

Geography

Part 6



Geography Optional Notes Part-6 (Indian Physiography)

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Himalayan Ranges

Major Physical Divisions of India

- The Himalayas (young fold mountains),
- Indo-Gangetic Plain (monotonous topography – featureless topography),
- The Peninsular Plateau (one of the most stable landmasses; one of the oldest plateaus of the world),
- Coastal Plains (Sediments due to fluvial action).
- The Indian Islands [Coral Islands = coral reef built up on atolls – Lakshadweep. Tectonic = Andaman and Nicobar Islands – Interaction between Indian Plate and Eurasian plate]

Peninsular Plateau

- Includes the entire south India, central India, Aravalis, Rajmahal hills, Meghalaya plateau, Kuchchh-Kathiawar region (Gujarat) etc.
- It is the oldest and the most **stable** landmass of India.

Himalayas

- Includes the Himalayas, Purvanchal and their extensions Arakan Yoma (Myanmar) and Andaman and Nicobar Islands (but we will consider these as islands only).
- It is the youngest and **highly unstable** landmass of India. [Continent – Continent Convergence]
- Tectonic movements are very common.

Indo-Gangetic Plain

- Between Peninsular and Himalayan region.
- Most youthful, monotonous [lack of change or variety] region prone to tectonic forces.

Coastal Plains

- Eastern Coastal Plains and Western Coastal Plains.
- Formed due to consolidation of sediments brought by rivers (fluvial deposits).
- Highly **stable** just like peninsular plateau.

Indian Islands

- Two major groups – Lakshadweep and, Andaman and Nicobar islands.
- Lakshadweep [Hotspot] are group of atolls occupied by coral reefs. No significant volcanism or tectonic activity in recent past. Highly vulnerable to sea-level rise.
- Andaman and Nicobar islands – Continuation of Arakan Yoma. Has active volcanoes and is tectonically active.

Type of Topography	Extent in %
Mountainous (more than 2135 m above sea level)	10.7
Hilly area (305 – 2135 m above sea level)	18.6
Plateau (305 – 915 m above sea level)	27.7
Plains	43

Division of the Himalayas

Formation of Himalayas explained in Continent – Continent Convergence.

- i. **Shivaliks or outer Himalayas**
- ii. **Lesser or Middle Himalayas**
- iii. **The Greater Himalayas**
- iv. **The Trans-Himalayas – Tibetan Himalayas.**
- v. **The Eastern Hills – Purvanchal: A chain of hills in North-East India.**

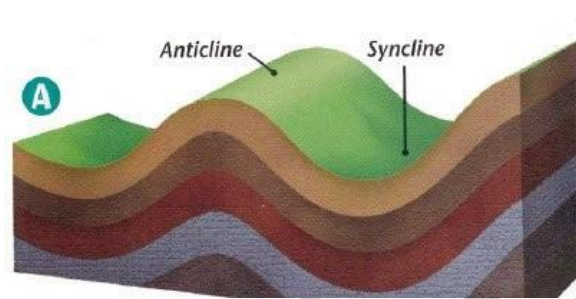
Himalayan Ranges

- Series of several **parallel or converging ranges**.
- The ranges are separated by deep valleys creating a highly **dissected topography** [(of a plateau or upland) divided by a number of deep valleys].
- The **southern slopes have steep gradients** and northern slopes have comparatively gentler slopes. [*Scaling Mount Everest is less hectic from the northern side. But China puts restrictions so climbers take the steeper southern slopes from Nepal*].
- Most of the Himalayan ranges fall in India, Nepal and Bhutan. The northern slopes are partly situated in Tibet (trans-Himalayas) while the western extremity lies in Pakistan, Afghanistan and Central Asia.
- Himalayas between Tibet and Ganga Plain is a succession of three parallel ranges.

Shivalik Range

- Also known as **Outer Himalayas**.
- Located in between the Great Plains and **Lesser Himalayas**.
- The altitude varies from **600 to 1500 metres**.
- Runs for a distance of 2,400 km from the **Potwar Plateau** to the **Brahmaputra valley**.
- The southern slopes are steep while the northern slopes are gentle.
- **The width of the Shivaliks varies from 50 km in Himachal Pradesh to less than 15 km in Arunachal Pradesh.**
- They are almost unbroken chain of low hills except for a gap of 80-90 km which is occupied by the valley of the **Tista River and Raidak River**.

- Shiwalik range from North-East India up to Nepal are covered with thick forests but the forest cover decreases towards west from Nepal (The quantum of rainfall decreases from **east to west** in Shiwaliks and Ganga Plains).
- The southern slopes of Shiwalik range in Punjab and Himachal Pradesh are almost devoid of forest cover. These slopes are highly dissected by seasonal streams called **Chos**.
- Valleys are part of synclines and hills are part of anticlines or antisynclines.



Formation (Formation of Himalayas already explained)

- Shiwaliks were formed last of all the ranges (2-20 million years ago).
- The Shiwaliks are consolidated sands, gravels and conglomerate deposits [Alluvial fans] which were brought by the rivers flowing from the higher ranges.
- These deposits were **folded and hardened** due to compression offered by the northward movement of Indian plate.

The Shiwaliks are known by different names in different areas

Region	Name of Shiwaliks
Jammu Region	Jammu Hills
Dafla, Miri, Abor and Mishmi Hills	Arunachal Pradesh
The Dhang Range, Dundwa Range	Uttarakhand
Churia Ghat Hills	Nepal

Explain the formation of Duns (Duras)

- Shiwalik Hills were formed by the accumulation of conglomerates (sand, stone, silt, gravel, debris etc.).
- These conglomerates, in the initial stages of deposition, obstructed the courses of the rivers draining from the higher reaches of the Himalayas and formed **temporary lakes**.
- With passage of time, these temporary lakes accumulated more and more conglomerates. The conglomerates were well settled at the bottom of the lakes.

- When the rivers were able to cut their courses through the lakes filled with conglomerate deposits, the lakes were drained away leaving behind plains called ‘duns’ or ‘doons’ in the west and ‘duars’ in the east.
- **Dehra Dun in Uttarakhand** is the best example [75 km long and 15-20 km wide].
- Kotah, Patli Kothri, Chumbi, Kyarda, Chaukhamba, Udhampur and Kotli are other important duns.

Middle or the Lesser Himalaya

- In between the Shiwaliks in the south and the Greater Himalayas in the north.
- Runs almost parallel to both the ranges.
- It is also called the **Himachal or Lower Himalaya**.
- **Lower Himalayan** ranges are 60-80 km wide and about 2400 km in length.
- Elevations vary from **3,500 to 4,500 m** above sea level.
- Many peaks are more than 5,050 m above sea level and are snow covered throughout the year.
- **Lower Himalayas** have **steep, bare southern slopes** [steep slopes prevents soil formation] and gentler, forest covered northern slopes.
- In Uttarakhand, the Middle Himalayas are marked by the **Mussoorie** and the **Nag Tibba** ranges.
- The **Mahabharat Lekh**, in southern Nepal is a continuation of the Mussoorie Range
- East of the Kosi River, the Sapt Kosi, Sikkim, Bhutan, Miri, Abor and Mishmi hills represent the lower Himalayas.
- The Middle Himalayan ranges are friendlier to human contact.

Majority of the Himalayan hill resorts like Shimla, Mussoorie, Ranikhet, Nainital, Almora and Darjeeling, etc. are located here.

Important ranges of Lesser Himalayas	Region
The Pir Panjal Range	Jammu and Kashmir (They are to the south of Kashmir Valley)
The Dhaola Dhar Range	Himachal Pradesh
The Mussoorie Range and The Nag Tibba Range	Uttarakhand
Mahabharat Lekh	Nepal

The Pir Panjal range

- The **Pir Panjal range** in Kashmir is the longest and the most important range.
- It extends from the **Jhelum River** to the **upper Beas River** for over 300 km.
- It rises to 5,000 meters and contains mostly volcanic rocks.

Passes in Pir Panjal

- Pir Panjal Pass (3,480 m), the Bidil (4,270 m), Golabghar Pass (3,812 m) and Banihal Pass (2,835 m).
- The **Banihal Pass** is used by the Jammu-Srinagar highway and Jammu-Baramula railway.
- The **Kishanganga**, the **Jhelum** and the **Chenab** cut through the range.
- Southeast of the Ravi, the Pir Panjal continues as **Dhaola Dhar range**, passing through Dalhousie, Dharmshala, and Shimla.

Important Valleys

- Between the Pir Panjal and the Zaskar Range of the main Himalayas, lies the valley of Kashmir. (Average elevation is 1,585 m above mean sea level)
- The synclinal basin of the valley is floored with alluvial, lacustrine [lake deposits], fluvial [river action] and glacial deposits. {Fluvial Landforms, Glacial Landforms}
- Jhelum River meanders through these deposits and cuts a deep gorge in Pir Panjal through which it drains. (Kashmir is like a basin with very few outlets)
- In Himachal Pradesh there is **Kangra Valley**. It is a **strike valley** and extends from the foot of the Dhaola Dhar Range to the south of Beas.
- On the other hand, the **Kulu Valley** in the upper course of the Ravi is **transverse valley**.

Strike valley vs. Transverse valley

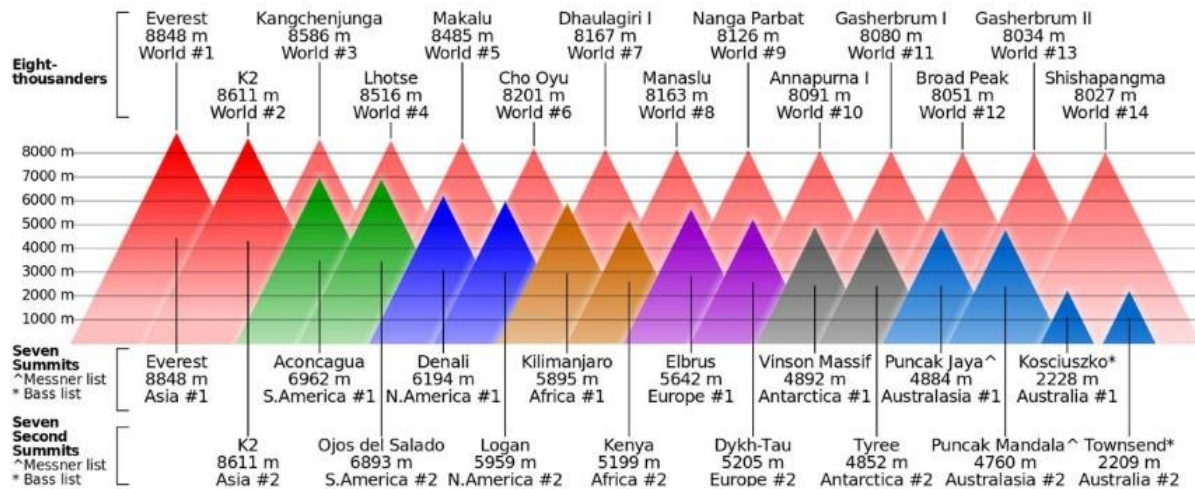
- A valley perpendicular to the slope or parallel to the ridge [also called as longitudinal valley]
- In contrast, transverse streams cut valleys parallel to the slope (along the dip).



The Great Himalaya

- Also known as **Inner Himalaya, Central Himalaya or Himadri**.
- Average elevation of 6,100 m above sea level and an average width of about 25 km.
- It is mainly formed of the central crystallines (granites and gneisses) overlain by metamorphosed sediments [limestone]. {Rock System}
- The folds in this range are asymmetrical with steep south slope and gentle North Slope giving 'hog back (a long, steep hill or mountain ridge)' topography.

- This mountain arc convexes to the south just like the other two.
- Terminates abruptly at the **syntaxial bends**. One in the **Nanga Parbat** in north-west and the other in the **Namcha Barwa** in the north-east.
- This mountain range boasts of the tallest peaks of the world, most of which remain under perpetual snow.



Regional name of Mount Everest	Region
Sagarmatha (The Goddess of the Sky)	Nepal
Chomlungma (Mother of the World)	China (Tibet)

- Mount Everest was first located by George Everest, the then Surveyor General of India in 1841 and in 1852 it was established as the highest peak of the world by the Great Trigonometrical Survey of India.

Passes in the Greater Himalayas

- The passes because they are generally higher than 4,570 m above sea level and are snowbound for most of the year.

State	Passes of Greater Himalayas	
Jammu and Kashmir		1. Burzil Pass 2. Zoji La [La means pass]
Himachal Pradesh		1. Bara Lacha La 2. Shipki La [The Hindustan-Tibet Road connecting Shimla with Gartok in Western]

	Tibet]
Uttarakhand	<ol style="list-style-type: none"> 1. Thaga La 2. Niti Pass 3. Lipu Lekh
Sikkim	<ol style="list-style-type: none"> 1. Nathu La 2. Jelep La [important trade route connecting Kalimpong (near Darjeeling) with Lhasa in Tibet, passes through Jelep La (4,386 m)]

The Trans Himalayas

- The Himalayan ranges immediately north of the Great Himalayan range. Also called the **Tibetan Himalaya** because most of it lies in Tibet.
- The **Zaskar**, the **Ladakh**, the **Kailas** and the **Karakoram** are the main ranges. It stretches for a distance of about 1,000 km in east-west direction.
- Average elevation is 3000 m above mean sea level. The average width of this region is 40 km at the extremities and about 225 km in the central part.
- The **Nanga Parbat (8126 m)** is an important range which is in The Zaskar Range.
- North of the Zaskar Range and running parallel to it is the Ladakh Range. Only a few peaks of this range attain heights of over 6000 metres.
- The Kailas Range (**Gangdise in Chinese**) in western Tibet is an offshoot of the Ladakh Range. The highest peak is Mount Kailas (6714 m). **River Indus originates from the northern slopes of the Kailas range.**
- The northern most range of the Trans-Himalayan Ranges in India is the Great **Karakoram Range** also known as the **Krishnagiri range**.
- **Karakoram Range** extends eastwards from the Pamir for about 800 km. It is a range with lofty peaks [elevation 5,500 m and above]. It is the **abode of some of the greatest glaciers** of the world outside the Polar Regions.
- Some of the peaks are more than 8,000 metre above sea level. **K2 (8,611 m) [Godwin Austen or Qogir]** is the second highest peak in the world and the highest peak in the Indian Union.
- The Ladakh Plateau lies to the north-east of the Karakoram Range. It has been dissected into a number of plains and mountains [Soda Plains, Aksai Chin, Lingzi Tang, Depsang Plains and Chang Chenmo]

Purvanchal or Eastern Hills

- Eastern Hills or The Purvanchal are the southward extension of Himalayas running along the north-eastern edge of India.
- At the **Dihang gorge**, the Himalayas take a sudden southward bend and form a series of comparatively low hills which are collectively called as the Purvanchal.
- Purvanchal hills are convex to the west.

- They run along the India-Myanmar Border extending from Arunachal Pradesh in the north to Mizoram in the south.
- **Patkai Bum** hills are made up of strong sandstone; elevation varying from 2,000 m to 3,000 m; merges into Naga Hills where **Saramati (3,826 m)** is the highest peak.
- Patkai Bum and Naga Hills form the watershed between India and Myanmar.
- South of Naga Hills are the Manipur hills which are generally less than 2,500 metres in elevation.
- The Barail range separates Naga Hills from Manipur Hills.
- Further south the Barail Range swings to west into **Jaintia, Khasi and Garo hills** which are an eastward continuation of the **Indian peninsular block**. They are separated from the main block by Ganga and Brahmaputra rivers.
- South of the Manipur Hills are the Mizo Hills (previously known as the **Lushai hills**) which have an elevation of less than 1,500 metres. The highest point is the **Blue Mountain (2,157 m)** in the south.

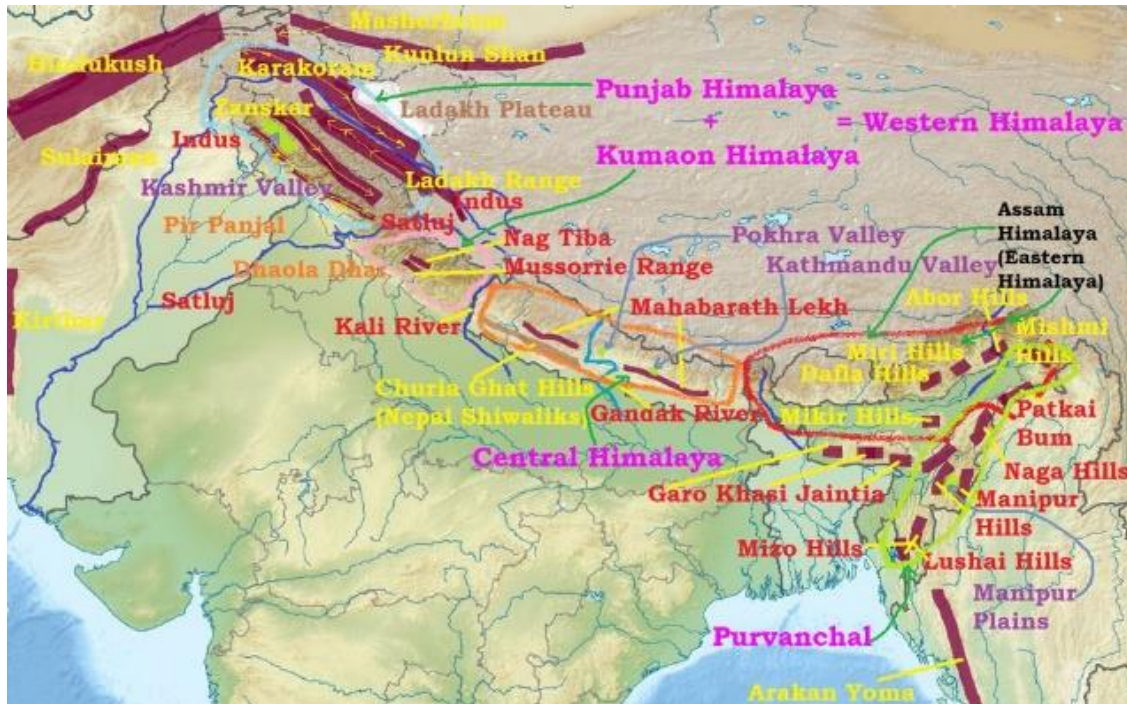


Syntactical Bends of the Himalayas

- Himalayas extend in the east-west direction from the Indus gorge in the west to the Brahmaputra gorge in the east.
- Himalayan ranges take sharp southward bends at these gorges. These bends are called syntactical bends of the Himalayas.
- The western syntactical bend occurs near the **Nanga Parbat** where the Indus River has cut a deep gorge.

- The eastern syntaxial bend occurs near the **Namche Barwa**.

Himalayas – Regional Divisions



Punjab Himalayas

- Between the **Indus** and the **Satluj** rivers [560 km long].
- All the major rivers of Indus river system flow through Punjab Himalayas.
- A large portion of Punjab Himalayas is in Jammu and Kashmir and Himachal Pradesh. Hence they are also called the **Kashmir and Himachal Himalaya**.
- **Karakoram, Ladakh, Pir Panjal, Zaskar and Dhaola Dhar** are the major ranges in this section.
- The general elevation **falls westwards**.

Assam Himalayas

- Spreads over Sikkim, Assam and Arunachal Pradesh.
- Elevation here is much lesser than that of the Nepal Himalayas.
- The southern slopes are very steep but the northern slopes are gentle.
- **The Lesser Himalayas are very narrow and are very close to the Great Himalayas.**

Western Himalayas

- Between the **Indus in the west and the Kali river in the east (880 km)**.
- Spread across three states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand.
- It encompasses three physiographic provinces namely **Kashmir Himalaya, Himachal Himalaya and Kumaon Himalaya (Uttarakhand Himalayas)**.
- The Ladakh plateau and the Kashmir valley are two important areas of the Kashmir Himalayan region.

- In Himachal Himalayas, The Greater Himalaya is represented by the **Zaskar range**, lesser Himalaya by **Pir Panjal** and **Dhauladhar ranges** and the Outer Himalaya by the **Shiwalik range**.
- The southern slopes are rugged, steep and forested while the northern slopes are bare, gentle and show plains with lakes.
- The Kumaon Himalayas lie in Uttarakhand and extend from the **Satluj to the Kali River**.
- The Lesser Himalayas in Kumaon Himalaya is represented by the **Mussoorie and Nag Tiba ranges**.
- The Shiwalik in this region runs south of the Mussoori range between the Ganga and the Yamuna rivers.
- The flat valleys **between the Lesser Himalaya and the Shiwalik range are called 'doons' or 'Duns'** of which Dehra Dun is the most famous.

Central Himalayas

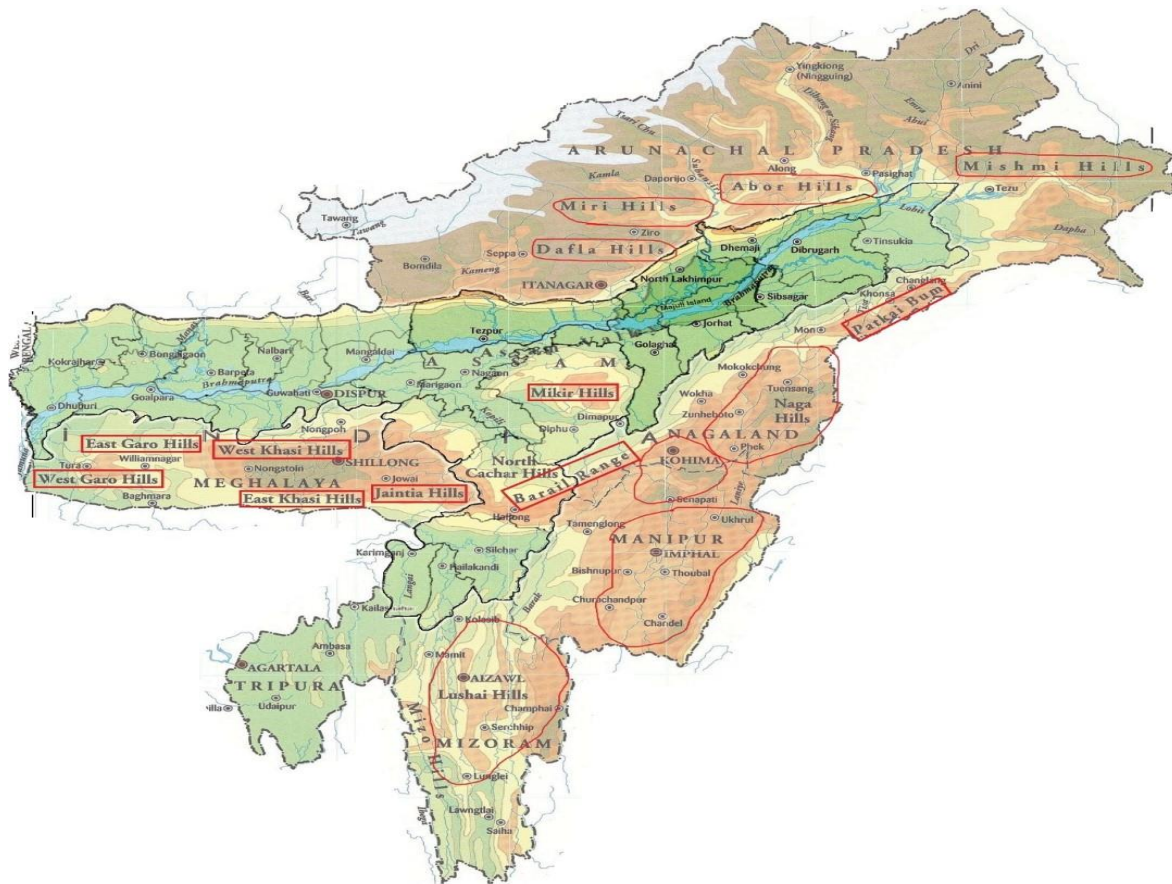
- 800 km between river Kali in the west and river Tista in the east.
- The Great Himalaya range attains maximum height in this portion.
- Some of the world famous peaks Mt. Everest, Kanchenjunga, Makalu, Annapurna, Gosainthan and Dhaulagiri are located here.
- The Lesser Himalaya is known as **Mahabharat Lekh** in this region.
- The range is crossed by rivers like Ghaghara, Gandak, Kosi, etc.
- In between the Great and the Lesser Himalayas, there are **Kathmandu and Pokhra** lacustrine **valleys** (previously, they were lakes).
- The Shiwalik range come very close to the lesser Himalaya towards the east and is almost non-existent beyond Narayani (Gandak).

Eastern Himalayas

- This part of the Himalayas lies between the Tista River in the west and the Brahmaputra River in the east and stretches for a distance of about 720 km.
- Also known as the **Assam Himalayas**, the Eastern Himalayas occupy mainly the areas of Arunachal Pradesh and Bhutan.
- The Assam Himalayas show a marked dominance of fluvial erosion due to **heavy rainfall**.
- The Himalayas take a sudden southward turn after the Dihang gorge and the hill ranges running in more or less north-south direction along India's border with Myanmar are collectively known as the Purvanchal.

These are known by various local names such as Patkai Bum, Naga Hills, Kohima hills, Manipur hills, Mizo hills (previously known as the Lushai hills), Tripura hills and Barail range.

- The extension of the Purvanchal Himalaya continues southwards up to Andaman and Nicobar Islands through the Myanmar range (Arakan Yoma) and even up to the Indonesian archipelago.
- In the eastern section the Himalayas rise abruptly from the plains of Bengal and Oudh and suddenly attain great elevations within a short distance from the foot of the mountains. Thus the peaks of **Kanchenjunga** and **Everest** are only a few kilometers from the plains and are clearly visible from there.
- In contrast, the western Himalayas rise gradually from the plains through a series of ranges. Their peaks of perpetual snow are 150 to 200 km away from the plain areas.



Major Passes of the Himalayas

- Most of the passes remain closed in winter (Nov – Apr) due to heavy snow fall.

Passes of the Western Himalayas

Jammu and Kashmir

NAME	SIGNIFICANCE (CONNECTS)	COMMENTS
Mintaka Pass	Kashmir and China	<ul style="list-style-type: none"> • Tri-junction of India-China and Afghanistan border

Parpik Pass	Kashmir and China	<ul style="list-style-type: none"> • East of Mintaka pass on the Indo-China border
Khunjerab Pass	Kashmir and China	<ul style="list-style-type: none"> • Indo-China border
Aghil Pass	Ladakh region of India with the Xinjiang (Sinkiang) Province of China	<ul style="list-style-type: none"> • 5000 m above sea level. • north of K2 Peak (the highest peak in India and the second highest peak in the world)
Banihal Pass	Jammu and Srinagar	<ul style="list-style-type: none"> • 2832 m • across the Pir-Panjaj Range • remains snow covered during winter season
		<ul style="list-style-type: none"> • The road from Jammu to Srinagar transversed Banihal Pass until 1956 when Jawahar Tunnel was constructed under the pass. The road now passes through the tunnel and the Banihal Pass is no longer used for road transport. • Another 11 km long tunnel provides railway link between Banihal and Kazigund. It was thrown open to railway transport in July, 2013
Chang-La	Ladakh with Tibet	<ul style="list-style-type: none"> • altitude of 5360 m • This has a temple dedicated to Chang-La Baba after whom the temple has been named
Khardung La	near Leh in the Ladakh range	<ul style="list-style-type: none"> • 5602 m • The world's highest motorable road passes through this pass remains closed in winter due to heavy snowfall
Lanak La	India and China (Akasai-Chin area of Jammu and Kashmir)	<ul style="list-style-type: none"> • This pass provides passage between Ladak and Lhasa. A road to connect Xinjiang Province with Tibet has been constructed by the Chinese

Pir-Panjal pass	across the Pir Panjal range	Provides the shortest and the easiest metal road between Jammu and Kashmir Valley. But this route had to be closed down as a result of partition of the subcontinent
Qara Tag La	Indo-China border across the Karakoram Range	<ul style="list-style-type: none"> located at an elevation of over six thousand metres
Imis La	Ladakh region of India and Tibet in China	
Pensi La	vital link between the Kashmir Valley and Kargil	<ul style="list-style-type: none"> remains closed to traffic from November to mid-May due to heavy snowfall
Zoji La	important road link between Srinagar on one side and Kargil and Leh on the other side	<ul style="list-style-type: none"> The road passing through this pass has been designated as the National Highway (NH-1D) Border Road Organisation (BRO) is responsible for maintaining the road and cleaning it off snow during winter. In spite of all these efforts, the road through this pass remains closed from December to mid-May
Himachal Pradesh		
Bara Lacha La	Himachal Pradesh and Jammu and Kashmir	<ul style="list-style-type: none"> Elevation: 4,890 m National highway connecting Mandi in Himachal Pradesh with Leh in Jammu and Kashmir passes through this pass. Being situated at high altitude, it remains snow covered in winter and is not used as a transport route.
Debsa Pass	link between Kullu and Spiti districts	<ul style="list-style-type: none"> elevation of 5270 m above sea level It offers a much easier and shorter alternative route to traditional Pin-Parbati Pass route between Kullu and

		Spiti
Rohtang Pass	road link between Kullu, Lahul and Spiti Valleys	<ul style="list-style-type: none"> Elevation: 3979 m Border Road Organisation (BRO) is responsible for constructing and maintaining roads in this area. Rohtang pass is a great tourist attraction and traffic jams are very common because this route is widely used by military, public and private vehicles.
Shipki La	Himachal Pradesh and Tibet	<ul style="list-style-type: none"> Elevation: 6000 m Remains closed in winter season (Nov – Apr)
Uttarakhand		
Lipu Lekh	trijunction of Uttarakhand (India), Tibet (China) and Nepal borders	This pass is used by pilgrims to Kailash-Mansarowar.
Mana Pass	Uttarakhand with Tibet	<ul style="list-style-type: none"> elevation of 5610 Situated a little north of the holy place of Badhrinath Remains closed in winter season (Nov – Apr)
Mangsha Dhura	Uttarakhand with Tibet	It is used by pilgrims going to Kailash-Mansarowar
Niti Pass	Uttarakhand with Tibet	<ul style="list-style-type: none"> Remains closed in winter season (Nov – Apr)
Muling La	Uttarakhand and Tibet	<ul style="list-style-type: none"> situated in the north of Gangotri at an elevation of 5669 m in the Great Himalayas

Passes of the Eastern Himalayas

Sikkim

Nathu La	Sikkim with Tibet	<ul style="list-style-type: none"> altitude of 4310 m it forms part of an offshoot of the ancient Silk Route an important trade route between India and China It was closed after the Chinese aggression on India in 1962 but was reopened in 2006 as the governments of the two countries decided to enhance their trade through land routes
Jelep La	Sikkim-Bhutan border	<ul style="list-style-type: none"> altitude of 4538 m passes through Chumbi Valley important link between Sikkim and Lhasa

Arunachal Pradesh

Bom Di La	Arunachal Pradesh with Bhutan	<ul style="list-style-type: none"> altitude of 4331 m Situated at an altitude of 4331 m near the western boundary of Arunachal Pradesh in the Greater Himalayas, this pass connects Arunachal Pradesh with Lhasa
Dihang Pass	Arunachal Pradesh and Myanmar.	<ul style="list-style-type: none"> elevation of more than 4000 m it provides passage
Yonggyap Pass	Arunachal Pradesh with Tibet	

Dipher Pass	trijunction of India, China and Myanmar	<ul style="list-style-type: none"> • Easy access between Arunachal Pradesh and Mandalay in Myanmar. It is an important land trade route between India and Myanmar and remains open throughout the year.
Kumjawng Pass	Arunachal Pradesh with Myanmar	
Hpungan Pass	Arunachal Pradesh with Myanmar	
Chankan Pass	Arunachal Pradesh with Myanmar	

Indo-Gangetic-Brahmaputra Plain

Formation of Indo – Gangetic – Brahmaputra trough

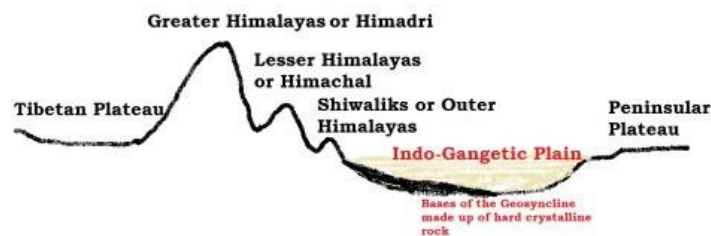
- The rivers which were previously flowing into **Tethys Sea** (Before Indian Plate collided with Eurasian Plate – continental drift, plate tectonics) deposited huge amount of sediments in the **Tethys Geosyncline**. [**Geosyncline – a huge depression**]
- Himalayas are formed out of these sediments which were uplifted, folded and compressed due to northern movement of Indian Plate.
- Northern movement of Indian Plate also **created a trough** to the south of Himalayas.

Depositional Activity

- During the initial stages of upliftment of sediments, the already existing rivers changed their course several times and they were **rejuvenated** each time (perpetual youth stage of rivers {Fluvial Landforms}).
- The rejuvenation is associated with intense **headward and vertical downcutting** of the soft strata overlying the harder rock stratum.
- Headward erosion and vertical erosion of the river valley in the initial stages, lateral erosion in later stages contributed huge amount of conglomerates (detritus) (rock debris, silt, clay etc.) which were carried downslope.
- [**Head ward erosion** = Erosion at the origin of a stream channel, which causes the origin to move back away from the direction of the stream flow, and so causes the stream channel to lengthen]
- These conglomerates were deposited in the **depression (Indo-Gangetic Trough or Indo-Gangetic syncline) (the base of the geosyncline is a hard crystalline rock)** between peninsular India and the convergent boundary (the region of present day Himalayas).

New rivers and more alluvium

- The raising of Himalayas and subsequent formation of glaciers gave rise to many new rivers. These rivers along with glacial erosion {Glacial Landforms}, supplied more alluvium which intensified the filling of the depression.
- With the accumulation of more and more sediments (conglomerates), the Tethys Sea started receding.
- With passage of the time, the depression was completely filled with alluvium, gravel, rock debris (conglomerates) and the Tethys completely disappeared leaving behind a monotonous aggradational plain.
- [**Monotonous** = featureless topography; **aggradational plain** = plain formed due to depositional activity. Indo-Gangetic plain is a monotonous aggradational plain formed due to fluvial depositions].
- Upper Peninsula Rivers have also contributed to the formation of plains, but to a very small extent.
- During the recent times (since few million years), depositional work of three major river systems viz., the Indus, the Ganga and the Brahmaputra have become predominant.
- Hence this arcuate (curved) plain is also known as **Indo-Gangetic-Brahmaputra Plain**.



Features of Indo – Gangetic – Brahmaputra Plain

- Indo-Gangetic-Brahmaputra Plain is the **largest alluvial tract of the world**.
- It stretches for about **3,200 km** from the mouth of the Indus to the mouth of the Ganga. Indian sector of the plain accounts for **2,400 km**.
- The northern boundary is well marked by the **Shiwaliks** and the southern boundary is a wavy irregular line along the northern edge of the Peninsular India.
- The western boarder is marked by **Sulaiman and Kirthar ranges**. On the eastern side, the plains are bordered by Purvanchal hills.
- The width of the plain varies from region to region. It is widest in the west where it stretches for about 500 km. Its width decreases in the east.
- The thickness of the alluvium deposits also vary from place to place. The maximum depth of the alluvium up to the basement rocks is about 6,100 m (not uniform and varies greatly from place to place).
- The cones or alluvial fans of Kosi in the north and those of Son in the south exhibit greater alluvial thickness while the intra-cone areas have relatively shallower deposits.
- Extreme horizontality of this monotonous plain is its chief characteristic.
- Its average elevation is about 200 m above mean sea level, highest elevation being 291 m above mean sea level near **Ambala (This elevation forms the drainage divide or watershed between Indus system and Ganga system)**.

- Its average gradient from Saharanpur to Kolkata is only 20 cm per km and it decreases to 15 cm per km from Varanasi to the Ganga delta.

Geomorphological features of Indo – Gangetic – Brahmaputra Plain

The Bhabar

- It is a **narrow, porous, northern most** stretch of Indo-Gangetic plain.
- It is about 8-16 km wide running in east-west direction **along the foothills** (alluvial fans) of the Shiwaliks.
- They show a remarkable continuity from the **Indus to the Tista**.
- Rivers descending from the Himalayas deposit their load along the foothills in the form of **alluvial fans**.
- These alluvial fans have merged together to build up the **bhabar belt**.
- The **porosity** of bhabar is the most unique feature.
- The porosity is due to deposition of huge number of **pebbles and rock debris** across the alluvial fans.
- The streams disappear once they reach the bhabar region because of this porosity.
- Therefore, the area is marked by **dry river courses** except in the rainy season.
- The Bhabar belt is comparatively **narrow in the east** and extensive in the western and north-western hilly region.
- **The area is not suitable for agriculture and only big trees with large roots thrive in this belt.**

The Terai

- Terai is an **ill-drained, damp (marshy) and thickly forested narrow tract** to the south of Bhabar running parallel to it.
- The Terai is about 15-30 km wide.
- The underground streams of the Bhabar belt **re-emerge** in this belt.
- **This thickly forested region provides shelter to a variety of wild life. [Jim Corbett National Park in Uttarakhand and Kaziranga National Park in Assam lie in terai region]**
- The Terai is more marked in the eastern part than in the west because the eastern parts receive comparatively higher amount of rainfall.
- Most of the Terai land, especially in Punjab, Uttar Pradesh and Uttarakhand, has been turned into agricultural land which gives good crops of **sugarcane, rice and wheat**.

The Bhangar

- The Bhangar is the **older alluvium** along the river beds **forming terraces higher than the flood plain**.
- The terraces are often impregnated with calcareous concretions known as **'KANKAR'**.
- **'The Barind plains'** in the deltaic region of Bengal and the **'bhur formations'** in the middle Ganga and Yamuna doab are regional variations of Bhangar.
- Bhangar contains fossils of animals like rhinoceros, hippopotamus, elephants, etc.

[**Bhur** denotes an elevated piece of land situated along the banks of the Ganga River especially in the upper Ganga-Yamuna Doab. This has been formed due to accumulation of wind-blown sands during the hot dry months of the year]

The Khadar

- The Khadar is composed of **newer alluvium** and forms the **flood plains** along the river banks.
- A **new layer of alluvium is deposited** by river flood almost every year.
- This makes them the **most fertile soils of Ganges**.

Reh or Kollar

- Reh or Kollar comprises **saline efflorescences** of drier areas in Haryana.
- Reh areas have spread in recent times with increase in irrigation (capillary action brings salts to the surface).

Regional Divisions of the Indo-Gangetic-Brahmaputra Plains [Great Plains]

- i. **Sindh Plain**
- ii. **Rajasthan Plain.**
- iii. **Punjab Plain.**
- iv. **Ganga Plain.**
- v. **Brahmaputra Plain.**
- vi. **Ganga – Brahmaputra Delta.**

Sindh Plain [Pakistan]

- Mainly formed of **Bhangar Plains**.
- Dhors: Long narrow depressions which are the remnants of the course of former rivers.
- Dhand: Alkaline lakes on some dhors.

Rajasthan Plain

- Occupied by Thar or the Great Indian Desert.
- This plain is an **undulating plain [wave like]** whose average elevation is about 325 m above mean sea level.
- The desert region is called **Marusthali** and forms a greater part of the **Marwar plain**.
- It has a few outcrops of gneisses, schists and granites which proves that geologically it is a part of the Peninsular Plateau. It is only at the surface that it looks like an aggradational plain.
- In general, the eastern part of the Marusthali is rocky while its western part is covered by shifting sand dunes locally known as
- The eastern part of the Thar Desert up to the Aravali Range is a semi-arid plain known as **Rajasthan Bagar**.
- It is drained by a number of **short seasonal streams** originating from the Aravali and supports agriculture in some patches of fertile tracts.
- Luni is an important seasonal stream which flows into Rann of Kuchchh. The tract north of the Luni is known as **thali** or **sandy plain**.

Saline Lakes

- North of the Luni, there is inland drainage having several saline lakes. They are a source of common salt and many other salts.

- **Sambhar**, Didwana, Degana, Kuchaman, etc. are some of the important lakes. The largest is the Sambhar Lake near Jaipur.

Punjab Plain

- This plain is formed by five important rivers of Indus system.
- The plain is primarily made up of 'doabs' —the land between two rivers.
- The depositional process by the rivers has united these doabs giving a homogenous appearance.
- Punjab literally means "(The Land of) Five Waters" referring to the following rivers: the **Jhelum, Chenab, Ravi, Sutlej, and Beas**.
- The total area of this plain is about 1.75 lakh sq km.
- The average elevation of the plain is about 250 m above mean sea level.
- The eastern boundary of Punjab Haryana plain is marked by subsurface **Delhi-Aravali ridge**.
- The northern part of this plain [Shivalik hills] has been intensively eroded by numerous streams called **Chos**. This has led to enormous gullying [Arid Landforms].
- 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.
- **The only river between the Yamuna and the Satluj is the Ghaggar which is considered to be the present day Successor of the legendary Saraswati River**

Ganga Plain

- This is the largest unit of the Great Plain of India stretching from Delhi to Kolkata (about 3.75 lakh sq km).
- The Ganga along with its large number of tributaries originating in the Himalayans have brought large quantities of alluvium from the mountains and deposited it here to build this extensive plain.
- The peninsular rivers such as Chambal, Betwa, Ken, Son, etc. joining the Ganga river system have also contributed to the formation of this plain.
- The general slope of the entire plain is to the east and south east.
- Rivers flow sluggishly in the lower sections of Ganges as a result of which the area is marked by local prominences such as **levees, bluffs, oxbow lakes, marshes, ravines**, etc. {Fluvial Landforms, Arid Landforms}
- Almost all the rivers keep on shifting their courses making this area prone to frequent floods. The Kosi River is very notorious in this respect. It has long been called the '**Sorrow of Bihar**'.

Regional divisions of Ganga plains

- **Rohilkhand plains**
- **Avadh Plains**
- **Mithila Plain**
- **Magadh Plain.**

Ganga-Brahmaputra Delta

- This is the **largest delta** in the world.

- The Ganga River divides itself into several channels in the delta area. The slope of the land here is a mere 2 cm per km. Two thirds of the area is below 30 m above mean sea level. [Highly vulnerable to sea level changes]
- The seaward face of the delta is studded with a large number of estuaries, mud flats, mangrove swamps, sandbanks, islands and forelands.
- Large part of the coastal delta is covered **tidal forests**. These are called the **Sunderbans** because of the predominance of Sundri tree here.

Brahmaputra Plain

- This is also known as the Brahmaputra valley or **Assam Valley** or **Assam Plain** as most of the Brahmaputra valley is situated in Assam.
- Its western boundary is formed by the Indo-Bangladesh border as well as the boundary of the lower Ganga Plain. Its eastern boundary is formed by **Purvanchal hills**.
- It is an **aggradational plain** built up by the depositional work of the Brahmaputra and its tributaries.
- The innumerable tributaries of the Brahmaputra River coming from the north form a number of alluvial fans. Consequently, the tributaries branch out in many channels giving birth to river meandering leading to formation of bill and ox-bow lakes.
- There are large marshy tracts in this area. The alluvial fans formed by the coarse alluvial debris have led to the formation of terai or semi-terai conditions.

Significance of the Plain

- This one fourth of the land of the country hosts half of the Indian population.
- Fertile alluvial soils, flat surface, slow moving perennial rivers and favorable climate facilitate intense agricultural activity.
- The extensive use of irrigation has made Punjab, Haryana and western part of Uttar Pradesh the granary of India (**Prairies** are called the granaries of the world).
- The entire plain except the Thar Desert, has a close network of roads and railways which has led to large scale industrialization and urbanization.
- Cultural tourism: There are many religious places along the banks of the sacred rivers like the Ganga and the Yamuna which are very dear to Hindus. Here flourished the religions of Budha and Mahavira and the movements of Bhakti and Sufism.

Plateaus in the Peninsular Region

Features of the Peninsular Plateau

- Roughly triangular in shape with its base coinciding with the southern edge of the great plain of North India. Apex of the triangular plateau is at Kanniyakumari.
- It covers a total area of about **16 lakh sq. km** (India as a whole is 32 lakh sq. km).
- The average height of the plateau is **600-900 m** above sea level (varies from region to region).
- Most of the peninsular rivers flow west to east indicating its general slope.
- Narmada-Tapti are the exceptions which flow from east to west in a **rift (rift is caused by divergent boundary)**.

- The Peninsular Plateau is one of the oldest landforms of earth.
- It is a highly stable block composed mostly of the **Archaean gneisses and schists** {Rock System}.
- It has been a stable shield which has gone through little structural changes since its formation.
- Since few hundred million years, peninsular block has been a land area and has never been submerged beneath the sea except in a few places.
- Peninsular Plateau is an aggregation of several smaller plateaus, hill ranges interspersed with river basins and valleys.

Minor Plateaus in the Peninsular Plateau

Marwar Plateau or Mewar Plateau

- It is the plateau of eastern Rajasthan. [**Marwar plain** is to the west of Aravalis whereas Marwar plateau is to the east].
- The average elevation is 250-500 m above sea level and it slopes down eastwards.
- It is made up of sandstone, shales and limestones of the Vindhyan period.
- The **Banas River**, along with its tributaries [**Berach River, Khari Rivers**] originate in the Aravali Range and flow towards northwest into **Chambal River**. The erosional activity of these rivers make the plateau top appear like a **rolling plain**.

[Rolling Plain: 'Rolling plains' are not completely flat: there are slight rises and falls in the land form. Ex: Prairies of USA]

Central Highland

- Also called the **Madhya Bharat Pathar** or **Madhya Bharat Plateau**.
- It is to the east of the Marwar or Mewar Upland.
- Most of the plateau comprises the basin of the **Chambal River** which flows in a **rift valley**.
- The **Kali Sindh**, flowing from **Rana Prataph Sagar**, The **Banas** flowing through Mewar plateau and The **Parwan** and the **Parbati** flowing from Madhya Pradesh are its main tributaries.
- It is a rolling plateau with rounded hills composed of sandstone. Thick forests grow here.
- To the north are the **ravines or badlands** of the Chambal river [They are typical to Chambal river basin] {Arid landforms}.

Bundelkhand Upland

- Yamuna River to the north, Madhya Bharat Pathar to the west, Vindhyan Scarplands to the east and south-east and Malwa Plateau to the south.
- It is the old dissected (divided by a number of deep valleys) upland of the 'Bundelkhand gneiss' comprising of **granite** and **gneiss**.
- Spreads over five districts of Uttar Pradesh and four districts of Madhya Pradesh.
- Average elevation of 300-600 m above sea level, this area slopes down from the Vindhyan Scarp toward the Yamuna River.
- The area is marked by a chain of hillocks (small hills) made of granite and sandstone.
- The erosional work of the rivers flowing here have converted it into an undulating (wave like surface) area and rendered it **unfit for cultivation**.
- The region is characterized by senile (characteristic of or caused by old age) topography.
- Streams like **Betwa, Dhasan** and **Ken** flow through the plateau.

Malwa Plateau

- The Malwa Plateau roughly forms a triangle based on the Vindhyan Hills, bounded by the Aravali Range in the west and Madhya Bharat Pathar to the north and Bundelkhand to the east.
- This plateau has two systems of drainage; one towards the Arabian Sea (The **Narmada**, the **Tapi** and the **Mahi**), and the other towards the Bay of Bengal (Chambal and Betwa, joining the Yamuna).
- In the north it is drained by the Chambal and many of its right bank tributaries like the Kali, the Sindh and the Parbati. It also includes the upper courses of the Sindh, the Ken and the Betwa.
- It is composed of extensive **lava flow and is covered with black soils**.
- The general slope is towards the north [decreases from 600 m in the south to less than 500 m in the north]
- This is a rolling plateau dissected by rivers. In the north, the plateau is marked by the **Chambal ravines**.

Baghelkhand

- North of the **Maikal Range** is the Baghelkhand.
- Made of limestones and sandstones on the west and granite in the east.
- It is bounded by the Son River on the north.
- The central part of the plateau acts as a water divide between the **Son** drainage system in the north and the **Mahanadi** river system in the south.
- The region is uneven with general elevation varying from 150 m to 1,200 m.
- The **Bhanrer** and **Kaimur** are located close to the trough-axis.
- The general horizontality of the strata shows that this area has not undergone any major disturbance.

Chotanagpur Plateau

- Chotanagpur plateau represents the north-eastern projection of the Indian Peninsula.
- Mostly in Jharkhand, northern part of Chhatisgarh and Purulia district of West Bengal.
- The **Son River** flows in the north-west of the plateau and joins the Ganga.
- The average elevation of the plateau is 700 m above sea level.
- This plateau is composed mainly of **Gondwana rocks**.
- The plateau is drained by numerous rivers and streams in different directions and presents a **radial drainage pattern**. {Drainage Pattern}
- Rivers like the **Damodar**, the **Subarnrekaha**, the **North Koel**, the **South Koel** and the **Barkar** have developed extensive drainage basins.
- The Damodar River flows through the middle of this region in a rift valley from west to east. Here are found the **Gondwana coal fields** which provide bulk of coal in India.
- North of the Damodar river is the **Hazaribagh plateau** with an average elevation of 600 m above mean sea level. This plateau has isolated hills. It looks like a peneplain due to large scale erosion.
- The **Ranchi Plateau** to the south of the Damodar Valley rises to about 600 m above mean sea level. Most of the surface is rolling where the city of Ranchi (661 m) is located.
- At places it is interrupted by **monadnocks** (an isolated hill or ridge of erosion-resistant rock rising above a peneplain. Ex: Ayers Rock in Australia) and conical hills.
- The **Rajmahal Hills** forming the north eastern edge of the Chotanagpur Plateau are mostly made of basalt and are covered by lava flows {Basaltic Lava}.
- They run in north-south direction and rise to average elevation of 400 m (highest mount is 567 m). These hills have been dissected into separate plateaus.

Meghalaya Plateau

- The peninsular plateau extends further east beyond the Rajmahal hills to form the **Meghalaya** or the **Shillong plateau**.
- **Garo-Rajmahal Gap** separates this plateau from the main block.
- This gap was formed by **down-faulting** (normal fault: a block of earth slides downwards). It was later filled by sediments deposited by the Ganga and Brahmaputra.
- The plateau is formed by Archaean quartzites, shales and schists.
- The plateau slopes down to Brahmaputra valley in the north and the Surma and Meghna valleys in the south.
- Its western boundary more or less coincides with the Bangladesh border.
- The western, central and the eastern parts of the plateau are known as the **Garo Hills** (900 m), the **Khasi-Jaintia Hills** (1,500 m) and the **Mikir Hills** (700 m).
- **Shillong (1,961 m) is the highest point of the plateau.**

Deccan Plateau

- It covers an area of about **five lakh sq. km.**
- It is triangular in shape and is bounded by the **Satpura** and the **Vindhya** in the north-west, the **Mahadev** and the **Maikal** in the north, the **Western Ghats** in the west and the **Eastern Ghats** in the east.
- Its average elevation is 600 m. It rises to 1000 m in the south but dips to 500 m in the north.
- Its general slope is from west to east which is indicated by the flow of its major rivers.
- Rivers have further subdivided this plateau into a number of smaller plateaus.

Maharashtra Plateau

- The Maharashtra Plateau lies in Maharashtra. It forms the northern part of the Deccan Plateau.
- Much of the region is underlain by **basaltic rocks** of lava origin [**Most of the Deccan Traps lies in this region**].
- The area looks like a rolling plain due to weathering.
- The horizontal lava sheets have led to the formation of typical Deccan Trap topography [step like].
- The broad and shallow valleys of the Godavari, the Bhima and the Krishna are flanked [bordered on the opposite sides] 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**. Lies to the south of the Maharashtra plateau. The area looks like a rolling plateau with an average elevation of 600-900 m.
- It is highly dissected by numerous rivers rising from the Western Ghats. The general trend of the hills is either parallel to the Western Ghats or across it.
- The **highest peak (1913 m) is at Mulangiri in Baba Budan Hills in Chikmagalur district**. 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.
- Its average elevation is 500-600 m.
- The southern part is higher than its northern counterpart.
- The region is drained by three river systems, the Godavari, the Krishna and the Penneru.
- The entire plateau is divided into Ghats and the Peneplains (a vast featureless, undulating plain which the last stage of deposition process).

Chhattisgarh Plain

- The Chhattisgarh **plain** is the only plain worth the name in the peninsular plateau.
- It is a saucer shaped depression drained by the upper Mahanadi.
- The whole basin lies between the **Maikala Range** and the **Odisha hills**.
- The region was once ruled by **Haithaivanshi Rajputs** from whose thirty six forts (Chhattisgarh) it derives its name.
- The basin is laid with nearly horizontal beds of limestone and shales.
- The general elevation of the plain ranges from 250 m in the east to 330 m in the west.

Hills of Peninsular India: Aravalis, Vindhyas, Satpurus, Western & Eastern Ghats

Aravali Range

- They are aligned in north-east to south-west direction.
- They run for about 800 km between **Delhi** and Palanpur in **Gujarat**.
- They are one of the **oldest (very old) fold mountains** of the world and the oldest in India. {Fold Mountains – Block Mountains}
- After its formation in Archaean Era (several 100 million years ago), its summits were nourishing glaciers and several summits were probably higher than the present day Himalayas.
- Now they are relict (remnants after severe weathering and erosion since millions of years) of the world's oldest mountain formed as a result of folding (Archaean Era).
- They continue up to **Hariddwar** buried under the alluvium of Ganga Plains.
- The range is conspicuous in Rajasthan (continuous range south of Ajmer where it rises to 900 m.) but becomes less distinct in Haryana and Delhi (characterized by a chain of detached and discontinuous ridges beyond Ajmer).
- According to some geographers, one Branch of the Aravalis extends to the Lakshadweep Archipelago through the Gulf of Khambhat and the other into Andhra Pradesh and Karnataka.
- Its general elevation is only 400-600 m, with few hills well above 1,000 m.
- At the south-west extremity the range rises to over 1,000 m. Here **Mt. Abu (1,158 m)**, a small hilly block, is separated from the main range by the **valley of the Banas**. **Guru Sikhar (1,722 m)**, the highest peak, is situated in Mt. Abu.
- **Pipli Ghat**, Dewair and Desuri passes allow movement by roads and railways.

Vindhyan Range

- The Vindhyan Range, overlooking (have a view of from above) the Narmada valley, rises as an escarpment (a long, steep slope at the edge of a plateau or separating areas of land at different heights) flanking (neighboring on one side) the northern edge of the Narmada-Son Trough (the rift through which the Narmada river flows)(trough is opposite of ridge. It is a narrow depression).
- It runs more or less parallel to the **Narmada Valley** in an east-west direction from Jobat in Gujarat to Sasaram in Bihar for a distance of over 1,200 km.
- The general elevation of the Vindhyan Range is 300 to 650 m.
- Most parts of the Vindhyan Range are composed of horizontally bedded sedimentary rocks of ancient age. {Rock System}
- The Vindhyan Range continues eastwards as the **Bhander** and **Kaimur hills**.
- This range acts as a watershed between the Ganga system and the river systems of south India.
- The rivers **Chambal**, **Betwa** and **Ken** rise within 30 km of the Narmada.

Satpura Range

- Satpura range is a series of seven mountains ('Sat' = seven and 'pura' = mountains)
- It runs in an east-west direction south of the Vindhyan Range and in between the Narmada and the Tapi, roughly parallel to these rivers.
- It stretches for a distance of about 900 km.
- Parts of the Satpuras have been folded and upheaved. They are regarded as structural uplift or '**horst**'.
- **Dhupgarh (1,350 m)** near **Pachmarhi on Mahadev Hills** is the highest peak.
- **Amarkantak (1,127 m)** is another important peak.

Western Ghats (or the Sahyadris)

- They form the western edge of the Deccan tableland.
- Run from the Tapi valley (21° N latitude) to a little north of Kanniyakumari (11° N latitude) for a distance of 1,600 km.
- The Western Ghats are steep-sided, terraced, flat-topped hills presenting a stepped topography facing the Arabian Sea coast.
- This is due to the horizontally bedded lavas, which on weathering, have given a characteristic '**landing stair aspect**' to the relief of this mountain chain.
- The Western Ghats abruptly rise as a sheer wall to an average elevation of 1,000 m from the Western Coastal Plain.
- But they slope gently on their eastern flank and hardly appear to be a mountain when viewed from the Deccan tableland.
- South of Malabar, the Nilgiris, Anamalai, etc. present quite different landscape due to the difference in geological structure.

The northern section

- The northern section of the Ghats from Tapi valley to a little north of Goa is made of horizontal sheets of **Deccan lavas (Deccan Traps)**.
- The average height of this section of the Ghats is 1,200 m above mean sea level, but some peaks attain more heights.

- **Kalasubai (1,646 m)** near Igatpuri, Salher (1,567 m) about 90 km north of Nashik, Mahabaleshwar (1,438 m) and Harishchandragarh (1,424 m) are important peaks.
- Thal ghat and Bhor ghat are important passes which provide passage by road and rail between the **Konkan Plains** in the west and the Deccan Plateau in the east.

[Konkan coast = Maharashtra coast and Goa coast; Malabar Coast = Kerala and Karnataka coast]

The Middle Sahyadri

- The Middle Sahyadri runs from 16°N latitude upto Nilgiri hills.
- This part is made of granites and gneisses.
- This area is covered with **dense forests**.
- The western scarp is considerably dissected by headward erosion of the west flowing streams.
- The average height is 1200 m but many peaks exceed 1500 m.
- The **Vavul Mala (2,339 m)**, the **Kudremukh (1,892 m)** and **Pashpagiri (1,714 m)** are important peaks.
- The Nilgiri Hills which join the Sahyadris near the trijunction of Karnataka, Kerala and TN, rise abruptly to over 2,000 m.
- They mark the junction of the Western Ghats with Eastern Ghats.
- **Doda Betta (2,637 m)** and **Makurti (2,554 m)** are important peaks of this area.

The southern section

- The southern part of the Western Ghats is separated from the main Sahyadri range by **Pal ghat Gap [Palakkad Gap]**.
- The high ranges terminate abruptly on either side of this gap.
- **Pal ghat Gap** it is a **rift valley**. This gap is used by a number of roads and railway lines to connect the plains of Tamil Nadu with the coastal plain of Kerala.
- It is through this gap that moist-bearing clouds of the south-west monsoon can penetrate some distance inland, bringing rain to Mysore region.
- South of the Pal ghat Gap there is an intricate system of steep and rugged slopes on both the eastern and western sides of the Ghats.
- **Anai Mudi (2,695 m)** is the highest peak in the whole of southern India.
- Three ranges radiate in different directions from Anai Mudi. These ranges are the **Anaimalai (1800-2000 m)** to the north, the **Palani (900-1,200 m)** to the north-east and the **Cardamom Hills** or the **Ealaimalai** to the south.

Eastern Ghats

- Eastern Ghats run almost parallel to the east coast of India leaving broad plains between their base and the coast.
- It is a chain of highly broken and detached hills starting from the **Mahanadi** in Odisha to the **Vagaiin** Tamil Nadu. They almost disappear between the Godavari and the Krishna.
- They neither have structural unity nor physiographic continuity. Therefore these hill groups are generally treated as independent units.
- It is only in the northern part, between the Mahanadi and the Godavari that the Eastern Ghats exhibit true mountain character. This part comprises the **Maliya** and the **Madugula Konda** ranges.
- The peaks and ridges of the Maliya range have a general elevation of 900-1,200 m and **Mahendra Giri (1,501 m)** is the tallest peak here.

- The Madugula Konda range has higher elevations ranging from 1,100 m and 1,400 m with several peaks exceeding 1,600 m. **Jindhagada Peak (1690 m)** in Araku Valley **Arma Konda (1,680 m)**, **Gali Konda (1,643 m)** and **Sinkram Gutta (1,620 m)** are important peaks.
- Between the Godavari and the Krishna rivers, the Eastern Ghats lose their hilly character and are occupied by **Gondwana formations** (KG Basin is here).
- The Eastern Ghats reappear as more or less a continuous hill range in Cuddapah and Kurnool districts of Andhra Pradesh where they are called as **Nallamalai Range** [Naxalite hideout in AP] with general elevation of 600-850 m.
- The southern part of this range is called the **Palkodna range**.
- To the south, the hills and plateaus attain very low altitudes; only **Javadi Hills** and the **Shevroy-Kalrayan Hills** form two distinct features of 1,000 m elevation.
- The **Biligiri Rangan Hills** in Karnataka (at its border with Tamil Nadu) attain a height of 1,279 m.
- Further south, the Eastern Ghats merge with the Western Ghats.

Significance of the Peninsular Plateau

- There are huge deposits of iron, manganese. Copper, bauxite, chromium, mica, gold, etc.
- 98 per cent of the Gondwana coal deposits of India are found in the Peninsular Plateau.
- Besides there are large reserves of slate, shale, sandstones, marbles, etc.
- A large part of north-west plateau is covered with fertile black lava soil which is extremely useful for growing cotton.
- Some hilly regions in south India are suitable for the cultivation of plantation crops like **tea, coffee, rubber, etc.**
- Some low lying areas of the plateau are suitable for growing rice.
- The highlands of the plateau are covered with different types of forests which provide a large variety of forest products.
- The rivers originating in the Western Ghats offer great opportunity for developing hydroelectricity and providing irrigation facilities to the agricultural crops.
- The plateau is also known for its hill resorts such as **Udagamangalam (Ooty), Panchmarhi, Kodaikanal, Mahabaleshwar, Khandala, Matheron, Mount Abu**, etc.

Coastal Plains of India

- India has a coastline of **7516.6 Km** [**6100 km of mainland coastline + coastline of 1197 Indian islands**] touching 13 States and Union Territories (UTs).
- The straight and regular coastline of India is the result of faulting of the Gondwanaland during the Cretaceous period. {**Continental Drift**}
- As such the coast of India **does not offer many sites for good natural harbours.**
- **Indented coastlines of Europe provide good natural harbours whereas African and Indian coastlines are not indented.**
- The Bay of Bengal and the Arabian Sea came into being during the **Cretaceous or early Tertiary period after the disintegration of Gondwanaland.**

East Coast of India

- Lies between the Eastern Ghats and the Bay of Bengal.

- It extends from the Ganga delta to Kanniyakumari.
- It is marked by deltas of rivers like the Mahanadi, the Godavari, the Krishna and the Cauvery.
- **Chilka Lake** and the **Pulicat Lake (lagoon)** are the important geographical features of east coast.

Regional Names of the East Coast of India

- In Orissa (Odisha) it is known as **Utkal coast**.
- From the southern limit of the Utkal plain, stretch the **Andhra coast**.
- In the south of the Andhra plain is the **Tamil Nadu coast**.
- The Tamil Nadu coast and parts of Andhra coast together are known as **Coramandal Coast** or **Payan Ghat** [False Divi Point in AP (Krishna River Delta) in the north to Kanyakumari in the south.].

West Coast of India

- The west coast strip extends from the **Gulf of Cambay (Gulf of Khambhat)** in the north to **Cape Comorin** (Kanniyakumari).
- Starting from north to south, it is divided into (i) the **Konkan coast**, (ii) the **Karnataka coast** and (iii) the **Kerala coast**.
- It is made up of alluvium brought down by the **short streams** originating from the Western Ghats.
- It is dotted with a large number of **coves (a very small bay)**, **creeks (a narrow, sheltered waterway such as an inlet in a shoreline or channel in a marsh)** and **a few estuaries**. {Marine Landforms}
- The **estuaries, of the Narmada and the Tapi** are the major ones.
- The Kerala coast (**Malabar Coast**) has some **lakes, lagoons and backwaters**, the largest being the **Vembanad Lake**.

Regional Names of the West Coast of India

- Konkan coast = Maharashtra coast and Goa coast;
- Malabar Coast = Kerala and Karnataka coast.

Coastlines

Already explained in Marine Landforms. I am discussing here for continuity.

1. Coastline of Emergence
2. Coastline of Submergence

Coastlines of Emergence and Submergence

- Coastline of emergence is formed either by an uplift of the land or by the lowering of the sea level. Coastline of submergence is an exact opposite case.
- **Bars, spits, lagoons, salt marshes, beaches, sea cliffs and arches** are the typical features of emergence. {Marine Landforms}
- The east coast of India, especially its south-eastern part (Tamil Nadu coast), appears to be a coast of emergence.
- The west coast of India, on the other hand, is both emergent and submergent.
- The northern portion of the coast is submerged as a result of faulting and the southern portion, that is the Kerala coast, is an example of an emergent coast.

1. **Coramandal coast (Tamil Nadu) ==> Coastline of emergence**

2. Malabar coast (Kerala Coast) ==> Coastline of emergence
3. Konkan coast (Maharashtra and Goa Coast) ==> Coastline of submergence.

Western Coastal Plains of India

- Rann of Kachchh in the north to Kanniyakumari in the South.
- These are **narrow plains** with an average width of about **65 km**.

Kutch and Kathiawar region

- Kutch and Kathiawar, though an extension of Peninsular plateau (because Kathiawar is made of the Deccan Lava and there are tertiary rocks in the Kutch area), they are still treated as integral part of the Western Coastal Plains as they are now levelled down.
- The Kutch Peninsula was an island surrounded by seas and lagoons. These seas and lagoons were later filled by sediment brought by the Indus River which used to flow through this area. Lack of rains in recent times has turned it into arid and semi-arid landscape.
- Salt-soaked plain to the north of Kutch is the **Great Rann**. Its southern continuation, known as the **Little Rann** lies on the coast and south-east of Kachchh.
- The Kathiawar Peninsula lies to the south of the Kachchh. The central part is a highland of **Mandav Hills** from which small streams radiate in all directions (**Radial Drainage**). **Mt. Girnar (1,117 m)** is the highest point and is of volcanic origin.
- The **Gir Range** is located in the southern part of the Kathiawar peninsula. It is covered with dense forests and is famous as home of the **Gir lion**.

Gujarat Plain

- The Gujarat Plain lies east of Kachchh and Kathiawar and slopes towards the west and south west.
- Formed by the rivers **Narmada, Tapi, Mahi** and **Sabarmati**, the plain includes the southern part of Gujarat and the coastal areas of the Gulf of Khambhat.
- The eastern part of this plain is fertile enough to support agriculture, but the greater part near the coast is covered by windblown loess (heaps of sand).

Konkan Plain

- The Konkan Plain south of the Gujarat plain extends from Daman to Goa (50 to 80 km wide).
- It has some features of marine erosion including cliffs, shoals, reefs and islands in the Arabian Sea.
- The **Thane creek** around Mumbai is an important embayment (a recess in a coastline forming a bay) which provides an **excellent natural harbour**.

Karnataka Coastal Plain

- Goa to Mangalore. It is a **narrow plain** with an average width of 30-50 km, the maximum being 70 km near Mangalore.
- At some places the streams originating in the Western Ghats descend along steep slopes and make waterfalls.
- The **Sharavati** while descending over such a steep slope makes an impressive waterfall known as **Gersoppa (Jog) Falls** which is **271 m high**. [**Angel falls** (979 m) in Venezuela is the highest waterfall on earth. **Tugela Falls** (948 m) in Drakensberg Mountains in South Africa is the second highest.]
- Marine topography is quite marked on the coast.

Kerala Plain

- The Kerala Plain also known as the **Malabar Plain**.
- Between Mangalore and Kanniyakumari.
- This is much **wider** than the Karnataka plain. It is a low lying plain.
- The existence of lakes, lagoons, backwaters, spits, etc. is a significant characteristic of the Kerala coast.
- The backwaters, locally known as **kayals** are the shallow **lagoons or inlets** of the sea, lying parallel to the coastline.
- The largest among these is the **Vembanad Lake** which is about 75 km long and 5-10 km wide and gives rise to a 55 km long spit {Marine Landforms}.

Eastern Coastal Plains of India

- Extending from the **Subarnarekha** River along the West Bengal-Odisha border to Kanniyakumari.
- A major part of the plains is formed as a result of the alluvial fillings of the littoral zone (relating to or on the shore of the sea or a lake) by the rivers Mahanadi, Godavari, Krishna and Cauvery comprising some of the largest deltas.
- In contrast to the West Coastal Plains, these are **extensive plains** with an average width of 120 km.
- This plain is known as the **Northern Circars** between the Mahanadi and the Krishna rivers and **Carnatic** between the Krishna and the Cauvery rivers.

Utkal Plain

- The Utkal Plain comprises coastal areas of Odisha.
- It includes the Mahanadi delta.
- The most prominent physiographic feature of this plain is the **Chilka Lake**.
- It is the **biggest lake** in the country and its area varies between 780 sq km in winter to 1,144 sq km in the monsoon months.
- South of Chilka Lake, low hills dot the plain.

Andhra Plain

- South of the Utkal Plain and extends upto **Pulicat Lake**. This lake has been barred by a long sand spit known as **Sriharikota Island** (ISRO launch facility).
- The most significant feature of this plain is the delta formation by the rivers Godavari and Krishna.
- The two deltas have merged with each other and formed a single physiographic unit.
- The combined delta has advanced by about 35 km towards the sea during the recent years. This is clear from the present location of the **Kolleru Lake** which was once a lagoon at the shore but now lies far inland {Coastline of Emergence}.
- This part of the plain has a straight coast and badly lacks good harbours with the exception of **Vishakhapatnam** and **Machilipatnam**.

Tamil Nadu Plain

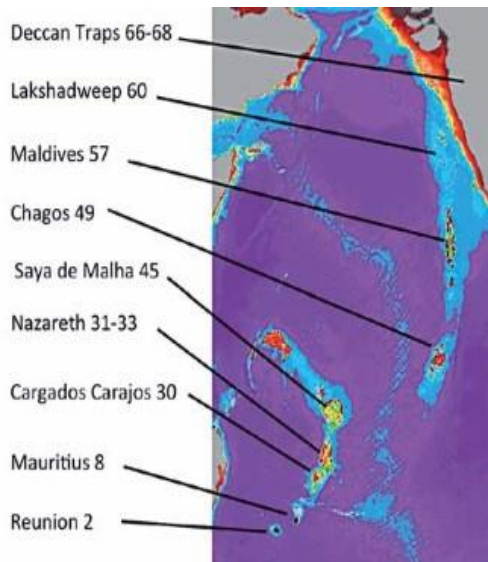
- The Tamil Nadu Plain stretches for 675 km from Pulicat Lake to Kanniyakumari along the coast of Tamil Nadu. Its average width is 100 km.
- The most important feature of this plain is the Cauvery delta where the plain is 130 km wide.
- The fertile soil and large scale irrigation facilities have made the Cauvery delta the granary of South India.

Significance of the Coastal Plains

- Large parts of the coastal plains of India are covered by fertile soils on which different crops are grown. Rice is the main crop of these areas.
- Coconut trees grow all along the coast. The entire length of the coast is dotted with big and small ports which help in carrying out trade.
- The sedimentary rocks of these plains are said to contain large deposits of mineral oil (KG Basin).
- The sands of Kerala coast have large quantity of **MONAZITE** which is used for **nuclear power**.
- Fishing is an important occupation of the people living in the coastal areas.
- Low lying areas of Gujarat are famous for producing salt. Kerala backwaters are important tourist destinations.
- Goa provides good beaches. This is also an important tourist destination.

Indian Islands

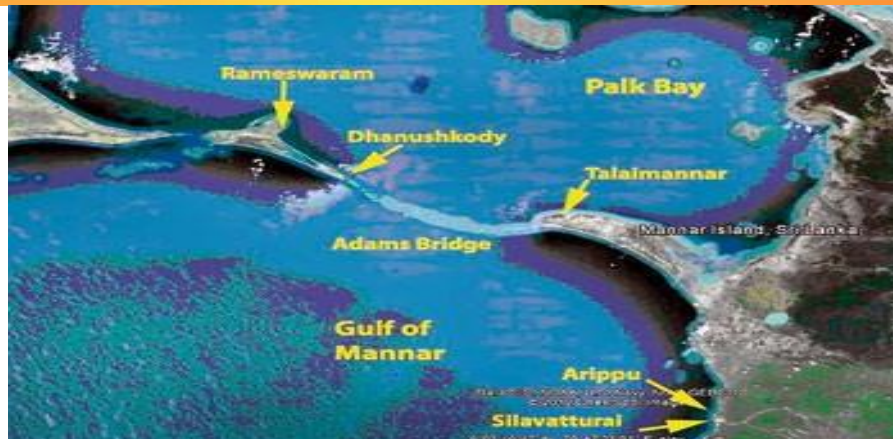
The major islands groups of India are Andaman and Nicobar Archipelago (A chain of islands similar in origin) in Bay of Bengal and Lakshadweep islands in Arabian Sea.



- Andaman and Nicobar Islands were formed due to collision between Indian Plate and Burma Minor Plate [part of Eurasian Plate] [Similar to formation of Himalayas].
- Andaman and Nicobar Islands are southward extension of Arakan Yoma range [Myanmar] [Arakan Yoma in itself is an extension of Purvanchal Hills].
- Lakshadweep Islands are coral islands. These islands are a part Reunion Hotspot volcanism. [Both these concepts are explained in previous posts]
- Other than these two groups there are islands in Indo-Gangetic Delta [they are more a part of delta than islands] and between India and Sri Lanka [Remnants of Adams Bridge or Rama's Bridge or Rama Setu; formed due to submergence].

Andaman and Nicobar Islands

This archipelago is composed of 265 big and small islands [203 Andaman Islands + 62 Nicobar Islands] [Numbers are just for understanding. You need not remember trivial facts]. The Andaman and Nicobar islands extend from 6° 45' N to 13° 45' N and from 92° 10' E to 94° 15' E for a distance of about 590 km.



- The Andaman Islands are divided into three main islands i.e. **North, Middle and South**.
- **Duncan passage** separates Little Andaman from South Andaman.
- The Great Andaman group of islands in the north is separated by the **Ten Degree Channel** from the Nicobar group in the south [*Prelims 2014*].
- **Port Blair**, the capital of Andaman Nicobar Islands lies in the South Andaman.
- Among the Nicobar Islands, the **Great Nicobar** is the largest. It is the southernmost island and is very close to Sumatra island of Indonesia. The **Car Nicobar** is the northernmost.
- Most of these islands are made of tertiary sandstone, limestone and shale resting on basic and ultrabasic volcanoes [Similar to Himalayas].
- **THE BARREN AND NARCONDAM ISLANDS**, north of Port Blair, are **volcanic islands** [these are the only active volcanoes in India][There are no active volcanoes in main land India].
- Some of the islands are fringed with **coral reefs**. Many of them are covered with thick forests. Most of the islands are mountainous.
- **Saddle peak (737 m)** in **North Andaman** is the highest peak.



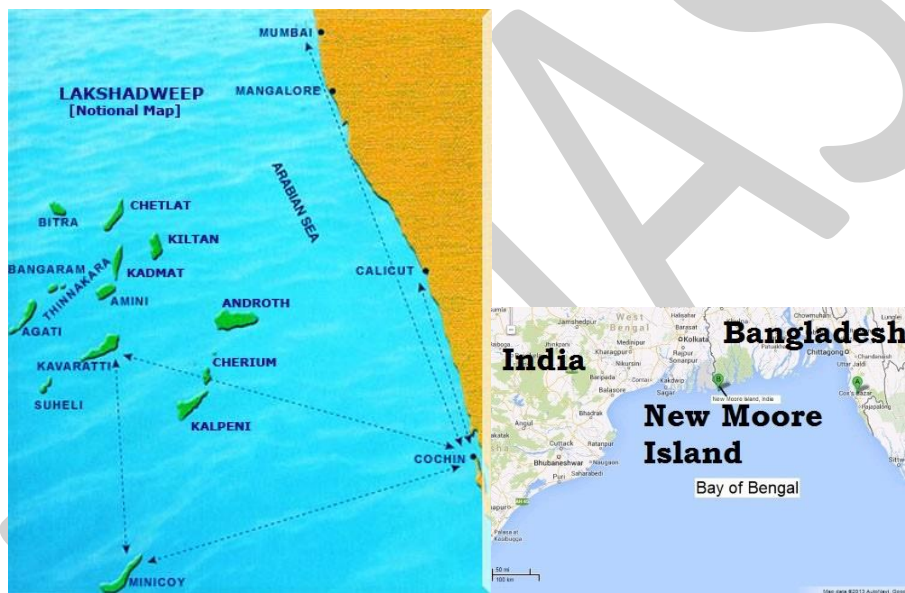
Lakshadweep Islands

In the Arabian Sea, there are three types of islands.

1. **Amindivi Islands** (consisting of six main islands of Amini, Keltan, Chetlat, Kadmat, Bitra and Perumul Par). [*don't have to remember all these names*]
2. **Laccadive Islands** (consisting of five major islands of Androth, Kalpeni, **Kavaratti**, Pitti and Suheli Par) and
3. **Minicoy Island**.

At present these islands are collectively known as Lakshadweep.

- The Lakshadweep Islands are a group of 25 small islands.
- They are widely scattered about 200-500 km south-west of the Kerala coast.
- **Amendivi Islands** are the northern most while the **Minicoy Island is the southernmost**.
- All are tiny islands of coral origin {Atoll} and are
- Surrounded by **fringing reefs**.
- The largest and the most advanced is the Minicoy Island with an area of 4.53 sq km.
- Most of the islands have low elevation and do not rise more than five meter above sea level (Extremely Vulnerable to sea level change).
- Their topography is flat and relief features such as hills, streams, valleys, etc. are absent.



- The largest and the most advanced is the **Minicoy Island** with an area of 4.53 sq km.
- Most of the islands have low elevation and do not rise more than five metre above sea level (Extremely Vulnerable to sea level change).
- Their topography is flat and relief features such as hills, streams, valleys, etc. are **absent**.

New Moore Island

- It is a small uninhabited offshore sandbar landform {Marine Landforms} in the Bay of Bengal, off the coast of the Ganges-Brahmaputra Delta region.
- It emerged in the Bay of Bengal in the aftermath of the **Bhola cyclone in 1970**. It keeps on emerging and disappearing.
- Although the island was uninhabited and there were no permanent settlements or stations located on it, both **India and Bangladesh claimed sovereignty over it because of speculation over the existence of oil and natural gas in the region**.
- The issue of sovereignty was also a part of the larger dispute over the **Radcliffe Award** methodology of settling the maritime boundary between the two nations.

Classification of Drainage Systems of India

Contribution of Water by Various Rivers

River	% Contribution of water
Brahmaputra	~ 40
Ganga	~ 25
Godavari	~ 6.4
Mahanadi	~ 3.5
Krishna	~ 3.4
Narmada	~ 2.9
Rest	~ 20

Classification of Drainage Systems of India

Drainage Systems Based on the Size of the Catchment Area

Division	Size of catchment area in sq km
Major river	20,000
Medium river	20,000 – 2,000
Minor river	2,000 and below

Drainage Systems Based on Origin

The Himalayan Rivers: **Perennial rivers**: Indus, the Ganga, the Brahmaputra and their tributaries. The Peninsular Rivers: **Non-Perennial rivers**: Mahanadi, the Godavari, the Krishna, the Cauvery, the Narmada and the Tapi and their tributaries.

Drainage Systems Based on the Type of Drainage

The river systems of India can be classified into four groups viz.

- Himalayan rivers, Deccan Rivers and Coastal Rivers that drain into the sea.
- Rivers of the inland drainage basin (**endorheic basin**). Streams like the Sambhar in western Rajasthan are mainly seasonal in character, draining into the inland basins and salt lakes. In the Rann of Kutch, the only river that flows through the salt desert is the Luni.

Drainage Systems Based on Orientation to the sea

- The Bay of Bengal drainage (Rivers that drain into Bay of Bengal)(East flowing rivers)
- Arabian Sea drainage (Rivers that drain into Arabian Sea) (West flowing rivers).
- The rivers Narmada (India’s holiest river) and Tapti flow almost parallel to each other but empty themselves in opposite directions (West flowing). The two rivers make the valley rich in alluvial soil and **teak forests** cover much of the land.

The Bay of Bengal drainage	Arabian Sea drainage
Rivers that drain into Bay of Bengal	Rivers that drain into Arabian sea
East flowing rivers	West flowing rivers
~ 77 per cent of the drainage area of the country is oriented towards the Bay of Bengal	~ 23 per cent of the drainage area of the country is oriented towards the Arabian sea
The Ganga, the Brahmaputra, the Mahanadi, the Godavari, the Krishna, the Cauvery, the Penneru, the Penneyar, the Vaigai, etc.	The Indus, the Narmada , the Tapi , the Sabarmati , the Mahi and the large number of swift flowing western coast rivers descending from the Sahyadris.

The area covered by The Bay of Bengal drainage and Arabian Sea drainage are not proportional to the amount of water that drains through them. **Over 90 per cent of the water drains into the Bay of Bengal; the rest is drained into the Arabian Sea or forms inland drainage.**

Lop sided distribution

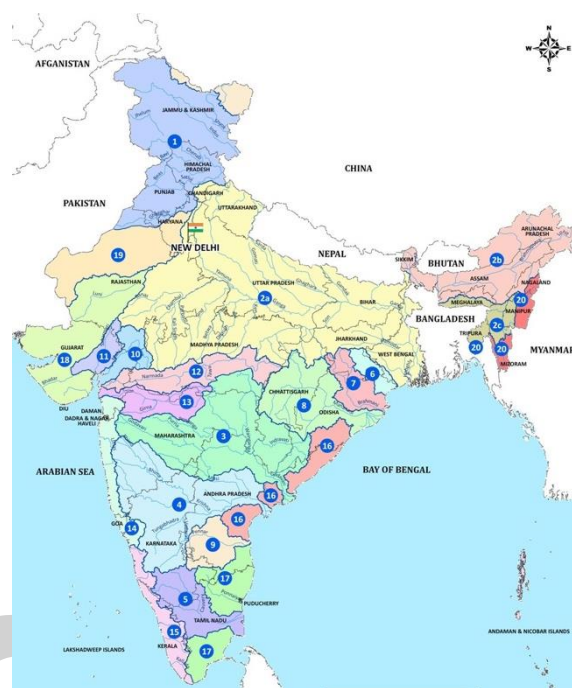
- The Arabian Sea drainage or Western drainage receive less rainfall [Rajasthan, Haryana and Punjab receive very low rainfall].
- The Eastern drainage or the Bay of Bengal drainage receives rainfall both from South-west and North-east monsoons.
- Most of the Himalayan waters (perennial rivers) flow into eastern drainage (Ganges and Brahmaputra).
- Indian Rivers that flow into Arabian Sea are seasonal or non-perennial (Luni, Narmada, etc.).
- Occurrence of more cyclonic rainfall in the eastern parts is another major reason.

Major River System or Drainage Systems in India

Himalayan River systems: Indus River System, Brahmaputra River System, Ganga River System.

Peninsular River Systems: Godavari River System, Krishna River System, Cauvery River System, Mahanadi River System.

West Flowing Peninsular River Systems: Narmada River System, Tapi River System.



The names of the basins along with their id and area are given in the table.

Sl. No	Basin Code	Basin Name	Area (sq.km)	Rank
1	1	Indus (Up to border)	3,21,289	3
2	2A	Ganga	8,61,452	1
3	2B	Brahmaputra	1,94,413	6
4	2C	Barak and others	41,723	
5	3	Godavari	3,12,812	4
6	4	Krishna	2,58,948	5

7	5	Cauvery	81,155	11
8	6	Subernarekha	29,196	
9	7	Brahmani and Baitarni	51,822	
10	8	Mahanadi	1,41,589	7
11	9	Pennar	55,213	
12	10	Mahi	34,842	
13	11	Sabarmati	21,674	
14	12	Narmada	98,796	9
15	13	Tapi (Tapti)	65,145	12
16	14	West flowing rivers from Tapi to Tadri	55,940	
17	15	West flowing rivers from Tadri to Kanyakumari	56,177	
18	16	East flowing rivers between Mahanadi and Pennar	86,643	10
19	17	East flowing rivers between Pennar and Kanyakumari	1,00,139	8
20	18	West flowing rivers of Kutch and Saurashtra including Luni	3,21,851	2
21	19	Area of inland drainage in Rajasthan		
22	20	Minor rivers draining into Myanmar & Bangladesh	36,202	

Indus River System

- The Indus, the Ganga and the Brahmaputra comprise the Himalayan river systems.
- The Himalayan Rivers existed even before the formation of Himalayas i.e. before the **collision of Indian Plate with the Eurasian plate**. {Antecedent Drainage}
- They were flowing into the **Tethys Sea**. These rivers had their source in the now **Tibetan region**.

- The **deep gorges** of the Indus, the Satluj, and the Brahmaputra etc. clearly indicate that these rivers are **older than the Himalayas**.
- They continued to flow throughout the building phase of the Himalayas; their banks rising steeply while the beds went lower and lower due to vertical erosion (Vertical down cutting was significant and was occurring at a rate faster than the rising of Himalayas), thus cutting deep gorges.
- Thus, many of the Himalayan Rivers are typical examples of **antecedent drainage**.

Sindhu	Sanskrit	
Sinthos	Greek	
Sindus	Latin	
Major Rivers of Indus River System	Source	Length
Indus	Glaciers of Kailas Range (Close to Manasarovar Lake)	2880 km total. 710 km in India
Jhelum	Verinag	720 km
Chenab	Bara Lacha Pass	1180 km
Ravi	Near Rohtang Pass	725 km
Beas	Near Rohtang Pass	460 km
Satluj	Manasarovar-Rakas Lakes	1450 km total
	List of important passes given in previous posts	1050 km in India

Indus River

- India got her name from Indus.
- 'The Indus Valley Civilization' was born around this river.
- It flows in north-west direction from its source (**Glaciers of Kailas Range** – Kailash range in Tibet near Lake Manasarovar) till the **Nanga Parbhat** Range.
- Its length is about 2,900 km. Its total drainage area is about 1,165,000 square km [more than half of it lies in semiarid plains of Pakistan]. It is joined by **Dhar River** near Indo-China border.
- After entering J&K it flows between the **Ladakh** and the **Zaskar Ranges**. It flows through the regions of Ladakh, Baltistan and Gilgit.
- The **gradient of the river in J&K is very gentle** (about 30 cm per km).

- Average elevation at which the Indus flows through JK is about **4000 m** above sea level.
- It is joined by the **Zaskar River at Leh** (these kind of points are important for prelims).
- Near **Skardu**, it is joined by the **Shyok** at an elevation of about 2,700 m.
- The **Gilgit, Gartang, Dras, Shiger, Hunza** are the other Himalayan tributaries of the Indus.
- It crosses the Himalayas (ends its mountainous journey) through a 5181 m deep gorge near **Attock**, lying north of the **Nanga Parbat**. It takes a sharp southerly bend here (**syntaxial bend**).
- **Kabul River** from Afghanistan joins Indus near **Attock**. Thereafter it flows through the **Potwar plateau** and crosses the **Salt Range** (South Eastern edge of Potwar Plateau).
- Some of the important tributaries below Attock include the **Kurram, Toch** and the **Zhob-Gomal**.
- Just above **Mithankot**, the Indus receives from **Panjnad (Panchnad)**, the accumulated waters of the five eastern tributaries—the Jhelum, the Chenab, the Ravi, the Beas and the Satluj.
- The river empties into the Arabian Sea south of **Karachi** after forming a huge delta.



Major Tributaries of Indus River

Jhelum River

- The Jhelum has its source in a **spring at Verinag** in the south-eastern part of the **Kashmir Valley**.
- It flows northwards into **Wular Lake** (north-western part of Kashmir Valley). From Wular Lake, it changes its course southwards. At **Baramulla** the river enters a gorge in the hills.
- The river forms steep-sided narrow gorge through **Pir Panjal Range** below **Baramulla**.
- At **Muzaffarabad**, the river takes a sharp hairpin bend southward.
- Thereafter, it forms the India-Pakistan boundary for 170 km and emerges at the Potwar Plateau near Mirpur.
- After flowing through the spurs of the Salt Range it **debouches (emerge from a confined space into a wide, open area)** on the plains near the city of Jhelum.
- It joins the Chenab at **Trimmu**.
- The river is **navigable for about 160 km** out of a total length of 724 km.

Chenab River

- The Chenab originates from near the **Bara Lacha Pass** in the **Lahul-Spiti** part of the **Zaskar Range**.
- Two small streams on opposite sides of the pass, namely **Chandra** and **Bhaga**, form its headwaters at an altitude of 4,900 m.
- The united stream **Chandrabhaga** flows in the north-west direction through the **Pangi valley**, parallel to the Pir Panjal range.
- Near **Kistwar**, it cuts a deep gorge.
- It enters the plain area near **Akhnur** in Jammu and Kashmir.
- From here it through the plains of Pakistani Punjab to reach Panchnad where it joins the **Satluj** after receiving the waters of Jhelum and Ravi rivers.

Ravi River

- The Ravi has its source in **Kullu hills** near the **Rohtang Pass** in Himachal Pradesh.
- It drains the area between the **Pir Panjal** and the **Dhaola Dhar ranges**.
- After crossing Chamba, it takes a south-westerly turn and cuts a deep gorge in the Dhaola Dhar range.
- It enters Punjab Plains near **Madhopur** and later enters Pakistan below Amritsar.
- It debouches into the Chenab a little above **Rangpur in Pakistani Punjab**.

Beas River

- The Beas originates near the **Rohtang Pass**, at a height of 4,062 m above sea level, on the **southern end of the Pir Panjal Range, close to the source of the Ravi**.
- It crosses the Dhaola Dhar range and it takes a south-westerly direction and meets the Satluj River at **Harike in Punjab**.
- It is a comparatively small river which is only 460 km long but **lies entirely within the Indian Territory**.

Satluj River

- The Satluj rises from the **Manasarovar-Rakas Lakes** in western Tibet at a height of 4,570 m within 80 km of the source of the Indus.
- Like the Indus, it takes a north-westerly course up to the Shipki La on the Tibet-Himachal Pradesh boundary.
- It cuts deep gorges where it pierces the Great Himalaya and the other Himalayan ranges.
- Before entering the Punjab plain, it cuts a gorge in Naina Devi Dhar, where the famous **Bhakra dam** has been constructed.
- After entering the plain at Rupnagar (Ropar), it turns westwards and is joined by the **Beas at Harike**.
- From near **Ferozpur to Fazilka** it forms the boundary between India and Pakistan for nearly 120 km.
- During its onward journey it receives the collective drainage of the Ravi, Chenab and Jhelum rivers. It joins the Indus a few kilometers above **Mithankot**.
- Out of its total length of 1,450 km, it flows for 1,050 km in Indian Territory.

Indus water treaty

- The waters of the Indus river system are shared by India and Pakistan according to the Indus Water Treaty signed between the two countries on **19th September, 1960**.
- According to this treaty, India can utilize only **20 per cent of its total discharge of water**.

Ganga-Brahmaputra River System

River	Source
Bhagirathi (Ganga)	Gangotri glacier
Yamuna	Yamnotri glacier on the Bandarpunch Peak
Chambal	Janapao Hills in the Vindhya Range
Banas	Aravali Range
Betwa	Bhopal district
Ken	Barner Range
Son	Amarkantak Plateau
Damodar ('Sorrow of Bengal')	Chotanagpur plateau
Ramganga River	Garhwal district of Uttarakhand
Ghaghra River	Gurla Mandhata peak, south of Manasarovar in Tibet (river of the trans-Himalayan origin)
The Kali River (border between Nepal and Uttarakhand)	Glaciers of trans-Himalayas
Gandak River	Tibet-Nepal border
Burhi Gandak	Sumesar hills near the India-Nepal border
Kosi ('Sorrow of Bihar')	Tumar, Arun and Sun Kosi unite at Triveni north of the Mahabharata Range to form the Kosi.

Ganga River

- The **Ganga** originates as **Bhagirathi** from the **Gangotri glacier** in Uttar Kashi District of Uttarakhand at an elevation of 7,010 m.
- **Alaknanda** River joins **Bhagirathi** at **Devaprayag**.
- **From Devaprayag the river is called as Ganga.**
- The Ganges was ranked as the fifth most polluted river of the world in 2007.
- Pollution threatens many fish species and amphibian species and the endangered Ganges river dolphin (Blind Dolphin).
- The Ganga Action Plan, an environmental initiative to clean up the river, has been a major failure thus far, due to corruption, lack of technical expertise, poor environmental planning, and lack of support from religious authorities.

Major tributaries of Alaknanda

- East Trisul (joins Alaknanda at Karan Prayag)
- Pindar (rises from Nanda Devi)
- Mandakini or Kali Ganga (joins Alaknanda at Rudra Prayag)
- Dhauliganga
- Bishenganga.

[Kishenganga is the tributary of Jhelum]

Major tributaries of Bhagirathi: Bheling

- Ganga **debouches** [emerge from a confined space into a wide, open area] from the hills into plain area
- It is joined by the **Yamuna** at **Allahabad**.
- Near Rajmahal Hills it turns to the south-east.
- At Farraka, it bifurcates into **Bhagirathi-Hugli** in **West Bengal** and **Padma-Meghna** in **Bangladesh** (it ceases to be known as the Ganga after Farraka).
- Brahmaputra (or the Jamuna as it is known here) joins Padma-Meghna at
- The total length of the Ganga River from its source to its mouth (measured along the Hugli) is 2,525 km.

Ganga – Brahmaputra Delta

- Before entering the Bay of Bengal, the Ganga, along with the Brahmaputra, forms the **largest delta of the world** between the **Bhagirathi/Hugli** and the **Padma/Meghna** covering an area of 58,752 sq km.
- The coastline of delta is a highly indented area.
- The delta is made of a web of distributaries and islands and is covered by dense forests called the
- A major part of the delta is a **low-lying swamp** which is flooded by marine water during high tide.

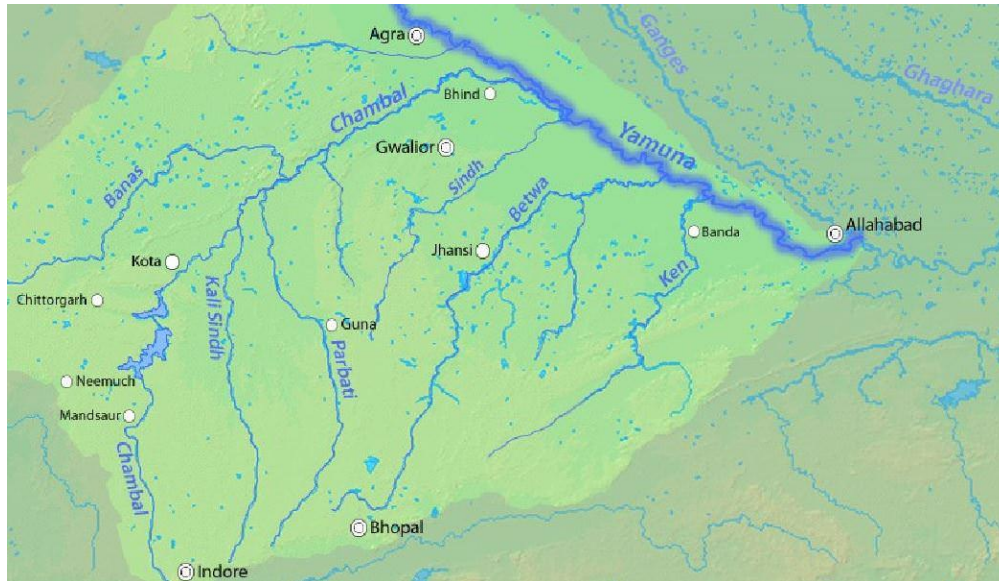
Right Bank Tributaries of the Ganga

Most of them **except Yamuna** originate in the peninsular region.

Yamuna River

- Largest and the most important tributary.
- It originates from the **Yamnotri glacier** on the **Bandarpunch Peak** in the Garhwal region in Uttarakhand at an elevation of about 6,000 meters.

- It cuts across the **Nag Tibba**, the **Mussoorie** and the Shivalik ranges.
- It emerges out of the hilly area and enters plains near
- Its main affluent in the upper reaches is the **Tons** which also rises from the **Bandarpunch glacier**.
- It joins Yamuna below Kalsi before the latter leaves the hills.
- At this site, the water carried by the Tons is twice the water carried by the Yamuna.



Non – Peninsular Tributaries

1. Rishiganga
2. Uma
3. Hanuman Ganga and
4. Tons join it in the mountains.
5. Hindon joins at Ghaziabad in the plain area

Peninsular Tributaries

Most of the Peninsular rivers flow into the Yamuna between Agra and Allahabad.

1. Chambal
2. Sind
3. Betwa
4. Ken.

- It unites with the Ganga near **Triveni Sangam, Allahabad**.
- The total length of the Yamuna from its origin till Allahabad is 1,376 km.
- It creates the highly fertile alluvial, **Yamuna-Ganges Doab** region between itself and the Ganges in the Indo-Gangetic plain.

Chambal River

- The Chambal rises in the highlands of **Janapao Hills** (700 m) in the **Vindhyan Range**.
- It flows through the **Malwa Plateau**.
- It joins the Yamuna in **Etawah district** of Uttar Pradesh.
- The river flows much below its banks due to severe erosion because of poor rainfall and numerous deep ravines have been formed in the Chambal Valley, giving rise to **badland topography**. {Arid Landforms}. The total length of the river is 1,050 km.

Dams on the Chambal

- **The Gandhi Sagar dam** is the first of the four dams built on the Chambal River, located on the Rajasthan-Madhya Pradesh border.
- **The Rana Pratap Sagar dam** is a dam located 52 km downstream of Gandhi Sagar dam on across the Chambal River in Chittorgarh district in Rajasthan.
- **The Jawahar Sagar Dam** is the third dam in the series of Chambal Valley Projects, located 29 km upstream of Kota city and 26 km downstream of Rana Pratap Sagar dam.
- **The Kota Barrage** is the fourth in the series of Chambal Valley Projects, located about 0.8 km upstream of Kota City in Rajasthan.
- Water released after power generation at Gandhi Sagar dam, Rana Pratap Sagar dam and Jawahar Sagar Dams, is diverted by Kota Barrage for irrigation in Rajasthan and in Madhya Pradesh through canals.
- Keoladeo National Park is supplied with water from Chambal river irrigation project.

Banas River

- The Banas is a tributary of the Chambal.
- It originates in the southern part of the **Aravali Range**.
- It join the Chambal on **Rajasthan – Madhya Pradesh border** near **Sawai Madhopur**.

Sind River

- The Sind originates in **Vidisha Plateau** of Madhya Pradesh.
- It flows for a distance of 415 km before it joins the Yamuna.

Betwa River

- The Betwa rises in **Bhopal district (Vindhyan Range)** and joins the Yamuna near
- It has a total length of 590 km.
- **The Dhasan** is its important tributary.

Ken River: The Ken River rising from the **Barner Range** of Madhya Pradesh joins the Yamuna near Chila.

Son River

- The Son River rises in the **Amarkantak Plateau**.
- Its source is close to the origin of the Narmada.
- It passes along the **Kaimur Range**.
- It joins the Ganga near Danapur in Patna district of Bihar.
- It flows for a distance of 784 km from its source.

- The important tributaries of the Son are the Johilla, the Gopat, the Rihand, the Kanhar and the North Koel. Almost all the tributaries **join it on its right bank**.

Damodar River

- The Damodar River rises in the hills of the **Chotanagpur plateau** and **flows through a rift valley**.
- Rich in mineral resources, the valley is home to large-scale mining and industrial activity.
- It has a number of tributaries and sub tributaries, such as **Barakar, Konar, Bokaro, Haharo, etc.**
- The **Barakar** is the most important tributary of the Damodar.
- Several dams have been constructed in the valley, for the generation of hydroelectric power. The valley is called **“the Ruhr of India”**.
- The first dam was built across the Barakar River, a tributary of the Damodar River.
- It used to cause devastating floods as a result of which it earned the name ‘Sorrow of Bengal’. Now the river is tamed by constructing numerous dams.
- It joins the **Hugli River** 48 km below Kolkata.
- The total length of the river is 541 km.

Left Bank Tributaries of the Ganga River

These rivers originate in the Himalayas. The major tributaries apart from the Yamuna, are **the Ramganga, the Gomati, the Ghaghra, the Gandak, the Burhi Gandak, the Bagmati, and the Kosi**.

Ramganga River

The Ramganga River rises in the **Garhwal** district of Uttarakhand. It enters the Ganga Plain near Kalagarh. The Khoh, the Gangan, the Aril, the Kosi, and the Deoha (Gorra) are important tributaries of Ramganga.

Ghaghra River

- Its source is near **Gurla Mandhata peak, south of Manasarovar in Tibet (river of the trans-Himalayan origin)**.
- It is known as the **Karnaili** in Western Nepal.
- Its important tributaries are the **Sarda, the Sarju (Ayodhya is located on its bank) and the Rapti**.
- The Ghaghara joins the Ganga a few kilometers downstream of Chhapra in Bihar.
- After reaching the plain area, its stream gets divided into many branches of which, Koriyab and Garwa are important.
- The river bed is sandy and sudden bends start occurring in the stream.
- The river has a high flood frequency and has shifted its course several times.

Kali River

Rises in the high glaciers of **trans-Himalaya**. It forms the boundary between **Nepal and Kumaon**. It is known as the **Sarda** after it reaches the plains near Tanakpur.

Gandak River

Originates near the Tibet-Nepal border at a height of 7,620 m. It receives a large number of tributaries in Nepal Himalaya. Its important tributaries are the **Kali Gandak, the Mayangadi, the Bari and the Trishuli**. It flows into Ganga at **Hajipur in Bihar**.

Burhi Gandak

Originates from the western slopes of **Sumesar hills near the India-Nepal border**. It joins the Ganga near Monghyr town.

Kosi River

- The Kosi river consists of seven streams namely **Sut Kosi, Tamba Kosi, Talkha, Doodh Kosi, Botia Kosi, Arun and Tamber** and is popularly known as
- These streams flow through **eastern Nepal** which is known as the **Sapt Kaushik region**.
- The sources of seven streams of the Kosi are located in snow covered areas which also receive heavy rainfall.
- Consequently, huge volume of water flows with tremendous speed.
- Seven streams mingle with each other to form three streams named the Tumar, Arun and Sun Kosi.
- They unite at **Triveni** north of the **Mahabharata Range** to form the Kosi.
- The river enters the Tarai of Nepal after cutting a narrow gorge in the Mahabharata Range.
- The joins the Ganga near
- Soon after debouching onto the plain the river becomes sluggish.
- Large scale deposition of eroded material takes place in the plain region.
- The river channel is braided and it shifts its course frequently. This has resulted in frequent devastating floods and has converted large tracts of cultivable land into waste land in Bihar. Thus the river is often termed as the **'Sorrow of Bihar'**.
- In order to tame this river, a barrage was constructed in 1965 near Hanuman Nagar in Nepal.
- Embankments for flood control have been constructed as a joint venture of India and Nepal.

Brahmaputra River System

Region	Name
Tibet	Tsangpo (meaning 'The Purifier')
China	Yarlung Zangbo Jianguin
Assam Valley	Dihang or Siong, South of Sadiya: Brahmaputra
Bangladesh	Jamuna River
	Padma River: Combined Waters of Ganga and Brahmaputra
	Meghana: From the confluence of Padma and Meghna [View image above]

- The Brahmaputra (meaning the son of Brahma). It is 2,900 km in length.

- Source: **Chemayungdung glacier (Kailas Range)** at an elevation of about 5,150 m. Its source is very close to the sources of Indus and Satluj.
- **Mariam La** separates the source of the Brahmaputra from the Manasarovar Lake.
- Brahmaputra flows eastwards in Southern Tibet for about 1,800 km.
- In Tibet it passes through the **depression formed by the Indus-Tsangpo Structure Zone** between the Great Himalayas in the south and the Kailas Range in the north.
- In spite of the exceptionally high altitude, the Tsangpo has a **gentle slope**. The river is sluggish and has a wide navigable channel for about 640 km.
- It receives a large number of tributaries in Tibet. The first major tributary is the Raga Tsangpo meeting the Tsangpo near **Lhatse Dzong**.
- The river Ngangchu flows through the trade Centre of Gyantse in the south and joins the main river.
- Towards the end of its journey in Tibet, its course abruptly takes a south ward turn around **Namcha Barwa (7,756 m) (Syntaxial Bend)**.
- Here it cuts across the eastern Himalaya through the **Dihang or Siang Gorge** and emerges from the mountains near **Sadiya** in the Assam Valley.
- Here it first flows under the name of Siong and then as the Dihang.
- In the north-eastern parts of Assam Valley, it is joined by two important tributaries viz, the **Dibang (or Sikang)** from the north and **Lohit from the south**.
- From Sadiya (Assam Valley) onwards, this mighty river is known as the
- The main streams merging with the Brahmaputra from the north are, Subansiri, Kameng, Dhansiri (north), Raidak, Tista etc.
- The Tista was a tributary of the Ganga prior to the floods of 1787 after which it diverted its course eastwards to join the Brahmaputra.
- The Brahmaputra has a **braided channel** (flow into shallow interconnected channels divided by deposited earth) for most of its passage through Assam where channels keep shifting. It carries a lot of silt and there is excessive meandering.
- The river is nearly 16 km wide at Dibrugarh and forms many islands, the most important of which is **MAJULI**. It is 90 km long and measures 20 km at its widest.
- With rainfall concentrated during the monsoon months only the river has to carry enormous quantities of water and silt which results in disastrous floods. The Brahmaputra is thus truly a **River of Sorrow**.
- The river is navigable for a distance of 1,384 km up to Dibrugarh from its mouth and serves as an excellent inland water transport route.
- Brahmaputra bends southwards and enters Bangladesh near Dhubri.
- It flows for a distance of 270 km in the name of **Jamuna river** and joins the Ganga at
- The united stream of the Jamuna and the Ganga flows further in the name of
- About 105 km further downstream, the Padma is joined on the left bank by the **Meghna**, originating in the mountainous region of Assam.
- From the confluence of Padma and Meghna, the combined river is known as the **Meghna** which makes a very broad estuary before pouring into the Bay of Bengal.

Himalayan River System vs. Peninsular River System

	The Himalayan River System	The Peninsular River System
	These rivets originate from the lofty Himalayan ranges and are named as the Himalayan rivers.	These rivers originate in the Peninsular Plateau and are named as Peninsular rivers.
Catchment-area	These rivers have large basins and catchment areas. The total basin area of the Indus, the Ganga and the Brahmaputra is 11.78, 8.61 and 5.8 lakh square kilometers respectively.	These rivers have small basins and catchment areas. The Godavari has the largest basin area of 3.12 lakh square kilometers only which is less than one-third the basin area of the Indus.
Valleys	The Himalayan rivers flow through deep V – shaped valleys called gorges. These gorges have been carved out by down cutting carried on side by side with the uplift of the Himalayas.	The Peninsular rivers flow in comparatively shallow valleys . These are more or less completely graded valleys. The rivers have little erosional activity to perform.
Drainage Type	These are examples of antecedent drainage .	These are examples of consequent drainage .
Water Flow	The Himalayan rivers are perennial in nature, i.e., water flows throughout the year in these rivers. These rivers receive water both from the monsoons and snow-melt. The perennial nature of these rivers makes them useful for irrigation.	The Peninsular rivers receive water only from rainfall and water flows in these rivers in rainy season only. Therefore, these rivers are seasonal or non-perennial . As such these rivers are much less useful for irrigation.
Stage	These rivers flow across the young fold mountains and are still in a youthful stage.	These rivers have been flowing in one of the oldest plateaus of the world and have reached maturity .
Meanders	The upper reaches of the Himalayan rivers are highly tortuous. When they enter the plains, there is a sudden reduction in the speed of flow of water. Under these circumstances these rivers form meanders and often shift their beds.	The hard rock surface and non-alluvial character of the plateau permits little scope for the formation of meanders . As such, the rivers of the Peninsular Plateau follow more or less straight courses .

Deltas and Estuaries

The Himalayan rivers form **big deltas** at their mouths. The Ganga-Brahmaputra delta is the largest in the world.

Some of the Peninsular rivers, such as the **Narmada** and the **Tapi** form **estuaries**.

Other rivers such as the Mahanadi, the Godavari, the Krishna and the Cauvery form **deltas**.

Several small streams originating from the Western Ghats and flowing towards the west enter the Arabian Sea without forming any delta.

East Flowing Peninsular Rivers

Mahanadi River, Godavari River, Krishna River, Kaveri (Cauvery) River, Pennar River, Subarnarekha River, Brahmani River, Sarada River, Ponnaiyar River, Vaigai River.

Mahanadi River

- The Mahanadi basin extends over states of Chhattisgarh and Odisha and comparatively smaller portions of Jharkhand, Maharashtra and Madhya Pradesh, draining an area of 1.4 lakh Sq.km.
- It is bounded by the Central India hills on the north, by the Eastern Ghats on the south and east and by the **Maikala range** on the west. The **Mahanadi ("Great River")** follows a total course of 560 miles (900 km).
- It has its source in the northern foothills of **Dandakaranya in Raipur District** of Chhattisgarh at an elevation of 442 m.
- The Mahanadi is one of the major rivers of the peninsular rivers, in water potential and **flood producing capacity**, it ranks second to the Godavari.
- Other small streams between the Mahanadi and the Rushikulya draining directly into the **Chilka Lake** also forms the part of the basin.
- The major part of basin is covered with agricultural land accounting to 54.27% of the total area.
- It is one of the **most-active silt-depositing** streams in the Indian subcontinent. After receiving the **Seonath River**, it turns east and enters Odisha state.
- At Sambalpur the **Hirakud Dam** (one of the largest dams in India) on the river has formed a man-made lake 35 miles (55 km) long.
- It enters the Odisha plains near Cuttack and enters the Bay of Bengal at False Point by several channels. **Puri**, at one of its mouths, is a famous pilgrimage site.



Tributaries of Mahanadi River

- Its upper course lies in the saucer-shaped basin called the '**Chhattisgarh Plain**'.
- This basin is surrounded by hills on the north, west and south as a result of which a large number of tributaries join the main river from these sides.
- Left bank Tributaries: The **Seonath**, the **Hasdeo**, the **Mand** and the **Ib**.
- Right bank Tributaries: The **Ong**, the **Tel** and the **Jonk**.

Projects on Mahanadi River

- Two important projects completed during pre-plan period in the basin are the **Mahanadi main canal** and **Tandula reservoir in Chhattisgarh**.
- During the plan period, the **Hirakud dam**, **Mahanadi delta project**, **Hasdeo Bango**, **Mahanadi Reservoir Project** were completed.

Industry in Mahanadi River Basin

- Three important urban centers in the basin are **Raipur**, **Durg** and **Cuttack**.
- Mahanadi basin, because of its **rich mineral resource** and **adequate power resource**, has a favorable industrial climate.
- The important industries presently existing in the basin are the **Iron and Steel plant at Bhilai**, **aluminium factories at Hirakud and Korba**, **paper mill near Cuttack** and **cement factory at Sundargarh**.
- Other industries based primarily on agricultural produce are sugar and textile mills. Mining of coal, iron and manganese are other industrial activities.

Floods in Mahanadi River Basin

- The basin is subject to **severe flooding** occasionally in the delta area due to inadequate carrying capacity of the channels.
- The multi-purpose **Hirakud dam** provides some amount of flood relief by storing part of flood water.
- However, the problem still persists and a lasting solution need to be evolved.

Godavari River

- The Godavari is the **largest river system of the Peninsular India** and is revered as **Dakshina Ganga**.
- The Godavari basin extends over states of Maharashtra, Andhra Pradesh, Chhattisgarh and Odisha in addition to smaller parts in Madhya Pradesh, Karnataka and Union territory of Puducherry (Yanam) having a total area of ~ 3 lakh Sq.km.
- The basin is bounded by **Satmala hills**, the **Ajanta range** and the **Mahadeo hills** on the north, by the Eastern Ghats on the south and the east and by the Western Ghats on the west.
- The Godavari River rises from **Trimbakeshwar in the Nashik district** of Maharashtra about 80 km from the Arabian Sea at an elevation of 1,067 m.
- The total length of Godavari from its origin to outfall into the Bay of Bengal is 1,465 km.



Tributaries of Godavari River

- The left bank tributaries are more in number and **larger** in size than the right bank tributaries.
- The **Manjra** (724 km) is the only important right bank tributary. It joins the Godavari after passing through the **Nizam Sagar**.
- **Left Bank Tributaries:** Dharna, Penganga, Wainganga, Wardha, Pranahita [conveying the combined waters of Penganga, the Wardha and Wainganga], Pench, Kanhan, Sabari, Indravati etc.
- **Right Bank Tributaries:** Pravara, Mula, Manjra, Peddavagu, Maner etc.
- Below Rajahmundry, the river divides itself into two main streams, the **Gautami Godavari** on the east and the **Vashishta Godavari** on the west and forms a large delta before it pours into the Bay of Bengal.
- The delta of the Godavari is of **lobate type** with a round bulge and many distributaries.

Mineral Resources in Godavari Basin

- The upper reaches of the Godavari drainage basin are occupied by the **Deccan Traps** containing minerals like **magnetite, epidote, biotite, zircon, chlorite** etc. (metallic minerals).
- The middle part of the basin is principally composed of **phyllites, quartzites, amphiboles and granites (rocks)**.
- The downstream part of the middle basin is occupied mainly by sediments and rocks of the **Gondwana group**.
- The Gondwanas are principally detrital (waste or debris, in particular organic matter produced by decomposition or loose matter produced by erosion) with some thick **coal seams**. [Singareni Coal Seam]
- The Eastern Ghats dominate the lower part of the drainage basin and are formed mainly from the **Khondalites**.

Projects on Godavari River

- Important projects completed during the plan period are **Srirama Sagar, Godavari barrage, Upper Penganga, Jaikwadi, Upper Wainganga, Upper Indravati, Upper Wardha**.
- Among the on-going projects, the prominent ones are **Prnahita-Chevala** and **Polavaram**.

Industry in Godavari Basin

- The major urban Centers in the basin are **Nagpur, Aurangabad, Nashik, Rajhmundry.**
- **Nashik and Aurangabad** have large number of industries especially **automobile.**
- Other than this, the industries in the basin are mostly based on agricultural produce such as rice milling, cotton spinning and weaving, sugar and oil extraction.
- Cement and some small engineering industries also exist in the basin.

Floods and Droughts in Godavari Basin

- Godavari basin faces flooding problem in its lower reaches.
- The coastal areas are cyclone-prone.
- The delta areas face drainage congestion due to flat topography.
- A large portion of Maharashtra falling (**Marathwada**) in the basin is **drought prone.**

Krishna River

- The Krishna is the second largest east flowing river of the Peninsula.
- The Krishna Basin extends over Andhra Pradesh, Maharashtra and Karnataka having a total area of ~2.6 lakh Sq.km.
- It is bounded by **Balaghat range** on the north, by the Eastern Ghats on the south and the east and by the Western Ghats on the west.
- The Krishna River rises from the **Western Ghats** near **Jor village of Satara district of Maharashtra** at an altitude of 1,337 m just north of **Mahabaleshwar.**
- The total length of river from origin to its outfall into the Bay of Bengal is 1,400 km.
- The major part of basin is covered with agricultural land accounting to 75.86% of the total area.
- The Krishna forms a large delta with a shoreline of about 120 km. The Krishna delta appears to merge with that formed by the Godavari and extends about 35 km into the sea.



Tributaries of Krishna River

- Right bank: **the Ghatprabha, the Malprabha and the Tungabhadra.**
- Left Bank: **the Bhima, the Musi and the Munneru.**
- The **Koyna** is a small tributary but is known for **Koyna Dam.** This dam was perhaps the main cause of the devastating **earthquake** (6.4 on Richter scale) in 1967 that killed 150 people.

- The Bhima originates from the **Matheron Hills** and joins the Krishna near Raichur after for a distance of 861 km.
- The Tungabhadra is formed by the unification of the **Tunga** and the **Bhadra** originating from **Gangamula** in the **Central Sahyadri**. Its total length is 531 km.
- At Wazirabad, it receives its last important tributary, the **Musi**, on whose banks the city of Hyderabad is located.

Projects on Krishna River

- Important ones are the **Tungabhadra, Ghataprabha, Nagarjunasagar, Malaprabha, Bhima, Bhadra** and **Telugu Ganga**.
- The major Hydro Power stations in the basin are **Koyna, Tungabhadara, Sri Sailam, Nagarjuna Sagar, Almatti, Naryanpur, Bhadra**.
- Tunagabhadra is a major inter-States project in the basin. In order to operate the project and to regulate the flows among the beneficiary States of Karnataka and Andhara Pradesh.

Resources in Krishna Basin

- The basin has rich mineral deposits and there is good potential for industrial development.
- Iron and steel, cement, sugar cane vegetable oil extraction and rice milling are important industrial activities at present in the basin.
- Recently oil has been struck in this basin which is bound to have an effect on the future industrial scenario of this basin.

Industry in Krishna Basin

- The major Urban Centers in the Basin are **Pune, Hyderabad**.
- Hyderabad is the state capital of Telangana and is now a major IT hub.
- Pune in Maharashtra has number of **automobile and IT industry** and is major education centre.

Drought and Floods in Krishna Basin

- Some parts of the basin, especially the Rayalaseema area of Andhra Pradesh, Bellary, Raichur, Dharwar, Chitradurga, Belgaum and Bijapur districts of Karnataka and Pune, Sholapur, Osmanabad and Ahmednagar districts of Maharashtra are **drought-prone**.
- The delta area of the basin is subject to flooding. It has been observed that the river bed in delta area is continuously raised due to silt deposition resulting in reduction in carrying capacity of the channel.
- The coastal cyclonic rainfall of high intensity and short duration makes the flood problem worse.

Cauvery River

- The Kaveri (Cauvery) is designated as the '**Dakshina Ganga**' or '**the Ganga of the South**'.
- The Cauvery River rises at an elevation of 1,341 m at **Talakaveri** on the **Brahmagiri range** near Cherangala village of **Kodagu (Coorg) district of Karnataka**.
- The total length of the river from origin to outfall is 800 km.
- The Cauvery basin extends over states of Tamil Nadu, Karnataka, Kerala and Union Territory of Puducherry draining an area of 81 thousand Sq.km.
- It is bounded by the Western Ghats on the west, by the Eastern Ghats on the east and the south and by the ridges separating it from Krishna basin and Pennar basin on the north.

- The Nilgiris, an offshore of Western ghats, extend Eastwards to the Eastern ghats and divide the basin into two natural and political regions i.e., Karnataka plateau in the North and the Tamil Nadu plateau in the South.
- Physiographically, the basin can be divided into three parts – the Western Ghats, the Plateau of Mysore and the Delta.
- The delta area is the most fertile tract in the basin. The principal soil types found in the basin are black soils, red soils, laterites, alluvial soils, forest soils and mixed soils. **Red soils** occupy large areas in the basin. Alluvial soils are found in the delta areas.
- The basin in Karnataka receives rainfall mainly from the S-W Monsoon and partially from N-E Monsoon. The basin in Tamil Nadu receives good flows from the North-East Monsoon.
- Its upper catchment area receives rainfall during summer by the south-west monsoon and the lower catchment area during winter season by the retreating north-east monsoon.
- It is, therefore **almost a perennial river** with comparatively less fluctuations in flow and is **very useful for irrigation** and hydroelectric power generation.
- Thus the Cauvery is **one of the best regulated rivers** and 90 to 95 per cent of its irrigation and power production potential already stands harnessed.
- The river drains into the Bay of Bengal. The major part of basin is covered with agricultural land accounting to 66.21% of the total area.

Tributaries of the Cauvery River

- Left Bank: the **Harangi**, the **Hemavati**, the **Shimsha** and the **Arkavati**.
- Right Bank: **Lakshmantirtha**, the **Kabbani**, the **Suvarnavati**, the **Bhavani**, the **Noyil** and the **Amaravati** joins from right.
- The river descends from the South Karnataka Plateau to the Tamil Nadu Plains through the **Sivasamudram waterfalls (101 m high)**.
- At Shivanasamudram, the river branches off into two parts and falls through a height of 91 m. in a series of falls and rapids.
- The falls at this point is utilized for power generation by the power station at Shivanasamudram.
- The two branches of the river join after the fall and flow through a wide gorge which is known as '**Mekedatu**' (**Goats leap**) and continues its journey to form the boundary between Karnataka and Tamil Nadu States for a distance of 64 km.
- At **Hogennekkal Falls**, it takes Southerly direction and enters the **Mettur Reservoir**.
- A tributary called Bhavani joins Cauvery on the Right bank about 45 Kms below **Mettur Reservoir**. Thereafter it enters the plains of Tamil Nadu.
- Two more tributaries Noyil and Amaravathi join on the right bank and here the river widens with sandy bed and flows as '**Akhanda Cauvery**'.
- Immediately after crossing Tiruchirapalli district, the river divides into two parts, the Northern branch being called '**The Coleron**' and Southern branch remains as Cauvery and from here the Cauvery Delta begins.
- After flowing for about 16 Kms, the two branches join again to form '**Srirangam Island**'.
- On the Cauvery branch lies the "**Grand Anicut**" said to have been constructed by a Chola King in 1st Century A.D.
- Below the Grand Anicut, the Cauvery branch splits into two, Cauvery and **Vennar**.
- These branches divide and sub-divide into small branches and form a network all over the delta.



Floods in Cauvery Basin: The Cauvery basin is fan shaped in Karnataka and leaf shaped in Tamil Nadu. The runoff **does not drain off quickly** because of its shape and therefore **no fast raising floods occur** in the basin.

Projects on Cauvery River: During the pre-plan period many projects were completed in this basin which included **Krishnarajasagar** in Karnataka, **Mettur dam** and **Cauvery delta system** in Tamil Nadu. Lower **Bhavani, Hemavati, Harangi, Kabini** are important projects completed during the plan period.

Industry in Cauvery Basin

- The city of Bangalore is situated just outside this basin.
- Important industries in the basin include **cotton textile industry in Coimbatore** and Mysore, cement factories in Coimbatore and Trichinapally and industries based on mineral and metals.
- The **Salem steel plant** and many engineering industries in Coimbatore and Trichinapally are also situated in this basin.

Pennar River

- The Pennar (also known as **Uttara Pinakini**) is one of the major rivers of the peninsula.
- The Pennar rises in the **Chenna Kasava hill** of the **Nandidurg range**, in **Chikkaballapura district of Karnataka** and flows towards east eventually draining into the Bay of Bengal.
- The total length of the river from origin to its outfall in the Bay of Bengal is 597 km.
- Located in peninsular India, the Pennar basin extends over states of Andhra Pradesh and Karnataka having an area of ~55 thousand Sq.km
- The fan shaped basin is bounded by the **Erramala range** on the north, by the **Nallamala** and **Velikonda** ranges of the Eastern Ghats on the east, by the **Nandidurg hills** on the south and by the narrow ridge separating it from the Vedavati valley of the Krishna Basin on the west.
- The other hill ranges in the basin to the south of the river are the **Seshachalam [famous for Red Sanders]** and **Paliconda ranges**.
- The major part of basin is covered with agriculture accounting to 58.64% of the total area.

Tributaries of Pennar River

- Left Bank: the **Jayamangali**, the **Kunderu** and the
- Right bank: the **Chiravati**, the **Papagni** etc.



Projects on Pennar River: Tungabhadra high level canal in Krishna basin irrigated areas in Pennar basin also. The only major project in the basin is the **Somasila project**.

Industry in Pennar Basin

- The only important town in the basin is
- With limited water and power potential and mineral resources, the scope for industrial development is limited in the basin.
- There are no major industries. The existing small industries are mostly based on agricultural produce such as cotton weaving, sugar mills, oil mills, rice mills etc.

Subarnarekha

- The Subarnarekha originates from the **Ranchi Plateau** in Jharkhand forming the boundary between West Bengal and Odisha in its lower course.
- It joins Bay of Bengal forming an estuary between the Ganga and Mahanadi deltas. Its total length is 395 km.

Brahamani River

- The Brahmani River comes into existence by the confluence of the **Koel** and the **Sankh rivers** near **Rourkela**. It has a total length of 800 km.
- The basin is bounded in the North by Chhotanagpur plateau, in the West and South by the Mahanadi basin and in the East by the Bay of Bengal.
- The basin flows through Jharkhand, Chhattisgarh and Orissa States and drains into Bay of Bengal.

Ponnaiyar River

- The Ponnaiyar is a small stream which is confined to the coastal area only.
- It covers a small area in the state of Tamil Nadu, Karnataka and Andhra Pradesh.
- The Basin is bounded on the North -West and South by various ranges of the Eastern Ghats like the Velikonda Range, the Nagari hills, the Javadu hills, the Shevaroy hills, the Chitteri hills and the Kalrayan hills and in the East by the Bay of Bengal.

Vaigai River

- South of the Cauvery delta, there are several streams, of which the Vaigai is the longest.
- The Vaigai basin is an important basin among the 12 basins lying between the Cauvery and Kanyakumari.
- This basin is bounded by the Varushanadu hills, the Andipatti hills, the Cardaman hills and the Palani hills on the West and by the Palk Strait and Palk Bay on the East.
- The Vaigai drains an area of 7,741 Sq. Km, which entirely lies in the state of Tamil Nadu.



West Flowing Peninsular Rivers

- The west flowing rivers of the Peninsular India are fewer and smaller as compared to their east flowing counterparts.
- The two major west flowing rivers are the **Narmada** and the **Tapi**.
- This exceptional behavior is because these rivers didn't form valleys and instead they flow through faults (linear rift, rift valley, and trough) created due to the bending of the northern peninsula during the formation process of Himalayas.
- These faults run parallel to the **Vindhya** and the **Satpuras**.

- The **Sabarmati, Mahi** and **Luni** are other rivers of the Peninsular India which flow westwards.
- Hundreds of small streams originating in the **Western Ghats** flow swiftly westwards and join the Arabian Sea.
- It is interesting to note that the Peninsular Rivers which fall into the Arabian Sea **do not form deltas, but only estuaries.** {Fluvial Depositional Landforms}
- This is due to the fact that the west flowing rivers, especially the Narmada and the Tapi flow through **hard rocks** and hence do not carry any good amount of silt.
- Moreover, the tributaries of these rivers are very small and hence they don't contribute any silt.
- Hence these rivers are not able to form distributaries or a delta before they enter the sea.

Estuary

- An estuary is a partially enclosed body of water along the coast where freshwater from rivers and streams meets and mixes with salt water from the ocean. [Primary productivity in estuaries is very high. Fishing is a dominant occupation around estuaries. Most of the estuaries are good **bird sanctuaries**].
- Estuaries and the lands surrounding them are places of transition from land to sea and freshwater to salt water.
- Although influenced by the tides, they are protected from the full force of ocean waves, winds, and storms by such land forms as barrier islands or peninsulas.
- Estuarine environments are among the most productive on earth, creating more organic matter each year than comparably-sized areas of forest, grassland, or agricultural land.
- The tidal, sheltered waters of estuaries also support unique communities of plants and animals especially adapted for life at the margin of the sea.
- Estuaries have important commercial value and their resources provide economic benefits for tourism, fisheries, and recreational activities.
- The protected coastal waters of estuaries also support important public infrastructure, serving as **harbors and ports** vital for shipping and transportation.
- Estuaries also perform other valuable services. Water draining from uplands carries sediments, nutrients, and other pollutants to estuaries. As the water flows through wetlands such as swamps and salt marshes, much of the sediments and pollutants are filtered out.
- Salt marsh grasses and other estuarine plants also help prevent erosion and stabilize shorelines [Mangroves].

Narmada River

- Narmada is the largest west flowing river of the peninsular India.
- Narmada flows westwards through a **rift valley** between the Vindhyan Range on the north and the Satpura Range on the south.
- It rises from **Maikala range near Amarkantak** in **Madhya Pradesh**, at an elevation of about 1057 m.
- Narmada basin extends over states of Madhya Pradesh, Gujarat, Maharashtra and Chhattisgarh having an area ~1 Lakh Sq.km.
- It is bounded by the Vindhyas on the north, Maikala range on the east, Satpuras on the south and by the Arabian Sea on the west.
- Its total length from its source in **Amarkantak** to its estuary in the **Gulf of Khambhat** is 1,310 km.

- The hilly regions are in the upper part of the basin, and lower middle reaches are broad and fertile areas well suited for cultivation.
- **Jabalpur** is the only important urban centre in the basin.
- The river slopes down near Jabalpur where it cascades (a small waterfall, especially one in a series) 15 m into a gorge to form the **Dhuan Dhar (Cloud of Mist) Falls**.
- Since the gorge is composed of marble, it is popularly known as the Marble Rocks.
- It makes two waterfalls of 12 m each at Mandhar and Dardi. Near Maheshwar the river again descends from another small fall of 8 m, known as the **Sahasradhara Falls**.
- There are several islands in the estuary of the Narmada of which **Aliabet** is the largest.
- The Narmada is navigable upto 112 km from its mouth.

Tributaries of Narmada River

- Since the river flows through a narrow valley confined by precipitous (dangerously high or steep) hills, it does not have many tributaries.
- The absence of tributaries is especially noted on the right bank of the river where the **Hiran** is the only exception.
- The other right bank tributaries are the **Orsang, the Barna and the Kolar**.
- A few left bank tributaries drain the northern slopes of the Satpura Range and join the Narmada at different places.
- The major Hydro Power Project in the basin are **Indira Sagar, Sardar Sarovar, Omkareshwar, Bargi & Maheshwar**.



Tapti River

- The Tapti (also known as the Tapi) is the second largest west flowing river of the Peninsular India and is known as 'the twin' or 'the handmaid' of the Narmada.
- It originates near **Multai reserve forest in Madhya Pradesh** at an elevation of 752 m.
- Flows for about 724 km before **outfalling into the Arabian Sea through the Gulf of Cambay [Gulf of Khambhat]**.
- The Tapti River along with its tributaries flows over the plains of **Vidharbha, Khandesh** and Gujarat and over large areas in the state of Maharashtra and a small area in Madhya Pradesh and Gujarat.
- The basin extends over states of Madhya Pradesh, Maharashtra and Gujarat having an area of ~ 65,000 Sq.km
- Situated in the Deccan plateau, the basin is bounded by the **Satpura range** on the north, **Mahadev hills** on the east, **Ajanta Range** and the **Satmala hills** on the south and by the Arabian Sea on the west.

- The hilly region of the basin is well forested while the plains are broad and fertile areas suitable for cultivation.
- There are two well defined physical regions, in the basin, viz hilly region and plains; the hilly regions comprising **Satpura, Satmalas, Mahadeo, Ajanta and Gawilgarh hills** are well forested.
- The plain covers the **Khandesh areas** (Khandesh is a region of central India, which forms the northwestern portion of Maharashtra state) which are broad and fertile suitable for cultivation primarily.

Tributaries of Tapti River

- **Right Bank:** the **Suki**, the **Gomai**, the **Arunavati** and the **Aner**.
- **Left Bank:** the **Vaghur**, the **Amravati**, the **Buray**, the **Panjhra**, the **Bori**, the **Girna**, the **Purna**, the **Mona** and the **Sipna**.

Projects on Tapti River

- Hathnur Dam of Upper Tapi Project (Maharashtra)
- Kakrapar weir and Ukai Dam of Ukai Project (Gujarat)
- Girna Dam and Dahigam Weir of Girna Project (Maharashtra)

Industry in the Tapti Basin: Important industries in the basin are **textile factories in Surat** and **paper and news print factory at Nepanagar**.



Sabarmati River

- The Sabarmati is the name given to the combined streams the **Sabar** and **Hathmati**.
- The Sabarmati basin extends over states of Rajasthan and Gujarat having an area of 21,674 Sq. km.
- The basin is bounded by **Aravalli hills** on the north and north-east, by Rann of Kutch on the west and by Gulf of Khambhat on the south.
- The basin is roughly triangular in shape with the Sabarmati River as the base and the source of the **Vatrak River** as the apex point.
- Sabarmati originates from **Aravalli hills** at an elevation of 762 m near village Tepur, in **Udaipur district of Rajasthan**.
- The total length of river from origin to outfall into the Arabian Sea is 371 km.
- The major part of basin is covered with agriculture accounting to 74.68% of the total area.

- Rainfall varies from a meager few mm in Saurashtra to over 1000 mm in southern part.
- Left bank tributaries: the Wakal, the Hathmati and the Vatrak.
- Right bank tributaries: the Sei.
- Projects: Sabarmati reservoir (Dharoi), Hathmati reservoir and Meshwo reservoir project are major projects completed during the plan period.

Industry in Sabarmati Basin

- **Gandhinagar** and **Ahmedabad** are the important urban centers in the basin.
- Ahmedabad is an industrial city situated on the banks of Sabarmati.
- Important industries are textiles, leather and leather goods, plastic, rubber goods, paper, newsprint, automobile, machine tools, drugs and pharmaceuticals etc.
- The industrial city of Ahmedabad poses the danger of water pollution.

Mahi River

- The Mahi basin extends over states of Madhya Pradesh, Rajasthan and Gujarat having total area of 34,842 Sq. km.
- It is bounded by **Aravalli hills** on the north and the north-west, by **Malwa Plateau** on the east, by the **Vindhyas** on the south and by the Gulf of Khambhat on the west.
- Mahi is one of the major interstate west flowing rivers of India.
- It originates from the northern slopes of Vindhyas at an altitude of 500 m in **Dhar district of Madhya Pradesh**.
- The total length of Mahi is 583 km.
- It drains into the Arabian Sea through the Gulf of Khambhat.
- The major part of basin is covered with agricultural land accounting to 63.63% of the total area
- Hydro Power stations are located in Mahi Bajaj Sagar dam and at Kadana Dam.
- **Vadodara** is the only important urban Centre in the basin. There are not many industries in the basin.
- Some of the industries are cotton textile, paper, newsprint, drugs and pharmaceuticals. Most of these industries are located at **Tatlam**.

Luni River

- The Luni or the **Salt River** (Lonari or Lavanavari in Sanskrit) is named so because its water is brackish below Balotra.
- Luni is the only river basin of any significance in Western Rajasthan, which form the bulk of arid zone.
- Luni originates from western slopes of the **Aravalli ranges** at an elevation of 772 m near **Ajmer** flowing in South West direction and traversing a course of 511 km in Rajasthan, it finally flow into the **Rann of Kachchh** (it gets lost in the marsh).
- Most of its tributaries drain the steep north west of Aravalli hills and join it on left side. Its total catchment area falls in Rajasthan.
- The peculiarity of this river is that it **tends to increase its width** rather than deepening the bed because the banks are of soils, which are easily erodible whereas beds are of sand. The floods develop and disappear so rapidly that they have no time to scour the bed.

West flowing Rivers of the Sahyadris (Western Ghats)

- About six hundred small streams originate from the Western Ghats and flow westwards to fall into the Arabian Sea.
- The western slopes of the Western Ghats receive heavy rainfall from the south-west monsoons and are able to feed such a large number of streams.
- Although only about 3% of the areal extent flow swiftly down the steep slope and some of them make waterfalls.
- The **Jog or Gersoppa Falls** (289 m) made by the **Sharavati river** is the most famous waterfall of India.

Ghaggar River – Inland Drainage

- Some rivers of India are not able to reach the sea and constitute inland drainage.
- Large parts of the **Rajasthan desert** and parts of **Aksai Chin** in **Ladakh** have inland drainage.
- The **Ghaggar** is the most important river of inland drainage. It is a seasonal stream which rises on the lower slopes of the Himalayas and forms boundary between **Haryana and Punjab**.
- It gets lost in the dry sands of Rajasthan near Hanumangarh after traversing a distance of 465 km.
- Earlier, this river was an affluent of the Indus, the dry bed of the old channel is still traceable.
- Its main tributaries are the Tangri, the Markanda, the **Saraswati** and the Chaitanya.
- It contains a lot more water in rainy season when its bed becomes 10 km wide at places.
- Most of the streams draining western slopes of the Aravalli Range dry up immediately after they enter the sandy arid areas to the west of this range.

Usability of Rivers

- Source of fresh water, irrigation, hydro-electric production, navigation etc.
- The Himalayas, Vindhya, Satpuras, Aravalis, Maikala, Chhotanagpur plateau, Meghalaya plateau, Purvachal, Western and the Eastern Ghats offer possibilities of large scale water power development.
- Sixty per cent of the total river flow is concentrated in the Himalayan rivers, 16 per cent in the Central Indian rivers (the Narmada, the Tapi, the Mahanadi, etc.), and the rest in the rivers of the Deccan plateau.
- The Ganga and the Brahmaputra in the north and northeastern part of the country, the Mahanadi in Odisha, the Godavari and the Krishna in Andhra and Telangana the Narmada and the Tapi in Gujarat, and the lakes and tidal creeks in coastal states possess some of the important and useful waterways of the country.
- In the past they were of great importance, which suffered a great deal with the advent of **rail and roads**.
- Withdrawal of large quantities of water for irrigation resulted in dwindling flow of many rivers.
- The most important navigable rivers are the Ganga, the Brahmaputra and the Mahanadi. The Godavari, the Krishna, the Narmada and the Tapi are navigable near their mouths only.

Mechanism of Indian Monsoons

- The term monsoon has been derived from the Arabic word **mausin** or from the Malayan word **monsin** meaning 'season'.
- Monsoons are **seasonal winds** (Rhythmic wind movements) (Periodic Winds) which **reverse** their direction with the change of season.
- The monsoon is a double system of seasonal winds – They flow from sea to land during the summer and from land to sea during winter.
- Some scholars tend to treat the monsoon winds as **land and sea breeze** on a large scale.
- Monsoons are peculiar to Indian Subcontinent, South East Asia, parts of Central Western Africa etc.
- They are more pronounced in the Indian Subcontinent compared to any other region.
- Indian Monsoons are **Convection cells** on a very large scale.
- They are **periodic or secondary winds** which **seasonal reversal in wind direction**.
- India receives south-west monsoon winds in summer and north-east monsoon winds in winter.
- South-west monsoons are formed due to intense low pressure system formed over the Tibetan plateau.
- North-east monsoons are associated with high pressure cells over **Tibetan** and **Siberian plateaus**.
- South-west monsoons bring intense rainfall to most of the regions in India and north-east monsoons bring rainfall to mainly **south-eastern coast** of India (Southern coast of Seemandhra and the coast of Tamil Nadu.).
- Countries like **India, Indonesia, Bangladesh, Myanmar** etc. receive most of the annual rainfall during south-west monsoon season where as **South East China, Japan** etc., during north-east rainfall season.

Factors responsible for south-west monsoon formation

- Intense heating of Tibetan plateau during summer months.
- Permanent high pressure cell in the South Indian Ocean (east to north-east of Madagascar in summer).

Factors that influence the onset of south-west monsoons

- Above points +
- Subtropical Jet Stream (STJ).
- Tropical Easterly Jet (African Easterly Jet).
- Inter Tropical Convergence Zone.

Factors that influence the intensity of south-west monsoons

- Strengths of Low pressure over Tibet and high pressure over southern Indian Ocean.
- Somali Jet (Findlater Jet).
- Somali Current (Findlater Current).
- Indian Ocean branch of Walker Cell.
- Indian Ocean Dipole.

Factors responsible for north-east monsoon formation

- Formation and strengthening of high pressure cells over Tibetan plateau and Siberian Plateau in winter.
- Westward migration and subsequent weakening of high pressure cell in the Southern Indian Ocean.

- Migration of ITCZ to the south of India.

All these will be discussed in detail.

Mechanism of Indian Monsoons

- The origin of monsoons is not fully understood.
- There are several theories that tried to explain the mechanism of monsoons.

Classical Theory

- Monsoons are mentioned in scriptures like the **Rig Veda**. But these scriptures didn't make any mention of the monsoon mechanism.
- The first scientific study of the monsoon winds was done by **Arab traders**.
- Arab traders used the sea route to carry out trade with India and monsoon patterns were of prime importance for them.
- In the tenth century, **Al Masudi**, an Arab explorer, gave an account of the **reversal of ocean currents and the monsoon winds** over the north Indian Ocean.
- In seventeenth century, Sir Edmund Halley explained the monsoon as resulting from **thermal contrasts** between continents and oceans due to their differential heating.

Indian Monsoons – Classical Theory: Sir Edmund Halley's Theory

Summer Monsoon

- In summer the sun's apparent path is vertically over the Tropic of Cancer resulting in high temperature and low pressure in Central Asia.
- The pressure is sufficiently high over Arabian Sea and Bay of Bengal. Hence winds flowed from Oceans flow towards landmass in summer.
- This air flow from sea to land bring heavy rainfall to the Indian subcontinent.

Winter Monsoon

- In winter the sun's apparent path is vertically over the Tropic of Capricorn.
- The north western part of India grows colder than Arabian Sea and Bay of Bengal and the flow of the monsoon is reversed.
- The basic idea behind Classical theory is similar to land and sea breeze formation except that in the case of monsoons the day and night are replaced by summer and winter.

Drawbacks: The monsoons do not develop equally everywhere on earth and the thermal concept of Halley fails to explain the intricacies of the monsoons such as the **sudden burst** of monsoons, **delay** in on set of monsoons sometimes, etc.

Modern Theories

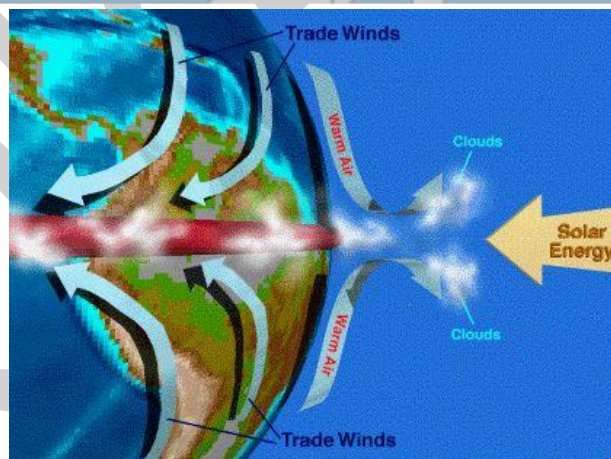
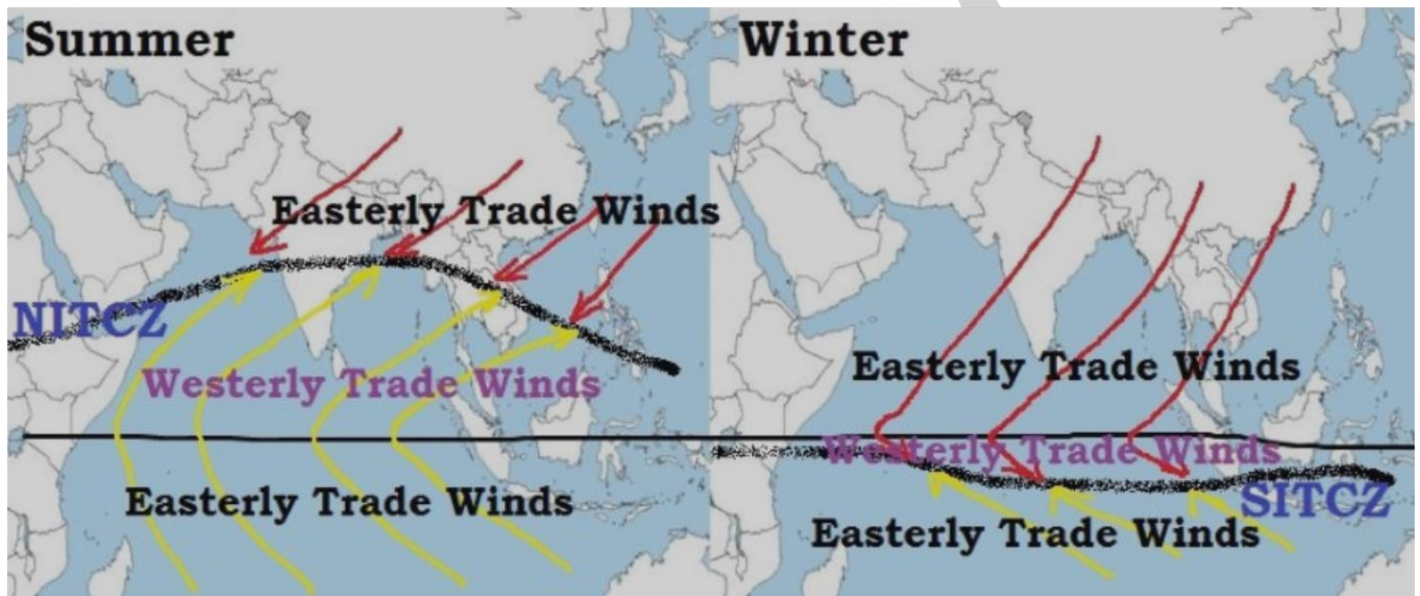
- Besides differential heating, the development of monsoon is influenced by the shape of the continents, orography (mountains), and the conditions of **air circulation in the upper troposphere {jet streams}**.
- Therefore, Halley's theory has lost much of its significance and modern theories based on air masses and jet stream are becoming more relevant.

Indian Monsoons – Modern theory: Air Mass Theory

- According to this theory, the monsoon is simply a **modification of the planetary winds of the tropics**.
- The theory is based on the migration of ITCZ based on seasons.

Indian Monsoons – Role of ITCZ [Inter-Tropical Convergence Zone]

- The southeast trade winds in the southern hemisphere and the northeast trade winds in the northern hemisphere meet each other near the equator.
- The meeting place of these winds is known as the **Inter-Tropical Convergence Zone (ITCZ)**.



- This is the region of ascending air, **maximum clouds** and **heavy rainfall**.
- The location of ITCZ **shifts** north and south of equator with the change of season.
- In the summer season, the sun shines vertically over the Tropic of Cancer and the ITCZ shifts northwards.
- The southeast trade winds of the southern hemisphere cross the equator and start blowing in southwest to northeast direction under the influence of **Coriolis force**.

- These displaced trade winds are called south-west monsoons when they blow over the Indian sub-continent.
- The front where the south-west monsoons meet the north-east trade winds is known as the **Monsoon Front (ITCZ)**. **Rainfall occurs along this front.**
- In the month of July the ITCZ shifts to 20° - 25° N latitude and is located in the Indo-Gangetic Plain and the south-west monsoons blow from the Arabian Sea and the Bay of Bengal. The ITCZ in this position is often called the **Monsoon Trough [maximum rainfall]**.
- The seasonal shift of the ITCZ has given the concept of Northern Inter-Tropical Convergence Zone (NITCZ) in summer (July – rainy season) and Southern Inter-Tropical Convergence Zone (SITCZ) in winter (Jan – dry season).
- NITCZ is the zone of clouds and heavy rainfall that effect India.

Indian Monsoon Mechanism – Jet Stream Theory

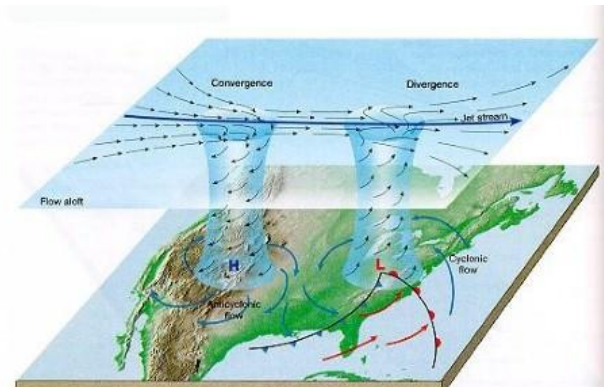
- Jet stream Theory is the latest theory regarding the origin of the monsoons and has earned worldwide acceptance from the meteorologists.
- To understand how Jet streams affect Indian monsoons, we need to know the basic mechanism of Jet Stream induced weather conditions.

How Jet Streams Affect Weather?

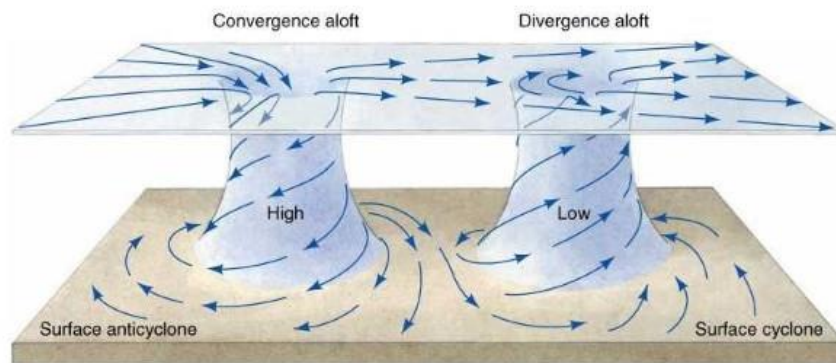
- Jet streams have distinct **peaks (ridges)** and **troughs**.
- Ridges occur where the warm air mass pushes against the cold air mass. Troughs occur where cold air mass drops into warm air.
- The region on earth below the trough is at low pressure and the region below ridge is at high pressure.
- This condition occurs due to weakening of jet stream due to lesser temperature contrast between sub-tropics and temperate region (Our concern is STJ only).
- Usually the trough region [the region exactly below the jet stream trough] creates cyclonic condition (low pressure) at the surface of earth whereas the ridge regions creates anticyclonic condition.
- Troughs create upper level divergence which is associated with convergence at the surface (low pressure – cyclonic conditions) and ridges create upper level convergence which is associated with divergence at the surface (high pressure – cyclonic conditions).
- These ridges and troughs give rise to jet streaks which are also responsible for cyclonic and anticyclonic weather conditions at the surface.
- The winds leaving the jet streak are rapidly diverging, creating a lower pressure at the upper level (Tropopause) in the atmosphere. The air below rapidly replaces the upper outflowing winds. This in turn creates the low pressure at the surface. This surface low pressure creates conditions where the surrounding surface winds rush inwards. The Coriolis Effect creates the cyclonic rotation (cyclonic vortex) that is associated with depressions [low pressure cells].
- The winds entering the jet streak are rapidly converging because of the high pressure at the upper level (Tropopause) in the atmosphere. This convergence at upper troposphere leads to divergence (high pressure) at the surface (anticyclonic condition).
- The Coriolis Effect creates the anticyclonic rotation that is associated with clear weather.



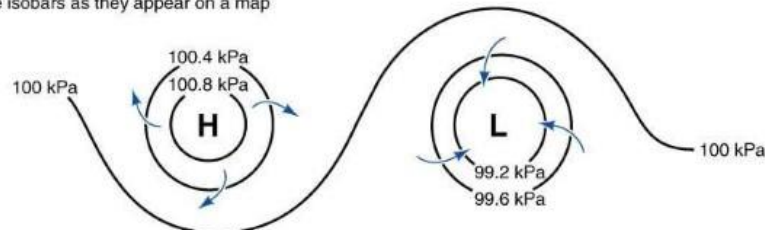
Vorticity provided by flow in the jet stream generates cyclonic flow near a trough and anticyclonic flow adjacent to a ridge.



Idealized depiction of the support that divergence and convergence aloft provide to cyclonic and anticyclonic circulation at the surface.



Surface isobars as they appear on a map



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But how does this mechanism of jet streams influence Indian Monsoons?

Indian Monsoon Mechanism – Role of Sub-Tropical Jet Stream (STJ)

Sub-Tropical Jet stream plays a significant role in both hindering the monsoon winds as well as in quick onset of monsoons.

STJ – Sub-Tropical Jet Stream

- Sub-Tropical Jet stream is a narrow band of fast moving air flowing from **west to east [Westerlies]**.
- STJ in northern hemisphere flows between 25° to 35° N in the upper troposphere at a height of about 12-14 km (all this already discussed in previous posts on Jet Streams). (Here we will consider STJ only. Polar Jet has no influence on Indian monsoons).
- The wind speeds in a westerly jet stream are commonly 150 to 300 kmph with extreme values reaching 400 kmph.

- The burst of monsoons depends upon the upper air circulation which is dominated by STJ.

Seasonal Migration of Sub-Tropical Jet Stream – STJ

- In winter STJ flows along the southern slopes of the Himalayas but in summer it shifts northwards, rather dramatically, and flows along the northern edge of Himalayas in early June and in late summer (July-August) along the northern edge of the Tibetan Plateau.
- The periodic movement of the Jet stream is often the indicator of the onset (STJ shifts to the north of Himalayas in a matter of days) and subsequent withdrawal (STJ returns back to its position – south of Himalayas) of the monsoon.
- Northward movement of the subtropical jet is the first indication of the onset of the monsoon over India.

Sub-Tropical Jet Stream – STJ in winter

- Westerly jet stream blows at a very high speed during winter over the sub-tropical zone.
- This jet stream is bifurcated by the Himalayan ranges and Tibetan Plateau.
- The two branches reunite off the east coast of China.
- The northern branch of this jet stream blows along the northern edge of the Tibetan Plateau.
- The southern branch blows to the south of the Himalayan ranges along 25° north latitude.
- A strong latitudinal thermal gradient (differences in temperature), along with other factors, is responsible for the development of southerly jet.

Western Disturbances

- Meteorologists believe that southern branch of jet stream exercises a significant influence on the winter weather conditions in India.
- The upper jet is responsible for steering of the **western depressions [Western Disturbances]** from the Mediterranean Sea.
- Some of the depressions continue eastwards, redeveloping in the zone of jet stream confluence about 30° N, 105° E (near east coast of China).
- Winter rain and heat storms in north-western plains and occasional heavy snowfall in hilly regions are caused by these disturbances.
- These are generally followed by cold waves in the whole of northern plains.
- The southern branch is stronger, with an average speed of about 240 km compared with 70 to 90 km p.h. of the northern branch.
- Air subsiding beneath this upper westerly current gives dry out blowing northerly winds from the subtropical anticyclone over northwestern India and Pakistan.

Why no south-west monsoons during winter?

- **Reason 1:** ITCZ has left India (the winds that blow over India are mostly offshore — land to land or land to ocean — so they carry no moisture).
- **Reason 2:** During winter, the southern branch of STJ is strong and is to the south of Himalayas. The ridge of the jet lies over north-western India and is associated with strong divergence of winds and creates a high pressure region (sub-tropical high pressure belt) over entire north India. *[This is how the mechanism of jet streams influence Indian Monsoons in winter season]*

- **Reason 3:** There is already a strong high pressure over Tibet. [High Pressure due to STJ + High Pressure over Tibet = strong divergence = no rainfall]

Sub-Tropical Jet Stream – STJ in summer

- With the beginning of summer in the month of March, the STJ [upper westerlies] start their northward march.
- The southerly branch of STJ remains positioned south of Tibet, although weakening in intensity.
- The weather over northern India becomes hot, dry and squally due to larger incoming solar radiation and hot winds like **loo**.
- Over India, the **Equatorial Trough (ITCZ)** pushes northwards with the weakening of the STJ [upper westerlies] south of Tibet, but the burst of the monsoon does not take place until the upper-air circulation has switched to its summer pattern.
- By the end of May the southern jet breaks and later it is diverted to the north of Tibet Plateau and there is sudden burst of monsoons (the ridge moves northwards into Central Asia = high pressure over north-west India moves northwards into Central Asia = makes way for south-west monsoon winds). An Easterly jet emerges over peninsular India with the northward migration of STJ.
- The upper air circulations are reversed with the emergence of Easterly jet [convergence in upper layers is replaced by divergence == divergence in lower layers is replaced with convergence == high pressure at lower layers is replaced by low pressure system]. The easterly winds become very active in the upper troposphere and they are associated with westerly winds in the lower troposphere (south-west monsoon winds).
- Western and eastern jets flow to the north and south of the Himalayas respectively. The eastern jet becomes powerful and is stationed at 15° N latitude.
- This results in more active south-west monsoon and heavy rainfall is caused.

Why no south-west monsoons in March – May (summer)?

There is good sun's insolation from March – May but still there is no s-w monsoons.

Reason: The ridge region of Southern branch of STJ creates strong divergence (high pressure) in north-west India. The diverging air blocks incoming winds and prevents strong convergence of winds along ITCZ.

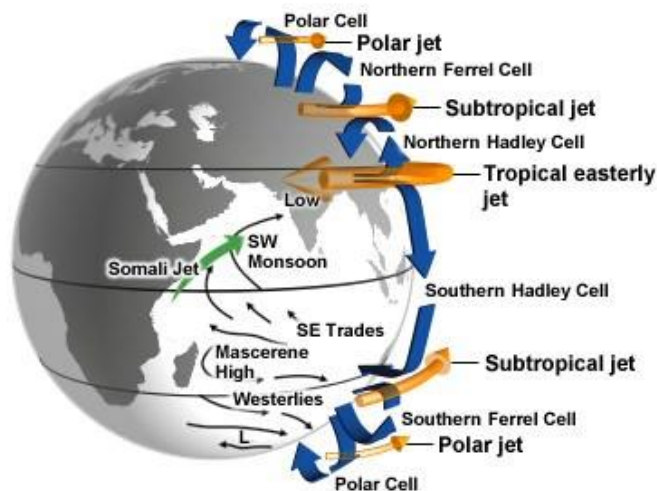
- During the summer season in the Northern Hemisphere, low pressure areas develop at the ground surface near Peshawar (Pakistan) and north-west India due to intense heating of ground surface during April, May, and June.
- As long as the position of the upper air jet stream is maintained above the surface low pressure (to the south of Himalayas), the dynamic anti-cyclonic conditions persist over north-west India.
- The winds descending from the upper air high pressure [because of the ridge of STJ] obstructs the ascent of winds from the surface low pressure areas, with the result that the weather remains warm and dry.
- This is why the months of April and May are generally dry and rainless in spite of high temperatures (low pressure on land) and high evaporation.

Indian Monsoons – Role of Tropical Easterly Jet (TEJ) [African Easterly Jet]

- The establishment and maintenance of the TEJ is not fully understood but it is believed that the jet may be caused by the uniquely **high temperatures and heights** over the Tibetan Plateau during summer.
- The TEJ plays an important role in **kick starting southwest monsoon**.
- This jet descends over the Indian Ocean (near Madagascar) and intensifies its high pressure cell so as to move as south-west monsoon.

Tropical Easterly Jet (TEJ)

- There are major high velocity winds in the lower troposphere called **low-level jets (LLJs)**.
- In the tropics, the most prominent of these are the **Somali Jet** and the **African Easterly Jet [Tropical Easterly Jet]**.
- The TEJ is a unique and dominant feature of the northern hemispheric summer over southern Asia and northern Africa. The TEJ is found near between 5° and 20° N.
- It is fairly persistent in its direction, and intensity from June through the beginning of October. Its position fluctuates between 5° and 20° N.
- *TEJ comes into existence quickly after the STJ has shifted to the north of the Himalayas (Early June).*
- TEJ flows from east to west over peninsular India at 6 – 9 km and over the Northern African region.
- The formation of TEJ results in the **reversal of upper air circulation patterns [High pressure switches to low pressure]** and leads to the quick onset of monsoons.
- Recent observations have revealed that the intensity and duration of heating of Tibetan Plateau has a direct bearing on the amount of rainfall in India by the monsoons.
- When the summer temperature of air over Tibet remains high for a sufficiently long time, it helps in strengthening the easterly jet and results in heavy rainfall in India.
- **The easterly jet does not come into existence if the snow over the Tibet Plateau does not melt. This hampers the occurrence of rainfall in India.**
- **Therefore, any year of thick and widespread snow over Tibet will be followed by a year of weak monsoon and less rainfall.**



NCAR / The COMET Program

Indian Monsoons – Role of Tibet

- The Tibetan Plateau is an enormous block of highland acting as a formidable barrier.
- Due to its protruded height it receives 2-3°C more insolation than the neighboring areas.
- The plateau affects the atmosphere in two ways: **(a) as a mechanical barrier, and (b) as a high-level heat sources.**
- At the beginning of June the subtropical jet stream is completely withdrawn from India and occupies a position along 40° N (to the north of Tibetan Plateau).
- The plateau **accentuates** the northward displacement of the jet stream. Hence the burst of monsoon in June is prompted by the Himalayas and not by the thermally induced low pressure cell over Tibet. **(Tibetan plateau is responsible for south-west monsoons. But it is the STJ that facilitates sudden outburst of monsoons with its sudden northward migration)**
- In the middle of October the plateau proves to be the most important factor in causing the advance of the jet south of the Himalayas or bifurcating it into two parts.
- The winter Tibetan Plateau cools rapidly and produces a high pressure cell. (Cyclonic condition over Tibet ceases and an anticyclonic condition is established). The high pressure cell over Tibet strengthens N-E monsoons.
- Tibet gets heated in summer and is 2°C to 3°C warmer than the air over the adjoining regions.
- Because the Tibet Plateau is a source of heat for the atmosphere, it generates an area of rising air (convergence) (intense low pressure cell).
- During its ascent the air spreads outwards in upper troposphere (divergence) and gradually sinks (subsidence) over the equatorial part of the Indian Ocean.
- It finally approaches the west coast of India as a return current from a south-westerly direction and is termed as equatorial westerlies.
- It picks up moisture from the Indian Ocean and causes rainfall in India and adjoining countries.

Indian Monsoons – Role of Somali Jet

- Polar and subtropical jet streams are the permanent jet streams which greatly influence the weather of temperate regions.
- Temporary jet streams are narrow winds with speeds more than 94 kmph in the upper, middle and sometimes in lower troposphere. They are few. Important ones are Somali Jet and The African Easterly jet or Tropical Easterly Jet.
- These two jet streams play an important role in the formation and progression of Indian Monsoons.
- The progress of the southwest monsoon towards India is greatly aided by the onset of Somali jet that transits Kenya, Somalia and Sahel.
- It was observed to flow from Mauritius and the northern part of the island of Madagascar before reaching the coast of Kenya at about 3° S.
- **It strengthens permanent high near Madagascar and also helps to drive S-W monsoons towards India at a greater pace and intensity.**
- The importance of the low level jet arises from the fact that its path around 9° N coincides with a zone of coastal upwelling.
- As the strong winds drive away the surface coastal waters towards the east, extremely cold water from the depths of the sea rise upwards to preserve the continuity of mass.
- The peculiar feature of Somali Current is **reversal in direction** with the onset of the summer monsoon.

- In winter, this current is from north to the south running southwards from the coast of Arabia to the east African coastline; but with the advent of the summer monsoon it reverses its direction and flows from the south to the north.

Indian Monsoons – Role of Indian Ocean Dipole

- Indian Ocean Dipole is a recently discovered phenomena that has a significant influence on Indian monsoons.
- Indian Ocean Dipole is a SST anomaly (Sea Surface Temperature Anomaly – different from normal) that occurs occasionally in Northern or Equatorial Indian Ocean Region (IOR).
- 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 Indian Ocean from April to May peaking in October.
- With a positive IOD winds over the Indian Ocean blow from east to west (from Bay of Bengal towards Arabian Sea). This results in the Arabian Sea (western Indian Ocean near African Coast) being much warmer and eastern Indian Ocean around Indonesia becoming colder and dry.
- In the negative dipole year, reverse happens making Indonesia much warmer and rainier.
- Positive IOD is good for Indian Monsoons as more evaporation occurs in warm water.
- Similar to ENSO, the atmospheric component of the IOD is named as Equatorial Indian Ocean Oscillation (EQUINOO) (Oscillation of pressure cells between Bay of Bengal and Arabian Sea).
- During the positive phase of the 'Equatorial Indian Ocean Oscillation (EQUINOO),' there is enhanced cloud formation and rainfall in western part of the equatorial ocean near the African coast while such activity is suppressed near Sumatra.
- While EQUINOO and IOD go in step during strong positive IOD events, they do not always do so.

Indian Climate

- India's climate closely resembles the climate that of a tropical country although it's northern part (north of tropic of cancer) is situated in the **temperate belt**.
- Indian subcontinent is separated from the rest of Asia by the **lofty Himalayan ranges** which block the **cold air masses** moving southwards from Central Asia.
- As a result, during winters, the northern half of India is warmer by **3°C to 8°C** than other areas located on same latitudes.
- During summer, due to over the head position of the sun, the climate in the southern parts resemble equatorial dry climate.
- The north Indian plains are under the influence of hot dry wind called '**loo**' blowing from the **Thar, Baloch and Iranian Deserts**, increasing the temperatures to a level comparable to that of the southern parts of the country.
- Thus the whole of India, south of the Himalayas can be climatically treated as a tropical country.
- The seasonal reversal of winds in Arabian Sea and Bay of Bengal give India a typical **tropical monsoon climate**.
- So Indian climate, to be precise, is **tropical monsoon type (a distinct wet and dry climate)** rather than just a tropical or half temperate climate.

Rainfall

- The climate in most of the regions is characterized by **distinct wet and dry seasons**. Some places like Thar Desert, Ladakh have no wet season.
- Mean annual rainfall varies substantially from region to region. **Mawsynram and Cherrapunji** in Meghalaya receives around 1,000 cm of annual rainfall while at Jaisalmer the annual rainfall rarely exceeds 12 cm.
- The Ganga delta and the coastal plains of Odisha see intense rainfall in July and August while the Coromandel Coast goes dry during these months.
- Places like Goa, Hyderabad and Patna receive south-west monsoon rains by the first quarter of June while the rains are awaited till early July at places in Northwest India.

Temperature

- Diurnal and annual temperature ranges are substantial. Highest diurnal temperature ranges occur in the Thar Desert and the highest annual temperature ranges are recorded in the Himalayan regions.
- Both diurnal and mean annual temperature ranges are least in coastal regions.
- In December, the temperature may dip to -40°C at some places in J&K while in many coastal regions average temperature is $20-25^{\circ}\text{C}$.
- Winters are moderately cold in most of the regions while the summers are extremely hot.
- Himalayan regions experience brutal winters while the summers are moderate.

Factors Influencing Indian Climate

1. Latitudinal location
2. Distance from the Sea
3. The Himalayas
4. Physiography
5. Monsoon Winds
6. Upper Air Circulation
7. El Nino and La Nina
8. Tropical Cyclones and Western Disturbances

Latitudinal location

- Indian climate resembles the climate of a tropical country. The mainland of India extends between **8°N to 37°N** .
- Areas south of the Tropic of Cancer are in tropics and hence receive high solar insolation. The summer temperatures are extreme and winters temperatures are moderate in most of the regions.
- The northern parts on the other hand lie in the warm temperate zone. They receive comparatively less solar insolation. But summer are equally hot in north India because of hot local wind called '**loo**'. Winter are very cold due to cold waves brought by the **western disturbances**.
- Some places in Himalayas record low temperatures particularly in winter. Coastal regions see moderate climatic conditions irrespective of latitudinal position.

Distance from the Sea

- Coastal regions have moderate or equable or maritime climate where as interior locations are deprived of the moderating influence of the sea and experience extreme or continental climate.
- The monsoon winds first reach the coastal regions and hence bring good amount of rainfall.

Himalayas and Indian Climate

This is the most important factor that influences Indian Climate. The Himalayas act as a **climatic divide** between India and Central Asia. During winter, Himalayas **protect India from cold and dry air masses of Central Asia**. During monsoon months these mountain ranges act as an **effective physical barrier for rain bearing south-west monsoon winds**. **Himalayas divide the Bay of Bengal branch of monsoon winds into two branches – one branch flowing along the plain regions towards north-west India and the other towards South-East Asia**. If the Himalayas were not present, the monsoon winds would simply move into China and most of the north India would have been a desert.

Why rainfall decreases from east to west in plains region (Indus-Ganga Plains)?

- In summer, there are many minor low pressure cells that exist all over the plain region.
- As the monsoon winds move from east to west the moisture levels decrease due to successive rainfall at each low pressure regions.
- By the time winds reach western parts of the plains (Delhi, Haryana etc.) all the moisture in the monsoon winds is **exhausted**.

Then how come Haryana and Punjab not deserts like Rajasthan?

They receive rainfall due to Western Disturbances in winter. (In summer the rainfall is very low.)

Physiography and Indian Climate

Physiography is the most important factor that determines the mean annual rainfall received by a region.

Why are some parts in peninsular India semi-arid?

- Places on the windward side of an orographic barrier receive great amount of rainfall where as those on the leeward side remain arid to semi-arid due to **rain-shadow effect**.
- Example: The south-west monsoon winds from the Arabian sea strike almost **perpendicular** at the Western Ghats and cause copious rainfall in the Western Coastal plain and the western slopes of the Western Ghats.
- On the contrary, vast areas of Maharashtra, Karnataka, Telangana, Andhra Pradesh and Tamil Nadu lie in rain-shadow or leeward side of the Western Ghats and receive scanty rainfall.

Why no significant rainfall in Gujarat and Rajasthan? Explain the formation of Thar Desert?

- Monsoons winds flowing in Rajasthan and Gujarat are **not obstructed by any orographic barrier** and hence these regions receive no rainfall.
- [Monsoon winds blow almost parallel to Aravalis and hence there is no orographic rainfall].
- [No convection cell or vertical wind movements arise in Rajasthan and Gujarat: Monsoon winds blow towards low pressure cells in Tibet and hence only horizontal wind movements exist in Gujarat and Rajasthan]
- [Sub-tropical high pressure belt: In winter the region experiences strong divergence because of the STJ – Sub-Tropical Jet.]

How come Cherrapunji and Mawsynram receive abnormally high rainfall?

- **Mawsynram and Cherrapunji** are the wettest places on earth with mean annual rainfall over 1000 cm.
- Copious rainfall in these places is due to **funneling effect** followed by **orographic upliftment**. [Funneling effect = clouds are channeled into a narrow region between mountains and hence the cloud density is extraordinary]

Monsoon Winds and Indian Climate

The most dominating factor of the Indian climate is the 'monsoon winds'.

Important features of Indian Monsoons are

1. **Sudden onset (sudden burst)**
2. **Gradual progress**
3. **Gradual retreat**
4. **Seasonal reversal of winds**

- The complete reversal of the monsoon winds brings about a **sudden change in the seasons**.
- The harsh summer season suddenly giving way to monsoon or rainy season.
- The south-west monsoons from the Arabian Sea and the Bay of Bengal bring rainfall to the entire country.
- The north-eastern winter monsoon do not cause much rainfall except along the Caromandel coast (TN coast) after getting moisture from the Bay of Bengal.

Upper Air Circulation

The changes in the upper air circulation over Indian landmass is brought about by Jet streams. **(Explained in detail in Indian Monsoons)**

Westerly Jet Stream

- Westerly jet stream blows at a very high speed during winter over the **sub-tropical zone**.
- Southern branch of the jet stream exercises a significant influence on the winter weather conditions in India.
- This jet stream is responsible for bringing **western disturbances** from the Mediterranean region in to the Indian sub-continent.
- Winter rain and heat storms in north-western plains and **occasional heavy snowfall** in hilly regions are caused by these disturbances.
- These are generally followed by cold waves in the whole of northern plains.

Easterly Jet Stream

- Reversal in upper air circulation takes place in summer due to the apparent shift of the sun's vertical rays in the northern hemisphere.
- The westerly jet stream is replaced by the easterly jet stream which owes its origin to the heating of the Tibet plateau.
- This helps in the **sudden onset of the south-west monsoons**.

Tropical Cyclones and Western Disturbances

- Tropical cyclones originate in the Bay of Bengal and Arabian Sea and influence large parts of the peninsular India.
- Majority of the cyclones originate in the **Bay of Bengal** and influence the weather conditions during the south-west monsoon season (**low intensity cyclones**).
- Some cyclones are born during the retreating monsoon season, i.e., in October and November (**high intensity cyclones**) and influence the weather conditions along the eastern coast of India.
- The western disturbances originate over the Mediterranean Sea and travel eastward under the influence of westerly jet stream.
- They influence the winter weather conditions over most of Northern-plains and Western Himalayan region.

El-Nino, La Nina, ENSO and Indian Climate

El Nino

Adversely affects monsoon rainfall and cyclogenesis in Bay of Bengal. Good for cyclogenesis in Arabian Sea. Droughts are common during El Nino events due to less monsoonal and cyclonic rainfall.

La Nina

Good for monsoons and cyclogenesis in Bay of Bengal. Suppressed cyclogenesis in Arabian Sea. Floods are common.

ENSO

- Southern Oscillation is simply the oscillation or alternating positions of low pressure and high pressure cells over eastern and western Pacific.
- Southern Oscillation coinciding with El Nino is called ENSO or El Nino Southern Oscillation. (SO usually coincides with El Nino. This why El Nino is usually referred to as ENSO)
- ENSO = [warm water in eastern Pacific + low pressure over eastern Pacific] + [cool water in western Pacific + high pressure in western Pacific]
- Climatic conditions same as El Nino.

Indian Climate: Summer & Winter Seasons

Indian Climate – Seasons

- The cold weather season or winter season,
- The hot weather season or summer season,
- The south-west monsoon season or Rainy season, and
- The season of the retreating monsoon or cool season.

Winter Season in India

- **November – March. January** is the coldest month.
- Sun's apparent path is to the south of equator.

- Clear sky, pleasant weather, low temperature, low humidity, high range of temperature, cool and slow north-east trade winds.
- The diurnal range of temperature, especially in interior parts of the country, is very high.

Temperature in Winter Season

- The isotherm of 20°C 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 experiences 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 in Winter Season

- High air pressure prevails over large parts of north-west India due to low temperatures coupled with divergence induced by the ridge of the STJ.
- Pressure is comparatively lower in south India.
- The winds start blowing from high pressure area of north-west to low pressure area of south-east. The wind velocity is low due to low pressure gradient.
- The path of the winds depend on pressure gradient and physiography.

Western Disturbances in Winter Season

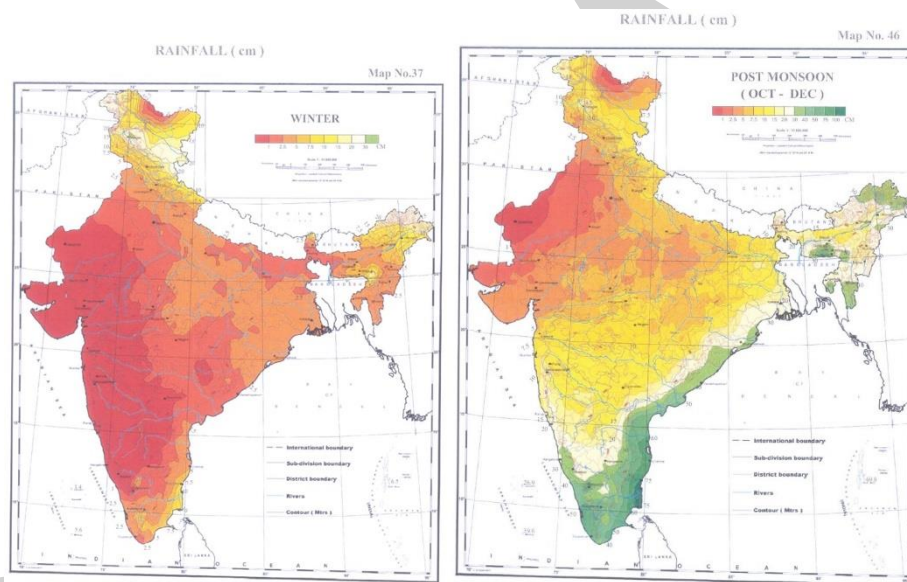
- The spell of fine weather over north-western and northern India is often broken due to inflow of western disturbances.
- They intensify over Rajasthan, Punjab, and Haryana.
- They move eastwards across the sub-Himalayan belt up to Arunachal Pradesh.
- They cause light rain in the Indus-Ganga plains and snowfall in the Himalayan belt.
- After the passage of the disturbance, widespread fog and cold waves lowering the minimum temperature by **5° to 10°C** below normal are experienced.
- Fog lowers visibility and causes great inconvenience for transportation.

Tropical Cyclones in Winter Season

- This is the season of least tropical cyclone activity.
- The frequency of tropical cyclones decreases with the advancement of the season.
- This is due to **low sea surface temperature and exit of ITCZ farthest south.**
- The storms which are born in the Bay of Bengal strike Tamil Nadu and bring heavy rainfall.
- Some of them cross the southern peninsula over to the Arabian Sea.
- Some storms originate in the Arabian Sea and move towards either north or west.

Precipitation in Winter Season

- 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 highest seasonal rainfall of about 75 cm between October and December.
- Most of it occurs along the south-eastern coast of Tamil Nadu and adjoining parts of Andhra Pradesh. Thereafter, it gradually decreases.
- The western disturbances also cause a little rainfall in north-west India.
- The amount of rainfall gradually decreases from the north and north-west to east (it is opposite in rainy season).
- The northeastern part of India also gets rainfall during the winter months.



Summer Season in India

March to June. High temperature and low humidity are the chief characteristics. Sometimes referred to as pre-monsoon period.

Temperature in Summer Season

- High sun's insolation due to apparent movement of sun between the equator and the Tropic of Cancer.
- The southern parts of the country are distinctly warmer in March and April whereas 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 where temperatures as high as 48°C may be recorded.
- In June the maximum temperature is in Punjab and Haryana.
- The highest temperatures recorded are **50.5°C at Alwar** on 10th May, 1956 and **50.6°C at Ganganagar** on 14th June, 1935.
- The highest temperatures are recorded just before the onset of the southwest monsoons (late May).

- The diurnal range of temperature is also very high. It may be as high as 18°C in some parts.
- The 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 those prevailing on the east coast due to the prevailing westerly winds.
- There is large contrast between land and sea temperatures.
- Northern and central parts of India experience heat waves in this season.

[A heat wave is an abnormally high temperature experienced by a regions. Temperature increase of the order of 6° to 7°C above normal is termed as 'moderate' and 8°C and more as 'severe' heat wave]

- Most of the heat waves develop over Rajasthan, Punjab and Haryana (location far away from the sea). From here they spread over Uttar Pradesh and Bihar.
- The strong north westerly winds (caused due to strong divergence in north-west India) with a long land journey over hot regions check the onward march of the sea breeze over eastern coastal belt and create heat wave conditions over Odisha and Andhra Pradesh.
- The heat waves strike by the end of April and their maximum occurrence is in May. They last till the onset of southwest monsoon.
- The normal duration of heat waves is 4 to 5 days. However, heat waves are rare over the peninsula south of 13°N latitude due to maritime conditions prevailing there.

Pressure in Summer Season

The atmospheric pressure is low all over the country due to high temperature. But strong dynamically induced divergence over north-west India prevents the onset of south-west monsoons.

Winds in Summer Season

There is a marked change in the direction and speed of the winds from winter. The winds are by and large light and variable.

Loo

- Loo winds originate over **Iranian, Baloch and Thar deserts**.
- In May and June, high temperature in northwest India builds steep pressure gradient.
- Hot, dust laden and strong wind known as loo blows.
- Loo normally starts blowing by 9.00 A.M., increases gradually and reaches maximum intensity in the afternoon.
- It blows with an average speed of 30-40 km per hour and persists for days.

Andhis

- 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.
- The wind velocity often reaches 50-60 kmph and the visibility is reduced to a few meters.
- Such dust storms are common in Rajasthan, Haryana, Punjab, and Jammu region, Delhi, Uttar Pradesh, Bihar and Madhya Pradesh.
- They are short lived. The squall and showers which follow these storms bring down the temperature sharply temporarily.

Frontal Thunderstorms in Summer Season

- The strong convectional movements related to the westerly jet stream lead to thunderstorms in eastern and north-eastern part of the country.
- They normally originate over Chotanagpur plateau and are carried eastwards by westerly winds.
- The areas with highest incidence of thunderstorms are Assam, Arunachal Pradesh, Nagaland, Mizoram, Manipur, Tripura, Meghalaya, West Bengal and the adjoining areas of Odisha and Jharkhand.

Norwesters and Thunderstorms in Summer Season

- 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**.
- They are often very violent with squall speeds of 60 to 80 km per hour.
- Hailstones sometimes accompany showers and occasionally attain the size of a golf ball.
- They cause heavy damage to standing crops, trees, buildings, livestock and even lead to loss of human lives.
- However, they are, sometimes, useful for tea, jute and rice cultivation. In Assam, these storms are known as '**Barodoli Chheerha**'.
- 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**, the black storms or a mass of dark clouds of Vaiasakha.

Convectional Thunderstorms in Summer Season

In the south the thunderstorms occur in **Kerala (Mango Showers)** and adjoining parts of **Karnataka (Blossom Showers)** and Tamil Nadu, particularly during evenings and nights.

Western Disturbances in Summer Season

- Their frequency and intensity gradually decrease with advancement of summer.
- Approximately 4, 3 and 2 western disturbances visit north-west India in March, April and May respectively.
- They cause snowfall in higher reaches of the Himalayas.

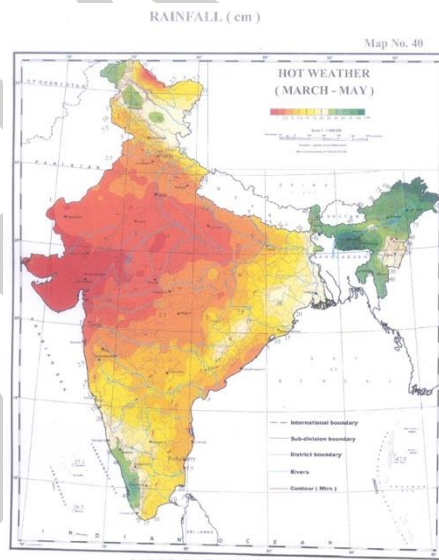
Tropical Cyclones in Summer Season

- Tropical cyclones originate in the Bay of Bengal and Arabian Sea.
- A few cyclones are formed in the Bay of Bengal in the month of March but they do not affect the mainland of India.
- Their frequency rises steeply in April and the number of cyclones originating in May is more than double than those originating in April.
- About three-fourths of the tropical cyclones are born in the Bay of Bengal and the rest originate in the Arabian Sea.
- Most of the depressions in April originate to the south of 10°N while those originating in May are born to the north of this latitude.
- Most of the storms of this season initially move west or north-west but later they re-curve northeast and strike **Bangladesh and the Arakan Coast of Myanmar**.
- Very few hit Indian coast while some dissipate over the sea itself.

- The whole of the east coast of India, the coastal areas of Bangladesh and Arakan Coast of Myanmar are liable to be hit by tropical storms in May.
- Many of them are quite severe and cause heavy damage to life and property.
- In the Arabian Sea, major storms are formed in May between 7° and 12° N latitudes.
- Most of them move away from the Indian coast in a north-westerly direction and dissipate in the sea.
- Few originate close to the Indian coast. They move towards the north-east and hit somewhere along the west coast of India.

Precipitation in Summer Season

- This season is not totally rainless (only one per cent of the annual rainfall).
- 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. The intensity of rainfall is high.
- The rainfall brought by the norwesters is known as the **spring storm showers**.
- This small amount of rainfall is very useful for the cultivation of tea, jute and rice and is known as **tea showers in Assam**.
- Coastal areas of Kerala and Karnataka receive rainfall from thunderstorms.
- Such showers are called **mango showers** in Tamil Nadu and Andhra Pradesh because they are very beneficial to mango crop.
- In Karnataka they are called **cherry blossoms** due to their effect on the coffee plantations.



Indian Climate: South West Monsoon Season

Isoline, Isobar, Isotherm & Isohyet

- **ISOLINE:** imaginary lines joining regions with equal rainfall or any other parameter.
- **ISOBAR:** imaginary lines joining regions with equal pressure.
- **ISOTHERM:** imaginary lines joining regions with equal temperature.
- **ISOHYET:** imaginary lines joining regions with equal rainfall.

Rainy Season – South West Monsoon Season

- South West Monsoon Season – **June to mid-September.**
- South West Monsoon Season is also known as **hot-wet season.**
- Sudden onset is the important feature of South West Monsoons.
- With the onset of monsoons, temperature falls drastically and humidity levels rise.

Temperature during South West Monsoon Season

- Sudden onset of South West Monsoons leads to significant fall in temperature [3° to 6°C].
- The temperature remains less uniform throughout the rainy season.
- The temperature rises in September with the cease of south-west monsoons.
- There is rise in temperature whenever there is **break in the monsoons.**
- The diurnal range of temperature is small due to clouds and rains.
- The highest temperatures are experienced at places west of the Aravali [38° to 40°C]. This is due to lack of clouds and hot continental air masses.
- Other parts of Northwest India also have temperatures above 30°C .
- The temperatures are quite low over the Western Ghats due to heavy rainfall.
- The coastal areas of Tamil Nadu and adjoining parts of Andhra Pradesh have temperatures above 30°C as they receive little rainfall during this season.

Pressure and Winds during South West Monsoon Season

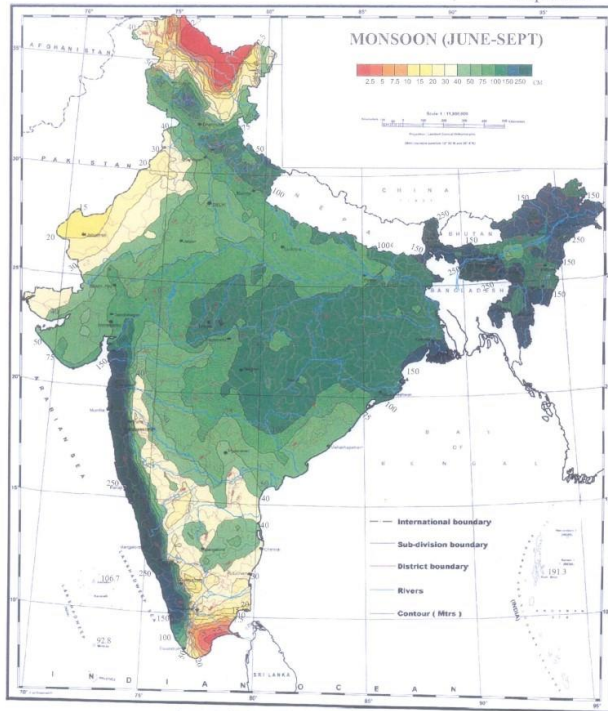
- Low pressure conditions prevail over northwest India due to high temperature.
- ITCZ (monsoon trough) lies along the Ganga plain. There are frequent changes in its location depending upon the weather conditions.
- The atmospheric pressure increases steadily southwards.
- Over the peninsular region, due to pressure gradient between north and south, winds blow in a southwest to northeast direction from Arabian Sea and Bay of Bengal.
- Their direction undergoes a change in Indo-Gangetic plain where they move from east to west.

Rainfall during South West Monsoon Season

- Three fourths of the total annual rainfall is received during this season.
- The average rainfall over the plains of India in this season is about 87 per cent.
- Normal date of the arrival of the monsoon is 20th May in Andaman and Nicobar Islands.
- The advance of the monsoon is **much faster in the Bay of Bengal than in the Arabian Sea.**
- The normal date of onset of the southwest monsoon over Kerala i.e. the **first place** of entry in the mainland of India is 1st June.
- The monsoons advance quickly accompanied with a lot of thunder, lightning and heavy downpour. This sudden onset of rain is termed as **monsoon burst.**
- Sometimes monsoons are delayed or they come much earlier than normal.
- Normally the onset occurs between 29th May and 7th June.
- The earliest onset was on 11th May in 1918 and 1955, while the most delayed onset was on 18th June in 1972.

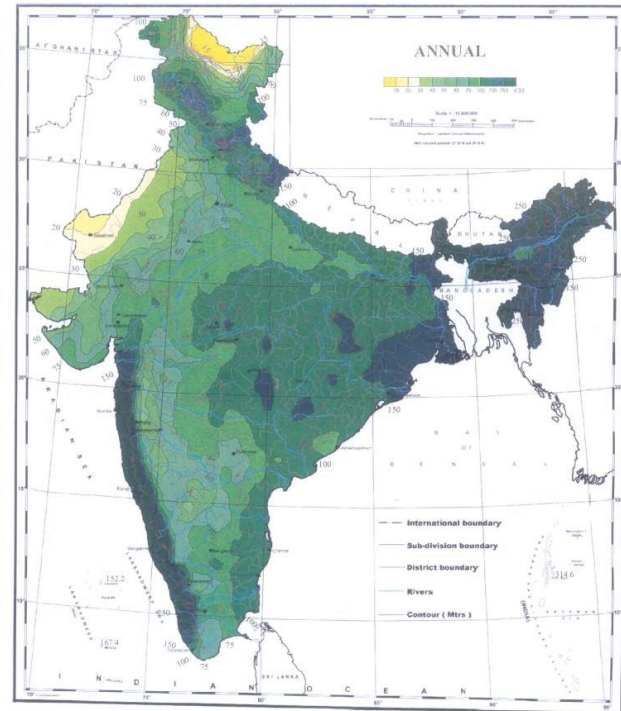
RAINFALL (cm)

Map No. 43



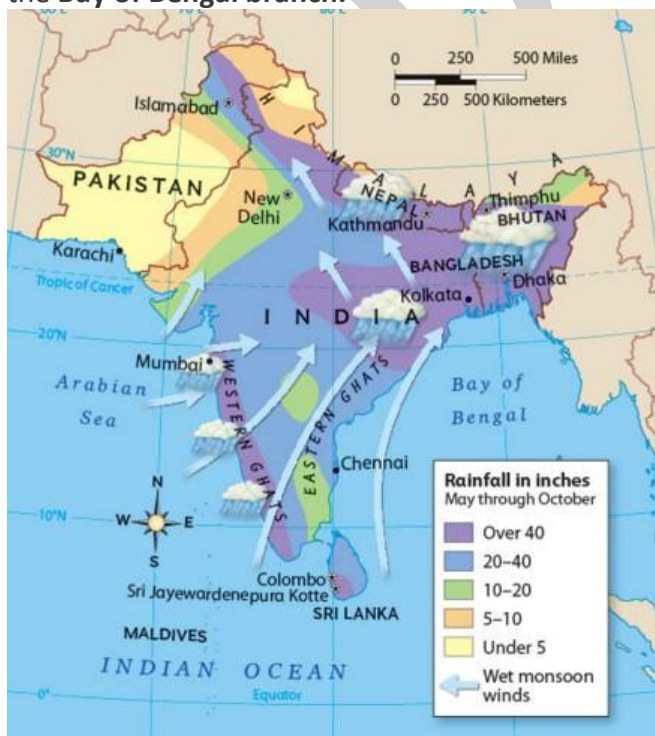
RAINFALL (cm)

Map No. 49



South West Monsoons – Arabian Sea branch and Bay of Bengal branch

Monsoon winds beyond south Kerala progress in the form of two branches viz. the **Arabian Sea branch** and the **Bay of Bengal branch**.



- The Arabian Sea branch gradually advances northwards. It reaches Mumbai by 10th June.
- The Bay of Bengal branch spreads rather rapidly over most of Assam. The normal date of its arrival at Kolkata is 7th June.
- On reaching the foothills of the Himalayas the Bay branch is deflected westward by the Himalayan barrier and it advances up the Gangetic plain.
- The two branches merge with each other mostly around Delhi to form a single current. Both the branches reach Delhi more or less at the same time.
- The combined current gradually extends to west Uttar Pradesh, Haryana, Punjab, Rajasthan and finally to Himachal Pradesh and Kashmir.
- By the end of June the monsoon is usually established over most parts of the country.

- By mid-July, the monsoon extends into Kashmir and the remaining parts of the country.
- By this time it reaches Kashmir, it has **shed most of its moisture**.
- Arabian Sea branch of the monsoon is much powerful than the Bay of Bengal branch for reasons:
 1. **The Arabian Sea is larger than the Bay of Bengal, and**
 2. **The entire Arabian Sea current advances towards India, whereas only a part of the Bay of Bengal current enters India, the remainder proceeding to Myanmar, Thailand and Malaysia.**

The Arabian Sea branch of the southwest monsoons is divided into three distinct streams on arriving in the mainland of India.

- The first stream strikes the west coast of India and gives extremely heavy rainfall of over 250 cm. It strike perpendicular to Western Ghats causing plentiful Orographic Rainfall [400 to 500 cm annual rainfall on the windward side].
- Rainfall is drastically reduced to about 30-50 cm on the leeward side of the crest.
- There is a narrow belt of marked aridity on the immediate leeward side of the Western Ghats. But once it is passed, the air starts rising again and the amount of rainfall increases further east.
- The second stream enters **Narmada—Tapi troughs (narrow rift valley)** and reaches central India. It does not cause much rain near the coast due to the absence of major orographic obstacle across the rift. Some parts of central India receive rainfall from this stream (Ex: Nagpur).
- The third stream moves parallel to the Aravali Range without causing much rainfall. Consequently the whole of Rajasthan is a desert area.
- However, some orographic effect is occurs on the south-eastern edge of the Aravali Range. **Mt. Abu** gets about 170 cm rainfall while the surrounding plains have only 60 to 80 cm rainfall.

The Bay of Bengal Branch of the southwest monsoon is divided into two distinct streams.

- The first stream crosses the **Ganga-Brahmaputra delta** and reaches **Meghalaya**. Here that the orographic effect results in intense rainfall. Cherrapunji receives an annual rainfall of 1,102 cm, major portion of which occurs from June to August.
- **Mawsynram (present champion)** located at 1,329 m above sea level just 16 km to the west of **Cherrapunji (X champion)** records higher annual rainfall of 1,221 cm.
- Both the stations are located on the southern slopes of the **Khasi hills** at the northern end of a deep valley running from south to north.
- The second stream of the Bay of Bengal branch moves along **Himalayan foothills** as they are deflected to the west by the Himalaya and brings widespread rainfall to Ganga plain.
- The rainfall by this stream is characterized by a **steady decline** as we move from east to west up the plain. [Previous Prelims Question]
- The **Tamil Nadu coast** remains relatively dry during the south-west monsoon period because of
 1. **Rain shadow effect of the Arabian Sea current and**
 2. **Bay of Bengal current which flows parallel to the coast.**

Break in the South West Monsoons

- During the Monsoon season, there are periods when the Monsoon trough shifts to the foothills of Himalayas, which leads to sharp decrease in rainfall over most parts of the country but increase along the Himalayas and parts of Northeast India and Southern Peninsula.
- 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 **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.

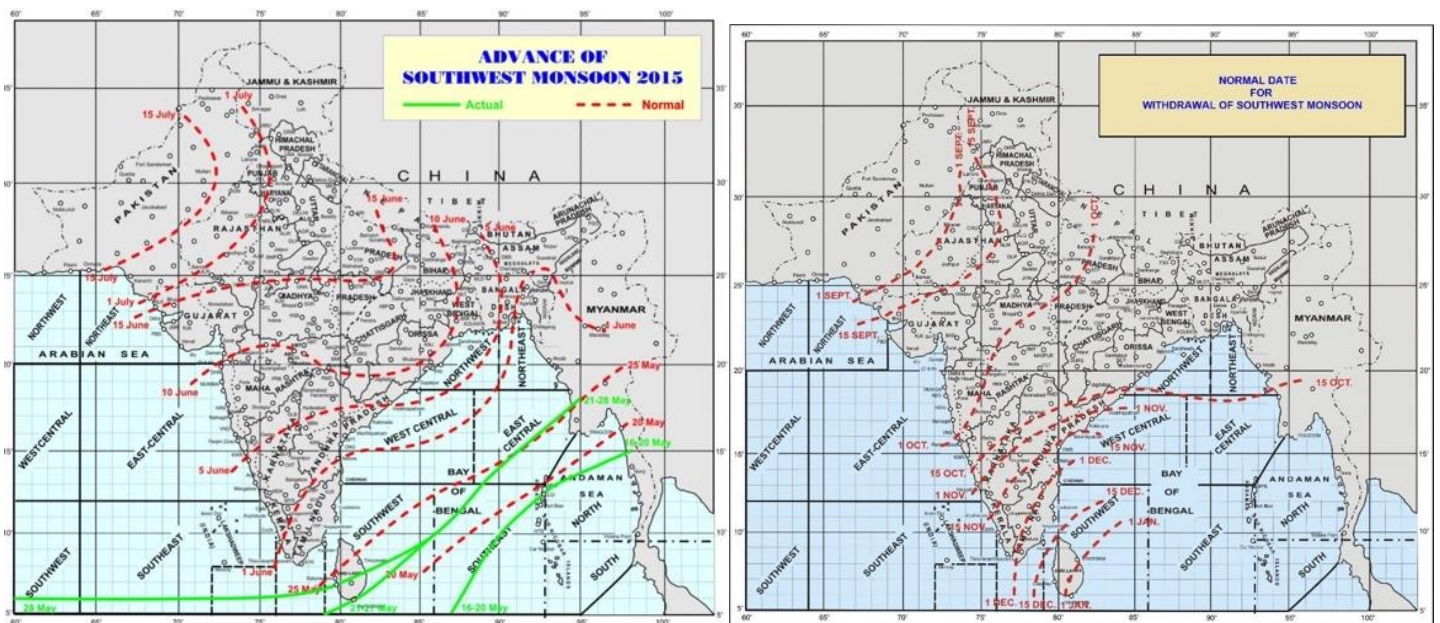
The monsoon trough is a portion of the Inter-tropical Convergence Zone as depicted by a line on a weather map showing the locations of minimum sea level pressure, and as such, is a convergence zone between the wind patterns of the southern and northern hemispheres.

- During the break period, heavy rainfall occurs over the sub-Himalayan regions and the southern slopes of the Himalayas.
- On an average one or two breaks do occur during the rainy season. 85 out of 100 years there is a break in the monsoons.

Depressions in South West Monsoon Season

- A major part of the South West Monsoon rainfall is generated by depressions [intense low pressure] originating in the Arabian Sea and Bay of Bengal. Some depressions develop over land also.
- About 3-4 depressions are formed per month from June to September.
- Almost all of them are sucked inward through the deltas of great rivers [They need moisture to be alive], the Ganga, the Mahanadi, the Godavari, the Krishna and the Cauvery and cause heavy rain in these areas.
- The location of depressions strongly coincide with the latitudinal position of ITCZ.
- Most of the depression originate to the west of 90° E in Bay of Bengal and move in north-west direction.
- In the Arabian Sea in June-July, the depressions move either in north-west or in northerly direction and may affect west Gujarat or Maharashtra.
- Storms during August and September are rare and are formed close to Maharashtra-Gujarat coast.
- Most of the rainfall in central and northern parts of the country is caused by these depressions.
- The absence of depressions or a change in their tracks result in deficit or no rain.

Advance and Withdrawal of South West Monsoons



Chief Characteristics of South West Monsoon Rainfall

- Major part of monsoon rains are received between **June and September**.
- Monsoonal rainfall is largely governed by **relief and is orographic** in its mode.
- The amount of rainfall decreases with increasing distance from the sea.
- The rainless interval during south west monsoon season is known as 'breaks'. The breaks in rainfall are related to tropical cyclones which originate in the Bay of Bengal.
- There are large scale spatial variations in the distribution of rainfall.
- Monsoons often fail to keep date. Sometimes the monsoons withdraw before the scheduled time causing considerable damage to the crops.

Retreating Monsoon Season (North East Monsoons)

- Starts with the beginning of the withdrawal of **southwest monsoon [middle of September – November]** and lasts till **early January**.
- The monsoons withdraw from the extreme north-west end of the country in September, from the peninsula by October and from the extreme south-eastern tip by December.
- In Punjab the south-west monsoons reach in the first week of July and withdraw from there in the second week of September.
- The south-west monsoons reach Coromandel Coast in the first week of June and withdraw from there only in the middle of December.
- Unlike the sudden burst of the advancing monsoons, the **withdrawal is rather gradual** and takes about three months.

Temperature during Retreating Monsoon Season

With retreat of the monsoons, the clouds disappear and the sky becomes clear. The day temperature starts falling steeply. The diurnal range of temperature increases due to lack of cloud cover.

Pressure and Winds during Retreating Monsoon Season

- As the monsoons retreat, the monsoon trough weakens and gradually shifts southward. Consequently the pressure gradient is low.
- Unlike south-west monsoon, the onset of the north monsoon is not clearly defined.
- The direction of winds over large parts of the country is influenced by the local pressure conditions.

Cyclones during Retreating Monsoon Season

- **Most severe and devastating tropical cyclones** originate in the Indian seas especially in the Bay of Bengal.
- The highest frequency of the cyclones is in the month of October and the first half of November.

More cyclones are born in October and then in November and more cyclones originate in the Bay of Bengal than in the Arabian Sea.

- In October, the Cyclones of the Bay of Bengal originate between 8°N and 14°N.
- Initially they move in a west or northwesterly direction, but many of them later recurve and move towards the north-east.
- Near 55 per cent of the Bay storms cross or affect the Indian coast.
- The area's most vulnerable to these storms include the coastal belts of Tamil Nadu, Andhra Pradesh, Odisha and West Bengal.
- Many of the cyclones which strike the eastern coast of India, south of 15°N latitude cross the southern Peninsula and enter Arabian Sea.
- During this process, they may weaken, but on re-entry over the Arabian Sea they intensify into cyclonic storms.
- The storms of Arabian Sea originate between 12°N and 17°N latitudes in October and between 8° N and 13° N latitudes in November.
- Generally they move away from the coast in a north-westerly direction. But about 25% of them later recurve northeast and strike the **Maharashtra or Gujarat coast**.
- In north-west India the western disturbances produce clouding and light rainfall in the otherwise fine weather.
- The precipitation is in the form of snow in higher reaches of Jammu and Kashmir, Himachal Pradesh and in Kumaon Hills.

Precipitation during Retreating Monsoon Season

- The humidity and cloud cover are much reduced with the retreat of the south-west monsoons and most parts of the country remain without much rainfall.
- October-November is the **main rainy season in Tamil Nadu** and adjoining areas of **Andhra Pradesh** to the south of the Krishna delta as well as a secondary rainy period for Kerala.
- The retreating monsoons absorb moisture while passing over the **Bay of Bengal** and cause this rainfall.

Annual Rainfall [South West Monsoons + Retreating Monsoons]

Areas of very high rainfall

- Areas receiving an annual rainfall of 200 cm and above.
- These include western side of Western Ghats [Thiruvananthapuram in the south to Mumbai in the north].

- The average annual rainfall in this belt is 200-400 cm.
- Assam, Nagaland, Meghalaya, Mizoram, Arunachal Pradesh, Sikkim, parts of Manipur, Tripura and north-eastern tip of West Bengal also receive 200 cm or more, with isolated pockets receiving over 400 cm.

Meghalaya (the abode of clouds) is the wettest part of the country with Mawsynram and Cherrapunji getting 1,221 and 1,102 cm of annual rainfall respectively.

Areas of high rainfall

- 100-200 cm annual rainfall.
- Eastern slopes of the Western Ghats, major part of the northern plain, Odisha, Madhya Pradesh, Andhra Pradesh and Tamil Nadu.

Areas of low rainfall

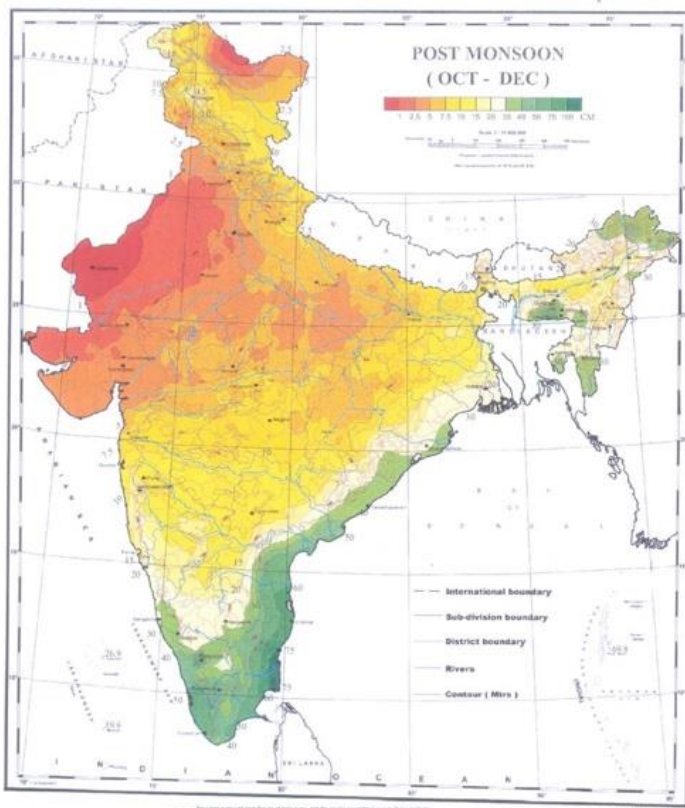
- 50-100 cm annual rainfall.
- Large parts of Gujarat, Maharashtra, western Madhya Pradesh, Andhra Pradesh, Karnataka, eastern Rajasthan, Punjab, Haryana and parts of Uttar Pradesh.

Areas of very low rainfall

- These are desert and semi-desert areas receiving less than 50 cm of annual rainfall.
- They include large areas of western Rajasthan, Kachchh and most of Ladakh region of Jammu and Kashmir.

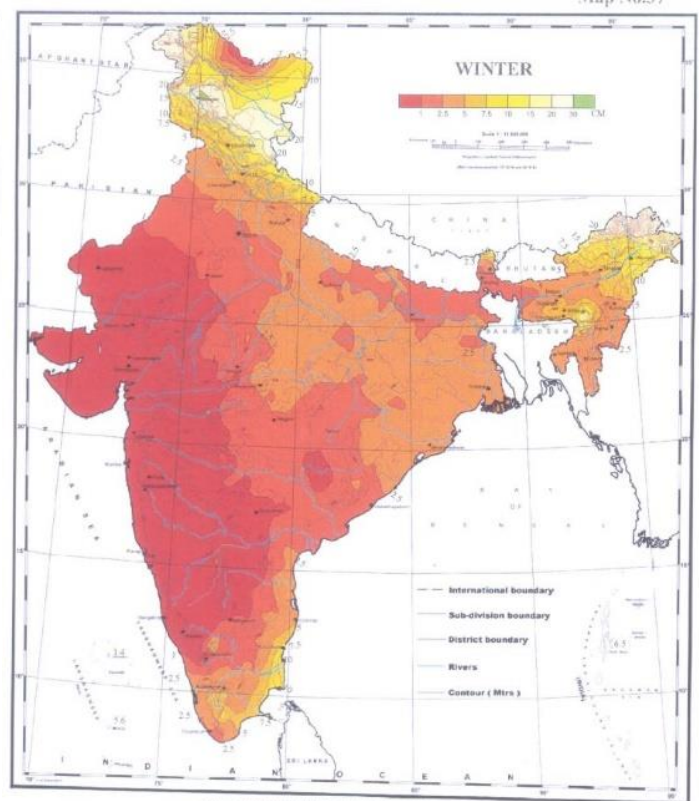
RAINFALL (cm)

Map No. 46



RAINFALL (cm)

Map No.37



Natural Vegetation of India

Classification of Natural Vegetation of India is primarily based on spatial and annual variations in rainfall. Temperature, soil and topography are also considered. India's vegetation can be divided into 5 main types and 16 sub-types as given below.

A. Moist Tropical Forests

- Tropical Wet Evergreen
- Tropical Semi-Evergreen
- Tropical Moist Deciduous
- Littoral and Swamp

B. Dry Tropical Forests

- Tropical Dry Evergreen
- Tropical Dry Deciduous
- Tropical Thorn

C. Montane Sub-tropical Forests

- Sub-tropical broad leaved hill
- Sub-tropical moist hill (pine)
- Sub-tropical dry evergreen

D. Montane Temperate Forests

- Montane Wet Temperate
- Himalayan Moist Temperate
- Himalayan Dry Temperate

E. Alpine Forests

- Sub-Alpine
- Moist Alpine scrub
- Dry Alpine scrub

Forest Type in India	% of Total Area
Tropical Moist Deciduous	37
Tropical Dry Deciduous	28
Tropical Wet Evergreen	8
Sub-Tropical Moist Hill	6
Tropical Semi-Evergreen	4
Rest below 4 %	

Moist Tropical Forests

Tropical Wet Evergreen Forests or Rain Forests

Climatic Conditions

- Annual rainfall exceeds 250 cm
- The annual temperature is about 25°-27°C
- The average annual humidity exceeds 77 per cent and
- The dry season is distinctly short.

Characteristics

- Evergreen: Due to high heat and high humidity, the trees of these forests do not shed their leaves together.
- **Mesophytic: Plants adopted to neither too dry nor too wet type climate.**

What are mesophytes?

- ✓ Unlike **hydrophytic plants**, such as water lily or pondweed, that grow in saturated soil or water, or **xerophytic plants**, such as cactus, that grow in extremely dry soil, mesophytes are ordinary plants that **exist between the two extremes**.
- ✓ Mesophytic environments are marked by average to hot temperatures and soil that is **neither too dry nor too wet**.
- Lofty: The trees often reach 45 – 60 meters in height.
- Thick Canopy: From the air, the tropical rain forest appears like a thick canopy of foliage, broken only where it is crossed by large rivers or cleared for cultivation.
- All plants struggle upwards (most **epiphytes**) for sunlight resulting in a peculiar layer arrangement. The entire morphology looks like a green carpet when viewed from above.

Epiphytes

Less undergrowth: The sun light cannot reach the ground due to thick canopy. The undergrowth is formed mainly of bamboos, ferns, climbers, orchids, etc.

Distribution

- Western side of the Western Ghats (500 to 1370 meters above sea level).
- Some regions in the Purvanchal hills.
- In the Andaman and Nicobar Islands.

Timber

- Hardwood: The timber of these forests is fine-grained, hard and durable.
- It has high commercial value but it is highly challenging to exploit due to **dense undergrowth, absence of pure stands and lack of transport facilities** [Read previous posts on Climatic regions to understand how lumbering industry works in Equatorial Rainforests (hardwood) and Taiga Climatic (softwood) conditions].
- The important species of these forests are **mahogany, mesua, white cedar, jamun, canes, bamboo** etc.

Tropical Semi-Evergreen Forests

They are transitional forests between tropical wet evergreen forests and tropical deciduous forests. They are comparatively drier areas compared to tropical wet evergreen forests.

Climatic Conditions

- Annual rainfall is 200-250 cm
- Mean annual temperature varies from 24°C to 27°C
- The relative humidity is about 75 per cent
- The dry season is not short like in tropical evergreen forests.

Distribution

- Western coast
- Assam

- Lower slopes of the Eastern Himalayas
- Odisha and
- Andamans.

Characteristics

- The semi-evergreen forests are less dense.
- They are more **gregarious [living in flocks or colonies – more pure stands]** than the wet evergreen forests.
- These forests are characterized by many species.
- Trees usually have **buttressed trunks with abundant epiphytes**.

Buttressed Trunks

The important species are laurel, rosewood, mesua, thorny bamboo – Western Ghats, white cedar, Indian chestnut, champa, mango, etc. – Himalayan region.

Timber

Hardwood: Similar to that in tropical evergreen forests except that these forests are less dense with **more pure stands** (timber industry here is better than in evergreen forests).

Tropical Moist Deciduous Forests

Climatic Conditions

- Annual rainfall 100 to 200 cm.
- Mean annual temperature of about 27°C
- The average annual relative humidity of 60 to 75 per cent.
- Spring (between winter and summer) and summer are dry.

Characteristics

- The trees drop their leaves during the spring and early summer when sufficient moisture is not available.
- The general appearance is bare in extreme summers (April-May).
- Tropical moist deciduous forests present irregular top storey [25 to 60 m].
- Heavily buttressed trees and fairly complete undergrowth.
- These forests occupy a much larger area than the evergreen forests but large tracts under these forests have been cleared for cultivation.

Distribution

- Belt running along the Western Ghats surrounding the belt of evergreen forests.
- A strip along the Shiwalik range including terai and bhabar from 77° E to 88° E.
- Manipur and Mizoram.
- Hills of eastern Madhya Pradesh and Chhattisgarh.
- Chotanagpur Plateau.
- Most of Odisha.
- Parts of West Bengal and
- Andaman and Nicobar islands.

Timber

- These provide valuable timber like **Teak**.
- The main species found in these forests are teak, sal, laurel, rosewood, amla, jamun, bamboo, etc.

- It is comparatively easy to exploit these forests due to their high degree of gregariousness (more pure stands).

Littoral and Swamp Forests

- They can survive and grow both in fresh as well as **brackish water** (The mixture of seawater and fresh water in estuaries is called brackish water and its salinity can range from 0.5 to 35 ppt).
- Occur in and around the deltas, estuaries and creeks prone to **tidal influences (delta or tidal forests)**.
- Littoral (relating to or on the shore of the sea or a lake) forests occur at several places along the coast.
- Swamp forests are confined to the deltas of the Ganga, the Mahanadi, the Godavari, the Krishna and the Cauvery.
- Dense mangroves occur all along the coastline in sheltered estuaries, tidal creeks, backwaters, salt marshes and mudflats. It provides useful fuel wood.
- The most pronounced and the densest is the **Sunderban in the Ganga delta** where the predominant species is Sundri (Heriteera).

Timber

- It provides hard and durable timber which is used for construction, building purposes and making boats.
- The important species found in these forests are Sundri, agar, rhizophora, screw pines, canes and palms, etc.

Dry Tropical Forests

Tropical Dry Evergreen Forests

Distribution: Along the coasts of Tamil Nadu.

Climatic Conditions

- Annual rainfall of 100 cm [mostly from the north-east monsoon winds in October – December].
- Mean annual temperature is about 28°C.
- The mean humidity is about 75 per cent.
- The growth of evergreen forests in areas of such low rainfall is a bit strange.

Characteristics

- Short statured trees, up to 12 m high, with complete canopy.
- Bamboos and grasses not conspicuous.
- The important species are jamun, tamarind, neem, etc.
- Most of the land under these forests has been cleared for agriculture or **casuarina plantations**.

❖ Casuarina plantation

- It resembles feathery conifer in general appearance.
- They are rapid-growing, carefree species for sites and climates as varied as coastal sand dunes, high mountain slopes, hot humid tropics, and semi-arid regions.
- They have the ability to **fix atmospheric nitrogen**. It grows 15 to 25 meters in height on an average.

Distribution: Casuarina is the most popular farm forestry in the states of Andhra Pradesh, Tamil Nadu, West Bengal, Odisha, Maharashtra, Gujarat, and Karnataka.

Benefits

- Reduces damage in the event of natural calamities.
- Line planting in the coastal areas helps in controlling the wind force.
- It is also used for tourism promotion in view of its ornamental appearance.
- It provides top quality firewood.
- The wood is suitable for paper pulp and useful raw material for the manufacture of paper for writing, printing, and wrapping.
- It is got some serious medicinal values as well.

Wasteland development: The characteristics which make it a suitable species for wasteland development include adaptability to wide range of habitats, fast growth, salt tolerant, drought resistant, ability to reclaim land and stabilize sand dunes. Intercrops such as groundnut, cucumber, watermelons, sesamum, and pulses can also be raised along with the plantation.

Tropical Dry Deciduous Forests

Climatic Conditions: Annual rainfall is 100-150 cm.

Characteristics

- These are similar to moist deciduous forests and shed their leaves in dry season.
- The major difference is that they can grow in areas of comparatively less rainfall.
- They represent a transitional type – moist deciduous on the wetter side and thorn forests on the drier side.
- They have closed but uneven canopy.
- The forests are composed of a mixture of a few species of deciduous trees rising up to a height of 20 meters.
- Undergrowth: Enough light reaches the ground to permit the growth of grass and climbers.

Distribution

- They occur in an irregular wide strip running from the foot of the Himalayas to Kanniyakumari except in Rajasthan, Western Ghats and West Bengal.
- The important species are teak, axlewood, rosewood, common bamboo, **red sanders**, laurel, satinwood, etc.
- Large tracts of this forest have been cleared for agricultural purposes.
- These forests have suffer from over grazing, fire, etc.

Tropical Thorn Forests

Climatic Conditions

- Annual rainfall less than 75 cm.
- Humidity is less than 50 per cent.
- Mean temperature is 25°-30°C.

Characteristics

- The trees are low (6 to 10 meters maximum) and widely scattered.
- Acacias and Euphorbias are very prominent.
- The Indian wild date is common. Some grasses also grow in the rainy season.

Distribution

- Rajasthan, south-western Punjab, western Haryana, Kachchh and neighbouring parts of Saurashtra.
- Here they degenerate into desert type in the Thar Desert.

- Such forests also grow on the leeward side of the Western Ghats covering large areas of Maharashtra, Karnataka, Telangana, Andhra Pradesh and Tamil Nadu.
- The important species are neem, babul, cactii, etc.

Montane Sub-Tropical Forests

Sub-tropical Broad-leaved Hill Forests

Climatic conditions

- Mean annual rainfall is 75 cm to 125 cm.
- Average annual temperature is 18°-21°C.
- Humidity is 80 per cent.

Distribution: Eastern Himalayas to the east of 88°E longitude at altitudes varying from 1000 to 2000 m.

Characteristics

- Forests of evergreen species.
- Commonly found species are evergreen oaks, chestnuts, ash, beech, sal and pines.
- Climbers and epiphytes [a plant that grows non-parasitically on a tree or other plant] are common.
- These forests are not so distinct in the southern parts of the country. They occur only in the Nilgiri and Palni hills at 1070-1525 metres above sea level.
- It is a “stunted rain-forest” and is not as luxuriant as the true tropical evergreen.
- The higher parts of the Western Ghats such as Mahabaleshwar, the summits of the Satpura and the Maikal Range, highlands of Bastar and Mt. Abu in the Aravali Range carry sub-types of these forests.

Sub-tropical Moist Pine Forests

Distribution: Western Himalayas between 73°E and 88°E longitudes at elevations between 1000 to 2000 meters above sea level. Some hilly regions of Arunachal Pradesh, Manipur, Naga Hills and Khasi Hills.

Timber: **Chir** or **Chil** is the most dominant tree which forms pure stands. It provides **valuable timber** for furniture, boxes and buildings. It is also used for producing resin and turpentine.

Sub-tropical Dry Evergreen Forests

Distribution: Found in the Bhabar, the Shiwaliks and the western Himalayas up to about 1000 meters above sea level.

Climatic Conditions: Annual rainfall is 50-100 cm (15 to 25 cm in December-March). The summers are sufficiently hot and winters are very cold.

Characteristics: Low scrub forest with small evergreen stunted trees and shrubs. Olive, acacia modesta and pistacia are the most predominant species.

Montane Temperate Forests

Montane Wet Temperate Forests

Climatic Conditions: Grows at a height of 1800 to 3000 m above sea level. Mean annual rainfall is 150 cm to 300 cm. Mean annual temperature is about 11°C to 14°C and the average relative humidity is over 80 per cent.

Distribution: Higher hills of Tamil Nadu and Kerala, in the Eastern Himalayan region.

Characteristics:

- These are closed evergreen forests. Trunks have large girth.
- Branches are clothed with mosses, ferns and other epiphytes.
- The trees rarely achieve a height of more than 6 meters.
- Deodar, Chilauni, Indian chestnut, birch, plum, machilus, cinnamomum, litsea, magnolia, blue pine, oak, hemlock, etc. are important species.

Himalayan Moist Temperate Forests

Climatic Conditions: Annual rainfall varies from 150 cm to 250 cm.

Distribution: Occurs in the temperate zone of the Himalayas between 1500 and 3300 meters. Cover the entire length of this mountain range in Kashmir, Himachal Pradesh, Uttarakhand, Darjeeling and Sikkim.

Characteristics

- Mainly composed of **coniferous species**.
- Species occur in mostly pure strands.
- Trees are 30 to 50 m high.
- Pines, cedars, silver firs, spruce, etc. are most important trees.
- They form high but fairly open forest with shrubby undergrowth including oaks, rhododendrons and some bamboos.

Timber: It provides fine wood which is of much use for construction, timber and railway sleepers.

Himalayan Dry Temperate Forests

Climatic Conditions: Precipitation is below 100 cm and is mostly in the form of snow.

Characteristics: Coniferous forests with xerophytic shrubs in which deodar, oak, ash, olive, etc. are the main trees.

Distribution: Such forests are found in the inner dry ranges of the Himalayas where south-west monsoon is very feeble. Such areas are in Ladakh, Lahul, Chamba, Kinnaur, Garhwal and Sikkim.

Alpine Forests

- Altitudes ranging from 2,900 to 3,500.
- These forests can be divided into: (1) sub-alpine; (2) moist alpine scrub and (3) dry alpine scrub.
- The sub-alpine forests occur lower alpine scrub and grasslands.
- It is a mixture of coniferous and broad-leaved trees in which the coniferous trees attain a height of about 30 m while the broad leaved trees reach only 10 m.
- Fir, spruce, rhododendron, etc. are important species.
- The moist alpine scrub is a low evergreen dense growth of rhododendron, birch etc. which occurs from 3,000 meters and extends up to snowline.
- The dry alpine scrub is the uppermost limit of scrub xerophytic, dwarf shrubs, over 3,500 meters above sea level and found in dry zone. Juniper, honeysuckle, artemesia etc. are important species.

Indian Soils & distribution

- Soil is the thin top layer on the earth's crust comprising rock particles mixed with organic matter.
- **Pedology** is the study of soils in their natural environment. **Pedogenesis** is the natural process of soil formation that includes a variety of processes such as weathering, leaching, calcification etc.
- The Soil formation is mainly related to the parent rock material, surface relief, climate and natural vegetation.
- The soil is formed by the breaking down of rocks by the action of wind, water and climate.

Soil Types – Sandy-Clayey-Loamy

The soil is classified on the basis of the proportion of particles of various sizes: If soil contains greater proportion of big particles it is called **sandy soil**. If the proportion of fine particles is relatively higher, then it is called **clayey soil**. If the amount of large and fine particles is about the same, then the soil is called **loamy soil**.

1. Water can drain quickly through the spaces between the sand particles. So, sandy soils tend to be light, well aerated and dry.
 2. Clay particles, being much smaller, pack tightly together, leaving little space for air. Unlike sandy soil, water can be held in the tiny gaps between the particles of clay. So clay soils have little air. But they are heavy as they hold more water than the sandy soils.
 3. The best topsoil for growing plants is Loamy soil is a mixture of sand, clay and another type of soil particle known as silt. Silt occurs as a deposit in river beds. The size of the silt particles is between those of sand and clay. The loamy soil also has humus in it. It has the right water holding capacity for the growth of plants.
- Clayey and loamy soils are both suitable for growing cereals like wheat, and gram. Such soils are good at retaining water.
 - For paddy, soils rich in clay and organic matter and having a good capacity to retain water are ideal.
 - For lentils (masoor) and other pulses, loamy soils, which drain water easily, are required.
 - For cotton, sandy loam or loam, which drain water easily and can hold plenty of air, are more suitable.
 - A vertical section through different layers of the soil is called the soil profile. Each layer differs in feel (texture), colour, depth and chemical composition.
 - A soil horizon is a layer generally parallel to the soil surface, whose physical characteristics differ from the layers above and beneath.



O (humus or organic)
A (topsoil)

E (eluviated horizon)

B (subsoil)

C (parent material)

R (bedrock)

O HORIZON
Surface litter: Partially decomposed organic matter

A HORIZON
Topsoil: Humus, living creatures, inorganic minerals

E HORIZON
Zone of leaching, materials move downward

B HORIZON
Subsoil: iron, aluminium humic compounds are accumulated and clay leached down from A and E horizons

C HORIZON
Weathered parent material: Partial breakdown of inorganic minerals

R HORIZON
Bedrock

- Horizons are defined in most cases by obvious physical features, chiefly colour and texture.
- The uppermost horizon is generally dark in colour as it is rich in humus and minerals. The humus makes the soil fertile and provides nutrients to growing plants.
- This layer is generally soft, porous and can retain more water. It is called the topsoil or the A-horizon.
- The next layer has a lesser amount of humus but more of minerals. This layer is generally harder and more compact and is called the B-horizon or the middle layer.
- The third layer is the C-horizon, which is made up of small lumps of rocks with cracks.

O Horizon

Layers dominated by organic material. Some O layers consist of undecomposed or partially decomposed litter (such as leaves, needles, twigs, moss, and lichens). They may be on top of either mineral or organic soils.

A Horizon or Surface soil

- It is the part of top soil. In this layer, organic matter is mixed with mineral matter.
- It is the layer of mineral soil with the most organic matter accumulation and soil life.
- This layer is depleted of (eluviated of) iron, clay, aluminum, organic compounds, and other soluble constituents.
- When depletion is pronounced, a lighter colored "E" subsurface soil horizon is apparent at the base of the "A" horizon.

E horizon

- "E" stands for eluviated layer.
- It is the horizon that has been significantly leached of clay, iron, and aluminum oxides, which leaves a concentration of resistant minerals, such as quartz, in the sand and silt sizes.
- These are present only in older, well-developed soils, and generally occur between the A and B horizons.

B Horizon or Subsoil

- It is subsurface layer reflecting chemical or physical alteration of parent material.
- This layer accumulates all the leached minerals from A and E horizon.
- Thus iron, clay, aluminum and organic compounds accumulate in this horizon [illuviation (opposite of eluviation)].

C Horizon or Parent rock

- Weathered parent material accumulates in this layer, i.e. the parent material in sedimentary deposits.
- It is a layer of large unbroken rocks.
- This layer may accumulate the more soluble compounds (inorganic material).

R Horizon or Bedrock

- This layer denotes the layer of partially weathered bedrock at the base of the soil profile.
- Unlike the above layers, R horizons largely comprise continuous masses of hard rock.
- Soils formed in situ will exhibit strong similarities to this bedrock layer.
- These areas of bedrock are under 50 feet of the other profiles.

Major Soil Types of India

- Alluvial soils,
- Black soils,
- Red soils,
- Laterite and Lateritic soils,
- Forest and Mountain soils,
- Arid and Desert soils,
- Saline and Alkaline soils
- Peaty and Marshy soils.

Alluvial Soils

- Alluvial soils are formed mainly due to silt deposited by Indo-Gangetic-Brahmaputra Rivers. In coastal regions some alluvial deposits are formed due to wave action.
- Rocks of the Himalayas form the parent material. Thus the parent material of these soils is of transported origin.
- They are the largest soil group covering about 15 lakh sq. km or about **46 per cent** of the total area.
- They support more than 40% of the India's population by providing the most productive agricultural lands.

Characteristics of Alluvial Soils

- They are **immature and have weak profiles** due to their recent origin.
- Most of the soil is Sandy and clayey soils are not uncommon.
- Pebbly and gravelly soils are rare. Kankar (calcareous concretions) beds are present in some regions along the river terraces.
- The soil is **porous** because of its loamy (equal proportion of sand and clay) nature.
- Porosity and texture provide good drainage and other conditions favorable for agriculture.
- These soils are constantly replenished by the recurrent floods.

Chemical properties of Alluvial Soils: The proportion of nitrogen is generally low. The proportion of Potash, phosphoric acid and alkalis are adequate. The proportion of Iron oxide and lime vary within a wide range.

Distribution of Alluvial Soils in India

- They occur all along the Indo-Gangetic-Brahmaputra plains except in few places where the top layer is covered by desert sand.
- They also occur in deltas of the Mahanadi, the Godavari, the Krishna and the Cauvery, where they are called deltaic alluvium (coastal alluvium)
- Some alluvial soils are found in the Narmada, Tapi valleys and Northern parts of Gujarat.

Crops in Alluvial Soils

- They are mostly flat and regular soils and are best suited for agriculture.
- They are best suited to irrigation and respond well to canal and well/tube-well irrigation.
- They yield splendid crops of rice, wheat, sugarcane, tobacco, cotton, jute, maize, oilseeds, vegetables and fruits.

Geological divisions of alluvial soils: Geologically, the alluvium of the Great plain of India is divided into newer or younger khadar and older bhangar soils.

Bhabar

- The bhabar belt is about 8-16 km wide running along the Shiwalik foothills. It is a porous, northern most stretch of Indo-Gangetic plain.
- Rivers descending from the Himalayas deposit their load along the foothills in the form of **alluvial fans**. These alluvial fans (often pebbly soils) have merged together to build up the bhabar belt.
- The porosity of bhabar is the most unique feature. The porosity is due to deposition of huge number of pebbles and rock debris across the alluvial fans.
- The streams disappear once they reach the bhabar region because of this porosity. Therefore, the area is marked by **dry river courses** except in the rainy season.
- **The area is not suitable for agriculture and only big trees with large roots thrive in this belt.**

Terai

- Terai is an **ill-drained, damp (marshy) and thickly forested narrow tract** (15-30 km wide) to the south of Bhabar running parallel to it.
- The underground streams of the Bhabar belt re-emerge in this belt. It is a swampy lowland with silty soils.
- The terai soils are **rich in nitrogen** and organic matter but are **deficient in phosphate**.
- These soils are generally covered by tall grasses and forests but are suitable for a number of crops such as wheat, rice, sugarcane, jute etc.
- **This thickly forested region provides shelter to a variety of wild life.**

Bhangar

- The Bhangar is the older alluvium along the river beds forming terraces higher than the flood plain (about 30 meters above the flood level).
- It is of a more clayey composition and is generally dark colored.
- A few meters below the terrace of the bhangar are beds of lime nodules known as **“Kankar”**.

Khadar

- The Khadar is composed of newer alluvium and forms the flood plains along the river banks.
- The banks are flooded almost every year and a new layer of alluvium is deposited with every flood. This makes them the most fertile soils of Ganges.
- They are sandy clays and loams, more dry and leached, less calcareous and carbonaceous (less kankary). A new layer of alluvium is deposited by river flood almost every year.

Black Soils

- The parent material for most of the black soil are the volcanic rocks that were formed in the Deccan Plateau (Deccan and the Rajmahal trap).
- In Tamil Nadu, gneisses and schists form the parent material. The former are sufficiently deep while the later are generally shallow.
- These are the region of high temperature and low rainfall. It is, therefore, a soil group typical to the dry and hot regions of the Peninsula.

Characteristics of Black Soils

- A typical black soil is highly argillaceous [Geology (of rocks or sediment) consisting of or containing clay] with a large clay factor, 62 per cent or more.
- In general, black soils of uplands are of low fertility while those in the valleys are very fertile.
- The black soil is highly retentive of moisture. It swells greatly on accumulating moisture. Strenuous effort is required to work on such soil in rainy season as it gets very sticky.
- In summer, the moisture evaporates, the soil shrinks and is seamed with broad and deep cracks. The lower layers can still retain moisture. The cracks permits oxygenation of the soil to sufficient depths and the soil has extraordinary fertility.

Colour of Black Soils

- The black colour is due to the presence of a small proportion of **titaniferous magnetite or iron and black constituents of the parent rock.**
- In Tamil Nadu and parts of Andhra Pradesh, the black colour is derived from crystalline schists and basic gneisses.
- Various tints of the black colour such as deep black, medium black, shallow black , a mixture of red and black may be found in this group of soils.

Chemical Composition of Black Soils

- 10 per cent of alumina,
- 9-10 per cent of iron oxide,
- 6-8 per cent of lime and magnesium carbonates,
- Potash is variable (less than 0.5 per cent) and
- **Phosphates, nitrogen and humus are low.**

Distribution of Black Soils: Spread over **46 lakh sq. km (16.6 per cent of the total area)** across Maharashtra, Madhya Pradesh, parts of Karnataka, Telangana, Andhra Pradesh, Gujarat and Tamil Nadu.

Crops in Black Soils

- These soils are best suited for cotton crop. Hence these soils are called as **regur and black cotton soils.**
- Other major crops grown on the black soils include wheat, jowar, linseed, Virginia tobacco, castor, sunflower and millets.
- Rice and sugarcane are equally important where irrigation facilities are available.
- Large varieties of vegetables and fruits are also successfully grown on the black soils.
- This soil has been used for growing a variety of crops for centuries without adding fertilizers and manures, with little or no evidence of exhaustion.

Red Soils

Red soils along with its minor groups form the **largest soil group of India**. The main parent rocks are crystalline and **metamorphic rocks** like acid granites, gneisses and quartzite.

Characteristics of Red Soils: The texture of these soils can vary from sand to clay, the majority being loams. On the uplands, the red soils are poor, gravelly, and porous. But in the lower areas they are rich, deep dark and fertile.

Chemical Composition of Red Soils: They are **acidic** mainly due to the nature of the parent rocks. The alkali content is fair. They are poor in lime, magnesia, **phosphates, nitrogen** and humus. They are fairly rich in **potash and potassium**.

Color of Red Soils

- The red colour is due to the presence of **iron oxide**.
- When limestone, granites, gneisses and quartzites are eroded the clay enclosed within the rocks remains intact with other forms of non-soluble materials.
- In oxidizing conditions, rust or iron oxide develops in the clay, when the soil is present above the water table giving the soil a characteristic red colour.
- The colour is more due to the **wide diffusion** rather than high percentage of iron oxide content.

Distribution of Red Soils

- These soils mostly occur in the regions of low rainfall.
- They occupy about 3.5 lakh sq. km (10.6 per cent) of the total area of the country.
- These soils are spread on almost the whole of **Tamil Nadu**.
- Other regions with red soil include parts of Karnataka, south-east of Maharashtra, Telangana, Andhra Pradesh, Madhya Pradesh, Chhattisgarh, Odisha, Chota Nagpur plateau; parts of south Bihar, West Bengal, Uttar Pradesh; Aravalis and the eastern half of Rajasthan (Mewar or Marwar Plateau), parts of North-Eastern states.

Crops in Red Soils: The red soils are mostly loamy and hence cannot retain water like the black soils. The red soils, with the proper use of fertilizers and irrigation techniques, give good yield of cotton, wheat, rice, pulses, millets, tobacco, oil seeds, potatoes and fruits.

Laterite – Lateritic Soils

Laterite soils are mostly the **end products of weathering**. They are formed under conditions of **high temperature and heavy rainfall** with alternate wet and dry periods. Heavy rainfall promotes **leaching (nutrients gets washed away by water)** of soil whereby lime and silica are leached away and a soil rich in oxides of iron and aluminium compounds is left behind. 'Laterite' means brick in Latin. They harden greatly on losing moisture. Laterite soils are red in colour due to little clay and more gravel of red sand-stones.

Chemical composition of Laterite – Lateritic Soils

- Laterite soils are rich in **bauxite or ferric oxides**.
- They are very **poor** in lime, magnesia, **potash and nitrogen**.
- Sometimes, the **phosphate** content may be **high** in the form of **iron phosphate**.
- In wetter places, there may be higher content of humus.

Distribution of Laterite – Lateritic Soils

- Laterite soils cover an area of 2.48 lakh sq. km.
- Continuous stretch of laterite soil is found on the summits of Western Ghats at 1000 to 1500 m above mean sea level, Eastern Ghats, the Rajmahal Hills, Vindhyan, Satpuras and Malwa Plateau.
- They also occur at lower levels and in valleys in several other parts of the country.
- They are well developed in south Maharashtra, parts of Karnataka etc. and are widely scattered in other regions.

Crops in Laterite – Lateritic Soils

- Laterite soils lack fertility due to **intensive leaching**.
- When manured and irrigated, some laterites are suitable for growing **plantation crops** like tea, coffee, rubber, cinchona, coconut, arecanut, etc.
- In some areas, these soils support **grazing grounds and scrub forests**.

Economic value of Laterite – Lateritic Soils

- Laterite and lateritic soils provide **valuable building material**.
- These soils can be easily cut into cakes but hardens like iron when exposed to air.
- As it is the end-product of weathering, it cannot be weathered much further and is durable.

Forest – Mountain Soils

These soils occupy about 2.85 lakh sq. km or 8.67% of the total land area of India. They are mainly **heterogeneous soils** found on the hill slopes covered by forests. The formation of these soils is mainly governed by the characteristic deposition of organic matter derived from forests and their **character changes with parent rocks**, ground-configuration and climate. Consequently, they **differ greatly even if they occur in close proximity to one another**.

Distribution of Forest – Mountain Soils: In the Himalayan region, such soils are mainly found in valleys, less steep and north facing slopes. The south facing slopes are very steep and exposed to denudation and hence do not support soil formation. Forest soils occur in Western and Eastern Ghats also.

Chemical properties of Forest – Mountain Soils: The forest soils are very **rich in humus**. They are deficient in potash, phosphorus and lime. They require good deal of fertilizers for high yields.

Crops in Forest – Mountain Soils: They are suitable for plantations of tea, coffee, spices and tropical fruits in peninsular forest region. Wheat, maize, barley and temperate fruits are grown in the Himalayan forest region.

Arid – Desert Soils

The desert soils consist of **Aeolian sand** (90 to 95 per cent) and clay (5 to 10 per cent). They cover a total area of 1.42 lakh sq. km (4.32%). The presence of sand inhibits soil growth. Desertification of neighboring soils is common due to intrusion of desert sand under the influence of wind [Aeolian sand].

Distribution of Arid – Desert Soils

- Occur in arid and semi-arid regions of Rajasthan, Punjab and Haryana. The sand here is blown from the Indus basin and the coast by the prevailing south-west monsoon winds.
- Sandy soils without clay factor are also common in coastal regions of Odisha, Tamil Nadu and Kerala.

Chemical properties of Arid – Desert Soils

- They are usually poor in organic matter. Some desert soils are **alkaline** with varying degree of soluble salts like **calcium carbonate**.
- Calcium content increases downwards and the subsoil has ten times more calcium.
- The **phosphate** content of these soils is as **high** as in normal alluvial soils.
- Nitrogen is originally low but some of it is available in the **form of nitrates**.

Crops of Arid – Desert Soils

- Phosphates and nitrates make these soil fertile wherever moisture is available.
- There is a possibility of reclaiming these soils if proper irrigation facilities are available.
- In large areas, only the drought resistant and salt tolerant crops such as barley, cotton, millets, maize and pulses are grown.

Saline – Alkaline Soils

- In Saline and Alkaline Soils, the top soil is **impregnated** (soak or saturate with a substance) with saline and alkaline efflorescences (become covered with salt particles).
- Undecomposed rock fragments, on weathering, give rise to **sodium, magnesium and calcium salts and sulphurous acid**.
- Some of the salts are transported in solution by the rivers.
- In regions with low water table, the salts percolate into sub soil and in regions with good drainage, the salts are wasted away by flowing water.
- But in places where the drainage system is poor, the water with high salt concentration becomes stagnant and deposits all the salts in the top soil once the water evaporates.
- In regions with high sub-soil water table, injurious salts are transferred from below by the **capillary action** as a result of evaporation in dry season.

Distribution of Saline – Alkaline Soils

- Saline and Alkaline Soils occupy 68,000 sq. km of area. These soils are found in canal irrigated areas and in areas of high sub-soil water table.
- Parts of Andhra Pradesh, Telangana, Karnataka, Bihar, Uttar Pradesh, Haryana, Punjab (side effects of improper or excess irrigation), Rajasthan and Maharashtra have this kind of soils.
- The accumulation of these salts makes the soil infertile and renders it unfit for agriculture.
- In Gujarat, the areas around the Gulf of Khambhat are affected by the **sea tides** carrying salt-laden deposits. Vast areas comprising the estuaries of the Narmada, the Tapi, the Mahi and the Sabarmati have thus become infertile.
- Along the coastline, saline sea waters infiltrate into coastal regions during **storm surges** (when cyclones make landfall) and makes the soil unfit for cultivation. The low lying regions of coastal Andhra Pradesh and Tamil Nadu face this kind of soil degradation.

Peaty – Marshy Soils

These are soils with **large amount of organic matter** and **considerable amount of soluble salts**. The most humid regions have this type of soil. They are black, heavy and **highly acidic**.

Distribution of Peaty – Marshy Soils

- Kottayam and Alappuzha districts of Kerala where it is called kari.
- Also occur in the coastal areas of Odisha and Tamil Nadu, Sunderbans of West Bengal, in Bihar and Almora district of Uttarakhand.

Chemical Properties of Peaty – Marshy Soils: They are deficient in potash and phosphate.

Crops of Peaty – Marshy Soils: Most of the peaty soils are under water during the rainy season but as soon the rains cease, they are put under paddy cultivation.

Characteristics of Indian Soils

- Most soils are old and mature. Soils of the peninsular plateau are much older than the soils of the great northern plain.
- Indian soils are largely **deficient in nitrogen, mineral salts, humus and other organic materials.**
- Plains and valleys have thick layers of soils while hilly and plateau areas depict thin soil cover.
- Some soils like alluvial and black soils are fertile while some other soils such as laterite, desert and alkaline soils lack in fertility and do not yield good harvest.
- Indian soils have been used for cultivation for hundreds of years and have **lost much of their fertility.**

Problems of Indian Soils

Soil erosion (Himalayan region, Chambal Ravines etc.), deficiency in fertility (Red, lateritic and other soils), desertification (around Thar desert, rain-shadow regions like parts of Karnataka, Telangana etc.), waterlogging (Punjab-Haryana plain) salinity and alkalinity (excessively irrigated regions of Punjab, Haryana, Karnataka etc.), wasteland, over exploitation of soils due to increase in population and rise in living standards and encroachment of agricultural land due to urban and transport development.