STUDY IQ PUBLICATIONS

SIP+

SUCCESS IN PRELIMS

- Comprehensive Prelims Content
- Coverage of Standard Books & NCERTs
- Charts, Tables & Diagram driven summaries
- Memorisation Friendly

GEOGRAPHY

STATIC REVISION SIMPLIFIED

For UPSC CSE Prelims & Other Competitive Exams

Geography

Static Revision Simplified

A quick revision booklet of Geography for UPSC Prelims and other competitive exams.

Study IQ Education Pvt. Ltd.
Geography: Static Revision Simplified 1st Edition by Study IQ Publications
Author/Copyright Owner: Study IQ Education Pvt. Ltd.

Publisher: Study IQ Publications
Printed at: ATOP Printers, Noida

Preface

Dear Aspirants,

CSE Prelims is just around the corner. It is considered to be the iron gate toward your goal to become a civil servant. Prelims is the most competitive part of UPSC CSE, and therefore, reading-revising and testing one's knowledge is imperative for clearing Prelims. According to the present competition, around 1 in 100 people who attempt UPSC Prelims clear it. Given the growing competition, there is an urgent requirement for content specially curated to crack Prelims. The need of the hour is simplified content that helps in a quick and complete revision of the UPSC syllabus.

Taking inspiration from the overwhelmingly positive response to our UPSC CSE books, we are taking another leap towards simplifying Prelims preparation. To fulfill our aspirants' demand, Study IQ Publications is delighted to present you with the first edition of 'SIP+ Static Revision Simplified booklets'.

The SIP+ booklet series has been strategically divided into 2 parts; SIP+ Static Revision Simplified and SIP+ Current Revision Simplified. The UPSC syllabus is huge, it is further complicated by information overload and increasingly difficult questions. These booklets have been created especially keeping in mind, the concerns and challenges that students face during their Prelims preparation. This is an honest attempt to tackle all of the student's issues and save their precious time before Prelims.

Special Features of This Book:

This booklet aims to make your preparation focused and relevant based on UPSC's current trends and patterns, revision-friendly, and up-to-date.

- The requirements of the UPSC Prelims are the exclusive focus of this book.
- We have taken great care to ensure that the material is written in a clear; ready revision format so that students can learn and recall key concepts and facts to their advantage.
- Wherever necessary, we've incorporated relevant tables, charts and mind-maps to help students grasp and revise key concepts and facts.
- The special feature of SIP+ booklet series is the availability of ready revision charts which students can take out and paste on their wall or study table to revise key concepts and facts anytime on their own discretion.

With all sincerity and humility, the StudyIQ team wishes you the best in your preparation, and we are hopeful that this book will help you in your journey.

Table of Contents

CHAPTER 1

Geomorphology

UNIVERSE AND SOLAR SYSTEM

The universe is a vast expanse of space that contains all of everything in existence.

Different Views on the Universe

View	Description
Geocentric View	Earth at the centre of the Universe
Heliocentric View	Sun at the centre of the Universe

BIG BANG THEORY

- The universe came into existence around 13.8 billion years ago.
- The idea is that the universe began as just a single point called the **singularity**-infinite mass with zero volume.
- During the Big Bang, the single point inflated and exploded violently. This resulted in expansion of the universe.

Evidences Supporting Big Bang

- **Red Shifting of Galaxies:** Distance between galaxies increased.
- **Cosmic Microwave Background Radiation**: Faint glow of light present in the Universe.

GALAXIES

A galaxy is a huge collection of gas, dust, and billions of stars and their solar systems. It is held together by gravity.

Types of Galaxies

Spiral Galaxies	Elliptical Galaxies	Irregular Galaxies
• Flat, disc-shaped with curved spiral arms. • great concentration of stars at the centre. • Actively forming stars. • Example: Milky Way	• Vary from nearly circular to very elongated in shape. • Possess comparatively little gas and dust. • Contain older stars and are not actively forming stars anymore. • Most abundant in the universe.	• Irregularly shaped. • Have very little dust.

MILKY WAY

- It is the galaxy in which our solar system is located.
- **Size:** Around 1,00,000 light-years across
- **Age:** Around 13.6 billion years.
- **Type:** Spiral Galaxy.
- **Structure:**
  - **Sagittarius A***: Supermassive black hole in the middle of the Milky Way. Everything in the galaxy revolves around this.

- **Galactic Bulge**: In the immediate surrounding of the Sagittarius A*, there is a tightly packed region of gas, dust, and stars. This space is known as the galactic bulge.
- **Galactic Disc**: Beyond the bulge, there is the galactic disc. The galactic disc hosts billions of stars, including our Sun.

- **Nearest Neigbour**: Andromeda

STARS

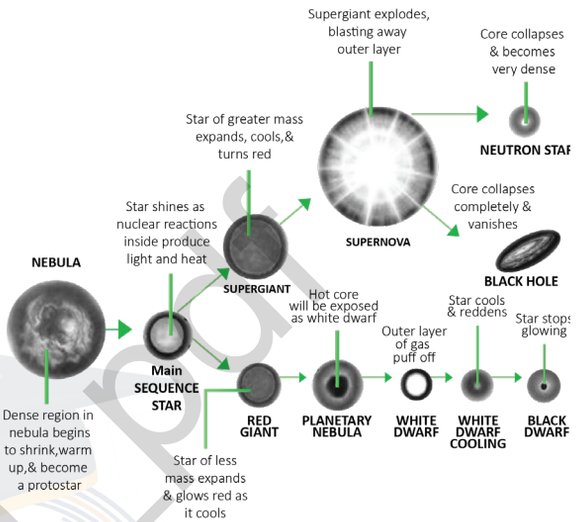
A giant, glowing ball of gas and dust held together by gravity.

Characteristics:

- Mainly composed of hydrogen and helium.
- Vary in size, mass and temperature.
- The color of the star is determined by its temperature. The hottest stars appear blue, while the coldest stars appear red.

Constellation

- A group of stars with a constant shape.
- Visibility of a particular constellation depends on the location and time.
- Generally named after objects, animals, and even mythological figures.
- At present, there are 88 officially recognized constellations.
- Used to name stars, meteor showers, and navigation.
- **Examples:** Ursa Major, Orion, Hunter, Ursa Minor, and The Little bear.

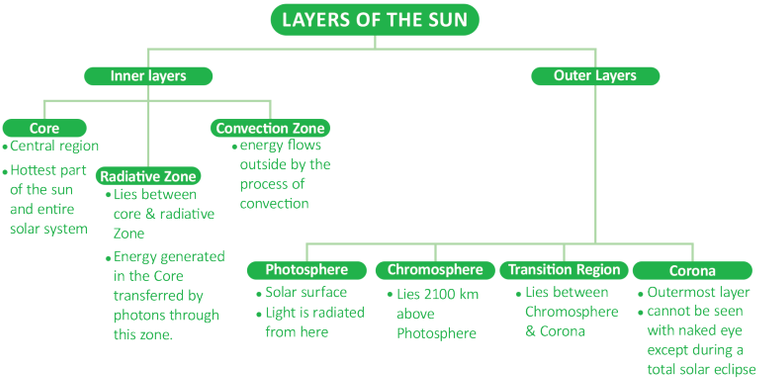


ORIGIN AND EVOLUTION OF THE SOLAR SYSTEM

Theory	Year	Proponent
Gaseous Hypothesis	1755	Immanuel Kant
Nebular Hypothesis	1796	Laplace
Planetesimal hypothesis	1905	T.C Chamberlin
Tidal Hypothesis	1919; modified in 1929	James Jeans
Binary Star Hypothesis	1937	H.N. Russel
Supernova Hypothesis	1946	F. Hoyle

THE SUN

- It is the central celestial body of our Solar System. It is a star.
- **Age**: It is believed to be 5 billion years old.
- **Composition**: Mainly composed of hydrogen and helium. It has a liquid inner section surrounded by a gaseous outer covering.
- **Size**: 13,92,000 km.
- **Temperature**: Varies from 15 million degrees Celsius at the core to 5,500 degrees Celsius at the surface.



Important Concepts

- **Sun Spots:** Dark patches on the surface of the Sun. They are dark because they are cooler than the surroundings.
- **Solar Wind**: It is a stream of plasma flowing outward from the Sun's corona.
- **Coronal mass ejection (CME):** It is the release of plasma and magnetic field from the Sun's corona. They occur when the Sun's magnetic field lines reorganize.
- **Solar Cycle**: It is the cycle that the Sun's magnetic field goes through approximately every 11 years. Every 11 years, the Sun's magnetic field completely flips, and Sun's north and south poles switch places.
- **Solar Flares:** These are large explosions from the surface of the sun that emit intense bursts of electromagnetic radiation.
  - They occur when magnetic energy builds up in the solar atmosphere and is released suddenly.
- **Auroras:** They are formed when the charged particles from the CME reach the earth's atmosphere and react with the different gases.
  - Lights seen near the North Pole are called aurora borealis or northern lights.
  - Lights near the South Pole are called aurora australis or southern lights.

Sun's Halo

- Also known as '22 degree halo', it is an optical phenomenon that occurs due to sunlight refracting in millions of hexagonal ice crystals suspended in the atmosphere.
- It takes the form of a rainbow-coloured ring with a radius of approximately 22 degrees around the sun or the moon.
- Circular halos specifically are produced by cirrus clouds.

Solar Eclipses

Total Solar Eclipse	Partial Solar Eclipse	Annular Solar Eclipse
Occurs when the sun, moon and earth are in a direct line. The dark shadow of the moon completely covers the intense bright light of the sun.	Occurs when the sun, moon and earth are not exactly lined up. The shadow of the moon appears on a small part of the sun.	Occurs when the moon is the farthest from the earth, which is why it seems smaller. In this type of eclipse, the moon does not block the sun completely, but looks like a dark disk on top of a larger sun colored disk forming a ring of fire.

PLANETS

- Planets are objects that orbit around a star in an elliptical path.
- **Dwarf Planets:** The dwarf planets are small. They don't have a distinct orbital path.
  - There are four dwarf planets in the Kuiper Belt viz. Pluto, Makemake, Haumea, and Eris. Ceres is another dwarf planet located in the main asteroid belt.

Pluto: It is the largest among dwarf planets:

- **Time taken to rotate on its axis**: Six earth days
- **Time taken to revolve around the sun**: 248 earth years
- **No. of Moons**: 5. Charon is the largest
- **Rings**: No

- **Exoplanets:** Planets outside our Solar System are called exoplanets.

Classification of Planets

Inner Planets	Outer Planets
• Mercury, Venus, Earth and Mars orbit near the Sun and are called Inner Planets. • The inner planets are also called Terrestrial (Earth-Like) Planets. • They are made up of a solid surface. • They are dense. There is a presence of an iron core.	• Jupiter, Saturn, Uranus, and Neptune are called Outer Planets. • The outer planets are called Jovian (Jupiter-like) Planets. • They do not have a solid surface. • They are less dense as they are made up of gases.

Planets and Important Facts

Planet	Order from the Sun	Time taken for rotation	Time Taken for revolution	No. of Moons	No. of Rings	Other Facts
Mercury	1	59 earth days	88 earth days	0	0	• Fastest planet in our solar system that travels through space at 47 kilometers per second
Venus	2	243 earth days.	225 earth days	0	0	• Hottest planet in our solar system • It rotates on its axis backward i.e., in clockwise direction. This implies that, on Venus, the Sun rises on the West and sets on the East.
Earth	3	About 24 hours	About 365 days	1	0	• **Shape:** Oblate Spheroid • Fifth Largest Planet • It is the only planet in the solar system with liquid water on its surface
Mars	4	Little over 24 hours	687 earth days	2-Phobos and Deimos.	0	• Appears like a reddish ball due to iron minerals on its surface
Jupiter	5	About 10 hours	12 earth years	80 Ganymede is the largest	Yes	• Largest planet in our solar system. • Mainly composed of gas and liquid and has no solid surface
Saturn	6	10.7 hours	29 earth years	83 Titan is the largest	Yes (7)	• Composed of gas and does not have a solid surface
Uranus	7	17 hours	84 Earth years	27	Yes (13)	• Known as the “Ice Giant” as most of its mass is a hot, dense fluid of icy materials- water, methane, and ammonia
Neptune	8	16 hours	165 earth years	14	Yes (9)	• Known as Uranus’s twin because of the striking similarity in size, structure, and composition

Protoplanet AB Aurigae b

- In 2022, the Hubble Space Telescope photographed a Jupiter-like protoplanet named AB Aurigae b.
- A protoplanet is a celestial body orbiting around a star and thought to be developing into a planet.

Kuiper Belt

- It is a donut-shaped region that lies beyond Neptune’s orbit from 30 to 55 AU.
- It contains hundreds of icy bodies called **Kuiper Belt objects (KBOs)** or **Trans-Neptunian objects (TNOs)**. They are remnants of the formation of the solar system

ASTEROIDS AND COMETS

Asteroid	Comets
• These are rocky objects. • They have an elliptical orbit • The orbital period is 1 to 100 years • They are smaller in size • They do not produce a tail. **Types of Asteroids:** • Asteroids occurring in the main asteroid belt, between Mars and Jupiter • **Trojans**:asteroids that share an orbit with a giant planet • **Near-Earth asteroids**. Asteroids that orbit close to the earth. Examples: Bennu, Apophis **Examples:** Vesta, Eros, Bennu	• These objects are made up of frozen gas, dust etc • They have eccentric orbit • The orbital period can be 75 years to more than 100,000 years. • They are large in size. • They form a tail that stretches in a direction away from the Sun. **Examples:** Hailey's comet In 2021, a new comet called **Bernardinelli-Bernstein comet** was identified. It is the biggest comet ever observed.

METEORS, METEOROIDS AND METEORITES

- **Meteoroids:** These are space rocks ranging in size from dust grains to small asteroids.
- **Meteor:** When meteoroids enter the earth's atmosphere or any other planet, it is called a meteor.
  - Meteors are also popularly known as **shooting stars.** The light (which is why a meteor is called a shooting star) is a result of the friction between the meteorite and the molecules present in the Earth's atmosphere because of which it burns.
- **Meteorite**: When a meteor survives in the atmosphere and hits the ground, it is called a meteorite.

Leonids Meteor Shower

- Leonids are annual meteor shower which peak during mid-November.
- The debris that forms this meteor shower originates from a small comet called **55P/Tempel-Tuttle** in the constellation **Leo.** The comet takes 33 years to orbit the sun.
- The Leonids are also called fireballs and earthgazer meteors.
- Every 33 years, a Leonid shower turns into a meteor storm. A meteor storm is when there are at least 1,000 meteors per hour.

Geminids Meteor Shower

- The Geminids are a meteor shower that occurs in December every year.
- It originates from the debris of the **asteroid 3200 Phaethon.** It orbits the Sun every 1.4 years.

GEOLOGICAL TIME SCALE

- It is the "calendar" of the events in Earth history.
- It divides the time into **eons, eras, periods, epochs, and ages**- in descending order of duration.

ERA	Years In Million	Period	Epoch	Fauna	Flora
Cenozoic	1	Quaternary	Recent (Holocene)	Age of mammals	Angiosperms Monocotyledons
	6		Pleistocene	Age of Human Being	Age of Angiosperms-Dicotyledons
	10	Tertiary	Pliocene	Human Evolution	
	15		Miocene	Mammals and birds	
	20		Oligocene		
	100		Eocene		
			Palaeocene		

ERA	Years In Million	Period	Epoch	Fauna	Flora
Mesozoic	125	Cretaceous		(Golden age of Reptiles) Rise of Danseurs	Sphenopsids, Ginkgos, Gnetales, (Dicotyledons)
	150	Jurassic			Herbaceous lycopods, Ferns, Conifers, Cycads
	180	Triassic			
Paleozoic	205	Permian		Mammal like reptiles	Arborescent lycopods
	230	Carboniferous	Pennsylvania	Earliest Reptiles	Seed ferns and Bryophytes
	255		Mississippian	Earliest Amphibians and abundant Echinoderms	
	315	Devonian		Age of fishes	Progymnosperms
	350	Silurian		Earliest fishes and land invertebrates	Zosterophyllum
	430	Ordovician		Dominance of invertebrates	Appearance of first land plants
	510	Cambrian		Fossil invertebrates	Origin of algae
Precambrian	3000	Upper		Multicellular organisms	
		Middle		Appearance of eukaryotes	
		Lower			Planktons prokaryotes

GEOGRAPHICAL GRID, LATITUDE AND LONGITUDE

Geographic grid is a set of imaginary lines placed at specific points on the planet. It is used to establish exact coordinates for every location on Earth.

LATITUDE

- It is the measurement of distance north or south of the Equator.
- It is measured with 180 imaginary lines known as parallels.
- **Equator:**
  - It is the line of 0 degrees latitude.
  - The equator divides the earth into two equal halves, the Northern Hemisphere and the Southern Hemisphere. Hence, it is also called the **Great Circle.**
- **North and South Pole**: The latitude of the North Pole is 90 degrees N. The latitude of the South Pole is 90 degrees S.
- **Tropics:** These are geographic locations that mark the northernmost and southernmost latitudes where the sun can be seen directly overhead during a solstice.
  - **Tropic of Cancer:** It is positioned approximately at 23.5 degrees north of the equator.
  - **Tropic of Capricon:** It is positioned approximately at 23.5 degrees south of the equator.
- **Arctic Circle:** It is a parallel of latitude on the Earth at approximately 66.5 degrees north of the equator.
- **Antarctic Circle**: It is a parallel of latitude on the Earth at approximately 66.5 degrees south of the equator.

Countries through which Equator passes	Countries through which Tropic of Cancer passes	Countries through which Tropic of Capricorn Passes
Ecuador, Colombia, Brazil, Sao Tome & Principe, Gabon, Republic of the Congo, Democratic Republic of the Congo, Uganda, Kenya, Somalia, Maldives, Indonesia and Kiribati.	Algeria, Niger, Libya, Egypt, Saudi Arabia, United Arab Emirates, Oman, India, Bangladesh, Myanmar, China, Taiwan, Mexico, Bahamas, Mauritania and Mali	Namibia, Botswana, South Africa, Mozambique, Madagascar, Australia, Chile, Argentina, Paraguay, and Brazil.

LONGITUDE

- Longitude is the measurement east or west of the prime meridian.
- Longitude is measured by imaginary lines that run around Earth vertically and meet at the North and South Poles. These lines are known as meridians.
- The widest areas of longitude are near the Equator, where Earth bulges out.
- All meridians meet at the North and South Poles.
- **Prime Meridian:** The meridian that runs through Greenwich, England, is internationally accepted as the line of 0 degrees longitude, or prime meridian.
  - The Prime meridian is taken as the point of reference for calculating time. The time measured at the Prime Meridian is called the **Greenwich Mean Time (GMT).**

Countries through which Prime Meredian passes: England, France, Spain, Algeria, Mali, Burkina Faso, Togo, Ghana and Antarctica.

- **Eastern and Western Hemisphere:**

  Half of the world, the Eastern Hemisphere, is measured in degrees east of the prime meridian.

  The other half, the Western Hemisphere, in degrees west of the prime meridian.

International Date Line

- The place where the day starts is the International Date Line.
- It is an imaginary line passing from the North Pole to the South Pole in the middle of the Pacific Ocean.
- It passes approximately the 180° meridian of longitude.
- There are **24 standarized time zones,** one for each hour of the earth's rotation

Daylight Saving Time

- The prcatice of advancing clocks in summer months by one hour.
- **Countries where practised**: USA, Canada, European Union Countries, Argentina, Cuba, etc

DIFFERENT MOTIONS OF THE EARTH

ROTATION

- The spinning movement of the earth around its axis is called rotation.
- The earth spins **counterclockwise.**
- The earth takes 23 hours, 56 minutes, and 4 seconds to complete one rotation on its axis.
- The period of the rotation is called **day or earth day.**
- The circle that divides the day from the night is called the **circle of illumination.**

Significance of Earth's Rotation

- Creates the diurnal cycle of lightness and darkness, temperature and humidity changes
- Drives the movement of water in the oceans.
- Responsible for deflection of tides.
- Responsible for the general circulation in the earth's atmosphere.
- Deflects wind and ocean currents. They are deflected towards the right in Northern Hemisphere and to the left in southern hemisphere.

Axis of the Earth

- An imaginary line passing from the North Pole through Earth's center to the South Pole is called the axis of the earth.
- The axis is not straight but inclines at angle of 23.5°. This means it makes an angle of 66.5° with its orbital plane (the plane formed by the orbit).
- According to a recent study, the massive melting of glaciers as a result of global heating has caused marked shifts in the Earth's axis of rotation since the 1990s.

REVOLUTION

- The movement of the earth along its elliptical orbit around the Sun is called revolution.
- The earth takes 365 days, 6 hours, 9 minutes to complete one revolution around the Sun. This amount of time taken by earth to revolve is called a **year.**
- **Leap Year:** A year with 366 days is called a leap year.

Significance of Earth's Revolution:

- The revolution of the earth causes seasons.
- Causes aphelion and perihelion.

Aphelion and Perihelion

- **Aphelion:** During its revolution around the sun, the earth is farthest from the sun (152 million km) on 4th July. This position of the earth is called aphelion.
- **Perihelion:** On 3rd January, the earth is the nearest to the sun (147 million km). This position is called perihelion.

SEASONS

There are mainly four seasons experienced on earth-Summer, Winter, Spring and Autumn. The change in seasons is due to the relative change in the position of the Earth as it revolves around the Sun.

Months	Northern Hemisphere	Southern Hemisphere
June to August	• Direct sun rays • More heat; warm weather conditions • **Summers** • Places beyond the Arctic Circle till the North Pole experience continuous daylight for about six months.	• Oblique sun ways • Less heat, cool conditions • **Winters** • Places beyond the Antarctic Circle till the South Pole experience night for about six months
December to February	• Oblique sun rays • Less heat, cool conditions • **Winters** • Places beyond the Arctic Circle till the North Pole experience night for about six months	• Direct sun rays • More heat; warm weather conditions • **Summers** • Places beyond the Antarctic Circle till the South Pole experience continuous daylight for about six months.
September to November	• Sun shines equally on both hemispheres • **Autumn**	• sun shines equally on both hemispheres • **Spring**
March to May	• N shines equally on both hemispheres • **Spring**	• sun shines equally on both hemispheres • **Autumn**

SOLSTICES AND EQUINOXES

Summer Solstice

- On 21st June, the Sun is vertical over the Tropic of Cancer. For every place, above the Tropic of Cancer, the sun is at the highest point in the sky.
- On this day, the northern hemisphere experiences longest day.

- The sun doesnot set below the horizon at the Arctic Circle.

Winter Solstice

- On 22nd December, the Tropic of Capricorn receives direct rays of the sun as the South Pole is tilted toward the sun.
- The sun's rays fall vertically at the Tropic of Capricorn.
- The sun doesnot set below the horizon at the Antarctic Circle.

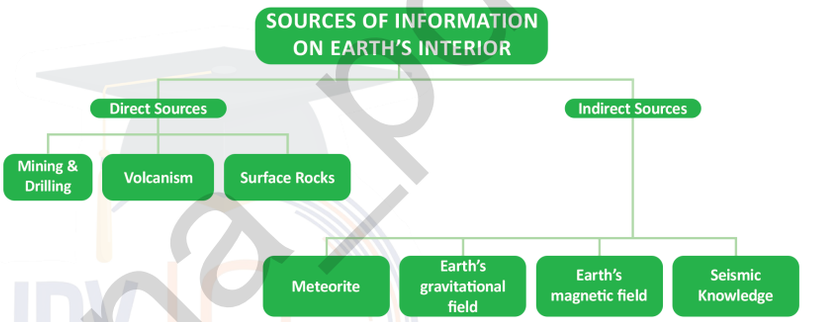
Equinoxes

- The equinoxes happen in March (March 21) and September (September 23).
- These are the days when the Sun is exactly above the Equator, which makes day and night of equal length.
- 23rd September is the Autumn Equinox while 21st March is Spring Equinox.

INTERIOR OF THE EARTH

IMPORTANCE OF STUDYING EARTH'S INTERIOR

- Helps understand the physical features on the earth
- Helps understand the evolution of life.
- Helps us explore and extract minerals and energy
- Helps us understand how and why Earth's climate has changed in the past
- Helps study and understand other planets in the solar system and distant stars
- Helps understand the earth's magnetic field.



SEISMIC WAVES

When an earthquake occurs shockwaves of energy, called **seismic waves**, are released from the earthquake focus.

- **Instrument of measurement:** seismometer.
  - The seismometer produces a graph called a **seismogram** which shows these waves.

Types of Seismic Waves

- **Body Waves:** Originate from inside the earth and travel through different layers of the earth.
- **Surface Waves:**. Travel on the earth's surface.

Classification of Body Waves

Primary waves or 'P' waves	Secondary Waves or 'S' Waves:
• P-waves are the first to arrive at the surface. • Fastest-traveling seismic waves- 5 to 14 km per second. • Similar to sound waves. • Travel through **gaseous, liquid and solid materials**. However, their speed is reduced in liquid and gases. • Also called compressional waves • When a particle is subjected to P wave, they move in the same direction as the wave is traveling in.	• S-waves arrive at the surface with some time lag Speed lower than P waves, around 3.5-7.2 km per second. • Can travel only through **solid** materials • Also called transverse waves/ shear waves

Surface Waves

- They are the last to reach the earth's surface.
- Only affect the surface of the earth and act obliquely.
- Most violent and destructive of all seismic waves.

Types of Surface Waves

- **Loves Waves**: It is the fastest surface wave. It moves the ground from side to side.
- **Rayleigh waves:** These waves roll over the ground like waves in oceans or seas. This causes the ground to move in an elliptical motion.

STRUCTURE OF THE EARTH

Crust

- It is the uppermost and thinnest layer of the Earth.
- **Divisions of Crust:**
  - **Upper Crust:**
  - It is granitic and forms the continental landmasses.
  - It is primarily composed of silica and alumina and is called "sial.
  - **Lower Crust:**
  - It is a continuous zone of dense basaltic rocks that forms the ocean floors.
  - It is mainly composed of silica and magnesium and is hence commonly referred to as the "sima."
- **Density:** The continental crust or the "Sial" is lower in density (2.7g/cm^3) as compared to the oceanic crust or the "Sima"(3.5g/cm^3).
- **Thickness:** The average thickness of the crust below the ocean is 5 km, whereas that of the continent is around 30 km.

Mantle

- It lies between the Earth's crust and its core.
- **Extent:** The mantle extends from Moho's discontinuity to a depth of 2,900 km.
- **Density:** The density of the mantle is about 4.5 g/cm^3.
- **Composition:** Minerals like pyroxene, olivine, garnet, plagioclase, and amphibolite.
- **Divisions of the Mantle:**
  - **Upper Mantle:**
    - Depth: It ranges from 403 to 660 km from the crust.
    - Temperature: It ranges from 500 to 900 degrees Celsius.
    - The upper mantle is more viscous than the lower mantle as there is less pressure than the lower mantle.
  - **Lower Mantle:**
    - Depth: is around 660 to 2,891 km.
    - Temperature: the lower mantle is much hotter, reaching 74,000 degrees Celsius.
- **Asthenosphere:** The upper mantle contains a weaker zone called the asthenosphere. It extends up to 400 to 500 km from the surface.
  - It is the primary source of magma that flows out to the surface during volcanic eruptions.
- **Lithosphere:** The crust and the uppermost part of the mantle above the Asthenosphere are collectively called the Lithosphere.

Core

- **Extent:** Extends from 2900km to approximately 6371km.
- **Composition:** The core comprises the heaviest materials like nickel and iron and is called "Nife" (Ni for Nickel and Fe for iron).
- **Division of Core:**

- **Outer Core:**
  - **Thickness:** It is about 2,200km thick.
  - **Temperature:** It ranges between 4,500° and 5,500 degrees Celsius.
  - **Density:** It is between 12.6-13 g/cm3.
  - The outer core is presumed to be liquid.
- **Inner Core:**
  - **Composition:** It is mainly composed of iron.
  - **Temperature:** It is about 5,200° Celsius.
  - The inner core is assessed as solid.
  - **Density:** It is between 9.9-12.2 g/cm^3

List of Seismic Discontinuities

Name of Seismic Discontinuity	Transition Between
Conrad Discontinuity	SIAL and SIMA
Mohorovicic Discontinuity	Crust and Mantle
Repiti Discontinuity	Outer Mantle and Inner Mantle
Gutenberg Discontinuity	Mantle and Core
Lehman Discontinuity	Outer Core and Inner Core

TEMPERATURE, PRESSURE AND DENSITY OF THE EARTH'S INTERIOR

TEMPERATURE

- There is a rise in temperature with increasing depth. However, the rate of increase is not uniform.
- **Geothermal Gradient:** The change in the earth's temperature with depth is called the geothermal gradient.
- **Sources of Heat:**
  - The frictional heat leftover from the collisions of large and small particles that created Earth
  - The decay of radioactive materials

PRESSURE

- The pressure is due to the huge weight of the overlying rocks.
- The pressure increases with increasing depth.
- The pressure at the centre of the earth is 364 GPa (Gigapascals).

DENSITY

- The density increases with increasing depth.
- The density of the core ranges between 9.5-14.5g/cm3.

EARTH'S MAGNETIC FIELD

- **Source of Earth's Magnetic Field:** The liquid outer core
- **Geodynamo:** Driven by the earth's rotation and convective forces, metallic minerals are continuously moved within the core, generating huge electric currents. The process is called geodynamo. It is responsible for creating and maintaining the earth's magnetic field.

- **Magnetic Poles:** Earth has two sets of poles, geographic pole and magnetic poles. The magnetic field does not align with the earth's axis of rotation. As a result, a compass needle points towards the magnetic north pole and not the geographic north (based on the axis of rotation of the Earth).
- **Declination Angle:** The angle between true North and magnetic North at any particular position on the Earth.

Polar Reversal

There is a complete reversal of the magnetic poles of the earth over several thousands of years. The reversal has been attributed to **changes in the convection pattern in Earth's core.**

Magnetosphere

It is the region above the ionosphere that is defined by the extent of the Earth's magnetic field in space.

- **Magnetopause:** It is the abrupt boundary between a magnetosphere and the surrounding solar wind plasma.
- **Magnetosheath:** It is the turbulent magnetic region just outside the magnetopause.
- **Bow Shock:** It is located sunward of the magnetopause. Here, the solar wind slows abruptly.
- **Plasmasphere:** It is located Inside the magnetosphere. It is a region containing low-energy charged particles.

Van Allen radiation Belt

It is a zone of energetic charged particles, most of which originate from the solar wind. By trapping the solar wind, the belts deflect the energetic particles and protect the atmosphere.

Geomagnetic Storm

40 satellites of Starlink project undertaken by Elon Musk were lost because of the geomagnetic storm.

What is Geomagnetic storm?

- Geomagnetic storm are disturbances of Earth's magnetrosphere.
- Magnetosphere located in the upper atmosphere of the Earth acts as a shield and protects Earth from dangerous solar and cosmic raditions.
- The magnetic storm is caused by the release of a high-speed stream of solar wind that emerges from the coronal holes of the sun.

Effects of Geomagnetic storm

- These radiations interact with Earth's magnetic field and affects the communication satellites.
- The radiations affect space-dependent technologies. Example: GPS, Radio, Flights, Electricity networks, etc.
- Affect the health conditions of the astronauts.

CONTINENTAL DRIFT THEORY, SEAFLOOR SPREADING AND PLATE TECTONICS

Criteria	Continental Drift	Seafloor Spreading	Plate Tectonics
Propounded by	Alfred Wegner in 1912	Harry Hess in 1960's	D.P. McKenzie, R.L Parker, W.C Morgan and X. Le Pichon in 1967-168
Theory	Explains that continental land masses are moving	Explains that sea-floor is spreading i.e. the oceanic plates are moving	It says that earth's lithospheric plates (both continental and oceanic) are moving horizontally
Forces of movement	Gravity, tidal currents	Convection current within the earth	Convection current within the earth

Criteria	Continental Drift	Seafloor Spreading	Plate Tectonics
Evidences	**Jigsaw Fit:** The outlines of the coasts on either side of the Atlantic Ocean-coastlines of South America and Africa are such that they can be joined together.	**Geology of the Ocean Floor:** On mapping of the floor of the Atlantic Ocean, it was observed that the seafloor was not flat, plain land but was an active area with giant peaks, cracks, and active volcanoes.	**Paleomagnetic Rocks**
	Paleoclimatic Evidence: There are coal deposits in the mid-latitude regions, stretching from North America to Europe to China	**Age of Rocks:** Young rocks were found right along the Mid-Atlantic ridge and older rocks away on either side of the ridge.	
	Evidence from Fossils: The fossil remains of Cynognathus (a Triassic reptile) have been found in Argentina and South Africa.	**The thickness of Sediments:** The thickness of the layer of sediments deposited on the ocean floor increases as we get further away from the mid-oceanic ridge.	
	Geological Evidence: Opposite coasts of the Atlantic Ocean also have similar rock types of the same age, suggesting that they were unified at a point in time.	**Paleomagnetism:** Magnetic Reversal or Polar Reversal are captured on solidified rocks on either side of the mid-oceanic ridge.	**Occurrence of earthquakes and volcanoes along Plate boundaries**
	Tillite Deposits: The Gondwana system of sediments – consisting of tillite deposits are found in Madagascar, Africa, Antarctica, Falkland Island, Australia, and India.		
	Polar Wandering: There have been changes in the position of the magnetic north and south poles over different geological periods – a phenomenon termed as polar wandering.		
Significance	Foundation for theory of seafloor spreading	Foundation for the theory of plate tectonics	Helps understand geomorphic features, distribution of earthquakes and volcanoes.

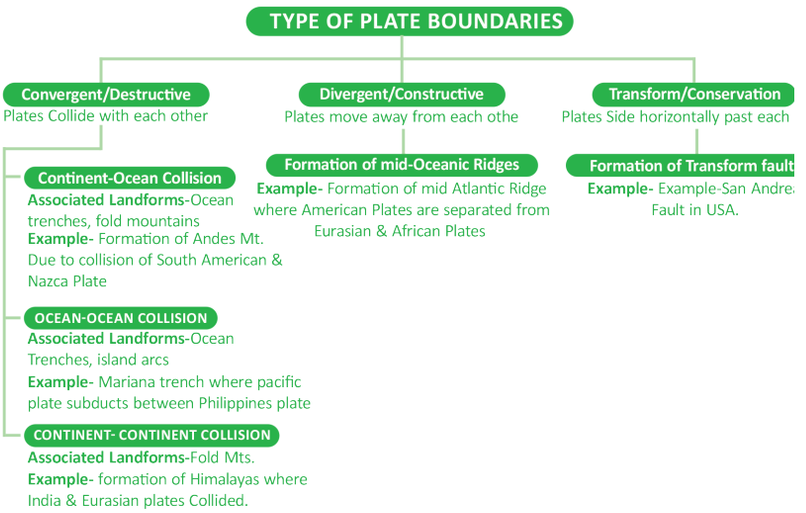
PLATE TECTONICS

The earth's lithosphere is divided into several rigid slabs or plates. These plates are moving horizontally over the viscous asthenosphere of the mantle.

Types of Plates

The Lithospheric plates are broadly classified into

- **Continental plates**: comprise the continental crust called "sial."
- **Oceanic plates**: made up of the oceanic crust called "sima.")



On the Basis of their size, they are further classified into

- **Major plates:** These include:
  - The **Antarctic (and the surrounding oceanic) plate**
  - The **North American plate** (with western Atlantic floor separated from the South American plate along the Caribbean islands)
  - The **South American plate** (with western Atlantic floor separated from the North American plate along the Caribbean islands)
  - The **Pacific plate**
  - The **India-Australia-New Zealand plate**
  - The **Africa with the eastern Atlantic floor plate**
  - **Eurasia and the adjacent oceanic plate**
- **Minor plates:** Important minor plates are:
  - **Cocos plate:** Between Central America and Pacific plate
  - **Nazca plate:** Between South America and Pacific plate
  - **Arabian plate:** Mostly the Saudi Arabian landmass
  - **Philippine plate:** Between the Asiatic and Pacific plate
  - **Caroline plate:** Between the Philippine and Indian plate (North of New Guinea)
  - **Fuji plate:** North-east of Australia
  - **Juan De Fuca plate:** South-East of North American Plate

Microcontinent Zealandia

A microcontinent is a landmass that has broken off from a main continent.

- Zealandia is a long, narrow microcontinent that is mostly submerged in the South Pacific Ocean. It broke off from Antarctica about 100 million years ago, and then from Australia about 80 million years ago.
- Part of it is on the Australian plate, while the other part is on the Pacific plate.

Tectonic Evolution of Greater Maldive Ridge

Researchers have traced the tectonic evolution and the nature of the Greater Maldive Ridge (GMR).
The study is significant as it would help in better understanding of the tectonic evolution of the Indian Ocean.

About Greater Maldive Ridge

- It is an aseismic ridge that is not associated with earthquake activities.
- **Location:** Western Indian Ocean, southwest of India.

EARTHQUAKES

An earthquake is the shaking or trembling of the earth's surface. It is a natural event caused due to the release of energy from the interior of the earth.

- **Hypocenter/ Focus:** The location/point below the earth's surface where the earthquake starts.
- **Epicentre:** The location on the earth's surface, directly above the focus.
- **Shallow Earthquakes:** Earthquakes with foci located at depths less than 70 km
- **Intermediate Earthquake**: An earthquake with focus at depths between 70 to 300 km.
- **Deep earthquakes:** Foci at depths from 300 to 700 km.
- **Aftershocks**: small-sized earthquakes following a moderate earthquake with shallow focus.
- **Foreshock**: A mild earthquake that may preceding a major earthquake
- **Earthquake Swarms:** A sequence of small earthquakes with no identifiable mainshock.

MEASUREMENT OF EARTHQUAKES

Richter Scale	Mercalli Scale
Measurement of Magnitude	Measurement of Intensity
Developed by: Charles F. Richter in 1935.	**Developed by:** Italian geologist Giuseppi Mercalli in 1902.

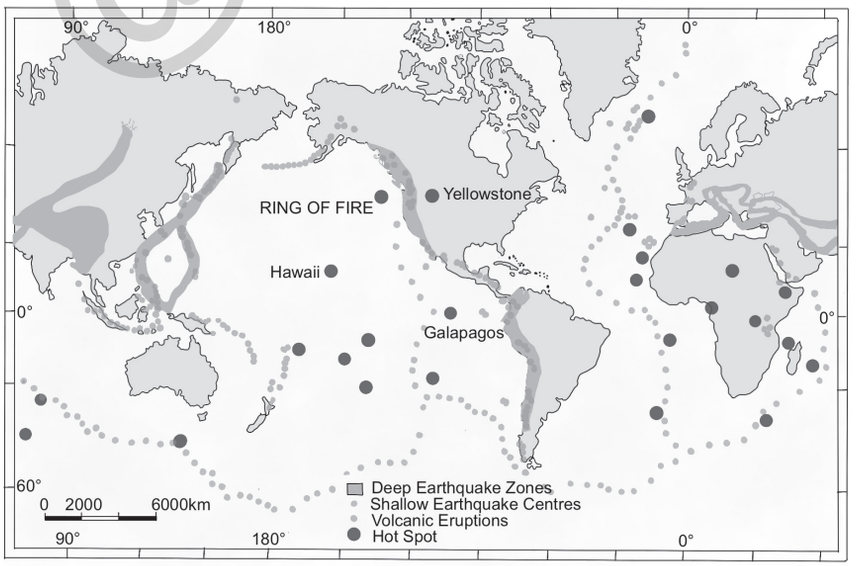
Richter Scale	Mercalli Scale
The magnitude is expressed in absolute numbers, 0-10	The range of intensity scale is from I to XII.

CAUSES OF EARTHQUAKES

Natural Factors	Anthropogenic Factors
Vulcanicity • Example: Eruption of Nevado Del Ruz in Columbia causing earthquakes in 1985	• Drilling activities, • Deep underground mining, • Blasting of rocks by dynamites, • Nuclear explosion tests • storage of massive volumes of water in big reservoirs
Faulting • Example: 1975 earthquake in Guatemala due to the movement along the Motagua Fault	
Plate Tectonics • Shallow Focus earthquakes along **divergent** plate boundaries • Very deep and high magnitude earthquakes along **convergent** plate boundaries • Earthquakes along **transform** boundaries	

GLOBAL DISTRIBUTION OF EARTHQUAKES

Zone	Extent	Cause
Circum-Pacific Zone	Eastern and western margins of the Pacific Ocean	The Pacific Plate that is thinner and denser meets several other plates in this region, such as Juan de Fuca, Cocos, Indian-Australian, Nazca, North American, and Philippine Plates and is subducted under these plates
Mid-Atlantic Belt	Along the mid-oceanic ridges and islands near the ridges of the Atlantic Ocean.	Seafloor spreading
Mid-Continental Belt	Alpine ranges, Mediterranean Sea, Northern and eastern Africa, and Himalayan ranges up to Myanmar's hills	Plate Convergence
Intra-Plate Earthquakes	regions away from the plate boundaries.	stress inside the plate is due to fractures created along ancient fault-lines or rift zones. Example: Earthquakes in the Western United States and Peninsular India. An intra-plate earthquake occurred in Latur, India in 1993.



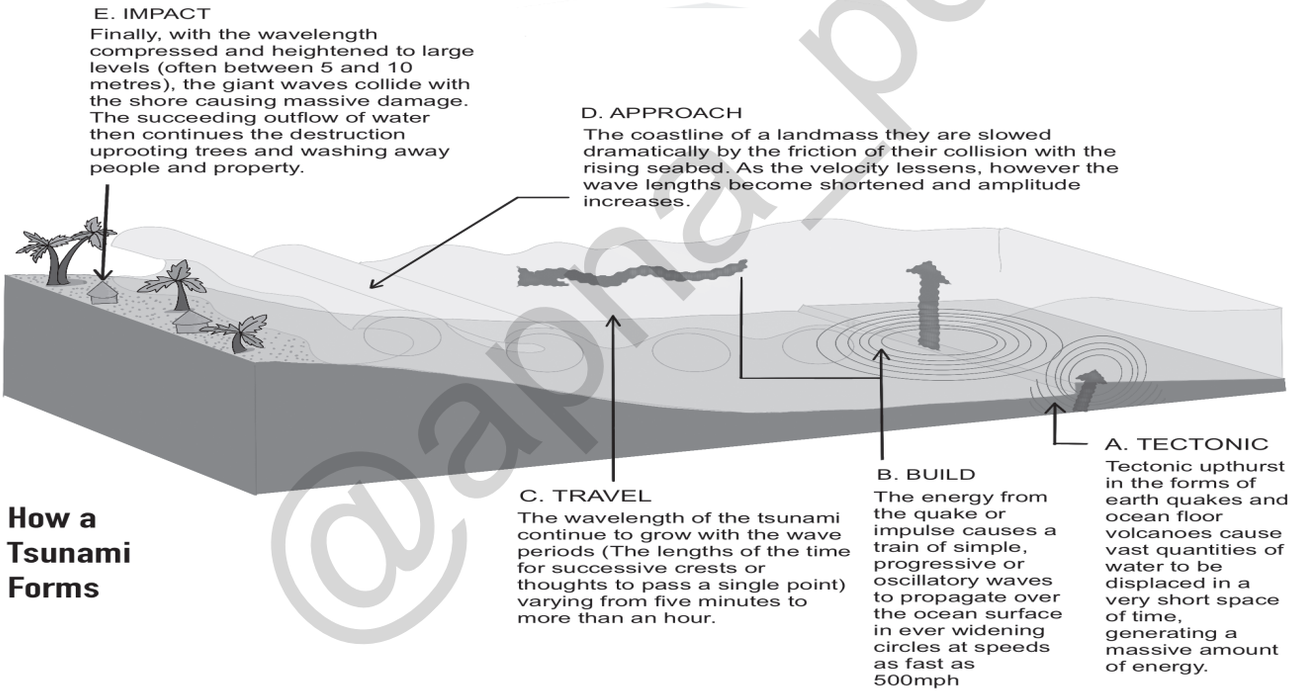
Distribution of Earthquake

DISTRIBUTION OF EARTHQUAKES IN INDIA

Zones	Regions
Zone V	Parts of Kashmir, the Western and Central Himalayas, North and Middle Bihar, the NorthEast Indian region, the Rann of Kutch and the Andaman and Nicobar
Zone IV	Parts of Jammu & Kashmir and Himachal Pradesh, Delhi, Sikkim, northern parts of Uttar Pradesh, Bihar and West Bengal, parts of Gujarat and small portions of Maharashtra near the west coast and Rajasthan.
Zone-III	Kerala, Goa, Lakshadweep, and the remaining parts of Uttar Pradesh, Gujarat, and West Bengal, parts of Punjab, Rajasthan, Madhya Pradesh, Bihar, Jharkhand, Chhattisgarh, Maharashtra, Odisha, Andhra Pradesh, Tamil Nadu, and Karnataka
Zone II	Covers the remaining parts of the country

CONSEQUENCES OF EARTHQUAKES

- Landslides
- Deformation of Ground Surface
- Tsunamis- Example: 2004 Indian Ocean Tsunami caused by Sumatran-Andaman Earthquake



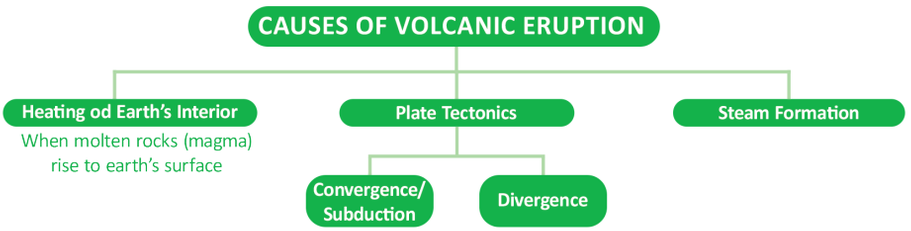
How a Tsunami Forms

Major Earthquakes in 2022

Earthquake	Key Facts
Afghanistan Earthquake, June 2022	Seismic activity in Afghanistan is influenced by the subduction of the Arabian Plate to the west and the subduction of the Indian Plate in the east.
Java, Indonesia Earthquake, November 2022	Java lies near an active convergent boundary that separates the Sunda Plate to the north and the Australian Plate to the south. The boundary is marked by the Sunda Trench, which generates earthquakes.
Papua New Guinea Earthquake, September 2022	The earthquake occurred in a tectonically complex region where the Australian Plate moves east-north-east-wards relative to the Pacific Plate.

VULCANISM

Volcano is a rift or a fissure from which molten rock called magma and other substances like gases and ashes erupt onto the earth's surface. The transfer of magma from the earth's interior onto the surface of the earth is called **"Vulcanicity" or volcanic activity.**



DISTRIBUTION OF VOLCANOES

Zone	Extent	Cause	Examples
Circum-Pacific Belt (Pacific Ring of Fire)	Volcanoes of eastern and western coastal areas, the island arcs along the east-Asian coast, and other small volcanic islands in the Pacific Ocean.	Volcanoes here are found on the margins of Pacific, Juan de Fuca, Cocos, Indian-Australian, Nazca, North American, and Philippine Plates	Fujiyama of Japan, Kadovar in Papua New Guinea, and Mayon in the Philippines
Mid-Continental Plate	Volcanoes of Alpine Mountain chains, those in the Mediterranean Sea, and volcanoes of the East African Rift Valley	Eruptions occur due to the collision of the Eurasian, Indo-Australian, and African plates.	Vesuvius, Stromboli, Kilimanjaro
Mid-Atlantic Ridge Belt	Volcanoes are found along the Mid-Atlantic Ridge.	Here, the North-American and Eurasian plates move away from each other, and a fissure-type eruption occurs.	The most active volcano area is located in Iceland.
Intra plate Volacanoes	Volcanoes are found in the inner parts of the plates, away from the tectonic plate boundaries.	They are associated with hotspots below the mantle.	The Hawaii islands in the Pacific Ocean.

Hotspot: A hotspot is an area above the mantle plume.

- **Mantle Plume:** It is an area under the crust where magma is hotter than the surrounding magma.
- Volcanic activity occurs above this plume due to very high heat caused by the extra hot magma, which causes **melting and thinning** of the crust.
- The lava produced by the hotspots is **alkaline and the crust thus formed is called Ocean Island Basalt.**
- These hotspots may also result in the formation of large volcanic provinces. For example, in the late Cretaceous, the Reunion **Hotspot** created the Deccan Traps as the Indian Plate drifted over it.

CLASSIFICATION OF VOLACNOES BASED ON PERIODICITY

Type	Detail	Examples
Active	Have a recent history of eruptions	Kīlauea in Hawaii, Mount Etna in Italy and Mount Stromboli in Italy, Barren Island in India
Dormant	Have not erupted for a very long time but may erupt at a future time	Mount Kilimanjaro, Tanzania, Africa and Mount Fuji in Japan
Extinct	Are not expected to erupt in the future.	Calupin Volcano in New Mexico · Ben Nevis in the UK · Mount Thielsen in Oregon

MAJOR ACTIVE VOLCANOES OF THE WORLD

Volcano	Location	Key Facts
Mount Etna	Sicily (Italy)	It is the highest Mediterranean island mountain. It is the most active stratovolcano in the world.
Mount Vesuvius	Southern Italy near the coastal city of Naples	The only active volcano on mainland Europe. It is a compound volcano/complex volcano.
Kīlauea	Located in Hawaii Volcanoes National Park on the southeastern part of the island of Hawaii, U.S.A	It is one of the world's most active volcanoes.
Mount Merapi (Mountain of Fire)	Indonesia	Indonesia's most active volcano, with 130 active volcanoes.
Sakurajima	Kyushu, Japan	It is an active stratovolcano
Pacaya Volcano	Guatemala	It is a complex basaltic volcano.
Arenal Volcano	North-western Costa Rica	It is a stratovolcano
Santa Maria	Western highlands of Guatemala	It is a stratovolcano. It is also the home of Santiaguito, one of the most active lava dome complexes in the world.
Stromboli	Italy	Stromboli is one of the world's most active volcanoes. It is known as the "Lighthouse of the Mediterranean".
Lascar	Northern Chile	It is a stratovolcano
Mt. St. Helens	southwestern Washington, U.S	It is an active stratovolcano. The volcano is part of the Cascade Volcanic Arc, a segment of the Pacific Ring of Fire.
Mt. Taal	Philippines	Taal Volcano is the smallest active volcano in the world.
Galeras	southwestern part of Colombia, South American	It is an andesitic stratovolcano that is part of an older volcanic complex.
Erebus	Antarctica	Mount Erebus is, located on Ross Island, Antarctica. It is one of the few volcanoes in the world with a persistent lava lake in its summit crater.
Heard Island	Australia	It is home to Big Ben, which is an active volcano

Types of Volcanic Eruption

Based on the **nature of the opening through which magma comes out,** volcanic eruptions can be classified into two types:

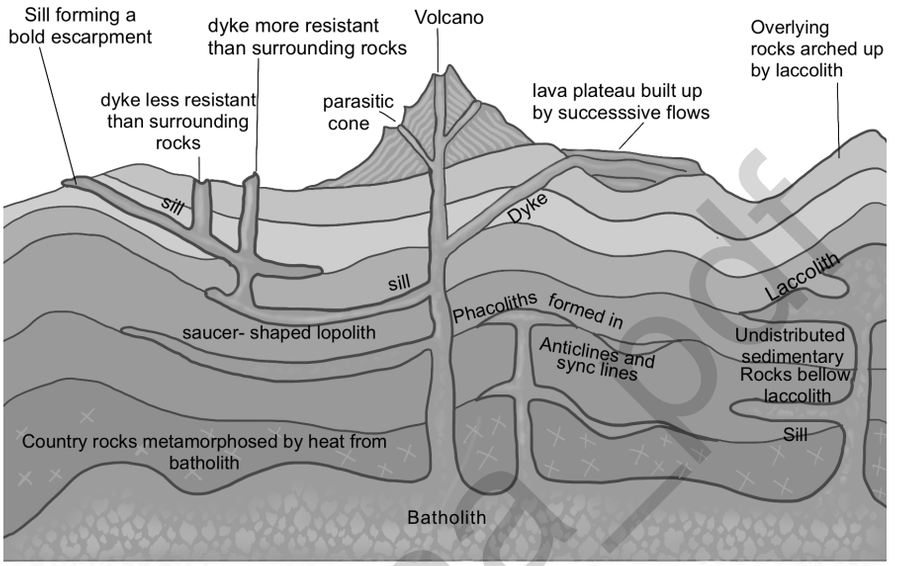
Fissure Eruption	Central Eruption
• Takes place along a fissure or a series of fissures. • There is no explosive activity. • Formation of lava plateaus and plains. **Example: Columbia plateau of the USA** (eruption took place during the **Miocene epoch**).	• Eruption occurs through a central vent or mouth. • Rock fragments, ash and lava are ejected that collect around the **mouth forming cone-like structures.**

Types of Central Eruption

Type	Characteristic Feature	Example
Hawaiian Type	Explosive activity is rare, and eruption is calm.	Mauna Loa and Kilauea of Hawaiian Islands.
Strombolian Type	Eruption is of **moderate intensity** and is **rhythmic or continuous.**	Stromboli Volcano
Vulcanian Type	Moderately explosive and eject a lot of gas and ash.	Mt. Vulcano of Lipari island

Type	Characteristic Feature	Example
Pelean Type	Forms an avalanche of gas, ash and rock fragments called Nuees Ardentes.	Mount Pelée on the Caribbean island of Martinique
Plinian Type	Lava is highly viscous; very violent eruption takes place.	Mount St. Helens

VOLACNIC LANDFORMS



Volcanic Landforms

Extrusive Volcanic Landforms

These are **formed due to the solidification of lava** on the earth's surface along with the accumulation of pyroclastic materials, dust, and ashes.

Landforms of Central Eruption

Landform	Characteristic Feature	Example
Cinder Cones	Low-height mounds of volcanic dust, ashes, and pyroclastic materials accumulated near the vent.	Cones of Mt Jorullo of Mexico.
Shield Volcano	Formed by piling up lava upon one another and the vent.	Mauna Loa in Hawaii-largest shield volcano.
Composite or Strato Volcano	Steep-sided, conical-shaped stratified volcanoes	Fujiyama, Cotopaxi, and Vesuvius
Crater	Basin or funnel-shaped depression. Sometimes a crater of an extinct volcano may get filled with water, forming **crater lakes.**	Crater Lake in Oregon, and Lake Toba in Indonesia.
Caldera	Large shallow cavity larger than a crater.	Caldera on Mt. Krakatoa.

Intrusive Volcanic Landforms

Intrusive volcanic landforms are formed due to the **solidification of magma inside the earth.**

Intrusive Landform	Characteristic Feature	Example
Dyke	Vertical or highly inclined sheet of igneous rock that cuts through rock.	Dykes in Chotonagpur Plateau

Intrusive Landform	Characteristic Feature	Example
Sill	Sheet of igneous rock formed horizontally between two layers of sedimentary rocks.	Tabular mass of quartz trachyte found near the summit of Engineer Mountain near Silverton, Colorado.
Laccolith	Large mound of igneous rock with the lower surface flat and upper surface arched up in the form of a dome.	Mt. Holmes in Yellowstone National Park, USA.
Lopolith	Large saucer-shaped mass of igneous rock.	Bushveld Igneous Complex of South Africa.
Phacolith	Lens-shaped masses of igneous rocks.	Phacoliths seen in the foothills of the Himalayas and the Alps.
Batholith	Dome-shaped mass of igneous rock whose sides plunge deep beneath the surface.	Wicklow Mountain of Ireland

IMPACT OF VOLCANIC ERUPTIONS

Volcanic eruptions **have both positive and negative impacts.**

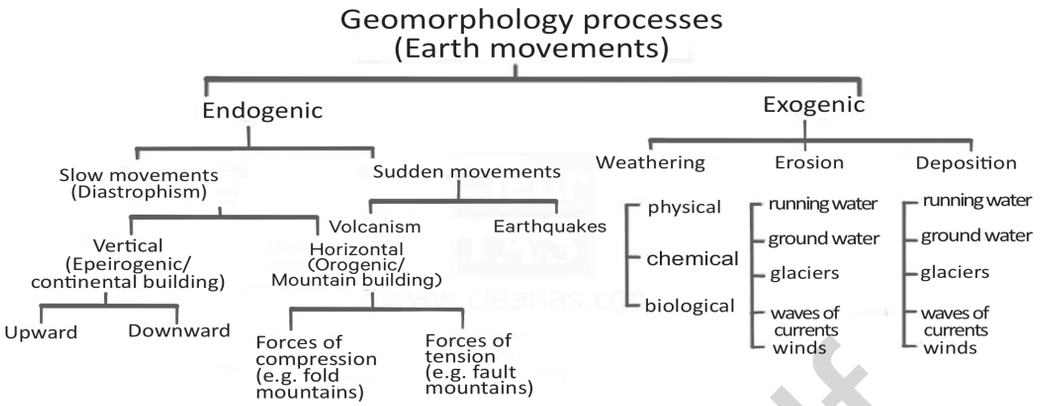
- **Positive Impact:**
  - Formation of fertile soil
  - Scope for geothermal energy
  - Promotion of Tourism
- **Negative Impact:**
  - Loss of Human Life and Property:
  - **Lahars:** When ash and mud from volcanic eruptions mix with rainwater or snow meltwater, mudflows called lahars are created.
  - Change in Climate

Volcanoes in News

Volcano	Location	Important Facts
Mt. Semeru	Java, Indonesia	Highest volcano in Java; one of the most active.
Fukutoku-Okanoba Submarine Volcano	In Pacific Ocean, north of Japan's South Iwo Jima Island	Sumbarine volcanoes are underwater fissures or vents. Basaltic lava is erupted forming new crust.
Mt. Sinabaug	North Sumatra, Indonesia	It is a stratovolcano.
Mt. Nyiragongo	Democratic Republic of Congo	One of the most active volcanoes. Associated with the Albertine rift.
Sangay	Eucador	It is a startovolcano. It was formed by volcanic processes associated with the subduction of the Nazca Plate under the South American Plate at the Peru–Chile Trench.
Hunga Tonga-Hunga Ha'apai	Tonga	Underwater Volcano (Pacific Ocean)Jan 2022 eruption had resulted in atmospheric shock waves, sonic booms, tsunami waves, disturbances in space and reshaped the Pacific ocean floor.
Mauna Loa	Hawaii	One of the five volcanoes that make up the Pacific Ocean's Hawaiian Island.

GEOMORPHIC PROCESSES

The forces bringing about changes in the Earth's surface configuration are called **Geomorphic Processes.**



Classification of Geomorphic Process

Endogenic Processes

- Internal Forces
- **constructive forces** as they are responsible for creating relief features like mountains
- **Source of Energy:** convective currents generated within the Earth.

Types of Endogenic Processes

- **Sudden forces and movements:** Earthquakes and Vulcanism
- **Slow forces and movements (Diastrophic forces):** responsible in continental building processes, mountain building processes, on the Earth surface.

Types of diastrophic movements

Epeirogenic Movement	Orogenic Movement
It is a vertical movement.	It is a horizontal movement.
It involves upliftment or subsidence of areas.	It involves forces of com- pression and tension.
It is responsible for formation of continents	It is responsible for folding, faulting and mountain building.

Folds

The crustal rocks are subjected to the compressional force generated by the horizontal movement of the plates. The rocks under this force form **wavy undulations** called **folds**.

Type of Folds	Details
Symmetrical Fold	These are folds where the axial plane is vertical and both the limbs incline uniformly.
Asymmetrical Fold	They are folds where the axial plane is inclined and the limbs of the anticline dip in opposite directions.
Overturned Fold	It is a type of fold where the axial plane is inclined and both the limbs dip in the same direction but at different angles.
Isoclinal Fold	These are folds where two limbs dip at equal angles in the same direction.
Recumbent Fold	These are characterised by a horizontal axial plane.
Chevron	These are folds with sharp and angular crests and troughs.
Fan Fold	Limbs of a fold are overturned to such an extent that it looks like a fan.
Open Fold	The angle between two limbs is usually greater than 90 degrees but less than 180 degrees, are called open folds.

Type of Folds	Details
Closed Fold	Folds where the angle between two limbs is less than 90 degrees
Nappe	These folds result from intense horizontal movement and high compressional forces. They are formed from recumbent folds.
Anticlinorium	Formed when there is a series of minor anticlines and synclines within one extensive anticline.
Synclinorium	Formed when there is a series of minor anticlines and synclines within one extensive syncline.

Faults

A fault is a fracture or cracks on the earth's crust. herTe is displacement of rocks on both sides of the fault and parallel to it. This displacement occurs due to both **tensional** and **compressional** forces acting horizontally or vertically or both together at the same point in time.

Types of Faults

Type of Faults	Details
Normal Fault	Formed due to tensional forces that tend to pull the crust apart.
Reverse Fault	Formed when both the blocks along the fracture are moving towards each other. These faults are formed due to compressional forces.
Strike-Slip Fault	Formed when the rock masses slip past one another parallel to the strike.
Transform Fault	These are a type of strike-slip fault.These faults can be seen in the transform plate boundary. For instance, the Dead Sea transform fault.

Graben and Horst

- A trench-like feature with straight, parallel walls is called **Graben** or **Rift Valley**. They are formed when a block of rock drops down between two normal faults.
- When a block is elevated between two normal faults, a **horst** is formed. They have a flat top but steep, straight sides. Horsts and Grabens are very common in the East African Rift Valley.

Exogenic Processes

- **Exogenic processes** are **destructive processess**.
- These result in wearing down of surfaces commonly known as **denudation**.
- **Source of energy:** Exogenetic processes derive energy from the sun

Types of Exogenic Processes

Weathering

Weathering is defined as mechanical disintegration and chemical decomposition of rocks through the actions of various elements of weather and climate.

- Weathering is the primary stage of denudation.
- **Factors Affecting Weathering:** climate, topography and vegetation, aspect etc.

Types of Weathering

- **Physical weathering**

Physical or **mechanical weathering** is the physical disintegration of minerals into fragment particles without any change in their chemical properties.

Type of Physical Weathering	Details
Frost Shattering	In cold regions, rocks have small cracks which are when filled with water in day time, freezes and expands and break the rock from within.

Type of Physical Weathering	Details
Insolation Weathering	In arid regions, during the day temperatures rise and heat the rock and it expands. Then at night, when temperatures fall, the rock also cools and contracts. This leads to exfoliation where the top layers of rock peel away.
Unloading	When igneous roks such as granites, are exposed to the surface by erosion or uplift, the intense pressure is released. As a result, developing cracks and joints parallel to the surface.
Salt Weathering	The saline water present in the pore spaces evaporates with rise in temperature in day time and leave behind salt crystals. The expanding salt crystals exert pressure on the walls of rock pores, thus, causing disintegration or foliation of rock

- **Chemical weathering**

Chemical weathering refers to decomposition of a rock to create a new chemically different material.

Type of Chemical Weathering	Details
Oxidation	The breakdown of rock by oxygen and water, often giving iron-rich rocks a rusty-coloured weathered surface.
Solution	Removal of rock in solution by acidic rainwater. Example: limestone is weathered by rainwater containing dissolved CO2 (process called carbonation)
Hydrolysis	The breakdown of rock by acidic water to produce clay and soluble salts.
Reduction	When oxidised minerals are placed in an environment where oxygen is absent, reduction takes place. Such conditions exist usually below the water table, in areas of stagnant water and waterlogged ground.

- **Biological weathering**

The weathering caused by living organisms is called Biological weathering. This type of weathering showcases both physical and chemical weathering.

Significance of Weathering

- Weathering weakens the surface materials on the surface of the Earth.
- It helps in soil formation by facilitating silt, clay, and sand.
- Weathering of rocks helps in making fertile plains, beach- es etc.
- Minerals created by the weathering process are supplied as nutrients for plant uptake.

MASS MOVEMENTS

Mass movements can be defined as the transferring of mass of rock and debris down the slopes under the direct influence of gravity. Mass movements are aided by gravity and not influenced by geomorphic agents like running water, glaciers, wind, waves and etc.

Modes of mass movement

The mass movement is followed by different modes of movements downhill, like slide, flow and heave.

- **Slide:**In slide movement, the maximum motion is found along the base of the moving mass. Clearly visible layer that divides the mobile upper layer and stable lower mass and the plane separating is called a **shear plane.**
- **Flow:** In flow movement the material above the shear plane reaches the maximum speed at top, while rate of movement diminishes with increasing depth till it reaches zero along the shear plane.
- **Heave:** This type of mechanism move particles ranging from the size of fine clay to large boulder. A very slow rate is maintained.

Types of mass movements

Mass Movement	Details
Solifluction	The soil flow cover the surface with water saturated mass. The ground that experiences solifluction is broken into gently, terrace-like features.
Soil Creep	Slow movement of soil along the slope under the influence of gravity.
Mudflow and Earthflow	The process of mud flow occurs in a large scale, earth flow happens on any surface in a localised manner.
Landslides	These are sudden rapid slide movements.They are common to areas that have steep slopes and unconsolidated soil surface. Triggering factors are heavy rainfall and earthquakes.
Liquefaction	Earthquakes result the clay rich rocks to behave like plastic matter, causing liquefaction.
Avalanches	A mass of snow, rock, ice, and soil that tumbles down a mountain.

Erosion and Deposition

- Erosion is the process in which earthen materials are worn away and transported by natural forces such as wind or water.
- Deposition is the laying down of sediment carried by wind, flowing water, the sea or ice. Sediment can be transported as pebbles, sand and mud, or as salts dissolved in water.

ROCKS AND MINERALS

MINERALS

A mineral is an inorganic natural compound. It has distinctive chemical and physical properties, composition, and atomic structure.

Types of Minerals

Minerals are classified based on their chemical composition.

Type	Description	Examples
Silicate Minerals	These minerals are composed of silicon and oxygen.	Quartz, feldspar, mica, olivine
Carbonate minerals	These are minerals that contain carbonate ions	Calcite
Sulphide Minerals	These are minerals containing sulphide or disulphides.	Pyrites, iron sulphides
Metallic Minerals	These minerals have metal content.	Iron, manganese, copper

ROCKS

Rocks are aggregates of one or more minerals. They are shaped and transformed by different geomorphic agents such as wind, water, etc. and are also transformed under extreme pressure and heat.

Igneous Rocks	Sedimentary Rocks	Metamorphic Rocks
• Do not have any stratification i.e., they do not have layers. • Usually granular and crystalline. • Primarily composed of silicate minerals. • Generally hard, and less porous • Least affected by chemical weathering. • Do not contain any fossils as they are formed directly from very hot magma. • Minerals like **iron ore, gold, silver, zinc, lead cop- per, aluminium, etc.**, are generally found in igneous rocks	• Stratified-layered structure. • Contain fossils embedded between different layers. • Non-crystalline in nature. • Permeable and porous. • Found over the largest surface area of the earth- around 75%. • Resources like coal, petroleum, and natural gas are contained in sedimentary rocks.	• Hard and therefore resistant to erosion and weathering. • Do not contain any fossils. • Show **lineation or foliation**. • Some metamorphic rocks are **banded rocks** • Metamorphic rocks supply building materials such as marbles and slates

Name of the Rock	Type of Rock	Name of the Metamorphic Rock
Limestone	Sedimentary Rock	Marble
Dolomite	Sedimentary Rock	Marble
Sandstone	Sedimentary Rock	Quartzite
Shale	Sedimentary Rock	Slate
Granite	Igneous Rock	Gneiss
Slate	Metamorphic Rock	Schist/ Phyllite
Phyllite	Metamorphic Rock	Schist

WORK OF RIVER

DRAINAGE SYSTEM

The flow of water across well-demarcated channels can be defined as "**drainage**" and the network of such channels is called the "**drainage system**".

Types of Drainage System

The drainage system can be broadly divided into two systems: Sequent Drainage Systems and Insequent Drainage Systems.

Type	Sub-Type	Details
Sequent Drainage System	**Consequent Drainage System**	The streams of the river follow the initial slope of the land surface. Example: **Godavari**, and **Kaveri**
	Subsequent Drainage System	The rivers have originated after the consequent stream. It is a tributary river. It has been formed due to erosion of non-resistant rock after the main drainage system has been established. Example: **Yamuna**.
	Obsequent Drainage System	The rivers flowing opposite the main consequent river are called obsequent streams. Example: the **tributary of Ganga** flowing northward from the Siwalik ranges.
	Resequent Drainage System	The river flow is in the direction of the main consequent river but originate at a much later stage. Since the stream is of recent evolution compared with the mainstream, they are called resequent streams.
Insequent Drainage System	**Antecedent Drainage System**	The streams that originated before the upliftment of the land. This means the rivers are older than the existing land itself. Example: **Indus**, **Sutlej**, river **Brahmaputra**.
	Superimposed Drainage System	The streams do not correlate with the underlying rock structure; they originally formed over rocks that have now been removed due to denudation. Example: **Damodar**, **Subarnarekha**, **Chambal**, and **Banas.**

DRAINAGE PATTERNS

It is the pattern or different geometric shapes formed by a river and its tributaries on a drainage basin.

Types of Drainage pattern

Drainage Patterns	Details
Dendritic Drainage	The drainage pattern holds a tree branch-like shape. Example: **Indus, Mahanadi,** and **Godavari**.

Drainage Patterns	Details
Trellised Drainage	The primary tributaries of the river flow parallel to each other and the secondary tributaries join them at right angles.Example: River **Seine** in France.
Rectangular Drainage	It is formed when the tributary rivers meet the main river at steep angles. Example: **Chambal, Betwa,** and **Ken**.
Radial Drainage	Formed when a river diverges outward from a central elevated point in all directions. Example: **South Koel, Subarnarekha, Kanchi,** and **Karo**.
Centripetal Drainage	Formed when streams converge at a point, that is the streams flows towards a central depression. Example: lower **Chambal** basin.
Annular/ Circular Drainage	Formed when the tributaries of the main river are developed in the form of a circle. Example: The Sonapet dome of Uttarakhand.
Parallel Drainage	The tributaries run parallel to each other and follow the normal slope of the land. Example: Several rivers emerging from the western ghats and flowing into the Arabian Sea
Barbed Drainage	Formed when the tributaries flow in opposite directions to the mainstream. Example: **Arun** River.
Pinnate Drainage	Resembles the veins of a leaf. Developed in narrow valleys surrounded by steep ranges. The tributaries from the steep ranges join the mainstream at acute angles. Example: **Son** and **Narmada**.

THE COURSE OF A RIVER

Generally the course of a river passes through three stages from its origin to join the ocean.

Youth Stage

- This stage begins from the origin of the river, generally from a mountain or a hill top.
- Under the influence of gravity, the river descends the slope swiftly.
- As the river's velocity is very high it cuts through the slopes in a vertical direction.
- This results in the formation of V-shaped valleys.

Mature Stage

- The river flows through a gentler slope. Lateral erosion becomes predominant over the vertical erosion.
- There is active erosion on the river banks. As a result, the V-shaped valley is widened.
- A large number of tributaries join the main river.
- As a result of the confluence, the volume of water increases resulting in an increase in the river's load.
- Marked by meanders, alluvial fans and cones, river terraces, levees, and flood plains.

Old Stage

- The river flows through large, flat surface.
- The slope of the land is very gentle.
- The river is heavy with large debris brought down from the upper course.
- As a result, the velocity of the river slows down.
- There is no vertical erosion, marked by lateral erosion of the banks.
- At the end of the old stage, the river forms old undulating plain known as the peneplain.

Landforms Formed by Rivers

Erosional Landforms		Depositional Landforms	
River Valleys	are extended depressions through which the river flows across its course.	**Alluvial Fans & Cones**	is a cone-shaped depositional landform built up by streams with sediment load.
Gorges	are narrow valley with steep, rocky walls between hills or mountains. Example, the Kali Gandaki Gorge.	**Flood Plains**	are the flat, gentle sloping land adjacent to the river.

Erosional Landforms		Depositional Landforms	
Waterfall	is the river water descending with a sudden fall from a height. Example: The Niagra Falls in the USA	**Natural Levees**	are low height ridges that are built by the deposition of sediments along the banks of the river.
Canyon	Is a deep gorge with a river flowing through it. Example: Grand Canyon of Colorado River in Arizona (USA)	**Point Bars**	are sedimentary deposits that are formed on the inner bank of the river bends.
Rapid	are smaller variant of waterfalls, formed when the river flowsthrough areas of unequal resistance of hard and soft rocks.	**Braided Channel**	A river with numerous distributaries is called a braided channel.
Potholes & Plunge Pools	are circular depressions found in the rocky beds of river valleys. Larger size potholes are called plunge pools.	**Deltas**	are triangular or fan-shaped features formed at the river's mouth due to regular deposition of the sediments.
River Terraces	These are narrow flat surfaces on either side of the valley floor.	**Arcuate Delta**	These deltas look like an arc of a circle. Example: Nile Delta, Ganga Delta
River Meanders	These are the bendings in course of a river. They are formed when river water erodes the banks on the outside of the channel and sediments are deposited inside the channel.	**Bird-foot Delta**	It has widely spaced distributaries, making it look like a bird's foot. Example: Mississippi River forms a bird-foot delta.
Ox-bow lakes	It is a small lake formed in an abandoned meander loop of a river channel. Example: **Kanwar Lake** in Bihar is Asia's largest ox-bow lake.	**Cuspate Delta**	They are formed when a river flows into the sea or ocean, and the sediment brought along collides with the waves. Example: **Tiber** River

WORK OF GLACIERS

A glacier is a large mass of ice that moves slowly, steadily and persistently over land by virtue of its own weight under the influence of gravity.

TYPES OF GLACIERS

Types	Details
Continental Glaciers	• Vast masses of ice sheets covering large stretches of land. • Found in Antarctica and in Greenland.
Ice Caps	• Thick layer of ice and snow that covers large areas of land. • Usually found in the North and South Poles on earth.
Pedimont Glaciers	• Occur when steep valley glaciers flow into relatively flat palins, where they spread out into a fan or bulb shaped lobe. • Example: The Malaspina Glacier in Alaska.
Valley Glaciers	• Streams of flowing ice that are confined within steep walled valleys, often following the course of an ancient river valley.

LANDFORMS FORMED BY GLACIERS

Erosional Landforms		Depositional Landforms	
Cirque / Corrie	**Cirques** (in French) or **Corries** (in Scotland) are bowl-shaped depressions.	**Snout**	It is the lowest end of a glacier. The glacier snout motion is extremely slow.

Erosional Landforms		Depositional Landforms	
Tarns	After the glacier melts, water fills up the cirques and these are later called **Tarns or Corrie lakes or Cirque lakes.**	**Erratics**	They are large rock fragments that have been transported by moving glaciers, from their original place and deposited in some other area.
Arete	An Arete is a steep sided ridge which is formed when two adjacent cirques erode towards each other.	**Moraines**	Moraines consist of pieces of rock that are embedded in the glaciers & brought down to the valley.
Pyramidal Peak	A pyramidal peak is formed when three or multiple cirque glaciers diverge from a single point.	**Terminal Moraines**	These are found at the snout of the glaciers. Formed due to deposition across the retreating ice sheet.
Horns	Horn is a single pyramidal peak which is formed when the summit is eroded by cirque basins on all the sides.	**Lateral Moraines**	They are formed on either side of the glaciers.
Bergschrund	A Bergschrund is a deep vertical crack which is formed during summers at the head of the glacier in the point where the glacier starts to flow.	**Medial Moraines**	They are formed due to the deposition of glacial sediments along the inner margins of two glaciers at their confluence.
Roche moutonnee	It is a resistant residual rock hummock or mound that has long thin stripes formed by ice-movements.	**Ground Moraines**	They are formed due to deposition of glacial sediments at the floor of glacial valleys.
Crag and tail	Crag is a mass of hard rock with a steep slope on the upward side, which protects the softer leeward slope from being completely worn down by the oncoming ice.	**Drumlins**	Drumlins are oval-shaped hills that are mostly found in clusters. They are formed as a result of deposition of glacial sediments.
U shaped glacial Troughs	As the glaciers make their downward journey, they are fed by ice from several corries like tributaries that join a river. The moving glaciers start to wear away the sides and floor of the valley down through which it moves. Forming the U shaped troughs.	**Eskers**	Eskers are long, narrow, sinuous ridges composed of sands & gravel deposited by meltwater in glacial tunnels.
Hanging Valleys	As the erosion takes place with the movement of the largest glacier, it forms the main valley that is joined by the tributary glaciers that create tributary valleys. After the ice has been melted, a tributary valley hangs above the main valley & water plunges down as a waterfall.	**Outwash Plains**	Outwash plains are created when the glaciers reaches its lowest point and melts and leaves behind a stratified deposition material that consists of rock debris, clay, sand, gravel.
Ribbon lakes	After the disappearance of the ice, the deep sections of long, narrow glacial troughs are filled with water forming Ribbon lakes.	**Kettle lake**	The kettle lakes are depressions in the outwash plain left by the melting of masses of stagnant ice.
Rock Basins	A glacier erodes & excavates the bedrock in an irregular manner. The unequal excavation gives rise to many rock basins later filled by lakes in valley trough.	**Kames**	They are small rounded hills made up of sand and gravels that cover a part of the plain. also called **Hummocks.**
Rock Steps	When a tributary valley joins a main valley, the additional weight of ice in the main valley cuts deep into the valley floor & deepest at the point of convergence forming rock steps.		
Fjord	As the glacier flows from the mountains to the sea, it drops the load of moraine that it carried along in the sea. As the lower end of the trough is drowned by the sea, it forms a deep, steep side inlet called a Fjord.		

WORK OF WIND

The wind is the most important agent of landscape development in arid and semi-arid regions of tropical and temperate environments. They are not active in cold deserts because the surface is always active with permanent ice sheets.

LANDFORMS FORMED BY WIND ACTION

Erosional Landforms		Depositional Landforms	
Blow-outs	Depressions formed in the deserts due to the removal of sands by the process of deflation.	**Ripple mark**	These are small wave-like features. They may be longitudinal or transverse.
Inselbergs	These are sharply rising residual hills of resistant rocks.	**Loess**	It is a wind-blown deposit of fine silt and dust.
Mushroom Rocks	These are rocks having broad upper parts and narrow bases. Formed due to abrasion by wind.	**Sand Dunes**	Dunes are mounds of loose sand. Sand dunes are formed by the accumulation of sand which occurs as the wind speed is decreased.
Zeugens	They are tabular masses of more resistant rocks resting on softer underlying rocks.		**Fluvial Desert Landforms**
Yardangs	They are sharp sinuous ridges and parallel depressions. They are formed due to differential abrasion of alternate vertical bands of hard and soh rocks.	**Wadis**	These are ravines like valleys often with interlocking spurs.
Ventifacts	They have one or more polished faceted surfaces. A ventifact with three faceted sides is called a **dreikanter.** A ventifact with two faceted sides is called **Einkanter.**	**Badlands**	A surface intensely dissected by numerous wadis produce a typical Badlands topography.
Demoiselles	They are rock pillars having resistant rocks at the top and soft rocks at the bottom.	**Playas**	Water collects in the centre of the bolsons and forms temporary lakes called Playas.
Wind bridges and windows	Wind windows are holes formed across rocks due to abrasion. When these holes enlarge in such a way that an arch-like feature with intact roof is formed, it is called a **wind bridge.**	**Bolsons**	The intermontane basins in arid and semi-arid areas are called bolsons.
		Mesas and Butes	When an arid plateau is capped by a resistant and horizontal bed, wind and water action erode it into mesas and buttes. Mesas are flat -topped, steep-sided tabular bodies detached from the main plateau. Smaller mesas are called buttes.
		Pediments	They are broad, extensive and gently sloping areas of rock-cut surfaces.
		Bajada	Gently sloping depositional plain between pediments and the playa is called Bajada.

GROUNDWATER AND ASSOCIATED LANDFORMS

The term groundwater refers to the water that is found below the earth's surface. It is estimated that groundwater accounts for about 0.6% of the earth's total water.

COMPONENTS OF GROUNDWATER

- **Unsaturated zone:** It lies immediately below the land surface.
  - It is also called vadose zone or aeration zone.
  - In this zone, the pore spaces of the rocks are partially filled with water and partially filled with air.
- **Saturated zone:** It is a zone in which all the pores and rock fractures are filled with water.
  - It underlies the unsaturated zone.
- **Water Table:** The top of the saturated zone is called the water table.
- **Aquifer:**

- These are storage pools of groundwater below the surface. The water keeps moving downwards until it reaches a layer of impermeable rocks where further downward movement stops.
- In an aquifer, there is enough groundwater that it can be pumped to the surface and used for drinking water, irrigation, industry, or other uses.

- **Aquicludes:** These are layers that are relatively impermeable to groundwater.
  - Examples of Aquiclude layers are Clay and shale beds.

- **Porosity**: It means the amount of empty space in a given material. These empty spaces are called pores and can hold fluid in them.
  - Porosity of rocks means the ability of the given rock to hold fluid within its pore space.
- **Permeability:** It measures the ease with which a fluid can move through porous rock.
  - High permeability means pore spaces are well connected.
  - Low permeability means the pore spaces are poorly connected and isolated.
  - Pebble, gravel, sand are permeable rocks.
  - Clay is an example of imperable rock.

WELLS

Wells: These are artificial/man-made holes dug on the earth's surface to procure water from the ground.

Types of Wells

- **Permanent well:** Wells dug up to the permanent water table.
  - Such wells contain water for all seasons.
- **Intermittent well:** Wells dug up to the temporary water table.
  - Such wells have water only during the rainy season.

Artesian Well

It is a well from where water gushes out automatically like a fountain on the ground due to hydraulic pressure. The type of well is named after the Artois province of France

- **Found in:** Areas where **synclinal folded structure** of saucer-shaped is present. It should have a layer of permeable rock lying between two layers of impermeable rock.
  - Examples: Found in New South Wales of Australia, Kansas in USA, Tarai region of Uttarakhand in India
- **Process of Formation:**
- Rainwater enters the permeable layer from the exposed ends, and the layer becomes saturated with water.
- When a well is dug, water is forced up by the hydraulic pressure.

SPRINGS

Spring is a **flow of water coming out naturally** from the ground.A spring can form under different conditions.For example, in areas of tilted strata, where permeable and impermeable rocks alternatively placed, water emerges at the base of the permeable layers.

Types of Springs

- **Perennial springs**: When water flow remains constant, it is called permanent or perennial springs.
- **Intermittent Springs:** When the supply of water in the spring ceases sometimes, it is called intermittent spring.
- **Hot springs:** Springs emitting hot water are called hot springs.
  - They are formed when the groundwater is heated by magma underneath the earth's surface.
  - Examples: Hot springs in Sakhalin Island (Russia), Rajgir of Jharkhand, Bakreshwar in West Bengal (India).
- **Geysers:** It is a special kind of hot spring. It spouts hot water and steam at a regular interval.
  - The main difference between a hot spring and geyser is that there is continuous flow of water in the former, while, the flow of water is intermittent in the latter.

- They are generally found in areas which have witnessed volcanic activities.
- Examples: Old Faithful Geyser in USA.

- **Scarp-foot spring:** These are springs occurring at the junction of two rock-beds on the scarp-fault region..
  - A series of springs may occur along the line of weakness of fault and is called **spring line.**
- **Vauclusian spring:** These are found in limestone regions where water enters holes and disappears underground.It then comes out as a fountain of water.
  - It is named after "Fountain de Vaucluse", a spring in France.

KARST TOPOGRAPHY

The term Karst is applied to limestone and dolomite areas that possess unique topographical features. These features are formed due to the action of groundwater.

Distribution of Karst Topography

- Central Massif region of France
- Pennies of England,
- Western slope of Appalachian Mountain in the USA
- Kumaon Himalayan region of Uttarakhand, Khasia Hills of Meghalaya in India.

Conditions for development of Karst Topography

- Well bedded, jointed, outcrop of a massive limestone/ dolomite.
- Sufficient rainfall to dissolve carbonate rocks.
- Rocks should be near the surface to allow easy penetration of rainfall.
- Highly folded or fractured or faulted rocks.
- Relief that allows good underground circulation of water.

Process of development of Karst Topography

- When rainwater falls, the atmospheric carbon dioxide combines with it and forms a weak acid called carbonic acid.
- The carbonic acid reacts with the carbonate in the limestone and forms bicarbonates which are soluble in water.
- This solution percolates through rock, dissolves limestone and forms a series of landforms.

Karst Topography Landforms

Erosional Landforms		Depositional Landforms	
Terra Rossa	It is red clayey soil formed when groundwater through the process of the solution weathers limestone or dolomite.	**Stalactites**	It is a formation that hangs from ceiling of caves that is composed of sand, lava, mud
Karren/Lapies or Clints	It is a surface characterized by numerous low ridges, clefts, and pits. They are formed by the solutional action of groundwater.	**Stalagmites**	It is an upward-growing mound of mineral deposits that have precipitated from water dripping onto the floor of a cave.
Sink Holes	These are saucer-shaped or funnel-shaped depressions of varying depths.	**Columns**	Stalactite and stalagmite may join to form a column.
Dolines	As a result of further solution of limestone, sinkholes combine to form dolines. They are larger in size and rounded or elliptical in shape.		
Solution Pan	A shallow doline covering a large area is called a solution pan. Example: The solution pan of Lost River of Indiana (USA).		
Karst Windows	These are formed due to the collapse of the upper surface of the sinkholes or dolines.		

Erosional Landforms		Depositional Landforms
Uvalas	Several dolines merge together to form a large depression called Uvalas.	
Poljes	These are large depressions formed by the coalescence of several Uvalas. Example- Livno Polje of Balkan Region.	
Caverns	They are an underground cave formed by water action by various methods in a limestone or chalk area.	
Natural Bridge:	When a part of the cavern collapses the portion, which keeps standing forms an arch or a natural bridge.	

ACTION OF SEA WATER

The sea waves and tsunamis are the most powerful agents of marine erosion.

- Currents are relatively less impactful means of erosion but are important means of transportation.
- Tides are mainly agents of deposition.

FORMATION OF SEA WAVES

Sea waves are undulations of seawater. The waves are caused by friction between the water and blowing wind.

- As the wind blows, it transfers its energy through friction, causing the water to move in a circular motion.
- As the wave nears the shore, friction of these circular waves with the seafloor causes the wave base to slow down.
- The top of the wave curves over until the wave crashes and breaks on the shore.
- Finally, the water recedes into the sea.

TYPES OF WAVES

- **Constructive Waves**: These waves gently roll over the coasts and help deposition on the coast.
- **Destructive waves:** These waves roll over the coast with tremendous force and erode coastal rocks.

COASTLINES AND SHORES

- **Seashore:** The zone of land immediately adjacent to the sea.
- **Shoreline:** The line of demarcation between the land and the sea.
  - **Division of shore**: The shore can be divided into three zones-nearshore, foreshore, and backshore.
  - **Nearshore**:It is always underwater.
  - **Foreshore:**It is the part extending from the mean low water line to the highest elevation reached by waves at normal high tide
  - **Backshore:** It is the part of the seashore between the foreshore and the coastline covered by water only during storms.
- **Coast:** The part of land adjoining the sea.
- **Coastline:** The boundary between the coast and the shore.

Types of Coastlines

- **Coastlines of submergence:** These are coasts formed due to the sinking of land or the rise of the sea.
  - **Ria coasts:** These are formed due to the submergence of river valleys. Example: The Ria de Aveiro lies on the Atlantic coast of Portugal.
  - **Fiord Coasts:** They are formed due to the submergence of U-shaped glacial valleys. TFiords are common along the coast of Norway, Alaska, and British Columbia.

- **Dalmatian Coasts:** They are formed by submerging mountain ridges with alternative crests and troughs. Example: Coast of Dalmatia, Yugoslavia, along the Adriatic Coast.
- **Drowned lowland:** It is formed by submergence of the low-lying areas and is characterised by bars and lagoons. Example: Baltic coast of East Germany.

- **Coastlines of Emergence:** These are formed due to rising land or lowering the sea. Example: Coromandel Coast, .
- **Neutral Coastlines:** These are formed by the deposition of materials into the sea. They are formed neither due to emergence or submergence. They comprise deltaic and alluvial plain, volcanic coastline, and coral reef coastline.
- **Compound coastlines:** These are formed by both emergence and submergence. Example: Coastlines of Norway and Sweden.
- **Faulted Coastline:** These are formed due to the submergence of a downthrown block along a fault. Example: Santa Lucia Mountain coast of central California.

Landforms Formed by Action of Sea Water

Erosional Landforms	
Chasms	Chasms are narrow and deep indents on the coastline. They are formed when on the sea-facing side, hard and soft rocks occur in alternative bands.
Bay	The wave action wears away the soft rocks forming indents. The chasm widens till it forms a bay.
Capes	The hard rocks which are left project as capes in the seawater.
Sea-cliffs	A steep rocky coast rising almost vertically above the seawater is called a sea cliff.
Wave-cut Platforms	When Sea waves strike a cliff continuously, the cliff gradually retreats over time. A rock cut flat surface is formed in front of the cliff, called a wave-cut platform.
Cave	Sea caves are formed at the base of a cliff. Sea waves erode softer rocks at the base quickly creating holes or hollows. These hollows over time enlarge to form sea caves.
Arch	It is formed when two caves develop on either side of projected rock and ultimately unite.
Stack	When the roof of the arch collapses and the end sides remain standing, a pillar-like structure on the coast is formed. It is called a stack.
Stump	When the stack is eroded further, the height of the stack is reduced to form a stump.
Blow-hole/ Gloup	Continued action of sea waves make holes on the cave roof. This hole is called a Gloup or blow hole.
Geo	With further erosion, the blowholes enlarge and the roof collapses. A long, narrow inlet calle Geo is developed.

Depositional Landforms	
Beaches	These are deposits of marine sediments consisting of sand, shingles, cobbles etc on the sea shore
Spits and bars	Spit is a low-lying ridge of sands and pebbles with one end connected to the mainland and the other end terminating into the sea.
Hook	A bended spit is called a hook
Bar	It is a ridge of sand lying parallel to the coast. They are submerged features.
Tombolo	When a bar extends and joins an island to the mainland or joins two islands, it is called a tombolo.
Lagoons	The enclosed area of seawater between a bar and the coast is called a lagoon. Example:Chilka lake on the Odisha coast

MOUNTAINS, PLATEAUS, PLAINS AND LAKES

Mountains, plains, plateaus and lakes are the major landforms on the earth's surface that are formed by the exogenic and endogenic forces.

MOUNTAINS

Mountains form the second order landform on the earth's surface. Around 27% of the world's land surface is covered by mountains. Mountains are the source for 80% of the earth's fresh surface water.

Types of Moutains

Based on Location

	Continental Mountains		Oceanic Mountains
	Coastal Mountains	Inland Mountains	
Location	Located near coastlines	Located in landlocked part or inland portion of continents	Located on continental shelves and ocean floor.
Examples	Rockies, Appalachians	Black Forest, Vosges	Mauna Kea- Highest Mountain in the ocean near Hawaii
Examples in India	Western Gahats, Eastern Ghats	Aravallis, Himalayas, Satpura, Vindhyas	

Based on Period

Precambrian Mountains	Caledonian Mountains	Hercian Mountains	Alpine System
The pre-Cambrian Mountains lasted more than 4 billion years. Rocks- upheaved, denuded, and metamorphosed and remnants look like residual mountains. **Examples:** Laurentian mountains.	Formed due to Late Silurian and early Devonian period's massive mountain-building processes and tectonic movements. Formed approximately 430 million years to 380 million years ago **Examples:** Appalachians, Aravallis, Mahadeo	First appeared in Europe from the Carboniferous to the Permian periods- Approximately 340 million years and 225 million years ago **Examples:**Vosges and Black Forest mountains, Altai, Asia's Tien Shan Mountains, Ural Mountains.	Formed by the collision of the African and Eurasian tectonic plates tens of millions of years ago. **Example:** The Alps- Europe's highest and largest mountain range system.

Based on the Mode of Origin

- **Fold Mountains:** Folded mountains are formed due to folding of crustal rocks by compressive forces generated by endogenetic forces coming from within the earth.They

  Characteristics of Folded mountains:

  - Fold mountains are formed when two continental tectonic plates moving towards each other and collide at the destructive plate boundary forming the mountain ranges.
  - Folded mountains are the youngest mountains on the earth's surface.
  - The lithological characteristics of folded mountains reveal that these have been formed due to folding of sedimentary rocks by strong compressive forces.
  - Folded mountains are generally round in arch shape having one side concave slope and the other side convex slope.
  - Folded mountains extend for greater lengths but their widths are far smaller than their lengths.
  - Folded mountains are found along the margins of the continents facing oceans.
- **Volcanic Mountains:** The mountains formed as a result of volcanic activity is referred to as a volcanic mountain.
  - **Example:** Mauna Loa in Hawaii, Mount Popa in Myanmar, Mount Fuji Yma in Japan.
- **Block Mountains:** Block mountains are formed due to the **faulting** on a large scale . **Faulting** occurs when large areas or blocks of earth are broken and displaced vertically or horizontally.
  - The blocks which are uplifted are known as **horsts**, and the lowered blocks are called **graben.**
  - Block mountains are also known as **fault-block mountains** as they are formed due to faulting as a result of tensile and compressive forces.
  - **Example**: The Great African Rift Valley (valley floor is graben), The Rhine Valley (graben) and the Vosges mountain (horst)
- **Residual Mountains:** These mountains are formed by wearing down from the existing mountains i.e. Fold, Block or Volcanic Mountains. These mountains are worn out by the agents of denudation i.e. wind, water, glacier, waves etc.

- **Example**: Aravali, Vindhya, and Satpura.

PLATEAUS

A plateau is a flat-topped table land. The plateaus cover about 18% of the earth's surface. The plateaus are formed by the processes that create mountain ranges. They are:

Cause	Description
Volcanism	The plateaus are formed where extensive lava flows and volcanic ash buries pre-existing terrain. **Example**: Deccan traps.
Thermal Expansion	Refers to thermal expansion of lithosphere, i.e the replacement of cold mantle lithosphere by hot asthenosphere. **Example**: Yellowstone plateau of USA, Massif Central in France.
Crustal Shortening	It is the process of plateau formation by thrusting of one block or slice of crust over another or by the folding of layers of rock. The large heights of some plateaus are due to crustal shortening. **Example**: Tibetan plateau.

Types of Plateaus

On the basis of their geographical location and structure of rocks, the plateaus can be classified as:

- **Intermontane Plateau:** The plateau which borders the fold mountain range or are partly or fully enclosed within them are the intermontane plateaus.
  - **Example:** High plateau of Tibet, The plateau of Colorado.
- **Piedmont Plateau:** The plateaus that are situated at the foot of the mountains and are bounded on other sides by a plain or an ocean are called piedmount plateau.
  - **Example:** Malwa plateau in India, the Patagonian plateau in Argentina and the Piedmont plateau in America.
- **Continental plateau:** These are formed either by an extensive continental uplift or by the spread of horizontal basic lava sheets completely covering the original topography to a great depth.
  - **Example**: The volcanic lava covered plateau of Maharashtra in India, Snake River Plateau in North West USA. These are also, called the ptateau of accumulation.
- **Volcanic plateau:** A volcanic plateau is formed by numerous small volcanic eruptions that slowly build up over time, forming a plateau from the resulting lava flows.
- **Dissected plateau:** A dissected plateau forms as a result of upward movement in the Earths crust. The uplift is caused by the slow collision of tectonic plates.
  - **Example:** The Colorado Plateau in USA, has been rising about .03 centimeter a year for more than 10 million years.

PLAINS

A plain is a lowlying relatively flat or slightly rolling land surface with very gentle slope and minimum local relief is called a plain. Plains occupy about 55% of the earth's surface. Most of the plains have been formed by the deposition of sediments brought down by rivers. Besides rivers, some plains have also been formed by the action of wind, moving ice and tectonic activity. Plains have an average height of less than 200 metres.

Types of Plains

Types	Features
Outwash Plain	These plains are formed by glaciers. These plains are formed when a glacier deposits sediments at its terminus. As a glacier moves, it erodes the bedrock and carries the sediments eroded downstream. These sediments are deposited by the meltwater of the glacier at the snout. Example: Outwash plains in Iceland.
Till Plain	Plain formed by glacial action is known as till plain. Such plains are formed by the deposition of glacial till. When a sheet of glacial ice gets broken away from the main glacier it melts into places, the sediments are deposited on the ground to result in the formation of a till plain.

Types	Features
Lava Field	A lava field can also be referred to as a lava plain. Such a plain is formed by the accumulation of layers of lava. The lava plains can stretch for miles and are easily visible from the air or in satellite images where they appear darker in color than the surrounding landscape.
Lacustrine Plain	Lacustrine plains are formed in areas previously occupied by lakes. When a lake drains out completely due to factors like evaporation, natural drainage, etc., the sediments are left behind on the lakebed to form a plain. Such lacustrine plains might be highly fertile and support agriculture or might form a wetland or even a desert depending on the composition of the sediments. Example: The Kashmir Valley of India.
Scroll Plain	Scroll plains are formed in areas where a river meanders across a low gradient. Deposition of sediments at such locations results in the formation of a plain. Oxbow lakes are common occurrences in such areas. Example: The Taieri River forms a scroll plain near Paerau in New Zealand.
Flood Plain	A floodplain refers to a plain that stretches from the banks of a river or stream to the enclosing valley walls. Flood plains are prone to flooding when the adjacent water body overflows. These plains are often fertile and are made of deposits of silts, sands, levees, etc., deposited by floodwaters.
Alluvial Plain	They are vast plains, that are formed by the deposition of sediments called alluvium. As a river flows down mountains or hills, it carries along with it sediments because of erosion and such sediments are transported to the lower plain. As the sediments build up, the elevation of the floodplain increases while the width of the river channel decreases. Unable to bear the pressure, the river now looks for an alternative course with a higher channel capacity. Thus, the river forms a meander and flows through a new channel.
Abyssal Plain	These plains are located at greater depths on the ocean floor. These plains comprises of 50% of the surface of our planet. Such plains are considered to be formed by the deposition of sediments, derived from land.

LAKES

A lake is a water body that is surrounded by land apart from a river or other outlet that serves to feed or drain the lake. Natural lakes are in the mountainous areas, rift zones and areas with ongoing glaciation. Majority of lakes on Earth are fresh water, and most lie in the Northern Hemisphere.

Endorheic lakes: They are the lakes that do not have a natural outflow and lose water solely by evaporation or underground seepage or both.

Types of lakes

Types	Features
Fresh Water lakes	Most of the lakes in the world are fresh-water lakes are fed by rivers and with out-flowing streams. Example: Great lakes of North America.
Saline lakes	These lakes are formed where there is no natural outlet or where the water evaporates rapidly and the drainage surface of the water table has a higher than normal salt content. Example: Aral Sea, Dead Sea.
Tectonic lakes	The lakes are formed due to the warping, subsidence, bending and fracturing of the Earth's crust. Example: Lake Titicaca and Caspian Sea.
Rift valley lakes	The lakes are formed after the water is collected in troughs of the valley rift and their floors are often below sea level. Example: Dead Sea, Lake Tanganyika.
Cirque lakes	Cirque is a hollow basin cut into a mountain ridge. It has steep sided slope on the three sides, an open end on one side and a flat bottom. When the ice melts, the cirque may develop into a tarn lake.
Caldera lakes	In dormant or extinct volcanoes, rain falls straight into the crater or caldera which has no superficial outlet and forms a crater or caldera lake. Example: Lonar in Maharashtra.
Karst lakes	The solvent action of rain-water on limestone carves out solution hollows. When these become clogged with debris lakes may form in them.

CHAPTER 2

Climatology

ATMOSPHERE

The atmosphere is a life-supporting envelope, that surrounds the earth with a blanket of gases extending thousands of kilometers above its surface. It is held by the earth's gravitational force.

SIGNIFICANCE OF THE ATMOSPHERE:

- Maintains the temperature that supports life on the earth.
- Provides oxygen to animals and carbondioxide to plants.
- Carries rain that is needed for the survival of life on earth.
- Protects the earth from harmful ultra-violet rays of the sun.
- Prevent extra-terrestrial objects like meteors from hitting the earth's surface

Permanent Gases			Variable Gases	
Gas	Symbol	Percent(by volume)Dry Air	Gas(and Particles)	Symbol
Nitrogen	O_2	78.08	Water Vapor	H_2O
Oxygen	O_2	20.95	Carbon dioxide	CO_2
Argon	A_r	0.93	Methane	CH_2
Neon	N_e	0.0018	Nitrous oxide	N_2O
Helium	H_e	0.0005	Ozone	O_3
Hydrogen	H_2	0.0006	Particles(dust,soot,etc)	
Xenon	X_2	0.000009	Chlorofluorocarbons	

COMPOSITION OF THE ATMOSPHERE

The atmosphere is mixture of many gases. It also consists of large number of solid and liquid particles, that are collectively called as **"aerosols".**

Permanent Gases

They remain in fixed proportions to the total gas volume

Gas	Details
Nitrogen	• Most abundant • Plays an important role in controlling the combustion by diluting oxygen. • Essential for the growth and survival of plants and animals. • Primary nutrient for producing amino acids, proteins, and nucleic acids.
Oxygen	• Mostly produced by plant life on the earth. • Plays an important role in supporting life on the earth and in the combustion process.
Argon	• Inert Gas • Do not undergo chemical reactions with other chemical substances

Variable gases:

These gases vary from palace to place and from time to time.

Gas	Details
Water Vapour	Mostly found over warm, moist surface areas, such as tropical oceans. • The water vapour content in the air can vary from 0.02% in the cold desert regions to 4% in hot and wet regions. • Around 90% of it lies within 6 kilometres of the atmosphere. • **Significance:** • The water vapour plays a vital role in a number of cooling and warming processes in the atmosphere. • Water vapour absorbs the heat radiated from the earth's surface and preserves it. It deters the earth from becoming either too cold or too hot.
Carbon dioxide	• Distributed uniformly in the lower layers of the atmosphere. • **Significance:** • Helps in keeping the lower atmosphere of the earth warm. • Largely responsible for the greenhouse effect.
Ozone	• Made up of three atoms of oxygen • Abundantly found in ozonosphere • **Significance:** Absorb the harmful ultraviolet solar radiation

Particulate Matter and Aerosols

An aerosol is a collection of both particles (liquid and solid) and air while the particulate matter is only the particles suspended in the air.

Sources of particulate matter:

- **Natural:** volcanoes, fires,, sea salt, and wind-blown soil and sand, pollen
- **Anthropogenic:**Fossil fuels, biomass burning, construction activity

Significance

- Scatter or/and absorb electromagnetic radiation at different wavelengths.
- Serve as cloud condensation nuclei.

STRUCTURE OF THE ATMOSPHERE:

- The atmosphere extends from the Earth's surface to about 660 km.
- Around 97% of the air is concentrated in the first 25 kilometres.
- The atmosphere is divided into five layers based on how the temperature varies with altitude.

Layer	Characteristics
Troposphere	• Lowermost part of the atmosphere • Consists of 75% of the total gaseous mass of the atmosphere.Almost all aerosol and water vapour is present here. • The present of water vapour triggers weather activities in this layer • The altitude of the troposphere from the earth surface varies from 8 km at the poles and 18 km at the equator. Reason for higher altitude at the equator is the presence of hot convection currents that pushes the gases upward. • **Temperature:** Decreases with increasing altitude. • **Tropopause:** • An abrupt change in the lapse rate occurs at the height of 14 kms. The zone where the temperature undergoes an abrupt change is called the tropopause. • The **tropopause** separates the troposphere from the stratosphere.

Layer	Characteristics
Stratosphere	• Second layer that extends above troposphere • Extends from the tropopause upto an altitude of 50 km from the earth's surface • **Temperature:** Remains constant for some distance, later it rises at a negative lapse rate to reach a level of 0 degree Celsius at 50 km height. • The rise in temperature is due to the absorption of light by the ozone molecules in the ozonosphere. • the Stratosphere is almost free from clouds and there is absence of weather phenomenon in this region. Hence, its considered ideal for flying aircrafts, • **Clouds**: Cirrus clouds, known as 'mother-of-pearl clouds' or 'nacreous clouds', appear in the lower stratosphere • **Ozone layer**: It is the lower portion of the stratosphere which has the maximum ozone concentration • It is confined between the height of 15 km to 35 km. • It absorbs UV rays of the sun • **Stratopause:** Upper boundary of the stratosphere
Mesosphere	• Third layer of the atmosphere and is found above the stratosphere. • Starts at 50 km above the surface of the earth and extends up to 80 km. • **Temperature**: Decreases with height throughout the mesosphere. The coldest temperatures in Earth's atmosphere, about -90° C are found near the top of this layer. • **Clouds:** High-altitude clouds called **"noctilucent clouds" or "polar mesospheric clouds"** sometimes form in the mesosphere near the poles. • Most of the meteorites burn up in this layer. • **Mesopause:** Upper boundary of the mesosphere
Iosnosphere	• Located between 80 and 400 km above the mesopause • Contains electrically charged particles called ions • **Temperature:** increase in temperature with increasing height. • The radio waves transmitted from the earth are reflected to the earth in this layer. This has made radio broadcasting possible. • The layer helps shield Earth from the harmful shortwave forms of radiation. • The auroras occur in the ionosphere.
Exosphere	• Uppermost layer of the atmosphere. • extends beyond 400 kilometres above the earth's surface. • The air is very thin in this layer. • It is predominated by hydrogen and helium gases. • **Temperature:** gradually increases through the layer.

HEAT TRANSFER AND ATMOSPHERIC TEMPERATURE

HEAT TRANSFER

Heat transfer is concerned with the conversion or exchange of thermal energy between two physical systems. Sun is the prime source of energy for earth. The radiated energy from the Sun is transferred to the earth's atmosphere by four fundamental processes- **Radiation, Conduction, Convection and Advection.**

Processes of Heat Transfer

Radiation	Conduction	Convection	Advection
Occurs when the heat waves or the energy are emitted through electromagnetic radiation	When two objects of varying temperatures come in contact, heat energy flows from the warmer object to the cooler one until the equilibrium is achieved.	Convection is the transfer of heat energy from one part of a kuid (liquid or gas) to another by the movement of particles themselves.	Heat transfer resulting from the movement of warm molecules of fluid to the cooler molecules of a fluid in a horizontal manner.
Does not require medium. Heat transferred in vacuum.	Requires a medium for heat transfer.	Requires a medium for heat transfer.	Requires a medium for heat transfer.

Radiation	Conduction	Convection	Advection
No physical contact is required between the bodies.	Physical contact is required.	Heat transfers through intermediarysubstances due to temperature difference.	Heat transfers through intermediary substances due to pressure and temperature differences.
The rate of heat transfer is fast.	The rate of heat transfer is slow.	The rate of heat transfer is slow.	The rate of heat transfer is slow.
Occurs between two bodies with or without a medium.	Occurs in solids through molecular collisions.	Occurs in fluids by flow of heat in the molecules in a vertical direction.	Occurs in fluids by flow of heat in the molecules in a horizontal direction.

INSOLATION

Insolation is defined as the amount of solar radiation received on a given surface in a given period of time.

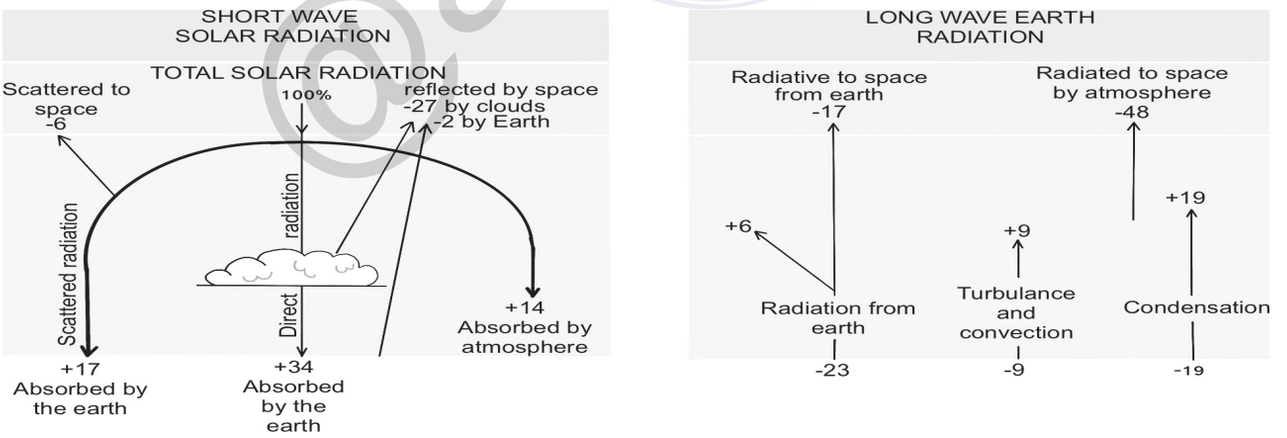
Factors influencing insolation

- Topographical variations.
- Revolution of earth in an elliptical path.
- Rotation of the earth on its axis.
- Length of the day.
- The transparency of the atmosphere.

Isohels are lines connecting points on the earth's surface that receive equal amounts of sunshine. Isohels are more or less parallel to latitudes, especially in the southern hemisphere.

HEAT BUDGET

The earth receives a certain amount of insolation (in the form of short waves) and gives back heat into space by terrestrial radiation (in the form of long waves). Through this give and take, the earth maintains a constant temperature. This is called as the heat budget of the earth.



TEMPERATURE

Temperature is the degree of hotness or coldness of a substance, object, or a region. In the atmosphere, the temperature is not the same and keeps varying. The temperature of a region primarily depends upon heat received by the regon from the sun.

Factors influencing distribution of temperature

- **Latitude of a region:** The amount of insolation is dependant on the inclination of the sun's rays. The inclination is determined by the position of the latitude. Suns's rays on the pole are inclined and sun's rays on the equator is direct.
- **Altitude of a region:** The atmosphere is indirectly heated by terrestrial radiation, Therefore, at the same latitudes, the lower layers of the atmosphere are warmer than the upper layers.
- **Differential heating of land and water:** The surface of the land tends to heat up faster as compared to that of the surface of the water.
- **Distance of a region from the sea:** The nearness to the sea produces a moderating effect on the air temperature on the coastal areas.
- **Effect of ocean currents:** There are fundamentally two types of ocean currents, that is, the warm ocean current and the cold ocean current and impact the temperature of the air.
- **Effect of the air mass:** The areas under the influence of a warm air mass experience higher temperatures and areas with cold air mass effect experience lower temperatures.
- **Effects of the local winds:**
  - At times, local winds can bring about a sudden change in temperature.
  - In northern India, a 'loo', localized warm air, raises the temperature so much that the heat lasts for several days in a row and many people die of sunstroke.
- **Location of the mountains:**
  - Higher insolation causes higher temperatures on the slopes of the mountains facing the sun.
  - A steeper slope experiences a rapid change in temperature rather than a gentler one.
  - Mountains having east-west alignment such as the Alps show a higher temperature on the south-facing 'sunny slope' than the north-facing 'sheltered slope'.
- **Nature of the region:**For instance, tropical deserts record high temperatures as they absorb the solar radiation. While snow contains high albedo and reflect insolation without absorption.

Temperature anomaly

The temperature anomaly can be defined as the difference between the mean temperature of any place and the mean temperature of its parallel. The temperature anomaly is also known as a thermal anomaly.

Lapse Rate

Lapse Rate	Environmental Lapse Rate	Adiabatic Lapse Rate
Definition: Rate of change in temperature observed while moving upward through the earth's atmosphere.	Definition: Rate of change in temperature observed while moving upward through the earth's atmosphere.	Definition: Rate of change in temperature observed while moving upward through the earth's atmosphere.

Temperature Inversion

The temperature inversion can be defined as the reversal of normal behaviour of temperature within the troposphere where the cooler air at the surface of the earth is overlaid by warmer air.

Conditions leading to temperature inversion:

- **Long winter nights:** In long winter nights the sky is mostly clear. This leads to faster cooling of the earth's surface due to faster terrestrial radiation.
- **Clear cloudless sky:** In cloudless skies the radiation pass unobstructed as a result the soil cools down faster and the air that comes in contact. But the upper air remains warmer.
- **Dry air:** Generally moist air absorbs the earth's radiation, but dry air does not block radiation and allows radiation to escape into the atmosphere. Thus, leading to a temperature inversion.
- **Ice covered area:** In ice-covered areas due to high albedo, less sunlight is received. At night due to earth's radiation, most of the heat is lost in the atmosphere and the surface is cooled. The air in contact with the surface is also cooled but the upper layer remains warm. Thus, leading to temperature inversion.

- **Calm atmosphere:** The blowing of winds brings warm and cold air into contact. Under conditions of calm atmosphere, the cold air stays put near the ground.

Types of Temperature inversion:

Types of temperature inversion	Features
Surface Inversion	The surface temperature inversion is a phenomenon that occurs when the air is cooled by coming in contact with a cold surface until the air becomes cooler than the overlying atmosphere.
Radiational Inversion	Radiational inversion develop on a long, cold winter night when a land surface rapidly emits longwave radiation into a clear, calm sky. The cold ground then cools the air above by the process of conduction.
Advection Inversion	Advection inversion develops when there is a horizontal inflow of cold air into an area. Advection inversions are usually short-lived.
Drainage Inversion	Drainage inversion is a type of surface inversion that results when cooler air slides down a slope into a valley, thereby displacing slightly warmer air.
Upper-air Inversion	Temperature inversions in the upper air are nearly always the result of air descending from above and are hence called as subsidence inversions. Usually associated with high-pressure conditions, which are particularly characteristic of subtropical latitudes throughout the year and of Northern Hemisphere continents in winter.

Significance of temperature inversion:

- The temperature inversion helps in precipitation, forming of clouds and frost.
- Temperature inversion brings stability to the atmosphere
- At times it checks the convection clouds from rising higher, thus, pouring less rainfall.
- Fog formed due to temperature inversion reduces visibility and is a concern for transportation.
- Intense thunderstorms and tornadoes are associated with temperature inversions.

Associated Concepts

- **Temperature Ranges:** The temperature range can be defined as the difference between the maximum and minimum temperatures. The two terms that are used to consider temperature ranges are:
- **Diurnal range of temperature:**The diurnal range of temperature can be defined as the difference between the maximum and minimum temperatures of the same days.
  - Desert areas have the highest diurnal temperature variations while the low-lying humid areas have the least range.
- **Annual average temperature**: It is the monthly range of temperature or the difference between the average temperature of the hottest month and the average temperature of the coldest month of the year. The annual range is lower in low latitudes and higher in high latitudes.

MAJOR HEAT ZONES OF THE EARTH

There are three major heat zones on the Earth classified based on the amount of insolation received from the Sun. They are based on the distance they have from the equator.

Heat Zones	Features
Temperate Zone:	• The temperate heat zone is the most habitable zone of the Earth. • There are two temperate zones in two respective hemispheres of the Earth. • The North Temperate Zone lies between the Tropic of Cancer and the Arctic Circle in the Northern Hemispheres. • The South Temperate Zone lies between the Tropic of Capricorn to Antarctic Circle in the Southern Hemisphere. • The sun's rays neither fall directly as that of the torrid zone nor are they slanting as that of the polar regions. • The major climate types found in these regions are, Western British Type climate, China Type of Climate, Laurentian Type of Climate, Mediterranean Type of Climate etc.

Heat Zones	Features
Torrid Zone:	• The torrid or the tropical zone is the hottest zone of the Earth. This region lies within the Tropic of Cancer and Tropic of Capricorn. • The Sun's rays directly fall on this region at least once a year. • This zone is characterized by Hot Desert, Sudan Type of Climate, Monsoonal Type of Climate, Hot and Wet Equatorial Type of Climate.
Frigid Zone:	• The Frigid zone or the Polar zones are the coldest zones of the Earth. • This zone lies to the north of the Arctic Circle and to the south of the Antarctic Circle. • The zone remains permanently frozen. • Arctic or Polar Type of Climate is found in this zone with Tundra Vegetation.

ATMOSPHERIC PRESSURE

Atmospheric pressure is the force exerted by the weight of the gas molecules on a unit of area on the earth's surface. The pressure decreases with increasing altitude.

- **'Barometer'** is used to measure the pressure exerted by the atmosphere.
- **Millibars (mb) and Pascal (Pa)** are units to measure atmospheric pressure.

FACTORS INFLUENCING ATMOSPHERIC PRESSURE:

Factor	Description
Temperature	As temperature increases, air expands because of which its density decreases which results in low pressure. Air shrinks due to low temperature as the density increases thus increasing the pressure.
Altitude	The atmospheric pressure decreases with altitude. The atmospheric pressure is highest at sea level.
Water Vapour	When water evaporates and enters the atmosphere as a gas, the water vapour molecules take the place of other gas molecules in the air. So, a volume of wet (or humid) air weighs less than an equal volume of dry air. Therefore, humid air is less dense and exerts less pressure than dry air.
Rotation of the Earth	Due to the rotation of the earth, the bulk of the air at the Poles is thrown away towards the Equator. As equatorial region receives a greater amount of heat throughout the year, the air becomes warm and light and therefore rises. This creates a low pressure. At poles, the cold, heavy air sinks and creates a high pressure.

PRESSURE BELTS

Two major factors namely thermal factor and rotational factor are responsible for formation of these pressure belts.

- Thermal factor originates because of differential heating of land and water
- The rotational factor originates because of rotation of the earth.

There are seven alternate belts of low and high pressures on the surface of the earth. Equatorial low-pressure belt and each of the three pressure belts in both the hemispheres.

	Equatorial Low Pressure Belt	Sub-Tropical High Pressure Belt	Sub-Tropical Low Pressure Belt	Polar High Pressure Belt
Location	Located in the equator between 10° N and 10° S latitudes.	Located between latitudes 25° to 35° in both hemispheres.	Located between 60° to 70° latitudes in both hemispheres	Located between 80° to 90° latitudes in both hemispheres

	Equatorial Low Pressure Belt	Sub-Tropical High Pressure Belt	Sub-Tropical Low Pressure Belt	Polar High Pressure Belt
Formation	The temperature is high as the vertical sun rays directly heats the ground. As a result the lower layers of air is heated and expands and becomes light. Consequently they rise upwards creating a low pressure along the ground. The belt shifts towards the north and south of the equator with the apparent movement of the Sun.	The high pressure belt in these latitudes is because of the settling down of winds that arose in the equatorial region and got deflected towards poles due to the earth's rotation. So these subtropical high pressure belts are dynamically induced and not thermally induced in spite of the temperatures being fairly high in these regions for a greater time of the year.	These low pressure belts are dynamically induced in spite of the fact that these regions experience low temperatures throughout the year. Due to the rotation of the earth (Coriolis effect), the air is thrown outwards. Winds from here are displaced towards subtropical high pressure and polar high pressure zones. As a result, a low pressure belt develops here.	The polar regions are characterized by low temperatures throughout the year and hence high pressure persists at the poles which overcomes even the high Coriolis effect in these regions. In the northern hemisphere it is called the North Polar High Pressure Belt and in the southern hemisphere it is known as South Polar High Pressure Belt.
Features	**Known as Doldrums:** Due to excessive heating horizontal movement of air or the surface wind is absent here and only conventional currents are present. Therefore this belt is called **doldrums** (the zone of calm) **Formation of ITCZ:** The equatorial trough of low pressure is the zone of convergence of trade winds blowing equatorwards from the subtropical belts of high pressure in the northern and southern hemispheres. Thus, north-east trade winds and South-East trade winds converge here to form the **Inter Tropical Convergence Zone (ITCZ).**	**Weather Conditions:** Calm conditions with feeble and variable winds are found here. **Known as Horse Latitudes:** In olden days, vessels or ships with cargo of horses passing through these belts found difficulty in sailing under these calm conditions. Hence, they were forced to throw the horses into the sea in order to make the vessels lighter. Therefore, these high pressure zones are also called horse latitudes. **Region of divergence:** These are the regions of divergence because winds from these areas blow towards equatorial and subpolar low pressure belts.	In the southern hemisphere, there is an uninterrupted belt of low pressure between latitudes 60° and 70°, where there is a very vast expanse of ocean. This pressure belt is broken in the northern hemisphere due to dominance of landmasses. However, there are well-defined low pressure cells over the northern oceans. The cells of these low pressure system lies near to Aleutian islands in the Pacific Ocean and between Greenland and Iceland in the Atlantic Ocean	**Movement of Winds**: Winds from these belts flow towards the subpolar low pressure belts.

WIND SYSTEM

Wind is the horizontal movement of air. Insolation is the main cause of wind. All winds originate from the same primary sequence of events; Unequal heating of different parts of Earth's surface resulting in temperature gradients that generate pressure gradients, which set air into motion.

FACTORS AFFECTING MOVEMENT AND DIRECTION OF WIND

Factors	Description
Pressure Gradient Force	The rate of change of pressure with respect to distance is the pressure gradient. If there is pressure differential between two pressure regions, the air will move from the higher pressure toward the lower pressure in response to the pressure gradient force.

Factors	Description
Coriolis Effect	The earth's rotation forms the Coriolis force that deflects moving air to the right of its initial direction in the northern hemisphere and to the left of its initial direction in the Southern Hemisphere.
Frictional Force	The uneven surface of the earth and complex mix of land and water affect the movement of air. This resistance of Earth's surface to the wind direction is known as Frictional Drag or Frictional Force.
Centripetal Force	This force applies when the isobars are curved, as within cyclones. The fact that air follows a curved path means that in addition to the pressure gradient and the Coriolis force, a third force acts centripetally, pulling air inwards. The wind in balance with these three forces is known as the **gradient wind.**

TYPES OF WINDS:

The winds are generalized under three categories. (a) planetary winds or permanent winds (b) periodic winds and (c) local winds.

Planetary Winds:

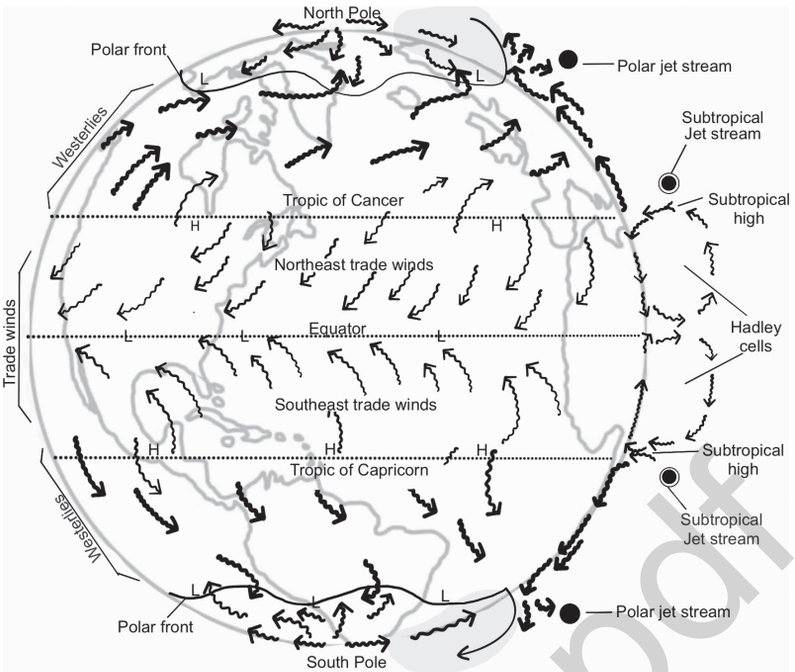
Planetary or permanent winds blow from high pressure belts to low pressure belts in the same direction throughout the year. They blow over vast area of continents and oceans.

Classification of Planetary Winds:

	Trade Winds or Tropical Easterlies	Westerlies	Polar Easterlies
Direction	Winds blow from subtropical high pressure areas towards equatorial low pressure areas are called trade or easterly winds.	Westerlies are the winds blowing from the sub-tropical high pressure belts towards the sub polar low pressure belts.	Polar easterlies blow from polar regions towards sub-polar low pressure regions.
Features	The winds are confined to a region between 30°N and 30°S throughout the earth's surface. The blow of trade wind means to blow steadily and constantly in the same direction'. The coriolis effect results the northern trade winds to move away from the subtropical high in north-east direction. In southern hemisphere the trade winds diverge out of the sub-tropical high towards the equatorial low from the southeast direction As the trade winds tend to blow mainly from the east, they are also known as the Tropical easterlies.	Winds blow from southwest to north-east in the northern hemisphere and north-west to south-east in the southern hemisphere. The westerlies of the southern hemisphere are stronger due to the vast expanse of water, while those of the northern hemisphere are irregular because of uneven relief of vast land-masses. Westerlies are found in land between 40-60 degrees South and are called 'roaring forties', 'furious fifties' and 'screaming sixties'.	Their direction in the northern hemisphere is from north-east to south- west and from south-east to north-west in the southern hemisphere.
Consistency	Great Force and Constant Direction	Less constant and less persistent than trade wind	Weak and Highly Variable
Humidity	Bring Moisture to the East Coast So west coast is left dried , Ultimately creation of Dessert Example: Sahara, Kalhari	Bring Moisture to West Coast (Specially 40 degrees to 60 degrees)	Cold and Dry area (Because High Pressure Belt)

General Circulation of the Atmosphere

The pattern of the movement of the planetary winds is called the general circulation of the atmosphere. The general circulation of the atmosphere sets in motion the ocean water circulation which influences the earth's climate.



GENERAL CIRCULATION

Three-Cell Circulation Model

In each hemisphere there are three cells (Hadley cell, Ferrel cell and Polar cell) in which air circulates through the entire depth of the troposphere.

	Hadely Cell	Ferrel Cell	Polar Cell
Location	Occurs between the Equator and the Tropics.	Occurs between 30 degrees north and south to 60 degrees north and south.	Occurs between 60 and 70 degrees north and south, towards the poles.
Formation	Thermally induced cell.	Dynamically induced cell.	Thermally induced cell.
Circulation Cycle	At the equator, the ground is intensely heated by the sun. This causes the air to rise which creates a low-pressure zone on the Earth's surface. As the air rises, it cools and forms thick clouds and results in heavy precipitation. This area is call the Inter-Tropical Convergence Zone (ITCZ).The air continues to rise up to the upper atmosphere The air separates and starts to move both north and south towards the poles. When it reaches about 30° north and south, the air cools and sinks towards the ground forming the subtropical high-pressure zone. The Hadley cell is then complete.	Air on the surface is pulled towards the poles, forming the warm south-westerly winds in the northern hemisphere and north-westerly winds in the southern hemisphere. These winds pick up moisture as they travel over the oceans. At around 60 degrees N and 60 degrees S, they meet cold air, which has drifted from the poles.The warmer air from the tropics is lighter than the dense, cold polar air and so it rises as the two air masses meet. This uplift of air causes low pressure at the surface and the unstable weather conditions that are associated with the mid-latitude depressions.	At the poles, air is cooled and sinks towards the ground forming high pressure, this known as the Polar high. It then flows towards the lower latitudes. At about 60 degrees N and S, the cold polar air mixes with warmer tropical air and rises upwards, creating a zone of low pressure called the subpolar low. The boundary between the warm and cold air is called the polar front. It accounts for a great deal of the unstable weather experienced in these latitudes.

PERIODIC WINDS

These are also called secondary winds. These winds change their direction with change in season.

Monsoon

Monsoon is a clearly predominant wind direction experienced in one season, but a reversal or a near reversal of wind direction takes place in the following season.

Land and Sea Breeze

It is a diurnal cycle of local wind in coastal areas. It is caused due to the differential heating of land and water, which produces low and high pressures.

Sea Breeze:	Land Breeze:
• The land gets heated more quickly than surrounding water during daytime which results in the rising of warm air and low-pressure area created over land. • As the water heats up slowely a thermal high pressure is developed over the water. Thus, the pressure gradient is developed and this causes the air to blow from high pressure to low pressure i.e. from sea to land. This is called Sea breeze. • The sea breeze causes a cooling effect on coastal lands.	• At night, the situation gets reversed. The land and the surrounding air cool more quickly than the nearby water body. • Thus, land has high pressure while the sea has comparatively a low-pressure area. • Gentle wind blows from land towards the sea. This is known as a land breeze.

Mountain and Valley Winds

The mountain and valley breezes are another class of daily wind reversals.

Valley Wind (Anabatic Wind)	Mountain Wind (Katabatic Wind)
• During the daytime, the slopes get heated up more than the valleys. • Hence, the pressure is low over the slopes while comparatively high in the valleys below. • Air moves up from the slope. The wind blows from the valley to the slopes to fill the resulting void created due to the heating of the slopes. This wind is called the valley breeze or anabatic wind.	• During the night, the slopes get cooled. The dense air descends into the valley as mountain wind. • The cool air of higher places (high plateaus and ice fields) draining into the valley is called mountain breeze or katabatic wind.

LOCAL WINDS

Certain types of winds are produced by purely local factors and, therefore, are called local winds. These local winds play an important role in the weather and climate of a particular locality.

Hot Local Winds	
Loo	• It is hot and dry wind which blows very strongly over the northern plains of India and Pakistan in the summers. • They blow from west to east. • They are usually experienced in the afternoons when the temperature varies between 45 0C to 500C.
Foehn	• 'Foehn' is the strong, dusty, dry and warm local wind. • It develops on the leeward side of the Alps mountain ranges. It occurs due to a regional pressure gradient that forces the air to ascend and cross the barrier. This ascent sometimes causes precipitation on the windward side of the mountains. • After crossing the crest of the mountains, it starts descending on the leeward side as warm and dry wind. • The temperature of the winds varies from 15 0C to 200C. This helps in the melting of snow. It makes the pasture land ready for animal grazing.
Chinook	• This wind moves down the eastern slopes of the Rockies (the U.S.A. and Canada). • The meaning of chinook is "snow eater' as they help in early melting of the snow.
Sirocco	• It is a hot, dry dusty wind. It originates in the Sahara desert. It occurs during spring. • After crossing the Mediterranean sea, the Sirocco is slightly cooled by the moisture from the sea. • Some of its local names are- Leveche in Spain, Khamsin in Egypt, and Gharbi in the Aegean Sea area.

Hot Local Winds	
Harmattan	• It is a strong dry wind that blows over northwest Africa from the northeast. • It blows directly from the Sahara desert. Thus, it is hot, dry, and dusty.

Cold Local Winds	
Mistral	• 'Mistral' is a cold wind of the Alps. It moves over France towards the Mediterranean Sea through the Rhone valley. • They are cold, dry, and of high velocity. • They reduce the temperature below the freezing point.
Bora	• Bora' is a cold, dry, high-speed north-easterlywind blowing down from the mountains in the Adriatic Sea region.
Blizzard	• 'Blizzard' is a violent wind. It is freezing, wind laden with dry snow.

ATMOPSHERIC WATER

Atmospheric moisture has a tremendous bearing on the weather and climatic conditions of a place.

HYDROLOGICAL (WATER) CYCLE

There is a constant and continuous circulation of water from the Earth's surface to the atmosphere and back to the Earth's surface. This circulation of water is called the water cycle or the hydrological cycle.

- The Sun's heat provides energy to evaporate water from the Earth's surface (oceans, lakes, etc.).
- Plants also lose water to the air (this is called **transpiration).** The term **evapotranspiration** denotes the combined process of evaporation and **transpiration.**
- The watervapour eventually condenses, forming tiny droplets in clouds.
- When the clouds meet cool air over land, precipitation (rain, sleet, or snow) occurs, and water returns to the land (or sea).
- Some of the precipitation soaks into the ground. Some underground water is trapped betheen rock or clay layers, called **groundwater**.
- Most of the water flows downhill as **runoff** (above ground or underground), eventually returning to the seas.

HUMIDITY

Water vapour present in the air is known as humidity.

Different expressions of Humidity

Absolute Humidity	Specific Humidity	Relative Humidity
• It is the weight of the actual amount of water vapour present in a unit volume of air. • Expressed in grams per cubic meter of air. • Decreases from the equator towards the poles. • Changes as air temperature or pressure changes. • However, if the temperature increases but there is no excess water for evaporation, absolute humidity will not change. • Determines the amount of precipitation.	• It is the weight of the actual amount of water vapour present in a unit weight of air. • Expressed as grams per kilogram of air.	• It is percentage of moisture present in the atmosphere compared to its full capacity at a given temperature. • Expressed in percentages. • Relative humidity of the air decreases with an increase in temperature and vice versa. • Evaporation decreases when there is high relative humidity and vice versa. • The equatorial region has the highest relative humidity. • Relative humidity gradually decreases towards the Tropical high-pressure belts (between 25degree—35degree latitudes) • The relative humidity again increases polewards. • The relative humidity is maximum in the mornings and minimum in the evenings. • Tells us about the possibility of rainfall

PHASE CHANGES OF WATER AND IMPORTANT CONCEPTS

Evaporation

- It is how liquid water changes into water vapor on heating.
- Factors Controlling Evaporation: aridity, temperature, and air movement.
- Evaporation is faster in dry air than in wet air.
- There is more evaporation from the ocean than from the land.
- **Latent Heat:** The heat absorbed and conserved in water vapour during evaporation
- **Latent heat of vaporization:** The temperature at which the water starts evaporating
- **Transpiration:** Loss of water from the leaves and stems of the plants.

Condensation

- The transformation of water vapour into water is called condensation.
- Sublimation: Direct condensation of water vapour into solid form.
- **Ways in which condensation takes place:**
  - Warm moist air rises upwards and expands.
  - Warm and moist air comes in contact with the cold surface.
  - Warm moist air mixes with the air coming from the colder regions.
- **Saturated Air:** The air containing moisture to its full capacity at a given temperature
- **Hygroscopic Nuclei:** Dust particles, smoke, oceanic salts or carbon dioxide etc. which act as nuclei to hold water.
- **Dew point:** The temperature at which saturation occurs in a given sample of air.

Forms of Condensation

Form	Details
Dew	• Deposition of moisture in the form of water droplets on cooler surfaces of solid objects • **Ideal conditions for Formation:** clear sky, calm air, high relative humidity, and cold and long nights, dew point should be above the freezing point
Fog	• It is a cloud with its base at or very near the ground. • Formed when the temperature of an air mass containing a large quantity of water vapour falls suddenly. • The condensation of water vapor takes place around the dust and smoke particles that remain suspended in the air. • Ideal Conditions: low temperature and high relative humidity. • The visibility is greatly reduced (less than one km). • Fogs are drier than mist.
Mist	• Type of fog but is relatively less dense. • Fog is called mist if the visibility range is between 1 and 2 km. • Mists are frequent over mountains as the rising warm air up the slopes meets a cold surface. • Mist can occur as part of natural weather or volcanic activity or could be created artificially.
Haze	• Occurs when dust, smoke, and dry particles reduce visibility. • visibility is reduced from 2 kilometers to 5 kilometers.
Frost	• frozen dew. • formed when the dew point temperature falls below the freezing point.
Clouds	• Droplets of water or tiny ice crystals which collect around the dust particles present in the atmosphere. • When the moist air ascends, it expands, loses temperature, becomes cool, and gets saturated. With a further decrease in temperature beyond the dew point, condensation of the moisture takes place high up in the air, resulting in the formation of clouds.

Types of Clouds

Type	Sub Types	Characteristics
High Clouds (16,500-45,000 feet)	**Cirrus**	• Delicate, feathery clouds • Made mostly of ice crystals.
	Cirrostratus	• Thin, white clouds . • Most commonly seen in the winter • Can cause the appearance of a halo around the sun or the moon.
	Cirrocumulus	• Thin, sometimes patchy, sheet-like
Mid-level Clouds (6,500-23,000 feet)	**Altocumulus**	• Have several patchy white or gray layers • Made of liquid water, but they don't often produce rain.
	Altostratus	• Grey or blue-grey mid-level clouds • Composed of ice crystals and water droplets. .
	Nimbostratus	• Dark, grey clouds that seem to fade into falling rain or snow.
Low Clouds (less than 6,500 feet):	**Cumulus**	• Look like fluffy, white cotton balls in the sky
	Stratus	• Look like thin, white sheets covering the whole sky. • Seldom produce much rain or snow.
	Cumulonimbus	• Grow on hot days when warm, wet air rises very high into the sky. • Rain bearing Clouds

PRECIPITATION

- Precipitation is water in liquid or solid forms falling on earth.
- It happens when continuous condensation in the body of air helps the condensed particles to contract in size and weight. Eventually, the air cannot hold them anymore. They start falling on earth under the force of gravity.

Forms of Precipitation

Form of Precipitation	Details
Drizzle	• Composed of tiny droplets of water with a diameter of less than 0.5 mm.
Rain	• When the diameter of the drops of water is greater than 0.5mm, it is called rain.
Snow	• Solid precipitation in the form of ice crystals, small pellets, or flakes • It is formed when water vapor is converted into ice through sublimation without an intermediate liquid stage.
Sleet	• It is frozen rain. • It is created when rain, before falling on the earth: passes through a cold layer of air and freezes.
Hail	• It is the precipitation of small balls or pieces of ice. The diameter ranges from 5 to 50mm. • Hail is produced in cumulonimbus clouds due to great instability and strong vertical air currents. • For hail to form, the cloud must have a lower part warmer than the freezing point of O degreeC and an upper part colder than this. • Hail is more common in summer than in the middle of winter.
Virga	• The streaks of rain that disappear before hitting the ground are called virga. • Formed when the relative humidity of the air below a precipitating cloud is relatively low, and the falling precipitation may evaporate before reaching the surface.

Types of Rainfall

Type of Raifall	Details
Convectional Rainfall	• On heating, the air becomes light and rises up in convection currents. • As the air rises, it expands and loses heat and consequently, condensation takes place and cumulous clouds are formed. • With thunder and lightening, heavy rainfall takes place but this does not last long. • Common in the summer or in the hotter part of the day. • Common in the equatorial regions and interior parts of the continents, particularly in the northern hemisphere.
Orographic Rainfall	• It occurs when warm air rises and cools because of a topographic barrier. • As the warm air rises, it cools and the temperature falls below the dew point, forming clouds. These clouds cause widespread rain on the windward slopes of the mountain range. • When their cross over the mountain range, it descends along the leeward slopes. After descending, they get warm and cause little rain on the leeward side. The region on the leeward side that receives less rain is called the **rain shadow area.** • **Eg:** Orographic rainfall occurs in Cherrapunji on the southern margin of the Khasi Hills in Meghalaya, India.
Frontal Rainfall	• When two different air masses meet, they do not mix. instead a zone of discontinuity called a front is established between them. • The warmer air rises over, the cooler air along this front. As the warmer air is forced to rise, it may be cooled to the dew point resulting in the formation of clouds and rainfall.

AIR MASS, FRONTS AND CYCLONES

AIR MASS

Air masses can be defined as a large body of air, usually, 1600kms or more, characterized by **homogenous physical properties** like temperature, moisture content at a given height.

Criteria to be recognized as air mass:

To be recognised as a distinct air mass, a parcel of air must meet three requirements:

- **It must be large.** A typical air mass is more than 1600 kilometres (1000 miles) across and several kilometres deep (from Earth's surface to the top of the air mass).
- It **must have uniform properties in the horizontal dimension** (at any given altitude its physical characteristics of temperature, humidity, and stability should be relatively homogeneous).
- It **must travel as a unit**. It must be distinct from the surrounding air, and when it moves it must **retain its original characteristics** and not be torn apart by differences in airflow.

Source Region of Air Masses

The surface of the Earth from which the air masses derive their properties is called a **source region.**

- Air masses retain their identity even after moving away from their source regions which are seen in the upper part of air masses while the lower surface is modified due to the heat transfer by convection.
- **Air masses develop only in the regions having:**
  - Extensive uniform topography.
  - Divergent airflow, thus providing a condition of high pressure.
  - The area should have a comparatively gentle and divergent airflow so that air stays in that region for a longer period.
  - High barometric pressure

Classification of Source Regions:

- Source regions are **broadly divided into continental (c) and maritime (m) source regions.** They are either continental interiors in temperate latitudes or large-maritime regions in higher latitudes.
- **Six major source regions are identified:**
  (a) Continental interiors of Siberia.
  (b) Vast regions of the Sahara.
  (c) Continental regions of Canada.
  (d) The Atlantic Ocean.
  (e) Pacific Ocean.
  (f) Southern Indian Ocean.
- If the air mass moving over a region causes stability or dry conditions then it is known as **stable air mass** (s). If it promotes precipitation then it is known as **unstable air mass** (u).

Classification of Air Mass:

Air masses are classified **based on their temperature and humidity characteristics.**

- Broadly, they are classified into **polar and tropical air masses.** Both Air masses can either have **maritime or continental source regions.** The following types of air masses are recognized:
  (a) Maritime tropical (mT)
  (b) Continental tropical (CT)
  (c) Maritime polar (mP)
  (d) Continental polar (cP)
  (e) Continental arctic (CA).
- Tropical air masses are warm, while polar air masses are cold.

Air Mass	Source Region	Features	Weather
Continental Polar Air Masses.	Arctic basin, northern North America, Eurasia, and Antarctica.	Dry, cold, and stable conditions	Winter: Frigid, clear, and stable. Summer: Less stable with the lesser prevalence of anticyclonic winds, warmer landmasses, and lesser snow.
Maritime PolarAir Masses.	Oceans between 40 and 60 degree latitudes with cool, moist, and unstable conditions.	Warm, moisture laden.	Winter: high humidity, overcast skies, and occasional fog and precipitation. Summer: clear, fair, and stable.
Continental Tropical Air Masses	Tropical and sub-tropical deserts of Sahara in Africa, West Asia and Australia	Dry, hot and stable and do not extend beyond the source	Dry throughout the year.
Matitime Tropical Air Masses	Oceans in tropics and sub-tropics such as Mexican Gulf, the Pacific and the Atlantic oceans.	Warm, humid, and unstable.	Winter: Mild temperatures, overcast skies with fog. Summer: High temperatures, high humidity, cumulous clouds, and convectional rainfall.

Significance Of Air Mass

The air masses after their formation, by acquiring the properties of the source region, move out and interact with new regions with different surface properties. In the process, they modify the weather of the region visited and also ger modified themselves.

- The interacting air masses result in the **creation of fronts and frontal weather patterns.**

FRONTS

When two different air masses meet, the boundary zone between them is called a **front.**The cold air mass tends to sink, and the warm air mass tends to rise because of which fronts are always inclined.

- The concept of fronts was propounded by the Norwegian meteorologists- V Bjerkens and J Bjerkens during World War I.

Frontogenesis: The process of formation of the fronts is known as frontogenesis. It involves convergence of two distinct air masses.

- Front development can mostly be found in the mid-latitude region (30-65 degrees North & South).
- In the northern hemisphere Frontogenesis (convergence of air masses) happens in anticlockwise direction and in southern hemisphere, clockwise direction. This is due to Coriolis effect.

Frontolysis: The process of dissipation of a front is known as Frontolysis.

Characteristics of Fronts

- **Influence of temperature contrast:** The temperature contrast influences the thickness of frontal zone in an inversely proportional manner.
- **Change in temperature accompanied by change in pressure:** With a sudden change in temperature through a front, there is a change in pressure also. This is reflected in bending of isobars towards the low pressure.
- **Location:** The fronts mostly lie in low pressure troughs.
- **Wind shift:** A front experiences wind shift, since the wind motion is a function of pressure gradient and Coriolis force.
- **Weather:** The frontal activity is associated with cloudiness and precipitation. This is because of rise of warm air which cools down adiabatically, condenses and causes rainfall.
  - The intensity of precipitation depends on the slope of ascent and amount of water vapour present in ascending air.

Types of Fronts

Front	Description
Stationary Front	• When two contrasting air masses converge and form a boundary without intermixing of winds is a stationary front. • Both the wind parcel fails to push each other and remains stationary. • The wind flow is parallel to the front but in opposite direction. • Such fronts are temporary fronts and are mostly short-lived.
Warm Front	• When a warm air mass moves towards the cold air mass, the contact zone is a warm front. • As the warm air ascends the slope it condenses and causes precipitation.
Cold Front	• Cold air moves towards the warm air zone. • As the cold air mass is dense, it remains at the ground. • The cold air mass uplifts the warm and less dense air mass. The front forms narrow band of clouds and precipitation.
Occluded Front	• Formed when a cold front overtakes a warm front. As the cold front moves faster than the warm front, the warm sector is reduced in size. • Warm air is completely dsiplaced. • Finally, the cold and warm front merge into one to form a long, backward swinging front. • Weather conditions are variable with erratic rain fall.

CYCLONES

Cyclones are fast inward moving air circulations, circulating around a low-pressure area.

- The word cyclone has been derived from the greek word **"cyclos"** meaning the **"coils of a snake"**.
- The air in a cyclone circulates in an anticyclockwise direction and clockwise direction in northern and southern hemisphere respectively.
- Cyclones are classified into two types:
  - The Temperate Cyclones
  - The Tropical Cyclones

Temperate Cyclones

The temperate cyclones are atmospheric phenomena that affect the weather in the middle latitudes. The temperate cyclones are otherwise known as **extra-tropical cyclones** i.e. the cyclones formed beyond the tropic of cancer and tropic of capricorn.

Features of temperate cyclones:

- **Emergence:** The temperate cyclones are formed in middle latitudes, mostly in 35-65 degree latitudes across both northern and southern hemispheres.
- **Formation:** The temperate cyclones are formed by the process of front formation with the interaction of two contrasting air masses.
- **Shape:** The shape of the temperate cyclone varies from circular and semi-circular to elliptical and elongated.
- **Spread:** The temperate cyclones stretches over 500 to 600 kms.
- **Velocity**:It is moderate around 30 to 40 km per hour.

Formation of temperate cyclone:

The formation of temperate cyclones is best understood by the Polar Front theory by Bjerkens and Bjerkens.

The formation of temperate cyclone can be explained through the following stages.

- **First Stage:** This involves the convergence of two air masses of contrasting physical properties and direction. Initially, the warm and cold air masses move parallel to each other and a stationary front is formed. This is called the **initial stage.**
- **Second Stage:** The warm and cold air masses penetrate into each others territory and a wave-like front is formed. This stage is called the **incipient stage.**
- **Third Stage:** Cyclone is fully developed and the isobars become almost circular. This is called the **mature stage.**
- **Fourth Stage:** The cold front having a greater speed of intrusion than the warm front intrudes into the warm sector. The warm sector is narrowed due to the advancement of the cold front than the warm front.
- **Fifth Stage:** The advancing cold front overtakes the warm front and an occluded front is formed. This is known as the **occlusion stage.**
- **Sixth Stage:** The warm sector completely disappears. The occluded front is eliminated. The cyclone eventually dies out.

Distribution of Temperate Cyclones

Temperate type of cyclones is primarily found between 35 degree to 65 degree north and south latitudes. They are found along teh following fronts:

- **Atlantic-Arctic Front:**
- **North America Polar Front:**
- **Mediterranean- Caspian Front:**
- **Southern Hemisphere**
  - They are developed with lesser intensity between 35 degrees to 65 degrees south latitudes and travel in south-easterly direction.

Bomb Cyclone

- A bomb cyclone is a large, intense mid latitude storm.
- The cyclone has a low pressure at its center, but it turns into a bomb when it undergoes **bombogenesis**. In other words, the pressure at the center decreases rapidly (around 24 milibars in 24 hours).

Why it is called a Bomb?

- A cyclone after undergoing bombogenesis rapidly intensify, while normal cyclones dont intensify in such a rapid rate.
- **Bombogenesis** is a combination of words **cyclogenesis** (i.e formation of a cyclone) and **bomb.**
- The bombogenesis occurs when a cold air mass collides with a warm air mass, such as air over warm ocean waters which rapidly strengthens the weather system.

How does a Bomb Cyclone form?

- Heat and moisture are abundantly found over the warmer ocean.
- However, as cool continental air moves over and creates a large difference in temperature, the lower atmosphere becomes unstable and buoyant.
- Then the air rises, cools and condenses, thus forming clouds and precipitation.

Most occurrences witnessed

- Events of bombogenesis are mostly witnessed over the coast of the USA.

Tropical Cyclones

Tropical cyclones are violent storms which originates in tropical areas. The tropical cyclones are responsible for bringing large-scale destruction in coastal areas lying between the tropic of cancer and tropic capricorn.

Features of tropical cyclones:

- **Location:** The tropical cyclones emerge within the tropics, that is, the **tropic of cancer** and the **tropic of capricorn**.
- **Spread:** Tropical Cyclones are confined between the tropics and are considerably smaller as compared to temperate or extra-tropical cyclones.
- **Origin:** They are of thermal origin. A tropical cyclone behaves like a self-generating heat engine propelled by the release of latent heat of condensation.
- **Shape and Size:** The tropical cyclones are spiral in shape and the diameter of the cyclone can vary from 30 km to 300 km.
- **Velocity:** The velocity varies from 32 km per hour to more than 180 Km per hour.
- **Direction of Movement:**
- The cyclonic wind movements are counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere due to the Coriolis Effect.

Tropical cyclones are called by different names in different regions

- **Cyclones-** India
- **Hurricane**- America
- **Typhoon-** Western Pacific and South China Sea
- **Willy Willies**- Australia

Favourable conditions required for the formation of tropical cyclones:

- Ready supply of moisture, Hence, most tropical cyclones are developed only over oceans.
- Warm Oceans temperature helps in continuous supply of moisture.
- The required temperature is around 27 degrees Celsius.
- Presence of coriolis force to achieve the required circular movement.
- Presence of a weak low pressure zone.
- Presence of a upper air circulation:

Structure of tropical cyclones:

Stage	Description
Eye	Constitutes the central region of the cyclone. Characterized by low surface pressure, calm conditions, descending air, and clear skies.
Eye Wall	A circular ring-shaped air envelope that surrounds the eye of the cyclone is known as the eyewall. Characterized by violent blowing winds, heavy rainfall, and deep convective cloud rise.
Rain Bands	Narrow rain bands aligned in the direction of horizontal winds radiate from eyewalls, and cumulonimbus clouds drift into the outer regions.

Formation of a tropical cyclone:

The tropical cyclones can broadly studied under three stages, that is:

Stage	Description
Early Stage	• Under favourable conditions warm ocean waters with a temperature above 27 degree Celsius, allows a body of warm air to evaporate from the ocean surface. • As the air rises, at a certain height, due to adiabatic lapse rate, it cools and condenses to form clouds spanning a large area in the troposphere. • Then the energy is released by the latent heat of condensation stored in the water vapor, thus, providing the cyclone with more energy. The Coriolis forces cause the rising currents of air to spiral around the center of the tropical cyclone.

Stage	Description
Mature Stage	• The cyclone matures, and the eye of the storm is created. • As the air rises and cools, some of the dense air descends to form the clear still eye. • The descending cold air and the spiraling wind creates multiple convective cells with successive calm and violent region. These regions are characterised by cumulonimbus clouds which are also called as rain bands are responsible for intense rainfall. • Once the cyclone is formed, it follows a track or pathway away from its source under the influence of the trade winds.
Death Stage	• Once the cyclone reaches the continent, it starts dying because of the frictional force on the ground and supply cut-off of the moisture.

Types of tropical cyclones:

Types of cyclones	Features
Tropical Disturbance	They are migratory wave-like cyclones and are associated with easterly trade winds. They are very extensive and widespread and influence weather conditions of both tropical and subtropical areas.
Tropical Depression	They are low-pressure centers and are very small in size that usually develop in the intertropical convergence but seldom develop in the trade wind belt.
Tropical Storm	They are low-pressure centers that are disastrous as they cause heavy rainfall and inundate low-lying areas.
Hurricane/ Typhoons	Extensive tropical cyclones are called hurricanes in the USA and typhoons in China. Their size ranges from 160 to 600 km.

Distribution of Tropical Cyclones

- **North Atlantic (western tropical part)**: Mainly over Caribbean sea and Gulf of Mexico and maximum frequency is during August to October;
- **Indian Ocean:** Bay of Bengal and Arabian Sea, with two maxima one in May and another in October-November;
- **South Indian Ocean:**The area extending from Madagascar and Reunion islands upto 90 degree E longitude and Timor sea in north-western Australia and mainly during January to March;
- **North Pacific Ocean (eastern tropical part):** Over western coastal areas of Mexico and Central America upto California coast and maximum occurrence is during August to October;
- **North Pacific Ocean (western tropical part)**:This region has maximum occurrence of cyclones in the world with maximum frequency in August and September and includes mainly, Philippines, China sea and areas around Japan;
- **South Pacific Ocean (western tropical part):** east coast of Australia, in and around Samoa and Fiji Islands and around the Coral Sea region and majority occur during January to March.

Tropical cyclones and their naming

The tropical cyclones are named to avoid confusion by the weather forecasters. Every year, the tropical cyclones are named in an alphabetical order. The list of the name is proposed by the National Meteorological and Hydrological Services (NMHS) of WMO of a specific region.

For instance in the Indian Ocean Region- India, Bangladesh, Maldives, Myanmar, Oman, Pakistan, Sri Lanka, and Thailand, contribute a set of names accorded whenever a cyclonic storm develops.

Significance of naming of cyclones:

- It helps in the identification of cyclones.
- Removes confusion in case of simultaneous occurrence of tropical cyclones over a region.
- It helps the scientific community to identify the cyclone and heightens the warnings and community preparedness.
- Helps the local and international media to disseminate warnings to a much wider range of audiences.

Difference between tropical and temperate cyclone

	Tropical Cyclones	Temperate Cyclones
Emergence	Limited to smaller areas and forms withing the tropics.	Affect much larger area and are formed beyond the tropics or known as extra-tropic cyclones.

	Tropical Cyclones	Temperate Cyclones
Origin	Tropical cyclones are of thermal origin.	Temperate cyclones are of frontal origin.
Formation	Forms with continuous supply of moisture with release of latent heat of condensation. Form on oceans with a temperature of 27 degrees Celsius.	The temperate cyclone gets energy from the contrasting air masses. Temperate cyclones can be formed on both continental land and oceans.
Velocity	The wind velocity is violent and destructive.	The velocity of wind is comparatively lower.
Duration	Does not last more than seven days.	Can last for duration of 15 to 20 days.

Anticyclones

They are extensive, migratory high-pressure cells of the midlatitudes. Typically, it is larger than a midlatitude cyclone and generally moves west to east with the westerlies.

Salient Features

- **Convergence of Air:** It has air converging into it from above while air **subsiding and diverging** at the surface.
- **Direction Of Movement:** Winds blow clockwise in the Northern Hemisphere and counter clockwise in the Southern Hemisphere.
- **No air-mass conflict or surface convergence** is involved, and so anticyclones contain no fronts.
- **Weather Conditions:** The weather is clear and dry, with little or no opportunity for cloud formation. In winter, anticyclones are characterized by very low temperatures
- **Wind movement:** It is very limited near the center of an anticyclone but increases progressively outward.
- **Stagnation:** Anticyclones are occasionally prone to stagnation and remain over the same region for several days. This may lead to stagnation of air pollutants in the air.

Difference between Cyclones and Anti-Cyclones

Cyclones	Anticyclones
They have low pressure at the centre, surrounded by high pressure on all sides	They have high pressure at the centre, surrounded by low pressure on all sides.
Winds blow towards the centre	Winds radiate out from the centre
Winds are violent and destructive	Winds are mild and not destructive
Winds blow in anti-clockwose in northern hemisphere and clockwise in the southern hemipshere	Winds blow in clock-wise direction in the northern hemisphere and anti-clockwise in the southern hemisphere
They present cloudy weather accompanied by thunder, lightning and heavy rain	They present calm and clear weather

Thunderstorms

A thunderstorm is an intense atmospheric circulation associated with large, dense cumulonimbus clouds in which there is a strong upward movement of air. Thunderstorms cause heavy downpours, but the rainfall is of very short duration.

Tornado

Tornadoes are funnel shaped storms with an intense low pressure at the center. Even though tornadoes are small they tend tend to be most violent and are disastrous of all the storms.

Distribution of tornadoes

- Tornadoes are absent in latitudes higher than 50 degrees North and South.
- The tornadoes are mostly frequented in tropical and temperate regions.
- Tornadoes can be seen across all continents except Antarctica.
- USA has the most violent tornadoes.Canda reports the second largest number of tornadoes.

- In Indian sub-continent, Bangladesh is most prone to tornadoes.

Significance of tornadoes

- Tornadoes provide plenty of nitrogen for the soil and water for the plants.
- On a size and time scale, a tornado is the most effective route to transfer air from one section of the atmosphere to another.
- Tornadoes help in the pollination of seeds through their massive movement.
- It also destroys old-growth trees, which provide habitat for local wildlife.
- Tornadoes are known for uprooting large trees out of the ground and transporting them to a new location.

Waterspouts

The tornadoes over the sea are called waterspouts. It usually occurs over warm tropical ocean waters. It is a rotating column of water that contains an intense vortex.

Lightning

Lightning is an electrical discharge that occurs when there is an imbalance between the storm clouds and the earth or within the clouds.

Types of Lightning

Lightning can be of two types:

- **Intercloud or Intracloud lightning** that are mostly harmless.
- **Cloud to Ground lightning** are generally harmful as the high electric current can lead to electrocution.

Lake Maracaibo in **Venezuela** is regarded as the lightning capital of the world.

JET STREAMS

Jet streams are the narrow bands of strong and rapidly flowing air which travels in the upper tropospheric region. The direction of flow of jet streams is from west to east.

Condition of formation

A jet stream is formed when a warm current from the tropics meets a cold current from the poles. The strong thermal contrast forces the air to flow horizontally and as the Earth rotates, this fast-moving air picks up speed and produces a jet stream.

Properties

- **Circulation:** The circulation of jet streams is from west to east with the height of 7.5 -14 km in the upper troposphere. Their circulation path (trajectory) is wavy and meandering
- **Region of circulation:** Generally, their circulation is observed between poles and 20° latitudes in both the hemispheres. These are also called circum-polar whirl because these move around the poles in both the hemispheres.
- **Variation in wind velocity:** The vertical wind shear of jet streams is 5-10m/second (18-36 km/hour), meaning thereby the wind velocity above or below the jet stream decreases by 18-36 km/hour. Lateral wind shear is 5 m/second (18km/hour). The minimum velocity of jet stream is 30m/second (108 km/hour).
- **Seasonal changes:** There is seasonal change in the wind velocity in jet streams wherein these become strong during winter season and the wind velocity becomes twice the velocity during summer season, maximum wind velocity is 480 km (per boar).
- **Extent of jet streams:** The extent of jet streams narrows down during summer season because of their northward shifting while these extend upto 20° latitudes during winter season.

TYPES OF JET STREAMS

Jet streams are divided into 5 types on the basis of locational aspect:

- **Polar front jet streams:**
  - They are formed above the convergence zone (40-60 latitudes) of the surface polar cold air mass and tropical warm air mass.
  - The thermal gradient is steepened because of convergence of two contrasting airmasses.
  - These move in easterly direction but are irregular.
- **Subtropical westerly jet streams:**
  - They move in the upper troposphere to the north of subtropical surface high pressure belt (at the poleward limit of the Hadley cell in both the hemispheres) i. e. above 30°-35° latitudes.
  - Their circulation is from west to east in more regular manner than the polar front jet streams.
- **Tropical easterly jet streams:**
  - They develop in the upper troposphere above surface easterly trade winds over India and Africa during summer season due to intense heating of Tibetan plateau and play important role in the mechanism of Indian
- **Polar night jet streams**
  - Also known as stratospheric subpolar jet streams, they develop in the winter season clue to steep temperature gradient in the stratosphere around the poles at the height of 30 km.
  - These jet streams become very strong westerly circulation with high wind velocity during winters but their velocity decreases during summer and the direction becomes easterly.
- **Local jet streams** are formed locally due to local thermal and dynamic conditions and have limited local importance.

Other types of Jet streams:

- **Barrier Jets:** In the low levels, a barrier jet forms just upstream of mountain chains, causing the jet to be oriented parallel to the mountains.
- **Coastal Low- Level Jets:** Coastal low-level jets are associated with a sharp contrast between high temperatures on land and lower temperatures at sea, and they play an important role in coastal weather, causing strong coast parallel winds. These are linked to oceanic high-pressure systems and land-based thermal lows.
- **Valley Exit Jets:** A valley exit jet is a strong, down-valley, elevated air current that flows above the valley's and adjacent plain's intersection. They have the ability to travel at high speeds and heights.
- **African Easterly Jets:** During the summer in the Northern Hemisphere, between 10°N and 20°N above West Africa, the mid-level African easterly jet occurs. The nocturnal poleward low-level jet occurs in East and South Africa's Great Plains.

IMPACT OF JET STREAMS

- **Jet-Streams and their influence on the weather conditions:**
  - Jet streams substantially contribute to originating cyclones, anticyclones, storms and depressions and influence their behavior. The cyclones intensify when the jet-streams are positioned above temperate cyclones.
- **Jet-Streams and Air travel:**
  - The violent wind shear within the jet streams poses a major threat to air travel.
  - The east flying flights take less flying time than the west flying flights.
- **Jet-Streams and their influence on Indian Monsoon:**
  - The bursting of the monsoon in India is closely related to Eastern Tropical Jet streams. In summers the subtropical jet streams tend to deflect northwards and cross the Himalayan Range. The altitude of the mountains hinders the jet streams but once cleared, results in the advent of monsoon

POLAR VORTEX

- Polar vortexes are referred to as whirling cones of low pressure over the poles that are strongest in the winters due to stark differences in the temperature between the polar regions and the mid-latitudes.
- The polar vortex spins in the stratosphere, above 10 to 48 kilometers above the ground and the troposphere.
- A strong jet stream contains the polar vortex behaving as a boundary wall. The strong jet checks the polar vortex from sliding south of the northern hemisphere.
- The polar vortex at times gets stronger and pushes jet-stream south and invades the northeast regions of the USA and Europe bringing severe cold.

- Retreating winters and the advent of summers weakens the polar vortex. This leads the polar vortex to withdraw and retreat back to the poles.

Sudden stratospheric warming

It is an event when rapid warming occurs high up in the stratosphere.

Cause:

- Every year in winter, strong westerly winds circle around the pole high up in the stratosphere-called the stratospheric polar vortex. It circulates around cold air high over the Arctic.
- In some years, the winds in the polar vortex temporarily weaken, or even reverse to flow from east to west.
- The cold air then descends very rapidly in the polar vortex. This causes the temperature in the stratosphere to rise very rapidly.

Impact:

As the cold air from the stratosphere disperses, it can affect the shape of the jet stream. This occurs as the cold air sinks from the stratosphere into the troposphere. The change in the jet stream causes weather to change.

Fujiwhara Effect

- The Fujiwhara Effect is any interaction between tropical storms formed around the same time in the same ocean region. Their eyes are at a distance of less than 1,400 km.
- It makes cyclones more unpredictable due to their rapid intensification, carrying of more rain, and newer ways of moving over warming oceans.
- Five different ways by which Fujiwhara Effect takes place. The interactions are:
  - Elastic Interaction (EI): In this interaction, only the direction of motion of the storms changes and is the most common case.
  - Partial STraining Out (PSO): In this interaction, a part of the smaller storm is lost to the atmosphere.
  - Complete Straining Out (CSO): In this interaction, the smaller storm is completely lost to the atmosphere and the straining out does not happen for storms of equal strength.
  - Partial Merger (PM): In this interaction, the smaller storm merges partially into the bigger one.
  - Complete Merger: In this interaction, a complete merger takes place between two storms of similar strength.

CHAPTER 3

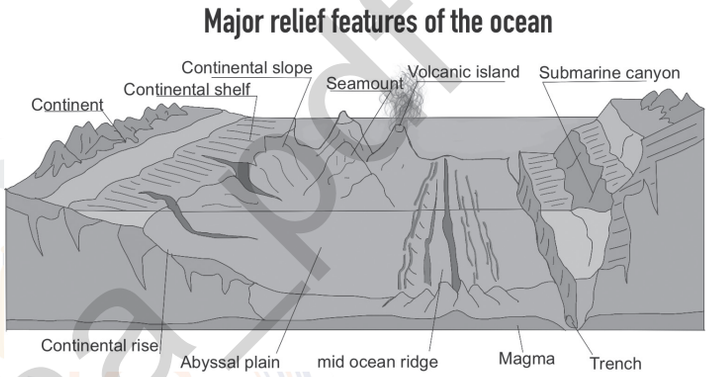
Oceanography

About 71 percent of the Earth's surface is water-covered, and the oceans hold about 97 percent of all Earth's water. Water also exists in the air as water vapor, in rivers and lakes, in icecaps and glaciers, in the ground as soil moisture and in aquifers.

OCEAN RELIEF

The oceanic part of the earth is divided into five oceans, namely the Pacific, the Atlantic, the Indian, Southern ocean and the Arctic.

- The various seas, bays, gulfs and other inlets are parts of these four large oceans.
- A major portion of the ocean floor is found between 3-6 km below the sea level.



MAJOR DIVISIONS OF THE OCEAN FLOOR

Division	Definition	Characteristic Features
Continental Shelf	It is the submerged part of the land adjoining the coast	• **Formed due to:** • Submergence of boundaries of the continent, • Erosional work of the waves • Extension of land from the sediments deposited by rivers • **Gradient**:1° or even less • **Average Width:** 70Km • It is broad where the mountains are away from the coast, for example, north-west Europe and eastern North America; • it is narrow where the mountains are nearer to the coast, for example, Western North America and South America. • **Shallow seas and gulfs** are found along the continental shelves. • Ends at a steep slope called **shelf break** • **Significance:** • Provide rich fishing grounds. • Source of minerals, sand, petroleum, natural gas, placer and phisphorite deposits.
Continental Slope	The zone of steep slope, extending from the continental shelf to the deep sea plains	• **Gradient:** varies between 2°-5°. • **Depth:** varies between 200 and 3,000 m. • The slope boundary indicates the end of the continents. • Canyons and trenches are observed • Continental shelf and slope together known as **continental margin** • **Continental Rise:** • The continental slope loses its steepness with depth. • When it reaches a level of between 0.5 to 1 degree, the slope is referred to as the continental rise. • It is made up of sediments that come from the continental shelf. • It lies between the continental slope and the abyssal plains.

Division	Definition	Characteristic Features
Deep Sea Plains (Abyssal Plains)	Gently sloping areas of the ocean basins extending from continental rise to the mid-oceanic ridges	• **Depth**:vary between 3,000 and 6,000m. • **Composition:** covered with fine-grained sediments like clay and silt. • **Slope:** very gentle, and it appears as a uniform flat and featureless plain. • **Significant Relief:** Long, narrow ridges, guyots etc
Oceanic Deeps or Trenches	Steep sided, narrow basins.	• **Formation:** • Tectonic origin and formed during convergence of plates (ocean-ocean convergence or ocean-continent convergence). • 3-5 km deeper than the surrounding ocean floor. • Occur at the bases of continental slopes and along island arcs • Associated with active volcanoes and strong earthquakes. • **Total No**: 57 of which 32 are in the Pacific Ocean; 19 in the Atlantic Ocean and 6 in the Indian Ocean. • Mariana Trench (Pacific Ocean) of the Guam Islands is the deepest trench.

MINOR RELIEF FEATURES

Feature	Characteristics	Examples
Submarine Canyons	• Narrow steep-sided valleys that cut into continental slopes and continental rises of the oceans. • Originate either within continental slopes or on a continental shelf. • Resemble canyons made by rivers on land.	Hudson Canyon (Atlantic Ocean), Columbia Canyon (Pacific ocean), Krishna Canyon (Indian Ocean)
Sea Mounts	• Large underwater mountains • Often formed by volcanic activity • **Significance:** • Provide critical habitat for a variety of ocean life, including corals, mollusks, crustaceans, fish, and marine mammals. • Has valuable minerals—such as nickel, copper, and cobalt	The Emperor seamount, an extension of the Hawaiian Islands in the Pacific Ocean
Guyots	• Isolated group of seamounts having a comparatively smooth flat top. • Also called tablemounts • Guyots have an average area of 2,500 km2, more than twice the average area of seamounts.	Kuko Guyot, Suiko Guyot and the Pallada Guyot.
Mid-Oceanic Ridges	• Narrow, elongated mountain ranges that rise steeply from the abyssal plain. • They are of tectonic origin and are evidence of the theory of plate tectonics. • The peaks of some of the ridges may rise above sea level to form islands, e.g., Azores, Ascension, and Philippine islands.	Mid-Atlantic Ridge (longest in the world)
Bank	• A bank is a flat-topped elevation, usually located in the continental margins. • Formed due to erosional and depositional activities • There is a thin layer of water over the bank; however, the depth is sumcient for navigation. • **Significance:** productive sites for fisheries:	The Dogger Bank in the North Sea and the Grand Banks of North-Western Atlantic.
Shoal	• An accumulation of sediment in a river channel or on a continental shelf • Potentially dangerous to ships.	_____
Coral Reefs	• A ridge or hummock formed in shallow ocean areas by algae and the calcareous skeletons, usually coral polyps. • A coral reef may grow into a permanent coral island.	Great Barrier Reef off the east coast of Australia (largest in the world)

CORAL REEFS

Corals: Corals are tiny, jelly-like animals that live in colonies in warm, clear, shallow waters close to the coast. Corals live symbiotically with photosynthetic algae, providing them shelter in return for food.

Coral Reefs: Corals build hard external skeletons from carbonates dissolved in seawater. These hard calcium-rich shells accumulate to form rock-like structures called coral reefs.

IDEAL CONDITIONS FOR THE DEVELOPMENT OF CORAL REEFS

Parameters	Ideal Condition Requirement
Temperature (Warm Water)	• Coral reefs cannot tolerate water temperatures below 18° Celsius. • Many grow optimally in the water temperature range of 23°–29° Celsius, but some can tolerate temperatures as high as 40° Celsius for short periods. • Coral don't flourish in areas with cold currents because of the temperature shock caused by the upwelling of cold water to the surface. • The **continent's eastern coast** is a preferable location for the growth of coral reefs over the west coast because of low temperature and associated upwelling.
Salinity (Saline Filled & Silt Free Water)	• Freshwater is not suitable for coral growth and muddy water clogs their pores, thus, causing death. • They require moderate to low levels of salinity of around 30-40 parts per 1000 and ocean water free from sediments
Depth and Clarity of Water (Clear Water)	• Coral polyps require a suitable platform within the favorable depth for its growth. • The water must also be clear and shallow so that a maximum amount of light penetrates it.
Water Movement (Moving Water)	• Moving water ensures the supply of oxygen and the avail-ability of planktons in abundance. • Corals do not grow in areas that are frequently visited by violent storms.
Type of surface (Rich Supply of Nutrients)	• For solidification of the Coral polyps, a semi-hard or hard surface is required.

TYPES OF CORAL REEFS

Type	Characteristics	Examples
Fringing Reefs (Shore Reefs)	• Reefs that grow near the coastline around islands and continents. • Separated from the shore by a shallow lagoon known as 'Boat channels'. • Runs as a narrow belt of around 1-2 km wide	Ningaloo Reef along the western coast of Australia (largest in the world)
Barrier Reefs	• Similar to fringing reefs in that they also parallel the coastline • They separated by deeper, wider lagoons.	Great Barrier Reef, Australia (largest in the world)
Atolls	• Rings of reefs located in the open ocean. • They form when fringing reefs grow around volcanic islands that eventually sink into the ocean or the sea level rises around them. • generally formed on mid-oceanic ridges • usually take a horse-shoe shape • lagoon is always found in the middle	French Polynesia, the Caroline and Marshall Islands, Micronesia, Cook Islands and Kiribati (Pacific Ocean) Chagos Archipelago (India Ocean)

DISTRIBUTION OF CORAL REEFS

- Mostly in areas around the equator where the water is warmer.
- More than 100 countries have a coral reef within their borders.
- Over half of the world's coral reefs are found within six countries: Australia, Indonesia, Philippines, Papua New Guinea, Fiji, and the Maldives.

- Coral reefs are absent on the west coast of tropical continents because of Presence of Cold coastal currents as upwelling causes cooling of warmer sea surface. For Example, west coast of Americas (Peru cold current), west coast of Africa (Benguela cold current and Canary current), West coast of Australia (west Australian cold current).

Coral Triangle:

- It is marine region spanning parts of Indonesia, Malaysia, Papua New Guinea, the Philippines, the Solomon Islands and Timor-Leste. It has the highest coral diversity in the world (76% of the world's coral species are found here)

Mesoamerican Reef:

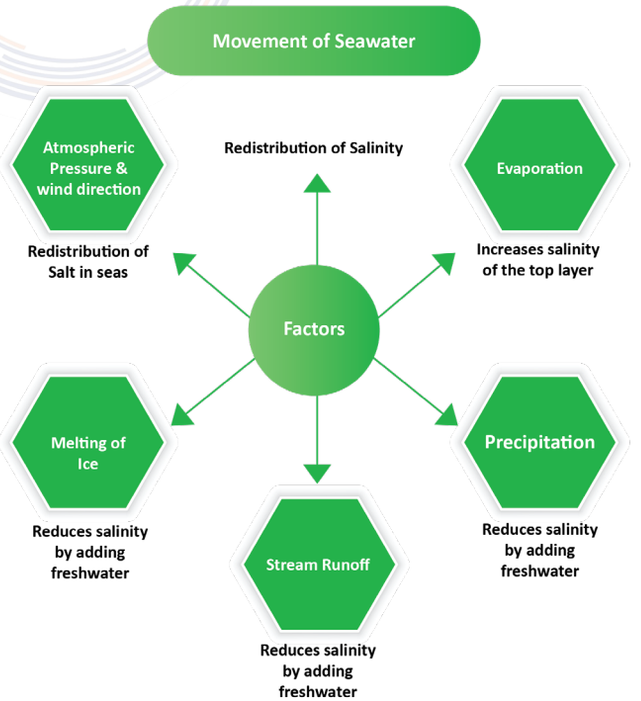
- It is located in the Atlantic Ocean. It stretches along the coast of Honduras, Guatemala, Belize and Mexico. It is the largest barrier reef in the Western Hemisphere.

Distribution of coral reefs in India

	Reef Type	Coral Reserve
Gulf of Mannar	Fringing type	Gulf of Mannar Biosphere Reserve
Andaman and Nicobar Islands	Fringing And Barrier type	1) Mahatma Gandhi Marine National Park 2) Rani Jhansi Marine National Park in Richie's Archipelago
Lakshadweep Islands	Atolls	_____
Gulf of Kutch	Fringing type	Gulf of Kutch Marine National Park

Significance of Coral Reefs

- **Biodiversity (Supporting Services):** Occupying **less than one percent of the ocean floor**, coral reefs are **home to more than 25%** of all marine life- Known as **Rainforests of the Ocean**
- **Coastal Protection (Regulating Services)**: They reduce wave energy, act as barriers to storms, prevent catastrophic erosion and stave off flooding, particularly in small island states and atoll nations.
- **Food (Provisioning Services)**: They are a **primary source of food** and protein for many coastal communities.
- **Medicine**: Many organisms found on reefs **produce chemical compounds** that have been used in treatments for cardiovascular diseases, ulcers, leukemia, lymphoma, and skin cancer etc.
- **Tourism (Cultural Services)**: The economic contribution of tourism to coral reefs is estimated at $36 billion to the global economy each year.
- **Meteorology**: Corals along the north-western coast **provide insights regarding the patterns of the onset and withdrawal of Indian monsoons.**
- **Carbon Sequestration:** Coral reefs are an **important reservoir of carbon** and help in the sequestration of ocean carbon.



Factors Influencing Distribution of Ocean Salinity

OCEAN PROPERTIES

SALINITY

Salinity is the term used to define the total content of dissolved salts in seawate.

- It is calculated as the amount of salt (in gm) dissolved in 1,000 gm (1 kg) of seawater. It is usually expressed as parts per thousand (o/oo) or ppt..

Major Components of Ocean Salinity:

The major dissolved ions in seawater are those that exist at concentrations of at least 1mg/kg (>O.OO1 or o/oo). The share of dissolved salts are

- Sodium chloride - 77
- Magnesium chloride - 1O
- Magnesium sulfate - 4.7
- Calcium sulfate -3.6
- Potassium sulfate -2.5

Horizontal Distribution of Salinity

- The salinity for normal open ocean ranges between **33o/oo and 37 o/oo.**
- Generally, the salinity decreases from the equator towards the poles.
- The highest salinity is found around the tropics, where there is active evaporation due to the clear skies, high temperature, and consistent trade winds.
- The freshwater intake due to the precipitation and reduction of the insolation due to the presence of clouds decreases the salinity at the equator compared to the tropics.

List of World's Saltiest Water Bodies

Salinity (o/oo)	Water Body	Location
433	Gaet'ale Pond	Ethipoia
400	Lake Retba	Senegal
350	Lake Vanda	Antarctica
350	Garabogazköl (lagoon)	Turkmenistan
348	Lake Assal	Dibjouti
338	Don Juan Pond	Antarctica
337	Dead Sea	Israel, Jordan, and Palestine

Salinity of Major Oceans

Pacific Ocean

- High Variation due to its shape and larger areal extent.
- The highest surface salinities in the open Pacific occur in the southeastern area, where they reach 37 parts per thousand
- The lowest salinities—less than about 32 parts—occur in the extreme northern zone of the Pacific.

Atlantic Ocean

- The average salinity of the Atlantic Ocean is around 36-37.
- low levels of salinity, ranging between 20 and 32 in polar areas due to low evaporation and large amounts of freshwater from melting of ice.
- Maximum salinity (37) is observed between 20° N and 30° N and 20° W – 60° W.

Indian Ocean

- The average salinity of the Indian Ocean is 35.
- Low salinity in Bay of Bengal due to the influx of freshwater
- Higher salinity in the Arabian Sea due to high evaporation and a low influx of fresh water.

Vertical Distribution of Salinity

- **Upper Layer:** The upper layer of the oceans experiences the maximum change in their salinity, because of its changing environment, like the influx of freshwater, subjection to evaporation, melting of ice etc.

- **Increase in Salinity with Depth:** Salinity increases with increasing depth from 300 meters to 1000 meters in high latitudes.
- **Halocline:** There is rapid rate of change of salinity (both increase and decrease) in the depth zone of 300m-1000m. This zone of steep gradient of salinity is called halocline.
- **Stabilization of Salinity:** Below the halocline, the salinity stabilizes with marginal change. High salinity seawater generally sinks below, leading to stratification by salinity.

Significance of Ocean Water Salinity

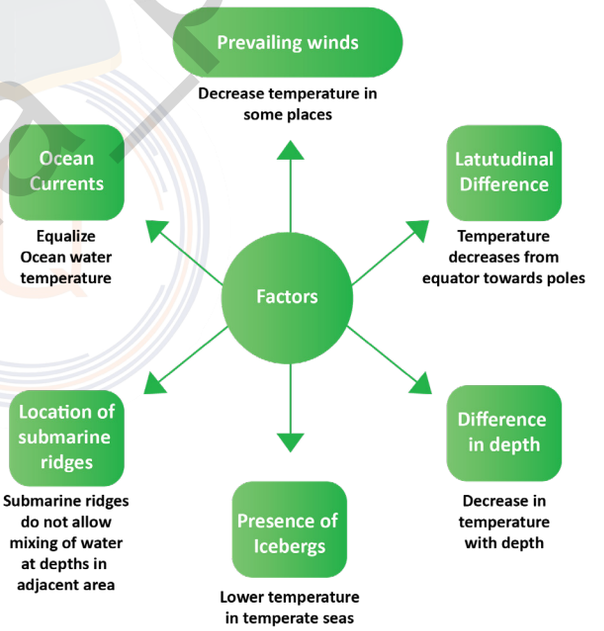
- Determines the absorption of insolation,
- Influences the evaporation,
- Affects the immediate humidity, the temperature of the water etc.
- Directly and indirectly, influences the movement of the sea water and the distribution of the fishes and other marine resources of the ocean.

TEMPERATURE OF OCEAN WATER

Water has higher specific heat than land. As a result, water is heated by the sun's rays much more slowly than land is. It also loses heat slower than land.

Horizontal Distribution of Temperature

- The annual average temperature at equator is 26.7ºC it decreases from the equator towards poles viz., at 2Oº latitude, it is 22ºC ; at 4Oº latitude, it is 14ºC and at 6Oº latitude, it is OºC near the poles.
- The highest temperatures are recorded in the enclosed tropical seas. The Red Sea has an average summer temperature of 3OºC.
- The annual range of temperature is greater in the Atlantic than in the Pacific Ocean.
- It is also greater in the northern hemisphere than in the southern hemisphere. It is due to the difference of size and due to the large expanse of sea-water.



Vertical Distribution of Temperature

The maximum temperature is at the surface. This is because it receives the direct solar insolation. The water temperature decreases with depth. The rate of decrease of temperature is not equal at all depths.

Three Layers

The temperature structure of oceans over middle and low latitudes can be described as a three-layer system from the surface to the bottom.

- **The first layer** represents the top layer of warm oceanic water, and it is about 5OOm thick with temperatures ranging between 2Oº and 25º C.
  - Within the tropical region, this layer is present throughout the year, but in mid-latitudes, it develops only during summer.
- **The second layer,** called the **thermocline layer**, lies below the first layer and is characterized by the rapid decrease in temperature with increasing depth.
- **The third layer** is very cold and extends up to the deep ocean floor.
  - In the Arctic and Antarctic circles, the surface water temperatures are close to Oº C, so the temperature change with the depth is very slight. Here, only one layer of cold water exists, extending from the surface to the deep ocean floor.

Influence of Ocean Water Temperature

- **On Climate:**
  - Winds passing over the warm ocean water absorb abundant water vapor and offer plenty of rain when they reach onshore regions.
  - The warm and cold ocean currents meeting often creates fog, storms, and cyclones.
  - Warm ocean currents keep ports, harbors, and coastal areas of the cold temperate region ice-free.
- **On Navigation:** Ships and ocean vessels cannot ply in when the ocean water temperature drops below the freezing point.
- **On Fishing:** The meeting of warm and cold currents in the temperate oceans favors the development of fishing grounds.

DENSITY OF OCEAN WATER

The density of fresh water is 1 g/cm3 at 4 degree C. The addition of salts and other dissolved substances increases surface seawater density to between 1.02 and 1.03 g/cm3.

- The density of seawater can be increased by reducing its temperature, increasing its salinity, or increasing the pressure.
- Pressure has the least impact on density as water is fairly incompressible, so pressure effects are not very significant except at extreme depths.

Distribution of Density

- Density is lowest at the surface, where the water is the warmest.
- As depth increases, there is a region of rapidly increasing density with increasing depth, which is called the **pycnocline.**
- The pycnocline coincides with the thermocline, as it is the sudden decrease in temperature that leads to the increase in density.
- Below the pycnocline, density may be fairly constant (as is temperature), or it may continue to increase slightly towards the bottom.

OCEAN DEPOSITS

The Earth's continental crust gets eroded by exogenic agents like wind, water, etc. and most of this eroded material is deposited in rivers or the coast, while the leftovers are dropped on the ocean floor.

- The ocean bottom is covered by various bottom sediments, deposits of mineral grains, and rock fragments from the continents, mixed with dissolved shells and bones of marine organisms.
- The sediment deposits in general, are the thickest near the continental shelves and thin or absent on the newly formed crust of mid-ocean ridges.

Types of Ocean Deposits

(a) Terrigenous Sediments:

- Terrigenous **means "of land origin."**
- They are land-derived silts and clays carried to the sea by rivers.
- Winds also carry earth sand out to sea and deposit them on the surface, that sink to the bottom.
- Terrigenous deposits are mostly found in the region of the continental shelf.
- These deposits **are also called muds.**

(b) Pelagic Sediments:

- These sediments are **also known as ooze**.
- They form in deep water and are commonly composed of **shells and skeletal remains of marine plants and animals.**
- Oozes have a fine, flour-like texture and either occur as accumulated deposits or float about in suspension.

(c) Glacial Marine Sediments:

- The majority of these sediments **(mud, rocks, sand, and boulders)** have been deposited by melting glaciers immediately after the ice age.
- Currently, these sediments are deposited by **icebergs** (pieces of glaciers that break off and float to the sea and melt).
- These sediments are **found primarily in high latitudes within the continental shelf.**

(d) Volcanic Sediments:

- They result from volcanic eruptions and are **primarily pumice and ash.**
- They are found in both deep and shallow water in all the world's oceans.
- They are red and are **also known as Red clays.**

Importance of Ocean Deposits

- Provide information on the history of the ocean
- Can be used to study changes in ocean currents
- Can be used to study the ocean floor
- Provide information on past climates
- Can be used to study the ocean's role in the carbon cycle
- Can be used to study the ocean's role in the global water cycle

TIDES

The rise and fall of sea water due to gravitational forces of the sun and moon are called tides. The sea waves generated by tides are called **tidal waves.**

- **High Tide:** When the highest part of the tide (crest) reaches the coast, high tide occurs.
- **Low tide:** It occurs when the lowest part of the wave, or its trough reaches the coast.
- **Tidal Range**: The difference in height between the high tide and low tide is called the tidal range.
- **Tidal Current:** It is horizontal movement of water that accompanies the rising and falling of tides.
- **Flood Current:** It is the incoming tide along the coast and into the bays and estuaries.
- **Ebb Current**: The outgoing tidal current is called ebb current.

FORCES RESPONSIBLE FOR FORMATION OF TIDES

- The moon's gravitational pull
- The sun's gravitational pull
- Centrifugal force- the force that acts to counter balance the gravity.
- The 'tide-generating' force: It is the difference between. the gravitational attraction of the moon and the centrifugal force.

TYPES OF TIDES

Tide	Characteristics
Semi-diurnal Tide	• It features two high tides and two low tides each day. • The tides recurr at an interval of 12 hours 26 minutes. • The successive high or low tides are approximately of the same height. • This is the most common form of tides
Diurnal Tide	• There is only one high tide and one low tide during each day. • The tides recurr at an interval of 24 hours 52 minutes daily. • The successive high and low tides are approximately of the same height. • Diurnal tidal cycles can be found in the Gulf of Mexico and on the East coast of the Kamchatka Peninsula.

Tide	Characteristics
Mixed Tide	• Tides having variations in height are known as mixed tides. • These tides generally occur along the west coast of North America and on many islands of the Pacific Ocean.
Spring Tides	• The earth , sun and moon align themselves along a line twice in a month around a new moon and a full moon • The combined gravitational force of the sun and moon produce higher tides almost 20 percent higher than the normal tides. These are called spring tides. • The position of sun, moon and earth in a straight line is called **'syzygy'** • When sun and moon are in one side of earth (that is solar eclipse position), the position is called **'conjunction'** • When earth is between sun and moon, the position is called **'opposition'** • During both conjunction and opposition positions, the resultant tides are spring tides.
Neap Tides	• When the sun and the moon are at right angles to each other they pull in opposite directions. • Although the Moon's attraction is more than twice as strong as the sun's, the solar tidal force partially cancels the Moon's gravitational force. • This results in formation of tides lower in height than normal tides. This is called a neap tide. • These types of tides happen when there is a quarter moon. • These tides occur twice a month, just as spring tides. • Normally, there is a seven day interval between the spring tides and neap tides.

TIDAL BORE

A tidal bore is a strong tide that pushes up the river, against the current. It occurs along a coast where a river empties into an ocean or sea.

Favourable Conditions for Formation of Tidal Bores

- Shallow river. The river must be fairly shallow.
- River must have narrow outlet to sea. However, the estuary, or place where the river meets the sea, must be wide and flat.
- The coast's tidal range must be quite large, usually at least 6 meters.

Examples:

- Occur in Qiantang River (the lower course of the Fuchun River), in Zhejiang province, China- It is the largest river tidal bore in the world.
- Occur in Hooghly River in India

Impact of Tidal Bores

- Adversely affect the shipping and navigation in the estuarine zone.
- Disrupt fishing zones in estuaries and gulfs.
- Adverse impact on the ecology of the river mouth.

Significance of Tides

Navigation: Strong tides aid navigation across river channels and estuaries with shallow entrances. For example, navigation to the tidal ports of London and Kolkata is reliant on the tides' aid.
Desiliting: Tides aid in sediment desilting and removing contaminated water from river estuaries.
Fishing: High tides aid in fishing.
Tidal electricity: Tidal energy is a good non-renewable energy source. For example: In India, a 3 MW tidal power project was built in the Sunderbans of West Bengal's Durgaduani.

OCEAN CURRENTS

A continuous general movement of ocean water in a specified direction is called ocean current.

FORCES RESPONSIBLE FOR OCEAN CURRENTS

Primary Forces

- **Solar energy**: Causes the water to expand. As a result, there is a very slight gradient and water tends to flow down the slope.
- **Influence of Wind:** Wind blowing on the surface of the ocean pushes the water to move.
  - Friction between the wind and the water surface affects the movement of the water body in its course. Example: Trade Winds.
- **Gravity:** It tends to pull the water down the pile and create gradient variation.
- **Coriolis force:** It causes the water to move to the right in the northern hemisphere and to the left in the southern hemisphere.

Secondary Forces:

- **Influence of geographical orientation:** Crustal land masses block and affect the course of a current due to their geographical orientation. Example: Peruvian Current is formed when part of the West Wind Drift is diverted northwards by the tip of southern Chile.
- **Salinity and Water Density:** Differences in water density affect the vertical mobility of ocean currents (vertical currents). Water with high salinity is denser than water with low salinity and in the same way cold water is denser than warm water. Denser water tends to sink, while relatively lighter water tends to rise.
  - Cold-water ocean currents occur when the cold water at the poles sinks and slowly moves towards the equator.
  - Warm-water currents travel out from the equator along the surface, flowing towards the poles to replace the sinking cold water.

Gyres

A gyre is a large system of rotating ocean currents.There are five major gyres: the North and South Pacific Subtropical Gyres, the North and South Atlantic Subtropical Gyres, and the Indian Ocean Subtropical Gyre.

TYPES OF OCEAN CURRENTS

BASED ON DEPTH

- **Surface currents:** are those that circulate to a depth of 400m from the surface; they roughly constitute about 10% of all the water in the ocean.
- **Deepwater currents:** are caused due to changes in density and under the influence of gravity. They make up the other 90% of the ocean water.

BASED ON TEMPERATURE

- **Cold currents:**
  - Transport cold water from high latitudes to low latitudes.
  - Most commonly seen on the west coasts of continents at low and middle latitudes (in both hemispheres) and the east coast at higher latitudes in the Northern Hemisphere.
- **Warm currents:**
  - Transport warm water from low to high latitudes.
  - Most commonly seen on the east coasts of continents in the low and intermediate latitudes (true in both hemispheres). They can be found on the west coasts of continents at high latitudes in the northern hemisphere.

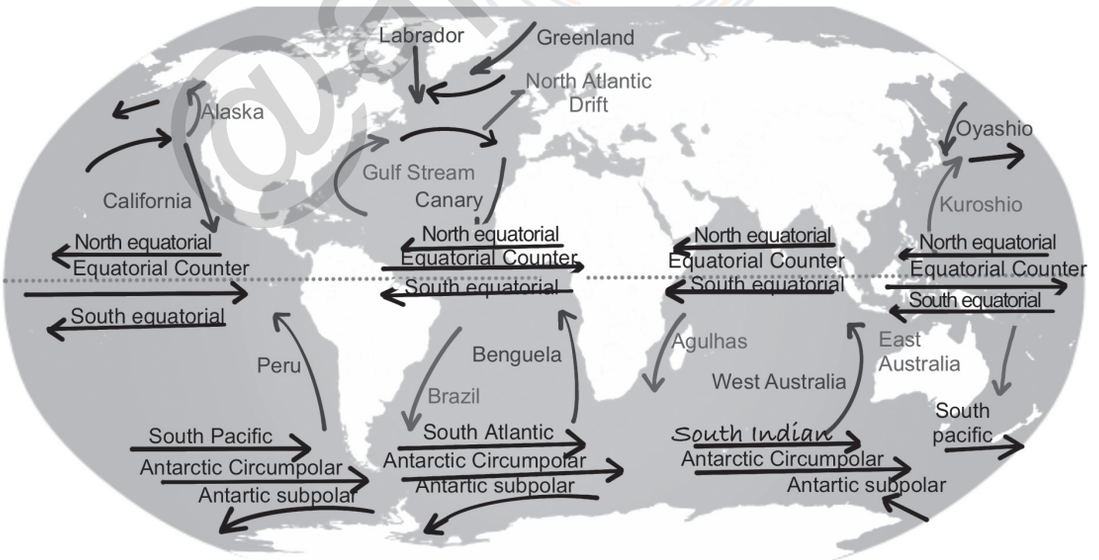
List Of The Warm Current And Related Important Facts		
Warm Ocean Current	**Region**	**Important Facts**
North Equatorial Current	Pacific Ocean & Atlantic Ocean	• It has no relation with the Equator. • The current forms the southern side of the clockwise subtropical gyre. • The North Equatorial Current flows east to west between 10º N to 20ºN.
Kuroshio Current	Pacific Ocean	• The word " Kuroshio" refers to "Black Stream". This is a west boundary current. • The average surface temperature of the current is warmer than the surrounding ocean. Due to this warm current, the temperature in Japan is regulated. • It is similar to the Gulf Stream in the Atlantic Ocean, as it is in the Pacific Ocean.
North Pacific Current	Pacific Ocean	• The North Pacific current circulates anti-clockwise direction along the Western North Pacific Ocean. • The current is formed when the Kuroshio currents and the Oyashio current meet.
Alaskan Current	North Pacific Ocean	• The northward diversion of a part of the North Pacific Ocean results in the formation of Alaskan current. • Two large eddies are formed, known as Haida Eddies and Sitka Eddy
Equatorial Counter Current	Atlantic Ocean, Pacific Ocean, and the Indian Ocean	• The current is also called North Equatorial Counter current. • This wind-driven current flows west to east between 3ºN-10ºN.
Tsushima Current	Sea of Japan	• It is a branch of Kuroshio Current
South Equatorial Current	Atlantic Ocean, Pacific Ocean, and the Indian Ocean	• Southern Hemisphere counter-part of North Equatorial counter current. • Directly driven by trade winds blowing from east to west.
East Australian Current	South-Western Pacific Ocean	• The East Australian Current transports the tropical marine fauna to habitats in subtropical regions along the southeast Australian coast.
Florida Current	South Atlantic Ocean & Caribbean Sea	• The Florida current was discovered by Spanish explorer Juan Ponce de León in 1513. • The Florida current flows around the Florida Peninsula and joins the Gulf Stream at Cape Hatteras.
Gulf Stream	North Atlantic Ocean	• The Gulf Stream splits into North Atlantic Drift (crossing Northern Europe & southern stream) and Canary Current (recirculating off West Africa). • This is an intensified current-driven mainly by wind stress.
Norwegian Current	North Sea (Atlantic Ocean) & Barents Sea (Arctic Ocean)	• It is a branch of North Atlantic Drift and sometimes is also considered as an extension of the Gulf Stream. • This wedge-shaped current is one of the two dominant Arctic inflows of water.
Irminger Current	North Atlantic Ocean	• The current is named after the Danish vice-admiral Carl Ludvig Christian Irminger. • The Irminger current is a part of the North Atlantic subpolar gyre.
Antilles Current	North Atlantic Ocean	• It is a part of the North Atlantic gyre. • It flows across the island chain which separates the Atlantic Ocean and the Caribbean Sea.

List Of The Warm Current And Related Important Facts		
Warm Ocean Current	**Region**	**Important Facts**
Brazilian Current	South Atlantic Ocean	• It flows along the south coast of Brazil till Rio de la Palta. • It joins the cold Falkland Current at the Argentine Sea, making it a temperate sea.
Mozambique Current	Indian Ocean	• Large anti-cyclonic Mozambique channel eddies are formed. • The Mozambique current flows between the south-east country of Africa-Mozambique and the island of Madagascar in the Mozambique Channel.
Agulhas Current	South-West Indian Ocean	• It flows south along the east coast of Africa. • This is the largest western boundary ocean current.
Southwest Monsoon Current	Indian Ocean	• The current extends into the Arabian Sea and the Bay of Bengal. • The Indian Ocean is dominated by this current during the southwest monsoon season (June-October).

List Of The Cold Current And Related Important Facts		
Cold Ocean Current	**Region**	**Important Facts**
Humboldt or Peruvian Current	South Pacific Ocean	• Along the west coast of South America, the Peruvian current flows from the southernmost tip of Chile to northern Peru. • The Current is named after Prussian naturalist and Geographer-Alexander Von Humboldt. • A large marine ecosystem which serves as the major nutrient system of the world is supported by this very low-salinity current.
Kurile or Oya shio Current	North Pacific Ocean	• It flows south of the Arctic Ocean via the Bering Sea in the North Pacific Ocean, while originating from the same Arctic Ocean. • This sub-arctic ocean current circulates in an anti-clockwise direction. • To form the North Pacific Drift, the cold Oyashio current collides with Kuroshio currents off the Japanese east. • The currents are rich in nutrients.
California Current	Pacific Ocean	• It forms a part of North Pacific Gyre. • The California current is an extension of the Aleutian Current that flows along the west coast of North America in a southward direction. • The region experiences a very strong upwelling.
Antarctic Circumpolar Current	Southern Ocean	• It is also known as West Wind Drift. • The current flows in a clockwise direction from east to west around Antarctica. • The Antarctic Circumpolar Current is considered to be the largest ocean current in the world.
Labrador Current	North Atlantic Ocean	• With the combination of warm Gulf Stream and cold Labrador Current is known for producing one of the richest fishing grounds of the world. • The Labrador Current meets the warm northward moving Gulf Stream with the Arctic Ocean after flowing south.
Canary Current	North Atlantic Ocean	• The current is named after the Canary Islands. • The Canary Current, also known as Eastern Boundary Current, is a part of the North Atlantic Gyre. • The region experiences upwelling.
Eastern Greenland Current	Arctic Ocean & North Atlantic Ocean	• The North Atlantic and the Arctic are directly connected by this current. • The Eastern Greenland Current is a Low salinity current that extends between Cape Farewell to Farm Strait. • It also contributes to the highest sea-ice export out of the Arctic. • The Eastern Greenland Current forms the major freshwater sink for the Arctic.

List Of The Cold Current And Related Important Facts		
Cold Ocean Current	**Region**	**Important Facts**
Benguela Current	South Atlantic Ocean	• The Benguela Current forms the eastern portion of South Atlantic Ocean Gyre. • The Benguela Current forms the branch of West Wind Drift in the Southern Hemisphere. • The current is characterized by high upwelling, presence of an excellent fishing zone and low salinity.
Falkland Current	South Atlantic Ocean	• The current has been named after the Falkland Islands. • The current is also known as Malvinas Current. • The Falkland Current is a branch of the Antarctic Circumpolar Current. • The Barzil-Malvinas Confluence zone is created by the mixing of the Falkland cold current and the warm Brazil current. This is also responsible for the region's temperate climate.
Northeast Monsoon Current	North Indian Ocean	• It is a seasonal ocean current that predominantly flows in the Bay of Bengal and the South China Sea. • It occurs during the northeast monsoon season, typically from December to early March, flowing southwestward along the eastern coast of India and then turning southeast towards the equator.
Somali Current	West Indian Ocean	• The Current is deeply influenced by the monsoon. • The Somali Current is similar to the Gulf Stream in the Atlantic Ocean. • The region experiences major upwelling.
Western Australian Current	Southern Ocean & South Indian Ocean	• The current is also a part of Antarctic Circumpolar Current. • The Western Australian Current is otherwise known as West Wind Drift. • The Western-Australian Current is a seasonal current-that is strong in summer and weak in winter.
South Indian Ocean Current	South Indian Ocean	• It flows westward along the southern edge of the Indian Ocean. • It is part of the larger Antarctic Circumpolar Current

SIGNIFICANCE OF OCEAN CURRENTS



Ocean Currents

- **Temperature Conditions:** The **warm Equatorial currents raise the temperature** of the region in which they flow. Similarly, the cold currents lower the temperature of the places where they flow.
  - For example, the hot climate of Peru is cooled by the cold Peru Current.

- **Rainfall:** The winds blowing over warm currents pick up and carry moisture and bring rainfall. On the contrary, cold currents do not bring rainfall and make the region cooler and drier.
  - For example, The Kalahari Desert hardly experiences rainfall due to the cold Benguela current.
- **Fog Formation:** The meeting of the warm and the cool currents results in the formation of fog.
- **Aids Fishing:** The mixing of warm and cold currents results in the deposition of plankton. Therefore, at such places, fish can be found in abundance.
- **Trade and Commerce:** Currents help ships to sail if they follow the directions of the currents.
- **Violent Storms:** At times the meeting line of a warm and a cold current may result in a violent storm.
  - For example, The hurricanes which occur off the coast of the U.S.A. follow the line where the Gulf Stream merges with the Labrador Current.

UNITED NATIONS CONVENTION FOR THE LAW OF THE SEA (UNCLOS)

The United Nations Convention on the Law of the Sea was adopted in 1982.

- It lays down a comprehensive regime of law and order in the world's oceans and seas establishing rules governing all uses of the oceans and their resources.

Maritime zones

UNCLOS divides marine areas into five main zones namely- Internal Waters, Territorial Sea, Contiguous Zone, Exclusive Economic Zone (EEZ) and the High Seas.

Internal Waters:

- Sea water lying between coastland and baseline is called internal waters.
- Each coastal state has full sovereignty over its internal waters as like its land territory.
- Examples of internal waters include bays, ports, inlets, rivers and even lakes that are connected to the sea.
- There is no right of innocent passage through internal waters.
  - The innocent passage means passing through the waters which are not prejudicial to peace and security.

Territorial Sea:

- The territorial sea extends seaward up to 12 nautical miles (nm) from its baselines.
- The coastal states have sovereignty and jurisdiction over the territorial sea. These rights extend not only on the surface but also to the seabed, subsoil, and even airspace.
- But the coastal states' rights are limited by the innocent passage through the territorial sea.

Contiguous Zone:

- The contiguous zone extends seaward up to 24 nm from its baselines.
- It is an intermediary zone between the territorial sea and the high seas.
- The coastal state has the right to both prevent and punish infringement of fiscal, immigration, sanitary, and customs laws within its territory and territorial sea.
- Unlike the territorial sea, the contiguous zone only gives jurisdiction to a state on the ocean's surface and floor. It does not provide air and space rights.

Exclusive Economic Zone (EEZ):

It extends upto a distance of 200 nautical miles from the baseline.

Within its EEZ, a coastal state has:

- Sovereign rights for the purpose of exploring, exploiting, conserving and managing natural resources, whether living or nonliving, of the seabed and subsoil.
- Rights to carry out activities like the production of energy from the water, currents and wind.

- It does not give a coastal state the right to prohibit or limit freedom of navigation or overflight, subject to very limited exceptions.

High Seas:

- The ocean surface and the water column beyond the EEZ are referred to as the high seas.
- It is considered as "the common heritage of all mankind" and is beyond any national jurisdiction.
- States can conduct activities in these areas as long as they are for peaceful purposes, such as transit, marine science, and undersea exploration.

South China Sea and nine-dash line

China claims 'indisputable sovereignty' over the South China Sea, and is refered to as the country's 'blue national soil' a term used to refer to the country's offshore waters.

Nine Dash line: It is an unspecified and ambiguous maritime area claimed by the People's Republic of China (PRC) out of its claims in the South China Sea.

- It is a U-shaped line.
- The line runs as far as 2,000km from the Chinese mainland to within a few hundred kilometres of the Philippines, Malaysia and Vietnam.

Background of Nine-Dash line:

- The nine-dash line was originally an 11-dash line, and Chinese geographer Yang Huairen helped to drew it.
- In 1952, it became the nine-dash line when in a moment of Communist camaraderie with Vietnam; Mao gave up China's claims over the Gulf of Tonkin.

Significance: It represents China's claim over the sea and all the land features that are contained within the line. It hence affects the economy of developing island countries.

INTERNATIONAL HYDROGRAPHIC ORGANIZATION (IHO)

It is an intergovernmental organization comprising of 94 Member States.

- **Aim:** The main goal of IHO is to ensure that the world's seas, oceans and navigable waters are charted and surveyed properly.
- **Functions:** The IHO develops hydrographic and nautical charting standards. These standards are further used by the member countries and others for surveys, nautical charts, and publications.

CHAPTER 4

World Economic Geography

RESOURCES

Resources are any objects or substances that provide us with utility and satisfy human needs.

CLASSIFICATION OF RESOURCES

On the basis of origin:

- **Biotic Resources:** For example, plants, fishes, etc.
- **Abiotic Resources:** These are inanimate resources. They do not have life. Examples include metals, minerals, water, etc.

On the basis of exhaustibility

- **Flow or Inexhaustible Resources:** For example, sunshine, wind, rainfall, etc.
- **Fund or Exhaustible or Non-renewable Resources:** For example, minerals and fuels.
- **Renewable Resources:** For example, trees in a forest, fertility of the soil, etc.

On the basis of Nature of ownership

- **Individual Resources:** For example, the land of a farmer, the house of an individual, etc.
- **National Resources:** TFor example, all the minerals, water resources, forests, wildlife, and land within the political boundaries of a nation.
- **International Resources:** For example, oceanic resources beyond 200 nautical miles of the Exclusive Economic Zone belong to the open ocean.

On the basis of status of Development

- **Potential Resources:** For example, there is huge potential for solar and wind energy in Gujarat, most of which remains untapped.
- **Developed Resources:** These are resources that have been utilized by a man using technical know-how.
- **Stock and Reserves:**
  - Stocks are resources that are unutilized due to a lack of technical knowledge and scientific development.
  - Reserves are a part of the stock. They are resources that can be used with existing technical knowledge but their utilization has not yet started. For example, a reserve of minerals.

MINERAL RESOURCES

A mineral is a naturally occurring substance of organic or inorganic origin with definite chemical and physical properties.

Ferrous Metallic Minerals

Iron Ore

Important Characteristics	Uses	Distribution	
Vary in color, ranging from rusty red, deep purple, a striking yellow, and dark grey. Generally rich in iron oxides	The primary use of iron ore (98%) is to make steel. The remaining 2% is used in various other applications, such as powdered iron for certain types of steel, auto parts and catalysts; radioactive iron for medicine; and iron blue in paints, inks, cosmetics and plastics.	**Australia (largest producer)**	Western Australia, Iron knob in South Australia
		Brazil	Minas Gerais
		China	Manchurian deposits at Anshan, Yangtze valley, Hopei
		US	Lake Superior region, Adirondacks, Alabama, Nevada, California.
		Canada	Labrador, Quebec, British Columbia.
		CIS	Krivoi Rog in Ukraine, Siberia, Urals region, Kursk Magnetic Anomaly (Lipetsk, Donbas)
		France	Lorraine, Normandy
		India	Orissa, Jharkhand
		South Africa	Postmasburg, Thabazimbi
		Peru	Nazca Marcona

Manganese

Important Characteristics	Uses	Distribution	
Ferroalloy metal. It is a hard, heavy, and silvery metal. It is exploited as ores as well as nodules on the deep seafloor. There are two types of manganese ores- Pyrolusite and Psilornelane.	Steel contains about 1% manganese, which increases its strength. It also improves workability and resistance. It is used in railway tracks, safes, rifle barrels, and prison bars. It is used in various chemical industries as an oxidizer to prepare disinfectants and other chemicals. It is also used in making electric batteries, paints, and plastics.	China (Largest Producer)	Guangxi, Hunan, and Cuizhou provinces.
		South Africa	Postmasburg, Kuruman and west of Kimberly
		CIS	Nikopol and Tokmak in Ukraine, Chiature in Georgia, UluTeljakin the Urals, Usa in Kuzbass.
		India	Balaghat,, Visakhapatnam, Singhbhum, Goa
		Ghana	Nsuta
		Brazil	Near Mecapa in Amapa, Minas Gerais, Urucum in western Mato Grosso.
		Others	Deposits as nodules, especially in the Pacific Ocean.

Cobalt

Important Characteristics	Uses	Distribution	
It is a hard ferromagnetic element that is silver-white, lustrous, and brittle. It is air-stable and does not react with water. It can be magnetized like other metals.	Many alloys and superalloys contain cobalt. They are used to make parts for aircraft engines, gas turbines, high-speed steels, corrosion-resistant alloys, and cemented carbides. Also used in the petroleum and chemical industries as a catalyst. Paints and inks use cobalt as a drying agent. It is also an essential mineral used for batteries in electric cars, computers, and cell phones.	Democratic Republic of Congo (Largest Producer)	Kolwezi
		Russia	Altai Republic
		Canada	Sudbury
		Zaire	Katanga
		Zambia	Kilemba
		Morocco	Bou Azzer
		Australia	New Caledonia

Chromium

Important Characteristics	Uses	Distribution	
Chromite is the primary source of chromium metal. Chromite ore is found mainly in mafic intrusive igneous rocks and sometimes in metamorphic rocks.	It is used to harden steel, anufacture stainless steel, and produce several alloys. Chromium salts and compounds such as chromates are used to manufacture paint pigments and in the chemical industry. Chromium is electroplated on metal and is known as chrome. It is used in the automotive industry.	South Africa(Largest producer)	Rustenburg
		Turkey	Adana Province
		Kazakhstan	Aqtobe region
		Zimbawe	Selukwe
		CIS	Sarany and Chromtay in Urals, Kukas is Albania

Nickel

Important Characteristics	Uses	Distribution	
It is a hard, silvery-white metal. Pentlaudite (a mixture of nickel, iron, and sulfur) is nickel ore. It is very hard and resistant to erosion. It is also very ductile and malleable.	• Nickel is corrosion resistant and is used to safeguard other metals by plating them. • Nickel is used in batteries. For example, rechargeable nickel-cadmium batteries and nickel-metal • hydride batteries in hybrid automobiles. • Nickel has a long history of use in coinage. The five-cent piece (known as a "nickel") in the United • States comprises 25% nickel and 75% copper. • Nickel is used as a catalyst to hydrogenate vegetable oils.	Indonesia (Largest Producer)	Sulawesi, Celebes
		Philippines	Rio Tuba
		Australia	Queensland and Kalgoorlie
		Canada	Sudbury, Lynn Lake
		CIS	Sverdlovsk and Orsk in the Urals, Kola Peninsula, Norilsk in Siberia.

Non-Ferrous Metallic Minerals

Copper

Important Characteristics	Uses	Distribution	
Copper is a soft brown metal found in igneous and metamorphic rocks. There are three primary copper ores viz. Chalcopyrite, copper sulfide, and basic carbonates. During the extraction of copper from ores, a few other minerals and metals, such as gold, silver, lead, zinc, etc., are also extracted. Copper is resistant to corrosion and does not rust.	• Copper is a good conductor of heat and electricity. It is widely used in electrical works for making • wires, generators, transformers, electronics, etc. • Due to its high malleability, copper is commonly used in the metallurgical industry. It is used to • make cables, fittings, and parts for automobiles. • It is used to make many alloys. When combined with tin, it produces bronze. When it is mixed with • gold, it produces guinea gold. With zinc, it produces brass, and with nickel, it produces monel metal. • When copper is mixed with aluminum, it produces duralumin.An alloy is a combination of a metal • with at least one other metal or nonmetal.	Chile (Largest Producer)	Copper Mountain of Chuquicamata, El Teniente, Rio Blanco, Braden
		Peru	Moquegua region
		USA	Arizona, Globe, Miami, Nevada, New Mexico
		Canada	Sudbury, Lynn Lake, Sheridon
		Sweden	Falun Mine
		Germany	Mansfield
		CIS	Degtyarsk, Kazakhstan
		Australia	Mt Isa, Mt. Morgan

Aluminum

Important Characteristics	Uses	Distribution	
Bauxite is the principal ore of aluminium. From bauxite alumina extracted dnd from alumina, aluminum is extracted. Aluminium is a good conductor of electricity. It is highly malleable.	• Uses of Aluminium • It is used in manufacturing aircraft, automobiles, rail wagons, ships, and machinery. • It is used in the manufacturing of domestic appliances and utensils. • It is also used to fabricate doors, windows, and screens. • Aluminum can be rolled into thin sheets called aluminum foils. These are used for wrapping and • packaging food.	Australia (Largest Producer)	Weipa, Cape York Peninsula.
		China	Shanxi, Shandong Henan, Cuizhou, Guangxi, and Yunnan
		Guinea	Fri a
		USA	Arkansas, Alabama, Georgia
		CIS	Urals, Turgay
		France	Brignoles
		India	Bihar
		Australia	Weipa, Cape York Peninsula.

Precious Metals and Gems

Gold

Important Characteristics	Uses	Distribution	
It is a lustrous yellow metal. It is highly malleable and ductile. It is a good conductor of heat and electricity. Cold is found in relatively pure form.	• It is used as an international reserve asset. • It is used to make jewelry. • Gold is also used as dental fillings. • It is also an essential industrial metal used in computers, communications equipment, spacecraft, jet aircraft engines	China (Largest Producer)	Dayingezhuang, Zaozigou
		Australia	Kalgoorlie, Coolgardie
		Canada	Yellow Knife, Red Lake, Timmins
		USA	South Dakota, Nevada, California, Alaska
		CIS	North-eastern Siberia, Lake Baikal
		South Africa	Witwatersrand, Lydenburg
		India	Kolar and Hutti in Karnataka, and Ramgiri in Andhra Pradesh

Diamond

Important Characteristics	Uses	Distribution	
It is not a metal but a precious stone. They are the hardest naturally occurring substances. Natural diamond is composed of carbon crystals. It is formed at high temperature and pressure conditions. It is usually 99.95 percent carbon.	• Almost 30% of diamonds taken from the earth's interior are used in the pure gem trade. • In addition to being used in jewellery, diamonds are a widely used metal. Poor quality diamonds are used in industries in cutting instruments, as abrasives, etc. • Diamonds are also used in the manufacture of automobiles. Every high-tech vehicle contains 1.5 carats of diamonds.	Russia (Largest Producer)	Aikhal- world's largest diamond mine
		Australia	Kimberley region
		Others include Botswana, Canada, Congo	

Silver

Important Characteristics	Uses	Distribution	
Pure silver is almost white, glossy, soft, highly ductile, and malleable. It is a good heat and electricity conductor. Its principal reflector ore is argentite.	• It is utilized in the production of jewellery and silver dinnerware. • Silver is used to build mirrors because it is the finest visible light reflector. • Dental alloys, solder and brazing alloys, electrical connections, and batteries are also made from it. • Silver paints are used to create printed circuit boards. • Silver iodide is used for cloud seeding.	Mexico (largest producer)	Penasquito
		USA	Idaho, Arizona, Utah
		Canada	Timmins, Yukon area
		CIS	Kazakhstan and western Siberia
		Peru	Cerro De Pasco

Platinum

Important Characteristics	Uses	Distribution	
Platinum is a silver-colored, smooth and shiny metal. It is also resistant to corrosion and has a high boiling point. Platinum is one of nature's most stable elements. It is known as the Noble metal due to its high stability.	• Platinum is widely used in jewellery. • Its primary application is in catalytic converters for automobiles, lorries, and buses. • Platinum is also utilized in the production of optical fibres, LCDs, turbine blades, spark plugs, pacemakers, and dental fillings. • Platinum compounds are chemotherapeutic medications that are used to treat cancer.	South Africa (Largest Producer)	Rustenburg region
		Canada	Sudbury district

Non-Metallic Minerals

Asbestos

Important Characteristics	Uses	Distribution	
Asbestos is a fibrous silicate mineral found in igneous rocks. There are two main ores of asbestos- chrysotile and actinolite. Asbestos is fireproof, heat resistant, and has low electrical conductivity.	• Vinyl floor tiles, vinyl sheet flooring backing, and adhesives • Panels for roofing and siding • Walls and ceilings with textured paint and patching materials • Asbestos paper, millboard, or cement sheets should be used to protect the walls and floors surrounding wood-burning stoves,	Russia (Largest Producer)	Urals
		Canada	Thetford mines in Quebec
		China	Gansu province
		Brazil	Sama's Minaqu mine

ENERGY RESOURCES

The capacity to perform work is defined as energy. The sun is the main source of energy on earth.

Classification of Energy Resources

- Sources of energy can be classified roughly into two categories: Conventional and Non- conventional sources.
- They can also be classified on the basis of availability in the future: Renewable sources and non-renewable sources. Renewable resources can also be called inexhaustible. However, non-renewable resources get exhausted upon over-utilization.

Conventional sources of energy	Non-conventional sources of energy
These are energy resources that have been in use for ages. Energy sources such as coal, petroleum, natural gas, and hydro-power are conventional sources of	These resources have been developing over the past few years. It covers solar, wind, tidal, biogas, biomass, and geothermal energy.
Except for water, they are finite and non-renewable in nature.	They are renewable in nature.
They pollute the environment when used since they emit smoke and ash. However, hydro-power is an exception	They are generally pollution-free.
They are highly expensive to maintain, store and transmit. This is because they are carried over large distances via transmission grids and lines.	They are generally less expensive and easier to maintain because they are used locally.

Conventional Sources of Energy

Coal

Classification of Coal:

The quality of coal is determined by its carbon concentration. Coal is classified as follows in terms of Carbon:

Anthracite	Bituminous coal	Lignite
This is the highest grade of coal, containing 80 to 95 percent carbon. It contains very few volatile substances and a negligible amount of moisture. It's a firm, compact, jet black coal with a semi-metallic luster. It has the highest heating value. It is the most valuable coal of all types. It releases coke as a by product. It is processed into gas coal, which is used to make city gas.	This type of coal is widely used. It accounts for 80 percent of global coal production. It varies greatly in carbon concentration (from 60 to 80 percent) and moisture content. It is dense, compact, and typically black in color, It contains no evidence of the original vegetable material from which it was created. Bituminous coal is utilized to generate steam, heat, and produce coke, gas, etc.	It is also called brown coal. Lignite is lower-grade coal because it contains about 40 to 55 percent carbon. It is an intermediate stage in the transformation of woody materials into coal. It ranges in color from dark to black brown. It has a high moisture content (over 35 percent). This is why it produces a lot of smoke but little heat. It is sometimes used in steel plants despite its limited heating capacity,

World Distribution of Coal:

China is the world's largest coal producer accounting for almost 47% of the world's entire output in 2019, It is followed by India and the United States.

Important Characteristics	Uses	Distribution	
Coal is generated when dead plant matter decays into peat. It is then transformed into coal over millions of years by the heat and pressure of deep burial. It is a mechanical combination of carbon, hydrogen, nitrogen, sulfur, and other elements.	• Coal is used to generate thermal energy. This thermal energy is the primary source of electricity to light up our homes, offices, industries, and other buildings. • The technology of obtaining coal has progressed significantly. • Transport within and between countries is quite simple. • Large supplies and reserves are available. • Coal is a versatile fuel that can be burned directly, converted to liquid, gas, or used as a feedstock. • Net usable energy yield is high. • It is cheaper in comparison to other energy sources. • It still remains the most common source of electricity. • It reduces reliance on imported oil. • The ash produced by burning can be utilized for concrete, highways, and other applications.	Asia	• China: Shansi, Shensi, Inner Mongolia, Kansu, Hopei, and Manchurian Coalfields-Fushun (world's longest strip mines and thickest seam recorded anywhere), Fushin, Kailan, and Hegang. **(Largest producer)** • Japan's Chikugo coalfield in northern Kyushu, Hokkaido's Ishikari fields, and Honshu's Joban and Ube. • India's Damodar Valley is located in the states of Bengal, Jharkhand, and Orissa,with major mines located at Raniganj, Bokaro, and Jharia. Chanda, Singarent, Tundur, and Pench have smaller deposits. • Quetta and Kalabagh in Pakistan, Iran-Kermanshah.
		Canada	Prairie Province-Alberta (bituminous & lignite): British Columbia Coalfields-Vancouver Islands; Nova Scotia Coalfields-Cape Breton Island.
		Australia	Sydney includes New South Wales' New castle, Queensland's Cippsland, Tasmania's Fingal, and Queensland's Ipswich (lignite).
		Europe	Donbas (anthracite and high-grade bituminous coal), Moscow-Tula coalfields (lignite); Kuznetsk (Kuzbass) coal basin (anthracite and coking coal): Karaganda field; Minor coal fields-Scattered deposits of the Urals, Pechora, and Taimyr fields of the Arctic. Caucasus mountain deposits and Siberian deposits
		USA	• Pennsylvania anthracite field-Scranton in the eastern province. Carbondale and Wilkes Barre are part of the Appalachian bituminous field, which includes Pittsburgh, Kentucky, West Virginia, Alabama, and Tennessee. • The Interior Province (Bituminous)-(a) Eastern Interior Field-Illinois, Indiana, and Kentucky (b) Lowa, Missouri, Oklahoma, and Arkansas in the western interior field. (C) Michigan's northern interior field. (d) Texas' south-western fields • Texas, Alabama, and Arkansas are part of the Gulf Province (lignite). • Utah, Colorado, Wyoming, Montana, New Mexico, and North Dakota are part of the Rocky Mountain Province (lignite and low-grade bituminous). Washington, Oregon, California, and Alaska make up the Pacific Province.
		S.Africa	S. Africa-Transvaal and Natal-Middleburg are tVé0 provinces of South Africa. Vereeniging and Witbank; Zimbabwe-Wankie; Zambia-Nkandabwe and Mamba; and Mozambique-Maniamba, Nigeria-Enugu.
		S. America	Santa Catarina and Rio Grande do Sul in Brazil; Concepa, Chile Columbia: coal in Cali, Cauca Valley, and Pas del Rio, northeast of Bogota. PiedrasNegras, Sabinas, and Lampazos are all in Mexico.

Petroleum

Important Characteristics	Uses	Distribution	
The term petroleum refers to rock oil. This rock oil is found in the form of a thick black liquid between layers of rocks. Petroleum is known as crude oil in its unprocessed state. It is extracted from offshore and coastal oil fields.	• It is a convenient liquid fuel that has transformed land, air, and sea transportation. • It creates no ash (unlike coal). It is one of the most essential lubricants. • It is a key raw element in a variety of petrochemical products. • It is easy to handle and feed into machinery because it flows through pipelines. • There are no issues with ash disposal because of the high energy level per unit of fuel.	Australia	• Queensland- Moonie Western Australia-near Alice Springs in Northern territory: Bass Strait.
		USA- Largest producer	Mid-Continent Region-Northern Texas, Oklahoma, and Kansas. • Gulf coast region-Southern Texas, Louisiana, Mississippi, and Arkansas. • Rocky Mountain Region-Wyoming. • Colorado, Montana, and New Mexico • California Region-Southern California • Appalachian Region-Pennsylvania, Kentucky and Ohio; Alaska region, other smaller fields of Mid-west in Il, linois, Indiana, and Michigan.
		Canada	• Provinces of the Prairies. Alberta and Saskatchewan are two provinces in Canada. Edmonton, Pembina, Redwater, Calgary, and Turner Valley (Canada's longest pipeline, the Intra- provincial Pipeline from Redwater to Toronto) are important fields.
		Europe	• Romänia Ploiesti, Arges, Ticleni and • Bacau. • Germany • Norway-Ekofisk. • Britain-Sharing oil deposits of North Sea

Natural Gas

Important Characteristics	Uses	Distribution	
Natural gas is a fossil energy source that formed deep beneath the earth's surface. Natural gas contains many different compounds. The largest component of natural gas is methane, a compound with one carbon atom and four hydrogen atoms (CH_4). Natural gas also contains smaller amounts of natural gas liquids (NGLs, which are also hydrocarbon gas liquids), and non-hydrocarbon gases, such as carbon dioxide and water vapor. We use natural gas as a fuel and to make materials and chemicals.	• It is used for heating, cooking, and power generation. • It's also used as car fuel and a chemical feedstock for making plastics. • It burns completely. Hence, it is cleaner as compared to other energy sources. • It emits 70% less carbon dioxide when compared to other fossil fuels. It does not create ashes afterreleasing energy. • It is cheaper when compared to coal.	North America	USA- Marcellus Shale, Hugoton **(Largest producer)** Canada- Elmworth Mexico-Cantrell
		Europe	Norway: Troll field Netherlands-Groningen
		Russia	West Siberia east of the Gulf of 0b, Urengoy, and Yamburg.
		Asia	Arabian-Iranian basin Qatar-North Field Indonesia-North Sumatra
		Africa	Algeria- Hassi R'Mel

SHALE GAS: Natural gas trapped within shale formations is known as shale gas. Since the beginning of the century, shale gas has grown in importance as a source of natural gas in the United States. A combination of horizontal drilling and hydraulic fracturing has significantly contributed to the change in shale gas production (fracking).

Hydroelectricity

World distribution of Hydropower sites:

The United States of America and Canada are the world's top hydroelectric power producers.

Important Characteristics	Uses	Distribution	
Hydroelectric energy, also called hydroelectric power or hydroelectricity, is a form of energy that harnesses the power of water in motion—such as water flowing over a waterfall—to generate electricity. The power plant where hydroelectricity is produced is known as a hydroelectric power plant or hydropower plant. In order to produce hydroelectricity dams are constructed on rivers.	• It is cheaper than other sources of energy. • Dams not only help in electricity generation but increase irrigation capacity. • It also provides drinking water to a large population. • It is less polluting than other sources of energy such as coal and petroleum.	North America **(Largest producer)**	The Appalachian Fall line, the Great Lake Falls-St. Lawrence canal, Niagara Falls and St. Anthony in Minneapolis, the Rocky Mountains, and the Laurentian shield are all notable natural hydel power sites.
		Europe	Italy, France, Norway, Sweden, Germany, and Switzerland produce the majority of Europe's hydroelectric electricity.
		Asia	Japan, India, Shanghai and Guangzhou in China, Cameron Highlands in Malaysia.
		South America	Brazil is the top generator. Paulo-Alfonso facility, located on the San Francisco River is an important hydropower plant.
		Africa	Aswan Dam in Egypt, Akosombo Dam in Ghana, Sennar Dam in Sudan.

Nuclear Energy

It is the energy released from the nucleus of atoms. The energy is released from the atom by the process of nuclear fission. Uranium is the most widely used mineral for generating nuclear energy. The place where the process of nuclear fission takes place to generate electricity is called a **nuclear power plant**

- Nuclear energy is considered a non-renewable energy source. This is because the materials used to generate nuclear energy are exhaustible. The world's largest nuclear power producers are the United States, the Commonwealth of Independent States, Canada, the United Kingdom, France, Japan, and Germany.

Non-Conventional Sources of Energy

Solar Energy

About	Present Status of Solar Energy
Solar power is energy from the sun that is converted into thermal or electrical energy. Solar energy is the cleanest and most abundant renewable energy source available. Solar technologies can harness this energy for a variety of uses, including generating electricity, providing light or a comfortable interior environment, and heating water for domestic, commercial, or industrial use.	At the end of 2019, 629 CW of solar power was installed throughout the world. China leads the world in the generation of solar power. Between 2016 and 2019, China, the USA, and India were the top three countries in the installation of solar power facilities.

Wind Energy

About	Present Status of Wind Energy
Wind power or wind energy describes the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water), or can be converted into electricity by a generator	Wind power generation's cumulative installed capacity has significantly expanded, reaching over 651 CW by the end of 2019. Asia accounted for around 50% of the wind power generation capacity. China dominated the new installations despite a large drop in the countrys annual market. Europe and North America account for the rest of 50%.

Geothermal Energy

About	Present Status of Geothermal Energy
It is derived from the Earth's natural heat. The decay of naturally radioactive isotopes of uranium, thorium, and potassium produces geothermal energy. Heat is transmitted from the Earth's core to the surface due to a large temperature difference.	Some 80 countries have identified geothermal resources, and about 50 have quantifiable geothermal utilization at present. Electricity is produced from geothermal in 21 countries and direct application is recorded in 35 countries.

Bioenergy

About	Present Status of Bioenergy
Bioenergy is one of many diverse resources available to help meet our demand for energy. It is a form of renewable energy that is derived from recently living organic materials known as biomass, which can be used to produce transportation fuels, heat, electricity, and products. **Biofuel** is a fuel created from biomass. A contemporary process is used to obtain it as opposed to the very slow geological processes required in the development of fossil fuels such as oil. An important Biofuel is biodiesel. This is produced through esterification from vegetable oils, animal fats, and grease. The resultant product is combined with regular diesel oil in amounts ranging from 5% to 20%. **Esterification:** is a broad term for a chemical process in which reactants combine to generate an ester as the reaction product. Esters are widely used in organic chemistry and biological materials. They usually have a fruity odor.	Many countries have increased their biofuels targets, resulting in significant output increases. The most notable countries are the United States and Brazil. Many demand and supply-side factors will influence growth in the usage of biomass resources in the mid-term period to 2030. Strong renewable energy targets set at the regional and national levels (such as the European Renewable Energy Directive) are likely to result in a large increase in demand. Other factors that may influence biomass potential include the impact of biotechnology, water availability, and the productivity consequences of climate change.

Wave Energy

About	Present Status of Wave Energy
Wave energy (or wave power) is the transport and capture of energy by ocean surface waves. The energy captured is then used for all different kinds of useful work, including electricity generation, water desalination, and pumping of water.	Wave energy is most abundant in Asia and Australasia. It is also found in South and North America. Western and Northern Europe have significant amounts of energy despite their tiny size. Central America, the Mediterranean Sea, and the Atlantic Archipelagos suffer poorly due to their mid-latitude location.

Tidal Energy

About	Present Status of Tidal Energy
It is a type of power generated by the natural rise and fall of tides caused by the gravitational interaction of the Earth, sun, and moon. Tidal energy can be transformed into useful kinds of power. For example electricity, by using properly designed generators at appropriate locations.	There are very few commercial-sized tidal power plants operating in the world. The first was located in La Rance, France. The largest facility is the Sihwa Lake Tidal Power Station in South Korea. The United States has no tidal plants and only a few sites where tidal energy could be produced at a reasonable price. China, France, England, Canada, and Russia have much more potential to use this type of energy.

MARINE RESOURCES

The resources that are derived from the oceans is called marine resources. Ocean resources are economically valuable (food, fuel, energy, medicines, minerals, and building materials) and provide support to billions of people by providing good, services, employment etc.,

There are two types of resources:

- Biotic resources
- Abiotic resources.

Marine biotic resources

Biotic refers to living things. Phytoplanktons, zooplankton, fish, crustaceans, molluscs, corals, reptiles, and mammals are among the marine biotic resources.

Plankton community	Plankton is a varied group of organisms that live in water (or air). They are commonly associated with water, but airborne forms, known as aeroplankton, spend part of their lives drifting through the air. Many small and large aquatic species, such as fish, and whales, rely on them for nutrition in water.

Zooplankton Community	They are minute aquatic microorganisms in the water column that include crustaceans, rotifers, insect larvae, and aquatic mites.
Nekton community	The active swimming aquatic organisms in the water body are called nekton, the most important of them being the fish. • **Demersal fish:** found on or near the bottom of the ocean. • **Reef fish:** connected with coral reefs. • **Pelagic fish**: live in the pelagic zone of ocean or lake waters, where they are neither close to the bottom nor near the shore.
Benthos Community	The benthic zone is a community of creatures that dwell on, in, or near the bottom of the ocean. • **Epifauna:** Epifauna resides on the surface of the ocean's bottom. They cling to hard surfaces such as pebbles, shells, and pilings. It includes Oysters, sponges, sea squirts, sea stars, barnacles, etc. • **Infauna:** Infauna dig into the sediments at the bottom of the ocean. Worms, clams, and other infauna develop their communities. Many diverse species can be found in a healthy infaunal community.

Abiotic Marine Resources

Abiotic resources are non-living resources that include mineral resources and energy resources.

Mineral Resources

Oceans contain both metallic and non-metallic resources. Running water transports the majority of these minerals from land to sea and the rest is made up of detritus from marine creatures and undersea volcanism.

Mineral Deposits

Mineral Deposits	Features
Surface Deposits	Found combined with sand on continental shelves and slopes. Examples:Sand is mined to obtain calcium carbonate.
Placer Deposits	It is a collection of valuable heavy minerals worn and eroded from their source rocks. They accumulate few kilometres away from their source rocks because of their high density. Examples: chromite (chromium), monazite (thorium), magnetite (iron), gold, and diamonds
Deep-Sea mineral Deposits	Manganese nodules (also known as polymetallic nodules) and metalliferous sediments are two economically important mineral deposits found in the deep sea. Manganese nodules are iron and manganese oxide concentrations. These nodules are formed by metal precipitation from seawater, hot springs associated with volcanic activity, and metal hydroxides generated by microorganism activity.
Monazite Sand Deposits	Thorium is derived from monazite sands. 90% of the world's monazite reserves are found in Kerala's placer deposits.
Hydrocarbon Deposits	Large amounts of hydrocarbons can be found at depths of 1,000 to 2,000 meters below sea level. Shales, salt domes, and anticlinal folds in the ocean are major sources of hydrocarbons. Apart from liquid hydrocarbons, natural gas is also found.
Marine Phosphorite Deposits	Phosphorites are phosphate-containing natural substances. Found in shallow water and as nodules on continental shelves and slopes.
Gas Hydrate Deposits	Gas hydrate is crystalline ice found at depths of the ocean and in shallow polar regions. It's made up of methane gas molecules wrapped in water molecules. Gas hydrates remain solid at great depths in the ocean because of freezing temperatures and high ocean pressure. Gas hydrate deposits are expected to form where the seafloor rises above 500 meters, and there is an unoxidized organic carbon source in marine sediments.
Evaporite Deposits	The major components of marine evaporites include anhydrite, gypsum (calcium sulphates), sodium, magnesium, and potash-bearing minerals. The evaporation of seawater generates them in geologic basins.

Marine Energy Resources

The energy carried by ocean waves, tides, salinity, and temperature differences is referred to as marine energy or marine power. The movement of water in the oceans generates a reservoir of kinetic energy, some of which can be used to generate electricity.

Ocean Thermal Energy Conversion (OTEC)

The process of generating electricity from the natural temperature difference (thermal gradient) of different ocean parts is called OTEC.

- The OTEC plants are also known as Solar Sea Power plants.
- Solar energy heats the ocean's surface. In tropical regions, surface water is generally warmer than deep water. This temperature difference is used to produce electricity and desalinate ocean water.

FOREST RESOURCES

Forest resources refers to the products that are used, valued and associated with forest land. Forest resources can be timber or non-timber resources, but does not include wildlife, migratory birds, water or fish.

- More than two-third of the world's forests are found in ten countries Russia, Brazil, Canada, the United States of America and China. Australia, Congo, Indonesia, Peru, and India.
- Forest resources can broadly be classified into:
  - Major forest products.
  - Minor forest products

Major forest products:

- Major forest products consist of timber, softwood, and fuelwood including charcoal. Indian forests produce numerous species of wood, 90% of which are commercially valuable.
- Hard woods include teak, mahogany, logwood, iron-wood, ebony, sal, greenheart, kikar, semal, etc, which used for furniture, wagons, tools, and other commercial products.
- Softwood includes deodar, poplar, pine, fir, cedar, balsam, etc. They are light, strong, durable, and easy to work on and are useful for construction work and the production of paper pulp.

Minor Forest products:

Product	Description
Grasses and Bamboos	Grasses like sabai, bhabar, and elephant grass are used for papermaking. Sabai grass is the most important raw material for the paper industry. Bamboo belongs to grass family but grows like a tree. It is woody, perennial, and tall There are more than 100 species. Bamboo is called the poor man's timber as it provides cheap material for roofing, walling, flooring, matting, basketry, cordage, carthoods, and a host of other things.
Tans and dyes	Tannins are secretion products of plant tissues. Tanning materials are used in the leather industry. The most commonly used tanning materials are mangrove, oak, hemlock, anwal, wattle, myrobalans, ratanjot, flowers of dhawri, babul, avaram, etc. Some of the important dyes are obtained from red sander, Khair, flowers of Palas, fruits of Mallotus phillipensis, bark of wattle, and roots of Morinda tinctoria.
Oils	Oils are obtained from sandalwood, lemongrass, khus and eucalyptus globules, etc. They are used for soaps, cosmetics, confectionery, pharma, etc.
Gums and resins	Gum is exuded from the stems or other parts of different trees partly as a natural phenomenon and partly by injury to the bark or wood of blazing the tree. They are used in textiles, cosmetics, confectionery, medicines, inks, etc.
Leaves	Different types of leaves are obtained from the trees and are used for different purposes, the most important being the tendu leaves used as wrappers for bidis.
Fiber and flosses	Fibers are obtained from the tissues of some trees. Most of such fibers are coarse and are used for rope making. However, the fibers of Ak (Calotropis spp.) is fine, strong, and silky which is used for making fishing nets. Flosses are obtained from certain fruits and are used for stuffing pillows, mattresses, etc.
Drugs, spices and poisons	Drugs are obtained from different parts of trees. Quinine is the most important drug. Spices include cinnamon, cardamom, etc. Some poisonous substances which taken in small, regular doses have medicinal value. Example: strychnine, aconite, datura, ganja, etc.

Indirect uses of forests:

- Prevention and control of soil erosion
- Flood control
- Checks on spreads of deserts
- Increase of soil fertility
- Forests regulates the extremes of climate
- Regulate evaporation

WORLD ECONOMIC ACTIVITIES

Economic activity may be defined as an activity that involves a man's endeavours for his earnings, living and economic well-being. There are three sectors of economic activity:

- The **Primary Sector** involves the extraction and production of raw materials. Such as farming, logging, hunting, fishing, forestry, and mining.
- The **Secondary Sector** involves manufacturing and the role of industries. Such as the production of finished products.
- The **Tertiary Sector** involves service industries that facilitate the transportation and distribution of goods produced in the secondary sector.

PRIMARY ACTIVITIES

Primary economic activities include the following types of activities, (i) agriculture, (ii) hunting and gathering of fruits and roots of the forest. (ii) animal rearing, (iv) fishing, (v) collection of forest products, (vi) collection of mineral resources.

Agriculture

Agriculture is the practice of tilling the soil to produce crops. It includes all the activities related to crop farming, stock raising, fisheries, mixed farming, etc.

Major Types of agricultural practices

Agricultural Region	Distribution	Major characteristics	Crops grown
Shifting Cultivation	Mexico and Central Africa, tropical South and Central America, South-East Asia, and South Asia. Known by different names- Milpa(Mexico and Central America), Taungya (Myanmar), Humah (Indonesia), Tamrai (Thailand), Conoco (Venezuela), Chena (Sri Lanka), Ladang (Malaysia), Keinzin (Philippines), Rosa (Brazil), Fang (South Africa), Masshole (Zaire), Jhum Cultivation(India).	Use of fire for clearing the land. Keeping the land fallow for regeneration for a number of years. Use of human labor as the main input. Small size of cultivated land	Manioc, Cassava, Yams, Tapioca, Maize, Millet, Beans, and upland rice.
Sedentary Farming	Hot and humid lowlands, hot-dry lowlands, subtropical plateaus, and highlands of the tropics, equatorial and subtropical parts, tropical Africa, Central America, and tropical South America.	Supports Sedentary life. Small landholdings. Crop rotations Employ a huge population. Use of power and transport. Type of subsistence agriculture.	Maize, Sorghums, Manioc, Yams, Peanut, Sugarcane, Cotton, Millets, rice, and wheat.
Intensive Farming	Monsoon lands of Asia namely practiced in China, India, Japan, Korea, Pakistan, Sri Lanka, Bangladesh, and parts of South-East Asia (Indonesia, Java, Sumatra, Malaysia).	Small Landholdings. Labour intensive. Use of fertilizers and High Yield Variety of Seeds. Need for irrigation infrastructure. Reduces the nutritional value of soil.	Rice, Wheat Jute, Cotton, Sugarcane, Tobacco, Oilseed, etc.

Agricultural Region	Distribution	Major characteristics	Crops grown
Extensive Farming	Practised in regions with large cultivable lands but small populations such as the U.S.A., Canada, Ukraine, Russia, Argentina, and Australia.	Huge farm lands. Use of big agricultural machines. Farming is highly market-oriented. Single cropping or monoculture is the feature.	Wheat, Maize, Millets, corn, Cotton, and fodders for animal rearing.
Commercial Grain Farming	Mid-latitudinal regions of North America, South America, Australia, and Europe namely the U.S.A., Canada, Argentina, France, Ukraine, Russia, Australia, and New Zealand.	Large Farmlands - hundreds of hectares. Capital Intensive. Cultivation mainly for the International market. Highly dependent on machines for almost every stage. Reduces soil fertility.	Cotton farming, Silk culture, and Jute farming
Mixed Farming	Throughout the world.	Production of crops and livestock simultaneously. Two enterprises are interwoven. Provides social security and high returns to the farmers. Rotation of crops practiced.	Wheat, Maize, Oat, Barley, Rye, Hay, Alfalfa, Soybeans and peanuts. Milk and meat are the two major dairy products
Plantation	Areas possessing a tropical climate namely Latin America, Asia, and Africa	Single Cropping or monoculture. Based on the scientific methods. Large Farmland. Capital intensive Export oriented. Long Gestation period.	Natural rubber, coconuts, oil palm, tea, cocoa, and coffee.
Mediterranean	Around the Mediterranean Sea as well as in parts of California, Chile, Australia, and South Africa	Intensive farming. Production for commercial as well as for local use. Known for fruit production.	Wheat, barley,citrus fruits, olives, grapes, and vegetables.
Livestock Ranching	Practise throughout the world but mostly concentrated in the USA, Canada, South America, East Asia, Australia, and Newzealand.	Practiced on large areas. Capital intensive. Organized on a scientific basis. Only one type of animal is reared.	Various dairy and meat products meet the nutritional demands of the world.
Dairying	Practised throughout the world but major areas are Western Europe, North America, the Australia-Newzealand region, and in Asia India, China, Japan, and South Korea.	Rearing of high breed milch animals. Focus on animal care and veterinary services. Single animal or mixed animal rearing.	Different range of dairy products.

Fishing

It refers to catching aquatic animals other than fish, such as molluscs, crustaceans, and echinoderms (starfish and sea urchins).

Based on the location, fishing is divided into Inland fishing and Marine Fishing.

- **Inland Fishing:** Practised in freshwaters such as canals, ponds, reservoirs, and rivers.
- **Marine Fishing:** Fishing in seawater or saltwater is referred to as marine fishing.

Major Fishing Regions of the World

Regions	Extent
North-East Pacific region	It extends from the Aleutians to the Philippines in the south. This region also includes the eastern coastal waters of Russia and areas of China, South Korea, Japan and the Philippines. China, Japan, and South Korea contribute 13, 8, and 3 percent of the world's catch.
North-East Atlantic region	It extends along European coasts from Portugal to Iceland. The major fishing countries are Norway, Great Britain, and Denmark. The North Sea is also a prominent fishing area.
North-West Atlantic region	It extends along the continental shelves of the New England region of the USA, New Brunswick, Novascotia, and Newfoundland of Canada.
South-East Pacific region	It extends along western coastal areas of South America, mainly the coasts of Chile and Peru.
West-Central Pacific region	It extends from the Philippines to the eastern coastal areas of Australia.

Reasons for the development of fishing grounds in Temperate regions:

- Plankton Availability
- Vast, open continental shelves
- The carbon fixation rate in most temperate upwelling systems, such as the Benguela and Canary systems, is optimal.
- Indented or broken coastline: Example: The Fjord coast of Norway.
- Fish variety and improved quality
- Temperate Climate
- Plain coastal areas are ideal for fishing.
- Presence of Forest

Reasons for backwardness in commercial fishing in tropical regions

- Plankton deficiency
- High Temperature
- Species Diversity
- Absence of a Shallow continental Shelf
- Indented coastline
- Transportation halt
- Unsanitary situation

SECONDARY SECTOR

An industry is a device for producing things wherein power-driven machines transform raw materials into valuable things or consumer products

Major Industrial Regions of the World

Country	Industrial Regions	Major Centres	Major Industries	Reasons for Development
USA	New England	Boston, Connecticut, Rhode Island	Ship building, textile, footwear, engineering industry.	Port cities, skilled workforce and technological advancement.
	Mid Atlantic States	New York, Newark, Trenton, Philadelphia, Wilmington, Baltimore	Food and allied products; textile products; printing and publishing; chemicals; electrical equipment; transport equipment; and instruments	Abundance of Coal,oil and natural gas.Also huge market due to densely populated area.

Country	Industrial Regions	Major Centres	Major Industries	Reasons for Development
	Pittsburgh-Lake Erie Region	Youngstown, Pittsburgh, Johnstown	Iron and Steel Industriel	Huge availability of coal, iron ore and natural gas.
	Detroit Industrial Region	Detroit	Automobile Industries	Historically poor railway connectivity(demand for alternate) and huge market for Automobiles.
	Lake Michigan Region	Chicago, Gary	Iron And Steel	Availability of Iron ore and coal, Well connected through railway.
	Southern Appalachian Region	Birmingham, Atlanta, Gadsden, Bessemer, Anniston	Steel making, Cotton textile, Chemicals	Availability of iron,coal,oil and hydropower.
	Eastern Texas	Dallas and Houston	Oil Refining, Chemicals, Clothes and Fashion Industry, Rubber Factory.	Region rich in sulphur, rock salt and phosphate rock which makes oil refining economical
	Pacific Coastal Region	San Francisco, Los Angeles, Portland, Seattle, Engine, Sacramento, San Diego	Beverages, automobiles, aircraft, metal fabrication, petrochemical and heavy chemical industries	Heavily Populated, established infrastructure with connectivity and coastal advantage.
Canada	Ontario and St. Lawrence Valley	Quebec, Ontario, Ottawa, Toronto, Hamilton	Agricultural products and agricultural machinery, Chemical Industry,Copper and Nickel smelting	Fertile soil,Heavily populated and well connected infrastructure.
	Prairie Region	Manitoba, Winnipeg, Edmonton, Alberta	Agro-based Industries, Petroleum Refinery, Chemicals	Gently rolling landscape, favourable climate, availability of oil and natural gas.
	Pacific Coastal Region	**Vancouver and Prince Rupert**	Paper and pulp, Furniture, Agricultural machinery.	Commercial farming, coastal advantage.
United Kingdom	London Basin	London	Consumer goods; furniture, ready-made clothing, musical instruments, patent and prepared foods	Demand Based industries due to heavily populated area.
	North Eastern Coast	Durham, Northumberland,Tyne, Billingham	Coal mining and iron and steel production, shipbuilding industry	Port cities, Large coal reserve.
	Lancashire	Manchester and Liverpool	Cotton and woollen Industry	Favourable Climate (temperate),port connectivity and historical establishments
	Midlands	Birmingham, Coventry, Leicester, Dudley, Stoke-on-Trent, Walsall, and Wolverhampton	Electrical equipment, plastics, machine tools, chemicals, glass and food, Coal And Steel Industries.	Huge market(Centre of England), well connected in all the directions
	Southern Wales Area	Cardiff	Ship building, Iron and Steel, Chemical	Historical factor(Wales was the first industrial nation), presence of threenbusy ports namely Newport,Cardiff and Swansea.
	Lower Scotland	Glasgow	Ship building, woollen and cotton, Iron & Steel, Chemical, Medicines	Proximity to port Glasgow, densely populated.

Country	Industrial Regions	Major Centres	Major Industries	Reasons for Development
Germany	**Rhine Industrial Region**	Duisburg, Essen, Bochum and Dortmund, Gelsenkirchen, Oberhausen, Rheinhausen	Iron and steel, heavy chemicals, engineering, cutlery, textiles.	High quality coal is available from the Ruhr coalfield. Apart technological advancement and skilled labour.
	The Hamburg Industrial Region	Hamburg	Ship-building, light chemicals, tobacco, non-ferrous industries, petro-chemical, and petroleum refining and engineering industries.	Port of Hamburg- Germany's biggest hub for import and export, connectivity through Elbe river.
	Berlin Industrial Region	Berlin and outskirts	Electrical, electronics, cosmetics, light chemicals and precision engineering	Capital city,densely populated,well connected, Human Capital
	Leipzig Industrial Region	Leipzig	Optical instruments, leather products, engineering goods and machine tools.	Located at the confluence of three rivers namely Pleisse, Parthe, and Weisse Elster rivers
France	The Lorraine Industrial Region	Mosselle valley, Longway-Villerap,Nancy	Iron and steel industries.	Proximity to Rhine river, huge reserves of natural resources.
	The Northern Industrial Region	Dunkirk, Douai, Denain, Lille, Armentieres and Cambrai	Iron and steel, textile and engineering	Availability of coal from Nord and Pas-de-Calais and iron from Lorraine.
	The Paris Industrial Region	Paris	Automobiles, locomotives, aircraft, chemicals, fashion and jewellery.	Centre of Paris, well connected and huge demand for the consumer goods.
Italy	The Northern Region	Lombardy, Piedmont, Liguria.	Textiles, iron and steel, paper, agricultural machinery, machine tools, electrical and automobiles.	Urban centres, fertile land and sustainable weather conditions. Skilled workforce with conducive Government Policies after WW-1
	The Southern Region	Naples.	Textiles, machinery and, iron and steel plants.	Presence of Coalfields and iron ores.
Switzerland	Swiss Plateau	Zurich, Basel, Baden, St. Gallen, Appenzell, La Chaux-de-Fonds, Biel and Le Locle	watch-making, engineering, chemicals and textiles	Safest place to invest, precise technical advancement with regular government policies.
Sweden	Stockholm region	Stockholm	Automobile, weapon industry, textiles, paper manufacturing, and footwears.	Cutting edge technology based manufacturing, demand based supply.
Netherlands	Rotterdam-Amsterdam region	Utrecht, Eindhoven, Perms and Europoort near Rotterdam, Groningen	Engineering industries, Chemical plants, extraction of natural gas, textiles, Dairying, brewing, sugar refining, food processing.	Huge amount of natural gas and oil, busiest port of Europe-Rotterdam, favourable conditions for Allied activities.
Belgium	Brussels-Antwerp industrial region	Liege, Brussels, Antwerp, and Ghent	Iron, steel and engineering goods.	Skilled workforce, Large coal deposits along the Sambre-Meuse river

Country	Industrial Regions	Major Centres	Major Industries	Reasons for Development
Eastern Europe	The Moscow-Tula Industrial Region	Gorky,Lipetsk,f Yaroslav, Ivanovo	ironsteel, heavy chemical, metallurgy, machine tools, refineries, textile, electrical, automo-bile	Capital City(Moscow), densely populated and huge reserves of natural gas and oil off the cost of Russia.
	The Ural Industrial Region	Nizhniy Tagil, Sverdlovsk, Serov, Chelyabinsk, Magnitogorsk and Orsk	machine tools, agricultural machinery, chemicals, Iron and steel.	Huge iron ore deposits of Magnitogorsk, Nizhny Tagil and Serov
	The Caucasus Industrial Region	Baku, Grozny, Maikop and Batum,Tbilisi, Kirovakam and Sumgait.	heavy chemical industries,h refineries and petro-chemical industries	Huge availability of crude oil locally and well connected through ports and railways.
	The Southern Industrial Region	Donbas and Krivoi Rog, Odessa and Zaparzhye, Konstantinovka, Zhdanov	iron- steel industry, precision manufacturing units.	Availability of Coal and iron ore locally and skilled labour.
	The Volga Industrial Region	Kuybyshev-Kazan and Volgograd	chemical and machine tool manufacturing.	Presence of Tartar oilfield and Kuybyshev oilfields forms the base of industries and Volga River.
	The Kuznetsk Industrial Region	Kuznetsk	Iron and Steel	Presence of coal and iron ore.
Japan	The Osaka-Kobe Region	Osaka, Kobe and Kyoto	cotton-textile, shipbuilding, oil refining, and petrochemical industries and Rubber Manufacturing.	Fertile land, port cities and availability of skilled labour.
	The Tokyo-Yokohama Region	Tokyo, Kawasaki and Yokohama	Electrical goods,shipbuilding, oil refining, petrochemicals and port industries.	Capital city(Tokyo), port connectivity, technically skilled workforce and technological advancement.
	The Nagoya Industrial Region	Nagoya	automobiles, locomotives and aircrafts,Textile, including silk reeling.	Proximity to Yamazaki river, well establishes infrastructure and connectivity.
	Northern Kyushu Region	Yumata, Kokura, Moji, Fukuoka	Iron and steel,oil refining, shipbuilding, Textiles.	Port cities, deposits of coal and iron ores.
China	The Manchuria Region	Anshan, Penki, Mukden, Dairen	Steel Industries, railway equipment, cement plants, chemical works, military arsenal	Resource rich area such as coal, iron, dolomite, magnesite, gold, silver, lead, zinc etc.
	The Yantze Valley Region	Shanghai, Hankow, Hanyang, Wuhan	consumer goods,Iron and steel, textiles, paper and pulp, machinery, cement, and chemicals	Huge population demand, prince of coal and iron and well connected to ports.
	The North China Region	Tientsin, Peking or Beijing and Tangshan	Coal, steel and heavy machinery	Presence of coal-fields in Shansi and Hopei.
Brazil	Brazilian southeast region	Rio de Janeiro, São Paulo	Textile and coffee industries.	Conducive weather and fertile soil

CHAPTER 5

Indian Geography

INDIA AND ITS NEIGNOURING COUNTRIES

India is vast country that completely lies in the Northern Hemisphere of Asia. India's vast geographical extent extends from the Himalaya ranges in the north to the shores of Indian Ocean in the south and the Arabian Sea on the south-west to Bay of Bengal on the south-east.

BASIC FACTS

Size	• India is the seventh largest country in the world in terms of size. • The Indian land mass has an area of 3.28 million square kilometre. • India accounts around 2.4 per cent of the total geographical area of the world.
Latitudunal and Logitudunal Extent	• The main land extends between latitudes $8^{o}4'$N and $37^{o}6'$N and longitudes $68^{o}7'$E and $97^{o}25'$E. • Both latitudinal and longitudinal extent is about thirty degrees. • Longitudinally India extends from Indira Col in Kashmir in the north to Kanniyakumari in Tamil Nadu in the south. • The distance from west to east is 2933 kilometres. • Latitudinal extent of India spans from Rann of Kutch in Gujarat in west to Kibuthu (the eastern most town) in Arunachal Pradesh in the east • The distance spanning from north to south is of 3214 kilometres.
Passing of Tropic of Cancer	• States through which the Tropic of Cancer passes: • Gujarat • Rajasthan • Madhya Pradesh • Chhattisgarh • Jharkhand • West Bengal • Tripura • Mizoram
Time Zones in India	• India uses only one time zone. • The Indian Standard Time (IST) is based on a longitude of $82^{o}30'$ E, which passes through Mirzapur, near Allahabad in Uttar Pradesh. • It is 5 hours 30 minutes ahead of Greenwich Mean Time (GMT), now called the Universal Coordinated Time (UTC). • The CSIR-NIPL (New Delhi) is the keeper of the time in India, it records time using five caesium atomic clocks.
Passing of Indian Standard Meridian	• It passes through the states of • Uttar Pradesh, • Madhya Pradesh, • Chhattisgarh, • Odisha, and • Andhra Pradesh.
Extreme Points	**North:** Indira Col (Ladakh) **South:** Indira Point (Great Nicobar) **South (Mainland):** Vivekanada Rock, Kanyakumari (Tamil Nadu) **East:** Kibithu (Arunachal Pradesh) **West:** Guhar Moti (Gujarat).

Boundaries of India

- **Land Boundary:** India's land boundary spans around 15200 kilometres in length.
- **Coastal boundary of India:** The length of the coastline including the mainland and the islands (Andaman & Nicobar Islands and Lakshadweep) is approximately 7516 kilometres.
- The length of the coastline of the mainland is approximately 6100 kilometres.

State	Length of Coastline in Kilometers
Gujarat	1214.7
Andhra Pradesh	973.7
Tamil Nadu	906.9
Maharashtra	652.6
Kerala	569.7
Odisha	476.4
Karnataka	280
Goa (Along with Daman & Diu)	160.5
West Bengal	157.5
Puducherry (Union Territory)	30.6

INDIA'S NEIGHBOURING COUNTRIES

India shares its land frontiers with Pakistan in the west and north-west, Afghanistan in the north-west, China, Nepal, and Bhutan in the north, and Bangladesh and Myanmar in the east. India shares its water frontier with Sri Lanka.

Country	Length of Border	Bordering States	Facts	Issues Faced
Afghanistan	**106km**	Jammu and Kashmir.	The border between India and Afghanistan is **Durand Line.** This is the shortest border amongst all other neighbouring countries	The international borderline between India and Afghanistan is under Pakistan's illegal occupation.
China	**3488 km**	Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Ladakh and Jammu and Kashmir.	The Line of Actual Control (LAC) separates Indian-controlled territory from Chinese-controlled territory.	The Western Sector of the border shared by UT Ladakh is disputed over **Aksai Chin** territory which is claimed by both the countries. Not much conflict in middle sector shared by Himachal Pradesh and Uttarakhand. In the eastern sector, China claims the state of Arunachal Pradesh the part of South Tibet.
Nepal	**1752 km**	Uttarakand, Uttar Pradesh, Bihar, West Bengal and Sikkim.	The NepalIndia border was delineated by the Sugauli Treaty of 1816. Under it Nepal, renounced all territory to the west of the river Kali, also known as the Mahakali or the Sarada river.	Areas like Kalapani and Susta are claimed by Nepal that lies in Uttarakhand and Uttar Pradesh states of India respectively.
Bhutan	**699 km**	Assam, Arunachal Pradesh, West Bengal and Sikkim.		India and Bhutan borders are most peaceful. China recently had shown some aggression in Chumbi Valley in Bhutan.

Country	Length of Border	Bordering States	Facts	Issues Faced
Bangladesh	**4098 km.**	Assam, Tripura, Mizoram, Meghalaya, West Bengal	The country shares the largest barder with India. The boundary has been demarcated by the **Radcliffe Line**.	The boundary question were unsettled for many enclaves(small pockets of territories) in each other's countries, which were recently swapped between India and Bangladesh.
Myanmar	**1643 km**	Arunachal Pradesh, Nagaland, Manipur, and Mizoram	The boundary runs through the watershed between **Brahmaputra** and **Irrawady** Rivers.	
Sri Lanka	**-**	**-**	Sri-Lanka shares water border with India. The Palk Strait separates India and Sri-Lanka. Adam's Bridge joins Pamban Island in Tamil Nadu to Mannar Island in Sri Lanka through soem small islets	India has handed over the Kachchatheevu Island to Sri-Lanka by Indian side in 1974.
Pakistan	**3323 km**	Jammu and Kashmir, Gujrat, Rajasthan and Punjab	Currently, Line of Control **(LOC)** is the existing border between India and Pakistan in Jammu and Kashmir.	POK and Gilgit –Baltistan were forcibly occupied regions of India by Pakistan. Pakistan has illegally ceded a part of POK to China in 1963. Siachen Glacier located in the eastern Karakorams in the Himalayas is administered by the Indians since 1984 post **Operation Meghdoot.** Sir Creek region: The Sir Creek region of Rann of Kutch is a marsh land that has been contested by both the countries. The entire marshy land is claimed by Pakistan while India invokes the **Thalweg Principle.**

INDIA GEOLOGY

GEOLOGICAL HISTORY OF INDIA

Some of the major geological events in the geological history of India are:

- The Peninsular India, the part of the old landmass, was formed with formation of Earth's crust.
- The upheaval of Himalayas in the tertiary period.
- The formation of the Indo-Gangetic plain during the Pleistocene period.

MAJOR ROCK SYSTEMS OF INDIA

Based on the geological history, The Geological Survey of India (GSI) classified the rock systems of the country into four major divisions:

Major Rock System	Sub-divisions	Distribution	Rock-type	Minerals
Archaean Rock System	Archaean Gneisses and Schists	Entire Bundelkhand and extend from Vadodara to Aravalis. Also occur in the roots of the mountain peaks along the Greater Himalayas, Trans-Himalayas of Zaskar, Ladakh, and the Karakoram	Metamorphic	Granite, graphite schists, mica, talc, and chlorite.
	Dharwar System	Parts of Karnataka, Tamil Nadu, Central and Eastern parts of Chotanagpur Plateau, Meghalaya Plateau, Aravalis, Himalayan region.	Metamorphic	Gold, copper, mica, quartzites, slates, lead, manganese, and iron ore.
Purana Rock System	Cuddapah system	Andhra Pradesh, Southern Chhattisgarh, Odisha, and the major axis of Aravallis	Sedimentary	Iron ores, copper, nickel, cobalt, quartzites, limestones and manganese
	Vindhyan system	Sasaram in Bihar to Chittorgarh in Rajasthan. Also found in parts of Chhattisgarh, Karnataka, and Andhra Pradesh	Sedimentary	Red sandstone, limestone, cement, gold, diamond
Dravidian Rock System		PirPanjal, Lider valley, Handwara, Annantnag of Kashmir, Gharwal, Kumayun of Uttarakhand, and Spiti, Shimli and Kangra of Himachal Pradesh; thinly scattered in Umaria district of Madhya Pradesh	Sedimentary	Sandstones, clays, quartzites, salts, slates, talc, marble, shales, and dolomite
Aryan Rock System	Gondwana System	Basin of the Damodar and the Mahanadi rivers in Odisha and Chhattisgarh, some parts of Godavari Valleys, and the southern part of Madhya Pradesh. In the Himalayan region, they are found in Darjeeling, Sikkim, and some parts of Kashmir.	Sedimentary	Uranium, copper, iron ore and antimony
	Jurassic System	Jaisalmer area of Rajasthan, Kutch, Guntur, and Rajamundry.	Sedimentary	Limestone, shales, and sandstones
	Deccan Trap	Kuchchh, Saurashtra, Maharashtra, the Malwa plateau, and northern Karnataka	Igneous	Quartz, calcite, agate
	Tertiary System	West Bengal, Gangetic Deltas, Andaman Islands, and some regions of Punjab, Assam	Sedimentary	Oil deposits, bauxite, and lignite

THE PHYSIOGRAPHY OF INDIA

The geological complexities pose a challenging task of dividing India into various physiographic regions. In general, India is divided into five physiographic divisions:

- The Himalayas.
- The Great Plains of North India.
- The Peninsular Plateau.
- The Coastal Plains.
- The Islands.

HIMALAYAS

The Himalayan Mountain system is the longest and highest young fold of mountains globally.

Origin of the Himalayas

The origin and the development of the Himalayas are explained through the Continental Drift Theory. It formed due to continent-continent convergence.

- **Pangea- Single Landmass:** Around 200 Millions of years ago from present, the single landmass that existed was named Pangea (Pan- All, Gea- Earth).
- **Disintegration of Pangea:** The Pangea broke to form two landmasses named "**Laurasia**" in North and "**Gondwanaland**" in South; the "**Tethys Sea**" separated these two lands.
- **Shrinking of Tethys Sea:** The movement of both landmasses approaching towards each other decreased the size of the Tethys Sea.
- **Indian & Eurassian Plate Collision:** 40-50 Millions of years ago from present, driven by plate movements, the **Indian plate** and **Eurasian plate** collided.
- **Formation of Himalayas:** Later the sediments gathered in the Tethys Sea, were compressed and several series of folds were formed and this is how the Himalayan fold mountains were formed.

Evidence supporting that the Himalayas are still rising

The northward movement of Indian plate is still in progress at a velocity of 5cm/year.

- **Fossils**: Presence of similar fossils in Shiwalik hills and Tibetan plateau confirms that the Shiwalik hills and Tibetan plateau shared common platform. Later Tibetan Plateau got uplifted.
- **Lake deposition**: Deposits signifying presence of lakes in Tibetan Plateau confirms that lakes used to exist in Tibet. The upliftment of the plateau discharged water while leaving the remnants deposited.
- **Earthquakes:** Frequent earthquakes reinforce the fact that there is continuous plate movement in the region and the rise of Himalayas is still in progress.
- **Youthful rivers:** The Youthful nature of rivers with high erosion, v-shaped valleys confirms the down cutting of mountains by the rivers is in process thus validating that the Himalayas are still rising.

Characteristic Features of the Himalyas

- **Extension:** 2400 kilometers from the Indus gorge to the Brahmaputra gorge in the east. The width of the Himalayas varies from 200 to 500 kilometers.
- **Link with Ranges of Central Asia:** The "**Pamir knot** " known as the roof of the world, connects the Himalayas with the mountain ranges of Central Asia.
- **High Elevation Peaks**: 14 peaks have a height of more than 8000 meters, and 20 peaks have a height of more than 7500 meters.
- **Syntaxial Bends:** Himalaya form an arcuate curve that is convex to the south. This curvature shape of the Himalayas is because of the maximum push offered at the two ends on the Indian Peninsula during the northward drift of the Indian plate. In the northwest direction, the push was offered by the Aravallis and in the northeast, it was pushed by the Assam ranges.
- **Uneven and unsymmetrical topography**: Mountain ranges are separated by deep valleys, gorges, and rivers. Physiographic features mark the youthful stage of mountains and rivers.
- **Slope:** The Himalayas facing India are steeper than the Himalayas facing the Tibetan side. The Tibetan side Himalayas has gentler slopes and a gradual gradient.
- **Width:** The Himalayas can be seen wider in the west than in the east. The width of the mountain ranges varies from 400 kilometres in Kashmir to 150 kilometres in Arunachal Pradesh.

Divisions of the Himalayas

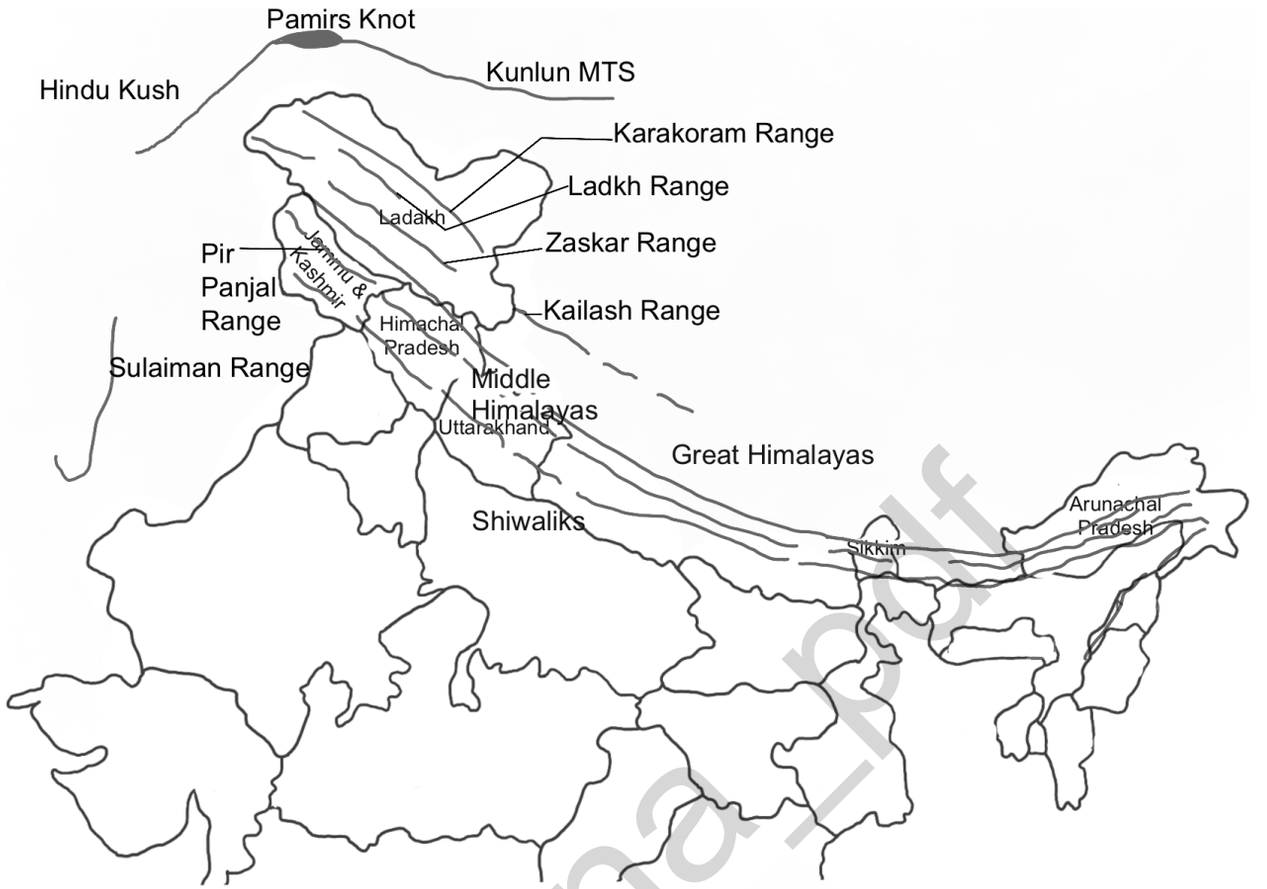
North-South Division

The Himalays are divided into Greater Himalayan Ranges (including- The Trans Himalays & The greater Himalayas or the Himadri), the lesser Himalayas or the Himachal and the outer Himalayas or the Shiwalik.

Features	Greater Himalayan Ranges		Lesser Himalayas or Himachal	Outer Himalayas or Shiwalik
	Trans Himalayas	Greater Himalayas or Himadri		
Location	Immediately north of the Great Himalayan range.	The northern most and the highest range of the Himalayas.	Lie between the Shiwaliks in south and the Greater Himalayas in the north.	Located between the Middle Himalayas and the Great Plains.
Extent	Stretches for a distance of about 1,000 km in east-west direction.	The mountain range terminates abruptly at the syntaxial bends: Nanga Parbat in the north-west and Namcha Barwa in the north-east.	Stretches northwest-southeast over the Indian subcontinent's northern border.	Extends west- northwestward from teesta river in Sikkim, through Nepal across northwestern India and into Pakistan.
Average Elevation	3000 metres above mean sea level.	6000 metres above mean sea level.	3700 to 4500 meters above mean sea level.	900-to 1100 meters above mean sea level.
Average Width	40 km at the extremities & 225 km in central part.	25 kilometres.	60 to 80 kilometers.	Varies from 50 kilometers to less than 15 kilometers.
Major Ranges	Zaskar, Kailas and the Karakoram.	Everest, Kanchenjunga, Nanga Parbat, Namcha Barwa.	Pir-Panjal range and the Dhauladhar range	Most of the ranges in Shiwalik are hills.
Other Features	Karakoram range is the northernmost range and has the biggest glaciers in the world outside the Polar Regions. To the North of the Zaskar Range lies the Ladakh Range that runs parallel to it. The Kailash range is located in western Tibet and is a part of the Ladakh Range. The Ladakh Plateau lies to the north-east of the Karakoram Range. It has been dissected into a number of plains and mountains.	Major glaciers include Siachen glacier, the Gangotri glacier, and the Yamunotri glaciers.	They are mostly made up of metamorphosed rocks. They have dense forest cover on the gentler slopes of the eastern part of the range. The south-facing slopes are steeper and without vegetation compared to gentler and densely vegetated slopes on north-facing slopes. Kashmir Valley, Kangra Valley, and Kullu Valley are located in this region.	Composed of unconsolidated sediments brought down by rivers from the northern Himalayas. With the rise of Shiwaliks, the rivers flowing were obstructed, and the lakes were formed. After the river's course was cut-off by the Shiwalik Ranges and lakes were drained away, they left plains known as **Duns** in the west and **Duars** in the east. The southern slopes of this range are frequented by seasonal streams. These areas are known as **Chhos**.

Longitudinal Divisions

The Western Himalays run from river Indus to river Kali and the Eastern Himalayas run from river Kali to river Brahmaputra. They can be classified as; **Western Himalayas** (Punjab Himalayas & Kumaon Himalayas), **Eastern Himalayas** (Nepal Himalayas, Sikkim Himalayas & Assam Himalayas) and **North Eastern Hills or Purvanchal**.



Major Ranges of Himalayas

Karakoram Anomaly'

It is termed as the stability or anomalous growth of glaciers in the central Karakoram, in contrast to the retreat of glaciers in other nearby mountainous ranges of the Himalayas and other mountainous ranges of the world.

Tuting-Tidding Suture Zone (TTSZ)

The Tuting-Tidding Suture Zone (TTSZ) is a part of the Eastern Himalayas, where the Himalayas take a sharp southward bend and connects with the Indo-Burma Range.

Himalayan Frontal Thrustal

- Himalayan Frontal Thrust also known as Main Frontal Thrust (MFT) is a geological fault along the boundary of the Indian and Eurasian tectonic plates.
- It demarcates a sharp physiographic and tectonic boundary between the Himalayan foothills and the Indo-Gangetic Alluvial Plains.
- It represents a discontinuous zone of active faulting between the Sub-Himalaya and the alluvial plain.

	Western Himalayas		Eastern Himalayas			Purvanchal
	Punjab Himalayas	Kumaon Himalayas	Nepal Himalayas	Sikkim Himalayas	Assam Himalayas	
Extent	Extends from river Indus to river Sutlej.	Extends between Sutlej River and Kali River.	Extends between Kali River and Kosi River.	Extends between Kosi River and Teesta River.	Extends between Teesta River and Dihang River	Extends through north-eastern states of India
Major Peaks	Karakoram, Ladakh, Pir Panjal, Zaskar and Dhaoladhar.	Nanda Devi, Trisul, Kedarnath, Dunagiri, Kamet, Badrinath	Everest, Annapurna, Dhaula Giri	Kanchenjunga	Namcha Barwa, Kula Kangri	Patkai Bum, Naga Hills, Manipur Hills and Mizo Hills

	Western Himalayas		Eastern Himalayas			Purvanchal
	Punjab Himalayas	Kumaon Himalayas	Nepal Himalayas	Sikkim Himalayas	Assam Himalayas	
Other Features	The Karewas are the lake deposits (lacustrine deposits) in Kashmir valleys, made up of glacial clays, silts and sands, on the sides of Pir-Panjal ranges. These deposits are made up of glacial clays, silts and sands. Karewas provide ideal spot for cultivation of saffron, almonds & apples.	Major hill stations include Mussorie, Nainital, Ranikhet, Almora and Bageshwar. Major passes include Thangla pass, Muling La, Lipu Lekh and etc.	They encompass the tallest section of Himalayas.	The Jelep-La pass (tri-junction of India-China-Bhutan) is located here.	Diphu pass (tri-junction between India-China-Myanmar) is located here.	Brahmaputra marks the eastern border of Himalayas. The Himalayas take a sharp bend to south and form the Purvanchal. They are composed of sedimentary rocks. The extension of Purvanchal extends in Myanmar as Arakan Yoma then Andaman & Nicobar Islands.

Comparison between The Western and Eastern Himalayas

Western Himalayas	Eastern Himalayas
The Western Himalayas extend from the Indus River to the Kali River.	The Eastern Himalayas extend from the Kali River to the Dihang River.
They have low and gradual slopes.	They have steep and sudden slopes.
Since the Western Himalayas are located at higher latitudes, they are colder.	The Eastern Himalayas are located at lower latitudes; hence, they are considerably warmer.
The snowlines here are at a lesser altitude than the Eastern Himalayas.	The snowline is at a higher altitude.
Example: Nanga Parbat, Nanda Devi, Badrinath, etc.	Example: Everest, Makalu, Annapurna, Dhaulagiri, etc.

PASSES IN THE HIMALAYAS

A pass is a gap, or break, in high, rugged terrain such as a mountain ridge.

Western Himalayas	Facts	Eastern Himalayas	Facts
Pir Panjal Pass	Connects Jammu and the Kashmir valley.	Niti Pass	Located in Uttarakhand. Connects Kailash and Mansarovar.
Banihal Pass	Located in Jammu and Kashmir. Connects Jammu and Srinagar.	Nathu La	Located in Sikkim. Connects Darjeeling and Tibet.
Burzil Pass	Connects the Kashmir valley with the Deosai plains of Ladakh.	Jelep La	Is a tri-junction between India-China- Bhutan
Zoji la	Located in the Zaskar range of Jammu and Kashmir. Connects Srinagar to Leh.	Bomdi La	The Bomdi-La pass connects Arunachal Pradesh with Lhasa, the capital city of Tibet.
Shipki la	Located in Himachal Pradesh. River Sutlej passes through this pass. Connects Shimla to Tibet.	Dihang Pass	Located in Arunachal Pradesh. Connects Arunachal Pradesh with Myanmar (Mandalay).
BaraLacha Pass	Located in Himachal Pradesh. Connects Mandi and Leh.	Pangsau Pass	Located in Arunachal Pradesh. Pass connects Arunachal Pradesh and Myanmar.
Rohtang Pass	Located in Himachal Pradesh. It links Manali and Leh.	Traill Pass	It is located in Uttarakhand. Situated at the Pindari glacier and connects the Pindari valley to Milam valley.

SNOWLINE AND GLACIERS

The lower altitudinal limit of permanent snow on a mountain is called the **snowline.** The snowline varies with varying altitude, precipitation, latitude, slope, moisture, and topography in the Himalayas.

Major Glaciers

Glaciers	States
Biafo Glacier	Jammu & kashmir (Karakoram range)
Hispar Glacier	Jammu & kashmir (Karakoram range)
Chogo lungma	Gilgit Baltistan (Karakoram range)
Baltoro	Gilgit Baltistan (Karakoram Range)
Godwin Austen	Jammu & kashmir (Karakoram range)
Siachen	Jammu & kashmir (Karakoram range)
Lolofond	Jammu & kashmir (Karakoram range)
Kang Yatsze massif	Ladakh (Markha valley)
Zing zing Bar	Himachal Pradesh
Bara Sigri	Himachal Pradesh
Gangotri	Uttarakhand
Pindari	Uttarakhand
Sutri Dhaka	Himachal Pradesh
Chhota Sigri	Himachal Pradesh
Jongsong	Sikkim
Zemu	Sikkim

NORTHERN PLAINS

The Northern plains are the youngest physiographic features in India. It comprise less than one third of the total area of the country but support over 40% of total population.

Evolution of Northern Plains:

With the evolution of the Himalayas the northern part of the Indian Peninsula was subsided and a large basin was formed. This basin started filling with sediments carried by the rivers that originated from the mountains in the north and the peninsular plateau from the south. The extensive alluvial deposits led to the formation of the north Indian plains.

Characteristic Features of The Northern Plains:

- **Location:** The northern plains are located, south of the Shiwaliks. The southern boundaries of the northern plains are along the northern edge of the Peninsular India while, the eastern side is flanked by the Puvanchal hills.
  - Three major river systems of India i.e. the Indus, the Ganga and the Brahmaputra with their tributaries formed the Northern Plains of India.
- **Size and Extension**: The northern plains of India form the largest alluvial tract of the world. They extend along east-west direction approximately 3200 kilometres
- **Average width**: Varies between 150 and 300 kilometres. The width of the plains increases from east to west.
- **The depth of alluvium deposits**: It varies from 1300-1400 metres towards the southern sides of the plains and over 8000 metres towards the Shiwaliks.
- **Topography**: The chief characteristics of the northern plains are the monotony of the landscape which is interspersed with micro level river levees.

Physiographic Divisions of Northern Plains of India

The Northern Plains of India are divided into three zones, the Bhabar, the Tarai and the Alluvial Plains. The Alluvial Plains are further divided into the Khadar and the Bhangar.

Bhabar	Tarai	Alluvial Plains	
		Bhangar	Khadar
• Bhabar forms a narrow belt of coarser sediments that run (8 to 10 kms) east-west direction along the foot hills of Himalayas. • They extend from river Indus to river Teesta. • The Bhabar belt is narrower in the east and broad in the west and north-west region. • The rivers that originate from the Himalayas deposit the sediment loads along the foothills, thus, forming alluvial fans. • These alluvial fans consists of coarser sediments that merge together to form the Bhabar or the Piedmont plain. • They are highly porous and most of the streams sink underground. Hence, the area is mostly characterised by dry rivers but gets flooded in rainy season. • The tract is unsuitable for agriculture; however, trees with deep penetrating roots thrive in this region.	• They are located south of Bhabar and runs parallel to it with an approximate width of 10 to 20 kilometres. • They are broad in eastern part of the Great Plains, especially in the Brahmaputra valley due to heavy rainfall. • They are basically the re-emergence of the under-ground streams that had sunk in the Bhabar belt. • This re-emergence of underground water turns rivers into badly drained marshy lands.	• Bhangar is the old alluvium deposits along the river beds that are in a shape of terraces higher than the flood plain. • They are dark in colour, rich in humus content and productive. • The soil is mostly clayey in composition and has lime distributed called **kankar**. • They are mostly seen in **doabs**. • "**Barind plains**" in the deltaic regions of Bengal and "**Bhur formations**" in middle Ganga and Yamuna doab are local variations of Bhangar.	• Khadar are composed of new alluvium that forms flood plains along the river banks. • They are light in colour, sandy in texture and are more porus. • They are mostly found adjacent to the river beds. • Every year a new layer of alluvium is deposited by rivers this makes the river beds fertile. • In Punjab, the khaddar rich flood plains are known as "**Bets**".

Bhur is an elevated land situated along the banks of Ganga River which has been formed due to the accumulation of sands due to the wind-blown during hot dry months of the year.In some areas, the Bhangar showcases small tracts of saline and alkaline powder minerals and salts that rises on the surface due capillary action and is known as "**Reh**","**Kallar**" or "**Bhur**".

REGIONAL DIVISION OF NORTHERN PLAINS

Brahmaputra Plains	• The Brahmaputra Plains are formed in the eastern part of the Northern Plains of India. • The Brahmaputra Plains is bounded by the Indo-Bangladesh border in the western flank and southern flank. The eastern flank is bounded by the Purvanchal Hills. • The zone is highly rich in bio-diversity and many national parks like Manas and Kaziranga are located here.
Ganga Plains	The Ganga plains encompass the area between the Yamuna in the west to the Bangladesh border in the east. • The lower part of Ganga plain has been formed due to the down warping of a part of the Peninsular India which lies between the Rajmahal hills and Meghalaya Plateau. • All the rivers flowing in these plains most of the rivers keep shifting their courses thus making this area frequently prone to floods. • The Ganga-Brahmaputra delta is the largest delta in the world which is densely covered by mangroves, the Sunderbans. • **Divisions:** The Ganga Plain is divided into Upper, Middle and Lower Ganga Plains.
Rajasthan Plains	• The Rajasthan plain is occupied by the great Indian desert or the Thar desert. • The Rajasthan plain is characterised by wavy topography (undulating plain). • The desert region is called **Marusthali** and forms a greater part of the Marwar plain. • The eastern part of the Thar desert is a semi-arid plain that is known as **Rajasthan Bagar.** • Luni is an important seasonal stream that flows into the Rann of Kutch. • North of the Luni, there is inland drainage having several saline lakes. They are a source of common salt and many other salts. • Examples: Sambhar, Didwana, Degana, Kuchaman, etc

Punjab Plains:

- Punjab plains encompass the western part of the northern plain.
- The Delhi-Aravali ridge separates the Punjab plains in the east from the Ganga plains.
- The Punjab plains are formed by the Indus and its tributaries like Jhelum, the Chenab, the Ravi, the Beas and the Sutlej.
- The rivers flowing in Punjab plains have broad flood plains of Khadar also known as "**Dhayas**".
- The enormous erosion in the northern part of the Shiwaliks have led to the formation of Chhos and the south-west part of the Punjab Plains are characterised by shifting sand-dunes.
- To the south of the Satluj river there is Malwa plain of Punjab.
- The area between the Ghaggar and the Yamuna rivers lies in Haryana and often termed as **'Haryana Tract'.** It acts as water-divide between the Yamuna and the Satluj rivers

DESERT

The Great Indian Desert or the **Thar Desert** is the world's **ninth largest** desert. Though the desert area can be classified under peninsular plateau due to geological significance, but is classified under plains for its plain surface.

Major Characteristic Features

- **Extent:** It extends from the north-west flank of the Aravali hills to the adjacent parts of Pakistan where it is known as Cholistan Desert.
- **Marusthali:** The deserts are also locally named as **Marusthali** meaning the **dead land** because of its arid climate and low vegetation.
  - The eastern part of this Marustalli region is rocky while the western part is covered by shifting sand dunes.
- **Bagar** is a semi-desert region that extends till west of Aravllis. It has a thin layer of sand that is drained by the Luni River in the south while the northern area has number of salt lakes.
  - The Bagar region is characterised by number of short seasonal streams that originates from the Aravallis. The streams support agriculture in the arid region.
- **Rohi**: The fertile patches are called as **Rohi** and are mostly found in the deserts of Rajasthan.
- **River Luni:** The most important river Luni is also a seasonal stream. The river Luni rises from Puskar valley of the Aravalli Range. North region of river Luni is called as **Thali** or the sandy plain.
- **Inland Drainage:**There are some streams that disappear after flowing a particular distance and showcases an inland drainage by joining a lake or **playa**.
  - These lakes comprise of brackish water forms the major source of salt production.
- **Major Landforms**:Some of the major landforms that are seen in deserts are Mushroom rocks, Shifting sand dunes, Barchans, Oasis that are dealt in separate chapter in Desert Landforms.

PENINSULAR PLATEAU

The Peninsular Plateau is the largest physiographic unit of India. It is a tableland composed of the old crystalline, igneous and metamorphic rocks. It has its formation associated with the fragmentation of the Gondwana land.

Major Characteristic Features:

- **Extent:** The Peninsular Plateau extends to the south of the northern plains of India. In the north-west it is bordered by Delhi-Aravali ridge and the eastern flank is surrounded by the Rajmahal hills.
  - An extension of Peninsular Plateau can be found in the north-eastern states of Assam and Meghalaya called as Shillong and Karbi-Anglong Plateau.
- **Elevation:** The average elevation of the plateau is around 600-900 metres.
- **Composition:** The peninsular plateau is made up of igneous and metamorphic rocks and is considered as the most stable landmass in the world.
- **Physiography:** The Peninsular Plateau region is a combination of several small plateaus and hill ranges that are interspersed with river basins and valleys.
- **Rift valleys:** The Narmada and Tapti rivers flow across a rift valley. The rift valley formation was the result of the formation of the Himalayas from the Tethys Sea.

- **Ravines:** The Peninsular Plateau of India is characterised by block mountains and rift valleys, ravines and gorges (Ravines of Chambal, Bhind, Morena), broad shallow valleys, bare rocky structures, **tors** (They are isolated mass of jointed, weathered rocks, usually granite) and etc.
- **Garo-Rajmahal Gap:** The Garo-Rajmahal Gap is two segments of the plateau that do not connect each other. The formation of this gap has been formed by the force exerted by the north-east movement of the Indian plate while Himalayas were originating. The fault created, separated Rajmahal Hills and Meghalaya Plateau and the gap was filled by sediments with due course of time.
- **Kutchh Kathiwar Region:** The Kutchh Kathiwar Region remains as an exception. The region is considered as the extension of Peninsular Plateau as the Kathiawar Plateau is made up of Deccan Lava but now they are treated as an integral part of western coastal plains as they have levelled down now.
- **Mineral Resources:** The peninsular plateau are rich in mineral resources in both metallic and non-metallic minerals.
  - Almost 98% of coal deposits in India are found in peninsular regions.
  - Minerals found are gold, copper, lead, zinc, uranium, coal, iron etc.

The plateaus of peninsular India

Central Highlands:	• The northern part of peninsular plateau is called as Central Highlands. • The Central Highlands are located to the North of Narmada River, West to Aravallis and Satpura ranges to the South. • The average elevation of Central Highlands is around 700 to 1000 metres and slopes towards north and north-eastern directions.
Marwar Upland	• The Marwar Upland lies to the east of Aravallis. It is also known as the Mewar plateau. • The average elevation of the uplands are 250 to 500 metres and slopes down eastwards. • It is made up of sandstone, shales, and limestones of the Vindhayan period. • The rivers like Banas river and Chambal river leads to high erosional activity that makes the plateau top appear like a rolling plain.
Malwa Plateau:	• The Malwa Plateau lies in Madhya Pradesh between Aravali and Vindhya ranges. • The general slope is towards the north that decreases from 600 meters in the south to less than 500 meters in the north. • The plateau is composed of the extensive lava flow and is covered with black soils.
Bundelkhand Plateau:	• The Bundelkhand Plateau lies within the borders of Uttar Pradesh and Madhya Pradesh. • It is the old dissected (divided by a number of deep valleys) upland. • The average elevation of 300-600 meters above sea leve. • The region is marked by a chain of hillocks that is made up of granite and sandstone. • The region is completely unfit for cultivation because of intensive erosion and semi-arid climate.
Chhotanagpur Plateau:	• Chhotanagpur Plateau lies on the north-east part of Peninsular Plateau. • The plateau includes parts of Jharkhand, Chhattisgarh and West Bengal. • The plateau also comprises of sub-plateaus called as **Patland Plateau** which is also known as **Ruhr of India.** • The Rajmahal Hills lies on the north-east part of Chhotanagpur Plateau. • The Chhotanagpur is mineral rich plateau.
The Deccan Plateau:	• The Deccan Plateau encompasses the area located south of Narmada River and is in a shape of an inverted triangle. It is the largest unit of peninsular plateau of India. • The Plateau is bordered by Western Ghats in the west, the Eastern Ghats in the east and the Satpura, Maikal Range and Mahadeo Hills in the north. • The average elevation is 600 meters. • The plateau is of volcanic origin and is made up of solidified lava forming a trap structure with step like appearance. • The sedimentary rocks are also found in the trapped structure. • Most of the rivers originating from Deccan traps flow from west to east. • The plateau provides suitable condition for the cultivation of cotton and is a home to rich mineral resources. • The Deccan plateau can further be sub-divided into, **Maharashtra Plateau, Karnataka Plateau** and **Telangana Plateau**.
Maharashtra Plateau	• The Maharashtra Plateau lies in Maharashtra and forms the northern part of the Deccan Plateau. • Much of the region is underlain by **basaltic rocks** of lava origin. • The broad and shallow valleys of the Godavari, the Bhima and the Krishna are flanked by flat-topped steep sided hills and ridges. • The entire area is covered by black cotton soil known as **regur.**

Karnataka Plateau	• The Karnataka Plateau is also known as the **Mysore plateau**. It lies to the south of the Maharashtra plateau. • The average elevation of the plateau is 600-900 meters. • It is highly dissected by numerous rivers rising from the Western Ghats. • The plateau is divided into two parts called **Malnad** and **Maidan.** • The Malnad in Kannada means hill country. It is dissected into deep valleys covered with dense forests. • The Maidan on the other hand is formed of rolling plain with low granite hills. • The plateau tapers between the Western Ghats and the Eastern Ghats in the south and merges with the **Niligiri hills** there.
Telangana Plateau	• The Telangana plateau consists of Archaean gneisses. • The average elevation of the plateau is 500-600 meters. • The region is drained by three river systems, the Godavari, the Krishna and the Penneru.
The North-eastern Plateau	• The North-eastern plateau comprises of Meghalaya or Shillong plateau which is separated from peninsular by the Garo-Rajmahal Gap. • There are several hill ranges called the Garo Hills, Khasi Hills, Jaintia Hills and Mikir Hills. Shillong is the highest point of the plateau. • The Meghalaya Plateau is endowed with mineral resources like coal, iron, uranium and limestone.

Hill Ranges of the Peninsular Plateau

The hills of peninsular India are of relict type (residual hills). They are the remnants of the hills that were formed millions of years ago. The denudation process has reduced their size to a large extent.

	Aravali Ranges	Vindhyan Ranges	Satpura Ranges	Western Ghats	Eastern Ghats
Extent	They stretch in north-east direction between Delhi and Rajasthan.	The Vindhyan mountain ranges rise as an escarpment and runs parallel to the Narmada valley.	Satpura ranges run parallel between Narmada and Tapti.	The Western Ghats forms the faulted part of Deccan plateau that runs parallel from Tapti to Kanyakumari	The Eastern Ghats stretches from Mahanadi valleys to the Nilgiris.
Elevation	400-600 mts	300-650 mts	600-900 mts	900-1600 mts	600 mts
Highest Peak	The **Gurusikhar Peak** in Mount Abu. The Dilwara Jain Temple located on Mount Abu.	The highest peak of the Vindhyas is **Kalumar peak**.	**Dhupgarh** on Mahadev Hills is the highest peak of the Satpura Range.	**Anai Mudi** is the highest peak of the western ghats and the entire southern India.	The highest peak for Eastern Ghats it is the **Mahendragiri.**
Passes	Pipli Ghat, Dewair Pass, Desuri Pass	No such significant passes	No such significant passes	Thal Ghat, Bhor Ghat, Palakkad Gap	No such significant passes
Features	The Aravali mountain ranges are the oldest fold mountain systems of the world. After its formation in Archaean Era, its summits were higher than the present day Himalayas. The Aravali mountain ranges are locally known as the "**Jarga**" in Udaipur and "**Delhi Ridge**" near Delhi.	Most of the Vindhyan ranges are made up of sedimentary rocks that are from ancient times. They act as watershed between the Gangetic River systems and Peninsular River systems.	The name Satpura is composed of series of seven mountain ranges or folds named are **Maikal Hills, Mahadeo Hills, Kalibhit, Asirgarh, Bijagarh, Barwani** and **Arwani**	The Western Ghats are locally known as Sahyadri. The western part is an escarpment & the eastern slope gently merges with the plateau. Western Ghats are continuous chains of mountain ranges that can only be passed through passes. Most of the rivers have their origin from Western Ghats. They receive orographic rainfall during south-west monsoon.	Eastern Ghats are discontinuous chain of mountain ranges. They lie parallel to the monsoons coming from Bay of Bengal and does not cause much rainfall. The mountain ranges of Eastern Ghats are Javadi Hills, Shervoy Hills, Panchmalai Hills, Palkonda Hills and etc.

Mountain Peaks of Peninsular India

Peak	Range	State
Anamudi	Western Ghats	Kerala
Doddabetta	Nilgiri Hills	Tamil Nadu
Phawngpui	Saiha District	Mizoram
Shillong Peak	Khasi Hills	Meghalaya
Mullayanagiri	Western Ghats	Karnataka
Guru Shikhar	Aravalli Range	Rajasthan
Arma Konda	Eastern Ghats	Andhra Pradesh
Deomali	Eastern Ghats	Odisha
Kalsubai	Western Ghats	Maharashtra
Mahendragiri	Eastern Ghats	Odisha
Dhupgarh	Satpura	Madhya Pradesh
Bailadila Range	Dantewada District	Chhattisgarh
Malaygiri	Garhjat Range	Odisha
Sonsogor	Western Ghats	Goa
Girnar	Junagadh District	Gujarat
Doli Gutta	Deccan Plateau	Telangana & Chhattisgarh
Amsot Peak	Shivalik Hills	Uttar Pradesh
Betalongchhip	Jampui Hills	Tripura
Someshwar Fort	West Champaran District	Bihar

Major Passes in Peninsular India

- **Thal Ghat:** Also known as Kasara Ghat. The Kasara ghat is located on the busy Mumbai-Nashik route and is one of the four major routes, rail, and road routes, leading to Mumbai. The railway line passing through this ghat is the steepest in India.
- **Bhor Ghat:** This was developed by the Satavahana Dynasty. The ghat is located in the Western Ghats in the Maharashtra state of India. The ghat lies between Palasdari and Khandala.
- **Pal Ghat:** The mountain pass is located in the Western Ghats in Tamil Nadu. It is also called the Palakkad Gap. The pass connects the Nilgiri Hills in the north and the Anamalai Hills to the south.
- **Haldighati Pass:** Famous for the Battle of Haldighati (Between Maharana Pratap and Man Singh in 1576). The pass is located in Rajasthan and connects Rajsamand and Pali districts. .

COASTAL PLAINS

The peninsular plateau of India is bordered by narrow coastal plains which vary in width from North and South. The coastline of India extends of 7515 km. The coastline is distributed among nine states and four union territories. Among the states, Gujarat and among the union territories, Andaman and Nicobar Islands have the longest coastline.

Classification of Coastal Plains

	Western Coastal Plains	Eastern Coastal Plains
Extent	The Western Coastal Plains runs with an average width of 50 km between the Arabian Sea and the Western Ghats. The Western Coastal Plains extends from **Gulf of Khambhat** in Gujrat to **Cape Comorin** in Kerala. The Kutchh Kathiwar Region remains an exception. It is considered as the extension of Peninsular Plateau. Starting from north to south, it is divided into • **Konkan coast (**Maharashtra**)** • **Karnataka coast** • **Malabar coast (**Kerala**)**	The Eastern Coast Lies between the Eastern Ghats and the Bay of Bengal. It extends from the Ganga delta to Kanniyakumari. • **Utkal coast (**in Odisha**)** • **Coromandel coast (**Tamil Nadu & Andhara Pradesh**)**
Coast Type	The Western Coastal Plains are an example of submerged coastal plain. West coast forms conditions for major ports of India. Example: Kandla, Mazagaon, Jawahar Lal Nehru port.	The Eastern Coastal Plain is an emergent coast. The plains are characterised with wide coast. The eastern coast, form less ports and harbours.
Rainfall	Since, the Western Coasts are encountered by south-west monsoon they get sufficient rainfall. Thus, Western Coastal Plains are wetter than their Eastern Coast.	Eastern coast lie almost parallel to the monsoons coming from Bay of Bengal and does not cause much rainfall.
Features	The rivers flowing in Western Coasts do not form any delta. A large number of **creeks** (a marshy channel) and **coves** (a small bay) and few estuaries are found in Western Coasts. The Malabar Coast is characterised with "**Kayals**" or Backwaters. Example: Vembanad Lake.	The Eastern Coastal Plains have form deltas. Include deltas of Mahanadi, Godavari, Krishna and Cauvery. **Chilika Lake** is the largest salt water lake in India located in Utkal Plains.

THE ISLANDS

In India two island groups are situated in two respective seas of the Indian Ocean. **Andaman & Nicobar Islands** (Bay of Bengal) & **Lakshadweep and the Minicoy Islands** (Arabian Sea).

	Andaman & Nicobar Islands	Lakshadweep and the Minicoy Islands.
Location	Bay of Bengal	Arabian Sea
Extent	The Landfall Island in the north (in the Andamans) to the Indira Point, formerly known as Pygmalion Point and Parsons Point in the south of the Great Nicobar.	The entire island is made up of coral deposits and comprises of around 36 islands out of which 11 are inhabited
Known	Emerald islands	Laccadive, Minicoy and Amindivi Island
Highest Peak	The Saddle Peak located in North Andaman.	No mountains or hills are present
Features	The origin of Andaman and Nicobar Island has a relation with the formation of the Himalayas. They form a part of its southern loop extending from the **Aralan Yoma Valley.** The island group is divided as the Andaman in the north and the Nicobar in the south. They are divided by the water body- the Ten Degree Channel. The Andaman Islands can further be classified under: • The Great Andamans ◆ North Andaman ◆ Middle Andaman ◆ South Andaman • Little Andamans (separated by the Duncan Passage) • The Nicobar Islands and the Andaman Islands are separated by Ten Degree Channel and comprises of three islands, the Car Nicobar, the Little Nicobar and the Great Nicobar.	The Islands are scattered forming an archipelago. The largest island among the island group is the Minicoy Island which lies to the south of nine degree channel. The Amindivi and Cannanore islands lie in the north. The islands while lying in a north-south direction are not more than 5 metres above sea level. The island is covered with vegetation of palm trees. The island group makes the smallest union territory of India

Other Important Islands

Islands	Features
Majuli Island	Located in Assam on the Brahamaputra River. It is the world's largest freshwater island. It is also India's first island district.
Salsette Island	India's most important island. Mumbai City is located on the island.
Sriharikota Island	This is a barrier island and is the satellite launching station of ISRO.
Alaibet Island	The Island is located in Gulf of Khambat in Gujarat and is India's first off-shore oil well site.
Wheeler Island	Located near the coast of Odisha and is the missile launching station in Bay of Bengal.
Pirotan Island	Comprises 42 islands that are located in the Marine National Park in the Arabian Sea in the Gulf of Khambat of Gujarat. The island consists of Mangroves.
Diu Island	The island is located on the southern coast of Gujarat's Kathiawar Peninsula.
Rameshwaram Island	Located in the state of Tamil Nadu. The island is 40 kilometers away from Sri Lanka. The island is connected to mainland India by the Pamban Bridge.
Hope Island	Located in Andhra Pradesh, Hope island is a small tadpole-shaped island on the Bay of Bengal.

INDIAN DRAINAGE

Indian river systems can be majorly categorized based on their origin, their orientation towards the sea, and their drainage basins.

A. Based on the orientation toward the sea (discharge of water)

The Indian drainage system can be divided into-

- The Bay of Bengal drainage system.
- The Arabian Sea drainage system.

	Bay of Bengal Drainage System	Arabian Drainage System
Orientation	Rivers flow east. The rivers drain into the Bay of Bengal.	Rivers flow west. The rivers drain into the Arabian Sea.
Drainage Area	77 % of the drainage area of the country is oriented towards the Bay of Bengal Sea.	23% of the drainage area of the country is oriented towards theArabian Sea.
Major Rivers	Ganga, Brahmaputra, Mahanadi, Godavari, Krishna, Cauvery, Vaigai, etc.	Narmada, Tapti, Sabarmati, Mahi, etc.
Discharge	90% of water drains into the Bay of Bengal.	Around 10% of water drains into the Arabian Sea.

B. Based on Origin

The drainage system in India can be classified based on origin as:

- The Himalayan River System. (Perennial Rivers)
- The Peninsular River System. (Non-Perennial Rivers)

C. Based on the type of drainage:

The drainage system in India can be classified based on drainage:

- Rivers that drain into the seas (the Arabian Sea or the Bay of Bengal Sea)
  - Himalayan rivers like the Ganga, the Indus, and the Brahmaputra; Peninsular rivers like the Godavari, the Krishna, the Cauvery, the Narmada, and the Tapti drain into either the Bay of Bengal Sea or the Arabian Sea.
- Rivers that have inland drainage (endorheic basins)

- The drainage basin that allows no outflow to any of the seas or oceans but converges into lakes or swamps are called endorheic basins.
- For example, the Sambhar Salt Lake. India's largest inland salt lake receives water from six rivers that converge into it. They are the river Mantha, river Rupangarh, river Khari, river Khandela, river Medtha, and river Samod.

Did you know?

Based on catchment size, Indian rivers are divided into major, medium and minor rivers. There are 12 major river systems whose total catchment area is 252.8 million heactare (M.Ha). Of the major rivers, the Ganga - Brahmaputra Meghana system is the biggest with catchment area of about 110 M.Ha. The catchment area of medium rivers is about 25 M.Ha and Subernarekha with 1.9 M.Ha. catchment area is the largest river among the medium rivers in the country.

Note: Refer the Chart for detail description of Indian Rivers:

MAJOR LAKES IN INDIA

NAME	STATE	IMPORTANT FEATURES
Satpara Lake	Gilgit Baltistan (Near J&K)	• It is a natural lake. • It supplies water to Skardu Valley.
Tsokar Lake	UT of Ladakh	• It is also called White lake due to the salt deposited around it. • This lake is also recognized as the 42nd Ramsar Site.
Tso Moriri Lake	UT of Ladakh	• Tso Moriri is the largest of the high altitude lake in Ladakh. • Also known as "Mountain Lake". • It was notified in Nov 2000 under the list of Ramsar Wetland.
Pangong Tso	UT of Ladakh	• Situated at the height of 4350m, it is the world's highest saltwater lake. • It is an endorheic lake. Pangong Tso Lake is 134km long and divided into five sub lakes, called Pangong Tso, Tso Nyak, Rum Tso and Nyak Tso. • 50% of its total length lies in Tibet, 40% in Ladakh, and the remaining 10% is disputed and considered a buffer zone between India and China.
Wular Lake	Jammu and Kashmir	• Situated in Bandipora District of Jammu and Kashmir. • It is one of the 49 Indian wetlands designated as a Ramsar site. • Wular Lake basin formed as a result of tectonic activity.
Dal Lake	(Srinagar) Jammu and Kashmir	• Dal Lake is an urban lake and the second largest lake in Jammu and Kashmir. • Its basin is divided into five parts: Nehru Park Basin, Nishat Basin, Hazrat Basin, Nagin, and Brari Nambal Basin. • Famous for Shikaras. Also known as "Lake of Flowers"
Mansar lake	Jammu and Kashmir	• Surinsar-Mansar Lakes were designated as Ramsar Convention in Nov 2005. • It supports CITES and IUCN red-listed Lissemys punctuate, Aspideretes gangeticus and Men Ariella lacusrris.
Chamera lake	Himachal Pradesh	• It is an artificial lake. • It is situated near the town Dalhousie of Chamba District.
Khajjiar lake	Himachal Pradesh	• It is situated close to Manimahesh Kailash Peak in the Pir Panjal Range in Chamba District. • It has a thick forest cover around the Kalatope Sanctuary.
Suraj Tal Lake	Himachal Pradesh	• It is also known as Tso Kamtsi or Surya Tal. It is situated just below the Bara – lacha – la pass in Lahaul and Spiti District. It is the 3rd Highest lake in India. • It is just below the source of the Bhaga River.
Maharana Pratap Sagar	Himachal Pradesh	• It is also known as Pong Reservoir or Pong Dam Lake. • It is one of the 27 International Wetland sites declared in India by the Ramsar Convention. • It is located on the Beas River, is one of the five major rivers of the Indus basin.
Govind Sagar	Himachal Pradesh	• It is situated in Una and Bilaspur District. It is formed by Bhakra Dam. • It is a reservoir on the river Sutlej and is named in honour of Guru Govind Singh, the 10th Sikh guru.

NAME	STATE	IMPORTANT FEATURES
Renuka lake	Himachal Pradesh	• It is situated in Sirmaur District and largest Lake of Himachal Pradesh. • It is named after the goddess Renuka & shaped like a profile of woman • It was designated as Ramsar Site from Nov 2005.
Gauri kund	Uttarakhand	• It is situated at an altitude of 6502 feet in the Garhwal Himalayas. • It is connected with God Shiva's wife Parvati, also known as Gauri.
Naini (Nainital Lake)	Uttarakhand	• It is formed as a result of tectonic activity in origin and is kidney-shaped. • It is also an integral part of Kumaoni folklore.
Bhimtal	Uttarakhand	• It is a lake in the town of Bhimtal in Kumaon, with a masonry Dam built in 1883. It is the largest lake in Kumaon. • It provides a drinking water supply and aquaculture with a variety of fishes.
Badkhal Lake	Haryana	• It is fringed by the Aravalli Range Hills and was a man made embankment. • It is now totally dried up due to unchecked mining in neighbouring areas.
Surajkund lake	Haryana	• It is an Artificial lake. • Its literal meaning is 'lake of the sun'. It was built by Surajpal of the Tomara dynasty. • It is also an important biodiversity area within the North Aravalli leopard wildlife corridor.
Harike wetland	Punjab	• Also known as "Hari-Ke-Pattan", the largest wetland in northern India. • Wetland and lake were formed by constructing the headworks across the Sutlej river in 1953. • The headwork is located downstream of the confluence of the Beas and Sutlej rivers.
Kanjli wetland	Punjab	• It was constructed in 1870 across the Perennial Bien River. Bien is a tributary of the Beas River.
Ropar wetland	Punjab	• Located on the Sutlej River, was created in 1952 by building a regulator to store and divert water for beneficial uses.
Sambhar Lake	Rajasthan	• The Aravalli Hills are surrounded by all sides of this lake. • It is India's largest Inland salt lake.
Pushkar lake	Rajasthan	• Pushkar Lake is a sacred lake of the Hindus. The Hindu scriptures describe it as "Tirtha-Guru " – the preceptor of pilgrimage sites related to a water body and relate it to the mythology of the creator-god Brahma, whose most prominent temple stands in Pushkar. • The mountain range known as Nag Parbat ("snake mountain") separates the lake from the city of Ajmer
Bal Samand lake	Rajasthan	• It is an artificial lake. • Lake by Balak Rao Pratihar in 1159 AD. It was designed as a water reservoir to provide water to Mandore.
Pachpadra lake	Rajasthan	• It is a saltwater lake. Its sodium chloride level is marketed at 98%.
Fateh Sagar	Rajasthan	• It is an artificial lake. It is named after Maharana Fateh Singh of Udaipur and Mewar. • Within the confines of the Fateh Sagar Lake, there are the small islands. The largest of these is the island in the Nehru Park.
Rajsamand lake	Rajasthan	• Built by Rana Raj Singh in 1685. It was built across the Gomti river which originates from Sewantri, Kelwa, and Tali rivers.
Dhebar lake	Rajasthan	• Asia's second-largest artificial Freshwater lake, which was built across the Gomati, Kelwa, and Tali Rivers. • It is India's first and world's oldest historical and second-largest artificial freshwater lake in India.
Hussain Sagar	Telangana	• Built by Ibrahim Quli Qutb Shah in 1563. It was built on a tributary of the River Musi to meet the water and irrigation needs of the city. • A large monolithic statue of the Gautama Buddha, erected in 1992, stands on Gibraltar Rock in the middle of the lake. • It also separates the city centre of Hyderabad from its neighbourhood Secunderabad.

NAME	STATE	IMPORTANT FEATURES
Kolleru lake	Andhra Pradesh	• It is also called Colair Lake. • The lake is fed directly by water from the seasonal Budameru and Tammileru streams and is connected to the Krishna and Godavari irrigation systems
Pulicat lake	On the border of Tamil Nadu and Andhra Pradesh on the Coromandel coast. Mainly located in Andhra Pradesh	• Second largest brackish water lagoon in India . • The lagoon is one of the three important wetlands to attract northeast monsoon rain clouds. • The lagoon encompasses the Pulicat Lake Bird Sanctuary.
Kaliveli lake	Tamil Nadu	• Coastal lake, located on the Coromandel Coast near the Bay of Bengal. • Lake is one of the largest wetlands in peninsular India and is considered a wetland of both national and international importance by the IUCN.
Lake Tsongmo (Changu Lake)	Sikkim	• It is a glacial lake. Lake remains frozen during the winter season. • The lake is the venue for the Guru Purnima festival which is also the Raksha Bandhan festival when the faith healers known as Jhakris of Sikkim assemble at the lake area. Alpine forests cover the catchment of the lake. • The Indian Postal Service released a commemorative stamp on the lake.
Menmecho lake	Sikkim	• Lake is the source of the river Rangpo Chu, a tributary of the river Teesta. • It lies on the way to the Jelep Pass. • The lake is noted for its trout fish, and has a large fish farm nearby.
Kanwar lake	Bihar	• Asia's largest freshwater oxbow lake. • In November 2020, it was declared as the first Ramsar site in Bihar.
Chilka lake	Odisha	• Brackish water lagoon. It is the biggest lake of India after Vembanad Lake. • This lake is the largest coastal lagoon in India and the largest brackish water lagoon in the world. • Largest wintering ground for migratory birds on the Indian subcontinent.
Lonar lake	Maharashtra	• It is a Notified National Geo-Heritage Monument. • It is a Saltwater lake. Lonar Lake was created by a meteorite collision impact during the Pleistocene Epoch. • Lonar Lake lies within the only known extraterrestrial impact crater found within the great Deccan Traps, a huge basaltic formation in India.
Umiam lake	Meghalaya	• It was created by damming the Umiam River in the early 1960s. It was built by the Assam State Electricity Board.
Himayat sagar	Telangana	• It lies parallel to a larger artificial lake, Osman Sagar. • The construction of reservoirs on the Esi, a tributary of the Musi River, was completed in 1927. It was built during the reign of the last Nizam of Hyderabad, Nizam VII, and is named after his youngest son Himayat Ali Khan.
Osman Sagar	Telangana	• Osman Sagar was created by damming the Musi River in 1920. It was constructed during the reign of the last Nizam of Hyderabad State, Osman Ali Khan.
Vembanad lake	Kerala	• Longest lake in India & the largest lake in Kerala. • Famous for Nehru Trophy Boat Race, • It is also a Ramsar Site Wetland.
Ashtamudi Lake	Kerala	• Ramsar Site wetland. • Palm Tree Shaped Lake. • Also known as Queen of backwaters. • Also famous for the President's Trophy Boat Race Event.
Loktak lake	Manipur	• Largest fresh water lake in India by area. • The only floating National Park in the world, the Keibul Lamjao National Park located on the Loktak Lake

INDIA- CLIMATE

In India, the monsoonal climate determines all social, cultural, and economic activities. The Indian climate is considered to be a tropical monsoon climate as monsoon plays a significant role in affecting people's lives.

FACTORS DETERMINING INDIA'S CLIMATE

- **Latitude:** The **Tropic of Cancer** passes through the central part of India in an east-west direction -so, the northern part of India lies in the sub-tropical and temperate zone and the southern part falls in the tropical zone.
- **The Himalayan Mountains**: The Himalayas act as an effective **climatic divide** between central Asia and the Indian subcontinent obstructing cold winds from Arctic Circle.
- **Distribution of Land and Water**: India is flanked by the Indian Ocean on three sides in the south and surrounded by a high and continuous mountain wall in the north. The water heats up and cools down more slowly than the landmass – the differential heating creates different air pressure zones in different seasons in and around the Indian subcontinent.
- **Distances from the Sea:** The coastal areas of India have an equable climate, because of the moderating influence of the sea. The interior parts experience climate variations and extremes due to the absence of this moderating influence.
- **Altitude**: The places situated at higher altitudes are cooler than places located at relatively lower heights. Eg: Agra and Darjeeling are located on the same latitude, but the temperature of January in Agra is 16°C whereas it is only 4°C in Darjeeling.
- **Relief**: The physiography or relief of India affects the temperature, air pressure, direction and speed of the wind, distribution of rainfall etc.
  - The windward sides of Western Ghats and Assam receive high rainfall during June-September whereas the southern plateau remains dry due to its leeward situation along the Western Ghats.

INDIAN SEASONS

The Indian meteorological department has categorised the following four annual seasons:

(a) The Winter Season (January – February)

(b) The Summer season (March-May)

(c) The Rainy Season (Southwest Monsoon Season -(June – September)

(d) The Autumn season (October – December)

Winter Season

Initiation	By the winter solstice in December (22nd December), the sun vertically shines over the tropic of Capricorn. As a result, India being in the northern hemisphere experience the winter season.
Span	In northern India, the cold weather season spans from mid-November to February. December and January are the coldest months in north India.
Regional Variations	There is a gradual decrease in temperature upon advancing from south to north in the winter season in India. The moderating impact of the sea and the closeness to the equator, subdue the winter season in the Peninsular region of India
Temperature Conditions	• The 20°C isotherm runs roughly parallel to the **Tropic of Cancer.** • To the south of this isotherm, **the temperatures are above 20°C.** Here there is no distinctly defined winter weather. Some parts of Kerala and Tamil Nadu typically experience temperatures near 30°C. • To the north mean temperatures are below 21°C and **the winter weather is distinct.** • The mean minimum temperature is about **5°C over north-west India and 10°C over the Gangetic plains.** • **Dras Valley** in Kashmir is the coldest place in India. The minimum temperature recorded at Dras was – 45°C in 1908.

Pressure Conditions	• High air pressure prevails over large parts of northwest India. • Pressure is comparatively lower in south India. • The winds start blowing from the high-pressure area of the north-west to the low-pressure area of the southeast.
Precipitation	• The northern part of India along with parts of peninsular India is characterized by dry weather due to prevailing north-east trade winds from land to sea • The retreating winter monsoons pick up some moisture while crossing the Bay of Bengal and cause winter rainfall in Tamil Nadu, south Andhra Pradesh, south-east Karnataka and south-east Kerala (Usually in the first weeks of November). • The western disturbances also cause little rainfall in northwest India.

Summer Season

Initiation	It is marked by the apparent movement of the sun towards tropics of cancer. • This movement begins after the march equinox(21st March) and continues till the summer solstice(21st June) every year.
Progress	• Intense heating of the Indian subcontinent (northern plains and the adjacent highlands of India) and the Tibetan Plateau. • Creation of low-pressure trough that extends from the Punjab plains in the northwest to the Bengal delta in the east. • During the month of March, the ITCZ is present predominantly around the equator and the sub-tropical jet streams are present around 20-25 degrees north latitude. • By the end of March and the beginning of April, there is northward movement of the STJ and the ITCZ. • During April, STJ splits into two branches, the northern branch and the southern branch. • The northern branch moves over the Himalayan mountain ranges and the southern below the Himalayas. • The movement of the ITCZ over the Indian subcontinent results in occasional thunderstorms in the regions where the ITCZ moves.
Temperature Conditions	• The **southern parts** of the country are **warmer in March and April** and in June, **north India has higher temperatures.** • In March, the highest temperatures occur in the southern parts (40-45°C). • In April the highest temperature of about 45°C is recorded in the northern parts of Madhya Pradesh. • In May the highest temperature shifts to Rajasthan (temperatures as high as 48°C). • In June the maximum temperature is in Punjab and Haryana. • Highest temperatures recorded just before the onset of the southwest monsoons (late May). • The diurnal range of temperature-very high. • Maximum summer temperatures are comparatively lower in the coastal and southern peninsular regions due to moderating effect of the sea. • The temperatures along the west coast are comparatively lower than on the east coast due to the **prevailing westerly winds.** • There is a **large contrast between land and sea temperatures.** • Northern and central parts of India experience heat waves
Pressure Conditions	• The atmospheric pressure is low all over the country due to high temperatures. • Strong dynamically induced divergence over northwest India prevents the onset of southwest monsoons.

Winds and Thunderstorms

Loo: Loo winds originate over the **Iranian, Baloch and Thar deserts.**

- In May and June, high temperature in northwest India builds a steep pressure gradient.
- Hot, dust-laden and strong wind (loo) blows.
- It blows with an **average speed of 30-40 km per hour** and persists for days.

Andhi: The strong dust storms resulting from the convective phenomena are locally known as andhis (blinding storms).

- They move like a solid wall of dust and sand.
- Common in Rajasthan, Haryana, Punjab, Jammu region, Delhi, Uttar Pradesh, Bihar and Madhya Pradesh.
- The wind velocity often reaches 50-60 kmph
- They are short-lived.

Norwesters:

- The strong convectional movements related to the westerly jet stream lead to thunderstorms in the eastern and northeastern part of the country.
- They originate over the Chota Nagpur plateau and are carried eastwards by westerly winds.
- Seen in Assam, Arunachal Pradesh, Nagaland, Mizoram, Manipur, Tripura, Meghalaya, West Bengal and the adjoining areas of Odisha and Jharkhand.
- In West Bengal and the adjoining areas of Jharkhand, Odisha and Assam, the direction of squalls is mainly from the northwest, and they are called norwesters.
- Called 'Barodoli Chheerha' in Assam
- The period of maximum occurrence of these storms is the month of Vaisakh (mid-March to mid-April) and hence, they are locally known as Kalabaisakhis

Mango Showers: Thunderstorms in Kerala
Blossom Showers: Thunderstorms in Karnataka and Tamil Nadu

Precipitation

- In the northeastern parts of the country, dust storms bring little rainfall.
- The precipitation in Kashmir is mainly in the form of snow caused by western disturbances.
- The norwesters bring some rainfall in Assam, West Bengal and Odisha.
- Coastal areas of Kerala and Karnataka receive rainfall from thunderstorms.

Western Disturbances

Western disturbances are low-pressure systems (disturbances) that flow from west to east (western winds) under the influence of the westerlies.

- Western disturbances emerge over the Mediterranean Sea as extra-tropical cyclones or mid latitude cyclones.
- A high-pressure condition is formed over Eastern Europe which leads to the intrusion of cold air from Polar Regions into the relatively warmer air regions resulting in a pressure change.
- This change in pressure creates a favorable condition for cyclogenesis in the upper layer of the atmosphere which then promotes the formation of an eastward-moving extratropical depression in the sea.
- These depressions travel across the Middle East, Iran, Afghanistan, and Pakistan and enter into the Indian subcontinent. These moisture-laden depressions or disturbances finally hit the Himalayas and fall over as precipitation in the form of rainfall and snowfall.
- **Benefits:** Brings winter rainfall which is highly beneficial for standing Rabi crops

What are heat waves?

A Heat Wave is a period of abnormally high temperatures, more than the normal maximum temperature that occurs during the summer season in the North-Western parts of India. Heat wave is considered if maximum temperature of a station reaches at least 40^0C or more for Plains and at least 30^0C or more for Hilly regions.

Monsoon Season

Monsoon describes a seasonal wind shift over a region that is usually accompanied by a dramatic increase in precipitation.

Characteristics of Monsoon:

- A system of winds, with marked seasonal shifts, caused by differential heating of land and sea.
- Largely confined to the tropics, a region between 20 degree N and 20 degree S on both the sides of equator.

- In the northern hemisphere, the winds are deflected to the right due to earth's rotation. Consequently winds blow in south westerly direction.
- In the southern hemisphere, they are deflected to the left due to earth's rotation. Consequently, winds blow in north westerly direction.

Regions of Monsoon

- **Indian Monsoon**
- **Others**: Seasonal wind changes have been known to occur in north-east Australia, Africa, South America (Brazil), southern USA and in Latin America.
  - Countries like India, Indonesia, Bangladesh, Myanmar etc. receive most of the annual rainfall during the southwest monsoon season
  - South East China, Japan etc., receive annual rainfall during the northeast rainfall season.

Different theories on the Development of Indian Monsoon

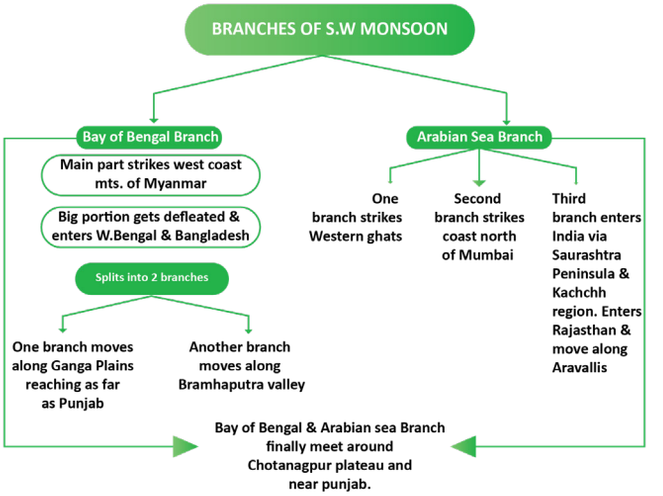
Theory	Propounded By	Theory
Classical Theory	Sir Admond Halley in 1686	The primary cause of the Indian monsoon circulation was the differential heating effects of the land and the sea.
Dynamic Concept or Shifting of Inter Tropical Convergence Zone (ITCZ) or Air Mass Theory	H. Flohn of the German Weather Bureau in 1951	Monsoon is the result of seasonal migration of planetary winds and pressure belts
Jet Stream Theory	____	• Over India, a subtropical westerly jet develops in the winter season that causes high pressure over northern parts of the subcontinent during the winter. This results in the north-to-south flow of the winds in the form of the northeast monsoon. • With the northward shift of the vertical sun, this jet shifts north, too. The intense heat over the Tibetan Plateau as well as Central Asia, coupled with associated terrain features of the Himalayas, generate the tropical easterly jet over central India. • This jet creates a low-pressure zone over the northern Indian plains, influencing the wind flow toward these plains and assisting the development of the southwest monsoon. • If the northward shift of the subtropical westerly jet is delayed, the onset southwest monsoon also gets delayed. An early shift results in an early monsoon. • A strong easterly tropical jet results in a strong southwest monsoon over central India, and a weak jet results in a weak monsoon.

Role of Tibetan Plateau

The Tibetan plateau remains warmer by 2 degree - 3 degreeC than the adjoining areas during summer. The low pressure created in Tibetan Plateau pushes westerly Jet further northward and strengthens the easterly Jet which coincides with the arrival of Indian Summer Monsoon.

Monsoon in India

- **India receives:**
  - Southwest monsoon winds in summer and
  - Northeast monsoon winds in winter.
- **Onset of monsoon**
  - While there is no specific date for the onset of the monsoon, the onset is marked by the movement of ITCZ to 20-25 °N latitude and the SubTropical Jet Stream moves completely over the Himalayas.
  - The northern and southern branches of the jet stream reunite as a single branch and flow to



the north of the Himalayas across the Tibetan plateau. This results in the sudden **burst of the monsoon** around the 1st week of June.

- **Branches of Southwest Monsoon**
  - The southwest monsoon winds are divided into two branches namely the **Bay of Bengal Branch** and the **Arabian Sea Branch**. The division into two branches is because of the **shape of peninsular India**.

Important Concepts

Walker Cell:
- The longitudinal (east-west) circulation across the equatorial Pacific is known as the Walker cell or Walker circulation.
- The Walker cell is driven by temperature and pressure gradients. Areas of high pressure form over the cooler eastern Pacific waters. Areas of low pressure form over the warmer western Pacific. Winds near the equator flow from areas of high pressure to low pressure, and so the near-surface winds cross the Pacific move from east to west as part of the trade winds.
- The Walker cell also drives east-west air flows over the Indian Ocean and equatorial Atlantic Ocean

Mascarene High:
- It is a semi-permanent subtropical high-pressure zone located between 20°S–40°S and 45°E–100°E near the Mascarene Islands in the Southern Indian Ocean.

- **Break in Monsoon**
  - During July and August, there are certain periods when the monsoons become weak. Rainfall practically ceases over the country outside the Himalayan belt and southeast peninsula. This is known as a **break in the monsoon.**
  - Breaks are likely to occur during the second week of August and last for a week.
  - The breaks are believed to be brought about by the northward shifting of the **monsoon trough (minimum low-pressure cell in ITCZ).** The axis of the trough lies at the foothills of the Himalayas during the break period.

Retreating Monsoon and North-east Monsoon

- The southwest monsoons start retreating in the first week of September from northwestern India. The monsoon winds follow the **last reach first withdraw pattern,** which means they withdraw earlier from the regions they reached last.
- The low-pressure trough that was built in the northwest part of India starts to disintegrate and there is an eventual shift to the equatorial region towards the end of September.
- The weakening is due::

1. The apparent movement of the Sun towards the equator
2. The lowering of the temperature due to the monsoonal rains.

Difference between South-west Monsoon and North-east Monsoon

South-West Monsoon	North-east Monsoon
Blow during June to September	Blow during December to February
Blow from high pressure area on sea to low pressure area on land	Blow from high pressure area on land to low pressure area on sea
Brings rain to large parts of India	Bring little rainfall to Tamil Nadu Coast
Two Branches- Bay of Bengal Branch and Arabian Sea Branch	Only one branch

Teleconnections of Indian Monsoon

Teleconnections are defined as linkages over great distances of atmospheric and oceanic variables.

El Nino

- El Nino is a temporary warm ocean current which appears off the coast of Peru in December in some years.
- El-Nino events are the result of weakening Easterly Trade winds. The Easterly trade winds are driven by a surface pressure pattern of higher pressure in the Eastern Pacific and lower pressure in the west.
- When the pressure gradient weakens, so do the trade winds. The weakening of easterly trade winds allows warmer water from the western Pacific to surge eastwards and replace the cold Peruvian currents, so the sea levels flatten out.
- Warmer water causes heat and moisture to rise from the ocean off Ecuador and Peru, resulting in more frequent storms and torrential rainfall over these normally arid countries, while drought-like conditions are formed in Australia.

Southern Oscillation

- Southern Oscillation is the see-saw pattern of atmospheric pressure between the eastern and western Pacific Ocean. The oscillation has a period varying from 2-7 years
- The pressure variation is measured by the **Southern Oscillation Index (SOI)**
- SOI is measured as difference in pressure between Tahiti (17º45'S, 149º30'W) in French Polynesia, representing the southern Pacific Ocean and Port Darwin (12º30'S, 131ºE), in northern Australia, representing the Indian Ocean.
- **Impact on Indian Monsoon**
  - **Positive SOI:** With a high positive SOI, there would be a zone of low atmospheric pressure over Australia and the Indonesian archipelago. The rising air from this region deflects in the upper atmosphere in both directions towards Africa and South America.
    - » In the Indian Ocean, the air descends down at a high-pressure zone from where surface winds blow as Southwest monsoon towards the Indian sub-continent in summers.
  - **Negative SOI:** During the appearance of El-Nino or negative SOI, the ascending branch of the Walker cell shifts to the central regions of the Pacific Ocean from the western pacific region. In a result, the Indian Ocean cell shifts towards the east.
    - » The surface winds or Southwest monsoon winds are weaker than normal conditions.

La Nina

- Unusual cooling takes place in the central and eastern Pacific in contrast to EL-Nino's unusual warming.
- La-Nina occurs due to an increase in the strength of the normal patterns of trade wind circulation.
- La-Nina is characterised by lower than normal air pressure over the western Pacific. These low-pressure zones contribute to increased rainfall.
- La-Nina usually brings colder winters to the Canadian west and Alaska, and drier, warmer weather to the American southeast coast.
- Together La-Nina and El-Nino are the cold and warm phases of the ENSO or El-Nino Southern Oscillation.

Godzilla and Triple Dip La Nina

El Niño and La Niña episodes typically last for about nine months to a year. They usually develop in the March-June period, and are the strongest during winter (November-January in the northern hemisphere), before weakening or dissipating by March or April of next year. Occasionally, however, they continue for much longer periods.
Godzilla: In recent years, the El Niño of 2015-16, spread over 19 months, was one of the longest on record, and was dubbed 'Godzilla' due to its sustained high intensity.
Triple Dip La Nina: The current La Niña episode has already surpassed that in length. Having started in September 2020, it has prevailed for the last 24 months, and looks set to continue for another six months, and has thus been classified as a 'triple dip' La Niña.

Indian Ocean Dipole

The Indian Ocean Dipole (IOD) is **defined by the difference in sea surface temperature between two areas (or poles, hence a dipole)** – a western pole in the Arabian Sea (western Indian Ocean) and an eastern pole in the eastern Indian Ocean south of Indonesia.

IOD develops in the equatorial region of **the Indian Ocean from April to May peaking in October.**

Two types of dipoles are seen over the Indian Ocean.

1. Positive Indian Ocean Dipole
2. Negative Indian Ocean DIpole

- Positive IOD
  - With positive IOD, the eastern Indian Ocean (Bay of Bengal and oceans parts off Sumatra in Indonesia) becomes colder than normal while the western tropical part of the Indian Ocean (Arabian Sea) near the African coast becomes warmer. Such an event strengthens the southwest monsoon.
- Negative IOD
  - With negative IOD, the eastern Indian Ocean (Bay of Bengal and oceans parts off Sumatra in Indonesia) becomes abnormally warm and the western tropical part of the Indian Ocean (Arabian Sea) near the African coast becomes relatively colder. This is not considered beneficial as the Indian southwest monsoon gets a severe hit.

Similar to ENSO**, the atmospheric component of the IOD is named as Equatorial Indian Ocean Oscillation (EQUINOO)**(Oscillation of pressure cells between the Bay of Bengal and the Arabian Sea).

- During the positive phase of EQUINOO, there is enhanced cloud formation and rainfall in the western part of the equatorial ocean near the African coast while such activity is suppressed near Sumatra.

1. **El-Nino** with **Positive IOD** results in **good rainfall** and strengthens Indian Monsoon. (Positive IOD facilitates good monsoon rainfall despite the El-Nino.)
2. **El-Nino** with **Negative IOD** results in **deficit rainfall** and weakens Indian Monsoon. (Deficit rainfall and droughts are mostly seen across the Indian continent.)
3. **La-Nina** with **Positive IOD** results in **very good rainfall** and heavily strengthens the Monsoon. (A rare phenomenon and this leads to heavy rainfall.)
4. **La-Nina** with **Negative IOD** results in **moderate rainfall**. (Though La-Nina strengthens, later it weakens monsoon, and this results in moderate rainfall.)

Somali Current

- It is a warm ocean boundary current that runs along the coast of Somalia and Oman in the Western Indian Ocean
- The Somalian current changes its direction of flow after every six months.
- During the North-East Monsoon, the Somali Current flows to the south-west, while during the South-West Monsoon it is a major western boundary current, comparable with the Gulf Stream.
- Normally, there remains a low-pressure area along the eastern coast of Somalia.
- After every six or seven years, the low-pressure area in the western Arabian Sea may become a high-pressure area. Such a pressure reversal results into a weaker monsoon in India.

Madden-Julian Oscillation (MJO)

The MJO is an eastward moving disturbance of clouds, rainfall, winds, and pressure that traverses the planet in the tropics and returns to its initial starting point in 30 to 60 days, on average. Unlike, ENSO, which is stationary, the MJO is traversing.

- **Impact on Indian Monsoon**
  - When MJO is over the Indian Ocean during the Monsoon season, it brings good rainfall over the Indian subcontinent.
  - On the other hand, when it witnesses a longer cycle and stays over the Pacific Ocean, MJO results in poor rainfall conditions during Indian Monsoon season.
  - If MJO periodicity is about 30 days, then it leads to heavy rainfall, but if MJO stays for more than 40 days, then it leads to a dry monsoon.

Boreal summer intraseasonal oscillation (BSISO)

- It is the movement of convection (heat) from Indian Ocean to western Pacific Ocean roughly every 10-50 days during the monsoon (June-September).
- The BSISO tends to have a northward propagation over the Indian summer monsoon (ISM) region.
- Northward propagation of the BSISO has profound impacts on Northern Hemisphere extreme weather events.
- Active phase of BSISO (between June and August) induce high wave activity in the north Indian Ocean and Arabian Sea.
  - Waves induced by active phases of BSISO are nearly 0.5 meters higher than those which occur during other phases of BSISO.

Disrtribution of Rainfall in India

Region	Rainfall	Areas
High Rainfall Regions	200cm	The coast of Thiruvananthapuram and Mumbai, the states of Assam, Meghalaya, Sikkim, Tripura, Arunachal Pradesh, and the Northeastern tip of West Bengal
Medium Rainfall Regions	100-200cm	Eastern slopes of Western Ghats, eastern Madhya Pradesh, Odisha, Tamil Nadu, Bihar, Jharkhand, and Manipur
Low Rainfall Regions	50-100cm	Large parts of Gujarat, Andhara Pradesh, Western Madhya Pradesh, Maharashtra, Eastern Rajasthan, Punjab, Haryana, and Uttar Pradesh.

Region	Rainfall	Areas
Inadequate Rainfall Regions	Less than 50 cm	Western Rajasthan, Kutch, Ladakh and parts of Andhra Pradesh, and parts of Karnataka.

KOPPEN'S CLASSIFICATION OF INDIAN CLIMATE

Tropical Savanna Climate (Aw):	• The temperature in the hottest month (**May)- 40 degrees celsius.** • Temp remains above 18 degrees celsius in the cold months. • The diurnal and annual ranges of **temperature are high.** • Found in Peninsular India like Jharkhand, Odisha, Chhattisgarh, Andhra Pradesh, WestBengal, and Maharashtra. • The region receives **rainfall during the southwest monsoon.**
Tropical Monsoon Climate (Amw):	• Short and dry winter season. • Vegetation- **ever-green rain forests** (as there is heavy rainfall during the southwest monsoon). • Found in parts of **Konkan Coast, Malabar Coast, and areas joining the western ghats, Tamil Nadu plateau, and areas of Tripura and Mizoram.**
Tropical Moist Climate (As):	• Mean annual temperature-**18 degrees Celsius** • The region covers a Narrow zone along the Coromandal Coast. • Average rainfall varies between 75 and 100 cm.
Semi-Arid Steppe Climate (BShw):	• Mean annual temperature- above 18 degrees celsius; experiences summer rainfall. • Stretches over **Eastern Rajasthan and rain shadow regions of Tamil Nadu, Karnataka, Gujarat, and parts of southwest Haryana.**
Hot Desert Climate (BWhw):	• Mean **annual rainfall is less than 25cm.** • Mean maximum summer temperature- 45 degrees. • Winter temperatures **drop to 0 degrees Celsius.** • **Vegetation: Thorny bushes.** • Lies to the west of the **Aravallis, Thar Desert.**
Mesothermal Climate-Gangetic Plain Type (Cwg):	• The climate is **marked by dry winter.** • Hot Summers • Avg Temperature in cold months is 15 degrees Celsius.
Cold Humid Winter Climate (Dfc):	• The **average summer temperature is -17 degrees Celsius** • Winter average temperature- **8 degrees Celsius.** • **Cold humid winters and short summers.** • Mostly found in the hilly states of **Sikkim and Arunachal Pradesh.**
Polar Type (E):	• Found in higher reaches of the mountainous **areas of Jammu and Kashmir, Himachal Pradesh, and Uttarakhand.** • Warmest month Temp- **less than 10 degrees.**
Tundra Type (ET):	• Higher latitudes of **Kashmir, Ladakh, Uttarakhand, and Himachal Pradesh.** • The warmest month Temperature lies between 0 to 10 degrees Celsius.

INDIAN- SOIL

SOIL

Soil is the loose surface material that forms the uppermost part of the Earth's crust. It is a mixture of inorganic material, minerals, organic matter, gas, and water.

SIGNIFICANCE OF SOIL

- It provides ecosystem services that are critical for life. It acts as a medium of growth for plants, filters and cleans water, and hosts millions of microorganisms.
- It helps combat climate change by storing carbon dioxide (C02) and other Greenhouse gases (GHGs).
- Soil provides nutrients to our plants and crops and is the cornerstone of our agricultural system providing us with food, feed, fibre, and fuel.
- It also provides humans with essential building and manufacturing materials and a platform for structures such as buildings, highways, etc.

PROPERTIES OF SOIL

Soil Texture:

- The soil is composed of different particles. These particles are of varying sizes. The larger particles are called sand. The mediumsized particles are called silt, and the particles of smaller sizes are called clay.
- The soil texture refers to the relative proportion of these particles in the soil.
- The soil texture triangle shows the relationship between sand, silt, and clay.
- When the relative percentage of sand, silt, and clay is more or less the same, it is called Loam.

Soil Structure

- It refers to how soil grains are clumped together into larger masses called **peds**.
- Small peds, shaped like spheres, give the soil a **granular structure.**
- Larger peds form an **angular and blocky structure.**
- **Platy structure** tends to indicate soil compaction by animals or human activity.
- A **columnar structure** can occur in arid or sandy soils.

Soil Porosity:

- Porosity means the amount of empty space in a given material. The porosity of the soil determines the flow of water (its intake and drainage) and air ventilation.
- The porosity of the soil largely influences soil productivity.

Soil Moisture: There are three types of water in soil:

- **Hygroscopic Water**: It is the water held by soil using molecular attraction. This hygroscopic water is located on the surfaces of individual soil particles. Hygroscopic water is largely unavailable to plants because molecular attractions hold it firmly.
- **Capillary water:** It is the water retained in pores that are small enough to resist gravity. It can get evaporated or absorbed by plant roots. Therefore, it is also known as avail able water. It is the primary source of moisture for plants.
- **Gravitational Water:** When the soil cannot hold excess water, the water starts percolating downwards under the force of gravity. This is known as gravitational water.

Soil pH:

- It measures how acidic or alkaline the soil is. Soil pH is an essential indicator of soil fertility . It affects how minerals dissolve in water solutions and their availability for uptake by plant roots.
- Soils in cold, humid climates are often highly acidic.
- Soils in arid climates are typically alkaline
- Most plants prefer a pH level between 6 and 8 for maximum growth.

Soil Colour: It allows us to learn about some of its most important properties such as mineral composition, age, and soilforming processes.

Following are some types of soil colors:

- Grassland soils are black or dark brown because they contain high humus.

- The presence of iron containing oxides creates red or yellow soils. Soil color is inherited from mineral material in some regions, although it is formed during soil formation in most cases.
- Dry climates often have soils with a white surface layer of mineral salts that have been brought upward by evaporation.
- In the cold, moist climate of the boreal forest, a pale, ashgray layer near the top of the soil is created. This happens when organic matter and colored minerals are washed downward. It leaves only pure, light colored mineral matter behind. The mineral matter of the soil consists of individual mineral particles that vary widely in size.

Soil Profile and Horizons

A soil profile is a vertical cross section of the soil made up of layers. These layers are referred to as soil horizons.

Types of Soil Horizons:

Organic horizon: Organic horizons are marked with the capital letter 0. They lie above mineral horizons. They are formed from plant and animal matter.

Mineral Horizons:

- The **A horizon** is enriched with organic matter. It is below the organic horizons.
- Next is the **E horizon.** Clay particles and aluminium and iron oxides are removed from the E horizon by downward percolating water. This leaves behind pure grains of sand or coarse silt.
- The **B horizon** receives the clay particles, aluminium, iron oxides, and organic matter washed down from the A and E horizons. It is dense and tough because its natural spaces are filled with clays and oxides.
- Beneath the B horizon is the **C horizon.** It consists of the parent mineral matter of the soil. Below this is the bedrock or sediments much older than the soil.

SOIL DEVELOPMENT PROCESSES

Soil development begins with the mineral material available to form the soil. Normally, this matter consists of regolith. There are four types of soil forming processes: soil enrichment, removal, translocation, and transformation.

- **Soil Enrichment:** By this process, the organic or inorganic matter is added to the soil.
- **Removal:** By this process, the material is removed from the soil body.
  - Leaching: It is the process of the loss of soil compounds and minerals from the top layer of the soil by percolating water.
- **Translocation:** It is the movement of materials upward or downward within the soil.
  - Eluviation is the process in which fine particles are translocated downward.
  - Illuviation is the process by which material brought down from the E horizon accumulates in the B horizon.
- **Transformation:** It involves the transformation of material within the soil body.
  - An example of this process is humification which involves the decomposition of organic matter by microorganisms producing humus.
  - Humus is the finely divided, partially decomposed organic matter in soils.

FACTORS INFLUENCING SOIL FORMATION:

- **Parent Material:** The rocks over which soils are formed are called parent materials. The parent rock primarily determines the soil's color, chemistry, and texture.
  - For example, ironrich bedrock produces soils rich in iron oxides, whereas limestone forms calciumrich soils.
- **Climate:**
  - **Precipitation:** Water will wash nutrients deeper into the soil and out of reach of plant roots if precipitation is high. Salts will build up in the soil and restrict fertility there is low rainfall.
  - The **temperature** affects the chemical development of soils and the formation of horizons.
- **Organisms:**
  - **Vegetation** is an essential factor in determining soil qualities. For example, some of America's richest soils are developed in the grasslands of the Middle West under the cover of thick grass.

- **Organisms living the soil** include many species like bacteria and burrowing mammals. Earthworms continuously rework the soil by burrowing and bypassing soil.

- **Relief:** soils differ depending on where they are located on the slope. Soil horizons are thick on gentle slopes and thin on steep slopes.
- **Time:** The characteristics and properties of soils require time for development. A soil scientist's rule of thumb is that it takes about 500 years to form 2.5 cm (1 in.) of topsoil.
- **Human Activities:** Human activity influences the physical and chemical nature of the soil. Clearing native vegetation for crops can induce erosion.

MAJOR SOIL TYPES

Zonal Soils:

Soils whose characteristics are dominated by the influence of climate and vegetation are called zonal soils. The main zonal soils of the world are:

- **Tundra Soil:** These soils are developed in the Tundra climatic region of North America and Eurasia. Due to cold, harsh climatic conditions, the organic matter in the soil is poor.
- **Podzol Soil:** Podzol means "ash-soil." It is found in moist, cool climates of midlatitudes. It develops in areas of coniferous forests. It is acidic soil and poor for agriculture.
- **Chernozem:** The word chernozem means black earth. It is fine, black or dark browncoloured soil. It is found in extensive areas of Russia, Ukraine, Kazakhstan, Canada, and the USA. The soil is rich in nutrients and thus fertile.
- **Chestnut Soil:** These soils occur in the arid steppe grass land areas. The grasses provide large humus content to the soil. The soil is dark brown in color. They are found in Turkey, Mongolia, northern China, the United States, and Argentina.
- **Brunizem or Prarie Soil:** It is a dark-colored soil formed in the continental interiors where annual rainfall varies be tween 60-100cm. They develop in grassland areas and are high in humus content. Brunizem is found in eastern Europe and USA, from southern Minnesota to Oklahoma.
- **Seirozem** is a desert soil found in cool, temperate arid regions. They are found in Turkmenistan and parts of the western USA. They are light grey in colour. They have poor humus content.
- **Latozols:** It is a lateritic soil developing in hot and humid areas. They are yellow to red in color and rich in iron, aluminum, and manganese oxides. It has scarce vegetation and poor organic matter. Latozols are found in Amazon and Zaire basin, the East coast of Brazil, Indonesia, eastern Madagascar, Sri Lanka, Myanmar, and Vietnam.

Intrazonal Soils:

These soils have been less influenced by climate and vegetation. They are more influenced by local factors such as poor drainage, terrain, excessive evaporation, or an unusual parent material such as limestone. They have a well defined soil profile.

- **Saline Soils:** Soils with high soluble salts are called saline soils. They occur in areas of high evaporation. These soils are alkaline. Solonchak is a type of slaine soil found in arid regions. Surface salts may be leached away if there is high rainfall, and the saline layer will occur in the B horizon. Such types of soils are called solonetz.
- **Peat Soils:** It is unconsolidated black or dark-brown colored soil. They are formed in waterlogged areas. The soil materials compose of partially decomposed vegetable matter. Such soils are formed in cold, humid climates. Peat is an important source of fuel.
- **Calcareous Soils:** These soils contain a large amount of calcium carbonate. They are formed over limestone rocks. Rendzina is dark greyishbrown calcareous with limestone or dolomite as the parent material.

Azonal soils:

These soils did not have sufficient time to develop. Thus, these soils are young and do not have a well developed soil profile.

- **Mountain soils or Scree soils** are developed on stony, unstable surfaces like scree slopes or glacial moraines. They consist of large rock fragments.
- **Alluvial Soils:** They are formed due to the deposition of sand, silt, and clay. Alluvial soils are intensively cultivated. The lndoGangetic plain, HwangHo, and YnagsteKiang regions of China are covered with alluvial soil.

- **Glacial Soils:** They are deposited by glacial and fluvioglacial processes. They contain tills, sands, and gravel. Glacial soils are poor in organic matter and not suitable for cultivation.
- **Loess soil:** They are formed by windblown dust and silt. They are fine textured and rich in minerals. Loess soil is found in northern China, the Great Plains of North America, parts of Russia and Kazakhstan, and Central Europe.

SOILS IN INDIA

Factors influencing Soil Formation in India

- **Parent Material:** In India, soils have been primarily formed out of ancient crystalline and metamorphic rocks. These include Cuddapah and Vindhyan rocks, Gondwana rocks, Deccan basalts, and Tertiary and Mesozoic sedimentary rocks.
  - The ancient crystalline and metamorphic rocks are the oldest rocks found in Peninsular India. They include granites, gneisses, and schists which are rich in ferromagnetic materials. These rocks, upon weathering, result in the formation of red soils.
  - The Cuddapah and Vindhyan rocks are very old sedimentary rocks. When they were weathered, they formed **calcareous soils**.
  - The much younger Gondwana rocks have resulted in the formation of less mature soils of low fertility.
  - The Decan Trap is composed of basalt. This basalt, when weathered, has led to the formation of dark-colored soils, popularly known as **Regur.**
- **Relief:** The slope of the land influences soil formation to a great extent. Steep slopes hinder soil formation as there is a swift flow of water. There is also high soil erosion on steeper slopes, for example, in the Chambal region.
  - On the other hand, gently sloping land encourages the deposition of silt. The soils are deep and mature in this region. For example, there are deep layers of fertile soil in the Northern Plains.
- **Climate:**
  - In high temperature and heavy rainfall regions, laterite soils are formed.
  - In arid climatic regions of Rajasthan, sandy soils are formed from sandstone and granite. These soils are poor in organic matter.
- **Natural Vegetation:** It affects soil type by adding humus. This humus increases the fertility of the soil. Some of the most forested regions in India have highly fertile soil.

Types of Soil in India

Soil Type	Distribution	Formation	Characteristics	Significance
Alluvial Soil	Most widespread, covering around 40% of the geographical area of India. Primarily found in the northern plains and the river valleys (Indo-Gangetic-Bramhaputra Plains).	Formed due to sand, silt, and clay deposition by rivers.	• Two different alluvial soils are found in the Upper and Middle Ganga Plain. Khadar is the new alluvium. Bhangar is older alluvium. Both Khadar and Bhangar contain calcareous deposits, known as Kankar. • **Texture:** sandy loam to clayey. • rich in potash. • Poor in Phosphorus • **Colour:** light grey to ash grey.	Intensively Cultivated Crops: wheat, rice, jute, tobacco, oilseeds
Black Soil	Found in parts of Madhya Pradesh, Maharashtra, Andhra Pradesh, Gujarat, and some parts of Tamil Nadu	In the Deccan plateau region, they are formed due to weathering of basaltic rocks. In Tamil Nadu, Andhra Pradesh, and Telangana, they are formed out of gneiss and schists.	• Also known as the 'Regur Soil' or the 'Black Cotton Soil'. • Clayey, deep, and impermeable. • Rich in lime, alumina, iron, and magnesium. • Poor in phosphorus, nitrogen and humus. • **Colour:** deep black to grey. The soil derives its black color from the titaniferous magnetite present in the parent material. • **Self ploughing**:They swell and become sticky when wet and shrink when dried. As a result, in the dry season, they develop cracks.	Best suitable for cotton cultivation Other crops:Millets, tobacco, wheat, castor, and sunflower

Soil Type	Distribution	Formation	Characteristics	Significance
Red and Yellow Soil	Jharkhand's Chotonagpur plateau, Odisha, Andhra Pradesh, Telangana, Chhattisgarh, Madhya Pradesh, Karnataka, and western Tamil Nadu.	Formed due to the weathering of crystalline and metamorphic rocks under dry conditions	• **Colour:** Red due to the presence of iron oxides derived from the parent material (granite, gneiss, and schist). • The soils look yellow when they are hydrated • Deficient in nitrogen, lime, humus, phosphoric acid, magnesium, etc. • Rich in potash. • In the uplands, red soils are thin, sandy, and porous. The red soils are dark-colored, fertile, and thick in the lower plains and valleys.	In the uplands, they are suitable only for the cultivation of millets like bajra. In lower plains and valleys, they are used for cultivating cotton, wheat, pulses, tobacco, potatoes, etc.
Laterite Soil	Karnataka, Tamil Nadu, Kerala, Madhya Pradesh, and Assam and Odisha's hilly areas	Formed as a result of intense leaching	• Poor in humus, nitrogen, calcium, and phosphate. • Rich in ferric or oxides of bauxite.	Used for growing cashew trees in Andhra Pradesh, Kerala, and Karnataka. They are widely cut as bricks for use in house construction.
Forest-Mountain Soils	Valley and hill slopes of the Himalayas, western and eastern ghats	Formed by the deposition of organic matter derived from the forest	• Depending on the mountain environment, they vary in structure and texture. They are loamy and silty on valley sides and coarse-grained on the upper slopes. • Rich in humus. • Poor in lime, potash, and phosphorus content.	In peninsular India, they are used for the plantation of tea, coffee, fruits, and spices. In the Himalayan region, wheat, barley, and maize are cultivated.
Arid or Desert Soil	Western Rajasthan (primarily the Thar Desert) and in Punjab and Haryana, where annual rainfall is below 50 cm	Covered by aeolian (wind-borne) sand. This sand is blown from the Indus basin by southwest monsoon winds.	• They are sandy and saline in nature. • They lack moisture and humus. • They are generally red to brown in color. • Lower horizons of the soil have a layer of calcareous deposits. These deposits hinder the infiltration of water. • The phosphate content in the soil is high.	Drought-resistant and salt-tolerant crops like millets and pulses are mostly grown. The soils can be reclaimed through irrigation and can be used for agriculture.
Saline-Alkaline Soil	Occur in arid and semi-arid regions and in waterlogged and swampy areas. They are found in western Gujarat, parts of Haryana, Punjab, deltas of the eastern coast, and Sundarbans of West Bengal.	Overirrigation, salt water intrusion	• They contain a high percentage of sodium, potassium, and magnesium. • They are infertile and not very conducive to vegetative growth. • The soils are also poor in nitrogen and calcium content.	They are not very suitable for agriculture. Legumes and paddy can be cultivated.
Peaty Soil	Southern part of Uttarakhand, the northern part of Bihar, and the coastal areas of West Bengal, Tamil Nadu, and Odisha.	Formed in high humidity and rainfall areas, which promote high vegetative growth.	• The soils are rich in humus and organic matter. • They are heavy and black in color. • They are poor in potash and phosphorus. • They are highly acidic.	Primarily used for the cultivation of rice and jute.

INDIA- NATURAL VEGETATION

Natural vegetation is a plant community that grows naturally over a period of time without human intervention. It is also known as **virgin vegetation.**

Classification of Natural Vegetation

Type	Distribution	Climate	Important Plant Species
Tropical evergreen forests	Western ghats, andaman and nicobar islands, assam	Heavy rainfall more than 250 cm	Rosewood, mahogany, ebony etc
Tropical Semi-Evergreen Forests	Western coast, Assam, lower slopes of the Eastern Himalayas, Orissa, and Andamans	The rainfall is 200-250 cm in a year temperature varies from 24°C to 27°C	White cedar, hollock, and kail
Tropical Dry Evergreen Forests	Visakhapatnam in Andhra Pradesh, Ramanathapuram in Tamil Nadu	the rainfall of 100 cm in a year annual temperature is about 28°C.	neem, jamun and tamarind.
Tropical Moist Deciduous Forests	Himalayas, Jharkhand, West Odisha, and Chhattisgarh,	rainfall between 100-200 cm. Annual temperature of about 27°C,	Bamboos, sal, teak, shisham, sandalwood, Khair, Kusum, Arjun, and mulberry
Tropical Dry Deciduous Forests	North India and southern regions of Deccan Plateau.	less rainfall (70 to 100 cm)	teak, neem, peepal, sal, khair, bel, axle wood, palas, laurel etc
Tropical Thorn Forests	Punjab, Haryana, Rajasthan, Gujarat, Madhya Pradesh, and Uttar Pradesh.	annual rainfall is less than 50 cm (semi-arid regions).	Babul, Palm, Acacia, Kokko, Ber, Neem, Khejri, Palas, etc
Sub-tropical Broad-leaved Hill Forests	Bengal and Assam, Amarkantak, Khasi, Nilgiri, Mahabaleshwar	annual rainfall is 75 cm to 125 cm. average annual temperature is 18°-21°C.	Chestnut, Evergreen oaks, Pines, ash, beech, pines
Sub-tropical Moist Pine Forests	Arunachal Pradesh hilly regions, Manipur Naga Hills, and Khasi Hills.	elevations ranging from 1000 to 2000 metres above sea level	Chir Pine, Oaks and Olives
Sub-tropical Dry Evergreen Forests	western Himalayas	The annual rainfall between 50 and 100 cm.	olive, acacia modesta, and pistacia.
Himalayan Dry Temperate Forests	Ladakh, Lahul, Chamba, Kinnaur, Garhwal, and Sikkim	Precipitation here is low, below 100 cm	Deodar, Chilgoza, oak, maple, ash, parrotia, olive
Himalayan Moist Temperate Forests	Kashmir, Himachal Pradesh, Uttaranchal, Darjeeling, and Sikkim.	Rainfall mostly in the form of snow.	oak, cedar, spruce, maple, walnut, deodar, chestnut
Montane Wet Temperate Forests	eastern Himalayas, Tamil Nadu and Kerala	high rainfall. Moderate temperature in summers but cold in winter.	Oak, Plum, Birch, Deodar, Indian chestnut, magnolia, blue pine, hemlock, chilaune
Alpine and Sub-Alpine Forests	western Himalayas and eastern Himalayas.	the region just below the snowline.	species: Larch, subalpinefir, spruce, rhododendron, douglas fir, pinus flexilis
Littoral and Swamp Forests	The deltas of the Ganga, the Mahanadi, the Krishna, the Godavari and the Kaveri	the rainfall varies from 75 cm to 500 cm depending upon the area	Nipa, Sundari, Keora, Agar, Bhendi, sundarban

Status of Forest Cover in India

According to the **India State of Forest Report 2021**:

- The Total Forest and Tree cover is 24.62% of the country's geographical area.
- The largest forest cover in India is in Madhya Pradesh, followed by Arunachal Pradesh, Chhattisgarh, Odisha, and Maharashtra.
- At the national level, forest cover has increased by 1,540 square kilometers.
- States that have shown a significant gain in forest cover are Andhra Pradesh, Telangana, Odisha, Karnataka, and Jharkhand.

INDIA -MINERAL AND ENERGY RESOURCES

DISTRIBUTION OF MINERAL RESOURCES IN INDIA

Regions	Details
Northwestern plateau Regions:	The minerals in this region are associated with the **Dharwar system of rocks**. This region stretches from Aravallis in Rajasthan to some parts of Gujarat. • Copper and zinc are important minerals found in this region. • Rajasthan is abundant in generating building materials like sandstone, granite, and marble. • Large deposits of gypsum are found in this region. Gujarat is well-known for its reserves of oil and gas. • Also, Rajasthan and Gujarat both have abundant salt reserves.
The South-Western Plateau Region:	This belt covers Karnataka, Goa, some parts of Tamil Nadu, and Kerala. • Abundant metals found in this belt are Bauxite and other ferrous metals. • High-grade iron ore, manganese, and limestone are also found in this belt. Coal deposits are absent in this belt except for Neyveli, where lignite is found. • In Kerala, monazite and thorium deposits are found. • In Goa, iron ore deposits are also found.
The North-Eastern Plateau Region:	Odisha Plateau, West Bengal, Chhotanagpur (Jharkhand), and parts of Chhattisgarh are all included in this belt. It contains many minerals, including coal, iron ore, bauxite, manganese, and mica.
Other Areas/Regions:	Eastern and Western parts of the Himalayan belt have minerals like copper, lead, zinc, cobalt, and tungsten. Assam Valley has mineral oil deposits. Besides, oil resources are also found in off-shore areas near Mumbai Coast (Mumbai High).

FERROUS METALLIC MINERALS

Iron Ore

Distribution in India
Orissa (Highest producer)- Iron ore occurs in a series of hill ranges in Sundergarh, Mayurbhanj. The important mines are Gurumahisani, Sulaipet, Badampahar (Mayurbhaj), Kiruburu (Kendujhar) and Bonai (Sundergarh).
Jharkhand- Important mines such as Noamundi and Gua are located in Poorbi and Pashchimi Singhbhum districts.
Chhattisgarh- The area extends to Durg, Dantewada, and Bailadila. Dalli, and Rajhara in Durg are the important mines of iron ore.
Karnataka Ballari district, Baba Budan hills, and Kudremukh in Chikmagalur district and parts of Shivamogga, Chitradurga, and Tumakuru districts.
Maharashtra: Chandrapur, Bhandara, and Ratnagiri
Telangana: Karimnagar and Warangal district
Andhra Pradesh: Kurnool, Cuddapah, and Anantapur districts

Manganese

Distribution in India
Madhya Pradesh (Highest producer): Balaghat-Chhindwara-Nimar-Mandla and Jhabua districts.
Maharashtra: Manganese is mined in Nagpur, Bhandara and Ratnagiri districts.
Orissa: Bonai, Kendujhar, Sundergarh, Gangpur, Koraput, Kalahandi and Bolangir.
Karnataka: Mines are located in Dharwar, Ballari, Belagavi, North Canara, Chikkmagaluru, Shivamogga, Chitradurg and Tumakuru

Distribution in India
Telangana, Goa, and Jharkhand are other minor producers of manganese.

NON-FERROUS METALLIC MINERALS

Copper

Distribution in India
Madhya Pradesh (Highest producer): Balaghat
Rajasthan: Jhunjhunu and Alwar districts
Jharkhand: Singhbhum district

Bauxite

Distribution
Orissa (Highest producer): The main deposits occur in Kalahandi, Koraput, Sundargarh, Bolangir, and Sambalpur districts.
Gujarat : Bhavanagar, and Jamnagar in Gujarat have the major deposits
Jharkhand : Bauxite reserves are found in extensive areas of Ranchi, Lohardaga, Palamu, and Gumla districts.
Maharashtra : Kolhapur district
Chattisgarh : The Maikala range in Bilaspur, Durg districts, and the Amarkantak plateau regions of Surguja, Raigarh, and Bilaspur
Tamil Nadu : Nilgiri and Salem
Madhya Pradesh : KatniJabalpur area and Balagha

PRECIOUS METALS AND GEMS

Gold

Distribution in India
Karnataka (Highest producer): Hutti Mine in the Raichur district, Kolar Gold Field
Jharkhand: Subarnarekha, Sonanadi
Kerala: PunnaPuzha and the Chaliyar Puzha

Diamond

Distribution in India
Panna belt in madhya Pradesh, Raipur in Chattisgarh, Kurnool and anantapur, Andhra Pradesh

Silver

Distribution in India
Rajasthan (Highest producer): Zawar mines in Udaipur
Jharkhand: Dhanbad district
Andhra Pradesh: Vizag

NON-METALLIC MINERALS

Non-Metallic Mineral	Characteristics	Areas found
Mica	It is a transparent mineral found in igneous rocks. Individual mica crystals can be easily divided into super-thin elastic plates. There are two main types of mica- muscovite and biotite. Mica is a non-conductor of heat and electricity. Mica is mainly used in the electrical/ electronic industries, which can be split into very thin, strong, and flexible sheets.	Andhra Pradesh (Largest Producer),Rajasthan and Karnataka
Limestone	Limestone is a sedimentary rock. It is composed of a calcium carbonate mineral, calcite with a chemical composition of $CaCO_3$. It is used in road bases, railroad ballast, foundation stone, drainfields, concrete aggregate, and other construction uses. Also used in production of cement.	Madhya Pradesh, Rajastha, Andhra Pradesh, Gujarat, Chattisgarh
Dolomite	Dolomite crystals are colorless, white, buff-colored, pinkish, or bluish. Granular dolomite in rocks tends to be light to dark gray, tan, or white. Most common use is in construction, and cement industries	Orissa, Chhattisgarh, Andhra Pradesh, Jharkhand, Rajasthan, and Karnataka
Asbestos	Asbestos is a fibrous mineral. It is widely used in industry due to its physical and chemical properties. Its resistance to heat, wear, alkalis and acids, and its flexibility, amongst other characteristics, makes it suitable material for use.	Andra Pradesh, Rajastan, Bihar, Karnataka, Tamil Nadu and Manipur
Magnesite	Magnesite is a magnesium carbonate mineral with a chemical composition of $MgCO_3$. It is named after the presence of magnesium in its composition. Magnesite usually forms during the alteration of magnesium-rich rocks or carbonate rocks by metamorphism or chemical weathering.	Uttarakhand, Tamil Nadu and Rajasthan. Tamil Nadu
Kyanite	Kyanite is a mineral found mainly in metamorphic rocks. It most often forms from the high-pressure alteration of clay minerals during the metamorphism of sedimentary rocks. It is found in the schists and gneisses of regionally metamorphosed areas and less often in quartzite or eclogite.	Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Meghalaya, Rajasthan and West Bengal
Sillimanite	Sillimanite (Al_2SiO_5) is a naturally occurring mineral found in many parts of the world. This mineral is mainly found in metamorphosed rocks and its formation is dependent on temperature and pressure. It is an economically important mineral in the industrial preparation of bricks, cement, ceramics, jewelry	Odisha, Tamil Nadu , Uttar Pradesh, Andhra Pradesh, Kerala and Assam.
Graphite	It is a greyish black, opaque substance. It is Lighter than diamond, and is smooth and slippery to touch. It is a good conductor of electricity and is a good conductor of heat.	Arunachal Pradesh, Jammu & Kashmir, Jharkhand, Tamil Nadu, and Odisha
Apatite and Rock phosphate	Apatite is the most abundant crystalline phosphate mineral found as an accessory mineral in practically all kinds of igneous rocks. Rock phosphates or phosphites are sedimentary phosphate deposits comprising fine grained mixture of various calcium phosphate	Jharkhand, Rajasthan, Madhya Pradesh, and then Uttar Pradesh & Uttarakhand
Gypsum	Gypsum is an evaporite mineral most commonly found in layered sedimentary deposits in association with halite, anhydrite, sulfur, calcite, and dolomite. gypsum contains two waters. Gypsum is the most common sulfate mineral.	Rajasthan which contributes about 99% of the total production; the remaining 1% is contributed by Jammu and Kashmir and Gujarat.
Potash	Potassium is the 7th most abundant element on earth, making up 2.4% of the earth's crust, by weight. Potassium, found in most soils, is an element that is essential for plant growth.	Sidhi district of Madhya Pradesh, Sonbhadra district of Uttar Pradesh, Kaimur district of Bihar and Sawai Madhopur and Karauli districts of Rajasthan.

Non-Metallic Mineral	Characteristics	Areas found
Kaolin	Kaolin appears as odorless white to yellowish or grayish powder. Kaolin is insoluble in water but darkens and develops an earthy odor when wet.	Kerala and Rajasthan carried out exploration for kaolin in the districts of Kannur and Kollam,Kerala state& Bikaner district of Rajasthan
Perlite	Hydrated, amorphous, volcanic glass of rhyolitic composition with pearly luster	Its found only in Gujarat at Patanav village
Wollastonite	It is composed of calcium and silica. Chemical formulais CaSiO3	It is found in Pali, sirohi, udaipur districts in Rajasthan, Dharmapuri and Tirunelveli in Tamil Nadu

ATOMIC MINERALS IN INDIA

- **Uranium**
  - The first uranium deposit in India was discovered in 1951 from Jaduguda in Jharkhand. The other major uranium deposits have been found in Chhattisgarh and Madhya Pradesh. Some Uranium is found in the copper mines of Udaipur in Rajasthan.
- **Thorium**
  - Kerala, Jharkhand, Bihar, Tami Nadu and Rajasthan are the main producers of thorium in India. Thorium is derived from monazite. It contains 10% thoria and 0.3% Urania.
- **Beryllium**
  - It is used as a moderator in nuclear reactors for atomic power generation. In India, beryllium is extracted from beryl ore. Large deposits are found in Andhra Pradesh, Rajasthan, and Bihar.
- **Lithium**
  - It is a light metal that is found in lepidolite and spodumene. Lepidolite is widely distributed in mica belts of Jharkhand, Madhya Pradesh, Rajasthan and in some parts of Chattisgarh.

RARE EARTH ELEMENTS

The International Union of Pure and Applied Chemistry (IUPAC) defines rare earth minerals as a set of seventeen chemical elements in the periodic table. These metals have similar properties.

- Thulium and lutetium are the two rare earth elements with the lowest abundance.
- Cerium, yttrium, lanthanum, and neodymium are the most plentiful rare earth elements.

Rare Earth Element	Present Applications
Yttrium	Phosphors, ceramics, metal alloys
Lanthanum	Batteries, catalysts for petroleum refining
Cerium	Autocatalysts, Chemical Catalyst, glass polishing, metal alloys
Praseodymium	High power magnets, yellow ceramic pigment
Neodymium	High power magnets
Promethium	Beta radiation source
Samarium	High temperature magnets,
Europium	fluorescent lighting
Gadolinium	Magnetic resonance imaging contrast agent, nuclear reactor rods
Terbium	Phosphors for lighting, high power high-temperature magnets
Dysprosium	High power high-temperature magnets, lasers
Holmium	Highest power magnets in existence

Rare Earth Element	Present Applications
Erbium	Lasers, glass colorant
Thulium	Ceramic magnetic materials which are still under development
Ytterbium	Fibre optic technology, solar panels
Lutetium	PET scanners

Trade and Production

China has one-third of the world's known rare earth element reserves. It controls 90% of the worldwide REE market.

India: Major rare earth minerals found in India are llmenite, sillimanite, garnet, zircon, monazite, and rutile. These minerals are collectively known as Beach sand minerals. (BSM) The Rare Earth Division of Indian Rare Earths Ltd. (under the Department of Atomic Energy) and Kerala Minerals and Metals Ltd. are the two government-owned REE producers (KMML).

ENERGY RESOURCES

INDIA'S ENERGY MIX

In 2020, coal continued to supply most (44%) of India's total energy consumption. Petroleum and other liquids accounted for 24% of total energy consumption, and traditional biomass and waste accounted for 21%. Other renewable fuel sources made up a small but growing portion of primary energy consumption (1%).

CONVENTIONAL SOURCES OF ENERGY

Coal

Types of Coal

	Anthracite	Bituminous	Lignite	Peat
Carbon content	80-95%	60-80%	40-55%	Less than 40%
Quality	Best quality		Lower grade	Lowest
Moisture content	Little moisture content	Higher than anthracite	High- over 35%	Lot of moisture
Volatile material	Very little	15-40%	Higher	highest
Heat content	Very high	High	low	Lowest
Features	• Hard • Compact • Deep black • Semi-metallic lustre	• Most widely used • Dense • Compact • Black • Used for production of coke	• Black to Dark Brown • Lot of smoke on heating	• Burns like wood • Less heat • Lot of smoke is emited • Leaves a lot of ash
Distribution	In India- only in Jammu & Kashmir- very small quantity	Jharkhand Odisha West Bengal Madhya Pradesh Chhattisgarh	Rajasthan Neyveli in Tamil Nadu Karewa of Jammu & Kashmir	Rajasthan, Lakhimpur (Assam) Tamil Nadu

Distribution of Coal in India

India is the second-largest coal producer in the world after China. Around 75% of the total coal production of coal is done by four states- Chhattisgarh, Odisha, Jharkhand & Madhya Pradesh. In 2020-21, Chhattisgarh and Odisha accounted for 43% of the country's total coal produced

Gondwana Coal	
Chhattisgarh	• Most of the coalfields in Northern part • Korba Coalfields • Birampur Coalfields • Hasdo Arand Coalfields • Lakhanpur • Taptapani-Ramkota
Jharkhand	• Jharia Coalfield- storehouse of the best metallurgical coal in the country • Bokaro Coalfield • Ramgarh Coalfield • Rajmahal Coalfields
Odisha	• Talcher coalfield- Thermal power generation • Rampur- Himgir coalfields
Madhya Pradesh-	• Singrauli Coalfields • Umaria Coalfields • Pench- Kanha- Tawa
West Bengal	• Raniganj- first coal mine of India • Dalingkot coalfield
Telangana & Andhra Pradesh	• Singareni coalfield
Tertiary Coal	
Assam	• Makum coalfield • Nazira coalfield
Meghalaya	• Garo-Khasi Jaintia hills
Arunachal Pradesh	• Namchik Namrup coalfield
Lignite	
Tamil Nadu	90% of reserves are of Lignite Neyveli Lignite fields
Gujarat	Kacchh District
Rajasthan	Bikaner district

Petroleum

Distribution in India

On-shore Oil fields in India-	
Assam	1. Digboi Field (Oldest oil field of India) 2. Naharkatiya Field 3. Moran-Hugrijan Field
Arunanchal Pradesh	Manabhum Field
Rajasthan	1. Barmer District 2. Mangala oil field 3. Saraswati & Rajeshwari

On-shore Oil fields in India-	
Gujarat	1. Ankleshwar 2. Lunej Field 3. Ahmedabad Field
Offshore Oilfields	
	Mumbai High
	Bassein
	Aliabet
	Krishna Godavari Basin
	Kaveri Delta

Natural Gas

Distribution in India

In India, total natural gas production in 2018-19 was about 90.1 million metric standard cubic meters per day. Offshore natural gas production accounts for more than 67% of the total natural gas production.Apart from that, onshore natural gas production is carried out in many states. Another form of natural gas production in India is from Coal Bed Methane held in Coalfields.

Offshore areas-	1. Cauvery Offshore 2. Khambat Basin 3. South Bassein Gas field 4. Mumbai offshore 5. Krishna- Godavari offshore
Onshore areas-	Assam (largest onshore producer)
	Rajasthan
	Tripura
	Tamil Nadu
	Gujarat
Coal Bed Methane	West Bengal (Raniganj)
	Jharkhand
	Madhya Pradesh

Hydroelectricity

Distribution in India

The hydropower potential of India is around 145 GW, and by the end of March 2022, the hydroelectricity installed capacity was about 46.2 GW. It accounts for a mere 11.7% of total electricity generation.

State Name	Project Name	River Name
Andhra Pradesh & Telangana	Nagarjunasagar Hydroelectric project- World's largest Masonry Dam.	Krishna
Andhra Pradesh & Telangana	Srisailam Hydroelectric project	Krishna
Uttarakhand	Tehri Dam- it's the highest dam in India	Bhagirathi
Himachal Pradesh	Bhakra Nangal Hydroelectric project	Satluj
Kerala	Idukki Hydroelectric project	Periyar
Gujarat	Sardar Sarovar Hydroelectric project	Narmada

State Name	Project Name	River Name
Karnataka	ShivaSamudra Hydroelectric project	Kaveri
Sikkim	Teesta Hydroelectric project	Teesta
Maharashtra	Koyna Hydroelectric project- largest hydel power project in India	Koyna
Jammu & Kashmir	Salal Hydroelectric project	Chenab
Punjab	Ranjit Singh Sagar Hydroelectric project	Ravi
Odisha	Hirakud Hydroelectric project- World's longest earthen Dam	Mahanadi
Madhya Pradesh	Indira Sagar Hydroelectric project	Narmada
Uttar Pradesh	Rihand Hydroelectric project	Rihand
Rajasthan	Rana Pratap Sagar Hydroelectric project	Chambal
Tamil Nadu	Mettur Dam	Kaveri

NON-CONVENTIONAL SOURCES OF ENERGY

Shale Gas

Distribution:

India has got technically recoverable shale gas of 96 trillion cubic feet. The recoverable reserves are identified in Cambay, Krishna – Godavari, Cauvery, Damodar Valley, Upper Assam, Pranahita – Godavari, Rajasthan, and Vindhya Basins.

Nuclear Energy

Distribution

Nuclear Power Plants operating	Nuclear power plants which are planned	Nuclear power plants under construction
• Kaiga- Karnataka • Narora- Uttar Pradesh • Kudankulam- TamilNadu • Kalpakkam -TamilNadu • Kakrapar-Gujarat • Rawatbhata – Rajasthan • Tarapur - Maharashtra	• Jaitapur - Maharashtra • Kovvada - Andhra Pradesh • Haripur - West Bengal • Gorakhpur - Haryana • Bhimpur - Madhya Pradesh • Mithi Virdi - Gujarat • Mahi Banswara - rajasthan • Kaiga- Karnataka • Chutka - Madhya Pradesh • Tarapur - Maharashtra	• Kudankulam 3&4- TamilNadu • Kalpakkam PFBR-TamilNadu • Kakrapar 3&4-Gujarat • Rawatbhata – Rajasthan

Solar Energy

Distribution

- Rajasthan has topped in installed capacity of solar energy in India with 7737.95MW as per the 2021 state-wise report released by the Ministry of New and Renewable Energy (MNRE).
- Karnataka comes second with 7469.01 MW, followed by Gujarat 5708MW, Tamil Nadu 4675MW and Andhra Pradesh 4380MW.

Wind Energy

Distribution

Seven states viz. Maharashtra, Gujarat, Tamil Nadu, Karnataka, Rajasthan, Andhra Pradesh and Madhya Pradesh are leading in promoting wind power generation in India.

Tidal Energy

- Tidal energy is still in Research & Development (R&D) phase and has not been implemented on a commercial scale in India.
- The potential areas with low/medium tidal wave strength are in the Gulf of Khambat, Gulf of Kutch & southern regions in Gujarat, Palk Bay- Mannar Channel in Tamil Nadu, and Hoogly river, South Haldia & Sunderbans in West Bengal.

Biogas

Distribution

The state of Maharashtra had the largest number of biogas plants in India, with over 931 thousand plants as of March 2021. Karnataka ranked second with nearly 513 thousand plants. India had a total of over five million biogas plants.

Geothermal Energy

Distribution

Geothermal resources in India have been mapped by the Geological Survey of India (GSI). A broad estimate suggests that there could be 10 GW of geothermal power potential per the Ministry of New and Renewable Energy (MNRE) in 2021.

The major areas for geothermal energy in India are

- **The Himalayas:** J&K, HP, and Sikkim; PUGA and Chhumathang hot spring in J&K and Manikaran & Beas valley in HP. Satluj and spiti valley.
- **Sohana:** Haryana, Rajasthan.
- **Son-Narmada-Tapi (SONATA):** MP, Chhattisgarh and Damodar valley basin in Jharkhand; Tattapani spring in Chhattisgarh.
- **Cambay:** Lasundra, Tuwa, and Chhabsar, mainly in Gujarat and some parts of Rajasthan
- **Godavari:** AP
- **Mahanadi:** Orissa, Taptapani Spring in Orissa.
- Andaman-Nicobar region
- Salbardi region, Unkeshwar and Konkan geothermal provinces in Maharashtra
- Tapoban geothermal field, Chamoli, Uttarakhand, and Alaknanda Valley

INDIAN INDUSTRIES

The manufacturing Sector refers to the Industries of transforming goods, the transformational process can be physical, chemical or mechanical. This sector majorly includes the automotive companies, chemical industry, metal fabrications, pulp and paper industries, pharmacy industry etc

FACTORS AFFECTING THE LOCATION OF INDUSTRIES

- **Availability of raw materials-** The availability of raw materials, of suitable quality and quantity and in feasible regions, is a prime requirement for any industry. The size of raw-material deposits determines the scale of production and Industrial location.
- **Power resources and water-** Availability of electric power supply and water over wider areas favours fulfilling manufacturing requiremnts and the mobility of labourers.
- **Favourable climate-** Industrial development is difficult in extremely hot, humid, dry or cold climatic regions. Favourable climate plays an important role in the establishment of industries at a place.
- **Labour-** Cheap and skilled labour is essential for an industrial location. Availability of labours on a frequent basis helps in the growth and rapid production.
- **Availability of market-** If the goods produced can not be sold in the market, it will result into the loss for the industry. Markets should be situated close to the industry, as long distance to a market place will result in higher transportational charges.

- **Transport facilities-** Transport facilities, influence the location of industry. Transportation with its three modes, i.e., water, road, and rail collectively play an important role. Transport junctions are one of the most favourable industrial places.
- **Finance-** The availability of capital at cheap rates of interest helps in rapid growth of industries.

Footloose industry:
The footloose industry is one, which does not have a strong locational preference as the input resources and output markets can be found in many places. As these industries are prone to location, hence they are called footloose.
Sunrise industry:
A sunrise industry is one that is new or relatively new, it grows fast.This type of Industry shows potential for substantial and rapid growth. Examples: food processing industry, petrochemical industry.
Weighloose Industries:
These are those industries, in which raw material is bulky, but the finished goods are very light. Weight Loose industries are located near raw materials. For eg. Sugar industries are located near Sugarcane areas.

AGRO-BASED INDUSTRIES

Cotton Industry

Cotton is fluffy, soft that grows in a protective case called a **boll.** The cotton fiber is spun into yarn or thread to make it into a durable textile.

Locational Factors:

The following are the favourable location factors of the cotton industry:

- Availability of raw cotton
- Availability of market facilities
- Transport facilities
- Accessibility of port
- Labour
- Moist climate
- Skilled and semi-skilled labor

Distribution of the industry in India:

Some other major cotton-producing regions in India are:

- **Maharashtra**- Jalgaon, Kolhapur, Pune, Sangli, Sholapur, and Nagpur.
  Maharashtra is the leading producer of cotton textiles in India. Mumbai is regarded as the "**Cottonpolis of India**".
- **Gujarat**: Ahmedabad, Vadodara, Bharuch, Surat, Rajkot, Porbandar, Bhavnagar, and Nadiad.
  Gujarat second largest producer of cotton yarn and also owns the second-largest number of mills in India.
- **Tamil Nadu**: Coimbatore, Tirupur, Madurai, Salem, Pollachi, Chennai, Tuticorin, and Tirunelvelli.
  Tamil Nadu owns the largest number of mills in India.
- **Andhra Pradesh**: Guntur, Vijayawada, Warangal, Anantapur, and Venkatagiri.
- **Karnataka**: Belgaum, Bengaluru, Mysore, Bellary, Hassan, and Mangalore.
- **Uttar Pradesh**: Kanpur, Moradabad, Etawah, Agra, Meerut, and Hathras.
- **Madhya Pradesh**: Gwalior, Jabalpur, Indore, Ujjain, Bhopal, and Dewas.
- **Rajasthan**: Udaipur, Bhilawada, Kota, Bhavanimandi, and Jaipur.
- **West Bengal**: Howrah, Kolkata, Murshidabad, Serampore, Saikia, and Shyamnagar.

Jute Industry

Jute is a soft, long, and shiny fiber that is used to produce long threads. Jute is a natural fiber that is affordable and cheap next to cotton fiber. Jute is also called golden fiber for its color.

Locational Factors:

- Jute plants require plain alluvial soil and standing water.
- It requires a warm and wet climate to grow and that is provided by the monsoon season prevailing in the Indian subcontinent.
- The temperatures vary from 20 to 40 degrees Celsius with a relative humidity of 70 to 80 percent.

Distribution of the industry in India:

- **West bengal:** Mills near Hugli River Basin.
- **Andhra Pradesh:** Guntur, Visakhapatnam, Ongle, and Eburu
- **Bihar:** Darbhanga, Samastipur, and Gaya
- **Chattisgarh:** Raigarh **Odisha:** Cuttack

Sugar Industry

The sugar industry is the **second** largest agro-based industry in India. after the textile industry. After Brazil, India is the **second-largest producer** of sugar in the world. The main by-products of the sugarcane industry are **bagasse**, **molasses,** and **press mud.**

Locational factors:

Factors affecting the location of the sugar industry are as follows.

- **Raw material**: Sugar cane are highly perishable. This makes the sugar industry to locate near the source of raw material. Sugar industry is a **weight losing industry**, therefore the industry tends to locate near the sugar cane farms.
- **Climate**: In cold climate the sucrose content in sugarcane donot dry easily, therefore, they require longer crushing periods. A warmer climate is suitable for sugarcane and this proves the increased sugarcane production in southern and western India .
- **Soil**: Black soil with high water retentation capacity is good for sugar cane growth. Hence, sugar industries are more concentrated in western India which has black lava soil.
- **Energy**: Bagasse is used as fuel in sugar industries to power sugar mills

Distribution of the industry in India:

- **Uttar Pradesh:** Saharanpur, Bijnor, Meerut, Muzaffarnagar, and Moradabad, Basti, Gorakhpur, Deoria, and Gonda.
- **Bihar:** Saran, Darbhanga, Muzaffarpur, and Champaran.
- **Maharashtra:** Pune, Satara, Sholapur, and Kolhapur.
- **Punjab:** Dhuri and Phagwara.
- **Karnataka:** Shimoga, Mandya, and Munirabad.
- **Tamil Nadu:** Coimbatore, Pugulur, Nalikipuram, and Pandyarajpur.
- **Andhra Pradesh:** West Godavari to East Godavari, Visakhapatnam, and Chittoor.
- **Telangana**: Medak and Nizamabad.
- **Odisha:** Rayagada and Bargarh
- **Madhya Pradesh:** Sihor

The reasons for the concentration of sugar industries in Uttar Pradesh and Bihar:

- Availability of fertile alluvial soil that is rich in potash and lime which helps the growth of sugarcane.
- The leveled topography of the land is suitable for irrigation.
- Availability of abundant water for processing and washing.
- Availability of cheap labor.
- Better transportation facilities coupled with the presence of densely populated markets in the surrounding regions.

Tea Industry

India is the largest consumer of tea in the world. Almost 3/4th of the total tea production of the country is consumed locally. Tea is grown in 16 states in India. Assam, West Bengal, Tamil Nadu, and Kerala account for about 95 per cent of total tea production.

Locational factors:

- Rainfall: 1500mm
- Temperature: it has to be less than 15 degrees C
- Tropical and subtropical climate is required. The soil needs to be rich in Humus and organic matter. It has to be well drained and deep and fertile.
- The tea crop requires a warm and moist free climate throughout the year.

Distribution of the industry in India:

India is the largest producer and consumer of black tea in the world. Tea is grown in 16 states in India. Assam, West Bengal, Tamil Nadu, and Kerala account for about 95 per cent of total tea production.

- **Assam:** Darrang, Goalpara, Kamrup, Lakhimpur , Dibrugarh, Nowgong, Sibsagar, Cachar , Karbi Anglong , North Cachar
- **West Bengal:** Darjeeling, Terai (west Dinajpur), Doors (Cooch Bihar).
- **Tamil Nadu:** Kanyakumari, Tirunelveli, Madurai, Coimbatore , Nilgiris
- **Kerala:** Cannanore, Palghat, Kozhikode, Malappuram, Trichur, Trivandrum, Quilon, Kottayam, Ernakulam, Idukki, Wynaad
- **Karnataka:** Chikmagalur, Coorg, Hassan

The Largest state with area under Tea Plantations in India is Assam.

Coffee Industry

Coffee is the second most consumed beverage crop in India after Tea. India is the third-largest producer as well as exporter of coffee in Asia. It is the sixth-largest producer and fifth-largest exporter of coffee in the world. Almost 80% of Indian coffee is exported.

Locational Factors for coffee cultivation:

- Coffee plantation requires hot and humid climatic temperatures.
- The temperature for coffee plantation varies between 15degrees C to 25 Degrees C
- Rainfall for the plantation varies between 150cm to 250cm.
- Snowfall, Frost, High temperatures are harmful for the coffee crop.
- Strong sun rays, and south-west monsoon winds can impact the crops.
- Soil having a good amount of humus and minerals containing iron and calcium are good for coffee cultivation.

Distribution of the industry in India:

India produces about 2.5% of the world's coffee. The restricted agro-climatic conditions have forced the coffee plantations to confine themselves to small areas in south India comprising hill areas around Nilgiris. Almost the entire production is shared by three states namely Karnataka, Kerala and Tamil Nadu .

- **Karnataka:** Kodagu, Chikmagalur, Shimoga, Hassan and Mysore.
  - Karnataka is the largest producer accounting for about 70% per cent of total coffee production and 60% of the area under coffee in India.
- **Kerala:** Kozhikode, Wayanad, Malappuram, Kollam, Kannur and Palakkad are the chief producing districts.
  - Kerala is the second largest producer of coffee.
- **Tamil Nadu:** Nilgiri district, Madurai, Tirunelveli, Salem and Coimbatore.
  - Tamil Nadu is the third largest producer.

Food Processing Industry

Food processing refers to the transformation of raw edible ingredients into food items. This may be direct manufacturing of food or value addition to an existing food. The objective of food processing is to enhance the shelf-life of food products and value addition to existing food items.

Distribution

- Most of the food processing industries are concentrated in the coastal states-Andhra Pradesh, Maharashtra, Karnataka, Kerala, Gujarat, and West Bengal.
- Punjab and Uttar Pradesh are some of the non-coastal states, which have major food processing industries.
- Maharashtra is the leading state in India as far as food processing is concerned.

FOREST-BASED INDUSTRIES

Paper Industry

Locational Factors:

Paper industries are located near raw material sources, as they are **weight losing industries.** The weight losing industries refer to the industries in which the amount of raw material required is more than the amount of finished product. In order to save the transportation cost of the raw materials, the weight losing industries tend to locate near the sources of raw materials.

Distribution:

- **West Bengal**: Titanagar, Kolkata, Kakinara, and Naihatti.
- **Maharashtra**: Mumbai, Pune, and Ballarpur.
- **Andhra Pradesh**: Rajahmundry.
- **Madhya Pradesh**: Indore, Bhopal, and Sehore.
- **Karnataka**: Belagola, and Shimoga.
- **Odisha**.

West Bengal remains one of the major paper-producing states because of locational advantages. Cheap labor is readily available in the state. Bamboo as raw material is readily available from Assam, Bihar, and Odisha. While some industries use bamboo as raw material. Districts like Karnataka's Belagola and Shimoga are major paper-producing industries that use bagasse as the raw material.

HEAVY ENGINEERING INDUSTRIES

Automobile Industry

Distribution:

The automobile sector in India is dependent on the availability of skilled labor at a cheap cost, low cost of steel, and extensive research and development. The automobile industry depends on the finished products of the steel and aluminum industry as raw materials to produce automobile vehicles. Hence, the automobile industries are mostly located near the iron and steel industries.

1. **Andhra Pradesh:** Penukonda, Sri City, Krishna district
2. **Gujarat:** Sanand, Rajkot, Ahmedabad
3. **Haryana:** Manesar, Bawal, Gurugaon, Faridabad
4. **Himachal Pradesh:** Amb, Jamshedpur, Nalagarah
5. **Jharkhand:** Jamshedpur
6. **Karnataka:** Mysore, Bengaluru, Bidadi, Dahrwad
7. **Madhya Pradesh:** Pithampur, Jabalpur, Mandideep, Dewas
8. **Maharashtra:** Pune, Aurangabad

MINERAL BASED INDUSTRIES

Iron and Steel Industry

The first industrial unit that was able to produce pig iron successfully in India came up at **Kulti** in **1874**. In **1907**, the Tatas set up a plant in **Sakchi** (now known as **Jamshedpur**) called **TISCO** (Tata Iron and Steel Company). It is the oldest iron and steel company in India. In **1919** the **IISCO** (Indian Iron and Steel Company) was set up in **Burnpur**.

Plant	Locational Factors
TISCO (Tata Iron and Steel Company)- Jamshedpur	**Iron ore:** The raw material iron ore (Haematite) is imported from Gurumahisani mines in the Mayurbhanj district of Odisha and the Noamundi mines of Singhbhum district of Odisha. **Coal:** Coal is brought from the nearby Jharia mines in Jharkhand and Raniganj mines in West Bengal. **Manganese:** Manganese is supplied from the Joda mines of the Kedujhar district in Odisha. **Limestone:** Limestone is supplied from the Sundergarh district of Odisha. **Water:** Water is derived from the nearby Subernarekha River. **Cheap labor:** Cheap labor is available from Jharkhand and Odisha. **Transportation facilities:** The Jamshedpur Steel plant is facilitated by nearness to the port (Paradwip port, Odisha) and National Highway -6 (Mumbai-Kolkata).
IISCO (Indian Iron and Steel Company)- Kulti-Hirapur-Burnpur	**Iron ore:** The iron ore is obtained from Pansiraburu and Gua iron mines in the Singbhum district of Jharkhand. **Coal:** Coal is procured from Raniganj coal mines while the coking coal is obtained from the Jharia mines of Jharkhand. **Limestone and Manganese:** Limestone and Manganese are obtained from Gangapur in Odisha. **Water:** The water is obtained from the Damodar River and the hydro-power electricity is obtained from the Damodar Valley Corporation (DVC) **Transportation:** The Delhi-Kolkata highway and the port facilities of Kolkata help in the movement of the finished goods
VISL (Visveswaraiya Iron and Steel Limited)- Bhadravati	**Iron ore:** The iron ore is procured from Kemangundi in Bababudan hills located south of Bhadravati River. **Hydro-electric power:** Initially charcoal obtained from the forests of Western Ghats was used instead of coal. Now the electricity from the Mahatma Gandhi and the Sharavati hydroelectric power centers are used. **Limestone:** Limestone is obtained from Vandigudda. **Manganese:** Manganese is obtained from Shimoga and Chitradurga. **Water:** Bhadra River supplies the required water for the plant.
Rourkela Steel Plant-Odisha	**Iron ore:** The iron ore is procured from the Mayurbhanj, Keonjhar, Barsuna, and Bonai mines located in the north of Odisha. **Coal:** Coal and coking coal is obtained from Bokaro, Talcher, Jharia, and Korba coalfields. **Manganese:** The Manganese is procured from Biramitrapur in the Sundergarh district of Odisha. **Limestone:** Limestone is obtained from Gangapur. **Electricity:** The Hirakud project supplies required electricity to the Rourkela steel plant. **Water:** The Rourkela Steel Plant is set up on the banks of the Brahmani River (near the confluence of the Sankha and Koel rivers). The water supplied from the water storage dams are constructed across the rivers Sankha and Brahmani. **Transportation:** The transportation facilities are provided by the Kolkata-Bombay railway line and the port of Vishakhapatnam provides the sea outlets.
Bhilai Steel Plant-Chhattisgarh	**Iron ore:** The iron ore is procured from Dhalli-Rajhara iron mines. **Coal:** Coal is obtained from Jharia, Raniganj, and Korba coalfields. **Manganese:** The Manganese is procured from Balaghat mines in Madhya Pradesh and Bhandara mines in Maharashtra. **Limestone:** Limestone is obtained from Nandini mines located north of Bhilai. **Electricity:** The Korba Thermal Power Station supplies electricity. **Water:** The water is supplied from the Tendula canal. **Transportation:** The transportation facilities are provided by the Kolkata-Bombay railway line. **Cheap Labour:** The cheap labor required for the plant is readily available from Maharashtra, Bihar, Madhya Pradesh, and Chhattisgarh.
Durgapur Steel Plant-Bardhaman	**Iron ore:** The iron ore is procured from Keonjhar mines in Odisha and Singhbhum mines in Jharkhand. **Coal:** Coal is obtained from Jharia, and Raniganj coalfields. **Manganese:** The Manganese is procured from Barbil and Bonai mines in Odisha. **Limestone:** Limestone is obtained from Birmitrapur in Odisha. **Water:** The water is supplied from the Damodar River. **Transportation:** The transportation facilities are provided by the Kolkata-Bombay railway line and Kolkata port. **Cheap Labour:** The cheap labor required for the plant is readily available from Bihar, West Bengal, and Odisha.

Plant	Locational Factors
Bokaro Steel Plant-Jharkhand	**Iron ore:** The iron ore is procured from Kiriburu mines, Noamudi mines, and Gua mines in Jharkhand. **Coal:** Coal is obtained from Jharia and Bokaro coal mines. **Manganese:** The Manganese is procured from Hiri mines in Chhattisgarh. **Limestone:** Limestone is obtained from Daltonganj and Latehar in the state of Jharkhand. **Water:** The steel plant is located near the confluence of the rivers of Damodar and Bokaro in the Giridih district of Jharkhand. The water is supplied from Tenughat Dam which is located on the river Damodar. **Transportation:** The transportation facilities are provided by excellent road and rail routes. **Cheap Labour:** The cheap labor required for the plant is readily available from Bihar, Jharkhand, Madhya Pradesh, and Odisha.
Salem Steel Plant-Tamil Nadu	**Iron ore:** The iron ore is procured from Salem mines. **Coal:** Coal is obtained from coal mines in Neyveli located in Tamil Nadu. **Manganese:** The Manganese is procured from Tumkur in Karnataka. **Electricity:** The electricity is supplied by the Metur hydroelectric power center located on river Cauvery. **Water:** The water is supplied from the river Cauvery. **Transportation:** The transportation facilities are provided by excellent road and rail routes and the port of Chennai.

Cement Industry

India is the second largest cement producer in the world and accounted for over 7% of the global installed capacity. India's overall cement production capacity was nearly 545 million tonnes (MT) in FY22.

Locational Factors:

- Manufacturing of cement requires low, heavy value and weight loose materials. It is primarily a raw material oriented industry.
- The main raw-material of the cement industry is Limestone. It comprises 60-65% of the total product. On an average 1.5 tonnes of limestone are required to produce one tonne of cement. Hence, mostly the location of a cement plant is dependent upon limestone deposits.

Distribution of Cement Industry:

1. **Tamil Nadu:** Durg, Shankar, Pulpur, Aaila, Dalmiapuram, Madurai, Alugang etc.
2. **Madhya Pradesh:**– Jamul, Satna, Ankle Tara, Banyor, Neemuch, Maihar, Kaisun, Gopal Nagar, Gwalior, Katni and Damoh etc.
3. **Andhra Pradesh:** Machraila, Mangalgiri, Panyam, Krishna, Vijayanagar, Tandur, Mancherial, Yerragutla, Bugnipali, Kistrina, Perampalli, Nalgonda, Hyderabad, Adilabad etc.
4. **Rajasthan:** Lakheri, Udaipur, Nimbahera, Chittorgarh, Beawar etc.
5. **Gujarat:** – Sikka, Okhla Mandal, Ahmedabad, Porbandar, Dwarka, Ranavab etc.
6. **Karnataka:** – Bagalkot, Bari, Bhadrawati, Bengaluru, Kurkanta, Shahbad, Aamsandra, Bijapur, Gulbarga, Tulkur etc.
7. **Jharkhand:** – Sindri, Khelari, Japla, Dalmia Nagar, Chaibasa, Banjari, Kalyanpur etc.
8. **Uttar Pradesh:** Churk, Chopan and Chunar are the new major cement producing districts.

CHEMICAL-BASED INDUSTRIES

Fertilizer Industry

India is ranked 2nd in the production of nitrogenous fertilizers and 3rd in phosphatic fertilizers.

Distribution:

1. **Gujarat and Maharashtra:** Important centers are Vadodara, Kalol, Ahmedabad, Kandla and Trombay
2. **Chotanagpur Plateau region:** Jamshedpur, Rourkela, Durgapur, Burnpur, Sindri, Bhilai, etc, Bhilai, Vizag
3. **Tamil Nadu Region:** Coimbatore, Neyveli, Alwaye (Kerala), Kochi (Kerala), Tuticorin, Ennore.

4. **Uttar Pradesh region:** Jagdishpur, Gorakhpur, Aonla, Shahjahanpur, Babrala etc.
5. **North west region:** Bhatinda, Nangal (Punjab), Panipat (Haryana) and Delhi.

Petrochemical Industry

Petrochemicals constitute the major portion of the organic chemical industry. Petrochemicals are the organic chemicals that are drawn from crude petroleum in the refining process. The chemicals are mostly used for producing synthetic rubber, insecticides, synthetic fiber, drugs, pharmaceuticals, and plastic. The petrochemical industry has been sub-grouped into the **polymer, synthetic fibers, elastomers,** etc**.**

Major locations in India that are concentrated in petrochemical industries are **Auraiya (Uttar Pradesh); Jamnagar, Gandhar, Hazira (Gujarat); Ratnagiri (Maharashtra); Haldia (West Bengal), and Vishakhapatnam (Andhra Pradesh)**. Most of the petrochemical industries are found near the refineries.

COTTAGE INDUSTRIES

The cottage industry are small and mostly family-run enterprises where the profits are majorly used to meet the daily needs of the households. This is the reason why it is also known as a small-scale industry.

Distribution of major cottage industries

The major cottage industries in India are cotton weaving, carpet making, silk weaving, leather industry, metal handicrafts, and small food processing industry.

- **Cotton weaving:** The cotton industry is majorly concentrated in Maharashtra, Tamil Nadu, and Gujarat.
- **Silk weaving:** The major silk production is in Karnataka and holds about 70% of the total silk weaving industries. Mulberry, Tassore, Muga, and Eri are the types of silk produced within our country.
- **Carpet making:** The carpet-making industry is divided throughout the country mainly found in Kashmir, Rajasthan, Punjab, Uttar Pradesh, Andhra Pradesh, and Punjab.
- **Leather works:** The regions of India producing leather are Tamil Nadu, West Bengal, and Uttar Pradesh.