61
20	68.79	110.70
30	68.88	110.85
40	68.99	111.04
50	69.12	111.23
60	69.23	111.41
70	69.32	111.56
80	69.38	111.66

18 Only 2 is correct statements.

19 1, 2 & 3 are correct statements. All meridians are considered as half of great circles, a circles, because they are smaller than the equator; their centers are not at the center of the north-south meridian line (which is an ellipse) is almost 40,008 km. The quadratic mean 40041.5 km.

One notable point is the geostationary satellites are *over the equator at a specific point on Earth,* ***in a circular orbit,*** so their position related to Earth is expressed in longitude degrees only. Their latitude is always zero, that is, over the equator. There are 180° of latitudes and each degree of latitude spans approximately 111 kilometers or 69 miles or 60 Nautical miles. But this distance varies **because Earth is NOT a perfect sphere.** From Equator to 40° towards both poles it is slightly less than 111 kilometers and from 41° towards both poles it is slightly more than 111 kilometers. Since the *latitudes are based on an ellipsoid earth, they are also called* ***Geodetic Latitudes***. The adjacent table shows the varying value of 1° latitude from equator to poles.

One nautical mile is 1,852 meters (approximately 6,076 feet) or 1.15077 miles. The 90° North and 90° South are used as reference points. Each degree is divided into 60 minutes and each minute divided into 60 seconds.

Model Question - 20.

An airplane takes off from a location at 17°S latitude and flies to a new location 55° due north of its starting point. What latitude has the plane reached?

A. 28°N
B. 38°N
C. 55°N
D. 72°N

Answer: 20

Longitudes

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

Latitudes and Longitudes in India

India lies to the north of the equator between 6° 44' and 35° 30' north latitude and 68° 7' and 97° 25' east longitude

Time and Time Zones

Till the first half of the nineteenth century, each town used to set their clocks according to the motions of the Sun. After that, due to the increased movement of people and development of new settlements, railroad etc, problems started to appear. The railroads experience major problems in constructing timetables for the various stops, because each stop had its own local time.

Thus, the need for standard times arose. In 1878, **Sir Sanford Fleming** suggested a system of worldwide time zones that would simplify the keeping of time across the Earth. Fleming proposed that the globe be divided into 24 time zones, each 15 degrees of longitude in width. Since the world rotates once every 24 hours on its axis and there are 360 degrees of longitude, each hour of Earth rotation would represent 15 degrees of longitude. In 1884, an International Prime Meridian Conference was held in Washington to adopt the standardize method of time keeping and determined the location of the Prime Meridian. In this conference, the longitude of Greenwich, England was assigned zero degrees longitude and established the 24 time zones relative to the Prime Meridian. It was also agreed that the measurement of time would be made relative to the astronomical measurements at the Royal Observatory at Greenwich. This time standard was called **Greenwich Mean Time** (GMT).

20 If one starts at 17°S and flies 55°N the destination point would be 38°N. First, you would travel to the equator (0°) that would be 17 of the 55 degrees. Then continue traveling northward until you have reached 38 degrees. 38 + 17 equals 55. Correct Answer is 38° N

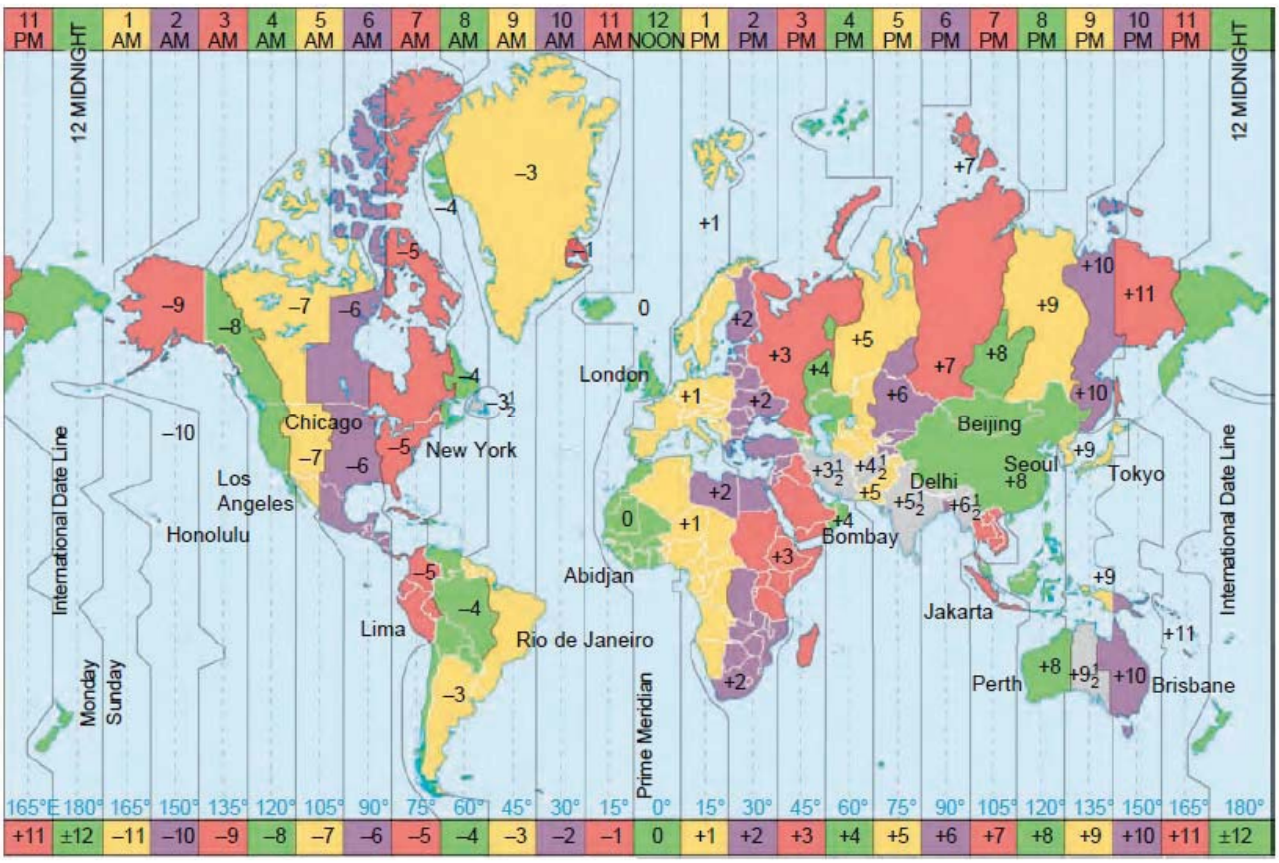
GMT versus UTC

The Greenwich Mean Time (GMT) refers to the mean solar time at the Royal Observatory in Greenwich. The term is in common use in United Kingdom, Australia, South Africa, India, Pakistan and Malaysia etc. The Coordinated Universal Time (UTC) is the same GMT; the only difference is that ***UTC is more precisely determined by the international scientific community***. The system was adjusted several times until leap seconds were adopted in 1972 to simplify future adjustments. A number of proposals have been made to replace UTC with a new system which would eliminate leap seconds but no consensus has yet been reached.

> UTC is based on atomic time and includes leap seconds. UTC was used beginning in the mid-twentieth century but became the official standard of world time on January 1, 1972. UTC is 24-hour time, which begins at 0:00 at midnight. 12:00 is noon, 13:00 is 1 p.m., 14:00 is 2 p.m. and so on until 23:59, which is 11:59 p.m.

Thus, **UTC can be called a successor of the GMT**. Today, time zones around the world are expressed as positive or negative offsets from UTC.

Zulu Time is another name of GMT. *Z refers to the "zone description" of zero hours. Phonetic word for Z is Zulu. That is why GMT is called Zulu Time*. Thus, *Greenwich Mean Time (GMT), Universal Coordinated Time (UTC), and Zulu Time are three different names for the same time zone.* This time zone is situated at the Prime Meridian, zero degrees longitude, and runs through the Royal Observatory at Greenwich, a section of London, England. It is the Prime Meridian from which other longitudes are determined, east and west.



International Date Line

We understand the importance of International Date Line with the following example:

We take a world map or globe with 15° meridians and start at the Greenwich 0° meridian and count along the 15° meridians in an eastward direction. We will find that the 180th meridian is number 12 and that the time at this meridian is therefore 12 hours later than Greenwich Time. Counting in a similar manner westward from the Greenwich meridian, we find that the 180th meridian is again number 12 but that the time is 12 hours earlier than Greenwich time. Here, we seem to be in a paradox. How can the same meridian be both 12 hours ahead of Greenwich time and 12 hours behind it? The answer is that each side of this meridian is experiencing a different day.

Doing the same experiment an hour later, at 1:00 A.M., stepping east you we find that we are in the early morning of June 26. But if we step west we will find that midnight of June 26 has passed, and it is now the early morning of June 27. So on the west side of the 180th meridian, it is also 1:00 A.M. but it is one day later than on the east side. For this reason, the 180th meridian serves as the international date line . This means that if we travel westward across the date line, we must advance your calendar by one day. If travelling eastward, we set our calendar back by a day. International Date Line does not follow the 180th meridian exactly. Like many time zone boundaries, it deviates from the meridian for practical reasons. As shown in above graphics, it has a zigzag offset between Asia and North America, as well as an eastward offset in the South Pacific to keep clear of New Zealand and several island groups.

- **A traveller crossing the International Date Line eastwards subtracts one day**. **Crossing the IDL westward results in 24 hours being added.**
- Philippines, as part of the New Spain, long had its most important communication with Acapulco in Mexico, and were accordingly placed on the east side of the date line, despite being at the western edge of the Pacific Ocean.
- The Samoan Islands (Samoa and American Samoa) were west of the date line until 1892; it was later shifted east of the dateline due to its business trading with California. In 2011, more than 119 years after that change was made, Samoa shifted back to west of the date line by skipping Friday 30 December 2011. This changed the time zone from UTC−11 to UTC+13 (and from UTC−10 to UTC+14 during daylight saving time). The International Date Line now passes between Samoa and American Samoa, with American Samoa remaining east of the International Date Line.

Daylight Saving Time

The daylight saving time system basically allows us to **cheat standard time** and transfer an hour of light to a time when it will be more useful. So, it is the practice of advancing clocks so that evenings have more daylight and mornings have less.

Why it is needed?

Often we wake up well after sunrise and continue being active until long after sunset, especially if we live in urban areas. So we adjust our clocks during the part of the year that has a longer daylight period to correspond more closely with the modern pace of society. By setting all clocks ahead by one hour, we steal an hour from the early morning daylight period—which is theoretically wasted while schools, offices, and factories are closed— and give it to the early evening, when most people are awake and busy.

In the United States of America, daylight saving time comes into effect on the **second Sunday in March** and is **discontinued on the first Sunday of November**. In the European Union, daylight saving time is called summer time . It begins on the **last Sunday in March** and **ends on the last Sunday in October**. India does not observe the Daylight Saving Time.

Implications of Daylight Saving Time

The advantages and disadvantages of the DST have been always subject to debate. Here are some of the points, **none of which is proved** to be absolutely correct scientifically:

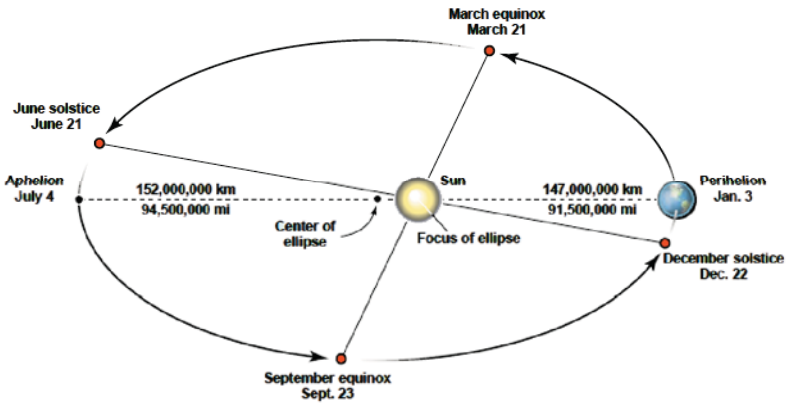
- Extra daylight might reduce the traffic accidents because people are more careful drivers during daylight hours.
- During the DST months, people used less energy. DST's potential to save energy comes primarily from its effects on residential lighting, which consumes about 3.5% of electricity in the US and Canada. Delaying the nominal time of sunset and sunrise reduces the use of artificial light in the evening and increases it in the morning.

- DST allows people to shop more and participate in more sporting activities at the end of the day, so DST is favourable to retailers.
- Daylight Saving Time allows for more daylight hours which induce tourists to stay out later and spend more money. DST also boosts transportation as taxis, buses and trains get increased business at the end of the day.
- People involved in agriculture have complained that less sunlight in the mornings is disadvantageous to their work. They are unable to adjust to the less day light in morning.
- DST causes sleep deprivation and health issues.
- DST causes changes in meeting times, travel, billing, broadcast times, and so on, which all cause a negative effect on the productivity of the economy.

Earth's Revolution

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

Perihelion and Aphelion



Earth travels 939,886,400 Kms along its elliptical orbit in a single revolution. The average distance is 150 million Kms, but the orbit is elliptical and there is the difference if 2.5 million Kms. On around January 3rd, Earth is closest to sun and this is called Perihelion. On about July 4th earth is Farthest from Sun and this is called Aphelion. Speed of Earth is fastest at Perihelion and slowest at Aphelion (Kepler's Second Law).

However, the distance between Sun and Earth varies only by about **3 percent** during one revolution because the elliptical orbit is shaped very much like a circle. For most purposes we can regard the orbit as circular.

Model Question - 21.

A person somewhere in space, looking down on the north pole of Earth, would see that ___

1. Earth rotates anti-clockwise
2. Earth revolves around sun clock wise
3. Moon revolves around Earth clockwise

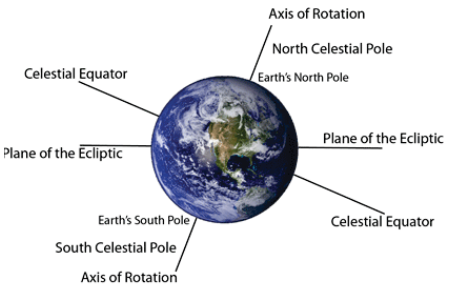
Which among the above statements is are correct?

Answer: **21**

If we imagine ourselves in space, looking down on the North Pole; from this viewpoint, the Earth travels counter-clockwise around the Sun. This is the same direction as the Earth's rotation and also in the same direction of moon's revolution around earth as well as its rotation around its own axis.

Celestial Poles

North and south celestial poles are the two imaginary points in the sky where the Earth's axis of rotation intersects the imaginary rotating sphere of stars called the celestial sphere. The north and south celestial poles appear directly overhead to an observer at the Earth's North Pole and South Pole respectively. The celestial poles do not remain

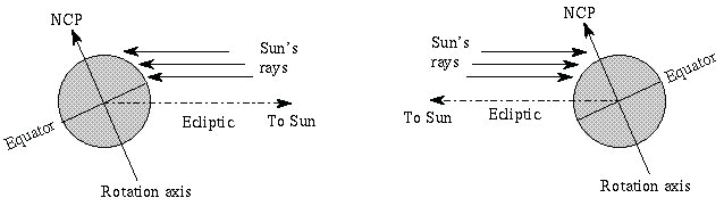


21 Only 1 is a correct answer.

permanently fixed against the background of the stars. Because of a phenomenon known as the precession of the equinoxes, the poles trace out circles on the celestial sphere, with a period of about 25,700 years. The Earth's axis is also subject to other complex motions such as nutation, polar motion and axial tilt. Finally, over very long periods the positions of the stars themselves change, because of the stars' proper motions.

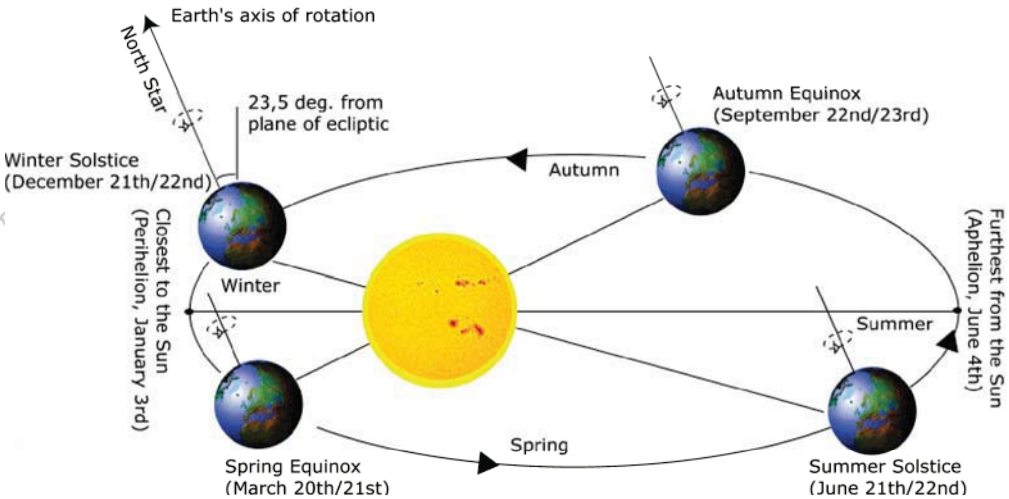
Seasons

The path of the Earth around the Sun is elliptical and slightly irregular. A constant angle is maintained between the earth's axis and its plane of elliptic, which is called **angle of inclination**. Earth's rotation axis is tilted by 23.44° with respect to the elliptic, and is **pointed towards** the celestial poles when the earth moves around the Sun. This phenomenon gives rise **to two solstices and two equinoxes** every year, thus causing four seasons.



Solstices

The solstice refers to the events when the Sun's apparent position in sky reaches its northernmost or southernmost extremes. On December 22, the north polar end of the Earth's axis leans at the maximum angle away from the Sun, 23 ½°. This event is called the **December solstice, or winter solstice** in the northern hemisphere. At this time, the southern hemisphere is tilted toward the Sun and enjoys strong solar heating. Six months later, on June 21, the Earth has travelled to the opposite side of its orbit. This is known as the **June solstice, or summer solstice** in the northern hemisphere.



Model Question - 22.

Consider the following statements:

1. Northern Solstice represents the longest day in Northern Hemisphere
2. Southern Solstice causes Midnight sun on North Pole

Which among the above statements is / are correct?

Answer: 22

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At Northern solstice, the places which are located at Arctic circle, posited at latitude 66.56° north will see the Sun just on the horizon during midnight. And all the places north of Arctic Circle will see Sun above horizon for 24 hours. This is called Midnight Sun or a Polar Day.

At Northern solstice which are located at Antarctic circle, posited at latitude 66.56° south will see the Sun just on the horizon during midday. And all the places south of Antarctic Circle will NOT see at anytime of the day. This is called Polar Night. At Southern solstice, Polar day occurs at Southern Pole and Polar Night occurs at Northern Pole.

Uttarayan & Dakshinayan

For 6 months of the year, the Sun appears to be moving north. This Northward migration of Sun appears to begin after December 22 and is completed on June 21, when the Sun is directly overhead 23.44° North. Due to this, In India we call this Uttarayan. After June 21, for the next 6 months, Sun appears to be moving South and this southward migration appears to get finished , when Sun is directly overhead the 23.44° South. In India we call this apparent migration Dakshinayan.

22 None of them is a correct statement.

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

This information has been summarized as below:

Comparison of December Solstice and June Solstice		
Variable	**December Solstice**	**June Solstice**
Date of Occurring	December 21/22	June 21/22
Also Known As	Winter solstice in Northern Hemisphere / **Northern Solstice**	Summer Solstice in Northern hemisphere / **Southern Solstice**
Sun Directly Over	Tropic of Capricorn	Tropic of Cancer
North Pole	Midnight Sun	Polar Night
South Pole	Polar Night	Midnight Sun
Longest Day	Southern Hemisphere	Northern Hemisphere

Equinoxes

The equinoxes occur midway between the solstice dates. At an equinox, the **Earth's axis is not tilted toward the Sun or away from it.** The March equinox (vernal equinox in the northern hemisphere) occurs near March 21, and the September equinox (autumnal equinox) occurs near September 23. The conditions at the two equinoxes are identical as far as the Earth–Sun relationship is concerned. The date of any solstice or equinox in a particular year may vary by a day or so, since the revolution period is not exactly 365 days.

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

Precession Movement of earth

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

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Contents

Part I. Concepts in Oceanography

Ocean Sediment

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

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

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

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

There are several types of marine sediments such as:

- Lithogenous sediment
- Biogenous Sediment
- Hydrogenous sediment

Lithogenous Sediment

This type of sediment is derived from pre-existing rock material that originates on the continents or islands from erosion, volcanic eruptions, or blown dust. The another term used for lithogenous sediment is **terrigenous** sediment. Obviously, the origin of Lithogenous Sediment begins as rocks on continents or islands. Over time,

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

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

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

Biogenous Sediment / Ooze

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

Ooze

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

Opal

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

Diatoms and Diatomaceous Earth

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

More on Diatoms

Diatoms are microscopic single-celled **photosynthetic** organisms. Each one lives inside a protective silica test, most of which contain two halves that fit together very much similar to a shoebox and its lid.

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

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

The fossil record indicates that diatoms have been on Earth since the Jurassic Period (180 million years ago), and at least 70,000 species of diatoms have been identified.

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

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

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

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

Hydrogenous Sediment

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

Manganese Nodules

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

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

Phosphates

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

Carbonates

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

Metal Sulfides

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

Resources from Ocean Sediments

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

Energy

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

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

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

Sand and Gravel

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

Evaporative Salts

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

Manganese Nodules and Crusts

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

Ocean Temperature

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

Measurement of Temperature

Standard type of thermometer is used to measure the surface temperature while reversing thermometers and **thermograph**s are used to measure the subsurface temperature. These thermometers record the temperature

Phytoplanktons and Zooplanktons

Plankton are those organisms in water which themselves are incapable of swimming against a current. They primarily work as a crucial source of food for aquatic organisms including animals, plants, Archaean, algae, bacteria etc. There are two types of Planktons:

1. **Phytoplankton,** which are autotrophic and photosynthetic algae that live near the water surface where there is sufficient light to support photosynthesis. Diatoms, cyanobacteria, dinoflagellates and coccolithophores are some of the main phytoplanktons. Prokaryotic Phytoplanktons are also known as Bacterioplankton, which include bacteria. These play role in remineralising organic material. .
2. **Zooplankton**, which are small protozoans, crustaceans and other animals that feed on other plankton. Zoo planktons also include the eggs of fish, crustaceans, and annelids.

up to the accuracy of ±0.02° centigrade.

Layers of Temperature in tropics

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

- The first layer represents the top-layer of warm, oceanic water and is 500m thick with temperature ranging between 20° and 25°C. This layer is present within the tropics throughout the year but it develops in mid· latitudes only during summer.

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

- The **thermocline layer** represents vertical zone of oceanic water below the first layer and is characterized ***by rapid rate of decrease of temperature with increasing depth***,
- The third layer is very cold and extends upto the deep ocean floor. The *polar areas have only one layer of cold water from surface (sea level) to the deep ocean floor*.

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

Daily Range of Temperature

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

The diurnal range depends on the

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

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

Annual Range of Temperature

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

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

Distribution Pattern of Temperature

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

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

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

Latitudes

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

Unequal distribution of land and water

Model Question - 1.

Consider the following statements:

1. Temperature of the surface of the Oceans is higher in Northern Hemisphere in comparison to Southern Hemisphere
2. The Isotherms drawn in the Northern Hemisphere are more regular
3. Highest Temperature of Oceans is on Equator

Which among the above statements is / are correct?

Answer: 1

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

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

Water hemisphere and Land Hemisphere

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

Prevailing wind

Wind direction largely affects the distribution of temperature of ocean water. The winds blowing from the land towards the oceans and seas (i.e. offshore winds) drive warm surface water away from the coast resulting into upwelling of cold bottom water from below. Thus, the 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.

Ocean currents

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

Other factors

Other factors include the following:

- ✓ *Submarine ridges*
- ✓ *Local weather conditions such as storms, cyclones, hurricanes, fog, cloudiness, evaporation and condensation*

1 Only 1 is correct answer. The Third statement is incorrect and will be discussed later in these modules.

- ✓ ***Location and Shape of area:*** *The enclosed seas in the low latitudes record relatively higher temperature than the open seas whereas the enclosed seas have lower temperature than the open seas in the high latitudes.*
- ✓

Horizontal Distribution of Temperature

Model Question - 2.

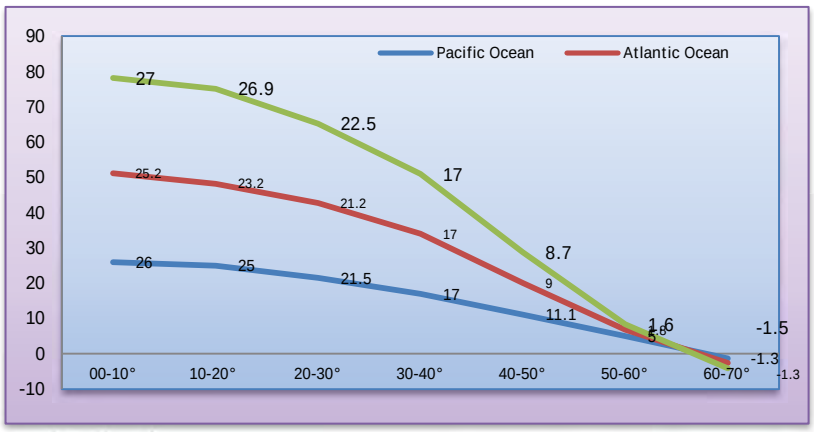
Consider the following statements:

1. Highest surface temperature of Oceans is recorded in the Northern Hemisphere
2. Temperature in Northern Atlantic rises when moving from Equator to North Pole

Which among the above statements is / are correct?

Answer: 2

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



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

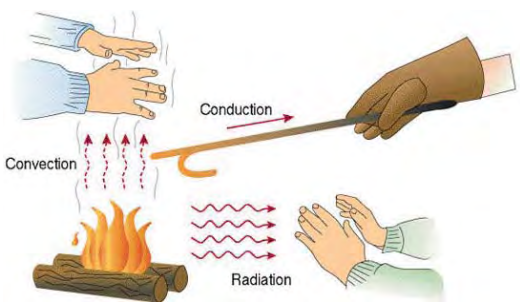
In Northern Atlantic, there is a **very low decrease of temperature** with increasing latitudes towards north. This is because of the Gulf Stream currents which are warm currents. However, in southern Atlantic, the decrease of temperature with increasing latitude is more pronounced. The table shows the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

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

Vertical Distribution of Temperature

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

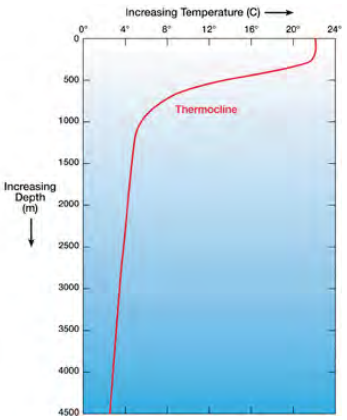
Solar rays very effectively penetrate up to 20m depth and they seldom go beyond 200m depth. Consequently, the temperature decreases from the ocean surface with increasing depth but the ***rate of decrease of temperature with increasing depth is not uniform everywhere***. The temperature falls very rapidly up to



2 Only 1 is a correct statement. Regarding statement 2, it's the gradient which is steep in southern Atlantic. The water is kept warm to greater latitudes because of Gulf Stream.

the depth of 200m and thereafter the rate of decrease of temperature is slowed down.

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



Photic Zone or Euphotic Zone

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

Thermocline

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

Deep Zone

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

Model Question - 3.

The temperature of the Ocean bottom is lowest beneath___?

A. Equator
B. Arctic Ocean
C. Southern Ocean
D. Pacific Ocean

Answer: 3

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Kindly note the following observations:

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

Though, the surface temperature of the oceans decreases from equator to the poles, the **temperature at the ocean bottom is uniform at all latitudes.** However, some studies have shown that the ***coldest bottom temperatures, just below — 0.25°C, occur at 60-70°S, near the Antarctic continent***. (http://bit.ly/Vx2S2s)

Salinity of Ocean Water

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

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

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

Evaporation

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

Temperature

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

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3 Southern Ocean

Precipitation

Precipitation is inversely related to salinity. Higher is the precipitation, lower is the proportion of salinity. The equatorial region records highest rainfall and that it is why it has low salinity in comparison to those which are near to tropics.

Influx of Freshwater

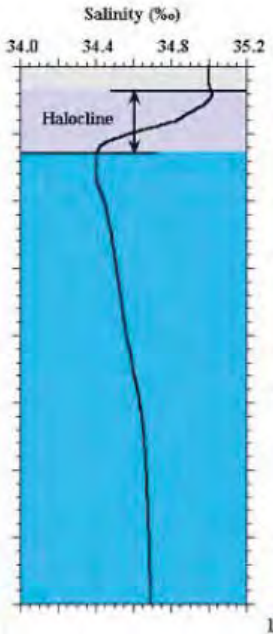
Low salinity will be found at the mouth of rivers. This salinity is minimum in the raining season.

Atmospheric Pressure

High pressure areas have high salinity and vice versa.

Circulation of Ocean water

Ocean currents play a major role in distribution of salinity.



Horizontal Distribution of Salinity of Ocean Water

As a general rule, the salinity of the oceans decreases on both sides from the tropic of Cancer. This is attributed to the high occurrence of precipitation on equator. Highest salinity of the seawater has been recorded between 20°N to 40°N. The average salinity of the Northern and Southern hemisphere is 3.5 and 3.4 ‰ respectively. This also because of the fact that the Northern Hemisphere is land dominated.

Vertical Distribution of Salinity of Ocean Water

There is no definite trend in the vertical distribution of salinity in the oceans, so there are no generalizations. However, it has been noted that **the salinity of the ocean increases with increasing depth in the higher latitudes and polar areas**. In the middle latitudes also, the same trends is seen but ONLY up to a depth of 370 meters after that it decreases with increasing depth.

Ocean Currents

Model Question - 4. (IAS 2002)

Consider the following statements:

1. Ocean currents are the slow surface movement of water in the ocean
2. Ocean currents assist in maintaining the Earth's heat balance
3. Ocean currents are set in motion primarily by prevailing winds
4. Ocean currents are affected by the configuration of the ocean

Which of these statements are correct?

Answer: 4

General Observations about Ocean Currents

Ocean current is the general movement of a mass of oceanic water in a definite direction, which is more or less similar to water streams flowing on the land surface of the earth. Ocean currents are most powerful of all the dynamics of oceanic waters because these drive oceanic waters for thousands of kilometers away. Ocean currents are divided on the basis of temperature into warm currents and cold currents.

On the basis of velocity, dimension and direction, they can be divided into drifts, currents and streams.

The forward movement of surface water of the oceans under the influence of prevailing winds is called drift whereas the ocean current involves the movement of Oceanic water in a definite direction with greater velocity.

Ocean stream involves movement of larger mass of ocean water like big rivers of the continent in a definite direction with greater velocity than the drifts and currents such as in Gulf Stream.

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4 Statements 2, 3 & 4 are correct. The First statement seems to be correct but actually judges whether a student has read something about the currents or not. Ocean currents are not always slow; in fact most of them are swift, deep and narrow. The slow and shallow currents are called Drifts. Then, this statement is also incorrect in the sense that when we talk only about the surface currents, we miss the more important Global Thermohaline circulation. Surface Currents are generally ***wind driven movements of water*** at or near the ocean's surface. **Thermohaline currents** (which are caused by variation of temperature and salinity and density) are slow deep currents that affect bulk of the seawater beneath the Pycnocline.

Model Question - 5.

Consider the following:

1. Rotation of Earth
2. Revolution of Earth
3. Gravitational Pull by Sun and Moon
4. Prevailing Winds

Which among the above cause the ocean circulation?

Answer: 5

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The currents in the oceans are originated due to combined effects of several internal as well as external factors, which control the origin and other characteristics of ocean current. They are related to different characteristics of ocean waters, rotational mechanism of the earth, external factors or atmospheric factors, topographic characteristics of the coasts and ocean basins. Besides, there are some factors which can modify the ocean currents.

- The factors relating to the earth's nature and its rotation include the gravitational force and deflective force by earth's rotation also known as **Coriolis force**.
- Oceanic factors include the **pressure gradient, temperature variations and salinity differences**. Ex-oceanic factors are atmospheric pressure and winds, evaporation and precipitation.
- Tides caused by the gravitational pull of the Moon and the Sun also play role in the forming of oceanic currents.
- The factors that can modify the currents are direction and shape of **coastlines**, **bottom reliefs of the ocean basins, seasonal variations** and ***rotation of the earth***.
- Ocean circulation is driven by winds and by differences in water density. Along with the winds, ocean currents distribute the tropical heat worldwide, thus they play a very important role in maintaining Earth's heat balance.
- Please note that water at the poles travels in slow creeps below the surface water towards equator, which is called Ocean Creep. **Ocean Creep** is not a surface movement of water. It is an undercurrent flow occasioned by the sinking of **cold and heavy water**. The water, on becoming cold, contracts and its density increases.
- Those currents that flow from the Equator towards the poles are warmer than the surrounding water and so *they are called warm currents*. The ocean currents that flow from the *polar areas towards the Equator are cooler compared to the surrounding water, so they are called cold currents*. The actual difference in temperature of warm and cold currents is only a few degrees.
- *The cold currents are usually found on the west coast of the continents in the low and middle latitudes in both the hemispheres and on the east coast in the middle latitudes in the Northern Hemisphere.*
- *The warm currents are usually observed on the east coast of the continents in the low and middle latitudes in both the hemispheres. In the Northern Hemisphere they are found on the west coasts of the continents in the high latitudes.*

5 Correct Answer 1, 3 and 4. Here, we don't include Revolution because as such directly it does not cause the currents. However, one thing must be noted that Revolution does **affect the**

- The main effect of temperature differences on the earth occurs in a north-south direction i.e. from equator to poles. Warm equatorial waters therefore move slowly along the surface towards the poles while heavier cold waters of the polar areas creep slowly towards the Equator along the bottom of the sea. Thus, the difference in the temperature of the ocean waters causes ocean currents. They are **convectional currents** giving rise to a transfer of heat energy in the ocean waters from the areas of **excess to the areas of deficit heat energy**.
- The density of the ocean water varies from place to place, a movement in the ocean waters occurs due to this.
- A gyre is any large system of rotating surface ocean currents, particularly those involved with large wind movements. Gyres are caused by the Coriolis Effect; planetary vorticity along with horizontal and vertical friction, which determine the circulation patterns from the wind curl (torque).

Coriolis Effect and Coriolis Force

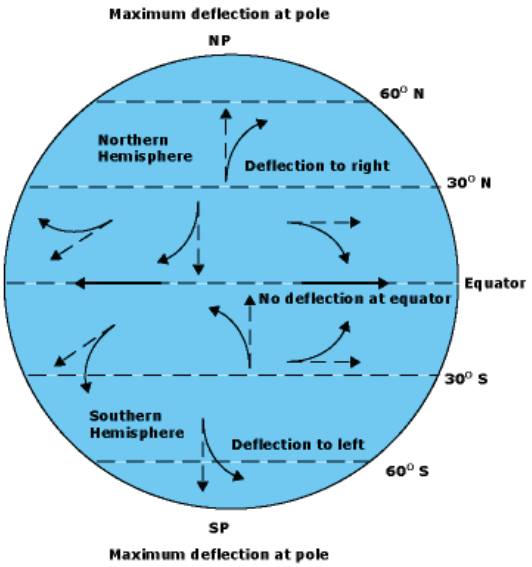
Coriolis Effect is a deflection of moving objects when they are viewed in a rotating reference frame. In a reference frame with clockwise rotation, the *deflection is to the left of the motion of the object*; in one with counter-clockwise rotation, the *deflection is to the right*. Coriolis Effect is causes ONLY in a rotating reference frame. The deflective force causes by the Coriolis Effect is caused Coriolis force. It has its own say in many geographical phenomena, most important being the deflection of the general direction of ocean currents.

Coriolis force Video

Video source: samwsm1@youtube.com

Important Observations:

- The currents flowing from equator towards the North Pole and from North Pole towards the equator are deflected to their right while the currents flowing north-south and south-north in the southern hemisphere are deflected towards their left.



- The rotational force of the earth causes movement of ocean water near the equator in opposite direction to **'the west to east rotation of the earth** and thus equatorial currents are generated. These currents flow from **east to west**. Some ocean water moves in the direction of the rotation of the earth i.e. from west to east and thus counter equatorial currents are also formed.
- Please note that the magnitude of the deflection, or "Coriolis effect," varies significantly with latitude. The **Coriolis Effect is zero at the equator** and **increases to a maximum at the poles**. The deflection is *proportional to wind speed; that is, deflection increases as wind strengthens*. The resultant balance between the pressure force and the Coriolis force is such that, in the absence of surface friction, air moves parallel *to isobars (lines of equal pressure).* This is called the geotropic wind.
- The Coriolis force explains why winds circulate around high and low pressure systems as opposed to blowing in the direction of the pressure gradient.

Impact of Physical Properties of Ocean on Ocean Currents

Local variations in the physical properties of the ocean such as pressure gradient, temperature differences, salinity differences, density variations etc. generate ocean currents.

Temperature

The amount of insolation received at the earth's surface and consequent temperature decreases from equator towards the poles. Due to high temperature in the equatorial region the water density decreases because of greater expansion of water molecules whereas the density of sea water becomes comparatively greater in the polar areas. Consequently water moves due to expansion of volume from equatorial region (of higher temperature) to polar areas (colder areas) of relatively very low temperature.

There is movement of ocean water below the water surface in the form of subsurface current from colder polar areas to warmer equatorial areas in order to balance the loss of water in the equatorial areas. Thus, the poleward surface current and Equatorward subsurface currents form a complete circulatory system of ocean water. The Gulf Stream and Kuroshio warm currents moving from equator towards north are examples of such currents.

Salinity

Oceanic salinity affects the density of ocean water and density variation causes ocean currents. Salinity increases the density of ocean water. If two areas having equal temperature are characterized by varying salinity, the area of high salinity will have greater density than the area of low salinity. The denser water sinks and moves as subsurface current whereas less saline water moves towards greater saline water as surface current. In other words, *ocean currents on the water surface are generated from the areas of less salinity to the areas of greater salinity. Such system of surface and subsurface currents caused by salinity variation is originated in open and enclosed seas.* For example, the current flowing from the Atlantic Ocean to the Mediterranean Sea via Gibraltar Strait is caused because of the difference in salinity.

The salinity of the Mediterranean Sea is much higher than the adjoining Atlantic Ocean. Consequently, water sinks in the Mediterranean Sea. In order to compensate the loss of water Atlantic water flows as surface current into the Mediterranean Sea. The sinking water in the Mediterranean Sea moves as subsurface current towards the Atlantic Ocean. Similarly, such system of surface and subsurface currents is generated between the Red Sea and the Arabian Sea via Bab-el- Mandeb Strait.

The salinity of the Baltic Sea is lowered due to the flow of fresh water by the rivers but the level of water is raised. With the result water moves northward as a surface current into the North Sea and subsurface current moves from the North Sea to the Baltic Sea.

Impact of Air Pressure and Winds on Ocean Currents

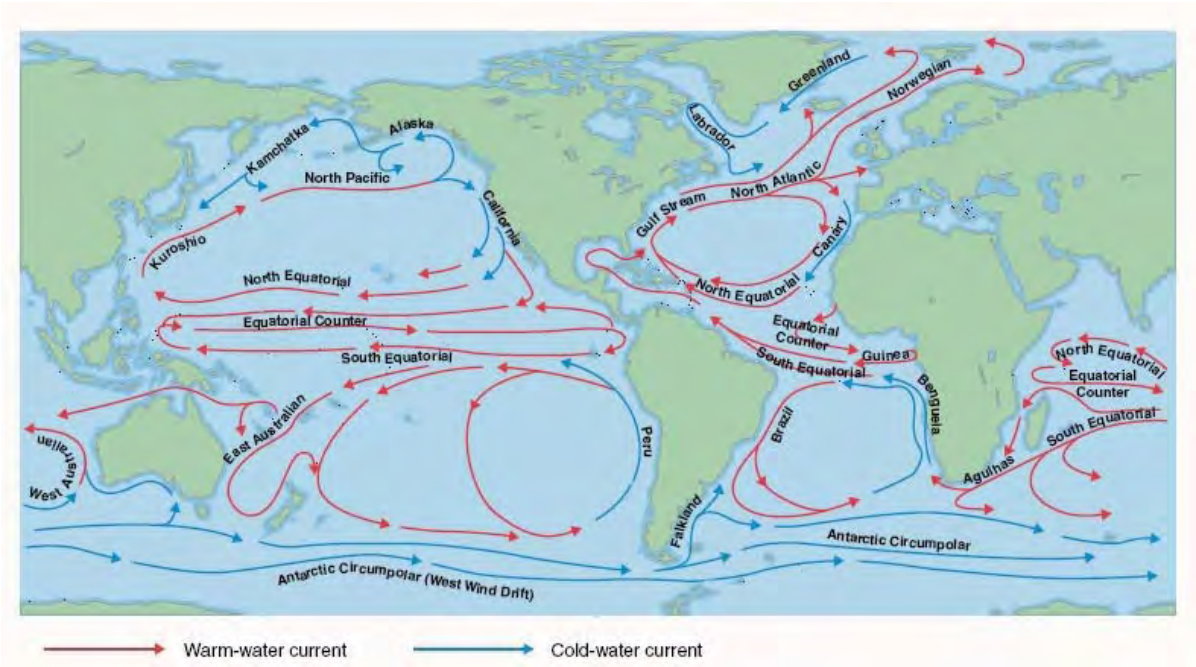
Air pressure on the oceanic water causes ocean currents through density variations. The areas of high atmospheric pressure are characterized by low volume of water and thus lowering of water level. Contrary to this the areas of low atmospheric pressure record higher volume of water and higher water level. Thus, water moves as surface current from the areas of higher water level (Low pressure areas) to low water level areas (high pressure areas).

Prevailing or planetary winds (e.g., trade winds, westerlies and polar winds) play major roles in the origin of ocean currents. The wind blowing on the water surface also moves water in its direction due to its friction with the water. Most of the ocean currents of the world follow the direction of prevailing winds. For example, equatorial currents flow westward under the influence of N.E. and S.B. trade winds. The Gulf Stream in the Atlantic and the Kuroshio in the Pacific move in northeastern direction under the influence of the westerlies. There is seasonal change in the direction of currents in the Indian Ocean twice a year (after every 6 months) due to seasonal change in the direction of monsoon winds. Friction caused by the wind sets the sea water in motion.

Types of Oceanic Currents

Ocean currents are of two type's viz. **Surface Currents** and **Deep Currents**. Surface currents affect surface water above the **pycnocline** (<10% of ocean water). These currents are primarily driven by major wind belts. The Deep currents affect deep water below pycnocline (90% of ocean water) and are primarily driven by **density differences**. The deep currents are larger and slower than surface currents.

The stress of wind blowing across the sea causes a surface layer of water to move. Due to the low viscosity of water, this stress is not directly communicated to the ocean interior, but is balanced by the Coriolis force within a relatively thin surface layer, 10-200m thick. **This layer is called the Ekman layer and the motion of this layer is called the Ekman transport**. Because of the deflection by the Coriolis force, the Ekman transport is not in the direction of the wind, but is 90° to the right in the Northern Hemisphere and 90° toward the left in the Southern Hemisphere. The amount of water flowing in this layer depends only upon the wind and the Coriolis force and is independent of the depth of the Ekman layer and the viscosity of the water. The major surface currents are shown below:



Currents of The Atlantic Ocean

North Equatorial Current (warm)

North equatorial current is a significant Pacific and Atlantic Ocean current that flows east-to-west between about 10° north and 20° north. This current is generated because of upwelling of cold-water near the west coast of Africa. This warm current is also pushed westward by the cold Canary current. On an average, the north equatorial warm current flows from east to west but this saline current is deflected northward when it crosses the mid-Atlantic Ridge near 15°N latitude. It again turns southward after crossing over the ridge. This current, after being obstructed by the land barrier of the east coast of Brazil, is bifurcated into two branches viz. Antilles current and Caribbean current. The Antilles current is diverted northward and flows to the east of West Indies islands, and helps in the formation of Sargass Sea eddy while the second branch known as the Caribbean current enters the Gulf of Mexico and becomes Gulf Stream.

South Equatorial Current (warm)

The South Equatorial Current is a significant Pacific, Atlantic, and Indian Ocean current that flows east-to-west between the equator and about 20 degrees south. In the Pacific and Atlantic Oceans, it extends across the equator to about 5 degrees north. South equatorial current flows from the western coast of Africa to the eastern coast of South America between the equator and 20°S latitude. This current is more constant, stronger and of greater extent than the north equatorial current. In fact, this current is the continuation of the cold **Benguela current.** This warm current is bifurcated into two branches due to obstruction of land barrier in the form of the east coast of Brazil.

The northward branch after taking north-westerly course merges with the north equatorial current near Trinidad while the second branch turns southward and continues as Brazil warm current parallel to the east coast of South America. This current is basically originated under the stress **of trade winds.**

Equatorial Counter Current

Equatorial Counter Current is a significant ocean current in the Pacific and Indian oceans that flows west-to-east at approximately five degrees north. The Counter Currents result from balancing the westward flow of water in each ocean by the North and South Equatorial currents.

In El Niño years, Equatorial Counter current intensifies in the Pacific Ocean.

The Equatorial Counter current flows from west to east in between the westward flowing strong north and south equatorial currents. This currents is less developed in the west due to stress of trade winds. In fact, the counter current mixes with the equatorial currents in the west but it is more developed in the east where it is known as the **Guinea Stream**. The Equatorial Counter current carries relatively higher temperature and lower density than the two equatorial currents. Several ideas have been put forth to explain the origin of the Equatorial Counter current. According to some scientists this current is originated because of the influence of the westerlies which blow from west to east in the calm zone of the doldrums or in the convergence zone of the north east and south east trade winds.

Gulf Stream

The Gulf Stream is a system of several currents moving in north-easterly direction. This current system originates in the Gulf of Mexico around 20°N latitude and moves in north easterly direction along the eastern coast of North America and reaches the western coasts of Europe near 70°N latitude. This system, named Gulf Stream because of its origin in the Mexican Gulf, consists of

1. Florida current from the strait of Florida to Cape Hatteras,
2. Gulf Stream from Cape Hatteras to the Grand Bank, and
3. North Atlantic Drift (current) from Grand Bank to the Western European coast.

North Equatorial Current flows westward off the coast of northern Africa. When this current interacts with the northeastern coast of South America, the current forks into two branches. One passes into the Caribbean Sea, while a second, the Antilles Current, flows north and east of the West Indies. These two branches rejoin north of the Straits of Florida. Thus, Florida current is in fact, the northward extension of the north equatorial current.

This current flows through Yucatan channel into the Gulf of Mexico, thereafter the current moves forward through Florida Strait and reaches 30°N latitude. Thus, the Florida warm current contains most of the characteristics of the equatorial water mass.

The trade winds blow westward in the tropics, and the westerlies blow eastward at mid-latitudes. This wind pattern applies a stress to the subtropical ocean surface with negative curl across the North Atlantic Ocean. The resulting Sverdrup transport is Equatorward. Because of conservation of potential vorticity caused by the northward-moving winds on the subtropical ridge's western periphery and the increased relative vorticity of northward moving water, transport is balanced by a narrow, accelerating poleward current, which flows along the western boundary of the ocean basin, outweighing the effects of friction with the western boundary current known as the Labrador Current. The conservation of potential vorticity also causes bends along the Gulf Stream, which occasionally break off due to a shift in the Gulf Stream's position, forming separate warm and cold eddies. This overall process, known as western intensification, causes currents on the western boundary of an ocean basin, such as the Gulf Stream, to be stronger than those on the eastern boundary.

As a consequence, the resulting Gulf Stream is a strong ocean current. It transports water at a rate of 30 million cubic meters per second through the Florida Straits. As it passes south of Newfoundland, this rate increases to 150 million cubic meters per second.

The average temperature of water at the surface is 24°C while the salinity is 3.6%. The temperature never falls below 6.5°C . The current becomes narrow while passing through the Florida strait but thereafter its width increases and current flows close to coast.

Canary Current (Cold)

The Canary current, a cold current, flows along the western coast of north Africa between Maderia and Cape Verde. In fact, this current is the continuation of North Atlantic Drift which turns sout.hward near the Spanish coast and flows to the south along the coast of Canaries Island. The average velocity of this current is 8 to 30 nautical miles per day. This current brings cold water of the high latitudes to the warm water of the low latitudes and finally merges with the north equatorial current. The Canary cold current ameliorates the otherwise hot weather conditions of the western coasts of North Africa.'

Labrador Current (Cold)

The Labrador Current, an example of cold current, originates in the Baffin Bay and Davis Strait and after flowing through the coastal waters of Newfoundland and Grand Bank merges with the Gulf Stream around 50°W longitude. The flow discharge rate of the current is 7.5 million ml of water per second. This current brings with it a large number of big icebergs as far south as Newfoundland and Grand Bank. These icebergs present effective hindrances in the oceanic navigation. Dense fogs are also produced due to the convergence of the Labrador cold current and the Gulf Stream near New-foundland.

Brazil Current (Warm)

The Brazil current is characterized by high temperature and high salinity. This current is generated because of the bifurcation of the south equatorial current because of obstruction of the Brazilian coast near Sun Rock. The northern branch flows northward and merges with the north equatorial current while the southern branch known as the Brazil current flows southward along the east coast of South America up to 40°S latitude. Thereafter it is deflected eastward due to the deflective force of the rotation of the earth and flows in easterly direction under the influence of westerlies. The Falkland cold current coming from south merges with Brazil current at 40° S.

Falkland Current (Cold)

The cold waters of the Antarctic Sea flows in the form of Falkland cold current from south to north along the eastern coast of South America up to Argentina. This current becomes most extensive and developed near 30°S latitude. This current also brings numerous icebergs from the Antarctic area to the South American coast.

South Atlantic Drift (Cold)

The eastward continuation of the Brazil current is called South Atlantic Drift. This current is originated because of the deflection of the Brazil warm current eastward at 40°8 latitude due to the deflective force of the rotation of the earth. The South Atlantic Drift, thus, flows eastward under the influence of the westerlies. This current is also known as the Westerlies Drift or the Antarctic Drift.

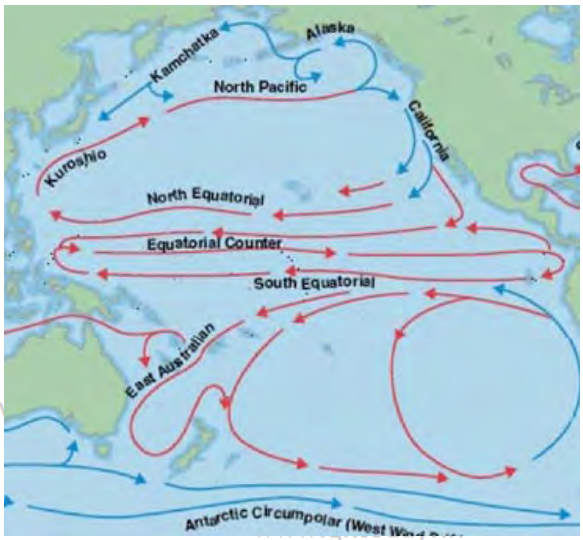
Benguela Current (Cold)

The Benguela current, a cold current, flows from south to north along the western coast of south Africa. In fact, the South Atlantic Drift turns northward due to obstruction caused by the southern tip of Africa. Further northward, this current merges with the South Equatorial Current.

Currents of The Pacific Ocean

North Equatorial Current (Warm)

The north equatorial current originates off the western coast of Mexico and flows in westerly direction and reaches the Philippines coast after covering a distance of 7500 nautical miles. This current is originated because of the Californian current and north-east monsoon. The volume of water continuously increases westward because numerous minor branches join this current from the north. A few branches also come out of the main current and turn towards - north and south. One branch emerges from the north equatorial current near Taiwan and flows northward to join **Kuroshio current** while the southern branch turns eastward to form counter equatorial current. It is significant to note that north equatorial current flows as a continuous current i n the north Pacific Ocean but there are seasonal variations in its northern and southern marginal areas. The velocity of the current ranges between 12 and 18 nautical miles per day. With the northward (northern summer) and southward (south northward and southward but it always remains to the north of equator.



South Equatorial Current (Warm)

The south equatorial current is originated due to the influence of south-east trade winds and flows from east to west. This current is stronger than the north equatorial current. The average velocity is 20 nautical miles per day while the maximum velocity becomes 100 nautical miles a day. Numerous minor currents join this current. from the left and thus. the volume of water continuously increases west-ward, The current is bifurcated into northern and southern branches near New Guinea. The northern branch turns eastward and flows as counter equatorial current w rule the southern branch –moves towards the northern and north-eastern coasts of Australia.

Counter Equatorial Current (Warm)

The current flowing west to east between the north and south equatorial currents is termed counter equatorial current. Because of trade winds immense volume of water is piled up in the western marginal parts of the ocean, with the result there is general slope gradient of water surface from west to east. This higher water level in the west and descending slope gradient of water surface from west to east make the oceanic water flow in easterly direction in the name of counter equatorial current which is the most developed counter current in the Pacific Ocean. This counter equatorial current is extended up to the Panama Bay.

Kuroshio System (Warm)

The Kuroshio System consists of several currents and drifts is similar to the Gulf Stream system of the Atlantic Ocean. This system runs from Taiwan to the Bering Strait and consists of the Kuroshio current, the Kuroshio extension, the north Pacific drift, the Tsushima current and the counter Kuroshio current.

Oyashio Current (Cold)

The Oyashio cold current is also known as Kurile cold current. This cold current flows through the Bering Strait in southerly direction and thus transports cold water of the Arctic Sea into the Pacific Ocean. Near 50°N latitude this current is bifurcated into two branches. One branch turns east-ward and merges with the Aleutian and Kuroshio currents. The second branch moves upto the Japanese coasts. This current is comparable to the cold **Labrador Current** of the North Atlantic Ocean. The convergence of cold Oyashio (Kurile) and warm Kuroshio Current causes dense fogs which become potential hazards for navigation.

California Current (Cold)

The California current, an example of cold current, is similar to the Canary cold current of the Atlantic Ocean in most of its characteristics. In fact, this current is the eastward extended portion of the North Pacific drift. The cold California current is generated because of the movement of oceanic water along the Californian coast from north to south in order to compensate the loss of water which is caused due to large-scale transport of water off the coast of Mexico under the influence of trade winds in the form of the north equatorial current. This current after reaching the Mexican coast turns west-ward and merges with the north equatorial current.

Peru Current (Cold)

The cold current flowing along the western coast of South America from south to north is called Peru current or Humboldt current. This current is known as Peru coastal current near the coast w bile it is called Peru oceanic current off the coast. Mean annual temperature ranges between 14°C and 17°C and the average velocity of moving water is 15 nautical miles (27km) per day. The temperature of sea water increases from the coast towards the ocean.

East Australia Current (Warm)

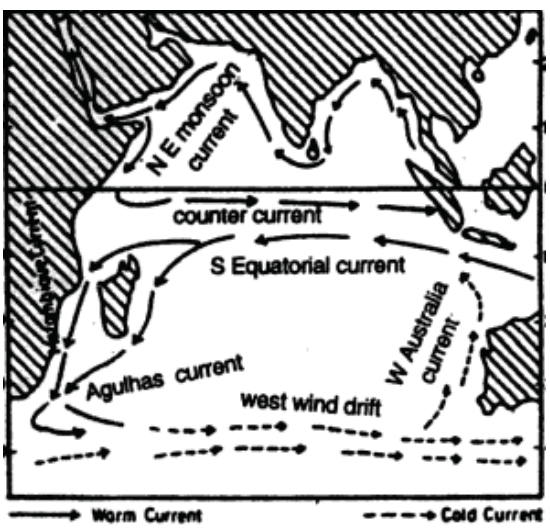
South equatorial current is bifurcated near the Australian coast into northern and southern branches. The southern branch flows as east Australia current from north to south along the eastern coasts of Australia. New Zealand is surrounded by this current. It is deflected eastward near 40°S latitude due to deflective force of the earth and flows in easterly direction under the influence of the westerlies. This is a warm and more consistent current. It raises the temperature of east Australian coast for considerable distance southward.

Currents of The Indian Ocean

Model Question - 6. (IAS -1997)

Which one of the following factors is responsible for the change in the regular direction of the ocean currents in the Indian Ocean?
a. Indian Ocean is 'half an ocean
b. Indian Ocean has Monsoon drift
c. Indian Ocean is a land-locked ocean
d. Indian Ocean has greater variation in salinity
Answer: 6

The current systems of the Indian Ocean are largely controlled and **modified by landmasses and monsoon winds**. Indian Ocean being surrounded by the Indian subcontinent, Africa and Australia does not present most favourable conditions for the development of consistent system of ocean currents. *The currents in the northern Indian Ocean change their flow direction twice a year due to north-east and south-west monsoon winds*.

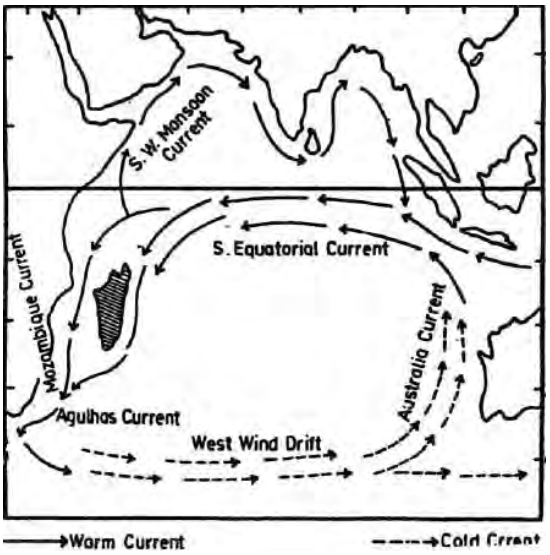


North-East Monsoon Current (Warm)

North-east monsoon winds blow from land to the ocean during winter season in the northern hemisphere and thus westward blowing north-east monsoon currents are produced in Indian

6 Corrent Answer is B.

Ocean. This current flows to the south of 5°N latitude. Besides, some independent currents originate in the Bay of Bengal and Arabian sea and flow in south-westerly direction.



S.W. Monsoon Current (Warm)

There is complete reversal in the direction of monsoon winds during summer season. The north-easterly direction of winter monsoon winds becomes south-westerly during summer season in the northern hemisphere. This reversal of direction of monsoon winds also reverses the direction of ocean currents of Indian Ocean during summer season. North-east monsoon ocean currents disappear and south-west monsoon ocean currents are developed. The general direction of monsoon currents is from south-west to north-east but several minor branches emerge from the main branch and move in the Bay of Bengal and Arabian Sea. The Indian counter current developed during winter season disappears due to this current.

Tides

Moon, the only natural satellite of Earth is at 384403 kilometers average distance. This distance is approximately 30 times of the diameter of earth. Moon revolves around Earth in an elliptical path and the nearest and farthest points are called Perigee (363,300 km) and Apogee (405,500 km). The mean radius of Moon is 1,737.10 km, which is 0.273 of Earth's mean Radius. Mass of moon is 7.3477 × 1022 Kg which is 0.0123 or $\frac{1}{81}$ of Earth's mass.

Some quasi-satellites have been proposed, but none of them has been verified. For example, 3753 Cruithne is sometimes called Earth's second moon, but so far, it is not correct to call it earth's second moon. Some other quasisatellites proposed are 54509 YORP, (85770) 1998 UP1, 2002 AA29, 2000 PG5, 2000 WN10.

Moon is Fifth largest satellite in the solar system. Ganymede of Jupiter is the largest satellite in the solar system. Second largest is Titan of Saturn, Third largest is Callisto of Jupiter and fourth largest is Lo of Jupiter. After moon, Europa is largest and it is a natural satellite of Jupiter.

The gravitation pull of Moon is 1/6 as compared to Earth, so an object weighing 1 Kg on earth would weigh 166 Gms on moon. A person who can high jump 1 meter would be able to jump 6 meters on Moon. Thus, we see that size of moon is considerable to impact some phenomena on earth. This considerable size of moon pulls Earth towards it and Earth pulls Moon towards herself. Besides, there is Sun's gravitational force.

Corresponding weights of 1000gms at other planets and moon	
Jupiter	2364
Saturn	1064
Venus	907
Mercury	378
Mars	377
Moon	166

The gravitation pull is evident as rise and fall of sea levels, which are called tides. Tides are a result of gravitational pull by **both Sun and Moon**, but the pull exerted by Sun is apparently weak. This is because of the larger distance as the gravitational force is inversely proportional to the square of the distance.

The gravitational attraction force between two point masses is directly proportional to the product of their masses and inversely proportional to the square of their separation distance. The force is always attractive and acts along the line joining them – **Inverse Square Law**.

The alignment of Sun and moon affects the size of the tides.

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

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

Stages of Tides

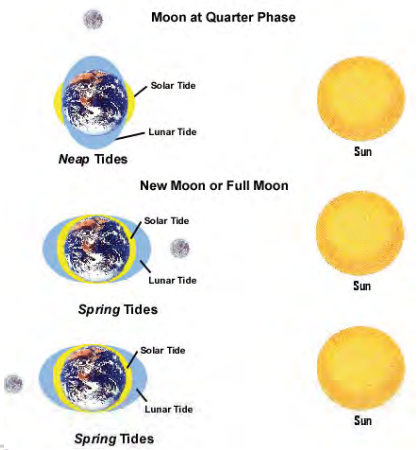
There are 4 distinct stages of tides:

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

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

Spring Tides and Neap Tides

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



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

Model Question - 7.

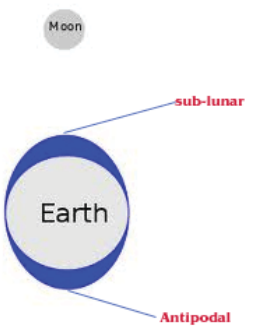
On which of the following dates, the amplitude of the tides would be maximum?

A. January 3, New Moon
B. January 3, Moon in second quarter
C. July 6, Full Moon
D. December 21, New moon

Answer: 7

Daily Frequency of Tides

Earth rotates around its own axis and it takes 24 hours to finish its rotation. The direction of Earth rotation is the same in which Moon revolves around earth. The gravitational attraction moon raises the water on two opposite sides of Earth; these points are called Sub-lunar and antipodal points. The tidal bulge shown in the adjacent graphics follows the revolution of the moon, and the earth rotates eastward through the bulge once every **24 hours and 50 minutes**. (This is because, of the relative distance covered by moon in its orbit). This tidal bulge shows that the water of the entire world ocean is pulled by the moon's gravity.



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

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7 Correct Answer is A. On New Moon or Full moon, the tides will have higher amplitude. In the given dates, on January 3, Earth is at perihelion. This means that Earth on January 2 0r 3 is at closest distance from Sun. So, the tide would be highest in the year on Perihelion-New Moon. This spring tide would be the highest in the entire year.

Duration and Frequencies of Daily Tides

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

Various Concepts related to Tides

Model Question - 8.

Consider the following statements:

1. Gulfs with narrow fronts and wider rears experience high tides
2. Tidal currents take place when a gulf is connected with the open sea by a narrow channel
3. Tidal bore occurs when a tide enters the narrow and shallow estuary of a river
4. The tidal nature of the mouth of the river Hooggly is of crucial importance to Kolkata as port

Which among the above statements is / are correct?

Answer: 8

Tidal datum

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

Tidal Flat

The sands uncovered by the low tides is called tidal flat

Tidal Range

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

Tidal Bore

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

Intertidal Zone

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

Apogean Tides and perigean tides

When moon is at closest point to Earth during its revolution around earth it is called Perigee. The high tides are higher than usual and low tides are lower than usual at this point. When moon is farthest, it is called apogee and the high tides are lower than usual and low tides are higher than usual at this point of time.

Tidal Power

Power can be generated exploiting the huge energy of the tides. This can be done by making dams and the tidal zones where best tides occur and allowing the water to enter and exit through a turbine. However, this is a complicated work and not much success as been achieved as of now.

Earth's Tides

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8 Correct statements are 1, 3 & 4. Regarding statement 1, please note that one such example of gulfs with narrow fronts and wider rears is Gulf of Mexico. The Gulf of Mexico has high tides because all the water must get in and out of the Gulf through the narrow Florida Straits. The second statement gives a wrong definition of Tidal Currents. In general, the range of tide and the velocity of tidal current are at a minimum in the open ocean or along straight coasts. The greatest tidal effects are usually encountered in estuaries, bays, and other coastal indentations. A vessel proceeding along an indented coast may encounter a set toward or away from the shore; a similar set is seldom experienced along a straight coast.

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

World's first Tidal Power Station

It is Rance Tidal Power Station, located on the estuary of the Rance River, in Brittany, France. It is also world's largest tidal power station which started working in 1966. Its annual output is 600 GWh.

Tides affect Earth's Magnetic Field

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

There are no ocean tides at Equator

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

If there is no moon:

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

Highest Spring tides

The highest Spring tides occur when the Moon is at its closest to the Earth...the so-called Perigee Tide.

The Tides Which Are Not Tides

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

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

- **Rip Tides:** Rip tides are strong channel of water flowing seaward from near the shore, typically through the surf line. They are again caused by the winds and not related to Tides.
- **Tsunami:** Tsunamis are called 'harbour wave', and they are result of displacement of a large volume of a body of water, usually an ocean due to Earthquakes, volcanic eruptions and other underwater explosions.

Model Question - 9.

Consider the following statements :

1. Tides are of great help in navigation and fishing.
2. High tide enables big ships to enter or leave the harbour safely.
3. Tide prevents siltation in the harbours.
4. Kandla and Diamond Harbour are tidal ports.

Which of these statements are correct?

Answer: 9

Tides and navigation

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

9 Correct statements are 1, 2, 3 & 4

Tides and Fishing

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

Tidal Ports

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

Tides and Siltation

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

Tides and Prevention of Rivers from Freezing

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

Application in Hydel Power

The water accumulation during high tides can be stored behind specially made dams. This can then be used for hydel power.

Part II. Atmosphere and Winds Circulation

Earth's atmosphere is mainly consisted of nitrogen, oxygen, and argon, which together constitute the major gases of the atmosphere. The remaining gases are often referred to as trace gases. The adjacent table shows the composition of Dry atmosphere. The upper boundary of the atmosphere is not clearly defined. There is a Kármán line or "Edge of space", named after Theodore von Kármán, that lies at 100 km above earth's Sea Level and makes a boundary between Earth's atmosphere and Outer space for **aeronautical purposes**.

Composition of Earth's Atmosphere

Gas	Volume
Nitrogen (N_2)	78.08%
Oxygen (O_2)	20.95%
Argon (Ar)	0.93%
Carbon dioxide (CO_2)	0.04%
Neon (Ne)	0.00%
Helium (He)	0.00%
Methane (CH_4)	0.00%
Krypton (Kr)	0.00%
Hydrogen (H_2)	0.00%
Nitrous oxide (N_2O)	0.00%
Carbon monoxide (CO)	0.00%
Xenon (Xe)	0.00%
Ozone (O_3)	0 to 7×10−6%
Nitrogen dioxide (NO_2)	0.00%
Iodine (I_2)	0.00%
Ammonia (NH_3)	trace

The Kármán line does not mean that there is no atmosphere beyond this line. The composition of the atmosphere above the 100 km level also includes mainly the nitrogen and oxygen. However, under the effect of the solar ultraviolet radiation the oxygen molecules split into atoms and oxygen become atomic. This is important for the formation of Ozone Layer.

Aeronautics versus Astronautics
The definition of Kármán Line is internationally accepted and is used to differentiate between aeronautics and astronautics. As per Fédération Aéronautique Internationale (FAI), Aeronautics is the aerial activity, including all air sports, within 100 kilometers of Earth's surface, while Astronautics is the activity more than 100 kilometers above Earth's surface.

Below the 100 kilometers or so, the atmosphere behaves like a fluid. The ***outermost layer of Earth's atmosphere is mainly composed of hydrogen and helium***. The particles are so far apart that they can travel hundreds of kilometers without colliding with one another. Since the particles rarely collide, the atmosphere no longer behaves like a fluid. These free-moving particles follow ballistic trajectories and may migrate into and out of the magnetosphere of the Earth.

The atmosphere has been divided into several layers on the basis of change in height and some other factors such as change in climate etc. These include the Troposphere (the lowermost), Stratosphere (stratified), Mesosphere, Thermosphere, Exosphere (outer space). Between individual spheres there are usually distinguished transitory layers, called 'PAUSES' where temperature varies but little with height The character and composition of the atmosphere changes as we go higher and higher. The atmosphere can be divided into several layers according to differences in temperature and rates of temperature change. There are 4 important spheres, with 3 pauses as follows:

- Troposphere with tropopause
- Stratosphere with stratopause
- Mesosphere with mesopause, and
- Ionosphere or thermosphere.

In this image, the orange-coloured troposphere, the lowest and most dense portion of the Earth's atmosphere is seen. The troposphere ends abruptly at the tropopause, which appears in the image as the sharp boundary between the orange- and blue- coloured atmosphere. The silvery-blue noctilucent clouds extend far above the Earth's troposphere.(source: Wikimedia Commons)

Troposphere

Troposphere is the lowest portion of Earth's atmosphere and contains approximately 80% of the atmosphere's mass and 99% of its water vapour and aerosols. The average depth of the troposphere is approximately 17 km in the middle latitudes.

Model Question - 10.

The Thickness of the atmosphere is maximum at equator due to the reason / reasons that __:

1. High insolation and strong convection currents occur in troposphere over the Equator
2. Air is less dense at Equator
3. Equator exerts more gravitational pull on atmospheric gases
4. The centrifugal force due to Earth's rotation is maximum at Equator

Which among the above is / are correct?

Answer: 10

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It thickness of the Troposphere is maximum at equator, deeper in the tropics, up to 20 km , and **shallower near the polar regions**, **at 7 km in summer**, and **indistinct in winter**. In India, it is taken to be around 16 Kilometers. The thickness of the troposphere and consequently the atmosphere is maximum at the equator due to the reasons discussed below:

High insolation and strong convection currents occur over the Equator

One of the laws of Ideal gases called Charles' law says that in an ideal gas, **density decreases with increasing temperature**, when pressure is constant. The hot air rises and the Earth is not equally heated everywhere. The troposphere is thicker over the equator than the poles **because the equator is warmer**. Heat differential on the planet's surface causes convection currents to flow from the equator to the poles. This implies that the warmer the weather, the thicker is the troposphere. Thus the simple reason is thermal expansion of the atmosphere at the equator and thermal contraction near the poles.

Air is less dense at Equator

Over equatorial regions, where the surface is being heated strongly throughout the year and air warmed by contact with it is expanding and rising, the air all the way up to the tropopause is less dense than air to the north and south. Thus, density of the air is maximum at the equator. But here, you must note that almost same amount of atmospheric ***mass*** *exists at both equator and poles but only the density of the air is less at equator and greater at poles*

10 1, 2, 3 & 4

Equator exerts more gravitational pull on atmospheric gases

Gravity increases from equator to poles as the earth is not a perfect sphere. That means the gravitational force is **more over poles**. Hence the atmosphere is pulled with more force near the poles and leads to contraction of the atmosphere.

The centrifugal force due to Earth's rotation is maximum at Equator

Because the speed of the rotating earth is greatest at the equator the atmosphere tends to bulge out due to friction and Coriolis force.

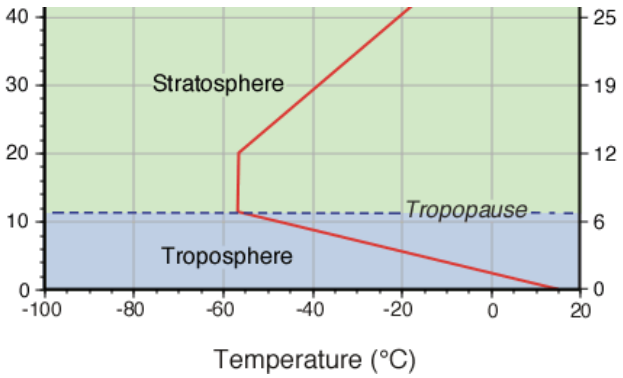
The boundary between troposphere and stratosphere, called the tropopause, is a temperature inversion. The characteristic features of the Troposphere are its **great density**. In addition to nitrogen and oxygen, carbon dioxide, and water vapour (***nearly all of the water vapour contained in the atmosphere is concentrated in the troposphere***) and of numerous particles of various origin.

Chemical Composition of Troposphere

The chemical composition of the troposphere is essentially uniform, with the notable exception of water vapour. The amount of water vapour decreases strongly with altitude. Thus the proportion of water vapour is normally *greatest near the surface* and decreases with height.

Temperature of Troposphere:

Temperature of the troposphere **decreases with height**. The rate at which the temperature decreases is called the **Environmental Lapse Rate** (ELR). The environmental lapse-rate (ELR) is about 0.6°C per every 100 meters. Temperature decreases at a *nearly uniform rate* with increased altitude.



The reason for lapse is that *maximum absorption of the sun's energy occurs at the ground* which heats the lower levels of the atmosphere, and the radiation of heat occurs at the top of the atmosphere cooling the earth, this process maintaining the overall heat balance of the earth.

Tropopause

Model Question - 11.

Consider the following statements:

1. Height of Tropopause is maximum at equator
2. Presence of a cyclone in troposphere increases the height of tropopause

Which among the above statements is / are correct?

Answer: 11

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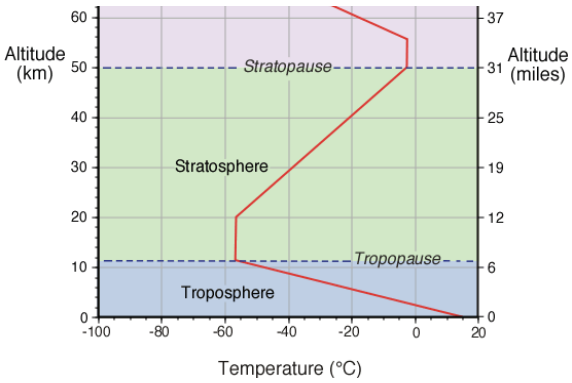
Tropopause refers to the altitude at which the fall in the temperature is stalled. This layer separates the troposphere from the stratosphere (the second layer of the atmosphere). This layer is usually quiet and no major movement of air takes place in it. Its height at Tropic of Cancer and Tropic of Capricorn is roughly 10 to 15 km, highest at the equator 18 km and at the poles it is about 8 km above the earth. In India, the tropopause is generally at a height of around 16 km. The altitude of the tropopause varies with the variations of sea — surface temperature, season, latitude, and weather systems, such as the passage of cyclones and anti-cyclones. So, Tropopause is not a hard lined boundary. The *higher is the temperature of the lower layers, the higher is the height of this layer*, the *layer is lower where there is a cyclone below it.* Also note that the tops of cumulus-nimbus clouds often float in his region.

11 Only 1 is correct.

Stratosphere

The stratosphere is the second major layer of Earth's atmosphere, just above the troposphere, and below the mesosphere. It is called stratosphere because **it is <u>stratified</u> in temperature**, with **warmer layers higher up** and **cooler layers farther down**. Top of the stratosphere has a temperature of about −3°C, just slightly below the freezing point of water. This is in contrast to the troposphere near the Earth's surface, which is cooler higher up and warmer farther down. This **<u>inversion begins in tropopause.</u>**



The stratosphere is situated between about 10 km and 50 km altitude above the surface at moderate latitudes, while at the poles it starts at about 8 km (5 mi) altitude. Thus, stratosphere is nearest to poles altitudinally.

Absence of Vertical Winds in Stratosphere

The increase in the temperature with height in the stratosphere makes this region very stable place where the air tends not to overturn vertically. Thus vertical winds are almost absent in Stratosphere.

Model Question - 12. (IAS 2011)

The jet aircrafts fly very easily and smoothly in the lower stratosphere. What could be the appropriate explanation?

1. There are no clouds or water vapour in the lower stratosphere.
2. There are no vertical winds in the lower stratosphere.

Which of the statements given above is/are correct in this context?

(a) 1 only.
(b) 2 only.
(c) Both 1 and 2.
(d) Neither 1 nor 2

Answer: 12

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In contrast with the atmosphere, where the vertical wind speeds are often several meters per second, in the stratosphere, they are seldom more than a few centimetres per second. The result is that it takes air a very long time to be transferred from the bottom of the stratosphere, unless there is a thrust of gases such as that during the highly explosive volcanic eruptions. The inability of the air to mix in vertical direction is also the principal reason *<u>why the Ozone depleting Chloro-Fluoro Carbons take so long to reach the altitudes where the Sun's energy is sufficient enough to break them apart.</u>* This also implies that some of the ozone depleting substances will still be there a centuries later from now.

Water vapour Methane Interaction in Stratosphere

Model Question - 13.

Consider the following statements:

1. Wetland rice cultivation is one of the sources of methane in Earth's atmosphere
2. Methane contributes in Ozone loss

Which among the above statements is / are correct?

Answer: 13

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The source of methane in Earth's atmosphere can be traced to its release at the surface through a variety of sources such as wood combustion, coal mining, oil and gas drilling and refining, landfills, **<u>wetland rice</u>**

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12 Correct answer is Only 2. Please note that in a much generalized sense, the statement 1 is also correct explanation because hardly there is any water vapor or clouds in Lower stratosphere. But if we further analyze this standalone statement, it stands incorrect, because stratosphere is known for complex water vapor-methane reactions and clouds too are present there. Via this question, what UPSC wanted to check in your knowledge remains an illusion to me. If you check this class IX Book of ICSE, it seems that the question was lifted from here: http://bit.ly/UHJpi2. The planes really rise high in the sky because they don't want clouds to come in their way. Stratosphere gives them such ambience.

13 Both 1 & 2 are correct statements.

cultivation, crop residue burning, industrial activities and the digestive action by grazing animals (such as cow flatulence) and to some extent human flatulence because *around half of us* produce methane in farts!

The tropopause is the very cold boundary between the troposphere and the stratosphere. Due to this, the water vapour is frozen out when moist air is lofted upward through the tropopause. *This means that the air that enters stratosphere is almost dry*. On the other hand, methane remains unaffected by the cold temperatures as it passes through this boundary. Only when methane reaches the upper stratosphere, it is depleted via oxidation reactions with OH. These reactions lead to the production of water vapour molecules. Indeed, each methane molecule eventually is converted in to two molecules of water vapour in the middle to upper stratosphere via the following reaction in which methane is converted into water vapour by a reaction with the hydroxyl radical OH.

$$CH_4 + OH \rightarrow CH_3 + H_2O$$

The second reaction involves a series of steps that begins with the methane reacting with the free oxygen form a hydroxyl radical (OH). This hydroxyl radical is then able to interact with non-soluble compounds like chlorofluorocarbons, and UV light breaks off chlorine radicals (Cl). These chlorine radicals break off an oxygen atom from the ozone molecule, creating an oxygen molecule (O2) and a hypochlorite radical (ClO). The hypochlorite radical then reacts with atomic oxygen creating another oxygen molecule and another chlorine radical, thereby preventing the reaction of monatomic oxygen with O2 to create natural ozone. This way, methane plays a role in hindering the formation of the Ozone layer. Above about 65 km, photodissociation of methane becomes an important mechanism for **Ozone loss**.

The temperature stratification in Stratosphere

In the stratosphere, temperature has a tendency to rise. This is due to the presence of Ozone. The first thing we have to note is that the air is highly rarefied and there are only eight ozone molecules to a million. The ozone (O3) here absorbs high energy Ultraviolet energy waves from the Sun and is broken down into atomic oxygen (O) and diatomic oxygen (O2). Atomic oxygen is found prevalent in the upper stratosphere due to the bombardment of UV light and the destruction of both ozone and diatomic oxygen. The mid stratosphere has less UV light passing through it, O and O2 are able to combine, and is where the majority of natural ozone is produced. It is when these two forms of oxygen recombine to form ozone that they release the heat found in the stratosphere. The lower stratosphere receives very low amounts of UV, thus atomic oxygen is not found here and ozone is not formed (with heat as the byproduct). This vertical stratification, with warmer layers above and cooler layers below, makes the stratosphere dynamically stable: there is ***no regular convection and associated turbulence in this part of the atmosphere.*** The top of the stratosphere is called the stratopause, above which the temperature decreases with height.

Aviation & Jet Streams in Stratosphere

Stratosphere is free from the violent weather changes which occur below in the Troposphere. So, it is preferred by commercial airliners. The commercial airliners typically cruise at altitudes of 9–12 km in the lower reaches of the stratosphere. They do this to **optimize fuel burn**. Jet liners, however, face another menace in stratosphere, namely jet streams. Jet streams are high velocity **horizontal** air currents. The main jet streams are located near the tropopause, the transition between the troposphere (where temperature decreases with altitude) and the stratosphere (where temperature increases with altitude). The location of the jet stream is extremely important for aviation. Jet streams are NOT always harmful for aviation. They are beneficial and used commercially as it reduced the trip time and fuel consumption. Commercial use of the jet stream began in 1950s when an aeroplane flew from Tokyo to Honolulu at an altitude of 7,600 meters cutting the trip time by over one-third. It also nets fuel savings for the airline industry.

Ozone Layer

As discussed above, the **Ozone layer is contained within the stratosphere.** In this layer ozone concentrations are about 2 to 8 parts per million, which is much higher than in the lower atmosphere but still very small compared to the main components of the atmosphere. It is mainly located in the lower portion of the stratosphere from about 15–35 km, though the thickness varies seasonally and geographically. About 90% of the ozone in our atmosphere is contained in the stratosphere.

The Ozone layer absorbs ultraviolet radiation from the sun and converts it into heat and chemical energy. It is this activity that is responsible for the rise in temperature. The layer is NOT of uniform thickness. ***Height at the equator is maximum and lowest at the poles.***

Mesosphere

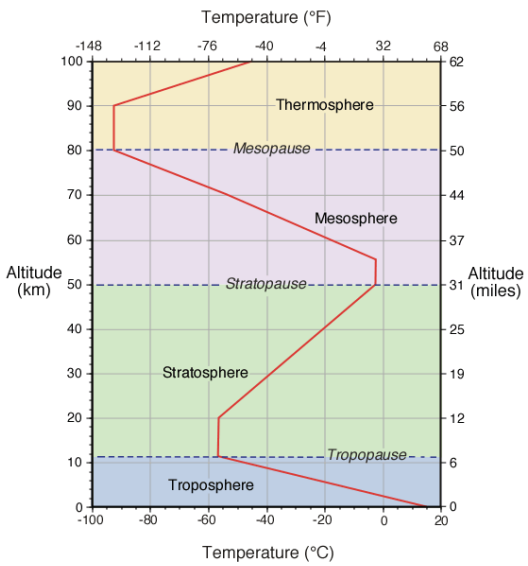
Model Question - 14.

While approaching towards Earth, most meteorites get burnt in the ___:

A. Troposphere
B. Stratosphere
C. Mesosphere
D. Ionosphere

Answer: 14

The mesosphere extends from the stratopause to 80–85 km. Most meteoroids get burnt in this layer. Temperature **decreases with height in the mesosphere**. The **mesopause**, the temperature minimum that marks the top of the mesosphere, is the coldest place around Earth and has an average temperature around −85 °C. At the mesopause, temperatures may drop to −100 °C. Due to the cold temperature of the mesosphere, water vapour is frozen, forming ice clouds. These clouds are called **noctilucent clouds**. This implies that the **noctilucent clouds are** the highest clouds in the Earth's atmosphere, located in the mesosphere at altitudes of around 76 to 85 kilometers (47 to 53 mi). They are normally too faint to be seen, and are visible only when illuminated by sunlight from below the horizon while the lower layers of the atmosphere are in the Earth's shadow. Noctilucent clouds are not fully understood and are a recently discovered meteorological phenomenon.



Mesopause, a thin layer of extremely cold atmosphere, separates the mesosphere from the Ionosphere above.

Ionosphere

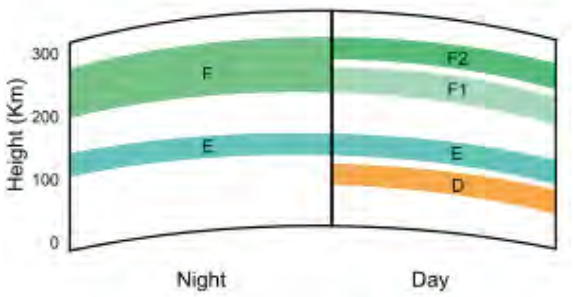
Ionosphere is called so because it is ionized by solar radiation. It plays an important part in **atmospheric electricity** and forms the inner edge of the magnetosphere. Ionosphere stretches from 50 to 1,000 km and typically overlaps both the exosphere and the thermosphere. It has practical importance because it influences, for example, radio propagation on the Earth. It is also *responsible for auroras.*

Ionosphere is also known as THERMOSPHERE because of the high temperatures because of the high temperatures prevailing there as much as **870°C over the equator** and **1427°C over the north pole**, the temperature near the upper boundary of the thermosphere may become higher than 1000-1500°C. Along with temperature rise sharp changes caused by the corpuscular and ultraviolet solar radiation are observed in it.

We note that the ionization depends primarily on the Sun and its activity. This means that the amount of ionization in the ionosphere varies greatly with the amount of radiation received from the Sun. This is the reason

that there are changes in the Ionosphere and there are diurnal effect and seasonal effects. The activity of the Sun is associated with the position of earth in the revolutionary orbit, sunspot cycle, with more radiation occurring with more sunspots. Radiation received also varies with geographical location (polar, auroral zones, mid-latitudes, and equatorial regions). There are also mechanisms that disturb the ionosphere and decrease the ionization. There are disturbances such as solar flares and the associated release of charged particles into the solar wind which reaches the Earth and interacts with its geomagnetic field.

Accordingly, Ionosphere has been divided into different sets of layers during day and night which are shown in this graphic:



The D layer explains **why the AM Radio gets disturbed during day time**, but quite smooth in night time. We see in the above graphics that the D layer is the innermost layer, 60 km to 90 km above the surface of the Earth. At this layer, the net ionization effect is low, but loss of wave energy is great due to frequent collisions of the electrons. This is the reason that the high-frequency (HF) radio waves are not reflected by the D layer but suffer loss of energy therein. The absorption is small at night and greatest about midday. This causes the disappearance of distant AM broadcast band stations in the daytime.

The E layer is the middle layer, 90 km to 120 km above the surface of the Earth, with primary source of ionization being soft X-ray (1-10 nm) and far ultraviolet (UV) solar radiation ionization of molecular oxygen (O2). This layer disappears in the night because primary source of ionization is no longer present. The practical value of this layer is that it reflects long radio-waves back to earth, which enables them to be received at a distance, rather than disappear into space. It is also known as HEAVYSIDE-KENNELY LAYER.

Why E-layer is important?

The E layer is a region of the ionosphere which influences long-distance communications by strongly reflecting radio waves in the 1-3 megahertz. It is also called E region, Heaviside layer, or Kennelly-Heaviside layer. This region reflects radio waves of medium wavelength and allows their reception around the surface of the Earth. The layer approaches the Earth by day and recedes from it at night. In technical terms, it is a cylinder of relativistic electrons gyrating in the magnetic field, which produces a self field strong enough to dominate the externally applied field and produces half reversal in the system. Since the mid '20s, another connection regarding the ionosphere has been hypothesized that lightning can interact with the lower ionosphere. According to this theory, thunderstorms could modulate the transient, localized patches of relatively high-electron density in the mid-ionosphere E layer, which significantly affects radio wave propagation.

The **F LAYER** extends from about 200 km to more than 500 km above the surface of Earth. The E-layer allows the penetration of short-radio waves, which continue until they reach the APPLETON LAYER. . Appleton layer reflects short-radio waves (which have penetrated the HEAVYSIDE-KENNELY LAYER) back to earth. This is also supposed to be the region where polar AURORAS occur and where most of the meteors burn themselves out.

Concept of Aurora

The luminous effect of electro-magnetic phenomena in the ionosphere is known as **Aurora**, visible *in high latitudes* as red, green and white arcs, draperies, streamers, rays and sheets in the night sky, best developed at a height of about 90 km. Probably, aurora is the result of magnetic storms and of electrical discharges from the sun during periods of sun-spot activity, causing ionization of gases, though this is still a matter of research. It is called the ***Aurora Borealis*** (or northern lights) in the northern hemisphere and the **Aurora Australis** in the southern hemisphere. Occasionally the Aurora borealis is seen in England, but it is more common in northern Scotland, presents a magnificent spectacle in northern Scandinavia and northern Canada.

Exosphere

The exosphere lies above the altitude of 800 kilometer and it needs further studies. Characteristic of exosphere is an extreme rarefaction of the air; gas particles, moving with tremendous velocities, nearly fail to meet one another and there takes place an outflow of gas particles into the interpreter space.

Atmosphere and Insolation

Sun is the major source of energy for the entire earth system. The earth does receive very small proportions of energy from other stars and from the interior of the earth itself (volcanoes and geysers provide certain amount of heat energy). However, when compared with the amount received from the sun, these other sources seem insignificant.

Earth's Albedo
The ratio between the total solar radiation falling (incident) upon a surface and the amount reflected without heating the earth, is called ALBEDO (expressed as a decimal or as a percentage). The earth's average albedo is about 0.4 (40 percent) ; that is , 4/10 of the solar radiation is reflected back into space. It varies from 0.03 for dark soil to 0.85 for a snow-failed. Water has a low albedo (0.02) with near-vertical rays, but a high albedo for low-angle slanting rays. The figure for grass is about 0.25. Over-pastured land and bare soil are more reflective of solar radiation than are crops and vegetation. A desert is much more reflective than a savanna or forest. If economic pressure on soil and vegetation increases, and drought then occurs, the effect overall is to increase the albedo of the surface.

The energy emitted by the sun which reaches the surface of the earth is called **Insolation**. The sun, a mass of intensely hot gases, with a temperature at the surface be 6000°C emits radiant energy in the form of waves, which consists of very short wave-length x-rays, gamma rays, and ultraviolet rays; the visible light rays and the longer infrared rays. The earth receives only about one **two-thousand-millionth** of the total insolation poured out by the sun, but this is vital to it; the amount received at the outer limit of the atmosphere is called **Solar Constant**. Thus **Solar Constant** is the rate per unit area at which solar radiation is received at the outer limit of the atmosphere.

Effects of the Atmosphere on Solar Radiation

Model Question - 15.

Diffusion of light in the atmosphere primarily takes place due to ___:

A. Carbon dioxide
B. Dust Particles
C. Helium
D. Water vapours

Answer: 15

When the sun's energy passes through the atmosphere several things happen to it. Around one fourth of this energy is directly reflected back to clouds and the ground. Around 8 percent is scattered by minute atmospheric particles and returned to space as diffuse radiation. Some 20 percent reaches the earth's surface as diffuse radiation after being scattered. Approximately 27 percent reaches the earth's surface as direct radiation and 19 percent is absorbed by the ozone layer and by water vapour in the clouds of the atmosphere.

On an average, 47 percent of the solar energy arriving at the outer limits of the atmosphere eventually reaches the surface, and 19 percent is retained in the atmosphere. This 19 percent of direct solar radiation that is retained by the atmosphere is locked up in the clouds and the ozone layer and is thus not available to heat the troposphere. The warmth of the atmosphere is due to the 47 percent of incoming solar energy reaching the earth's surface (that is, both land and bodies of water) and in the transfer of heat energy from the earth back to the atmosphere through such physical processes such as **Long-Wave Radiation, Conduction and Convection**. Some related phenomena such as **advection** and **Latent Heat of Condensation** also contribute to the warmth of the atmosphere.

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15 Correct Answer is B, Dust Particles.

Radiation as method of Heat Energy Transfer

Model Question - 16.

The atmosphere of the Earth primarily get heated due to ___:

A. Conduction of Heat Energy by Atmosphere
B. Convection of Heat Energy
C. Radiation from Earth
D. Absorption of Solar light

Answer: 16

Model Question - 17.

Consider the following statements:

1. Atmosphere of the Earth does not get heated by the solar radiation directly
2. Solar radiation is mostly shorter waves in comparison to Earth's radiation

Which among the above statements is / are correct?

Answer: 17

Radiation is the process by which most energy is transferred through space from the sun to the earth. Radiation is given off by all bodies including earth and human being. The ***hotter is the body, shorter are the waves***.

We can simply say that the radiation from Sun comes to earth in the form of smaller waves and earth being cooler body, gives off energy in the form of long-wave. These are then radiated back to the atmosphere. This Long-Wave Radiation from the earth's surfaces heats the lower layers of the atmosphere. It is evident that the atmosphere is primarily heated from below by radiation from the heated Earth surface.

As we discussed above, the most important cause of atmospheric temperature is the energy received from the sun. The ***atmosphere of the earth does not heat up directly as solar radiation is in the form of short waves and air cannot absorb the short waves.*** The earth absorbs the short wave energy and then radiates in the form of long wave terrestrial radiation that can be absorbed by the air. So, air heats up when comes in contact with the surface of the earth.

Conduction as Method of Heat Transfer

Conduction is the means by which heat is transferred from one part of a body to another or between two touching objects. Heat flows from the warmer to the cooler (part of a) body in order to equalize temperature. Conduction actually occurs through molecular movement, with one molecule bumping into another. The Atmospheric conduction occurs at the interface of (zone of contact between) the atmosphere and the earth's surface. However, it is actually a insignificant method of heat transfer in terms of warming the atmosphere since it affects only the layers of air closest to the earth's surface. This is because air is a very poor conductor of heat.

Convection as Source of Heat Transfer

When the pockets of air near the surface are heated, they expand in volume, become less dense than the surrounding air, and therefore rise. This vertical transfer of heat through the atmosphere is called convection, and is the same type of process by which heated water circulates in a pan while heating. The currents set into motion by the heating of a fluid (liquid or gas) make up a convectional system. Most vertical transfer of heat within the atmosphere & Oceans occurs via Convection and is a major cause of clouds and precipitation.

Advection as Source of Heat Transfer

Advection is the horizontal heat transfer within the atmosphere. Obviously the wind is the transfer agent of advection. Wind brings about the horizontal movement of large portions of lower atmosphere. This advection transports warmer or accounts for a major proportion of the lateral heat transfer that takes place within the atmospheric system.

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16 Correct Answer is C.

17 Both statements are True

Latent Heat of Condensation

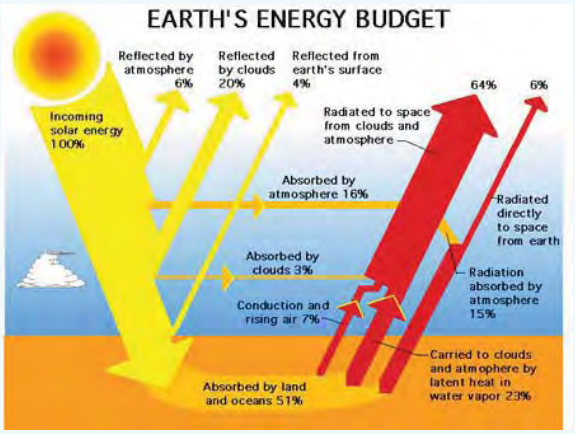
A proportion of the solar energy is used to change liquid water from rivers, lakes, and oceans to water-vapour. The solar energy used to do this is then stored in the water-vapour as latent or potential energy. Later the water-vapour in the atmosphere may change to form liquid water again through a process called CONDENSATION. The energy released through this process is known as the **Latent Heat of Condensation**. Like other means of heat transfer in the earth system, latent heat of condensation plays a major role in warming of the atmosphere and in addition, is a **source of energy for STORMS**.

Earth's Energy Budget

Earth's Energy Budget

Incoming Heat Energy

- Solar radiation (99.97%)
- Geothermal energy (0.025%)
- Tidal energy (0.002%)
- Fossil fuel consumption (about 0.007%)
- Minor Sources: remains part



Outgoing Heat Energy

- The average albedo (reflectivity) of the Earth is about 0.3, which means that 30% of the incident solar energy is reflected into space, while 70% is absorbed by the Earth and reradiated as infrared. This 30% of the incident energy is reflected, consisting of 6% reflected from the atmosphere, 20% reflected from clouds and 4% reflected from the ground (including land, water and ice). The remaining 70% of the incident energy is absorbed, out of 51% is absorbed by land and water, and then emerges in the following ways:
- 23% is transferred back into the atmosphere as latent heat by the evaporation of water, called latent heat flux
- 7% is transferred back into the atmosphere by heated rising air, called Sensible heat flux
- 6% is radiated directly into space
- 15% is transferred into the atmosphere by radiation, then reradiated into space
- 19% is absorbed by the atmosphere and clouds, including:
- 16% reradiated into space
- 8. 3% transferred to clouds, from where it is radiated back into space.

The above figures are the averages for the whole earth over a year's time.

Model Question - 18.

Earth's Heat energy budget is most balanced near ___?

A. Equator
B. Tropic of Capricorn & Cancer
C. Around 40° N and S Latitudes
D. Poles

Answer: 18

For any particular location, the factors discussed may not be balanced, and adjustments must be made within the entire earth system. Some places have a surplus of incoming solar energy over outgoing energy loss in their budget, while others have a deficit. The main cause of these variations is the differences in latitude, and the seasonal fluctuations.

We know that the amount of insolation received is directly related to the latitude. The tropical zone where insolation in high throughout the year; more solar energy is received at the earth's surface and in the atmosphere than can be emitted back into space. In the arctic and Antarctic zones there is so little insolation during the winter, when the earth is still emitting long-wave radiation, that there is a large deficit for the year. Places in the midlatitude zone have lower deficits or surpluses, but only at about **latitude 38° is the budget balanced**. It is the *heat energy transfer within the atmosphere that prevents a situation whereby the tropical zones get hotter and hotter and the arctic and Antarctic zone get colder and colder.*

18 Correct Answer is C.

Temperature differs from one part of the world to the other. Since Insolation is the basic source of energy for the atmosphere, the distribution of insolation would determine the temperature of the earth. Thus **latitude, altitude, distance from sea, features of the surface, nature of the landscape** are some important factors that affect the distribution of temperature.

Since, the insolation is highest at equator; temperature should be highest at the equator and lowest near the poles, however actually it is not. *Highest temperature on earth is recorded at a few degrees north of equator*. Altitude is the second major control of temperature of a place. The temperature depends upon albedo of the surface also.

One major factor affecting the distribution of the temperature of Earth is distribution of Land and Oceans. Since there is more land in Northern Hemisphere and more waters in Southern hemisphere and *there is a big difference between the specific heat of land and water;* the **loss of heat from the continents is bigger than the oceans**. The continents get heated faster and get cooled faster in comparison to the Oceans. This is the reason that the *temperatures of the Oceans are moderate while that of continents is extreme*. The moderating effect on temperature of the land due to proximity of the seas is called **Maritime influence**. The increasing effect on temperature of the land at interior of the continents is called **Continental Influence**.

Three Broad Temperature Zones

The earth can be generally divided into three broad temperature zones.

Model Question - 19.

Consider the following statements:

1. Highest temperature on earth is recorded in the Torrid Zones
2. Torrid zones have Four Seasons
3. Sun is always overhead in Torrid Zones
4. Sun is never overhead in Temperate Zones

Which among the above statements is / are correct?

Answer: 19

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Torrid Zone:

Torrid Zone is the tropical region. The temperature remains high. Sun is directly overhead at least once during the year. In the Northern Hemisphere, the overhead Sun moves north from the equator until it reaches 23.5 °North (Tropic of Cancer) for the June solstice after which it moves back south to the equator. The year is consequently divided nearly into four equal parts by the two times at which the sun crosses the equator (Equinoxes) and those two at which it attains greatest declinations (Solstices). The Torrid Zone forms the hottest region of the world with ***two annual seasons namely a dry and a wet season***. This zone includes most of Africa, southern Asia, Indonesia, New Guinea, northern Australia, southern Mexico, Central America and northern South America.

Temperate Zones:

Temperate zones are the mid latitudinal areas, where the temperature is moderate. There are two temperate areas viz. North and South. In the two Temperate Zones, consisting of the tepid latitudes, the **Sun is never directly overhead**, and the climate is mild, generally ranging from warm to cool. The **four annual seasons, Spring, Summer, Autumn and Winter occur in these areas.** The North Temperate Zone includes Great Britain, Europe, northern Asia, North America and northern Mexico. The South Temperate Zone includes southern Australia, New Zealand, southern South America and South Africa.

19 Correct statements are 1 and 4. Second statement is for temperate Zones.

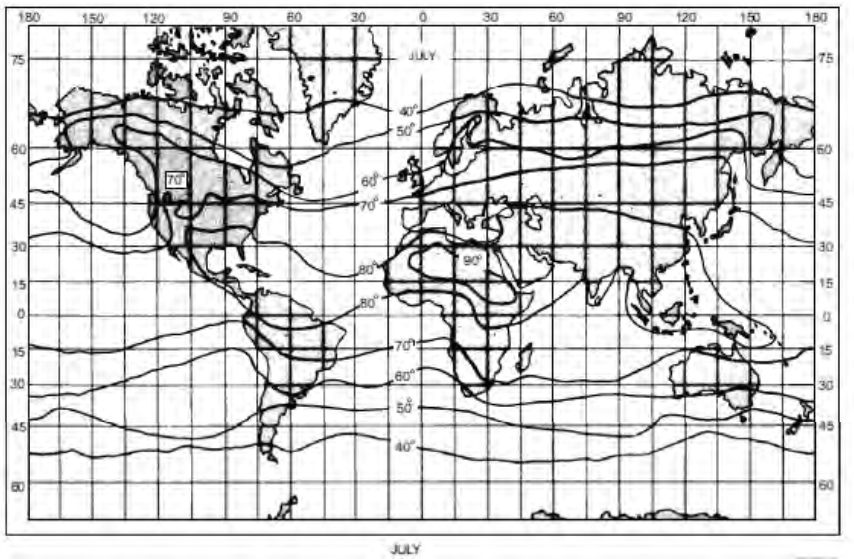
Frigid Zones

The two Frigid Zones, or polar regions, experience the midnight sun and the polar night for part of the year - the cliff of the zone experiences one day at the solstice when the Sun doesn't rise or set for 24 hours, while in the centre of the zone (the pole), the day is literally one year long, with six months of daylight and six months of night. Please note that the Frigid Zones are not the coldest parts of the earth, and are covered with ice and snow. The *coldest temperature on earth has been recorded a few degrees below the 90°N.*

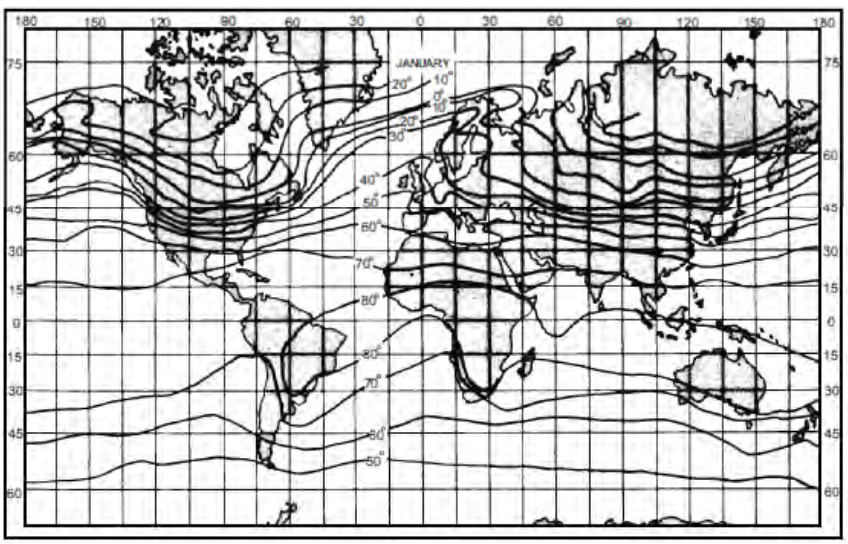
Patterns of Global Isotherms

The global distribution of temperature can be represented with the help of isotherms. Isotherms are the lines that join the places with the identical temperatures. Please note that isotherms are drawn after correcting the temperature of a *place to the sea level so that the differences due to altitude can be minimized.* The *Isotherms on the earth run parallel to the latitudes*.

Due to the difference between the specific heat between water and land, at any latitude, the temperature over the landmass is higher in summer and lower in winter in comparison to the seas. Here we discuss about the global isotherms drawn in the month of January and July. As shown in the picture, Isotherms for the month of July bend towards Northward while moving from Sea to Land.



JULY



JANUARY

For the Month of January, the isotherms bend towards south while moving from sea to land. The only thing you have to note about Isotherms is that water in the South Atlantic and Pacific is absorbing greater amounts of energy during January and the land is rapidly heating and reradiating energy. Please also note that due to difference in the specific heat, both highest and lowest temperatures are observed in the interiors of the continents.

Vertical Distribution of Temperature

The vertical distribution of temperature on earth is also unequal. As we studied above in detail that in troposphere, the temperature falls uniformly with height as per the Environmental Lapse Rate. The normal value of this Lapse Rate is 6.4°C per kilometers. When a parcel of air rises upwards and cools this is known as adiabatic cooling. This adiabatic cooling is the result of the expansion of air as it is lifted upwards. When the air descends, it gets warmed and this is called adiabatic warming.

Inversion of the Temperature

In the mountain valleys, the temperature of the air is **found increasing with increasing altitude**. Thus there is an inversion of the temperature. This is because during the night, the quick radiation from the upper exposed

slopes of the mountains causes the surface and air over it to cool rapidly. This cooler air is denser and gets drained by the valley slopes and displaces the warmer air toward up. So, when we go up in a valley, the temperature seems to getting increased. This phenomenon is also called **drainage inversion**.

Mean Thermal Equator

Thermal equator is a **global isotherm having the highest mean annual temperature at each longitude around the globe.** Thermal equator does not coincide with the geographical equator. The ***highest absolute temperatures are recorded in the Tropics*** but the ***highest mean annual temperatures are recorded at equator***. But because local temperatures are sensitive to the geography of a region, and mountain ranges and ocean currents ensure that smooth temperature gradients (such as might be found if the Earth were uniform in composition and devoid of surface irregularities) are impossible, the location of the thermal equator is not identical to that of the geographic Equator.

Some Iso Words NOT worth cramming:

- Isallobars, isanomal, isobar (pressure);
- Isobase (elevation or depression of land);
- Isochrones (travelling time);
- Isogon, or isogonic lines (magnetic variation),
- Isohaline (salinity);
- Isohel (sunshine);
- Isohyets (rainfall);
- Isomer (the mean monthly rainfall as a percentage of the average annual amount).
- Isoneph (cloudiness);
- Isophene (flowering dates and other botanical and biological occurrences);
- Isoryme (frost);
- Isoseismal (earthquake intensity);
- Isostade (significant dates);
- Isotherm (temperature);
- Isotach (equal wind-speed);

Further, we know that the Earth reaches perihelion (the minimum distance from the Sun in its orbit) in early January and is at aphelion (maximum distance) in early July. During winter season of the respective hemispheres, the angle of incidence of the sun's rays is low in tropics. The average annual temperature of the tropical regions is therefore lower than the observed near the equator, as the change in the angle of incidence is minimum at equator.

The thermal equator shifts towards north and south with north south shift in the position of vertical rays of the sun. *However, annual average position of the Thermal equator is 5° N latitude*. The reason is that highest mean annual temperature shifts towards northwards during the summer solstice to a much greater extent than it does towards south at the time of winter solstice.

Daily variation of Temperature

Model Question - 20.

The highest daily temperature on earth is not recorded at 1200 hours during summer. What could be the most correct explanation to this?

A. The specific heat of Land is more than water
B. The land takes substantial time to get heated in comparison to it gets cooled
C. Atmosphere does not get heated directly by Sun's radiation
D. None of the above is a correct explanation.

Answer: 20

Sun is at the highest point at noon but the highest temperature does not occur at 1200 hours because the ***atmosphere does not get the heat directly from the Sun***. It receives heat from the earth's surface slowly and that is why maximum temperature is generally attained by 1400 hours (2.00p.m.). The daily minimum temperature at a place does not occur at about 0400 hours (4.00 p.m.) in the morning because radiation of heat continues upto the sun rise.

Model Question - 21.

Consider the following statements:

1. Highest range of variation of the daily temperature is found in Deserts
2. Lowest range of variation of the daily temperature is found in snow bounded areas
3. Continents record higher range of variation of daily temperature in comparison to Oceans

Which among the above statements is / are correct?

Answer: 21

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20 C is the correct answer.

21 All are correct answers.

Here are some notable observations on daily temperature ranges:

- Daily temperature range is **low in clouded areas** because the clouds obstruct the receipt and loss of insolation.
- The sky is clear in hot desert's areas. Insolation is received without obstruction in the day and lost without obstruction in the night. This causes **high temperature range in deserts.**
- Ice or snow absorbs less and reflects the insolation more. Hence, the daily temperature range is low is snow bound areas.
- The air is thin in areas of high altitude. There is great loss of insolation in the night. There is no obstruction in the receipt of insolation in the day. Such places have a high temperature range.
- There is a higher temperature range in than interior areas of continents than at seas because the sea heats and cools slowly but the land heats and cools rapidly.
- Warm and cool winds also disturb the temperature range.

Annual temperature range

Model Question - 22.

Consider the following statements:

1. Lowest annual temperature range is found in equatorial areas
2. Tibet will record high annual range of temperature in comparison to Indonesia

Which among the above statements is / are correct?

Answer: 22

On Equator

The duration of the day or night is the same in equatorial countries. The sun's rays are vertical all through the year. Hence, there is no worthwhile difference between the summer and winter seasons. This is the reason that the ***lowest annual temperature range is found in equatorial areas.***

On Poles

Towards the poles, the duration of the day and the inclination of the sun rays go on increasing. It causes a lot of difference between the temperatures of the two seasons. Hence, towards the poles, the annual temperature range goes on increasing.

Near Oceans

Near the seas and oceans, the equalizing effect of sea water makes the winter less cold and the summer less hot. This reduces the annual range of temperature near the seas. The equalizing effect of the sea water cannot reach land areas, away from the seas. The countries like Mongolia and Tibet which are situated far into the interior of the continent have a high annual range of temperature. The ocean currents near the coasts also affected the temperature range. Due to the warm gulf stream, the winter of western Europe is less cold than what it Europe is less cold than what it should have been without the gulf stream. This reduces the annual temperature range.

The shifting attitude of ocean currents has a lot of effect on the annual temperature range. For example, the weather and seasons have to undergo greater changes on the eastern coasts of Indian and Australia due to the shifting of ocean currents. It increases the annual temperature range on these coasts as compared to that on the opposite side coasts.

Impact of Winds

The prevailing winds also have a greater effect on the annual temperature range. Winds from the land blow in Arabian countries and therefore increase the annual range of temperature. Winds from the oceans and seas blow into Western Europe and reduce the annual temperature range. The variation in the annual temperature range in west and east European countries is due to land and sea winds. The effect of winds from the ocean has a far smaller effect in Eastern Europe than in Western Europe. It is why the annual temperature range is higher in eastern than in Western Europe.

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22 Both are correct statements.

Air has weight and a column of air extending vertically over a given area on earth's surface exerts pressure. The atmospheric pressure is measured as a force per unit of area and most common unit of measuring the air pressure is millibar. The instrument used for measuring pressure is Barometer. Some barometers are calibrated to show pressure in mercury inches. At constant temperature of 0°C and latitude of 45°, 1049 millibar is equal to 31 inches of mercury. Barograph is used to take continuous readings of air pressure.

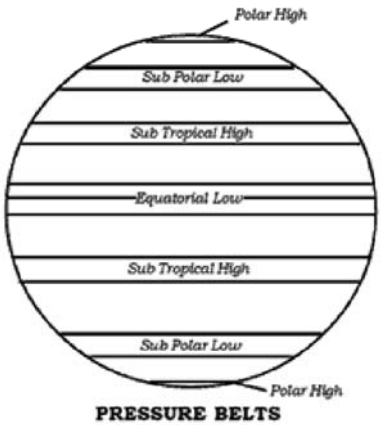
Measuring Atmospheric Pressure
Bar is a unit of pressure equal to 100 kilopascals and roughly equal to the atmospheric pressure on Earth at sea level. Other units derived from the bar are the megabar (symbol: Mbar), kilobar (symbol: kbar), decibar (symbol: dbar), centibar (symbol: cbar), and millibar (symbol: mbar or mb). Bar is neither an SI unit nor a CGS unit. 1 bar is 1% smaller than the atmosphere (symbol: atm), which now is defined to be 1.01325 bar exactly. One millibar is also equal to 1000 dynes per cm^2.

Pressure Belts of Earth

The distribution of pressure **on earth is uneven**. Usually pressure is inversely related to the temperature and pressure reduced with altitude. The major factors are earth's rotation and ascent and descent of air to affect distribution of pressure.

Creation of the Pressure Belts

Due to high amount of insolation over the equator, the air ascends and this air rising in the equatorial region descends at around 30° north and south latitudes. This means that the air at the equatorial region is thrown away from the earth and air at the Polar Regions is pulled towards earth. *This implies that there is a low pressure is on equator and there is a high pressure area on poles*. This gives rise to two belts of high pressure on Polar Regions each and one belt of low pressure on equator. The air that descends at 30°N and 30°S also created two belts of high pressures in the subtropical regions of both the hemispheres. Further, the rotation of the earth pulls the air at Polar Regions causes a rarification of air pressure at sub-polar regions. This also produces two belts of low pressure around 60°N and S latitude. This means that there are 7 belts of pressure as shown in the adjacent graphics.

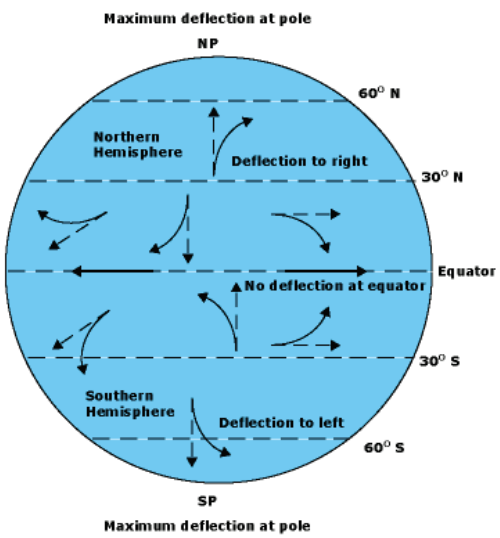


PRESSURE BELTS

The planetary distribution of pressure, in the 7 belts is determined by two major factors viz. **thermal factor and dynamic factor**. Please note that equatorial belt of low pressure and polar belts of high pressures are due to the thermal factor while, the subtropical belts of high pressure and subpolar belts of low pressure are primarily due to **earth's rotation or dynamic factors**.

Pressure and Winds

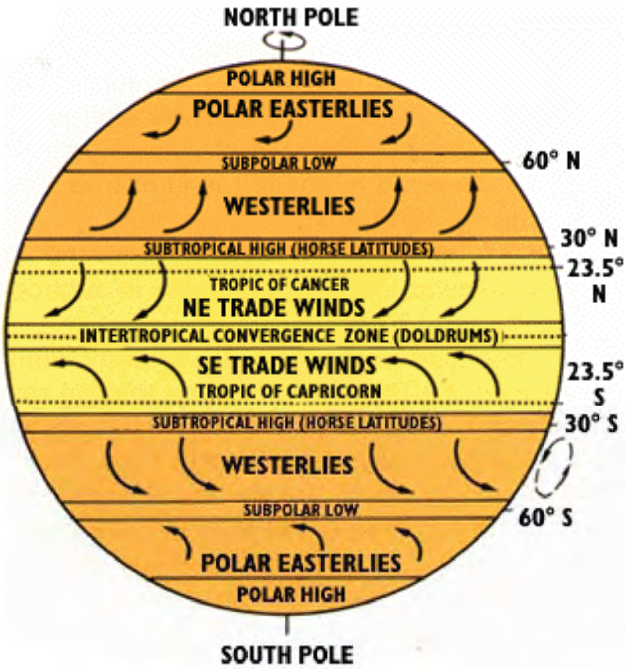
When air moves in a definite direction, it is called wind. If the winds move in west, they are called **westerlies**. If they move in east they are called **easterlies.** There are winds because there are differences in pressures. The direction of wind is also affected by coriolis affect. This affect, as we studied previously is caused by the rotation of earth. Due to Coriolis Force, the wind flowing from equator towards the North Pole and from North Pole towards the equator are deflected to their right while the winds flowing north-south and south-north in the southern hemisphere are deflected towards their left. The magnitude of the deflection, or "Coriolis effect," varies significantly with latitude. The **Coriolis Effect is zero at the equator** and **increases to a maximum at the poles**. The effect is proportional to wind speed; that is, deflection increases as wind strengthens. The resultant balance between the pressure force and the Coriolis force is such



that, in the absence of surface friction, air moves parallel to isobars (lines of equal pressure). This is called the **geotropic wind**. The Coriolis force explains why winds circulate around high and low pressure systems as opposed to blowing in the direction of the pressure gradient. Central idea behind the Coriolis force is that when the earth rotates from west to east, it produces the centrifugal force and due to this force, there is a change in the direction of the wind. There is Ferrel's law derived from Coriolis Effect, which says that in northern hemispheres, wind deflects towards the right and in southern hemisphere wind deflects towards left. This means that in northern hemisphere, wind deflects clockwise, while in southern hemisphere, wind deflects anti-clockwise.

Intertropical Convergence Zone / Doldrums

The pressure belt between the 0° to 5°N and S is called **Equatorial Low Pressure Belt**. This belt is characterized by intense heating, with expanding air and ascending convectional currents. Because the air is largely moving upward, surface winds are light and variable. This region is known as the **doldrums.**



The term doldrums has been used by the sailors as it has been marked by erratic weather patterns with stagnant calms and violent thunderstorms.

Doldrums are ***belt of calms and variable winds*** occurring at times along the equatorial trough. Doldrums are characterised by:

- Low atmospheric Pressure
- High Humidity
- Thunderstorms

The same area is also called the **Intertropical Convergence Zone** (ITCZ) or **Doldrums**. This is the area encircling the earth near the equator where winds originating in the northern and southern hemispheres come together. Please note that the location is not precisely defined as location of the Intertropical convergence zone varies over time. Over land, it moves back and forth across the equator following the sun's zenith point. Over the oceans, where the convergence zone is better defined, the seasonal cycle is more subtle, as the convection is constrained by the distribution of ocean temperatures. Sometimes, a double ITCZ forms, with one located north and another south of the equator. When this occurs, a narrow ridge of high pressure forms between the two convergence zones, one of which is usually stronger than the other. Between 10° and 15° North and South, there are high pressure belts, where air is comparatively dry, light and calm. This region is beneficial to the maritime trade.

Subtropical High / Horse Latitudes

Horse Latitudes or Subtropical High are subtropical latitudes between 30 and 35 degrees both north and south. This region, under a ridge of high pressure receives little precipitation and has variable winds mixed with calm. The air is **comparatively dry and calm**. This is also the region of descending air current and is marked by some

cyclonic activities. The consistently *warm, dry conditions of the horse latitudes also contribute to the existence of temperate deserts, such as the Sahara Desert in Africa, the southwestern United States and northern Mexico, and parts of the Middle East in the Northern Hemisphere; and the Atacama Desert, the Kalahari Desert, and the Australian Desert in the Southern Hemisphere.*

Other Belts

30°-60°North and South Belt region is of temperate low pressure belt or anti-trade wind area. It is marked by cyclones and anticyclones. 60°North and South are the two Temperate Low Pressure belts which are also called zones of convergence with Cyclonic activity. The 90° North and South are called Polar High belts.

Trade winds

Model Question - 23.

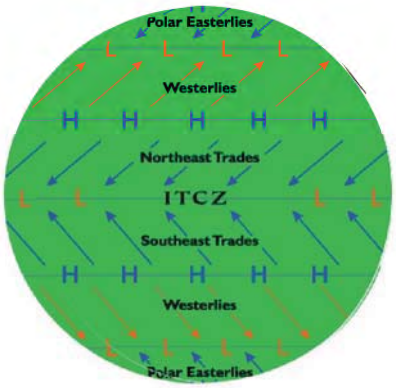
In context with the Trade Winds, Consider the following statements:

1. They are most regular winds on Earth
2. They blow towards east
3. They originate at high pressure areas
4. They are preferred by the sailors

Which among the above statements is / are correct?

Answer: 23

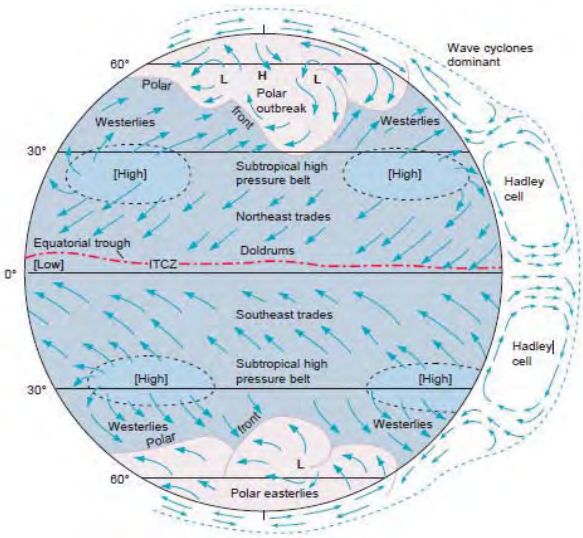
Trades wind blow out from the Subtropical High Pressure belts. In the northern hemisphere, they blow towards the equatorial low and called **North East Trade Winds.** In the Southern hemisphere they blow towards the equatorial low and become the **South East Trade winds**. This implies that Trade winds blow from <u>North east towards equator in Northern hemisphere and South East Towards equator in southern hemisphere.</u> It has been shown in the following graphics.



The trade winds are **<u>most regular winds of all kinds on earth</u>**. They blow with great force and in constant direction that is why they are preferred by the sailors. The trade winds bring heavy rain falls and sometimes contain intense depressions.

Trade winds and Hadley cells

There are three primary circulation cells on earth known as the Hadley cell, Ferrel cell, and Polar cell. The Hadley cell mechanism provides an explanation for the trade winds. Hadley cell is a closed circulation loop, which begins at the equator with warm, moist air lifted aloft in equatorial low pressure areas (the Intertropical Convergence Zone, ITCZ) to the tropopause and carried pole ward. At about 30°N/S latitude, it descends in a high pressure area. Some of the descending air travels equatorially along the surface, closing the loop of the Hadley cell and creating the Trade Winds. Hadley Cells is described to be lying on equator but it follows sun's zenith point, or what is termed the "thermal equator".



Origin of Trade Winds

Trade winds are part of the Hadley cell circulation. At the equator, a low-pressure area of calm, light variable winds is known Intertropical Convergence Zone as we discussed above. The air lifts from here and at around 30° North and South, the air begins to descend toward the surface in subtropical high-pressure belts known as subtropical ridges. At the surface, the air flows from these

23 1, 3 & 4 are correct answers. They blow from East and not to East.

subtropical high-pressure belts toward the Equator but is deflected toward the west in both hemispheres by the Coriolis Effect. Thus, these winds blow predominantly from the northeast in the Northern Hemisphere and from the southeast in the Southern Hemisphere. Because winds are named for the direction from which the wind is blowing, these winds are called the northeast trade winds in the Northern Hemisphere and the southeast trade winds in the Southern Hemisphere. **The trade winds meet at the doldrums.**

You can visualize more about trade winds & Hadley Cells in this animation: http://bit.ly/UfHnbt

Implications of Trade winds

- Trade winds are the surface winds in low latitudes, representing the low-level airflow. Back in history, two large belts of winds were discovered blowing toward the equator called North East and South East trade winds. The word trade in those days referred to advance steadily and was synonymous with efficient sailing. The trade winds allowed the sailing vessels to advance steadily—and, of course, to set up patterns of international trade. However, you must note that trade winds are not totally steady in force or direction, but they do trend in the general direction of southwest and northwest.
- Hawaii is located south of Tropic of Cancer, yet, the temperatures are pleasant, temperatures and humidity tends to be a bit less extreme. This makes it one of the most famous tourist destinations of the world. What make such a climate are Trade Winds.

Westerlies

Model Question - 24. (IAS 2011)

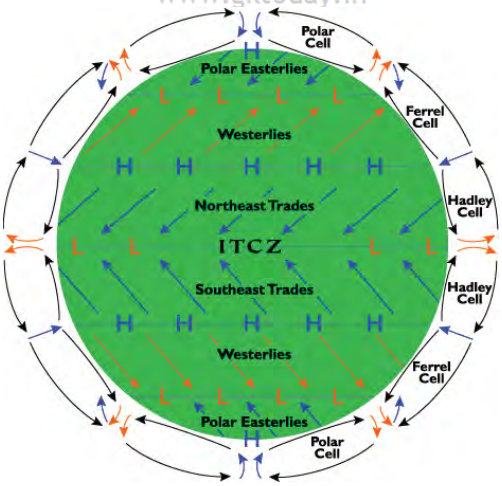
Westerlies in southern hemisphere are stronger and persistent than in northern hemisphere. Why?

1. Southern hemisphere has less landmass as compared to northern hemisphere.
2. Coriolis force is higher in southern hemisphere as compared to northern hemisphere.

Which of the statements given above is/are correct?

Answer: 24

The directions of the Westerlies are opposite to trade winds and that is why they are also called **antitrade winds**. Westerlies blow in the middle latitudes between 30 and 60 degrees latitude, and originate from the high pressure area in the horse latitudes towards the poles. Under the effect of the Coriolis force, they become the south westerlies in the northern hemisphere and Northern westerlies in the southern hemisphere. Please note that in the southern hemisphere, there is more of ocean and less of land in comparison to the northern hemisphere. Due to this reason, the westerlies blow with much greater force in southern hemisphere in comparison to northern hemisphere.



This also has implications in the Ocean currents. The currents in the Northern Hemisphere are weaker than those in the Southern Hemisphere due to the differences in strength between the Westerlies of each hemisphere.

Model Question - 25.

Consider the following statements:

1. Strongest westerlies blow in the winter hemisphere
2. Westerlies play role in the formation of tropical cyclones
3. Roaring Forties are a kind of westerlies

Which among the above statements is / are correct?

Answer: 25

Generally, **Westerlies are strongest in the winter hemisphere** and at times when the pressure is lower over the poles, while they are weakest in the summer hemisphere and when pressures are higher over the poles.

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24 Only 1 is correct.

25 Only 1 & 3 are correct answer.

Please note the westerlies are also associated with the "**extra tropical**" cyclones which refer to the fact that this type of cyclone generally occurs outside of the tropics, in the middle latitudes of the planet, where the Westerlies steer the system generally from west to east. Whenever there is a convergence of the cold and denser polar winds and warm and light westerlies, there are much variation in the weather. The velocity of the westerlies increases southward and they become stormy. When we move towards poles, the velocity of the westerlies is given different terms as follows:

- Roaring Forties between the 40-50°S
- Furious Fifties at the 50°S and Shrieking Sixties at 60°S.

Polar Easterlies

Polar easterlies blow from the polar high pressure belts towards the temperate low pressure belts. These are extremely cold winds that come from the Tundra and Icecap regions of the poles. The Polar Easterlies ***are more regular in the southern hemisphere in comparison to the northern hemisphere***. These polar cold winds converge with the warm easterlies near 60° latitudes and form the Polar front or Mid Latitude front. This mid-latitude front becomes the centre of the origin of the Temperate Cyclones.

Local Winds

How they are formed?

The Local winds around the world are formed through the *heating of land*. In coastal regions, the sea breezes and land breezes are important factors in a location's prevailing winds. The sea is warmed by the sun more slowly because of water's greater specific heat compared to land. As the temperature of the surface of the land rises, the land heats the air above it by conduction. The warm air is less dense than the surrounding environment and so it rises. This causes a pressure gradient of about 2 millibar from the ocean to the land. The cooler air above the sea, now with higher sea level pressure, flows inland into the lower pressure, creating a cooler breeze near the coast. At night, the land cools off more quickly than the ocean because of differences in their specific heat values. This temperature change causes the daytime sea breeze to dissipate. When the temperature onshore cools below the temperature offshore, the pressure over the water will be lower than that of the land, establishing a land breeze, as long as an onshore wind is not strong enough to oppose it.

Local winds near Mountains

There is a different explanation for local winds near mountains. Over elevated surfaces, heating of the ground exceeds the heating of the surrounding air at the same altitude above sea level, creating an associated thermal low over the terrain and

Major Local Winds

- **Abroholos:** squall frequent wind that occurs from May through August between Cabo de Sao Tome and Cabo Frio on the coast of Brazil
- **Amihan :** northeasterly wind across the Philippines
- **Bayamo :** violent wind on Cuba's southern coast
- **Bora :** northeasterly from eastern Europe to northeastern Italy
- **Calima :** dust-laden south to southeasterly wind blowing in the Saharan Air Layer across the Canary Islands
- **Cape Doctor :** dry south-easterly wind that blows on the South African coast in summer
- **Chinook :** warm dry westerly off the Rocky Mountains
- **Elephanta :** strong southerly or southeasterly wind on the Malabar coast of India
- **Föhn :** warm dry southerly off the northern side of the Alps and the North Italy, the name gave rise to the fén-fēng or 'burning wind' of Taiwan
- **Fremantle Doctor :** afternoon sea breeze from the Indian Ocean which cools Perth, Western Australia during summer
- **Gregale :** northeasterly from Greece
- **Habagat :** southwesterly wind across the Philippines
- **Harmattan :** dry northerly wind across central Africa
- **Karaburan :** "black storm", a Spring and Summer Katabatic wind of central Asia
- **Khamsin :** southeasterly from north Africa to the eastern Mediterranean
- **Khazri :** cold north wind in the Absheron Peninsula of the Azerbaijan Republic
- **Kona :** southeast wind in Hawaii, replacing trade winds, bringing high humidity and often rain
- **Košava :** strong and cold southeasterly season wind in Serbia
- **Lodos :** southwesterly towards Turkey. Strong "Lodos" events occur 6 - 7 times a year bringing 35 kt winds into Marmara Sea. The winds are funneled SE from the Mediterranean and through the Dardanelles Strait.
- **Loo :** hot and dry wind which blows over plains of India and pakistan.
- **Mistral :** cold northerly from central France and the Alps to Mediterranean
- **Monsoon :** mainly south-westerly winds combined with heavy rain in various areas close to the equator
- **North wind :** northern cold winds blowing from the Gulf of Mexico to the Isthmus of Tehuantepec
- **Nor'easter :** strong storm with winds from the northeast in the eastern United States, especially New England
- **Nor'wester :** wind that brings rain to the West Coast, and warm dry winds to the East Coast of New Zealand's South Island, caused by the moist prevailing winds being uplifted over the Southern Alps, often accompanied by a distinctive arched cloud pattern
- **Pampero :** Argentina, very strong wind which blows in the Pampa
- **Simoom :** strong, dry, desert wind that blows in the Sahara, Israel, Jordan, Syria, and the desert of Arabia
- **Sirocco :** southerly from north Africa to southern Europe
- **Sundowner :** strong offshore wind off the California coast
- **Zonda wind :** on the eastern slope of the Andes in Argentina

enhancing any thermal lows that would have otherwise existed, and changing the wind circulation of the region. In areas where there is rugged topography that significantly interrupts the environmental wind flow, the wind circulation between mountains and valleys is the most important contributor to the prevailing winds.

Barrier Jet

The mountains and valleys are capable to distort the airflow by increasing friction between the atmosphere and landmass by acting as a physical block to the flow, deflecting the wind parallel to the range just upstream of the topography, which is known as a **barrier jet**. This barrier jet can increase the low level wind. Wind direction also changes because of the contour of the land. If there is a pass in the mountain range, winds will rush through the pass with considerable speed because of the Bernoulli principle that describes an inverse relationship between speed and pressure. The airflow can remain turbulent and erratic for some distance downwind into the flatter countryside. These conditions are dangerous to ascending and descending airplanes.

Monsoon

The word monsoon derived from the Arabic word *mausim* means seasonal winds. In this system, the direction of the winds reverses seasonally. The first thing we note is that Monsoon is typically considered a phenomenon of tropical south Asia, but it is also experienced over parts of North America and Africa.

Origin of Monsoon: Traditional View

Traditionally, monsoon has been considered a result of the differential heating of land and sea.

- In summer, southern Asia develops a low pressure while the pressure over the sea is relatively higher. As a result the air starts flowing towards land from the Indian oceans. The winds coming from ocean carry moisture and thus cause rainfall in summer reason. This is known as the southwest monsoon or summer monsoon.
- In winter, the pressure over land is higher than over the sea and consequently the air starts flowing from land to sea. The air coming from land being dry, these winds do not cause rainfall.

The above explanation is known as the thermal theory of monsoon. This theory explains monsoon as a regional phenomenon but fails to explain the total amount of energy / processes involved in the global monsoon circulation.

Origin of Monsoon: Modern View

The modern meteorologists seek explanation for the phenomenon of monsoon on the basis of *seasonal shift in the position of the global belts of pressure and winds*. This is also known as **Dynamic Theory**.

According to the dynamic theory, monsoons are a result of the *shift of the inter-tropical convergence zone (ITCZ) under the influence of the vertical sun.* Though the average position of the ITCZ is taken as the equator, it keeps shifting vertical sun towards with the migration of the vertical sun towards the tropics during the summer of the respective hemisphere.

- During summer in the northern hemisphere in the months of May and June, the sun shines vertically over the tropic of cancer. Due to the northward shift of the zone of maximum heating and low pressure at this time the ITCZ also shifts northwards and approaches, the tropic of cancer. The ITCZ being the zone of the lowest pressure in the tropical region is the destination of the trade winds blowing from both the hemispheres.
- With ITCZ situated close to the tropic of cancer the northeast trade winds are confined to an area extending to its north while the southeast trade winds blowing from the southern hemisphere have to cross the equator to reach this area of low pressure. However as the winds blowing from the southern hemisphere cross the equator their direction is altered due to Coriolis effect, i.e. they are direction is their right and thus it give rise to the formation of a belt of equatorial westerlies in the months of many of June northeast and they are called the southwest monsoon.

- As the ITCZ again moves southwards at the end of the summer of the northern hemisphere the areas north of the equator which experienced the equatorial westerlies during the summer season come under the influence of the northeast trade winds. These northeasterly winds are called the northeast monsoons. The onset of winter season the ITCZ shifts south of the equator and reaches as far south at this time. in this season the northeast trades blowing towards the ITCZ have to cross the equator towards south and as a result they get deflected giving rise to the equatorial westerlies in the southern hemisphere. these westerlies blow form the northwest to the southwest, replacing the trade winds of the southern hemisphere between the ITCZ and the equator. They form the summer monsoon of the southern hemisphere.

We can say that due to the seasonal shift of the wind belts under the influence of the north-south migration of the vertical sun the areas situated in the tropical zone in the both the hemisphere come under the influence of the trade winds during the respective winter and the equatorial westerlies during the respective summer season. The direction of the winds is thus reversed seasonally and it makes up the monsoon system of these regions.

Please note that though, dynamic theory provides a much better explanation of the system of monsoon as a global phenomenon, it does not negate the influence of differential heating of land and sea.

Differential heating still plays an important role in making monsoon much stronger in certain of the south-west monsoon factor that explains the extension of the southwest monsoon even to the north of the tropic of cancer in northern India.

Rainfall

The amount of moisture in air is commonly recorded as **relative humidity**; which is the percentage of the total water vapour air can hold at a particular air temperature. The presence of warm, moist and unstable air and sufficient amount of the hygroscopic nuclei is a prerequisite condition for rainfall. The warm and moist air after being lifted upwards becomes saturated and clouds are formed after condensation of water vapour around the hygroscopic nuclei such as dust particles.

How much water vapour a parcel of air can contain before it becomes saturated (100% relative humidity) and forms into a cloud (a group of visible and tiny water and ice particles suspended above the Earth's surface) depends on its temperature. Warmer air can contain more water vapour than cooler air before becoming saturated.

Cooling

The process of condensation begins only when the relative humidity of the ascending air becomes 100% and air is cooled through four main mechanisms to its dew point: adiabatic cooling, conductive cooling, radiational cooling, and evaporative cooling.

- **Adiabatic cooling** occurs when air rises and expands. The air can rise due to convection, large-scale atmospheric motions, or a physical barrier such as a mountain (orographic lift).
- **Conductive cooling** occurs when the air comes into contact with a colder surface, usually by being blown from one surface to another, for example from a liquid water surface to colder land.
- **Radiational cooling** occurs due to the emission of infrared radiation, either by the air or by the surface underneath.
- **Evaporative cooling** occurs when moisture is added to the air through evaporation, which forces the air temperature to cool to its wet-bulb temperature, or until it reaches saturation.

Further, we note that the very small rain drops are almost spherical in shape. As drops become larger, they become flattened on the bottom, like a hamburger bun. Very large rain drops are split into smaller ones by air resistance which makes them increasingly unstable. When water droplets fuse to create larger water droplets, it is called Coalescence. When water droplets freeze onto an ice crystal, which is known as the **Bergeron process**.

Air resistance typically causes the water droplets in a cloud to remain stationary. When air turbulence occurs, water droplets collide, producing larger droplets. As these larger water droplets descend, coalescence continues, so that drops become heavy enough to overcome air resistance and fall as rain. Coalescence generally happens most often in clouds above freezing, and is also known as the warm rain process.

Convectional Rainfall

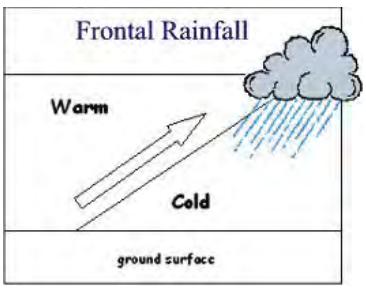
The convectional rainfall occurs due to the thermal convection currents caused due to the heating of ground due to insolation. The convectional rainfall is prevalent in equatorial regions. In these, the warm air rises up and expands then, reaches at a cooler layer and saturates, then condenses mainly in the form of **cumulus or cumulonimbus clouds**. In the equatorial regions, the precipitation due to convectional rainfall occurs in the afternoon. The rainfall is of very short duration but in the form of heavy showers.

Cyclonic / Frontal Rainfall

Frontal rainfall occurs due to the upward movement of the air caused by the convergence of different air masses with different temperatures. The warm air rises over the cold air and cyclonic rain occurs. The cold air pushes up the warm air and sky gets clear again.

Orographic Rainfall

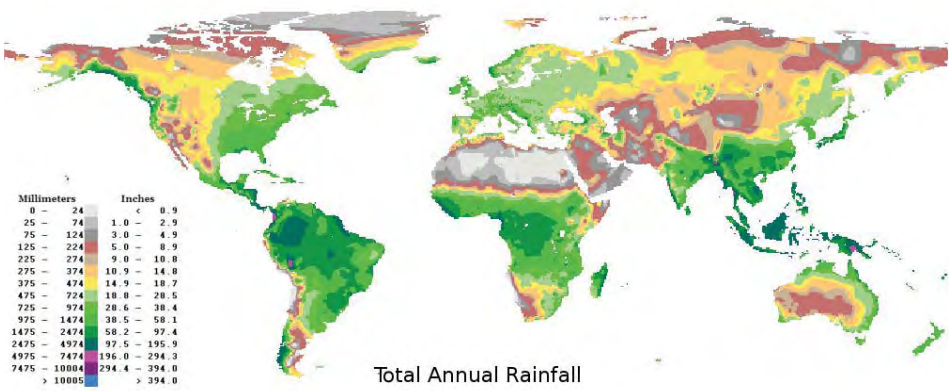
The orographic rainfall occurs due to the ascent of air forced by the mountain barrier. The mountain barrier should be across the wind direction. So that the moist air is forced in obstruction to move upward and get cooled. In Rajasthan, the Aravalli is not an obstructing barrier to the highly moist air coming from Arabian Sea and that is why they don't play very important role in rainfalls. Thus they produce a Rain shadow area. A rain shadow is a dry area on the lee side of a mountainous area. The mountains block the passage of rain-producing weather systems, casting a "shadow" of dryness behind them. In south India, the Mangalore is located on the western windward slope and gets 2000 mm of rainfall. But Bangalore is in rain shadow area and that is why receives less than 500 mm of rainfall.



Please note that the amount of the rainfall increases with increasing height of the barrier such as mountain, but this is up to a certain limit. After that there is a marked decrease due to lesser moisture content of the air and this phenomenon is called "**Inversion of Rainfall**"

Distribution of Rainfall

The regions having high temperature and abundance of water receive higher amount of rainfall, such as equatorial regions. In the subtropical regions, the western parts receive lesser rainfalls. This is due to anticyclone activities.



Mean annual rainfall for earth is 970mm. The equatorial regions receive rainfall through out the year while the other regions receive rainfall seasonally. The Mediterranean region receives rainfall during the winter generally.

Air Mass & Fronts

Air mass is a volume of air defined by its temperature and water vapour content. An air mass may be of many hundreds or thousands of square miles, and adopt the characteristics of the surface below them. An air mass can be so extensive that it may cover the large portion of a continent below it and may be vertically so thick that may cover the troposphere. The vertical distribution of the temperature in an air mass and moisture content of the air are the two properties of air air mass which control the weather conditions of an area under that particular air mass. The air mass is considered to be cold air mass if its temperature is lower than the underlying surface, while an air mass is terms warm air mass when its temperature is higher than the underlying surface. The boundary between the two air masses is called the **front.**

Air masses are classified according to latitude and their continental or maritime source regions. Colder air masses are termed polar or arctic, while warmer air masses are deemed tropical. Continental and superior air masses are dry while maritime and monsoon air masses are moist. Weather fronts separate air masses with different density (temperature and/or moisture) characteristics. Once an air mass moves away from its source region, underlying vegetation and water bodies can quickly modify its character.

Frontogenesis and Frontolysis

The boundary between the two air masses is called the **front.** A temperature difference is essential in the definition of a front because it implies a density difference. The air masses of different densities don't mix readily and tend to retain their identity as far as we care for the moisture. The front represents a transition zone between two air masses of different density. Generally, an air mass from one region moves to the other region which is occupied by some other air mass. When a warmer and lighter air mass moved against a cold and denser air mass, the former rides over the other and it is called **warm front.** If the cold air mass forces its way under a warm air mass, it is called **cold front.** When new fronts are created or old fronts are regenerated, it is called Frontogenesis. Please note that fronts don't appear all of a sudden. They appear only after a process of Frontogenesis which is there in place for quite some time. When winds converge towards a point it would lead to **Frontogenesis**.

Frontogenesis takes place only when two conditions are met. First, two air masses of different densities must exist adjacent to one another; and second, a prevailing wind field must exist to bring them together. There are three basic situations, which are conducive to Frontogenesis and satisfy the two basic requirements. The wind flow is cross isothermal and flowing from cold air to warmer air. The flow must be cross isothermal, resulting in a concentration of isotherms (increased temperature gradient). The flow does not have to be perpendicular; however, the more perpendicular the cross isothermal flow, the greater the intensity of Frontogenesis.

On the other hand, the dying of a front is called **Frontolysis.** Frontolysis also does not happen all of a sudden. The process of Frontolysis must happen for quite some time to destroy the existing front.

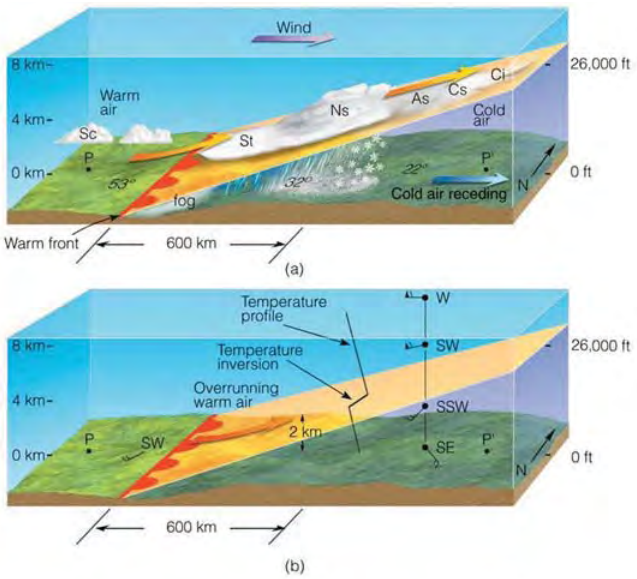
Types of Fronts

Cold Front

When a cold air invades the warm air, it remains at the ground and forcibly **uplifts the warmer and lighter air mass.** This is known as **Cold front.** This upward motion causes lowered pressure along the cold front and can cause the formation of a narrow line of showers and thunderstorms when enough moisture is present. Cold fronts can move up to twice as fast as warm fronts and can produce sharper changes in weather. Since cold air is denser than warm air, it rapidly replaces the warm air preceding the boundary. Cold fronts are usually associated with low-pressure areas. Cold front usually causes a shift of wind from southeast to northwest, and in the southern hemisphere a shift from northeast to southwest.

Warm front

When a warmer and lighter air mass moved against a cold and denser air mass, the former rides over the other and it is called **warm front.** Being lighter, the warm air mass is unable to displace the cooler air mass and instead is forced upward along the upper boundary of the colder air in a process known as overrunning. The boundary between the two air masses has a gradual slope of 130 and lifting is slow but persistent. As the air mass rises into regions of lower pressure, it expands and cools. As it cools, water vapour condenses and forms extensive cloud coverage. The first clouds to form along the sloping surface of the cold air are high cirrus, which thicken to cirrostratus and altostratus.



Occluded front

An occluded front is a front that is formed when a cold front overtakes a warm front. The cold front moves rapidly than the warm front. Ultimately, the cold front overtakes the warm front and completely displaces the warm air at the ground.

Contents

Part I. Some Concepts in Climatology

Cyclones

Cyclone is a *system of low atmospheric pressure in which the barometric gradient is steep*. Cyclones represent circular fluid motion **rotating in the same direction as the Earth.** This means that the inward spiralling winds in a cyclone rotate anticlockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere of the Earth. Most large-scale cyclonic circulations are centred on areas of low atmospheric pressure. The cyclones can be tropical cyclones or temperate cyclones (extra-tropical cyclones).

Model Question - 1.

Consider the following statements in context with Tropical Cyclones and Extra-tropical cyclones:

1. While tropical cyclones are warm core, the extra tropical cyclones are cold core
2. While tropical cyclones extract much of their energy from the upper layer of the ocean, Extratropical cyclones derive much of energy from land

Which among the above statements is / are correct?

Answer: 1

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Basic difference between Tropical Cyclone and Extra-tropical Cyclone

The term "tropical cyclone" is used to refer to **warm-core**, low-pressure systems that develop over tropical or subtropical oceans. This definition differentiates tropical cyclones from extra tropical (midlatitude) cyclones that exhibit a **cold-core** in the upper troposphere and often form along **fronts in higher latitudes**. Subtropical cyclones are hybrid systems that exhibit some characteristics of tropical cyclones and some characteristics of extra-tropical cyclones.

Tropical cyclones extract much of their energy from the upper layer of the ocean, while extratropical cyclones derive much of their energy from the *baroclinic temperature gradients in which they form*.

Tropical Cyclones

The tropical cyclone is a system of low pressure occurring in tropical latitudes characterized by very strong winds. Here are the important notes which you must note about the Tropical Cyclones:

Distribution

- The tropical cyclones are found over the North Atlantic Ocean, Southern Atlantic Ocean, the eastern, central and western North Pacific Ocean, the central and western South Pacific Ocean and the northern and southern Indian Ocean.

Formation in Low Pressure areas

- All tropical cyclones are formed in areas of low atmospheric pressure in the Earth's atmosphere.

Minimum Pressure is at centre

- The pressures recorded at the centers of tropical cyclones are among the lowest that occur on Earth's surface at sea level.

1 Only 1 is a correct statement.

Driver is the Large Heat of Condensation

- Tropical cyclones are driven by the release of large amounts of latent heat of condensation, which occurs when moist air is carried upwards and its water vapour condenses. This heat is distributed vertically around the center of the storm. Thus, at any given altitude, environment inside the cyclone is warmer than its outer surroundings.

Eye is the sinking air

- There is an area of sinking air at the center of circulation, which is known as Eye. *Weather in the eye is normally calm and free of clouds, although the sea below it may be extremely violent*. Eye is normally circular in shape, and is typically 30–65 km in diameter.

Stadium Effect

- The mature tropical cyclones sometimes exhibit an outward curving of the eye wall's top, making it resemble an arena football stadium. It is called Stadium Effect.

Greatest Wind speeds are at eye walls

- Greatest wind speeds in a tropical cyclone is found at the eye wall, which is a circle of strong thunderstorms that surrounds the eye. Here, the clouds reach the highest, and precipitation is the heaviest. The heaviest wind damage occurs where a tropical cyclones eye wall passes over land.

Source of the huge Energy

- Primary energy source is the release of the heat of condensation from water vapour condensing, with solar heating being the initial source for evaporation. So a tropical cyclone can be visualized as a giant vertical heat engine supported by mechanics driven by physical forces such as the rotation (Coriolis force) and gravity of the Earth. Inflow of warmth and moisture from the underlying ocean surface is critical for tropical cyclone strengthening.

Impact of Earth's Rotation

- The rotation of the Earth causes the system to spin (Coriolis Effect) giving it a cyclonic characteristic and affecting the trajectory of the storm. In Northern Hemisphere, where the cyclone's wind flow is counterclockwise, the fastest winds relative to the surface of the Earth occur on the eastern side of a northward-moving storm and on the northern side of a westward-moving one; the opposite occurs in the Southern Hemisphere, where the wind flow is clockwise.

Movement of Clouds

- In Lower troposphere, motion of clouds is toward the center. At upper-level, there is outward flow of clouds.

Formation in Northern Atlantic Ocean

- Northern Atlantic cyclone season occurs from June 1 to November 30, sharply peaking from late August through September. The statistical peak of the Atlantic hurricane season is 10 September.

Formation in North East Pacific

- The Northeast Pacific Ocean has a broader period of activity, but in a similar time frame to the Atlantic.

Formation in North West Pacific

- The Northwest Pacific sees tropical cyclones year-round, with a minimum in February and March and a peak in early September.

Formation in North Indian basin

- Storms are most common from April to December, with peaks in May and November.

Formation in Southern Hemisphere

Tropical cyclone year begins on July 1 and runs all year-round and encompasses the tropical cyclone seasons, which run from November 1 until the end of April, with peaks in mid-February to early March.

Requirements for formation:

- Water temperatures of at least 26.5 °C down to a depth of at least 50 m, so that it may cause the overlying atmosphere to be *unstable enough to sustain convection and thunderstorms*.
- Rapid cooling with height, so that it may cause release of the heat of condensation that powers a tropical cyclone.

- High humidity
- Low amounts of wind shear as high shear is disruptive to the storm's circulation.
- A **distance from the Equator is necessary,** which should be at least 555 km or 5° of latitude, so that it *allows the Coriolis effect to deflect winds blowing towards* the low pressure center and creating a circulation. Because the Coriolis effect initiates and maintains tropical cyclone rotation, tropical cyclones rarely form or move within about 5° of the equator, where the Coriolis effect is weakest.
- A pre-existing system of disturbed weather.

Movement

Coriolis Effect causes cyclonic systems to turn towards the poles in the absence of strong steering currents. The pole ward portion of a tropical cyclone contains easterly winds, and the Coriolis effect pulls them slightly more pole ward. The westerly winds on the Equatorward portion of the cyclone pull slightly towards the equator, but, because the Coriolis effect weakens toward the equator, the net drag on the cyclone is pole ward. Thus, tropical cyclones in the Northern Hemisphere usually turn north (before being blown east), and tropical cyclones in the Southern Hemisphere usually turn south (before being blown east) when no other effects counteract the Coriolis Effect.

High speed of rotation

- It is caused by Coriolis effect as well as energy released by heat of condensation.

Fujiwhara effect

When two cyclones approach one another, their centers will begin orbiting cyclonically about a point between the two systems. The two vortices will be attracted to each other, and eventually spiral into the center point and merge. *When the two vortices are of unequal size, the larger vortex will tend to dominate the interaction, and the smaller vortex will orbit around it. This phenomenon is called the Fujiwhara effect.*

Impact on passing over land

We should note that the ***deep convection is a driving force for tropical cyclones***. The convection is strongest in a tropical climate; it defines the initial domain of the tropical cyclone. This is a major difference between the Tropical cyclones with other mid-latitude cyclones as the later derive their energy mostly from pre-existing horizontal temperature gradients in the atmosphere. To continue to drive its heat engine, a *tropical cyclone must remain over warm water,* which provides the needed atmospheric moisture to keep the positive feedback loop running. When a tropical cyclone passes over land, it is cut off from its heat source and its strength diminishes rapidly. The moving over land deprives it of the warm water it needs to power itself, quickly losing strength. Thus, most strong storms lose their strength when the pass on to land, but if it manages to move back to ocean, it will regenerate.

Impact of passing over cold water

When a tropical storm moves over waters significantly below 26.5 °C, it will lose its strength. This is because of losing its tropical characteristic of the warm core.

Project Stormfury

The United States Government attempted in 1960s and 1970s to artificially weaken the Cyclones. During this project, Cyclones were seeded with silver iodide. It was thought that the seeding would cause supercooled water in the outer rainbands to freeze, causing the inner eye wall to collapse and thus reducing the winds. The ***Hurricane Debbie*** lost as much as 31% of its strength, when seeded with Silver Iodide in this project but Debbie regained its strength after each of two seeding forays. So, it was not a good idea. There were some more ideas applied which were as follows:

- Cooling the water under a tropical cyclone by towing icebergs into the tropical oceans and covering the ocean in a substance that inhibits evaporation

- Dropping large quantities of ice into the eye at very early stages of development (so that the latent heat is absorbed by the ice, instead of being converted to kinetic energy that would feed the positive feedback loop)
- Blasting the cyclone apart with nuclear weapons.
- A Project called Project Cirrus involved throwing dry ice on a cyclone.
- None of the idea was very much practical because the tropical storms are too large and too momentary.

Naming of Cyclones

Tropical cyclones are classified into three main groups, based on intensity: tropical depressions, tropical storms, and a third group of more intense storms, whose name depends on the region. If a tropical storm in the North-western Pacific reaches hurricane-strength winds on the Beaufort scale, it is referred to as a typhoon. If a tropical storm passes the same benchmark in the Northeast Pacific Basin, or in the Atlantic, it is called a hurricane. Neither "hurricane" nor "typhoon" is used in either the Southern Hemisphere or the Indian Ocean. In these basins, storms of tropical nature are referred to simply as "cyclones".

Types of the Tropical Cyclones

There are three kinds of Tropical cyclones:

- **Tropical Depression:** A tropical depression is a system with low pressure enclosed within few isobars and with the wind speed of 60 kmph. It lacks marked circulation
- **Tropical Storm:** It is a system with several closed isobars and a wind circulation of 115 kmph.
- **Tropical Cyclone:** It is a warm core vortex circulation of tropical origin with small diameter , circular shape and occurs in oceanic areas.

Anticyclones

An 'anticyclone' is opposite to a cyclone, in which winds move into a low-pressure area. In an anticyclone, winds move out from a high-pressure area with wind direction clockwise in the northern hemisphere, anti-clockwise in the southern hemisphere. Such a high pressure area is usually spread over a large area, created by descending warm air devoid of moisture. The absence of moisture makes the dry air denser than an equal quantity of air with moisture. When it displaces the heavier nitrogen and oxygen, it causes an anti-cyclone.

Tornado

Basically, hurricanes and typhoons form over water and are huge, while tornados form over land and are much smaller in size. A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud. In the United States, twister is used as a colloquial term for tornado.

What is it?

Technically, a tornado is a rotating column of air that is in contact with both the surface of the earth and a cloud, which is generally cumulonimbus and occasionally cumulus. Most tornadoes have wind speeds less than 110 miles per hour and travel several kilometers before dissipating.

How it is formed?

First the rotating cloud base lowers. This lowering becomes a funnel, which continues descending while winds build near the surface, kicking up dust and other debris. Finally, the visible funnel extends to the ground, and the tornado begins causing major damage.

Where they are seen?

Tornadoes have been observed on every continent except Antarctica.

How they are detected?

Tornadoes can be detected before or as they occur through the use of Pulse-Doppler radar by recognizing patterns in velocity and reflectivity data.

What is Fujitsa Scale?

Fujita scale rates tornadoes by damage caused, and has been replaced in some countries by the updated Enhanced Fujita Scale. An F0 or EF0 is the weakest tornado, while F5 or EF5 is the strongest tornado.

What is Torro Scale?

TORRO scale ranges from a T0 for extremely weak tornadoes to T11 for the most powerful known tornadoes.

Funnel Cloud as predecessor

Tornadoes often begin as funnel clouds with no associated strong winds at the surface, although not all evolve into a tornado. However, many tornadoes are preceded by a funnel cloud. Most tornadoes produce strong winds at the surface while the visible funnel is still above the ground, so it is difficult to discern the difference between a funnel cloud and a tornado from a distance.

Infrasonic signature

Tornadoes produce identifiable inaudible infrasonic signatures. Due to the long distance propagation of low-frequency sound, efforts are ongoing to develop tornado prediction and detection devices with additional value in understanding tornado morphology, dynamics, and creation.

Electromagnetic Spectrum

Tornadoes emit on the electromagnetic spectrum. There are observed correlations between tornadoes and patterns of lightning.

When they occur?

Tornadoes are most common in spring and least common in winter. Spring and fall experience peaks of activity as those are the seasons when stronger winds, wind shear, and atmospheric instability are present. Tornado occurrence is highly dependent on the time of day, because of solar heating. Worldwide, most tornadoes occur in the late afternoon, between 3 pm and 7 pm local time, with a peak near 5 pm.

Temperate Cyclones

Temperate cyclones are generally called depressions. The have low pressure at the centre and increasing pressure outwardly. They are of varying shapes such as circular, elliptical. The formation of tropical storms as we read above are confined to oceans, the temperate cyclones are ***formed over land and sea alike.*** Temperate Cyclones are formed in 35-65° North as well as South Latitudes. While the tropical cyclones are largely formed in summer and autumn, the temperate cyclones are formed in generally winter. Rainfall in these cyclones is low and continuous not as furious as in case of tropical cyclones.

Part II. Concepts of Biogeography

Biogeography is the study of the distribution of plants and animals and related eco-system, the geographical relationship with related environments over time. Biogeography is an integrative field of inquiry that unites concepts and information from ecology, evolutionary biology, geology, and physical geography. Some fundamental concepts in biogeography include

- **Biospheres:** global sum of all ecosystems.
- **Evolution:** Change in genetic composition of a population
- **Extinction:** Disappearance of a species
- **Dispersal:** Movement of populations away from their point of origin, related to migration
- **Geodispersal:** The erosion of barriers to biotic dispersal and gene flow, that permit range expansion and the merging of previously isolated biotas
- **Vicariance :** The formation of barriers to biotic dispersal and gene flow, that tend to subdivide species and biotas, leading to speciation and extinction

Biosphere

Biosphere is the **global sum of all ecosystems**. Biosphere is the zone of life on earth and is a closed (apart from solar and cosmic radiation) and self-regulating system. So, Biosphere is the global ecological system integrating all living beings and their relationships, including their interaction with the elements of the lithosphere, hydrosphere and atmosphere. The origin of Biosphere

Biosphere-2 and BIO-3

There is a man made Biosphere developed for research purposes in Arizona of United States. This manmade Biosphere is known as Biosphere-2. Biosphere-2, which is enclosed by Glass structures, is the largest closed system ever created. It studies the possibility of creating artificial Biospheres in space.

Apart from this Biosphere-2, we have one BIOS-3 developed by Russia. It has been constructed by Institute of Biophysics in Krasnoyarsk, Russia. The work on BIOS-3 started in 1965 and finished in 1972. BIOS-3 consists of a 315-cubic-metre habitat suitable for up to three persons, and was initially used for developing closed ecosystems capable of supporting humans. The Chlorella algae were used to recycle air breathed by humans, absorbing carbon dioxide and replenishing it with oxygen through photosynthesis. The BIOS-3 was used for conducting 10 manned closure experiments with a one to three man crew.

was through *Biogenesis or Biopoesis*. Biopoesis started 3.5 billion years ago. Since, Humans have not been able to discover life beyond earth as of now, Earth's life system is the only biosphere currently known. This has been fashionably named as **Biosphere-1**. Biospheres contain the smaller units known as Ecosystems. The ecosystems may be natural or artificial.

Elements of Biosphere

Elements of the biosphere are divided in four categories on functional basis:

Abiotic or Physical Elements

These include basic elements of the habitats and dead organic compounds.

Producers

These are primarily autotrophic green plants and are intermediaries between abiotic and biotic components of the biosphere because they manufacture their food through photosynthesis and derive nutrients from the soils through root osmosis. Herbivores and carnivores (consumers) depend for their food on producers.

Consumers

Consumers are heterotrophic organisms which include animals and man and are further divided into primary consumers (herbivores), secondary consumers (carnivores) and omnivores.

Decomposers

Decomposers are microorganisms which decompose dead plants and animals.

Ecosystem

An ecosystem is a biological environment consisting of all the organisms (biota) living in a particular area, as well as all the nonliving (abiotic), physical components of the environment with which the organisms interact, such as air, soil, water and sunlight. Organisms (plants and animals) or biotic communities interact among themselves as well as with their physical environment like soil, air and water. The living organisms interact with one another through their food chains in which one organism consumes another organism. The living organisms like plants interact with soil to get essential nutrients; with air to get carbon dioxide and also with water bodies, for carrying out the process of photosynthesis.

Types of Ecosystems

We can say that the Biotic Communities like plants and animals along with soil, air and water of that region form a self-sustaining or functional unit of the living world. This 'functional unit' or 'system' made up of **living + non-living components** which is **capable of independent existence** is called an Ecosystem. *In an Ecosystem, the Biotic and Non-Biotic components are linked to each other via nutrient cycle and energy flow.*

An ecosystem can be **natural or manmade.** The Natural ecosystems are Terrestrial ecosystem, Aquatic ecosystem, **Lentic Ecosystem**-the ecosystem of a lake, pond or swamp or **Lotic Ecosystem**- the ecosystem of a river, stream or spring. The Artificial Ecosystems are manmade. Best example of an artificial ecosystem is an aquarium.

Ecosystem Services

Services derived from ecosystems are referred to as **Ecosystem Services**. Ecosystem services may include facilitating the enjoyment of nature, which may generate many forms of income and employment in the tourism sector, often referred to as eco-tourisms, Water retention, thus facilitating a more evenly distributed release of water, Soil protection, open-air laboratory for scientific research, etc.

When new elements are introduced in an ecosystem, whether biotic or abiotic, they tend to

There are four categories of Ecosystem Services as follows:

Supporting services
- Nutrient dispersal and cycling
- Seed dispersal
- Primary production

Provisioning services
- Food (including seafood and game), crops, wild foods, and spices
- Water
- Minerals (including diatomite)
- Pharmaceuticals, biochemical, and industrial products
- Energy (hydropower, biomass fuels)

Regulating services
- Carbon sequestration and climate regulation
- Waste decomposition and detoxification
- Purification of water and air
- Crop pollination
- Pest and disease control

Cultural services
- Cultural, intellectual and spiritual inspiration
- Recreational experiences (including ecotourism)
- Scientific discovery

have a disruptive effect. In some cases, this can lead to ecological collapse or "**trophic cascading**" and the death of many species within the ecosystem.

Biomes

Model Question - 2.

What is / are the difference(s) between an Ecosystem and a Biome?

1. An ecosystem comprises biotic as well as abiotic components , while a biome has only biotic components
2. An ecosystem is generally larger part of Biosphere, while a Biome is a smaller part.

Which among the above statements is/ are correct?

Answer: 2

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Biomes are groups of ecosystems that share similar conditions in an environment. The first thing we have to note that a Biome is a larger part that may comprise many ecosystems. Technically, **Biomes are groups of ecosystems** that share similar conditions in an environment. A biome is a large area with similar flora, fauna, and microorganisms. Most of us are familiar with the tropical rainforests, tundra in the arctic regions, and the evergreen trees in the coniferous forests. Each of these large communities contains species that are adapted to its varying conditions of water, temperature, and soil. For instance, polar bears thrive in the arctic while cactus plants have a thick skin to help preserve water in the hot desert. So, the typical characteristics of the Biomes are that they have:

- Similar climatic conditions
- Same kind of abiotic and biotic factors spread over a large area creating a typical ecosystem over that area.

However, please note that *a Biome as well as an ecosystem may have many species*. In fact, the biomes are divided on the basis of factors such as plant structures (such as trees, shrubs, and grasses), leaf types (such as broadleaf and needle leaf), plant spacing (forest, woodland, savanna), and climate.

Please note that Earth is often divided into generally six terrestrial biomes and two aquatic biomes, each of which contains a number of distinct ecosystems. Terrestrial biomes are those that occur on the land and include deserts, grasslands, tropical forests, temperate forests, taiga, and tundra.

- The Aquatic Biomes occur in water and are often divided into the marine and freshwater biomes, depending on the salinity of the water.
- Each biome may contain several different ecosystems such as coral reefs, seagrass beds, kelp forests, and salt marshes.

Ecozones

Model Question - 3.

Question: What is the difference between an Ecozone and a Biome?

1. An Ecozone comprises only land parts of Earth surface, while the Biomes comprise both aquatic and land parts
2. Each Ecozone has some finite number of species , while each biome has infinite number of species
3. Ecozone is a larger ecosystem. A biome is a group of ecosystems.

Which among the above statements is/ are correct?

Answer: 3

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Ecozones are the Biogeographic division of the Earth's land surface, based on distributional patterns of terrestrial organisms. This means that they include **ONLY terrestrial part of the Biosphere** and that is why they are alternatively called "**Terrestrial Ecozones**". Further, Ecozones are defined by **genetic, taxonomic, or Geological similarities,** rather than the Morphology, plant structures, leaf types, plant spacing or climates. Then, an Ecozone can include a number of different biomes. They both are groups of ecosystems.

Types of Ecozones

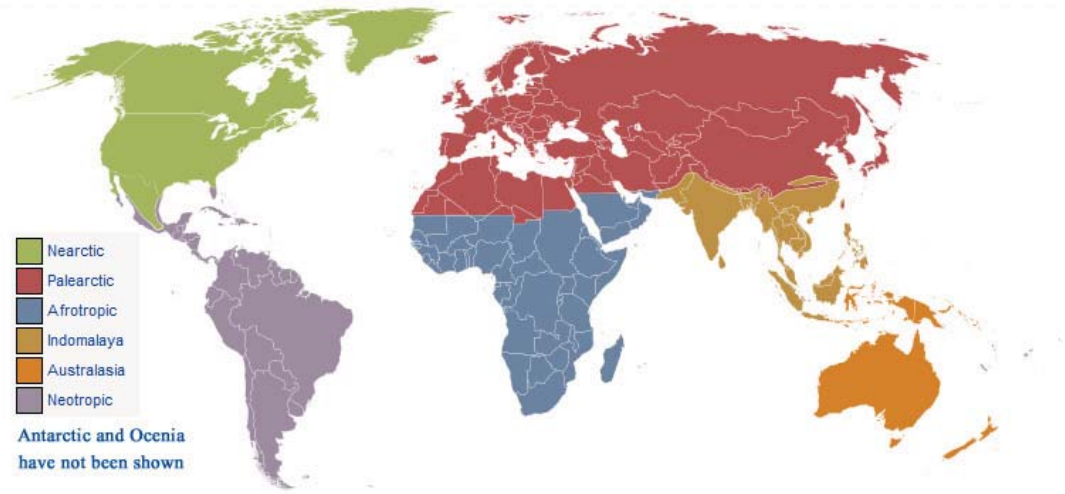
There are 8 Ecozones on earth as shown in the following table:

---

2 Both are incorrect.

3 Only first statement is correct.

Ecozone	Area Km^2	Included regions
Palearctic	54.1	Includes the bulk of Eurasia and North Africa, This is largest
Nearctic	22.9	Includes most of North America
Afrotropic	22.1	Includes Sub-Saharan Africa
Neotropic	19.0	Includes South America and the Caribbean
Australasia	7.6	Includes Australia, New Guinea, and neighbouring islands. The northern boundary of this zone is known as the Wallace line.
Indo-Malaya	7.5	Includes the Indian subcontinent and Southeast Asia
Oceania	1.0	Includes Polynesia, Melanesia, Micronesia, New Zealand and some parts of Australia
Antarctic	0.3	Includes Antarctica.



Each Ecozone has been further subdivided into the bioregions. The WWF defines the bioregions as "geographic clusters of ecoregions that may span several habitat types, but have **strong biogeographic affinities, particularly at taxonomic levels** higher than the species level (genus, family)". For example, **Indomalaya Ecozone** has three bioregions viz. Indian subcontinent, Indochina and Sunda Shelf and Philippines

Major Biomes and Ecozones of the World

The following tables mentions the major Biomes and Ecozones of the world.

Terrestrial Biomes	
Polar/montane	1. Tundra 2. Taiga, Boreal forests 3. Montane grasslands and shrublands
Temperate	1. Coniferous forests 2. Broadleaf and mixed forests 3. Grasslands, savannas, and shrublands
(Sub)tropical	1. Coniferous forests 2. Moist broadleaf forests 3. Dry broadleaf forests 4. Grasslands, savannas, and shrublands
Dry	1. Mediterranean forests, woodlands, and scrub 2. Deserts and xeric shrublands
Wet	1. Flooded grasslands and savannas 2. Riparian 3. Wetland

Aquatic Biomes	Ecozones
1. Pond	1. Endolithic zone
2. Littoral	2. Afrotropic
3. Intertidal zone	3. Antarctic
4. Mangrove forest	4. Australasia
5. Kelp forest	5. Indomalaya
6. Coral reef	6. Nearctic
7. Neritic zone	7. Neotropic
8. Continental shelf	8. Oceania
9. Pelagic zone	9. Palearctic
10. Benthic zone	
11. Hydrothermal vents	
12. Cold seeps	

The word **Montane** is derived of *Mountain*. The Montane biome lies between 1800-2000 metres above mean sea level and has cooler temperatures and often have high rainfalls in comparison to the adjacent lowland areas.

Arctic Tundra

The word Tundra is derived of a Finnish word "*tunturi*" which means **treeless mountain tract**. In Tundra Biome, the tree growth is hindered by low temperatures and short growing seasons. The vegetation in Tundra is composed of Dwarf Shrubs, mosses, lichens etc. Some scattered trees are also found. The ecological boundary (ecotone) between the tundra and taiga forests is called tree line or timberline.

- There are three types of Tundra Regions in the world viz. **Arctic Tundra, Alpine Tundra and Antarctic Tundra**. In Northern hemisphere, the Tundra occurs north of the Taiga belt.
- The **most important characteristic of Tundra is the Permafrost**. Permafrost is the permanently frozen soil. Permafrost is consisting mostly of gravel and finer material. The soil is frozen from 25-90 cms down and **very few plants can grow in it**, so the permafrost is plain without many trees. Some parts of the permafrost are bare and support growth of ***some lichens***.
- There are **ONLY two seasons in Polar Tundra regions viz. summer and winter**. During winter, it is very cold and dark, while during summer, the temperature rises a bit and the permafrost melts at some points, making the ground soggy.
- The Arctic Tundra is known for its cold, desert-like conditions. In winter the temperature of Arctic Tundra regions may drop as down as -50°C. The average winter temperature is -34° C (-30° F), but the average summer temperature is 3-12° C (37-54° F) which enables this biome to sustain life. Rainfall may vary in different regions of the arctic. Annual precipitation, including melting snow, is 15 to 25 cm.
- In summer, the upper layer of Permafrost gets melted and when water saturates the upper surface, bogs and ponds may form, providing moisture for plants. There are ***no deep root systems*** in the vegetation of the arctic tundra; however, there are still a wide variety of plants that are able to resist the cold climate. There are about 1,700 kinds of plants in the arctic and subarctic, and these include low shrubs, sedges, reindeer mosses, liverworts, and grasses, more than 400 varieties of flowers and crustose and foliose lichen.
- The plants of the Arctic Tundra region are adapted to sweeping winds and disturbances of the soil. Plants are short and group together to resist the cold temperatures and are protected by the snow during the winter. *They can carry out photosynthesis at low temperatures and low light intensities.* The growing seasons are short and most plants reproduce by budding and division rather than sexually by flowering.
- The fauna in the arctic is also diverse. They include herbivorous mammals such as lemmings, voles, caribou, arctic hares and squirrels, Carnivorous mammals such as arctic foxes, wolves, and polar bears, Migratory birds such as ravens, snow buntings, falcons, loons, sandpipers, terns, snow birds, and various species of gulls, Insects such as mosquitoes, flies, moths, grasshoppers, black flies and arctic bumble bees and Fishes such as cod, flatfish, salmon, and trout.
- The animals of the Arctic Tundra are adapted to handle long, cold winters and to breed and raise young quickly in the summer. Animals such as mammals and birds also have additional insulation from fat. Many animals hibernate during the winter because food is not abundant. Another alternative is to migrate south in the winter, like birds do. Reptiles and amphibians are few or absent because of the extremely cold temperatures. Because of constant immigration and emigration, the population continually oscillates.

Fragile Ecosystem of the Arctic Tundra

From the above description, it is quite evident that the ecosystem of Arctic Tundra is extremely fragile because of the lack of abundant plant life so if the primary consumers can't find enough food, the predators can't eat.

In the Arctic Ecosystem, the primary producers, or the plants are on the bottom of the pyramid. These are very limited resources, which are thrown off by the slightest lack of sunlight and water available to them. The permafrost in the ground also throws off the drainage of the water leaving the plants there hard to digest. In the

middle are the primary consumers such as lemmings, musk oxen and insects who feed on the limited plant life available. On top are the small predators such as the snowy owl and arctic fox and polar bears. Due the scarcity of the primary producers, the fragile ecosystem and food chain causes the population continually oscillate. This means that extinction of just one species has the capability to destroy the entire ecosystem in Tundra regions.

Global Warming & Tundra Climate

Due to global warming, the future of the tundra becomes more uncertain. The global warming has caused spread of more woody plants by the increasing temperatures, and it has been feared that it may endanger moss and lichen species in two fifths of the biome in the years to come.

Oil Drilling in Tundra

Oil Drilling is popular in the tundra because it is rich in mineral resources. The pollution caused by Oil drilling would kill the habitats of fish, and animals. The major problem of oil drilling is the risk of oil spills. When a large spill occurs, it can kill many tiny organisms when it comes in contact with it. As a result, plants will die and will not be able to produce oxygen that we need to live. Also, the herbivores in the ecosystem will die because they will have no food to eat. This can cause major damage to the food chain.

Alpine Tundra

Model Question - 4.

Consider the following statements about the Alpine Tundra:

1. The Alpine Tundra is located on latitudes which are south of Arctic Tundra and North of Antarctic Tundra.
2. The soil of Alpine Tundra is frozen in winters known as Permafrost
3. The plants and animals of Alpine Tundra are almost similar to that of Arctic Tundra

Which among the above statements is/ are correct?

Answer: 4

While the Arctic Tundra is located in Polar regions, the Alpine tundra is located on mountains **throughout the world at high altitude where trees cannot grow**. Alps and Pyrenees of Europe, the Rift Mountains of Africa (such as Mount Kilimanjaro), and a large portion of the Tibetan Plateau are best examples of Alpine Tundra. The growing season is approximately 180 days. The night-time temperature is usually below freezing. The major difference between the arctic Tundra and Alpine Tundra is that unlike the arctic tundra, the soil in the alpine is well drained. The Alpine Tundra does not have permafrost. The *plants of Alpine Tundra are very similar to those of the arctic ones, however there is a major difference in the fauna of Arctic Tundra* and Alpine Tundra. Kea parrot, marmot, mountain goats, chinchilla, woodland caribou, and pika are some of the best known species of Alpine Tundra.

Antarctic Tundra

Antarctic Tundra occurs on Antarctica and on several Antarctic and subantarctic islands. Most of it is too cold and dry to support vegetation. In some portions of Antarctica, there are areas of rocky soil that support plant life. The flora presently consists of around 300–400 lichens, 100 mosses, 25 liverworts, and around 700 terrestrial and aquatic algae species, which live on the areas of exposed rock and soil around the shore of the continent. Antarctica's two flowering plant species, the Antarctic hair grass (Deschampsia antarctica) and Antarctic pearlwort (Colobanthus quitensis), are found on the northern and western parts of the Antarctic Peninsula. The major difference between Arctic Tundra and Antarctic Tundra is that Antarctic Tundra lacks a large mammal fauna, while in Arctic Tundra we find an array of mammals as mentioned above. The reason is that Antarctica is physically isolated from other continents. However, the shores are inhabited by Sea mammals and sea birds, including seals and penguins. Further, some small mammals, like rabbits and cats, have been introduced by humans to some of the subantarctic islands.

4 All are incorrect statements

Taiga Biome

Taiga is also known as Boreal Forest. Taiga is **earth's largest terrestrial biome, covering 29% of World's Forest cover** and is characterized by coniferous forests. It covers in North America most of inland Canada and Alaska as well as parts of the extreme northern continental United States; and in most of Sweden, Finland, inland and northern Norway, much of Russia (Siberia), northern Kazakhstan, northern Mongolia, and northern Japan (Hokkaidō Island).

- As mentioned above, Taiga is the world's largest land biome, and makes up 29% of the world's forest cover.
- Largest areas under Taiga are located in Russia and Canada. Please note that there is no Taiga on Southern hemisphere.

It accounts for *lowest annual average temperatures after the tundra and permanent ice caps*. Please note that the **extreme minimums temperatures of Taiga are typically lower than those of the tundra.** In Tundra it is around -50°C, in Taiga it has been recorded -68°C at Verkhoyanks in Siberia.

Model Question - 5.

Despite being located at southern latitudes than Tundra, why the extreme minimum temperatures have been recorded lowest in Taiga?
A. Because winters of Taiga get colder due to Polar winds
B. Because Tundra is near to Arctic Ocean
C. Because Taiga has clearer skies in comparison to Tundra
D. All of above reasons.
Answer: 5

In winter, there are long periods of frozen Ice on Polar Tundra, yet the nearby **Arctic Ocean contains enough heat to tweak the temperature a little bit.** This is the reason that lowest reliably recorded temperatures in the Northern Hemisphere were *recorded in the taiga of northeastern Russia*. The soil in Taiga is young with little development and profile. This is mainly because of the fact that cold hinders the development of soil. The taiga ***soil is also poor in nutrients***.

Taiga: Nutrient Poor Soil

The Taiga soil is **poor in nutrients** in comparison to the temperate deciduous forests. This is because the fallen leaves and moss can remain on the forest floor, **without decomposing** for a long time in the cool, moist climate. This would result in poor organic contribution to the soil. Further, the **Taiga soil is acidic** due to the ***falling pine needles***. Since the soil is acidic, the acidity aids in the decomposition of the mineral components and the minerals are washed away in the lower horizons. This leaching of the minerals makes them inaccessible to the tree roots. This causes infertility of the soil.

The leaching of the nutrients, along with the permeability of the soil gives Taiga a *light colored eluvial soil horizon leached of most base forming cations such as Calcium. Since the soil is acidic due to the falling pine needles, the forest floor has only lichens and some moss growing on it.*

However, please note that *diversity of soil organisms in the boreal forest (southern Taiga) is high, comparable to the tropical rainforest.* The Taiga soils are dominated by the microscopic fungi. These microscopic fungi play an important role in the decomposition of the dead phytomass. So, the above mentioned infertility is compensated by the activity of the microorganisms in the upper soil horizons. In summary the soil of the Taiga Biome and Boreal forests is

- ✓ Young with little development
- ✓ Poor in Nutrients
- ✓ Rich with Soil organisms in comparison to Tropical Forests
- ✓ Acidic due to fallen leaves

5 Correct Answer is B.

Taiga Flora

The first thing we note about Taiga is that - it is spread over both Asia and North America. Both of them were connected by the 1600 kilometers wide **Bering land bridge** at various times during the Pleistocene ice ages in the Geological history. (It connected Alaska to Siberia). So, due to this reason, a number of animal and plant species were able to colonize both continents and are distributed throughout the taiga biome that spreads in both of them like Tundra.

The forests of the taiga are **largely coniferous,** dominated by larch, spruce, fir, and pine. There are also some small-leaved deciduous trees like birch, alder, willow, and poplar; mostly in areas escaping the most extreme winter cold. Southernmost parts of the taiga has trees such as oak, maple, elm, and tilia scattered among the conifers, and there is usually a gradual transition into a temperate mixed forest. The Southern Taiga is a closed canopy forest consisting closely spaced trees with mossy ground cover. It also has shrubs and wildflowers such as the fireweed. Wherever the trees are located at a father space, land is covered by lichens and mosses. These lichens and mosses are more common in the northernmost taiga. In northernmost taiga the forest cover is not only more sparse, but often stunted in growth.

The trees are coniferous which an adaptation to cold harsh climate is. **Most of the species of Taiga such as spruce, fir, and pine are Evergreen.** This is because the sun is low in the horizon for most of the year; it is difficult for plants to generate energy from photosynthesis. The trees do not lose their leaves seasonally and are able to photosynthesize with their older leaves in late winter and spring when light is good but temperatures are still too low for new growth to commence. The leaves are **needle shaped** to curb loss of water and with **dark green color** to increase absorption of sunlight.

However, Larch, which seems to be most cold-tolerant, is deciduous. The **roots of Taiga Trees are shallow**, which is basically to take advantage of the young thin soils. The conical shape and downward-drooping limbs help them shed snow. Further, there are also some broadleaf plants found in Taiga. Examples are birch, aspen, willow, and rowan.

Taiga : Wildfires

One of the most important environmental factors that affect the Taiga Forests is **Wildfires.** *Wildfires have been an integral part of the Taiga environment for several thousand years*. The main natural reason of the wildfires in Taiga is lightening strikes. However, the spread of the fire is dependent on weather, soil conditions, topography and the amount of dry organic matter (fuel) on the soil surface. The combination of these factors forms the fire regime, which is characterized by the intensity, pattern of distribution and type of fire (i.e. ground or crown fire).

By knowing a specific site's *forest type, habitat and local climate*, it is possible to determine the natural frequency of fire, which can vary from just a few years to hundreds of years. For example, wildfires develop more often in forests under a more continental climate (e.g. in Eastern Siberia) and in drier habitats with sandy soils (e.g. on the fluvial-glacial plains of Western Siberia).

Plant Adaptations to Wildfires

Where fires occur more frequently, plant communities often have special ecological mechanisms to make them more resistant or even adapted to fire. For example the older trees of the Taiga Zones have thicker bark. There are some plants in which the seed cones open just after a wildfire (.g. Jack Pine, an excellent adoption to pioneer the development of new trees.

Advantage Wildfires

Due to heavy and thick bark, and due to the canopy made by the trees, usually, the wildfire would burn away the upper canopy of the trees and let sunlight reach the ground. New plants will grow and provide food for animals that once could not live there because there were only evergreen trees. This is how even wildfires add in development of new forests in Taiga environment. Many smaller herbaceous plants that grow closer to the ground may survive in the Crown wildfires that eliminate only the canopies. The periodic wildfires clear out the

tree canopies, allowing sunlight to invigorate new growth on the forest floor. That is why the wildfires have become a necessary part of the life cycle in the taiga.

Taiga Environment Challenges

The Taiga is being destroyed everyday by both humans and nature. Nature causes forest fires with lighting, diseased by parasites or herbicides, and spruce trees that grow on top thick moss are frequently blown over by strong winds. Large-scale clear cutting, plantation forestry, introduction of exotic tree species, soil scarification, ditching, and use of pesticides or herbicides have led to habitat loss. Large-scale industrial forestry, or logging, is the greatest important threat effecting the boreal forest. Other threats to the Taiga are oil and gas exploration, road building, mining, human triggered forest fire, and climate change. Animals of the Taiga are being hunted and trapped for their fur which decreases their population greatly. Hydroelectric power has ruined the water system. Many fish have mercury poisoning. The Taiga is being destroyed equal to that of the rainforest.

Montane grasslands and shrublands

This biome is defined in the WWF Classification. It includes all the high altitude (montane, subalpine, and alpine) grasslands and shrublands around the world. They are located in plenty of subtropical and tropical regions. In India, the elevations of Western Ghats are included in Montane grasslands and shrublands. Plants of these habitats display adaptations such as rosette structures, waxy surfaces, and hairy leaves.

Tropical Broadleaf Evergreen Forest: The Rainforest

The tropical rainforest is **earth's most complex biome** in terms of both structure and species diversity. It occurs under optimal growing conditions: abundant precipitation and year round warmth. The World Wildlife Fund's biome classification puts the tropical rainforests under **Tropical Moist Broadleaf Forest.** The Tropical rain forests is roughly located within **28° north or south** of the equator , spread in Asia, Australia, Africa, South America, Central America, Mexico and on many of the Pacific Islands. They roughly cover 6-7% of earth's area and are home to half of its biodiversity. The largest rainforests are in Brazil (South America), Democratic Republic of Congo (Africa), and Indonesia. Other tropical rainforests lie in Southeast Asia, Hawaii, and the Caribbean Islands. The Amazon rainforest in South America is the world's largest, covering an area about two-thirds the size of the continental United States.

Etymology: Rainforests

Rainforests are called so because they are wet due to round the year rains. There are apparently no seasons in Tropical rain forests near the equator, yet the tropical rainforests which are away from equator have only wet and dry seasons. Tropical rainforests receive 175 to 300 inches precipitation annually. Tropical rain forests are found in regions where temperatures and precipitation are high year-round. Mean monthly temperatures exceed 18 °C during all months of the year, due to location near to equator. Please note that there is no annual rhythm to the forest; rather each species has evolved its own flowering and fruiting seasons. Sunlight is a major limiting factor.

Layers of Trees:

A tropical rainforest consists of four layers: the **emergent trees**, **canopy**, the **understory**, and the **forest floor.**

- ✓ The emergent and canopy layers make up the very top of the rainforest, where a few trees, called emergent, poke out above the green growth to reach the sun. Most of the plant growth in rainforests is here, close to the sun.
- ✓ Most rainforest animals, including monkeys, birds, and tree frogs, live in the canopy.
- ✓ Below the canopy are the young trees and shrubs that make up the understory. The plants in this layer cannot grow to large sizes because the canopy blocks most of the sunlight.
- ✓ The forest floor is almost bare because very little sunlight can get through the canopy and understory to reach the ground. This is where fallen leaves and branches rot quickly to release nutrients for other plants to grow.

- ✓ Large mammals such as South American tapirs and Asian elephants who are too heavy to climb up into the canopy layer live in the dim light of the understory and forest floor.

Complex Ecosystem of Rainforests

In Rainforests, the plants and animals depend on each other for survival. For example, some insects can only survive in one type of tree, while some birds only eat one type of insect. If this tree is destroyed, the insects will have no home. If the insects die, the birds who rely on them for food will starve to death. Because of this interdependence, if one type of plant or animal becomes extinct, several others could be in danger of extinction as well.

Rainforest Soils:

Model Question - 6. (IAS 2011)

If a tropical rain forest is removed, it does not regenerate quickly as compared to a tropical deciduous forest. This is because?

A. The soil of rain forest is deficient in nutrients.
B. Propagules of the trees in a rain forest have poor viability.
C. The rain forest species are slow-growing.
D. Exotic species invade the fertile soil of rain forest.

Answer: 6

It would appear to us that tropical soils are very fertile in order to support this high productivity. **But, it is incorrect to say so.** If we closely look at the system, we find that **soils of Tropical Rain Forests are very thin** and the rock below them highly weathered. An analysis of soils of tropical regions shows them to be virtually devoid of soluble minerals. *Rocks weather rapidly due to high temperatures and abundant moisture, and millennia of rapid weathering and torrential rains to wash away nutrients from the soils have left the soils very low in nutrient stocks.*

It has also been supported by the analysis of stream water draining tropical regions, which likewise reveals a scarcity of dissolved nutrients. Most tropical soils are clays with little soluble mineral content, and moderate to strong acidity which interferes with the ability of roots to take up nutrients. Only about 20% of the humid tropics has soils that can support agriculture, and most of this area is already in use. In soils of the Tropical Rain Forests, the nutrients are found mainly in living plant biomass and in the layer of decomposing litter; there is little nutrient content of the deeper soil, as there is in temperate-zone ecosystems. This suggests that plants are intercepting and taking up nutrients the moment they are released by decomposition. Many organisms play role in decomposition process: termites, bacteria, fungi, various invertebrates.

Recycling of Nutrients

Due to the above mentioned reasons, the rainforest reuses almost everything that falls to the ground and decays. When leaves fall from the trees, when flowers wilt and die, and when any animal dies on the forest floor, it decays and all of the nutrients in the decayed species are recycled back into the roots of the trees and plants. Only the top few inches of rainforest soil have any nutrients. Most of the nutrients are in the biomass, the bulk of animal and plant life above the ground. The roots of rainforest trees are not very deep; that way they can collect all of the nutrients in the top few inches of the soil. Rainforests even recycle their own rain. As water evaporates in the forest it forms clouds above the canopy that later fall as rain.

Why a Tropical Rain Forest cannot be replaced very quickly?

A rainforest cannot be replaced. Once it is destroyed it is gone forever (almost thousands of years). We have read above that only the top few inches of rainforest soil have any nutrients. Below that it is **deficient in nutrients.** There is a high temperature and this high temperature leads to decomposition of the organic material as well as the inorganic parent material of the soil. There are frequent rains and these rains leach the decomposing material off the soil, out of the root zone quickly. So, the result is that the Tropical rain Forests have adapted themselves and quickly take up the nutrients and most nutrients in the tropical rain forests is stored in the vegetation.

6 Correct Answer is A

When the forest is harvested for timber or other plant products, or the forest is burned, nutrients will be lost from the ecosystem, but the outputs cannot exceed inputs for very long because the stock of nutrient capital in the system will be depleted. When forests are burned, or the cut timber is removed as in logging, the nutrients that were in the tree biomass are either washed out in the case of burning or simply removed from the system.

Because there was only a small stock of nutrients in the soil and most of the nutrients were in the biomass, there is little nutrient stock remaining to support regrowth.

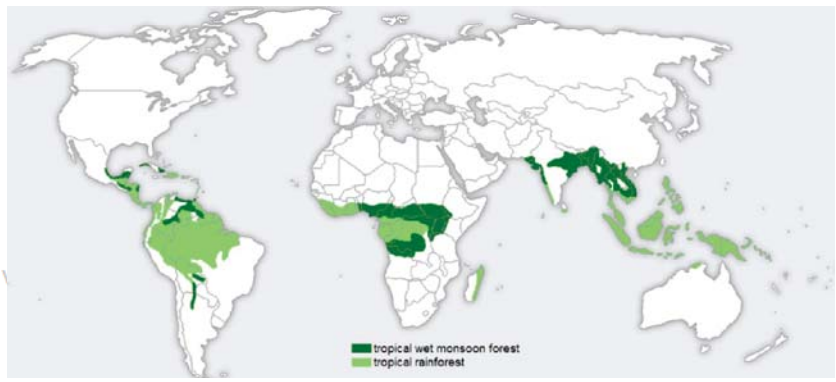
Thus, we can't simply "regrow" tropical forests once they are burned -- once they are lost they are gone forever (or at least for 1000s of years, and even then the species that regrow will be different from the original forest species).

Biodiversity in Rainforests

Rainforests are home to half of all the living animal and plant species on the planet. High biodiversity appears related to high ecological specialization of species. The rainforests are home to more worldwide species than all other biomes added together.

Tropical Monsoon Forests

Throughout the world, the tropical monsoon climate experiences abundant rainfall like that of the tropical rain forest climate, but it is concentrated in the high-sun season. Such forests are called Tropical Monsoon Forests. They are *located in the monsoon climate beyond the equatorial region between 10◦ and 25 ◦ and North and South of the equator.* The countries are along the coastal regions of southwest India, Sri Lanka, Bangladesh, Myanmar, South western Africa, French Guiana, and northeast and south-eastern Brazil.



Please note that the major controlling factor over the monsoon climate is its relationship to the monsoon circulation. Monsoon circulation of Asia exhibits an onshore flow of air (air moving from ocean towards land) during the summer or high-sun season, and offshore air flow (air moving from land toward water) during the winter or low-sun season. The change in direction is due to the difference in the way water and land heat. In India, the west coastal lowlands, the Western Ghats, and southern parts of Assam have this climate type. It is characterized by high temperatures throughout the year, even in the hills. The rainfall here is seasonal, but heavy and is above 78 cm in a year. Most of the rain is received in the period from May to November, and is adequate for the growth of vegetation during the entire year. December to March are the dry months with very little rainfall. The heavy rain is responsible for the tropical wet forests in these regions, which consists of a large number of species of animals. Evergreen forests are the typical feature of the region. The adjacent graphics shows the location of Tropical Rain Forests and Tropical Monsoon Rainforests throughout the world.

Temperate rainforests

Temperate rainforests are dense rainforests that occur in the regions of high rainfall in the temperate zone. We know that the north temperate zone extends from the Tropic of Cancer (at about 23.5 degrees north latitude) to the Arctic Circle (at approximately 66.5 degrees north latitude). The South Temperate Zone extends from the Tropic of Capricorn (at approximately 23.5 degrees south latitude) to the Antarctic Circle (at approximately 66.5 degrees south latitude).

The regions in these latitudes, with annual precipitation over 1400 mm and mean annual temperature between 4 and 12 °C. (39 and 54 °F) are called Temperate Rain Forests. The adjacent graphics shows the distribution of the Temperate Rainforests throughout the world.

Tropical & Temperate Deciduous Forests

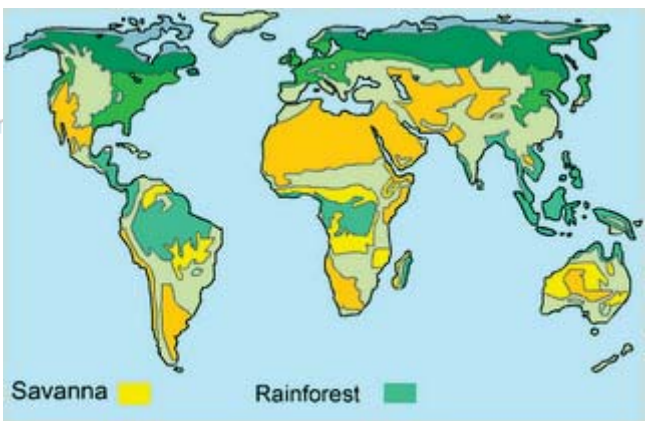
The deciduous biomes lie on the margin of equatorial and tropical rain forest. The deciduous trees lose their leaves during the dry season just a few months before the advent of summer rains. The monsoon forest average 15m high with no continuous canopy of leaves. Caatinga of Brazil is a suitable example. The others are Chaco in Paraguay and northern Argentina, the brigalow scrub of Australia, and the dorveld of South Africa. The tropical deciduous forest are also found in Angola, India, Indonesia, Malaysia, Myanmar, North-Eastern Thailand, Zambia, And Zimbabwe. The wood of the trees, especially teak wood is valuable for fine cabinetry. In addition, some of the trees with dry season adaption produce usable waxes and gums, such as carnauba and palm-hard waxes. Trees include Maple, many Oaks, Elm, Aspen, and Birch, among others, as well as a number of coniferous genera, such as Larch and Metasequoia. Deciduous shrubs include honeysuckle, viburnum, and many others.

Most temperate woody vines are also deciduous, including grapes, poison ivy, virginia creeper, wisteria, etc. The characteristic is useful in plant identification; for instance in parts of Southern California and the American Southeast, deciduous and evergreen oak species may grow side by side.

Temperate deciduous forest has a temperate of 4 seasons. Temperate deciduous forests get about 950 to 1500 millimeters of rain annually, which is the second most of all the biomes. They have summer highs of about 27 to 32° Celsius with winter highs temperatures of around -1 to -15° Celsius.

Savannahs

A savannah is a grassland ecosystem. In Savannah, the trees are sufficiently small or **widely spaced so that the canopy does not close.** The open canopy allows sufficient light to reach the ground to support an unbroken herbaceous layer consisting grasses. Please note that some classifications put only those lands in Savannahs which don't have trees. However, most classifications characterize Savannah which is grassy woodland with a significant woody plant component.



The water availability in Savannahs is season and majority of the rainfall is confined to one season. Savanna covers approximately 20% of the Earth's land area. **The largest area of savanna is in Africa.** The following graphics shows Savannah as well as Rainforests so you are able to distinct the two regions.

The above discussions make it clear that **Savannahs are the grasslands with trees**. But this is not a strict definition and savanna biome also includes **treeless tracts of grasslands**.

Please note that ***forest fires are common in Savannahs also*** but that is ***mainly because of human interference and not because of the natural reasons as the lightning in case of Taiga Biome***. In Taiga, usually the forest fires are crown fires which destroy the canopy, but in Savannahs, these fires are usually confined to the herbaceous layer and do little long term damage to mature trees. These fires either kill or suppress tree seedlings, thus preventing the establishment of a continuous tree canopy which would prevent further grass growth.

Large areas of savanna have been cleared of trees, and this clearing is continuing today. For example until recently 480,000 ha of savanna were cleared annually in Australia alone primarily to improve pasture production.

There are several types of Savannahs as following:

Tropical and subtropical savannas

Tropical and subtropical grasslands and shrublands as the tropical and subtropical grasslands, savannas, and shrublands biome. The savannas of Africa, including the Serengeti, famous for its wildlife, are typical of this type.

Temperate savannas

Mid-latitude savannas with wetter summers and drier winters. Examples are Great Plains of the United States.

Mediterranean savannas

Mid-latitude savannas in Mediterranean climate regions, with mild, rainy winters and hot, dry summers, part of the Mediterranean forests, woodlands, and scrub biome. The oak tree savannas of California, part of the California chaparral and woodlands ecoregion are examples.

Flooded savannas

That are flooded seasonally or year-round.

Montane savannas

These are high-altitude savannas; example is highland savannas of the Angolan Scarp savanna and woodlands ecoregions.

Savannah covered more than 40 per cent of the earth's surface once upon a time, before the human caused fire started damaging them. Fire occurs annually throughout the biome. The timing of these fires is important. Early in the dry season, they are beneficial and increase tree cover; if late in the season, they are very hot and kill trees and seeds.

Adaptations in Savannahs

Savanna shrubs and trees are xerophytes or drought resistant, with various adaptations like small thick leaves, rough bark, or waxy leaf surface to protect them from the dryness.Africa has the largest region of this biome, including the famous Serengeti plains and the Sahel region. Some of the local names of these grasslands include the

- ✓ Llanos in Venezuela,
- ✓ Campo cerrado in brazil, and
- ✓ Pantanal of southern brazil. They are also found in Australia, India, Ethiopia, Kenya, and Somalia.

Soil of Savannahs:

Savannah grasslands are **much richer in humus than the equatorial forests**. The C4 grasses are found in majority in Savannah.

Animals in Savannahs

Savanna are the home of large mammals that graze on savanna grasses or the savanna grasses or feed upon the grazers themselves ; these are lions, cheetah, zebra, giraffe, buffalo, gazelle, wild beast, antelope, rhinoceros, and elephant. Some of the animal species like the black and white rhino have become extinct during recent time.

Temperate grasslands

Temperate grasslands are found in the regions with temperate and semi-arid to semi-humid climates. The most important characteristic of the Temperate Grasslands is that *they have almost no trees and large shrubs* and have grasses as the dominant vegetation. Please note that the amount of rainfall is less in temperate grasslands than in savannas. The **Veldts of South Africa**, the **Puszta of Hungary**, the **Pampas of Argentina and Uruguay,** the **Steppes of the former Soviet Union,** and the plains and **Prairies of Central North America** are Temperate Grasslands.

Climate in Temperate Grasslands

Temperate grasslands have hot summers and cold winters. Rainfall is moderate. The amount of annual rainfall influences the height of grassland vegetation, with taller grasses in wetter regions. Akin to Savannah, seasonal drought and occasional fires are very important to biodiversity. However, their effects aren't as dramatic in temperate grasslands as they are in savannas. Few natural prairie regions remain because most have been turned into farms or grazing land. This is because they are flat, treeless, covered with grass, and have rich soil. Prairies are grasslands with tall grasses while steppes are grasslands with short grasses.

Soils of Temperate Grasslands:

The soil of the temperate grasslands is deep and dark, with fertile upper layers. It is nutrient-rich from the growth and decay of deep, many-branched grass roots. The rotted roots hold the soil together and provide a food source for living plants. Each different species of grass grows best in a particular grassland environment (determined by temperature, rainfall, and soil conditions). The seasonal drought, occasional fires, and grazing by large mammals all prevent woody shrubs and trees from invading and becoming established. However, a few trees, such as cottonwoods, oaks, and willows grow in river valleys, and some nonwoody plants, specifically a few hundred species of flowers, grow among the grasses. The various species of grasses include purple Needlegrass, Blue Grama, Buffalo Grass, and Galleta. Flowers include asters, blazing stars, coneflowers, goldenrods, sunflowers, clovers, psoraleas, and wild indigos.

Rainfall in the Temperate Grasslands

Precipitation in the temperate grasslands usually occurs in the late spring and early summer. The annual average is about 50.8 to 88.9 cm. The temperature range is very large over the course of the year. Summer temperatures can be well over 38° C (100 degrees Fahrenheit), while winter temperatures can be as low as -40° C (-40 degrees Fahrenheit).

Fauna in the Temperate Grasslands

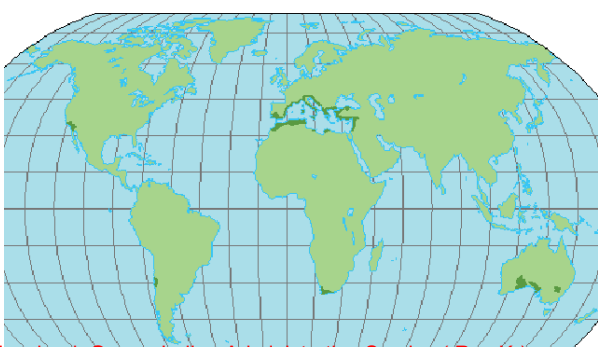
Animals include gazelles, zebras, rhinoceroses, wild horses, lions, wolves, prairie dogs, jack rabbits, deer, mice, coyotes, foxes, skunks, badgers, blackbirds, grouses, meadowlarks, quails, sparrows, hawks, owls, snakes, grasshoppers, leafhoppers, and spiders.

The following graphics sourced from Britannica online shows grasslands of the World.

Grasslands of the World © 2010 EB Inc.

Mediterranean Shrublands

This biome is found along the coasts of the Mediterranean Sea, California, Central Chile, south-western part of South Africa and southwestern parts of Australia. They have been shown in the adjacent graphics as darker green patches.



The Mediterranean climate has hot and dry summers and mild-wet winters. The natural vegetation of this biome adapted ac-cording to the dry and hot summer conditions. Plant ecologists are of the opinion that this biome is well

adapted to frequent fires, for many of its characteristically deep-rooted plants have the ability to re-sprout from their roots after a fire.

The dominant shrubs that occupy these regions are stunted and tough in their ability to with-stand hot- summer drought. The vegetation is called sclerophyllous. it averages as metre or two in height and has deep, well developed roots, leathery and uneven low branches.

Location:

Mediterranean-type climate regions occur roughly between 30° and 40° latitude on the west coasts of continents, where offshore there are cold ocean currents. Each region in which the Mediterranean shrublands and woodlands occur is island-like in character and thus there is frequently a high degree of endemism.

Climate:

In Mediterranean regions, wet season coincides with the low sun or winter period. Summers are dry. Total annual precipitation ranges between 40 and 90 cms per year. Temperatures are those of the subtropics moderated by maritime influence and fogs associated with the cold ocean currents. The result is a very limited, but predictable, growing season when there is both sufficient soil moisture and adequately warm temperatures. Many plants are adapted to withstand drought.

Flora:

Throughout the world, the Mediterranean biome is characterized by shrubs. In most regions these shrubs are evergreen and have small, leathery (sclerophyllous) leaves with thick cuticles. Sometimes the leaves are so reduced as to appear needle-like. Many typical members of the shrub flora are aromatic (for example, sage, rosemary, thyme, and oregano) and contain highly flammable oils. Mediterranean regions have long been impacted by humans especially through the use of fire and the grazing of livestock.

Regional Names:

- ✓ In the Mediterranean proper--Europe, North Africa, and Asia Minor, they are known as **Maquis**.
- ✓ In California they are called **Chaparral**
- ✓ In Chile, they are known as **Matorral**
- ✓ In Australia, they are expressed by the **Mallee** scrub vegetation of subtropical Australia.

The Mediterranean region of Europe and Asia has a significant concentration of cork-oak, olive, fig, and citrus fruits. In Australia the bulk of the eucalyptus species is sclerophyllous in form and structure.

Desert biome

Deserts and xeric shrublands are characterized by small amount of moisture. They receive an annual average rainfall of ten inches (25 cms) or less, and have an arid or hyperarid climate, characterized by a strong moisture deficit, where annual potential loss of moisture from evapotranspiration well exceeds the moisture received as rainfall.

The desert biome of the earth covers about 35 per cent of the total land area of the world. Deserts are very dry, receiving less than 25cm. In the desert of Atacama of northern Chile, only a negligible amount of rain has ever been recorded-a 30-year annual average of only 0.005cm, making it driest part of Earth.

The area of the desert biome is increasing as there is increasing desertification because of human over interaction. Deserts and xeric shrublands occur in all tropical, subtropical, and temperate climate regions. Desert soils tend to be sandy or rocky, and low in organic materials. Soil is generally saline or alkaline.

Adaptations in Desert Biome

Plants and animals in deserts and xeric shrublands are adapted to low moisture conditions. Hyperarid regions are mostly devoid of vegetation and animal life, and include rocky deserts and sand dunes. Vegetation in arid climate regions can include sparse grasslands, shrublands, and woodlands. Deserts are inhabited by the Xerophytes which include succulent plants, geophytes, sclerophyll, and annual plants. Animals, including insects, reptiles, arachnids, birds and mammals, are frequently nocturnal to avoid moisture loss. In the southern Arizona, the unique Saguaro

cactus grows to many metres in height and can survive up to 200 years of age if left undisturbed. First blooms do not appear until it is 50 to 75 years old.

Cold Deserts:

Cold desert occur where seasonal shifting of the subtropical high is of some influence less than six months of the year. Specifically interior locations are dry because of their distance from moisture sources or their location in rain shadow areas on the leeward side of mountain ranges such as Himalayas and Andes. Winter snows occur in the cold deserts but are generally light. Summers are hot-with highs varying between 30° and 40°C. Night time lows-even in the summer, can cool 10° to 20°C from the daytime high.

Part III. Soil Basics

Origin and types of soils

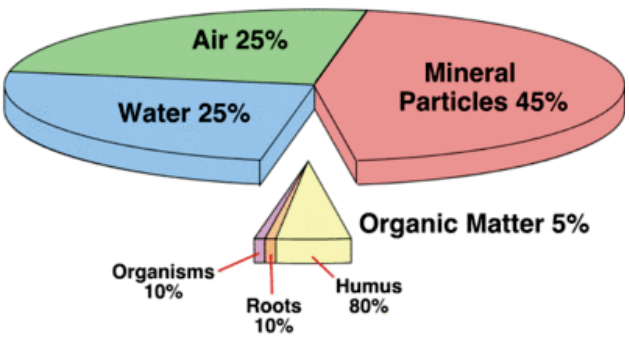
The fine particles of the solid rocks along with the organic / inorganic matter are called soil. The naturally occurring soil is influenced by parent material, climate, relief and the physical, chemical and biological agents such as microorganisms living in it. The naturally occurring soil is influenced by

- Parent rocks
- Climate
- Organic content
- Topography
- Land use practices/ Human interference
- Time

Soil contains mineral particles, decayed organic material, soil water, soil atmosphere, and living organisms, which exist in a complicated and dynamic relationship with one another. Soil is a dynamic natural body made up of the materials covering the earth's surface in which plants grow. It is composed of both mineral and organic matter.

Complex Nature of Soil

The above mentioned factors do not work on soil independently or in isolation, but in close association with each other, leading to a whole network of inter-relationships of quite a complex nature. The material of the soil or the parent material is derived from the rocks ex-posed on the surface. The relief and slope along with the work of various materials. Soils weathering determine conditions for the disintegration of the rock materials. Soils may be transported by the running water, wind or other agents of the rock materials. Soils remain in the original position. When the soil remains in its original position, it is said to be in situ, and in that state it is further modified by the climate, particularly moisture supply, plant growth ,and bacterial activity dependent on these factors . A brief supply, plant growth ,and bacterial activity dependent on these factors.



A soil is made up of four elements: **inorganic or mineral fraction** (derived from the parent material), **organic material, air and water.** The abundance of each component and its importance in the functioning of the soil system vary from horizon to horizon and from one soil to another.

Humus:

The end-product of the breakdown of dead organic material is known as Humus. Humus is a structure-less, dark-brown or black jelly found beneath the soil surface. In uncultivated land, the humus is derived from the natural decay of previous generations of plants, while in the ploughed and cultivated land it is supplied as some kind of manure. The humus of ordinary soil is black, and is thus responsible for making the soil darker than the subsoil. It plays an important but very complicated part in maintaining the fertility of soil. The amount of humus in different

soils varies considerably; some, like the peat soil, consist largely of slightly decomposed organic matter which has not yet become humus.

Soil Texture

A soil is generally characterized by the size of its particles. A clayey soil may thus be described as fine, a sandy soil as coarse, while a silly soil is intermediate. If one handles a moist soil sample of each of these he feels gritty, sticky and silky, respectively. The standard unit for the measurement of soil particles is the millimeter, but a smaller unit is the micron (1 micron= 0.001 mm), which is applicable, for instance, to the measurement of soil colloids.

Sandy Soil

Sandy soil is a light soil that consists mainly of sand, i.e., grains of quartz with considerable air spaces between them. The sand may either be 'coarse' where the particles are between 0.2 and 2 mm in diameter, or 'fine' where the grains between 0.05 and 0.2 mm are just visible to the naked eye. These light soils allow water to drain through rapidly, taking soluble plant foods with it. Sandy Soils are known as 'hungry' soils, which not only **need constant manuring** but **may dry out completely during a period of drought** so that shallow-rooted crops fail and pastures 'burn'. They are good for horticulture (vegetables and fruits), legumes (such as moth and pulses), ground nut and bajra.

Clayey Soil

Clayey soil is an exceptionally fine grained soil, very retentive of moisture. It often becomes plastic when mixed with water. The individual grains of clayey soil are 0.002 mm in diameter. These particles consist mainly of **hydrated aluminum silicates**.

Clay **contains little air and can hold more water, so forming a sticky mass,** but when it dries out completely, it forms a hard, concrete like surface, seamed with numerous cracks. Sometimes, a compacted solid layer of clay in the subsoil is formed, which is known as **claypan**, and is often hard and difficult to dig or plough. Clayey soils are often rich in plant food and give much better yields than that of sandy soils. They are devoted to rice, perennial grasses other crops such as clover. Efficient drainage methods, modern machinery and careful liming enable clayey soils to grow roots, green crops and cereals.

Silty Soil

Silty soil is finer than sand but coarser than clay. Its particles are assumed to have a diameter between 0.02 and 0.002 mm. These soils are rich in humus contents and are devoted to numerous cereal and non-cereal crops.

Loamy Soil

It is highly fertile soil consisting mainly of a mixture of sand and day, together with silt and humus. It has the good qualities of both sand and clay, but not their bad qualities. It comprises an almost equal mix of sand and silt with less than 30 per cent clay. It can retain some moisture and plant food even under the adverse weather and climatic conditions. It is well· aerated and drained, and can be readily worked. It is generally devoted to wheat, barley, legumes, sugarcane, sugar beet, maize, millets, rice, grasses, vegetables and orchards.

Soil pH

Soil pH is a measure of the acidity or basicity in soils. As we know, the pH below 7 is acidic and above 7 is basic. Soil pH is considered a master variable in soils as it controls many chemical processes that take place. It specifically affects plant nutrient availability by controlling the chemical forms of the nutrient. The **optimum pH range for most plants is between 6 and 7.5,** however many plants have adapted to thrive at pH values outside this range.

The first thing we should note that in cool and moist areas, percolating groundwater leaches out the soluble bases (such as calcium). As a result, the soils gradually become lime-deficient which increases the acidity of the soil.

Both the highly acidic and alkaline soils are injurious to crops. If the soil becomes unduly acidic, the farmers **apply lime** in various forms to meet the requirements of the soil. In practice, a pH value between 6 and 6.5, i.e.,

very slightly acidic, is desired. Lime not only helps to neutralize the excess adds and so 'sweeten' the soil, but it also **encourages bacteria** and helps to improve the physical , texture of heavy soils. **High soil acidity is typical of cold, humid climates. In arid climates, soils are typically alkaline.**

How to Increase soil pH?

Acidity can be corrected by the application of lime, a compound of calcium, carbon and oxygen (CaCO3), which removes add ions and replaces them with the base calcium.

How to Decrease soil pH?

To decrease the pH of the soil, the Iron sulphates or aluminium sulphate as well as elemental sulfur (S) are used through the formation of sulphuric acid. Further, Urea, urea phosphate, ammonium nitrate, ammonium phosphates, ammonium sulphate and monopotassium phosphate fertilizers have a organic matter in the form of plant litter, compost, and manure will decrease soil pH through the decomposition process.

Certain acid organic matter such as pine needles, pine sawdust and acid peat are effective at reducing pH.

The problem of Alkaline Soils

Alkali or alkaline soils are the soils with high pH (> 9). The fist visible impact of Alkaline soil is that it has a **poor soil structure and a low infiltration capacity.** The Alkali soil is generally having **a hard calcareous layer at 0.5 to 1 metre depth**. Alkali soils have dominated presence of minerals such as Sodium Carbonate which causes the soil to swell. Please note that **all alkaline soils are basic, but NOT all basic soils are alkaline.** This is because even presence of basic salts, the soil may not become alkaline due to other chemical reactions. For example, pH of a solution can be lowered by the addition of CO2. This will reduce the basicity; however, the alkalinity will remain unchanged.

The reason is that net reaction produces the same number of equivalents of positively contributing species (H+) as negative contributing species (HCO^{3-} and/or CO_3^{2-}).

How Gypsum helps in Treatment of Alkali soils?

Gypsum (calcium sulphate, CaSO4. 2H2O) can be applied as a source of Ca++ ions to replace the sodium at the exchange complex in the soil. However, there must be enough natural drainage to the underground, or else an artificial subsurface drainage system must be present, to permit leaching of the excess sodium by percolation of rain and/or irrigation water through the soil profile, while using Gypsum.

Soil Air

Soil air is vital both to soil itself and to organic life within it. A certain amount of air is contained between the individual particles except for the waterlogged soils. The air in the soil helps in the process of oxidation which converts part of the organic material into nitrogen in a form readily available to the plants.

On the other hand, too high degree of oxidation may consume so much organic material that the soil becomes increasingly sterile.

Soil fertility

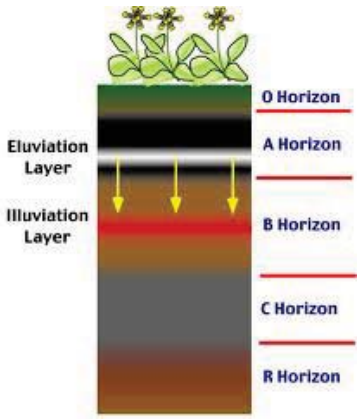
Soil fertility is the ability of soil to sustain plants. Soil has fertility when it contains organic substances and clay minerals that absorb water and certain elements needed by plants. The boundary between horizons is usually visible in the field, using the properties of colour, texture consistency, porosity, the presence or absence of certain minerals, moisture, and chemical processes.

Soil horizons

Soil horizons are the building blocks of soil classification. The various layers exposed in a pedon; roughly parallel to the surface and identified as O,A,E,B, and C are known as soil horizon. The O horizon is the topmost layer of most soils. It is composed mainly of plant litter at various levels of decomposition and humus.

- The **O horizon** is the topmost layer of most soils. It is composed mainly of plant litter at various levels of decomposition and humus.

- **A horizon** is found below the O layer. This layer is composed primarily of mineral particles and has two characteristics: it is the layer in which humus and other organic materials are mixed with mineral particles, and it is a zone of translocation from which eluviation has removed finer particles and soluble substances, both of which may be deposited at a lower layer. Thus the A horizon is dark in color and usually light in texture and porous. The A horizon is commonly differentiated into a darker upper horizon or organic accumulation, and a lower horizon showing loss of material by eluviation.



- The **B horizon** is a mineral soil layer which is strongly influenced by illuviation. Consequently, this layer receives material eluviated from the A horizon. The B horizon also has a higher bulk density than the A horizon due to its enrichment of clay particles. The B horizon may be colored by oxides of iron and aluminium or by calcium carbonate illuviated from the A horizon.
- The **C horizon** is composed of weathered parent material. The texture of this material can be quite variable with particles ranging in size from clay to boulders. The C horizon has also not been significantly influenced by the pedogenic processes, translocation, and/or organic modification.

The final layer in a typical soil profile is called the **R horizon**. This soil layer simply consists of unweathered bedrock.

Soil Taxonomy

Soil classification based on observable soil properties actually seen in the field is known as soil taxonomy. There are a number of soil classifications presented by the experts of soil science. The major types of the soils have been discussed here:

Oxisols

These soils develop in the hot and humid climates of the equatorial region. These soils are called oxisols because they have distinctive horizon with a mixture of iron and aluminium oxides. Related vegetation is the luxuriant and diverse tropical and equatorial rain forest. Typical are red-dish and yellowish from the iron and aluminium oxides left behind, with a weathered clay-like texture. In fact, these are the lateritic soils in which the leaching process is very strong. The Laterite can be quarried in blocks and used as building material. They are traditionally being used for shifting cultivation. When oxisols are disturbed, soil loss can exceed a thousand tones per sq km per year. The regions dominated by oxisols by oxisols and rain forests are attracting the much worldwide environmental attention.

Aridisols (desert soils)

The largest single soil order occurs in dry regions of the world. These soils occupy nearly 19 per cent of the earth's land surface. Pale and light near the surface, deficit in moisture. Lack in organic matter. Salinisation is the main problem of these soils. Salinisation complicates farming in Aridisols.

Mollisols (grassland soils)

- They are most productive soils of the earth. They are rich in humus content. They have dark –colored surface.
- Mollisols are soft, even when dry, with granular pads, loosely arranged when dry. These humus rich organic soils are high in basic cations and have high fertility.
- **Soils of the steppes and prairies of the world belong to this group.** These soils are being utilized for large-scale commercial grain farming and grazing.

Contents

Introduction to Geography of India

India is mostly located on the **Indian Plate**, which is generally called the northern portion of the Indo-Australian Plate. India is located between 8°4' and 37°6' N latitude and 68°7' and 97°25' E longitude. This implies that India is located entirely in the Northern Hemisphere and Eastern Hemisphere.

Total geographical area of India is of 3,287,240 kms^2, which makes it 7th largest country in the world after Russia, Canada, China, United States, Brazil and Australia. India measures 3,214 Kms from north to south and 2,933 Kms from east to west. India's land border is 15200 kilometers while its coastline is 7517 kilometers.

Indian Plate

Indian Plate is a tectonic plate that was originally a part of the ancient continent of Gondwana from which it split off, eventually becoming a major plate. About 55 to 50 million years ago it fused with the adjacent Australian Plate. It is today part of the major Indo-Australian Plate, and includes most of South Asia – i.e., the Indian subcontinent – and a portion of the basin under the Indian Ocean, including parts of South China and Eastern Indonesia, and extending up to but not including Ladakh, Kohistan and Balochistan. (Wikipedia)

India shares its land borders with *China, Pakistan, Bangladesh, Nepal, Bhutan and Myanmar*, (Afghanistan also when we count PoK) while it shares its maritime boundary with *Burma, Thailand and Indonesia*.

Kanyakumari is the southernmost tip of the Indian mainland, while the **southernmost point in India is Indira Point** on Great Nicobar Island.

India's borders with Pakistan and Bangladesh are based upon the Radcliffe Line. The border with Pakistan is 3,323 kms. India also claims its 106 km border with Afghanistan in PoK. The border with Bangladesh runs

4,096.70 kms. This border is spotted by **Chitmahals** which are known as **Enclaves** or **Indo-Bangladeshi Enclaves.**

India and China border runs along the Line of Actual Control for 4,057 km along Jammu and Kashmir, Uttarakhand, Himachal Pradesh, Sikkim and Arunachal Pradesh. India's border with Myanmar runs 1,643 km along the southern borders of India's northeastern states viz. Mizoram, Manipur, Nagaland and Arunachal Pradesh. India's border with Bhutan runs 699 km. The border with Nepal runs 1,751 km along the foothills of the Himalayas in northern India. The **Siliguri Corridor,** narrowed sharply by the borders of Bhutan, Nepal and Bangladesh, connects rest of India with the northeastern states.

Story of Chitmahals

Indo-Bangladesh enclaves or Chitmahals are the enclaves along the Bangladesh–India border. There are 102 Indian enclaves inside Bangladesh and 71 Bangladeshi ones inside India, with a combined population between 50,000 to 100,000. Inside those enclaves are also 28 counter-enclaves and one counter-counter-enclave, called Dahala Khagrabari. In September 2011, the Prime Ministers of the two countries (Manmohan Singh of India and Sheikh Hasina of Bangladesh) signed an accord on border demarcation and exchange of adversely held enclaves. Under this agreement, the enclave residents may continue residing at their present location or move to the country of their choice. The story of the Chitmahals is as follows:

The Raja of Cooch Behar and the Nawab of Rangpur, the rulers of two minor kingdoms that faced each other near the Teesta River, staked games of chess with plots of land. To settle their debts, they passed chits — pieces of paper representing the territory won or lost — back and forth. When Sir Cyril Radcliffe, the law lord who partitioned India, drew the 1947 border, Cooch Behar went to India and Rangpur to Bangladesh — including the people who lived on the two kings' 162 "chit mahals," or paper palaces. Their villages, caught on the wrong side of the border, are now small islands of India surrounded by Bangladesh or vice versa. Elsewhere in this same stretch of border are villages that simply refuse to accept the lines drawn by Radcliffe's pen. New Delhi backs those that want to stay in India, despite the legal claim of Bangladesh, and Dhaka does likewise. There are 1,696 acres (690 hectares) of these "adverse possessions," where India and Bangladesh effectively occupy each other's territory. That means 21 miles (34.5 km) of border that cannot be fenced, cannot be floodlit or gated and in many cases is simply not policed at all. (Source: Time Magazine)

Part I. Geology, Plate Tectonics & Rock System of India

Geological History

Model Question - 1.

Consider the following statements:

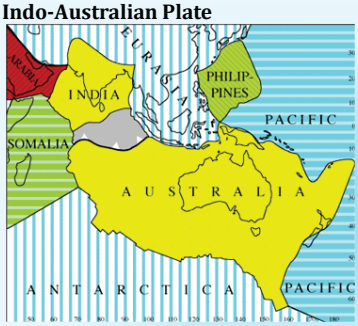
1. India and Australia share a common geological History
2. India was a part of Gondwana supercontinent in its geological history
3. Himalayas were the northernmost boundary of Gondwana Supercontinent

Which among the above statements is / are correct?

Answer: 1

Indian subcontinent, Australia, New Guinea, and Tasmania, New Zealand etc. have a common geological history by virtue of being an integral part of the Mesozoic **Gondwana super-continent** until 160 million years ago.

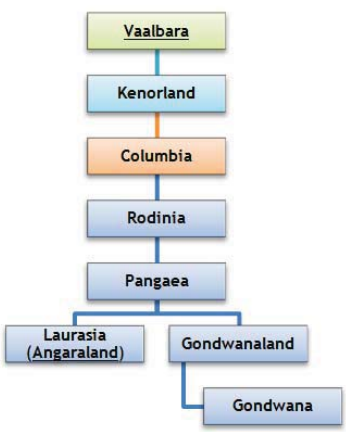
Indo-Australian Plate



Indo-Australian plate is a major tectonic plate that includes Australia and surrounding ocean and extends northwards to cover the entire Indian subcontinent and its adjacent waters. The studies show that this Indo-Australian plate may be in the process of breaking up in **two separate plates** due the stress caused by collision of the Indo-Australian Plate with Eurasia along the Himalayas. These two separate plates are known as Indian Plate and Australia Plate.

Indian Plate is currently moving northeast at 5 cm/yr, while the Eurasian Plate is moving north at only 2 cm/yr. The result is that the Eurasian Plate gets deformed this leads to the India Plate to compress at a rate of 4 mm/yr. This is one of the reasons of earthquakes in Himalayan region.

The earth is 4700 million years old and the earliest supercontinent **Vaalbara** started forming around 3600 million years ago. It took nearly 400 million years to get completed and was ready by 3100 million years ago. Then, around 2500 years ago, Vaalbara started breaking. The result of this breaking was that another supercontinent **Kenorland** formed around 2700-2500 million years ago. The breaking kept on and then Supercontinent **Columbia** formed around 1800-1500 million years ago. Around 750 million years ago, a new supercontinent was formed that was called **Rodinia**. In the late Paleozoic period (542 - 250 million years ago) super continent **Pangaea** was formed that existed during the Paleozoic and Mesozoic eras. Pangaea started beginning to break up



1 Only 1 & 2 are correct statements

approximately 200 million years ago, before the component continents were separated into their current configuration. It first broke into Northern **Laurasia** (**Angaraland**) and Southern **Gondwanaland**.

Later, the Laurasia and Gondwana drifted apart. Gondwana included Antarctica, South America, Africa, Madagascar, Australia-New Guinea, and New Zealand, as well as Arabia and the Indian subcontinent, which have now moved entirely into the Northern Hemisphere.

Thus, from geological history two main structural divisions of India are the **Himalayan Mountain Chain**, **which is a part of Laurasia or Angaraland** and the southern pan called Gondwanaland of which Peninsular India formed one of the blocks. The intervening space between the two giant continental blocks was filled with water. It was a shallow sea called **Tethy's Sea**. During the subsequent geological periods, the Indian Peninsular block began drifting northward leaving a huge gap filled with water which truly came to be called the Indian Ocean. As the peninsular block continued its drift northward, the Indian Ocean continued to advance and filled up the depressions on either side of the landmass when it compressed the Tethy's Sea. Thus, the Arabian Sea and Bay of Bengal were formed. What was once the Tethy's Sea ***has become the Mediterranean Sea***. Other remnants are the Black, Caspian, and Aral Seas (via a former inland branch known as the Paratethys).

TRIASSIC
200 million years ago

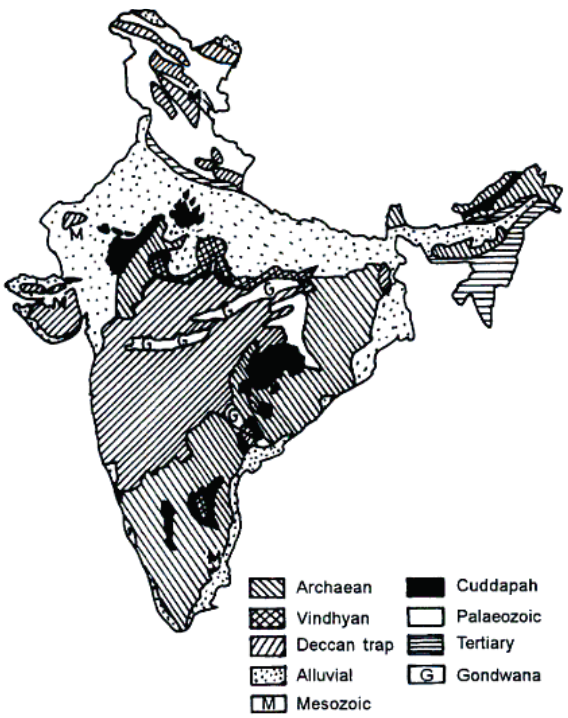
The similarity in the geological formation produced more or less similar type of mineral wealth in both India and Australia. Despite the variance in the biotic life between India and Australia, there are certain endemic plant and animal species, pointing to the super continent connection.

Please note that **Strait of Lombok** is part of the biogeographical boundary between the fauna of Indomalaya ecozone and the distinctly different fauna of Australasia. The boundary is known as the **Wallace Line**, for Alfred Russel Wallace, who first remarked upon the striking difference between animals of Indo-Malaysia from those of Australasia and how abrupt the boundary was between the two biomes.

Rock Formations (Stratigraphy)

Structurally the Indian landmass is divided into three main divisions consisting of

- The Himalayan Mountain Chain
- The North Indian Plain; and
- The Peninsular Plateau.



However, stratigraphically, India can be divided into several divisions:

1. **Archean System**
2. **Dharwar System**
3. **Cudappah**
4. **Vindhyan**
5. **Paleozoic**
6. **Mesozoic**
7. **Gondwana**
8. **Deccan Trap**
9. **Tertiary**
10. **Alluvial**

India, being a large country, has diverse geology. Different regions in India contain rocks of all types belonging to different geologic periods. Some of the rocks are badly deformed and transmuted while others are recently deposited alluvium that has yet to undergo diagenesis. Mineral deposits of great variety are found in the subcontinent in huge quantity.

Archean formations

Model Question - 2.

Consider the following statements:

1. More than half of Deccan peninsula is made up Archean Rocks
2. Archean Rocks are generally igneous
3. Archean rocks are rich in minerals

Which among the above statements is/ are correct?

Answer: 2

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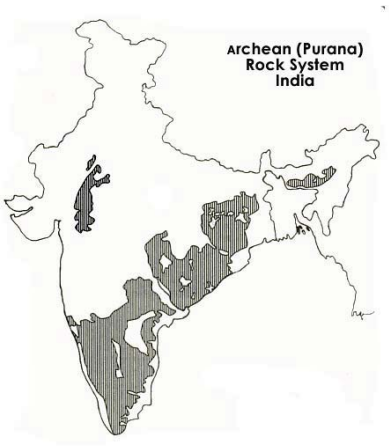

Archean rocks, also known as **Pre-Cambrian rocks** are the oldest rocks of the earth's crust. The Archean period covers 86.7% of Total geological history time of earth and therefore is very significant. This period marks the development of first photosynthesis, the life support atmosphere.

The major characteristic of the Archean rocks is that **they are azoid,** means that are *devoid of any form of remnants of life in them.* They serve as the basement complex or fundamental gneisses.

The Archean rocks in India are called **Purana Rocks** *means the oldest rocks*. The Archean or Purana rock system in India is found in Aravallis mountains, 2/3rd of the Deccan peninsula and some parts of north east. These rocks have abundant metallic and non-metallic minerals such as iron, copper, manganese, bauxite, lead, zinc, gold, silver, tin, tungsten, mica, asbestos, graphite, etc.

Dharwar system

Model Question - 3.

Consider the following statements:

1. India's first metamorphic sedimentary rocks are from Dharwar System
2. Champions series & Champaner series belong to Dharwar System of Rocks
3. In India, Dharwar Rocks are known for finding of Gold

Which among the above statements is / are correct?

Answer: 3

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Dharwar system is later than the Archean system but older than the other systems. The Dharwar period of rock formation has been largely fixed from 2500 million years ago to 1800 million years ago. Dharwar Rock System is special because it is the ***first metamorphic sedimentary rocks*** in India.

They are named Dharwar system because they were first studied in Dharwar region of Karnataka. But they are also found in Aravallis, Tamil Nadu, Chotanagpur plateau, Meghalaya, Delhi, and the Himalayas region.

The Dharwar rocks are rich in iron ore, manganese, lead, zinc, gold, silver etc.

The **Champions series** containing gold mines lie within this system. This Champion system is named after the Champion reef in the Kolar Gold Fields. The Kolar Gold Fields contain one of the deepest gold mines of world.

The other series of Dharwar system are as follows:

- Champaner series that is found near Baroda. This is source of a lush green variety of marble.
- Closepet series that is found in Balaghat and Chhindwara of Madhya Pradesh. It is rich in Copper ores.

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2 All are correct statements

3 All are correct statements.

- Chilpi Series that is found in and around the Closepet series in Balaghat and Chhindwara
- Iron-Ore series that is located in Singhbhum, Mayurbnhanj and Keonjhar rangaes.

The Cudappah System & Vindhyan System

Model Question - 4.

Which among the following rocks system in India is spread from Chittorgarh in Rajasthan in west to Sasaram in Bihar in east?

A. Gondwana
B. Dharwar
C. Vindhyan
D. Cudappah

Answer: **4**

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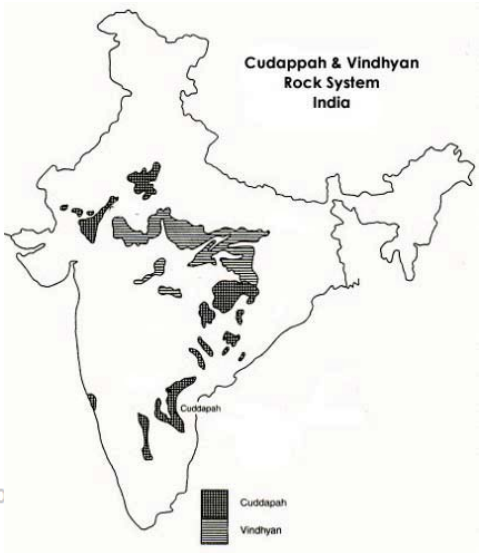
Cudappah System

Cudappah System rocks are rich in metamorphic rocks such as sandstone, shale, limestone, quartzite, and slate. They contain iron and other inferior quality of ores and minerals. They are mainly found in Cudappah district of Andhra Pradesh along with other places such as Chhattisgarh, Rajasthan, Delhi, and the lesser Himalayas. One of the important series of Cudappah System is Papaghani series, named after the river of same name in Andhra Pradesh.



Vindhyan System

The Vindhyan Mountains form a dividing line between the Ganges plain and Deccan Plateau. The Vindyan system is named after Vidhyan Mountains. This system rocks are extensively distributed in India from Chittorgarh (Rajasthan) to Sasaram (Bihar). The Vindhyan System is separated from Aravallis by the *Great Boundary Fault*. They are famous sources of Red Sandstone and other building material. The well known Panna and Golconda diamonds are found in this formation. The important series of this system are **Bhander series, Bijwar series and Kaimur series**. All are rich sources of Building material.

The Gondwana System or Carboniferous period System or Dravidian System

As the name suggests, these are the **major coal deposits of India.** This system contains famous **Damuda and Panchet series** which are *famous for coal deposits (discussed below).* The important coal bearing areas of this series are Raniganj, Jharia, Karanpur, and Bokaro of the Damodar basin in Odisha, and the Pench valley in Chhattisgarh and Madhya Pradesh, the jhingurda coal seam (Chhattisgarh). The Gondwana Supergroup forms a unique sequence of fluviatile rocks deposited in Permo-Carboniferous time. Damodar and Sone river valley and Rajmahal hills in the eastern India is depository of the Gondwana rocks.

The Cretaceous system or the Deccan Trap

Model Question - 5.

In context with the Deccan Trap, consider the following statements:

1. Deccan trap is spread in all states of Peninsular India
2. The rocks in Deccan trap are generally Igneous

Which among the above statements is / are correct?

Answer: 5

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Some people broadly divide the geographical land area of India into three parts viz. Deccan trap, Gondwana and Vindhyan. The Deccan Trap covers almost all of Maharashtra, some parts of Gujarat, Karnataka, Madhya Pradesh and marginally Andhra Pradesh. Deccan Trap is thought to have formed as result of sub-aerial volcanic activity associated with the continental deviation in this part of the Earth during the Mesozoic era. This implies that generally, the **rocks of Deccan Trap are igneous**.

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4 Correct Answer is C.

5 Only 2 is a correct statement

The Deccan system is marked by a transgression of the sea at Coromandal coast and Narmada valley and the upwelling of huge quantity of Lava/ basalt , so the Cretaceous system or Deccan Trap is made up of Basalt rocks. This system is also called lava trap and is 3000 meters deep. The rocks of this system are found in Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh, Jharkhand, Orissa, and Karnataka.

Deccan Trap and Paleontological Murder Mystery
Some scientists believe that a series of monumental volcanic eruptions in India may have killed the dinosaurs 65 million years ago, not a meteor impact in the Gulf of Mexico. The eruptions, which created the gigantic Deccan Traps lava beds of India, are now the prime suspect in the most famous and persistent paleontological murder mystery, say scientists who have conducted a slew of new investigations honing down eruption timing. The main phase of the Deccan eruptions spewed 80 percent of the lava which spread out for hundreds of miles. It is calculated to have released ten times more climate altering gases into the atmosphere than the nearly concurrent Chicxulub meteor impact, according to volcanologist Vincent Courtillot.

How it was formed?

When the Indian Plate mobbed northward after breaking off from the rest of Gondwana, it passed over a geologic hotspot, the Réunion hotspot, which caused extensive melting underneath the Indian craton. The melting broke through the surface of the craton in a massive flood basalt event, creating what is known as the Deccan Traps. It is also thought that the Reunion hotspot caused the separation of Madagascar and India.

The Tertiary System

The Tertiary rock system belongs to Cenozoic era. The Cenozoic era has two periods' viz. tertiary and quaternary. The beginning of the tertiary period is about 66 million years back. The final break-up of the Gondwana land occurred in this era and the Tethys sea got lifted in the Himalayas. The most important rocks of this system are in northern plains of India, karewas of Kashmir and bhadarwah, **Bhangar,** and **Khadar** of the Great Plains. The terraces of Jeelum Narmada, Taptii, Godavari, Krishna, Kaveri, etc. are of this period. The rocks of this system are also found in coast of Kachchh, Katiawar, Konkan, Malabar, Nilgiri, and the Eastern Ghats.

Bhangar Plains Versus Khadar Plains
Please note that both of them are of Cenozoic origin. The Bhangar represents the upland alluvial tracts of the Great Plains of India formed by the older alluviums while the new alluvium tracts along the courses of the rivers are known as Khadar. So, historically, Bhangar is older while Khadar is new. The Bhangar soil is dark in color, rich in humus and is more productive. The Khadar is enriched by fresh deposits of silt every rainy season. Khadar consists of silt, clay and mud and is less productive in comparison to Bhangar. In India, both Bhangar and Khadar are under cultivation of many important crops.

The Gondwana and Tertiary Coal Deposits of India

Model Question - 6.

Consider the following statements:

1. The distribution of coal in India is more abundant on the eastern side of the country.
2. Most coal produced in India is from Gondwana Coal Fields

Which among the above statements is / are correct?

Answer: 6

The India coal fields have been classified in two parts viz. Gondwana coal fields and Tertiary coal fields. The Gondwana Fields account for 98% of the total reserve and 99% of the total coal production in India. Rest 2% is the tertiary coal. Please note that *distribution of coal in India is more abundant on the eastern side of the country*. While Gondwana coal is about 200 million years old, tertiary deposits are approximately 55 million years old.

Gondwana Coal

The Gondwana coal fields **occur mostly in the river valleys** such as Damodar, Mahanadi, Godavari, and Narmada. The Gondwana coal is a **laminated bituminous coal within which dull and bright layers alternate**. This coal is *almost free from moisture but it contains variable quantities of sulphur and phosphorous*. In general, Gondwana coal is good steam or gas coal. *This is also known as metallurgical coal.*

The largest resources of Gondwana coal are located in the Damodar valley (West Bengal, Jharkhand), Jharia, Raniganj and Bokaro. The Godavari, Mahanadi, Son and Wardha valleys also contain coal deposits.

6 Both are correct statements.

The following table shows the list of Gondwana Coalfields in India:

State	Area	Coalfields
West Bengal	Damodar Valley	Raniganj (Trans Barakar),Bankura
	Darjeeling District	Bagrakote, Tindharia
Bihar	Damodar Valley	Ranigunj (Cis Barakar), Jharia, Bokaro, Chandrapura, South Karampura, North Karampura, Ramgarh
	Rajmahal Area	Hura, Gilhuria and Jilbari, Chuparbhita, Pachwara, Brahmini
	Deogarh Area	Kundit Kuria, Sahajuri, Jainti
	Hazaribagh District	Giridhi, Chope, Itkhori.
	Palamu Region	Anuranga, Daltongunj, Hutar
Madha Pradesh	South Rawa Region	Singrauli, Korar, Johilla river, Umaria, Sohagpur
	North Chattishgarh Region	Jhilmili, Tatapani-Ramkola, Sanhat, Jharkhand, Chirimiri-Kurasia, Koreagarh, Bassar, Bisrampur, Lakhanpur, Panchbhaini, Dambhamunda, Sendargarh
	South Chattishgarh Region	Hasdo -Rampur, Korba, Raigarh, Mand River, Kankani.
	Satpura Region	MOhpani, Sonada, Sahpur (Tawa), Dulhara (Tawa), Pathakera, Bamhanwara, Upper Tawa Valley, Kanhan Valley, Pench Valley.
Maharashtra	Wardha Valley	Kamptee, Bandar, Warora, Rajur (Wun), Ghugus – Telwasa, Chanda, Ballarpur, Wamanapalli, Antargaon – Aksapur, Sasti – Rajpura.
Orissa	Mahanadi Valley	Talcher, Ib river (Rampur – Hingir).
Andhra Pradesh	Pranhita – Godavari Valley	Tandur Kanala, North Godavari, South Godavari, Jangam, Chinur-Sendrapalli, Kamavaram, Bandala – Alapalli, Singareni (yellendu), Lingala, Kothagudium, Damar-cherla, Kannergiri, Beddadanuru.
Uttar Pradesh		Kota (in Mirzapur District)
Assam		Abor, Aka and Daphla Hills
Sikkim		Ranjit Valley

Tertiary coal

Tertiary coal accounts for **only 2% of coal in India.** Tertiary coal has low percentage of fixed carbon and high moisture content. It also includes the Lignite. The Tertiary coal deposits are found in Assam, Meghalaya, Nagaland, Arunachal Pradesh, Jammu & Kashmir and Tamil Nadu. ***Out of them, Neyveli is the biggest lignite deposit of tertiary period.*** The other fields are as follows:

- **Assam:** Makum coalfield in Dibrugarh district is the main coalfield. Other include Nahorkatiya, Doigrung, Nambor and Longoi.
- **Meghalaya:** Khasi Jaintia and Mikir hills, Balyong, Doigring and Waimong coal-fields
- **Arunachal Pradesh:** Namchick- Namphuk (Tirap) Abor hills, Miri, Daphla, Aka hills and Miao Bum
- **Nagaland:** Nazira, Janji, Disai and Barjan are important coalfields of Nagaland.
- **Jammu and Kashmir:** Kalakot, Mohogala, Metka, Ladda and Saugar Marg

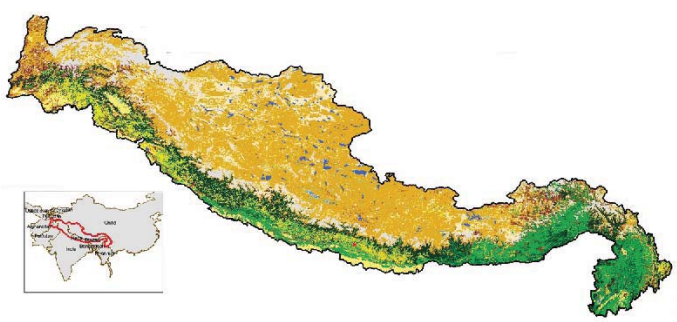
Part II. Physiographic Features of India

India can be divided into six physiographic regions. They are

- The Himalayan Mountains
- Northern Plains
- The Great Indian Desert
- The Peninsular Plateau
- Coastal Plains
- Islands

The Himalayan Mountains

Himalaya Range or Himalaya Mountains also includes the Karakoram, the Hindu Kush, and other, lesser, ranges that extend out from the Pamir Knot. The Himalayan mountain system is the world's highest, and home to the world's highest peaks, the Eight-thousanders, which include Mount Everest and K2.



After Himalayan peaks, it is Aconcagua, in the Andes, at 6,962 metres, known to be the highest peak outside Asia.

There are over 100 mountains in Himalaya system that exceeds 7,200 m. The main Himalayan ranges run from Indus river valley in the west to the Brahmaputra river valley in east forming an arc 2,400 km long, which varies in width from 400 km in the western Kashmir-Xinjiang region to 150 km in the eastern Tibet-Arunachal Pradesh

region. In this 2400 kilometer long arc, there are *three coextensive sub-ranges, with the northernmost, and highest, known as the Great or Inner Himalayas*. Some other classifications divide the Himalayas into four mountain ranges viz. the **Trans-Himalaya or the Tethys Himalaya**, the **Greater Himalaya, Lesser Himalaya** and / or **Shivalik Himalaya.**

Himalaya system gives rise to some of world's major river systems. The combined drainage basin is home to slightly less than half of world's population. The highest peak Everest is located in Nepal. Another peak K2 is on the border of Pakistan and China. Kanchenjunga is located on the border of Nepal and India. Nanda Devi is the highest peak within India.

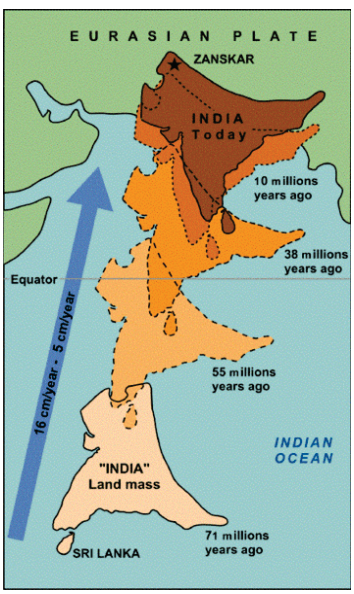
Himalayan Orogeny

Geologically, the origin of the Himalayas is the impact of the Indian tectonic plate travelling northward at 15 cm per year to impact the Eurasian continent, about 40-50 million years ago. The formation of the Himalayan arc resulted since the lighter rock of the seabeds of that time was easily uplifted into mountains. The proof cited for this fact is that ***summit of Mount Everest is made of marine limestone*.**

Indian subcontinent was part of Gondwana and was separated from Eurasia by the **Paleo-Tethys Ocean** during Late Precambrian and the Paleozoic periods. Then, in the early Carboniferous, an early stage of rifting developed between the Indian continent and the **Cimmerian Superterranes,** which surrounded India in the Precambrian era towards north-eastern side.

During the Early Permian, this rift developed into the **Neotethys Ocean**. From that time on, the Cimmerian Superterranes drifted away from Gondwana towards the north. Nowadays, Iran, Afghanistan and Tibet are partly made up of these terrenes.

Approximately 210 Million Years Ago, a major rifting episode split Gondwana in two parts. The Indian continent became part of East Gondwana, together with Australia and Antarctica. Later, the Indian plate broke off from Australia and Antarctica in the Early Cretaceous (130-125 Million Years Ago) with the opening of the "South Indian Ocean".



Around 85 Million Years Ago, during the Upper Cretaceous, the Indian plate began its very rapid northward drift covering a distance of about 6000 km, with the oceanic-oceanic subduction continuing until the final closure of the oceanic basin and the abduction of oceanic ophiolite onto India and the beginning of continent-continent tectonic interaction starting at about 65 Ma in the Central Himalaya.

This rapid relative speed between the Indian and Asian plates was very fast (18-19.5 cm/yr), and it later became fast (4.5 cm/yr) at 55 Million Years Ago. Since then there has been about 2500 km of crustal shortening and rotating of India by 45° counterclockwise in North-western Himalaya to 10°-15° counterclockwise in North Central Nepal relative to Asia.

During this process, most of the oceanic crust was "simply" subducted below the Tibetan block during the northward motion of India.

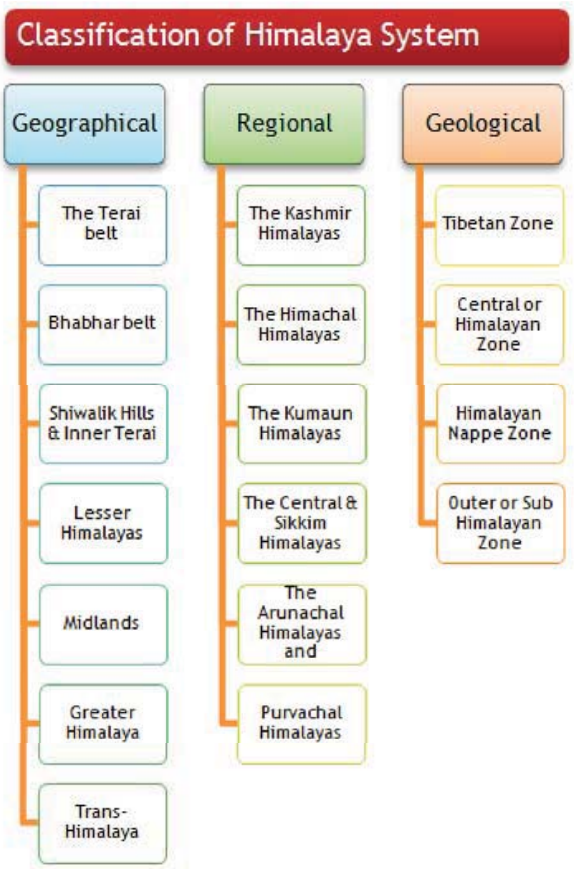
But a question where the continental crust of 2500 kilometers gone, which India travelled during this period has been largely under studies. Several theories have been put forward to explain what happened, since collision, to

the 2500 km of "missing continental crust". The first mechanism says that is 2500 kilometer continental crust also got subducted below Tibet.

Second is the extrusion or escape tectonics mechanism (Molnar & Tapponnier 1975) which sees the Indian plate as an indenter that squeezed the Indochina block out of its way. The third proposed mechanism is that a large part (~1000 km (Dewey, Cande & Pitman 1989) or ~800 to ~1200 km) of the 2500 km of crustal shortening was accommodated by thrusting and folding of the sediments of the passive Indian margin together with the deformation of the Tibetan crust. Out of them, it is the last mechanism which explains the creation of the high topographic relief of the Himalaya.

Classification of the Himalaya System

The Indian Himalayan region (IHR) with 250-300 km across stretches over 2,500 km from Jammu & Kashmir in the west to Arunachal Pradesh in the east. This great chain of mountains in Indian territory extends all along the northern border of the country from the eastern border of Pakistan on the west to the frontiers of Myanmar in the east covering partially/fully twelve states of India, viz., Jammu & Kashmir, Himachal Pradesh, Uttaranchal, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya and hills of Assam & West Bengal. This region represents about 16.2% of total area and 3.86% of total population of India. The region is vast, rugged and versatile. It supports remarkable cultural, ethnic and biological diversity. Multiple ethnic compositions are a striking feature of the region; more than a third of all scheduled tribes of India inhabit the region. Ethnic spectra of central and western Himalaya differ conspicuously from that of the north eastern Himalaya. The region is characterized by mountain specificities viz. inaccessibility, fragile, marginality, diversity (heterogeneity), niche (natural suitability) and adaptability. The region occupies the strategic position of entire northern boundary (North-West to North-East) of the nation and contains snow-clad peaks, glaciers of higher Himalaya and dense forest cover of mid-Himalaya.



Some scholars don't confine the extent of Himalayas between the Indus and Brahmaputra rivers and opine that Himalayas extend beyond Indus in the form of Hazara, Sulaiman, Bugati and Makaran ranges that spread up to the Arabian Sea. In the same opinion, in east, Himalayas extend till Bay of Bengal in the form of Indo-Myanmar hills, Arakan Yoma and Tenasirim ranges.

In others view, Himalayas extend from Indus in the west to beyond the Brahmaputra **Gorge** in the east.

Model Question - 7. (IAS 2012)

When you travel in Himalayas, you will see the following :

1. Deep gorges
2. U-turn river courses
3. Parallel mountain ranges
4. Steep gradients causing land sliding

Which of the above can be said to be the evidences for Himalayas being **young fold mountains**?

Answer: 7

7 1, 2, 3 & 4

The Himalaya extends like a curve of parallel ranges for nearly 2500 kilometres across southern Asia. The young fold mountains consist of a series of parallel ranges with deep valleys between them. Being **young fold mountains**, Himalaya has variety of rock structures, deep gorges and high pyramidal peaks. In High Himalayas the rivers have steep gradients, which result from the differential uplift of the High Himalayas. It has been suggested that a long and narrow arc of High Himalayas has been uplifted during quaternary.

The classification of the Himalayan Ranges is done on three bases viz. **Geographical**, **Regional** and **Geological.**

Geographical Regions of Himalaya

Himalayas can be divided into several regions, which are distinct in flora and fauna also. These different regions, demarcated at various thrust and faults, make the climate of Himalayas diverse. The climate ranges from **tropical at the base of the mountains** to **permanent ice and snow at the highest elevations**. The *amount of yearly rainfall increases generally from west to east along the front of the range.* This diversity of climate, altitude, rainfall and soil conditions generates enormous biodiversity region making it one of the Biodiversity Hotspots of the world. Himalayas can be divided into the following ecological regions:

1. The Terai belt
2. Bhabhar belt
3. Shiwalik Hills & Inner Terai
4. Lesser Himalayas
5. Midlands
6. Greater Himalaya
7. Trans-Himalaya

Terai belt

Terai belt is the zone of sand and clay soils at the junction of northern plains and Himalayas. As the name suggests, Terai region gets higher rainfall than the plains. The speed of the Himalayan Rivers is slowed down in the Terai region and these *rivers deposit fertile silt during the monsoons*. The water table in this region is high and vegetation is largely savannah in a mosaic of deciduous and evergreen forests called **Terai-Duar forests**.

Bhabhar belt

Bhabar belt is located above the Terai belt, also sometimes known as **Himalayan foothills**. It is made up of porous and rocky soils that get made of the debris washed down from the higher ranges. The climate here is subtropical and vegetation is *Himalayan subtropical pine forests* and *Himalayan subtropical broadleaf forests*. The *Himalayan subtropical pine forests* are dominated by **Chir trees** and *Himalayan subtropical broadleaf forests* are dominated by the sal tree *(Shorea robusta)*.

Shivalik Hills & Inner Terai

Shivaliks or Churia or Margalla Hills are the outermost range of foothills extending across the Himalayan region through Pakistan, India, Nepal and Bhutan. This is mainly located along a Himalayan Frontal Thrust (HFT). The vegetation here is dominated by Himalayan subtropical pine and broadleaf forests. The Inner Terai valleys are open valleys north of Shiwalik Hills or nestled between Shiwalik sub ranges. Examples include Dehra Dun in India and Chitwan in Nepal.

Lesser Himalaya

Lesser Himalaya is also known as Mahabharat Zone. The hills here range 2000 to 3000 meters and are located along the Main Boundary Thrust (MBT) fault zone. This zone is home to ***some of the deepest canyons in the world***. The vegetation here is Himalayan subtropical forests.

Midlands

This region is located north of the Mahabharata range or Lesser Himalaya. It is located along the Main Central Thrust fault zone, where the Greater Himalaya begin. Here the vegetation is along with coniferous forests along with broadleaf forests.

Greater Himalaya

The Great Himalayas which is a **single range and the oldest** of the three ranges with a height above 6,000 m including Mount Everest, K2 and Kanchendzonga and nine of the 14 highest peaks in the world. Greater Himalayas is located north of the Main Central Thrust. Here the highest ranges rise abruptly into the realm of perpetual snow and ice. The vegetation here is Himalayan alpine shrub and meadows. The shrublands are composed of junipers as well as a wide variety of rhododendrons. They also possess a remarkable variety of wildflowers. **Valley of Flowers National Park** in the western Himalayan alpine shrub and meadows contains hundreds of species. The upper limit of the grasslands increases from west to east, rising from 3,500 meters to 5,500 meters.

Trans-Himalayas

The trans-Himalaya is the rain-shadow region just behind the main peaks of the towering Himalayan Mountains. Notable places of the trans-Himalayas include the Tibetan Plateau, the Ladakh area of the Northern Indian Himalayas (Indus Valley) along with the Lahaul-Kinnaur-Spiti region and in north-western Nepal the Dolpo/Dolpa, Mustang, Manang, Humla and Mugu areas. The Trans-Himalayas, mainly composed of granites and volcanic rocks of Neogene and Paleogene age are bounded by the Kailas (southwest), Nganglong Kangri (north), and Nyainqêntanglha (southeast) mountain ranges and by the Brahmaputra River.

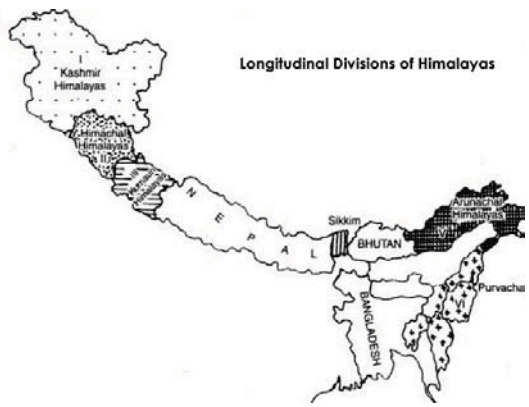
Regional Divisions of Himalayas

From west to East, Himalayas have been divided into:

- The Kashmir Himalayas
- The Himachal Himalayas
- The Kumaun Himalayas
- The Central & Sikkim Himalayas
- The Arunachal Himalayas and Purvachal Himalayas

The Kashmir Himalayas

The Kashmir Himalayas has the *largest number of Glaciers in India*. The Ladakh region of the Kashmir Himalayas is India's Cold Desert Biosphere reserve.



A special feature of the valleys of Kashmir Himalayas is the Karewa deposits which are made up of silt, clay and sand. The Karewas are known for saffron cultivation and have orchards of fruits and dry fruits such as apple, peach, almond, and walnut. The major characters of Kashmir Himalayas are Glaciers, snow peaks, deep valleys and High Mountain passes. The important passes are Pir-Panjal, Banihal, Zoji-La, Saser-La, Chang-La, Jara-La etc.

The Himachal Himalayas

Himachal Himalayas are spread in Himachal Pradesh. The Rohtang, Bara-Lacha, Shipki-La are important passes joining India and China. The valleys of Kullu, Kangra, Manali, Lahaul, Spiti are known for orchards and tourist spots.

The Kumaun Himalayas / Central Himalayas / Garhwal Himalayas

Model Question - 8. (IAS 2003)

Nanda Devi peak forms a part of ___:

A. Assam Himalayas
B. Kumaon Himalayas
C. Nepal Himalayas
D. Punjab Himalayas

Answer: **8**

8 Correct Answer is B.,

Kumaun Himalayas are located between the Sutlej and Kali rivers. They are home to **India's highest peak Nanda Devi**. Other peaks located in Kumaun Himalayas are Kamet, Trishul, Badrinath, Kedarnath, Dunagiri, Gangotri etc. Gangotri and Pindar are important glaciers.

Garhwal Himalaya versus Kumaon Himalaya
The western part of Kumaon Himalaya is known as Garhwal Himalayan while East as Kumaon. Geographically, Garhwal Himalaya lies between the lat. 29°31' 9'' N and 31°26' 5"N and long. 77°33' 5"E and 80°6' 0"E with a total geographical area of 29,089 km.

The Sikkim (Central) Himalayas

Sikkim Himalayas are located beyond the Kali River up to the Teesta River. Most of them are located in Nepal and known as Central Himalayas. These Himalayas are home to *highest peaks of Himalayas such as Everest, Kanchenjunga, Makalu, Dhaulagiri, Annapurna* etc. ***It is characterized by very few passes***. Two passes viz. Nathu La and Jelep-La are important as they connect India's Sikkim to Tibet of China.

Eastern Himalayas & Purvanchal Hills

The Eastern Himalayas occupy the Arunachal Pradesh and Bhutan. The important hills in this region are *Aka Hills, Daphla Hills, Miri Hills, Mishmi Hills, Namcha Barwa* etc. The *Dihang and Debang passes of Arunachal Pradesh are its parts.* Passing from Arunachal Pradesh, there is an eastward extension of the Himalayas in the north-eastern region of India. This is known as Purvanchal Hills. Purvanchal Hills comprises the *Patkai hills, the Manipur hills, Bairal range, the Mizo hills and the Naga hills*. It is a densely forested area, mainly composed of strong sandstones.

Syntaxial bends in Himalayas
Himalaya is marked at the both the western and eastern ends by geological Syntaxial bends in rock structure wherein the tight, fault bounded, trapdoor or pop-up uplifts of Naga Parbat on the west and Namche Barwa at the east have occurred in past few million years. These mark the end of Himalayas at both end, more prominently at the western end.

Geological Divisions of Himalayas

From a geological point of view, Himalayas can be divided into four zones. These zones are identified on the basis of age and composition of the rocks.

- **Tibetan Region:** This region lies north of the Greater Himalayas. Rocks in this region date back from the Palaeozoic Era to Pleistocene Epoch.
- **Central or Himalayan Zone:** This zone has **Isoclinal folds** and it includes the Greater Himalayas and some parts of Lesser Himalayas. *The Isoclinal folds are essentially parallel to each other* and thus approximately parallel to the axial plane. This region has abundant rocks such as granite as well as metamorphic rocks like schists and gneiss. This region also has sedimentary rocks.
- **Himalayan Nappe Zone:** A nappe (literally means tablecloth) is a large sheetlike body of rock that has been moved some kilometers away from its original position. Nappes form during continental plate collisions, when folds are sheared so much that they fold back over on themselves and break apart. The resulting structure is a large-scale recumbent fold. The nappes are most common in Kashmir and Kumaun Himalayas.
- **Outer or Sub-Himalayan Zone:** This zone includes the Siwalik range which is mainly composed of sedimentary deposits of upper tertiary period. This implies that the Shivalik hills are mainly derived from the eroded material of the main Himalayan ranges.

Important Mountain passes in Himalayas

The rugged terrain makes few routes through the mountains possible. Some of these routes include:

- ✓ ***Banihal*** *is an important pass connecting the hill areas of Jammu to the Kashmir Valley. The Jawahar Tunnel (named after Pandit Jawaharlal Nehru), inaugurated in December 1956, was constructed for round-the-year surface transport*
- ✓ ***Zoji La*** *lies between the valley of Kashmir and the Kargil district, and is the only Western entrance to the highlands of Ladakh.*

- ✓ *Rohtang Pass in Himachal Pradesh, India.*
- ✓ *Mohan Pass is the principal pass in the Shiwalik Hills, the southernmost and geologically youngest foothills running parallel to the main Himalayas in Sikkim.*
- ✓ ***Kora La** at 4,594 meters elevation on the Nepal-Tibet border at the upper end of Mustang. The Kali Gandaki Gorge transects the main Himalaya and Transhimalayan ranges. Kora La is the lowest pass through both ranges between K2 and Everest, but some 300 metres higher than Nathula and Jelepla passes further east between Sikkim and Tibet.*
- ✓ ***Aghill Pass:** Situated to the north of K2 in the Karakoram at an elevation of 5000 meters, joins Ladakh with the Xinjiang Province of China.*
- ✓ ***Bara-Lacha:** Bara-lacha la also known as Bara-lacha Pass is located in the Zanskar range connecting Lahaul district in Himachal Pradesh to Ladakh in Jammu and Kashmir, situated along the Leh-Manali highway.*
- ✓ ***Bomdi-La:** It connects Arunachal Pradesh with Lhasa, the capital of Tibet.*
- ✓ ***Chang-La:** The Changla Pass or Chang La Pass (el. 5,360 m is located in Ladakh, India. It is the third highest motorable road in the world.*
- ✓ ***Debsa Pass:** Debsa Pass is a 5,360-metre (17,590 ft) high mountain pass in the Himalaya mountains between the Kullu and Spiti Districts of Himachal Pradesh.*
- ✓ ***Dihang-Debang:** Situated in the state of Arunachal Pradesh at an elevation of about 4000 feet this pass connects Arunachal Pradesh with Mandalay (Myanmar). The Dihang-Debang Biosphere reserve is located around this area.*

Important Peaks of Himalayas

Peak Name	Other names and meaning	Elevation
Everest	Sagarmatha (Nepali), "Head of the World",	8,848
K2	Chogo Gangri, Qogir Feng, Mount Godwin Austen, Dapsang	8,611
Kangchenjunga	Kangchen Dzö-nga, "Five Treasures of the Great Snow"	8,586
Lhotse	South Peak	8,516
Makalu	The Great Black	8,462
Cho Oyu	Qowowuyag, "Turquoise Goddess"	8,201
Dhaulagiri	White Mountain	8,167
Manaslu	Kutang, "Mountain of the Spirit"	8,156
Nanga Parbat	Diamir, "Naked Mountain"	8,126
Annapurna	Goddess of the Harvests	8,091
Gasherbrum I	Beautiful Mountain	8,080
Broad Peak	Faichan Kangri	8,047
Gasherbrum II	–	8,035
Shishapangma	Xixiabangma, "Crest Above The Grassy Plains", Gosainthan	8,013
Gyachung Kang	unknown	7,952
Gasherbrum IV	–	7,925
Masherbrum	unknown	7,821
Nanda Devi	Bliss-giving Goddess	7,817
Rakaposhi	Shining Wall	7,788
Tirich Mir	King of Shadows or "King of Tirich Valley"	7,708
Gangkhar Puensum	Gankar Punzum, "Three Mountain Siblings"	7,570
Ismoil Somoni Peak	Stalin Peak 1933–1962	7,495
Machapuchare	Fish Tail	6,993
Ama Dablam	Mother And Her Necklace	6,848
Kailash	Sanskrit: Kailāsa Parvata, Tibetan: Kang Rinpoche (Precious Snow Peak), Mandarin Chinese: Gāngrénbōqí fēng	6,638

(Don't Cram) source wikipedia

Eastern Himalayas versus Western Himalayas

Model Question - 9. (IAS 2007)

The alpine vegetation in the western Himalayas is found only up to a height of 3000 meters while in the eastern Himalayas it is found up to a height of 4000 meters. The reason for this variation in the same mountain range is that

A. Eastern Himalayas are higher than western Himalayas
B. Eastern Himalayas are nearer to the equator and sea coast than western Himalayas
C. Eastern Himalayas get more monsoon rainfall than the western Himalayas
D. Eastern Himalayan rocks are more fertile than the western Himalayan rocks

Answer: 9

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Himalayas are also divided in terms of Eastern and Western Himalayas, the two parts which are different from each other in many ways.

9 Correct Answer is C

The following table makes these important distinctions:

Western Himalayas	Eastern Himalayas
• Extends till west of River Kali (around 80°E Longitude). • Height of the mountains from the plains in this part rises in a number of stages. The high mountain ranges are at a long distance from the plains • Amount of rainfall here is ***less and is 1/4th of that of Eastern Himalayas.*** • ***The dominant vegetation in the western Himalayas is Coniferous forests and alpine vegetations.*** The Natural vegetation reflects the impact of lower rainfall. • ***The altitude of the Western Himalayas is higher than the Eastern Himalayas*** • Snowline is HIGHER than Eastern Himalayas • Western Himalayas receive more precipitation from ***northwest in the winters*** • ***Less biodiversity in comparison to eastern Himalayas***	• This is considered to be ranging from east of the Singalila ranges in Sikkim (88°E Longitudes) to eastern boundaries of Himalayas. • This part rises abruptly from the plains, thus peaks are not faraway from the plains (Example: Kanchenjunga) • This region received 4 times more rainfall than western Himalayas. Due to high rainfalls, it is covered with dense forests. • Snowline is LOWER than Western Himalayas • **Eastern Himalayas receive more precipitation from south-eastern monsoon** in the summers. • **Much ahead from western Himalayas in terms of Biodiversity and is one of the Biodiversity hotspots**

Some more observations:

- Western Himalayas are above 36°N Lat. (Mt. Godwin-Austin), and eastern Himalayas are below 28°N Lat. (Kanchenjunga). Thus the 8° difference in the latitude between the two ends of the Himalayas has affected the altitude of the regional snowline so that it is lower in western Himalayas and higher in the east. .
- The difference in the observed level of the snowline in western and eastern Himalayas is also due to yearly changes in the climatic conditions of the region. In the Himalayas, volume of precipitation changes from year to year, and with that the altitude at which snow falls also changes. In the years of high precipitation, often snow falls at lower altitude than the years of low precipitation.
- Himalayas are oriented east-west and their southern slopes are in direct sunshine for a larger part of the year so the snowline on the southern slopes of the ridges is higher than the northern slopes.
- Volume of precipitation decreases from the south towards the north, therefore southern ranges in eastern Himalayas have lower snowline than the northern ranges.
- Volume of precipitation *increases with altitude.*

The Northern Slopes and Southern Slopes of Himalayas

Model Question - 10.

Consider the following observations about the southern slopes and northern slopes of Himalayas:

1. Southern slopes in Himalayas are covered with thick vegetation, while the northern slopes are generally barren
2. The snowline on southern hemisphere is higher in comparison to the northern slopes

Which among the above observations is/ are correct?

Answer: 10

The Southern slopes in Himalayan region are covered with thick vegetation, while the northern slopes are generally barren. The reasons are many. The first is that Southern slopes receive more precipitation, as we all know and northern slopes in a rain shadow area. Further, the northern slopes usually receive sun rays only for a few hours during the day at a low angle. The southern slopes receive comparatively vertical rays during the middle of the day. As a result, southern slopes being warmer fall in the area of greater evapotranspiration, and that is why the vegetation is up to a higher altitude in southern slopes. Longer periods of sunshine also have an effect on the volume of snow accumulation on the southern slopes. Due to longer period of sunshine, less snow accumulates on the southern slopes than on the northern slopes. That is why; the snowline on southern slopes is lower in comparison to the northern slopes.

Great Plains

The Indo-Gangetic plains or the Great Plains are large alluvial plains dominated by three main rivers, the Indus, Ganges, and Brahmaputra. The great plains of India run parallel to the Himalayas, from Jammu and Kashmir in the

10 Only 1 is correct

west to Assam in the east, and drain most of northern and eastern India. The plains stretch 2400 kilometers from west to east and encompass an area of 700,000 km^2.

The major rivers in this region are the Ganges, Indus, and Brahmaputra along with their main tributaries– Yamuna, Chambal, Gomti, Ghaghara, Kosi, Sutlej, Ravi, Beas, Chenab, and Teesta—as well as the rivers of the Ganges Delta, such as the Meghna.The Great plain is home to nearly 1/7 of the world's population. It is bound on the north by the abruptly rising Himalayas, which feed its numerous rivers and are the source of the fertile alluvium deposited across the region by the two river systems. The southern edge of the plain is marked by the Vindhya- and Satpura Range, and the Chhota Nagpur Plateau. On the west rises the Iranian Plateau.The Great Plains of India consists largely of **alluvial deposits** brought down by the rivers originating in the Himalayan and the peninsular region. The exact depth of alluvium has not yet been fully determined. As per recent estimates the average depth of alluvium in the southern side of the plain (north of Bundelkhand) varies between 1300 to 1400 meters, while towards the Shivaliks, the depth of alluvium increases. The maximum depth of alluvium has been recorded in Haryana near Ambala and Yamunanagar.

Divisions of Great Plain

Model Question - 11.

Consider the following comparisons of Bhabar belt and Bhangar belt of northern Plains of India:

1. Bhabar is a narrow belt Bhangar is a wider belt
2. Bhabar has new alluvium deposits , Bhangar has old alluvium deposits

Which among the above comparisons is/ are correct?

Answer: 11

Great plains are generally classified into four divisions:

The Bhabar belt

Bhabar belt is adjacent to the foothills of the Himalayas and consists of **boulders and pebbles** which have been carried down by the river streams. As the porosity of this belt is very high, the streams flow underground. The Bhabar is generally narrow about 7–15 km wide. B*habar is wider in the western plains in comparison to the eastern plans of Assam*. The porosity of Bhabar is so high that most of the narrow streams get disappeared in this belt only and some of them go underground. This is also one reason that it is not suitable for crops and only big trees are able to survive.

Thus, Bhabar belt is a **narrow belt** that is located above the Terai belt, also sometimes known as **Himalayan foothills.** It is made up of porous and rocky soils that get made of the debris washed down from the higher ranges. *Streams disappear in this belt.*

The Terai belt

The Terai belt lies next to the Bhabar region and is composed of newer alluvium. The underground streams reappear in this region. The region is excessively moist and thickly forested. It also receives heavy rainfall throughout the year and is populated with a variety of wildlife. The Terai tract lies south of the Bhabar belt. The tract is *marshy and lots of mosquitoes thrive there*. The *Terai belt is wider in eastern side especially in the Brahmaputra valley.* The high rainfall, newer alluvium makes it excessive damp and lots of forests are found here. This implies that Terai belt is rich in biodiversity. Over the period of time, the forests have been cleared in various states such as Uttarakhand, Uttar Pradesh, Haryana, Punjab, and Jammu Divisions for cultivation of crops. Terai belt is known for the good cultivation of sugar-cane, rice, wheat, maize, oilseeds, pulses, and fodder.

The Bhangar belt

This is the largest part of the Northern Plains made up of **old alluvium** and forms the alluvial terrace of the flood plains. The soil in this region consists of **calcareous deposits called kankar**. The Bangar or Bhangar belt consists of **older alluvium**. In the Gangetic plains, it has a low upland covered by Laterite deposits. The Bhangar formations were deposited during the middle Pleistocene Period. The Bhangar land lies above the flood limits of

11 Both are correct statements.

the rivers. The older alluvium soil is dark in colour, rich in humus content and productive. Bhangar is generally a well drained and the **most productive land of the Great Plains of India**.

The Khadar belt

The Khadar belt lies in lowland areas after the Bhangar belt. It is made up of fresh newer alluvium which is deposited by the rivers flowing down the plain. The Khadar tracts are enriched by fresh deposits of silt every year during the rainy season. The Khadar land consists of sand, silt, clay and mud. After Independence, most of the Khadar land has been brought under cultivation and devoted to sugarcane, rice, wheat, maize, oilseeds. legumes, and fodder crops.

The Delta Plains

The deltaic plain is an extension of the Khadar land. It covers about 1.9 lakh sq km of area in the lower reaches of the Ganga River. It is an area of deposition as the river flows in this tract sluggishly. The deltaic plain consists mainly of old mud, new mud and marsh. *In the delta region, the uplands are called 'Char' while marshy areas are known as 'Bili.* The delta of Ganga being an active one, is extending towards the Bay of Bengal.

Importance of Great Plains

The Indo-Gangetic belt is the world's most extensive expanse of uninterrupted alluvium formed by the deposition of silt by the numerous rivers. The plains are flat and mostly treeless, making it conducive for irrigation through canals. The area is also rich in ground water sources. The plains are the world's most intensely farmed areas. The main crops grown are rice and wheat, which are grown in rotation. Others include maize, sugarcane and cotton.

The Indo-Gangetic plains rank among the world's most densely populated areas. The Great Plains of India are covered with one of the most productive soils of the world. Its soils have the capacity to grow any crop of the tropical and temperate regions. The plains are often termed as the 'Granary of India'. Most of the rivers traversing the Northern Plains of India are perennial in nature. A number of canals have been carved out of these rivers which make agriculture more remunerative and sustainable. The water table is high and suitable for tube well irrigation. The gentle gradient makes it navigable over long distances.

The Thar Desert

Thar Desert or Great Indian Desert is the **world's ninth largest desert**. It forms a significant portion of western India and covers an area of about 200,000 km^2 to about 238,700 km^2. In Pakistan is continues as **Cholistan Desert**. Most of the Thar Desert is situated in Rajasthan, covering 61% of geographic area of Rajasthan. About 10 percent of this region comprises sand dunes, and the remaining 90 percent consist of craggy rock forms, compacted salt-lake bottoms, and interdunal and fixed dune areas. Annual temperatures can range from 0°C in the winter to over 50°C during the summer. Most of the rainfall received in this region is associated with the short July–September southwest monsoon that brings around 100–500 mm of precipitation. Water is scarce and occurs at great depths, ranging from 30 to 120 m below the ground level. Rainfall is precarious and erratic, ranging from below 120 mm in the extreme west to 375 mm eastward. The soils of the arid region are generally sandy to sandy-loam in texture. The consistency and depth vary as per the topographical features. The low-lying loams are heavier and may have a hard pan of clay, calcium carbonate or gypsum.

Origin of Thar Desert

The origin of the Thar Desert is a controversial subject. Some consider it to be 4000 to 10,000 years old, whereas others state that aridity started in this region much earlier. Another theory states that area turned to desert relatively recently: perhaps around 2000 - 1500 BC. Around this time the Ghaggar-Hakra ceased to be a major river. It now terminates in the desert but at one time was a water source for the Indus Valley Civilization centre of Mohenjodaro.

It has been observed through remote sensing techniques that *Late Quaternary climatic changes and neotectonics have played a significant role in modifying the drainage courses in this part and a large number of palaeochannels*

*exist.*Most studies did not share the opinion that the palaeochannels of the Sarasvati River coincide with the bed of the present-day Ghaggar and believe that the Sutlej along with the Yamuna once flowed into the present riverbed. It has been postulated that the Sutlej was the main tributary of the Ghaggar and that subsequently the tectonic movements might have forced the Sutlej westwards, the Yamuna eastwards and thus dried up the Ghaggar-Hakra. Studies on Kalibangan in the desert region by Robert Raikes indicate that it was abandoned because the river dried up. Prof. B. B. Lal (retd. Director General of Archaeological Survey of India) supports this view by asserting: *"Radiocarbon dating indicates that the Mature Harappan settlement at Kalibangan had to be abandoned around 2000-1900 BCE.*

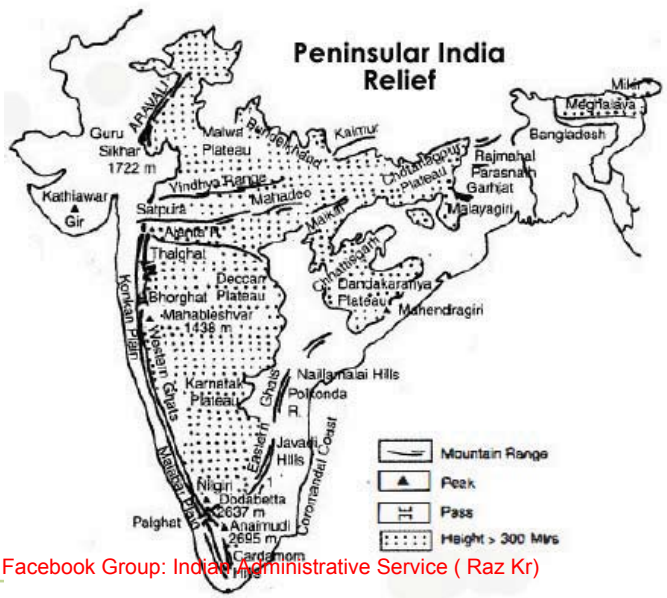
And, as the hydrological evidence indicates, this abandonment took place on account of the drying up of the Ghaggar-Hakra. This latter part is duly established by the work of Raikes, an Italian hydrologist, and of his Indian collaborators". (source: wikipedia)

Part III. Peninsular India

The Peninsular India comprises the diverse topological and climatic patterns of South India. The Peninsula is in shape of a vast inverted triangle, bounded on the west by the Arabian Sea, on the east by the Bay of Bengal and on the north by the Vindhya and Satpura ranges. The line created by the Narmada River and Mahanadi river is the traditional boundary between northern and southern India. Covering an area of about 16 Lakh km^2, the peninsular upland forms the largest physiographic division of India. It is bounded by the Aravallis in the North West, Hazaribagh and Rajmahal Hills in the northeast, the Western Ghats (Sahayadri Mountains) in the west and the Eastern Ghats in the east.

- The **highest peak of Peninsular India is Anamudi** that is 2695 metres above sea level.

The narrow strip of verdant land between the Western Ghats and the Arabian Sea is the Konkan region; the term encompasses the area south of the Narmada as far as Goa. The Western Ghats continue south, forming the Malnad (Canara) region along the Karnataka coast, and terminate at the Nilgiri mountains, an inward (easterly) extension of the Western Ghats. The Nilgiris run in a crescent approximately along the borders of Tamil Nadu with northern Kerala and Karnataka, encompassing the Palakkad and Wayanad hills, and the Satyamangalam ranges, and extending on to the relatively low-lying hills of the Eastern Ghats, on the western portion of the Tamil Nadu–Andhra Pradesh border. The Tirupati and Anaimalai hills form part of this range.



these mountain ranges. No major elevations border the plateau to the east, and it slopes gently from the Western Ghats to the eastern coast.

The Peninsular India can be divided into following:

A. Central Highlands
B. Deccan Plateau
C. Western Ghats or Sahayadri
D. The Eastern Ghats

Central Highlands

The northern central highlands of peninsular India include the Aravallis, the Malwa Plateau, and some parts of Vindhyan Range.

Aravallis:

Aravallis Range literally meaning 'line of peaks' running approximately 800 km from northeast to southwest across states of Rajasthan, Haryana, and Gujarat and Pakistan's provinces of Punjab and Sindh. The northern end of the range continues as isolated hills and rocky ridges into Haryana state, ending in Delhi. The famous **Delhi Ridge** is the last leg of the Aravalli Range, which traverses through South Delhi and terminates into Central Delhi. The southern end is at **Palanpur near Ahmadabad**, Gujarat. The highest peak is Guru Shikhar in Mount Abu. Rising to 1722 meters, it lies near the southwestern extremity of the range, close to the border with the Gujarat. The city of Udaipur with its lakes lies on the south slope of the range in Rajasthan. Numerous rivers arises amidst the ranges including, Banas River, Luni River, Sakhi, Sabarmati River. The Great Boundary Fault (GBF) separates the Aravallis from the Vindhyan Mountains.

Origin of Aravallis:

The Aravallis Range is the eroded stub of a range of ancient folded mountains that rose in a Precambrian event called the **Aravalli-Delhi Orogeny**. The range joins two of the ancient segments that make up the Indian craton, the Marwar segment to the northwest of the range, and the Bundelkhand segment to the southeast. It has been postulated that the Aravalli peaks were extremely high once but since have worn down almost completely by millions of years of weathering. In stark contrast Himalayas are continuously rising young fold mountains of today. Aravallis is rich in mineral resources. The erosion of Aravalli has a great concern for the environment because the ranges from a natural barrier against the spread of the Thar desert northwards into the Gangetic plains in the Gangetic basin and Gujarat.

Malwa Plateau

The Malwa region occupies a plateau in western **Madhya Pradesh** and south-eastern **Rajasthan with Gujarat** in the west.

- The region includes the Madhya Pradesh districts of Dewas, Dhar, Indore, Jhabua, Mandsaur, Neemuch, Rajgarh, Ratlam, Shajapur, Ujjain, and parts of Guna and Sehore, and
- Rajasthan districts of Jhalawar and parts of Banswara and Chittorgarh.
- The plateau is bound in north-east by the Hadoti region, in the north-west by the Mewar region, in the west by the Vagad region and Gujarat. To the south and east is the Vindhya Range and to the north is the Bundelkhand upland. The average elevation of the plateau is 450-500 m.

The western part of the Malwa Plateau is drained by the Mahi River, while the Chambal River drains the central part, and the Betwa River and the headwaters of the Dhasan and Ken rivers drain the east. The Shipra River is of

historical importance because of the Simhasth mela, held every 12 years. Other notable rivers are Parbati, Gambhir and Choti Kali Sindh.

- The Vindhya Range marks the southern boundary of the plateau, and is the source of many rivers of the region.

Vegetation in the Malwa Plateau is tropical dry forest, with scattered teak (*Tectona grandis*) forests. The other main trees are Butea, Bombax, Anogeissus, Acacia, Buchanania and Boswellia. The shrubs or small trees include species of G*rewia, Ziziphus mauritiana, Casearia, Prosopis, Capparis, Woodfordia, Phyllanthus,* and *Carissa.*

The Malwa plateau is considered to be an extension of the Deccan Traps and was formed at the end of Cretaceous period. Black, Brown and Bhtatori or stony soil is abundant in the Malwa Plateau. The black soil requires less irrigation because of its high capacity for moisture retention. The other two soil types are lighter and have a higher proportion of sand.

Vindhyan Range

The Vindhyan range is bounded by the Central Highlands on the south and the Aravalis on the northwest. It extends from Jobat (Gujarat) and Chittorgarh (Rajasthan) to Sasaram in Bihar for about 1050 km with general elevation between 450 to 600 metres. The western end of the Vindhyan range is in Gujarat at the eastern side of the Gujarat peninsula, near the border with Rajasthan and Madhya Pradesh. Reaching the sub-continent proper, the range runs east and north nearly to the Ganges River at Mirzapur. The area to the north and west of the range are arid and inhospitable, located in the shadow of both the Vindhya and the higher Aravalli range to the south blocking the prevailing winds.

The southern slopes of the Vindhyan Range are drained by the Narmada River, which proceeds westward to the Arabian Sea in the wide valley between the Vindhya Range and the parallel Satpura Range farther to the south. The northern slopes of the range are drained by tributaries of the Ganges, including the Kali Sindh, Parbati, Betwa, & Ken (both are tributary of the Yamuna,), Son & Tamsa or Tons both are tributary of the Ganges, drains the southern slopes of the range at its eastern end.

Vindhyachal Plateau

The Vindhyachal plateau lies to the north of the central part of the range. The cities of Bhopal, the capital of Madhya Pradesh, and Indore lie on this plateau, which rises higher than the Indo-Gangetic plain to its north.

Satpura Range

The Satpura range parallels the Vindhya Range to the north, and these two east-west ranges divide Indian Subcontinent into the Indo-Gangetic plain of northern India and the Deccan Plateau of the south. Satpura range rises in eastern Gujarat state near the Arabian Sea coast, running east through the border of Maharashtra and Madhya Pradesh to the east till Chhattisgarh.

- The Narmada River originates from north-eastern end of Satpura & runs in the depression between the Satpura and Vindhya ranges, draining the northern slope of the Satpura range and southern slopes of Vindhyan range, running west towards the Arabian Sea.
- The Tapti River originates from eastern-central part of Satpura, crosses the range in the center & further runs at the southern slopes of Satpura towards west meeting the Arabian Sea at Surat, draining central & the southern slopes of the Satpura Range.
- Please note that Mount Dhupgarh or Dhoopgarh is the highest point in the Satpura Range and in Madhya Pradesh, India. Located near Pachmarhi, it has an elevation of 1,350 metres.

The Chhotanagpur Plateau

Chhotanagpur Plateau covers much of Jharkhand state. It also covers the adjacent parts of Odisha, West Bengal, Bihar and Chhattisgarh. The Indo-Gangetic plain lies to the north and east of the plateau, and the basin of the Mahanadi River lies to the south. The total area of the Chhotanagpur Plateau is approximately 65,000 square

kilometres. This Plateau consists of three steps. The highest step is in the western part of the plateau, ranging from 3,000 -3500 feet. The next part contains larger portions of the old Ranchi and Hazaribagh districts and some parts of old Palamu district, before these were broken up into smaller administrative units. The general height is 2,000 feet. The lowest step of the plateau is at an average level of around 1,000 feet, covering the old Manbhum and Singhbhum districts.

The Chhotanagpur Plateau is composed of *Archaean granite and gneiss rocks with patches of Dharwar* and Damuda series of the Gondwana Period, and the lava flow of the Cretaceous Period. The western higher plateau of the Chhotanagpur Plateau is called Pat region. It is believed to be composed of Deccan lava. The largest part of the Chhotanagpur Plateau is called **Ranchi Plateau**. Damodar River originates here and flows through a rift valley. Damodar basin forms a trough between the Ranchi and Hazaribagh plateaus resulting from enormous fractures at their present edges, which caused the land between to sink to a great depth and incidentally preserved from denudation the Karanpura, Ramgarh and Bokaro coalfields. The plateau is covered with a variety tropical and subtropical dry broadleaf forests of which Sal forest is predominant. The plateau is home to the Palamau Tiger Reserve. Chhotanagpur plateau is a store house of minerals like mica, bauxite, copper, limestone, iron ore and coal. The Damodar valley is rich in coal and it is considered as the prime centre of coking coal in the country. Massive coal deposits are found in the central basin spreading over 2,883 km2. The important coalfields in the basin are Jharia, Raniganj, West Bokaro, East Bokaro, Ramgarh, South Karanpura and North Karanpura.

Karbi-Meghalya plateau

Karbi-Meghalya plateau is in fact an extension of the main Indian peninsular plateau and are originally two different plateaus - Karbi Anglong plateau and Meghalya plateau. It is believed that due to the force exerted by the north-eastwardly movement of the Indian plate at the time of the Himalayan origin, a huge fault was created between the Rajmahal hills and the Karbi-Meghalaya plateau. Later, this depression was filled up by the depositional activity of numerous rivers. Today the Maghalaya and Karbi Anglong plateau remains detached from the main Peninsular block. This area receives maximum rainfall from the South-West monsoon.

Deccan Plateau

The Deccan Plateau covers the majority of the southern part of the country. It is located between three mountain ranges and extends over **eight Indian states**. The plateau covers 4,22,000 sq. km., *43 percent of India's landmass*. On the west of the plateau are the Western Ghats and in the east are the Eastern Ghats. These mountain ranges rise from their respective nearby coastal plains and nearly meet at the southern tip of India. The mountains make the southward-pointing vertex of a triangle. The northern boundary of the triangle is made up by the Satpura Range and Vindhyan Range. These northern ranges separate the plateau from the heavily populated riverine plains of northern India.

Important Observations:

- This Plateau makes up a triangle nested within the familiar downward-pointing triangle of the Indian sub-continent's coastline.
- In the south, the plateau is mostly over 1,000 metres above sea level. In the north it is mostly about 500 m above sea level. The Deccan Plateau is **higher in the west and slopes gently eastwards**. This would imply that *most Deccan plateau rivers flow from west to east*. The rivers flowing through the Deccan plateau have cut deep valleys and divided the plateau into several smaller plateus such as the Maharastra Plateau, Andhra Plateau and Karnataka Plateau.
- The plateau is very big and there are many habitats: different Ecosystems with different sorts of vegetation, climate, geology and animals. The *forests on the plateau are older than the Himalayan mountains*.

- The Western Ghats mountain range is tall and blocks the moisture from the southwest monsoon from reaching the Deccan Plateau, this is the reason that the Deccan Plateau region receives very little rainfall.
- The Godavari River and its tributaries, including the Indravati River, drain most of the northern portion of the plateau, rising in the Western Ghats and flowing **east towards the Bay of Bengal**. The Tungabhadra River, Krishna River and its tributaries, including the Bhima River, which also run from west to east, drain the central portion of the plateau.
- The southernmost portion of the plateau is drained by the Kaveri River, which rises in the Western Ghats of Karnataka and bends south to break through the Nilgiri Hills at Hogenakal Falls into Tamil Nadu, then forming the *Sivasamudram Falls* at the island town of Shivanasamudra, the second-biggest waterfall in India and the sixteenth-largest in the world, before flowing into the Stanley Reservoir and the Mettur Dam that created the reservoir and finally emptying into the Bay of Bengal.
- The two main rivers which do not flow into the Bay Of Bengal are the Narmada and Tapti. They start in the Eastern Ghats and flow into the Arabian Sea.
- *All Deccan plateau rivers depend on the rains and dry up in the summers.*

Western Ghats

The Western Ghats or Sahyādri runs north to south along the western edge of the Deccan Plateau, and separates the plateau from a narrow coastal plain along the Arabian Sea. The range starts near the border of Gujarat and Maharashtra, south of the Tapti River, and runs approximately 1600 km through the states of Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala ending at Kanyakumari, at the southern tip of India. These hills cover 160,000 km^2 and form the catchment area for complex riverine drainage systems that drain almost 40% of India. The average elevation is around 1,200-1300 metres.

Observations about Western Ghats

- In India, there are two biodiversity hotspots viz. Eastern Himalayas and Western Ghats. Western Ghats are home to over 5000 species of flowering plants, 139 mammal species, 508 bird species and 179 amphibian species, many undiscovered species lives. At least 325 globally threatened species occur in the Western Ghats.
- The mountains of the Western Ghats are **Block Mountains** formed due to the down warping of a part of land into the Arabian Sea. As per other view, they are not true mountains, but are the *faulted edge of the Deccan Plateau.*
- All the important rivers of Peninsular India, like the Godavari, Krishna and Kaveri rise from the Western Ghats.
- Western Ghats are home to many hill stations like Matheran, Lonavala-Khandala, Mahabaleshwar, Panchgani, Amboli Ghat, Kudremukh and Kodagu.
- The range is called
    - Sahyadri in northern Maharashtra
    - Sahya Parvatam in Kerala
    - Nilagiri Malai in Tamil Nadu
- The confluence of the Eastern and the Western Ghats is at Biligirirangan Hills in Karnataka.
- Anamudi 2,695 metres in Kerala the highest peak in Western Ghats. Chembra Peak 2,100 metres, Banasura Peak 2,073 metres, Vellarimala 2,200 metres and Agasthya mala 1,868 metres are also in Kerala. Mullayanagiri is the highest peak in Karnataka 1,950 meters.

Consider the following statements about Cardamom Hills:
1. They are located in Western Ghats
2. They make a border between Kerala and Tamil Nadu
3. They are in World Heritage Sites list
Which among the above statements is / are correct?
[A]Only 1 is correct
[B]1 & 2 are correct
[C]1, 2 & 3 are correct
[D]1 & 3 are correct
Answer:**12**

- The smaller ranges of the Western Ghats include the Cardamom Hills and the Nilgiri Hills. Cardamom hills are located in southeast Kerala and southwest Tamil Nadu. They cover about 2,800 km^2 of mountainous terrain with deep valleys, and includes the drainages of the west flowing Periyar, Mullayar and Pamba rivers. It includes Idukki Dam and Mullaperiyar Dam. They conjoin the Anaimalai Hills to the northwest, the Palni Hills to the northeast and the Agasthyamalai Hills to the south as far as the Ariankavu pass. The crest of the hills form the boundary between Kerala and Tamil Nadu. Anamudi is also located in Cardamom Hills.
- The Nilgiri Hills are home to the hill station Ooty. In the southern part of the range in the Anaimalai Hills, in western Tamil Nadu and Kerala.
- The major gaps in the range are the Goa Gap, between the Maharashtra and Karnataka sections, and the Palghat Gap on the Tamil Nadu/Kerala border between the Nilgiri Hills and the Anaimalai Hills.
- The northern portion of the narrow coastal plain between the Western Ghats and the Arabian Sea is known as the Konkan Coast or simply Konkan, the central portion is called Kanara and the southern portion is called Malabar region or the Malabar Coast.
- The foothill region east of the Ghats in Maharashtra is known as Desh, while the eastern foothills of the central Karnataka state is known as Malenadu. The largest city within the mountains is the Pune in the Desh region on the eastern edge of the range.
- The mountains intercept the rain-bearing westerly monsoon winds, and are consequently an area of high rainfall, particularly on their western side. The dense forests also contribute to the precipitation of the area by acting as a substrate for condensation of moist rising orographic winds from the sea, and releasing much of the moisture back into the air via transpiration, allowing it to later condense and fall again as rain. The Jog Falls in Karnataka, one of the most spectacular waterfalls in India are located in Western Ghats.
- The climate is humid and tropical in the lower reaches tempered by the proximity to the sea. Elevations of 1,500 m and above in the north and 2,000 m and above in the south have a more temperate climate. Average annual temperature here is around 15 °C. In some parts frost is common, and temperatures touch the freezing point during the winter months. Mean temperature range from 20 °C in the south to 24 °C in the north. It has also been observed that the coldest periods in the south western ghats coincide with the wettest.
- During the monsoon season between June and September, the unbroken Western Ghats chain acts as a barrier to the moisture laden clouds. The heavy, eastward-moving rain-bearing clouds are forced to rise and in the process deposit most of their rain on the windward side. Rainfall in this region averages 3,000–4,000 mm. The eastern region of the Western Ghats which lie in the rain shadow, receive far less rainfall averaging about 1,000 mm bringing the average rainfall figure to 2,500 mm.

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12 1 & 2 are correct Cardamom Hills are parts of Western Ghats located in Kerala and Tamil Nadu. Famous for cultivation of cardamom, pepper and coffee. They are not yet , but under consideration by the UNESCO World Heritage Committee for selection as a World

- The vegetation in Western Ghats is tropical and subtropical moist broadleaf forest ecoregions. The northern portion of the range is generally drier than the southern portion, and at lower elevations makes up the North Western Ghats moist deciduous forests ecoregions, with mostly deciduous forests made up predominantly of teak. Above 1,000 meters elevation are the cooler and wetter North Western Ghats Montane rain forests, whose evergreen forests are characterized by trees of family Lauraceae.
- The evergreen Wayanad forests of Kerala mark the transition zone between the northern and southern ecoregions of the Western Ghats. The southern ecoregions are generally wetter and more species-rich. At lower elevations are the South Western Ghats moist deciduous forests. The moist forests transition to the drier South Deccan Plateau dry deciduous forests, which lie in its rain shadow to the east.
- Above 1,000 meters are the South Western Ghats montane rain forests, also cooler and wetter than the surrounding lowland forests, and dominated by evergreen trees, although some montane grasslands and stunted forests can be found at the highest elevations.
- The South Western Ghats montane rain forests are the most species-rich ecoregion in peninsular India; eighty percent of the flowering plant species of the entire Western Ghats range are found in this ecoregion.
- The forest in the Western Ghats has been severely fragmented due to human activities, especially clear felling for tea, coffee, and teak plantations during 1860 to 1950.
- Species that are rare, endemic and habitat specialists are more adversely affected and tend to be lost faster than other species. Complex and species rich habitats like the tropical rainforest are much more adversely affected than other habitats. The area is ecologically sensitive to development. Though this area covers barely five percent of India's land, 27% of all species of higher plants in India (4,000 of 15,000 species) are found here. Almost 1,800 of these are endemic to the region. The range is home to at least 84 amphibian species, 16 bird species, seven mammals, and 1,600 flowering plants which are not found elsewhere in the world.
- Western Ghats is home to India's 2 biosphere reserves, 13 National parks, several wildlife sanctuaries and many Reserve Forests.
- The Nilgiri Biosphere Reserve comprising 5500 km^2 of the evergreen forests of Nagarahole, deciduous forests of Bandipur National Park and Nugu in Karnataka and adjoining regions of Wayanad and Mudumalai National Park in the states of Kerala and Tamil Nadu forms the largest contiguous protected area in the Western Ghats.
- The Silent Valley National Park in Kerala is among the last tracts of virgin tropical evergreen forest in India.
- A critically endangered mammal of the Western Ghats is the nocturnal Malabar Large-spotted Civet. The arboreal Lion-tailed Macaque is endangered. Only 2500 of this species are remaining. The largest population of Lion Tailed Macaque is in Silent Valley National Park. Kudremukh National Park also protects a viable population.
- These hill ranges serve as important wildlife corridors, allowing seasonal migration of endangered Asian Elephants.
- The *Nilgiri Bio-sphere is home to the largest population of Asian Elephants* and forms an important Project Elephant and Project Tiger reserve. Brahmagiri and Pushpagiri wildlife sanctuaries are important elephant habitats. Karnataka's Ghat areas hold over six thousand elephants (as of 2004) and ten percent of India's critically endangered tiger population.

Eastern Ghats

Eastern Ghats or Pūrbaghāṭa are a **discontinuous range** of mountains along India's eastern coast. They run from West Bengal through Orissa and Andhra Pradesh to Tamil Nadu in the south passing some parts of Karnataka. They are eroded and cut through by the four major rivers of southern India, the Godavari, Mahanadi, Krishna, and Kaveri. The mountain ranges run parallel to the Bay of Bengal. The Deccan Plateau lies to the west of the range, between the Eastern Ghats and Western Ghats.

The *Eastern Ghats are not as high as the Western Ghats.* The climate of the higher hill ranges is generally cooler and wetter than the surrounding plains and the hills are home to coffee plantations and enclaves of dry forest. The Bilgiri Hills, which run east from the Western Ghats to the River Kaveri, forms a forested ecological corridor that connects the Eastern and Western Ghats, and allows the second-largest wild elephant population in India to range between the South Eastern Ghats, the Biligiri and Nilgiri Hills, and the South Western Ghats. The famous temple Malai Mahadeshwara Hills Temple is situauted in Chamarajanagar District in the Karnataka state on the Eastern Ghat.

Some other Observations

- Jindhagada is the highest mountain in the Eastern Ghats situated in Araku, district Vishakapatnam in Andhra Pradesh.
- The region boasts of fertile soil but hydropower generation here is not as profitable as it is in the Western Ghats.
- Eastern Ghats are older than the Western Ghats, and have a complex geologic history, related to the assembly and break-up of the ancient supercontinent of Rodinia and the assembly of the Gondwana supercontinent.
- The Eastern Ghats is the homeland for many Buddhist ruins from Orissa to south andhra.
- The Eastern Ghats harbour primarily tropical moist deciduous vegetation, which represents species of high economic, timber, medicinal potential. Eastern Ghats are highly significant in terms of its biodiversity. Of the estimated 3,200 flowering plant taxa, there are about
- 528 tree taxa under 271 genera belonging to 80 families distributed in different regions of Eastern Ghats. In total 454 species under 243 genera and 78 families are endemic to Eastern Ghats.
- Based on geological and tectonic considerations, the Eastern Ghats in Orissa starts from North of Similipal in Mayurbhanj district and runs through Malkangiri.
- Seventeen districts of Orissa come under the Eastern Ghats including 14 protected areas (13 wild life sanctuaries, one Biosphere reserve, one National Park, two tiger reserve and one Ramser Wetland).

Important Observations: Mountains, Hills and Hill Ranges of India

Mount Abu

- ✓ *Highest peak in the Aravalli Range*
- ✓ *Located in Sirohi district, Rajasthan.*
- ✓ *Highest peak on the mountain is Guru Shikhar, at 1,722 metres*
- ✓ *Ancient name of Mount Abu is "Arbudaanchal"*
- ✓ *Only hill station in Rajasthan*
- ✓ *Mount Abu Wildlife Sanctuary was established in 1960 and covers 290 km^2 of the mountain.*
- ✓ *Mount Abu is home to a number of Jain temples. The Dilwara Temples are a complex of temples, carved of white marble, that were built between the 11th and 13th centuries AD. The oldest of these is the Vimal Vasahi temple, built in 1021 AD by Vimal Shah and dedicated to the first of the Jain Tirthankaras.*
- ✓ *Home to famous Nakki Lake.*
- ✓ *The Achalgarh fort, built in the 14th century by Rana Kumbha of Mewar, stands nearby. It encloses several Jain temples*

- ✓ *Location of Madhuban which is the headquarters of the Brahma Kumaris World Spiritual University.*

Cardamom Hills

- ✓ *Part of the southern Western Ghats located in southeast Kerala and southwest Tamil Nadu.*
- ✓ *Name comes from the cardamom spice grown in much of the hill's cool elevation, which also grows pepper and coffee.*
- ✓ *Home to drainages of the west flowing Periyar, Mullakudy and Pamba rivers. It includes Idukki Dam and Mullaperiyar Dam.*
- ✓ *They conjoin the Anaimalai Hills to the northwest, the Palni Hills to the northeast and the Agasthyamalai Hills to the south as far as the Ariankavu pass. The highest peak in the range is Anamudi, with a height of 2,695 metres.*
- ✓ *The central part of the hills comprises the Periyar Wildlife Sanctuary covering an area of 777 km^2. The 350 km^2 core zone of the sanctuary is the Periyar National Park and Tiger Reserve. Periyar is a major ecotourism destination.*

Anamudi

- ✓ *Located in Kerala, Highest peak of western Ghats and also in south India.*
- ✓ *Elevation 2695 meters.*
- ✓ *Anamudi literally translates to "elephants forehead," a reference to the resemblance of the mountain to an elephant's head.*
- ✓ *Highest point in India outside the Himalaya-Karakoram mountain range.*

Anginda peak

- ✓ *Anginda peak is in the Nilgiri Hills of the Western Ghats in Kerala.*
- ✓ *Highest peak in Silent Valley National Park.*

Phawngpui

- ✓ *Phawngpui or the Blue Mountain of Mizoram is a highly revered peak, considered to be the abode of the Gods.*
- ✓ *Phawngpui Peak is the highest mountain peak in Mizoram (2165 metres).*
- ✓ *Famous for orchids and rhododendrons.*

Doddabetta

- ✓ *Doddabetta is highest mountain in the Nilgiri Hills, at 2637 metre.*

Kangchenjunga

- ✓ *Kangchenjunga is the third highest mountain of the world with an elevation of 8,586 m.*
- ✓ *Located along the India-Nepal border in the Himalayas.*
- ✓ *Kangchenjunga is also the name of the section of the Himalayas and means "The Five Treasures of Snows", as it contains five peaks, four of them over 8,450 m*
- ✓ *The treasures represent the five repositories of God, which are gold, silver, gems, grain, and holy books.*
- ✓ *Until 1852, Kangchenjunga was assumed to be the highest mountain in the world, but calculations made by the Great Trigonometric Survey of India in 1849 came to the conclusion that Mount Everest (known as Peak XV at the time) was the highest and Kangchenjunga the third-highest*

Nanda Devi

- ✓ *Second highest mountain in India and highest entirely within the country.*
- ✓ *Part of the Garhwal Himalayas, and is located in the state of Uttarakhand, between the Rishiganga valley on the west and the Goriganga valley on the east.*
- ✓ *Peak is regarded as the patron-goddess of the Uttarakhand Himalaya.*

Garo Hills

- ✓ *Part of the Garo-Khasi range in Meghalaya, India.It is one of the wettest places in the world. The range is part of the Meghalaya subtropical forests ecoregion.*
- ✓ *Two mountain ranges - the Arabella range and the Tura range, pass through the Garo Hills, forming the great Balpakram valley in between.*
- ✓ *Largest town Tura.*

- ✓ *Shillong also located in Garo Hills.*

Khasi Hills

- ✓ *Khasi Hills are part of the Garo-Khasi range in the Indian state of Meghalaya, and is part of the Patkai range and of the Meghalaya subtropical forests ecoregion.*

Jaintia Hills

- ✓ *Tribal region located in HImalaya.*
- ✓ *Home to Monolith in Nartiang which is touted as one of the tallest monolith in the world.*

Mizo Hills

- ✓ *Lushai Hills (or Mizo Hills) are part of the Patkai range in Mizoram and partially in Tripura, India.*

Naga Hills

- ✓ *Located on India Myanmar border,*
- ✓ *Naga hills, reaching a height of around 3825 metres, lie on the border of India and Burma (Myanmar). These hills are part of a complex mountain system, and the parts of the mountain ranges inside the Indian state of Nagaland and the Burmese region of Sagaing are called the Naga Hills.*
- ✓ *In British India, the major part of the hills came under the Naga Hills district.*
- ✓ *The hills, due to their complexity and position form a barrier between the two countries. The Naga Hills are part of the Arakan Range (Rahkine Range) which to the north rise to 12,552 feet.*

Palni Hills

- ✓ *Palni Hills or Palani Hills are in Tamil Nadu.*
- ✓ *They are eastward extension of the Western Ghats ranges, which run parallel to the west coast of India.*
- ✓ *Home to one of the shrines of Lord Karthikeyan or Murugan.*

Patkai Hills

- ✓ *Located on India's North Eastern border with Burma.*
- ✓ *Mawsynram and Cherrapunji, on the windward side of these hills are the world's wettest places, having the highest annual rainfall.*
- ✓ *Climate ranges from temperate to alpine due to altitude.*

Shivalik Hills

- ✓ *Was known as Manak Parbat in ancient times.*
- ✓ *Also known as Churia and Margalla hills.*
- ✓ *Southernmost and geologically youngest east-west mountain chain of the Himalayas ranging from Indus to Brahamputra.*
- ✓ *Chiefly composed of sandstone and conglomerate rock formations, which are the solidified detritus of the great range in their rear, but often poorly consolidated.*
- ✓ *Bounded on the south by a fault system called the Main Frontal Thrust, with steeper slopes on that side.*
- ✓ *Sivapithecus or Ramapithecus is among many fossil finds in the Siwalik region.*
- ✓ *The Siwalik Hills are also among the richest fossil sites for large animals anywhere in Asia.*

Zanskar Range

- ✓ *Located in Jammu & Kashmir of India , seperates Zanskar from Ladakh.*
- ✓ *Geologically, the Zanskar Range is part of the Tethys Himalaya, an approximately 100-km-wide synclinorium formed by strongly folded and imbricated, weakly metamorphosed sedimentary series.*
- ✓ *The average height of the Zanskar Range is about 6,000 m (19,700 ft).*
- ✓ *Its eastern part is known as Rupshu.*

Basics of Drainage System

A drainage system is the pattern formed by the streams, rivers, and lakes in a particular **drainage basin**. A drainage basin is an extent or an area of land where surface water from rain and melting snow or ice converges to a single point or where the waters join another water body, such as a river, lake, reservoir, estuary, wetland, sea, or ocean.

Model Question - 13.

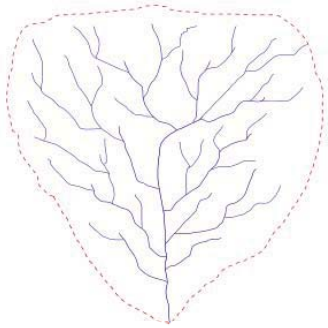
Consider the following statements:

1. Majority of rivers in India have open basin
2. Majority of rivers in India drain in Bay of Bengal

Which among the above statements is / are correct?

Answer: 13

The basin can be **closed basin or open Basin.** In **open basin**, the water body is hydro-logically toward the sea. **The rivers which drain to oceans and seas have open basins.**



In closed drainage basins the water converges to a single point inside the basin, known as a sink, which may be a permanent lake, dry lake, or a point where surface water is lost underground.

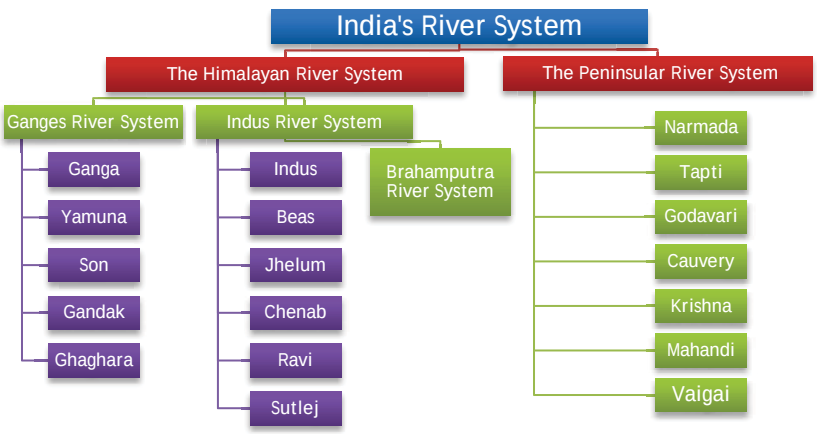
The drainage basin includes both the streams and rivers that convey the water as well as the land surfaces from which water drains into those channels, and is separated from adjacent basins by a drainage divide. The other words used for basin are **catchment, catchment area, catchment basin, drainage area, river basin, water basin** and **watershed.** The dashed line in the adjacent graphic shows a basin.

The river basins are controlled by the topography of the land such as rock types, gradient, soil type etc. The stream in a basin can be runoff, through flow or underground flow. The topographic barriers make watersheds. A watershed would represent all the stream tributaries that flow to some distance along the main stream. *Almost all of India's rivers are of open basin as more than 90% of total surface water runoff would go to Bay of Bengal*. Rest goes to Arabian Sea. There is just a small area in parts of Ladakh, northern parts of the Aravalli range and the arid parts of the Thar Desert, that have inland drainage.

Indian River System

All major rivers of India originate from one of the three main watersheds:

- The Himalaya and the Karakoram ranges
- Vindhya and Satpura ranges and Chhotanagpur plateau in central India
- Sahyadri or Western Ghats in western India



13 Both are correct statements.

Indus River System

Indus River

- Indus River originates in Tibetan plateau at **Bokhar Chu** (glacier) in northern slopes of Mt. Kailas, in the vicinity of Lake Mansarovar in Tibet, runs a course through the Ladakh of India and then enters Pakistan via the Northern Areas (Gilgit-Baltistan), flowing through the North in a southerly direction along the entire length of Pakistan, to merge into the Arabian Sea near Karachi.
- The total length of the river is 3,180 kilometers, making it Pakistan's longest river and world's 21st largest river in terms of annual flow. The river basin is 11,165,000 square kilometers.
- Several tributaries of Indus River in Pakistan side are Nagar River, Astor River, Balram River, Dras River, Gar River, Ghizar River, Gilgit River, Gumal River Kabul River, Kurram River, Panjnad River, Shigar River, Shyok River, Sohan River, Tanubal River, Zanskar River etc.
- On the eastern side, portion of it does run through Indian territory, as do parts of the courses of its five major tributaries viz. Beas, Chenab, Jhelum, Ravi and Sutlej. These tributaries are the source of the name of the Punjab region.

Indus Water Treaty

After the independence of India and Pakistan in 1947, the use of the waters of the Indus and its five eastern tributaries became a major dispute between India and Pakistan. The irrigation canals of the Sutlej valley and the Bari Doab were split - with the canals lying primarily in Pakistan and the headwork dams in India disrupting supply in some parts of Pakistan. The concern over India building large dams over various Punjab rivers that could undercut the supply flowing to Pakistan, as well as the possibility that India could divert rivers in the time of war, caused political consternation in Pakistan. India and Pakistan signed the Indus Waters Treaty in 1960. The treaty, which was brokered by World Bank, gave India control of the three easternmost rivers of the Punjab, the Sutlej, the Beas and the Ravi, while Pakistan gained control of the three western rivers, the Jhelum, the Chenab and the Indus. India retained the right to use of the western rivers for non irrigation projects.

Beas River

- Originates in the southern slopes of Pir Panjal ranges near Rohtang Pass in Himachal Pradesh.
- It flows south past Manali and through the Kullu Valley before entering the Punjab plains. It meets the Sutlej River near the **Harike Wetland** south of Amritsar. The Sutlej continues into Pakistani Punjab and joins the Chenab River at Uch near Bahawalpur to form the Panjnad River; the latter in turn joins the Indus River at Mithankot. So, originating in India and running for 470 kilometers, the river meets Sutlej in Punjab of India.

- The river is of Historic, known as *Arjikuja* and *Vipasa* in ancient times and **Hyphasis to ancient Greeks.**
- Some of the tributaries of the river Beas are as
    - **Parbati** which rises in the snowy wastes above Manikaran. It joins the river Beas near Shamshi in the Kulu valley;
    - **Haria** which joins the river Beas near Bhuntar;
    - **Sainj** which rises in the snows of an off-shoot of the Pir Panjal range that marks the watershed of the Seas and Satluj rivers. It joins the river Beas near Larji;
    - **Tirthan** which rises in the snows of an off-shoot of the Pir Panjal range. It joins the river Beas near Larji.

Jhelum River

- Jhelum rises from **northern slopes of Pir Panjal ranges at Verinag spring** (which is main source) which girdles the valley of Kashmir. It flows through Srinagar and the Wular Lake before entering Pakistan through a deep narrow gorge.
- **The Kishenganga (Neelum) River, the largest tributary of the Jhelum**, joins it, at Domel Muzaffarabad. The Jhelum enters the Punjab in the Jhelum District. From there, it flows through the plains of Pakistan's Punjab, forming the boundary between the Chaj and Sindh Sagar Doabs.

- It ends in a confluence with the Chenab at Trimmu in District Jhang. The Chenab merges with the Sutlej to form the **Panjnad River** which joins the Indus River at Mithankot. Thus, In India it flows on in Jammu & Kashmir State.

- *Jhelam is the largest and most western of the five rivers of Punjab.* Chenab is its tributary. It was called **Vitasta in Rigveda** and **Hydaspes by the ancient Greeks.** Alexander the Great and his army crossed the Jhelum in BC 326 at the Battle of the Hydaspes River where it is believed that he defeated the Indian king, Porus.
- Verinag is situated at a distance of approximately 80 km from Srinagar. Considered to be the source of the River Jhelum, often termed as the lifeline of the province of Jammu and Kashmir, the beautiful region of Verinag a weekend getaway from Srinagar. The important dams and barrages on Jhelam river are **Mangla Dam, Rasul Barrage, Trimmu Barrage.**
- Its major tributaries are –
    - Liddar which originates in the snowy wastes at Chandanwari. It joins the river Jhelum in the central pan of the Kashmir valley;
    - Sind River which originates in the southern slopes of the great Himalayan range which hems the Kashmir valley;
    - Kishenganga which also originates on the southern slopes of the great Himalayan range.

Kishenganga Power Project

- Kishan Ganga River is known as Neelum River in Pakistan and PoK. The river flows from India to Pakistan.
- India is building a 330 MW hydroelectric power project. This project was awarded to Hindustan Construction Company Ltd, with a timeline of 7 years. This project involves the diverting of the water of the river to Jhelum through a 27 kilometer tunnel. Pakistan is also building a 969 MW hydroelectric power project. This project has been awarded to a Chinese consortium.
- Pakistan says that India is violating the 1960 Indus Water Treaty by diverting the route of the river. India denies this. Pakistan has taken this issue to the United Nations.
- According to India, the treaty allows it to divert Kishanganga waters to the Bonar Madmati Nallah, another tributary of the Jhelum, which falls into the Wullar Lake before joining the Jhelum again. Pakistan has objected to this saying India's plans to divert waters will obstruct the flow of the river affecting its Neelum-Jhelum project downstream.
- Pakistan can take this issue in UN because the Indus Water treaty between India and Pakistan was signed in 1960 under the aegis of the United Nations. This treaty provides an arbitration court, which has to have seven members, including the chairman. India and Pakistan have named two international experts each to represent them. Since the issue could not be solved by the bilateral talks, it is under arbitration. On 30th October 2010, Judge Stephen M. Schwebel, former President of the International Court of Justice, has been appointed head of the Court of Arbitration being constituted to resolve the Kishanganga hydroelectric project dispute between India and Pakistan. Judge Schwebel is an expert on international law and dispute settlement.
- Pakistan's bid to stall construction work at the Kishenganga power project in Jammu and Kashmir, was thwarted on January 14, 2010 when it was forced to withdraw a petition in this regard at the International Court of Arbitration. During the first hearing of the Kishenganga Arbitration Court in The Hague in The Netherlands, the Indian side put up a spirited argument for construction of the 330-MW project on Kishenganga, a tributary of the Jhelum river.
- The project is slated to be completed by 2016.

Chenab River

Chenab River was called **Ashkini in Vedic times.** It originates at snow melt from the **Bara Lacha Pass in the Himachal Pradesh**. The waters flowing south from the pass are known as the **Chandra River** and those that flow north are called the **Bhaga River.** Eventually the Bhaga flows around to the south joining the Chandra at the village of Tandi, forming the **Chandrbhaga River at Tandi.**

It becomes the Chenab when it joins the Marau River at Bhandera Kot, 12 km from Kishtwar Town in Jammu and Kashmir. It flows in the Indian state of Jammu & Kashmir, then Pakistan Province of Punjab and merges with Jhelum River at Trimmu, Ravi River Ahmedpur Sialand Sutlej River near Uch Sharif, Pakistan to form the Panjnad or the 'Five Rivers', the fifth being the Beas River which joins the Satluj near Ferozepur, India. The Chenab then

joins the Indus at Mithankot, Pakistan. The total length of the Chenab is approximately 960 kilometres.The waters of the Chenab are allocated to Pakistan under the terms of the Indus Waters Treaty. **It was known as Acesines to the Ancient Greeks.**

Baglihar Dam Project

- Baglihar Dam or Baglihar Hydroelectric Power Project of India is on Chenab River Doda , Jammu and Kashmir. This project was conceived in 1992, approved in 1996 and construction began in 1999. The project is estimated to cost USD $1 billion. The first phase of the Baglihar Dam was completed in 2004. With the second phase completed, on 10 October 2008, Prime Minister Manmohan Singh of India dedicated the 450-MW Baglihar hydro electric power project to the nation.

Baglihar Dam Controversy

- The Dam has been a controversial issue between India and Pakistan. When the construction of this dam began in 1999, Pakistan claimed that design parameters of Baglihar project violated the Indus Water Treaty of 1960. The Indus Water Treaty provided India with exclusive control over three eastern rivers ,Near Beacon tunnel while granting Pakistan exclusive control to three western rivers, including Chenab River. However it contained provisions for India to establish river-run power projects with limited reservoir capacity and flow control needed for feasible power generation. Availing this provision India established several run-of-the-river projects, with Pakistan objecting to these. Also in the case of the Baglihar and Kishenganga Hydroelectric Plants, Pakistan claimed that some design parameters were too lax than were needed for feasible power generation and provided India with excessive ability to accelerate, decelerate or block flow of the river, thus giving India a strategic leverage in times of political tension or war.
- There was no result of several rounds of talks between India and Pakistan. Issue was taken to World Bank, a broker and signatory of Indus Water Treaty. World Bank appointed a neutral expert Raymond Lafitte, a Swiss civil engineer, to adjudicate the difference.
- The overall design of the Baglihar dam being built by India on the Chenab as a run-of-river plant was upheld by Prof. Raymond Lafitte, the Neutral Expert (NE) appointed by the World Bank to consider Pakistan's objections to the Baglihar project, in his decision delivered on 12-February, 2007 in Berne to the representatives of India and Pakistan.
- The decision of the NE recognized India's right to utilize the waters of the Western Rivers more effectively, within the ambit of the Treaty, for power generation.
- This was the first time since the signing of the Indus Waters Treaty 1960 that a Neutral Expert was appointed.

Ravi River

The Ravi or **Iravati or Purushni of ancient India** is smallest of Five Punjab Rivers. It originates in Bara Bhangal, District Kangra in Himachal Pradesh and gets hemmed by Dhauladhar range in the south and the Pir Panjal in the north. It originates in Bara Bangahal as a joint stream formed by:

- The Bhadal. which is fed by glaciers.
- The Tant Gari, which is also fed by glaciers.

The river Ravi flows in more or less westerly direction before it cuts across the Dhauladhar range to enter the plains of Punjab. Its main northern bank tributaries are the snow fed Siul and Baira streams. It follows a north-westerly course, flows through Barabhangal, Bara Bansu and Chamba districts. It flows in rapids in its initial reaches with boulders seen scattered in the bed of the river.The Budhil River, in Himachal Pradesh is a major tributary of the Ravi River. Another major tributary that joins the Ravi River, just below Bharmour, the old capital of Chamba, is the Seul River from the northern direction.

The valley formed by the river was also exploited for its rich timber trees. However, the valley has large terraces, which are very fertile and known as "the garden of Chamba". crops grown here supply grains to the capital region and to Dalhousie town and its surrounding areas. One more major tributary that joins the Ravi River near Bissoli is the Siawa. It enters the Punjab plain near Madhopur and Pathankot. It then flows along the Indo–Pak border for80 kilometres (50 mi) before entering Pakistan and joining the Chenab River. The total length of the river is about 725 kilometres.

Since this river flows at the boundary of India and Pakistan, studies have shown that the river is changing its course towards India due to heavy constructions in its way by Pakistan.

Major Dams and Projects on Ravi

- Baira Suil Hydroelelectric Power Project of 198 MW capacity was the first project on Ravi River.
- Chamera-I of 540 MW capacity commissioned in 1994,
- Ranjitsagar Multipurpose Project (600 MW) completed in 1999 and the Chamera-II of 300 MW capacity in the upstream of Chamera-I commissioned in 2004.It is also known as Thein dam as it is located in Thein village.

Sutlej River

Sutlej River was known as Śutudri in ancient India and is longest of the five rivers of Punjab. It originates near Lake Rakshastal in Tibet. It flows for a considerable distance before entering Indian Territory near Shipki La.

Thereafter, it drains past the trans-Himalayan zone of Spiti. The major tributary which joins the river Satluj in this tract is the river Spiti. This tributary rises on the northern slopes of the great Himalayan range which hems the Lahaul and Spiti valleys. It drains the latter valley and flows in a eastern and south westerly direction before joining the river Satluj. The river Satluj has cut across the great Himalayan range through a deep gorge.

Just upstream of this gorge, it is joined by the river Baspa which drains the north eastern part of Himachal Pradesh. After crossing the great Himalayan range, the river Satluj flows in a more or less S W direction before emerging into the plains near Bhakra. In Pakistan, it waters the ancient and historical former Bahawalpur state. The region to its south and east is arid, and is known as Cholistan, is a part of Bahawalpur Division.

The Sutlej is joined by the Beas River in Hari-Ke-Patan, Amritsar, Punjāb, India, and continues southwest into Pakistan to unite with the Chenab River, forming the Panjnad River near Bahawalpur. The Panjnad joins the Indus River at Mithankot. Indus then flows through a gorge near Sukkur, flows through the fertile plains region of Sindh, and terminates in the Arabian Sea near the port city of Karachi in Pakistan.The waters of the Sutlej are allocated to India under the Indus Waters Treaty between India and Pakistan, and are mostly diverted to irrigation canals in India.

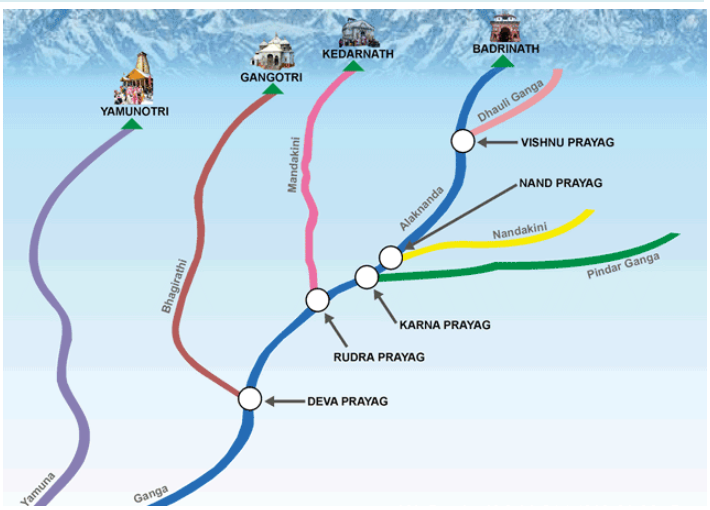
Projects on Sutlej River

- There are several major hydroelectric projects on the Sutlej, for example, the 1,000 MW Bhakra Dam, the 1,000 MW Karcham-Wangtoo and the 1,530 MW Nathpa Jhakri Hydroelectric Dam.
- There has been a proposal to build a 214-kilometre (133 mi) long heavy freight canal, known as the Sutlej-Yamuna Link (SYL), in India to connect the Sutlej and Yamuna rivers. However, the proposal met obstacles and was referred to the Supreme Court.

The Ganga River System

The major river Ganga and its tributaries like Yamuna, Son, and Gandak make the biggest cultivable plains of north and eastern India, known as the Indo-Gangetic plains. The main river, Ganga forms by the joining of the Alaknanda River and Bhagirathi River at Devprayag. The Bhagirathi, which is considered the Ganga' true source, starts from Gomukh.

Understanding Course of Ganga



Gangotri is called the origin of the River Ganga and seat of the goddess Ganga. However, it is actually the source of one of the Ganga's **6 headstreams** known as **Bhagirathi. Bhagirathi itself is joined by two headstreams called Bhilangna River and Jahnavi River.** Another mighty headstream is river **Alaknanda**. Bhagirathi and Alaknanda are the two major rivers of the Garhwal Himalaya, both originating from the mighty **Chaukhamba range of glaciers**. Chaukhamba is a mountain massif in the Gangotri Group of the Garhwal Himalaya. Its main summit, **Chaukhamba I,** is the highest peak in the group. It lies at the head of the Gangotri Glacier and forms the eastern anchor of the group. Other peaks are Chaukhamba II, Chaukhamba III and Chaukhamba IV.

Bhagirathi has its origin at Gangotri (which is called Gangotri Glacier) on the north-western face of Chaukhamba. Alaknanda rises at the confluence and feet of the **Satopanth and Bhagirath Kharak glaciers,** on the south-eastern slopes of glacier fields of Chaukhamba.

Gangotri & Gaumukh

Gangotri is one of the four sites in the Char Dham pilgrimage circuit, other being Yamunotri, Kedarnath and Badrinath. The Gangotri Glacier is located in Uttarkashi District, Uttarakhand. The terminus of the Gangotri Glacier is said to resemble a cow's mouth, and the place is called Gomukh. Gaumukh is the source of Bhagirathi

river. Gomukh is situated near the base of Shivling; in between lies the Tapovan meadow. The river Bhagirathi flows from Gangotri and at Devprayag, it meets another headstream of Ganga called Alaknanda.

Alaknanda

As written above, Alaknanda rises at the confluence and feet of the Satopanth and Bhagirath Kharak glaciers, on the south-eastern slopes of glacier fields of Chaukhamba. It meets the Bhagirathi river at Devprayag after flowing for approximately 190 km through the Alaknanda valley. After originating, it first meets the Saraswathi River and then flows in front of the Badrinath temple. After this, it meets its tributary and another headstream of Ganga called **Dhauliganga**. When Alaknanda meets Dhauliganga, it is called **Vishnu Prayag.** The two streams now become one and go ahead. Next headstream is Nandakini, which meets Alaknanda at Nandaprayag.

- From here, the Alaknanda river becomes mighty and now meets Pindar River at Karnaprayag.
- After Karnaprayag, the Mandakini river meets this stream and it is called Rudraprayag.
- Finally, the Alaknanda meets Bhagirathi at Devprayag and from here, it is called Ganga.
- These five Prayags or confluences are collectively called **Panchaprayag**. The Alaknanda contributes a significantly larger portion to the flow of the Ganga than the Bhagirathi.

Thus in all there are 6 headstreams that contribute in the making of Ganga. These are Alaknanda, Dhauliganga, Nandakini, Pindar, Mandakini, and Bhagirathi rivers.

Further Course of Ganga Till Kanpur

After flowing 250 kilometers, Ganga emerges from the mountains at Rishikesh, and then debouches onto the Gangetic Plain at Haridwar.

Some of the Ganga water at Haridwar is diverted into the Ganga Canal, which irrigates the Doab region of Uttar Pradesh. Till Haridwar, the route of Ganga is little southwest, from here it begins to flow southeast through the plains of northern India. It flows 800 kilometers passing via Kannauj, Farukhabad, and reaches Kanpur. Before Ganga reaches Kanpur, two important rivers join it. One is **Kali River** and another is Ramganga. Kali River is also known with this name in Nepal but is known as **Sharda River in India**. It originates at Kalapaani in Pithoragarh district of Uttarakhand. Kali River makes India's eastern boundary with Nepal at some places and when it reaches the plains of Uttarakhand and Uttar Pradesh, it would be called as Sharda.

Next is Ramganga. Please note that there are two Ramganga rivers. One of them starts from Doodhatoli ranges in Pauri Garhwal and another from Namik Glacier of Pithoragarh. The Bareilly of Uttar Pradesh is located on the banks of the first. After Bareilly , it meets Kali River. The Kali river keeps flowing till Bahraich, by then it is known as **Saryu River.** Saryu River meets Ganga in the Bahraich of Uttar Pradesh.

After Kanpur

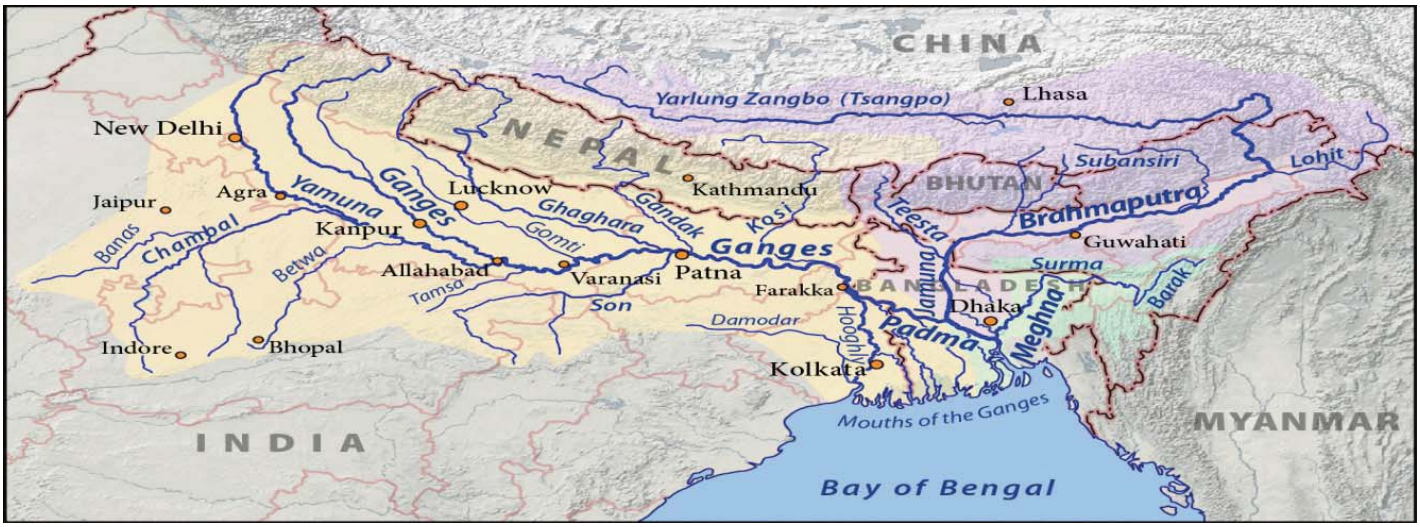
After Kanpur, Ganga joins the Yamuna at the **Triveni Sangam** at Allahabad, a holy confluence in Hinduism. At their confluence the Yamuna is larger than the Ganga. After this, several stream such as Tamsa River, Ghaghara river, Gandaki River, Kosi River join it at various places which shall be discussed in this module. Ganga remains one stream flowing southeast till Bhagalpur. From Pakur in Jharkhand, Ganga starts dividing into various distributaries. In the Murshidabad District of West Bengal at the Farakka Barrage, Ganga's first distributor **Bhāgirathi-Hooghly** gets branched out. This Bhāgirathi-Hooghly river later becomes Hooghly river and then enters the twin cities of Kolkata and Howrah. At Nurpur it enters an old channel of the Ganga and turns south to empty into the Bay of Bengal.

The Farakka Barrage controls the flow of the Ganga, diverting some of the water into a feeder canal linked to the Hooghly for the purpose of keeping it relatively silt-free. Before the Hooghly river empties into Bay of Bengal, it meets Damodar River. But, the main branch of Ganga has to go a long way still. It enters Bangladesh from India near Chapai Nababganj and now its name is **Padma River**. Here Padma meets one of the distributaries of Brahmaputra called **Jamuna or Jomuna**.

This combined stream meets Meghna river, that is another distributary of Brahmaputra at Chandpur in Bangladesh. The Meghna River finally flows into the Bay of Bengal.

The above discussion makes it clear that various distributaries of Ganga and Brahmaputra meet along the Bay of Bengal and these make one of the **largest delta in the world called Gangaes Delta** or **Ganges-Brahmaputra** delta.

They also create underwater Bengal Fan, which is one of the largest submarine fans on Earth. The fan is about 3000 km long, 1000 km wide with a maximum thickness of 16.5 km. Most of the sediment is supplied by the confluent Ganga and Brahmaputra Rivers through the Ganga Delta in Bangladesh and West Bengal, India, with several other large rivers in Bangladesh and India providing smaller contributions.



Tributaries of Ganga

Son River

Son River is largest of **southern tributaries of Ganga** that originates near Amarkantak in Madhya Pradesh near the source of Narmada River, and flows north-northwest through Madhya Pradesh before turning sharply eastward where it encounters the southwest-northeast-running Kaimur Range.

- The Son parallels the Kaimur hills, flowing east-northeast through Uttar Pradesh, Jharkhand and Bihar states to join the Ganga just above Patna. Geologically, the lower valley of the Son is an extension of the Narmada Valley, and the Kaimur Range an extension of the Vindhya Range.
- Chief tributaries of Son river are **Rihand and the North Koel.** The Son has a steep gradient (35–55 cm per km) with quick run-off and ephemeral regimes, becoming a roaring river with the rain-waters in the catchment area but turning quickly into a fordable stream.
- The Rihand River is a tributary of the Son River and flows through the Indian states of Chhattisgarh and Uttar Pradesh. It rises in Chhattisgarh at Matiranga hills and there is a Rihand Dam that was constructed at Pipri in Sonbhadra district of Mirzapur division in 1962 for hydropower generation. The reservoir of this dam is called Govind Ballabh Pant Sagar. Rihand meets Son at Sonbhadra of Uttar Pradesh.

Ghaghara River

Karnali or Ghaghara originates in glaciers of Mapchachungo on the Tibetan Plateau near Lake Mansarovar, cuts through the Himalayas in Nepal and joins the Sarda River at Brahmaghat in India.

With a length of 507 kilometers it is the largest river in Nepal. The total length of Ghaghara River up to its confluence with the Ganga at Doriganj in Bihar is 1,080 kilometers.

It is the largest tributary of the Ganga by volume and the second longest tributary of the Ganga by length after Yamuna.

In Chinese it is called ***K'ung-ch'iao Ho***, in Nepali it is called Kauriala and Karnali.

- Before Ghaghara joins the Ganga, river **West Rapti** joins it as an important tributary.

- West Rapti is known as "Gorakhpur's Sorrow".
    - West Rapti is itself tributed by Rohni River in Gorakhpur.

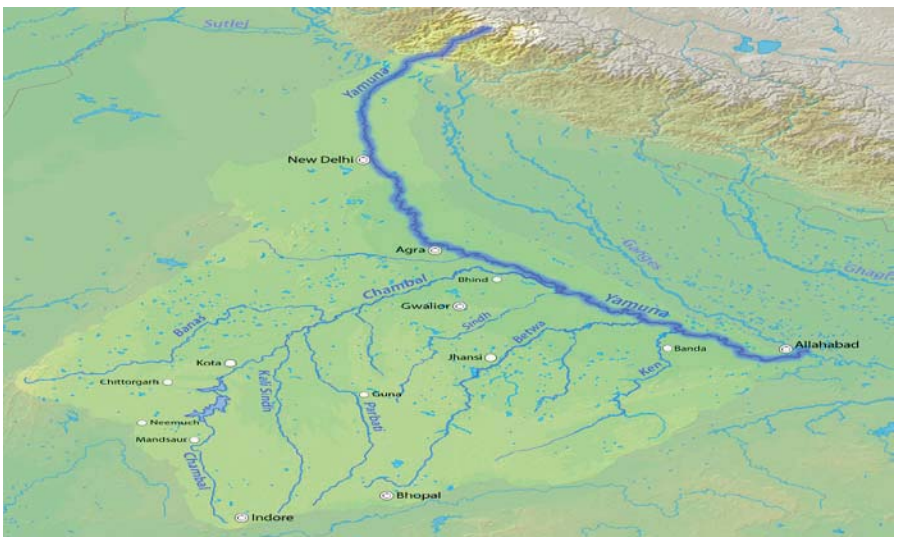
Gomti River

The Gomti originates from Gomat Taal which formally known as Fulhaar jheel, near Madho Tanda, Pilibhit, India. It extends 900 km through Uttar Pradesh and meets the Ganga River near Saidpur, Kaithi in Ghazipur.

Yamuna River

India's Yamuna River is largest tributary of Ganga River, while Bangladesh's Jamuna River is largest distributary channel of the Brahmaputra River. Yamuna is another sacred river of India that origins from Yamunotri Glacier at height 6,387 metres, on the south western slopes of **Banderpooch peak**, in the Lower Himalayas in Uttarakhand. From there it travels a total length of 1,376 kilometers and has a drainage system of 366,223 km^2, 40.2% of the entire Ganga Basin, before merging with the Ganga at Triveni Sangam or Prayag at Allahabad.

- From Uttarakhand, Yamuna river flows for some 200 kilometers in Lower Himalayas and Shivalik Ranges.
- Its largest tributary **Tons River** flows through Garhwal region in Uttarakhand, and meets Yamuna near Dehradun.
- The other rivers such as Giri, Rishi Ganga, Kunta, Hanuman Ganga and Bata tributaries meet Yamuna, before it descends on to the plains of Doon Valley, at Dak Pathar near Dehradun.
- Further down, Yamuna is met by the Assan River, lies the Assan barrage, which hosts a Bird Sanctuary as well.
- After passing Paonta Sahib, it reaches Tajewala in Yamuna Nagar district, of Haryana, where a dam built in 1873, is the originating place of two important canals, the Western Yamuna Canal and Eastern Yamuna Canal, which irrigate the states of Haryana and Uttar Pradesh.
- The Western Yamuna Canal (WYC) crosses Yamuna Nagar, Karnal and Panipat before reaching the Haiderpur treatment plant, which supplies part of municipal water supply to Delhi, further it also receives waste water from Yamuna Nagar and Panipat cities.
- Yamuna is replenished again after this by seasonal streams and groundwater accrual, in fact during the dry season, it remains dry in many stretches from Tajewala till Delhi, where it enters near Palla village after traversing 224 km.



Along with Ganga to which run almost parallel after it touches the Indo-Gangetic plain and creates the Ganga-Yamuna Doab region. From Delhi onwards Yamuna gets polluted due to discharge of waste water through 15 drains between Wazirabad barrage and Okhla barrage renders the river severely polluted after Wazirabad in Delhi

Tributaries of Yamuna

Betwa River

- ✓ *Betwa or Vetravati originates in Vindhya Range just north of Hoshangabad in Madhya Pradesh and flows north-east through Madhya Pradesh and flow through Orchha to Uttar Pradesh. It meets Yamuna at Hamirpur town in Uttar Pradesh.*

Sindh River

- ✓ *Sindh River originates on the Malwa Plateau in Vidisha district, and flows north-northeast through the districts of Guna, Ashoknagar, Shivpuri, Datia, Gwalior and Bhind in Madhya Pradesh to join the Yamuna River in Etawah district, Uttar Pradesh.*
- ✓ *Manikheda Dam has been constructed across the Sindh River in Shivpuri district, Madhya Pradesh.*

Hindon River

- ✓ *Hindo River is a rainfed river that originates in the Saharanpur District. It flows between Ganges and Yamuna rivers and joins Yamuna river just outside Delhi.*

Chambal River

- ✓ *Chambal River is one of the most pollution free rivers of India.*
- ✓ *It's a 960 Kilometer long river that originates at the Singar Chouri peak in the northern slopes of the Vindhyan mountains, 15 km West-South-West of Mhow in Indore District in Madhya Pradesh.*
- ✓ *From there, it flows in a northerly direction in Madhya Pradesh(M.P.) for a length of about 346 km and then in a generally north-easterly direction for a length of 225 km through Rajasthan.*
- ✓ *It enters U.P. and flows for about 32 km before joining the Yamuna River in Etawah District at an elevation of 122 m, to form a part of the greater Gangetic drainage system. Chambal is a rainfed river and its basin is bounded by the Vindhyan mountain ranges and on the north-west by the Aravallis.*

Dams in Chambal Valley Project

- » **Gandhi Sagar Dam:** This is the first of the four Chambal Valley Projects, located on the Rajasthan-Madhya Pradesh border. It is a 64 metre high masonry gravity dam, with a live storage capacity of 6,920 Mm3 and a catchment area of 22,584 km2, of which only 1,537 km2 are in Rajasthan. The dam was completed in the year 1960. The hydro-power station is located at the dam site and comprises five generating units, four of 23 MW each and one 27 MW capacity. The water released after power generation is utilised for irrigation through Kota Barrage. Rajasthan has a 50% share in the power generation of this station.
- » **Rana Pratap Sagar Dam: R**ana Pratap Sagar dam is the second in the series of Chambal Valley Projects, located 52 km downstream of Gandhi Sagar dam across the river Chambal in Rajasthan. This dam was completed in the year 1970. It is a straight masonry gravity structure, 54 meters high. The power house is located on the left side of the spillway and consists of 4 units of 43 MW each, with firm power generation of 90 MW at 60% load factor. The total catchment area of this dam is 24,864 km2, of which only 956 km2 are in Rajasthan. The free catchment area below Gandhi Sagar dam is 2,280 km2. The live storage capacity is 1,566 Mm3.Rajasthan State has a 50% share in the power generation of this station.
- » **Jawahar Sagar Dam:** Jawahar Sagar dam is the third dam in the series of Chambal Valley Projects, located 29 km upstream of Kota city and 26 km downstream of Rana Pratap Sagar dam, across the river Chambal. It is a concrete gravity dam, 45 meter high and 393 m long, generating 60 MW of power with an installed capacity of 3 units of 33 MW. The work was completed in 1972. The total catchment area of the dam is 27,195 Km2, of which only 1,496 km2 are in Rajasthan. The free catchment area below Rana Pratap Sagar dam is 2,331 km2. Rajasthan has a 50% share in the power generation of this station.
- » **Kota Barrage:** Kota Barrage is the fourth in the series of Chambal Valley Projects, located about 0.8 km upstream of Kota City in Rajasthan. Water released after power generation at Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar Dams, is diverted by Kota Barrage for irrigation in Rajasthan and in Madhya Pradesh through canals on the left and the right sides of the river. The work on this dam was completed in 1960. The total catchment area of Kota Barrage is 27,332 km2, of which the free catchment area below Jawahar Sagar Dam is just 137 km2. The live storage is 99 Mm3. It is an earthfill dam with a concrete spillway. The right and left main canals have a headworks discharge capacity of 188 and 42 m3/sec, respectively. The total length of the main canals, branches and distribution system is about 2,342 km, serving an area of 229 kha of CCA.50% of the water intercepted at Kota Barrage has been agreed to be diverted to MP for irrigation. (Source: Ministry of water resources, Rajasthan)

Tributaries of Chambal:

- ✓ ***Banas River:*** *Banas river is a rainfed river that flows in Rajasthan. Banas means hope of forests. It originates in Khamnor Hills of the Aravalli Range, about 5 km from Kumbhalgarh in Rajsamand and flows northeast through Mewar region of Rajasthan, meets the Chambal near the village of Rameshwar in Sawai Madhopur District. The cities of Nathdwara, Jahanpur, and Tonk lie on the river.*
- ✓ ***Kali Sindh River:*** *The Kali Sindh is a river in the Malwa region of Madhya Pradesh, that joins the Chambal River at downstream of Sawai Madhopur in Rajasthan*
- ✓ ***Parbati River:*** *Parbati River is a river in Madhya Pradesh, India that flows into the Chambal River. It is one of the Chambal River's three main tributaries, along with the Banas River and the Kali Sindh River.*

Brahmaputra River System

Brahmaputra originates on the Angsi Glacier located on the northern side of the Himalayas in Burang County of Tibet as the Yarlung Tsangpo River and flows southern Tibet to break through the Himalayas in great gorges. Tsangpo enters India after taking a **U turn at Namcha Barwa** and flows in Arunachal Pradesh and here we call it **Dihang River or Siang River**. This U turn marks the starting point of the Grand Canyon, known as **Yarlung Zangbo Grand Canyon**, which has been confirmed as the largest in the world. It is 496.3 kilometers long, 56.3 kilometers longer than the Colorado Grand Canyon, previously considered the world's longest. It is 5,382 meters deep, much deeper than the 3,200 meters of Peru's Colca Canyon, previously known as the world's deepest canyon.

After taking this U -turn, Dihang meets Dibang River and the Lohit River at the head of the Assam Valley and then flows southwest through the Assam Valley, where it is known as Brahmaputra. In Assam it becomes a wide stream. Then its enters Bangladesh. In Bangladesh, the Brahmaputra is joined by the Teesta River, one of its largest tributaries. Below the Teesta, the Brahmaputra splits into two distributary branches. The western branch, which contains the majority of the river's flow, continues due south as the Jamuna to merge with the lower Ganges, called the Padma River. The eastern branch is called the lower or old Brahmaputra . It curves southeast to join the Meghna River near Dhaka. The Padma and Meghna converge near Chandpur and flow out into the Bay of Bengal. Brahmaputra is 3,848 km long, and its drainage area is 712,035 km^2.

The waters of the River Brahmaputra are shared by China, India, and Bangladesh. In the 1990s and 2000s, there was repeated speculation about China building a dam at the Great Bend, with a view to divert the waters to the north of the country. This was denied by the Chinese government, later on.

Important Tributaries of Brahmaputra

Teesta River:

- ✓ *Teesta River is lifeline of Sikkim and makes a border between Sikkim and West Bengal before joining the Brahmaputra as a tributary in Bangladesh. The total length of the river is 315 kilometres .*
- ✓ *It originates at Tso Lhamo Lake in North Sikkim and is formed by the melting of the Tista Khantse glacier.*
- ✓ *Just before the Teesta Bridge, which joins Kalimpong with Darjeeling, the river is met by its main tributary, the Rangeet River.*
- ✓ *At this point, it changes course southwards flowing into West Bengal. The river hits the plains at Sevoke, at a distance of 22 Km from Siliguri, where it is spanned by the Coronation Bridge which links the north-east states to the rest of India.*
- ✓ *The river then courses its way to Jalpaiguri and then to Rangpur District of Bangladesh, before finally merging with the mighty Brahmaputra at Fulchori.*

Manas River:

- ✓ *Manas River folows in India and Bhutan and is the largest river system of Bhutan. Three other river systems of Bhutan are Amo Chu or Torsa, Wong Chu or Raidak, Mo Chu or Sankosh. It is met by three other major streams before it again debouches into India in western Assam.*
- ✓ *After flowing a total of 376 kilometers, it meets Brahmaputra River at Jogighopa. Its river valley is home to Royal Manas National Park in Bhutan and the contiguous Manas Wildlife Sanctuary of India which is a Project Tiger Reserve, an Elephant Reserve and a Biosphere Reserve as well as a UNESCO World Heritage Site.*

Rivers of Peninsular India

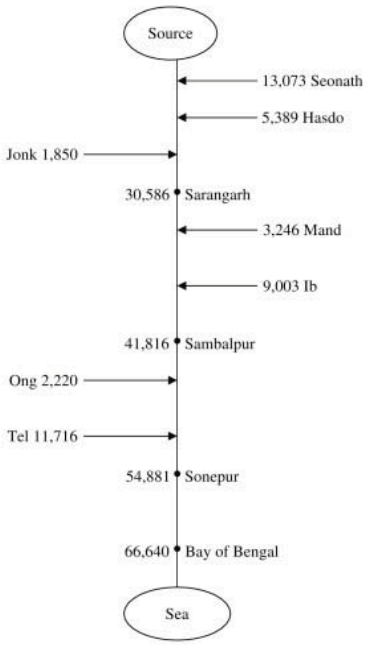
As a general observation, the Rivers of Peninsular India are rainfed and they shrink during the dry season. The line created by the Narmada River and Mahanadi River is the traditional boundary between northern and southern India. The Narmada flows westwards in the depression between the Vindhya and Satpura ranges. The plateau is watered by the east flowing Godavari and Krishna rivers. The other major rivers of the Deccan plateau are the Pennar and the Tungabhadra, a major tributary of the Krishna. There are numerous very small rivers on

the Deccan plateau which flow mostly north to south and also south to north mixing with any of the west or east flowing major rivers.

Mahanadi River Basin

The 858 Kilometers long Mahanadi river flows through the states of Chhattisgarh and Orissa. It gets formed by numerous mountain streams and the farthest headstream is located in hills of the Dhamtari district of Chhattisgarh. These hills are extensions of the Eastern Ghats and are a source of many other streams which then go on to join the Mahanadi. The river first flows in north and drains Raipur. After Bilaspur, it is joined by its major tributary river Seonath.

After that the river flows eastward and joined by Jonk, Hasdeo rivers and reaches Odisha. Near Sambalpur of Odisha, the largest dam of the world Hirakud Dam blocks its water, spread between Lamdungri and Chandili Dunguri hills. After reaching Dholpur in Odisha, the rivers rolls towards the Eastern Ghats and passes the Satkosia Gorge. After crossing the Gorge, it meets the plains of Odisha and reaches Cuttak. Before entering Cuttack city, it gives off a large distributary called the Kathjori. Cuttack is located between these two channels. The Kathjori then throws off many streams like the Kuakhai, Devi and Surua and becomes Jotdar River, which fall into the Bay of Bengal after entering Puri district. The main stream of Mahandi gets divided into several distributaries such as Paika, Birupa, Chitartala, Genguti and Nun. These all distributares form the Mahandi Delta which is one of the largest deltas in India. The Mahandi river empties into Bay of Bengal via several channels near Paradeep at False Point, Jagatsinghpur.



The numbers represent average annual flow in cumec

Importance of Mahanadi River

- ✓ *Mahanadi valley is best known for its fertile soil and flourishing agriculture. Before the Hirakud dam was built, the river carried a huge amount of silt and its delta had one of the highest yield per acre in the whole of India. At present, agriculture primarily depends on a network of canals that arise from the river. Rice, oilseeds and sugarcane are the principal crops here.*
- ✓ *The river was notorious for devastating floods, but the construction of Hirakud Dam has altered the situation.*

Tributaries of Mahanadi

The following flowchart shows the flow of Mahanadi from Source to Sea.

The major tributaries of Mahanadi are Seonath, Jonk, Hasdo, Mand, Ib, Ong, Tel etc.

- ✓ ***Seonath River:*** *The Seonath River is the longest tributary of Mahanadi. It rises in an undulating region with numerous small groups of hills at Kotgal and flows 383 kilometers to join Mahanadi at its left bank at Khargand.*
- ✓ ***Tributaries of Seonath*** *are Kharahara, Tandula, Kharun, Surhi, Agar, Arpa rivers. The total drainage area of Seonath is 22% of the total drainage area of Mahanadi Basin.*
    - o ***Jonk River:*** *Jonk River originates from the Khariar Hills of Kalahandi district of Odisha at an elevation of 762 meters. It flows 196 kilometers to join the Mahanadi on ints right at Sheorinarayan.*
- ✓ ***Hasdo River:*** *It rises in the Sarguja district of Chhattisgarh and traverses 333 kilometers to meet Mahanadi at Mahuadih.*
- ✓ *Gej River is a principle tributary of Hasdo River*
- ✓ ***Mand River:*** *Mand River originates at an elevation of 686 meters in Sarguja district of Odisha and flows 241 kilometers to meet Mahanadi at Chandarpur.*

- ✓ ***Ib River :*** *Ib originates in Pandrapat of the Raigarh distriuct of Chhattishgarh and flows 251 kilometers to fall into Hirakud Dam. Its a rainfed river.*
- ✓ ***Ong River:*** *It rises at an elevation of 457 meters on a hill in the northern outskirts of hills located on the course of Jonk River and flows 204 kilometers to meet Mahandi at Sonepur.*
- ✓ ***Tel River:*** *Tel river originates in plain in the Koraput of Odisha. It traverses 296 kilometers to meet Mahanadi at Sonepur.*

Hirakud Dam

- Built across Mahanadi River, about 15 km from Sambalpur in Odisha.
- Built in 1957, the dam is one of the world's longest earthen dam.
- Behind the dam extends a lake, Hirakud Reservoir, 55 km long.
- Initially proposed Sir M. Visveswararya in 1937, Central Waterways, Irrigation and Navigation Commission took up the work, and in 1946, Sir Howthrone Lewis, then the Governor of Orissa, laid the foundation stone of the Hirakud Dam.
- Pandit Jawaharlal Nehru laid the first batch of concrete on 12 April 1948. The dam was completed in 1953 and was formally inaugurated by Prime Minister Jawaharlal Nehru on 13 January 1957. The total cost of the project was Rs. 100.02 crores in 1957. Power generation along with agricultural irrigation started in 1956, achieving full potential in 1966.
- There are two observation towers on the dam one at each side. One is "Gandhi Minar" and the other one is "Nehru Minar". Both the observation towers present breathtaking views of the lake.
- Helps control floods in the Mahanadi delta and irrigates 75,000 square kilometres of land. Hydroelectricity is also generated.
- Cattle Island is located in one of the extreme points of Hirakud Reservoir, a natural wonder. Completely inhabited by wild cattle, with out any trace of humans.
- Debrigarh wildlife sanctuary is located here.

Brahmani River

Brahmani River is NOT a tributary of Mahanadi. It's a seasonal river that flows in Odisha. It is formed by the confluence of the Sankh and South Koel rivers near Raurkela, and flows through the districts of Sundargarh, Kendujhar, Dhenkanal, Cuttack and Jajapur. Together with the rivers Mahanadi and Baitarani, it forms a large delta before entering into the Bay of Bengal at Dhamra. Both headstreams of Brahmani river viz. Sankh and South Koel originate in Choota Nagpur Plateau.

- ✓ *Sankh has its origins near the Jharkhand-Chhatisgarh border, near Netarhat Plateau.*
- ✓ *South Koel too arises in Jharkhand, near Lohardaga, on the other side of a watershed that also gives rise to the Damodar River.*

Brahmani river is 480 kilometers long and is the second longest river in Orissa after the Mahanadi.

Tributaries of Brahmani River

- ✓ ***Baitarni River:*** *Baitarani River is another one of six major rivers of Odisha, which earn the name of coastal plains of Odisha as "Hexadeltaic region". The river originates in Guptaganga hills in Gonasika of Keonjhar district in Odisha and flows to make a natural boundary between Odisha and Jharkhand. It travels a distance of 360 km to drain into the Bay of Bengal after joining of the Brahmani at Dhamra mouth near Chandabali.*

Krishna River

The 1300 Kilometers long Krishna River or Krishnaveni is one of the longest rivers in Peninsular India. It is the fourth largest river in India after the Ganga, Godavari and the Narmada.

Origin & Course:

Krishna River rises at Mahabaleswar in district Satara, Maharashtra in the west and meets the Bay of Bengal at Hamasaladeevi in Andhra Pradesh, on the east coast. It flows through **Maharastra, Andhra Pradesh and Karnataka**. The delta of this river is one of the most fertile regions in India and was the home to ancient Satavahana and Ikshvaku Dynasty kings. Vijayawada is the largest city on the River Krishna.

The river flows quickly, causing much erosion in June and August. During this time, Krishna takes fertile soil from Maharashtra, Karnataka and western Andhra Pradesh towards the delta region.

The river has a number of tributaries but Tungabhadra is the principal

tributary. Other tributaries include the Mallaprabha, Koyna, Bhima, Ghataprabha, Yerla, Warna, Dindi, Musi and Dudhganga. Leaving Mahabaleswar behind, the Krishna takes the form of the Dhom lake in Panchgani, a popular hill station just 17 km from Mahabaleswar. Crisscrossing its way through Wai, Narsobachi and Wadi (near Kolhapur) in Maharashtra, the river enters Karnataka at Kurundwad, 60 km from Kolhapur. In Karnataka, the river passes through the Belgaum, Bijapur and Gulbarga districts, covering a total distance of 220 km. The Krishna enters Andhra Pradesh near Deosugur in Raichur district and meanders through Mehbubnagar, Kurnool, Guntur and Krishna districts. The river merges into the Bay of Bengal at Hamasaladeevi. Two dams, Srisailam and Nagarjuna Sagar are constructed across the Krishna River. Nagarjuna Sagar Dam is world's tallest masonry dam (124 meters).

Krishna River Basin:

Krishna Basin extends over an area of 258,948 square kilometers which is nearly 8% of total geographical area of the country. The basin lies in the states of Andhra Pradesh (113,271 km2), Karnataka (76,252 km2) and Maharashtra (69,425 km2). Most part of this basin comprises rolling and undulating country except the western border which is formed by an unbroken line of ranges of the Western Ghats. The important soil types found in the basin are black soils, red soils, Laterite and lateritic soils, alluvium, mixed soils, red and black soils and saline and alkaline soils. An average annual surface water potential of 78.1 km^3 has been assessed in this basin. Out of this, 58.0 km^3 is utilizable water. Culturable area in the basin is about 203,000 km2, which is 10.4% of the total culturable area of the country. In 2009 October heavy floods occurred, isolating 350 villages and leaving millions homeless, which is believed to be first occurrence in 1000 years. The flood resulted in heavy damage to Kurnool, Mahabubnagar, Guntur, Krishna and Nalagonda Districts.

Tributaries of Krishna:

Major Tributaries of Krishna River are as follows:

- ✓ ***Left: B****hima, Dindi, Peddavagu, Halia, Musi, Paleru, Munneru*
- ✓ ***Right:*** *Venna, Koyna, Panchganga, Dudhganga, Ghataprabha, Malaprabha, Tungabhadra*

Tungabhadra:

Most important tributary of Krishna River is the Tungabhadra River, which is formed by the Tunga River and Bhadra River that originate in the Western Ghats. Tungbhadra flows in Karnataka and Andhra Pradesh. It was known as Pampa during the epic period. The name of famous tourist spot Hampi is derived from Pampa, which is the old name of the Tungabhadra River on whose banks the city is built.

The Tunga and Bhadra Rivers rise at Gangamoola, in Varaha Parvatha in the Western Ghats forming parts of the Kuduremukh Iron Ore Project, at an elevation of 1198 metres. Bhadra flows through Bhadravati city and is joined by numerous streams. At Koodli, a small town near Shimoga City, Karnataka, the two rivers meet and called with the common name Tungabhadra. From here, Thungabhadra meanders through the plains to a distance of 531 km (330 mi) and mingles with the Krishna at Gondimalla, near Mahaboobnagar in Andhra Pradesh.

Importance of Tungabhadra River

There are a number of ancient and holy sites on the banks of the Tungabhadra River.

- ✓ *At Harihara there is a temple dedicated to Harihareshwara.*
- ✓ *The river surrounds the modern town of Hampi, where are the ruins of Vijayanagara, the site of the powerful Vijayanagara Empire's capital city and now a World Heritage Site. The site, including the Vijayanagara temple complex ruins, is being restored.*
- ✓ *Alampur, on the left - northern bank of the river, known as Dakshina Kashi in Mahabubnagar Dist. The Nava Brahma Temples complex is one of the earliest models of temple architecture in India.*
- ✓ *Bhadravthi, Hospet, Hampi, Mantralayam, Kurnool are located on its bank.*

Tributaries of Tungabhadra:

- ✓ *Tunga River, Kumudvati River, Varada River, Bhadra River, Vedavathi River, Handri River*

Bhima River

Bhima River originates in Bhimashankar hills near Karjat in Maharashtra and flows southeast for 861 km through Maharashtra, Karnataka, Andhra Pradesh states. Bhima is a major tributary of the Krishna River. Its banks are densely populated and form a fertile agricultural area. During its 861 kilometer journey, many smaller rivers flow into it. Kundali River, Kumandala River, Ghod river, Bhama, Indrayani River, Mula River, Mutha River and Pavna River are the major tributories of this river around Pune. Of these Indrayani, Mula, Mutha and Pawana flow through Pune and Pimpri Chinchwad city limits. Chandani, Kamini, Moshi, Bori, Sina, Man, Bhogwati and Nira are the major tributaries of the river in Solapur. Of these Nira river meets with the Bhima in Narsingpur, in Malshiras taluka in Solapur district.

- ✓ *The holy city of Pandharpur is on the bank of Bhima River.*
- ✓ *Bhimashankar is one of the twelve esteemed Jyotirlinga shrines.Other temples are Siddhatek, Siddhivinayak Temple of Ashtavinayak Ganesh Pandharpur Vithoba Temple in Solapur district., Sri Dattatreya Temple, Ganagapura, Gulbarga district, Karnataka, Sri Kshetra Rasangi Balabheemasena Temple in Rasanagi, Jevargi Taluq, Gulbarga district, Karnataka*
- ✓ *Tributaries of Bhima are:*
  - o *Ghod, Sina, Kagini, Bhama, Indrayani, Mula-Mutha, Nira*

Malaprabha River

Malaprabha River is another important tributary of Krishna River , which flows in Karnataka.It rises at Kanakumbi in the Belgaum district and joins Krishna River at Kudalasangama in Bagalkot district. It also flows through Dharwar District. Hubli city gets its drinking water from this reservoir.

- ✓ *Tributaries of Malprabha: Bennihalla, Hirehalla and Tuparihalla are the major tributaries to Malaprabha.*

Ghataprabha River

Ghataprabha is a tributary of Krishna that flows in Karnataka. The Ghataprabha Project at Hidkal is a hydroelectric and irrigational dam across the river.

Tributaries of Ghataprabha:

- ✓ *Hiranyakeshi and Markandeya rivers are tributaries of Ghataprabha*

Other Tributaries of Krishna

Other tributaries include the Kudali river, Venna River, Koyna River, Yerla River, Warna River, Dindi River, Paleru River, Musi River, Urmodi River, Tarli River and Dudhganga River. The rivers Venna, Koyna, Vasna, Panchganga, Dudhganga, Ghataprabha, Malaprabha and Tungabhadra join Krishna from the right bank; while the Yerla River, Musi River, Maneru and Bhima rivers join the Krishna from the left bank.

Important places on banks of River Krishna:

Mahabaleshwar

- ✓ *Mahabaleshwar besides being a popular hill station and a weekend getaway from Mumbai is also the source of the Krishna River*
- ✓ *Mahabaleshwar is located at an altitude of 1,372 meters in the Western Ghats.*
- ✓ *Mahabaleshwar can also be called the 'land of five rivers', since the holy streams Krishna, Koyna, Venna, Gayatri and Savitri emerge from here.*
- ✓ *There are many places of tourist interest in Mahabaleshwar. Lodwick Point is an important landmark in Mahabaleshwar. It is considered one of the finest locations in Mahabaleshwar from where one can enjoy the beauty of the surrounding area. This point was earlier known as Sydney Point. Arther Point is the queen of all points. It is fascinating to see the barren deep valley Savitri on the left and shallow green valley on the right.*
- ✓ *Other places of tourist interest in Mahabaleshwar include Elphinstone Point, Tiger's Spring, Kate's Point, Bombay Point, Wilson Point, Venna Lake and Kate's Point. Lingmala, Chinaman and Dhobi Waterfalls are also worth visiting in Mahabaleshwar. Kate's Point (also known as sunrise point) in particular offers fabulous view of the Krishna River.*

Srisailam

- ✓ *Leaving Mahabaleshwar behind, the Krishna river takes the form of Dhom in Panchgani, a beautiful hill station close (17 km) to Mahabaleshwar.*
- ✓ *It meanders through Narsobachi, Wadi in Maharashtra and crisscrosses its way through Karnataka before entering Andhra Pradesh.*
- ✓ *Srisailam (in Andhra Pradesh) is a holy town located on the banks of the Krishna. Srisailam is surrounded by lush greenery and has beautiful locations around.*
- ✓ *It is a wonderful weekend getaway from Hyderabad. Srisailam Sanctuary is the main attraction that covers an area of 3568 sq kms. The down waters Srisailam dam is home to a variety of crocodiles.*

Nagarjuna Sagar

- ✓ *Popularly known for the Nagarjuna Sagar Dam, Nagarjuna Sagar is approximately 170 km from Hyderabad. The dam is an engineering marvel. Stretching across the mighty river Krishna, the barrage also has another distinction to its credit - it has created one of the world's largest man-made lake.*
- ✓ *The dam has played an important role in agricultural sector of the state.*
- ✓ *Nagarjunakonda was the largest and most important Buddhist centres in South India . The place derives its name from Acharya Nagarjuna, a renowned Buddhist scholar and philosopher, who had migrated here from Amaravati to propagate and spread the Buddha's message of universal peace and brotherhood.*
- ✓ *Not too far from Nagarjunakonda is Anupa, where a Buddhist University and Stadium were excavated.*

Amaravati

- ✓ *Situated on the banks of the Krishna, Amaravati is a small town in Guntur district of Andhra Pradesh. Amaravati is an excavation site and was once the capital of Satavahanas. It is one of the important Buddhist sites in India. Amaravati is located about 60 km from Vijayawada.*
- ✓ *Amareswara Temple is the major tourist attraction in Amaravati. The temple is dedicated to Lord Shiva. It is believed that Lord Shiva is present here in the form of five lingams -Pranaveswara, Agasteswara, Kosaleswara, Someswara and Parthiveswara. The temple is built in the Dravidian style of architecture and has many legends associated with it.*
- ✓ *The remains of a 2000-year-old Buddhist settlement along with the great Buddhist stupa are among the main attractions in Amaravati. Mahachaitya or the Great Stupa was constructed approximately 2000 years ago. The stupa is made of brick with a circular vedika and depicts Lord Buddha in a human form, subduing an elephant.*

Vijayawada

- ✓ *Vijayawada being a popular trade and commerce centre is also referred to as 'the business capital of Andhra Pradesh'. Vijayawada is the 3rd largest city in Andhra Pradesh and is the largest city on the banks of Krishna River.*

Kaveri River Basin

Kaveri or Cauvery flows in Karnataka and Tamil Nadu. The river covers a distance of about 765 km and flows through the state of Karnataka and Tamil Nadu. On its journey to the Bay of Bengal, the river is joined by its tributaries, which include Shimsa, Hemavathi, Honnuhole, Arkavathi, Kapila, Lakshmana Theertha, Kabini, Lokapavani, Bhavani, Noyil and Amaravathy.

Talacauvery (also Talakaveri) located about 5000 ft above sea level is considered the source of the Cauvery.

Talacauvery is located in Coorg district of Karnataka and is 47 km from Maidekri.

Talacauvery is considered a famous pilgrimage site in Karnataka. At the source of the Cauvery there is a temple where every year on Tula sankramana thousands of pilgrims gather to pay their respects to the Cauvery.

The river then flows through Mysore district where two islands Srirangapatnam and Shivanasamudram are formed. At Sivasamudram the river drops 98 meters forming famous falls known as Gagan Chukki and Bara Chukki. After meandering through Karnataka, the river then enters Tamil Nadu and forms the boundary between the Erode and Salem districts. The Cauvery is joined by the Bhavani River at Bhavani. Hogenakkal is a major landmark on the course of the Cauvery in Tamil Nadu. Trichy and Thanjavur are other important towns on the banks of the Cauvery.

The river after covering a distance of 765 km merges into the Bay of Bengal through two principal mouths. One of the important distributory is Kollidam , which is is the northern distributary of the Kaveri River as it flows through the delta of Thanjavur. It splits from the main branch of the Kaveri River at the island of Srirangam and flows eastward into the Bay of Bengal.

Summary of Cauvery River

Tributaries

- Amaravati · Arkavathy · Bhavani · Chinnar · Hemavati · Honnuhole · Kabini · Kannika · Kollidam · Lakshmana Tirtha · Lokapavani · Noyyal · Pambar · Shimsha · Sujyothi

Important Dams

- Banasura agar · Bangara Doddi Nala · Grand Anicut · Krishna Raja Sagara · Madadkatte · Mettur Dam · Stanley Reservoir · Upper Anaicut · Lower Anaicut

Important Cities and Towns

- Bhagamandala · Bhavani · Chidambaram · Erode · Karaikal · Karur · Kodumudi · Kodagu · Kudavasal · Kumbakonam · Kushalanagara · Mannargudi · Mandya · Mayiladuthurai · Mettur · Mysore · Nagapattinam ·Nannilam · Papanasam · Puhar · Peralam · Sakleshpur · Sikkal · Sirkali · Srirangam · Srirangapatna · Swamimalai · Talakad · Talakaveri · Thanjavur · Tharangambadi · Thirunallar · Thiruvaiyaru · Thiruvarur ·Thiruveezhimizhalai · Tiruchirapalli · Vaitheeswarankoil

Riparian States and UTs

- Karnataka · Kerala · Pondicherry · Tamil Nadu

Cauvery River Basin:

The Kaveri basin is estimated to 72,000 km2 with many tributaries including the Shimsha, the Hemavati, the Arkavati, Honnuhole, Lakshmana Tirtha, Kabini, Bhavani River, the Lokapavani, the Noyyal and the Amaravati River.

Tributaries of Cauvery

- ✓ ***Amaravathi River:*** *Amaravati River is a tributary of Kaveri River in Coimbatore. It is continuation of the Pambar and Chinnar rivers in Kerala. It begins at Manjampatti Valley between the Annamalai Hills and the Palni Hills in Indira Gandhi Wildlife Sanctuary and National Park. It descends in a northerly direction through Amaravathi Reservoir and Amaravathi Dam at Amaravathinagar. It is joined by the Kallapuram River at the mouth of the Ajanda valley in Udumalaipettai. It joins with the Kaveri at Thirumukkudal, about 10km from Karur.*
- ✓ ***Arkavati River:*** *It originates in Nandi Hills of Karnataka and joins Cauvery at Kanakapura, called Sangama in Kannada, after flowing through Kolar District and Bangalore Rural district. The river is used by the Bangalore Water Supply and Sewerage Board to provide 135 million liters of drinking water per day to the city of Bangalore, or about 20% of all the city's water. The river drains into the Chikkarayappanahalli Lake near Kanivenarayanapura.*
- ✓ *Tributaries of Akravati:*
  - o *Kumudavathi and Vrishabhavathi rivers are tributaries to this river.*
- ✓ ***Bhavni River:*** *Its is a major tributary of Cauvery River. It originates in Nilgiri Hills, where 12 major rivulets join Bhavani. The west and East Varagar tributaries coming from the Nilgiris are the largest and each have dams in Tamil Nadu. The Bhavani is a 217 km. long perennial river fed mostly by the southwest monsoon and supplemented by the northeast monsoon. Its watershed drains an area of 6,200 km² spread over Tamil Nadu (87%), Kerala (9%) and Karnataka (4%).*

- ***Hemavati River:*** *It starts in the Western Ghats at an elevation of about 1,219 meters near Ballala rayana durga in the Chikmagalur District of the state of Karnataka, in southern India, and flows through Chikkamagaluru, Hassan District and Mysore district before joining the Kaveri near Krishnarajasagara.*

Godavari River Basin

With a length of 1465 Kilometers, Godavari is India's second largest river that runs within the country and also the longest river in South India. It originates near Trimbak in Nashik District of Maharashtra state and flows east across the Deccan Plateau into the Bay of Bengal near Narasapuram in West Godavari district of Andhra Pradesh.

- *The river is also known as Dakshin Ganga and Gautami. The Manjra and Indravati rivers are its major tributaries.*
- *The Godavari is sacred river and there are several places of pilgrimage on its banks. Trimbakeshwar and Nasik are major pilgrimage sites where one of the four Sinhastha Kumbh Mela takes place.*
- *Every twelve years, Pushkaram, a major bathing festival, is held on the banks of the Godavari. The next Pushkaram festival is scheduled to be held in 2015.*

Course of Godavari River

The river originates from Trimbak and then flows in the east across the Deccan Plateau traversing through the Trimbakeshwar, Nashik, Kopargaon, Paithan, Nanded, Rajahmundry, Adilabad and Bhadrachalam. Just after Rajahmundry, the river splits into two streams that widen into a large river delta, which provides an extensive navigable irrigation. In Nizamabad district of Andhra Pradesh, there is a multipurpose project on the Godavari, which is called the Sriramsagar Project. Godavari empties into the Bay of Bengal near Narasapuram in West Godavari district of Andhra Pradesh.

- *A barrage was built on the river at Dowleswaram by Sir Arthur Cotton in 1852. As it was damaged in 1987 floods, it was rebuilt as a barrage and roadway during 1987 and named after him. The roadway connects Dowleswaram in East Godavari and Vijjeswaram in West Godavari.*
- *There is also a big dam built just after the source of the river at Trimbakeshwar. The dam is in the town of Gangapur, which literally means a town on a river. The dam provides drinking water to the residents of Nashik and also supplies water to the thermal power station situated downstream at Eklahara, which provides power to the town.*
- *There is another multipurpose project on the Godavari River named Sriram Sagar Project on the borders of Adilabad and Nizamabad District. It is in the town of Pochampad, 60 km away from Nizamabad. It irrigates 4 districts of Northern Telangana Region of Andhra Pradesh and supplies power.*
- *The Jayakwadi dam near Paithan is one of the largest earthen dam in India. This dam was built to address the problem of drought in Marathwada region and problem of flood along the bank of river. Two 'left' and 'right' canals provide the irrigation to fertile land up to Nanded district. This dam has major contribution in industrial development of Aurangabad Maharashtra.*
- ***Havelock bridge is on Godavari River.*** *It was constructed under the supervision of F.T. Granville Walton who had constructed the Dufferin Bridge over the Ganges, and Granville Mills, British engineers. Spanning over 3 km in length, it linked the East Godavari and West Godavari districts. The brige has been a vital link enabling trains to run between Chennai and Howrah. Trains continued to ply over the bridge for a century until 1997, when train services over the bridge were suspended after the construction of 2 additional bridges.*
- *The* ***Coringa mangrove forests in the Godavari delta*** *are the second largest mangrove formation in the country. Part of this has been declared as the Coringa Wildlife Sanctuary, renowned for its reptiles. They also provide an important habitat to a wide variety of fish and crustaceans. These forests also act as barriers against cyclones, tropical storms and tidal waves thus protecting the nearby villages.*
- *The Krishna Godavari basin is one of the main nesting sites of the endangered Olive Ridley turtle.*

Important Places on the Bank of River Godavari

- ✓ ***Trimbakeshwar:*** *The source of the Godavari – Trimbakeshwar is one of the holy places in the country. It is located about 40 km from Nashik. Trimbakeshwar is one of the twelve Jyotirlingas of Lord Shiva. It is believed that there is no sacred place like Trimbakeshwar, no river like Godavari and no mountain like Bhrahmagiri.*
- ✓ ***Nashik:*** *Nashik is the first major city on the banks of the Godavari after Trimbakeshwar. Nashik is located about 185 km from Mumbai. It is an important religious center and attracts thousands of pilgrims every year from different parts of the country.*
- ✓ ***Paithan:*** *Famous for its Paithani sarees, Paithan is located on the banks of the Godavari in Aurangabad district of Maharashtra. It is 56 km south of Aurangabad, the ancient capital city of the Satvahanas. Paithan is associated with great saint Eknath. His 'samadhi' is located here. The Eknath Shrine comes alive during 'Paithan Yatra', also known as Nath Shashti, when devotees from Maharashtra and neighbouring states come to pay their respects to the saint.*
- ✓ ***Nanded:*** *Nanded is famous for the Sikh gurudwara - Takhat Sachkhand Shri Hazur Abchalnagar Sahib. A town of great antiquity, Naded was earlier known as 'Nandigram'. Gurudwara Shri Hazur Sahib is the main landmark in Nanded. It is one of the four high seats of authority of the Sikhs. This is the place where Shri Guru Gobind Singhji breathed his last. The gurudwara was built by Maharaja Ranjit Singh.*
- ✓ ***Bhadrachalam:*** *Bhadrachalam is situated on the banks of the Godavari and is 161 km from Rajahmundry and 200 km from Vijayawada. Bhadrachalam is regarded to be one of the holiest shrines in South India.*

Tributaries of Godavari

- ✓ ***Indravati River:*** *Indravati River rises in the Eastern Ghats in Kalahandi Orissa, and flows west to join the Godavari, forming the boundary between Maharashtra and Chhattisgarh states at places. The river flows for a length of 535 km with a drainage area of 41,665 sq.km.The Indravati is sometimes known as the "lifeline" of the Bastar District, one of the most green districts in India.*
- ✓ ***Pranahita River:*** *Pranhita River flows on the border of Gadchiroli district in Maharashtra and Adilabad district in Andhra Pradesh. It forms with the confluence of two rivers called Wardha and Wainganga.The Painganga River joins Vainganga near Aheri. The river then flows up to Sironcha before it empties into the Godavari River,near Sironcha in Maharashtra. The River course is mainly through the dense forests which are rich in Sagwan (timber).*

Other important Rivers of India

Narmada River

Narmada or Rewa River is the third largest river that completely flows within India after Ganga & Godavari. It forms the traditional boundary between North India and South India. Narmada flows in a rift valley between the Satpura and Vindhya Ranges. It has been mentioned as Nammadus in the Periplus of Erythrean Sea.

Source and Course:

Narmada origins in a small tank called Narmada Kund located on the Amarkantak hill in the Anuppur District of eastern Madhya Pradesh. The river descends from the Amarkantak hill range at the Kapildhara falls over a cliff and meanders in the hills flowing through a tortuous course crossing the rocks and islands up to the ruined palace of Ramnagar. Between Ramnagar and Mandla, (25 km (15.5 mi)), further southeast, the course is comparatively straight with deep water devoid of rocky obstacles. The Banger joins from the left. The river then runs north–east in a narrow loop towards Jabalpur. Close to this city, after the Dhuandhara falls, Narmada enters three narrow valleys between the Vindhya scarps in the north and the Satpura range in the South. The southern extension of the valley is wider at most places. These three valley sections are separated by the closely approaching line of the scarps and the Satpura hills. It forms the traditional boundary between North India and South India and flows westwards over a length of 1,312 km before draining through the Gulf of Cambey into the Arabian Sea, 30 km (18.6 mi) west of Bharuch of Gujarat

Basin:

Between Vindya and Satpura ranges, Narmada extends over an area of 98,796 km^2 . The basin covers large areas in the states of Madhya Pradesh (86%), Gujarat (14%) and a comparatively smaller area (2%) in Maharashtra. In the river course of 1,312 km, there are 41 tributaries, out of which 22 are from the Satpuda range and the rest on the right bank are from the Vindhya range.

Importance:

Narmada is one of the most sacred rivers of India. *Geologically, Narmada River is older than the river Ganges*. The river has been mentioned by Ptolemy in the Second century AD as Namade. In Puranas, it has been mentioned as Rewa. In Indian history, Kannada emperor from Chalukya dynasty Pulakeshin II is said to have defeated emperor Harshavardhana of Kannauj on the banks of Narmada. The valley is famous for the gorgeous Maheshwari saris, which are handwoven; comfortable in warm and cold weather, dressy and yet light; these saris have a dedicated, select following among Indian women. The Bhimbetka caves are located in a dyke of the Narmada valley at about 45 km northeast of Bhopal.

Mahi River

Mahi rises in Minda Village, in sardarpur district Madhaya Pradesh and, after flowing through the Vagad region of Rajasthan, enters Gujarat and falls into the sea by a wide estuary near Khambhat. Mahi encircles entire Banswara District in Rajasthan and first dam known as Mahi dam is at right side in Rajasthan. Kadana Dam is on Mahi in Gujarat. It is one of only three major rivers in peninsular India that runs from east to west along with the Tapti River and the Narmada River.

Tapti River

Tapi River, with length of 724 km, is one of only three rivers in peninsular India that run from east to west - the others being the Narmada River and the Mahi River. The river rises in the eastern Satpura Range of southern Madhya Pradesh state, and flows westward, draining Madhya Pradesh's Nimar region, Maharashtra's Kandesh and east Vidarbha regions in the northwest corner of the Deccan Plateau and south Gujarat, before emptying into the Gulf of Cambay of the Arabian Sea, in the Surat District of Gujarat. The river, along with the northern parallel Narmada river, form the boundaries between North and South India. The Western Ghats or Sahyadri range starts south of the Tapti River near the border of Gujarat and Maharashtra. The Tapti (Tapi) River empties into the Gulf of Khambhat near the city of Surat in Gujarat. Tapti Basin lies in the states of Maharashtra (51,504 km^2), Madhya Pradesh (9,804 km^2) and Gujarat (3,837 km^2).

Ghaggar-Hakra River

Ghaggar-Hakra River flows in monsoon season only. It is known as Ghaggar before the Ottu barrage and as the Hakra downstream of the barrage. It originates in the Shivalik Hills of Himachal Pradesh and flows through Punjab and Haryana states into Rajasthan; just southwest of Sirsa, Haryana and by the side of talwara jheel in Rajasthan, this seasonal river feeds two irrigation canals that extend into Rajasthan. The downstream Hakra is a dried up stream that possibly end in Rann of Katch.

Basics of Indian Coasts

Introduction to Coasts of India

The first observation about the coasts of India is that they **fall within the Tropics**. The coasts of India include:

- West coast
- East coast
- Coast of Lakshadweep and Andaman and Nicobar islands.

The total coastline of India measures about 7,517 km, which is distributed among *nine coastal states* and *four Union Territories.* The **nine coastal states** are Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha and West Bengal. The **Four coastal Union Territories** are Puducherry, Lakshadweep, Daman & Diu and Andaman & Nicobar Islands.

Largest states by Coastline:

Gujarat *is strategically located with* ***largest share in India's coastline,*** *followed by Andhra Pradesh and Tamil Nadu.*

(Please note that if you search on web about the second longest coastline in India, you will get confused. The official TN Government sources cite the coastline of Tamil Nadu to be 1076 kilometers which is second after Gujarat. Some other official sources say that Tamil Nadu has an uninterrupted coastline of 922 Kms. Similarly, some government data of Andhra Pradesh say that their state has second largest (972-974Kms). Almost all information on internet is copied from each other and seems that not a single source is authentic. The data in the adjacent table, I have sourced from a report ***of Centre for Environment Studies*** *and it seems to be correct to my belief, though I am still doubtful.* The Length of Coastline of Indian mainland is around 6100 km, which has been divided as shown in the adjacent table)

State	Coastline
Gujarat	1915.29
Andhra Pradesh	1037
Tamil Nadu	864.73
Kerala	560
Maharashtra	510.31
Orissa	457.2
West Bengal	374
Karnataka	258.15
Goa	113.03
Daman & Diu	--
Total	6089.71

Over 22.6% of total coasts of India are of islands (Andaman and Nicobar, Lakshadweep and Diu islands). The Exclusive Economic Zones (EEZs) of India cover an area of about 2,305,143 km^2, enclosed within 200 nautical miles (that is : 370.4 km) from the land. Out of this, 1,641,514 km^2 is shared by India's coasts of mainland while 663,629 km^2 is of Andaman and Nicobar Islands. This implies that *all the areas on the continental shelves (Indian Continental Shelf-468,000 km2) are under national sovereignty*.

Model Question - 1.

Consider the following statements in context with India's Exclusive Economic Zones (EEZs):

1. Exclusive Economic Zones refers to the area from the edge of the territorial sea out to 200 nautical miles from the baseline
2. The Foreign vessels are not allowed to navigate freely in the Exclusive Economic Zones of India
3. India can make legislations regarding the taxation and customs in its Exclusive Economic Zones (EEZs)

Which among the above statements is / are correct?

Answer: **1**

From various points of view, Indian coasts are very much important. India has *large* ***coastal wetlands*** *which cover an area of over 41,401 km^2.* This is 27.13% of the Total area covered by wetlands in India. *In contrast with the*

---

1 In this question only first statement is correct. Please note these three things:

Territorial waters extend to 12 Nautical Miles from appropriate base

Contiguous zone extends to 24 Nautical Miles from baseline

Exclusive Economic Zones refers to the area from the edge of the territorial sea out to 200 nautical miles from the baseline.

In the EEZ, the country has sole exploitation rights over all natural resources. The most important reason to introduce EEZ was to halt the clashes over the Fishing Rights and Oil Rights. In the EEZ, the foreign vessels have freedom of navigation and over flight, subject to the regulation of the coastal countries. Foreign states are allowed to lay submarine pipes and cables. Thus statement 2 is incorrect. As far as statement 3 is concerned please note that a country can enforce laws only in 4 areas viz. pollution, taxation, customs, and immigration of the Contiguous Zone i.e. 24 Nautical miles from the baseline.

Inland wetlands, coastal wetlands are much less however. The inland wetlands of India cover 105649 Km^2, which accounts Inland wetlands of India share around 69.22% of Total wetland area (a question was asked in Prelims 2012 on this)

Origin of the western and eastern coasts of India is generally attributed to the faulting and subsidence of the Arabian Sea and the Bay of Bengal towards the close of the Eocene Period. This implies that the alluvial deposits along these coasts are of very recent origin, ranging from Pliocene to recent times.

West Coast of India

The Western Coastal plain lies between Kerala and Gujarat and stretches from the Arabian Sea to the Western Ghats. The total length of the western coasts is 1400 kilometers and its width varies from 10 kilometers to 80 kilometers. The elevation of the land ranges from 150m to 300m above sea level. The most important characteristics of the Western Coastal Plain are *sandy beaches, coastal sand-dunes, mud-flats, lagoons, alluvial tracts, estuaries, lateritic -platforms and residual hills.*

On the west coast, we have coastal plains of Gujarat and the coasts of the Peninsular India between Western Ghats and Arabian Sea. We divide the west coast into these three parts:

1. Coasts and Coastal Plains of Gujarat
2. Konkan Coast
3. Malabar Coast

Coastal Plains of Gujarat

Model Question - 2.

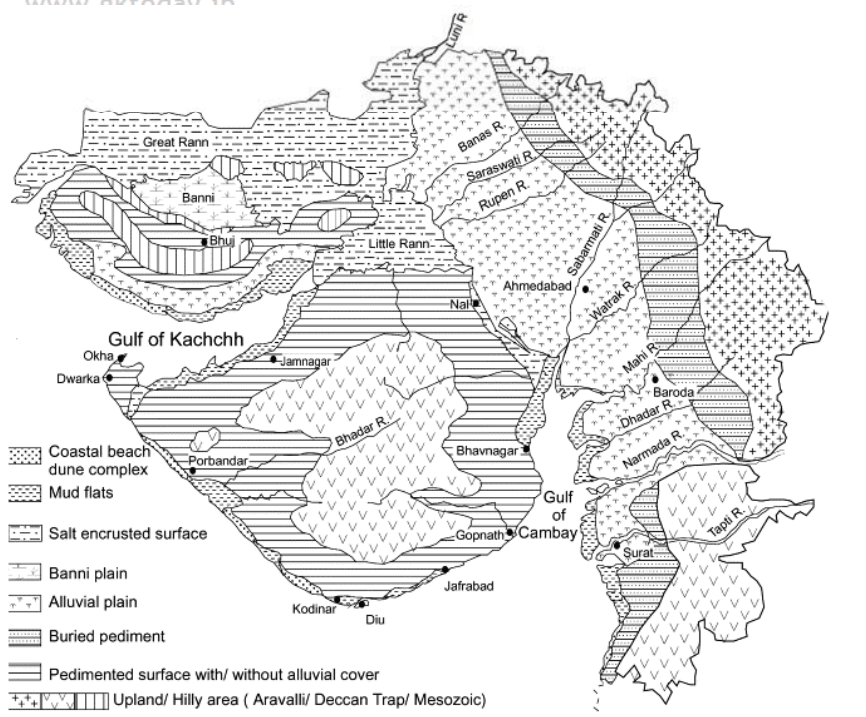
Consider the following rivers:

1. Luni
2. Banas
3. Mahi

Which among the above is / are inland rivers?

Answer: 2

Physiographically, Gujarat is divided into three regions viz. Mainland Gujarat, Saurashtra Peninsula and Katch. Out of them, the **Mainland Gujarat** consists of eastern rocky highlands, the extensions of mountains of western India and the western Alluvial Plains including the coastal plains.



The **Saurashtra Peninsula** forms a rocky table land fringed by the coastal plains with the central part made up of the undulating plain broken by hills and dissected by various rivers flowing in all directions.

The eastern fringe is a low land which marks the site of the former sea connection between the Gulfs of Katch and Gulf of Cambay.

Then, the **Katch region** is made up of Ranns which is basically a salt encrusted wasteland just a few meters above sea level. It gets denudated in the monsoon. It is divided into Great Rann in the north and Little Rann in the east. Between Great Rann and Rocky mainland lies the **Banni Plains**.

The above discussion makes it clear that plains of Gujarat cover almost the entire state of Gujarat, except two districts viz. Banaskantha and Sabarkantha. These plains have become mainly due to the alluvial deposits of Sabarmati, Mahi, Luni and other rivers and also the depositional activity of winds.

- Luni and Banas rivers discharge into Rann forming inland drainage during rainy season, both of them are inland rivers.

Konkan Coast

From South of Gujarat plain, Konkan coastal plain extends from Daman to Goa. Its last boundary down south is Gangavalli River.

The Konkan coast is generally narrow, not exceeding 65 km. It is widest near Mumbai. It is rocky and uneven, a few hills protrude up to the sea and that is why we find numerous light houses across the costs to warn the ships remain away from the rocky area. The coast is rich in oil resources such as Bombay High. The northern part is sandy while the southern part is rugged.

Malabar Coast

The Malabar Coast starts from south of Goa to Kanyakumari or Cape Comorin on India's southern tip extends. This is known for numerous **lagoons** aka. Kayals, which run parallel to the coast in southern part of Kerala. A chain of brackish lagoons and lakes lying parallel to the Malabar Coast in Kerala are called Backwaters. The network of Kerala Backwaters includes five large lakes linked by canals, both manmade and natural, fed by 38 rivers, and extending virtually half the length of Kerala state. *The backwaters were formed by the action of waves and shore currents creating low barrier islands across the mouths of the many rivers flowing down from the Western Ghats range.*

Some important landmarks of this coast are the Vembanad lake, the longest lake of India and the **National Water Way-3**, that stretches Kottapuram to Kollam.

Importance of Kerala Coasts

Kerala coastal zone is famous for its beautiful beaches, backwaters and lagoons. The coastal belt, a narrow strip of lowland, is the most picturesque region of Kerala, interspersed with extensive backwaters, lagoons and canals and flanked by luxuriant coconut groves and green rice fields. The lagoons and backwaters are never far from the sea and at several places they have established a permanent connection with it. The backwaters, rivers and the canal system form a navigable waterway of about 1,920 km.

This offers an unique ecological niche with great potential for brackish water fish farming in the state. The sea off Kerala is one of the most productive zones for marine fish in India. Kochi is the major port located along the coast. The entitre coastline is of natural beauty with vast beaches. *The tidal implications are felt deep into inland areas through the network of backwaters*. These tides have **high utility for fishing, navigation and boating**.

Eastern Coast of India

Model Question - 3.

Consider the following states:

1. The eastern coast of India is spread in more states in comparison to the western coast
2. The eastern Coast is generally wider than the western coast
3. While eastern coast is an emergent coast, western coast is submerging coast

Which among the above statements is / are correct?

Answer: 3

The eastern coasts cut through the **three states** viz. Tamil Nadu, Andhra Pradesh and Odisha. The **Cauvery delta** is most important sub region in Tamil Nadu, the **Krishna Godavari Delta** is most important landmark in Andhra Pradesh while the **Mahanadi Delta** is most important landmark in Odisha.

Eastern Coastal plain lies between the Eastern Ghats and the Bay of Bengal and is more extensive and wide than its western counterpart. They represent an **emergent coast** while it's western counterpart is an example of **submerging coast**. The region receives both the Northeast and Southwest monsoon rains with its annual rainfall averaging between 1,000 mm and 3,000 mm. The width of the plains varies between 100 to 130 kilometers. The

3 Only 2 & 3are correct.

region is *wider, gets more rainfall, more hot and humid, more discontinuous and more fertile & irrigated in comparison to the western plains.* At places the plains are bordered with dunes. Mangrove forests also grow in this region. Lagoons are also found here.

This plain is broadly divided into

1. **Coromandal Coast:** Ranges from Kanyakumari in Tamil Nadu to **False Divi Point** in Andhra Pradesh, which is just at the apex of the Krishna River delta.
2. The region between the Krishna and Mahanadi for which an old tem Northern Circars is sometimes used. Some classify it as Andhra Pradesh coastal plains.
3. Mahanadi Delta. Another broader term used is Utkal Coast, which also includes the **Chilika Lake.**

Model Question - 4.

In context with the west coast of India, consider the following statements:

1. Majority of Tropical Cyclones in India have their initial genesis over the Arabian Sea and strike the west coast of India
2. West coast of India is influences by both the South West and North East Monsoons

Which among the above statements is / are correct?

Answer: **4**

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Comparison of the East Coast and West Coast

West Coast	East Coast
• Stretching from Rann of Katch to Kanyakumari as a ***narrow strip*** between Arabian Sea and Western Ghats • Divided into costal plains of Gujarat, Konkan Coast and Malabar Coast • Highly influenced by ***south west monsoon*** • *Lagoons and Estuaries are common* • *Submerging Coast* • *Less attacked by Cyclones*	• Stretching from Kanyakumari to Sunderbans as a relatively ***broader (than western coast)*** between Eastern Ghats and Bay of Bengal. • Divided into Coromandal Coast and North Sircar coastal plains • Influenced by *North East Monsoon. Also receives rains from South West Monsoon.* • *Deltas are common* • *Emergent Coast* • *More attacked by Cyclones*

Important Observations about the Coastal Landmarks of India

Gulf of Katch

Model Question - 5.

Consider the following statements about a marine animal:

1. Its a mammal, which mostly depends upon Sea-grass
2. Its is found in Gulf of Katch off the Saurashtra Coast as well as Gulf of Mannar in India
3. It is close to extinction because of its hunting for meat and oil

Identify the animal from the given options:

a. Dwarf Sperm Whale
b. Dugong
c. Blue Whale
d. Sea Rabbit

Answer: **5**

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Gulf of Katch is the largest coastal habitat in the West coast of India

- *It is a shallow water body with depth extending from 60 m at the mouth to less than 20 m at the head of the Gulf. Average depth is 30 meters. Around the **Lushington Island**, the depth is just 5 meters.*
- *Bordered by Katch in the north and Saurashtra in the south.*
- *Home to a **Marine National Park and Marine Sanctuary** at the southern shore, which includes 42 islands and a complex of fringing reefs backed by mudflats and sand flats, coastal salt marsh and mangrove forests, sand and rocky beaches which support a great diversity of fauna and flora.*
- *Many islands are **fringed with corals and mangroves** which provide disturbance free habitats for many species of nesting birds.*

4 Both are incorrect. The Indian subcontinent is one of the worst affected regions in the world. India's coats are exposed to around 10 per cent of the world's tropical cyclones. Of these, the majority have their initial genesis over the Bay of Bengal and strike the east coast of India. On an average, five to six tropical cyclones form every year, of which two or three could be severe. More cyclones occur in the Bay of Bengal than the Arabian Sea and the ratio is approximately 4:1. Tropical cyclones occur in the months of May-June and October-November.

5 Dugong

- *Apart from the islands, there are a large number of **wavecut**s (eroded shallow banks) such as Pirothan, Deda, Donna, Sankhodhar Beyt, Paga, Adatra and Boria, many of them have corals within.*
- *Gulf of Katch is the home for more than 800 species of organisms; 32 hard corals (Scleractinia) and 12 soft corals (Alcyonaria), 150-200 species of fishes, more than 100 species of algae, great diversity of sponges and worms, brittlestars, marine turtles and other reptiles, over 200 species of migratory and resident bird species.*
- *Gulf of Katch is home to the rare and endangered marine mammal, the **dugong (Sea Cow).***
- *Gulf of Kutch produces **95% of the salt requirements of the country.** Salt pans are located close to inter-tidal area and deep into the land.*
- *Gulf of Katch area is home for intermediate and major ports like **Kandla, Adani, Okha and Salaya**. Kandla is one of the major ports of India.*
- *The Asia's largest oil refinery is located at Jamnagar in the Gulf of Kutch.*

Fact Box: Dugong

Dugong or Sea Cow is a sea-grass eating mammal which is found in waters of as many as 37 countries. It is now on verge of extinciton, because it has been hunted for meat and oil. In India also, its meat is considered to be aphrodisiac. Some notes:

- Maximum Population of Dugong is found in Red Sea, followed by the Persian Gulf.
- Largest Dugong was as long as 13.5 ft and was found in Gulf of Katch in India. In India, they are found in Gulf of Kutch, the only population remaining in western India and Gulf of Mannar. The Gulf of Mannar Biosphere (GoMB) has the largest population of dugongs in India. They are also found near the Andaman and Nicobar Islands.
- With fewer than 200 dugongs (commonly known as sea cow) in its waters, India is strongly encouraging its neighbours in South Asia to sign the Dugong United Nations Environment Programme/Convention of Migratory Species (UNEP/CMS) MoU as early as possible.
- Currently classified as vulnerable to extinction under the IUCN Red List of Threatened Species, the dugongs are vulnerable to human-related influences due to their life history and dependence on sea grasses that are restricted to coastal habitats under increased pressure from human activities.
- Reasons for the decline in population are: sea grass habitat loss and degradation, gill netting, chemical pollutants, indigenous use and hunting.

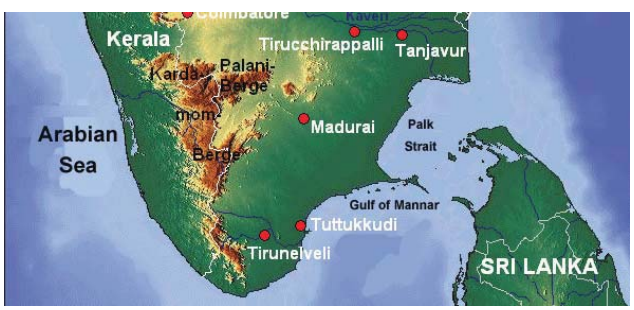
Gulf of Cambay

- *Gulf of Cambay or Gulf of Khambat is a 80 miles long gulf that divides the Kathiawar peninsula to the west from the eastern part of Gujarat state on the east.*
- *Two major rivers of Gujarat viz. **Narmada and Tapti** empty here.*
- *The Gulf of Cambay is known for its extreme tides.*
- *The Gulf of Cambay is home to Alang shipyard, which is known for marine salvage industry, half of all ships salvaged around the world are recycled here. The state government wants to make it largest International Maritime Organization-compliant ship recycling yard in the world and for that Gujarat has joined hands with Japan. The industry is benefited a lot by the tides here. Large ships are beached during the twice-monthly highest tides, and are dismantled when the tide recedes.*
- *The Gulf is encircled by a string of historical port towns such as Bharuch, Surat, Khambhat, Bhavnagar, and Daman.*
- *The Gulf is shallow and abounds in shoals and sandbanks. Mangroves are also found here, mainly in the Piram island.*

Tidal Power Estimates of India

- The Gulf of Cambay and the Gulf of Kutch in Gujarat on the west coast have the maximum tidal range of 11m and 8m with average tidal range of 6.77m and 5.23m respectively. (Note that waves are more furious in Cambay)
- Then, the Ganges Delta in the Sundarbans is approximately 5m with an average tidal range of 2.97m. According to the estimates of the Indian government, the country has a potential of 8,000 MW of tidal energy. This includes about 7,000 MW in the Gulf of Cambay in Gujarat, 1,200 MW in the Gulf of Kutch and 100 MW in the Gangetic delta in the Sunderbans region of West Bengal.
- In 2012, Gujarat state government sanctioned Rs. 50 crore to develop such a tidal plant in Gulf of Katch.

Gulf of Mannar



- *The Gulf of Mannar is a shallow bay, part of the Laccadive Sea in the Indian Ocean. A chain of low islands and reefs known as Adam's Bridge, also called Ramsethu, which includes Mannar Island, separates the Gulf of Mannar from Palk Strait, which lies to the north between India and Sri Lanka.*
- *The Thamirabarani River of south India and the Aruvi Aru of Sri Lanka drain into the Gulf of Mannar.*
- *The gulf of Mannar is home to thousands of species of*

flora and fauna and is known as one of the richest coastal regions in India. The corals, sharks, dugongs, dolphins and sea cucumber.

- *The Gulf of Mannar Marine National Park was declared in 1986. The national park and its 10km buffer zone were declared Biosphere Reserve in 1989. The Gulf of Mannar is famous for its pearl banks of Pinctada radiata and Pinctada fucata for at least two thousand years.*

Palk Strait

- *Palk Strait connects the Bay of Bengal in the northeast with the Palk Bay anc connects the Palk bay to Gulf of Mannar in the southwest. It is 53-80 kilometers wide, studded with a chain of low islands and reef shoals that are collectively called Adam's Bridge. This chain extends between Dhanushkodi on Pamban (Rameswaram) Island in Tamil Nadu and Mannar Island in Sri Lanka.*
- *The shallow waters and reefs of the strait make it difficult for large ships to pass through, although fishing boats and small craft carrying coastal trade have navigated the strait for centuries. Large ships must travel around Sri Lanka. Construction of a shipping canal through the strait was first proposed to the British government of India in 1860, and a number of commissions have studied the proposal up to the present day. It is curently in news because of the Sethusamudram Shipping Canal Project.*

Part II. Islands of India

Model Question - 6.

Consider the following statements:

1. India has more islands in its territory in Bay of Bengal in comparison to Arabian Sea
2. The Islands of Bay of Bengal are largely tectonic and volcanic in origin, while the islands of the Arabian Sea are mainly coral formations.

Which among the above statements is are correct?

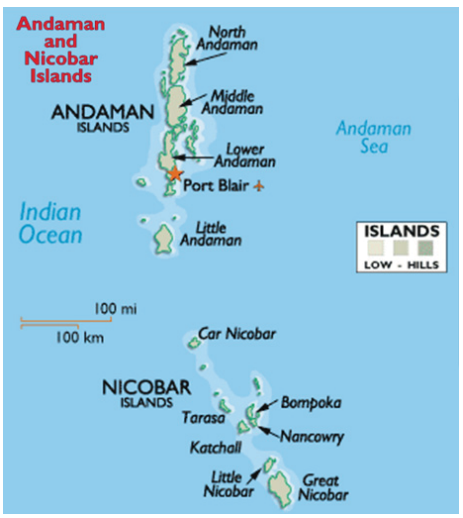
Answer: **6**

The islands of India constitute Andaman and Nicobar group of islands (Bay of Bengal), Lakshadweep Islands (Arabian Sea), riverine and off shore islands. The Lakshadweep and the Andaman & Nicobar Islands are India's two major island formations. Other significant islands in India include Diu Daman, a former Portuguese enclave; Majuli, a river island of the Brahmaputra; Elephanta in Bombay Harbour; and Sriharikota, a barrier island in Andhra Pradesh. **Salsette Island is India's most populous island** on which the city of Mumbai (Bombay) is located. 42 islands in the Gulf of Kutch constitute the Marine National Park. *The number of islands of India in Bay of Bengal* ***is approximately 5 times*** *the islands in the Arabian Sea.*

Andaman and Nicobar Islands which are largely tectonic and volcanic in origin, while the islands of the Arabian Sea are mainly coral formations.

Andaman & Nicobar Islands (ANI)

The Andaman and Nicobar Archipelago consists of over 345 islands, islets and rocky outcrops, with land area extending up to 8,249 km² and a coastline stretch of 1,962 km; the Andaman Islands constitute 6408 km² and the Nicobars 1841 km².



The Andaman Islands are the extension of the submerged **Arakan Yoma Tertiary Mountain range of Myanmar** and the Nicobars are the continuation of the **Mentawai Islands to the south and southeast of Sumatra**. The main rocks of these islands are sandstone, limestone and shale. These two island groups situated in the Bay of Bengal span 6°45′ N to 13°41′ N (740 km) and 92°12′ E to 93°57′ E (190 km).

The *nearest land mass to Great Nicobar Island is Sumatra*, 145 km southeast; and the Myanmar coast is roughly 280 km north of Landfall Island, the northern- most island in the Great Andaman group.

The topography of the Andaman and Nicobar Islands is hilly and undulating, the elevation in the Andamans is from 0 to 732 m, *Saddle Peak being the highest in North Andaman*

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6 Both are correct statements. Regarding second statement, please note that the Physiography of Nicobar Islands is also considered to be Coral origin, yet the statement is correct because it's a general observation.

Island. In the Nicobars the elevation rises from 0 to 568 m, *Mt Thuillier being the highest peak on Great Nicobar Island*.

The Andaman Islands support one of the world's most extensive mangrove ecosystems. Due to their long isolation, these islands have evolved significant diversity of flora and fauna with a **high level of endemism**.

The land area of 6408 km² in the Andamans constitutes ***90% as reserves*** and protected areas of which 36% is tribal reserves. The *entire Nicobar group is a tribal reserve* and has four wildlife sanctuaries, two national parks and one biosphere reserve.

Important Observations about the Ecological Profile of Andaman and Nicobar Islands

- *The ANI consists of very fragile island ecosystems and some of the most pristine in the world, which supports very unique flora and fauna. The landscape for large islands emerges from **sea grass beds, coral reef or rocky outcrops, to beaches, littoral forest, Andaman slope forests, hilltops, into valleys and streams**. Some of the dominant tree species in these luxuriant forests reach heights of 40- 60 m.*
- *In some areas in the Andamans along the west and the east coast, the landscape starts from reefs or rocky outcrops to steep rock faces with wind blown vegetation.*
- *The topography of all large islands in the Andamans, Little Andaman, Little Nicobar and Great Nicobar Islands, is mostly interlaced with perennial and seasonal freshwater streams and in some areas a matrix of mangrove creeks extending into marshes.*
- *Little Andaman Island has ecosystems that do not occur anywhere else in the Andamans or the Nicobars, mainly extensive fresh and saline water marshes and peat*
- *85.9% Dense Forests, 1.7% Open Forests, 12% Mangroves. Mangroves cover an area of 929 km² and in the Nicobar the extent is 37 km² (Balakrishnan, 1989; Andrews & Sankaran, 2002).*
- *ANI are fringed by one of the most spectacular **coral reefs** in the world.*
- *The **only primate**, the Nicobar crab eating macaque (Macaca fascicularis umbrasa) occurs in the southern group of the Nicobar Islands. The islands are a birdwatcher's paradise with as many as 250 species recorded.*
- *The complex geological history of these islands and the submergence of land bridges leading to isolation have left the islands with high levels of endemism. The widespread distribution of certain species indicates that there was an early evolution and dispersal throughout the archipelago. Endemism in reptiles and amphibians appears relative to species richness, islands with larger diversity have greater number of endemics.*
- *Protected areas in the islands are tribal reserves, national parks, wildlife sanctuaries, reserve, protected and preserved forest; and a biosphere reserve.*
- *An area of 513.70km² along the **west coast of South Andaman Island** is notified as a tribal reserve for the Jarawa people. This reserve extends north along the same coast into **Middle Andaman Island**, extending the reserve for another 338. 69 km². A 5 km distance into the sea from the high tide line right along the entire stretch of the Jarawa Reserve is also notified as part of the reserve.*
- ***Strait Island**, 6.01 km² in area, on the east coast of Middle Andaman Island supports a population of 45-50 of the last remaining Great Andamanese people.*
- *To the south west of South Andaman Island is North Sentinel Island with an area of 59. 67 km² and is inhabited by the Sentinalese people.*
- *The southern most island Little Andaman Island with a geographical area of 731. 57 km² and of this, 706. 49 km² with a distance of 3 km from the high tide line and into the sea along the coast has been notified as a tribal reserve for the Onge people.*
- *The entire group of 24 Nicobar Islands is notified as tribal areas; only 1,499.65 ha along the east coast from Campbell bay and up to 35 km is outside the Tribal Area and is inhabited by ex-servicemen, traders, government departments and the residents. Great Nicobar has a total area of 1044. 54 km² and of which 853. 19 km² is the tribal reserve, for both, the 380 Shompen people and the Nicobarese people.*
- *There are four national parks in the Andamans, Mahatma Gandhi Marine, Mount Harriet, Rani Jhansi Marine and Saddle Peak National Parks. The Nicobars have two areas notified as national parks and an area in Great Nicobar designated as the **Great Nicobar Biosphere Reserve.** Within the area of 960.40 km² in Great Nicobar Island, 110 km² is the **Galathea National Park**, situated on the south east of the island. On the east coast an area of 476. 73 km² is notified as the **Campbell Bay National Park**. An area of 885 km² includes the Nicobar Biosphere Reserve and all these parks are within the tribal area.*
- *The Barren Island in the Andamans has an active volcano. In the Bay of Bengal, there are two volcanic islands (Barren and Narcondam) situated within 80 km east of the Andaman Islands.*
- *Rice is the main crop in Andaman and Nicobar Islands. Coconut and Arecanut are the main cash crops of Nicobar.*

Model Question - 7.

Consider the following:

1. Ritchie's Archipelago
2. Havelock Island
3. Neil Island
4. Chiriya Tapu
5. The Viper Island

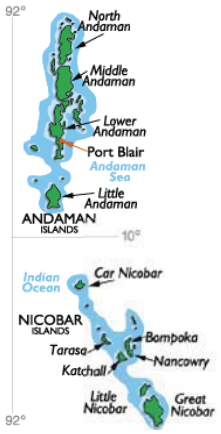
Which among the above is / are located in Bay of Bengal?

Answer: **7**

Kalapani

- *Andaman & Nicobar were known as 'Kalapani' because of their having been a penal settlement under the British Rule. First establishment of East India Company was in 1789 which was abandoned in 1796. Following the first war of Indian Independence in 1857, the British India Government founded the penal settlement in these islands in 1858, primarily known as Kalapani, for the deportation of freedom fighters from the mainland India, which continued till the Second World War During the Second World War, the Japanese forces occupied the Andaman and Nicobar Islands in 1942. Further following the surrender of the Japanese forces in the Second World War, the British India Government reoccupied these islands in 1945 and continued their administration till the Independence of the country in 1947.*

10 Degree Channel



- *It is a channel that separates the Andaman Islands from the Nicobar Islands in the Bay of Bengal. The channel is approximately 150 km wide, 400 fathoms deep running essentially along an east-west orientation. It is so named because it lies on the 10-degree line of latitude, north of the equator.*

Landfall Islands

- *The northern most point is Landfall Island which is 901kms away from the mouth of Hoogly River and about 190kms from Burma.*

Indira Point

- *The southern-most island is Great Nicobar, the southern-most tip of which Pygmalian Point now Indira Point is about 150kms away from Sumatra (Indonesia).*

Saddle Peak

- *Saddle Peak in North Andaman at a height of 732 meters above sea level is the highest point in these islands.*

Tribes

- *The original inhabitants of Andaman & Nicobar Islands lived in the forests on hunting and fishing. There are four Negrito tribes; viz., the Great Andamanese, Onge, Jarawa and Sentinalese in the Andaman group of islands and and the Nicobarese and Shompens in the Nicobar group.*
- *Around 50 percent of the population is made up of settlers from the mainland India, some people call Andamans as a Little India or a mini-India. The settlers or ancestors of these settlers came either prior to 1947 or after 1947.*

Chatam Island

- *The centre of activity of the Forest Department is Chatham Island. It has perhaps the biggest Saw Mill of its kind in Asia. Here logs are extracted with the help of elephants.*

Mount Harriet

- *It is the highest hill around South Andaman and is about 365m . Formerly it was the headquarters of the Chief Commissioner.*

Ross Islands

- *Seat of British Administration.*
- *The place came into decay with the shifting of the Chief Commissioner's Office in 1942 as areas close to the shore had developed serious cracks and it was felt that the building was not safe. Ross Island was occupied by Japanese in March 1942. In October 1945 the Islands were re-occupied by the British. Today the Island is deserted.*

Madhuban

- *A training ground for elephants.*

Ritchie's Archipelago

- *Ritchie's Archipelago is a cluster of smaller islands which lie some 25–30 km (16–19 mi) east of Great Andaman. The archipelago comprises some 4 larger islands, 7 smaller islands and several islets. The 4 large islands are Havelock Island, Henry Lawrence Island, John Lawrence Island and Sir William Peel Island.*

Havelock Island

- *Known for Coral Reefs*

Neil Island

- *Known for timbering operations.*

Chiriya Tapu

---

7 All of them

- *Also known as Bird Island*

The Viper Island

- *There was a jail prior to commissioning of Cellular jail.*

Car Nicobar

- *Most of the Nicobarese people are Christians.*

Cellular Jail

Regarded by the freedom fighters all over the country as a place of pilgrimage and meant for "dangerous prisoners". The construction of the Cellular Jail was taken up in 1898 and completed by about 1906. Whole jail consists of cells and each cell was meant for one inmate only. Cellular Jail originally had seven, three storied wings with a total of 698 cells, radiating from a central tower which had an additional storey to facilitate watch and ward.

"Tyranny of our Freedom Fighters"

Convicts who were sentenced to transportation for life were sent to these islands and interned in the Cellular Jail. Many political prisoners and revolutionaries were incarcerated here during the freedom struggle. Against the tyranny of the Jail management political prisoners were not allowed to communicate with their friends and relatives on the mainland except once in a year. Even the letters coming from mainland and newspapers subscribed by the prisoners were censored before being given to them. While fighting against this tyranny some political leaders had to lay down their lives. Many prisoners had gone insane in the Jail and ended their live by committing suicide rather than subjecting themselves to the indignities heaped on them.

Damage to Building:

In 1941 earthquake caused considerable damage to the Jail building. During the Japanese occupation from March 1942 to October 1954 further damage was caused to the building. All this finally resulted in the demolition of four out of the seven wings of the Jail. At present there are only three wings and these stand as silent monument to the great patriot's and martyrs who were interned in this Jail, who had to sacrifice their lives at the altar of their country's freedom.

Lakshadweep Islands

Model Question - 8.

In context with the Lakshadweep Islands of India, consider the following statements:

1. Majority of them are uninhabited by humans
2. Majority of them have a shallow lagoon on their western coast
3. Majority of them are fringed by coral sands
4. There are no dogs and poisonous snakes on most of them

Which among the above is / are correct statements?

Answer: 8

Model Question - 9.

Which among the following islands of Lakshadweep is known by its speakers of Mahl Language?

A. Amini
B. Minicoy
C. Agati
D. Kadamat

Answer: **9**

Lakshadweep is an archipelago consisting of 12 attols, 3 reefs and 6 newly formed/ submerged sand banks.

It is comprised of - 11 inhabited islands, 16 uninhabited islands; six newly formed/ submerged sand banks and 3 reefs.

- The Inhabited islands are Kavaratti, Agatti, Bangaram, Amini, Kadmat, Kiltan, Chetlat, Bitra, Andrott, Kalpeni and Minicoy.
- Bitra is the smallest of all having only a population of 267 (Census 2001).

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8 All are correct.

9 Minikoy

Though, the land area of this Coral paradise is only 32 Sq.kms. the inclusion of about 4200 Sq.Kms. of its lagoon area, 20,000 Sq.km. of its territorial waters and almost 4, 00,000 Sq.kms of Exclusive Economic Zone makes it one of the largest territories of the country. Kavaratti is its capital (Headquarters). The total population of these islands is 60650 (as per 2001 census). Malayalam is traditional vernacular spoken in all the islands, *except Minicoy; where people speak Mahl, which is written in Divehi script and is the language of Maldives.*

Aminidivi group (All Inhabited)
- Amini . Kadmat . Kiltan . Chetlat. Bitra

Laccadive group (First four Inhabited)
- Andrott. Kavaratti. Agatti. Kalpeni . Kalpitti . Bangaram . Tinnakkara . Parali . Tilakkam . Pitti . Cheriyam . Suheli . Valiyakara . Pakshi Pitti . Kodithala

Minicoy group (Minicoy Inhabited)
- Minicoy. Veiningili

Submerged Reefs
- Beliapani. Cheriapani. Perumul Par

Submerged Banks
- Bassas de Pedro . Sesostris Bank . Cora Divh. Amini Pitti . Kalpeni Bank

The entire indigenous population because of their economic and social backwardness and geographical isolation is classified as Scheduled Tribes.

The tribes have, however not been named. The islanders are Muslims by religion. These islands lie about 220 to 440 kilometers away from the coastal city of Kochi in Kerala between 8o and 12° 13'' North Latitude and 71° and 74° East Longitude.

Important Observations:

- *Each island of Lakshadweep is fringed by coral sands. A common feature of these islands is that **a shallow lagoon exists invariably in their western side** separating the outer reef rim from low-lying coral islands composed essentially of calcareous sand and soil.*
- *Elevation of the Lakshadweep islands range from 0.5-7.0m above mean sea level. This implies that the danger from storm tides is tremendous over here.*
- *The origin of Lakshdweep Islands is attributed to theory of Sir Charles Darwin, according to whom the origin of these Islands can be traced to gradual submergence of some of the volcanic ridge into the Indian Ocean followed by accumulation of coralline deposits on the peaks and craters of these mountains. These deposits grew into coral islands resting on submerged mountaintops over a period of time.*
- *The islands are mostly coralline and their alignment appears to be in continuation of the Aravalli Strike of Rajasthan.*
- *Lakshadweep Islands are rich in marine wealth and an abode of plethora of coastal and marine bio-diversity with pristine Coral Reef Ecosystem which support variety of ornamental and food fishes belonging to various species besides the sedentary and slow moving creature such as Sea Cucumbers, shelled animals (Molluscs) and Hermit Crabs, Lobsters and Shrimps.*
- *The common farm species which are tend by the people are Cows, Goats, Ducks and Hens. Cats are common, but **dogs are almost wholly absent. There are no poisonous snakes on the islands**, and the islands are infested with rats and mosquitoes. The rats bring about a great deal of damage to coconut trees.*
- *The flora of Lakshadweep mainly consists of palm trees with coconut as the only commercial crop.*
- *Coastal bleaching and Coral erosion is one of the serious problems being faced by the Lakshadweep group of islands. During 1998 the strongest El Nino was recorded in Lakshadweep islands leading to rise in temperature in a range of 3-5° C above normal which resulted into severe coral bleaching, with mortality rates as high as 90% in some parts of these Islands. Rising sea levels may also lead to potentially acute erosion*

Diu Island

Diu is an off - shore island on the western coast, off the Gulf of Cambay, bordering Junagarh district. It is separated from the Gujarat Coast by a **tidal creek**. The coast has limestone cliffs, rocky coves and sandy beaches, the best of which are at Nagoa. A massive fort built by the Portuguese dominates the skyline. Nagoa beach is the most famous in Diu. Another beautiful beach is Ghoghla beach. The Diu fort was constructed between 1535 and 1541 AD after the defence alliance concluded between the Sultan of Gujarat and the Portuguese. The fort commands a magnificent view of sea.

Majuli Island

Mājuli is a large river island in the Brahmaputra river, in Assam with an area of 1,250 Kms^2 once upon a time but but having lost significantly to erosion it has left with only a third of it. It was formed due to course changes by the river Brahmaputra and its tributaries, mainly the Lohit. It was originally a piece of land between Brahamputra River (north) and Burhidihing river (south). Due to earthquakes back in mediveal times, the change of Brahamputra river course caused the formation of the Majuli Island. Mājuli is also the abode of the Assamese neo-Vaisnavite culture. A wetland, Mājuli is rich biodiversity spot and is home to many rare and endangered avifauna species including migratory birds that arrive in the winter season. Among the birds seen here are: the Greater Adjutant Stork, Pelican, Siberian Crane and the Whistling Teal. After dark wild geese and ducks fly in flocks to distant destinations. The island is almost pollution free owing to the lack of polluting industries and factories and also the chronic rainfall.

Islands Off Mumbai

Butcher Island

- *Butcher Island (Jawahar Dweep) is an island off the coast of Mumbai. It has an oil terminal used by the port authorities to offload it from oil tankers. The crude oil is stored in oil containers on the island. From there they are piped to Wadala, in Mumbai where they are refined. This keeps the city relatively safe from a mishap. It is a restricted area and most of the island is covered with dense vegetation. A hillock rises from the centre of the island. It is located 8.25 kilometres (5.13 mi) from the Gateway of India. (wikipedia)*

Elephanta Island

- *Elephanta Island or Gharapuri Island is in Mumbai Harbour. It is home to the Elephanta Caves, that have been carved out of rock.*

Oyster Rock

- *Oyster Rock is an island in the Mumbai harbour, Mumbai, India. It is fortified, and owned by the Indian Navy.*

Pamban Island

- *Pamban Island or Rameswaram Island is in Tamil Nadu. The chain formed by Pamban Island, the shoals of Adam's Bridge, and Mannar Island of Sri Lanka separate Palk Bay and the Palk Strait in the northeast from the Gulf of Mannar in the southwest. Pamban Island extends for around 30 kilometres in width from the township of Pamban in the west to the remains of Dhanushkodi towards the south-east.*

Sri Harikota

Sriharikota is a barrier island off the coast of Andhra Pradesh. It houses India's only satellite launch centre in the Satish Dhawan Space Centre (also known as SHAR) and is used by the Indian Space Research Organisation to launch satellites using multi-stage rockets such as the Polar Satellite Launch Vehicle and the Geosynchronous Satellite Launch Vehicle. Sriharikota separates the Pulicat Lake from the Bay of Bengal, and is home to the town of Pulicat.

Part III. India's Climatology

General Observations about the Indian Climate

India is home to an extraordinary variety of climatic regions, ranging from tropical in the south to temperate and alpine in the Himalayan north, where elevated regions receive sustained winter snowfall. India's climate is strongly influenced by the Oceans, Himalayas and the Thar Desert. The Himalayas act as a barrier to the frigid katabatic winds flowing down from Central Asia keeping the bulk of the Indian subcontinent warmer than most locations at similar latitudes.

The climate of India may be broadly described as **tropical monsoon type**. India's climate is affected by **two seasonal winds** viz. the north-east monsoon and the south-west monsoon.

- The north-east monsoon commonly known as winter monsoon **blows from land to sea** whereas south-west monsoon known as summer monsoon **blows from sea to land** after crossing the Indian Ocean, the Arabian Sea and the Bay of Bengal.
- The south-west monsoon brings most of the rainfall during the year in the country.

As such, land areas in the north of the country have a continental climate with severe summer conditions that alternates with cold winters when temperatures plunge to freezing point. In contrast are the coastal regions of the country, where the warmth is unvarying and the rains are frequent. India, not only its physiographic divisions are diverse but also far more contrasting in nature. Each one of these factors (Size, Shape, location extent etc.,) has an impact on climatic conditions of India, be it temperatures, atmospheric pressure, wind system or precipitation.

Factors influencing the Indian climate

Location and Latitudinal Extent

- The Tropic of Cancer passes through the middle of the country. The southern parts being closer to the Equator, experience high temperatures throughout the year. The northern parts on the other hand lie in the warm temperate zone. Hence they experience low temperatures particularly, in winter.
- For example, Bangalore would be hotter than Faridabad. Broadly speaking parts lying south of the Tropic of Cancer receive more solar heat than those lying north of it.

Distance from the Sea

- Southern or peninsular India is surrounded by the Arabian Sea, the Indian Ocean and the Bay of Bengal, hence the climate of coastal regions of India is equable or maritime.
- Contrary to this, the climates of the regions located in the interior of the country are cut off from the oceanic influence. As a result, they have an extreme or continental type of climate.

Altitude

- The atmosphere becomes less dense and temperature also decreases with the height. For example, the cities located on the hills are cooler like Shimla whereas the cities lying in the plains will have hot climate like Ludhiana.

Mountain Ranges

- These ranges protect India from the bitterly cold and dry winds of Central Asia during winter. Further more, they act as an effective physical barrier for the rain bearing southwest monsoons winds to cross the northern frontiers of India.

- On the other hand, they check rain bearing South-West Monsoon winds and compel them to shed their moisture in India.
- Similarly, Western Ghats force rain bearing winds to cause heavy rain fall on the Western slopes of the Western Ghats.

Direction of Surface Winds

- The wind system also affects the Indian climate. This system consists of monsoon winds, land and sea breeze, and local winds. In winter the winds blow from land to sea so they are cold and dry.
- On the other hand, in summer wind blow from sea to land bringing the moisture along with them from the sea and they cause wide spread rain in most part of the country.

Upper air Currents

- Besides surface winds, there are strong air currents called Jet streams which also influence the climate of India. These jet streams are a narrow belt of fast blowing winds located generally at 12,000 metre height above the sea level. They bring western cyclonic disturbances along with them. These cyclonic winds originate near the Mediterranean Sea and move eastwards. On their way, they collect moisture from Persian Gulf and shed it in the North western part of India during winter seasons. These Jet streams shift northwards during summer season and blow in Central Asia. Thus helps in the onset of monsoons.

Physiography

- The physical features influence the air temperature, atmospheric pressure, direction of winds and the amount of rainfall in different parts of the country.

El-Nino & La Nina

- Weather conditions in India are also influenced by El-Nino which causes wide spread floods and droughts in tropical regions of the world. This warming of tropical Pacific waters affects the global pattern of

pressure and wind systems including the monsoon winds in the Indian Ocean. It is believed that the severest droughts in India have been caused by El-Nino.

- La Nina is thought to be favourable to India as it brings rains.

Monsoon and Seasons in India

Monsoon Mechanism

Model Question - 10.

In context with the Monsoon winds, consider the following statements:

1. They are generally regular and equally distributed winds
2. They show a complete reversal of direction during a year
3. They are generally orographic in nature

Which among the above statements is / are correct?

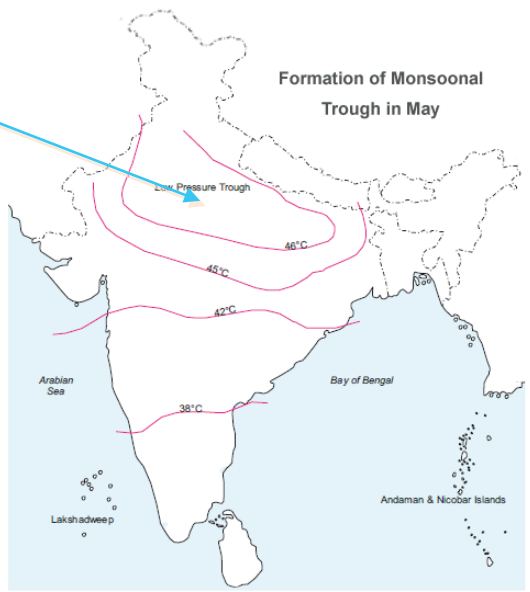
Answer: **10**

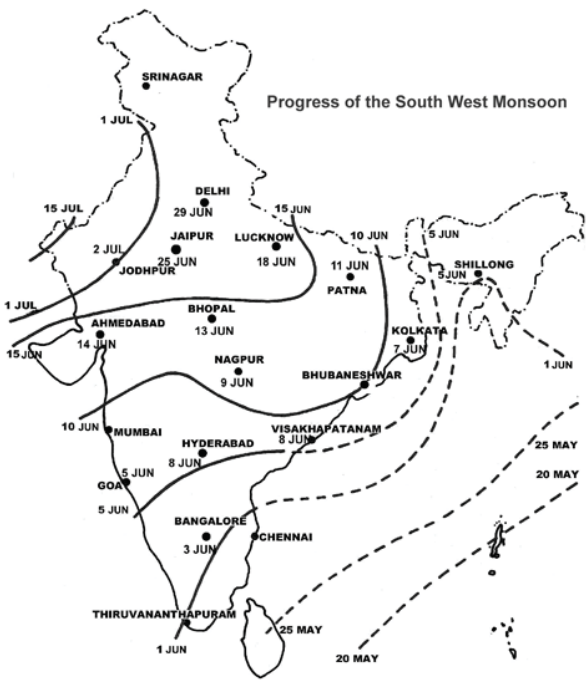
The word monsoon is derived from the Arabic word 'Mausim' which means season. Monsoon refers to the ***seasonal reversal in the wind direction*** during a year. During summer, the interior parts of North Indian Plains covering Rajasthan, Punjab, Haryana, and Western Uttar Pradesh are intensely hot. The daily maximum temperature in some of these parts is as high as 45° to 47° C. The following table shows the varying temperature and rainfall at different locations in India in a year.

		January	February	March	April	May	June	July	August	September	October	November	December
LEH	Temp.	-8	-7	-1	9	10	14	17	17	12	6	0	-6
	Rainfall	10	8	8	5	5	5	13	13	8	5	0	5
SHILLONG	Temp.	10	11	16	19	19	21	21	21	20	17	13	10
	Rainfall	14	29	56	146	295	476	359	343	302	188	36	10
DELHI	Temp	14	17	23	29	34	35	31	30	29	21	20	15
	Rainfall	21	24	13	10	10	68	186	170	125	14	2	9
JAISALMER	Temp	16	20	25	30	33	34	32	31	30	28	22	17
	Rainfall	0.2	0.1	0.3	0.1	0.5	0.7	0.9	86	14	1	0.5	0.2
MUMBAI	Temp	24	24	24	28	30	29	27	27	27	28	27	25
	Rainfall	4	2	2	2	18	465	613	329	286	65	18	2
CHENNAI	Temp	25	26	28	31	33	33	31	31	30	28	26	25
	Rainfall	4	13	13	18	38	45	87	113	119	306	350	135
THIRUVANANTHAPURAM	Temp	27	27	28	29	29	27	26	26	27	27	27	27
	Rainfall	23	21	39	106	208	356	223	146	138	273	206	75

Summer Monsoon

The average maximum temperature is above 33°C in the month of May at Delhi, Jodhpur and Jaisalmer. Such high temperature heats up the air of that region. Hot air rises and due to this a low pressure area is created under it. This low pressure is also known as **monsoonal trough**. It lies between western Rajasthan to Odisha On the other hand temperature over Indian Ocean is relatively low. So a relatively high pressure region is created over the sea. The pressure difference between Indian Ocean and North Central Indian Plains causes the air from high pressure region of the sea move towards the low pressure region of North India. This implies that the general movement of air is in June is from equatorial region of Indian





10 Only 2 & 3 are correct statements

Ocean to the Indian subcontinent in the South-West to North-East direction. This direction is exactly opposite to that of the trade winds (North – East to South-West) prevailing during winter in India. This complete reversal of wind direction from North-East to South West and vice-versa is known as monsoons. The winds contain a lot of moisture. When these moisture laden winds move over the Indian sub-continent they cause wide spread rain throughout India and from June to September. Thus, most of the total rainfall in India is confined to these four months only.

Winter Monsoon

During the winter season, **North-East trade winds** prevail over India. They blow from land to sea and that is why that for most part of the country, it is a dry season. A part of North-East trade winds blow over Bay of Bengal. They gather moisture which causes rainfall in the Coromandal coast while the rest of the country remains dry. Strictly speaking these winds are planetary winds known as **Northeast Trades**. In India they are essentially land bearing winds.

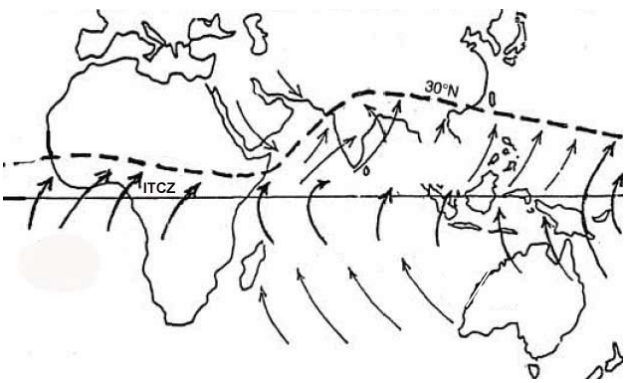
Monsoons winds are irregular in nature affected by different atmospheric conditions. They are also not equally distributed. Coastal areas like Kerala West Bengal and Odisha receive heavy rain fall, whereas interior regions like Haryana, Madhya Pradesh, receive less rainfall. When monsoon arrives, it gives heavy rainfall which continues for several days. This is known as 'burst of monsoon', which generally occurs at the Kerala coast.
The monsoon tends to have 'breaks' in its rainfall which causes wet and dry spells. This means that monsoon rains occur only a few days at a time. Rainless dry spells occur in between.

The above simple story is based upon a mechanism proposed by **Halley and is also known as Thermal Concept**. However, it fails to answer the following questions:

- ? *Why the low pressure areas on land are not stationary and why they suddenly change their location?*
- ? *Why there is no antimonsoon circulation in the upper troposphere, which must be there if the monsoon winds are thermally induced?*
- ? *Low Pressure are in northern India is in April and May, but rains start in the end of June or beginning of July.*
- ? *Monsoon rains are an amalgamation of convectional, orographic and cyclonic rainfall, the thermal concept is unsatisfactory to explain in details.*

Another gentleman **Fohn** tried to link the Monsoon with the ITCZ or Intertropical Convergence Zone, which is called **Dynamic Concept**.

This concept says that monsoon is the result of seasonal migration of planetary winds and pressure belts around Equator. The Inter-Tropical Convergence Zone (ITCZ) is formed due to the convergence of north-east and south-east trade winds near the equator. In summer when the rays of Sun are directly above the Tropic of Cancer, the Northern Intertropical Zone gets extended up to 30° N latitude, thus covers the South Asia as well as South East Asia, where a low pressure area develops.



When this happens, the trade winds of the Southern Hemisphere need to cross the equator in order to reach the ITCZ. Thus, the trade winds of the Southern Hemisphere cross the equator but are deflected towards right under the Coriolis Effect. In this manner a new belt of "*equatorial westerlies*" is developed and Indian landmass receives the south west monsoon due to these winds.

This theory further explains that in winter, the ITCZ shifts towards south of Equator and the North East Trade winds have to cross the equator to reach the ITCZ. These winds blowing from the northern hemisphere to southern hemisphere deflected left due to Coriolis Effect and blow as North westerly Monsoon there. Since the winds blowing over the Indian subcontinent at this time are usual trade winds of these latitudes, they blow from North East to South West and so become the North East Monsoon.

There are four seasons in India as follows:

1. Winter (December-February),
2. Hot weather summer (March-May)
3. Rainy south-western monsoon (June-September)
4. Post-monsoon, also known as north-east monsoon in the southern Peninsula (October-November).

Winter Season

Model Question - 11.

Consider the following statements:

1. The winter rains in Punjab, Haryana and Western Uttar Pradesh are caused by western disturbances
2. The winter rains in Tamil Nadu are caused by North East Monsoon

Which among the above statements is / are correct?

11

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Model Question - 12.

Consider the following statements:

1. The general direction of the prevailing winds over Indian subcontinent is North East in March and South-West in July
2. North-East Trade winds generally blow over Indian subcontinent in winter

Which among the above statements is / are correct?

12

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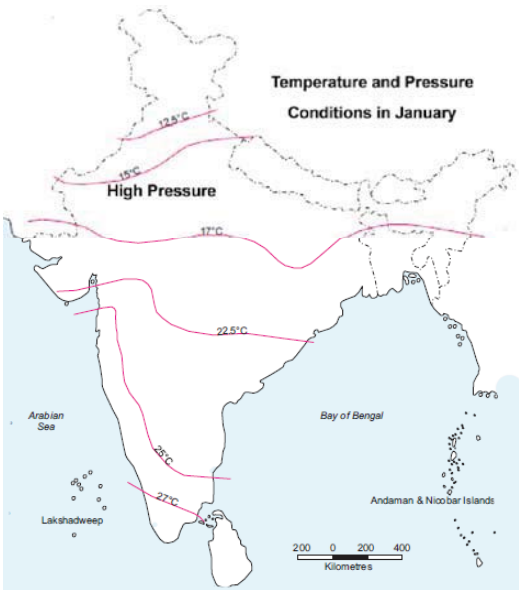
During the winter season, the temperature decreases with increasing latitude in India from 25°C in South to near zero temperature on north. This season is characterised by Fog and Frost in North and North-West India. There is light rainfall in this region due to Western disturbances. There is a sustained snowfall on the higher slopes of the Himalayas.

North East Monsoon

In India, rains occur in winter due to the North East Monsoon. During the winter season, **North-East trade winds** prevail over India. They blow from land to sea and that is why that for most part of the country, it is a dry season. A part of North-East trade winds blow over Bay of Bengal. They gather moisture which causes rainfall in the Coromandal coast while the rest of the country remains dry. In the northern part of the country the weather is marked by clear sky, low temperatures and low humidity. The winter rainfall is very important for the cultivation of 'Rabi' crops.



Impact of Jet streams in Winter

Model Question - 13.

Consider the following statements in context with the Jet streams:

1. Jet stream are slow, regular, wide and moisture laden winds blowing in the stratosphere
2. They help to bring the Western Disturbances Into India In winter
3. They generally blow from West to East
4. They generally blow in straight path

Which among the above statements is / are correct?

Answer: **13**

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Jet streams are **fast flowing**, **narrow** air currents located ***near the Tropopause***, the transition between the troposphere and the stratosphere. The **major jet streams on Earth are westerly winds** (flowing west to east). Their paths typically have a **meandering shape**; jet streams may start, stop, split into two or more parts, combine into one stream, or flow in various directions including the opposite direction of most of the jet.

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11 Both are correct statements.

12 Both are correct statements

13 2 & 3 are correct statements.

The **strongest jet streams are the polar jets**, at around 7–12 km above sea level, and the higher and somewhat weaker subtropical jets at around 10–16 km. The Northern Hemisphere and the Southern Hemisphere each have both a polar jet and a subtropical jet. The northern hemisphere polar jet flows over the middle to northern latitudes of North America, Europe, and Asia and their intervening oceans, while the southern hemisphere polar jet mostly circles Antarctica all year round.

The Jet streams are upper level, irregular, concentrated, meandering bands of westerly winds that travel at speeds of 300 to 400 kmph and come to India from the Mediterranean side in winter. This jet stream is bifurcated due to the physical obstruction of the Himalayas and Tibetan Plateau. One branch is located to the south of the Himalayas, while the second branch is positioned to the north of the Tibetan Plateau. The southern branch blows eastwards south of the Himalayan ranges along 25° N latitude (Rajasthan., MP, Chhattisgarh etc.) . These winds tend to descend over the north-western parts of India, resulting into the development of atmospheric stability and **dry conditions**. It is believed that this branch of jet stream exercises a significant influence on the winter weather conditions in India. *This jet stream is responsible for bringing western disturbances from the Mediterranean region into Indian sub-continent.* Winter rain and hail storms in north western plains and occasional heavy snowfall in hilly regions are caused by these disturbances. These are generally followed by cold waves in whole of northern plains.

Western Disturbances

Western Disturbances are basically the **temperate cyclones** that originate in the Mediterranean Sea and west Asia and happen to reach Afghanistan and Pakistan. In winters, they cross the North West borders of India and reach up to Central India. These disturbances bring small winter rains in India which are locally called *Mahavat* (Rajasthan, Haryana, Punjab) and are beneficial for the Rabi Crops. They also bring cold waves and snowfall in the higher altitudes of the Jammu and Kashmir and Himachal Pradesh.

Summer Season

By the end of February the temperature starts rising and there is a hot weather season in India from March to May. During these months the central part of peninsular India expiries extreme hot weather and an elongated low pressure belt which is called monsoonal trough created, which extends from Jaisalmer in western Rajasthan to Jharkhand and parts of Odisha to the East.

However, over Indian Ocean south of the equator high pressure belt begins to develop in this season. In North-West India, afternoon dust storms are common. During summer, very hot and dry winds blow over North Indian plains. They are locally called 'Loo'. At the same time, localized thunderstorms, associated with violent winds, torrential downpours, often accompanied by hail occur in many parts of India.

- *In West Bengal, these storms are known as the '**Kaal Baisakhi**' (calamity for the month of Baisakh).*
- *Towards the close of the summer season, pre-monsoon showers are common, especially in Kerala and Karnataka, which help in the early ripening of mangoes, and are often referred to as '**mango showers**'.*
- *The thunderstorms which occur during summer to bring some rainfall in Karnataka are also known as **Cherry Blossom Showers**.*

Rainy south-western monsoon (June-September)

June to September are the months of advancing South-West monsoon season. By the end of May, the monsoon trough further intensifies over north India due to high temperature. The General direction of the wind during this season is from South-West to north-east. These winds are strong and blow at an average velocity of 30 km per hour. These moisture laden winds first hit at Andaman and Nicobar Islands in the last week of May and Kerala coast in the first week of June with violent thunder and lightning. This South-West monsoon that flows in to India brings about a major change in its weather. Two branches of south-west monsoon originate from:

- *Arabian Sea*
- *Bay of Bengal.*

The Arabian Sea Branch obstructed by Western Ghats gives heavy rainfall on the Western side of Western Ghats. It reaches Mumbai by 10th June. When this branch crosses the Western Ghats and reaches the Deccan Plateau and parts of Madhya Pradesh, it gives less rainfall as it is a rain shadow region. Further, this branch reaches in Northern Plain by 20th June.

The monsoon winds that move from Bay of Bengal strike Andaman and Nicobar Islands North-Eastern states and coastal areas of West Bengal and cover the whole of India by the 15th of July. They cause heavy rainfall in the region. However, quantity of rainfall decreases as they move towards West over the Northern plains. For examples rainfall at Kolkata is 120 cm, Allahabad 91 cm and Delhi 56cm.

Rains in Bangalore versus Mangalore

Bangalore receives less rainfall in comparison to Mangalore because Bangalore is located in the rain shadow (Leeward Side) of Western Ghats and when the wind blows from the west, it gets obstructed by the hills. Thus the moisture laden wind blows to the windward side of the ghats, causing heavy rainfall in the coastal region and ghat areas and the rainfall in Bangalore is limited. However, you must note here that during weak monsoon condition when there is ample sunshine, the lower levels of the atmosphere are warm which gives rise to convection current. The air goes up leading to the formation of clouds, resulting in rainfall in the city.

Similarly, **Pune** receives less rainfall because it is also located on lewardside of western Ghats. Other examples are **Shillong** and **Hyderabad.** Shillong lies on the northern leeward slopes of the Khasi Hills and therefore receives less rain.

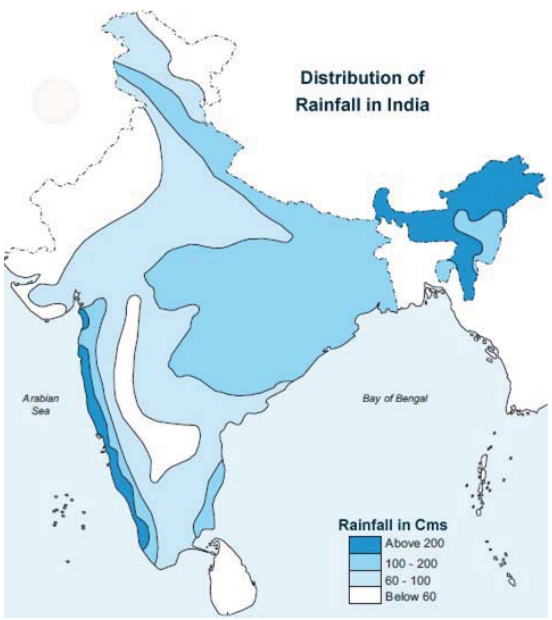
Post Monsoon Season

October and November are the months of post (or retreating) monsoon season. The temperatures during September-October start decreasing in north India. Monsoonal trough also becomes weak over North-West India. This is ***gradually replaced by a high pressure system***. The South-West monsoon winds weaken and start withdrawing gradually from North Indian Plains by November. In October the weather remains humid and warm due to continuing high temperature and moist land in month of October. *In Northern plains hot and humid weather becomes oppressive at this time. It is commonly called 'October Heat'. However, towards the end of October, temperature starts decreasing, making nights pleasant.*

By the month of November, the low pressure of North India shifts to Bay of Bengal and this is the time of cyclonic storms which develop in the Bay of Bengal. These storms create havoc in coastal areas of Odisha, Andhra Pradesh and Tamil Nadu, especially in the deltas of Mahanadi, Godavari and Krishna rivers.

Distribution of Rainfall in India

Rainfall in India is highly uneven over a period of time in a year. The western coasts and North East India receive rainfall of over 400 cm. It is less than 60 cms in western Rajasthan and adjoining parts of Gujarat, Haryana and Punjab. Similarly, rainfall is *low in the interiors of the Deccan Plateau and east of Western Ghats*. Then, Leh in Jammu and Kashmir is also an area of low precipitation.



Here are some more observations:

- As we move from Meghalaya to Haryana or Punjab in Northern plains, we observe that the rainfall decreases.
- In peninsular India, rainfall decreases from coast to interior parts.
- In North-East India, the *rainfall increases with altitude.*
- Maximum rainfall (above 200 cms) in India occurs in the western coast, sub Himalayan regions of north-east and Garo, Khasi and Jaintia hills of Meghalaya.
- Moderate rainfall (100-200cm) occurs in some parts of the Western Ghats, West Bengal, Odisha and Bihar and many states.

- Low rainfall (60 to 100cm) occurs in parts of Uttar Pradesh, Rajasthan, and interior Deccan plateau.
- Inadequate rainfall (Less than 60cm) occurs in western part of Rajasthan and Gujarat, Ladakh and south central part receives a rainfall of less than 20cm.

El Niño/La Niña–Southern Oscillation

Model Question - 14. (IAS 2011)

La Nina is suspected to have caused recent floods in Australia. How is La Nina different from EI Nino ?

1. La Nino is characterized by un-usually cold ocean temperature in equatorial Indian ocean whereas EI Nino is characterized by unusually warm ocean temperature in the equatorial pacific ocean.
2. EI Nino has adverse effect on south-west monsoon of India, but La Nina has **no effect** on monsoon climate.

Which of the statements given above is/are correct?

Answer: **14**

El Niño was originally recognized by fisherman off the **coast of Peru** in South America as the appearance of unusually warm water in the Pacific Ocean, occurring near the beginning of the year. The eastern equatorial Pacific is usually dominated by coastal upwelling that is- the upsurge **of deep, nutrient-rich cold water** to the ocean's surface. This cold water provides excellent breeding grounds for various levels of the food chain from phytoplankton to tiny fishes. Exploitation of these small fishes is what made **Peru** the number one fishing nation in the world by the early 1970s.

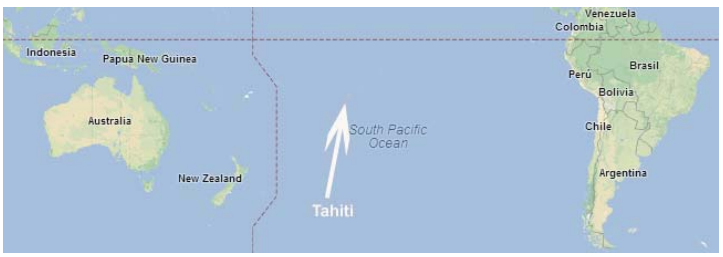
But, every Christmas season the winds that blow along the coast from the southeast slacken, the strength of the upwelling weakens, and the **surface waters begin to warm and the fish population is less available to the fishing boats.** This warming trend usually lasts for a few months and by March or so the strong upwelling resumes again. Occasionally the warm water continues to accumulate in the eastern and central equatorial Pacific, resulting in a large area of warm surface water. The accumulation of large mass of warm water bring reduction in the fish catches off the coast of Peru and with destructive rains that occur in normally dry areas of Peru and Chile. The same was also associated with the development of drought in Bolivia and northeast Brazil, and other impacts such as outbreaks of malaria and cholera in various parts of South America.

Thus, it was known in medieval times that such a phenomenon happens and it was named "Christ Child" or "The Little Boy" in the vernacular languages.

Basically, El Niño can be defined as *an invasion of **warm surface water** from the western part of the equatorial Pacific into the normally cooler waters of the central and eastern part of the Pacific Basin off the western coast of South America – mainly Peru and Ecuador.*

La Niña, which means "The Little Girl" or "El Viejo" or "anti-El Niño" or simply "a cold event" or "a cold episode is the is the **cooling of water in the Pacific Ocean.**

Although El Niño originally referred to local conditions off the coast of Peru and Ecuador, the use of the term has been broadened by many scientists to represent all surface temperature warming in the eastern and central Pacific. Both **El Nino** and **La Nina** are part of a larger cycle called ENSO, or **El Niño–Southern Oscillation**. While El Nino **may be caused by underwater volcanoes** in the Pacific, the **Southern Oscillation is the atmospheric counterpart** of the event which refers to a **seesaw-like shift in sea level pressure systems across the Pacific Basin**. When sea level pressure is high at **Darwin, Australia**, it tends to be **low at Tahiti**, and vice versa.



14 Both are incorrect statements. La Niña is characterized by unusually cool ocean surface temperatures in the central and eastern tropical Pacific. It is the opposite of El Niño, which is marked by unusually warm ocean surface temperatures. Both are strongly coupled to the atmospheric circulation in the tropics and are major – but not the only - determinants of the seasonal and year-to-year fluctuations of our climate. La nina is good for Indian monsoon as we have been told.

The El Niño (warm event) and La Nina (Cold event) both have now established themselves as the integral part of the global climate system. It is a recurrent phenomenon with an average return period of $4^{1/2}$ years, but can recur as little as 2 or as much as 10 years apart. Such events have occurred for millennia, and can be expected to continue to occur in the future.

The impacts of El Niño , which haven been well documented include the following:

- *Drought in Zimbabwe, Mozambique, South Africa*
- *Drought-related food shortages in Ethiopia*
- *Warm winter in the northern half of the United States and southern Canada*
- *Heavy rains in southern Ecuador and northern Peru*
- *Drought in northeast Brazil, while Flooding in southern Brazil*
- *Drought and fires in Indonesia*
- *Drought in the Philippines in the tropical Atlantic*
- *Coral bleaching worldwide*
- *Droughts in various South Pacific island nations*
- *Drought in eastern Australia*
- *Heavy rains in southern California*

The following table summarizes El Niño and La Nina weather:

El Nino Weather	La Nina Weather
Rain and flooding along the Pacific coast	Snow and rain on the west coast
Warm water disrupts food chain of fish, birds, and sea mammals	Unusually cold weather in Alaska
Tornadoes and thunderstorms in southern US	Unusually warm weather in the rest of the USA
Fewer than normal hurricanes in the Atlantic	Drought in the southwest
	Higher than normal number of hurricanes in the Atlantic

Impact of El Niño and La Nina on Indian Weather

- El Nino and La Nina are among the most powerful phenomenon on the Earth. These are known to alter climate across more than half the planet and dramatically impact weather patterns.
- Over Indian subcontinent, El Nino during winter results in development of warm conditions. During summer, it leads to dry conditions and deficient monsoon. It also leads to drought in Australia. On the other hand, La Nina results in better than normal monsoon in India. At the same time, in Australia it has caused floods.
- In the recent past, India experienced deficient rainfall during El Nino years 2002 and 2009 whereas monsoon was normal during El Nino years 1994 and 1997. *This so far implies that in about 50 per cent of the years with El Nino during summer, India experienced droughts during monsoon*.
- This implies that *El Nino is not the only factor that affects monsoon in India*. There are other factors that affect India's rainfall pattern. These include North Atlantic SST, Equatorial SE Indian Ocean SST, East Asia Mean Sea Level Pressure, North Atlantic Mean Sea Level Pressure and North Central Pacific wind at 1.5 km above sea level.

Part IV. 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. Components of the soil are mineral particles, humus, water and air as we discussed in SGS 27. The actual amount of each of these depends upon the type of soil. Some soils are deficient in one or more of these, while there are some others that have varied combinations. India is a diverse country with variety of relief features, landforms, climatic realms and vegetation types. These have contributed in the development of various types of soils in India.

In ancient times, soils used to be classified into two main groups – **Urvara and Usara**, which were fertile and sterile, respectively. In medieval times, the soils were classified on the basis of the external features such as texture, colour, slope of land and moisture content in the soil. So, the soils were identified as sandy, clayey, silty and loamy, etc. Then, they were also classified on the basis of colour such as red soil, yellow soil, black soil, etc.

The Indian soils have been classified by ICAR on the basis of characters as per the United States Department of Agriculture (USDA) Soil Taxonomy. These types are as follows:

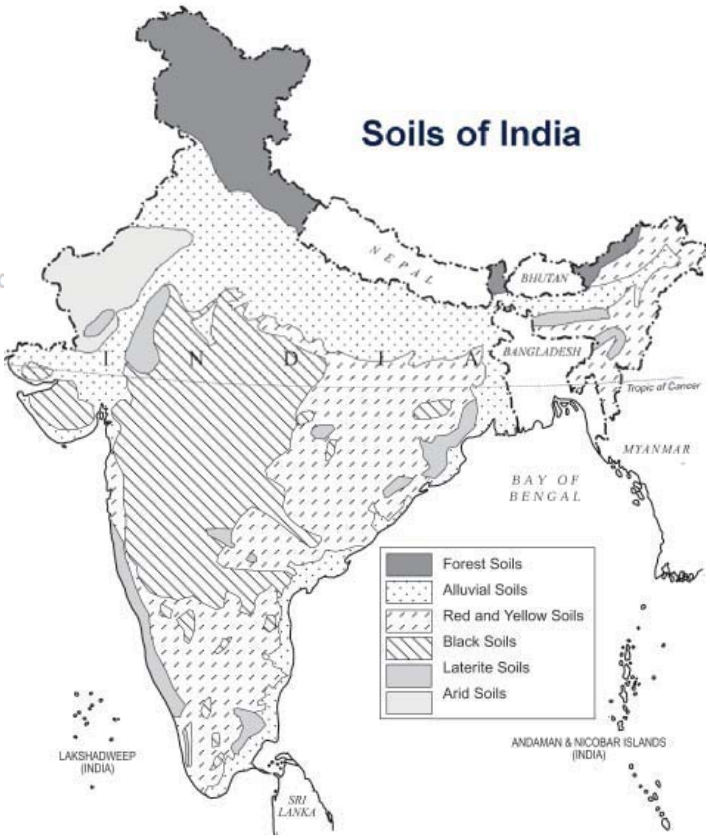
Types of Soils in India			
Soil Type	General Characters / Position in entire world soil classification	Area	% of Total area of India
Inceptisols	These are usually the **weakly developed young soil** though they are more developed than entisols.	130372.9	39.74
Entisols	Usually young or underdeveloped. Lack vertical development of horizons. These are less fertile soils.	92131.71	28.08
Alfisols	Pale, grayish brown to reddish in colour with moderate-to-high reserves of basic cations and are fertile. However, their productivity depends on moisture and temperature. They are supplemented by the moderate application of lime and other chemical fertilizers.	44448.68	13.55
Vertisols	These are expandable clay soils , composed of more than 30 per cent clays. Vertisol clays are black when wet and become iron hard when dry. When drying, Vertisols crack and the cracks widen and deepen as the soil dries ; this produces cracks 2-3 cm wide. These are productive soils. The regur soils of India are an example of vertisols.	27960	8.52
Aridisols	Ardisoil is the largest single soil order occurs in dry regions of the world. These soils occupy nearly 19 per cent of the earth's land surface. These are pale and light near the surface, deficit in moisture. Lack in organic matter. Salinisation is the main problem of these soils. Salinisation complicates farming in Aridisols.	14069	4.28
Ultisols	Highly weathered forest soil, which tend to be reddish in colour because of residual iron and aluminum oxides in the a horizon. The increased precipitation in ultisol regions means greater mineral alteration, more leaching, and therefore,a lower level of fertility. Fertility is further reduced by certain agricultural practices and the effect of soil damaging crops such as cotton and tobacco. These soils need substantial management.	8250	2.51
Mollisols	Most productive soils of the earth. They are rich in humus content. They have dark –colored surface. Mollisols are soft, even when dry, with granular pads, loosely arranged when dry. These humus rich organic soils are high in basic cations and have high fertility. Soils of the steppes and prairies of the world belong to this group	1320	0.4
Others		9503.1	2.92

The Indian Classification of Soils

On the basis of genesis, colour, composition and location, the soils of India have been classified into:

- *Alluvial soils*
- *Black soils*
- *Red and Yellow soils*
- *Laterite soils*
- *Arid soils*
- *Saline soils*
- *Peaty soils*
- *Forest soils*

Important Observations have been written down in the below descriptions:



Alluvial Soils

Model Question - 15.

Consider the following statements:
1. Alluvial soil is most common soil in India
2. Alluvial soil is an in-situ soil

Which among the above is / are correct?
Answer: 15

- 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**.

15 Only 1 is correct. Please note that in situ or residual soils are the soil which are found where they were formed. Example of in-situ soil is Red Soil. The Alluvial is a transported soil.

- In the Upper and Middle Ganga plain, two different types of alluvial soils have developed, viz. Khadar and Bhangar.
    - Khadar is the new alluvium and is deposited by floods annually, which enriches the soil by depositing fine silts.
    - Bhangar represents a system of older alluvium, deposited away from the flood plains.
        - Both the Khadar and Bhangar soils contain calcareous concretions (Kankars). These soils are more loamy and clayey in the lower and middle Ganga plain and the Brahamaputra valley. The sand content decreases from the west to east.
- The colour of the alluvial soils varies from the light grey to ash grey. Its shades depend on the depth of the deposition, the texture of the materials, and the time taken for attaining maturity. Alluvial soils are intensively cultivated.
- **Coastal Alluvium:** Please note that the alluviums of the peninsular coastal strip are darker in colour than the alluvium of the northern plains because the rivers of the peninsula flow over the Deccan Plateau composed of basalt, and over black soil are only to deposit It in coastal areas . Maharastra has no alluvial soils but coastal alluvium is found in that state.

Black Soil

Model Question - 16.

Consider the following statements:

1. X is a soil known for its self-ploughing quality and the capacity to hold moisture.
2. Y is a soil formed by the weathering of old crystalline rocks, lacking in humus

Identify X and Y from the given options:

A. X-Black Soil, Y-Red Soil
B. X-Black Soil, Y- Alluvial Soil
C. X-Red Soil Y- Laterite Soil
D. X-Laterite soil Y-Black soil

Answer: 16

Model Question - 17.

In context with the Black soils found in India, consider the following statements:

1. It is of volcanic origin
2. It has self aerating properties
3. It is best suitable for sugarcane and Cotton

Which among the above statements is / are correct?

Answer: 17

- Most of the Deccan plateau, including Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh and some parts of Tamil Nadu has black soils .
- In the upper reaches of the Godavari and the Krishna, and the north western part of the Deccan Plateau, such as parts of Gujarat, the black soil is very deep. These soils are also known as the 'Regur Soil' or the 'Black Cotton Soil'. This soil is of volcanic origin.
- The black soils are generally clayey, deep and impermeable. They swell and become sticky when wet and shrink when dried. So, during the dry season, these soil develop wide cracks. Thus, there occurs a kind of '**self ploughing**'. Because of this character of slow absorption and loss of moisture, the black soil retains the moisture for a very long time, which helps the crops**, especially, the rain fed crops**, to sustain even during the dry season.
- Chemically, the **black soils are rich in lime, iron, magnesia and alumina.** They also contain potash. But they lack in phosphorous, nitrogen and organic matter. The colour of the soil ranges from deep black to grey.

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16 Correct answer is A

17 All are correct.

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

Model Question - 18.

The laterite soils are not fertile soils because___:

1. They are coarse grained and non-retentive of moisture.
2. They lack humus .
3. They are highly acidic In nature
4. They have excess iron

Choose the correct statements:

Answer: **18**

- 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.

18 All are correct

Saline Soils

- Saline soils or **Usara soils** contain a larger proportion of sodium, potassium and magnesium, and thus, they are infertile, and do not support any vegetative growth.
- They have more salts, largely because of dry climate and poor drainage. They occur in arid and semi-arid regions, and in waterlogged and swampy areas.
- Their structure ranges from sandy to loamy. They lack in nitrogen and calcium.
    - Saline soils are more widespread in western Gujarat, deltas of the eastern coast and in Sunderban areas of West Bengal.
    - In the Rann of Kuchchh, the Southwest Monsoon brings salt particles and deposits there as a crust. Seawater intrusions in the deltas promote the occurrence of saline soils. In the areas of intensive cultivation with excessive use of irrigation, especially in areas of green revolution, the fertile alluvial soils are becoming saline.
    - Excessive irrigation with dry climatic conditions promotes capillary action, which results in the deposition of salt on the top layer of the soil. In such areas, especially in Punjab and Haryana, farmers are advised to add gypsum to solve the problem of salinity in the soil.

Peaty Soils

- Peaty soils arte found in the areas of heavy rainfall and high humidity, where there is a good growth of vegetation. Thus, large quantity of dead organic matter accumulates in these areas, and this gives a rich humus and organic content to the soil.
- Organic matter in these soils may go even up to 40-50 per cent.
- These soils are normally heavy and black in colour. At many places, they are alkaline also.
- These soils occur widely in the northern part of Bihar, southern part of Uttaranchal and the coastal areas of West Bengal, Orissa and Tamil Nadu.

Forest Soils

- Forest soils are formed in the forest areas where sufficient rainfall is available. The soils vary in structure and texture depending on the mountain environment where they are formed.
    - They are loamy and silty on valley sides and coarse-grained in the upper slopes.
    - In the snow-bound areas of the Himalayas, they experience denudation, and are acidic with low humus content. The soils found in the lower valleys are fertile.

Major Soils and crops grown in them

Alluvial Soils
- Rice, wheat, sugarcane, cotton and jute all grow well in these soils.

Black Soils
- Rice, wheat, sugarcane and cotton apart from groundnut, millet and oilseeds.

Arid Soils
- Only drought-resistant crops such as barley and millet can grow in this type of soil.

Laterite Soils
- It is an acidic soil and is rich in iron, which gives the soil a somewhat red appearance. Cash crops such as cashew, rubber, coconut, tea and coffee.

Red and Yellow Soils
- Derive names from the very large amounts of iron oxide & Hydroxides present in them. They are sandy and somewhat acidic, and are also low in nitrogen and phosphorous. Despite this, red and yellow soils are used to grow rice, wheat, sugarcane, millet, groundnut, ragi and potato.

The decline in soil fertility, when the nutritional status declines and depth of the soil goes down due to erosion and misuse is called Soil degradation. Soil degradation is the main factor leading to the depleting soil resource base in India. The degree of soil degradation varies from place to place according to the topography, wind velocity and amount of the rainfall.

Soil Erosion

The soil forming processes and the erosion processes of running water and wind go on simultaneously. However, generally, there is a balance between these two processes. Sometimes, such a balance is disturbed by natural or man made factors, leading to a greater rate of removal of soil.

- With increasing population, the pressure on the land increases and forests are removed for human settlement, for cultivation, for grazing animals and for various other needs.

The two most important agents of soil erosion are wind and water. Wind erosion is significant in arid and semi-arid regions. Water erosion is significant in regions with heavy rainfall and steep slopes. Water erosion which is more serious and occurs extensively in different parts of India, takes place mainly in the form of sheet and gully erosion.

There are four kinds of soil erosion which can be arranged in an order of Splash erosion, Sheet erosion, Rill erosion, Gully erosion

Splash Erosion

Raindrop splash erosion is a result of the energy of falling raindrops causing detachment of soil particles and and down-slope movement of sediment. Maintenance of ground cover, such as in reduced- or no-till operations, use of cover crops, and enhancement of the stability of soil aggregates can be important in reducing detachment of soil particles. The effect of manure application in enhancing soil aggregation also leads to reducing soil erodibility due to the raindrop splash effect.

Sheet Erosion

Sheet erosion, although less noticeable than other types of erosion, typically is the main erosive force. Sheet erosion is less noticeable, as it does not leave obvious cuts in the soil surface as with gully erosion. Sheet erosion is the removal of a relatively uniform, although thin, layer of soil from the land surface by unchanneled runoff, or sheet flow.

Sheet erosion takes place on level lands after a heavy shower and the soil removal is not easily noticeable. But it is harmful since it removes the finer and more fertile top soil.

Rill Erosion

Rill erosion is the process by which numerous small channels--less than three inches in depth--are formed. This type of erosion results from concentration of overland water flow associated with sheet erosion. Rill erosion can be especially serious on recently cultivated land. Rill erosion is best minimized by minimizing sheet flow, such as by maintaining crop residues and utilizing cover crops. Physical barriers, such as terraces, and vegetative barriers can be effective in stopping or reducing rill erosion.

Gully Erosion

Gully erosion refers to the cutting of narrow channels called gullies. The gullies can be caused by small channels of approximately 3 to 12 inches deep. Gullies may be one to several feet deep. Gully erosion cuts deep and removes the **surface soil as well as deeper soil** that may still have substantial amounts of total nutrients but less compared to the surface soil.

Gully erosion needs to be prevented, as it is difficult to check once started. Gully erosion is common on steep slopes. Gullies deepen with rainfall, cut the agricultural lands into small fragments and make them unfit for cultivation.

- A region with a large number of deep gullies or **ravines** is called **badland topography**. Ravines are widespread, in the Chambal basin, which have been caused due to gully erosion. Apart from Chambal valley, the ravines are also found in Tamil Nadu and West Bengal.

Some more observations

- The Indian soils have been formed under varied geographical conditions and differ widely in their physical properties, chemical composition and fertility level. *Most soils are old and mature*.
- Soils of the peninsular plateau are much older then the soils of the great northern plain.
- Indian soils are largely deficient in nitrogen, minerals salts, humus and other organic materials.
- Plains and valleys have thick layers of soils while hilly and plateau areas depict thin soil cover.
- Some soils like alluvial and black soils are fertile while some other soils such as Laterite, desert and alkaline soils lack in fertility and do not yield good harvest.
- Indian soils have been used for cultivation for hundreds of years and have lost much of their fertility. As such there is urgent need of giving scientific treatment to our soils.
- Indian climate is characterized by seasonal rainfall and our soils need irrigation during the dry period.
- Indian soils suffer from soil erosion and other allied problems.

Contents

Determinism and Possibilism

Human geography studies the inter-relationship between the physical environment and sociocultural environment created by human beings through mutual interaction with each other.

Determinism and possibilism

Determinism and possibilism are two philosophical approaches in human geography.

Determinism

Philosophy of Determinism is based upon the interaction between primitive human society and strong forces of nature. This is an older philosophy which persisted till World War II. It says that the strong forces of environment control the course of human action. This implies that the history, culture, mode of life, and the level of development of the societal groups and countries are exclusively or largely controlled by the physical environment.

- According to Determinism, man is a passive agent, and nature is active agent, which controls and determines the action and decision-making processes of man.
- As per determinism, the human actions can be explained as a response to the natural environment.

Environmental determinism

This philosophy says that aspects of physical geography, particularly climate, influenced the psychological mind-set of individuals, which in turn defined the behaviour and culture of the society that those individuals formed. For example, tropical climates were said to cause laziness, relaxed attitudes and promiscuity, while the frequent variability in the weather of the middle latitudes led to more determined and driven work ethics.

- The core philosophy is that the supreme achievements of civilisation in any region were always bound up with a particular type of climate and variation in climate led to pulsations in the history and culture of the people.

These geographers who propound this theory say that the civilisations of Egyptians, Mesopotamians, Indus-valley, disappeared because of the climatic changes. The attacks of the central Asian nomads in different directions in the 13th century were also attributed to the drying up of their pastures directions of climatic change.

Possibilism

Possibilism is reaction to determinism and environmental determinism. It is based upon the assumption that environment sets certain constraints or limitations, but culture is otherwise determined by social conditions. This theory says that the true and only geographical problem is that to **utilisation of possibilities**.

Essence of Possibilism is that:

- Nature provides possibilities and man utilises them according to his culture, traditions, and levels of socioeconomic development.
- People are not just the products of their environment or just pawn of natural environment.
- *Nature is never more than an adviser.*
- There are not necessities but everywhere possibilities.
- The range of possibilities in every region is limited more by the price man is willing to pay of what he wants than by the dictates of environment. For instance, man through his technical skill can grow banana, rice and rubber plants in tundra, Greenland, and Antarctica, but he has to take into consideration the input cost.
- The prohibitive cost of production of these crops in the extremely cold conditions of these areas will compel man not to grow them in the tundra climate.

This approach has been criticised on several accounts. For example, despite numerous possibilities, man, has not been able to get rid of the obstacles set by the physical forces. The possibilities may be many in the temperate regions but they are very limited in the deserts, equatorial, tundra, and high mountainous regions.

Neo-determinism

Australian geographer Griffith Taylor, in 1920 argued that the limit of agricultural settlements in Australia has been set by factors of the physical environment such a distribution of rainfall. He further said that the best economic programme for a country to follow has in large part been determined by nature ,and it is the geographer's duty to interpret this programme. Man is able to accelerate, slow, or stop the progress of a country's regions development. But he should not, if he is wise, *depart from directions as indicated by natural environment.* He is like the traffic controller in a large city who alters the rate but not the direction of progress.

- This theory is also called ''stop and go determinism''.
- It says that man follows nature's plan only if he is wise, presuming he can act foolishly ,which admits the possible contention that within broad limits set by environment, man can choose at the very least. But wisdom and folly are human concepts. The nature knows nothing of them.\
- This theory says that in no environment are the possibilities limitless and for every choice a price must be paid. Man makes his choice and man himself judges its relative wisdom or folly by reference to goals he himself has established.

World Population

The world at the beginning of 21st century recorded the presence of over 6 billion population. Current human population is 7.062 Billion. As per the United States Census Bureau (USCB), world population exceeded 7 billion on March 12, 2012. According to the United Nations Population Fund, it reached this milestone in 2011.

In the initial phase of human history, human population grew at a very slow speed. The hazardous climatic conditions the migratory character of hunters and gatherers, poor nourishment and poor technology were unfavourable for the growth of human population.

The first major landmark in growth of human population was agriculture revolution which refers to the domestication of the animals and plants some 10,000 years ago. The domestication of plants and animals resulted in somewhat assured supply of food and a settled life in addition to hunting provided better nourishment.

Year	World Population (millions)
8000bc	5
1 ad	200
1000ad	300
1650 ad	500
1850 ad	1000 (1 biiion)
1930 ad	2000 (2 billion)
1960 ad	3000 (3 billion)
1975 ad	4000 (4 billion)
1987 ad	5000 (5 billion)
1999 ad	6000 (6 billion)
2050 ad*	7500-10500 (7.5-10.5 billion)

***Projected figures**

The steady growth in human population till 14th century was briefly interrupted by the Great Famine and the Black Death in 1350, when it stood at around 370 million. After that it has increased and has been fastest in the 1960s and 1970s. Population growth since the beginning of agriculture until 1850 was very slow. The estimated population of the world in 1850 was about one billion, which grew to two billion in 1930, three billion in 1960, and became six billion in 1999. Thus, fastest growth of population occurred between 1960 and 1999. The following table shows the Milestones of the world population.

Population	1	2	3	4	5	6	7	8	9
Year	1804	1927	1960	1974	1987	1999	2012	2025-2030	2045–50
Years elapsed	123	33	14	13	12	13	15-20	20–25	
Figures in Billion.									

We observe the above table that

- *Time elapsed from 1 billion to 2 billion was maximum i.e. 123 years.*
- *This elapsing time decreased till 1999, when Population became 6 Billion.*
- *The projected time elapsed is now increasing till the population becomes 9 Billion.*

Important Observations

- Current projections show a continued increase in population in the near future (but a steady decline in the population growth rate), with the global population expected to reach between 7.5 and 10.5 billion by 2050.
- Broadly, 90 per cent of the world population lives in about 10 per cent of its land area.
- The 10 most populous countries of the world contribute about 60 per cent of the world's population. Of these 10 countries, 6 are located in Asia.
- Most dense areas of the world are the North -Eastern part of U.S.A., North-Western part of Europe, South, South-East and East Asia
- Other areas like those near the North and South Poles, the hot and the cold deserts and high rainfall zones near the Equator have very low density of population. These are the sparsely populated regions of the world with less than 01 person per sq km.

Distribution among Continents

- Asia is the most populous continent, with its 4.2 billion inhabitants accounting for over 60% of the world population.
- The world's two most-populated countries alone, China and India, together constitute about 37% of the world's population.
- Africa is the second-most-populated continent, with around 1 billion people, or 15% of the world's population
- Europe's 733 million people make up 11% of the world's population, while the Latin American and Caribbean regions are home to around 600 million (9%).
- Northern America, primarily consisting of the United States and Canada, has a population of around 352 million (5%), and Oceania, the least-populated region, has about 35 million inhabitants (0.5%).
- Though it is not permanently inhabited by any fixed population, Antarctica has a small, fluctuating international population, based mainly in polar science stations. This population tends to rise in the

summer months and decrease significantly in winter, as visiting researchers return to their home countries.

Distribution among countries

- The following table shows the top 10 most populous countries of the world:

Rank	Country / Territory	Population	% of world Population
1	China	1.36 Billion	19.20%
2	India	1.21 Billion	17%
3	United States	31 Million	4.46%
4	Indonesia	24 Million	3.37%
5	Brazil	20 Million	2.80%
6	Pakistan	18 Million	2.58%
7	Nigeria	17 Million	2.41%
8	Bangladesh	16 Million	2.28%
9	Russia	14.3 Million	2.01%
10	Japan	12.7 Million	1.81%

Demography:

- Earth's overall population density is around 50 people per km^2, without including Antarctica. Nearly two-thirds of the population lives in Asia and is predominantly urban and suburban, with about 1.3 billion in the country of China.
- The World's fairly low literacy rate (83.7%) is attributable to impoverished regions. Extremely low literacy rates are concentrated in three regions, the Arab states, South and West Asia, and Sub-Saharan Africa.
- Christianity, Islam, Hinduism and Buddhism are the four largest religions encompassing a little over 75% of the total world population.
- The world's largest ethnic group is **Han Chinese.**
- Although English (4.83%) is spoken by many as a second language, *Mandarin Chinese (12.44%) and Spanish (4.85%) are the languages with the highest number of speakers*.
- Urban population has increased from 29% in 1950; to 50.5% in 2005. Tokyo is the largest urban conglomeration in the world. Second largest urban conglomeration in the world is Delhi.
- The total fertility rate of the World is estimated as 2.52 children per woman, which is above the replacement fertility rate of approximately 2.1.
- World population growth is unevenly distributed, going from .91 in Macau, to 7.68 in Niger. There are approximately 3.38 billion females in the World. The number of males is about 3.41 billion. World sex ratio is thus: 991
- People under 14 years of age made up over a quarter of the world population (26.3%), and people age 65 and over made up less than one-tenth (7.9%) in 2011.
- Current growth rate of the world population is approximately 1.09%.

Census of India and Demography Basics

Census Basics

The earliest references of Census in India can be traced back to the Mauryan period in Kautilaya's 'Arthashastra' (321-296 BC) and later during the Mughal period in the writings of Abul Fazl (1595-96) in the 'Ain-e-Akbari'.

Census, in its present scientific form was conducted non-synchronously between 1865 and 1872 in different parts of the country. This effort culminating in 1872 has been popularly labelled as the first Census of India. This Census was not a synchronous census.

- The first synchronous Census in India was carried out in 1881. An unbroken chain of censuses since then gives the Indian Census a unique historical legacy unparalleled in the world. Census 2011 is the fifteenth Census in this continuous series from 1872 and the seventh since Independence.

Indian population census organisation is considered as the largest administrative network in the world. For full utility of the data, Indian census attempts to collect information on various socio-economic characteristics of the entire population

Census Act 1948

For the success of an operation of such magnitude and importance as the Population Census, it needs necessary backing of legislation by parliament, so that the Census Organisation is armed with necessary authority to have access to households and canvass the prescribed questionnaires and to expect the people to answer truthfully. The law should also protect the interests of the people by guaranteeing the secrecy of the information collected. Most countries have permanent Census law requiring periodic censuses to be taken in accordance with a scheme to be notified from time to time.

If in any country no such permanent law exists, suitable ad-hoc legislative approval should be obtained before launching on a census operation.

India also has a permanent legislation viz the Census Act of India 1948. This act empowers Central Government to notify the date for the census and to appoint a Census Commissioner and Superintendents of Census Operations in States. The Act enjoins upon every citizen to assist in the taking of census. The Act lays down that services of any citizen can be requisitioned for census work and takes obligatory on every person occupying a house, enclosure etc. to allow access to census officers, and to allow them to paint on or affix to the place such letters, marks or numbers as may be necessary for census purposes.

Obligations of Citizens

Under the Census Act, the following are obligations of the Citizens of India:

- The law makes it obligatory on the part of every citizen to answer the census question truthfully.

- The Act provides penalties for giving false answer or not giving answers at all to the census questionnaire.

Obligations of the Census Officers

- The law calls upon the census officers to discharge their duties faithfully and warns them against putting any question to a person which is not covered by the questionnaire and they are required to record the answers as given by the person enumerated.

Secrecy of Information

- One of the most important provision of the Census Act 1948 is that it makes provisions for the maintenance of secrecy of the information collected at the census of each individual.
- The Act requires strict secrecy to be maintained about the individual's record which should not be used for any purpose against the individual except for an offence in connection with the census itself.
- The census records are not open to inspection and also not admissible in evidence. The answers ascertained at the census can be used only for statistical purposes in which the individual data get submerged.

Universal Coverage

- In organising a Population Census the primary objective to be achieved is to ensure coverage of the entire area in a great territory, without omission or overlapping.
- Therefore, a fundamental task in preparing for a census involves the location of every local area and building up of a suitable organisation to adequately cover it.

Operational Unit of enumeration:

- The Household Census aims at enumerating every individual. But the operational unit is not the Individual but the physical entity of the household which is generally understood as a group of persons commonly living together and partaking of food from the same kitchen.

- A household may occupy an entire house, or more than one household may share a house. In organising a census, one should locate every house and household. In order to achieve this clear delimitation of territory has to be undertaken by which every single household is accounted for.

Territorial Units

- The country is divided into states and sub-divided into districts and further sub-divided into sub-districts, sub-divisions, taluks etc. The smallest unit of administration will ultimately be a village or a town.

What is a Census Village?

- A village may not be mere cluster of houses with a local name. It may be made up of the chief area of habitation and the surrounding area falling within certain demarcated boundaries. Hamlets or scattered farm houses within such areas will have to be assigned to definite villages.

What is a Town / Urban Area?

- Generally all places with local administration of its own such as a City Corporation, Municipality etc., are automatically treated as urban. For others, a minimum limit of population size is recognised for qualifying a place as urban. It is 5,000 in some countries and in some others as little as 1,500 or 2,000. A minimum density of population is also laid down as a criterion to qualify a place as urban. It may be 1,000 per sq. Mile (or say 400 per sq. Km) as in India.

Model Question - 1.

The method of Census followed in India is __:
A. De-facto Canvasser Method
B. De-jure Household Method
C. De-facto Household Method
D. De-jure Canvasser method
Answer: **1**

'Canvasser' method and 'householder' method of enumeration

'Canvasser' and the 'Householder' methods are the two recognised methods of census enumeration. Under the 'Canvasser' method the enumerator approaches every household and records the answer on the schedules himself after ascertaining the particulars from the head of the household or other knowledgeable persons in the household. This is followed in India.

Under the 'householder' method the enumerator distributes the census schedules to each household in his jurisdiction and the head of the household is expected to fill the answer for all members of his household and the enumerator later collects back the answered schedules soon after the census day is over. Since literacy is still low, the 'canvasser' method is the only practical method in India.

The **Census of India is conducted once in a decade, following an extended de facto canvasser method**. Under this approach, data is collected from every individual by visiting the household and canvassing the questionnaire all over the country, over a period of three weeks. The count is then updated to the reference date and time by conducting a Revisional Round. In the Revisional Round, changes in the entries that arise on account of births, deaths and migration between the time of the enumerator's visit and the reference date/time are noted down and the record is updated.

De facto and De Jure Enumeration

An important question pertaining to enumeration that always arises at a Population Census is whether the population should be counted on a de-facto basis i.e. at the place where a person is actually found on the reference date of the census or on a de-jure basis i.e., count a person only according to the place of normal residence.

Of these, the enumeration on de-jure basis is more difficult to achieve without the risks of omission or double count. Enumeration of de-facto population though may appear simple will be difficult unless the movement of population is restricted on the census day and the entire enumeration is got through on a single night which is operationally difficult specifically when large population has to be covered by canvasser method.

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1 De-facto Canvasser Method

In practice, therefore, enumeration on a 100 per cent de-facto or de-jure basis is impossible and often times a variation or even a combination of the two is resorted to. The census instructions should clearly lay down who are the persons who should be enumerated during the census enumeration period.

Census as a Union List Subject

In India, the population census is a Union subject (Article 246) and is listed at serial number 69 of the seventh schedule of the constitution.

The Census Act 1948 forms the legal basis for conduct of census in independent India. Although the Census Act is an instrument of Central legislation, in the scheme of its execution, state hierarchy is setup at all levels by State Governments for the purpose of carrying out census.

The Census Organisation under the Union Home Ministry has been functioning on permanent footing ever since 1961 and provides a vital continuity to conceive, plan and implement the programme of census taking in country. The Organisation headed by the Registrar General and Census Commissioner, India has field offices in thirty three States and Union territories.

These are permanent Directorates headed by the Directors of Census Operations, who are mainly responsible for the conduct of census in their respective jurisdiction. The states appoint State Co-ordinators for furthering co-ordination between the Directorate, Government of India and the State Government. Deputy Commissioners under the guidance of Divisional Commissioners function as Divisional Census Officers at the Division level in states. District Collectors as Principal Census Officers are responsible for the census work in their respective districts.

Objective of conducting a Census

India is a welfare State. Since independence, Five Year Plans, Annual Plans and various welfare schemes have been launched for the benefit of the common man. All these require information at the grass root level. This information is provided by the Census. Census is the basis of how the number of seats in Parliamentary/Assembly Constituencies, Panchayats and other local bodies are determined. Similarly, Census helps on how the boundaries of such constituencies are demarcated. Census provides information on a large number of areas. House listing and Housing Census has immense utility as it provides comprehensive data on the conditions of human settlements, housing deficit and consequently a wide range of data on amenities and assets available to the households, information much needed by various departments of the Union and State Governments and other non Governmental agencies for development and planning at the local level as well as the State level. This would also provide the base for Population Enumeration.

Two Phases of Census 2011

The Census of India 2011 was conducted in two phases as follows:

- House listing and Housing Census
- Population Enumeration.

The first phase of the Census was conducted in the period April to September, 2010 in different States/Union Territories depending upon local conditions. The field work of the second phase (Population Enumeration) was carried out during February-March, 2011.

Services of Teachers in census

Section 27 of The Right of Children to Free and Compulsory Primary Education Act, 2009 reads as follows : "*No teacher shall be deployed for any non-educational purpose other than the decennial population Census, disaster relief duties or duties relating to elections to the local authority or the State Legislatures or Parliament, as the case may be." This Act overrides all the existing judgments, whatsoever, on the subject matter ofappointment of teachers for performing Census related duties*. In view of the above it is clear that the services of teachers can be used for works of national importance like Census. (Kindly note this). **It's a legal obligation for a teacher** to work for Census.

Can records of census be used as evidence?

No person shall have a right to inspect any book, register or record made by a Census officer in the discharge of his duty as such, or any schedule delivered under section 10, and notwithstanding anything to the contrary in the Indian Evidence Act, 1872, no entry in any such book, register, record or schedule shall be admissible as evidence in any civil proceeding whatsoever or in any criminal proceeding other than a prosecution under this Act or any other law for any act or omission which constitutes an offence under this Act.

Meaning of Square and Triangle boxes in Enumeration lists of Census

A square means a pucca house. A triangle means a kuccha house as follows.

Examples of different situations along with the boxes are given below :

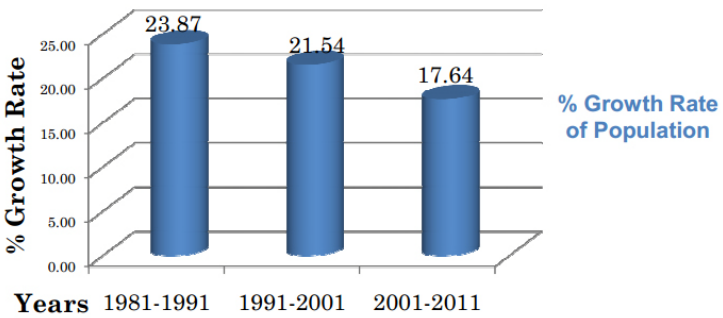
- □ – Pucca building, whether wholly or partly residential
- ▨ – Pucca building, wholly non-residential
- △ – Kutcha building, whether wholly or partly residential
- ◬ – Kutcha building, wholly non-residential.

Basic Population Profile of India

All Figures are approximate:

- Total Population: 1.21 Billion = 1210 Million = 121 Crore
- Males: 623.7 million = 62.37 Crore
- Females: 586.5 Million = 58.65 Crore
- National Sex Ratio: 940
- Urban Population: 377.1 Million
- Rural Population: 833 Million
- Rural Population as percentage of Total: 68.84%
- Urban Population as percentage of Total: 31.16%
- Urban males: 195.8 Million
- Urban Females: 181.3 Million
- Urban Sex Ratio: 926
- Rural Males: 427.9 Million
- Rural Females: 405.1 Million
- Rural Sex Ratio: 947
- Population Density of India: 382

Growth Rate of Population



The population of India has increased by more than 181 million during the decade 2001-2011 The absolute addition is slightly lower than the population of Brazil, the fifth most populous 10 country in the world The population of India, at 1210.2 million, is almost equal to the combined population of U.S.A., Indonesia, Brazil, Pakistan, Bangladesh and Japan put together (1214.3 million) 2001-2011 is the first decade (with the exception of 1911- 1921) which has actually added lesser population compared to the previous decade. The percentage decadal growth 14 during 2001-2011 has registered the sharpest decline since Independence - a decrease of 3.90 percentage points from 21.54 to 17.64 percent Uttar Pradesh (200 million) is the most populous State in the country - population is more than the population of Brazil. Uttar Pradesh and Maharashtra (312 million), is greater than the population of USA.

To 10 states with highest and lowest population

Rank	State	Population(2011 Census)
1	Uttar Pradesh	19,95,81,477
2	Maharashtra	11,23,72,972
3	Bihar	10,38,04,637
4	West Bengal	9,13,47,736
5	Andhra Pradesh	8,46,65,533
6	Madhya Pradesh	7,25,97,565
7	Tamil Nadu	7,21,38,958
8	Rajasthan	6,86,21,012
9	Karnataka	6,11,30,704
10	Gujarat	6,03,83,628

Rank	State	Population(2011 Census)
18	Jammu and Kashmir	1,25,48,926
19	Uttarakhand	1,01,16,752
20	Himachal Pradesh	68,56,509
21	Tripura	36,71,032
22	Meghalaya	29,64,007
23	Manipur	27,21,756
24	Nagaland	19,80,602
25	Goa	14,57,723
26	Arunachal Pradesh	13,82,611
27	Mizoram	10,91,014
28	Sikkim	6.07.688

States of India with equivalent countries of the World in Terms of Population

State in India	Population-2011	Country	Population (2010)
Uttar Pradesh	199.6	Brazil	195.4
Maharashtra	112.4	Japan	127
Bihar	103.8	Mexico	110.5
West Bengal	91.3	Philippines	93.6
Andhra Pradesh	84.7	Germany	82.1
Madhya Pradesh	72.6	Turkey	72.7
Tamil Nadu	72.1	Thailand	68.1
Rajasthan	68.6	France	62.8
Karnataka	61.1	United Kingdom	61.9
Gujarat	60.4	Italy	60.1
Orissa	41.9	Argentina	40.7
Kerala	33.4	Canada	33.9
Jharkhand	33	Morocco	32.4
Assam	31.2	Iraq	31.5
Punjab	27.7	Malaysia	27.9
Chhattisgarh	25.5	Saudi Arabia	26.2
Haryana	25.4	Australia	21.5
State of World Population 2010			

Top District in terms of Population

1. Thane : 1 Crore 10 Lakh
2. North Twenty Fourth Pargana (WB) : 1 crore 82 Thousand

Bottom Districts in terms of Population

1. Dibang Valley : 7948
2. Anjaw: 21089

Both in Arunachal Pradesh

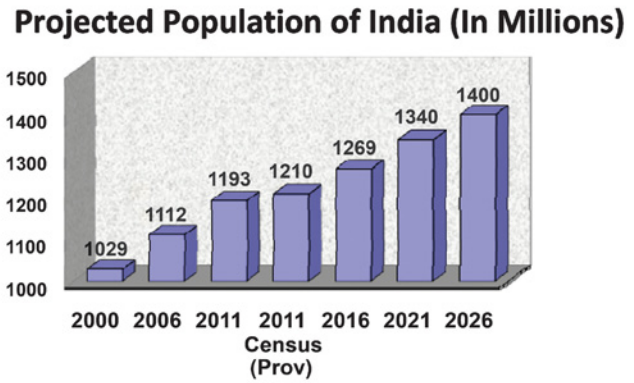
Growth rate observation

All top populated states show decline in decadal growth rate in 2001-2011 in comparison to 1991-2001.

State	Growth Rate 1991-2001	Growth Rate 2001-2011
Uttar Pradesh	25.85%	20.09%
Maharashtra	22.73%	15.99%
Bihar	28.62%	25.07%
West Bengal	17.77%	13.93%
Andhra Pradesh	14.59%	11.10%
Madhya Pradesh	24.26%	20.30%

- Highest Decadal Growth rate among states is that of : Meghalaya: 27.80%
- Lowest Decadal Growth Rate among states is that of Nagaland : Negative 0.47%
- Highest Decadal Growth Rate among Uts : Dadra & Nagar Haveli : 55%
- Lowest decadal Growth rate among Uts : Lakshadweep: 6%
- During 2001-2011, as many as 25 States/UTs with a share of about 85% of the country's population registered an annual growth rate of less than 2% as compared to, 15 States/UTs with a share of about 42% during the period 1991-2001 15 States/UTs have grown by less than 1.5 percent per annum during 2001-2011, while the number of such States/UTs was only 4 during the previous decade.

- District with highest decadal growth rate was Kurung Kumey in Arunachal Pradesh that registered 111% growth rate.
- District with lowest decadal growth rate was Longleng in Nagaland which registered -58.39% Growth rate.



Age Group 0-6 Years

- The total number of children in the age-group 0-6 is 158.8 million (-5 million since 2001). Uttar Pradesh (29.7 million), Bihar (18.6 million), Maharashtra (12.8 million), Madhya Pradesh (10.5 million) and Rajasthan (10.5 million) constitute 52% Children in the age group of 0-6 years.
- The proportion of Child Population in the age group of 0-6 years to total Population is 13.1 percent while the corresponding figure in 2001 was 15.9 percent. The decline has been to the extent of 2.8 points.
- The proportion of Child Population in the age group of 0-6 years to total Population is indicative of fall/rise in fertility.

	2001		2011 (Provisional)	
	Population (in mn)	Proportion (in %)	Population (in mn)	Proportion (in %)
Males	532.2	51.74	623.7	51.54
Females	496.5	48.26	586.4	48.46
Sex Ratio	933		940	

Gender Composition

- Overall Sex ratio at the National level has increased by 7 points since Census 2001 to reach 940 at Census 2011 . This is the highest Sex Ratio recorded since Census1971 and a shade lower than 1961.
- Increase in Sex Ratio is observed in 29 States/UTs
- Three major States (J&K, Bihar & Gujarat) have shown decline in Sex Ratio as compared to Census2001.
- **Top Sex Ratio:** Kerala,
- **Lowest Sex Ratio :** Daman & Diu
- **District with highest sex ratio:** Mahe
- **District with lowest sex ratio:** Daman
- *Child sex ratio in India (0-6 years) is lowest since independence that is 914.*

Top 2 States/UTs		Bottom 2 States/UTs	
States/UTs	Sex Ratio	States/UTs	Sex Ratio
Kerala	1,084	Daman & Diu	618
Puducherry	1,038	Dadra & Nagar Haveli	775

Top 2 Districts		Bottom 2 Districts	
District	Sex Ratio	District	Sex Ratio
Mahe (Puducherry)	1,176	Daman (Daman & Diu)	533
Almora (Uttarakhand)	1,142	Leh (Ladakh) (Jammu & Kashmir)	583

Literacy in census

- 2011 India's literacy rates stands at 74.04 % for age 7 and above. The literacy has increased by 9.2% from 2001 Census.
- Male literacy stands at 82.14 and female literacy stands at 65.46.
- Ten States and Union Territories viz., Kerala, Lakshadweep, Mizoram, Tripura, Goa, Daman & Diu, Puducherry, Chandigarh, NCT of Delhi and Andaman & Nicobar Islands have achieved literacy rate of above 85 per cent, the target set by the Planning Commission to be achieved by 2011-2012.

	2001	2011	Difference
Persons	64.83	74.04	9.2
Males	75.26	82.14	6.9
Females	53.67	65.46	11.8

Top 2 Districts		Bottom 2 Districts	
District	Literacy Rate	District	Literacy Rate
Serchhip (Mizoram)	98.76	Alirajpur (Madhya Pradesh)	37.22
Aizawl (Mizoram)	98.50	Bijapur (Chhattisgarh)	41.58

- The gap of 21.59 percentage points recorded between male and female literacy rates in 2001 Census has reduced to 16.68 percentage points in 2011. Planning Commission has set up target of reducing this gap to 10 percentage points by the year 2011-2012

Top 2 States/UTs			Bottom 2 States/UTs	
States/UTs	Literacy Rate		States/UTs	Literacy Rate
Kerala	93.91		Bihar	63.82
Lakshadweep	92.28		Arunachal Pradesh	66.95

Population Density

As per the provisional data of Census 2011, population density of India stands at 382, which is 17.5% more than 325 in Census 2001. NCT of Delhi with 11297 is has highest density in India, followed by Chandigarh where population density stands at 9252.

Top 2 Districts			Bottom 5 Districts	
District	Density		District	Density
North East (NCT of Delhi)	37,346		Dibang Valley (Arunachal Pradesh)	1
Chennai (Tamil Nadu)	26,903		Samba (Jammu & Kashmir)	2

- Population density of Arunachal Pradesh is 17, lowest among all states and Uts in India.
- Lowest Population density among Uts is of Andaman & Nicobar Islands (46).

India's Population Policy

India was the first country to realise the importance of population as early as in 1951-52 , but a rigid policy was not adopted to check the population growth.

Government has adopted a National Population Policy in February, 2000. The main objective is to provide or undertake activities aimed to achieve population stabilisation, at a level consistent with the needs of sustainable economic growth, social development and environment protection, by 2045. The other objectives are:

- To promote and support schemes, programmes, projects and initiatives for meeting the unmet needs for contraception and reproductive and child health care.
- To promote and support innovative ideas in the Government, private and voluntary sector with a view to achieve the objectives of the National Population Policy 2000.
- To facilitate the development of a vigorous people's movement in favour of the national effort for population stabilisation.

Concept of Total Fertility Rate

Total Fertility Rate may be defined as *average number of children that would be born to a woman if she experiences the current fertility pattern throughout her reproductive span (15-49 years).* The total fertility rate is a **more direct measure of the level of fertility than the birth rate, since it refers to births per woman**. This indicator shows the potential for population change in a country. A TFR of *2.1 i.e., two children per women is considered the replacement rate for a population, resulting in relative stability in terms of total population numbers*. Rates above two children per woman indicate population *growing in size and whose median age is declining*. Rates below two children per woman indicate population decreasing *in size and growing older*. Office of Registrar General, India estates TFR annually through Sample Registration System, a large scales demographic Survey Conducted by them.

National Commission on Population (NCP)

With a view to monitor and direct the implementation of the National Population Policy, the NCP was constituted in 2000 and it was re-constituted in 2005. The Chairman of the re-constituted Commission continued to be Prime Minister of India, whereas Deputy Chairman of the Planning Commission and the Minister of Health & FW are the two Vice-Chairmen and Secretary, H&FW, is the Member-Secretary of the Commission. 20 states also have their own population commission.

Janasankhya Sthirata Kosh (JSK)

The Jansankhya Sthirata Kosh (JSK) has been set up as an autonomous body in the Ministry of Health and Family Welfare, duly registered as a Society under the Societies Registration Act, 1860. The objective of JSK is to facilitate the attainment of the goals of National Population Policy 2000 and support projects, schemes, initiatives and

innovative ideas designed to help population stabilization both in the Government and Voluntary sectors and provide a window for canalizing resources through voluntary contributions from individuals, industry, trade organizations and other legal entities in furtherance of the national cause of population stabilization.

Migration, Demographic Transition and Transhumance

Migration, fertility and mortality are the basic fundamental elements determining population growth and demographic structure of a country. Migration may be international, intra-national, interregional, intra-urban, rural-to-urban, , and urban-to-rural.

Migration is permanent or semi-permanent change of residence of an individual or group of people over a significant distance. On the basis of distance, it may be long or short distance. On the basis of number, migration may be individual or mass; it may be politically sponsored or voluntary. On the basis of social organisation, migration may be that of family, community, clan, or individual. On the basis of causes, migration may be economic, social, cultural, religious or political. Migration may be stepwise or direct from the place of origin to the destination.

There can be various causes of migration such as over population, economic causes, Technology, Political causes, socio-religious causes, demographic causes and wars.

People migrate for a better economic and social life. There are two sets of factors that influence migration.

- The **Push factors** make the place of origin seem less attractive for reasons like unemployment, poor living conditions, political turmoil, unpleasant climate, natural disasters, epidemics and socio-economic backwardness.
- The **Pull factors** make the place of destination seem more attractive than the place of origin for reasons like better job opportunities and living conditions, peace and stability, security of life and property and pleasant climate

Migration has a direct and indirect consequence on society, demography, economy, and environment. Some of the main consequences of migration are:

Reallocation of resources

Generally, people from the crowded and overpopulated areas emigrate to the areas of sparse population with better re-source base, which helps in maintaining a balance between population and physical resources.

Change in demographic characteristics

Migration brings tangible change in demographic characteristics of place of origin and place of destination. The absolute number of population, the density of population, age composition, and literacy rates are either favourably or adversely affected.

Change in sex ratio

The sex ratio at the place of destination drops as the male members have been added while the sex ratio at the place of origin increases.

Economic gains

There is more intensive and judicious utilisation of physical resources at the place of destination, leading to higher agricultural and industrial production. The migrants send money back to home to their families which brings prosperity to the place of origin of migration also.

Transformation of ethnic characteristics

The physical and marital contacts of people belonging to different ethnic groups may change the biological characteristic of the migrants and that of the host population.

Transformation of cultural values

When large scale migration takes place, the cultural values of the people undergo radical transformation. The dietary habits of the people are also significantly transformed.

As mentioned above, there are three components of population change viz. births, deaths and migration.

Crude Birth Rate

The Crude Birth Rate (CBR) is expressed as number of live births in a year per thousand of population. It is calculated as:

$$CBR = \frac{Bi}{P} X\ 1000$$

Where: Bi= Live Births during the year

P= Mid-year population of the area.

Death rate plays an active role in population change. Population growth occurs not only by increasing births rate but also due to decreasing death rate.

Crude Death Rate

Crude Death Rate (CDR) is a simple method of measuring mortality of any area. CDR is expressed in terms of number of deaths in a particular year per thousand of population in a particular region

$$CDR = \frac{D}{P} X\ 1000$$

Where: D= Number of deaths

P=Estimated mid year population

By and large mortality rates are affected by the region's demographic structure, social advancement and levels of its economic development.

Model Question - 2. (IAS 2012)

Consider the following specific stages of demographic transition associated with economic development:

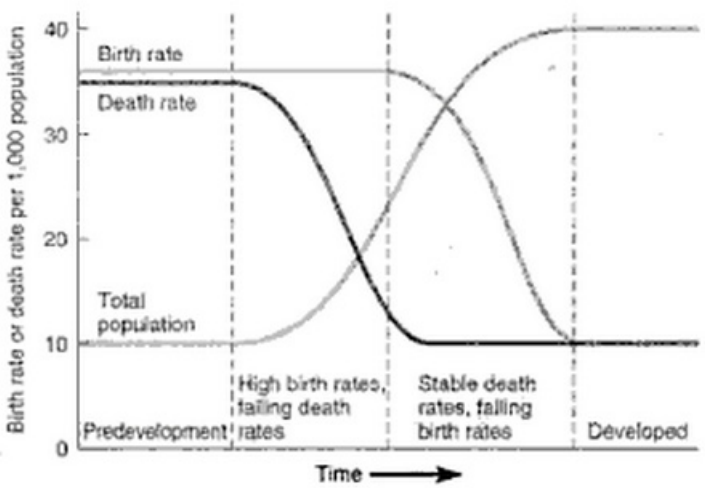
1. Low birth rate with low death rate
2. High birth-rate with high death rate
3. High birth-rate with low death rate

Select the correct order of the above stages using the codes given below :

[A]1 2 3
[B]2 1 3
[C]2 3 1
[D]3 2 1

Answer: 2

The theory of Demographic transition is used to describe and predict the future population of any area. The theory tells us that population of any region changes from high births and high deaths to low births and low deaths as society progresses from rural agrarian and illiterate to urban industrial and literate society. These changes occur **in stages** which are collectively known as the demographic cycle.



First Stage:

The first stage has high fertility and high mortality because people reproduce more to compensate for the deaths due to epidemics and variable food supply. The population growth is slow and most of the people are engaged in agriculture where large families are an asset. Life expectancy

2 2, 3 1 is the correct order.

is low, people are mostly illiterate and have low levels of technology. Two hundred years ago all the countries of the world were in this stage.

Second stage:

Fertility remains high in the beginning of second stage but it declines with time. This is accompanied by **reduced mortality rate**. Improvements in sanitation and health conditions lead to decline in mortality. Because of this gap the net addition to population is high.

Third stage

In the last stage, both fertility and mortality decline considerably. The population is either stable or grows slowly. The population becomes urbanised, literate and has high technical knowhow and deliberately controls the family size. This shows that human beings are extremely flexible and are able to adjust their fertility. In the present day, different countries are at different stages of demographic transition.

Age Structure, Demographic Dividend, Dependency Ratio and Longevity Dividend

Age structure represents the number of people of different age groups. This is an important indicator of population composition, since a large size of population in the **age group of 15-59** indicates a large working population. A greater proportion of population above 60 years represents an ageing population which requires more expenditure on health care facilities. Similarly high proportion of young population would mean that the region has a high birth rate and the population is youthful.

Demographic Dividend

Model Question - 3. (IAS 2011)

India is regarded as a country with "Demographic Dividend". This is due to?
(a) Its high population in the age group below 15 years.
(b) Its high population in the age group of 15-64 years.
(c) Its high population in the age group above 65 years.
(d) Its high total population.
Answer: 3

India is a nation of young people - out of a population of above 1.1 billion, 672 million people are in the age-group 15 to 59 years, - which is usually treated as the "working age population".

A few years back, it was proposed that India in near future (30 years) will see a sharp **decline in the dependency ratio** over, which will constitute a major 'demographic dividend' for India. In 2001, 11% of population of the country was in age group of 18-24 years which is expected to rise to 12% by the end of XI Five Year Plan.

However, recent data says that India's old age dependency ratio is increasing consistently:

Model Question - 4.

Consider the following statements:
1. The Government data shows that India's old age dependency ratio is increasing consistently
2. Increased old age dependency ratio has no impact on productive part of the population

Which among the above statements is / are correct?
[A]Only 1 is correct
[B]Only 2 is correct
[C]Both 1 & 2 are correct
[D]Neither 1 nor 2 is correct

The increasing **dependency ratio** brings more economic pressure on working population. As the ratio increases there may be an increased burden on the productive part of the population to maintain the means of livelihood of the economically dependent. This results in direct impacts on financial expenditures on things like social security, as well as many indirect consequences.

Longevity Dividend

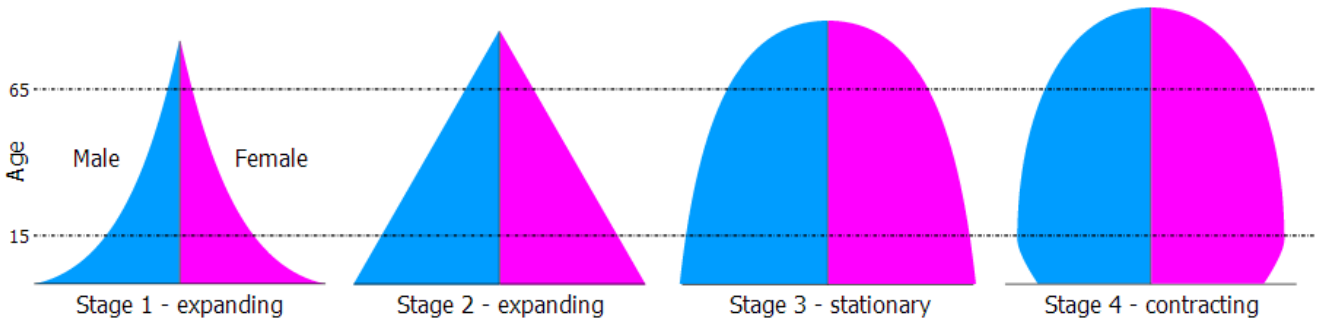
When people live longer, it offers society a chance to reap a 'longevity' dividend. This implies that the *elderly continue to contribute significantly for an unprecedented period of time. However, in order to reap that benefit, it is necessary that the* challenges of an ageing population and understood and effective policy are made in time.

3 Correct Answer is B.

Age Sex Pyramid:

The age-sex structure of a population refers to the number of females and males in different age groups. A population pyramid is used to show the age-sex structure of the population.

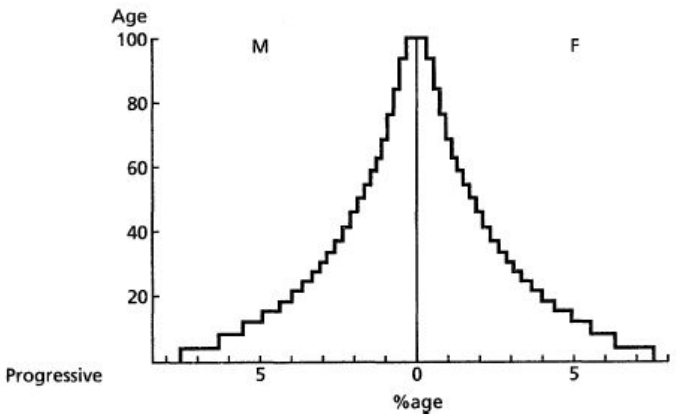
The shape of the population pyramid reflects the characteristics of the population and also indicates whether the population is experiencing growth or decline or stability.



In an age sex pyramid, the left side shows the percentage of males while the right side shows the percentage of women in each age group.

Triangle Shaped Pyramid:

A Triangle shaped pyramid with a wide base reflects that the number of people with lower age groups is larger and thus there would be **high birth rates**.



This kind of age sex pyramid is typical for Nigeria, Bangladesh or Mexico or such less developed countries. These have larger populations in lower age groups due to high birth rates. If you construct the pyramids for Bangladesh and Mexico, it would look the same.

Bell shaped Pyramid tapered at top

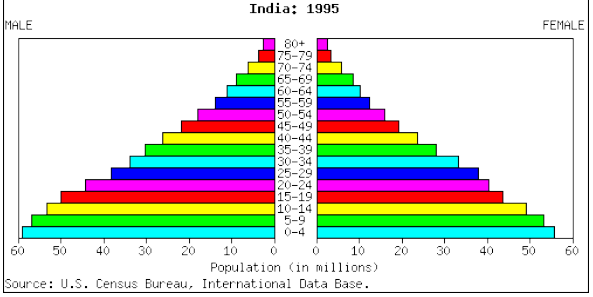
Australia's age-sex pyramid is bell shaped and tapered towards the top. This shows birth and death rates are almost equal leading to a near constant population.

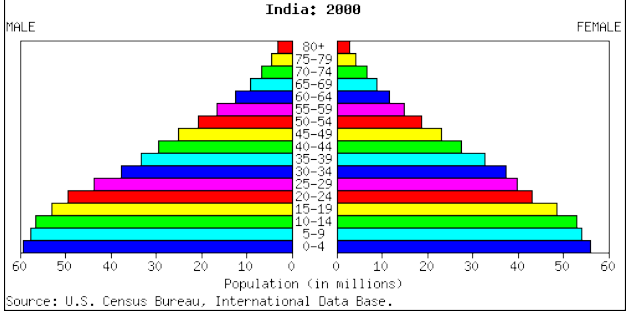
Bell shaped Pyramid tapered at top and bottom

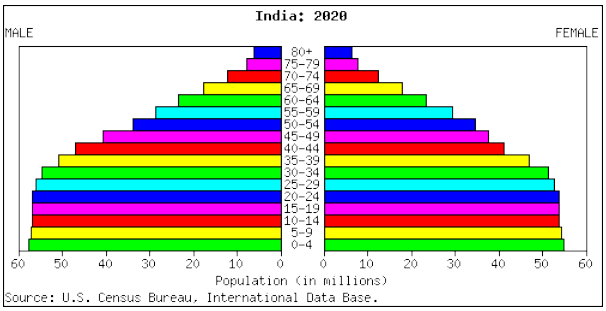
The Japan pyramid has a narrow base and a tapered top showing low birth and death rates. The population growth in developed countries is usually zero or negative.

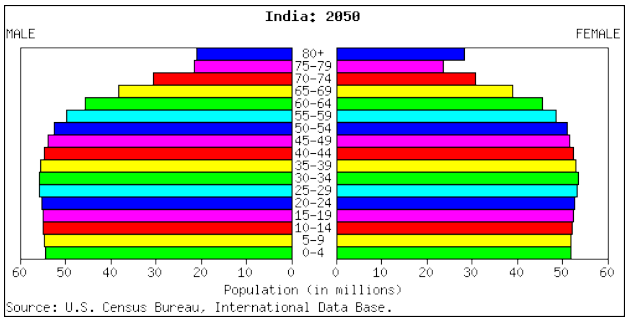
India's Age Sex Pyramid

India's population is to grow by just over 57% between 2000 and 2050. This overall growth will, in part, be due to increased life expectancy and, therefore, a larger elderly population - around 10 million aged 80 years and over in 2005 to grow to around 50 million in 2050. However, the population is expected to begin to decline beyond 2050, with the 0-4 year old group falling from over 110 million in 2005 to just over 105 million. This means that India's Age Sex Pyramid was on stage 1 in past and expected to be at stage 4 in 2050.









Human Development Report and HDI

(Note: The next Human Development Report – "The Rise of the South: Human Progress in a Diverse World" – will be published in March 2013. This section takes reference from 2011 report)

The Human Development Report (HDR) is an annual publication of the United Nations Development Programme (UNDP). The report was first launched in 1990 by the Pakistani Economist **Mahbub ul Haq** and Indian Nobel laureate Amartya Sen. Its goal was to place people at the centre of the development process in terms of economic debate, policy and advocacy. Development was characterised by the provision of choices and freedoms resulting in widespread outcomes.

People are the real wealth of a nation

- "*People are the real wealth of a nation*," was the opening line of the first report in 1990.

Independent Report

- The United Nations General Assembly has formally recognized the Report as "an independent intellectual exercise" and "an important tool for raising awareness about human development around the world." Human Development Report does NOT represent UN policy or UNDP Policy.
- Human Development Report is an independent report, commissioned by the United Nations Development Programme (UNDP), and is the product of a selected team of leading scholars, development practitioners and members of the Human Development Report Office of UNDP.
- The Report depends on statistics from a wide array of UN and other multilateral agencies, but its analysis and conclusions are the product and responsibility of the Report's authors alone.
- Its editorial autonomy is protected by a special resolution of the General Assembly (A/RES/57/264), which recognizes the Human Development Report as "an independent intellectual exercise" and "an important tool for raising awareness about human development around the world."

Objective:

Report's ultimate goal is to help advance human development. This means placing as much emphasis on health, education, and the expansion human freedoms and abilities as economic growth.

2011 Human Development Report

- The 2011 Report – "Equity and Sustainability: A Better Future for All" – addresses the integral links between long-term environmental protection and greater social equality.
- The main message of the Report is that continuing human development progress must be both sustainable and equitable – or it will be neither.

Countries Covered

- The 2011 HDI covers a record 187 countries and territories, 18 more than the 169 included in the 2010 HDI.

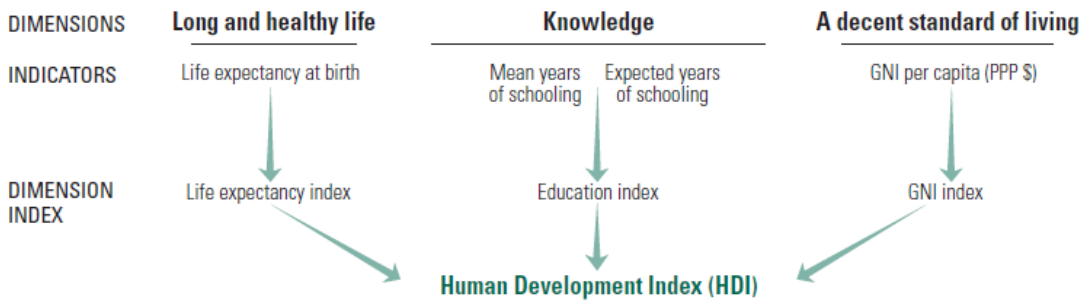
- This major expansion of HDI coverage is the result of intensified efforts by the Human Development Report office to work with international data providers and national statistical agencies to obtain required development indicators for the HDI which had been unavailable for some countries in previous years.

Human Development Index

The Human Development Index (HDI) is a summary measure of human development. It measures the average achievements in a country in **three basic dimensions of human development**:

- A long and healthy life
- Access to knowledge
- A decent standard of living.

The HDI is the geometric mean of normalized indices measuring achievements in each dimension. They are shown in the following graphics:



How HDI is calculated?

There are two steps to calculating the HDI.

- Step 1. Creating the dimension indices
- Step 2. Aggregating the subindices to produce the Human Development Index

In the first step, the Minimum and maximum values (goalposts) are set in order to transform the indicators into indices between 0 and 1.

- The maximums are the highest observed values in the time series (1980–2011). The minimum values can be appropriately conceived of as subsistence values.
- The minimum values are set at 20 years for life expectancy, at 0 years for both education variables and at $100 for per capita gross national income (GNI).
- The low value for income can be justified by the considerable amount of unmeasured subsistence and nonmarket production in economies close to the minimum, not captured in the official data. The following table shows the Goalposts for the Human Development Index in the 2011 report.

Dimension	Observed maximum	Minimum
Life expectancy	83.4 (Japan, 2011)	20.0
Mean years of schooling	13.1 (Czech Republic, 2005)	0
Expected years of schooling	18.0 (capped at)	0
Combined education index	0.978 (New Zealand, 2010)	0
Per capita income (PPP $)	107,721 (Qatar, 2011)	100

Having defined the minimum and maximum values, the subindices are calculated as follows:

$$\text{Dimension Index} = \frac{\text{actual value} - \text{minimum value}}{\text{maximum value} - \text{minimum value}}$$

After that, the HDI is calculated as geometric mean of the three dimension indices.

Example: The following calculation shows an example of Vietnam:

Indicator	Value
Life expectancy at birth (years)	75.2
Mean years of schooling (years)	5.5
Expected years of schooling (years)	10.4
GNI per capita (PPP $)	2,805

Note: Values are rounded.

$$\text{Life expectancy index} = \frac{75.2 - 20}{83.4 - 20} = 0.870$$

$$\text{Mean years of schooling index} = \frac{5.5 - 0}{13.1 - 0} = 0.478$$

$$\text{Expected years of schooling index} = \frac{10.4 - 0}{18 - 0} = 0.576$$

$$\text{Education index} = \frac{\sqrt{0.478 \cdot 0.576} - 0}{0.978 - 0} = 0.503$$

$$\text{Income index} = \frac{\ln(2{,}805) - \ln(100)}{\ln(107{,}721) - \ln(100)} = 0.478$$

$$\text{Human Development Index} = \sqrt[3]{0.870 \cdot 0.503 \cdot 0.478} = 0.593$$

Inequality-adjusted HDI (IHDI)

- The Inequality-adjusted Human Development Index (IHDI) adjusts the Human Development Index (HDI) for inequality in distribution of each dimension across the population.
- The IHDI accounts for inequalities in HDI dimensions by "discounting" each dimension's average value according to its level of inequality.
- The IHDI equals the HDI when there is no inequality across people but is less than the HDI as inequality rises. In this sense, the IHDI is the actual level of human development (accounting for this inequality), while the HDI can be viewed as an index of "potential" human development (or the maximum level of HDI) that could be achieved if there was no inequality.
- The "loss" in potential human development due to inequality is given by the difference between the HDI and the IHDI and can be expressed as a percentage.

Gender Inequality Index (GII)

- The Gender Inequality Index (GII) reflects women's disadvantage in three dimensions—reproductive health, empowerment and the labour market—for as many countries as data of reasonable quality allow. The index shows the loss in human development due to inequality between female and male achievements in these dimensions.
- It ranges from 0, which indicates that women and men fare equally, to 1, which indicates that women fare as poorly as possible in all measured dimensions.

Multidimensional Poverty Index (MPI)

The Multidimensional Poverty Index (MPI) identifies **multiple deprivations** at the individual level in health, education and standard of living. It uses **micro data from household surveys**, as basis of deprivation of Cooking fuel, Toilet, Water, Electricity, Floor, Assets. Each person in a given household is classified as poor or nonpoor depending on the number of deprivations his or her household experiences. These data are then aggregated into the national measure of poverty.

Model Question - 5. (IAS 2012)

The Multi-dimensional Poverty Index developed by Oxford Poverty and Human Development Initiative with UNDP support covers which of the following?

1. Deprivation of education, health, assets and services at household level
2. Purchasing power parity at national level

3. Extent of budget deficit and GDP growth rate at national level

Select the correct answer using the codes given below:

[A]1 Only

[B]2 & 3 Only

[C]1 & 3 Only

[D]1, 2 & 3

Answer: 4

Top 10 Countries in Human Development Index 2011-11-26

Rank	Country	HDI
1	Norway	0.943
2	Australia	0.929
3	Netherlands	0.910
4	United States	0.910
5	New Zealand	0.908
6	Canada	0.908
7	Ireland	0.908
8	Liechtenstein	0.905
9	Germany	0.905
10	Sweden	0.904

Bottom 10 Countries with Lowest HDI

Rank	Country	HDI
178	Guinea	0.344
179	Central African Republic	0.343
180	Sierra Leone	0.336
181	Burkina Faso	0.331
182	Liberia	0.329
183	Chad	0.328
184	Mozambique	0.322
185	Burundi	0.316
186	Niger	0.295
187	Democratic Republic of Congo	0.286

India's Rank

India has been placed at **134th Place in the HDI 2011**. When **inequality is factored in, it experiences a 30% drop in human development values, ranking 129th** out of 146 countries. India's Gender Inequality Index (GII) worsened slightly between 2008 and 2011, and India now ranks 129 out of 146 countries on the GII, better only than Afghanistan in south Asia.

The Goalposts for calculation of HDI for India were as follows:

HDI rank	Human Development Index (HDI) Value	Life expectancy at birth (years)	Mean years of schooling (years)	Expected years of schooling (years)
	2011	2011	2011[a]	2011[a]
134 India	0.547	65.4	4.4	10.3

In the 2010 Human Development Report, prepared by UNDP, India had been ranked at 119 out of 169 countries. But the new report for 2011 says it is misleading to compare values and rankings with those of previously published reports, because the underlying data and methods have changed, as well as the number of countries included in the Human Development Index. India's Human Development Index (HDI) value for 2011 was 0.547 positioning the country in the 'medium human development category'. Neighbouring Pakistan was ranked at 145 (0.504) and Bangladesh at 146 (0.500) respectively in terms of HDI.

Concepts in Economic Geography - Primary Activities

Human activities which generate income are known as economic activities. Economic activities are broadly grouped into primary, secondary, tertiary and quaternary activities.

Primary activities are directly dependent on environment as these refer to utilisation of earth's resources such as land, water, vegetation, building materials and minerals. It, thus includes, hunting and gathering, pastoral

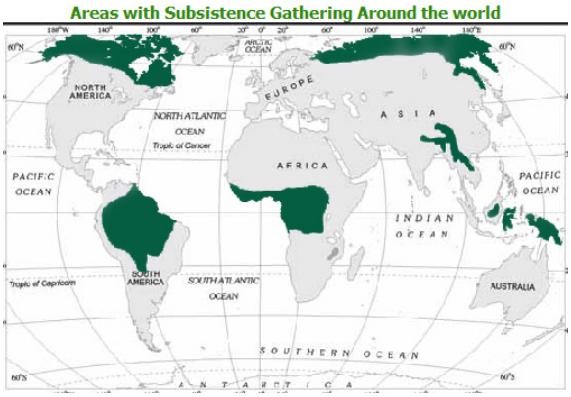
activities, fishing, forestry, agriculture, and mining and quarrying. We have already studied the primary sector of India economy, this section focuses on some core concepts.

Red Collar workers

People engaged in primary activities are called red collar workers due to the outdoor nature of their work.

Gathering

Gathering and hunting are the oldest economic activity known. Gathering is practised in regions with harsh climatic conditions. It often involves primitive societies, who extract both plants and animals to satisfy their needs for food, shelter and clothing.



The main features of Gathering and Hunting activities are:

- Low Capital / Skill Investment
- Low Yield Per Person
- No Surplus in production

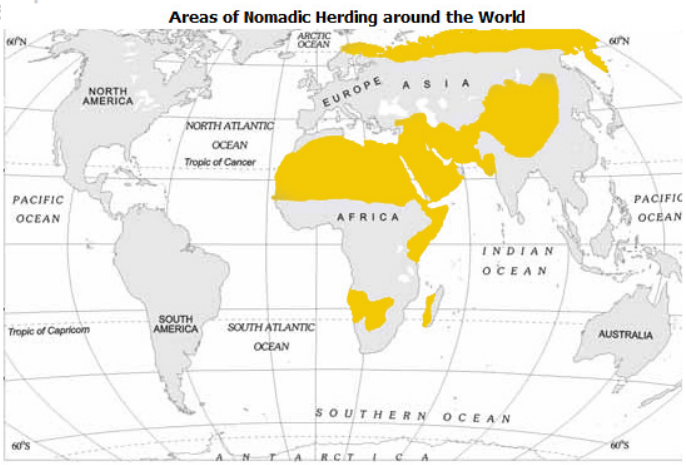
Gathering is practised in the following areas of the world:

- Northern Canada, northern Eurasia and southern Chile (High Altitude Areas)
- Low latitude zones such as the Amazon Basin, tropical Africa, Northern fringe of Australia and the interior parts of Southeast Asia.

Nomadic herding or pastoral nomadism

Nomadic herding or pastoral nomadism is a primitive subsistence activity, in which the herders rely on animals for food, clothing, shelter, tools and transport. They move from one place to another along with their livestock, depending on the amount and quality of pastures and water, **thus there is an irregular pattern of movement**. It is different from **Transhumance** *in which there is a fixed seasonal pattern of movement*.

Nomadic pastoralism is commonly practised in regions with little arable land, typically in the developing world. Of the estimated 30–40 million nomadic pastoralists worldwide, most are found in **central Asia and Northern and western region of Africa**, some parts of southern Africa and Tundra regions.



Transhumance

Transhumance is the **seasonal movement** of people with their livestock between fixed summer and winter pastures. In montane regions (vertical transhumance) it implies movement between higher pastures in summer and lower valleys in winter. Herders have a permanent home, typically in valleys. Only the herds travel, with the people necessary to tend them. In contrast, horizontal transhumance is more susceptible to being disrupted by climatic, economic or political change.

Transhumance in India & World

In mountain regions, such as Himalayas, Gujjars, Bakarwals, Gaddis and Bhotiyas migrate from plains to the mountains in summers and to the plains from the high altitude pastures in winters. In Rajasthan also the herders from desert regions move towards central India during summer season.

Similarly, in the tundra regions, the nomadic herders move from south to north in summers and from north to south in winters. The number of pastoral nomads has been decreasing and the areas operated by them shrinking. This is due to imposition of political boundaries and new settlement plans by different countries.

Commercial Livestock Rearing

Commercial livestock rearing is more organised and capital intensive activity in comparison to the Nomadic pastoralism. It is generally practised in permanent ranches.

Ranches

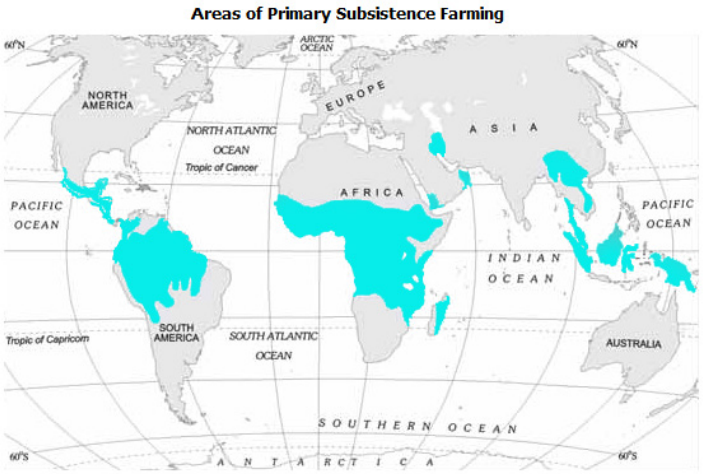
Ranches refers to the large stock farms, usually fenced in, where animals are bred and reared on a commercial scale. They are found especially in the United States.

Products such as meat, wool, hides and skin are processed and packed scientifically and exported to different world markets emphasis is on breeding, genetic improvement, disease control and health care of the animals. New Zealand, Australia, Argentina, Uruguay and United States of America are important countries where commercial livestock rearing is practised.

Primary Subsistence Agriculture

Subsistence agriculture is one in which the farming areas **consume all, or nearly so, of the products locally grown**. It is of two types viz. **Primitive Subsistence Agriculture** and **Intensive Subsistence Agriculture**. Primitive subsistence agriculture is also known as **Shifting Cultivation.** It is widely practised by many tribes in the tropics, especially in Africa, south and Central America and south East Asia.

When the vegetation is cleared by fire, and the ashes add to the fertility of the soil, it is called slash and burn agriculture. After sometime (3 to 5 years) the soil looses its fertility and the farmer shifts to another parts and clears other patch of the forest for cultivation.



The farmer may return to the earlier patch after sometime. Major problem of shifting cultivation is that the cycle of jhum becomes less and less due to loss of fertility in different parcels. It is prevalent in tropical region in different names, e.g.

- *Jhuming in North eastern states of India*
- *Milpa in central America and Mexico*
- *Ladang in Indonesia and Malaysia,*
- *Caingin in Philippines,*
- *Ray in Vietnam,*
- *Taungya In Myanmar*
- *Tamrai in Thailand,*
- *Chena in Sri Lanka,*
- *Conuco in Venezuela,*
- *Roca in Brazil,*
- *Masole in central Africa.*

Intensive subsistence agriculture

Intensive subsistence agriculture is predominant in the densely populated regions of monsoon Asia. There are two types as follows:

Intensive subsistence agriculture dominated by wet paddy cultivation

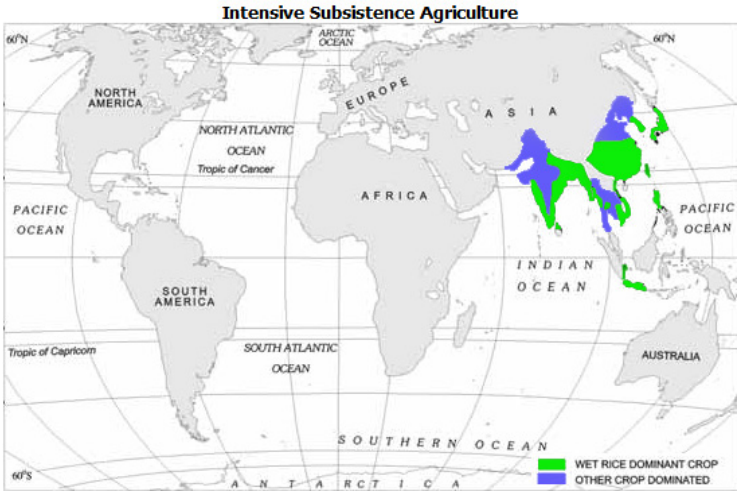
This is dominated by the paddy crop and is prevalent in the Eastern India. The Land holdings are very small due to the high density of population. Farmers work with the help of family labour leading to intensive use of land. Use of machinery is limited and most of the agricultural operations are done by manual labour. Farm yard manure is used to maintain the fertility of the soil. In this type of agriculture,

- *The yield per unit area is high*

- *Per labour productivity is low.*

Intensive subsidence agriculture dominated by crops other than paddy:

Wheat, soyabean, barley and sorghum are grown in northern China, Manchuria, North Korea and North Japan. In India wheat is grown in western parts of the Indo-Gangetic plains and millets are grown in dry parts of western and southern India. Most of the characteristics of this type of agriculture are similar to those dominated by wet paddy except that irrigation is often used.



Plantation Agriculture

Plantation agriculture was introduced by Europeans in their tropical colonies. Some of the important plantation crops are tea, coffee, cocoa, rubber, cotton, oil palm, sugarcane, bananas and pineapples.

The characteristic features of this type of farming are

- Large estates or plantations,
- Large capital investment,
- Managerial and technical support
- Scientific methods of cultivation
- Single crop specialisation
- Cheap labour,
- Good system of transportation which links the estates to the factories and markets for the export of the products.

- The French established cocoa and coffee plantations in West Africa.
- The British set up large tea gardens in India and Sri Lanka, rubber plantations in Malaysia and sugarcane and banana plantations in West Indies.
- Spanish and Americans invested heavily in coconut and sugarcane plantations in the Philippines.
- The Dutch once had monopoly over sugarcane plantation in Indonesia.
- Some coffee fazendas (large plantations) in Brazil are still managed by Europeans.

Extensive Commercial Grain Cultivation

Commercial grain cultivation is practised in the interior parts of semi-arid lands of the midlatitudes. Wheat is the principal crop, other crops being corn, barley, oats and rye . This is characterised by very large farms and entire operation mechanised. Predominant in Eurasian steppes, the Canadian and American Prairies, the Pampas of Argentina, the Velds of South Africa, the Australian Downs and the Canterbury Plains of New Zealand.

Mixed Farming

Mixed Farming is a type of farming in which **cultivation of crops and raising of livestock go hand in hand**. Both these activities play an important part in the economy.

Mixed Farming is predominant in highly developed parts of the world, e.g. North-western Europe, Eastern North America, parts of Eurasia and the temperate latitudes of Southern continents. The important features of Mixed Farming are:

- Medium to large size farms
- **Crop rotation and intercropping for maintaining soil fertility.**
- **Crop cultivation and equal importance on animal husbandry**.

Animals like cattle, sheep, pigs and poultry provide the main income along with crops. Mixed farming is characterised by high capital expenditure on farm machinery and building, extensive use of chemical fertilisers and green manures and also by the skill and expertise of the farmers.

Dairy is the most advanced and efficient type of rearing of milch animals. It is highly capital intensive.

Some Other terms:

Rotation of Crops

A systematic succession of different crops on a given piece of land carried out in order to avoid exhaustion of the soil.

Sedentary Agriculture

Farming practised more or less permanently on the same piece of land, the same as settled agriculture.

Truck Farming

Growing of vegetables around the urban centres to meet the daily demand of the people is known as truck farming. It is governed by the distance a truck can cover overnight between the farm and the market.