What and Where are the Coral Reefs?

Coral reefs first formed more than 500 million years ago in warm tropical climates, and since that time they have successfully developed and supported a tremendous array of plant and animal life. Covering less than 0.2% of the ocean floor, it is estimated that coral reefs contain approximately 25% of the ocean's species. Approximately 5,000 species of reef fish have been identified, and more than 2,500 species of coral, of which almost 1,000 are reef-building hard corals. About 4,000 species of mollusks alone live on the Great Barrier Reef in Australia. This vast diversity of life has given coral reefs the name "rainforests of the sea." Rainforests, which are habitat for more than 30 million insects, have a greater number of species, however coral reefs have a larger number of **vertebrates** (animals with backbones) and more major animal groups (**phyla**). Studies have shown that the most important contributors to the mass of a living reef are calcareous red algae, green alga Halimeda, foraminifera, and hard corals.

WHAT IS CORAL?

Coral is an **invertebrate** (animal without a backbone) marine organism of the class Anthozoa (phylum Cnidaria). Members of this class are characterized by a body that only opens at one end, the mouth, and by skeletons, either internal or external, of a stonelike, horny, or leathery consistency. Some **cnidarians**, such as jellyfish, float through the water. Others, such as sea anemones and corals, attach themselves to the reef.

Basically, there are two groups of corals: **hermatypes**, or hard corals that build reefs; and **ahermatypes**, or corals (both soft and a few hard) that do not. The major difference between hard corals and soft corals is that hard corals contain **zooxanthellae** (microscopic algae) within their tissue and the soft corals do not.

The term coral is also used to describe the skeletal remains of these animals, particularly those of the hard corals which form a limestone base that becomes the foundation of the reef.

DID YOU KNOW? The **Great Barrier Reef** is the largest structure built by living organisms on Earth, and it is the only living structure visible from outer space. Located along the northeast coast of Australia, it measures 1,240 miles (2,000km) in length.

THE CORAL BODY

The body of a coral animal is called the **polyp**, a hollow sac-like structure that is smaller than a common pencil eraser. At its free end is a **mouth** surrounded by **tentacles,** and inside the body is a **stomach**. The sticky tentacles contain harpoon-like stinging structures, called **nematocysts**, that enable the polyp to gather food by paralyzing its passing prey. The tentacles then deposit the food in the mouth where it passes down into the stomach. Nutrients are absorbed from the food and any solid waste materials are passed back out through the mouth. Within the stomach are long, tubular **mesenterial filaments** that the polyp extends to defend itself from attack by other encroaching coral.

In addition, the polyps of the hard corals extract **calcium carbonate** from the sea water and use it to build a hard external **limestone skeleton** beneath and around their base which secures the fragile polyp to a surface and serves as its protection (Figure 1-1).

DID YOU KNOW? Polyps have a mouth but they don't have a head or any teeth for chewing**.**

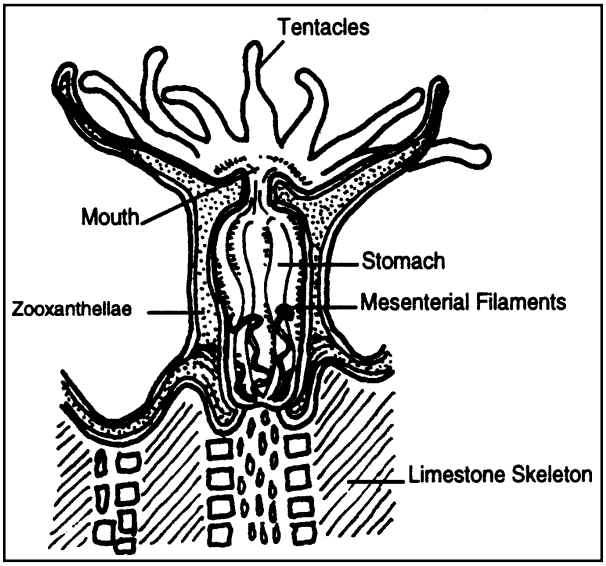


Figure 1-1. A cross-section of the coral polyp structure. (Illustration: Wendy Weir)

CORALS AND THEIR PLANT PARTNERS

Within the tissue of the polyp live many microscopic algae or plant cells called **zooxanthellae** (also called **endosymbionts**). These algal cells have a **symbiotic** (mutually beneficial) relationship with the coral.

The algae provide the polyp with food through the process of **photosynthesis** in which the plant cells use sunlight coming through the water to convert the carbon dioxide and water in the polyp tissue into oxygen and carbohydrates. The oxygen is used by the polyp for respiration and the carbohydrates are used for energy to build its limestone skeleton. In return, the polyp provides the zooxanthellae with nutrients, protection, a place to live, and carbon dioxide, a by-product of respiration which is vital for photosynthesis.

DID YOU KNOW? The color of the coral comes from the color of the zooxanthellae living in the polyp's tissue. This color can vary from white, yellow, brown, and olive to red, green, blue, and purple. The color of the coral's limestone skeleton without the zooxanthellae is white.

FOOD SOURCES

In addition to getting food internally from the zooxanthellae, some corals eat **plankton**. Plankton are creatures, both plant and animal, that move passively through the water at the mercy of wind and ocean currents. Most plankton are too small for you to see unaided.

The plant plankton are called **phytoplankton** and the animal plankton are called **zooplankton**. They acquire their nutrients and energy from a different, distant ecosystem. It is estimated that as much as 60% of the plankton on the reef are eaten by the coral polyps as they drift by.

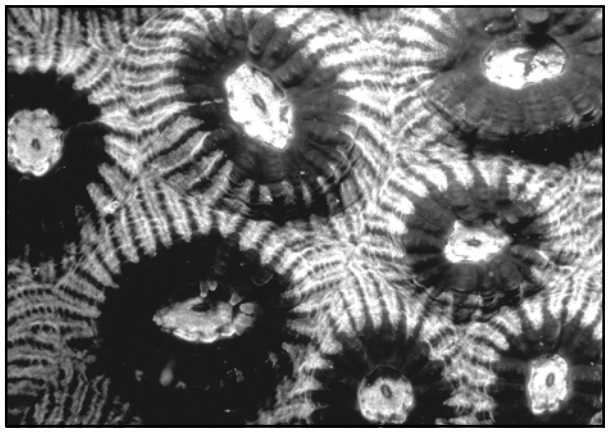
Most corals feed only at night, extending their tentacles when they are less likely to be preyed upon. During the day, the tentacles are withdrawn into the skeleton for protection (Figure 1-2).

DID YOU KNOW? Since corals are animals, those that eat only plants (phytoplankton) are called **herbivores**, and those that eat only animals (zooplankton and small fishes) are called **carnivores**.

REPRODUCTION AND GROWTH

Coral polyps reproduce both sexually (with a partner) and asexually (by themselves). **Sexual reproduction** occurs when the corals **spawn** (Figure 1-3a), releasing eggs and sperm into the water. The sperm then fertilizes the egg, creating a new individual called a **planula** or coral larva. Spawning usually occurs in mass in order to give the eggs and sperm a better chance of fertilizing themselves and surviving predators. Although most hard corals are **hermaphroditic**, containing both male and female sex cells, they sometimes fertilize the sex cells of other colonies thereby ensuring the coral's ability to maintain genetic diversity and adapt to new conditions.

(a)



(b)

Figure 1-2. (a) The coral polyp at night with extended tentacles (Photo: Jim Larson), and (b) during the day with hidden tentacles. (Photo: Terry Brown)

Once produced, the planula, which already contains zooxanthellae from the parent, floats up towards the light and drifts with the plankton from several hours up to several weeks. Those that survive then swim back down, settle on a solid, rocky surface, and develop into polyps. This is the only way in which the stationary hard corals can move to a new location. This is also how corals develop on concrete blocks, shipwrecks, and oil drilling platforms.

DID YOU KNOW? Once a year in Australia, for a few nights following the full moon in spring (October in the southern hemisphere), more than 130 species of corals along the **Great Barrier Reef** release millions and millions of eggs and sperm into the water at the same time. Reef organisms, like anemones, sea cucumbers, and the crown-of-thorns starfish, also spawn at this time.

Asexual reproduction occurs by **budding** (Figure 1-3b). The parent polyp clones itself by dividing to form a new polyp which remains attached to the parent polyp's tissue. A coral **colony** develops by the constant addition of new buds. As the new polyps grow, the old polyps beneath them die, adding their limestone skeletons to the foundation of the reef. In optimum conditions in nature, massive corals may grow up to .8 inches (2cm) a year and branching corals up to 4 inches (10cm) a year. Because of the corals' slow growth, the creation of a reef can take hundreds of years.

Coral colonies may also be attached to others of the same or different species, forming large and complex reef structures. Some of these colonies fight one another for more space and light by extending their long arms or mesenterial filaments that the polyp uses to attack and kill the other encroaching polyps. In the right conditions, new colonies can also grow from broken-off fragments of the original colony. In this way, reefs are able to regrow themselves after damage from storms, hurricanes, and cyclones.

DID YOU KNOW? In the 1970's, it was discovered that the age of a coral could be determined in the same way as a tree. By passing an X-ray through the coral, annual growth rings become visible and can be counted. Some of the corals along the Great Barrier Reef are estimated to be more than 800-1000 years old. This means that they first began growing around the time that the Battle of Hastings was fought in England (1066AD) and the first Crusade left France for Jerusalem (1096AD).

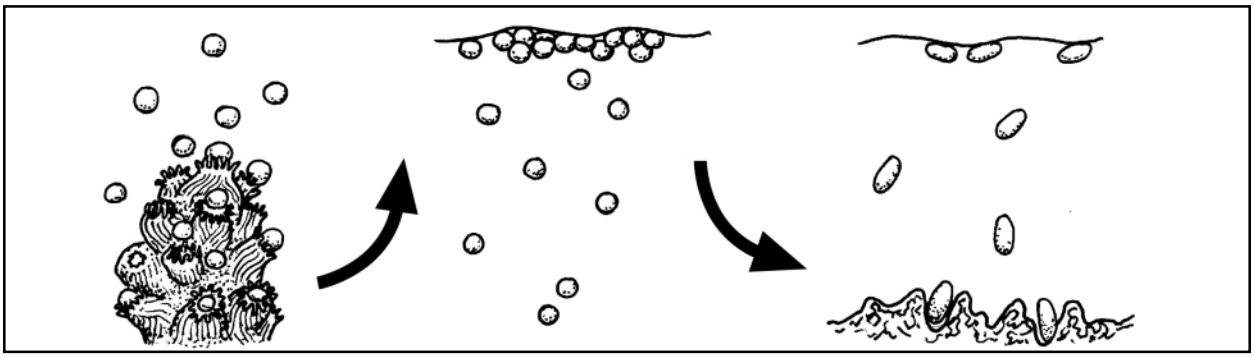


Figure 1-3 (a). Coral spawning: planula float to the surface, then swim down and settle on a solid surface to grow.

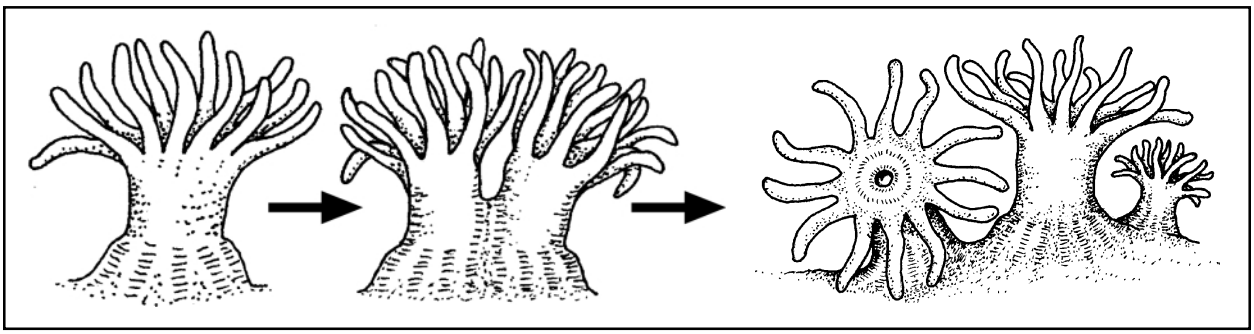


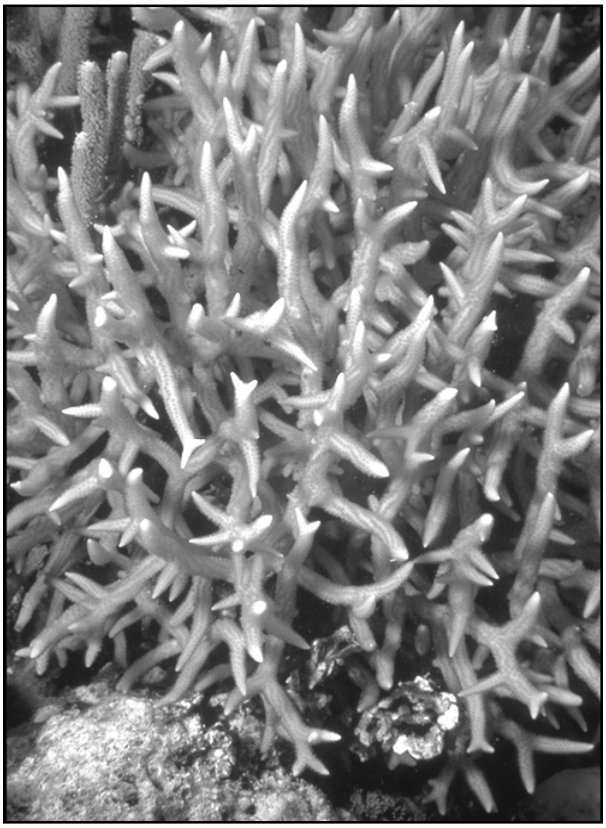
Figure 1-3 (b). Coral budding: polyps divide but remain interconnected by tissue to form a coral colony. (Illustrations: Wendy Weir)

TYPES OF CORALS

Hard Corals

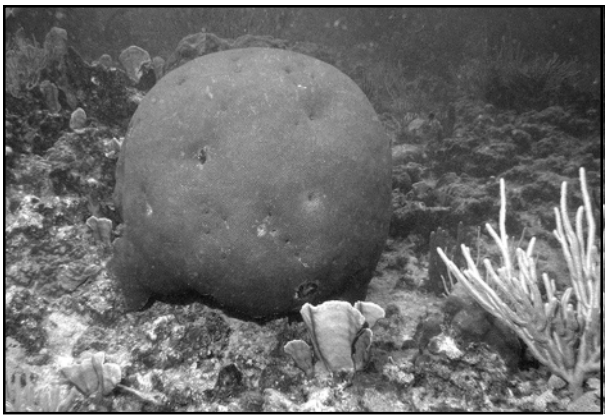
Reef-building corals, which secrete a hard external limestone skeleton, are commonly known as **hard (stony) corals**. They characteristically have tentacles in multiples of six and can be found either individually or in colonies. These hard coral colonies exhibit three basic growth forms: branching, massive, and plate (Figure 1-4).

Common types of hard corals are brain coral, mushroom coral, pillar coral, staghorn coral, and plate (or table) coral. Water movement influences the shape of the corals. Where strong waves hit the reef front, corals have thick branching, massive (boulder), or flattened shapes. Where the water is calmer and deeper, the coral branches become more delicate and some take on the shape of large thin plates to absorb a maximum amount of light for their zooxanthellae. The mushroom coral is one of the few corals that does not grow in colonies.



(a)

DID YOU KNOW? Hard corals are the most widely distributed form of coral, occurring in all oceans from the shallow tidal zone to depths of 20,000 feet (6,000m).



(b)

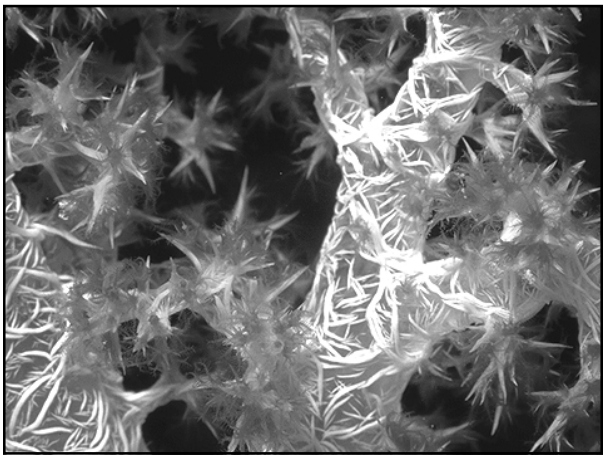
(c)

Figure 1-4. Hard coral growth forms: (a) branching (Photo: Jim Larson), (b) massive, and (c) plate. (Photos: Jim Thompson)

Soft Corals

Some types of corals secrete a flexible or soft skeleton. These are called **octocorals**, so named for their characteristic eight tentacles. Octocorals include the soft coral, sea fan, black coral, whip coral, and blue coral (Figure 1-5).

Octocorals also grow in colonies on the reef, but do not build reefs. They have branching, ribbon-like shapes and their soft internal skeleton allows them to bend, wave, sway, and spread out in the water. Some of the soft corals produce toxic compounds that make them unappetizing to predators. Soft corals thrive in strong currents where they have access to lots of plankton. They also grow well in areas where hard corals cannot grow, such as dark caves and overhangs.



(a)

(b)

Figure 1-5. (a) Soft coral, and (b) close-up of soft coral with nudibranch. (Photos: Terry Brown)

DID YOU KNOW? Coral jewelry is made from harvesting soft coral, such as black coral and whip coral. Killing coral to make jewelry and ornaments harms the reef.

LOCATION OF CORAL REEFS

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.

DID YOU KNOW? The reefs of the Western Atlantic region evolved later than those of the Indo-Pacific/ Red Sea region because of the youth of the Atlantic Ocean. These reefs do not have the great abundance and diversity of reef species that are found in the older Indo-Pacific/Red Sea area where the prehistoric Tethys Sea was located.

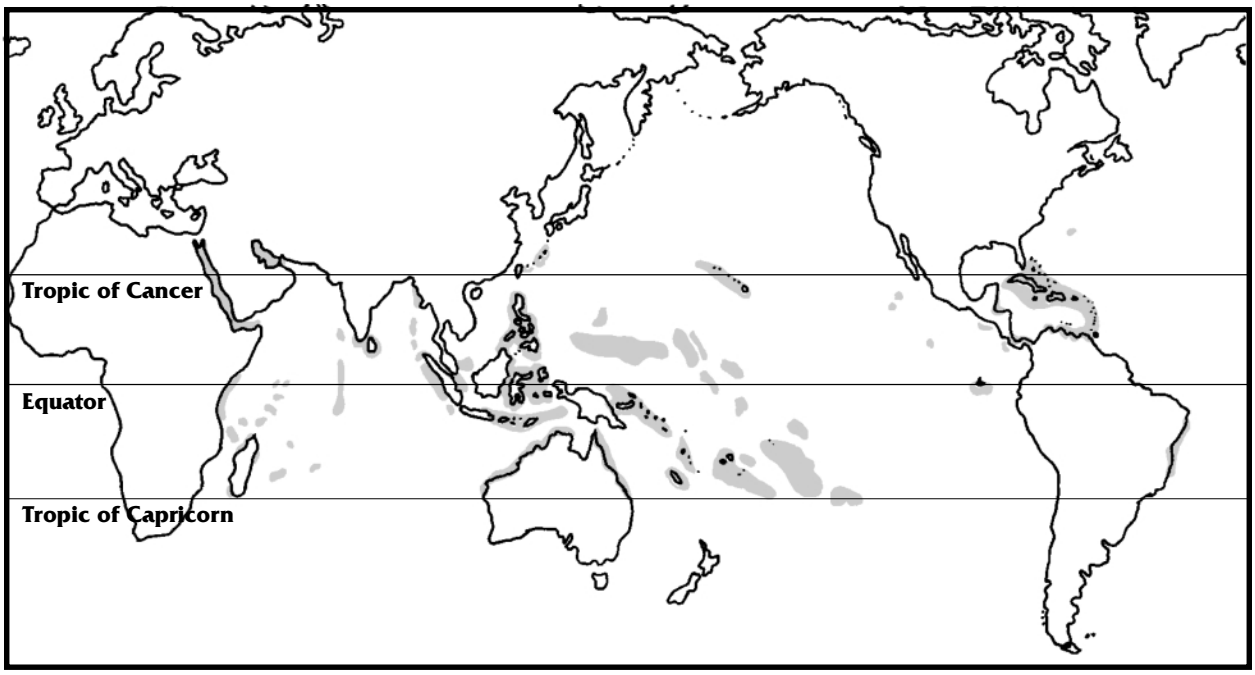


Figure 1-6. Coral reefs of the world. (Illustration: Wendy Weir)

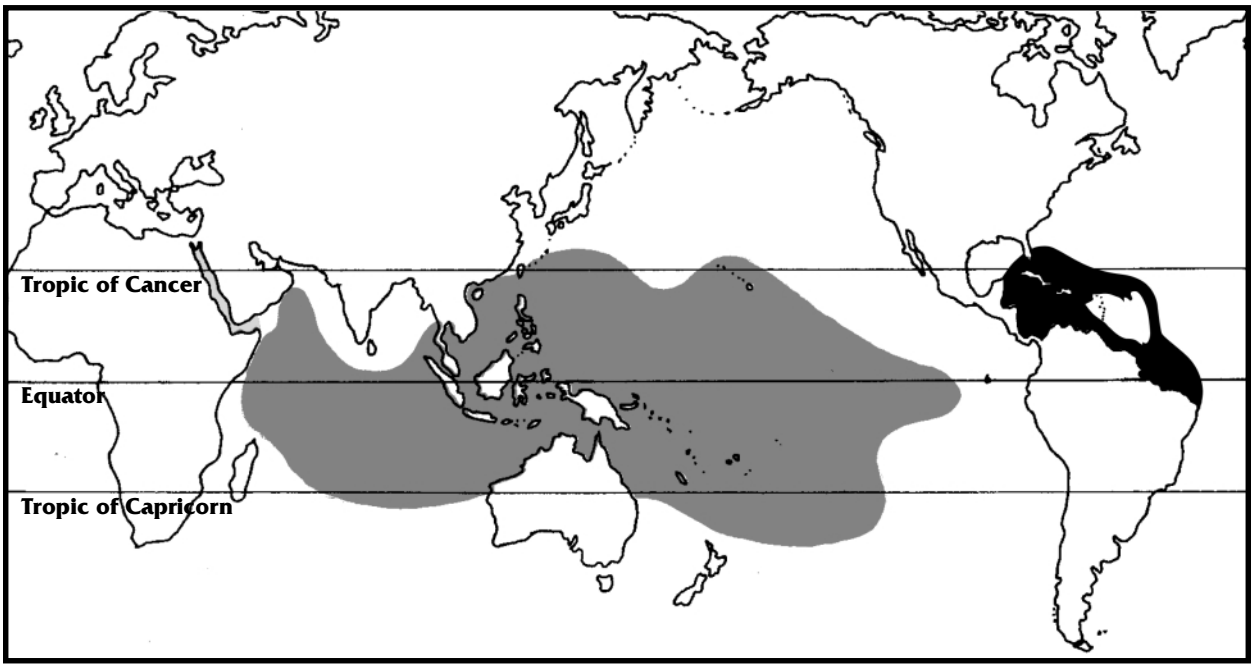


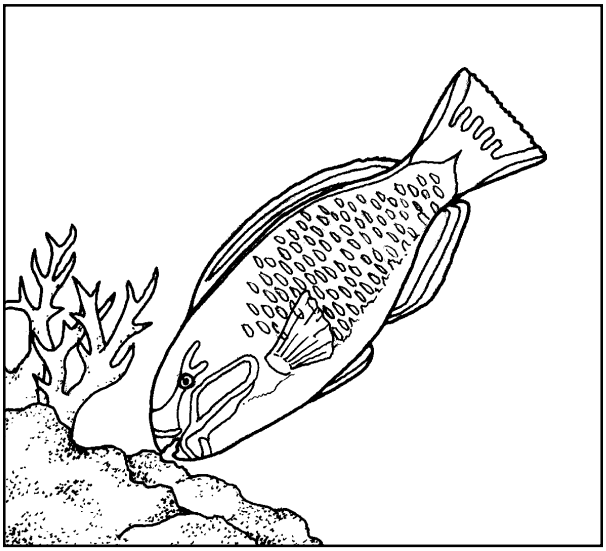
Figure 1-7. Coral reef regions of the world: Indo-Pacific (dark gray), Western Atlantic (black), and Red Sea (light gray). (Illustration: Wendy Weir)

CORAL REEF FORMATION

Today's coral reefs have accumulated during the last 10,000 years since the last glacial periods of the Pleistocene epoch. As glacial ice melted and sea levels and temperatures rose, present-day reefs began to form.

Hard corals provide the main structural framework. Other organisms, such as coralline algae and protozoans, bind and cement everything together with sheetlike growth that stabilizes the reef. Sand and sediments are created by boring organisms, such as sponges and bivalves (i.e. clams, oysters); green calcified algae (Halmedia) which has calcium carbonate plates that drop off; and, grazers, such as parrotfish and sea urchins, which attack the coral for food, extracting nutrition from the polyps, breaking down their limestone bases, and excreting the waste as sand (Figure 1-8).

DID YOU KNOW? The calcium carbonate from the sand, shells, and coral maintains the pH balance in the ocean which in turn maintains life as we know it.



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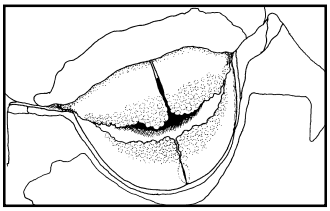


Figure 1-8. A source of sand: (a) parrotfish grazing tail-up on hard coral, and (b) close-up of the parrotfish's "beak." (Illustrations: Wendy Weir)

TYPES OF REEFS

There are three major types of coral reefs: fringing reef, barrier reef, and atoll. In tropical areas, **fringing reefs** grow directly from the shorelines of continents and islands. **Barrier reefs** are found further out, separated from the shore by a stretch of protected water, the lagoon. **Atolls** are offshore ring-like coral formations that surround a shallow, central lagoon.

Darwin's Theory of Atoll Formation: In 1842, Charles Darwin provided the theory of atoll formation which offers the most widely accepted explanation of coral reef formation today.

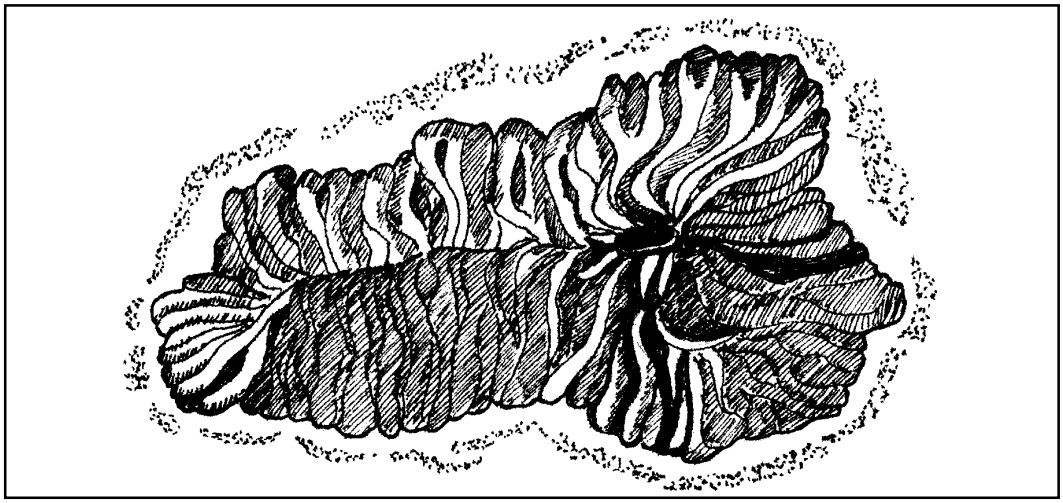
The theory is best understood in terms of reef formation on a tropical island. A tropical volcanic island furnishes the shallow underwater base on which the coral grows. Eventually, the island becomes surrounded by a fringing reef which is separated in places from the island by only a shallow, narrow strip of water (Figure 1-9a).

If the island sinks gradually into the water, then a channel develops between the land and the coral forming a barrier reef (Figure 1-9b). A similar process can occur with larger land masses due to the shifting of crustal plates. The Great Barrier Reef is the best example of this.

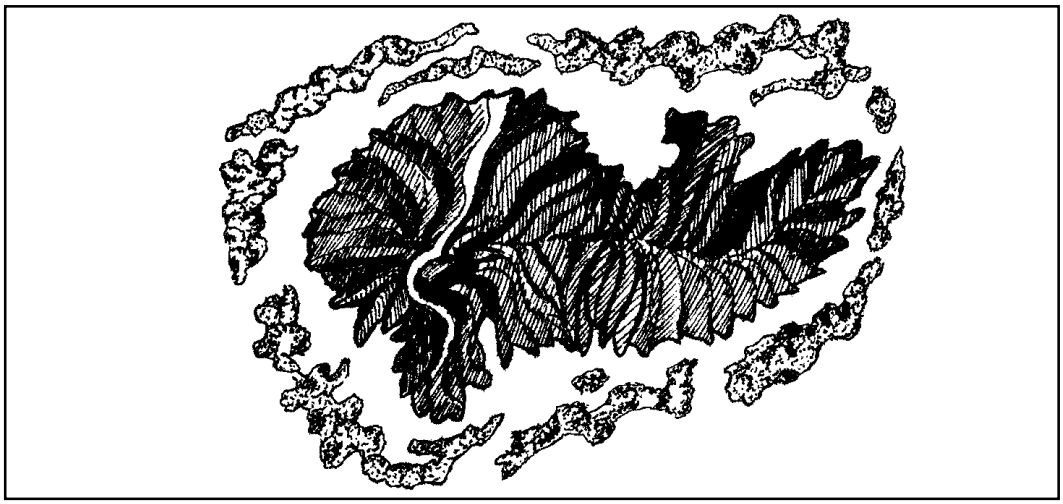
If the island continues to sink slowly enough beneath the surface of the water, coral growth is able to keep pace and the reef survives as an atoll (Figure 1-9c). Rather than being a closed ring, the atoll usually consists of numerous tiny islands separated by channels. These channels allow for water exchange between the open sea and the lagoon.

Atolls are found in deep, clear water throughout remote areas of the Indo-Pacific region. Located in the Marshall Islands in the Pacific, **Kwajalein**, the world's largest atoll, is almost 80 miles long (129km).

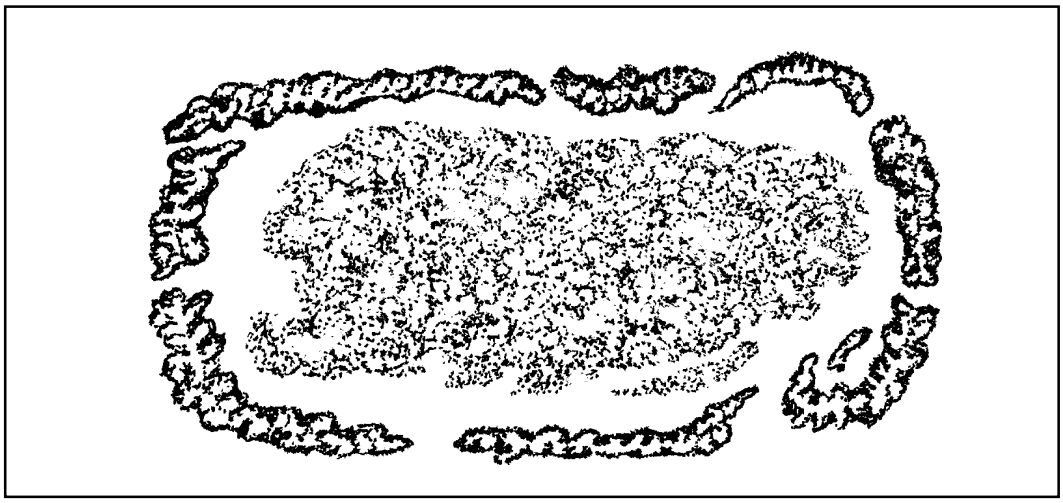
DID YOU KNOW? Darwin's theory of atoll formation was very controversial in his time. Most people did not believe that land could sink. They did not understand, as we do today, that the Earth is a dynamic mass, constantly moving and changing its form.



(a) Fringing reef



(b) Barrier reef



(c) Atoll

Figure 1-9. Types of coral reefs: (a) fringing reef, (b) barrier reef, and (c) atoll. The dotted areas represent coral. (Illustrations: George Mauro)