Corals and Coral Reefs

by the Smithsonian Ocean Portal
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Online at http://ocean.si.edu/corals-and-coral-reefs

Corals, sponges and seaweeds cover most of the surface of many coral reefs. Credit: Wolcott Henry

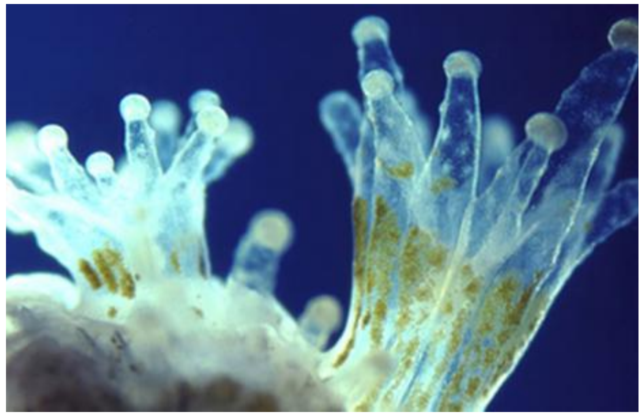
Coral reefs are the most diverse of all marine ecosystems. They teem with life, with perhaps one quarter of all ocean species depending on reefs for food and shelter. This is a remarkable statistic when you consider that reefs cover just a tiny fraction (less than one percent) of the earth's surface and less than two percent of the ocean bottom. Because they are so diverse, coral reefs are often called the rainforests of the sea.

Coral reefs are also very important to people. The value of coral reefs has been estimated at 30 billion U.S. dollars and perhaps as much as 172 billion U.S. dollars each year, providing food, protection of shorelines, jobs based on tourism, and even medicines.

Unfortunately, people also pose the greatest threat to coral reefs. Overfishing and destructive fishing, pollution, warming, changing ocean chemistry, and invasive species are all taking a huge toll. In some places, reefs have been entirely destroyed, and in many places reefs today are a pale shadow of what they once were.

What are Corals?

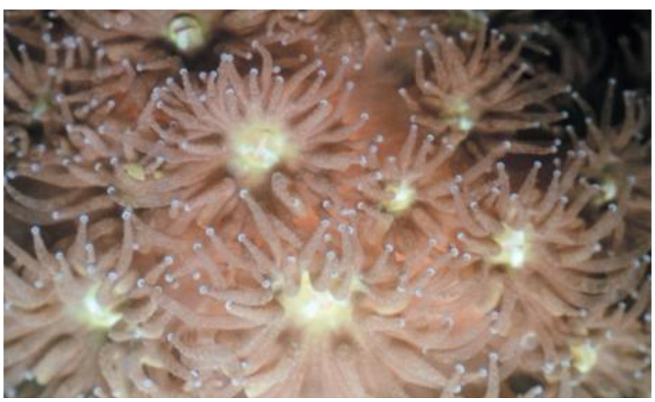
Animal, Vegetable & Mineral


The brownish-green specks are the zooxanthellae that most shallow, warm-water corals depend on for much of their food. Credit: © osf.co.uk.

Corals are related to sea anemones, and they all share the same simple structure, the polyp. The polyp is like a tin can open at just one end: the open end has a mouth surrounded by a ring of tentacles. The tentacles have stinging cells, called nematocysts, that allow the coral polyp to capture small organisms that swim too close. Inside the body of the polyp are digestive and reproductive tissues. Corals differ from sea anemones in their production of a mineral skeleton.

Shallow water corals that live in warm water often have another source of food, the zooxanthellae (pronounced zo-o-zan-THELL-ee). These single-celled algae photosynthesize and pass some of the food they make from the sun's energy to their hosts, and in exchange the coral animal gives nutrients to the algae. It is this relationship that allows shallow water corals to grow fast enough to build the enormous structures we call reefs. The zooxanthellae also provide much of the color that corals have.

Coral Diversity


Flower-like clusters of pink polyps make up this coral colony. Credit: Dr. James P. McVey, NOAA Sea Grant Program

In the so-called true stony corals, which compose most tropical reefs, each polyp sits in a cup made of calcium carbonate. Stony corals are the most important reef builders, but organpipe corals, precious red corals, and blue corals also have stony skeletons. There are also corals that use more flexible materials or tiny stiff rods to build their skeletons—the seafans and sea rods, the rubbery soft corals, and the black corals.

The family tree of the animals we call corals is complicated, and some groups are more closely related to each other than are others. All but the fire corals (named for their strong sting) are anthozoans**,** which are divided into two main groups. The hexacorals (including the true stony corals and black corals, as well as the sea anemones) have smooth tentacles, often in multiples of six, and the octocorals (soft corals, seafans, organpipe corals and blue corals) have eight tentacles, each of which has tiny branches running along the sides. All corals are in the phylum Cnidaria, the same as jellyfish.

Reproduction

Corals have multiple reproductive strategies – they can be male or female or both, and can reproduce either asexually or sexually. Asexual reproduction is important for increasing the size of the colony, and sexual reproduction increases genetic diversity and starts new colonies that can be far from the parents.

ASEXUAL REPRODUCTION

A purple hard coral releases bundles of pink eggs glued together with sperm. Credit: Chuck Savall

Asexual reproduction results in polyps or colonies that are clones of each other - this can occur through either budding or fragmentation. Budding is when a coral polyp reaches a certain size and divides, producing a genetically identical new polyp. Corals do this throughout their lifetime. Sometimes a part of a colony breaks off and forms a new colony. This is called fragmentation, which can occur as a result of a disturbance such as a storm or being hit by fishing equipment.

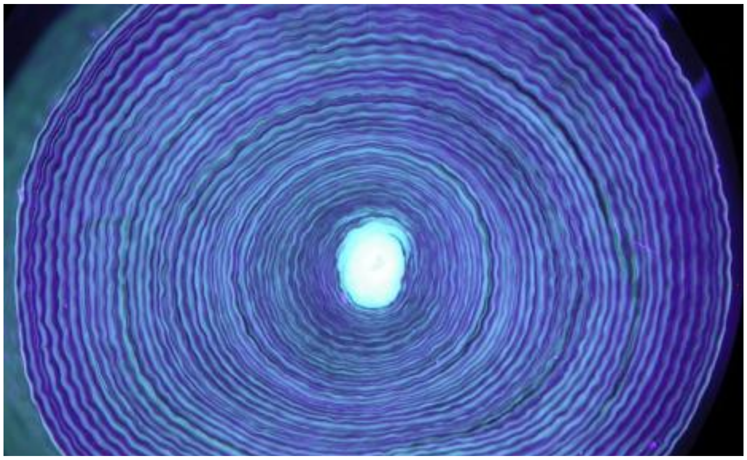
SEXUAL REPRODUCTION

In sexual reproduction, eggs are fertilized by sperm, usually from another colony, and develop into a free-swimming larva. There are two types of sexual reproduction in corals, external and internal. Depending on the species and type of fertilization, the larvae settle on a suitable substrate and become polyps after a few days or weeks, although some can settle within a few hours!

Most stony corals are broadcast spawners and fertilization occurs outside the body (external fertilization). Colonies release huge numbers of eggs and sperm that are often glued into bundles (one bundle per polyp) that float towards the surface. Spawning often occurs just once a year and in some places is synchronized for all individuals of the same species in an area. This type of mass spawning usually occurs at night and is quite a spectacle. Some corals brood their eggs in the body of the polyp and release sperm into the water. As the sperm sink, polyps containing eggs take them in and fertilization occurs inside the body (internal fertilization). Brooders often reproduce several times a year on a lunar cycle.

From Corals to Reefs

Coral Growth



Ultraviolet light illuminates growth rings in a cross-section of 44-year-old Primnoa resedaeformis coral found about 400 m (1,312 ft) deep off the coast of Newfoundland. Credit: Owen Sherwood

Individual coral polyps within a reef are typically very small—usually less than half an inch (or ~1.5 cm) in diameter. The largest polyps are found in mushroom corals, which can be more than 5 inches across. But because corals are colonial, the size of a colony can be much larger: big mounds can be the size of a small car, and a single branching colony can cover an entire reef.

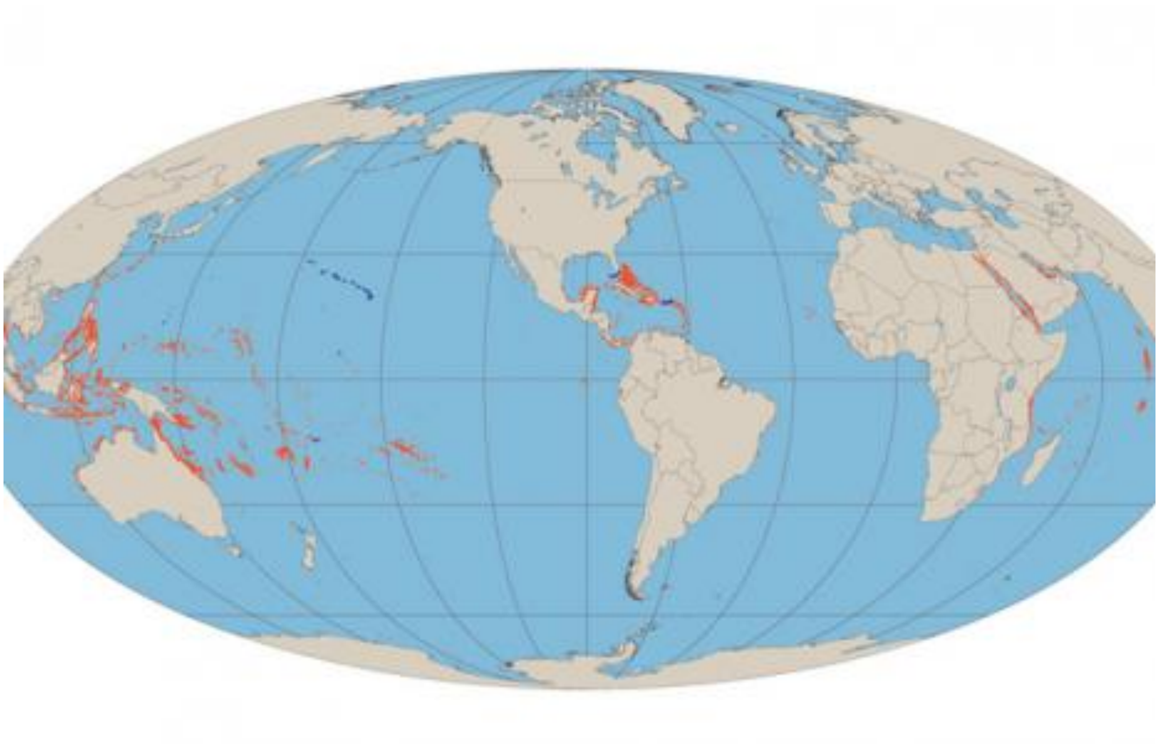
Reefs, which are usually made up of many colonies, are much bigger still. The largest coral reef is the Great Barrier Reef, which spans 1,600 miles (2,600 km) off the east coast of Australia. It is so large that it can be seen from space!

It takes a long time to grow a big coral colony or a coral reef, because each coral grows slowly. The fastest corals expand at more than 6 inches (15 cm) per year, but most grow less than an inch per year. Reefs themselves grow even more slowly because after the corals die, they break into smaller pieces and become compacted. Individual colonies can often live decades to centuries, and some deep-sea colonies have lived more than 4000 years. One way we know this is because corals lay down annual rings, just as trees do. These skeletons can tell us about what conditions were like hundreds or thousands of years ago. The Great Barrier Reef as it exists today began growing about 20,000 years ago.

Where Are Reefs Found?

Corals are found across the world's ocean, in both shallow and deep water, but reef-building corals are only found in shallow tropical and subtropical waters. This is because the algae found in their tissues need light for photosynthesis and they prefer water temperatures between 70-85°F (22-29°C).

There are also deep-sea corals that thrive in cold, dark water at depths of up to 20,000 feet (6,000 m). Both stony corals and soft corals can be found in the deep sea. Deep-sea corals do not have the same algae and do not need sunlight or warm water to survive, but they also grow very slowly. One place to find them is on underwater peaks called seamounts.



Shallow water coral reefs straddle the equator worldwide, shown here in red. Credit: ©UNEP World Conservation Monitoring Centre

Reefs as Ecosystems

Scientists have been studying why populations of crown-of-thorns sea stars (Acanthaster planci) have mushroomed in recent decades. Coral reefs can suffer when the sea star's numbers explode; the echinoderm has a healthy appetite and few predators. Credit:

Reefs are the big cities of the sea. They exist because the growth of corals matches or exceeds the death of corals – think of it as a race between the construction cranes (new coral skeleton) and the wrecking balls (the organisms that kill coral and chew their skeletons into sand).

When corals are babies floating in the plankton, they can be eaten by many animals. They are less tasty once they settle down and secrete a skeleton, but some fish, worms, snails and sea stars prey on adult corals. Crown-of-thorns sea stars are particularly voracious predators in many parts of the Pacific Ocean. Population explosions of these predators can result in a reef being covered with tens of thousands of these starfish, with most of the coral killed in less than a year.

Corals also have to worry about competitors. They use the same nematocysts that catch their food to sting other encroaching corals and keep them at bay. Seaweeds are a particularly dangerous competitor, as they typically grow much faster than corals and may contain nasty chemicals that injure the coral as well.

Corals do not have to only rely on themselves for their defenses because mutualisms (beneficial relationships) abound on coral reefs. The partnership between corals and their zooxanthellae is one of many examples of symbiosis, where different species live together and help each other. Some coral colonies have crabs and shrimps that live within their branches and defend their home against coral predators with their pincers. One kind of goby chews up a particularly nasty seaweed, and even benefits by becoming more poisonous itself.

These corals in the Gulf of Mexico are bleached as the result of increased water temperatures. Credit: Emma Hickerson/NOAA

Conservation

GLOBAL THREATS

The greatest threats to reefs are rising water temperatures and ocean acidification linked to rising carbon dioxide levels. High water temperatures cause corals to lose the microscopic algae that produce the food corals need—a condition known as coral bleaching. Severe or prolonged bleaching can kill coral colonies or leave them vulnerable to other threats. Meanwhile, ocean acidification means more acidic seawater, which makes it more difficult for corals to build their calcium carbonate skeletons. And if acidification gets severe enough, it could even break apart the existing skeletons that already provide the structure for reefs.

LOCAL THREATS

Unfortunately, warming and more acid seas are not the only threats to coral reefs. Overfishing and overharvesting of corals also disrupt reef ecosystems. If care is not taken, boat anchors and divers can scar reefs. Invasive species can also threaten coral reefs. The lionfish, native to Indo-Pacific waters, has a fast-growing population in waters of the Atlantic Ocean. With such large numbers the fish could greatly impact coral reef ecosystems through consumption of, and competition with, native coral reef animals.

Even activities that take place far from reefs can have an impact. Runoff from lawns, sewage, cities, and farms feeds algae that can overwhelm reefs. Deforestation hastens soil erosion, which clouds water—smothering corals.

Coral Bleaching


Compare the healthy coral on the left with the bleached coral on the right. Credit: Wolcott Henry

"Coral bleaching" occurs when coral polyps lose their symbiotic algae, the zooxanthellae. Without their zooxanthellae, the living tissues are nearly transparent, and you can see right through to the stony skeleton, which is white, hence the name coral bleaching. Many different kinds of stressors can cause coral bleaching – water that is too cold or too hot, too much or too little light, or the dilution of seawater by lots of fresh water can all cause coral bleaching. The biggest cause of bleaching today has been rising temperatures caused by global warming. Temperatures more than 2 degrees F (or 1 degree C) above the normal seasonal maximimum can cause bleaching. Bleached corals do not die right away, but if temperatures are very hot or are too warm for a long time, corals either die from starvation or disease. In 1998, 80 percent of the corals in the Indian Ocean bleached and 20 percent died.

Protecting Coral Reefs

There is much that we can do locally to protect coral reefs, by making sure there is a healthy fish community and that the water surrounding the reefs is clean. Well-protected reefs today typically have much healthier coral populations, and are more resilient (better able to recover from natural disasters such as typhoons and hurricanes).

Fish play important roles on coral reefs, particularly the fish that eat seaweeds and keep them from smothering corals, which grow more slowly than the seaweeds. Fish also eat the predators of corals, such as crown of thorns starfish. Marine protected areas (MPAs) are an important tool for keeping reefs healthy. Large MPAs protect the Great Barrier Reef and the Northwestern Hawaiian Islands, for example, and in June 2012, Australia created the largest marine reserve network in the world. Smaller ones, managed by local communities, have been very successful in developing countries.

A bluefin trevally swims in Hawaii's Maro Coral Reef, part of the Papahānaumokuākea Marine National Monument. Credit: ©James D. Watt

Clean water is also important. Erosion on land causes rivers to dump mud on reefs, smothering and killing corals. Seawater with too many nutrients speeds up the growth of seaweeds and increases the food for predators of corals when they are developing as larvae in the plankton. Clean water depends on careful use of the land, avoiding too many fertilizers and erosion caused by deforestation and certain construction practices. In the long run, however, the future of coral reefs will depend on reducing carbon dioxide in the atmosphere, which is increasing rapidly due to burning of fossil fuels. Carbon dioxide is both warming the ocean, resulting in coral bleaching, and changing the chemistry of the ocean, causing ocean acidification. Both making it harder for corals to build their skeletons.

Corals at the Smithsonian

Collections

A few corals are part of this small sampling of the approximately 35 million species represented in the invertebrate zoology collection housed at the National Museum of Natural History. Credit: Chip Clark/Smithsonian Institution

The coral collection housed at the National Museum of Natural History may be the largest and best documented in the world. Its jewel is a collection of shallow-water corals from the U.S. South Seas Exploring Expedition of 1838-1842—one of the largest voyages of discovery in the history of Western exploration. The expedition brought back many unknown specimens that scientists used to name and describe almost all Pacific reef corals. These are known as type specimens in the collection. Altogether, the collection includes specimens of about 4,820 species of corals, and about 65 percent of those species live in deep water.

Research

Carrie Bow Cay Field Station

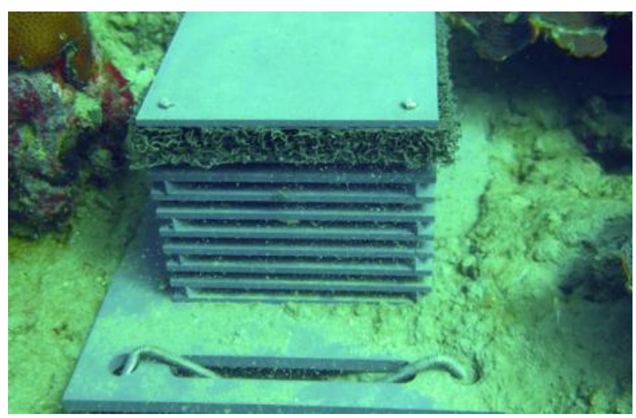
In the late 1960s, several Smithsonian scientists set themselves an ambitious goal: understanding the inner workings of Caribbean coral reefs. To study this complex ecosystem, they needed a field station where they could conduct research in one location, from multiple disciplines, over a long period of time.


The sun sets over the Smithsonian's marine field station at Carrie Bow Cay, Belize. Credit: Chip Clark/Smithsonian Institution

In 1972 they came across a tiny island with three shuttered buildings. It was near all the major habitats and isolated enough to permit study of the coral reef's natural dynamics. It was the perfect spot. More than three decades later, Carrie Bow Cay in Belize is still home to the Caribbean Coral Reef Ecosystem Program. Scientists and students from around the world continue to survey the area's reefs, seagrass beds, and mangroves; discover new species; and pioneer new research techniques. Check out this video of Smithsonian scientists monitoring Acroporid populations near Carrie Bow.

The ARMS Project

It's not very colorful. And it's not made of coral. But by mimicking the nooks and crannies of real coral reefs, this Autonomous Reef Monitoring Structure (ARMS) attracts crabs, shrimps, worms, urchins, sponges, and many other kinds of marine invertebrates.


The Autonomous Reef Monitoring Structure was developed to help scientists study coral reef diversity and have now been adopted broadly to study diversity around the world. Credit: Laetitia Plaisance

Researchers from the Census of Marine Life's CReefs Initiative set up these temporary plastic "apartment houses" near coral reefs to learn more about the diversity of reef species. They leave the structures underwater for about a year. Then they retrieve the ARMS and analyze what life forms have taken up residence. CReefs researchers have deployed hundreds of ARMS around the world in places like Hawaii, Australia, Moorea, Taiwan, and Panama in order to compare biodiversity among different, and often distant, reefs.

Smithsonian Scientists

Credit: Christian Ziegler

Dr. Nancy Knowlton

Coral reef biologist Dr. Nancy Knowlton is leading the Smithsonian's effort to increase public understanding of the world's ocean. She has studied the ecology and evolution of coral reefs for many years and is deeply concerned about their future. "During the three decades I've been studying coral reefs in the Caribbean, we've lost 80% of the reefs there," she says. But she remains hopeful. "You have to make people realize that the situation is incredibly serious, but that there's something they can do."

Besides holding the Smithsonian's Sant Chair for Marine Science, Dr. Knowlton currently serves on the Pew Marine Fellows Advisory Committee, the Sloan Research Fellowship in Ocean Sciences committee, and the national board the Coral Reef Alliance. She is an Aldo Leopold Leadership Fellow, winner of the Peter Benchley Prize and the Heinz Award, and author of Citizens of the Sea.

Dr. Stephen Cairns

Credit: Margaret Cairns

When he was 10 years old, Stephen Cairns lived in Cuba and collected sea shells. That's when he decided to become a marine scientist. Today he is a research zoologist at the Smithsonian's National Museum of Natural History, focusing on the diversity, distribution, and evolution of deep-water corals—both fossil and living. Deep-water corals live up to 4 miles deep in cold, dark waters. So Dr. Cairns conducts much of his field work on oceangoing research vessels and in deep-sea submersibles. Dr. Cairns has published about 150 papers and books, in which he has described more than 400 new species of deep-water corals. He assures us there are still many more to be discovered.