Coral Reef Ecology

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What is **ecology**?

- Study of organisms and their interactions with each other and their environments
  - The interaction of biotic and abiotic factors
  - Ecosystems

Why do we pursue the study of ecology?

- Preserve our natural resources
- Understand how human impacts affect:
  - The survival of species
  - The diversity of ecosystems
  - The balance of global cycles
- Because we are curious about how nature works!

Ecosystems are made up of Communities

- **Population**
  - Group of individuals of the same species residing in a defined habitat
- **Community**
  - Groups of populations residing in a defined habitat, interacting with one another

Evolution and ecology are linked through natural selection

- Populations are larger than environment can support
- Not all individuals in the population will survive
- Those that do survive must have advantages (in their genes!) over those that don't
- The survivors pass on their genes to the next generation

How do organisms survive in their environments?

re inherited trai

Biodiversity is important

- It is the number of different species and their abundance in a particular **community**
- Healthy communities have high **biodiversity**
  - Lots of species
  - High abundance of individual species

Which coral reef is healthier? Why?

How are coral reefs important to Hawaiian culture?

- They provide food
  - Fish
  - Invertebrates
  - Algae (*limu*)
- They provide materials
  - Coral for building
  - Algae for medicine (*limu kala*)
  - Shells for decoration and lure making
  - Shark teeth for weaponry
  - Whale bone/teeth worn by the Ali‘i

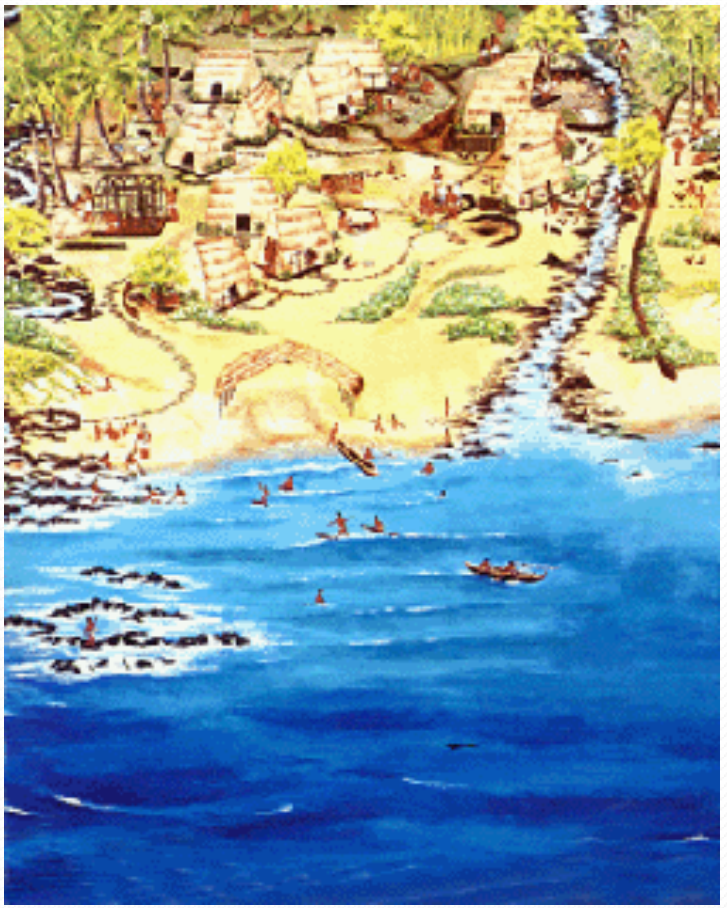
When space turned around, the earth heated
When space turned over, the sky reversed
When the sun appeared standing in shadows
To cause light to make bright the moon,
When the Pleiades are small eyes in the night,
From the source in the slime was the earth formed
From the source in the dark was darkness formed
From the source in the night was night formed
From the depths of the darkness, darkness so deep
Darkness of day, darkness of night
Of night alone
Did night give birth
Born was Kumulipo in the night, a male
Born was Po'ele in the night, a female
Born the coral polyp

Born of him a coral colony emerged....

pp. 3-4, Johnson, R.K., 1981. The Kumulipo: Hawaiian hymm of creation. Vol. 1. Topgallant Publishing Co., Ltd., Honolulu, Hawai'

Hawaiians were excellent ecologists!

- They maintained healthy ecosystems because they knew there was a balance to nature
- They knew they were not separate from nature
- If you care for nature, nature will take care of you!



Let's talk about corals and coral reefs

What is a reef building **coral**?

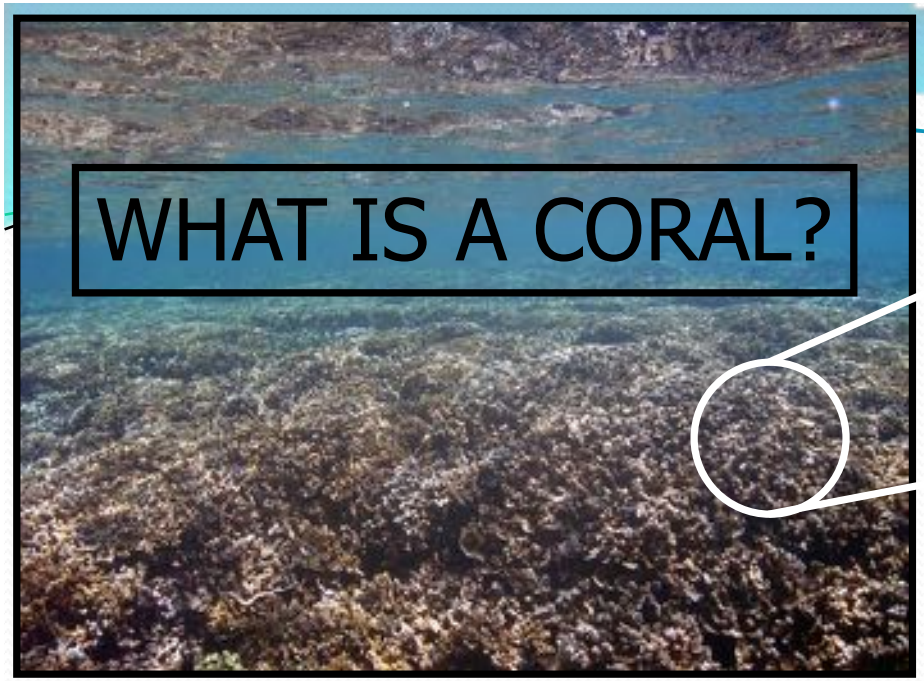
- Simple animal related to sea jellies and anemones
- Forms a symbiotic relationship with single celled alga called **zooxanthellae**
- Forms colonies
- Secretes calcium carbonate skeletons, the foundation of coral reef ecosystems

Where do reef building corals live?

- Shallow, clear, warm waters where their algal symbionts can photosynthesize

This is a coral colony, what do you notice?

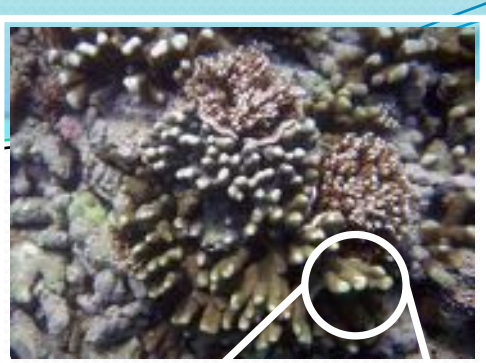
WHAT IS A CORAL?



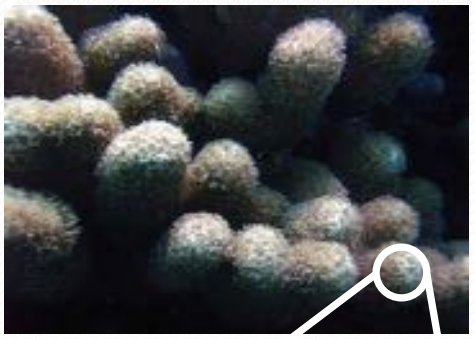
This is a typical Hawaiian reef

Coral is an ANIMAL that has a plant (ALGAE) living inside it's cells, and together they form the calcium carbonate (MINERAL) reef structure that is the foundation of the coral reef ecosystem

A closer look reveals separate colonies of coral on the reef



Each colony has many coral individuals, all of them identical clones within the colony

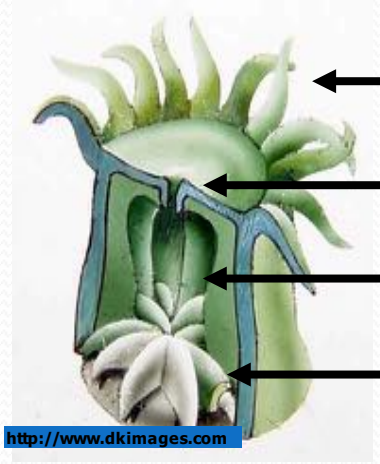


Each individual coral animal is called a polyp, the brown/green specs inside the polyp tissue are actually the symbiotic algae or zooxanthellae

CORAL FACTS

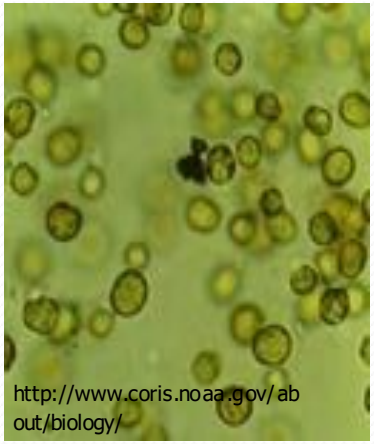
Reefs are living structures that can be seen from space!

Corals have a simple body plan



The algae/coral symbiosis allows these corals to grow massive reef structures, and is also why reefs are found in shallow (<300 feet), clear waters.

The Great Barrier Reef in Australia



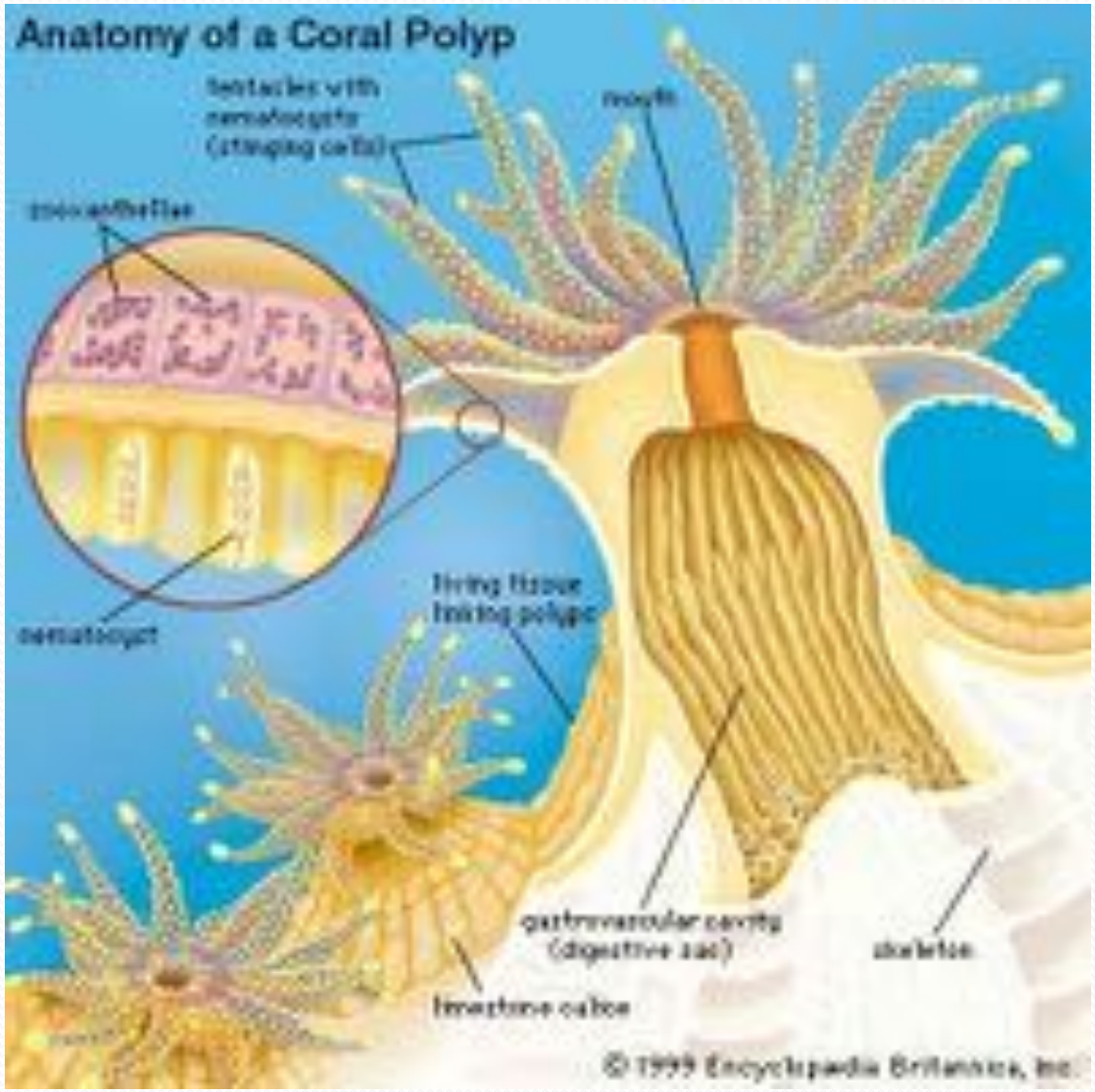
Zooxanthellae live inside the cells of reef building coral and through photosynthesis provide 95% of the corals metabolic needs.

Coral bleaching is a stress response by both the coral and the algae that results in a breakdown of their symbiotic partnership. If the algae do not return to high enough densities within the coral cells soon after the bleaching episode, the coral will die.

Coral Colonies

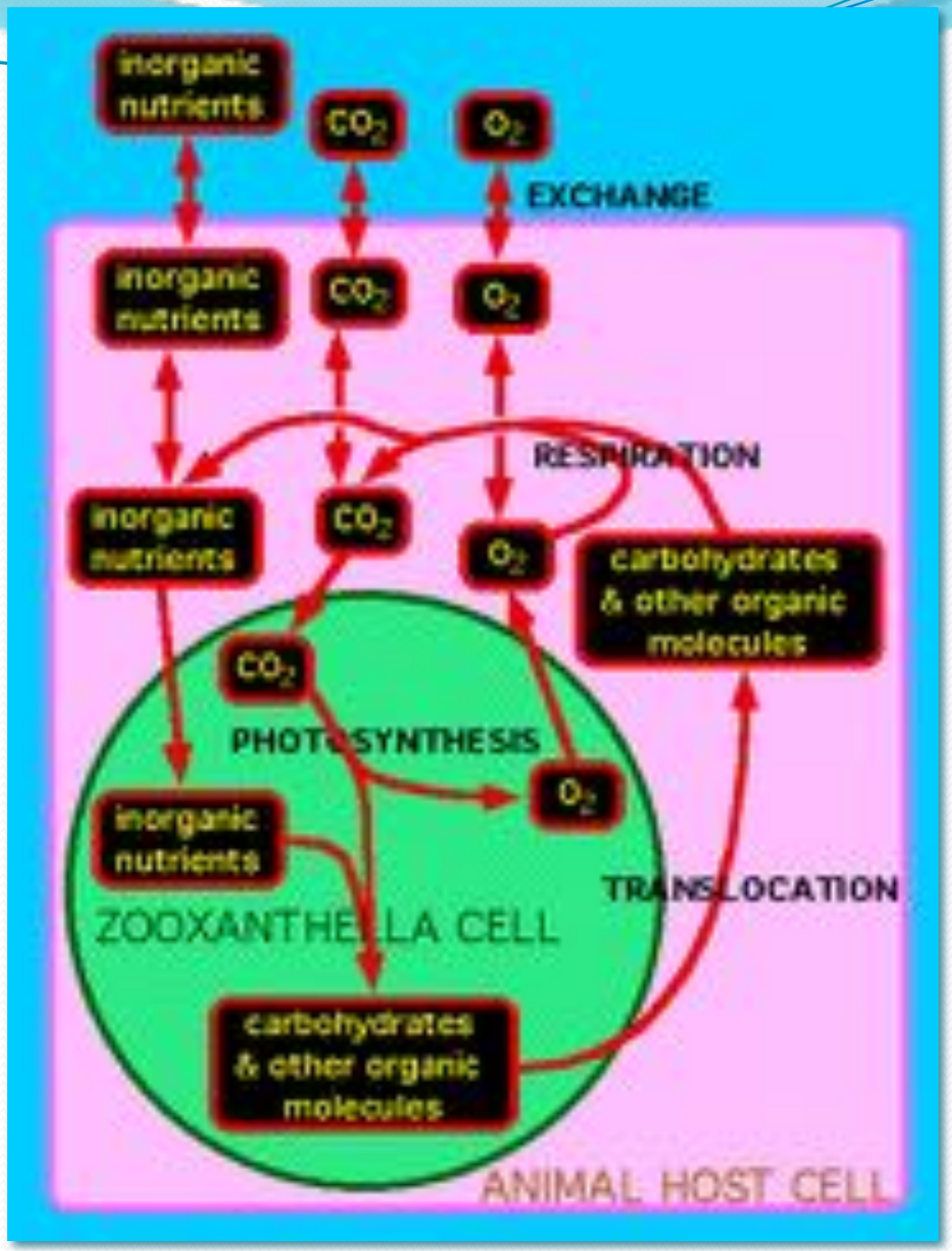
All polyps in one colony are genetically identical, which makes them *clones*.

Anatomy of coral polyp



The symbiosis

Corals give up nutrients (waste) to the algae and the algae give food and Oxygen to corals



Benefits to the Coral Host

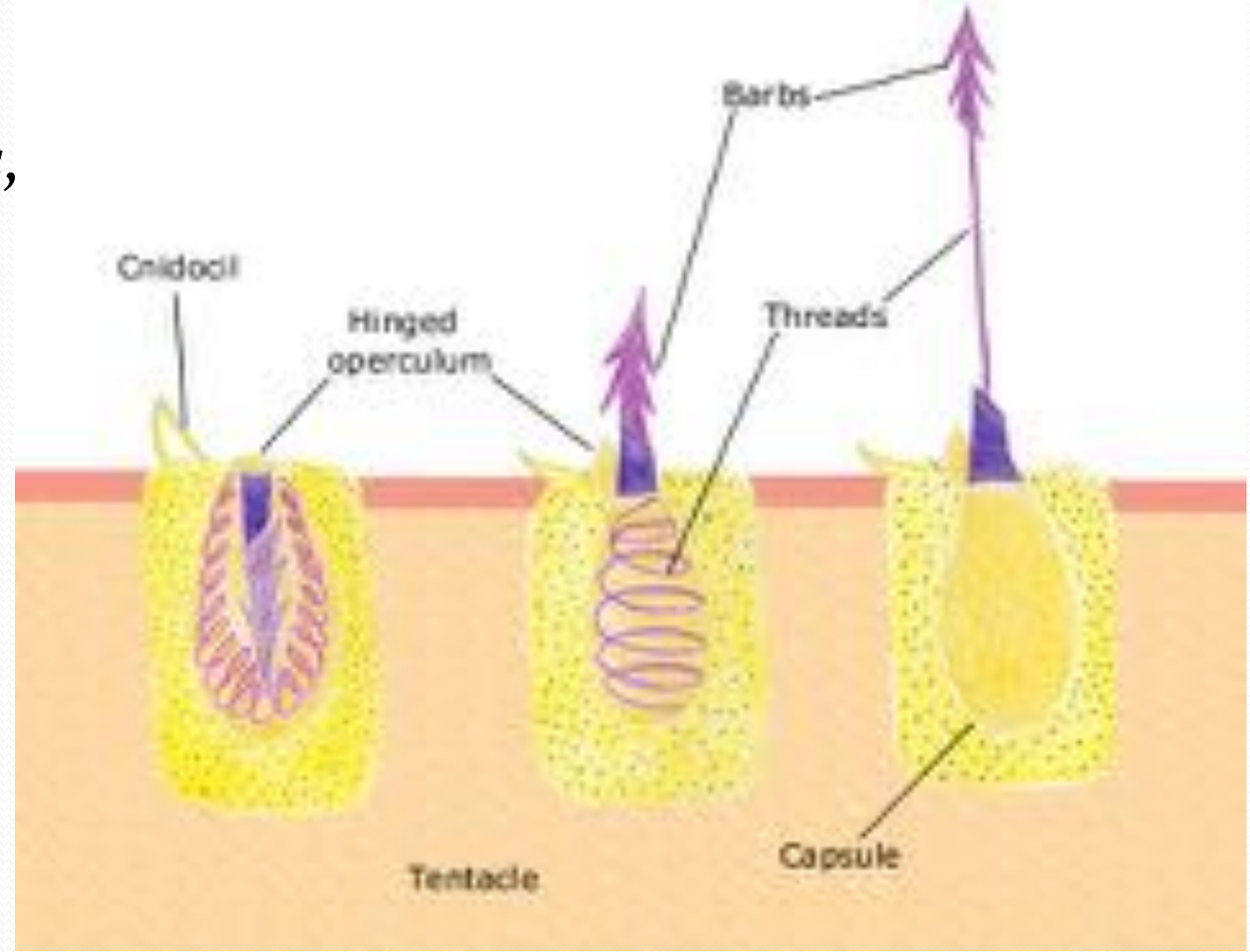
- Higher rates of calcification (skeleton deposition).
- Energy and materials for growth, repair, and reproduction.
- Removal of chemical wastes from animal metabolism (nutrient recycling).
- Receive chemicals that absorb damaging ultraviolet light.

Benefits to the Algal Symbiont

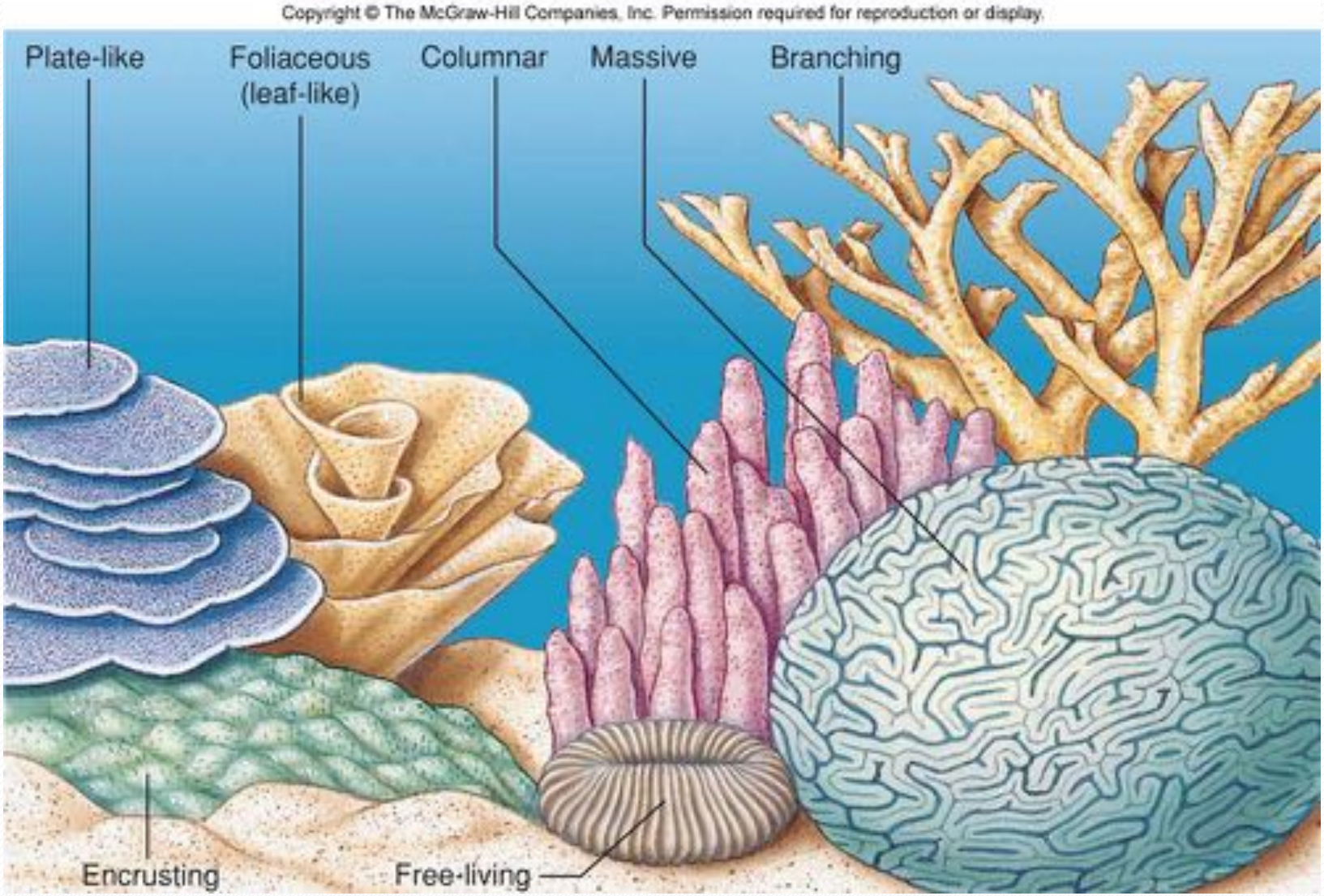
- Chemical wastes from animal metabolism are important inorganic nutrients for plants (nutrient recycling).
- Protection on the reef and from UV light.
- The zooxanthellae, non-motile single cells, get a place to live in the crowded reef environment.

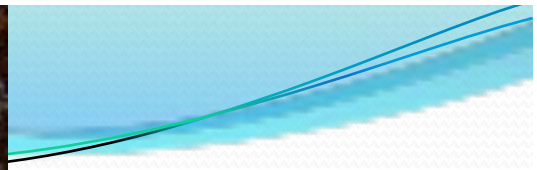
Coral Feeding: some reef building corals eat occasionally

Using ***nematocysts***, which are stinging cells on their tentacles



Coral colonies make different forms



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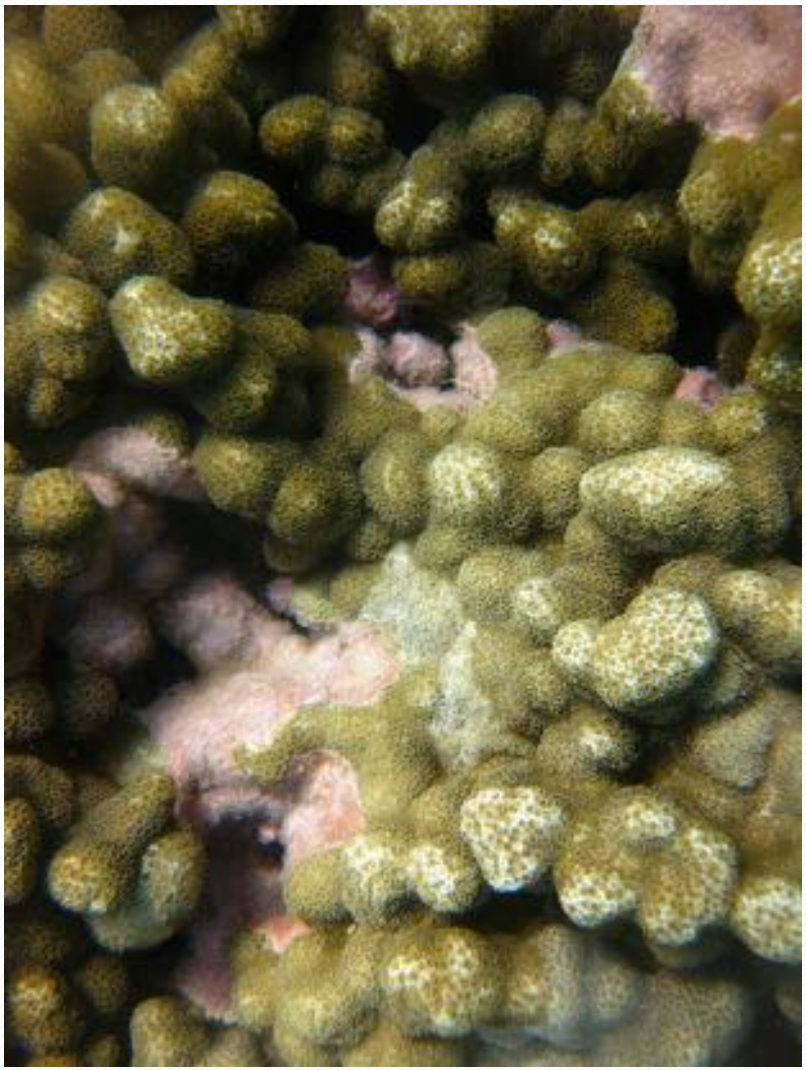
This is a Hawaiian reef community, what do you see?

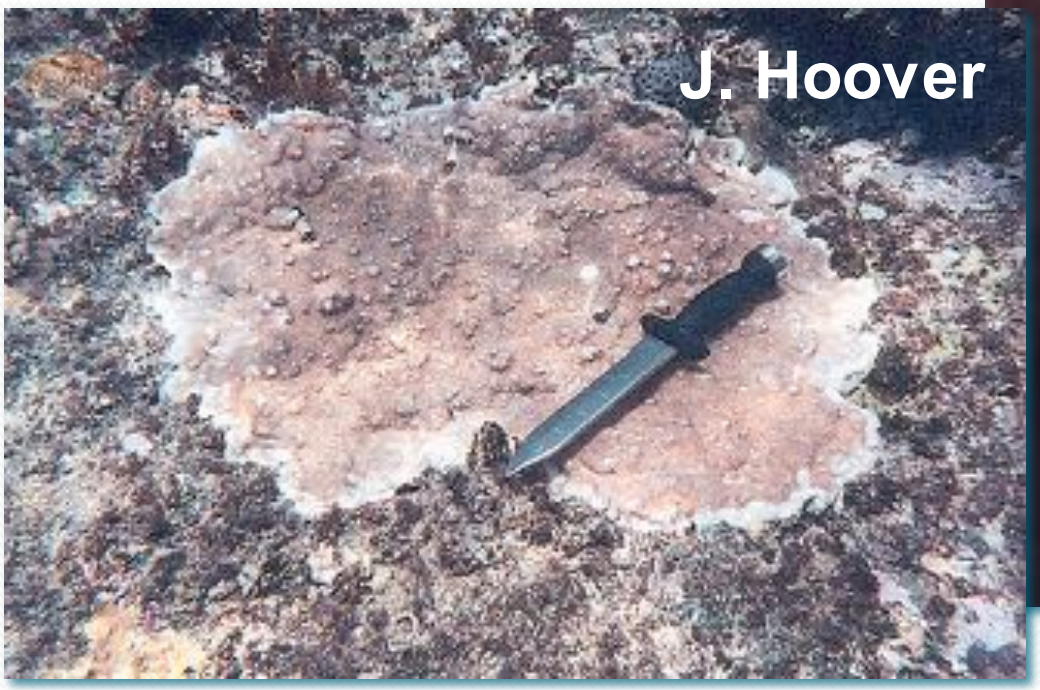
How does a coral reef grow?

- Reef Growth is a balance between **Construction** and **Erosion**
- **Construction Steps**:
  - **Framework** Building: corals
  - **Sediment** Production: algae, shells, protists
  - **Cementation**: encrusting coral and encrusting algae

Corals build the framework, sediment provides living space and food resources, and encrusting algae and corals cement the reef together



Encrusting coral also helps cement reef together



Erosion breaks down the reef

- **Mechanical**: storm events, waves, gravity
- **Biological**: animals that bore into or scrape the reef
- **Chemical**: with increasing acidity of ocean waters, the reefs could start to dissolve!

Mechanical erosion

- Storms
- Run off

Storm Wave Damage

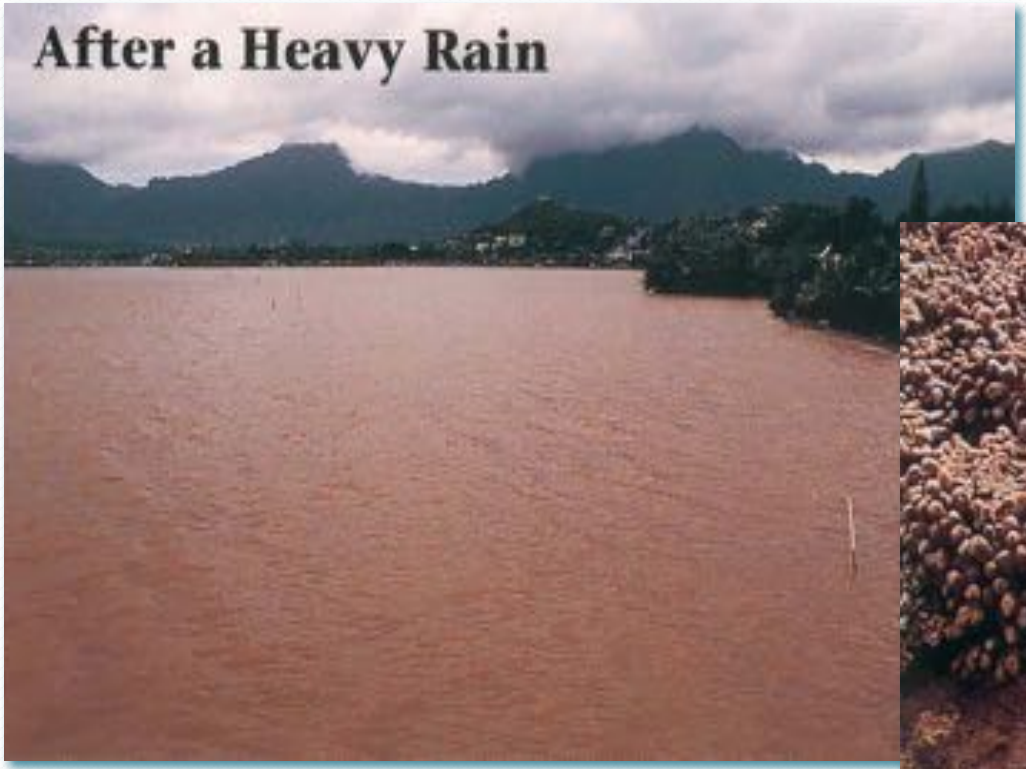
Before

After

Storm Damage

Stream and River Runoff increases nutrients and sediments in the water

Freshwater from heavy rains can damage corals



Bioerosion: Browsers

- Those who rasp or scrape the surface t material growing *on top of* coral.
- Invertebrates: Sponges and Urchins
- Parrotfish

Bioerosion: Grazers

- Those who consume plant material down to, and often including, the coral
- Corallivorous Fishes
- Crown-of-Thorns Seastar (Acanthaster)

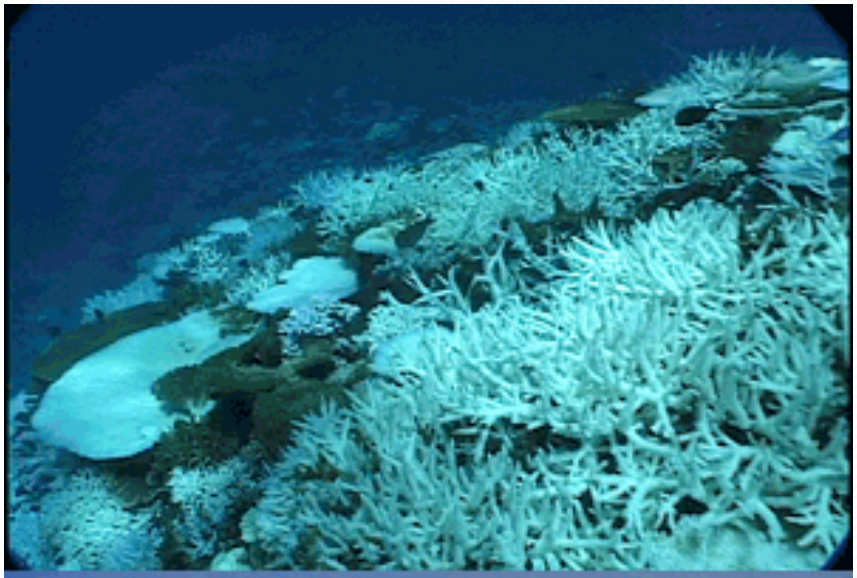
Chemical erosion

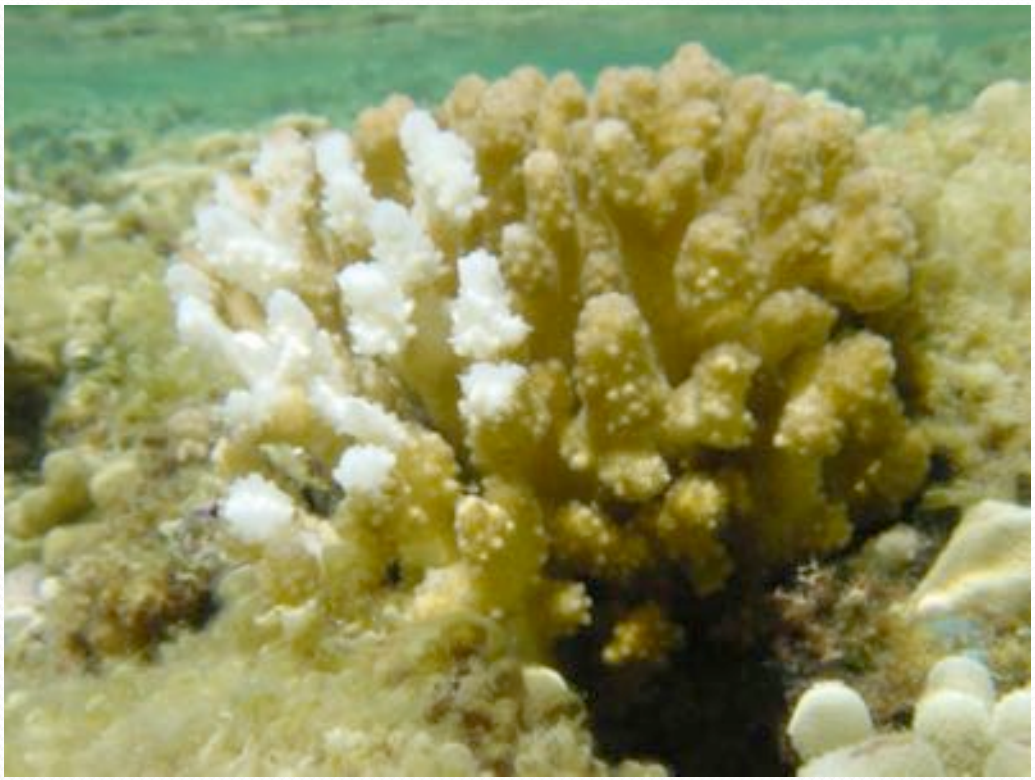
- Increasing ocean acidity can reduce the growth potential of reefs
- This can result in fragile reefs that more easily break during storm events
- Other calcifying organisms can sustain reduced growth and also be affected

Coral reef bleaching

- When corals loose their algal symbionts
- If they cannot regain their symbionts, the corals will die
- Stress causes bleaching, causes include:
  - High temperatures
  - Pollution
  - Sedimentation
  - Disease

Bleaching is when the algae leave the coral





Reef growth

- As long as construction outpaces erosion the reef will continue to grow
- What conditions promote optimal growth?

Factors Correlated with Healthy Coral Reef Growth

- Water Temperature Range: 18–29°C
- Normal Seawater Salinity: 32–35 ‰
- Low Inorganic Nutrient Concentration
- Clear, Transparent Water
- Little or No Sedimentation
- Vigorous Water Motion

Three types of oceanic reefs form under these conditions

Fringing

Barrier

Atolls

Types of Oceanic Reefs

Fringing Reefs

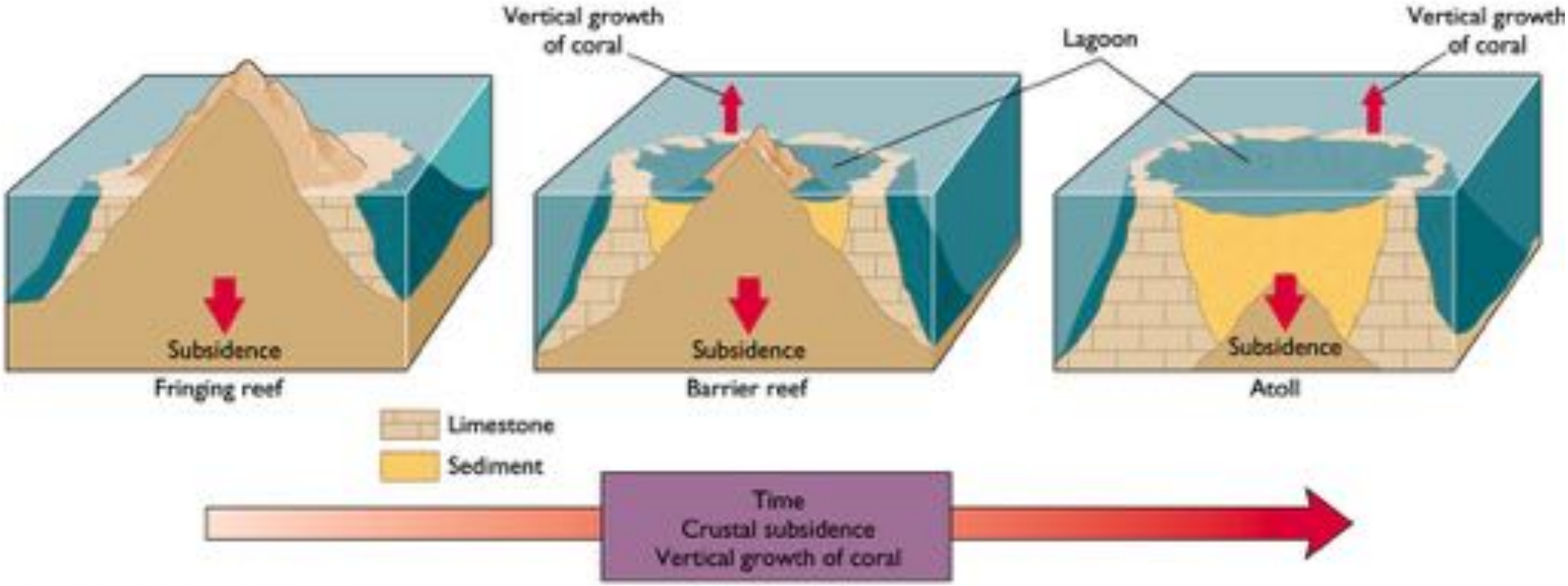
Types of Oceanic Reefs

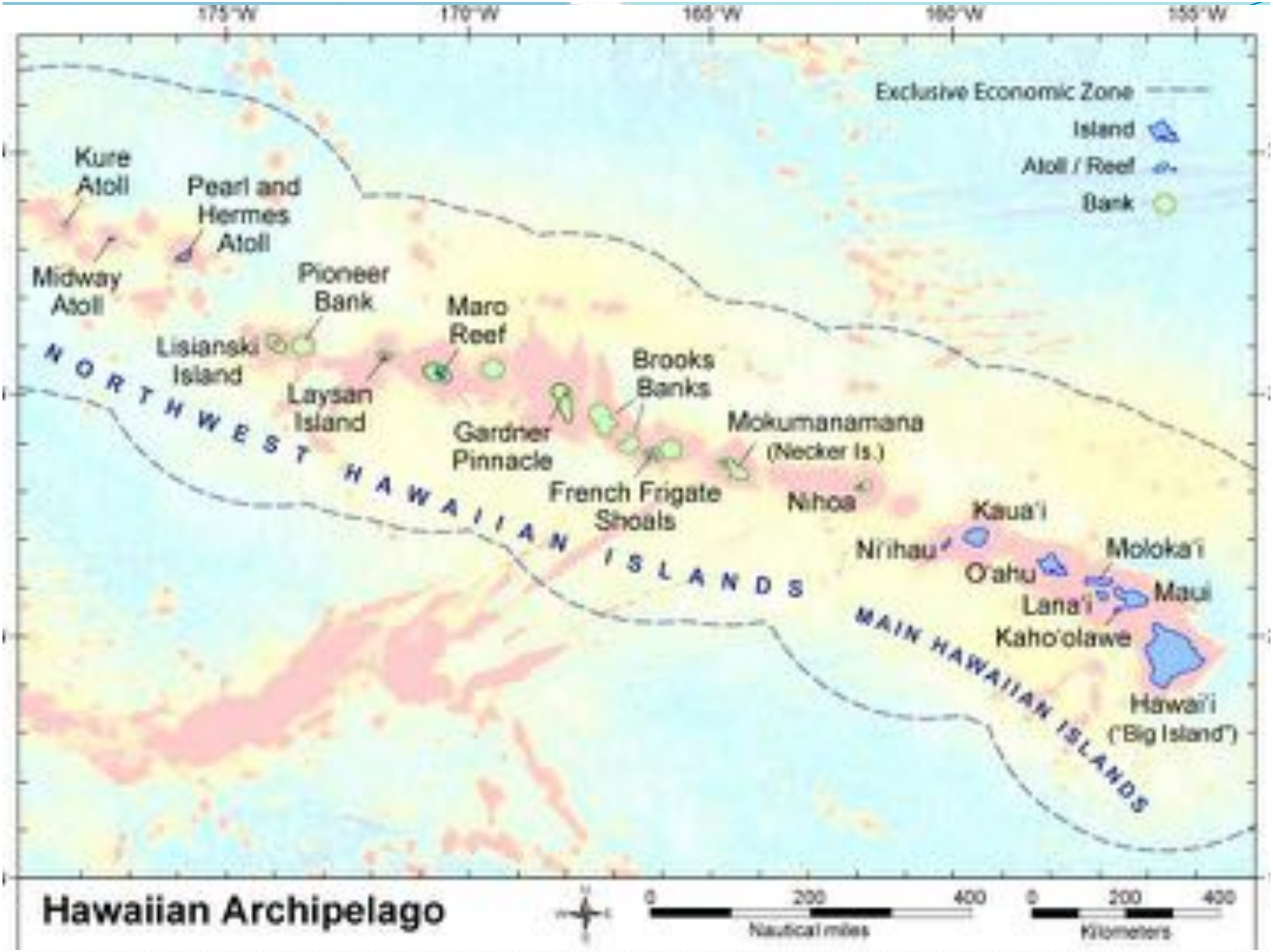
Barrier Reef Lagoon Systems

Types of Oceanic Reefs

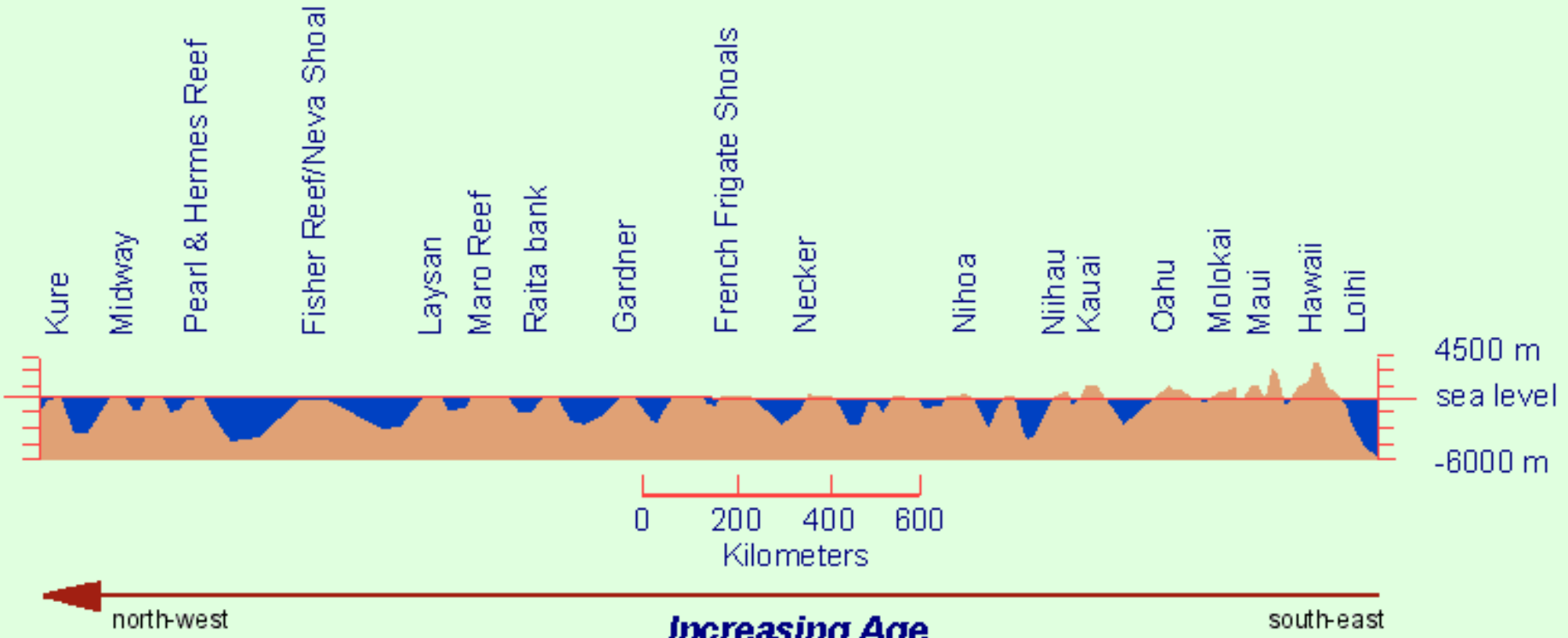
Coral Atolls

Coral Atoll Formation: a sinking island surrounded by living coral




175°W
170°W
165°W
160°W
155°W
Exclusive Economic Zone
Island
Atoll / Reef
Bank
Kure Atoll
Pearl and Hermes Atoll
Midway Atoll
Pioneer Bank
Lisianski Island
Laysan Island
Maro Reef
Gardner Pinnacle
Brooks Banks
French Frigate Shoals
Mokumanamana (Necker Is.)
Nihoa
NORTHWESTHAWAIIAN ISLANDS
Kaua'i
Ni'ihau
O'ahu
Moloka'i
Lana'i
Maui
Kaho'olawe
Hawai'i ("Big Island")
MAIN HAWAIIAN ISLANDS
Hawaiian Archipelago
0 200 400
Nautical miles
0 200 400
Kilometers

The Hawaiian Archipelago



Web graphic by Ken Rubin, modified after: Stearns (1946) Geology of the Hawaiian Islands, Hawaii Division of Hydrography Bulletin 8.

Ecological Role of Corals in Coral Reefs

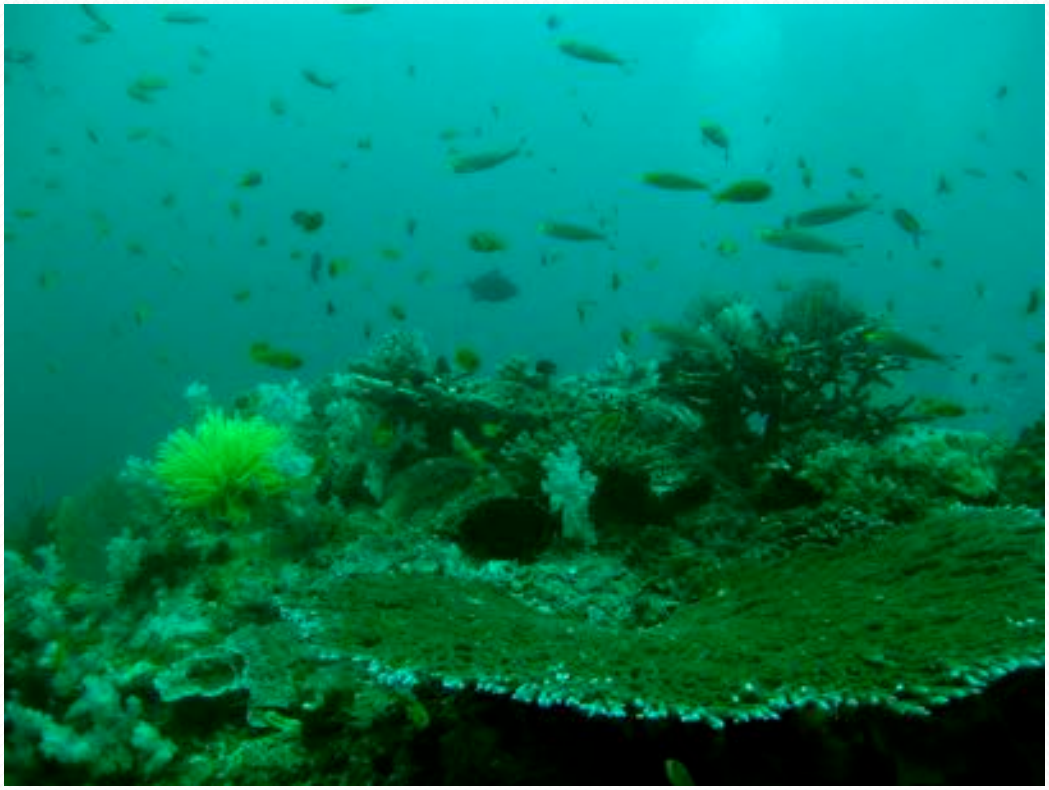
- Provide habitats for reef organisms
  - Porous framework
  - Solid substrate for attachment
  - Source of sand
- Absorb wave energy
- Provide food for corallivorous animals

Ecological Role of Corals in Coral Reefs

- Absorb inorganic nutrients from the water
- Feed on organic detritus and zooplankton
- Compete with other organisms (and with each other) for space and light

Corals form the foundation of the coral reef ecosystem

- Coral reefs are much more than aggregations of coral



Herbivores

- Some fish
- Some snails and sea hares
- Sea urchins
- Green sea turtles
- They eat the algae on the reef, keep it from overgrowing corals and other organisms that can't move (sessile).
- Keep substrate clear for recruitment of sessile organisms.

Parrotfishes

- They eat the algae on or zoox in corals
- Important bioeroders: poop out crushed up coral skeleton

Surgeonfishes

- Macroalgae eaters
- Some form schools

Sea urchins

- Important macroalgae eaters on the reef!
- Can be seen in day but come out in the evening to graze

Green sea turtle

- Also major grazer on the reef
- Filamentous algae from shore to shallow reefs

Corallivores

- Butterfly fishes
- Many species feed on corals
- Shape of mouth determines feeding style
- Tearers: Threadfin
- Pickers: Multiband
- Biters: Ornate

Corallivores

- Crown of thornes sea star
- BIG sea star with toxic spines
- Extrudes stomach onto coral head
- Symbiotic crabs and shrimp can pinch it away
- Triton's trumpet
  snail eats these guys

Outbreaks can
devastate reefs

Mucus feeders

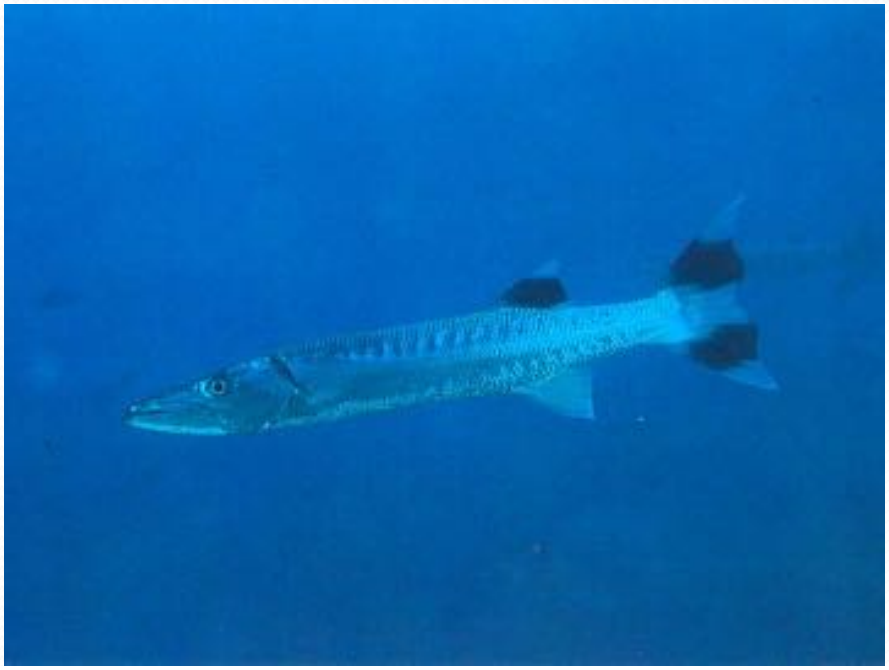
- Symbiotic crabs and shrimps: gall, trapezid crabs and alpheid shrimp
- Protect coral from predators
- In turn feed on coral mucus that is rich in high energy molecules
- They receive protection from living in coral

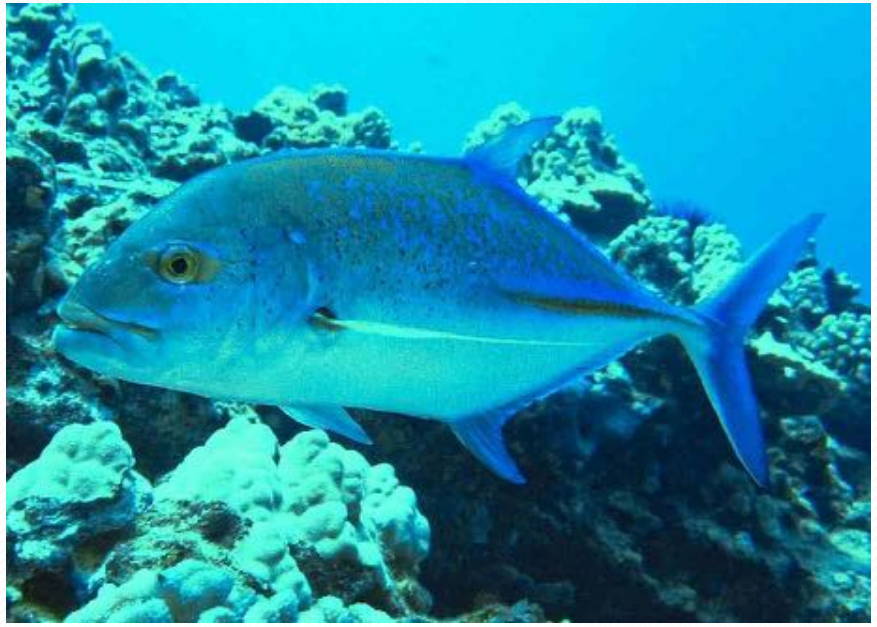
Planktivores

- Pickers selectively pick zooplankton from water column
- Strainers are non selective feeders
- sergeant major *mamo*

Piscivores

- Predators of fish
- Ambush predators
- Fish chasers
- Fish stalkers





Omnivores and scavengers

- **Omnivores**: eat a variety of things: algae, fish, inverts etc
  - Filefish, pufferfish, trunkfish
- **Scavengers**: Clean up the reef of dead or dying debris
  - Lobsters, shrimps, crabs, sharks, wrasses

Filter Feeders

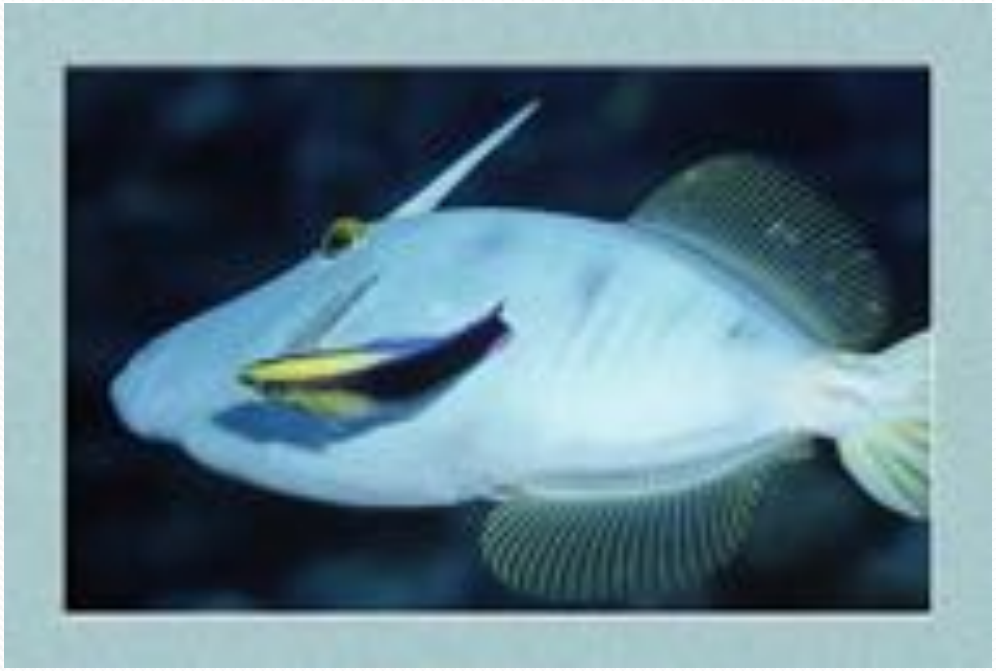
- Passively feed on plankton in the water column

Detritivores

- Sift through sand and sediments and ‘clean’ it of decomposing organic material and nutrients

Symbioses on the reef

- **Obligate**: one symbiont cannot live without the other
  - Corals and their symbiotic algae; Hawaiian cleaner wrasse



Symbioses on the reef

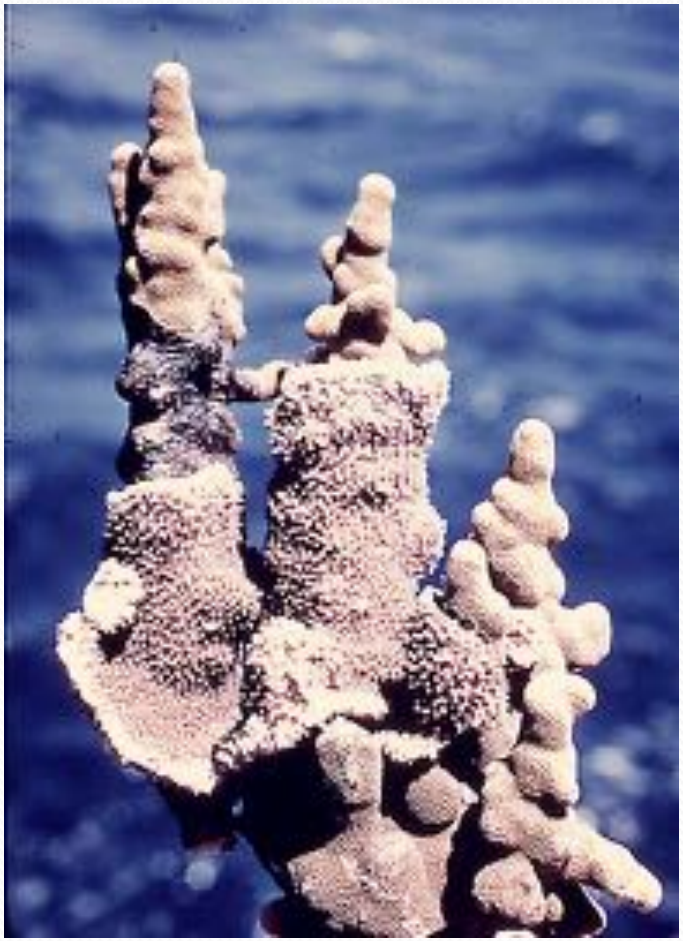
- **Facultative**: usually found together in nature but can survive without one another

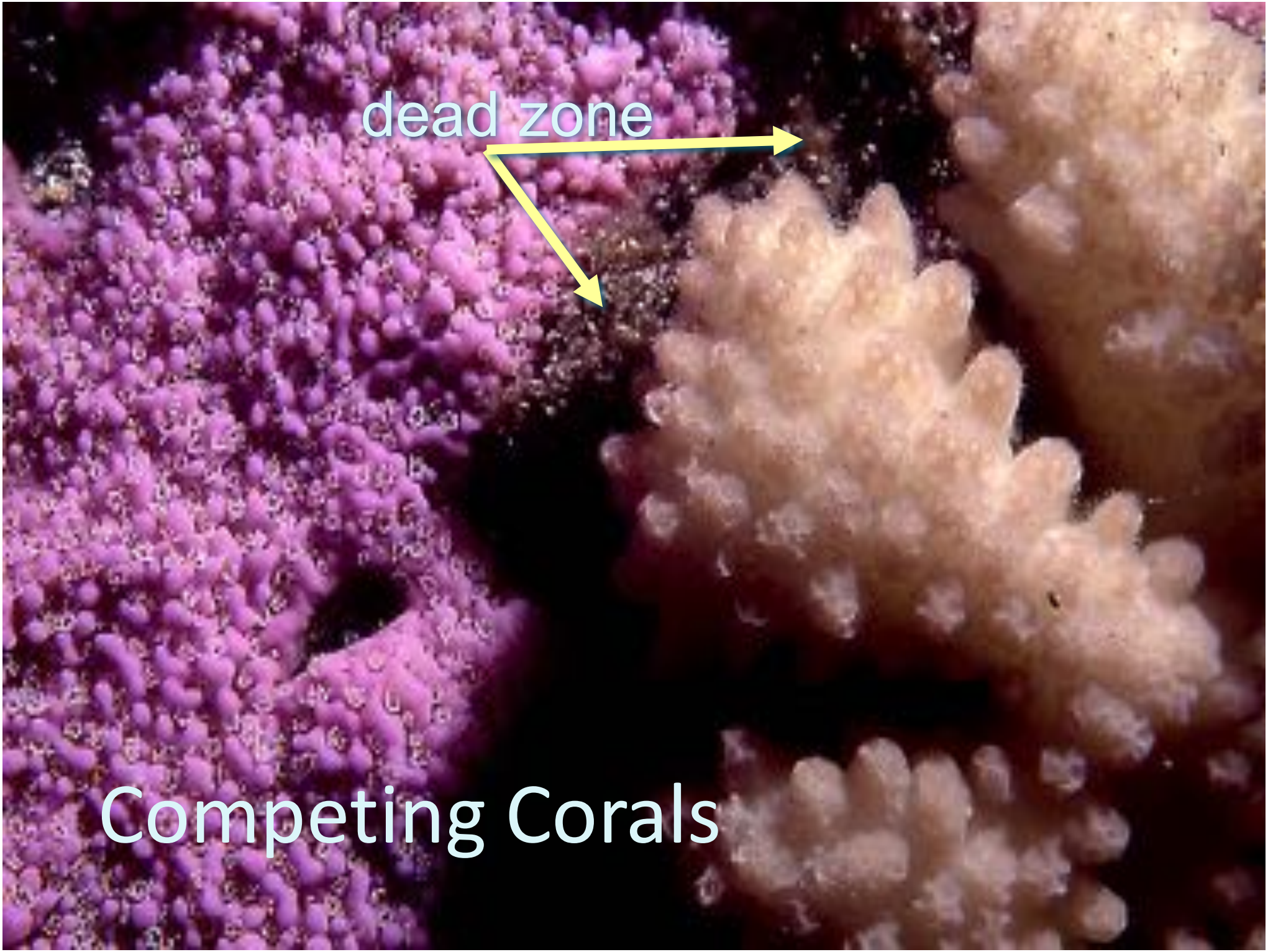
Coral Competition

- Corals compete for space and light

- They can grow over one another or shade one another
- They can attack neighbors with nemaotcysts

Overgrowth and Shading





Competing Corals

Coral reef ecosystems

- Are extremely diverse and dynamic ecosystems!
- They provide humans with:
  - Food
  - Income from tourism and fishing
  - Coastal protection from storms
  - Medicine potential from the diversity of organisms
  - And much more!

Tourism & Recreation

Coral reefs attract millions of tourists every year, bringing important income to coral reef communities. Some countries derive **more than half of their gross national product** from coral reef industries.

Coral Reef

Ecosystem Services

Medicine

Coral reef species are **providing new medical compounds and technology** to treat serious diseases. More than half of all new cancer drug research is focusing on marine organisms.

Food & Fishing

Coral reefs sustain the fish and shellfish populations that **provide protein for 1 billion people.** Reefs are nurseries for many commercially valuable species.

Coral reefs provide nearly **$400 billion a year to millions of people** in economic goods and ecosystem services.

Coastal Protection

Coral reefs act as natural wave barriers that **protect coastal communities and beaches** from storm damage.

Coral reefs act as homes and nurseries for 25% of all marine life.

Though they cover less than 1% of the ocean floor, coral reefs provide habitat for **250,000 known species**, including more than **4,000 species of fish and 700 species of coral.**

Many coral reef species have yet to be discovered. Scientists believe that **more than 1 million species** are associated with coral reefs.

Coral Reefs

are created by many tiny animals called coral polyps.

The coral polyps' **limestone skeletons** build up over time, forming the base of the complex reef habitat that supports the world's **highest level of marine biodiversity.**

Coral reef ecosystems are under threat!

- Over fishing
- Destructive fishing practices
- Climate change: increase temps and acidity
- Pollution
- Sedimentation
- Over exploitation
- Resource extraction

What can we do to protect our coral reefs?

Pau!