

UPPSC PRELIMS

QRS

**QUICK
REVISION
SERIES**

Last-Minute Revision Notes

GEOGRAPHY

Physical, World & Indian

Physical • World • India

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CHAPTER 01

The Universe, The Earth, Volcano, Earthquake

Origin of the Universe

- Universe/Cosmos = all of space, time and contents (planets, moons, stars, galaxies, intergalactic matter/energy).
- Contains billions of galaxies, each with billions of stars.
- Age of universe $\approx$ 13.8 billion years.
- Astronomy: scientific study of celestial objects/phenomena originating outside Earth's atmosphere (e.g. solar wind, gravitational waves).
- Practitioners of astronomy are called Astronomers.

Big Bang Theory (Modern/Accepted Theory)

- Aka Expanding Universe Hypothesis.
- Propounded by Georges Lemaître.
- Edwin Hubble (1929) gave observational evidence of expansion.
- Universe exploded from a gravitational singularity (infinite density/temperature, all mass-time condensed) $\sim$ 13.8 billion years ago, the Big Bang.
- Light nuclei (hydrogen and helium) formed within the first 3 minutes (Big Bang nucleosynthesis); neutral atoms formed only $\sim$ 3.8 lakh years later.
- Cosmic microwave background (CMB) radiation was released $\sim$ 3.8 lakh years after the Big Bang; discovered by Penzias & Wilson (1965) and mapped by COBE, WMAP and Planck missions. It is the key proof of the theory.
- A period of darkness followed, then stars and galaxies formed.
- Steady State Theory (Hermann Bondi, Thomas Gold, Fred Hoyle, 1948): universe has no beginning or end and new matter is created continuously; rejected after the discovery of CMB.
- Pulsating/Oscillating Universe Theory (Allan Sandage): universe expands and contracts in cycles.

Big Bang: Evidence vs Criticism

Evidence: Doppler effect/redshift of distant galaxies (moving apart)

Evidence: Cosmic microwave background radiation

Evidence: Hubble's Law, recession speed of galaxies $\propto$ distance

Criticism: Implies universe began from nothing, tension with 1st Law of Thermodynamics

Criticism: Doesn't explain the energy/time/space of creation

Early (Superseded) Theories on Origin of the Universe

Superseded Theories of Universe/Solar System Origin

Theory	Proponent(s)	Core Idea	Limitation
Nebular Hypothesis	Immanuel Kant (1755); revised by Pierre-Simon Laplace (1796); modern revised version by Otto Schmidt (1943) and Carl von Weizsäcker (1944)	Denser material at centre of a Nebula (H, He, dust) $\rightarrow$ flattened disk $\rightarrow$ friction/collision $\rightarrow$ accretion $\rightarrow$ central denser ball becomes the Sun, rest becomes planets; leftover debris formed Asteroid belt, Kuiper belt, Oort cloud	Cannot explain why the Sun holds $\sim$ 99.8% of the mass but only $\sim$ 2% of the angular momentum of the solar system
Protoplanet Hypothesis	Carl von Weizsäcker (1944); Gerard Kuiper (1951)	Rapidly rotating nebula developed large vortexes on the disc; each accreted material via gravity $\rightarrow$ protoplanets; smaller vortexes within larger ones became satellites	Insufficient ring mass for gravitational planet formation

Theory	Proponent(s)	Core Idea	Limitation
Planetesimal Hypothesis	Thomas Chamberlin & Forest Moulton (1904)	Planets formed by aggregation of planetesimals (small orbiting gas/dust bodies); explains meteorite falls	Hot interior material would disperse as gas rather than condense
Tidal Hypothesis (Gaseous Tidal Theory)	James Jeans (1917–19); modified by Harold Jeffreys (1929)	A wandering star passing the Sun drew out a cigar-shaped extension that condensed into planets (bi-parental origin)	A star passing so close to the Sun is extremely improbable; hot gas pulled out of the Sun would disperse rather than condense into planets

Important Terminologies

- Doppler effect: apparent change in frequency/wavelength of light (or sound) as the source moves closer to or farther from the observer.
- Red shift: object receding, wavelength lengthens.
- Blue shift: object approaching, wavelength shortens.
- Galaxy: billions of stars + dust/gases bound by gravity.
- Galaxy size varies widely; the Milky Way is ~1 lakh light years across (a barred spiral galaxy).
- Our home galaxy: Milky Way (aka Akashganga).
- Nearest large galaxy: Andromeda (~25 lakh light years away); expected to merge with the Milky Way in a few billion years.
- Light year: distance light travels in 1 year at 3×10^8 m/s.
- Light year = 9.5×10^{12} km = 63,241 AU.
- Astronomical Unit (AU): mean Sun–Earth distance $\approx 1.496 \times 10^8$ km (~15 crore km); sunlight takes ~8 min 20 s to reach Earth.
- Nebula: dense aggregation of H, He and dust; birthplace of stars.
- Parallax: apparent shift of a nearby star against distant background stars when viewed from two points of Earth's orbit six months apart; distance is found by trigonometry. 1 parsec = 3.26 light years.

Key Scientists/Astronomers

Scientist	Period	Contribution
Pythagoras	6th c. BC	Coined the term 'Cosmos'
Aristotle	4th c. BC	Gave the first observational proof of a spherical Earth (curved shadow of Earth on the Moon during a lunar eclipse); supported the geocentric view
Ptolemy	c. AD 100–170	Systematised the Geocentric model in his work Almagest
Copernicus	1473–1543	Proposed the Heliocentric model (De Revolutionibus, 1543)
Johannes Kepler	1571–1630	Three Laws of Planetary Motion; planets move in elliptical orbits with the Sun at one focus
Aryabhata	5th c. AD (b. 476)	Aryabhatiya (499 AD): stated that the Earth rotates on its axis and explained eclipses as shadows of the Earth and Moon (not Rahu-Ketu)
Varahamihira	6th c. AD	Pancha-Siddhantika and Brihat Samhita; compiled five astronomical systems; one of the Navaratnas of Vikramaditya's court
Galileo Galilei	1564–1642	"Father of Observational Astronomy"; discovered the 4 Galilean moons of Jupiter (1610), observed phases of Venus, sunspots and Saturn's "ears" (the rings were identified later by Huygens, 1655); supported heliocentrism
Edwin Hubble	1889–1953	Proved galaxies exist beyond the Milky Way (1924); gave evidence of the expanding universe (Hubble's Law, 1929)

Formation of Stars

- Star formation began ~200 million years after the Big Bang, per NASA's WMAP (2003) mission.

- WMAP (2003) confirmed universe age at the time as ~13.7 billion years.
- Localised clumps in Nebulae condense under own gravity → denser gaseous bodies.
- These bodies heat/radiate via thermonuclear fusion of $H \rightarrow He$ + light at the core.
- On exhausting hydrogen, a star cools/expands into a red giant/red supergiant.
- Star's lifecycle depends on its mass: higher mass burns faster.

Stellar Evolution Sequence

Stage	Description
Red giant	Core hydrogen exhausted; hydrogen fuses into helium in a shell around the core, the outer layers expand and cool (red colour)
Planetary nebula → White dwarf	Low/medium-mass stars (like the Sun) whose remnant core is below the Chandrasekhar limit ($1.44 M_{\odot}$, given by S. Chandrasekhar, Nobel 1983) shed their outer layers as a planetary nebula, leaving a small, hot, dense white dwarf
Black dwarf	Theoretical cold, dark white dwarf after it stops emitting heat and light (none exists yet, as the universe is too young)
Supernova	Massive stars (above $\sim 8 M_{\odot}$) become red supergiants; when the core exceeds the Chandrasekhar limit it collapses and the star explodes as a supernova
Neutron star	Post-supernova remnant, mainly neutrons, extreme density/gravity
Pulsar	Rapidly rotating neutron star with pulsating light/magnetic field
Magnetar	Neutron star with an extremely powerful magnetic field (about 1,000 times that of an ordinary neutron star); rotates more slowly than most pulsars
Black hole	Remnant of very massive stars (above $\sim 20 M_{\odot}$); gravity so extreme that even light cannot escape (boundary = event horizon); detected through effects on nearby matter (e.g. Sagittarius A*, the Milky Way's supermassive black hole, imaged by the Event Horizon Telescope in 2022; M87* imaged in 2019)

Formation of Planets

- Sun and planets formed together ~4.6 billion years ago from the solar nebula.
- Collapse likely triggered by a nearby supernova's shock wave.
- Sun formed at the centre, planets in the surrounding disc.
- Stages of planet formation: gas lumps in nebula become stars with a surrounding gas/dust disc → disc condenses into planetesimals → planetesimals collide and attract → accretion sticks planetesimals into a planet.
- Asteroid belt (between Mars–Jupiter) divides the planets into two groups.
- Kuiper Belt: beyond Neptune, ~30–50 AU; its objects are called TNOs/KBOs (e.g. Pluto, Makemake, Haumea, Arrokoth).
- Beyond the Kuiper Belt: Termination Shock (~85–95 AU), then Heliopause (~120 AU) marking the edge of the heliosphere (Voyager 1 crossed it in 2012, Voyager 2 in 2018); the Oort Cloud (~2,000–1,00,000 AU) lies far beyond.

IAU Definition of "Planet" (Prague, 2006)

Condition 1: Orbits the Sun

Condition 2: Sufficient mass for near-spherical shape (hydrostatic equilibrium)

Condition 3: Has cleared its orbital neighbourhood

Meeting only conditions 1–2 → classified a 'Dwarf planet'

Dwarf planet examples: Pluto, Eris, Makemake, Haumea, Ceres

Pluto was reclassified from planet to dwarf planet in 2006 because it has not cleared its orbital neighbourhood

Terrestrial vs Jovian Planets

Group	Planets	Nature	Cause
Terrestrial (Inner)	Mercury, Venus, Earth, Mars	Rocky/metal, high density	Distance from Sun; solar winds (strongest near Sun) stripped gases from inner planets; lower gravity of terrestrial planets
Jovian (Outer /Gas Giant)	Jupiter, Saturn, Uranus, Neptune	Larger, thick H/He atmosphere	Farther from Sun, weaker solar wind effect, higher gravity retains gases

Mnemonic: Order of 8 Planets

"My Very Efficient Mother Just Served Us Nuts!!"

Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune

Asteroids, Comets, Meteoroids

- Asteroids (minor planets): incomplete-planet remains orbiting the Sun between Mars–Jupiter, mostly 4.6 billion years old.
- Comets: icy bodies orbiting the Sun; outgas near the Sun, showing a tail pointing away from the Sun.
- Short-period comets (orbital period < 200 yrs): mainly originate from the Kuiper Belt; e.g. Halley's Comet, Encke's Comet.
- Long-period comets (> 200 yrs): originate from the Oort Cloud; e.g. Hale-Bopp, Comet Tsuchinshan–ATLAS (2024).
- Halley's Comet: periodic (short-period) comet returning every ~76 years; last seen in 1986, next return in 2061.
- Meteoroids: small rocky or metallic bodies travelling through space.
- Meteorite: a meteoroid that hits Earth's surface; can form craters.
- Meteorite crater examples: Lonar crater (Maharashtra), Chicxulub crater (Mexico).
- Meteor: streak of light when a meteoroid burns up in the atmosphere (aka shooting star; a very bright one is a fireball).

The Sun

- Central star of the solar system, primarily composed of hot gases.
- Orbits the Milky Way's centre at ~8.3 lakh km/hr (~230 km/s); one orbit (galactic year/cosmic year) takes ~225–250 million years.
- Composition: ~73% hydrogen, ~25% helium by mass; holds ~99.86% of the solar system's mass; light takes ~8.3 minutes to reach Earth.

Layers of the Sun (Core to Surface)

Layer	Key Facts
Core	Innermost layer; temperature ~15 million °C
Radiative zone	Temperature ~2 million °C
Convection zone	Energy flows outward by convection
Photosphere	Visible surface, ~5,500°C; emits visible light; sunspots appear here
Chromosphere	Reddish layer above the photosphere, visible only during a total solar eclipse
Corona	Outermost layer, extremely hot (1–3 million °C, hotter than the photosphere: the "coronal heating problem"); seen as a white halo during a total eclipse; source of solar wind and coronal mass ejections (CMEs)

- Sunspots: dark, relatively cooler patches (~3,500–4,000°C) caused by intense magnetic activity, mostly within 30° N/S of the solar equator.
- Sunspots follow an ~11-year sunspot cycle tied to solar magnetic activity (Solar Cycle 25 peaked around 2024–25).
- Solar winds: plasma ejected from the corona.
- Solar flare: sudden brightness surge releasing stored magnetic energy, often with a CME (coronal mass ejection).

- Solar flares and CMEs (solar storms) can disrupt radio communication, satellites, GPS and power grids, and trigger Aurora Borealis/Aurora Australis (Northern/Southern Lights) near the poles. India's Aditya-L1 (launched 2 Sept 2023, at Lagrange point L1) studies these phenomena.

The Planets

The Eight Planets: Key Facts

Planet	Key Facts	Moons/Rings	Rotation Period	Revolution Period
Mercury	Closest to the Sun and smallest planet; 2nd hottest (after Venus); extreme day–night temperature range due to no atmosphere	No moon, no ring	58.6 days	88 days
Venus	Hottest planet (90–95% CO ₂ atmosphere, sulphuric-acid clouds); "Earth's twin" in size; no magnetic field; high albedo → brightest planet, called morning/evening star; retrograde (East–West) rotation	No moon	243 days (E→W)	224.7 days
Earth	Only known habitable planet, in the Goldilocks Zone; densest planet; shape Geoid/oblate spheroid; equatorial diameter 12,756 km, polar diameter ~12,714 km; land:water ≈ 29:71; called the Blue Planet; avg surface temp ~15°C	1 moon	23 h 56 min (sidereal)	365.25 days
Mars	"Red Planet" (iron-oxide soil); cold desert, thin atmosphere; only planet besides Earth with polar ice caps; Olympus Mons = tallest mountain in the solar system	Moons: Phobos, Deimos	1.03 days	1.88 years
Jupiter	Largest planet; H/He-rich atmosphere; Great Red Spot (giant storm)	Faint ring system; moons include the Galilean satellites Io, Europa, Ganymede (solar system's largest moon), Callisto; 97 confirmed moons as of 2025 (count still rising)	0.41 days	11.86 years
Saturn	2nd largest planet; least dense planet (lighter than water); pale yellow colour (ammonia crystals)	7 main rings (A to G); record holder for most moons (274 confirmed after 128 new moons were announced in March 2025) incl. Titan (2nd largest moon; dense N ₂ atmosphere with methane lakes), Enceladus (water-ice geysers), Phoebe, Tethys, Mimas	0.45 days	29.5 years
Uranus	Coldest planetary atmosphere (min ~ -224°C); blue-green colour from methane in an H/He atmosphere; largest axial tilt (~98°), so it appears to "roll" on its side; retrograde rotation like Venus	13 rings; 29 moons (S/2025 U1 found by JWST in 2025) incl. Titania (largest), Oberon, Miranda, Ariel, Umbriel	0.72 days (E→W)	84 years
Neptune	Farthest planet; first planet found by mathematical prediction (Le Verrier & Adams, observed 1846); strongest winds in the solar system	5 main rings; 16 moons incl. Triton (retrograde orbit), Nereid	0.67 days	165 years

Pole Star (Polaris)

Fixed along Earth's north axis; used historically for direction
 Known in India as Dhruva Tara
 Not visible from the Southern Hemisphere

Moon, Asteroid Belt/Kuiper Belt Recap

- Moon: Earth's only natural satellite; has virtually no atmosphere (only a thin exosphere), so it has no weather and extreme temperatures.
- Moon's distance from Earth: ~3,84,400 km.
- Moon's orbital period: ~27.3 days (sidereal month); new moon to new moon ~29.5 days (synodic month).
- Moon is tidally locked: one side always visible from Earth.
- Moon's diameter ~3,475 km (about 1/4 of Earth's); gravity ~1/6 of Earth's; moonlight takes ~1.3 seconds to reach Earth.
- Indian missions: Chandrayaan-1 (2008; confirmed water molecules), Chandrayaan-2 (2019; orbiter still working), Chandrayaan-3 (soft landing near the lunar south pole on 23 August 2023, now National Space Day; landing site named Shiv Shakti Point).

Theories of Moon's Origin

Theory	Status	Explanation
Giant Impact/Big Splat theory	Most accepted	Moon formed ~4.4 billion years ago when a Mars-sized object struck early Earth, debris coalescing into the Moon
Fission hypothesis	Older, less accepted	Moon split from a rapidly spinning early Earth, with the Pacific Ocean basin as the site (George Darwin, 1879)
Capture theory	Rejected	Moon formed elsewhere and was captured by Earth's gravity; fails to explain the similar composition of Earth and Moon

Evolutionary History of the Earth**Age of Earth: Methods of Estimation****Methods of Estimating Earth's Age**

Method	Status	Basis	Result
Radioactive dating	Most reliable; gives the accepted figure	Constant-rate radioactive decay (parent→daughter), expressed as half-life; common methods - Uranium-lead, Thorium-lead, Potassium-argon, Radiocarbon	Age of Earth ≈ 4.54 billion years (4.6 billion as per NCERT)
Salinity clock	Superseded	Sodium build-up in ocean (John Joly, 1899)	~90–100 million years
Rate of cooling	Superseded	Lord Kelvin; assumes a molten start	~20–100 million years

- Early Earth was barren, hot, with a thin H/He atmosphere, not life-conducive.
- Earth's interior is differentiated by density (rising inward) into crust, mantle, outer core, inner core.

Geological Time Scale (GTS)

- Earth's history is divided by major change into 4 Eons: Hadean, Archean, Proterozoic, Phanerozoic.
- The first three Eons (Hadean, Archean, Proterozoic) together form the Precambrian Supereon.

Geological Time Scale

Years Before Present	Eon/Era/Period	Major Events
13,700 million	-	Big Bang / Origin of the Universe

Years Before Present	Eon/Era/Period	Major Events
5,000–13,700 million	-	Origin of stars; Supernova
5,000 million	-	Origin of the Sun
4,600 million	-	Origin of the Earth
3,800–4,800 million	Hadean (Precambrian)	Oceans and continents form; ocean and atmosphere rich in CO ₂
2,500–3,800 million	Archean (Precambrian)	Blue-green algae; unicellular bacteria
570–2,500 million	Proterozoic (Precambrian)	Soft-bodied arthropods; oxygen build-up (Great Oxidation Event ~2,400 million); Snowball Earth glaciations
570–4,800 million (span)	Precambrian (Hadean + Archean + Proterozoic)	~88% of Earth's history
505–570 million	Cambrian (Palaeozoic)	Cambrian explosion; no terrestrial life; marine invertebrates
438–505 million	Ordovician (Palaeozoic)	First fish; end-Ordovician: 1st mass extinction (~444 Mya)
408–438 million	Silurian (Palaeozoic)	First trace of life on land: plants
360–408 million	Devonian (Palaeozoic)	Amphibians ("Age of Fishes"); Late Devonian: 2nd mass extinction (~372 Mya)
286–360 million	Carboniferous (Palaeozoic)	First reptiles; vertebrates; coal beds (Gondwana coal of India is Permian–Carboniferous)
245–286 million	Permian (Palaeozoic)	Reptiles dominate, replacing amphibians; end-Permian "Great Dying": 3rd and most severe mass extinction (~252 Mya)
208–245 million	Triassic (Mesozoic)	Frogs and turtles; first dinosaurs and mammals; end-Triassic: 4th mass extinction (~201 Mya)
144–208 million	Jurassic (Mesozoic)	Age of dinosaurs; first bird (Archaeopteryx)
65–144 million	Cretaceous (Mesozoic)	Flowering plants spread; end-Cretaceous (K–Pg): 5th mass extinction (~66 Mya) wiped out dinosaurs (Chicxulub asteroid impact + Deccan Trap volcanism)
24–65 million (Palaeocene, Eocene, Oligocene)	Tertiary (Cenozoic)	Palaeocene: small mammals (rats, mice); Eocene: rabbits and hare; Oligocene: anthropoid apes
5–24 million (Miocene)	Tertiary (Cenozoic)	Apes; flowering plants and trees; main uplift of the Himalayas
2–5 million (Pliocene)	Tertiary (Cenozoic)	Early human ancestors; formation of the Great Northern Plains of India begins
10,000–2 million (Pleistocene)	Quaternary (Cenozoic)	Homo sapiens; Ice Age
0–10,000 (Holocene)	Quaternary (Cenozoic)	Modern man; ongoing 6th mass extinction (human-driven)

Years Before Present	Eon/Era/Period	Major Events
GTS: Revised ICS Dates (for cross-checking) NCERT figures above are rounded; the International Commission on Stratigraphy (ICS) chart gives: Cambrian begins 538.8 Mya Permian–Triassic boundary 251.9 Mya Cretaceous–Palaeogene boundary 66 Mya Quaternary begins 2.58 Mya Holocene begins 11,700 years ago The "Anthropocene" was rejected as a formal epoch by the IUGS in March 2024; it remains an informal term		

- Era spans: Palaeozoic (245–570 Mya), Mesozoic (65–245 Mya), Cenozoic (65 Mya–present). Palaeozoic + Mesozoic + Cenozoic = Phanerozoic Eon.

Permian–Triassic Extinction

Occurred ~252 Mya
 Most severe known mass extinction
 Up to 96% marine species lost
 Up to 70% terrestrial vertebrate species lost
 The only known mass extinction of insects

- Snowball Earth: below-zero global temperatures, extensive glaciation, lowered sea levels.
- Ice Age: prolonged cold period of expanded ice sheets.
- Glacial: cold pulses within an Ice Age.
- Interglacial: intermittent warm periods within an Ice Age.
- Quaternary glaciation began 2.58 million years ago and is still ongoing.

Origin of Life & Evolution of Atmosphere/Hydrosphere

- Life began to evolve ~3,800 million years ago from complex self-duplicating organic molecules; fossil blue-green-algae-like structures date to ~3,000 million years ago.
- Present N_2/O_2 -rich atmosphere evolved from a primordial H/He atmosphere in 3 stages.
- Stage 1: loss of the primordial H/He atmosphere to solar wind.
- Stage 2: the hot interior released gases and water vapour (degassing); volcanic eruptions added water vapour, CO_2 , N_2 and others.
- Stage 3: composition modified by the living world through photosynthesis; oceans became saturated with O_2 ~2,000 million years ago and O_2 then filled the atmosphere.
- Hydrosphere formed by condensation of degassing-released water vapour.

Latitude, Longitude & Motions of the Earth

Latitudes

- Latitude: angular distance of a location N/S of the equator.
- Parallels of Latitude form concentric circles: largest at Equator (0°), shrinking to a point at the Poles ($90^\circ N/S$).
- Earth has 181 latitudes in total at 1° interval ($90^\circ N + 90^\circ S + \text{Equator}$).
- Distance per 1° of latitude ≈ 111 km (near-constant).

Equator

- The Equatorial circle passes through Earth's centre, perpendicular to the rotation axis.
- Equator divides Earth into Northern and Southern Hemispheres.
- Equator passes through South America: Ecuador, Colombia, Brazil.
- Equator passes through Africa: Sao Tome & Principe (waters), Gabon, Republic of Congo, DR Congo, Uganda, Kenya, Somalia.
- Equator passes through Asia: Maldives (waters) and Indonesia; also Kiribati in Oceania. Total: 13 countries (incl. waters).

Equinox Dates

Vernal (Spring) Equinox: 21 March, Sun directly over the equator
 Autumnal Equinox: 23 September, Sun directly over the equator

Tropical Circles

- Tropic of Cancer: $23\frac{1}{2}^{\circ}\text{N}$. Tropic of Capricorn: $23\frac{1}{2}^{\circ}\text{S}$.
- Tropic of Cancer passes through North America: Bahamas, Mexico.
- Tropic of Cancer passes through Africa: Egypt, Libya, Niger, Algeria, Mali, Western Sahara, Mauritania.
- Tropic of Cancer passes through Asia: Taiwan, China, Myanmar, Bangladesh, India, Oman, UAE, Saudi Arabia.
- Tropic of Cancer touches 16 countries + Western Sahara; it does not pass through Nepal, Pakistan or Sri Lanka.
- In India, Tropic of Cancer passes through 8 states: Gujarat, Rajasthan, Madhya Pradesh, Chhattisgarh, Jharkhand, West Bengal, Tripura, Mizoram.
- Tropic of Capricorn passes through South America: Argentina, Brazil, Chile, Paraguay.
- Tropic of Capricorn passes through Africa: Namibia, Botswana, South Africa, Mozambique, Madagascar.
- Tropic of Capricorn also passes through Australia.
- Tropic of Capricorn passes through 10 countries; it touches Madagascar in Africa and only one continent-country, Australia, in Oceania.
- Polar circles: Arctic Circle ($66\frac{1}{2}^{\circ}\text{N}$), Antarctic Circle ($66\frac{1}{2}^{\circ}\text{S}$).
- Polar circles are the minimum latitude with a 24-hr day/night at least once a year.
- In the Northern Hemisphere: 24-hr day on 22 June, 24-hr night on 22 December.

Solstices

21 June (Summer Solstice): Sun overhead at Tropic of Cancer; 24-hr daylight within the Arctic Circle

22 December (Winter Solstice): Sun overhead at Tropic of Capricorn; 24-hr daylight within the Antarctic Circle

Both result from Earth's 23.5° axial tilt

- Uttarayan: Sun's apparent northward shift (22 Dec → 21 June).
- Dakshinayan: Sun's apparent southward shift (21 June → 22 Dec).

Heat Zones of the Earth

Zone	Extent	Characteristics
Torrid Zone	23.5°N – 23.5°S	Max heat; mid-day sun overhead at least once/year everywhere in this zone
Temperate Zone	23.5° – $66\frac{1}{2}^{\circ}$ N and S	Moderate temperature; sun never directly overhead
Frigid Zone	$66\frac{1}{2}^{\circ}$ to poles	Sun stays near the horizon; very cold

Longitude

- Longitudes/Meridians: semi-circular lines joining the poles.
- Longitude = angular distance E/W of the Prime Meridian.
- All meridians are equal in length, but inter-meridian distance shrinks from equator to poles.
- 360 meridians total.
- Distance between meridians: ~111 km at the equator, ~55.5 km at 60° , zero at the poles.
- Prime Meridian (0°) passes through Greenwich (London).
- Prime Meridian also passes through UK, France, Spain, Algeria, Mali, Burkina Faso, Togo, Ghana and Antarctica.
- GMT: mean solar time at the Royal Observatory, Greenwich; now superseded by UTC (Coordinated Universal Time, based on atomic clocks).
- Moving East of Prime Meridian → gains time. Moving West → loses time. Mnemonic: "East-Gain-Add, West-Lose-Subtract".

International Date Line (IDL)

- IDL = 180° longitude, through the mid-Pacific.
- IDL zig-zags at the Bering Strait (Siberia–Alaska), Fiji and Tonga to avoid splitting countries.
- Date changes by exactly one day on crossing the IDL.

Indian Standard Time (IST)

Indian Standard Time

Standard meridian: 82°30'E

5:30 hrs ahead of GMT

Passes near Mirzapur/Naini (Uttar Pradesh); 5 states: UP, MP, Chhattisgarh, Odisha, Andhra Pradesh

IST is maintained by CSIR-National Physical Laboratory (NPL), New Delhi; the draft Legal Metrology (IST) Rules, 2025 propose making IST the mandatory time reference for official and commercial use

Local Time vs Standard Time

Does India Need Two Time Zones?

- India currently has 1 time zone.
- India spans Gujarat (68°7'E) to Arunachal Pradesh (97°25'E), a 30° extent.

Number of Time Zones by Country

Country	No. of Time Zones
India	1
China	1
Russia	11
Canada	6
USA	9 standard (11 incl. territories)
France	12 (13 incl. Antarctic claim); the most of any country

Two Time Zones: Key Facts

Assam tea gardens follow an unofficial "Chaibagan time" (Bagan time), ~1 hour ahead of IST, since the British period CSIR-NPL study (2018) proposed IST-I (UTC+5:30) and IST-II (UTC+6:30) for the Northeast, divided at ~89°52'E. Government has so far retained a single time zone.

Motions of the Earth

- Rotation: Earth spins west to east on its axis in ~24 hours.
- Rotation speed decreases from equator to poles.
- Only half of Earth faces the Sun at a time.
- Rotation effects: Day and Night.
- Rotation effect, Coriolis force: deflects moving objects right in N. Hemisphere, left in S. Hemisphere.
- Axial Tilt: Earth's axis is tilted 23.5° from the perpendicular to its orbital plane (aka obliquity of the ecliptic).
- Axial tilt causes day/night-length variation with seasons.
- Earth's axis currently points to Polaris; will point to Vega in ~13,000 years.
- Revolution: Earth orbits the Sun in an elliptical orbit in ~365 days 6 hours (365.2422 days), at ~30 km/s.
- The extra ~6 hrs accumulate into a Leap Year every 4 years (century years must be divisible by 400, e.g. 2000 was a leap year, 1900 was not).
- 3 types of poles: True North/South Poles (axis-of-rotation endpoints); Geomagnetic poles; Magnetic poles (compass-indicated).

Perihelion & Aphelion

Perihelion (closest to Sun): ~3 January, distance ~147.1 million km

Aphelion (farthest from Sun): ~4 July, distance ~152.1 million km

Seasons are caused by the axial tilt, not by distance: the N. Hemisphere has winter when Earth is closest to the Sun

Eclipses

- Eclipse: one celestial object entering another's shadow when three bodies align (syzygy).
- Eclipses do not occur every month because the Moon's orbit is inclined $\sim 5^\circ$ to the plane of Earth's orbit (ecliptic); they occur only when the Moon is near a node.

Lunar vs Solar Eclipse

Eclipse	Alignment	Occurs On	Sub-types
Lunar Eclipse	Sun–Earth–Moon	Full moon day only	Penumbral: Moon passes only through Earth's outer shadow; Partial: part of Moon enters the umbra; Total: whole Moon in the umbra, appears red ("Blood Moon") due to refraction of red light
Solar Eclipse	Sun–Moon–Earth	New moon day only	Partial: sunlight partly blocked; Annular: Sun visible as a bright "ring of fire" (Moon near apogee, looks smaller); Total: Sun fully blocked, corona visible; Hybrid: annular in some places, total in others

Sources of Information

Direct Sources

- Mean radius of Earth $\approx 6,371$ km.

Drilling & Mining Sources

Site/Project	Location	Detail
Mponeng Gold Mine	South Africa	Deepest mine in the world; reaches ~ 4 km
Deep Sea Drilling Project (DSDP)	-	Ocean-floor drilling (1968–83); confirmed sea-floor spreading
Kola borehole	Kola Peninsula, Russia	Deepest artificial borehole; ~ 12.26 km (Kola Superdeep Borehole)

- Findings from drilling: temperature, pressure, density all increase with depth.
- Temperature rises $\sim 1^\circ\text{C}$ per 32 m of depth near the surface (geothermal gradient $\sim 25\text{--}30^\circ\text{C}$ per km); the rate slows down at greater depth.

Indirect Sources

- External celestial objects: meteors/meteorites share the nebular origin with Earth, so their composition gives clues to Earth's interior.
- Gravitational anomaly: gravity is greater at poles, less at equator.
- Magnetic field: study reveals distribution of magnetic material inside Earth.
- Seismic waves: mechanical waves from sudden fault-energy release; speed/direction change across layers by density, key tool for interior study.

Structure of the Earth's Interior

- Three main layers: Crust, Mantle, Core.

Earth's Interior: Layer-wise Overview

Layer	Depth Range	% of Volume	% of Mass	Composition	Density
Crust	0 – $\sim 30/70$ km (continental), ~ 5 km (oceanic)	1%	$\sim 0.5\%$	SiAl (continental) / SiMa (oceanic)	2.7 g/cm^3 (continental), 3 g/cm^3 (oceanic)

Layer	Depth Range	% of Volume	% of Mass	Composition	Density
Mantle	Moho to 2,900 km	~84%	~67%	Silicate rocks rich in iron and magnesium (peridotite)	~3.4 g/cm ³ (upper) – 5.6 g/cm ³ (lower)
Core	2,900–6,400 km	~16%	~32.5%	NiFe (Iron + Nickel)	Highest: ~10 (outer) to ~13 g/cm ³ (inner)

Crust

- Solid, fragile, outermost layer.

Continental vs Oceanic Crust

Feature	Continental Crust ('SiAl')	Oceanic Crust ('SiMa')
Thickness	~30 km, up to ~70 km in mountains	~5 km
Density	~2.7 g/cm ³	~3 g/cm ³ (heavier)
Composition	Silica + Aluminium	Silica + Magnesium
Main rock	Granite	Basalt

Mantle

- Extends from Moho to Outer Core (Gutenberg Discontinuity).
- ~84% of Earth's volume and ~67% of its mass.
- Divided into Upper Mantle and Lower Mantle.
- Mantle convection drives: plate tectonics, seafloor spreading, earthquakes, volcanoes, orogeny.
- Solid overall (asthenosphere is partially molten/plastic): high pressure raises rock's melting point despite high temperature.

Mantle Sub-layers

Sub-layer	Composition/Extent	Depth/Thickness	Nature
Lithosphere	Entire crust + uppermost (rigid) mantle	~10–200 km thick (thinnest under oceans)	Hard, rocky
Asthenosphere	Layer below lithosphere	~80/100 km to ~400 km depth (NCERT: up to 400 km)	Partially molten, plastic; main source of magma; plates move over it
Lower Mantle	From Repetti Discontinuity (~700 km) to Gutenberg Discontinuity (2,900 km)	-	Solid/rigid

Core

- Innermost layer.
- ~16% of Earth's volume but ~32.5% of its mass (dense material).
- 'NiFe' layer: mainly Iron (Fe) and Nickel (Ni).
- Divided into Outer Core (liquid, 2,900–5,150 km) and Inner Core (solid due to extreme pressure, 5,150–6,371 km; temperature ~5,400°C, about as hot as the Sun's surface).
- Outer Core and Inner Core are separated by the Lehmann Discontinuity.
- Outer-core liquid motion generates Earth's magnetic field.

Discontinuities

Discontinuities and What They Separate

Discontinuity	Boundary Between
Conrad	Upper crust (SiAl) and lower crust (SiMa)
Moho (Mohorovicic)	Crust and upper Mantle
Repetti	Upper mantle and lower mantle
Gutenberg	Mantle and Outer core
Lehmann	Outer core and Inner core

Minerals

- Elements are rarely found exclusively.
- Minerals: naturally occurring organic/inorganic substances with an orderly atomic structure and definite chemical/physical properties.
- Composed of one element (sulphur, copper, silver, gold) or two or more elements (e.g., bauxite).
- Hot magma in Earth's interior is the basic source of all minerals; mineral crystals form as magma cools.
- Usually solid, crystalline, inorganic.
- Exceptions: coal, petroleum, natural gas, these are organic (solid/liquid/gaseous respectively).

Classification of Minerals

Category	Sub-type	Examples
Metallic	Precious	Platinum, gold, silver
Metallic	Ferrous (magnetic)	Iron
Metallic	Non-ferrous	Copper, lead, zinc, aluminium
Non-metallic	No metal content	Sulphur, phosphates, nitrates

Physical Characteristics**Physical Characteristics of Minerals**

Property	Description
Crystal form	Internal molecular lattice arrangement: cubes, octahedrons, hexagonal, etc.
Cleavage	Breaks along definite plane(s)
Fracture	Irregular breakage, not along cleavage
Lustre	Sheen, irrespective of color (metallic, silky, glossy)
Colour	Some minerals distinctive by internal arrangement (malachite, chalcopryrite); others by impurities
Streak	Color of the powder
Transparency	Transparent / translucent / opaque
Structure	Fine / medium / coarse grained
Specific gravity	Weight in air ÷ (weight in air – weight in water)

Mohs Hardness Scale (Softest → Hardest, 1-10)

1 Talc, 2 Gypsum, 3 Calcite, 4 Fluorite, 5 Apatite, 6 Feldspar, 7 Quartz, 8 Topaz, 9 Corundum, 10 Diamond

Key Minerals and Uses

Key Minerals and Their Uses

Mineral	Composition	Share of Earth's Crust	Use/Note
Feldspar	Ca/K/Na aluminosilicate	~half of Earth's crust	Ceramics, glass-making
Quartz	Silica	Second most abundant mineral (~12%)	Prime constituent of sand and granite; insoluble in water; hard (7 on Mohs scale); used in radio, radar, watches (piezoelectric)
Pyroxene	Ca, Mg, Fe silicates; green or black	~10% of crust	Common in meteorites
Amphibole	Inosilicate, prism crystals (hornblende, tremolite, asbestos)	~7% of crust	Asbestos industry
Mica	K, Mg, Al, Fe, silica	~4% of crust	Found in metamorphic/igneous rocks; used in electronics
Olivine	Mg, Fe, silica; olive-green	-	Found in basaltic rock; gem variety is peridot (jewellery)

Major Elements of Earth's Crust

- ~99% of the crust is made up of 8 elements: Oxygen (46.6%), Silicon (27.7%), Aluminium (8.1%), Iron (5%), Calcium (3.6%), Sodium (2.8%), Potassium (2.6%), Magnesium (2.1%).

Rocks

- Rock = aggregation of one or more minerals.
- Properties vary: hard ↔ soft (granite hard, soapstone soft), dark ↔ white, layered ↔ unlayered.
- Petrology = science of rocks.
- Classified by origin into: Igneous, Sedimentary, Metamorphic.

Igneous Rocks

- Primary rocks.
- Form when magma/lava solidifies (on or beneath surface).
- Hard, granular, crystalline.
- No fossils/sediments present.
- Non-permeable.

Intrusive (Plutonic) Igneous Rocks

- Magma solidifies below the surface, at depth.
- Large grains due to slow cooling.
- Coarse-grained, crystalline texture; exposed at the surface only after long denudation (e.g. granite of the Peninsular plateau).

Intrusive Igneous Rock Sub-types

Sub-type	Key Feature
Plutonic	Very deep, large grains
Hypabyssal	Solidify at intermediate depth (between plutonic and volcanic), e.g. dolerite in dykes and sills
Batholith	Granitic, great depth/area, cooled magma chamber, exposed after denudation

Sub-type	Key Feature
Laccolith	Dome-shaped intrusion with a level base, fed by a pipe-like conduit from below; e.g. granite domes of the Karnataka plateau (NCERT)
Lapolith	Saucer-shaped, concave-to-sky
Phacolith	Wavy mass at syncline base/anticline top in folds, conduit-fed
Sill/Sheet	Near-horizontal; thin = sheet, thick = sill
Dyke	Magma solidified in vertical cracks, wall-like; common in western Maharashtra, where dykes acted as feeders for the Deccan Trap eruptions

- Examples of intrusive igneous rocks: Granite, Diorite, Gabbro, Peridotite; Dolerite (hypabyssal).

Extrusive Igneous Rocks

- Lava cools on the surface.
- Fine grains due to rapid cooling.
- Examples: Basalt (Deccan Trap of India), Rhyolite, Andesite, Obsidian (volcanic glass), Pumice (floats on water).

Caldera

Explosive volcano collapses into itself, forming a depression.

Signals a large magma chamber below; e.g. Lake Toba (Indonesia), Crater Lake (USA), Yellowstone (USA).

Chemical Classification

Chemical Classification of Igneous Rocks

Type	Silica Content	Cooling	Color	Hardness/Weathering	Landform	Examples
Acidic	High (> 65%)	Viscous lava, solidifies quickly near the vent	Light	Hard, weathering-resistant	High volcanic cones/mountains	Granite, Rhyolite
Intermediate	52–65%	Moderate	Grey	Moderate	Composite (strato) cones	Andesite, Diorite
Basic	Low (45–52%)	Fluid lava, flows far before solidifying	Dark	Weak weathering resistance	Plateaus/shields/lava traps	Basalt, Gabbro
Ultrabasic	< 45%	Very fluid	Very dark/green	Weathers easily	Rare at surface	Peridotite, Dunite, Komatiite

Rock Composition Terms

Term	Rich In
Felsic	Si, O, Al, Na, K
Mafic	Mg, Fe
Ultramafic	High Mg and Fe

Significance

- Chief source of metallic ores (iron, copper, nickel, lead, zinc, gold) and diamonds (kimberlite pipes); high economic value.

Sedimentary Rocks

- Form by deposition/compaction of eroded material = lithification.
- Denuded rock fragments transported by water/wind, deposited, then compacted into rock.

- Layered.
- Contain fossils.
- Permeable, porous.

Sedimentary Rock Coverage

Form ~75% of the crust's surface area.
But only ~5% of the crust's volume.

Classification by Mode of Formation

Sedimentary Rock Classification

Formation Mode	Process	Examples
Mechanically formed	Weathering fragments parent rock, cemented by silicate minerals	Sandstone, limestone, shale
Organically formed	Plant/animal remains change composition under heat/pressure	Coal, limestone, chalk
Chemically formed	Evaporation of mineral-laden water leaves rock	Chert, potash, halite

Significance

- Rich source of energy minerals (coal, petroleum, natural gas, shale gas) and of building materials (sandstone, limestone).

Metamorphic Rocks

- Pre-existing rocks transform physically/chemically under Pressure, Volume, Temperature (PVT).
- This transformation = metamorphosis (recrystallisation/reorganization).
- E.g. granite → gneiss; clay/shale → slate → schist; limestone → marble; sandstone → quartzite.

Two Processes

Metamorphic Processes

Process	Mechanism	Examples
Dynamic	Rocks forced to lower levels by tectonics, recrystallised under pressure, no major chemical change	Granite→Gneiss; Clay→Slate/Schist
Thermal	Recrystallisation via temperature	Sandstone→Quartzite; Coal→Graphite/Anthracite; Limestone→Marble

- Thermal metamorphism has two types: Contact and Regional.

Thermal Metamorphism Types

Type	Description
Contact	High-temperature contact with intruding magma/lava; may add new material
Regional	Tectonic shear plus temperature/pressure

Types by Appearance

- Foliated: layered/banded (gneiss, phyllite, schist, slate).

Characteristics

- Generally hard, erosion/weathering-resistant.
- Marble (from limestone) reacts with dilute acid (effervescence of CO₂); most other metamorphic rocks do not.

Significance

- Slate, marble: building materials.

Rock Cycle

- Cyclic process driven by plate tectonic activity, weathering, erosion.
- Six steps:

Rock Cycle Steps

Step	Description
Igneous rock forms	Melted rock oozes as lava, cools, crystallizes
Sedimentary rock forms	Igneous rock weathers/erodes, sediments compact under pressure
Metamorphic rock forms	Igneous/sedimentary rock buried deep under high temperature/pressure
Weathering	All rock types broken down by geomorphic agents
Transportation	Sediments carried by rain, streams, rivers, wind
Deposition	Deposited sediments are compacted into sedimentary rock; deep burial/heat turns rocks metamorphic; melting forms magma, which solidifies into igneous rock; the cycle repeats

Geomorphic Processes

- Internal (endogenic) forces: driven by Earth's internal heat (mantle convection, radioactivity); build up relief.
- External (exogenic) forces: derive energy from the Sun and gravity; act through running water, wind, glaciers, waves and groundwater; wear down relief.
- Geomorphic process: physical/chemical changes to surface configuration from exogenic + endogenic forces.
- Exogenic forces cause degradation (wearing down of relief) and aggradation (filling up of basins/depressions); the combined levelling process is called gradation.

Endogenic Processes

- Originate deep inside Earth.
- Driven by mantle convection, Earth's rotation, radioactive heat.

Sudden Movements**Diastrophism**

- Slow internal-force movements forming continents, mountains, rift valleys.
- Classified: 1. Epeirogenic (continent-building); 2. Orogenic (mountain-building).

Epeirogenic vs Orogenic Movement

Feature	Epeirogenic Movement	Orogenic Movement
Direction	Vertical movement	Horizontal movement
Force	Upliftment or subsidence	Compression or tension
Result	Formation of continents	Folding, faulting, mountain-building

Epeirogenic Process

- Vertical crustal movement: uplift or subsidence (warping) of large parts of the crust without much folding.

Epeirogenic Movement Direction

Direction	Effect	Examples
Upward (emergence)	Whole/part of continent or coast rises	Eastern coast of India (Coromandel); parts of the Malabar coast (Kerala); raised beaches
Downward (submergence)	Forms Ria, Fjord, Dalmatian coasts	Western coast of India (submerged; e.g. ancient Dwarka); part of the Rann of Kutch subsided in the 1819 earthquake, while Allah Bund was uplifted

Orogenic Process

- Mountain formation (block and fold) via horizontal plate movement.
- Divergent/tensional movement → faults, rifts, block mountains.
- Convergent/compressional movement → fold mountains.

Fold Mountains

- Folds: wave-like structures from compressional tangential force.
- Two sides of a fold = limbs.
- Fold mountains form at converging plate boundaries.
- Called "true mountains".
- Lofty, high peaks, small width, seismically active.
- Examples: Himalayas (India), Rockies (N. America), Alps (Europe), Atlas (Africa), Andes (S. America).

Fold Mountain Classification

Basis	Type	Description/Examples
Nature of folds	Simple folded mountains	Well-developed anticline-syncline system
Nature of folds	Complex folded mountains	Complex folds from extreme compression, e.g. Himalayas
Period of origin	Old fold mountains	Formed before the Tertiary period; heavily eroded into residual mountains, e.g. Aravallis (Precambrian, India), Appalachians, Urals (Palaeozoic)
Period of origin	New fold mountains	Formed in the Tertiary (Alpine orogeny), still rising: Himalayas, Alps, Andes, Rockies, Atlas
New fold: sub-type	Andean type	Oceanic-continental convergence; volcanism & seismicity, e.g. Rockies, Andes
New fold: sub-type	Himalayan type	Continental-continental convergence; no volcanism; marine sediments via geosyncline, e.g. Great Himalayas

Himalaya Growth Rate

Himalayas are a "new fold mountain", still forming.

Rising at ~5 mm to 1 cm per year as the Indian Plate moves north at ~4–5 cm/year.

Block Mountains (Fault Mountains)

- Form when crust drifts apart under tensional force.
- Fault: fracture in the crust along which rocks are displaced; caused by tensional or compressional forces.
- Faults cause rift valleys and block mountains.
- Horst = uplifted block.
- Graben = depressed block.
- Rift valley: lowland formed from plates moving apart.
- Examples: Great Rift Valley of East Africa (Graben); Rhine Valley (Graben) between the Vosges and Black Forest (Horsts); Narmada, Tapi and Damodar valleys in India; Satpura and Vindhya are block mountains.

Fault Types

Fault Type	Description
Normal fault	Caused by tension; hanging wall moves down relative to the footwall
Reverse fault (Thrust)	Caused by compression; hanging wall moves up over the footwall (a low-angle reverse fault = thrust fault, e.g. Main Boundary Thrust of the Himalayas)
Strike-slip fault	Blocks slide past each other horizontally, little vertical movement; right- or left-lateral (e.g. San Andreas Fault, USA)

Great Rift Valley System

- Stretches ~6,000 km from the Jordan Valley (Middle East) in the north to Mozambique in the south.
- East African Rift (EAR): active continental rift, part of this system.

African Plate Split

African continent splitting into Somali and Nubian Plates.

Rate of split: 6–7 mm/year.

Within 10 million years, Somali Plate breaks off, forming a new ocean basin.

Other Mountain Types

Mountain Types by Formation

Type	Formation	Examples
Volcanic mountains	Accumulated volcanic material	Mt. Kilimanjaro (Tanzania), Mt. Fuji (Japan), Mauna Loa & Mauna Kea (Hawaii), Barren Island & Narcondam (India)
Residual/relict mountains	Erosion/denudation	Parasnath hill, Aravalli range, Girnar hill
Dome mountains	Magma hardens before reaching surface, forms dome	Black Hills (South Dakota, USA), the Weald (SE England)

Significance of Mountains

- Natural barrier: Himalayas block cold continental winds from Central Asia/Siberia and trap the monsoon winds.
- Storehouse of water: glaciers source Indus, Ganga, Brahmaputra.

Isostatic Movement

Isostasy

Gravitational equilibrium between lithosphere and asthenosphere.

Plates float at elevation depending on thickness/density.

High-altitude landforms have greater crustal thickness, lighter material than oceanic crust.

Erosion → weight loss → uplift (and vice versa).

Airy: mountains have deep "roots" (same density, varying thickness) | Pratt: higher blocks are less dense (varying density, uniform depth)

Example: post-glacial rebound of Scandinavia and Canada (land rising after ice-sheet melt)

Exogenic Processes

- Denudation: collective term for weathering, mass movement/wasting, erosion, transportation.

Weathering

- In-situ mechanical disintegration/chemical decomposition via weather/climate.

- In-situ process: little or no movement of material (unlike erosion).
- Erosion = mobile process; disintegrated material transported elsewhere by geomorphic agents.

Weathering Types

Category	Sub-type	Description
Physical	Unloading & expansion	Removal of overlying load releases pressure → expansion/disintegration; sheet removal = exfoliation; large smooth domes = exfoliation domes
Physical	Insolation weathering (diurnal exfoliation)	Daytime heating/expansion, nighttime cooling/contraction disintegrates into sheets ("exfoliated tors"); more effective in drier, high diurnal-range climates; distinct from pressure-release exfoliation above
Physical	Freezing, thawing, frost wedging	Water in pores freezes (expands) and thaws cyclically, tearing rock apart
Physical	Salt weathering (Haloclasty)	Salt expands via thermal action/hydration/crystallization, exerting pressure
Chemical	Hydration	Minerals absorb water, expand, aiding physical weathering; reversible, repeated cycles disintegrate molecules
Chemical	Carbonation	Minerals react with carbonic acid (water + CO ₂), dissolve (e.g. limestone); causes karst formations
Chemical	Solution	Material dissolves in water/CO ₂ ; affects phosphate/sulfate rocks; leached in rainy climates, accumulates in dry regions
Chemical	Oxidation & Reduction	Oxygen combination (oxidation) or removal (reduction) disturbs structure, e.g. rusting exposes new surface to further oxidation
Biological	-	Organism growth/movement removes mineral ions; burrowing, ploughing expose surfaces to chemical attack/water-air penetration; roots and fungus exert pressure

Significance of Weathering

- Initial stage of soil formation.
- Enriches/concentrates valuable ores (iron, manganese, copper).

Mass Movement

- Transfer of mass/debris downslope under direct gravity.
- Preceding factors: increased slope gradient, base-support removal, heavy rainfall/lubrication, load removal from above, deforestation/overgrazing, earthquakes.
- Classified: Slow, Rapid, Landslide.

Mass Movement Types

Category	Type	Description
Slow	Soil creep	Slow continuous soil/rock movement along slope; evidenced by bent trees, inclined poles
Slow	Solifluction	Slow flow of water-saturated soil/debris; common in glacial/periglacial zones
Rapid (top soil flows)	Mud flow	Fully saturated soil flows fast, soup-like to wet-concrete consistency; Lahars = volcanic mudflows
Rapid	Debris avalanche	High-velocity large-volume collapse of mountain slope; travels far
Landslide	Rock fall	Rock dislodges from steep slope, free-falls
Landslide	Slump	Material rotates, leaves crescent scar; upper block undisturbed; triggered by earthquakes/heavy rain

- Talus: rock debris accumulated at base of a steep slope (from landslides).

Erosion and Transportation

Erosion Processes

Type	Description
Abrasion (Corrasion)	Rocks rub against each other during transport; Vertical (downward) and Lateral (sideways) corrasion
Attrition	Material collides during transport, breaking into smaller pieces
Corrosion	Chemical/solvent action of water on soluble/partly soluble rocks
Hydraulic action	Erosion by fast-moving water
Plucking	During glacier movement; drags/breaks rock fragments
Deflation	Wind lifts and removes loose, dry, fine particles, creating deflation hollows (e.g. Qattara Depression, Egypt)

Weathering vs Erosion vs Mass Movement

Earthquakes

- Definition: sudden shaking from quick release of accumulated energy as seismic waves along a fault.
- Focus: sub-surface source of the earthquake.
- Epicenter: surface point directly above the focus.
- Isoseismals: contours of equal intensity.

Earthquake Shock Sequence

Foreshocks: smaller shocks, before the mainshock, same location

Mainshock: the largest shock

Aftershocks: always follow the mainshock

Major Earthquake Examples

Date	Magnitude	Location	Deaths/Note
24 Jun 2026	7.5 & 7.2 (twin quakes)	Venezuela (La Guaira offshore & Yaracuy)	>6,500 deaths; deadliest quake of 2026
31 Aug 2025	6.0	Afghanistan (Kunar)	~2,200 deaths; shallow focus
29 Jul 2025	8.8	Russia (Kamchatka offshore)	Strongest quake since 2011 (Japan); Pacific-wide tsunami alerts
28 Mar 2025	7.7	Myanmar (Sagaing Fault, strike-slip)	>5,400 deaths; India launched Operation Brahma for relief
7 Jan 2025	7.1	China (Tingri/Dingri, Tibet)	126+ deaths; near Mt Everest region
1 Jan 2024	7.5	Japan (Noto Peninsula)	~500 deaths incl. disaster-related
6 Feb 2023	7.8	Turkey-Syria	>59,000 deaths; one of deadliest quakes of the century

Classification by Depth of Focus

Earthquake Classification by Depth

Type	Depth	Cause/Note
Shallow	0-70 km	Most destructive but felt over smaller area

Type	Depth	Cause/Note
Intermediate	70–300 km	Mostly within subducting slabs (Wadati–Benioff zone); e.g. Hindu Kush region
Deep	300–700 km	Deep within subducting slabs; e.g. Fiji–Tonga, Japan; none occur below ~700 km

- Deeper focus → felt over a larger area but less destructive locally.

Measurement and Recording

- Seismograph: instrument that records quakes.

Magnitude vs Intensity: Commonly Confused

Magnitude = energy released; measured by Richter Scale or Moment Magnitude Scale

Intensity = damage/local impact; measured by Mercalli Scale (1–12)

Earthquake Scales

Scale	Measures	Range/Nature	Note
Richter Scale	Magnitude (amplitude of waves)	Logarithmic, open-ended (Charles Richter, 1935); reliable for moderate quakes	+1 unit = 10× wave amplitude and ≈ 32× more energy; M7.5 ≈ 32× energy of M6.5
Moment Magnitude Scale	Magnitude (energy)	Kanamori & Hanks (1979); used by USGS for large quakes (does not saturate above M8)	Based on fault area × slip × rock rigidity (seismic moment)
Mercalli Scale (Modified, MM)	Intensity (damage/local impact)	Range 1–12	12 = total destruction

Seismic Waves

- Two broad types: Body Waves and Surface Waves.
- Surface Waves: generated when body waves meet surface rock; travel through the crust only; low frequency; arrive last; most destructive.
- Arrival order: P → S → L → R.

Types of Seismic Waves

Feature	P-Wave (Primary)	S-Wave (Secondary)	Love Wave (L)	Rayleigh Wave (R)
Category	Body wave	Body wave	Surface wave	Surface wave
Also called	Longitudinal / Compressional / Pressure wave	Transverse wave	–	–
Speed	Fastest; first to arrive	Slower than P	Fastest surface wave	–
Medium	Solid, liquid, gas	Solid only (liquids lack shear strength)	Crust only	Crust only
Particle motion	Parallel displacement (compression-rarefaction)	Perpendicular (transverse), like ripples	Horizontal, perpendicular motion	Water-wave-like roll
Destructiveness	–	–	More destructive than Rayleigh	Causes most felt shaking
Velocity order	Solid > Liquid > Gas	–	–	–

Shadow Zones

- Within 105° of epicenter: both P and S waves are recorded.
- Beyond 145°: only P waves are recorded.
- 105°–145°: shadow zone for both P and S.
- Beyond 105°: total S-wave shadow zone (liquid outer core stops S waves entirely).
- Cause: S waves cannot cross the liquid outer core; P waves refract through it.

Determining the Epicenter

- S–P interval (time gap between P and S wave arrival) grows with distance from the epicenter.
- Intersection of circles from ≥3 stations locates the epicenter.

Wadati–Benioff Zone

- Subduction zone where an oceanic plate converges/subducts under a continental plate.
- Prone to the most powerful, deep earthquakes.

Types and Causes of Earthquake

Types and Causes of Earthquakes

Type	Cause	Example
Tectonic	Plate movement along faults, usually at boundaries	Ring of Fire; most common type
Volcanic	Near-surface, tied to active volcanism	Earthquakes preceding eruptions, e.g. Mt St. Helens (1980), Kilauea (2018)
Human-Made: Collapse	Karst/mining subsidence	Rock bursts in deep mines, e.g. Kolar Gold Fields (Karnataka)
Human-Made: Explosive	Chemical/nuclear blasts	Nuclear tests, e.g. Pokhran (1974, 1998)
Human-Made: Reservoir-induced	Reservoir loading	Koyna earthquake (1967, M6.3, Maharashtra): best-known reservoir-induced quake

Earthquake Swarm

- Sequence of low-magnitude quakes in a localized area, with no discernible main shock.

Effects and Consequences of Earthquakes

- Triggers landslides and tsunamis (plate movement displaces water).
- Examples of quake-triggered landslides: 2005 Kashmir earthquake (Hattian Bala landslide), 2015 Nepal (Gorkha) earthquake (Langtang valley avalanche).
- Surface rupture/ground displacement creates new faults; damages roads, railways, infrastructure.
- Soil liquefaction: shaking turns water-saturated sand from solid to liquid; buildings tilt/sink.
- Coastline/land-level change example: Kutch, Gujarat (1819: Allah Bund uplifted, Sindri area subsided).
- River course change examples: Indus/Kori Creek (1819 Kutch quake), Brahmaputra tributaries (1950 Assam–Tibet quake, M8.6).

Seismic Mapping and Earthquake Zones in India

- NDMA: ~59% of India's land area is vulnerable to moderate to severe earthquakes.
- Share of land area (IS 1893: 2016 map): Zone V ~11%, Zone IV ~18%, Zone III ~30%, Zone II ~41%.
- Entire Himalayan belt is prone to quakes >8.0 magnitude.
- Peninsular (stable continental) India is also vulnerable: Koyna (1967), Latur (1993, M6.2), Jabalpur (1997), Bhuj (2001, M7.7).

- Bureau of Indian Standards (BIS), in its code IS 1893, divides India into 4 seismic zones (II–V) based on the MSK-64 intensity scale (Zone I was merged into Zone II in 2002).

Seismic Zones of India

Zone	Description
Zone II	Low damage risk; MSK VI or less; e.g. parts of Karnataka, Tamil Nadu, Rajasthan
Zone III	Moderate damage risk; MSK VII; e.g. Kerala, Goa, most of UP's south, Chennai, Mumbai, Kolkata
Zone IV	High damage risk; MSK VIII; e.g. Delhi, Indo-Gangetic plains incl. northern UP, Sikkim, parts of J&K, HP
Zone V	Very high damage risk; MSK IX and above; entire North-East India, parts of J&K, Himachal Pradesh, Uttarakhand, Rann of Kutch (Gujarat), North Bihar, Andaman & Nicobar

Revised Seismic Code: Current Status (2026)

BIS notified a revised IS 1893 (2025) that added a new Zone VI covering the entire Himalayan arc and placed ~60% of India's land in moderate-to-high hazard zones. After objections (high construction cost, inadequate consultation), BIS withdrew the 2025 version by a gazette notification dated 3 March 2026. Current position: the IS 1893: 2016 map with four zones (II–V) remains the operative standard.

Reasons for Frequent Seismic Activity in Himalayan Region

- Young fold mountains located at continental margins.
- Formed from ongoing Indian–Eurasian Plate collision.

Reasons for Earthquake Proneness in India

- Plate movement: the Indian Plate is moving north-northeast into Eurasia at ~4–5 cm/year.
- Subduction of the Indian Plate beneath the Burma microplate (Andaman–Sumatra arc) builds strain, as seen in the 2004 Sumatra–Andaman quake.
- Andaman & Nicobar lie on an active subduction zone, prone to sea-floor displacement and submarine volcanism (Barren Island).
- Peninsular faults and weak zones get reactivated: Latur–Osmanabad (1993), Koyna, Jabalpur (Narmada–Son lineament).

Global Distribution of Earthquakes

Global Earthquake Belts

Belt	Share of Quakes	Notes/Examples
Circum-Pacific Seismic Belt ("Ring of Fire")	~81% of world's largest quakes	Pacific-rim subduction zones; Chile (1960, M9.5, strongest recorded; 2010), Japan (2011), Kamchatka (2025)
Alpine Earthquake Belt	~17% of largest quakes	Java–Sumatra → Himalayas → Iran–Turkey → Mediterranean → Atlantic; incl. 2004 Sumatra–Andaman quake
Submerged Mid-Atlantic Ridge	–	Quake-prone, divergent plate boundary

Earthquake Hazard Management and Mitigation

- Early warning systems: signals travel faster than quake waves (per Japan model).
- India: IIT Roorkee's Earthquake Early Warning system in Uttarakhand (BhuDEV app); Google's Android Earthquake Alerts launched in India in 2023 with NDMA and NCS.

- National Center for Seismology (NCS), under the Ministry of Earth Sciences, is India's nodal agency for monitoring earthquakes.
- Construction regulation curbing high-rise/industrial builds in vulnerable zones.

Tsunami

- Etymology: Japanese, "Tsu" (Harbor) + "Nami" (Wave).
- A large, seismically generated sea wave.
- Caused by violent ocean-floor plate movement.

Tsunami Triggers and Examples

Trigger	Example
Earthquake	Great 1960 Chilean Tsunami (M9.5); 2004 Indian Ocean Tsunami (Sumatra-Andaman quake)
Submarine volcanic eruptions	Krakatoa (Indonesia), 1883
Volcanic flank collapse/eruption	Anak Krakatau (Indonesia), Dec 2018; Hunga Tonga–Hunga Ha'apai (Tonga), Jan 2022

Properties of Tsunami Waves

- Very long wavelength (100–500 km) and long period.
- Low amplitude in deep ocean (often < 1 m), so ships at sea barely notice it.
- High velocity: ~700–800 km/hr in deep water (speed = $\sqrt{g \times \text{depth}}$).

Tsunami Approaching Shore: What Changes

Depth decreases → friction increases
Wavelength decreases
Amplitude increases
Potential energy increases
Kinetic energy decreases
Wave speed decreases, but the wave height may rise to 10–30 m

- The wave after the first receding wave is usually the most destructive (people are unaware).
- Receding coastal water signals an approaching tsunami.

Tsunami in India

- No tsunami has hit the Indian coast since 2004, though Northern Bay of Bengal seismicity has produced high waves.
- Tsunami-prone coastal zones: Puri, Kakinada, Machilipatnam, Nizampatnam-Vetapalem, Chennai, Cuddalore-Puducherry, Rameswaram, Thoothukudi (east coast); Alappuzha-Chavara, Kochi (west coast).
- 2004 Indian Ocean Tsunami (Boxing Day Tsunami, Sumatra-Andaman quake): hit Tamil Nadu, Andhra Pradesh, Kerala, A&N Islands (especially Little Andaman).
- Killed ~2.3 lakh people in 14 countries; in India ~10,700 deaths (worst hit: Nagapattinam, Tamil Nadu, and the A&N Islands).
- Indira Point (India's southernmost point, Great Nicobar) subsided and was partly submerged.

Tsunami Early Warning System in India (TEWS)

- INCOIS (Indian National Centre for Ocean Information Services), Hyderabad.
- Established 1999 under the Ministry of Earth Sciences; the Indian Tsunami Early Warning Centre (ITEWC) became operational in October 2007.
- ITEWC uses a network of seismic stations, Bottom Pressure Recorders (BPRs) and tide gauges to detect tsunamigenic earthquakes within minutes.
- Provides tsunami advisories to ~25 Indian Ocean countries under the UNESCO-IOC framework (IOTWMS).
- One of 3 Regional Tsunami Advisory Service Providers (with Australia, Indonesia).
- India is part of the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) set up by UNESCO-IOC after 2004.

Tsunami Ready Villages (UNESCO-IOC)

Venkatraipur (Ganjam) and Noliasahi (Jagatsinghpur), Odisha, were the first Tsunami Ready communities in the Indian Ocean region (2020)

More Odisha villages were recognised in 2024; with 75 added in September 2026, Odisha now has 100 Tsunami Ready villages

Verification by the National Tsunami Ready Board (NTRB), convened by INCOIS; Odisha aims to cover all 381 tsunami-prone coastal villages

Volcanoes

- Volcano: vent that releases gases, ash, and molten rock (lava) to the surface.
- Gases released: mainly water vapour, CO₂ and SO₂, with smaller amounts of nitrogen, hydrogen, chlorine and argon compounds.

Tallest Volcanoes

Olympus Mons (Mars): tallest volcano in the Solar System

Mauna Kea (Hawaii): tallest volcano on Earth (taller than Everest measured from its oceanic base)

Ojos del Salado (Chile–Argentina, ~6,893 m): highest volcano above sea level

Volcanism vs Magma vs Lava**Parts of a Volcano**

- Magma chamber: magma/gas reservoir.
- Conduit: pipe to the surface.
- Vent: surface opening, usually one main vent.
- Crater: bowl-shaped depression at the top of the vent, formed by explosion or collapse.
- Slopes: flanks extending from the central vent.

Factors Responsible for Volcanism

- Plate tectonics (subduction at a converging limb).
- Ocean floor spreading (divergence at ridges, magma wells up).
- Plate movement over a hotspot.

Classification of Volcanoes**Volcano Classification by Activity Status**

Type	Description
Active	Erupted in historic times/last ~10,000 years and may erupt again; e.g. Barren Island, Etna, Stromboli
Dormant	Not extinct but no recent eruption; may erupt again; e.g. Narcondam (India), Mt Fuji, Vesuvius (before AD 79)
Extinct	Erupted in the distant geological past; no indication of future activity; e.g. Arthur's Seat (Edinburgh), Dhosi Hill (Haryana)

Volcano Classification by Lava Type

Type	Characteristics	Examples
Andesitic	Explosive; acidic, viscous, silica-rich lava; solidifies quickly, building steep, high cones	Mt St. Helens (USA), Mt Pinatubo (Philippines)

Type	Characteristics	Examples
Basaltic	Quiet (effusive); basic, fluid, iron-magnesium-rich lava; flows far before solidifying, building broad, gentle slopes	Kilauea & Mauna Loa (Hawaii); Mt Etna (Italy)
Composite (intermediate)	Alternate explosive and effusive phases; layers of lava and ash	Mount Fuji (Japan), Mount Kilimanjaro (Tanzania), Mt Vesuvius (Italy)

Benefits of Volcanoes

- Fertilizer: ash/dust makes fields fertile.
- Minerals/gems: e.g. Kimberlite pipes (named after Kimberley, South Africa) bear diamonds; Majhgawan, Panna (MP) is India's only active diamond mine.
- Landforms: plateaus, volcanic mountains.
- Geothermal energy: geysers/hot springs, e.g., Puga Valley (Ladakh), Manikaran (HP).

Effects of Volcanoes

- Air pollution/acid rain from nitrogen/sulphur oxides.
- Ozone depletion (sulphur aerosols in the stratosphere).
- Can trigger earthquakes/tsunamis.

Volcanic Cooling Effect

Stratospheric SO₂ → sulphuric acid → sulphate aerosols → reflects solar radiation → cools lower atmosphere
 Mt Pinatubo (1991) cooled global temperature by ~0.5°C for about 2 years; Tambora (1815) caused the "Year Without a Summer" (1816)

- Pollution: volcanoes are the largest natural source of SO₂ (though human emissions are larger overall); SO₂ causes acid rain.

Volcanic Landforms

- Classified by lava-cooling location: Extrusive (cools above crust) vs Intrusive (cools within crust).

Extrusive Volcanic Landforms

Landform	Properties & Features	Examples
Composite/Stratovolcano	Layered solidified lava; acidic, viscous lava → steep slope, violent eruptions	Mount St. Helens, Mt. Stromboli ("Lighthouse of the Mediterranean"), Mt. Vesuvius, Mt. Fuji
Cinder Cone	Steep circular hill of loose pyroclastic fragments; erupts once; flank or individual vent; usually summit crater	Parícutin (Mexico)
Crater	Inverted-cone vent; depression when inactive; rain/snowmelt forms a crater lake	Crater Lake, USA
Shield Volcano	Broad, gently sloping cone like a warrior's shield; fluid basaltic lava flows far; largest volcanoes on Earth; non-explosive unless water enters the vent	Mauna Loa and Kilauea (Hawaii)
Caldera	Most explosive; collapses into a depression; wet granitic magma rises fast; forms a caldera lake	Lake Toba, Indonesia (largest volcanic lake; super-eruption ~74,000 yrs ago)
Fissure Vent	Narrow/linear vents, basaltic, usually non-explosive	Laki (Iceland)
Flood Basalt Plateau	Giant eruptions over a large area via cracks/mantle plume	Deccan Traps (India); Columbia-Snake River Plateau (USA); Siberian Traps (Russia)
Mid-Ocean Ridge Volcano	Oceanic; basaltic lava spreads on both sides of the ridge; drives seafloor spreading	Iceland (on the Mid-Atlantic Ridge)

Hot Springs and Geysers

Hot Spring vs Geyser

Feature	Hot Spring	Geyser
Mechanism	Geothermally heated groundwater pools near surface, steams	High-pressure boiling groundwater erupts intermittently
Color	Colorful, from cyanobacteria	-
Example	Tattapani (HP & Chhattisgarh), Manikaran (HP), Rajgir (Bihar), Yumthang (Sikkim); Mammoth Hot Springs (Yellowstone)	Old Faithful (Yellowstone, USA); Strokkur (Iceland). India has no true geyser.

Hotspot / Mantle Plumes

- Hotspot volcanism occurs at interior plate spots, not at plate margins.
- Hotspot: mantle spot where plumes rise via convection, melting rock at the lithosphere's base into magma, which is pushed through crustal cracks.
- Mantle plumes: hot columns rising from the mantle; have a bulging head and a narrow tail.
- Hotspots are relatively stationary versus moving plates → volcano chains form as plates drift over them (e.g., Hawaiian Archipelago).
- Examples: Hawaiian, Yellowstone, Iceland and Réunion hotspots (the Réunion hotspot produced the Deccan Traps ~66 Mya).

Volcano in India

Volcanoes in India

Barren Island (Andaman Sea): India's only active volcano

First recorded eruption 1787; active again in 1991, 1994–95, 2005–07, 2017, 2022 and minor eruptions in September 2025

Narcondam: dormant volcanic island (GSI), NE of Barren Island; home of the endemic Narcondam hornbill

No active volcano on mainland India; extinct volcanic hills include Dhosi Hill (Haryana) and Dhinodhar (Gujarat); Baratang (Andaman) has mud volcanoes

Global Distribution of Volcanoes

- ~75% of active volcanoes and ~90% of earthquakes lie along the Ring of Fire (~40,000 km).
- Ring of Fire path: New Zealand → Indonesia/Philippines → Japan → Kamchatka → Aleutians/Alaska → west coast of North and South America → southern tip of South America.
- Many volcanoes form where a dense oceanic plate subducts under a lighter continental plate.

Select Active Volcanoes Worldwide

Volcano	Location
Kilauea	Hawaiian Island, USA
Mount Etna	Sicily, Italy
Mount Sinabung	Karo Plateau, North Sumatra, Indonesia
Anak Krakatau	Indonesia
Mount Nyiragongo	DR Congo (Virunga National Park)
Taal volcano	Philippines
Hayli Gubbi	Afar, Ethiopia (erupted Nov 2025 for the first time in ~12,000 years; ash plume reached Yemen, Oman, Pakistan and India)

Pseudo Volcanic Landforms

Landform	Description
Salt Plug/Dome	Pressurized salt deposits turn ductile, pierce sediments, form a crater-like dome
Mud Volcanoes	Mud/water/gas eruptions near subduction zones and oilfields (emit methane); e.g. Baratang Island (Andaman), the only mud volcanoes in India
Meteorite Craters	Impact depressions, often forming crater lakes; e.g. Lonar Lake (Buldhana, Maharashtra); impact crater in basalt, ~5.7 lakh years old (2019 dating), Ramsar site since 2020; Dhala crater (MP)

CHAPTER 02

Continents, World Mountains, Plateaus, Valleys

Introduction

- Explained by five theories: Continental Drift Theory, Convectional Current Theory, Seafloor Spreading Theory, Plate Tectonic Theory, Wilson Cycle.

Continental Drift Theory

Wegener's Continental Drift

Proposed by Alfred Wegener (German meteorologist) in 1912; book "The Origin of Continents and Oceans" (1915)
 Single landmass: Pangaea; single surrounding ocean: Panthalassa
 Broke apart ~200 MYA (Mesozoic age)
 Formed Laurasia (North) and Gondwanaland (South), separated by the Tethys Sea

- Laurasia (North): N. America, Greenland, Eurasia (excluding Arabia/India), drifted north.
- Gondwanaland (South): S. America, Africa, Australia, Antarctica, India, drifted south.

Forces for Drift (per Wegener)

Wegener's Proposed Forces

Force	Mechanism
Polar fleeing force	Earth's rotation and equatorial bulge push continents from the poles towards the equator
Tidal force	Moon/sun attraction pulls continents westward
Buoyant force	Light continental crust (sial) floats on denser sima

Evidence in Support

- Jigsaw fit: S. America–Africa coastlines match closely.
- India, Madagascar, and Africa margins appear to have once joined.
- Earliest marine deposits along the coasts of S. America and Africa are of Jurassic age, implying the ocean did not exist between them before that.
- Ancient (~2,000 million-year-old) rock belts of the Brazil coast match those of Western Africa (radiometric dating).
- Glacial tillite of the same age found in India, Madagascar, Africa, Antarctica, Falkland Islands, Australia.
- Fossils found across now-separated continents: Mesosaurus (S. Africa & Brazil), Glossopteris (plant), Lystrosaurus, Cynognathus; lemur fossils in India, Madagascar and Africa led to the idea of "Lemuria".
- Placer gold deposits off Ghana (W. Africa coast) have no local gold-bearing rock source.
- Polar wandering: pole positions shifted due to plate movement.

Criticism

- Proposed forces (polar fleeing, tidal) were far too weak to move continents.
- Real cause of drift is asthenosphere convection, not Wegener's forces.

Post-Drift Theories

Convectional Current Theory

- Propounded by Arthur Holmes (1930s).
- Radioactive-element heating creates mantle convection currents throughout the mantle.
- These currents are responsible for lithospheric plate movement.
- Rising limb of convection → oceanic ridge (plate divergence).
- Descending limb of convection → trenches (plate convergence).

Observations from Ocean Floor Mapping

- Floor sediments are nowhere older than 200 million years.
- Rock age increases moving away from the ridge toward trenches.
- Similar rock types occur symmetrically on either side of the ridge at equal distances.
- Trenches show deep-seated earthquake foci.
- Ridge areas show shallow earthquake foci.

Seafloor Spreading Theory

- Proposed by Harry Hess (1960s).
- Earth does not expand: the crust created at ridges is consumed at trenches, so the total surface area stays constant.
- Magma rises at the ridge and cools into new crust.
- Crust near the ridge is younger than crust near trenches.
- Evidence: ocean-floor geology, rock age, paleomagnetism, sediment thickness.

Paleomagnetism

- Study of these rocks shows rock age increases moving away from the oceanic ridge.

Plate Tectonic Theory

- Proposed by McKenzie and Parker (1967), later outlined by Morgan (1968).
- Broken lithospheric plates (continental and/or oceanic crust) float on the asthenosphere.
- Plate interactions produce phenomena: volcanoes, earthquakes, tsunamis.
- Asthenosphere convection drives movement: rising current → divergent boundary; subsiding current → convergent boundary; opposite-direction convection in adjacent plates → transform boundary.

Plate Types by Crust

Type	Density/Thickness	Behaviour
Continental (Sialic) plate	Less dense, thicker	Too buoyant to subduct; crumples into fold mountains
Oceanic (Simatic) plate	Denser, thinner	Subducts under continental plate

Major Plates

Major Tectonic Plates

Plate	Notes
Antarctic	Antarctica + surrounding oceanic plate
North American	Western Atlantic floor; separated from the South American plate along the Caribbean islands
South American	Western Atlantic floor
Pacific	Largest plate; almost entirely oceanic

Plate	Notes
India-Australia-New Zealand	Includes the Indian subcontinent and Australia; now often treated as separate Indian and Australian plates
Africa	+ eastern Atlantic floor
Eurasia	+ adjacent ocean floor

Minor Plates

Minor Tectonic Plates

Plate	Location
Cocos	Central America–Pacific
Nazca	S. America–Pacific
Arabian	Mostly Saudi landmass
Philippine	Asia–Pacific
Caroline	Philippine–Indian, N of New Guinea
Fiji (spelt "Fuji" in NCERT)	NE Australia
Turkish	Anatolia (Turkey)
Aegean	Mediterranean
Caribbean	Caribbean Sea, between N. and S. American plates
Juan de Fuca	Pacific–N. American
Iranian	Iran

Types of Plate Boundaries

Boundary Type	Nature	Key Features
Divergent (constructive)	Plates move apart due to tension in asthenosphere	New crust formed at spreading site; rift valleys, fault/block mountains, mid-oceanic ridges
Convergent (destructive)	Plates collide; denser plate subducts	Trenches, fold mountains, volcanic arcs
Transform (conservative)	Plates slide past each other horizontally	Crust neither created nor destroyed; earthquake-prone, not volcanically active

Divergent Plate Boundary

- Plates diverge from tension in the asthenosphere at a spreading site, a constructive movement.
- New crust forms via basaltic magma eruption at the mid-oceanic ridge.
- This produces a Rift Valley and fault/block mountains.
- Rift = initial continental-breakup stage; continued divergence can form new ocean basins.
- Example: Afar Rift (Ethiopia), expected to diverge further, potentially forming the world's newest ocean and splitting Africa (separating the Horn of Africa from the mainland).
- Zealandia, a largely submerged continent (~94% under water), rifted away from Gondwana (Antarctica–Australia) about 85–80 million years ago, opening the Tasman Sea.

Convergent Plate Boundary

- Two plates collide; the heavier/denser one subducts under the lighter plate, with part of it lost to the mantle, a destructive boundary.
- Three sub-types: Oceanic–Oceanic, Continental–Continental, Oceanic–Continental.

Convergent Plate Boundary Sub-types

Sub-type	Mechanism	Landform Result	Examples
Oceanic-Oceanic	Heavier plate subducts, forming a deep trench; the subducting slab partially melts and the magma rises to form a volcanic arc	Volcanic island arcs	Philippines, Indonesia, Papua New Guinea; Mariana Trench (world's deepest: Pacific plate subducting beneath Mariana plate); also Japan, Philippine, Tonga, Aleutian, Bougainville, Kurile trenches
Oceanic-Continental (Cordilleran convergence)	Denser oceanic plate subducts beneath continental plate, compressing it into fold mountains; trench shallower than oceanic-oceanic type	Volcanically active fold mountains along the continental margin (continental arc)	Andes, Rockies; NE California volcanoes (Lassen Peak, Mount Shasta, Medicine Lake volcano) and the Cascades, from Juan de Fuca–North American subduction
Continental-Continental (Orogenic Collision)	Little subduction: rock too light to sink into dense mantle; folding instead	Fold mountains; no volcanism (magma can't penetrate thick crust), intrusive rock like granite forms instead; earthquake-prone; sedimentary basins/geosynclines form along squeezed margin	Himalayas (Indian–Eurasian collision, Tethys geosyncline sediments uplifted); Alps (African–Eurasian); Urals (ancient collision)

Ring of Fire**Ring of Fire**

Also called the Circum-Pacific Belt

Path along the Pacific Ocean marked by active volcanoes and earthquakes

Trenches form where plates overlap at convergence

Also a ring of mineral deposits, since the magma here is mineral-rich, aids mineral exploration

Transform Plate Boundary

- Plates slide horizontally past each other in opposite directions, also called a Conservative plate boundary.
- Crust is neither created nor destroyed at this boundary.
- Not volcanically active, but earthquake-prone.
- Example: San Andreas Fault, western USA.

Rate of Plate Movement

- Determined from the strip of normal/reverse magnetic field along the mid-oceanic ridge.
- Rate of movement varies across plates.
- Slowest: Arctic Ridge (< 2.5 cm/yr); fastest: East Pacific Rise near Easter Island (> 15 cm/yr) (NCERT). Modern measurement uses GPS/VLBI.

Evidence & Significance of Plate Tectonic Theory**Summary Table of Theories****Summary of Major Tectonic Theories**

Parameter	Continental Drift	Seafloor Spreading	Plate Tectonics
Propounded by	Alfred Wegener (1912)	Harry Hess (1960s)	McKenzie, Parker, Morgan (1967-68)

Parameter	Continental Drift	Seafloor Spreading	Plate Tectonics
Significance	Breakdown of single landmass (Pangaea) into pieces that drifted apart forming present continents	Due to volcanic action along Mid-Oceanic Ridge, oceanic plates move, sea-floor spreads in either direction from MOR	Horizontal movement of lithospheric plates (oceanic and continental crusts) over the asthenosphere
Evidence	Jigsaw fit of continents, polar wandering, fossil deposits, placer deposits, glacial tillite	Paleomagnetic rocks, age of rocks increases towards continental margin from MOR, thickness of sediments	Paleomagnetic rocks, occurrence of earthquake, volcano, tsunami
Forces of movement	Polar fleeing force, tidal force, gravitational force	Convection current within mantle	Convection current within mantle
Led to	Foundation for further studies: seafloor spreading theory, convectional current theory	Led foundation of plate tectonic theory	Helps understand occurrence of earthquakes/volcanoes, formation of mountains

Movement of Indian Plate

- India was a large island off Australia's coast (Southern Hemisphere), separated from the Eurasian plate by the Tethys Sea until ~225 million years ago.
- When India collided with Eurasia, the buoyant continental crust could not subduct; the sediments of the Tethys geosyncline were squeezed, folded and uplifted to form the Himalayas.

Indian Plate Movement & Himalayan Formation

~200 MYA: as Pangaea broke, India began moving north

~140 MYA: India near 50°S

~40–50 MYA: India collided with Eurasia → rapid uplift of the Himalayas

Himalayas still rising ~1 cm/year today

En route, the Indian plate passed over the Réunion hotspot → fissure eruptions of flood basalt formed the Deccan Traps (~66–60 MYA)

Evolution of Landforms

Introduction

Plateau

- Also called Tableland: flat-terrain highland raised on at least one side relative to surroundings.
- Can be old (e.g. Deccan Plateau, India, among the oldest) or young.

Types of Plateau

Type	Formation	Example
Tectonic plateau	Upward movement of Earth's crust due to slow collision of tectonic plates	Tibetan Plateau
Volcanic plateau	Formed by basaltic lava covering large distance as a sheet, near continental margin/volcanic hotspot	Deccan Traps (India), Columbia Plateau (USA)
Intermontane plateau	Plateau enclosed by hills and mountains	Tibetan Plateau (surrounded by Himalayas and Kunlun range); Mongolian Plateau
Dissected plateau	Evolved by process of denudation	Colorado Plateau (USA)

Type	Formation	Example
Continental plateau	Formed away from mountains, bordered by plains or seas	Antarctic Plateau (East Antarctica)
Oceanic plateau	Surrounded by seas/oceans	Ontong Java Plateau (Pacific), Kerguelen Plateau (Indian Ocean)
Piedmont plateau	Surrounded by mountains on one side, oceans/seas on other	Patagonia Plateau (South America); Malwa Plateau (India)
Dome-shaped plateau	Middle portion of landmass raised against all surrounding sides	Chota Nagpur Plateau (India)

Plains

- Lowland areas of gentle slope and minimal relief, found on all continents except Antarctica.
- Originate from diastrophic movement (further shaped by fluvial erosion/deposition and glaciation), or from emergence of submerged coastal land.

Types of Plains

Type	Description	Example
Structural	Horizontally bedded rock; structurally depressed, tectonically undisturbed	Great Plains (USA), Russian Platform
Erosional (Peneplains)	Elevated land brought down to sea level by erosional agents	Canadian Shield, West Siberian Plain
Depositional – Alluvial/riverine	Built from river-deposited eroded material	Ganga-Brahmaputra plain
Depositional – Lacustrine/lake	Built from lake sediment	Kashmir valley
Depositional – Drift/glacial	Built from glacial deposition	North German Plain, Canadian Prairies
Depositional – Loess	Built from wind-deposited material	Loess Plateau (China), Mississippi valley

Deserts

- Areas receiving no more than 25 cm precipitation/year; dry, arid, seldom inhabited.

Types of Deserts

Type	Conditions	Example
Hot	Western margins of continents between 15°–30° N/S, under subtropical high pressure and along cold ocean currents; high annual/diurnal temperature range	Sahara, Kalahari, Arabian, Thar, Great Australian
Coastal	Western continental margins along cold currents, 15°–30° latitude; less hot than hot deserts due to the water's moderating effect	Atacama Desert
Mid-latitude/cold	Continental interiors at higher latitude, beyond moisture-bearing winds; continentality is the main cause of aridity	Gobi, Taklamakan
Ice and snow	Polar regions	Antarctica, Greenland

Fluvial Landforms

- Formed by running water's degradational action (erosion) and subsequent aggradational work (deposition).

Erosional Landforms (Fluvial)

- Youth stage forms a deep V-valley (Gorge) via vertical downcutting.
- Canyon = extended, wider-topped gorge; a Gorge has near-equal top/bottom width.
- Maturity brings dominant lateral erosion and a broader, flat-floored valley (a U-shaped valley is glacial, not fluvial).
- Valley evolution sequence: Rills (shallow water-erosion channels, removable by tilling) → Gullies (enlarged rills, not removable by tilling, further deepen) → Valley.
- Waterfall: forms where a river crosses alternating soft/hard rock layers (soft rock erodes faster).
- Potholes: kettle-shaped riverbed depressions from swirling rocks/pebbles/boulders in water eddies (pothole-drilling mechanism).
- Plunge pool: large depression at a waterfall's foot from sustained boulder/pebble action.
- Rapids: undulated bed from differential erosion of alternating soft/hard rock.
- River terrace: old floodplain surface left by the stream's own vertical erosion into its floodplain; paired/unpaired by elevation symmetry on either side.
- Meanders: sinuous course from dominant lateral erosion on gentle, low-kinetic-energy slopes.
- Incised meanders occur in deep, hard-rock areas with strong vertical + lateral erosion.
- Outer bend = cliff-slope/concave side (intensive erosion); inner bend = slip-off/convex side (deposition, gentle slope).

Depositional Landforms (Fluvial)

- Alluvial fans and cones: a river losing velocity (lower gradient) on leaving a mountain valley sheds its load in a cone at the foothills, e.g. Bhabar region, Himalayan foothills.
- Deltas: sediment (size-stratified) deposited at a river's mouth, unlike fans, from reduced velocity near sea level and saltwater action.

Types of Deltas

Type	Description	Example
Arcuate	Fan-shaped, convex toward sea	Ganga-Brahmaputra
Cuspate	Arrow-shaped, from strong waves on a straight shoreline	Tiber river, Italy
Bird's foot	Fine-particle, distributary-branched; river stronger than waves	Mississippi
Lacustrine	Formed into a lake	Lough Leanne, Ireland
Abandoned	River shifts mouth, leaving the old delta	Yellow river, China
Estuarine	Delta absent/limited; river ends in a submerged mouth (estuary) where tides remove sediment	Narmada, Tapi (India), Seine, Thames

- Levees: natural raised embankments along the channel, acting as flood barriers.
- Point/meander bars: sediment deposited along a meander's convex side.
- Ox-bow lake: forms when a meander loop separates from the mainstream via erosion/deposition.
- Braided channel: a stream divides into smaller, rejoining streams with temporary islands, from heavy sediment load, e.g. river Brahmaputra.

Marine Landforms

Erosional Landforms (Marine)

- Chasms: narrow, deep indentations from active headward wave erosion.
- Sea cliff: steep vertical shoreline from active wave erosion.
- Wave-cut platform: horizontal platform from lateral wave erosion of a cliff.
- Sea caves: cliff-base holes widened/deepened by continuous wave action, e.g. Flamborough Head, England.
- Sea arches: form when caves from either side of a cliff unite (arcuate/rectangular, opening below water level).
- Stacks: cylindrical remnant left when an arch's roof collapses.
- Blow-hole: vertical shaft from a sea cave growing landward/upward; water is forced out at the top when waves enter forcefully.

Depositional Landforms (Marine)

- Beach: wave/current-deposited debris and loose sediment on shore.
- Bars: deposited sediment accumulating offshore, submerged.
- Barrier bars: deposited sediment accumulating offshore, emerged.
- Lagoon: water enclosed by bars and barriers, e.g. Chilika (Odisha), Pulicat (AP-TN), Vembanad (Kerala).
- Spit: deposit joined to shore at one end, free in sea at the other.
- Tombolo: narrow sand bar connecting an island to the mainland.

Glacial Landforms

- A glacier: a large ice mass moving under its own weight like a slow river, carrying debris.
- Erodes by Abrasion: frozen rock/stone rubbing the underlying/lateral surface.
- Erodes by Plucking: bedrock plucked and frozen in as the glacier moves, leaving a jagged landscape.

Erosional Landforms (Glacial)

- Cirque/Corrie: deep, armchair-shaped hollow at the head of a glacial valley; holds a tarn (cirque lake) after the ice melts.
- Horn: sharp, pyramidal peak formed where several cirques erode headward, e.g. Matterhorn (Alps), Everest (NCERT).
- Arete: steep-sided, sharp, zig-zag summit cut from two sides by glacial activity.
- Glacial trough: U-shaped valley from uniform horizontal/vertical glacial erosion.
- Hanging valley: a smaller tributary glacier, cutting less deeply than larger ones, left hanging above the main valley.
- Fjord: deep glacial trough drowned by the sea at the coast; common in Norway, Greenland, Chile, New Zealand.

Depositional Landforms (Glacial)

- Unsorted coarse/fine debris dropped by a melting glacier = glacial till, forming Moraine ridges.

Types of Moraine

Type	Location
Terminal	Glacier's toe
Lateral	Sides, parallel to the valley
Ground	Sheets left by rapid valley-glacier retreat
Medial	Centre of the valley floor, formed where lateral moraines of two merging glaciers join

- Outwash plain: stratified deposits (rock debris, clay, silt) left as the glacier melts at its lowest point.
- Esker: a long sand/gravel ridge deposited by subglacial meltwater, exposed when the glacier melts.
- Drumlins: smooth, oval glacial-till ridges ("Basket of Egg topography") that reveal ice-movement direction.
- Kames: small bedded sand/gravel mounds deposited by melted glaciers.

Arid Landforms

Erosional Landforms (Arid)

- Water-eroded sequence: Rill (narrow shallow channel) → Gully (widened/deepened) → Ravine (further eroded) → Badlands topography (extensive ravines/gullies from linear fluvial erosion).
- Bolsons: intermountain basins/depressions.
- Playas: temporary lakes formed when a small stream flows into a bolson.

Wind-eroded Arid Landforms

Landform	Description
Deflation basins/blow-outs	Hollows from wind-removed particles
Mushroom rocks	Deflation/abrasion-shaped, slender stalk, broad cap
Inselberg/monadnock	Isolated residual hill rising abruptly from a plain, e.g. Uluru/Ayers Rock (Australia)

Landform	Description
Demoiselles	Resistant-rock pillar over eroded soft rock
Yardangs	Wind-eroded ridges, usually parallel to wind direction
Zeugen	Tabular blocks of hard rock capping softer layers, cut by wind abrasion into ridge-and-furrow forms in deserts with horizontal rock layers

Depositional Landforms (Arid)

Types of Sand Dunes

Type	Description
Barchan	Crescent-shaped; horns point downwind; gentle convex windward side, steep concave leeward side
Transverse	Perpendicular to wind
Longitudinal	Parallel to wind
Parabolic	Reverse of barchan: horns point upwind, anchored by vegetation; common in coastal areas
Seif	Long, sharp-crested dune like a barchan with one horn elongated (from shifting winds)
Star	Central peak radiating multiple directions
Reversing	From opposite, balanced winds
Whaleback	Coarse sand left as longitudinal dunes migrate; large ones called draas

- Loess: fine silt/dust layer deposited by wind over a large plain.

Karst Landforms

- From chemical erosion/deposition by groundwater and surface water, mainly in limestone-dominated landscapes.
- Conditions: soluble rock (limestone, dolomite, gypsum) at/below surface.

Erosional Landforms (Karst)

- Caverns: underground caves from groundwater dissolving limestone (carbonation).
- Sinkhole/Doline: a depression from subsurface limestone dissolution becoming unstable and collapsing.
- Uvala: multiple smaller sinkholes coalesced into a compound sinkhole.
- Karst window: open area from collapse of multiple adjoining sinkholes.
- Polje: large, flat-floored karst depression (e.g. Dinaric Karst); Blind valley: valley ending abruptly where its stream sinks underground.
- Hums: residual limestone hills left standing on a karst plain.

Depositional Landforms (Karst)

- Stalactite: ceiling-down calcium carbonate deposit precipitated from solution.
- Stalagmite: ground-up calcium carbonate deposit precipitated from solution.
- Column: pillar formed where a stalactite and stalagmite join.
- Indian karst: Borra Caves (Araku, AP), Belum Caves (AP), Krem Liat Prah (Meghalaya, India's longest natural cave), Mawsmai Cave (Meghalaya).

Important World Landforms: Continent-wise

Asia

- Home to largest country Russia and most populous country China.
- Bounded by Arctic Ocean (N), Pacific Ocean (E), Indian Ocean (S), Red Sea/Mediterranean & Black Sea (SW), Europe (W).

- Largest watershed: Ob River. Largest desert: Gobi. Longest river: Yangtze (3,915 miles).

World's Highest Peak

Mount Everest: 8,848.86 m, world's highest elevation (Asia)

Asia: Plateaus, Plains, Basins & Peninsulas

Feature	Location/Country	Key Facts
Central Siberian Plateau	Russia (Krasnoyarsk Krai)	Bounded by Yenisey and Lena rivers
Tibetan Plateau	China/Tibet	Highest plateau on Earth, "Roof of the World"; sources Salween, Mekong, Yellow, Yangtze rivers
Anatolia Plateau	Turkey	Intermontane plateau between Pontic and Taurus ranges; Tigris–Euphrates flow through
Deccan Plateau	Southern India	Includes the Deccan Traps, one of the largest volcanic (flood basalt) provinces on Earth; general slope towards the east
West Siberian Plain	Russia	Between Ural Mts (west) and Yenisei valley (east); drained by Ob, Irtysh, Yenisei; aka Northern Lowlands
Szechwan Plains	China	"Rice Bowl of China"; fertile basin of Yangtze river
Turanian Plains	Turkmenistan, Uzbekistan, Kazakhstan	Between Amu Darya and Syr Darya rivers
Tarim Basin	NW China	Arid, endorheic, intermontane basin
Indian Peninsula	South of Indo-Gangetic Plain	Formed after Gondwana breakup; Granite-gneissic (undulating plains) + Deccan Trappean (flat-topped, stepped hills) landscapes
Arabian Peninsula	-	Largest peninsula in the world; Arabian Desert is the largest hot desert after the Sahara; home of Bedouin tribes
Thar Desert	India & Pakistan	Hot desert, east of Indus basin
Takla Makan	China	Intermontane cold desert
Gobi Desert	N. China & S. Mongolia	Cold desert

Asia: Mountain Ranges

Range	Location	Key Facts
Altay (Altai)	East-Central Asia	Russia, China, Mongolia, Kazakhstan meet here
Caucasus	Europe–Asia junction	Between Black Sea (west) and Caspian Sea (east)
Himalayas	North of Indian subcontinent	World's highest mountain range; world's highest peaks
Kunlun	W. China / Tibetan Plateau	One of the longest mountain chains in Asia
Tien (Tian) Shan	Central Asia	North/west of Taklamakan Desert; Kazakhstan–Kyrgyzstan–W. China border
Ural	-	Natural border between Asia and Europe
Zagros	Iran & Iraq	Largest mountain range in Iran and Iraq
Arakan Yoma	Myanmar	Southward extension of Himalayas; includes Andaman & Nicobar, Sumatra, Java
Hindukush	Afghanistan & Pakistan	Westward extension of Pamir
Sulaiman, Kirthar & Makran Ranges	Pakistan	Southward extension of Pamir to Arabian Sea coast

Range	Location	Key Facts
Taurus	S. Turkey	Along Mediterranean coast

Asia: Lakes

Lake	Location	Key Facts
Lake Toba	Indonesia	Caldera lake
Sea of Galilee	Israel	World's lowest freshwater lake; 2nd lowest water body after Dead Sea (saline)

- Malacca Strait: between Malay Peninsula and Indonesia's Sumatra; key shipping channel linking Indian Ocean and Pacific Ocean.
- Kra Isthmus: narrowest part of Malay Peninsula; Andaman Sea (west) to Gulf of Thailand (east).

Asia: Major Rivers

River	Source	Mouth	Notes
Salween	Tibetan Plateau (as Nu)	Andaman Sea	Tibet & Myanmar
Ganges	Gangotri Glacier	Bay of Bengal	India
Indus	Bokhar Chu glacier near Mansarovar (Tibet), known as Singi Khamban	Arabian Sea (near Karachi, Pakistan)	Tibet, India, Pakistan
Irrawaddy	MaliKha river	Andaman Sea	Myanmar
Tigris	Lake Hazar, Armenian Highland	Persian Gulf	Turkey, Syria, Iraq

Africa

- Only continent through which Equator, Tropic of Cancer, and Tropic of Capricorn all pass.
- Bounded by Atlantic Ocean (W), Mediterranean Sea (N), Red Sea/Indian Ocean (E), Atlantic & Indian Oceans (S).
- 54 countries plus dependencies: Western Sahara (disputed), Reunion, Mayotte (France), Saint Helena (UK).
- Highest elevation: Mount Kilimanjaro (dormant volcano, Tanzania).
- Longest river (world): Nile (4,132 miles).
- Largest hot desert: Sahara.
- Largest lake (Africa): Lake Victoria (largest tropical lake; 2nd largest freshwater lake by area after Lake Superior); source of the White Nile.

Africa: Plateaus

Feature	Location	Key Facts
Ethiopian Highlands	Ethiopia & Central Eritrea	Volcanic origin
Katanga Plateau	DR Congo (formerly Zaire)	Rich in copper and cobalt (Copperbelt extends into Zambia)
East African Plateau	Kenya, Tanzania, Uganda	Cut by the Great Rift Valley; Serengeti plains

Africa: Lakes

Lake	Location	Key Facts
Danakil Depression	Afar region, Ethiopia	Among the hottest and lowest places on Earth (~125 m below sea level); salt flats and the Dallol hydrothermal field
Lake Chad	Chad, Cameroon, Niger, Nigeria	Large, shallow, endorheic lake; shrunk by ~90% since the 1960s
Lake Volta	Ghana (Volta River, Akosombo Dam)	Largest artificial reservoir in the world by surface area

Lake	Location	Key Facts
Lake Kariba	Zambezi River, Zambia–Zimbabwe border	Largest man-made lake/reservoir by volume
Lake Assal	Djibouti	Saline lake in the Afar depression; lowest point in Africa (~155 m below sea level)

- Sahel: narrow semi-arid transition zone between Sahara (N) and Savanna (S).
- Sahel spans Burkina Faso, Cameroon, Chad, Gambia, Guinea, Mauritania, Mali, Niger, Nigeria, Senegal.
- Serengeti Plains stretch 30,000 sq km from Kenya's Maasai-Mara to Tanzania's Serengeti NP, with high concentrations of large mammals (lions, hyenas, zebras, giraffes, elephants).
- Congo Basin: world's 2nd largest tropical rainforest, defined by the Congo River watershed, primarily in DR Congo.

Africa: Mountain Ranges & Peaks

Range/Peak	Location	Key Facts
Atlas Mountains	Algeria, Morocco, Tunisia	NW Africa
Drakensberg	SE Africa	Encloses Central Southern African Plateau
Mt. Kilimanjaro	Tanzania	Africa's highest peak (5,895 m); isolated dormant stratovolcano (Kibo cone)
Mt. Cameroon	Cameroon	Prominent active volcano
Tibesti Massif	N. Chad	Highest mountain of the Sahara (Emi Koussi); volcanic origin

Africa: Major Rivers

River	Source	Mouth	Notes
Zambezi / Limpopo	Mwinilunga / Marico & Crocodile rivers	Indian Ocean	Zambezi has Victoria Falls
Orange	Drakensberg, Lesotho	Atlantic Ocean	-

Europe

- Described as "Peninsula of Peninsulas".
- Bordered by Arctic Ocean (N), Atlantic Ocean (W), Mediterranean, Black, and Caspian Seas (S, W to E).
- 44 countries total.
- Highest mountain: Mount Elbrus. Longest river: River Volga.

Europe: Deserts

Desert	Location	Key Facts
Tabernas Desert	Spain	Europe's only true desert

Europe: Mountain Ranges

Range	Location	Key Facts
Alps	8 countries: France, Switzerland, Monaco, Italy, Liechtenstein, Austria, Germany, Slovenia	Highest and most extensive range entirely in Europe; highest peak Mont Blanc (France–Italy border); also home to the Matterhorn (Switzerland–Italy)
Dinaric Alps	S & SE Europe	Separates Balkan Peninsula from Adriatic Sea
Carpathians	Central & Eastern Europe	Forms an arc; 3rd longest European mountain chain
Pyrenees	-	Natural border between Spain and France

Range	Location	Key Facts
Caucasus	Between Black Sea & Caspian Sea	Separates Europe & Asia; Mt. Elbrus (highest peak of Europe) here
Urals	Western Russia	Natural boundary between Europe and Asia
Mt. Etna, Mt. Vesuvius, Mt. Stromboli	Mediterranean Sea area	Active volcanoes of Europe

Europe: Major Rivers

River	Source	Mouth	Notes
Danube	Black Forest	Danube Delta (Black Sea)	2nd longest European river
Seine	Commune of Seine	English Channel	-
Loire	Central Massif	Atlantic Ocean	Longest river in France
Rhine	Swiss Alps	North Sea	-
Rhone	Rhone Glacier, Swiss Alps	Mediterranean Sea	Flows through Lake Geneva

North America

- 3rd largest continent; lies mostly between the Arctic Circle and the Tropic of Cancer.
- Largest freshwater lake (by area) in the world: Lake Superior.
- Highest peak: Denali (Mt McKinley), Alaska. Longest river: Missouri; the Mississippi–Missouri forms the longest river system.

North America: Mountain Ranges

Range	Location	Key Facts
Cordilleras	Canada to Isthmus of Panama	Young fold mountain system with volcanic ranges; includes Rockies, Sierra Nevada, Cascades, Brooks Range, Alaska Range, Pacific coastal ranges and the volcanic ranges of Central America
Rockies	-	Largest mountain chain of North America
Alaska Range	Alaska	Denali peak: highest peak in North America; highest range in world outside Asia & South America
Sierra Nevada	-	Mt. Whitney: highest peak of the contiguous USA
Appalachian Mountains	-	Among oldest mountains on Earth (~480 MYA); example of a relict mountain

- Yucatan Peninsula: separates Gulf of Mexico from Caribbean Sea.

North America: Great Lakes & Other Lakes

Lake	Key Facts
Lake Erie	Shallowest and smallest by volume (4th by area)
Lake Ontario	Easternmost and smallest by area; drains into the St. Lawrence River
Great Slave Lake	Canada; deepest lake in North America
Lake Winnipeg	Canada

North America: Plateaus

Plateau	Location	Key Facts
Great Basin	Nevada, Utah, California, etc. (USA)	Largest intermontane plateau of the continent
Colorado Plateau	-	Cut through by Colorado River and tributaries
Columbian Plateau	Between Rockies and Cascades	Basaltic lava plateau

North America: Major Rivers

River	Source	Mouth	Notes
Columbia	Columbia Lake, British Columbia (Canada)	Pacific Ocean	-
Yukon	British Columbia (Canada)	Bering Sea	-
Colorado	Rockies, USA	Gulf of California	-
Hudson	Adirondack Mountains	Atlantic Ocean	-
St. Lawrence	Lake Ontario (Canada-USA)	Atlantic Ocean	-

South America

- Lies entirely in the Western Hemisphere.
- Isthmus of Panama connects it to North America.
- Separated from Antarctica by the Drake Passage, south of Cape Horn.
- Highest peak: Mount Aconcagua.
- Largest drainage system by volume (world): Amazon River.
- Largest country: Brazil, touches every South American country except Chile and Ecuador.
- Highest waterfall (world): Angel Falls (~979 m), Guiana Highlands, Venezuela.

South America: Highlands, Plateaus & Peaks

Feature	Location	Key Facts
Guiana Highlands	Guyana, Suriname, French Guiana, parts of Venezuela, Colombia, Brazil	Densely forested
Brazilian Highlands	Brazil (mostly)	Ancient crystalline shield, rich in minerals (iron ore of Minas Gerais), with Paraná flood basalts in the south; drained by Amazon tributaries, Paraná, São Francisco
Altiplano Plateau	Bolivia-Peru	Most extensive high plateau in the world outside Tibet
Andes	Venezuela, Colombia, Ecuador, Peru, Bolivia, Chile, Argentina	Longest continental mountain range in the world (~7,000 km); highest range outside Asia
Aconcagua	Andes	Highest peak of the Andes (6,961 m, Argentina); highest mountain outside Asia
Ojos del Salado	Chile-Argentina border	World's highest active volcano (~6,893 m)

- Amazon rainforest is often called the "lungs of the planet", but its net oxygen contribution is near zero (it consumes most of what it produces); it is a vital carbon sink and rainfall regulator.
- Lake Titicaca: bordered by Bolivia and Peru; world's highest navigable lake.

South America: Major Rivers

River	Source	Mouth	Notes
Orinoco	Guiana Highlands, Venezuela	Atlantic Ocean	-

Australia & Oceania

- Oceania: collective name for island nations/territories across the Pacific between Asia and the Americas.
- Traditionally divided into Australasia (Australia & New Zealand), Melanesia, Micronesia, Polynesia.
- Australia: smallest continent; 6th largest country; often called the "island continent".
- Lies in the Southern Hemisphere, surrounded by Indian & Pacific Oceans.
- The Great Barrier Reef, the world's largest coral reef system, lies off Queensland in the Coral Sea.
- Highest peak in Australia: Mount Kosciuszko. Longest river: Murray.

Australia: Key Features

Feature	Location/Notes
Great Dividing Range	Australia's largest mountain range, aka Eastern Highlands; among the longest land-based ranges in the world; divides east-flowing and west-flowing rivers
Australian Alps	Highest range within the Great Dividing Range; highest peak Mt. Kosciuszko
Great Victoria Desert	Australia's largest desert; active sand-ridge desert (SA and WA)
Great Artesian Basin	Largest and deepest artesian basin in the world; underlies about one-fifth of Australia

- Micronesia: 4 smaller island groups, Northern Mariana, Caroline, Marshall, Gilbert (now Kiribati); Guam (Mariana) is the largest island.
- Polynesia: includes Hawaii, Tonga, Tuvalu, Samoa, Cook Islands, Easter Island, French Polynesia, Niue, Pitcairn Islands, Tokelau, Wallis and Futuna; New Zealand lies in the Polynesian Triangle.
- Melanesia: Western Pacific, dominated by volcanic islands, between Equator and Tropic of Capricorn; includes Irian Barat, Papua New Guinea, the Bismarcks, Solomon Islands, New Caledonia, Fiji, Vanuatu.
- Zealandia: ~94% submerged; identified as an 8th geological continent, formerly part of Gondwanaland.

Antarctica

- ~90% of world's ice and 70% of freshwater found here.
- No countries or native population.
- 7 nations claim parts: New Zealand, Australia, France, Norway, UK, Chile, Argentina.

Antarctica: Governance & India

Antarctic Treaty (1959, in force 1961): continent reserved for peace and science; India joined in 1983
 Indian stations: Dakshin Gangotri (1983, decommissioned), Maitri (1989), Bharati (2012); new Maitri-II planned
 Indian Antarctic Act, 2022 regulates Indian expeditions and activities; nodal body: NCPOR, Goa

Antarctica: Key Features

Feature	Key Facts
Ellsworth Mountains	Highest mountain range in Antarctica; western margin of Ronne Ice Shelf; southwestward extension of the Antarctic Andes
Mount Vinson (Vinson Massif)	Highest point of the continent (~4,892 m); in the Sentinel Range of the Ellsworth Mountains
Trans-Antarctic Mountains (TAM)	Highest peak Mt. Kirkpatrick (~4,528 m); divides continent into Lesser/West Antarctica and Greater/East Antarctica
Mt. Erebus	On Ross Island; southernmost active volcano on Earth
McMurdo Dry Valley	One of world's most extreme deserts; row of snow-free valleys; includes Lake Vida (saline) and Onyx River (Antarctica's longest river, a meltwater stream)
Don Juan Pond	McMurdo valley; world's most saline water body; resists freezing to -50°C

Major Straits of the World

Strait	Separates (Landmass)	Joins (Seas/Water Bodies)
Formosa Strait	China and Taiwan	South China Sea and East China Sea
Yucatan Strait	Mexico and Cuba	Gulf of Mexico and Caribbean Sea
Cook Strait	New Zealand (North & South Islands)	Tasman Sea and South Pacific Ocean
Mozambique Channel	Mozambique and Madagascar	Indian Ocean
Bab-el-Mandeb	Yemen (Arabian Peninsula) and Djibouti-Eritrea (Africa)	Gulf of Aden and Red Sea
Hormuz Strait	Iran and Oman	Gulf of Oman and Persian Gulf
Ten Degree Channel	Little Andaman and Car Nicobar	Andaman Sea and Bay of Bengal
Sunda Strait	Java and Sumatra islands (Indonesia)	Java Sea and Indian Ocean
Florida Strait	Cuba and USA	Gulf of Mexico and Atlantic Ocean
Korea Strait	Japan and South Korea	East China Sea and Sea of Japan
Bering Strait	Russia (Asia) and Alaska (North America)	Chukchi Sea (Arctic Ocean) and Bering Sea (Pacific Ocean)
Strait of Gibraltar	Spain and Morocco	Atlantic Ocean and Mediterranean Sea
Strait of Malacca	Malay Peninsula and Sumatra	Andaman Sea (Indian Ocean) and South China Sea (Pacific Ocean)
Bosphorus Strait	Divides Europe from Asia	Black Sea and Sea of Marmara
Palk Strait	India and Sri Lanka	Bay of Bengal (NE) and Palk Bay (SW)
Bass Strait	Tasmania and mainland Australia	Indian Ocean (Great Australian Bight side) and Tasman Sea
Strait of Dover	UK and France	English Channel and North Sea
Dardanelles	Europe (Gallipoli) and Asia (Anatolia), Turkey	Sea of Marmara and Aegean Sea
Strait of Magellan	Mainland South America and Tierra del Fuego	Atlantic and Pacific Oceans
Nine Degree Channel	Kavaratti/Kalpeni and Minicoy (Lakshadweep)	Arabian Sea
Eight Degree Channel	Minicoy (India) and Maldives	Arabian Sea
Six Degree Channel (Great Channel)	Great Nicobar (India) and Sumatra (Indonesia)	Andaman Sea and Indian Ocean
Duncan Passage	South Andaman and Little Andaman	Andaman Sea and Bay of Bengal

CHAPTER 03

Atmosphere, Cyclones and Winds, World Forests, World Climate

Composition of Atmosphere

- Atmosphere = air mixture (mainly Nitrogen, Oxygen) surrounding Earth, held by gravity.

Atmospheric Composition by Gas

Constituent	% by Volume	Concentration (PPM)
Nitrogen	78.084	780,840
Oxygen	20.946	209,460
Argon	0.934	9,340
Carbon Dioxide	0.036 (NCERT); now ~0.042%	360 (NCERT); 423.9 ppm global average in 2024 (WMO) vs ~278 ppm in 1750

Permanent vs Variable Gases

Type	Gases	Feature
Permanent Gases	Nitrogen, Oxygen, Argon, Neon, Helium, Krypton, Hydrogen, Xenon	Constant proportion
Variable Gases	CO ₂ , water vapour, ozone, methane, nitrous oxide, CFCs, particles	Proportion varies by place/time

Carbon Dioxide

- Trace gas, ~0.04% of atmosphere (423.9 ppm in 2024, WMO); 2nd most important greenhouse gas after water vapour.

Argon

- Third most abundant gas (0.93%).

Nitrogen

- Most abundant gas (78% by volume).
- Cycled through nitrogen fixation (N₂ → usable compounds by bacteria/lightning) and denitrification (returns N₂ to air).

Water Vapour

- Varies from nearly 0 to ~4% by volume: up to 4% in warm, wet tropics; < 1% in cold, dry polar areas and deserts.
- Decreases from equator to poles.
- Contributes to greenhouse effect.
- Transparent to incoming shortwave solar radiation but opaque to outgoing longwave terrestrial radiation → heats surface and lower atmosphere.

Oxygen

- Essential for respiration/combustion.

Dust Particles

Ozone

- Found mostly 10–50 km above the surface (~90% in the stratosphere, densest at ~15–35 km).
- Absorbs/filters UV radiation.
- Good Ozone: natural stratospheric ozone, acts as protective UV shield.
- Bad/Surface Ozone: forms in troposphere near ground when pollutants (cars, power plants, industries) react with sunlight, a harmful pollutant.
- Ozone Hole: depletion especially over Antarctica/Arctic.
- Caused mainly by chlorine and bromine compounds: CFCs, halons, carbon tetrachloride (CCl₄), methyl bromide; one Cl atom can destroy ~1 lakh O₃ molecules.
- Dobson Unit: measure of total ozone in a column if compressed into one layer.
- Polar Stratospheric Clouds (PSCs/nacreous clouds): contain water, nitric acid, sulfuric acid; form at very low temperatures; enhance chlorine-catalysed ozone depletion.

Ozone: Key Dates & Numbers

Ozone hole = area with total ozone below 220 DU; minimum values inside fall to ~100 DU

World Ozone Day: 16 September

Vienna Convention (1985): framework for protecting the ozone layer

Montreal Protocol (1987): first treaty with universal ratification, phases out ODS

Kigali Amendment (2016): phases down HFCs; India to cut HFCs by 85% by 2047 (reduction starts 2032); India ratified in 2021

UNEP/WMO assessment (2023): ozone layer on track to recover to 1980 levels by ~2040 (most of world), ~2045 (Arctic), ~2066 (Antarctic)

Structure of Atmosphere

- Classified by (a) chemical composition, (b) temperature variation.

Atmosphere by Chemical Composition

Layer	Extent	Key points
Homosphere	Surface to 80 km	Uniform composition (density decreases with altitude); comprises Troposphere, Stratosphere, Mesosphere
Heterosphere	80–10,000 km	Gases separated by molecular diffusion; lighter gases more abundant with height; includes the Thermosphere and Exosphere. The Kármán line (100 km) is the conventional boundary of outer space

Atmosphere by Temperature Variation

Layer	Altitude range	Temperature behaviour	Key features
Troposphere	~18 km equator, 13 km mid-latitude, 8 km poles (avg 13 km)	Falls per Normal Lapse Rate; reaches -80°C over equator, -45°C over poles at tropopause	Weather layer; ~75–80% of atmospheric mass and nearly all water vapour; thicker at equator (strong convection); "convective region"; ends at tropopause; theatre of cyclones, anticyclones, precipitation
Tropopause	Boundary troposphere–stratosphere	Constant (~-80°C equator, ~-45°C poles)	Marks end of troposphere
Stratosphere	Up to 50 km	Temperature rises with height (ozone absorbs UV) to -0°C at the stratopause (~50 km)	Free of clouds/weather except nacreous clouds; contains the ozone layer; jet aircraft fly in the lower stratosphere

Layer	Altitude range	Temperature behaviour	Key features
Mesosphere	50–80 km	Decreases to about -90°C to -100°C at ~ 80 km (mesopause), the coldest part of the atmosphere	Topmost layer of homosphere; most meteors burn up here; noctilucent clouds
Thermosphere	80–400 km	Rises very rapidly; air extremely rarefied	Contains Ionosphere, aids radio transmission; incoming space vehicles/meteorites begin heating via friction; a person wouldn't feel warm despite high temperature (very low pressure); ISS/satellites orbit here
Exosphere	Beyond ~ 400 km	Gradually increases (direct sunlight)	Uppermost layer; extremely rarefied; light gases (He, H) escape to space; coincides with space

Normal Lapse Rate

6.5°C per 1,000 m ($6.5^{\circ}\text{C}/\text{km}$) in the troposphere

Standard reference rate: exam-important

Also written as 1°C per 165 m

- Ionosphere: between upper mesosphere and thermosphere (~ 80 – 400 km).
- Ionosphere is electrically charged by cosmic rays, gamma/X-rays, short UV.
- Reflects radio waves, aiding telecommunication.
- Auroras occur in its lower part near Arctic/Antarctic Circles ($\sim 66.5^{\circ}\text{N/S}$).
- Aurora Borealis = north; Aurora Australis = south.

Insolation and Heat Budget

Insolation

- Insolation = energy received by Earth's surface as short waves.
- Measured in Langley (Ly).
- Diffuse Radiation: solar radiation reaching surface after change of direction via scattering.
- Tropics receive the highest annual insolation, decreasing poleward.

Factors Affecting Insolation

Factor	Effect
Distance from Sun	Avg Earth–Sun distance ~ 149.6 million km; Earth receives slightly more insolation at perihelion (Jan) than at aphelion (July)
Path length of rays	Small-angle rays traverse more atmosphere $\rightarrow$ more reflection/absorption $\rightarrow$ less intensity
Atmospheric transparency	Cloud cover/thickness, dust (reflect/absorb), water vapour (absorbs) all reduce insolation
Duration of daily sunlight	Longer day $\rightarrow$ more insolation
Angle of incidence	Higher latitude $\rightarrow$ smaller angle $\rightarrow$ slant rays spread over larger area + traverse more atmosphere $\rightarrow$ lower insolation per unit area
Land configuration	Tropics $\sim 320 \text{ W}/\text{m}^2$, poles $\sim 70 \text{ W}/\text{m}^2$; max over subtropical deserts (clear atmosphere, least cloud); at same latitude, land $>$ oceans

Aphelion and Perihelion

Length of Day and Angle of Inclination

Scattering, Reflection, Absorption, Diffusion

- Scattering: radiation striking small atmospheric objects disperses in all directions.
- Scattering explains sky colour: blue sky, red sunrise/sunset.
- Reflection: incoming waves bounce back without converting to heat.
- Absorption: insolation absorbed by dust/clouds/water vapour and converted to heat.

Twilight

- Twilight = light from scattering of sunlight in upper atmosphere when Sun is below horizon, illuminating lower atmosphere/surface.
- Duration grows with latitude: shortest at the equator (civil twilight ~20–25 minutes).

Stages of Twilight

Stage	Sun position below horizon	Light conditions
Daylight	Above horizon	-
Civil Twilight	Sunset to -6°	Bright; western sky bright, few brightest stars visible east; outdoor light sufficient
Nautical Twilight	-6° to -12°	Much darker; artificial light needed; brighter stars visible
Astronomical Twilight	-12° to -18°	Very dark; hundreds of stars visible
Darkness	More than -18°	Sky black (no light pollution); thousands of stars, Milky Way visible

Albedo

- Albedo = ability of a surface to reflect sunlight.
- High Albedo: light surfaces (ice, snow).
- Low Albedo: dark surfaces, absorb more → warming.
- Earth's average (planetary) albedo ≈ 0.30 (depends on clouds, ice, deserts, oceans, forests).

Heat Budget

- Heat Budget = exact balance between incoming heat (insolation) and outgoing heat (terrestrial radiation).

Four Heating Processes

Process	Mechanism
Radiation	Earth absorbs shortwave insolation, re-radiates longwave terrestrial radiation; atmosphere heated from below
Conduction	Heat transfers from surface to adjacent air, then upward, key to heating lower atmosphere
Convection	Vertical heat transfer via rising air, limited to troposphere, needs a medium
Advection	Horizontal heat transfer via wind; more significant than convection for diurnal mid-latitude weather; tropical local winds e.g. Loo of Northern India result from it

Earth's Heat Budget Breakdown

Category	Share	Breakdown
Reflected back to space	35%	27 units from cloud tops; 2 from snow/ice-covered areas; 6 scattered by the atmosphere (NCERT)

Category	Share	Breakdown
Absorbed energy	65%	14 units absorbed directly by the atmosphere; 51 units absorbed by the Earth's surface
Terrestrial radiation returned to space	65% (17%+48%)	17 units radiated directly from the surface to space; 48 units radiated by the atmosphere (14 absorbed from insolation + 34 received from the surface: 6 by direct absorption, 9 by convection/turbulence, 19 by latent heat of condensation)

- Heat absorbed (65%) equals heat returned (65%) → Earth neither warms nor cools despite continuous transfer.
- Terrestrial Radiation = longwave radiation from surface/atmosphere; includes Latent heat transfer (phase-change heat) and Sensible heat transfer (heat without state change).

Latitudinal Heat Balance

- Surplus net radiation between 40°N and 40°S.

Temperature

Factors Influencing Air Temperature

Factor	Effect
Latitude	Temperature depends on insolation received, which varies with latitude
Altitude	Atmosphere heated indirectly from below; places near sea level warmer than high elevations, per the Normal Lapse Rate
Distance from sea	Land heats/cools faster than sea ("moderating effect of sea"); coastal places have lower temperature extremes (e.g., Jaisalmer hotter, Mumbai cooler)
Prevailing winds	Warm winds (trades, westerlies) raise temperature; cold polar easterlies lower it
Air masses/ocean currents	Cold Labrador Current → more snowfall, lower temp on Labrador coast; warm Gulf Stream → makes NW Europe warmer than peers at same latitude
Mountain barriers	Obstruct wind/air-mass movement; e.g. Himalayas block cold winds from Central Asia, keeping North India warmer in winter
Cloudiness	Cloudy sky blocks solar radiation (lowers day temp) and traps terrestrial radiation (raises night temp); clear sky raises day temp but loses more at night (tropical deserts hot by day, cold by night)
Nature of surface	Snow reflects more (lower temp); dense forest absorbs more (higher temp)
Excess landmass in NH	Makes isotherms irregular (land-sea contrast)
Continentality	Diurnal/annual temperature range highest in continental interiors; lowest temperatures in polar/sub-polar continental regions

Global Temperature Distribution

- Horizontal: shown via Isotherms (lines of equal temperature, reduced to sea level).
- Isotherms are generally parallel to latitude (temperature falls poleward).
- Sudden bends occur at ocean-continent boundaries (differential heating).

Seasonal Distribution (January and July)

- January: isotherms deflect poleward over oceans (e.g., North Atlantic, kept warm by Gulf Stream/North Atlantic Drift).
- January: isotherms deflect equatorward over continents (overcooled, polar cold penetrates south, e.g. Siberian plain).
- July: equatorial oceans >27°C; subtropical continental Asia (30°N) >30°C.

Temperature Anomaly

- Temperature Anomaly = difference between a place's mean temperature and its latitude's mean temperature.
- Positive anomaly = Local > Latitude mean.
- Negative anomaly = Local < Latitude mean.

Heat Zones of the Earth

Atmospheric Pressure

- Atmospheric pressure = force per unit area from weight of air molecules above surface.
- Measured in millibar (mb); avg sea-level pressure = 1013.2 mb.
- Pressure difference drives horizontal air movement = wind (high to low pressure).
- Vertical distribution: highest at sea level, falls rapidly with altitude (~1 mb per 10 m, varying with temperature/topography/sea proximity).
- Shown via Isobars (lines of equal pressure at constant levels).

Factors Affecting Pressure

Factor	Effect
Temperature	Inversely related: rising temp expands/raises air → pressure drops; falling temp densifies air → pressure rises
Altitude	Inversely related: more spaced molecules at height → lower pressure
Water Vapour	Molecular weight of water (18 g/mol) < air (29 g/mol) → humid air lighter → reduces pressure

Factors Affecting Wind Velocity/Direction

Force	Description
Pressure Gradient Force	Rate of pressure change with distance: strong when isobars close, weak when apart
Frictional Force	Greatest at surface, decreases with height, extends up to 1–3 km; minimum over sea
Coriolis Force	Deflects wind right in NH, left in SH; proportional to latitude: max at poles, absent at equator
Centripetal Force	Perpendicular to wind movement, inward toward rotation centre, lets air follow curved path (parallel to isobars) around pressure centres

Pressure and Wind Circulation

- Geostrophic Wind: with no friction and straight isobars, pressure gradient force balances Coriolis force → wind blows parallel to isobars.

Pressure Belts

Pressure Belts

Belt	Latitude	Nature	Key notes
Equatorial Low (Doldrums/ITCZ)	0°–10° N & S	Thermally induced (low)	Warm air rises; trade winds from both hemispheres converge; vertical currents dominate, little horizontal wind ("zone of calm"); also Inter Tropical Convergence Zone

Belt	Latitude	Nature	Key notes
Sub-tropical High (Horse Latitudes)	25°–35° N & S (~30°)	Dynamically induced (high)	Rising equatorial air deflects poleward, sinks at 30°N/S, completing Hadley Cell; diverges poleward as westerlies, equatorward as trade winds; calm, sunny, little precipitation; name from stalled ships throwing horses overboard
Sub-polar Low	55°–65° (~60°) N & S	Dynamically induced (low)	Convergence of sub-tropical westerlies & polar easterlies; rising air completes the Ferrel Cell
Polar High	Near poles	Thermally induced (high)	Low temperature compresses/densifies air; sinking air from sub-polar low adds to it; more pronounced over Antarctic landmass than Arctic Ocean; completes Polar Cell

- Azores High: semi-permanent subtropical high over the North Atlantic near the Azores; largest and strongest in summer.

Shifting of Pressure Belts

- Due to Earth's $23\frac{1}{2}^\circ$ tilt, belts shift seasonally with the sun.
- Shift 5° northward when sun is over Tropic of Cancer (21 June).
- Shift 5° southward when sun is over Tropic of Capricorn (22 December).
- Mediterranean climate example: winter rain from westerlies, dry offshore trades in summer.

Winds

Classification

Classification of Winds

Category	Types
Surface Winds: Primary/Planetary/Permanent	Trade Winds, Westerlies, Polar Easterlies
Surface Winds: Secondary/Seasonal	Monsoons, Cyclones
Surface Winds: Tertiary/Local	Sea/land breeze, mountain/valley wind, named local winds
High Altitude Winds	Jet Streams

Permanent (Planetary) Winds

Wind	Location/Range	Direction/Deflection	Key characteristics
Trade Winds	30°N–30°S (subtropical high → equatorial low)	NE in NH, SE in SH	Warm, moisture-carrying, heavy rain on eastern sides of tropical islands; regular, speed constant; linked with depressions/cyclones; substituted by monsoon in Indian/Pacific oceans
Westerlies	30°–60° N/S (subtropical high → sub-polar low)	South Westerlies (NH), North Westerlies (SH)	Strong and variable, dominated by cyclones/anticyclones; bring rain to western coasts of temperate lands; in SH blow over open ocean as the Roaring Forties, Furious Fifties and Shrieking Sixties
Polar Easterlies	60°–90° N/S (polar high → sub-polar low)	NE in NH, SE in SH; deflected west by Coriolis	Cold and dry (from ice caps); meet westerlies along the polar front

- Doldrum: quiet/stagnant ITCZ zone; ships historically stuck for lack of wind.
- Horse Latitudes: sub-tropical high over N. Pacific/Atlantic; weak variable winds, frequent calms.

Seasonal (Periodic) Winds

- Monsoon (Arabic "Mausim" = season): seasonal wind reversal from unequal land-water heating.
- Monsoon blows sea→land in summer, land→sea in winter.

Local Winds

Wind	Description
Sea Breeze	Sea→land by day; land heats faster → air rises → low pressure → cool humid sea air flows in
Land Breeze	Land→sea by night; land loses heat faster → air above sea stays warmer, rises → land air (higher pressure) flows to sea
Valley Breeze (Anabatic)	Valley→mountain by day; sun-warmed slopes heat adjacent air → rises up slope
Mountain Breeze (Katabatic)	Mountain→valley after sunset; slopes cool fast → denser air flows downslope; if ice-covered, blows day and night

Named Local Winds

Wind	Direction/Nature	Region
Bora	Cold, dry, NE	Adriatic coast (Croatia, Slovenia, NE Italy)
Chinook	Warm, dry, westerly (foehn type); "snow eater"	Eastern (leeward) slopes of the Rockies (USA-Canada)
Fohn	Warm, dry, descending	Northern (leeward) slopes of the Alps, Switzerland
Harmattan	Dry, dusty, NE trade wind from the Sahara; called "Doctor wind" for its relief from humid heat	West Africa (Gulf of Guinea coast)
Khamsin	Hot, dry, dusty, southerly/SE	Egypt (N. Africa) → E. Mediterranean
Loo	Hot, dry, westerly (May-June)	Plains of North India & Pakistan
Mistral	Cold, northerly	Rhône valley (France) → Gulf of Lion (Mediterranean)
Nor'wester	Warm, dry foehn wind on the east; brings rain to the West Coast	New Zealand (South Island). Note: in India, "Nor'westers" = Kalbaisakhi thunderstorms of West Bengal/Odisha
Pampero	Cold, strong polar wind	Pampas (Argentina, Uruguay)
Simoom	Strong, dry, desert wind	Sahara, Israel, Jordan, Syria, Arabian desert
Sirocco	Hot, dry, dusty southerly; becomes humid over the sea ("blood rain" when dust-laden)	Sahara → Italy, Sicily, S. Europe
Zonda	Warm, dry foehn type	Eastern slope of Andes, Argentina
Santa Ana	Hot, dry, offshore; fans wildfires	Southern California (USA)
Mango showers / Cherry blossoms	Pre-monsoon showers (Apr-May)	Kerala & Karnataka (help mango and coffee crops)

Polar Vortex

- Large low-pressure, cold-air area surrounding both poles.
- When weak → low-pressure system breaks off, jet stream turns wavy, cold air pushes south.
- In NH winter it expands, sending cold air south with the jet stream (regular seasonal pattern, Arctic outbreaks in US).

Jet Streams

- High-altitude, fast westerly wind belts near the tropopause (~9–16 km).
- Speeds commonly 150–300 km/hr, up to ~400 km/hr in winter; wavy (Rossby waves); present in both hemispheres.

Surface-Weather Effects of Jet Streams

Effect	Mechanism
Cold waves	A wavy polar jet lets frigid polar-vortex air spill south → severe cold waves in N. America/Eurasia
Sudden SW-monsoon burst	Sudden northward shift of the subtropical westerly jet from south of the Himalayas to north of the Tibetan Plateau (early June) triggers the monsoon burst
Western disturbances	Polar westerly jet carries Mediterranean-cyclone rain over Punjab/Haryana, aiding wheat
Aviation	Eastbound flights use jet streams to save time and fuel; cause clear-air turbulence

Types of Jet Streams

Type	Characteristics
Polar Front Jet Stream	Thermally induced; parallel to surface fronts, west to east, sinusoidal; strongest at 200–300 mb; swings between 40–60° latitude; non-continuous, year-round; speeds 160–200 km/hr
Sub-tropical (Tropical) Westerly Jet Stream	Year-round at ~25°–30° latitude, at the poleward edge of the Hadley cell (~200 mb); more stable than the polar jet; strongest in winter over East Asia/Japan; in Indian winter it flows south of the Himalayas and steers Western Disturbances
Tropical Easterly Jet (TEJ)	Summer only (June–Sept), easterly, at ~13–16 km over peninsular India (~15°N); linked with a strong SW monsoon; weak TEJ means weak monsoon
Somali Jet (Findlater Jet)	Low-level (~1.5 km) cross-equatorial jet off the Somali coast in summer; carries moisture to India's west coast

Air Masses

- Air Mass: extensive body of air with fairly uniform temperature/humidity at a given altitude horizontally.
- Identified by temperature/humidity characteristics and geographic origin (e.g. dry + warm + tropical continental = continental Tropical, cT).
- Fronts form where two differing air masses meet.
- Source Region: where an air mass acquires its characteristic properties (e.g. oceans, snow-covered land, wide deserts).

Classification

Air Mass Classification

Air Mass	Temperature	Stability	Source Region	Humidity
Maritime tropical (mT)	Warm (~22–30°C)	Conditionally unstable; unstable in summer	Tropical/subtropical oceans (e.g. Gulf of Mexico, Bay of Bengal)	High
Continental tropical (cT)	Hot (~30–42°C by day)	Unstable but too dry for much rain	Subtropical hot deserts (Sahara, Arabia, Australia, Thar)	Low
Continental arctic (cA)	Extremely cold	Very stable; strong surface inversion	Arctic Basin, Greenland, Antarctica	Very low
Maritime polar (mP)	Cool to cold	Unstable in winter (over warmer water); stable in summer	Oceans poleward of ~40°–50° (N. Pacific, N. Atlantic)	Moderate

Air Mass	Temperature	Stability	Source Region	Humidity
Continental polar (cP)	Cold; very cold in winter	Stable	Continental interiors 45°–65° N (Canada, Siberia)	Low

Modification of Air Mass

Thermodynamic Modification of Air Masses

Designation	Trigger	Effect
'W' (warm)	Cooled from below (moves over colder surface)	Temperature inversion, increased stability, opposes ascent; e.g. cT/mT moving poleward → cTW/mTW
'K' (Kalt/cold)	Heated from below (moves over warmer surface)	Increased lapse rate/instability, favours ascent/condensation/precipitation; e.g. polar air to tropics → cPK/mPK

- Anticyclone: divergence → subsidence → stability, suppresses precipitation.
- Cyclone: convergence → ascent → instability, favours precipitation.

Fronts

- Fronts: boundaries between air masses of differing temperature/humidity/density.
- Typical of mid-latitudes (30°–65° N/S); uncommon in tropics/poles.
- Frontogenesis: front formation; causes temperate/extra-tropical cyclones.
- Frontolysis: dissipation of a front.
- Frontal activity → instability → cloudiness/precipitation (ascending warm air cools adiabatically, condenses, rains).

Types of Fronts

Front	Mechanism	Weather
Cold Front	Cold air moves rapidly into warm air (~65 km/hr); being denser it cuts through and replaces warm air; frontolysis once warm air is fully uplifted	Sharp weather change, temperature can drop >15°C within the first hour; narrow band of cloudiness, rapid showers/thunderstorms, possible tornadoes (common in warm sector e.g. USA); clouds progress cirrus → altocumulus → dark nimbus/cumulonimbus at the front → heavy rain; short-lived but violent
Warm Front	Warm (less dense) air rides over retreating cold air rather than displacing it; slope less steep; frontolysis once warm air is fully above cold air	Gradual temperature/wind change; light to moderate, steady precipitation over a wide belt for many hours; temperature rises after passage; no cumulonimbus (gentle slope); cirrostratus ahead forms a halo around the sun/moon
Occluded Front	Cold air mass overtakes and undercuts a warm air mass (cold front of rotating low catches warm front); frontolysis once warm sector is fully undertaken by cold air	Mixed cold/warm-front weather; common in western Europe; associated with mid-latitude cyclone formation
Stationary Front	Surface position unchanged (neither air mass can push the other); warm/cold air flow parallel	Cumulonimbus forms over the front → heavy rain, flooding

Temperature Inversion

- Inversion: reversal, temperature rises with altitude, warm air over cold.

Conditions Favouring Temperature Inversion

Condition
Long winter nights (greater radiation loss)
Cloudless clear sky (unobstructed heat loss)
Dry air near ground (limits re-absorption)
Slow air movement (less vertical mixing)
Snow-covered ground (high albedo, max heat loss by reflection)

Types

Types of Temperature Inversion

Type	Description
Air Drainage (Intermontane Valley Inversion)	In mountains/valleys; surface cools fast, cold denser air flows downslope, settles as a low-temperature zone while upper layers stay warmer
Frontal/Cyclonic Inversion	Warm front rises, cold front sinks where they meet; has considerable slope (unlike the mostly horizontal others); occurs in temperate zone, causes varied precipitation; unstable, destroyed by weather change
Ground/Surface Inversion	Air cooled by contact with colder surface until below overlying air's temperature; favoured by clear nights (rapid radiative ground cooling); if surface air falls below dew point → fog; common at higher latitudes; at lower/middle latitudes seen on cold winter nights, destroyed by day
Subsidence (Upper Surface) Inversion	Descending air compressed/heated by increased pressure → reduced lapse rate → higher elevation warmer than lower; frequent over northern continents in winter (dry air) and subtropical oceans (subsiding air under high-pressure centres); occurs aloft

Effects

- Causes frost.
- Traps dust/pollutants at surface.
- Reduces rainfall (convection suppressed, hurting agriculture).
- Can intensify thunderstorms/tornadoes (energy release when inversion blocks normal convection).

Tropical Cyclones

- Rotation: counterclockwise in NH, clockwise in SH.
- Tropical cyclones: violent storms over tropical oceans moving to coasts.
- Have closed circulation around a low-pressure Eye, whirling from rapid upward hot-air movement under Coriolis force.

Conditions for Formation

Conditions for Tropical Cyclone Formation

Condition
Large sea surface with temperature $> 27^{\circ}\text{C}$
Sufficient Coriolis force (zero at equator: no cyclones there; significant from $\sim 5^{\circ}$ latitude; $\sim 65\%$ of cyclonic activity between 10° – 20°)
Small vertical wind-speed variation
Pre-existing weak low-pressure area/low-level cyclonic circulation
Upper divergence above the system

Condition
High relative humidity in the lower and middle troposphere
Warm water (26–27°C) extending 60–70 m deep (so convection doesn't mix in cooler water)

- Western-margin preference: cold currents cool eastern ocean margins (unfit for breeding); warm currents favour the west.
- Most frequent over the Western Pacific (South China Sea), Bay of Bengal, Arabian Sea, Caribbean/Gulf of Mexico: all are tropical seas with warm SST driving evaporation/cloud/rain.

Types by Intensity

IMD Classification of Cyclonic Disturbances (North Indian Ocean)

IMD Category	Wind speed (knots)	Wind speed (km/h)
Depression	17–27	31–49
Deep Depression	28–33	50–61
Cyclonic Storm (named from this stage)	34–47	62–88
Severe Cyclonic Storm	48–63	89–117
Very Severe Cyclonic Storm	64–89	118–166
Extremely Severe Cyclonic Storm	90–119	167–221
Super Cyclonic Storm	≥ 120	≥ 222

Structure

- Eye: roughly circular centre, mild winds/favourable weather, little/no precipitation, blue sky.
- Eyewall: ring of deep convection around eye, strongest surface winds.

Life Cycle

- Formation: evaporative water-vapour/heat transfer from warm ocean is key; convection + condensation builds cumulus clouds.
- Mature Stage: thunderstorm air rises, spreads horizontally at tropopause → high-altitude positive pressure accelerates downward convection → subsidence warming compresses a warm low-pressure Eye.
- Decay: begins when warm moist air supply weakens/cuts off (core pressure, warmth, wind speed decline), typically after landfall or over cold water.

Naming

- Regional naming conventions apply.
- WMO has six Regional Specialised Meteorological Centres (RSMCs) and five Tropical Cyclone Warning Centres worldwide; RSMC New Delhi (IMD) issues advisories and names cyclones for the North Indian Ocean.
- Naming of North Indian Ocean cyclones began in 2004 (first name: Onil, contributed by Bangladesh).
- Advisories go to 13 WMO/ESCAP Panel countries: Bangladesh, India, Iran, Maldives, Myanmar, Oman, Pakistan, Qatar, Saudi Arabia, Sri Lanka, Thailand, UAE, Yemen.
- A new list of 169 names (13 from each of the 13 countries) was released in April 2020; names are used in sequence and never repeated.

Regional Names for Tropical Cyclones

Region	Name used
Caribbean Sea, Atlantic & NE Pacific	Hurricanes
Indian Ocean	Tropical cyclones
China Sea	Typhoons
Northern Australia	Willy willies

Region	Name used
Coast of USA	Hurricanes (tornadoes are a different, small-scale phenomenon)
Japan	Taifu
Philippines	Baguio

- IMD Colour-coded Warnings: Green (no warning), Yellow (be updated/watch), Orange (be prepared), Red (take action).

Recent North Indian Ocean Cyclones (Quick Recall)

2024: Remal (May, West Bengal–Bangladesh), Asna (Aug, rare land-origin Arabian Sea storm off Gujarat), Dana (Oct, Odisha), Fengal (Nov–Dec, Puducherry/TN)
 2025: Shakhti (Oct, Arabian Sea, near Oman), Montha (Oct, landfall near Narasapuram, Andhra Pradesh), Senyar (Nov, rare Strait of Malacca storm, Sumatra), Ditwah (Nov–Dec, Sri Lanka)
 2026 (till mid-October): only depressions/deep depressions so far; no named cyclonic storm

Arabian Sea vs Bay of Bengal

Arabian Sea vs Bay of Bengal: Key Numbers

Arabian Sea: historically ~1 extremely severe cyclone per 4–5 years
 1891–2000: ~308 cyclones crossed east coast (103 severe); 48 crossed west coast (24 severe)
 IITM Pune study (2021): in 2001–2019 vs 1982–2000, Arabian Sea cyclone frequency rose ~52% and very severe cyclones ~150%
 Arabian Sea surface warming is a key driver of this trend

- Bay of Bengal's historical edge: high SST + humidity trigger strong cyclones.
- Ganga-Brahmaputra freshwater inflow keeps warm surface water from mixing below.
- Arabian Sea's historical weakness: stronger winds dissipate heat.
- Rising Arabian Sea activity (due to global warming) → active convection, heavy rain, intense cyclones.
- El Niño Modoki ("pseudo El Niño"): unfavourable for Bay of Bengal cyclogenesis but favourable for Arabian Sea.

Thunderstorm

- Violent, short-lived disturbance, almost always with lightning, thunder, dense clouds, heavy rain/hail, strong gusty winds.

Three Stages of a Thunderstorm

Stage	Description
Cumulus	Strong updrafts of warm, moist air build towering cumulus clouds; no rain yet
Mature	Updrafts and downdrafts coexist; cloud reaches the tropopause (anvil top); heaviest rain, hail, lightning, gusty winds
Dissipating	Downdrafts dominate and cut off the supply of warm moist air; rain weakens and the storm dies out

Tornado

- Narrow, violently rotating air column from a thunderstorm to the ground (vortex of rapidly moving air).
- Formation: horizontal spin within storm cell (wind speed/direction change) → tipped vertical by rising air through thunderclouds → updraft verticalizes the column → storm becomes a supercell thunderstorm → tornado may descend.
- USA has the most tornadoes ("Tornado Alley" of the Great Plains); Bangladesh has recorded the deadliest (Daulatpur–Saturia, 1989).

Tornado Numbers

Funnel wind speed may exceed 500 km/hr

Intensity rated on the Enhanced Fujita scale (EF0–EF5) based on damage

Extra-Tropical / Temperate / Mid-Latitude Cyclones

- Active over 35°–65° latitude in both hemispheres; dynamic origin via frontogenesis.
- Also called Temperate, Extra-Tropical, Frontal, or Wave Cyclones.
- Move west to east; more pronounced in winter.
- Form from dynamic interaction of warm tropical and cold polar air at the polar front.

Polar Front Theory

- Warm-humid tropical air collides with dry-cold polar air, forming the polar front (a discontinuous surface).
- Pressure drop along the front → warm air moves north, cold moves south → sets up anticlockwise cyclonic circulation (NH, Coriolis).
- Produces a well-developed cyclone with warm + cold fronts, warm sector wedged between cold sectors.
- Once warm air fully lifted → front occludes → cyclone dissipates.

Characteristics

- Large: ~1,000–2,000 km across, much larger than tropical cyclones.
- Height: 8–11 km.
- Individual frontal cyclones last 3–10 days, moving west to east, path controlled by the polar jet stream.

Distribution and Seasonality

- Occur nearly year-round but most common in winter, late autumn, early spring (greater temperature disparity).
- Main tracks: North Atlantic (towards NW Europe), North Pacific (Aleutian Low), Mediterranean in winter (source of India's Western Disturbances).

Anticyclone

- Opposite of a cyclone: outward-spiralling circulation around a high-pressure centre.
- Winds swirl clockwise in NH.
- Usually brings fair weather.

Humidity

- Specific Humidity: mass of water vapour per unit mass of air (g/kg); unaffected by changes in volume/pressure.
- Absolute Humidity: mass of water vapour per unit volume of air.
- Relative Humidity: percentage of moisture present vs. saturation capacity at a given temperature.
- Dew Point: temperature at which an air sample becomes saturated.

Evaporation and Condensation

- Evaporation: liquid→gas conversion on heating; continuous process.
- Evaporation contributes ~90% of atmospheric moisture.

Factors Affecting Evaporation Rate

Factor	Effect
Water available	Directly proportional
Temperature	Increase at constant pressure increases evaporation
Wind speed	Removes saturated air, replaces with dry → more evaporation; high temp + low RH + strong wind can dehydrate soil to depth of many inches
Water composition	Inversely proportional to salinity: fresh water evaporates faster than salt water; ocean water evaporates ~5% more slowly than fresh water under similar conditions

Forms of Condensation

Dew

- Water droplets deposited on cooler surfaces of solid objects (stones, grass, leaves), not on airborne nuclei.

Frost

- Forms on cold surfaces when condensation occurs below freezing, deposited as ice crystals (not droplets).

Mist and Haze

- Mist: tiny vapour suspended near Earth's surface, causes visibility loss.

Fog

Types of Fog

Type	Formation
Radiation Fog	Radiational cooling of long-wave radiation → temperature inversion → cools moist near-ground air to dew point
Advection Fog	Moist air over colder surface cools below dew point, over land or water (e.g. steam fog)
Frontal Fog	Three types: warm-front pre-frontal, cold-front post-frontal, frontal-passages

Clouds

- Clouds: mass of minute water droplets/ice crystals from condensation of water vapour in free air at elevation.

Four Basic Types (by height/expanse/density/transparency)

Four Basic Cloud Types

Type	Description
Cirrus	Thin, detached, feathery, always white; formed at high altitudes (8,000–12,000 m)
Cumulus	Cotton-wool appearance, forms at 4,000–7,000 m, scattered patches, flat base
Stratus	Layered, spreads across large sky area, from heat loss or mixing of differing-temperature air masses
Nimbus ("to rain")	Black/dark grey, shapeless, thick, at middle levels or near surface, opaque to sunlight

Grouping by Altitude

Cloud Types: Height, Colour, Weather, Shape

Type of Cloud	Height	Colour	Weather Indication	Shape/Appearance
Cirrus	High (>6,000 m)	White	Approaching warm front	Transparent, wispy, covers most/all sky
Cirrostratus	High	Transparent/White	Variable weather	Halo/ring of light around sun or moon
Altostratus	Mid	White/Light Grey	Warmer weather coming; light precipitation possible	Layer blanketing sky; sun as dim disk; no blue sky patches
Stratus	Low	Dark Grey	Gloomy, sometimes light precipitation	Featureless flat layer; mostly cloudy

Type of Cloud	Height	Colour	Weather Indication	Shape/Appearance
Nimbostratus	Low	Dark Grey	Steady rain/snow	Thick dark layer, heavy precipitation
Cumulus	Low	White	Typically sunny	Fluffy, tall, cauliflower-like; early-day in sunny weather
Cumulonimbus	Low (vertical development)	Dark Grey	Thunderstorm	Dense, towering; classic "thunderstorm cloud"

Precipitation and Rainfall Types

- Three types by origin: Convictional, Cyclonic/Frontal, Orographic/Relief.

Convictional Rainfall

- Heavy, short-duration rain with lightning/thunder; most common rainfall type globally.
- Forms from Cumulus, Cumulonimbus clouds.
- India: pre-SW-monsoon summer convectional rain includes Mango showers (Karnataka, Kerala, Konkan, Goa), Kal Baisakhi (West Bengal), Bardoli cheera (Assam).

Snowfall, Sleet, Hailstones, Drizzle

- Snowfall: condensation below freezing → ice crystals grow into flakes too heavy to stay suspended.
- Snowfall common in Western Himalaya, mid/high latitudes in winter.
- Sleet: rain passing through a cold layer, freezing into small ice balls before reaching ground, liquid when formed, freezes while falling.
- Hailstones: form in thunderstorms; strong convective currents carry moist air to great heights where it freezes into rounded ice that falls under its own weight.
- Drizzle: drop size <0.5 mm.
- Rainfall (proper): drop size >0.5 mm.

Cyclonic/Frontal Rainfall

- Leads to condensation into stratus cloud; saturated cloud precipitates gradually over hours to a few days.
- Prevalent in north-west Europe (warm oceanic meets cold continental air).
- In India: winter Western Disturbances bring frontal-type rain/snow to NW India, which benefits rabi crops (wheat).

Orographic/Relief Rainfall

- Moist sea wind obstructed by mountain → rises, cools, forms clouds, precipitates on the windward side.
- On the leeward side, descending air warms and its moisture-holding capacity rises → stays dry (Rain Shadow Zone).

Orographic Rainfall Example: Western Ghats

Mahabaleshwar (windward): >600 cm/yr
Pune (leeward, rain shadow): ~70 cm/yr

World Distribution of Rainfall

- Coastal areas get more rain than continental interiors (seas are better moisture sources).
- Eastern coasts between 35°–40° N/S get more rain, decreasing westward (trade wind/monsoon influence).
- Due to Westerlies, western coasts between 45°–65° N/S receive rain first, decreasing eastward.

World Rainfall Zones

Zone	Amount	Examples
Heavy	>200 cm/yr	Equatorial belt, windward mountain slopes on west coasts of cold temperate zone, coastal monsoon lands

Zone	Amount	Examples
Moderate	100–200 cm/yr	Interior continental areas
Low	50–100 cm/yr	Central tropical lands; eastern & interior parts of temperate lands
Very low	<50 cm/yr	Rain shadow zones of continental interiors; high latitudes

World Climate Classification

- Climate = average weather of a place over a long period (30+ years).
- Koeppen's Classification (most widely accepted), by Wladimir Koeppen, a Russian-born German climatologist (first scheme 1884, revised 1918 and 1936).
- Five main types (capital letters A, B, C, D, E), based on temperature/precipitation.

Koeppen Climate Classification

Code	Group	Characteristics
A	Tropical Climate	Coldest-month average $\geq 18^{\circ}\text{C}$
B	Dry Climate	Potential evaporation exceeds precipitation
C	Temperate/Continental (warm temperate)	Coldest-month average between -3°C and 18°C
D	Continental Climate	Coldest-month average $\leq -3^{\circ}\text{C}$
E	Polar Climate	All months average $< 10^{\circ}\text{C}$
H	Highland Climate	Cold due to elevation

Climate Types by Latitude Belt and Margin

Latitude belt	Western Margin	Continental/Interior	Eastern Margin
0°–10°	Equatorial: no winter, precipitation throughout	–	Monsoon: seasonal wind reversal, summer rain, influenced by easterlies & tropical cyclones
10°–30°	Desert: very low precipitation	Savannah: summer rain	Monsoon
30°–45°	Mediterranean: dry summer, cold wet winter (winter rainfall)	Steppe: summer rain	China: warm moist summer, cool dry winter; precipitation throughout
45°–65°	British: chilly rainy winter & warm rainy summer, precipitation throughout (ocean currents, temperate cyclones)	Boreal/Siberian: very low precipitation, lack of vegetation	Laurentian: long winter & pleasant summer, precipitation throughout
65°–90°	Tundra: lack of flora/fauna diversity	–	Tundra

Hot, Wet Equatorial Climate (Koeppen Af)

- Location: 5°–10° N/S of equator; lowlands of Amazon, Congo, Malaysia, East Indies.
- Temperature: uniform, mean monthly $24\text{--}27^{\circ}\text{C}$, no winter.
- Precipitation: heavy, well-distributed year-round, annual average $>150\text{ cm}$.
- Vegetation: luxuriant tropical rainforest (Amazon = Selvas); evergreen hardwood (mahogany, ebony, dyewoods); coastal mangrove swamps.
- Economy: plantation crops (rubber, cocoa); primitive hunting/collecting or shifting cultivation.

Tropical Monsoon and Tropical Marine Climates

- Large-scale seasonal land/sea breezes: on-shore wet monsoon in summer, off-shore dry monsoon in winter.

- Best developed in Indian subcontinent, Burma, Thailand, Laos, Cambodia, Vietnam, south China, northern Australia.
- Outside this zone, year-round on-shore Trade Winds modify it into Tropical Marine Climate (more even rainfall): Central America, West Indies, NE Australia, Philippines, parts of East Africa, Madagascar, Guinea Coast, eastern Brazil.
- Vegetation: deciduous (sheds leaves in dry period).
- Valuable hardwood, e.g. Teak (Myanmar has historically been the leading producer of natural teak).
- Monsoon mechanism, Summer: sun over Tropic of Cancer heats Central Asia $>10^{\circ}\text{C}$ above normal (intense low; Himalayas trap heat) while seas stay cool; SH winter high over Australian interior sends South-East Monsoon to Java, crossing equator and drawn to the continental low, arriving as South-West Monsoon over India.
- Monsoon mechanism, Winter: sun over Tropic of Capricorn makes Central Asia extremely cold/high-pressure, sending out North-East Monsoon, crossing equator and drawn to the Australian low as North-West Monsoon in northern Australia.
- Punjab plains (the last to receive the SW monsoon) are the first to see its withdrawal.
- Cash crops: sugarcane (Brazil and India are the largest producers; cane gives ~80% of world sugar), jute (Ganga-Brahmaputra delta), cotton (major commercial crop of the Indian subcontinent).
- Lumbering: teak (Myanmar leading producer, durable/fungus-resistant), also Neem, Banyan, Mango, Sal, Acacia, Eucalyptus.
- Shifting cultivation is the most primitive farming type (clears new forest on exhaustion, for subsistence).

Savanna / Sudan Climate

- Between equatorial rainforests and trade-wind deserts, 8° – 20° N/S.
- Best developed in Sudan ("Sudan Climate").
- Regions: Africa, South America, Australia, India, Myanmar, Thailand, Madagascar.
- South American: north of equator, Llanos (Orinoco basin); south, Campos (Brazilian Highlands).
- Indian: Northern Karnataka, Southern Maharashtra, Telangana.
- Average annual rainfall 80–160 cm.
- Vegetation: tall grass + low deciduous trees ("bush-veld").
- "Big game country", herbivores: zebra, antelope, giraffe, deer, gazelle, elephant.
- Carnivores: lion, leopard, cheetah, hyena, jackal (jaguar in South American savannas).
- Tribes: Masai (East African plateau, pastoralists), Hausa (N. Nigeria, settled cultivators).

Hot Desert and Mid-Latitude Desert Climates

- Deserts: evaporation exceeds precipitation.
- Two types: Hot (Saharan type) and Temperate/mid-latitude (Gobi type).
- Hot Deserts ("Trade Wind Deserts"): western coasts, 15° – 30° N/S.
- Examples: Sahara (3.5 million sq mi), Great Australian Desert, Arabian, Iranian, Thar, Kalahari, Namib (Asia/Africa/Australia); Mohave, Sonoran, California, Mexican (N. America); Atacama/Peruvian (rain shadow + offshore trades).
- Atacama/Peruvian is the driest desert on Earth, <2 cm/yr.
- Temperature: $>30^{\circ}\text{C}$ average, no cold season, large diurnal range.
- Mid-Latitude Deserts: arid, 30° – 60° N/S, continental interiors.
- Examples: Gobi, Taklamakan (China), Kazakhstan, Uzbekistan; Great Basin (USA); Patagonian (Argentina, Andes rain shadow).
- Vegetation: xerophytic (cacti, prickly shrubs, long-rooted wiry grasses, scattered dwarf acacias, date palms).

Warm Temperate Western Margin (Mediterranean) Climate

- 30° – 45° N/S on western margins; best developed around the Mediterranean Sea; also Central California, Central Chile, SW Africa (Cape Town), Southern/SW Australia (Perth, Adelaide).
- Agriculture: "orchard land of the world", citrus (oranges, lemons, limes, citrons; deep roots, thick skin; 70% of world citrus exports).
- Olive = most representative crop.
- Viticulture: ~75% of world wine production.
- Wheat = most common food crop, then barley.

Temperate Continental (Steppe) Climate

- Continental interiors, in the Westerly wind belt; grasslands practically treeless (continentality).

Regional Names of Steppe Climate

Region name	Location
Steppes	Eurasia: Black Sea shores to Altai foothills
Puszta	Hungary and surrounding regions
Prairies	North America (Rockies foothills to Great Lakes)
Pampas	Argentina and Uruguay
Bush-veld (more tropical)	Northern South Africa
High Veld (more temperate)	Southern South Africa
Downs	Murray-Darling basin, southern Australia
Canterbury	New Zealand

- Vegetation: practically treeless, shorter grasses than savanna.
- Economy: ploughed for mechanized wheat/maize → "Granaries of the world" (Prairies).

Warm Temperate Eastern Margin (China Type) Climate

- Subtypes: China, Gulf, Natal.

Subtypes of China Type Climate

Subtype	Region	Key feature
China Type	Central & north China, southern Japan	Temperate monsoonal; summer low over "heart of Asia" draws tropical Pacific air as SE Monsoon (rain-bearing); winter steep gradient (cold Mongolia/Siberia vs. warm Pacific) drives dry, bitterly cold continental polar NW Monsoon
Gulf Type	South-eastern United States	Similar but weaker monsoonal character; no full seasonal wind reversal; warm Gulf Stream + on-shore Trades narrow temperature range
Natal Type	Non-monsoonal SH warm temperate eastern margin: Natal (S. Africa)/Brazil, eastern Australia, southern Brazil, Paraguay, Uruguay, northern Argentina	Narrow continents + dominant maritime influence eliminate monsoonal elements seen in NH equivalents

Cool Temperate Western Margin (British Type) Climate

- Belt: Britain to NW Europe lowlands, France, Belgium, Netherlands, Denmark, western Norway, northern/western Iberia.
- Vegetation: deciduous woodland (oak, elm, ash, birch, beech, poplar; shed leaves for winter).
- Dairy thrives in Denmark, Netherlands, New Zealand.

Cool Temperate Continental (Siberian/Boreal/Taiga) Climate

- Belt: Alaska, Canada, Scandinavia, northern European Russia and Siberia (50°–70°N).
- Verkhoyansk (~67.5°N, 133°E) and Oymyakon in Siberia are among the coldest inhabited places on Earth ("cold pole" of NH, below -67°C recorded).
- Vegetation: evergreen coniferous forest dominant (needs little rain); belt runs Alaska→Canada→Labrador and continues across Eurasia.

Cool Temperate Eastern Margin (Laurentian Type) Climate

- Found only in NH: NE North America (Eastern Canada incl. Newfoundland, NE USA incl. Maritime Provinces & New England) and eastern Asia (Eastern Siberia, North China, Manchuria, Korea, northern Japan).
- Climate: cold dry winters (well below freezing, heavy snow), warm wet summers (~25°C, would be hotter without offshore cold Arctic currents).

- Meeting of warm Gulf Stream and cold Labrador Current off Newfoundland produces dense mist/fog and heavy precipitation.
- Vegetation: coniferous forest north of 50°N (Asian part continues the Taiga belt), giving way to deciduous (oak, beech, maple, birch) south of 50°N.
- Fishing most significant economic activity, especially Newfoundland and Japan (shallow continental shelves rich in plankton where warm/cold currents meet).

Tundra / Polar / Arctic Climate

- Covers roughly one-fifth of Earth's land surface (incl. alpine tundra); the coldest biome.
- Distribution: north of Arctic Circle, south of Antarctic Circle.
- Vegetation: no trees; sparse mosses, lichens, low vegetation.
- Fauna: wolves, foxes, musk-ox, Arctic hare, lemmings, polar bears (Arctic only); penguins live only in the Southern Hemisphere.
- Inuit (Eskimos) in Greenland, northern Canada, Alaska: igloos in winter; subsist on fish, seals, walruses; Sami (Lapps) of Scandinavia herd reindeer.

World Forests

- Forests cover ~32% of world's land area (4.14 billion hectares, FAO Global Forest Resources Assessment 2025).
- Russia has the single largest forest area of any country (mostly Taiga/Boreal forest).
- Brazil holds the largest area of tropical forest.
- Global deforestation (2015–2025) averaged ~10.9 million ha/year; net forest loss slowed to ~4.12 million ha/year due to afforestation and natural expansion (FRA 2025).
- India in FRA 2025: 9th in total forest area (up from 10th) and 3rd in annual net forest area gain.
- International Day of Forests: 21 March.
- REDD+ (Reducing Emissions from Deforestation and Forest Degradation): UN framework incentivizing developing countries to conserve forest carbon stocks.

Major World Forest Types

Forest Type	Location	Key Features
Tropical Rainforest (Equatorial)	Amazon (Brazil, Peru, Colombia, Venezuela, Ecuador, Bolivia, Guyana, Suriname, French Guiana); Congo Basin (DR Congo, Congo, Cameroon, Gabon, CAR); SE Asia (Indonesia, Malaysia)	Hot, wet, no dry season; dense multi-layered canopy, broadleaf evergreen hardwoods (mahogany, ebony); highest biodiversity/species density of any biome; thin, nutrient-poor soils (nutrients held in biomass, not soil)
Tropical Monsoon/Deciduous Forest	Indian subcontinent, Myanmar, Thailand, Indo-China	Distinct wet/dry seasons; trees shed leaves in dry season; less dense than rainforest; valuable hardwoods e.g. teak
Savanna Woodland	Sub-Saharan Africa (largest extent), Llanos/Campos (South America), northern Australia, parts of India	Tall grass with scattered drought-resistant, fire-resistant trees (acacia, baobab); marked wet/dry seasons; rich large-mammal fauna
Mediterranean (Sclerophyllous) Forest/Scrub	Mediterranean Basin, California chaparral, central Chile (matorral), SW Australia (mallee), Cape Region (South Africa, fynbos)	Hot dry summers, mild wet winters; small, tough, waxy-leaved (sclerophyllous) evergreen trees/shrubs (oaks, pines); fire-adapted, rapid post-fire regeneration
Temperate Deciduous Forest	NW Europe (British type), NE USA, parts of China, Japan, Korea	Four distinct seasons; broadleaf trees (oak, beech, maple, birch) shed leaves in winter; moderate rainfall year-round; moderately fertile brown-earth soils
Temperate Coniferous/Evergreen Forest	Pacific NW USA, parts of Chile, NZ	Heavy rainfall, mild temperatures; tall evergreen conifers (redwood, Douglas fir); among highest biomass density of any forest type

Forest Type	Location	Key Features
Taiga / Boreal Forest	Sub-Arctic belt: Siberia/Russia (largest share), Scandinavia, Canada, Alaska (50°–70°N)	World's largest terrestrial forest biome by area; cold winters, short cool summers; evergreen coniferous softwoods (spruce, fir, pine); thin, acidic, nutrient-poor podzol soils; low biodiversity but major global carbon sink
Mangrove Forest	Tidal/estuarine coasts of tropics & subtropics: Sundarbans (India–Bangladesh, world's largest mangrove forest), Indonesia, Amazon delta, Niger delta	Salt-tolerant trees in brackish tidal zones; stilt/prop roots and pneumatophores for aeration in waterlogged soil; nursery for marine life, storm-surge/coastal buffer

CHAPTER 04

Arid Regions/Deserts, Grasslands, Countries & Borders, World Capitals, Geographical Sobriquets

World Deserts

- Desert: region receiving very low precipitation (generally <25 cm/year), classified as Hot (tropical) or Cold (temperate/polar).
- Hot deserts lie mostly along 15°–35° latitudes (Horse Latitudes) due to descending dry air of sub-tropical high-pressure belts.

Major World Deserts

Desert	Location	Type	Key Fact
Sahara	North Africa (Algeria, Libya, Egypt, Mali, Niger, Chad, Sudan, Morocco, Tunisia, Mauritania, Western Sahara)	Hot	Largest hot desert in the world (~9.2 million sq km)
Antarctic Desert	Antarctica	Cold/Polar	Largest desert in the world overall (by area, polar desert)
Gobi	Mongolia & northern China	Cold	Largest desert in East Asia; rain-shadow cold desert (Himalayas)
Kalahari	Southern Africa (Botswana, Namibia, South Africa)	Hot/Semi-arid	Famous for Okavango Delta on its fringe
Patagonian	Argentina & Chile (South America)	Cold	Largest desert in the Americas; rain-shadow desert east of the Andes
Great Victoria	Australia	Hot	Largest desert in Australia
Arabian Desert	Saudi Arabia & neighbouring Gulf states	Hot	Contains Rub' al Khali (Empty Quarter), largest contiguous sand desert
Great Basin	Western USA (Nevada, Utah etc.)	Cold	Largest desert in the USA; cold desert between the Sierra Nevada and the Wasatch Range
Chihuahuan	Mexico & south-western USA	Hot	Largest hot desert in North America
Thar (Great Indian Desert)	India (Rajasthan) & Pakistan	Hot	Most densely populated desert in the world
Mojave	South-western USA	Hot	Driest desert in North America; location of Death Valley
Atacama	Chile (South America)	Hot/Cold coastal	Driest non-polar place on Earth (some areas have never recorded rainfall)
Namib	Namibia & Angola (south-west Africa)	Hot/Coastal	Considered the oldest desert in the world; cooled by the Benguela Current
Iranian Desert (Dasht-e-Kavir/Dasht-e-Lut)	Iran	Hot	Dasht-e-Lut has recorded the hottest land-surface temperatures on Earth (~70°C, satellite data)

Desert	Location	Type	Key Fact
Taklamakan	Xinjiang, China	Cold	One of the largest sandy (shifting-dune) deserts in the world

- Rain-shadow deserts: formed on the leeward side of mountains (e.g., Patagonian Desert in lee of the Andes).
- Coastal/cold-current deserts: formed due to cold ocean currents suppressing rainfall (e.g., Atacama – Peru/Humboldt Current; Namib – Benguela Current).

World Grasslands

- Broadly divided into Temperate Grasslands (mid-latitudes) and Tropical Grasslands/Savanna (low latitudes, with wet-dry seasons).

Major World Grasslands

Grassland	Local Name	Continent/Region	Key Features
Temperate Grassland	Prairies	North America (USA, Canada)	Known as the "granary/breadbasket" of North America; wheat and maize belt
Temperate Grassland	Pampas	South America (Argentina, Uruguay)	Famous for cattle ranching and alfalfa; fertile, used for wheat too
Temperate Grassland	Steppes	Asia & Europe (Russia, Central Asia, Ukraine, Mongolia)	Largest continuous belt of temperate grassland; cold winters
Temperate Grassland	Veld	South Africa	On the plateau of South Africa; cattle and sheep rearing, maize
Temperate Grassland	Downs	Australia (south-east)	Used mainly for sheep grazing (merino wool)
Tropical Grassland	Savanna	Africa (esp. East & Central Africa)	Largest tropical grassland; associated with Big Five wildlife (Serengeti, Maasai Mara)
Tropical Grassland	Llanos	Venezuela & Colombia (Orinoco basin)	Seasonal flooding tropical grassland
Tropical Grassland	Campos	Brazil (Brazilian Highlands)	Tropical/sub-tropical grassland, also called Cerrado in parts

Countries and Their Borders

- There are about 44 landlocked countries; largest: Kazakhstan; doubly landlocked: Liechtenstein and Uzbekistan.

Border & Neighbour Facts

Countries with the most land neighbours (14 each): China and Russia (tied for most international borders).

China's 14 neighbours: Afghanistan, Bhutan, India, Kazakhstan, North Korea, Kyrgyzstan, Laos, Mongolia, Myanmar, Nepal, Pakistan, Russia, Tajikistan, Vietnam.

Russia's 14 neighbours: Norway, Finland, Estonia, Latvia, Lithuania, Poland, Belarus, Ukraine, Georgia, Azerbaijan, Kazakhstan, China, Mongolia, North Korea.

Country with longest total international land border: China (followed closely by Russia).

Longest single bilateral international border in the world: Canada–USA border (~8,891 km, including Alaska).

Indian context: India–China (~3,488 km) is India's second longest land border.

Second longest bilateral border: Kazakhstan–Russia border (~7,644 km).

India's longest border with a neighbour: Bangladesh (~4,096.7 km); Bangladesh is surrounded by India on three sides.

India shares borders with 7 countries: Pakistan, China, Nepal, Bhutan, Bangladesh, Myanmar, Afghanistan (via POK), plus maritime neighbours Sri Lanka, Maldives, Indonesia, Thailand (and Myanmar, Bangladesh, Pakistan).

India's shortest land border: with Afghanistan (~106 km, via Pakistan-occupied Kashmir).

Special Border/Geography Terms

Term	Meaning/Example
Landlocked country	No coastline; e.g., Nepal, Bhutan, Mongolia, Switzerland, Austria
Double landlocked (landlocked country surrounded only by other landlocked countries)	Only 2 in the world: Liechtenstein (surrounded by Switzerland & Austria) and Uzbekistan (surrounded by 5 landlocked neighbours)
Enclave	Territory entirely surrounded by another country's territory; e.g., Lesotho (surrounded by South Africa), San Marino & Vatican City (surrounded by Italy)
Exclave	Part of a country's territory geographically separated from its main part; e.g., Kaliningrad (Russia, separated by Lithuania/Poland), Alaska (USA, separated by Canada)
Semi-enclave	Territory almost entirely surrounded by another country except for a coastline; e.g., Gambia (within Senegal, but with Atlantic coast)
Tripoint	Point where three countries' borders meet; e.g., India–China–Myanmar area near Diphu Pass

- Smallest country in the world by area: Vatican City.
- Russia is the largest country in the world by area, spanning Europe and Asia (11 time zones).
- Longest coastline: Canada (~2 lakh km including islands); India's coastline is ~11,098 km after the 2023–24 re-measurement (earlier 7,516.6 km).

Capital Cities of the World and Towns**Major World Capitals (Capital vs Largest-City Mismatches & Key Facts)**

Country	Capital	Note (Largest city if different / Key fact)
Australia	Canberra	Largest city is Sydney, NOT the capital
Brazil	Brasília	Largest city is São Paulo; Rio de Janeiro was the former capital; Brasília a planned city since 1960
USA	Washington, D.C.	Largest city is New York City
Canada	Ottawa	Largest city is Toronto
India	New Delhi	Mumbai is the largest city proper; Delhi has the largest urban agglomeration
Pakistan	Islamabad	Largest city is Karachi (former capital)
Turkey	Ankara	Largest city is Istanbul (former capital, Constantinople)
South Africa	Pretoria (administrative), Cape Town (legislative), Bloemfontein (judicial)	Has THREE capital cities; largest city is Johannesburg
Switzerland	Bern (officially the "federal city")	Largest city is Zürich
Nigeria	Abuja	Largest city is Lagos (former capital)
Myanmar	Naypyidaw	Largest city is Yangon/Rangoon (former capital)
Sri Lanka	Sri Jayawardenepura Kotte (administrative/legislative)	Colombo is the commercial capital and largest city
Tanzania	Dodoma (official)	Dar es Salaam is the largest city and de facto commercial capital
Kazakhstan	Astana (also called Nur-Sultan 2019–2022)	Largest city is Almaty (former capital)
Vietnam	Hanoi	Largest city is Ho Chi Minh City (Saigon)
Ivory Coast (Côte d'Ivoire)	Yamoussoukro (official)	Abidjan is the largest city and economic capital

Country	Capital	Note (Largest city if different / Key fact)
Benin	Porto-Novo (official)	Cotonou is the seat of government and largest city
Netherlands	Amsterdam (constitutional capital)	The Hague is the seat of government/judiciary (ICJ, ICC)
Israel	Jerusalem (claimed capital)	Tel Aviv hosts most foreign embassies/is the largest metro
Malaysia	Kuala Lumpur	Putrajaya is the administrative capital
Montenegro	Podgorica (official)	Cetinje is the "Old Royal Capital"
Bolivia	Sucre (constitutional)	La Paz is the seat of government (administrative capital); Santa Cruz de la Sierra is the largest city
China	Beijing	Largest city is Shanghai
Egypt	Cairo	Also the largest city; a New Administrative Capital is being built east of Cairo
Saudi Arabia	Riyadh	Jeddah is a major commercial hub
UAE	Abu Dhabi	Largest city is Dubai
Japan	Tokyo	Also the largest city; former capital was Kyoto
Indonesia	Jakarta (relocation to Nusantara, East Kalimantan, in progress)	Nusantara on Borneo is being built as the new capital
Germany	Berlin	Former West Germany capital was Bonn
Bangladesh	Dhaka	-
Nepal	Kathmandu	-
Bhutan	Thimphu	-
Afghanistan	Kabul	-
Maldives	Malé	-
Philippines	Manila (capital), Quezon City (largest city)	-

Geographical Sobriquets

Sobriquet	Place
Land of the Rising Sun	Japan
Land of the Midnight Sun	Norway
Land of the White Elephant	Thailand
Land of the Thunderbolt	Bhutan
Land of the Golden Pagoda	Myanmar
Land of the Golden Fleece	Australia
Land of a Thousand Lakes	Finland
Land of the Dawn-lit Mountains	Arunachal Pradesh (India)
Land of the Morning Calm	Korea
Land of the Maple Leaf	Canada
Emerald Isle	Ireland
Roof of the World	Tibetan Plateau / Pamir Knot
Pearl of the Orient / Pearl of the East	Hong Kong, Philippines (Manila); Sri Lanka is the "Pearl of the Indian Ocean"
Pink City	Jaipur, India

Sobriquet	Place
Windy City	Chicago, USA
Sugar Bowl of the World	Cuba
Gift of the Nile	Egypt
Garden City of India	Bengaluru
Eternal City	Rome
City of Lights	Paris (France)
City of Lakes	Udaipur, India
City of Palaces	Kolkata, India
City of Dreams / City of Seven Islands	Mumbai, India
Manchester of India	Ahmedabad, India
Granary of the World / Breadbasket of the World	Prairies of North America
Sorrow of Bihar	River Kosi
Sorrow of Bengal	River Damodar (before dams)
Blue Mountains	Nilgiri Hills, India
Forbidden City	Lhasa, Tibet (the Imperial Palace in Beijing is also called the Forbidden City)
Hermit Kingdom	North Korea (historically Korea)
Venice of the East	Alappuzha/Kochi (Kerala, India), also Bangkok (historically)
Land of the Long White Cloud (Aotearoa)	New Zealand
Island of Cloves	Zanzibar (Tanzania)
Spice Garden of India	Kerala
Switzerland of the East	Kashmir, India
Abode of Clouds	Meghalaya (India)
Land of Five Rivers	Punjab (India/Pakistan)
Queen of the Arabian Sea	Kochi, Kerala
Scotland of India	Kodagu (Coorg), Karnataka
Silicon Valley of India	Bengaluru
Sorrow of China	River Hwang Ho (Yellow River), due to frequent flooding

CHAPTER 05

Hydrosphere

Introduction

Water Distribution on Earth

Reservoir	Share
Oceans	97.25% (~97% of all water)
Ice caps/Glaciers	2.05%
Groundwater	0.68%
Lakes	0.01%
Soil Moisture	0.005%
Atmosphere	0.001%
Streams/Rivers	0.0001%
Biosphere	0.00004%

Hydrological Cycle

Circulation of water on, in, and above the Earth (liquid, solid, gaseous).

Begins with evaporation from the ocean surface.

Evaporation: liquid→gas, driven by solar radiation.

Transpiration: water vapour discharge from plant leaves.

Sublimation: snow directly to vapour.

Condensation: vapour to droplets, forming fog/clouds.

Precipitation: rain/snow/hail.

Runoff: stored basin water draining via rivers/creeks/lakes.

Snowmelt: runoff from melting snow.

Percolation: vertical flow of water through soil/rock under gravity.

Oceans: Overview

- Oceans merge naturally into one another (unlike continents), making demarcation difficult.
- Earth's oceanic part is divided into five oceans: Pacific, Atlantic, Indian, Southern, Arctic.

Relief of the Ocean Floor

- Ocean floor has 4 sections: Continental Shelf, Continental Slope, Deep Sea Plain (Abyssal Plain), Oceanic Deep/Trench.

Continental Shelf

- Extended, shallowest margin of each continent, occupied by shallow seas/gulfs.
- Average gradient 1° or less; depth generally up to ~150–200 m; ends at the shelf break.
- Narrow where high mountains lie close/parallel to coast, e.g., almost absent off Chile (parallel to Andes).
- World's largest shelf: Siberian shelf (Arctic Ocean), up to 1,500 km.

Continental Shelf Width in India

Coast	Width	Note
Eastern coast	~50 km	Narrower (deltaic coast)
Western coast	~150 km	Far broader, widest off Gujarat–Maharashtra

- India's Exclusive Economic Zone (EEZ) covers ~2.02 million sq km; India has also filed claims to an extended continental shelf with the UN CLCS.

Significance of Continental Shelf

Significance	Example/Detail
Mineral and Hydrocarbon	Commercial exploitation of metallic/non-metallic iron ore and hydrocarbons
Richest zone of Fishing	Chilika Lagoon (E. coast India), Palk Bay (TN), Kanyakumari Coast (Bay of Bengal); Grand Banks of Newfoundland, North Sea, Sunda shelf
Biological diversity	Sunlight reaching shallow bottom promotes plankton growth (fish food); shelves often contain coral reefs

Continental Slope

- Generally no marine deposits (steep gradient) and less marine life than the shelf.
- Gradient 2–5°; depth 200–3,000 m.
- Sediment at its foot forms the Continental Rise.

Abyssal Plain (Deep Sea Plain)

- The most extensive feature of the ocean floor.
- Fine-grained sediments (clay, silt) cover the floor.
- Oozes: calcareous or siliceous sediments made of the shells/skeletons of plankton, where such organisms are abundant.

Ocean Trenches and Deepes

- Trenches: long, narrow linear depressions.
- Mariana Trench (western North Pacific, east of the Philippines near Guam) is the deepest trench; Challenger Deep ~10,935 m (~11 km).
- The Pacific Ocean has the most trenches overall.

Minor Relief Features of Ocean Floor**Minor Relief Features**

Feature	Key facts
Seamounts	Mountains with pointed summits rising from the seafloor that do not reach the surface; volcanic; 3,000–4,500 m tall; e.g. Emperor Seamount (extension of the Hawaiian Islands)
Guyots	Flat-topped seamounts; show gradual subsidence (summits flattened by waves earlier); ~10,000 seamounts and guyots in the Pacific alone (NCERT)
Mid-Oceanic Ridges	Two mountain chains separated by a large depression; peaks up to 2,500 m; some emerge above surface (e.g. Iceland)
Submarine Canyons	Long, narrow, deep valleys cut into shelves and slopes, often off large river mouths; e.g. Hudson Canyon (USA), Ganga (Swatch of No Ground, Bay of Bengal)
Atoll	Low tropical islands; coral reefs around a central depression; may enclose a freshwater/brackish/saline lagoon

Temperature of Ocean Waters

- Reason: water has a high specific heat, sunlight penetrates to depth, and waves/currents mix the heat through a large volume.
- Measurement: Bathythermograph (depth temperature).

Factors Affecting Temperature Distribution

Factor	Effect
Latitude	Temperature decreases equator→poles with falling insolation; tropical average ~27°C; falls ~0.5°C per degree latitude
Land–water distribution	NH (more land) oceans receive more heat than SH (more water) oceans
Prevailing winds	Offshore winds (land→ocean) reduce temperature; Onshore winds pile up warm water, raising it
Ocean Currents	Warm currents raise temperature in cold areas (e.g. Gulf Stream warms E. N. America/W. Europe); Cold currents lower it in warm areas (e.g. Labrador Current cools NE North America)
Minor factors	Submarine ridges, local weather (cyclones, fog), shape/extent of seas

- Vertical distribution: temperature is maximum at surface, falls rapidly to 200 m, then slows.

Thermocline

Transition layer between warm mixed surface water and cold deep water.
 Relevant to forecasting: e.g. hurricane risk, since warm water above it fuels hurricanes.
 Main thermocline occurs in the mesopelagic zone (sharpest temperature change).
 No permanent thermocline in polar regions (both layers cold, little gradient).
 A small seasonal summer thermocline forms in polar regions, but mixing continues near year-round.

Salinity of Ocean Water

- Salinity: total dissolved salt (in grams) per 1,000 g (1 kg) of seawater, expressed in ‰ or ppt; average ~35‰.

Composition of Dissolved Salts

Salt	Percentage
Sodium Chloride	77.8%
Magnesium Chloride	10.9%
Magnesium Sulphate	4.7%
Calcium Sulphate	3.6%
Potassium Sulphate	2.5%

Factors Affecting Salinity

Factor	Effect
Evaporation	Direct relation; higher salinity at tropics than Equator due to high evaporation/dry air
Precipitation	Inverse relation; equatorial regions (high rainfall) have lower salinity than subtropical high-pressure belts; polar ice-melt also reduces salinity
River influx	Lowers salinity at mouths (e.g. Ganga, Congo, Niger, Amazon; Danube/Dniester/Dnieper reduce Black Sea salinity); strongest in rainy season, weakest in dry season
Pressure/winds	Anticyclones with high temperature and clear skies raise surface salinity (e.g. Subtropical High-Pressure Belt)

Factor	Effect
Ocean circulation	Currents redistribute salt: the North Atlantic Drift raises salinity in the North Sea; the cold Labrador Current lowers it off NE North America

- Horizontal distribution: open-ocean salinity is 33–37‰; it is highest in the subtropics and lower near the equator and towards the poles.
- Highest salinity between 20°–40°N, ~36‰ (high evaporation, low rainfall).
- Isohalines: lines of equal surface salinity.
- Halocline: sharp salinity change, at 300–1,000 m depth (same depth range as the Thermocline, but a distinct boundary).

Salinity of Notable Water Bodies

Water Body	Salinity	Notes
The Baltic Sea	7 ppt	Low: large river-water influx
The Mediterranean Sea	~38–39 ppt	High: high evaporation
The Black Sea	18 ppt	Low: large river-water influx
Dead Sea	~340 ppt (NCERT: 238 ppt)	Nearly 10× saltier than average seawater (35 ppt); between Jordan, Israel and the West Bank
Red Sea	~41 ppt	High evaporation, no river inflow
Caspian Sea	~12 ppt	World's largest enclosed water body; classed as both sea and lake

- Measurement: via electric current between two electrodes of a salinity meter.

Sea-Bordering Countries: Memory Tricks

Sea	Mnemonic	Countries
Caspian Sea	TARIK	Turkmenistan, Azerbaijan, Russia, Iran, Kazakhstan
Black Sea	Turkish BURGeR	Turkey, Bulgaria, Ukraine, Russia, Georgia, Romania
Red Sea	DESSEY	Djibouti, Eritrea, Sudan, Saudi Arabia, Egypt, Yemen
Adriatic Sea	MBA ICS	Montenegro, Bosnia, Albania, Italy, Croatia, Slovenia
North Sea	-	Denmark, England, Netherlands, Germany, France, Belgium, Scotland, Norway
Baltic Sea	-	Russia, Denmark, Germany, Sweden, Estonia, Latvia, Lithuania, Poland, Finland

- Red Sea lies between Africa and Asia; its northern arms are the Gulfs of Suez and Aqaba, and it opens into the Gulf of Aden through Bab-el-Mandeb; the Suez Canal links the Mediterranean to the Indian Ocean via the Red Sea.
- Baltic Sea is an arm of the Atlantic; 8 of its 9 littoral states are NATO members (Finland joined 2023, Sweden 2024), leaving Russia as the only non-NATO littoral state.

Density of Ocean Water

- Pure water's maximum density = 1 unit at 4°C, determined only by temperature and pressure.
- Seawater density is affected by temperature, pressure and salinity.
- Horizontal/latitudinal distribution: upper-layer density generally increases tropics→poles.
- Vertical distribution: low density at surface, increasing toward the bottom.

Movement of Ocean Water

- Two movement types: Horizontal (Currents) and Vertical (Upwelling/Downwelling).

Waves

- Waves receive energy from wind, travel across the ocean, and release energy on shorelines.
- Wave speed slows near the beach due to friction with the sea floor.

Wave Terminology

Term	Definition
Wave crest / trough	Highest / lowest points of a wave
Wavelength	Horizontal distance between two successive crests
Wave height	Vertical distance, trough bottom to crest top
Wave amplitude	One-half of the wave height
Wave period	Time between successive crests/troughs at a fixed point
Wave speed	Rate of movement, in knots
Wave frequency	Waves passing a point per second

- Three main wave formation factors: Wind velocity, Fetch (uninterrupted distance wind blows over), Duration.

Coastal Wave Action

Term	Description
Swash	Water/sediment moving up the beach; direction set by prevailing wind
Backwash	Water moving back down the beach; direction set by beach slope
Longshore Drift	Swash + backwash moves sediment along the coast in a zig-zag, eroding up-current and depositing down-current
Constructive waves	Swash > backwash → gentle beach; low, low-frequency waves; from distant storm swell
Destructive waves	Backwash > swash → steeper beach; steeper, higher, more frequent waves

Tides

- Tides: rise/fall of sea levels from combined gravitational pull of Moon and Sun plus Earth's rotation.
- Influencing factors: Moon's pull (greater), Sun's pull (lesser), Centrifugal Force (opposes Earth's gravity).

Types of Tides

Basis	Type	Description
Sun-Moon-Earth position	Spring Tide (the highest perigean spring tides are popularly called "King Tides")	Twice monthly at new/full moon when Sun-Earth-Moon nearly align; pulls add up → higher highs, lower lows
Sun-Moon-Earth position	Neap Tide	~7 days after spring tide; Sun and Moon at right angles (first/third quarter moon); Sun's bulge partly cancels Moon's → moderate tides
Perigee/Apogee	Perigee (Moon closest)	Unusually high/low tides, greater range
Perigee/Apogee	Apogee (Moon farthest)	Lesser tidal range
Frequency	Semi-diurnal	Most common: two near-equal highs and lows daily
Frequency	Diurnal	One high, one low daily
Frequency	Mixed	Variable height, e.g. west coast of North America

Tidal Bore

A strong tide pushing up a river mouth against the current, a true "tidal wave".
 Positive surge = channel suddenly deeper; negative surge = shallower.
 Amazon River's shallow, island-dotted mouth produces the pororoca bore.
 Strong tides and coastal currents sweep the Amazon's sediment away, so it has no true delta.
 Tides are predictable; bores less so (depend on wind, river depth).
 Human river management eliminated the Seine's bore (the mascaret).
 India: tidal bores occur in the Hooghly (West Bengal) and in the Gulf of Khambhat (Narmada, Mahi estuaries)

- Tidal energy potential in India: Gulf of Khambhat and Gulf of Kutch (Gujarat), Sundarbans (West Bengal).

Ocean Currents

Forces Behind Ocean Currents

Category	Force	Effect
Primary	Insolation	Equatorial water expands, standing ~8 cm higher than mid-latitudes
Primary	Wind	Pushes surface water via friction
Primary	Gravitation	Creates gradient/piling
Primary	Coriolis Force	Deflects moving water right in NH, left in SH
Primary	Accumulation of Water	Forms Gyres (large circular currents in each basin)
Secondary	Density	Saline/cold water denser, sinks; less dense water rises
Secondary	Temperature	Cold-water currents from sinking polar water moving toward the equator; warm-water currents from the equator along the surface toward the poles

Warm vs Cold Currents

Aspect	Warm Current	Cold Current
Usually observed	East coast of continents, lower/middle latitudes	West coast of continents, lower/middle latitudes
Effect	Brings warm water into cold-water areas	Brings cold water into warm-water areas
In Northern Hemisphere	On west coast, found in higher latitudes	On east coast, found in higher latitudes

Effects/Significance of Ocean Currents

- Climate: British Isles would be extremely cold without the warm North Atlantic Drift.
- Climate: Peru's hot climate is cooled by the cold Peru Current.
- Rainfall suppression: the cold Benguela Current keeps the Namib Desert (and western Kalahari) almost rainless.
- Rainfall suppression: cold Peru (Humboldt) Current is a primary cause of the Atacama Desert's aridity (world's driest).
- Fishing zones: cold currents are nutrient-rich and encourage plankton (good fishing).
- Best fishing grounds form where warm and cold currents meet, e.g. Labrador + Gulf Stream, one of the world's richest fishing grounds.

Equatorial Current System

- The Pacific and Atlantic have a North and a South Equatorial Current flowing east→west; in the north Indian Ocean the currents reverse with the monsoon.
- An Equatorial Counter Current flows between them, west→east.

Major Ocean Currents by Ocean

Current	Nature	Key Facts
Labrador Current	Cold	Flows from Arctic Ocean south; meets warm Gulf Stream off Newfoundland
Canary Current	Cold	Eastern boundary current of the North Atlantic Gyre (off NW Africa); upwelling → excellent fishing; keeps the Canary Islands and the Sahara coast cool and dry
Benguela Current	Cold	Also causes Namib Desert aridity; upwelling, rich fishing
Falkland (Malvinas) Current	Cold	Branch of Antarctic Circumpolar Current; mixes with warm Brazil Current forming the Brazil–Malvinas Confluence Zone (temperate climate)
Somali Current	Seasonal; coastal upwelling makes it cold during the SW monsoon	Monsoon-driven western boundary current off Somalia; reverses with seasons; strong upwelling (cold) in summer
California Current	Cold	Southward extension of Aleutian Current; part of North Pacific Gyre; strong upwelling
Kurile/Oyashio Current	Cold	Sub-Arctic, counter-clockwise, via Bering Sea; nutrient-rich; meets Kuroshio off Japan to form North Pacific Drift
Kuroshio Current	Warm	"Black Stream"; Pacific analogue of Gulf Stream; keeps Japan relatively warm
North Pacific Current	Warm	Formed by the Kuroshio–Oyashio meeting; flows eastward across the North Pacific as part of the clockwise North Pacific Gyre
Humboldt/Peruvian Current	Cold	Low salinity; major nutrient system; Chile to Peru along S. America's west coast
Antarctic Circumpolar Current (West Wind Drift)	Cold	Flows west to east (clockwise when viewed from above the South Pole) around Antarctica; strongest ocean current by volume
Norwegian Current	Warm	Branch/extension of North Atlantic Drift/Gulf Stream; a dominant Arctic inflow
Brazilian Current	Warm	Flows along south Brazil to Rio de la Plata; joins cold Falkland Current → temperate sea
Mozambique Current	Warm	Between Mozambique and Madagascar
Agulhas Current	Warm	One of the strongest western boundary currents; flows south along Africa's east coast
Southwest Monsoon Current	Warm	Dominates Indian Ocean June–October; flows into Arabian Sea and Bay of Bengal
Gulf Stream	Warm	Wind-driven, western-intensified; splits into North Atlantic Drift and Canary Current
East Australian Current	Warm	Transports tropical fauna to sub-tropical SE Australian coast

Gyres

El Nino, La Nina & ENSO

El Nino

- El Nino is part of the El Nino Southern Oscillation (ENSO).
- It is an unusual warming of surface waters in the eastern tropical Pacific along Ecuador and Peru.
- Irregular, recurring every 2–7 years; it can now be forecast a few months ahead by models.

El Nino Mechanism

Trigger: trade winds weaken as air pressure falls over the eastern Pacific and rises over the western Pacific (Southern Oscillation), weakening or reversing the Walker Cell.

Normal condition: descending limb of Walker circulation over Peru/Chile creates high pressure.

Normal condition: winds blow East Pacific coast → West Pacific, driving warm surface water away → upwelling of the cold Peruvian (Humboldt) Current.

In El Nino: this reverses, Humboldt upwelling stops.

In El Nino: normal west-Pacific low pressure is replaced by weak high pressure; the Walker Cell weakens.

In El Nino: the Equatorial Counter Current (along the doldrums) accumulates warm water along Peru/Ecuador.

El Nino vs Normal Conditions

Region	Normal Condition	El Nino
Eastern Pacific (Coast of Peru & Ecuador)	Cold ocean water → good for fishing	Warm ocean water → fishing industry takes a hit
Western Pacific (Indonesia & Australia)	Warm ocean water → plenty of rain	Cold ocean water → drought

Impacts of El Nino

Region	Impact
Australia & Indonesia	Droughts (settling air mass) → forest fires; large-scale coral bleaching
India & monsoon Asia	High chance of drought: hurts agricultural productivity, raises food inflation, affects agricultural credit/subsidy (both monsoon-linked)

La Nina

- Spanish for "the Little Girl"; the cold ENSO phase.
- Impact: usually above-normal SW monsoon rainfall in India and colder winters in North India.

PYQ Trap (2011): La Nina

La Nina = unusually cold ocean temperature in the equatorial Pacific.

Common trap: La Nina is NOT about the Indian Ocean.

El Nino has adverse effects on India's SW monsoon.

La Nina usually favours the Indian monsoon, so "La Nina has no effect on the monsoon" is also false (UPSC 2011 answer: neither statement correct)

ENSO Modoki

- El Nino Modoki: anomalous cooling in the eastern & western tropical Pacific with anomalous warming in the central tropical Pacific.
- La Nina Modoki: eastern & western tropical Pacific rather warm, with low SST in the centre.

Indian Ocean Dipole (IOD)

- IOD is an atmosphere-ocean coupled phenomenon: a sea-surface temperature difference across the Indian Ocean.
- IOD develops April–May, peaking in October.

IOD Phases and Monsoon Effect

Phase	Mechanism	Effect on Indian Monsoon
Positive IOD	Equatorial westerlies weaken → warm water moves toward Africa; cool water upwells in the east → cooler-than-normal east, warmer-than-normal west	Beneficial for monsoon; often co-occurs with El Nino
Negative IOD	Equatorial westerlies intensify → warm water concentrates near Australia → warmer-than-normal east, cooler-than-normal west	Obstructs monsoon progression; often co-occurs with La Nina
Neutral Phase	Baseline state, no strong dipole	-

PYQ Trap (2017): IOD

IOD concerns SST difference between tropical Western and Eastern Indian Ocean.
 Common trap: IOD is NOT about the Eastern Pacific.
 IOD can modulate an El Nino's impact on the monsoon.

Water Resources

- India: ~2.4% of world's land area, ~4% of world's water resources, ~18% of world's population.
- Utilisable water resource ≈ 1,122 cubic km (690 surface + 432 groundwater) (NCERT).
- Groundwater: replenishable resources ≈ 432 cubic km (NCERT). CGWB Dynamic Ground Water Assessment 2024: annual recharge ~447 BCM, extraction ~246 BCM, stage of extraction ~60%.

Sectoral Water Use in India

Sector	Surface Water Use	Groundwater Use
Agricultural	89%	92%
Domestic	9%	3%
Industrial	2%	5%

Oceanic Resources

- Biotic: global fisheries + aquaculture output reached a record ~223 million tonnes in 2022; aquaculture (51%) overtook capture fisheries for the first time (FAO SOFIA 2024).
- Abiotic: continental shelf: oil/gas (the Persian Gulf region holds about half of world's proven oil reserves; Bombay High is India's main offshore field), plus gravel/sand/mud.
- Abiotic: ocean floor: manganese, cobalt, nickel, copper, zinc, phosphates, sulphides, gold, silver and methane (gas) hydrates.
- India became the first country to receive Pioneer Investor status (1987) for polymetallic-nodule exploration in the Central Indian Ocean Basin (CIOB).
- India now retains ~75,000 sq km in the CIOB under an International Seabed Authority (ISA) contract; it also holds an ISA contract for polymetallic sulphides in the Indian Ocean ridges (2016).

Blue Economy

Concept from Dr. Gunter Pauli's "The Blue Economy: 10 years, 100 innovations, 100 million jobs".
 Uses local, renewable resources ("ocean-as-a-resource") for sustainable development.
 India's Indian Ocean Region is rich in fisheries, aquaculture, ocean energy, sea-bed minerals, marine tourism and shipping.
 Fisheries and minerals are the most commercially viable sectors.

Needs R&D in Ocean Energy, Marine Biology, Biotechnology.

Blue economy is ~4% of India's GDP; key initiatives: Draft Blue Economy Policy (2021), Sagarmala, Deep Ocean Mission (2021; Samudrayaan with submersible Matsya-6000), PM Matsya Sampada Yojana.

Strategically important since most Indian oil/gas is sea-imported.

Linked to UN SDG 14 (conserve and sustainably use oceans/seas/marine resources).

UNCLOS (United Nations Convention on the Law of the Sea)

- UNCLOS III (1973–1982) produced the current convention, replacing the 1958 Convention on the High Seas.
- The 1982 Convention took effect in 1994.

Initiatives/Bodies under UNCLOS

Body	Role
International Tribunal for the Law of the Sea (ITLOS)	Independent judicial body for disputes under the Convention; seated in Hamburg (Germany); functional since 1996 (Convention signed 10 Dec 1982, in force 16 Nov 1994)
International Seabed Authority	Formed 1994; HQ Kingston (Jamaica); regulates mineral exploration/exploitation of the international seabed ("the Area")
Commission on the Limits of the Continental Shelf (CLCS)	Helps establish continental-shelf outer limits beyond 200 nm
International Maritime Organization (IMO)	UN agency (HQ London) for shipping safety and marine pollution; implements many UNCLOS provisions

- India is a party to the convention since 1995.
- India shares maritime boundaries with Bangladesh, Indonesia, Myanmar, Sri Lanka, Thailand, Maldives, Pakistan.

High Seas Treaty (BBNJ Agreement)

Agreement on Marine Biodiversity of Areas Beyond National Jurisdiction, adopted June 2023 under UNCLOS

Entered into force on 17 January 2026 after crossing 60 ratifications (Morocco was the 60th, September 2025)

Covers marine genetic resources and benefit sharing, high-seas Marine Protected Areas, environmental impact assessments, capacity building and technology transfer

India signed it in September 2024; ratification is pending (domestic legal framework under preparation)

Enrica Lexie Case

2012: Italian oil tanker Enrica Lexie, off Kerala, approached by Indian fishing vessel St. Antony.

Italian marines shot dead 2 Indian fishermen.

Italy approached ITLOS in 2015; case heard by the Permanent Court of Arbitration.

May 2020 ruling: Italy had jurisdiction over its marines (immunity from Indian criminal courts) but must pay India compensation.

India's Supreme Court (2021) quashed criminal proceedings against the marines after Italy paid ₹10 crore compensation.

Maritime Zones

UNCLOS Maritime Zones

Zone	Extent	Key Rights/Features
Baseline	-	Low-water line along the coast, as officially recognized by the coastal state
Internal Waters	Landward of baseline	Full sovereignty as over land (bays, ports, inlets, rivers, connected lakes); no right of innocent passage

Zone	Extent	Key Rights/Features
Territorial Sea	Up to 12 nautical miles (nm)	Coastal-state sovereignty over surface, seabed, subsoil, airspace, limited by right of innocent passage (1 nm = 1.852 km)
Contiguous Zone	Up to 24 nm	Coastal state may prevent/punish fiscal, immigration, sanitary, customs infringements; jurisdiction on surface/floor only, no air/space rights
Exclusive Economic Zone (EEZ)	Up to 200 nm	Sovereign rights to explore/exploit/manage living & non-living resources and to produce energy from water/currents/wind; does not permit restricting navigation/overflight (limited exceptions)
High Seas	Beyond EEZ	Freedom of the high seas for all states (navigation, overflight, fishing, research, laying cables); the seabed beyond national jurisdiction ("the Area") is the common heritage of mankind

CHAPTER 06

Rivers of the World, Islands, Lakes & Waterfalls, Straits, Canals & Dams

Rivers of the World

Major Rivers of the World

River	Continent	Length (km)	Origin	Outflow
Nile	Africa	~6,650	Rukarara stream, Burundi (via Kagera, Lake Victoria)	Mediterranean Sea
Amazon	South America	~6,400	Andes Mountains, Peru	Atlantic Ocean
Yangtze (Chang Jiang)	Asia	~6,300	Tibetan Plateau, China	East China Sea
Mississippi-Missouri	North America	~6,275	Rocky Mountains, Montana, USA	Gulf of Mexico
Yenisei-Angara-Selenga	Asia	~5,539	Mongolia	Kara Sea (Arctic Ocean)
Yellow River (Huang He)	Asia	~5,464	Tibetan Plateau, China	Bohai Sea
Ob-Irtysh	Asia	~5,410	Altai Mountains, Kazakhstan/Russia	Gulf of Ob (Arctic Ocean)
Paraná-Río de la Plata	South America	~4,880	Brazilian/Paraguayan highlands	Río de la Plata, Atlantic Ocean
Congo	Africa	~4,700	Central African highlands (Zambia)	Atlantic Ocean
Amur-Argun	Asia	~4,444	Mongolia/Russia border	Sea of Okhotsk
Lena	Asia	~4,400	Baikal Mountains, Siberia, Russia	Laptev Sea (Arctic Ocean)
Mekong	Asia	~4,350	Tibetan Plateau, China	South China Sea
Mackenzie	North America	~4,241	British Columbia, Canada	Beaufort Sea (Arctic Ocean)
Niger	Africa	~4,200	Guinea Highlands	Gulf of Guinea
Brahmaputra	Asia	~2,900	Chemayungdung Glacier, Tibet (as Yarlung Tsangpo)	Joins Ganga, Bay of Bengal
Murray-Darling	Australia	~3,672	Queensland/New South Wales highlands	Southern Ocean (via Lake Alexandrina)
Volga	Europe	~3,645	Valdai Hills, Russia	Caspian Sea
Euphrates (with Shatt al-Arab)	Asia	~3,596	Eastern Turkey highlands	Persian Gulf
Madeira	South America	~3,380	Bolivia/Peru highlands	Amazon River

- Rivers are also classified as perennial (fed by rain, snow, groundwater throughout the year, e.g., Ganga, Amazon) or non-perennial/seasonal (rain-fed only, e.g., many peninsular Indian rivers).

Islands

Types of Islands

Type	Formation	Example
Continental	Formed on the continental shelf	Newfoundland (Canada), Great Britain, Sri Lanka
Volcanic	Formed when an underground volcano ejects material above sea surface	Japan, Philippines
Coral	Formed from coral remains; smaller but more numerous than volcanic/continental islands; rich biodiversity	Lakshadweep (India)
Alluvial	Formed by sediment deposition in a river channel or at a river mouth	Majuli (Brahmaputra, Assam; India's largest river island); New Moore/Purbasha (Bay of Bengal, now submerged)

Largest Islands of the World

Largest Islands by Area

Island	Area (approx., km ²)	Country/Region	Ocean/Sea
Greenland	2,130,800	Denmark (autonomous)	North Atlantic/Arctic
New Guinea	785,753	Indonesia & Papua New Guinea	Southwest Pacific
Borneo	748,168	Brunei, Indonesia, Malaysia	Southeast Asia
Madagascar	587,041	Madagascar	Indian Ocean
Baffin Island	507,451	Canada	Arctic
Sumatra	~443,000–473,000	Indonesia	Indian Ocean
Honshu	~227,960	Japan	Pacific Ocean
Victoria Island	217,291	Canada	Arctic
Great Britain	~209,331	United Kingdom	North Atlantic
Ellesmere Island	196,236	Canada	Arctic

Islands: Key Facts

Greenland is the world's largest island (Australia is excluded, classed as a continent).

Galápagos Islands (Ecuador, Pacific): volcanic hotspot archipelago; Darwin's observations here (finches, giant tortoises) shaped the theory of evolution.

Svalbard Island, Norway: site of the Global (International) Seed Bank.

Mass nesting (arribada) of Olive Ridley turtles: Gahirmatha, Rushikulya and Devi river mouth (Odisha); also Mexico and Costa Rica

Other Notable Islands

- Aleutian Islands (USA, North Pacific): mark the NW extent of the American Cordillera (which extends south to the Isthmus of Panama).

Lakes and Waterfalls

Major Lakes of the World

Lake	Location	Area/Rank Fact	Standout Fact
Caspian Sea	Europe/Asia (Russia, Kazakhstan, Turkmenistan, Azerbaijan, Iran)	~371,000 km ² ; world's largest lake (by far)	Technically a lake though called a "sea"; both saline and fed by freshwater rivers (chiefly Volga)
Lake Superior	USA/Canada (Great Lakes)	~82,100 km ²	World's largest freshwater lake by surface area
Lake Victoria	Uganda/Kenya/Tanzania	~68,800 km ²	Largest lake in Africa; major source of the Nile (via Victoria Nile)
Lake Huron	USA/Canada	~59,600 km ²	Contains ~30,000 islands (most of any lake); Manitoulin Island largest lake-island in world
Lake Michigan	USA	~57,750 km ²	Only Great Lake located entirely within the USA
Lake Tanganyika	Burundi/DR Congo/Tanzania/Zambia	~32,900 km ²	World's longest freshwater lake; among the deepest (~1,470 m)
Lake Baikal	Russia (Siberia)	~31,700 km ²	World's deepest (~1,642 m) and oldest freshwater lake; holds ~20% of world's unfrozen freshwater
Lake Malawi (Nyasa)	Malawi/Mozambique/Tanzania	~29,600 km ²	Ancient rift lake; exceptional cichlid-fish biodiversity
Lake Titicaca	Bolivia/Peru (Andes)	~8,370 km ²	World's highest navigable lake (~3,812 m altitude)
Dead Sea	Israel/Jordan	-	Lowest point on Earth's land surface; hypersaline: no aquatic life

Major Waterfalls of the World

Waterfall	Country/River	Standout Fact
Angel Falls	Venezuela, on the Churún River (Canaima National Park)	World's tallest waterfall: ~979 m (uninterrupted drop)
Tugela Falls	South Africa, Drakensberg Mountains	Among the world's tallest; five distinct drops, ~948 m total
Victoria Falls	Zambia/Zimbabwe border, Zambezi River	Largest continuous curtain of falling water in the world (~1,700 m wide, ~108 m high); called "Mosi-oa-Tunya" (the smoke that thunders)
Niagara Falls	Canada/USA border, Niagara River	Not the tallest, but very high flow rate; major hydroelectric source; comprises Horseshoe Falls (Canada), American Falls and Bridal Veil Falls (USA)
Iguazu Falls	Brazil/Argentina border, Iguazu River	System of ~275 separate falls across ~2.7 km; highest single drop is the "Devil's Throat" (~82 m)

Canals and Dams

Major Canals of the World

Canal	Country	Connects	Key Fact
Suez Canal	Egypt	Mediterranean Sea and Red Sea	Opened 1869; no locks (sea-level canal); ~193 km long; carries a large share of Europe-Asia seaborne trade, avoiding the route around Africa
Panama Canal	Panama	Atlantic Ocean and Pacific Ocean	Opened 1914; ~82 km long; uses a lock system to cross the isthmus; drastically shortens the sea route between US east and west coasts
Kiel Canal	Germany	North Sea and Baltic Sea	Built 1887–1895; world's busiest artificial waterway by ship count; avoids the longer route around the Jutland/Denmark peninsula
Grand Canal	China	Yangtze River and Yellow River (and Beijing–Hangzhou)	World's longest and oldest artificial canal (~1,776 km, Beijing–Hangzhou), crossing the Yellow and Yangtze rivers; construction began ~5th century BCE; UNESCO World Heritage Site

Major Dams of the World

Dam	Country	River	Key Fact
Three Gorges Dam	China	Yangtze River	World's largest hydroelectric power station by installed capacity (~22,500 MW)
Itaipu Dam	Brazil/Paraguay (border)	Paraná River	One of the world's largest by generation capacity (~14,000 MW); rivals Three Gorges in annual energy output due to steady year-round flow
Hoover Dam	USA (Nevada–Arizona border)	Colorado River	Historic concrete arch-gravity dam (~221 m high); creates Lake Mead, the largest reservoir by volume in the USA
Aswan High Dam	Egypt	Nile River	Completed 1970; created Lake Nasser, one of the world's largest artificial lakes; central to controlling the Nile's annual flooding and irrigation
Grand Ethiopian Renaissance Dam (GERD)	Ethiopia	Blue Nile	Africa's largest hydropower project (~5,150 MW); inaugurated September 2025; disputed by Egypt and Sudan
Yarlung Tsangpo (Medog) Project	China (Tibet)	Yarlung Tsangpo (upper Brahmaputra)	Construction began July 2025; planned ~60 GW, would be the world's largest; India and Bangladesh concerned about downstream flows

CHAPTER 07

Species/Tribes: World Agriculture and Livestock

World Tribes / Indigenous Peoples

- World's Indigenous Peoples Day: 9 August.

Major World Tribes/Indigenous Groups

Tribe	Region	Key Characteristics
Pygmies	Congo Basin (Zaire Basin), Central Africa	Nomadic hunter-gatherers; short stature; tropical rainforest dwellers
Bushmen (San)	Kalahari Desert (Namibia, Botswana, Angola)	Hunter-gatherers; among oldest lineages in Africa; declining population
Maasai	Kenya, Northern Tanzania, Eastern Uganda	Semi-nomadic pastoralists; rear Zebu (humped cattle) for milk and blood; homesteads (enkang/manyatta) with thorn-fenced cattle enclosures (kraals); spiritual leader called Laibon
Bantu	Central, East & Southern Africa	Bantu-speaking agriculturist-pastoralist peoples
Aborigines (Indigenous Australians)	Australia	Traditionally hunter-gatherers; oldest continuous cultures on Earth
Maori	New Zealand	Polynesian tribe; hunting, farming and gathering
Inuit (Eskimo)	Arctic: Alaska to Greenland/Siberia	Hunters of seal, walrus and caribou; use dog sleds, kayaks; build igloos; self-name "Inuit" means "the people"
Bedouins	Arabian Peninsula & North African deserts	Semi-nomadic pastoralists; rear camels, sheep, goats, horses; camel-herding sub-group called Ruwala
Sami (Lapps)	Northern Scandinavia & NW Russia (Lapland)	Caucasoid; traditional reindeer herders
Kirghiz	Tien Shan & Pamir plateaus (Central Asia)	Mongoloid; herding; produce Kumis (fermented mare's milk)
Kazakhs/Mongols	Central Asian steppes	Nomadic pastoralists of the steppe; herd horses, sheep, goats, camels
Native American tribes	North, Central & South America	Mongoloid racial stock; varied: hunting, farming, pastoral depending on region

Endangered/Small Tribes (exam trivia)

Hadza: Tanzania, ~1,000 people (only a few hundred still fully hunter-gatherers).
 Onge: Little Andaman (India), ~100-odd, critically endangered.
 Yanomami: Amazon, Brazil-Venezuela border.
 Sentinelese: North Sentinel Island, India, among world's most isolated.

World Livestock

Dairy Farming Belt

- Major belts: North-Western Europe (Denmark, Netherlands, UK, Germany, France) and around the Great Lakes region of the USA (Wisconsin, "Dairy State", and neighbouring states), also New Zealand and South-East Australia.

Wool-Producing Regions

- Chief Merino sheep belts: Australia, New Zealand, South Africa, Argentina, fine, high-quality wool for apparel.

Top Wool-Producing Countries (by volume)

Rank	Country	Note
1	China	Largest producer by volume (~21% global)
2	Australia	Largest exporter by value; Merino benchmark (~18% global)
3	New Zealand	Mainly carpet-grade wool
-	South Africa	"Cape Wool": fine wool

Cattle Ranching

- Classic commercial ranching regions: Pampas (Argentina), Prairies (USA/Canada), parts of Australia, New Zealand, South Africa, Uruguay.
- India: Largest cattle meat (buffalo meat) exporter in some years; holds ~57% of world's buffalo population and ~14% of world cattle population; largest milk producer in the world.

Reindeer Herding

- Region: Arctic/Sub-Arctic tundra, Lapland/Scandinavia (Sami people), Northern Russia/Siberia.

Leading Producer Countries: Key Livestock

Animal	Leading Producer(s)/Notes
Cattle (population)	Brazil and India among top holders; USA largest beef producer
Cattle meat (beef)	USA: world's largest beef producer
Milk	India: world's largest milk producer
Pigs	China: dominant global producer; also strong in USA (Midwest), Germany, Spain, Poland
Sheep	China, Australia, India among top; Australia/NZ/Argentina/South Africa lead in fine (Merino) wool

CHAPTER 08

World: Minerals, Industries, Transport, Miscellaneous

World Minerals

Major World Minerals: Top Producers

Mineral	Top Producing Countries	Notes
Iron Ore	Australia, Brazil, China, India, Russia	Australia and Brazil are top exporters; China is top consumer/importer; major Australian deposits in Pilbara (Western Australia)
Coal	China, India, Indonesia, USA, Australia, Russia	China is largest producer and consumer by far; Australia and Indonesia are leading exporters
Petroleum (Crude Oil)	USA, Saudi Arabia, Russia, Canada, Iraq, China	USA leads in total production (shale boom); Saudi Arabia is largest OPEC producer and swing producer
Natural Gas	USA, Russia, Iran, China, Qatar	Russia holds largest proven reserves; Qatar/Russia major LNG exporters
Gold	China, Russia, Australia, Canada, USA	China is largest producer; South Africa historically dominant, now declined sharply
Copper	Chile, DR Congo, Peru, China, USA	Chile is by far the largest producer and holds the largest reserves (Escondida, Chuquibambilla); DR Congo is now the 2nd largest producer
Bauxite (Aluminium ore)	Guinea, Australia, China, Brazil, India	Guinea has overtaken Australia as the largest producer and holds huge reserves; India is among the top five
Diamonds	Russia, Botswana, Canada, DR Congo, South Africa	Russia (Alrosa) is the largest producer by volume; Botswana leads in Africa; Australia's Argyle mine closed in 2020
Uranium	Kazakhstan, Canada, Namibia, Australia, Russia	Kazakhstan produces ~40% of world uranium
Manganese	South Africa, Australia, Gabon, China	South Africa holds largest reserves; used in steel-making
Nickel	Indonesia, Philippines, Russia, New Caledonia	Indonesia now produces about half of world nickel; used in stainless steel and EV batteries
Lithium	Australia, Chile, China, Argentina	"Lithium Triangle": Chile, Argentina, Bolivia (salt-flat brines); Bolivia has the largest resources; demand driven by EV batteries. India: lithium resources reported in Reasi (J&K) in 2023
Cobalt	DR Congo	DR Congo produces about three-fourths of world cobalt, mostly as a by-product of copper mining
Phosphate	China, Morocco, USA	Morocco (incl. Western Sahara) holds about 70% of world's phosphate reserves

OPEC and Petroleum

OPEC = Organization of the Petroleum Exporting Countries, formed 1960; headquartered in Vienna, Austria.

Founding members: Iran, Iraq, Kuwait, Saudi Arabia, Venezuela.

Saudi Arabia is the largest producer within OPEC and often acts as the "swing producer."

OPEC+ includes non-OPEC oil exporters like Russia in coordinated output decisions.
 Persian Gulf region holds the largest share of world's proven oil reserves (Saudi Arabia, Iran, Iraq, Kuwait, UAE).
 Venezuela holds the largest proven crude oil reserves in the world (mostly heavy/extra-heavy oil, Orinoco Belt).

- Witwatersrand ("the Rand", South Africa) has produced roughly 40% of all gold ever mined.
- Rare Earth Elements (REEs): China accounts for ~70% of mining and ~90% of global processing; India launched the National Critical Mineral Mission (2025).

World Industries

Major World Industrial Regions

Industrial Region	Country	Specialization
Ruhr Region	Germany	Heavy industry: iron & steel, coal-based chemicals; one of Europe's oldest/largest industrial belts
Manchester-Lancashire	United Kingdom	Cotton textiles (historically); birthplace of Industrial Revolution-era textile mills
Detroit	USA	Automobile manufacturing ("Motor City")
Pittsburgh	USA	Iron and steel (historically, near Appalachian coal)
Silicon Valley	USA (California)	Electronics, software, information technology hub
Kobe-Osaka	Japan	Shipbuilding, textiles, heavy machinery, steel
Tokyo-Yokohama	Japan	Diversified industry: automobiles, electronics, shipbuilding
Shanghai / Pearl River Delta (Guangdong)	China	Manufacturing hub: electronics, textiles, light & heavy industry; major export processing zones

- China is often called the "World's Factory" due to its dominance in manufacturing/export-oriented industry.

World Transport

Shipping Routes

- Trans-Atlantic Route: connects Europe with North America (eastern coast of USA/Canada); one of the busiest ocean trade routes historically, carrying manufactured goods, machinery.
- Trans-Pacific Route: connects western coast of North America with East Asia (Japan, China, South Korea); among the busiest routes today given Asia-Pacific trade volumes.
- Cape Route: around the Cape of Good Hope (South Africa), historically linking Europe/Americas to Asia before the Suez Canal; still used by very large vessels that cannot transit Suez, or when Suez is disrupted.

Major World Railways

Railway	Region/Countries	Key Facts
Trans-Siberian Railway	Russia	World's longest railway line (~9,289 km), connects Moscow to Vladivostok, crossing Siberia
Trans-Canadian Railway	Canada	Connects Atlantic coast (Halifax) to Pacific coast (Vancouver); one of the longest national railway systems
Trans-Australian Railway	Australia	Connects Port Augusta (South Australia) to Kalgoorlie (Western Australia) across the Nullarbor Plain; includes one of the world's longest straight railway stretches
Union Pacific/First Transcontinental Railroad	USA	First railway linking the US eastern rail network with the Pacific coast (completed 1869)

Aviation Hubs

- Dubai International Airport is a key hub connecting Europe, Asia and Africa due to UAE's central geographic location.

Miscellaneous (World Geography Superlatives & Facts)

World Geography Superlatives

Superlative	Place/Feature
Highest mountain peak	Mount Everest (8,849 m), Nepal–China border
Lowest point on land (exposed)	Dead Sea shore (~430 m below sea level), Israel–Jordan border
Deepest point in the ocean	Challenger Deep, Mariana Trench (Pacific Ocean, ~10,900+ m)
Largest country by area	Russia
Smallest country by area	Vatican City
Most populous country	India (surpassed China in population in recent years)
Longest mountain range (above water)	Andes (South America), ~7,000+ km
Largest coral reef system	Great Barrier Reef, Australia
Largest freshwater lake by volume	Lake Baikal, Russia (also the deepest lake in the world)
Largest peninsula	Arabian Peninsula
Largest archipelago	Indonesia
Largest landlocked country	Kazakhstan
Coldest inhabited place	Oymyakon, Russia (Siberia)
Largest delta	Sundarbans (Ganga–Brahmaputra Delta), India–Bangladesh
Largest gulf	Gulf of Mexico (officially renamed "Gulf of America" by the USA in 2025; the international name remains Gulf of Mexico)
Largest bay	Bay of Bengal
Deepest canyon	Yarlung Tsangpo Grand Canyon (Tibet); the Grand Canyon (USA) is the best known
Largest active volcano	Mauna Loa, Hawaii, USA

Quick-Fire Miscellaneous Facts

Seven Natural Wonders of the World (commonly cited list): Grand Canyon, Great Barrier Reef, Harbour of Rio de Janeiro, Mount Everest, Aurora, Paricutin Volcano, Victoria Falls.

Ring of Fire: horseshoe-shaped zone around the Pacific Ocean with intense seismic and volcanic activity; home to about 75% of world's active volcanoes.

International Date Line is roughly along 180° longitude in the Pacific Ocean, with deviations to avoid splitting countries. Equator passes through 13 countries, including Brazil, Ecuador, Kenya, Indonesia.

Tropic of Cancer (23.5°N) passes through India; Tropic of Capricorn (23.5°S) passes through Australia, Brazil, South Africa, Chile.

CHAPTER 09

India: General Introduction, Physical Divisions

Location & Extent

- India lies entirely in the Eastern part of the Northern Hemisphere.
- Mainland extent: 8°4'N–37°6'N and 68°7'E–97°25'E.
- N-S extent: 3,214 km (Indira Col, Kashmir to Kanyakumari).
- E-W extent: 2,933 km (Rann of Kutch to Arunachal Pradesh).
- 7th largest country in the world by area: 32,87,263 sq km (~3.28 million sq km).
- India's area = 2.4% of world's total surface area.
- Land boundary: 15,106.7 km (MHA).
- Land boundary runs through 16 states & 2 UTs.
- Coastline (mainland only): 5,422.6 km officially (NCERT cites ~6,100 km).
- Coastline (incl. islands, 2,094 km): 7,516.6 km (traditional figure); re-measured at 11,098.81 km in 2023–24 using a new methodology (larger-scale maps, all bends included), as released by MHA in 2025.
- Coastline touches 9 states & 4 UTs.
- Andaman & Nicobar Islands lie southeast of the mainland, in the Bay of Bengal.
- Lakshadweep lies southwest of the mainland, in the Arabian Sea.

Tropic of Cancer: States & Places Crossed

State	Place
Gujarat	Jasdan
Rajasthan	Kalinjarh
Madhya Pradesh	Shajapur
Chhattisgarh	Sonhat
Jharkhand	Lohardaga
West Bengal	Krishnanagar
Tripura	Udaipur
Mizoram	Champhai

Tropic of Cancer & IST Meridian

Tropic of Cancer (23°30'N) nearly bisects India, passing through 8 states
 It intersects the IST meridian in Korai district, Chhattisgarh (Baghelkhand Plateau)
 IST Meridian = 82°30'E; IST = GMT + 5:30

- India is considered a tropical country although nearly half its area lies north of the Tropic of Cancer.
- Reason 1: dominance of the tropical monsoon.
- Reason 2: the Great Himalayas block cold temperate air masses from the north.
- Reason 3: primary economic activities (agriculture, settlement patterns) are tropical in nature.

Extreme Points

Extreme Points of India

Point	Location	Details
Southernmost (overall)	Indira Point (Pygmalion Point), Great Nicobar	6°45'N
Southernmost (mainland)	Kanyakumari	8°4'N; meeting point of Bay of Bengal, Arabian Sea, Indian Ocean
Northernmost	Indira Col	Near Siachen Glacier, Ladakh
Westernmost	Guhar Moti/Guhar Mota	Kutch region, Gujarat (~68°7'E)
Easternmost	Kibithu	Arunachal Pradesh

- Easternmost state: Arunachal Pradesh.
- Westernmost state: Gujarat.

Neighbouring Countries & Border Lengths

- Land neighbours (7): Pakistan, Afghanistan, China, Nepal, Bhutan, Myanmar, Bangladesh.
- Maritime-only neighbours: Sri Lanka, Maldives.
- Boundaries with Pakistan, Afghanistan, China, Bangladesh are man-made.

India's Natural Boundaries

Direction	Natural Feature
North	Himalayas
Southeast	Bay of Bengal
South	Indian Ocean
Southwest	Arabian Sea

- Land border length, longest→shortest: Bangladesh > China > Pakistan > Nepal > Myanmar > Bhutan > Afghanistan (shortest).

Named Boundary Lines

Radcliffe Line: India-Pakistan & India-Bangladesh; by Sir Cyril Radcliffe (1947); example of a superimposed boundary
 McMahon Line: India-China (Eastern Sector)
 Durand Line: Afghanistan-Pakistan; separates Afghanistan from India's erstwhile frontier
 Palk Strait (named after Robert Palk, Governor of Madras 1763-67) & Gulf of Mannar separate India from Sri Lanka (nearest maritime neighbour)

Neighbouring Countries: Border Details

Country	Indian States/UTs Sharing Border	Border Length	Notes
Bangladesh	West Bengal, Assam, Meghalaya, Tripura, Mizoram	4,096.7 km (longest)	Padma, Jamuna, Teesta are trans-boundary rivers
China	Ladakh, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh	3,488 km (2nd longest)	3 sectors: Western, Middle, Eastern (McMahon Line)
Pakistan	Gujarat, Rajasthan, Punjab, J&K, Ladakh	3,323 km	International Border + Line of Control (LoC)
Nepal	Uttarakhand, Uttar Pradesh, Bihar, West Bengal, Sikkim	1,751 km	Porous border; Terai belt

Country	Indian States/UTs Sharing Border	Border Length	Notes
Myanmar	Arunachal Pradesh, Nagaland, Manipur, Mizoram	1,643 km	Along Brahmaputra-Irrawaddy watershed, Purvanchal hills
Bhutan	Sikkim, West Bengal, Assam, Arunachal Pradesh	699 km	-
Afghanistan	Ladakh	~106 km (shortest)	Gilgit-Baltistan (part of Ladakh as per India; under Pakistan's occupation) meets Afghanistan's Wakhan Corridor

Indo-China Border

Indo-China Border Sectors

Sector	States/Region	Key Facts
Western Sector	Ladakh vs Xinjiang	Disputed areas: Aksai Chin, Changmo valley, Pangong Tso, Spongegar Tso
Middle Sector	Himachal Pradesh & Uttarakhand vs China	Barahoti plains (Uttarakhand) are the main disputed area; relatively less contested
Eastern Sector	McMahon Line	Runs ~1,140 km from the eastern limit of Bhutan to near Diphu Pass (India-China-Myanmar tri-junction); China claims Arunachal Pradesh as "South Tibet"

Disputed Boundary Lines (Aksai Chin)

Johnson's Line (1865): shows Aksai Chin as part of J&K (now Ladakh); India's claimed official border

Macartney-MacDonald Line (1899): shows Aksai Chin as part of China; China's claimed official border

LAC (Line of Actual Control): notional demarcation separating Indian- and Chinese-controlled territory in the Western Sector

Indo-Pakistan Border

- International Border: runs from the LoC (north) to Zero Point (Gujarat-Sindh, south).
- Line of Control (LoC): separates PoK from J&K/Ladakh.
- LoC: originally the Ceasefire Line of 1949 (Karachi Agreement), redesignated as the LoC under the Shimla Agreement (1972).
- Sir Creek: 96 km marshland, Rann of Kutch, Arabian Sea.
- Sir Creek is disputed; separates Kutch (India) from Sindh (Pakistan).

Other Borders (Maritime)

- Indo-Maldives maritime boundary fixed by treaty (1976).
- 8-degree Channel separates Minicoy (India) from Maldives.
- Indo-Sri Lanka border is maritime, separated by the Palk Strait.
- Ram Setu (Adam's Bridge): chain of limestone shoals from Dhanushkodi (Pamban Island, Tamil Nadu) to Talaimannar (Mannar Island, Sri Lanka), ~48 km.

India as a Subcontinent

- Subcontinent = political-geographical separation of a part of a continent from the rest.
- India = landmass that drifted north from Gondwanaland; peninsular region in South-Central Asia.

Subcontinent Boundaries

Direction	Delineating Feature
North	Himalayas, Karakoram, Hindu Kush
West	Sulaiman, Kirthar, Brahui mountains + Western Fold Belt (between Sulaiman range & Chaman fault)
East	Patkai, Naga, Lushai, Chin hills
South	Indian Ocean
Southwest	Arabian Sea
Southeast	Bay of Bengal

- Indian subcontinent = 7 countries: India, Pakistan, Nepal, Bhutan, Bangladesh, Sri Lanka, Maldives.

Significance of India's Location

Historical: Himalayas + oceans shielded India from invaders, giving it a unique cultural identity

Invaders who did come (Mughals, Europeans) added to India's cultural diversity

Economic: diverse climate/landforms → rich flora-fauna and crop diversity (temperate wheat to tropical rice)

Strategic Indian Ocean location commands sea routes (Europe-Africa-SE Asia-Far East-Oceania) → ancient trade relations

Mountain passes enabled trade/travel (e.g. Fa-Hien, Hiuen-Tsang) and cultural exchange

Geological Structure of India (Rock Systems)

- GSI classifies Indian rocks into 4 major divisions (oldest to youngest): Archaean → Purana → Dravidian → Aryan.

Rock Systems of India

System	Sub-systems	Age/Period	Key Facts
Archaean	Archaean Gneisses & Schists; Dharwar	~4 billion yrs (Gneisses/Schists); 2.5-1.8 billion yrs (Dharwar)	Oldest, igneous, azoic; basement/foundation rocks; rich in Fe, Mn, Cu, bauxite, gold, lead, mica; covers 2/3 of peninsular India + roots of Greater Himalaya/Trans-Himalaya (Karakoram, Ladakh, Zaskar)
Purana	Cuddapah; Vindhyan	1,400-600 million yrs	Cuddapah = synclinal folds, shale/slate/quartzite/limestone (type area: Cuddapah dist., AP); Vindhyan = named after Vindhya range, ~4000 m thick, Deccan Trap overlap, diamond-bearing (Panna, Golconda), no metals but ornamental/durable stone
Dravidian (= Carboniferous)	Cambrian, Ordovician, Silurian, Devonian, Carboniferous	600-300 million yrs (Palaeozoic)	Mainly in extra-peninsular Himalaya & Gangetic plain (little in Peninsula at Umaria, Rewa); marks beginning of life/coal formation (not abundant in India)
Aryan	Upper Carboniferous; Gondwana, Deccan Trap, Jurassic (Mesozoic); Eocene-Oligocene-Miocene-Pliocene (Cenozoic/Tertiary); Pleistocene-Holocene (Quaternary)	Post-Carboniferous to present	Covers Mesozoic to recent

Key sub-systems detail

- Dharwar rock system was first studied in Dharwar (Karnataka).
- Dharwar rocks also found in Aravalli, Chhotanagpur plateau, Meghalaya, Tamil Nadu.

Dharwar Series & Associated Minerals

Series	Location	Mineral
Champion series	Kolar	Gold
Champaner series	Baroda	Marble
Chilpi series	Balaghat	Copper

- Gondwana rock system named after the Gond tribe.
- Gondwana system formed in the Permian period (~250 MYA) by synclinal trough deposition.
- Found in Raniganj (WB), Jharia & Bokaro (Jharkhand), Damodar valley, Mahanadi valley (Talcher, Odisha), Pench-Kanhan valley (MP), Godavari valley (Telangana), Rajmahal hills (Jharkhand).
- Source of Gondwana coal: ~98% of India's coal reserves; lower carbon than Carboniferous coal.
- Gondwana rocks also rich in Fe, Mn, Antimony, Uranium.
- Jurassic system: marine transgression → shallow water deposits in Rajasthan & Kutch (limestone, sandstone, conglomerate, shale).

Deccan Trap

Formed at the end of the Mesozoic era; basaltic lava via the Reunion Hotspot as the Indian plate passed over it
 Coincided with the end-Cretaceous (K-Pg) mass extinction (~66 Mya)
 Weathering → black soil (Regur)
 Spreads over 5 lakh sq km (Kachchh, Saurashtra, Maharashtra, Malwa plateau, northern Karnataka)
 Thickness: ~2,000 m along the west coast, ~800 m in Kachchh and ~150 m at the eastern margin
 ~95% of the lava = tholeiitic basalt

- "Trap" means stair/step in Swedish: reflects the flat-topped, steep-sided terrain.

Deccan Trap: 3 Groups

Group	Region	Ash Present	Intertrappean Beds
Upper Trap	Maharashtra/Saurashtra	Yes	Present
Middle Trap	Central India/Malwa	Yes	Rare
Lower Trap	-	Rare	Present

- Tertiary system marked by the final Gondwanaland breakup + Himalayan upliftment.
- Tertiary period has 4 epochs: Eocene, Oligocene, Miocene, Pliocene.

Himalaya Formation Sequence

Range	Epoch
Great Himalayas	Oligocene
Lesser Himalayas	Miocene
Shivaliks	Pliocene/Upper Pliocene

- Tertiary rocks include: Shiwalik system, Murree beds, Potwar plateau, outer Himalaya, and the oil-bearing rocks of Assam (Digboi), Gujarat and Rajasthan.
- Quaternary system = Pleistocene + Recent deposits: Bhangar (old alluvium), Khadar (new alluvium), Karewas of Kashmir.
- Rann of Kutch formed by sedimentary filling of a former ocean.
- Marine Transgression: sea level rise relative to land, shoreline moves inland, causing flooding.

Meghalayan Age

Latest stage of the Holocene epoch (ratified by the ICS in 2018)
 Began ~4,200 years ago with an abrupt mega-drought
 Caused collapse of Egypt, Greece, Syria, Palestine, Mesopotamia, Indus Valley, and Yangtze River Valley civilizations
 Evidence from the Mawmluh caves, Meghalaya

The Himalayas

Formation

- Highest, loftiest, youngest fold mountain range in the world.
- Formed by collision of the Indian Plate with the Eurasian Plate.
- Covers ~10.7% of India's land area.
- Runs W-E, arcuate, ~2,400 km long.
- Width: 400 km in Kashmir → 150 km in Arunachal Pradesh.
- Altitudinal variation is greater in the eastern half than the western half (NCERT); the eastern Himalaya rise abruptly from the plains.

Highest Peak: Mount Everest

Height: 8,849 m (revised figure: 8,848.86 m)

Located in the Great Himalayas (Himadri)

Characteristic Himalayan features: arcuate shape convex to south, steep jagged peaks, deep valleys, alpine glaciers, syntaxial bends

Greater altitudinal variation occurs in the eastern Himalayas

- Formation sequence: India was an island off Australia, separated from Asia by the Tethys Sea (~225 MYA).
- Indian plate began moving north ~200 MYA when Pangaea broke; it collided with the Eurasian plate ~40–50 MYA.
- Convergence with the Eurasian plate → folding of sediments → Himalayas formed.
- Himalayas are still rising, by a few mm to ~1 cm per year.
- Evidence of ongoing rise: frequent earthquakes, similar fossils in the Shiwalik & Tibetan plateau, youthful V-shaped river valleys (down-cutting).

Syntaxial Bends

Bend	Location
Western syntaxial bend	Near Nanga Parbat
Eastern syntaxial bend	Near Namcha Barwa

- Hindu Kush–Himalaya is called the "Third Pole of Earth": largest store of ice outside the polar regions (e.g. Siachen, Gangotri, Baltoro glaciers).
- Major river systems originating here: Indus, Ganga, Brahmaputra.
- Major lakes: Pangong Tso, Tso Moriri (Ladakh), Yamdrok Tso (Tibet), Tilicho (Nepal).
- The snowline is lower in the Western Himalaya than in the Eastern Himalaya, because the west lies at higher latitudes (Karakoram ~36°N vs Kanchenjunga ~28°N) and receives heavy winter snowfall from Western Disturbances.
- On southern (steeper, wetter) slopes, the snowline is lower than on northern slopes in the Great Himalayas.

Classification Overview

Himalaya Classification Systems

Classification Type	Sequence
Longitudinal (parallel ranges, N→S)	Trans-Himalaya → Great Himalaya (Himadri) → Middle/Lesser Himalaya (Himachal range) → Outer Himalaya (Shiwalik range)
Regional (Sidney Burrard, W→E)	Kashmir/Punjab Himalaya (Indus–Satluj) → Kumaon Himalaya (Satluj–Kali) → Nepal Himalaya (Kali–Tista) → Assam Himalaya (Tista–Dihang)

Longitudinal Divisions (Trans/Greater/Lesser/Shivalik)

Trans-Himalayan Range (Tibetan Himalayas)

- Lies north of the Himadri, in the Tibet region.
- Composed of granites & volcanic rocks.
- These ranges pre-date Himalaya formation and have marine sediments.

Trans-Himalayan Ranges

Range	Key Facts
Karakoram	Northernmost range of the Trans-Himalaya (aka Krishnagiri); Siachen (~76 km) is the 2nd longest glacier outside the polar regions (after Fedchenko); K2 (Godwin Austen, 8,611 m) is the highest peak of India (in PoK)
Ladakh	South of Karakoram; merges with the Kailash range in Tibet
Zaskar	Between the Ladakh range & the Great Himalaya
Kailash (Gangdise Range)	SW Tibet, ~1,600 km long; its western extension in eastern Ladakh runs along the southern bank of Pangong Tso (Chushul sector); Mount Kailash is sacred to Hindus, Buddhists, Jains and Bon followers

- Pamir Knot = convergence point of the Tian Shan, Karakoram, Kunlun Shan, Hindu Kush, Pamir ranges.
- Pamir Knot is located in the Gorno-Badakhshan autonomous region, eastern Tajikistan.

The Great Himalayas (Himadri)

- Northernmost, highest range; avg height 6,000 m.
- Perennially snow-covered (hence the name "Himadri").
- Continuous range; separated from the Lesser Himalaya by the Main Central Thrust (MCT).
- Contains the most prominent peaks: Mt. Everest (8,848.86 m), Kanchenjunga (8,586 m; highest peak within India's administrative control), Nanga Parbat (western end).
- Folds are asymmetrical; core rock = granite.
- Glaciers: Gangotri, Satopanth, Yamunotri, Pindari, Milam, Zemu.
- Passes: Bara Lacha La, Shipki La, Niti, Lipulekh, Nathu La, Zoji La, Bom Di La.

The Lesser/Middle Himalayas (Himachal Range)

- Also called Middle/Inner/Lower Himalaya.
- Lies between the Great Himalaya & the Shiwaliks.
- Width ~50–80 km; altitude ~3,700–4,500 m (NCERT).
- Main Boundary Thrust (MBT) separates it from the Shiwalik.
- Steep, barren southern slope; gentle, forested northern slope.
- Mainly composed of metamorphosed rocks.
- Prominent ranges: Pir Panjal (south of Kashmir valley), Dhauladhar (HP), Mussoorie & Nag Tibba (Uttarakhand), Mahabharat Range (Nepal).
- Hill stations here: Shimla, Mussoorie, Nainital, Almora.
- Valleys here: Kashmir, Kullu, Kangra.

Lesser Himalaya Ranges

Range	Location	Key Facts
Pir Panjal Range	J&K	Westernmost Lesser Himalayan range; extends from the Kishanganga (Neelum) river to the upper Beas, ~300+ km; contains Panjal volcanics; highest peak Indrasan (~6,221 m); passes: Banihal (Jawahar & Navyug tunnels), Pir Panjal Pass (Mughal Road to Rajouri/Poonch), Rohtang (Atal Tunnel)

Range	Location	Key Facts
Dhauladhar Range	Himachal Pradesh	Rises near Dalhousie (Chamba) and runs SE through Dharamshala towards Mandi and the Beas; elevation 3,500–6,000 m; mostly granite; peaks include Hanuman Tibba (~5,982 m); glacial lake Lam Dal; main pass Indrahara (Kangra–Chamba)
Mussoorie & Nag Tibba Range	Uttarakhand	Nag Tibba = highest peak of Lesser Himalaya in Uttarakhand; Bugyals (high-altitude meadows) found here; lies on Garhwal Himalaya foothills, NE of Mussoorie
Mahabharat Range	Nepal	Lesser Himalaya of Nepal; elevation ~1,500–2,700 m; steep southern face; Kathmandu valley lies north of it

Kashmir Valley

Lies between the Great Himalaya and the Pir Panjal range
 Rich lacustrine deposits (Karewas) support saffron (Zafran), apple, peach, almond, walnut, apricot cultivation
 Synclinal basin filled with alluvial/lake/glacial deposits
 Jhelum river flows through it, drains to Wular Lake, largest freshwater lake in India

The Outer Himalayas (Shivalik Range)

- Also known as Manak Parbat.
- Southernmost & youngest Himalayan range; lies between the Lesser Himalaya & the plains.
- Width 10–50 km, decreasing west→east (50 km in HP → <15 km in Arunachal Pradesh).
- Avg height 900–1,100 m.
- Composed of sandstone & conglomerate (solidified Himalayan detritus).
- Himalayan Front Fault separates the Shivalik from the plains.
- Bhabar = belt of coarse gravel and pebble deposits along the Shivalik foothills, forming a transition zone to the plains.
- Almost unbroken chain except for an 80–90 km gap occupied by the Teesta & Raidak river valleys.
- Local names include Jammu hills, Dhang and Dundwa ranges (Uttarakhand), Churia Ghat hills (Nepal); the Margalla Hills (Pakistan) are their western continuation.

Local Names of the Shivalik

Region	Local Name
Jammu region	Jammu Hills
Uttarakhand	Dhang Range & Dundwa Range
Nepal	Churia Ghat (Churia) Hills
Arunachal Pradesh	Dafla, Miri, Abor, Mishmi Hills

- Duns/Doons/Duars = longitudinal valleys between the Lesser Himalaya & the Shivalik.
- Formed by the India–Eurasia collision; filled with coarse alluvium carried by Himalayan rivers.
- Called Duns in the west, Duars in the east (e.g. Dehradun, Kotlidan, Patlidan).
- Chos = badland-type, highly dissected slopes cut by seasonal streams on the deforested southern Shivalik slope of Punjab/HP.
- Chos are typical in Hoshiarpur district, Punjab.

Regional Divisions (Punjab/Kumaon/Nepal/Assam Himalaya)

Regional Divisions of the Himalaya

Region	Extent	Key Facts
Kashmir/Punjab Himalaya	Between Indus River & Satluj River, ~560 km	Contains Karakoram, Ladakh, Pir Panjal, Zaskar, Dhauladhar ranges; famous for Karewa (saffron); glaciers: Baltoro, Siachen; key areas, Ladakh plateau, Kashmir valley

Region	Extent	Key Facts
Kumaon Himalaya	Between Satluj River & Kali River, ~320 km	Western part = Garhwal Himalaya, eastern = Kumaon Himalaya; higher elevation than Punjab Himalaya; peaks: Nanda Devi, Kamet, Trisul, Badrinath, Kedarnath, Gangotri; with Punjab Himalaya forms the Western Himalaya; connects to Tibet via Thang La, Mana Pass, Lipu Lekh, Niti La
Nepal/Central Himalaya	Between Kali River (west) & Tista River (east), ~800 km	Great Himalaya attains maximum height here: Mt. Everest, Mt. Kanchenjunga, Mt. Makalu, Annapurna, Dhaulagiri; Lesser Himalaya here = Mahabharat Lekh; lacustrine valleys, Kathmandu, Pokhara
Assam Himalaya	Between Tista River (west) & Dihang/Brahmaputra River (east), ~720 km	Southern slope very steep vs gentle northern slope; tea plantations; prominent Duars (e.g. Bengal Duars); dominated by fluvial erosion (heavy rainfall); Jelep La links Sikkim to Tibet's Chumbi valley, near the India-China-Bhutan tri-junction (Doklam)

Western vs Eastern Himalaya

Feature	Western Himalaya	Eastern Himalaya
Extent	West of river Kali	East of Kali, from Singalila range (Sikkim) to eastern Himalaya boundary
Rise from plains	Height rises in stages, long distance from plains	Rises abruptly, peaks close to plains
Rainfall	Much lower rainfall	Heavy rainfall
Snowline	Lower	Higher
Precipitation type	Mostly snowfall	Both rainfall & snowfall
Biodiversity	Less	High

Purvanchal Hills (NE Hills)

- Eastward extension of the Himalaya after a sudden southward turn at the Dihang gorge.
- Runs N-S along the India-Myanmar border.
- Composed of sedimentary rock, dense forest.

Purvanchal Component Hills

Hill Range	State/Region
Patkai Bum Range	Arunachal Pradesh
Naga Hills	Nagaland
Manipur Hills	Manipur-Myanmar border
Barail Hills	Assam (separates Naga & Manipur Hills)
Garo-Khasi-Jaintia Hills	Meghalaya (eastward extension of the peninsular block)
Mizo/Lushai Hills	Mizoram

Important Peaks

Major Himalayan & Karakoram Peaks

Peak	Height	Range	Country
Mount Everest	8,848 m (revised 8,848.86 m)	Himalayas	Nepal

Peak	Height	Range	Country
Kangchenjunga	8,586 m	Himalayas	Nepal, India
Lhotse	8,516 m	Himalayas	Nepal, China
Makalu	8,485 m	Himalayas	Nepal, China
Cho Oyu	8,188 m	Himalayas	Nepal, China
Dhaulagiri I	8,167 m	Himalayas	Nepal
Manaslu	8,163 m	Himalayas	Nepal
Nanga Parbat	8,126 m	Himalayas	Pakistan (Gilgit-Baltistan)
Annapurna I	8,091 m	Himalayas	Nepal
Mt. Godwin Austen (K2)	8,611 m	Karakoram	PoK (Gilgit-Baltistan)/China; 2nd highest peak in the world; highest peak of India as per its territorial claim
Gasherbrum I (K5)	8,080 m	Karakoram	Pakistan, China
Broad Peak (K3)	8,051 m	Karakoram	Pakistan, China
Gasherbrum II (K4)	8,035 m	Karakoram	Pakistan, China
Shishapangma (Gosainthan)	8,027 m	Himalayas	China

Himalayan Glaciers by Region

Glacier(s)	Region
Siachen, Baltoro, Biafo, Hispar, Chong Kumdan, Trango	Karakoram
Gangotri, Satopanth, Pindari, Milam, Kafni, Sunderdhunga, Namik, Panchchuli, Ralam, Sona, Bhagirath Kharak, Sonapani	Kumaon-Garhwal
Zemu, Kanchenjunga glacier (Sikkim); Rongbuk, Khumbu (Everest)	Kanchenjunga-Everest region
Bara Shigri, Chhota Shigri	Lahaul-Spiti (Pir Panjal-Great Himalaya, HP)
Lonak	Sikkim Himalaya

Fedchenko Glacier

Longest glacier in the world outside the polar regions
 Located in the Pamir Mountains, Tajikistan (~77 km)

Important Passes

Important Himalayan Passes

Pass	State/Region	Feature/Remark
Mintaka Pass	Gilgit-Baltistan (PoK)-Xinjiang	Near the tri-junction of China, Afghanistan (Wakhan) and PoK
Karakoram Pass	Ladakh (Karakoram)	Connects Ladakh with Xinjiang Province, China
Khunjerab Pass	Karakoram	Connects Gilgit-Baltistan (PoK) with Xinjiang; Karakoram Highway passes through it
Aghil Pass	Karakoram	Connects Ladakh (via the Shaksgam valley) with Xinjiang
Zoji La	J&K/Ladakh	Connects Srinagar (Kashmir) to Kargil (Ladakh)
Banihal Pass	J&K	Connects Jammu with Srinagar, across Pir Panjal range; snow-covered in winter; gateway to Kashmir valley

Pass	State/Region	Feature/Remark
Sia La	Ladakh	Near Siachen Glacier, Saltoro ridge
Changla Pass	Ladakh	Between Leh and Changthang
Khardung La	Ladakh	Connects Leh and the Nubra valley; once billed as the highest motorable pass; Umling La (Ladakh, ~5,798 m) now holds the record for the highest motorable road
Kongka Pass / Lanak Pass	Ladakh	Indo-China border, connects Kashmir & China
Saseer La	Ladakh	Connects the Nubra valley with the Shyok valley towards the Karakoram Pass
Tanglang La; Imis La; Spanggur Gap	Ladakh	Tanglang La lies on the Leh–Manali highway; Imis La and Spanggur Gap lead towards Tibet
Bara Lacha La	Himachal Pradesh	Connects Lahaul (HP) with Ladakh on the Manali–Leh road; source area of the Bhaga and Chandra rivers
Kunzum Pass	Himachal Pradesh	Connects Lahaul and Spiti valley
Debsa Pass	Himachal Pradesh	Links Kullu and Spiti districts
Rohtang Pass	Himachal Pradesh	Links Kullu with the Lahaul and Spiti valleys; bypassed by the Atal Tunnel (2020, world's longest highway tunnel above 10,000 ft)
Shipki La	Himachal Pradesh	Connects HP with Tibet; Sutlej river enters India near this pass; significant Indo-China pass
Lipu Lekh	Uttarakhand	Tri-junction of Uttarakhand (India), Tibet (China) and Nepal; route of the Kailash Mansarovar Yatra (resumed 2025)
Mana Pass	Uttarakhand	Connects Uttarakhand with Tibet
Niti La	Uttarakhand	Connects Uttarakhand with Tibet
Nathu La	Sikkim	Connects Sikkim with Tibet; historic trade route; also used for the Kailash Mansarovar Yatra
Jelep La	Sikkim	Connects Sikkim with Tibet's Chumbi valley, near the India–China–Bhutan tri-junction
Bom Di La	Arunachal Pradesh	Connects Arunachal Pradesh (Tawang) with Tibet
Diphu Pass	Arunachal Pradesh	Near the India–China–Myanmar tri-junction; eastern end of the McMahon Line
Pangsau Pass	Arunachal Pradesh	India–Myanmar; on the historic Stilwell (Ledo) Road

Northern Plains

Formation

- Formed by the Indo-Gangetic trough: a shallow syncline between the newly formed Himalayas and the Peninsular plate.
- Himalayan rivers deposited sediment here as the Tethys Sea disappeared, leaving monotonous depositional plains.
- Also known as the Indus-Ganga-Brahmaputra Plain / Great Northern Plain.
- World's largest aggradational plain.
- India's youngest physiographic feature.
- Lies south of the Shivaliks (boundary = Himalayan Frontal Fault).
- Bounded by: Peninsular Plateau (S), Purvanchal Hills (E), Sulaiman & Kirthar ranges (W).
- Stretches ~2,400 km West to East.
- Width 240–320 km (NCERT); broader in the west, narrowest in Assam.
- Average elevation ~200 m ASL.
- Highest point near Ambala (~291 m): the drainage divide/watershed between the Indus and Ganga river systems.

Significance of Northern Plains

- Densely populated: home to roughly two-fifths of India's population.
- Agricultural significance: fertile alluvial soil, flat surface, perennial rivers, favourable climate.
- Punjab, Haryana, western UP called the "Granaries of India".

Bhabar/Tarai/Bhangar/Khadar (North to South sub-division)

- Sub-division is based on the nature of deposited sediments: Bhabar → Tarai → Bhangar/Khadar.
- Bhabar: ~8–16 km wide belt of heavy deposits (gravels, pebbles) along the Shivalik foothills.
- Bhabar is the northernmost layer of the Indo-Gangetic plain; wider in the west than the east.
- High porosity in Bhabar → river streams disappear here; unsuitable for agriculture.
- Tarai (Terai): ~15–30 km wide, ill-drained, marshy, thickly forested.
- Streams that vanish in the Bhabar re-emerge in the Tarai, running parallel south of it.
- Tarai thickness increases west to east (east gets more rainfall).
- Tarai soil rich in nitrogen and organic matter → cleared for cultivation (sugarcane, rice, wheat, maize, oilseeds, fodder) in Punjab, Haryana, UP.
- Tarai is forested: shelters tiger, elephant, rhino, etc.

Bhangar vs Khadar

Feature	Bhangar	Khadar
Alluvium	Old alluvial deposits	New alluvial deposits
Elevation	Higher floodplain terraces	Lower floodplain
Kankar (lime nodules)	Present	Absent/very rare
Fertility	Less fertile	More fertile
Flood-proneness	Less prone to floods (above flood limit, not renewed yearly)	Prone to floods (renewed yearly)

- Bhangar: old alluvium forming terraces above the flood limit; not renewed yearly; contains Kankar (calcareous concretions).
- Saline/alkaline efflorescence in Bhangar's dry tracts is called Reh or Kallar; Reh areas are expanding due to irrigation-driven capillary action.
- Bhur formation occurs in the upper Ganga-Yamuna Doab (wind-blown sand).
- Barind plains (Bengal delta) = a regional variant of Bhangar.
- Khadar: new alluvium forming the floodplain, renewed yearly by floods; highly fertile.
- In Punjab, Khadar is locally called "Betlands"/"Bets".
- The Deltaic Plain is an extension of Khadar (old mud + new mud + marsh).
- In the Deltaic Plain, uplands are called Chars and marshy areas are called Bils.

Regional Division of Northern Plains (geo-climatic)

- Four regional divisions: Rajasthan Plain, Punjab-Haryana Plain, Ganga Plain, Brahmaputra Plain.
- Rajasthan Plain: undulating plain, avg elevation ~325 m.
- Rajasthan Plain is occupied by the Thar/Great Indian Desert; formed by the Indus river system.
- Has outcrops of gneiss, granite → geologically part of the Peninsular Plateau.
- Luni river (important seasonal river) flows into the Rann of Kutch.
- Punjab-Haryana Plain: "Punjab" means "land of five waters", shaped by the Jhelum, Chenab, Ravi, Sutlej, Beas.
- Bounded by Shivaliks (N), Yamuna (E), arid Rajasthan (S), Ravi & Sutlej (NW/SW).
- The Delhi ridge separates the Punjab-Haryana Plain from the Ganga Plain.
- Saline efflorescence (Reh/Kallar) is seen here in drier areas.

Punjab-Haryana Doabs

Doab	Between
Sindh Sagar	Indus and Jhelum
Chaj	Chenab and Jhelum

Doab	Between
Rachna	Ravi and Chenab
Bari	Beas and Ravi
Bist Jalandhar	Sutlej and Beas

- Ganga Plain: ~1,400 km west-east, average width 300 km.
- Lies between the Yamuna catchment (west) and the Bangladesh border (east).
- Built by the Ganga + tributaries' alluvium, with peninsular rivers (Chambal, Betwa, Ken, Son) also contributing.
- Sub-divided into Upper Ganga Plain, Middle Ganga Plain, Lower Ganga Plain.

Divisions of the Ganga Plain

Division	Area Covered	Key Points
Upper Ganga Plain	Ganga-Yamuna doab, Rohilkhand division, Awadh, part of Agra division	General slope E/SE; Green Revolution success region, highly productive
Middle Ganga Plain	Central/eastern UP + part of Bihar up to Muzaffarpur	Thick alluvium, less Kankar; low gradient → river shifts course often; Kosi = "Sorrow of Bihar" (notorious meandering)
Lower Ganga Plain	Patna to Bay of Bengal	River suddenly turns south into Bay of Bengal; flood-prone, rich in Khadar; rice cultivation & aquaculture prominent

- Regional divisions of the Ganga Plain: Rohilkhand plains, Avadh plains, Mithila plains, Magadh plains.
- Brahmaputra Plain: also called Brahmaputra valley / Assam valley / Assam plain.
- Easternmost part of the Indo-Gangetic plains; bounded by the Lower Ganga Plain (west), Purvanchal Hills (east).
- Formed by sediment deposition of the Brahmaputra and its tributaries.
- Low gradient → highly braided river → riverine islands, including Majuli.
- Jute and rice are the major crops.
- The Ganga-Brahmaputra delta = the biggest delta in the world; protected by the tidal Sundarbans forest.

Malda Gap / Garo-Rajmahal Gap

- A fault formed between the Rajmahal Hills and the Meghalaya Plateau, due to NE movement of the Indian plate during Himalayan orogeny.
- Later filled by river deposits, separating the Meghalaya Plateau from the main Peninsular Block.

Peninsular Plateau

- Roughly triangular shaped; oldest and most stable landmass of India.
- Mostly composed of Archaean gneisses and schists.
- Bounded by: Northern Plains (N), Delhi ridge (NW), Rajmahal Hills (E), Gir range (W), Western & Eastern Ghats (SW/SE).
- Covers ~16 lakh sq km; avg elevation 600–900 m ASL.
- General slope is West to East.
- Peninsular rivers mostly flow west→east into the Bay of Bengal, due to this slope.
- Exceptions: Narmada and Tapi flow east→west, through rift valleys.

Hill Ranges

- Most hills of the Peninsular Plateau are residual hills, remnants of fold mountains/uplifted blocks.

Major Hill Ranges of the Peninsular Plateau

Range	Alignment/Length	Highest Peak	Key Facts
Aravalli Range	NE-SW, ~800 km, Delhi to Ahmedabad	Guru Shikhar (~1,722 m), Mt. Abu	One of the oldest mountains in the world, summits probably once higher than present-day Himalayas; passes through Delhi, Haryana, Rajasthan, Gujarat; rivers originating here: Banas, Luni, Sabarmati; passes (Udaipur-Ajmer): Piplighat, Dewair, Desuri; lakes: Sambhar, Dhebar, Jaisamand; separated from the Vindhyan range by the Great Boundary Fault (GBF)
Vindhyan Range	E-W, >1,200 km, roughly parallel to the Narmada valley	-	Series of scarps/block mountains formed by faulting along the Narmada rift (to their south); general elevation 300–650 m; watershed between the Ganga system and the peninsular rivers; comprises Vindhyachal, Bhandar and Kaimur ranges
Satpura Range	E-W, ~900 km, between Narmada and Tapti	Dhupgarh (1,350 m), on Mahadeo Hills near Pachmarhi	Series of scarped plateaus (folding + structural uplift); includes Mahadeo hills, Maikal range (E), Rajpipla hills (W); Amarkantak (~1,065 m) on the Maikal range = source of the Narmada and Son; Dhuandhar falls on the Narmada near Jabalpur

Western Ghats

- Western edge of the Peninsular Plateau, parallel to the Arabian Sea.
- 2nd largest mountain range in India after the Himalayas.
- Spans 6 states: Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu.
- Extends from the Tapti river valley to Kanyakumari, 1,600 km.
- Gentle slope on the eastern side.
- Appears abrupt (rises to ~1,000 m) when viewed from the western coastal plains.

Western Ghats: Sections

Section	Also Known As	States	Avg Height	Key Rivers/Peaks
Northern Section	Sahyadri	Maharashtra	~1,200 m ASL	Rivers: Godavari (Nasik), Bhima (Bhimashankar), Krishna (Mahabaleshwar); Peaks: Kalasubai (highest of Sahyadri), Salher, Harishchandragarh; Passes: Thal Ghat (Nasik-Mumbai), Bhor Ghat (Mumbai-Pune)
Middle Section	-	Goa, Karnataka (ends at Nilgiris, meets Eastern Ghats)	~1,200 m	Peaks: Kudremukh, Pushpagiri; Rivers: Tungabhadra, Cauvery (Brahmagiri); Bababudan hills (Karnataka) famous for coffee
Southern Section	-	Kerala, Tamil Nadu	-	Annamalai hills, Cardamom hills (see details below)

Western Ghats Highlights

Palghat Gap: largest gap in the Western Ghats; separates the Nilgiris from the Anamalai hills
 Anamudi peak (Annamalai hills): highest peak of the Peninsula
 Agasthyamalai hill: southernmost point of the Western Ghats (Kerala-Tamil Nadu)

- Palani hills form the eastern spur of the Anamalai hills (Kodaikanal hill station).
- Periyar river rises in the Sivagiri hills of the Western Ghats and flows to the Arabian Sea.
- The Shencottah (Shenkottai) Gap separates the Cardamom Hills from the Agasthyamalai Hills to the south.
- Vaigai river originates from the Varushnad hills (part of the Cardamom hills).

Eastern Ghats

- Eastern edge of the Peninsular Plateau, parallel to the Bay of Bengal.

- Discontinuous and lower than the Western Ghats.
- Extends from the Mahanadi valley (Odisha) to the Nilgiris in the south (NCERT).
- Between the Mahanadi & Godavari: true mountain character.
- Highest peak in this stretch: Jindhagada Peak (1,690 m), Araku valley.
- Nearly disappears between the Godavari and Krishna rivers.
- Reappears as the Nallamala range (Cuddapah, Kurnool districts, AP), whose southern part = the Palkonda range.
- Further south lie the Javadi, Shevaroy (Yercaud), Kollimalai and Pachaimalai hills of Tamil Nadu.

Western Ghats vs Eastern Ghats

Feature	Western Ghats	Eastern Ghats
Position	Western edge of Deccan Plateau	Eastern edge of Deccan Plateau
Continuity	Continuous, crossed only via passes	Discontinuous, irregular, dissected by rivers
Vegetation	Evergreen to deciduous forest	Scrub vegetation (overgrazing, deforestation)
Highest peak	Anaimudi (2,695 m)	Jindhagada (~1,690 m, AP); Deomali (~1,672 m) is the highest in Odisha
Slope	Steep; height increases N to S	Gentle slope
Rivers	Source of Godavari, Krishna, Kaveri; short fast west-flowing rivers (Sharavathi, Netravati, Periyar, Bharathapuzha)	Cut across by Mahanadi, Godavari, Krishna, Kaveri (rivers break the range into hill groups)

Central Highlands

- Also called Madhya Bharat Pathar/Plateau.
- Drained by the Chambal, Betwa and Ken, which flow north-east to the Yamuna.
- Rolling plateau with rounded sandstone hills.
- The Ravines/Badlands of the Chambal River lie north of the Central Highlands.

Plateaus of the Central Highlands

Plateau	Location/Bounds	Key Facts
Malwa Plateau	Aravalli (W/NW), Vindhya (S), Bundelkhand (E)	Triangular plateau of Deccan lava over Vindhyan rocks; two drainage systems: Arabian Sea (Mahi; Narmada along its southern edge) and Bay of Bengal (Chambal, Kali Sindh, Betwa via the Yamuna); avg elevation ~500 m; covered by black soil
Bundelkhand Plateau	Yamuna (N), Central Highlands (W), Vindhyan Scarplands (E/SE), Malwa (S)	Old dissected upland of Bundelkhand granite & gneiss; badly eroded with ravines, semi-arid; rivers: Betwa, Dhasan, Ken
Baghelkhand Plateau	North of Maikala range; bounded by Son (N) and Mahanadi (S) drainage	Limestone/sandstone (west), granite (east); elevation 150–1,200 m; Bhaner and Kaimur near the trough-axis
Chotanagpur Plateau	Parts of Jharkhand, N. Chhattisgarh, Purulia (WB)	Avg elevation 700 m; Gondwana rocks: major coal source; radial drainage; Damodar River flows through a rift valley (W-E); Hazaribagh plateau (N of Damodar), Ranchi plateau (S); Rajmahal Hills (basalt, lava) to NE; rich in iron ore, coal, bauxite
Meghalaya Plateau	Eastward extension beyond Rajmahal Hills	Locally: Shillong Plateau, Karbi Anglong plateau, North Cachar plateau; separated from Peninsular Plateau by the Malda fault (= Garo-Rajmahal Gap); hills (W to E): Garo, Khasi, Jaintia; composed of Archaean quartzites, shale, schists with granite intrusion; Brahmaputra basin to the north; Shillong = highest point
Dandakaranya Plateau	NE of Deccan Plateau; Abujhmar hills (W), Eastern Ghats (E)	Covers Chhattisgarh, Odisha, Telangana, AP, part of Maharashtra; drained by Mahanadi & Godavari systems; thickly forested
Mewar Plateau	East of Aravalli (Marwar lies west of Aravalli)	Eastward slope, elevation 250–500 m ASL; Banas river carved the rolling plain

Plateau	Location/Bounds	Key Facts
Chhattisgarh Plain	Between Maikala range and Odisha hills	Only notable plain within the Peninsular Plateau; saucer-shaped depression drained by the upper Mahanadi; elevation 250–330 m, W–E gradient

Deccan Plateau

- Triangular shape; bounded by Satpura & Vindhyan ranges (NW), Mahadeo & Maikal hills (N), Western & Eastern Ghats (W/E).
- Avg elevation 600 m; gradient slopes W→E.
- Major rivers: Mahanadi, Godavari, Krishna, Cauvery.
- Sub-divided into Maharashtra Plateau, Karnataka Plateau, Telangana Plateau.

Sub-Plateaus of the Deccan

Sub-plateau	Key Facts
Maharashtra Plateau	Northern part of the Deccan Plateau; basaltic lava rocks → Deccan Trap (horizontal lava spread); looks like rolling plain due to weathering; rivers: Godavari, Bhima, Krishna; covered by black/Regur soil
Karnataka Plateau	Also called Mysore Plateau; south of Maharashtra Plateau; elevation 600–900 m; highest peak Mullayanagiri (~1,930 m, Baba Budan Hills, Chikkamagaluru); divided into Malnad (hill country, dense forest) and Maidan (rolling plain, low granite hills); the Western & Eastern Ghats converge in the Nilgiris to its south
Telangana Plateau	Made of Archaean gneiss and Dharwar rocks (mineral-rich); elevation 500–600 m; drained by the Godavari, Krishna (with Manjira, Musi) and Penneru

Natural Resource Potential of Deccan Plateau

- Black (Regur) soil: formed from Deccan Trap weathering; rich in iron, lime, aluminium, magnesium, potassium; used for cotton, millets, tobacco, citrus.
- Bauxite: Odisha (largest; Panchpatmali, Koraput), Jharkhand, Gujarat, Chhattisgarh, MP, Maharashtra.
- Iron ore: Odisha (largest), Chhattisgarh, Karnataka and Jharkhand are the leading producers; Goa is a major exporter.
- Coal: ~98% of India's coal (Gondwana) lies in the peninsular plateau; also copper (Khetri, Malanjkhand), gold (Kolar, Hutti), diamonds (Panna).
- Agriculture: black lava soil (NW) good for cotton; hilly tracts support tea, rubber, coffee.
- Oil & gas occur in the sedimentary basins at the plateau margins (Krishna–Godavari, Cauvery, Cambay), not in the crystalline plateau itself.

Himalayan Region vs Peninsular Plateau

Feature	Himalayan Region	Peninsular Plateau
Age	Recent, fold mountains	Oldest landmass, part of Gondwanaland
Relief	Loftiest mountains, deep valleys	Rounded hills, broad shallow valleys
Formation	Collision of Indian & Eurasian plates	Breaking/drift of Gondwanaland
Rock type	Mostly sedimentary (with metamorphic rocks and a granite core)	Mainly igneous and metamorphic (gneiss, granite, basalt)
Tectonic status	Tectonically active, still rising	Stable landmass
Rivers	Indus, Ganga, Brahmaputra, Yamuna	Godavari, Krishna, Narmada, Cauvery

Indian Desert (Thar)

- Located NW of the Aravalli hills; a large arid region in NW India.
- Bordered by Aravalli (NE), Punjab & Haryana (N), Indus alluvial floodplain (NW), Rann of Kutch.
- Also called the Thar Desert.
- Forms a natural boundary between India-Pakistan; only ~15% of it lies in Pakistan.
- Covers ~4.56% of India's geographical area, across Rajasthan and Gujarat.
- The 9th largest hot subtropical desert in the world.
- Rainfall < 150 mm in the extreme west to ~500 mm in the east; also called Marusthali ("land of the dead").
- Luni river: the main ephemeral river, begins in the Pushkar valley (Aravalli), flows into the Rann of Kutch.

Thar Desert: Local Terms

Term	Meaning
Thali	Sandy plain region north of the Luni
Rohi	Fertile patches supported by small seasonal streams from the Aravalli
Playas	Dry lakes/depressions filled by surface water, dry up in summer (evaporation); brackish water; source of salt, e.g. Sambhar Lake
Bagar (also Bagad/Bar)	Sandy tract of NW India/E Pakistan, "dry country"
Jhang Bar	Upland (bar) in Pakistani Punjab between the Chenab and Ravi

Protected Areas in the Thar Desert

Protected Area	Area	Notes
Desert National Park	~3,162 km ²	One of the largest Thar ecosystems
Tal Chhapar Sanctuary	~7 km ²	Churu district: foxes, blackbuck, partridge
Sundha Mata Conservation Reserve	117.49 km ²	Jalore district
Lal Suhanra Biosphere Reserve & National Park	-	Pakistan's Thar portion; UNESCO biosphere reserve

- Fauna: Great Indian Bustard (Godawan, state bird of Rajasthan, Critically Endangered), Blackbuck, Chinkara, Desert Fox, Caracal, Wolf, Sand Grouse, Desert Cat.

Coastal Plains

- Two narrow plains flank the peninsular plateau: Eastern Coastal Plain and Western Coastal Plain.

Western Coastal Plain

- ~50 km wide strip between the Arabian Sea and the Western Ghats.
- Extends from the Gulf of Cambay (Khambhat) to Kanyakumari.
- States: Gujarat, Maharashtra, Goa, Karnataka, Kerala.

Western Coastal Plain: Regional Names

State	Local Name
Gujarat	Kathiawar coast
Maharashtra, Goa	Konkan coast
Karnataka	Kannada coast
Kerala	Malabar coast

- Kathiawar plain: covers Kutch & Kathiawar, now levelled, treated as part of the western coastal plain.
- Great Rann of Kutch (dry salt plain) lies north of the Kutch Peninsula; its southward extension = the Little Rann.

- Mt. Girnar (volcanic origin) = highest point of the Kathiawar plain.
- Gir range (south of Kathiawar) = Gir lion habitat.
- Konkan plain: extends from Daman to Goa; a submerged coast with cliffs, creeks and estuaries.
- Thane Creek (Ramsar site, 2022) flanks Mumbai, India's finest natural harbour.
- Karnataka (Kannada) plain: narrow, indented; from Goa to Mangaluru.
- Kayals (backwaters/shallow lagoons running parallel to the coast) are characteristic of the Malabar (Kerala) coast.
- Malabar plain: wider than the Karnataka plain; from Mangaluru to Kanyakumari.

Eastern Coastal Plain

- Broad alluvial plain between the Eastern Ghats and the Bay of Bengal.
- Extends from the Ganga delta to Kanyakumari.
- Formed by Mahanadi, Godavari, Krishna, Cauvery alluvium.
- Wider than the Western Coastal Plain; an emergent coast.

Eastern Coastal Plain: Regional Names

Region	Local Name
Odisha coast	Utkal coast
South of Utkal	Andhra Coast
Tamil Nadu + south Andhra coast	Coromandel coast
Between Mahanadi-Krishna	Northern Circars
Between Krishna-Cauvery	Carnatic plain

- Chilika lake and Pulicat lake (lagoons) lie along this coast.
- Utkal plain: covers the Odisha coast + Mahanadi delta; Chilka lake = the biggest lagoon/brackish lake here.
- Andhra plain: lies south of Utkal, up to Pulicat lake.
- Godavari & Krishna deltas have merged into a single unit.
- The Andhra plain has a straight coast, lacking good harbours (exceptions: Visakhapatnam, Machilipatnam).
- Tamil Nadu plain: from Pulicat lake to Kanyakumari; includes the Cauvery delta.

Western Coastal Plain vs Eastern Coastal Plain

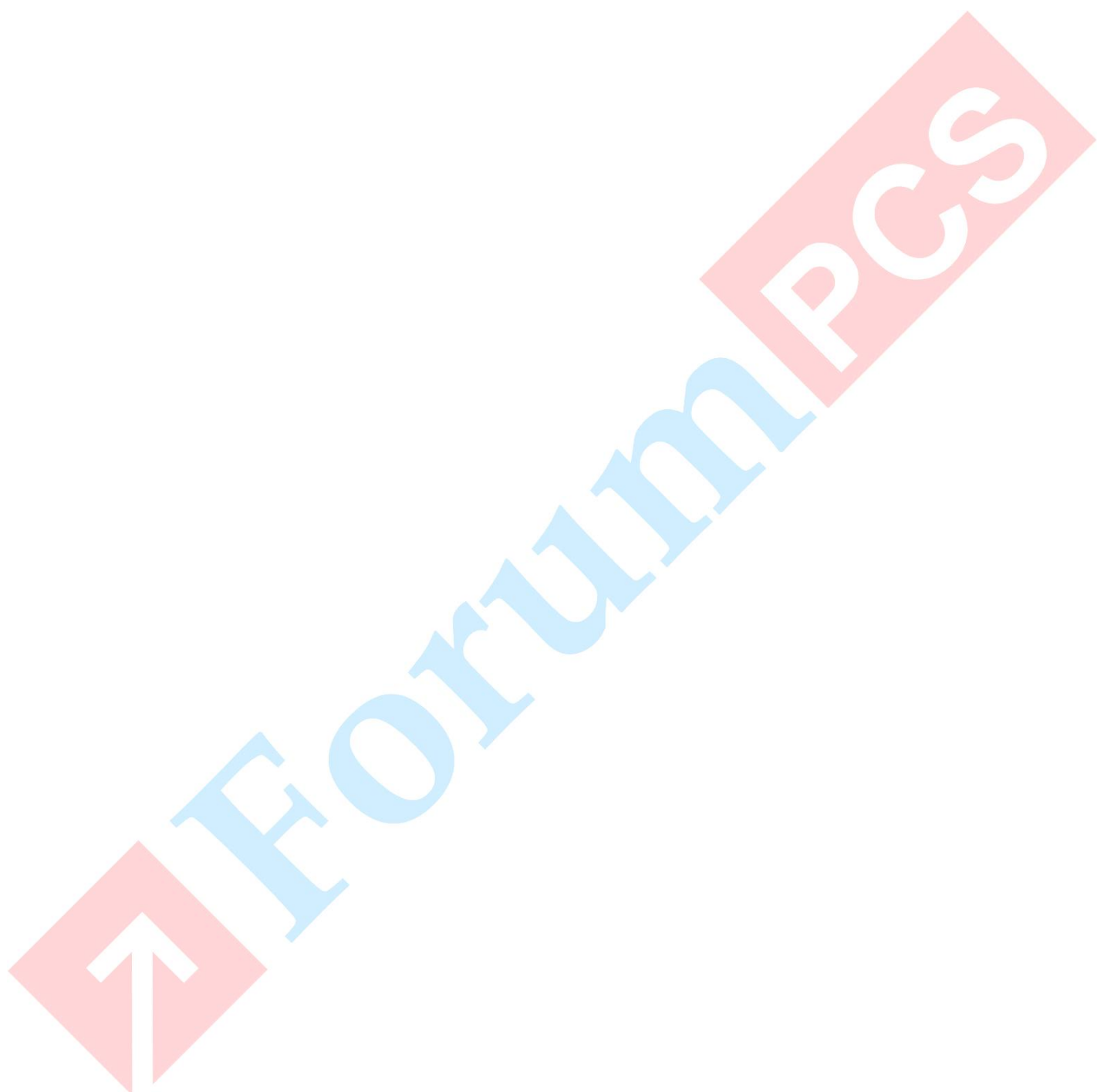
Feature	Western Coastal Plain	Eastern Coastal Plain
Location	Between Western Ghats & Arabian Sea	Between Eastern Ghats & Bay of Bengal
Extent	Gulf of Khambhat to Kanyakumari	Ganga Delta to Kanyakumari
Orientation	Parallel to Western Ghats	Parallel to Eastern Ghats
Coast type	Mostly submerged (north); emergent features in Kerala	Emerged coastal plain
Width	Narrower, elongated	Broader
Deltas	Rivers do NOT form deltas	Rivers form well-developed deltas
Natural ports	Kandla, JNPT, Marmagaon, Mangaluru, Cochin	Comparatively fewer natural ports/harbours
Sub-divisions	Kathiawar, Konkan, Kannada, Malabar	Utkal, Andhra, Coromandel

Types of Coastlines

- Emerged coastline: formed by land upliftment or sea-level fall.
- Emerged coastline features: bars, spits, lagoons, salt marshes, sea cliffs, arches.
- The eastern coast and the southern part of the western coast are emergent, e.g. Coromandel coast (TN), Malabar coast (Kerala).
- Submerged coastline: formed by coastal subsidence or sea-level rise.
- Northern part of the western coast: Kathiawar and Konkan coasts, is submerged, due to faulting.

Significance of Coastline

- Agriculture: rice is the main crop; coconut trees grow along the coast.
- Economic: ports handle ~95% of India's trade by volume, ~70% by value.
- Minerals: monazite sands (source of thorium) along the coasts of Andhra Pradesh (largest resources), Tamil Nadu, Odisha and Kerala; ilmenite and zircon in Kerala's Chavara beach.
- Tourism: beaches of Maharashtra, Goa, Kerala; Kerala backwaters support houseboat and Ayurveda/wellness tourism.



CHAPTER 10

India: Coastal Regions & Islands, States/UTs, Species/Tribes

Coastal Regions

Islands

- India has two major island groups: Andaman & Nicobar Archipelago (Bay of Bengal) and Lakshadweep (Arabian Sea).

Andaman & Nicobar Islands

- About 572 islands (including islets); only a few dozen are inhabited; a Union Territory with Sri Vijaya Puram (formerly Port Blair, renamed in 2024) as capital.
- Located at the juncture of the Bay of Bengal and the Andaman Sea; the islands are elevated parts of a submerged mountain range (extension of the Arakan Yoma); Barren and Narcondam are volcanic.
- The Ten Degree Channel separates the Andaman group (north) from the Nicobar group (south).

Andaman Group

- Divided into North, Middle, South Andaman islands; Duncan Passage separates Little Andaman from South Andaman.
- Terrain: sandstone, shale, limestone.

Andaman Peaks & Volcanoes

Saddle Peak (732 m): highest peak of the archipelago, North Andaman
 Mount Harriet (renamed Mount Manipur in 2021): South Andaman
 Barren Island: India's only active volcano
 Narcondam Island: another (dormant) volcanic island

Renamed Islands (Andaman & Nicobar)

Old Name	New Name
Ross Island	Netaji Subhas Chandra Bose Dweep
Neil Island	Shaheed Dweep
Havelock Island	Swaraj Dweep
Port Blair (capital)	Sri Vijaya Puram (2024)
Mount Harriet	Mount Manipur (2021)
21 largest unnamed islands	Named after 21 Param Vir Chakra awardees (January 2023)

Nicobar Group

- About 22 main islands, close to Sumatra (Indonesia).
- Great Nicobar: largest & southernmost island, ~150 km from Sumatra; Indira Point (Pygmalion Point) here is India's southernmost point; site of the Great Nicobar Holistic Development Project (transshipment port, airport, township).
- Car Nicobar: northernmost island, coral-formed.

Indigenous Tribes of Andaman & Nicobar

- 4 "Negrito" tribes (Andaman): Great Andamanese, Onge, Jarawa, Sentinelese, all classified as Particularly Vulnerable Tribal Groups (PVTGs).
- 2 "Mongoloid" tribes (Nicobar): Shompen and Nicobarese.

Andaman Tribes: Status

Great Andamanese: nearly extinct (~59 persons, 2020); settled on Strait Island; once spoke 10 distinct languages, now largely Hindi/creole
 Onge: inhabit Little Andaman; PVTG
 Jarawa: inhabit South Andaman & western Great Andaman; maintained isolation/hostility to outsiders until the 1990s–2000s
 Sentinelese: inhabit North & South Sentinel Island; most isolated tribe in the world, resist all outside contact
 Nicobarese: largest tribal community of the islands; Mongoloid stock, found across Nicobar group
 Shompen: inhabit interior of Great Nicobar; hunter-gatherers, among the most isolated tribes

Lakshadweep

- Coral (atoll) origin islands in the Arabian Sea, SW of the Kerala coast; smallest Union Territory of India (area-wise).
- 36 islands (including islets), of which 10 are inhabited; Kavaratti = capital; total area only ~32 sq km.
- Amindivi islands = northernmost group; Minicoy Island = southernmost island.
- Vulnerable to rising sea level (low elevation); topographically flat: no hills, streams, or valleys.

Lakshadweep: Island Groups

Group	Islands
Amindivi islands	Amini, Kiltan, Chetlat, Kadmat, Bitra, Perumul Par
Laccadive islands	Androth, Kalpeni, Kavaratti, Pitti, Suheli Par
Minicoy	Minicoy: 2nd largest island (after Androth); the 9° Channel separates it from the Laccadive group, and the 8° Channel from the Maldives

Other Notable Islands

- Majuli: world's largest freshwater riverine island (Brahmaputra, Assam); India's first island district.
- Salsette: India's most populous island (Mumbai city).
- Sriharikota: barrier island, ISRO satellite launch station (Andhra Pradesh coast).
- Abdul Kalam Island (Wheeler Island): satellite/missile launch station off the Odisha coast, Bay of Bengal; renamed in 2015.
- Aliabet: India's first offshore oil well site, ~45 km off Bhavnagar, Gujarat (Gulf of Khambhat).
- Pamban Island (Rameswaram): connected to the mainland by the new Pamban Bridge (2025), India's first vertical-lift sea bridge; Ram Setu extends from its tip (Dhanushkodi) toward Sri Lanka.
- New Moore Island (Purbasha/South Talpatti): a small island in the Sundarbans delta, once disputed between India and Bangladesh; it has since disappeared under the sea (erosion and sea-level rise).

States/Union Territories of India

- India comprises 28 States and 8 Union Territories (as of 2026).

States of India: Capital, Formation Year, Notes

State	Capital	Formation Year	Notes
Andhra Pradesh	Amaravati	1 Nov 1956	Bifurcated in 2014 to form Telangana
Arunachal Pradesh	Itanagar	20 Feb 1987	Easternmost state of India
Assam	Dispur	26 Jan 1950	Most populous state of NE India (Arunachal Pradesh is the largest by area in NE)
Bihar	Patna	26 Jan 1950	Jharkhand carved out of it in 2000
Chhattisgarh	Raipur	1 Nov 2000	Carved out of Madhya Pradesh
Goa	Panaji	30 May 1987	Smallest state by area

State	Capital	Formation Year	Notes
Gujarat	Gandhinagar	1 May 1960	Formed with Maharashtra by bifurcating Bombay State; Westernmost state
Haryana	Chandigarh	1 Nov 1966	Carved out of Punjab
Himachal Pradesh	Shimla	25 Jan 1971	Became a full state in 1971
Jharkhand	Ranchi	15 Nov 2000	Carved out of Bihar
Karnataka	Bengaluru	1 Nov 1956	Formerly Mysore State; renamed Karnataka in 1973
Kerala	Thiruvananthapuram	1 Nov 1956	Highest Human Development Index among states
Madhya Pradesh	Bhopal	1 Nov 1956	2nd largest state by area (after Rajasthan)
Maharashtra	Mumbai	1 May 1960	2nd most populous state; financial capital Mumbai
Manipur	Imphal	21 Jan 1972	Became a full state in 1972
Meghalaya	Shillong	21 Jan 1972	"Abode of Clouds"; matrilineal society
Mizoram	Aizawl	20 Feb 1987	High literacy rate
Nagaland	Kohima	1 Dec 1963	First state formed under Article 371A (special provisions)
Odisha	Bhubaneswar	26 Jan 1950	Separate province since 1 April 1936 (Utkal Divas)
Punjab	Chandigarh	1 Nov 1956	Reorganised in 1966 (Haryana carved out); shares capital Chandigarh with Haryana
Rajasthan	Jaipur	1 Nov 1956	Largest state by area
Sikkim	Gangtok	16 May 1975	Merged with India in 1975 as the 22nd state (36th Amendment Act, 1975); least populous state
Tamil Nadu	Chennai	26 Jan 1950	Renamed from Madras State in 1969
Telangana	Hyderabad	2 Jun 2014	Newest state; Hyderabad was the joint capital with Andhra Pradesh until 2 June 2024
Tripura	Agartala	21 Jan 1972	Became a full state in 1972
Uttar Pradesh	Lucknow	26 Jan 1950	Most populous state
Uttarakhand	Dehradun	9 Nov 2000	Carved out of Uttar Pradesh
West Bengal	Kolkata	26 Jan 1950	-

Union Territories of India

Union Territory	Capital	Notes
Delhi (NCT)	New Delhi	National Capital Territory; has its own legislature
Puducherry	Puducherry (Pondicherry)	Former French colony; has its own legislature
Jammu & Kashmir	Srinagar (summer) / Jammu (winter)	UT with legislature, since 31 Oct 2019
Ladakh	Leh	UT without legislature, since 31 Oct 2019
Chandigarh	Chandigarh	Shared capital of Punjab & Haryana
Andaman & Nicobar Islands	Sri Vijaya Puram (formerly Port Blair)	Island UT in the Bay of Bengal; mostly elevated parts of a submerged mountain range (Barren and Narcondam are volcanic)
Lakshadweep	Kavaratti	Coral-origin island UT, Arabian Sea; smallest UT by area
Dadra & Nagar Haveli and Daman & Diu	Daman	Merged into one UT in 2020

States Formed After 2000

Chhattisgarh (1 Nov 2000): carved out of Madhya Pradesh
 Uttarakhand (9 Nov 2000): carved out of Uttar Pradesh
 Jharkhand (15 Nov 2000): carved out of Bihar
 Telangana (2 Jun 2014): carved out of Andhra Pradesh; newest (29th) state at creation

J&K/Ladakh UT Reorganisation (2019)

Jammu and Kashmir Reorganisation Act, 2019: bifurcated the former state of Jammu & Kashmir
 Effective 31 October 2019
 Jammu & Kashmir: UT with a legislative assembly
 Ladakh: UT without a legislature, comprising Leh and Kargil districts
 Dadra & Nagar Haveli and Daman & Diu were merged into a single UT in Jan 2020

Species/Tribes (India)

- Scheduled Tribes constitute ~8.6% of India's population (Census 2011).
- Largest tribal group in India: Bhils; largest tribal group in Central India: Gonds.

Major Scheduled Tribes of India

Tribes	State/Region	Key Facts
Gonds	Madhya Pradesh, Chhattisgarh, Maharashtra, Andhra Pradesh, Odisha	One of the largest tribal groups in India; speak Gondi; known for Gond art; Gondwana rock system named after this tribe
Bhils	Rajasthan, Gujarat, Madhya Pradesh, Maharashtra	Largest tribal group in India by population; known for Bhil folk dance and archery skill
Santhals	Jharkhand, West Bengal, Odisha, Bihar, Assam	3rd largest tribal community; speak Santhali (Ol Chiki script); known Santhal Rebellion (1855-56, "Hul")
Mundas	Jharkhand, Odisha, West Bengal, Chhattisgarh	One of the oldest tribes of India; Austroasiatic (Munda) language family; led by Birsa Munda in the Ulgulan revolt
Todas	Nilgiri Hills, Tamil Nadu	Small pastoral community; famous for barrel-vaulted huts and buffalo-herding; Dravidian (Toda) language
Khasis	Khasi Hills, Meghalaya	Matrilineal society: inheritance and lineage pass through the mother; Mon-Khmer (Austroasiatic) language
Garos	Garro Hills, Meghalaya	Also matrilineal; Tibeto-Burman language family
Nagas	Nagaland, Manipur, Assam, Arunachal Pradesh	Umbrella term for many sub-tribes (Angami, Ao, Sema, Konyak, etc.); known for Hornbill Festival
Bodo	Assam (Bodoland Territorial Region)	Largest plains tribe of Assam; Tibeto-Burman language; Bodo Accord (2020)
Gaddis	Himachal Pradesh (Chamba, Kangra)	Transhumant pastoral (sheep/goat-herding) community of the Dhauladhar region
Nicobarese	Across Nicobar Islands	
Shompen	Interior of Great Nicobar	PVTG; hunter-gatherers, among the most isolated groups in India

Particularly Vulnerable Tribal Groups (PVTGs)

Sub-category of Scheduled Tribes identified as more vulnerable (pre-agricultural level of technology, low literacy, declining/stagnant population)
 Andaman PVTGs: Great Andamanese, Onge, Jarawa, Sentinelese

Nicobar PVTG: Shompen

Mainland examples: Toda & Kurumba (TN), Chenchu (AP), Bonda & Dongria Kondh (Odisha), Baiga, Bharia & Sahariya (MP), Birhor (Jharkhand), Kathodi (Gujarat/Rajasthan)

India has 75 PVTGs in 18 States and 1 UT (A&N); Odisha has the most (13); PM-JANMAN (2023) targets their development



CHAPTER 11

India: Drainage System, Climate, Natural Disasters, Soils

Basic Terminology

- Drainage: flow of water through defined passages
- Drainage system: network of such passages (snowfall, ice-melt, rainfall, streams, floods etc.)
- Catchment area: area from which a river collects water
- Drainage basin: area drained by a river + its tributaries
- Watershed: line separating one drainage basin from another
- Large-river catchments called river basins (e.g., Ganga, Indus)
- Small-river catchments called watersheds (e.g., Yamuna, Chambal)
- Distributary: small river diverting from main river, reducing its volume; common at delta; helps form alluvial fans/cones
- Tributary: small river joining main river, increasing its volume
- Mouth: point where river enters sea
- Delta: depositional feature at mouth, dividing river into distributary channels
- Estuary: meeting of fresh/saline water from submergence of river mouth due to sea-level rise
- Doab: Persian term for area between two rivers

Division of Rivers (by catchment area)

River Size Classification

Category	Catchment Area
Large	≥20,000 sq km
Medium	2,000–20,000 sq km
Small	≤2,000 sq km

Drainage Patterns

By Origin

Discordant (path unaffected by topology/geology)

- Antecedent: retains original course despite land uplift; vertical erosion → deep gorges; e.g. Sutlej, Indus (Himalayan)
- Superinduced/Superimposed: flows through initial path/slope unaffected by surface rocks, influenced by rock hardness/faults; e.g. Damodar, Chambal (Peninsular)

Concordant (correlated with slope/topography)

Concordant Drainage Patterns

Pattern	Description	Example
Dendritic	Tree-branch-like	Godavari, Mahanadi
Trellis	Primary tributaries parallel, secondary join at right angles	Upper Himalayan rivers; old folded hills of Singhbhum (Chhotanagpur)
Rectangular	River + tributaries bend at right angles on rocky terrain	Streams of the Vindhyan range

Pattern	Description	Example
Radial	Rivers radiate from a hill, like lava from a volcano	Narmada, Son and Mahanadi from Amarkantak
Centripetal	Rivers discharge into a lake/depression (opposite of radial)	Loktak lake (Manipur), streams of Ladakh
Parallel	Regions of long parallel landforms/slopes	Short, swift west-flowing rivers of the Western Ghats
Annular	Tributaries flow circular/whirlpool-like from erosion of hard/soft rock beds; rare in India	Pithoragarh (Uttarakhand), Nilgiri hills (TN & Kerala)
Angular	Tributaries join main river at acute angles; common in Himalayan regions	-
Braided	High sediment, steep-slope rivers; shallow channels diverging/rejoining around small islands	Brahmaputra
Deranged	Uncoordinated pattern on recently glaciated terrain with many lakes/swamps	Canadian Shield; parts of Ladakh
Barbed	Tributary joins main river flowing in apparent opposite direction	Arun river (Nepal), tributary of Kosi
Pinnate	Narrow valleys flanked by steep slopes; tributaries join at acute angles like the barbs of a feather	Narmada and Tapi valleys

By Flow Type

- Consequent: flow in direction of original slope; e.g. Godavari, Krishna, Kaveri
- Subsequent: tributary path eroded after consequent river established; e.g. Vindhya/Satpura rivers flowing north to Ganga-Yamuna, Chambal, Sind, Ken, Betwa

Himalayan vs Peninsular Rivers

Feature	Himalayan Rivers	Peninsular Rivers
Origin	Lofty Himalayan ranges	Hills of Peninsular Plateau
Basin size	Large basins	Small basins
Landform	Deep V-shaped valleys (gorges)	Broad, shallow, graded valleys
Water flow	Perennial (snowmelt + monsoon)	Seasonal (rainfall only)
Courses	Meander, shift beds in plains	Straight (hard, non-alluvial surface)
Delta	Big deltas	Smaller; Narmada & Tapi form estuaries
Age	Younger	Older (mature stage/base level)

- Bay of Bengal drainage (east-flowing: Ganga, Brahmaputra, Mahanadi, Godavari etc.) = 77% of country's drainage area
- Arabian Sea drainage (west-flowing: Indus, Narmada, Tapi etc.) = 23% of country's drainage area
- Peninsular rivers much older; non-perennial; max discharge in rainy season
- Peninsular rivers: low velocity & load capacity (low gradient); broad, shallow, mature valleys
- Inland/Endorheic drainage: arid/semi-arid NW India, Aksai Chin, Ladakh streams draining into inland lakes/swamps
- e.g. Luni (into marshy Rann of Kutch), streams into Sambhar Lake (Rajasthan)

Evolution of Himalayan Drainage

- Himalayas formed by collision of Indo-Australian & Eurasian plates; young fold mountains of sedimentary rock
- Evolution traced from the Shiwalik/Indo-Brahma river
- Indo-Brahma ran Assam (NE) → Punjab (N) → Sindh (W), discharging into the Gulf of Sind
- Later divided into Indus, Ganga, Brahmaputra by Pleistocene upheaval

- This included upliftment of Potwar Plateau (aka Delhi Ridge), main divider between Indus & Ganga systems
- Malda gap (Rajmahal hills–Meghalaya plateau) diverts Ganga & Brahmaputra towards Bay of Bengal
- Indus, Sutlej and Brahmaputra predate the Himalayas (antecedent).
- These rivers kept flowing as mountains rose, cutting deep gorges (proof of being older)

Features of Himalayan Drainage System

- Perennial, antecedent, dendritic; fed by glacier melt & precipitation
- Youthful stage: large gorges, V-shaped valleys, ox-bow lakes (meandering), large deltas
- Braided channels → flood plains

Himalayan River System

The Indus

- Also called Sindhu; 1,114 km in India, 2,880 km total
- Origin: glacier near Bokhar Chu, Tibet (4,164 m), Kailash range
- Called Singi Khamban ("Lion's Mouth") in Tibet
- Flows NW through Ladakh, Gilgit, Baltistan
- Cuts a spectacular gorge across the Ladakh range near Gilgit.
- Enters Pakistan near Chillar (Dardistan region) and flows to the Arabian Sea near Karachi.
- Home to the blind Indus River Dolphin (IUCN: Endangered)

Indus Tributaries

Bank	Tributaries
Right Bank	Shyok, Gilgit, Zhob, Hunza, Nubra, Shigar, Kabul, Kurram, Gomal, Tochi
Left Bank	Zaskar, Sutlej, Beas, Chenab, Ravi, Jhelum

Jhelum

- Rises at spring in Verinag (foot of Pir Panjal, Kashmir valley)
- Flows north-west through Srinagar and Wular Lake.
- Largest tributary: Kishanganga
- Cuts steep gorge through Pir Panjal before entering Pakistan
- Joins Chenab near Jhang (Pakistan)

Ravi

- Rises west of the Rohtang Pass in the Kullu hills (HP); perennial.
- Flows through the Chamba valley; joins the Chenab near Sarai Sidhu (Pakistan).
- Enters Punjab plains near Madhopur
- Waters allocated to India (IWT 1960)

Ravi: Key Projects

Ranjit Sagar Dam
 Shahpur Kandi dam: completed/commissioned 2024-25
 Shahpur Kandi stops Ravi water earlier released to Pakistan

Beas

- Originates near Rohtang pass (4,062 m) at Beas Kund
- Flows via Kullu valley, meets Sutlej at Harike
- Short river (~470 km), entirely within India.
- Waters allocated to India (IWT 1960)

Satluj (Sutlej)

- Only Indus tributary originating outside India: in Tibet (Rakshas Tal, near Mansarovar, 4,570 m)

- Known as Langchen Khambab
- Enters India at Shipki La, cuts a gorge at Naina Devi (Bhakra), enters the plains at Rupnagar (Ropar) and turns west.
- Joined by the Beas at Harike (Punjab).
- Forms India-Pakistan boundary for ~120 km
- Receives collective drainage of Ravi, Chenab, Jhelum
- Waters allocated to India (IWT 1960)

Chenab

- 1,180 km; largest Indus tributary
- Formed by confluence of Chandra + Bhaga (= Chandra-Bhaga) in Himachal
- Originates in Lahaul-Spiti (Zaskar range)
- Flows through Pakistani Punjab to Panchnad
- Joins Sutlej after receiving Jhelum & Ravi
- Waters allocated to Pakistan (IWT)
- Baglihar dam built on it
- Famous for the Chenab Bridge (Reasi): world's highest railway arch bridge (~359 m above the river), opened in June 2025 on the Udhampur-Srinagar-Baramulla Rail Link.

Indus Water Treaty (1960)

- Signed by PM Jawaharlal Nehru & Pakistan President Ayub Khan, brokered by World Bank
- India controls eastern rivers: Ravi, Beas, Sutlej
- Pakistan controls western rivers: Indus, Jhelum, Chenab
- India gets ~20% of the system's waters (eastern rivers); Pakistan ~80% (western rivers).
- Permanent Indus Commission must meet at least once a year.
- Graded dispute mechanism: Permanent Indus Commission (questions) → Neutral Expert appointed by the World Bank (differences) → Court of Arbitration (disputes).
- e.g. Kishanganga (J&K): the Court of Arbitration (2013) upheld India's diversion subject to a minimum environmental flow; Kishanganga-Ratle issues later went to a Neutral Expert and a Court of Arbitration.
- On western rivers, India may build run-of-river hydro projects and use water for limited irrigation and domestic needs.
- India must not restrict flow of Pakistan-controlled rivers

Indus Waters Treaty: Current Status

India placed treaty "in abeyance" from April 2025, post-Pahalgam terror attack

Cited reason: Pakistan's continued support to cross-border terrorism

As of 2026, India has reaffirmed treaty stays in abeyance

Abeyance to continue until Pakistan "credibly and irrevocably" ends such support

The Ganga

- Rises in Uttarakhand from Gangotri glacier as Bhagirathi
- Meets Alaknanda at Devprayag → becomes Ganga
- Tehri Dam (on Bhagirathi, ~260 m) = highest dam in India and among the tallest in the world.
- Alaknanda originates from Satopanth glacier
- Alaknanda formed by Dhuli + Vishnu Ganga meeting at Joshimath/Vishnuprayag
- Other Alaknanda tributaries: Pindar (at Karnaprayag), Mandakini/Kali Ganga (at Rudraprayag)
- Largest river system in India: perennial Himalayan + non-perennial peninsular waters
- Total length 2,525 km, across 5 states: Uttarakhand, UP, Bihar, Jharkhand, West Bengal
- Ganga-Brahmaputra delta = largest delta in the world, between Hugli & Meghna, before Bay of Bengal
- Joined by Yamuna at Prayagraj
- At Farakka, bifurcates into Bhagirathi-Hugli (WB) and Padma-Meghna (Bangladesh)
- Loses the name "Ganga" after Farakka

The Five Prayags (Uttarakhand Sacred Confluences)

Prayag	Confluence	District
Vishnuprayag	Alaknanda + Dhauliganga	Chamoli

Prayag	Confluence	District
Nandaprayag	Alaknanda + Nandakini	Chamoli
Karnaprayag	Alaknanda + Pindar	Chamoli
Rudraprayag	Alaknanda + Mandakini	Rudraprayag (Kedarnath 86 km away)
Devprayag	Alaknanda + Bhagirathi	Tehri (continues as Ganga)

Ganga Major Tributaries

Bank	Tributaries
Left bank (major)	Ramganga, Gomti, Gandak, Kosi, Ghaghara, Mahananda
Right bank (major)	Yamuna, Damodar, Son

Yamuna

- Longest Ganga tributary
- Originates at Yamunotri glacier, Bandarpunch range
- Flows near-parallel to Ganga, merges at Prayag
- Passes through HP, Uttarakhand, Haryana, Delhi, UP

Yamuna Tributaries

Bank	Tributaries
Right bank	Chambal, Sind, Betwa, Ken
Left bank	Hindon, Rind, Sengar

Chambal

- 1,024 km; Yamuna tributary; perennial
- Originates at Singar Chouri peak, Vindhya, near Mhow (Malwa plateau, MP)
- Flows north to Kota (Rajasthan)
- Forms part of the MP-Rajasthan and MP-UP boundaries; the main perennial river of Rajasthan.
- Flows through MP, Rajasthan, UP
- Tributaries: Banas, Kalisindh, Parbati
- Known for Badlands topography (ravines)
- Protected area: National Chambal (Gharial) Sanctuary at the MP-Rajasthan-UP tri-junction.
- Major dams: Gandhi Sagar (MP; Gandhi Sagar WLS became the second home for cheetahs in 2025), Rana Pratap Sagar, Jawahar Sagar, Kota barrage (Rajasthan).

Betwa

- Yamuna tributary; aka Betravati/Vetravati; 590 km
- Rises in the Vindhya near Bhopal (Raisen district, MP).
- Meets Yamuna near Hamirpur
- Catchment 46,580 sq km (~70% MP, 30% UP)
- Major tributaries: Halali (longest), Dhasan

Ken

- Originates in the Kaimur hills (Katni district, MP); joins the Yamuna at Chilla (Banda district, UP).
- Passes through Panna Tiger Reserve
- Main tributaries: Sonar, Bearma, Urmil.

Ken-Betwa River Linking Project

- Conceived under the National Perspective Plan (1980) for interlinking rivers; transfers surplus Ken water to the Betwa basin in Bundelkhand.
- Memorandum of Agreement signed in March 2021 between the Jal Shakti Ministry, UP and MP.

- India's first river-interlinking project under the National Perspective Plan.
- Aims: irrigation, drinking water, hydropower, solar power
- Involves Daudhan dam & canal
- Foundation stone laid by PM Modi at Khajuraho (Dec 2024)

Ken-Betwa Link: Concerns

Submergence of Panna Tiger Reserve
Affects Nauradehi, Rani Durgawati, Ranipur sanctuaries
Tribal displacement/migration
Forest/environment clearance issues

Son River

- Originates at Amarkantak plateau (MP)
- Largest south-bank tributary of Ganga
- Flows through MP, Chhattisgarh, UP, Jharkhand and Bihar, past the Kaimur range.
- Merges into the Ganga near Danapur (Patna).
- Main tributaries: Rihand (rises in Matiranga hills, Chhattisgarh), Koel
- Projects: Bansagar dam (Son, MP); Rihand dam (Govind Ballabh Pant Sagar, on the Rihand, UP).

Damodar River

- Originates in the Chotanagpur plateau (Chandwa, Latehar/Palamu, Jharkhand); flows through a rift valley.
- Joins the Hugli south of Kolkata.
- Main tributaries (collectively called "the Damodar"): Barakar, Konar, Bokaro, Jamunia
- Historically devastating floods: called 'Sorrow of Bengal' (now dam-controlled)
- The Damodar valley is called the "Ruhr of India" for its coal-based heavy industry (Bokaro, Dhanbad, Durgapur, Asansol); Damodar Valley Corporation (1948) was India's first multipurpose river valley project, modelled on the Tennessee Valley Authority.

Other Ganga Tributaries

River	Key Facts
Gandak	Formed by Kaligandak + Trishul Ganga, Nepal Himalayas (Dhaulagiri–Everest); enters plains near Champaran (Bihar); joins Ganga at Sonpur near Patna
Ghaghara	Originates at Mapchachungo glacier; tributaries Tila, Seti, Beri, Sarda (Kali Ganga); merges with Ganga at Chhapra (Bihar)
Kosi	Antecedent; originates north of Mount Everest, Tibet; main tributary Arun; called 'Sorrow of Bihar': devastating floods, now tamed via embankments/barrages/dams
Ramganga	Originates in the Garhwal hills near Gairsain; flows through Corbett NP, enters the plains at Kalagarh and joins the Ganga near Kannauj
Sarda/Sarayu	The Kali (Sarda) rises near Kalapani (Uttarakhand), forms the Indo-Nepal border, receives the Goriganga (from Milam glacier) and joins the Ghaghara
Mahananda	Rises in Darjeeling hills; last important left-bank Ganga tributary; joins in West Bengal

Jim Corbett National Park (Ramganga)

India's first National Park
Project Tiger launched here (1973)
Originally established 1936 as "Hailey National Park"

The Brahmaputra

- One of world's largest rivers; name means 'Son of the Brahma'
- Originates at Chemayungdung glacier, Kailash range, near Man Sarovar lake

- Known as Tsangpo ("the purifier") in Tibet
- Rango Tsangpo = major right-bank Tibet tributary
- Tamchok Khambab = main origin point
- Takes a U-turn, enters India near Namcha Barwa (west of Sadiya) in Arunachal Pradesh
- Emerges as Siang/Dihang on entering India
- Main stem flows through Arunachal Pradesh and Assam; its basin also covers Meghalaya, Nagaland, Sikkim and West Bengal.
- 916 km in India; known for NE floods (large tributaries, heavy sediment)
- Enters Bangladesh near Dhubri as Jamuna
- Joined by Ganga and (right bank) Tista → becomes Padma → Bay of Bengal
- National Waterway 2 (Brahmaputra) connects with National Waterway 1 (Ganga, Bhagirathi, Hugli, Haldia)

Brahmaputra Tributaries

Tributary	Key Facts
Barak	Not a Brahmaputra tributary: 564 km; rises in the Manipur hills; flows through Manipur, Mizoram and Assam (Barak valley) into Bangladesh as Surma–Kushiyara and joins the Meghna system
Lohit	Originates in Tibet (Zayu river, Zayal Chu range); through Arunachal, Mishmi Hills; joins Siang to form Brahmaputra; carries lateritic (reddish) soil
Subansiri	Antecedent, trans-Himalayan; largest Brahmaputra tributary; flows through the Miri hills; joins at Jamurighat (Assam); Subansiri Lower HEP (2,000 MW, largest in India) on it
Dhansiri	Originates in Nagaland; through Intanki NP; joins in Assam plains
Manas	Transboundary (Bhutan–India), Himalayan foothills; through Royal Manas NP (Bhutan) & Manas WLS
Kameng	Rises near Gorichen mountains, Arunachal (Indo–Tibet border); between Eagle Nest Sanctuary (W) & Pakke Tiger Reserve (E)
Dibang	Originates in Arunachal near Indo–China border; Mishmi hills form N boundary
Tista	Rises near Tso Lhamo lake/Zemu glacier (North Sikkim); flows south through Sikkim and West Bengal; deep gorge in the Darjeeling hills; joins the Brahmaputra (Jamuna) in Bangladesh; major tributary Rangeet; India–Bangladesh water-sharing issue; South Lhonak GLOF (Oct 2023) destroyed the Teesta–III dam at Chungthang

Melting of Glaciers: Impact on Drainage

- Himalayas called the "third pole"
- Glaciers are lifeline for Pakistan, India, Nepal, Bhutan, Bangladesh
- Impact: glacial hazards, e.g. Chamoli rock-ice avalanche (Uttarakhand, Feb 2021), South Lhonak GLOF (Sikkim, Oct 2023).
- Impact: flooding in some areas / drought in others
- Impact: longer summer/heat waves (e.g. HP & Uttarakhand 2022)
- Impact: increased river flow → floods, landslides, bridge collapse (Assam/Arunachal floods, HP landslides)

Causes of Water Scarcity

Cause
Non-uniform monsoon rainfall
Poor groundwater recharge in rocky/mountainous terrain
Over-extraction
Agriculture unsuited to water table (e.g. Punjab/Haryana wheat/rice)
Rainfall concentrated in 3–4 months (storage difficulty/floods)
Unpredictable monsoon onset/withdrawal

Peninsular River System

Features

- Older than Himalayan drainage
- Shaped by the subsidence of the western flank of the peninsula (Arabian Sea) and the eastward tilt of the plateau; the Narmada and Tapi follow rift valleys.
- Except Narmada & Tapi, most peninsular rivers are east-flowing
- Major rivers: Mahanadi, Godavari, Krishna, Kaveri
- Seasonal (monsoon-dependent); smaller, fixed-course basins
- Patterns seen: Trellis, Radial, Rectangular

Peninsular East-Flowing Rivers

Mahanadi

- 851 km; 3rd largest peninsular river (after Godavari & Krishna)
- Originates near Sihawa (Dhamtari district), Chhattisgarh.
- Flows through Chhattisgarh and Odisha to the Bay of Bengal; its basin also covers parts of MP, Jharkhand and Maharashtra.
- Major tributaries: Seonath, Hasdeo, Mand, Ib, Tel
- Fertile valley soil, known for silt deposition
- Hirakud Dam near Sambalpur: one of the longest earthen dams in the world (~25.8 km including dykes); irrigation, flood control and power.
- Chilika lake is part of its basin
- Cuttack lies at the head of its delta; Paradip port lies near its mouth.

Godavari

- 1,465 km; largest peninsular river, called "Dakshin Ganga"
- Originates at Trimbakeshwar, Nasik (Maharashtra)
- Flows through Maharashtra, Telangana and Andhra Pradesh; its basin also covers MP, Chhattisgarh, Odisha, Karnataka and Puducherry (Yanam).
- Major tributaries: Penganga, Indravati, Pranhita, Manjara, Pravara, Wainganga, Wardha, Pench, Kanhan, Bindusara, Sabari
- Kumbh Mela is held at Nashik (Godavari); the others are at Haridwar (Ganga), Prayagraj (Ganga-Yamuna-Saraswati Sangam) and Ujjain (Shipra).
- Godavari Water Disputes Tribunal (1969; award 1980): Maharashtra, Karnataka, MP, Odisha and undivided AP.

Godavari Interlinking Projects

Sriram Sagar (Pochampad), Nizamabad; Kaleshwaram Lift Irrigation Project (Telangana): one of the world's largest multi-stage lift irrigation schemes

Polavaram: hydroelectric + irrigation, pisciculture, tourism; transfers water to Krishna basin

Godavari-Kaveri link (proposed): via Nagarjuna Sagar and Somasila to the Grand Anicut, serving the Krishna, Pennar and Kaveri basins

Inchampalli (proposed): on the Godavari below the Pranhita confluence (Telangana-Maharashtra-Chhattisgarh)

Krishna

- 1,401 km; 2nd largest peninsular river
- Rises near Mahabaleshwar, Sahyadri hills (Western Ghats)
- Flows W→E through Maharashtra, Karnataka, AP, Telangana
- Largest cities on banks: Sangli (Maharashtra), Vijayawada (AP)
- Seasonal, monsoon-fed; deposits productive soil in Karnataka & AP
- Krishna & Godavari connect with National Waterway 4

Krishna Tributaries

Bank	Tributaries
Right bank	Venna, Koyna, Panchganga, Dudhganga, Ghataprabha, Malaprabha, Tungabhadra

Bank	Tributaries
Left bank	Bhima, Dindi, Peddavagu, Halia, Musi, Paleru, Munneru

- Major dams/stations: Koyna, Tungabhadra, Nagarjuna Sagar, Srisailem, Almatti Dam, Prakasham Barrage

Kaveri

- 800 km; called "Ganga of the South"
- Originates at Brahmagiri hills, Kodagu (Karnataka)
- Perennial (fed by SW + retreating/NE monsoon)
- Descends Karnataka → TN plains via Shivasamudram waterfalls
- Main course through Karnataka and Tamil Nadu; its basin also covers Kerala and Puducherry (Karaikal).
- Bounded by Western Ghats (W), Nilgiris (S), Eastern Ghats (E)
- Major tributaries: Kabini, Bhavani, Amravati
- Forms delta in TN/Puducherry (black, laterite, alluvial, forest soils)
- Shivanasamudra hydroelectric station (1902) was Asia's first; it supplied power to the Kolar Gold Fields and Bengaluru.
- Wayanad WLS (Kerala) is contiguous with Nagarhole and Bandipur (Karnataka) and Mudumalai (TN) tiger reserves, all part of the Nilgiri Biosphere Reserve.

Other Small East-Flowing Rivers

River	Key Facts
Brahmani	Formed by Koel + Shankh near Rourkela; 800 km; bounded by Chota Nagpur plateau (N), Mahanadi basin (W&S), Bay of Bengal (E); through Jharkhand, Chhattisgarh, Odisha
Vamsadhara	Between Rushikulya & Godavari basins (Odisha & AP); originates in Kalahandi district, Eastern Ghats; joins Bay of Bengal at Kalingapatnam (AP); ~254 km
Nagavali (aka Langulya)	Main river of S. Odisha & N. AP, between Rushikulya & Godavari basins; originates in Kalahandi District, Eastern Ghats
Subarnarekha	Originates at Ranchi Plateau (Jharkhand); forms WB-Odisha boundary in lower course; joins Bay of Bengal, estuary between Ganga & Mahanadi deltas; 395 km

West-Flowing Rivers

Narmada

- 1,312 km; originates at Maikala range, Amarkantak plateau
- Lifeline of MP & Gujarat; perennial
- Flows west in a rift valley between Satpura (S) and Vindhya (N)
- Faults run parallel to Vindhyas/Satpuras
- Famous for Sardar Sarovar project & Statue of Unity
- Basin: MP, Gujarat, Maharashtra, Chhattisgarh
- Major projects: Indira Sagar, Omkareshwar (also a large floating solar park), Bargi, Maheshwar (MP); Sardar Sarovar (Gujarat).

Tapi

- 724 km; west-flowing; called "twin" of Narmada
- Originates in Betul district (MP)
- Flows in rift valley south of Satpura ranges
- Through Maharashtra, MP, Gujarat; into Arabian Sea via Gulf of Khambhat
- Projects: Ukai and Kakrapar (Gujarat); Hathnur (Maharashtra).

Rift Valley (concept)

Luni

- Ephemeral; known as Sagarmati in its upper course.

- Rises in the Naga hills near Pushkar/Ajmer (Aravalli) as the Sagarmati, and is joined by the Saraswati at Govindgarh to become the Luni.
- Not saline until Balotra (then high salt content)
- Discharges into Rann of Kutch
- Tributaries: Jojri, Lilri, Guhiya, Bandi, Sikri, Khari
- Major dam: Jaswant Sagar (Pichiyak), Jodhpur.

Sabarmati

- West-flowing; originates in Aravalli hills near Tepur village, Udaipur (Rajasthan)
- Bounded by Aravallis (N), Rann of Kutch (W), Gulf of Khambhat (S)
- Main dam: Dharoi (Gujarat); tributaries: Wakal, Sei, Harnav, Hathmati, Watrak.

Mahi River

- Basin: MP, Rajasthan, Gujarat
- Originates on N slopes of Vindhya, Dhar district (MP)
- Drains into Gulf of Khambhat; 580 km
- Hydro stations: Mahi Bajaj Sagar dam, Kadana Dam
- Crosses the Tropic of Cancer twice

Why Arabian-Sea Peninsular Rivers Don't Form Deltas

- Flow through hard rocks → little silt accumulation, only estuaries
- Short distance to sea → no time to deposit sediment
- West-flowing rivers have small catchments and few tributaries, so they carry less silt.
- Fixed courses (no meandering) → estuaries & lagoons instead
- The west coast is a submerged coast with estuaries, unlike the emergent east coast.

Why Most Indian Rivers Flow West to East

- Majority flow W→E into Bay of Bengal, except Narmada & Tapi
- During Western Ghats formation, Peninsular Plateau tilted slightly east (apparent western upliftment)

Inter-State River Disputes

- Governed by Inter-State Water Disputes Act, 1956
- States approach Centre for a tribunal; tribunal decision is final
- Tribunal: a Chairman and two other members nominated by the Chief Justice of India from among judges of the SC or HCs; since 2002 its award has the force of a Supreme Court decree.
- Inter-State River Water Disputes (Amendment) Bill, 2019 (passed by Lok Sabha): proposes a single permanent Tribunal with benches and a Disputes Resolution Committee (DRC).
- DRC to resolve disputes amicably within one year (extendable by six months) before reference to the Tribunal.
- Notable disputes: Cauvery Water Dispute, Satluj Yamuna Link Canal

Inter-State River Water Tribunals

Tribunal	Year	States Involved
Krishna Water Disputes Tribunal II	2004	Karnataka, Telangana, Andhra Pradesh, Maharashtra
Mahanadi Water Disputes Tribunal	2018	Odisha, Chhattisgarh
Mahadayi Water Disputes Tribunal	2010	Goa, Karnataka, Maharashtra
Ravi & Beas Water Tribunal	1986	Punjab, Haryana, Rajasthan
Vansadhara Water Disputes Tribunal	2010	Andhra Pradesh, Odisha
Cauvery Water Disputes Tribunal	1990	Karnataka, Tamil Nadu, Kerala, Puducherry (final award 2007; SC verdict 2018; Cauvery Water Management Authority set up 2018)
Godavari Water Disputes Tribunal	1969	Maharashtra, AP, Karnataka, MP, Odisha (award 1980)

Tribunal	Year	States Involved
Narmada Water Disputes Tribunal	1969	Gujarat, MP, Maharashtra, Rajasthan (award 1979)

National Interlinking River Project (NIRP)

- First suggested under British rule, for navigation
- Now managed by National Water Development Agency (Ministry of Jal Shakti)
- Component 1 (Himalayan): 14 links, with storage reservoirs on the Ganga, Brahmaputra and their tributaries.
- Component 2 (Peninsular): 16 links transferring surplus water to deficit basins (total 30 links under the National Perspective Plan).
- Benefits: hydropower
- Benefits: transport/navigation (reduces road congestion & air pollution)
- Benefits: converts flood water to irrigation via inter-basin transfer
- Concerns: inter-state disputes (Cauvery, Godavari)
- Concerns: international issues with Bangladesh (Teesta) and Nepal (Kosi, Gandak, Mahakali), whose cooperation is needed for Himalayan links.
- Concerns: high environmental cost (deforestation, flora/fauna impact)
- Concerns: displacement/humanitarian issues
- Example executed link: Godavari-Krishna via the Pattiseema lift irrigation scheme (AP, 2015).

Waterfalls

- Mostly in mountainous/southern India; vertical/steep, natural or artificial
- Caused by rapid erosion of soft rock vs hard rock
- Jog Falls (Sharavathi, Karnataka, ~253 m) is among India's highest plunge waterfalls; Chitrakote (Indravati, Chhattisgarh) is the widest.
- By volume: Shivasamudram (Cauvery) = India's largest

Highest Waterfall: Disputed Ranking

Kunchikal (Varahi river, Karnataka): ~455 m cascade, long cited as India's highest waterfall
 Nohkalikai (Meghalaya, ~340 m): India's tallest plunge waterfall
 Dudhsagar (Goa-Karnataka, ~310 m) and Jog (~253 m) are other commonly asked high falls
 UPPSC has historically used Kunchikal as the highest

Major Waterfalls

Waterfall	River / Location
Chitrakote ("Niagara of India")	Indravati river, Bastar (Chhattisgarh); height 29 m
Doodhsagar/Dudhsagar	Mandavi (Mandovi) River, Goa
Dhuandhar	Narmada River, Jabalpur (MP)
Lansing (Langshiang)	Meghalaya
Nohkalikai	Meghalaya (tallest plunge waterfall in India)
Kunchikal	Varahi river, Karnataka (historically cited as highest)
Jog	Sharavati river, Shivamogga (Karnataka); ~253 m
Shivasamudram	Cauvery river, Karnataka
Barkana	Seetha river, Karnataka
Khandadhar	Odisha (Sundargarh/Keonjhar)
Gokak	Ghatprabha river, Belagavi, Karnataka
Duduma	Machhkund river, Koraput, Odisha

Waterfall	River / Location
Hundru	Subarnarekha river (about 45 km from Ranchi, Jharkhand); ~98 m
Budha Ghagh (Lodh Falls)	Burha river, Latehar district, Jharkhand; ~143 m; highest in Jharkhand
Amritdhara	Hasdeo river, Koriya (Chhattisgarh)
Kapildhara, Dugdhdhara (near Amarkantak), Dhuandhar (Bhedaghat)	Narmada river
Chulia	Chambal river (Rajasthan–MP)

Lakes

- Vembanad: largest lagoon/lake in Kerala
- Chilika lagoon: saline, at Mahanadi's mouth, Odisha, largest lake on India's east coast / largest brackish water lake in India
- Roopkund lake: "Mysterious/Skeleton lake", glacial, Uttarakhand, famous for human skeletons
- Ashtamudi lake: lagoon, Kollam district, Kerala; name means "eight branches"; Ramsar site
- Chembarambakkam lake: west of Chennai (TN); source of the Adyar river; a major source of Chennai's water supply.
- Kolleru: freshwater lake in AP (between the Godavari and Krishna deltas); one of India's largest freshwater lakes; Ramsar site.
- Pushkar Lake: sacred lake, Ajmer district, Rajasthan.
- Sambhar: India's largest inland saline water lake, Rajasthan
- Pulicat: 2nd largest brackish water lake in India (after Chilika); TN-AP border; Sriharikota Island separates it from Bay of Bengal
- Wular lake: largest freshwater lake of India, J&K (fed by the Jhelum).
- Dal lake: Srinagar (Zabarwan Range)
- Periyar lake: Kerala (artificial, not a lagoon)
- Loktak lake: largest freshwater lake in Manipur/NE India; floating islands (phumdis); Keibul Lamjao NP on it, only floating national park
- Kanwar (Kabar Tal) lake: Begusarai, Bihar, Asia's largest freshwater oxbow lake, Ramsar site
- Yaya Tso lake: Ladakh, ~4,820 m altitude; Ladakh's first Biodiversity Heritage Site (Biological Diversity Act); known as "bird's paradise"
- Didwana, Kuchaman, Sargol, Khatu: saline lakes of Rajasthan

Major Lakes by State/UT

Lake	State/UT
Vembanad	Kerala
Loktak	Manipur
Dal	Jammu & Kashmir
Pulicat	Tamil Nadu–Andhra Pradesh border
Kolleru	Andhra Pradesh
Wular	Jammu & Kashmir
Chilika	Odisha
Sambhar	Rajasthan
Nakki	Rajasthan
Lonar	Maharashtra
Roopkund	Uttarakhand
Ashtamudi	Kerala

Ramsar Convention (1971)

- International treaty for conservation/sustainable use of wetlands
- Adopted at Ramsar (Iran) on 2 February 1971 (World Wetlands Day); in force from 1975; India joined in 1982.
- Only global environmental treaty dealing with a specific ecosystem
- India has 101 Ramsar sites (August 2026; 101st: Glaw Lake, Arunachal Pradesh's first); first sites: Chilika and Keoladeo (1981); most sites: Tamil Nadu; largest: Sundarban Wetland (WB).

Climate of India

- Climate: sum of weather conditions/variations over a large area for a long period (>30 years), heat, moisture, air movement.
- Weather: atmospheric condition over a region at a given time.
- Climate and weather share the same elements: temperature, pressure, wind, humidity, precipitation.

Why North India Isn't Temperate Despite Latitude

Himalayas block cold Central Asian air masses.

Northern India winters are milder by 3°C–8°C than other places on the same latitude.

Peninsular India, surrounded by sea on three sides, has no distinct cold season.

Loo (hot dry wind from Thar/Baloch/Iranian deserts) raises north Indian plains' temperature to south-India levels.

All of India south of the Himalayas is tropical.

- India has a tropical monsoon climate (distinct wet & dry) from seasonal wind reversal over the Arabian Sea & Bay of Bengal.

Salient Features of Indian Climate

- Alternating high/low pressure over land: high pressure over north India in winter (low temp).
- Thermally induced low over NW India in summer (temp up to 50°C).
- Late summer → high relative humidity & widespread rain.
- Reversal of winds, Winter: trade winds NE→SW (dry, cold, high pressure).
- Reversal of winds, Summer: complete reversal, SW→NE.
- Natural calamities (floods, droughts, famines, epidemics) result from rainfall variability.
- Rain failure → drought; heavy continuous rain → floods.
- Climatic extremes support 3 cropping seasons (Rabi, Kharif, Zaid) via crop diversity (arctic/temperate/tropical).
- Diversity: regional differences arise from location, altitude, distance from sea/mountains, relief.
- Example of diversity: Phalodi (Rajasthan) recorded 51°C (May 2016); Drass (Ladakh) winter can fall to about -40°C.
- Multiplicity of seasons: broadly 3 major seasons, but finer division gives 6 seasons/year (winter, fall of winter, spring, summer, rainy, autumn).
- Spring & autumn are "weaker seasons" (3–6 weeks each).
- Seasonal & variable rainfall: Upper Himalayas get snow, rest of the country gets rain.
- Mawsynram/Cherrapunji (Meghalaya) get >1,100 cm rainfall vs Ladakh/western Rajasthan < 10 cm.
- ~75% of annual rainfall falls during June–September (SW monsoon) in most of the country.
- Coastal regions have less temperature contrast than interior regions.
- Northern Plains rainfall decreases east→west.

Factors Determining the Climate of India

Factors Related to Location and Relief

- Latitude: Tropic of Cancer passes through the middle (Rann of Kachchh to Mizoram).
- North of Tropic of Cancer = subtropical/temperate; south = tropical.
- Altitude: temperature falls with height, e.g. Agra (16°C) vs Darjeeling (4°C) in January despite similar latitude.
- Relief/Physiography shapes temperature, pressure, wind speed/direction, rainfall amount/distribution.
- Example: leeward southern plateau (east of Western Ghats) stays dry June–September while windward Western Ghats & Assam get heavy rain.
- Himalayas act as a climate divide: block cold northern winds from Central Asia (origin near Arctic Circle) → warmer subcontinent winters.

- Himalayas also block monsoon winds, forcing moisture to be shed within the subcontinent.
- Distribution of land & water: India is bordered by sea on 3 sides, mountain wall on the north.
- Differential land/water heating produces varying pressure zones → changes monsoon wind direction.
- Distance from sea moderates climate; interior areas show continentality (extreme summers/winters).

Orographic Effects on Rainfall

Area	Mechanism	Effect
Western Ghats (windward)	Struck almost perpendicularly by Arabian Sea branch	Heavy windward rain
Maharashtra, Karnataka, Telangana, AP, Tamil Nadu (leeward)	Rain-shadow of Western Ghats	Low rainfall
Rajasthan & Gujarat	Monsoon winds flow parallel to Aravallis; no orographic barrier; only horizontal movement toward Tibet low	Scanty rainfall
Meghalaya Plateau	Funnelling effect + orographic uplift	Extreme rain; Mawsynram & Cherrapunji mean annual rainfall >1100 cm, among wettest places on Earth
Western Ghats, Eastern Ghats, NE Himalayan ranges	Funnelling effect: clouds channelled into narrow mountain gaps	Increases cloud density & wind speed
Indus-Ganga Plains	Many small summer low-pressure cells progressively deplete moisture east→west	Rainfall decreases east→west; Delhi/Haryana moisture nearly exhausted, get winter rain via Western Cyclonic Disturbances instead

Factors Related to Air Pressure and Wind

- Three factors shape local climate:
- (1) Surface wind/pressure distribution.
- (2) Upper air circulation (global factors, air masses, jet streams).
- (3) Arrival of tropical depressions (SW monsoon) and western cyclonic disturbances (winter).

Mechanism of Weather Conditions in Winter

- Season: November–March, distinct north of Tropic of Cancer; coldest months December–January.
- In January, mean temperature over most of north India stays below 21°C; isotherms run roughly parallel to latitude.
- South of the Tropic of Cancer there is no well-defined cold season (e.g. Chennai ~24–25°C in January).
- NW India mean minimum ~5°C; Gangetic plains ~10°C; Punjab/Rajasthan nights occasionally below freezing.
- Extreme north Indian cold from: (1) continental climate (Punjab, Haryana, Rajasthan, far from sea).
- (2) Himalayan snowfall causing cold waves.
- (3) Western disturbances: low-pressure systems from the Mediterranean entering via Iran–Afghanistan (Dec–Feb) bring rain/snow, followed by cold waves, frost and fog.
- Coastal regions show minimal seasonal variation (sea's moderating effect + equator proximity).
- Example: Thiruvananthapuram January max 31°C vs June 29.5°C.
- Winter characteristics: clear skies, pleasant weather, wide temperature range, low humidity, cool slow NE trade winds, high diurnal range (interior).
- In winter, westerlies affect W & Central Asia at 9–13 km altitude.
- North of the Himalayas they flow near-parallel to the Tibetan Highlands as subtropical westerly jet streams (~27°–30°N).
- Himalaya/Tibet obstruction splits this winter upper westerly jet into two branches: northern (north of Tibet) and southern (south of Himalayas, flows eastward), strongly shapes Indian winter weather.
- Western Cyclonic Disturbances: winter phenomena from westerly flow originating in the Mediterranean; affect north & NW India.
- Tropical cyclones develop over the Indian Ocean & Bay of Bengal as part of easterly flow; affect Tamil Nadu, Andhra Pradesh, Odisha coasts; mostly very destructive (rain + high winds).

- Surface Pressure and Winds: high pressure north of Himalayas in winter → dry continental air moves south through Central Asia.
- This dry air meets trade winds over NW India; the contact zone can shift as far east as mid-Ganga valley, bringing dry NW winds to that whole stretch.

Mechanism of Weather Conditions in Summer

- Season: March–May (hot weather season); high temperature, low humidity.
- Temperature rises with northward sun movement: south India warms first (March–April), north catches up by June.
- Peninsular India: temperature rises coast→interior (not N–S).
- Coastal areas stay moderate due to the sea; hill stations of the Western Ghats remain below 25°C.
- Heat waves common across north & central India.
- Highest temperatures occur just before SW monsoon onset.
- Large diurnal range (up to 18°C in places); coastal/southern peninsular regions cooler (sea's moderating effect).
- Upper Air Circulation & Jet Streams: sun shifts north, wind circulation (upper & lower) fully reverses.
- By mid-July ITCZ (low-pressure zone) moves north, roughly parallel to Himalayas between 20°N–25°N, linked to withdrawal of the westerly jet from the North Indian plain.
- ITCZ draws winds from several directions; maritime Tropical air mass (mT) from the southern hemisphere crosses the equator toward this low → the southwest monsoon.
- Easterly Jet Stream: in June, max speed ~90 km/hr, passes over southern peninsula.
- Reaches 15°N by August, 22°N by September, never north of 30°N.
- Directs tropical depressions toward India; their tracks mark the highest-rainfall areas, and their frequency/direction/intensity determine SW monsoon rainfall pattern.
- Tropical cyclones also occur during the monsoon & in October–November, affecting coastal regions.
- Loo: extremely hot, dry wind from Thar, Baloch, Iranian deserts, drawn into north Indian plains in May–June by the steep pressure gradient of high temperatures.
- Aandhis (dust storms): from low pressure & strong convection; originate in northern plains (Rajasthan to Bihar).
- Common evenings in Punjab, Haryana, eastern Rajasthan, UP in May.
- Reduce visibility to a few metres but bring relief (moderate rain, cool breeze).
- Convictional Thunderstorms: strong convection + moist winds → thunderstorms countrywide.

Regional Summer Thunderstorms/Local Winds

Name	Region	Timing	Notes
Norwesters	West Bengal, Jharkhand, Odisha, Assam	Most common in Vaisakh (mid-March–mid-April)	Short rain + hailstones; locally "Kalabaisakhi"; damaging to cattle/crops/property but useful for rice, jute, tea; also called Barodoli Chheerha/Tea Showers in Assam
Blossom Showers	Kerala and Karnataka (Kodagu, Chikkamagaluru)	Evening/night	Aids coffee-flower blossoming
Mango Showers	Kerala and coastal Karnataka	Late summer (April–May)	Benefits mango crop

Indian Monsoon

- "Monsoon" derived from Arabic "Mausim" (season), used by Arab traders for seasonal wind-direction reversal.
- Occurs generally between 20°N and 20°S.
- Key mechanism: differential land/water heating → low pressure over Indian landmass, high pressure over surrounding seas.
- High-pressure area at ~20°S over the Indian Ocean (east of Madagascar) influences the monsoon by its intensity/position.
- Intense summer heating of the Tibetan Plateau creates a surface low and strong rising currents; in the upper troposphere (~9–12 km) a strong anticyclone (Tibetan High) forms, from which the Tropical Easterly Jet flows south.
- Westerly jet moves north of Himalayas while the tropical easterly jet stream forms over the peninsula.

Inter-Tropical Convergence Zone (ITCZ)

- Wide equatorial low-pressure trough where NE & SE trade winds converge and air rises.
- Shifts north/south with the sun (near-parallel to equator).
- Lies across the Gangetic plain in July, between 20°N–25°N, as the monsoon trough.
- Causes a thermal low over north/NW India.
- This shift pulls southern-hemisphere trade winds across the equator between 40°E–60°E.
- Coriolis force deflects them SW→NE there, giving the SW monsoon.

Different Theories on Indian Monsoon

Monsoon Theories

Theory	Core Idea
Thermal/Classical Theory (Sir Edmund Halley, 17th century)	Monsoon = large-scale land/sea breeze from thermal disparity between continents & oceans. Winter: Asia cools faster → high pressure → cold dry air outflow to low latitudes. Summer: reversed - Asia heats into a strong low (strengthened by ITCZ's poleward shift) while oceans form high pressure → warm moist oceanic air drawn inland
Air Mass Theory	Landmass north of Indian Ocean heats strongly in April–May (sun over Tropic of Cancer) → strong NW-subcontinent low; ITCZ shifts north; Coriolis deflects southern-hemisphere SE trade winds across equator to blow NE-ward, becoming SW monsoons. In winter ITCZ shifts south (sun over Tropic of Capricorn) → trade winds blow NE as North-East Monsoons
Dynamic Theory (most recent, widely accepted)	Treats monsoon as a dynamic system whose frequency/intensity/regularity depend jointly on differential land-sea heating, ITCZ shift, Tibet Plateau heating, jet streams (Subtropical, Somali, Tropical Easterly), Indian Ocean Dipole, and El Nino/La Nina

- Coriolis Force: apparent force from Earth's rotation, deflecting wind right in N. Hemisphere, left in S. Hemisphere; also called "Ferrel's Law".
- Al Masudi (10th century) gave a detailed account of monsoon wind/ocean-current reversal across the north Indian Ocean.

Recent Concept About Origin of Indian Monsoon

- Post-WWII upper-atmosphere studies showed monsoon circulation isn't produced by land-sea temperature difference alone.
- Himalayas & Tibetan Plateau found in the 1970s to be essential for commencing monsoon circulation.
- Air over the plateau is 2–3°C warmer than air at the same height over adjoining regions.
- This heating drives clockwise mid-troposphere circulation, producing two wind streams.
- One stream flows south, developing into the Tropical Easterly Jet (TEJ).
- The other flows toward the North Pole over Central Asia, becoming the westerly jet stream.
- Role of Jet Stream: in winter, Tibet splits the subtropical westerly jet into two branches.
- Northward branch reaches 20°N–35°N.
- TEJ (diverging from the Tibet anticyclone) sometimes reaches the tip of Peninsular India; jet-speed winds reported over other peninsular regions too.
- This jet descends over the Indian Ocean, intensifying the Mascarene High.
- From the Mascarene High, onshore winds blow toward the thermal low in the northern Indian Ocean.

Role of ENSO, IOD & Somali Current on Indian Monsoon

- El Nino, Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD) and the Somali Current all affect the Indian monsoon.
- The full ENSO/El Niño/La Niña/Walker Cell/IOD mechanism is in Chapter 5 (Hydrosphere); only monsoon-specific effects are given below.
- El Nino years generally correlate with a weak/below-normal monsoon/drought in India and hurt agriculture.
- Southern Oscillation Index (SOI) = pressure difference between Tahiti and Darwin.
- Negative SOI → high pressure over northern Indian Ocean in winter + weak monsoon.
- La Nina years generally bring abundant/above-normal Indian monsoon rains.

- Walker Cell's Indian Ocean branch (high pressure, driving SW monsoon winds toward India) strengthens during La Nina (good monsoon).
- Walker Cell's Indian Ocean branch shifts east during El Nino/negative SOI (weaker monsoon).
- IOD: Positive phase (western Indian Ocean warmer): favorable for Indian monsoon.
- IOD: Negative phase (eastern Indian Ocean warmer): obstructs monsoon progression.
- Somali Current: a significant western boundary current (Gulf Stream equivalent) that reverses direction with the monsoon.
- Flows with the SW Monsoon in summer, aiding monsoon moisture transport to India.

Nature of Indian Monsoon

Onset & Advance

- In May, the intensifying ITCZ low over north India pushes southern-hemisphere trade winds northward.
- SE trade winds cross the equator via the Arabian Sea & Bay of Bengal, gaining moisture over equatorial warm currents and merging into India's circulation.
- With ITCZ's northward shift, an easterly jet stream develops over 15°N.
- Rain starts abruptly (the monsoon "burst") with violent thunder/lightning, sharply lowering temperature.

Monsoon Arrival Dates

Location	Arrival Date
Andaman & Nicobar Islands	~20–22 May (Andaman Sea)
Kerala coast	1 June (normal); 2025: 24 May (earliest since 2009); 2026: 4 June
Mumbai & Kolkata	~10–11 June
Covers all of India by	8 July (revised normal since 2020; earlier 15 July)

Branches (Arabian Sea / Bay of Bengal)

- Near the southern tip of the peninsula, the SW monsoon splits into the Arabian Sea Branch and Bay of Bengal Branch.
- Arabian Sea Branch is ~3x stronger than the Bay of Bengal branch; heads toward the Thar Desert low; splits into 3 sub-branches.

Arabian Sea Branch: 3 Sub-Branches

Sub-branch	Path	Effect
1st	Blocked by the Western Ghats	Windward side gets 250–400 cm orographic rain; winds descend, heat up, lose humidity beyond the Ghats, creating the rain-shadow area to the east
2nd	Hits coast north of Mumbai → central India (Narmada & Tapi valleys) → Chhota Nagpur Plateau → Ganga plains	Delivers 15 cm to Chhota Nagpur Plateau; merges with Bay of Bengal branch in the Ganga plains
3rd	Strikes Kutch & Saurashtra → crosses west Rajasthan & Aravallis	Barely any rain; joins Bay of Bengal branch in Punjab/Haryana, strengthening rainfall in western Himalayas

- Bay of Bengal Branch originates in the Bay of Bengal; rains the north Indian plains.
- Also affects SE Bangladesh & Myanmar's coast, though the Arakan Hills divert much of it into the subcontinent, so it enters West Bengal/Bangladesh from the south/southeast (not SW).
- Under Himalayan + NW-India thermal-low influence it splits into two flows: (1) a westward flow along the Ganga plains to Punjab.
- (2) a NE/northward flow along the Brahmaputra valley, with a sub-branch hitting the Garo & Khasi Hills of Meghalaya.
- Mawsynram (Khasi Hills) has the world's highest average annual rainfall.
- Tamil Nadu's coast stays dry this season (rain-shadow of the Arabian Sea branch + parallel alignment to the Bay branch).

- Bay of Bengal depression frequency varies yearly and tracks the ITCZ/monsoon trough's oscillation (with the sun's apparent movement between the Tropics), causing year-to-year rainfall variation.
- North India sees 1–3 depressions/month, each lasting ~1 week.
- Rain falls in spells, declining west→east on the west coast and SE→NW across the northern peninsula.
- Rajasthan's desert gets little rain despite lying in the Arabian Sea branch's path, since the branch doesn't discharge moisture flowing unobstructed parallel to the Aravallis.

Break in the Monsoon

- A break in the monsoon = no rain for 1+ weeks during the SW monsoon period after initial rains; common in the wet season.
- In north India: caused by infrequent rain-bearing storms along the ITCZ/monsoon trough.
- On the west coast: caused by winds flowing parallel to the coastline.
- A prolonged break also occurs when the monsoon trough shifts north to the Himalayan foothills; rain then falls mainly over the Himalaya and NE India while the plains stay dry.

Retreat of Monsoon: North-East Monsoon (Retreating Monsoon Season)

- October–November: as the sun's apparent movement shifts south, the monsoon trough/low over the northern plains weakens and is gradually replaced by high pressure.
- SW monsoon winds weaken and withdraw: from the Northern Plains by beginning of October.
- Transition (moist rainy → dry winter): clear skies, rising temperature, hot days but cool pleasant nights.
- "October heat": unpleasant daytime weather from high temperature + humidity; north India's mercury drops rapidly in late October.
- By early November, low-pressure shifts from NW India to the Bay of Bengal, linked to cyclonic depressions over the Andaman Sea.
- These generally cross India's eastern coast with heavy, often damaging rain.
- Frequently hit the densely populated Godavari, Krishna, Kaveri deltas; occasionally reach Bangladesh, West Bengal, Odisha.
- These depressions/cyclones are the main rainfall source on the Coromandel Coast.

Seasons of India

- A distinctive feature of Indian climate: differing temperature, pressure, wind direction, rainfall amount/duration; meteorologists identify 4 seasons.

Four Meteorological Seasons of India

Season	Duration	Characteristics	Temperature	Wind & Pressure	Rainfall
Winter/Cold Weather	Mid-November–February	Clear skies, fine weather, low humidity	N. India mean daily <21°C; some areas below freezing; temp rises N→S	High pressure over NW India; winds NW→SE; westerly jet carries 4–5 western disturbances	Western disturbances bring rain to northern plains (decreases W→E, rises again in NE from Bay of Bengal); S. Andhra Pradesh, Tamil Nadu get winter rain via NE monsoon
Summer/Hot Weather	March–May	Excessive heat, hot Loo, dust storms, dryness	N. India up to 45°C (some >50°C); S. India less extreme	Low pressure over NW India, high pressure over S. Bay of Bengal; ITCZ extends to Ganges plain; afternoon dust storms in northern plains	Dry season; dust/thunderstorms give some rain; east gets relatively more than west

Season	Duration	Characteristics	Temperature	Wind & Pressure	Rainfall
Southwest Monsoon	June–September	Whole India under SW Monsoon; severe cyclones, thunderstorms	May–June hottest before onset; temperature falls in July–August, rises slightly in September as rain decreases	SW winds over the peninsula; SE/E winds over the northern plains (Bay of Bengal branch)	~75% of India's annual rainfall in this season; decreases E→W in the northern plains
Retreating Monsoon	October–November	Abrupt temp surge ("October heat"); monsoon gradually retreats	High day temp, cool/pleasant nights; avg min <20°C	NE-erly winds; clear skies, calm	Rain in S. Peninsula (Tamil Nadu, Kerala, S. Andhra Pradesh); increased cyclonic activity in Peninsular region

Traditional (Indian Calendar) Seasons

- Indian calendar divides the year into 6 seasons of 2 months each.

Season	Indian Calendar Months	English Calendar Months
Vasant (Spring)	Chaitra–Vaishakh	March–April
Girishma (Summer)	Jyeshtha–Ashadh	May–June
Varsha (Rainy)	Shravan–Bhadrapada	July–August
Sharada (Autumn)	Ashvin–Kartik	September–October
Hemanta (Pre-winter)	Margshirsh–Paush	November–December
Shishir (Winter)	Magha–Phalgun	January–February

Rainfall Distribution & Variability

- General pattern: in the northern plains rainfall decreases from east to west; in the peninsula it decreases from the west coast towards the east (except the Coromandel coast).

Rainfall Distribution Categories

Category	Annual Rainfall	Regions
Areas of High Rainfall	>200 cm	Western side of Western Ghats (Mumbai to Thiruvananthapuram); Assam, Nagaland, Meghalaya, Mizoram, Arunachal Pradesh, Sikkim, parts of Manipur/Tripura, NE tip of West Bengal (isolated pockets >400 cm); wettest: Meghalaya, Mawsynram (1,221 cm), Cherrapunji (1,102 cm)
Areas of Moderate Rainfall	100–200 cm	Eastern slopes of Western Ghats, most of northern plain, Odisha, MP, Andhra Pradesh, Tamil Nadu
Areas of Low Rainfall	50–100 cm	Parts of Maharashtra, Gujarat, UP, western MP, Andhra Pradesh, Karnataka, eastern Rajasthan, Punjab, Haryana
Areas of Very Low Rainfall	<50 cm	Semi-arid/desert: most of J&K's Ladakh, parts of western Rajasthan, Kachchh

- Monsoon rainfall decreases with distance from sea (SW monsoon season figures): Kolkata 119 cm, Patna 105 cm, Prayagraj 76 cm, Delhi 56 cm.

Characteristics of Monsoon Rainfall

- Relief/topography-driven: windward Western Ghats >250 cm; Eastern Himalayas & NE hill ranges also get significant rain.
- Unconventional/Sudden Burst: heavy downpour causes significant runoff & soil erosion.
- Uneven spatial distribution: from < 10 cm (Ladakh, western Rajasthan) to > 1,000 cm (Mawsynram).

- Delay in Arrival: onset sometimes delayed across all/parts of the country.
- Early Withdrawal: rains end earlier than expected, damaging standing crops and delaying Rabi sowing.

Variability of Annual Rainfall

- Coefficient of Variation (C.V.) = $(\text{Standard Deviation} / \text{Mean}) \times 100$.
- Difference between actual & average annual rainfall ranges 10%–60%.

Rainfall Variability by Region

Variability (C.V.)	Annual Rainfall	Regions
<25%	>100 cm	Western coasts, Western Ghats, NE Peninsula, eastern Ganga plains, NE India, Uttarakhand, Himachal Pradesh, SW J&K
25–50%	50–100 cm	Rest of India
>50%	<50 cm	Western Rajasthan, northern J&K, interior Deccan plateau

Climate Change and Indian Monsoon

- CSE data: India was hit by extreme-weather disasters on 331 of 334 days in 2025 (up from 295 days in 2024 and 292 days in 2022).
- Low-pressure systems/depressions shifting south of usual positions signal changing monsoon tracks.
- IPCC AR6: Indian summer monsoon rainfall is projected to increase in the long term, with greater year-to-year and within-season variability.

Monsoon 2026 (Quick Facts)

Onset over Kerala on 4 June 2026 (3 days late); IMD had forecast a below-normal season due to a strong El Niño
 Season (June–Sept) rainfall: 759.4 mm = 87% of LPA (868.6 mm), a 12.6% deficit, the lowest since 2015 (deficient category: below 90% of LPA)
 East & NE India: 25.6% deficit (driest monsoon since 1901); South Peninsula: 24.3% deficit; NW India: 5.9% deficit; Central India: 2.6% deficit
 IMD rainfall categories (all-India): Deficient < 90% | Below normal 90–95% | Normal 96–104% | Above normal 105–110% | Excess > 110% of LPA

Climatic Regions of India

Koeppen's Classification

- Based on monthly averages of temperature & precipitation.

Koeppen's Classification of Indian Climate

Code	Type	Region
Amw	Monsoon type with short dry season	Western coastal region south of Goa
As	Monsoon type with dry season in summer	Coromandel coast
Aw	Tropical Savanna type	Most of the peninsular plateau south of the Tropic of Cancer
BShw	Semi-arid steppe climate	North-western Gujarat, parts of western Rajasthan and Punjab; rain-shadow interior of the Deccan
BWhw	Hot desert type	Extreme western Rajasthan
Cwg	Monsoon type with dry winters	Ganga plain, eastern Rajasthan, northern MP, most of NE India
Dfc	Cold-humid winter, short summer	Arunachal Pradesh
E	Polar type	Jammu & Kashmir, Ladakh, Himachal Pradesh, Uttarakhand (high mountains)

Stamp's Classification

- Used 18°C January mean monthly isotherm to divide India into Temperate/Continental zone (north) and Tropical zone (south).
- Further divided (by temperature & rainfall) into 11 regions.

Stamp's Classification: Part 1

Region	Areas	Avg. Temperature	Annual Rainfall
Himalayan Region	J&K, Ladakh, HP, Uttarakhand, Sikkim, Arunachal	Low; falls with altitude, very cold winters	Heavy in the east, light in the west and in Ladakh
Northwestern Region	Jammu region, northern Punjab	Hot summers, cold winters	Moderate; part comes in winter from Western Disturbances
Region of Moderate Rainfall	Punjab, Haryana, western UP, Delhi UT, NW Plateau (MP), eastern Rajasthan	Winter 15–18°C; Summer 33–35°C	40–80 cm
Arid Lowland	Thar Desert (Rajasthan), SW Haryana, Kachchh (Gujarat)	Winter 16–24°C; Summer 48°C	Under 25 cm in the west to ~50 cm in the east
Transitional Zone	Bihar, Eastern UP	Winter 15–19°C; Summer 30–35°C	100–150 cm

Stamp's Classification: Part 2

Region	Areas	Avg. Temperature	Annual Rainfall
Region of very heavy rainfall	Assam, Tripura, Mizoram, Meghalaya, Nagaland	Winter 18°C; Summer 32–35°C	Over 200 cm
Region of moderate rainfall	Between Western & Eastern Ghats	Winter 18–24°C; Summer 32°C	50–100 cm
Region of heavy rainfall	Chhattisgarh, Jharkhand, Gangetic West Bengal, Odisha, coastal Andhra Pradesh	Winter 18–24°C; Summer 29–35°C	100–200 cm
Konkan Coast	Mumbai (north) to Goa (south)	Annual 27°C	Over 250 cm
Malabar Coast	Goa to Kanyakumari	Annual ~27°C	Over 250 cm
Tamil Nadu	Tamil Nadu & adjoining Andhra Pradesh	Annual 24–27°C	100–150 cm (much of it from the NE monsoon)

Natural Disasters

Droughts

- India's rainfall variability directly causes periodic droughts.
- Monsoon failure most severely affects regions lacking irrigation infrastructure.
- Drought/flood frequency has risen sharply (CSE: extreme weather on 331 of 334 days in 2025), linked to climate change; 2026 monsoon was deficient (87% of LPA).
- Bundelkhand is a chronic drought-prone region of India.

Floods

- Caused primarily by continuous/excessive rainfall, cyclonic depressions, and monsoon variability.
- Low-lying/densely populated river deltas (e.g. Godavari, Krishna, Kaveri) are especially vulnerable.
- Particularly vulnerable to post-monsoon (retreating) cyclones from the Andaman Sea.

- Central Water Commission (CWC) issues flood warnings using IMD's meteorological assistance.

IMD Colour-Coded Weather Warnings

Colour	Meaning	Description
Green	All is well	No warnings
Yellow	Be Aware	Harsh weather lasting several days; may disrupt day-to-day activities
Orange/Amber	Be Prepared	Exceptionally harsh weather; possible travel disruption (road/rail closures), power supply interruptions
Red	Take Action	Exceptionally unfavourable conditions; serious risk to life, disrupts travel & power

Cyclones in India

- Defining feature: rapid inward air circulation around a low-pressure area.
- Anticlockwise in N. Hemisphere, clockwise in S. Hemisphere.
- Develop over the Indian Ocean, Arabian Sea, Bay of Bengal as large-scale surface wind circulation systems over tropical/subtropical oceans.
- Most destructive coastal states: Tamil Nadu, Andhra Pradesh, West Bengal, Odisha, Gujarat.
- Cyclone seasons in the North Indian Ocean: pre-monsoon (April–June) and post-monsoon (October–December, the more intense).
- Of India's coastline, about 5,700 km is vulnerable to cyclones and related hazards; the east coast is more susceptible than the west.

Cyclone Consequences

Strong winds/squalls: building/communication/tree damage.

Inland floods & torrential rain: soil erosion, embankment damage.

Storm surge: abnormal sea-level rise near shore; inundates low-lying coast.

Storm surge drowns people/cattle, erodes beaches/embankments, destroys flora, lowers soil fertility.

Cyclone Management Measures

Type	Measures
Structural	Cyclone shelters, cyclone-resistant infrastructure, road linkages, culverts, bridges, canals, drains, saline embankments, surface water tanks, communication/power transmission networks
Non-structural	Early warning systems, coastal zone management, disaster risk management, capacity building

- National Cyclone Risk Mitigation Project (NCRMP): World Bank-financed; implements both structural & non-structural measures state-by-state.
- Coastal Regulation Zones (CRZ): regulate coastal land use.

Heat Waves

- A period of unusually high regional temperatures.
- IMD criteria: maximum temperature at least 40°C (plains), 37°C (coastal stations) or 30°C (hills), together with the departure criteria below.

Heat Wave Declaration Criteria

Station's Normal Max	Heat Wave	Severe Heat Wave
≤40°C	5–6°C above normal	≥7°C above normal
>40°C	4–5°C above normal	≥6°C above normal

- Also declared when the actual maximum is $\geq 45^{\circ}\text{C}$ (heat wave) or $\geq 47^{\circ}\text{C}$ (severe heat wave), regardless of normal.

Soils: Introduction

- Soil: mixture of rock debris and organic material on earth's surface.
- Most important layer of earth's crust; evolved over thousands of years.

Soil Classification (ICAR / USDA)

- ICAR (Indian Council of Agricultural Research) classifies Indian soils by nature/character, based on the USDA system.

Soil Orders of India (ICAR/USDA)

Soil Order	% Area	Key Feature
Inceptisols	39.74%	Young soils at inception
Entisols	28.08%	Recently formed soils
Alfisols	13.55%	High aluminium & iron
Vertisols	8.52%	Inverted profile; high clay; cracks in dry season; rich in lime/manganese/calcium
Aridisols	4.28%	Soils of arid/dry regions
Ultisols	2.51%	Almost all nutrients leached out
Mollisols	0.40%	Soft, chernozem-like
Others	2.92%	Oxisols (highly weathered, rich in iron & aluminium oxides), Andisols (volcanic ash), Gelisols (permafrost), Histosols (organic/peat), Spodosols (ash-coloured, like podzols)

ICAR: Key Facts

Apex body coordinating agriculture/horticulture/fisheries/animal sciences research & education
 Registered society under Societies Registration Act, 1860
 Autonomous body under the Department of Agricultural Research and Education (DARE), Ministry of Agriculture & Farmers Welfare; set up in 1929
 Union Agriculture Minister is the ex-officio President of the ICAR Society

Soil Profile

- Vertical arrangement of soil layers.
- Particle size order: Stone > Gravel > Sand > Silt > Clay.
- Soil horizon: horizontal layer parallel to surface, differing from adjacent layers in colour/texture.

Soil Profile Layers (Top to Bottom)

Layer	Description
O	Undecomposed/partially decomposed organic matter: leaves, twigs, mosses, lichens
A	Topsoil; decomposed organic matter + weathered minerals; most fertile layer
E	Heavily leached; little/no nutrients; rich in quartz/sand/silt
B	Illuviation zone: accumulates clay, iron, aluminium and humus washed down from the A and E horizons
C	Loose parent rock material; source for layers above
R	Continuous, unbroken parent/bedrock

Soil Characteristics

- Texture: depends on sand/silt/clay proportion.
- Fertility: decides quantity/quality of plant life supported.
- pH: scale 0–14 (7 = neutral); different pH suits different crops (acidic soils limed, alkaline soils treated with gypsum).
- Permeability: ability to filter water/air; depends on structure.
- Porosity: amount/structure of pores.
- Salinity: salt accumulation, natural or human-induced (e.g. over-irrigation).

Types of Soils of India (Genesis/Colour/Composition/Location)

Major Soil Types of India

Soil Type	Key Properties	Main Area
Alluvial	Sandy-loamy to clayey; generally rich in potash, poor in phosphorus, nitrogen and humus; light grey-ash grey; intensively cultivated; covers ~40% of India's area (NCERT); largest soil group	Northern plains, river valleys; Rajasthan corridor into Gujarat plains; east-coast deltas & river valleys of Peninsular India
Black/Regur	Clayey, deep, impermeable; high moisture-holding, self-ploughing (wide dry-season cracks); rich in lime, iron, potash, magnesium, alumina; poor in phosphorus, nitrogen, organic matter; deep black-grey; ~5.46 lakh sq km	Most of Deccan plateau: Maharashtra, MP, Gujarat, Andhra, parts of TN, Karnataka, Telangana
Red & Yellow	Forms on crystalline igneous rocks under low rainfall; red from iron diffusion, yellow when hydrated; fertile if fine-grained; poor in nitrogen, phosphorus, humus; ~3.5 lakh sq km	Eastern & southern Deccan plateau; narrow Western Ghats strip; Odisha, Chhattisgarh, Jharkhand (Chotanagpur); southern middle-Ganga plains
Laterite	High temp + rainfall → intense leaching; lime/silica leached away, rich in iron oxide, aluminium; humus breaks down fast; poor in nitrogen, potash, calcium; good for plantation crops (tapioca, cashew) with fertilizer; used for bricks; ~2.48 lakh sq km, mostly Kerala (Malabar coast), then Maharashtra	Karnataka, Kerala, Tamil Nadu, MP, and hilly areas of Odisha and Assam; also Western/Eastern Ghats, Meghalaya, south Maharashtra
Arid/Desert	Red-brown, sandy, saline; high temp, fast evaporation, dry; lacks moisture/humus; insufficient nitrogen, some phosphate; kankar layer below prevents seepage; cultivable if irrigated; ~1.42 lakh sq km	Mostly western Rajasthan; also Saurashtra (Gujarat), Kutch, southern Punjab
Saline/Alkaline (Usara)	High sodium/potassium/magnesium; infertile, no vegetative growth; sandy-loamy, lacks nitrogen/calcium; worsened by seawater intrusion near deltas and excess irrigation in Green Revolution areas; local names: Reh, Thur, Chopan, Kallar, Rakar	Western Gujarat, Sundarbans (WB), east-coast deltas, Punjab, Haryana, Western UP
Peaty/Marshy	Heavy rainfall + high humidity + good vegetative growth; rich in organic content/humus; heavy, black, can be alkaline	Northern Bihar, southern Uttarakhand; coastal WB, Odisha, Tamil Nadu
Forest/Mountain	Varies with environment; loamy/silty on valley sides, coarse on upper slopes; acidic, low humus in Himalayan snow-bound areas	Forest areas with sufficient rainfall

Alluvial Soil: Additional Detail

- Depositional, transported by rivers/streams.
- Upper/mid-Ganga plains: Bhangar (older alluvium, pale reddish-brown, calcareous nodules, above flood reach) and Khadar (new alluvium, deposited annually by floods, always fertile).
- Bhabar: gently sloping coarse alluvial zone below Shiwalik Hills where streams vanish into permeable sediment.
- Tarai/Terai: marshy lowland south of Bhabar, rich in nitrogen/organic matter, poor in phosphate.
- Generally rich in potash and lime but poor in nitrogen, phosphorus and humus (NCERT).

- Good for wheat, rice, sugarcane, jute, cotton, maize, oilseeds, fruits, vegetables.
- Also found in Narmada/Tapi valleys; coastal alluvium; deltaic alluvium in Mahanadi, Godavari, Krishna, Cauvery deltas.

Black Soil: Additional Detail

- Also called Tropical Chernozem.
- Formed by weathering of basaltic/Deccan trap lava.
- Very suitable for cotton cultivation; extends to Godavari and Krishna valleys.
- Karewas: thick lacustrine (lake) deposits of the Kashmir valley, famous for saffron (zafran) cultivation (distinct from regur).

Laterite Soil: Additional Detail

- First researched by F. Buchanan-Hamilton (1807).
- Name from Latin "later" = brick.
- Soft like butter when wet, hard like bricks when dry.

Soil Erosion

- Soil erosion: removal of topsoil by wind/water (alone or together); disrupts profile, impacts fertility.
- Wind erosion areas: Rajasthan, Gujarat, parts of Haryana, Ladakh (arid/semi-arid).
- Water erosion areas: Western Ghats, North Eastern states (heavy-rainfall + steep-slope regions).

Types of Soil Erosion

Type	Mechanism / Feature
Splash erosion	Heavy rainfall; raindrops detach soil particles at high speed
Sheet erosion	Thin soil layer moves uniformly where vegetation is sparse; common on steep hilly slopes; entire top layer can wash/blow away
Rill erosion	Concentrated runoff cuts small finger-shaped channels (rills) that can be removed by ploughing
Gully erosion	Rills deepen into gullies that cannot be ploughed out; extensive gullying forms ravines/badlands (e.g. Chambal; Chos of the Shiwalik foothills in Punjab)

Human Activities Causing Erosion

- Deforestation: roots bind soil; worst in hilly regions; reduces percolation, increases runoff.
- Faulty agricultural methods: wrong-direction ploughing promotes runoff.
- Monoculture reduces fertility.
- Imbalanced and excessive chemical fertiliser use degrades soil structure.
- Excess nitrogenous fertilizer increases acidity/leaching.
- Shifting cultivation: clearing → intense cultivation → abandonment causes erosion.
- Overgrazing: trampling, worse in long dry periods.

Soil Forming Processes (Pedogenesis)

- Pedogenesis: soil formation shaped by Parent material, Climate, Topography (relief/slope/aspect), Biological factors, Time.

Principal Pedogenesis Processes

Process	Mechanism
Podzolization/Cheluviation	Cool, moist climates under conifers: acidic humus and chelating agents leach iron and aluminium from the upper layers, leaving an ash-grey horizon (podzols)
Desilication (Laterization)	Hot, humid tropics: silica is leached away, leaving hard lateritic layers rich in iron and aluminium oxides
Translocation	Material movement via leaching (downward) or capillary action (upward)

Process	Mechanism
Salinization	Capillary action in arid/semi-arid areas (or over-irrigation, e.g. Green Revolution areas) accumulates salts in upper layers, forming saline soils
Alkalisiation	Calcium/sodium carbonate accumulation makes soil impermeable, forms sodic soil
Gleying	In waterlogged conditions, anaerobic decomposition reduces iron oxides to soluble state (soil turns bluish-grey), forming sticky gley horizon

Soil Conservation

- Maintains fertility, prevents erosion/exhaustion, improves degraded soil.

Soil Conservation Methods

Method	Feature
Contour bunding	Prevents runoff on slopes
Contour terracing	Farms slopes without much altering them
Regulated forestry	One tree planted per tree cut
Cover cropping	Crop residue covers soil
Mixed farming	Crops + animal rearing
Crop rotation	-
Conservation agriculture	Minimum tillage, residue cover, regional rotation
Zero tillage	No soil disturbance/residue burning; aids carbon sequestration

- Soil Health Card Scheme: identifies soil requirement, prescribes fertilizer quantity, checks fertilizer overuse.
- Gully erosion prevention: terracing, check dams, cover vegetation at gully heads.
- Shelterbelts of trees in arid regions prevent desertification ("green wall").
- Afforestation under CAMPA in degraded regions.

CHAPTER 12

India: Natural Vegetation, Irrigation & Canals, Multi-Purpose River Valley Projects

Natural Vegetation and Forests

- Natural Vegetation: plant community undisturbed long enough for species to adjust to climate/soil; always natural, never manmade.
- Forests: ecologically, tree-dominated communities with closed canopy on uncultivated/uninhabited land, closely linked to the ecosystem; can be natural or manmade.
- Factors determining forest development: Physiography (topography, soil), Climate (temperature, rainfall).

Types of Forests in India

- Tropical Evergreen & Semi-Evergreen.
- Tropical Deciduous (Moist/Dry).
- Tropical Thorn & Scrub.
- Littoral & Swamp (Mangrove).
- Montane (Northern Himalayan & Southern).

Forest Type Coverage in India (Approx. Share of Forest Area)

Forest Type Coverage Share

Forest Type	Share of Forest Area (Champion & Seth/NCERT)
Tropical moist deciduous	37%
Tropical dry deciduous	28%
Tropical wet evergreen	8%
Subtropical moist	6%
Tropical semi-evergreen	4%
Others	<4%

- FSI's forest-type mapping shows Tropical Dry Deciduous as the largest group in actual cover (~42%), followed by Tropical Moist Deciduous (~20%).

Tropical Evergreen Forests

Tropical Evergreen Forest Sub-types

Sub-type	Rainfall	Distribution	Characteristics	Major Species
Tropical Wet Evergreen/Rainforests	>250 cm	Western slopes of Western Ghats, NE region, Andaman & Nicobar Islands	No annual leaf shedding; lofty, dense multi-layered canopy, sunlight barely reaches ground; abundant epiphytes/creepers/bamboo; buttressed roots; very high biodiversity; high commercial timber value	Ebony, Mahogany, Rosewood, Jamun

Sub-type	Rainfall	Distribution	Characteristics	Major Species
Tropical Semi-Evergreen/Moist Evergreen	200–250 cm	Eastern Western Ghats, southern Assam, coastal Odisha, Eastern Himalayan slopes, eastern Andaman Islands	Transition between evergreen & deciduous, borders evergreen; less dense; rougher/thicker bark; abundant epiphytes, less bamboo	Champa, Mango, Indian chestnut, Semul, Kadam

Tropical Deciduous Forests

Tropical Deciduous Forest Sub-types

Sub-type	Rainfall	Distribution	Characteristics	Major Species
Moist Deciduous	100–200 cm	Terai belt, Himalayan foothills; wetter peninsular areas/plains (UP, Bihar); Eastern Himalaya foothills; eastern Western Ghats slopes; western/central Odisha; Chotanagpur plateau; Terai & Bhabar plains; Mizoram, Manipur	Closed, uneven canopy; light reaches the ground giving good undergrowth; heavily exploited for timber	Teak, Sal, Shisham, Mahua, Amla, Kusum, Jamun, Semal, Sandalwood, Bamboo
Dry Deciduous	70–100 cm	Central Gangetic plains to southern India	Sheds leaves in spring/early summer; buttress roots, fair undergrowth; climber/bamboo patches; less dense, easily exploited, much cleared for agriculture; economically valuable timber; among world's most degraded forests	Teak, Tendu, Palash, Khair, Bel, Axlewood, Rosewood, Red Sanders (Andhra Pradesh)

Tropical Thorn & Shrub Forests

- Areas with less than 50 cm rainfall (NCERT).
- Distribution: NW Rajasthan; SW Punjab & Haryana; western UP, parts of MP; Kutch & Saurashtra (Gujarat); rain-shadow side of the Western Ghats; drier parts of Andhra Pradesh and Karnataka.
- Characteristics: widely scattered, long deep roots; thick small glossy leaves conserve water; xerophytic adaptations; some species grow only in rainy season; some undergrowth.
- Major species: Date, Palm, Babul, Cacti, Khair, Neem.

Littoral and Swamp (Mangrove) Forests

- Found in tidal and brackish water areas, deltas, estuaries, creeks (Ganga, Krishna, Kaveri, Mahanadi, Godavari).
- Hard durable timber used for boats; salt-tolerant species; halophytic adaptations.
- Major species: Sundari, Mangroves, Agar, Coconut, Palms, Canes, Rhizophora.
- Sundari (*Heritiera fomes*): dominant/principal mangrove species of Sundarbans.

State-wise Mangrove Belts

State	Key Mangrove Belts
Maharashtra	Achra-Ratnagiri, Raigad, Devgarh-Vijaydurg, Malvan, etc.
Karnataka	Coondapur, Honnavar, Karwar
Kerala	Vembanad, Kannur
Tamil Nadu	Pichavaram, Muthupet, Ramnad, Pulicat
West Bengal	Sundarbans

State	Key Mangrove Belts
Odisha	Bhitarkanika, Devi, Dhamra, Chilika

- West Bengal (Sundarbans) has the largest mangrove cover (~42% of India's), followed by Gujarat and A&N Islands (ISFR).

Montane Forests

- Northern Montane/Himalayas: vegetation succession from Tropical to Tundra with altitude.
- Alpine vegetation grows above ~3,000–3,600 m up to the snowline.

Key Montane Trees/Plants

Species	Zone / Altitude	Notes
Deodar (<i>Cedrus deodara</i>)	Western Himalaya, 1500–3000 m	Himachal Pradesh, Uttarakhand, J&K
Chir pine	Himalaya, 900–1800 m	Native to Himalayas; source of Lisa (resin) distilled into turpentine; important for Uttarakhand's rural economy
Sal	Sub-Himalayan belt	Mainly sub-Himalayan belt and NE Peninsula
Cinchona	Darjeeling hills (WB) and Nilgiris (TN)	Source of quinine; plantations at Mungpoo (Darjeeling) and in the Nilgiris

- Southern Montane Forests: Western Ghats & Nilgiris, Vindhyas, Satpura & Maikal ranges, southern hill complexes of TN & Kerala.
- Shola Forests: unique ecosystem ~1500 m in Nilgiri region; temperate vegetation higher up, tropical lower; unique temperate broad-leaved forest with grassland/open-forest patches interspersed with dense forest; species: Magnolia, Cinchona, Wattle.

Deforestation

- Mining (coal, iron ore, oil, natural gas) clearing large tracts.
- Urbanisation (e.g. Aravallis shrinking from Haryana/Rajasthan city growth).
- Effects: increased man-animal conflict (habitat loss).
- Greater desertification/land degradation vulnerability.
- Biodiversity/ecological-balance loss.
- Impact on forest-dwelling communities' livelihoods.

India's Forest Policies

Policy	Key Provisions
Forest Policy of 1894 (British)	First forest policy; aimed at commercial timber and state control; classified forests for protection and production
Forest Policy of 1952	Acknowledged local tribal rights and forest-management importance; no concrete laws/solutions; social/ecological objectives unmet; commercial exploitation continued
Draft National Forest Policy 2018	Proposed but not yet adopted; emphasises climate change, forest certification and public-private partnership
Forest Policy of 1988	Declared all natural/traditional forests ecologically sensitive; banned commercial logging/timber activity in ecologically important forests; gave tribes limited rights to collect minor forest produce (firewood, fodder, leaves); promoted captive forestry (timber/commercial) and social/agroforestry (cottage industries, local communities); target: 33% of geographical area under forest cover; aimed at maintaining/restoring forests for ecological stability

Social Forestry

- Management/protection of forests + afforestation of barren lands for environmental, social, rural development.
- Grows trees for dependent communities' needs, relieving pressure on traditional forests.
- Plantation on vacant panchayat/government land (roads, rivers, railways).

Components of Social Forestry

Component	Feature
Farm forestry	Farmers grow trees commercially/non-commercially on farmland, replacing crops (unlike agroforestry); state forest departments give free seedlings
Agroforestry	Forestry + agriculture together: food, fodder, fruit, timber on the same land; India was the first country to adopt a National Agroforestry Policy (2014)
Urban forestry	Trees in/around cities: green belts, parks, roadsides; Nagar Van Yojana (2020) creates urban forests

- Evaluation: meant to benefit locals via participatory plantations, but compromised by choosing Eucalyptus (not economically beneficial, ecologically disastrous alien species, no fuel/firewood benefit).
- Khejri: "king of the desert," multipurpose social-forestry tree, fuel, charcoal, firewood, fodder, green manure, goat-proof thorny fences; frost- and drought-resistant, needs minimal rainfall.

Laws & Initiatives for Forest/Wildlife Conservation

Key Forest/Wildlife Conservation Laws

Law/Initiative	Key Provisions
Wildlife Protection Act, 1972	Enacted in 1972 (constitutional backing added later via Arts. 48A and 51A(g) by the 42nd Amendment, 1976); provides for wildlife advisory boards/wardens, protected areas (sanctuaries, national parks, conservation and community reserves), Central Zoo Authority, NBWL and NTCA; 2022 amendment reduced schedules from six to four (I & II animals, III plants, IV CITES specimens) and aligned the Act with CITES (India joined CITES in 1976)
Forest (Conservation) Act, 1980 (renamed Van (Sanrakshan Evam Samvardhan) Adhiniyam in 2023)	Checks diversion of forest land for non-forest purposes; prior Central approval needed; 2023 amendment limits coverage to legally notified forests and land recorded as forest on or after 25 Oct 1980, and exempts some strategic/linear projects near borders
Compensatory Afforestation Fund Act, 2016 (CAMPA)	Compensates forest-land loss, maintains sustainability; funds held at national/state level under Public Accounts; national:state fund division = 10:90; a company diverting forest land must provide alternative land + afforestation funding elsewhere (e.g. Coal India clearing Chhattisgarh forest must plant trees elsewhere)
Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006	Recognises individual and community forest rights of tribals and forest dwellers; Gram Sabha is central
Biological Diversity Act, 2002 (amended 2023)	National Biodiversity Authority (Chennai), State Biodiversity Boards, Biodiversity Management Committees; access and benefit sharing

India State of Forest Report (ISFR) 2023 [Latest, 18th Report]

- Prepared by Forest Survey of India (FSI), Dehradun, and released by MoEF&CC every 2 years (ISFR 2023 released in December 2024; previous: ISFR 2021).
- Forest Cover vs Forest Area: Forest cover can be on government or private land; Forest Area is strictly land recorded as forest in government records.

- Tree cover: patches <1 hectare, outside recorded forest area.

Forest Canopy Density Categories

Category	Canopy Density
Very dense forest	>70%
Moderately dense forest	40–70%
Open forest	10–40%
Scrub (also surveyed)	<10%

ISFR 2023: Headline Figures

Total forest + tree cover: 8,27,357 sq km = 25.17% of geographical area
 Forest cover alone: 21.76%; Tree cover: 3.41%
 Up 1,445 sq km over ISFR 2021
 Total mangrove cover: 4,992 sq km (slight net decrease vs ISFR 2021)
 Total carbon stock in India's forests: 7,285.5 million tonnes (up 81.5 million tonnes since ISFR 2021)

- Largest forest cover (area-wise): Madhya Pradesh > Arunachal Pradesh > Chhattisgarh.
- Maximum increase in forest+tree cover: Chhattisgarh > Uttar Pradesh = Odisha.
- Highest forest cover (% of state area): Lakshadweep (91.33%) > Mizoram (85.34%) > Andaman & Nicobar Islands (81.62%).
- 19 states/UTs have >33% geographical area under forest cover.
- 8 states/UTs have >75% forest cover: Mizoram, Lakshadweep, Andaman & Nicobar, Arunachal Pradesh, Nagaland, Meghalaya, Tripura, Manipur.
- Madhya Pradesh has the largest dense deciduous forest cover.

Tiger Reserve Special Chapter (ISFR)

- Assesses forest cover in Tiger reserves, lion conservation areas (Gir), tiger corridors.
- ISFR 2021: during 2011–21, forest cover increased in 20 tiger reserves and decreased in 32.
- Increase (ISFR 2021): Buxa (WB), Anamalai (TN), Indravati (Chhattisgarh).
- Loss (ISFR 2021): Kawal (Telangana), Bhadra (Karnataka), Sundarbans (WB).
- Pakke Tiger Reserve (Arunachal) has the highest forest cover share (~97%).

Forest Fires / Wildfires

- Spread unpredictably via "fire triangle" (fuel, oxygen, heat), extinguished if one element is denied.
- Man-made causes: campfires, cigarettes, electric sparks, land clearing.

Climate Change and Forest Fires

Climate change makes heat waves and droughts more frequent and intense, lengthening fire seasons
 Global warming drives extreme weather, disrupted natural cycles
 Atmospheric CO₂ crossed 420 ppm in 2022, the highest in millions of years
 India: ~35% of forest cover is fire-prone (ISFR 2021); FSI runs a satellite-based near-real-time forest fire alert system;
 Uttarakhand saw severe fires in 2024

Types of Forest Fires

Type	Feature
Surface fire	Starts at ground level using litter/dead wood/fallen leaves as fuel; can spread to tall trees but easily put out; common in pine forests where seeds survive and forests regrow naturally
Crown fire	Spreads tree-top to tree-top without ground interaction, fastest-spreading, most dangerous, very hard to contain

Type	Feature
Ground fire	Consumes organic material below surface litter (underground/subsurface fire), where humus/peat accumulate; moves slowly, hard to detect, can burn for months

Effects of Wildfires

- Vegetation loss causes soil erosion, landslides in hilly regions.
- Poisonous gases released raise lung cancer/skin disease risk.
- Flora/fauna badly impacted, may take years to recover.

Ecological Benefits of Wildfires

- Many species require fire to survive/thrive (e.g. pine cone seeds need burning/melting to release; certain lilies need fire for germination).
- Removes litter build-up (which blocks nutrient/sunlight access) in controlled manner.
- Nutrients from burned plants/animals reach soil faster than natural decay, boosting fertility.

Forest Fire Governance & Facts (CEEW Study)

- Currently managed by state forest departments: underfunded, understaffed.
- CEEW recommendation: classify forest fires as "natural disasters" (currently not) to bring them under NDMA purview.

CEEW Findings on Forest Fires

Frequency, intensity, and fire-prone months per year have risen over two decades
 Over 62% of Indian states are prone to large-scale forest fires
 36% of India's forest cover is fire-prone
 Over 30% of districts are hotspots for extreme fire events
 Mizoram had the highest forest-fire incidence in the last two decades

Irrigation Systems

- Irrigation = artificial water application to land/soil, substituting/supplementing rainwater.

Well & Tube Well Irrigation

- Wells mainly in UP, Bihar, Tamil Nadu (shallow, deep, tube, artesian types).
- Tube wells (often electric) irrigate larger areas; mostly UP, Haryana, Punjab, Bihar, Gujarat.

Canal Irrigation

- Effective in low-relief, deep fertile soil, perennial water source, extensive command area.
- Concentrated in northern plains (UP, Haryana, Punjab); absent on Peninsular plateau, some in South India coastal/delta regions.

Canal Types

Type	Feature
Inundation canals	No regulating structure, direct from rivers, flood/rainy season
Perennial canals	From perennial rivers via barrage: most Indian canals

Tank Irrigation

- Small earth/stone bund across a stream.
- Most important in the peninsular plateau: Tamil Nadu, Telangana, Andhra Pradesh, Karnataka; also Odisha, MP (Bundelkhand), Rajasthan.

Micro-Irrigation (Drip & Sprinkler)

- Slow continuous drips/tiny streams/sprays above or below soil surface.
- Saves water, raises water-use efficiency vs flooding; reduces weeds, soil erosion, cultivation cost; usable on all land types.

Drip vs Sprinkler Irrigation

Type	Mechanism	Best For	Not Suitable For	Merits	Demerits
Drip	Water/nutrients via "dripper lines" near root (2-20 litres/hour); most efficient	Vegetables, orchards, flowers, plantation crops	-	Minimizes fertilizer/nutrient loss; no field leveling needed; can use recycled non-potable water	Higher initial cost; clogging risk
Sprinkler	Water sprayed like rainfall via pressure nozzles (droplets 0.5-4mm)	Uneven land/shallow soils, dry crops, vegetables, flowers, orchards, tea/coffee	Paddy, jute; unsuitable windy sites	30-50% water saving, higher yield, no bunds needed	Higher initial cost; poor efficiency in strong wind/high temperature (drift and evaporation)

- Govt promotion: PMKSY ("more crop per drop"), subsidy up to 55% (small/marginal farmers), 45% (others).
- Adoption challenges: capital-intensive (favors large farmers), technology/knowledge gap, fragmented holdings, awareness gap.
- Measures to improve adoption: lower capital cost (economies of scale), Krishi Vigyan Kendra technical support, relaxed farm-size subsidy limits, single state-level SPV.
- Israel success story: desert water-scarce nation became water-surplus via drip irrigation, saving ~3/4th of water vs open canals.
- Benefits: 25-40% water saving (vs overhead), 45-60% (vs surface).

Water Use Efficiency (WUE) & Fertigation

- WUE = carbon assimilated as biomass/grain per unit water used.
- Fertigation = fertilizer applied via drip-irrigation water (liquid/water-soluble).
- Fertigation raises fertilizer-use efficiency to 80-90%.
- Fertigation gives greater nutrient absorption, possible 25-50% higher yield, saves ≥25% nutrients plus time/labour/energy.
- National Watershed Project (Neeranchal): World Bank-assisted, supports Integrated Watershed Management Program (IWMP) for natural-resource conservation (water/soil/forests) + yield enhancement.

Multi-Purpose River Valley Projects

- Multi-purpose river valley project: a single dam/reservoir scheme serving several objectives together, irrigation, hydroelectric power, flood control, navigation, water supply, fisheries, afforestation/recreation.
- First multi-purpose river valley project in independent India: Damodar Valley Corporation (1948).

Major Multi-Purpose River Valley Projects of India

Project	River	States	Key Facts (purpose, notable superlative)
Bhakra Nangal Project	Sutlej	Himachal Pradesh / Punjab (border); benefits Punjab, Haryana, Rajasthan	Bhakra Dam ~225 m high: one of India's highest gravity dams; Gobind Sagar reservoir; Nangal Dam downstream regulates flow into canals; irrigation + hydropower + flood control
Hirakud Dam	Mahanadi	Odisha	Longest dam in India (~25.8 km including dykes/earthen sections); creates Hirakud Reservoir; flood control for Mahanadi delta, irrigation, hydropower

Project	River	States	Key Facts (purpose, notable superlative)
Damodar Valley Corporation (DVC)	Damodar	Jharkhand / West Bengal	India's first multi-purpose river valley project (1948), explicitly modeled on USA's TVA; multi-dam system (Tilaiya, Konar, Maithon, Panchet); flood control (Damodar historically called "Sorrow of Bengal"), irrigation, power, navigation
Nagarjuna Sagar Project	Krishna	Andhra Pradesh / Telangana (border)	One of the world's largest/tallest masonry dams; creates one of the largest artificial lakes; irrigation (via Right & Left Bank canals) + hydropower
Tungabhadra Dam	Tungabhadra (Krishna tributary)	Karnataka / Andhra Pradesh (joint project)	Joint venture between Karnataka & Andhra Pradesh; irrigation + hydropower; reservoir called Pampa Sagar
Rihand Dam (Govind Ballabh Pant Sagar)	Rihand (Son tributary)	Uttar Pradesh (Sonbhadra)	Govind Ballabh Pant Sagar is one of India's largest artificial lakes; irrigation + hydropower; feeds thermal power hubs of Singrauli
Indira Gandhi Canal Project (Rajasthan Canal)	Draws from Harike Barrage (Sutlej-Beas confluence, Punjab)	Rajasthan (mainly), Punjab	Longest canal in India; irrigates/greens the Thar Desert region of Rajasthan; drinking water + irrigation, little hydropower role
Sardar Sarovar Project	Narmada	Gujarat (dam site); benefits Gujarat, Maharashtra, Madhya Pradesh, Rajasthan	Terminal/largest dam of the Narmada Valley Project; among the largest dams in the world by structure volume; irrigation + drinking water (incl. for arid Kutch/Saurashtra) + hydropower
Tehri Dam	Bhagirathi	Uttarakhand	Tallest dam in India (~260.5 m) and among the tallest in the world; irrigation + hydropower (1,000 MW) + drinking water supply

- Criticism common to large multi-purpose projects: large-scale submergence and displacement (e.g. Sardar Sarovar, Tehri), seismic risk in Himalayan valleys (Tehri), inter-state water-sharing disputes (Tungabhadra; Krishna basin), and loss of forest/agricultural land.

CHAPTER 13

India: Agriculture, Food Crops, Silk, Animal Husbandry, Miscellaneous

Indian Agriculture: Key Data & Facts

Indian Agriculture: Headline Numbers

Largest employer: ~46% of the workforce (PLFS 2023-24).

Share of Gross Value Added: ~16% (Economic Survey 2024-25); it was ~20% in the pandemic year 2020-21.

Horticulture now contributes about one-third of agricultural GVA (Economic Survey 2025-26).

Foodgrain production: from ~51 MT (1950-51) to a record 357.73 MT in 2024-25 (rice 150.18 MT, wheat 117.94 MT, pulses 25.68 MT, nutri/coarse cereals 63.92 MT); oilseeds 42.99 MT.

- Gross cropped area: ~210 million ha (cropping intensity ~150%).
- Net sown area: ~140 million ha; a little over half of it is irrigated.
- >80% of India's water used in irrigation.
- Horticulture: about 13% of gross cropped area but a much larger share of value (details & rank under Horticulture Sector below).
- NITI Aayog's 3 strategies to double farmers' income (target 2022): modernizing agriculture; policy & governance reforms; value chain & rural infrastructure creation.

Salient Features of Indian Agriculture

- Dependent on the monsoon: roughly half of the net sown area is rainfed.
- Vast relief/climate/soil diversity → tropical, subtropical & temperate crops all grown.

Types of Farming / Agricultural Systems

Gathering and Hunting

- Commercial gathering: leaves, bark, medicinal plants for beverages/drugs/cosmetics/fibres.
- India: Chenchus, Kadars tribals.

Nomadic Herding / Pastoral Nomadism

- Primitive subsistence; herders depend on animals for food/clothing/shelter/tools/transport.
- Irregular movement (pasture/water-driven); differs from Transhumance (fixed seasonal pattern).
- Regions: arid/semi-arid Africa/Asia/Europe (cattle, goats, sheep, camels); tundra Asia/Europe (reindeer, horses, musk-oxen, yaks).
- Himalayan transhumant pastoralists: Gujjars, Bakarwals, Gaddis, Bhotiyas.

Commercial Livestock Rearing (Ranching)

- Capital-intensive, organized, scientific, specialized (single animal type), export-oriented.
- Products: meat, wool, hides/skin.
- Major countries: USA, Argentina, Uruguay, New Zealand, Australia, parts of South Africa.
- India: underdeveloped (lack of expertise/investment).

Primitive Subsistence Agriculture (Shifting Cultivation)

- Small-holding food-crop farming, primitive tools, small patches.
- Practised in tropics (Africa, S/Central America, SE Asia).

Shifting Cultivation: Local Names

Country/Region	Name
India (general)	Dhya, Penda, Bewar, Nevad, Podu
India (NE)	Jhum
Indonesia	Ladang
Philippines	Caingin
Central America/Mexico	Milpa
Vietnam	Ray
Myanmar	Taungya
Thailand	Tamrai
Sri Lanka	Chena
Venezuela	Conuco
Brazil	Roca
Central Africa	Masole

Intensive Subsistence Agriculture

- ~86% of Indian farmers are small and marginal (Agriculture Census 2015-16) and practise this type.
- Dominance of rice; very small holdings, high population density.
- Govt efforts: Intensive Agriculture Development Program (IADP).

Mixed Farming

- Highly developed regions: NW Europe, Eastern North America, parts of Eurasia, temperate Southern continents.
- Moderate-sized farms; crops: wheat, barley, oats, rye, maize, fodder, root crops.
- Uses crop rotation/intercropping.

Plantation Agriculture

- Single commercial crop (tea, coffee, sugarcane, cashew, rubber, banana, cotton) = monoculture.
- Features: large estates, large capital, managerial/technical support, scientific cultivation, cheap labour, good transport linking estate↔factory↔market.
- India: NE hills (tea); Nilgiri/Annamalai/Baba Budan/Cardamom hills (coffee, rubber).

World Plantation Crop Leaders

Crop	Leading Country
Tea	China (India 2nd; India is the largest black-tea consumer)
Banana	India (largest producer); Ecuador is the largest exporter
Sugarcane/Sugar	Brazil (India 2nd)
Coffee	Brazil
Rubber	Thailand (Indonesia 2nd)

Extensive Commercial Agriculture

- Large land tracts, highly mechanized, low yield per unit area, monocropping.

Extensive Commercial Agriculture: Regions

Region	Soil/Area
Eurasian steppes	Chernozem soil

Region	Soil/Area
Canadian/American Prairies	-
Pampas	Argentina
Veld	South Africa
Australian Downs	-
Canterbury Plain	New Zealand

Mediterranean Agriculture

- Mediterranean-climate regions; famous for high-quality wines/grapes.
- Four aspects: orchard farming, viticulture, cereal/vegetable cultivation, limited animal husbandry.

Five World Regions of Mediterranean Agriculture

Region	Countries/Areas
Mediterranean Basin	France, Spain, Italy, Algeria, Morocco, Turkey, Tunisia, Israel, N. Nile valley
California	USA
Central Chile	-
Lower Murray-Darling basin	S. Australia
Southern South Africa	-

Market Gardening & Horticulture (incl. Truck Farming)

- High-value crops (vegetables, fruits, flowers) for urban markets; small farms near transport links.
- Truck farming: vegetable-only specialization; market distance = overnight truck-haul distance.

Dairy Farming

- Breeding/raising/using dairy animals (mainly cows) for milk & products.
- India: largest milk producer globally (about one-fourth of world production); per capita availability 485 g/day (2024-25).
- Milk output: 146.31 MMT (2014-15) → 247.87 MMT (2024-25) (BAHS 2025); top states: UP, Rajasthan, MP, Gujarat, Maharashtra.

Amul Example

Amul founded 1946.

Run by Gujarat Co-operative Milk Marketing Federation Ltd (GCMMF).

Represents 3.6 million milk producers of Gujarat.

Dry Zone / Dryland Farming

- Conserves max water via soil/water management; arid/desert NW & Central India.
- Crops: gram, jowar, bajra, millet; important for coarse grains, pulses, oilseeds, raw cotton.

Types of Dryland Agriculture

Type	Rainfall	Notes/Regions
Dry farming	< 750 mm	Growing season < 200 days; frequent crop failures; W. Rajasthan
Dryland farming	> 750 mm	Dry spells occur but failures less frequent
Rainfed farming	~1150 mm	Sub-humid/humid: E. Rajasthan, Gujarat, W. UP, Tamil Nadu, Kashmir, AP; low failure risk

Type	Rainfall	Notes/Regions
(Semi-arid category)	-	Central India plateau, Ganga-Yamuna plains, Central Highlands (Gujarat/Maharashtra/MP), Deccan rain-shadow (Maharashtra)

Dryland Agriculture: Govt Initiatives

Initiative	Note
Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)	Launched 1 July 2015, "Har Khet Ko Paani"
Year of Millets	India observed 2018 as the National Year of Millets
International Year of Millets	2023 (UN, on India's proposal); millets rebranded "Shree Anna"

Organic Farming

- Per FSSAI: agri-ecosystem design without synthetic external inputs (chemical fertilisers, pesticides, synthetic hormones, GMOs).
- Principles: Health, Ecology, Fairness, Care.
- Types: Pure organic (avoids all unnatural chemicals); Integrated organic (integrated nutrient + pest management).
- Advantages: export demand, no GMOs, soil-friendly, lower emissions, water-saving, sustainable.
- Disadvantages: lower yields in the transition period, residual contamination risk, poor infrastructure, high initial investment, lengthy certification (3-year conversion).

Organic Farming: India's Standing

India has the largest number of organic producers in the world (FiBL-IFOAM).

India is among the top countries by certified organic area.

Madhya Pradesh has the largest area under organic certification.

Sikkim = first fully organic state of the world (declared 2016).

Maharashtra, Rajasthan, HP, Karnataka, J&K lead adoption; NE India traditionally organic.

Organic Certification Schemes

Certification	Feature
PGS (Participatory Guarantee System)	Green tag for chemical-free transition produce (3-yr), domestic market
NPOP (National Program for Organic Production)	Third-party certification for exports

- Other schemes: Paramparagat Krishi Vikas Yojana (PKVY), Mission Organic Value Chain Development for NE Region (MOVCDNER), National Mission on Natural Farming (Nov 2024), Rashtriya Krishi Vikas Yojana, One District-One Product, National Mission on Edible Oils, Agri-Export Policy 2018.

Popularised by Subhash Palekar; now promoted as "Bhartiya Prakritik Krishi Paddhati" and the National Mission on Natural Farming.

4 Elements of ZBNF

Element	Description
Bijamrita	Seed treatment (native cow dung + urine); protects from fungal/seed-borne disease
Jiwamrita/Jeevamrutha	Fermented microbial culture (dung, urine, jaggery, pulse flour, soil), adds nutrients, boosts soil carbon
Acchadana/Mulching	Topsoil cover (crop waste/cover crops): conserves soil/water, controls weeds

Element	Description
Waaphasa/Moisture (Soil Aeration)	Improves humus/water-holding via Jiwamrita + mulching

- Benefits: 50–60% less water, less electricity, reduced methane, avoids residue burning, lower cost, better soil ecosystem, less disease, less chemical use.
- Andhra Pradesh Community-managed Natural Farming (APCNF, 2016) aims to bring all ~60 lakh farmers of the state under natural farming.

Crop Classification

Crop Classification by Use

Type	Description	Examples
Food crops	Cereals (grass-like, starchy seeds) & pulses	Rice, wheat, maize; gram, tur
Horticulture	Fruits & vegetables	Apple, mango, banana; onion, tomato
Cash crop	Grown for sale (raw/processed)	Cotton, tobacco, oilseeds
Plantation crop	Grown on large estates	Tea, coffee, coconut, rubber, spices

Cropping Seasons in India

Three Cropping Seasons

Season	Duration	Conditions	Example Crops
Kharif	June–October	SW Monsoon; tropical crops	Rice, cotton, jute, jowar, bajra, tur, maize, millet, sugarcane
Rabi	Oct/Nov–Mar/Apr	Winter onset; temperate/subtropical	Wheat, gram, mustard, tobacco
Zaid	Short summer, after Rabi	Irrigated lands; not distinct in south	Watermelon, cucumber, vegetables, fodder, fruits

Cropping Patterns, Rotation & Diversification

- Cropping intensity = $(\text{Gross cropped area} \div \text{Net sown area}) \times 100$; India ~150%.

Types of Cropping Intensity

Type	Description
Monocropping	One crop; can reduce soil fertility
Mixed Cropping	2+ crops together (e.g. wheat+gram): minimizes total-failure risk
Intercropping	2+ crops in a definite row pattern, raises productivity/unit area

Intercropping Sub-Types

Sub-Type	Description
Row	Alternate rows
Strip	Wide strips, separately managed but interacting
Relay	Second crop sown before first harvested, e.g. Rice–Cauliflower–Onion–Summer gourds

- Crop Rotation = pre-planned succession on same land (1/2/3-year cycles).
- Rotation logic: legumes restore fertility; high-demand crops follow legumes; low-input crops follow high-input.

Crop Rotation Examples

Cycle Length	Example
1-year	Maize–Mustard
1-year	Rice–Wheat
3-year	Rice–Wheat–Mung–Mustard

Agricultural Regionalization: Major Agricultural Regions of India**Major Agricultural Regions of India**

Region	Key States/Areas	Rainfall	Crops
Rice-Jute-Tea Region	Assam, Arunachal Pradesh, Tripura, Meghalaya, WB, Odisha, N&E Bihar, parts Jharkhand/Chhattisgarh, Tarai (UP)	High (lowlands/deltas)	Rice, jute, tea
Wheat & Sugarcane Region	Bihar, UP, Punjab, Haryana, Western MP, NE Rajasthan	-	Wheat, sugarcane
Cotton Region	Regur/black-cotton soil, Deccan plateau	75–100 cm	Cotton (main); jowar, bajra, gram, sugarcane, wheat
Maize & Coarse Crops Region	Western Rajasthan, Northern Gujarat	Scanty, <50 cm	Bajra, jowar, pulses; maize on the Mewar plateau
Millets & Oilseeds Region	Karnataka plateau, parts of Tamil Nadu, AP, eastern Kerala	75–125 cm	Bajra, ragi, jowar (millets); groundnut, castor; pulses; mango, banana
Fruits, Vegetables & Barley Region	Kashmir Valley to Assam	60cm (W) to 200cm (E)	Apple, peach, cherry, plum, apricot (W); orange (E); rice, maize, ragi, potato, chillies, vegetables

Horticulture Sector in India

- India = 2nd largest producer of fruits & vegetables (after China).
- India = largest producer of bananas and mangoes.
- Production: ~355 MT in 2023–24 (fruits ~113 MT, vegetables ~207 MT), well above foodgrain output.

Horticulture Schemes

Scheme	Detail
MIDH (Mission for Integrated Development of Horticulture)	Centrally sponsored, since 2014–15, Ministry of Agriculture & Farmers Welfare
NHM (National Horticulture Mission)	Via State Horticulture Missions, 18 states + 6 UTs
HMNEH (Horticulture Mission for NE & Himalayan States)	-

Key Horticulture Crops

Crop	Notes	Leading States/Facts
Cashew nut	India: world's largest processor/consumer and among the top raw-nut producers (Côte d'Ivoire leads raw output)	Maharashtra (29.9%), Andhra Pradesh (15.7%), Odisha, Kerala, Karnataka, Tamil Nadu

Crop	Notes	Leading States/Facts
Mango	Native to the Indian subcontinent; India produces about 40–50% of the world's mangoes but exports only a small share (Mexico is the largest exporter); Alphonso, Kesar, Banganapalli are GI-tagged varieties	Uttar Pradesh, Bihar, Andhra Pradesh, West Bengal, Odisha
Banana	Tropical/subtropical; peninsular India ideal; Bhusawal (Maharashtra) famous	Andhra Pradesh, Maharashtra, Gujarat, Tamil Nadu lead; India is the largest banana producer
Apple	Needs avg temp ~22°C in growing season, sunny climate with gentle winds; tolerates low temp in non-growing season	Jammu & Kashmir, Himachal Pradesh (Kullu, Shimla), Uttarakhand hills
Orange	Mostly rainfed, grown in most states	Hilly Uttarakhand; also Kangra valley (HP), Darjeeling (WB), Khasi & Jaintia Hills (Meghalaya), Kodagu (Karnataka), Nagpur (Maharashtra)

Major Food Crops

Wheat

- 2nd most important cereal after rice; India produces about 13–14% of world's wheat.
- Temperate-zone crop grown in Rabi season.
- ~85% of area in north/central India: Indo-Gangetic Plain, Malwa Plateau, Himalayas up to 2,700m.
- Rainfed in Himalayan highlands & parts of Malwa Plateau.
- India = 2nd largest wheat producer in the world as an individual country (after China; Russia 3rd).
- Record production: 117.94 MT (2024-25), up from 101.20 MT (2018-19).

Top Wheat-Producing States (2024-25, % share)

Rank	State	% Production (approx., recent years)
1	Uttar Pradesh	31.27
2	Madhya Pradesh	19.97
3	Punjab	15.69
4	Haryana	9.90
5	Rajasthan	8.58

- Top 5 states = ~85% of national wheat output; UP alone ≈ 1/3rd.
- Madhya Pradesh has overtaken Punjab into 2nd place in recent years.

Wheat: Growing Conditions

Factor	Requirement
Temp (sowing)	10–15°C
Temp (ripening/harvesting)	21–26°C, bright sunlight
Rainfall	50–75 cm (NCERT); grown with irrigation in drier areas
Soil	Well-drained fertile loamy/clayey-loamy (Ganga-Satluj plains; black soil of Deccan)

- Varieties: Kalyan Sona, Sonalika, Lerma Rojo, Chhoti Lerma, Arjun, Sujata.

Rice

- Kharif crop; needs temp above 25°C, high humidity, rainfall above 100 cm.

- Irrigated in low-rainfall areas (enabled canal/tube-well cultivation in Punjab & Haryana).
- Grown in plains of N/NE India, coastal/deltaic regions; ~1/4th of total cropped area.
- ~3,000 varieties; grown from sea level to ~2,000m altitude.
- Southern states & WB: 2-3 crops/year. Himalayas/NW India: kharif only.
- WB's three rice crops: 'aus', 'aman', 'boro'.

Rice Sowing Methods

Method	Feature
Broadcast	Manual, low labour/yield
Japanese	Nursery-raised, transplanted, for HYVs
Transplantation	Most common, best yield, heavy labour
Drilling	Exclusive to India: one ploughs, one sows, using ox

- Pokkali variety (saltwater-resistant): coastal Alappuzha, Ernakulam, Thrissur (Kerala).
- Flooded paddy fields are a major source of methane (~10% of global anthropogenic methane); livestock (enteric fermentation) is the largest agricultural source.

Rice: Production & Trade Facts

Production: record 150.18 MT (2024-25); India has overtaken China to become the world's largest rice producer. India is the largest rice exporter (~40% of world rice trade).
 Export curbs imposed in 2022-23 (broken rice ban, duty on non-basmati white rice) were lifted in 2024-25.
 Basmati rice (GI-tagged, Indo-Gangetic plains) is a major premium export.
 Rice is India's top agricultural export by value.

Other Cereals

Barley, Rye, Oats Compared

Cereal	Key Facts
Barley	Dry crop, poorer soil/lower precipitation than wheat, more tolerant of adverse conditions. Leading producers: UP, Bihar, MP
Rye	"Winter hardy cereal": withstands all adverse weather except heat; only rabi cereal suited for sandy soil. India: Punjab, Haryana, UP
Oats	Cool moist climate, sensitive to hot dry weather between head emergence & maturity. India: Punjab, Haryana, UP, limited MP/Odisha/Bihar/WB; used as cattle feed & human food

Maize

- Semi-arid crop, food + fodder; temp 21-27°C, rainfall 50-100 cm, alternate rain/sunny spells ideal.
- Kharif generally (rabi in Bihar).
- Grows well in alluvial & red soils (good drainage), also mountainous soils.
- Grown on about 5% of gross cropped area.
- Leading states: Karnataka, Madhya Pradesh, Maharashtra, Bihar, Telangana, Andhra Pradesh.
- Demand is rising for poultry feed and for ethanol (India reached E20 petrol blending in 2025).

Plantation & Beverage Crops

Tea

Tea: Growing Conditions

Factor	Requirement
Temperature	20-30°C
Rainfall	150-300 cm
Soil	Acidic (pH 4.5-5.5), deep fertile humus-rich well-drained
Topography	Undulating hilly, humid/sub-humid tropics & subtropics

- India: 2nd largest producer after China (~1,300 million kg a year).
- India = largest producer & consumer of black tea; grown in 16 states.
- Assam, WB, Tamil Nadu, Kerala ≈ 95% of production; Assam = largest by area.

Tea-Growing Districts by State

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

- Trade: India became the world's 2nd largest tea exporter in 2024 (254.67 million kg), overtaking Sri Lanka; Kenya is the largest exporter.

Coffee

Coffee: Growing Conditions

Factor	Requirement
Temperature	15-28°C (hot humid climate)
Rainfall	150-250 cm
Soil	Well-drained rich friable loams (humus, iron, calcium)
Other	Dry weather needed at berry ripening; elevation 600-1,600 m

- Karnataka, Kerala, Tamil Nadu = India's largest producers.
- India produces about 3-4% of world coffee and exports about 70% of its output (Coffee Board).
- Top producers: Brazil, Vietnam, Colombia, Indonesia, Ethiopia; India ranks around 7th.
- Species grown in India: *Coffea Robusta* (canephora) & *Coffea Arabica*.

World Coffee Types

Type	Notes
Robusta	Africa/Brazil, also S/SE Asia (Vietnam major); inferior to Arabica but less care needed, 2× caffeine
Arabica	Indigenous Ethiopia/Arab world ("Coffee Shrub of Arabia"); first cultivated variety; naturally low caffeine

Cocoa

Cocoa: Growing Conditions

Factor	Requirement
Altitude	Most areas below 1,000m; within 20° latitude of equator
Temperature	~27°C in shade; never below 16°C at night; low seasonal range
Rainfall	≥125 cm, no prolonged dry season
Soil	Well-drained deep porous soils
Other	Harmed by direct sun/strong winds (shade-grown)

- India: Kerala, Karnataka, Andhra Pradesh, Tamil Nadu.
- Andhra Pradesh leads in area and production; Kerala has the highest productivity.

Tobacco

- Grown largely in Andhra Pradesh and Gujarat; also Karnataka, Maharashtra.
- India is the 2nd largest producer of tobacco (after China); Brazil is the largest exporter.

Tobacco: Economic Contribution

Tobacco Board (Guntur, AP) regulates Flue-Cured Virginia (FCV) tobacco.
 FCV tobacco is grown mainly in Andhra Pradesh and Karnataka.
 A significant source of excise revenue and export earnings.
 Bidi industry uses tendu leaves collected from forests of central India.
 Important for rural women, tribals, weaker sections.

Fibre Crops

Cotton

- Tropical/subtropical, semi-arid crop (mainly Deccan Plateau).
- Needs ≥210 frost-free days (hard frost injurious); light rainfall (50-100 cm, can be irrigated).
- Needs high temp/bright sunshine/clear sky at flowering.
- Soil: light well-drained; Black cotton soil (Regur) best.
- Grown: Punjab, Haryana, N. Rajasthan (NW); Gujarat, Maharashtra (west); Telangana, AP, Karnataka, Tamil Nadu plateaus (south).
- Leading producers: Gujarat, Maharashtra, Telangana; also MP, Karnataka, AP, Tamil Nadu, Punjab, Haryana, UP.
- India = 2nd largest cotton & cellulosic fibre producer after China.
- India has the largest area under cotton in the world (about one-third) but low yields; Bt cotton covers over 90% of the area.

Cotton Textile Industry

One of India's oldest and largest industries; a major employer after agriculture.
 Centres: Mumbai ("Cottonopolis of India"), Ahmedabad ("Manchester of India"), Coimbatore ("Manchester of South India"), Kanpur ("Manchester of North India").
 PM MITRA scheme (2021): 7 mega integrated textile parks.
 Cotton production 2024-25: ~29.7 million bales (170 kg each).

- Varieties: 4 cultivated species, *G. arboreum*, *G. herbaceum* (old-world/Asiatic); *G. hirsutum* (American/upland), *G. barbadense* (Egyptian), latter two = new-world cotton.
- Hybrid cotton = cross of two genetically different strains.
- Bt Cotton = GM pest-resistant variety.

Jute

- Temp 25-30°C, high humidity 70-90%.

- Soil: alluvial/loamy (red soil needs pH 4.8-5.8); warm climate, good drainage + water-holding capacity.
- India now produces ~3/5th of world jute.
- West Bengal = ~3/4th of India's production; Bihar & Assam other areas.
- >99% from 5 states (WB, Bihar, Assam, AP, Odisha); jute = only ~0.5% of total cropped area.
- Sector: direct employment to 3.70 lakh workers, supports ~40 lakh farm families.
- Jute substitute: Banana-plant fibre (Musa sapientum), strong/soft/coarse.

Rubber

- Natural rubber from latex; ~20,000 plant species produce latex, only ~2,500 contain rubber.
- India: cultivated in 16 states; Kerala leads (>600,000 ha), then Tripura (>85,038 ha); also Karnataka, Tamil Nadu, Assam, NE states.
- World: SE Asia = 97% of natural rubber.
- Thailand largest producer, then Indonesia, Vietnam (Thailand+Indonesia+Malaysia ≈ 72%).
- India is the 2nd largest consumer of natural rubber (after China) and among the top producers; the automobile tyre sector is the main user.

Sugarcane

- Tropical & sub-tropical crop.

Sugarcane: North vs South India

Region	Variety	Sugar Content/Yield
North India	Sub-tropical variety	Low sugar content; factories shut in winter
South India	Tropical variety	High sugar content & yield

- Needs hot humid climate, temp 21-27°C, rainfall 75-100 cm, medium/heavy soils with irrigation.
- Soil-exhausting (needs regular manure/fertilizer).
- One of the most water-intensive crops.
- Major producers: Uttar Pradesh (largest cane producer), Maharashtra (often the largest sugar producer), Karnataka, Tamil Nadu, Bihar, Gujarat, Haryana, Punjab.
- India = 2nd largest sugarcane producer after Brazil.
- India overtook Brazil as the largest sugar producer in 2021-22; Brazil is ahead again in recent seasons; India is the largest sugar consumer.

Sugarbeet

Agriculture Revolutions in India

Revolution	Product Related	Father/Person Associated
Green Revolution	Food grains	Norman Borlaug (global); M.S. Swaminathan (India); term coined by William Gaud (USAID, USA, 1968)
White Revolution (Operation Flood)	Milk Production	Vergheze Kurien
Blue Revolution	Fish Production	Dr. Arun Krishnan / (also: Hiralal Chaudhuri)
Yellow Revolution	Oilseed Production (esp. Mustard & Sunflower)	-
Golden Revolution	Fruits / Honey Production / Horticulture Development	Nirpakh Tutej
Pink Revolution	Onion Production / Pharmaceuticals / Prawn Production	Durgesh Patel
Silver Revolution	Egg Production / Poultry Production	Indira Gandhi

Revolution	Product Related	Father/Person Associated
Red Revolution	Meat Production / Tomato Production	Vishal Tewari
Protein Revolution	Higher production (tech-driven 2nd Green Revolution)	Coined by PM Narendra Modi and FM Arun Jaitley

Land Resources & Land Use

- Per 2011 Census: India has 2.4% of world's surface area but supports >17.5% of world's population.

Land Use Categories

Category	Definition
Non-agricultural use	Settlements, infrastructure, industries, shops
Net area sown	Crops/orchards, counted once
Permanent pastures & grazing lands	-
Misc. tree crops & groves	Not in net sown: casuarina, thatching grass, bamboo, bushes, fuel groves
Current fallow	<1 year uncultivated
Fallow other than current	1-5 years
Barren & unculturable land	Land that cannot be cultivated with available technology (barren hills, rocky land, deserts)
Culturable wasteland	Cultivable but left uncultivated for more than 5 years
Land put to agricultural use	Per OECD: arable, permanent-crop, or permanent-pasture land
Forests	Per FAO: >0.5 ha, canopy cover >10%, non-agri/urban

Land Degradation & Desertification

- Per GEF: land degradation = deterioration/loss of soil's productive capacity.
- Desertification = environmental degradation reducing dryland ecosystem productivity (reduced plant cover, soil/organic-matter loss, growing sand dunes, higher run-off).
- ISRO's "Desertification and Land Degradation Atlas" shows rising degradation.
- 29.77% of India's TGA under land degradation (2018-19), up from 2011-13.
- Nine states (Rajasthan, Maharashtra, Gujarat, Karnataka, Ladakh UT, Jharkhand, Odisha, MP, Telangana) together account for ~24% of India's area under degradation.
- States with >50% area degraded/desertified: Jharkhand, Rajasthan, Delhi, Gujarat, Goa.

Drivers of Land Degradation (2018-19, % share)

Driver	% Share
Water erosion	11.01%
Vegetation degradation	9.15%
Wind erosion	5.46%

- Large-scale soil damage seen at: Shivalik range, Chos of Punjab, Chambal valley ravines.

Regional Degradation Patterns

Region	Pattern
Punjab-Haryana	Over-irrigation salinity
Bundelkhand	Gully/rill erosion

Region	Pattern
Kerala coast, Gulf of Cambay (Gujarat), Odisha coast, KG Delta (AP)	Coastal salinization
Himalayas & Western Ghats	High water erosion

- Land Degradation Neutrality (LDN) (SDG target 15.3): land-resource quantity/quality for ecosystem functions/food security stays stable or improves.

Government & Global Steps against Land Degradation

- Integrated Watershed Management Programme (IWMP): restores ecological balance via conservation of degraded resources + rural employment; now the Watershed Development Component of PMKSY (WDC-PMKSY), run by the Department of Land Resources (Ministry of Rural Development).

Key Government Programmes against Land Degradation

Programme	Year	Focus
Desert Development Programme	1977-78 (revised 1995)	Minimizes drought impact, rejuvenates resources in hot deserts (Rajasthan, Gujarat, Haryana) & cold deserts (J&K, HP)
National Afforestation Programme	2000	Degraded forest-land afforestation (MoEFCC)
National Action Programme to Combat Desertification	2001	-
National Mission on Green India	2014	Protect/restore/enhance forest cover, 10-year deadline

- UNCCD (est. 1994) = only legally binding treaty linking environment & development to sustainable land management.
- Bonn Challenge (Germany & IUCN): restore 150 million ha by 2020, 350 million ha by 2030.
- India joined Bonn Challenge 2015, pledged 21 MHA (raised to 26 MHA by 2030, Delhi UNCCD CoP Sept 2019).
- Great Green Wall: African Union-led initiative across the Sahel to restore 100 million ha by 2030; India launched an "Aravalli Green Wall Project" (2023) along the Aravallis.
- Combat techniques: salt traps, irrigation improvements, cover crops, crop rotation, rotational grazing, terrace farming, contour bunding, windbreaks, sand-dune stabilization.

Oilseeds

- Major crops: Toria, Mustard, Sesame (til), Linseed, Castor seed, Sunflower, Soybean, Groundnut, Coconut, Cotton seed.
- Yellow Revolution = rise in oilseed production.
- Total production (2024-25, 3rd Advance Estimates, PIB): 42.99 MT (record high).
- Largest total-oilseed producer (2024-25): Rajasthan > Madhya Pradesh > Maharashtra.

Oilseed Production (2024-25, MT)

Oilseed	Production (MT)
Soyabean	15.27
Rapeseed & Mustard	12.67
Groundnut	11.94
Sesamum	0.83

Oil Content by Oilseed

Oilseed	Oil Content
Sesame	52% (highest)
Groundnut	48.2%
Sunflower	42%

Oilseed	Oil Content
Soybean	~18–20% (but ~40% protein)
Rapeseed & Mustard	~38–42%

Groundnut (Peanut)

- Kharif crop of tropical climate: temperature 20–30°C, rainfall 50–75 cm; light sandy-loam soils; gypsum (calcium) improves pod filling.
- Called the "King of Oilseeds" and "poor man's almond"; well suited to dryland farming.
- Leading producers (2024–25): Gujarat (5.22 MT) > Rajasthan (2.14 MT) > Madhya Pradesh (1.55 MT).
- Top productivity (kg/ha): West Bengal > Gujarat > Tamil Nadu.

Mustard/Rapeseed

- Rabi crop: temperature 10–25°C, rainfall 25–40 cm; sown Oct–Nov, harvested Feb–Mar.
- Leading producer (2024–25): Rajasthan > Uttar Pradesh > Haryana.

Soybean

- Kharif crop (sown June, harvested October); needs 3–4 irrigations.
- Temperature 20–30°C, rainfall 60–100 cm, well-drained loamy soil, pH 6–7.5.
- Contains ~40% protein and ~20% oil; called the "golden bean"/"miracle bean".
- Madhya Pradesh: 48.642 lakh ha under soybean = 42.46% of India's total soybean area (SOPA 2025).
- Leading producers (2024–25): Maharashtra (7.37 MT) > Madhya Pradesh (5.38 MT) > Rajasthan (1.18 MT).

Sunflower & Other Oilseeds

Pulses

- Major protein source; major crops: gram, urad, green gram (moong), mash, tur (arhar), lentils (masoor).
- India = world's largest producer (2022), consumer and importer of pulses (followed by Canada, China in production).
- Leading total-pulses producer (2024–25): Madhya Pradesh > Maharashtra > Rajasthan.
- Most productive state for gram: Madhya Pradesh.
- Urad: kharif crop in North India; both kharif & rabi in South India.
- Rajma (kidney bean, native to Central/South America): poor nodulation, hence weak nitrogen fixation compared with other pulses.
- Area under pulses: about 28 million ha; production 25.68 MT in 2024–25 (record).

Pulse Varieties

Pulse	Varieties
Gram/Chana	Pant-114, Gaurav, Radhe, K-4 (UPAS-120 is an Arhar variety, not gram, common trap)
Tur/Arhar (origin India)	Malviya Chamatkar, Amar, Azad, Malviya Vikas, MA6, Paras, Bahar
Pea	Aparna = leafless high-yielding variety

Sericulture (Silk)

- India = 2nd largest silk producer in world after China.
- Silk = protein secreted by silkworm caterpillar.
- Life cycle: Egg → Caterpillar → Pupa → Moth.
- Four natural silk types produced in India: Mulberry, Tasar, Muga, Eri.

Leading Silk-Producing States (Central Silk Board 2023-24)

Silk Type	Leading State	Share
Mulberry	Karnataka	44.15%
Tasar	Jharkhand	71.06%
Eri	Assam	56.56%
Muga	Assam	65.6%

- Karnataka: largest raw silk producer of India (about two-fifths of national output; mulberry silk).
- Andhra Pradesh: 2nd largest mulberry silk producer; weaving clusters at Dharmavaram and Hindupur (Pochampally ikat is in Telangana).
- Tamil Nadu: famous for Kanchipuram silk sarees (GI-tagged).
- West Bengal: mulberry silk of Malda and Murshidabad; Baluchari and Murshidabad silk sarees.
- Assam: ~65% of Muga silk (golden silk, unique to India) and, with Bodoland Territorial Region, ~57% of Eri silk ("peace/ahimsa silk").
- Tasar has two types (Tropical & Oak): Jharkhand = largest Tropical Tasar & largest Tasar overall (71.06%); Manipur = major Oak Tasar producer.

Silk City Tags

City	Tag
Bhagalpur (Bihar)	"Silk City of India"
Mysuru (Karnataka)	Known for silk textiles

Animal Husbandry**Livestock Census & Breeds**

- 20th Livestock Census (2019): total livestock 535.78 million, up 4.6% over 2012 (cattle 192.9 M, goats 148.9 M, buffaloes 109.9 M, sheep 74.3 M, pigs 9.1 M).
- 21st Livestock Census (enumeration Oct 2024–Feb 2025) covers 16 species and pastoral communities for the first time; national results awaited.

Cattle Breed Types

Type	Breeds
Milch (dairy) cow	Gir, Sahiwal, Sindhi, Devni, Tharpakar
Draught	Nagori, Bhalavi, Hallikar, Kangayam, Khillar, Ponwar, Siri
Buffalo	Murrah, Bhadawari, Zafarabadi, Suttari, Mehsana, Nagpuri, Nili Ravi, Pandharpuri

- Highest sheep population state (2019): Telangana.
- Best quality sheep from: Kashmir, Kullu, Chamba, Kangra valleys.

Livestock Population Rankings (2019)

Metric	Top 3 States (descending)
Cattle population	West Bengal (19.1M) > UP (19.0M) > MP (18.8M)
Total livestock	UP > Rajasthan > MP
Buffalo-owning	UP > Rajasthan > Gujarat

Dairy/White Revolution & Meat

- White Revolution launched July 1970 via Operation Flood-I.
- Dr. Verghese Kurien = "Father of White Revolution," founder of NDDB (est. 1965) & Indian Dairy Corporation (est. 1970, Baroda, Gujarat).
- Avg yield/animal/day: exotic crossbred 9.05 kg, indigenous/non-descript 3.86 kg.

Top 5 Milk-Producing States (2024-25)

Rank	State	Share
1	Uttar Pradesh	15.66%
2	Rajasthan	14.82%
3	Madhya Pradesh	9.12%
4	Gujarat	7.78%
5	Maharashtra	6.71%

- Total meat production (2024-25): 10.50 MT, +2.46% YoY.

Top 5 Meat-Producing States (2024-25)

Rank	State	Share
1	West Bengal	12.46%
2	Uttar Pradesh	12.20%
3	Maharashtra	11.57%
4	Andhra Pradesh	10.84%
5	Telangana	10.49%

Poultry

- Total egg production (2024-25): 149.11 billion.

Top 5 Egg-Producing States (2024-25)

Rank	State	Share
1	Andhra Pradesh	18.37%
2	Tamil Nadu	15.63%
3	Telangana	12.98%
4	West Bengal	10.72%
5	Karnataka	6.67%

Fisheries

- Blue Revolution = fish production.
- Leading inland + marine fish states (Handbook on Fisheries Statistics 2023, for 2022-23): Andhra Pradesh (51.06 lakh tonnes) > West Bengal (20.45) > Karnataka (12.25) > Odisha (10.52) > Kerala (9.21).
- India is the 2nd largest fish-producing country (~8% of world output) and 2nd in aquaculture; Andhra Pradesh leads in shrimp/aquaculture.

Leading Fish-Producing States (2022-23, lakh tonnes)

Rank	State	Production
1	Andhra Pradesh	51.06

Rank	State	Production
2	West Bengal	20.45
3	Karnataka	12.25
4	Odisha	10.52
5	Kerala	9.21



CHAPTER 14

India: Mineral & Energy Resources, Industry, Research Centers

Manufacturing Industries

Introduction & Secondary Sector

- Industries = backbone of economy: provide employment, GDP, national income, goods/services.
- Contribution to National Income: Agriculture >16%, Services ~55%, Industry ~29%.
- Agriculture & Industry are interdependent: agriculture supplies raw materials; industrial growth pushes agriculture toward higher productivity.

Three Economic Activities

Activity	Nature	Collar Type	Examples
Primary	Env-dependent (land/water/forest)	Red-Collar	Hunting, fishing, pastoralism
Secondary	Transforms raw materials	Blue-Collar	Manufacturing, processing, construction
Tertiary	Services	White-Collar	Transport, healthcare, banking, advertising

- Manufacturing contributes ~16–17% of GVA; industry as a whole ~26–28%.
- Secondary sector includes agro-based, automobile, and iron-steel industries.

Classification of Industries

Basis	Types	Examples
Strength of labour & size	Large scale	Superior tech, large labour/capital: cotton, textile, automobile
Strength of labour & size	Small scale	Few workers, less investment: cottage, handicrafts, power looms
Ownership	Private	Bajaj Auto, Mahindra & Mahindra, TISCO
Ownership	Public	BSNL, PSUs, steel plants
Ownership	Joint	Govt + private: OIL, Gujarat State Fertilizers, Maruti Udyog
Ownership	Cooperative	Owned by producers/suppliers/workers: sugar, AMUL
Raw materials	Agro-based	Cotton, jute, sugar, tea, coffee, rubber
Raw materials	Mineral-based	Iron, steel, aluminium, cement
Raw materials	Forest-based	Paper, resins, leaf utensils, baskets
Mode of operation	Basic	Supply inputs to other industries: iron & steel, machine tools
Mode of operation	Consumer-based	FMCG
Mode of operation	Cottage	Artisans at home/village: handloom, khadi, wood work
Mode of operation	Ancillary	Parts/components for big industries
Mode of operation	Capital Intensive	Iron & steel
Mode of operation	Labour Intensive	Shoe making

Basis	Types	Examples
Finished goods	Heavy	Bulky raw material & output: iron & steel
Finished goods	Light	Light products: fans, sewing machines

Significance of Industrial Sector in India

- Industrial sector is the backbone of national development.
- With development, primary sector share normally falls and is replaced by industrial sector.
- India transitioned straight from primary to tertiary sector without realising industry's potential.
- Mechanisation of agriculture/mining pushes labour into industry.
- Sectoral transformation is a precondition for eradicating unemployment/poverty.
- Manufacturing's share has stayed around 15–17% of GDP, low compared with East Asian economies (25–30%).
- Industry has rarely been the leading sector except during the 2nd and 3rd Five-Year Plans.

Industrial Policy Targets

Raise manufacturing to 25% of GDP

Create 100 million jobs

India's coming demographic dividend + cheap labour attract global value/supply chains

Advanced manufacturing + skilled capital aid this further

- Export enhancement via SEZs/NIMZs.
- Equitable growth: industries in tribal/backward areas cut regional disparity (e.g., Vidarbha, Maharashtra).

Geographical Distribution of Major Industrial Regions in India

Major Industrial Regions

Region	States/Area Covered	Key Features
Hugli Region	Haldia, Kolkata, Serampore, Titagarh, Belur, Triveni, Bansberia	Kolkata port as nucleus; Darjeeling tea, Damodar coalfields, iron ore; cotton, paper, jute, textile, pharma, fertilizer, petrochemical
Bangalore–Chennai Region	Karnataka, Tamil Nadu	No coalfields: grew via hydroelectric power & cotton textile; Aircraft (HAL), machine tools, telephone, silk, sugar, leather, radio; Chennai refinery, Salem steel plant
Gujarat Region	Ahmedabad, Vadodara, Surat, Jamnagar, Rajkot	Grew on decline of Mumbai cotton textile; Gulf of Khambhat oilfields → petrochemicals (Ankleshwar, Vadodara, Jamnagar); Kandla port; also heavy chemicals, textile machinery, pharma, dyes, dairy, food processing
Chotanagpur Region	Jharkhand, Odisha, West Bengal	Heavy metallurgy; Damodar coalfields; steel plants: Jamshedpur, Burnpur-Kulti, Durgapur, Bokaro, Rourkela; heavy engineering, locomotives, electricals, machine tools, fertilizers, cement, paper
Mumbai–Pune Region	Mumbai–Thane to Pune, Nashik, Solapur	Began with Mumbai cotton textile; Mumbai High petroleum → chemicals; nuclear energy projects; leather, synthetic, plastic goods, electronics, food
Visakhapatnam–Guntur Region	Visakhapatnam to Kurnool, Prakasam (AP)	Visakhapatnam & Machilipatnam ports; refinery, petrochemicals, sugar, textile, jute, paper, fertilizer, cement, aluminium; Lead–Zinc smelter (Guntur); steel plant (Visakhapatnam)
Gurgaon–Delhi–Meerut Region	Gurgaon, Delhi, Faridabad, Meerut, Ghaziabad, Agra, Mathura	Light, market-oriented, away from mineral/power resources; Agra–Mathura: glass, leather, oil refinery; electronics, cotton, woollen, synthetic fabrics, hosiery, sugar, cement, machine tools, chemical, Vanaspati

Region	States/Area Covered	Key Features
Kollam-Thiruvananthapuram Region	Thiruvananthapuram, Kollam, Alwaye, Ernakulam, Alappuzha	Plantation agriculture, hydropower, cotton textiles, sugar, rubber, glass, chemical fertilizer, fish-based, food processing, coconut products, aluminium, cement

Factors Influencing Location of Industries

Geographical Factors

- Raw Materials: most important factor; weight-loss industries locate near source.
- E.g. sugar industry near sugarcane states (UP, Maharashtra).
- E.g. iron & steel near coalfields (Bokaro, Durgapur).
- Power: uninterrupted supply essential; e.g. power-intensive Aluminium industries locate near power sources.
- Labour: cheap/abundant skilled-to-unskilled labour available in India.
- E.g. UP: glass (Firozabad), brassware (Moradabad), silk (Varanasi), carpets (Bhadohi-Mirzapur).
- Markets: drives demand for machine tools/equipment/fertilizers.
- Non-weight-losing cotton industries sited in urban centers (Mumbai, Ahmedabad).
- Petroleum products industries locate near markets.
- Transport: land/water/air needed for raw-material movement.
- E.g. Agra (textile), Delhi (textiles, drugs, pharma), Ghaziabad (synthetic fiber, electronics).
- Water: large quantities needed for iron & steel, textile, chemical industries.
- Kolkata, Mumbai, Chennai grew as industrial centers on water availability.
- Climate: extreme climate obstructs development (e.g. NW India).
- Cotton textile needs humid climate (thread breaks if dry), flourished in coastal Maharashtra/Gujarat.
- Sugar industry shifted South as climate raises sucrose content/retention.

Non-Geographical Factors

- Capital: easy capital/subsidy access decides location.
- Capital-intensive industries (telecom, auto) need huge capital.
- Agglomeration Economies: industries cluster near a leader-industry (one's output = another's input).
- Historical Factors: Mumbai, Kolkata, Chennai shaped by colonial-era European trader head-starts.
- Cotton industry grew in Mumbai/western Maharashtra; SE Asian trade aided Chennai/Kochi ports & shipbuilding.
- Industrial Inertia: industry stays despite declining advantage (relocation hassle, new-asset cost, labour-migration issues).
- Government Policies: Five-Year Plans shape industry location.
- 2nd Industrial Policy (1956) (socialist) → BHEL, Durgapur & Bhilai (public sector).
- Competitive federalism, e.g. Gujarat's policy pulled TATA's Nano plant from West Bengal.
- Port/highway development pushes industries from congested markets toward economical routes (e.g. Vizag steel plant near Visakhapatnam port).

Major Industries in India

Iron & Steel Industry

- First metallurgical furnace at Kulti (1870); production started 1874 (Bengal Iron Works).
- TISCO, Jamshedpur: founded 1907 (vision of Jamsetji Tata, set up by Dorabji Tata); steel production from 1912; by 1939 the largest steel plant in the British Empire.
- Hindustan Steel Ltd set up three public-sector plants in the 2nd Five-Year Plan: Rourkela (German), Bhilai (Soviet), Durgapur (British collaboration).

Iron & Steel: Key Stats

India: world's 2nd largest producer of crude steel (over 150 MT in FY 2024-25)

India: world's largest producer of sponge iron (DRI); among the top iron ore producers

Steel capacity: about 200 MT (2024-25); National Steel Policy 2017 targets 300 MT by 2030-31

China leads world steel production

- Kalinganagar and Bokaro emerged as leading hubs in early 21st century due to proximity to coal, minerals, power, water.

- Critical for rail tracks, agriculture, shipbuilding, automobile parts, equipment.

Major Iron & Steel Plants

Plant	Location	Notes
TISCO	Jamshedpur	Near Mumbai-Kolkata railway & Kolkata port
Rourkela	Sundargarh dist., Odisha	Iron ore of Bonai/Keonjhar; coal from Jharkhand; German collaboration
Bhilai	Durg dist., Chhattisgarh	Iron ore from Dalli-Rajhara; coal from Korba; water from Tandula Dam; Soviet collaboration
Visvesvaraya	Bhadravati, Karnataka	-
Visakhapatnam	Andhra Pradesh	Rashtriya Ispat Nigam Ltd (RINL); first shore-based integrated steel plant
Salem	Tamil Nadu	-
Durgapur	West Bengal	Raniganj/Jharia coal belt; Kolkata-Delhi route; Damodar valley water
IISCO	Asansol, West Bengal	-
Bokaro	Jharkhand	Set up 1964, Russian collaboration

World Steel Regions

Country	Key Regions
China	Manchuria, Wuhan
Germany	Ruhr
Japan	Osaka-Kobe, Tokyo-Yokohama
USA	Pittsburgh
Russia	Ural-Kuznetsk Siberia

- Significance: backbone of physical infra, forward-backward industrial linkages, regional development/employment especially in backward areas.
- National Steel Policy (2017) target: per-capita steel consumption 160 kg by 2030-31.

Copper Industry

- Highly malleable and an excellent conductor of heat and electricity; one of the oldest metals used by humans.
- World's 3rd most important metal after steel & aluminium.
- Largest consumer of copper = electricity sector.
- India holds only ~2% of world copper reserves.

Copper Distribution in India

State	Key Belts/Areas
Madhya Pradesh (largest producer)	Taregaon, Malanjkhand belt, Balaghat
Rajasthan	Khetri-Singhana belt (Jhunjhunu)
Jharkhand	Singbhum (most important)

Major Copper Companies

Company	Location/Note
Hindustan Copper Ltd (1967)	5 units: Rajasthan, MP, Jharkhand, Maharashtra, Gujarat

Company	Location/Note
Sterlite Copper (Vedanta)	Thoothukudi, Tamil Nadu: once the largest smelter; closed since 2018 after protests
Hindalco	Aditya Birla Group; copper smelter at Dahej (Gujarat); also a major aluminium producer

Aluminium Industry

- 2nd most important industry after iron & steel.
- India is the 2nd largest aluminium producer in the world (after China).
- Bauxite = principal ore.
- Aluminium discovered 1886; Indian production began 1937 (Aluminium Corporation of India).
- 2nd FYP: INDAL (Alupuram, Hirakud); HINDALCO (Renukoot, UP, 1962).
- 3rd FYP: MALCO (Mettur, Tamil Nadu, 1965), BALCO (Korba, Chhattisgarh); later NALCO (1981; Damanjodi mines/refinery, Angul smelter, Odisha).
- Two purposes: primary production from bauxite mining; processing into semi-finished goods (rods, bars, castings, forgings).
- Uses: electricity conduction, household utensils, appliances, aeroplanes, rail coaches, nuclear/defence.

Major Aluminium Plants

Plant	State/Company
Korba	BALCO
Alupuram	HINDALCO
Renukoot	HINDALCO
Mettur	MALCO
Hirakud	HINDALCO
Angul	NALCO
Jharsuguda	VAL (Vedanta)

Bauxite Distribution in India

State	Key Areas
Odisha (largest producer, >half of India's total)	Kalahandi & Koraput belt extending into AP
Jharkhand	Ranchi, Lohardaga, Palamu, Gumla
Maharashtra	Kolhapur
Chhattisgarh	Maikala range (Bilaspur, Durg), Amarkantak plateau
Madhya Pradesh	Amarkantak plateau, Maikala range (Shahdol, Mandla, Balaghat)
Others	AP (Visakhapatnam, E/W Godavari), Kerala, Rajasthan (Kota), UP, J&K, Goa

- World bauxite producers: Australia, Guinea, China, Brazil, Indonesia, India.

Zinc Industry

- Main ores: sphalerite (zinc blende, ZnS), smithsonite, calamine; usually found with lead (galena).
- Uses: alloying, sheets, zinc dust/compounds/salts, paints, ceramics, dry batteries, die-casting, rubber, sunscreens, solar cells, nuclear reactors.
- Uses: galvanising steel against corrosion; zinc oxide in rubber/tyre vulcanisation; an essential micronutrient for humans, animals and plants.

- India: Rajasthan produces >99% of zinc: Rampura Agucha (Bhilwara, among the world's largest zinc mines), Zawar (Udaipur), Sindesar Khurd (Rajsamand); Hindustan Zinc Ltd.
- Minor zinc producers: AP, Kerala, MP, Bihar, Maharashtra, Sikkim.

Lead Smelting Industry

- Not found freely; main source = Galena (crystalline rocks, pre-Cambrian rocks, Vindhya).
- Uses: malleable thin sheets, bronze alloy, anti-friction metal.
- Uses: lead oxide, cable covers, ammunition, paints, glass, rubber; automobiles, aeroplanes, machines.
- India: Rajasthan has >90% of total lead output (Zawar, Debari mines, Udaipur).
- Other lead areas: AP (Kurnool, Nalgonda), Himalayas, Tamil Nadu.

Cotton Textile Industry

- Among the oldest industries (Harappan to British era); famous for Muslin.
- Maharashtra leads area under cotton; Gujarat is 2nd.
- World monopoly in cotton textiles since ~1500 BC (Muslins of Dhaka, Chintzes of Masulipatnam famed in Europe).
- First mill: 1818, Fort Gloster near Kolkata; first successful mill: 1854, Mumbai (C.N. Davar).
- Ahmedabad called "Manchester of India" from Shahpur mill (1861).
- Swadeshi (1906) & Non-cooperation (1920-22) movements boosted the industry.
- Early 20th century: centered in Maharashtra/Gujarat (Mumbai, Surat, Ahmedabad), cotton tract, cheap labour/capital, market.
- Railways spread the industry to Solapur, Nagpur, Indore, Jaipur, Kanpur.
- South India's development was delayed by lack of coal until Pykara Dam hydel power enabled Coimbatore, Madurai, Tirunelveli.
- 100% FDI allowed via automatic route.
- Schemes: PM MITRA parks (2021), PLI scheme for textiles (MMF and technical textiles), SAMARTH (skilling), RoDTEP (export remission, replaced MEIS in 2021).

Cotton Textile Centers by State

State	Centers
Uttar Pradesh	Kanpur, Moradabad, Etawah, Meerut, Ghaziabad
West Bengal	Calcutta, Howrah, Serampore, Shyamnagar (24-Parganas)
Madhya Pradesh	Gwalior, Indore, Ujjain, Raipur, Bhopal, Jabalpur (W. Malwa Plateau)
Karnataka	Bangalore, Bellary, Mysore
Andhra Pradesh	Hyderabad, Warangal, Guntur
Rajasthan	Kota, Jaipur, Jodhpur, Bhilwara
Punjab	Amritsar, Ludhiana, Phagwara
Tamil Nadu	Coimbatore ("Manchester of South India"), Tiruppur (knitwear hub), Madurai, Salem; largest number of spinning mills
Gujarat	Ahmedabad ("Manchester of India"), Surat, Vadodara, Rajkot
Maharashtra	Mumbai ("Cottonopolis"), Solapur, Nagpur, Pune, Ichalkaranji, Bhiwandi

- World cotton producers: China, India, USA, Brazil, Pakistan, Australia.

Jute Textile Industry

- 2nd most important textile industry after cotton; concentrated in eastern India (West Bengal); labour-intensive.
- British exported raw jute from Bengal from the 1840s; large-scale development from 1855, Calcutta.
- 1947 Partition sent >80% of jute area to Bangladesh (East Pakistan).
- India = largest producer of jute products, but Bangladesh leads acreage/trade (3/4 of global exports vs India's 7%).
- West Bengal = 80% of India's jute industry, then Andhra Pradesh.
- >90% of jute output is consumed domestically.

Why Jute Concentrates in Hooghly Basin

- Ganga-Brahmaputra delta grows ~3/4 of India's jute (raw material)
- Raniganj coal provides power
- Cheap water transport available
- Humid climate suits jute processing
- Kolkata port for export; cheap dense labour; banking/capital access

Jute Distribution in India

State/Region	Key Areas
West Bengal	Hugli region
Bihar	Gaya, Darbhanga, Katihar
Andhra Pradesh	Visakhapatnam, Guntur
Uttar Pradesh	Kanpur, Gorakhpur
Odisha	Cuttack
Others	Assam, Tripura

- World jute producers: Bangladesh, China, Myanmar, Nepal.
- Location factors: climate & soil; cheap fast transport; domestic market (gunny bags); Mesta crop grown alongside jute.
- Govt initiative: Jute Packaging Materials (Compulsory Use) Act, 1987, mandates 100% food grains & 20% sugar in jute bags.
- Govt initiative: jute crop placed under MSP.
- Govt initiative: Jute Geo-Textiles (JGT) under Technical Textiles Mission, for soil erosion/road/riverbank use.
- Govt initiative: Golden Fiber Revolution & Technology Mission on Jute and Mesta.
- Govt initiative: Jute SMART (2016), e-governance procurement; Jute ICARE, certified seeds, weeders, seed drills.

Sugar Industry

- One of the largest producers of sugarcane & cane sugar.
- 2nd largest agro-based industry in India.
- India is the 2nd largest sugar producer (Brazil 1st; India topped in 2021-22) and the largest sugar consumer.
- Introduced by British Indigo planters as indigo demand declined.
- >80% of sugarcane is grown in tropical/subtropical regions.
- Cane is heavy, low-value, weight-losing, perishable: so industry locates near cultivation.
- Two concentrations: North (UP, Bihar, Haryana) & South (Maharashtra, Karnataka, Tamil Nadu).
- There has been a marked shift of production from the north (UP, Bihar) to the peninsula (Maharashtra, Karnataka, Tamil Nadu).

Why Sugar Industry Shifted South

Factor	South's Advantage
Climate	Tropical climate gives higher yield & sucrose
Crushing season	South 7-8 months vs North's 4 months
Cooperative movement	Stronger, secures better prices via FRP & SAP
Mills	Newer, higher-productivity mills

Sugar Industry Centers

State	Notes/Centers
Maharashtra	Now top producer (Ahmednagar, Kolhapur)
Uttar Pradesh	More mills but smaller, so lower output (Meerut, Gorakhpur)
Tamil Nadu	Highest yield (sucrose, recovery, crushing season): Coimbatore, Karur

- World sugar producers: Brazil, India, Thailand, Australia.
- Rangarajan Committee Formula: cane price factors in sugar & by-product prices; cess-funded gap-bridging if price falls below reasonable payment.

Rubber Industry

- Commercial cultivation introduced 1873 by British planters.
- Plantations established in Kerala, Karnataka, Tamil Nadu from 1902.
- Natural rubber comes from latex (tapped from bark); favoured over synthetic rubber for strength/toughness/crack-resistance.
- Kerala leads rubber production (~74-75% of total).
- Uses: tyres, tubes, erasers, construction, automobiles.

Rubber Distribution in India

State	Key Areas
Kerala	Kottayam, Kollam, Ernakulam, Kozhikode
Karnataka	Chikmagalur, Kodagu
Tamil Nadu	Nilgiri, Madurai, Kanyakumari, Coimbatore
Others	Assam, Tripura, Meghalaya, A&N Islands

- World rubber producers/consumers: Thailand, Indonesia, Malaysia, Vietnam, China.
- Govt initiatives: Rubber Plantation Development Scheme; 100% FDI; National Rubber Policy (2019); Rubber Board for growers' welfare.

Fertilizer Industry

- India is among the top three fertilizer producers and the 2nd largest consumer.
- One of 8 core industries; grew out of the Green Revolution.
- Nitrogenous units locate near petrochemical sources.
- Major states: Gujarat, Tamil Nadu, UP, Punjab, Kerala, Maharashtra, MP, AP.
- Growth factor: pipelines (Hajira, Vijaipur, Jagdishpur) enable cheap distribution.
- Industry produces urea, phosphatic, ammonia, nitrogen, phosphate, potash fertilizers.
- Rajasthan/MP phosphorus reserves cut import dependence.

Petrochemical Industries

- Crude-refining products (LPG, petrol, diesel, polymers, synthetic fibers) feed many downstream industries.
- Mumbai and Digboi are the western and eastern hubs respectively.

Petrochemical Hubs

State	Centers
Maharashtra	Mumbai, Pune, Nagpur
Gujarat	Jamnagar, Gandhinagar, Vadodara, Hajira
Uttar Pradesh	Auraiya
West Bengal	Haldia
Andhra Pradesh	Visakhapatnam

- Western coast favoured due to crude-oil proximity (India & Gulf).
- Nylon/polyester units located at Kota, Mumbai, Modinagar, Pune, Ujjain.
- NE units: Assam (Guwahati, Digboi), Arunachal Pradesh.

Automobile Industry

- India is the 3rd largest automobile market (overtook Japan in 2022) and the largest manufacturer of two-wheelers and tractors.
- Key industry for raw-material transport to other industries.
- Location factors: near steel & iron (cost/wastage cut); port cities (easy import/export); market-oriented and raw-material proximity; decentralization aids remote/backward areas.

IT Industry and Service Sector

- IT industry processes/distributes/stores information.
- Demand rose with globalization & socio-political-economic shifts; major forex earner.
- Location factors: resource availability, infrastructure, IT professionals.
- Major IT hubs in India: Mumbai, Hyderabad, Pune, Delhi (Noida, Gurugram), Kolkata, Chennai, Bangalore.
- International IT hub: Silicon Valley (California).

Service Sector Significance

Metric	Value
Services share in GVA	~55%
Workforce employed	~30% (PLFS)
Developed-country services employment	>80%

- Service sector = about 55% of GVA.
- Services account for about 45% of India's total exports (IT, business services, travel).
- Services employ about 30% of the labour force (trade, tourism, healthcare, education, IT-BPM, including Ayurveda/Yoga tourism).
- Competitive edge from skilled low-cost manpower (BPO/KPO).
- Policy support via Make In India, Digital India.

Industrial Corridors (IC) & Related Strategy

Industrial Corridors

- Envisaged along transport routes for industrial thrust, exports, employment, environment management.
- Creates global manufacturing/investment hubs with smart industrial cities; complements National Manufacturing Policy (NMP) 2011.
- Node-based: Investment Regions (IRs) & Industrial Areas (IAs), self-sustaining townships with world-class infra.
- Significance: growth, freight corridors act as manufacturing/investment backbone.
- Significance: logistics, Transport, Warehousing, Forwarding, Value-added logistics.
- Significance: ease of doing business, faster clearances, permits, registration.
- Significance: employment via forward/backward logistics/warehousing linkages.

Corridor	States Covered	Notes
Delhi-Mumbai (DMIC)	UP, Haryana, Rajasthan, MP, Gujarat, Maharashtra	Since 2006; funded by JICA (Japan) + India's Public Sector Financial Intermediaries
Amritsar-Kolkata (AKIC)	Punjab, Haryana, UP, Uttarakhand, Bihar, Jharkhand, West Bengal	-
Chennai-Bengaluru (CBIC)	Andhra Pradesh, Karnataka, Tamil Nadu	-
Bengaluru-Mumbai (BMEC)	Karnataka, Maharashtra	-
East Coast-Chennai (ECEC)	West Bengal, Odisha, AP, Tamil Nadu	-

- National Industrial Corridor Development Programme: 11 corridors; in August 2024 the Cabinet approved 12 new industrial smart cities across 10 states.

- Facilities include: high-speed road/rail; modern airports/ports with world-class cargo handling; smart townships; logistic parks; financial hubs.

Mineral & Energy Resources

- Minerals: naturally occurring substances (solid/liquid) in Earth's crust/mantle/core.
- Cooling and crystallisation of magma is the basic source of minerals; they also form through sedimentary and metamorphic processes.
- Minor Minerals: defined under Mines and Minerals (Development and Regulation) Act, 1957, Sec. 3(e).
- Minor Minerals list: boulder, sand, shingle, chalcedony pebbles, lime shell, kankar, limestone, brick-earth, fuller's earth, bentonite, road metal, slate, marble, quartzite, sandstone, saltpeter, ordinary earth.
- State Govt regulates quarry/mining leases for minor minerals (via Gazette notification); Centre declares a mineral "minor."
- Major Minerals: specified under the 1957 Act, not declared minor.
- Major Minerals list: Lignite, Chromite, Uranium, Kyanite, Coal, Gold, Iron ore, Lead-Zinc, Magnesium, Sillimanite, Tungsten, Diamond.
- Energy resource: any material used as a basis for energy; fundamental to growth.
- Strong correlation exists between energy consumption and economic development.

Types of Minerals (Metallic vs Non-Metallic)

Metallic vs Non-Metallic Minerals

Basis	Metallic Minerals	Non-Metallic Minerals
Form	Natural raw form in magma-derived rock strata	Accumulation/concentration in Earth's crust
On melting	New product formed	New product not formed
Conductivity	Good conductors of heat & electricity	Poor conductors
Appearance	Generally shiny	Not shiny
Malleability/ductility	High	Low
Examples	Iron ore, copper, gold, manganese	Mica, limestone, gypsum, salt; fuel minerals such as coal and petroleum
Occurrence	Igneous & metamorphic rocks	Fold mountains & sedimentary rocks
Sub-types	Ferrous (chromite, iron ore, manganese) & Non-ferrous (lead, silver, gold, copper)	Inorganic (mica, limestone, graphite) & Organic/fossil fuels (coal, petroleum)

Distribution of Mineral Resources by Region in India

Mineral Resources by Region

Region	States Covered	Minerals Found
North-Eastern Plateau	Chhotanagpur (Jharkhand), Odisha plateau, West Bengal, Chhattisgarh	Kyanite, Iron, Chromium, Manganese, Coal, Bauxite
Himalayan	E & W Himalayas; Assam valley (oil); off-shore Mumbai	Copper, Zinc, Cobalt, Tungsten
Northwestern	Rajasthan (Aravalli), Gujarat (Kutch)	Copper, Zinc, Sandstone, Granite, Gypsum, Dolomite, Limestone
South-Western Plateau	Karnataka, Goa, Tamil Nadu uplands, Kerala	Iron, Manganese, Bauxite, Monazite, Thorium

Region	States Covered	Minerals Found
South-Eastern (Telangana-AP-TN)	Karnataka, AP, Telangana, Tamil Nadu	Bauxite, high-quality lignite, Mica, Iron

Metallic Minerals

Iron Ore

- India: 4th largest producer, 5th largest exporter of iron ore.
- Haematite and magnetite form the bulk of India's iron ore resources.
- High-quality deposits: Baba Budan hills (Chikmagalur), Sanur-Hospet (Bellary).

Types of Iron Ore

Type	Appearance/Quality	Key Locations
Haematite	Reddish, high content	Peninsular India, Dharwad & Cuddapah systems; Odisha, Jharkhand, Chhattisgarh, AP, Karnataka, Goa
Magnetite	Black, rich content	Same rock systems; Karnataka, AP, Kerala, Tamil Nadu, Rajasthan
Limonite	Yellow, lower density, cheap to mine	Uttarakhand (Garhwal), UP (Mirzapur), HP (Kangra)

- Odisha, Jharkhand, Chhattisgarh, Karnataka and Goa hold about 95% of India's iron ore reserves; Odisha produces over half of India's iron ore.

Iron Ore Distribution in India

State	Key Areas
Odisha (largest producer)	Sundargarh, Keonjhar (Joda-Barbil), Mayurbhanj (Gorumahisani), Bonai
Jharkhand	>25% reserves, >15% production: Singhbhum, Noamundi, Gua
Chhattisgarh	Bastar, Durg (Dalli, Rajhara); Bailadila mine feeds Vizag steel plant
Karnataka	Baba Budan hills, Chikmagalur, Kudremukh, Shivamogga
Maharashtra	Ratnagiri, Chandrapur, Bhandara
Others	Goa, Tamil Nadu, AP

- World iron ore producers: Australia, Brazil, China, India, Russia, South Africa, Canada.

Manganese

- India is among the leading manganese producers (South Africa, Gabon and Australia lead).

Manganese Distribution in India

State	Key Areas
Odisha (largest reserves)	Sundargarh, Rayagada, Keonjhar, Mayurbhanj, Koraput, Kalahandi
Karnataka	Dharwar, Ballari, Belagavi, Chikmagalur, Shivamogga
Maharashtra	Nagpur, Bhandara, Ratnagiri
Madhya Pradesh	Balaghat-Chhindwara-Nimar-Mandla
Minor producers	AP, Telangana, Goa, Jharkhand

Gold

- Raw-stage occurrence: Bihar, Rajasthan, Karnataka, West Bengal, AP, MP.

- Key fields: Karnataka (largest producer): Hutti (Raichur, the only major working gold mine); Kolar Gold Fields closed in 2001.
- Also found in: Andhra Pradesh (Ramagiri, Anantapur) and Jharkhand (Singhbhum).

Silver

- Found mainly in Rajasthan (Udaipur), Jharkhand (Dhanbad, Singhbhum), AP (Vizag).

Tin

Non-Metallic Minerals

Mica

- India is the leading producer of sheet mica; Koderma (Jharkhand) was historically famous, and Andhra Pradesh (Nellore) is now the largest producing state.

Mica Distribution in India

State	Key Areas
Andhra Pradesh	Nellore, Visakhapatnam, Godavari
Rajasthan	Jaipur, Bhilwara, Udaipur
Bihar	Gaya, Munger, Bhagalpur
Jharkhand	Dhanbad, Hazaribagh, Singhbhum (Koderma well-known)
Karnataka	Mysore, Hasan
Tamil Nadu	Coimbatore, Tiruchirappalli, Madurai
Others	Maharashtra (Ratnagiri), West Bengal (Purulia, Bankura)

Limestone

- Top users: cement, iron & steel, chemicals; also paper, sugar, fertilizers.
- Rajasthan is the largest producer; Madhya Pradesh, Andhra Pradesh, Chhattisgarh and Gujarat follow.

Asbestos

- Two types: chrysotile (white, serpentine) and amphibole asbestos; India stopped granting new asbestos mining leases in 1986 due to health hazards (asbestosis).
- Historically produced in Rajasthan (Udaipur, Ajmer) and Andhra Pradesh (Cuddapah).

Magnesite

- Major states: Tamil Nadu (Salem), Uttarakhand (Almora, Pithoragarh), Karnataka.

Kyanite

- India has some of the world's largest kyanite deposits (Lapsa Buru, Jharkhand).
- Major states: Jharkhand, Maharashtra, Karnataka.

Dolomite

- Limestone rich in magnesium carbonate is called dolomite.
- Odisha & Chhattisgarh together give over half of India's output.
- Also found in: Karnataka (Belgaum, Bijapur, Chitradurg), AP, Jharkhand, Rajasthan.

Sillimanite

- Similar to kyanite; found in coastal states: Tamil Nadu, Kerala, Orissa, AP, West Bengal.
- Orissa and Kerala: largest producers.

Salt

- Gujarat (Kutch, Saurashtra coast) produces ~80% of India's salt; also Tamil Nadu and Rajasthan (Sambhar).

Gypsum

- Found in sedimentary rocks (limestone, sandstone, shale).
- Major deposits: Rajasthan (Jodhpur, Bikaner, Nagaur, Barmer).

Atomic Minerals

Uranium

- Found in: Jharkhand (Jaduguda, Singhbhum), Andhra Pradesh (Tummalapalle, Kadapa), Meghalaya (Domiasiat), Rajasthan, Karnataka.
- Natural uranium composition: U-238 (99%) and U-235 (1%, fissile, reactor fuel).
- Monazite (beach-sand mineral) is the main source of thorium and rare earths, not uranium.

Monazite Fact

Among the world's richest beach-sand monazite deposits: Chavara (Kollam), Kerala

- Major uranium production areas: Jaduguda, Narwapahar, Singhbhum mines; Tummalapalle (Cuddapah Basin), operating/future potential.

Thorium

- Present in large quantities in India's coastal monazite sands; India has about a quarter of the world's thorium.
- Used as nuclear fuel (through U-233) in the 3rd stage of India's three-stage nuclear programme; not used for weapons.

Monazite Resources by State (IBM, million tonnes)

Rank	State	Monazite (million tonnes)
1	Andhra Pradesh	3.72
2	Tamil Nadu	2.46
3	Odisha	2.41
4	Kerala	1.90
5	West Bengal	1.22

Conventional Energy Sources

- Classified as Commercial (Coal, Petroleum, Electricity) vs Non-Commercial (Firewood, Straw, Dried Dung).

Coal

- Found in older Gondwana Formations (peninsular India) and younger Tertiary formations (NE region).
- Most important & abundant fossil fuel in India, meets ~55% of energy needs.
- Gondwana coal: ~98% of India's coal reserves; mostly bituminous, low in sulphur but high in ash.
- Gondwana coal fields: Raniganj, Jharia, Bokaro, Giridih, Karanpura, Rajmahal.
- Tertiary coal: lower carbon content, high moisture and sulphur.
- Tertiary coal areas: Assam (Makum, Nazira), Arunachal Pradesh (Namchik-Namrup), Meghalaya (Garo, Khasi, Jaintia hills, Cherrapunji).
- Tertiary Lignite areas: Tamil Nadu, Gujarat, J&K, Kerala, Rajasthan, West Bengal.

Top Coal-Reserve States (approx.)

State	Reserves (bn tonnes)	% of total
Jharkhand	80.71	26.76

State	Reserves (bn tonnes)	% of total
Odisha	75.07	24.89
Chhattisgarh	52.53	17.42
West Bengal	31.31	10.38

Coal Fields by State

State	Fields
Madhya Pradesh	Singrauli, Sohagpur, Pench-Kanha
Chhattisgarh	Korba, Lakhanpur, Chirmiri
Odisha	Talcher, Ib river, Rampur
Maharashtra	Wardha, Kamptee, Bhandara
Telangana	Singareni (Godavari valley)
West Bengal	Raniganj, Barjora

Coal Grades

Grade	Carbon Content	Key Features	Main Locations
Anthracite	>80% carbon	Best grade, low moisture/impurities, coking coal for iron & steel	India's deposits small, largest in J&K
Bituminous	60–80% carbon	Low moisture, high calorific value, thermal power/coke/gas	India's dominant type: West Bengal, Jharkhand, Damodar valley
Lignite	40–55% carbon	High moisture, dark, smoky	Rajasthan, Assam, Tamil Nadu (also Jharkhand, WB, Odisha, Chhattisgarh, MP)
Peat	<40% carbon	First stage of coal formation, low calorific value, smoky	-

Coking vs Non-Coking Coal

Type	Features	Indian States	International
Coking	Low moisture, high carbon, produces coke for iron & steel; also called metallurgical coal	Jharkhand, WB, Chhattisgarh, Odisha, MP	Australia, USA, India, China
Non-Coking	High sulfur, unsuitable for iron & steel; used for thermal power	AP, Chhattisgarh, Jharkhand, Odisha, MP	China, USA, Russia, South Africa

- Rat-hole mining: narrow 3–4 ft tunnels dug unscientifically, practised in Meghalaya; banned by the NGT in 2014.
- India imports about 250–270 MT of coal a year (mainly coking coal and high-grade thermal coal), from Indonesia, Australia, Russia, South Africa.
- India's coal production crossed 1 billion tonnes in FY 2024–25; Coal India Ltd produces about three-fourths of it.

Petroleum

- Also called mineral oil or crude; formed from ancient marine organisms buried in sedimentary rocks, mostly of Tertiary age.

Petroleum Distribution in India

Region	Areas
Assam	Digboi, Naharkatiya, Moran–Hugrijan, Lakwa (oilfields)

Region	Areas
On-shore	Brahmaputra valley (NE), Rajasthan (Barmer), Gujarat (Ahmedabad, Ankaleshwar), Tamil Nadu (Cauvery basin), AP
Off-shore	Mumbai High, Bassein

Petroleum Milestones

India's first oil refinery: Digboi, 1901
Mumbai High and Gulf of Khambhat are the most-produced areas
Jamnagar refinery (Gujarat) is the world's largest

- India imports about 85–88% of its crude oil needs.
- Russia has been India's largest crude supplier since 2022–23, followed by Iraq and Saudi Arabia; also UAE, USA, Latin America and Africa.
- Strategic Petroleum Reserve (SPR): 5 MMT at Visakhapatnam, Mangalore, Padur (Udupi).

Natural Gas

- Mixture of hydrocarbons, mainly methane, with ethane, propane and butane; often found with crude oil.
- Distribution in India: KG basin, Assam, Gulf of Khambhat, Cuddalore (Tamil Nadu), Barmer (Rajasthan).
- Gas-based plants provide only about 2–3% of India's electricity generation.

Non-Conventional/Renewable Energy

Solar

- India: 3rd largest installed solar capacity globally (after China & USA), surpassing Germany/Japan.
- Installed solar capacity ~168 GW (end-August 2026, MNRE), up from just ~2.6 GW in 2014; total RE incl. large hydro ~296 GW.
- Rajasthan leads state-wise installed solar capacity (~44 GW), followed by Gujarat, Maharashtra, Tamil Nadu, Karnataka; Gujarat leads in total RE capacity.
- IREDA: NBFC (Navratna PSU) under the Ministry of New and Renewable Energy (MNRE) for renewable-energy loans.
- Other initiatives: solar parks/ultra-mega projects; PM-KUSUM (solar pumps for farmers); PM Surya Ghar: Muft Bijli Yojana (Feb 2024, rooftop solar for 1 crore households); PLI for solar modules; Suryamitra (skilling); Renewable Purchase Obligation; Green Energy Corridors.
- International Solar Alliance (ISA): launched by India and France at COP21 Paris (2015); HQ Gurugram; 120+ signatory countries.
- National Green Hydrogen Mission (Jan 2023): 5 MMT green hydrogen per year by 2030; Green Hydrogen Policy (2022): inter-state transmission charges waived for 25 years, land in RE parks, manufacturing zones.

Major Solar Plants in India

Plant	State	Capacity/Note
Bhadla Solar Park	Rajasthan (Jodhpur)	Among the world's largest solar parks; ~14,000 acres; 2,245 MW
Pavagada Solar Park	Karnataka (Tumkur)	World's 2nd largest PV park; 2,050 MW
Kurnool UMSP	Andhra Pradesh	5,932 acres; 1,000 MW
Rewa Ultra Mega Solar	Madhya Pradesh	First to break grid parity; Asia's largest single-site; supplies Delhi Metro; first solar-railway-traction project
Charanka Solar Park	Gujarat (Patan)	2,000 hectares
Kamuthi Solar Power Project	Tamil Nadu (Ramanathapuram)	2,500 acres

Plant	State	Capacity/Note
Khandwa Floating Solar	Madhya Pradesh	Omkareshwar (Narmada) floating solar; planned 600 MW; first phase commissioned 2024
Ramagundam Floating Solar PV	Telangana (NTPC)	100 MW, fully operational
Khavda Renewable Energy Park	Gujarat (Kutch)	Planned ~30 GW solar + wind; set to be the world's largest RE park (Adani Green and others)

Wind

- India ranks 4th in wind power installed capacity (after China, USA, Germany).
- Installed wind capacity ~58.5 GW (end-August 2026).
- Gujarat leads state-wise installed wind capacity (~16.7 GW), having overtaken Tamil Nadu (2nd); Maharashtra, Rajasthan, Karnataka follow.
- National Institute of Wind Energy (Chennai): wind potential ~1,164 GW at 150 m hub height (695 GW at 120 m).
- Initiatives: National Offshore Wind Energy Policy; Onshore Wind Power Project guidelines; Renewable Purchase Obligation (Electricity Act 2003); Green Energy Corridors Project.

Hydro (Hydropower)

- Uses kinetic energy of moving/falling water via dams & turbines (hydel power).
- Cheaper than thermal/nuclear once built; clean but disturbs habitats.

Tidal Energy

- Harnesses tidal flow; needs mean tidal range >5 m.

Wave Energy

- Captures ocean-surface wave energy for electricity, desalination, water pumping.

Geothermal Energy

- Three categories: Geopressured zones, Hot-rock zones, Hydrothermal convection zones, only the last currently commercially exploited.
- India: NW Himalayas and western coast are geothermal areas.
- GSI identified 350+ hot spring sites.
- Puga valley (Ladakh): most promising geothermal field.

Biomass

- From plant/animal waste; energy generated via combustion or breaking organic molecules' chemical bonds (from photosynthesis).
- Solid fuels: wood logs/pellets, charcoal, agri waste, animal dung, aquatic plants (kelp, water hyacinth), urban waste.

Hydrogen Energy

- Potential "fuel of the future".
- Limitation: occurs combined with other elements, so production from water/methane is energy-intensive/costly.

Energy Security & Policy

- Energy Security: uninterrupted availability of energy at affordable price.
- Access: near-universal household electrification achieved under Saubhagya (2017–19).
- Clean cooking: PM Ujjwala Yojana (2016) has provided over 10 crore LPG connections, though many households still use firewood/dung.

India's Climate & Energy Targets (Panchamrit, COP26, 2021)

500 GW non-fossil electricity capacity by 2030
 50% of installed electricity capacity from non-fossil sources by 2030 (achieved in June 2025)
 Reduce emissions intensity of GDP by 45% by 2030 (vs 2005)
 Cut 1 billion tonnes of projected CO₂ emissions by 2030
 Net-zero emissions by 2070
 Nuclear Energy Mission (Budget 2025): target of 100 GW nuclear capacity by 2047

Nationally Determined Contributions (NDCs): Paris Accord

- Updated NDC to UNFCCC translates PM's "Panchamrit" (5 nectar elements, COP26 Glasgow) into enhanced climate targets.

National Mineral Policy 2019

- Key proposal: raise major mineral production by 200% in 7 years.
- Key proposal: cut mineral-sector trade deficit by 50% in 7 years.
- Key proposal: revenue-sharing model for private exploration.
- Key proposal: private-investment concessions (financial package, right of first refusal in auctions).
- Key proposal: No-Go areas for ecologically fragile zones.
- Key proposal: District Mineral Fund for welfare/rehabilitation.
- National Critical Mineral Mission (2025) aims to secure lithium, cobalt, nickel, REEs; KABIL (Khanij Bidesh India Ltd) acquires mineral assets abroad (e.g. lithium blocks in Argentina).

Conservation of Mineral & Energy Resources

- Measures: address exploitative-mining damage (e.g. Aravalli mining issue).
- Measures: shift to alternative/renewable energy (solar, tidal, wind, geothermal).
- Measures: zero-wastage mining promotion under the new mineral policy.

Research Centers in India

ICAR and Agricultural Research

- ICAR (Indian Council of Agricultural Research): apex body for agricultural research & education in India; HQ New Delhi; est. 1929; functions under DARE (Dept. of Agricultural Research & Education), Ministry of Agriculture & Farmers Welfare.

Key ICAR Institutes

Institute	Full Name	Headquarters	Focus Area
IARI	Indian Agricultural Research Institute (Pusa Institute)	New Delhi	Crop improvement; birthplace of India's Green Revolution wheat varieties
NRRI (formerly CRRI)	National Rice Research Institute (renamed from Central Rice Research Institute in 2015)	Cuttack, Odisha	Rice research (old acronym CRRI clashed with CSIR's Central Road Research Institute, Delhi)
IISR	Indian Institute of Sugarcane Research	Lucknow, UP	Sugarcane research
CAZRI	Central Arid Zone Research Institute	Jodhpur, Rajasthan	Desert/arid-zone agriculture
NBSS&LUP	National Bureau of Soil Survey & Land Use Planning	Nagpur, Maharashtra	Soil survey & land-use planning
CIFE	Central Institute of Fisheries Education	Mumbai, Maharashtra	Fisheries education/research

CSIR and Key National Laboratories

- CSIR (Council of Scientific & Industrial Research): autonomous R&D body under Ministry of Science & Technology; HQ New Delhi; runs a pan-India network of ~37 national laboratories, each with its own specialization.

Key CSIR Laboratories

Institute	Full Name	Headquarters	Focus Area
NGRI	National Geophysical Research Institute	Hyderabad, Telangana	Geophysics: seismology, mineral/groundwater/hydrocarbon exploration
NIO	National Institute of Oceanography	Goa (Dona Paula)	Oceanography: marine science, coastal/ocean research
CRRI	Central Road Research Institute	New Delhi	Road engineering & transportation research (not to be confused with the ICAR rice institute at Cuttack, formerly CRRI, now NRRI)
CBRI	Central Building Research Institute	Roorkee, Uttarakhand	Building & construction technology
NEERI	National Environmental Engineering Research Institute	Nagpur, Maharashtra	Environmental engineering
CIMFR	Central Institute of Mining & Fuel Research	Dhanbad, Jharkhand	Mining & fuel research
NML	National Metallurgical Laboratory	Jamshedpur, Jharkhand	Metallurgy
CSMCRI	Central Salt & Marine Chemicals Research Institute	Bhavnagar, Gujarat	Salt & marine chemicals

Geological & Survey Organizations**Survey Organizations**

Institute	Full Name	Headquarters	Focus Area
GSI	Geological Survey of India	Kolkata, West Bengal	Geological mapping, mineral resource assessment; under Ministry of Mines; est. 1851
SoI	Survey of India	Dehradun, Uttarakhand	National topographic mapping & surveying; oldest scientific department of Govt of India (est. 1767); under Dept. of Science & Technology; headed by Surveyor General of India
NATMO	National Atlas and Thematic Mapping Organisation	Kolkata, West Bengal	Prepares the National Atlas and thematic maps; under Dept. of Science & Technology

Biological Surveys & Forestry/Wildlife Institutes**Biological & Forestry Institutes**

Institute	Full Name	Headquarters	Focus Area
ZSI	Zoological Survey of India	Kolkata, West Bengal	Faunal surveys & taxonomy; est. 1916; under Ministry of Environment, Forest & Climate Change
BSI	Botanical Survey of India	Kolkata, West Bengal	Floral surveys & plant taxonomy; est. 1890; under MoEFCC
FRI	Forest Research Institute	Dehradun, Uttarakhand	Forestry research; est. 1906; deemed university

Institute	Full Name	Headquarters	Focus Area
WII	Wildlife Institute of India	Dehradun, Uttarakhand	Wildlife research & training; est. 1982; autonomous institute under MoEFCC

ISRO Centers Relevant to Geography

ISRO Centers			
Institute	Full Name	Headquarters	Focus Area
NRSC	National Remote Sensing Centre	Hyderabad, Telangana	Remote sensing, satellite data acquisition/processing, GIS applications
SAC	Space Applications Centre	Ahmedabad, Gujarat	Satellite-based remote sensing, communication & navigation applications
ISRO HQ	Indian Space Research Organisation	Bengaluru, Karnataka	Apex space agency; under Dept. of Space

Other Relevant Research Bodies

- IITM (Indian Institute of Tropical Meteorology): Pune, Maharashtra, under Ministry of Earth Sciences; monsoon/climate research.
- NCPOR (National Centre for Polar and Ocean Research): Goa, under Ministry of Earth Sciences; polar (Arctic/Antarctic/Himalaya) & Southern Ocean research.
- NIH (National Institute of Hydrology): Roorkee, Uttarakhand, under the Ministry of Jal Shakti; hydrology research.

CHAPTER 15

India: Transportation, Tourism, Miscellaneous

Introduction

- Transport carries passengers/goods between places.
- Cheap, efficient transport is vital for a vast developing country like India.
- India spans Kashmir (N) to Kanyakumari (S) and Kachchh (W) to Arunachal Pradesh (E).
- Three modes: land (road + rail), water, air, compete with and complement each other.
- Together they form one integrated network.

Mode-wise Character

Rail: handy/cheap for large goods over long distances
 Road: better for short distances, door-to-door delivery
 Water: slow but cheapest; good for bulky goods
 Air: fast but costly; saves time/energy
 Road and rail are ancient modes (as old as nomadic man)
 Air transport is relatively new

Road Transport

Overview

- India has the second largest road network in the world.
- Total length ~66.71 lakh km (MoRTH 2023).
- A twenty-year road plan (1961) was introduced post-Independence to improve road conditions.
- Roads remain concentrated in/around urban centres.
- Rural/remote areas are the least connected.
- Carry ~85% of passenger traffic annually.
- Carry ~70% of freight traffic annually.

Grand Trunk (GT) Road History

Built by Sher Shah Suri as the Shahi (Royal) Road
 Original route: Indus Valley to Sonar Valley (Bengal)
 Renamed Grand Trunk (GT) Road in British period
 British-era route: Calcutta–Peshawar
 Today extends Amritsar–Kolkata
 Earlier NH-1 (Delhi–Amritsar) and NH-2 (Delhi–Kolkata); after the 2010 renumbering, largely NH-44 and NH-19

Classification of Roads

- Roads are classified (for construction/maintenance) as: National Highways (NH), State Highways (SH), District Roads, Rural Roads.
- NH total length: ~1,46,145 km (2023).
- This is up ~60% from 91,287 km in 2014.

Road Classification

Category	Maintained by	Share of total road length	Key function
National Highways	Central Government	~2% (carries 40% of road traffic)	Inter-state transport, defence movement, connects state capitals/major cities/ports/rail junctions
State Highways	State Governments	4%	Connects state capitals with district HQs/important towns; linked to NH
District Roads	District authorities	14%	Links District HQs with other important nodes in the district
Rural Roads	-	~80%	Links in rural areas; density varies regionally with terrain

National Highways / Expressways

- Expressways are the highest road class.
- Features: 6 to 8 lane controlled-access.
- Modern features: access ramps, grade separation, lane dividers, elevated sections.
- Limited entry/exit, no crossing roads.
- Fewer accidents than highways.
- Freeways: highest class of controlled-access highway for high-speed traffic.
- India has two freeways, both in Mumbai: the Eastern Freeway and the Western Freeway (Bandra–Worli Sea Link section).
- Both freeways aim to reduce congestion in Mumbai island.

Major Road Initiatives**Major Road/Highway Corridors**

Initiative	Route	Length
Golden Quadrilateral	Delhi–Mumbai–Chennai–Kolkata (4/6-lane)	5,846 km
North–South Corridor	Srinagar (J&K)–Kanyakumari (TN), incl. Kochi–Salem Spur	4,076 km
East–West Corridor	Silchar (Assam)–Porbandar (Gujarat)	3,640 km

- Bharatmala Pariyojana Phase-I (approved 2017): ~34,800 km of economic corridors, inter-corridors, feeder routes, border and coastal roads and expressways.
- It subsumed the earlier National Highways Development Project (NHDP).
- Original completion target 2022, later extended; expressways include Delhi–Mumbai Expressway (~1,380 km, India's longest) and Delhi–Amritsar–Katra.
- Bharatmala components: state roads along coastal/border areas (incl. non-major port connectivity).
- Bharatmala components: backward/religious/tourist connectivity.
- Bharatmala components: Setu Bharatam Pariyojana (~1,500 major bridges + 200 rail-over/under bridges).
- Bharatmala components: District HQ Connectivity Scheme (~9,000 km new NH).
- Electronic Toll Collection (FASTag): recommended by the Nandan Nilekani committee; FASTag made mandatory on NHs from February 2021; GNSS-based tolling being introduced.
- ETC piloted 2012 on NH-5 (Delhi–Parwanoo).
- NATRIP = National Automotive Testing and R&D Infrastructure Project.
- NATRIP is under Dept. of Heavy Industry.
- NATRIP provides testing/validation/R&D infra across 7 locations.
- SARDP-NE = Special Accelerated Road Development Programme for NE.
- SARDP-NE improves connectivity between State Capitals and District HQs.

Border Road Organisation (BRO)

- Established 1960, under Ministry of Defence.
- Purpose: defence preparedness, strategic roads along northern/NE boundary.

- Premier multifaceted construction agency.
- Built high-altitude road joining Chandigarh–Manali (HP)–Leh (Ladakh).
- Average altitude of this road: 4,270 m MSL.

National Highways Authority of India (NHAI)

- Operationalized 1995.
- Autonomous body under MoRTH.
- Apex body for NH development, maintenance, operation, quality.

Factors Influencing Road Density

- Terrain: cheaper/easier to build in plains than in hilly/plateau areas.
- Climate: better road quality in plains vs high-altitude/rainy/forested regions.
- Economic development: higher road density with development (e.g. Maharashtra > Himachal Pradesh).
- Industries: higher density with industrial concentration (e.g. Jamshedpur > Patratu, Jharkhand).
- Cities/towns: denser road network than rural areas.

Rail Transport

Overview

- Indian Railways: 4th largest rail network in the world (after USA, China, Russia).
- Among the largest passenger carriers in the world.
- 4th largest freight volume in the world.
- Largest government undertaking in the country.
- Slogan: "Lifeline of the Nation".

Indian Railways Key Facts

First passenger train: 16 April 1853 (Lord Dalhousie's tenure)

First route: Bori Bunder (Bombay)–Thane, 34 km

Mascot: Bholu, the Guard Elephant

Longest train route: Dibrugarh (Assam)–Kanyakumari (Vivek Express), over 4,000 km

Route length: about 69,000 km; 18 zones (South Coast Railway, Visakhapatnam, began operations on 1 June 2026); broad-gauge network almost fully electrified

2 UNESCO World Heritage Sites: Chhatrapati Shivaji Maharaj Terminus (Mumbai); Mountain Railways of India (Darjeeling Himalayan, Nilgiri Mountain, Kalka–Shimla)

Udhampur–Srinagar–Baramulla Rail Link completed (June 2025) with the Chenab Bridge (world's highest railway arch) and Anji Khad (India's first cable-stayed rail bridge); Vande Bharat trains since 2019

- Extremes: Northernmost, Baramulla (J&K).
- Extremes: Westernmost, Naliya near Bhuj (Gujarat).
- Extremes: Southernmost, Kanyakumari.
- Extremes: Easternmost, Ledo (branch of Tinsukia).
- 18 zones: Northern Railway (largest by route length), North Eastern, Northeast Frontier, Eastern, South Eastern, South Central, Southern, Central, Western, South Western, North Western, West Central, North Central, South East Central, East Coast, East Central, Kolkata Metro, South Coast Railway (newest, 2026).

Gauge Types (March 2016 data; Project Unigauge is converting most MG/NG to broad gauge)

Rail Gauge Types

Gauge	Distance between rails	Total length (Mar 2016)
Broad gauge	1.676 m	60,510 km
Metre gauge	1 m	3,880 km
Narrow gauge	0.762 m or 0.610 m	2,297 km (mostly hilly areas)

Density/Regions of Rail Network

- Dense regions: Northern plains, eastern coastal areas, level land, fertile soils, dense population, industries.
- Dense regions also include: Gujarat/Saurashtra plains, central Tamil Nadu, Chhotanagpur Plateau.
- Moderate: rest of peninsular region (except TN & Chhotanagpur), hilly/plateau terrain.
- Moderate regions have trunk routes via gaps/tunnels connecting industrial cities/ports.
- Sparse: Himalayan region (J&K, HP, Uttarakhand, Sikkim, Arunachal Pradesh).
- In Himalayan region, railheads exist only at foothill towns: Jammu, Kathgodam, Kotdwar, Dehradun.
- The Udhampur–Srinagar–Baramulla line (completed June 2025) now links the Kashmir valley to the national network.
- Narrow-gauge lines: Kalka–Shimla and Siliguri–Darjeeling.
- North-East: main line along the Brahmaputra valley; capital connectivity is being extended (Bairabi–Sairang line reached Mizoram's capital region in 2025).
- Sparse: Western Rajasthan desert, sparse meter-gauge (mostly converted to broad gauge).
- Reasons for Rajasthan sparseness: sparse population, hot/dry climate, sandy winds obstructing tracks.

Role of Railways

- Transports coal: the most dominant commodity carried.
- Helps industrialize coal-starved areas.
- Carries raw materials to industrial centres.
- Distributes semi-finished/finished goods (pig-iron, steel).
- Promotes exports of iron ore, cement, food grains.
- Carries cement, fertilisers, mineral oil from ports/refineries to the interior.

Government Initiatives / Way Forward

- Dedicated Freight Corridors: Eastern DFC (Ludhiana–Sonmargar, ~1,337 km) is fully operational; Western DFC (Dadri–JNPT, ~1,506 km) is nearing completion.
- Roll-on roll-off model for trucks cuts carbon footprint.
- Privatisation based on Amitabh Kant Panel: private players allowed in operations.
- Railway Board restructuring based on Bibek Debroy Committee: merged technical/non-technical services; restructured on company-board functional lines.
- Rail Development Authority: sets rational tariffs, performance standards, tech upgrades.
- National Rail Plan: integrates rail with other modes for multimodal network.
- Modernisation: electrification, green corridors, bio-toilets.
- "Rashtriya Rail Sanraksha Kosh" finances safety projects.
- Also: commercialisation of Production Units.
- Also: outsourcing medical services.
- Also: fare/subsidy rationalisation.
- Also: station modernisation, ease of doing business.
- Electrification cuts coal dependency: India is a 2015 Paris Agreement signatory.

Water Transport

Overview

- Fuel-efficient, eco-friendly.
- Two types: (a) Inland waterways, (b) Oceanic waterways.
- India has 14,500 km of navigable waterways (rivers, canals, backwaters, creeks).
- These contribute ~1% to transportation.
- Only ~2,000 km of this is actually used.
- Inland waterways carry <2% of freight traffic.
- 5,685 km of major rivers are currently navigable by mechanised flat-bottom vessels.

Inland Waterways / National Waterways

- Inland Waterways Authority (IWA) set up in 1986.
- Set up under the Inland Waterways Authority of India Act, 1985.

- IWAI regulates/develops national waterways.
- National Waterways Act, 2016 declared 111 rivers/stretches/creeks/estuaries as National Waterways.
- Kerala's backwaters (kayals) hold special significance for cheap transport + tourism.

National Waterways

Waterway	River/Route	Stretch	Length
NW-1	Ganga	Haldia to Allahabad	1,620 km
NW-2	Brahmaputra	Sadiya to Dhubri	891 km
NW-3	West Coast Canal + Champakkara & Udyogmandal Canals	Kottapuram to Kollam	205 km
NW-4	Godavari, Krishna rivers + canals	Kakinada–Puducherry stretch	1,078 km
NW-5	Brahmani/Mahanadi rivers, delta channels + East Coast Canal	Talcher/Geonkhali to Paradip/Dhamra	588 km

- The National Waterways Act, 2016 raised the number of NWs from 5 to 111; most are still being developed.
- NW-1 serves: Uttar Pradesh, Bihar, Jharkhand, West Bengal (terminals at Varanasi, Sahibganj, Haldia).
- NW-2 lies entirely in Assam (Dhubri–Sadiya).

Benefits of Inland Water Transport

Cost & Fuel Efficiency Comparison

Mode	Cost	Fuel efficiency (ton-km per litre, World Bank)
IWT	Rs 0.25/km	105
Rail	Rs 1.5/km	85
Road	Rs 2.5/km	24

- Fewer emissions than road.
- Large capacity for bulk cargo (e.g. coal).
- Boosts exports via lower costs.
- Decongests highways/railways.
- Gives accessibility to remote areas (e.g. NE states get coal/food grains via IWT).

Legislative Efforts / Schemes

- Indian Vessels Act, 1917 (amended 2007): survey/registration of inland vessels, navigation obstruction removal, cargo/passenger carriage, pollution control.
- Inland Water Transport Policy, 2001: promotes IWT as economical, fuel-efficient, eco-friendly; encourages private participation.
- Jal Marg Vikas Project (JMVP): improves NW-1 navigational capacity, with World Bank technical/investment assistance.
- Sagarmala Project: develops coastal shipping + inland waterways.
- Sagarmala aims to raise domestic waterways share in modal mix from current 6%.
- Sagarmala also covers port connectivity, coastal economic zones, single-window clearances, new ports.
- Interlinking of Rivers: potential navigation benefits.
- Project Arth Ganga: re-engineers JMVP with local community focus.
- Arth Ganga builds small jetties along Ganga in UP, Bihar, Jharkhand, West Bengal.
- RoPax Ferry: roll-on-roll-off cum passenger ferry (Ministry of Shipping).
- RoPax reduces travel time/pollution/congestion.
- Example: Ghogha–Hazira Ferry, reduces 370 km route to 90 km; gateway to South Gujarat/Saurashtra.

Oceanic Routes / Major Ports

- Coastline: 7,516.6 km (traditional; incl. islands), re-measured as 11,098.81 km (2025).

- 12 major ports (under the Ministry of Ports, Shipping and Waterways) and about 200 non-major ports (under state maritime boards); VadHAVAN (Maharashtra), approved in 2024, will be the 13th major port.
- ~95% of foreign trade by volume moves via ocean routes.
- ~70% of foreign trade by value moves via ocean routes.

Major Ports of India

Port	State/Coast	Key feature
Chennai	Tamil Nadu (East)	Oldest artificial major port on the east coast
Ennore (Kamarajar Port)	Tamil Nadu (East)	Artificial port; India's first corporatised major port
Tuticorin (V.O. Chidambaranar)	Tamil Nadu (East)	Southernmost major port of mainland India; outer harbour being developed for transshipment
Kolkata (Syama Prasad Mookerjee Port)	West Bengal (East)	India's only riverine major port, on the Hugli; Haldia Dock Complex downstream
Visakhapatnam	Andhra Pradesh (East)	Deep, land-locked natural harbour; handles iron ore, coal, crude
Paradip	Odisha (East)	Deep-water port; a leading cargo handler of the east coast (coal, iron ore, petroleum)
New Mangalore	Karnataka (West)	Exports Kudremukh iron ore (historically); handles crude and LPG
Kochi	Kerala (West)	Located on Willingdon Island in the Vembanad backwaters; natural harbour; spices and seafood
Kandla (Deendayal Port)	Gujarat (West)	Tidal port; India's first Export Processing Zone (1965); the largest major port by cargo volume
Mormugao	Goa (West)	On estuary of river Zuari; handles iron ore exports
Mumbai Port Trust	Maharashtra (West)	Largest natural harbour in India; oldest major port on the west coast
JNPA (Jawaharlal Nehru Port, Nhava Sheva)	Maharashtra (West)	Largest container port in India
VadHAVAN (Palghar, Maharashtra)	Maharashtra (West)	Under construction (approved 2024); planned as one of the world's top-10 container ports

Air Transport

- Began 1911: airmail over 10 km between Allahabad and Naini.
- Airport Authority of India (AAI) is responsible for safe, efficient air traffic & aeronautical communication in Indian airspace.
- AAI manages ~125 airports.
- Operational airports have roughly doubled since 2014 (to about 160); India is the 3rd largest domestic aviation market.
- Passenger traffic growing faster than global average.
- First-class rail passengers shifting to aviation (faster, safer).
- Cargo traffic currently low but expected to rise with investment/technology, huge untapped domestic market.

Pipeline Transport

- Most convenient/efficient mode for liquids and gases over long distances.
- Even solids can move as slurry.

Advantages

- Convenient for liquids/gases with minimal transit losses.
- Easy to lay even in difficult terrain/underwater.
- Unaffected by floods/snowfall/cyclones.

- Low maintenance and energy needs.
- Environment-friendly, safe, accident-free.
- Cheap compared to other modes.
- Spurs nearby industrial development.

Disadvantages

- Inflexible: serves only fixed destinations with fixed, non-expandable capacity.
- High initial capital cost.
- Vulnerable to sabotage, theft and leakage; cross-border pipelines (e.g. the proposed TAPI) face security risks.
- Underground pipelines are hard to repair; leakage detection is difficult.

Key Pipelines

- Oil India Limited (OIL): under Ministry of Petroleum & Natural Gas, incorporated 1959.
- OIL handles exploration, production, transportation of crude oil/natural gas.

Major Oil & Gas Pipelines

Pipeline	Route	Length	Notes
Naharkatiya–Barauni	Naharkatiya (Assam)–Barauni refinery (Bihar)	1,157 km	Asia's first cross-country pipeline, by OIL; extended to Kanpur in 1966
Salaya–Mathura	Salaya (Gujarat)–Mathura (UP)	1,256 km	Supplies crude oil from Gujarat to Punjab (Jalandhar) via Mathura
Numaligarh–Siliguri	Numaligarh (Assam)–Siliguri (WB)	660 km	Petroleum product pipeline
Kandla–Gorakhpur LPG Pipeline	Kandla (Gujarat)–Gorakhpur (UP)	~2,800 km	Billed as the world's longest LPG pipeline (IOCL-BPCL-HPCL; slated for commissioning from 2025)
HBJ Pipeline	Hazira–Bijaipur–Jagdishpur	1,730 km	India's first major cross-state gas pipeline (GAIL); feeds fertiliser plants and gas power stations; Jagdishpur–Haldia–Bokaro–Dhamra ("Pradhan Mantri Urja Ganga", ~3,300 km) extends gas to eastern India

- Western region network: Ankleshwar–Koyali, Mumbai High–Koyali, Hazira–Vijaipur–Jagdishpur (HVJ).
- HBJ pipeline supports gas-based power plants at Kawas (Gujarat), Anta (Rajasthan) and Auraiya (UP).
- HBJ pipeline supports fertiliser plants at Vijaipur (MP), Sawai Madhopur (Rajasthan), Jagdishpur, Aonla and Shahjahanpur (UP).

Communication Networks

Overview

- Communication aids economic growth, social interaction, cultural unity, rapid emergency response.
- Communication brings the world closer.
- Personal modes: letters, telephone, telegram, fax, e-mail, internet.
- Mass modes: radio, television, cinema, satellite, newspaper, magazines/books, public meetings, seminars, conferences.

Postal Services

- Most commonly used communication mode in India.
- Vital in rural areas: ~99% of villages covered.
- ~1.6 lakh post offices: the largest postal network in the world.
- PIN (Postal Index Number) aids prompt delivery.
- Speed Post provides fast delivery.
- Satellite Money Order Scheme introduced 1994 (pilot), for hilly/backward/remote areas, from six principal cities.

- International mail via air and sea links India with foreign countries.

Telecommunication

- Main means: telegraph, telephone, telex, fax.
- Telegraph: India's 163-year-old telegram service was discontinued on 15 July 2013.
- India is the 2nd largest telecom market in the world; 5G services were launched in October 2022.
- BharatNet aims to connect all gram panchayats with optical fibre.
- Telex and paging services have become obsolete.
- Satellites have revolutionized telecommunication.

Mass Communication

- Radio: wide range of information/news/entertainment.
- Akashvani (All India Radio) has about 480 stations reaching ~92% of area and ~99% of population.
- FM Radio extended reach further.
- Television began 1959; real growth after 1980.

Broadcasting: Key Facts

Metric	Fact
Television in India began	15 September 1959 (Delhi)
Prasar Bharati	Autonomous public broadcaster (1997) running Doordarshan and Akashvani
DD Free Dish	Free-to-air DTH platform of Prasar Bharati
Analogue terrestrial transmitters	Phased out (2022) in favour of digital/satellite delivery
SITE (1975-76)	Satellite Instructional Television Experiment using NASA's ATS-6
DD channels	DD National, DD News, DD Kisan, regional channels
Community radio	Licensed to educational institutions and NGOs
Satellites used	GSAT series

- Cinema entertains millions daily.
- Print Media expanded rapidly post-Independence.

Satellite Communication

- Serve as both communication medium and regulator of other communication modes.
- Enable continuous, synoptic regional coverage: vital economically/geopolitically.
- Uses: weather forecasting, disaster monitoring, border surveillance.
- Capture multi-spectral-band data, broadcast to ground stations.
- National Remote Sensing Centre (NRSC), Hyderabad, provides data collection/processing services for natural resource management.

Tourism

Overview

- Tourism is a major service-sector contributor to India's GDP, employment, and foreign exchange earnings.
- Nodal ministry: Ministry of Tourism, Government of India.
- "Incredible India": official international tourism branding/marketing campaign of the Ministry of Tourism, launched 2002.
- India ranks 6th globally by number of UNESCO World Heritage Sites (45 sites, as of 2026).
- Italy and China lead in number of World Heritage Sites, followed by Germany, France and Spain.

UNESCO World Heritage Sites in India (2026)

- Total: 45 sites, 37 Cultural, 7 Natural, 1 Mixed.

- Latest additions: Maratha Military Landscapes of India (44th, 2025); Ancient Buddhist Site of Sarnath, UP (45th, July 2026, 48th WHC session, Busan, South Korea).

UNESCO World Heritage Sites in India: Cultural

Site	State	Year
Ajanta Caves	Maharashtra	1983
Ellora Caves	Maharashtra	1983
Agra Fort	Uttar Pradesh	1983
Taj Mahal	Uttar Pradesh	1983
Konark Sun Temple	Odisha	1984
Group of Monuments at Mahabalipuram	Tamil Nadu	1984
Churches and Convents of Goa	Goa	1986
Khajuraho Group of Monuments	Madhya Pradesh	1986
Group of Monuments at Hampi	Karnataka	1986
Fatehpur Sikri	Uttar Pradesh	1986
Group of Monuments at Pattadakal	Karnataka	1987
Elephanta Caves	Maharashtra	1987
Great Living Chola Temples	Tamil Nadu	1987
Buddhist Monuments at Sanchi	Madhya Pradesh	1989
Humayun's Tomb	Delhi	1993
Qutb Minar Complex	Delhi	1993
Mountain Railways of India	WB/TN/HP (multiple)	1999
Mahabodhi Temple Complex, Bodh Gaya	Bihar	2002
Rock Shelters of Bhimbetka	Madhya Pradesh	2003
Chhatrapati Shivaji Terminus	Maharashtra	2004
Champaner-Pavagadh Archaeological Park	Gujarat	2004
Red Fort Complex	Delhi	2007
Jantar Mantar, Jaipur	Rajasthan	2010
Hill Forts of Rajasthan	Rajasthan	2013
Rani-ki-Vav (Queen's Stepwell)	Gujarat	2014
Archaeological Site of Nalanda Mahavihara	Bihar	2016
Architectural Work of Le Corbusier	Chandigarh	2016
Historic City of Ahmedabad	Gujarat	2017
Victorian Gothic and Art Deco Ensembles of Mumbai	Maharashtra	2018
Jaipur City	Rajasthan	2019
Dholavira: A Harappan City	Gujarat	2021
Kakatiya Rudreshwara (Ramappa) Temple	Telangana	2021
Santiniketan	West Bengal	2023
Sacred Ensembles of the Hoysalas	Karnataka	2023
Moidams – Mound-Burial System of the Ahom Dynasty	Assam	2024
Maratha Military Landscapes of India	Maharashtra/Tamil Nadu (multiple)	2025

Site	State	Year
Ancient Buddhist Site of Sarnath	Uttar Pradesh	2026

UNESCO World Heritage Sites in India: Natural & Mixed

Site	State	Type
Kaziranga National Park	Assam	Natural
Manas Wildlife Sanctuary	Assam	Natural
Keoladeo National Park	Rajasthan	Natural
Sundarbans National Park	West Bengal	Natural
Nanda Devi and Valley of Flowers National Parks	Uttarakhand	Natural
Western Ghats	Karnataka/Kerala/TN/Maharashtra (multiple)	Natural
Great Himalayan National Park	Himachal Pradesh	Natural
Khangchendzonga National Park	Sikkim	Mixed

Tourism Circuits & Government Schemes

- Swadesh Darshan Scheme: launched 2014-15 by Ministry of Tourism for integrated, theme-based tourism circuit development (Buddhist, Coastal, Desert, Eco, Heritage, Himalayan, Krishna, North-East, Ramayana, Rural, Spiritual, Tribal, Wildlife circuits, etc.).
- Swadesh Darshan 2.0: revamped version shifting focus to destination-centric, sustainable/responsible tourism development.
- PRASHAD Scheme (Pilgrimage Rejuvenation And Spiritual Augmentation Drive): launched 2014-15 by Ministry of Tourism for integrated development of pilgrimage and heritage destinations.
- Dekho Apna Desh initiative: promotes domestic tourism among Indian citizens.
- "Atithi Devo Bhava": campaign promoting hospitable/responsible behaviour toward tourists.

Miscellaneous

Geographical Indication (GI) Tags: Select Examples

- GI tag identifies a product as originating from a specific geographical region, possessing qualities/reputation due to that origin; administered under the Geographical Indications of Goods (Registration & Protection) Act, 1999.
- Darjeeling Tea (West Bengal) was India's first GI-tagged product (2004).

Select GI-Tagged Products by State

Product	State
Darjeeling Tea	West Bengal
Banarasi Saree	Uttar Pradesh
Nagpur Orange	Maharashtra
Kolhapuri Chappal	Maharashtra & Karnataka
Mysore Silk	Karnataka
Pochampally Ikat	Telangana
Tirupati Laddu	Andhra Pradesh
Basmati Rice	Punjab, Haryana, UP, Himachal Pradesh, J&K, Delhi, Uttarakhand

UP-PSC 2026

PRELIMS

SIMULATOR TESTS

Write Your
Prelims before the
Actual Prelims



SCAN TO
REGISTER

ENGLISH &
हिंदी माध्यम

SIMULATOR - 0
25 OCT
2026

SIMULATOR - 1
01 NOV
2026

SIMULATOR - 2
11 NOV
2026

SIMULATOR - 3
22 NOV
2026

SIMULATOR - 4
29 NOV
2026

Know your real All-India
rank and percentile—no
illusions, no comfort zones.

Validate **elimination**
techniques, risk-taking
and accuracy at scale.

**WHY
SIMULATOR
TESTS**

Experience exam - day
pressure before the actual
D-Day.

Identify **blind spots** and
course-correct in time.

ONLINE & OFFLINE TEST AT



DELHI



LUCKNOW



PRAYAGRAJ



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