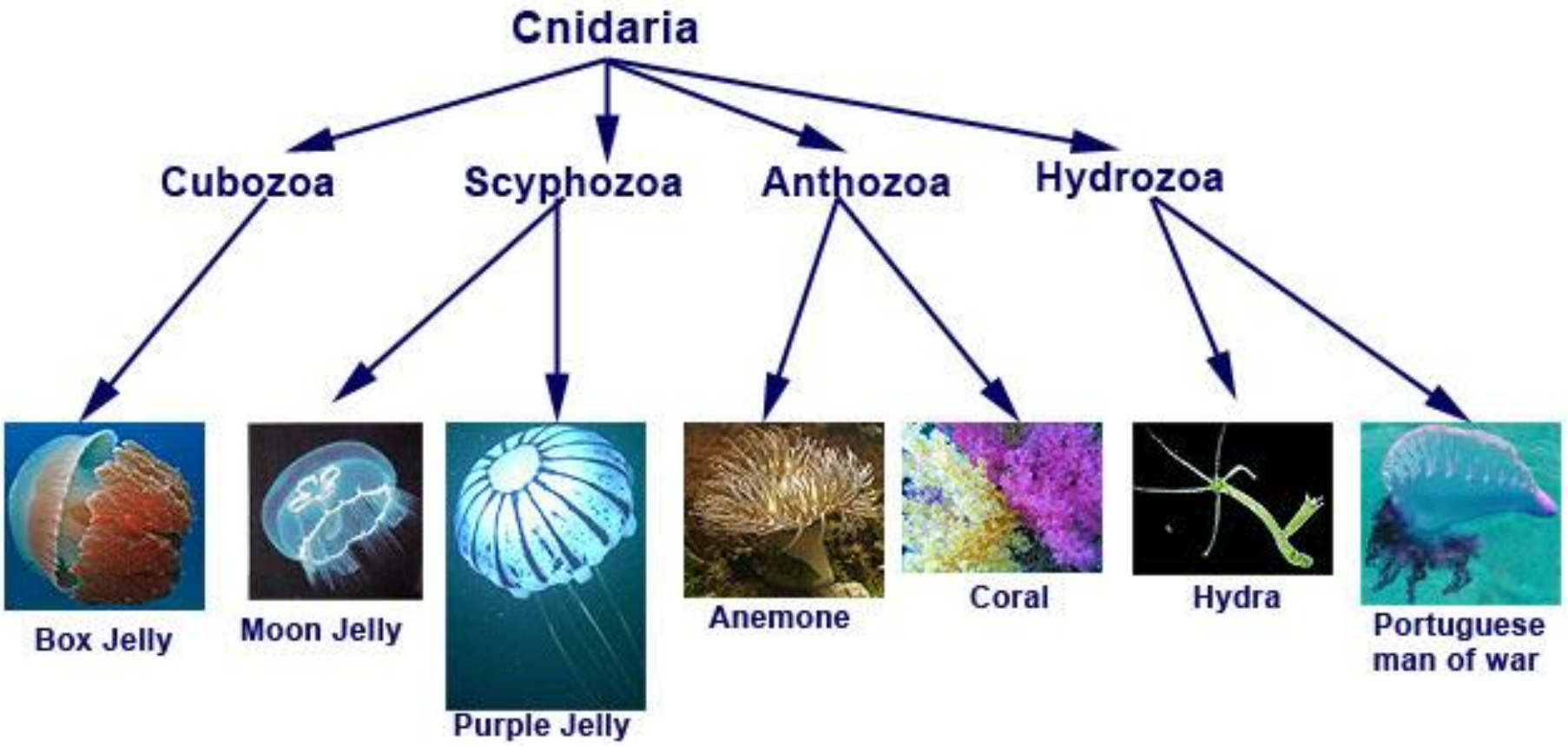
CORAL REEFS

Dr. P. SANTHANAM
Assistant Professor
Marine Planktonology & Aquaculture Lab.,
Department of Marine Science, School of Marine Sciences
Bharathidasan University, Tiruchirappalli-620 024, Tamil Nadu.
E-mail: santhanam@bdu.ac.in
Website: www.mpalbdu.weebly.com

Coral & Coral Reefs Scientific Classification

Phylum - Cnidaria (Formerly Coelenterata)

This diverse *invertebrate* group includes corals, sea anemones, hydras, sea jelly, and their relatives. All cnidarians are *radially symmetrical* (the body is symmetrical around a central axis), lack a head, usually have a crown of tentacles around the mouth, and possess nematocysts. About 9,000 living species are known.



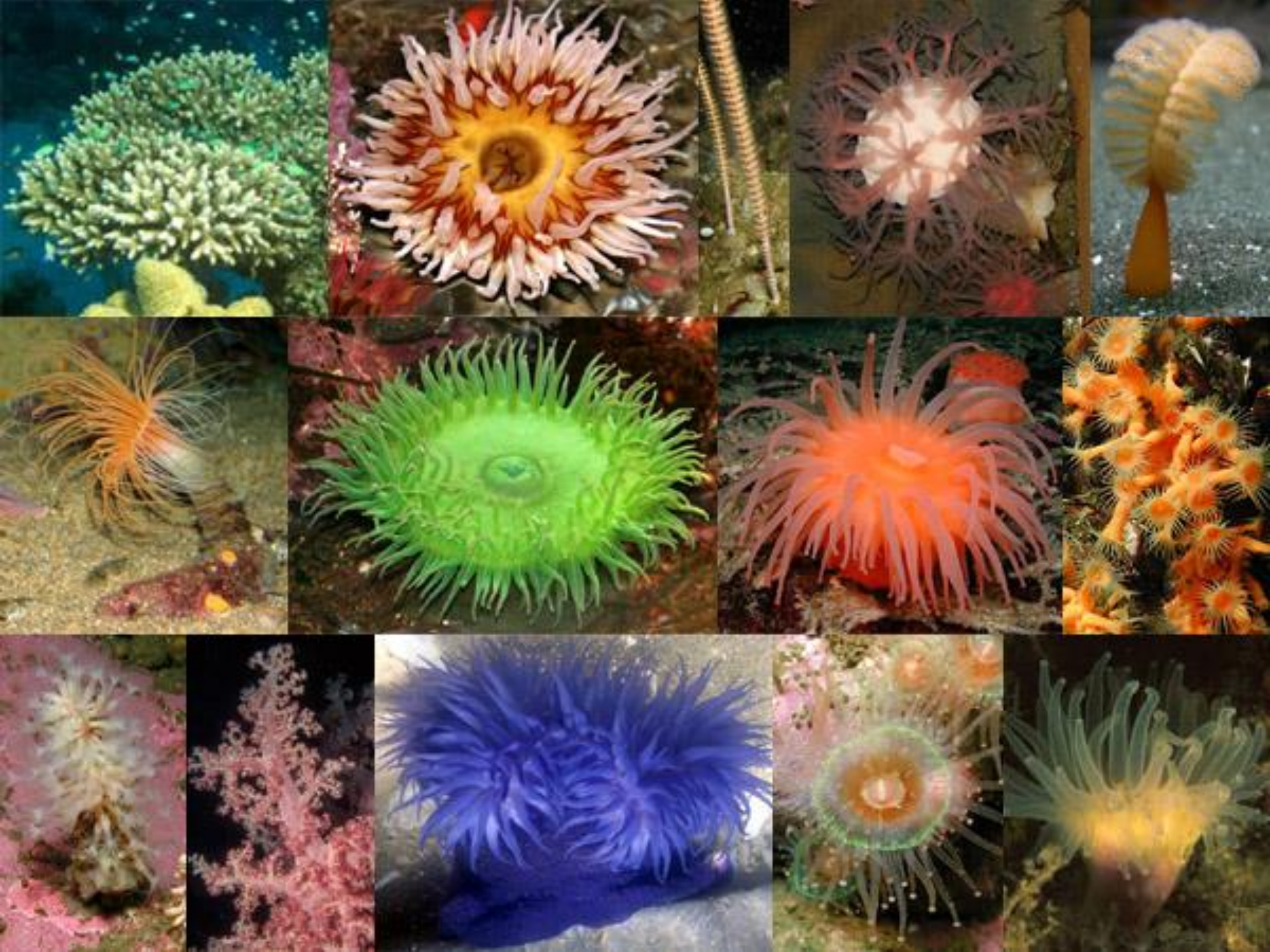
Class – Anthozoa

Anthozoans include corals, sea anemones, sea pens, and sea pansies.

These animals are either solitary or colonial polyps that live attached to a substrate (surface).

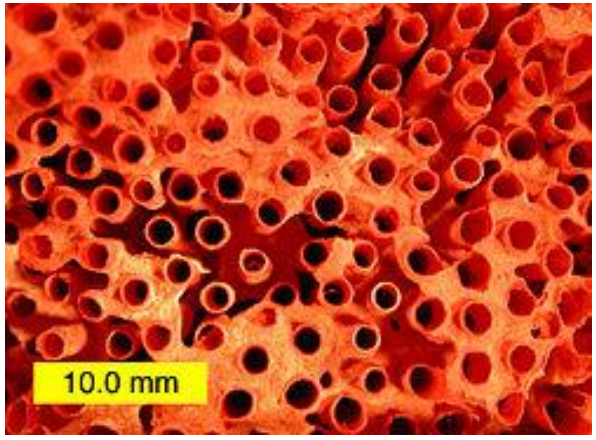
Of the 6,000 known anthozoan species, corals comprise about 2,500 species.

The Class Anthozoa is further divided into three subclasses: Octocorallia, Zoantharia, and Tabulata (extinct colonial corals).



Coral & Coral Reefs Scientific Classification

Subclass Octocorallia. Polyps are characterized by having eight pinnate (side-branching) tentacles. Octocorallians include gorgonian corals, sea pens, sea pansies, organ- pipe corals, and soft corals (order Alcyonacea). Most are colonial.



Coral & Coral Reefs Scientific Classification

Subclass Zoantharia. Polyps are characterized by having tentacles in multiples of six. Zoantharian tentacles are rarely pinnate. Black corals and reef-building corals (order Scleractinia) are members of this subclass. Reef-building corals are also known as "hard corals" or "stony corals". Zoantharians may be either solitary or colonial.

In this resource, the term "corals", refers to both Octocorallians and Zoantharians unless otherwise noted



Coral & Coral Reefs Scientific Classification

Fire Coral

Fire or stinging coral is not a true coral. It is a hydrocoral (Class Hydrozoa).

Fossil History

The earliest reefs developed two billion years ago in the mid- to late Precambrian era. These reefs were built by colonies of calcareous algae, not corals.

Corals, sponges, bryozoans, and calcareous algae enhanced the growing reef community in the Paleozoic era, 245 to 570 million years ago. During this era, natural environmental changes led to periodic reef demise.

Hard corals developed into the prominent reef builders during the Mesozoic era, 65 to 245 million years ago. Coral reefs flourished until a devastating demise at the end of the era, when many coral families disappeared.

The species of corals that made up the reefs of the Tertiary period, 2 to 65 million years ago, were similar to today's species.

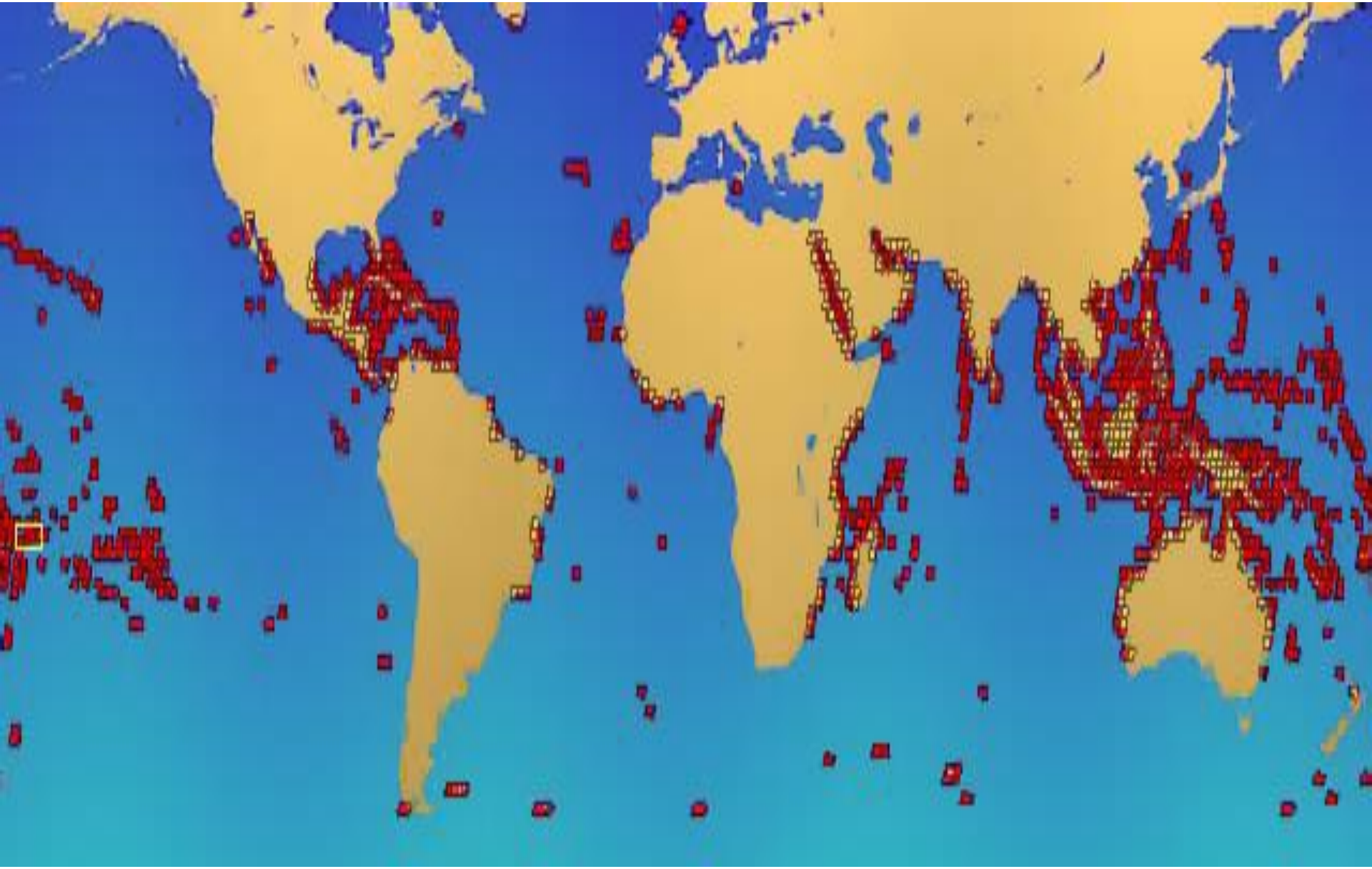
Global Distribution of Coral Reefs

The vast majority of large reefs created by corals in shallow waters (< 50 m water depth) are located within a tropical zone located between 30º N and 30º S latitude with a preferred temperature range of approximately 22º to 29º C.

Corals also grow best in areas with little suspended sediment in the water, so large coral reefs systems are not common to locations where there is a large input of sediment to the coastal zone by river systems.

Although there are cold, deep water types of coral present in the ocean basins, they do not create large nearshore reef structures that affect adjacent coasts.

Global Distribution of Coral Reefs



Red dots indicate the global distribution of coral reefs. Reef systems built primarily out of calcium carbonate secreting organisms.

Global Distribution of Coral Reefs

There are three main types of shallow water coral reef structures: 1) barrier reefs, 2) fringing reefs, and 3) coral atolls.

These three types are differentiated on the basis of proximity to land, the overall scale of the reef structure, and the shape of the reef.

Barrier reefs are typically large-scale, linear features that extend parallel to a shore with a lagoon between the reef and the mainland.

Fringing reefs are directly attached to the shore with no well-developed lagoon between the reef structure and the mainland.

Coral atolls are circular reefs that often start out as fringing reefs attached to a volcanic island. As the volcanic islands subside, the reef grows upward and a lagoon develops behind the reef and inside the submerging island. Eventually, the island can subside below the water level, and a ring like coral reef structure remains.

Barrier reefs

Satellite image of a portion of the Great Barrier Reef on the east coast of Australia. Note the parallel trend of the reef to the coast and the lagoon that separates the reef from the mainland. The arrows identify sediment plumes that are entering the lagoon by the inflow of water. There are substantial concerns because such plumes can also deliver excess nutrient and pollution loads that are deadly to the coral organisms.

Fringing reefs

Australia's largest fringing coral reef, Ningaloo Reef, on the western shore of Australia. Close examination of the image reveals that the reef is in close contact to the land and there exists a little lagoon between the reef and the mainland.

Coral atolls

Wake Island atoll in the central Pacific Ocean is located 4,000 km west-southwest of Hawaii. The central blue lagoon area is approximately the outline of the now submerged crater of the volcano around which the atoll developed. Note the aircraft landing strips and other structures that are maintained by the U.S. Department of the Interior for U.S. Air Force and Army operations in this remote Pacific location.

Distribution

Various species of corals are found in all oceans of the world, from the tropics to the polar regions.

Reef-building corals are scattered throughout the tropical and subtropical Western Atlantic and Indo-Pacific oceans, generally within 30°N and 30°S latitudes.

Western Atlantic reefs include these areas: Bermuda, the Bahamas, the Caribbean Islands, Belize, Florida, and the Gulf of Mexico.

The Indo-Pacific ocean region extends from the Red Sea and the Persian Gulf through the Indian and Pacific oceans to the western coast of Panama.

Corals grow on rocky outcrops in some areas of the Gulf of California.

Habitat Requirements

Although various types of corals can be found from the water's surface to depths of 19,700 ft. (6,000 m), reef- building corals are generally found at depths of less than 150 ft (46 m), where sunlight penetrates. Because reef- building corals have a symbiotic relationship with a type of microscopic algae, sunlight is necessary for these corals to thrive and grow.

Reefs tend to grow faster in clear water. Clear water allows light to reach the symbiotic algae living within the coral polyp's tissue. Many scientists believe that the algae, called zooxanthellae, promote polyp calcification. See adaptations for more information on this algae and its relationship with coral.

Light-absorbing adaptations enable some reef- building corals to live in dim blue light.

Reef-building corals require warm ocean temperatures (68° to 82° F, or 20° to 28° C). Warm water flows along the eastern shores of major land masses.

Reef development is generally more abundant in areas that are subject to strong wave action. Waves carry food, nutrients, and oxygen to the reef; distribute coral larvae; and prevent sediment from settling on the coral reef.

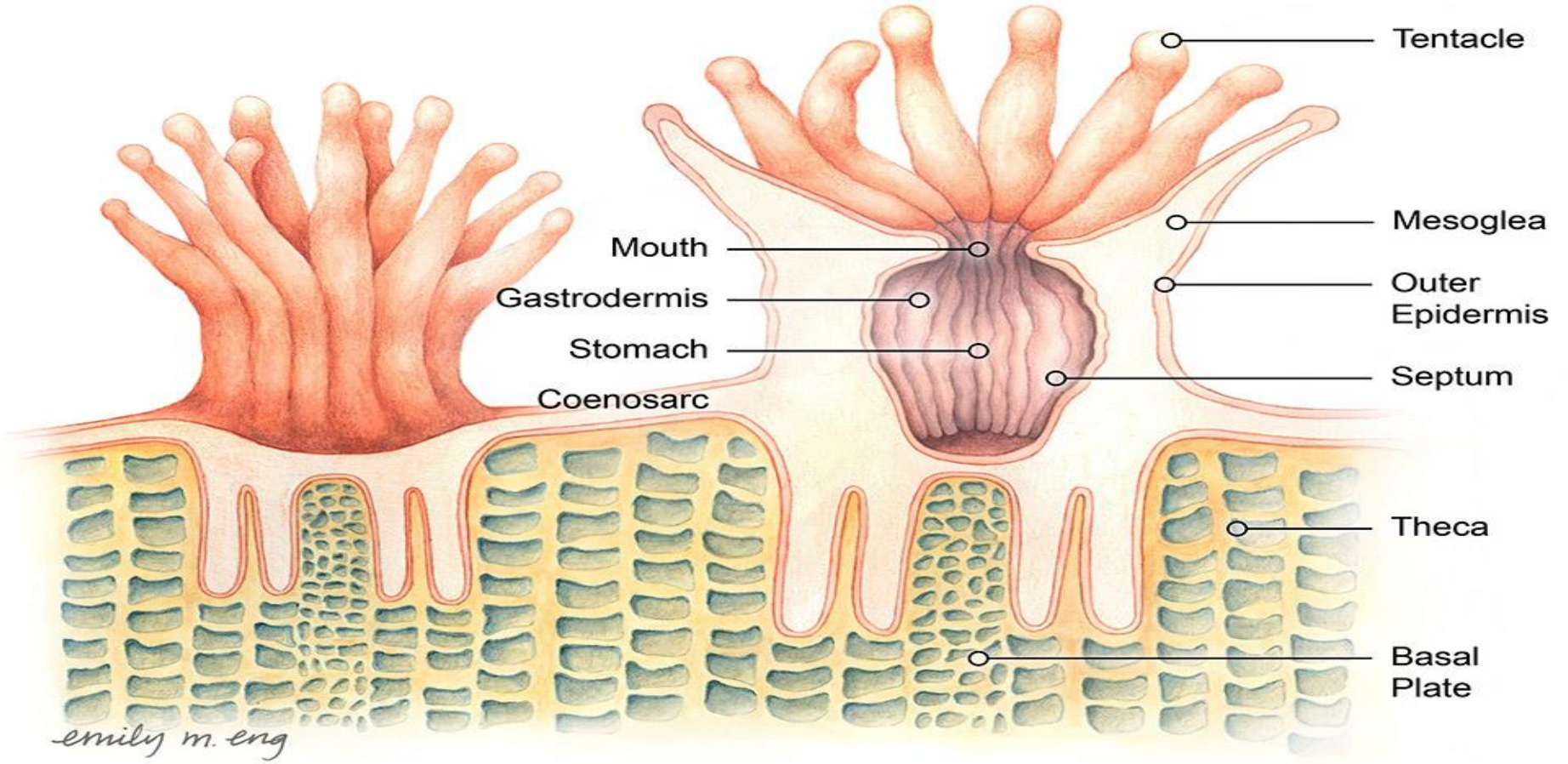
Precipitation of calcium from the water is necessary to form a coral polyp's skeleton. This precipitation occurs when water temperature and salinity are high and carbon dioxide concentrations are low. These conditions are typical of shallow, warm tropical waters.

Most corals grow on a hard substrate.

Coral & Coral Reefs Physical Characteristics

Body Shape

A coral polyp is a tubular saclike animal with a central mouth surrounded by a ring of tentacles. The end opposite the tentacles, called the base, is attached to the substrate.



Coral & Coral Reefs Physical Characteristics

Size

Depending on the species, coral polyps may measure less than an inch to several inches in diameter (a few millimeters to several centimeters).

One of the largest corals, *Fungia* (mushroom coral), is a solitary coral that can extend 10 in. (25 cm) in diameter.

Colonial coral polyps are much smaller and average 0.04 to 0.12 in. (1-3 mm) in diameter.

Coral colonies also vary in size. Some corals form only small colonies. Others may form colonies several feet (a few meters) high. Star coral (*Montastrea annularis*) colonies reach an average height of 10 to 13 ft. (3-4m).

Coral & Coral Reefs Physical Characteristics

Color

Natural pigments in coral tissue produce a range of colors including white, red, orange, yellow, green, blue, and purple.

Colored calcareous *spicules* (needle-shaped structures) give some octocorallians their colors.

Algae that live within the tissues of some corals may make the coral appear brown, green, or orange.

Coral & Coral Reefs Physical Characteristics

Tentacles

Tentacles are for defense and for moving food to the mouth.

Depending on the subclass, a coral polyp's tentacles are arranged in multiples of six or eight.

The tentacles contain microscopic stinging capsules called nematocysts. A nematocyst is a bulbous double-walled structure containing a spirally folded, venom-filled thread with a minute barb at its tip. A tiny sensor projects outside the nematocyst. When the sensor is stimulated physically or chemically, the capsule explodes and ejects the thread with considerable force and speed. The barb penetrates the victim's skin and injects a potent venom.

Coral & Coral Reefs Senses

Nervous System

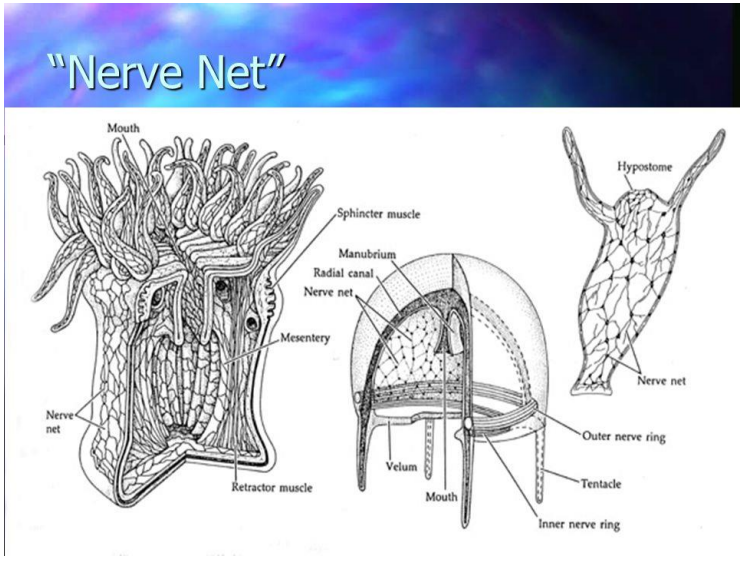
Corals lack a brain but have a simple nervous system called a nerve net. The nerve net extends from the mouth to the tentacles.

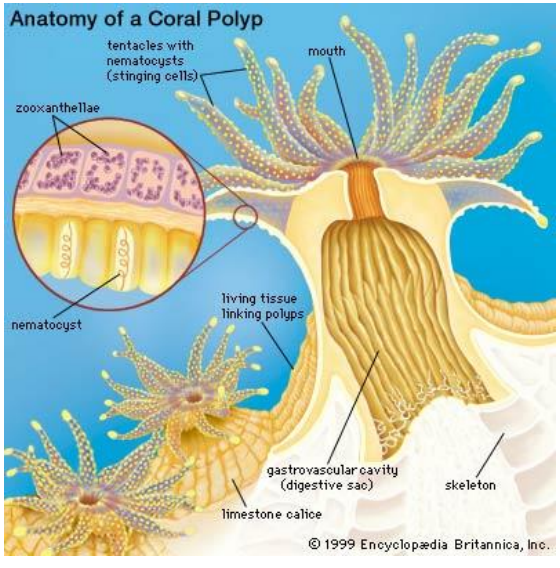
Chemoreception

Polyps can detect certain substances such as sugars and amino acids. This sense, similar to our senses of smell and taste, enables corals to detect prey.

Nematocyst Sensors

Tiny sensors in the ends of nematocysts in polyp's tentacles trigger the nematocyst to eject. These sensors are stimulated either chemically or physically.

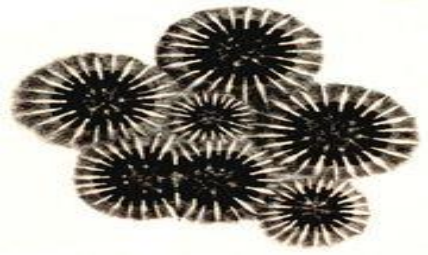




Coral & Coral Reefs Adaptations for an Aquatic Environment

Attachment

Most coral polyps attach themselves to a hard substrate and remain there for life.



Coral & Coral Reefs Adaptations for an Aquatic Environment

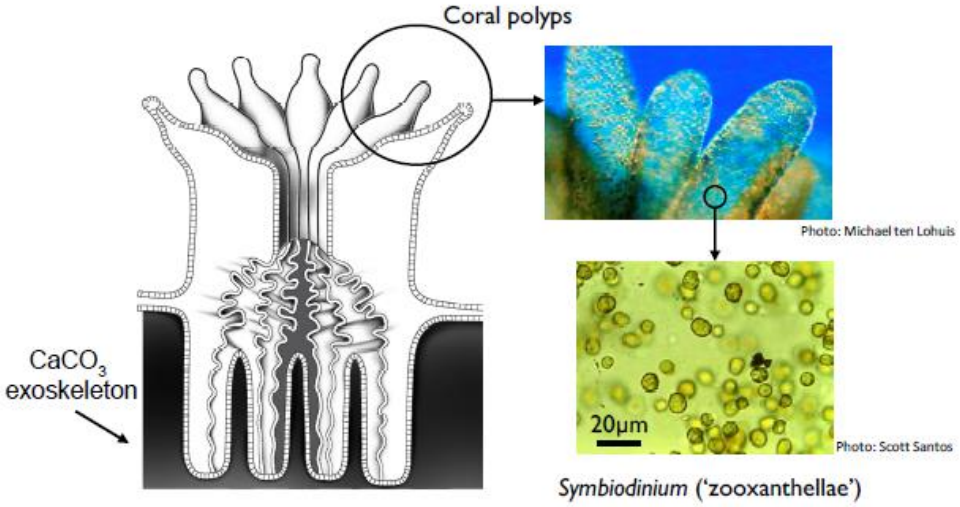
Symbiosis

Reef-building corals have a mutualistic relationship with zooxanthellae, microscopic algae that live with coral polyp's tissues. Both the polyp and the zooanthellae benefit. For this reason, reef-building corals are found only in areas where symbiotic zooxanthellae can take in light for photosynthesis.

Through photosynthesis, zooxanthellae convert carbon dioxide and water into oxygen and carbohydrates. The coral polyp uses carbohydrates as a nutrient. The polyp also uses oxygen for respiration and in turns, returns carbon dioxide to the zooxanthellae. Through this exchange, coral saves energy that would otherwise be used to eliminate the carbon dioxide.

Nitrogen and phosphorus are cycled between zooxanthellae and coral polyps. For example, zooxanthellae take in ammonia given off as waste by the polyp, and return amino acids.

Zooxanthellae also promote polyp calcification by removing carbon dioxide during photosynthesis. Under optimum conditions, this enhanced calcification builds the reef faster than it can be eroded by physical or physical or biological factors.



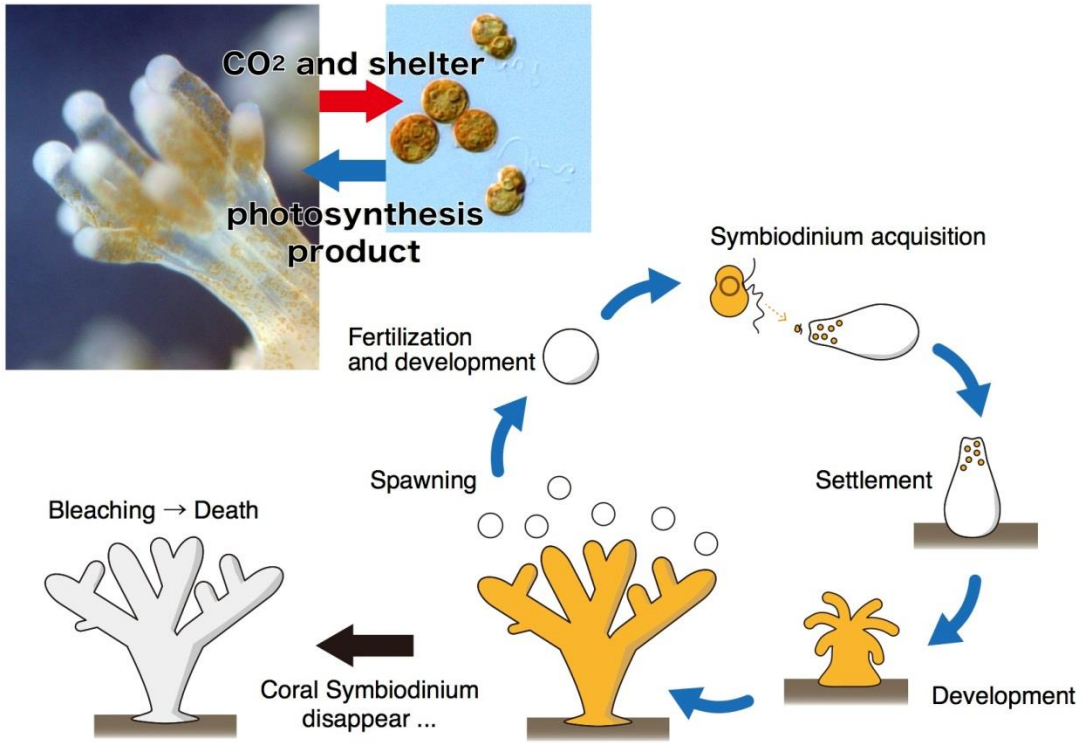


Figure 2. A symbiotic relationship between corals and Symbiodinium

Toxins

Certain toxic compounds in soft corals (Order Alcyonacea) may make the corals unappetizing and deter predators.

Corals compete for living space on the reef. Some soft corals secrete toxins to eliminate competitors. Some reef-building corals can actually digest the tissue of an invading coral.

Coral & Coral Reefs Diet & Eating Habits

Food

Some corals eat *zooplankton* (tiny drifting animals) or small fishes. Others consume organic debris. Many reef- building corals derive their nutrition from zooxanthellae.

Method Of Eating

Coral polyps are generally nocturnal feeders. At night, they extend their tentacles to capture food with the aid of nematocysts.

Some corals secret films or strands of mucus to collect fine organic particles.

In reef-building corals, to mobile filaments originating from the stomach cavity can capture larger food particles. These filaments are also capable of digestion.

Nutrient Transfer

The stomach cavities of colonial corals are interconnected. Food obtained by one polyp can be passed to other polyps in the colony.

Waste Excretion

A polyp excretes solid wastes through its mouth.




Coral & Coral Reefs: Reproduction

Reproductive Modes

Corals can reproduce both sexually and asexually. An individual polyp may use both reproductive modes within its lifetime.

Sexual Reproduction

Corals reproduce sexually by either internal or external fertilization. The reproductive cells are borne on *mesenteries* (membranes) that radiate inward from the layer of tissue that lines the stomach cavity.

Internally fertilized eggs are brooded by the polyp for days to weeks. Free-swimming larvae are released into the water and settle within hours.

Externally fertilized eggs develop while adrift. After a few days, fertilized eggs develop into free-swimming larvae. Larvae settle within hours to days.

Some corals are hermaphroditic (having both male and female reproductive cells). Others are either male or female. Both sexes can occur in a colony, or a colony may consist of individuals of the same sex.

Coral & Coral Reefs: Reproduction

Synchronous spawning occurs in many corals. Polyps release eggs and sperm into the water at the same time. This spawning method disperses eggs over a larger area. Synchronous spawning depends on four factors: time of the year, water temperature, and tidal and lunar cycles.

Spawning is most successful when there is little variation between high and low tides. The less water movement over the reef, the better the chance that an egg will be fertilized.

At least one-third of the reef-building corals of the Great Barrier Reef are synchronous spawners. These corals *spawn* (release eggs) annually in the spring. Spawning occurs on the third through sixth nights after a full moon. Larvae usually settle in four to ten days.

Once the larva settles on a substrate, it develops into a polyp. Some scientists believe that most larvae settle within 2,000 ft. (600 m) of the parent reef. Others contend that some larvae travel longer distances. Research is ongoing.

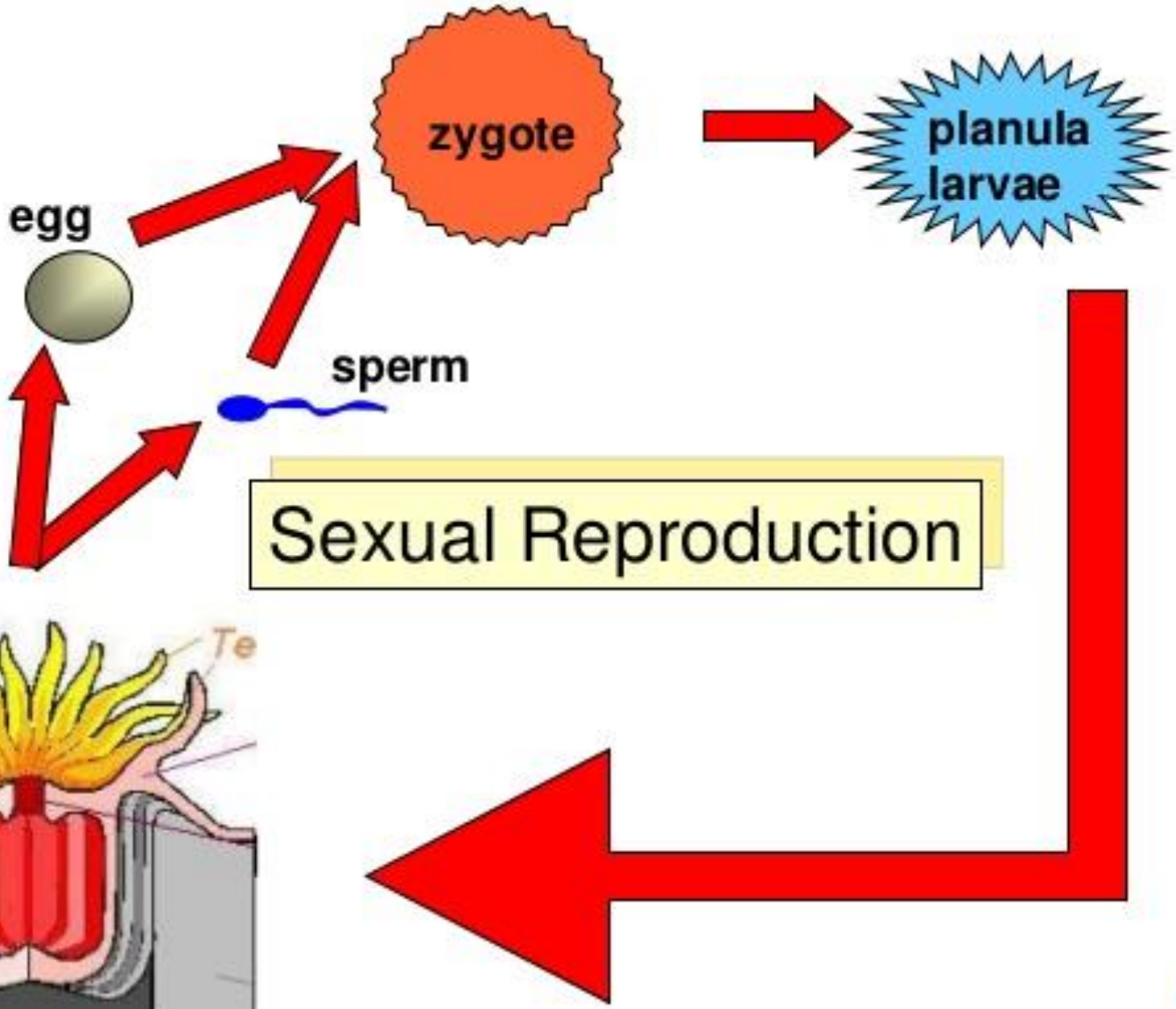

zygote
planula larvae
egg
sperm
Sexual Reproduction
Te

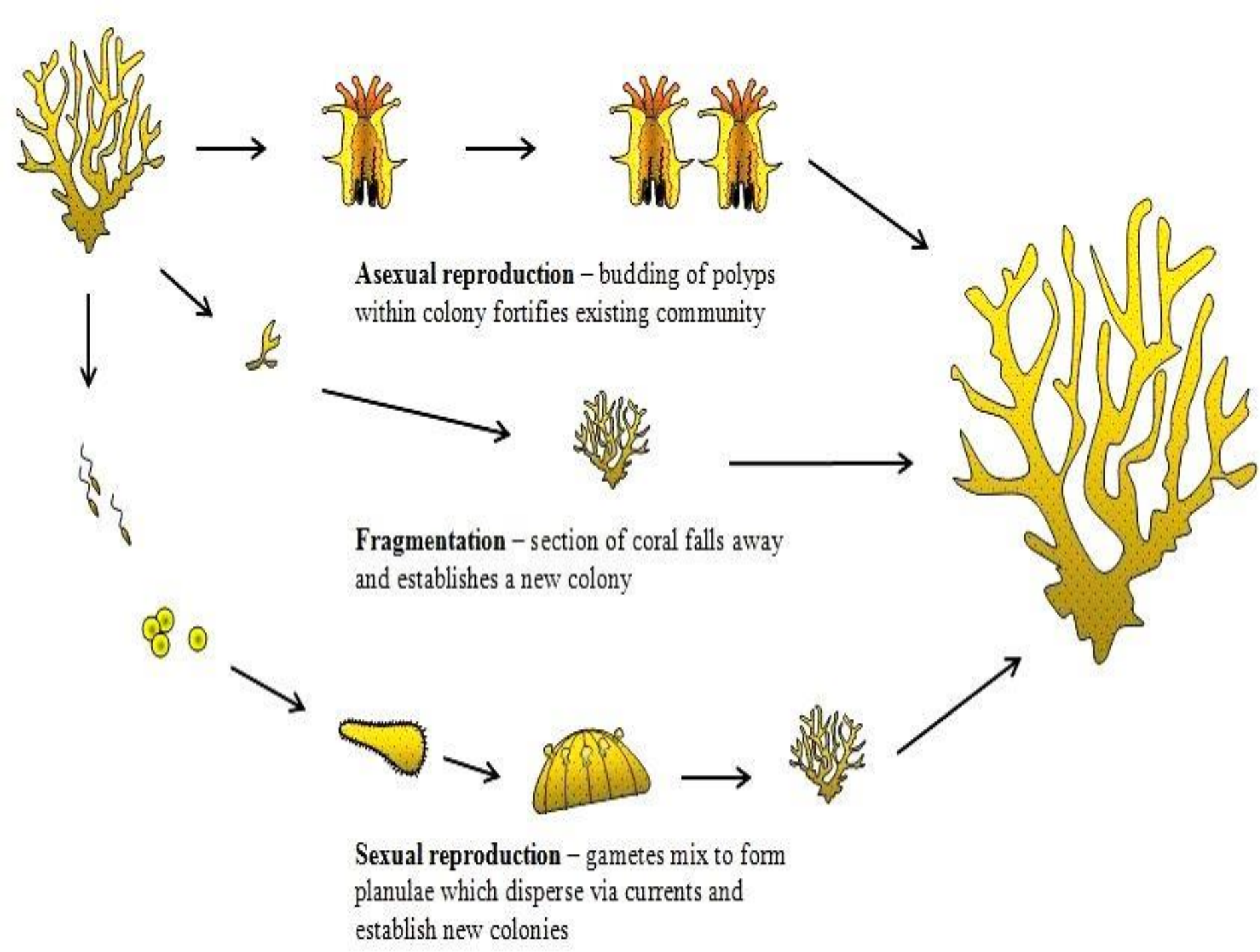

Photo: Peter Harrison

Asexual Reproduction

Environmental disturbances may dislodge some polyps or portions of colonies from the parent colony and deposit them on another part of the reef.

Sometimes, newly developing coral colonies split and form separate colonies.

Often a polyp produced by sexual reproduction initiates growth of a colony asexually by budding. Budding occurs when a portion of the parent polyp pinches off to form a new individual. Budding enables the polyp to replicate itself several times and at the same time maintain tissue connections within the colony. Later, the same polyp may reproduce sexually.

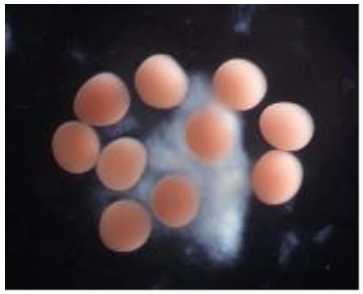

Asexual reproduction – budding of polyps within colony fortifies existing community
Fragmentation – section of coral falls away and establishes a new colony
Sexual reproduction – gametes mix to form planulae which disperse via currents and establish new colonies

Coral & Coral Reefs: Reproduction

Growth

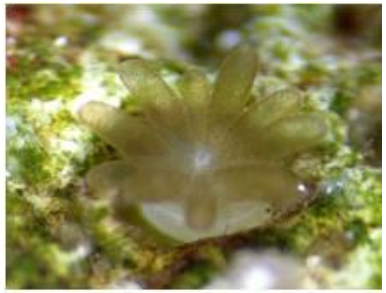
Coral colonies growing in shallow water are often heavily branched. In contrast, deeper water corals often grow in sheets or plates. These flattened forms allow for more efficient use of lower light intensities in deeper waters.

The growth rate of corals and coral reefs depends on factors such as light intensity, water temperature, salinity, turbidity, food availability, competition for space, and predation. Upward growth of coral colonies is generally between 0.5 to 4 in. (1-10 cm) a year.

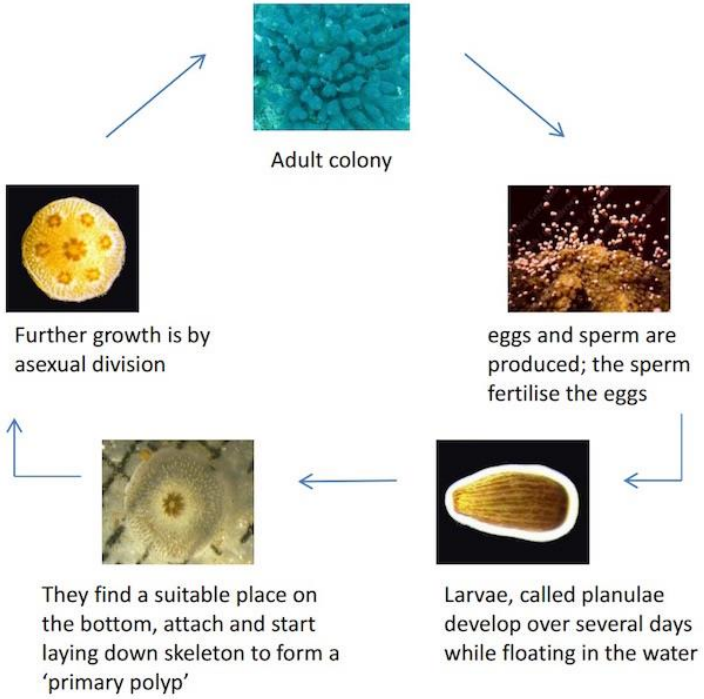


Eggs of coral

Settlement of larvae



Juvenile coral (polyp)



Colonial Corals

Individual coral polyps within a colony are connected by common tissue.

Skeleton

Octocorallians have an internal skeleton. Some internal skeletons contain calcareous spicules. Spicules are either scattered of fused. They stiffen and protect the polyps. Other octocorallians have internal skeletons made of protein.

Reef-building corals secrete an external skeletal cup of calcium carbonate. This skeletal cup protects the polyp: when the polyp contracts, it's almost completely inside the skeletal cup. The stomach cavity of reef-building corals also contains radiating calcareous walls. These walls extend up form the polyp's base and reinforce the skeleton.

Digestive System

The mouth leads into the stomach cavity.

The stomach cavity is partitioned by longitudinal membranes called mesenteries.

Mesenteries increase the surface area of the stomach cavity, which aids in digestion.

The edges of the mesenteries in reef-building corals support long mobile filaments.

These mesentery filaments can protrude through the mouth to capture food.

Mesenteries also contain the reproductive cells.

Respiration

Respiration (gas exchange) takes place through the body surface.

Coral & Coral Reefs: Reef Formation and Types

Reef Composition

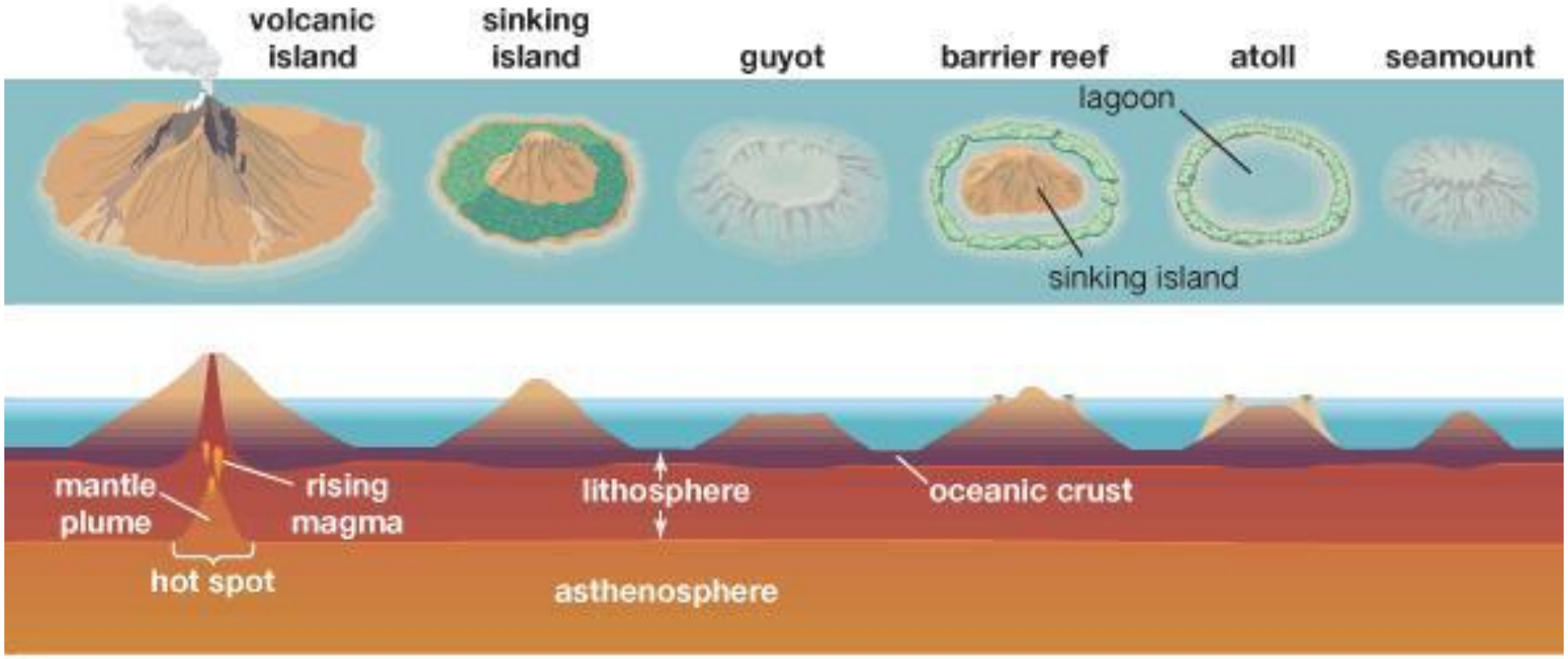
Hard corals build by secreting calcium carbonate skeletons.

Boring organisms such as sponges, worms, and bivalves; along with grazers such as parrotfish and sea urchins break down the coral skeletons. Borers and grazers usually attack dead coral. The resulting sediment settles into spaces in the reef.

Coralline algae, encrusting bryozoans, and minerals cement the dead organic matter, stabilizing the reef structure.

Reef Formation & Types Of Reefs

At one time it was mistakenly thought that coral grew at the bottom of deep tropical seas and succeeding generations grew on top of the dead calcium carbonate skeletons. This idea was dispelled by dredging operations that indicated that reef corals were able to grow only in shallow water.



Coral & Coral Reefs: Reef Formation and Types

Reef Formation & Types Of Reefs

Naturalist Charles Darwin's theory of coral formation is widely accepted. This theory recognizes three types of reefs: the fringing reef, the barrier reef, and the atoll. The first type is a fringing reef. Fringing reefs border shorelines of continents and islands in tropical seas. Fringing reefs are commonly found in the South Pacific Hawaiian Islands, and parts of the Caribbean.

The next type is the barrier reef, which occurs farther offshore. Barrier reefs form when land masses sink, and fringing reefs become separated from shorelines by wide channels. Land masses sink as a result of erosion and shifting crustal plates of the earth. (Crustal plates lift or sink the seafloor and adjacent land masses.) Barrier reefs are common in the Caribbean and Indo-Pacific. The Great Barrier Reef off northern Australia in the Indo-Pacific is the largest barrier reef in the world. This reef stretches more than 1,240 miles (2,000 km).

If the land mass is a small island, it may eventually disappear below the ocean surface, and the reef becomes an atoll. Atolls are reefs that surround a central lagoon. The result is several low coral islands around a lagoon. Atolls commonly occur in the Indo- Pacific. The largest atoll, named Kwajalein, surrounds a lagoon over 60 miles (97 km) long.

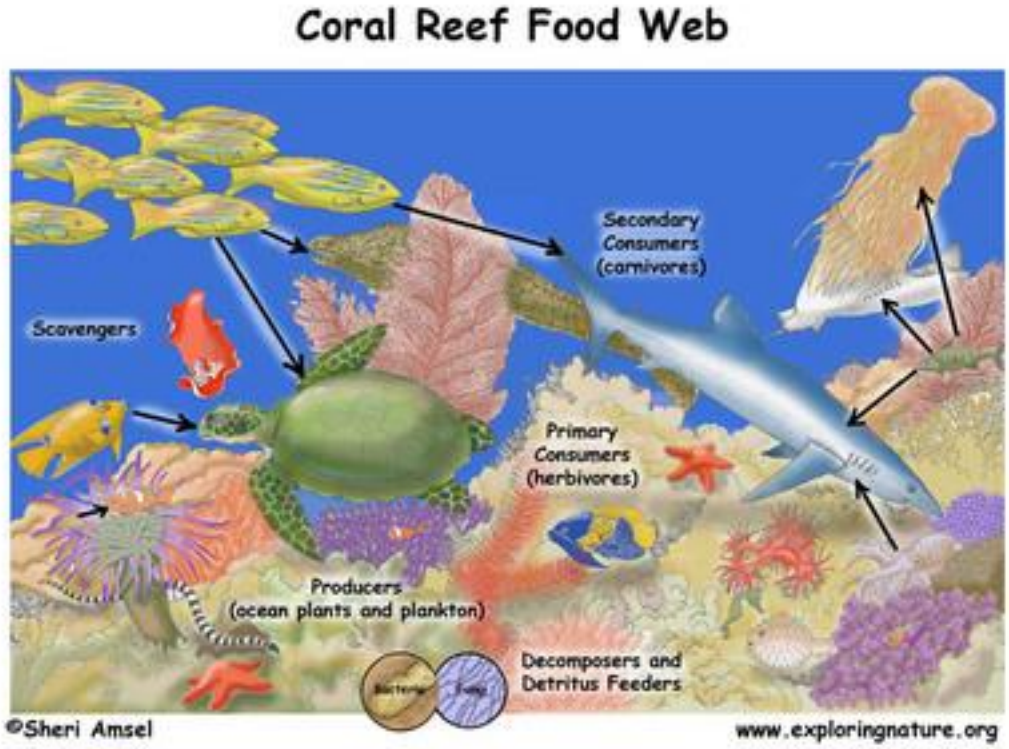
Coral & Coral Reefs: Reef Formation and Types

Reef Formation & Types Of Reefs

Existing coral reefs have been formed since the last of three glacial periods in the Pleistocene epoch, 10,000 years ago. Seawater trapped as ice in enormous glaciers caused sea level to fall. Consequently, all previously formed coral reefs probably died from exposure. When the glaciers melted, sea level rose to its current position and present-day reefs began to develop.

Interactions & Energy

The coral reef ecosystem is a diverse collection of species that interact with each other and the physical environment. The sun is the initial source of energy for this ecosystem. Through photosynthesis, phytoplankton, algae, and other plants convert light energy into chemical energy. As animals eat plants or other animals, a portion of this energy is passed on.



Coral Reef Animals

Sponges have been a part of the coral reef ecosystem from early on. Several species of these porous animals inhabit reefs. Sponges provide shelter for fishes, shrimps, crabs, and other small animals. They appear in a variety of shapes and colors.

Reef Ecosystem

Coral Reef Animals

Sea anemones are close relatives of corals. Indo- Pacific reef anemones are known for their symbiotic relationships with clownfish and anemone fishes. An anemone's tentacles provide refuge for these fishes and their eggs. In return, anemone fishes may protect the anemone from predators such as butterfly fishes. Anemone fishes may even remove parasites from their host anemones.

Reef Ecosystem

Coral Reef Animals

Bryozoans encrust the reef. These microscopic invertebrates from branching colonies over coral skeletons and reef debris, cementing the reef structure.

Coral Reef Animals

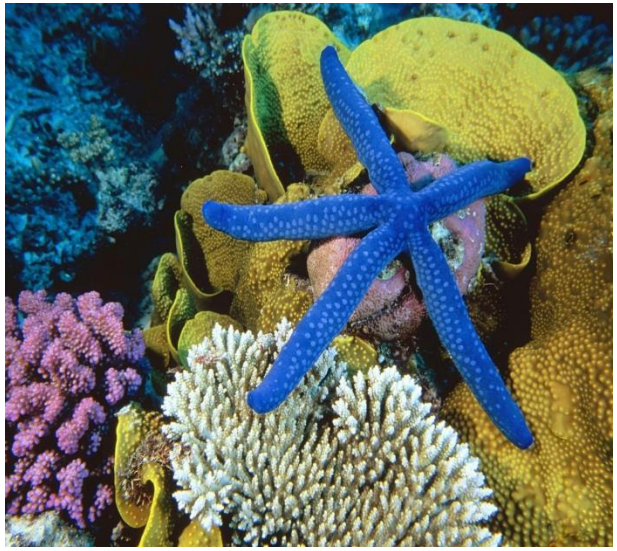
The reef is also home to a variety of worms, including both flatworms and polychaetes.

Flatworms live in crevices in the reef. Some polychaetes such as Christmas tree worms and feather duster worms bore into coral skeletons. Other familiar species include bristle worms.

Reef Ecosystem

Coral Reef Animals

Sea stars, sea cucumbers, and sea urchins live on the reef. The crown-of-thorns sea star is a well- known predator of coral polyps. Large numbers of these sea stars can devastate reefs, leaving behind only the calcium carbonate skeletons. In dead reefs, recently killed by the crown-of-thorns sea star, larger food and game fish are almost totally absent. Even deep-sea fish populations may be affected by this breakdown in the food chain.



Coral Reef Animals

Shrimps, crabs, lobsters, and other crustaceans find protection from predators in crevices or between coral branches. Crustaceans are also predators. The coral crab crushes sea urchins and clams with its strong claws. The banded coral shrimp is an example of a cleaner shrimp. It removes parasites and dead skin from reef fishes.

Coral Reef Animals

Octopuses, squids, clams, scallops, marine snails, and nudibranchs are all molluscs that live on or near the reef. Many feed by filtering food particles from the water. Carnivorous snails are capable of drilling holes into clams or other shelled animals and then eating them. One of the largest molluscs on the reef is the giant clam. This clam may reach a length of 4 ft. (1.2 m).

Reef Ecosystem

Coral Reef Animals

Both schooling and solitary fishes are essential residents of the reef ecosystem. Fishes play a vital role in the reef's food web, acting as both predators and prey. Their leftover food scraps and wastes provide food or nutrients for other reef inhabitants.Some species of sharks, skates, and rays live on or near the reef. Others swim in to eat. Shark species include lemon, nurse, Pacific blacktip, white-tipped reef, and zebra sharks. These sharks as well as rays generally eat crabs, shrimps, squids, clams, and small fishes.

Parrotfish use chisel-like teeth to nibble on hard corals. These fish are herbivores and eat the algae within the coral. They grind the coral's exoskeleton to get the algae, and defecate sand. A single parrotfish can produce about five tons of sand per year.

Wrasses comprise a large group of colorful cigar-shaped fishes. Some species are known as cleaners, and set up cleaning stations along the reef. When a larger fish aligns itself at one of these cleaning stations, a cleaner wrasse removes parasites from the fish.

Eels are one of the reef's top predators. These fishes live in crevices in the reef and venture out at night to hunt and feed. They have sharp teeth set in a powerful jaw. Eels eat small fishes, octopuses, shrimps, and crabs.

Other fishes found on the reefs include angelfishes, butterflyfishes, damselfishes, triggerfishes, seahorses, snappers, squirrelfishes, grunts, pufferfishes, groupers, barracudas, and scorpionfishes.

Coral Reef Animals

Some sea turtles frequent reef areas. Green, loggerhead, and hawksbill sea turtles live in the warm waters of the Great Barrier Reef.

Coral Reef Animals

Sea snakes are rarely found on reefs but do inhabit the waters around reefs in the Indo-Pacific. They possess small fangs but inject a potent venom.

Coral & Coral Reefs: Longevity & Causes of Death

Longevity

Little is known about the lifespan of corals. Generally, coral colonies may live for several decades to centuries.

Predators

Coral polyps face many predators including parrotfishes, butterflyfishes, and sea stars.

Since the 1960's, unnaturally high rates of crown-of-thorns sea star predation in certain regions of the Great Barrier Reef resulted in as much as 95% loss of living coral in these areas.

An increase in crown-of-thorns predation events may be at least partly caused by human activities. Increased runoff from forest clearing and agriculture may lower the salinity and increase nutrients, which may cause crown-of-thorns populations to flourish. In addition, targeted fishing may reduce populations of crown-of-thorns predators such as pufferfish, triggerfish, emperor fish, and tritons.

During the larval stage, corals are particularly subject to predation. They may also drift into areas where the substrate isn't suitable for coral growth.

Human & Climate-Based Threats

Ocean pollution poisons coral polyps. Pollution takes on many forms including oil slicks, pesticides and other chemicals, heavy metals, and garbage.

Fertilizer runoff and untreated sewage introduce added nutrients to coastal ecosystems. These elevated nutrient levels promote algae growth. Unfortunately, high concentrations of algae or solid sewage can overwhelm and smother coral polyps. Under normal conditions, herbivorous fish and some invertebrates keep the algae population balanced.

Deforestation degrades more than just land habitats. When tropical forests are cut down to clear land for agriculture, pasture, or homes, topsoil washes down rivers into coastal ecosystems. Soil that settles on reefs smothers coral polyps and blocks out the sunlight needed for corals to live.

Coastal development and dredging ravages reefs. This development includes building seaside homes, hotels, and harbors.

Coral & Coral Reefs: Longevity & Causes of Death

Human & Climate-Based Threats

Fishing with dynamite, cyanide, or bleach has killed coral reefs in the Indo-Pacific region. Between 1986 and 1991, half of the coral reefs in the Philippines have been demolished by these and other destructive fishing methods.

Besides fishes, fishermen harvest a variety of exotic seafood from the reef including conchs and lobsters. Overharvesting could lead to these species' demise. Careless handling of nets, lines, and lobster traps has led to some reef damage.

International seashell and aquarium trades have put a strain on coral reefs and reef inhabitants. Excessive collecting decimates reef species and upsets the balance of the reef ecosystems. Careful monitoring of these trades will help make sure that the demand for reef species doesn't exceed the sustainable supply.

The souvenir trade has created an international market for coral skeletons, shells, sponges, and other reef animals. Coral skeletons are used as aquarium decorations or fashioned into jewelry and sculptures.

Coral skeletons are also sold as "live rock". Live rock is popular in home saltwater aquariums because it is permeated with living bacteria and algae and acts a natural biological filter.

The tropical fish trade has created a demand for reef fishes. These attractive fishes are popular in saltwater aquariums.

Coral & Coral Reefs: Longevity & Causes of Death

Human & Climate-Based Threats

Careless water recreation damages reefs. Divers and snorklers that sit or stand on or handle corals can injure the delicate polyps. Dropped boat anchors can gouge the reef and crush corals.

Coral bleaching results when the coral polyps expel their zooxanthellae symbionts from their tissues revealing their underlying, white skeleton. Without zooxanthellae, the coral polyps lose nutrition and have less energy available for growth or reproduction.

Coral bleaching is linked to higher than normal temperatures, pollution, and exposure to air.

Within a region, massive coral bleaching events can occur with as little of a temperature increase as 1 to 2°C above normal for a few weeks.

Since 1979, these mass bleaching events seem correlated with severe El Niño Southern Oscillation events.

Full recovery of coral reefs from these events often takes decades.

Coral & Coral Reefs: Longevity & Causes of Death

Human & Climate-Based Threats

In the oceans, global climate change - caused by excess emission of carbon dioxide and other greenhouse gases - is linked to a rise in global ocean temperatures, which may lead to a variety of impacts for ocean animals, plants, and even entire ecosystems such as coral reefs.As the ocean warms, the melting of the polar ice caps is projected to raise sea level. A rise in sea level would decrease the amount of available sunlight necessary for the zooxanthellae symbionts to use in photosynthesis and may ultimately inhibit coral growth.

As ocean temperatures warm due to climate change, incidences of coral bleaching may increase.

Major tropical storms can strip corals from miles of reef habitat. Extreme weather events, such as hurricanes, may become more frequent as a result of climate change and provide a further risk to coral reefs.

Coral & Coral Reefs: Longevity & Causes of Death

Human & Climate-Based Threats

In addition to climate change effects, increases in atmospheric carbon dioxide increases ocean acidification. Traditionally, corals have removed excess carbon dioxide from the atmosphere. However, the amounts of carbon dioxide in the atmosphere have gone beyond what corals can uptake, and the oceans are becoming more acidic as higher amounts of carbon dioxide dissolve into the water. Increasing acidity reduces corals' ability to construct their calcium carbonate skeletons.

The coral reef is an intricate ecosystem and contains a diverse collection of organisms. If coral reefs decline, populations of fishes and other animals that rely on coral reefs for food and shelter may decrease as a result.

Importance Of Corals & Coral Reefs

Reefs protect coastlines from harsh ocean storms and floods.

Coral reefs support a variety of commercial and artisanal fisheries including those for nearshore fishes, crustaceans, and molluscs.

Coral reefs attract millions of scuba divers, snorkelers, and other tourists every year.

Some evidence suggests that corals and other reef inhabitants could potentially provide important medicines, including anti-cancer drugs, painkillers, and anti-inflammatory compounds.

National & International Regulations

Corals should not be collected, either alive or dead. The United States federal government prohibits the removal or destruction of corals from all areas of the continental shelf within a three-mile limit.

The Florida Fish and Wildlife Conservation Commission prohibits the collection of living or dead stony corals (Order Scleractinia) or fire corals (*Millepora* spp.) within Florida waters.
Collection of hard corals is also banned in Hawaii, Guam, and Puerto Rico.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) regulates international trade of certain animals and plants. More specifically, the Convention regulates the import, export, re-export, and introduction from the sea of certain plants and animals. Species for which CITES controls trade are included in one of three appendices. These appendices classify animals in terms of their vulnerability. Many corals are classified by CITES as Appendix II species. These species are not necessarily threatened with extinction but may become so unless their trade is strictly controlled. Appendix II includes the following corals:

Indo-Pacific blue coral (*Heliopora coerulea*; Family Helioporidae, Order Helioporacea)

Organ-pipe coral (*Tubipora musica*; Family Tubiporidae, Order Stolonifera)

All corals in the Order Scleractinia (1634 species of reef- building, stony corals)

All corals in the order Antipatharia (245 species of black corals)

Reef Distribution

- Coral reefs are highly productive with annual production rates ranging from 2,000 to 5,000 g C/m^2/yr.

- In the Indian subcontinent, the reefs are distributed along the east and west coasts at restricted places and all the major reef types are present.

- Fringing reefs are found in the Gulf of Mannar and Palk Bay. Platform reefs are seen along the Gulf of Kachchh. Patchy reefs are found near Ratnagiri and Malwan coasts. Atoll reefs are found in the Lakshadweep archipelago. Fringing and barrier reefs are found in Andaman and Nicobar islands.

- A total of 155 hermatypic coral species belonging to 50 genera and 44 ahermatypic species belonging to 21 genera have been recorded from the Indian coral reef areas.

Reef Distribution

Category	Extent of Coral Reef (Km^2)			
	Gujarat	Tamil Nadu	Lakshadweep Islands	A&N Islands
Reef flat	148.4	64.9	136.5	795.7
Sand over reef	11.8	12.0	7.3	73.3
Mud over reef	117.1	-	-	8.4
Coraline shelf	-	-	230.9	45.0
Coral heads	-	-	6.8	17.5
Live coral platform	-	-	43.3	-
Algae	53.8	0.4	0.4	-
Seaweeds	-	-	0.7	-
Seagrass	-	-	10.9	-
Reef vegetation	112.1	13.3	-	8.9
Vegetation over sand	17.0	3.6	0.4	10.5
Lagoon	-	0.1	322.8	-
Sandy substrate	-	-	(67.4)	-
Reef patch	-	-	(13.4)	-
Deep	-	-	(98.5)	-
Uncertain	-	-	(143.5)	-
Total	460.2	94.3	816.1	959.3

Source: DOD & SAC, 1997

Reef Distribution

- **The worlds largest coral reefs is Australia's Great Barrier Reef, with area of 3,49,000 km^2.**

- **0.1% of ocean surface area of the Great Barrier Reefs contains about 8% of the world's fish species (Goldman and Talbot, 1976)**

Reef Distribution

- **In Indian waters, totally 218 species under 60 genera and 15 families were reported (Venkataraman *et al*., 2003)**

- **Among the four major reef areas of India, Andaman and Nicobar islands are rich in coral species diversity whereas those of Gulf of Kachchh is poorer**

- **Lakshadweep islands have more number of species than the Gulf of Mannar**

Reef Distribution

Among the deepwater corals, so far 686 species belonging to 110 genera and 12 families have been reported from the world of which 227 species belonging to 71 genera and 12 families have been reported from the Indian Ocean region

Species composition in different areas of India

Andaman & Nicobar island - 180

Gulf of Mannar - 92

Lakshadweep - 91

Gulf of Kuchchh - 36

CORAL REEF DISTRIBUTION OF KERALA COAST

- A well preserved, submerged assemblage of Scleractinian corals observed from a well dug to a depth of 8 m from the present mean sea level (MSL) and about 8 km inland, at Vazhakala near Cochin (Kerala).

Family	Name of Species
Pocilloporidae	*Pocillopora damicornis*
	P. verrucosa
Acroporidae	*Acropora formosa*
	Montipora tuberculosa
Poritidae	*Porites* sp. (indeterminable)
Faviidae	*Favia palliada*
	Goniastrea retiformis
	Leptastrea transersa
	Platygyra lamellina
	Leptoria phrygia
Oculidae	*Galaxea astreata*
Caryophylliidae	*Heterocyanthus aequicostatus*

CORAL REEF DISTRIBUTION OF GOA COAST

- **Three species of reef building corals : *Porites (Porites) lutea, Favites pentagona* and *Turbinaria mesenterina* were recorded near Grandi island, off Marmagoa (Goa).**

- **A non-reef building solitary coral of the Atlantic region *Astrangia* sp. was also recorded and could have been introduced in Indian waters due to maritime activities**

CORAL REEF DISTRIBUTION OF THE GULF OF KACHCHH

- **The coral fauna of the Gulf of Kachchh includes 26 species coming under 20 genera. The scleractinian coral fauna present in this area is very less when compared to those of other Indo-Pacific coral reef areas.**

- **Patel (1978) classified the intertidal reefs into 3 types viz. rock pool facies, eulittoral and submerged reefs.**

- **Rock pool reefs were found in small temporary pools located on the top of the knife-edged barren rocks, sprinkled at hightide, with small scattered colonies of encrusting coral species such as *Favia* and *Montipora*.**

- **The eulittoral pools had discontinuously distributed coral species such as *Turbinaria, Montipora, Favia, Leptoria, Porites, Leptastrea, Goniopora* and *Goniastrea*.**

- **The submerged reefs of this area can be classified into four zones such as Shoreward reef, Back reef, Surface reef and Oceanic reef. Coral composition of the submerged reefs was made of *Turbinaria, Montipora, Porites, Symphyllia, Favia, Favites, Goniopora, Goniastrea, Leptoria, Podabacia, Pavona, Hydnophora* and *Leptastrea*.**

CORAL REEF DISTRIBUTION OF THE LAKSHADWEEP ISLANDS

- **A total of 104 scleractinian corals belonging to 37 genera was reported from this region (Gopinadha Pillai and Jasmine, 1990)**

- **The genus *Acropora* is the commonest as is the case with all the Indian Ocean reefs and forms about 25% of the total species known from Minicoy. A notable feature of the coral fauna of Lakshadweep is the absence of foliaceous forms such as *Montipora foliosa* and *Echinopora lamellosa*. The massive coral species such as *Porites solida, P. lutea* and *Diploastrea* sp. are very common in Minicoy (Gopinadha Pillai, 1986)**

CORAL REEF DISTRIBUTION OF THE GULF OF MANNAR

- **Ninety four scleractinian coral species under 37 genera were recorded in the Gulf of Mannar and Palk Bay (Gopinadha Pillai, 1973)**

- **Of the 18 species of stony corals recorded from Tuticorin, *Acropora formosa*, *Porites compressa*, *P. somaliensis*, *Favia valenciennesi* and *Tubipora* sp. alone contribute 82% (Santhanam and Venkataramanujam, 1996).**

- ***Montipora* and *Acropora* put together constitute 39% of the total species recorded and species belonging to *Poritidae* and *Faviidae* constitute the dominant reef builders here (Gopinadha Pillai, 1971)**

CORAL REEF DISTRIBUTION OF THE ANDAMAN AND NICOBAR ISLANDS

- **Andaman and Nicobar islands comprise 135 species of scleractinian coral species belonging to 59 genera. Species of *Alveopora, Coeloseris, Seriatopora, Plerogyra, Physogyra* and *Oulastrea* are present here**

- **The reefs of Andaman are dominated by either *Acropora* sp. or massive *Porites* sp. in different parts. Wherever *Acropora* sp. is dominant *Porites* sp. is scarce and *vice versa.***

- **Nearly 4% of the reef area of Mahatma Gandhi Marine National Park was covered with live and luxuriant corals of different species. Soft corals formed about 3% and dead corals 36% of the reef areas. Of the 31 corals recorded under 25 genera, *Acropora, Porites* and *Millepora* were the dominant forms**

Reef Distribution Limiting factors

- Temperature-Nearly all found within the 20°C surface isotherm
- Depth-25 m of water or less due to hermatypic requirement for light to support symbiotic algae (zooxanthellae)
- Light Intensity-Compensation intensity appears to be about 1-2% of surface intensity
- Salinity-intolerant of salinities that deviate significantly from normal seawater
- Runoff/Sedimentation-cannot withstand heavy sedimentation. Sedimentation also causes turbidity which impacts light intensities

Reef Distribution Limiting factors

Species Interaction

- Competition-Space is a primary limiting factor in coral reefs
- Exploitative Competition-one species extends itself up and over another in competition for light. Where this occurs, the encrusted species does not get sufficient light and the part in the shade dies.
- At surface levels, faster growing corals will overtop massive, slower growing corals and kill them.
- Adaptation of slower growing corals include shade tolerance, so they can grow at greater depth
- Interference Competition-slow growing species can extend digestive filaments which kill adjacent competing species.
- There is also competition between corals and other species, especially algae. Competition among corals and algal forms is reduced by grazing

Reef Distribution Limiting factors

- Predation-Many species graze the coral polyps as well as the algae in reefs.
- Species tend to be dietary specialists, feeding on only one type of coral and have a tendency to prey on faster growing corals.
- Crown of thorns starfish is capable of destroying an entire colony, if not controlled by symbiotic shrimp that repulse the starfish.
- 2 groups of grazers: the corallivores which specifically target the coral polyps, and the multivores, which remove coral polyps to get at algae or other boring invertebrates

Reef Distribution Limiting factors

Role of Algae

- Cementing action of coralline algae
- Formation of algal ridge breaks velocity of waves allowing for presence of other organisms in the reef flats
- Green algae are contributors to sand found in reefs
- Some algae are important as nitrogen fixers
- *Primary Producers*

Reef Distribution Limiting factors

Catastrophic Mortality and Reef Recovery

- Suffer from major large-scale destructive forces.
- Severe tropical storms.
- Population explosions of predators, especially the sea star.
- El nino – causes temperature elevation and local redirection of water levels which result in large tracts of reef being damaged.
- Coral bleaching – corals expel their zooxanthellae. This can be a result of higher water temperature due to changing local weather patterns and may be an early warning sign of global warming.

Reef Distribution Limiting factors

Human activity

- dredging
- Pollution
- Overfishing