**OCEAN DEPOSITS**

**Introduction to Ocean Deposits:**

The unconsolidated sediments, derived from various sources, deposited at the sea floors are in­cluded in ocean deposits. The study of ocean (marine) deposits includes the consideration of types of sediments, their sources, methods of their transportation, horizon­tal distribution, lithological successions or vertical variations in their distribution and composition etc.

The sediments derived from weathering and erosion of continental rocks are transported to the oceans by rivers, winds etc. Volcanic eruptions also provide sediments. Besides, the decay and decomposition of marine organisms (both plants and animals) also con­tribute sediments to ocean deposits.

**Classification of Ocean Deposits:**

**Ocean deposits are classified on different bases e.g.:**

(1) On the basis of location,

(2) On the basis of depth,

(3) On the basis of the origin of sediments etc.

**1. On the Basis of Location:**

This classification is based on typical locations of particular marine sediment. Though several scien­tists have attempted to classify ocean deposits on the basis of their locations, the classifications of Sir John Murray and J.T. Jenkins are widely acclaimed.

1. **Classification of Murray:**

**Sir John Murray has classified the ocean deposits into two broad categories viz.:**

(a) Terrigenous deposits and

(b) Pelagic deposits.

Terrigenous deposits are found mainly on the continental shelves and slopes whereas pelagic deposits predominate on the deep sea floor. Terrigenous deposits are composed of coarser materials and are derived from the continents through weathering and erosional processes and are trans­ported to the oceans by various agencies.

Their colour may be blue, yellow, grey or red. Pelagic deposits consist of fine materials formed of skeletons and shells of marine organisms and a few inorganic substances. They are generally blue, grey or red in colour.

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### **Terrigenous Deposits:**

Terrigenous deposits are derived from the wear and tear of land and volcanic and organic products. The greater part of the deposits on the continental shelf and slopes is derived from rock material let loose by disintegration and decomposition by the agents of weathering and carried to sea by the agents of erosion, such as running water, wind, etc.

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The process and extent of disintegration depends on the nature of rock material, climate and time taken. The larger particles of the terrigenous deposits are found near the shore and the finer ones carried deeper. The extent to which they are carried outwards depends on the size of rock material and the strength of sea waves and currents

On the basis of size of particles, the terrigenous deposits may be categorised into three classes— mud, sand and gravel. Mud refers to the finest particles which comprise the minute particles of rock forming minerals, principally quartz. Murray has classified the mud deposits into blue, green and red types, based on the colour of constituents. Sand refers to the coarser particles, while gravel has even bigger particles.

#### Volcanic Products:

In volcanic regions the deposits of continental shelf and slope consist chiefly of products of volcanism, which are subject to chemical and mechanical weathering and are carried to the ocean by actions of running water and wind. The volcanic deposits differ from the ordinary terrigenous deposits in one respect—they are made of pyroclastic volcanic products and lava, rather than quartz.

Organic Products Such deposits consist of shells and skeletons of various plants and animals that live and grow on the sea floor and are changed into mud and sand by chemical and mechanical processes. They differ from the ordinary terrigenous deposits in the sense that they consist of calcium carbonate only.

Their colour may be blue, yellow, grey or red. Pelagic deposits consist of fine materials formed of skeletons and shells of marine organisms and a few inorganic substances. They are generally blue, grey or red in colour.

**Pelagic deposits**

Pelagic deposits are the most conspicuous of all deposits—covering about 75% of the total sea floor. This is because, except for fine volcanic ash, little terrigenous material is carried into the deeps. The pelagic deposits consist of both organic and inorganic material.

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#### Organic Material:

This is in the form of a kind of liquid mud, called ooze, which contains shells and skeletons of various marine organisms. The ooze is said to be calcareous when the shell is made of calcium carbonate. The calcareous ooze may be either pteropod ooze or globogerina ooze. Most parts of the Indian and Atlantic Oceans have calcareous ooze as deposits (Fig. 3.13). When the shell is made of silica, the ooze is said to be siliceous ooze, which can be either the diatom type or the radiolarian type of ooze. The southern fringes of the Indian and the Atlantic Oceans have the siliceous type of ooze.

#### Inorganic Material:

This is in the form of red clay, which is apparently of a volcanic origin. The chief constituents of red clay are silicon and aluminium dioxide, while other constituents include iron, manganese, phosphorus and radium. The red clay is the most widely spread pelagic deposit and covers 38% of the sea floor. The red clay covers more than half of the Pacific floor

1. **Classification of Jenkins:**

**Jenkins has di­vided marine deposits into three groups viz.:**

(a) Deep sea deposits,

(b) Shallow water deposits, and

(c) Littoral deposits.

**The following is the detailed classification of Jenkins:**

**(A) Pelagic deposits:**

(1) Red clay,

(2) Radiolarian ooze,

(3) Diatom ooze,

(4) Globigerina ooze, and

(5) Pteropod ooze.

**(B) Terrigenous deposits**:

(1) Blue mud,

(2) Red mud,

(3) Green mud,

(4) Coral mud,

(5) Volcanic mud,

(6) Gravel, and

(7) Sand.

**2. On the Basis of Depth:**

1. **Deep sea deposits (Below 100 fathoms):**

**(a) Pelagic Deposits:**

(1) Red clay,

(2) Radiolarian ooze,

(3) Diatom ooze,

(4) Globigerina ooze, and

(5) Pteropod ooze.

**(b) Terrigenous Deposits:**

(1) Blue mud,

(2) Red mud,

(3) Green mud,

(4) Coral mud, and

(5) Volcanic mud.

**(B) Shallow sea deposits (between low tide water and 100 fathoms):**

(1) Gravels,

(2) Sands, and

(3) Mud.

**(c) Littoral deposits (Between high and low tide water):**

(1) Gravels,

(2) Sands,

(3) Mud.

**2. General Classification**:

**(1) Terrigenous Deposits:**

i. Littoral deposits,

ii. Shallow water deposits, and

iii. Terrigenous mud.

**(2) Neritic Deposits:**

i. Shallow water neritic deposits,

ii. Deep sea water neritic deposits, and

iii. Pelagic deposits.

**3. Classification on the Basis of Origin of Sediments**:

**(1) Littoral deposits (derived from land)):**

(i) Shore deposits.

(ii) Shelf deposits.

**(2) Hemipclagic deposits (Partly from land and partly from marine origin):**

(i) Green mud.

(ii) Volcanic mud.

(iii) Coral mud.

**(3) Eupelagic deposits (Of marine and cosmic origin):**

(i) Red clay.

(ii) Radiolarian ooze.

(iii) Globigerina ooze.

(iv) Pteropod ooze.

**CORAL REEF**

Coral reefs are the colonies of tiny living creatures that are found in oceans. They are the underwater structures that are formed of coral polyps that are held together by calcium carbonate. Coral reefs are also regarded as the tropical rainforest of the sea and occupy just 0.1% of the ocean’s surface but are home to 25% of marine species. They are usually found in shallow areas at a depth less than 150 feet. However, some coral reefs extend even deeper, up to about 450 feet.

Coral polyps are the individual corals that are found on the calcium carbonate exoskeletons of their ancestors. Corals can be found in all the oceans but the biggest coral reefs are mostly found in the clear, shallow waters of the tropics and subtropics. The largest of these coral reef systems, The Great Barrier Reef in Australia, the largest coral reef is more than 1,500 miles long.

**Factors affecting Coral Reefs**

* **Extreme climate conditions:** High temperature of water leads to the declination of these corals as they cannot survive in high temperature. As estimated by scientists, most of the coral reefs of the world will soon decline with the increasing rates of ocean warming.
* **Overfishing:** It is another major concern as it is leading to an ecological imbalance of the coral reefs.
* **Coastal development:** Development of coastal infrastructure and tourist resorts on or close by these coral reefs causes significant damages.
* **Pollution:** The toxic pollutants which are dumped directly into the ocean can lead to the poisoning of the coral reefs as it increases the nitrogen level of the seawater leading to an overgrowth of algae.
* **Sedimentation:** Construction along the coasts and islands lead to soil erosion increasing the sediments in the river. As a result, it can smother corals by depriving them of the light needed to survive.

**Growth conditions for Coral Reefs**

1. The temperature of the water should not be below 20°C. The most favourable temperature for the growth of the coral reefs is between 23°C to 25°C. The temperature should not exceed 35°C.
2. Corals can survive only under saline conditions with an average salinity between 27% to 40%.
3. Coral reefs grow better in shallow water having a depth less than 50 m. The depth of the water should not exceed 200m.

Most coral reefs were formed after the [Last Glacial Period](https://en.wikipedia.org/wiki/Last_Glacial_Period) when melting ice caused [sea level](https://en.wikipedia.org/wiki/Sea_level) to rise and flood [continental shelves](https://en.wikipedia.org/wiki/Continental_shelf). Most coral reefs are less than 10,000 years old. As communities established themselves, the reefs grew upwards, pacing rising [sea levels](https://en.wikipedia.org/wiki/Sea_level). Reefs that rose too slowly could become drowned, without sufficient light. Coral reefs are found in the deep sea away from [continental shelves](https://en.wikipedia.org/wiki/Continental_shelf), around [oceanic islands](https://en.wikipedia.org/wiki/Island#Oceanic_islands) and [atolls](https://en.wikipedia.org/wiki/Atoll). The majority of these islands are [volcanic](https://en.wikipedia.org/wiki/Volcano) in origin. Others have [tectonic](https://en.wikipedia.org/wiki/Tectonics) origins where [plate movements](https://en.wikipedia.org/wiki/Plate_tectonics) lifted the deep ocean floor.

In [*The Structure and Distribution of Coral Reefs*](https://en.wikipedia.org/wiki/The_Structure_and_Distribution_of_Coral_Reefs), [Charles Darwin](https://en.wikipedia.org/wiki/Charles_Darwin) set out his theory of the formation of atoll reefs, an idea he conceived during the [voyage of the *Beagle*](https://en.wikipedia.org/wiki/Second_voyage_of_HMS_Beagle). He theorized that [uplift](https://en.wikipedia.org/wiki/Tectonic_uplift) and [subsidence](https://en.wikipedia.org/wiki/Subsidence) of Earth's [crust](https://en.wikipedia.org/wiki/Oceanic_crust) under the oceans formed the atolls.[[17]](https://en.wikipedia.org/wiki/Coral_reef#cite_note-cr-17) Darwin set out a sequence of three stages in atoll formation. A [fringing reef](https://en.wikipedia.org/wiki/Fringing_reef) forms around an extinct [volcanic island](https://en.wikipedia.org/wiki/High_island) as the island and ocean floor subsides. As the subsidence continues, the fringing reef becomes a barrier reef and ultimately an atoll reef.



* Darwin's theory starts with a [volcanic island](https://en.wikipedia.org/wiki/High_island) which becomes extinct



* As the island and ocean floor subside, coral growth builds a [fringing reef](https://en.wikipedia.org/wiki/Fringing_reef), often including a shallow lagoon between the land and the main reef.



* As the subsidence continues, the fringing reef becomes a larger barrier reef further from the shore with a bigger and deeper [lagoon](https://en.wikipedia.org/wiki/Lagoon) inside.



* Ultimately, the island sinks below the sea, and the barrier reef becomes an [atoll](https://en.wikipedia.org/wiki/Atoll) enclosing an open lagoon.

Darwin predicted that underneath each [lagoon](https://en.wikipedia.org/wiki/Lagoon) would be a [bedrock](https://en.wikipedia.org/wiki/Bedrock) base, the remains of the original volcano. Subsequent research supported this hypothesis. Darwin's theory followed from his understanding that coral polyps thrive in the [tropics](https://en.wikipedia.org/wiki/Tropics) where the water is agitated, but can only live within a limited depth range, starting just below low [tide](https://en.wikipedia.org/wiki/Tide). Where the level of the underlying earth allows, the corals grow around the coast to form fringing reefs, and can eventually grow to become a barrier reef.



A fringing reef can take ten thousand years to form, and an atoll can take up to 30 million years.

Where the bottom is rising, fringing reefs can grow around the coast, but coral raised above sea level dies. If the land subsides slowly, the fringing reefs keep pace by growing upwards on a base of older, dead coral, forming a barrier reef enclosing a lagoon between the reef and the land. A barrier reef can encircle an island, and once the island sinks below sea level a roughly circular atoll of growing coral continues to keep up with the sea level, forming a central lagoon. Barrier reefs and atolls do not usually form complete circles, but are broken in places by storms. Like sea level rise, a rapidly subsiding bottom can overwhelm coral growth, killing the coral and the reef, due to what is called *coral drowning*. Corals that rely on [zooxanthellae](https://en.wikipedia.org/wiki/Zooxanthellae) can die when the water becomes too deep for their [symbionts](https://en.wikipedia.org/wiki/Symbionts) to adequately [photosynthesize](https://en.wikipedia.org/wiki/Photosynthesis), due to decreased light exposure.

The two main variables determining the [geomorphology](https://en.wikipedia.org/wiki/Geomorphology), or shape, of coral reefs are the nature of the [substrate](https://en.wikipedia.org/wiki/Substrate_%28biology%29) on which they rest, and the history of the change in sea level relative to that substrate.

The approximately 20,000-year-old [Great Barrier Reef](https://en.wikipedia.org/wiki/Great_Barrier_Reef) offers an example of how coral reefs formed on continental shelves. Sea level was then 120 m (390 ft) lower than in the 21st century. As sea level rose, the water and the corals encroached on what had been hills of the Australian coastal plain. By 13,000 years ago, sea level had risen to 60 m (200 ft) lower than at present, and many hills of the coastal plains had become [continental islands](https://en.wikipedia.org/wiki/Island#Continental_islands). As sea level rise continued, water topped most of the continental islands. The corals could then overgrow the hills, forming [cays](https://en.wikipedia.org/wiki/Cay) and reefs. Sea level on the Great Barrier Reef has not changed significantly in the last 6,000 years. The age of living reef structure is estimated to be between 6,000 and 8,000 years. Although the Great Barrier Reef formed along a continental shelf, and not around a volcanic island, Darwin's principles apply. Development stopped at the barrier reef stage, since Australia is not about to submerge. It formed the world's largest barrier reef, 300–1,000 m (980–3,280 ft) from shore, stretching for 2,000 km (1,200 mi).

Healthy tropical coral reefs grow horizontally from 1 to 3 cm (0.39 to 1.18 in) per year, and grow vertically anywhere from 1 to 25 cm (0.39 to 9.84 in) per year; however, they grow only at depths shallower than 150 m (490 ft) because of their need for sunlight, and cannot grow above sea level.

### **Material**

As the name implies, coral reefs are made up of coral skeletons from mostly intact coral colonies. As other chemical elements present in corals become incorporated into the calcium carbonate deposits, [aragonite](https://en.wikipedia.org/wiki/Aragonite) is formed. However, shell fragments and the remains of [coralline algae](https://en.wikipedia.org/wiki/Coralline_algae) such as the green-segmented [genus](https://en.wikipedia.org/wiki/Genus) [*Halimeda*](https://en.wikipedia.org/wiki/Halimeda) can add to the reef's ability to withstand damage from storms and other threats. Such mixtures are visible in structures such as [Eniwetok Atoll](https://en.wikipedia.org/wiki/Eniwetok_Atoll).

## **Types**

Since Darwin's identification of the three classical reef formations – the fringing reef around a volcanic island becoming a barrier reef and then an atoll – scientists have identified further reef types. While some sources find only three, Thomas and Goudie list four "principal large-scale coral reef types" – the fringing reef, barrier reef, atoll and table reef] – while Spalding *et al.* list five "main types" – the fringing reef, barrier reef, atoll, "bank or platform reef" and patch reef.

###  **Fringing reef**



**Fringing reef**



Fringing reef at [Eilat](https://en.wikipedia.org/wiki/Eilat) at the southern tip of [Israel](https://en.wikipedia.org/wiki/Israel)

[***Fringing reef***](https://en.wikipedia.org/wiki/Fringing_reef)

A fringing reef, also called a shore reef, is directly attached to a shore,or borders it with an intervening narrow, shallow channel or lagoon. It is the most common reef type. Fringing reefs follow coastlines and can extend for many kilometres. They are usually less than 100 metres wide, but some are hundreds of metres wide. Fringing reefs are initially formed on the shore at the [low water](https://en.wikipedia.org/wiki/Low_water) level and expand seawards as they grow in size. The final width depends on where the sea bed begins to drop steeply. The surface of the fringe reef generally remains at the same height: just below the waterline. In older fringing reefs, whose outer regions pushed far out into the sea, the inner part is deepened by erosion and eventually forms a [lagoon](https://en.wikipedia.org/wiki/Lagoon). Fringing reef lagoons can become over 100 metres wide and several metres deep. Like the fringing reef itself, they run parallel to the coast. The fringing reefs of the [Red Sea](https://en.wikipedia.org/wiki/Red_Sea) are "some of the best developed in the world" and occur along all its shores except off sandy bays.

### **Barrier reef**



Barrier reef

Barrier reefs are separated from a mainland or island shore by a deep channel or [lagoon](https://en.wikipedia.org/wiki/Lagoon). They resemble the later stages of a fringing reef with its lagoon, but differ from the latter mainly in size and origin. Their lagoons can be several kilometres wide and 30 to 70 metres deep. Above all, the offshore outer reef edge formed in open water rather than next to a shoreline. Like an atoll, it is thought that these reefs are formed either as the seabed lowered or sea level rose. Formation takes considerably longer than for a fringing reef, thus barrier reefs are much rarer.

The best known and largest example of a barrier reef is the Australian [Great Barrier Reef](https://en.wikipedia.org/wiki/Great_Barrier_Reef). Other major examples are the [Belize Barrier Reef](https://en.wikipedia.org/wiki/Belize_Barrier_Reef) and the [New Caledonian Barrier Reef](https://en.wikipedia.org/wiki/New_Caledonian_Barrier_Reef). Barrier reefs are also found on the coasts of [Providencia](https://en.wikipedia.org/wiki/Providencia_%28Colombia%29),[Mayotte](https://en.wikipedia.org/wiki/Mayotte), the [Gambier Islands](https://en.wikipedia.org/wiki/Gambier_Islands), on the southeast coast of [Kalimantan](https://en.wikipedia.org/wiki/Kalimantan), on parts of the coast of [Sulawesi](https://en.wikipedia.org/wiki/Sulawesi), southeastern [New Guinea](https://en.wikipedia.org/wiki/New_Guinea) and the south coast of the [Louisiade Archipelago](https://en.wikipedia.org/wiki/Louisiade_Archipelago).

### **Platform reef**



Platform reef

Platform reefs, variously called bank or table reefs, can form on the [continental shelf](https://en.wikipedia.org/wiki/Continental_shelf), as well as in the open ocean, in fact anywhere where the seabed rises close enough to the surface of the ocean to enable the growth of zooxanthemic, reef-forming corals. Platform reefs are found in the southern Great Barrier Reef, the Swain and Capricorn Group on the continental shelf, about 100–200 km from the coast. Some platform reefs of the northern [Mascarenes](https://en.wikipedia.org/wiki/Mascarenes) are several thousand kilometres from the mainland. Unlike fringing and barrier reefs which extend only seaward, platform reefs grow in all directions. They are variable in size, ranging from a few hundred metres to many kilometres across. Their usual shape is oval to elongated. Parts of these reefs can reach the surface and form sandbanks and small islands around which may form fringing reefs. A lagoon may form In the middle of a platform reef.

Platform reefs can be found within atolls. There they are called patch reefs and may reach only a few dozen metres in diameter. Where platform reefs form on an elongated structure, e. g. an old, eroded barrier reef, they can form a linear arrangement. This is the case, for example, on the east coast of the [Red Sea](https://en.wikipedia.org/wiki/Red_Sea) near [Jeddah](https://en.wikipedia.org/wiki/Jeddah). In old platform reefs, the inner part can be so heavily eroded that it forms a pseudo-atoll. These can be distinguished from real atolls only by detailed investigation, possibly including core drilling. Some platform reefs of the [Laccadives](https://en.wikipedia.org/wiki/Lakshadweep) are U-shaped, due to wind and water flow.

### **Atoll**



Atolls or [atoll reefs](https://en.wikipedia.org/wiki/Atoll_reef) are a more or less circular or continuous barrier reef that extends all the way around a lagoon without a central island. They are usually formed from fringing reefs around volcanic islands. Over time, the island [erodes](https://en.wikipedia.org/wiki/Erosion) away and sinks below sea level. Atolls may also be formed by the sinking of the seabed or rising of the sea level. A ring of reefs results, which enclose a lagoon. Atolls are numerous in the South Pacific, where they usually occur in mid-ocean, for example, in the [Caroline Islands](https://en.wikipedia.org/wiki/Caroline_Islands), the [Cook Islands](https://en.wikipedia.org/wiki/Cook_Islands), [French Polynesia](https://en.wikipedia.org/wiki/French_Polynesia), the [Marshall Islands](https://en.wikipedia.org/wiki/Marshall_Islands) and [Micronesia](https://en.wikipedia.org/wiki/Micronesia).

Atolls are found in the Indian Ocean, for example, in the [Maldives](https://en.wikipedia.org/wiki/Maldives), the [Chagos Islands](https://en.wikipedia.org/wiki/Chagos_Islands), the [Seychelles](https://en.wikipedia.org/wiki/Seychelles) and around [Cocos Island](https://en.wikipedia.org/wiki/Cocos_Island). The entire Maldives consist of 26 atolls.

### **Other reef types or variants**



**A small** [**atoll**](https://en.wikipedia.org/wiki/Atoll) **in the** [**Maldives**](https://en.wikipedia.org/wiki/Maldives)



Inhabited [cay](https://en.wikipedia.org/wiki/Cay) in the [Maldives](https://en.wikipedia.org/wiki/Maldives)

* **Apron reef** – short reef resembling a fringing reef, but more sloped; extending out and downward from a point or peninsular shore. The initial stage of a fringing reef.
* **Bank reef** – isolated, flat-topped reef larger than a patch reef and usually on mid-shelf regions and linear or semi-circular in shape; a type of platform reef.
* **Patch reef** – common, isolated, comparatively small reef outcrop, usually within a [lagoon](https://en.wikipedia.org/wiki/Lagoon) or [embayment](https://en.wikipedia.org/wiki/Embayment), often circular and surrounded by sand or [seagrass](https://en.wikipedia.org/wiki/Seagrass). Can be considered as a type of platform reef[[*who?*](https://en.wikipedia.org/wiki/Wikipedia%3AManual_of_Style/Words_to_watch#Unsupported_attributions)] or as features of fringing reefs, atolls and barrier reefs.[[40]](https://en.wikipedia.org/wiki/Coral_reef#cite_note-CRI-40) The patches may be surrounded by a ring of reduced seagrass cover referred to as a *grazing halo*.
* **Ribbon reef** – long, narrow, possibly winding reef, usually associated with an atoll lagoon. Also called a shelf-edge reef or sill reef.
* **Habili** – reef specific to the [Red Sea](https://en.wikipedia.org/wiki/Red_Sea); does not reach near enough to the surface to cause visible [surf](https://en.wikipedia.org/wiki/Breaking_wave); may be a hazard to ships (from the [Arabic](https://en.wikipedia.org/wiki/Arabic) for "unborn")
* [**Microatoll**](https://en.wikipedia.org/wiki/Microatoll) – community of species of corals; vertical growth limited by average tidal height; growth morphologies offer a low-resolution record of patterns of sea level change; fossilized remains can be dated using [radioactive carbon dating](https://en.wikipedia.org/wiki/Radiocarbon_dating) and have been used to reconstruct [Holocene](https://en.wikipedia.org/wiki/Holocene) [sea levels](https://en.wikipedia.org/wiki/Sea_level)
* [**Cays**](https://en.wikipedia.org/wiki/Cay) – small, low-elevation, sandy islands formed on the surface of coral reefs from eroded material that piles up, forming an area above sea level; can be stabilized by plants to become habitable; occur in tropical environments throughout the [Pacific](https://en.wikipedia.org/wiki/Pacific_Ocean), [Atlantic](https://en.wikipedia.org/wiki/Atlantic_Ocean) and [Indian Oceans](https://en.wikipedia.org/wiki/Indian_Ocean) (including the Caribbean and on the [Great Barrier Reef](https://en.wikipedia.org/wiki/Great_Barrier_Reef) and Belize Barrier Reef), where they provide habitable and agricultural land
* [**Seamount**](https://en.wikipedia.org/wiki/Seamount) or [**guyot**](https://en.wikipedia.org/wiki/Guyot) – formed when a coral reef on a volcanic island subsides; tops of seamounts are rounded and guyots are flat; flat tops of guyots, or *tablemounts*, are due to erosion by waves, winds, and atmospheric processes

## **Zones**



The three major zones of a coral reef: the fore reef, reef crest, and the back reef

Coral reef ecosystems contain distinct zones that host different kinds of habitats. Usually, three major zones are recognized: the fore reef, reef crest, and the back reef (frequently referred to as the reef lagoon).

The three zones are physically and ecologically interconnected. Reef life and oceanic processes create opportunities for exchange of [seawater](https://en.wikipedia.org/wiki/Seawater), [sediments](https://en.wikipedia.org/wiki/Sediment), nutrients and marine life.

Most coral reefs exist in waters less than 50 m deep. Some inhabit tropical continental shelves where cool, nutrient-rich [upwelling](https://en.wikipedia.org/wiki/Upwelling) does not occur, such as the [Great Barrier Reef](https://en.wikipedia.org/wiki/Great_Barrier_Reef). Others are found in the deep ocean surrounding islands or as atolls, such as in the [Maldives](https://en.wikipedia.org/wiki/Maldives). The reefs surrounding islands form when islands subside into the ocean, and atolls form when an island subsides below the surface of the sea.

Alternatively, Moyle and Cech distinguish six zones, though most reefs possess only some of the zones.



Water in the reef surface zone is often agitated. This diagram represents a reef on a [continental shelf](https://en.wikipedia.org/wiki/Continental_shelf). The water waves at the left travel over the *off-reef floor* until they encounter the *reef slope* or *fore reef*. Then the waves pass over the shallow *reef crest*. When a wave enters shallow water it [shoals](https://en.wikipedia.org/wiki/Wave_shoaling), that is, it slows down and the wave height increases.

**The reef surface** is the shallowest part of the reef. It is subject to [surge](https://en.wikipedia.org/wiki/Tidal_surge) and [tides](https://en.wikipedia.org/wiki/Tide). When waves pass over shallow areas, they [shoal](https://en.wikipedia.org/wiki/Wave_shoaling), as shown in the adjacent diagram. This means the water is often agitated. These are the precise condition under which corals flourish. The light is sufficient for [photosynthesis](https://en.wikipedia.org/wiki/Photosynthesis) by the symbiotic zooxanthellae, and agitated water brings plankton to feed the coral.

**The off-reef floor** is the shallow sea floor surrounding a reef. This zone occurs next to reefs on continental shelves. Reefs around tropical islands and atolls drop abruptly to great depths, and do not have such a floor. Usually sandy, the floor often supports [seagrass meadows](https://en.wikipedia.org/wiki/Seagrass_meadow) which are important foraging areas for reef fish.

**The reef drop-off** is, for its first 50 m, habitat for reef fish who find shelter on the cliff face and [plankton](https://en.wikipedia.org/wiki/Plankton) in the water nearby. The drop-off zone applies mainly to the reefs surrounding oceanic islands and atolls.

**The reef face** is the zone above the reef floor or the reef drop-off. This zone is often the reef's most diverse area. Coral and [calcareous](https://en.wikipedia.org/wiki/Calcareous) algae provide complex habitats and areas that offer protection, such as cracks and crevices. Invertebrates and [epiphytic](https://en.wikipedia.org/wiki/Epiphytic) algae provide much of the food for other organisms.[[48]](https://en.wikipedia.org/wiki/Coral_reef#cite_note-MoyleCech556-48) A common feature on this forereef zone is [spur and groove formations](https://en.wikipedia.org/wiki/Spur_and_groove_formation) that serve to transport sediment downslope.

**The reef flat** is the sandy-bottomed flat, which can be behind the main reef, containing chunks of coral. This zone may border a lagoon and serve as a protective area, or it may lie between the reef and the shore, and in this case is a flat, rocky area. Fish tend to prefer it when it is present.[[48]](https://en.wikipedia.org/wiki/Coral_reef#cite_note-MoyleCech556-48)

**The reef lagoon** is an entirely enclosed region, which creates an area less affected by wave action and often contains small reef patches.[[48]](https://en.wikipedia.org/wiki/Coral_reef#cite_note-MoyleCech556-48)

However, the "topography of coral reefs is constantly changing. Each reef is made up of irregular patches of algae, [sessile](https://en.wikipedia.org/wiki/Sessility_%28zoology%29) invertebrates, and bare rock and sand. The size, shape and relative abundance of these patches changes from year to year in response to the various factors that favor one type of patch over another. Growing coral, for example, produces constant change in the fine structure of reefs. On a larger scale, tropical storms may knock out large sections of reef and cause boulders on sandy areas to move."

## **Locations**



**Locations of coral reefs**



Boundary for 20 °C [isotherms](https://en.wikipedia.org/wiki/Contour_line). Most corals live within this boundary. Note the cooler waters caused by upwelling on the southwest coast of Africa and off the coast of Peru.



This map shows areas of [upwelling](https://en.wikipedia.org/wiki/Upwelling) in red. Coral reefs are not found in coastal areas where colder and nutrient-rich upwellings occur.

Coral reefs are estimated to cover 284,300 km2 (109,800 sq mi), just under 0.1% of the oceans' surface area. The [Indo-Pacific](https://en.wikipedia.org/wiki/Indo-Pacific) region (including the [Red Sea](https://en.wikipedia.org/wiki/Red_Sea), [Indian Ocean](https://en.wikipedia.org/wiki/Indian_Ocean), [Southeast Asia](https://en.wikipedia.org/wiki/Southeast_Asia) and the [Pacific](https://en.wikipedia.org/wiki/Pacific)) account for 91.9% of this total. Southeast Asia accounts for 32.3% of that figure, while the Pacific including [Australia](https://en.wikipedia.org/wiki/Australia) accounts for 40.8%. [Atlantic](https://en.wikipedia.org/wiki/Atlantic) and [Caribbean](https://en.wikipedia.org/wiki/Caribbean) coral reefs account for 7.6%.

Although corals exist both in temperate and tropical waters, shallow-water reefs form only in a zone extending from approximately 30° N to 30° S of the equator. Tropical corals do not grow at depths of over 50 meters (160 ft). The optimum temperature for most coral reefs is 26–27 °C (79–81 °F), and few reefs exist in waters below 18 °C (64 °F). However, reefs in the [Persian Gulf](https://en.wikipedia.org/wiki/Persian_Gulf) have adapted to temperatures of 13 °C (55 °F) in winter and 38 °C (100 °F) in summer. 37 species of scleractinian corals inhabit such an environment around [Larak Island](https://en.wikipedia.org/wiki/Larak_Island).

[Deep-water coral](https://en.wikipedia.org/wiki/Deep-water_coral) inhabits greater depths and colder temperatures at much higher latitudes, as far north as Norway. Although deep water corals can form reefs, little is known about them.

Coral reefs are rare along the west coasts of the [Americas](https://en.wikipedia.org/wiki/Americas) and [Africa](https://en.wikipedia.org/wiki/Africa), due primarily to [upwelling](https://en.wikipedia.org/wiki/Upwelling) and strong cold coastal currents that reduce water temperatures in these areas (the [Peru](https://en.wikipedia.org/wiki/Peru_Current), [Benguela](https://en.wikipedia.org/wiki/Benguela_Current) and [Canary Currents](https://en.wikipedia.org/wiki/Canary_Current) respectively). Corals are seldom found along the coastline of [South Asia](https://en.wikipedia.org/wiki/South_Asia)—from the eastern tip of India ([Chennai](https://en.wikipedia.org/wiki/Chennai)) to the [Bangladesh](https://en.wikipedia.org/wiki/Bangladesh) and [Myanmar](https://en.wikipedia.org/wiki/Myanmar) borders—as well as along the coasts of northeastern [South America](https://en.wikipedia.org/wiki/South_America) and Bangladesh, due to the freshwater release from the [Amazon](https://en.wikipedia.org/wiki/Amazon_River) and [Ganges](https://en.wikipedia.org/wiki/Ganges) Rivers respectively.

* The [Great Barrier Reef](https://en.wikipedia.org/wiki/Great_Barrier_Reef)—largest, comprising over 2,900 individual reefs and 900 islands stretching for over 2,600 kilometers (1,600 mi) off [Queensland, Australia](https://en.wikipedia.org/wiki/Queensland)
* The [Mesoamerican Barrier Reef System](https://en.wikipedia.org/wiki/Mesoamerican_Barrier_Reef_System)—second largest, stretching 1,000 kilometers (620 mi) from [Isla Contoy](https://en.wikipedia.org/wiki/Isla_Contoy) at the tip of the [Yucatán Peninsula](https://en.wikipedia.org/wiki/Yucat%C3%A1n_Peninsula) down to the [Bay Islands of Honduras](https://en.wikipedia.org/wiki/Bay_Islands_%28department%29)
* The [New Caledonia Barrier Reef](https://en.wikipedia.org/wiki/New_Caledonia_Barrier_Reef)—second longest double barrier reef, covering 1,500 kilometers (930 mi)
* The [Andros, Bahamas](https://en.wikipedia.org/wiki/Andros%2C_Bahamas) Barrier Reef—third largest, following the east coast of Andros Island, Bahamas, between [Andros](https://en.wikipedia.org/wiki/Andros) and [Nassau](https://en.wikipedia.org/wiki/Nassau%2C_Bahamas)
* The [Red Sea](https://en.wikipedia.org/wiki/Red_Sea)—includes 6,000-year-old fringing reefs located along a 2,000 km (1,240 mi) coastline
* The [Florida Reef Tract](https://en.wikipedia.org/wiki/Florida_Reef_Tract)—largest continental US reef and the third largest coral barrier reef, extends from [Soldier Key](https://en.wikipedia.org/wiki/Soldier_Key), located in [Biscayne Bay](https://en.wikipedia.org/wiki/Biscayne_Bay), to the [Dry Tortugas](https://en.wikipedia.org/wiki/Dry_Tortugas) in the Gulf of Mexico
* [Pulley Ridge](https://en.wikipedia.org/wiki/Pulley_Ridge)—deepest photosynthetic coral reef, [Florida](https://en.wikipedia.org/wiki/Florida)
* Numerous reefs around the [Maldives](https://en.wikipedia.org/wiki/Maldives)
* The [Philippines](https://en.wikipedia.org/wiki/Philippines) coral reef area, the second largest in Southeast Asia, is estimated at 26,000 square kilometers. 915 reef fish species and more than 400 scleractinian coral species, 12 of which are endemic are found there.
* The [Raja Ampat Islands](https://en.wikipedia.org/wiki/Raja_Ampat_Islands) in [Indonesia](https://en.wikipedia.org/wiki/Indonesia)'s [West Papua](https://en.wikipedia.org/wiki/West_Papua_%28province%29) province offer the highest known marine diversity.
* [Bermuda](https://en.wikipedia.org/wiki/Bermuda) is known for its northernmost coral reef system, located at [32°24′N 64°48′W﻿ / ﻿32.4°N 64.8°W﻿ / 32.4; -64.8](https://geohack.toolforge.org/geohack.php?pagename=Coral_reef&params=32.4_N_64.8_W_). The presence of coral reefs at this high latitude is due to the proximity of the [Gulf Stream](https://en.wikipedia.org/wiki/Gulf_Stream). Bermuda coral species represent a subset of those found in the greater Caribbean.
* The world's northernmost individual coral reef is located within a bay of Japan's [Tsushima Island](https://en.wikipedia.org/wiki/Tsushima_Island) in the [Korea Strait](https://en.wikipedia.org/wiki/Korea_Strait).
* The world's southernmost coral reef is at [Lord Howe Island](https://en.wikipedia.org/wiki/Lord_Howe_Island), in the Pacific Ocean off the east coast of Australia.

## **Coral**



When alive, corals are [colonies](https://en.wikipedia.org/wiki/Colony_%28biology%29) of small animals embedded in [calcium carbonate](https://en.wikipedia.org/wiki/Calcium_carbonate) shells. Coral heads consist of accumulations of individual animals called [polyps](https://en.wikipedia.org/wiki/Polyp_%28zoology%29), arranged in diverse shapes. Polyps are usually tiny, but they can range in size from a pinhead to 12 inches (30 cm) across.

Reef-building or [hermatypic corals](https://en.wikipedia.org/wiki/Hermatypic_coral) live only in the [photic zone](https://en.wikipedia.org/wiki/Photic_zone) (above 50 m), the depth to which sufficient sunlight penetrates the water.

### **Zooxanthellae**

Coral polyps do not photosynthesize, but have a symbiotic relationship with microscopic [algae](https://en.wikipedia.org/wiki/Algae) ([dinoflagellates](https://en.wikipedia.org/wiki/Dinoflagellate)) of the genus [*Symbiodinium*](https://en.wikipedia.org/wiki/Symbiodinium), commonly referred to as [zooxanthellae](https://en.wikipedia.org/wiki/Zooxanthellae). These organisms live within the polyps' tissues and provide organic nutrients that nourish the polyp in the form of [glucose](https://en.wikipedia.org/wiki/Glucose), [glycerol](https://en.wikipedia.org/wiki/Glycerol) and [amino acids](https://en.wikipedia.org/wiki/Amino_acids). Because of this relationship, coral reefs grow much faster in clear water, which admits more sunlight. Without their symbionts, coral growth would be too slow to form significant reef structures. Corals get up to 90% of their nutrients from their symbionts. In return, as an example of [mutualism](https://en.wikipedia.org/wiki/Mutualism_%28biology%29), the corals shelter the zooxanthellae, averaging one million for every cubic centimeter of coral, and provide a constant supply of the [carbon dioxide](https://en.wikipedia.org/wiki/Carbon_dioxide) they need for photosynthesis.



[Zooxanthellae](https://en.wikipedia.org/wiki/Zooxanthellae), the microscopic algae that lives inside coral, gives it colour and provides it with food through photosynthesis



Close up of polyps arrayed on a coral, waving their tentacles. There can be thousands of polyps on a single coral branch.



Corals are animals and not plants. They can appear like plants because they are [sessile](https://en.wikipedia.org/wiki/Sessility_%28motility%29) and take root on the ocean floor. But unlike plants, corals do not make their own food.



[**Table coral**](https://en.wikipedia.org/wiki/Acropora)

The varying pigments in different species of zooxanthellae give them an overall brown or golden-brown appearance, and give brown corals their colors. Other pigments such as reds, blues, greens, etc. come from colored proteins made by the coral animals. Coral that loses a large fraction of its zooxanthellae becomes white (or sometimes pastel shades in corals that are pigmented with their own proteins) and is said to be [bleached](https://en.wikipedia.org/wiki/Coral_bleaching), a condition which, unless corrected, can kill the coral.

There are eight [clades](https://en.wikipedia.org/wiki/Clade) of *Symbiodinium* [phylotypes](https://en.wikipedia.org/wiki/Phylotype). Most research has been conducted on clades A–D. Each clade contributes their own benefits as well as less compatible attributes to the survival of their coral hosts. Each photosynthetic organism has a specific level of sensitivity to photodamage to compounds needed for survival, such as proteins. Rates of regeneration and replication determine the organism's ability to survive. Phylotype A is found more in the shallow waters. It is able to produce [mycosporine-like amino acids](https://en.wikipedia.org/wiki/Mycosporine-like_amino_acid) that are [UV resistant](https://en.wikipedia.org/wiki/Ultraviolet), using a derivative of [glycerin](https://en.wikipedia.org/wiki/Glycerin) to absorb the UV radiation and allowing them to better adapt to warmer water temperatures. In the event of UV or thermal damage, if and when repair occurs, it will increase the likelihood of survival of the host and symbiont. This leads to the idea that, evolutionarily, clade A is more UV resistant and thermally resistant than the other clades.

Clades B and C are found more frequently in deeper water, which may explain their higher vulnerability to increased temperatures. Terrestrial plants that receive less sunlight because they are found in the undergrowth are analogous to clades B, C, and D. Since clades B through D are found at deeper depths, they require an elevated light absorption rate to be able to synthesize as much energy. With elevated absorption rates at UV wavelengths, these phylotypes are more prone to coral bleaching versus the shallow clade A.

Clade D has been observed to be high temperature-tolerant, and has a higher rate of survival than clades B and C during modern [bleaching events](https://en.wikipedia.org/wiki/Coral_bleaching).

### **Skeleton**

Reefs grow as polyps and other organisms deposit calcium carbonate, the basis of coral, as a skeletal structure beneath and around themselves, pushing the coral head's top upwards and outwards. Waves, grazing fish (such as [parrotfish](https://en.wikipedia.org/wiki/Parrotfish)), [sea urchins](https://en.wikipedia.org/wiki/Sea_urchin), [sponges](https://en.wikipedia.org/wiki/Sea_sponge) and other forces and organisms act as [bioeroders](https://en.wikipedia.org/wiki/Bioerosion), breaking down coral skeletons into fragments that settle into spaces in the reef structure or form sandy bottoms in associated reef lagoons.

Typical shapes for coral [species](https://en.wikipedia.org/wiki/Species) are named by their resemblance to terrestrial objects such as [wrinkled brains](https://en.wikipedia.org/wiki/Brain_coral), cabbages, [table tops](https://en.wikipedia.org/wiki/Acropora), [antlers](https://en.wikipedia.org/wiki/Staghorn_coral), wire strands and [pillars](https://en.wikipedia.org/wiki/Pillar_coral). These shapes can depend on the life history of the coral, like light exposure and wave action,[[68]](https://en.wikipedia.org/wiki/Coral_reef#cite_note-68) and events such as breakages.

### **Reproduction**

Corals reproduce both sexually and asexually. An individual polyp uses both reproductive modes within its lifetime. Corals reproduce sexually by either internal or external fertilization. The reproductive cells are found on the [mesenteries](https://en.wikipedia.org/wiki/Mesentery_%28zoology%29), membranes that radiate inward from the layer of tissue that lines the stomach cavity. Some mature adult corals are hermaphroditic; others are exclusively male or female. A few [species](https://en.wikipedia.org/wiki/Species) change sex as they grow.

Internally fertilized eggs develop in the polyp for a period ranging from days to weeks. Subsequent development produces a tiny [larva](https://en.wikipedia.org/wiki/Larva), known as a [planula](https://en.wikipedia.org/wiki/Planula). Externally fertilized eggs develop during synchronized spawning. Polyps across a reef simultaneously release eggs and sperm into the water en masse. Spawn disperse over a large area. The timing of spawning depends on time of year, water temperature, and tidal and lunar cycles. Spawning is most successful given little variation between high and low [tide](https://en.wikipedia.org/wiki/Tide). The less water movement, the better the chance for fertilization. Ideal timing occurs in the spring. Release of eggs or planula usually occurs at night, and is sometimes in phase with the lunar cycle (three to six days after a full moon). The period from release to settlement lasts only a few days, but some planulae can survive afloat for several weeks. During this process the larvae may use several different cues to find a suitable location for settlement. At long distances sounds from existing reefs are likely important. while at short distances chemical compounds become important. The larvae are vulnerable to predation and environmental conditions. The lucky few planulae that successfully attach to substrate then compete for food and space.