Coral Reefs in Latin America
Coral Reefs: Definitions

The primary criteria for classification as a reef are:
1) It is constructed of material of biological origin, mostly calcium carbonate.
2) It is a rigid structure due to interlocked and in-place framework elements.
3) It stands topographically above the surrounding seafloor and exerts some control on local oceanographic processes.

http://cima.uprm.edu
Importance of Coral Reefs

- High Economic Value, $1.6 billion to the economy of Florida. Up to half of the GDP of some countries is supported by coral reefs
- Storm Protection
- Biodiversity
Conditions for modern reef development:

Modern reefs are highly dependent on the requirements of the main reef builders, *scleractinian corals* and *calcareous algae*, as follows:

1) **Water must be warm, shallow, and of normal salinity:**
   - shallow water (<100m): within the local photic zone. Both calcareous algae, and the zooxanthellae which live symbiotically within scleractinian corals, depend on light for photosynthesis
   - warm water (18 to 36°C; optimum 25 to 29°C) is required for the growth of hermatypic (reef-forming) scleractinian corals
   - normal marine salinity (22- 40 parts per thousand).

2) **Bottom must be firm and not too much mud in the water**
   - low terrigenous clastic (mud and sand) input: some reef-building organisms are killed by sand and mud.
   - stable and firm seafloor is needed for reef builders to attach
Corals are animals!
The individual polyp is an invertebrate of the phylum *Cnidaria*.
The body is soft and tubular, with an oral opening surrounded by six (or multiples of six) tentacles. At night, these extend to trap plankton. The body wall consists of three layers, the innermost of which (gastrodermis) contains zooxanthellae.
Zooxanthellae

symbiotic photosynthetic single-celled algae
• Contained within the coral gastrodermal cells
• Use photosynthesis to create food for the coral host

Symbiotic relationship between coral (animal) and zooxanthellae (plant)

From coral:
- Nutrients,
- Carbon dioxide
- Shelter

From zooxanthellae:
- Lipids, sugars, and O₂

Nitrogen and phosphorous derived from captured plankton are shared between symbiont (zooxanthellae) and host (coral).
Scleractinian Corals

- Hard corals or stony corals
- Secrete calcium carbonate (CaCO₃)
- Most important group of organisms on a reef, because Scleractinian corals are reef building (= hermatypic).
- Contain zooxanthellae.
Reef activity is concentrated in the Photic Zone

• The 'photic zone' is the uppermost part of the ocean, it reaches a maximum of 200 meters in the open sea, to which sunlight penetrates. This determines the depth to which photosynthesis can occur.

• Scleractinian corals cannot grow - and reefs cannot form - if zooxanthellae cannot survive.
Precipitation of Calcium Carbonate by Corals (1)

The ocean is saturated with the three major polymorphs of CaCO$_3$ (aragonite, calcite and magnesian-calcite). Yet, CaCO$_3$ rarely precipitates spontaneously in seawater. As a result, biologically mediated CaCO$_3$ precipitation by corals is the most important contributor to building reefs. Coral polyps absorb calcium ions from seawater and move them to the site of calcification, where they are deposited as aragonite.
Aragonite

Orthorhombic CaCO$_3$

Crystal of twinned Aragonite from Spain

SEM image of Aragonite.
Precipitation of Calcium Carbonate by Corals (2)

Calcium carbonate formation is described by the formula:
\[ \text{Ca}^{+2} + 2\text{HCO}_3^- \leftrightarrow \text{CaCO}_3 + \text{CO}_2 + \text{H}_2\text{O} \]

\((\text{HCO}_3^- = \text{bicarbonate ion})\)

The production rate of aragonite is thus related to the abundance of \(\text{Ca}^{+2} + \text{HCO}_3^-\) in the water. The addition of \(\text{CO}_2\) to water yields bicarbonate through the following process:
\[ \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- + \text{Ca}^{+2} \]

\((\text{H}_2\text{CO}_3 = \text{carbonic acid})\)

Free \(\text{H}^+\) lowers the pH (i.e. makes the solution acidic). Calcium carbonate dissolves in weak acid, so unless the excess \(\text{H}^+\) is removed, no aragonite can precipitate. Stony corals remove excess \(\text{H}^+\) from seawater and allows aragonite to precipitate.
Alcyonarian Corals

- Soft corals
- Internal skeleton
- Large and feathery
- Not reef building
- Rely more on suspension feeding
Calcareous Algae
As important as corals in reef and beach building.
Distribution is similar to that of coral.
Approximately 30 marine species
Early coloniser of tropical habitats, succeeded by sea-grasses
Accounts for a significant amount of CaCO₃ deposits.
Produces up to 50% of all tropical beach sand
Highly productive

Udotea
Halimeda
Distribution of Reefs

- Defined by environmental requirements:
  - Light
  - Clear water (areas poor in nutrients)
  - Warm constant temperature water, > 20 °C
  - Low turbidity (not off Amazon and Orinoco)
- Thus, limited to within 30° North and South of equator
Temperature Control

20°C = 68°F
Global distribution of Coral Reefs

Note that most of the reefs in Latin America are in the Caribbean and Greater Antilles, well north of the equator! Why?
Maximum biodiversity is found in the Western Pacific and Indian oceans. Biodiversity of hard corals is much less in the Atlantic (and Caribbean) than in the Pacific. 75% more genera and 85% more species in the Pacific compared to Caribbean. Why is Biodiversity so low in Latin American reefs?
Figure 7.7a. Morphological expression of the major reef types
Fringing Reef
Barrier Reef
Radar image of Bora-bora barrier reef
Great Barrier Reef, Australia

Most famous reef on Earth. GBR extends 2 000 kilometers and covers an area of 35 million hectares on the north-east continental shelf of Australia. BGR covers an area that is bigger than Italy.
• Seaward side: reef front and crest
  – Rise from depth to near the surface
  – Typically steep
  – Major surge area; waves determine species
  – Finger-like projections – spurs
• Back reef: beach and lagoon (reef flat)
  – Different assemblage of species than on seaward side
  – Coral rubble, sands, sea grass, patches of coral
  – Intertidal pools
• Position determines growth form
Growth forms of the coral *Pocillopora damicornis*
Coral forms

- Columnar
- Branching
- Solitary
Typical reef profile
A. Pal. = Acropora palmata
Discovery Bay
Jamaica

Reef flat

Reef crest

Reef front
Stick coral

Platy coral

Finger coral
Reef Front
A = coarse sediments  B = fine sediments
C = daily temperature variation  D = number of different species
(according to H. Schumacher 1967)
Evolution of Reefs and Formation of Atolls
Darwin’s sequence of Atoll formation

Stage 1
- 25 Km
- Volcanic Islands

Stage 2
- Bora Bora Atoll
- Volcanic Islands
- Coral Reefs

Stage 3
- Tupuai Atoll
- Lagoon without Volcanic Island
- Coral Reefs
- Raiatea & Tahaa Islands

First: fringing reef
Second: barrier reef
Third: Atoll
Caribbean Reefs

- About 14% of the area of the world's coral reefs are found here.
- Fringing and patch reefs are common around islands, on the side facing the prevailing winds (windward side).
- There is a long barrier reef system off Belize (approximately 220 kilometers) and the Andros barrier reef (approximately 176 kilometers) in the Bahamas.
Belize

- Territorial disputes between the UK and Guatemala delayed the independence of Belize (formerly British Honduras) until 1981. Guatemala refused to recognize the new nation until 1992. Tourism has become the mainstay of the economy.

- **Area:**
  - *total:* 22,966 sq km
  - slightly smaller than Massachusetts

- **Climate:**
  - tropical; very hot and humid; rainy season (May to November); dry season (February to May)

- **Elevation extremes:**
  - *lowest point:* Caribbean Sea 0 m
  - *highest point:* Victoria Peak 1,160 m

- **Geography - note:**
  - only country in Central America without a coastline on the Pacific

- **Population:**
  - 272,945

- **GDP - per capita:**
  - purchasing power parity - $4,900 (2002 est.)

- **Languages:**
  - English (official), Spanish, Mayan, Garifuna (Carib), Creole

The Belize Barrier Reef and the three offshore atolls [STS060-85-W, 1994].
Belize

• Bank or bank-barrier reefs are common. Atolls are also found.
Reefs of Greater & Lesser Antilles

- Reef development is often greater on the smaller, low islands with low rainfall and little sedimentary runoff such as Barbuda, Antigua, St. Croix, Grande Terre and the Southern Grenadines.

- The Greater Antilles (Cuba, Hispaniola and Puerto Rico) generally have larger reefs than the Lesser Antilles (Putney 1982).
Reefs of Florida and the Greater Antilles

Florida and Bahamas

Cuba
Reefs in the Western Atlantic Brazil

- The distribution of coral reefs in the South Atlantic is limited to tropical areas along the coastline and offshore islands of Brazil.
- According to UNEP/IUCN (1988) the Brazilian coral fauna has long been considered of interest on account of its high proportion of endemic species.
- Some 3,000 kilometers of coast have reefs. Ten of the 18 hermatypic coral species known from Brazil are endemic.

http://www.ramsar.org/w.n.brazil_coral_atlas.htm
Brazil Reefs

- Two main coral reef localities are found on the Brazilian coast.
  - *Grupo Recifal do Cabo São Roque*, from Cabo de São Roque to Natal in Rio Grande do Norte State, including the Fernando de Noronha archipelago and the Rocas atoll
  - Coral reefs along the south coast of Bahia State (the Abrolhos Archipelago), the richest and most developed coral reef formation in the region.
- Coral reefs also occur between Natal and the São Francisco river mouth and on the latitude of Salvador Bahia (both usually associated with calcareous reefs).
- The northeast coast formations are rocky calcareous outcappings forming reefs and hence differ from the coral reef formations such as those of the Abrolhos archipelago.
The Pacific Reefs

- Coral reefs of the Eastern Pacific are not nearly so extensive or diverse as those along the Atlantic coast of Central America and in the Caribbean.

- Coral formations have been described off the coasts of El Salvador, Costa Rica, Ecuador, Panama, Colombia, and many of the offshore islands (Glynn and Wellington 1983). The northern limit of distribution of coral reefs for the Eastern Pacific lies in the Gulf of California, with the southern limit at Machalilla in Ecuador and the Galápagos Islands (both at around 1° 30'S).

- In Central America, the upwelling of colder water inhibits reef development (UNEP/IUCN 1988).
Why so few reefs around South America?

Reefs are concentrated around the equator, but not in South America. Why?
Coral Reefs at Risk
Natural Threats

- Hurricanes & Typhoons
- Natural Predators
- Disease
- Sea-level rise and fall

Black band disease
Threats From Humans

• Over-fishing and poor fishing practices
• Sedimentation from development and mining
• Water pollution (runoff from above, poor waste removal, Oil spills)
• Careless eco-tourism, divers, boat anchor damage
• Global climate change (global warming, UV radiation)
Almost two-thirds of Caribbean reefs are threatened

- Reefs in the Caribbean are under severe threat.
- Problems include coastal erosion from dredging and construction, pollution from sewage and fertilizers, removal of large quantities of fish (including use of toxic and hazardous materials to flush out fish), and resulting changes in fish populations, as well as damage from boat anchors and recreational misuse (Wilson 1987).
- Bermuda’s reefs are severely affected by coral diseases, particularly Black Band disease.
Some Excellent websites for Coral reefs

http://cima.uprm.edu/~morelock/corgeol.htm
NASA just released a coral reef library - see
http://www.nasa.gov/vision/earth/lookingatearth/coralreef_image.html
And
http://www.reefbase.org/
Reefbase includes a GIS system so you can examine things interactively
http://earth.jsc.nasa.gov/newsletter/CoralReefs/
Astronaut photography of coral reefs