Coral Biology & Diversity

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The tropical latitudes of the oceans can be called the deserts of the ocean due to their similarity with terrestrial deserts, which are barren and relatively sterile places. The reason for this phenomenon is that the surface waters of the tropical oceans are so warm and thus they tend to float on top of the colder water underneath, inhibiting nutrient upwelling from the deep which brings nutrients to the ocean surface. However, coral reefs are a brilliant exception to the general scarcity of life in tropical oceans; they are known as the oases of ocean deserts. If we consider the area of coral reefs, it comprises less than 0.2% of the world's ocean, yet it is home to a wide array of marine organisms. Karlson and Cornell (1999) note that when considering the entire marine ecosystem, coral reefs exhibit the greatest diversity per unit area. It is estimated that almost 4-5% of all species or about 91,000 are found on coral reefs. We can find 32 out of 34 recognized animal phyla in coral reefs where there are only 9 phyla in the tropical rainforests (Porter and Tougas, 2001). Although corals are found in polar and temperate waters, coral reefs only develop in the tropics. This is primarily because there are two types of corals: hermatypic corals, which produce reefs, and ahermatypic corals, which do not form reefs. While ahermatypic corals have a worldwide distribution, hermatypic corals are found only in the tropics.

Coral reefs are vital ecosystems, both economically and ecologically. They provide a source of income, food, and coastal protection to millions of people who depend on them for their daily lives. Studies have shown that the goods and services provided by coral reefs amount to an annual net benefit of US$30 billion (Cesar and Chong, 2003). Additionally, corals fulfill their ecological role by providing a habitat for a wide variety of marine organisms. Unfortunately, these bizarre and beautiful coral reefs are also among the most vulnerable ecosystems in the world. Various threats, including bleaching, overfishing, pollution, improper waste disposal, coastal development, SCUBA diving, anchor damage, outbreaks of predators, invasive species, epidemic diseases, sedimentation, and river runoff, collectively undermine the health and resilience of coral reefs. About 70% of the world's corals are threatened, and 20% of that is damaged beyond repair (Wilkinson, 2004).

Coral Biology

Understanding coral reef biology is the key to understanding the ecology of reefs. Coral reef formations are the product of a symbiotic relationship between coral polyps and the photosynthetic microorganisms called zooxanthellae. The zooxanthellae which reside inside the gastrodermal tissue of coral polyps capture the sun's energy and pass a portion of it to their host. Using this extra energy gained from their guests the host corals secrete calcium carbonate to create shells around their bodies. This process continues over time and the mineral deposition grows upward and outward, with only the very surface of the structure inhabited by living polyps, the interior of the coral reef is made up of eons worth of abandoned polyp homes.

Coral anatomy

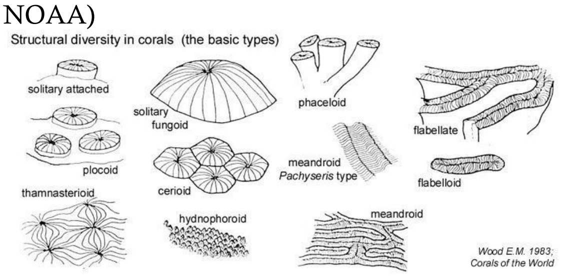
Hundreds of thousands of coral polyps like this one (Fig: 1) form most of the corals except some corals like mushroom coral which are only formed by a single polyp. The size range of coral polyps varies from one to three millimeters in diameter. These are anatomically very simple organisms, most of their body is taken up by their digestive system. Like all coelenterates, the body wall is mostly made up of two cell layers: the interior gastrodermis and the exterior ectodermis. These layers are separated by the mesoglea, initially acellular, and may evolve to incorporate various cells following initial development, serving as a divider between layers. In corals possessing tiny corallites, the mesoglea appears extremely thin under a microscope, whereas in certain species, such as the large corallite varieties of *Lobophyllia*, it can reach thicknesses of several millimeters and has a robust structure. Polyps, when extended, resemble anemones in appearance. Typically, the mouth is slit-shaped and can be encircled by an oral cone. The area between the cone or mouth might form into an oral disc.

The tentacles are tubular, sharing the same dual tissue layers as the rest of the polyp, meaning their internal cavity is an extension of the coelenteron. In corals that consume detritus, the tentacles are smooth, whereas those that rely on defense or capturing food typically possess stinging cells. These stinging cells, known as nematocysts, are minuscule but are often clustered together in visible, wart-like formations called nematocyst batteries, which can be seen underwater.

There is only one opening through which they collect food and expel waste. Food capturing and waste expelling is done with the help of a ring of tentacles surrounding the opening (Mouth). Most of the food is captured with the help of specialized stinging cells known as nematocysts which are located inside the polyp's outer epidermis. Reef-building coral polyps secrete calcium carbonate which forms a protective cup-like structure known as the calyx upon which the coral polyp sits is called the basal plate. Calyx is surrounded by a wall known as theca. Each polyps are connected to the neighboring ones with the help of coenosarc which is a thin band of living tissue and this helps the polyps to become a successful colonial organism.

The structure of corallite

Corals are colonial animals, a single individual is known as a polyp, and a polyp's skeleton is known as a corallite. This is a tube with vertical plates extending from the center. Structural alignment of the coral polyps can be used to identify different corals. Some examples are Plocoid corallites which have their separate walls, Phaceloid colonies also have separate corallites but they are tubular shaped. Cerioid Corallites are divided into polygonal sections, with each corallite keeping its wall. Meandroid corallites have walls shared and valleys enclose many mouths. Thamnasteroid corallites are with confluent septa and lack defined boundaries (Fig. 2). Fig.1 Anatomy of coral polyp (Image: NOAA)



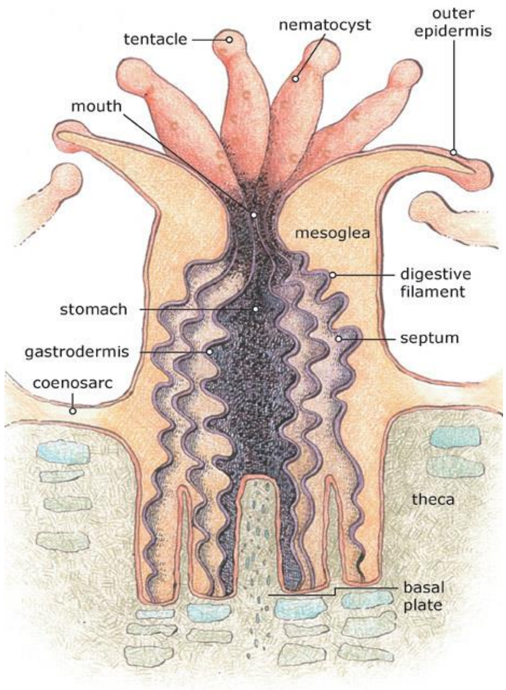


Fig.2 Structural diversity of corallites (Image: Wood E.M. 1983)

Coral Growth Forms

As colonies of hard coral grow and spread, they can evolve into various shapes or growth patterns. Typically, these patterns are identified as encrusting (forming a thin layer over surfaces), branching (developing branches), arborescent (resembling a tree), columnar (forming columns),laminar (resembling plates, sometimes in layers), free-living or solitary corals that do not form colonies and finally massive corals which are often large and solid often form hemispherical to spherical shapes (Fig. 3).

Growth rates are usually measured as linear extension of the coral branches, plates, or upward expansion of massive corals. The growth rate in coral can greatly differ among species. Under ideal tropical conditions, certain species like the branching *Acropora sp.* can exhibit rapid growth, advancing 10-20 cm annually, whereas other species, like *Porites*, expand at a much slower pace, approximately 1 cm each year.

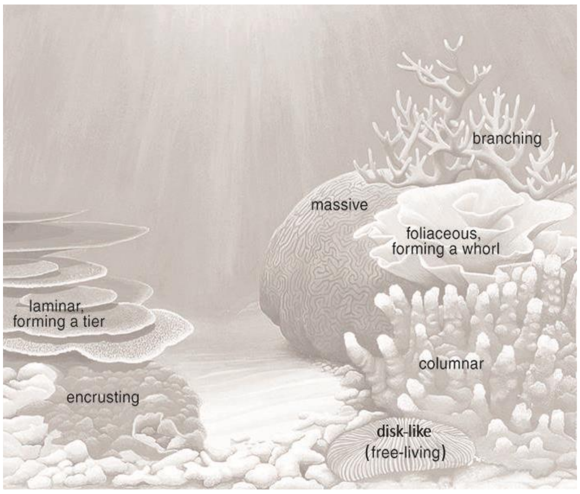


Fig:3. A range of tropical coral growth forms
(Veron, corals of the world)

Coral Nutrition

It has been known for a long time that reef corals are carnivorous animals, similar to most other cnidarians. Most corals feed at night, capturing mainly small planktonic organisms with their tentacles, which are equipped with nematocysts, also known as stinging cells. These cells are capable of delivering powerful toxins that are often lethal to their prey (Barnes, R.D., 1987). Coral reefs are recognized as colonial organisms due to their vast number of colonies and the extensive area available for feeding. In addition to their nematocysts, the ciliated outer epidermis of corals produces mucus. This ciliary mucus mechanism helps corals rid themselves of sediments settling on their surface and, in some cases, aids in feeding as well.

Given the large numbers of corals and the nutrient-poor surrounding ocean, how corals obtain enough food has puzzled generations of coral biologists. Johannes et al. (1970) calculated that demersal plankton is only sufficient to satisfy 5-10% of corals' total nutrient requirements. The remainder of their food comes from zooxanthellae found in the coral tissue. Further experimental studies conducted on large tentacled corals, which were kept in the dark, showed that they would expel their symbionts but could survive for a few weeks without them. This survival is possible because corals can capture microorganisms and feed on them. Corals obtain zooxanthellae either directly from the parent or indirectly from the environment. Initially, it was thought that there was only one type of zooxanthellae, but later studies revealed there are 16 clades of zooxanthellae, each with different properties. Some are more heat tolerant, some are capable of fixing more energy, and corals harboring these types of zooxanthellae are capable of growing at a faster rate. Therefore, different zooxanthellae may also characterize different reef microclimates.

Coral Growth and Calcification

Light is the primary factor for active coral growth; without it, or if corals are kept in shaded areas, their growth ceases. Long-term deprivation of light can lead to the death of the coral organism. This phenomenon is closely related to the role of zooxanthellae, which require light to fix energy, significantly enhancing the calcification and growth rate of coral reefs.

The growth rate of corals varies by species, reef location, and the age of the colony. Young colonies grow more rapidly than older ones. Moreover, corals vary in morphology, which influences their growth rates. Generally, branched corals grow more rapidly than massive corals. The growth rate is also influenced by the location within the reef, with the same species of coral growing in shallow water and deep water exhibiting differences. Deepwater corals are often thinner and more fragile than those in shallow water, likely due to reduced calcification. Furthermore, wave action causes branching corals to form shorter and stubbier branches, while ocean currents influence the arrangement of branches in branching corals.

Coral reef structures

Coral reefs are typically categorized into three principal types based on their structural features. The first one is fringing reefs, which is the most commonly found type, stretching outward from the shoreline, occasionally separated by a slim waterway or lagoon. They usually exist in shallow waters, with the reef flats becoming visible during low tide. The second one is barrier reefs, which lie parallel to the coast but are separated from it by a sizable lagoon that can be quite deep. These reefs often consist of a complex of individual reef formations, including fringing reefs that extend from islands situated offshore. Finally, the atolls are coral islands that form a ring or horseshoe shape around a central lagoon.

Coral Reproduction

Corals exhibit both sexual and asexual modes of reproduction, mirroring the life history of a typical sedentary animal. Dispersal primarily occurs through small planktonic larvae, often called planulae, which are produced in large numbers. After existing briefly in this motile form, a planula larva settles and metamorphoses into a polyp. Once it has grown to a certain size, the polyp divides, forming an ever-expanding clone. Asexual reproduction is achieved when new individuals bud off from the parent. Observations by Highsmith (1982) indicated that fragmentation plays a significant role in starting new colonies in some species. While most corals are broadcast spawners, releasing eggs and sperm into the open water, a few species act as brooders, retaining fertilized eggs in the gastrovascular cavity until they develop into planula larvae.

Taxonomy and Diversity of corals

Coral Taxonomy & Classification

Corals refer to marine invertebrates within the phylum Cnidaria and the class Anthozoa, possessing either external or internal calcareous skeletons. These skeletal structures, known as coral, can be found both externally and internally within these organisms. Corals typically manifest as small polyps, akin to other members of the Cnidaria group, often forming colonies attached to solid surfaces. While they share a close kinship with sea anemones, which fall under the Anthozoa class, sea anemones are classified in the Actiniaria order. Corals and sea anemones belong to Anthozoa, a class within the invertebrate phylum Cnidaria. The name of this phylum is derived from cnidocytes, specialized cells that contain stinging organelles. Other members of the Cnidaria phylum include jellyfish, sea pens, sea pansies, sea wasps, and small freshwater hydra. Within Anthozoa, there are two main groups: Alcyonaria and Zoantharia. Both subclasses encompass species commonly referred to as corals. Zoantharia also encompasses sea anemones (Order Actiniaria) and tube-dwelling anemones (Order Ceriantharia), among others. Polyps in the Zoantharia subclass lacking skeletons are typically termed anemones.

The classification of corals into orders as follows (Chen et al. 1995, France et al. 1996, Myers et al. 2006):

- Subclass Alcyonaria (= Octocorallia) (eight tentacles)
- Alcyonacea (soft corals)
- Gorgonacea (sea fans, sea feathers)
- Helioporacea (Indo Pacific blue coral)
- Pennatulacea (sea pens and sea pansies)
- Stolonifera (organ pipe coral)
- Subclass Zoantharia (= Hexacorallia) (more than 8 tentacles - typically 12)
- Antipatharia (black corals, thorny corals)
- Scleractinia (=Madreporaria) (stony corals)
- Corallimorpharia
- Ptychodactiaria

Extinct orders, from the Paleozoic (570-245 mya) (Oliver 1996):

- Rugosa
- Kilbuchophyllida
- Cothoniida
- Tabulata
- Tabulacondia
- Heliolitida
- Heterocorallida
- Numidiaphyllida

Coral Diversity

Scleractinian Diversity in India

Coral reefs are among the most valuable ecosystems in India. Despite India's extensive coastline of around 8,000 km, the major reef formations are confined to the Gulf of Mannar, Palk Bay, the Gulf of Kutch, Andaman and Nicobar Islands, and the Lakshadweep Islands. India is home to three major reef types: atoll, fringing, and barrier. The reefs in Lakshadweep are atolls, whereas those in the other locations are primarily fringing reefs, with some barrier reefs found in the Andaman and Nicobar Islands. Among these four reef formations, the Andaman and Nicobar Islands are the most diverse and richest in species, while the Gulf of Kutch has the lowest species diversity. Pillai documented a total of 199 species across 37 genera from India, encompassing both hermatypic (reef-building) and ahermatypic corals from the four major coral reefs of India. A more recent study by Venkataraman et al. (2003) identified 15 families, 60 genera, and 208 species of Scleractinia (solely reef-building, hermatypic corals) from these locations, including the Gulf of Kachchh having 36 species, 20 genera, Lakshadweep hosts 91 species spanning 34 genera, while the Gulf of Mannar and Palk Bay is home to 82 species across 27 genera. The Andaman and Nicobar Islands boast an even richer diversity with 177 species distributed among 57 genera