SCLERACTINIAN CORALS

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Introduction

The tropical regions of the oceans are often referred to as the "oceanic deserts" because they share similarities with terrestrial deserts, characterized by barrenness and relatively low productivity. The reason for this phenomenon is that the surface waters of the tropical oceans are so warm. 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. Nevertheless, coral reefs stand out as a remarkable exception to the typical scarcity of life in tropical oceans, earning them the title of "oases" within the oceanic 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, economically and ecologically. They provide a source of income, food, and coastal protection to millions of people who depend on them daily. 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 world's most vulnerable ecosystems. 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 key to understanding reef ecology. 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. Leveraging the additional energy obtained from their symbiotic algae, the corals produce calcium carbonate to construct protective shells around their bodies. This ongoing process results in mineral deposition that expands both upward and outward. While only the outermost layer of the structure supports living polyps, the interior of the coral reef comprises a complex network of abandoned polyp dwellings accumulated over eons.

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. The mesoglea, initially acellular, separates these layers 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 defence 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.

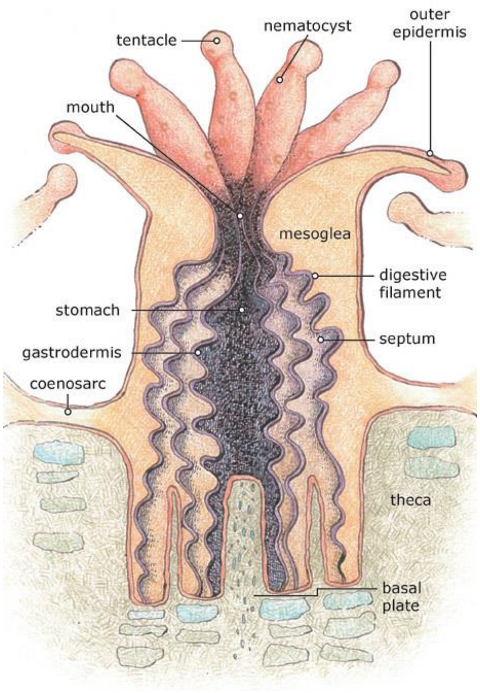

Fig.1 Anatomy of coral polyp (Image: NOAA)

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 centre. 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).

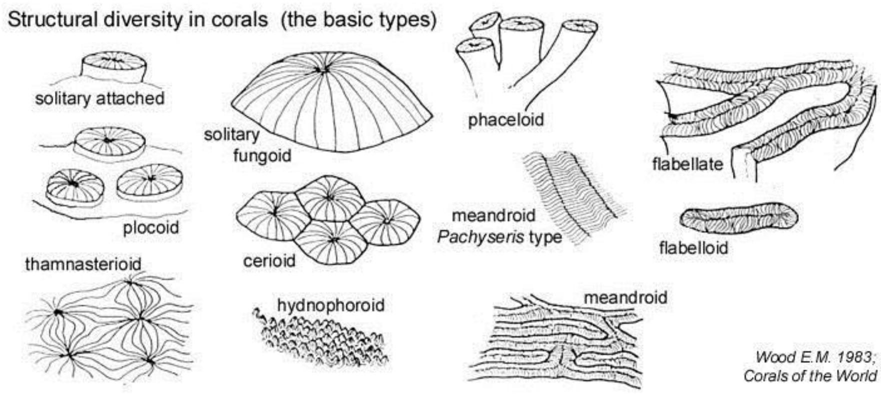

Fig.2 Structural diversity of corallites (Image: Wood E.M. 1983)

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.

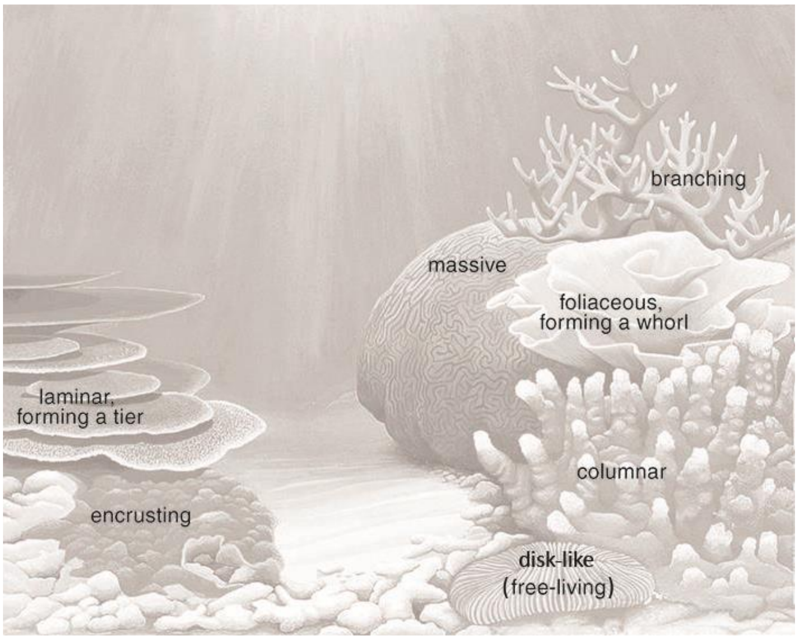

Fig:3. A range of tropical coral growth forms (Veron, corals of the world)

Coral Nutrition

It has long been known that reef corals are carnivores, like 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, coral's ciliated outer epidermis 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 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 faster than older ones. Moreover, corals vary in morphology, which influences their growth rates. Generally, branched corals grow faster 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

The term "coral" is often used interchangeably to refer to both "soft" and "hard" corals. It occasionally encompasses other colonial animals within the phylum Cnidaria, also known as Coelenterata. 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.

The classification of corals

- Kingdom: Animalia (Animals)
- Phylum: Cnidaria (Cnidarians)
  - Class Hydrozoa (Hydroids)
    - Order Anthoathecata (Fire corals)
    - Order Anthoathecata (Athecate hydroids)
  - Class Scyphozoa (Jellyfish)
  - Class Cubozoa (sea wasps)
  - Class Anthozoa (Anthozoans)
    - Subclass: Octocorallia (Colonial polyps with 8-fold symmetry)
      - Order Helioporacea (The blue coral is the only extant species)
      - Order Alcyonacea (soft corals, sea fans, and sea whips)
      - Order Pennatulacea (sea pens)
    - Subclass: Hexacorallia (Hard corals and sea anemones)

- Order Actiniaria (Sea anemones)
- Order Zoanthidea (Zoanthids)
- Order Corallimorpharia (They are closely related to stony corals)
- Order: Scleractinia (True hard corals)
- Order: Alcyonacea (Soft corals)
- Order Rugosa (Extinct order of Palaeozoic corals)
- Order Tabulata (Extinct order of Palaeozoic corals)

Coral Diversity

Scleractinian Diversity in India

Coral reefs represent invaluable ecosystems in India, serving as habitats for a diverse array of marine life and playing a critical role in shoreline protection from erosion. Despite India's extensive coastline of approximately 8,000 km, significant reef formations are primarily concentrated in specific regions, notably the Gulf of Mannar, Palk Bay, the Gulf of Kutch, Andaman and Nicobar Islands, and the Lakshadweep Islands.

India hosts three main types of coral reefs: atoll, fringing, and barrier. The reefs in Lakshadweep are predominantly atolls, while those in other locations, such as the Andaman and Nicobar Islands, consist mainly of fringing reefs, with some barrier reefs present. Among these formations, the Andaman and Nicobar Islands stand out as the most diverse and species-rich, whereas the Gulf of Kutch exhibits the lowest species diversity. Research conducted by Pillai documented a total of 199 species across 37 genera from India, encompassing both hermatypic (reef-building) and ahermatypic corals found in the four major coral reef regions of the country. This underscores the significant biodiversity harboured within India's coral reef ecosystems. 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.

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