

INDIAN PHYSICAL GEOGRAPHY



PMF IAS

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1. India as a Geographical Unit



Location

- India lies entirely in the northern hemisphere. It is located in the south-central part of the continent of Asia, bordering the Indian Ocean and its two arms — the **Bay of Bengal** and the **Arabian Sea**.
- The **mainland** of India extends from **Ladakh** in the north to **Kanyakumari** in the south and **Arunachal Pradesh** in the east to **Gujarat** in the west.
- India's **territorial limit** extends towards the sea up to **12 nautical miles** (~21.9 km) from the coast.
- The country's southernmost point is the **Pygmalion Point**, or **Indira Point**, at **6° 45' N latitude**. It was submerged under sea water in 2004 during the Tsunami.
- The distance between the northernmost part of India in **Ladakh** and **Kanyakumari** is **3,214 km**, while the distance from the **Rann of Kutch** to **Arunachal Pradesh** is **2,933 km**.

East-West Extent (~30°)	68° 7' East to 97° 39' East longitude
North-South Extent of the mainland (Including POK) (~29°)	8° 4' North to 37° 6' North latitude

South-North Extent of India (Including POK and the Andaman and Nicobar Islands) (~31°)

6° 45' North to 37° 6' North latitude

- The **latitudinal** and **longitudinal extent** of India is about **30 degrees**. In contrast, the distance measured from north to south extremity is **3,214 km**, and from east to west is only **2,933 km**. This is because the **distance between any two longitudes decreases towards the poles**, whereas the **distance between any two latitudes remains the same everywhere**.

Distance between two adjacent Latitudes (~111 km)

At the Equator

110.5 km

(The slight difference is because of the **Geoid** shape of the earth)

At Poles

111.7 km

Distance between two adjacent Longitudes

At the Equator

111.3 km

At Poles

Zero

[UPSC 2000] Along which one of the following meridians did India experience the first light of the sunrise of the new millennium?

- a) 82°30' W
- b) 82°30' E
- c) 92°30' W
- d) 92°30' E

Explanation

- Sunrise occurs first in the east. Since India is located in the **eastern hemisphere**, the first light of the sunrise would be experienced at a location situated at the **easternmost longitude**.
- Longitude values **increase** from **west to east**. So, higher longitude values represent more eastward locations within India.
- Among the given options, 92°30' E is the highest eastern longitude.

Answer: d) 92°30' E

[UPSC 2015] Which one of the following pairs of States of India indicates the easternmost and westernmost State?

- a) Assam and Rajasthan
- b) Arunachal Pradesh and Rajasthan
- c) Assam and Gujarat
- d) Arunachal Pradesh and Gujarat

Explanation

- Arunachal Pradesh** is the easternmost state of India, bordering **Bhutan, China, and Myanmar**. Its easternmost point, **Kibithu**, is located at **97°25'E longitude**.
- Gujarat** is the westernmost state of India, bordering **Pakistan** and the **Arabian Sea**. Its westernmost point, **Sir Creek**, is located at **68°7'E longitude**.

Answer: d) Arunachal Pradesh and Gujarat

Indian Subcontinent

- The Indian subcontinent comprises five countries — Pakistan, Nepal, Bhutan, Bangladesh, and India.
- The **Himalayas** stand almost like a strong and long wall between the Indian subcontinent and the Central and East Asian countries.
- The Himalayas are not only a physical barrier but also a **climatic, drainage, and cultural divide**. This unique geography has contributed to the distinct regional identity of the Indian subcontinent.

[UPSC 2021] Why is India considered as a subcontinent? Elaborate your answer.

India's large size, distinct geographical features, unique geological history, diverse cultural heritage, and significant political and economic influence contribute to its designation as a subcontinent.

Geography

- India is geographically large, with an area of over **3.2 million square kilometres**, making it significantly larger than most other countries. Its sheer size sets it apart from other nations and contributes to its subcontinental status.
- India is characterised by **diverse geographical features**, including the towering **Himalayan Mountain range** in the north, which acts as a **natural barrier** separating it from the rest of Asia.
- The presence of the **Deccan Plateau** in the south, bordered by coastal plains on both sides, further adds to its distinctiveness.

Geological History

- India was once part of the **Gondwana supercontinent**, which separated and **drifted northward** millions of years ago. This **distinct geological history** contributed to the development of unique geological features and biodiversity.

Diversity

- India boasts a **rich tapestry of cultures, languages, religions, and traditions**. This **diversity** is reflected in its cuisine, festivals, clothing, architecture, and more. Various ethnic groups coexist within its borders, contributing to the subcontinental identity.

History

- India has a **long and complex history**, with civilisations dating back thousands of years. It has been home to ancient civilisations such as the **Harappan** and **Vedic** civilisations, as well as being a crucible for **various empires**, including the **Maurya, Gupta, Mughal, and British Empires**. This rich historical legacy has shaped India's identity as a subcontinent.

Unity

- Despite its cultural and linguistic diversity, India has maintained **political unity** for much of its history. Since gaining independence from British rule in 1947, India has remained a single nation-state, albeit with federal governance structures to accommodate its diversity.

Strategic Location

- India's **geographic location** at the **crossroads** of South Asia, Central Asia, and the Indian Ocean has endowed it with **strategic significance** throughout history. Its position has made it a hub for trade, commerce, and cultural exchange, further reinforcing its subcontinental status.

India, Tropical or Temperate Country?

- The Tropic of Cancer (23.5° N) passes through **eight states** of India, namely **Gujarat, Rajasthan, Madhya Pradesh, Chhattisgarh, Jharkhand, West Bengal, Tripura, and Mizoram**.
- It divides the country into **two latitudinal halves**, with the **temperate part (north of the Tropic of Cancer)** being **almost twice as large** as the tropical part. However, India has always been **treated as a tropical country** for two different reasons – physical and cultural.

Physical Geographical (Climatic) Reasons

- ❖ It is primarily because of the **Himalayas** that India is a predominantly tropical country. The Himalayas separate India from the rest of Asia and **block the cold temperate air masses**.
- ❖ The **tropical monsoons** dominate India's climate.
- ❖ Although winter night temperatures are low, **clear skies** and **intense insolation** raise the day temperatures to a tropical level.

Cultural and Geographical Reasons

- ❖ Settlements, **diseases**, agricultural and primary economic activities are all tropical in nature.

Size

- India, with its area of **3.28 million sq km**, accounts for **2.4 per cent** of the **world's land surface area** and stands as the **seventh largest country** in the world.

Comparing India with The Top 10 Largest Countries by Area

Rank	Country	Capital City	Continent	Area (km ²)
1	Russia	Moscow	Europe	1,70,98,242
2	Canada	Ottawa	North America	99,84,670
3	USA	Washington DC	North America	98,26,675
4	China	Beijing	Asia	95,96,961
5	Brazil	Brasilia	South America	85,14,877
6	Australia	Canberra	Oceania	77,41,220
7	India	New Delhi	Asia	32,87,263
8	Argentina	Buenos Aires	South America	27,80,400
9	Kazakhstan	Astana	Asia	27,24,900

10	Algeria	Algiers	Africa	23,81,741
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Indian Standard Time

- Countries around the world select a standard meridian in **multiples of 7°30' of longitude**. India has chosen **82°30' E** as its **standard meridian**. Hence, the **Indian Standard Time** is **5 hours and 30 minutes ahead** of **Greenwich Mean Time (GMT)**.
- There is a variation of nearly 30 degrees, which causes a **time difference of nearly two hours** between the easternmost and the westernmost parts of our country (A difference of 1° longitude will make a difference of 4 minutes in time. $\sim 30 \times 4 = \sim 120$ minutes or ~ 2 hours).
- India chose to have a single time zone**, unlike **longitudinally extensive (greater east-west extent)** countries such as **Canada (6)**, **USA (11)**, and **Russia (11)**, which have multiple time zones.
- While the sun rises in the northeastern states about two hours earlier compared to Jaisalmer, the watches in Dibrugarh and Imphal in the east and Jaisalmer, Bhopal, or Chennai in the other parts of India **show the same time**.

⇒ **France (12 time zones)**, the **United Kingdom (9)**, etc., have **multiple time zones** despite their **mainland not being longitudinally extensive**. This is because they have **multiple overseas territories**, some of which are in regions far away from the mainland.

[UPSC 1999] If it is 10.00 am. I.S.T., then what would be the local time at Shillong on 92° E longitude?

- a) 9.38 a.m.
- b) 10.38 a.m.
- c) 10.22 a.m.
- d) 9.22 a.m.

Explanation

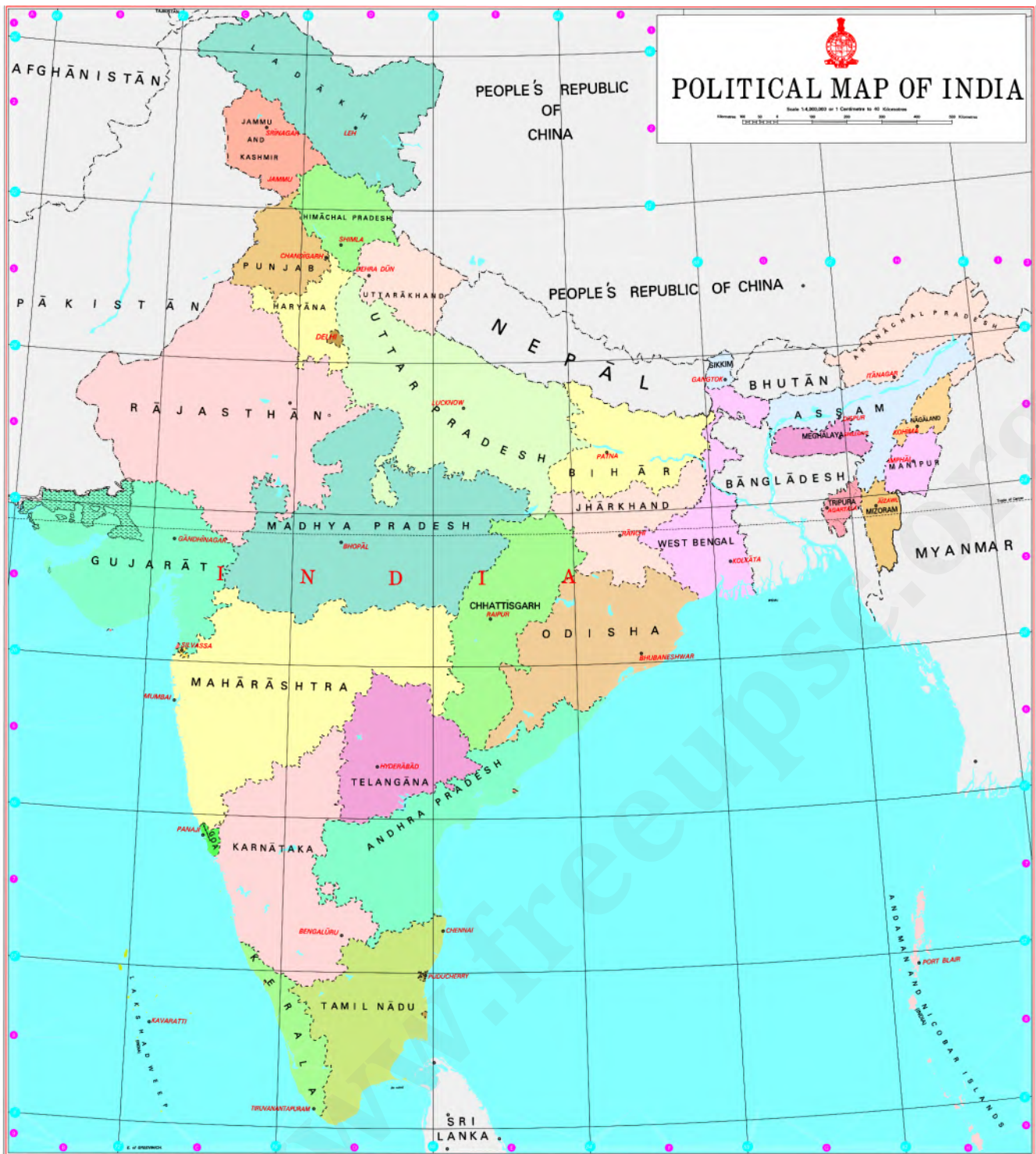
- Shillong is located at 92° E longitude, while the standard meridian for IST is 82.5° E.
- Each degree** of longitude corresponds to approximately **4 minutes** of time difference.
- Therefore, the time difference between Shillong and IST is $(92^\circ - 82.5^\circ) \times 4 \text{ minutes} = 38 \text{ minutes}$.
- Since Shillong is **east of the standard meridian** for IST, its local time will be **ahead** of IST by 38 minutes.
- If it is 10.00 am IST, adding the time difference (38 minutes), we get 10.00 am + 38 minutes = 10.38 am. Therefore, the local time in Shillong when it is 10.00 am IST is 10.38 am.

Answer: b) 10.38 a.m.

India's Frontiers

- India has a **15106.7 km land border** running through **16 states and 2 UTs**. It has a coastline of **7516.6 Km** (**6100 km of mainland** coastline + coastline of **1416.6 Indian islands**), touching **9**

States and 4 Union Territories (UTs) — Lakshadweep, Dadra and Nagar Haveli and Daman and Diu, Puducherry, and Andaman and Nicobar Islands.



- Barring **Telangana, Madhya Pradesh, Chhattisgarh, Jharkhand, Delhi** and **Haryana**, **all other States** in the country have **one or more international borders or a coastline** and can be regarded as **frontline States** from the point of view of border management.

[UPSC 2008] In India, how many states share the coastline?

- 7
- 8

- c) 9
d) 10

Explanation

- There are **nine states** in India that share the coastline:
 - ❖ **West Coast:** Gujarat, Maharashtra, Goa, Karnataka and Kerala.
 - ❖ **East Coast:** Tamil Nadu, Andhra Pradesh, Odisha and West Bengal.
- Additionally, there are **four Union Territories** with a coastline:
 - ❖ Lakshadweep Islands in the Arabian Sea
 - ❖ Dadra and Nagar Haveli and Daman and Diu on the Arabian Sea
 - ❖ Puducherry on the Bay of Bengal
 - ❖ Andaman and Nicobar Islands on the Bay of Bengal

Answer: c) 9

The Length of India's Land Borders with Neighbouring Countries

- India's **longest border** is with **Bangladesh**, while the **shortest border** is with **Afghanistan**.
- The length of India's land borders with neighbouring countries is given in the table below.

Neighbours	Border Length	Frontier States/UTs
1. Bangladesh	4,096.7 km	5 States: WB, Assam, Meghalaya, Tripura and Mizoram.
2. China	3,488 km	4 States / 1 UT: Ladakh, HP, Uttarakhand, Sikkim and AP
3. Pakistan	3,323 km	3 States / 2 UTs: Gujarat, Rajasthan, Punjab, J&K, and Ladakh
4. Nepal	1,751 km	5 States: Uttarakhand, UP, Bihar, West Bengal and Sikkim
5. Myanmar	1,643 km	4 States: Arunachal Pradesh, Nagaland, Manipur and Mizoram
6. Bhutan	699 km	4 States: Sikkim, West Bengal, Arunachal Pradesh and Assam
7. Afghanistan	106 km	1 UT: Ladakh
Total	15,106.7 km	16 states and 2 UTs

Border with China

Line of Actual Control (LAC)

- The **LAC** is the demarcation that separates **Indian-controlled territory** from **Chinese-controlled territory**. India considers the LAC to be **3,488 km** long, while the Chinese consider it to be only around **2,000 km**.

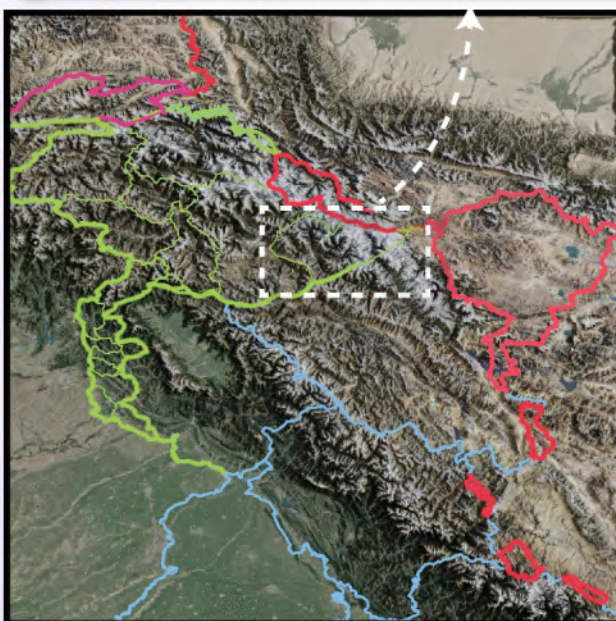
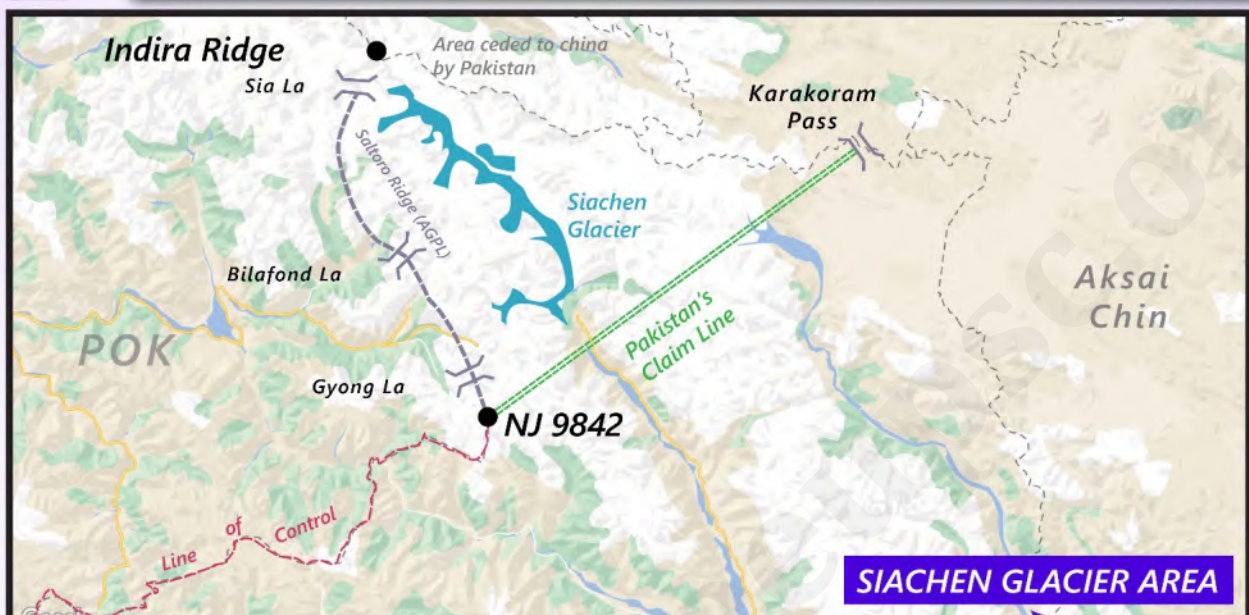
Brief History of LAC

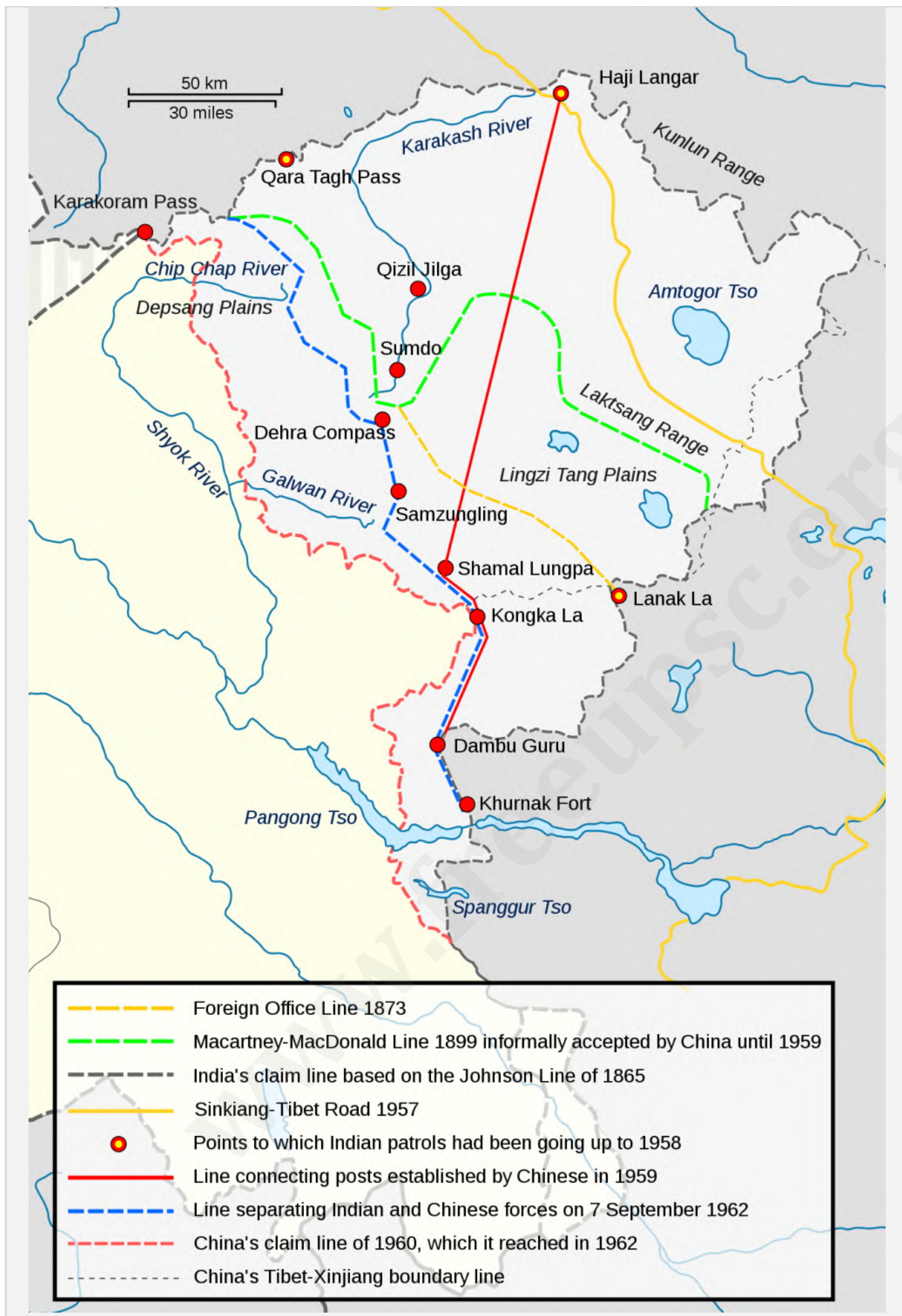
- The **Johnson's Line** (proposed in 1865) shows **Aksai Chin** in erstwhile Jammu and Kashmir (now Ladakh), whereas the **McDonald Line** (proposed in 1893) **places it under China's control**.
- The **McDonald Line** placed the **Lingzi Tang plains**, which are **south** of the **Lakhsang Range**, in **India**, and **Aksai Chin** proper, which is **north** of the **Lakhsang Range**, in **China**.

- **India considers** the **Johnson Line** as a correct, rightful national border with China, while on the other hand, **China considers** the **McDonald Line** as the correct border with India.
- **Shimla Agreement 1914:** The **McMahon Line** was established and was accepted by Tibet and British Indian authorities. Chinese authorities have been against this from 1914 till today.
- In 1950, China annexed Tibet and thereafter started claiming the other parts of India as per its **Five Fingers of Tibet theory** — a policy attributed to **Mao Zedong** that considers **Tibet to be China's right-hand palm**, with **five fingers** — **Ladakh, Nepal, Sikkim, Bhutan, and Arunachal Pradesh** — on its periphery.
- In 1957, **China occupied Aksai Chin**. This episode was followed by intermittent clashes along the border, which finally culminated in the border war of 1962.



Map of Jammu, Kashmir and Ladakh showing the Occupied Regions

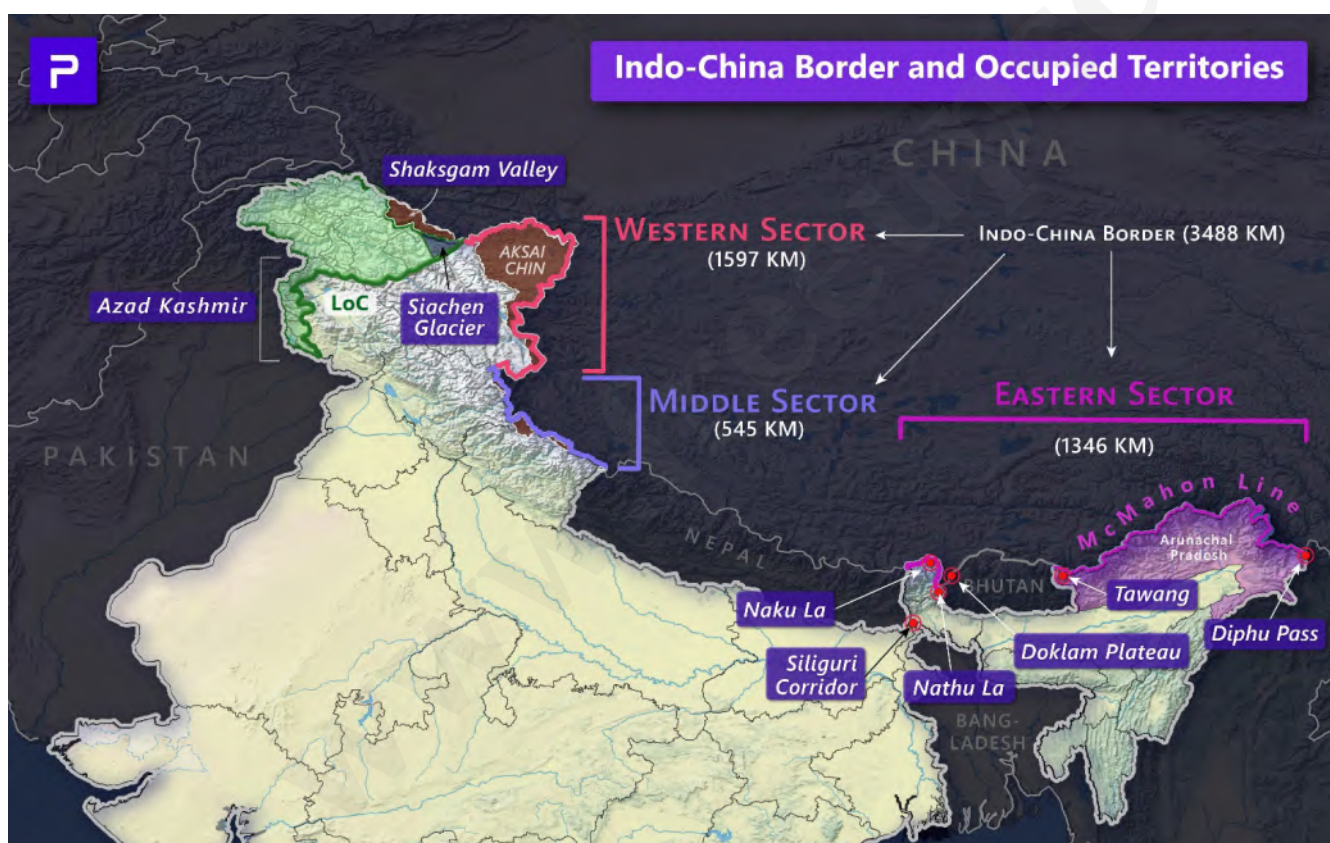




- On October 20, 1962, the People's Liberation Army (PLA) of China invaded India in Ladakh and across the **McMahon line** in **Arunachal Pradesh**.
- After a month-long War, China unilaterally declared a ceasefire on 19 November 1962. China achieved its objective of acquiring control in the **Aksai Chin**.
- In the eastern sector, their troops went back to the north of the **McMahon Line**. The boundary, which came into existence after the war, came to be known as the **Line of Actual Control (LAC)**.

How is the Line of Actual Control (LAC) different from the Line of Control (LoC)?

- The LoC emerged from the **1948 ceasefire line** negotiated by the **UN** after the Kashmir War. It was designated as the LoC in **1972**, following the **Shimla Agreement** between the two countries.
 - LoC is **delineated on a map** signed by **DGMOs** of both armies and **has the international sanctity of a legal agreement**.
 - The **LAC, in contrast, is only a concept**. It is not agreed upon by either India or China, **neither delineated on a map nor demarcated on the ground**.
- LAC is divided into three sectors:
 - The **Eastern sector**, which spans Arunachal Pradesh and Sikkim,
 - The **Middle sector** in Uttarakhand and Himachal Pradesh, and
 - The **Western sector** in Ladakh.



Western Sector

- The western sector boundary is largely the outcome of the **British policy** towards the erstwhile Jammu and Kashmir. It separates the **Ladakh** of India from the **Xinjiang** province of China.

- Independent India used the **Johnson Line** and claimed the **entire Aksai Chin** as well as the **Shaksgam valley** (Trans-Karakoram/Shaksgam Tract — **gifted to China by Pakistan**).
- China contests Indian control over **Daulat Beg Oldi** (a tehsil in Leh; **believed to host the world's highest airstrip**).
- **China claims** the **Aksai Chin**, the **Changmo Valley**, **Pangong Tso** and the **Spanggur Tso**, as well as a strip of about 5,000 sq km down the entire length of eastern Ladakh. It also claims part of the **Huza-Gilgit area in North Kashmir**, which was **ceded to it by Pakistan in 1963**.

Pangong Tso lake

- Pangong Tso is a long, narrow, deep, **endorheic (landlocked) saline** lake situated at a height of more than **4,225 m** in the Ladakh Himalayas near **Leh**.
- The **135 km-long** lake sprawls over 604 sq km in the shape of a boomerang and is **6 km wide** at its broadest point. **One-third** of the water body, its 45 km stretch, is in **Indian control**, while the rest of the 90 km is under Chinese control.
- By itself, the lake does not have major tactical significance. But it lies in the path of the **Chushul approach**, one of the main approaches that China can use for an offensive into Indian-held territory.

Middle Sector

- The middle sector boundary includes **Uttarakhand** and **Himachal Pradesh**. It is the only area where India and China have exchanged maps on which they broadly agree.

Eastern Sector

- The eastern sector boundary between India and China runs from the eastern limit of Bhutan to a point near **Diphu Pass (Talu-Pass)** at the **tri-junction of India, Tibet and Myanmar**.

⇒ **Diphu Pass** is a mountain pass around the **disputed tri-point border** of India, China, and Myanmar. It is the **Talu pass** on the **Burmese side**, and the **Diphu pass** on the **Indian side**.

- The disputed boundary in the Eastern Sector is over the **MacMahon Line**. India controls the boundary up to the **McMahon Line**.
- The region south of the McMahon Line came to be known as the state of **Arunachal Pradesh**. The **Tawang tract** claimed by China was taken over by India in **1951**.
- China never accepted the McMahon Line and formally claimed Arunachal Pradesh as its **North East Frontier Agency**, a part of its **Tibet Autonomous Region**.

Doklam

- **Doklam** (Zhoglam/Donglang) is a narrow plateau lying in the **tri-junction** of **India, China** and **Bhutan**.
- China believes Doklam to be a **disputed** territory between **Bhutan** and **China**. It, therefore, contests the presence of the **Indian army** in the region as a transgression.

- The disputed region is **very close to India's Siliguri Corridor (Chicken's Neck)**, which connects the seven northeastern states to the Indian mainland.

The Indo-Pakistan Boundary

- The Indo-Pakistan boundary is the result of the partition of the country in 1947 under the **Radcliffe Award**, of which Sir Cyril Radcliffe was the chairman. Jammu, Kashmir, and **Sir Creek** are the major disputed regions.



Creeks in the Kutch Region



Gilgit-Baltistan and Azad Kashmir

- **Gilgit-Baltistan** is situated on the northwestern corner of the Kashmir Valley. It is a picturesque, hilly region to the north of **Azad Kashmir** and east of **Khyber Pakhtunkhwa**.
- Though both **Azad Kashmir** and **Gilgit-Baltistan** are ruled directly from Islamabad, **neither is officially listed as the territory of Pakistan**. They **do not** find a mention in Pakistan's Constitution.
- For India, on the other hand, as per the **resolution** passed by Parliament in 1994, **Azad Kashmir** and **Gilgit-Baltistan (GB)** are **both part of the State of Jammu and Kashmir**.

⇒ **Pakistan has four provinces:** Punjab, Khyber Pakhtunkhwa (it includes the Federally Administered Tribal Areas), Baluchistan, and Sindh. **Azad Kashmir** and **GB** are **autonomous territories**.

⇒ The **China–Pakistan Economic Corridor (CPEC)** has changed the dynamics of **Gilgit-Baltistan**.

⇒ Pakistan gifted **Shaksgam Valley**, a portion of Gilgit-Baltistan, to China in 1963.

Other Borders

The India-Nepal Boundary

- A major portion of the Indo-Nepalese border runs in the east-west direction, almost along the foot-hill of the **Shiwaliks**.
- **Five states** of India, namely Uttarakhand, Uttar Pradesh, Bihar, West Bengal and Sikkim, touch the Nepalese border with India.
- The border is a **porous** one with an unrestricted movement of goods and people.

The India-Bangladesh Border

- India's 4,096 km-long border with Bangladesh is the **longest**. This boundary was determined under the **Radcliffe Award**, which divided the erstwhile province of Bengal into two parts.

India-Myanmar Boundary

- This boundary runs roughly along the watershed between the Brahmaputra and **Irrawaddy** rivers. It passes through thickly forested regions, with **Mizo Hills**, Manipur and Nagaland on the Indian side and **Chin Hills**, **Naga Hills** and Kachin state on the Myanmar side.
- Recently, the India Government has decided to **construct a fence** along the entire 1,643 km Indo-Myanmar border.

India-Sri Lanka Boundary

- The **Gulf of Mannar** and **Palk Strait** (a narrow and shallow sea) separates Sri Lanka from India.
- **Dhanushkodi (Pamban Island)** on the Tamil Nadu coast in India is only 32 km away from **Ta-laimanar** in the Jaffna peninsula in Sri Lanka. These two points are joined by a group of islets forming **Rama Setu (Adam's Bridge)**.

⇒ Among our neighbours, **Sri Lanka** and **Maldives** are the two island countries in the Indian Ocean.

Major Geological (Physical) Divisions of India

- India can be divided into the following physiographic divisions:

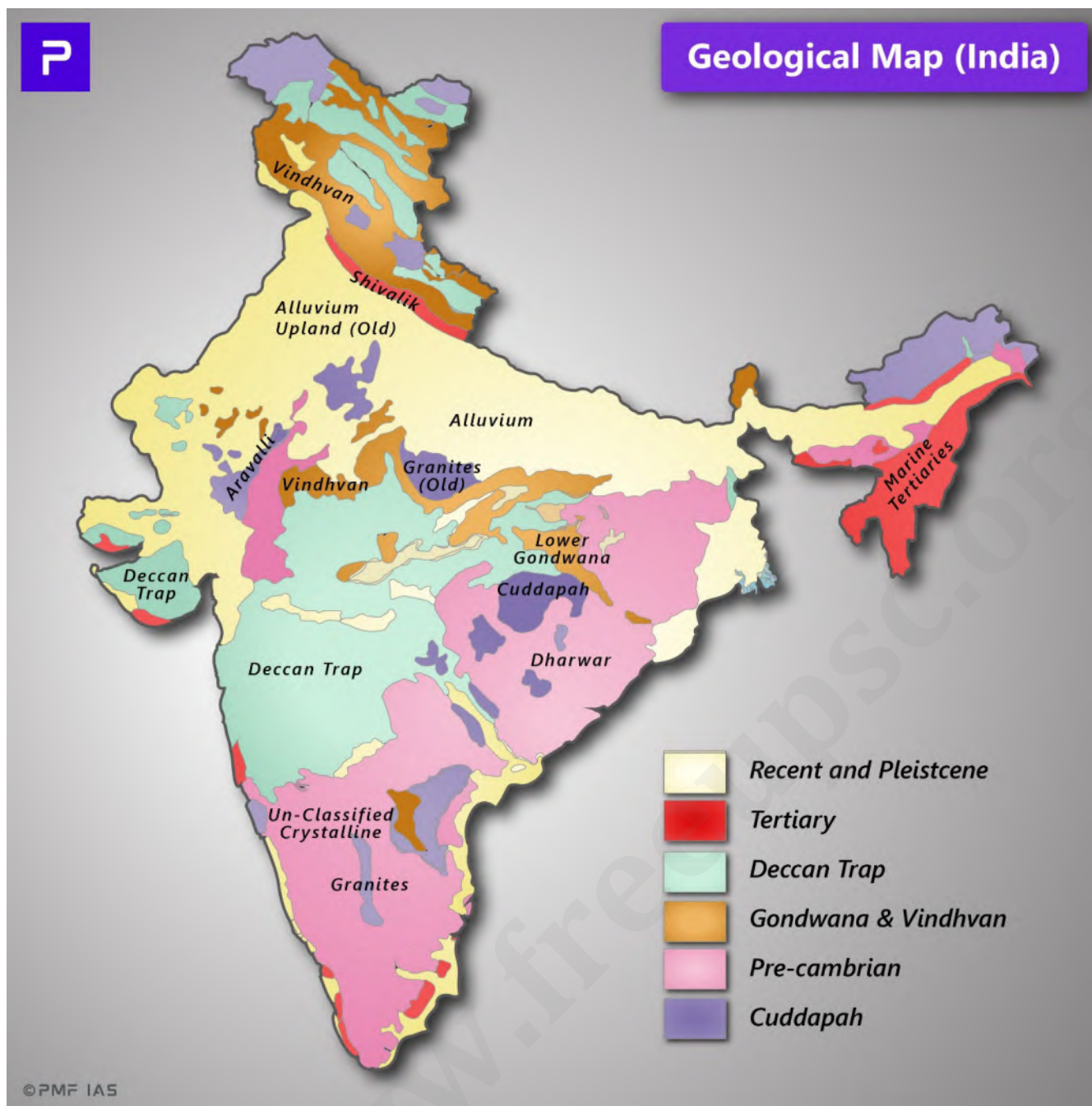
1. The **Himalayas (young fold mountains)**,
2. The **Indo-Gangetic Plain** (monotonous featureless topography); the Thar Desert is a part of it,
3. The **Peninsular Plateau** (one of the **most stable landmasses**; one of the oldest plateaus of the world),
4. The Coastal Plains (sedimentation due to fluvial action).
5. The Indian Islands (**Coral Islands** → **coral reef** built up on **atolls**. E.g. **Lakshadweep Islands**; Tectonic → Andaman and Nicobar Islands — formed due to the interaction between the Indian Plate and Eurasian plate).

Type of Topography			Extent in %	
Plains			43	
Mountains	Mountainous (more than 2135 m above sea level)		10.7	29.3
	Hilly area (305 – 2135 m above sea level)		18.6	
Plateau (305 – 915 m above sea level)			27.7	

- Each of these divisions has its **unique** geological features and resources based on its **geological structure**. The Peninsular Plateau, for example, is rich in minerals such as iron ore, manganese, and mica. The Himalayas are home to glaciers, snow-capped peaks, and valleys, while the Indo-Gangetic Plain is known for its fertile soil and agricultural productivity.
- These **geological divisions** play a crucial role in shaping India's topography, climate, and natural resources, influencing various aspects of its environment and socio-economic development.

----- End of Chapter -----

2. Rock System Based on the Geological History of India



Based on the Geological History of India, the rock systems can be classified into four types:

- 1) **The Archaean Rock System**
- 2) **The Purana Rock System**
- 3) **The Dravidian Rock System**
- 4) **The Aryan Rock System**

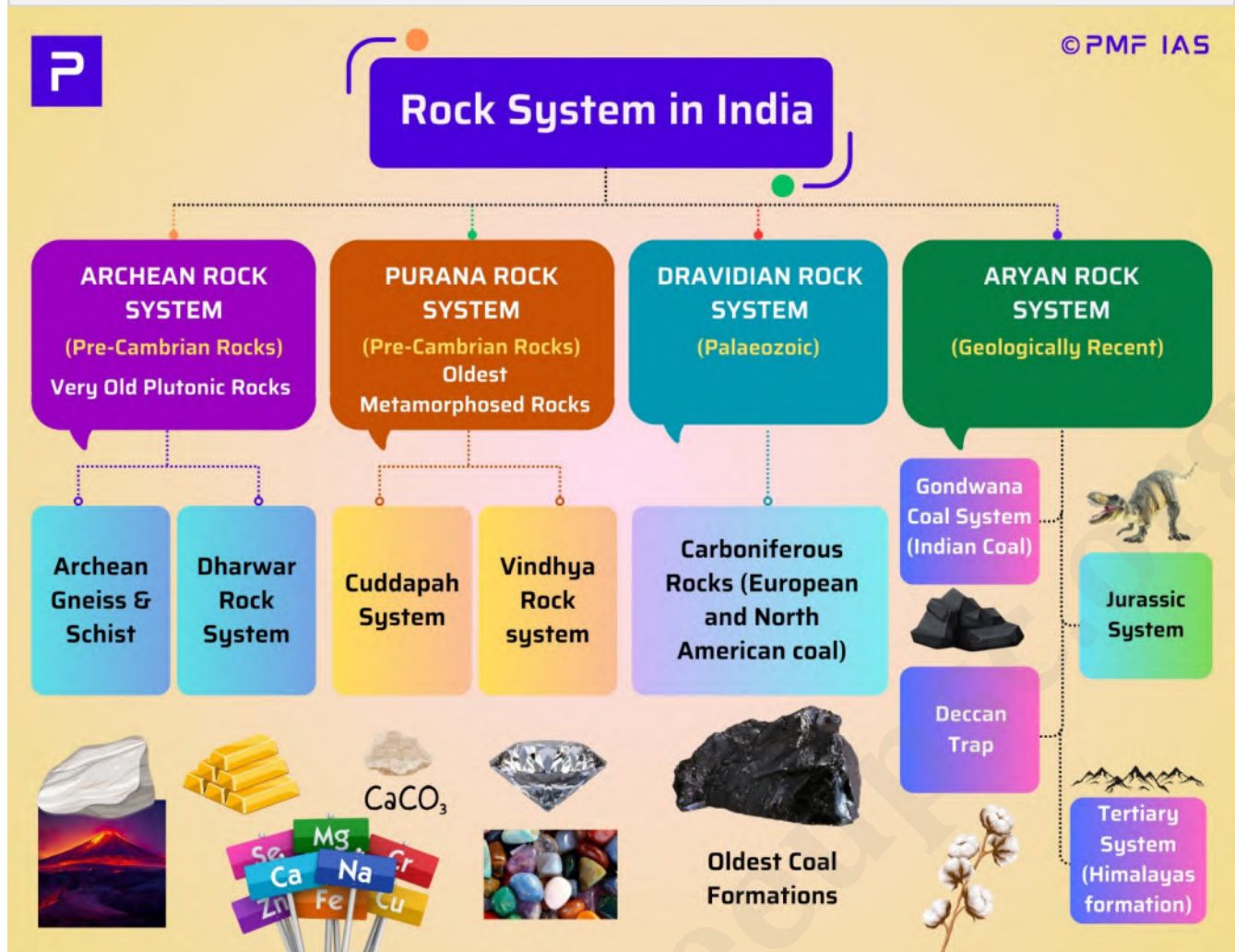
Archaean Rock System (Pre-Cambrian Rocks)

- **Archaean Rocks** formed **prior to the Cambrian system**. These are the **oldest rocks in India**. They are mainly found in the **Peninsular Shield** and are composed of **igneous** and **metamorphic** rocks.

Archaean Gneisses and Schists (4 billion years old)

Gneiss → Mineral composition varies from granite to gabbro.

Schists → mostly crystalline, including mica, talc, hornblende, chlorite, etc.



- Archaean Gneisses and Schists are the **oldest rocks** (formed in the **pre-Cambrian era**). They were formed due to the cooling and solidification of molten magma in the **upper crust** (the earth's surface was scorching back then).
- They are known as the **'Basement Complex'** (they are the oldest and form the base for new layers).
- They are **azoic or unfossiliferous plutonic intrusions** (magma solidified below the surface).
- They are **foliated** (layered) and are thoroughly **crystalline** (as they are volcanic in origin).
- Distribution in India:** Central and southern regions of the **Indian Peninsula**, as well as in portions of **Odisha, Meghalaya, Madhya Pradesh, Chhattisgarh, Bundelkhand region and the Chotanagpur Plateau** in Jharkhand.

Dharwar System (4 to 1 billion years old)

- They are highly **metamorphosed sedimentary systems** formed due to the **metamorphosis** of sediments of **Archaean gneisses and schists**. The formation period ranges from 4 billion years ago to 1 billion years ago.

- The rocks of this system encompass the **oldest metamorphosed rocks**, arising from **both igneous and sedimentary** origins. They are found in abundance in **the Dharwar district of Karnataka**.
- They are **economically the most important rocks** because they possess **valuable minerals** like **high-grade iron-ore, manganese, copper, lead, gold**, etc.
- **Distribution in India:** **Dharwar-Bellary-Mysore** belt of Karnataka, the **central and eastern parts of India** in the states of Odisha, Jharkhand, Madhya Pradesh, and Chhattisgarh and parts of **Aravallis**.

Purana Rock System (1400 to 600 million years old)

- These rocks include a **mix of sedimentary, volcanic, and metamorphic rocks**, indicating varied geological processes during this period.
- **Location:** **Peninsular Shield** and **parts of the Himalayas**.
- **Rock Types:** Diverse, including **sedimentary rocks (quartzites, sandstones, limestones)**, **volcanic rocks (basalts)**, and **metamorphic rocks (marble, slates)**.
- **Divisions:** the **Cuddapah System** and the **Vindhyan System**.

Cuddapah System

- These rocks were formed due to the **deposition of unfossiliferous clay, slates, sandstones and limestones in synclinal basins** (depressions between two folds).
- Outcrops of these rocks are best observed in the **Cuddapah district of Andhra Pradesh**. The system has also been developed in parts of Chhattisgarh, Jharkhand, and Odisha.
- These rocks contain **ores of iron, manganese, copper, cobalt, nickel, etc.** They contain large deposits of **cement-grade limestones**.

Vindhyan System

- This system derives its name from the Vindhyan mountains. It comprises of **ancient sedimentary rocks** (4000 m thick) superimposed on the Archaean base. They are mostly **unfossiliferous**.
- The rock deposits of this system can be classified as Lower Vindhyan (1300 – 1100 million years) and Upper Vindhyan (1000 – 600 million years).
- This system is also found in **parts of Karnataka (Bhima Valley)**, Chhattisgarh and Andhra Pradesh.
- The Vindhyan system has **diamond-bearing regions** from which **Panna and Golconda diamonds** have been mined.
- It is **devoid of metalliferous minerals** but provides **large quantities of durable stones, ornamental stones, limestone, pure glassmaking sand, etc.**

Dravidian Rock System (Palaeozoic)

- The Dravidian Rock System formed about **600-300 million years ago**. It is found in the **extra-Peninsular region (the Himalayas and Ganga Plain)** and is **very rare in Peninsular India**. (The name 'Dravidian' doesn't mean they are found in South India!)

- The rocks of **Cambrian, Ordovician, Silurian, Devonian** and **Carboniferous periods** fall under the Dravidian system. They are **sedimentary rocks** with **abundant fossils**.

Carboniferous Rocks (350 million years)

- The **Carboniferous rocks (350 million years)** comprise mainly of **limestone, shale, and quartzite**.
- **Mount Everest** is composed of Upper **Carboniferous limestones**.
- **Coal formation** started in the **Carboniferous (coal-bearing) age**.
- **High-quality coal** from the **Great Lakes Region of the USA, UK** and **Ruhr region of Germany** is **Carboniferous coal (oldest coal)**.

⇒ Most of the **coal found in India (Gondwana Coal)** is of **poor quality** as it is **not from the Carboniferous period**.

Aryan Rock System

- **Age:** 400 million years old to present (Upper **Carboniferous to the Recent**)
- **Location:** Diverse, including the **Himalayas, Gondwana basins, Deccan Traps**, and **alluvial plains**.
- **Rock Types:** These rocks include **sedimentary deposits**, such as **sandstone, shale, and limestone**, as well as volcanic rocks in some regions.

Gondwana System

- The **Gondwana System** derives its name from the **Gond** tribes from **Telangana** and **Andhra Pradesh**. They are deposits laid down in **synclinal troughs** on ancient plateau surfaces.
- As the sediments accumulated, the loaded troughs subsided. Freshwater and sediments accumulated in these troughs, and terrestrial plants and animals thrived. This happened since the **Permian period (250 million years ago)**.
- **Distribution in India:** **Damodar valley, Mahanadi valley**, series of troughs along the **Godavari River valley, Kashmir, Sikkim, etc.,**
- **Gondwana rocks** have **rich deposits of iron ore, copper, uranium and antimony**. Sandstones, slates and conglomerates, which are used as building materials, are also found.

Gondwana Coal

- **Gondwana rocks** contain nearly **98 per cent of India's coal reserves**. **Gondwana coal** is **much younger** than the **Carboniferous coal**, and hence, its **carbon content is low**.

[UPSC 2010] Which one of the following is the appropriate reason to considering the Gondwana rocks as most important of rock systems of India?

- More than 90% of limestone reserves of India are found in them
- More than 90% of India's coal reserves are found in them
- More than 90% of fertile black cotton soils are spread over them
- None of the reasons given above is appropriate in this

Explanation

- **Coal:** Coal is a major source of energy in India. Therefore, the vast coal reserves found in the Gondwana rocks make them particularly important for India's economy.
- **Limestone:** Only a small portion of India's limestone reserves come from Gondwana formations. The majority are found in other geological units like **Vindhyan** and **Himalayan rocks**.
- **Black cotton soils:** While Gondwana rocks may contribute to some black cotton soil formations, they are **not the primary source**.
- The black cotton soils are mainly derived from **Deccan Trap basalts** and other **volcanic rocks**.

Answer: b) More than 90% of India's coal reserves are found in them

Triassic System

- India's Triassic system is mainly concentrated in the **Himalayan belt**, stretching from Kashmir in the north to Kumaon in the southeast. Well-developed sequences are documented in areas like **Spiti, Zaskar, Kashmir, Kumaon, and Chamba**.
- The **Peninsular Shield lacks any significant exposure to Triassic rocks**. This is because it **remained stable** while the **Tethys Sea (predecessor to the Himalayas)** formed to the north.

Jurassic System

- The **marine transgression** in the latter part of the Jurassic gave rise to a thick series of **shallow water deposits** in **Rajasthan and Kutch**.
- Another transgression on the east coast is found between **Guntur and Rajahmundry**.
- Coral limestone, sandstone, conglomerates, and shales occur in Kutch.

Cretaceous System

- **Age:** 145 to 66 million years ago.
- It is **widely distributed** in **both** Peninsular and the Himalayan regions.
- It consists of a variety of rocks deposited in land, sea estuaries and lakes.

Deccan Traps

- The outburst of **basaltic lava** from fissures due to **hotspot volcanism** over a vast area of **10 lakh square kilometres** of Peninsular India from the end of the **Cretaceous** till the beginning of the **Eocene** gave rise to the **Deccan Traps**.
- These volcanic deposits have **flat tops** and **steep sides** and are therefore called **traps**, meaning a 'stair' or 'step' in Swedish.
- The process of **weathering** and **erosion (denudation)** for millions of years has reduced the Deccan Traps to almost half of their original size.
- At present, Deccan Traps cover about **5 lakh square kilometres**, mainly in parts of **Kutch, Saurashtra, Maharashtra, the Malwa plateau and northern Karnataka**.

- The **thickness** of the Deccan Traps is **3,000 metres along the west**, which is reduced to 600-800 metres towards the south, 800 metres in Kutch and **only 150 metres at the eastern limit**.
- The weathering of these rocks for a long time has given birth to **black cotton soil** known as **regur**.

Trap Groups

Group	Found in	Inter-trappean beds	Layers of volcanic ash
The Upper Trap	Maharashtra and Saurashtra	Present	Present
The Middle Trap	Central India and Malwa	Very rare to absent	Present
The Lower Trap	Madhya Pradesh	Present	Very rare to absent

⇒ In **basaltic volcanism (Deccan traps, Siberian shield, Laurentian shield)**, some sediments settle on the cooled and solidified basaltic layer. This sediment layer is covered further by basaltic volcanism, and again, some sediments settle over it. These **successive layers of sediments** separated by the basalt are called **inter-trappean beds**.

Tertiary System

- They are formed between Eocene and Pliocene (60 to 7 million years ago) — **Age of Mammals**.
- The tertiary is the most significant period in India's geological history because the **Himalayas** were born, and India's present form came into being in this period.

Eocene System (60 million years ago)

- This system was formed due to the **deposition of sedimentary rocks** such as sandstones, shales, and limestones in marine, fluvial, and deltaic environments.
- The formation of this system coincides with the initiation of **India's collision** with the **Eurasian Plate**, leading to the formation of the Himalayan Mountain range.
- **Distribution:** Jammu & Kashmir, Himachal Pradesh, Rajasthan, Gujarat, etc. In the eastern part, it is found in parts of the Meghalaya plateau, Naga hills, Surma valley, etc.,

Oligocene and Lower Miocene System (40-25 million years)

- The formation of this system coincides with the **uplift of the Tibetan Plateau** and the gradual emergence of the Himalayas.
- Slowing of India's northward drift allowed the accumulation of sedimentary layers of sandstones, conglomerates, and mudstones in the growing Himalayan foreland basin.
- **Distribution:** Barail series of Assam, Muree series in Jammu hills, parts of Garo hills, etc.,

Shiwalik System (14 to 0.2 million years)

- Deposition of thick sequences of sedimentary rocks, such as sandstones, conglomerates, and clays, formed the Shiwalik or Siwalik hills.
- Fossils within the Shiwalik sediments provide insights into the evolution of mammalian fauna, earning it the title of the "**Age of Mammals**."

Pleistocene System

- The Pleistocene Epoch is **part of the Quaternary Period** and represents a significant geological era characterised by multiple glacial and interglacial cycles.
- Age: 2.6 million to 11,700 years ago** (within the Quaternary period).
- The Pleistocene rock system in India is primarily composed of sedimentary deposits, glacial formations, and volcanic activity, reflecting the diverse climatic and geological processes.
- Glacial features** dominate the Himalayan region, while **alluvial plains** stretch across the Indo-Gangetic plain. **Loess** deposits enrich soils in Punjab and Haryana, while **lacustrine deposits** are found in basins like **Dal Lake** in Jammu and **Chilika Lake** in Odisha.

[UPSC 1997] Match List-I with List-II and select the correct answer:

List-I	List-II
A. Deccan Traps	1. Late Cenozoic
B. Western Ghats	2. Precambrian
C. Aravalli	3. Cretaceous Eocene
D. Narmada-Tapi alluvial deposits	4. Cambrian
	5. Pleistocene

Codes:

- a) A – 3; B – 5; C – 1; D – 4
- b) A – 3; B – 1; C – 2; D – 5
- c) A – 2; B – 1; C – 3; D – 4
- d) A – 1; B – 4; C – 2; D – 5

Explanation

A. Deccan Traps — 3. Cretaceous Eocene

- The Deccan Traps are volcanic rock formations primarily formed during the Cretaceous and Eocene periods.

B. Western Ghats — 1. Late Cenozoic

- The Western Ghats mountain range has undergone significant geological processes during the Late Cenozoic period.

C. Aravalli — 2. Pre-Cambrian

- The **Aravalli Range** is **one of the oldest fold mountain ranges in India**, formed during the **pre-Cambrian period**.

D. Narmada-Tapi alluvial deposits — 5. Pleistocene

- The Narmada-Tapi alluvial deposits are relatively recent geological formations, primarily associated with the Pleistocene period.

Answer: b) A – 3; B – 1; C – 2; D – 5

----- **End of Chapter** -----

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3. The Himalayan Ranges – Part I

- The Himalayan Ranges (Himalayas) are a series of parallel or converging mountain ranges of **tectonic origin** (**continent-continent convergence**). Theoretically, they include the **Himalayas, Purvanchal** and their extensions, **Arakan Yoma (Myanmar)** and **Andaman and Nicobar Islands**.
- Most of the Himalayan Ranges fall in India, Nepal, and Bhutan, with parts of the northern slopes extending into **Tibet (Trans-Himalayas)** and the western extremity reaching Pakistan, Afghanistan, and **Central Asia**.
- The Himalayas are characterised by a young, weak, and flexible geological structure, making them the **most unstable landmass** in India. As a result, they're still influenced by both external and internal forces, leading to widespread tectonic movements such as **faulting, folding, and thrusting**.
- They are intricately **dissected** by **fast-flowing rivers**, which are currently in their **youthful stage** of development. The presence of highly dissected topography and landforms such as **gorges, V-shaped valleys, rapids, and waterfalls** indicate this stage.

[UPSC 2012] When you travel in Himalayas, you will see the following:

1. Deep gorges
2. U-turn river courses
3. Parallel mountain ranges
4. Steep gradients causing land-sliding.

Which of the above can be said to be the evidence for Himalayas being young fold mountains?

- a) 1 and 2 only
- b) 1, 2 and 4 only
- c) 3 and 4 only
- d) 1, 2, 3 and 4

Explanation

Deep Gorges

- **Young fold mountains** are constantly being **uplifted** due to **ongoing tectonic forces**. This rapid upliftment **doesn't allow rivers enough time to widen their valleys** through erosion. As a result, they carve **deep, narrow gorges** like the ones seen in the Himalayas.
- The gorges are characterised by **steep**, rocky cliffs and narrow channels. During their early stages, glaciers flow down gorges and valleys and reshape them into **U-shaped valleys**.

U-Turn Rivers

- Young fold mountains, like the Himalayas, often show evidence of past glaciation in the form of these **U-shaped valleys** and the **U-turn River courses**.

Parallel Ranges

- The **parallel ranges** we see in the Himalayas are formed by the folding and compression of rock layers due to tectonic plate movement. This is a characteristic feature of **young fold mountains**, where the parallel ridges and valleys **haven't had enough time to be eroded**.

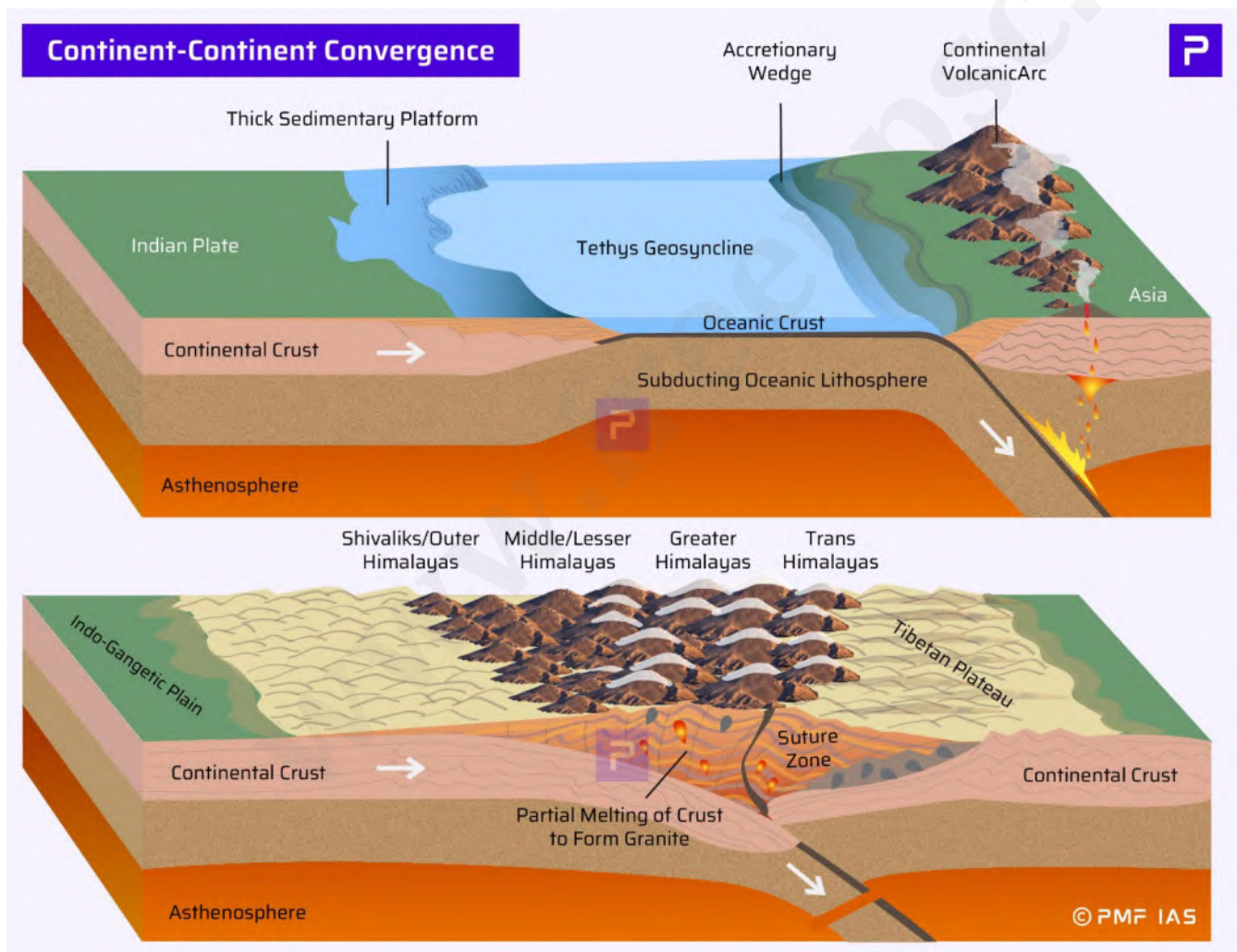
Landslides

- As young fold mountains are still rising, they tend to have **steep slopes** and **unstable terrain**. This makes them **prone to landslides**, which further contribute to their rugged and young appearance.

Answer: d) 1, 2, 3 and 4

The Formation of The Himalayas and The Indo-Gangetic-Brahmaputra Plain

- Around **250 million years ago**, there was a **supercontinent** called **Pangea** surrounded by a super ocean called **Panthalassa**. Around **150 million years ago**, the **Pangea broke** into:
 - Laurasia** or **Angaraland** (present-day North America, Europe, and Asia)
 - Gondwanaland** (present-day South America, Africa, South India, Australia, and Antarctica)
- Due to the breaking of Pangea, a long, narrow sea, called **Tethys Sea**, was created between **Angaraland** and **Gondwanaland**. Huge amounts of **sediments** were **deposited** in the **Tethys Sea** by the rivers flowing into it.



Prechambrian Supereon (4.5 bya – 541 mya)

Hadean Eon (4.5 bya – 4.0 bya)

Archean Eon (4.0 bya – 2.5 bya)

Proterozoic Eon (2.5 bya – 541 mya)

Unnamed Supereon (541 mya – present)

Phanerozoic Eon (541 mya – present)

Paleozoic Era (541 mya – 250 mya)

Mesozoic Era (250 mya – 66 mya)

- Madagascar drifted away from Africa, which continued its move north.
- The northward drift of India continued, and Australia split from Antarctica.
- Zealandia, a microcontinent nearly half the size of Australia, broke away from the Gondwanan supercontinent about 83 million years ago.



Cenozoic Era (66 mya – present)



Cambrian Period (541 – 485 mya)

Ordovician Period (485 – 440 mya)

Silurian Period (440 – 415 mya)

Devonian Period (415 – 360 mya)

Carboniferous Period (360 – 300 mya)

Permian Period (300 – 250 mya)

Triassic Period (250 – 200 mya)

Early Triassic Epoch (250 – 247 mya)

Middle Triassic Epoch (247 – 237 mya)

Late Triassic Epoch (237 – 200 mya)

Jurassic Period (200 – 145 mya)

Early Jurassic Epoch (200 – 175 mya)

Middle Jurassic Epoch (175 – 163 mya)

Late Jurassic Epoch (163 – 145 mya)

Cretaceous Period (145 – 66 mya)

Early Cretaceous Epoch (145 – 100 mya)

Late Cretaceous Epoch (100 – 65 mya)

Paleogene Period (65 – 23 mya)

Paleocene Epoch (65 – 56 mya)

Eocene Epoch (56 – 33 mya)

Oligocene Epoch (33 mya – 23 mya)

Neogene Period (23 – 2.58 mya)

Miocene Epoch (23 mya – 5.3 mya)

Pliocene Epoch (5.3 mya – 2.58 mya)

Quaternary Period (2.58 mya – present)

Pleistocene Epoch (2.58 mya – 11,700 ya)

Holocene Epoch (11,700 ya – present)

Geologic Time Scale & Tectonics



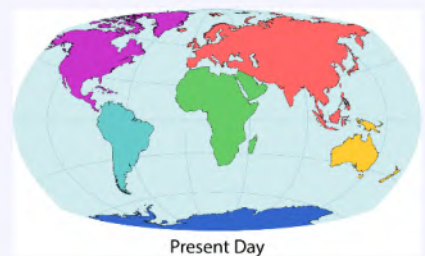
- Pangea Intact
- Pangea was covered by a mighty ocean called as Panthalassa



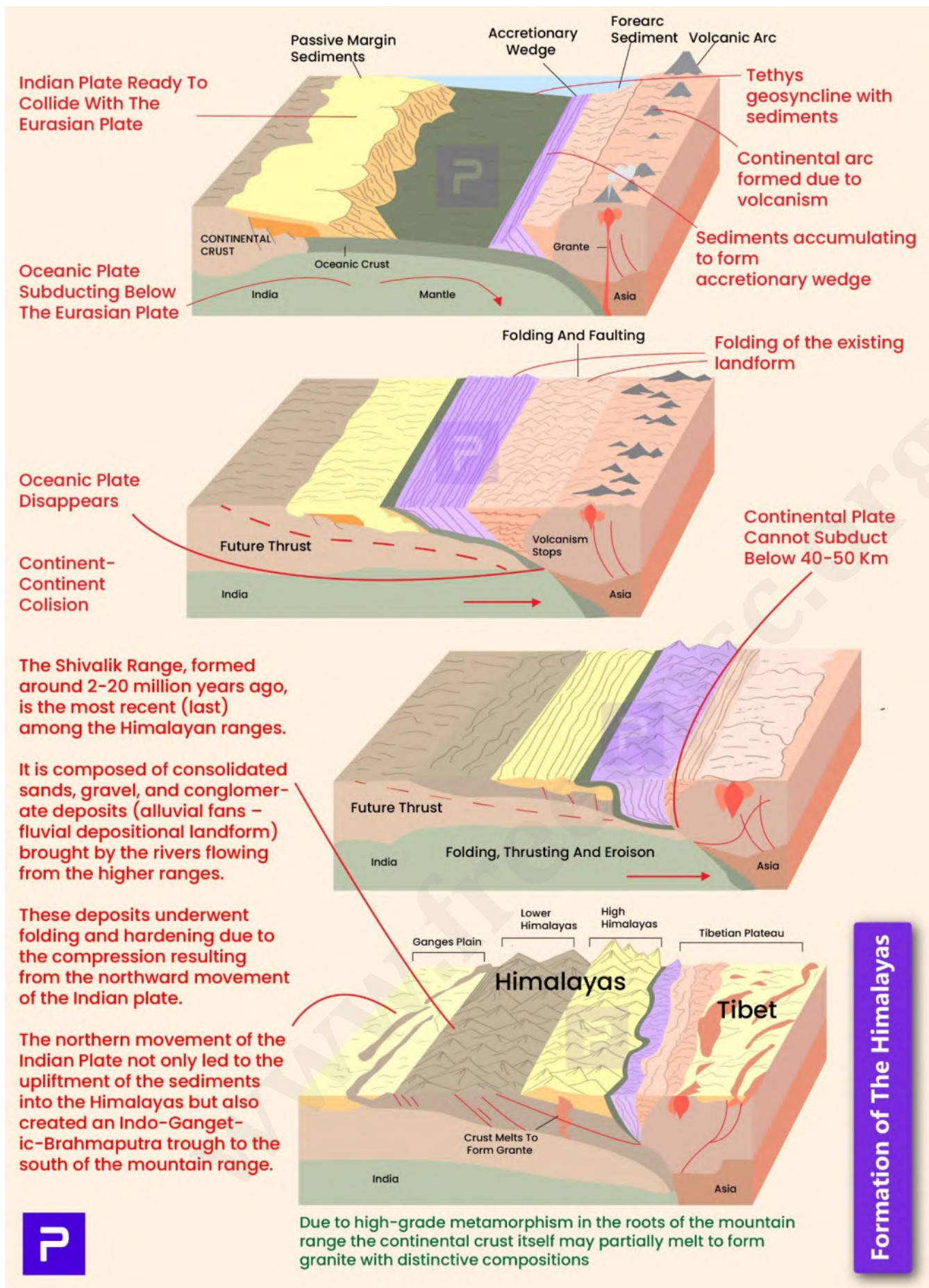
- Pangea broke up into Laurentia (Laurasia) to the north and Gondwanaland to the south
- The Tethys sea separated Laurentia and Gondwanaland
- Rifts formed splitting West Gondwana from east Gondwana.
- India separated from Antarctica.
- Laurasia split from South America and Africa.



- Seafloor spreading further opened the central North Atlantic and Indian oceans.
- At the end of the period, a new rift split South America from Africa.



Tertiary is the former term for the geologic period from 66 million to 2.58million years ago. The term is now obsolete.

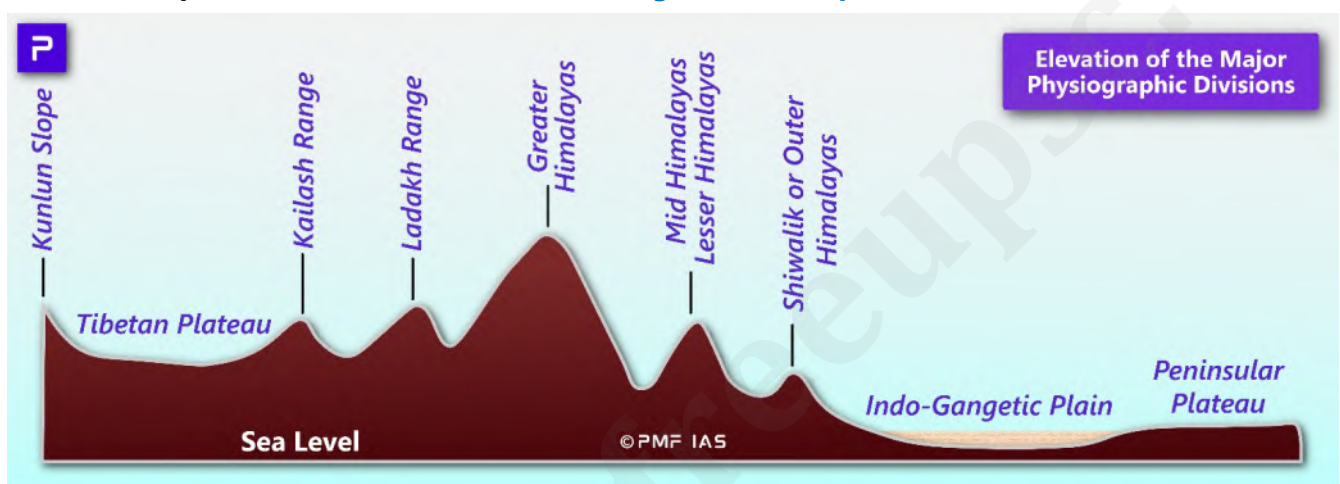


The Formation of The Himalayas

- The **Indian Plate**, which was once a part of the **Gondwanaland**, separated from it and began its northward movement around **150 million years ago**, eventually colliding with the **Eurasian Plate**.
- Due to the northward movement of the Indian Plate, the sediments deposited in the **Tethys Geosyncline** were subjected to **compression**. This resulted in the formation of the **Himalayas** and the **Indo-Gangetic-Brahmaputra trough** to the south of the mountain range.
- The Indian Plate's subduction beneath the **Eurasian Plate** has also led to the formation of several geological features, such as the **Indus-Tsangpo Suture Zone** and the **Main Central Thrust**.

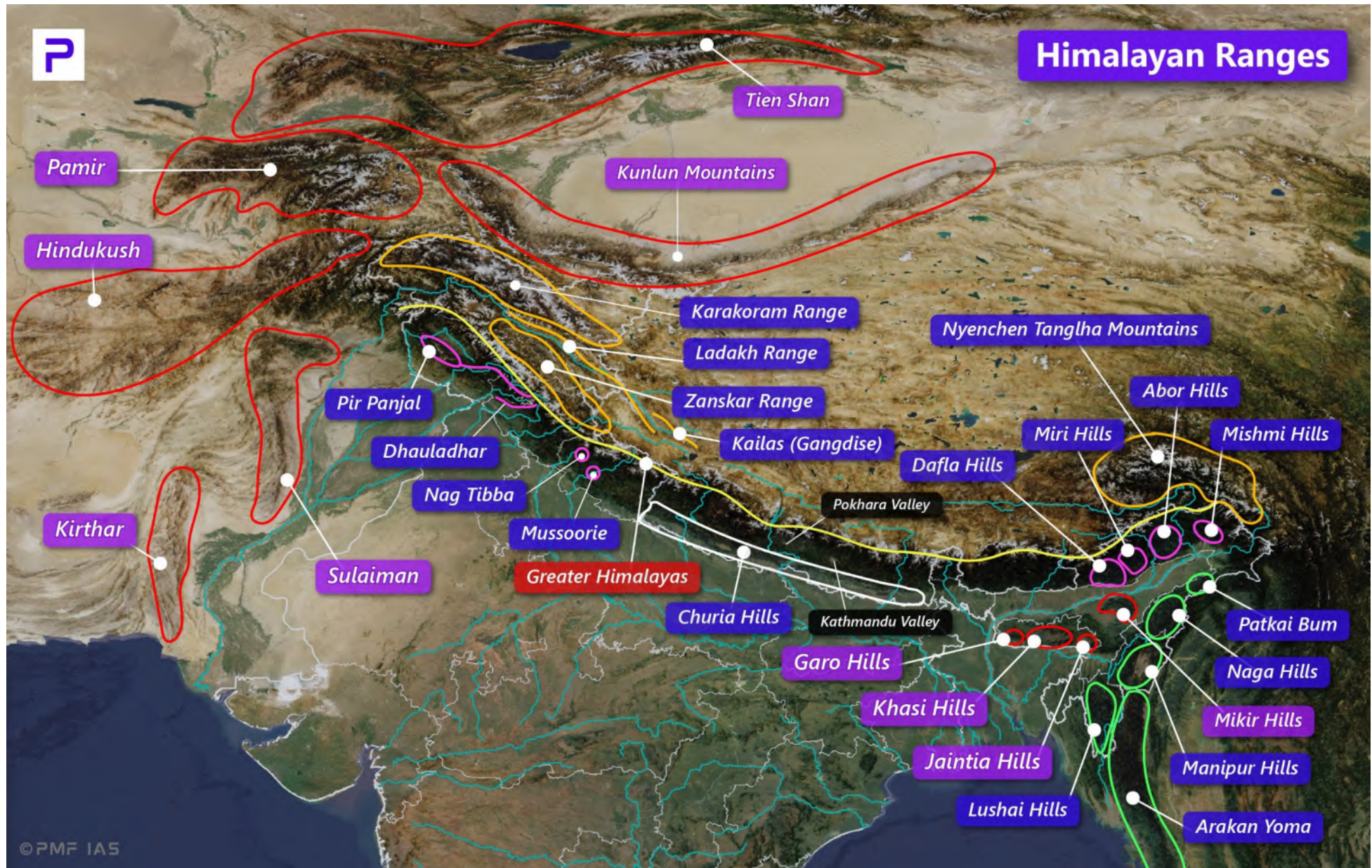
The Formation of Indo-Gangetic-Brahmaputra Plain

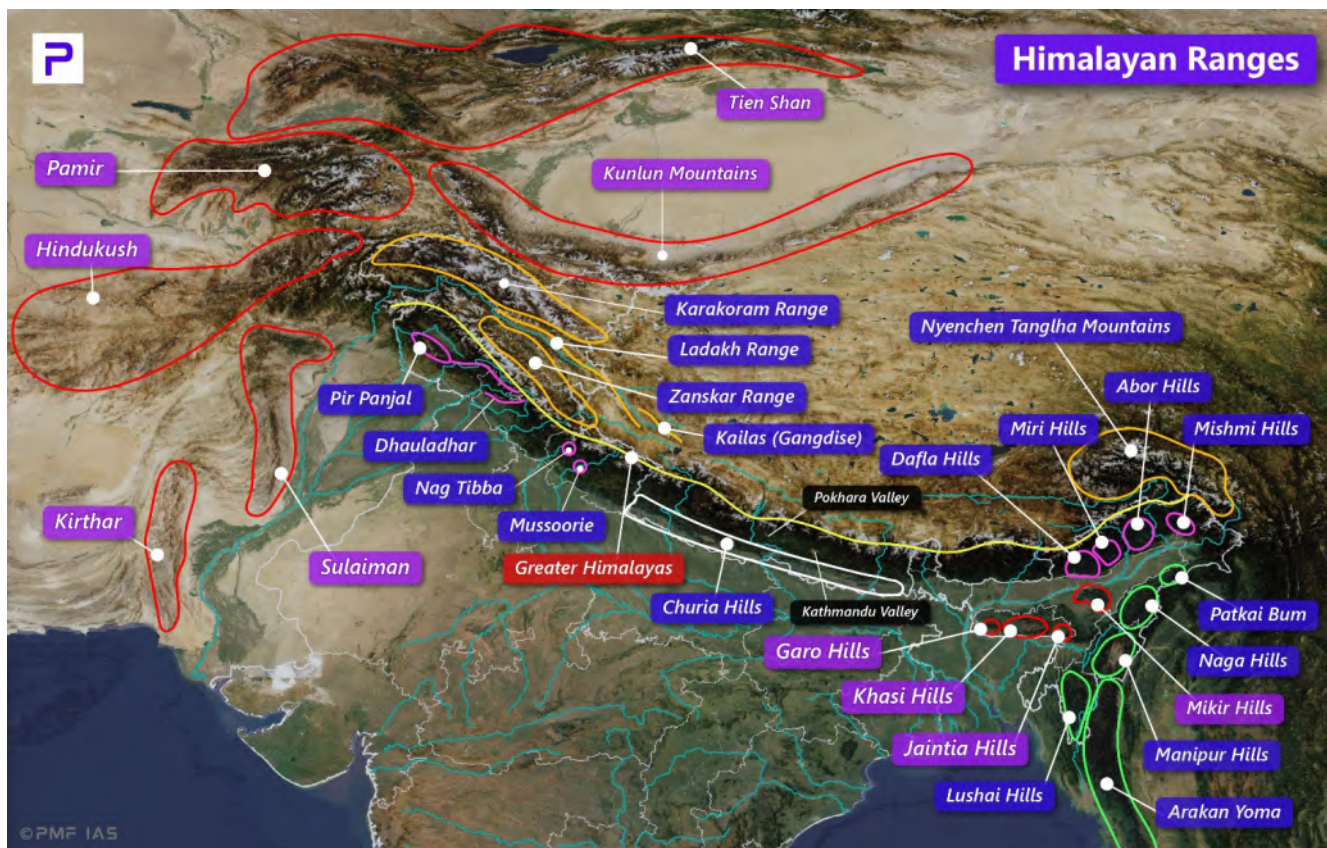
- The rise of the Himalayas and the subsequent formation of glaciers gave rise to many new rivers. These rivers supplied huge amounts of alluvium and started **filling the depression**.
- With time, the depression was filled with alluvium, and the **Tethys completely disappeared**, leaving behind a **monotonous aggradational plain** (plain formed due to depositional activity).
- **Upper Peninsular rivers** have **also** contributed to the formation of plains, but to a **minimal** extent.
- In recent times (since a few million years ago), 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 the **Indo-Gangetic-Brahmaputra Plain**.



Classification of The Himalayan Ranges

- The Himalayan Ranges can be broadly classified into:
 1. **The Trans-Himalayas or Tibetan Himalayas**
 2. **The Greater Himalayas or The Himadri**
 3. **The Lesser Himalayas or The Middle Himalayas or The Himachal**
 4. **The Shiwaliks or The Outer Himalayas**
 5. **The Eastern Hills or Purvanchal — A chain of hills in North-East India**





The Three Parallel Ranges

- Between Tibet and the Ganga Plain, the Himalayas form three parallel ranges — **Greater Himalayas**, **Lesser Himalayas** and **Shivaliks**. They form an arc and cover a distance of about **2400 km**. The width varies from **400 km in Kashmir** to **150 km in Arunachal Pradesh**.

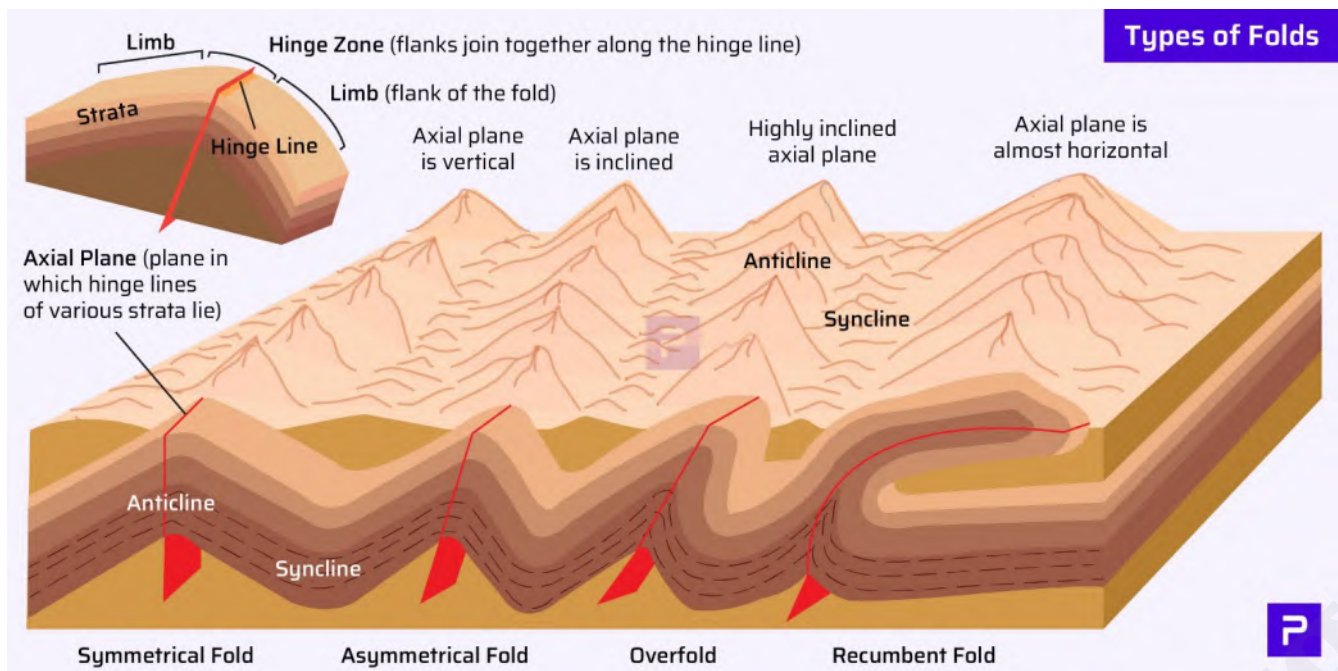
General Orientation

- All three ranges curve **convexly to the south**.
- The **attitudinal variations** are **greater** in the **eastern half** than in the western half.

Parts of Himalayas	Orientation
North-western part of India	Northwest to Southeast direction
Darjeeling and Sikkim regions	East-West direction
Arunachal Pradesh	Southwest to the Northeast
Nagaland, Manipur and Mizoram	North-South direction

Slope

- The **folds** in these ranges are **asymmetrical**, with **valleys** being a part of **synclines**, and the **hills** are part of **anticlines or anti-synclines**. This creates a topography with **steep south slopes** and **gentle north slopes**, giving hogback (a long, steep hill or mountain ridge) topography.



⇒ Scaling Mount Everest is less challenging from the **northern side**. However, China imposes restrictions, so climbers often choose the **steeper southern slopes** from Nepal.

Syntaxial Bends

- The Himalayas stretch in an east-west direction from the **Indus Gorge** in the west to the **Brahmaputra Gorge** in the east. At these gorges, the Himalayan ranges **sharply bend southward**. These bends are referred to as the **syntaxial bends** of the Himalayas.
- The **western syntaxial bend** is situated near **Nanga Parbat**, the western tip of the **Zaskar Range** (where the Indus River has carved a deep gorge). The **eastern syntaxial bend** is located near **Namche Barwa**.

The Trans Himalayas

- The **Trans-Himalayas** are the mountain ranges situated **immediately north** of the **Great Himalayan range**. This range is predominantly located in **Tibet** and is commonly called the **Tibetan Himalayas**.
- The average elevation is around **3000 meters** above mean sea level, and it spans approximately **1,000 km** in the east-west direction, occurring **only in the western part of the Himalayas** (Ladakh, J&K and Himachal Pradesh). The average width is about **40 km** at its **extremities** and **widens** to around **225 km** in the **central part**.

Ranges in The Trans Himalayas

- The Trans-Himalayas have several main ranges — **Karakoram, Ladakh, Zaskar, and Kailas**.

Karakoram Range

- The **Karakoram Range**, also known as **Krishnagiri**, is the northernmost Trans-Himalayan range in India. It extends **800 km eastwards** from the **Pamirs of Pakistan**.

- It has lofty peaks, including **K2 (8611 m)**, also known as **Godwin Austen** or **Qogir**, the **second highest globally** and the **highest in the Indian Union**.
- The Ladakh Plateau lies northeast of the Karakoram Range, divided into various plains and mountains, such as **Soda Plains**, **Aksai Chin**, **Lingzi Tang**, **Depsang Plains**, and **Chang Chenmo**.

Ladakh Range

- It is situated **south** of the **Karakoram** Range and **north** of the **Zaskar** Range and runs parallel to the **Zaskar** Range. **Only a few peaks** of this range exceed a height of **6000 meters**.

Zaskar Range

- The **Zaskar Range** is situated south of the **Ladakh Range**. The average height of the Zaskar Range is about 6,000 m. It houses **Nanga Parbat**, standing at **8126 m**.

Kailas Range

- The **Kailas Range** (**Gangdise** in Chinese) in western Tibet is an **offshoot of the Ladakh Range**.
- **Mount Kailas**, with an elevation of **6714 meters**, is the highest peak in this range.
- The **Indus River** originates from the southern slopes of the **Kailas Range** near **Lake Manasarovar (Mapang Yongcuo)**.

The Greater Himalaya

- The Greater Himalaya, also known as Inner Himalaya, Central Himalaya, or Himadri, extends over 2500 km from **Nanga Parbat** to **Namcha Barwa**. Its width varies between **160-400 km**. It has an average elevation of 6000 meters above sea level.
- This mountain range has the tallest peaks in the world, such as **Kamet** and **Nanda Devi** in Uttarakhand, **Annapurna**, **Dhaulagiri** and **Mt. Everest** in Nepal and **Kanchenjunga** in Sikkim.
- The Himadri abruptly terminates at the **syntaxial bends**, one near **Nanga Parbat** in the **northwest** and the other near **Namcha Barwa** in the **northeast**.
- **Composition:** The Himadri is primarily composed of central crystallines, including **granites** and **gneisses**, overlain by **metamorphosed sediments** such as **limestone**.
- **Folds:** The folds in this range are **asymmetrical**, creating a topography with **steep south slopes** and **gentle north slopes**, giving hogback (a long, steep hill or mountain ridge) topography.

⇒ **Karakoram Range** and **The Greater Himalayas** boast of the **tallest peaks** of the world, most of which remain under perpetual snow.

⇒ **Nanga Parbat** means **Naked Mountain**. It is called so due to its **isolation** from the **Karakoram Range**, which has many similar high peaks (eight thousanders)

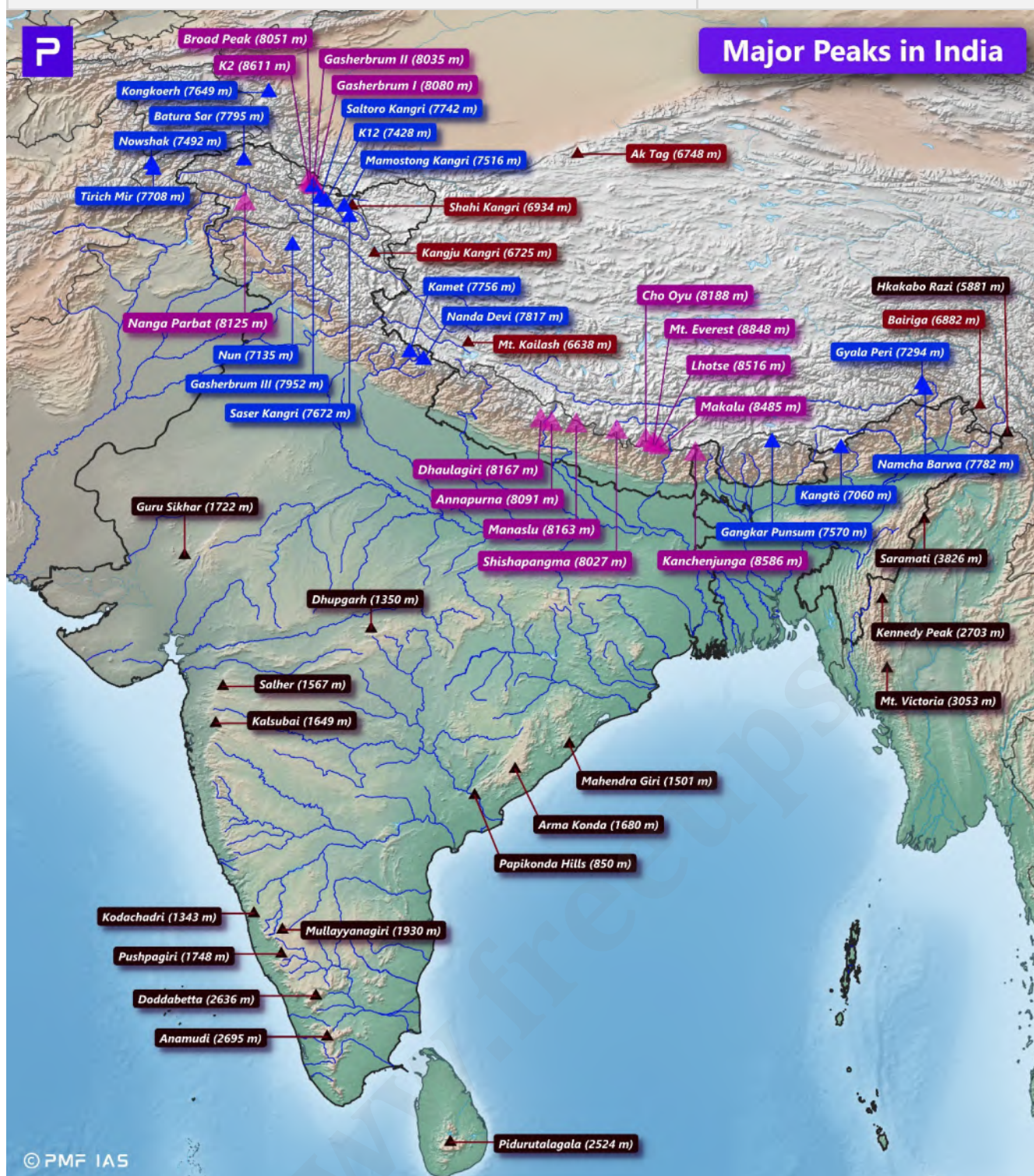
⇒ Mount Everest was first located by **George Everest**, the then Surveyor General of India, in 1841. It was established as the highest peak in the world by the Great Trigonometrical Survey of India.

Regional name of Mount Everest

Sagarmatha (The Goddess of the Sky)

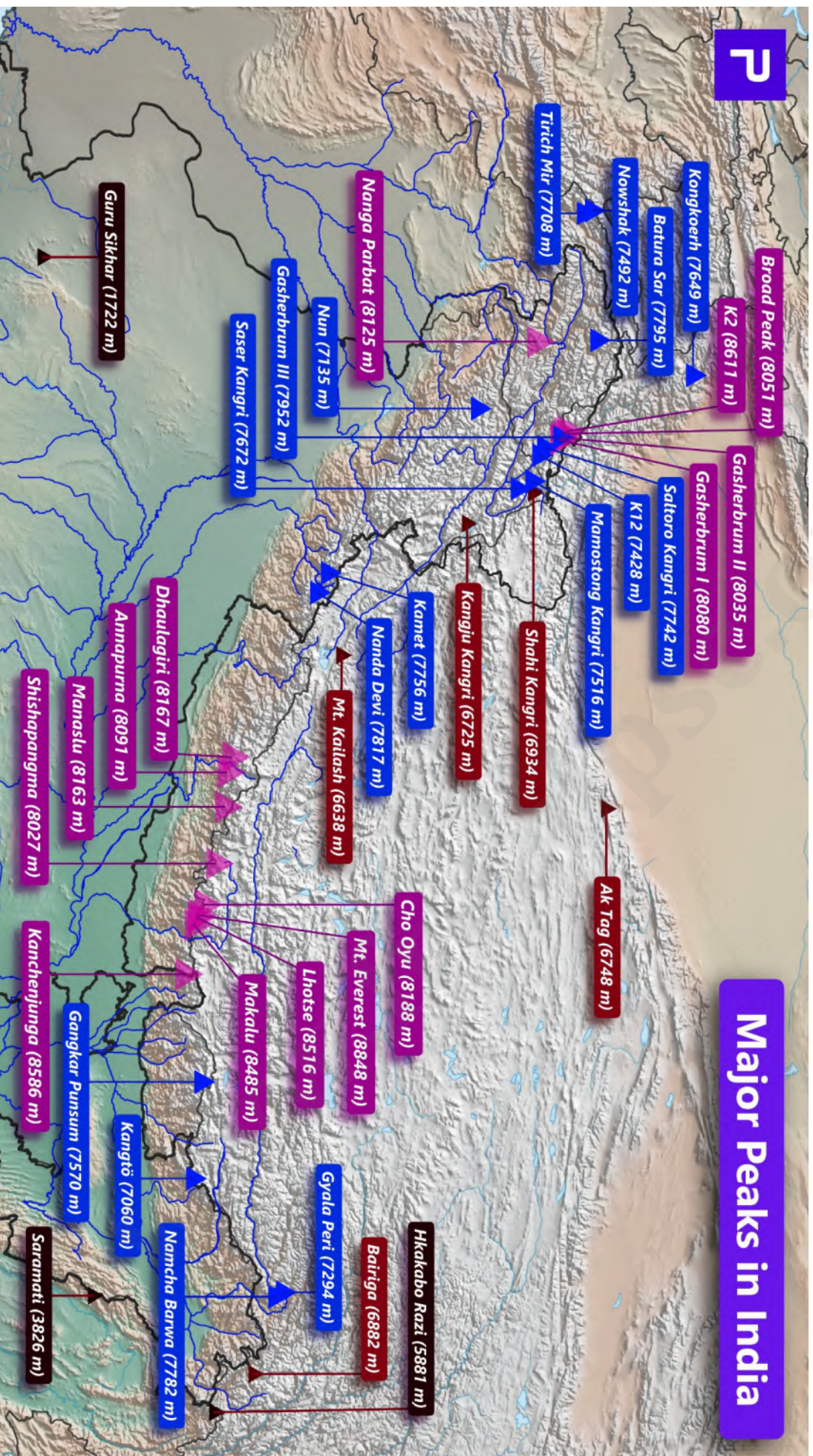
Region

Nepal



The Lesser Himalayas or The Middle Himalayas or The Himachal

- The Middle Himalayas, also known as the **Lower Himalayas**, lie between the Greater Himalayas in the north and the Shiwaliks in the south, running almost parallel to both ranges.
- These ranges are **50 km wide** and about **2400 km long**. They have elevations ranging from **3,500 to 4,500 meters** above sea level. Many peaks within this range surpass **5,050 meters** and remain **snow-covered** throughout the year.



- The Lower Himalayas have steep, **barren southern slopes** (**steep slopes prevent soil formation**) and gentler, **forest-covered northern slopes**.
- In Uttarakhand, the Middle Himalayas are represented by the **Mussoorie** and **Nag Tibba** ranges.
- The **Mahabharat Lekh** in **southern Nepal** is a continuation of the **Mussoorie Range**.
- To the east of the **Kosi River**, areas such as **Sapta Kosi, Sikkim, Bhutan, Miri, Abor**, and **Mishmi** hills represent the lower Himalayas.
- The Middle Himalayan ranges are more accessible for human interaction. Most **Himalayan hill resorts**, such as **Shimla, Mussoorie, Ranikhet, Nainital, Almora**, and **Darjeeling**, are situated in the Middle Himalayas.
- This region consists of the famous valleys of **Kashmir**, the **Kangra**, the **Kullu**, the **Katmandu** and **Pokhara**.

Important Ranges in the Lesser Himalayas

Region	Ranges
Jammu and Kashmir and HP	The Pir Panjal Range
Himachal Pradesh	The Dhauladhar Range
Uttarakhand	The Mussoorie Range and The Nag Tibba Range
Nepal	Mahabharat Lekh
Arunachal Pradesh	Dafla, Miri, Abor and Mishmi

The Pir Panjal Range

- The **Pir Panjal Range** in **Kashmir** and **Himachal Pradesh** is the most significant range of the Lesser Himalayas, stretching over **300 km** from the **Jhelum River** to the **upper Beas River (near Manali)**.
- The **Kishanganga, Jhelum**, and **Chenab** rivers cut through this range.
- It reaches heights of 5,000 meters and is primarily composed of **volcanic rocks**.

Dhauladhar Range

- To the southeast of the **Ravi River**, the **Pir Panjal** continues as the **Dhauladhar Range**, traversing through **Dalhousie** and **Dharamshala** and ends at **Hanuman Tibba (near Manali)**.

Shiwalik Range (Shiwaliks)

- The **Shiwalik Range**, also known as the **Outer Himalayas**, is situated between the Great Plains and Lesser Himalayas. The width varies from **50 km** in HP to less than **15 km** in Arunachal Pradesh.
- With altitudes ranging from 900 to 1100 meters, it spans 2,400 km from the **Potwar Plateau (Paki-stan)** in the west to the **Brahmaputra Valley** in the east.
- It runs mostly as a **continuous chain** of low hills for over **1200 km** from **northwestern India** to the **Gandak River**. Between the **Gandak** and the **Teesta Rivers**, it becomes **discontinuous**, with many streams and rivers highly dissecting the hills.

- **Beyond Teesta**, the valleys of the **Teesta River** and **Raidak River** create a **gap of 80-90 km**. From here on, the Shivalik hills have been either **highly discontinuous** or **even non-existent** in most locations due to the **numerous streams and rivers** and **high annual rainfall in the region**.
- The Shiwalik Range, extending from North-East India to Nepal, is covered with thick forests. However, the forest cover decreases towards the west of Nepal due to a **decrease in rainfall** from east to west.
- The southern slopes are steep, while the northern slopes are gentle. The **southern slopes in Punjab** and **HP lack significant forest cover** and are highly dissected by **seasonal streams** known as **Chos**.



Chos in Punjab

The Shiwaliks are known by different names

Name of Shivaliks	Region
Jammu Hills	Jammu Region
Shivalik Hills	Himachal Pradesh
The Dhang Range and Dundwa Range	Uttarakhand
Churia Ghat Hills	Nepal

Duns

- The **longitudinal valleys** lying between the **Lesser Himalayas** and **Shivaliks** are known as **Duns**.
- Duns were once part of the **floodplains** of the rivers flowing in the region.
- **Dehra Dun** is the largest dun, with an approximate length of 35-45 km and a width of 22-25 km.



Formation of Duns (Duars/Dooars)

- Shiwalik Hills were formed by the **accumulation** and **deposition** of **conglomerates** (such as sand, stone, silt, gravel, and debris) brought down by the fast-flowing Himalayan Rivers.
- During the initial deposition, the conglomerate depositions constantly **obstructed** and **changed the courses of rivers** draining from the higher Himalayan reaches, forming **temporary lakes**. Over time, these lakes gathered more conglomerates, which kept settling and filling the lake bottoms.
- As rivers gradually cut through the lakes filled with conglomerate deposits, the lakes were drained away, leaving behind plains known as **duns** or **doons** in the **west** and **duars** in the **east**.

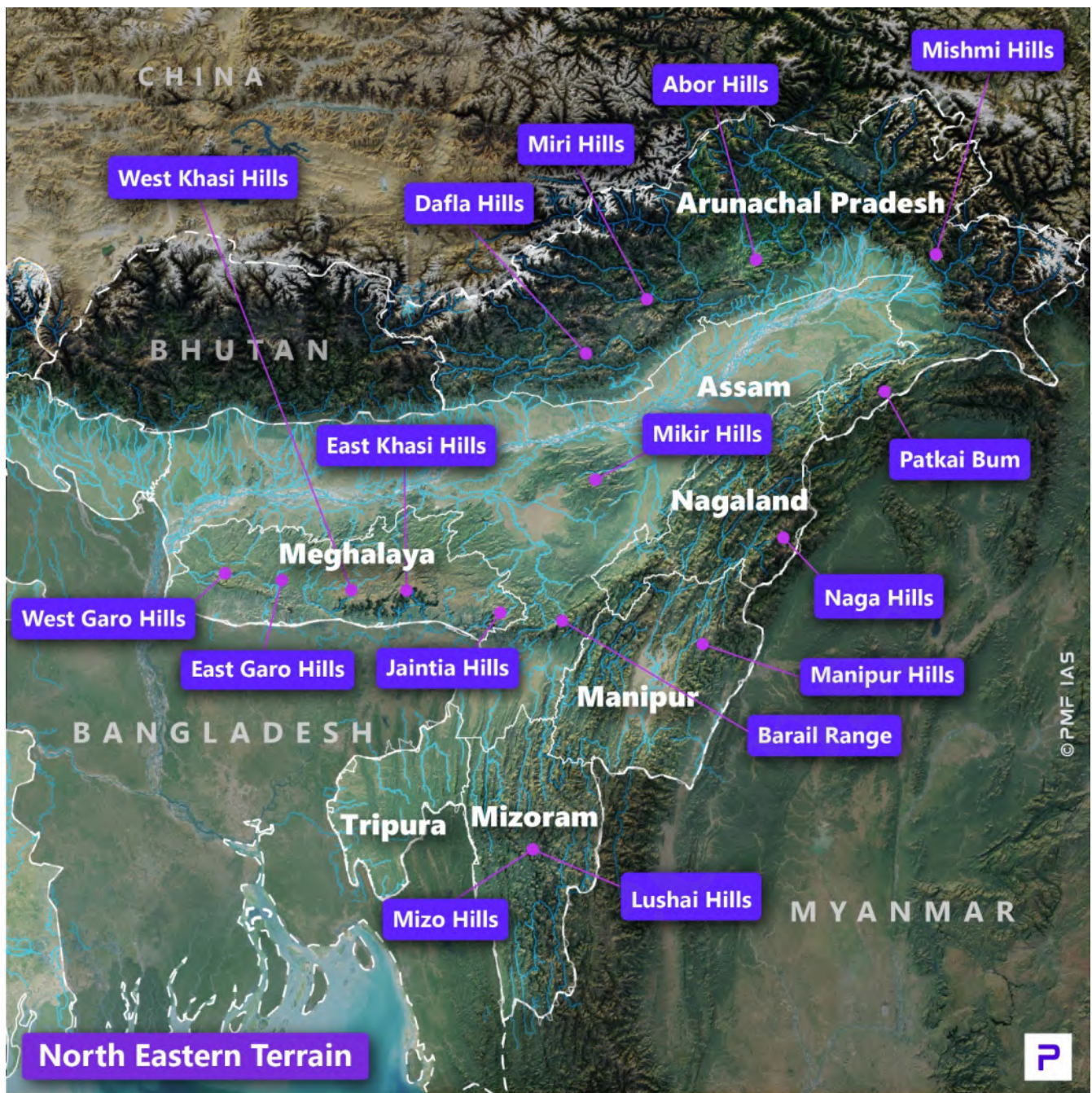
Duars

- The **duars** are at the **foothills of the eastern Himalayas** in North-East India around Bhutan. Duar, which means 'door', are like **passes** in the Eastern Himalayas near Bhutan. The Western duars lies in northern West Bengal and is a portion of the Terai.

Purvanchal or Eastern Hills

- At the **Dihang Gorge**, the Himalayas abruptly take a **southward bend**, giving rise to a series of relatively **low hills** collectively known as the **Purvanchal** — the southward extensions of the Himalayas that run along the north-eastern edge of India.
- These hills exhibit a **convex shape to the west** and stretch along the India-Myanmar Border, extending from Arunachal Pradesh in the north to Mizoram in the south.
- Most of the rivers in Nagaland form the tributary of the **Brahmaputra**. Some rivers of Mizoram and Manipur are the tributaries of the **Barak River** (Manipur and Mizoram), which in turn is the tributary of **Meghna**.
- The rivers in the eastern part of Manipur are the tributaries of **Chindwin**, which in turn is a tributary of the **Irrawaddy** of Myanmar.

- The physiography of Manipur is unique due to the presence of a large lake known as **Loktak Lake** at the centre, surrounded by mountains from all sides.



⇒ The **Meghalaya (Shillong) plateau** is technically a part of the **Deccan Peninsula**. It was separated from the peninsular rock base (at the **Rajmahal Hills**) by the **Garo-Rajmahal gap** created by the Ganga-Brahmaputra River system. The region has the **Garo, Khasi, Jaintia and Mikir (Rengma) hills**.

Regional Hills of The Purvanchal

- The regional hills in the Purvanchal are low hills separated from each other by numerous small rivers. The hills are inhabited by numerous tribal groups practising **Jhum cultivation**.

Patkai Bum and Naga Hills

- The Patkai Bum hills, composed of strong **sandstone**, have elevations ranging from 2,000 to 3,000 meters. These hills merge into the **Naga Hills**, where **Saramati (3,826 m)** is the highest peak.
- The Patkai Bum and Naga Hills form the watershed between India and Myanmar.

Manipur hills

- South of the Naga Hills lies the Manipur hills, generally below 2,500 meters in elevation. The **Barail Range** serves as the separation between the Naga Hills and Manipur Hills.

Mizo (Lushai) Hills

- To the south of the Manipur Hills are the Mizo Hills, formerly known as the **Lushai Hills**, with elevations of less than 1,500 meters. The highest point is the **Blue Mountain (2,157 m)** in the south.

States	Highest Peaks
Arunachal Pradesh	Kangto
Nagaland	Saramati (3,841 m)
Manipur	Mt. Tempu (Esii/ISO)
Mizoram	Blue Mountain (2,157 m)
Tripura	Betling Sib (Betlingchip)

Regional Division of Himalayas

Western Himalayas

- The Western Himalayas include the Himalayan region from the **Indus** in the west to the **Kali River (Sharda River — flows along the Nepal-Uttarakhand border; right-bank tributary of Ghaghara River)** in the east, covering a distance of 880 km. This region is distributed across three states:
 1. Jammu and Kashmir and Ladakh (Punjab Himalayas)
 2. Himachal Pradesh (Himachal Himalayas)
 3. Uttarakhand (**Kumaon**/Uttarakhand Himalayas)
- **All three ranges** of the Himalayas are **prominent** in this section.

Punjab Himalayas

- The **Punjab Himalayas** include the Himalayan region situated between the **Indus** and **Sutlej** rivers, spanning a length of 560 km. It is predominantly located in Jammu and Kashmir and Himachal Pradesh and is commonly known as the **Kashmir** and **Himachal Himalayas**.
- The major ranges in this section include the **Karakoram**, **Ladakh**, **Pir Panjal (J&K and HP)**, **Zaskar**, and **Dhauladhar (HP)**.
- The general **elevation falls westwards**, and all the major rivers of the **Indus River system** flow **westwards** through the Punjab Himalayas.



Kashmir Himalayas

- Kashmir Himalayas comprise a series of ranges such as the **Karakoram**, **Ladakh**, **Zaskar** and **Pir Panjal**. Important glaciers of South Asia, such as the **Baltoro** and **Siachen**, are found in this region. The northeastern part (**Aksai Chin**) is a **cold desert**.
- Between the **Great Himalayas** and the **Pir Panjal** range lies the **valley of Kashmir** and the **Dal Lake**.
- Some of the important passes of the region are **Zoji La** on the **Zaskar Range**, **Banihal** on the **Pir Panjal**, **Photu (Fotu) La** on the **Zaskar** and **Khardung La** on the **Ladakh Range**.
- Some of the important fresh lakes, such as **Dal** and **Wular**, and **saltwater lakes**, such as **Pangong Tso** and **Tso Moriri**, are also in this region.
- This region is drained by the river **Indus** and its tributaries, such as the **Jhelum** and the **Chenab**. **Srinagar** is located on the banks of the **Jhelum River**.
- Some famous places of pilgrimage, such as **Vaishno Devi**, **Amamath Cave**, **Charar-e-Sharif**, etc., are also located in the Kashmir Himalayas.

Himachal Himalayas

- This part lies approximately between the **Ravi** in the west and the **Kali (Sharda River)** in the east. It is drained by two major river systems of India, i.e. the Indus and the Ganga.
- Tributaries of the Indus include the river **Ravi**, the **Beas** and the **Sutlej**, and the tributaries of Ganga flowing through this region include the **Yamuna** and the **Ghaghara**.
- All three ranges of the Himalayas are prominent in this section. The **Lesser Himalaya** is represented by the **Pir Panjal** and **Dhauladhar (HP)** ranges, and the **Outer Himalaya** by the **Shiwalik range**.

- The **southern slopes** are rugged, steep, and **forested**, while the **northern slopes** are **bare** and gentle.
- The northernmost part of the Himachal Himalayas is an extension of the **Ladakh cold desert**, which lies in the Spiti subdivision of district **Lahul and Spiti**.
- In the Himachal Himalayas, in areas with altitude between 1,000-2,000 m, the British colonial administration established and developed important **hill stations** such as **Dharamshala, Mussoorie, Shimla, Kaosani** and the cantonment towns and health resorts such as **Shimla, Mussoorie, Kasauli, Almora, Lansdowne** and **Ranikhet**, etc.

Kumaon Himalayas

- The **Kumaon Himalayas** is situated in **Uttarakhand** and extends from the **Sutlej** to the **Kali River**.
- In the Greater Himalayan range, the valleys are mostly inhabited by the **Bhotias (nomadic groups)**, who migrate to '**Bugyals**' (the **summer grasslands** in the higher reaches) during the summer months and return to the valleys during winter.
- In this region, the **Lesser Himalayas** are represented by the **Mussoorie** and **Nag Tibba** ranges.
- The **Shiwalik range** in this region runs south of the Mussoorie range, situated between the **Ganga** and **Yamuna** rivers.
- The two distinguishing features of the Himachal and Kumaon Himalayas from the point of view of physiography are the '**Shiwalik**' and '**Dun formations**' — flat valleys **between** the **Lesser Himalaya** and the **Shiwalik range**. E.g. **Dehra Dun**.

Central Himalayas

- The Central Himalayas cover an 800 km region between the **Kali River** in the west and the **Teesta River** in the east.
- In this section, the Great Himalaya range reaches its **maximum height**, featuring some of the world-famous peaks such as **Mt. Everest, Kanchenjunga, Makalu, Annapurna, Gosainthan**, and **Dhaulagiri**.
- The **Lesser Himalaya** is referred to as **Mahabharat Lekh** in this region. Rivers like **Ghaghara, Gandak, Kosi**, etc, traverse the range.
- Between the Great and Lesser Himalayas lie the **Kathmandu** and **Pokhara** valleys, which were **once lakes**.
- Towards the east, the Shiwalik range comes close to the Lesser Himalaya and becomes discontinuous beyond **Narayani (Gandak)**.

Eastern Himalayas

- The Eastern Himalayas, also called the **Assam Himalayas**, are situated between the **Teesta River** in the west and the **Brahmaputra River** in the east, covering a distance of about 720 km.
- In this region:
 - ❖ The mountains exhibit a marked dominance of **fluvial erosion** due to **heavy rainfall**.

- ❖ The **elevation is notably lower** compared to the Nepal Himalayas.
- ❖ The **southern slopes are steep**, while the northern slopes are more gentle.
- ❖ The **Lesser Himalayas are narrow** and closely situated to the Greater Himalayas.
- ❖ The **Shiwalik range** becomes **almost non-existent**.
- ❖ After the **Dihang Gorge**, the Himalayas **abruptly turn southward** as the **Purvanchal**.

Sikkim Himalayas

- This region is known for its **fast-flowing rivers**, such as **Teesta**. It is a region of **high mountain peaks** like **Kanchenjunga** and **deep valleys**.
- **Lepcha tribes** inhabit the higher reaches of this region, while the southern part, particularly the **Darjeeling Himalayas**, has a mixed population of Nepalis, Bengalis and tribals from Central India.
- As compared to the other sections of the Himalayas, these, along with the Arunachal Himalayas, are conspicuous by the **absence of the Shiwalik formations**.
- In place of the Shiwaliks here, the '**duar formations**' are important, which have also been used for the development of **tea gardens**.
- **Sikkim and Darjeeling Himalayas** are also known for their scenic beauty and rich flora and fauna, particularly various types of orchids.

The Arunachal Himalayas

- These extend from the east of the Bhutan Himalayas up to **the Diphu (Dipher) Pass in the east**.
- Some of the important mountain peaks of the region are **Kangtu** and **Namcha Barwa**.
- These ranges are **dissected by fast-flowing rivers** from the north to the south, forming **deep gorges**. The Brahmaputra flows through a deep gorge after crossing **Namcha Barwa**.
- Due to rugged topography, the inter-valley transportation linkages are nominal. Hence, most of the interactions are carried through the **duar region** along the **Arunachal-Assam border**.

Hydroelectricity

- Some of the important rivers are the **Kameng**, the **Subansiri**, the **Dihang**, the **Dibang** and the **Lohit**.
- These are **perennial with a high rate of fall**, thus having the **highest hydroelectric power potential** in the country.

Tribal Inhabitants

- An important aspect of the Arunachal Himalayas is the numerous ethnic tribal communities inhabiting in these areas. Some of the prominent ones from west to east are the **Monpa, Daffla, Abor, Mishmi, Nishi** and the **Nagas**.
- Most of these communities practise **Jhumming**. It is also known as **shifting or slash-and-burn cultivation**. This region is rich in biodiversity, which has been preserved by the indigenous communities.

Tea Plantation

- The British, taking advantage of the physical conditions such as **moderate slopes, thick soil cover with high organic content, well-distributed rainfall throughout the year**, and **mild winters**, introduced **tea plantations** in this region.

Eastern Section vs Western Section of The Himalayas

- In the **eastern section**, the Himalayas **rise abruptly** from the plains of Bengal and Oudh and **suddenly attain great elevations within a short distance**. Thus, the peaks of **Kanchenjunga** and **Everest** are only a few kilometres from the plains.
- 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.

[UPSC 2022] Consider the following pairs:

Peak	Mountains
1. Namcha Barwa	— Garhwal Himalaya
2. Nanda Devi	— Kumaon Himalaya
3. Nokrek	— Sikkim Himalaya

Which of the pairs given above is/are correctly matched?

- 1 and 2
- 2 only
- 1 and 3
- 3 only

Explanation

Pair 1 is incorrect

- Namcha Barwa** is situated at the **easternmost edge of the Himalayas** in Arunachal Pradesh. It holds significance as the Brahmaputra River bends sharply near its base, forming a notable U-turn.
- Garhwal Himalayas** and **Kumaon Himalayas** are a part of **Uttarakhand**.

Pair 2 is correct

- Nanda Devi**, the second-highest peak in India after **Kangchenjunga**, is situated within the **Kumaon Himalayas**.
- Located in the Chamoli district of Uttarakhand, Nanda Devi stands prominently between the **Rishiganga Valley** to the west and the **Goriganga Valley** to the east.
- The encompassing Nanda Devi National Park, designated as a UNESCO World Heritage Site in 1988, adds to the significance of this majestic mountain region.

Pair 3 is incorrect

- The **Nokrek Peak**, situated in the **Tura Range** of the **West Garo Hills** of the **Meghalaya Plateau**.
- It stands as the highest point in the **Garo Hills**, rising to an elevation of 1,412 meters.

Answer: b) 2 only

[UPSC 2003] Nanda Devi Peak forms a part of

- a) Assam Himalayas
- b) Kumaon Himalayas
- c) Nepal Himalayas
- d) Punjab Himalayas

Explanation

- Situated in the Indian state of Uttarakhand (Chamoli district) in the **Kumaon Himalayas**, **Nanda Devi** is the **second-highest mountain peak in India** after Kangchenjunga.
- The surrounding area, including **Nanda Devi National Park**, has been designated as a UNESCO World Heritage Site due to its outstanding natural beauty and ecological importance.

Answer: b) Kumaon Himalayas

Summary

Range	J&K	HP	Uttarakhand	Nepal	AP/ Assam
Trans Himalayas	Karakoram Ladakh & Zanskar	Zanskar	—		
Greater Himalayas ❖ <u>Average Height:</u> 6000 m ❖ <u>Width:</u> 160-400 km	Greater Himalayas				
Lesser Himalayas ❖ <u>Average Height:</u> 4000 m ❖ <u>Width:</u> 50 km	Pir Panjal	Dhauladhar	Mussoorie Nag Tibba	Mahabharat Lek	Miri Abor Mishmi Dafla
Shivaliks ❖ <u>Average Height:</u> 1000 m ❖ <u>Width:</u> 10-50 km	Jammu Hills	Shivalik	Dhang Dundwa	Churia Ghat	—

----- End of Chapter -----

4. The Himalayan Ranges – Part II

Important Valleys in the Himalayas

- The most important valleys in the Himalayan region are:
 - Kashmir Valley:** Between the **Greater Himalayas** and the **Pir Panjal Range** of the **Lesser Himalayas**.
 - Kangra Valley (HP):** Between **Lesser Himalayas** and **Shivalik Range**.
 - Kulu Valley (HP):** The **Upper Beas River** flows in this valley.
 - The **Dun Valley** (Doon Valley, Dehradun Valley), the **Bhagirathi Valley** (near Gangotri) and the **Mandakini Valley** (near Kedarnath) in Uttarakhand.
 - The Kathmandu Valley (Nepal):** Between the **Great Himalayas** and **Lesser Himalayas**.
 - The Pokhara Valley (Nepal):** The second largest valley of Nepal after the Kathmandu Valley. Both valleys are **extremely vulnerable to earthquakes** due to the **liquefaction potential** of the **loosely deposited clayey alluvium**.

Kashmir valley

- The valley of Kashmir lies between the **Greater Himalayas** and the **Pir Panjal Range** of the **Lesser Himalayas**. It has an average elevation of 1,585 meters above mean sea level.
- The **synclinal basin** of the valley is covered with alluvial, **lacustrine (lake deposits)**, fluvial (river action), and glacial deposits.
- The **Jhelum River meanders** through these deposits, cutting a **deep gorge** in the **Pir Panjal** through which it drains. (Due to **limited outlets**, Kashmir is **highly susceptible to flooding**).

Karewas

- Karewas** are thick deposits of glacial clay, **lacustrine deposits** (deposits in the lake) and other materials embedded with glacial **moraines** (material left behind by a moving glacier). They are found in the **Valley of Kashmir** and **Bhadarwah Valley** of the Jammu Division.
- In the Kashmir Valley, karewas appear as **flat-topped mounds** that **border the valley on all sides**. They are characterised by the presence of **mammal fossils** and, in some areas, **peat** (accumulation of partially decayed vegetation or organic matter).

Formation

- During the Pleistocene Period, approximately one million years ago, the entire Valley of Kashmir was submerged underwater. Subsequently, endogenic forces led to the creation of the **Baramullah Gorge**, through which the lake was drained. Karewas are the **deposits left behind** in this process.
- Over time, these karewas have been elevated, dissected, and removed by denudation, as well as by the action of the **Jhelum River**, resulting in their current position where the thickness of karewas is approximately **1400 meters**.

Economic Significance

- Karewas are useful for the cultivation of **Zafran**, a local variety of **saffron**. They are also devoted to the cultivation of **almonds, walnuts, apples**, and **orchards**.

Zabarwan Range

- The Zabarwan Range is a small mountain range between **Sind River Valley** and **Lidder River Valley** in the north-central part of the **Kashmir Valley**.
- The range overlooks the famous **Dal Lake** and holds the **Mughal gardens** of Srinagar. The recently built **Indira Gandhi Memorial Tulip Garden** is considered the **largest tulip garden in Asia**.
- The **Dachigam National Park**, which hosts the last viable population of **Critically Endangered Kashmir stag (Hangul)**, is the main feature of the range.

Kangra Valley (Himachal Pradesh)

- The Kangra Valley is a **strike valley** situated between the **Dhauladhar Range** (north) and the **Shivalik Hills** (south). It extends from the **foot of the Dhauladhar Range** to the **Beas River**.
- Kangra tea** is a registered **Geographical Indication (GI)**. Tea gardens are spread across **Dharamshala, Palampur** and **Baijnath** regions.

Kulu Valley (Himachal Pradesh)

- The Kulu Valley, located in the upper course of the Ravi, is a **transverse valley**. It is formed by the **Beas River** between Manali and Larji. This valley is famous for its tourism industry and apple orchards.

Strike Valley vs. Transverse Valley

- A **strike valley** is a valley that runs **perpendicular to the slope** or **parallel to the ridge**, often referred to as a **longitudinal valley**. On the other hand, **transverse valleys** are formed by streams cutting **across the slope**, creating **valleys parallel to the slope** and along the dip.



Strike Valley vs. Transverse Valley

Snow in the Himalayas – Snowline

- The name Himalaya means “**abode of snow**” in Sanskrit. The snow line, which marks the lowest level of perpetual snow, varies across different regions of the Himalayas based on factors such as latitude, precipitation levels, and local topography.
- In the **Eastern Himalayas** and **Kumaon Himalayas**, the snow line is situated at around **3,500 meters** above sea level, while in the **Punjab Himalayas**, it is approximately **2,500 meters** above sea level.
- This difference in the snow line is influenced partly by the **increase in latitude** from 28° N in Kan-chenjunga to 36° N in the Karakoram. However, the primary factor is **precipitation**.
- The western Himalayas experience **comparatively lower precipitation**, primarily in the form of **snowfall** (mostly brought by **Western Disturbances**), while the **eastern Himalayas** receive **greater precipitation**, mostly in the form of **rain**, primarily caused by the **summer monsoon**.
- In the Great Himalayan ranges, the snow line is positioned at a **lower elevation** on the **southern slopes** than on the northern slopes. This is because the **southern slopes** receive **more precipitation** than the northern slopes.

Major Glaciers in the Himalayas

- A glacier is formed due to the perennial accumulation of crystalline ice, snow, rock, sediment, and often liquid water on land or in valleys. It moves downslope slowly but steadily under the influence of gravity.

⇒ *Over multiple decades, the continuous accumulation of snow results in the presence of a large enough mass of snow for the metamorphism from snow to glacial ice.*

- The ISRO study showed that there are **34,919** glaciers spread over **75,779** sq km in the Indus, Ganga, and Brahmaputra basins, covering Himalaya and Trans-Himalaya, including the Karakoram region.

Glaciers of the Karakoram Range

- The **maximum development** of glaciers occurs in the **Karakoram range**. The **southern side** of this range has many gigantic glaciers. Some of the **largest glaciers** outside the polar and sub-polar regions are found in this range.
- Notable glaciers in the Karakoram Range include:
 1. **Siachen Glacier:** Stretching 75 km in the **Nubra Valley** (**Nubra River** is a tributary of the **Shyok River**), it is the **largest glacier outside the polar and sub-polar regions**.
 2. **Hispar Glacier:** Occupying a tributary of the **Hunza River**, this glacier is the **third largest**, extending over 62 km.

⇒ **Fedchenko Glacier:** Located in the **Pamirs**, it is the **second-largest** glacier outside the polar and sub-polar regions, measuring 74 km in length.

Glaciers of the Pir Panjal Range

- The glaciers of the Pir Panjal Range are **fewer** in number and **smaller** in size compared to those in the Karakoram Range. The longest among them is the **Sonapani Glacier** in the **Chandra Valley** of **Lahul and Spiti region**, measuring only 15 km in length.



Glaciers of Ladakh

Siachen Glacier

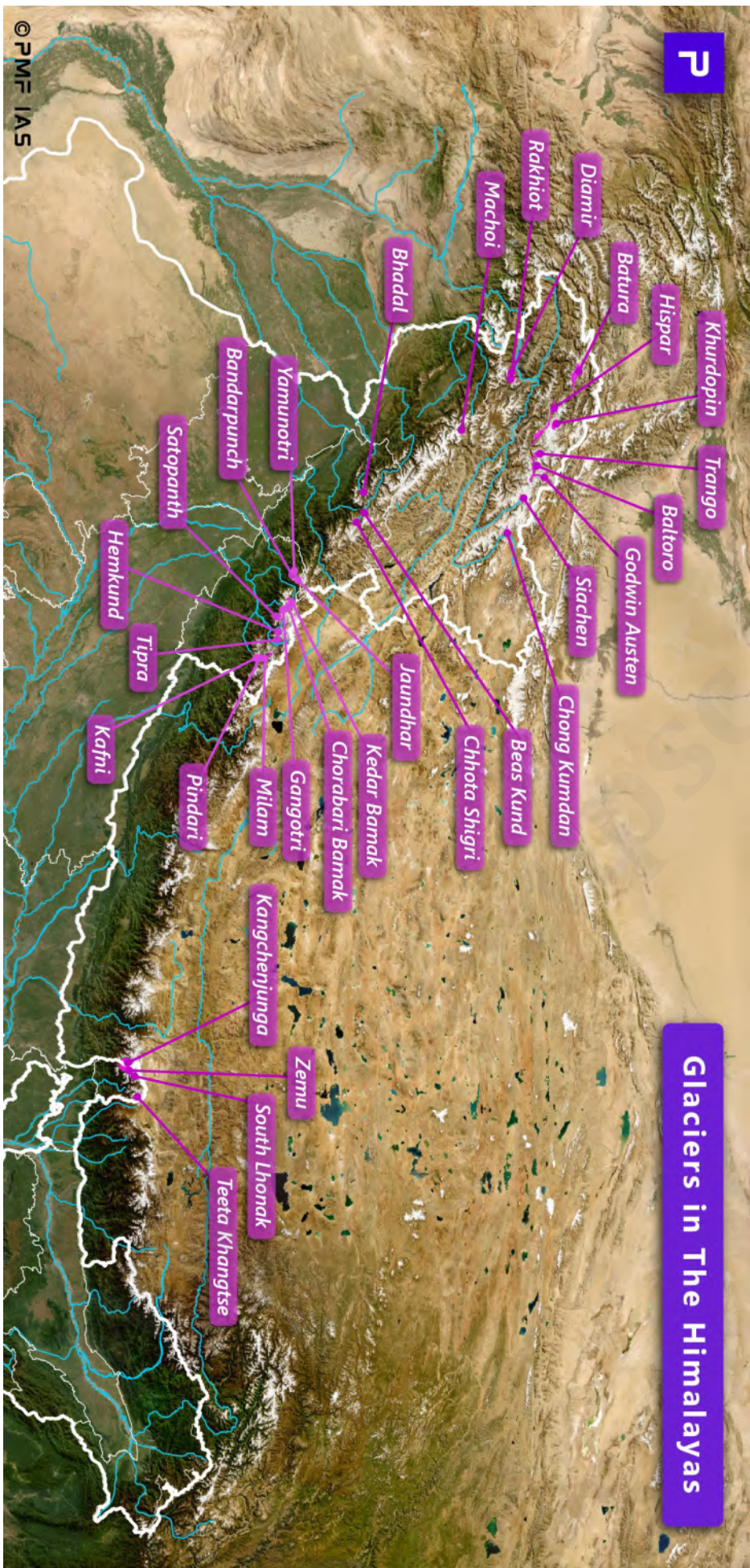
- The **Siachen** in **Ladakh** near the **Karakoram Pass** is a **piedmont glacier** of the "Third Pole" between the **Saltoro Ridge**, a subrange of the Karakoram, and the main **Karakoram Range**.
- It originates at the base of the **Indira Col West**, a **col (low point)** on the **Indira Ridge**.
- It is the **highest battleground in the world**, and the temperature here drops to -50°C .
- It is the source for the **Nubra River** that waters the **Nubra Valley** near **Leh** in the **Trans Himalayas**. The waters of the Nubra drain into the **Shyok River**, which drains into the **Indus River**.

⇒ A **piedmont glacier** forms when valley glaciers spread into a flat area at the base of a mountain range.

⇒ The **Third Pole** is Asia's extensive high mountain region, including the Himalayas, Karakoram Range, Hindu Kush, and Tibetan Plateau, hosting the largest non-polar ice mass.

Glacier is in the Karakoram range of the Pakistan-Occupied Kashmir (PoK)

- K2/Godwin-Austen Glacier:** It is close to the K2 peak, the world's second-highest peak.
- Biafo Gyang Glacier:** Its primary stream feeds into the **Shigar River** (joins the **Indus** at **Skardu**).
- Baltoro Glacier:** It is the source of the **Braldo River**, which flows into the **Shigar River**.
- Hispar Glacier:** It converges with the Biafo Glacier at the **Hispar La Pass (5,128 m; Karakoram Range)**. It feeds the **Hispar River**, which flows into the **Hunza River** (a tributary of the **Indus River**).
- Khurdopin Glacier:** It is the source of the **Shimshal River**, a tributary of the **Hunza River**.
- Others:** Rakhiot Glacier, Diamir Glacier, Trango Glacier, etc.



Machoi Glacier

- **Machoi Glacier** is in the **Zaskar Himalayas** of the **Drass region** of Ladakh. It is located near **Zoji La Pass**. It is the source of the **Sind River** (a tributary of the **Jhelum River**) and the **Drass River** (a tributary of the **Shingo River**; the combined waters form the **Suru River**).

Glacier	Significance / Key Points
Chong Kumdan	• It is on the lower slopes of the Karakoram Range . It feeds the Shyok River .
Rimo Glacier	• Rimo Glacier is located in the Karakoram Range near the Siachen. • The Shyok River originates in the Rimo Glacier .
Drang Drung	• Drang Drung glacier is near the Pensi La Pass in the Zaskar Himalayas . • It is the source of the Doda River , the largest tributary of the Zaskar River .
Shafat Glacier	• Located in the Zaskar, it feeds the Suru River , a tributary of the Indus River .
Pensilungpa	• Located at the north-western corner of Zaskar Valley. It also feeds the Suru .

Glaciers of Jammu and Kashmir

Glacier	Significance / Key Points
Kolahoi Glacier	• Located near Pahalgam, it is the highest and largest glacier in Kashmir . • It is the source of the Lidder River , a tributary of the Jhelum River .
Thajiwas Glacier	Ganderbal district
Harmukh Glacier	Ganderbal district near Gangabal Lake (or Haramukh Ganga)

Glaciers of Himachal Pradesh

Bara Shigri Glacier

- **Bara Shigri Glacier**, located in the **Lahaul region**, is the **largest glacier** in **Himachal Pradesh**.
- It feeds the **Chandra River**, which, after merging with the **Bhaga River** at Tandi, forms the **Chandrabhaga** or **Chenab River**.

⇒ In HP, glaciers are locally called **shigri**.

⇒ The old name of **Chenab** is **Askini**.

Beas Kund

- **Beas Kund** is located on the **Pir Panjal Range** near the **Rohtang Pass** in the **Kullu district**.
- This glacial lake is the **source** of the **Beas River**, a tributary of the **Sutlej River**.

Chhota Shigri Glacier

- Chhota Shigri Glacier lies near the **Rohtang Pass** in the Lahaul and Spiti Valley, **Pir Panjal Range** in HP. It also feeds the **Chandra River**.

Suraj Tal or Tso Kamtsi

- **Suraj Tal Lake** is a glacial lake near the **Baralacha Pass** in HP's Lahaul and Spiti district. The **Bhaga River** rises from this lake.

Bhadal Glacier

- **Bhadal Glacier** is located in the **Pir Pangal Range** in Kangra district. Bhadal Nallah originates from the Bhadal glacier.
- The confluence of **Bhadal Nallah**, **Rai Nallah (from Rai Ghar Glacier)**, and **Tantgari Nallah (from Tantgari and Karu Glaciers)** forms the **Ravi River**.

Glacier/Glacial Lake	Location	Significance
Gangtang Glacier Sonapani Glacier	Lahaul-Spiti	Streams into Shahsha nullah , which joins the Chenab River
Miyar Glacier		Source of the Miyar River , a tributary of the Chenab River
Dudhon Glacier Parbati Glacier	Kullu district	Feeds the Parbati River , a tributary of the Beas River
Mantalai Lake		Source of the Parbati River
Lady of Keylong Glacier	Lahaul-Spiti	It has a dark, bare patch in the middle, resembling a woman carrying a load on her back.
Chandranahan Lake	Shimla District	Feeds the Pabbar River , a tributary of the Tons River (a tributary of the Yamuna River)
Others in Lahaul-Spiti: Perad Glacier, Mukkila Glacier and Gora Glacier		

Glaciers of Uttarakhand



Gangotri Glacier

- Gangotri Glacier is located in **Uttarkashi district**. It has many tributaries, which include Raktavarn, Chaturangi, Satopant, and Kirti glaciers.
- It is the **largest glacier** in the **Garhwal Himalaya** and the **source** of the **Ganga River**.
- The terminus of the Gangotri Glacier is called **Gomukh**, the **source** of the **Bhagirathi River**.

- The **Bhagirathi** and **Alaknanda** (**Satopanth Glacier** is the source) rivers merge at **Devprayag** in Garhwal to form the **Ganga** River.

Garhwal Region

- The Garhwal region, situated in the Himalayas, is bordered by Tibet to the north, the Kumaon region to the east, Uttar Pradesh to the south, and Himachal Pradesh to the northwest.

Chorabari/Chorabari Bamak Glacier

- **Chorabari Glacier** is situated in the **Rudraprayag** district. It is close to the **Kedarnath shrine**.
- Its one snout serves as a source for the **Mandakini River**, a tributary of the **Alaknanda** River.
- Another snout drains into **Chorabari Tal** or **Gandhi Sarovar** (named so due to the immersion of Mahatma Gandhi's ashes in the lake).
- **Glacial Lake Outburst Flood (GLOF)** in this glacial lake caused the **Kedarnath Flood in 2013**.

Glacial Lake Outburst Flood (GLOF)

- Glacial lakes form when a glacier erodes the land, and the depression is filled by glacial meltwater. It typically forms at the foot of a glacier but may form on, in, or under it.



- As glacial lakes grow, they become more dangerous because they are mostly **dammed by unstable ice or sediment**.
- In case the boundary around them breaks, vast amounts of water are released, causing catastrophic floods downstream. This is called **glacial lake outburst floods (GLOF)**.
- GLOF is triggered by several factors, like **earthquakes, heavy rains** and **ice avalanches**.

Tipra Glacier

- Tipra Glacier is in the **Alaknanda River basin**. It is the source of the **Pushpawati** River, which joins the **Laxman Ganga**, a tributary of the **Alaknanda River**.
- **Pushpawati River** replenishes the groundwater table and helps flowers bloom in the **Valley of Flowers**, a **UNESCO World Heritage Site**.

Hemkund/Lokpal Lake

- **Hemkund Lake** is a glacial lake in the Chamoli district. It is nourished by glaciers from Saptrishi peaks and Hathi Parvat.
- It is the source of **Laxman Ganga**/Bhyundar Ganga/Hemganga, a tributary of the **Alaknanda River**.
- **Hemkund Shahib**, the **world's highest gurudwara**, is located on the banks of this lake.

Bandarpunch Glacier

- Bandarpunch Glacier is in the **Uttarkashi** district. It is part of the Sankari Range and lies within the **Govind Pashu Vihar National Park** and Sanctuary.
- The significance of this glacier is that it **feeds both** the **Yamuna** and **Ganga** Rivers.

⇒ The Bandapunch massif consists of three peaks, Bandar Punch I, Bandar Punch II, and the Kala Nag, Black Cobra or Black Peak.

Yamunotri Glacier

- Yamunotri Glacier is in the **Uttarkashi** district. It is located close to **Bandarpunch Glacier**. **Yamuna River**, the **longest** and **second largest tributary** of the Ganga, originates from this glacier.

Jaundhar Glacier

- Jaundhar Glacier is located in the Swargarohini, a mountain massif in the **Bandarpunch Range**. It is the source of the **Supin** River. The confluence of the **Rupin** and **Supin** Rivers forms the **Tons River**, the **largest tributary** of the **Yamuna River**.

⇒ Rupin Rivers originates from a glacier near the Rupin Pass on the border of Uttarakhand and HP.

Glacier	Location	Significance
Bhagirath Kharak	Garhwal	Source of Uttar Ganga , which merges with the Alaknanda River
Pindari Glacier	Kumaon	Source of the Pindar River, a major tributary of the Alaknanda
Milam Glacier	Kumaon	Source of Gori Ganga , a tributary of the Sharda River , a tributary of the Ghagra River .
Khatling Glacier	Garhwal	Source of the Bhilangna River, a tributary of the Bhagirathi
Kafni Glacier	Kumaon	Source of the Kafni River, a tributary of the Pindar River
Namik Glacier	Kumaon	Source of the Ramganga River, a tributary of the Ganga
Meola Glacier	Kumaon	It merges with the Sona Glacier to shape the popular Panchachuli Glacier
Bagini Glacier	Nanda Devi National Park	
Kedar Bamak Glacier	Gangotri National Park	It forms Kedar Tal Lake , the source of the Kedar Ganga River , a tributary of the Bhagirathi River
Kalabaland Glacier	Kumaon Himalayas	It joins with two glaciers of Yangchar and Sankalp, feeding the Ralam Gad River

Panpatia Glacier	Garhwal	It connects the Kedarnath and Badrinath areas
Arwa Glacier	Garhwal	Located inside Nanda Devi National Park
Poting Glacier	Kumaon Himalayas	

Glaciers of Sikkim

Zemu Glacier

- The **Zemu Glacier**, the **largest in the Eastern Himalayas**, is in Sikkim. It is at the base of the **Kanchendzonga**, the **world's third-highest mountain** and drains its eastern side.
- It feeds numerous rivers, including the **Teesta River**, a major tributary of the **Brahmaputra**.

Teesta Khangse Glacier

- Teesta Khangse glacier in Sikkim forms a glacial lake at its snout called **Khangchung Chho**.
- Teesta River** originates as **Chhombo Chhu** from this glacial lake.

South Lhonak Lake

- South Lhonak Lake is a glacial lake in Sikkim's far northwestern region. It is one of the **fastest expanding lakes** in the Sikkim Himalaya region.
- In 2023, **disastrous flash floods** occurred in Sikkim due to the **GLOF** of **South Lhonak Lake**.

Glacier	Significance
Rathong Glacier	Source of the Rathong River, a tributary of the Rangeet River (a tributary of the Teesta River)

[UPSC 2014] Bring out the relationship between the shrinking Himalayan glaciers and the symptoms of climate change in the Indian sub-continent.

The shrinking of Himalayan glaciers is not merely an isolated environmental phenomenon; it's a critical symptom of global climate change and has significant consequences for the Indian subcontinent.

Altered Water Flow Patterns

- Melting glaciers act as natural reservoirs, releasing water throughout the year to feed major rivers like the Indus, Ganges, and Brahmaputra. However, shrinking glaciers disrupt this flow, leading to:
 - ❖ **Increased Floods:** Rapid glacial melt during specific seasons can cause sudden floods, jeopardising lives and infrastructure.
 - ❖ **Reduced Water Availability:** As glaciers recede, water availability during the dry season diminishes, impacting agriculture, drinking water supplies, and hydropower generation.

Extreme Weather Events

- Changing dynamics contribute to altered weather patterns, making the region vulnerable to:
 - ❖ **More Intense Heatwaves:** Reduced snow cover and altered atmospheric circulation can lead to more frequent and **severe heatwaves**, impacting agriculture and human health.

- ❖ **Changes in Monsoon Patterns:** **Unpredictable monsoons** due to **altered atmospheric circulation** can lead to droughts in some regions and floods in others, causing agricultural losses and economic instability.

Impact on Ecosystems and Biodiversity

- Glaciers are crucial for maintaining fragile mountain ecosystems. Their shrinkage:
 - ❖ Disrupts the natural water cycle, affecting flora and fauna dependent on specific water regimes.
 - ❖ Leads to habitat loss and fragmentation, threatening sensitive species unique to these high-altitude regions. For example, the **decline in snow leopard populations**.

Sea Level Rise

- While not as significant as other impacts, melting glaciers contribute marginally to the **rise of global sea level**, potentially impacting coastal communities in the Indian subcontinent.

Socioeconomic Consequences

- The combined effects of water scarcity, extreme weather events, and ecosystem degradation have significant socioeconomic consequences:
 - ❖ **Reduced agricultural productivity:** Impacts food security and livelihoods, particularly for communities reliant on agriculture.
 - ❖ **Increased distress migration:** Water scarcity and resource depletion can force people to migrate in search of better opportunities.
 - ❖ **Health risks:** Heatwaves, floods, and waterborne diseases pose health risks to vulnerable populations.

The shrinking Himalayan glaciers serve as a clear indicator of the pressing need to confront climate change. This underscores the **interconnectedness of our planet** and emphasises the necessity for unified action to address climate change and its repercussions.

[UPSC 2020] How will the melting of Himalayan glaciers have a far-reaching impact on the water resources of India?

The melting of Himalayan glaciers will have profound implications for water resources in India, affecting agriculture, energy production, drinking water supply, and interstate relations.

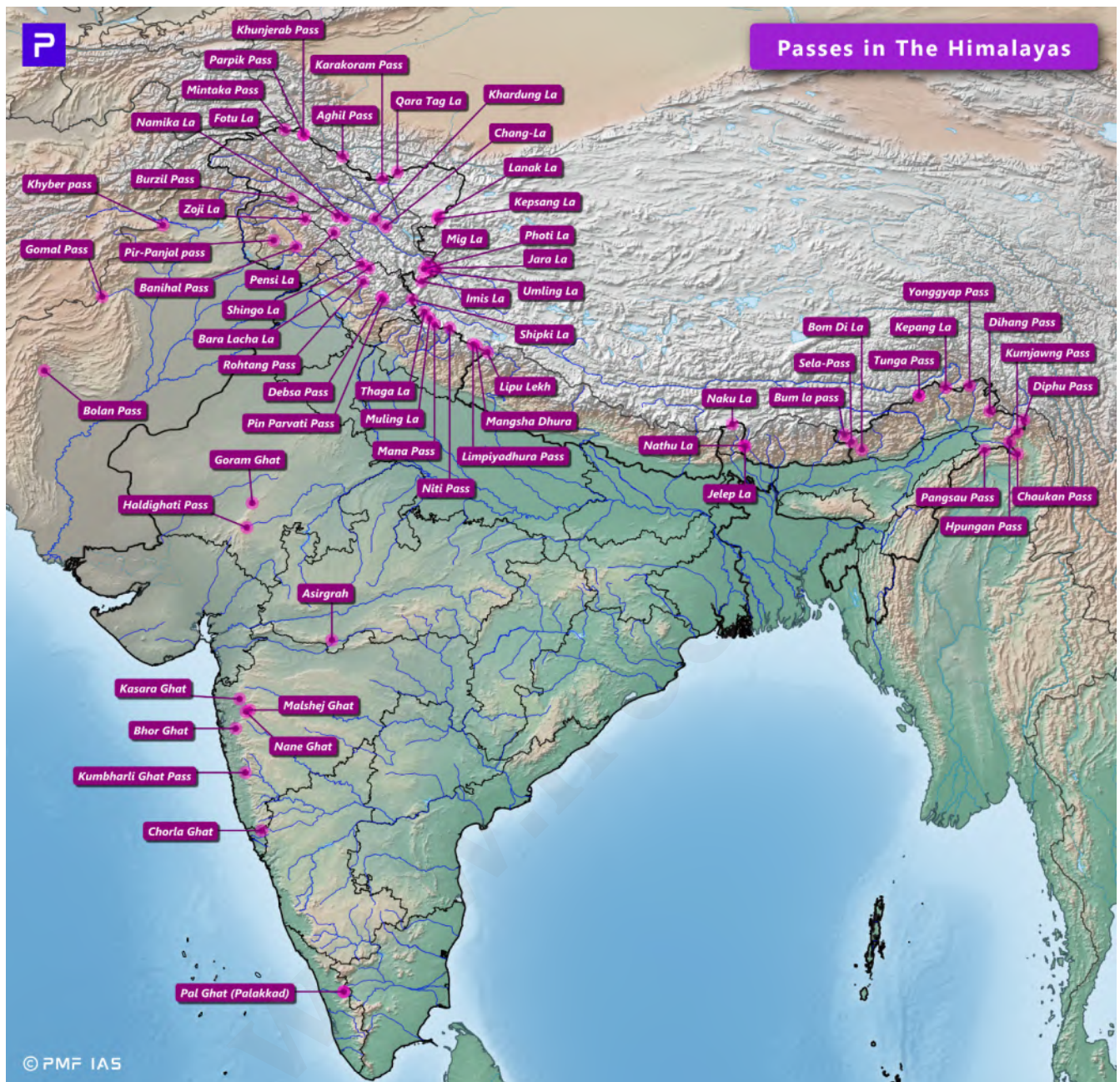
Altered Water Flow Patterns

- **Increased Floods in Monsoon Season:** Rapid melt during peak monsoon can cause sudden floods, jeopardising lives and infrastructure. For example, the 2013 Uttarakhand floods were attributed to **glacial outburst floods triggered by heavy rains**.
- **Reduced Water Availability in Dry Season:** Shrinking glaciers decrease the water stored for later release, leading to water scarcity during dry months. For example, declining water levels in the Ganges and Indus rivers impact agriculture and drinking water supplies.

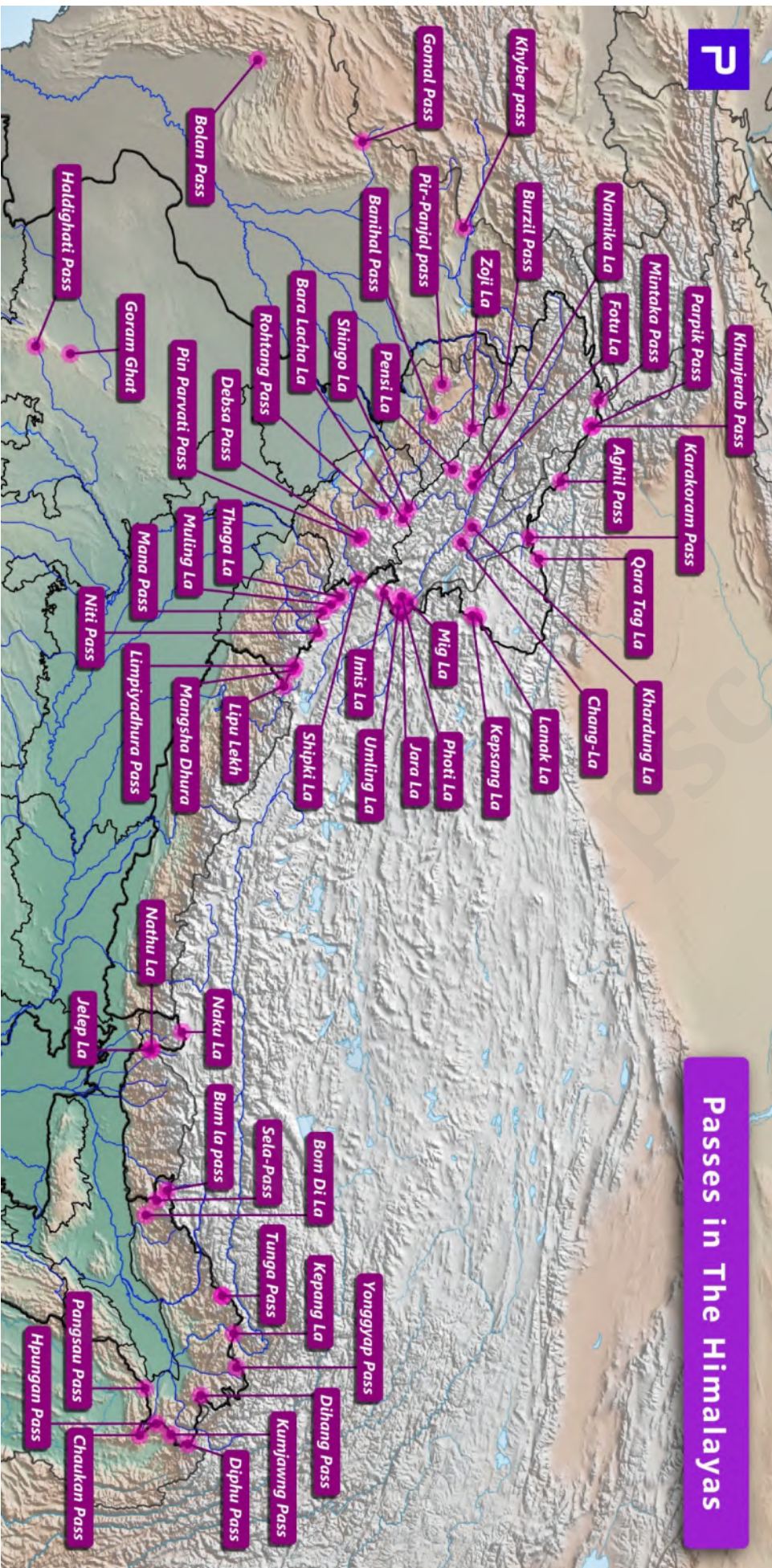
Unpredictable Monsoons

- Glacial melt affects atmospheric circulation, potentially leading to:
 - ❖ **Increased Droughts:** Reduced monsoon rainfall due to altered atmospheric patterns can lead to droughts, impacting agricultural production and food security.
 - ❖ **Intense Rainfall Events:** Unpredictable monsoons can cause intense rainfall events, leading to flash floods and soil erosion.

Major Mountain Passes in The Himalayas



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

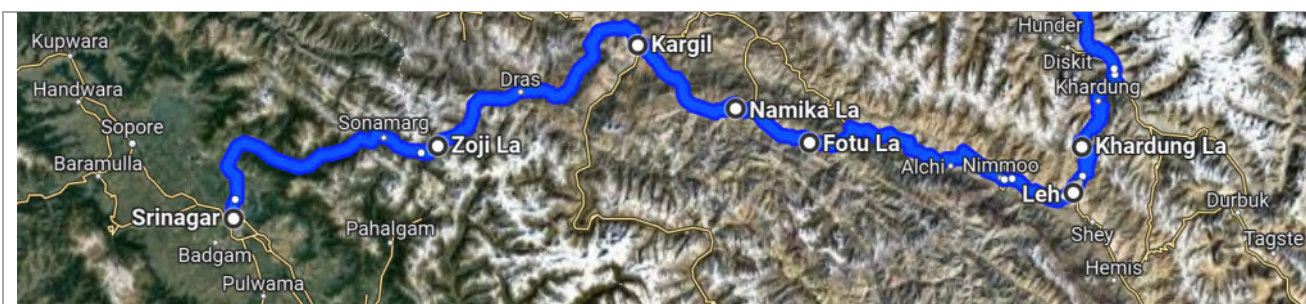


Ladakh and Jammu and Kashmir

Pass	Elevation	Connects	Comments
Mintaka Pass	4,709 m	Ladakh-China across the Karakoram Range	Near India-China-Afghanistan trijunction
Parpik Pass	5,608 m		East of Mintaka pass
Khunjerab	4,693 m		CPEC passes through this pass
Aghil Pass	4,978 m		North of K2 Peak
Qara Tag La	6,000 m		Both were an offshoot of the ancient Silk Route.
Karakoram Pass	5,540 m		
Lanak La	5,466 m	Ladakh-Tibet	At the eastern edge of the Karakoram Range
Imis La	5,795 m		On the Ladakh Range, close to the Demchok sector
Umling La	5,882 m		The world's highest motorable road pass.
Mig La	5,913 m		Once completed, Likaru-Mig La-Fukche (advanced landing pad) road in the Demchok sector will be the world's highest motorable road.
Photi La	5,524 m		Near Mig La
Banihal Pass	2,832 m	Jammu-Srinagar across the Pir-Panjal Range	
- The Banihal Pass served as a route for the Jammu-Srinagar highway and the Jammu-Baramulla railway until the Jawahar Tunnel (elevation of 2,194 m) was constructed under the pass in 1956. - The Banihal Qazigund Road Tunnel (elevation of 1,790 m) was constructed in 2021 below the Jawahar Tunnel to widen National Highway 44 (Srinagar to Kanyakumari). It is one of the longest tunnels in India, with a length of 8.45 km. - Another 11 km long tunnel provides a railway link between Banihal and Qazigund. It was thrown open to railway transport in 2013.			
Chang La	5,391 m	Leh-Pangong Lake-Aksai Chin	This temple is dedicated to Chang-La Baba, after whom the temple was named.
Khardung La	5,359 m	Indus-Shyok River Valleys	- One of the world's highest motorable road passes. - Gateway to the Nubra and Shyok Valleys. - Lies on the major caravan route from Leh to Kashgar in Central Asia.



Pir-Panjal pass	3,490 m	Kashmir Valley-Jammu	Provides the shortest route between Jammu and Kashmir Valley. But this route is closed after partition.
Razdan Pass	3,556 m	Kashmir-Gurez Valley	
Pensi La	4,400 m	Zaskar Valley and Kargil 	
Zoji La	3,528 m	Srinagar-Kargil-Leh	- Connects the Kashmir Valley with the Dras and Suru valleys. - An all-weather Zoji La Tunnel (14.2 km) and Z-Morh Tunnel (6.5 km) are under construction.
Fotu (Photu) La	4,108 m		The two high mountain passes between Leh and Kargil.
Namika La	3,700 m		



Himachal Pradesh

Pass	Elevation	Connects	Comments
Bara Lacha La	4,850 m		- The national highway connecting Manali with Leh passes through this pass. - Tunnels are being constructed at Lachung La Pass and Tanglang La Pass to bypass the Bara Lacha La. - The Chandra and the Bhaga (Streams of Chenab) originate from the southwest and northwest faces of this Pass, respectively, in Lahul and Spiti Valley.
Debsa Pass	5,360 m	Kullu-Spiti	It offers a much easier and shorter alternative route to the traditional Pin-Parvati Pass route between Kullu and Spiti .
Pin Parvati Pass	5,319 m	Parvati-Pin valleys	The shepherds from Spiti use it to graze their sheep in the lush green Parvati valley .
Rohatang Pass	3,980	Kullu-Lahul-Spiti 	- Located along Leh-Manali Highway (NH 3 — Atari (near Amritsar) to Leh via Manali). - It is on the eastern end of the Pir Panjal Range, around 51 km from Manali. Atal Tunnel is a 9 km highway tunnel built under the Rohatang Pass.
Shingo La	5,091 m	Lahaul (HP)-Zaskar (Ladakh)	With the existing Atal Tunnel and after the completion of the under-construction Shinku La Tunnel, the Leh-Manali Highway via Nimmu-

			Padum–Darcha road (an alternative to the existing Leh-Manali Highway) will become an all-weather road . It will reduce the Manali to Kargil distance by 522 km.
Shipki La	3,930	Shimla (HP)-Gartok (Tibet)	- River Sutlej enters India near Shipki La. - The pass is one of India's border trading points with Tibet, along with Nathu La in Sikkim and Lipulekh in Uttarakhand.

Uttarakhand

- Most of the major passes in Uttarakhand are a part of the ancient trade route between Uttarakhand and Tibet and have been closed since the 1962 war.

Pass	Elevation	Connects	Comments
Lipulekh Pass	5,115 m	Uttarakhand-Tibet	- Near the tri-junction of India-China-Nepal. Kailash-Mansarovar pilgrims use this pass.
Mana Pass	5,632 m		Located within the Nanda Devi Biosphere Reserve, a little north of Badrinath.
Mangsha Dhura Pass	5,674 m		Kailash-Mansarovar pilgrims use this pass.
Niti Pass	5,800 m		Ancient trade route.
Muling La	5,669 m		Situated to the north of Gangotri.

Eastern Himalayas

Sikkim

Pass	Elevation	Connects
Nathu La	4,310 m	Jelep La is 4 km south of Nathu La. - They connect Kalimpong (near Darjeeling in WB) and Gangtok to Chumbi Valley (in the Tibetan Region between Bhutan and Sikkim). - They are on a route that connects Lhasa to India along an offshoot of the ancient Silk Route.
Jelep La	4,386 m	

Doklam

- Doklam** is an area of **strategic importance** in **Bhutan** with a **high plateau** and a **valley** lying to the **north of China's Chumbi Valley**. In June 2017, a military standoff occurred between China and India as China attempted to extend a road on the Doklam plateau near the **Doka La pass**.

Arunachal

Pass	Elevation	Connects	Comments
Bom Di La	2,217 m	Itanagar-Tawang-Lhasa (Tibet)	
Bum La	4,600 m	Tawang-Tibet	Near India-Tibet-Bhutan tri-junction
Sela Pass	4,170 m	Itanagar-Tawang	Between Bum La and Bom Di La
Dihang (Siang)	4,590 m	Connects Arunachal and Tibet.	
Yonggyap Pass	3,962 m		
Dipher (Diphu) Pass	4,587 m	India-Myanmar	Tri-junction of India-China-Myanmar
Kumjawng Pass (2,929 m), Hpungan Pass (3,072 m), Chaukan Pass (2,400 m) and Pangsau Pass (1,136 m) connect Arunachal Pradesh with Myanmar.			

The Significance of The Himalayas

Influence on Indian Climate

- The Himalayas **intercept the summer monsoons** coming from the **Bay of Bengal** and the **Arabian Sea**, causing precipitation in the entire **Ganga Plains** and **North-Eastern Hills**.
- They **direct the monsoon winds towards north-western India** (Punjab, Haryana, etc.). (But these regions receive most of the rainfall due to **Western Disturbances** coming from the **Mediterranean regions**.)
- They **protect northern plains** from the **cold continental air masses** of central Asia. Without the Himalayas, **India would likely be a desert with severe winters**.
- They influence the path of the **Sub-tropical Jet stream** flowing in the region. They **split the jet stream**, and this split jet stream plays an important role in **bringing monsoons** to India.

[UPSC 2010] If there were no Himalayan ranges, what would have been the most likely geographical impact on India?

- Much of the country would experience the cold waves from Siberia.
- Indo-gangetic plain would be devoid of such extensive alluvial soils.
- The pattern of monsoon would be different from what it is at present.

Which of the statements given above is/are correct?

- 1 only
- 1 and 3 only
- 2 and 3 only
- 1, 2 and 3

Explanation

Cold Waves from Siberia

- The Himalayas act as a massive barrier, **blocking cold winds from central Asia**. Without them, India would experience much colder winters, particularly in the northern plains.

Indo-Gangetic Plain and Alluvial Soils

- The Himalayas are the source of major rivers like the Indus, Ganges, and Brahmaputra. These rivers carry vast amounts of **fertile alluvial soil** eroded from the mountains and deposit them in the Indo-Gangetic plain, making it one of the world's most fertile regions.
- Without the Himalayas, these rivers wouldn't exist, and the **plain** would likely be **arid or semi-arid** (as the region would be under the influence of the **descending dry air** of **subtropical high-pressure zone**, just like the **Sahra Desert**), devoid of its current fertile soil.

Monsoon Pattern

- The Himalayas play a crucial role in influencing the monsoon winds. They force the moisture-laden winds to rise, leading to heavy rainfall in the northern and eastern parts of India.
- Without the Himalayas, the monsoon pattern would almost be **nonexistent in the plains region**.

Answer: d) 1, 2 and 3

Source of Rivers

- Rivers that feed nearly half a billion population of India originate in the Himalayas.
- All the rivers in this area are **perennial**, which supply water throughout the year.

Fertile Soil

- The swift-flowing rivers from the Himalayas bring an enormous amount of **silt (alluvium)**, which continually **enriches** the Ganga and Brahmaputra plains.

Hydroelectricity

- Natural topography and **swift-flowing perennial rivers** offer great potential for hydroelectric power generation. Many hydroelectric power plants have already been built, but **at the expense of the environment**.

Forest Wealth

- The Himalayas host rich **coniferous** and **evergreen forests**. Tropical evergreen forests cover lower levels, while higher elevations have Alpine vegetation.
- The Himalayan forests provide fuelwood and a large variety of timber for industries. These forests also house **medicinal plants**.
- Several patches are covered with grass, offering rich **pastures** for grazing animals.

Agriculture

- Due to rugged and sloped terrain, the Himalayas are not potential agricultural sites. Terraced slopes are used for cultivation, with rice being the main crop. Other crops include wheat, maize, and potatoes.

- **Tea** is a unique crop that can be grown only on the **Shiwalik hill slopes** in the region. **Fruit cultivation** is a principal occupation. A wide variety of fruits, such as **apples, pears, grapes, mulberries, walnuts, cherries, peaches, apricots**, etc., are also grown in the Himalayan region.

Tourism

- The hilly areas in the Himalayas are not affected by hot winds like the **loo**. Hence, they offer a cool and comfortable climate. Hence, they host many tourist spots. The increasing popularity of winter sports has increased the rush of tourists in winter.
- **Srinagar, Dalhousie, Dharamshala, Chamba, Shimla, Kulu, Manali, Mussoorie, Nainital, Rani-khet, Almora, Darjeeling, Mirik, Gangtok**, etc. are important tourist centres in the Himalayas.

Cultural Tourism

- The Himalayas host many Hindu and Buddhist shrines.
- **Kailas, Amarnath, Badrinath, Kedarnath, Vaishno Devi, Jwalaji, Uttarkashi, Gangotri, Yamunotri**, etc., are important places of pilgrimage.

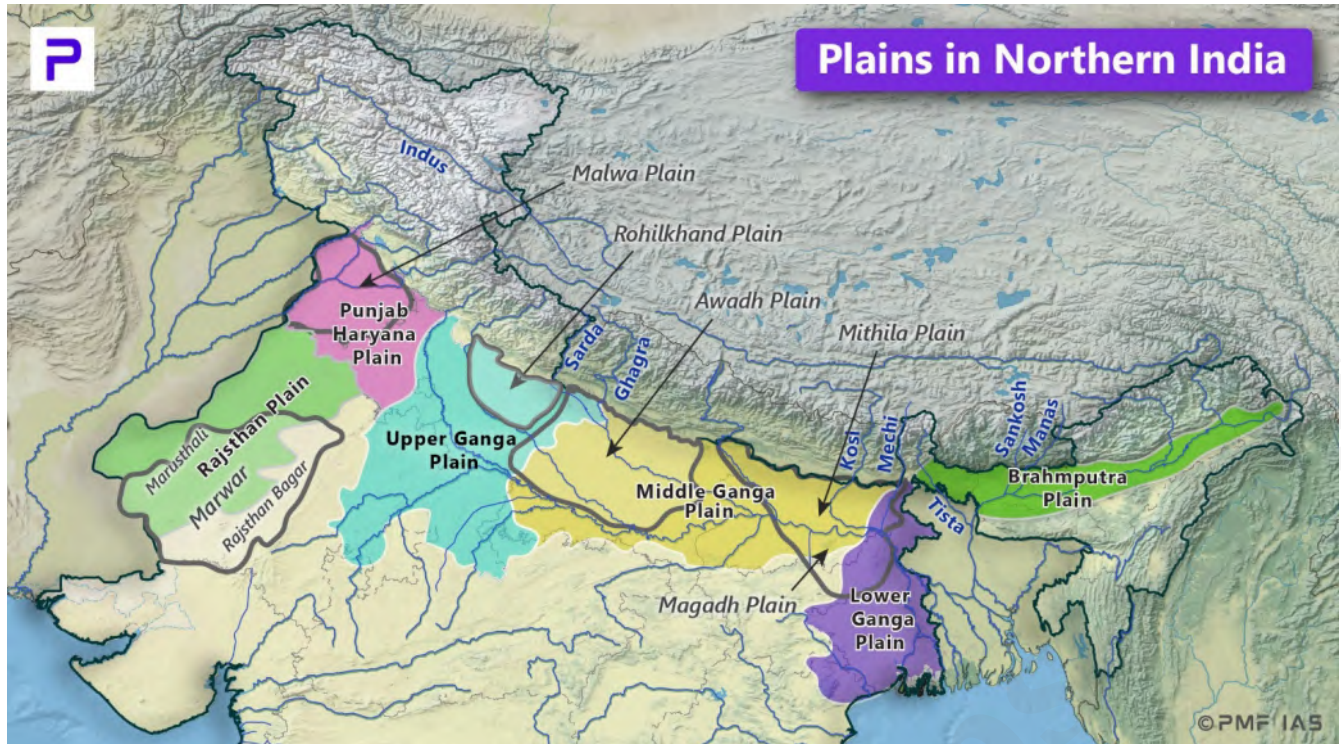
Mineral Resources in the Himalayas

- Geosynclinal (geosynclinal) deposits in tertiary rocks offer potential **coal (peat)** and oil reserves.
- Coal is found in **Kashmir**, and copper, lead, zinc, gold, silver, limestone, semi-precious, and precious stones occur in some places in the Himalayas. However, exploiting these resources requires advanced technologies that are not yet available.
- In February 2023, the Geological Survey of India (GSI) established **lithium**-inferred resources of **5.9 million tonnes** in the **Salal-Haimana area of the Reasi district** in Jammu and Kashmir (J&K). This discovery makes India the **seventh-largest source of lithium** globally.

----- End of Chapter -----

5. Indo-Gangetic-Brahmaputra Plain

- The Indo-Gangetic-Brahmaputra Plains is a **monotonous** region (featureless topography) between the Peninsular and Himalayan regions. It is also a **youthful** region prone to tectonic forces.



Features of Indo-Gangetic-Brahmaputra Plain

- The Indo-Gangetic-Brahmaputra Plain is the **world's largest alluvial tract**. It extends for about **3,200 km**, with **2,400 km** in India.
- The **Shiwaliks** bound the plain in the north, **Peninsular India** in the south, the **Sulaiman** and **Kirthar ranges** in the west, and the **Purvanchal hills** in the east.
- The plain's average width is **150-300 km**. It is **widest in the west (about 500 km)**. Its width decreases towards the east.
- The average depth of alluvial deposits in these plains ranges from **1,000-2,000 m**. The thickness of the deposits varies from place to place, with the maximum depth reaching to about **6,100 m**.
- The plain is **extremely horizontal** and has an average elevation of only about **200 m** above sea level. Its elevation peaks near **Ambala (291 m)**, forming the **watershed** between the Indus and Ganga systems.
- The average gradient from Saharanpur (Western UP) to Kolkata is only 20 cm per km, decreasing to 15 cm from Varanasi to the Ganga delta.

Physiographic Division of Indo-Gangetic-Brahmaputra Plain

- The Indo-Gangetic-Brahmaputra Plain (or **northern plains**) can be divided into the following major zones from the north to the south:

1. The Bhabar
2. The Tarai
3. The Alluvial Plains
4. The Delta Plains

The Bhabar

- The **Bhabar** is a narrow **northernmost stretch** of the Indo-Gangetic plain. It is formed by the **amalgamation of alluvial fans** formed by the Himalayan rivers.

⇒ **Alluvial fan:** *It is a fan-shaped deposit of sediment (made up of gravel, sand, and silt) that accumulates where a stream or river exits a narrow mountain valley and enters a flatter area.*

- The **Bhabar** is **only 8-10 km wide**, extending **along** the **foothills of Shiwaliks**. It displays notable continuity from the **Indus** to the **Teesta**. It is narrower in the east and more extensive in the west.
- The uniqueness of Bhabar is its **porosity**, resulting from the deposition of pebbles and rock debris on the alluvial fans. Hence, **streams tend to disappear** once they reach the Bhabar region, resulting in **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.

The Tarai (Terai)

- The **Tarai** spans about **10-20 km** in width and is situated to the **south of the Bhabar**, running parallel to it. Here, the **underground streams** from the Bhabar **re-emerge**.
- The Tarai is **more pronounced** in the **eastern part** due to **higher rainfall** than the western part.
- This **thickly forested region** provides shelter to a variety of wildlife. For example, **Jim Corbett National Park in Uttarakhand** and **Kaziranga National Park in Assam** lie in the **Tarai** region.



The Terai Marshes

- The Terai is **ill-drained** and **damp (marshy)**. The soils are silty, **rich in nitrogen** and **organic matter**, but **deficient in phosphate**.
- Most of the Terai land, especially in Punjab, UP, and Uttarakhand, has been **turned into agricultural land**, which provides good crops of **sugarcane, rice, and wheat**.

Alluvial Plains

- Alluvial plains are situated in the **south** of the **Tarai region**, and it comprises:
 1. **Bhangar (old alluvial deposits)**
 2. **Khadar (new alluvial deposits)**

- These plains exhibit **mature fluvial erosional and depositional landforms** like sandbars, meanders, ox-bow lakes, and braided channels.

The Bhangar

- The **Bhangar** is the **older alluvium** along riverbeds. It lies **above the floodplains** of the river and presents a **terrace-like feature**.
- It contains **fossils** of animals such as rhinoceroses, hippopotamuses, elephants, etc.
- The soil in Bhangar is **more clayey** and is generally **dark-coloured**. It **often contains calcareous concretions** (beds of lime nodules) known as **Kankar**.
- Regional variations of Bhangar include the **Barind plains** and the **Bhur formations**.

Barind Plains

- **Barind** lies in the **deltaic region of Bengal**, **northwest of the confluence of the upper Padma (Ganga) and Jamuna (Brahmaputra in Bangladesh) rivers**.
- It is bordered by the floodplains of the **Mahananda River** to the west and the **Karatoya River** to the east – tributaries of the upper Padma and of the Jamuna, respectively.
- Barind is a comparatively high, undulating region with reddish and yellowish clay soils. It is **cut by ravines** and is divided into separate sections by the Atrai River.

Bhur

- Bhur denotes an **elevated piece of land situated in the upper Ganga-Yamuna Doab**. It is formed by the **accumulation of wind-blown sand** during the hot, dry months of the year.

The Khadar

- The **Khadar** is composed of **newer alluvium** and **forms the flood plains** along the riverbanks.
- River floods deposit fresh alluvium annually, making these soils **very fertile**. They are **sandy clays and loams, drier, more leached, and less calcareous**.

Reh or Kollar

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

The Delta Plains

- The mouths of the mighty rivers in the region create **some of the world's largest deltas**, like the famous **Sundarbans delta**. They are **featureless plain areas** with a general elevation of **50-150 m** above the mean sea level.

Regional Division of the Indo-Gangetic-Brahmaputra Plain

- The Indo-Gangetic-Brahmaputra Plain is regionally classified into:
 1. **Sindh Plain**
 2. **Rajasthan Plain**

3. **Punjab Plain**
4. **Ganga Plain**
5. **Brahmaputra Plain**
6. **Ganga-Brahmaputra Delta**

Sindh Plain (Pakistan)

- Sindh Plain in Pakistan is mainly formed of **Bhangar Plains**. It features:
 1. **Dhors**: Long, narrow depressions representing remnants of the course of former rivers.
 2. **Dhand**: Alkaline lakes on some dhors.

Rajasthan Plain

- The Rajasthan Plain is located **west of the Aravallis**. This undulating plain has an average elevation of around 325 m.
- Although it appears as an aggradational plain, it contains outcrops of **gneisses, schists, and granites**, indicating **geological connections** to the **Peninsular Plateau**.
- West of the Aravalli Range, there is a **semi-arid plain** called **Rajasthan Bagar** and an **arid plain** called **Marwar**. Further west, there is the **Thar Desert**.
- The **Bagar** region, fed by seasonal streams from the Aravallis, sustains agriculture in some fertile areas called **rohi**.

The Thar Desert

- The **Thar Desert** (or the **Great Indian Desert**) primarily occupies the region northwest of the **Aravali hills** in the **Rajasthan Plains** region.
- It is a land of **undulating (wavey) topography** dotted with **longitudinal dunes** and **barchans**.
- This region receives low rainfall **below 150 mm per year**. Hence, it has an arid climate with low vegetation cover. It is because of these characteristic features that this is also known as **Marusthali**.
- The **Marusthali** constitutes a significant part of the **Marwar plain**. The eastern Marusthali is rocky, while the western part is covered by shifting sand dunes, called **dhrian**, locally.
- It is believed that during the Mesozoic era, this region was **under the sea**. This can be corroborated by the evidence available at the **wood fossils park at Aakal** and **marine deposits** around **Brahmsar, near Jaisalmer** (the approximate age of the wood fossils is estimated to be 180 million years).
- Though the underlying rock structure of the desert is an extension of the **Peninsular plateau**, due to extreme arid conditions, its surface features have been carved by weathering and wind actions.
- Some of the well-pronounced desert land features present here are **mushroom rocks, shifting dunes** and **oases** (mostly in its southern part).
- On the basis of the orientation, the desert can be divided into two parts — the **northern part slopes towards Sindh**, and the **southern part slopes towards the Rann of Kachchh**.

Rivers

- Most of the rivers in this region are **ephemeral (short-lived)**. Some streams disappear after flowing for some distance and present a typical case of inland drainage by joining a lake or **playa**.
- The lakes and the **playas** have **brackish water**, which is the main source of **obtaining salt**.
- The **Luni River** flowing in the southern part of the Thar Desert is of some significance. It is a seasonal stream that flows into the **Rann of Kutch**. The area north of the Luni is known as **thali** or sandy plain.

Saline Lakes

- North of the **Luni**, the region experiences **inland drainage** with numerous **saline lakes**. These lakes serve as sources of common salt and various other salts.
- **Sambhar, Didwana, Degana, Kuchaman**, etc., are some important lakes. The largest among them is the **Sambhar Lake**, which is located near Jaipur.

[UPSC 2021] With reference to India, Didwana, Kuchaman, Sargol and Khatu are the names of

- a) glaciers
- b) mangrove areas
- c) Ramsar sites
- d) saline lakes

Answer: d) saline lakes

Punjab Plain

- The name "Punjab" means "The Land of Five Waters", as it is formed by these five rivers of the Indus system: **Jhelum, Chenab, Ravi, Sutlej**, and **Beas**.
- The plain is primarily composed of **doabs**, the land areas situated between two rivers. The five doabs of the Punjab region are:
 1. **Bist Doab (Jalandhar Doab):** Between **Beas** and **Sutlej**
 2. **Bari Doab (Majha):** Between **Beas** and **Ravi**
 3. **Rechna Doab:** Between **Chenab** and **Ravi**
 4. **Jech Doab (Chaj Doab):** Between **Jhelum** and **Chenab**
 5. **Sindh Sagar Doab:** Between **Indus** and **Jhelum**
- The rivers' deposits have merged the doabs, creating a uniform appearance. The average elevation is approximately 250 m above mean sea level.
- The eastern boundary of the Punjab-Haryana plain is marked by the **Delhi-Aravali ridge**.
- In the plain's north, the Shiwalik hills have undergone **extensive erosion** by numerous streams called **Chos**, leading to enormous **gullying**.
- To the **south** of the **Sutlej River** lies the **Malwa Plain** of Punjab.
- The region between the **Ghaggar** and **Yamuna** rivers in Haryana is called the **Haryana Tract**, which serves as a **water divide** between the Yamuna and Sutlej rivers.

⇒ The **Ghaggar** is the sole river between the **Yamuna** and **Sutlej** and is believed to be the modern successor of the legendary **Saraswati River**.

Ganga Plain

- Ganga plain is the largest section of the Great Plain of India, extending from Delhi to Kolkata and covering approximately 3.75 lakh sq. km.
- The Ganga River and its Himalayan tributaries carried significant alluvium to form this vast plain. Additionally, Peninsular rivers such as **Chambal**, **Betwa**, **Ken**, **Son**, etc., which join the Ganga River system, have also contributed to the formation of this plain.
- Lower sections of Ganga flow sluggishly, creating features like **levees**, **bluffs**, **oxbow lakes**, **marshes**, and **ravines**.
- Rivers in the area often change course, leading to frequent floods. **Kosi River**, called the **Sorrow of Bihar**, is infamous for this characteristic.

Regional Divisions of Ganga Plain

Upper Ganga Plain

- It stretches up to the western UP, and it comprises:
 1. **Rohilkhand Plains**: Northern part of the Gangetic Plain; lies in UP
 2. **Ganga-Yamuna Doab**: Largest doab of India
 3. **Yamuna-Chambal Basin**: **Badlands region (Chambal Ravines)** because of gully erosions and ravines.

Middle Ganga Plain

- It covers eastern UP and Bihar, and it comprises:
 1. **Avadh Plains**: The central part of the Gangetic Plain; lies in Uttar Pradesh.
 2. **Mithila Plain**: Lies in Bihar and Nepal
 3. **Magadh Plain**: Lies in Bihar

Lower Ganga Plain

- It comprises primarily West Bengal and Bangladesh.
- The river here forms **braided channels**, lakes, marshes, and delta plains.
- It forms the famous **Sundarbans delta**, which is known for its mangrove forests.

Brahmaputra Plain

- The Brahmaputra Plain is also known as **Assam Valley** as it is predominantly situated in Assam.
- The **Eastern Himalayas** bounds it in the north, **Patkai** and **Naga Hills** in the east, the **Garo-Khasi-Jaintia** and **Mikir Hills** in the south, and the **Indo-Bangladesh border** and the **Lower Ganga Plain** in the west.
- It is primarily built up by sediment from the Brahmaputra River and its tributaries. **Majuli**, the **world's largest river island**, is formed by the Brahmaputra River.

- The Brahmaputra River and its tributaries **meander** through the plain, forming **oxbow lakes**.
- **Extensive braiding** of Brahmaputra results in many small riverine islands called **chars**.
- The region also has extensive **marshy tracts**. Coarse alluvial debris from the alluvial fans has formed terai or semi-terai conditions in this area.

Ganga-Brahmaputra Delta: Sundarbans

- Sundarbans is a **mangrove area** in the delta formed by the confluence of the **Ganges, Brahmaputra, and Meghna Rivers** in the Bay of Bengal. It is the **world's largest and fastest-growing delta**. It is a **UNESCO World Heritage Site**.
- The Sundarbans Delta gets its name from the **Sundari tree**, which thrives in marshy regions. It is also the home of the Royal Bengal tiger.
- **Sundarbans Reserve Forest (SRF) of Bangladesh** is the **largest mangrove forest in the world**.
- The seaward side of the delta is characterised by numerous **estuaries, mudflats, mangrove swamps, sandbanks, islands, and forelands**.
- The land **slope here is minimal**, measuring only 2 cm per km. Two-thirds of the area lies below 30 m above mean sea level, making it **highly vulnerable to sea level changes**.

The Significance of the Indo-Gangetic-Brahmaputra Plain

- The significance of the Great Plain lies in its profound impact on various aspects of Indian geography, economy, and culture:
 1. **High Population Density:** This **one-fourth of the country's landmass** hosts half of the Indian population, making it a densely populated region.
 2. **Agricultural Productivity:** **Fertile alluvial soils**, a flat surface, slow-moving **perennial rivers**, and a favourable climate contribute to intense agricultural activity. The extensive use of irrigation has made Punjab, Haryana, and the western part of UP the **granary of India**.

⇒ The **Prairies** are called the **granaries of the world**.

3. **Economic Development:** The extensive road and rail network across the plain, except the Thar Desert, has enabled significant industrialisation and urbanisation.
4. **Cultural and Religious Significance:** The plain hosts many religious sites significant to Hindus, Buddhists, Jains, and the Bhakti and Sufi movements.

[UPSC 2000] Assertion and Reasoning

Assertion (A): Ganga plain is the most densely populated part of India.

Reason (R): Ganga is the most harnessed river of India.

- a) Both A and R are true and R is the correct explanation of A
- b) Both A and R are true but R is not a correct explanation of A
- c) A is true but R is false
- d) A is false but R is true

Explanation

The Ganga Plain is indeed the **most densely populated region** in India. It accounts for about **one-fourth** of the country's population. This is due to various factors, including:

- ❖ **Fertile soil:** The alluvial plains formed by the Ganga River and its tributaries are highly fertile, supporting intensive agriculture and sustaining large populations.
- ❖ **Favourable climate:** The region has a warm and **humid climate**, suitable for growing a variety of crops throughout the year.
- ❖ **Historical and cultural significance:** The Ganga plain has been a centre of civilisation for centuries, leading to the development of numerous cities and towns with dense populations.
- While the Ganga River is the **most harnessed river** in India in terms of the number of dams and barrages built on it, this fact does not directly explain why the Ganga Plain is the most densely populated.
- Thus, the **high population density** in the Ganga plain is primarily due to its **fertile soil, favourable climate**, and **historical significance**, not solely because of the river's harnessing.

Answer: b) Both A and R are true but R is not a correct explanation of A

[UPSC 2011] The lower Gangetic plain is characterised by a humid climate with high temperature throughout the year. Which one among the following pairs of crops is most suitable for this region?

- a) Paddy and Cotton
- b) Wheat and Jute
- c) Paddy and Jute
- d) Wheat and Cotton

Explanation

Paddy

- Rice cultivation in India spans a wide geographic range, encompassing latitudes between **8** and **35** degrees north. It **thrives across altitudes**, from sea level to elevations reaching 3000 meters.
- Rice is ideally cultivated in regions with **hot** and **humid** climates. Optimal conditions include high humidity levels, ample sunshine, and a consistent water supply.
- The temperature range conducive to rice growth spans from 21 to 37 degrees Celsius, with the crop tolerating maximum temperatures of 40 to 42 degrees Celsius.

Jute

- **Jute** cultivation is suited to **humid tropical** climates. It flourishes in areas with **well-distributed rainfall** of around 250 cm over the vegetative growth period, devoid of prolonged cloud cover.
- Locations experiencing mean rainfall below 100 cm, **persistent rainfall**, or **waterlogging** are **unsuitable** for jute cultivation.

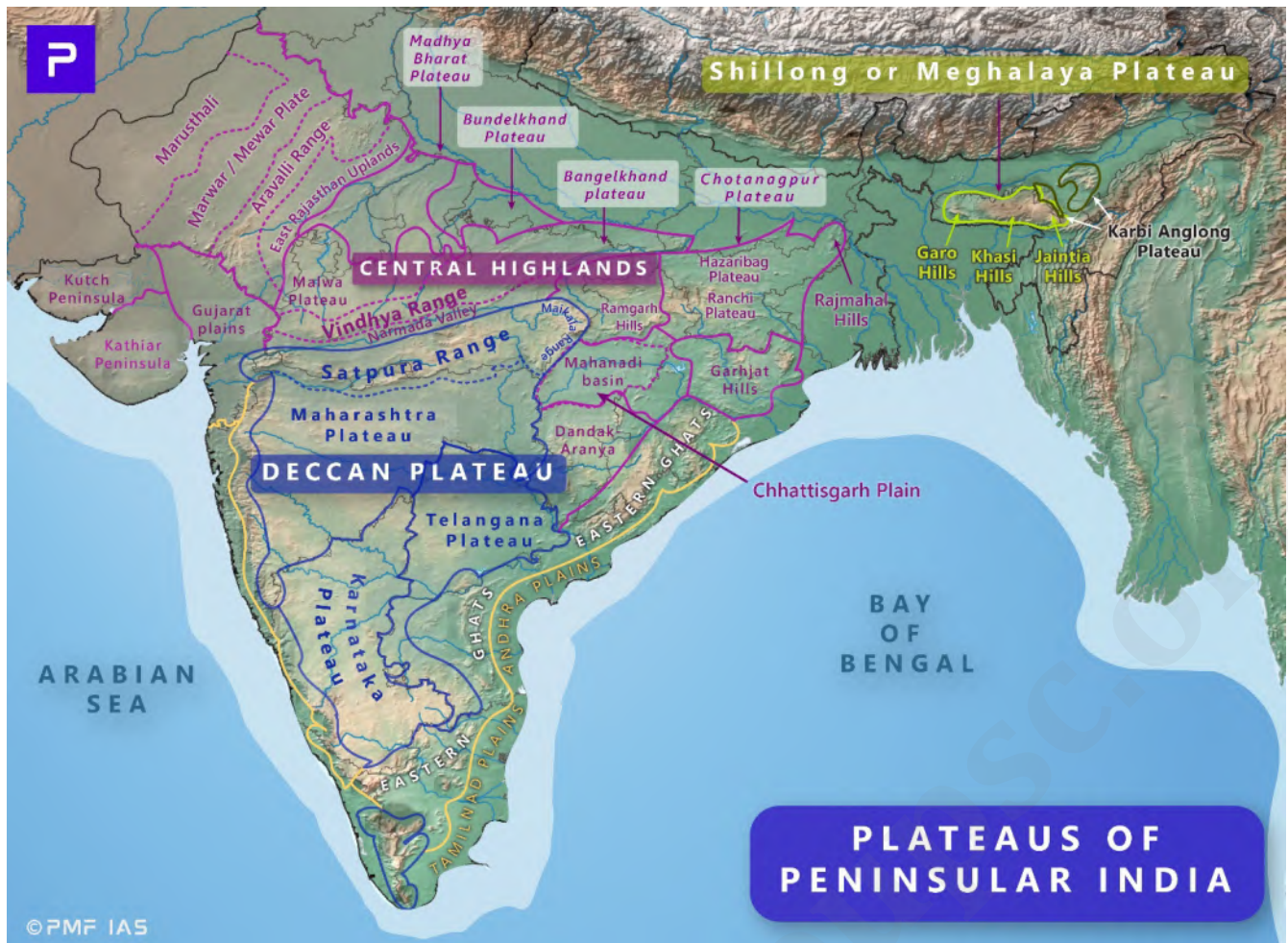
- Optimal temperature conditions range from a mean maximum of 34 degrees Celsius to a minimum of 15 degrees Celsius, with a mean relative humidity of 65%.
- Extreme temperatures outside the range of 15 to 43 degrees Celsius during the growth phase are unfavourable for jute crops.

Answer: c) Paddy and Jute

----- **End of Chapter** -----

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6. Peninsular Plateau



- South of 22° north latitude, the Indian mainland tapers off into the Indian Ocean as the peninsula. It is a tableland of **old crystalline, igneous, and metamorphic** rocks. It is mainly composed of **four billion years old Archaean gneisses and schists**.
- It is formed from the **Gondwana land breakup**, thus making it a part of the **oldest landmass** and the most **stable** landmass of India.
- The Peninsular Plateau covers around **16 lakh km²** with an average elevation of 600-900 m above sea level. It has been above sea level for millions of years, except in some areas.
- The outer extent constitutes the **Delhi Ridge** in the northwest, **Rajmahal Hills** in the east, **Gir range** in the west, and **Cardamom Hills** in the south.
- The **Karbi Anglong** and the **Meghalaya Plateau** in the northeast and **Rajasthan** in the west are also extensions of this plateau.
- Hence, the peninsular plateau includes the entire south India (**Deccan Plateau** and the **Eastern Ghats** and **Western Ghats**), **central India**, **Aravallis**, **Rajmahal hills**, **Meghalaya plateau** and the **Kutch-Kathiawar region** (Gujarat).
- Most peninsular rivers flow west to east, indicating a general slope. **Exceptions** include the **Narmada** and **Tapti**, which **flow from east to west in a rift valley**.

- The Peninsular Plateau has undergone recurrent phases of upliftment and submergence accompanied by crustal faulting and fractures. E.g. The **Bhima fault**, which experiences recurrent seismic activities.

Divisions of the Peninsular Plateau

Marwar Plateau or Mewar Plateau

- The **Marwar Plateau** is situated in **eastern Rajasthan, east of the Aravallis**. It comprises sandstone, shales, and limestones from the **Vindhyan period**. Its average elevation is 250-500 m.

⇒ The **Marwar Plain** is located **west of the Aravallis**.

- The **Banas River**, along with its tributaries such as the **Berach** and **Khari Rivers**, originates in the **Aravallis** and flows into the **Chambal River**. River erosion creates a rolling plain on the plateau.

⇒ **Rolling Plain:** They are not completely flat; there are slight undulations or rises and falls in the landform. E.g., **Prairies** of the USA

Central Highlands

- The Central Highland is also known as **Madhya Bharat Pathar** or **Madhya Bharat Plateau**. It forms the **northernmost boundary of the Deccan plateau**.
- It is located **east of the Marwar or Mewar Upland**. It is a classic example of **relict mountains**, highly denuded and forming disjointed ranges.
- It is wider in the west but narrower in the east. Its average elevation is 700 to 1000 m above sea level. A rolling landscape with rounded hills of **sandstone** characterises it.
- Most of the plateau constitutes the basin of the **Chambal River**, which flows through a **rift valley**. Kali Sindh, Banas, and Parbati are its main tributaries. To the north are the **Chambal ravines**.

Bundelkhand Upland

- This plateau, which covers UP and MP, comprises the old, dissected upland of **granite** and **gneiss**. Its average elevation is 300 to 600 meters above sea level.
- The **Yamuna River** borders Bundelkhand Plateau to the north, **Central Highlands** to the west, **Vindhyan Scarplands** to the east and southeast, and **Malwa Plateau** to the south.
- Various streams, including **Betwa** and **Ken**, flow through the plateau. The plateau is characterised by **senile topography** (indicative of old age) and **river erosion** has rendered the plateau **uneven**, making it **unfit for cultivation**.

Malwa Plateau

- The **Malwa Plateau** roughly forms a triangle based on the **Vindhyan Hills**, bounded by the **Aravalli Range** in the west, **Madhya Bharat Pathar** to the north, and **Bundelkhand** to the east.
- This rolling plateau is composed of extensive **lava flow**, covered with black soil.
- It is dissected by rivers, with the northern part marked by the **Chambal ravines**.

- It has two drainage systems – one **towards the Arabian Sea** (**Narmada, Tapti, Mahi**) and the other **towards the Bay of Bengal** (**Chambal, Betwa**, joining the Yamuna).

Baghelkhand

- Baghelkhand is located north of the **Maikal Range** and bounded by the **Son River** on the north.
- The western part comprises **limestone** and **sandstone**, while the eastern part features **granite**.
- It has **uneven topography**, with general elevation varying from 150 to 1,200 m.
- The central part of the plateau serves as a **water divide** between the **Son River system** in the north and the **Mahanadi River system** in the south.

Chotanagpur Plateau

- Chotanagpur Plateau represents the **northeastern projection** of the Indian Peninsula. It covers **Jharkhand, Chhattisgarh**, and the **Purulia** district of WB.
- It consists of a series of plateaus of different elevations. The average elevation is 700 m.
- It is primarily composed of **Gondwana rocks**. The **Gondwana coal fields** are situated here.
- Drained by numerous rivers, the plateau exhibits a **radial drainage** pattern.
- Rivers like the Damodar, Subarnarekha, North Koel, South Koel, and Barkar have developed extensive drainage basins.

Hazaribagh Plateau

- **North of the Damodar River** is the Hazaribagh plateau, with an average elevation of 600 m. This plateau features isolated hills and appears like a **penplain** due to extensive erosion.

Ranchi Plateau

- To the **south of the Damodar Valley** is the Ranchi Plateau, rising to about 600 m. The surface is mainly rolling, with **monadnocks** and conical hills interrupting the landscape.

Rajmahal Hills

- The **Rajmahal Hills** forms the **northeastern edge** of the Chotanagpur Plateau. They have been dissected into separate plateaus.
- They are predominantly made of **basalt** and covered by lava flows.
- The average elevation is 400 m, with the highest peak at 567 meters.

⇒ **Penplain:** It is a gently undulating, almost featureless plain produced by fluvial erosion during the final stage of geomorphic cycles.

⇒ **Monadnock:** An isolated hill of bedrock standing above the general level of the surrounding area.

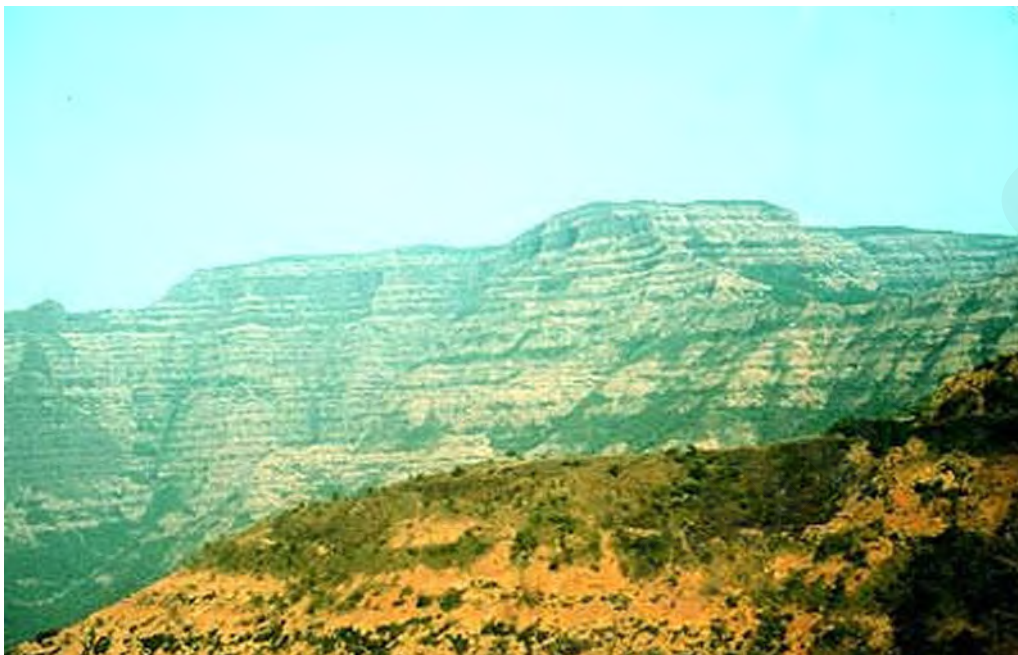
Deccan Plateau

- The Deccan Plateau, triangular in shape, is the **largest unit of the Peninsular Plateau**. Rivers have further subdivided this plateau into smaller plateaus.

- The **Satpura** and **Vindhya Ranges** border the Deccan Plateau in the northwest, the **Mahadev** and **Maikal Ranges** in the north, the **Western Ghats** in the west, and the **Eastern Ghats** in the east.
- The average elevation of the plateau is 600 m. Its general slope is from west to east, indicated by the flow of its major rivers like **Mahanadi**, **Godavari**, **Krishna**, and **Cauvery**.

Maharashtra Plateau

- The Maharashtra Plateau constitutes the northern part of the Deccan Plateau. It is mostly underlain by **basaltic rocks** originating from volcanic lava (part of the **Deccan Traps**). The horizontal lava sheets have given rise to **Deccan Trap topography** (step-like formations).
- The landscape resembles a **rolling plain** due to weathering. The broad and shallow valleys of the Godavari, Bhima, and Krishna Rivers are bordered by flat-topped, steep-sided hills and ridges.
- The entire area is covered by **black cotton soil** known as **regur**.



The step-like appearance of Deccan Traps

Karnataka Plateau or Mysore Plateau

- The Karnataka Plateau is located south of the Maharashtra Plateau. The area appears as a rolling plateau with an average elevation of 600 to 900 m.
- It is extensively dissected by numerous rivers originating from the Western Ghats.
- The plateau is divided into two regions:
 1. **Malnad** (which means hill country in Kannada) has deep valleys with dense forests.
 2. **Maidan** consists of rolling plains with low granite hills.
- The hills are generally parallel or perpendicular to the Western Ghats. The highest peak of the plateau, **Mulangiri** (1913 m), is situated in the **Baba Budan Hills** of **Chikmagalur**.
- The plateau gradually narrows between the Western Ghats and the Eastern Ghats in the south, finally merging with the Nilgiri Hills.

Telangana plateau

- The Telangana Plateau has an average elevation of 500 to 600 m. The southern part of the plateau is higher than its northern counterpart.
- The plateau features **Ghats** (hill ranges), **hillocks** and **peneplains**.
- The region is drained by three river systems — **Godavari**, **Krishna**, and **Penneru**.

Chhattisgarh Plain

- The Chhattisgarh Plain is the **only true plain** in the Peninsular Plateau. It is a saucer-shaped depression drained by the **upper Mahanadi** River.
- The entire basin is situated between the **Maikal Range** and the **Odisha hills**. The general elevation of the plain ranges from 250 to 330 m.
- **Haithavanshi Rajputs** historically ruled the region. Its name, Chhattisgarh, is derived from its **thirty-six forts**.

Meghalaya Plateau or Shillong Plateau

- **Meghalaya Plateau** is an **eastward extension** of the peninsular plateau beyond **Rajmahal Hills**.
- The **Garo-Rajmahal Gap** (or **Malda fault**) in West Bengal separates this plateau from the main block. The gap is filled with sediments deposited by the Ganga and Brahmaputra rivers.
- The eastward extension of the Meghalaya Plateau is called the **Karbi Anglong Plateau**. Its western boundary roughly coincides with the Bangladesh border.
- The western, central, and 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**, with an elevation of **1,961 m**, is the highest point on the plateau.
- Like the **Chotanagpur plateau**, the **Meghalaya plateau** is **rich in mineral resources** like coal, iron ore, sillimanite, limestone, and **uranium**.
- This area receives **maximum rainfall** from the southwest monsoon. **Mawsynram** in Meghalaya, India, is the **wettest place on the Earth**.

[UPSC 2007] Assertion and Reasoning

Assertion (A): River Kalinadi is an east-flowing river in the southern part of India.

Reason (R): The Deccan Plateau is higher along its western edge and gently slopes towards the Bay of Bengal in the east.

- Both A and R are true and R is the correct explanation of A
- Both A and R are true but R is not a correct explanation of A
- A is true but R is false
- A is false but R is true

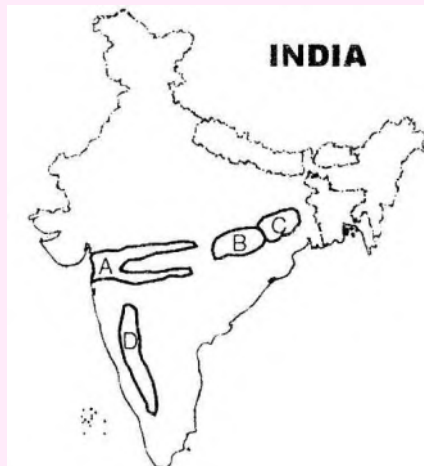
Explanation

Kaalinali

- The Kali River, also known as Kaalinadi, flows through the Uttara Kannada district of Karnataka.
- The river, spanning 184 kilometers, rises in the Western Ghats and flows into the **Arabian Sea**.

Answer: d) A is false but R is true

[UPSC 1997] Consider the map given below:



The place marked A, B, C and D in the map are respectively:

- a) Rift valley region, Chhattisgarh plain, Rain shadow region and Chota Nagpur
- b) Chhattisgarh plain, Chota Nagpur plateau, Rift valley region, and Rain shadow region
- c) Rift valley region, Chhattisgarh plain, Chota Nagpur plateau and Rain shadow region
- d) Chhattisgarh plain, Rain shadow region, Chota Nagpur plateau and Rift valley region

Explanation

- Regions such as the Rift Valley, the Chhattisgarh Plain, the Chota Nagpur Plateau, and the Rain Shadow region are notable geographical features in India.
- The Rift Valley experiences **crustal spreading**, leading to deeper erosion. Major rivers flowing through the Rift Valley include the **Narmada, Tapti**, (west-flowing), and the **Damodar** River in the **Chota Nagpur Plateau**.
- The **Chhattisgarh Plain**, characterized by vast **undulating tracts**, boasts rich rice fields and serves as a significant area for cotton and oilseed cultivation. It is also rich in coal, iron ore, bauxite, manganese, and commercial clays.
- The **Chota Nagpur Plateau** spans across Jharkhand, parts of Odisha, West Bengal, Bihar, and Chhattisgarh. It is bordered by the Indo-Gangetic plain to the north and east, and the basin of the **Mahanadi River** lies to the south.
- A rain shadow region refers to a dry area on the **leeward side of mountain ranges**. These mountains obstruct rain-producing weather systems, creating a dry "shadow" behind them.
- Notable examples include the **eastern side of the Sahyadri ranges** on the Deccan Plateau, encompassing regions like northern Karnataka, Sholapur, Beed, Osmanabad, and Vidarbha.

Answer: c) Rift valley region, Chhattisgarh plain, Chota Nagpur plateau and Rain shadow region

Hills of the Peninsular Plateau

- The hills in the peninsular region are mainly of the **relict type (residual hills)**. They are the remnants of the hills and horsts formed many million years ago. These hill ranges, along with river valleys, separate the plateaus of the Peninsular region.

⇒ **Horst:** uplifted block; **Graben:** subsided block



Aravalli Range

- The Aravalli Range stretches 800 km from **Delhi** to **Palanpur (near Ahmedabad)** in Gujarat in a north-east to south-west direction.
- The general elevation is 400-600 m, with some hills exceeding 1,000 m.
- It is among the world's **oldest fold mountains** and is the **oldest in India**.
- It extends up to Haridwar beneath the Ganga Plains' alluvium.
- Some geographers suggest its branches extend to the Lakshadweep Archipelago via the **Gulf of Khambhat** and into Andhra Pradesh and Karnataka.
- The range is **prominent in Rajasthan**, reaching up to **900 m**, but becomes **less distinct in Haryana** and **Delhi**, with detached ridges beyond Ajmer.
- Mt. Abu (1,158 m)**, a small hilly block, is separated from the main range by the **Banas Valley**. **Guru Shikhar (1,722 m)**, the highest peak of the Aravalli Range, is in **Mt. Abu**.
- Pipli Ghat, Dewair, and Desuri** passes facilitate road and railway movement.

Vindhyan Range

- The Vindhyan Range runs **parallel to the Narmada Valley** in an east-west direction from **Jobat in Gujarat** to **Sasaram in Bihar** for over 1,200 km.
- It forms a steep escarpment along the northern edge of the **Narmada-Son Trough**.
- It is predominantly composed of ancient horizontally bedded **sedimentary rocks**.
- The general elevation of the Vindhyan Range is **300 to 650 m**.
- Extending eastwards, the Vindhyas continue as the **Barner** and **Kaimur hills**.
- It serves as a **watershed, separating** the **Ganga system** from **South India's river systems**.
- The rivers like **Chambal, Betwa, and Ken** originate within 30 km of the Narmada.

Satpura Range

- The Satpura Range is a series of **seven mountains** ('Sat' = seven and 'pura' = mountains) running in an east-west direction for about 900 km.
- Situated south of the Vindhyas, it lies **between** the **Narmada** and **Tapti** rivers, roughly parallel to these water bodies.
- **Dhupgarh (1,350 m)** near **Pachmarhi on Mahadev Hills** is the highest peak in the Satpura Range.
- **Amarkantak (1,127 m)** is another significant peak in the region.

Western Ghats (or The Sahyadris)

- The Western Ghats or the **Sahyadris** form the western edge of the Deccan tableland. It rises abruptly from the Western Coastal Plain, and it slopes gently on its eastern flank.
- It stretches for 1,600 km from the **Tapti Valley** to slightly **north of Kanniyakumari**.
- The Western Ghats are steep-sided hills with a stepped topography facing the Arabian Sea coast. It has an average elevation of 900-1600 m, and it increases from north to south.
- The stepped appearance results from **horizontally bedded lavas**, creating a characteristic 'landing stair aspect' to the mountain chain's relief.
- The **Western Ghats** is a **UNESCO World Heritage site**. Along with **Sri Lanka**, it is one of the world's eight '**hottest hotspots**' of biological diversity.

The Northern Section

- It stretches from the **Tapti valley** to the **north of Goa** and comprises Deccan lavas (Deccan Traps).
- This section has an average height of 1,200 m and has notable peaks, including **Kalasuba, Salher, Mahabaleshwar, and Harishchandragarh**.
- Key passes like **Thal Ghat** and **Bhor Ghat** provide passage between the Konkan Plains and the Deccan Plateau.

⇒ **Konkan coast → Maharashtra coast and Goa coast**

⇒ **Malabar Coast → Kerala and Karnataka coast**

The Middle Sahyadri

- It extends from 16°N latitude up to the Nilgiri hills and is characterised by dense forests.
- Western scarp in this region is significantly dissected due to the **headward erosion** of streams.

- The average height is around 1200 m, and numerous peaks surpass 1500 m.
- Notable peaks include **Vavul Mala**, **Kudremukh**, and **Pushpagiri**.
- The **Nilgiri Hills** abruptly rise to over 2,000 m, **joining** the **Sahyadris** near the **tri-junction of Karnataka, Kerala, and TN**. This junction marks the **convergence** of the **Western Ghats** with the **Eastern Ghats**.
- Important peaks in this area include **Doda Betta (2,637 m)** and **Mukurti (2,554 m)**.

The Southern Section

- The southern part of the Western Ghats is separated from the main Sahyadri range by the **Palghat Gap (Palakkad Gap)**.
- The Palghat Gap serves as a **rift valley connecting** the plains of **TN** with the coastal plain of **Kerala** via roads and railway lines.
- This gap serves as a **passage for southwest monsoon clouds**, bringing rain to the Mysore region.
- **Anai Mudi (2,695 m)** is the **highest peak in southern India**. From Anai Mudi, **three ranges** radiate in different directions:
 1. The **Anaimalai** (1800-2000 m) to the north
 2. The **Palani** (900-1,200 m) to the northeast
 3. The **Cardamom Hills** or the **Ealaimalai** to the south

[UPSC 2013] There is no formation of deltas by rivers of the Western Ghats. Why?

- Compared to major delta-forming rivers like the Ganges, **Western Ghats Rivers lack** the **distance**, **time** and **sediment load** needed for extensive sediment deposition and delta formation.
- Instead of deltas, many **Western Ghats Rivers form estuaries** (funnel-shaped openings where freshwater mixes with seawater).

Steep Gradient

- The Western Ghats have a **steep gradient**, meaning the rivers descend rapidly towards the sea. This high velocity **doesn't allow them to deposit much sediment for long distances**.

Short Course

- The distance from the source to the sea is **relatively short**, further limiting the rivers' ability for sediment accumulation.

Limited Sediment

- The Western Ghats have a predominantly **rocky terrain** and **thick vegetation**, with **less easily erodible soil** compared to plains. This means there's **less sediment available** for the rivers to transport and deposit at their mouths.
- **High rainfall** and **rapid flow** further contribute to the limited sediment availability.

Strong Wave Action

- The **Arabian Sea coast**, where these rivers meet the sea, experiences **strong wave action (due to SW Monsoons)**. These waves erode and disperse any sediment deposited by the rivers, hindering delta formation.
- Thus, **sediment deposition isn't enough for delta formation**, and **estuaries become the dominant feature** at the river mouths.

Eastern Ghats

- The Eastern Ghats run parallel to India's east coast. They are often seen as separate units lacking structural unity and continuous physiography, leaving **vast plains between** their base and the coast.
- With an average elevation of 600 m, they are a chain of **fragmented hills** extending from the **Mahanadi in Odisha** to the **Vagai in TN**.
- The Eastern Ghats exhibit **true mountain character** in the northern part, **between** the **Mahanadi** and the **Godavari**. This region comprises:
 1. **Maliya Range (900-1,200 m): Mahendra Giri** is the tallest peak in this range
 2. **Madugula Konda Range (1,100-1,400 m):** The **tallest peak of the Eastern Ghats, Jindhagada Peak (1690 m)**, is here. Other peaks are **Arma Konda, Gali Konda, and Sinkram Gutta**.
- Between the Godavari and the Krishna, the Eastern Ghats **lose their hilly character** and are occupied by **Gondwana formations**.
- They reappear as a hill range in the **Cuddapah** and **Kurnool** districts of Andhra Pradesh, referred to as the **Nallamalai Range** (naxalite hideout), with a general elevation of 600-850 m.
- The southern part of this range is called the **Palkodna range**.
- To the south, the hills reach lower altitudes, with only **Javadi Hills** and **Shevroy-Kalrayan Hills** standing out at 1,000 m elevation. Further south, the Eastern Ghats merge with the Western Ghats.

[UPSC 2017] From the ecological point of view, which one of the following assumes importance in being a good link between the Eastern Ghats and the Western Ghats?

- a) Sathyamangalam Tiger Reserve
- b) Nallamala Forest
- c) Nagarhole National Park
- d) Seshachalam Biosphere Reserve

Explanation

Sathyamangalam Tiger Reserve

- **Sathyamangalam Tiger Reserve** is located at the **southern tip of the Eastern Ghats**, bordering the **Nilgiri Hills**, which form part of the **Western Ghats**.
- This unique geographical position makes it a **crucial ecological corridor** connecting the two mountain ranges.

- The Sathyamangalam forest range, as a vital wildlife corridor, connects various protected areas, including the **Biligiriranganatha Swamy Temple Wildlife Sanctuary**, **Sigur Plateau**, **Mudumalai National Park**, and **Bandipur National Park**.

Nallamala Forest

- Located in the Kurnool district of Andhra Pradesh, the **Nallamala Forest** forms **part of the larger Nagarjunasagar Srisailem Tiger Reserve** nestled within the **Eastern Ghats**.
- **Amrabad Tiger Reserve** also finds its home in the picturesque Nallamala Hills of Telangana.

Nagarhole National Park

- Situated across Kodagu and Mysore districts of Karnataka, the Nagarhole National Park, also known as **Rajiv Gandhi National Park**, forms an integral part of the **Nilgiri Biosphere Reserve** alongside **Bandipur National Park** and **Mudumalai Wildlife Sanctuary**.

Seshachalam Biosphere Reserve

- Located in the southern region of Andhra Pradesh within the **Eastern Ghats**, the Seshachalam Biosphere Reserve is famous for **Red Sanders**.

Answer: a) Sathyamangalam Tiger Reserve

[UPSC 2023] Consider the following statements:

1. Amarkantak Hills are at confluence of Vindhya and the Sahyadri Ranges.
2. Biligirirangan Hills constitute the easternmost part of Satpura Range.
3. Seshachalam Hills constitute the southernmost part of Western Ghats.

How many of the statements given above are correct?

- a) Only one
- b) Only two
- c) All three
- d) None

Explanation

Amarkantak Hills

- **Amarkantak Hills** are situated at the **meeting point** of the **Vindhya** and **Satpura Ranges** in Madhya Pradesh.
- **Amarkantak** is renowned as a **significant pilgrimage site** because it is considered the **source of** several important rivers, including the **Narmada**, **Son**, and Johila.

Biligirirangan Hills

- The **Biligirirangan Hills** are located in the **southern part of Karnataka**.
- The Biligirirangan Hills are a part of the Western Ghats mountain range and are known for their rich biodiversity, particularly as a habitat for various species of flora and fauna.

- They are also home to the **Biligiriranganatha Swamy Temple Wildlife Sanctuary**, which is a protected area.

Seshachalam Hills

- The Seshachalam Hills are situated in the southern part of Andhra Pradesh, near Tirupati. They are not the southernmost part of the Western Ghats but rather belong to the Eastern Ghats mountain range.
- The Seshachalam Hills are significant for their religious and ecological importance.
- The region is known for the **Tirumala Venkateswara Temple**, one of the most visited pilgrimage sites in India, located atop the Tirumala Hills within the Seshachalam range.
- Additionally, the hills are home to diverse wildlife and serve as an **important ecological hotspot**.

Answer: d) None

[UPSC 2008] Which of the following hills are found where the Eastern Ghats and the Western Ghats meet?

- a) Anamalai Hills
- b) Cardamom Hills
- c) Nilgiri Hills
- d) Shevaroy Hills

Explanation

Nilgiri Hills

- The **Nilgiri Hills** are a part of the **larger Western Ghats mountain range** and are located at the **junction** of the **Western Ghats** and the **Eastern Ghats** in southern India.

Anamalai Hills

- Also known as the "**Elephant Hills**," the Anamalai Hills are a mountain range located in the southern Western Ghats, spanning the border of **Kerala** and **Tamil Nadu** in southern India.
- The area is also home to several wildlife sanctuaries and national parks, such as the **Anamalai Tiger Reserve**, which supports a variety of endangered species like the **Bengal tiger**, **Asian elephant**, and **Nilgiri Tahr (EN)**.

Cardamom Hills

- The Cardamom Hills, also known as the **Yela Mala**, are part of the southern Western Ghats in the Indian states of Kerala and Tamil Nadu.
- The hills are characterised by rolling terrain covered with dense forests, primarily consisting of **tropical evergreen** and **moist deciduous vegetation**.
- The Cardamom Hills are famous for the **cultivation of spices**, particularly **cardamom**. Other spices such as black pepper, cloves, and cinnamon are also cultivated here.
- Several protected areas are located within the Cardamom Hills, including the **Periyar Tiger Reserve** and the **Silent Valley National Park**, which are important biodiversity hotspots.

Shevroy Hills

- The Shevaroy Hills, also known as the **Servarayan Hills**, are situated in the **Eastern Ghats** of Tamil Nadu, India.
- The highest peak in the Shevaroy Hills is **Shevaroyan Temple Peak**, which rises to an elevation of about 1,623 meters.
- **Yercaud**, a hill station nestled in the Shevaroy Hills, is a well-known tourist spot with attractions like the **Yercaud Lake**, **Anna Park**, and **Killiyur Falls**.

Answer: c) Nilgiri Hills

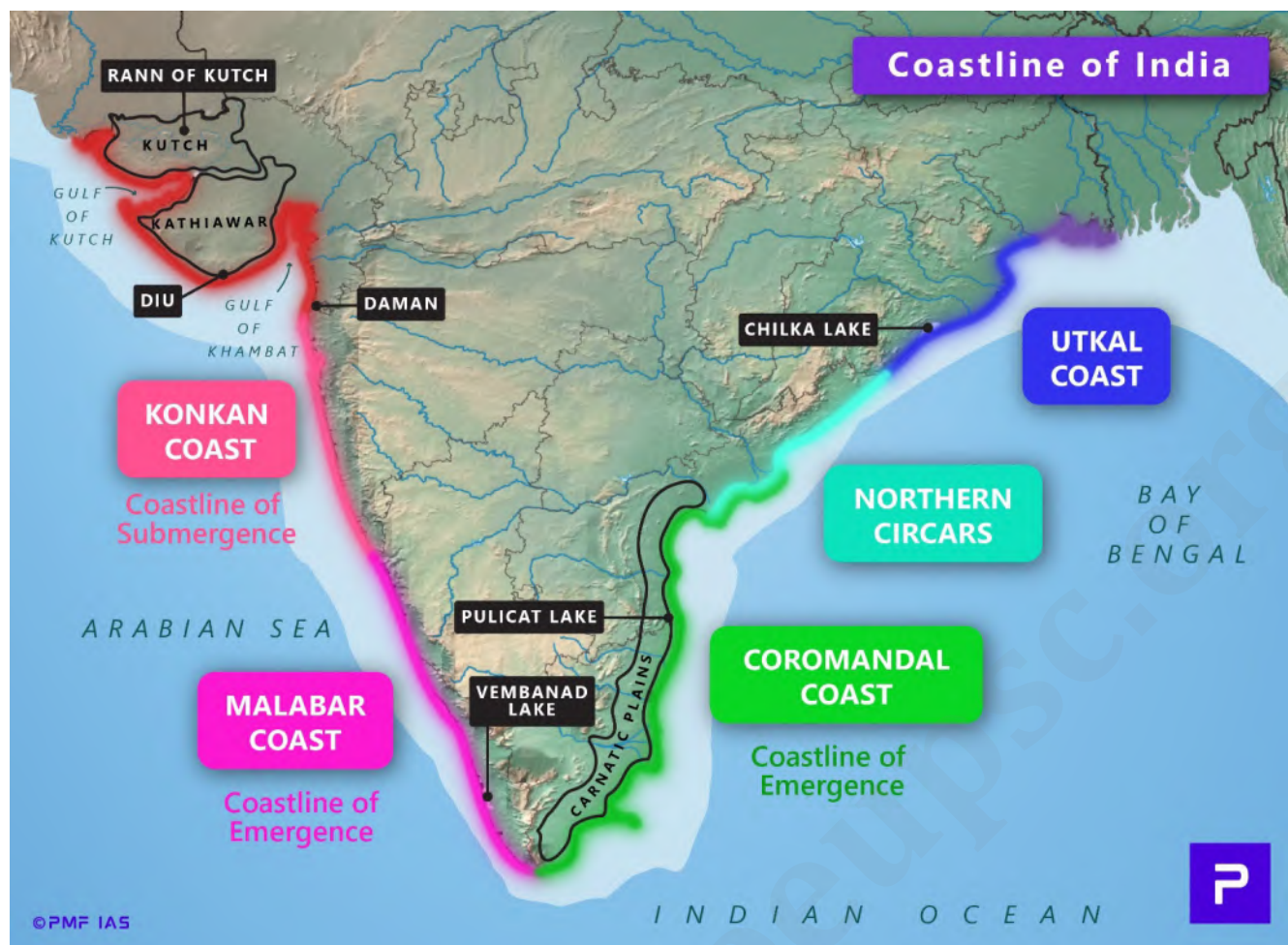
The Significance of the Peninsular Plateau

- **Primary Mineral Deposits:** The plateau is rich in minerals like iron, manganese, copper, bauxite, chromium, mica, and gold. It has **98%** of India's **Gondwana coal** deposits.
- **Diverse Geological Reserves:** The plateau also contains substantial reserves of slate, shale, sandstones, marbles, and other valuable geological resources.
- **Agricultural Potential:**
 - ❖ The north-western plateau has fertile **black lava soil** ideal for cultivating crops like **cotton**.
 - ❖ Certain **hilly areas** are suitable for growing **plantation crops** like tea, coffee, and rubber.
 - ❖ **Low-lying regions** support **rice cultivation**.
- **Forest Resources:** Plateau highlands have diverse forests, providing a range of forest products.
- **Hydroelectric and Irrigation Opportunities:** Rivers from the Western Ghats offer opportunities for hydroelectricity and irrigation for crops.
- **Tourist Attractions:** The plateau boasts hill resorts like **Udagamangalam (Ooty)**, **Panchmarhi**, **Kodaikanal**, **Mahabaleshwar**, **Khandala**, **Matheran**, and **Mt. Abu**.

----- End of Chapter -----

7. Coastline, Coastal Plains, and Indian Islands

Coastline of India



Length of India's Coastline		
State (9) / UT (4)		Length (in km)
1	Andaman and Nicobar Islands	1962
2	Gujarat	1214.7
3	Andhra Pradesh	973.7
4	Tamil Nadu	906.9
5	Maharashtra	652.6
6	Kerala	569.7
7	Odisha	476.4
8	Karnataka	280
9	Goa	118
10	West Bengal	157.5
11	Lakshadweep Islands	132
12	Puducherry	30.6

13	Dadra-Nagar Haveli & Daman-Diu	42.5
Mainland Coastline		5422.6
Islands Coastline		2094
Total Coastline		7516.6

- India's **straight coastline** was formed from **Gondwanaland faulting** during the **Cretaceous period**.
- Despite its length, the Indian coast **does not provide many sites for good natural harbours**.

- ⇒ The **indented coastlines** provide **sheltered inlets, creeks** and **estuaries** where constructing a port and maintaining it becomes **easy** and **economical**.
- ⇒ **Indented coastlines of Europe** provide **good natural harbours**, whereas **African** and **Indian** coastlines are **not indented**.



Aerial view of Port of Rotterdam, the largest seaport in Europe

Coastlines of Emergence and Submergence

- The Indian coastline can be categorised into two types: Coastline of Emergence and Submergence.

Coastline of Emergence

- It is formed due to the **uplift of land** or **lowering of the sea level**. For example, the **Coromandel coast (TN coast)** and the **Malabar coast (Kerala Coast)**.
- Its typical features are **bars, spits, lagoons**, salt marshes, beaches, sea cliffs, and arches.

Coastline of Submergence

- It is formed due to the **subsidence of land** or the **rise of the sea level**. E.g., parts of **Konkan Coast (Maharashtra and Goa Coast)**.

Coastal Plains of India

- Based on the location and active geomorphological processes, coastal plains can be divided into:

1. Eastern Coastal Plains
 2. Western Coastal Plains
- The coastal plains are formed due to the consolidation of sediments brought by rivers (fluvial deposits). They are highly **stable**, just like the peninsular plateau.

Western Coastal Plains of India

- They stretch from **Rann of Kachchh** to **Kanyakumari**. With an average width of 65 km, these plains are **narrow in the middle** and broader towards the north and south.
- The rivers flowing through this coastal plain **do not form any delta**.
- The western coastal plains are an example of a **submerged coastal plain**. Due to its submergence, it is a **narrow belt** and **provides natural conditions for developing ports and harbours**.
- **Kandla, Mazagaon, JLN Port Nava Sheva, Marmagao, Mangalore, Cochin**, etc., are some of the important **natural ports** located along the West Coast.

Kutch and Kathiawar Region

- Kutch and Kathiawar, extensions of the Peninsular plateau in Gujarat, are integral to the Western Coastal Plains due to their **flat terrain**.
- In the past, the Kutch Peninsula was an island surrounded by seas and lagoons. It changed as sediment brought by the **Indus River** filled these water bodies. The lack of recent rainfall has transformed the landscape into an **arid** and **semi-arid** environment.
- Key features of the region include:
 - ❖ **Great Rann and Little Rann**: The **salt-soaked plain** north of Kutch is the Great Rann, while its southern continuation, the Little Rann, lies southeast of Kachchh.
 - ❖ **Kathiawar Peninsula**: South of Kachchh, the Kathiawar Peninsula features the **Mandav Hills**, with radial drainage). Volcanic origin **Mt Girnar (1,117 m)** is the highest point of Gujarat.
 - ❖ **Gir Range**: Located in the southern Kathiawar Peninsula, it is renowned for the **Gir lion**.

Gujarat Plain

- The Gujarat Plain is situated **east of Kachchh and Kathiawar**. **Shaped by the rivers Narmada, Tapi, Mahi, and Sabarmati**, this plain covers southern Gujarat and the coastal areas of the **Gulf of Khambhat**.
- While the eastern part is fertile, most coastal areas are covered by **windblown loess**, resulting in a semi-arid landscape.

Konkan Plain

- The Konkan Plain, located south of the Gujarat Plain, **stretches from Daman to Goa**.
- This coastal plain, which exhibits marine erosional features, covers **Maharashtra and Goa**.
- **Thane Creek** around Mumbai is a significant embayment (a recess in a coastline forming a bay) and serves as an **excellent natural harbour**.

Karnataka Coastal Plain

- It extends from **Goa to Mangalore**. Marine topography is very marked along this coast.
- In some places, Western Ghats streams cascade down steep slopes, forming **waterfalls**. One notable example is the **Sharavati River**, which forms the **Gersoppa (Jog) Falls**.

Kerala (Malabar) Plain

- The Kerala Plain extends from **Mangalore to Kanyakumari**. It is wider than the Karnataka Plain and is characterised by its low-lying terrain.
- A distinctive feature of the Kerala coast is the presence of **lakes, lagoons, backwaters, and spits**.
- **Kayals or backwaters** are shallow lagoons or inlets of the sea that run parallel to the coastline. The largest among these is **Vembanad Lake**, which is about 75 km long and 5-10 km wide.
- The famous **Nehru Trophy Vallamkali** (boat race) is annually held in **Punnamada Kayal (Punnamada Lake)**, a southern extension of the **Vembanad Lake** in Kerala.

Eastern Coastal Plains of India

- The Eastern Coastal Plains of India stretch from the **Subarnarekha River** along the WB-Odisha border to **Kanyakumari**.
- This plain is known as the **Northern Circars** between the **Mahanadi** and the **Krishna** rivers and as **Carnatic** between the **Krishna** and the **Cauvery** rivers.
- Much of the eastern plains result from **alluvial deposits** in the littoral zone by rivers like **Mahanadi, Godavari, Krishna, and Cauvery**, forming **large deltas**.
- In contrast to the western plains, the eastern plains are **extensive**, with an average width of 120 km.
- Unlike the west coast, the east coast has **very few natural harbours**. The eastern coastal plain is an **emergent coast** with an **extensive continental shelf** that extends **up to 500 km into the sea**. Hence, the sea here is not sufficiently deep, **posing challenges for port development**.

Utkal Plain

- The Utkal Plain comprises the coastal areas of **Odisha** and includes the **Mahanadi Delta**.
- A notable feature of this plain is the **Chilka Lake**, the **largest brackish water lake** in India.
- South of Chilka Lake, the Utkal Plain has low hills.

Andhra Plain

- The Andhra Plain is situated south of the **Utkal Plain** and extends to **Pulicat Lake**. Pulicat Lake is blocked by **Sriharikota Island**, which is used as an ISRO launch site.
- The key feature of this plain is the **delta** formed by the **Godavari** and **Krishna** rivers. The two deltas have merged and formed a single physiographic unit.
- Recently, the combined delta moved toward the sea, shifting **Kolleru Lake** from a **coastal lagoon** to an **inland position**.
- The Andhra Plain coast is straight and **lacks good harbours**, except for **Vishakhapatnam** and **Machilipatnam**.

Tamil Nadu Plain

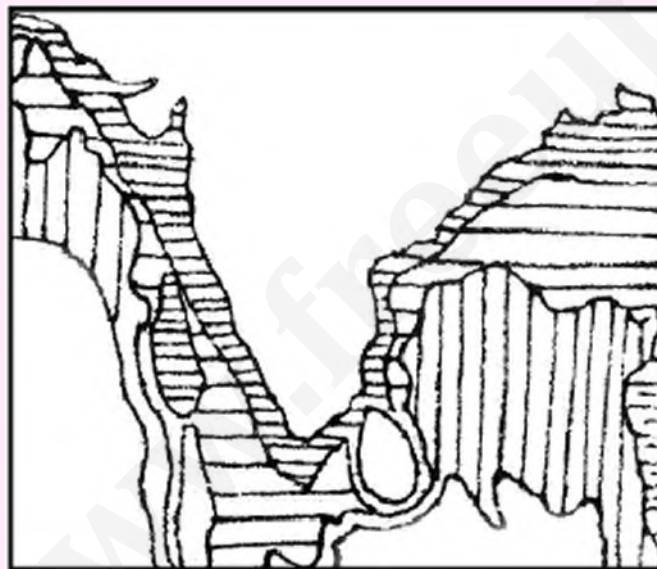
- Tamil Nadu Plain extends from **Pulicat Lake to Kanyakumari** with an average width of 100 km.
- Its most significant feature is the **Cauvery Delta**, where the plain widens to 130 km.
- The fertile soil and ample irrigation in the Cauvery delta have made it **South India's granary**.

⇒ **Coromandel Coast or Payan Ghat:** The combined region of the **Tamil Nadu Coast** and **parts of the Andhra Coast**.

The Significance of the Coastal Plains

- ✓ **Fertile Soil for Agriculture:** Rice is a major crop grown in these areas. Coconut trees thrive along the coastline.
- ✓ **Mineral Oil Deposits:** Sedimentary rocks in these plains are believed to contain substantial deposits of mineral oil.
- ✓ **Monazite Reserves:** The **sands along the Kerala** coast contain significant quantities of **monazite**, a material used in **nuclear power**.
- ✓ **Salt Production:** Low-lying areas in Gujarat are famous for salt production.
- ✓ **Tourist Destinations:** Beaches and backwaters are significant tourist attractions.
- ✓ **Ports for Trade**
- ✓ **Fishing Industry**

[UPSC 1995] Consider the map given below:



The division along India's coastal region indicate:

- a) coastal pollution zones
- b) salinity density isopleths
- c) the areas upto which Indian sovereignty extends
- d) underwater relief contours

Explanation

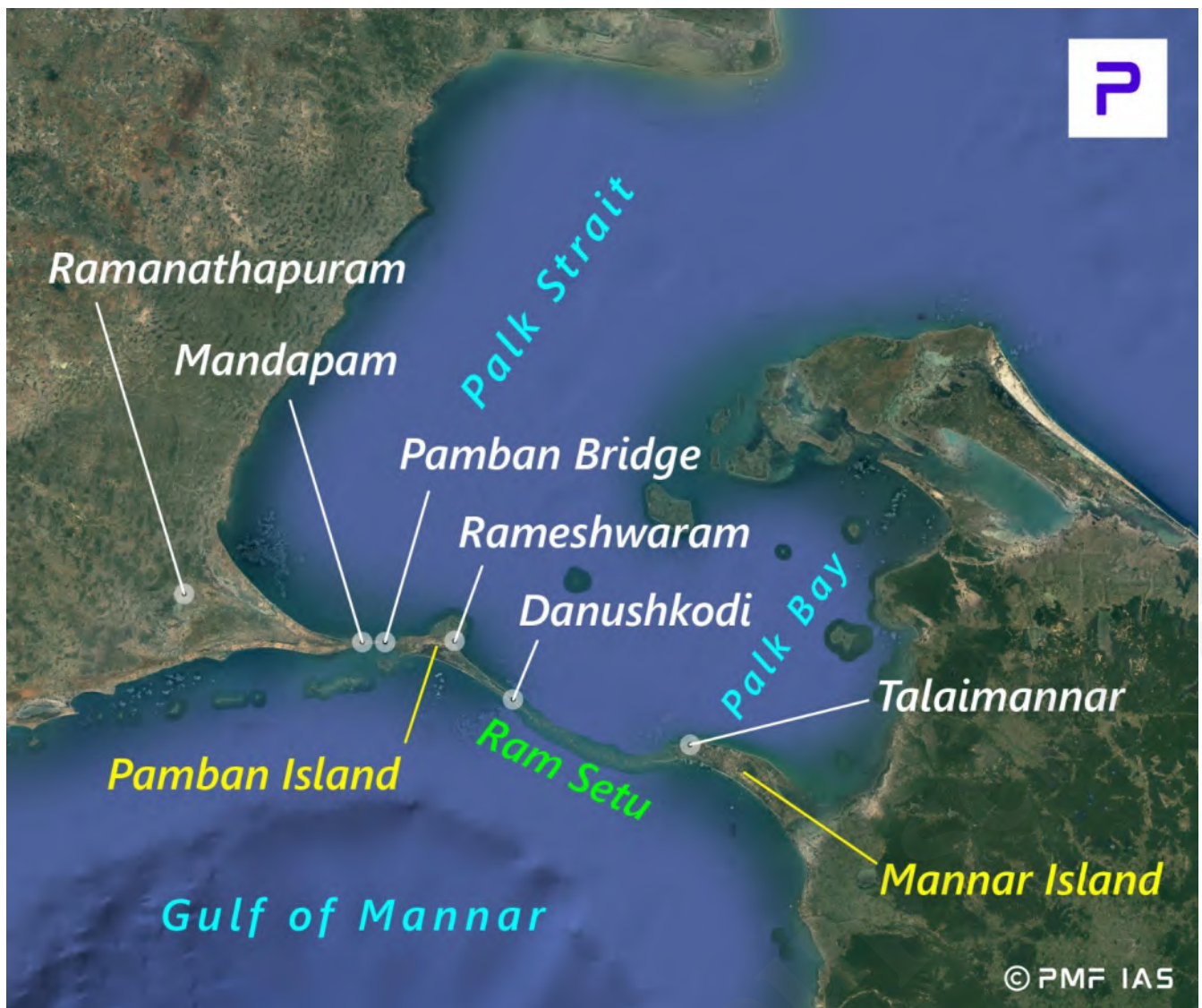
- The map depicts the **underwater topography of India's coastal region**, showcasing the different depths and shapes of the seafloor using contour lines.
- These **lines connect points of equal depth**, providing valuable information about the underwater landscape.
- Understanding underwater topography is crucial for various purposes. For example, knowledge of submarine features helps in determining safe routes for shipping and fishing activities, locating suitable sites for offshore oil and gas exploration, and studying ocean currents and habitats.

Answer: d) underwater relief contours

Indian Islands



- There are two major groups of islands in India:
 1. **Lakshadweep (coral islands):** Lakshadweep (part of the **Reunion Hotspot Volcanic chain**) is a group of atolls occupied by **coral reefs**. There has been **no significant volcanism or tectonic activity** in the recent past. The islands are highly vulnerable to rising sea levels.
 2. **Andaman and Nicobar Islands (tectonic islands):** Andaman and Nicobar Islands are continuations of **Arakan Yoma**. The islands have volcanoes (**Barren Island is the only active volcano**) and are tectonically active.
- Apart from these two groups, there are **islands in the Indo-Gangetic Delta**, which are integral parts of the delta. Additionally, there are islands between India and Sri Lanka, known as **Remnants of Rama Setu** or Adams Bridge, formed by submergence.



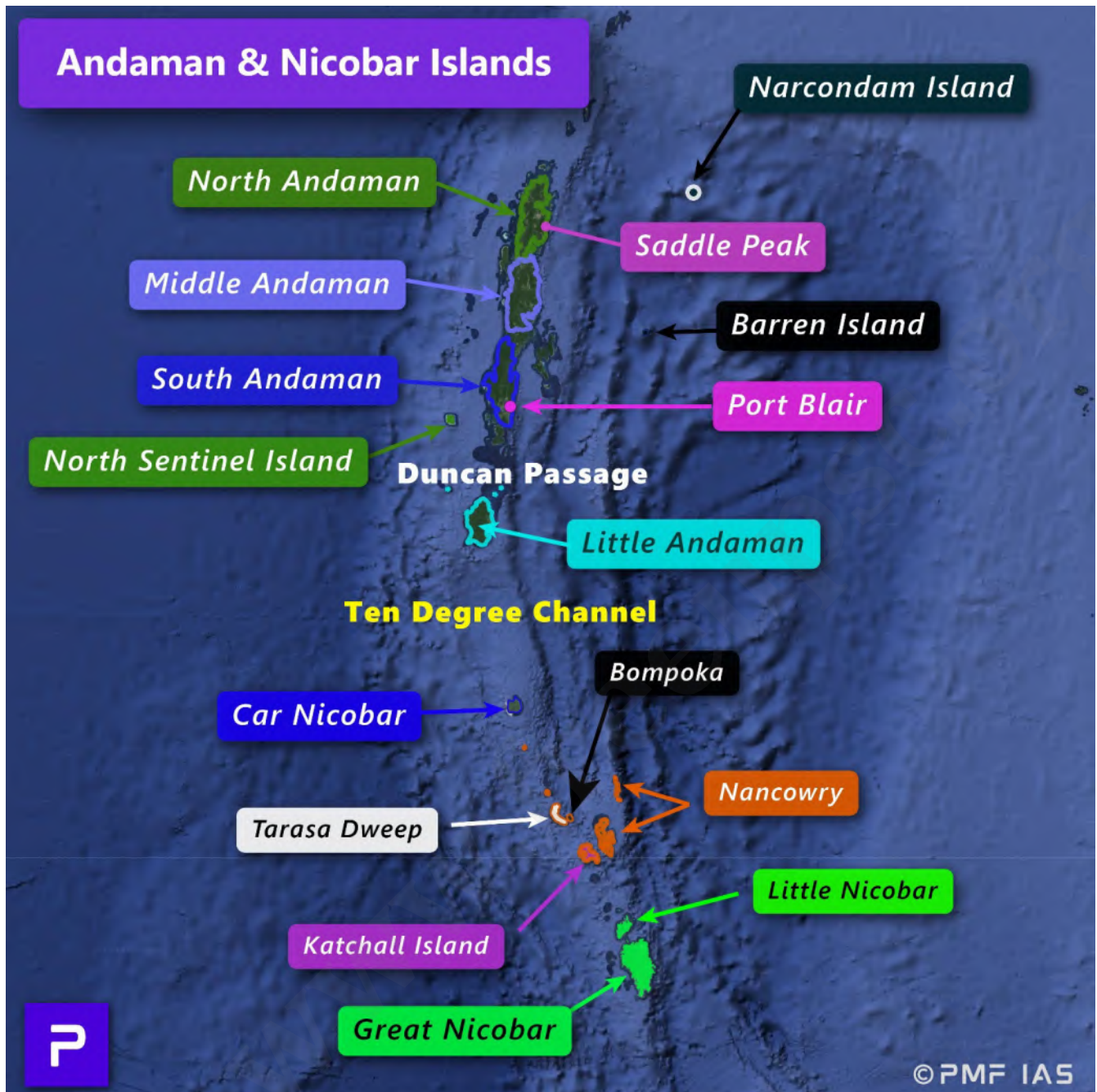
Andaman and Nicobar Islands (A&N Islands)

- The A&N Islands formed due to the **collision** between the **Indian Plate** and the **Burma Minor Plate**, part of the Eurasian Plate in the Bay of Bengal.
- These islands represent a southward extension of the **Arakan Yoma range** in Myanmar, which is an extension of the **Purvanchal Hills**.
- The A&N Islands extends from 6°45'N to 13°45'N and from 92°10'E to 94° 5'E, spanning 590 km. They are divided into two broad categories:
 1. The Andaman (in the north)
 2. The Nicobar (in the south)
- The **10° Channel** separates the **Andaman** group from the **Nicobar** group.
- These islands receive **convectonal rainfall** and have an **equatorial type of vegetation**.

Andaman Islands

- Andaman is a closely-knit group of about 200 islands. It is broadly divided into two categories:
 1. **Great Andaman** — **North, Middle, and South**
 2. **Little Andaman**

- The Little Andaman is separated from South Andaman by the **Duncan Passage**.
- The capital, **Port Blair**, is situated in **South Andaman**.
- **Saddle Peak (737 m)** in **North Andaman** is the highest peak in the archipelago.
- The volcanic islands include **Barren Island (the only active volcano in India)** and **Narcondam Islands (an extinct or dormant volcano)**.
- The islands are primarily composed of tertiary sandstone, limestone, and shale. The coastal line has some coral deposits.



Nicobar Island

- Nicobar group consists of 7 big and several small islands. **Car Nicobar** is the **northernmost**. **Great Nicobar** is the largest and southernmost, lying close to **Sumatra Island** of Indonesia.

[UPSC 2014] Which one of the following pairs of islands is separated from each other by the 'Ten Degree Channel'?

- a) Andaman and Nicobar
- b) Nicobar and Sumatra
- c) Maldives and Lakshadweep
- d) Sumatra and Java

Explanation

- The Andaman Islands and the Nicobar Islands are situated in the southeastern part of the Bay of Bengal, forming a chain of islands that extends from north to south.
- The **Ten Degree Channel** acts as a **natural maritime boundary** between these two island groups.
- The channel is a narrow stretch of water **approximately ten degrees latitude north** of the equator, hence its name.

Answer: a) Andaman and Nicobar

[UPSC 2018] Consider the following statements:

1. The Barren Island volcano is an active volcano located in the Indian Territory.
2. Barren Island lies about 140 km east of Great Nicobar.
3. The last time the Barren Island volcano erupted was in 1991, and it has remained inactive since then.

Which of the statements given above is/are correct?

- a) 1 only
- b) 2 and 3
- c) 3 only
- d) 1 and 3

Explanation

- **Barren Island**, situated in the **Andaman Sea**, holds a unique distinction as the **only confirmed active volcano in the Indian subcontinent**.
- It stands as a **solitary sentinel of volcanic activity** along a chain of volcanoes extending from **Sumatra** in Indonesia to Myanmar.
- Located approximately **138 km (86 mi) northeast of Port Blair**, the capital of the Indian Union territory of Andaman and Nicobar Islands, Barren Island is a remote and rugged volcanic outpost.
- The volcanic activity on Barren Island has been documented since the late 18th century. The last major eruption occurred in 2017, followed by intermittent volcanic activity.

Answer: a) 1 only

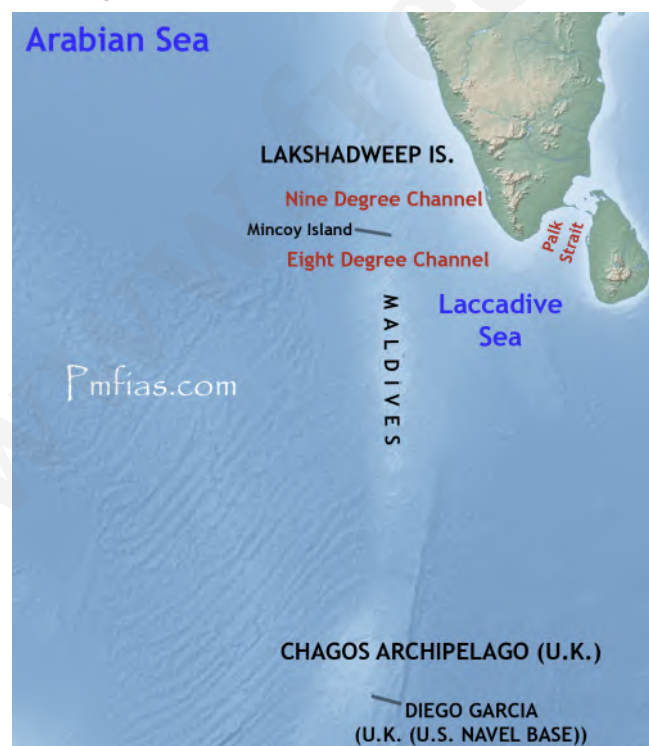
Lakshadweep Islands

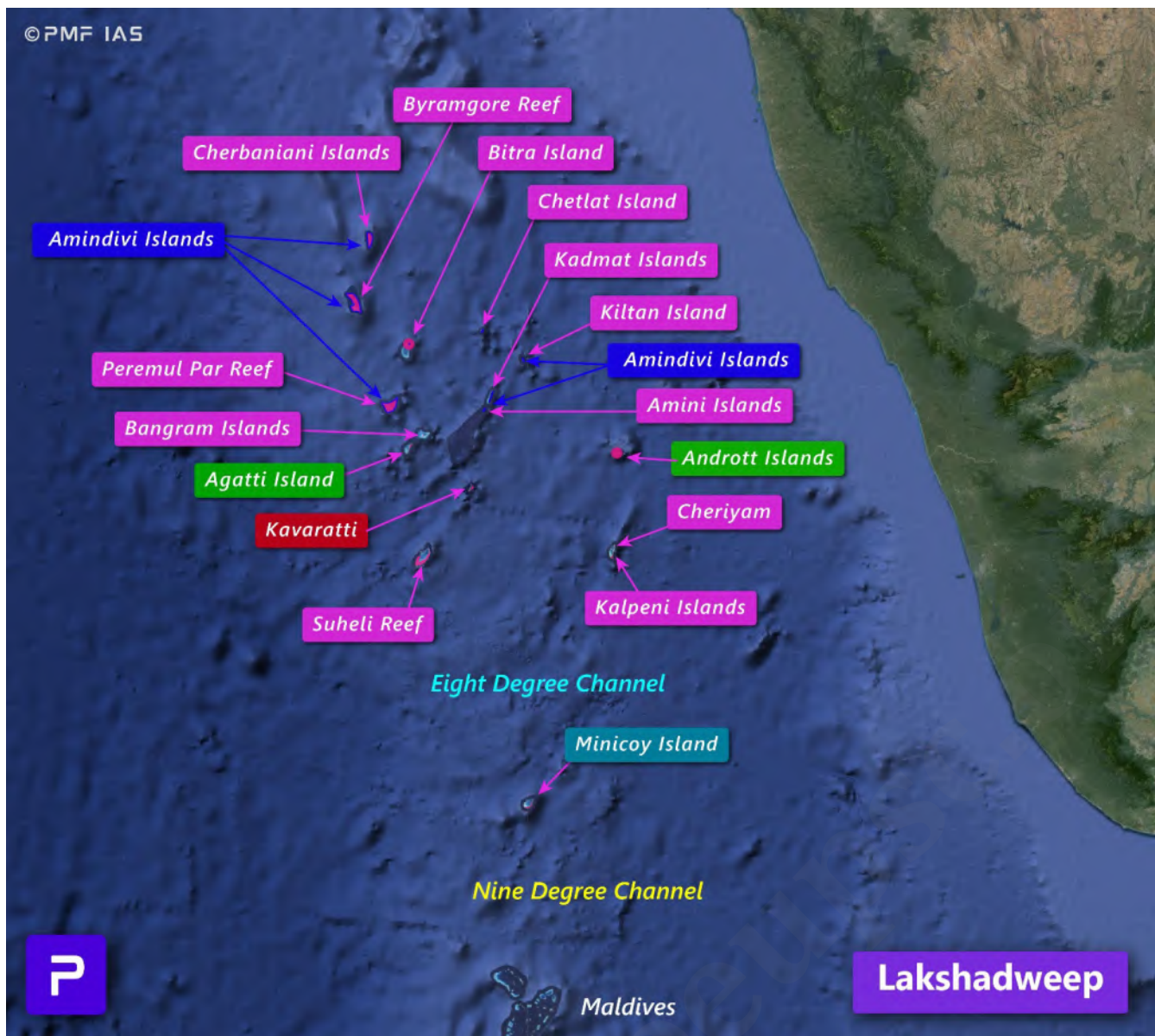
- In Malayalam and Sanskrit, the name Lakshadweep translates to **a hundred thousand islands**.

- The Lakshadweep Islands are **coral islands** situated in the Arabian Sea. They are a group of 36 islands extending **between 8°N and 12°N latitude**. They are located 280 km to 480 km off the Kerala coast.
- The Lakshadweep is a uni-district UT and the **smallest UT in India**.
- The main islands under the Lakshadweep Islands group are:
 1. **Kavaratti** (capital; lies 360Km off the coast of the State of Kerala)
 2. **Agatti** (the only Airport of Lakshadweep is located on this island)
 3. **Minicoy** (4.80 sq km; second largest; southernmost)
 4. **Aminidivi** (northernmost)
 5. **Andrott** (4.90 sq km; largest among the Lakshadweep Islands)
- These islands were earlier known as **Laccadive, Minicoy, and Amindivi Islands**. In **1973**, these were collectively named as Lakshadweep.
 - ❖ **Amindivi Islands:** consists of six main islands.
 - ❖ **Laccadive Islands:** consists of five major islands; **Kalpeni** and **Kavaratti** are the major ones).
 - ❖ **Minicoy Island:** the **southernmost island of Lakshadweep**.
- These islands are a part of **Reunion Hotspot volcanism**. They have storm beaches consisting of unconsolidated pebbles, shingles, cobbles, and boulders.
- The topography of these islands is flat, lacking relief features such as hills, streams, and valleys. They typically have low elevations, with most not rising <5 m above sea level, making them highly **vulnerable to changes in sea level**.

Important Channels

- ❖ **11° channel:** Separates **Aminidivi Islands (north)** from **Canannore Island (south)**.
- ❖ **9° channel:** Separates main **Lakshadweep (north)** from **Minicoy Island (south)**.
- ❖ **8° channel:** Separates **Minicoy Island (north)** from **Maldives (south)**.





Other Islands

New Moore Island

- New Moore Island is a small, **uninhabited offshore sandbar landform** situated in the **Bay of Bengal**, off the coast of the **Ganges-Brahmaputra Delta region**.
- It initially emerged in the aftermath of the **Bhola cyclone** in 1970. It tends to **appear** and **disappear** intermittently.
- Although the island was uninhabited, 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.

Sagar Island

- **Sagar Island** is situated in the **Ganges delta** and lies on the continental shelf of the Bay of Bengal.
- It lies at the mouth of the **Hooghly River**, with an arm of the river separating it from the mainland.

- It is best known for **Ganga Sagar Mela**, one of the largest agglomerates after Kumbh Mela.

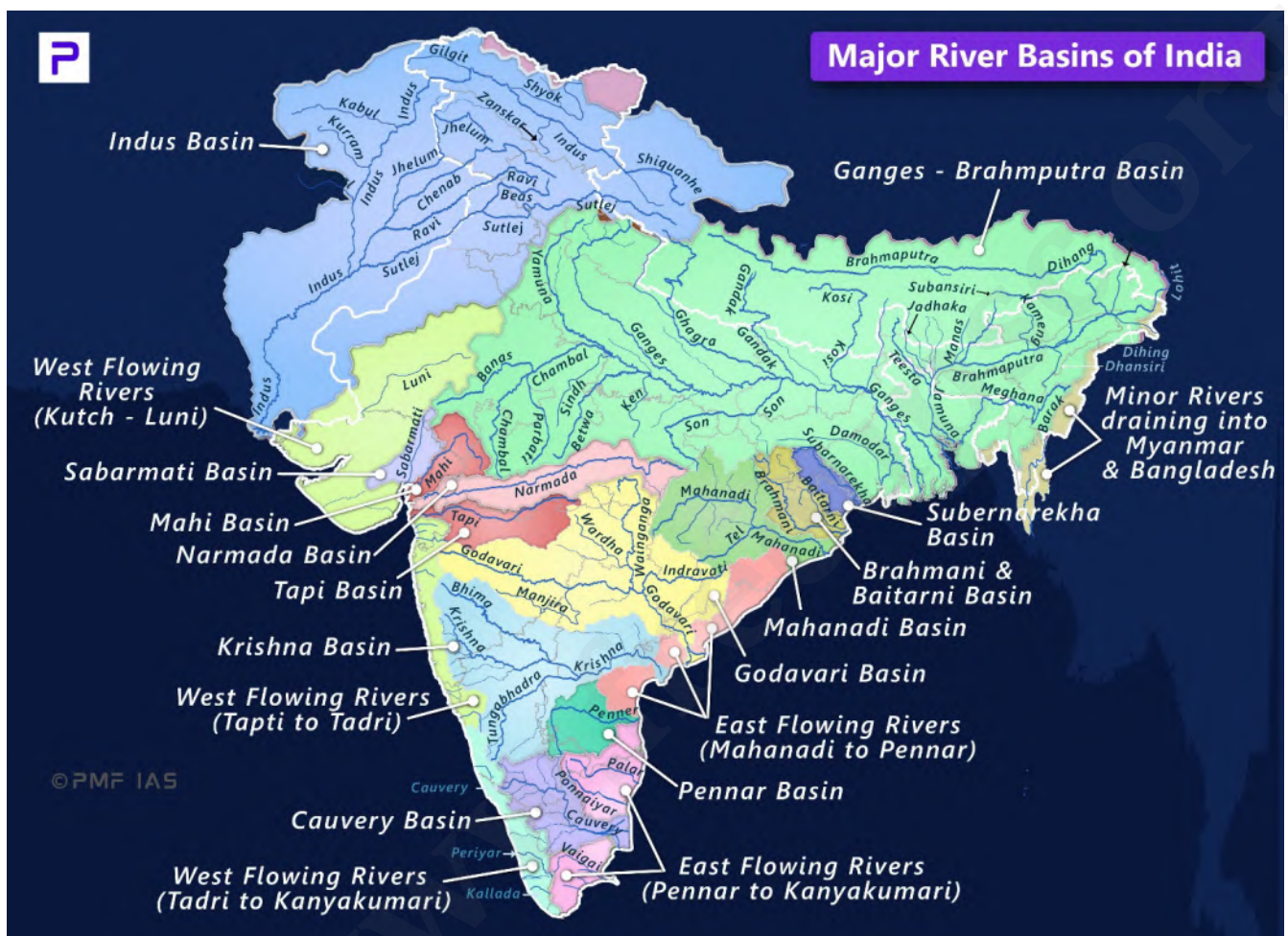
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8. Indian Rivers, Water Disputes and River Interlinking

- A river drains the water collected from a specific area, which is called its '**catchment area**'.
- An area drained by a river and its tributaries is called a **drainage basin**.
- The flow of water through well-defined channels is known as **drainage**. The network of such channels is called a **drainage system**. Such systems give rise to various **drainage patterns**.
- The boundary line separating one drainage basin from the other is known as the **drainage divide**.
- The catchments of large rivers are called **river basins**, while those of small rivulets and rills are often referred to as **watersheds**. The watersheds are small in area, while the basins cover larger areas.

For more detailed information, refer to [PMF IAS Physical Geography](#) > **Fluvial Landforms and Cycle of Erosion** > **Drainage Basin | Drainage Systems (Drainage Patterns)**



Classification of the Indian Drainage System

Based on Discharge of Water (Orientations to the Sea)

- Based on the discharge of water (orientations to the sea), Indian drainage is grouped into:
 1. **The Arabian Sea drainage (West flowing rivers):** 23% of India's drainage, including the **Indus, Narmada, Tapi, Mahi, Sabarmati** and **Periyar** systems, flows towards the Arabian Sea.

2. **The Bay of Bengal drainage (East flowing rivers): 77%** of India's drainage, including **Ganga, Brahmaputra, Mahanadi, Krishna**, etc. flows towards the Bay of Bengal

- Both river groups are separated from each other by **Delhi Ridge, Aravallis**, and **Western Ghats**.



Why the Bay of Bengal receives more fresh water compared to the Arabian Sea?

- ✓ The Arabian Sea drainage receives **less rainfall**. On the other hand, the Bay of Bengal drainage receives rainfall from **both southwest and northeast monsoons**.
- ✓ Most of the **Himalayan waters** flow into the Bay of Bengal in the form of the Ganga-Brahmaputra River system. Moreover, all the major rivers of the **peninsular region** drain into the Bay of Bengal.
- ✓ More **cyclonic rainfall** occurs in the Bay of Bengal drainage area.

Based on the Size of the Watershed

- Based on the size of the watershed, India's drainage basins are grouped into:
 - Major river basins with > 20,000 km² of catchment area:** It includes **14 drainage basins** such as Ganga, Brahmaputra, Krishna, Tapi, Narmada, **Mahi, Pennar, Sabarmati, Barak**, etc.

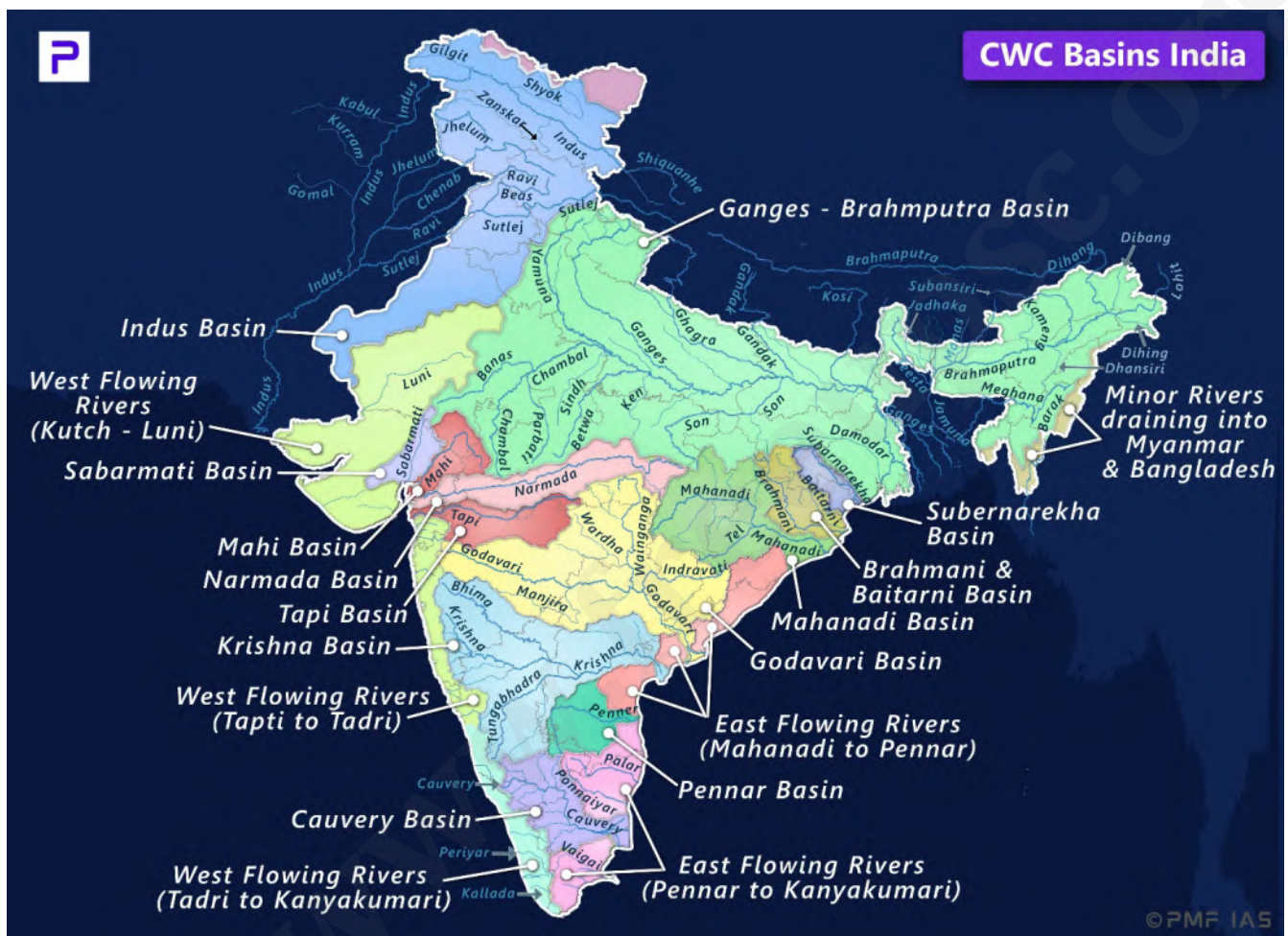
2. **Medium river basins with a catchment area between 2,000-20,000 km²:** These include **44 river basins** such as **Kali Nadi, Periyar, Meghna**, etc.
3. **Minor river basins with < 2,000 sq km catchment area:** It includes a fairly good number of rivers flowing in low rainfall areas.

Based on Drainage

- Based on the type of drainage, Indian rivers can be grouped into:
 1. **Rivers draining into seas:** Ganga, Godavari, Narmada.
 2. **Rivers with inland drainage (endorheic basin):** Luni, Ghaggar, etc.

Based on Origin

- Based on origin, Indian drainage can be grouped into:
 1. **The Himalayan Drainage**
 2. **The Peninsular Drainage**



The Himalayan Drainage

- Most Himalayan rivers are **perennial** as both **snowmelt** and **precipitation** feed them.
- The Himalayan drainage comprises the **Ganga**, the **Indus**, and the **Brahmaputra** basins.
- They perform intense erosion in their upper courses and transport large silt and sand loads. In the upper courses, they form **deep gorges, V-shaped valleys, rapids**, and **waterfalls**.

- In the middle and lower courses, they form depositional features like flat valleys, **ox-bow lakes**, flood plains, **braided channels**, and deltas.
- In the Himalayas, these rivers have winding courses, while on the plains, they **meander** and frequently change paths.

⇒ **River Kosi**, also called the '**sorrow of Bihar**', is notorious for **frequently changing its course**. It brings a huge quantity of sediments from its upper reaches and deposits it in the plains.

The Peninsular Drainage

- The Peninsular drainage comprises all the river basins in India that are to the south of the Himalayan Drainage.

⇒ **Chambal, Sind, Betwa, Ken, and Son**, originating in the northern part of the Peninsula, belong to the Ganga River system.

- The Peninsular drainage system is **older than** the Himalayan drainage system. This is evident from the broad, largely graded shallow valleys and the maturity of the rivers.
- The **Western Ghats** form the main water divide in Peninsular India. **Most major rivers** flow eastwards and **drain into the Bay of Bengal**. Numerous small streams are flowing west and draining into the Arabian Sea.
- Peninsular rivers have a **fixed course**, **no meanders**, and **non-perennial** flow.

Exceptions

- **Narmada** and **Tapi** are the **only major peninsular rivers flowing west** into the Arabian Sea. Unlike other peninsular rivers, **these rivers have a meandering course** and **perennial** flow. They show this exceptional behavior because they flow through **rift valleys**.

West Flowing Peninsular Rivers Do Not Form Deltas

- West-flowing peninsular rivers drain into the **Arabian Sea**, making **estuaries**. They **do not have enough silt to form deltas** because:
 1. The Western Ghats have a steep slope, resulting in the **rapid flow** of these rivers.
 2. They do not have to travel much distance to drain into the sea.
 3. The topography of Western Peninsular India is **rocky**.

Difference Between the Himalayan and Peninsular River Systems

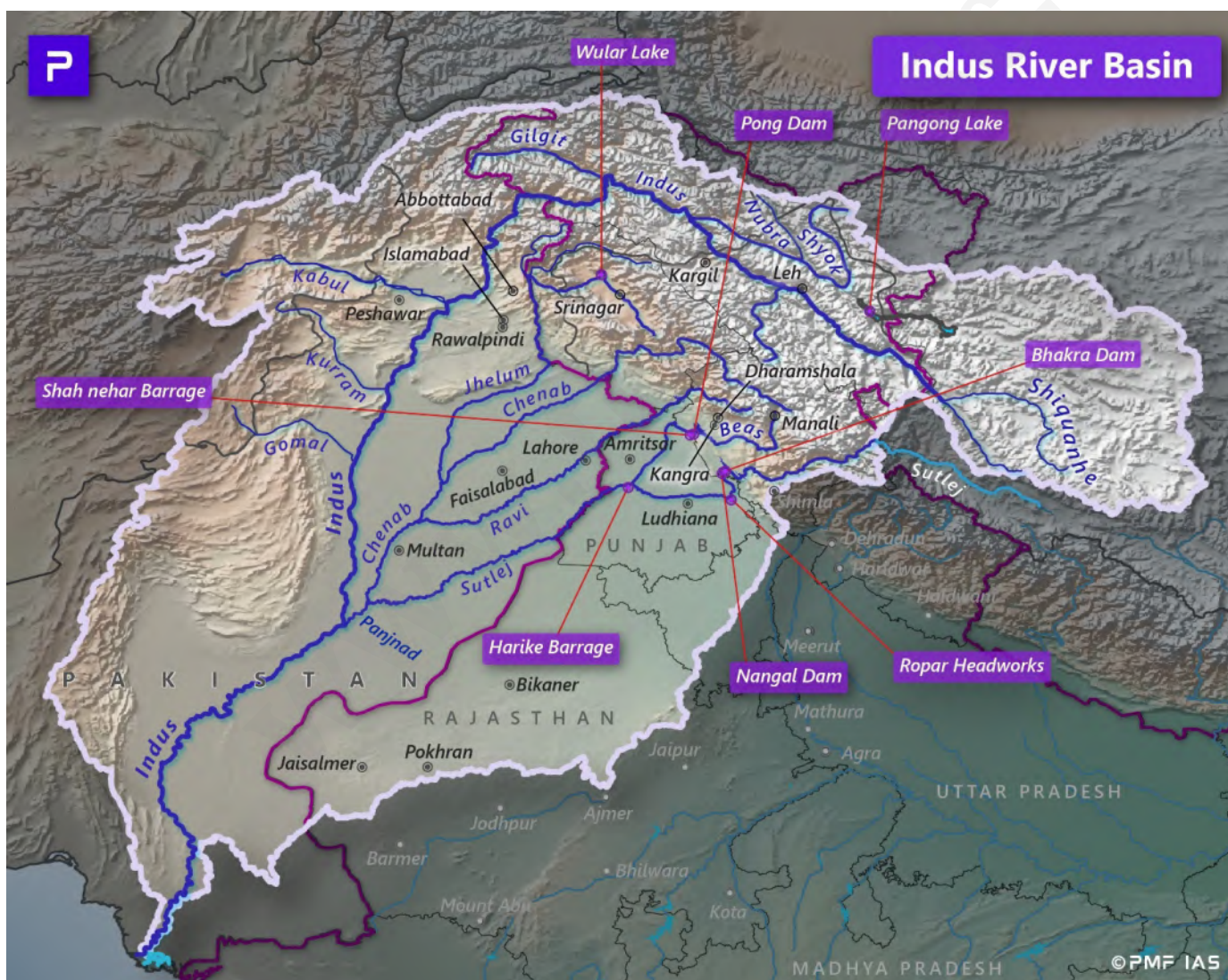
Aspect	Himalayan River System	Peninsular River System
Origin of Rivers	Originates from the Himalayan glaciers and snowmelt	Originates from the plateaus and hills of peninsular India
Length of Rivers	Generally longer	Generally shorter
Water Volume and Discharge	Higher water volume and discharge	Lower water volume and discharge
Sediment Load	Higher sediment load due to erosion in the Himalayas	Lower sediment load due to older geological formations

Dependency on Monsoon	Relatively less dependent on monsoon rainfall	Heavily dependent on monsoon rainfall
Hydroelectric Potential	High hydroelectric potential due to steep gradients	Lower hydroelectric potential due to gentler gradients

Difference Between East and West Flowing Rivers of Peninsular India

Feature	East Flowing Rivers	West Flowing Rivers
Origin	Eastern slopes of Western Ghats	Western slopes of Western Ghats
Length	Generally longer with larger basins	Generally shorter and smaller basins
Tributaries	A well-developed dendritic tributary system	Fewer and less developed tributaries
Delta Formation	They form large, fertile delta plains that are crucial for agriculture, irrigation, and navigation (e.g., Mahanadi Delta, Krishna Delta, etc.	Estuaries are formed at the river mouths. Delta formation is almost non-existent . They generate hydroelectricity and support limited agriculture (e.g., Narmada Estuary, Tapi Hydropower Projects).

Indus River System

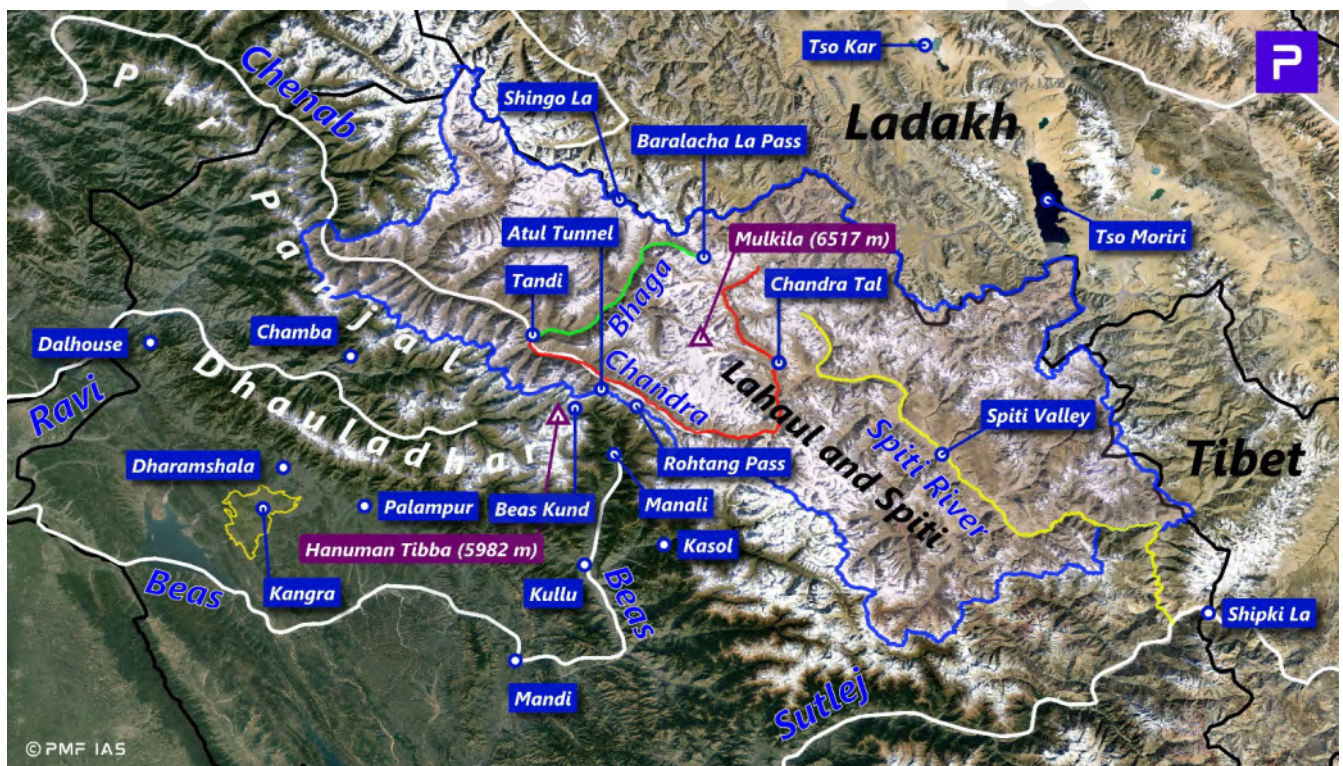


- The Indus basin extends over **Tibet, India, Afghanistan, and Pakistan**.
- In India, the basin spreads over **J&K, HP, Punjab, Rajasthan, Haryana, and Chandigarh**, covering nearly **9.8%** of the total geographical area.
- The basin is surrounded by the **Himalayas** to the east, the **Karakoram** and **Haramosh** ranges to the north, the **Sulaiman** and **Kirthar** ranges to the west, and the **Arabian Sea** to the south.
- The **Indus Waters Treaty**, brokered by the World Bank in 1960, governs the distribution and management of the river's waters between India and Pakistan.

Indus River

- The **2,880 km** long Indus River rises from a **glacier near Bokhar Chu** in the **Kailash Mountain range** in Tibet. It is known as '**Singi Khamban**' (**Lion's mouth**).
- In India, it flows for **1,114 km** through **Ladakh**. It enters Pakistan near Chilas of **Dardistan** region and finally discharges into the Arabian Sea.
- **Left bank tributaries:** **Jhelum, Chenab, Ravi, Beas, Sutlej, Zaskar** etc.
- **Right bank tributaries:** **Shyok, Gilgit, Kabul, Kurram, Gomal, Shigar**, etc.
- **Important place:** **Leh** is located on the **right bank** of the **Indus River**. **Nimoo Bazgo Dam** is an important hydroelectric project on the Indus River located in Leh.

Chenab (or Chandra Bhaga)



- **Chenab** is the **largest tributary of the Indus River**. It is formed after the two streams, **Chandra** and **Bhaga**, originating near **Baralacha La Pass** in **Lahul and Spiti**, merge with each other at **Tandi**.
- The drainage area of the Chenab River basin within India is located in the two states — **Himachal Pradesh** and **Jammu & Kashmir**.
- Chenab River joins the Indus River near **Shorkot** in Pakistan.

- Thiro, Sohal, **Bhut Nallah**, Liddrari, and Marusudar are the main tributaries of the Chenab River.
- **Major hydroelectric projects:** **Baglihar Dam** (Ramban, Jammu & Kashmir), **Dulhasti Dam** (Kishtwar, Jammu & Kashmir) and **Salal Dam** (Reasi, Jammu & Kashmir).

Jhelum

- Jhelum originates from a spring at **Verinag in J&K**, located at the foot of the **Pir Panjal Range**.
- It is called Vyeth in Kashmiri, Vetesta in Sanskrit, and Hydaspes in Greek.
- It is the main waterway of the **Kashmir Valley**, which flows through **Srinagar** and **Wular Lake**.
- This transboundary river **joins the Chenab** near **Jhang in Pakistan**.
- **Major tributaries:** **Liddar**, **Dudhganga** and **Sindh**.
- **Important cities:** **Srinagar**, **Baramulla** and **Uri**.
- **Uri Dam** in Baramulla, Jammu & Kashmir, is an important hydroelectric project of the Jhelum River.

Ravi

- Ravi, a transboundary river, rises **near Rohtang Pass** in the **Kullu hills** of HP and flows through the **Chamba Valley**. It **joins the Chenab** near **Sarai Sidhu in Pakistan**.
- It drains the area lying between the **Pir Panjal** and **Dhauladhar ranges**.
- It passes through Himachal Pradesh, Jammu & Kashmir, and Punjab.
- **Major hydroelectric projects:** **Bassi Dam** (Mandi, HP), **Chamera Dam – I, II, III** (Chamba, HP), **Ranjit Sagar Dam** (Kathua, Punjab), etc.,
- **Important cities:** **Amritsar** and **Pathankot**.

Beas

- Beas originates from the **Beas Kund** near **Rohtang Pass**.
- The river flows through the **Kullu valley** and forms gorges in the **Dhauladhar** range.
- It enters the Punjab plains, where it **meets the Sutlej** near **Harikela**.
- It passes through Himachal Pradesh and Punjab.
- **Important cities:** **Manali**, **Kullu** and **Mandi**.
- **Major hydroelectric projects:** **Pandoh Dam** (Mandi, HP), **Pong Dam (Maharana Pratap Sagar)** (Kangra, HP), etc.,

Sutlej

- Sutlej rises in **Raksas Tal** near **Mansarovar** in Tibet, where it is called **Langchen Khambab**.
- It flows almost parallel to the Indus before entering India. It is the **longest tributary of the Indus**.
- It passes through **Shipki La** in the Himalayan range and enters the Punjab plains.
- It is an **antecedent river (it existed even before the formation of the Himalayas)**.
- It is an important tributary that feeds the canal system of the **Bhakra Nangal project**.
- The main tributaries of the Sutlej River in India are **Ravi** and **Beas**.
- **Important cities:** **Ferozpur** and **Ludhiana**.

- **Major hydroelectric projects:** **Bhakra Dam** (Bilaspur, HP), **Kol Dam** (Bilaspur, HP), **Nathpa Jhakri Dam** (Kinnaur, HP), etc.,

⇒ The name Punjab is made of two words — Punj (Five) + Aab (Water), i.e. land of five rivers. These five rivers of Punjab are Sutlej, Beas, Ravi, Chenab, and Jhelum. **Only** the **Sutlej, Ravi, and Beas** rivers **flow in today's Punjab**. The other two rivers are now in the Punjab state of Pakistan.

Panjnad River

- The **Panjnad River** joins the Indus River a little above **Mithankot**. It is created by the merging of five rivers: **Jhelum, Chenab, Ravi, Beas, and Sutlej**.
- **Jhelum** and **Ravi** join the **Chenab**; **Beas** River joins the **Sutlej**; and **Sutlej** and **Chenab** join to form the **Panjnad River**.

[UPSC 2021] With reference to the Indus river system, of the following four rivers, three of them put into one of them which joins the Indus direct. Among the following, which one is such river that joins the Indus direct?

- Chenab
- Jhelum
- Ravi
- Sutlej

Explanation

- **Sutlej River** is the **longest** among the five tributaries.

Answer: d) Sutlej (According to UPSC)

[UPSC 2009] Which one of the following rivers does not originate in India?

- Beas
- Chenab
- Ravi
- Sutlej

Explanation

- The source of the **Sutlej River** is **Lake Rakshastal** of Tibet. The rest originate in **HP**.

Answer: d) Sutlej

[UPSC 2006] From North towards South, which one of the following is the correct sequence of the given rivers in India?

- Shyok-Spiti-Zaskar- Sutlej
- Shyok-Zaskar-Spiti-Sutlej
- Zaskar-Shyok-Sutlej- Spiti
- Zaskar-Sutlej-Shyok-Spiti

Explanation

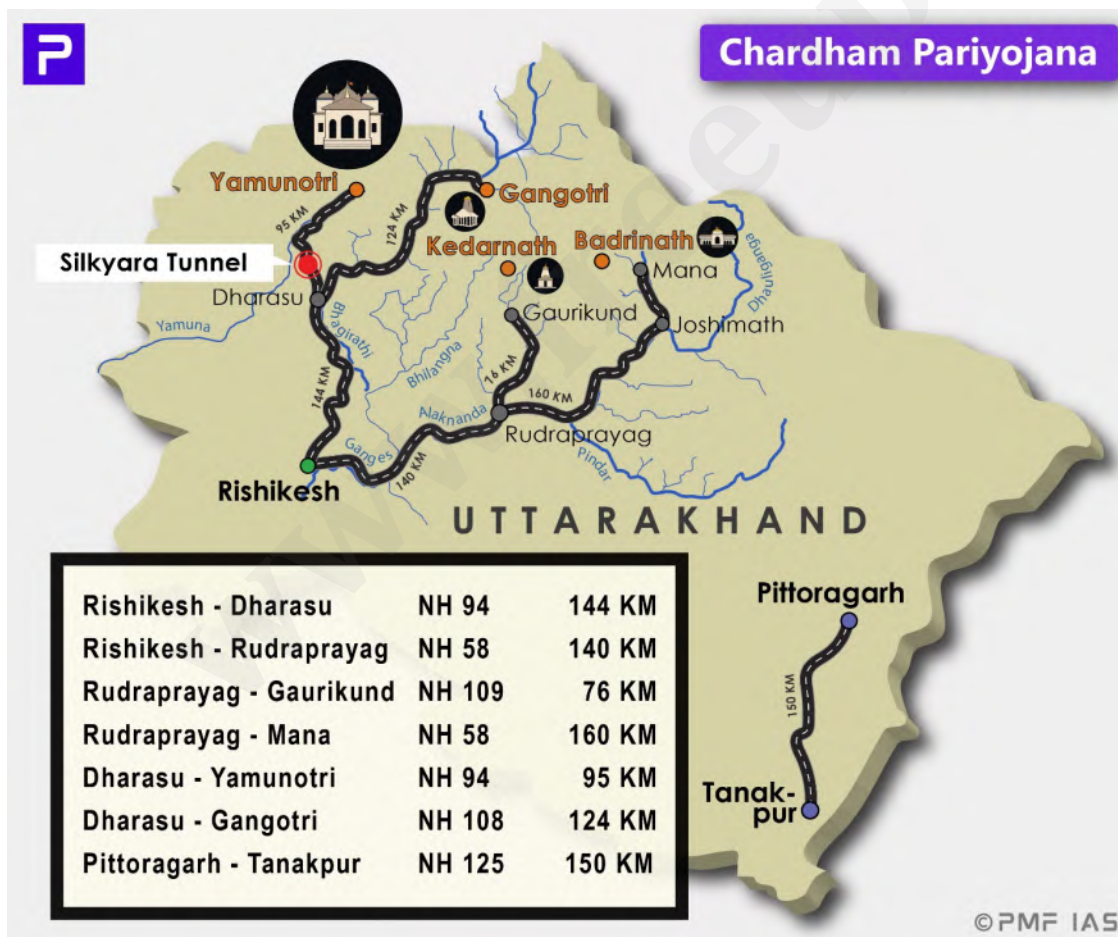
- **Shyok River** originates in Tibet. **Nubra River** joins it in **Ladakh**.
- The **Zaskar River** originates in the **Zaskar Range** in **Jammu and Kashmir** and joins the **Indus River** downstream of Leh.
- **Spiti River** originates near **Chandra Tal** and joins the **Sutlej River** in Himachal Pradesh.

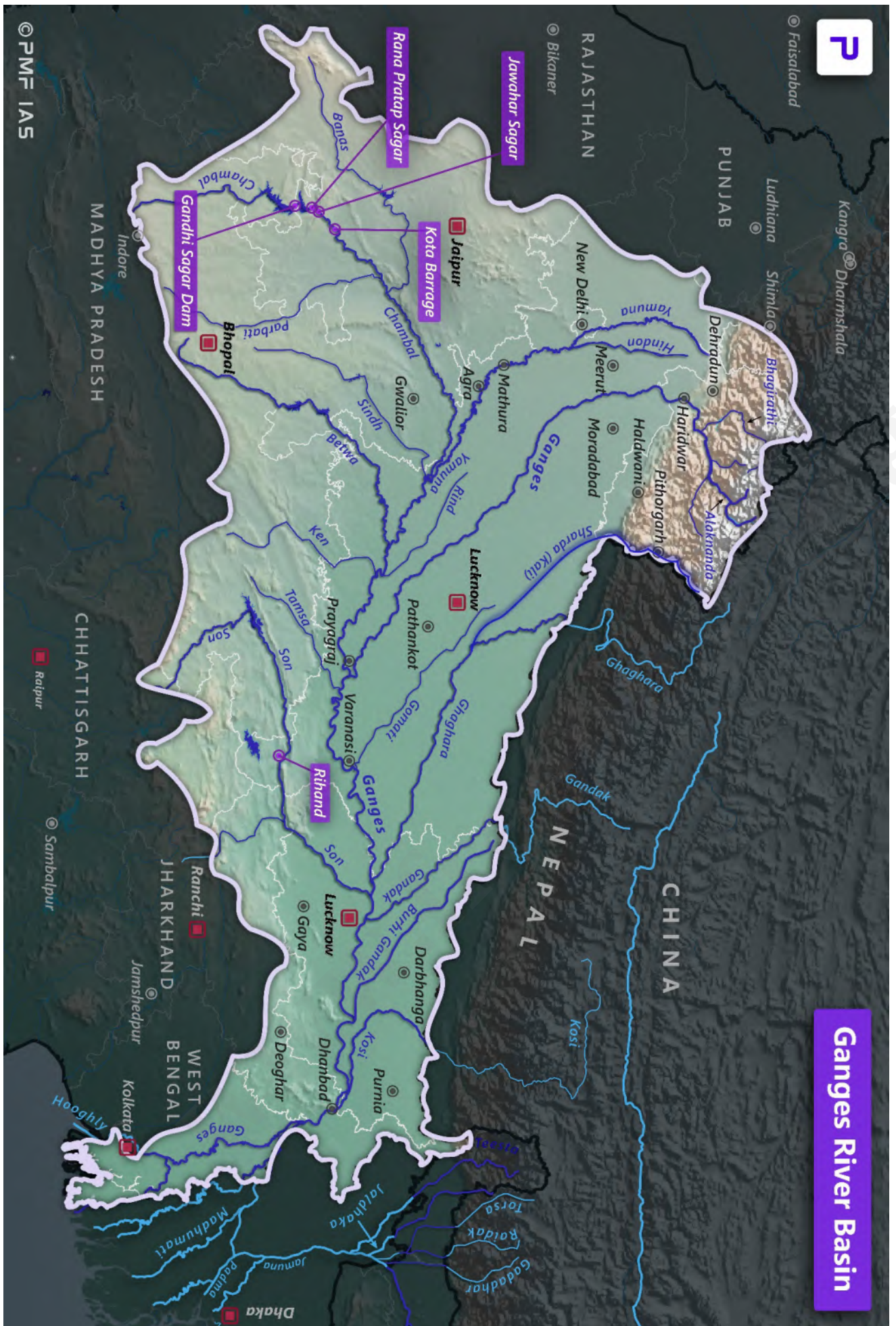
Answer: b) Shyok-Zaskar-Spiti-Sutlej

Major Hydro-electric Projects (HEP) in the Indus Basin

HEP	State(s)	River
Bhakra HEP	HP	Sutlej
Dulhasti HEP	J&K	Chenab
Kishenganga HEP	J&K	Kishenganga, a tributary of Jhelum
Parvati HEP	HP	Parbati
Pong HEP	HP	Beas
Rampur HEP	HP	Sutlej
Ranjit Sagar Dam HEP	HP, J&K, Punjab	Ravi
Upper Sindh HEP	J&K	Sindh Nallah, tributary of Jhelum

Ganga River System





P

Ganges River Basin

- The Ganga basin extends over **India, Tibet (China), Nepal, and Bangladesh.**
- In India, the basin covers **UP, MP, Rajasthan, Bihar, WB, Uttarakhand, Jharkhand, Haryana, Chhattisgarh, HP, and Delhi,** covering nearly **26%** of the total geographical area.
- The basin is bounded by the **Himalayas** to the north, **Aravalli** to the west, **Vindhyas** and **Chhotanagpur Plateau** to the south, and **Brahmaputra Ridge** to the east.

Ganga River

- The Ganga River rises in the **Gangotri glacier** in the Himalayas at Uttarkashi of Uttarakhand. At its source, the river is called the **Bhagirathi.**
- At **Devprayag,** the Bhagirathi meets the **Alaknanda;** hereafter, it is known as the **Ganga.**
- The **Alaknanda** has its source in the **Satopanth glacier** above **Badrinath.**

Panch Prayag

1. **Vishnuprayag:** Confluence of **Alaknanda** and **Dhauliganga** Rivers.
 2. **Rudraprayag:** Confluence of **Alaknanda** and **Mandakini (Kali Ganga)** Rivers.
 3. **Nandprayag:** Confluence of **Alaknanda** and **Nandakini** Rivers.
 4. **Karnaprayag:** Confluence of **Alaknanda** and **Pindari** Rivers.
 5. **Devprayag:** Confluence of **Alaknanda** and **Bhagirathi** Rivers.
- The **2,525 km long Ganga River** enters the plains at **Haridwar.** At **Farakka** in West Bengal (the northernmost point of the Ganga delta), the Ganga River bifurcates:
 1. The **Bhagirathi-Hooghly** (a distributary) flows through the deltaic plains and discharges into the Bay of Bengal near **Sagar Island.**
 2. The mainstream flows into **Bangladesh** and drains into the Bay of Bengal.
 - **Right bank tributaries:** **Yamuna, Tamsa and Son (Sone).**
 - **Left bank tributaries:** **Ramganga, Ghaghra, Gandak, Bhuri Gandak, Kosi, Mahananda, etc.**

Ramganga

- Ramganga is a small river rising in the Garhwal hills near Gairsain. It joins the Ganga near Kannauj.
- It is situated entirely within Uttarakhand and Uttar Pradesh.

Mahananda

- Mahananda is another important tributary of the Ganga rising in the **Darjeeling hills.**
- It joins the Ganga as its last left bank tributary in West Bengal.

Yamuna

- The Yamuna is the **westernmost** and the **longest tributary** of the Ganga.
- Its source is in the **Yamunotri Glacier** on the **Banderpunch Range.**
- It joins the Ganga at **Prayagraj** (Allahabad).
- Much of its water feeds the **Agra canals** for irrigation purposes.
- **Right bank tributaries:** **Tons, Chambal, Sind, Betwa and Ken.**

- **Left bank tributaries:** Hindan, Rind, Sengar, and Varuna.
- **Important cities:** Delhi, Mathura, Agra, Prayagraj.

Tons River

- It is a 150 km long tributary of the Yamuna River. It is the **largest tributary of Yamuna**.
- It originates at an elevation of 3900 m at the confluence of two streams, the Supin River and the Rupin River. It flows **along the HP-Uttarakhand border** and joins the Yamuna near Dehradun.

[UPSC 2010] Rivers that pass through Himachal Pradesh are:

- Beas and Chenab only
- Beas and Ravi only
- Chenab, Ravi, and Satlej only
- Beas, Chenab, Ravi, Satlej and Yamuna

Explanation

- **Beas, Ravi and Chenab** have their origin in **HP**.
- **Sutlej River**, while originating in Tibet, enters India and flows through Himachal Pradesh before moving further south.
- **Yamuna River**, while originating in the Uttarkashi district of **Uttarakhand**, flows briefly through the southern tip of **Himachal Pradesh**.

Answer: d) Beas, Chenab, Ravi, Satlej and Yamuna

Chambal

- The Chambal rises near **Mhow (in the Vindhya Range)** in the **Malwa plateau** of MP.
- It is famous for its **badland topography** called the **Chambal ravines**.
- It flows through the states of Madhya Pradesh, Rajasthan and Uttar Pradesh.
- **Major dams:** Rana Pratap Sagar (Rajasthan), **Gandhi Sagar (Madhya Pradesh)**, Jawahar Sagar Dam, and Kota Barrage.
- **Tributaries:** Kali Sindh, Banas, Sipra, **Parvati**, etc.

Betwa

- Betwa rises in the **Vindhya Range** just north of Hoshangabad (Narmadapuram) in MP and flows northeast through the **Malwa Plateau** of Madhya Pradesh and then flows into Yamuna in Uttar Pradesh.
- The National Board for Wildlife (NBWL) has given clearance for the **Ken-Betwa inter-linking project**.

Ken

- The **Ken River** is one of the major rivers in the **Bundelkhand** region. It flows through the states of Madhya Pradesh and Uttar Pradesh.

- It originates near the north-west slopes of the **Barner Range** (southern extension of Kaimur Range) in Katni district of MP and travels a distance of 427 km, before merging with the **Yamuna**.
- Ken passes through **Panna National Park**. A stretch of the river after this in **MP** is **Ken Gharial Sanctuary**, established for the conservation of **gharial (CR)** and **mugger (marsh) crocodile (VU)** populations.

Gandak (Narayani)

- Gandak comprises two streams, namely **Kaligandak** and **Trishulganga**. They rise in the **Nepal Himalayas** between the **Dhaulagiri** and **Mount Everest**.
- Gandak drains the **central part of Nepal** and joins the Ganga at **Sonpur** near **Patna**. It was declared as **National Waterway (NW)-37** from Bhaishalotan Barrage to its confluence with the Ganga River vide **National Waterways Act, 2016**.
- **Valmiki National Park (Bihar)** and Chitwan National Park (Nepal) are located on the banks of this river.
- **Tributaries:** Kali Gandak, Mayangadi, Bari, Panchand, etc.

Burhi Gandak River

- The **Burhi Gandak** is a **tributary** of the **Ganges**. It originates in the district of West Champaran in **Bihar**. It flows into the Ganges between the cities of **Begusarai** and **Bhagalpur**.
- It flows **parallel** to and **east** of the **Gandak River** in an **old channel of the Gandak River**. This old channel is a reason for the formation of the **Kanwar Lake, a residual oxbow lake**.

Ghaghara

- The Ghaghara (known as **Karnali** in Nepal) originates in the glaciers of **Mapchachungo**.
- **Sharda River (Kali or Kali Ganga)** joins it before it finally meets the Ganga at Chhapra.
- **Tributaries:** Sharda (Kali), Seti River, etc.

Sharda or Saryu

- Sharda rises in the **Milam glacier** in the **Nepal Himalayas**, where it is known as **Goriganga**.
- Along the **Indo-Nepal border**, it is called **Kali** or **Chauk**, where it joins the Ghaghara.

Kosi

- **Kosi** is a transboundary river that flows through **Nepal, Tibet (China), and India**.
- It is formed by the confluence of three streams — **Sun Kosi, Arun Kosi, and Tamur Kosi**, all originating in the Himalayan region of Nepal and Tibet.
- Kosi, the **Sorrow of Bihar**, tends to change its course generally in the westward direction and cause devastating floods.
- It is also called **Sapt Kosi** because of its **seven tributaries**.
- The tributaries (right bank) are Trijuunga, Kamala Balan, Bagmati, etc.,

Son (Sone) River

- Son is a large south-bank tributary of the Ganga, originating in the **Amarkantak plateau**, close to the origin of the Narmada.
- It flows through the states of Chhattisgarh, Madhya Pradesh, Uttar Pradesh, and Jharkhand. It passes along the Kaimur Range and joins the Ganga near Danapur in Patna district of Bihar.
- **Tributaries:** Rihand and the North Koel.

[UPSC 1998] Which one of the following east flowing rivers of India has rift valley due to down warping?

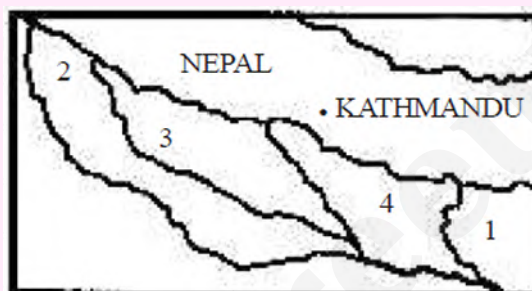
- a) Damodar
- b) Mahanadi
- c) Sone
- d) Yamuna

Explanation

- The **Damodar River Valley** is a well-known example of a **rift valley** formed due to **down warping** caused by the tectonic activity associated with the movement of the Indian Plate.

Answer: a) Damodar

[UPSC 1997] In the map shown, rivers labelled as 1, 2, 3 and 4 respectively:



- a) Kosi, Gomti, Ghaghara and Gandak
- b) Kosi, Ganga, Gomti and Ghaghara
- c) Gandak, Ganga, Gomti and Ghaghar
- d) Teesta, Gomti, Ghaghara and Kosi

Explanation

- From the map, it is clear that all the rivers are flowing into India from Nepal. Hence, Ganga and Teesta can be easily eliminated.
- The **Kosi, Gomti, Ghaghara, and Gandak** are all tributaries of the Ganges River in India. They are all **snow-fed rivers** that originate in the Himalayas and flow through the northern plains of India.
- The Gomti River flows through Uttar Pradesh. It originates in the **Pilibhit** district and flows through the cities of **Lucknow** and **Kanpur** before joining the Ganges River at **Prayagraj**.

Answer: a) Kosi, Gomti, Ghaghara and Gandak

Damodar

- Damodar River, also called **Deonadi** in its initial reaches, is an important tributary of Ganga.
- It rises in the hills of the **Chottanagpur Plateau** of the Palamau district of Bihar.
- **Barakar** is its main tributary, and it joins the **Hugli River** south of Kolkata.
- Once known as the **Sorrow of Bengal**, the Damodar has been now tamed by the **Damodar Valley Corporation**, a multipurpose project.

Ganga in Bangladesh

- Ganga is called **Padma** in Bangladesh and is joined by the **Jamuna River**, the **largest distributary of the Brahmaputra**.
- Further downstream, the **Padma** joins the **Meghna River** (the converging flow of the **Surma-Barak** River System) and empties into the Bay of Bengal by taking the name of **Meghna**.

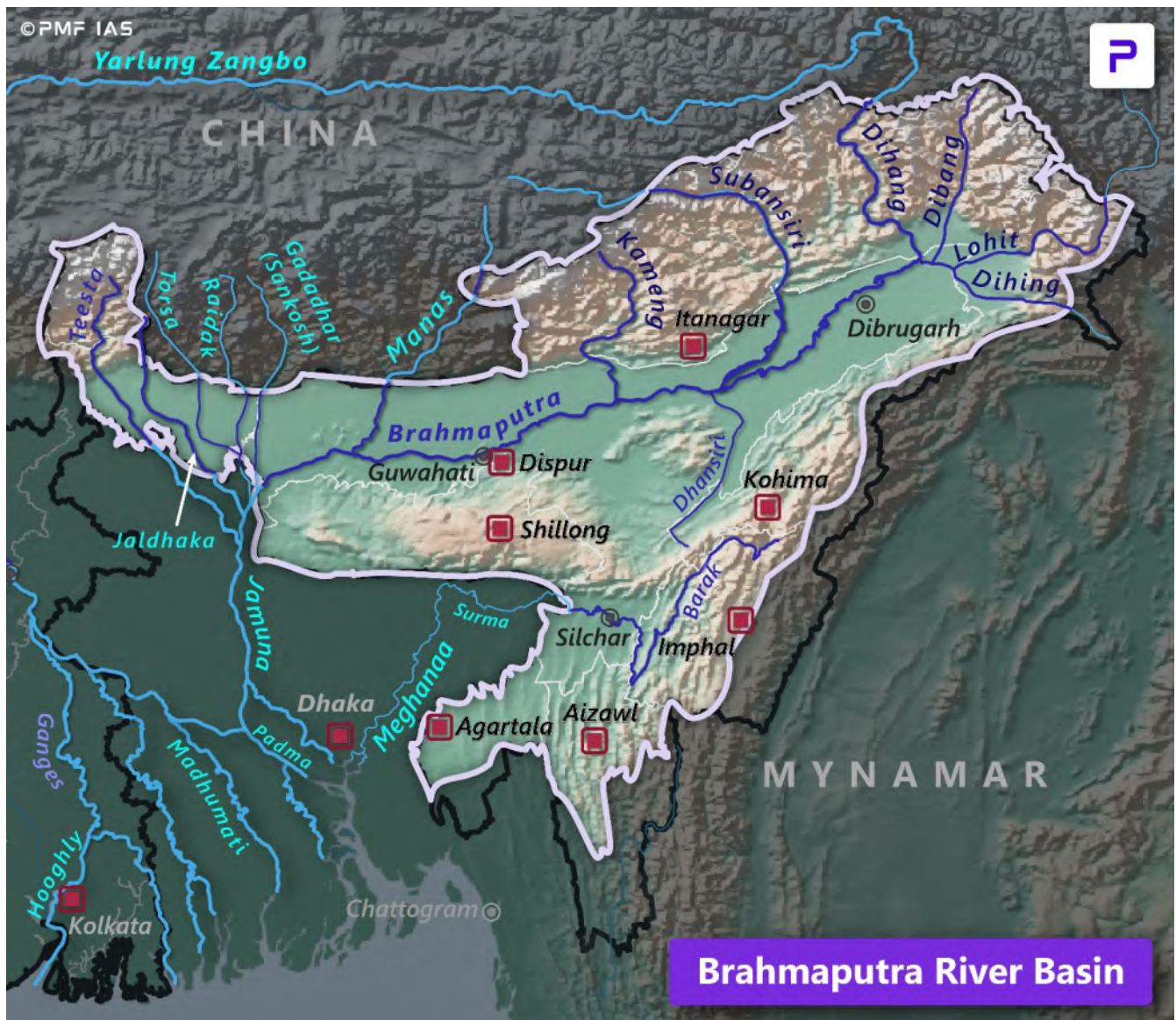
Important Hydro-electric Projects (HEP) in the Ganga Basin

Name	States	River
Chambal HEP	MP, Rajasthan	Chambal
Damodar Valley HEP	Jharkhand	Damodar and its tributaries
Dhauliganga HEP	Uttarakhand	Dhauliganga
Jaldhaka HEP	WB	Jaldhaka
Kosi HEP	Bihar	Kosi
Rihand HEP	MP, UP	Rihand
Tehri HEP	Uttarakhand	Bhagirathi
Western Yamuna Canal Stage I & II HEP	Haryana	Yamuna
Yamuna HEP	UP, Uttarakhand	Yamuna

Brahmaputra River System

- The Brahmaputra basin spreads over **Tibet (China)**, **Bhutan**, **India**, and **Bangladesh**.
- The total length of the Brahmaputra River is **2,900 km**, and in India, it is **916 km**.
- In India, the basin spreads over **Arunachal Pradesh**, **Assam**, **West Bengal**, **Meghalaya**, **Nagaland**, and **Sikkim**, which is nearly **5.9 %** of the total geographical area.
- The Brahmaputra River originates in the **Chemayungdung glacier** of the **Kailash range** near **Man-sarovar Lake** in Tibet, where it is called the **Tsangpo** ('the purifier') or **Yarlung Zangbo**.
- It carves a deep gorge in the Central Himalayas near **Namcha Barwa** and turns southwards. Then, it enters India through Arunachal Pradesh as **Siang** or **Dihang**.
- After receiving its main left bank tributaries, **Dibang** (or **Sikang**) and **Lohit**, the river is then known as the Brahmaputra.
- The Brahmaputra enters Bangladesh as the **Jamuna River**, where it joins the Ganga (**Padma** in Bangladesh) and continues to flow as the Padma.

- Padma finally joins **Meghna River**, which falls into the Bay of Bengal.
- The confluence of the Ganges, Brahmaputra, and Meghna Rivers forms the Sundarbans delta.
- The Brahmaputra is infamous for floods, channel shifting, and bank erosion. This is because most of its tributaries bring large quantities of sediments owing to heavy rainfall in its catchment area.



Major Tributaries of Brahmaputra

- **Right bank tributaries:** Rango Tsangpo (in Tibet), Subansiri, Kameng (Jiabharali), Dhansiri, Manas, Sankosh, Teesta.
- **Left bank tributaries:** Lohit, Dibang, Burhidihing, Disang, Dikhow, Dhansiri, Kopili.

Subansiri

- Subansiri (or Gold River) is the **largest tributary** of the Brahmaputra River.
- It is an **antecedent river** that rises in the mountains of **Tibet**.

Kameng (Jiabharali)

- Its source is in a glacial lake near the **Nyegi Kangsang**, one of the highest mountains in Arunachal Pradesh.

Dhansiri

- Dhansiri rises in Nagaland below the **Laishiang peak**. From its source up to Dimapur, it forms the **boundary** between **Assam** and **Nagaland**.

Manas

- Manas River is a transboundary river in the Himalayan foothills between Bhutan and India. It meets the Brahmaputra near Jogighopa.
- Along its sides, there are **Royal Manas National Park** (Bhutan) and **Manas National Park** (Assam), a **UNESCO World Heritage Site**.

Kopili

- Kopili is a major tributary of the Brahmaputra on its left bank. It originates in the Saipong Reserve Forest of **Meghalaya** and then flows to Assam.

Teesta

- Teesta River, a transboundary river, rises in the Himalayas near **Chunthang in Sikkim**.
- It is the **largest river in North Bengal**.
- It joins the **Jamuna River (Brahmaputra)** in Bangladesh.

[UPSC 2017] With reference to river Teesta, consider the following statements:

1. The source of river Teesta is the same as that of Brahmaputra but it flows through Sikkim.
2. River Rangeet originates in Sikkim and it is a tributary of river Teesta.
3. River Teesta flows into Bay of Bengal on the border of India and Bangladesh.

Which of the statements given above is/are correct?

- a) 1 and 3 only
- b) 2 only
- c) 2 and 3 only
- d) 1, 2 and 3

Explanation

- The Teesta River is the main river in the state of Sikkim. It originates as the **Chhombo Chhu** from a frozen lake called **Khangchung Chho**. This lake is located where the **Teesta Khangse glacier** flows down from Pauhunri peak (which is about 7,056 meters high) towards the northwest.
- The Teesta River flows into the Bay of Bengal after entering Bangladesh, although not exactly on the border. It merges with the Brahmaputra River near **Gaibandha** in Bangladesh.

Answer: b) 2 only

[UPSC 2016] Which of the following is/are tributary/ tributaries of Brahmaputra?

1. Dibang
2. Kameng
3. Lohit

Select the correct answer using the code given below.

- a) 1 only
- b) 2 and 3 only
- c) 1 and 3 only
- d) 1, 2 and 3

Explanation

Dibang River

- It originates in the **Upper Dibang Valley district** near the Indo-Chinese border in Arunachal Pradesh.
- It runs through the **Mishmi Hills** in the **Dibang** and **Lower Dibang Valley** districts before merging with the **Lohit River** north of the Dibu-Saikhowa sanctuary near Sadiya, Assam.

Kameng River

- It originates in the Tawang district of Arunachal Pradesh, bordering Tibet. It flows southward through the West Kameng district before joining the Brahmaputra River near **Tezpur**, Assam.

Lohit River

- It originates in the Eastern Himalayas in Tibet, where it is known as the **Zayu River**.
- It enters India through Arunachal Pradesh, flows southward through the **Lohit district**, and merges with the **Dibang River** before joining the Brahmaputra River near Sadiya, Assam.

Answer: d) 1, 2 and 3

[UPSC 2011] The Brahmaputra, Irrawady and Mekong rivers originate in Tibet and flow through narrow and parallel mountain ranges in their upper reaches. Of these rivers, Brahmaputra makes a "U" turn in its course to flow into India. This "U" turn is due to

- a) Uplift of folded Himalayan series
- b) Syntaxial bending of geologically young Himalayas
- c) Geo-Tectonic disturbance in the tertiary folded mountain chains
- d) Both (a) and (b) above

Explanation

- The Brahmaputra River, along with the other rivers (Irrawaddy, Mekong), originates in Tibet and flows through narrow and parallel mountain ranges in its upper reaches.
- However, unlike the others, the **Brahmaputra makes a distinct "U" turn** in its course. This peculiar feature is primarily due to the **syntaxial bending** of the geologically young Himalayas.
- **Syntaxial bending** refers to the bending or folding of rock layers due to tectonic forces.

- In the case of the Brahmaputra River, as it approaches the Himalayas, it encounters the young and **actively growing mountain ranges**.
- The intense tectonic activity in this region causes the rocks to bend, resulting in the unique U-shaped course of the river as it navigates around the eastern end of the Himalayas and flows into India.

Answer: b) Syntaxial bending of geologically young Himalayas

Barak River System

- The Barak basin covers parts of **India, Bangladesh, and Myanmar**.
- In India, the basin spreads over **Meghalaya, Manipur, Mizoram, Assam, Tripura, and Nagaland**, which is nearly 1.38% of the country's total geographical area.
- The basin is bounded by the **Barail range** on the north, **Naga** and **Lushai hills** on the east, **Mizo hills** on the south, and **Bangladesh** on the west.
- The **Barail range** separates the Barak basin from the Brahmaputra basin.
- Barak River rises from the **Manipur hills**. It flows then along the **Nagaland-Manipur border** and enters Assam. It further enters Bangladesh, where it is known as **Surma** and **Kushiyara**.
- Later, it is called the **Meghna** before receiving the combined flow of the Ganga (**Padma** in Bangladesh) and the Brahmaputra (**Jamuna** in Bangladesh).
- **Right bank tributaries:** Jiri, Chiri, Modhura, Jatinga, Harang, Kalain, and Gumra.
- **Left bank tributaries:** Dhaleswari, Singla, Longai, Sonai, and Katakhal.

Important Hydro-electric Projects (HEP) on the Brahmaputra Basin

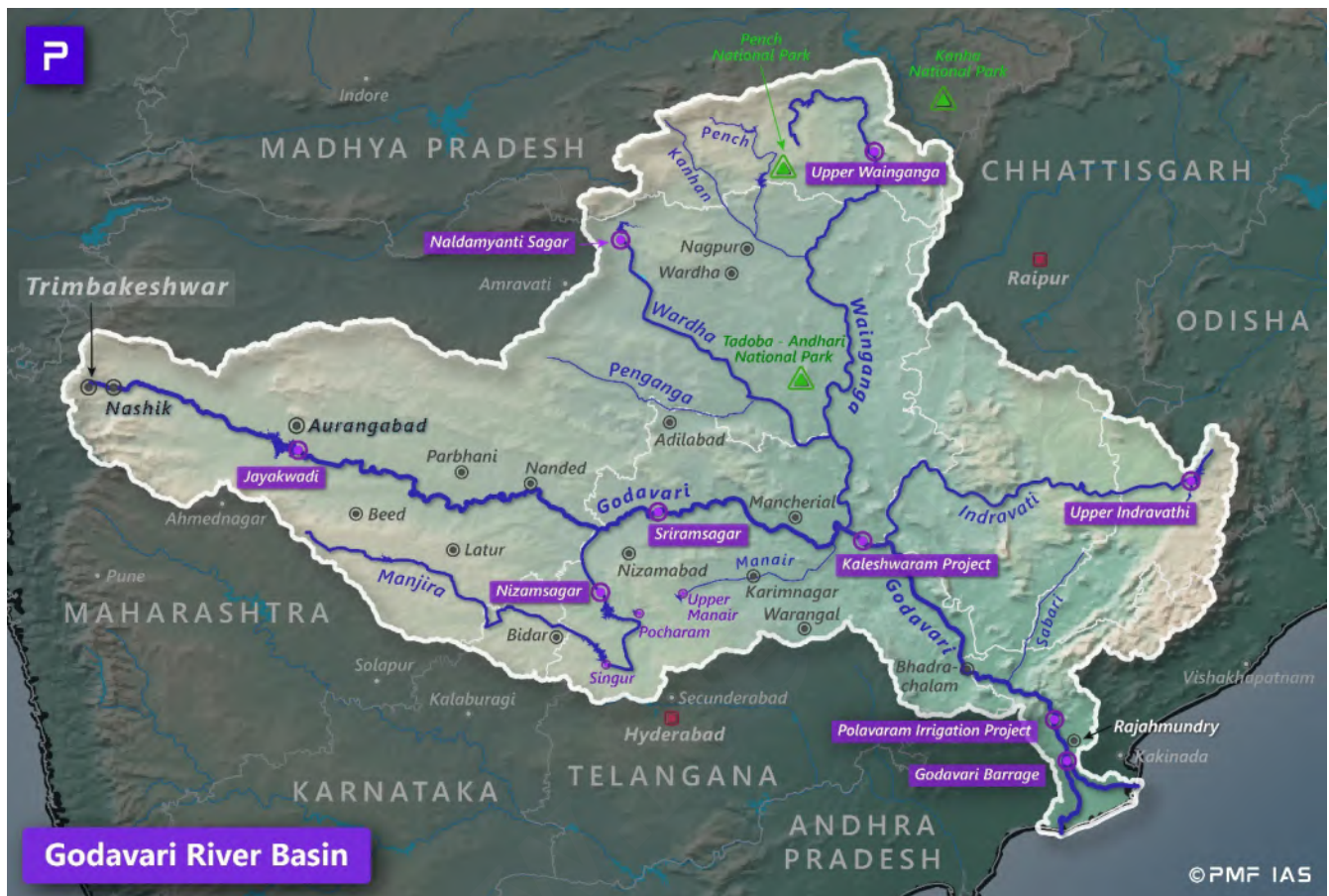
Name	States	River
Kopili HEP	Assam	Kopili and its tributary, Umrong
Karbi Langpi HEP	Assam	Borapani
Lower Subansiri HEP	Arunachal Pradesh, Assam	Subansiri
Ranganadi HEP	Arunachal Pradesh	Ranganadi
Kameng HEP	Arunachal Pradesh	Bichom & Tenga
Teesta-V HEP	Sikkim	Teesta
Teesta Low Dam Stage-III HEP	WB	Teesta
Uiam-III HEP	Meghalaya	Umium & Umtru

East Flowing Peninsular Rivers

Godavari River System

- The Godavari basin extends over **Maharashtra, Andhra Pradesh, Chhattisgarh, and Odisha**, in addition to smaller parts in **Madhya Pradesh, Karnataka, and Puducherry**.
- This basin accounts for nearly 9.5% of the country's total geographical area.

- The basin is bounded by **Satmala hills**, **Ajanta range**, and **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 basin is the **second largest basin in India**.
- **Godavari River** rises from **Trimbakeshwar** in the Nashik district of Maharashtra. Also called **Daksina Ganga** or **Vridha Ganga**, it is the **largest Peninsular India river** that drains into the **Bay of Bengal**.
- The river divides 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 the **lobate type** with a round bulge and many distributaries.
- **Important cities**: Nashik, Paithan, Nizamabad, Rajahmundry, etc.,
- **Right bank tributaries**: Pravara, **Manjira**, and **Maner**.
- **Left bank tributaries**: **Purna**, **Pranhita**, **Indravathi**, and **Sabari**.



Important Hydro-electric Projects (HEP) on the Godavari Basin

Name	States	River
Nizamsagar HEP	Telangana	Godavari
Pench HEP	MP, Maharashtra	Pench
Upper Indravati HEP	Odisha	Indravati

Pranhita River

- The **Penganga River**, which rises in the **Ajanta Range** in Maharashtra, is a **tributary** of the **Wardha River**, which is itself a **tributary** of the **Wainganga River**.

- The **Wardha** originates in the **Satpura Range** in Madhya Pradesh. It flows southward and eventually joins the **Wainganga River** in Maharashtra.
- The **Wainganga River** originates in the **Mahadeo Hills** of Madhya Pradesh.
- The combined waters of the **Penganga River**, the **Wardha River**, and the **Wainganga Rivers** are known as the **Pranahita River**, the **largest tributary of the Godavari River**.
- It forms the boundary between **Maharashtra** and **Telangana**.
- **Major Tributaries: Wainganga, Wardha, Penganga and Peddavagu.**

[UPSC 2015] Consider the following rivers:

- 1) Vamsadhara
- 2) Indravati
- 3) Pranahita
- 4) Pennar

Which of the above are tributaries of Godavari?

- a) 1, 2 and 3
- b) 2, 3 and 4
- c) 1, 2 and 4
- d) 2 and 3 only

Explanation

Vamsadhara River

- The **Vamsadhara River** is a river that flows through the states of **Odisha** and **Andhra Pradesh**.
- It originates in the **Eastern Ghats** in the Kalahandi district of Odisha and **drains into the Bay of Bengal** at **Kalingapatnam** in Andhra Pradesh.

Indravati River

- The **Indravati River** is a river that flows through the states of Chhattisgarh, Odisha, and Andhra Pradesh in India.
- It originates in the **Eastern Ghats** in the Kalahandi district of **Odisha** and flows for a distance of 535 kilometres before joining the **Godavari River** at **Bhadrachalam** in Telangana.

Pranahita River

- It flows through the states of Maharashtra, Telangana, and Andhra Pradesh in India.
- It joins the Godavari River at **Khammam** in Telangana.

Pennar River

- The **Pennar River** is a river that flows through the states of **Karnataka** and **Andhra Pradesh** in India. It originates in the **Nandi Hills** in the Chikaballapur district of Karnataka.
- It empties into the Bay of Bengal at Nellore in Andhra Pradesh.

Answer: d) 2 and 3 only

[UPSC 1996] Consider the following rivers:

1. Kishenganga
2. Ganga
3. Wainganga
4. Penganga

The correct sequence of these rivers when arranged in the north-south direction is

- a) 1, 2, 3, 4
- b) 2, 1, 3, 4
- c) 2, 1, 4, 3
- d) 1, 2, 4, 3

Explanation

- **Kishenganga River:** This river is a **tributary** of the **Jhelum River** and flows primarily in Jammu and Kashmir. While it originates in the Himalayas, its location is further north compared to the source of the Ganga River.

Answer: a) 1, 2, 3, 4

Krishna River System

- Krishna Basin extends over **Andhra Pradesh, Maharashtra, and Karnataka**, which is nearly 8% of the total geographical area of the country.
- The basin is bounded by the **Balaghat range** on the north, the **Eastern Ghats** on the south and the east, and the **Western Ghats** on the west.
- Krishna River rises near **Mahabaleshwar**, Maharashtra, and drains into the **Bay of Bengal**.
- It is a major source of irrigation for the states through which it flows, namely Andhra Pradesh, Maharashtra, and Karnataka.
- The delta of the Krishna River is one of the largest in India.
- **Right bank tributaries:** Ghatprabha, Malprabha, and Tungabhadra.
- **Left bank tributaries:** Bhima, Musi, and Munneru.

Tungabhadra River

- The Tungabhadra River is formed by the confluence of two rivers, the **Tunga** and **Bhadra**. It flows through Karnataka, Telangana and AP and ultimately joining the **Krishna River** in Telangana.
- The wedge of land that lies north of the Tungabhadra River, between the Tungabhadra and the Krishna, is known as the **Raichur Doab**.
- The **Tungabhadra Dam** also known as **Pampa Sagar** is constructed across the river near the **iron ore mining town of Hosapete**.
- **Hampi**, a **UNESCO World Heritage Site**, is situated on its banks.

Important Hydro-electric Projects (HEP) in the Krishna Basin

Name	States	River
Dudhganga HEP	Maharashtra	Dudhganga
Ghatprabha HEP	Karnataka	Ghatprabha
Nagarjunasagar HEP	Telangana, Andhra Pradesh	Krishna
Srisaillam HEP	Telangana, Andhra Pradesh	Krishna
Tungabhadra HEP	Andhra Pradesh, Karnataka	Tungabhadra



[UPSC 2023] Consider the following statements:

1. Jhelum River passes through Wular Lake.
2. Krishna River directly feeds Kolleru Lake.
3. Meandering of Gandak River formed Kanwar Lake.

How many of the statements given above are correct?

- a) Only one
- b) Only two
- c) All three
- d) None

Explanation

Jhelum River and Wular Lake

- **Wular Lake**, situated in Jammu and Kashmir, is the **largest freshwater lake in India**.
- It covers approximately 189 square kilometers during monsoon season, though its size can diminish to as little as 30 square kilometers in the dry season.
- The lake, **crucial for controlling the flow of the Jhelum River**, lies about 20 miles (32 km) north-northwest of **Srinagar**.
- Jhelum River courses through the lake, entering from the south and exiting from the north, playing a vital role in the region's hydrology.

Kolleru Lake

- **Kolleru Lake** is located **between the deltas** of **Krishna** and **Godavari** Rivers in Andhra Pradesh.
- The lake receives water from the seasonal **Budameru and Tammileru streams**, which are integral to its ecosystem.
- Kolleru Lake functions as a **natural flood-balancing reservoir** for the region, interconnected with numerous inflowing drains and channels from both the Krishna and Godavari systems.

Kanwar Lake and Gandak River

- **Kanwar Lake**, alternatively known as **Kabar Taal**, is **Bihar's largest freshwater oxbow lake**. It is situated about 22 kilometres northwest of **Begusarai** between the **Bhuri Gandak (a tributary of the Ganges)** and the **Bagmati River (a tributary of Kosi)**.
- The lake's formation is attributed to the historical **meandering** of the **Gandak River**, a tributary of the Ganges, over geological epochs.
- Its shallow waters are now sustained by both the **Bhuri Gandak River (which flows in the former channel of Gandak)** and rainwater.

Answer: b) Only two

[UPSC 1997] The Alamatti is on the river:

- a) Godavari
- b) Kaveri
- c) Krishna
- d) Mahanadi

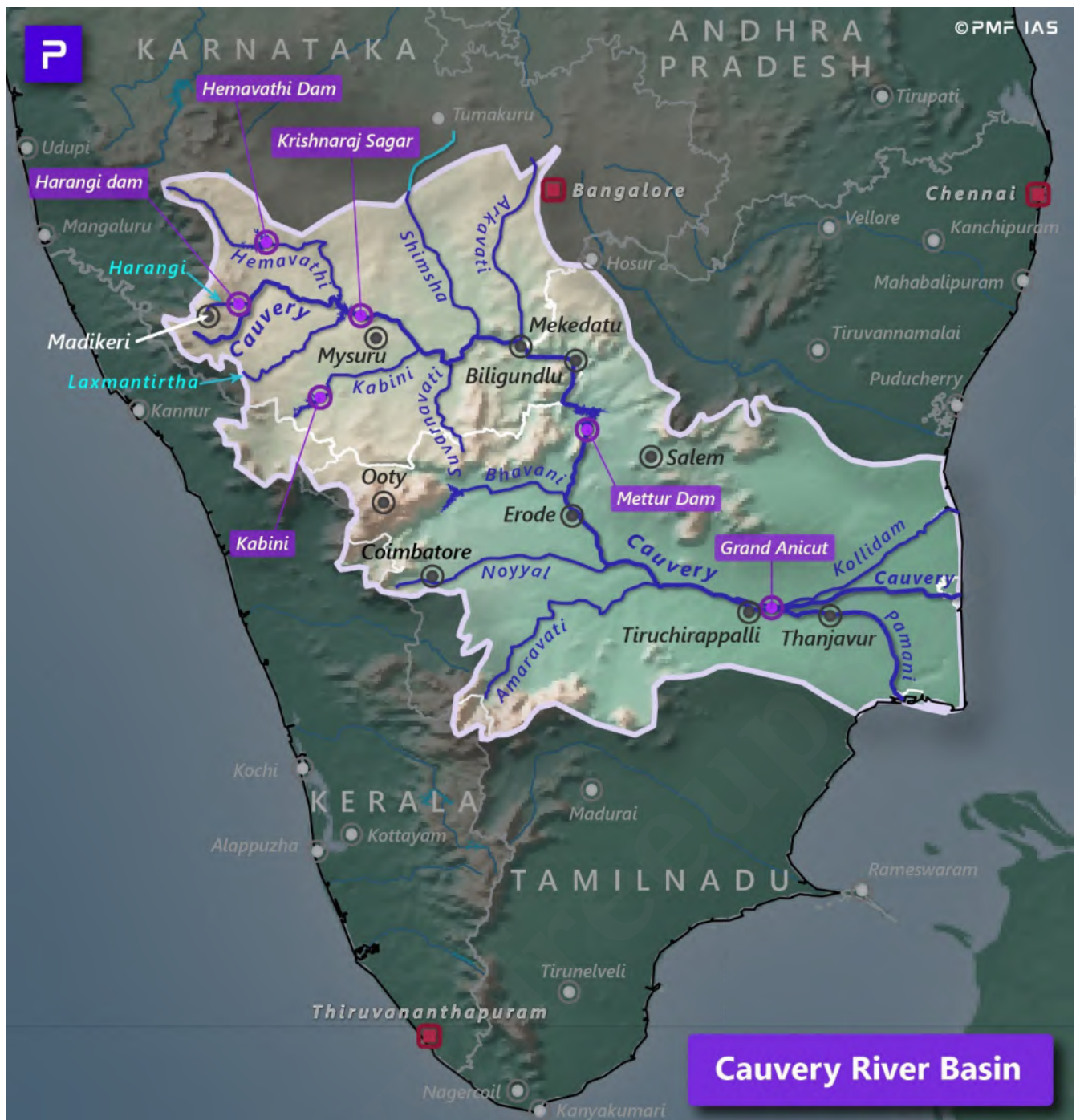
Explanation

- The **Alamatti Dam**, also known as the **Lal Bahadur Shastri Dam**, is a hydroelectric project located on the **Krishna River** in the Bijapur district of Karnataka. The dam was completed in 2005 and is the main reservoir of the **Upper Krishna Irrigation Project**.

Answer: c) Krishna

Cauvery River System

- The Cauvery basin extends over **Tamil Nadu, Karnataka, Kerala, and Puducherry**, which is nearly 2.7% of the country's total geographical area.



- The **Western Ghats** bounds the basin on the west, the **Eastern Ghats** on the east and the south, and the ridges separate it from the **Krishna Basin** and **Pennar Basin** on the north.
- The Cauvery (Kaveri) River rises on the **Brahmagiri Hills** of Kodagu district, Karnataka, and drains into the **Bay of Bengal**. It is the **second largest east-flowing river of Peninsular India**.
- **Left bank tributaries:** Harangi, Hemavati, Shimsha, and Arkavati.
- **Right bank tributaries:** Lakshmantirtha, Kabini, Suvarnavati, Bhavani, Noyyal, and Amaravati.

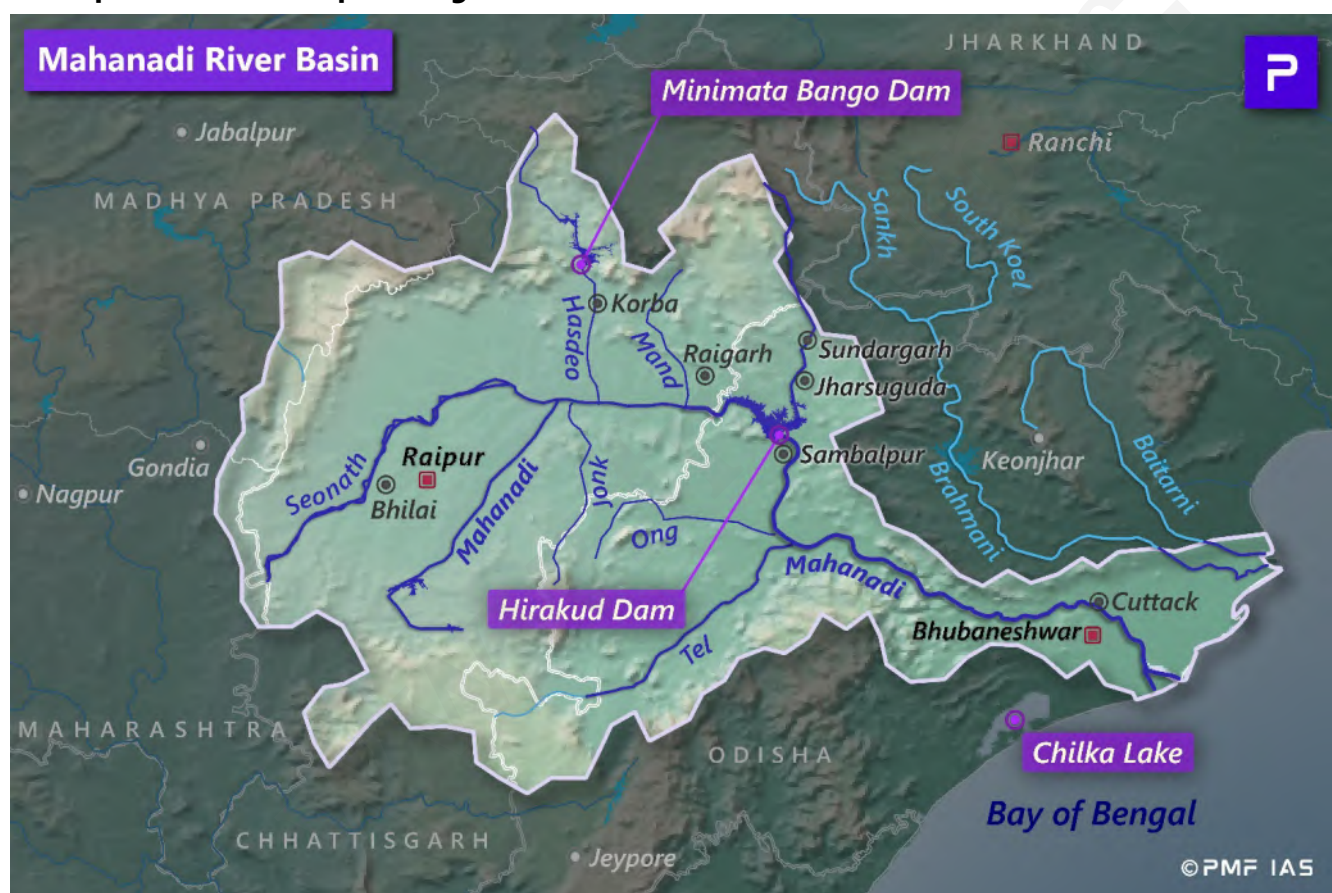
Important Hydro-electric Projects (HEP) in the Cauvery Basin

Name	States	River
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Mettur HEP	TN	Cauvery
Lower Bhavani HEP	TN	Bhavani
Seshadhri Iyer (Sivasamudram) HEP	Karnataka	Cauvery
Simshapura HEP	Karnataka	Cauvery

Mahanadi River System

- Mahanadi basin extends over **Chhattisgarh, Odisha**, and comparatively smaller portions of **Jharkhand, Maharashtra**, and **Madhya Pradesh**, nearly 4.3% of the country's total geographical area.
- The basin is bounded by the **Central India hills** on the north, the **Eastern Ghats** on the south and east, and the **Maikala range** on the west.
- Six small streams between the Mahanadi and the **Rushikulya** draining directly into the **Chilka Lake** are also part of the basin.
- In water potential and flood-producing capacity, the Mahanadi River ranks second to the **Godavari**.
- It originates from the **Raipur** district of **Chhattisgarh**.
- **Left bank tributaries:** Seonath, Hasdeo, Mand, and Ib.
- **Right bank tributaries:** Ong, Tel, and Jonk.
- **Important cities:** Raipur, Durg, Cuttack, etc.



Important Hydro-electric Projects (HEP) on the Mahanadi Basin

Name	States	River
Hasdeo Bango HEP	Chhattisgarh	Hasdeo

Hasdeo River

- The Hasdeo River, the largest tributary of **Mahanadi River**, flows through **Hasdeo Arand forest**. The forest is a catchment area of **Hasdeo Bango Dam**.
- Called as **lungs of Chhattisgarh**, **Hasdeo Arand** is a large forest in Korba, Sujapur and Sarguja districts with a sizeable tribal population. It is the largest unfragmented forest in Central India consisting of pristine **Sal** and **teak** forests.

Subernarekha River System



- Subernarekha basin extends over **Jharkhand**, **Odisha**, and **West Bengal**.

- Situated in the north-east corner of Peninsular India, the basin is bounded by the **Chota Nagpur plateau** on the north and west, ridges separating it from **Baitarani basin** on the south, **Bay of Bengal** on the south-east and **Kasai Valley** on the east.
- The **Subernarekha River** rises in the **Ranchi district** of Jharkhand and flows into the Bay of Bengal.
- **Right bank tributaries:** Kanchi, Karkari, and Kharkai.
- **Left bank tributaries:** Dulang.

Brahmani and Baitarni River System

- The basin consisting of Brahmani and Baitarni extends over **Odisha, Jharkhand, and Chhattisgarh**, which is nearly 1.7% of the total geographical area of the country.
- The basin is bounded by the **Chhotanagpur Plateau** on the north, by the ridge separating it from the **Mahanadi Basin** on the west and the south and by the Bay of Bengal on the east.
- The Brahmani sub-basin is larger and has a long sausage shape. The Baitarni sub-basin is smaller and roughly circular.
- **Brahmani River** is the **second largest river in Odisha**. It comes into existence by the confluence of **South Koel** and **Sankh** Rivers.
- Sankh River and South Koel Rivers originate in **Chhattisgarh** and **Jharkhand** respectively.
- **Important tributaries of Brahmani:**
 - ❖ **Left bank:** Karo, Sankh
 - ❖ **Right bank:** Tikra
- **Baitarni River** rises in **Kendujhar, Odisha** and is known as Dhamra in its lower reaches.
- **Tributaries of Baitarni:** Salandi and Matai.
- Brahmani and Baitarni **form a common delta** area before draining into the Bay of Bengal.
- **HEP:** Rengali HEP (Odisha)

[UPSC 2011] Two important rivers- one with its source in Jharkhand (and known by a different name in Odisha), and another, with its source in Odisha- merge at a place only a short distance from the coast of Bay of Bengal before flowing into the sea. This is an important site of wildlife and biodiversity and a protected area. Which one of the following could be this?

- Bhitarkanika
- Chandipur-on-sea
- Gopalpur-on-sea
- Simlipal

Explanation

- **Bhitarkanika National Park** is located in the state of Odisha. The park is **known for its mangrove forests**, which serve as a critical habitat for the **endangered saltwater crocodile**.
- **Brahmani** and **Baitarani rivers** merge at a place close to the coast of the Bay of Bengal before flowing into the sea. This merging point is within the **Bhitarkanika National Park**.

Answer: a) Bhitarkanika

Pennar (Uttara Pinakini) River System

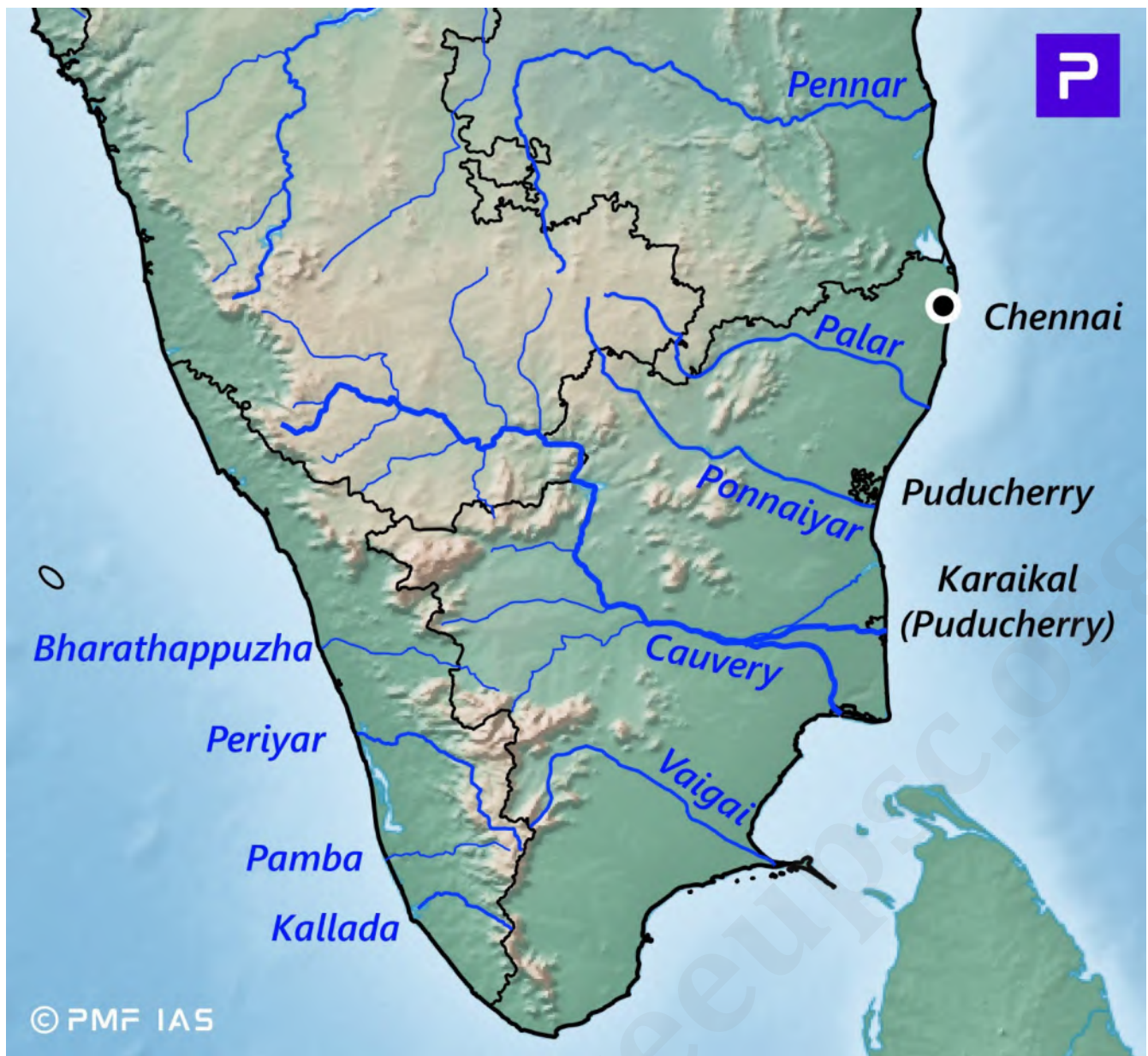
- The fan-shaped Pennar basin extends over **Andhra Pradesh** and **Karnataka**.
- The basin is bounded by the **Erramala range** on the north, **Eastern Ghats** on the east, **Nandidurg hills** on the south and a ridge separating it from the **Krishna Basin** on the west.
- Pennar River rises in the **Chenna Kasava hill** of the **Nandidurg range** in Karnataka.
- **Left bank tributaries:** Jayamangali, Kunderu, and Sagileru.
- **Right bank tributaries:** Chiravati, Papagni, and Cheyyeru.



Other East-Flowing Peninsular Rivers

Palar River

- It rises in the **Nandi Hills** in Chikaballapura district of Karnataka state. It flows through Karnataka, Andhra Pradesh and Tamil Nadu before emptying into the Bay of Bengal at Vayalur, about 75 kilometres south of Chennai.
- **Palar River** water from Palar Anicut is diverted to **Chembarambakkam Lake**, which is located in the **Adayar River** (flows through **Chennai**) basin.



Ponnaiyar River

- The **Ponnaiyar (South Pennar) River** originates in the **Nandi Hills** in the Chikkaballapura district of Karnataka and flows through Tamil Nadu before emptying into the Bay of Bengal. It flows between the Palar River and the Cauvery River.
- **Bangalore**, Hosur, Kaveripattinam, and Cuddalore are the important cities on its banks. Hence, it ends up as one of the **most severely polluted rivers in the region**.

Vaigai River

- The Vaigai is a river in Tamil Nadu. It passes through the towns of Madurai and Ramanathapuram.
- It originates in the **Varusanadu Hills** of the **Western Ghats** and flows northeast through the Kam-bam Valley, which lies between the **Palani Hills** to the north and the **Varushanad Hills** to the south.
- The **Vattaparai Falls** are located on this river. The river empties into the **Palk Bay** near Alagankulam, close to **Pamban Bridge** in Ramanathapuram District.



[UPSC 2022] Gandikota canyon of South India was created by which one of the following rivers.

- a) Cauvery
- b) Manjira
- c) Pennar
- d) Tungabhadra

Explanation

- The **Pennar River** flows through the **Kadapa district**, where it carves through the rocky landscape, forming the **Gandikota Canyon**. It is also known as the **Grand Canyon of India**.
- The **Gandikota region** is home to several historical and cultural attractions, including:
 - ❖ **Gandikota Fort**: A 13th-century fort perched atop the canyon cliffs, offering panoramic views of the surrounding area.
 - ❖ **Belum Caves**: The second-largest cave system in India, known for its **stalactites** and **stalagmites**.

Answer: c) Pennar

[UPSC 2021] Consider the following rivers:

- 1. Brahmani
- 2. Nagavali
- 3. Subarnarekha
- 4. Vamsadhara

Which of the above rises from the Eastern Ghats?

- a) 1 and 2
- b) 2 and 4
- c) 3 and 4
- d) 1 and 3

Explanation

Brahmani River

- The convergence of the **Sankh** and **South Koel** rivers near **Rourkela** forms the Brahmani River.

Nagavali River

- The **Nagavali River** is spread across the states of **Odisha** and **Andhra Pradesh**. Originating in the Kalahandi District within the Eastern Ghats, it flows **between** the **Rushikulya** and **Godavari** basins.
- It drains into the Bay of Bengal near Srikakulam. It has an **independent drainage basin**.

Subarnarekha River

- Originating from the **Ranchi Plateau in Jharkhand**, the **Subarnarekha River** delineates the **boundary** between **West Bengal** and **Odisha** in its **lower course**.
- This river forms an **estuary** between the deltas of the Ganga and Mahanadi rivers before emptying into the Bay of Bengal.

Vamsadhara River

- Emerging from the Kalahandi district of Odisha within the Eastern Ghats, the **Vamsadhara River** flows through **Odisha** and along its **boundary** with **Andhra Pradesh**.
- It **drains into the Bay of Bengal** at Kalingapatnam, Andhra Pradesh.
- The Vamsadhara River serves as a vital water source for the **northeastern Andhra region**, supporting irrigation through projects like the Boddepalli Rajagopala Rao Project.

Answer: b) 2 and 4

[UPSC 2009] Consider the following statements:

- There are no east flowing rivers in Kerala.
- There are no west flowing rivers in Madhya Pradesh.

Which of the statements given above is/are correct?

- a) 1 only
- b) 2 only
- c) Both 1 and 2
- d) Neither 1 nor 2

Explanation

- All **major rivers** in **Kerala** (**Periyar**, **Bharathappuzha** and **Pamba**) **flow westward** into the Arabian Sea. Very few rivers, like the **Kabini River** (which originates in the **Wayanad district**), flow **eastward**.

- Most rivers in **Madhya Pradesh** flow **eastward**. However, the two major rivers, **Narmada** and **Tapti**, flow **westward**.

Answer: d) Neither 1 nor 2

[UPSC 2008] Which of the following pairs are correctly matched?

Waterfalls	River
1. Kapildhara Falls	Godavari
2. Jog Falls	Sharavathi
3. Shivasamudram Falls	Cauvery

Select the correct answer using the codes given below:

- a) 1 and 2 only
- b) 2 and 3 only
- c) 1 and 3 only
- d) 1, 2 and 3

Explanation

The pair 'Kapildhara Falls — Godavari' is incorrect

- Kapildhara Falls** is located near the **Narmada River** in Madhya Pradesh.

The pair 'Jog Falls — Sharavathi' is correct

- Jog Falls** is **one of the highest waterfalls in India** and is formed by the **Sharavathi River**.
- The **Sharavathi River** originates in the Western Ghats of Karnataka and plunges into four distinct segments to form the **Jog Falls**.

The pair 'Shivasamudram Falls — Cauvery' is correct

- Shivasamudram Falls** is formed by the **Cauvery River** and is located in the state of Karnataka.
- The waterfall is divided into two segments — **Gaganachukki** and **Bharachukki**.

Answer: b) 2 and 3

[UPSC 2002] The correct sequence of the eastward flowing rivers of the peninsular India from north to south is :

- a) Subarnarekha, Mahanadi, Godavari, Krishna, Pennar, Cauvery and Vagai
- b) Subarnarekha, Mahanadi, Krishna, Godavari, Cauvery and Vagai
- c) Mahanadi, Subarnarekha, Godavari, Krishna, Cauvery, Pennar and Vagai
- d) Mahanadi, Subarnarekha, Krishna, Godavari, Cauvery, Vagai and Pennar

Explanation

- Subarnarekha River:** Flows through Jharkhand, Odisha, and West Bengal.
- Mahanadi River:** Flows through Chhattisgarh and Odisha.
- Godavari River:** Flows through Maharashtra, Telangana, Andhra Pradesh, and Chhattisgarh.

- **Krishna River:** Flows through Maharashtra, Karnataka, Telangana, and Andhra Pradesh.
- **Pennar River:** Flows through Karnataka and Andhra Pradesh.
- **Cauvery River:** Flows through Karnataka, Tamil Nadu, and Puducherry.
- **Vaigai River:** Flows through Tamil Nadu before draining into the **Palk Strait**.

Answer: a) Subarnarekha, Mahanadi, Godavari, Krishna, Pennar, Cauvery and Vagai

[UPSC 2006] Which one of the following statements is not correct?

- a) Mahanadi River rises in Chhattisgarh
- b) Godavari River rises in Maharashtra
- c) Cauvery River rises in Andhra Pradesh
- d) Tapti River rises in Madhya Pradesh

Explanation

- The Cauvery River originates at **Talakaveri** in the Western Ghats in the **Kodagu district** of Karnataka. It then flows through Tamil Nadu and **Puducherry** before draining into the Bay of Bengal.

Answer: c) Cauvery River rises in Andhra Pradesh (not correct)

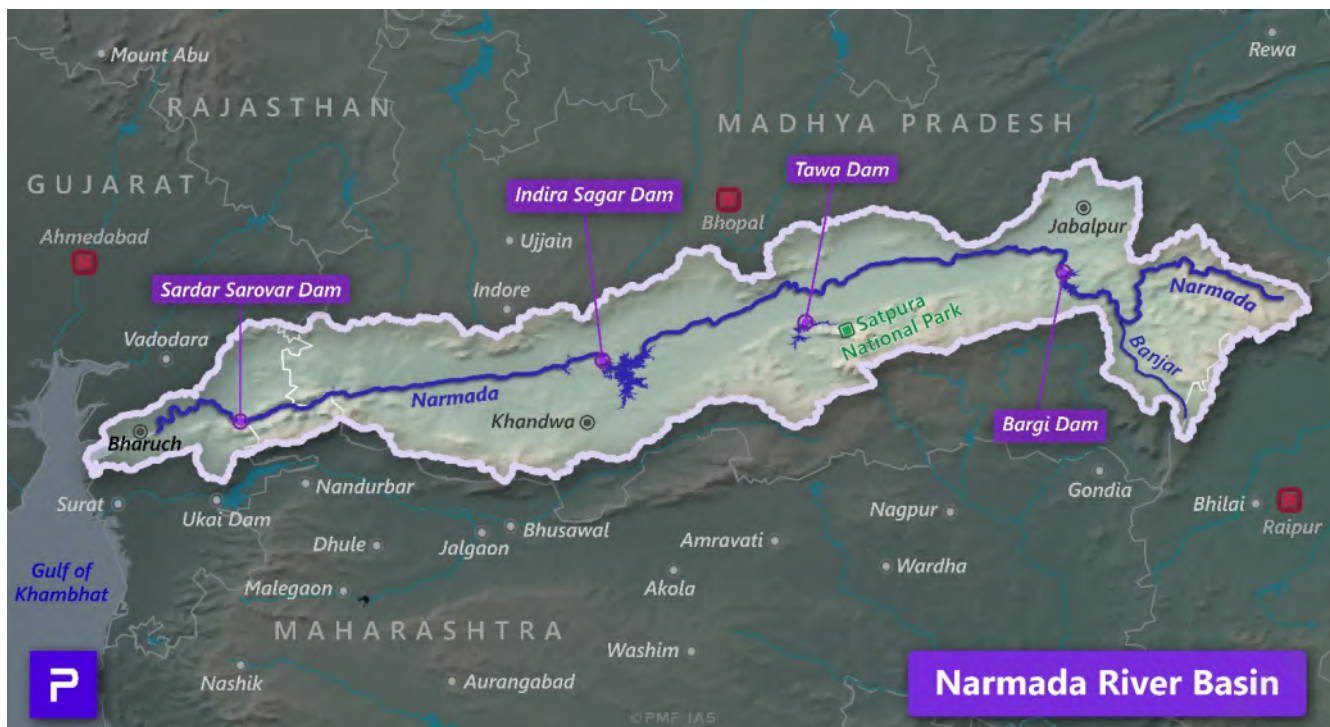
West Flowing Peninsular Rivers

Narmada River System

- The Narmada basin extends over **MP, Gujarat, Maharashtra**, and **Chhattisgarh**, which is nearly 3% of the country's total geographical area.
- The basin is bounded by **Vindhyas** on the **north**, by the **Maikala range** on the **east**, by **Satpuras** on the **south**, and by the **Arabian Sea** on the west.
- Narmada, with a length of **1,312 km**, is the **largest west-flowing river in peninsular India**. It flows through the states of Madhya Pradesh and Gujarat.
- It is the fifth-largest river in the country and the largest one in Gujarat.
- It originates from the **Amarkantak plateau** of MP. It flows **westwards** in a **rift valley** between the **Satpura** in the south and the **Vindhyan range** in the north.
- It forms a picturesque gorge in marble rocks and **Dhuandhar waterfall** near Jabalpur.
- It drains into the **Arabian Sea** through the **Gulf of Khambhat**.
- **Left bank tributaries:** Burhner, **Banjar**, Sher, Shakkar, Dudhi, **Tawa**, Ganjal, Kundi, Goi, and Karjan.
- **Right bank tributaries:** Hiran, Tendoni, Barna, Kolar, Man, Uri, Hatni, and Orsang.

Important Hydro-electric Projects (HEP) in the Narmada Basin

Name of HEP	States	River
Indira Sagar HEP	MP	Narmada
Sardar Sarovar HEP	Gujarat, MP, Maharashtra	Narmada
Tawa HEP	MP	Tawa



[UPSC 2013] The Narmada River flows to the west, while most other large peninsular rivers flow to the east. Why?

1. It occupies a linear rift valley.
2. It flows between the Vindhyas and the Satpuras.
3. The land slopes to the west from Central India.

Select the correct answer using the codes given below.

- a) 1 only
- b) 2 and 3
- c) 1 and 3
- d) None

Explanation

- The Narmada River flows through a **linear rift valley**. This valley is a long, narrow depression in the Earth's crust formed by tectonic plate movements. The formation of the rift valley created a slope in the land, tilting westward.
- While the mountain ranges do flank the Narmada River, they are not the direct cause of its westward flow. The presence of these mountain ranges is a consequence of the same geological processes that created the Rift Valley.
- While the land does have a slight westward tilt from central India, it's not the main factor determining the Narmada River's direction.

Answer: a) 1 only

[UPSC 2019] At which one of the following places do two important rivers of India originate; while one of them flows towards north and merges with another important rivers flowing towards Bay of Bengal, the other one flows towards Arabian Sea?

- a) Amarkantak
- b) Badrinath
- c) Mahabaleshwar
- d) Nasik

Explanation

Narmada River

- The Narmada River originates at **Amarkantak** and **flows westwards** into the Arabian Sea.

Son River

- The **Son River** also originates at **Amarkantak** and flows **northward**, eventually merging with the **Ganges River (Ganga)**, an important river that flows into the Bay of Bengal.

Answer: a) Amarkantak

[UPSC 2007] Which one of the following rivers originates in Amarkantak?

- a) Damodar
- b) Mahanadi
- c) Narmada
- d) Tapi

Answer: c) Narmada

[UPSC 2008] With which one of the following rivers is the Omkareshwar Project associated?

- a) Chambal
- b) Narmada
- c) Tapi
- d) Bhima

Explanation

- The Omkareshwar Project is a **multipurpose river valley project** located on the **Narmada River** in the Khandwa district of Madhya Pradesh.
- It is named after the **Omkareshwar Temple**, which is located nearby.
- The project includes the construction of the Omkareshwar Dam, which serves multiple purposes, such as hydroelectric power generation, irrigation, and flood control.

Answer: b) Narmada

[UPSC 2008] Consider the following pairs:

Tributary River	Main River
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1. Chambal	Narmada
2. Sone	Yamuna
3. Manas	Brahmaputra

Which of the pairs given above is/are correctly matched?

- a) 1, 2 and 3
- b) 1 and 2 only
- c) 2 and 3 only
- d) 3 only

Explanation

- The **Chambal River** is a tributary of the **Yamuna River**.
- The **Sone River** is a tributary of the **Ganges (Ganga) River**.
- The **Manas River** is indeed a tributary of the **Brahmaputra River**. It originates in Bhutan, flows through the state of Assam in India, and eventually joins the Brahmaputra River.

Answer: d) 3 only

Tapti (or Tapi) River System

- Situated in the **Deccan plateau**, the Tapti basin extends over **MP, Maharashtra, and Gujarat**.
- The basin is bounded by the **Satpura Range** on the **north**, by the **Mahadev Hills** on the **east**, by the **Ajanta Range** and the **Satmala Hills** on the **south** and by the **Arabian Sea** on the west.
- Tapti River originates near the **Multai reserve forest** in the Betul district of **MP**.
- It is the **second-largest west-flowing river in peninsular India**.
- It is known as 'the twin' or 'the handmaid' of the Narmada.
- **Right bank tributaries:** Suki, Gomai, **Arunavati**, and Aner.
- **Left bank tributaries:** Vaghur, **Amravati**, Buray, **Panjhra**, **Bori**, **Girna**, **Purna**, Mona, and Sipna.



Important Hydro-electric Projects (HEP) in the Tapi Basin		
Name	States	River
Ukai HEP	Gujarat	Tapi

Sabarmati River System

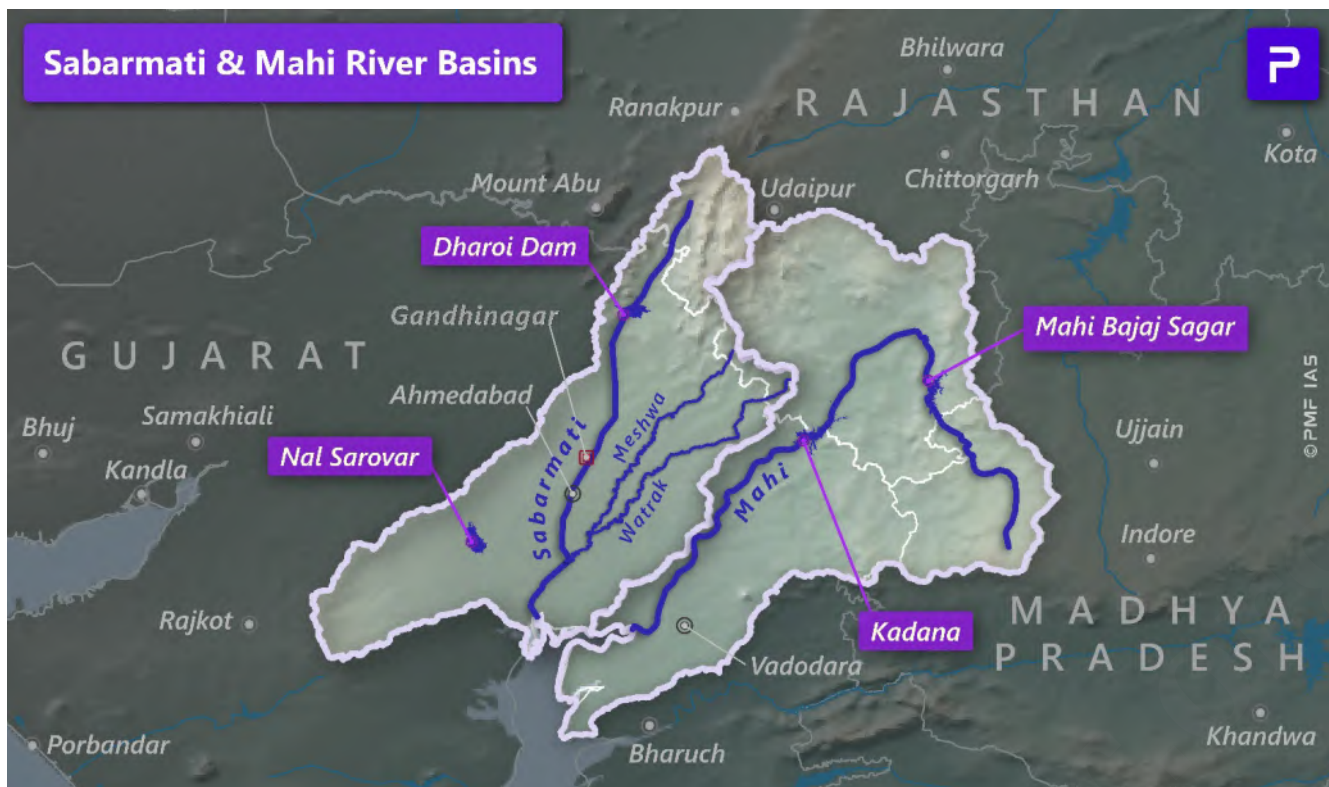
- The Sabarmati basin extends over the states of **Rajasthan** and **Gujarat**.
- The basin is bounded by **Aravalli hills** on the north and northeast, by **Rann of Kutch** on the west, and by the **Gulf of Khambhat** on the south.
- The basin is **roughly triangular**, with the Sabarmati River as the base and the source of the **Vatrak River** as the apex point.
- The **seasonal Sabarmati River** rises from **Aravalli hills** in **Udaipur**, Rajasthan, and drains into the Arabian Sea. It flows through the **Dharoi gorge**.
- **Left bank tributaries:** Wakal, Hathmati, and **Vatrak**.
- **Right bank tributaries:** Sei.
- **HEP:** Ukai HEP (Gujarat)



Mahi River System

- Mahi basin extends over **Madhya Pradesh**, **Rajasthan**, and **Gujarat**.
- The basin is bounded by **Aravalli hills** on the north and the northwest, by the **Malwa Plateau** on the east, by the **Vindhyas** on the south, and by the Gulf of Khambhat on the west.
- The **Mahi River** originates from the **Vindhyas** in the Dhar district of MP. It drains into the **Arabian Sea** through the Gulf of Khambhat. It crosses the Tropic of Cancer twice.
- **Right bank tributaries:** Som.

- **Left bank tributaries:** Anas and Panam.
- **HEP:** Kadana HEP (Gujarat), Mahi HEP (Rajasthan).



Periyar River System

- **Periyar River**, which rises in the **Sivagiri Hills** in Western Ghats, is the **longest river of Kerala**.
- It flows through **Tamil Nadu** and **Kerala**.
- It bifurcates into two branches:
 1. One branch joins the Chalakudi River and then expands into a broad sheet of water.
 2. Another branch falls into the **Vembanad Lake**.
- **Major tributaries:** Muthirapuzha, Mullayar, Cheruthoni, Perinjankutti, Edamala.
- **Important hydroelectric projects:** **Idduki HEP (Kerala)**, **Periyar HEP (TN)**.

Bharathapuzha (Ponnani) River System

- Bharathapuzha basin spreads over **Tami Nadu** and **Kerala**. This basin is bounded to the east by the **Cauvery Basin** and to the west by the **Arabian Sea**.
- The basin experiences **heavy rainfall** during the southwest monsoon, varying from 2,00 to 2,80 cm in the hilly region and up to 3,00 cm in the coastal area.
- **Bharathapuzha River** is **Kerala's second longest west-flowing river**.
- It rises in the **Anamalai hills (TN)** of the Western Ghats and drains into the **Arabian Sea**.
- It originates as **Aliyar**, and when it enters Kerala, it is called the **Kannadipuzha**.
- After its confluence with the **Kalpathipuzha**, it is known as Bharathapuzha.
- **Right bank tributaries:** Kalpathipuzha, Pulanthode.
- **Left bank tributaries:** Gayathripuzha.

Pamba River

- The **Pamba (Pampa) River** is the **third longest river in Kerala** after **Periyar** and **Bharathappuzha**.
- It originates at **Pulachimalai Hill** in the Western Ghats and empties into the **Vembanad Lake**.
- The river is also known as **Dakshin Bhagirathi**. **Sabarimala temple**, dedicated to **Lord Ayyappa**, is located on its banks.

Luni River System

- **Luni** originates from the **Aravalli ranges** near Ajmer in Rajasthan, where it is called **Sagarmati**.
- It is primarily **endorheic**, and it **does not drain into the sea**. It dissipates into the **Rann of Kachchh**.
- It is the **largest river in the Thar Desert** of northwest India.
- **Left bank tributaries**: Jawai, Sukri, Guhiya, Bandi, Liladi River.
- **Right bank tributaries**: Jojari.

[UPSC 2010] With reference to, the river Luni, which one of the following statements is correct?

- a) It flows into Gulf of Khambhat
- b) It flows into Gulf of Kutch
- c) It flows into Pakistan and merges with a tributary of Indus
- d) It is lost in the marshy land of the Rann of Kutch

Explanation

- The Luni River is **lost in the marshy land of the Rann of Kutch**. This means that the river does not have a definitive endpoint where it flows into the sea or merges with another major river.
- Instead, it **dissipates into the marshy and desert landscape** of the Rann of Kutch, which is a vast salt marsh located in the western part of Gujarat and the southeastern part of Pakistan.

Answer: d) It is lost in the marshy land of the Rann of Kutch

[UPSC 2004] Assertion and Reasoning

Assertion (A): West-flowing rivers of Peninsular India have no deltas

Reason (R): These rivers do not carry any alluvial sediments.

- a) Both A and R are individually true and R is the correct explanation of A
- b) Both A and R are individually true but R is not the correct explanation of A
- c) A is true but R is false
- d) A is false but R is true

Explanation

- The **Narmada, Tapti** and **other west-flowing rivers of Peninsular India do not form deltas**. Instead, they have **estuaries or small, irregular mouths** where they meet the sea.
- This absence of deltas is characteristic of these west-flowing rivers in Peninsular India.

- The topography of western peninsular India is **rocky terrain** that **lacks loose sediments**, especially in the areas through which the Narmada and Tapti rivers flow.
- Additionally, the rivers in this region **do not carry significant amounts of alluvial sediments** due to their **shorter courses** and the nature of the geological formations they traverse.

Answer: a) Both A and R are individually true and R is the correct explanation of A (according to UPSC). This solution is debatable as the phrase "do not carry any" is too absolute to be true.

Major Facts About Indian Rivers

Top 10 Longest Rivers of India

River Name	Length (in km)
1. Ganga	2525
2. Godavari	1465
3. Krishna	1400
4. Yamuna	1376
5. Narmada	1312
6. Indus	1114 in India; Total length: 3180
7. Brahmaputra	916 in India; Total length: 2900
8. Mahanadi	851
9. Cauvery	800
10. Tapti	724

In terms of total length, Indus > Brahmaputra > Ganga

Rivers and Major Cities on Their Banks

Major City	River
Ferozpur, Ludhiana	Sutlej
Patna, Kanpur, Kannauj, Varanasi, Haridwar	Ganga
Badrinath	Alaknanda
Rishikesh	Confluence of the Chandrabhaga and Ganga
Purnia	Kosi (a tributary of Ganga)
Delhi, Agra, Mathura	Yamuna (a tributary of Ganga)
Gaya	Falgu or Neeranjana (a tributary of Ganga)
Gwalior, Kota	Chambal (a tributary of Ganga)
Ujjain	Shipra River (a tributary of Chambal)
Prayagraj (Allahabad)	At the confluence of Ganga, Yamuna, and Saraswati
Ayodhya	Sarayu, a tributary of Sharda; Sharda is a tributary of Ghaghra, which is a tributary of Ganga

Lucknow	Gomti (a tributary of Ganga)
Asansol	Ajay and Damodar (tributaries of Hooghly)
Durgapur	Ajay (tributary of Hooghly)
Murshidabad, Hooghly, Serampore, Dakshineswar, Howrah, Kolkata	Hooghly (distributary of Ganga)
Burnpur, Kulti	Barakar
Dibrugarh, Guwahati	Brahmaputra
Cuttack	Mahanadi
Rourkela	Brahmani
Barmer	Luni
Ahmedabad	Sabarmati
Surat	Tapi
Vadodara	Vishwamitri (a tributary of Dhadhar, a small west-flowing river of Gujarat)
Bharuch	Narmada
Nashik, Nizamabad	Godavari
Vijayawada, Machilipatnam, Kurnool, Guntur, Amaravati	Krishna
Kurnool	Tungabhadra (a tributary of Krishna)
Pune	Mula and Mutha (tributaries of Bhima , a tributary of Krishna)
Hyderabad	Musi (a tributary of Krishna)
Madurai	Vaigai
Bangalore	Vrishabhavathi and Ponnaiyar ; Vrishabhavathi is a tributary of Arkavathy , which is a tributary of Cauvery
Mangalore	Netravati
Thiruvananthapuram	Karamana
Thrissur, Palakkad	Bharatappuzha
Kochi	Periyar

Major Dams

Name	River	State	Length (m)	Height (m)
Tehri Dam	Bhagirathi	Uttarakhand	575	261
Idukki Dam	Periyar	Kerala	366	169
Bhakra Nangal Dam	Satluj	Himachal Pradesh	518	168
Sardar Sarover	Narmada	Gujarat	1210	163
Ranjit Sagar Dam	Ravi	Punjab	617	145

Srisaileam Dam	Krishna	Telangana	512	145
Pong Dam	Beas	Himachal Pradesh	1951	133
Ramganga Dam	Ramganga	Uttarakhand	630	128
Nagarjuna Sagar Dam	Krishna	Telangana	4865	125
Koyna Dam	Koyna	Maharashtra	808	103
Rihand Dam	Rihand	Uttar Pradesh	932	91
Indira Sagar Dam	Narmada	Madhya Pradesh	654	91
Hasdeo Bango Dam	Hasdeo	Chhattisgarh	555	87
Ukai Dam	Tapi	Gujarat	4927	81
Hirakud Dam	Mahanadi	Odisha	4800	61

- **Tehri Dam** is the **tallest (highest) dam in India**. It is built on the **Bhagirathi River** in Tehri Garhwal district in **Uttarakhand**.
- **Hirakud Dam**, near **Sambalpur** in **Odisha**, is the **longest earthen dam in the world**, measuring 25.8 km, including dykes across the river Mahanadi. The main dam has an overall length of 4.8 km.
- The **Indira Sagar Dam** on the **Narmada River** in MP is the **largest reservoir in India** in terms of the volume of water stored in it. **Nagarjuna Sagar Dam** on the **Krishna River** is the second largest.

Relevant PYQs

[UPSC 2003] What is the correct sequence of the rivers Godavari, Mahanadi, Narmada and Tapi in the descending order of their lengths?

- Godavari–Mahanadi–Narmada–Tapi
- Godavari–Narmada–Mahanadi–Tapi
- Narmada–Godavari–Tapi–Mahanadi
- Narmada–Tapi–Godavari–Mahanadi

Explanation

❖ Godavari River: 1,465 km; Narmada River: 1,312 km; Mahanadi River: 851 km; Tapi River: 724 km

Answer: b) Godavari–Narmada–Mahanadi–Tapi

[UPSC 2019] Consider the following pairs:

Famous Place	River
1. Pandharpur	Chandrabhaga
2. Tiruchirappalli	Cauvery
3. Hampi	Malaprabha

Which of the pairs given above are correctly matched?

- 1 and 2 only
- 2 and 3 only
- 1 and 3 only

d) 1, 2 and 3

Explanation

The pair 'Pandharpur — Chandrabhaga' is correct

- The **Chandrabhaga River**, also known as the **Bhima River**, flows through the town of **Pandharpur** in Maharashtra, India.

⇒ A small river called **Chandrabhaga River** merges with the **Ganges** at Mayakund in **Rishikesh**.

⇒ The **Chenab** or **Chandra Bhaga** is the combined waters of the Chandra and Bhaga rivers.

The pair 'Tiruchirappalli — Cauvery, is also correct

- The **Cauvery River** is the lifeline of **Tiruchirappalli**.

The pair 'Hampi — Malaprabha' is incorrect

- The **Malaprabha River** is a **tributary of the Krishna River**. The **Tungabhadra River**, another **tributary of the Krishna**, is the prominent river associated with **Hampi**, Karnataka, India.

Answer: a) 1 and 2 only

[UPSC 2007] Match List I with List II and select the correct answer using the code given below the lists:

List-I (Town) List-II (River Nearer to it)

- | | |
|--------------|--------------|
| A. Betul | 1. Indravati |
| B. Jagdalpur | 2. Narmada |
| C. Jabalpur | 3. Shipra |
| D. Ujjain | 4. Tapti |

Codes:

- a) A-1; B-4; C-2; D-3
- b) A-4; B-1; C-2; D-3
- c) A-4; B-1; C-3; D-2
- d) A-1; B-4; C-3; D-2

Explanation

A. Betul - Tapti (4)

- Betul is located in the western part of Madhya Pradesh.
- Tapi river originates near Multai reserve forest in Betul district of Madhya Pradesh.

B. Jagdalpur - Indravati (1)

- Jagdalpur is the administrative headquarters of the Bastar district in Chhattisgarh.
- The Indravati River is a **major tributary of the Godavari River** and flows through the Bastar district of Chhattisgarh.

C. Jabalpur - Narmada (2)

- Jabalpur is a city situated on the **banks of the Narmada River** in Madhya Pradesh.
- The Narmada River is one of the largest west-flowing rivers in India and flows through Jabalpur.

D. Ujjain - Shipra (3)

- Ujjain is an ancient city located on **the banks of the Shipra River** in Madhya Pradesh.
- The Shipra River is a tributary of the Chambal River and flows through Ujjain.

Answer: b) A-4; B-1; C-2; D-3

[UPSC 2010] Which one of the following pairs is not correctly matched?

Dam/Lake	River
a) Govind Sagar	Sutlej
b) Kolleru Lake	Krishna
c) Ukai Reservoir	Tapi
d) Wular Lake	Jhelum

Explanation

The pair 'Govind Sagar — Sutlej' is correct

- **Govind Sagar** is a reservoir formed by the **Bhakra Dam** on the **Sutlej River** in **Himachal Pradesh**.
- The Bhakra Dam is one of the **highest gravity dams in the world** and is a crucial water management and hydroelectric power generation facility in India.

The pair 'Kolleru Lake — Krishna' is incorrect

- **Kolleru Lake** is located inland **between** the **deltas** of the Krishna and Godavari rivers.

The pair 'Ukai Reservoir — Tapi is correct

- The **Ukai Dam**, located on the **Tapi River** in Gujarat, forms the Ukai Reservoir. It is a multipurpose project providing irrigation water, hydropower generation, and flood control to the region.

The pair 'Wular Lake — Jhelum' is correct

- **Wular Lake** in Jammu and Kashmir is the **largest freshwater lake in India** and is connected to and fed by the **Jhelum River**.

Answer: b) Kolleru Lake

River Water Disputes

India-Pakistan: Indus Waters Treaty

- In 1947, after the partition, the **Inter-Dominion Accord (1948)** was adopted. It required India to provide water to Pakistan in return for annual payments. The agreement failed.
- Both countries applied to the World Bank for funding of irrigation projects on the Indus System. It was then the **World Bank** offered to mediate the water-sharing dispute.

- In **1960**, the **World Bank mediated Indus Waters Treaty (IWT)** was signed by former **PM Jawaharlal Nehru** and then **President of Pakistan, Ayub Khan**. The former Vice President of the World Bank, **W.A.B. Iliff**, also signed the IWT.

Key Provisions of the Indus Waters Treaty (IWT)

Water Sharing

- IWT prescribed how water from the **six rivers** would be shared between India and Pakistan.
- It allocated the three **western rivers** (i.e., **Indus, Chenab, and Jhelum**) to Pakistan for **unrestricted use**, barring certain non-consumptive, agricultural and domestic uses by India.
- It allocated the three **eastern rivers** (i.e., **Ravi, Beas, and Sutlej**) to India for **unrestricted usage**.
- This meant that **80% of the water went to Pakistan**, leaving 20% of the water for use by India.

Annexure C and D

- Though Pakistan has rights over the waters of Jhelum, Chenab, and Indus,
 - ❖ **Annexure C** of the IWT **allows India certain agricultural uses**
 - ❖ **Annexure D allows India to build 'run of the river' hydropower projects** (projects not requiring live storage of water).
- However, IWT also provides,
 - ❖ **Design specifications** that India **must follow** while developing HEPs.
 - ❖ India **must share the project design** or alterations made to it **with Pakistan**.
 - ❖ **Pakistan can raise objections**, if any, within three months of receipt.
- IWT also allowed India to have a **minimum storage level** on the western rivers for **conservation and flood storage purposes**.

Permanent Indus Commission

- The treaty required that both countries should establish a **Permanent Indus Commission** constituted by permanent commissioners of both sides.
- It functions as **the first step for the resolution of conflicts**. It should meet **at least once a year**.

Dispute Resolution Mechanism

- The IWT also provides a **three-step** graded dispute resolution mechanism.
 1. **First Step:** Disputes can be resolved at the Permanent Commission or inter-government level.
 2. **Second Step:** For unresolved disputes, either side can approach the **World Bank** to appoint a Neutral Expert (NE) to come to a decision.
 3. **Third Step:** If either party is not satisfied with NE's decision or in case of disputes in the interpretation of the treaty, matters can be referred to a **Court of Arbitration (CoA)**.

Issue of India's Hydro Electricity Projects (HEP): The Core of Contention

- The present dispute between the countries involves **Kishanganga** and **Ratle HEP** in J&K, India.
- India considers these projects crucial for the region's energy needs and development.
- While Pakistan has raised objections, citing violations of the treaty and potential negative effects.

- In 2007, India proposed to build the Kishenganga Hydroelectric Project (KHEP).

- ⇒ **Kishenganga HEP:** located on the Bandipore district, J&K, India.
- ⇒ **Kishenganga or Neelum:** a tributary of Jhelum; originates in J&K and joins the Jhelum in PoK.
- ⇒ **Ratle HEP:** It is built on the Chenab River in Kishtwar district, J&K, India

Other Objections Raised by Pakistan Under IWT

- **Salal Dam Project:** Built on the Chenab River in the Reasi district, J&K.
- **Baglihar Hydropower Project:** Built on the Chenab River in the Doda district, J&K.
- **Pakal Dul Project:** Built on the Chenab River in the Kishtwar district, J&K.
- **Lower Kalnai Project:** Built on Kalnai River (a tributary of Chenab) in Kishtwar and Doda, J&K
- **Kiru Project:** Built on the Chenab River in the Kishtwar district, J&K.
- In 2010, Pakistan took the KHEP dispute to the **Permanent Court of Arbitration** at Hague.
- CoA gave its final ruling in 2013 in favour of India, citing that KHEP is a run-of-river dam. However, the CoA stated that India must maintain a minimum flow of water.
- The conflict did not end, and in 2016, **Pakistan** requested the **World Bank** to form a **CoA**. In response, **India** requested a **Neutral Expert (NE)** be appointed to deal with the dispute.
- At that time, the World Bank paused the works on the Kishanganga and Ratle HEP. Despite the pause, **work on KHEP continued**, and in 2018, it was inaugurated.
- In 2022, the World Bank appointed **Michel Lino** as the **Neutral Expert** and **Professor Sean Murphy** as **Chairman of the CoA**.

India's Stand at Present on the Dispute Redressal

- India has been **abstaining from participating** in the proceedings at the Permanent CoA. But it has been **participating** in the Neutral Expert's proceedings.
- India says that in 2015, Pakistan asked for the appointment of a Neutral Expert. But later, in 2016, Pakistan changed its request and requested that the CoA should examine the issue.
- India alleges that Pakistan has violated IWT's dispute resolution mechanism. According to India, such parallel considerations on the same issues were not covered under any provision of the IWT.
- **In July 2023, the Permanent CoA rejected India's objections** and confirmed its competence to resolve the dispute.
- India still **maintains that it will not join Pakistan-initiated proceedings** at the CoA as a Neutral Expert is already examining the dispute under the framework of the IWT.

India's Call for Modification of Indus Water Treaty (IWT)

- India's call for modification of IWT comes after **Pakistan's intransigence** over its implementation.

Reasons for IWT Modification

- IWT should be modified to incorporate the following changes:
 - ❖ More than provisions for dispute redressal through court, the need is **to incorporate "equitable and reasonable utilisation"** and the **"no harm rule"** in the IWT.

- ❖ There is a need to **involve local stakeholders** also in any negotiation process between India and Pakistan on shared water issues.
- ❖ To recognise common interests of both for optimum development of the Indus Rivers System.
- ❖ IWT was signed 62 years ago; amendments may be needed due to changes in the situation in the Indus River Basin region.

Karnataka-Tamil Nadu: Cauvery Water Dispute

History

- The Cauvery dispute stems from the colonial era when the British government allocated the river's waters between the **princely state of Mysore** and **Madras presidency**. These pacts, known as the **1892 and 1924 agreements**, laid the foundation for the dispute.
- In 1924, a definitive agreement allocated fixed water shares to both regions for **50 years**. It allocated **75%** of the Cauvery water to TN and Puducherry, **23%** to Mysore, and the remainder to Kerala (then Travancore).
- It stated that the upper riparian state must obtain **consent** from the lower riparian state for any construction, like reservoirs, on the Cauvery River.
 - ❖ The dams **Krishna Raja Sagar**, Harangi, Hemavati, and Kabini were constructed in Karnataka.
 - ❖ The **Mettur Dam** has been constructed across the mainstream of Cauvery in Tamil Nadu.
- In 1974, after the lapse of the 1924 agreement, Karnataka started diverting water without the consent of Tamil Nadu.

Cauvery Water Disputes Tribunal (CWDT)

- **Union Government**, in 1990, by using the powers of the **Inter-State River Water Disputes Act of 1956**, constituted the **Cauvery Water Disputes Tribunal (CWDT)**.
- In 2007, CWDT issued its final award, specifying water allocations among the states:
 - ❖ **419 TMC to TN**
 - ❖ **270 TMC to Karnataka**
 - ❖ **30 TMC to Kerala**
 - ❖ **7 TMC to Puducherry**

Supreme Court Intervention and the Final Verdict

- In 2018, the **Supreme Court** declared the Cauvery River a national asset and **upheld the CWDT's award**. It also directed the formalisation of the **Cauvery Water Management Scheme**.
- In 2018, SC, in its final verdict, granted **Karnataka** an **additional 14.75 TMC** of river water. Thus, the final allocation for a total of 740 TMC is:
 - ❖ **284.75 (270 + 14.75) TMC to Karnataka**
 - ❖ **404.25 (419 – 14.75) TMC to TN**
 - ❖ **30 TMC to Kerala**
 - ❖ **7 TMC to Puducherry**

- The water allocation arrangement will stand unchanged for the **next 15 years**.
- The Court defined "**surplus water**" as water exceeding the allocated and committed share during high-flow seasons. This surplus water was to be divided equally among the four states: Tamil Nadu, Karnataka, Kerala, and Puducherry.
- The Court directed the establishment of a permanent **Cauvery Management Board (CMB)** to:
 - ❖ Oversee and implement the water-sharing formula.
 - ❖ Monitor water flows and reservoir levels.
 - ❖ Resolve disputes between states related to water allocation.

Cauvery Water Management Authority (CWMA)

- In 2018, under the **Inter-State River Water Disputes Act of 1956**, the Union Government established the **Cauvery Water Management Scheme**, including the **CWMA** and **Cauvery Water Regulation Committee (CWRC)** among its provisions.
- The Authority ensures **compliance** and **implementation** of the **CWDT's Award** as modified by the Supreme Court:
 - ❖ **storage, apportionment, regulation, and control of Cauvery waters**
 - ❖ supervision of the operation of reservoirs and regulation of water releases
 - ❖ **regulated release by Karnataka** at the inter-state contact point presently identified as **Billigundulu gauge** and discharge station, located on the Karnataka-TN border.
- CWRC monitors the **daily water levels, inflows, and storage position** at major reservoirs storing the Cauvery water.

How is the Water Being Shared?

- Cauvery River water is shared between **Karnataka** and **TN** according to a **monthly schedule**.
- In a **Normal Water Year** (June to May), Karnataka will release 177.25 TMC of water to TN.
- During the SW monsoon season (June to September), a total of 123.14 TMC is to be released.
- The Monsoon (deficit) Season is when the Cauvery issue typically flares up.

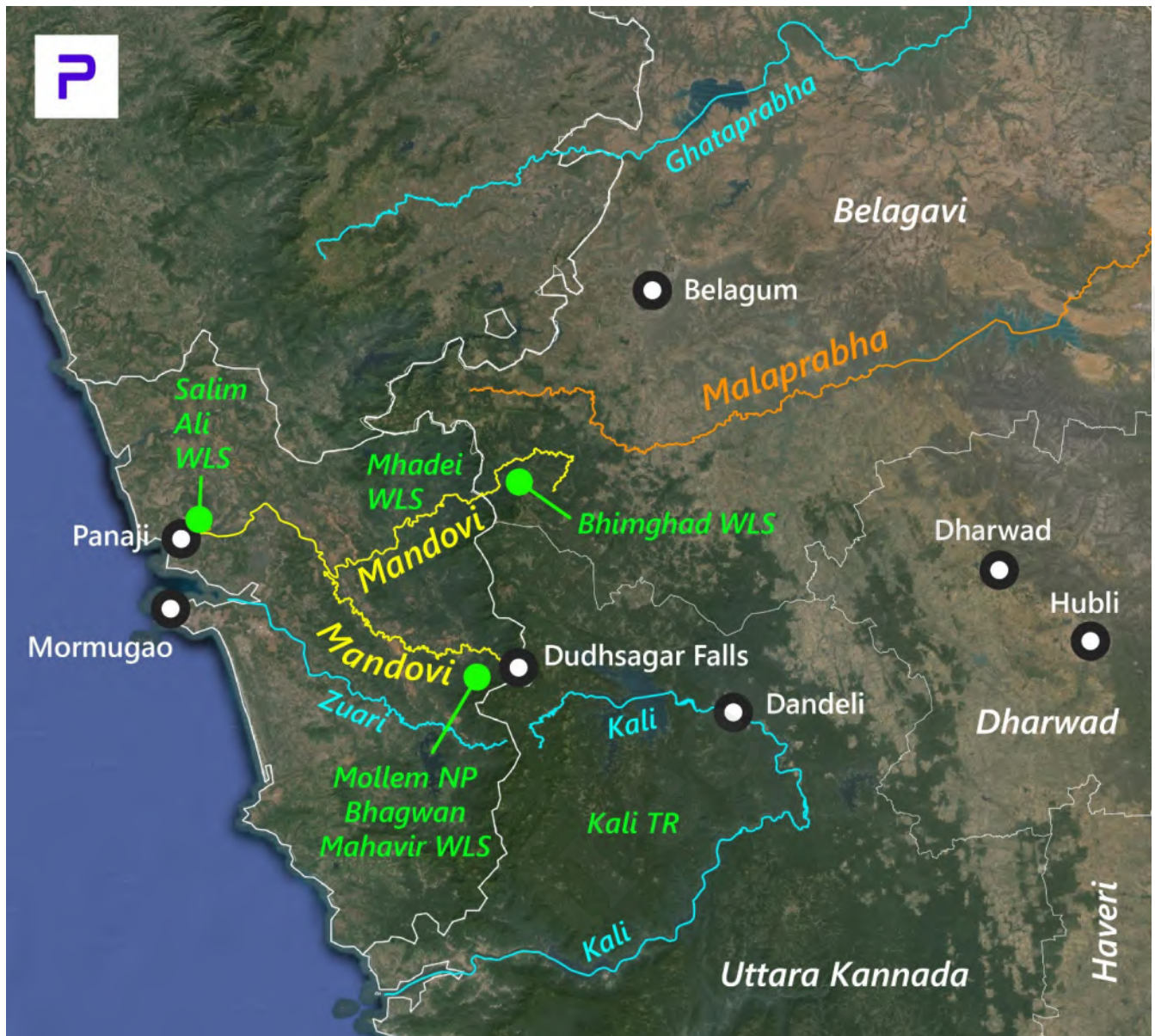
Kuruvai and Samba Cultivation

- **Kuruvai paddy** is a **short-duration (90-120 days) high-yielding** variety of paddy.
- The **Kuruvai season** in Tamil Nadu typically occurs between **June and September**.
- **Samba** is the **second main season of paddy** cultivation in Tamil Nadu, after Kuruvai. The Samba season typically occurs **between August and November**.
- The cultivation of **kuruvai** and **samba paddy** crops relies entirely on water release from the **Mettur dam**, which depends solely on **flows from Karnataka**.
- It is important because the Cauvery Delta receives **very little rainfall** during the southwest monsoon.

Mekedatu Reservoir Project

- The **Mekedatu Reservoir Project** aims to **provide water for drinking purposes to Bengaluru city** and generate approximately **400 megawatts (MW) of power**.
- TN opposes any projects in the upper riparian region unless they receive approval from the Supreme Court to ensure water flow protection to TN.

Karnataka-Goa: Kalasa-Banduri Nala Project



- The **Kalasa-Banduri Nala Project** is a project undertaken by the **Karnataka Government** to improve the **drinking water supply** to the three districts of **Belagavi, Dharwad, and Gadag**.
- It involves building barrages across **Kalasa and Banduri** (two tributaries of the **Mahadayi River**) to divert water to the **Malaprabha River** (a tributary of the **Krishna River**).
- The project was planned in 1989, but Goa objected to it. **Mahadayi Water Disputes Tribunal** was set up in 2010, and Goa, Karnataka, and Maharashtra are parties to the tribunal.
- In 2018, the tribunal awarded 13.42 TMC water from Mahadayi river basin to Karnataka, 1.33 TMC to Maharashtra and **24 TMC to Goa**. The Union Government notified the same in February 2020.

Mahadayi River

- The Mahadayi River (also called **Mhadei** and **Mandovi**) originates in the Western Ghats from the **Bhimgad Wildlife Sanctuary** in the Belagavi district of **Karnataka**.
- It is a westward flowing river that flows through Karnataka and Goa and then drains into the Arabian Sea. It is the lifeline of Goa. (**Mandovi** and **Zuari** are the two primary rivers of Goa).

Interlinking of Rivers (ILR) or Inter Basin Water Transfer (IBWT)

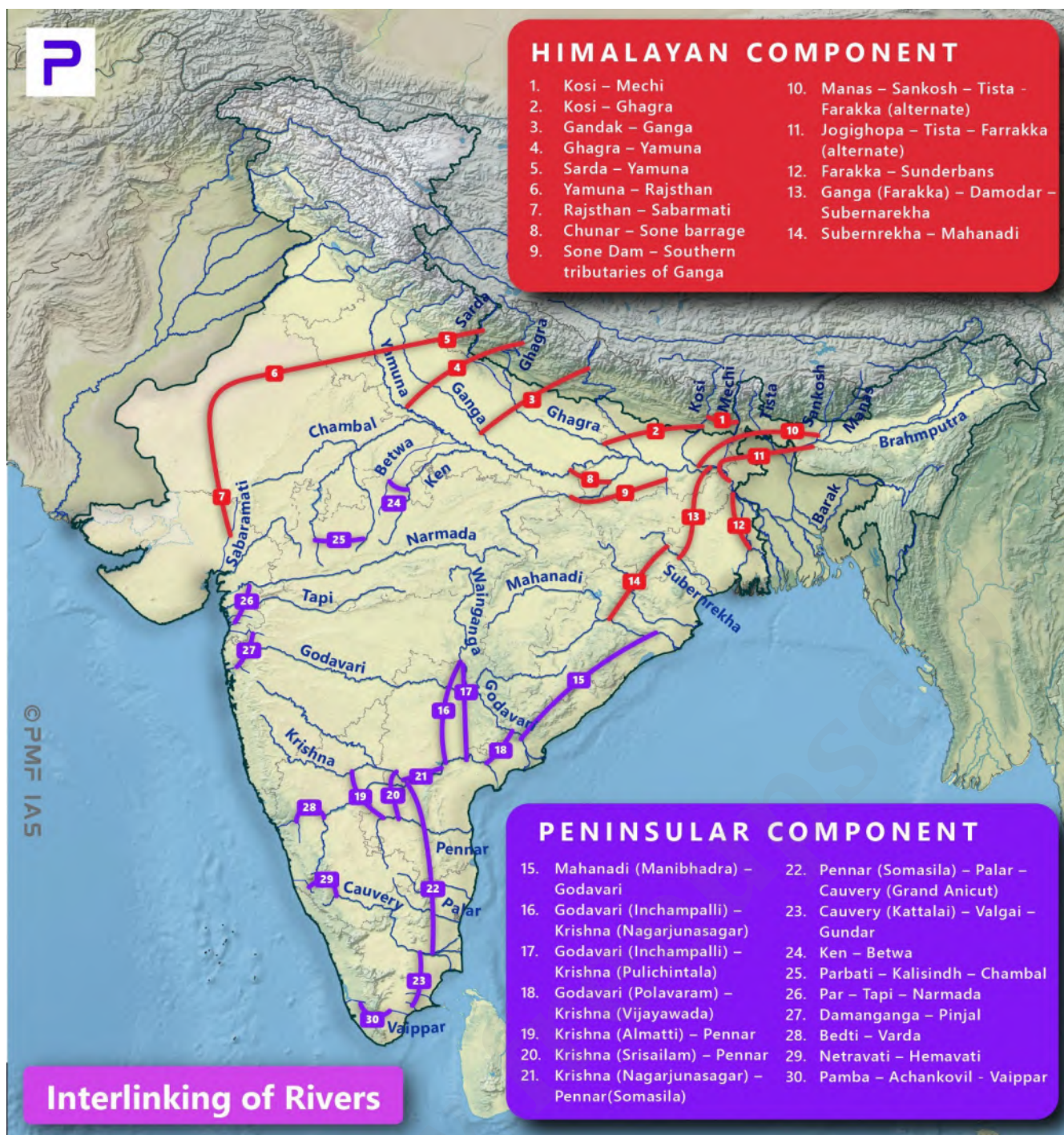
- River linking is a project of linking two or more rivers by creating a network of manually created reservoirs and canals.
- **Objective:** To **transfer water** from **water-surplus regions** to **water-deficient** and **rain-fed areas** through inter-basin transfers to ensure greater **equity** in the distribution of water.
- In 1919, the idea of linking rivers was first presented by **Sir Arthur Cotton**, chief engineer of the Madras Presidency.

Significance of Interlinking of Rivers

- ✓ **Redistributing water flow:** Flood control in the Ganga-Brahmaputra-Meghna basin and drought control and irrigation in the western and peninsular states like Rajasthan, Gujarat, Karnataka, and TN.
- ✓ **Hydropower potential:** It would add approx. **34,000 MW** of hydropower to the nation's energy pool addressing the electricity woes of industrial, agricultural, and rural households.
- ✓ **Commercial benefits:** Creation of logistics infrastructure enables freight movement through environmentally friendly **inland waterways**.
- ✓ **Sustainable development:** It would help address the **critical groundwater situation** in the country by utilising surface water and preventing the flow of freshwater into the sea.
- ✓ **Other benefits:** Reduced burden on women to fetch water from long distances, employment opportunities in rural areas, multiple benefits through backward and forward linkages, etc.

Challenges with Interlinking of Rivers

- **Environmental challenges:** It may result in evaporation losses, water-logging and salinity, and land submergence. For example, the **Ken Betwa** link may imperil areas of **Panna National Park**.
- **Lack of Transparency and Information:** Economic, social, and ecological implications have not been assessed properly.
- **Impact of Climate change:** Changing rainfall patterns with changing climate makes the implementation and achievement of the intended benefits of ILR projects uncertain.
- **Federal aspects:** Water is a **state subject**, and it is **difficult to resolve issues** of water sharing between states. E.g., Kerala and TN.
- **Objections:** Challenges in coordination with neighbouring countries like Bhutan, Nepal, etc.
- **Unexplored alternatives:** Watershed development, rainwater harvesting, optimising existing infrastructure, and cropping methods could well address the water woes of the country.



National Perspective Plan (NPP) for Water Resources Development

- NPP was formulated by the then **Ministry of Irrigation** (now **Ministry of Jal Shakti**) in 1980, envisaging inter-basin water transfer in the country. NPP has two components, viz.,
 1. Himalayan Rivers Development Component
 2. Peninsular Rivers Development Component
- The **National Water Development Agency (NWDA)** was set up in **1982** by Gol as a **Society** under the **Societies Registration Act 1860** under the then Ministry of Water Resources. It has been entrusted with the work of inter-linking of rivers under NPP.
- NWDA has identified **30 link projects**; **14** are under the **Himalayan Rivers Development Component**, and **16** are under the **Peninsular Rivers Development Component**.

- The implementation of the ILR projects depends on the **consensus of the concerned States**.
- In 2002, the **Supreme Court asked the GoI to complete this plan expeditiously**.

National Interlinking of Rivers Authority (NIRA)

- NIRA is an **independent autonomous body** for planning, investigating, financing, and the implementation of the river interlinking projects in India. It will **replace** the **National Water Development Agency** (NWDA).
- It will **coordinate** with **neighbouring countries** and **concerned states and departments** "as directed" by the Ministry of Jal Shakti/Ministry of External Affairs.
- It shall have **powers on issues of environment, wildlife, and forest clearances** under the project.
- It can **raise funds** and act as a **repository of borrowed funds** or money received on deposit or loan given on interest.
- It shall have the power to set up a **Special Purpose Vehicle** (SPV) for individual link projects.

Ken-Betwa River Interlinking Project

- It was the **first project under the NPP** to interlink rivers.
- It will **transfer water** from the **Ken River (MP)** to the **Betwa River (UP)**.
- It will have Phase I (Daudhan dam) and Phase II (Lower Orr dam, Bina complex and Kotha barrage).
- It will generate hydroelectricity along with water supply.

Issues

- Significant areas of the **Panna Tiger Reserve** (Ken River passes through it) of MP will be impacted by the project.
- **Lower Orr Dam** is objected on the grounds that the state had not taken formal clearance from the Environment Ministry for the project.

Godavari-Krishna Link Project

- The Godavari-Krishna Link is a major proposed project under the ILR program. It aims to divert surplus water from the Godavari River, flowing through Andhra Pradesh, to the Krishna River.
- The **Pattiseema Lift Irrigation Project** is the first successful river interlinking project of the Godavari-Krishna Link.
- It will supply water to the **Prakasam Barrage** on the Krishna River, which would enable the saved water of the Krishna River for the irrigation of the **Rayalaseema region** by the **Pothireddypadu canal** and the **Handri Neeva lift** from the **Srisailem reservoir**.

[UPSC 2016] Recently, linking of which of the following rivers was undertaken?

- Cauvery and Tungabhadra
- Godavari and Krishna
- Mahanadi and Son
- Narmada and Tapi

Explanation

- The **Pattiseema (Polavaram) project** is a key component of the **ILR**.

Answer: b) Godavari and Krishna

Ganga-Amravati Interlinking Project

- The Ganga-Amravati Link envisions transferring water from the Ganga River in Bihar to the water-scarce **Marathwada region** of Maharashtra through the **Amravati River**.
- The project could significantly alleviate water scarcity in Marathwada, benefiting millions of people and enabling agricultural development.
- The project is still in the preliminary stages, with feasibility studies and ongoing environmental impact assessments.

[UPSC 2020] The interlinking of rivers can provide viable solutions to the multi-dimensional inter-related problems of droughts, floods, and interrupted navigation. Critically examine.

- The concept of interlinking rivers, often referred to as **river linking or interbasin water transfer**, involves diverting water from surplus river basins to deficit ones through a network of canals, reservoirs, and dams.
- River interlinking can address various water-related challenges, such as droughts, floods, and navigation interruptions.

Drought Mitigation

- Interlinking rivers can help **redistribute water** from water-rich regions to water-scarce regions during droughts, ensuring water supply for irrigation, drinking water, and industrial purposes.

Flood Management

- By **transferring excess water from flood-prone areas** to regions facing water scarcity, river interlinking projects can help mitigate the impacts of floods.
- Properly designed reservoirs and canal systems can regulate water flow, reducing flood risks downstream and providing additional water storage during monsoon seasons.

Navigation

- Interlinking rivers can improve inland navigation by **creating interconnected waterways**, facilitating the movement of goods and people.
- This can boost economic development by reducing transportation costs and promoting trade and commerce between regions.

Hydropower generation

- Interlinking projects can create opportunities for constructing hydropower dams, contributing to renewable energy production.

Salinity control

- Transferring freshwater to coastal areas can help **prevent saltwater intrusion** and maintain the health of ecosystems and agricultural land.

----- End of Chapter -----

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9. Indian Monsoons

- The term monsoon has been derived from the Arabic word **mausin** or from the Malayan word **monsin**, meaning 'season'.
- Monsoons are **Periodic** or **Secondary winds** that **reverse** their direction with the change of season. They can be called **land and sea breezes on a large scale** or **convection cells** on a large scale.
- They are a **double system of seasonal winds** — they flow from **sea to land during the summer (south-west monsoon winds)** and from **land to sea during winter (north-east monsoon winds)**.
- Monsoons are peculiar to the **Indian Subcontinent, South East Asia**, parts of **Central Western Africa**, etc. They are more pronounced in the Indian Subcontinent compared to any other region.
- Other areas like **Australia** and parts of Africa also have seasonal shifts in wind patterns and precipitation.
- **India, Indonesia, Bangladesh, Myanmar**, etc., receive most of the annual rainfall during the **south-west monsoon season**, whereas **South East China, Japan**, etc., during the **north-east rainfall season**.
- **South-west monsoons** bring intense rainfall to most of the regions in India, and **north-east monsoons** bring rainfall to mainly the **south-eastern coast** of India (the **southern coast of Andhra Pradesh and the coast of Tamil Nadu**).
- South-west monsoons form due to intense **low-pressure** systems over the **Tibetan plateau**. North-east monsoons are associated with **high-pressure** cells over the **Tibetan** and **Siberian plateaus**.

[UPSC 2014] The seasonal reversal of winds is the typical characteristic of

- a) Equatorial climate
- b) Mediterranean climate
- c) Monsoon climate
- d) All of the above climates

Explanation

- The **seasonal reversal of winds** is a phenomenon where the **prevailing wind direction changes** significantly between different seasons.
- The seasonal reversal of winds dominates the **monsoon climate**. They dictate wet and dry seasons by bringing moisture from the ocean in one season and dry air from the land in the other season.

Answer: c) Monsoon climate

Influencing Factors

Factors responsible for south-west monsoon formation

- ❖ **Intense heating** of the **Tibetan Plateau** during summer months.

- ❖ **Permanent high-pressure cell (Mascarene High)** in the **South Indian Ocean** (east to northeast 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 (ITCZ)**

Factors that influence the intensity of south-west monsoons

- ❖ Strengths of Low pressure over Tibet and high pressure over the 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 the **Tibetan Plateau** and **Siberian Plateau** in winter.
- ❖ **Westward migration** and subsequent **weakening of high-pressure cell (Mascarene High)** in the **Southern Indian Ocean**.
- ❖ Migration of ITCZ to the south of India.

[UPSC 1996] High temperature and low pressure over the Indian subcontinent during the summer season draws air from the Indian Ocean leading to the in-blowing of the:

- South-east monsoon
- South-west monsoon
- Trade winds
- Westerlies

Explanation

- During summer in the Indian subcontinent, high temperatures and low pressure create a **thermal low** over the region. This low-pressure system acts like a "vacuum," **drawing in air from surrounding areas** with higher pressure.
- **South-west monsoon winds:** Due to the **Earth's rotation (Coriolis effect)**, the air masses moving towards the low-pressure system from the Indian Ocean **get deflected and flow in a south-westerly direction**, bringing moisture-laden air from the ocean towards the land. This is the south-west monsoon that brings crucial rainfall to India and other parts of South Asia.

Answer: b) South-west monsoon

[UPSC 2023] Why is the South-West Monsoon called 'Purvaiya' (easterly) in Bhojpur Region? How has this directional seasonal wind system influenced the cultured ethos of the region?

- The term "Purvaiya" refers to the **easterly winds** that bring the **South-West Monsoon** to the Bhojpur region. The "Purvaiya" monsoon's timely arrival and sufficient rainfall are **vital** for agricultural activities, especially for crops like paddy.

Why Purvaiya?

- The South-West Monsoon is called "Purvaiya" (meaning "easterly") in the Bhojpur region of India due to the **geographical orientation** and **local language** influence.

Geographical factor

- While the South-west Monsoon originates in the **south-west** and travels **north-east**, when it reaches the Bhojpur region situated in the eastern part of India, **the winds primarily blow from the east** due to the **deflection caused by the Himalayan and Meghalaya plateau** mountain ranges. These geographical features alter the initial direction of the monsoon winds, **making them appear as easterly winds in the Bhojpur region**.

Linguistic factor

- "Purvai" means "**east**" in the Bhojpuri language, which is significantly influenced by Hindi.

Influence of "Purvaiya" on the Cultural Ethos of Bhojpur Region

The seasonal arrival of the "Purvaiya" has a profound impact on various aspects of life in the Bhojpur region, shaping its cultural ethos in several ways:

- **Culture:** Traditional festivals like "**Chath Puja**" and "**Dura Puja**" **coincide with the monsoon**.
- **Cuisine:** The monsoon season brings about a shift in dietary habits, with people consuming lighter and **healthier foods** like "**Dahi-chura**" (beaten rice with curd) and "**Pakor**s" (fritters) to cope with the humid weather.
- **Folklore and Literature:** The "Purvaiya" is mentioned in various forms of **Bhojpuri folk songs** and stories. The wind is often personified and depicted as a **symbol of hope** and prosperity.
- **Language:** The word "Purvaiya" itself has become ingrained in the local language, signifying the **cultural significance of the monsoon winds** in the region.

The term "Purvaiya" for the South-West Monsoon reflects both the **geographical reality** observed in the Bhojpur region and the **deep cultural connection** between the people and this vital seasonal phenomenon. It serves as a unique example of how local language and cultural practices **adapt** and **evolve** in response to environmental factors.

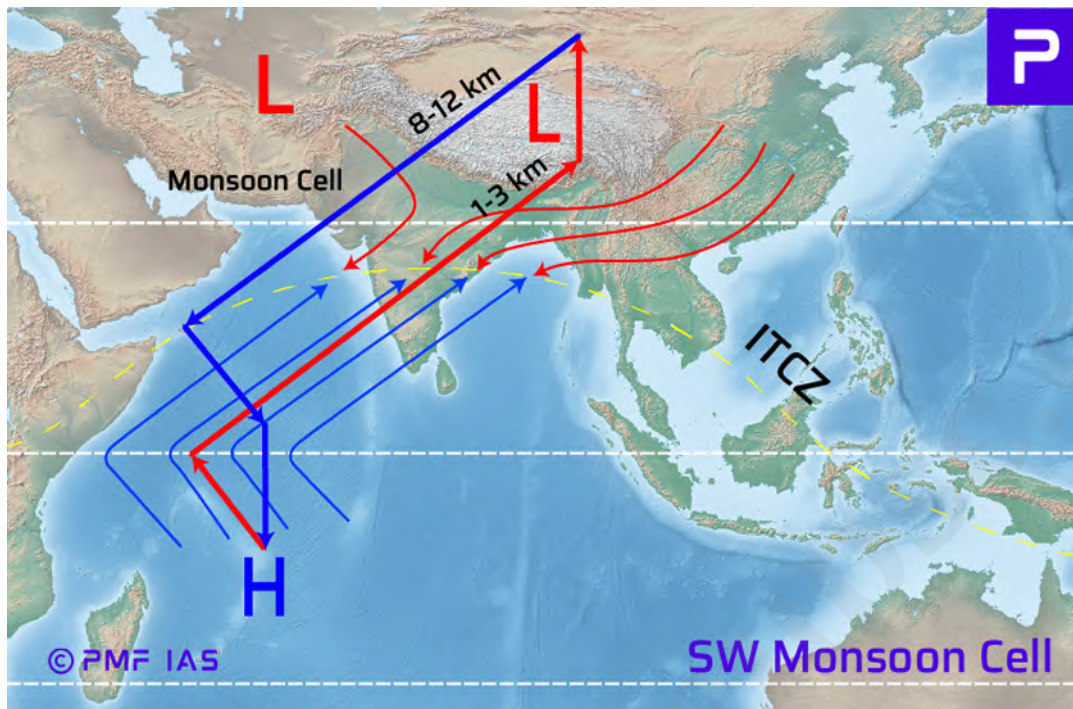
Mechanism of Indian Monsoons – Classical Theory

- The origin of monsoons is not fully understood. Several theories tried to explain the mechanism.

- Arab traders did the first scientific study of the monsoon winds. They used the sea route to carry out trade with India, and monsoon patterns were of prime importance to 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.

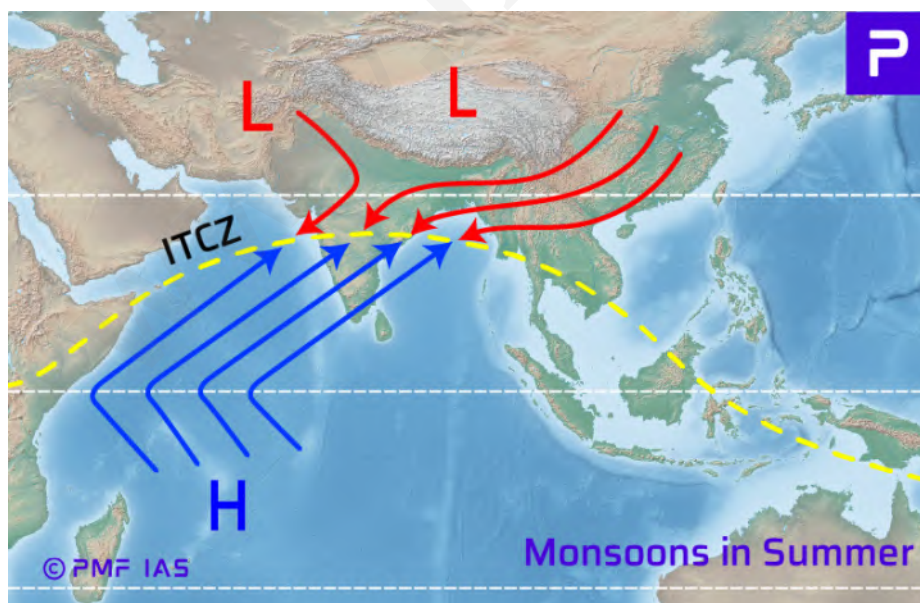
Indian Monsoons – Classical Theory: Sir Edmund Halley's Theory

- In the seventeenth century, Sir Edmund Halley explained the monsoon as resulting from **thermal contrasts** between continents and oceans due to their differential heating. This theory considers Indian Monsoons as **Land and Sea Breeze on a large scale**.



Summer Monsoon

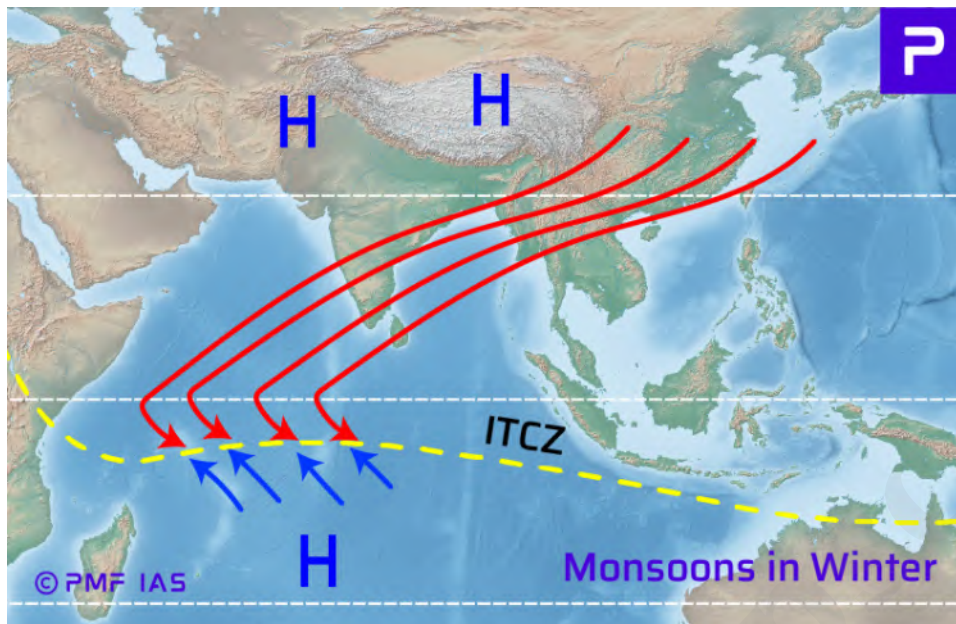
- In summer, the sun's apparent path is vertically over the Tropic of Cancer, resulting in high temperatures and **low pressure** in Central Asia.



- The pressure is sufficiently high over the Arabian Sea and Bay of Bengal. Hence, winds from the ocean flow towards the landmass in summer. This airflow from sea to land brings heavy rainfall to the Indian subcontinent.

Winter Monsoon

- In winter, the sun's apparent path is vertically over the Tropic of Capricorn. The northwestern part of India grows colder than the Arabian Sea and the Bay of Bengal, and the flow of the monsoon is reversed.



Drawbacks of Sir Edmund Halley's Theory

- 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 the onset of monsoons sometimes, etc.,
- With the development of other significant factors that influence monsoons, Halley's theory lost its relevance.

Mechanism of Indian Monsoons – Based on Modern Theories

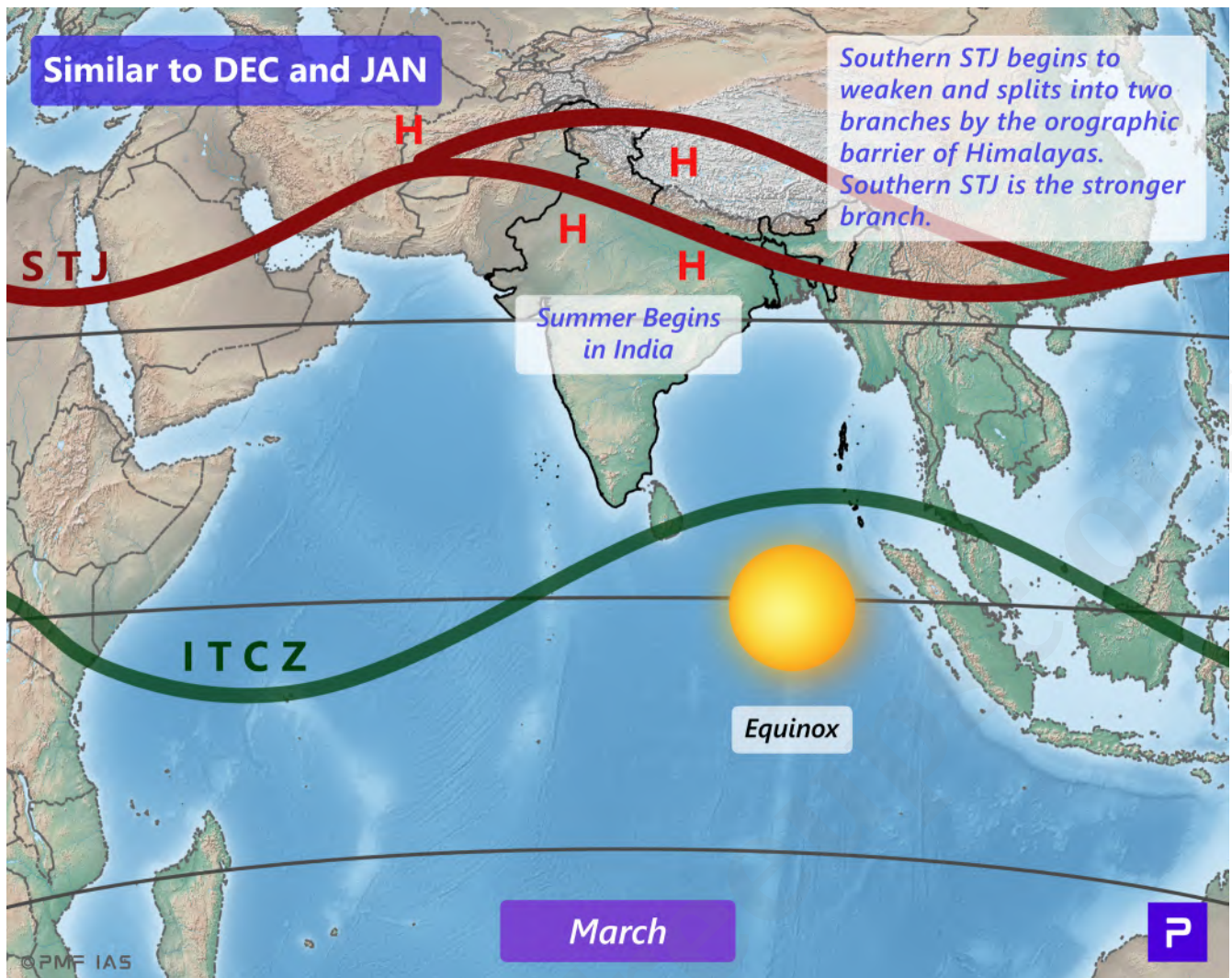
- Besides differential heating, the development of monsoons is influenced by the shape of the continents, orography (mountains), and the conditions of **air circulation in the upper troposphere (jet streams)**.

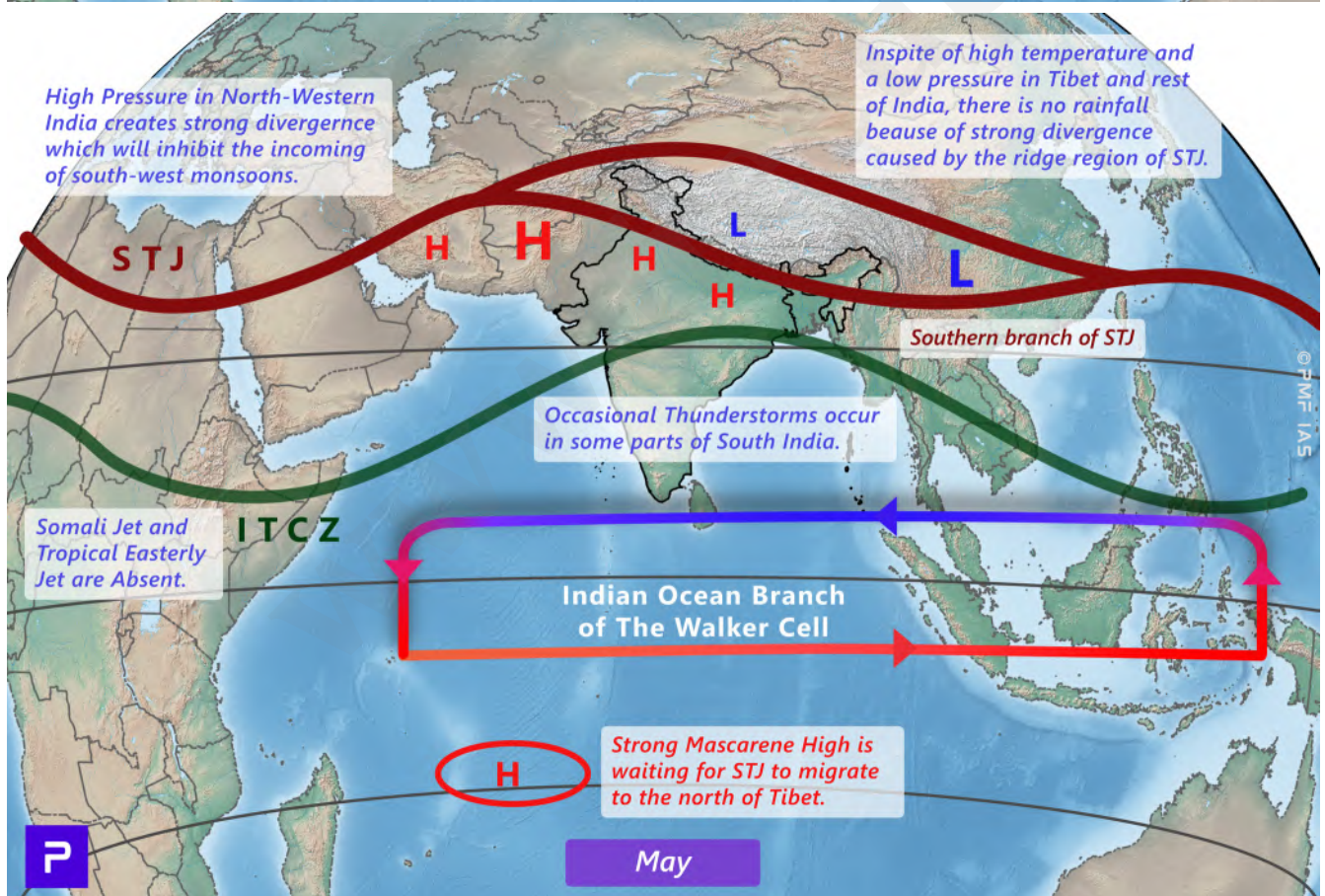
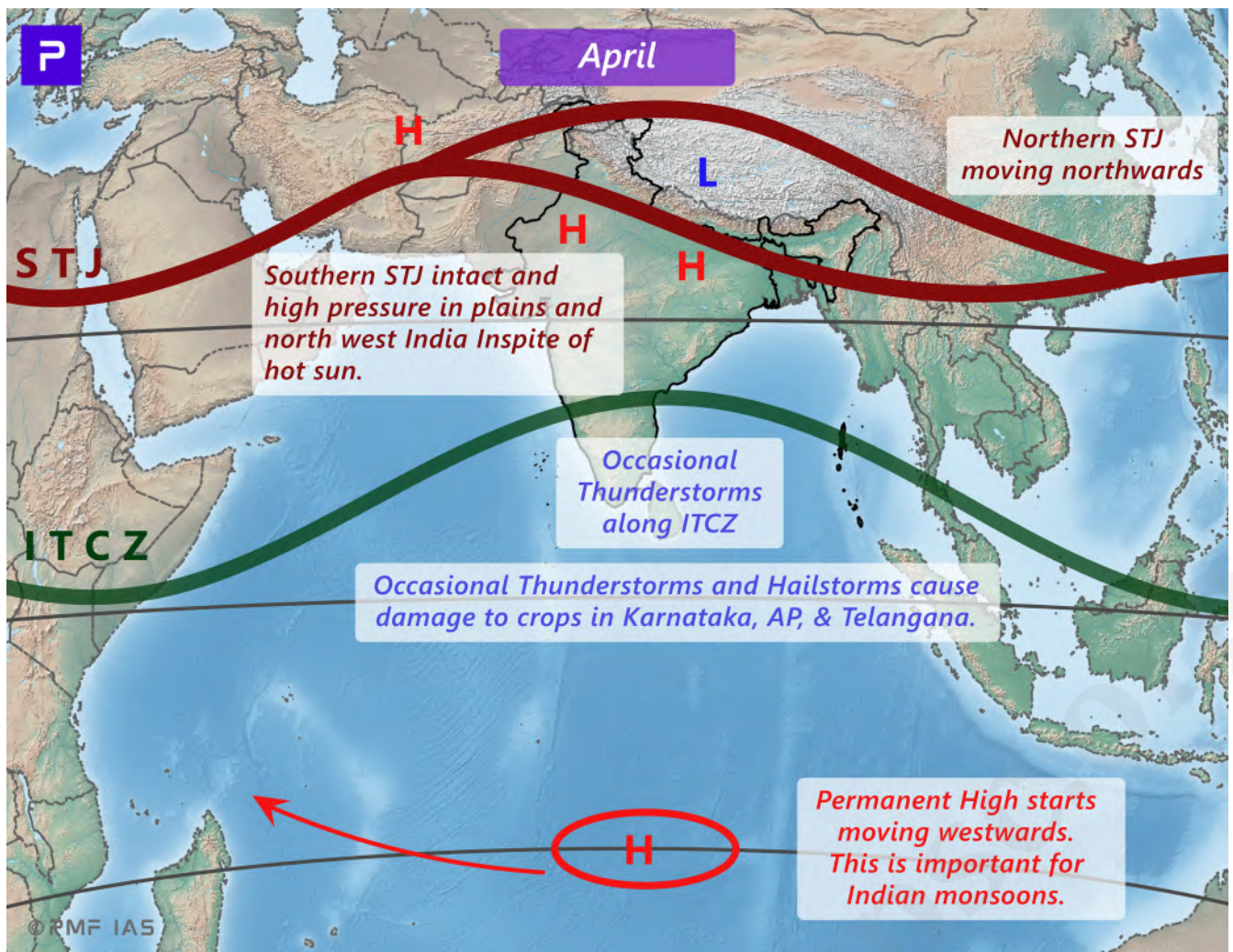
Indian Monsoon Mechanism – Seasonal Rhythm

March to May

- As the summertime approaches, there is increased solar heating of the Indian subcontinent and the Tibetan Plateau.
- The **Subtropical High-Pressure Belt** occupies northwest India and the Plains region. This high-pressure belt **undermines the influence of low-pressure cells** over Tibet.

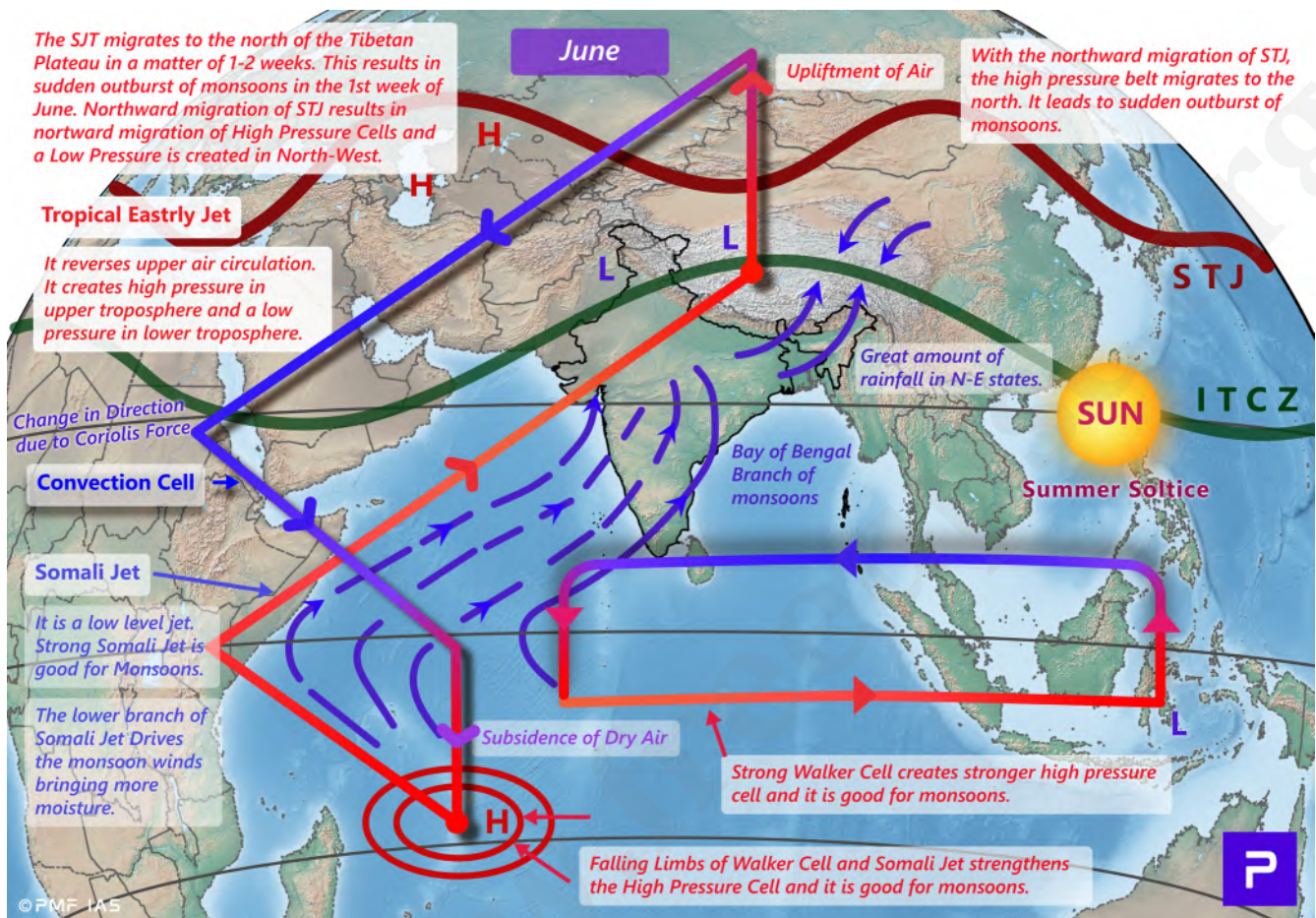
- From **March to May**, the building up of the **monsoon cell is blocked** by the **Subtropical Jet Stream (STJ)**, which tends to blow to the **south of the Himalayas**.
- **As long as the STJ is in this position**, the development of summer monsoons is **inhibited** (the high-pressure belt stays over north India).





Between Late May and Early June

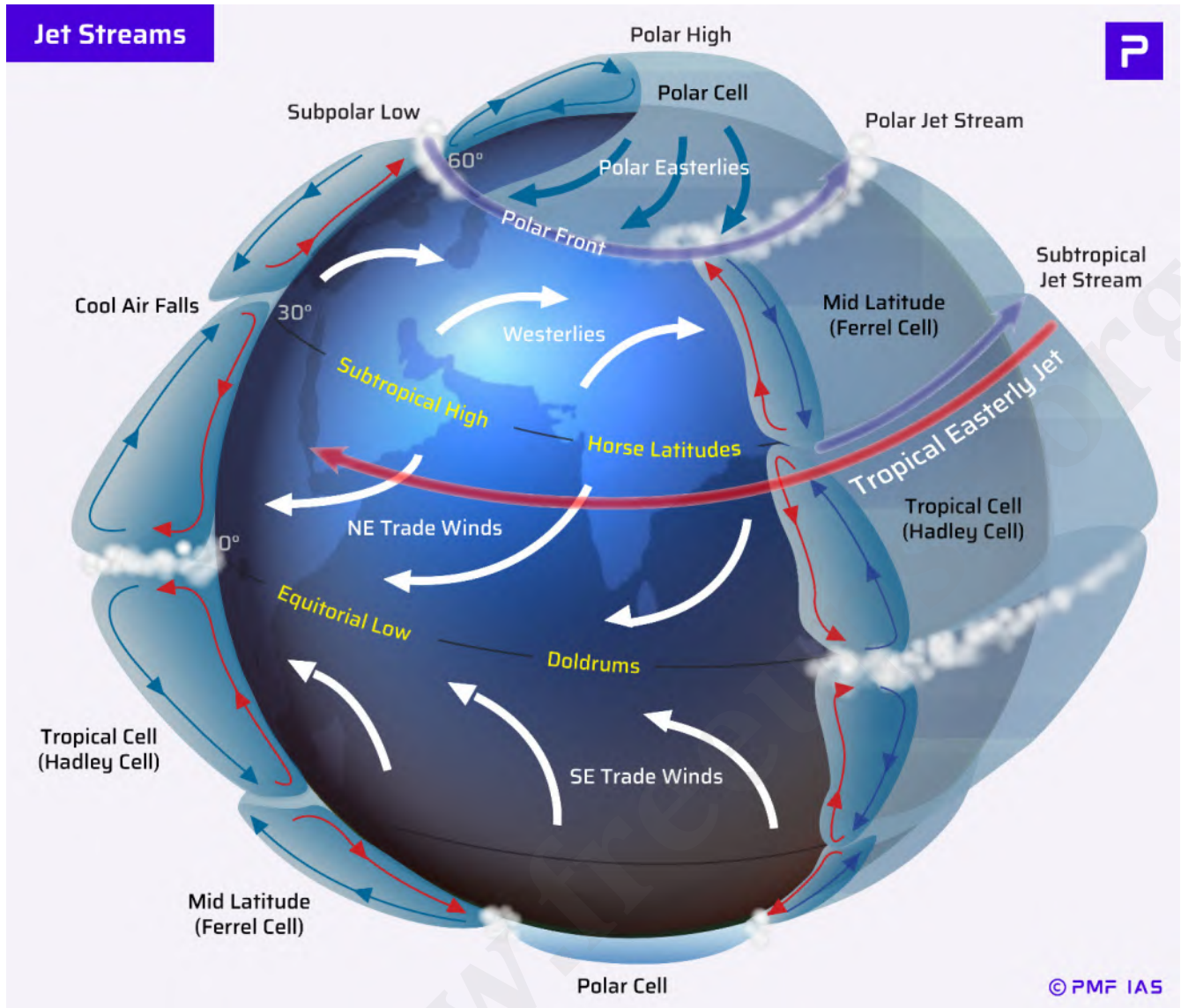
- In the peak summer months (25th of May – 10th of June), with the apparent northward movement of the sun, the **southern branch of the Sub-Tropical Jetstream (STJ)**, which flows to the south of the Himalayas, **shifts to the north of the Himalayas**.
- When the sun's position is about to reach the Tropic of Cancer (June), the STJ shifts to the north of the Tibetan Plateau (1st of Jun – 20th of June). The **ITCZ** is **close to its peak position** over the **Tibetan Plateau**.
- The altitude of the mountains initially disrupts the jet, but once it has cleared the summits, it is able to reform over central Asia. **Its movement towards the north** is one of the **main features associated with the onset of the monsoon over India**.



The onset of Monsoons (1st or 2nd week of June)

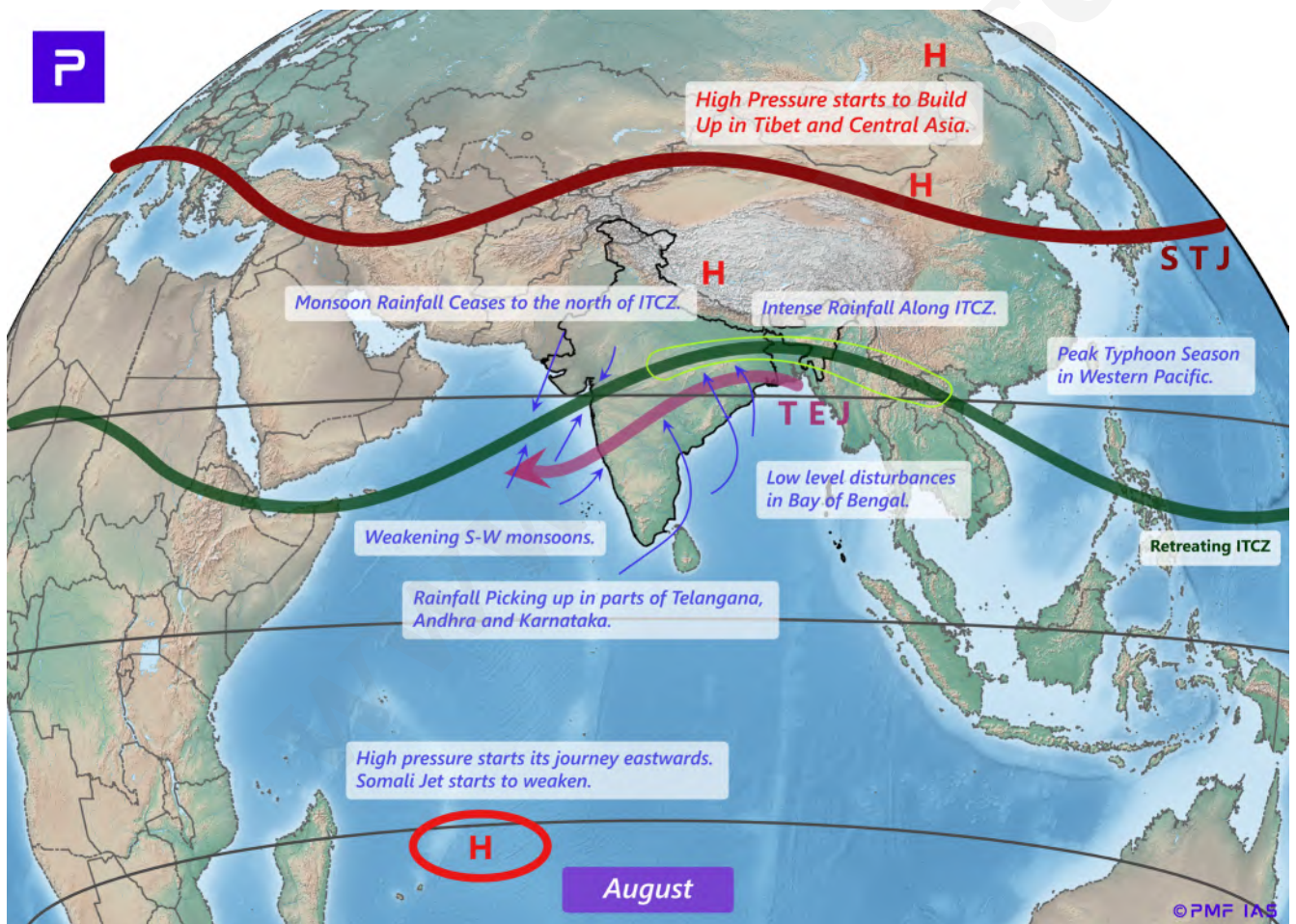
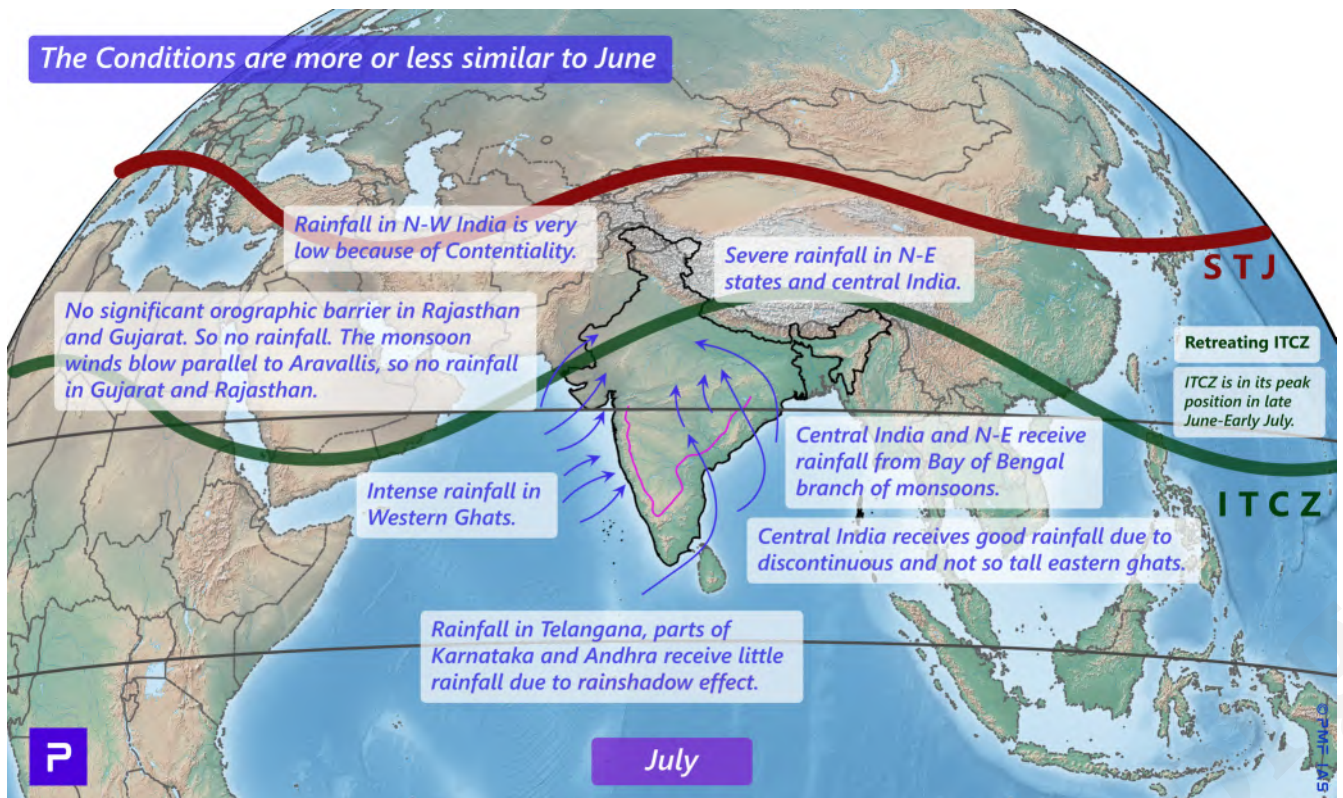
- With the **northward shift of STJ**, an **Easterly Jet is formed over the Indian plains**. It generally forms in the **first week of June and lasts till late October**. It can be traced in the **upper troposphere** right up to the **west coast of Africa**.
- The **northward shift of STJ and ITCZ moves the subtropical high-pressure belt to the north of the Tibetan Plateau**, and the **Easterly Jet creates a low-pressure region in the Indian plains** (**Easterly Jet** creates anticyclonic conditions in the upper troposphere and **cyclonic conditions** in the **lower atmosphere**).

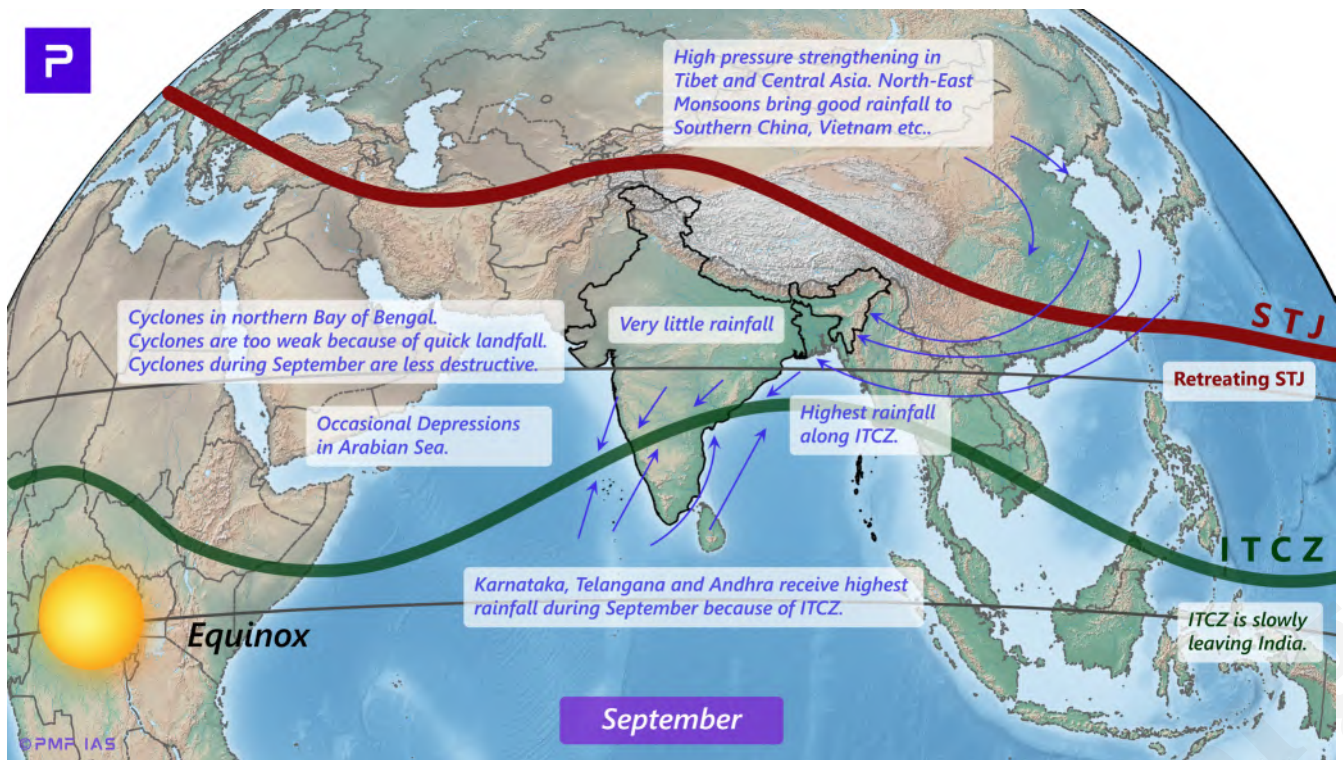
- With the **STJ out of the way** (the high-pressure belt migrates to the north of Tibet), the **subcontinental monsoon cell develops very quickly, often in a matter of a few days**.
- The **low pressure in the northern plains** coupled with the **intense low of the Tibetan Plateau** leads to the **sudden onset** of south-west monsoon winds (1st of Jun – 20th of June).
- The **monsoon cell** is situated between the Indian Ocean (**North of Madagascar**) (**High-Pressure Cell**) and the **Tibetan Plateau (Low-Pressure Cell)**.



Rainy season

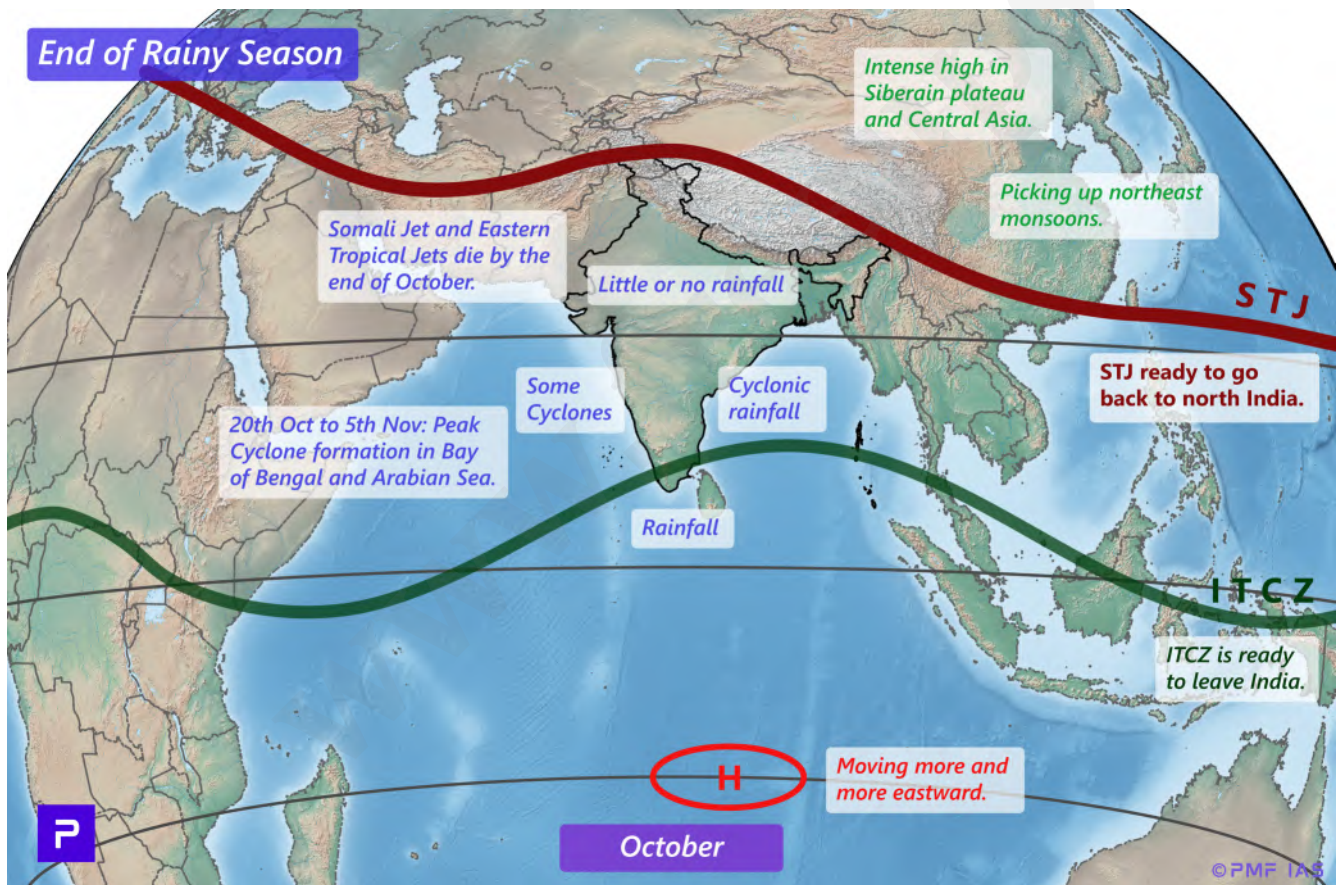
- The **sub-tropical easterly jet fluctuates** between the **plains** region of India and **peninsular** India, **varying the intensity of rainfall** from location to location.
- Warmth and moisture are fed into the cell by a **lower-level tropical jet stream (Somali Jet)**, which brings with it air masses laden with moisture from the Indian Ocean.





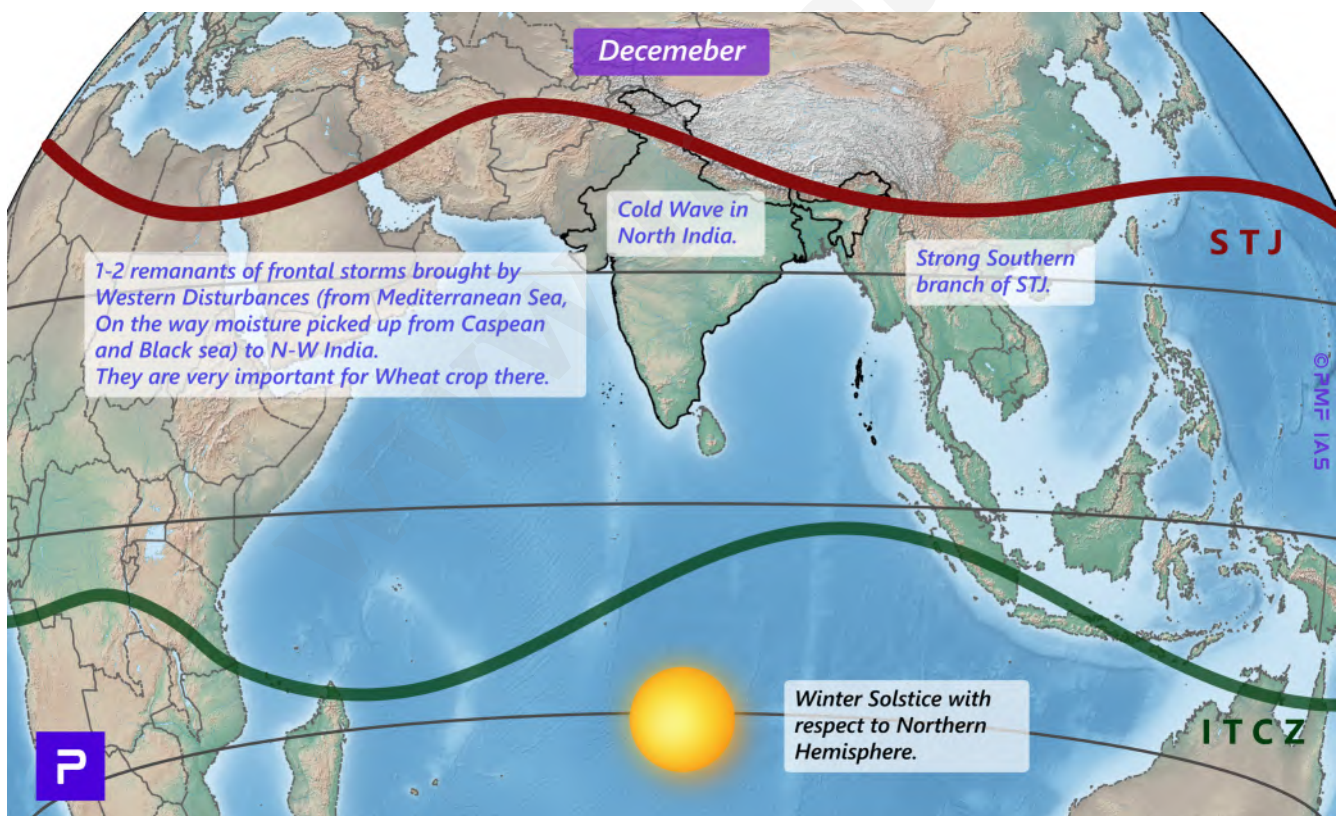
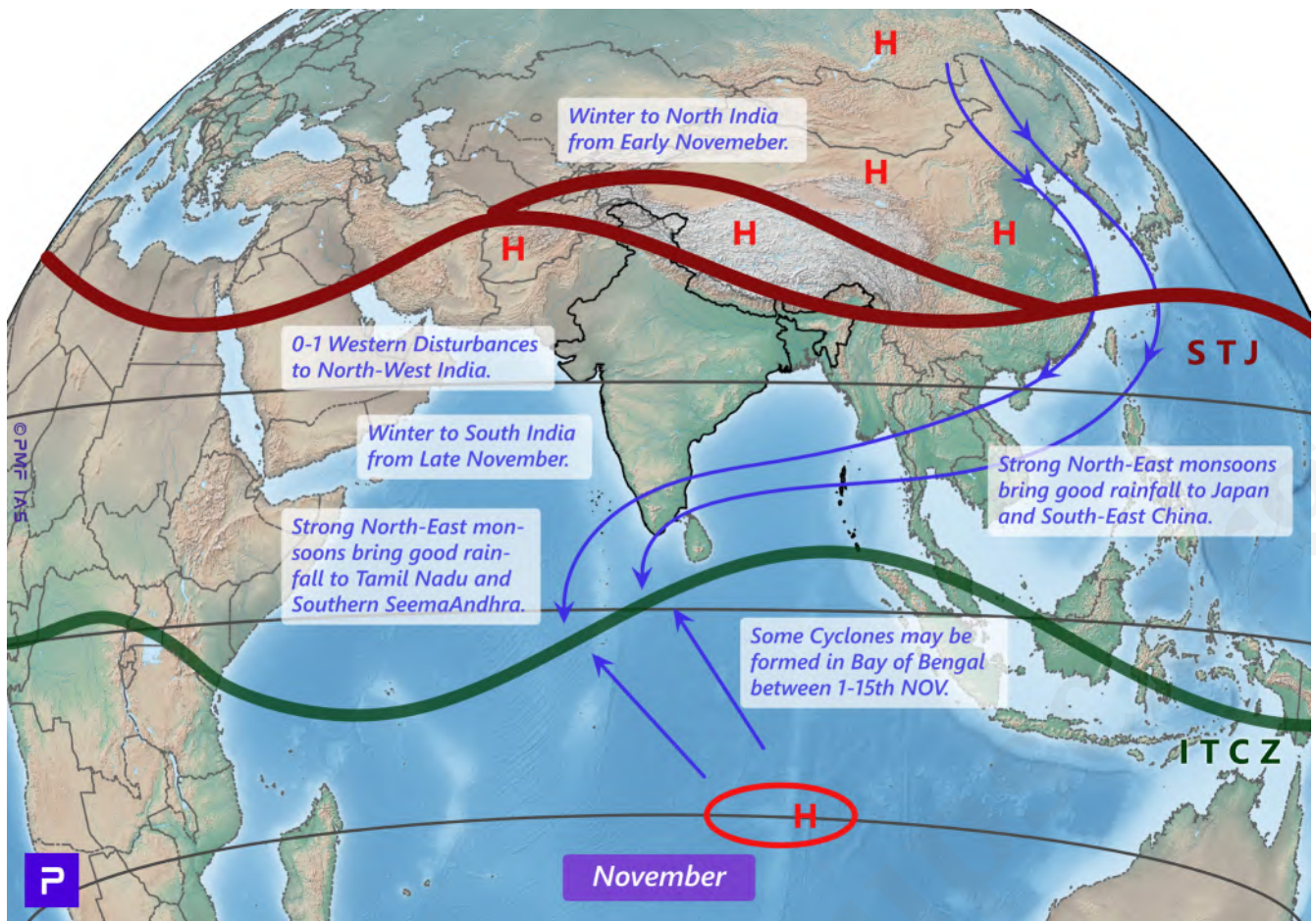
The end of the Monsoon season

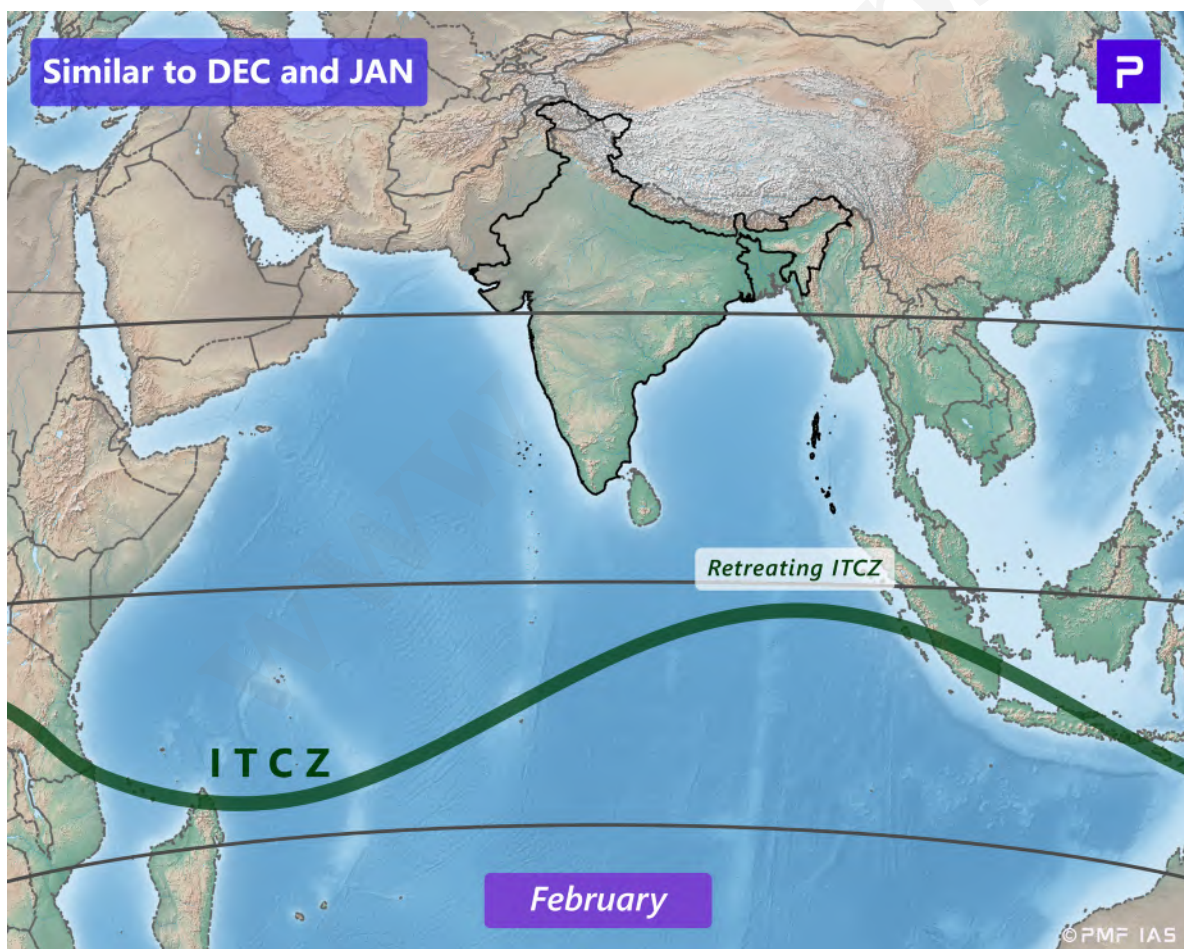
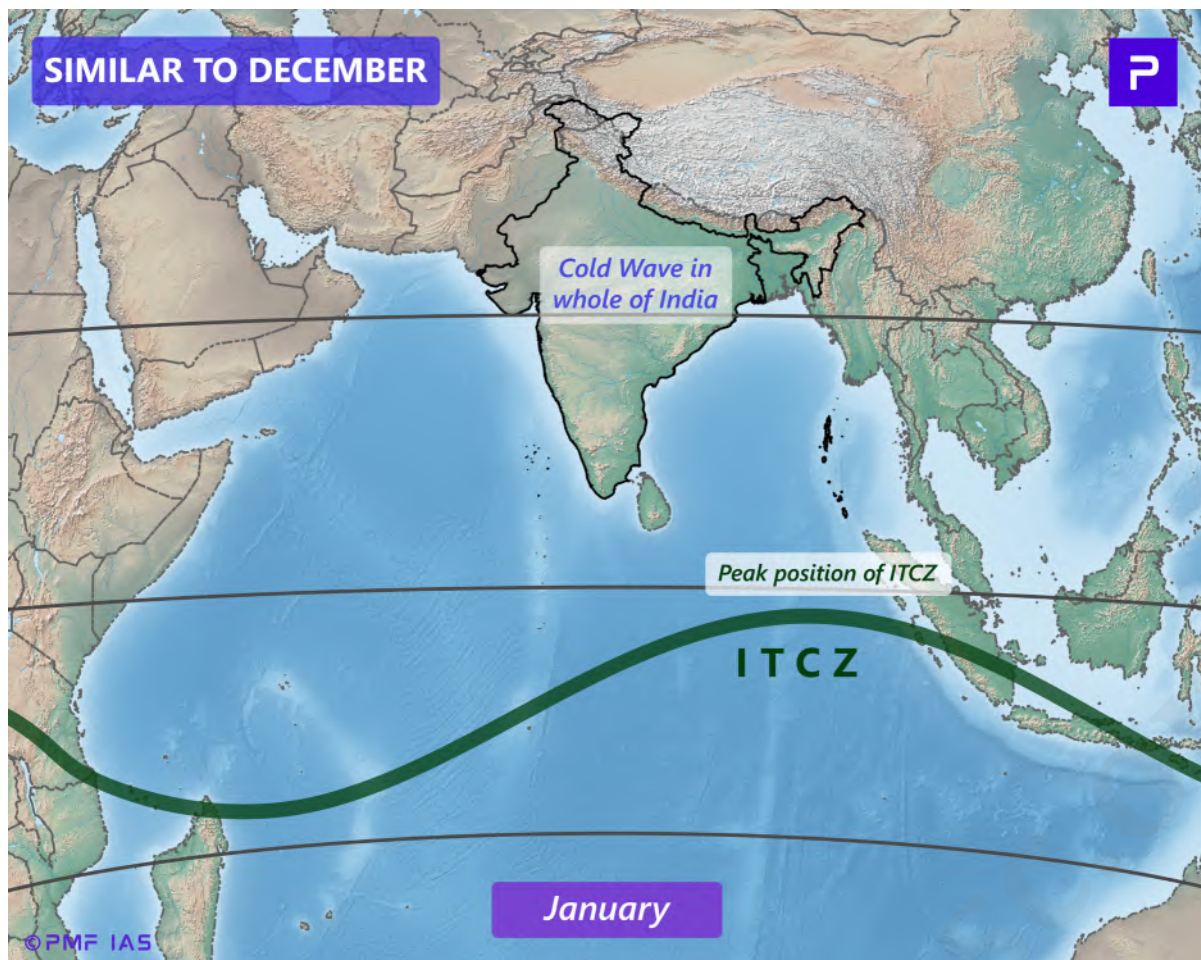
- The end of the monsoon season is brought about when the atmosphere over the **Tibetan Plateau** begins to cool (August – October). This enables the **STJ to transition back across the Himalayas**.



- With the **southward shift of ITCZ**, the **subtropical high-pressure belt returns** to the Indian plains, and the rainfall ceases.

- This leads to the formation of an **anticyclonic winter monsoon cell** typified by sinking air masses over India and relatively **moisture-free winds that blow seaward**.
- This gives rise to relatively settled and **dry weather** over India during the winter months.



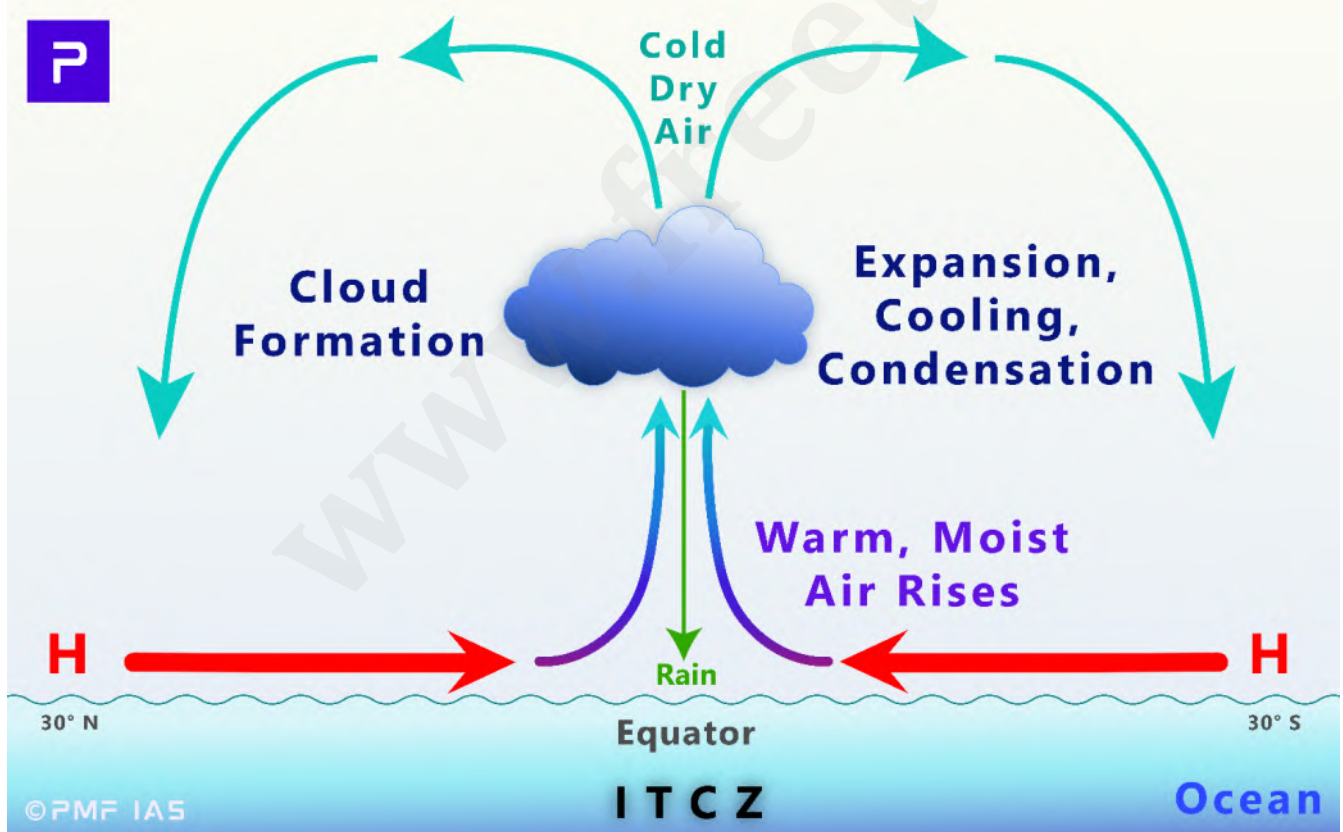
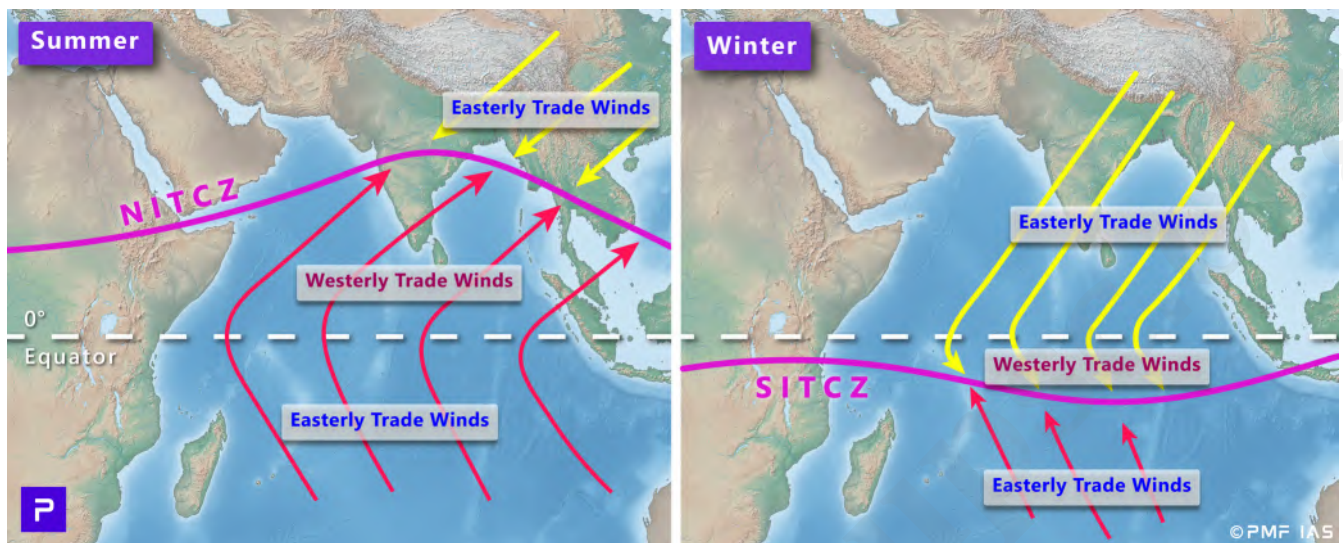


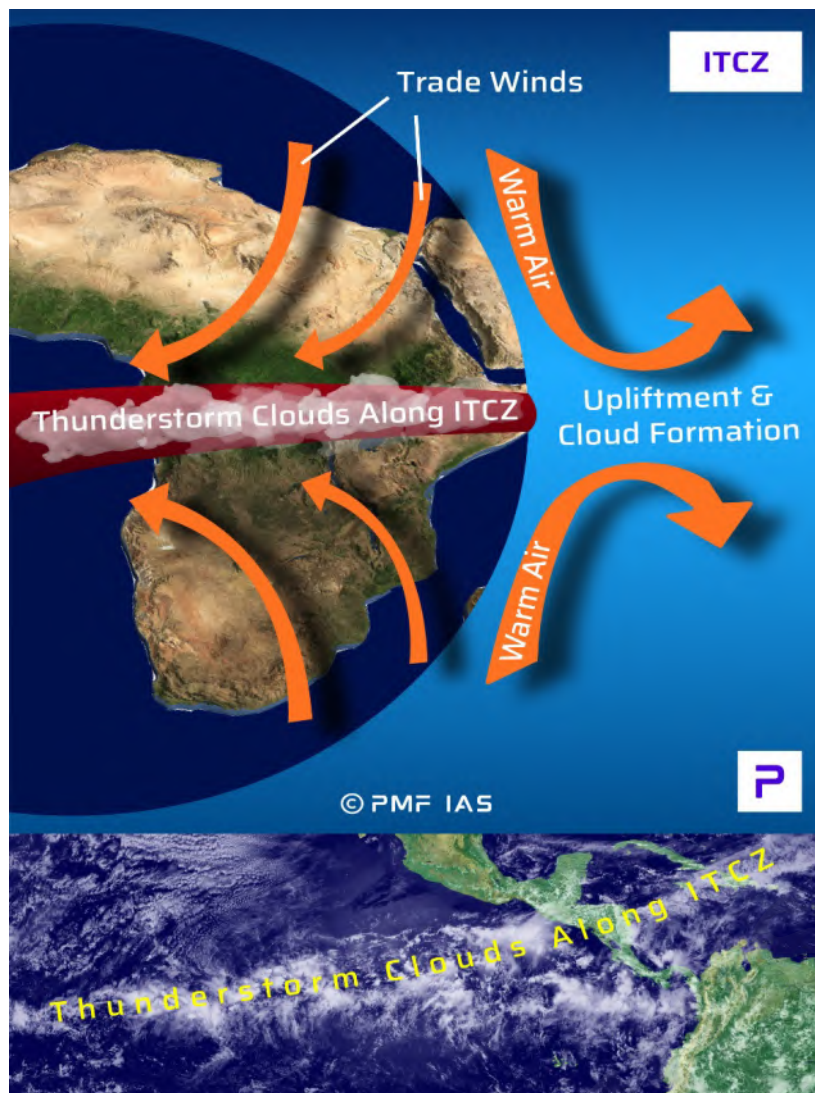
Indian Monsoon Mechanism – Air Mass Theory

- 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.
- This theory suggests that the monsoon winds during the south-west monsoon season are simply the expanded **equatorial westerlies** which lie embedded in the great mass of **tropical easterlies** or the trade winds.

Role of ITCZ (Inter-Tropical Convergence Zone)

- The **south-east trade winds** in the southern hemisphere and the **north-east 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)**.

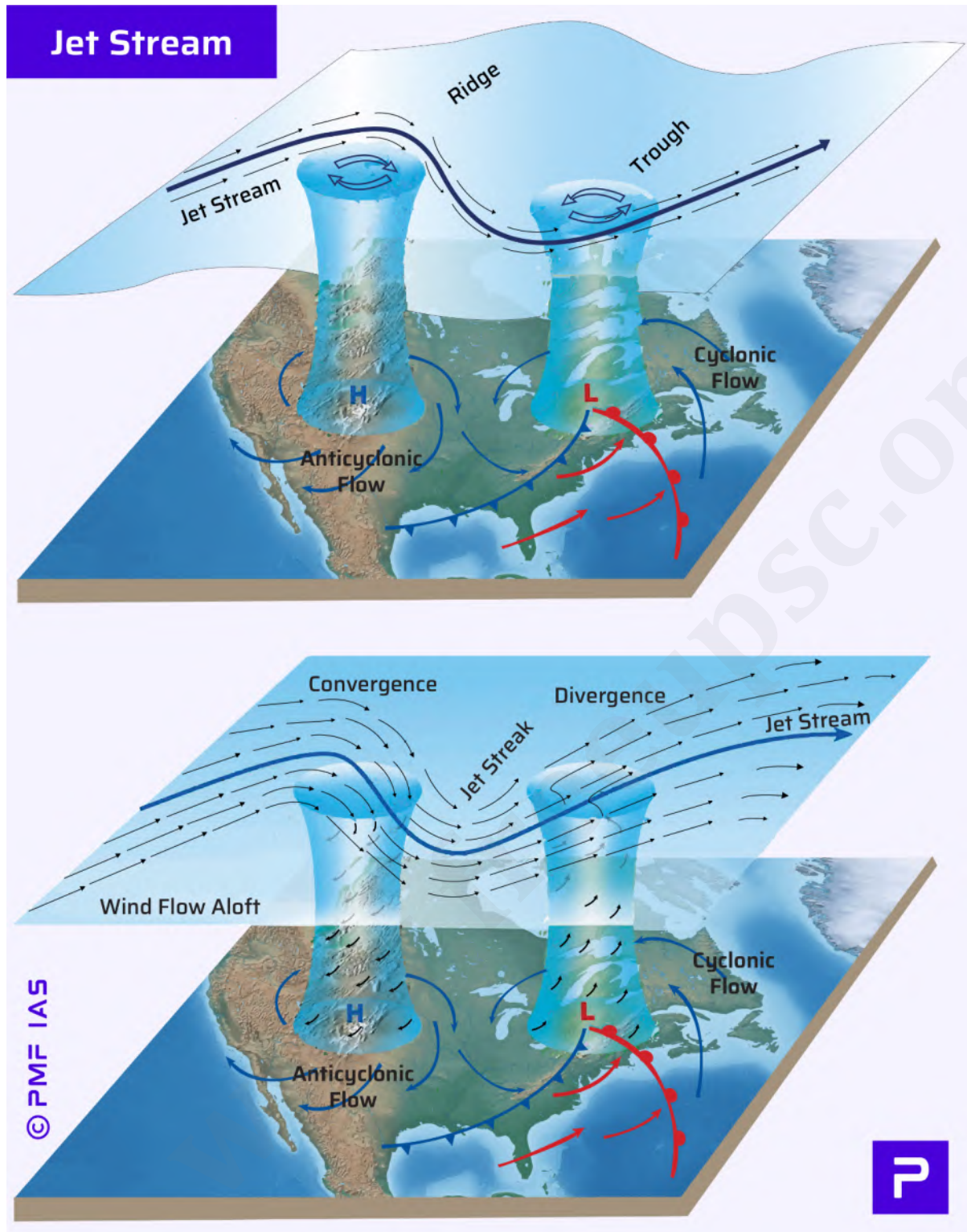




- **ITCZ** is the region of ascending air, **maximum clouds**, and **heavy rainfall**. Its location **shifts** north and south of the equator with the change of season.
- In the summer season, the sun shines vertically over the Tropic of Cancer, and the ITCZ shifts northwards.
- The south-east trade winds of the southern hemisphere cross the equator and start blowing in the **south-west** to a **north-east** 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 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 (a series of thunderstorms and maximum rainfall)**.
- The seasonal shift of the ITCZ has given the concept of a **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 affect India.**

Indian Monsoon Mechanism – Modern Theory: Jet Stream Theory

- **Jet stream Theory** is the latest theory regarding the origin of the monsoons. To understand how Jet streams, affect Indian monsoons, we need to know the basic mechanism of Jet Stream induced weather conditions.



How do Jet Streams Affect Weather?

- Jet streams have distinct **peaks (ridges)** and **troughs**. **Ridges** occur when the warm air mass pushes against the cold air mass. **Troughs** occur when cold air mass drops into warm air.

- The **region on earth below the trough is at low pressure**, and the **region below the ridge is at high pressure**. This condition occurs due to the **weakening of the jet stream** due to **lesser temperature contrast** between sub-tropics and temperate regions (our concern is STJ only).
- Usually, the **trough region (the region exactly below the jet stream trough)** creates a **cyclonic condition (low pressure)** at the surface of the earth. In contrast, the **ridge regions** create an **anti-cyclonic condition**.
- These ridges and troughs give rise to **jet streaks**, which are also responsible for cyclonic and anticyclonic weather conditions at the surface.

Jet Streaks and Cyclonic Conditions

- The winds leaving the jet streak are rapidly **diverging (anticyclonic)**, 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)**.
- When a jet streak passes over a region, it **can enhance** the development of **surface low-pressure systems** by increasing convergence and lift in the atmosphere. This can lead to the **formation of cyclones or areas of stormy weather**.

Jet Streaks and Anticyclonic Conditions

- 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 the 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**.

*These mechanisms of the Sub-Tropical Jet Stream (STJ) influence the Indian Monsoons by **shifting the pressure cells**.*

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

- **Sub-tropical jet stream** plays a significant role in **both hindering the monsoon winds** and in the **quick onset** of monsoons.

Sub-Tropical Jet Stream (STJ)

- The sub-tropical Jet stream is a narrow band of fast-moving air flowing from **west to east (Westerlies)**.
- STJ in the northern hemisphere flows between **25° to 35° N** in the upper troposphere at the height of about 12-14 km (the height of each portion of the jet stream varies when there is meandering. Their path is sometimes influenced by the Greater Himalayas).
- 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**. In **summer**, it **shifts northwards** rather **dramatically** and flows along the northern edge of the Himalayas in early June and along the northern Tibetan Plateau in late summer (July-August).
- The **periodic movement** of the Jet stream is often the **indicator of the onset** (STJ shifts to the north of the Himalayas in a matter of days) and subsequent **withdrawal** (STJ returns to its position — south of the 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

- STJ blows at a very high speed during winter over the sub-tropical zone. It is **bifurcated** by the **Himalayan ranges (physical barrier)** and **Tibetan Plateau (thermal barrier)**. 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.
- The **southern branch is stronger**, with an average speed of about 240 kmph compared with 70 to 90 kmph of the northern branch.
- **Air subsiding** beneath this upper westerly current gives **dry, out-blowing northerly winds** from the **subtropical anticyclone** over **north-western India and Pakistan**.

Why there are 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 the ocean — so they carry no moisture).
- **Reason 2:** During winter, **the southern branch of STJ is strong** and is to the south of the Himalayas. The ridge of the jet lies over north-western India. It is associated with a **strong divergence of winds and creates a high-pressure region** (sub-tropical high-pressure belt) over the entire north India. **(This is how the mechanism of jet streams influences the Indian Monsoons in the 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 March, the STJ (upper westerlies) **starts its northward march**. The southerly branch of the STJ remains positioned south of Tibet, although it is weakening in intensity.
- The weather over northern India becomes hot, dry, and squally due to larger incoming solar radiation and hot winds like the **loo**.

- Over India, the **Equatorial Trough (ITCZ)** pushes northwards with the weakening of the STJ (upper westerlies) south of Tibet. Still, 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 the Tibet Plateau. There is a **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 (convergence in upper layers is replaced by divergence → divergence in lower layers is replaced with **convergence** → high pressure at lower layers is replaced by the **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 (STJ)** 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 a **more active south-west monsoon** and causes heavy rainfall.

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

- There is good insolation from March-May, but still, there are no south-west monsoons.
- The **ridge region of the 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 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 the Himalayas), the **dynamic anticyclonic conditions persist over north-west India**.
- The winds descending from the upper air high pressure (because of the ridge of STJ) **obstruct the ascent of winds** from the surface low-pressure areas, resulting in warm and dry weather.
- This is why the months of April and May are generally **dry and rainless in spite of high temperatures** and high evaporation.

STJ and Cloudbursts

- A **cloudburst** is an **intense torrential rainfall** brought by a thunderstorm that lasts for a relatively **short duration** (a few minutes to a few hours). **Cloudbursts lead to flash floods** and cause a lot of damage to life and property.
- Every intense rainfall is not a Cloudburst. Cloudburst specifically occurs when an air mass with **high humidity is struck at a place due to various reasons**.

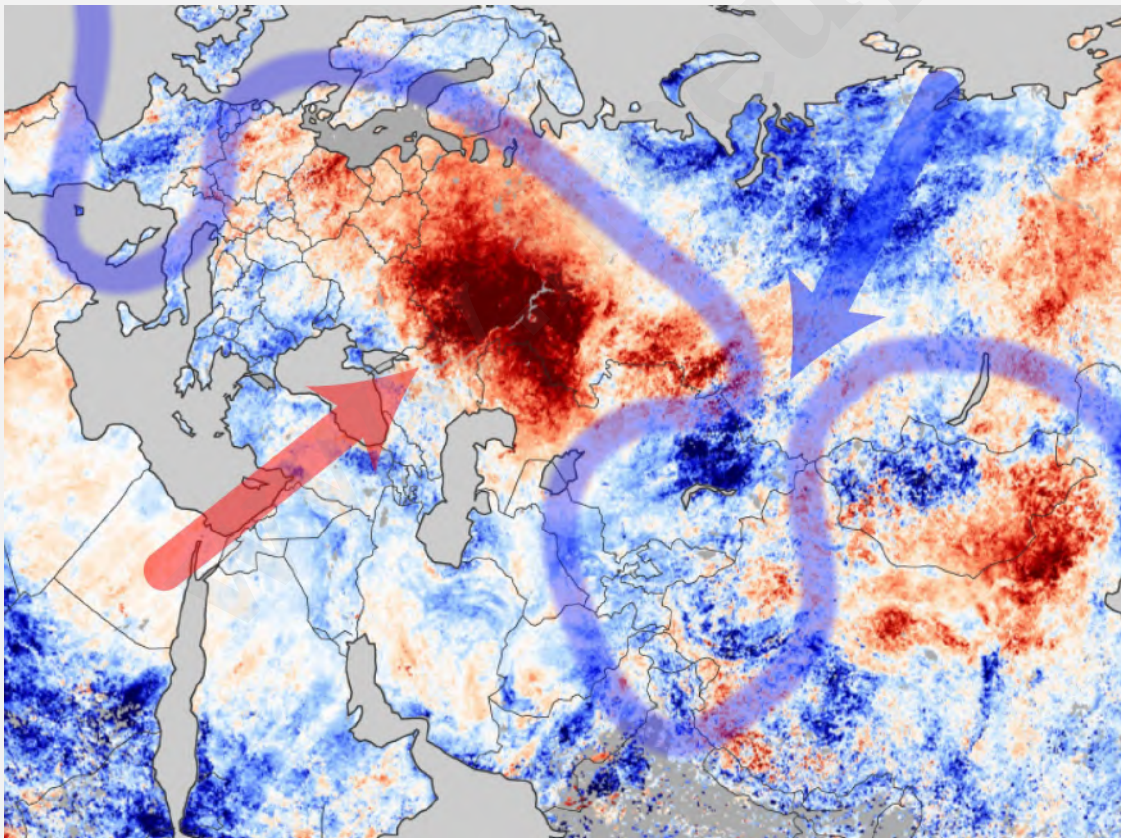
Cloudbursts in Himalayas

- In 2010, South-western strip of Russia (Caucasus Region, Moscow, etc.,) saw higher than normal temperatures (highest in the last 100 years), and there were **numerous cloudbursts in Jammu and Kashmir**.



Cloudburst

- A strong **upper-atmospheric high** over European Russia diverted the jet stream (meandering of Sub-Tropical Jet Stream) and its rain-giving train (trough) of summer storms farther north than usual, giving much of **Southern European Russia drought conditions**.
- The stalled system prevented weather systems from being drawn across Russia, and the obstacle acted as a barrier **trapping hot air to the south** and **cold air to the north**. The consequence of this static mass of hot air was the heat wave that devastated Russia.



- With the jet stream stalled, the **Subtropical Jet was unable to transit across the Himalayas** as it would ordinarily. The monsoon cell to the south, fed by warmer waters in the Indian Ocean, had nowhere to go. As a consequence, it deposited vast amounts of rain over Pakistan, Himachal Pradesh, Jammu, and Kashmir, leading to **extensive flooding**.

Indian Monsoons – Influencing Factors

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

- The establishment and maintenance of the TEJ are not fully understood. However, 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 the south-west monsoon**. This jet **descends over the Indian Ocean (near Madagascar)** and **intensifies its high-pressure cell, aiding the south-west monsoon winds**.

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 between 5° and 20°N**. It is fairly persistent in its direction and intensity from **June** through the beginning of **October**.
- TEJ comes into existence **quickly after the STJ has shifted to the north** of the Himalayas (Early June). It flows from **east to west** over **peninsular India** the **Northern Africa** at 6-9 km.
- 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**.

Indian Monsoons – Role of Tibet

- The Tibetan Plateau is an enormous block of highland, acting as a formidable barrier. It gets heated in summer and is 2 to 3 °C warmer than the air over the adjoining regions.
- The plateau affects the atmosphere in two ways: **1) as a mechanical barrier** and **2) as a high-level heat source**.
- 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 the upper troposphere (divergence) and gradually sinks (subsidence) over the equatorial part of the Indian Ocean (**monsoon cell**).
- 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.

- In winter, the Tibetan Plateau cools rapidly and produces a high-pressure cell. (Cyclonic condition over Tibet ceases, and an anticyclonic condition is established). **This high-pressure cell over Tibet strengthens N-E monsoons.**

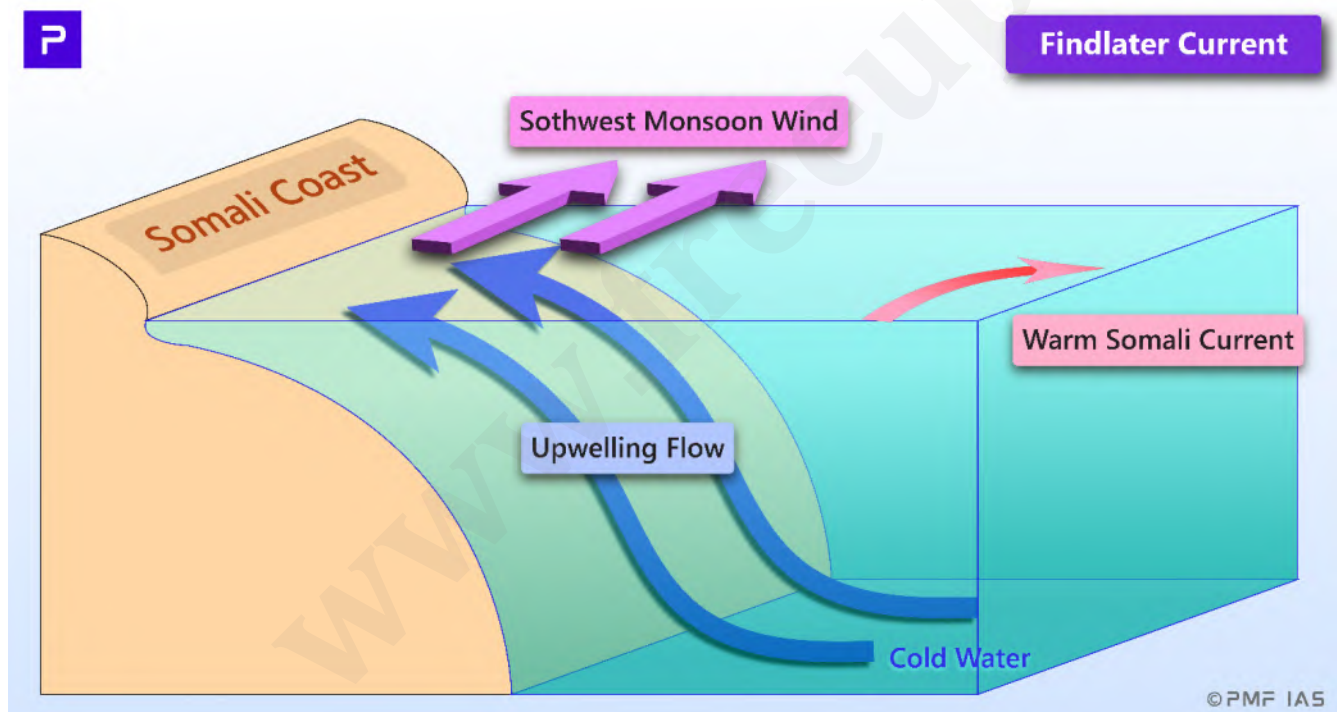
Tibetan Plateau and TEJ

- Recent observations have revealed that the intensity and duration of **heating of the 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 strengthen 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 monsoons and less rainfall.**

Tibetan Plateau and STJ

- The plateau **accentuates the northward displacement of the STJ**. 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 the Tibetan Plateau).
- 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.

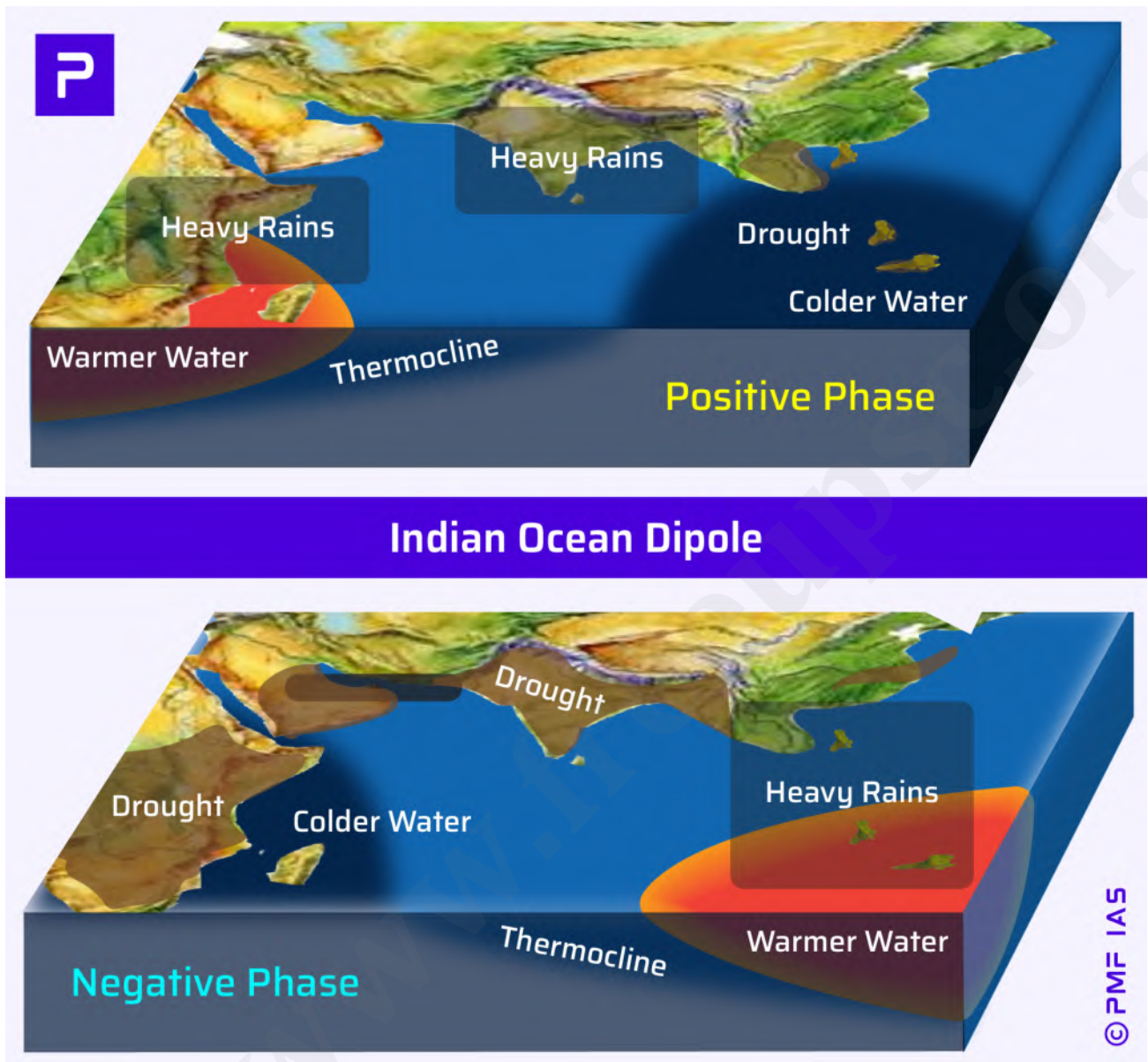
Indian Monsoons – Role of Somali Jet



- The progress of the south-west monsoon towards India is **greatly aided by the onset of the Somali jet** that transits Kenya, Somalia, and the 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 south-west monsoons towards India** at a greater pace and **intensity** (it intensifies the monsoon cell).
- The current in the Arabian Sea associated with the **Somali Jet** is called the **Findlater Current**. The monsoon winds influence its direction. It **reverses its direction** with the monsoon winds.
- **Findlater Current** in the south-west monsoon season creates a **zone of coastal upwelling near the horn of Africa (good for fishing)**. It **doesn't have a significant impact** on Indian Monsoons because the zone of upwelling is very small unlike in the case of Indian Ocean Dipole.

Indian Monsoons – Role of Indian Ocean Dipole



- Indian Ocean Dipole is a recently discovered phenomenon that has a **significant influence** on Indian monsoons. It is a **Sea Surface Temperature (SST) Anomaly** (different from normal) that occurs **occasionally** in the 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 the Indian Ocean from April to May, **peaking in October**.
- With positive IOD, winds over the Indian Ocean blow from **east to west** (from the Bay of Bengal towards the Arabian Sea). This results in the **Arabian Sea being much warmer** and the eastern Indian Ocean around Indonesia becoming colder and dry.
- In the negative dipole year, the 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 **Equatorial Indian Ocean Oscillation (EQUINOO)** (Oscillation of pressure cells between the Bay of Bengal and the Arabian Sea).
- During the **positive phase** of the EQUINOO, there is **enhanced cloud formation** and rainfall in the **western part** of the equatorial ocean near the African coast. At the same time, such activity is suppressed near Sumatra.

[UPSC 2017] With reference to 'Indian Ocean Dipole (IOD)' sometimes mentioned in the news while forecasting Indian monsoon, which of the following statements is/are correct?

1. IOD phenomenon is characterised by a difference in sea surface temperature between tropical Western Indian Ocean and tropical Eastern Pacific Ocean.
2. An IOD phenomenon can influence an El Nino's impact on the monsoon.

Select the correct answer using the code given below:

- a) 1 only
- b) 2 only
- c) Both 1 and 2
- d) Neither 1 nor 2

Explanation

- The IOD can act as a "moderator" for El Nino's impact. **Positive IOD** events often **coincide with El Nino**, while **negative IOD** events are associated with **La Nina**.
- Although external factors like **El Nino can trigger IOD events**, they can also develop independently due to local circulations within the **equatorial Indian Ocean**.
- IOD events can impact each other and **sometimes compensate for deficit rainfall** during the monsoon season, as observed in the case of the **strong IOD event in 2019**.

Answer: b) 2 only

Characteristics of the Indian Monsoon

- Monsoon rainfall is a vital component of India's climate, as it plays a crucial role in determining agricultural productivity, water resources, and overall socio-economic development.

Seasonal Reversal

- Monsoon refers to the seasonal reversal of winds. In India, the monsoon season typically lasts from June to September. During this time, winds blow from the south-west, bringing moist air from the Indian Ocean. This is known as the south-west monsoon.
- After September, winds reverse their direction, coming from the north-east, marking the onset of the north-east monsoon.

Variability

- Monsoon rainfall in India exhibits significant variability **both spatially and temporally**.
- Different regions experience varying amounts of rainfall, with some areas receiving abundant precipitation while others face drought-like conditions. This variability can occur within the same monsoon season or between different years.
- For example, the Indian states of Rajasthan and Gujarat are known for their arid climate and often experience scanty rainfall during the monsoon season.

Long Period Average

- India Meteorological Department (IMD) brands the monsoon as 'normal' or 'deficient' based on how it fares against its benchmark Long Period Average (LPA).
- LPA is the average rainfall received by the country as a whole during the south-west monsoon, for a 50-year period.
- The current LPA is 89 cm, based on the average rainfall between 1951 and 2000. This serves as a benchmark against which the rainfall in any monsoon season is measured.
- The country is said to have received deficient rainfall if the actual rainfall falls below 90% of LPA. Similarly, the country is said to have received excess rainfall if the rainfall is greater than 110% of LPA. It is deemed 'normal' when the actual rainfall received falls between 96 and 104 % of LPA.

Category	Rainfall Range (% of LPA)
Deficient	< 90
Below Normal	90 – 96
Normal	96 – 104
Above Normal	104 – 110
Excess	> 110

Spatial Distribution

- India experiences large variations in rainfall across regions.
- **High Rainfall:** **Western Ghats, north-east India, Meghalaya** (250-400 cm) receive abundant rain.
- **Moderate Rainfall:** Central India, Gangetic plains (100-200 cm) see moderate amounts of rainfall.
- **Low Rainfall:** Western Rajasthan, Ladakh (<100mm) witness scarce rainfall.
- Mountains like the Himalayas influence rainfall patterns, causing orographic uplift and **increased precipitation on windward sides**.

Monsoon Break

- The **monsoon trough** is the elongated low-pressure area over the Indian subcontinent formed by the northward shifting of ITCZ. It serves as a focal point for the convergence of moisture-laden winds, leading to widespread rainfall.
- The **position and intensity of the monsoon trough** influence the distribution of rainfall across different parts of India. When the monsoon trough shifts northward, it brings rainfall to the northern plains and parts of central India.
- **Monsoon break** occurs when the monsoon trough **shifts northward to the Himalayan foothills**. This **enhances rainfall in the Himalayan states**, while **for the rest of India, rainfall is suppressed or temporarily interrupted**.
- Monsoon break happens especially in the **core monsoon zone area** (the region stretching from Gujarat in the west to West Bengal and Odisha in the east). These breaks can last for several days to a few weeks and are characterised by the weakening of the monsoon circulation.
- Shifting of monsoon trough southward resumes vigorous monsoon over major part of India.
- Climatologically, a monsoonal break is declared when the normalised rainfall anomaly index (i.e., deviation from the long-term rainfall average over the core monsoon zone) exceeds the -1 threshold, and the situation persists for **at least three consecutive days**.

Factors that Can Cause Monsoon Break

- **El Nino Event:** El Nino is the warm phase of ENSO, which is characterised by cooler ocean temperatures in the western Pacific. It leads to a weaker monsoon with prolonged breaks.
- **Indian Ocean Dipole (IOD):** A negative IOD is characterised by cooler sea surface temperatures in the western Indian Ocean. This can lead to a weaker monsoon in India.
- **Cyclones:** A cyclonic circulation in the Arabian Sea sucks up moisture that's supposed to reach India. If it turns westwards towards Yemen, it will further take away moisture and stall the monsoon.
- **Madden-Julian Oscillation (MJO):** It is an **eastward-moving trough** (series of thunderstorms) in the tropics that **recurs every 30 to 60 days**. It is characterised by **alternating periods** of enhanced and suppressed rainfall. A **suppressed MJO** can lead to a monsoon break in India.

Hard to Predict

- The Indian monsoon system is the most complex weather system in the world as it depends on many factors:
 - ❖ El Nino, La Nina, Indian Ocean Dipole, etc.
 - ❖ Sub-tropical Jet Stream, Somali Jet, etc.
 - ❖ Atlantic Zonal Mode or Atlantic Nino
 - ❖ Madden-Julian Oscillation
 - ❖ Pollution, aerosols, Asian desert dust, etc.

Atlantic Zonal Mode or Atlantic Nino

- The warming or cooling of the Atlantic Ocean (**Atlantic Zonal Mode or Atlantic Nino**) influences the Kelvin waves, which are **eastward-moving disturbances** in the **troposphere**.
- These waves move towards the tropical Indian Ocean and either increase or decrease the atmospheric temperature. This, in turn, influences the temperature gradient between the Indian Ocean and the subcontinent thereby affecting the monsoon.

Poor Monsoon Prediction Models

- IMD issues five kinds of forecasts:
 1. Nowcast is for less than 24 hours.
 2. The short range forecast is for up to three days.
 3. The medium range is from three to 10 days.
 4. The extended range is for 10-30 days.
 5. The long-range is on a seasonal scale (e.g. monsoons).

Statistical models of monsoon prediction

- **Statistical models** involved identifying **climate parameters** linked to the performance of the monsoon — for instance, the sea surface temperature gradient between the North Atlantic and North Pacific, the volume of warm water in the equatorial Pacific, the Eurasian snow cover, etc.
- Their values are **correlated** to values of actual rainfall over a hundred years and then, using statistical techniques, extrapolated to forecast a particular year's monsoon.
- This is how the IMD dispenses its **long-range forecasts**. This has, however, proved wrong as the **IMD missed its mark** on forecasting major droughts and rain deficits.

Digital System since 2015

- IMD started to use the dynamic model along with the statistical model.
- The dynamic system **simulates the weather** at a chosen set of locations on a given day, and the computers calculate how these weather variables will change over days, weeks, and months.

Drawbacks

- Dynamical models **need data** about current weather conditions for accurate prediction. However, IMD **doesn't have enough data collection centres** to collect weather data for the entire country.
- They are not entirely reliable for forecasting longer-term weather phenomena like monsoon.

High-resolution computer models

- The IMD and several private weather agencies are increasingly relying on more sophisticated and high-resolution computer models to give localised forecasts or warn farmers of changes in weather 10-15 days ahead.
- These **shorter forecasts** are far more reliable. These models are also useful for anticipating heat waves or cold waves and, therefore, useful to urban planners and the government.

Over the years, IMD has moved to a mix of crude and advanced models to predict the weather. However, the **statistical model** continues to be the bedrock of the IMD's forecast. Hence, the monsoon forecast by IMD is rarely accurate.

Impact on Agriculture

- Monsoon rainfall is critical for agriculture in India, as the majority of the country's farmland is rain-fed. Adequate monsoon rains ensure optimal soil moisture for crop growth and support the cultivation of various crops such as rice, wheat, sugarcane, and cotton.
- Conversely, deficient monsoon rainfall can lead to droughts, crop failures, and food shortages, affecting millions of farmers and rural communities.

[UPSC 2012] Consider the following statements:

1. The duration of the monsoon decreases from southern India to northern India.
2. The amount of annual rainfall in the northern plains of India decreases from east to west.

Which of the statements given above is/are correct?

- a) 1 only
- b) 2 only
- c) Both 1 and 2
- d) Neither 1 nor 2

Explanation

Duration of the monsoon season

- The duration of the monsoon season decreases gradually from southern to northern India. This is because the monsoon season begins in southern India (Kerala) around June and extends northward, covering the entire country by **mid-July**. The retreat of the monsoon begins first in the north and gradually progresses towards the south.

Rainfall in the northern plains decreases from east to west

- The northern plains receive most rainfall from south-west monsoon winds carrying moisture from the Indian Ocean.
- As the monsoon progresses inland in the northern plains, **it loses moisture**, resulting in a **decrease in rainfall from east to west** across the northern plains.
- States like **West Bengal** and **Bihar** in the eastern part of the northern plains receive higher rainfall compared to states like **Haryana** and **Punjab** in the western part.

Answer: c) Both 1 and 2

[UPSC 2002] For short-term climatic predictions, which one of the following events, detected in the last decade, is associated with occasional weak monsoon rains in the Indian subcontinent?

- a) La Nina

- b) Movement of Jet Stream
- c) El Niño and Southern Oscillations
- d) Greenhouse effect at global level

Explanation

Impact of El Niño on Indian Monsoon

- During El Niño events, the **central and eastern equatorial Pacific Ocean becomes warmer** than usual. This **disrupts the atmospheric circulation patterns**, impacting global weather patterns, including the Indian monsoon.
- **El Niño-related changes in wind patterns can weaken the Indian monsoon**, leading to reduced rainfall over the subcontinent.

Answer: c) El Niño and Southern Oscillations

[UPSC 2015] How far do you agree that the behaviour of the Indian monsoon has been changing due to humanizing landscapes? Discuss.

- Human activities have significantly altered Earth's natural systems, and the monsoon system is no exception.

Land-Use Changes

Deforestation

- Large-scale deforestation **reduces the amount of moisture** transpired from trees back into the atmosphere. This **disrupts the moisture recycling and rainfall patterns**, impacting the monsoon's intensity and distribution of rainfall.
- For example, studies have linked **reduced rainfall in the Western Ghats to deforestation**, potentially affecting monsoon patterns in downwind areas.

Urbanisation

- The creation of **urban heat islands** and changes in surface roughness due to cities **alters local temperature and wind patterns**, influencing monsoon circulation.
- For example, rapid urbanisation in cities like Mumbai and Delhi is associated with **increased extreme rainfall events** during the monsoon.

Agricultural Practices

- Irrigation systems, especially in regions like the Indo-Gangetic Plain, can increase moisture levels in the atmosphere. However, over-irrigation can lead to local effects that might disrupt larger monsoon patterns.

Aerosols and Pollution

Black carbon and other aerosols

- High levels of air pollution, **especially black carbon**, have **solar-absorbing properties** that can change atmospheric temperature profiles. This can **alter wind patterns** and weaken the monsoon system.
- For example, **aerosols over the Indo-Gangetic Plain disrupt the monsoon flow toward central India**.

Climate Change

Global Warming

- Rising temperatures associated with **climate change alter sea surface temperatures** and atmospheric dynamics, impacting the complex ocean-atmosphere interactions driving the monsoon.
- For example, increased warming in the Indian Ocean has been linked to **more frequent and intense monsoon extremes**.

[UPSC 2017] What characteristics can be assigned to monsoon climate that succeeds in feeding more than 50 percent of the world population residing in Monsoon Asia?

Seasonal Reversal

- Monsoon climates are characterised by a **seasonal reversal of winds**, typically driven by temperature differences between land and ocean. This seasonal reversal creates alternating conditions driving diverse economic activity.

Heavy Rainfall

- Monsoon climates experience heavy rainfall during the wet season, which is essential for replenishing water sources, irrigating crops, and supporting ecosystems.

Predictability (to some extent)

- While there is annual variability, farmers in Monsoon Asia have **adapted to the general timing of the wet and dry seasons** through traditional agricultural practices.

High Agricultural Productivity

- The **combination of seasonal rainfall and fertile soils** in monsoon regions supports high agricultural productivity.
- Farmers can cultivate multiple crops throughout the year, taking advantage of the wet and dry seasons to grow a variety of crops, including rice, wheat, millet, and pulses.

Biodiversity

- Monsoon climates support rich biodiversity, with diverse ecosystems ranging from **tropical rainforests to dry deciduous forests**.

----- End of Chapter -----

10. Indian Climate

- India's climate closely resembles the climate of a **tropical** country, although its northern part (north of the Tropic of Cancer) is situated in the **temperate belt**.
- The 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 the same latitudes.
- During summer, due to the head position of the sun, the climate in the southern parts resembles an **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 the Arabian Sea and Bay of Bengal gives India a typical **tropical monsoon climate**. Thus, the Indian climate, to be precise, is **tropical monsoon type (a distinct wet and dry climate)** rather than just a tropical or half-temperate climate.

Features of Indian Climate

- India has high regional climatic diversity because of its topographical diversity (location, altitude, distance from sea and relief).



Typical Indian Climate

Rainfall

- The climate in most of the regions is characterised by **distinct wet and dry seasons**. Some places like **Thar desert and Ladakh have no wet season**.

- Mean annual rainfall varies substantially from region to region. **Mawsynram** and **Cherrapunji** in Meghalaya receive **around 1,100 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 (Tamil Nadu coast and Southern AP 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 in India.
- The **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 **the lowest 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.

[UPSC 2002] The average annual temperature of a meteorological station is 26°C , its average annual rainfall is 63 cm and the annual range temperature is 9°C . The station in question is

- a) Allahabad
- b) Chennai
- c) Cherrapunji
- d) Kolkata

Explanation

- The climatic condition of Chennai fits into the **tropical savannah type**, characterised by an **average annual temperature of 26°C** , an average annual rainfall between **60-70 cm annually**.
- Chennai experiences warm temperatures throughout the year, with winters averaging around 24°C and summers around 30°C .

Answer: b) Chennai

[UPSC 2001] Identify



In the shaded area of the above map, the mean temperature for the month of July varies between:

- a) 22.5°C–25.0°C
- b) 25.0°C–27.5°C
- c) 27.5°C–30.0°C
- d) 30.0°C–32.5°C

Explanation

- The shaded area on the map denotes the **tropical wet and dry region** (distinct periods of rainfall and dryness throughout the year), characterised by mean temperatures ranging from **27.5°C to 30°C** during July.

Answer: c) 27.5°C–30.0°C

Factors Influencing Indian Climate

- ❖ **Latitudinal location**
- ❖ **Distance from the Sea**
- ❖ **The Himalayas**
- ❖ **Physiography**
- ❖ **Monsoon Winds**
- ❖ **Upper Air Circulation – Westerly and Easterly Jet Streams**
- ❖ **El Nino and La Nina**
- ❖ **Tropical Cyclones**
- ❖ **Western Disturbances**

Latitudinal location

- Areas south of the Tropic of Cancer are in the **tropics** and hence receive **high solar insolation**. The summer temperatures are extreme, and winter 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 is equally hot** here because of the **hot local wind** called the **loo**. Winter here is very cold due to **cold waves brought by the western disturbances**.
- **Coastal regions** see **moderate climatic conditions** irrespective of latitudinal position.

Distance from the Sea

- Coastal regions have a moderate or equable or maritime climate, whereas 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 a good amount of rainfall.

[UPSC 2005] Which one of the following is the correct sequence of Indian cities in the decreasing order, of their normal annual rainfall?

- a) Kochi–Kolkata–Delhi–Patna
- b) Kolkata–Kochi–Patna–Delhi
- c) Kochi–Kolkata–Patna–Delhi
- d) Kolkata–Kochi–Delhi–Patna

Explanation

Kochi

- Located in the south-western coastal region of India, Kochi experiences heavy rainfall due to its **proximity to the Arabian Sea** and the **influence of the southwest monsoon**.

Kolkata

- Kolkata, situated in the eastern part of India, also receives significant rainfall, **primarily from both the southwest and northeast monsoons**.
- Being close to the Bay of Bengal, Kolkata is **prone to cyclonic storms** and receives substantial precipitation from such storms.

Patna

- Patna, located in the northern part of India, receives **moderate to high rainfall annually**.
- The city experiences a **humid subtropical climate** with a distinct dry season, contributing to its lower average rainfall.

Delhi

- Delhi, being **further inland (continentality)** and away from coastal areas, typically receives less rainfall compared to the other cities mentioned.

Answer: b) Kolkata–Kochi–Patna–Delhi

Himalayas

- The Himalayas act as a **climatic divide** between India and Central Asia.
- During winter, the 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 (Orographic Rainfall)**.
- The **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 move into China, and **most of north India would have been a desert**.

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

- As the monsoon winds move from east to west, the **moisture levels decrease** due to successive rainfall at each low-pressure region.

- By the time winds reach the western parts of the plains (Delhi, Haryana, etc.,) all the moisture in the monsoon winds is **exhausted**.

Then how come Haryana and Punjab are not deserts like Rajasthan?

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

Physiography

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

Why are some parts of peninsular India semi-arid?

- Places on the **windward side** of an orographic barrier receive a **great amount of rainfall**, whereas those on the **leeward side remain arid to semi-arid** due to the **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 the **rain-shadow or leeward side of the Western Ghats** and receive scanty rainfall.

Why is there no significant rainfall in Gujarat and Rajasthan? (Explain the formation of the Thar Desert.)

- Monsoon 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 Aravallis**, and also, they are **not of imposing height** to cause an orographic effect except for some places like **Mount Abu**; hence, there is no orographic rainfall.

No convection cell or vertical wind movements

- Monsoon winds blow towards low-pressure cells in Tibet, and hence, **only horizontal wind movements exist in Gujarat and Rajasthan**.

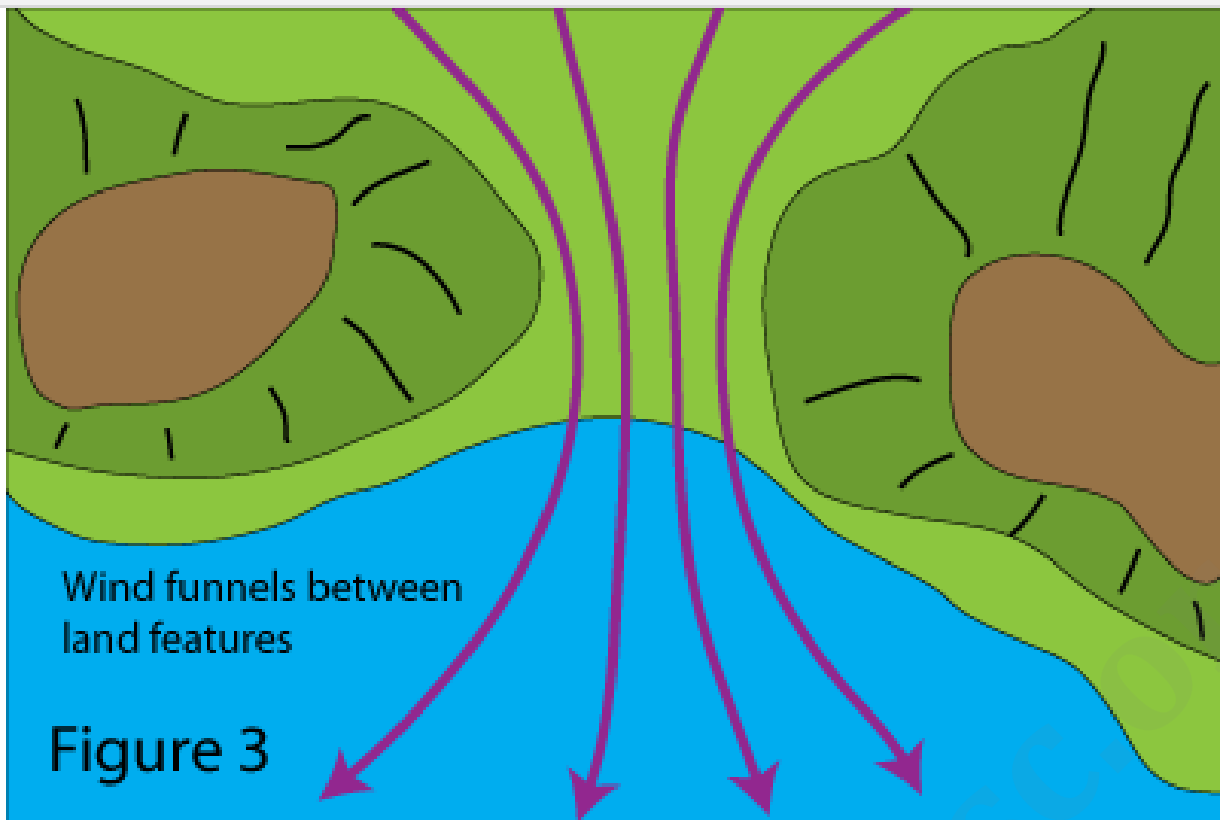
Sub-tropical high-pressure belt

- In winter, the region experiences **strong divergence** because of the **Sub-Tropical Jet (STJ)**.

How come Cherrapunji and Mawsynram receive abnormally high rainfall?

- **Mawsynram** and **Cherrapunji (both places in Khasi Hills, Meghalaya)** are the **wettest places on earth**, with a mean annual rainfall of over 1100 cm.
- **Copious rainfall in these places is due to the funnelling effect followed by orographic upliftment — the monsoon winds, saturated with moisture, are forced to ascend as they encounter the steep slopes of the Khasi Hills.**

⇒ **Funnelling effect:** clouds are channelled into a narrow region between mountains, and hence, the cloud density is extraordinary.



Funnelling Effect

Monsoon Winds

- 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 gives way to monsoon or rainy season.
- The south-west monsoons from the Arabian Sea and the Bay of Bengal bring rainfall to the country.
- The **north-eastern winter monsoon** does not cause much rainfall except along the **Coromandel coast (TN coast)** after getting moisture from the Bay of Bengal.

Upper-Air Circulation

- The changes in the upper air circulation over Indian landmass are brought about by Jet streams.

Westerly Jet Stream

- Westerly jet stream blows at a very high speed during winter over the **sub-tropical zone**.

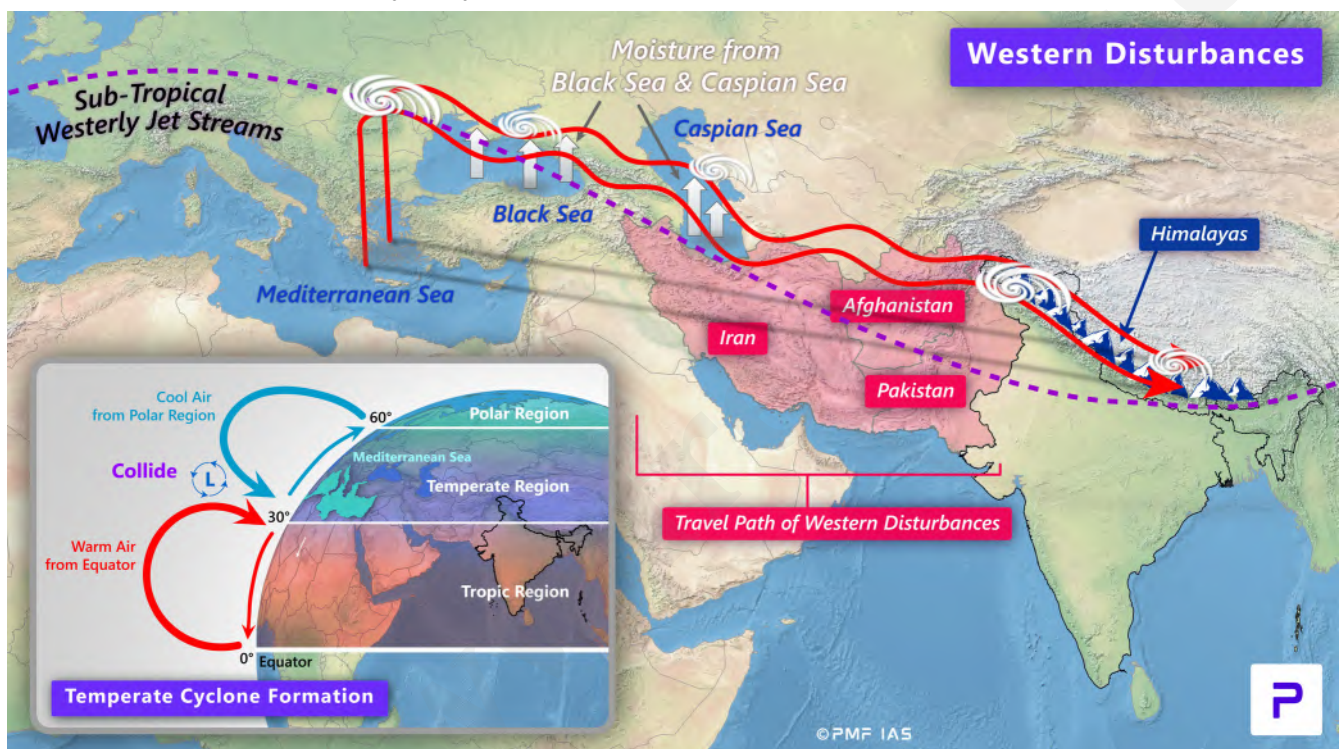
- The southern branch of the jet stream exercises a significant influence on the winter weather conditions in India. This jet stream is responsible for bringing **western disturbances** from the **Mediterranean region** into the Indian sub-continent.

Easterly Jet Stream

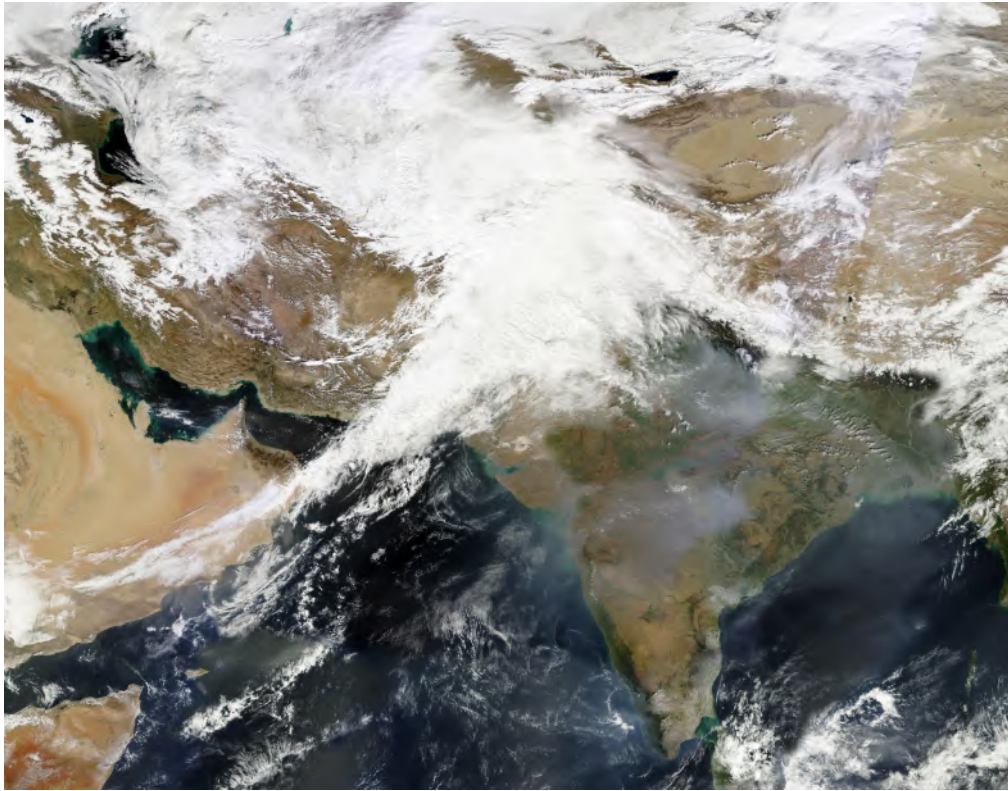
- The **reversal in upper air circulation** takes place in summer due to the apparent shift of the sun's vertical rays in the northern hemisphere.
- The westerly jet stream is replaced by the easterly jet stream, which **owes its origin to the heating of the Tibet plateau**. This helps in the **sudden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

Western Disturbances

- Meteorologists believe that the **southern branch of the jet stream** exercises a significant influence on the winter weather conditions in India.
- The **southern branch of the jet stream** is responsible for steering the **western depressions (Western Disturbances)** from the **Mediterranean Sea**.
- These depressions are **residual frontal cyclones** that move at the height of 2000 meters from the mean sea level. On the way, they pick up moisture from the **Caspian Sea** and the **Black Sea**.



- On average, 4 to 6 cyclonic waves reach north-western India between October and April each year.
- Some of the depressions continue eastwards, redeveloping in the zone of jet stream confluence about 30° N, 105° E (near the east coast of China).
- According to recent studies, the number of Western Disturbances reaching India has increased in the early summer period and that outnumbers the number of disturbances reaching India in the late winter.



A strong western disturbance in February 2013

Weather Associated with Western Disturbances

- The arrival of these **temperate storms (remnants of temperate cyclones)** causes **precipitation**, leading to an **abrupt decrease in air temperature** over North-West India.
- **Winter rain** and **heat storms in north-western plains**, occasional **heavy snowfall in hilly regions**, and **cold waves** in **the northern plains** are **caused by these disturbances**.

Importance of Western Disturbances

- The western disturbances affect weather conditions during the winter season up to Patna (Bihar) and give occasional rainfall, which is **highly beneficial for the standing rabi crops (wheat, barley, mustard, gram, lentil, etc.)**.

Tropical Cyclones

- Tropical cyclones originate in the Bay of Bengal and the Arabian Sea and influence large parts of 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.

El-Nino, La Nina and ENSO

El Nino

- ❖ **Adversely affects monsoon rainfall and cyclogenesis in the Bay of Bengal.**

- ❖ **Good for cyclogenesis in the Arabian Sea.**
- ❖ Droughts are common during El Nino events due to less monsoonal and cyclonic rainfall.

La Nina

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

El Nino Southern Oscillation (ENSO)

- ❖ Southern Oscillation coinciding with El Nino is called ENSO. (SO usually coincides with EL Nino. This is 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 are similar to El Nino.**

- During El Nino events, the atmospheric pressure is lower in the eastern Pacific and higher in the western Pacific, while during La Nina events, the reverse occurs.
- **ENSO** encompasses **both** the **oceanic** and **atmospheric** components of **El Nino**. It refers to the coupled **ocean-atmosphere interaction** characterized by the **warming (El Nino)** or **cooling (La Nina)** of **sea surface temperatures** in the western and eastern equatorial Pacific, along with **changes in atmospheric circulation patterns**.
- The **Southern Oscillation** refers specifically to the **atmospheric component** of the ENSO. It involves the **see-sawing of atmospheric pressure (oscillation of low-pressure and high-pressure cells)** between the **eastern** and **western** tropical Pacific Ocean.

[UPSC 1997] Match List-I with List-II and select the correct answer:

List-I (Climatic conditions)	List-II (Reasons)
A. Madras is warmer than Calcutta	1. North-east monsoon
B. Snowfall in Himalayas	2. Altitude
C. Rainfall decreases from West Bengal to Punjab	3. Western depressions
D. Sutlej-Ganga plain gets some rain in winter	4. Distance from the sea
	5. Latitude

Codes:

- a) A – 1; B – 2; C – 4; D – 5
- b) A – 4; B – 5; C – 1; D – 3
- c) A – 5; B – 2; C – 4; D – 3
- d) A – 5; B – 1; C – 3; D – 4

Explanation

A. Chennai is warmer than Kolkata — Latitude

- Chennai, located near the southern tip of India, has a **lower latitude compared to Kolkata**, which is situated further north.
- Generally, **areas closer to the equator receive more direct sunlight** throughout the year, leading to warmer temperatures.

B. Snowfall in the Himalayas — Altitude

- Altitude plays a crucial role in determining the climate and weather patterns of an area. As **altitude increases, temperatures drop**, leading to cooler conditions.

C. Rainfall decreases from West Bengal to Punjab — Distance from sea

- West Bengal, located on the eastern coast of India, is closer to the Bay of Bengal, while Punjab, situated in the northwest, is farther away from the sea.
- As these winds move inland, they lose moisture**, leading to decreased rainfall farther away from the coast.

D. Sutlej-Ganga Plain gets some rains in winter — Western depressions

- During winter, the Sutlej-Ganga Plain receives some rainfall, primarily due to the influence of **western depressions**.

Answer: c) A – 5; B – 2; C – 4; D – 3

Indian Climate – Seasons

- The Monsoon Climate of India has four distinct seasons:
 - The cold weather season or winter season
 - The hot weather season or summer season
 - The south-west monsoon season or Rainy season
 - The season of the retreating monsoon or cool season

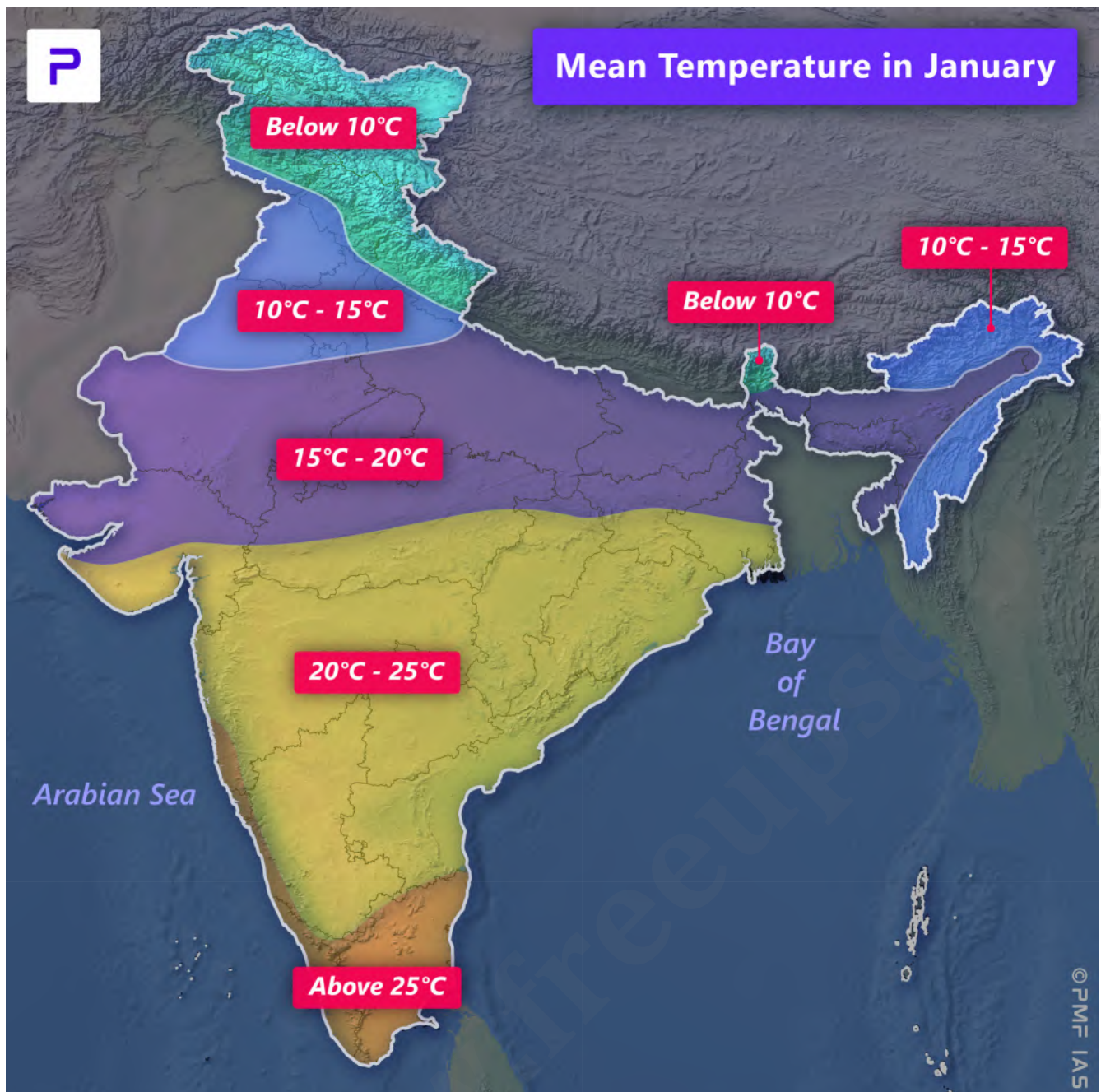
Winter Season: November to March

- During the winter season, the sun's apparent path is to the **south of the equator**. **January** is the coldest month during this season.
- The weather is marked by **clear skies, pleasant weather, low temperature, low humidity**, a **high range of temperature**, and **cool and slow northeast trade winds**.
- The **diurnal range** of temperature, especially in **interior parts** of the country, is **very high**.

The Temperature in the Winter Season

- The isotherm of **20°C** runs roughly **parallel to the Tropic of Cancer**. To the south of this isotherm, temperatures remain above 20 °C, resulting in the **absence of distinct winter weather**. Some parts of Kerala and Tamil Nadu experience temperatures near 30 °C during this time.
- 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 region in India, recording a minimum temperature of -45°C in 1908.



The Pressure in the Winter Season

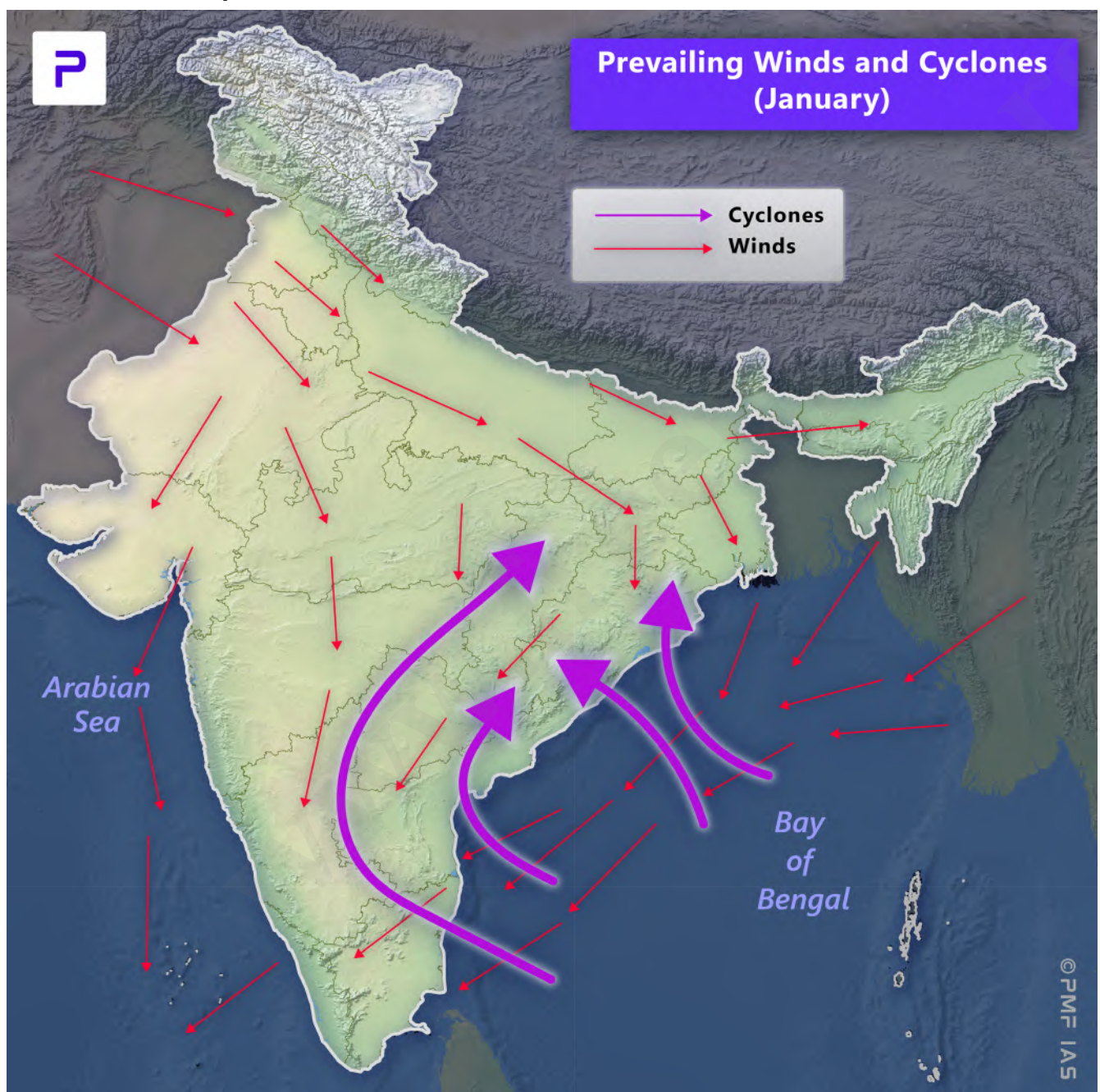
- **High air pressure prevails** over large parts of **north-west India** due to **low temperatures** coupled with **divergence induced** by the ridge of the **Sub-Tropical Jet Stream (STJ)**. In comparison, **South India experiences lower pressure**.
- This pressure difference sets in motion winds flowing from the high-pressure northwest towards the low-pressure southeast. However, the **difference in pressure (pressure gradient) is small**, resulting in weak winds.

Western Disturbances in Winter Season

- The spell of **fine weather** over northwestern and northern India is often **broken** due to the inflow of **western disturbances**.
- These disturbances intensify over Rajasthan, Punjab, and Haryana before moving eastwards across the sub-Himalayan belt up to Arunachal Pradesh.
- They **bring light rain** in the **Indus-Ganga plains** and **snowfall in the Himalayan belt**.
- After the passage of the disturbance, **widespread fog and cold waves** are experienced, leading to a significant drop in minimum temperature by **5° to 10°C** below normal.

Tropical Cyclones in the Winter Season

- This is the season with the **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**.



- However, some cyclones may still form in the Bay of Bengal, **bringing heavy rainfall to Tamil Nadu**.
- Occasionally, these cyclones cross the southern peninsula and enter the Arabian Sea. Also, some storms may **originate in the Arabian Sea and move northward or westward**.

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). Most of it occurs along the **south-eastern coast of Tamil Nadu and adjoining parts of Andhra Pradesh**.
- 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 the east** (it is the opposite in the rainy season).
- The **north-eastern part** of India also gets rainfall during the winter months through local weather systems like cyclones or remnants of monsoons.

[UPSC 2001] Assertion and Reasoning

Assertion (A): Anticyclonic conditions are formed in winter season when atmospheric pressure is high and air temperatures are low.

Reason (R): Winter rainfall in northern India causes development of anticyclonic conditions with low temperatures.

- Both A and R are true and R is the correct explanation of A
- Both A and R are true but R is not a correct explanation of A
- A is true but R is false
- A is false but R is true

Explanation

- **Anticyclones** are areas of **high pressure where air sinks and diverges outward**. They are generally associated with **clear skies, stable weather, and cool temperatures**.
- Winter rainfall can **temporarily cool** the air in the immediate area of precipitation. This can lead to a **localized** increase in air pressure, but not necessarily the development of a large-scale anticyclone.
- The **cooling of the larger landmass due to reduced sunlight** in the winter months plays the most significant role in creating high-pressure systems and subsequent anticyclones.

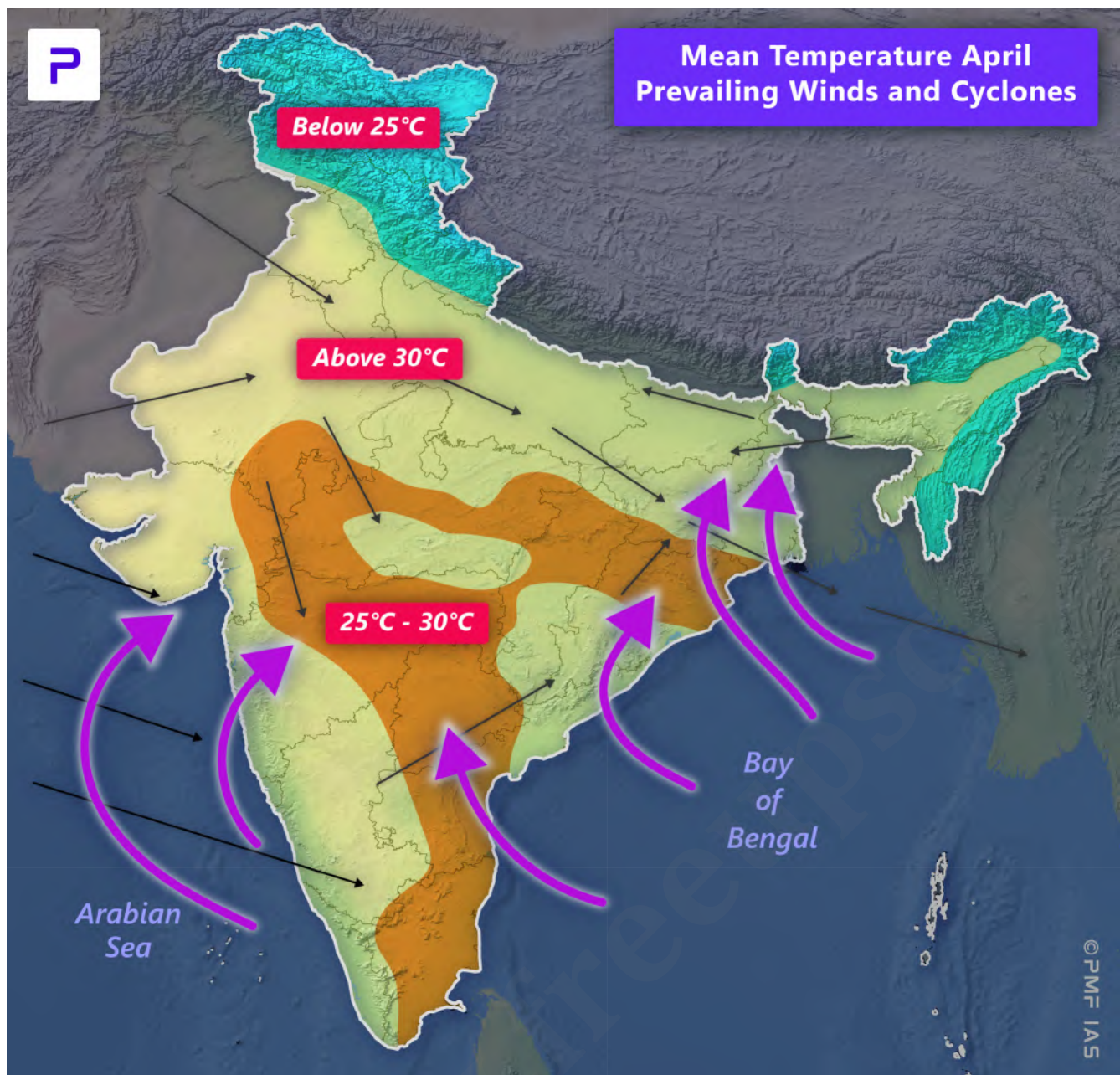
Answer: c) A is true but R is false

Summer Season in India (March to June)

- The summer season in India prevails from **March to June**. It is characterized by **high temperatures and low humidity**. It is sometimes referred to as the **pre-monsoon period**.

The temperature in Summer Season

- Summers are characterised by high insolation due to the sun's apparent movement 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 was 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 temperatures along the west coast are comparatively lower than those prevailing on the east coast due to the prevailing westerly winds.
- Northern and central parts of India experience **heat waves** in this season. The heat waves strike by the end of April, and their maximum occurrence is in May.
- Most heat waves develop over Rajasthan, Punjab, and Haryana (locations far away from the sea). From here, they spread over Uttar Pradesh and Bihar.
- The **strong northwesterly winds** (caused by a **strong divergence in northwest India**) with a long land journey over hot regions **check the onward march of the sea breeze** over the eastern coastal belt and create **heatwave conditions over Odisha and Andhra Pradesh**.
- **Heat waves are rare over the peninsula south of 13 °N latitude** due to **maritime conditions** prevailing there.

The pressure in Summer Season

- The atmospheric pressure is low all over the country due to high temperatures. 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 the **Iranian, Baloch, and Thar deserts**.
- In May and June, the high temperature in northwest India builds a **steep pressure gradient**, causing **strong, hot, and dust-laden** loo winds to blow.
- 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 several 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, Jammu region, Delhi, Uttar Pradesh, Bihar and Madhya Pradesh. They are **short-lived**.
- The **squalls** and **showers** that follow these storms bring down the temperature sharply temporarily.
- Andhis typically occur during the **pre-monsoon season (March-May)** and are also known by other names like **Kali Andhi (Black Storm)**.

Frontal Thunderstorms in the Summer Season

- The strong convectional movements related to the westerly jet stream lead to thunderstorms in the **eastern and north-eastern parts of the country**. They normally **originate over the Chota Nagpur plateau** and are carried eastwards by westerly winds.
- The highest incidence of thunderstorms occurs in 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.
- The rainfall brought by the norwesters is known as the **spring storm showers**.
- **Hailstones** sometimes accompany showers and occasionally attain the size of a golf ball. They cause heavy damage to standing crops, and livestock and even lead to loss of human lives.
- They are sometimes **useful for growing tea, jute, and rice**. In **Assam**, these storms are known as **Tea Showers and 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 Vaïasakha.

Convectional Thunderstorms in the Summer Season

- In the south, thunderstorms occur in Kerala and adjoining parts of Karnataka and Tamil Nadu, particularly during evenings and nights.
- In **Karnataka**, they are called **cherry blossoms or blossom showers** due to their effect on the **coffee plantations**.
- Such showers are called **mango showers** in **Kerala, Tamil Nadu**, and **Andhra Pradesh** because they are **very beneficial to mango crops**.

Western Disturbances in Summer Season

- Their frequency and intensity **gradually decrease** with the advancement of summer.
- Approximately 4, 3, and 2 western disturbances visited 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 the **Arabian Sea**.
- A few cyclones are formed in the Bay of Bengal in 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 that of 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 **recurve northeast** and **strike Bangladesh and the Arakan Coast of Myanmar**, where the coastal areas are liable to be hit by tropical storms in May.
- Many of these storms are quite severe and **cause heavy damage to life and property**.
- **Very few hit the Indian coast**, while some dissipate over the sea itself.
- 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 **north-eastern** 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 with **high intensity of rainfall**. Coastal areas of Kerala and Karnataka receive rainfall from **thunderstorms**.

Rainy Season – South-West Monsoon Season

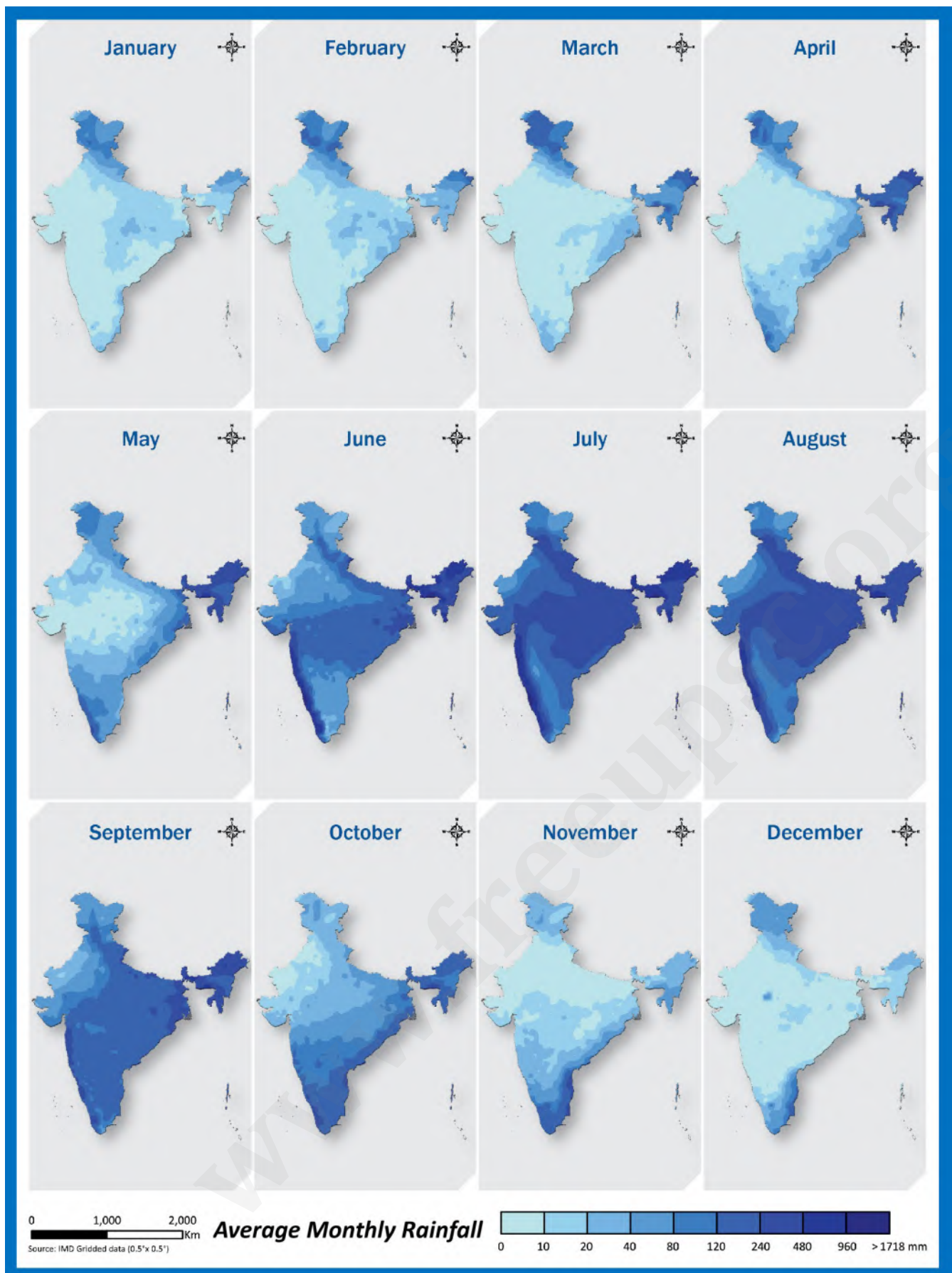
- The South-West Monsoon Season, also known as a **hot-wet season**, occurs from **June to mid-September**.

The Temperature During South-West Monsoon Season

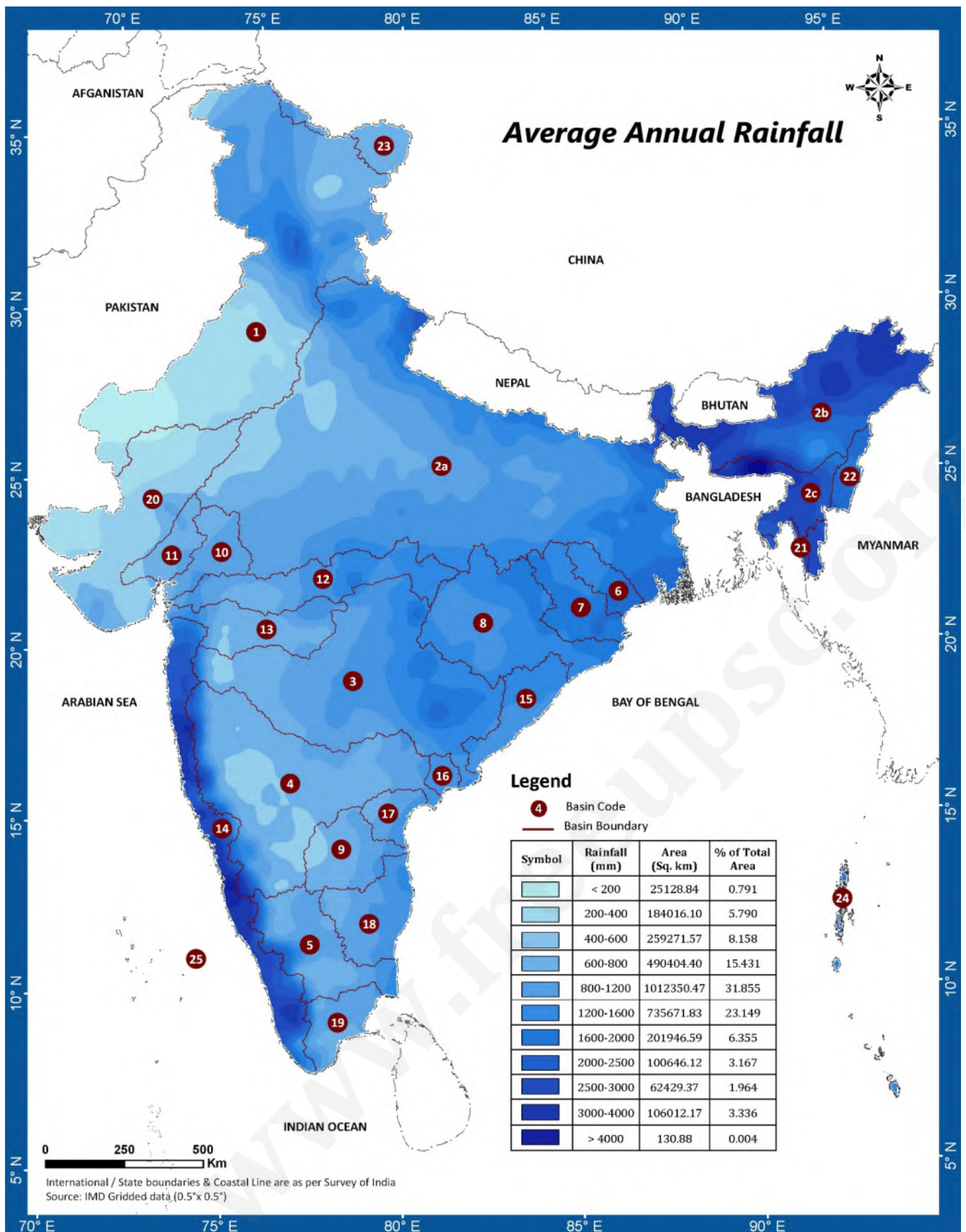
- The sudden onset of South-West Monsoons leads to a significant fall in temperature (3° to 6 °C).
- The temperature varies more throughout the rainy season compared to other seasons.
- The temperature **rises in September** with the cessation of southwest monsoons.
- There is a rise in temperature whenever there is a **break in the monsoons**.
- The **diurnal range of temperature is small** due to clouds and rain.
- The highest temperatures are experienced at places **west of the Aravalli** (38° to 40 °C) due to the 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 temperatures.
- **ITCZ (monsoon trough)** lies **along the Ganga plain** and **shifts location frequently** depending on the weather conditions.



- The **atmospheric pressure increases steadily southwards**.
- Over the peninsular region, due to the pressure gradient between north and south, winds blow in a **southwest-to-northeast** direction from the Arabian Sea and the Bay of Bengal.



- These winds change direction in the **Indo-Gangetic plain**, where they **move from east to west**.

Rainfall during South-West Monsoon Season

- This season contributes **three-fourths of the total annual rainfall**, with the average rainfall over the plains of India being about **87%**.

- The 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 by a lot of thunder, lightning, and heavy downpours. This sudden onset of rain is termed a **monsoon burst**.
- The monsoon onset can sometimes be delayed or arrive earlier than usual, typically occurring **between May 29th and June 7th**.

Break in the South-West Monsoons

- The breaks are believed to be caused by the **northward shifting of the monsoon trough** to the **foothills of the Himalayas**.
- This leads to a **sharp decrease in rainfall over most parts of the country** but **increases along the sub-Himalayan regions** and the **southern slopes of the Himalayas**, **parts of Northeast India**, and the **southeast peninsula**.
- On average, one or two breaks occur during the rainy season, with a chance of a break occurring in 85 out of 100 years. In most years, the breaks occur in the **second week of August**.

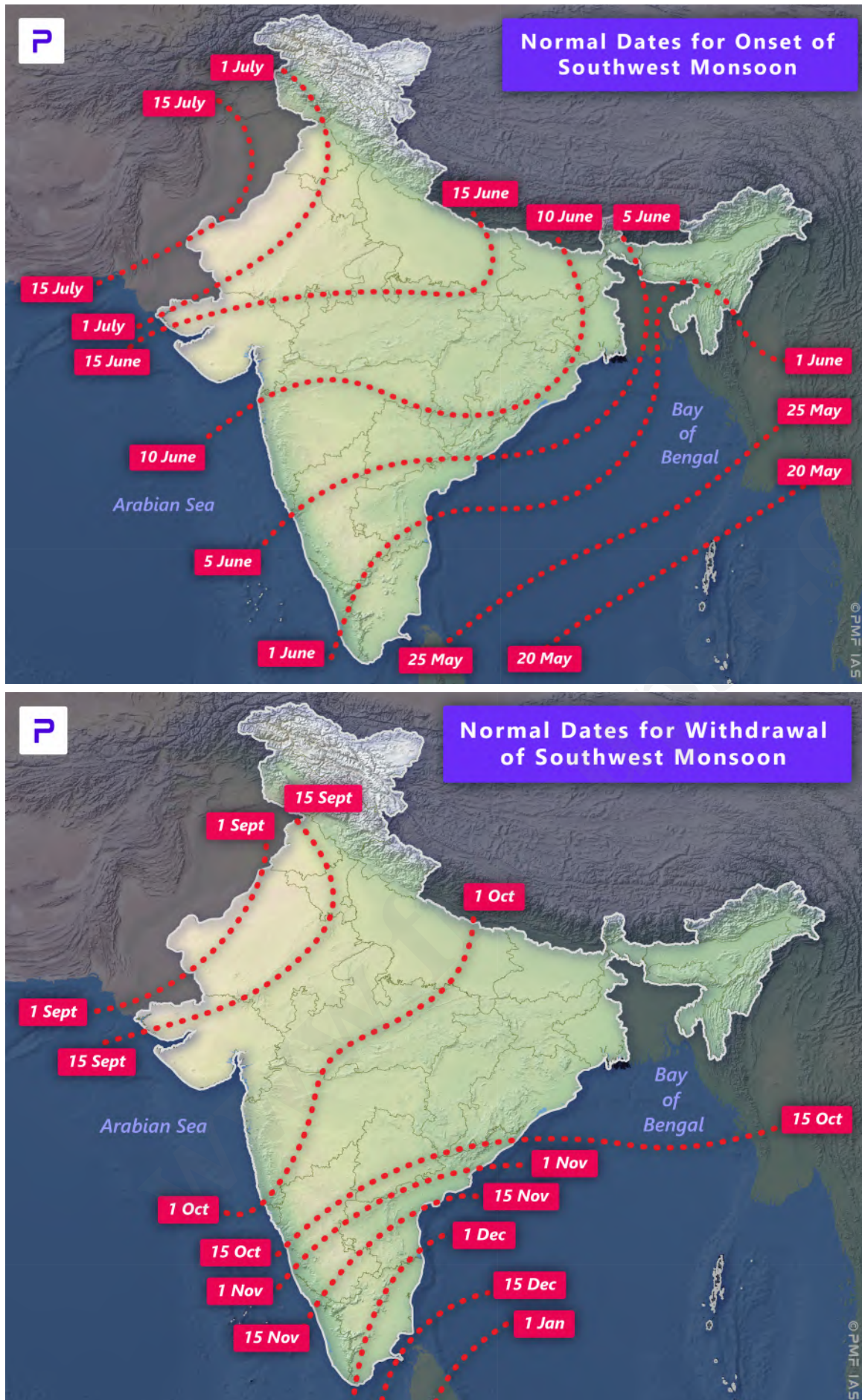
Depressions in South-West Monsoon Season

- A major part of the south-west monsoon rainfall is generated by **depressions (intense low-pressure systems)** originating in the **Arabian Sea, Bay of Bengal** and sometimes even over **land**.
- 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** (depressions need moisture to be alive), the Ganga, the Mahanadi, the Godavari, the Krishna, and the Cauvery and cause heavy rain in these areas.
- Most of the depressions originate to the west of 90° E in the Bay of Bengal and **move in the north-west direction**. The location of depressions strongly coincides with the latitudinal position of **ITCZ**.
- In the Arabian Sea from June to July, the depressions move either in the northwest or in the northerly direction and may affect west **Gujarat** or Maharashtra.
- Most of the rainfall in **central** and **northern parts** of the country is caused by these **depressions**.
- **Storms** during August and September are **rare** and are formed close to Maharashtra-Gujarat coast.
- The absence of depressions or a change in their tracks result in deficit or no rain.

Chief Characteristics of South-West Monsoon Rainfall

- ❖ A major part of monsoon rains is 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 the south-west monsoon season is known as **breaks**.
- ❖ There are large-scale **spatial variations** in the distribution of rainfall.
- ❖ Monsoons often fail to keep the date. Sometimes, the monsoons withdraw before the scheduled time, causing considerable damage to the crops.

Advance and Withdrawal of South-West Monsoons



South-West Monsoon – 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 and **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**.
- By the end of June, the monsoons are usually established in most parts of the country.
- By **mid-July**, the monsoon extends into Kashmir and the remaining parts of the country. By the time it reaches Kashmir, it has shed **most of its moisture**.
- The **Arabian Sea branch** of the monsoon is **much more powerful** than the Bay of Bengal branch for two 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.

Arabian Sea Branch

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

Stream 1

- The **first stream strikes the west coast of India** and gives extremely heavy rainfall of over 250 cm.
- It **strikes perpendicular to the 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.

Stream 2

- The second stream enters the **Narmada-Tapti troughs (narrow rift valley)** and reaches central India. It does not cause much rain near the coast due to the absence of major orographic obstacles across the rift. Some parts of central India receive rainfall from this stream (**E.g., Nagpur**).

Stream 3

- The **third stream moves parallel to the Aravalli Range** without causing much rainfall. Consequently, the whole of Rajasthan is a desert area.

- However, **some orographic effect** is occurring on the south-eastern edge of the Aravalli Range. **Mount Abu** gets about 170 cm of rainfall, while the surrounding plains have only 60 to 80 cm of rainfall.

Bay of Bengal Branch

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

Stream 1

- The first stream crosses the **Ganga-Brahmaputra delta** and reaches **Meghalaya**, where the **orographic effect** results in intense rainfall.
- **Cherrapunji** receives an annual rainfall of 1,102 cm, a 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 stations are located on the **southern slopes** of the **Khasi hills** at the northern end of a deep valley running from south to north.

Stream 2

- The second stream of the Bay of Bengal branch moves along **Himalayan foothills** as they are **deflected to the west by the Himalayas** and bring widespread rainfall to the Ganga plain.
- The rainfall by this stream is characterised by a **steady decline as we move from east to west** up the plain.

Why is Tamil Nadu Dry During the SW Monsoon?

- The **Tamil Nadu coast** remains relatively dry during the south-west monsoon period because of
 1. **Rain shadow effect** of the **Western Ghats** to the **Arabian Sea current** and
 2. **Bay of Bengal current which flows parallel to the coast.**

North-East Monsoon Season – Retreating Monsoon Season

- The North-East Monsoon Season **begins** with the **withdrawal of the southwest monsoon** (mid-September – November).
- 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**.
- For example, the southwest monsoon reaches **Punjab in the first week of July** and withdraws in the **second week of September**. It reaches the **Coromandel Coast in the first week of June** but **doesn't withdraw until mid-December**.
- Unlike the sudden burst of the advancing monsoons, the **withdrawal is rather gradual** and takes about three months.

The temperature during Retreating Monsoon Season

- With the retreat of the monsoons, the **clouds disappear**, and **the sky becomes clear**.

- The daytime temperature starts falling steeply, and the **diurnal range of temperature increases due to the lack of cloud cover.**

Pressure and Winds during Retreating Monsoon Season

- As the monsoons retreat, the **monsoon trough weakens** and gradually shifts southward.
- Unlike the south-west monsoon, the onset of the northeast 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.
- **More cyclones** originate in the **Bay of Bengal** than in the Arabian Sea, with the highest frequency occurring in **October and the first half of November.**
- In October, the Cyclones of the Bay of Bengal originate between **8°N and 14°N**. Initially, they move in west or **north-westerly direction**, but many of them later **recurve and move towards the north-east.**
- **Nearly 55% of Bay of Bengal cyclones cross or affect the Indian coast**, with the coastal belts of Tamil Nadu, Andhra Pradesh, Odisha, and West Bengal being the most vulnerable.
- Some cyclones that strike the eastern coast of India **south of 15°N latitude** may cross the southern peninsula and enter the Arabian Sea. They may weaken during this process but often **re-intensify into cyclonic storms** upon re-entering the Arabian Sea.
- The storms of the Arabian Sea originate between **12°N and 17°N** latitudes in October and between **8° N and 13° N** latitudes in November. They generally move away from the coast in a north-westerly direction, but around **25% later recurve northeast** and strike the **Maharashtra or Gujarat coast.**
- In northwest India, **western disturbances** bring **cloudy skies** and **light rainfall** during this generally clear-weather season. Precipitation falls as **snow** in the higher reaches of Jammu and Kashmir, Himachal Pradesh, and the 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)

Isohyet (the line joining places of equal rainfall) [Compare this with isotherm (temperature), isobar (pressure)]

Areas of very high rainfall (200 cm and above)

- These include areas in the **western side of Western Ghats** (Thiruvananthapuram in the south to **Mumbai in the north**), where the average annual rainfall is **200-400 cm**.
- **Assam, Nagaland, Meghalaya, Mizoram, Arunachal Pradesh, Sikkim, parts of Manipur, Tripura,** and the **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)

- These areas include the **eastern slopes of the Western Ghats**, most of the **northern plains, Odisha, Madhya Pradesh, Andhra Pradesh,** and **Tamil Nadu**.

Areas of low rainfall (50-100 cm)

- These include large parts of eastern Rajasthan, Punjab, Haryana, parts of Uttar Pradesh, Gujarat, Maharashtra, western Madhya Pradesh, and the **rain-shadow regions** of **Andhra Pradesh, Karnataka** and **Telangana**.

Areas of very low rainfall (less than 50 cm)

- 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 the Ladakh region of Jammu and Kashmir.

[UPSC 2004] Assertion and Reasoning

Assertion (A): *Bangalore receives much higher average annual rainfall than that of Mangalore.*

Reason (R): *Bangalore has the benefit of receiving rainfall both from south-west and north-east monsoons.*

- a) Both A and R are individually true and R is the correct explanation of A
- b) Both A and R are individually true but R is not the correct explanation of A
- c) A is true but R is false
- d) A is false but R is true

Explanation

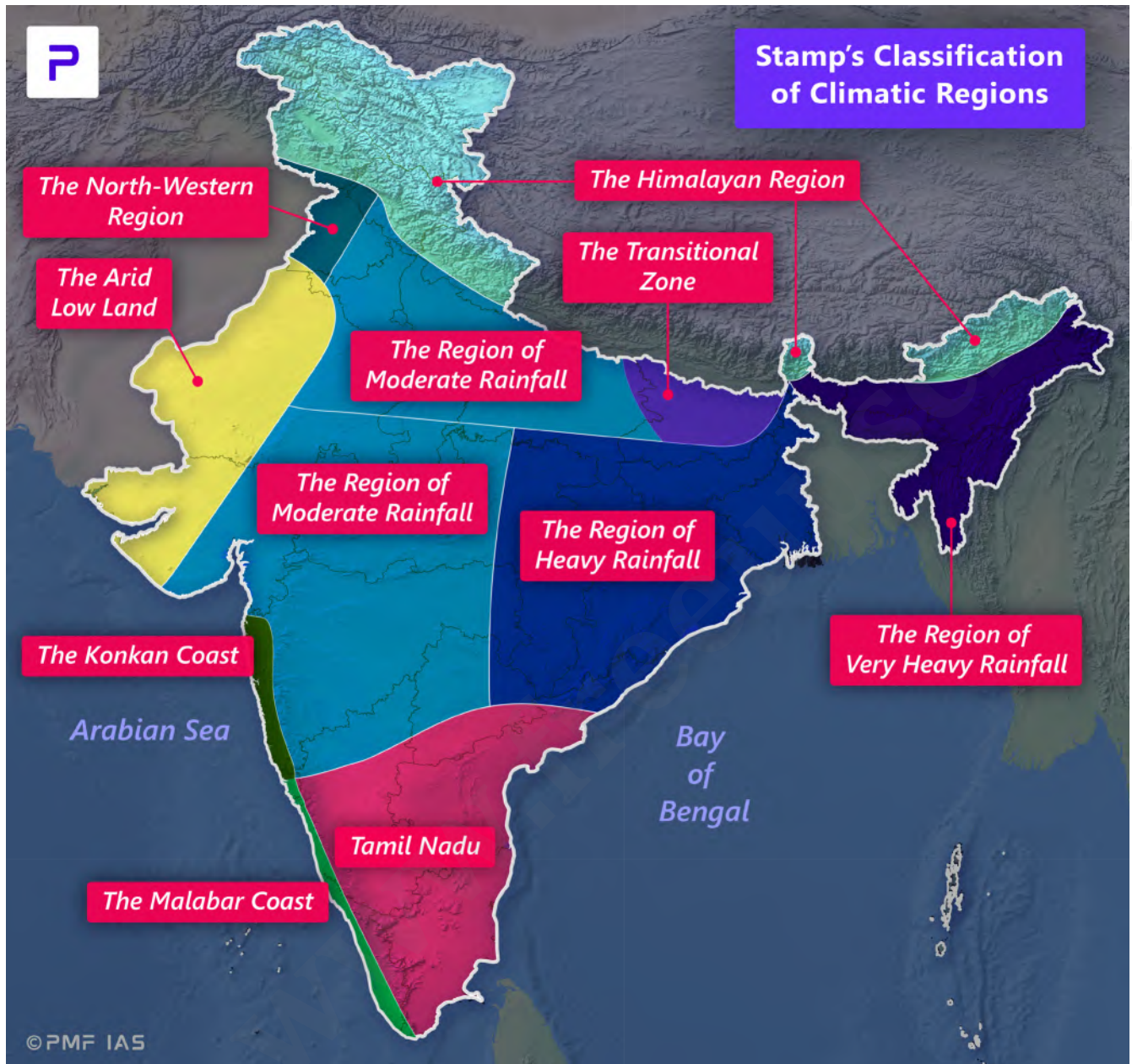
- Mangalore receives significantly higher average annual rainfall compared to Bangalore.
- **Mangalore is a coastal city** located on the southwest coast of India, directly facing the Arabian Sea. This proximity to the ocean **allows moisture-laden winds to rise and condense readily**, leading to higher precipitation.
- Compared to Mangalore, **Bangalore is located further inland on the Deccan Plateau**. This distance from the coast and the **rain shadow effect of the Western Ghats** limit the amount of moisture it receives, leading to lower average annual rainfall.

- **Bangalore** is located in a region that **receives rainfall from both** the **southwest monsoon (June to September)** and the **northeast monsoon (November to February)**.

Answer: d) A is false but R is true

Climatic Regions of India

- When classifying India's climatic regions, most geographers have given more importance to **rainfall** than to temperature, as variations in rainfall are much more marked than those in temperature. Here, we will study two such classifications — Stamp's and Koppen's.



Stamp's Classification of Climatic Regions of India

- Stamp used the **18 °C isotherm** of the mean monthly temperature for January to divide the country into two broad climatic regions — the temperate or continental zone in the north and the tropical

zone in the south. This line roughly follows the **base of the Indian peninsula**, more or less along or parallel to the Tropic of Cancer.

- The two major climatic regions are further divided into **eleven regions** depending upon the amount of **rainfall** and **temperature**.

Temperate or Continental India

1. The Himalayan region (heavy rainfall)
2. The north-western region (moderate rainfall)
3. The arid low land
4. The region of moderate rainfall
5. The transitional zone

Tropical India

1. Region of very heavy rainfall
2. Region of heavy rainfall
3. Region of moderate rainfall
4. The Konkan Coast
5. The Malabar Coast
6. Tamil Nadu

Temperate or Continental India		
Region	Avg. Temperature	Annual Rainfall
Himalayan Region	Summer: 4-7 °C Winter: 13-18 °C	East: Over 200 cm West: much less
North-western Region Northern parts of Punjab and southern parts of Jammu and Kashmir	Summer: 16 °C Winter: 24 °C	Below 200 cm
Arid Lowland Thar desert of Rajasthan, South-Western part of Haryana and Kachchh of Gujarat	Winter: 16-24 °C Summer: 48 °C	Below 40 cm
Region of moderate rainfall Punjab, Haryana, western Uttar Pradesh, Union Territory of Delhi, north-west Plateau area of Madhya Pradesh and eastern Rajasthan	Winter: 15-18 °C Summer: 33-35 °C	40-80 cm
Transitional Zone Eastern Uttar Pradesh and Bihar	Winter: 15-19 °C Summer: 30-35 °C	100-150 cm
Tropical India		
Region of very heavy rainfall Meghalaya, Assam, Tripura, Mizoram and Nagaland	Winter: 18 °C Summer: 32-35 °C	Over 200

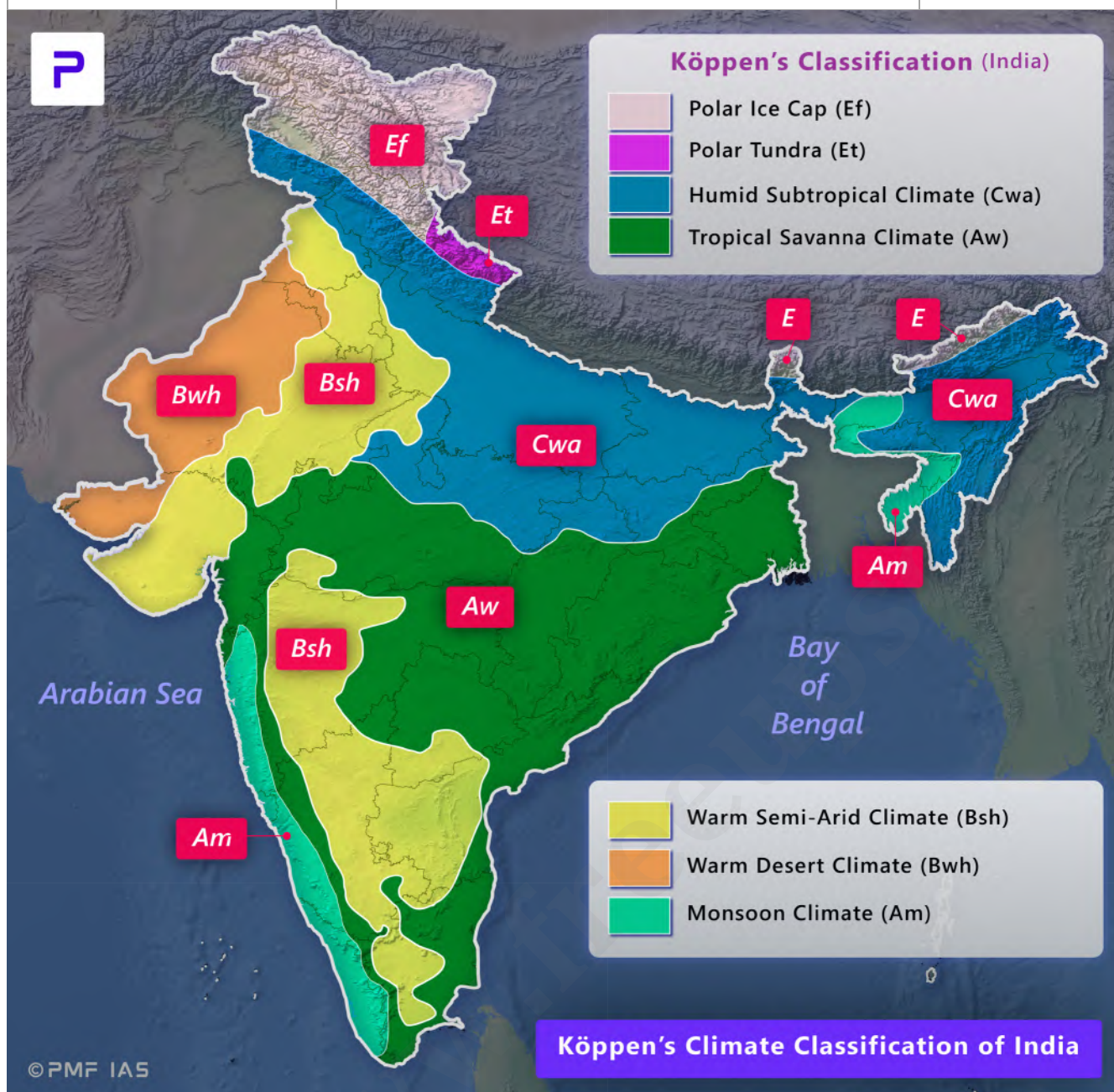
Region of heavy rainfall Chhattisgarh, Jharkhand, Gangetic West Bengal, Odisha and coastal Andhra Pradesh	Winter: 18-24 °C Summer: 29-35 °C	100-200 cm
Region of moderate rainfall Between Western and Eastern Ghats	Winter: 18-24 °C Summer: 32 °C	50-100 cm
Konkan Coast Mumbai in the north to Goa in the south	Annual: 24-27 °C.	Over 200 cm
Malabar Coast Goa to Kanyakumari	Annual: 27 °C	Over 250 cm
Tamil Nadu Tamil Nadu and adjoining areas of Andhra Pradesh, Karnataka and Telangana	Annual: 24 °C	100 to 150 cm

Koppen's Classification of Climatic Regions of India

- Koppen identified a close relationship between the **distribution of vegetation** and **climate**. He selected certain values of temperature and precipitation and related them to the distribution of vegetation and used these values for classifying the climates.
- Koppen divided India into **nine climatic regions** making use of the above scheme.

Koppen's Scheme – Climatic Regions of India		
Climate type	Region	Annual rainfall
Amw: Monsoon type with short dry winter season	Western coastal region, south of Mumbai	over 300 cm
As: Monsoon type with dry season in high sun period	Coromandel coast: Coastal Tamil Nadu and adjoining areas of Andhra Pradesh	75-100 cm Wet winters Dry summers
Aw: Tropical Savanah type	Most parts of the peninsular plateau barring Coromandel and Malabar coastal strips	75 cm
BShw: Semi-arid Steppe type	Some rain shadow areas of Western Ghats, large part of Rajasthan and contiguous areas of Haryana and Gujarat	12-25 cm
BWhw: Hot desert type	Most of western Rajasthan	less than 12 cm
Cwg: Monsoon type with dry winters	Most parts of the Ganga Plain, eastern Rajasthan, Assam and in Malwa Plateau	100-200 cm
Dfc: Cold, Humid winters type with shorter summer	Sikkim, Arunachal Pradesh and parts of Assam	~200 cm
Et: Tundra Type	Mountain areas of Uttarakhand The average temperature varies from 0 to 10°C	Rainfall varies from year to year.

E: Polar Type	Higher areas of Jammu & Kashmir and Himachal Pradesh in which the temperature of the warmest month varies from 0° to 10°C	Precipitation occurs in the form of snow

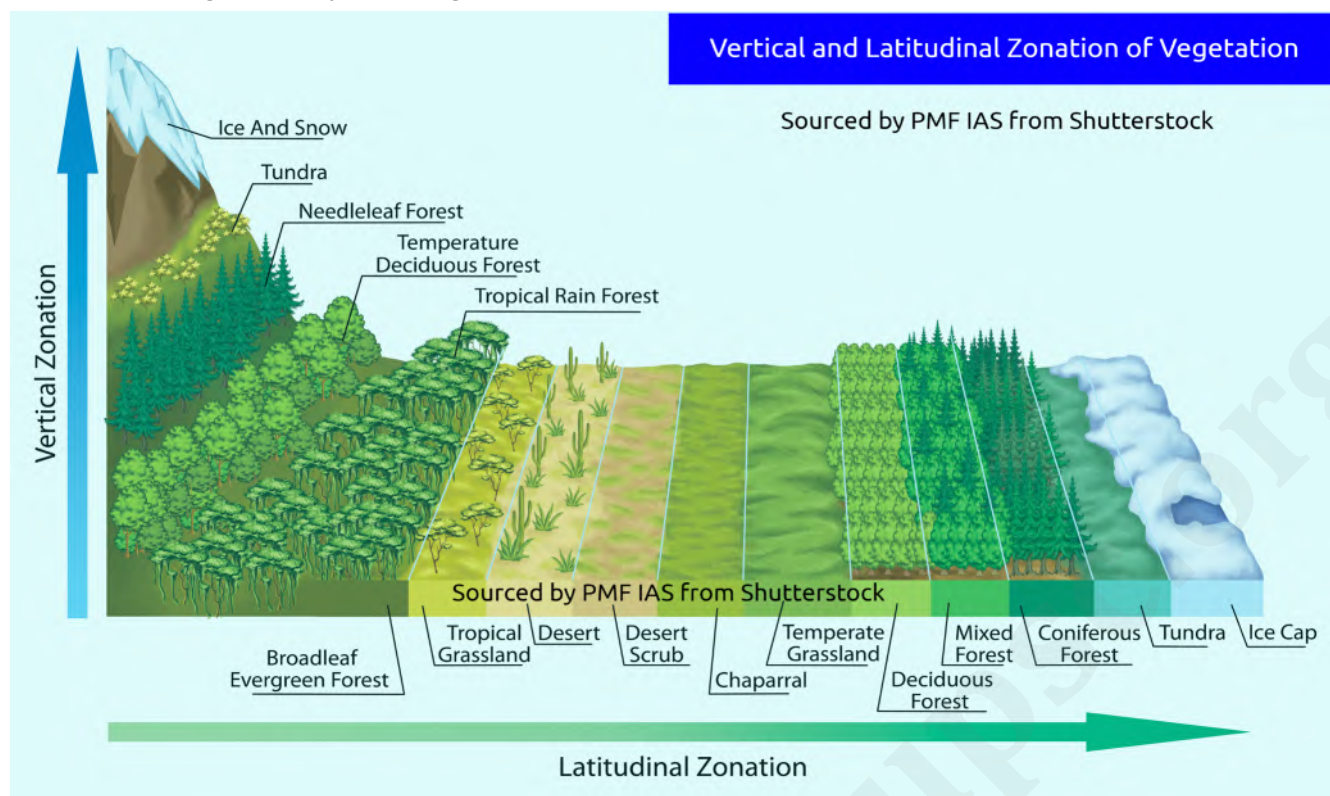


For more information on Köppen's Scheme of Classification, refer to PMF IAS Physical Geography > Climatology > Climatic Regions.

----- End of Chapter -----

11. Natural Vegetation of India

- **Climate, soil and topography** are the major factors that influence the natural vegetation of a place. The main climatic factors are **rainfall** and **temperature**. The amount of annual rainfall has a significant bearing on the type of vegetation.



Annual Rainfall	Type of Vegetation
200 cm or more	Evergreen Rain Forests
100 to 200 cm	Monsoon Deciduous Forests
50 to 100 cm	Drier Deciduous or Tropical Savanna
25 to 50 cm	Dry Thorny Scrub (Semi-arid)
Below 25 cm	Desert (Arid)

- Temperature is the primary factor in the Himalayas and other hilly regions with an elevation of more than 900 metres. As the temperature falls with altitude, the vegetal cover changes with altitude from **tropical to sub-tropical, temperate** and **finally alpine**.
- The soil is an equally determining factor in a few regions. **Mangrove forests** and **swamp forests** are some examples of areas where the soil is a major factor.
- Topography is responsible for certain minor types, e.g. **alpine flora, tidal forests, etc.**

Classification of Natural Vegetation of India

- **H.G. Champion** first enunciated a classification system for forests of undivided India in 1935. **S.K. Seth** subsequently joined Champion in refining the earlier work in 1968. Subsequently, their system became the standard in forest-type classification in the country.
- **Champion and Seth's system** is based on the premise that a **forest type** could be **treated** as a **distinct ecosystem** (many preceding classification systems are based on **climate, soil** or **vegetation**). It has **5 climate-based major groups** sub-divided into **16 precipitation and temperature range-based groups**.

A. Moist Tropical Forests

1. Tropical Wet Evergreen
2. Tropical Semi-Evergreen
3. Tropical Moist Deciduous
4. Littoral and Swamp

B. Dry Tropical Forest

1. Tropical Dry Evergreen
2. Tropical Dry Deciduous
3. Tropical Thorn

C. Montane Sub-Tropical Forests

1. Sub-tropical broad-leaved hill

2. Sub-tropical moist hill (pine)

3. Sub-tropical dry evergreen

D. Montane Temperate Forests

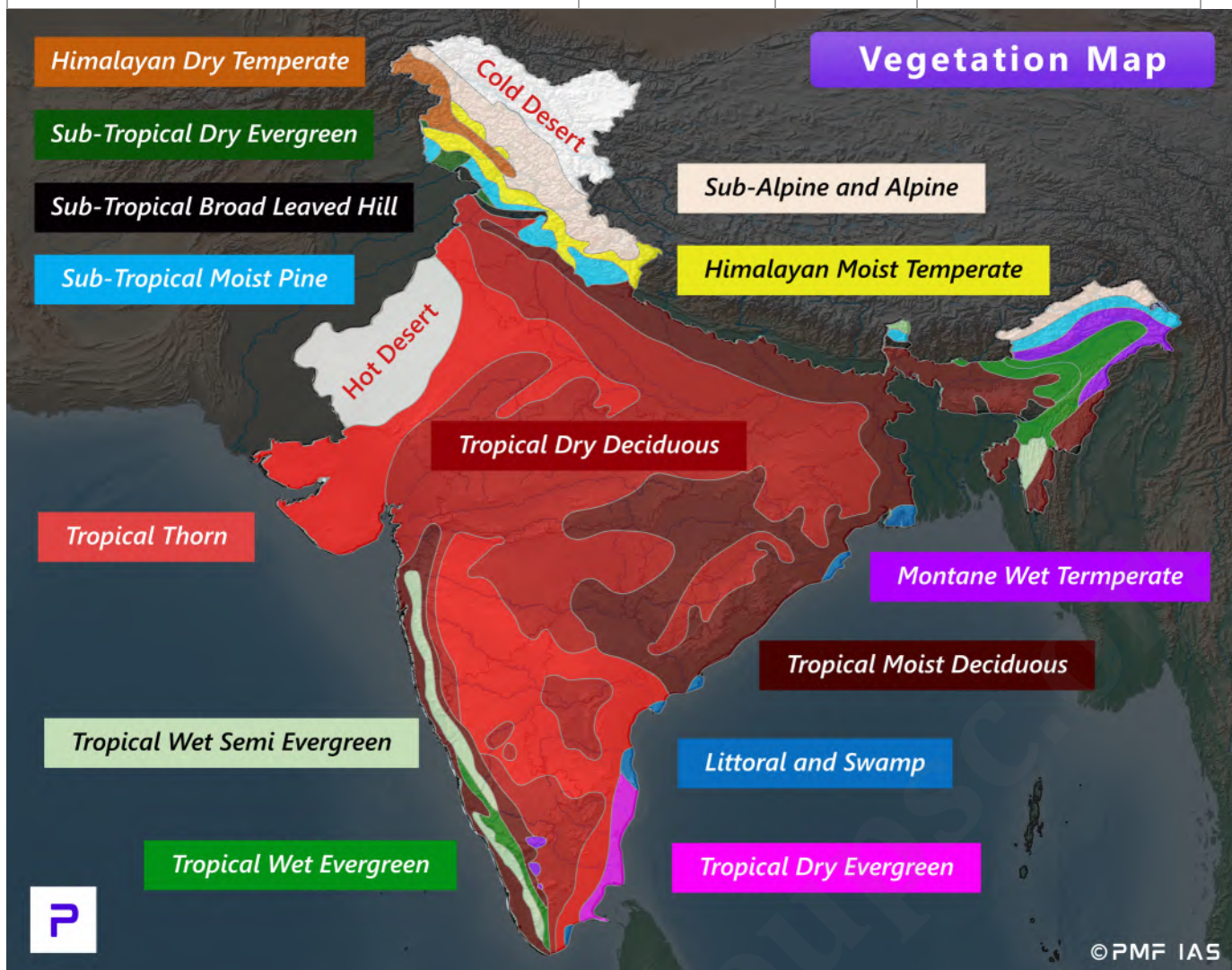
1. Montane Wet Temperate
2. Himalayan Moist Temperate
3. Himalayan Dry Temperate

E. Alpine Forests

1. Sub-Alpine
2. Moist Alpine scrub
3. Dry Alpine scrub

Forest (Vegetation) Type (ISFR 2021)		Area in sq km	% of Total	Carbon stock in mt
1	Tropical Dry Deciduous Forests	2,80,547	39.30	2176.8
2	Tropical Moist Deciduous Forests	1,31,805	18.47	1302.7
3	Plantation/TOF	75,221	10.54	529.5
4	Tropical Semi-Evergreen Forests	69,195	9.69	686.0
5	Subtropical Broadleaved Hill Forests	31,015	4.35	432.6
6	Himalayan Moist Temperate Forests	28,727	4.02	646.7
7	Montane Wet Temperate Forests	20,185	2.83	342.5
8	Tropical Wet Evergreen Forests	19,572	2.74	345.6
9	Subtropical Pine Forests	17,801	2.49	239.4
10	Tropical Thorn Forests	13,259	1.86	49.6
11	Sub-Alpine Forests	12,672	1.78	232.4
12	Littoral and Swamp Forests	5,478	0.77	72.6
13	Himalayan Dry Temperate Forests	4,255	0.60	103.9
14	Dry Alpine Scrub	2,396	0.34	27.5
15	Tropical Dry Evergreen Forests	835	0.12	7.7
16	Moist Alpine Scrub	652	0.09	5.6
17	Subtropical Dry Evergreen Forest	173	0.02	2.7

Total	7,13,789	100	7,203.8
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- **Maximum tree diversity** has been found in **tropical wet evergreen** and **semi-evergreen forests of Western Ghats** (TN, Kerala, and Karnataka), followed by **Northeastern states**.
- **Low tree diversity** has been noticed in the **subtropical dry evergreen forests** of Jammu and Kashmir and forest deficit States like Punjab, Haryana and Rajasthan.
- **Karnataka** has the **maximum species richness** for **trees**, **Arunachal Pradesh** for **shrubs** and **J&K** for **herbs**.
- **Arunachal Pradesh** has the **maximum richness of species** when all three types of plants are considered, followed by **TN** and **Karnataka**.

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 **dry season** is distinctly **short**.

Characteristics

- **Evergreen Trees:** Due to **high heat** and **high humidity**, the trees of these forests **do not shed their leaves together**.
- **Vegetation is mesophytic:** Plants are adapted to **neither too dry nor too wet** type climate or soil.
 - ⇒ **Hydrophytic plants** are plants like water lilies or pondweed that grow in **saturated soil**.
 - ⇒ **Xerophytic plants** are plants like **cacti** that grow in extremely dry soil.
 - ⇒ **Mesophytic plants** are ordinary plants that **exist between the two extremes — adapted to moderate moisture conditions**.
- **Lofty:** The trees often reach 45-60 metres in height.
- **Thick Canopy:** From the air, the tropical rainforest appears like a thick canopy of foliage. All plants struggle upwards for sunlight, resulting in a peculiar layer arrangement.
- **Less undergrowth:** The sunlight cannot reach the ground due to thick canopy. The undergrowth is formed mainly of bamboo, ferns, climbers, orchids, etc.

Distribution

- The **western side of the Western Ghats** (500 to 1370 metres 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 but is hard to exploit. The important species of these forests are **mahogany, mesua, white cedar, jamun, canes, bamboo**, etc.

[UPSC 2021] “Leaf litter decomposes faster than in any other biome and as a result the soil surface is often almost bare. Apart from trees, the vegetation is largely composed of plant forms that reach up into the canopy vicariously, by climbing the trees or growing as epiphytes, rooted on the upper branches of trees.” This is the most likely description of

- a) coniferous forest
- b) dry deciduous forest
- c) mangrove forest
- d) tropical rain forest

Explanation

- Tropical rainforests feature **rapid decomposition of leaf litter** due to **high temperatures, abundant moisture**, and diverse biodiversity. This leads to a soil surface that is often almost bare, highlighting **efficient nutrient recycling**.

- For example, the **Amazon Rainforest in South America** exemplifies this rapid decomposition, with warm, humid conditions facilitating the quick breakdown of leaf litter. Enriched soil supports lush vegetation growth, showcasing the ecosystem's vitality.

Vegetation and Canopy Structure

- Multi-layered canopy** dominated by towering trees characterises tropical rainforests.
- Apart from canopy trees, various plant forms utilise unique strategies to access sunlight.

Climbers and Epiphytes

- Climbers** like lianas use trees for support, climbing into the canopy for sunlight.
- Epiphytes** grow on tree branches without soil, benefiting from the moist, nutrient-rich canopy environment.

Answer: d) tropical rain forest

[UPSC 2015] Consider the following States:

- Arunachal Pradesh
- Himachal Pradesh
- Mizoram

In which of the above States do 'Tropical Wet Evergreen Forests' occur?

- 1 only
- 2 and 3 only
- 1 and 3 only
- 1, 2 and 3

Explanation

- The Tropical Wet Evergreen forests are primarily found in the following regions of India:
 - ❖ **Andaman and Nicobar Islands**
 - ❖ **Western Ghats (along the western coast of India)**
 - ❖ **North-eastern states (including Assam, Meghalaya, Mizoram, Arunachal Pradesh)**

Answer: c) 1 and 3 only

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 to 27 °C.
- 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 characterised by **many species**.
- Trees usually have **buttressed trunks with abundant epiphytes**.



Tress with 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.
- 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

- The 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.
- Hills of eastern Madhya Pradesh and Chhattisgarh.
- **Chota Nagpur Plateau**
- Manipur and Mizoram
- Most of Odisha
- Parts of West Bengal
- 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**).

[UPSC 2015] In India, in which one of the following types of forests is teak a dominant tree species?

- a) Tropical moist deciduous forest
- b) Tropical rain forest
- c) Tropical thorn scrub forest
- d) Temperate forest with grasslands

Explanation

- **Teak** thrives in **warm and humid climates** with **distinct wet and dry seasons**.
- **Tropical moist deciduous forests** receive heavy rainfall during the monsoon season, followed by a distinct dry season. This seasonal variation aligns perfectly with the growth requirements of teak.

Answer: a) Tropical moist deciduous forest

Littoral and Swamp Forests

- Littoral and Swamp Forests can survive and grow both in fresh water and **brackish water** (the mixture of seawater and freshwater; salinity can range from 0.5 to 35 ppt). They 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 (Coringa Wildlife Sanctuary)**, 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 fuelwood.

- The most pronounced and the densest is the **Sundarbans in the Ganga delta**, where the predominant species is **Sundri (Heriteera)**.

Timber

- They provide hard and durable timber that is used for construction, building purposes, and boat-making.
- The important species found in these forests are **sundri, agar, rhizophora**, etc.

[UPSC 2015] In a particular region in India, the local people train the roots of living trees into robust bridges across the streams. As the time passes, these bridges become stronger. These unique 'living root bridges' are found in

- a) Meghalaya
- b) Himachal Pradesh
- c) Jharkhand
- d) Tamil Nadu

Explanation

- The northeast Indian state of **Meghalaya** is renowned for its **stunning living root bridges**.
- The **Khasi** and **Jaintia** people have a long tradition of cultivating these bridges using the **aerial roots** of the *Ficus elastica* (**Indian rubber tree**) over bamboo and betel nut tree trunks.

Answer: a) Meghalaya

[UPSC 1997] Which one of the following pairs is correctly matched?

- a) Teak : Jammu and Kashmir
- b) Deodar : Madhya Pradesh
- c) Sandalwood : Kerala
- d) Sundari : West Bengal

Explanation

- Sundari trees are the dominant trees in the Sundarbans mangrove forests, located in the southwestern part of West Bengal.
- The Sundarbans delta is the largest contiguous mangrove forest in the world, and Sundari trees are a crucial part of its ecosystem.

Tree	Major Distribution Areas	Climate Preference
Teak	Central and South India (Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu)	Warm and humid with distinct wet and dry seasons
Deodar	Himalayan region (Himachal Pradesh, Uttarakhand, Jammu and Kashmir)	Temperate with well-defined seasons and moderate to high rainfall
Sandalwood	Southern peninsular region (Karnataka, Tamil Nadu, Kerala, Andhra Pradesh)	Warm and dry with low to moderate rainfall

Answer: d) Sundari : West Bengal

B. Dry Tropical Forests

Tropical Dry Evergreen Forests

Distribution

- ❖ Along the **coasts of Tamil Nadu**.

Climatic Conditions

- The annual rainfall is **100 cm** (mostly from the northeast monsoons).
- Mean annual temperature is about 28 °C.
- 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.
- Bamboo and grasses are **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

- The casuarina trees generally resemble a feathery conifer.
- They are **rapid-growing, carefree species** that can grow in various climates.
- They **can fix atmospheric nitrogen**.

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 coastal areas helps control the wind force.



Casuarina plantation

- It is a suitable species for **wasteland development** because of its adaptability to a wide range of habitats, fast growth, salt tolerance, drought resistance, and ability to reclaim land and stabilise dunes.

Tropical Dry Deciduous Forests

Climatic Conditions

- Annual rainfall is around **100 cm**.

Characteristics

- These are **like moist deciduous forests** and **shed their leaves in the 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 a closed but uneven canopy.
- The forests are composed of a mixture of a few species of deciduous trees rising to a height of 20 metres.
- **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 Kanyakumari except in Rajasthan, Western Ghats and West Bengal.
- The important species are **teak, axlewood, rosewood, common bamboo, red sanders, laurel**, etc.
- Large tracts of this forest have been cleared for agricultural purposes.
- They have suffered from overgrazing, fire, etc.

[UPSC 2023] Consider the following trees:

1. Jackfruit (*Artocarpus heterophyllus*)
2. Mahua (*Madhuca indica*)
3. Teak (*Tectona grandis*)

How many of the above are deciduous trees?

- a) Only one
- b) Only two
- c) All three
- d) None

Explanation

Tree Name	Deciduous
Jackfruit	No
Mahua	Yes
Teak	Yes

Answer: b) Only two

Tropical Thorn Forests

Climatic Conditions

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

Characteristics

- The trees are low 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, southwestern Punjab, western Haryana, Kutch 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 (Vidarbha), Karnataka (Hyderabad-Karnataka), Telangana, Andhra Pradesh and Tamil Nadu.
- The important species are **neem, babul, cacti**, etc.

[UPSC 2021] Consider the following statements:

1. Moringa (drumstick tree) is a leguminous evergreen tree.
2. Tamarind tree is endemic to South Asia.
3. In India, most of the tamarind is collected as minor forest produce.
4. India exports tamarind and seeds of moringa.
5. Seeds of moringa and tamarind can be used in the production of biofuels.

Which of the statements given above are correct?

- a) 1, 2, 4 and 5
- b) 3, 4 and 5
- c) 1, 3 and 4
- d) 1, 2, 3 and 5

Explanation

- **Moringa** is not a leguminous tree. Moringa is also **not evergreen**. It is a **deciduous tree**.
- While tamarind is widely cultivated in South Asia, its origin is traced back to **tropical Africa**.
- Tamarind trees often grow naturally in forests and uncultivated areas, and their fruits are harvested as **Minor Forest Produce (MFP)** in many parts of India.
- India is a **major producer and exporter** of both tamarind and moringa seeds.
- The oil extracted from **seeds** of both **moringa**, and **tamarind** can be processed into **biodiesel**.

Answer: b) 3, 4 and 5

[UPSC 2002] Open stunted forests with bushes and small trees having long roots and sharp thorns or sharp thorns or spines are commonly found in:

- a) Eastern Orissa
- b) North-Eastern Tamil Nadu
- c) Shivalik and Terai region
- d) Western Andhra Pradesh

Explanation

- **Western Andhra Pradesh (Rayalaseema) region** has a **semi-arid climate** with low rainfall. This region is known for **thorn scrub forests**.
- These forests are an **adaptation to the dry climate**, with the specific features helping the plants to conserve water and resist browsing by animals.

Answer: d) Western Andhra Pradesh

C. 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.

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, sals and pines**.
- Climbers and **epiphytes** (plants that grow 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 **Nil-giris, Annamalai and Palani hills** at 1070-1525 metres above sea level.
- It is a "stunted rainforest" 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 Aravalli 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 metres 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 metres 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.

D. 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 to 14 °C.

Distribution

- Higher hills of Tamil Nadu and Kerala in the Eastern Himalayan region.

Characteristics

- These are **closed evergreen forests**. Trunks have a **large girth**.
- Branches are clothed with **mosses**, **ferns** and other **epiphytes**.
- The trees rarely achieve a height of more than **6 metres**.
- **Deodar**, **Chilauni**, **Indian chestnut**, **birch**, **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 metres.

- 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.
- They are open forests with shrubby undergrowth, including **oaks, rhododendrons** and some bamboo. **Pines, cedars, silver firs, spruce**, etc., are the most important trees.

Timber

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

[UPSC 2014] If you travel through the Himalayas, you are likely to see which of the following plants naturally growing there?

1. Oak
2. Rhododendron
3. Sandalwood

Select the correct answer using the code given below.

- a) 1 and 2 only
- b) 3 only
- c) 1 and 3 only
- d) 1, 2 and 3

Explanation

- **Oak:** Several oak species, like *Quercus leucotrichophora* (Himalayan oak), are well-adapted to the temperate and subtropical mountain slopes of the Himalayas.
- **Rhododendron:** Rhododendrons thrive in the cool, moist conditions of the Himalayas, with various species like *Rhododendron arboreum* (tree rhododendron) commonly found in the region.
- **Sandalwood:** Sandalwood (*Santalum album*) prefers **warm and dry climates** and is not typically found in the Himalayas. It is more prevalent in **southern India**.

Answer: a) 1 and 2 only

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 the south-west monsoon is very feeble. Such areas are in **Ladakh, Lahul, Chamba, Kinnaur, Garhwal and Sikkim**.

[UPSC 2008] Which one of the following is not essentially a species of the Himalayan vegetation?

- a) Juniper
- b) Mahogany
- c) Silver fir
- d) Spruce

Explanation

- Mahogany** is native to **tropical and subtropical regions of Central and South America and the Caribbean islands**. They are known for their **valuable hardwood** and are **not naturally found in the Himalayas**.

Answer: b) Mahogany

E. 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 as 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 metres and extends up to the snowline.
- The **dry alpine scrub** is the uppermost limit of scrub **xerophytic dwarf shrubs**, over 3,500 metres above sea level, and is found in the dry zone. **Juniper, honeysuckle, artemesia**, etc., are important species.
- Bamboos are one of the **fastest-growing perennial grass** plants. They can thrive in an extreme range of climatic and **edaphic** (soil) conditions. They are found in the **tropical, sub-tropical** and **mildly temperate regions** of the world.

The alpine vegetation in the Western Himalayas is found only up to a height of 3000 metres while in the Eastern Himalayas it is found up to a height of 4000 metres. The reason for this variation in the same mountain range is that:

- a) Eastern Himalayas are higher than Western Himalayas
- b) Eastern Himalayas are nearer to the equator and sea coast than the Western Himalayas
- c) Eastern Himalayas get more monsoon rainfall than the Western Himalayas
- d) Eastern Himalayan rocks are more fertile than the Western Himalayan rocks

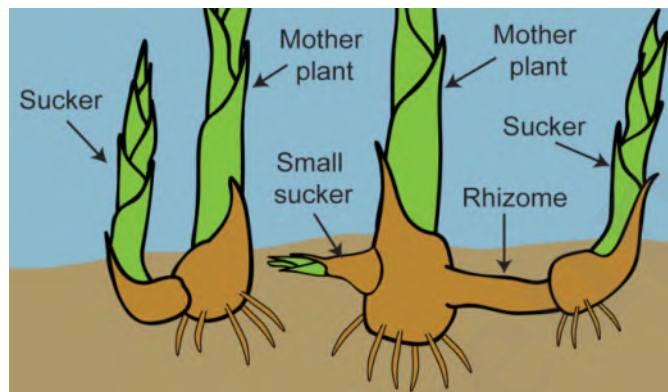
Explanation

- Monsoon winds provides substantial rainfall to the Himalayas, with the **southern slopes** experiencing the greatest impact due to the **orographic effect**.
- The **Eastern Himalayas**, closer to the **Bay of Bengal**, receive more monsoon rainfall than the Western Himalayas.
- This increased rainfall in the **Eastern Himalayas supports a higher altitude limit for alpine vegetation**, allowing these plants to thrive at higher elevations compared to the Western Himalayas.

Answer: c) Eastern Himalayas get more monsoon rainfall than the Western Himalayas

Bamboo

- Bamboo culms grow from the dense **root rhizome** system.
- The **monopodial rhizome** grows horizontally, and the buds develop either upward, generating a culm, or horizontally, with a new tract of the rhizome.
- The **sympodial rhizomes** are short and thick, and the culms, which are above the ground, are close together in a compact clump, which expands evenly around its circumference.



- The clump-forming species are naturally found in **tropical regions**, and they are **not invasive**. Some bamboos are **non-clump forming** and can be **invasive**. They are generally found in **temperate regions**.

Distribution

- Bamboo distribution is uneven and largely depends on climatic factors, altitude, and soil. They are naturally abundant in **East and SE Asia and the Islands of the Pacific and Indian Oceans**. Large tracts of natural bamboo forest are found in Asian countries between **15° and 25° N latitudes**.
- In India, bamboo **grows naturally everywhere except in the Kashmir region**. They are abundant in the **deciduous** and **semi-evergreen forests of the North-Eastern region** and the **tropical moist deciduous forests of Northern and Southern India**.
- The **Northeastern states and West Bengal** account for **more than 50% of India's bamboo resources**.
- Other bamboo-rich areas of the country are the **Andaman and Nicobar Islands, Chhattisgarh, Madhya Pradesh, and the Western Ghats**.

Importance of Bamboo

- ✓ Bamboo is an essential component of the **subsistence economy** in providing livelihood to the tribals. It is, therefore, called **green gold**, **poor man's timber**, **cradle-to-coffin timber**, etc.
- ✓ Young bamboo shoots are used as **vegetables** in many cuisines. Stems can be split up as pipes in channelling water. Raw leaves of many species are a source of fodder for cattle.
- ✓ Large stems are used as planks for houses and rafts, while large and small stems are latched together to form the scaffoldings at construction sites.
- ✓ Bamboo is an essential **non-wood forest product** used in making normal and fine-quality paper, furniture, flooring, handicrafts, walking sticks, fishing poles, etc.
- ✓ Bamboo plays an important role in **carbon sequestration** and **soil moisture conservation**.

Forest Fringe Villages

- As per the Census 2011, there are about 6,50,000 villages in the country, out of which nearly 1,70,000 villages are in the proximity of forest areas. They are often termed **Forest Fringe Villages**.
- The population in these villages is dependent on the forests to meet the needs of fuelwood, fodder, small timber, bamboo, and Non-timber forest products (NTFPs). States with the highest dependence on forests:
 - ❖ *Fuelwood: Maharashtra > Odisha > Rajashtan > **MP***
 - ❖ *Fodder: **MP** > Maharashtra > Gujarat > Rajashtan*
 - ❖ *Bamboo: **MP** > Chhattisgarh > Gujarat > Maharashtra*
 - ❖ *Small Timber: **MP** > Gujarat > Maharashtra*

Initiatives to Promote Bamboo in India

- According to the National Bamboo Mission, **India has the highest area (15 million ha) under bamboo** and is the **second richest country after China in bamboo diversity**, with 136 species. However, **China exports 68%** of the world's bamboo and rattan products.
- The **Indian Forest Act 1927** was amended in 2017 **to remove bamboo from the category of trees**. As a result, **anyone can undertake cultivation and business in bamboo** and its products. Hence, **bamboo grown outside forests no longer needs felling and transit permissions**.

National Bamboo Mission (NBM)

- The restructured **NBM** was launched in 2018. It envisages promoting **holistic growth of the bamboo sector** by adopting an **area-based, regionally differentiated strategy** and increasing the area under bamboo cultivation & marketing.
- It will focus on the development of bamboo **only in the significant bamboo-growing states** with a social, commercial, and economic advantage, particularly in the **North-eastern** region and states, including Madhya Pradesh, Maharashtra, Chhattisgarh, Odisha, Karnataka, Uttarakhand, Bihar, Andhra Pradesh, etc.

- The bamboo plantations will be promoted predominantly in farmers' fields, homesteads, community lands, arable wastelands, and along irrigation canals, water bodies, etc.
- Primary processing centres are being set up close to the plantations, which will enable the cost of transportation of whole bamboo to be reduced.
- To address forward integration, it will **strengthen the marketing of bamboo products** and handi-craft items.
- The **Sector Skill Councils** established under the **National Skill Development Agency** will impart skills and Recognition of Prior Learning to traditional artisans.

Project Bold

- The project named **"Bamboo Oasis on Lands in Drought" (BOLD)** was launched to create **bamboo-based green patches in arid and semi-arid land zones**.
- BOLD is a scientific exercise initiated by the **Khadi and Village Industries Commission (KVIC)**. It serves the combined objectives of **reducing desertification** and **providing livelihood** and **multi-disciplinary rural industry support**.

[UPSC 2016] Recently, our scientists have discovered a new and distinct species of banana plant which attains a height of about 11 metres and has orange-coloured fruit pulp. In which part of India has it been discovered?

- Andaman Islands
- Anaimalai Forests
- Maikala Hills
- Tropical rain forests of northeast

Explanation

- Scientists from the **Botanical Survey of India (BSI)** have made a remarkable discovery in the Andaman Islands: a completely new species of banana named ***Musa indandamanensis***.
- The new banana is characterized by its remarkable sweetness and vibrant orange-coloured pulp.
- The size of *Musa indandamanensis* reaches **11 meters in height**, which is three times the size of a typical banana plant.

Answer: a) Andaman Islands

[UPSC 1998] Forest areas have been labelled as 1, 2, 3 and 4 in the map:



Among these, those which were threatened in 1997 by a serious epidemic include:

- a) teak forests of 3
- b) oak forests of 1 and sal forests of 2
- c) sal forests of 3
- d) sandalwood forests of 4

Explanation

- In 1997, central **India's sal forests** were disrupted by millions of **tiny "borer" beetles**. These hungry insects drilled into the majestic sal trees, causing widespread damage across several districts. The infestation affected hundreds of thousands of trees, leaving vast areas of forest in ruin.

Answer: c) sal forests of 3

[UPSC 2023] Identify and discuss the factors responsible for diversity of natural vegetation in India. Assess the significance of wildlife sanctuaries in rain forest regions of India.

Factor	Explanation
Geographical Extent and Topography	• The vastness and varied topography of India, encompassing mountains, plateaus, plains, and coastal areas, create unique environmental conditions in each region, influencing the type of vegetation that can thrive there. • For example, the Himalayas provide a habitat for alpine meadows at higher altitudes, while the Indo-Gangetic plains support grasslands and deciduous forests.
Climatic Variations	• India experiences diverse climates (tropical, subtropical, temperate, and alpine) and rainfall patterns, ranging from the high-rainfall Western Ghats to the arid regions of Rajasthan, which determines the type and distribution of vegetation.
Monsoon Influence	• The seasonal monsoon winds significantly impact vegetation distribution and growth. • The southwest monsoon brings heavy rain to the south and west, fostering tropical and deciduous forests, while the northeast monsoon supports tropical dry evergreen forests in the Coromandel coast.
Altitude	• As elevation increases, temperature and rainfall patterns change. This leads to distinct vegetation zones, with tropical forests at the foothills of the Himalayas transitioning to temperate forests, alpine meadows, and eventually becoming barren at extreme altitudes.
Soil Variations	• The type of soil plays a crucial role in supporting specific vegetation.

- **Alluvial soils** in the Indo-Gangetic plains are fertile, supporting diverse crops, while **laterite soils** on the west coast are suitable for **coconut palms** and **cashew trees**.
- Sandy desert soils, poor in nutrients, support sparse vegetation.

Significance of Wildlife Sanctuaries in Rainforest Regions of India

- Wildlife sanctuaries are designated areas where the primary focus is to protect and conserve the local wildlife and their habitat.

Habitat Protection

- Rainforests provide a **critical habitat for a diverse range of flora and fauna**, including rare and endangered species.

Biodiversity Conservation

- Wildlife sanctuaries **act as refuges** for a wide variety of plant and animal species.
- Protection of these can ensure the continued survival of many threatened species and maintain the rich biodiversity of rainforests.

Ecological Balance

- Rainforests play a crucial role in **regulating the climate and maintaining water flows**.
- Wildlife sanctuaries help to ensure the ecological balance of these areas by protecting the vegetation, which helps to prevent soil erosion, regulate local temperatures, and maintain healthy water cycles.

Research and Education

- Wildlife sanctuaries provide valuable opportunities for researchers to study the flora and fauna of rainforests. It helps in understanding the functioning of these ecosystems and develop strategies for their conservation.

Sustainable Tourism

- Wildlife sanctuaries can be managed for sustainable tourism, generating revenue that can be used for conservation efforts.

----- End of Chapter -----

12. India State of Forest Report (ISFR)

- Every **two years**, the **Forest Survey of India (FSI)** assesses the country's forest resources. The results are presented as the '**India State of Forest Report (ISFR – biennial report)**'.
- The first report was published in 1987. The 2021 assessment is the **17th** in the series. The 2023 assessment report (ISFR 2023) will be released in 2024.

Forest Survey of India (FSI)

- **Forest Survey of India (FSI)** is a national organisation under the Ministry of Environment, Forest and Climate Change (**MoEFCC**). It was established in **1981** at **Dehradun**.

Objectives of FSI

- ❖ To prepare the **State of Forest Report biennially**.
- ❖ To conduct **inventory assessments** in forest and non-forest areas and develop a **database on forest resources**.
- ❖ To function as a **nodal agency** for collecting and disseminating spatial databases on forest resources.
- ❖ To conduct **training** of forestry personnel in the application of [remote sensing](#), [GIS](#), etc.
- ❖ To support State/UT Forest Departments (SFD) in forest resources survey, mapping, and inventory.

The Major Activities of FSI

1. **Remote sensing based nationwide forest cover mapping** in a **biennial cycle**,
2. **National forest inventory**,
3. **Forest fire monitoring**,
4. **Forest carbon assessment**,
5. **Forest-type mapping** and projects on emerging issues.

Sustainable Development Goals and Forests



14.2.1: Percentage change in area under mangroves (2 years)

14.5.2: Percentage change in area under Mangroves (Annual)



15.1.1: Forest area as a proportion of total land area

15.1.2: Percentage of Tree Outside Forest (TOF) in total forest cover

15.2.1: Percentage change in Forest area coverage

15.2.3: Total tree cover achieved outside forest area

15.3.2: Increasing Tree/Forest cover in degraded area

15.4.1: Increase in forest/vegetative cover in mountain areas

- The **UNFCCC** guidelines for implementation of **REDD+** require that every country should have a satellite-based **National Forest Monitoring System (NFMS)** and a **National Forest Inventory**.

- The primary objective is to assess the **growing stock** of trees (volume of all living trees), the number of trees, bamboo, soil carbon, non-timber forest products (NTFP), invasive species, etc.

Major Terms/Definitions in ISFR



Very Dense Forest



Moderately Dense Forest



Open Forest



Scrub

Recorded Forest Area (RFA)

- **RFA (extent of forest in terms of legal status)** primarily consists of **Reserved Forests (RF)** and **Protected Forests (PF)**, which have been constituted under the provisions of the **Indian Forest Act 1927** or its **counterpart State Acts**.
- The term RFA is used for **all lands (irrespective of tree cover or canopy density)** which have been **notified as forest under any Government Act or Rules** or **recorded as 'forest'** in the Government records (**RFs, PFs, lands classified as forest in revenue records**). That is, a **RFA may or may not have forest cover!**
- FSI obtains boundaries of recorded forest areas from the **State Forest Departments (SFD)**, as the **SFDs are the custodians of the RFAs**. The freedom to define which tracts of forest qualify as **RFA** has been the **prerogative of States** since 1996.

⇒ The **Forest Advisory Committee (FAC)**, the **apex body of the Centre** that **deliberates on granting permission to industry to fell forests**, said, "... States, having well-established Forest Departments **should frame criteria for their forests... criteria so finalised by a State need not be subject to approval by the MoEF**".

Deemed Forests

- **Deemed forests**, which **comprise about 1% of India's forest land**, are a controversial subject as they refer to **land tracts that appear to be a forest but have not been notified so by the state government**.

Forest Cover (FC)

- Forest Cover (FC) includes all patches of land with a **tree canopy density of more than 10%** and **more than 1 ha in area, irrespective of land use** (agroforestry, compensatory forestry), **ownership** (public or private), and **species of trees** (it can even be a plantation!).
- FC includes three classes of forests (including mangrove forests):
 - Very Dense Forest (VDF — tree canopy density $\geq 70\%$)**
 - Moderately Dense Forest (MDF — tree canopy density $\geq 40\%$ but $< 70\%$)**
 - Open Forest (OF — tree canopy density $\geq 10\%$ but $< 40\%$)**



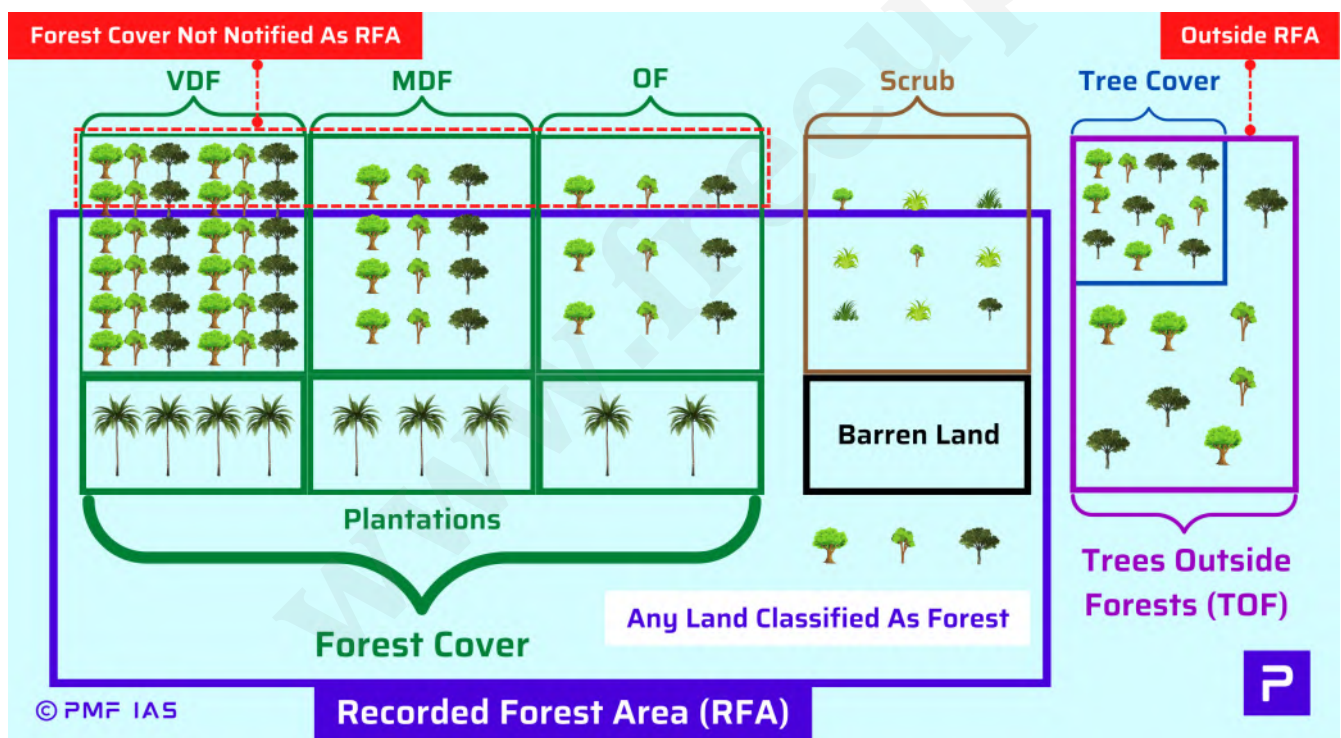
Tree Cover

- Tree cover includes **all patches of trees** occurring **outside RFA** which are of **size less than 1 ha**, **irrespective of canopy density**.
- Forest cover and tree cover together are called **Forest and Tree Cover**. It is the **parameter** for **monitoring progress** against the **National Forest Policy goal of 33%** of the country's geographical area under forests.
- The total tree cover of the country has been estimated at **95,748 sq km** (a slight **increase** since 2019).
- States/UTs having maximum tree cover are **Maharashtra** (12,108 sq km), **Rajasthan** (8,733 sq km), and **Madhya Pradesh**.
- Considering the percentage of the geographical area of States/UTs, the UT of **Chandigarh** shows the **highest percentage of tree cover** (13.16%) followed by Delhi (9.91%) and Kerala (7.26%).

Tress Outside Forests (TOF)

- TOF refers to **all trees outside RFA irrespective of patch size** or **canopy density**, which **could also be larger than 1 ha**. Thus, **tree cover is a subset of TOF**.
- Maharashtra** (26,866 sq km) has the largest extent of TOF, followed by **Odisha**.
- In terms of the percentage of GA, the UT of **Lakshadweep** (90%) has the highest percentage of TOF, followed by Kerala (37%).

Comparison



- Recorded Forest Area (RFA):** **any** lands **notified as forest** under **any Government Act or Rules**. (A RFA may or may not have a forest!)

- **Forest Cover (FC)**: all patches of land with a **tree canopy density of more than 10%** and **more than 1 ha in area**, **irrespective of land use, ownership** (public or private), and **species of trees**.
- **Tree Cover (TC)**: all patches of trees **less than 1 ha outside RFA**. (Canopy density does not matter)
- **Tress Outside Forests (TOF)**: **all trees outside RFA** irrespective of patch size. (Tree Cover is a **subset** of TOF)

- ⇒ **Recorded Forest Area (RFA)** → Any land that the government calls a forest area
- ⇒ **Tree Cover** → less than 1 ha + outside RFA
- ⇒ **Trees Outside Forests (TOF)** → Any tree outside RFA
- ⇒ **Forest cover** → more than 1 ha + tree canopy density $\geq 10\%$
- ❖ **Very Dense Forest (VDF — tree canopy density $\geq 70\%$)**
 - ❖ **Moderately Dense Forest (MDF — tree canopy density $\geq 40\%$ but $< 70\%$)**
 - ❖ **Open Forest (OF — tree canopy density $\geq 10\%$ but $< 40\%$)**

A Change in FC Does Not Mean a Change in RFA

- Forest Cover and Recorded Forest Area overlap, but they are **not coterminous**.
- In **RFAs**, there are areas with a **tree density of less than 10%** and **some even without trees!**
- On the other hand, there are areas **outside the RFA** with tree stands of **more than 10% canopy density** and **size 1 ha or more**, such areas constitute **forest cover**.
- Therefore, the **change** in the **forest cover** is **not** necessarily **due to changes within the RFA but also outside RFA**.

Status of India's Forest Resources in 2021 (ISFR 2021)

Forest and Tree Cover of India

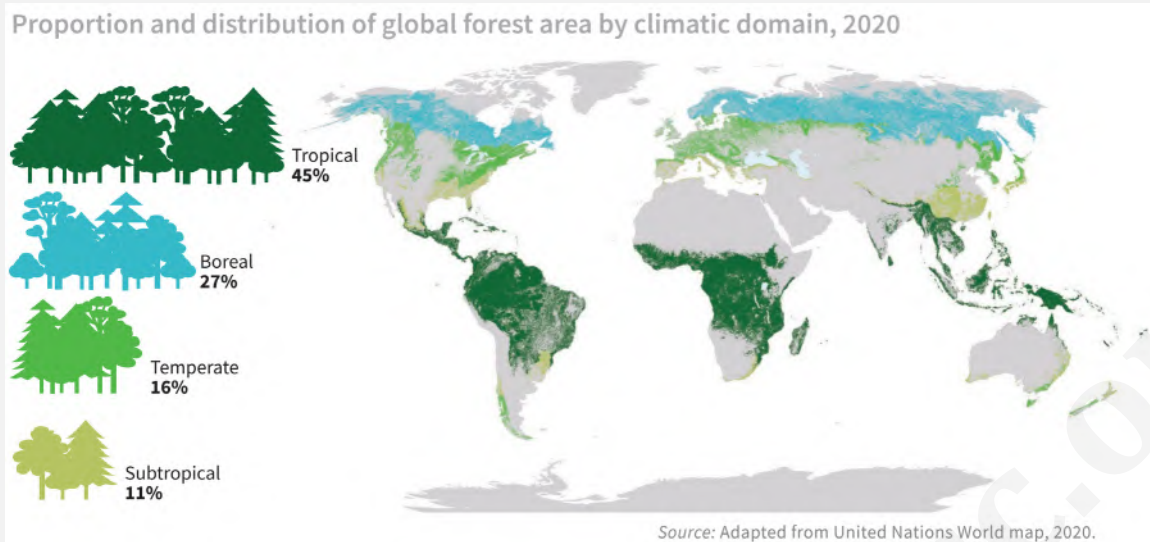
Class (GA: Geographical Area)	ISFR 2019		ISFR 2021	
	Area (km ²)	% of GA	Area (km ²)	% of GA
VDF (tree canopy density $\geq 70\%$)	99,278	3.02	99,779	3.04 (↑)
MDF (tree canopy density $\geq 40\%$ but $< 70\%$)	3,08,472	9.38	3,06,890	9.33 (↓)
OF (tree canopy density $\geq 10\%$ but $< 40\%$)	3,04,499	9.26	3,07,120	9.34 (↑)
Forest Cover (Mangroves + VDF + MDF + OF)	7,12,249	21.67	7,13,789	21.71 (↑)
Tree Cover	95,027	2.89	95,748	2.91 (↑)
Total Forest and Tree Cover	8,07,276	24.56	8,09,537	24.62 (↑)
Scrub (forest with canopy density $< 10\%$)	46,297	1.41	46,539	1.42 (↑)
Non-Forest	25,28,923	76.92	25,27,141	76.87 (↓)
Total Geographic Area	32,87,269	100	32,87,469	100

Non-Forest: Tree Cover + Water Bodies + Land not under Forest Cover)

VDF and MDF constitute 57 per cent of the total Forest Cover. (VDF + MDF > OF)

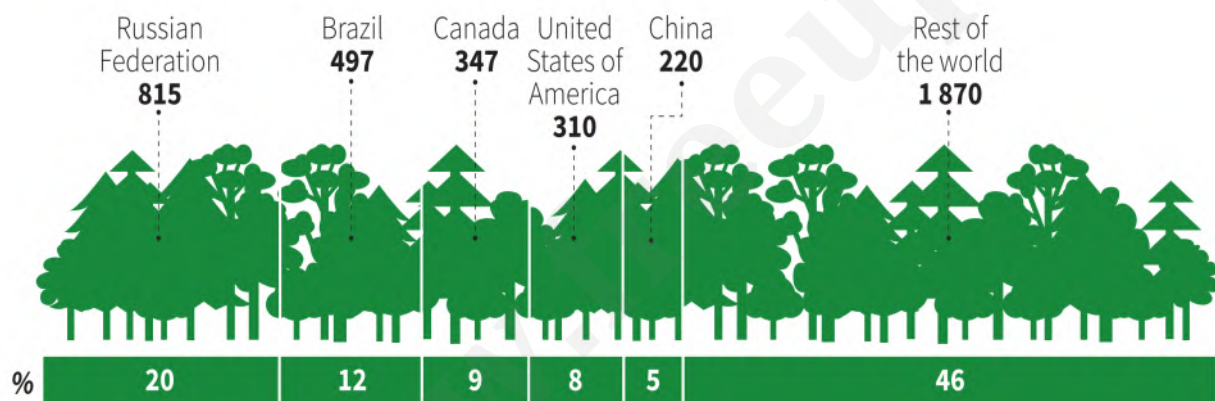
Global Forest Resources Assessment (GFRA)

- The **GFRA**, done by **FAO** once **every five years**, provides information about the forest resources of almost all countries. The latest report of GFRA was released in **2020**.
- According to GFRA, the **top 3 countries** that recorded the **maximum average annual net gains in forest area** during 2010-20 are:
 - China (1.9 mha)**
 - Australia (0.44 mha)**
 - India (0.26 mha)**



Tropical > Boreal > Temperate > Subtropical

Top five countries for forest area, 2020 (million ha)



- ⇒ **Russia (↑) > Brazil (↑) > Canada > US > China (↑) > Australia > Democratic Republic of Congo > Indonesia > Peru > India (↑) (10th)**
- ⇒ **Brazil** saw an **increase** in forest area despite the unprecedented destruction of Amazon forests!
- ⇒ **India** accounts for only **2% of the total global forest area**.
- ⇒ **Brazil**, the **Democratic Republic of Congo** and **Peru** have **more than half of their GA** under forests.
- ⇒ In terms of growing stock, **Brazil > Russia > Canada > USA**

GFRA and India

- The FRA 2020 has credited India's **Joint Forest Management Programme** for the significant increase in the community-managed forest areas on the Asian continent.
- The forest area managed by local, tribal, and indigenous communities in India **increased** from zero in 1990 to about 25 million ha in 2015.
- India reported the **maximum employment** (nearly 50%) in the world's forestry sector. Globally, 12.5 million people were employed in the forestry sector.

Forest Cover

Δ indicates % Change w.r.t ISFR 2019

State/UT		2021 Forest Cover in sq km			Total	% of GA	Δ
		VDF	MDF	OF			
1	Madhya Pradesh	6,665	34,209	36,619	77,493	25 (20)	11
2	Arunachal Pradesh	21,058	30,176	15,197	66,431	79 (4)	-257
3	Chhattisgarh	7,068	32,279	16,370	55,717	41 (13)	106
4	Odisha	7,213	20,995	23,948	52,156	34 (17)	537
5	Maharashtra	8,734	20,589	21,475	50,798	17 (27)	20
6	Karnataka	4,533	20,985	13,212	38,730	20 (22)	155
7	Andhra Pradesh	1,994	13,929	13,861	29,784	18 (26)	647
8	Assam	3,017	9,991	15,304	28,312	36 (16)	-15
9	Tamil Nadu	3,593	11,034	11,792	26,419	20 (21)	55
10	Uttarakhand	5,055	12,768	6,482	24,305	45 (12)	2
11	Jharkhand	2,601	9,689	11,431	23,721	30 (18)	110
12	Jammu and Kashmir	4,155	8,117	9,115	21,387	39 (14)	29
13	Kerala	1,944	9,472	9,837	21,253	55 (10)	109
14	Telangana	1,624	9,119	10,471	21,214	19 (25)	632
15	Mizoram	157	5,715	11,948	17,820	85 (2)	-186
16	Meghalaya	560	9,160	7,326	17,046	76 (5)	-73
17	West Bengal	3,037	4,208	9,587	16,832	19 (24)	-70
18	Rajasthan	78	4,369	12,208	16,655	5 (33)	25
19	Manipur	905	6,228	9,465	16,598	74 (6)	-249
20	Himachal Pradesh	3,163	7,100	5,180	15,443	28 (19)	9
21	Gujarat	378	5,032	9,516	14,926	8 (31)	69
22	Uttar Pradesh	2,627	4,029	8,162	14,818	6 (32)	12
23	Nagaland	1,272	4,449	6,530	12,251	74 (7)	-235
24	Tripura	647	5,212	1,863	7,722	74 (8)	-4
25	Bihar	333	3,286	3,762	7,381	8 (30)	75
26	A&N Islands	5,678	683	383	6,744	82 (3)	1
27	Sikkim	1,102	1,551	688	3,341	47 (11)	-1
28	Ladakh	2	512	1,758	2,272	1 (36)	18
29	Goa	538	576	1,130	2,244	61 (9)	7

30	Punjab	11	793	1,043	1,847	4 (34)	-2
31	Haryana	28	445	1,130	1,603	4 (35)	1
32	Dadra-NH-D&D	1	86	141	228	38 (15)	0
33	Delhi	7	57	132	195	13 (28)	0
34	Puducherry	0	18	36	53	11 (29)	1
35	Lakshadweep	0	16	11	27	90 (1)	0
36	Chandigarh	1	14	8	23	20 (23)	1
Total in 2019		99,278	3,08,472	3,04,499	7,12,249	21.67	0.56
Total in 2021 (Δ)		99,779 (↑)	306,890 (↓)	307,120 (↑)	7,13,789 (↑)	21.71 (↑)	0.22 (↓)

Forest Cover as a Percentage of Geographic Area

- ⇒ **Lakshadweep (90%) > Mizoram (85%) > A&N Islands (82%) > Arunachal Pradesh (79%) > Meghalaya (76%) > Manipur (74%) > Nagaland (74%) > Tripura (74%) > Goa (61%) > Kerala (55%)**
- ⇒ **NE States: Mizoram (85%) > Arunachal Pradesh (79%) > Meghalaya (76%) > Manipur (74%) > Nagaland (74%) > Tripura (74%) > Sikkim (47%) > Assam (36%).**
- ⇒ **Non-NE States: Goa (61%) > Kerala (55%) > Uttarakhand (45%) > Chhattisgarh (41%) > Odisha (34%) > Jharkhand (30%) > HP (28%) > MP (25%) > TN (20%) > Karnataka (20%) > Chandigarh (20%) > WB (19%) > Telangana (19%) > AP (18%) > Maharashtra (17%) > Bihar (8%) > Gujarat (8%) > UP (6%) > Rajasthan (5%) > Punjab (4%) > Haryana (4%)**
- ⇒ **Non-NE and Non-Himalayan States: Goa (61%) > Kerala (55%) > Chhattisgarh (41%) > Odisha (34%) > Jharkhand (30%) > Madhya Pradesh (25%)**
- ⇒ **States with a positive change in FC: Andhra Pradesh (647 sq km) > Telangana > Odisha > Karnataka > Jharkhand (110 sq km)**
- ⇒ **States with a negative change in FC: Arunachal Pradesh (257 sq km) > Manipur > Nagaland > Mizoram > Meghalaya (73 sq km)**

- Forest cover in the **NE region** is 1,69,521 sq. km (**64.66% of the GA**), a **decrease** of 1,020 sq. km.
- Forest cover in the **140 hill districts** is 2,83,104 sq. km (**40.17% of the GA**), a **decrease** of 902 sq. km.
- Forest cover in the **tribal districts** is 4,22,296 sq. km (**37.53% of the GA**), a **decrease** of 655 sq. km of forest cover **inside** the RFA in the tribal districts and an **increase** of 600 sq. km **outside**.
- Forest Cover in the seven major cities is **509.72 sq km** which is **10.21%** of the total geographical area of the cities.
- **Delhi** has the largest Forest Cover (194 sq km), followed by **Mumbai** (111 sq km), **Bengaluru** (89 sq km), **Hyderabad** (82 sq km), **Chennai** (23 sq km), **Ahmedabad** (9.4 sq km) and **Kolkata** (1.7 sq km).
- Maximum gain in Forest Cover is seen in **Hyderabad** (48.66 sq km) followed by **Delhi** (19.91 sq km).
- **Ahmedabad** and **Bengaluru** have **lost Forest Cover** of 8.55 sq km and 4.98 sq km, respectively.

[UPSC 2019] Consider the following states:

1. Chhattisgarh
2. Madhya Pradesh
3. Maharashtra
4. Odisha

With reference to the States mentioned above, in terms of percentage of forest cover to the total area of State, which one of the following is the correct ascending order?

- a) 2-3-1-4
- b) 2-3-4-1
- c) 3-2-4-1
- d) 3-2-1-4

Explanation

- Chhattisgarh (41%) > Odisha (34%) > Madhya Pradesh (25%) > Maharashtra (17%)

Answer: c) 3-2-4-1

[UPSC 2012] A particular State in India has the following characteristics:

1. It is located on the same latitude which passes through northern Rajasthan.
2. It has over 80% of its area under forest cover.
3. Over 12% of forest cover constitutes Protected Area Network in this State.

Which one among the following States has all the above characteristics?

- a) Arunachal Pradesh
- b) Assam
- c) Himachal Pradesh
- d) Uttarakhand

Explanation

- Arunachal Pradesh is located on the same latitude as northern Rajasthan, which falls roughly between **26°N and 30°N**.
- According to the India State of Forest Report (ISFR) 2021, Arunachal Pradesh has a forest cover of **79.33%** (79.72% in 2019).
- Over **12%** of the state's forest cover falls under the Protected Area Network.

Answer: a) Arunachal Pradesh

[UPSC 2010] In India, which type of forest among the following occupies the largest area?

- a) Montane Wet Temperate Forest
- b) Sub-tropical Dry Evergreen Forest
- c) Tropical Moist Deciduous Forest
- d) Tropical Wet Evergreen Forest

Explanation

- Montane Wet Temperate Forest — 20,185 sq km (2.83%)
- Sub-tropical Broadleaved Hill Forest — 31,015 sq km (4.35%)
- **Tropical Moist Deciduous Forest — 1,31,805 sq km (18.47%)**
- Tropical Wet Evergreen Forest — 19,572 sq km (2.74%)

Answer: c) Tropical Moist Deciduous Forest

[UPSC 2005] Consider the following statements:

1. The forest cover in India constitutes around 20% of its geographical area. Out of the total forest cover, dense forest constitutes around 40%.
2. The National Forestry Action Programme aims at bringing one third of the area of India under tree forest cover.

Which of the statements given above is/are correct?

- a) 1 only
- b) 2 only
- c) Both 1 and 2
- d) Neither 1 nor 2

Explanation

- VDF (tree canopy density $\geq 70\%$) – **3.02%**
- MDF (tree canopy density $\geq 40\%$ but $< 70\%$) – **9.38%**

Answer: b) 2 only

[UPSC 2004] Amongst the following Indian States which one has the minimum total forest cover?

- a) Sikkim
- b) Goa
- c) Haryana
- d) Kerala

Explanation

- India State of Forest Report (ISFR) 2021:
 - ❖ Sikkim – 3,341 sq. km (47.08%)
 - ❖ Goa – 2,244 sq. km (60.62%)
 - ❖ Haryana – 1,603 sq. km (3.63%)
 - ❖ Kerala – 21,253 sq. km (54.70%)

Answer: c) Haryana

[UPSC 2010] The approximate representation of land use classification in India is:

- a) Net area sown 25%, forests 33%, other areas 42%
- b) Net area sown 58%, forests 17%, other areas 25%
- c) Net area sown 43%; forests 29%, other areas 28
- d) Net area sown 47%, forests 23%, other areas 30%

Answer: d) Net area sown 47%, forests 23%, other areas 30%

[UPSC 1999] The minimum land area recommended for forest cover to maintain proper ecological balance in India is:

- a) 25%
- b) 33%
- c) 43%
- d) 53%

Explanation

- The **National Forest Policy of 1988** states that a minimum of **one-third (33%)** of the total land area of the country should be under forest cover. This target aims to ensure ecological balance, environmental stability, and conservation of natural resources.

Answer: b) 33%

[UPSC 2020] Examine the status of forest resources of India and its resultant impact on climate change. (250words)

Status of Forest Resource of India

- The total forest cover of India is **713,789 sq km**, which is **21.71%** of the country's geographical area. There has been an increase of 1,540 sq km of forest cover since the last assessment in 2019.
- The top five states with the most significant increase in forest cover are **Andhra Pradesh, Telangana, Odisha, Karnataka, and Jharkhand**.
- Forest cover in the country's hill districts is **283,104 sq km**, which is **40.17%** of the total geographical area of these districts. Since the last assessment, forest cover in these districts has **decreased** by 902 sq km.
- The total forest cover in the tribal districts of the country is 422,296 sq km, and there has been a **decrease** of 655 sq km of forest cover inside the RFA/GW in these districts since the last assessment (2019).

Impact on Climate Change

Reduced Carbon Sequestration

- Forests act as **carbon sinks**, absorbing carbon dioxide from the atmosphere during photosynthesis.
- When forests are degraded or cleared, they **release stored carbon back into the atmosphere**, contributing to **increased greenhouse gas emissions**.

Altered Microclimates

- Forests influence local and **regional climates** by **regulating** temperature, humidity, and precipitation patterns. Deforestation can disrupt these patterns, leading to **changes in rainfall and temperature regimes**.
- For example, the **loss of forests in the Western Ghats** region has been linked to changes in monsoon patterns, affecting agriculture and water availability in southern India.

Loss of Biodiversity

- The loss of biodiversity due to deforestation **reduces the ability of ecosystems to adapt to climate change** and increases their susceptibility to disturbances.

Impact on Livelihoods

- Forests provide livelihoods for millions of tribal and indigenous communities who depend on forests for food, fuel, medicine, and other resources.
- Deforestation and degradation threaten these livelihoods, leading to poverty and **social unrest**.

Disasters

- Increased frequency and intensity of heatwaves** across India are partly attributed to reduced forest cover, which reduces the cooling effect.
- More frequent and severe droughts** can be linked to deforestation as forests play a role in regulating water cycles.
- Increased risk of landslides and soil erosion** in areas with depleted forest cover.

Recorded Forest Areas (RFAs) in States and UTs

S.No.	State/ UT	RFA (in different categories)			Total RFA (2021)	% of GA
		RF	PF	Unclassed		
1.	Madhya Pradesh	61886 (1)	31098 (1)	1705	94689	30.72
2.	Maharashtra	50865 (2)	6433	4654	61952	20.13
3.	Odisha	36049 (3)	25133 (3)	22	61204	39.31
4.	Chhattisgarh	25897	24036	9883 (3)	59816	44.25 (9)
5.	Arunachal Pradesh	12371	11857	27312 (1)	51540	61.55 (6)
6.	Karnataka	28690	3931	5663	38284	19.96
7.	Uttarakhand	26547	9885	1568	38000	71.05 (4)
8.	Himachal Pradesh	1883	28887 (2)	7178	37948	68.16 (5)
9.	Andhra Pradesh	31959	5069	230	37258	22.86
10.	Rajasthan	12176	18543	2144	32863	9.6
11.	Telangana	25800	1592	296	27688	24.7
12.	Assam	17864	0	8972	26836	34.21
13.	Jharkhand	4500	18922	1696	25118	31.51
14.	Tamil Nadu	20523	1053	1612	23188	17.83
15.	Gujarat	14574	2898	4398	21870	11.14

16.	J&K	17648	2551	0	20199	36.98
17.	Manipur	984	3254	13180 (2)	17418	78.01 (3)
18.	Uttar Pradesh	11560	296	5528	17384	7.22
19.	West Bengal	7054	3772	1053	11879	13.38
20.	Kerala	11522	0	0	11522	29.66
21.	Meghalaya	1113	12	8371	9496	42.34 (10)
22.	Nagaland	234	0	8389	8623	52.01 (8)
23.	Mizoram	4499	1823	1157	7479	35.48
24.	Bihar	693	6183	566	7442	7.9
25.	A&N Islands	5613	1558	0	7171	86.93 (1)
26.	Tripura	3588	2	2704	6294	60.02 (7)
27.	Sikkim	5452	389	0	5841	82.31 (2)
28.	Punjab	44	1137	1903	3084	6.12
29.	Haryana	249	1158	152	1559	3.53
30.	Goa	119	755	397	1271	34.33
31.	Dadra-NH-D&D	203	5	6	214	35.55
32.	Delhi	78	25	0	103	6.95
33.	Chandigarh	32	0	3	35	30.7
34.	Puducherry	0	2	11	13	2.65
35.	Ladakh	7	0	0	7	0
36.	Lakshadweep	0	0	0	0	0
Total in 2019		434,853	218,924	113,642	767,419	23.34
Total in 2021		4,42,276 (↑)	2,12,259 (↓)	1,20,753 (↑)	7,75,288 (↑)	23.58 (↑)

FRA as a Percentage of Geographic Area

- ⇒ **A&N (87%) > Sikkim (82%) > Manipur (78%) > Uttarakhand (71%) > HP (68%) > Arunachal Pradesh (62%)**
- ⇒ **NE States: Sikkim (82%) > Manipur (78%) > Arunachal Pradesh (62%) > Tripura (60%) > Nagaland (52%) > Meghalaya (42%) > Mizoram (35) > Assam (34%)**
- ⇒ **Non-NE States: Uttarakhand (71%) > HP (68%) > Chhattisgarh (44%) > Odisha (39%)**
- ⇒ **Non-NE and Non-Himalayan States: Chhattisgarh (44%) > Odisha (39%)**

Mangrove Cover

State/UT		VDM	MDM	OM	GA
1	West Bengal	994 (1)	692	428	2114 (↑)
2	Gujarat	0	169	1006	1175 (↓)
3	A&N Islands	399 (2)	168	49	616
4	Andhra Pradesh	0	213	192	405 (↑)
5	Maharashtra	0	90	234	324 (↑)
6	Odisha	81 (3)	94	84	259 (↑)

7	Tamil Nadu	1	27	17	45
8	Goa	0	21	6	27 (1)
9	Karnataka	0	2	11	13 (1)
10	Kerala	0	5	4	9
11	D&NH and D&D	0	0	3	3
12	Puducherry	0	0	2	2
Total in 2019		1,476	1,479	2,020	4,975
Total in 2021		1,475 (↓)	1,481 (↑)	2,036 (↑)	4,992 (↑)

VDM: Very Dense Mangrove; MDM: Moderately Dense Mangrove; OM: Open Mangrove

- ⇒ **South 24 Parganas district of WB** alone accounts for **47.74 %Mangrove cover** of the country.
- ⇒ The mangrove cover in the country has **increased by 364 sq. km.** in 2021 as compared to 2013.

Bamboo Resources of the Country

- The total bamboo-bearing area of the country has been estimated to be **15.0 million ha**.
- Madhya Pradesh** has a **maximum bamboo-bearing area** of 1.84 m ha, followed by **Arunachal Pradesh** (1.57 million ha), **Maharashtra** (1.35 million ha) and **Odisha** (1.12 million ha).
- As compared to the estimates of ISFR 2019, the total bamboo-bearing area in the country has **decreased** by 1.06 million ha.
- Mizoram** has shown the highest increase, followed by **Arunachal Pradesh**. Similarly, **Madhya Pradesh** has shown the highest decrease, followed by **Maharashtra**.

Carbon Stock in India's Forests

World's Forest Carbon Stocks

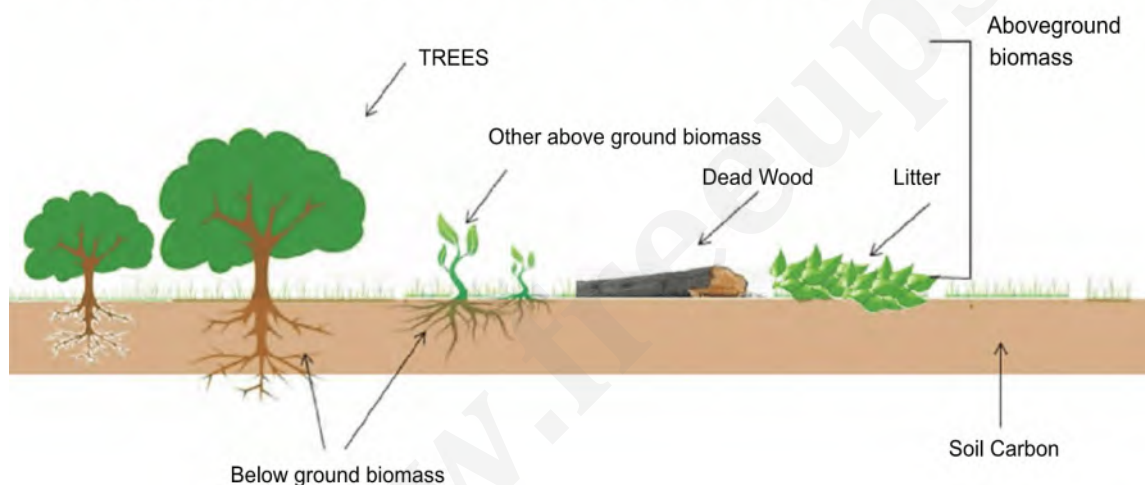
- The **world's forests and forest soils** currently store more than **one trillion tons (1000 Gt) of carbon**, which is nearly **1.3 times larger** than the **carbon stored in fossil fuel reserves** (estimated at **800 Gt**) and **more** than the carbon added to the atmosphere because of **human activities** since 1870 (about **600 Gt**).
- It has been estimated that since 1750, **forests** have been responsible for about **half of the carbon emissions naturally sequestered** from the atmosphere; the **oceans have absorbed the rest**.
- Forests store an estimated **296 Gt** of carbon above and **below the ground biomass**, which contains **almost half of the total carbon stored in forest areas**, the other half being the **soil organic carbon**.
- Globally, over the last 25 years, the **carbon stock** in **forest biomass** has **decreased** by almost **17.4 Gt**, equivalent to a reduction of **697 million tons per year** or about **2.5 Gt of carbon dioxide** equivalent.
- The carbon stock for 2021 has been estimated at **7,204 million tonnes (mt)**, a slight **increase (79.4 mt)** since 2019. This translates into **carbon emissions sequestered through forest and tree cover**, which is equivalent to **30.1 billion tonnes of CO₂**.

- The **maximum carbon stock** has been stored in:
 - ✓ **Tropical Dry Deciduous Forest** (2,177 mt), **Tropical Moist Deciduous Forest** (1,303 mt) & **Tropical Semi-Evergreen Forest** (686 mt).
 - ✓ **Arunachal Pradesh** (1,023.84 mt), **Madhya Pradesh** (609.25 mt), Chhattisgarh and Maharashtra.
- The **least carbon stock** has been stored in **Subtropical Dry Evergreen Forest**, **Moist Alpine Scrub** and **Tropical Dry Evergreen Forests**.
- The **maximum per hectare carbon stock** has been stored in:
 - ✓ **Himalayan Dry Temperate Forests** (244.19 tonnes/ha), **Himalayan Moist Temperate Forests**, **Sub-Alpine Forests** and **Equatorial Wet Evergreen Forests**.
 - ✓ **Jammu and Kashmir** (173.41 tonnes/ha), **Himachal Pradesh** (167.10 tonnes/ha), Sikkim and Andaman and Nicobar Islands (162.86 tonnes/ha).
- The **least per hectare carbon stock** has been stored in **Tropical Thorn Forests** & **Tropical Dry Deciduous Forests**.
- **Soil organic carbon** is the **largest pool of forest carbon** accounting for (56%) followed by **AGB** (32%), BGB (10%), Litter (1.5%) and dead wood (0.7%). In all the NE states, it is observed that SOC is almost double the carbon in AGB.

CARBON POOLS (IPCC GPG)

The IPCC GPG (2003) - five carbon pools:

Aboveground biomass, belowground biomass, litter, dead wood, and soil organic carbon



Pools	Description
Living Biomass	Above Ground biomass (AGB): All living biomass above the soil.
	Below Ground biomass (BGB): All living biomass of live roots.
Dead Organic Matter	Dead Wood: Includes all non-living woody biomass not contained in the litter.
	Litter: Includes all non-living biomass with a diameter less than the minimum diameter chosen by the country, lying dead, in various states of decomposition.
Soil	Soil organic matter: Includes organic carbon in mineral and organic soils (including peat) to a specific depth.

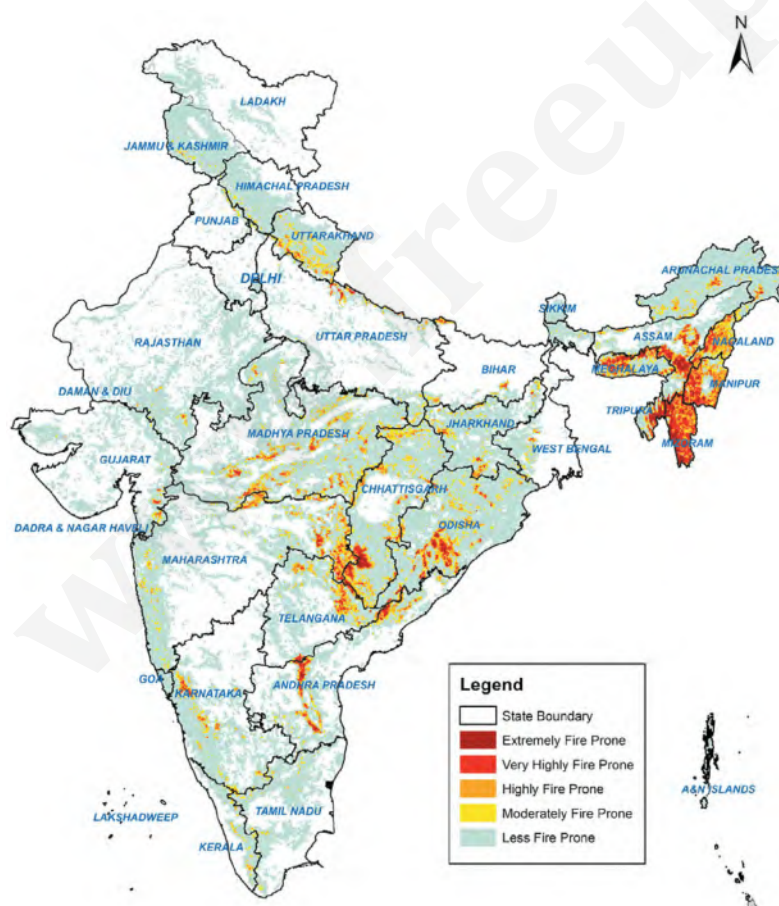
Meeting NDC Target

- According to the forestry target under the **Paris Agreement (2015) Nationally Determined Contributions (NDC)**, India has committed to creating an **additional carbon sink of 2.5 to 3.0 billion tonnes of CO₂ equivalent** through **additional forest and tree cover** by **2030**.
- The projection for 2030 shows a **shortfall of 0.25 billion tonnes** and **0.75 billion tonnes of CO₂ equivalent**.
- The shortfall can be bridged through the **restoration of open forests**, which is the **most cost-effective strategy** — above 70% of forest cover in India falls in **tropical semi-evergreen, tropical moist deciduous** and **tropical dry deciduous forest** types, and more than 30% of these areas fall in the category of **open forest**.

Growing Stock

- Growing stock is an indicator of **forest productivity**. It is estimated at **56.60 cum per ha**.
- Among states, **Kerala, Uttarakhand**, and Goa have the highest per ha growing stock in a forest.
- Among the UTs, the highest per ha growing stock in a forest is in **Ladakh**, followed by J&K.
- In respect of the total volume of growing stock, **Arunachal Pradesh** has the maximum growing stock (419 m cum) in forests, followed by Uttarakhand, Chhattisgarh, and MP.
- In TOF, **Maharashtra** has the maximum growing stock (188 m cum), followed by Karnataka.
- **Sal, teak**, and **pine** trees have the highest growing stocks in forests and TOF.
- **Mango** and **neem** have the highest-growing stocks in TOF.

Fire Proneness



- **More than 36%** of India's forest cover is prone to frequent forest fires, nearly **4% is extremely prone**, and **6% is very high fire prone**.
- The MoEF formulated the **National Action Plan on Forest Fires (NAPFF)** in 2018 to minimize forest fires by empowering **forest fringe communities** and incentivizing them to work in tandem with the **State Forest Departments (SFDs)**.

Criticism of FSI's approach and ISFR

Criticism of the definition of 'Forest Cover'

- Under the current definition of 'forest cover' a **rubber plantation or any other plantation of 1 ha or more can be considered as a forest**. This gives a **false impression** of the state of forests as the **ecological importance of plantations is well below that of a natural forest**.
- Unlike the roots of trees in a natural forest, the **roots of plantation crops don't run deep**. Hence, they **cannot hold the soil tight** which means replacing natural forests with plantation trees like rubber, palm, etc. **can increase the frequency and scale of landslides (slope failure)**.
- **Massive landslides occurring in Western Ghats** in recent times are said to be due to replacement of natural forest by plantation agriculture. **(Remember the landslides in Kerala in 2018? Plantation crops!)**
- Plantations **cannot retain moisture** or supporting wildlife the way natural forests do. Also, the **carbon stock** in plantations is **far below** than that of a natural forest.

Positives are exaggerated and negatives are suppressed

- The claims of **increase in forest cover** **doesn't reflect the ground reality** as the **land acquired for compensatory afforestation is included** in the quantitative accounting of forests **without taking into consideration** the **loss or diversion of forest land** for mining and other projects.

Not enough tree cover but still a forest! Forest on paper!

- ISFR data doesn't explain why **30% of the RFA (2,15,000 sq. km) has no forest cover!** Such data is crucial to evaluate the effect of policies on forest loss and degradation.

Anything green is a forest?

- The ISFR methodology relies primarily on **remote-sensing techniques** that can **pick anything that is green** and **of a certain scale** on its radar. This is used to generate data on the extent of '**green cover**'!
- For years, foresters and ecologists have said that this report **does not distinguish** between **natural forests, commercial plantations, orchards, and bamboo groves** while enumerating forests.
- According to them, areas with '**tree stands**' of **over 10% canopy cover** are counted as forests, **irrespective of whether they function ecologically as forests or not**.

13. Indian Soils

- Soil is the thin top layer on the earth's crust comprising **rock** particles mixed with **organic matter**. It is a complex natural resource that sustains life by supporting plant growth, regulating water flow, and providing habitat for numerous organisms.
- **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.

Soil Types: Sandy, Clayey and Loamy

- The soil is classified on the basis of the proportion of particles of various sizes:
 1. If the soil contains a greater proportion of **big particles**, it is called **sandy soil**.
 2. If the proportion of **fine particles** is relatively higher, then it is called **clayey soil**.
 3. If the amount of **large** and **fine particles** is about the same, then the soil is called **loamy**.
- Water can drain quickly through the spaces between the sand particles. So, sandy soils tend to be light in colour (as all the **organic matter is leached away**), well-aerated and dry.
- 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.
- The **ideal topsoil** for growing plants is **loam**. Loamy soil is a **mixture** of **sand, clay** and another type of soil particle known as **silt**. Silt occurs as a deposit in riverbeds. 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.

Humus

- **Humus** is a **dark organic matter** that's rich in **decayed remains** of plants and animals, like leaves, roots, and bugs, that break down over time.
 - Humus holds onto water and nutrients. It is a **natural fertiliser** for the soil. It is the main ingredient in **fertile soils**.
- **Clayey** and **loamy soils** are both suitable for growing **cereals** like wheat and gram.
 - For **paddy**, soils rich in **clay** and **organic matter** with **good water retention capacity** are ideal.
 - For lentils (masoor) and other **pulses**, loamy soils, **which drain water easily**, are required.
 - For **cotton**, **sandy loam** or loam, which **drains water easily** and can **hold plenty of air**, is more suitable.

Soil Profile (Soil Horizon)

- 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. These layers are referred to as **horizons**.

SOIL PROFILE

ORGANIC HORIZON (O)

*SURFACE LITTER:
PARTIALLY DECOMPOSED ORGANIC MATTER*

TOPSOIL HORIZON (A)

HUMUS, LIVING CREATURES, INORGANIC MINERALS.

ELUVIATED HORIZON (E)

ZONE OF LEACHING, MATERIALS MOVE DOWNWARD

SUBSOIL HORIZON (B)

*IRON, ALUMINIUM HUMIC COMPOUNDS
ARE ACCUMULATED AND CLAY LEACHED
DOWN FROM A AND E HORIZONS.*

PARENT HORIZON (C)

*WEATHERED PARENT MATERIAL:
PARTIAL BREAKDOWN OF
INORGANIC MINERALS.*

BEDROCK HORIZON (R)

*THIS HORIZON IS COMPOSED OF UNWEATHERED
ROCK AND IT IS NOT TECHNICALLY PART OF THE
SOIL. RATHER, ALL OF THE SOIL LAYERS LIE ON
TOP OF COMPACTED BEDROCK.*

- A soil horizon is a layer generally parallel to the soil surface, whose physical characteristics differ from the layers above and beneath. 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 and **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 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

- It is a layer dominated by **organic material**. They may be on top of either mineral or organic soils.
- Some O layers consist of **undecomposed or partially decomposed litter** (such as leaves, needles, twigs, moss, and lichens) and can also include **fully decomposed organic matter (humus)**.

A Horizon or Surface soil

- It is part of the **topsoil**. In this layer, **organic matter** is **mixed** with **mineral matter**. It's often **darker** in colour due to its **high organic content**. It is the layer rich in **life**.
- This mineral soil layer is **depleted of (eluviated of)** iron, clay, aluminium, organic compounds, and other soluble constituents.
- The degree of depletion varies depending on factors like climate, vegetation, and drainage.
- When depletion is pronounced, a **lighter-coloured "E" subsurface soil horizon** is apparent at the base of the "A" horizon.

E horizon

- "E" stands for an **eluviated layer**. Eluviation refers to the **movement of minerals and organic matter** out of the soil horizons due to **percolating water**.
- It is the horizon that has been significantly **leached** of **clay, iron, and aluminium oxides**, which leaves a concentration of resistant minerals, such as quartz, in the sand and silt sizes.
- These are present generally in **older, well-developed soils** and generally occur **between** the **A** and **B** horizons.

B Horizon or Subsoil

- It is a subsurface layer reflecting a chemical or physical alteration of **parent material**. It **accumulates all the leached minerals** from the **A** and **E** horizons.
- The B horizon can also **accumulate minerals** from the **weathering** of the **parent material**. Thus, iron, clay, aluminium, and organic compounds accumulate in this horizon (**illuviation**).
- One of the distinguishing features of the B horizon is its **higher clay content** compared to the overlying horizons.

⇒ **Illuviation** is a **soil-forming process** whereby materials, such as clay, minerals, and organic matter, are **transported downward** through the soil profile and **accumulate in a lower horizon**.

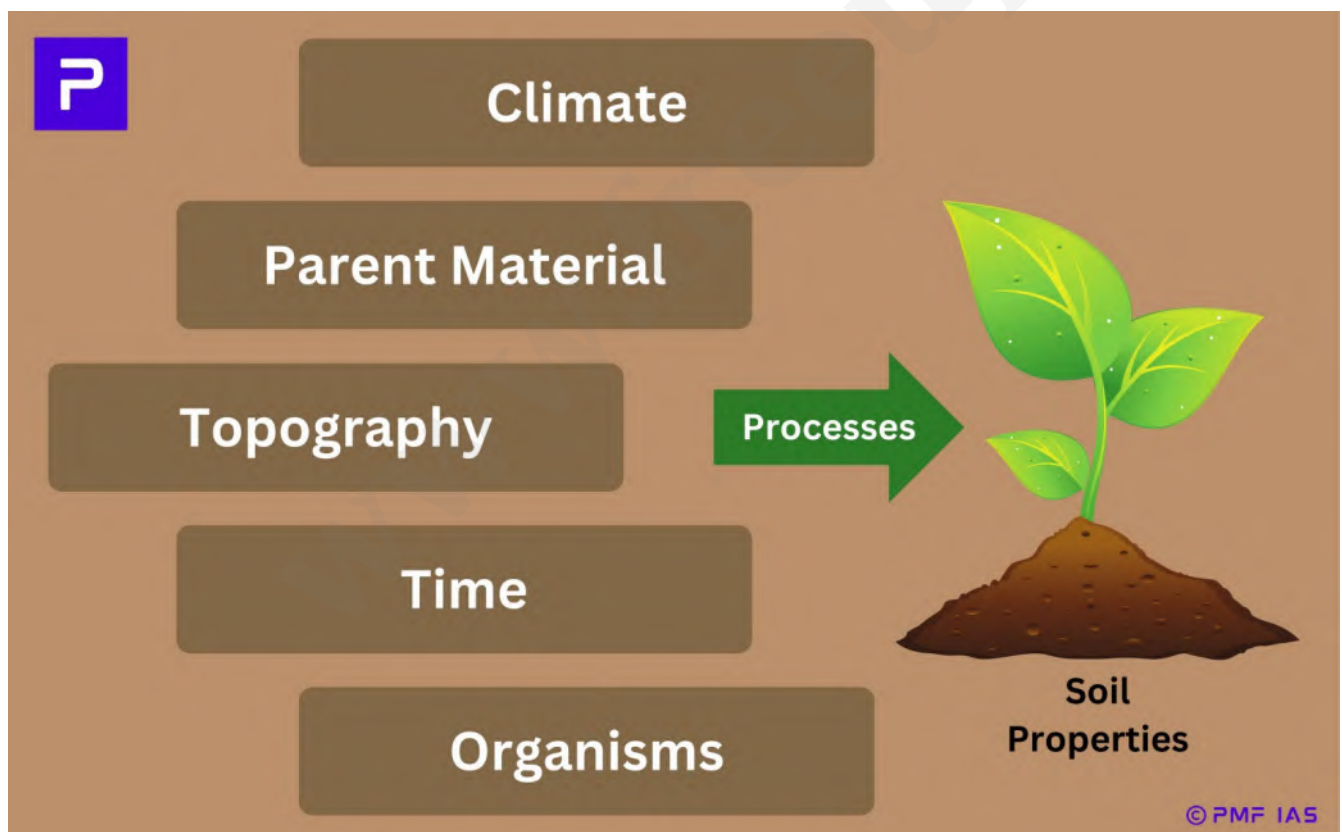
C Horizon or Parent rock

- It is a layer of **large, unbroken rocks**. **Weathered parent material** accumulates in this layer, i.e. the parent material in sedimentary deposits.
- This horizon serves as a **transition zone** between the **soil** and the underlying **bedrock**. It may accumulate **more soluble compounds (inorganic material)**.
- Characteristics of Horizon C may include larger rock fragments, **less organic matter**, and evidence of weathering processes.

R Horizon or Bedrock

- Unlike the above layers, R horizons largely comprise **continuous masses of hard rock**. It denotes the **layer of partially weathered bedrock** at the base of the soil profile.
- This layer serves as the **ultimate foundation for soil development** and provides the **parent material** from which soils derive their physical and chemical properties.
- Soils formed in situ will exhibit strong similarities to the bedrock layer. These areas of bedrock are under 50 feet of the other profiles.
- While Horizon R may not directly contribute to soil fertility, its characteristics **influence** soil drainage, texture, and mineral composition, which in turn affect plant growth and ecosystem dynamics.

Factors that Influence Soil Formation in Indian Conditions



- Soil represents the product of intricate interactions between geological, biological, climatic, and anthropogenic factors over millennia. Its formation and properties depend on the **parent rock** material, surface relief, climate, and natural vegetation.

Parent Material

- The rocks from which soils are formed are called **parent materials**. In most cases, the parent material determines the **colouration, mineral composition, and texture** of the soil.
- Climatic factors induce **chemical changes**, which affect the physical properties of the soil. Hence in some cases, the soil formed **may or may not** have the **same physical properties** as the parent rock.
- The surface rocks are exposed to the process of weathering. In this process, the rocks are converted into fine grains and provide a base for soil formation.
- In Indian Conditions, the parent material is generally categorised into:
 1. **Ancient crystalline and metamorphic rocks**
 2. **Cuddapah and Vindhyan rocks**
 3. **Gondwana rocks**
 4. **Deccan basalts**
 5. **Tertiary and Mesozoic sedimentary rocks of extra-peninsular India**
 6. **Recent and sub-recent rocks**

Ancient crystalline and metamorphic rocks

- They are the **Oldest rocks** (pre-Cambrian era) (formed due to the solidification of molten magma about 4 billion years ago). They form the '**Basement Complex**' of peninsular India.
- They are basically **granites, gneisses, and schists**. They are rich in **ferromagnetic materials** and give rise to **red soils** on weathering due to the presence of **iron oxide**.

Cuddapah and Vindhyan rocks

- They are **ancient sedimentary rocks** (4000 m thick). On weathering, they give **calcareous** (containing calcium carbonate) and **argillaceous** (consisting of or containing clay) soils, **mostly devoid of metalliferous minerals**.

Gondwana rocks

- These rocks are also **sedimentary**, and they are **much younger**. On weathering, they give rise to comparatively **less mature soils with low fertility but more or less uniform character**.

Deccan basalts

- A volcanic outburst over a vast area of Peninsular India gave rise to the **Deccan Traps**. **Basaltic lava** flowed out of fissures, covering a vast area of about **ten lakh sq km**.
- **Basalts** are **rich in titanium, magnetite, aluminium, and magnesium**. Consequently, the weathering of these rocks has given rise to soils of **darker colour**.

- The **soil is fertile** with **high moisture holding capacity** and is popularly known as **regur or black cotton soil**.

Tertiary and Mesozoic sedimentary rocks

- The generally **younger sedimentary rocks** of **extra peninsular India (plains and Himalayas)** have given rise to **immature alluvial soils (high porosity)** on weathering. These soils have **little relation with the original parent rocks**.

Peninsular Soils vs. Extrapeninsular Soils

- The soils of **Peninsular India** are formed by the decomposition of **rocks in situ**, i.e. directly from the underlying rocks. They are transported and re-deposited to a limited extent and are known as **sedentary soils**.
- The soils of the **Extra-Peninsula (Indo-Gangetic-Brahmaputra plains)** are formed due to the **depositional work** of rivers and wind. They are **very deep**. They are often referred to as **transported** or **azonal soils**.
- Most of the extra peninsular soils are **alluvial soils**, which are **very fertile** because of the presence of **fine silt and clay** and **constant replenishment** by the **Himalayan rivers**.
- Unlike the alluvial soils of the plains, the soils of the **peninsular plateau** are generally **coarse-grained**. These soils are **generally more mature** but **less fertile**.

Relief

- The relief is the most important factor for soil formation in places with steep slopes like the hilly regions, edges of plateaus, etc.
- Soil erosion on **barren slopes** is rampant, and it **hinders soil formation**. Examples include **Chambal ravines**, **higher reaches of the Himalayas** where there is minimal or no forest cover, etc.
- The areas of low relief or gentle slope generally experience deposition and have **deep soils**. Examples include **Indo-Gangetic plain** and **plateau river basins** where the soil layers are sufficiently deep.

Climate

- Temperature and rainfall are the most important factors in soil formation. They determine the **effectiveness of weathering** of the parent material, the quantity of water seeping through the soil, and the type of micro-organisms present therein.
- Two different parent materials may develop the same soil in the same type of climate. Similarly, the same parent material may produce two different types of soils in two different types of climates.
 - ❖ The **crystalline granites** produce **laterite (reddish clayey soils) soil** in relatively **moist parts** of the monsoonal region and **non-laterite soil** in **drier areas**.
 - ❖ **Hot summer** and **low rainfall** develop **black soil**, as is found in some parts of **Tamil Nadu**, irrespective of the parent rock.
 - ❖ In **Rajasthan**, both **granite** and **sandstone** give birth to **sandy soil** under an **arid climate**.

- In **arid and semi-arid regions**, evaporation always exceeds precipitation. There is little vegetation, and the soils badly **lack humus** content. Hence, the soils are invariably of **light colour**.
- The soils here are **lime accumulating**. Hence, the soil is **pedocal** in nature (soil that forms in semiarid and arid regions. It is **rich in calcium carbonate** and has **low soil organic matter**).
- In cold climates of the **Himalayan region**, the process of vegetation **decay is prolonged**, and the soils are **acidic**.

In areas of heavy rainfall and high temperature, the soils are red or lateritic. Why?

- Torrential rainfall during the rainy season washes the upper soil and **leaches** the materials into the deeper horizon. During the dry summer season, the evaporation exceeds precipitation, and through **capillary action**, **iron** and **aluminium oxides** are transported to the surface, making the soil red.
- In areas of **alternate wet and dry climate**, the **leached material** that goes deep down in the horizon is **brought up**, and the blazing sun **bakes the topsoil** so hard that it resembles a brick. Therefore, this soil is called **lateritic**, which **means brick**.

Natural Vegetation

- Natural vegetation reflects the combined effects of relief and climate and hence influences the formation and development of soil very much.
- The **densely forested areas** contain some of the **best soils** in India. The decayed leaf material adds much-needed **humus** to soil, thereby **increasing their fertility**.

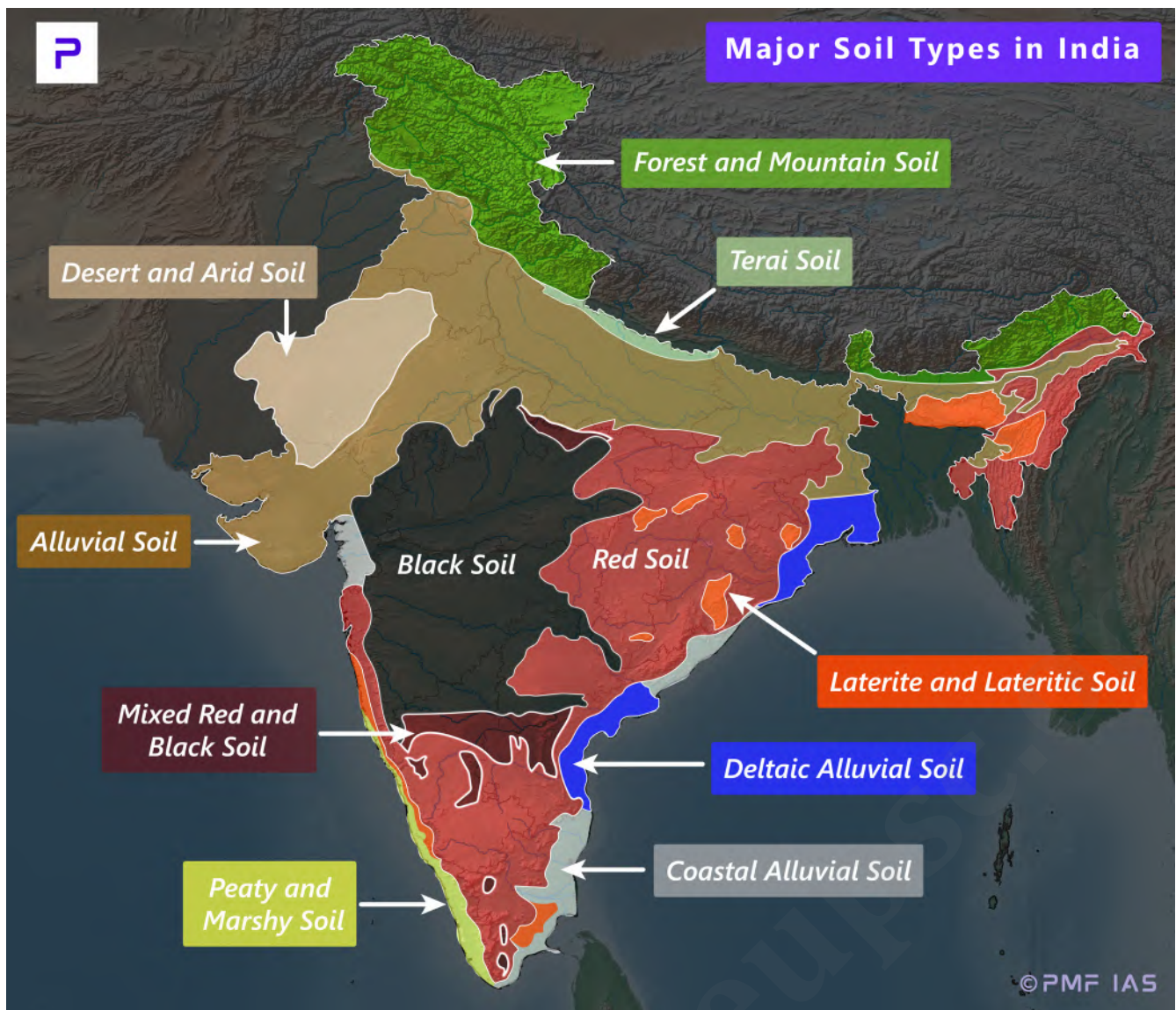
Major Soil Groups of India

- 1) **Alluvial soils**
- 2) **Black soils**
- 3) **Red soils**
- 4) **Laterite and Lateritic soils**
- 5) **Forest and Mountain soils**
- 6) **Arid and Desert soils**
- 7) **Saline and Alkaline soils**
- 8) **Peaty and Marshy soils**

Alluvial Soils

- **Alluvial soils** are formed mainly due to **silt deposited** by **Indo-Gangetic-Brahmaputra rivers** (**transported** or **azonal soils**). Rocks of the Himalayas form the parent material. In coastal regions, some alluvial deposits are formed due to wave action.
- Alluvial soils are the **largest soil group**, covering about **15 lakh sq km** or about **45.6 percent** of the total area. They support more than 40% of 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 **loamy**. Sandy and clayey soils are not uncommon.
- The soil is **porous** because of its loamy (equal proportion of sand and clay) nature.
- Porosity and texture provide **good drainage** and other conditions **favourable for agriculture**.
- Recurrent floods constantly replenish these soils.
- Pebbly and gravelly soils are rare.
- **Kankar (calcareous concretions)** beds are present in some regions along the river terraces.

Chemical Properties of Alluvial Soils

- The proportion of nitrogen is generally low.
- The proportion of potash, phosphoric acid (phosphate), and alkalis (lime) are adequate.
- The proportion of iron oxide and lime varies widely.

Distribution of Alluvial Soils in India

- They occur all along the **Indo-Gangetic-Brahmaputra plains** except in a few places where the top layer is covered by desert sand.

- They also occur in **deltas** of the **Mahanadi, Godavari, Krishna, and Cauvery**, where they are called **deltaic alluvium** (coastal alluvium).
- Some alluvial soils are found in the **Narmada** and **Tapti 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**, etc.

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.

Black Soils

- The parent material for most of the black soil is the **volcanic rocks** that were formed in the **Deccan Plateau**.
- In Tamil Nadu, **gneisses** and **schists** form the parent material. The former are sufficiently deep, while the latter are generally shallow.
- These are the regions 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 (containing clay)** with a **large clay factor**, 62 percent or more. Hence, black soil is good at **retaining moisture** for a longer duration.
- In summer, the moisture evaporates, and the soil shrinks and is seamed with broad and deep cracks. The lower layers can still retain moisture. The cracks permit **oxygenation** to sufficient depths.
- In the rainy season, the **soil swells greatly** on accumulating moisture and **gets very sticky**. Hence, ploughing and other agricultural activities demand more effort.
- In general, black soils of uplands are of low fertility, while those in the valleys are very fertile.

Colour of Black Soils

- Various black tints may be found in this group of 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**.

Chemical Composition of Black Soils

- They comprise 10 percent of **alumina**, 10 percent of **iron oxide**, and 6-8 percent of lime and magnesium carbonates.
- **Potash** is variable (less than 0.5 percent), **and phosphates, nitrogen, and humus are low**.

Distribution of Black Soils

- They are spread over **5.46 lakh sq km (16.6 percent 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 crops**. Hence they are called **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 fertilisers and manures, with little or no evidence of exhaustion.

[UPSC 2021] The black cotton soil of India has been formed due to the weathering of

- a) brown forest soil
- b) fissure volcanic rock
- c) granite and schist
- d) shale and limestone

Explanation

- The **parent rock** of **black cotton soil** is **fissure volcanic rock**.
- These are **igneous rocks** formed from the cooling and solidification of lava flows that erupted from fissures (cracks) in the Earth's crust.
- The **Deccan Traps**, a vast region of volcanic rock formations in India, are the **primary source of parent material for black cotton soil**.

Answer: b) fissure volcanic rock

Red Soils

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

Characteristics of Red Soils

- The texture of these soils can vary from **sand to clay**, the **majority being loams**. On the uplands, they 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**.

Colour of Red Soils

- The red colour is due to the presence of **iron oxide**.
- The colour is more due to the **wide diffusion** rather than the high percentage of iron oxide content.

Distribution of Red Soils

- These soils mostly **occur in regions of low rainfall**.
- They occupy about **3.5 lakh sq km (10.6 percent)** 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; **Aravallis** 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 fertilisers and irrigation techniques, give a good yield of **cotton**, wheat, rice, pulses, millets, tobacco, oilseeds, potatoes, and fruits.

[UPSC 2010] When you travel to certain parts of India, you will notice red soil. What is the main reason for this colour?

- Abundance of magnesium
- Accumulated humus
- Presence of ferric oxide
- Abundance of phosphates

Explanation

- **Ferric oxide** is a chemical compound formed by **iron** and **oxygen**, specifically iron in its trivalent (Fe^{3+}) state. It has a **reddish-brown color**, which contributes to the overall colour of **red soil**.

Answer: c) Presence of ferric oxide

Laterite or 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 get washed away by water)** of soil whereby lime and silica are leached away, and 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 sandstone**.

The 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**.
- The continuous stretch of laterite soil is found on the **summits of Western Ghats** at 1000 to 1500 m, **Eastern Ghats**, the **Rajmahal Hills**, **Vindhyan**, **Satpuras**, and **Malwa Plateau**.
- 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**.

The Economic Value of Laterite – Lateritic Soils

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

[UPSC 2013] Which of the following statements regarding laterite soils of India are correct?

1. They are generally red in colour.
2. They are rich in nitrogen and potash.
3. They are well-developed in Rajasthan and UP.
4. Tapioca and cashew nuts grow well on these soils.

Select the correct answer using the codes given below:

- a) 1, 2 and 3
- b) 2, 3 and 4
- c) 1 and 4
- d) 2 and 3 only

Explanation

- **Laterite soils** are characteristically **reddish-brown** due to the presence of iron oxides, particularly **hematite**.
- Laterite soils are **poor in essential nutrients** for plant growth and are primarily composed of iron and aluminum oxides, **leaving little room for other minerals**.
- They are mainly found in areas with **high rainfall** and **warm temperatures**, such as the Western Ghats, Eastern Ghats, and central India.

- Crops such as **Tapioca** and **cashew nuts** are relatively **tolerant of acidic and low-nutrient soils** like **laterite**. Also, their **deep roots** allow them to access moisture stored deeper in the soil.

Answer: c) 1 and 4

Forest or 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**.
- Their character changes with parent rocks, ground configuration, decomposition of organic matter, mineral weathering 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 the 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 a good deal of fertilisers for high yields.

Crops in Forest/Mountain Soils

- They are suitable for **plantations** of **tea, coffee, spices**, and tropical fruits in the peninsular region.
- Wheat, maize, barley, and temperate fruits are grown in the Himalayan forest region.

Arid or Desert Soils

- The desert soils consist of **aeolian sand** (90 to 95 percent) and clay (5 to 10 percent). They cover a total area of **1.42 lakh sq km (4.32%)**.
- The presence of sand inhibits soil growth. Desertification of neighbouring soils is common due to the intrusion of aeolian sand (wind action).

Distribution of Arid/Desert Soils

- They 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 southwest 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 degrees 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

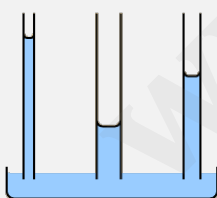
- **Phosphates** and **nitrates** make these soils **fertile** wherever moisture is available.
- There is a possibility of reclaiming these soils if proper irrigation facilities are available.
- In large areas, only drought-resistant and salt-tolerant crops such as barley, cotton, millets, maize, and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

Saline or Alkaline Soils

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

Capillary Action

- Capillary action is the **ability of a liquid to flow in narrow spaces** without the assistance of, and in opposition to, external forces like gravity. The force behind capillary action is **surface tension**.
- Surface tension is the elastic tendency of liquids (a membrane-like surface) that makes them acquire the least surface area possible.
- Surface tension causes insects (e.g. water striders), usually denser than water, to float and stride on the water surface.



- Surface tension offers the **necessary buoyant force (buoyancy)** required for an object to float in water (ships float because of difference in density as well as surface tension).
- When a water drop is on a surface, it acquires the **shape of a hemisphere** (half a sphere). All this is due to **surface tension**.

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 **areas of a 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 soil.
- 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 make the soil unfit for cultivation. The low-lying regions of coastal Andhra Pradesh and Tamil Nadu face this kind of soil degradation.

Peaty or Marshy Soils

- These are soils with a **large amount of organic matter** and a **considerable amount of soluble salts**. The **most humid regions** have this type of soil. They are black, heavy, and **highly acidic**.
- Most of the peaty soils are underwater during the rainy season, but as soon as the rains cease, they are put under **paddy cultivation**.

Distribution of Peaty/Marshy Soils

- They are found in the **Kottayam** and **Alappuzha** districts of Kerala, coastal areas of Odisha and Tamil Nadu, Sundarbans of West Bengal, Bihar, and the Almora district of Uttarakhand.
- They are deficient in potash and phosphate.

Issues and soil conservation measures associated with the Indian Soils is discussed in the PMF IAS Environment Book.

----- End of Chapter -----