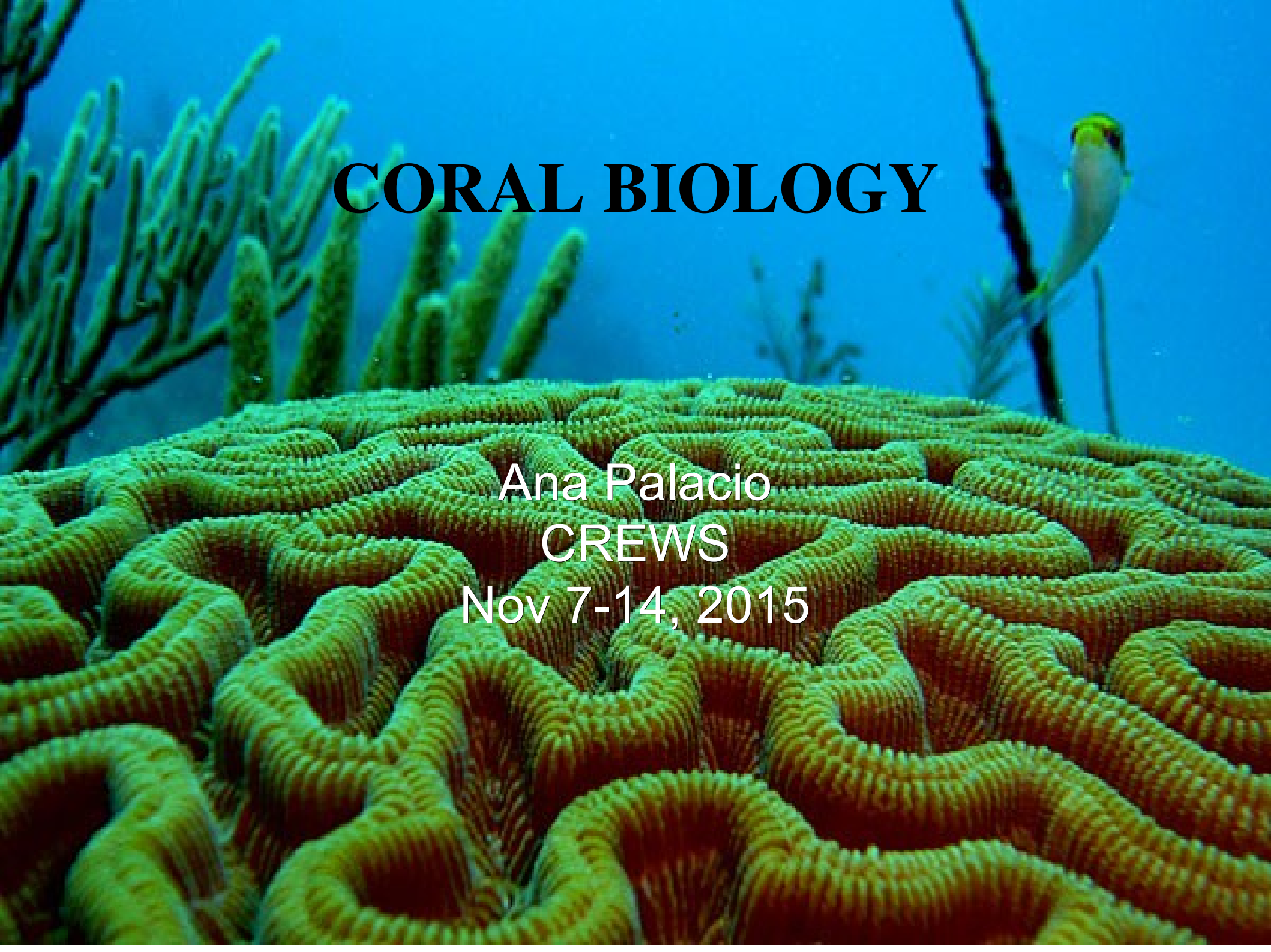
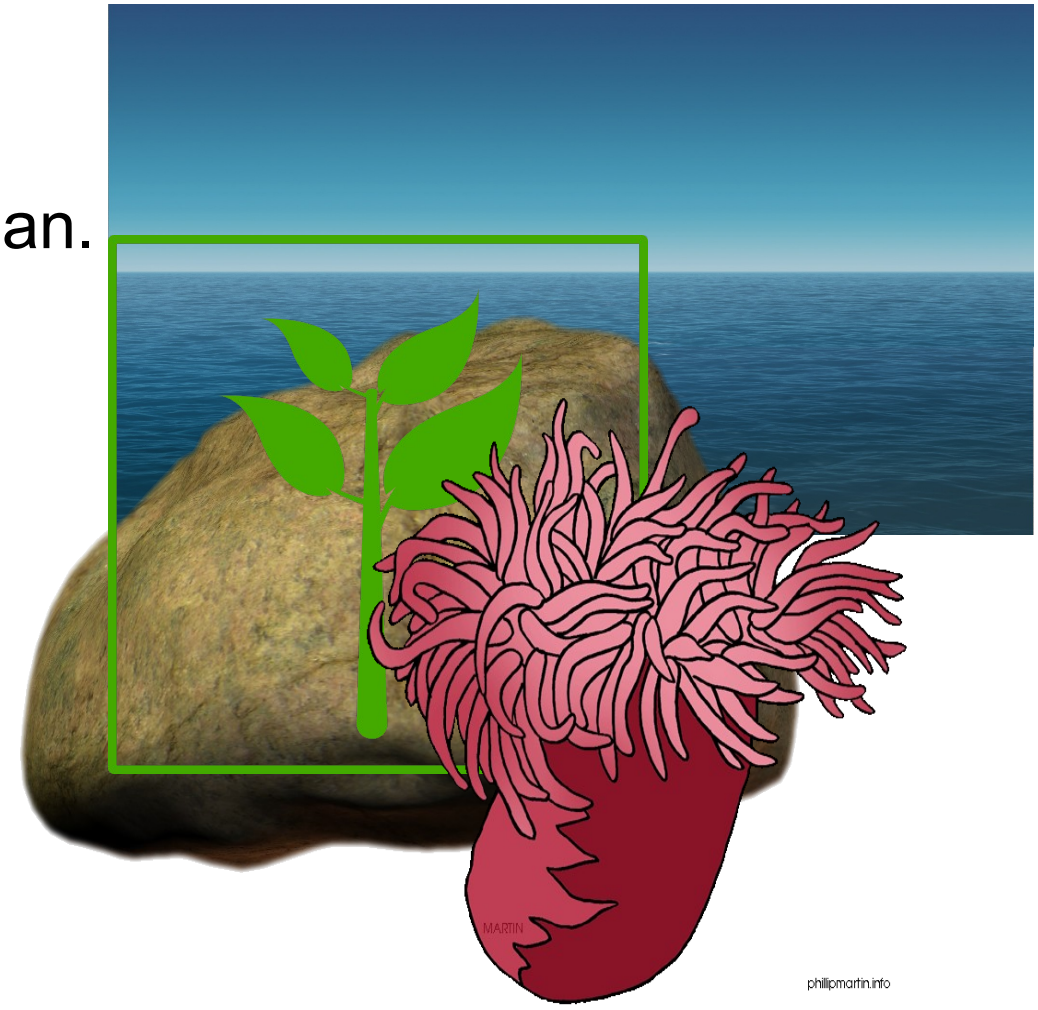


CORAL BIOLOGY

Ana Palacio
CREWS
Nov 7-14, 2015

What is a coral?
My family survey

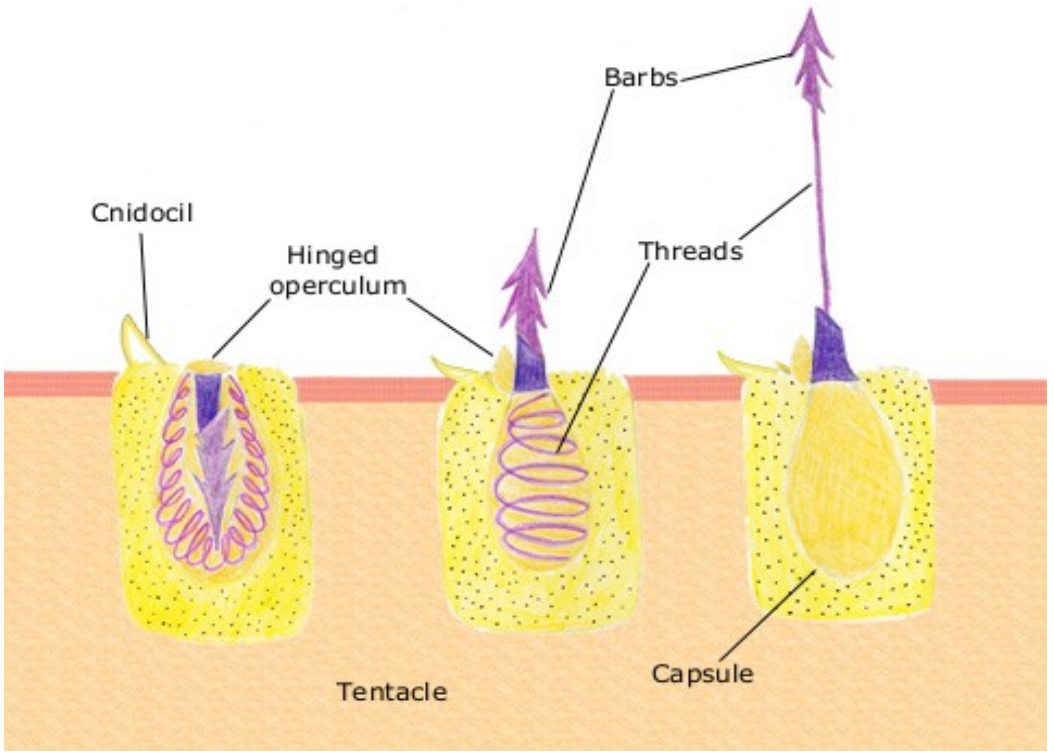
- 60%: $^&%^&?
  However, they are in the ocean.
- 20%: A plant
- 14%: A Rock
- 6% An animal



What is a coral?
A cnidarian

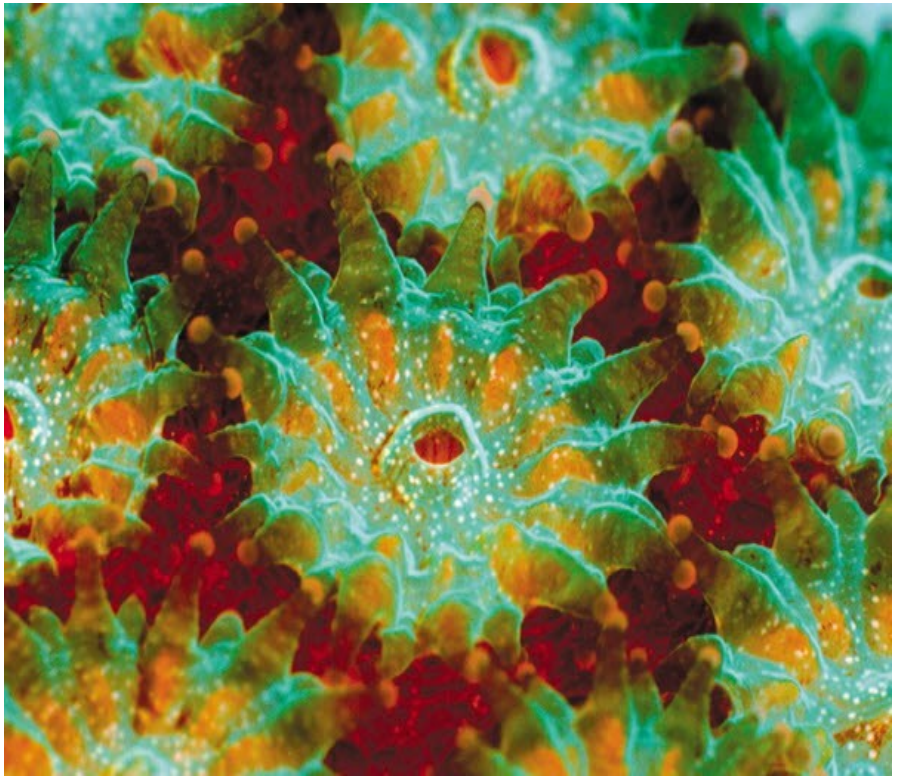
Corals are closely related to jellyfish and anemones, so they share many characteristics. All of them belong to the phylum cnidaria (Latin *cnide:* nettle; + -*arius:* of or related to).

- Are aquatic **animals**
- Sting (have cnidocytes)
- Have tentacles and mouth



What is a coral?
A colonial and sessile cnidarian

- Corals are **colonial** organisms. Instead of a single polyp they have many interconnected polyps.
- On the reef, try to identify the tentacles and mouths!
- All corals have them, but some species are “open” only at night or while feeding.
- Of course, try not to touch them
  - They are going to retract
  - Is bad for the coral
  - You may be stunned
- All corals are **sessile** (not able to move about)



What is a coral?
Stony corals vs others

We use the word coral to call many different organisms. As stony corals are very important we separate them from other kind of corals:

“Other” corals

Fire coral
Zoanthids like *Palythoa*

8 tentacles
- Blue coral
- Gorgonians
- Sea fans and sea whips
- Sea pens
- Red coral

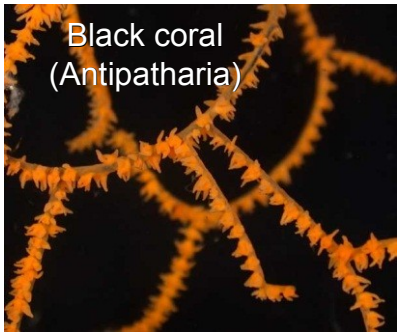
6(X) Tentacles, not skeletal
- Anemones
- Black coral

Hard (Stony) corals

*** 6(X) Tentacles**
*** Calcium carbonate skeleton!**

- Fleshy corals (scolemia)
- Branching corals (Elkhorm, Staghorn)
- Brain corals
- Encrusting corals (Lettuce corals)

I. Non stony corals



II. Hard (stony) corals:
Skeletons with different shapes

BRANCHING


Elkhorn coral


Staghorn coral

LEAF


Lettuce coral

BRAIN

BOULDER


Mountainous star coral


Great star coral

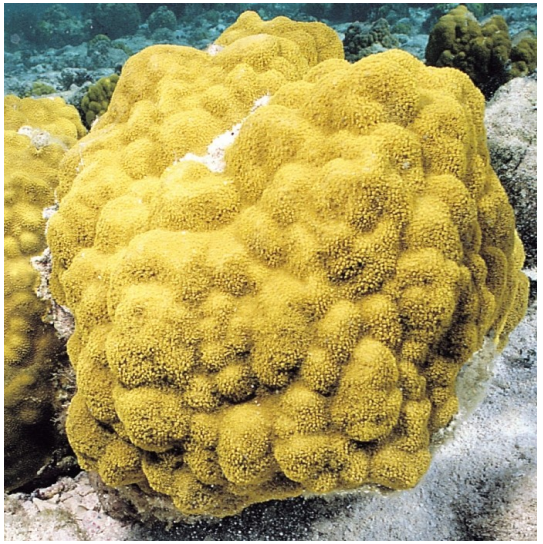
Cozumel hard corals

Smooth Flower coral

Great star coral

Finger coral

Cozumel hard corals

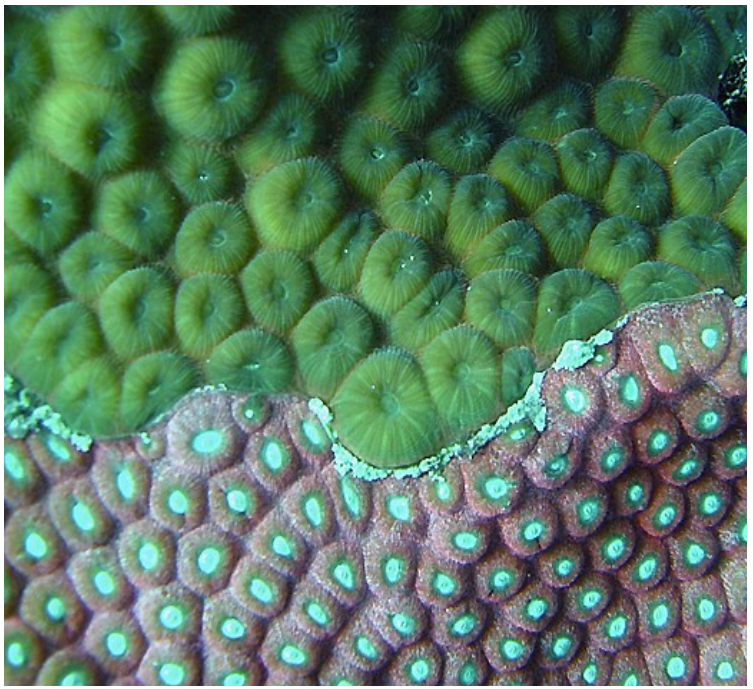


Mustard hill coral

Brain corals

II. Hard (stony) corals:
Different colors

- There is a variety of colors and tones in the same species
- Coral pigments are like sunscreen



- Do not be pay attention to differences in coloration to identify corals.
- But, some differences are important to identify coral bleaching or paling.

II. Hard (stony) corals

Great star coral **vs**

- *Montastrea cavernosa*
- Stony coral
- Hard skeleton

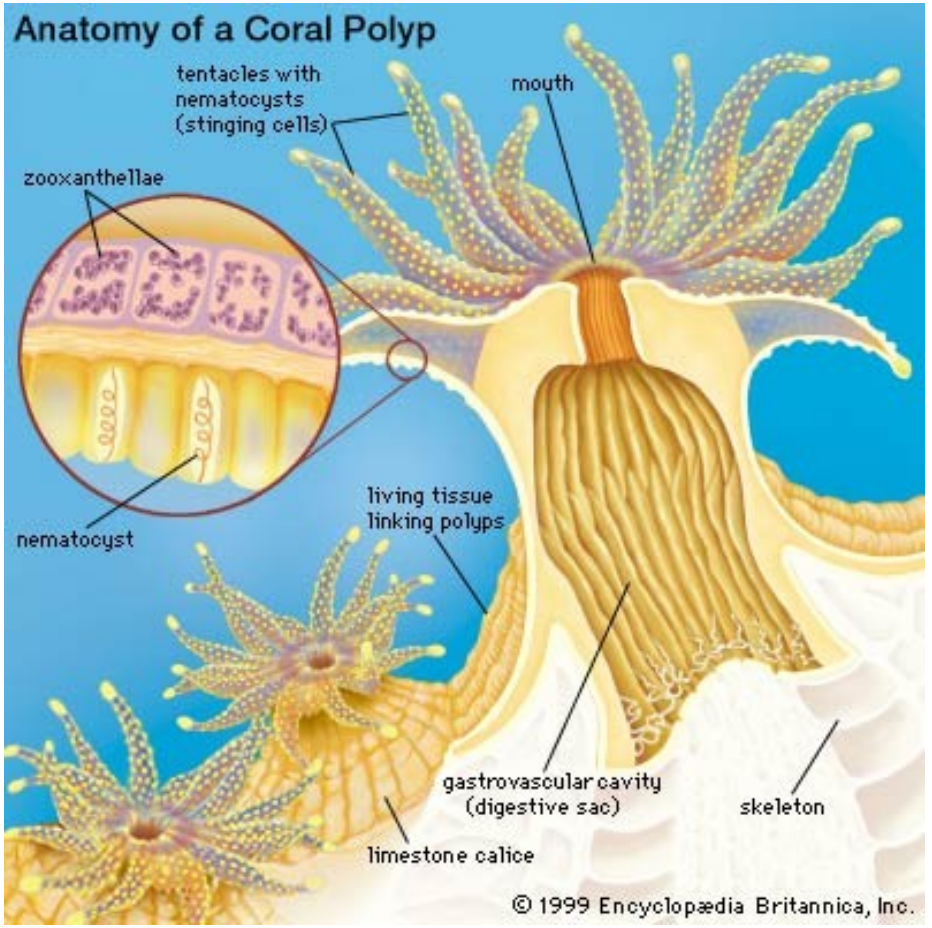
Zoanthid

- *Palythoa caribaeorum*
- Cork-like in consistency
- It has palytoxins!

Try to differentiate them in the reef since they play very different roles in the ecosystem!

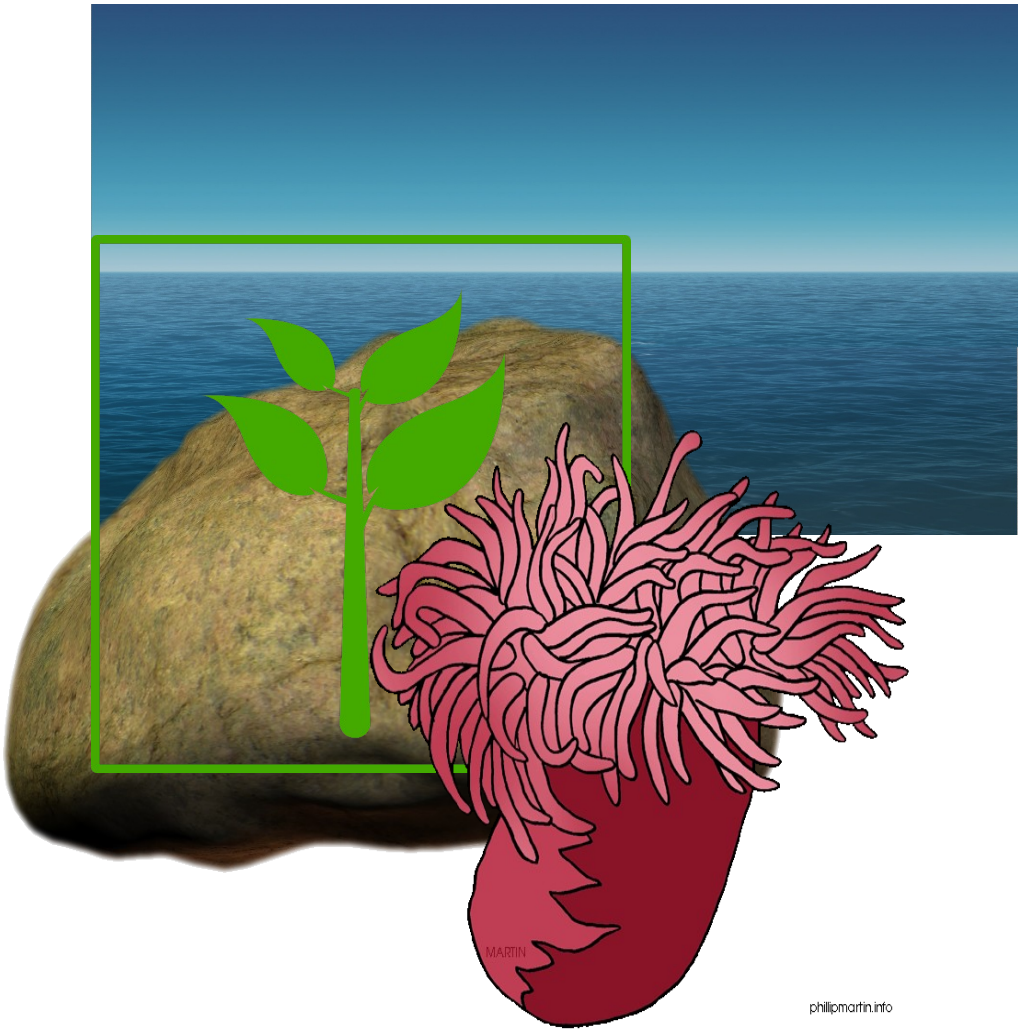
Palythoa caribaeorum

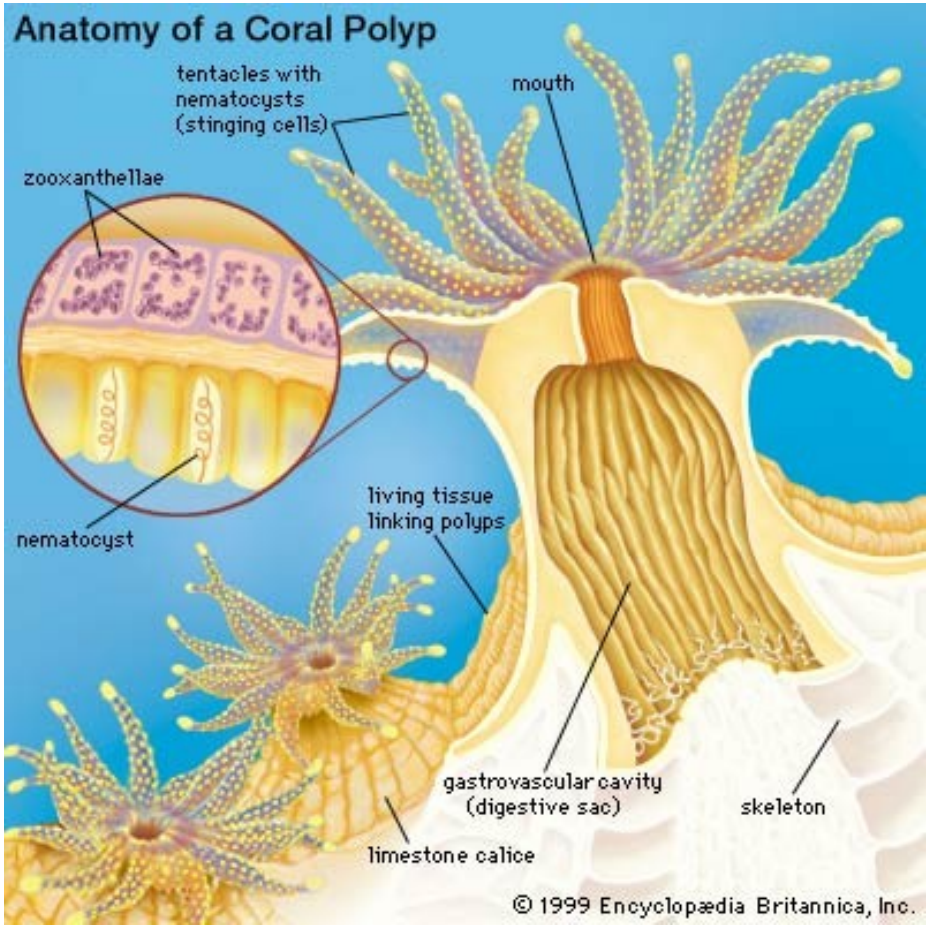
Coral anatomy



- Mouth (eat and excrete)
  - Pharynx / gut
  - Gastrovascular cavity
  - Mesenteries (curtains) inside gut for digestion / polyp retraction / gonads
  - Mesenterial filaments
- 6(x) tentacles (food capture / defense / aggression)
  - Up to 10,000 cnidocytes (stinging cells) per mm^2
- **Skeleton**
- **Zooxanthellae**

Again... What is a coral?





Again... What is a coral?

Coral anatomy
Defense and aggression

Be faster!

Corals cannot move, but can fight! Look around the colonies. When different species are close together they may fight to keep their space!

Coral anatomy
Defense and aggression

- Sweeper tentacles

- Mesenterial filaments

Corals cannot move, but can fight! Look around the colonies.
When different species are close together they may fight to keep their space!

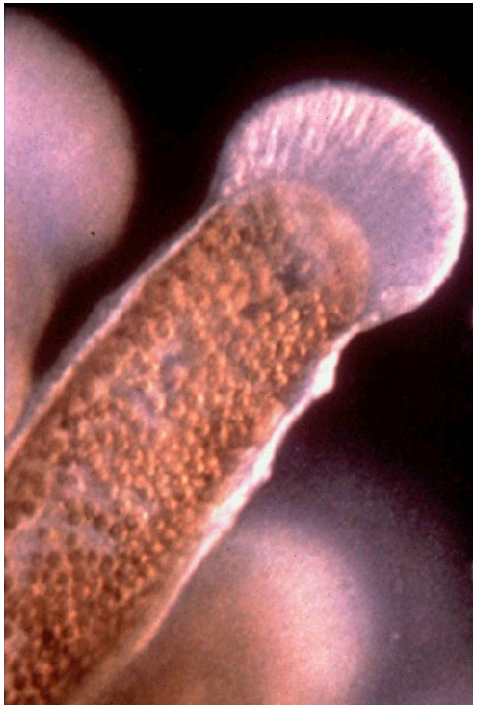
Coral anatomy
Defense and aggression

Corals cannot move, but can fight! Look around the colonies. When different spp. are close together they may fight to keep their space!

Coral nutrition

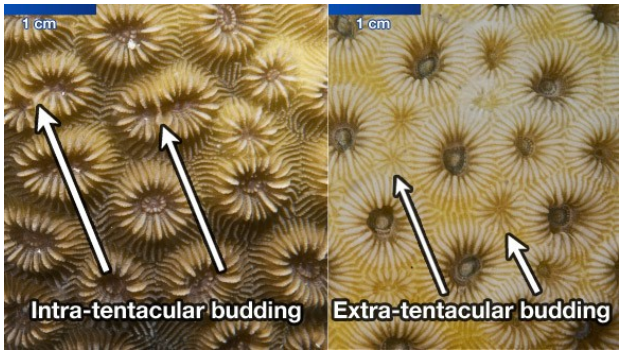
- Corals eat plankton

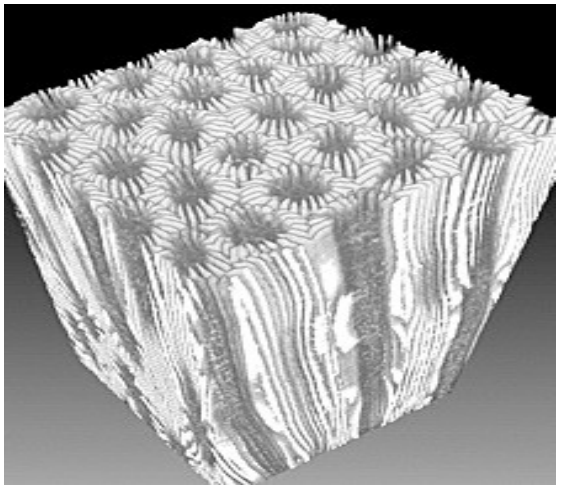
- Get carbohydrates and amino acids from Zooxanthellae (Up to 95% of the photosynthesis products are translocated to the coral)



Coral growth and reproduction

Corals “widen” their surface by dividing their polyps.





Get “taller” by calcifying under the coral tissue.

Reproduce asexually through fragmentation

Reproduce sexually by releasing gametes

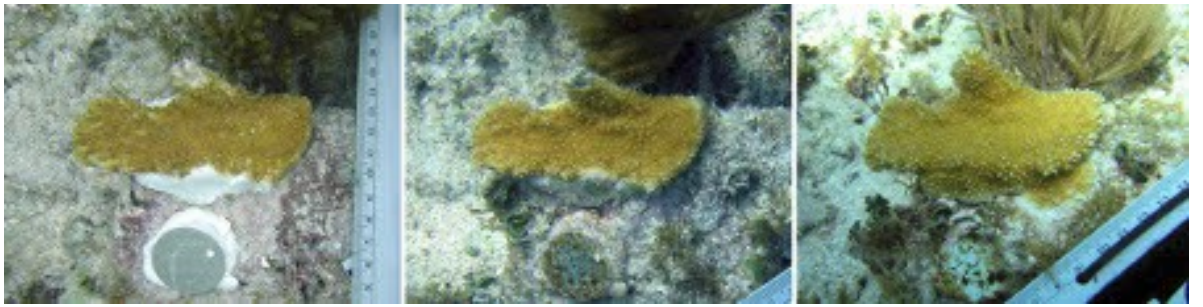
Asexual reproduction:
1. New polyps formation

Asexual reproduction:
1. New polyps formation

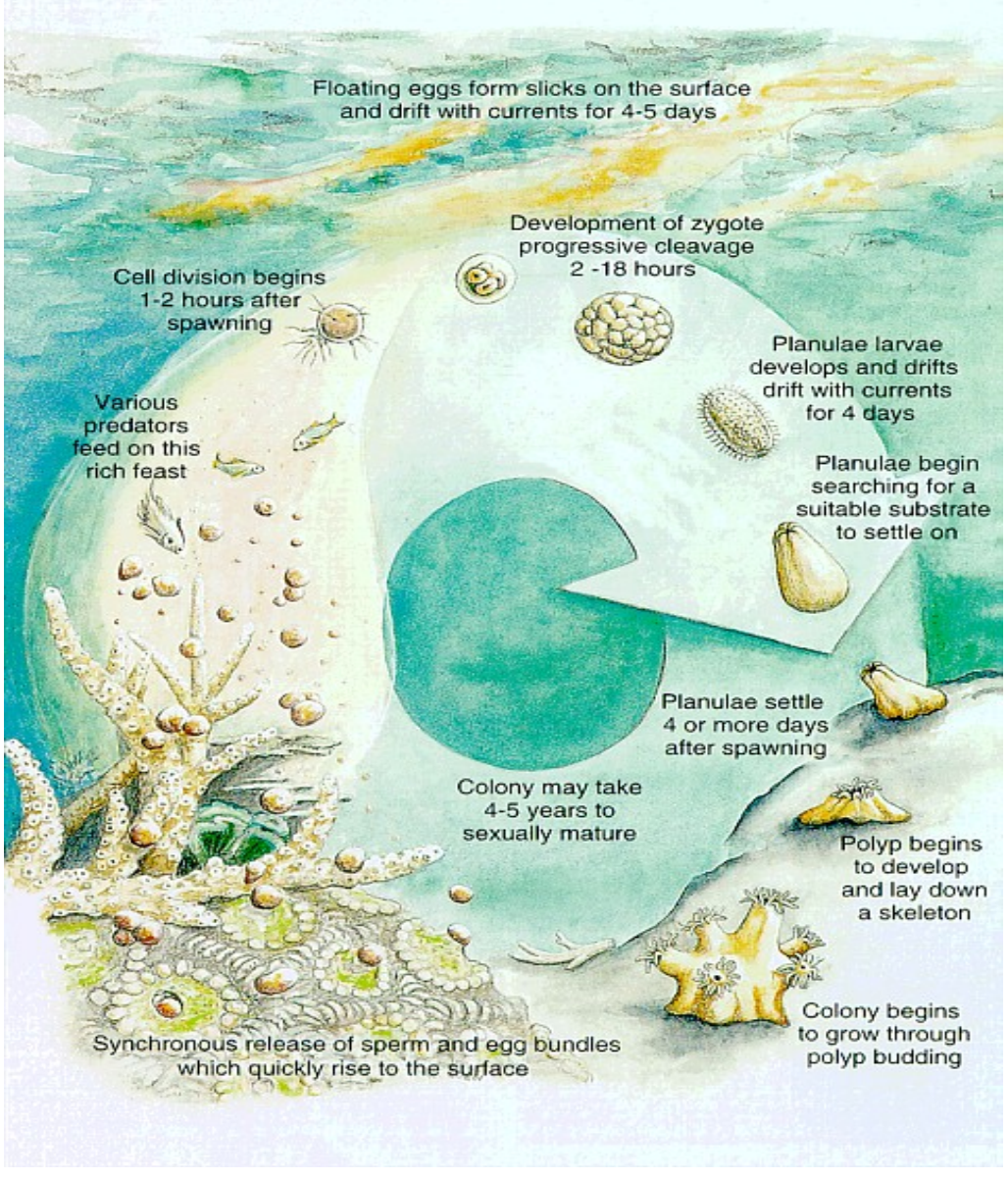
What kind of budding do brain corals have?

Asexual reproduction:
2. Fragmentation

Fragmentation may occur naturally by wave action, storms or by the other animals



Sexual reproduction
1. Broadcast Spawning



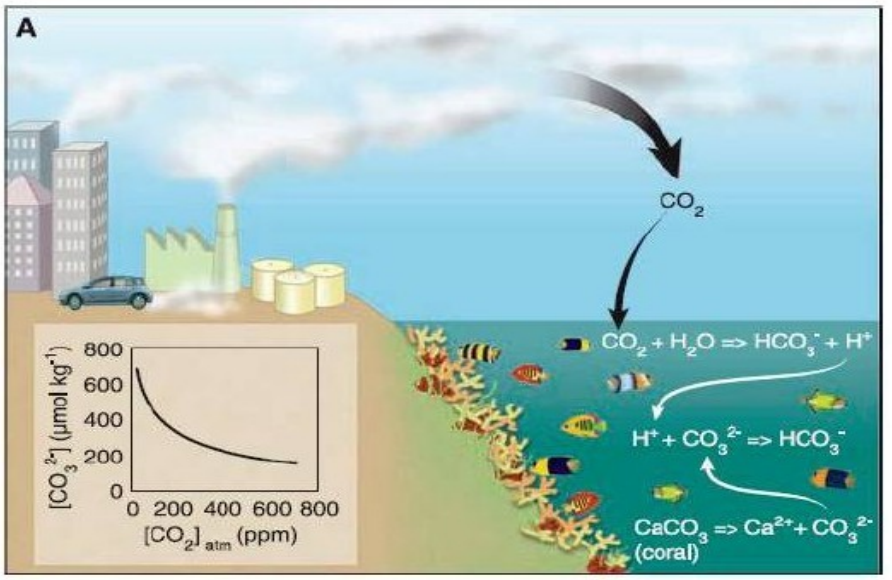
Sexual reproduction
2. Brooders

Coral calcification and Ocean Acidification

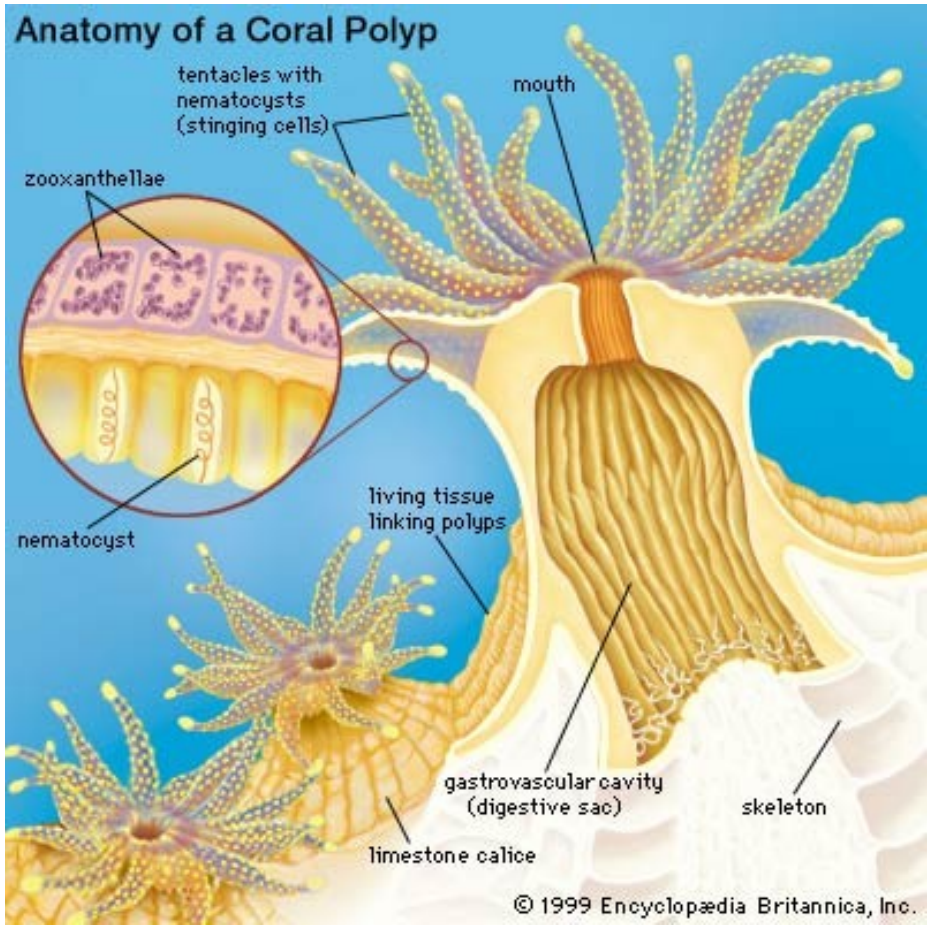
Calcification is a very expensive process

- Massive corals: 0.5-1cm/year
- Branching corals (10-20cm/year)
- Growth rate depends upon environmental conditions (light, water chemistry, zooxanthellae community).

As anthropogenic CO_2 emissions are increasing the carbon in the ocean, that is changing the water chemistry of seawater, reducing coral skeletal growth.

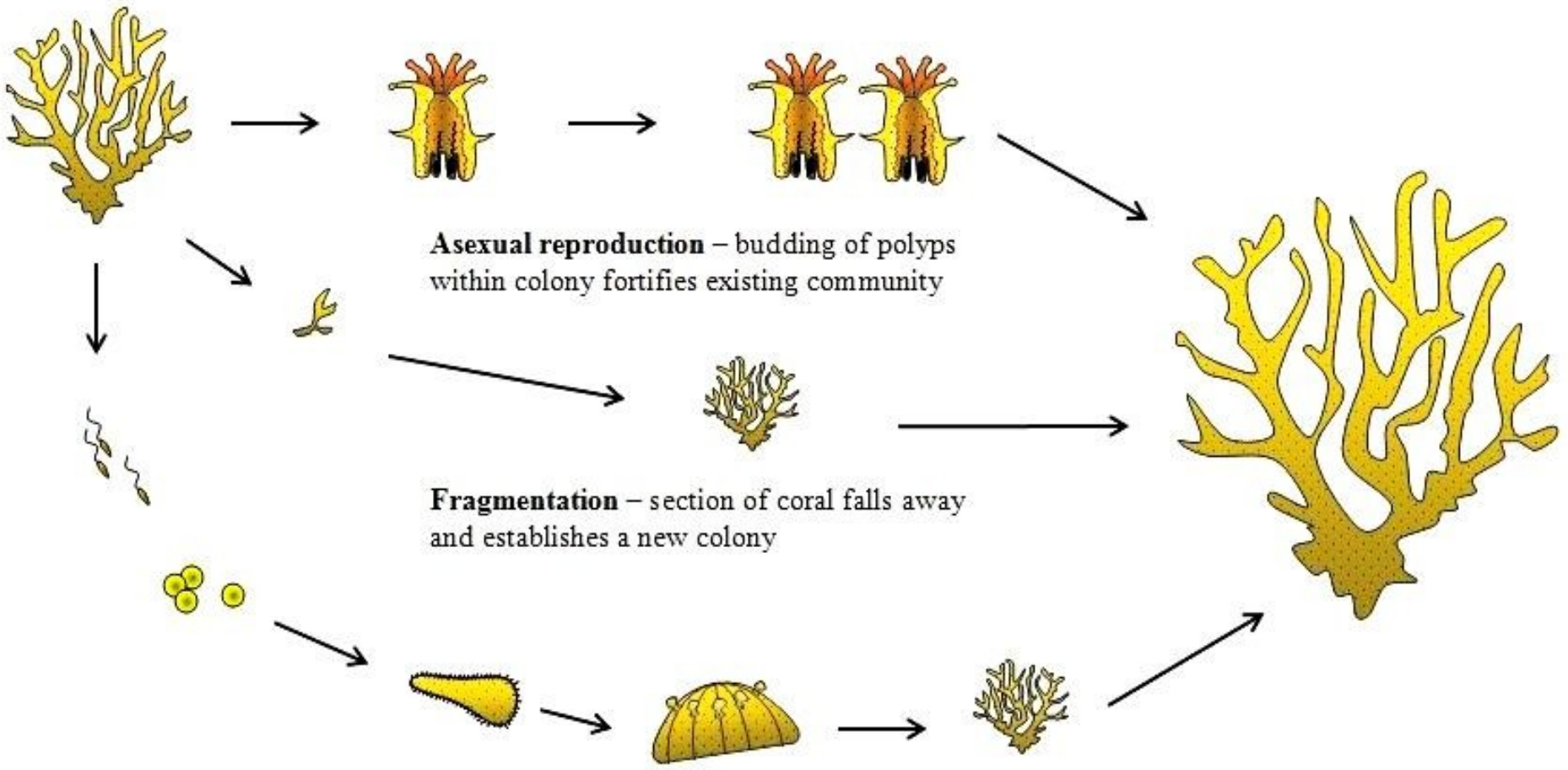


Summary:
Coral definition and anatomy



- Sessile marine animals in the phylum **cnidaria**
- Can have many different shapes and colors.
- Are **colonial** (formed by many polyps) each one with tentacles and a mouth
- Some of them fight with mesenterial filaments and sweeper tentacles
- They also harbor zooxanthellae, which provides most of the energy for the coral growth
- Stony corals calcify to form their skeletons.

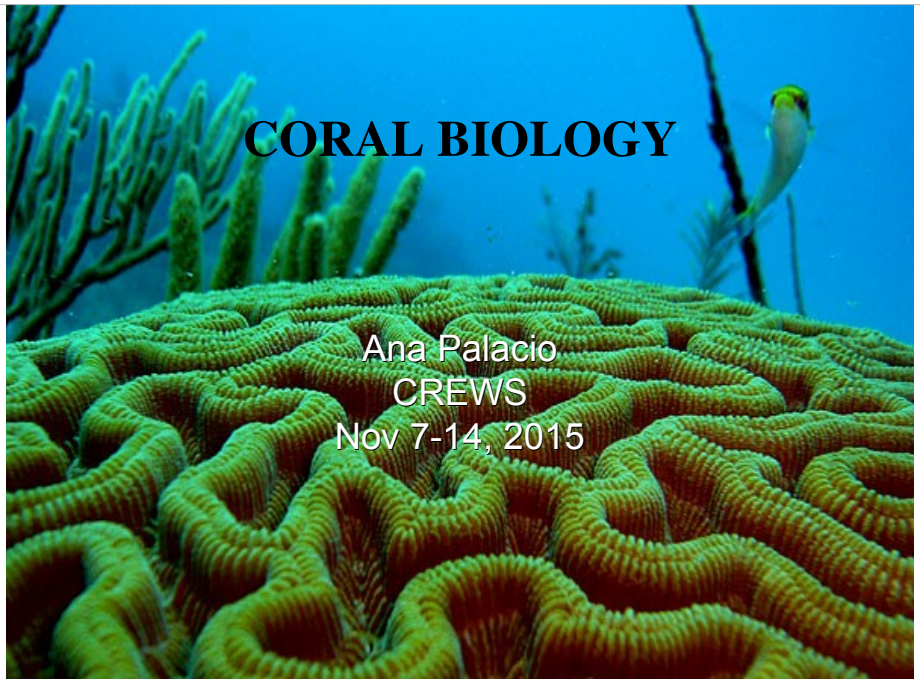
Summary:
Coral reproduction



Asexual reproduction – budding of polyps within colony fortifies existing community

Fragmentation – section of coral falls away and establishes a new colony

Sexual reproduction – gametes mix to form planulae which disperse via currents and establish new colonies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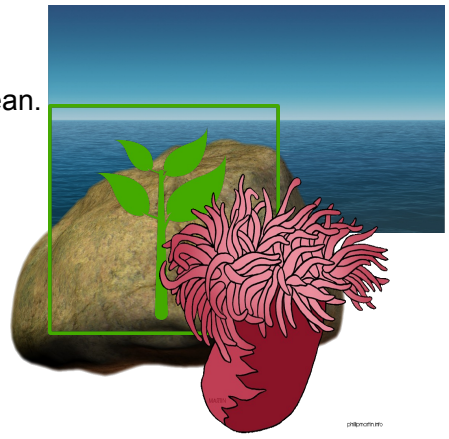

As divers, you are probably more familiarized with underwater life than many other people. However, when talking about corals and other marine animals (different than fish), you should probably be very careful about being sure that you are on the same page as your audience.

I recently had the opportunity to meet with my whole family and I took advantage of that huge group of people and made them take small survey. I asked all of them what a coral is. About 60% did not know, but associated corals with the ocean. 20% said it is a plant. This people looked very secure about their answer, unlike the 14% that answered “ a rock”. Those last ones were not sure why a rock was not simply called rock, but associated corals with precious rocks.

My mom, dad and I answered that corals are animals, but it is not that simple.

What is a coral?
A cnidarian

Corals are closely related to jellyfish and anemones, so they share many characteristics. All of them belong to the phylum cnidaria (Latin *cnide:* nettle; + *-arius:* of or related to).

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- Sting (have cnidocytes)
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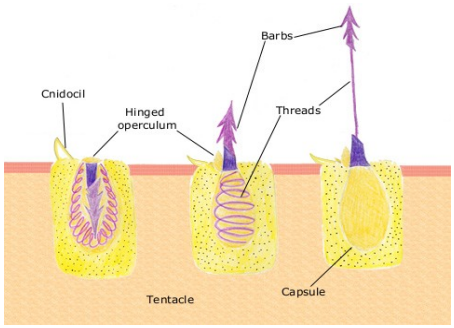
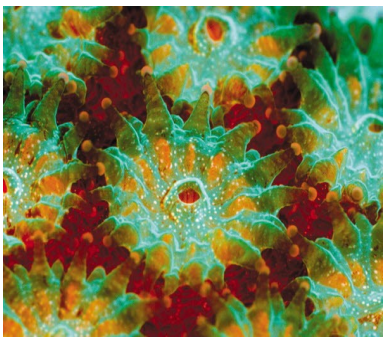


If someone asks you ... you will be safe answering that corals are marine animals. They belong to the phylum **cnidarian,** which also groups jellyfish, anemones, sea fans and fire corals between other similar organisms.

All of them share characteristics, like the presence of some cells called **cnidocytes**. These cells are important since cnidarians use them to catch food and are the responsible for that painful sensation when we touch a fire coral or a jellyfish. Corals also sting, but we are less sensitive to them.

What is a coral?
A colonial and sessile cnidarian

- Corals are **colonial** organisms. Instead of a single polyp they have many interconnected polyps.
- On the reef, try to identify the tentacles and mouths!
- All corals have them, but some species are “open” only at night or while feeding.
- Of course, try not to touch them
  - They are going to retract
  - Is bad for the coral
  - You may be stunned
- All corals are **sessile** (not able to move about)

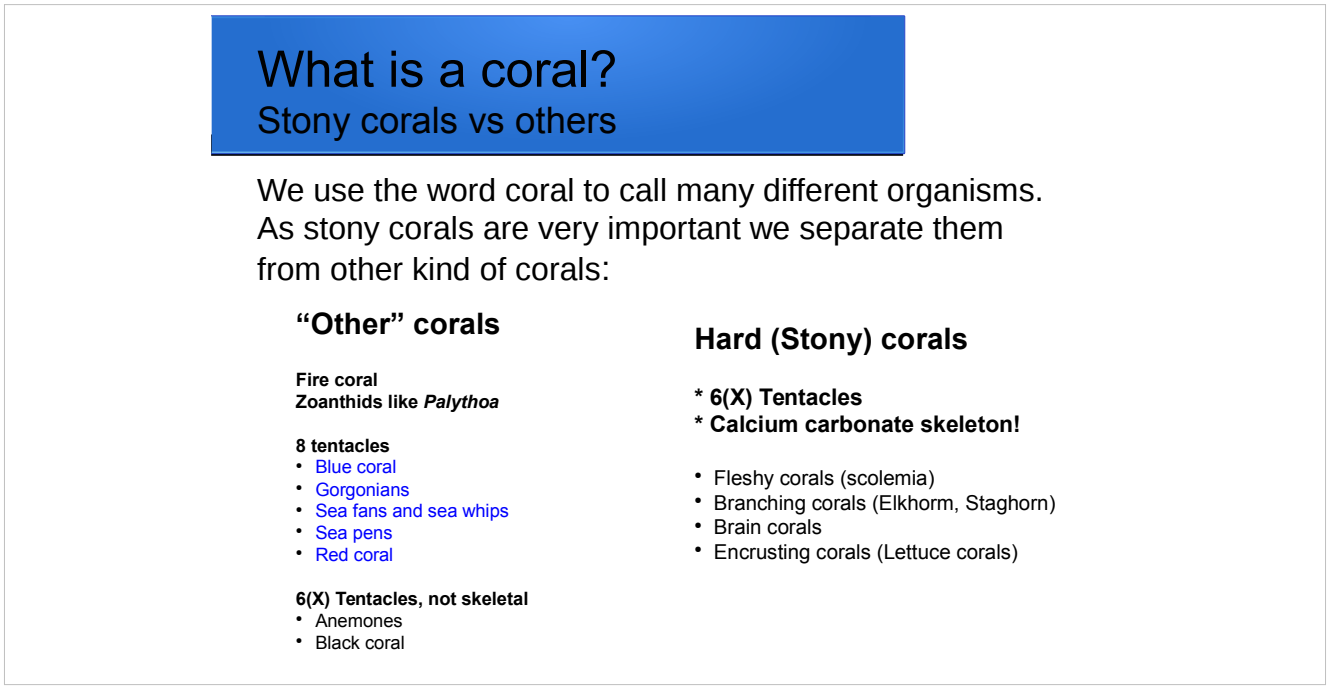


However, the majority of corals, unlike jellies and anemones, are **colonial** organisms. That means that a coral colony is composed of many identical individual **polyps** connected by tissue between them. You may think about a coral colony as a collection of identical and very small anemones growing side by side.

Each polyp, even if interconnected with its neighbors, also has some independence. You can identify them on the reef by trying to see the large number of individual mouths and tentacles in a colony. If one polyp dies or is eaten by a fish, that hardly affects its neighbors that keep developing and reproducing.

Another difference between corals and jellies/anemones is that corals are **sessile** organisms. Once a coral larva finds a place to live and settle, that colony will stay attached in the same substrate (unless someone else detaches it)

And yeap. Anemones may move!
Swimming anemone:
https://www.youtube.com/watch?v=-6lMD9h_ix4

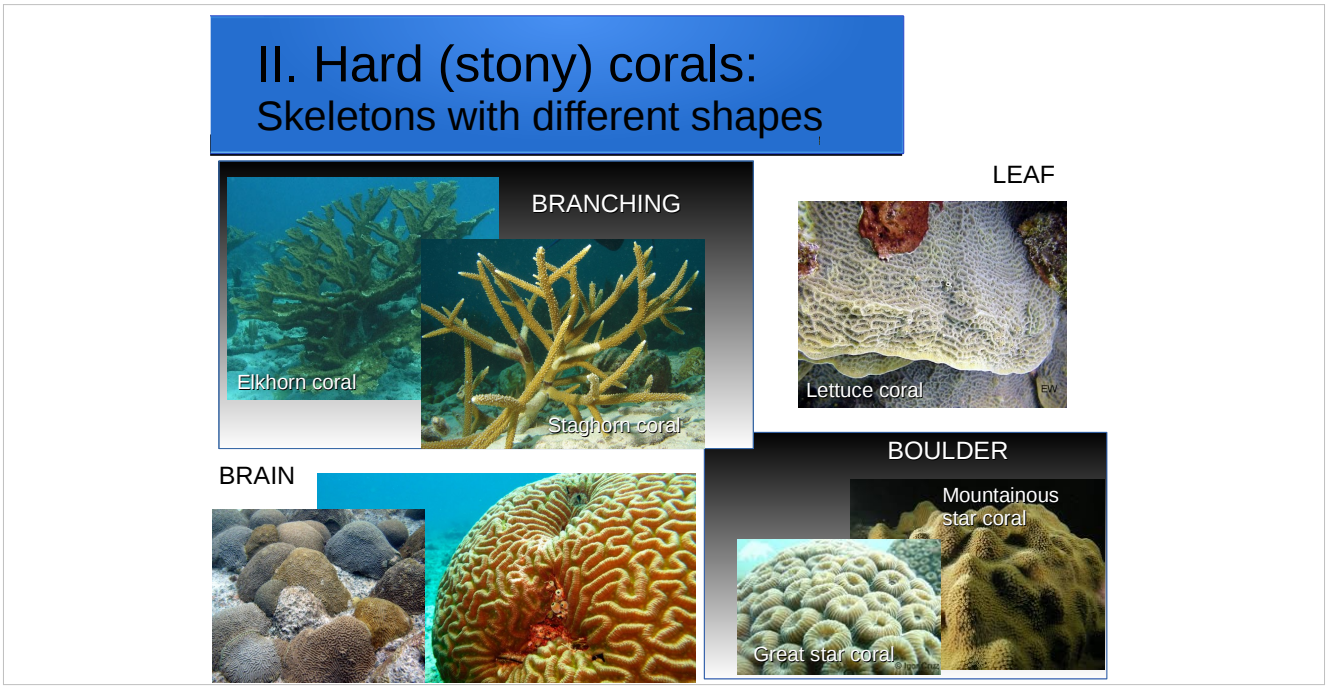


The word coral may describe a variety of cnidarians habiting reefs and the ocean in general. We divided them into soft corals and hard corals, being the last ones corals that secrete calcium carbonate skeletons. This division is important since only stony corals build strong, durable reef frames. Also, hard corals have always 6 or multiples of 6 tentacles (in case you want to go in detail, but it is very hard to count them!)

Between the "other corals" there are multiple groups of organisms like zooanthids, fire corals and octocorals (these ones have 8 tentacles in each polyp). They do not form calcium carbonate skeletons and therefore does not contribute that much to the reef structure.

I. Non stony corals

Gorgonians (sea fans and sea whips) and zoanthids are non stony corals commonly present in Caribbean reefs. Other organisms are not present in this region, or live in deeper areas.



Hard corals have a very variable morphology. However, all of them secrete hard calcium carbonates skeletons underneath of the coral tissue and have 6(x) tentacles per polyp.

These are some of the most common stony coral species present in the Caribbean. They form calcium skeletons, creating a perdurable and complex topography that is use for other species as shelter. This structure or “reef frame” protects the coasts from wave action and then helps to keep beaches away from erosion.

Some of the colony growth forms are:

- Ramose or branching
- Columnar
- Massive or lobate
- Laminar or plate-like
- Foliaceous
- Encrusting

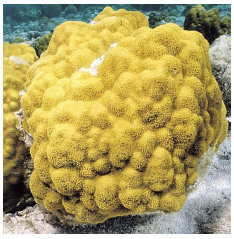
Cozumel hard corals

Smooth Flower coral

Great star coral

Finger coral

Cozumel hard corals

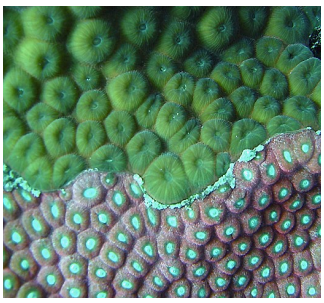


Mustard hill coral

Brain corals

II. Hard (stony) corals:
Different colors

- There is a variety of colors and tones in the same species
- Coral pigments are like sunscreen



- Do not be pay attention to differences in coloration to identify corals.
- But, some differences are important to identify coral bleaching or paling.

- Corals may have different pigments that are used for photoprotection.
- However, most of its brownish coloration comes from the algae that lives inside them.
- Coloration is not an important feature to identify different species, but the loss of coloration is indicative of coral bleaching or paling, suggesting a source of stress.

II. Hard (stony) corals

Great star coral **vs**

- *Montastrea cavernosa*
- Stony coral
- Hard skeleton

Zoanthid

- *Palythoa caribaeorum*
- Cork-like in consistency
- It has palytoxins!

Try to differentiate them in the reef since they play very different roles in the ecosystem!

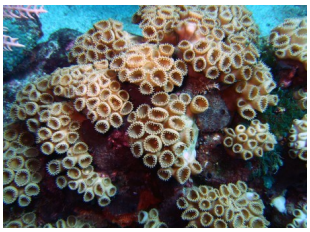
If hard corals may look very different, also other organisms may look very similar to them. In Caribbean reefs, the zoanthid *Palythoa caribaeorum* may be mistaken for the great star coral (*Montrastraea cavernosa)*.

Palythoa has similar coloration and polyp shape and size. However, it does not form a strong skeleton, but grows over the reef bottom including over dead coral colonies. When it grows over a dead colony boulder, it may look very similar to a great star coral!

Try to differentiate them in the reef!

Palythoa species also have a toxin, so be especially careful about not touching them!

Palythoa caribaeorum



This is how *Palythoa* looks when it is growing on different surfaces

The shape and appearance of a coral colony depends on each species. However, the individual polyps are almost the same in all stony corals.

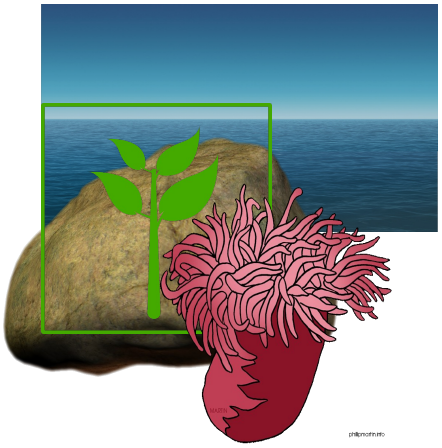
Each polyp has:

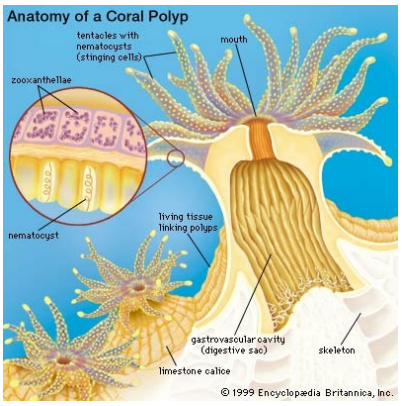
- A **mouth** that connects to a **gastrovascular cavity**. Inside, it has mesenteries (curtains) that help with corals digestion and hold the **mesenterial filaments** (filaments full of nematocysts used for digestion and competition).
- 6(x) **tentacles** (food capture / defense / aggression)
  - Up to 10,000 cnidocytes (stinging cells) per mm^2

- **Skeleton:** Calcium carbonate structure formed under the coral tissue

Zooxanthellae: a yellowish-brown symbiotic algae that lives inside coral tissue. Corals and algae have a mutualistic relationship in which the coral provides the algae with a protected environment and compounds they need for photosynthesis. In return, the algae supply the coral with carbohydrates and amino acids, which are the products of photosynthesis. The coral uses these products to make proteins, fats, and carbohydrates, and to produce calcium carbonate skeleton

Again... What is a coral?





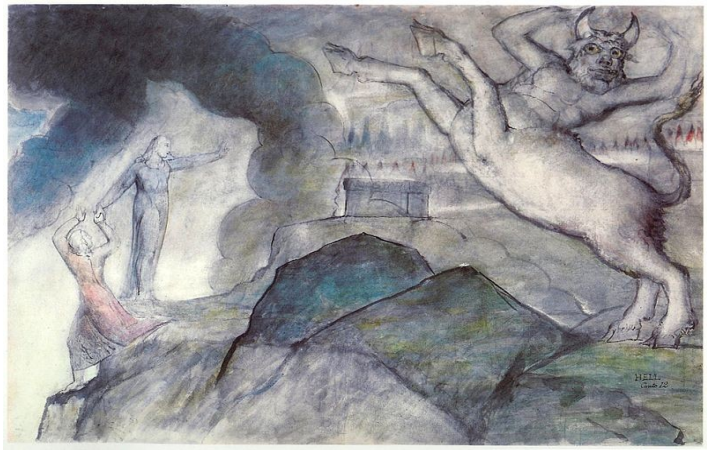
Now that we know what a coral is, we should revisited my family survey. A coral is definitely an animal, but since they make carbonate skeletons and live in symbiosis with microscopic algae, they also have some characteristics of rocks and plants.

Taking this into account will be very important to understand how climate change affects corals as an assembly in which the animal, the algae and the rock parts are important:

- Ocean acidification affects coral calcification
- Global warming affects the coral-alga symbiosis

We will discuss that later on.

Again... What is a coral?



Coral anatomy
Defense and aggression

Be faster!

Corals cannot move, but can fight! Look around the colonies. When different species are close together they may fight to keep their space!

Coral anatomy
Defense and aggression

- Sweeper tentacles
- Mesenterial filaments

Corals cannot move, but can fight! Look around the colonies.
When different species are close together they may fight to keep their space!

Corals are sessile organisms and therefore cannot run to avoid predation or find another place with more space to grow. However, they have other defense mechanisms to deal with these problems.

- About 70% of corals are toxic to fish
- Stinging cnidocytes (nematocysts)
- **Sweeper Tentacles**: Longer than usual tentacles full of nematocysts.
- **Mesenterial Filaments**: filaments can kill or devour other coral polyps through a process similar to digestion

Coral anatomy
Defense and aggression

Corals cannot move, but can fight! Look around the colonies. When different spp. are close together they may fight to keep their space!

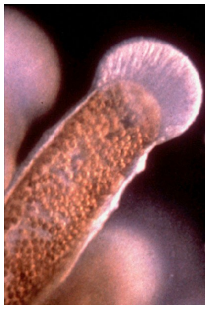
Coral aggression generally happens at night and that is why we normally do not see the sweeper tentacles or mesenterial filaments on action.

However, you can see the patches of dead tissue between coral colonies that are very close together.

Coral nutrition

- Corals eat plankton

- Get carbohydrates and amino acids from Zooxanthellae (Up to 95% of the photosynthesis products are translocated to the coral)



Corals acquire energy from a variety of sources, but are very dependent on the food transferred from the algae.

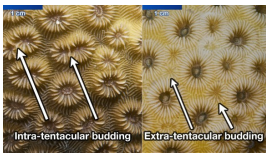
- Up to 95% of the inorganic carbon fixed by zooxanthellae is translocated to the coral host.
- That is supplemented by opportunistic heterotrophic feeding:
  - Capture food (tentacles grab passing food items and pass to the mouth, where they are ingested)
  - Ciliary feeding (the mucus sheath covering the coral traps tiny organic particles which are wafted to the mouth by small hairs called cilia).
  - Take up dissolved organics from the water.

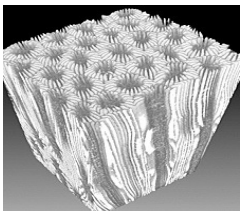
In turn, the zooxanthellae receive inorganic nutrients from the coral host, which are passed along to the zooxanthellae as animal waste products.

Since most of the energy in the coral diet is coming from the zooxanthellae, corals are very dependent on the algae photosynthates (carbohydrates and amino acids).

Coral growth and reproduction

Corals “widen” their surface by dividing their polyps.





Get “taller” by calcifying under the coral tissue.

Reproduce asexually through fragmentation

Reproduce sexually by releasing gametes

Reproduction is the process by which new individuals are formed. In colonial organisms like corals, the limit between growth and reproduction it is not always clear.

- Corals grow in height by calcifying and producing “new floors” or layers in their skeleton.
- Also grow in width by producing new polyps, which is a form of asexual production at the same time
- May reproduce asexually by the fragmentation of parts of the colony, that later survive and become a new colony.
- Reproduce sexually with the release of gametes into the water.

Asexual reproduction:
1. New polyps formation

A coral colony expands through the formation of new polyps. However, if you think about a polyp as an individual (remember they are sort of independent), the process of **budding** is more of a case of asexual reproduction in which a new “individual” is formed, as a copy of its predecessors.

Budding may occur inside a polyp. In that case, one polyp grows laterally to widen and then narrows in the middle, dividing that polyp in two identical ones. This is call **intratentacular** budding.

In the **extratentacular** budding, a parent polyp produces a new polyp, external to the wall. The new one tends to be smaller than its neighbors

Asexual reproduction:
1. New polyps formation

What kind of budding do brain corals have?

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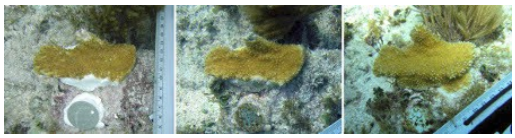
Asexual reproduction:
2. Fragmentation

Fragmentation may occur naturally by wave action, storms or by the other animals

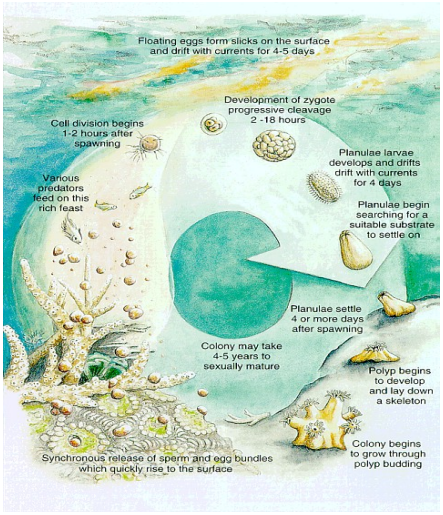


Corals may reproduce through the survival of fragments generated when branching colonies are broken off as a result of wave action, storms or animal activities.

Fragmentation is also possible in massive species where fish like triggerfish may generate pieces of coral after they bite.

Since coral pieces may keep growing and develop as a new colony, especially if it attaches quickly to the substrate, many coral restoration programs intentionally fragment and stabilize colonies to later on transplant them back into the reefs.

Sexual reproduction
1. Broadcast Spawning



There are two types of sexual reproduction in corals: Broadcast spawning and brooding.

Both of them include:

- Gamete development (inside the colony)
- Gamete release
- Fertilization (internal or external)
- Embryonic and larval development
- Dispersal
- Settlement: The larvae attaches to hard substrate
- Metamorphosis

In **broadcast** species, large quantities of male and female gametes are released to the water column at the same time. Eggs and sperm fertilize in the water, forming larvae that will disperse until they are ready to settle. Since the eggs are released into the water, coral spawning events occur on some particular nights per year with high synchronization achieved from multiple environmental cues as to time of the year (water temperature, and tidal and lunar cycles).

During massive events, trillions of eggs and sperm are simultaneously released into the water in such quantities that can be observed from the air.

Sexual reproduction
2. Brooders

Most of the corals are broadcast spawners, but a quarter of coral species are brooders. In this case, only male gametes are released into the water column.

Male gametes are negatively buoyant and are transported by the current before sinking. Meanwhile, female coral polyps containing egg cells are “catching” male gametes and “eating them.” Fertilization occurs inside the female polyp and the egg develops inside until it becomes a larva.

This larva is released later through the mouth of the female coral at an advanced stage of development so that it is capable of settling onto hard substrate very soon after its release.

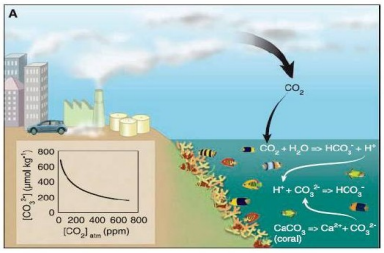
A difference from spawners that need huge synchronism, brooders show extended reproductive seasons from a few months to almost continuously throughout the year. In general, they produce bigger larvae that already contain zooxanthellae, contrary to broadcast spawners' larvae that generally take up their zooxanthellae after settlement.

Coral calcification and Ocean Acidification

Calcification is a very expensive process

- Massive corals: 0.5-1cm/year
- Branching corals (10-20cm/year)
- Growth rate depends upon environmental conditions (light, water chemistry, zooxanthellae community).

As anthropogenic CO_2 emissions are increasing the carbon in the ocean, that is changing the water chemistry of seawater, reducing coral skeletal growth.

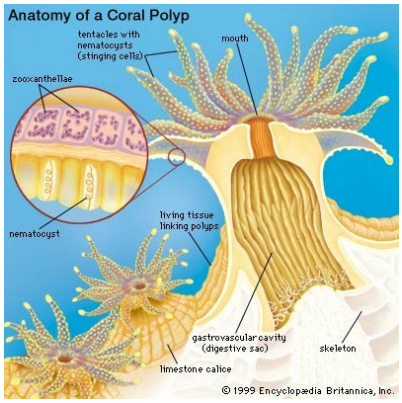


Calcification is the process whereby free Ca^{2+} and CO_3^{2-} ions dissolved in water combine to form the solid mineral calcium carbonate.

As a consequence, corals need to get and stick together a bunch of Ca^{2+} and CO_3^{2-} ions from the water to build their skeletons. With ocean acidification, the availability of CO_3^{2-} ions in the sea water is decreasing, making the process of calcification more expensive for the corals.

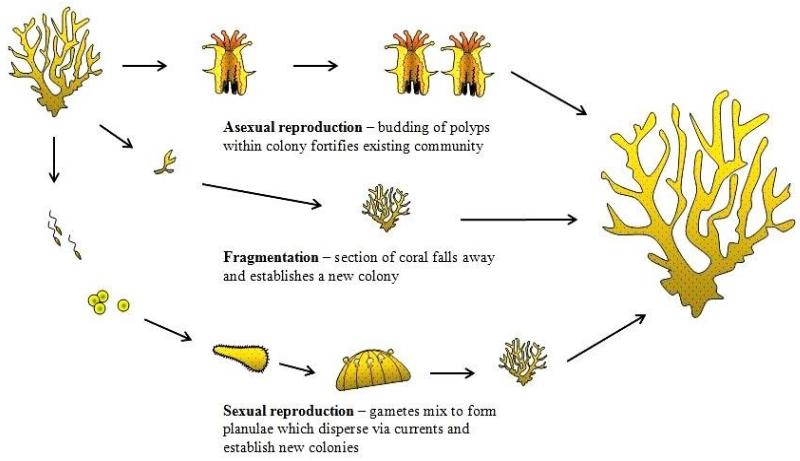
Since calcification is a very energy-expensive process, the energy derived from the symbiosis with zooxanthelle is very important. So, calcification is faster when the coral has a healthy symbiont community and enough light to power photosynthesis

Summary:
Coral definition and anatomy



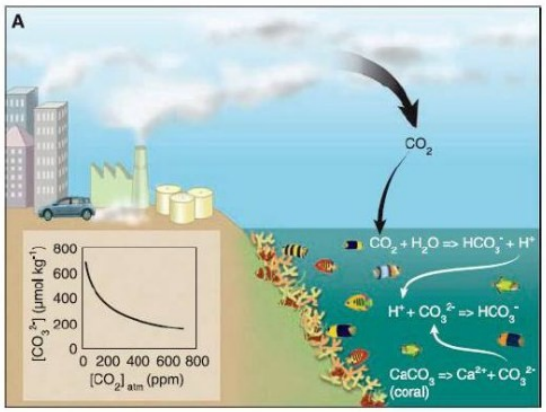
- Sessile marine animals in the phylum **cnidaria**
- Can have many different shapes and colors.
- Are **colonial** (formed by many polyps) each one with tentacles and a mouth
- Some of them fight with mesenterial filaments and sweeper tentacles
- They also harbor zooxanthellae, which provides most of the energy for the coral growth
- Stony corals calcify to form their skeletons.

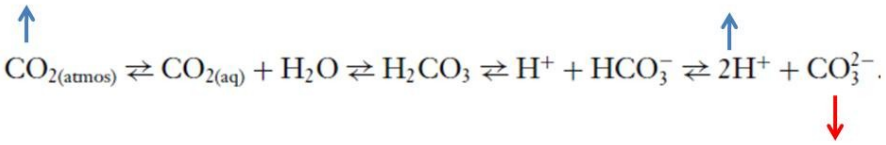
Summary: Coral reproduction



Extras for questions

Acidification and calcification




$CO_{2(atmos)} \rightleftarrows CO_{2(aq)} + H_2O \rightleftarrows H_2CO_3 \rightleftarrows H^+ + HCO_3^- \rightleftarrows 2H^+ + CO_3^{2-}.$