13. Taxonomy of Hard Corals: Classification and Identification

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Introduction to Hard Corals

Scleractinian corals, commonly known as hard corals, are invertebrates found exclusively in marine ecosystems. They belong to the class *Anthozoa* and order *Scleractinia* and are characterized by their calcium carbonate exoskeletons, which provide structural rigidity. They are the keystone species of coral reefs, often referred to as the "rainforests of the sea," due to their extraordinary biodiversity. The hard corals primarily exist as solitary or in colonial forms. The colonial organisms are composed of thousands of individual polyps. Each polyp secretes a calcium carbonate skeleton that connects with others, forming intricate reef structures.

Hard corals are broadly categorized into two types:

Hermatypic Corals: They are known as reef-building corals and they require sunlight for survival due to their symbiotic relationship with *zooxanthellae* (photosynthetic algae).

Ahermatypic Corals**:** They are non-reef-building coral species. They can thrive in regions which are non-conducive for hermatypic corals to exist like deeper, darker waters.

Hermatypic corals are the primary architects of coral reefs, and are crucial for maintaining marine biodiversity, providing food and shelter for species ranging from fish to invertebrates. Coral reefs act as natural barriers, reducing wave energy and protecting coastlines from erosion, storm surges, and tsunamis. Reefs provide a habitat for commercially important fish and invertebrates, sustaining local and global fisheries. The vibrant beauty of coral reefs attracts millions of tourists annually, supporting the economies of coastal communities. Hard corals play a role in the global carbon cycle by sequestering carbon dioxide through the formation of their calcium carbonate skeletons. The health of hard coral populations reflects the overall condition of marine ecosystems. Stressors such as bleaching, disease, and mortality indicate environmental degradation and climate change impacts. Since many coral species are integral to fisheries, tourism, and coastal protection, taxonomy is critical to assess the coral diversity in a region. Taxonomy allows the accurate identification of hard coral species based on morphological and molecular characteristics. Species level coral identification helps in prioritizing ecologically significant species that require protection.

Distinguishing Characteristics Between Hard and Soft Corals:

Sl No:	Characters	Hard Corals	Soft Corals
1.	Skeleton Structure	Rigid calcium carbonate skeleton	Lack a hard skeleton. The colony is flexible, leathery bodies supported by spicules.
2.	Polyp Arrangement	Polyps are arranged in multiples of six	Polyps are arranged in multiples of eight
3.	Appearance	Stony and compact appearance	Appear bushy, tree-like, or feathery
4.	Zooxanthellae Relationship	Host zooxanthellae	Host zooxanthellae
5.	Habitat Contribution	Major reef builders, providing structure and habitat	Contribute less to reef building but add biodiversity

Hard coral identification using morphological features

Hard corals are identified based on several morphological, structural, and ecological characteristics. When identifying hard corals based on morphological features, careful observation of the coral colony is essential. Begin by examining the colony as a whole to understand its overall structure and shape. Consider its growth form, which can vary widely, such as branching, massive, encrusting, foliose, or plate-like. Growth forms often provide initial clues about the coral's genus or ecological adaptation.

Next, observe the corallite arrangement—how the individual skeletal cups (corallites) that house the polyps are distributed. They may be isolated, arranged in rows, fused, or share walls, helping to distinguish between species and genera. Finally, inspect the septal characters within the corallite. These include the number, size, and ornamentation of the septa (radial skeletal plates), as well as their symmetry and any unique features like teeth or ridges. A detailed understanding of these features is crucial for accurate identification, as these microstructures are often species-specific.

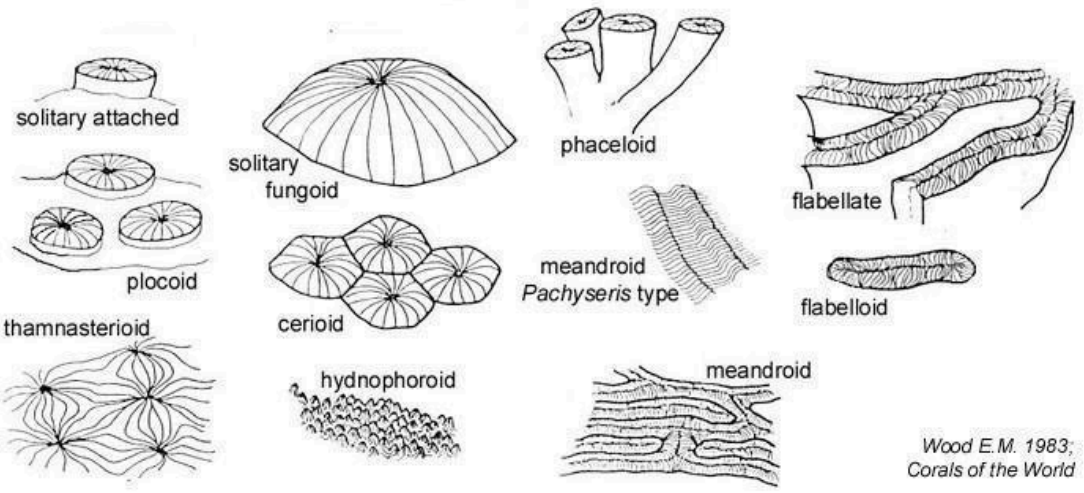
1. Habitat

- **Zooxanthellate Corals:** Found in the photic zone of tropical and subtropical reefs.
- **Azooxanthellate Corals:** Found in both photic and aphotic zones. The only type of corals found in deeper waters, caves, or cooler environments without light.

2. Skeletal Structure- Coral Colony

- **Growth Form:** Colonies can be branching, massive, encrusting, foliose (leaf-like), or solitary. The details of common growth forms are given in details below.

- **Corallite Structure:** The skeletal cup housing each polyp has distinct radial septa, columella (central structure), and calices (depressions where polyps reside). The arrangement of corallites in colony differs with various coral genus. The common types are given in the figure below.



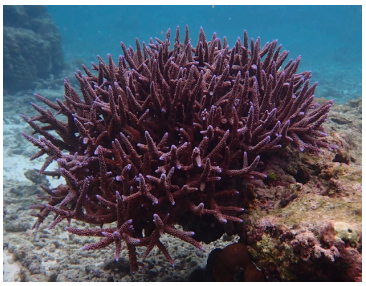
Common type of Corallite arrangement (Drawing take from Wood E. M. 1983, Corals of the World)

3. Septa and Septal Arrangement- Corallite

- The radial partitions (septa) are arranged in multiples of six (hexameral symmetry).
- The number, thickness, and ornamentation of septa vary among species. The terminology used about various parts of corallites are given in various diagrams below.

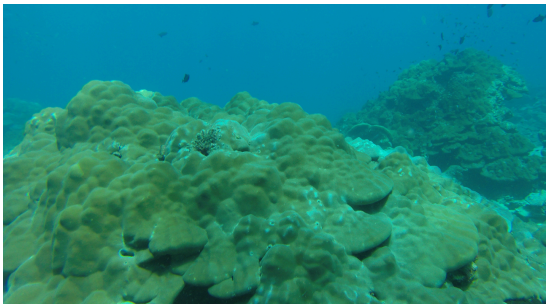
Hard corals exhibit various growth forms depending on species and environmental conditions. Here are the main types:

1. Branching: Corals with branches that grow upward and outward, resembling antlers or trees. These forms allow for rapid growth and colonization of reef spaces.



2. Encrusting: Corals that grow flat and spread over surfaces like rocks, creating a thin layer that adheres closely to the substrate.

3. Massive: Dome-shaped or boulder-like corals that grow slowly but are highly resistant to damage. These corals form solid, heavy skeletons.



4. Foliaceous (Leafy): Corals that grow in thin, leaf-like layers or whorls, creating a more delicate appearance compared to plating forms.

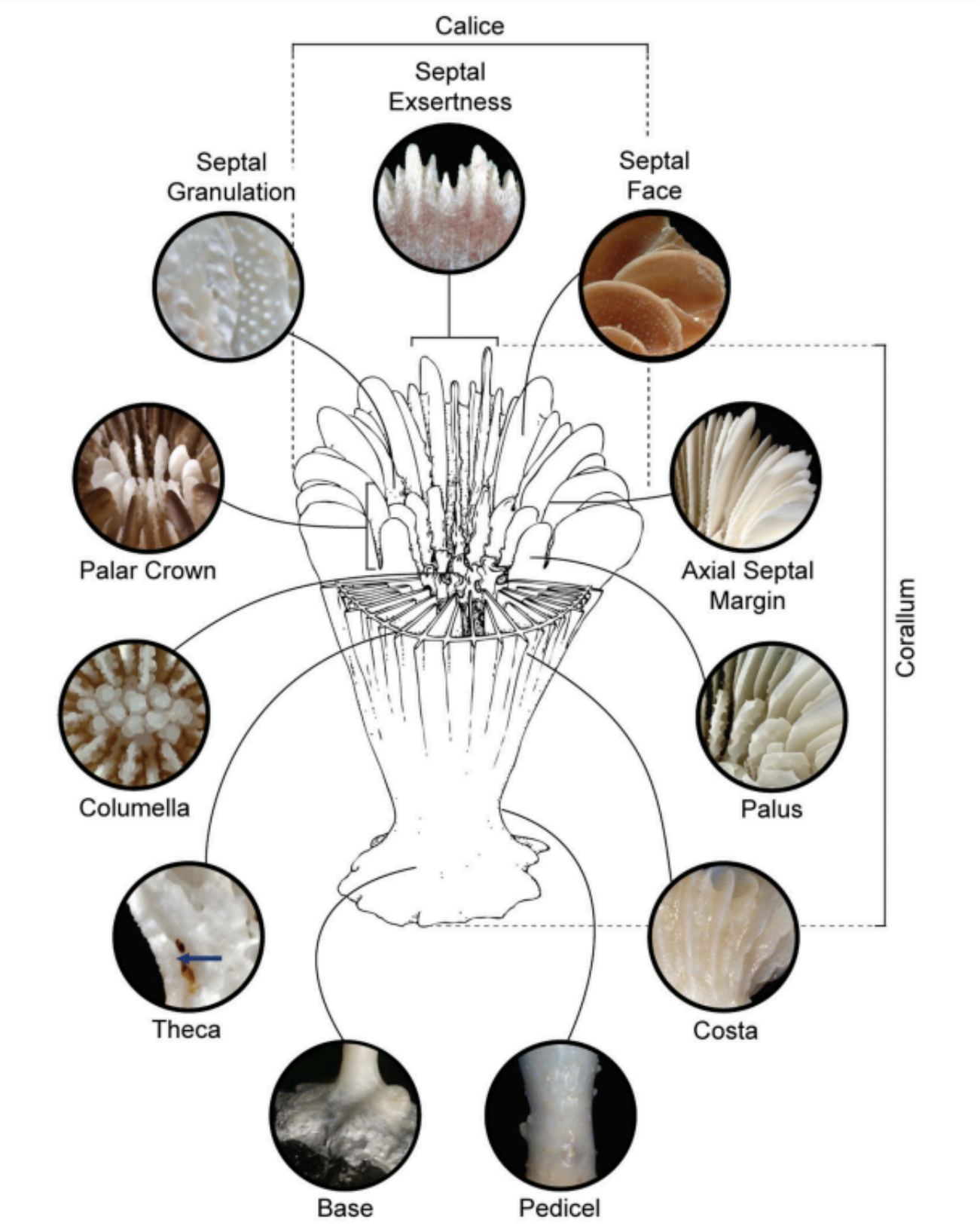
5. Table: Corals with a horizontal, table-like structure that spreads out to maximize sunlight exposure in shallow waters.

6. Digitate: Corals that form finger-like projections without branching, resembling stubby fingers growing upward from the colony base.

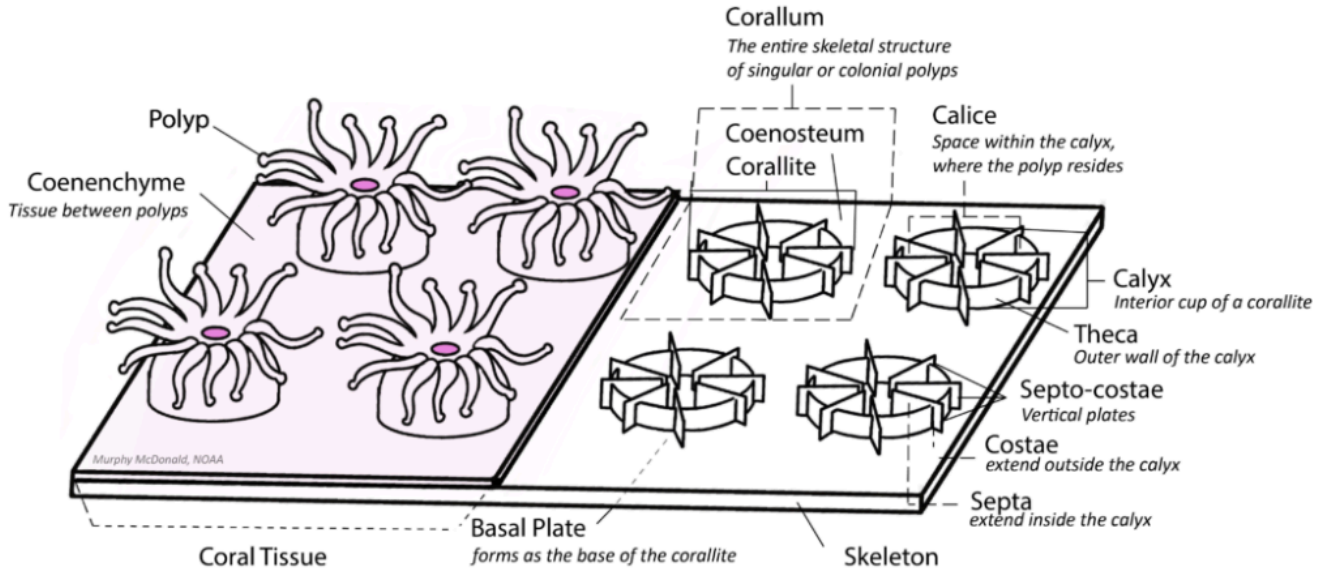
7. Columnar corals: Columnar corals are characterized by their cylindrical, pillar-like structures that can stand upright. These corals often grow in distinct columns or mounds, which can vary in height and width.

8. Solitary/ Free living: Corals are single, unattached coral polyps that live independently on sandy or soft substrates, unlike colonial corals that form interconnected reefs.

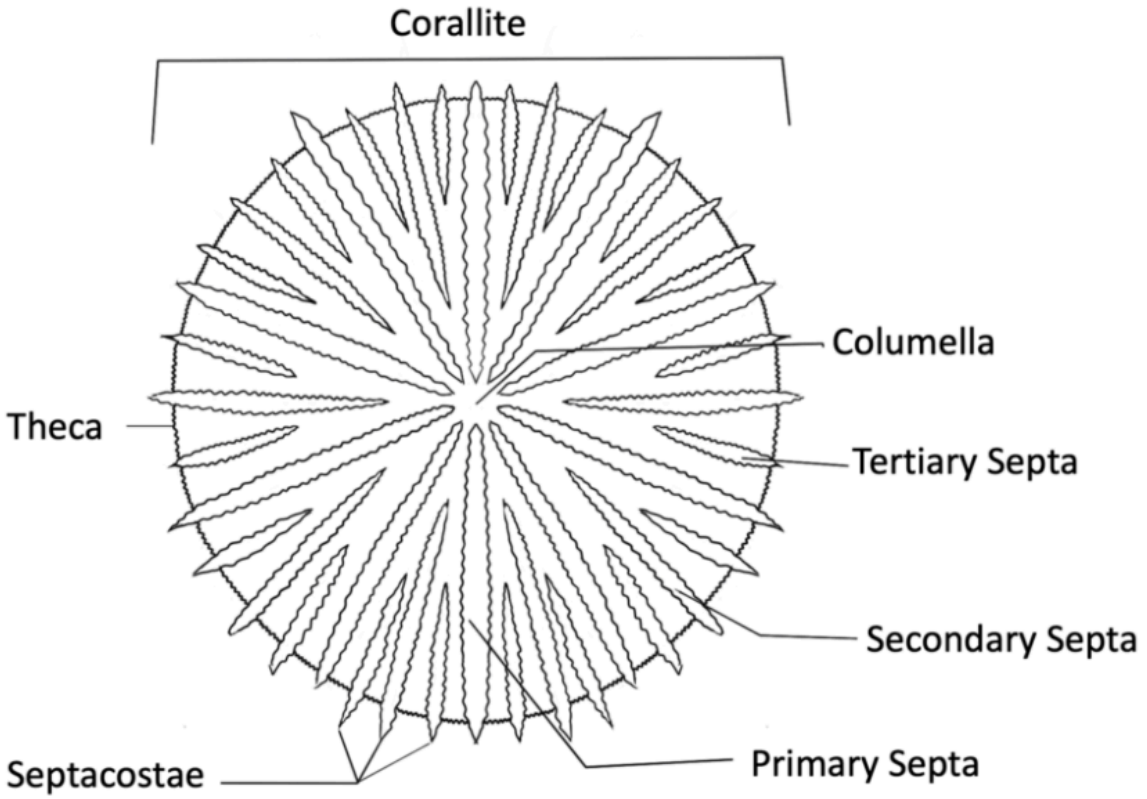
These diverse growth forms enable corals to adapt to different environmental conditions and play various roles in the structure and health of coral reefs.



Cutaway diagram of hard coral to understand the coral morphological terms used for identification (Schematic diagram taken from Cairns and Kitahara, 2012)



Schematic diagram of coral colony with terms used for identification (Credit: Murphy McDonald, NOAA)



Schematic diagram of corallite (Credit: Murphy McDonald, NOAA)

Classification of Hard Corals

Phylum Cnidaria: Cnidarians are radially symmetrical, diploblastic animals with two cellular layers—epidermis and gastrodermis—separated by a jelly-like mesoglea. They possess a

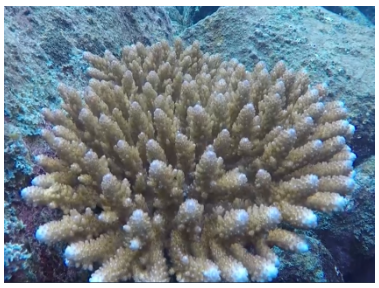
simple nerve net and specialized stinging cells called cnidocytes, containing cnidae (e.g., nematocysts) for prey capture and defense. Cnidarians exhibit alternation of generations, with an asexually reproducing polyp stage and a sexually reproducing medusa stage, and their life cycle includes a motile, ciliated planula larva. They display simple tissues and structures that contribute to their functional diversity.

Class Anthozoa: Anthozoans, known as "flower animals," are entirely marine and exist only in the polyp form, with no medusa stage. They often have a mesoglea with many cells, can be solitary or colonial, and most secrete skeletons made of calcium carbonate or protein.

Order Scleractinia: The order Scleractinia comprises sedentary hexacorallian Anthozoa that can be either colonial or solitary and exist solely in a polypoid form. These polyps are supported by an external skeleton made of aragonitic calcium carbonate, known as the corallum. Typically, each polyp has six or a multiple of six pairs of mesenteries, with each pair enclosing a calcareous radial structure called a septum. Scleractinian corals commonly possess 12, 24, 48, 96, or more septa, arranged in a radially hexameral pattern. They are commonly known as stony corals, true corals, or hard corals. Scleractinians are diploblastic organisms, having two tissue layers: the ectoderm and the endoderm. A typical scleractinian polyp features a central stoma (mouth) encircled by a ring of tentacles. These tentacles house cnidae, or nematocysts—specialized structures comprising a poison sac and a hollow tubule. When activated, the tubule injects toxin, aiding in prey capture and providing defense against threats.

Family Acroporiidae: Colonial, hermatypic, mostly extant. Colonies have all growth forms known for hermatypic corals. This group of hard corals are known for its branching structures, with coral tips often having larger, tube-like ends called axial corallites. Corallites are small with septa in two cycles or less, columellae are poorly developed.

Genus Acropora: These corals are easily recognized by their branching growth forms, with distinct axial corallites at the tips of branches and smaller radial corallites along the sides. They typically form large colonies that can grow into staghorn, table, or bush-like shapes.



Acropora sp.

Family Poritidae: These corals exhibit diverse growth forms, including massive, laminar, or ramose. Their corallites are small, compact, and cerioid, with extratentacular budding. The walls and septa are porous, while the coenosteum is poorly developed or absent.

Genus Porites: *Porites* form massive, branching, or laminar colonies with a smooth colony surface. Their corallites are tiny, and the plates. Species are distinguished by the specific arrangement of corallite structures.

Porites sp.

Genus Goniopora*:* These corals form columnar, massive, or encrusting colonies with polygonal corallites. They possess 24 long-stalked tentacles that are typically extended during the day, giving them a distinctive appearance.

Family Pocilloporidae: These corals generally form ramose colonies with plocoid to cerioid corallites, about 1–2 mm across, arising from extratentacular budding. When present, columellae are styliform, and the coenosteum is covered with distinctive spinules.

Genus Pocillopora: These corals have branching colony morphology with very small corallites. The colony surface is bumpy due to structures called verrucae, with corallites located on and between these verrucae.

Pocillopora sp

Family Agariciidae: These corals have very fine tentacles which are seldom extended during the day. Little is known about their sexual reproduction, except that different species may be separately sexed or hermaphrodite and may brood planula larvae or release gametes. The genera in this family are colonial, hermatypic. Colonies are massive, laminar or foliaceous. Corallites are immersed with poorly defined walls formed by thickening of the septo-costae. Septa seldom fuse and are continuous between adjacent corallite centres. They have smooth or finely serrated margins and are closely packed.

Genus *Pavona*: These corals form massive, encrusting, columnar, or foliaceous colonies and can develop bifacial leafy fronds. Their corallite walls are poorly developed, giving a distinctive structural appearance.

Pavona sp (Image credit: Corals of the world)

Family Psammocoridae: Corals of this family are relatively small and cryptic. Colonies are typically encrusting, submassive, or platy. Corallites are small to medium-sized, closely spaced, and sometimes arranged irregularly. Corallite walls are distinct but often thin. Septa are well-developed, thin, and may have fine teeth. The coenosteum (skeletal tissue between corallites) is granulated or finely costate (ribbed). Polyps are small and retracted during the day, emerging at night to feed.

Genus *Psammocora*: These corals are characterized by a variety of growth forms, including massive, columnar, branching, laminar, or encrusting colonies. The corallites are small, with septa fusing to form a distinct flower-like pattern. The coenosteum is granular, giving the surface a rough texture.

Psammocora sp.

Family Lobophylliidae: Family of large polyp stony corals distinguished by their unique skeletal features and morphology. Members of this family typically exhibit irregular lobate or bulbous teeth, which are characterized by elliptical bases. The corallites are adorned with rounded granules, and these are often surrounded by extensive thickening deposits that enhance their structural integrity. Between the teeth, vertical palisade-like structures are present, contributing to the overall complexity of the coral's skeleton. Notably, there is a

significant variation in the size and shape of teeth among different septal cycles, which adds to the diversity within the family

Genus *Lobophyllia:* These corals are identified by phaceloid, flabello-meandroid, or meandroid colonies, with or without gaps between valleys. Colonies can grow very large, with corallites being monocentric or arranged in long valleys. The septa have large, spiky teeth, and colonies feature a fleshy mantle that can fully retract when exposed at low tide.

Family Merulinidae: Most species are encrusting or massive, featuring large circular or hexagonal calices with robust septal walls. Others have a brain-like structure, characterized by indistinct calices embedded within sinuous valleys.

Genus *Favites:* These corals form massive or encrusting colonies with corallites measuring 6-20 mm in diameter, either angular or round. Corallites are monocentric and often share walls, with groove and tubercle formations separating them. Paliform lobes are poorly developed, septal teeth can be large, and budding occurs either intratentacular or extratentacular.

Family Fungiidae: These corals are commonly known as mushroom corals, includes species that are usually free-living, though some remain attached even in their adult stages. Their distinguishing feature is the septo-costae, which radiate from the central mouth as septa on the upper surface and as costae from the center on the under-surface.

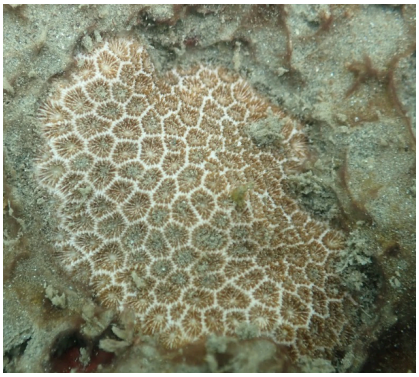
Genus *Fungia:* These corals are characterized by solitary, free-living corolla that are either circular or elongate in shape. The septal teeth are distinctly pointed, contributing to its identification.

Family *Dendrophyllidae:* These corals were characterized by corallite walls that are porous. The septa are fused in a distinctive pattern known as the Pourtalès plan, particularly evident in immature corallites.

Genus *Turbinaria:* Coral is characterized by colonies that are plate-like, foliose, or encrusting. Corallites measure 1-5 mm in diameter and can be either immersed or exsert. The coenosteum is smooth, and the columellae are well-developed, aiding in its identification.

Family *Siderastreidae*: The corals of this family are characterized by colonial, massive, or laminar colonies. Corallites are small, immersed, and have numerous thickened septo-costae. The septa are closely compacted and equally spaced, while the corallite walls are very poorly defined.

Genus *Pseudosiderastrea*: These corals form small massive or encrusting colonies with ceroid corallites (shared walls) that are shallow and greater than 10 mm in diameter. The corallite walls are distinctively white, aiding in its identification.



Geographic Distribution and Diversity in India

Indian waters are home to an extensive and diverse array of coral ecosystems. The major reef with maximum diversity of hard corals is located in the Andaman and Nicobar Islands, the Lakshadweep archipelago, the Gulf of Mannar, and the Gulf of Kutch. Other than these sites the hard corals are found in the fringing reefs to atolls and submerged banks. Minor reefs, such as those at Enayam, Netrani, Grande, and Malvan, along with submerged reefs like the Gaveshini and Angria Banks. Hard corals, or scleractinians, dominate these ecosystems and are expected to be distributed from intertidal zones to ocean depths exceeding 600 meters in many locations along the Indian EEZ. A total of 586 species belonging to 110 genera and 25 families are recorded from Indian EEZ. Among recorded Scleractinia corals one species (*Tubastraea coccinea* Lesson, 1830) is reported as invasive in Indian waters. Detailed taxonomy and species delineation are described in detail in many coral taxonomic references. Few of these references are given in Mondal and Raghunathan (2024).

Challenges in Coral Taxonomy

One of the key challenges in coral taxonomy is the presence of cryptic species and hybridization. Cryptic species are morphologically similar but genetically distinct, making them difficult to differentiate based on physical traits alone. This can lead to misidentification and underestimation of biodiversity. Hybridization further complicates taxonomy, as interbreeding between closely related coral species produces hybrids with traits that blur species boundaries. These phenomena are prevalent in corals due to their overlapping habitats and reproductive timings. Advanced molecular tools, such as DNA barcoding and genomic analyses, are essential to accurately identify and understand these complexities in coral taxonomy.

Further Reading

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7. Scleractinia. Version 1.0. Zoological Survey India.