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CONTENT

INTRODUCTION

Corals are invertebrate animals belonging to a large group of colourful and fascinating animals called Cnidaria. Other animals in this group that you may have seen in rock pools or on the beach include jelly fish and sea anemones. Although Cnidarians exhibit a wide variety of colours, shapes and sizes, they all share the same distinguishing characteristics; a simple stomach with a single mouth opening surrounded by stinging tentacles. Each individual coral animal is called a polyp, and most live in groups of hundreds to thousands of genetically identical polyps that form a 'colony'. The colony is formed by a process called budding, which is where the original polyp literally grows copies of itself.

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.

Corals

➢ ***Definition***

Corals are two-layered invertebrates that live in groups (i.e. they are colonial) and are related to jellyfi sh and sea anemones.

Corals are made up of tiny individuals called polyps. Each polyp is like a fl uid-fi lled bag with a ring of tentacles surrounding its mouth, and looks like a tiny anemone. Polyps within a colony are linked by living tissues and can share their food (Allen & Steene, 1994). In some corals, the polyp extracts calcium carbonate from the sea and secretes it as a cup of calcium carbonate from the bottom half of its body. These cups provide anchorage for the polyps but when threatened, the polyp can retreat into the safety of the hard cup. When the calcium carbonate cups of many billions of these polyps fuse together, they form coral reefs (Veron, 2000).

➢ ***Types***

There are two main types of corals:

1) Stony Corals

2) Soft Corals.

1) Stony (Hard) Corals:

Some stony corals obtain their food from one-celled organisms called zooxanthellae. Zooxanthellae are single-celled organisms that use sunlight for photosynthesis and transfer 95% of the food they produce to coral polyps. Both coral and the zooxanthellae benefi t from this association. The zooxanthellae receive protection from currents and herbivores, as well as some nutrients from waste produced by coral polyps. This kind of association - where two different kinds of organisms benefi t from each other - is called a mutualistic association. These corals are called hermatypic corals. Individuals polyps of hermatypic corals secrete calcium carbonate
(limestone) skeletons which, in time form coral reefs. Therefore, hermatypic corals are also known as reef building corals.

Because of this association with zooxanthellae that need sunlight to produce food, hermatypic corals are dependent on sunlight and only grow in clear shallow waters less than 60m deep, which have a temperature range between 25° and 30°C. Hermatypic corals prefer narrow salinity and low turbidity ranges. Therefore, hermatypic corals need.

- a particular range of temperature;
- sunlight;
- generally clear water (low turbidity); and
- a narrow range of salinity (Allen & Steene, 1994).

There are about 845 species of reef-building corals (Global Marine SpeciesAssessment, 2008). There also are some stony corals which do not have zooxanthellae and do not build reefs. These are called ahermatypic corals and can live in both shallow and deep water (some up to 6,000m deep).

2) Soft corals:

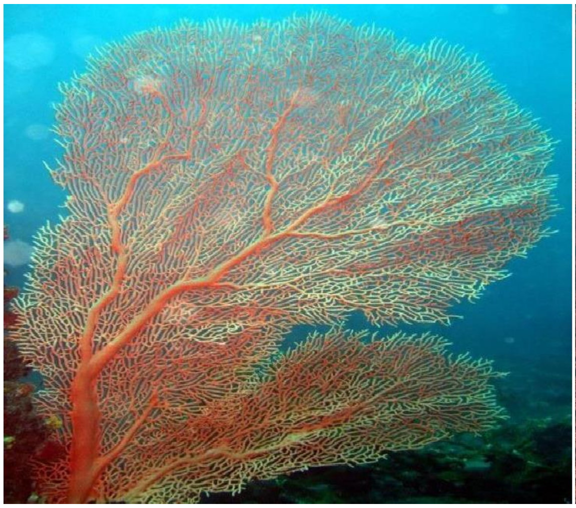
Soft corals lack a calcium carbonate skeleton, hence their common name. However, in their bodies are tiny hardened calcium particles called spicules that provide support.

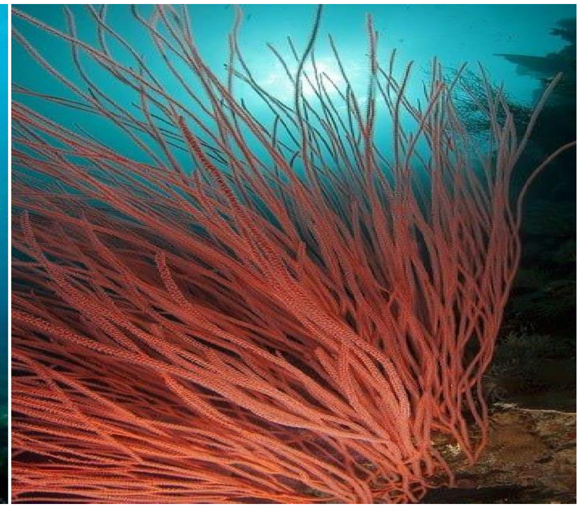
Some selected soft corals are shown below.

Fire and Lace Corals

Black or Thorny Corals

Sea Fan **Sea Whip**





➢ *Classification*

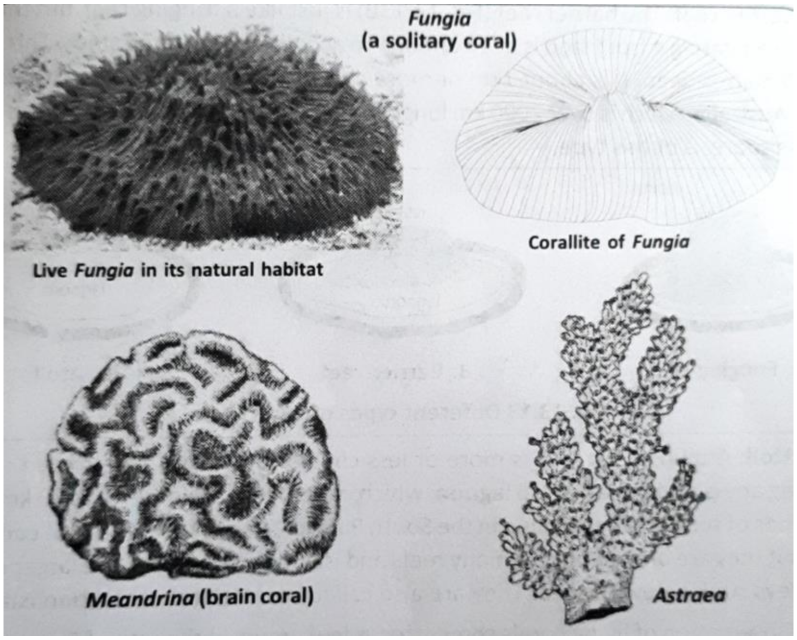
Presently, corals are classified as species of animals within the sub-classes Hexacorallia and Octocorallia of the class Anthozoa in the phylum Cnidaria.

- **Hexacorallia**

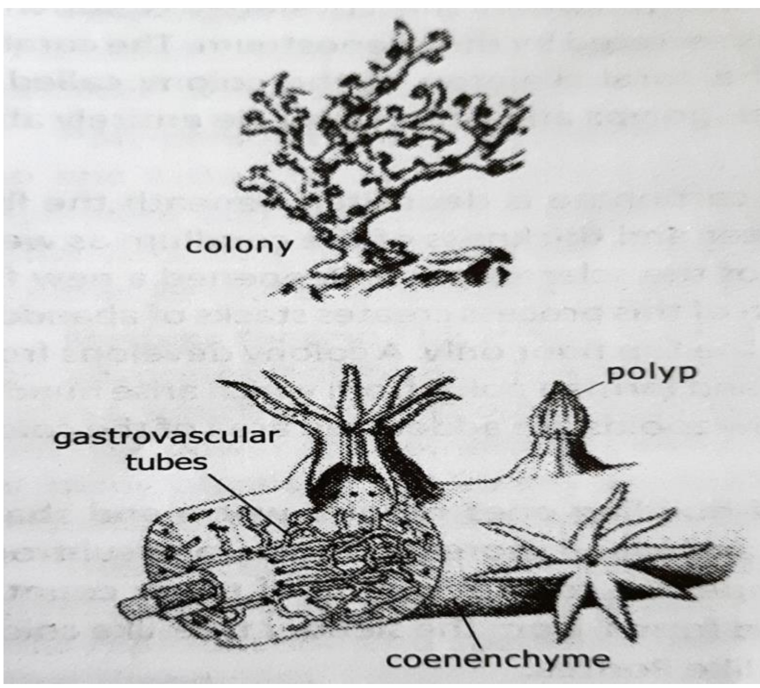
  Hexacorallia includes the stony corals and these groups have polyps that generally have a 6-fold symmetry.

- **Octocorallia**

  Octocorallia includes blue coral and soft corals and species of Octocorallia have polyps with an eightfold symmetry, each polyp having eight tentacles and eight mesenteries. The group of corals is paraphyletic because the sea anemones are also in the sub-class Hexacorallia.



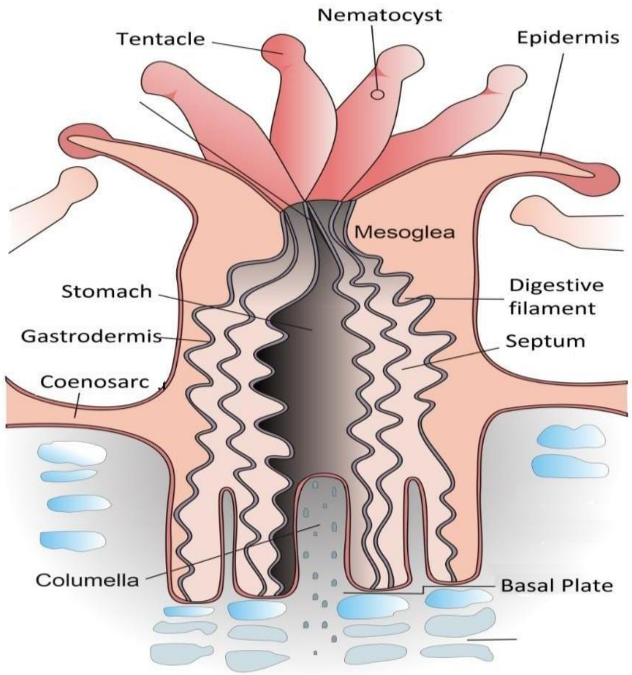
Hexacorallia



Octocorallia

➤ *Anatomy*

For most of their life corals are sessile animals of colonies of genetically identical polyps. Each polyp varies from millimeters to centimeters in diameter, and colonies can be formed from many million individual polyps. Stony coral, also known as hard coral, polyps produce a skeleton composed of calcium carbonate to strengthen and protect the organism. This is deposited by the polyps and by the coenosarc, the living tissue that connects them.



The polyps sit in cup-shaped depressions in the skeleton known as corallites. Colonies of stony coral are very variable in appearance; a single species may adopt an encrusting, plate-like, bushy, columnar or massive solid structure, the various forms often being linked to different types of habitat, with variations in light level and water movement being significant.

The body of the polyp may be roughly compared in a structure to a sac, the wall of which is composed of two layers of cells. The outer layer is known technically as the ectoderm, the inner layer as the endoderm. Between ectoderm and endoderm is a supporting layer of gelatinous substance termed mesoglea, secreted by the cell layers of the body wall.[8] The mesoglea can contain skeletal elements derived from cells migrated from ectoderm.

The sac-like body built up in this way is attached to a hard surface, which in hard corals are cup-shaped depressions in the skeleton known as corallites. At the center of the upper end of the sac lies the only opening called the mouth, surrounded by a circle of tentacles which resemble glove fingers.

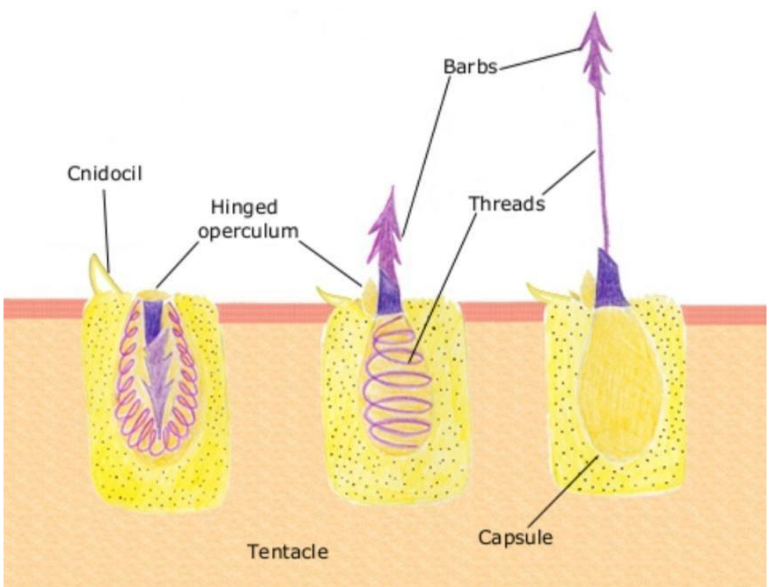
The tentacles are organs which serve both for the tactile sense and for the capture of food Polyps extend their tentacles, particularly at night, often containing coiled stinging cells (cnidocytes) which pierce, poison and firmly hold living prey paralysing or killing them. Polyp prey includes plankton such as copepods and fish larvae.

Longitudinal muscular fibers formed from the cells of the ectoderm allow tentacles to contract to convey the food to the mouth. Similarly, circularly disposed muscular fibres formed from the endoderm permit
tentacles to be protracted or thrust out once they are contracted.In both stony and soft corals, the polyps can be retracted by contracting muscle fibres, with stony corals relying on their hard skeleton and cnidocytes for defence. Soft corals generally secrete terpenoid toxins to ward off predators.

In most corals, the tentacles are retracted by day and spread out at night to catch plankton and other small organisms. Shallow water species of both stony and soft corals can be zooxanthellate, the corals supplementing their plankton diet with the products of photosynthesis produced by these symbionts.[7] The polyps interconnect by a complex and well- developed system of gastrovascular canals, allowing significant sharing of nutrients and symbionts.

➢ ***Feeding***

Polyps feed on a variety of small organisms, from microscopic zooplankton to small fish. The polyp's tentacles immobilize or kill prey using stinging cells called nematocysts. These cells carry venom which they rapidly release in response to contact with another organism.



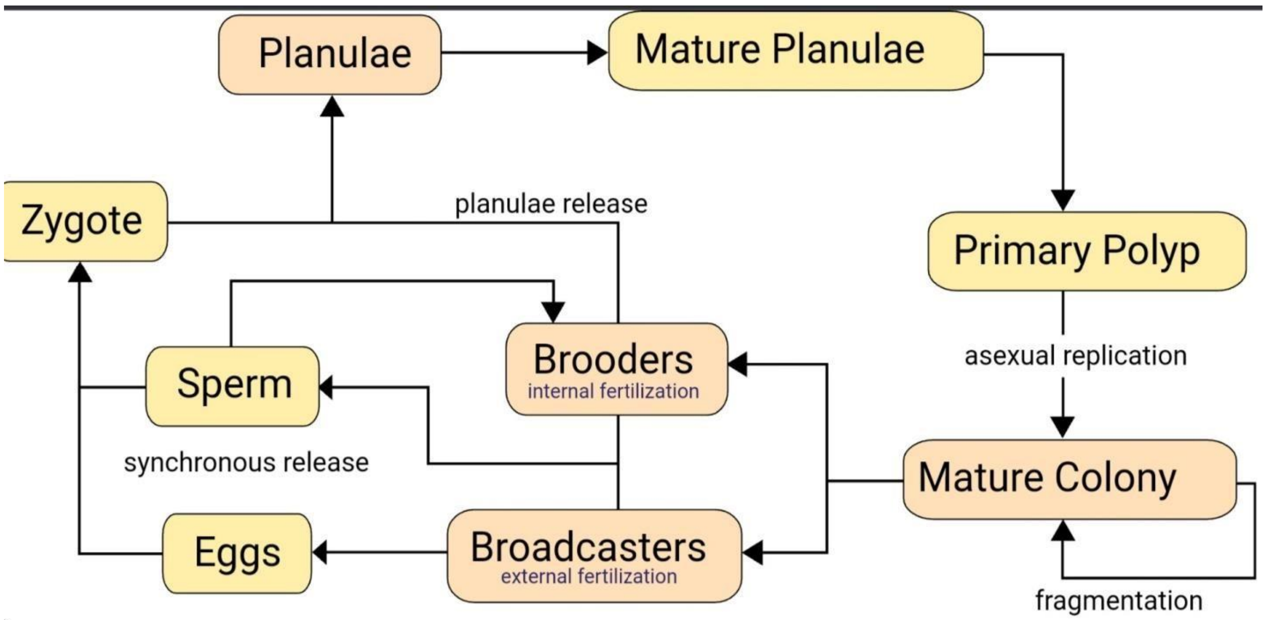
A dormant nematocyst discharges in response to nearby prey touching the trigger (Cnidocil). A flap (operculum) opens and its stinging apparatus fires the barb into the prey. The venom is injected through the hollow filament to immobilise the prey; the tentacles then manoeuvre the prey into the stomach. Once the prey is digested the stomach reopens allowing the elimination of waste products and the beginning of the next hunting cycle.

➢ ***Reproduction***

Corals can be both gonochoristic (unisexual) and hermaphroditic, each of which can reproduce sexually and asexually. Reproduction also allows coral to settle in new areas. Reproduction is coordinated by chemical communication.

- **Sexual**

Life cycles of broadcasters and brooders Corals predominantly reproduce sexually. About 25% of hermatypic corals (stony corals) form single sex (gonochoristic) colonies, while the rest are hermaphrodit.



- **Asexual**

Within a coral head, the genetically identical polyps reproduce asexually, either by budding (gemmation) or by dividing, whether longitudinally or transversely.

Budding involves splitting a smaller polyp from an adult.[26] As the new polyp grows, it forms its body parts. The distance between the new and adult polyps grows, and with it, the coenosarc (the common body of the colony). Budding can be intratentacular, from its oral discs, producing same sized polyps within the ring of tentacles, or extratentacular, from its base, producing a smaller polyp.

➢ *Coral Microbiome*

• Coral Holobiont

Reef-building corals are well-studied holobionts that include the coral itself together with its symbiont zooxanthellae (photosynthetic dinoflagellates), as well as its associated bacteria and viruses. Co-evolutionary patterns exist for coral microbial communities and coral phylogeny.

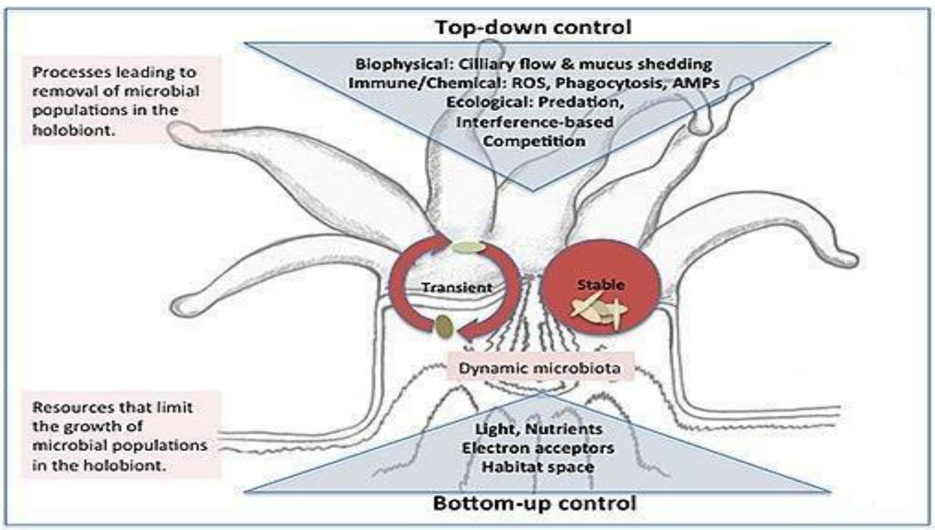


FIG:Top- down and bottom-up control of microbiota structure in the coral holobiont .Stable microbes may be introduced to the holobiont through horizontal or vertical transmission and persist in ecological niches within the coral polyp where growth (or immigration) rates balance removal pressures from biophysical processes and immune or ecological interactions. Transient microbes enter the holobiont from environmental sources (e.g., seawater, prey items, or suspension feeding) and removal rates exceed growth/immigration rates such that a dynamic and high diversity microbiota results. Transient and stable populations compete for resources including nutrients, light and space and the outcome of resource-based competition (bottom up control) ultimately determines population growth rate and thus ability to persist when subject to removal. Whether a population is categorized as stable or transient may depend on the timeframe considered.

CORAL REEFS

➢ ***Definition***

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 tony corals, whose polyps cluster in groups.

➢ ***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. 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.

➢ ***Structure and Distribution***

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 Earth's crust under the oceans formed the atolls.

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.

➢ ***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 green segmented 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***

Charles Darwin who originally classified coral reefs as to their structure and morphology, and described them as follows:

- **Fringing Reefs:**

Fringing reefs are coral reefs that grow in shallow waters. They closely border the coastline are separated from it by a narrow stretch of water. Many of the reefs round Sri Lanka and Thailand are fringing reefs.

- **Barrier Reefs:**

Barrier reefs grow parallel to the coast, but are separated from land by a lagoon. They are found sometimes many kilometres from shore (10–100km). Barrier reefs can grow in fairly deep water, because, often, the living coral builds upon remains of corals that grew in the same area when

sea level was lower, during the last ice age. The Great Barrier Reef of Australia extends about 2,010km parallel to the east coast.

- **Atolls:**

Atolls grow surrounding (or partly surrounding) an island which then sinks relative to sea level (usually because volcanic activity forming the island stops), or was fl ooded as sea level rose after the last ice age. Atolls surround (or partly surround) a central lagoon. The Maldives consists of 26 atolls.

Although these are the three main types of reefs, there are many reefs that do not fit these models.

Other reef types or variants

- **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 or embayment, often circular and surrounded by sand or seagrass. Can be considered as a type of platform reef or as features of fringing reefs, atolls and barrier reefs.The patches may be surrounded by a ring of reduced seagrass cover referred to as a grazing halo.

- **Ribbon Reefs**

  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; does not reach near enough to the surface to cause visible surf; may be a hazard to ships (from the Arabic for "unborn")

- **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 and have been used to reconstruct Holocene sea levels.

➢ ***Zones***

Alternatively, Moyle and Cech distinguish six zones, though most reefs possess only some of the zones. The reef surface is the shallowest part of the reef. It is subject to surge and tides. When waves pass over shallow areas, they shoal, 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 by the symbiotic zooxanthellae, and agitated water brings plankton to feed the coral.

- **The off-reef floor**

  It 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 which are important foraging areas for reef fish.

- **The reef drop-off**

  It is, for its first 50 m, habitat for reef fish who find shelter on the cliff face and plankton in the water nearby. The drop-off zone applies mainly to the reefs surrounding oceanic islands and atolls.

- **The reef face**

  It 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 algae provide complex habitats and areas that offer protection, such as cracks and crevices. Invertebrates and epiphytic algae provide much of the food for other organisms.[48] A common feature on thisforereef zone is spur and groove formations that serve to transport sediment downslope.

- **The reef flat**

  It 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.

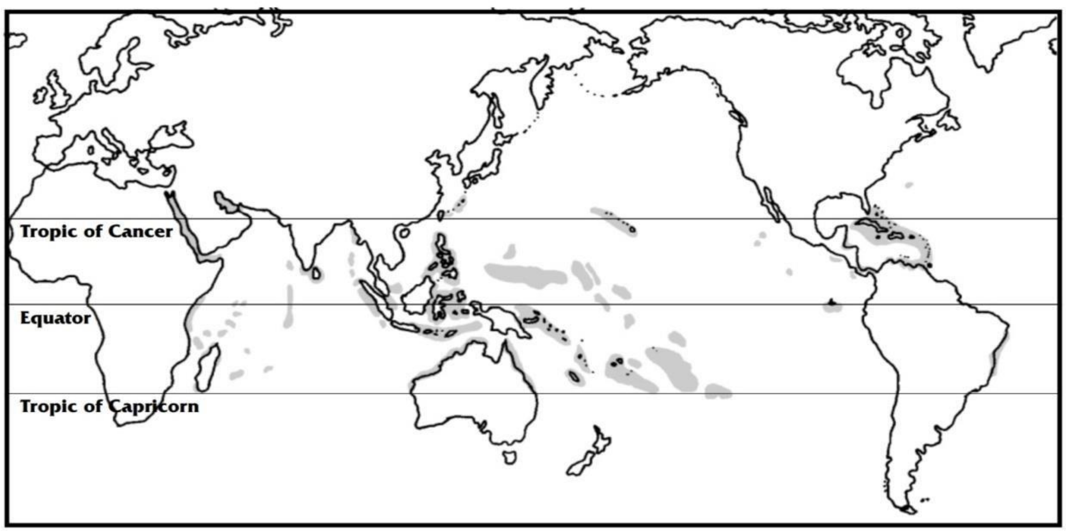
➢ ***Location:***

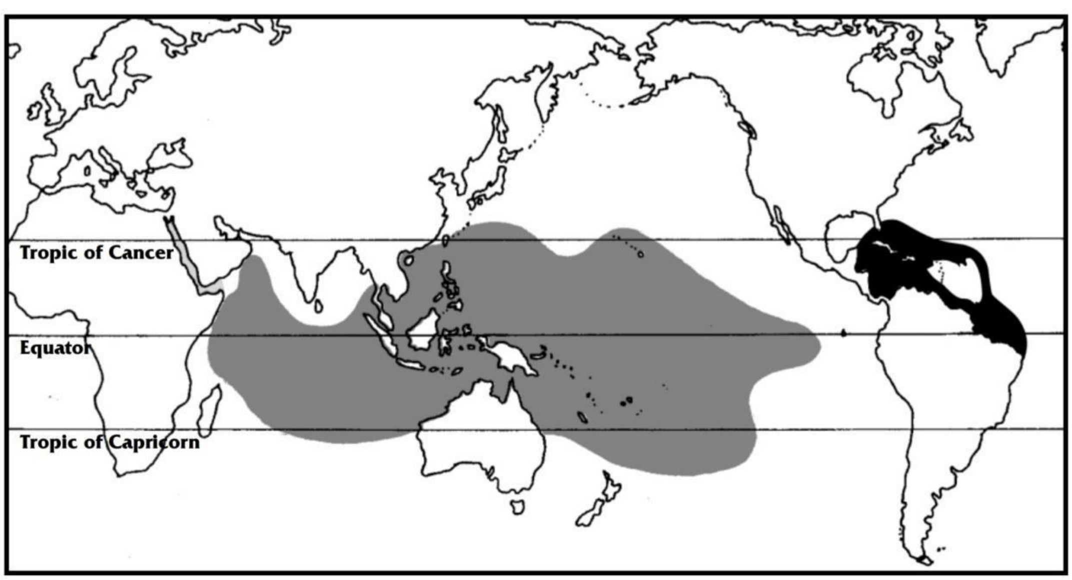
Most corals thrive in shallow, clear, sunlit saltwater with a temperature between 79°F and 81°F (26°C and 27°C). If the temperature goes below 68°F (20°C) or above 84°F (29°C) for a prolonged period of time, most coral will die. The coral also needs plenty of sunlight to grow, so maximum coral growth will be found in clear water at depths of less than 30 feet (9m). However, the greatest diversity of coral can be found on reefs at a depth of 30 feet (9m) to 60 feet (18m). Below 165 feet (50m), the reef-building hard corals start to diminish, then gradually disappear.

➢ ***Distribution:***

Most coral reefs are located between 20°N (tropic of Cancer, 23°27') and 20°S (tropic of Capricorn, 23°27') of the equator (Figure 1-6). They are divided into three primary regions: the Indo-Pacific, the Western Atlantic, and the Red Sea (Figure 1-7). The Indo- Pacific region stretches from southeast Asia through Polynesia and Australia, eastward across the Indian Ocean to Africa. This is the largest and richest assemblage of reefs in terms of coral and fish species present. The Western Atlantic region stretches from Florida to Brazil, including Bermuda, the Bahamas, the Caribbean, Belize and the Gulf of Mexico. The Red Sea is the smallest of the three regions, located between Africa and Saudi Arabia. It is considered a separate region because of the high number of coral reef life found only in this area.

Based upon geographic distribution, 60% of the world's reefs are in the Indian Ocean and Red Sea, 25% are in the Pacific Ocean, and 15% in the Caribbean.





➢ *Importance*

Coral reefs are extremely productive ecosystems and provide humans with many services.

- **Provisioning Services:**

Coral reefs support human life and livelihoods and are important economically. Nearly 500 million people depend - directly and indirectly – on coral reefs for their livelihoods, food and other resources (Wilkinson, 2004). Further, it is estimated that nearly 30 million of the poorest human populations in the world depend entirely on coral reefs for their food (Wilkinson, 2004).

• A km2 of well-managed coral reef can yield an average of 15 tonnes of fi sh and other seafood every year (http://www.panda.org/ about _wwf/ what_we_do/marine/blue_planet/ coasts/coral_reefs/coral_importance/).
• In 1985, the world export value of the marine aquarium trade was estimated at 25-40 million USD per year. In 1996, the world export value was about 200 million USD. The annual export of marine aquarium fi sh from Southeast Asia alone is estimated to be between 10-30 million fi sh, with a retail value of up to 750 million USD (Bruckner, 2006).

Many coral species and species associated with coral reefs have medicinal values. Several species are used in Traditional Chinese Medicine (TCM) and many are now providing novel resources for allopathic medicine.

• In TCM, 394 marine species are collected globally for their medicinal value. The majority of these species are used in Asia (Hunt & Vincent, 2006).
• Some hard coral species are used in bone grafts. Others contain chemicals which might be used as natural sunscreen products (Demers et al., 2002; http://www.coralfi lm.com/about html).
• The Caribbean sea squirt (Ecteinascidia turbinata) has a chemical that is being used to treat diffi cult cancers (http://www.ehponline.org).

• There are some 500 species of cone snails that live in and around coral reefs. These species have a range of venoms which are being investigated currently for use as non-addictive pain killers (Chivian, 2006).

- **<u>Regulating Services</u>**:

❖ Coral reefs protect the shoreline and reduce fl ooding.

Very importantly, coral reefs protect the shoreline, providing a physical barrier – a wall against tidal surges, extreme weather events, ocean currents, tides and winds. In doing so, they prevent coastal erosion, fl ooding and loss of infrastructure. Because of this, they serve to reduce huge costs involved with destruction and displacement due to extreme weather events.

The value of this protective service of coral reefs is estimated at 314 million USD in Indonesia (Burke et al., 2002).

- **<u>Supporting Services:</u>**

❖ Coral reefs are an essential part of land accretion.

The natural action of waves breaks pieces of calcifi ed coral and these are washed up onto beaches. Through the process of natural physical breakdown, these larger pieces are broken into smaller and smaller pieces and eventually become part of the rubble, building these beaches. Corals, therefore, contribute, in part, to the process of accretion – which is the opposite of erosion.

❖ Coral reefs are very diverse.

Corals do not even cover 1% of the Earth’s surface, but they are extremely diverse. In fact they are dubbed the rain forests of the sea because of this immense diversity. The nooks and crannies formed within reefs by constant beating of waves provide shelter to many species.

• They are the home (they provide shelter and nursery grounds) of 25% of marine fi sh (Burke et al., 2002).

• Thirty two out of the 34 described groups of organisms are found in coral reefs. (As a comparison, only nine groups are found in tropical rain forests.) (Wilkinson, 2002).

• Coral reefs support a complex and interdependent community of photosynthesising organisms
and animals. There is an incredible diversity of life on coral reefs such as algae, corals (there may be as many as 750 species on one coral reef), sponges, marine worms, echinoderms (sea stars and their relatives), molluscs (snails, mussels and their relatives), crustaceans (crabs, shrimps and their relatives) and fi sh (http://assets.panda.org/).

❖ Coral reefs have high primary productivity.

Zooxanthellae photosynthesise and produce their own food (like green plants do on land) and corals benefi t from this association. Because of the immense diversity of coral reefs, there is a great deal of exchange of nutrients and primary productivity (food production) is very high.

Primary productivity of coral reefs is estimated at 5-10g C/m2 /day (Sorokin, 1995).
This productivity is derived mainly from algae.

- **Cultural services:**

❖ Coral reefs have intrinsic, aesthetic and recreational values

.

The beauty of coral reefs and their diversity are essential parts of many cultures in different parts of the world. Because of their easy access, visiting coral reefs is an important recreation for snorkelers, scuba divers, recreational fi shermen and beach lovers.

• In Seychelles, tourism was estimated to have generated one fi fth of GDP and over 60% of foreign exchange earnings in 1995 (Mathieu et al., 2000).

• In the Maldives, 'tourism contributes more than 60% of foreign exchange receipts, over 90% of government tax revenue comes from import duties and tourism-related taxes, and almost 40% of the workforce is employed in the industry' (Emerton, 1997, 2006).

➢ ***Threats***

Despite their immense ecological, economical and aesthetic values, it is estimated that 20% of the world's coral reefs have been destroyed (Wilkinson, 2004). Another 24% are at high risk of collapse, and yet another 26% at risk from long term collapse as a result of human activities. If the present rate of destruction continues, 70% of the world's coral reefs will be destroyed by the year 2050

The coral reefs of Southeast Asia are the most threatened in the world (Burke et al. 2002).

• In South Asia, 45% of 19,210 km2 of coral reefs have been destroyed, another 10% are critically threatened and 25% are threatened. Only 20% are at low risk from human activities (Tun et al., 2004).

• In Southeast Asia, 38% of 91,700 km2 of coral reefs have been destroyed, another 28% are critically threatened and 29% are threatened. Only 5% are at low risk from human activities (Tun et al., 2004).

- **Overexploitation (Over-fi shing):**

❖ For food

A recent report states that ‘centuries of over-fi shing by man have emptied the world’s oceans of giant fi sh, whales and other large sea creatures, destroying coastal environments’ (Jackson et al., 2001).

The human global population is expected to double in the next 50 years, and with it, an ever increasing demand for life essentials such as food. Fish is the primary source of protein for one fi fth of the world’s population. The demand for fi sh has doubled in the last 50 years, and fi sh production would have to double again in the next 25 years to keep up with the demand and population growth.

Because coral reefs are within the reach of small boats, they are especially vulnerable to over-fi shing. Particular groups of coral reef fi sh such as groupers, snappers and large wrasses have been overexploited. In Southeast Asia, the live fi sh trade (both as food fi sh and as ornamentals) is estimated to be over a billion USD per year in (mostly) illegal trade.

• The average wholesale price for reef fi sh is 20 USD/kg. The estimated total annual value of live reef fi sh imported into Hong Kong for food is, therefore, more than 500 million USD (Sham, 1997 in litt. TRAFFIC, 1999).

• In the 1990s, 60% of the fi sh caught for the live fi sh food trade were from the Indonesian archipelago (Bentley, 1999).

• Hong Kong and other Asian markets are the primary buyers of live reef fi sh for food (Donaldson et al., 2003)

• The Giant grouper (Epinephelus lanceolatus) and Humphead wrasse (Cheilinus undulates) are listed in the 2007 IUCN Red List as Vulnerable and Endangered, respectively, as a direct consequence of over-fi shing (Baillie & Groombridge, 2007).

❖ For the aquarium trade

The practice of keeping marine aquaria as a hobby has increased in the last decade. It is reported that, globally, between 1.5 -2 million people keep saltwater aquaria (Wabnitz et al., 2003). As a result, more than 800 species of reef fi sh, hundreds of coral species and other invertebrates are exported now for aquarium markets. The majority of fi sh come from reefs in the Philippines and Indonesia, while most stony corals come from Indonesia. The biggest importer is the USA (Sadovy et al, 2003).

• A total of 1,471 species of fi sh are traded globally, comprising 20-40 million individuals.
• One hundred and forty species of stony corals and 61 species of soft corals (comprising 11-12 million and 390,000 pieces respectively) are traded.
• The Banggai cardinal fi sh (Pterapogon kauderni) is only found in the Banggai Archipelago, near Sulawesi, Indonesia. It is very valued in the aquarium industry, with approximately 900,000 harvested every year. It is now considered Endangered.
• Barbour's seahorse (Hippocampus barbouri) is now listed as Vulnerable, mainly as a result of harvesting for the aquarium trade.

❖ For the trinket trade

Other species are at risk from overexploitation for use as curios or trinkets. As many as 5000 species of molluscs are processed or used raw to make curios and trinkets; some 40 species of coral are also traded for this purpose; and many sea stars, sea urchins, sand dollars and their relatives are also traded (Vincent, 2006). At least 32 species of fi sh or fi sh parts - such as seahorses, porcupine fi sh, sharks' teeth and the 'noses' of sawfi sh are also used for the trinket trade.

The USA is the biggest importer of such trinkets. Much of these trinkets are bought by tourists on holiday in the tropics, who do not know the damage they cause to coral reefs ecosystems in the tropics (Vincent, 2006).

• Six out of seven species of marine turtles are Red Listed as Endangered or Critically Endangered, partly as a result of overexploitation for the use of their shells in the trinket trade. He Hawksbill turtle (Eretmochelys imbricata), with its ornate shell, is Critically Endangered (Baillie & Groombridge, 2007).
• Corallium spp. are a group of about 31 species of coral that have a global distribution, whose dominant colour ranges from white to pink, to orange and red. They are used extensively to make jewellery and curios and are now threatened with extinction due to over-harvesting.

❖ For medicinal purposes

Species are also overexploited for medicinal purposes, mainly in traditional medicine. Many pieces such as sea horses and pipefish are over-harvested for Traditional Chinese Medicine TCM (Hunt & Vincent, 2006).

Another emerging threat is marine bio prospecting. Coral reefs are relatively easy to access and have many species of non-moving, soft-bodied organisms, who are armed with an wide of epical as deface weapons. These chemicals have a range of potential medical and industrial uses and because of this, reefs are targeted for bio prospecting. In order to extract enough chemicals for development of medicines and clinical trials, the quantities required are in the order of tons or thousands of tons (Melanie, undated). Therefore, the potential for overexploitation is very high.

• Thirteen species of seahorses (*Hippocampus spp.)* used in traditional medicine are Red Listed (Hunt & Vincent, 2006).
• The Smooth Tail Devil ray (*Modula Thurston*), Devil ray (*M. japonica*) and Giant manta *Manta birostris*) are all Near Threatened because of the demand for their gill fi laments used for medicinal purposes (Baillie & Groombridge, 2007).
• In 2001, India banned the collection of all *Bêche de mer* (Sea cucumbers) which were being exported for TCM and as a delicacy as well
(Nithyanandan, 2003).

❖ Destructive fishing practices

Often accompanying over-fi shing are destructive fi shing practices - such as purse seining, fi ne esh fi shing, ‘moxy’ nets, cyanide fi shing and blast fi shing - that result in unsustainable damage (Wilkinson, 2004). It should be noted, though, that all of these have been made illegal in South and Southeast Asia.

Burke et al. (2002) estimate that more than 53% of Indonesia's coral reefs are threatened by destructive fi shing practices.

• In Sulawesi, Indonesia, 15% of the fi shermen are blast fi shermen, with their catches making up 10-40% of the total landings (Pet-Soede & Erdmann, 1998).

• In regularly blasted reefs 50-80% of the coral could be dead. The net economic loss to Indonesia from blast fi shing over the next 20 years will be at least 570 million USD (Burke et al., 2002).

The use of poison (cyanide) stuns fi sh so that they can be taken for the live fi sh trade. Such poison not only affects target species but also has an effect on all living organisms nearby.

• It is estimated that over 6,000 divers annually use about 150,000kg of cyanide on 33 million coral polyps worldwide (Briggs, 2003).

• Eighty fi ve percent of the world's traded aquarium fi sh are caught using cyanide, mainly from Indonesia and the Philippines (Licuanan & Gomez, 2000).

• A large percentage of these fi sh caught using cyanide die – 50% for food fi sh species and above 80% of ornamental fi sh species – and even those that do survive usually die four to six weeks after capture (Briggs, 2003).

'Moxy' nets, fi ne-mesh nets and bottom trawlers all damage coral reefs.

Both over-fi shing and destructive fi shing disrupt ecological interconnections and upset the balance of coral reef ecosystems, resulting in changes in species diversity and abundance.

- **Coral mining (Overexploitation/ Habitat Destruction)**:

In South and Southeast Asia, corals are mined for limestone and construction materials. In this process, the reef is blasted and coral removed, causing immediate destruction but also resulting in indirect detrimental effects such as sand erosion and sedimentation. In 1995, it was estimated hat 20,000m3 of coral per year were collected in the Maldives for construction materials (Brown t al, 1995). Coral mining is prevalent in most South and Southeast Asian countries (Rajasuriya et al., 2004).

- **Sediment, nutrient and chemical pollution:**

One of the greatest threats to coral reefs is human development that alters either the marine or land-based physical environment. Certain development activities lead to increases in freshwater runoff, resulting in large amounts of sediment being washed into the sea. To a limited extent, soil washes naturally into rivers, but poor agricultural and land use practices intensify this process, resulting in excessive sedimentation. Upland activities such as logging, land conversion, river modifi cations (dams and diversions) and road construction hugely increase erosion. The sediment from such erosion carries with it not only particulate matter but also high levels of nutrients from agricultural areas or sewage systems. To make this problem worse, many areas in South and Southeast Asian countries lack proper sewage systems and waste is discharged directly into the sea.

Direct sedimentation onto the reef increases the turbidity of the water, and this can lead to the smothering of corals, while associated increases in nutrients can lead to eutrophicationl. Both turbidity and eutrophication result in a decrease in the amount of sunlight that reaches the coral. Reef building corals need sunlight for the zooxanthellae that live among them to photosynthesise and provide them with nutrients. Thus, if corals are unable to get enough light, they stop growing and eventually die (Nybakken, 1993). In addition to this, changes in nutrient levels may favour the growth of other organisms such as sponges and algae, causing a disruption in the balance of the coral reef ecosystem.

• Land reclamation by dumping sand and dirt directly onto coral reefs has been particularly bad in Singapore, which has lost 60% of its coral reefs to reclamation.
• It is estimated that 25% of the reefs of Southeast Asia are threatened by coastal development and 5% are under high threat. Coral reefs of Singapore, Vietnam, Taiwan, the Philippines and Japan are the most threatened from coastal development in the region, each with over 40% of their reefs under medium or high threat.

• Twenty one percent of Southeast Asia’s reefs are at risk from sedimentation and inland development; Vietnam, Taiwan and the Philippines are at most risk with 35-50% of their reefs threatened by sedimentation.

• Indonesia’s coral diversity has decreased 30-60% as a direct result of sedimentation.

In addition to nutrient and sediment pollution, industrial effl uents washed into waterways and agricultural runoff carry with them chemical pollutants such as petroleum products including oils and insecticides.

- **Marine based pollution**:

Marine pollution in the form of oil (that often leaks into the seas), discharge of ballast water, umping of solid waste from ships is also causing damage to coral reefs in the region. Anti-fouling bottom paints used on boats form toxic compounds harmful to corals and other species. Of the above forms of pollution, oil pollution is the most common. Oil damages the life cycle of corals. Although major oil spills make the news, minor spills occur all the time in the seas of the region, for example, through the discharge of ballast water, marine traffi c and when ship engines are cleaned.

• Jakarta Bay, Singapore and Manila Bay are affected by oil pollution. This can affect the diversity coral reefs.

• In 2006, a 200 tonne oil spill in the Philippines caused damage to 1,100ha of mangrove forests, 58ha of seaweed farms and 200km of coastline.

- **Irresponsible tourism**

Tourism is essential for the economic development of many countries in the region. For example, arine and coastal tourism is the largest industry in the Maldives and accounts directly for 20% of GDP and its wider effects help produce 74% of national income; almost 40% of the workforce is employed in the industry (Emerton, 2006). When carried out in a controlled and sustainable manner, tourism can be a positive economic earner and should be an incentive for countries to invest in managing coral reef ecosystems to continue attracting tourist revenue.

However, when managed poorly, tourism has both direct and indirect negative effects on coral reefs. Snorkelling, diving and boating can cause direct physical damage to reefs, while overexploitation of reef species as food, for aquaria and as curios for tourist markets can threaten the survival of species. In some cases, bad tourism practices are not prevented. For example, tourists are allowed to walk on reefs, causing physical damage to the reef structure and stirring up sediment. Sometimes they even directly collect species off reefs. Boats carrying tourists can damage reefs by dropping anchors directly onto reefs, disturbing species and also causing marine pollution through excessive traffic.

Indirectly, careless and irresponsible building of infrastructure directly onto reefs or too close to beaches, river mouths and lagoons, results in increased sedimentation and leaves the infrastructure vulnerable to damage from extreme weather events.

Another indirect effect of tourism is often the irresponsible disposal of sewage and solid waste. Two decades ago, sewage and solid waste were mostly disposed directly into the sea but the urrent situation has improved greatly.

• It has been estimated globally that the world’s cruise ships discharge 90,000 tons of raw sewage and garbage each day into the world’s oceans (Mastny, 2001).
• It is reported that every year, plastic bags kill about 100,000 marine animals including endangered whales and sea turtles. Plastic bags, which resemble edible squid and jellyfish, choke marine animals that feed on them.

- **Global warming and climate change:**

Global warming and resultant climate change is posing an emerging and severe additional threat to already stressed coral reefs (Wilkinson, 2004). Sea level rise and changed weather patterns such as altered El Niño and La Niña events are already affecting coral reefs.

- El Niño is Spanish for ‘the little boy’, referring to the Christ child, because this event is noticed usually around Christmas time. It is a fl uctuation of the ocean-atmosphere system in the tropical Pacifi c ocean that is important for the world’s climate. In normal, non-El Niño conditions, trade winds (prevailing tropical winds) blow towards the west across the tropical Pacifi c, piling up warm surface water in the west Pacifi c, so that the sea surface is about 0.5m higher in height and 8°C warmer at Indonesia than at Ecuador. The waters off South America are cool because of an upwelling from the deep and are nutrient-rich, with high marine primary productivity which supports fi sheries.
- During El Niño, the air pressure over the Indian Ocean, Indonesia, and Australia rises, but drops over Tahiti and the rest of the central and eastern Pacifi c Ocean. The trade winds in the outh Pacifi c weaken. Warm air rises near Peru causing rain in its deserts, while warm water spreads from the West Pacifi c and Indian Ocean to the East Pacifi c Ocean. When it spreads, it takes the rain with it, causing rainfall in normally dry areas and drought in normally wet areas. El Niño also results is less upwelling, less nutrients, warmer sea surface temperatures (+0.5°C) nd decreased marine primary production near South America.
- La Niña, means ‘the little girl’ in Spanish, meant to refl ect that its effects are the opposite to that of El Niño. Here, the result is a lowering of sea surface temperatures by about 0.5°C. It usually follows an El Niño event.

❖ Effects of the increase in ocean temperatures: coral bleaching

Because reef building coral species can live only within a small temperature range, even a tiny change in temperature causes seriously detrimental effects, as exemplifi ed by the wide scale coral bleaching of 1998, as a result of an El Niño event. When hermatypic corals are stressed uch as with an increase in temperature - the critical balance that maintains their mutualistic elationship with zooxanthellae is lost. The coral may lose some or most of their zooxanthellae, a major source of nutrition and colour. In this condition, corals are referred to as ‘bleached.’ In some species, their life cycles are disrupted.

As a result of El Niño event in 1998 and an associated rise in ocean temperatures, coral bleaching destroyed 16% of the world's coral reefs and 50% in the Indian Ocean (Wilkinson, 2004).

- Effects of sea level rise

Light is essential for zooxanthellae to photosynthesise in coral reefs. Photosynthesis promotes the production of oxygen, which, in turn, stimulates coral polyp growth and increased deposition of calcium carbonate and coral reef growth. Changes in sea levels and associated water depths will change the amount of sunlight reaching coral reefs.

Although healthy reefs are likely to be able to adapt to projected sea level changes, coral reefs already stressed by other human activities - such as sedimentation and erosion - will not.

- Effects of more dissolved carbon dioxide

Increased CO2 dissolves in the oceans forming a weak acid - carbonic acid - making them more acidic and reducing calcium carbonate precipitation by coral polyps. It has been estimated that the precipitation of calcium carbonate has already fallen by an average of between six and 11% since the industrial revolution. If future atmospheric CO2 levels reach double the level of pre-industrial times, then it is predicted that calcium precipitation will fall by a further eight to 17% (Caldeira & Wickett, 2003). This affects the availability of carbonate atoms for building exoskeletons and with it, reduces reef calcifi cation. This, in turn, slows down a reef's ability to grow vertically to keep up with sea-level rise and affects its protective function.

Ocean acidifi cation will likely disrupt marine food webs and affect the services that coral reefs provide to humans.

Predators and Protection

➢ *Methods*

Many reef animals feed on plankton. Plankton consists of both animals (zooplankton) and plants (phytoplankton), and some reef animals feed on both while others just feed on animals. For instance, coral polyps and Christmas tree worms extend their tentacles to catch plankton as it floats by. Like its relative the coral polyp, the sea anemone, a carnivore, attaches itself to a piece of limestone rock and extends its poisonous tentacles to catch the zooplankton and tiny fish that float by in the ocean current.

Lion fisf

Trumpetfish

The **lionfish** uses camouflage to hide itself among the coral and then ambushes unsuspecting prey as it passes. Some sharks and barracuda use speed to chase down their prey. The **trumpetfish** uses stealth, hiding behind another fish or within a waving gorgonian coral in order to sneak up on its prey.

Clown triggerfish *Trunkfish*

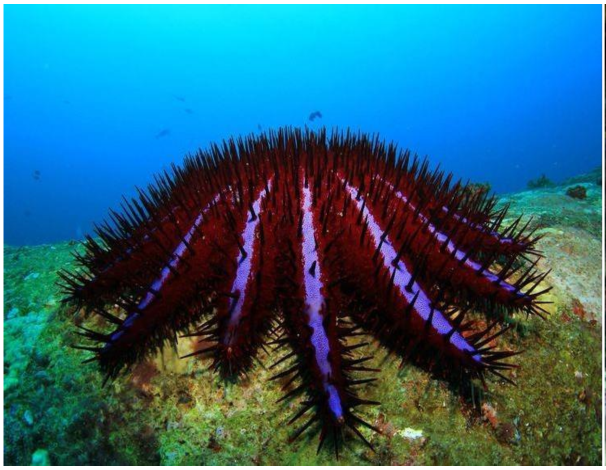
The **clown triggerfish** and **trunkfish** catch small crustaceans and fish that hide in the sand by blowing streams of water out of their mouth to move the sand, or by removing the sand with their fins or snout.

Moray eel

The **moray eel** glides along the reef, searching for crabs and small fish that hide in coral crevices. Its strong, narrow head and flexible body give it the ability to enter difficult spaces to attack its prey. Some moray eels are even able to wiggle out of the water and up on the beach to catch crabs.

Sea star

Sea stars live on and around the coral reef, eating coral polyps and buried mollusks, such as clams and scallops, by enveloping their stomach around the food item. All sea stars are characterized by radial symmetry wherein the body parts are repeated around a center, like the spokes of a wheel.



Crown-of-thorns *Giant triton*

One type of sea star, the **crown-of-thorns** is very threatening to coral reefs because it eats coral polyps, killing the coral. Entire reef eco systems along the Great Barrier Reef of Australia and parts of the Philippines have been temporarily devastated due to population explosions of the crown-of- thorns. There is quite a controversy regarding whether the crown-of-thorns population explosion is a natural, cyclical occurrence or the result of reef disturbances by humans. Some scientists believe population explosions are caused by nutrient overload from sewage which supplies a rich source of food for baby crown-of-thorns. The only natural predator on the crown-of-thorns is the **giant triton** a large marine mollusk which has been overcollected for its beautiful shell. Some scientists believe that this is another reason the crown-of-thorns has been able to multiply unchecked in certain areas.

Benefits

- ***Values***

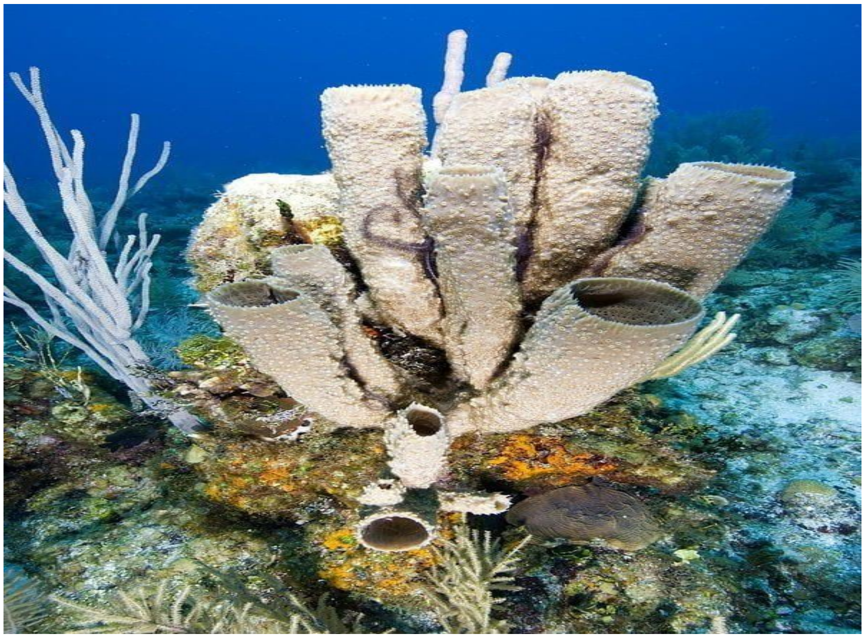
Coral reefs enrich the life of our oceans. They provide food and shelter to countless thousands of species of plants and animals, and they exchange energy and nutrients with other marine ecosystems, such as the open ocean.

But people also directly benefit from reefs in many ways. Coral reefs break waves, protecting shorelines from erosion and keeping beaches and coastal communities intact.

Healthy coral reefs supply finfish and shellfish upon which many national economies depend. Reef dependent fisheries include subsistence (providing a protein source in coastal people's diets),commercial (providing jobs through supplying the world market demand for fish), recreational (providing jobs through fishing and tourism), and ornamental (providing jobs and income for tropical fish gatherers). The world consumption of seafood exceeds that of either pork or beef.

Scuba diver on Cuban reef.

Tourism is also an economic mainstay for many countries with coral reefs, as people come to dive, snorkel, boat and fish. There are an estimated four million divers around the world, many of whom make more than one dive trip each year. The Florida Keys and many other coral reef areas are economically dependent upon their reefs for tourism and fishing. In the Caribbean, costal tourism generates about US $7 billion each year.



Caribbean sponges are used in the treatment of cancer and herpes simplex.

Treatments for cancer, AIDS, infection, arthritis, asthma, herpes, and even broken bones are being discovered in coral reef ecosystems around the world. For example, compounds derived from **Caribbean sponges** are being used in the treatment of cancer and herpes simplex. Compounds from sea squirts have been useful in treating tumors, viruses, and immune related illnesses. Hard corals are being used to replace shattered bones as the human body more readily accepts coral than artificial replacements.

Many commercial products are also derived from coral reefs. Calcium carbonate from the skeletons of coral animals is used to produce lime which when added to mortar and cement helps it set more quickly. The internal shell of the cuttlefish, called cuttlebone, is sold in pet stores to cut calcium deficiency in the diet of pet birds. Chitin, derived from the shells of shellfish, crabs, lobster, and shrimp, is a component of chitosan, which is used in violin varnish to make it dry hard to provide good tone.

Much can be learned from reefs about historical conditions in the marine environment. Annual growth bands, elemental ratios, and isotopic signatures can be used to infer past sea levels, growing conditions, the effects of environmental management and other important phenomena.

The beautiful sand that makes up the beaches of tropical islands is another benefit from coral reefs, formed by the breakdown of dead corals and algae by reef life.

Like rainforests, wetlands and savannas, coral reef ecosystems are integral parts of a healthy environment for all of the Earth’s living creatures, including people.

CONCLUSION

Coral reefs sit at the interface of two powerful societal trends. On the one hand, coral reef ecosystems provide vast resources to human communities, resources that are increasingly needed as the human population grows. On the other hand, coral reef ecosystems are existentially threatened by increased human-driven stresses, particularly the extensive coral mortality from severe bleaching events caused by warming seas on top of local stressors such as sedimentation, pollution, invasive species, and overfishing. Continuing disease threats and concerns about increasingly acidifying waters compound the risk posed to coral reefs. The increased reliance by humans on an ecosystem increasingly at risk of collapse has led to a widespread call for interventions that might preserve the services provided by coral reefs into the future.

A growing body of research on coral ecology, molecular biology, and responses to stress has revealed the complex nature of corals and their associated micro biome (including symbiotic algal, prokaryotic, fungal, and viral components). Some of this knowledge is poised to provide practical interventions in the short term, whereas other discoveries are poised to facilitate search that may later open the doors to additional interventions.

The committee reviewed the current literature on new approaches with the potential to increase the resilience and persistence of coral reefs as global environmental conditions deteriorate. Current approaches that focus on management of local stressors, while important to continue, are not adequate, nor are they particularly designed to address these rapidly

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