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GEOGRAPHY OPTIONAL PAPER I

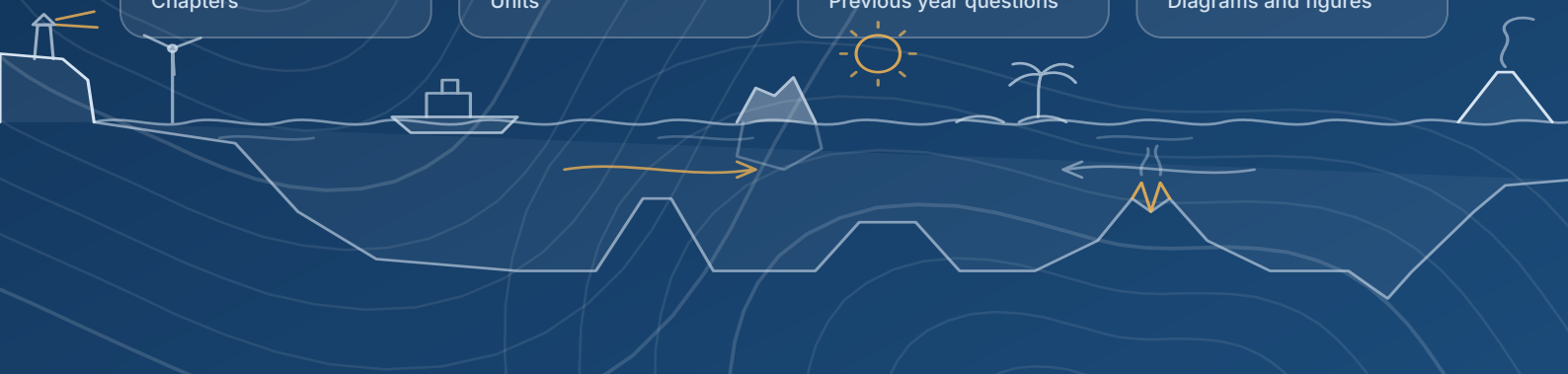
Oceanography Notes

The complete Oceanography section of Paper I — ocean floor, temperature and salinity, budgets and deposits, waves, currents and tides, marine resources, coral reefs, sea level and the law of the sea, with previous year questions.

Compiled by Arvind KrS

OCEAN FLOOR | TEMPERATURE AND SALINITY | CURRENTS AND TIDES | CORAL REEFS | MARINE RESOURCES | LAW OF THE SEA

24	8	72	88
Chapters	Units	Previous year questions	Diagrams and figures



IN THIS BOOK

01 The Ocean Floor and Bottom Topography

02 Temperature, Salinity and Density

03 Heat and Salt Budgets and Ocean Deposits

04 Waves, Currents and Tides

05 Marine Resources

06 Coral Reefs and Coral Bleaching

07 Sea-Level Changes

08 Law of the Sea and Marine Pollution

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Geography Optional — Oceanography

Paper I · Physical Geography: Oceanography

Mains 2027 Edition · Compiled October 2026

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How to read these notes

Every chapter is marked against the questions UPSC has actually asked on it, so the points that matter most stand out on the first read and are quick to find at revision.

Uplift is rapid and short-lived, and erosion starts only after uplift ends.

Yellow marker: key point. A point that carries the ideas UPSC has asked about in this chapter. Read these first, and make sure each one is in your answer.

Isostasy is the state of balance between the crust and the denser mantle beneath.

Blue marker: definition. The cleanest definition of a term, ready to open an answer with.

The landscape is a function of **structure, process and stage**.

Saffron underline: PYQ term. A key term or phrase that appears in this chapter's previous year questions.

Davis's General Theory PYQ 2019 · 2014

PYQ tag on a heading. The years in which UPSC asked about this section. Sections without a tag are background or linking material.

PYQ RADAR **5** questions Last asked **2023**

PYQ radar. At the start of each chapter: how many times the topic has been asked, and how recently. The contents page shows the same count for every chapter.

Suggested method. First read: the whole chapter. Revision: the yellow and blue marks, the tagged headings and the PYQ list at the end of the chapter. Last week before Mains: the PYQ list alone, answering each question in your head from the marked points.

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UNIT 01 | 6 CHAPTERS

The Ocean Floor and Bottom Topography

Bottom topography of the Atlantic, Indian and Pacific Oceans.

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Ocean Morphology and Bottom Relief

PYQ RADAR **6** questions Last asked **2026** 2026 · 2010 · 1999 · 1996 · 1991 · 1989

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01 Studying the Ocean Floor
02 The Continental Margin
03 The Deep Ocean Floor
04 Previous Year Questions

- **Ocean morphology** is the study of the **shape and relief of the ocean basins**: the size, form and arrangement of the features that make up the sea floor. Areas of the floor that share a common relief and origin are grouped as **marine (physiographic) provinces**.
- The ocean floor is not the flat, featureless plain early navigators imagined. It carries the **longest mountain chain** (the mid-ocean ridge system), the **deepest depressions** (trenches) and the **flattest plains** (abyssal plains) on the planet.
- Its relief is built by the same forces that shape the continents, **tectonic, volcanic and depositional**, but with one key difference: **there is almost no subaerial weathering**. Volcanic and faulted forms therefore keep their sharp original shapes.
  - The sea floor is also **young**. Oceanic crust is created at ridges and destroyed at trenches, so almost none of it is older than about **180 million years**, while continental rocks reach 4 billion years.

01 Studying the Ocean Floor PYQ 1996

Bathymetry: measuring ocean depth

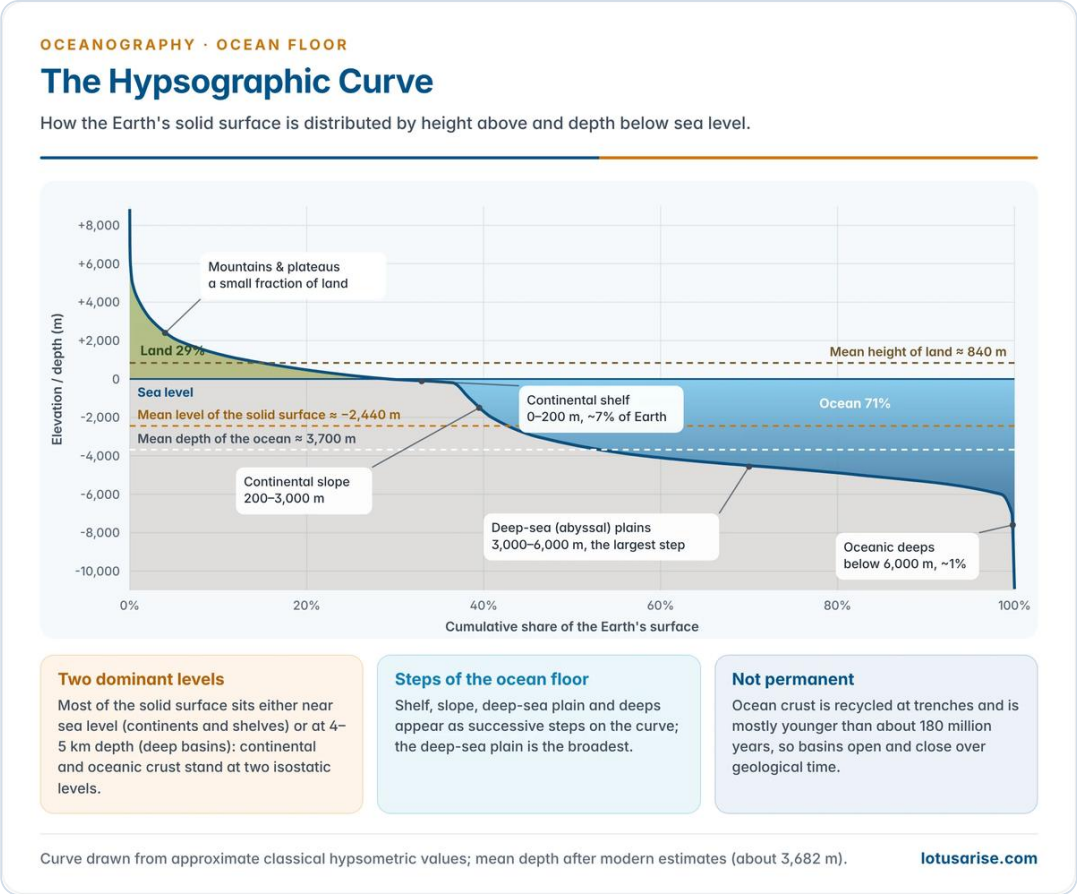
- **Bathymetry** (Greek *bathos*, depth + *metron*, measure) is the measurement of ocean depths and the mapping of submarine relief. It is the marine counterpart of **hypsometry**, which measures land heights.
  - Hypsometry records **positive relief** above sea level; bathymetry records **negative relief** below it.

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- **Line (wire) sounding** was the only method for centuries. A weighted hemp line, and later piano wire, was lowered until it touched bottom.
  - It was slow, since one deep sounding took hours, and inaccurate, because currents bowed the line. Its one advantage was that it could **bring up a bottom sample**.
  - **Matthew Fontaine Maury** used such soundings to publish the first bathymetric chart of the North Atlantic (1854), which helped route the trans-Atlantic telegraph cable (1858).
  - The **Challenger Expedition (1872–76)**, led scientifically by **Charles Wyville Thomson**, made the first systematic deep soundings of the Atlantic, Pacific and Indian Oceans.
- **Echo sounding** times a sound pulse to the bottom and back: depth = ½ × speed of sound in seawater (about 1,500 m/s) × travel time.
  - The German **Meteor Expedition (1925–27)** made the first systematic echo-sounding survey of an ocean, running repeated profiles across the South Atlantic. It revealed the rugged, continuous form of the **Mid-Atlantic Ridge**.
  - **Precision depth recorders** (1950s) gave continuous profiles from moving ships.
- **Modern methods** map swaths and whole basins rather than single lines:
  - **Multibeam echo sounders** map a strip several kilometres wide beneath the ship.
  - **Side-scan sonar** (for example the long-range **GLORIA** system) images the texture of the floor.
  - **Satellite altimetry** measures tiny bulges and dips in the sea surface produced by the gravity of seamounts and trenches, and so maps the whole ocean floor at coarse resolution.
  - **Seismic reflection** and **deep-sea drilling** (the *Glomar Challenger* from 1968, and its successors) reveal the sediments and crust below the floor.
- **Mapping is still incomplete.** The international Seabed 2030 project reported in April 2026 that only about **28.7%** of the world's sea floor has been mapped by direct measurement. The rest is known only from satellite-derived estimates.
- **Marie Tharp** and **Bruce Heezen** drew the first physiographic diagrams of the ocean floors (1950s–1977). Their maps made the global ridge and rift system visible, and so prepared the ground for **sea-floor spreading**.

METHOD	PRINCIPLE	STRENGTH	LIMITATION
Line sounding	Weighted line lowered to the bottom	Brings up a bottom sample	Slow; one point at a time; inaccurate in deep water
Single-beam echo sounding	Time of a sound echo	Continuous profile from a moving ship	Only a line beneath the ship
Multibeam and side-scan sonar	Fan of sound beams	Swath maps of relief and texture	Ship-based, costly, slow to cover the ocean
Satellite altimetry	Sea-surface height reflects gravity of the floor	Whole-ocean coverage	Coarse; small features missed

The hypsographic curve PYQ 1991



- The **hypsographic (hypsometric) curve** plots the **cumulative percentage of the Earth's surface** against **elevation above and depth below sea level**.
  - About 29% of the surface is land and 71% is ocean.
  - The mean height of land is about 840 m. The mean depth of the ocean is about 3,700 m (a 2010 recalculation gives 3,682 m).
  - The **mean level of the solid surface**, if all relief were levelled, lies about 2,440 m below sea level.
- On the ocean side the curve shows **four steps**: the **continental shelf**, the **continental slope**, the **deep-sea plain** and the **oceanic deeps**. The deep-sea plain, at about 3–6 km, is by far the broadest step.
- **The curve has two dominant levels**, one near sea level and one at 4–5 km depth.
  - This reflects **two kinds of crust** floating at different **isostatic** levels: thick, light **continental (granitic)** crust and thin, dense **oceanic (basaltic)** crust.
- **Are these units permanent?** The older idea of the **permanence of continents and ocean basins** has been abandoned.
  - Oceanic crust is **continually created and consumed**, so ocean basins open, widen and close over **Wilson cycles** of a few hundred million years. The Atlantic is opening while the Pacific is shrinking.
  - **Continental margins are not fixed either.** Sea-level change floods or exposes the shelves, which were dry land at the last glacial maximum.

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Marine provinces: classifications

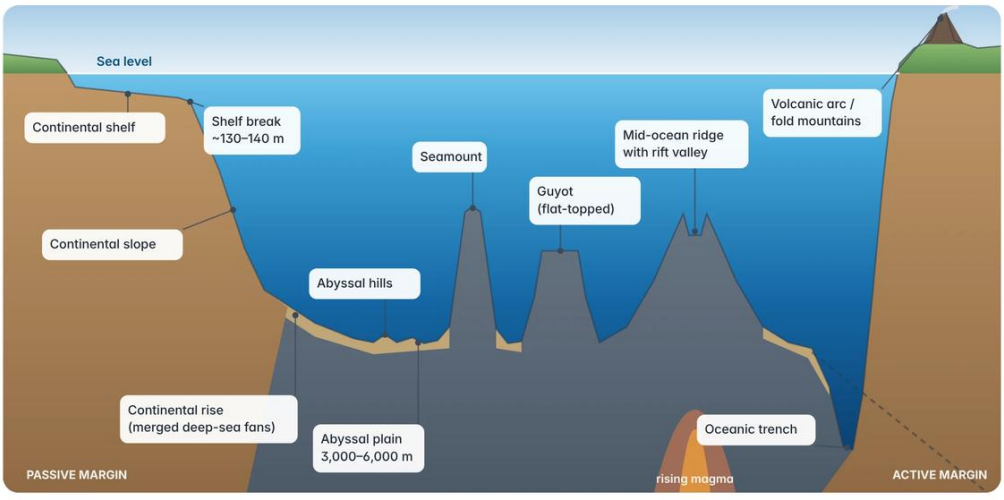
- The **classical four-fold division**, read off the hypsographic curve, is: continental shelf, continental slope, deep-sea plain and oceanic deeps.
- A **modern three-fold, process-based division** is now common:
  - **continental margins** (shelf, slope and rise);
  - **deep-ocean basins** (abyssal plains, abyssal hills, seamounts, guyots and trenches);
  - **mid-ocean ridges**.
- **Combining the two** gives the scheme used here, which treats submarine canyons, the continental rise, ridges and trenches as distinct elements.

SCHEME	UNITS	BASIS	WEAKNESS
Classical (four-fold)	Shelf, slope, deep-sea plain, deeps	Depth zones of the hypsographic curve	Ignores ridges and the rise
Modern (three-fold)	Continental margin, deep-ocean basin, mid-ocean ridge	Crust type and plate setting	Lumps very different forms together
Combined (used here)	Shelf, slope, canyons, rise, abyssal floor, seamounts and guyots, trenches, ridges	Form and origin	Longer, but complete

OCEANOGRAPHY · OCEAN FLOOR

Relief Features of the Ocean Floor

A transect from a passive continental margin across the deep basin and a mid-ocean ridge to a trench at an active margin.



Continental margin
- Shelf, slope and rise
- Built of continental (granitic) crust
- About a fifth of the ocean floor

Deep ocean basin
- Abyssal plains, hills, seamounts, guyots
- Basaltic oceanic crust
- Flattest surfaces on Earth

Ridges and trenches
- Ridges: new crust at divergent margins
- Trenches: crust consumed at subduction zones
- Set by plate tectonics

Schematic; vertical scale exaggerated about 100 times. lotusarise.com

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02 The Continental Margin

- The **continental margin** is the submerged edge of a continent: **shelf, slope and rise**.
  - Geologically it is still **continent**, built of **continental crust** and a wedge of land-derived sediment, even though it lies under the sea.
  - Taken together, the margins cover roughly **a fifth of the ocean floor**.
- There are **two types of margin**, depending on their plate setting:

FEATURE	PASSIVE (ATLANTIC-TYPE) MARGIN	ACTIVE (PACIFIC-TYPE) MARGIN
Plate setting	Inside a plate; an old rifted edge	At a convergent or transform plate boundary
Shelf	Wide	Narrow or absent
Slope and rise	Gentle slope; broad rise of coalesced fans	Steep slope; little or no rise
Next to the deep floor	Abyssal plain	Oceanic trench
Activity	Quiet: few earthquakes, no volcanoes	Earthquakes, volcanoes, young fold mountains
Examples	East coasts of the Americas; India's east and west coasts	West coast of South America; Japan; Sumatra–Java

Continental shelf

- The **continental shelf** is the **gently sloping, shallow submerged platform** that fringes a continent. It runs from the shore out to the **shelf break**, where the gradient steepens sharply.
  - **Gradient:** very gentle, on average about 0.1° (roughly 2 m per km) and rarely more than 1°.
  - **Depth at the break:** averages about 130–140 m. It is traditionally taken as the 100-fathom (about 180–200 m) line, and reaches about 350 m around Antarctica, where the weight of the ice sheet has pushed the crust down.
  - **Width:** averages about 70–80 km, but ranges from almost nothing to more than 1,200 km. The broadest shelves are off northern Siberia in the Arctic, the Sunda Shelf of South-East Asia, and the Yellow and East China Seas.
  - **Area:** about 7–8% of the ocean floor. It is proportionately largest in the Atlantic, with its many marginal seas, and smallest in the Indian Ocean.
- Width is controlled by the coast behind it:
  - Narrow where young fold mountains run along the coast. The shelf off Chile and Peru is often under 20 km wide because the Andes rise straight from the sea at an active margin.
  - Wide off broad lowlands, large deltas and glaciated coasts, as on the Atlantic coast of North America and in the North Sea.

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- The shelves were dry land during glacial periods.
  - At the last glacial maximum (about 20,000 years ago) sea level stood about 120–130 m lower. Most shelves were exposed, crossed by rivers and grazed by animals; mammoth teeth are still dredged from the North Sea.
  - **Drowned river valleys, relict beaches and terraces** survive on many shelves.
- The shelf has great economic and strategic value:
  - Sunlight reaches the bottom and nutrients arrive from land, so shelves yield most of the **world's fish catch**. Examples are the Grand Banks, Dogger Bank (North Sea) and Sunda Shelf.
  - Their thick sediments hold a large share of **offshore oil and gas** (Mumbai High, about 160 km off Mumbai; North Sea; Gulf of Mexico) and **placer deposits** such as tin off Malaysia and Indonesia, and ilmenite and monazite sands along the Kerala coast and inner shelf.
  - They give coastal states sovereign rights over the **legal continental shelf** under **UNCLOS**.
  - A broad, shallow shelf **slows and heightens tides and storm surges**. This is why the head of the Bay of Bengal suffers some of the world's highest cyclone surges.

Origin of continental shelves

- **No single process explains all shelves.** Most are **polygenetic**:

VIEW	PROCESS	TYPICAL EXAMPLE
Drowning (submergence)	Rise of sea level or sinking of the continental edge floods the coastal plain	Most shelves after the post-glacial sea-level rise
Constructional (depositional)	Rivers build a wedge of sediment that grows seaward while the margin slowly subsides under its load	Off the Amazon and Ganga–Brahmaputra
Wave-cut and wave-built	Waves cut a platform; the eroded debris builds a terrace at its outer edge	Narrow shelves round Iceland and the Faroes
Glacial control (Reginald Aldworth Daly)	Pleistocene sea-level fall exposed margins to glacial and wave erosion; the platforms were drowned when the ice melted	Glaciated shelf off Norway, with deep troughs and moraines
Faulting	Coast-parallel faults let the margin subside	Red Sea; west coast of India
Delta growth	A fast-growing delta extends a local shelf	Mississippi delta
Coral-built	Reef growth forms a platform with a very steep outer slope	Lakshadweep, Gulf of Mannar, Great Barrier Reef

- **The modern explanation** comes from plate tectonics. A **passive-margin shelf** is the top of a thick sediment wedge resting on stretched continental crust.
  - The crust was thinned when the continents rifted apart. It has **subsided as it cooled**, and the wedge has kept pace through sedimentation.

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- **Quaternary sea-level swings** have repeatedly planed and drowned its surface.

Continental shelf of India

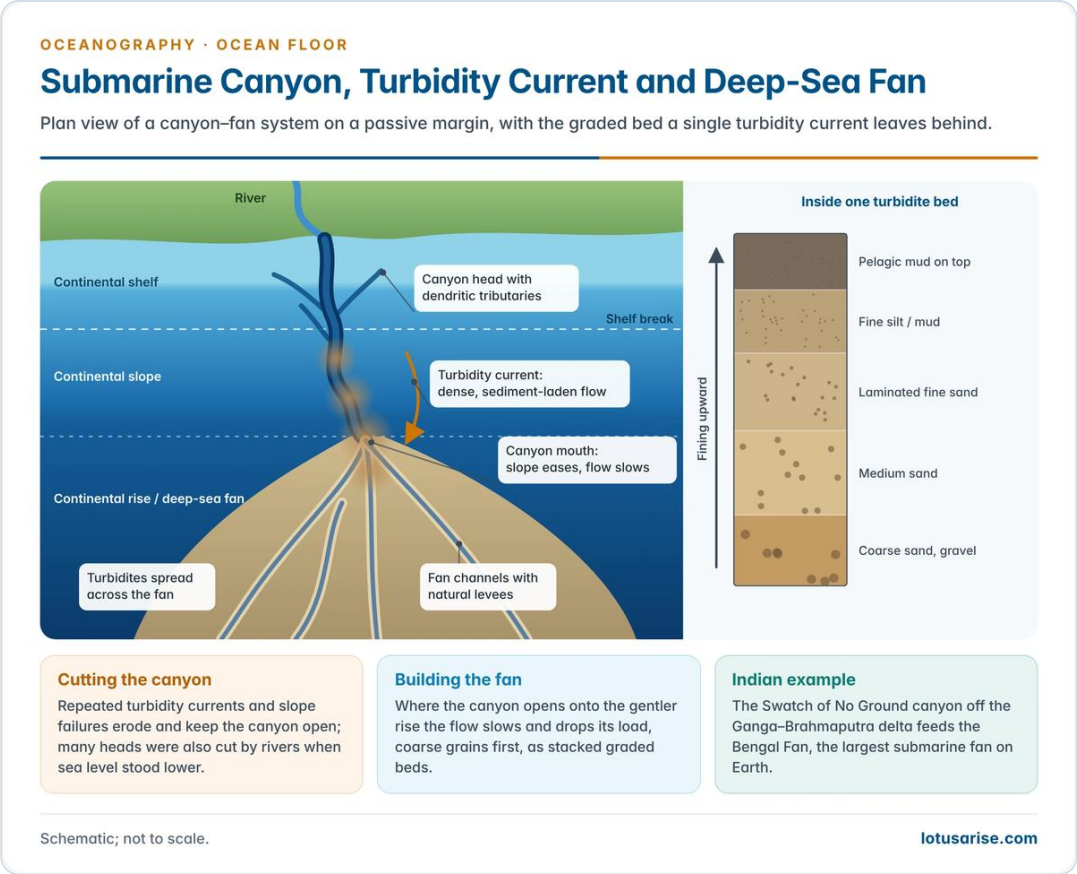
- The west coast shelf is far wider than the east coast shelf.
  - The west coast shelf is widest off Gujarat and Maharashtra, where it forms the Bombay offshore basin.
  - The east coast shelf is narrow, especially off the deltas of the Ganga, Mahanadi, Godavari, Krishna and Kaveri, where sediment builds outward and the slope plunges quickly.
- **Different processes shaped different stretches:**
  - **faulting and subsidence** along the west coast, part of the rifted margin left when India broke from Madagascar and the Seychelles;
  - **deltaic growth** off the east-coast rivers;
  - **sedimentation with subsidence** along the Coromandel coast;
  - **coral growth** around Lakshadweep, the Andaman–Nicobar Islands and the Gulf of Mannar.

Continental slope

- The **continental slope** descends from the shelf break (about 130–200 m) to about 2,000–3,000 m. It is the true **edge of the continent**, where continental crust gives way to oceanic crust.
  - **Gradient:** averages about 4° and ranges from 1° to over 25°. It is steepest off **volcanic islands and active margins**, where it averages above 5° around the Pacific, and gentlest off large deltas.
  - **Area:** about 8.5% of the ocean floor.
  - **Relief:** the slope is cut by **submarine canyons** and scarred by **slumps and slides**.
- **Sediments are thin** for three reasons: material **slides or is carried down** to the rise, the slope lies far from land-derived supply, and **turbidity currents** sweep it clean.
  - With little light, plant life is scarce and **benthic life is sparse**.
- **The slope has more than one origin:**
  - **Fault scarps**, mainly on active and rifted margins.
  - The **prograding front of the sediment wedge**, mainly on passive margins.
  - **Down-warping (flexure)** of the continental edge.
  - **Reef talus** below coral platforms.

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Submarine canyons PYQ 1999



- **Submarine canyons** are **long, narrow, steep-walled, V-shaped valleys** cut into the continental shelf and slope. They often run on to the rise and the deep-sea fans.
  - Many are comparable in size to the Grand Canyon of the Colorado. Monterey Canyon off California is the classic example.
  - Most run **at right angles to the coast** and many lie **opposite large river mouths**, such as the Hudson, Congo and Indus. Others have no river connection.
  - Some are **winding**. Many have **dendritic tributaries** at their heads, like land valleys.
  - Their **walls expose rocks of many ages**, from soft shales to granite. Their **floors carry coarser sediment** (sand, gravel, pebbles) than the shelf on either side, which shows that strong currents pass through them.
- **Size and form:**
  - **Average length** is a few tens of kilometres. Large canyons extend for hundreds, and the Congo Canyon continues seaward as a fan valley for hundreds of kilometres.
  - **Wall height** is commonly a few hundred metres to over 1,000 m.
  - **Longitudinal gradient** is steeper than that of land canyons. It averages a few per cent and is steepest off islands.
- **Distribution:**
  - **No latitudinal control.** Canyons are common along **straight coasts** of both **stable and active** margins.

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- Major areas are the US Atlantic coast from Cape Cod to Cape Hatteras, California and Mexico, Japan and the Aleutians, the northern Mediterranean, the Bay of Biscay and Portugal (Nazaré Canyon, one of Europe's deepest), and West Africa.
- Hudson Canyon was the first to be described, in 1885.

- **Indian examples:**
  - The **Swatch of No Ground** is a canyon cutting diagonally across the shelf south of the Ganga–Brahmaputra delta. Its flat floor is about 5–7 km wide and about 1,200 m deep at the shelf edge. It is a channel that feeds sediment to the Bengal Fan, and a known cetacean habitat.
  - Smaller **east-coast canyons** lie off the Mahanadi (Paradip), Godavari, Krishna, Penneru, Palar, Puducherry and Cuddalore coasts.
  - The Indus Canyon lies off the Indus delta on the western margin.

Theories of origin of submarine canyons

- **Glacial canyons** are broad troughs cut by ice on high-latitude shelves, as off Norway and in the Arctic. They are easy to explain. The debate concerns the far more numerous **non-glacial canyons**:

THEORY	MAIN PROPONENTS	MECHANISM	CRITICISM
Subaerial erosion (drowned river valleys)	James Dwight Dana; **Francis Parker Shepard** (early view)	Rivers cut valleys across the exposed shelf and slope when sea level was low; the valleys were later drowned	Pleistocene sea level fell only about 120–130 m, which cannot explain canyons cut to 2,000 m and more. Shepard later accepted that several processes are involved
Diastrophic (tectonic)	De Andrade, Andrew Cowper Lawson, John Walter Gregory, Jacques Bourcart	Faulting, warping and graben formation along the margin	Faults usually run parallel to the coast, canyons across it; dendritic tributaries are not tectonic; many canyons lie on quiet Atlantic margins
Density currents	François-Alphonse Forel (for lake trenches)	Dense river water flowing along the floor erodes a channel and builds levees	Such currents are weak and are mostly confined to lakes and enclosed seas
Turbidity currents	**Reginald Aldworth Daly (1936)**; later **Philip Henry Kuenen**, **Bruce Heezen and Maurice Ewing**	Dense, sediment-laden flows rush down the slope, erode the floor and keep canyons open	Early doubts that they could cut hard rock; now regarded as the main agent of canyon cutting below the shelf
Slumps and mudflows	Shepard and Kenneth Orris Emery	Slope failures and mudflows deepen and widen canyons	Deepen existing canyons rather than create them

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THEORY	MAIN PROPONENTS	MECHANISM	CRITICISM
Spring sapping	Douglas Wilson Johnson (1939)	Groundwater emerging on the slope dissolves and undermines rock	Too slow and too local to explain canyons worldwide
Tsunami currents	—	Powerful backwash of tsunamis scours the slope	Tsunamis are mostly a Pacific phenomenon, while canyons are found worldwide

- The 1929 Grand Banks earthquake proved the turbidity-current idea. A slope failure off Newfoundland broke **trans-Atlantic telegraph cables in sequence**, farther and farther downslope over about 13 hours.
  - From the timing of the breaks, **Bruce Heezen and Maurice Ewing (1952)** showed that a **turbidity current** had raced down the slope at **tens of kilometres per hour**, spreading a graded sand layer over the abyssal plain.
- **Present-day monitoring confirms it.** A **2015–17 instrumented study of Monterey Canyon** recorded 15 flows.
  - Most began near the canyon head in under about 300 m of water. The three largest ran more than 50 km down the canyon.
  - The study found that the upper metres of the canyon floor itself move as a dense, fluid sediment layer. The dilute sediment cloud above is only a secondary effect.
- **The accepted view is polygenetic,** close to the position of **Philip Henry Kuenen**:
  - Many canyon heads began as **river valleys cut at low sea levels**.
  - **Turbidity currents, slumps and other mass flows** have **deepened and extended** them down the slope.
  - **Tectonics** decides where canyons form on active margins.

Continental rise and deep-sea fans

- **Deep-sea (submarine) fans** are **fan- or cone-shaped piles of sediment** at the mouths of submarine canyons, at the foot of the slope. They are the marine counterpart of alluvial fans.
  - They are built by **turbidity currents**, which slow and spread out where the canyon opens onto the gentler floor.
  - Each flow leaves a **turbidite**, a bed that **fines upward** from coarse sand at the base to silt and mud at the top (**graded bedding**).
  - The fan surface is crossed by **channels flanked by natural levees** that branch like distributaries, and by abandoned channels.
- **Coalescing fans form the continental rise:**
  - a **gentle apron** with a gradient of about 1:100 to 1:800, between about 1,500 and 5,000 m deep, up to several hundred kilometres wide, merging seaward into the abyssal plain;
  - well developed in the Atlantic and Indian Oceans;
  - **rare in the Pacific**, where trenches at the foot of the slope trap the sediment before it can spread.

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- The Indian Ocean has the world's two largest fans:
  - The **Bengal Fan** is the **largest submarine fan on Earth**, about 3,000 km long and 1,400 km wide, with sediment up to about 16.5 km thick. It is built of Himalayan sediment delivered by the Ganga–Brahmaputra through the Swatch of No Ground.
  - The **Indus Fan** in the Arabian Sea is the **second largest**.
  - Both are a record of **Himalayan uplift and monsoon erosion** over tens of millions of years.

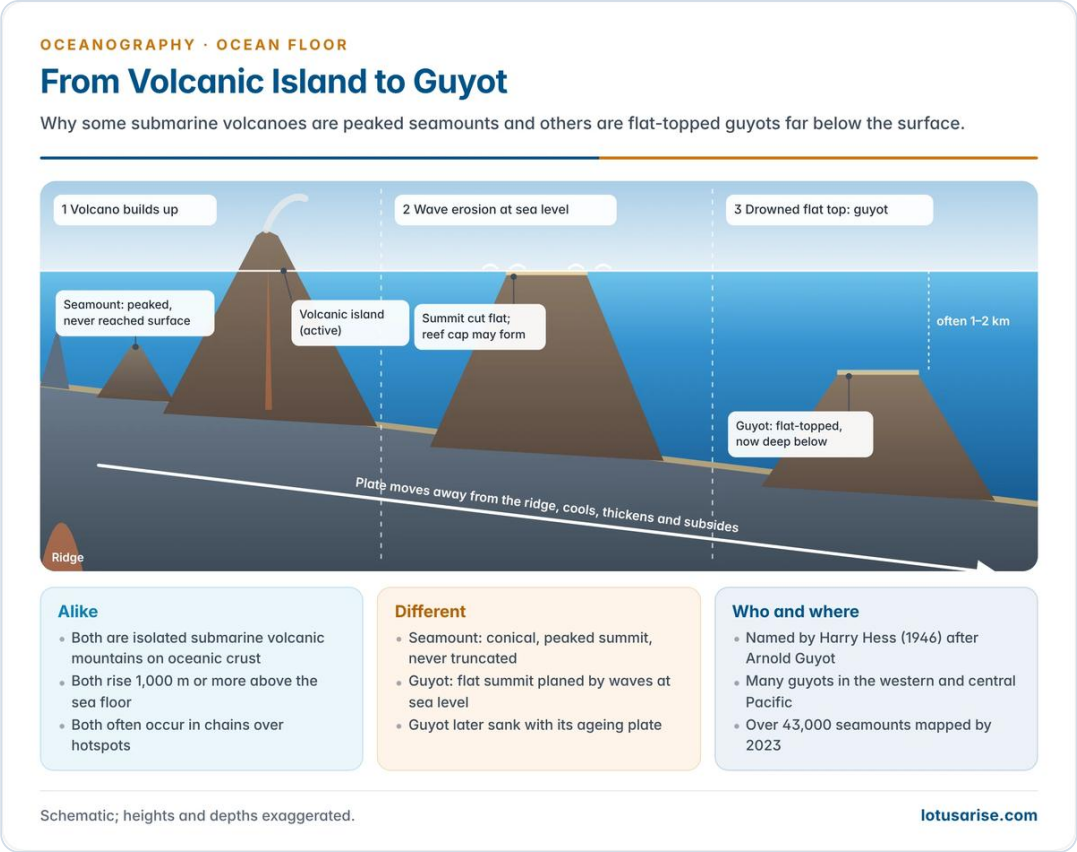
03 The Deep Ocean Floor PYQ 1996

Abyssal plains

- **Abyssal (deep-sea) plains** are **very flat, sediment-covered surfaces** at about 3,000–6,000 m. They are the **flattest surfaces on Earth**, with slopes gentler than 1:1,000, flatter than any land plain.
- **How they form:**
  - Turbidity currents and slow **pelagic settling** blanket the **rough basaltic crust** and **bury the abyssal hills** beneath hundreds of metres of sediment.
  - **Turbidites** spread from the rise. Far from land, the floor carries **pelagic oozes** made of plankton shells, and **red clay**, which is fine wind-blown and volcanic dust in the deepest basins.
- **Their extent differs between the oceans:**
  - **Extensive in the Atlantic and Indian Oceans.** Their **passive margins** let land sediment reach the deep floor; the Bengal and Indus fans feed the Indian Ocean plains.
  - **Limited in the Pacific. Trenches round its rim trap** the sediment, so the Pacific floor is dominated by abyssal hills.
- Even the "plains" carry relief. Continuous echo sounding shows **hills, seamounts, fracture zones and channels** rising sharply from them.

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Abyssal hills, seamounts and guyots PYQ 2026



- **Abyssal hills** are the **most widespread landform on Earth**, covering much of the deep floor on the ridge flanks.
  - They are low hills, usually under 1,000 m high and a few kilometres across, arranged in lines **parallel to the ridge**.
  - Most are **fault blocks and small volcanoes** formed as new crust is stretched at the ridge axis. They are best exposed in the Pacific, where little sediment buries them; such areas are called **abyssal hill provinces**.
- **Seamounts** are **isolated submarine volcanoes**, conventionally more than 1,000 m high, with **peaked, conical summits** that stay below sea level. Smaller ones are called **knolls**.
  - They occur singly or in **chains over hotspots**. The Hawaiian–Emperor chain records the Pacific Plate moving over the Hawaiian hotspot.
  - Satellite gravity mapping in 2023 added about 19,300 new seamounts, bringing the catalogue to about 43,000. Many thousands more are thought to remain undetected.
  - Seamounts are **biological hotspots**, because currents deflected up their flanks bring nutrients up. They are also targets for **cobalt-rich ferromanganese crusts**.
- **Guyots (tablemounts)** are **flat-topped seamounts**. The term was coined by **Harry Hammond Hess (1946)**, after the geographer **Arnold Henry Guyot**.
  - **Their origin, as Hess explained it:**
    - The volcano grows into an island near a ridge or over a hotspot.
    - Once extinct, its summit is **planed flat by waves at sea level**, and a coral reef may cap it.

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        - The plate carries it away and **cools and subsides**, so the flat top sinks, often 1–2 km below the surface.
    - Dredged **shallow-water fossils, rounded cobbles and reef limestone** from guyot tops confirm that the summits were once at sea level.
    - Guyots are most numerous in the western and central Pacific, between Hawaii and the Marianas.

FEATURE	SEAMOUNT	GUYOT
Origin	Submarine volcano	Submarine volcano that once reached sea level
Summit	Peaked, conical	Flat, wave-planed, sometimes reef-capped
Depth of summit	Never reached the surface	Commonly 1–2 km below sea level after subsidence
Evidence	Volcanic rock	Shallow-water fossils, beach cobbles, reef limestone
Link to coral atolls	—	A drowned atoll is one route to a guyot when subsidence outpaces reef growth

- The link to atolls is the same subsidence that **Charles Darwin** invoked for **coral reefs and atolls**. A guyot is in effect a reef platform that sank too fast for coral growth to keep pace.

Oceanic trenches and deeps

- **Trenches** are **long, narrow, steep-sided, arc-shaped depressions**, the **deepest parts of the ocean**, commonly 6,000–11,000 m deep.
    - **Troughs** are broader, gentler-sided depressions. **Deeps** are the deepest spots within a trench.
- **Form:** trenches are **asymmetric**. The **landward (arc-side) wall is steeper** than the seaward wall. They run parallel to young fold mountains or to the convex side of island arcs.
- **Origin:** trenches mark **subduction zones**, where **oceanic lithosphere bends down beneath another plate**.
    - This explains their **belts of deep earthquakes** (the **Wadati–Benioff zone**), the **volcanic arcs** beside them, and their concentration round the **Pacific Ring of Fire**.
    - They are **rare in mid-ocean**. In the Atlantic they occur only at the Puerto Rico and South Sandwich arcs, and in the Indian Ocean mainly at the Java (Sunda) Trench off Sumatra and Java.
- **The deepest point on Earth** is the **Challenger Deep** in the **Mariana Trench**. A 2021 NOAA analysis put it at about 10,935 m, so Mount Everest would sink with about 2 km of water to spare.
    - It was first reached in 1960 by **Jacques Piccard and Don Walsh** in the bathyscaphe *Trieste*.
    - India's **Deep Ocean Mission** is building the crewed submersible Matsya-6000, designed for 6,000 m.

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OCEAN	DEEPEST POINT	APPROXIMATE DEPTH (M)
Pacific	Challenger Deep, Mariana Trench	10,935
Atlantic	Puerto Rico Trench	8,376
Southern	South Sandwich Trench (southern end)	7,434
Indian	Java (Sunda) Trench	7,192
Arctic	Molloy Deep, Fram Strait	5,550

- Other very deep trenches are all in the Pacific: the Tonga (about 10,800 m), Philippine (about 10,500 m), **Kuril–Kamchatka** and **Kermadec** trenches.

Mid-ocean ridges

- The **mid-ocean ridge system** is the **longest mountain range on Earth**, about **65,000 km** long. It winds through every ocean like the seam of a ball and rises about 2–3 km above the abyssal floor.
  - It is 1,000–4,000 km wide, broad and gentle rather than peaked, and occupies about **a third of the ocean floor**.
  - It is **not always central.** The **Mid-Atlantic Ridge** and the Carlsberg and Central Indian Ridges lie near mid-ocean, but the **East Pacific Rise** lies well to the east of the Pacific's centre.
  - Where it is **built up by excess volcanism** it rises above sea level, as in Iceland and the Azores.
- **Origin:** ridges are **divergent plate boundaries**. As plates move apart, pressure on the hot mantle falls, it partly melts, and **basaltic magma** wells up to form **new oceanic crust** (**pillow lavas** on the sea floor).
  - Hot, young crust stands high. It **cools, thickens and subsides** as it moves away. This is why **ocean depth increases with crustal age** and why ridges are broad swells.
- **Spreading rate shapes the crest:**

FEATURE	SLOW-SPREADING RIDGE (MID-ATLANTIC RIDGE)	FAST-SPREADING RIDGE (EAST PACIFIC RISE)
Spreading rate	About 2–5 cm/yr	Up to about 15 cm/yr
Crest	Deep **axial rift valley** 1–3 km deep, rugged flanks	Smooth, broad **rise** with no deep rift valley
Profile	Narrower, steeper	Broader, gentler

- **Transform faults** offset the ridge into segments. Their inactive extensions, **fracture zones** such as the Romanche in the equatorial Atlantic, form long scarps and troughs **at right angles to the ridge**.

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- **Hydrothermal vents** were first found in **1977 on the Galápagos Rift**, by the submersible *Alvin*.
  - Seawater seeping into the hot crust is heated and returns rich in dissolved metals.
  - **Black smokers** vent water at about 350–400 °C, laden with metal sulphides. **White smokers** are cooler and rich in barium, calcium and silica.
  - Vents support **chemosynthetic ecosystems** of tube worms, clams and bacteria, independent of sunlight.
  - They build **polymetallic sulphide** deposits. India holds an International Seabed Authority contract (2016) to explore these on the Central and South-West Indian Ridges.

Relief features compared

FEATURE	TYPICAL DEPTH	GRADIENT OR FORM	ORIGIN
Continental shelf	0 to about 130–200 m	About 0.1°	Drowned continent, sediment wedge, sea-level change
Continental slope	200 to about 3,000 m	About 4°	Edge of continental crust; faulting, prograding sediment
Submarine canyon	Cuts shelf and slope	V-shaped, steep-walled	Low-sea-level rivers plus turbidity currents and mass flows
Continental rise and fans	About 1,500–5,000 m	1:100 to 1:800	Coalescing turbidite fans
Abyssal plain	3,000–6,000 m	Under 1:1,000	Sediment burying rough oceanic crust
Seamount and guyot	Summit below the surface	Conical or flat-topped	Intraplate or ridge volcanism; guyots subsided after wave planation
Trench	6,000–11,000 m	Narrow, asymmetric	Subduction of oceanic lithosphere
Mid-ocean ridge	Crest about 2,500 m	Broad swell, rift or rise	Sea-floor spreading at divergent boundaries

Previous Year Questions

2026 How are seamounts and Guyots the same and different? Comment.

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2010	Explain the scientifically sound methods of bathymetry and give an account of the bottom topography of the Atlantic Ocean.
1999	Write short note: Submarine canyons.
1996	Explain and illustrate the ocean floor topography and give a detailed account of the Mid-Atlantic Ridge.
1991	Draw a hypsographic curve to represent the major physiographic units of the ocean and comment on their permanency.
1989	Write short note on ocean bottom relief in about 200 words.

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UNIT 06 | 2 CHAPTERS

Coral Reefs and Coral Bleaching

Coral reefs, coral bleaching.

CHAPTERS

19 Coral Reefs and Coral Bleaching 270
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Coral Reefs and Coral Bleaching

PYQ RADAR 7 questions Last asked **2025** 2025 · 2022 · 2020 · 2017 · 2014 · 2008 · 1988

CONTENTS

01 Corals and Reef Growth
02 Types and Distribution of Reefs
03 Coral Bleaching
04 Importance, Threats and Conservation
05 Previous Year Questions

- A **coral reef** is a wave-resistant mass of **limestone built by living organisms**, chiefly corals and coralline algae, in shallow tropical seas.
- Reefs cover less than 0.1% of the ocean floor but shelter about **a quarter of all marine species**: the rainforests of the sea.
- **Coral bleaching**, the loss of the algae that feed corals, is now their greatest threat; four global events have struck since 1998.

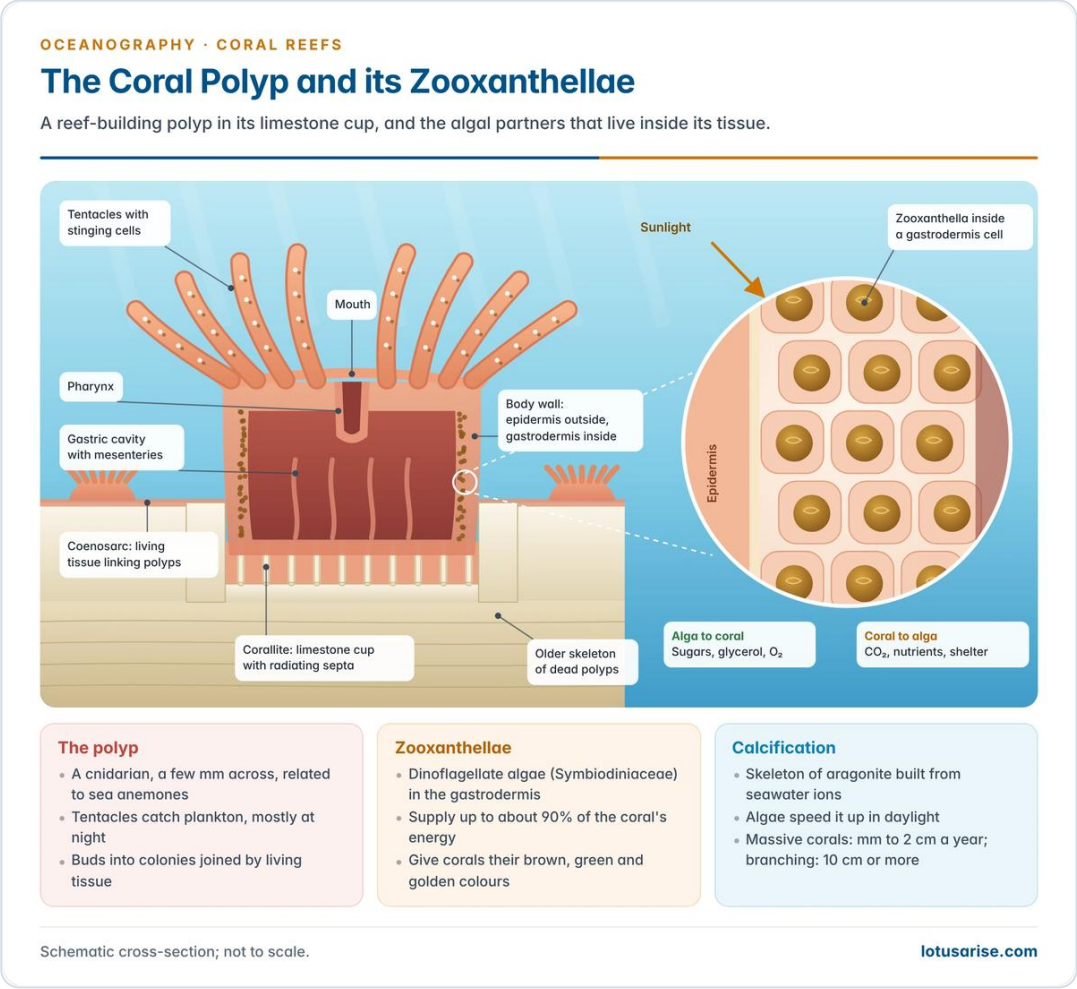
01 Corals and Reef Growth

PYQ 2025 · 2008 · 1988

The coral polyp and its partner alga

- A **coral polyp** is a tiny **cnidarian**, a relative of sea anemones: a tube of tissue with a mouth ringed by stinging tentacles.
  - It secretes a **limestone cup (corallite)**, divided by radiating septa, beneath itself.
  - Polyps bud into a **colony** linked by living tissue. New polyps grow on dead skeletons, so the reef builds upward and outward.
- **Hermatypic corals** build reefs and carry symbiotic algae. **Ahermatypic corals** are mostly solitary, lack the algae and range into cold and deep water.

- **Zooxanthellae** are single-celled **dinoflagellate algae** (family Symbiodiniaceae) living inside the polyp's inner tissue.
  - Their photosynthesis supplies **up to about 90% of the coral's energy**, speeds up skeleton building and gives corals their colour.
  - The coral gives them shelter, light, carbon dioxide and nutrients. This **mutualism** lets reefs thrive in clear, nutrient-poor water.
- **Calcification:** the skeleton is **aragonite** (calcium carbonate). Massive corals add a few millimetres to about 2 cm a year; branching *Acropora* can add 10 cm or more.
  - **Coralline algae** cement the rubble and build the algal ridge that faces the surf.



Conditions for coral growth PYQ 2008

FACTOR	REQUIREMENT	REASON
Latitude	Mostly 30°N–30°S	Only tropical water is warm enough all year
Temperature	Optimum about 23–29 °C; reefs rarely form below about 18–20 °C	Narrow thermal range; heat causes bleaching

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FACTOR	REQUIREMENT	REASON
Light and depth	Most growth in the upper 25–30 m; little below 50–60 m	Zooxanthellae need sunlight
Salinity	About 32–40 ‰	Fresh and very saline water both stress polyps
Clear water	Little suspended mud	Silt cuts light and smothers polyps
Firm base	Rocky platform in shallow water	Larvae settle only on hard ground
Water movement	Open water with waves and currents	Brings oxygen and plankton, clears sediment
Exposure	Not above low-tide level for long	Polyps die when dried out

- **Reefs are scarce on tropical west coasts** (Peru, Namibia, California, north-west Africa), where **cold currents and upwelling** chill the water. Warm currents feed the east-coast reefs of Queensland, East Africa and the Caribbean.
  - **Western Australia is the exception:** the warm Leeuwin Current sustains **Ningaloo Reef**.
- Reefs **break off at large river mouths**, such as the Ganga–Brahmaputra, because of fresh, muddy water.
- Corals **grow faster on the seaward side**, where surf brings food and oxygen; hence the raised outer rim and slow growth in lagoons.
- **Warm currents carry reefs poleward:** the Gulf Stream to Bermuda (32°N), the Kuroshio to southern Japan.

Zones of a reef

ZONE	POSITION	FEATURES
Fore reef (reef front)	Steep outer slope	Spurs and grooves (buttress zone); fore-reef talus below
Reef crest and algal ridge	Seaward edge at low-tide level	Breaking waves; coralline algae
Reef flat	Behind the crest	Rubble and sand platform; coral cays may form
Back reef and lagoon	Sheltered side	Patch reefs, coral pinnacles, fine sediment

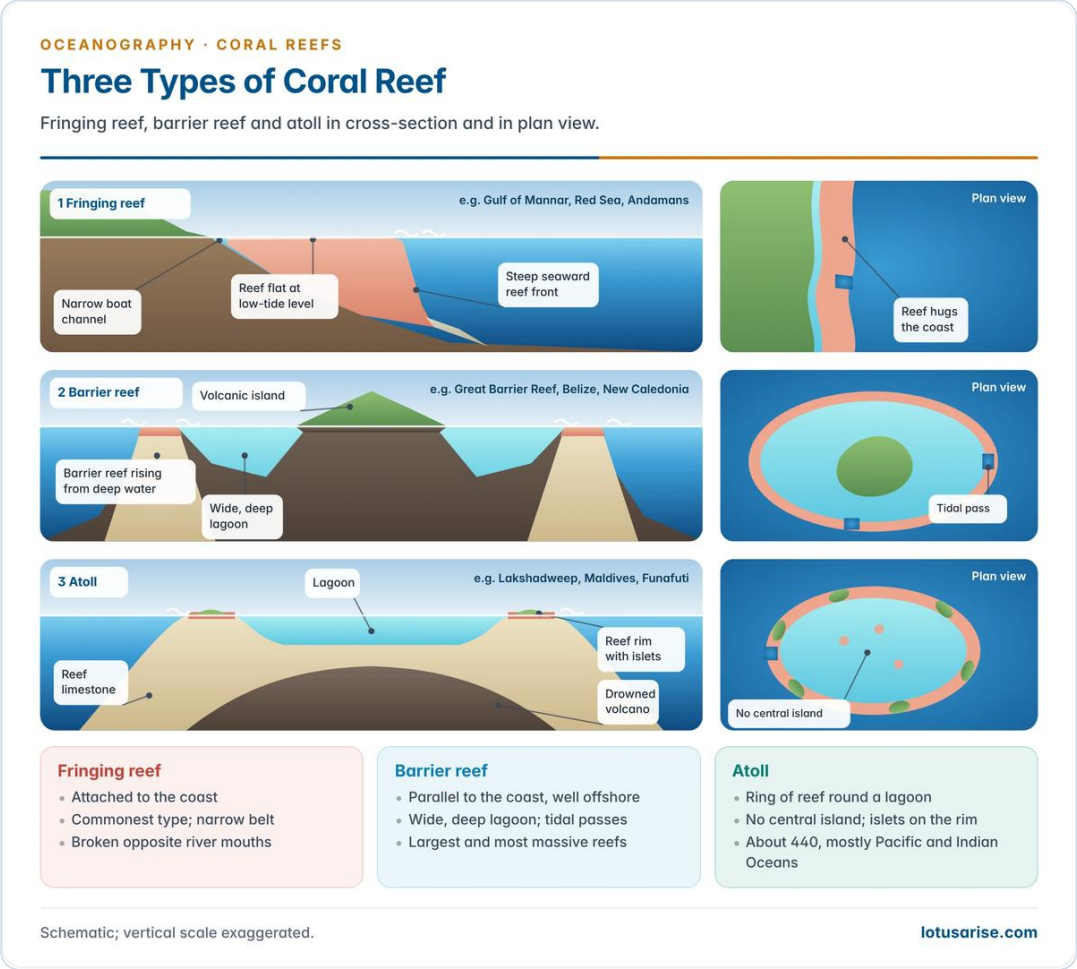
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02 Types and Distribution of Reefs PYQ 2025 · 2008 · 1988

Types of coral reefs PYQ 2025 · 2008 · 1988

- **Charles Darwin (1842)** divided reefs by their relation to land into fringing reefs, barrier reefs and atolls, the scheme still used.
- **Fringing reefs** are **attached to the shore**, or separated only by a narrow boat channel. They are the commonest type.
- **Barrier reefs** run **parallel to the coast but well offshore**, beyond a wide, deep lagoon, and are broken by tidal passes.
  - The **Great Barrier Reef**, the largest reef system on Earth, runs about 2,300 km off Queensland (about 10°S–24°S) as nearly 3,000 separate reefs.
- **Atolls** are **ring-shaped reefs enclosing a lagoon** with no central island. About 440 exist, almost all in the Pacific and Indian Oceans.
  - The Maldives also have **faros**, small ring reefs on the rim of a larger atoll.
- **Minor forms:** patch reefs (small reefs in lagoons or on shelves), platform (table) reefs (flat-topped shelf reefs with little or no lagoon) and coral banks (shapeless submerged reefs).
- Barrier reefs and atolls **rise from depths far below the limit of living coral**. **Theories of their origin** invoke a subsiding island, as Darwin argued, or platforms shaped by **Pleistocene sea-level change**.

FEATURE	FRINGING REEF	BARRIER REEF	ATOLL
Relation to land	Attached or nearly so	Parallel to coast, well offshore	Encircles a lagoon; land absent or only islets
Lagoon	None, or a narrow boat channel	Wide and deep	Central, enclosed, a few tens of metres deep
Size	Narrow belt, up to a few km wide	Hundreds to thousands of km long	A few km to tens of km across
Base	Shallow platform near the shore	Rises from deep water	Rises from the deep floor, often on a drowned volcano
Examples	Gulf of Mannar, Red Sea, Andamans, Ningaloo	Great Barrier Reef, Belize, New Caledonia	Lakshadweep, Maldives, Funafuti (Tuvalu), Marshall Islands



Coral coasts and low-energy coasts

- A **coral coast** is a **biogenic coast built by reef growth**; its reef crest takes the surf, sheltering the lagoon and shore.
- A **low-energy coast** has **weak waves** (shelter, a wide shallow shelf or short fetch) and is built of fine sediment, as in the Sundarbans mangroves.

BASIS	CORAL COAST	LOW-ENERGY COAST
Builder	Living organisms (corals, algae)	Fine marine and river sediment
Water	Warm, clear, low in nutrients	Often turbid and nutrient-rich
Wave energy	High at the reef front, low behind	Low throughout
Landforms	Reef flat, lagoon, cays, atolls	Mudflats, salt marshes, mangroves
Latitude	Tropical	Any

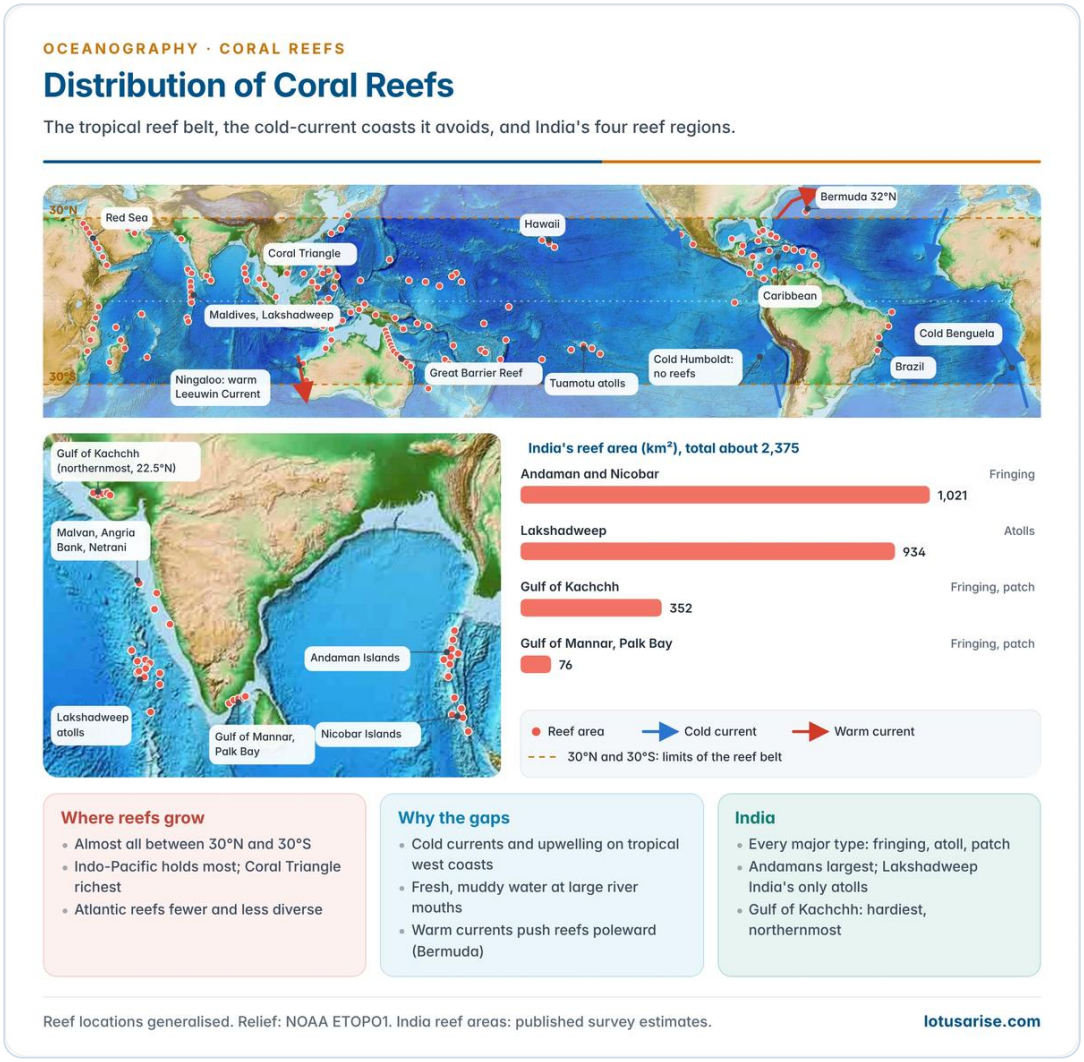
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World distribution

REGION	MAIN REEFS
Coral Triangle	Indonesia, Philippines, Malaysia, Papua New Guinea, Timor-Leste, Solomon Islands
Australia and south-west Pacific	Great Barrier Reef, New Caledonia, Fiji
Central Pacific	Atolls of the Marshall, Caroline and Tuamotu Islands, Hawaii
Indian Ocean	Maldives, Chagos, Lakshadweep, Andamans, Seychelles, East Africa, Madagascar
Red Sea and Persian Gulf	Fringing reefs to about 29°N in the Gulf of Aqaba
Atlantic	Caribbean, Mesoamerican Reef, Florida, Bahamas, Bermuda, Brazil
Eastern Pacific	Scattered reefs off Panama, Costa Rica and the Galápagos

- Shallow tropical reefs cover roughly **250,000–285,000 km²**, almost all **between 30°N and 30°S**.
- The **Indo-Pacific** holds most of them. The **Coral Triangle** is the centre of diversity, with about three-quarters of all coral species, and Indonesia has the largest national reef area.
- Atlantic reefs are fewer and **less diverse**. The eastern Pacific is isolated from the Indo-Pacific larval supply and stressed by El Niño.

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Coral reefs of India

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REGION	MAIN REEF TYPE	APPROXIMATE REEF AREA	FEATURES
Andaman and Nicobar Islands	Mainly fringing reefs	About 1,021 km²	Richest reefs in India; Mahatma Gandhi Marine National Park, Wandoor (1983)
Lakshadweep	Atolls	About 934 km²	India’s only atolls: 12 atolls, 3 reefs and 5 submerged banks
Gulf of Kachchh	Fringing and patch reefs	About 352 km²	Northernmost reefs; Marine National Park (1982)
Gulf of Mannar and Palk Bay	Fringing and patch reefs round 21 islands	About 76 km²	Marine National Park; Biosphere Reserve (1989)

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REGION	MAIN REEF TYPE	APPROXIMATE REEF AREA	FEATURES
West coast	Patchy and submerged reefs	Small	Malvan, Netrani Island, Angria and Gaveshani Banks

- India's reefs cover about **2,375 km²**. The Andamans hold the largest share, then the **Lakshadweep atolls** such as Kavaratti, Agatti and Maliku (Minicoy).
- India has **every major type**: fringing reefs in the Andamans and the two gulfs, atolls in Lakshadweep, drowned reefs on west-coast banks.
- The **Gulf of Kachchh** reefs, at about 22.5°N, survive turbid, saline water and a large tidal range: among the hardiest anywhere.

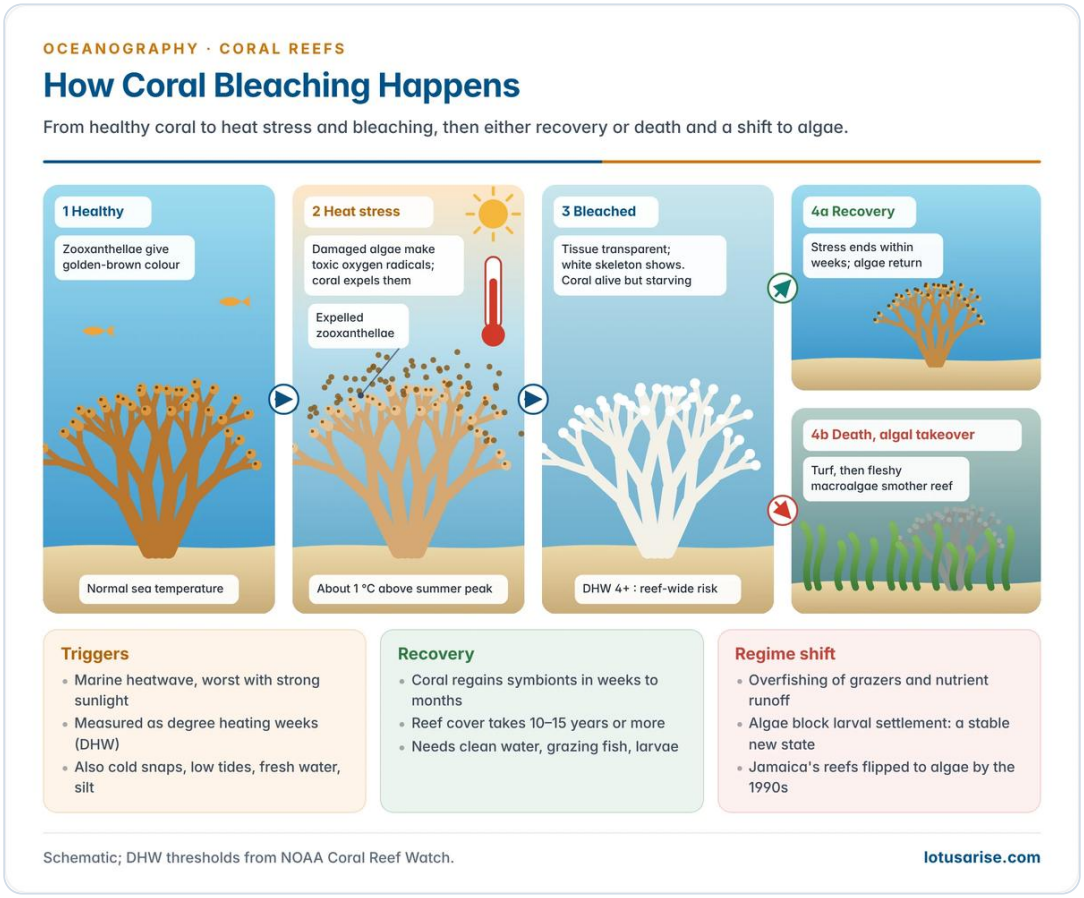
03 Coral Bleaching

PYQ 2025 · 2022 · 2020 +4

What bleaching is

- **Coral bleaching** is the **whitening of corals** when the **polyp–zooxanthellae symbiosis breaks down**. The coral expels its algae, or the algae lose their pigment, and the white skeleton shows through transparent tissue.
  - A bleached coral is **alive but starving**.
- **Under heat stress**, warm water and strong sunlight damage the algae's photosynthetic system. They release **toxic reactive oxygen species**, and the coral ejects them.
- **Outcomes:**
  - **Recovery:** if the stress ends within weeks, the coral regains symbionts and colour, though growth, reproduction and disease resistance suffer for months.
  - **Mortality:** if the stress persists, corals die and turf algae cover the skeletons within weeks.
- **Mass bleaching** of whole regions has been recorded since the 1982–83 El Niño.

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Causes of bleaching

STRESSOR	HOW IT ACTS	EXAMPLE
High sea temperature	About 1 °C above the warmest monthly mean for weeks	Global events of 1998, 2010, 2014–17, 2023–25
Strong sunlight and UV	Adds to heat damage in clear, calm water	Shallow reef flats and colony tops bleach first
Low temperature	Sudden cold from upwelling or cold-air outbreaks	Florida Keys, 2010
Sub-aerial exposure	Extreme low tides, sea-level drops, tectonic uplift	North Andaman reefs lifted by the 2004 earthquake
Fresh water	Heavy rain and runoff lower salinity	Floods after cyclones
Sediment and nutrients	Cut light, favour algae and disease	Siltation in the Gulf of Kachchh

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STRESSOR	HOW IT ACTS	EXAMPLE
Pollution and disease	Oil, sewage, cyanide, bacteria such as *Vibrio*	Polluted harbour reefs

- **Heat is the dominant cause.** **Marine heatwaves**, amplified by **El Niño**, drove every global event. **Ocean acidification** adds stress by slowing calcification.
- NOAA's Coral Reef Watch measures heat stress by satellite as **degree heating weeks (DHW)**: the temperature excess above the bleaching threshold, summed over 12 weeks. India's **INCOIS** runs a similar coral bleaching alert system.

NOAA ALERT LEVEL	DHW (°C-WEEKS)	EXPECTED EFFECT
Alert 1	4 to under 8	Risk of reef-wide bleaching
Alert 2	8 to under 12	Reef-wide bleaching; heat-sensitive corals die
Alert 3	12 to under 16	Risk of multi-species mortality
Alert 4	16 to under 20	Over half the corals die
Alert 5	20 and above	Near-complete mortality, over 80% of corals

Recovery and regime shifts PYQ 2020

- **Reef recovery** means regrowth of coral cover by larval recruitment and growth of survivors. Branching corals can restore cover in **about 10–15 years**; massive corals take decades.
  - It needs **time between disturbances**: a 2025 study of three Lakshadweep atolls found good recovery only after **six or more bleaching-free years**.
  - It is fastest where water is clean, herbivorous fish are plentiful and nearby reefs supply larvae.
- A **regime (phase) shift** is a lasting flip from **coral to fleshy macroalgae**.
  - **Drivers:** coral death, overfishing of grazing fish, loss of grazing urchins and nutrient runoff.
  - **Feedbacks:** algae block larval settlement, shade young corals and trap sediment, so the algal state persists after the stress ends (**hysteresis**).
  - **Jamaica:** overfishing, Hurricane Allen (1980) and the die-off of the urchin *Diadema* (1983) cut coral cover from about half to a few per cent by the early 1990s.
  - Reversal needs restored grazing and cleaner water, the basis of reef-resilience management.

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Mass bleaching events

GLOBAL EVENT	YEARS	REEFS UNDER BLEACHING-LEVEL HEAT STRESS	TRIGGER
First	1998	21%	Very strong 1997–98 El Niño
Second	2010	37%	2009–10 El Niño
Third	2014–2017	68%	2015–16 El Niño; three years long
Fourth	2023–2025	84%	2023–24 El Niño on record ocean warmth

- **The fourth global event** began in early 2023 and was declared by **NOAA on 15 April 2024**. It reached **84% of the world's reef area** and at least 83 countries and territories, the most extensive on record.
  - Severe bleaching off Western Australia in early 2025 was its last major episode. In June 2026 NOAA confirmed that it had **ended in mid-2025**.
  - Scientists now expect **near-annual bleaching**; the El Niño forecast for late 2026 raises the risk again.
- The **Great Barrier Reef** has bleached en masse in 1998, 2002, 2016, 2017, 2020, 2022, 2024 and 2025. Its northern and central coral cover was recovering again in 2026.

Clive Wilkinson and the Status of Coral Reefs of the World reports

PYQ 2025 · 2014 · 2008 +1

- **Clive Wilkinson**, of the Australian Institute of Marine Science, Townsville, coordinated the **Global Coral Reef Monitoring Network (GCRMN)** under the International Coral Reef Initiative. He edited the **Status of Coral Reefs of the World** reports of **1998, 2000, 2002, 2004 and 2008**.
- **His key observations:**
  - The **1998 bleaching destroyed about 16% of the world's reefs in nine months**, the largest single cause of reef loss, and perhaps half of these would never recover adequately.
  - The **Indian Ocean was worst hit**: most shallow corals died in parts of the Maldives, Sri Lanka, Kenya and the Seychelles, with heavy losses in Lakshadweep and the Andamans.
  - Damage was graded catastrophic, severe (about 50–70% mortality), moderate (with quick recovery) and insignificant.
  - **Climate change**, not local damage, had become the main threat, and bleaching would grow more frequent.

REPORT	KEY FINDING
2000	About 27% of reefs effectively lost: 16% to the 1998 bleaching, 11% to human pressure

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REPORT	KEY FINDING
2008	About 19% lost, only about 45% healthy; many intact reefs at risk within 20–40 years
2020 (released October 2021)	14% of the world's coral (about 11,700 km²) died after 2009; algal cover up about 20%
2025 (released August 2026)	Hard-coral cover fell from 30.2% (1980–2009) to 25.8% in 2024; the 8.9% drop of 2023–24 is the largest one-year decline on record

Bleaching in India

- **Indian reefs bleached in 1998, 2010, 2016 and 2024**, in step with the global events. In 1998, warming of about 2 °C killed many corals in the island groups and the Gulf of Mannar.
- **Lakshadweep, 2024:** a marine heatwave from late October 2023, more than 1 °C above normal, caused **severe bleaching**.
  - Live coral cover on three atolls had already fallen from about **37% (1998) to 19% (2022)**. The 2010 event was the most severe.
- **Gulf of Mannar, 2024:** reefs were **severely bleached**, while Palk Bay fared better.
- **Local stresses** add to heat: siltation in the Gulf of Kachchh, past coral mining in the Gulf of Mannar, sewage, trawling, and the 2004 uplift and subsidence of Andaman and Nicobar reefs.

04 Importance, Threats and Conservation

Importance of coral reefs

PYQ 2025 · 2008 · 1988

- **Biodiversity:** the richest marine ecosystem, home to fish, molluscs, turtles and dugongs (Gulf of Mannar, Andamans).
- **Food and livelihoods** for hundreds of millions of tropical coastal people.
- **Coastal protection:** a healthy reef **absorbs up to about 97% of wave energy**.
- **Land itself:** reefs build atoll nations such as the Maldives and Tuvalu, and islands such as Lakshadweep.
- **Tourism, medicines, climate archives** in growth bands, and long-term carbon storage in **calcareous deposits**.

Threats

- **Global:** warming and marine heatwaves, acidification, stronger cyclones, and sea-level rise faster than reef growth.
- **Local:** sediment and nutrient runoff, overfishing and dynamite or cyanide fishing, coral mining, **marine pollution**, crown-of-thorns starfish outbreaks, coral diseases, tourism and coastal construction.
- **Stresses compound:** a reef weakened by silt and overfishing recovers slowly from bleaching and is more likely to shift to algae.

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Conservation

LEVEL	MEASURES
International	International Coral Reef Initiative (1994) and its GCRMN; Coral Triangle Initiative (2009); Global Fund for Coral Reefs (2020); marine protected areas under the 30 by 30 target (2022)
Restoration	Coral gardening and transplanting, larval seeding, biorock, heat-tolerant corals, protection of grazers
India	Schedule I of the Wildlife (Protection) Act, 1972; CRZ Notification, 2019; marine national parks; INCOIS bleaching alerts

- **All reef-building corals** are protected under **Schedule I of the Wildlife (Protection) Act, 1972**; reefs are ecologically sensitive areas under the **Coastal Regulation Zone** rules.
- **Restoration in India:**
  - In the **Gulf of Mannar**, more than 51,000 fragments of 20 native species have been transplanted onto concrete frames since 2002, raising coral cover severalfold.
  - The **Zoological Survey of India**, with the Gujarat Forest Department, restored branching *Acropora* in the **Gulf of Kachchh (2015)** and has trialled **biorock** since 2020.
  - The National Institute of Oceanography translocated corals from Mumbai's coastal-road site in 2020.

Previous Year Questions

2025	Why are coral reefs in India most important with respect to its dynamic ecosystem? Explore.
2022	When corals are affected by stress it causes them to turn completely white. Explain the reasons of such an occurrence.
2020	Discuss the concept of coral bleaching, its recovery and microalgal regime shifts due to this process.
2017	Distinguish between low energy coasts and coral coasts.
2014	Give an account of recent observations on coral bleaching with reference to Clive Wilkinson's Report.

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2008 Describe the ideal conditions for coral reef formation and discuss the glacial control theory of coral reef formation.

1988 Write short note on Coral reefs in about 200 words.

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24	8	72	335
Chapters	Units	Previous year questions	Pages

IN THE COMPLETE BOOK

01 **The Ocean Floor and Bottom Topography**
6 chapters · from page 6

02 **Temperature, Salinity and Density**
3 chapters · from page 92

03 **Heat and Salt Budgets and Ocean Deposits**
2 chapters · from page 137

04 **Waves, Currents and Tides**
6 chapters · from page 162

05 **Marine Resources**
1 chapter · from page 250

06 **Coral Reefs and Coral Bleaching**
2 chapters · from page 269

07 **Sea-Level Changes**
1 chapter · from page 294

08 **Law of the Sea and Marine Pollution**
3 chapters · from page 304

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