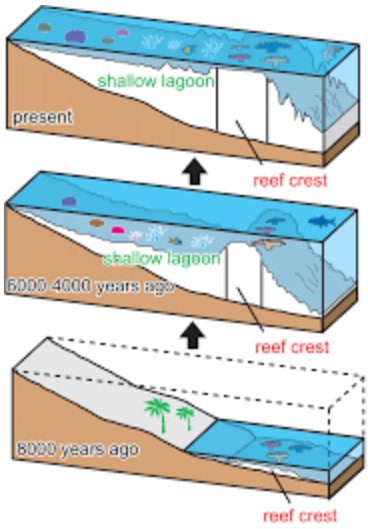
OCEANOGRAPHY
CORAL REEF
PAPER- DSE IV SEM-VI

A **coral reef** is an underwater ecosystem characterized by reef-building corals. Reefs are formed of colonies of coral polyps held together by calcium carbonate. Most coral reefs are built from stony corals, whose polyps cluster in groups. Coral belongs to the class *Anthozoa* in the animal phylum *Cnidaria*, which includes sea anemones and jellyfish. Unlike sea anemones, corals secrete hard carbonate exoskeletons that support and protect the coral. Most reefs grow best in warm, shallow, clear, sunny and agitated water. Coral reefs first appeared 485 million years ago, at the dawn of the Early Ordovician, displacing the microbial and sponge reefs of the Cambrian.[1] Sometimes called *rainforests of the sea*, shallow coral reefs form some of Earth's most diverse ecosystems. They occupy less than 0.1% of the world's ocean area, about half the area of France, yet they provide a home for at least 25% of all marine species, including fish, mollusks, worms, crustaceans, echinoderms, sponges, tunicates and other cnidarians. Coral reefs flourish in ocean waters that provide few nutrients. They are most commonly found at shallow depths in tropical waters, but deep water and cold water coral reefs exist on smaller scales in other areas. Coral reefs deliver ecosystem services for tourism, fisheries and shoreline protection. The annual global economic value of coral reefs is estimated between US$30–375 billion and US$9.9 trillion.[10] Coral reefs are fragile, partly because they are sensitive to water conditions. They are under threat from excess nutrients (nitrogen and phosphorus), rising temperatures, oceanic acidification, overfishing (e.g., from blast fishing, cyanide fishing, spear fishing on scuba), sunscreen use,[11] and harmful land-use practices, including runoff and seeps (e.g., from injection wells and cesspools).

Formation

Most coral reefs were formed after the last glacial period when melting ice caused sea level to rise and flood continental shelves. Most coral reefs are less than 10,000 years old. As communities established themselves, the reefs grew upwards, pacing rising sea levels. Reefs that rose too slowly could become drowned, without sufficient light.[15] Coral reefs are found in the deep sea away from continental shelves, around oceanic islands and atolls. The majority of these islands are volcanic in origin. Others have tectonic origins where plate movements lifted the deep ocean floor. In *The Structure and Distribution of Coral Reefs*,[16] Charles Darwin set out his theory of the formation of atoll reefs, an idea he conceived during the voyage of the *Beagle*. He theorized that uplift and subsidence of the Earth's crust under the oceans formed the atolls.[17] Darwin set out a sequence of three stages in atoll formation. A fringing reef forms around an extinct volcanic 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 predicted that underneath each lagoon would be a 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 where the water is agitated, but can only live within a limited depth range, starting just below low 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. 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*.[19] Corals that rely on zooxanthellae can die when the water becomes too deep for their symbionts to adequately photosynthesize, due to decreased light exposure.[20] The two main variables determining the geomorphology, or shape, of coral reefs are the nature of the substrate 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 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.[21][22] 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. As sea level rise continued, water topped most of the continental islands. The corals could then overgrow the hills, forming cays and reefs. Sea level on the Great Barrier Reef has not changed significantly in the last 6,000 years.[22] The age of living reef structure is estimated to be between 6,000 and 8,000 years.[23] 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).[24] 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.[25]

CONDITIONS

Sunlight: Corals need to grow in shallow water where sunlight can reach them. Corals depend on the *zooxanthellae* (algae) that grow inside of them for oxygen and other things, and since these algae needs sunlight to survive, corals also need sunlight to survive. Corals rarely develop in water deeper than 165 feet (50 meters).

Clear water: Corals need clear water that lets sunlight through; they don’t thrive well when the water is opaque. Sediment and plankton can cloud water, which decreases the amount of sunlight that reaches the zooxanthellae.

Warm water temperature: Reef-building corals require warm water conditions to survive. Different corals living in different regions can

withstand various temperature fluctuations. However, corals generally live in water temperatures of 68–90° F or 20–32° C.

Clean water: Corals are sensitive to pollution and sediments. Sediment can create cloudy water and be deposited on corals, blocking out the sun and harming the polyps. Wastewater discharged into the ocean near the reef can contain too many nutrients that cause seaweeds to overgrow the reef.

Saltwater: Corals need saltwater to survive and require a certain balance in the ratio of salt to water. This is why corals don't live in areas where rivers drain fresh water into the ocean ("estuaries").

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 is formed. However, shell fragments and the remains of coralline algae such as the greensegmented genus *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.[

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[27] – scientists have identified further reef types. While some sources find only three,[28][29] Thomas and Goudie list four "principal large-scale coral reef types" – the fringing reef, barrier reef, atoll and table reef[30] – while Spalding *et al.* list five "main types" – the fringing reef, barrier reef, atoll, "bank or platform reef" and patch reef.[

Fringing reef

A fringing reef, also called a shore reef,[32] is directly attached to a shore,[33] or borders it with an intervening narrow, shallow channel or lagoon.[34] It is the most common reef type.[34] Fringing reefs follow coastlines and can extend for many kilometres.[35] They are usually less than 100 metres wide, but some are hundreds of metres wide.[36] Fringing reefs are initially formed on the shore at the 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.[37] 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 are"some of the best developed in the world" and occur along all its shores except off sandy bays.[38

Barrier reef

Barrier reefs are separated from a mainland or island shore by a deep channel or lagoon.[34] 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 takesconsiderably 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.[34][39] Other major examples are the Belize Barrier Reef and the New Caledonian Barrier Reef.[39] Barrier reefs are also found on the coasts of Providencia,[39] Mayotte, the Gambier Islands, on the southeast coast of Kalimantan, on parts of the coast of Sulawesi, southeastern New Guinea a d the south coast of the Louisiade Archipelago.

Platform reef

Platform reefs, variously called bank or table reefs, can form on the 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.[40] Platform reefs are found in the southern Great Barrier Reef, the Swain[41] and Capricorn Group[42] on the continental shelf, about 100–200 km from the coast. Some platform reefs of the northern Mascarenes are several thousand kilometres from the mainland. Unlike fringing and barrier reefs which extend only seaward, platform reefs grow in all directions.[40] 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 near Jeddah. In old platform reefs, the inner part can be so heavily eroded that it forms a pseudo-atoll.[40] These can be distinguished from real atolls only by detailed investigation, possibly including core drilling. Some platform reefs of the Laccadives are U-shaped, due to wind and water flow.

Atoll

Atolls or atoll reefs are a more or less circular or continuous barrier reef that extends all the way around a lagoon without a central island.[43] They are usually formed from fringing reefs around volcanic islands.[34] Over time, the island erodes away and sinks below sea level.[34] 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
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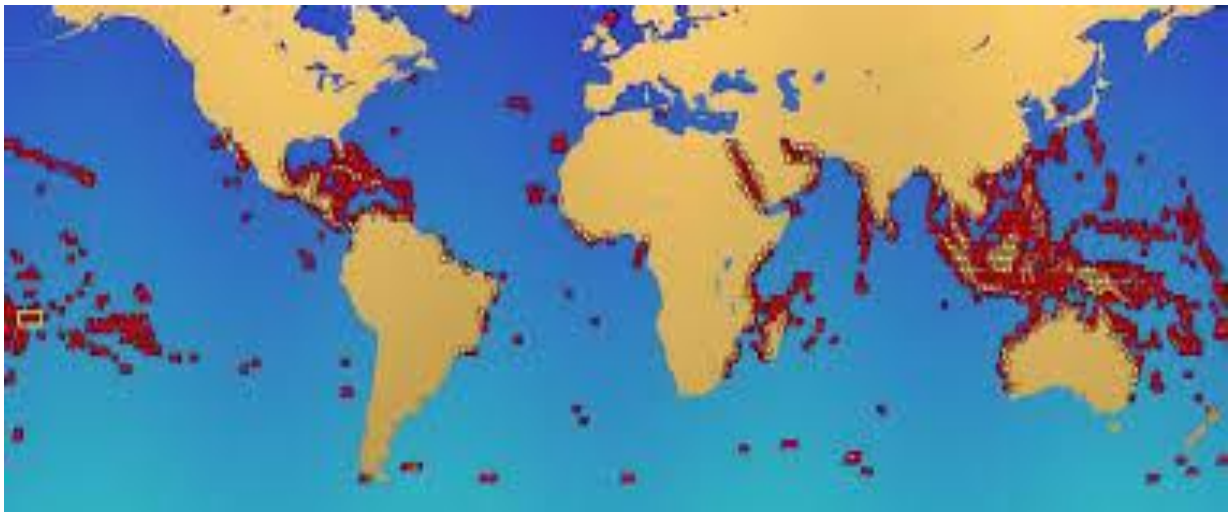
Locations

Coral reefs are estimated to cover 284,300 km2 (109,800 sq mi),[49] just under 0.1% of the oceans' surface area. The Indo-Pacific region (including the Red Sea, Indian Ocean,Southeast Asia and the Pacific) account for 91.9% of this total. Southeast Asia accounts for 32.3% of that figure, while the Pacific including Australia accounts for 40.8%. Atlantic and Caribbean coral reefs account for 7.6%.[4] 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 below18 °C (64 °F).[50] However, reefs in the Persian Gulf have adapted to temperatures of 13 °C (55 °F) in winter and
38 °C (100 °F) in summer.[51] 37 species of scleractinian corals inhabit such an environment around Larak Island.[52] Deep-water coral inhabits greater depths and colder temperatures at much higher latitudes, as far north as Norway.[53] Although deep water corals can form reefs, little is known about them. Coral reefs are rare along the west coasts of the Americas and Africa, due primarily to upwelling and strong cold coastal currents that reduce water temperatures in these areas (the Peru, Benguela and Canary Currents respectively).[54] Corals are seldom found along thecoastline of South Asia—from the eastern tip of India(Chennai) to the Bangladesh and Myanmar borders[4]— as well as along the coasts of northeastern South America and Bangladesh, due to the freshwater release from the Amazon and Ganges Rivers respectively.
The 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 The Mesoamerican Barrier Reef System—second largest, stretching 1,000 kilometers (620 mi) from Isla Contoy at the tip of the Yucatán Peninsula down to the Bay Islands of Honduras The New Caledonia Barrier Reef—second longest double barrier reef, covering 1,500 kilometers (930 mi) The Andros, Bahamas Barrier Reef—third largest, following the east coast of Andros Island, Bahamas, between Andros and Nassau The Red Sea—includes 6,000-year-old fringing reefs located along a 2,000 km (1,240 mi) coastline
The Florida Reef Tract—largest continental US reef and the third largest coral barrier reef, extends from Soldier Key, located in Biscayne Bay, to the Dry Tortugas in the Gulf of Mexico[55]
Pulley Ridge—deepest photosynthetic coral reef, Florida Numerous reefs around the Maldives
The 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 in Indonesia's West Papua province offer the highest known marine
diversity.[56]
Bermuda is known for its northernmost coral reef system, located at 32.4°N 64.8°W. The presence of coral reefs at this high latitude is due to the proximity of the Gulf Stream. Bermuda coral species represent a subset of those found in the greater Caribbean.[57]
The world's northernmost individual coral reef is located within a bay of Japan's Tsushima Island in the Korea Strait.[58]
The world's southernmost coral reef is at Lord Howe Island, in the Pacific Ocean off the east coast of Australia.



Threats

Since their emergence 485 million years ago, coral reefs have faced many threats, including disease,[139] predation,[140] invasive species, bioerosion by grazing fish,[141] algal blooms, geologic hazards, and recent human activity.

This include coral mining, bottom trawling,[142] and the digging of canals and accesses into islands and bays, all of which can damage marine ecosystems if not done sustainably. Other localized threats include blast fishing, overfishing, coral overmining,[143] and marine pollution, including use of the banned anti-fouling biocide tributyltin; although absent in developed countries, these activities continue in

places with few environmental protections or poor regulatory enforcement.[144][145][146] Chemicals in sunscreens may awaken latent viral infections in zooxanthellae[11] and impact reproduction.[147] However, concentrating tourism activities via offshore platforms has been shown to limit the spread of coral disease by tourists.[148]

Greenhouse gas emissions present a broader threat through sea temperature rise and sea level rise,[149] though corals adapt their calcifying fluids to changes in seawater pH and carbonate levels and are not directly threatened by ocean acidification.[150] Volcanic and manmade aerosol pollution can modulate regional sea surface temperatures.[151]

In 2011, two researchers suggested that "extant marine invertebrates face the same synergistic effects of multiple stressors" that occurred during the end-Permian extinction, and that genera "with poorly buffered respiratory physiology and calcareous shells", such as corals, were particularly vulnerable.[152][153][154]

A major coral bleaching event took place on this part of the Great Barrier Reef in Australia

Corals respond to stress by "bleaching," or expelling their colorful zooxanthellate endosymbionts. Corals with Clade C zooxanthellae are generally vulnerable to heat-induced bleaching, whereas corals with the hardier Clade A or D are generally resistant,[155] as are tougher coral genera like Porites and Montipora.[156]

Every 4–7 years, an El Niño event causes some reefs with heat-sensitive corals to bleach,[157] with especially widespread bleachings in 1998 and

2010.[158][159] However, reefs that experience a severe bleaching event become resistant to future heat-induced bleaching,[160][161][156] due to rapid directional selection.[161] Similar rapid adaption may protect coral reefs from global warming.[162]

A large-scale systematic study of the Jarvis Island coral community, which experienced ten El Niño-coincident coral bleaching events from 1960 to 2016, found that the reef recovered from almost complete death after severe events