Queensland marine science syllabus guide

Unit 3 Marine systems - connections and change

Topic 1: The reef and beyond

Coral reef development

Topic 1: The reef and beyond

B. Coral reef development

T076 Coral groups

T077 Classify to genus

T078 Coral anatomy

T079 Coral limestone skeleton

T080 Coral feeding

T081 Coral symbiosis

T082 Coral life cycle

T083 Larval dispersal

T084 How reefs grow

T085 Abiotic factors affecting reef distribution

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Syllabus references

Marine Science

Unit 1
Oceanography

- Topic 1: An ocean planet
- Topic 2: The dynamic shore

Unit 2
Marine biology

- Topic 1: Marine ecology and biodiversity
- Topic 2: Marine environmental management

Unit 3
Marine systems — connections and change

- Topic 1: The reef and beyond
- Topic 2: Changes on the reef

Unit 4
Ocean issues and resource management

- Topic 1: Oceans of the future
- Topic 2: Managing fisheries

Classification of verbs – degree of difficulty

★	★★	★★★
calculate (e.g. numerical answer; mathematical processes)	analyse	appraise
clarify	apply	appreciate
comprehend (meaning)	categorise	argue
construct (e.g. a diagram)	classify	assess
define	compare	comment (make a judgment)
demonstrate	consider	conduct (e.g. investigations)
describe	contrast	construct (e.g. an argument)
document	critique	create (e.g. a unique product/ artefact; language texts; meaning)
execute	deduce	decide/determine
explain	derive	discuss/explore
identify	determine	evaluate
implement (e.g. a plan, proposal)	discriminate	experiment/test (e.g. ideas, methods)
recall	distinguish	generate/test (e.g. hypotheses)
recognise (e.g. features)	identify	investigate/examine
select	infer/extrapolate	justify/prove (e.g. an argument, statement or conclusion)
understand	interpret (e.g. meaning)	modify
use		predict (e.g. a result)

Approximate exam paper match

Unit 3: Marine systems – connections and change

Topic 1 The reef and beyond

B. Coral reef development						**Exam example**	
Power point titles		**Matching syllabus statements**				**School**	**Public**
T076	Three coral groups	T 76	Recall the three main groups of coral (i.e. Alcyonacea: soft corals, sea fans and Scleractinia: stony/hard corals)				P1. M/c Q25
T077	Classify to genus	T 77	Classify a specific coral to genus level only, using a relevant identification key			P2. S/a Q2	P1. M/c Q5
T078	Coral anatomy	T 78	Identify anatomy of typical reef-forming coral including skeleton, corallite, coelenteron, coral polyp, nematocyst, mouth and zooxanthellae				P2. S/a Q2
T079	Coral limestone skeleton	T 79	Recall that the limestone skeleton of a coral is built when calcium ions [Ca2+] combine with carbonate ions [CO_3^{2}–]			P1. M/c Q9 P2 S/a Q7	
T080	How corals feed	T 80	Describe the process of coral feeding (including night-feeding patterns and the function of nematocysts)			P1. M/c Q17	
T081	Coral symbiosis	T 81	Identify and describe the symbiotic relationships in a coral colony (including polyp interconnections and zooxanthellae)			P1. M/c Q1	
T082	Coral life cycle	T 82	Recall the life cycle stages of a typical reef-forming hard coral (asexual: fragmentation, polyp detachment; sexual: gametes, zygotes, planulae, polyp/asexual budding)				P1. M/c Q13
T083	Laval dispersion	T 83	Explain the process of larval dispersal, site selection, settlement and recruitment				P2. S/a Q4
T084	How corals grow	T 84	Explain that growth of reefs is dependent on accretion processes being greater than destructive processes			P1. M/c Q6	
T085	Assess reef data	T 85	Assess data of abiotic factors (e.g. dissolved oxygen, salinity, substrate) that affect the distribution of coral reefs.				P1. M/c Q4

T076 Coral groups

Adam Richmond

Syllabus statement

At the end of this topic you should be able to ...

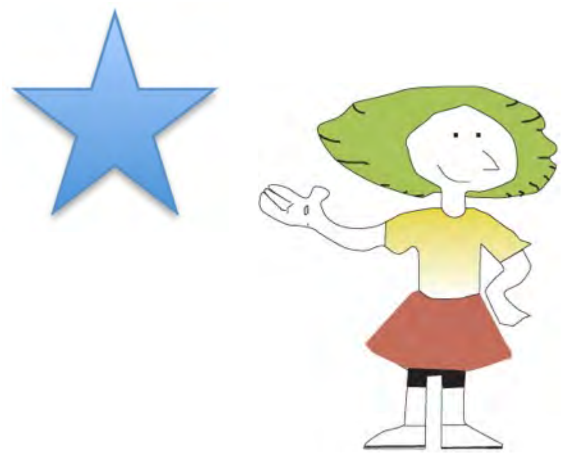
Recall

the following groups of coral: Alcyonacea 'soft corals'

and

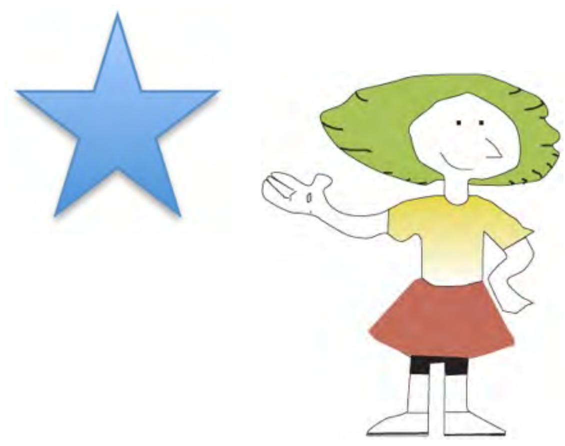
the two morphological groups within Scleractinia 'hard corals'

- reef-forming/ hermatypic and
- non-reef forming/ ahermatypic



Recall

- remember; present remembered ideas, facts or experiences;
- bring something back into thought, attention or into one's mind



Objectives

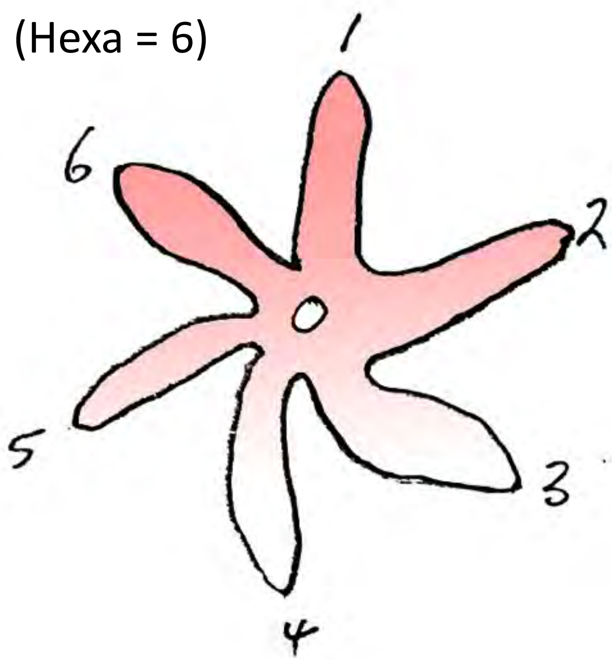
To recall

- the main groups of corals.
- two main types of hard corals.

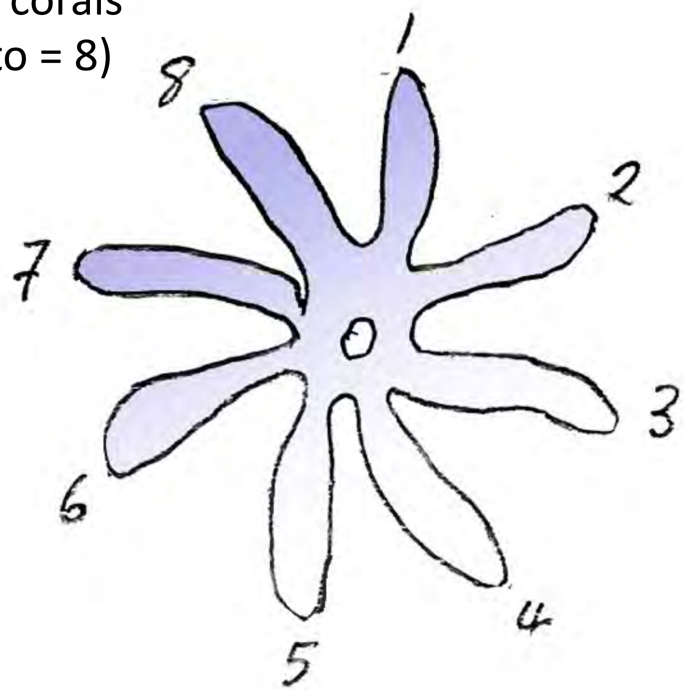
Coral classification

There is a multitude of different kinds of coral on the Great Barrier Reef, including hundreds of species of both hexacorals (hard corals) and octocorals (sea pens, blue corals, soft corals and sea fans).

Hard corals
(Hexa = 6)



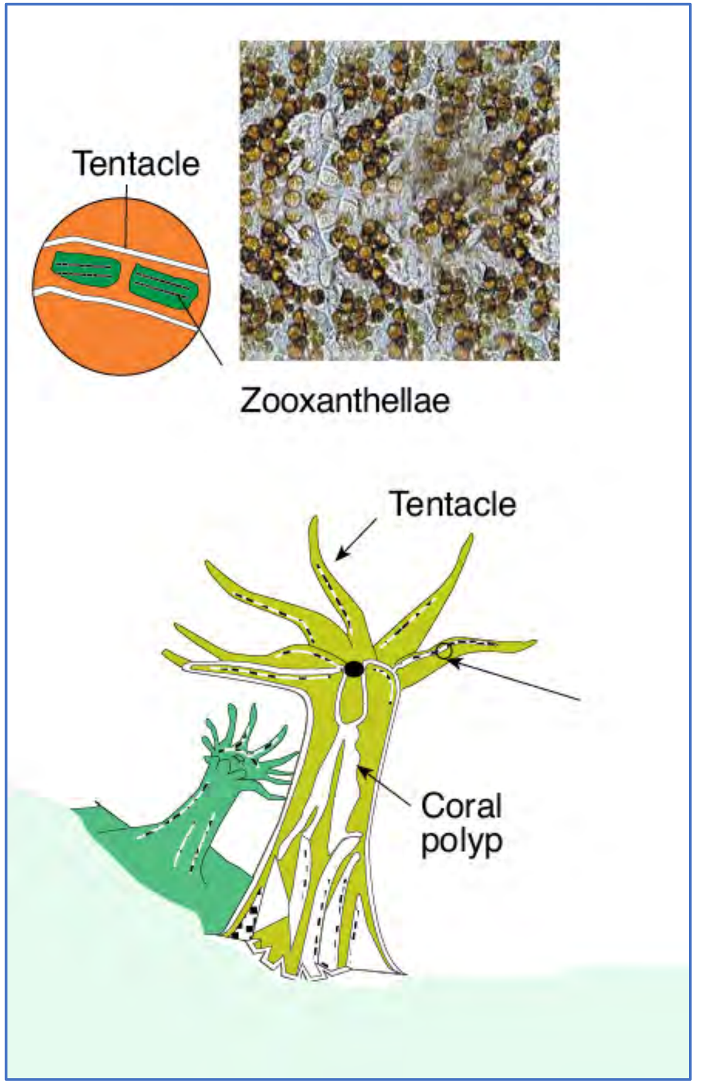
Soft corals
(Octo = 8)



Hard corals can be further separated into two sub-groups[1].

- The **zooxanthellate** (reef-building or **hermatypic**)
  - corals are ones that depend on *zooxanthellae* algae for nutrients.
  - they are shallow water corals having a major reef-building function and are generally found in clear water less than 50 metres deep as the algae need light for photosynthesis.

- The **azooxanthellate** (deep water or **ahermatypic**) corals that do not contain zooxanthellae and therefore gain their nutrition solely from filtering plankton from seawater.
  - they are usually isolated, solitary or colonial forms which rarely build big constructions
  - many of these coral species are present in non-reef environments in coastal areas such as Moreton Bay in Queensland.



1
Queensland Museum, Creative common
http://www.qm.qld.gov.au/microsites/biodiscovery/03sponges-and-corals/types-of-corals.html

Coral classification

Phylum Cnidaria	Radially symmetrical animals with cnidocytes
Class Anthozoa	anemones, corals with polyps
Subclass Ceriantharia	tube anemones
Subclass Hexacorallia	6-fold symmetry:
Order Actiniaria	sea anemones
Order Antipatharia	black corals
Order Corallimorpharia	corallimorphs
Order Rugosa (extinct)	rugose corals
Order Scleractinia	stony corals
Order Zoantharia	zoanthids
Subclass Octocorallia	8-fold symmetry:
Order Alcyonacea	soft corals
Order Helioporacea	blue corals
Order Pennatulacea	sea pens
Class Cubozoa	box jellyfish
Class Hydrozoa	hydroids and bluebottles
Class Myxozoa	parasitic
Class Scyphozoa	jellyfish
Class Staurozoa	stalked jellyfish

Hard and soft corals

Phylum Cnidaria		Radially symmetrical animals with cnidocytes
Class Anthozoa		anemones, corals with polyps
Subclass Ceriantharia		tube anemones
Subclass Hexacorallia	**Hard corals are in this Subclass**	6-fold symmetry:
Order Actiniaria		sea anemones
Order Antipatharia		black corals
Order Corallimorpharia		corallimorphs
Order Rugosa (extinct)		rugose corals
Order Scleractinia		stony corals
Order Zoantharia		zoanthids
Subclass Octocorallia	**Soft corals are in this Subclass**	8-fold symmetry:
Order Alcyonacea		soft corals
Order Helioporacea		blue corals
Order Pennatulacea		sea pens
Class Cubozoa		box jellyfish
Class Hydrozoa		hydroids and bluebottles
Class Myxozoa		parasitic
Class Scyphozoa		jellyfish
Class Staurozoa		stalked jellyfish

Hard and soft corals

Phylum Cnidaria	Radially symmetrical animals with cnidocytes
Class Anthozoa	anemones, corals with polyps
Subclass Ceriantharia	tube anemones
Subclass Hexacorallia	6-fold symmetry:
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Order Antipatharia	black corals
Order Corallimorpharia	corallimorphs
Order Rugosa (extinct)	rugose corals
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Order Pennatulacea	sea pens
Class Cubozoa	box jellyfish
Class Hydrozoa	hydroids and bluebottles
Class Myxozoa	parasitic
Class Scyphozoa	jellyfish
Class Staurozoa	stalked jellyfish

Hard corals are in this Subclass and this Order (Subclass Hexacorallia, Order Scleractinia)

Soft corals are in this Subclass and this Order (Subclass Octocorallia, Order Alcyonacea)

Soft corals

Soft corals are in Order Alcyonacea and are referred to as alcyonacean corals.

Subclass Octocorallia	colonial corals with 8-fold symmetrical polyps
Order Alcyonacea	Soft corals (and gorgonians)
Order Helioporacea	Helioporacea (blue corals) have an calcium skeleton
Order Pennatulacea	Sea pens

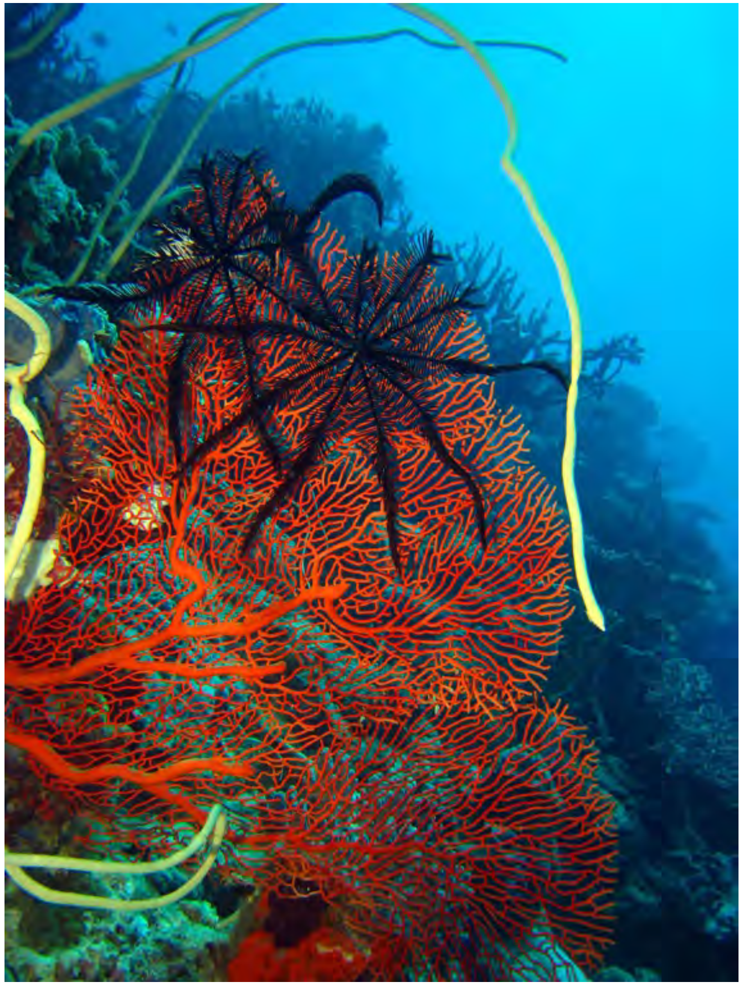
A soft coral with tentacles fully extended
Image: K. Anthony, Copyright Commonwealth of Australia (GBRMPA) 120854

Soft corals are often brightly coloured.
Their polyps have 8 feathery tentacles.

Soft corals have calcified spicules for support and to deter predators.

Soft corals are not considered to be reef building corals because they do not produce a hard calcium carbonate skeleton.

The spicules are visible in this soft coral



Gorgonian corals are now part of the Order Alcyonacea

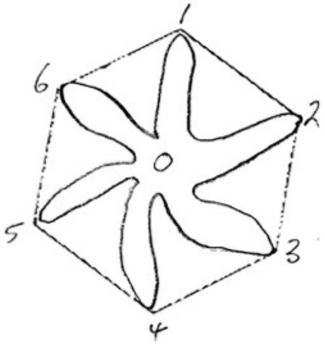
Hard corals

Hard or stony corals are in Order Scleractinia and are referred to as scleractinian corals.

Subclass Hexacorallia	6-fold symmetry:
Order Actiniaria	sea anemones
Order Antipatharia	black corals
Order Corallimorpharia	corallimorphs
Order Rugosa (extinct)	rugose corals
Order Scleractinia	stony corals
Order Zoantharia	zoanthids

Image:K. Anthony, Copyright Commonwealth of Australia (GBRMPA) 130137

Hard corals polyps have six (or multiples of six) smooth tentacles, such as this *Goniopora sp.*

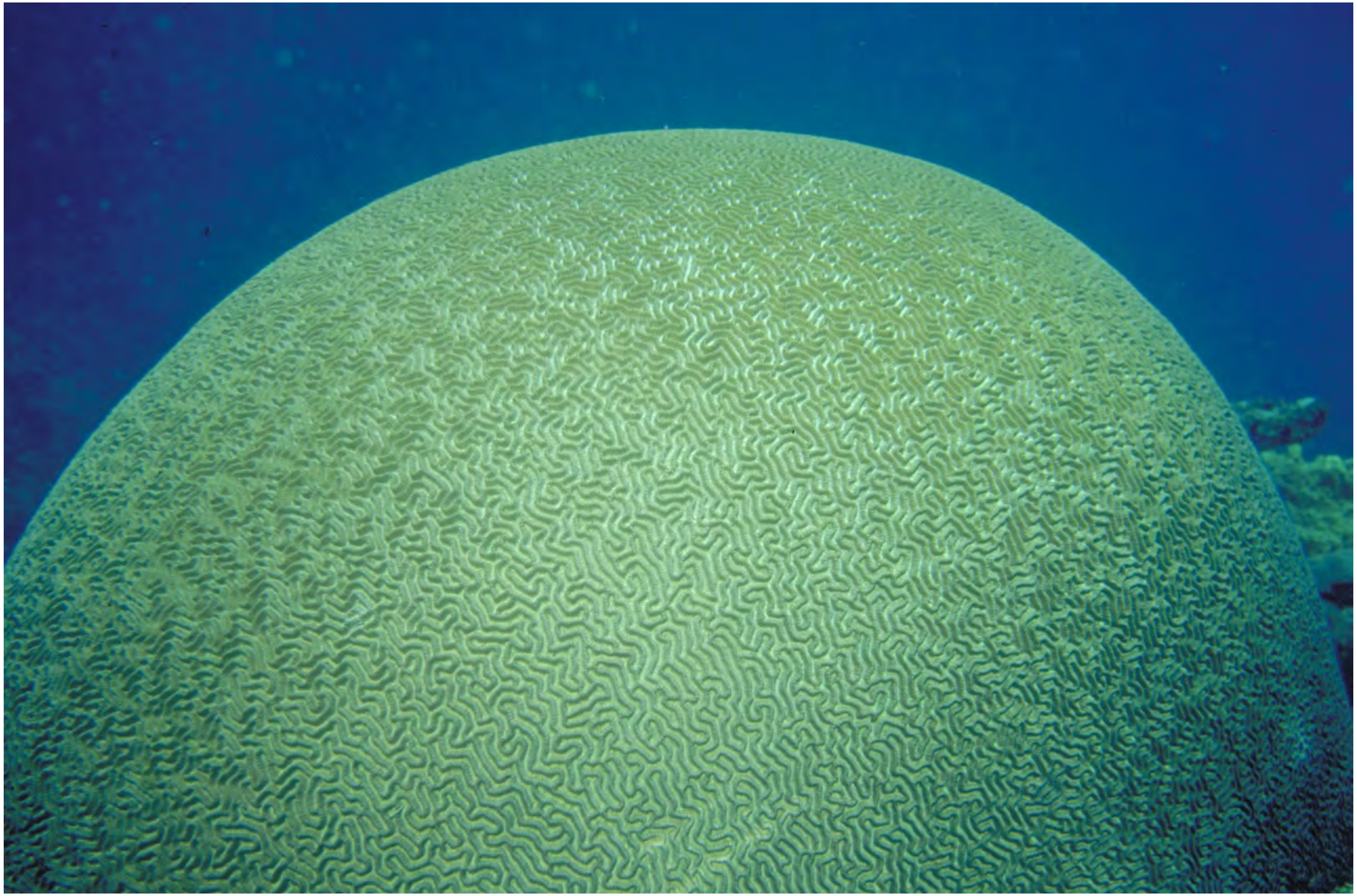


In most cases, a hard coral consists of hundreds, thousands or even millions of individual coral polyps living together as a colony.

Colonies of hard corals produce limestone skeletons to support themselves, which then act as building blocks for the reef.

Common types of hard coral include brain coral and staghorn coral.

Brain coral



D. Wachenfeld, Copyright Commonwealth of Australia (GBRMPA) 119059

Staghorn coral

K. Anthony, Copyright Commonwealth of Australia (GBRMPA) 129825

Hermatypic and ahermatypic corals

There are two further categories of Scleractinian (hard) corals.

Hermatypic corals are those corals that deposit calcium carbonate, which can form a reef. They are also known as **reef-forming** corals.

Ahermatypic corals do not contribute to reef development and are **non-reef forming** corals.

Hermatypic	Ahermatypic
Reef-forming	**Non reef-forming**
Are present on coral reefs	Are present on coral reefs
Many have zooxanthellae and live in warm shallow water	Many have zooxanthellae and live in warm shallow water
Mostly colonial, some are solitary	Solitary or colonial
Some species live on cold, dark, deep-water reefs and have no zooxanthellae	Some species live on cold, dark, deep-water reefs and have no zooxanthellae
Hermatypic coral species living in “marginal” environments can deposit calcium carbonate, yet not build a reef.	

Comparison of Hermatypic and Ahermatypic corals

The term "hermatypic" is sometimes misused, to apply to all corals with symbiotic zooxanthellae.

About 50% of corals with zooxanthellae are reef-building, and some reef-building corals do not have zooxanthellae.

FURTHER
See Schuhmacher, H. & Zibrowius, H. Coral Reefs (1985) 4: 1.

https://doi.org/10.1007/BF00302198 for more information

Video

https://youtu.be/s7-GrlnCaf0

This video discusses carbonate and non carbonate coral reefs, deep water mesophotic reefs and more:

You don't need to remember it all!
We will revisit the calcium carbonate content soon.

Stop after 3:30 or wait until T079 when this video features again!

UQx TROPIC101x 2.2.3 Types of Reefs

Questions

1. What are the main groups of corals?

2. What are the two main types of hard corals?

3. Which one of these is reef-forming?

Image: C. Jones, Copyright Commonwealth of Australia (GBRMPA) 141458

Further activities

See

https://coralwatch.org/index.php/education-2/curriculum-materials/marine-science/

by

CORALWATCH

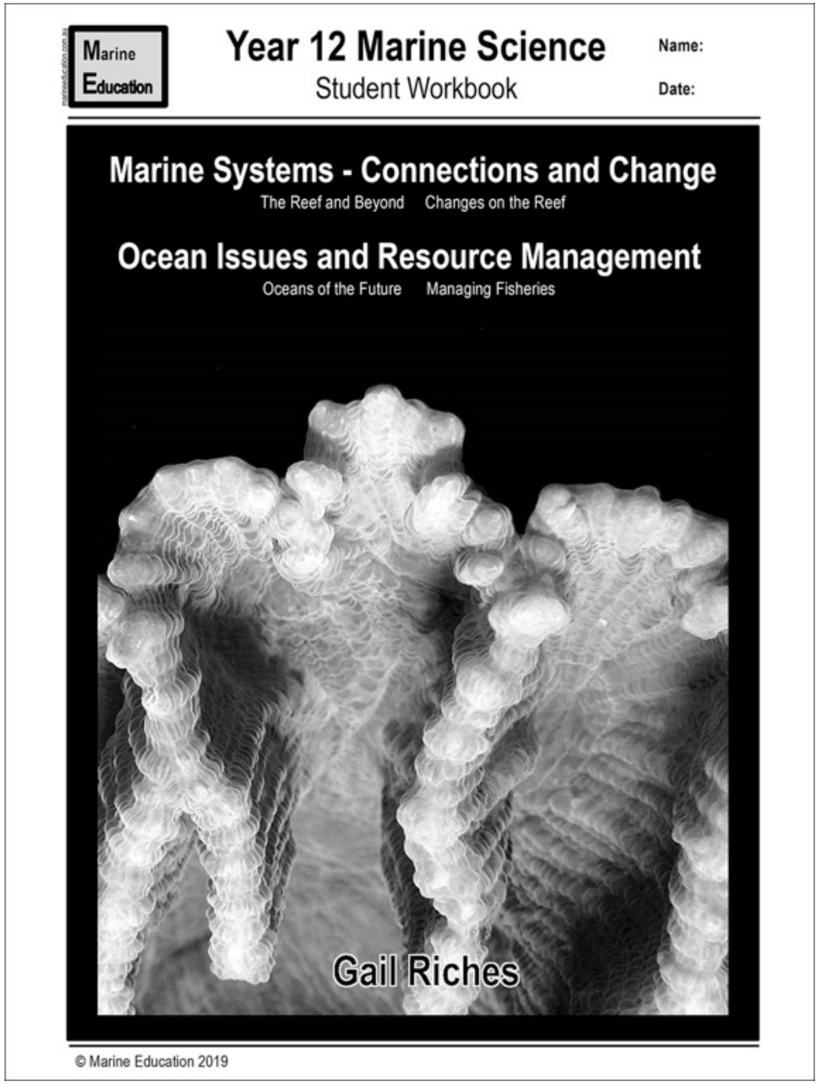
Worksheet

Coral Classification

by

Gail Riches

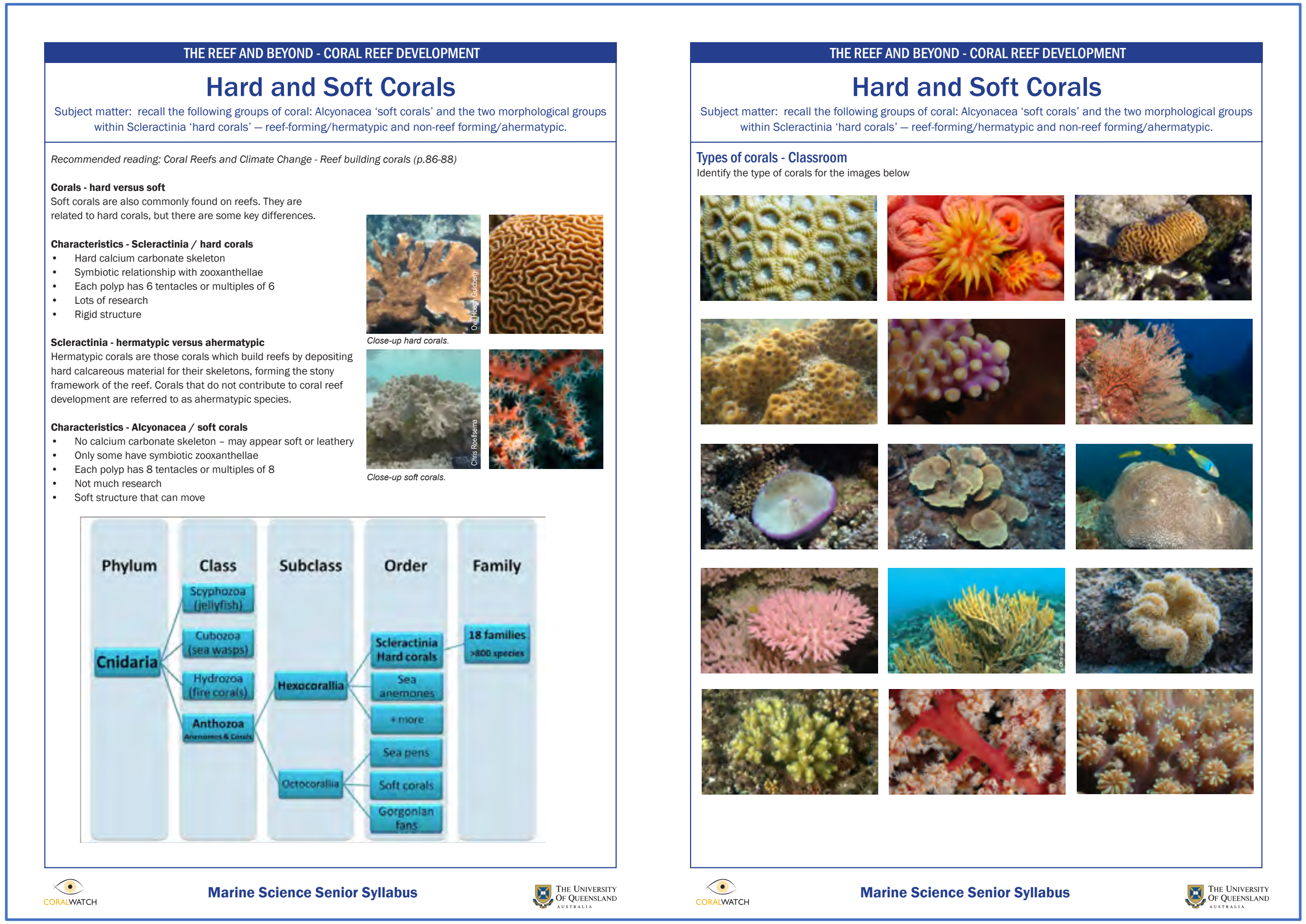
www.marineeducation.com.au



Example

Worksheet –

Hard and Soft corals


THE REEF AND BEYOND - CORAL REEF DEVELOPMENT

Hard and Soft Corals

Subject matter: recall the following groups of coral: Alcyonacea 'soft corals' and the two morphological groups within Scleractinia 'hard corals' — reef-forming/hermatypic and non-reef forming/ahermatypic.

Recommended reading: Coral Reefs and Climate Change - Reef building corals (p.86-88)

Corals - hard versus soft
Soft corals are also commonly found on reefs. They are related to hard corals, but there are some key differences.

Characteristics - Scleractinia / hard corals
- Hard calcium carbonate skeleton
- Symbiotic relationship with zooxanthellae
- Each polyp has 6 tentacles or multiples of 6
- Lots of research
- Rigid structure

Scleractinia - hermatypic versus ahermatypic
Hermatypic corals are those corals which build reefs by depositing hard calcareous material for their skeletons, forming the stony framework of the reef. Corals that do not contribute to coral reef development are referred to as ahermatypic species.

Characteristics - Alcyonacea / soft corals
- No calcium carbonate skeleton – may appear soft or leathery
- Only some have symbiotic zooxanthellae
- Each polyp has 8 tentacles or multiples of 8
- Not much research
- Soft structure that can move

Close-up hard corals.

Close-up soft corals.

CORALWATCH Marine Science Senior Syllabus THE UNIVERSITY OF QUEENSLAND AUSTRALIA

THE REEF AND BEYOND - CORAL REEF DEVELOPMENT

Hard and Soft Corals

Subject matter: recall the following groups of coral: Alcyonacea 'soft corals' and the two morphological groups within Scleractinia 'hard corals' — reef-forming/hermatypic and non-reef forming/ahermatypic.

Types of corals - Classroom

Identify the type of corals for the images below

CORALWATCH Marine Science Senior Syllabus THE UNIVERSITY OF QUEENSLAND AUSTRALIA


T077 Classify to genus
Adam Richmond

Syllabus statement

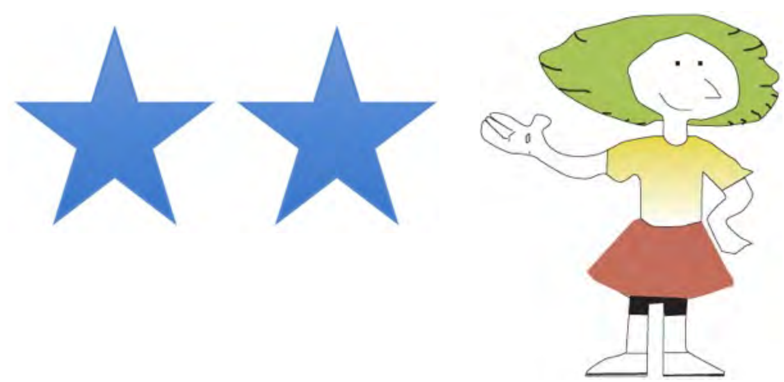
At the end of this topic you should be able to ...

Classify

Place in or assign to a particular class or group;

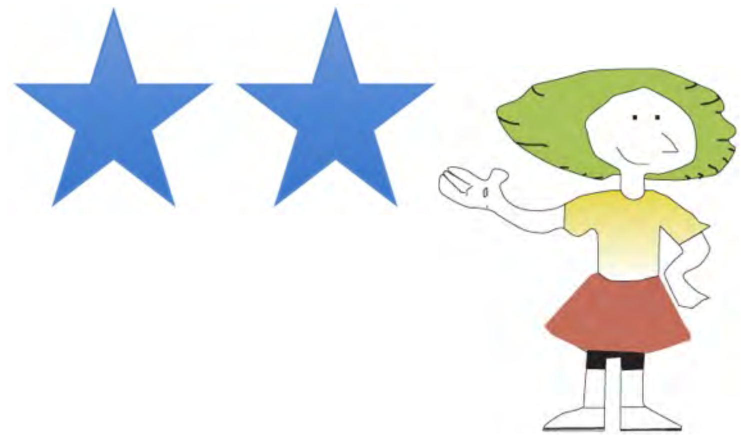
Arrange or order by classes or categories;

Classify, sort out, sort, separate



Classify

Place in or assign to a particular class or group;
Arrange or order by classes or categories;
Classify, sort out, sort, separate



Objective

Classify a specific coral to genus level only, using a relevant identification key.

Coral growth forms

Introductory video

https://youtu.be/SFdmIQe-gLQ

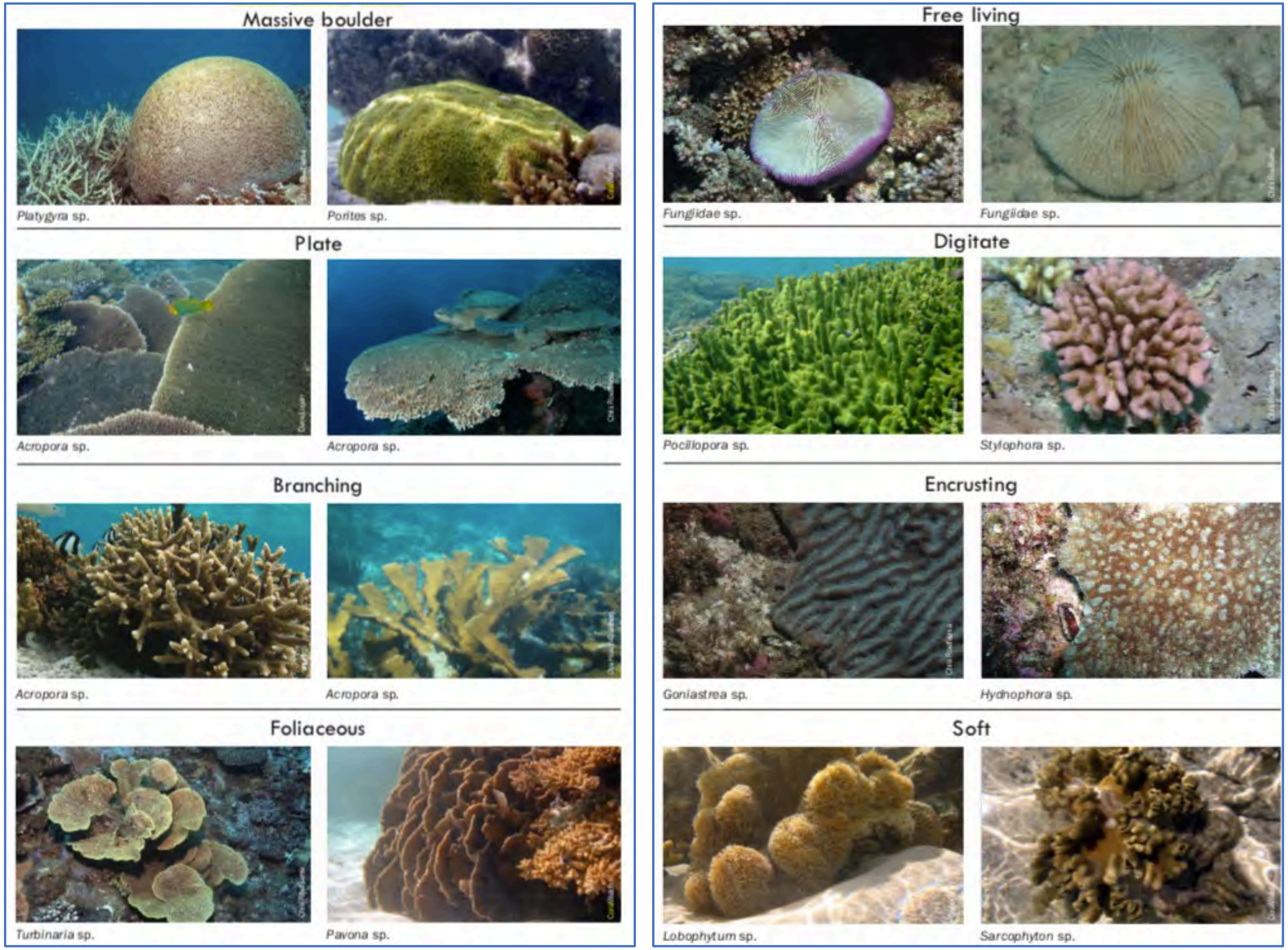
UQx TROPIC101x 2.2.2 Coral Growth Forms

UQx Tropic101x Tropical Coastal Ecosystems, Creative Commons Attribution license,
https://youtu.be/SFdmIQe-gLQ

Coral classification

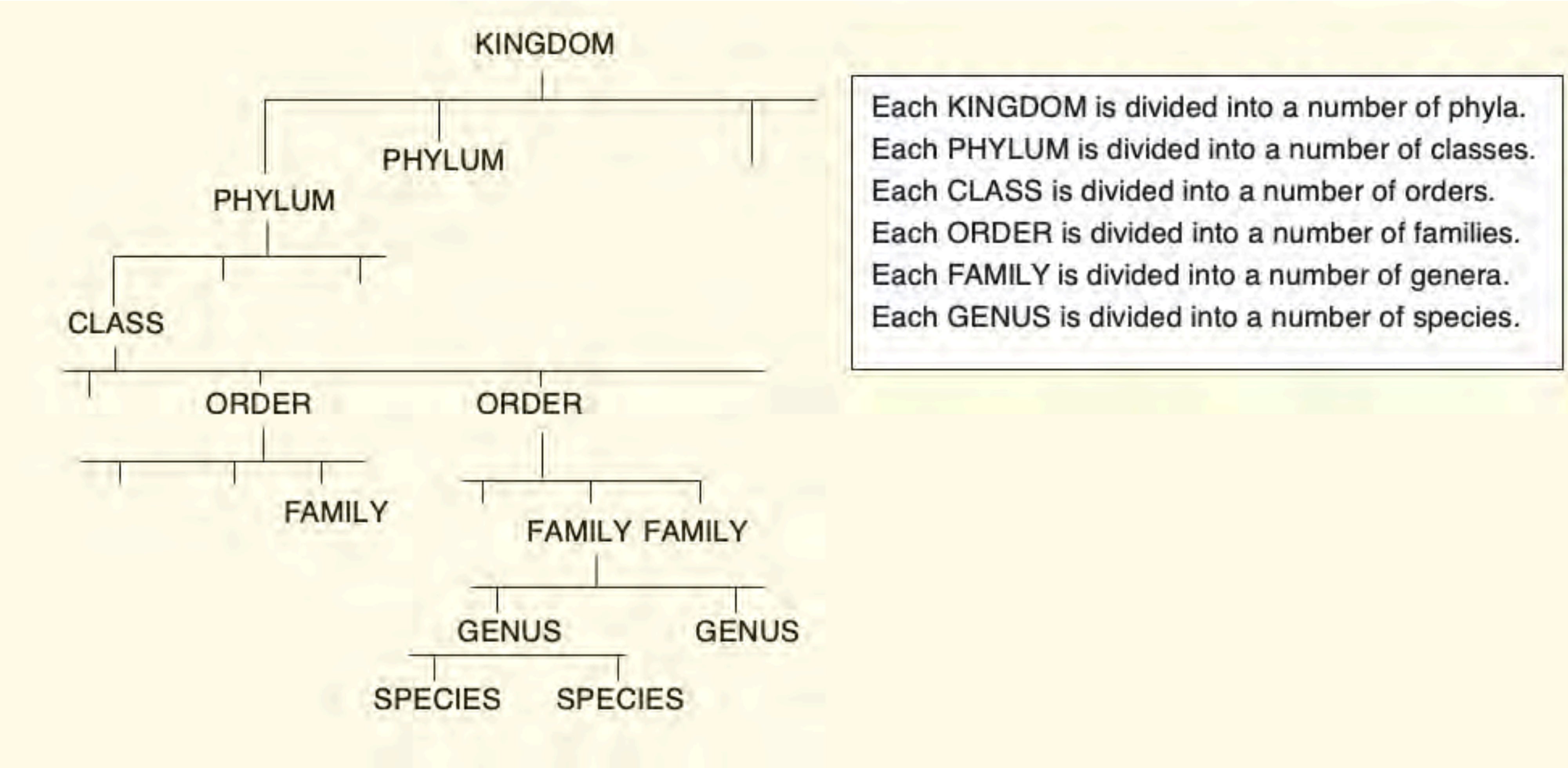
Coral classification in the field is usually based on morphology rather than genus.

There are many growth forms including boulder, plate, branching and soft.



Coral growth forms

Coral taxonomy



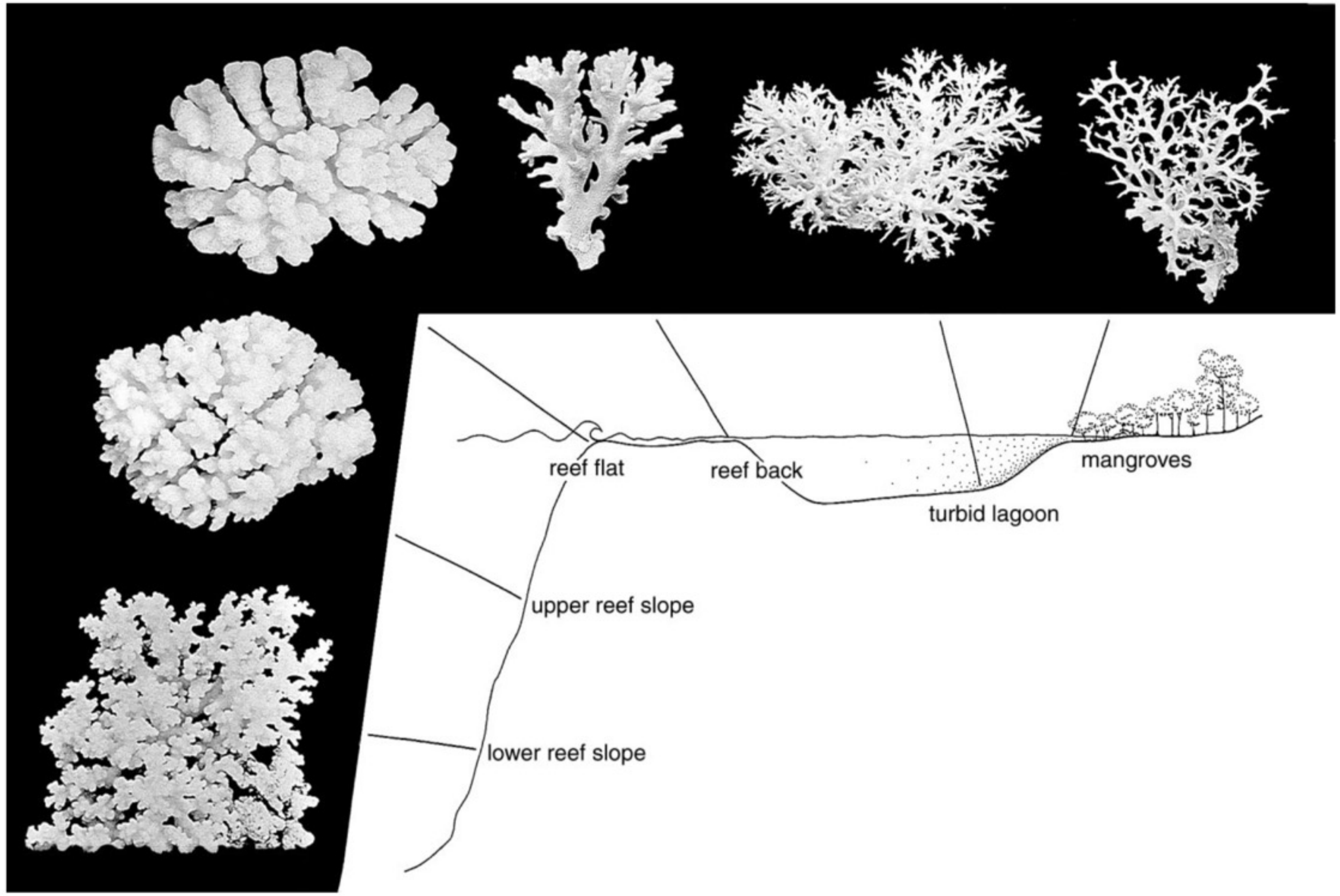
The taxonomic hierarchy of classification systems

Identifying corals to species level is difficult for a variety of reasons, including a lack of type specimens.

Corals are sometimes identified in the field, sometimes by skeletons, and more recently by molecular taxonomy.

Furthermore, the same species can look significantly different in different habitats.

And then there's over 400 species of hard corals in the Great Barrier Reef region.



Variation in *Pocillopora damicornis*

Image: Veron, J. (2013). Overview of the taxonomy of zooxanthellate Scleractinia. *Zoological Journal Of The Linnean Society*, *169*(3), 485-508. doi: 10.1111/zoj.12076 CC 3.0 BY NC SA

Identifying coral

Here is the most accurate way:

Learn all the corals of the world, by reading this book.

Or by visiting this website:
http://www.coralsoftheworld.org

Either way is difficult because you have to know (or guess) which coral you have in order to look it up.

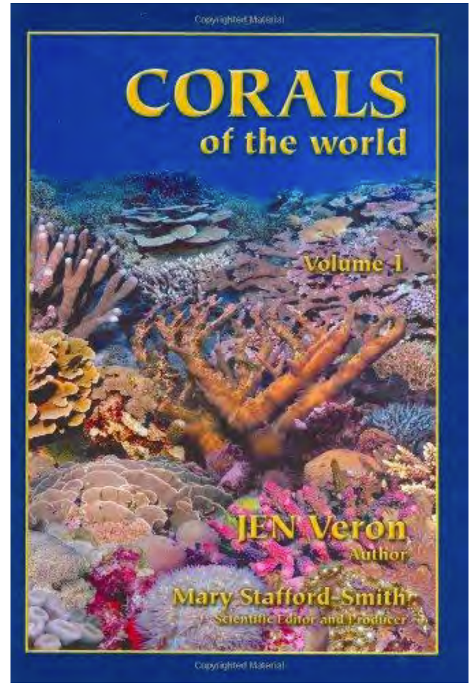


Image: Stock photo, AbeBooks.co.uk

Image: From http://www.coralsoftheworld.org/species_factsheets/species_factsheet_summary/favia-speciosa/

Using a field guide is much simpler.

This only works if someone has already identified the corals that occur in your local area.

CoralWatch have produced this field guide to common corals in Moreton Bay.

Download a copy here:

https://coralwatch.org/wp-content/uploads/2018/12/MB-coral-ID-guide_2017.pdf

Coral Finder 3.0

Coral Finder 3.0 is a user-friendly way to identify corals to genus level using a simple visual key to narrow your target coral to a key group, then refining the selection.

This guide will help identify the most common Scleractinian corals in the Indo-Pacific region.

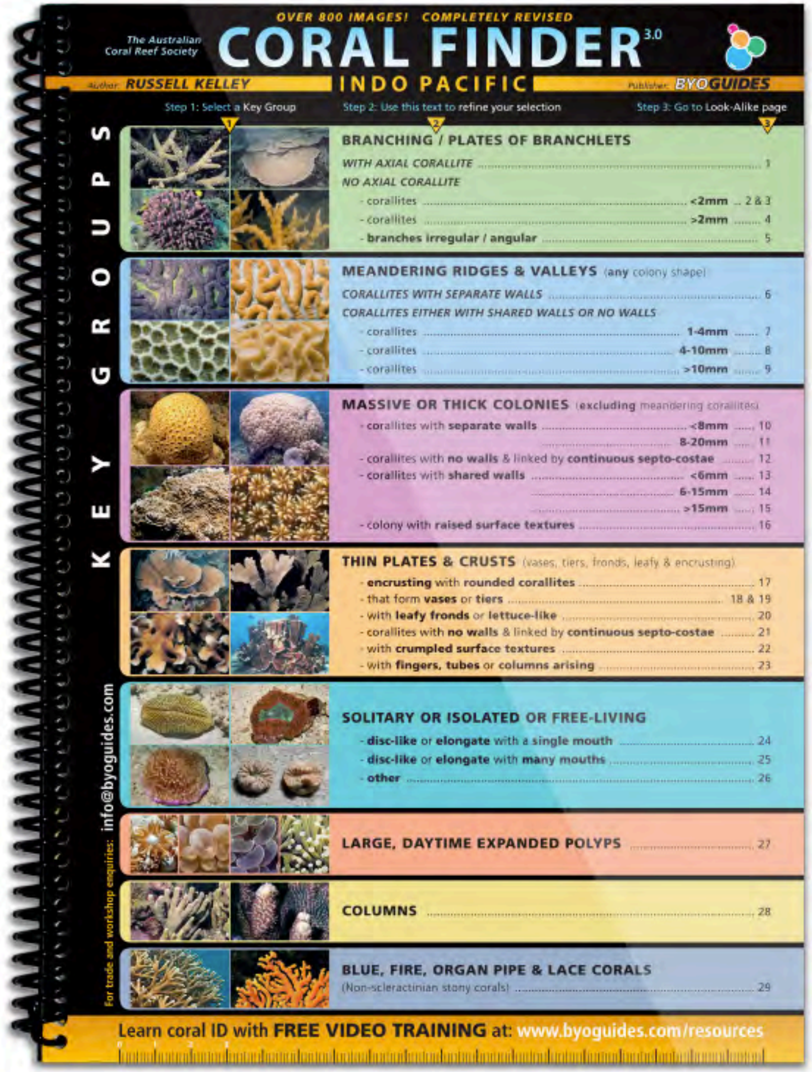


Image: Courtesy Russell Kelley, www.byoguides.com

CoralWatch have created this field guide to common genera at Heron Island

Download a copy here:
https://coralwatch.org/wp-content/uploads/2018/11/F5_Identifying-coral-types_CoralWatch_Yr7Science.pdf

Watch this video on coral finder 3.0

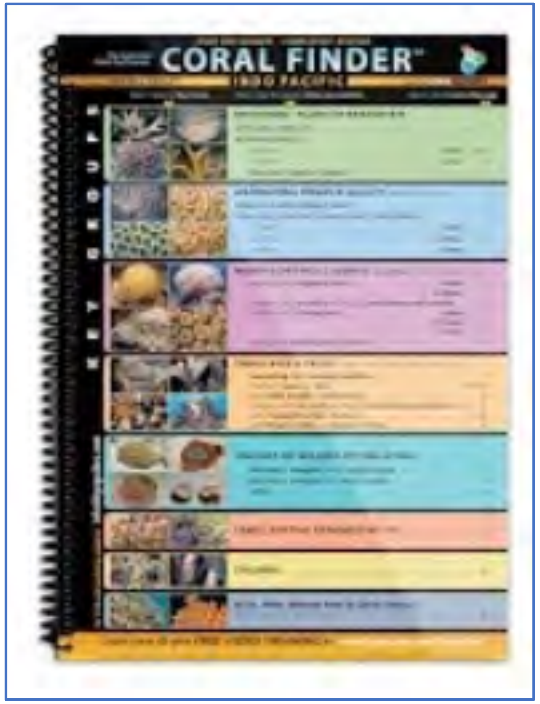


Image copyright: Courtesy Russell Kelley, www.byoguides.com

Video available on YouTube

https://youtu.be/ZS8vRGTw58w

Please note there is a full video training course at:

https://www.byoguides.com/resources/coral-finder-resources

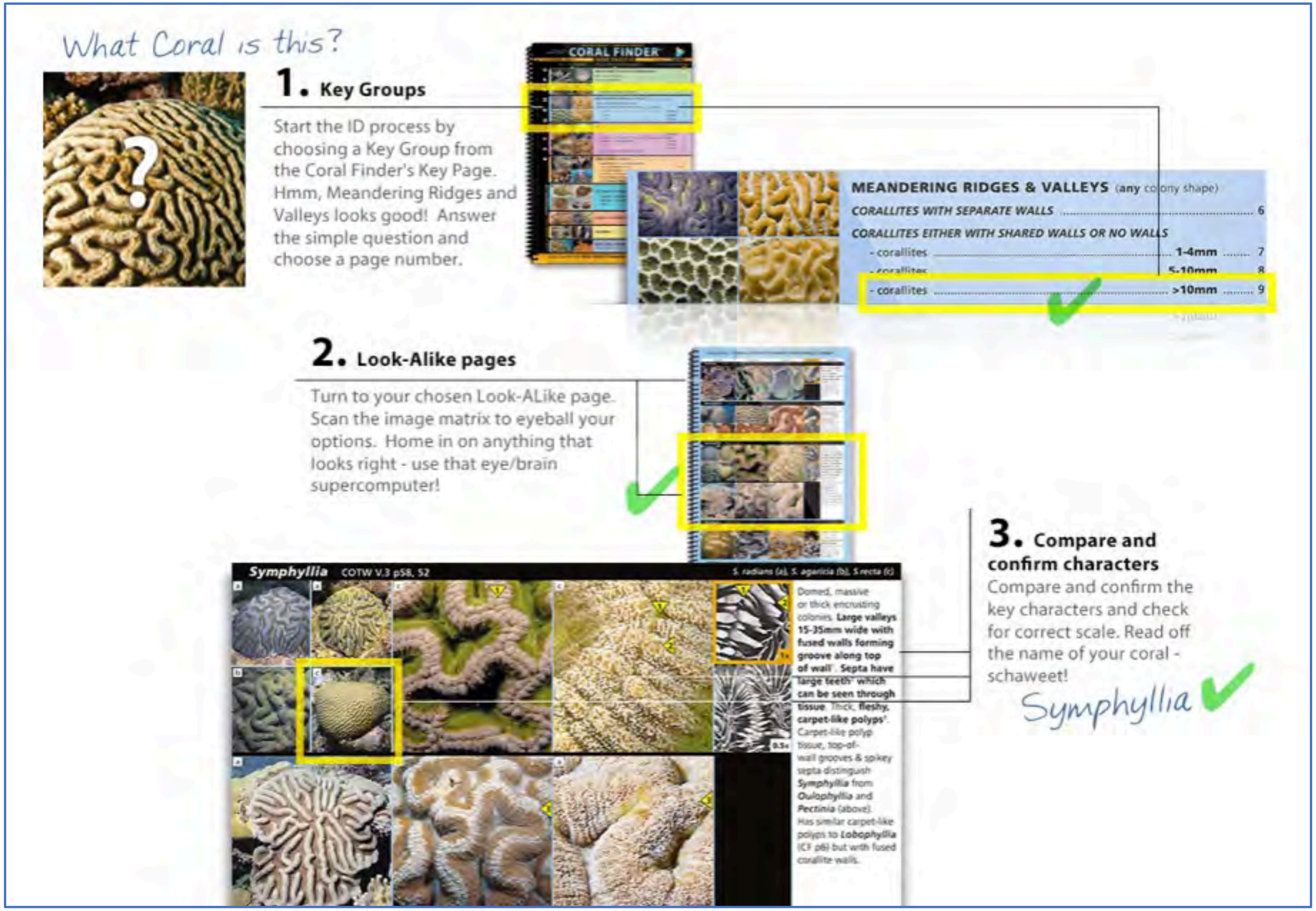
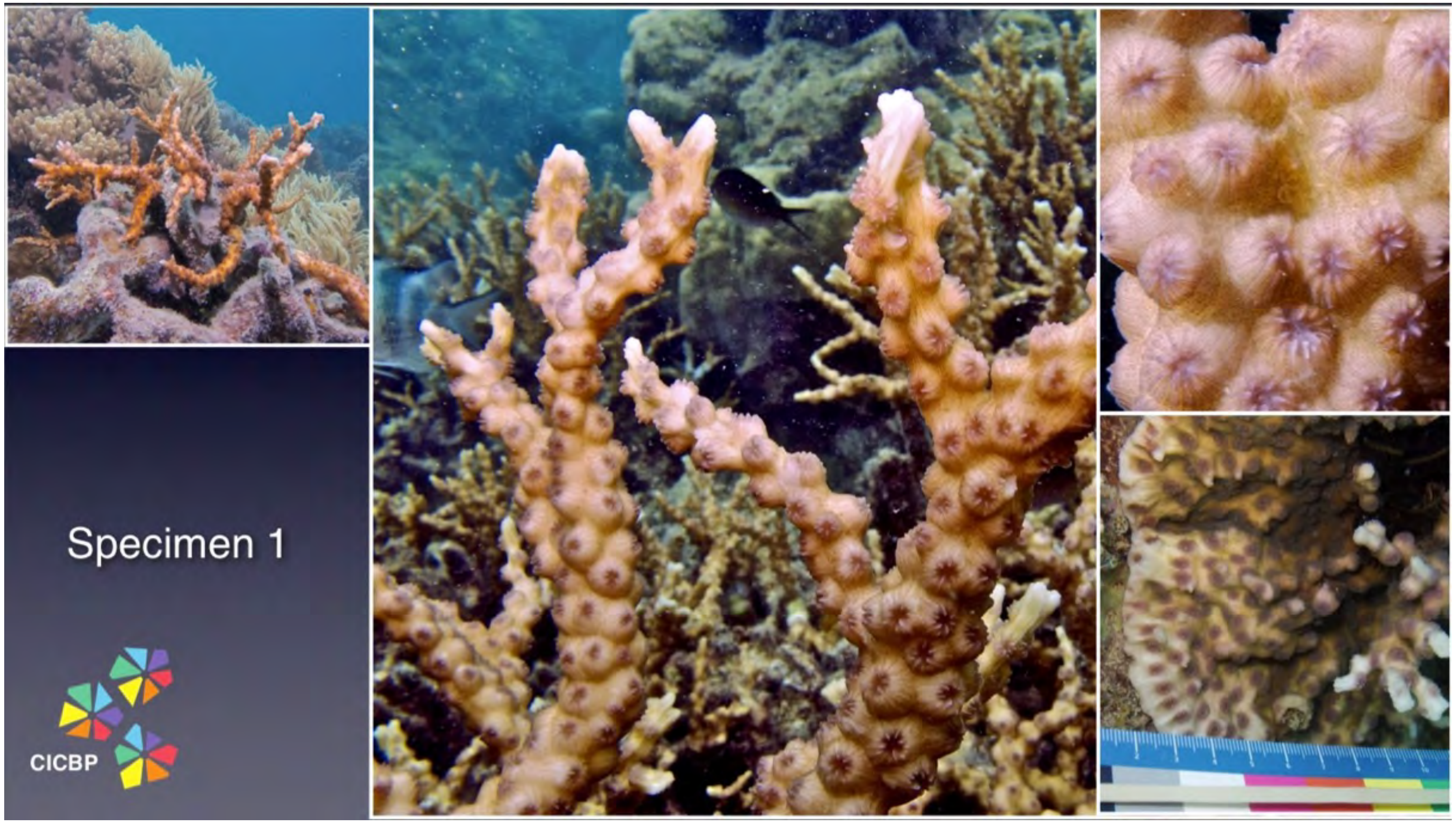


Image copyright: Courtesy Russell Kelley, www.byoguides.com

There are a range of resources available at the BYO guides webpage, including high quality images to test your coral identification skills.



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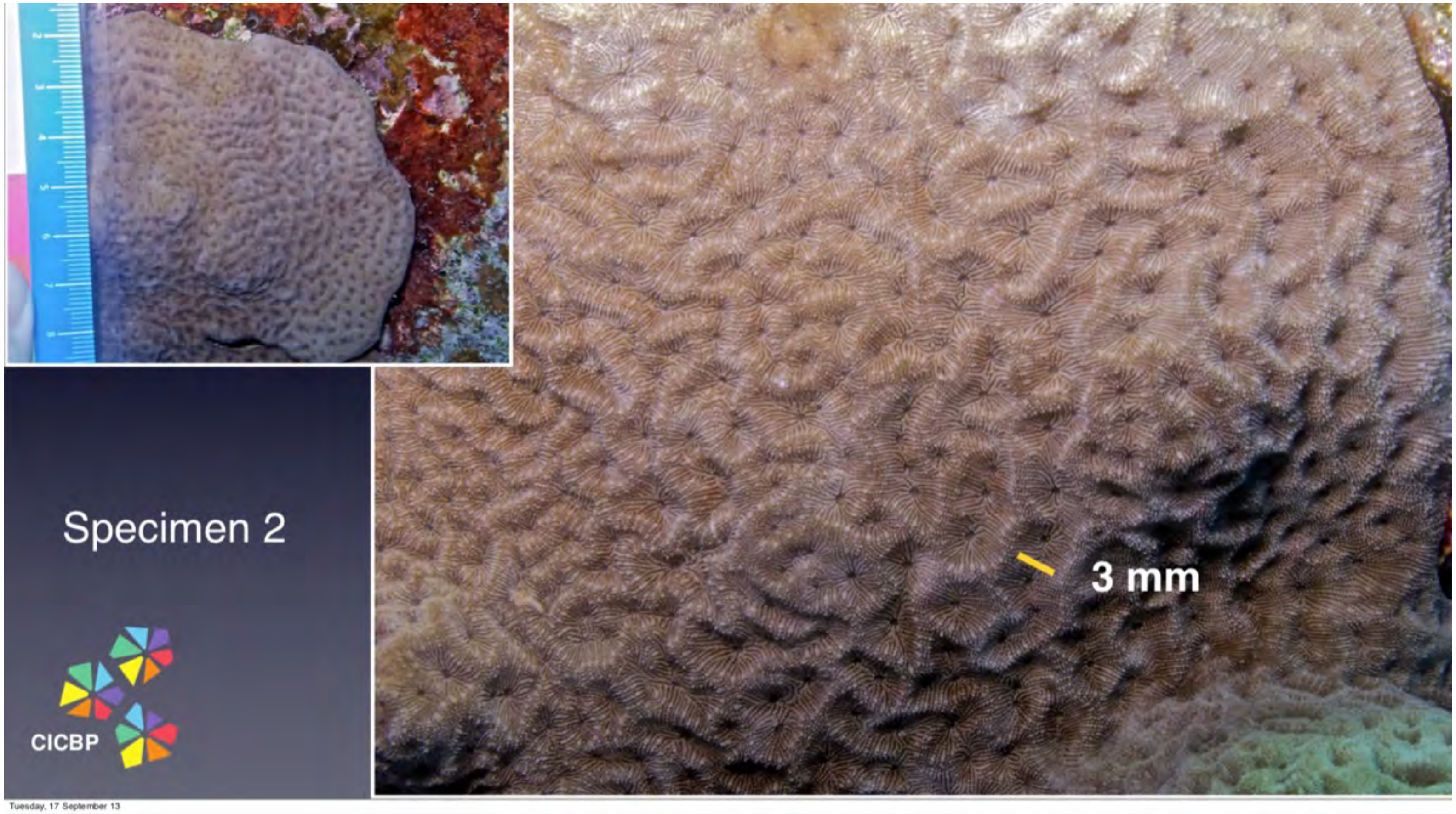
Find these images and 78 more at:
https://www.byoguides.com/resources/coral-finder-resources/



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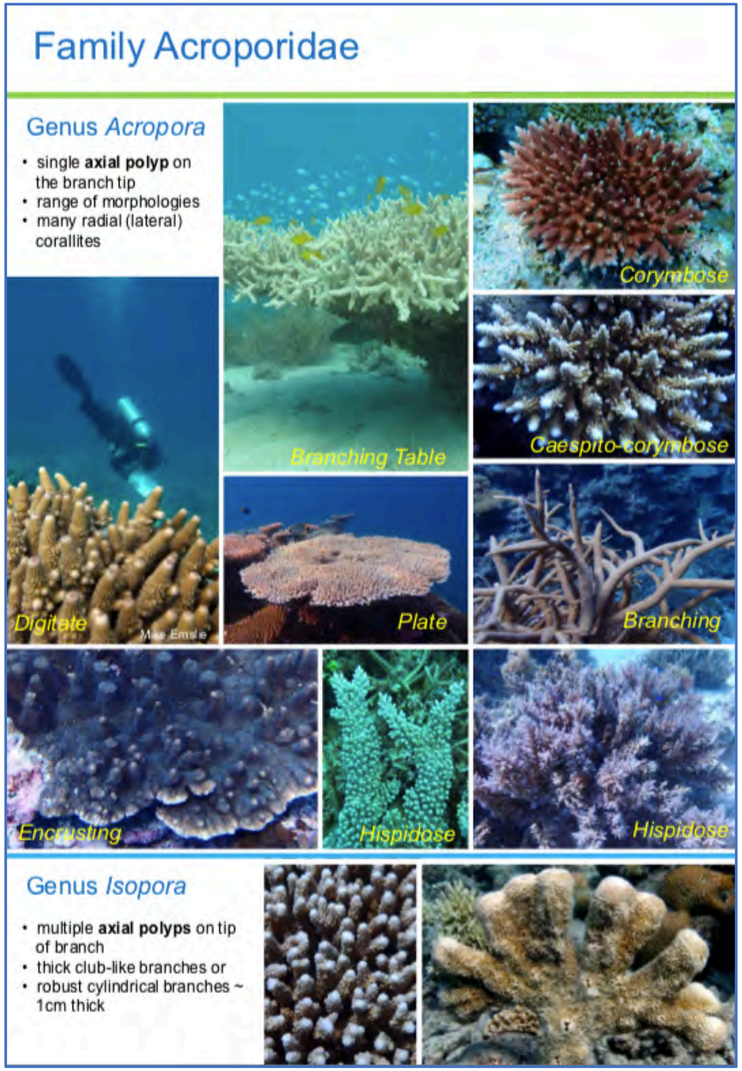
The coral compactus

The coral genera found in Western Australia are the same as the ones found in Queensland.

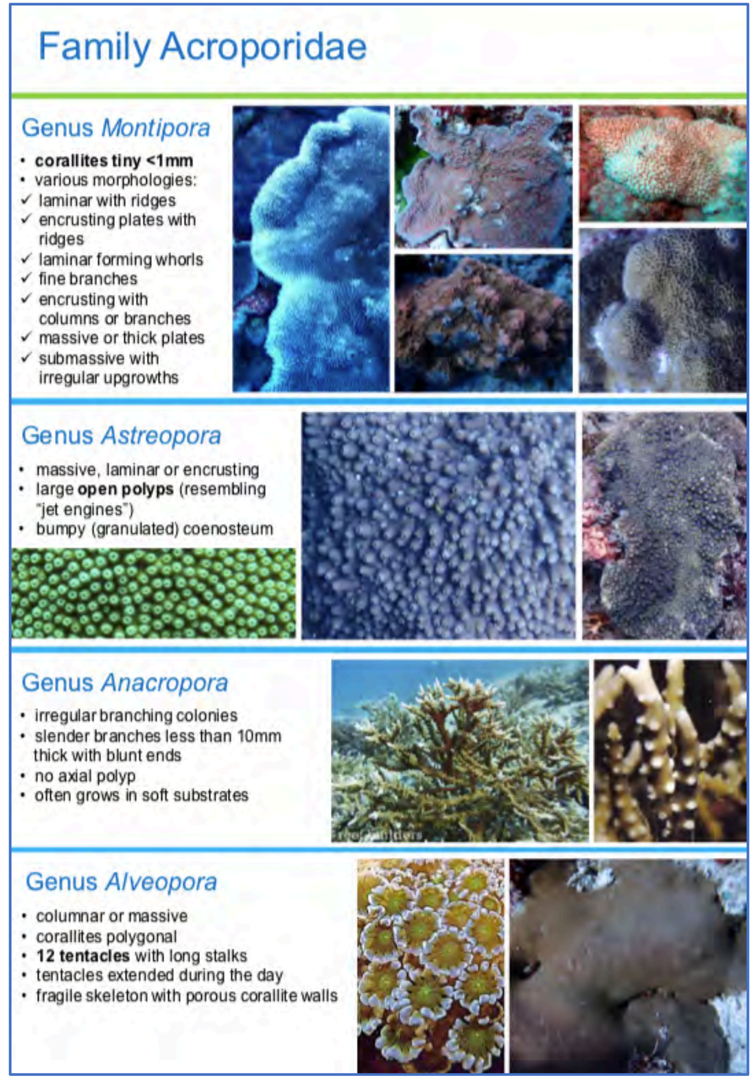


http://museum.wa.gov.au/kimberley/sites/default/files/WA%20Coral%20CompactusV2_May2018.pdf

Coral compactus

Free to download here:

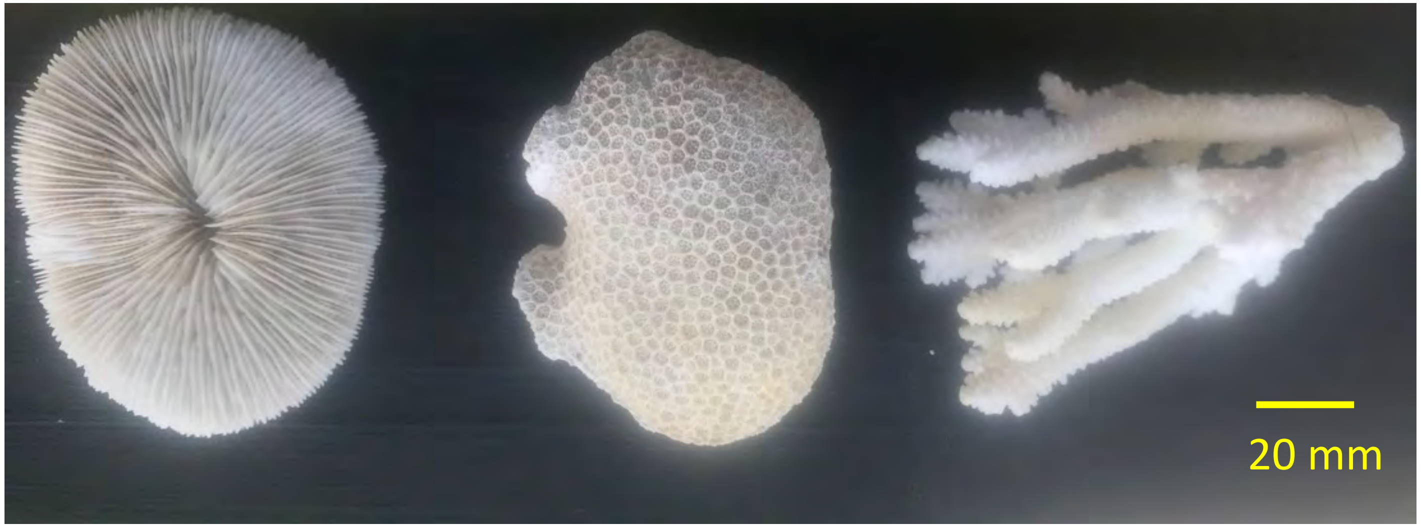
http://museum.wa.gov.au/kimberley/sites/default/files/WA%20Coral%20CompactusV2_May2018.pdf



http://museum.wa.gov.au/kimberley/sites/default/files/WA%20Coral%20CompactusV2_May2018.pdf

Practice your identification skills with coral rubble found on an excursion, or at the local aquarium store.

Remember to include a scale in your pictures!



Question

Classify these corals to genus level only, using a relevant identification key.

1

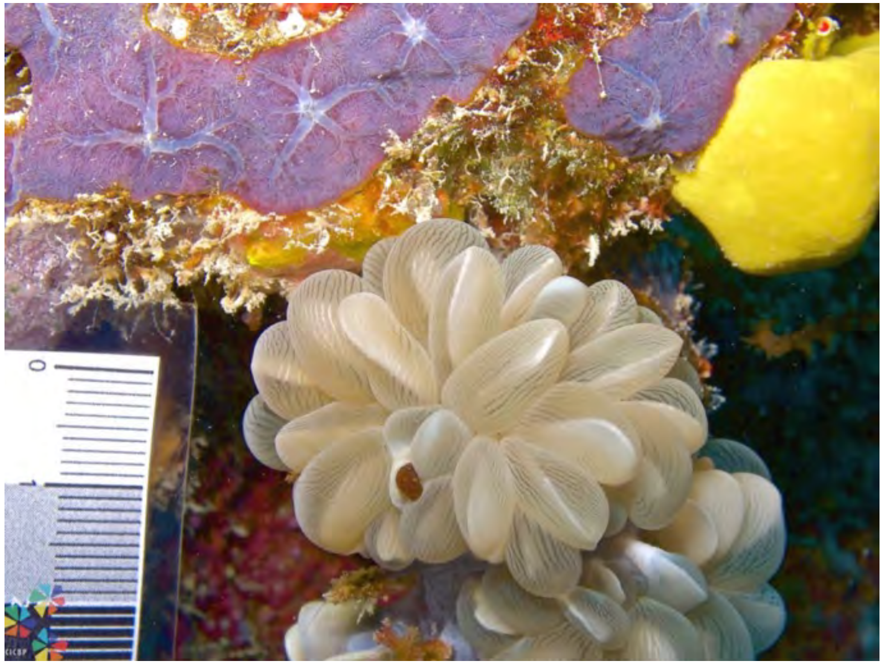
2

Images Courtesy Russell Kelley, www.byoguides.com from Coral Finder Toolkit Test Yourself Image Series 4

Question

Classify these corals to genus level only, using a relevant identification key.

1 *Ans:* Plerogyra



2 *Ans:* Lobophyllia

Images Courtesy Russell Kelley, www.byoguides.com from Coral Finder Toolkit Test Yourself Image Series 4

Further activities

See

https://coralwatch.org/index.php/education-2/curriculum-materials/marine-science/

by

CORALWATCH

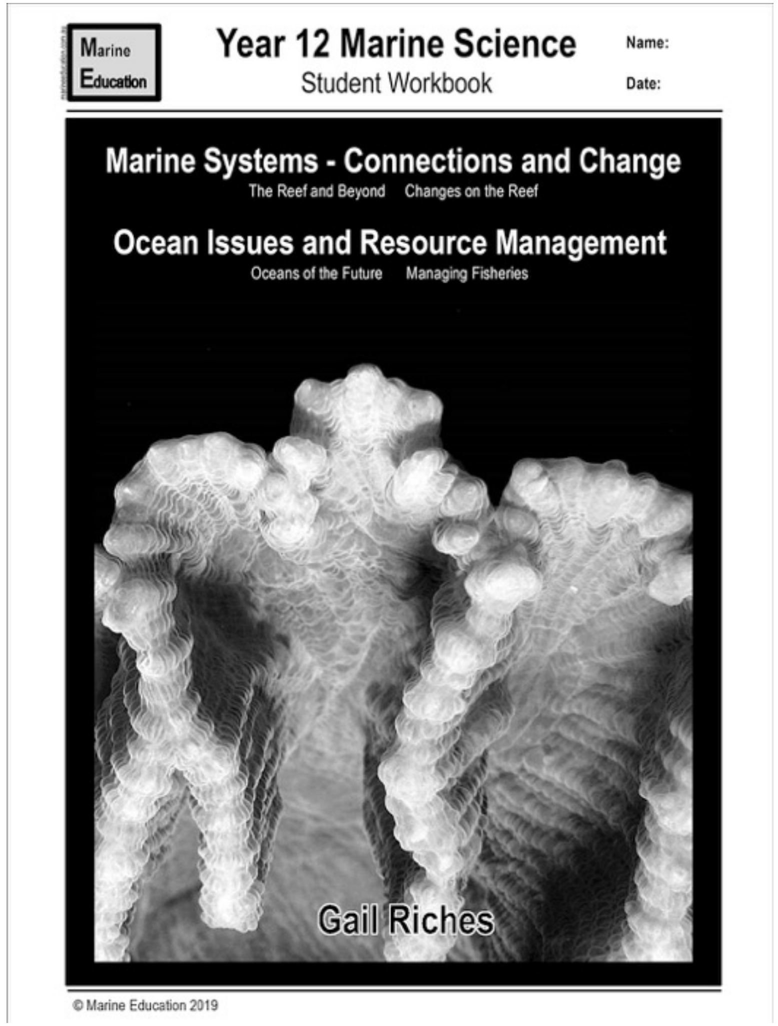
Worksheet

Dichotomous decisions

by

Gail Riches

www.marineeducation.com.au



T078 Coral anatomy

Adam Richmond

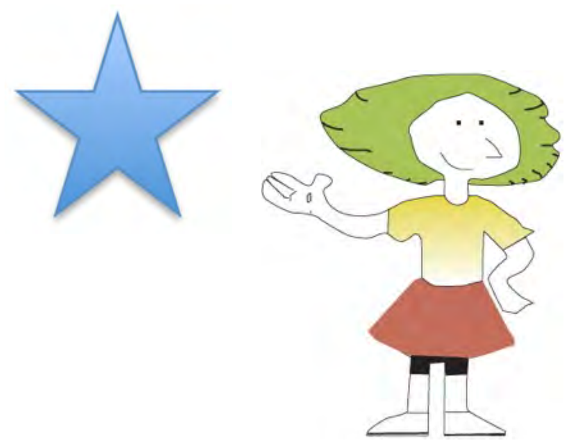
Syllabus statement

At the end of this topic you should be able to ...

Identify

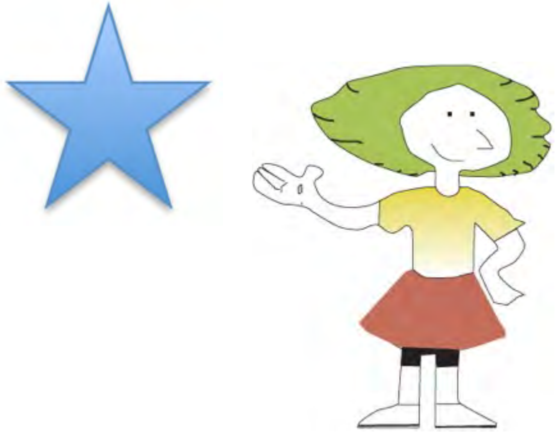
The anatomy of a typical reef-forming hard coral including

- skeleton,
- corallite,
- coelenteron,
- coral polyp,
- tentacles,
- nematocyst,
- mouth and
- zooxanthellae.



Identify

- distinguish;
- locate, recognise and name;
- establish or indicate who or what someone or something is;
- provide an answer from a number of possibilities;
- recognise and state a distinguishing factor or feature



Objective

Label a diagram of a typical coral polyp with the following terms:

- *coelenteron,*
- *coral polyp,*
- *corallite,*
- *mouth,*
- *nematocyst,*
- *skeleton,*
- *tentacles,*
- *zooxanthellae.*

Review coral reefs so far, and learn about the structure of a polyp

https://youtu.be/VuBYpPL2c9k

UQx TROPIC101x 2.2.1 Coral Reef Ecosystems

Youtube video available: https://youtu.be/VuBYpPL2c9k

Coral polyp facts

A polyp is the benthic stage of a cnidarian lifecycle.

One individual coral animal is a coral polyp.

Colonial corals consist of colonies of many genetically identical individual polyps joined together.

Colonial coral polyps are typically only a few mm in diameter.

Solitary corals remain as one individual and can be up to 25 cm across.

Colonial coral polyps

Solitary mushroom coral polyp

Coral polyp anatomy

Coral polyps are multicellular, but made up of only three tissues: the epidermis, mesoglea and gastrodermis.

- The tentacles contain stinging cells, or nematocysts, surround the central mouth.
- The mouth is the only opening to the gut cavity or coelenteron, which is divided by mesenteries.
- Polyps are connected to each other with the coenosarc, which is the living tissue on top of the skeleton.

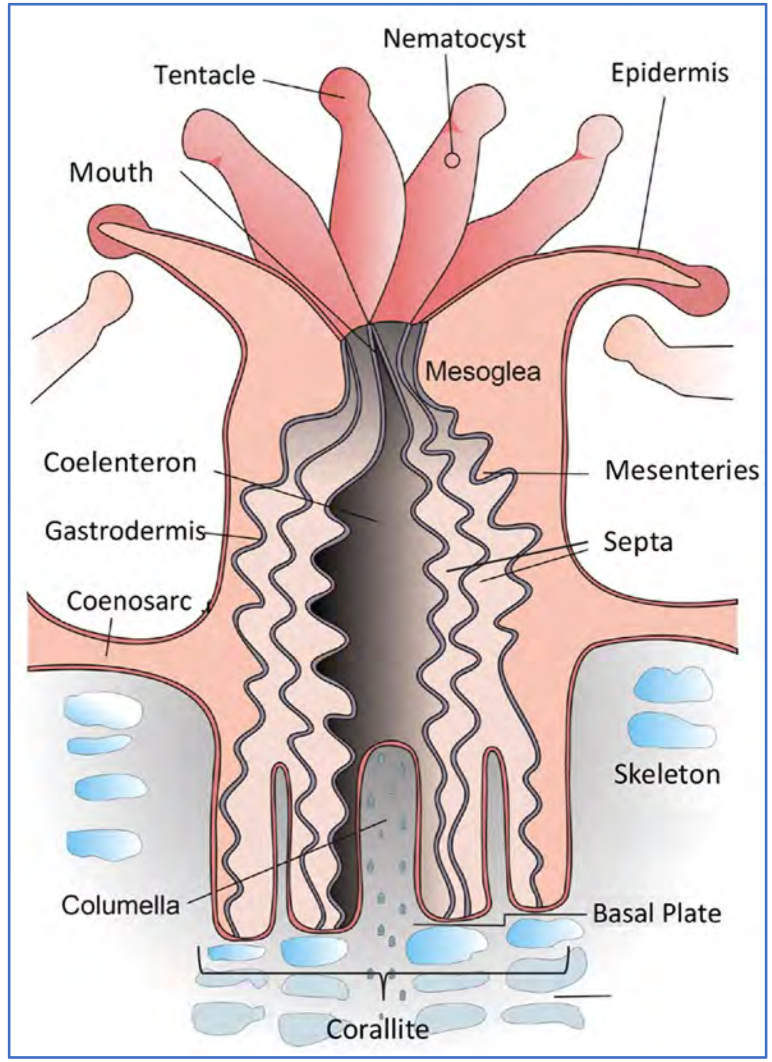


Image: modified from Coral_polyp.jpg: NOAAderivative work: MarkusZi [Public domain], via Wikimedia Commons

Cross section through a stylised colonial coral polyp

The zooxanthellae in the coral tissue can be seen in this macro photograph of a coral polyp.

The following external structures are also visible:

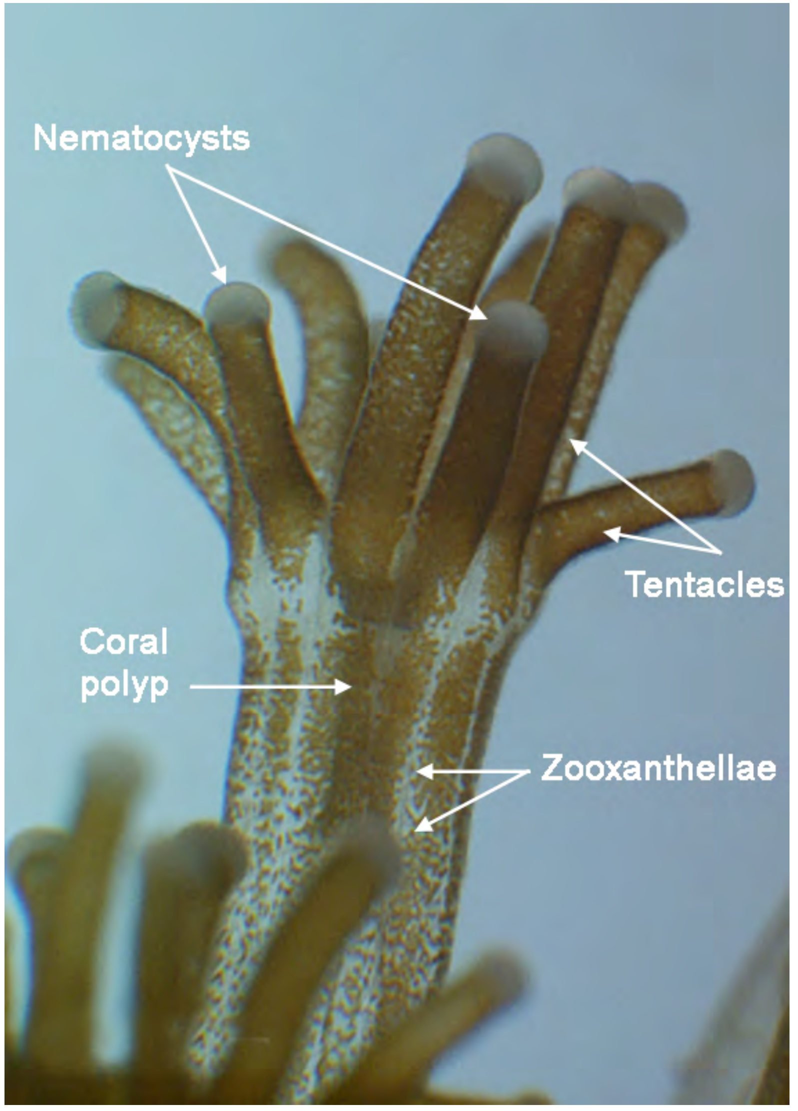
- coral polyp
- nematocysts
- tentacles
- zooxanthellae

Close-up of coral polyp

The zooxanthellae in the coral tissue can be seen in this macro photograph of a coral polyp.

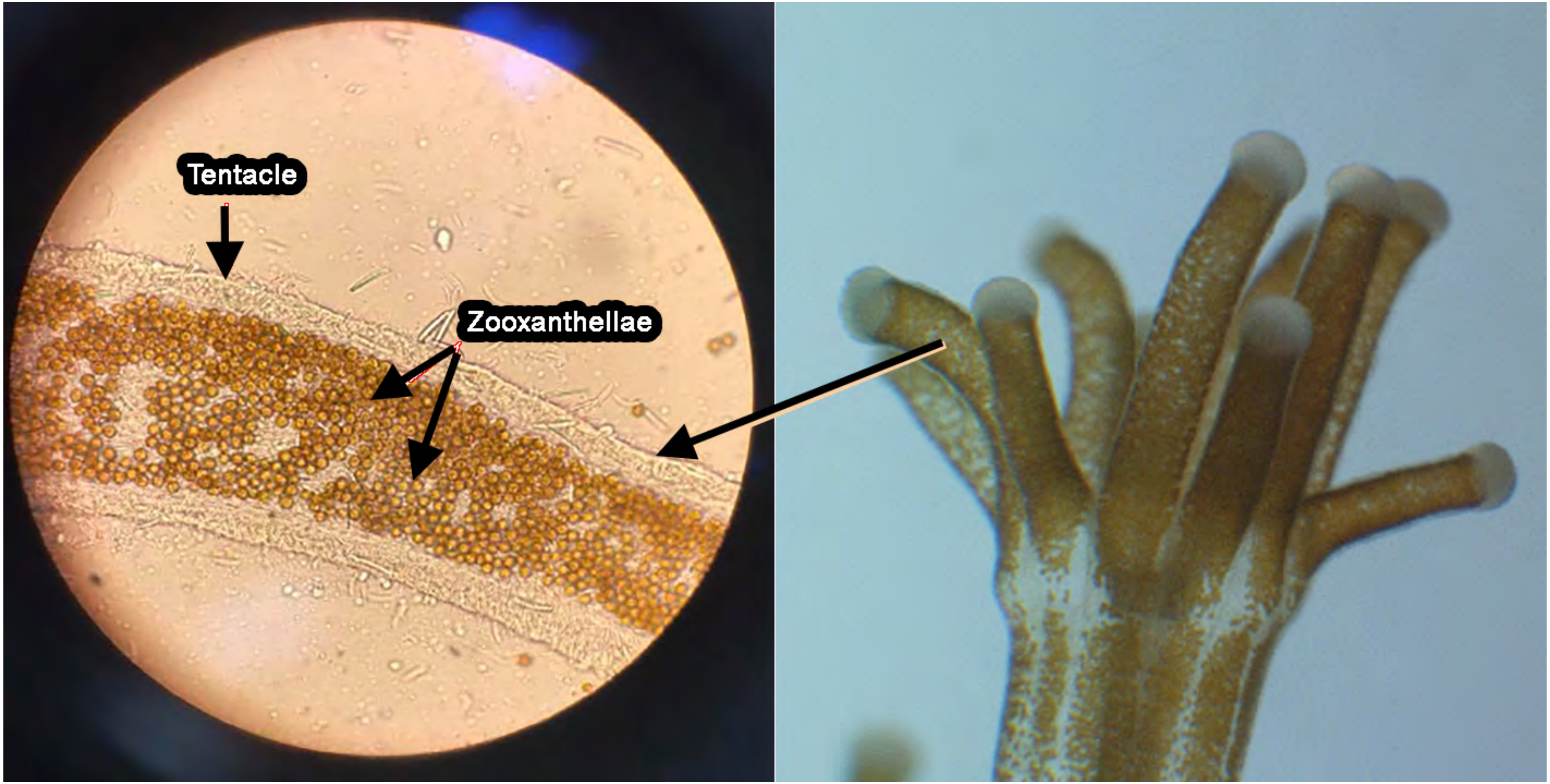
The following external structures are also visible:

- coral polyp
- nematocysts
- tentacles
- zooxanthellae



Close-up of coral polyp

Zooxanthellae as seen in tentacle under a microscope.



Parts of the coral skeleton

The skeleton of an individual polyp is called the corallite.

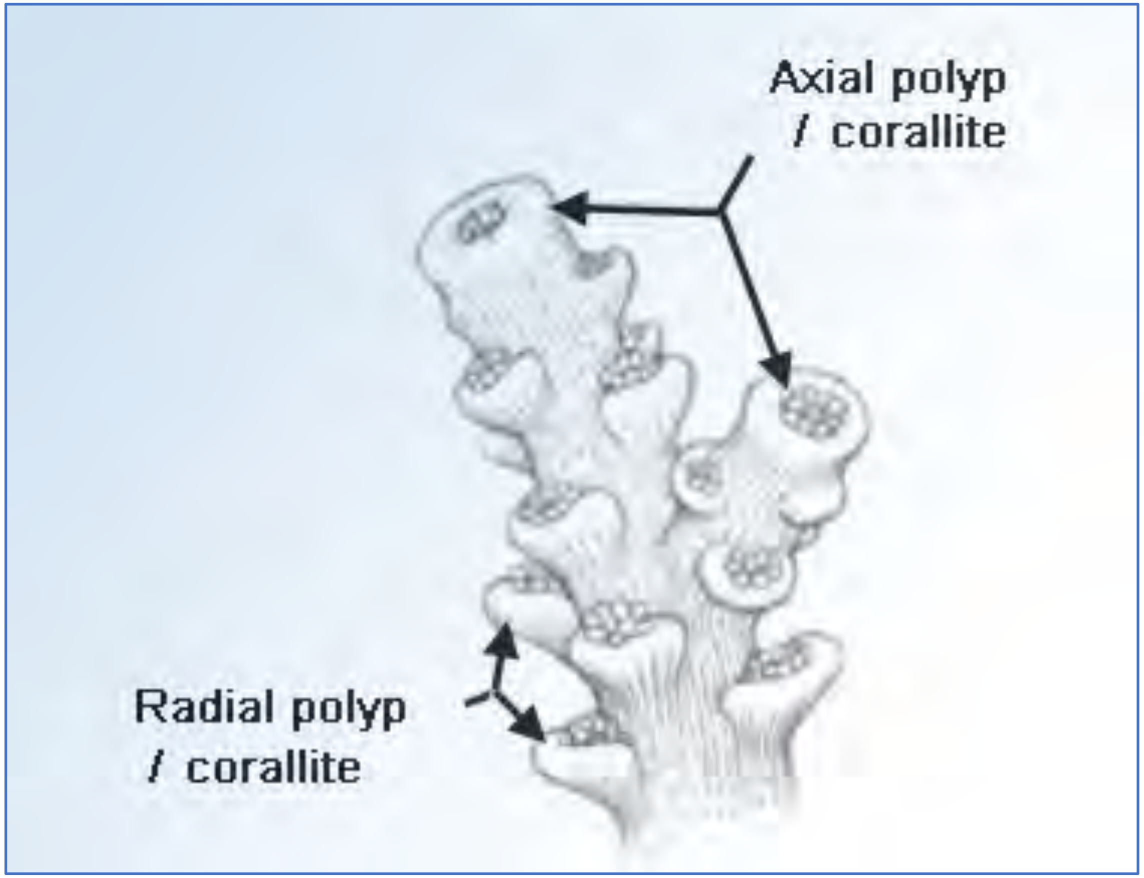


Image: Courtesy Russell Kelley, www.byoguides.com

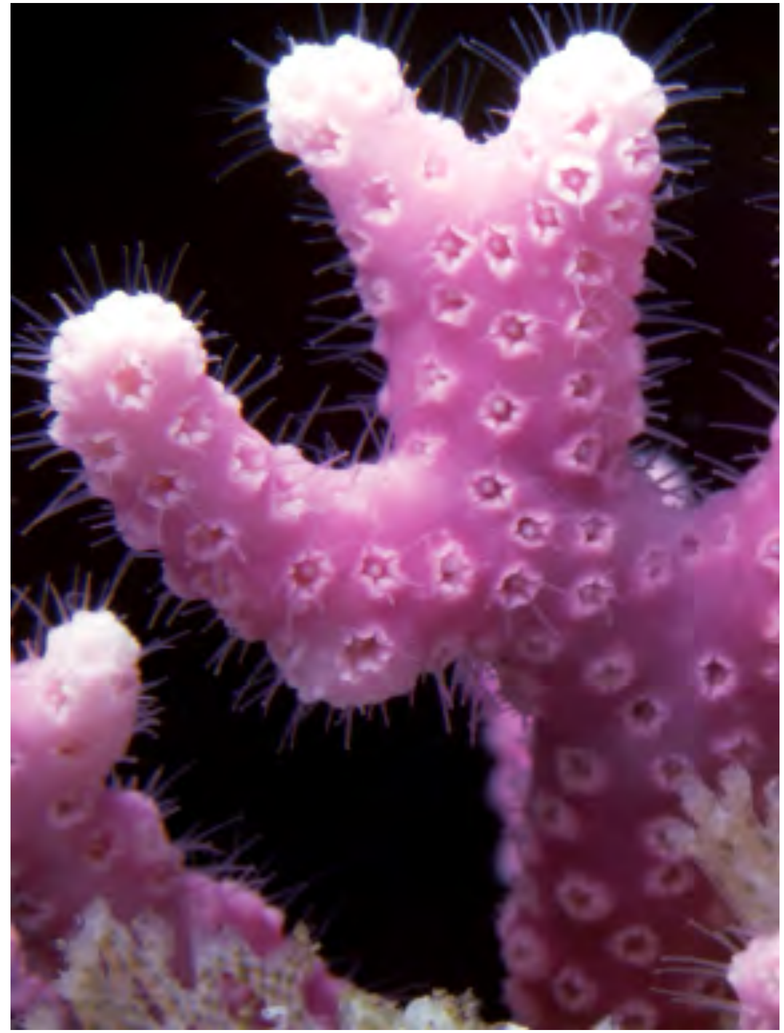


Image copyright : Deep voyage Reproduced with permission

Visual glossary of coral polyp and corallite.

The cup-shaped corallite is divided by vertical blades or septa.

- Individual corallites are sometimes separated by corallite walls.
- Septa that cross corallite walls are called costae.

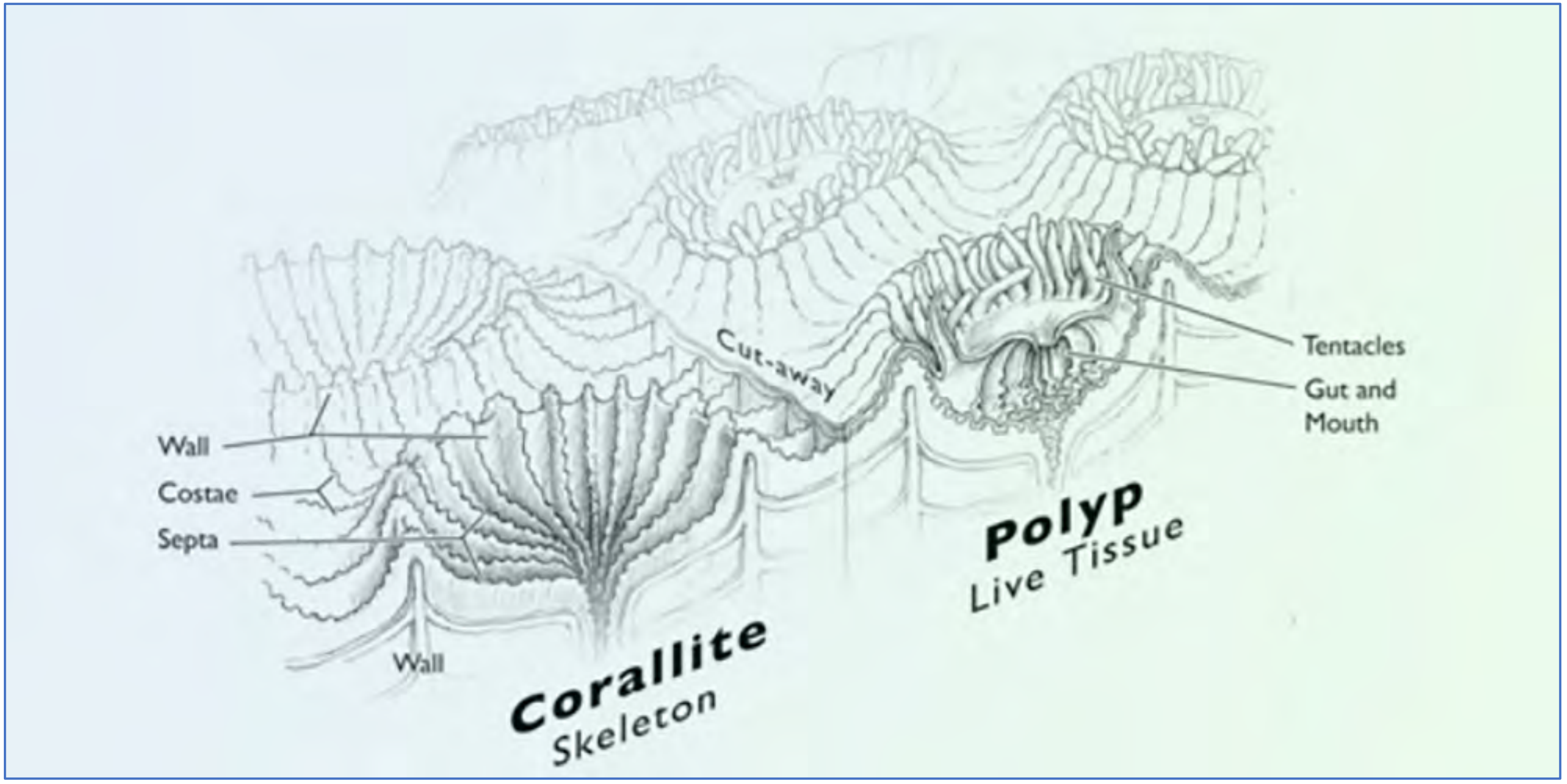


Image: Courtesy Russell Kelley, www.byoguides.com

Coral skeletons show great variety.

Corals can be identified by the size, shape and arrangement of costae, septa and walls.



Questions

1. Label a diagram of a typical coral polyp with the following terms:
    - coelenteron,
    - coral polyp,
    - corallite,
    - mouth,
    - nematocyst,
    - skeleton,
    - tentacles,
    - zooxanthellae

2. What is the thin layer of living tissue that connects colonial polyps together?

3. Which part of a coral polyp is also called a "stinging cell"?

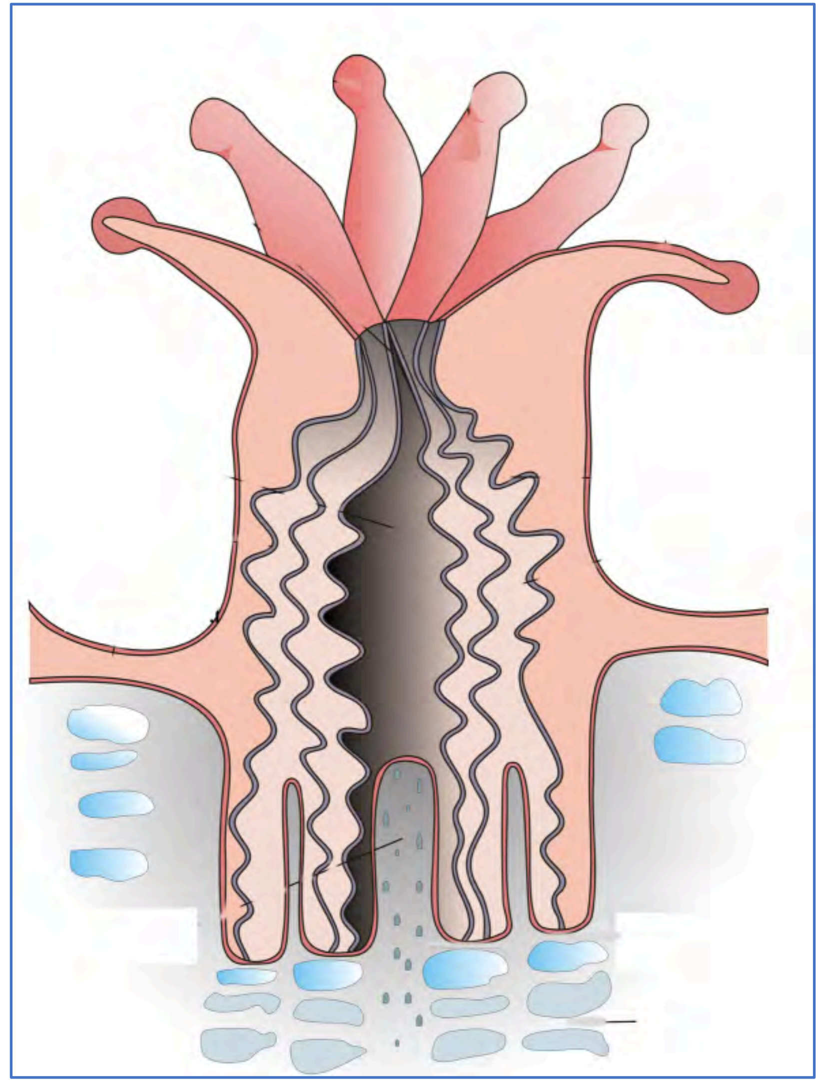
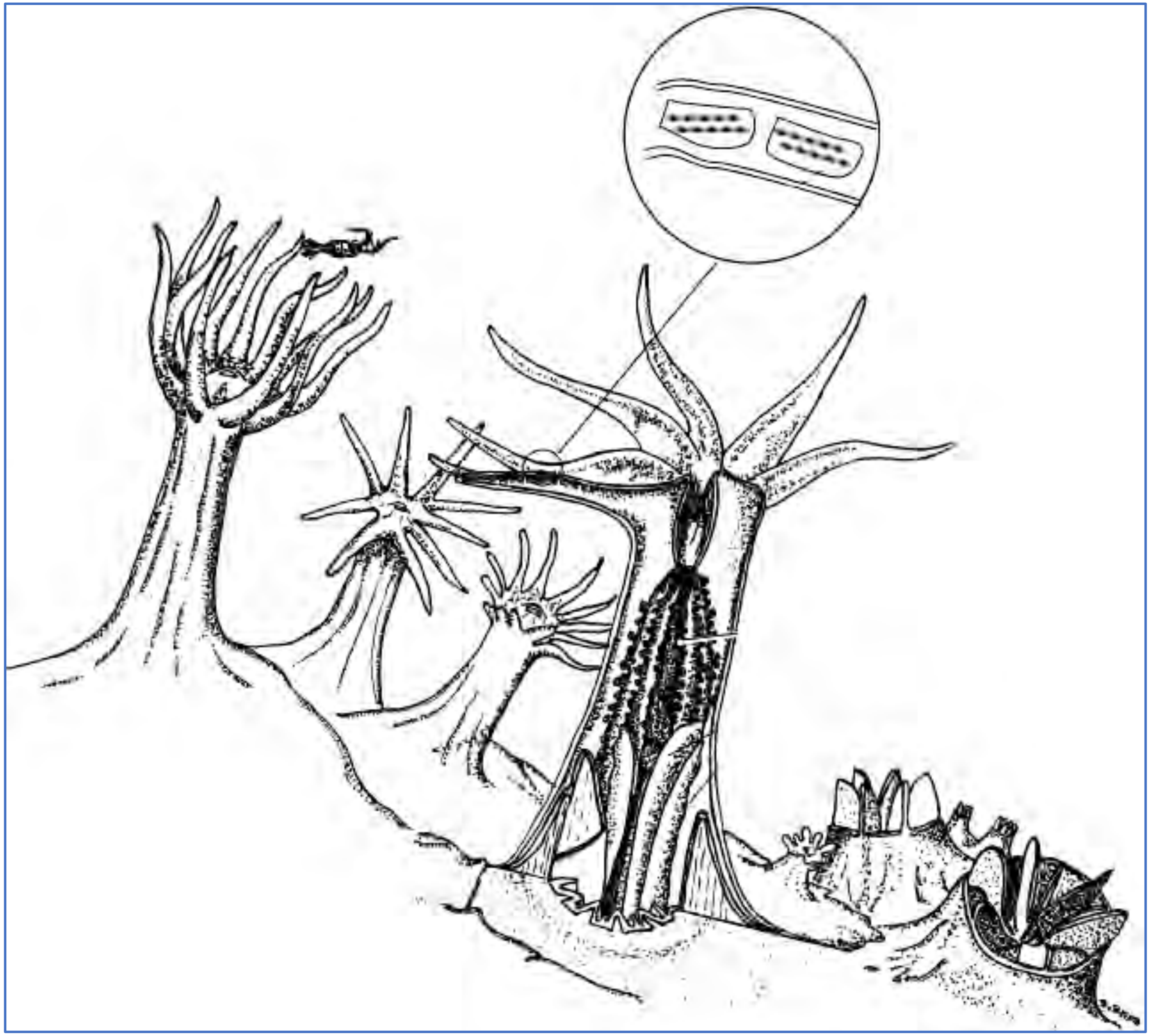


Image: modified from Coral_polyp.jpg: NOAA derivative work: MarkusZi [Public domain], via Wikimedia Commons

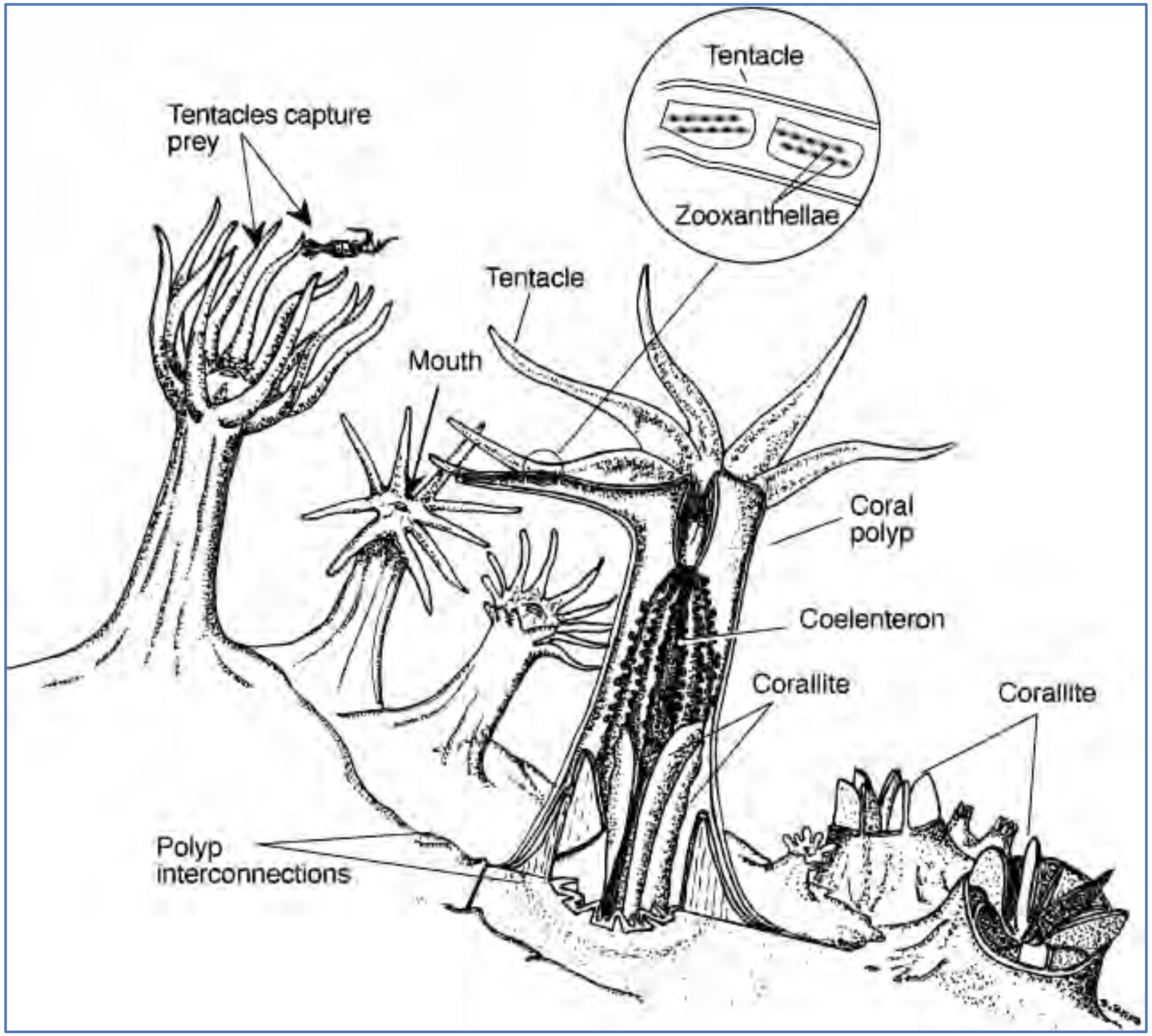
Activity

Redraw this in your notebook marking the following:

coelenteron,
coral polyp,
corallite,
mouth,
nematocyst,
skeleton,
tentacles,
zooxanthellae

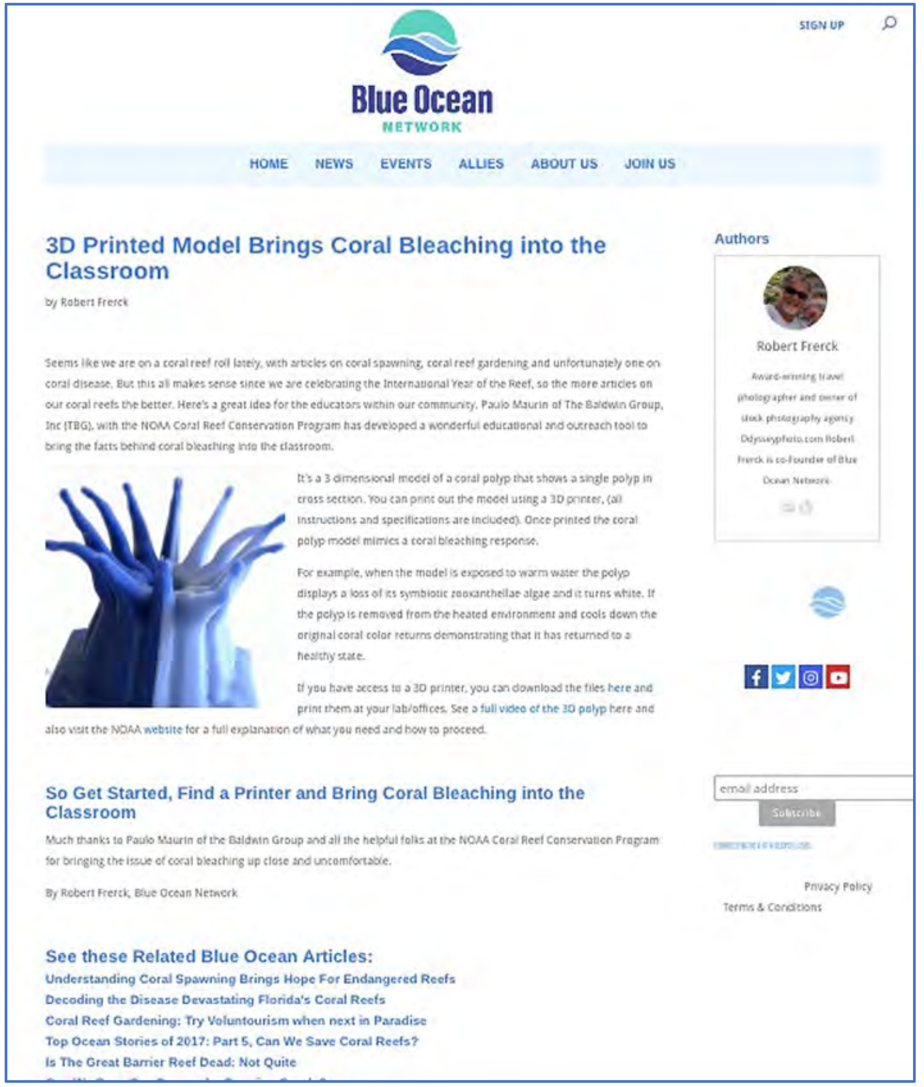


Answer


Tentacle
Zooxanthellae
Tentacles capture prey
Tentacle
Mouth
Coral polyp
Coelenteron
Corallite
Corallite
Polyp interconnections

Activity

Have a 3D printer? Print a 3D coral polyp here: https://blueocean.net/3d-printed-model-brings-coral-bleaching-into-the-classroom/



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3D Printed Model Brings Coral Bleaching into the Classroom

by Robert Frerck

Seems like we are on a coral reef roll lately, with articles on coral spawning, coral reef gardening and unfortunately one on coral disease. But this all makes sense since we are celebrating the International Year of the Reef, so the more articles on our coral reefs the better. Here's a great idea for the educators within our community. Paulo Maurin of The Baldwin Group, Inc (TBG), with the NOAA Coral Reef Conservation Program has developed a wonderful educational and outreach tool to bring the facts behind coral bleaching into the classroom.

It's a 3 dimensional model of a coral polyp that shows a single polyp in cross section. You can print out the model using a 3D printer, (all instructions and specifications are included). Once printed the coral polyp model mimics a coral bleaching response.

For example, when the model is exposed to warm water the polyp displays a loss of its symbiotic zooxanthellae algae and it turns white. If the polyp is removed from the heated environment and cools down the original coral color returns demonstrating that it has returned to a healthy state.

If you have access to a 3D printer, you can download the files here and print them at your lab/offices. See a full video of the 3D polyp here and also visit the NOAA website for a full explanation of what you need and how to proceed.

So Get Started, Find a Printer and Bring Coral Bleaching into the Classroom

Much thanks to Paulo Maurin of the Baldwin Group and all the helpful folks at the NOAA Coral Reef Conservation Program for bringing the issue of coral bleaching up close and uncomfortable.

By Robert Frerck, Blue Ocean Network

See these Related Blue Ocean Articles:

Understanding Coral Spawning Brings Hope For Endangered Reefs
Decoding the Disease Devastating Florida's Coral Reefs
Coral Reef Gardening: Try Voluntourism when next in Paradise
Top Ocean Stories of 2017: Part 5, Can We Save Coral Reefs?
Is The Great Barrier Reef Dead: Not Quite

Authors

Robert Frerck

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https://blueocean.net/3d-printed-model-brings-coral-bleaching-into-the-classroom/

Further activities

See

https://coralwatch.org/index.php/education-2/curriculum-materials/marine-science/

by

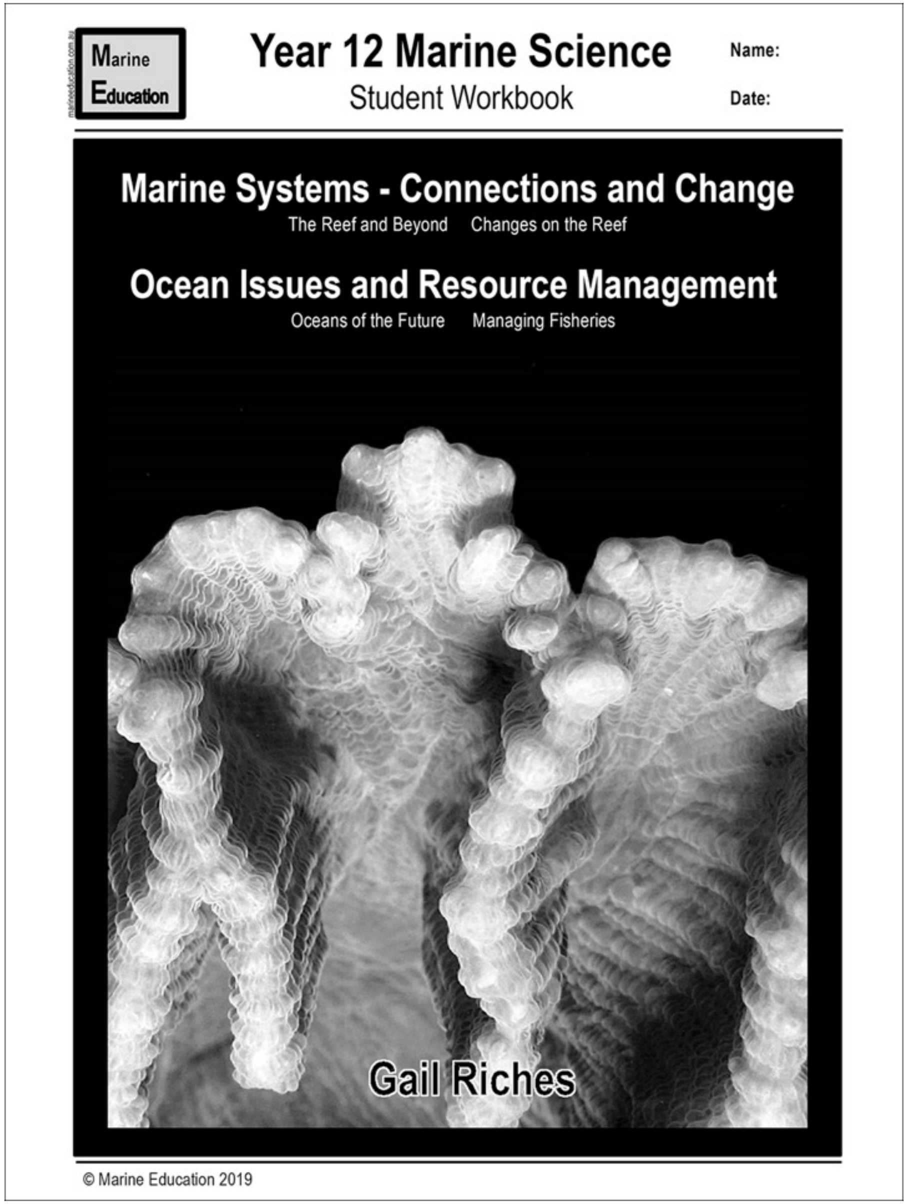
CORALWATCH

Further activity

Worksheet –

Garden of Stone Flowers

by
Gail Riches



T079   Coral limestone skeleton

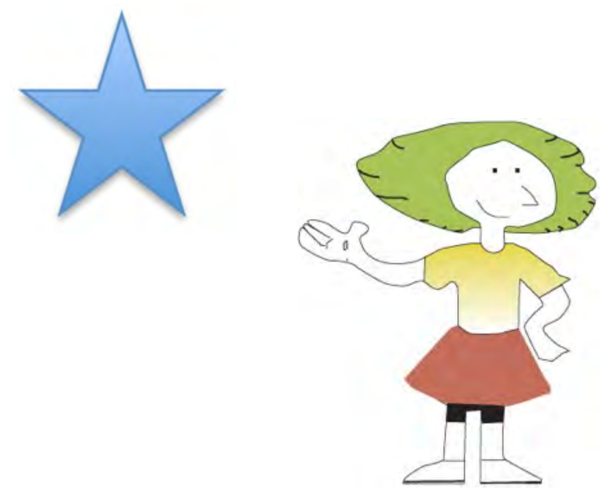
Adam Richmond

Syllabus statement

At the end of this topic you should be able to ...

Recall

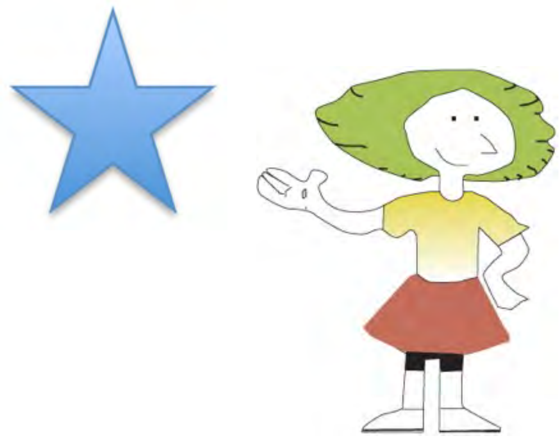
that the limestone skeleton of a coral is built when calcium ions $[Ca^{2+}]$ combine with carbonate ions $[CO_3^{2-}]$



Recall

- remember; present remembered ideas, facts or experiences;

- bring something back into thought, attention or into one's mind



Objective

Describe how a coral builds its skeleton.

You will need to include calcium ions [$Ca^{2}+$] and carbonate ions [CO_3^{2-}] in your explanation.

Video review

Reef types and calcium carbonate

https://youtu.be/s7-GrlnCaf0

UQx TROPIC101x 2.2.3 Types of Reefs

You tube video available: https://youtu.be/s7-GrlnCaf0

Calcium carbonate

Calcium carbonate is a chemical compound with the formula $CaCO_3$.

You have probably performed some science experiments with limestone, chalk or marble- which are composed of $CaCO_3$.

Calcium carbonate chips

Image:Ferdous [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)], from Wikimedia Commons

Just like broccoli is a good source of calcium carbonate for our bodies.

Image:Fir0002 [GFDL 1.2 (http://www.gnu.org/licenses/old-licenses/fdl-1.2.html)], from Wikimedia Commons

Photograph Copyright Viewfinder. Reproduced with permission.

So is calcium carbonate for corals.

By Yumi Yasutake, NOAA - http://www.hawaiianatolls.org/research/Sept_Oct2007/FFS.php, Public Domain, https://commons.wikimedia.org/w/index.php?curid=4209726

The two main types of calcium carbonate are argonite and calcite.

They have the same chemical formula, but the molecules are different shapes (called polymorphs).

Aragonite

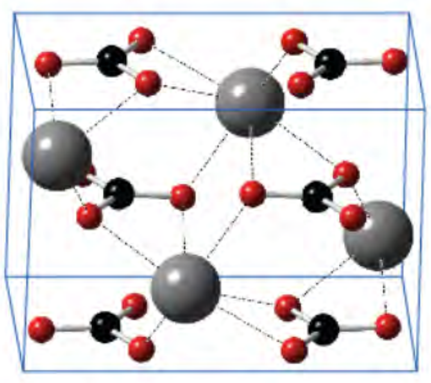
Image: Didier Descouens [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)], from Wikimedia Commons

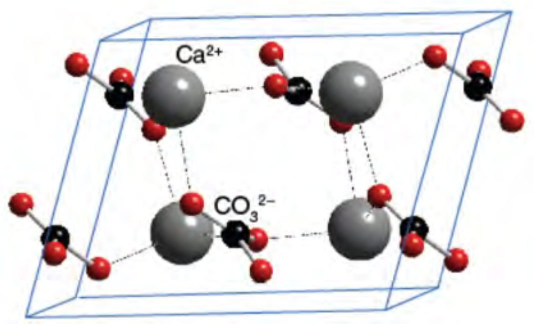
Calcite

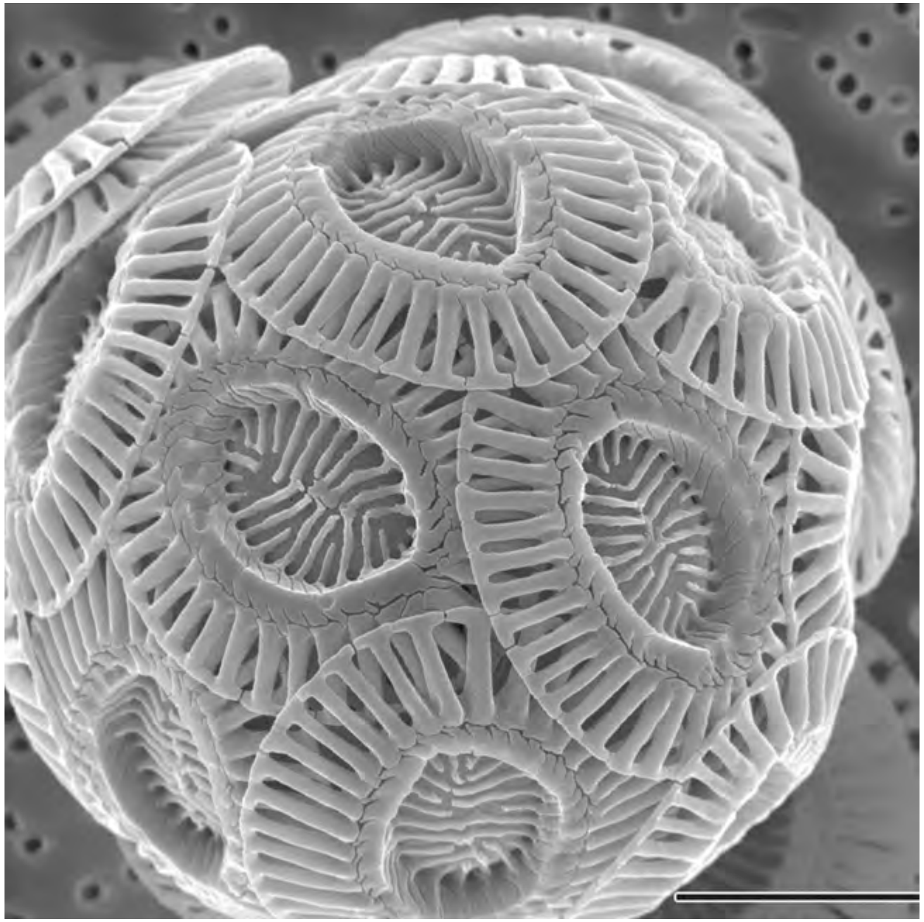
Image: Rob Lavinsky, iRocks.com – CC-BY-SA-3.0 [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)]

Aragonite and calcite

Aragonite	Calcite
Aragonite is denser and more resistant to stress in high energy environments.	Calcite is the most stable polymorph of calcium carbonate.
Corals make their skeletons from aragonite.	Echinoderms, brachiopods, coccolithophores and forams make their shells from calcite.
Many molluscs, such as mussels make shells from aragonite	Coralline algae create calcite with high magnesium content (HMC).

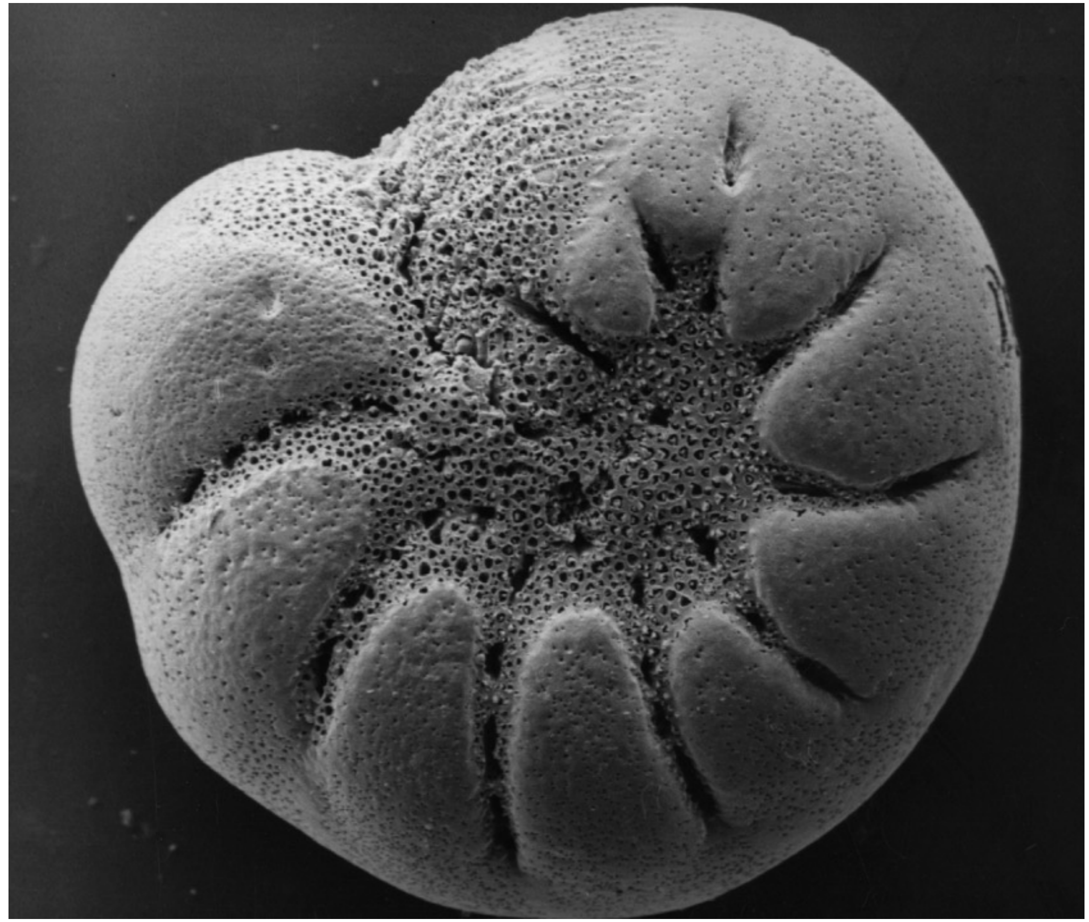






Coccolithophore

Image: Alison R. Taylor (University of North Carolina Wilmington Microscopy Facility) [CC BY 2.5 (https://creativecommons.org/licenses/by/2.5)], via Wikimedia Commons

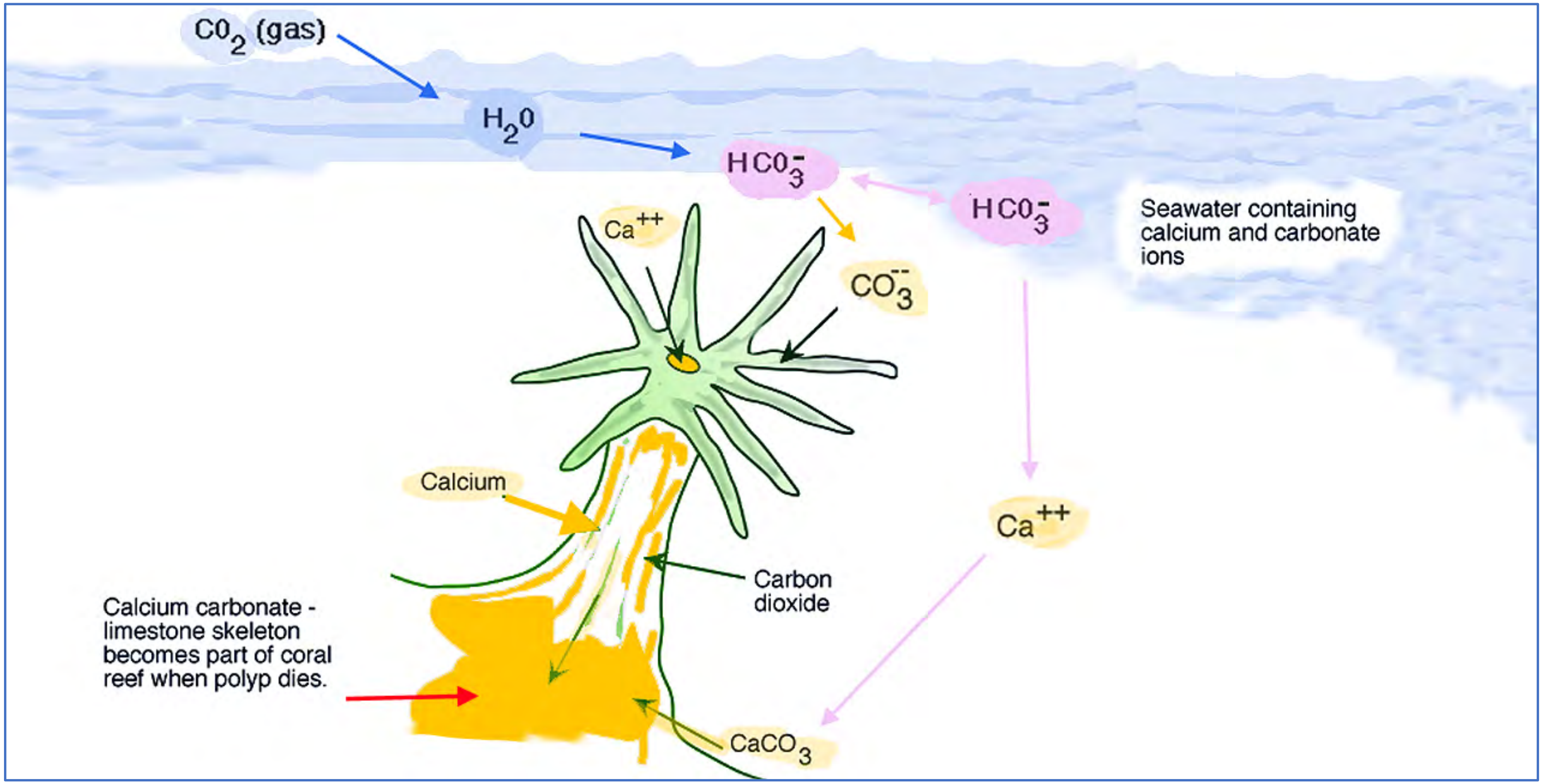


Foraminifera

Image: Hannes Grobe [CC BY 3.0 (https://creativecommons.org/licenses/by/3.0)], from Wikimedia Commons

Calcium ions and Carbonate ions react to form calcium carbonate according to this reaction.

$$Ca^{2+} + CO_3^{2-} \underset{\text{dissolves}}{\overset{\text{precipitates}}{\rightleftharpoons}} CaCO_3$$



The aragonite saturation state of seawater is found by

$$\Omega_{arag} = \frac{([Ca^{2+}] \times [CO_3^{2-}])}{[CaCO_3]}$$

the calculated saturation state (Ω_{arag})

the concentration of calcium ions, ($[Ca^{2+}]$)

the concentration of carbonate ions ($[CO_3^{2-}]$)

the solubility of aragonite ($[CaCO_3]$)

If $\Omega > 1$, the water is supersaturated with aragonite and aragonite will precipitate.

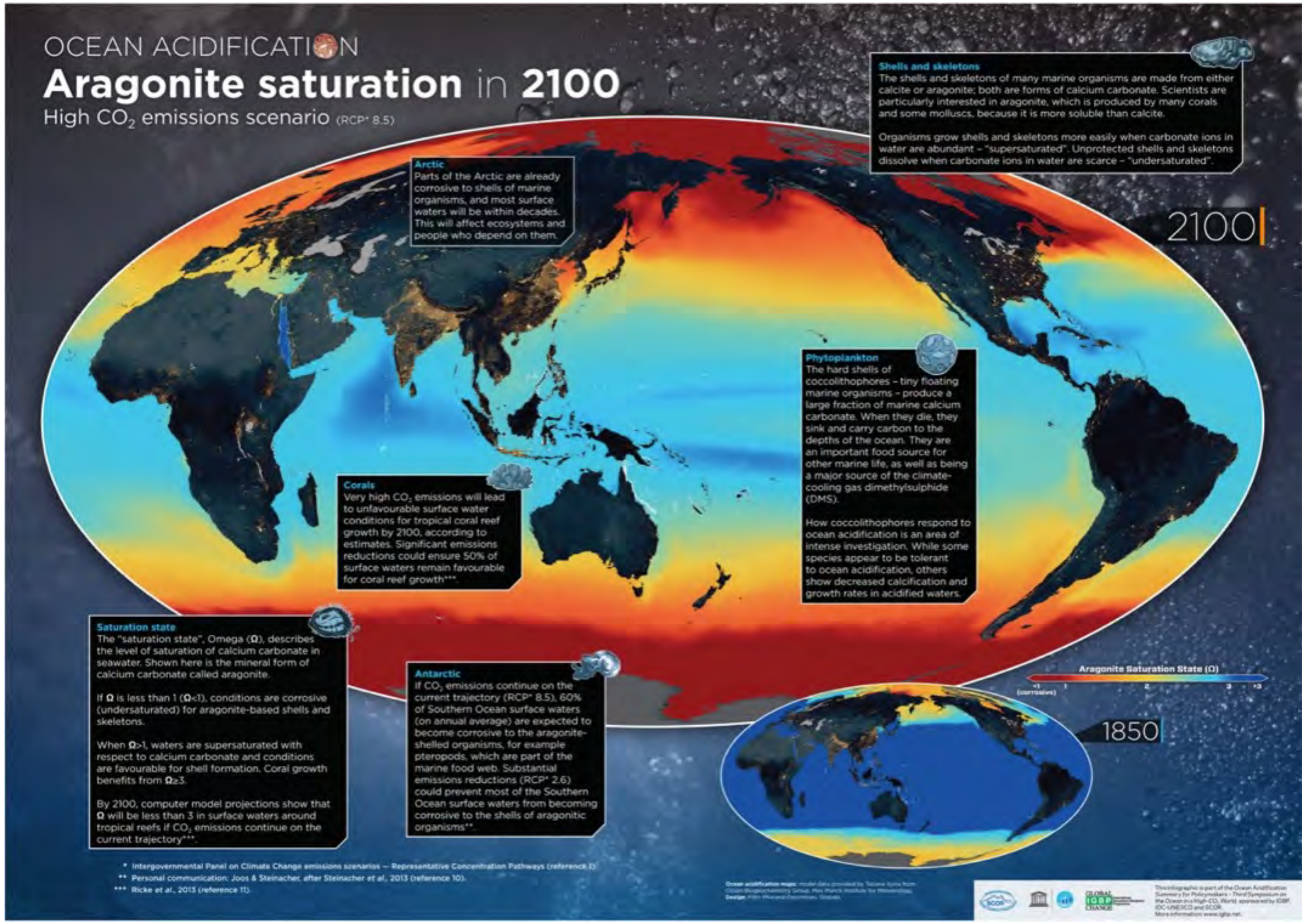
If $\Omega < 1$, the water is undersaturated and aragonite will dissolve to Ca^{2+} and CO_3^{2-} ions.

If $\Omega = 1$, the water is in equilibrium and aragonite neither dissolves or precipitates.

You should not have to remember these equations, but it will help if you understand them!

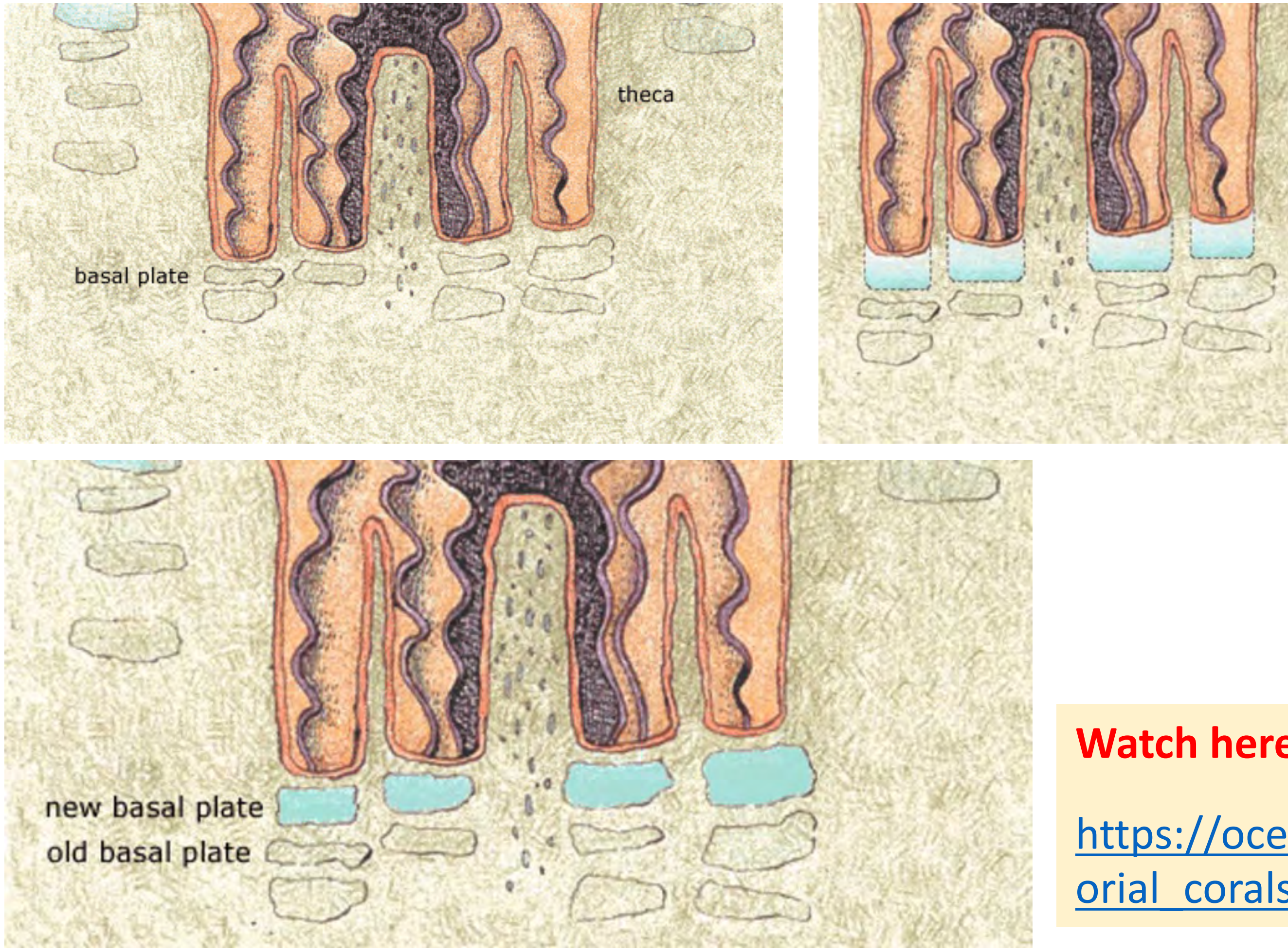
Modern reefs developed in waters with an aragonite saturation state of $\Omega_a > 4$.

This has already reduced and is predicted to continue to fall.



Infographic: IGBP, IOC, SCOR (2013). *Ocean Acidification Summary for Policymakers – Third Symposium on the Ocean in a High-CO2 World.* International Geosphere-Biosphere Programme, Stockholm, Sweden. Accessed: http://www.igbp.net/images/18.30566fc6142425d6c9115f2/1386581387793/OAspm-aragonite-high.jpg, [CC BY-NC-SA 3.0](CC BY-NC-SA 3.0).

The coral polyp grows vertically by depositing more calcium carbonate at the bottom of the polyp.



The polyp lifts itself up and away from its corallite (cup-like skeleton), leaving an empty space (dashed lines).

The polyp secretes $CaCO_3$ to fill in that space, creating a new, higher basal plate.

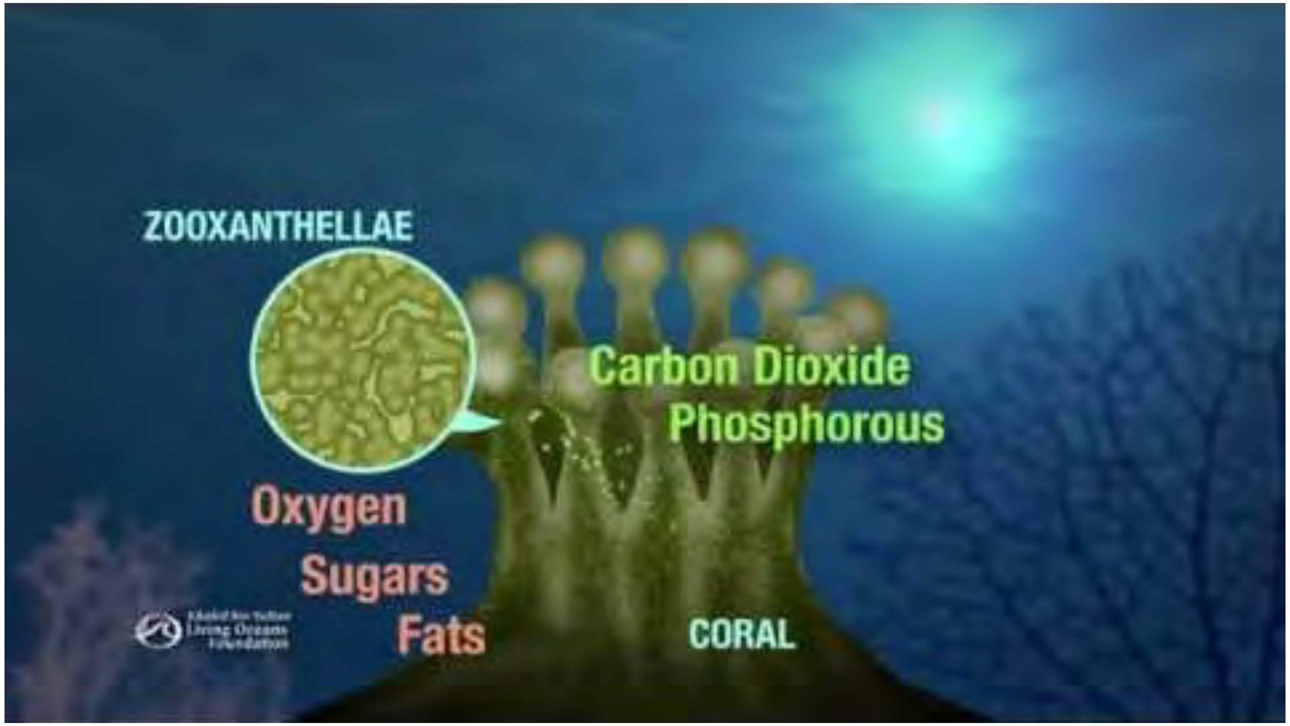
Watch here

https://oceanservice.noaa.gov/education/tutorial_corals/media/coral03a_480.gif

Animated GIF of a polyp growing

Credit: NOAA, available: https://oceanservice.noaa.gov/education/tutorial_corals/media/coral03a_480.gif

This YouTube video revises how corals make their skeleton, and introduces some new concepts for a few lessons' time.



Khaled bin Sultan Living Oceans Foundation, https://youtu.be/IEWJAEkGeNk

Video link

Coral: What is it?

https://youtu.be/IEWJAEkGeNk

Questions

Describe how a coral builds its skeleton. You will need to include calcium ions [Ca^{2}+] and carbonate ions [CO_3^{2-}] in your explanation.

Make reference to

- What the skeleton is made from.
- The type of substance corals use to build reefs.
- How the coral obtains this material.
- If this material is always available.
- How the polyp actually grows.

Further activities

See

https://coralwatch.org/index.php/education-2/curriculum-materials/marine-science/

by

Further activity

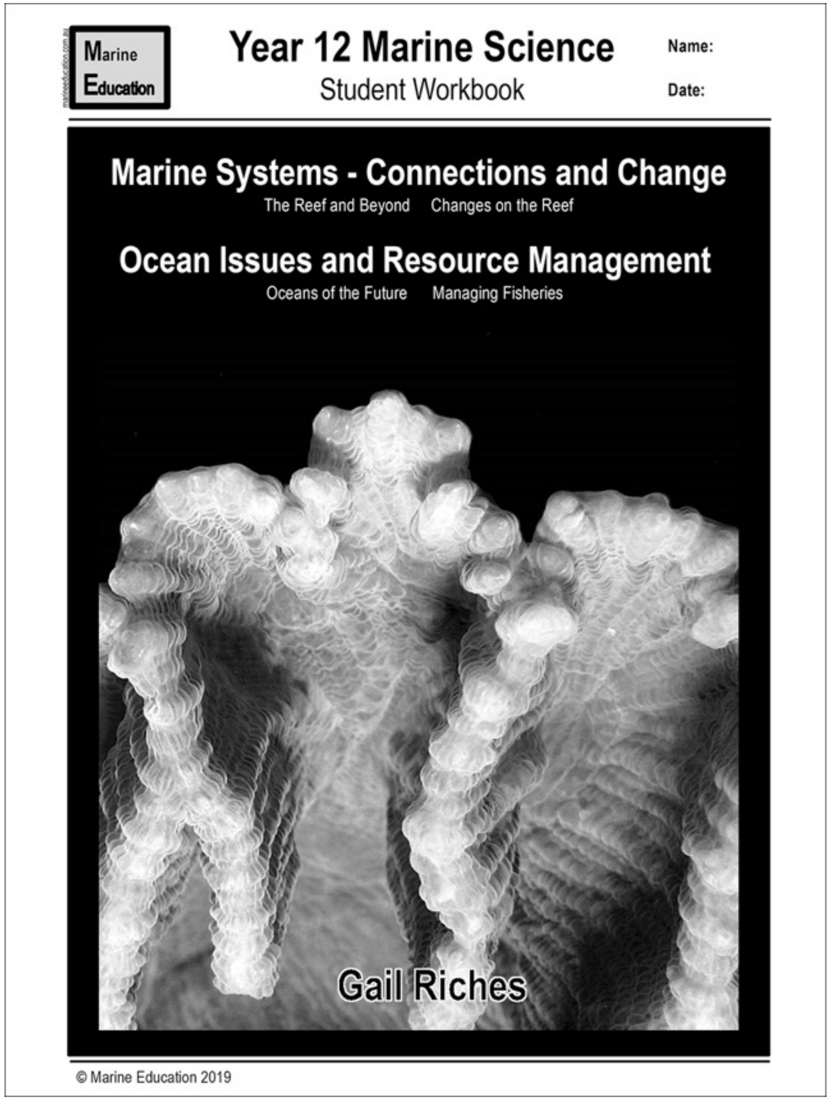
Worksheet –

Carbonate Count down

by

Gail Riches

www.marineeducation.com.au



T080 Coral feeding

Adam Richmond

Syllabus statement

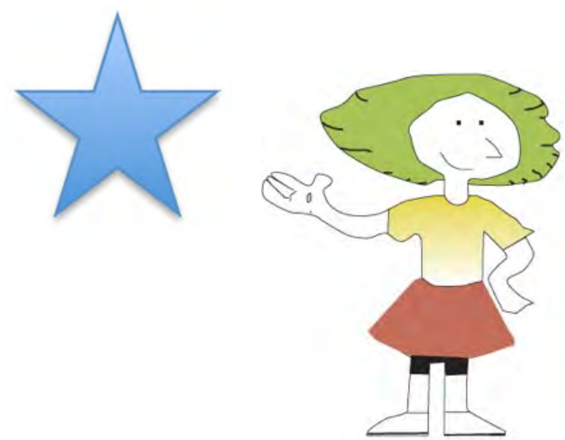
At the end of this topic you should be able to ...

Describe

the process of coral feeding

including

- night-feeding patterns and
- the function of nematocysts



Describe

- give the meaning of a word, phrase, concept or physical quantity;
- state meaning and identify or describe qualities

Objective

Describe the process of coral feeding, with reference to a diagram of a coral polyp.

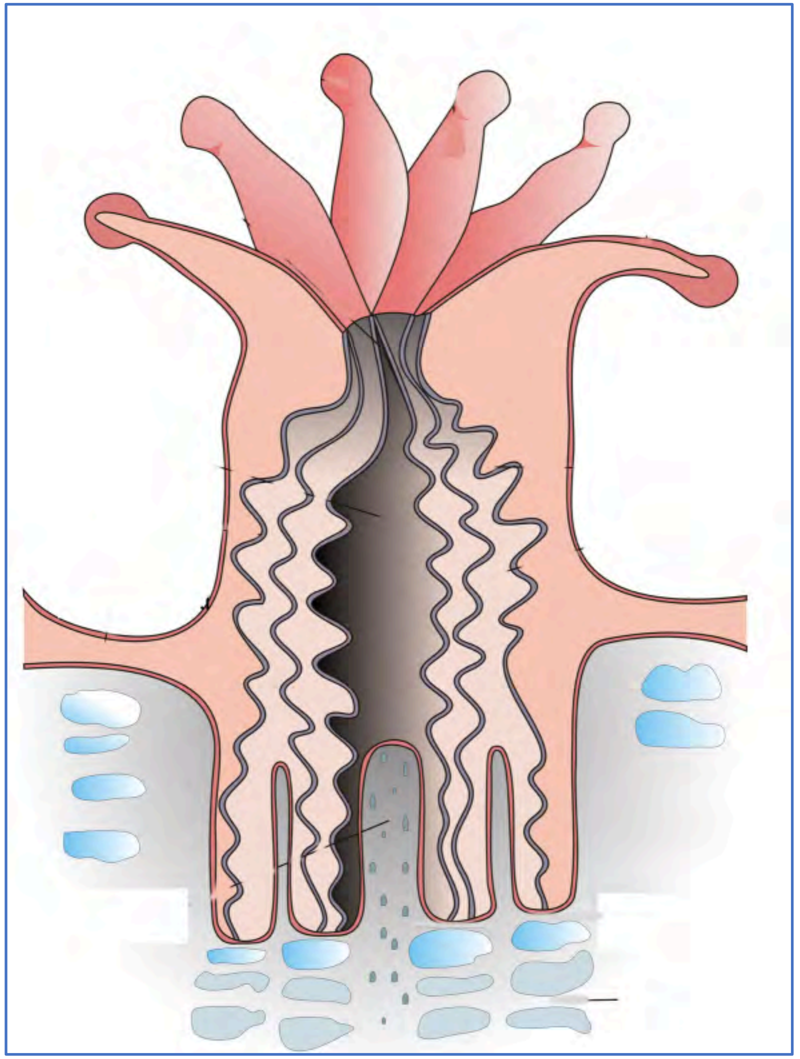
When do corals generally feed? What are the exceptions?

How do nematocysts work?

Review coral anatomy

Recall the following parts of a coral polyp:

Tentacle
Nematocysts
Mouth
Gastrodermis
Coelenteron



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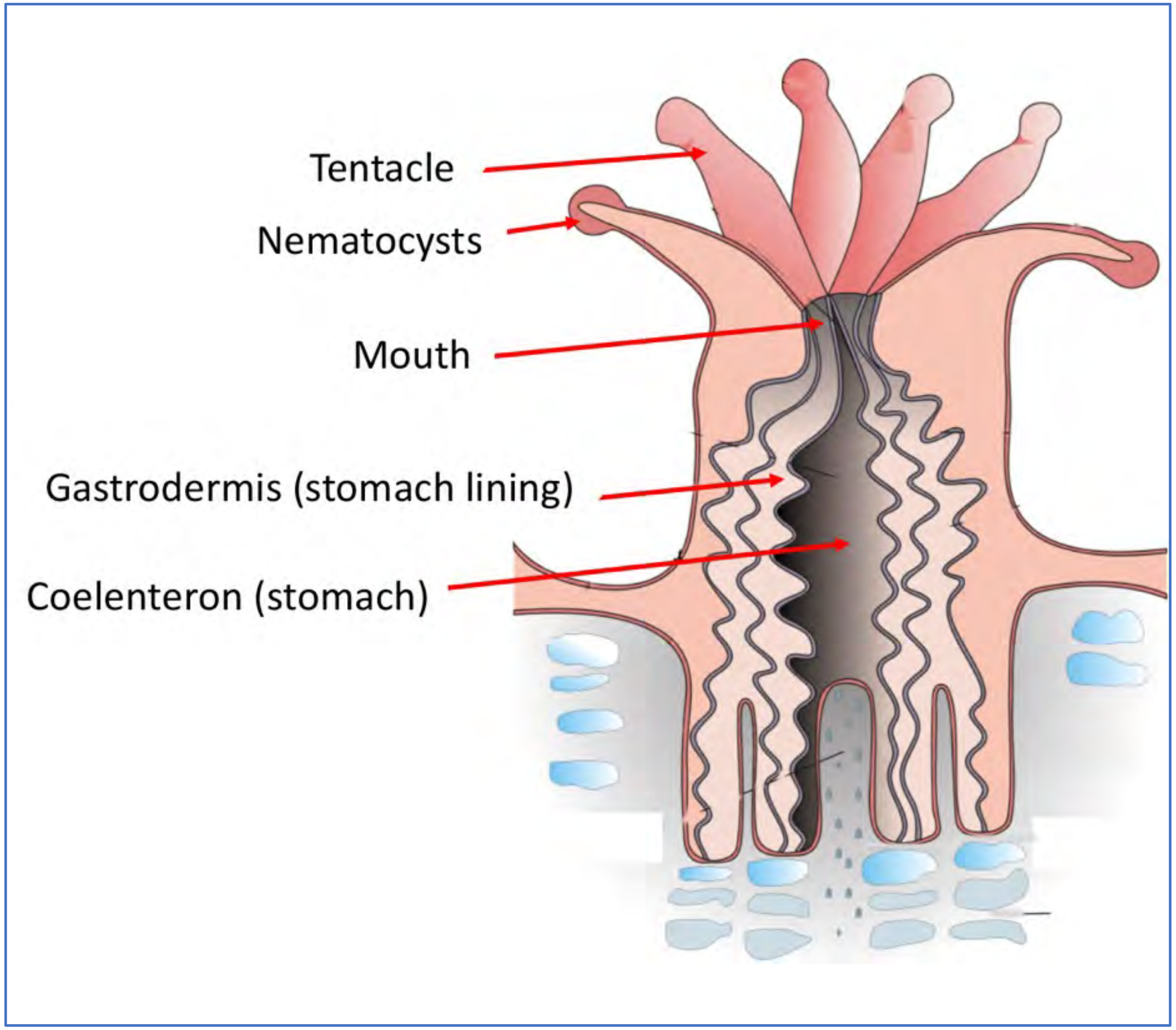
Review coral anatomy



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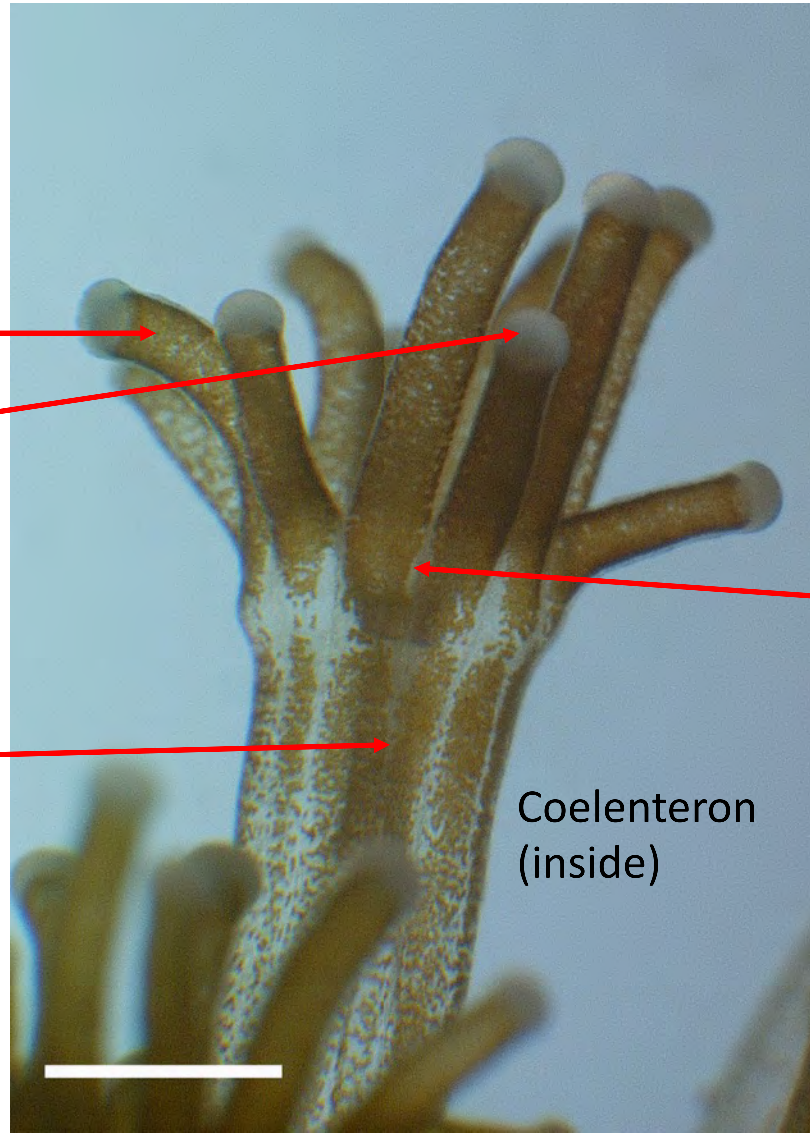
Recall the following parts of a coral polyp:

- *Tentacle*
- *Nematocysts*
- *Mouth*
- *Gastrodermis*
- *Coelenteron*

Close-up of coral polyp

Image copyright Oregon State University, accessed: https://www.housingcamera.com/blog/wp-content/uploads/2017/01/3551766692_db6d19de8f_b.jpg / Reproduced with permission.



Close-up of coral polyp

Porites coral polyps. The tentacles form a ring around the central mouth.

Image: K. Anthony, Copyright Commonwealth of Australia (GBRMPA), 1199

How do corals eat?

Corals are cnidarians- like jellyfish.
Like jellyfish, coral polyps have tentacles equipped with batteries of nematocysts (stinging cells).

These nematocysts sting, immobilize or kill zooplankton; which is then drawn through the polyp's mouth and into the stomach. Some corals use cilia and mucous.

Some corals capture suspended organic matter or detritus from the water, and others absorb dissolved organic matter.

Food is digested by the gastrodermis, which lines the inside of the polyp.

Tentacles of a soft coral feeding

Image: K. Anthony, Copyright Commonwealth of Australia (GBRMPA), 120901

Watch this YouTube video of coral polyps feeding:

https://www.youtube.com/watch?v=LoMEmKNGNEg

Coral polyps feeding

This YouTube video shows hard and soft corals being fed copepods and rotifers in an aquarium.

https://youtu.be/NuCt0-m3VI8

Coral feeding in close-up

YouTube video by Coralpublications, available: https://youtu.be/NuCt0-m3VI8

You can see polyps using their tentacles and microscopic cilia to move prey into their mouth.

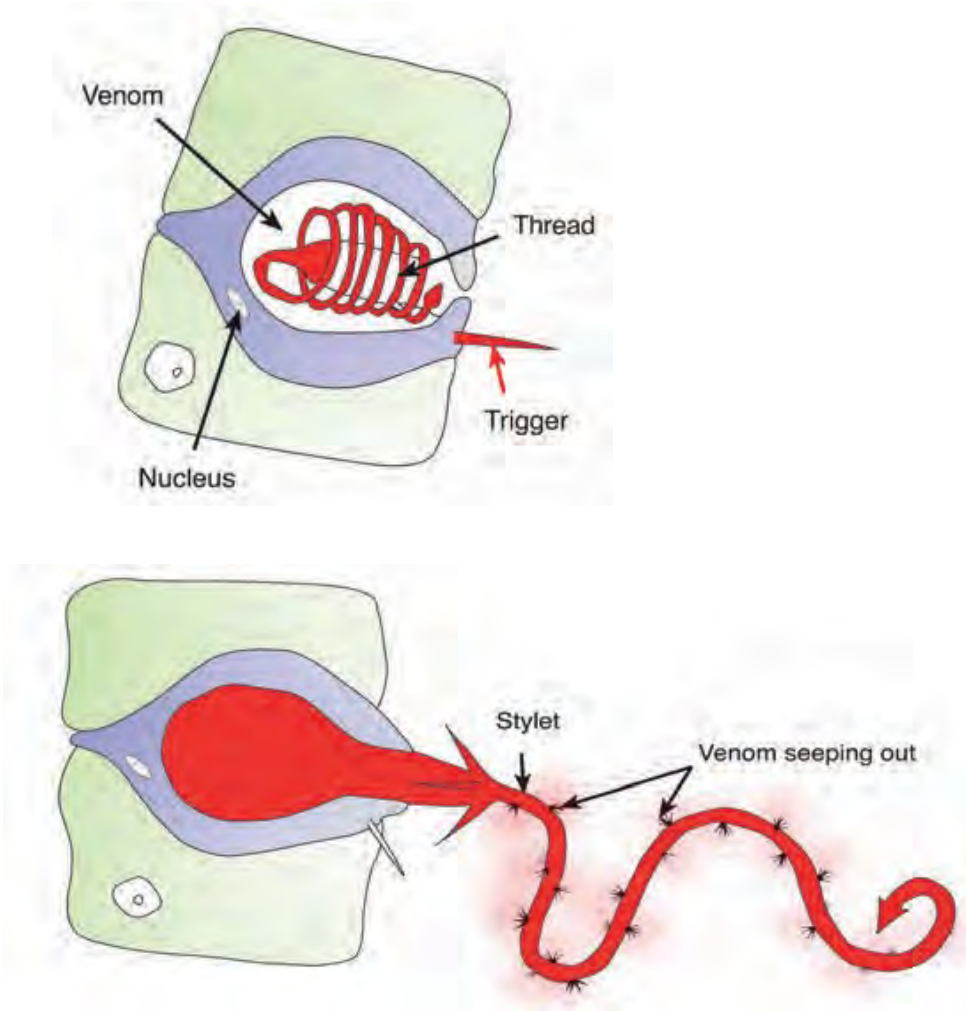
Mucous and nematocysts cause prey items to remain attached to the coral's tentacles.

Nematocysts

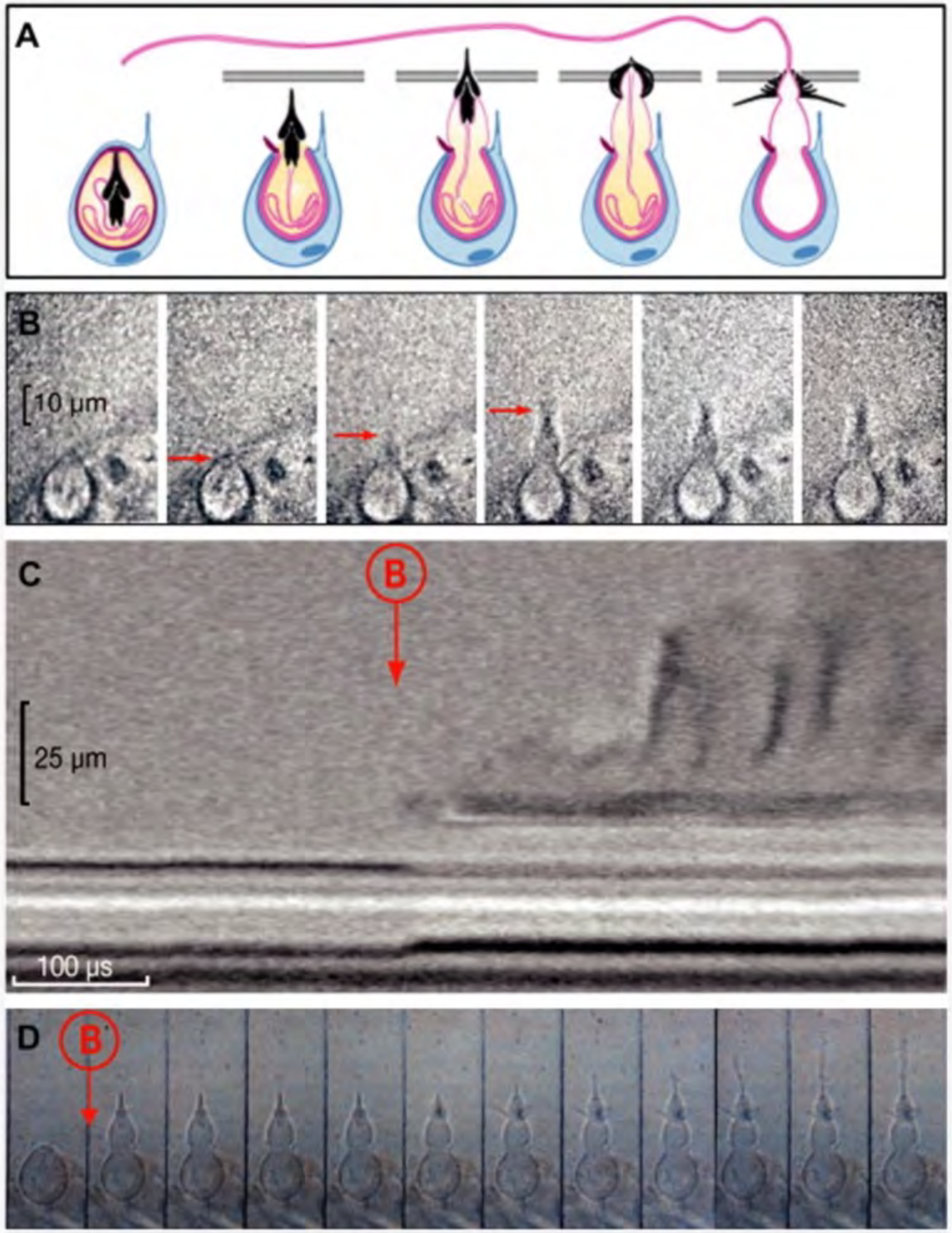
Nematocysts (also known as cnidocytes, hence Phylum Cnidaria) are specialised cells that fire a venomous thread in response to contact with a trigger.

When triggered, osmotic pressure within the cell is released, firing a strong and flexible spiked tube (stylet) out of the cell and into the contacting tissue with an acceleration over 5 million times gravity- and a pressure on impact comparable to a bullet!

Nematocysts are used for defense as well as feeding.



An undischarged and discharged nematocyst



Nematocyst discharge

Image: Asknature.org CC BY NC, original from Özbek, S., Balasubramanian, P., & Holstein, T. (2009). Cnidocyst structure and the biomechanics of discharge. *Toxicon*, *54*(8), 1038-1045. doi: 10.1016/j.toxicon.2009.03.006

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Watch this YouTube video of nematocysts firing:

https://youtu.be/6zJiBc_N1Zk

Jellyfish stinging in microscopic slow motion

Smarter Every Day 120, YouTube video available: https://youtu.be/6zJiBc_N1Zk
Reproduced with permission

Night feeding patterns

Flowing translucent white tentacles of *Favia sp.* polyps at Hook Island, at night

Image: T . Fontes, Copyright Commonwealth of Australia (GBRMPA), 107780

Most hard corals are nocturnal feeders, that only extend their tentacles at night.

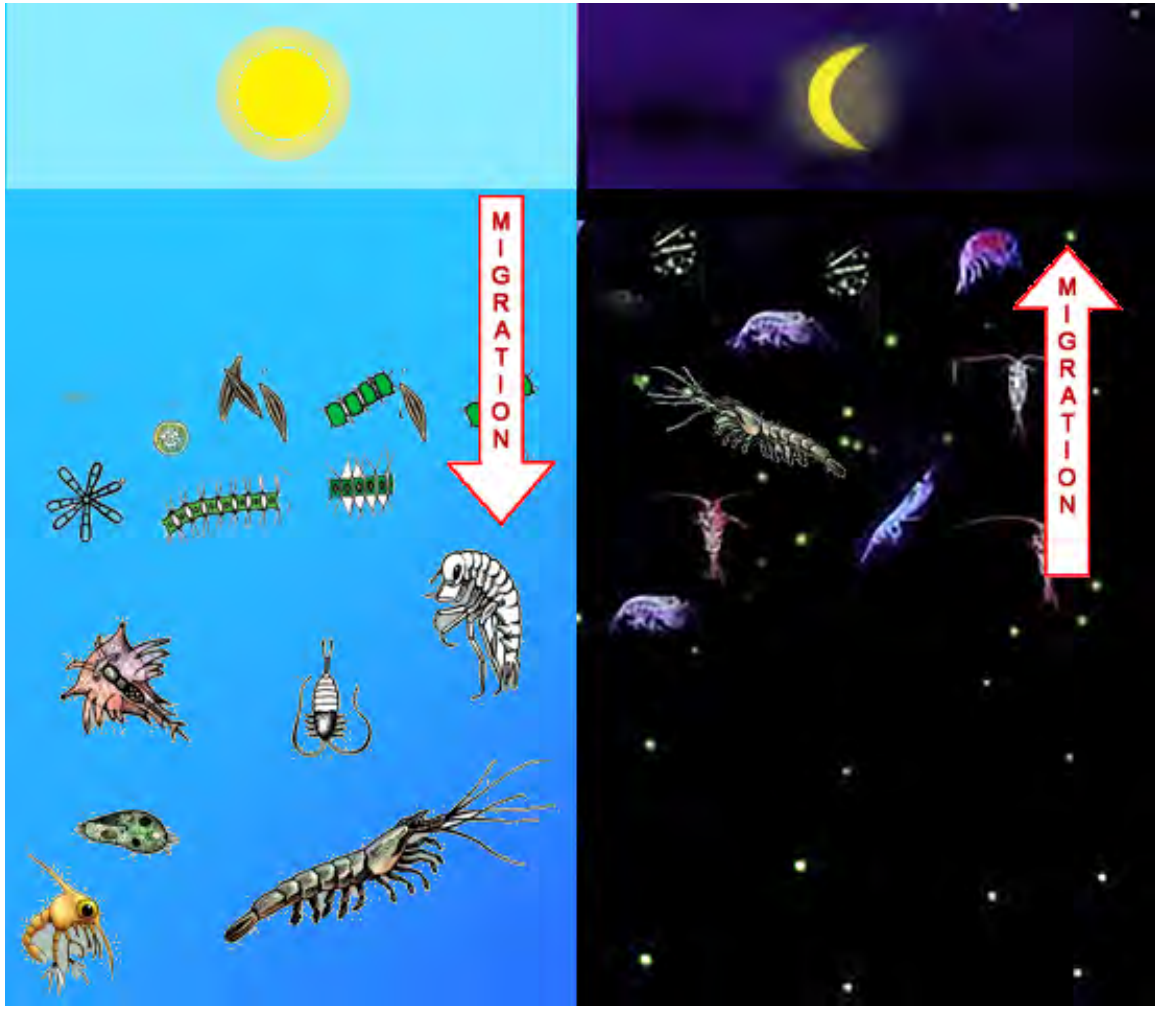
Diel migration*

* Also know as diurnal vertical migration.

It is widely accepted that corals feed at night because their zooplankton prey are more abundant in surface waters during the night.

Zooplankton hide in deeper water to avoid predation during the day, and migrate towards the surface to feed at night.

This daily migration is known as diel migration.

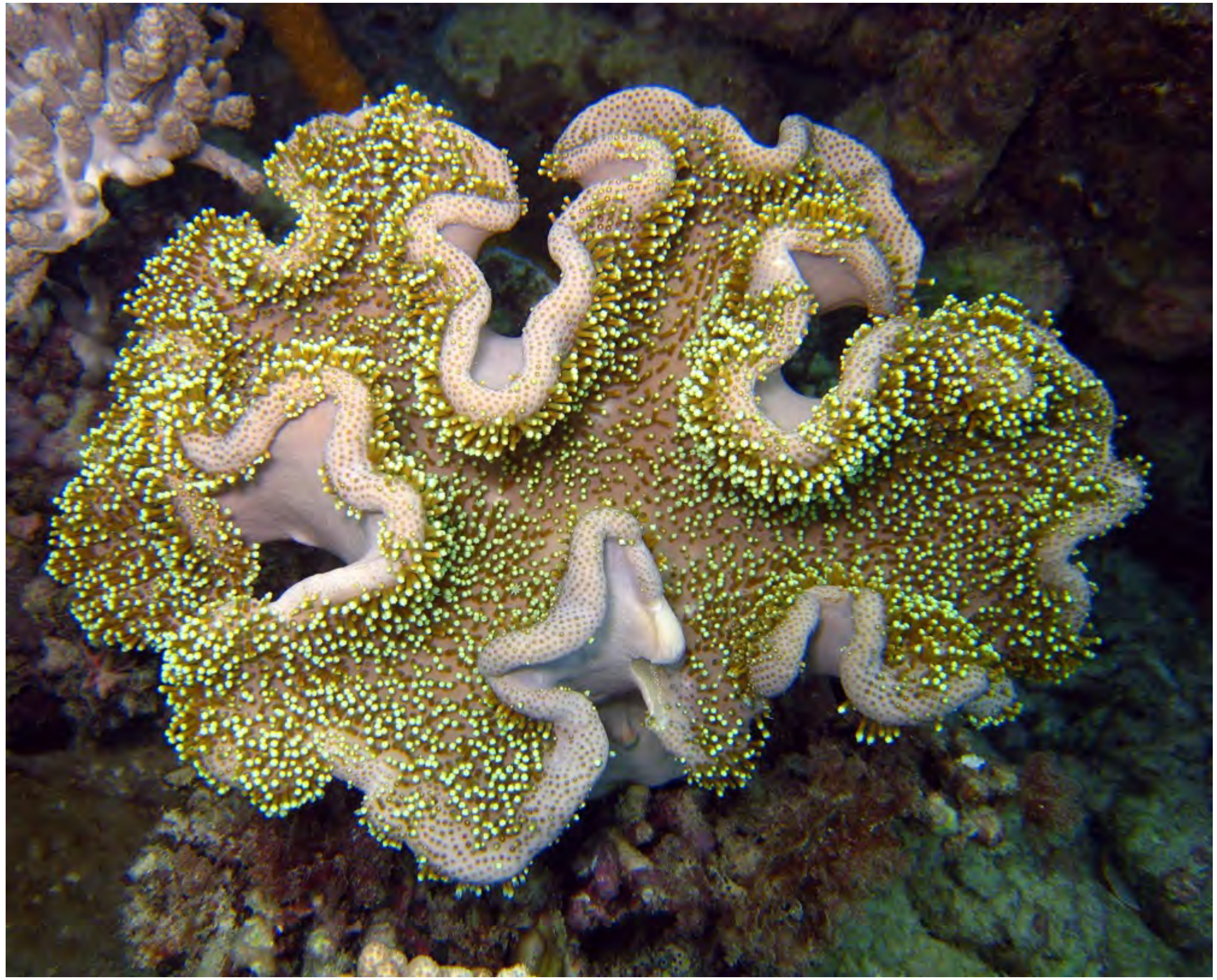


Zooplankton migrate to the surface at night.

Some corals, including most soft corals, extend their tentacles during the day.

Soft corals obtain more nutrition from phytoplankton, bacteria and detritus than they do from zooplankton. These food items are present during the day and night.

Day feeding corals often have less symbiotic zooxanthellae and can live in areas with less light.



Soft coral with some tentacles extended

Some species always have their tentacles extended, eg *Goniopora sp.*, but retract them quickly when touched.

Polyps withdraw their tentacles back into their skeleton when disturbed or not feeding, to avoid predation, or conserve nutrients and energy.

Studies suggest that the extent that corals extend their tentacles is affected by light levels, water flow, food availability and the presence of predators.

Goniopora sp. coral polyps with tentacles extended

Image: K. Anthony, Copyright Commonwealth of Australia (GBRMPA), 130137

Heterotrophs and autotrophs

Since corals receive their nutrition by capturing plankton and particulate matter from the water column, they are heterotrophs.

Corals with photosynthetic zooxanthellae living within their tissues receive most of their nutrition from this mutualistic symbiosis. This suggests that the coral/zooxanthellae combination are autotrophs.

Since coral colonies often rely on the nutrients from autotrophy from the the zooxanthellae and heterotrophy from plankton consumption, they are considered to be mixotrophic.

Porites polyp with tentacles extended and zooxanthellae visible.

Image: National Coral Reef Institute - NOAA [Public domain], via Wikimedia Commons CC 3.0 BY SA

Questions

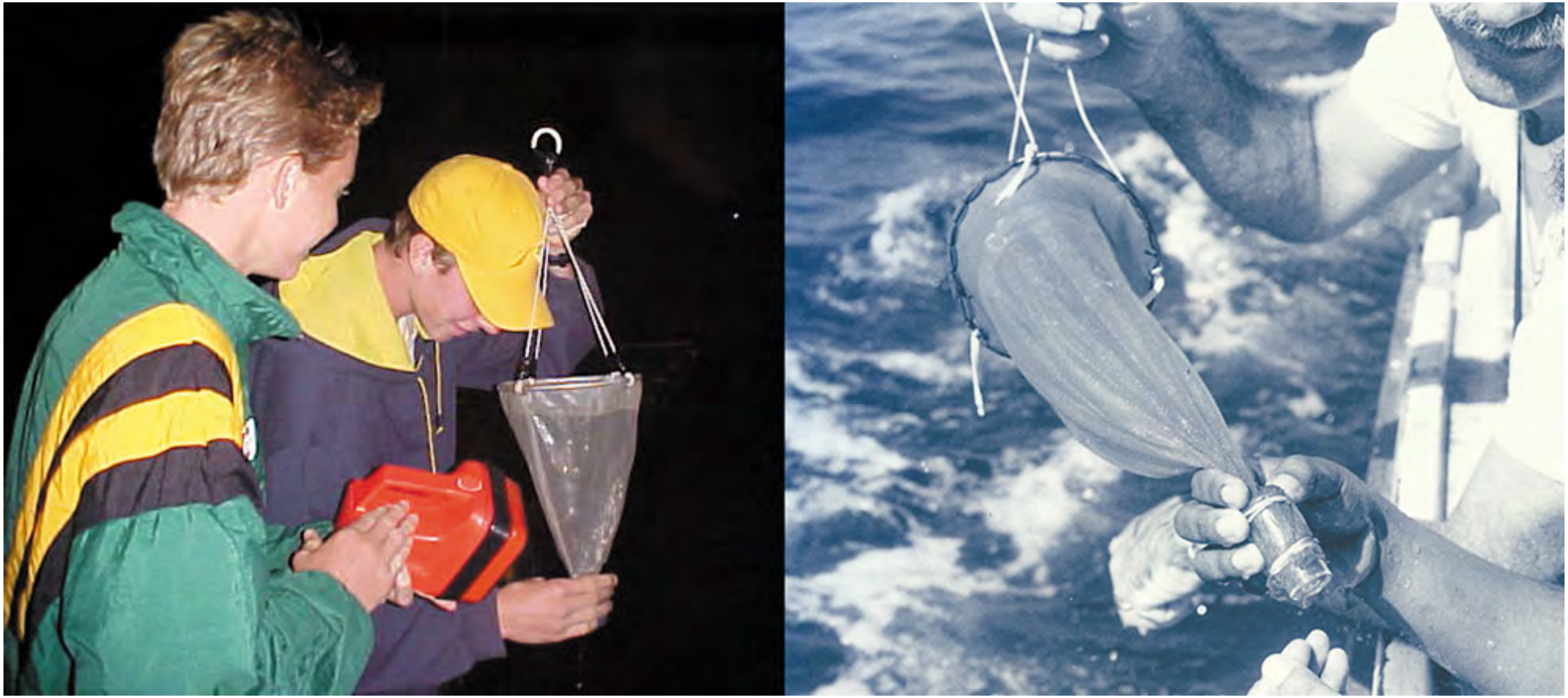
1. Describe the process of coral feeding. Refer to a diagram of a coral polyp.

2. When do corals generally feed? What are the exceptions?

3. How do nematocysts work?

Field work

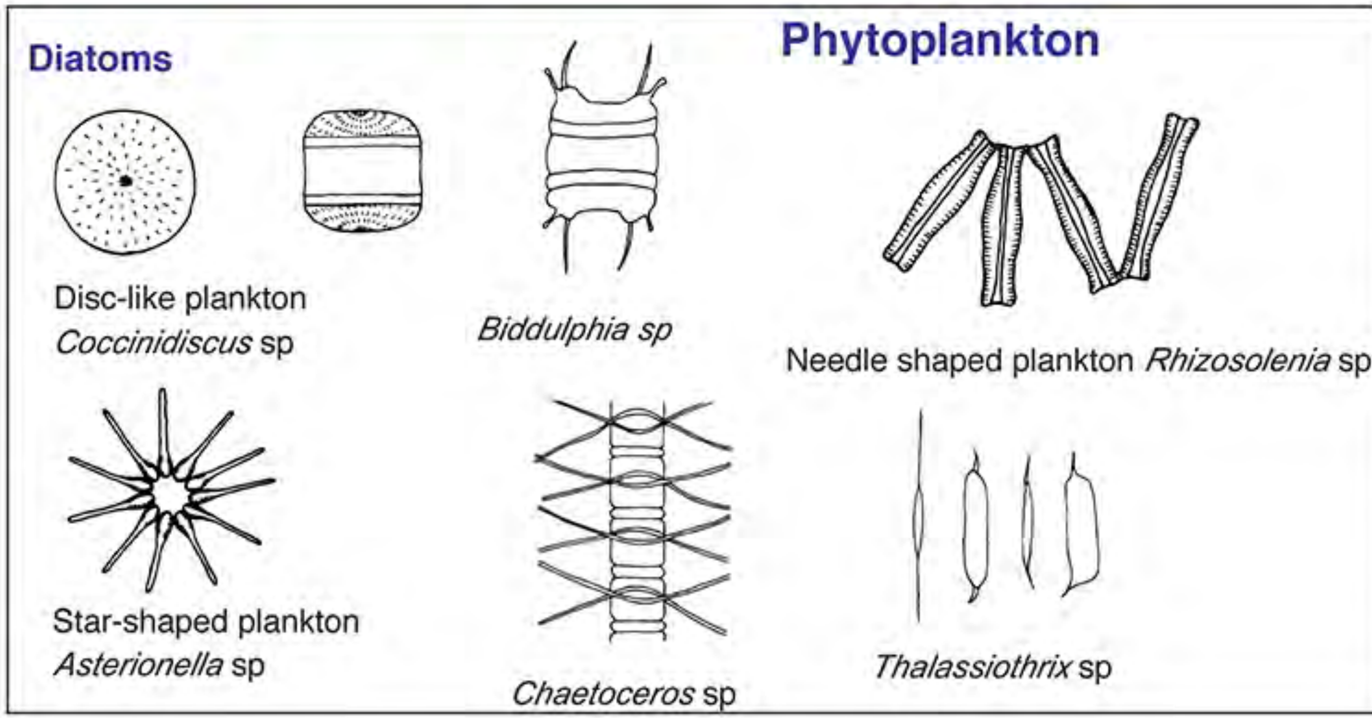
Plankton trawl

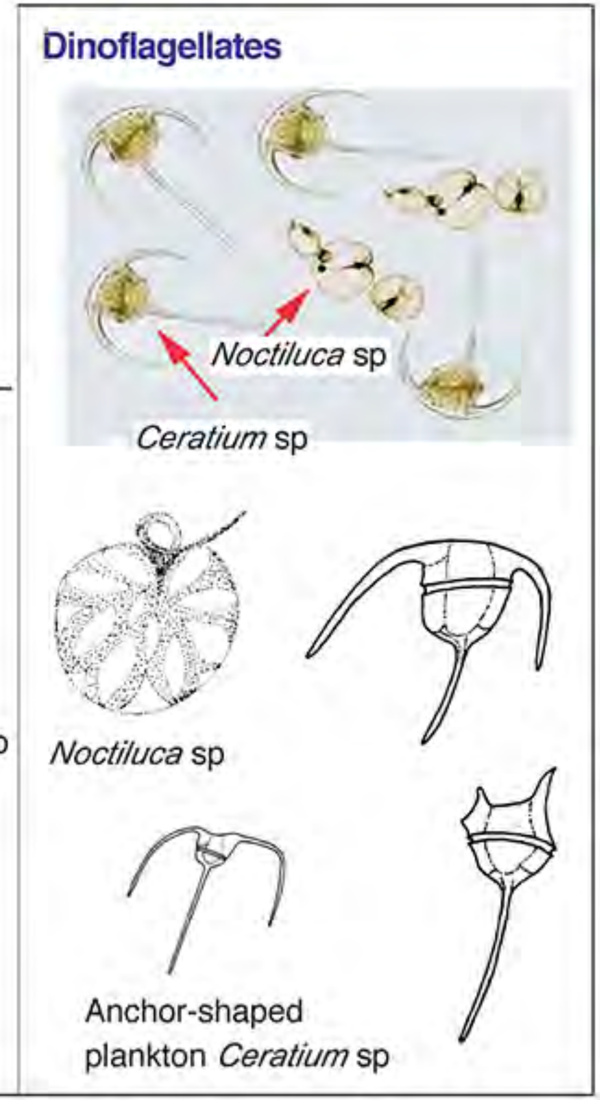


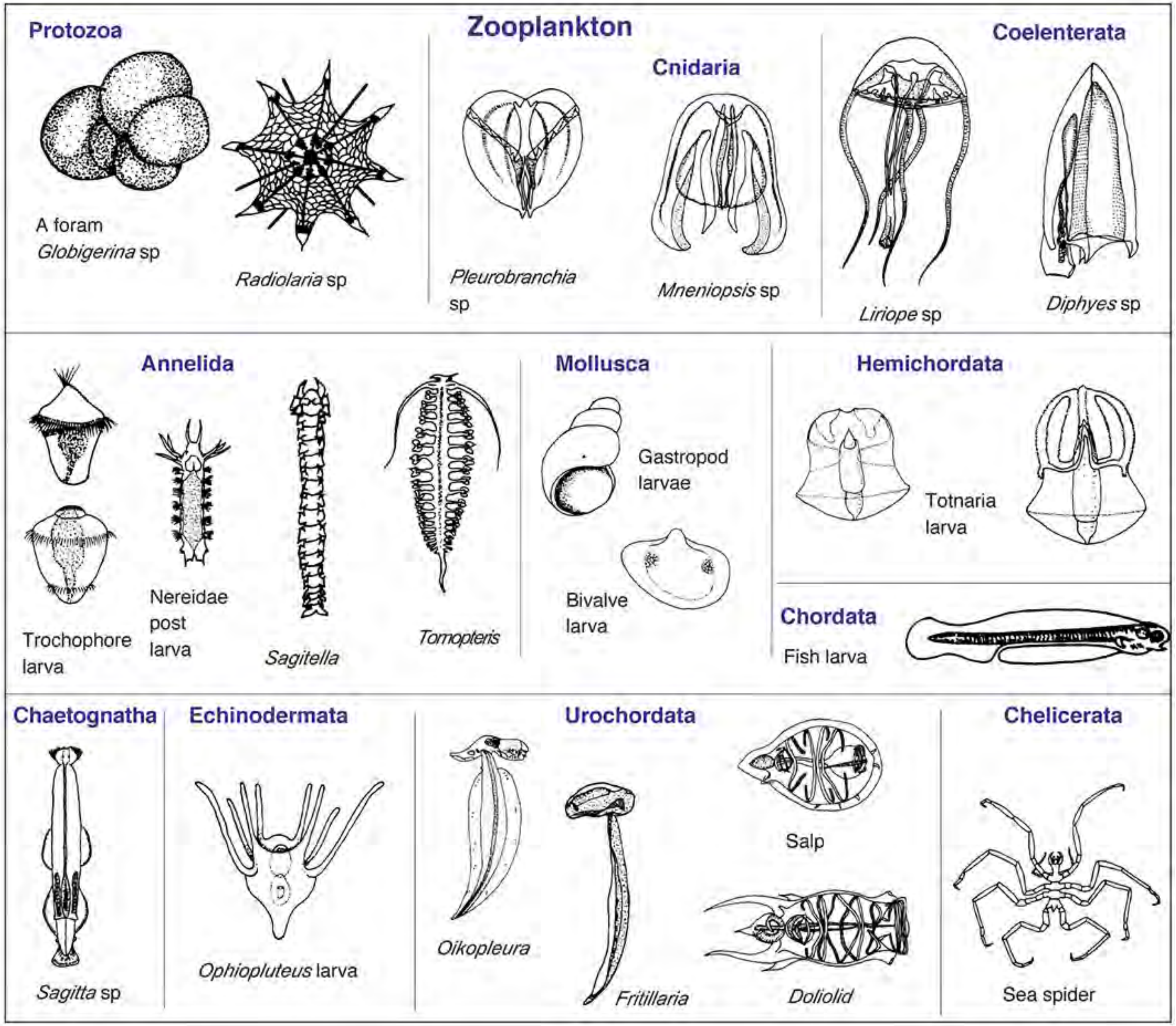
Acknowledgement

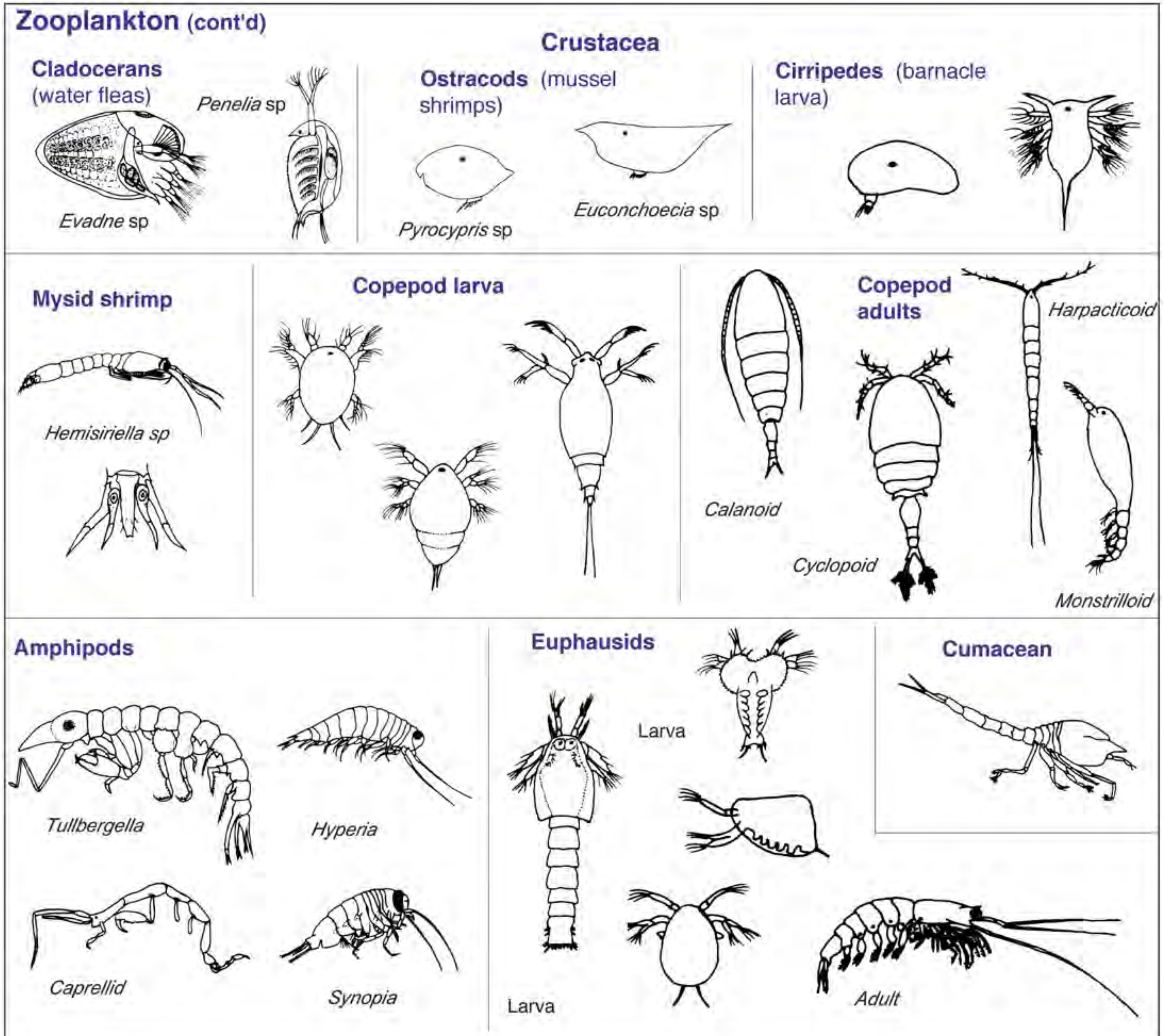
Drawings by
Dr Jack Marsh and Dr David Tulip

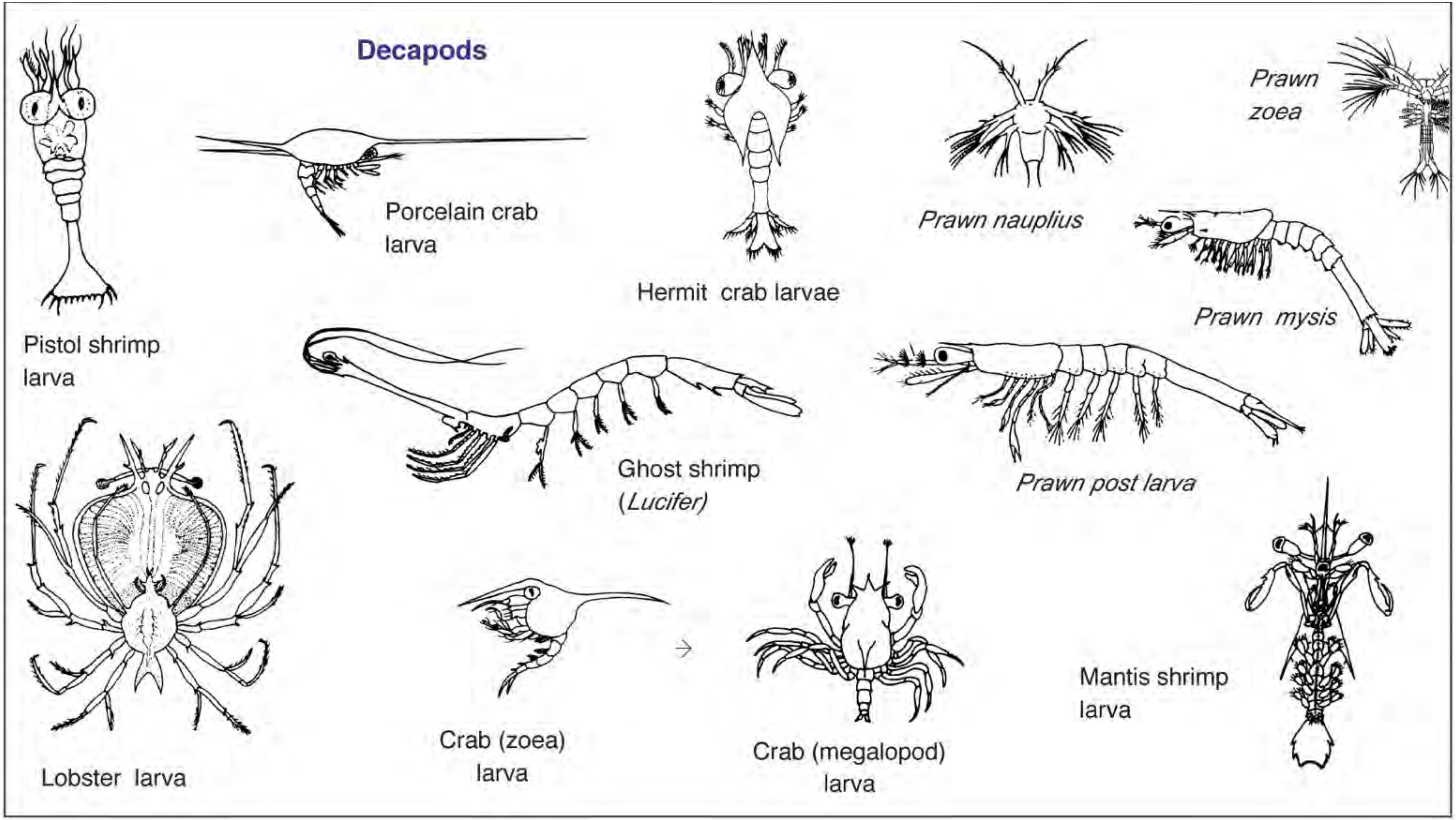
Foundation lecturers in Queensland Marine Science






Zooplankton
Protozoa
A foram
Globigerina sp
Radiolaria sp
Cnidaria
Pleurobranchia sp
Mneniopsis sp
Coelenterata
Liriope sp
Diphyes sp
Annelida
Trochophore larva
Nereidae post larva
Sagitella
Tomopteris
Mollusca
Gastropod larvae
Bivalve larva
Hemichordata
Totnaria larva
Chordata
Fish larva
Chaetognatha
Sagitta sp
Echinodermata
Ophiopluteus larva
Urochordata
Oikopleura
Fritillaria
Salp
Doliolid
Chelicerata
Sea spider


Zooplankton (cont'd)
Crustacea
Cladocerans
(water fleas)
Penelia sp
Evadne sp
Ostracods (mussel
shrimps)
Pyrocypris sp
Euconchoecia sp
Cirripedes (barnacle
larva)
Mysid shrimp
Hemisiriella sp
Copepod larva
Copepod
adults
Harpacticoid
Calanoid
Cyclopoid
Monstrilloid
Amphipods
Tullbergella
Hyperia
Caprellid
Synopia
Euphausids
Larva
Larva
Adult
Cumacean


Decapods
Pistol shrimp larva
Porcelain crab larva
Hermit crab larvae
Prawn nauplius
Prawn zoea
Prawn mysis
Ghost shrimp (*Lucifer*)
Prawn post larva
Lobster larva
Crab (zoea) larva
Crab (megalopod) larva
Mantis shrimp larva

Further activities

See

https://coralwatch.org/index.php/education-2/curriculum-materials/marine-science/

by

Further activity

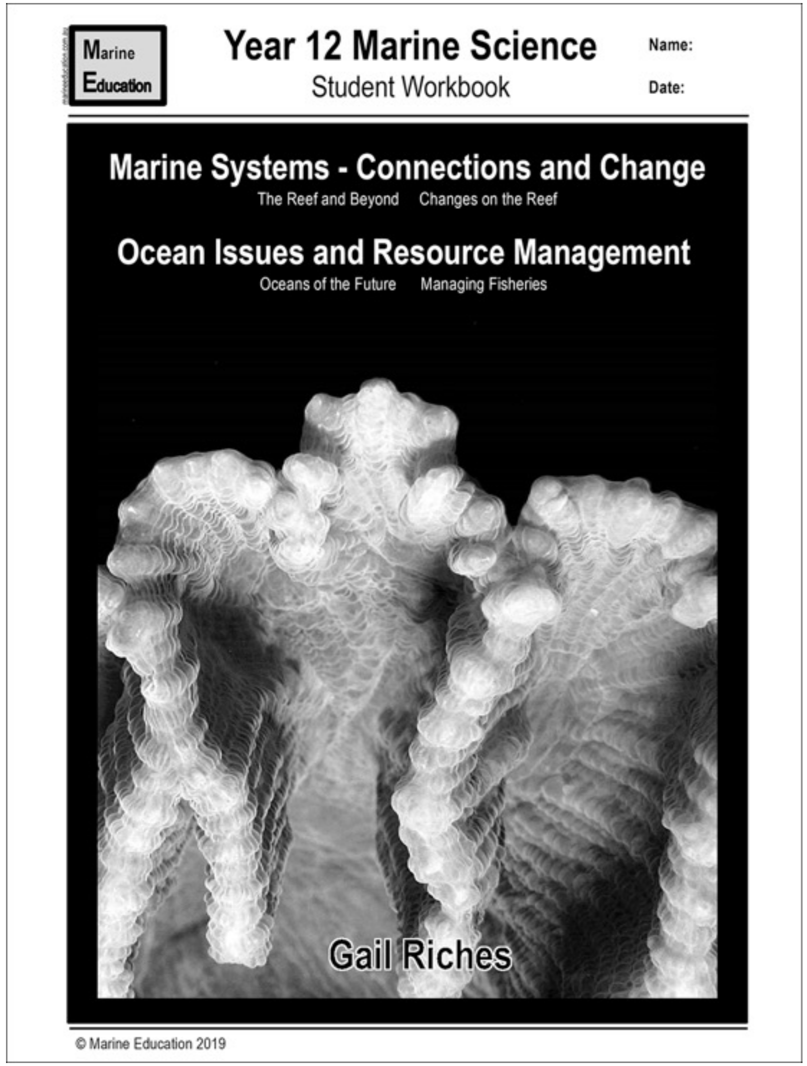
Worksheet –

Midnight munchies

by

Gail Riches

www.marineeducation.com.au



T081 Coral symbiosis

Adam Richmond

Syllabus statement

At the end of this topic you should be able to ...

Identify and describe

the symbiotic relationships in a coral colony (including polyp interconnections and zooxanthellae)

Identify

- distinguish;
- locate, recognise and name;
- establish or indicate who or what someone or something is;
- provide an answer from a number of possibilities;
- recognise and state a distinguishing factor or feature

Describe

- give the meaning of a word, phrase, concept or physical quantity;
- state meaning and identify or describe qualities

Objectives

1. Recall the types of symbiotic relationships

2a. Describe the relationship between coral and zooxanthellae

2b. Describe the relationship between individual polyps in a colony

3. Identify which types of symbiotic relationships are demonstrated in A and B above

Symbiosis

Recall symbiosis from T046 Biotic interactions in ecosystems:

Definition

Symbiosis (from the Greek "living together”),

is any type of a close and long-term biological interaction between two different biological organisms

be it,

- Parasitism
- Mutualism
- Commensalism or
- Amensalism

Symbiosis

is any type of a close and long-term biological interaction between two different biological organisms.

<u>Typically there are four:</u>

Parasitism - a relationship between species, where one organism, the parasite benefits by living on or in another organism, the host, causing it harm, and is adapted structurally to this way of life. (- +)

Mutualism - the way two organisms of different species exist in a relationship in which each individual benefits from the activity of the other. (+ +)

AND

Commensalism - a long term biological interaction (symbiosis) in which members of one species gain benefits, while those of the other species, are neither benefited nor harmed. (0 +)

Image: Duncan Wright (User:Sabine's Sunbird) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], via Wikimedia Commons

Amensalism - an asymmetric interaction where one species is harmed or killed by the other, and one is unaffected by the other. (0 -)

An example is where surgeonfish graze algae, destroying habitat for smaller animals such as amphipods.

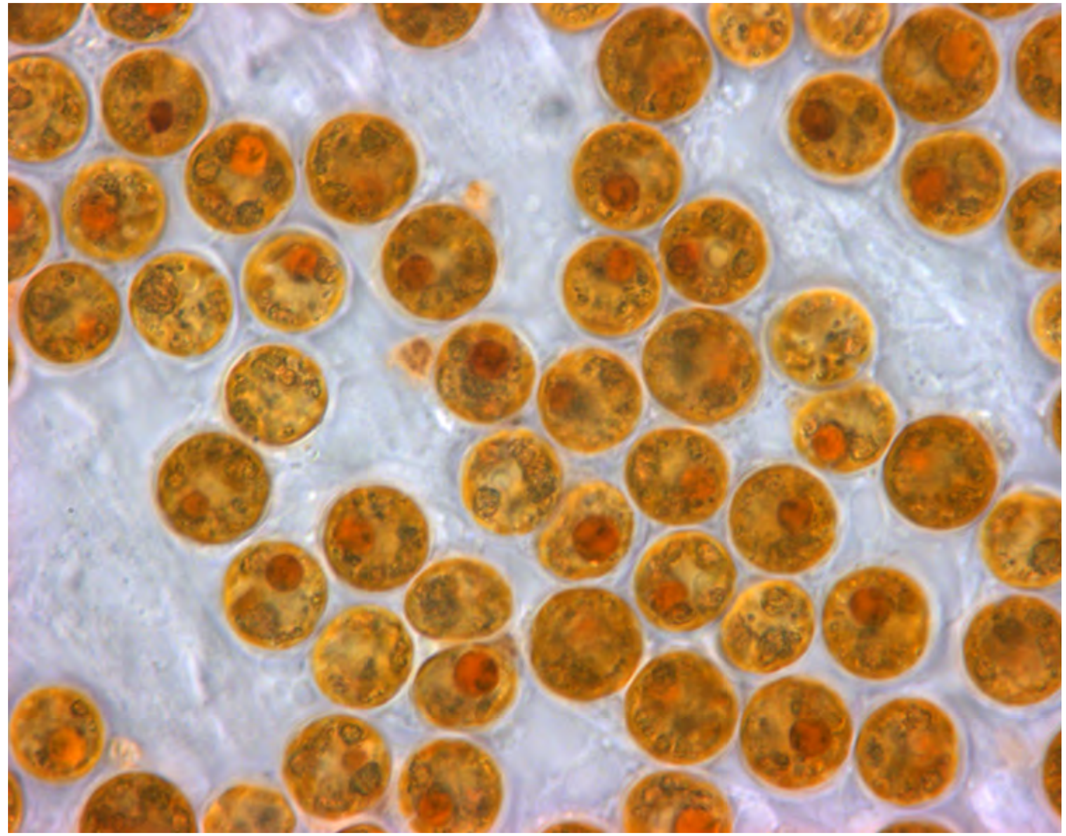
Image: Uxbona [CC BY 3.0 (https://creativecommons.org/licenses/by/3.0)], from Wikimedia Commons.

So what is this close and long-term biological interaction between two different biological organisms in corals?

Zooxanthellae

Zooxanthellae are a unicellular dinoflagellate algae found in hard and soft corals, anemones, jellyfish, giant clams, sponges and flatworms.

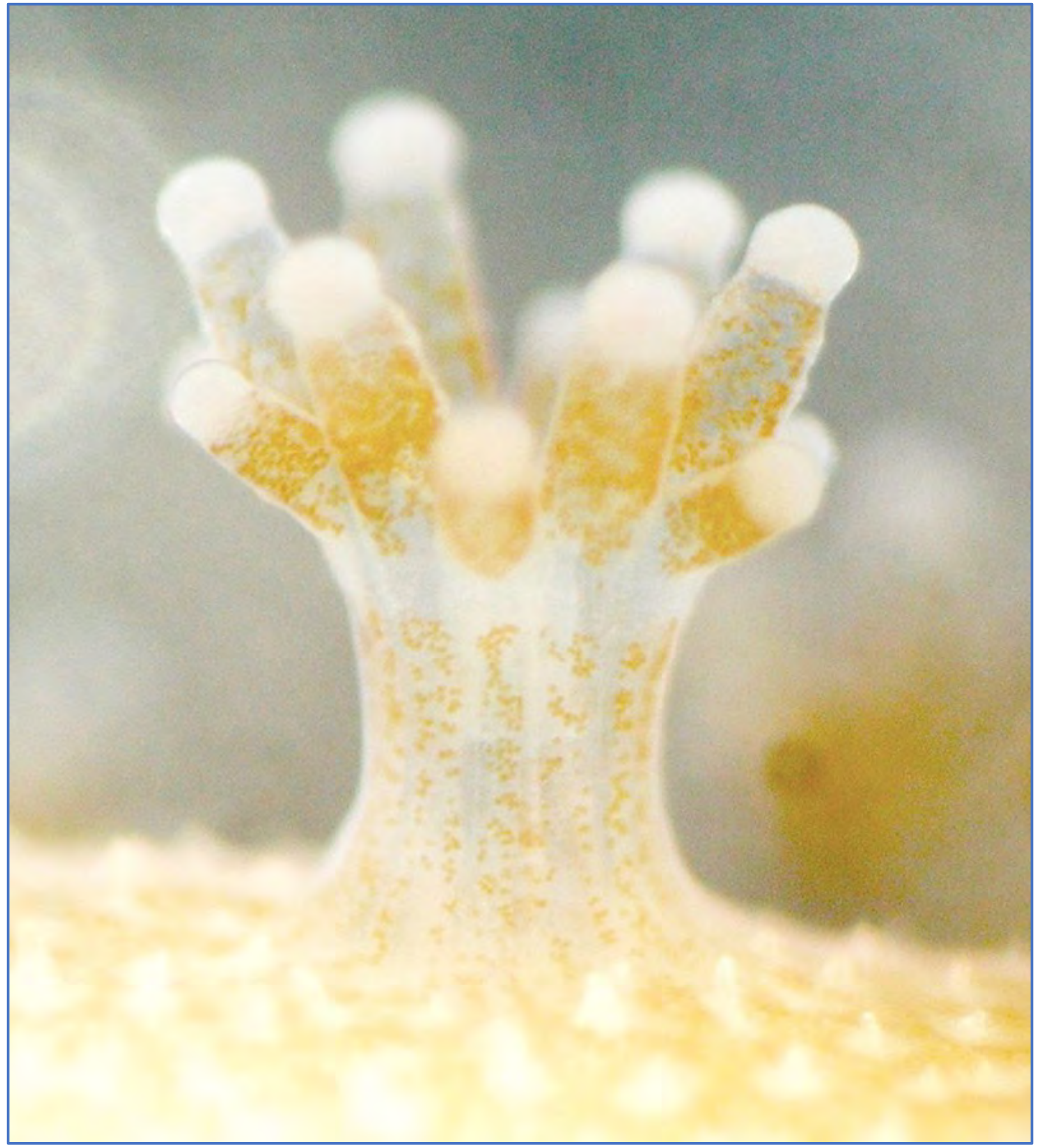
Zooxanthellae were thought to be all the same species, *Symbiodinium microadriaticum*. Different genetic types of zooxanthellae are called "clades".



Zooxanthellae

Zooxanthellae can live independently, but occur in greater numbers in the tissues of hosts.

Corals can have 1 000 000 – 5 000 000 zooxanthellae in 1 cm^2 of tissue.

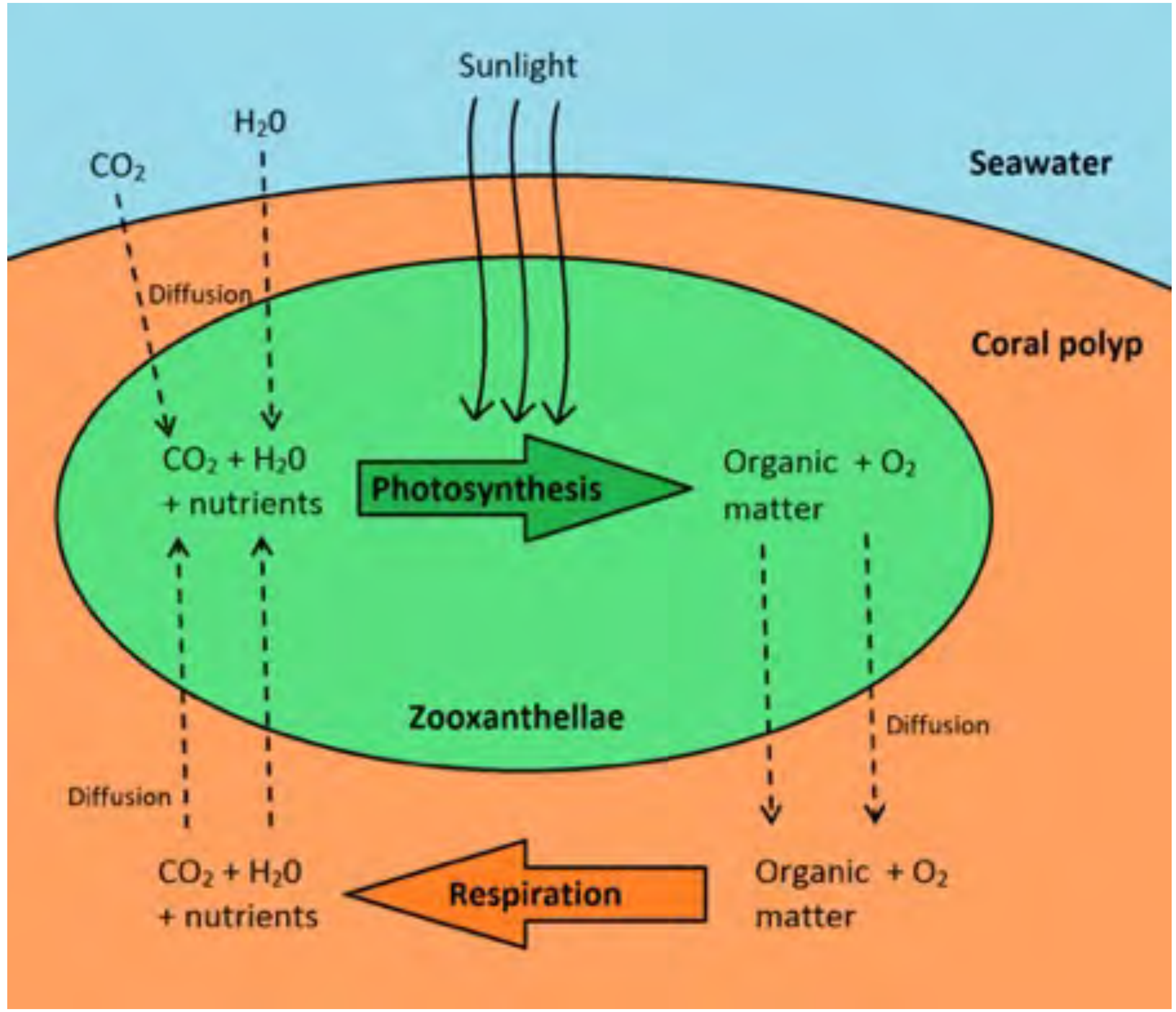


Wiki commons: https://commons.wikimedia.org/w/index.php?curid=78944190

Coral polyps provide the zooxanthellae with a protected environment and waste nutrients (ammonia and phosphate) needed for photosynthesis.

Zooxanthellae supply the coral with oxygen, glucose, glycerol, and amino acids, which are the products of photosynthesis.

- 90- 95 percent of the organic material produced by the zooxanthellae is transferred to the host coral tissue.
- The coral uses these products to make proteins, fats, and carbohydrates, and produce calcium carbonate.



Nutrient exchange between zooxanthellae and coral
Image: Adam Richmond, after McGraw-Hill

Mutualism

- the way two organisms of different species exist in a relationship in which each individual benefits from the activity of the other. (+ +)

The mutually-beneficial relationship between zooxanthellae and coral polyp facilitates a "tight recycling of nutrients", which is responsible for the high levels growth and productivity of coral reefs in nutrient-poor tropical waters.

Coral polyp interconnections

Many corals are made up of colonies of 100s or 1000s of individual polyps.

Polyps are connected together by a thin layer of living tissue called the coenosarc.

Polyps within a colony share nutrients and energy demands through the coenosarc.

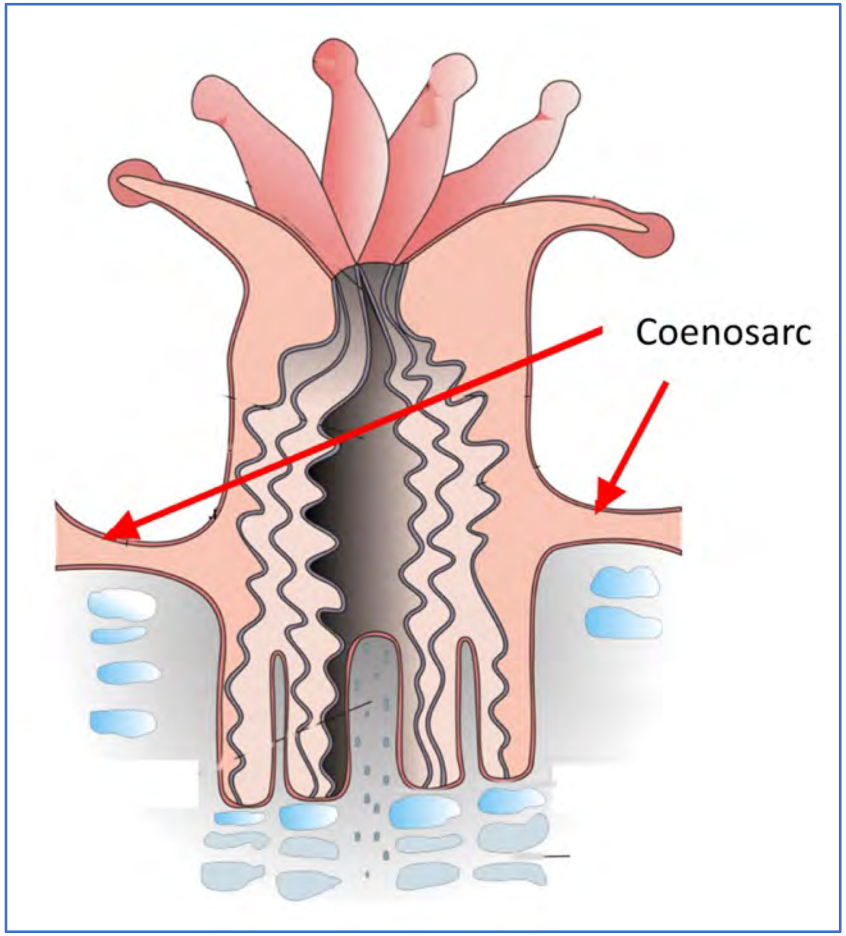


Image: modified from Coral polyp.jpg: NOAA derivative work: MarkusZi [Public domain], via Wikimedia Commons

A colony of coral polyps. The coenosarc is the “skin” connecting individual polyps.

Image: A Chinn. Copyright Commonwealth of Australia (GBRMPA). 116563

Other symbiotic relationships

Coral and fish

Grunts (Family Haemulidae) feed away from the reef at night and return to rest over the reef during the day.

The nitrogen excreted by these migratory fish is an important source of nutrients in coral reef ecosystems. [1]

Oblique-banded Sweetlips at Lizard Island

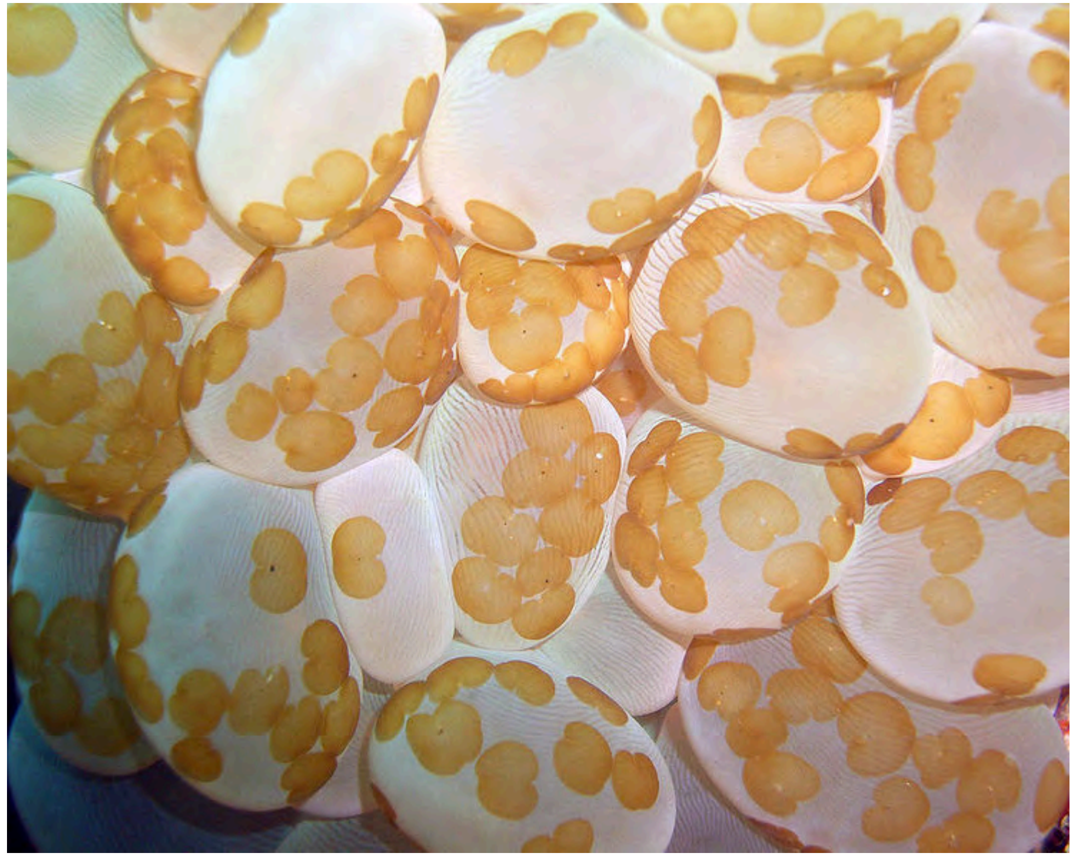
Image: Graham Edgar / Reef Life Survey. License: CC by Attribution
Retrieved: http://fishesofaustralia.net.au/home/species/457

1. Francis, F., & Côté, I. (2018). Fish movement drives spatial and temporal patterns of nutrient provisioning on coral reef patches. *Ecosphere*, *9*(5), e02225. doi: 10.1002/ecs2.2225

Coral and flatworms

Flatworms of the genus *Waminoa* have been found to consume the coral's mucous layer, compete for zooplankton prey, and reduce photosynthesis through shading. [1]

The coral does not benefit from this parasitic association.



The flatworm *Waminoa sp.* on bubble coral

Image: Samuel Chow [CC BY 2.0 (https://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons
Retrieved: https://commons.wikimedia.org/wiki/File:Waminoa_on_Plerogyra.jpg

1. Wijgerde, T., Spijkers, P., Verreth, J., & Osinga, R. (2011). Epizoic acoelomorph flatworms compete with their coral host for zooplankton. *Coral Reefs*, *30*(3), 665-665. doi: 10.1007/s00338-011-0781-z

Coral and barnacles

Coral-associated barnacle larvae bury themselves in the coral's tissue, where they feed on plankton.

The barnacles use some of the carbon produced by the zooxanthellae, and the zooxanthellae use ammonia (nitrogen) wastes produced by the barnacles. [1]

The coral do not appear to be negatively affected by this commensal relationship.

Coral barnacles (Pyrgoma sp.)

Image: Courtesy Ria Tan (reproduced with permission), www.wildsingapore.com, 070618rlhg0562

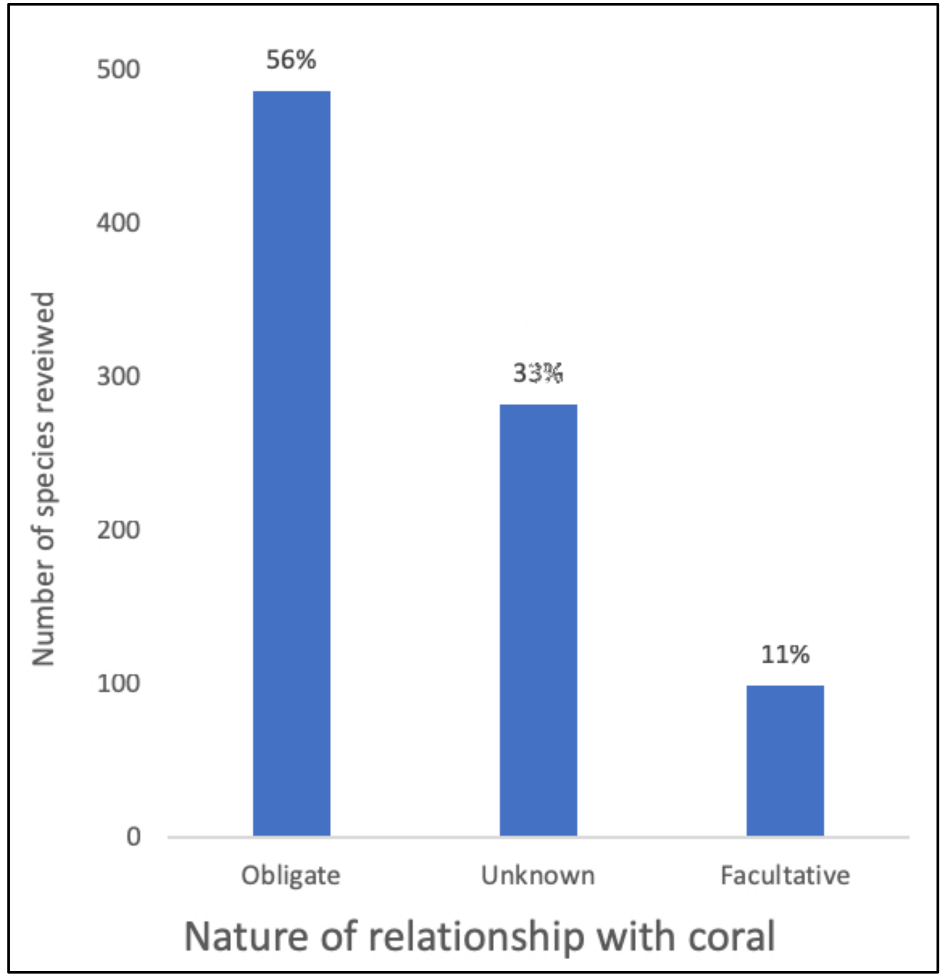
1 Chan, B., Xu, G., Kim, H., Park, J., & Kim, W. (2018). Living with marginal coral communities: Diversity and host-specificity in coral-associated barnacles in the northern coral distribution limit of the East China Sea. *PLOS ONE*, *13*(5), e0196309. doi: 10.1371/journal.pone.0196309

There's a lot more symbioses on a reef than you think!

A James Cook University review[1] identified 869 species of invertebrates that associate with hard corals.

Many of these were decapod crustaceans that rely on the coral for food, habitat and reproduction.

Over half of these symbioses were **obligate** relationships: necessary for the survival of the organisms. Only 11% were **facultative**: meaning the organisms may benefit from coral but can survive without it.



1. Stella JS, Pratchett MS, Hutchings PA, Jones GP. Coral-associated invertebrates: diversity, ecological importance and vulnerability to disturbance. Oceanography and Marine Biology: An Annual Review. 2011;49:43–104.
Available: https://www.researchgate.net/publication/230604775_Coral-associated_invertebrates_diversity_ecological_importance_and_vulnerability_to_disturbance

Questions

1. Recall the types of symbiotic relationships.

2a. Describe the relationship between coral and zooxanthellae
2b. Describe the relationship between individual polyps in a colony

3. Identify which types of symbiotic relationships are demonstrated in A and B above

Questions

1. Recall the types of symbiotic relationships

Symbiotic relationship	Criteria	Example
Parasitism	one organism, the parasite benefits by living on or in another organism, the host, causing it harm, and is adapted structurally to this way of life	parasitic isopod, a fish parasite, replacing fish tongue.
Mutualism	two organisms of different species exist in a relationship in which each individual benefits from the activity of the other.	The clownfish and sea anemone is a mutual service-service symbiosis.
Commensalism	one species gain benefits, while those of the other species, are neither benefited nor harmed.	Remoras attach themselves to larger fish that provide locomotion and food.
Amensalism	one species is harmed or killed by the other, and one is unaffected by the other	algal blooms that kill large numbers of fish.

Questions

2a. Describe the relationship between coral and zooxanthellae
2b. Describe the relationship between individual polyps in a colony

3. Identify which types of symbiotic relationships are demonstrated in A and B above

Ans: Mutualism

Further activities

See

https://coralwatch.org/index.php/education-2/curriculum-materials/marine-science/

by

CORALWATCH

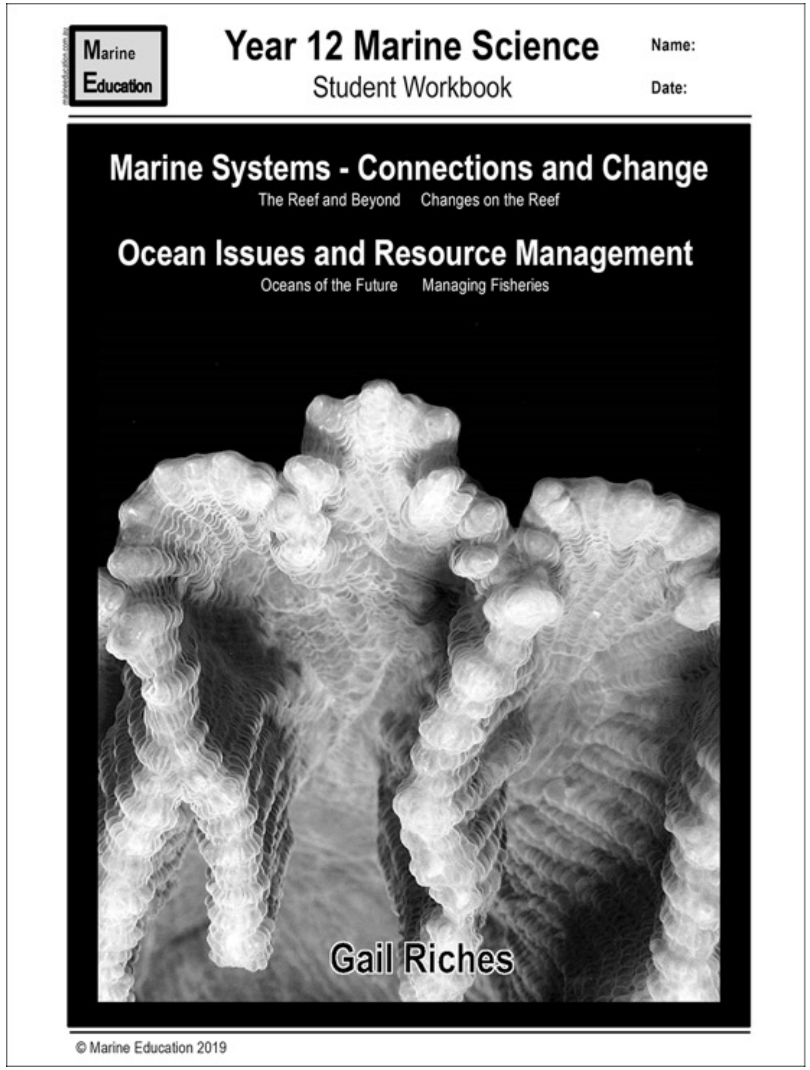
Further activity

Worksheet –

Plant or Animal

by
Gail Riches

www.marineeducation.com.au



T082 Coral life cycle

Adam Richmond

Syllabus statement

At the end of this topic you should be able to ...

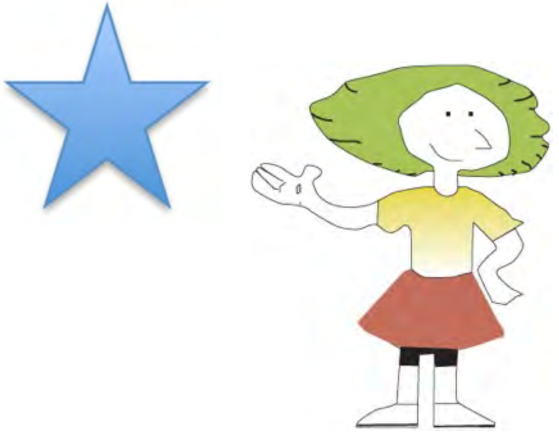
Recall

the life cycle stages of a typical reef-forming hard coral:

- asexual: fragmentation, polyp detachment;
- sexual: gametes, zygotes, planulae,
- polyp/asexual budding

Recall

- remember; present remembered ideas, facts or experiences;
- bring something back into thought, attention or into one's mind



Objectives

1. Sketch the life-cycle of a typical reef-forming hard coral.
2. Describe the stages of sexual reproduction
3. List three ways corals can reproduce asexually.
4. Describe how budding enables a coral colony to grow.
5. Describe genetically how the offspring of sexual reproduction and asexual reproduction different?

Watch this YouTube video as an introduction to this topic:

https://www.youtube.com/watch?v=VorXse4HrHs

The Amazing Coral Lifecycle- From Dusk till Spawn!

You tube video by Reef Patrol, available: https://www.youtube.com/watch?v=VorXse4HrHs

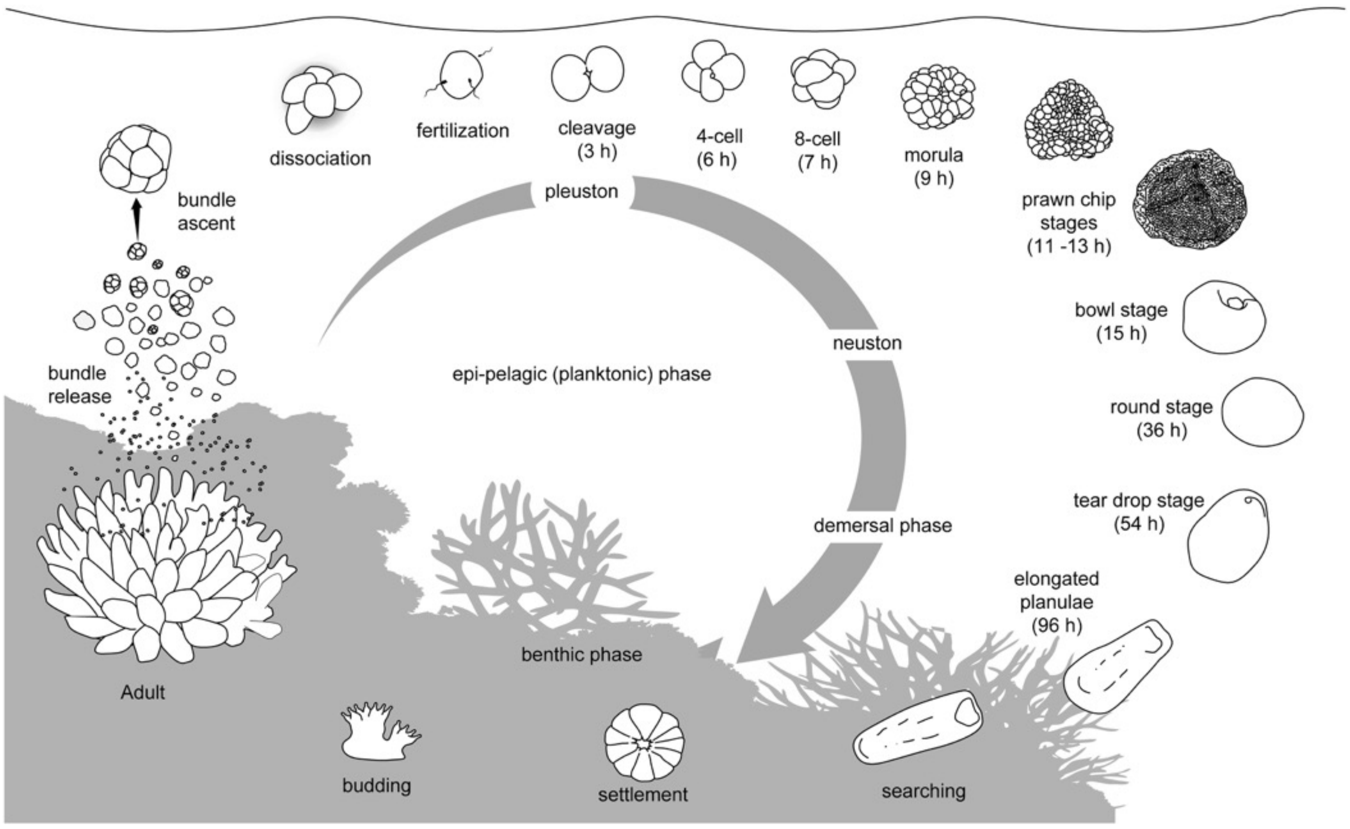
Coral life cycle

Coral lifecycles are complex and have several stages.

Acropora sp. are typical broadcast spawning hard corals. This will be explained over the next few slides.

This diagram (and article) is freely available for download here:

https://www.sciencedirect.com/science/article/pii/S0025326X15005251?via%3Dihub



Reproductive cycle of *Acropora sp.* coral

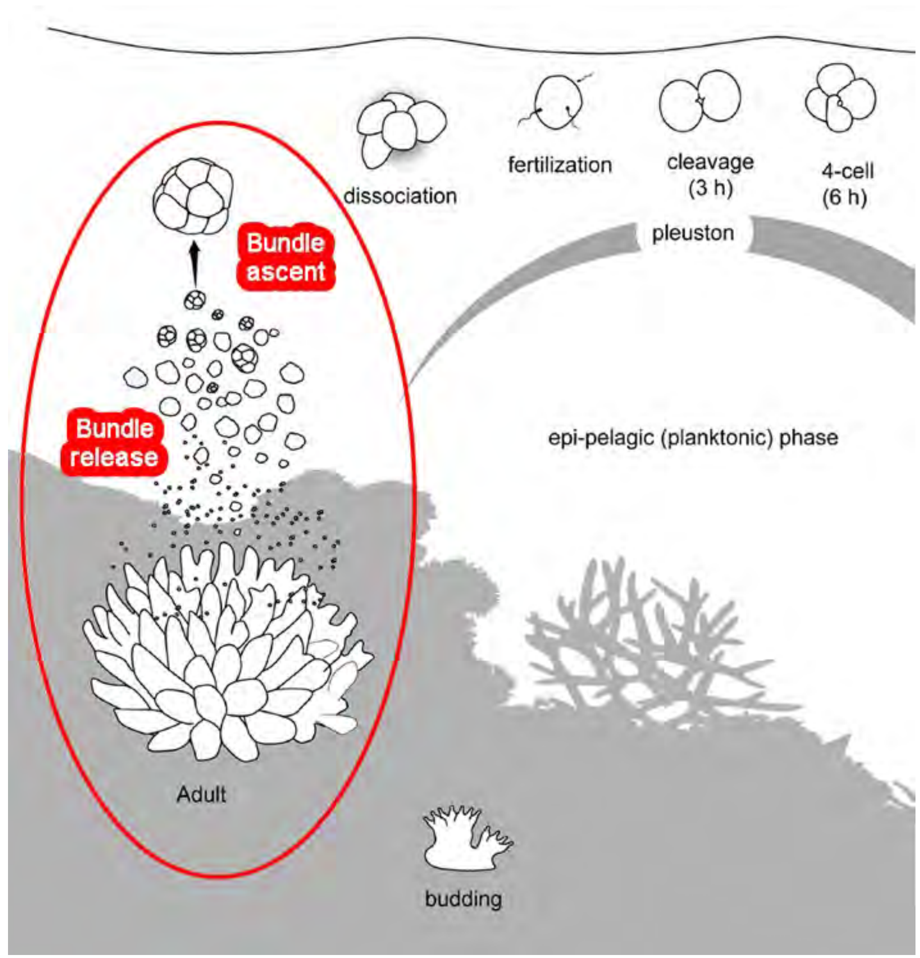
Image: Jones, R., Ricardo, G., & Negri, A. (2015). Effects of sediments on the reproductive cycle of corals. *Marine Pollution Bulletin*, *100*(1), 13-33. doi: 10.1016/j.marpolbul.2015.08.021 CC BY 4.0

Adult corals develop eggs and sperm (known as gametogenesis) for several months leading up to a mass spawning event.

These events are always at night and timed to coincide with full moon in October-December.

Some corals are gonochoric (have separate sexes), whilst many are hermaphrodites (both male and female).

Acropora corals release compact bundles of gametes from their gut cavity, that then float to the water surface.



Adult corals releasing gamete bundles

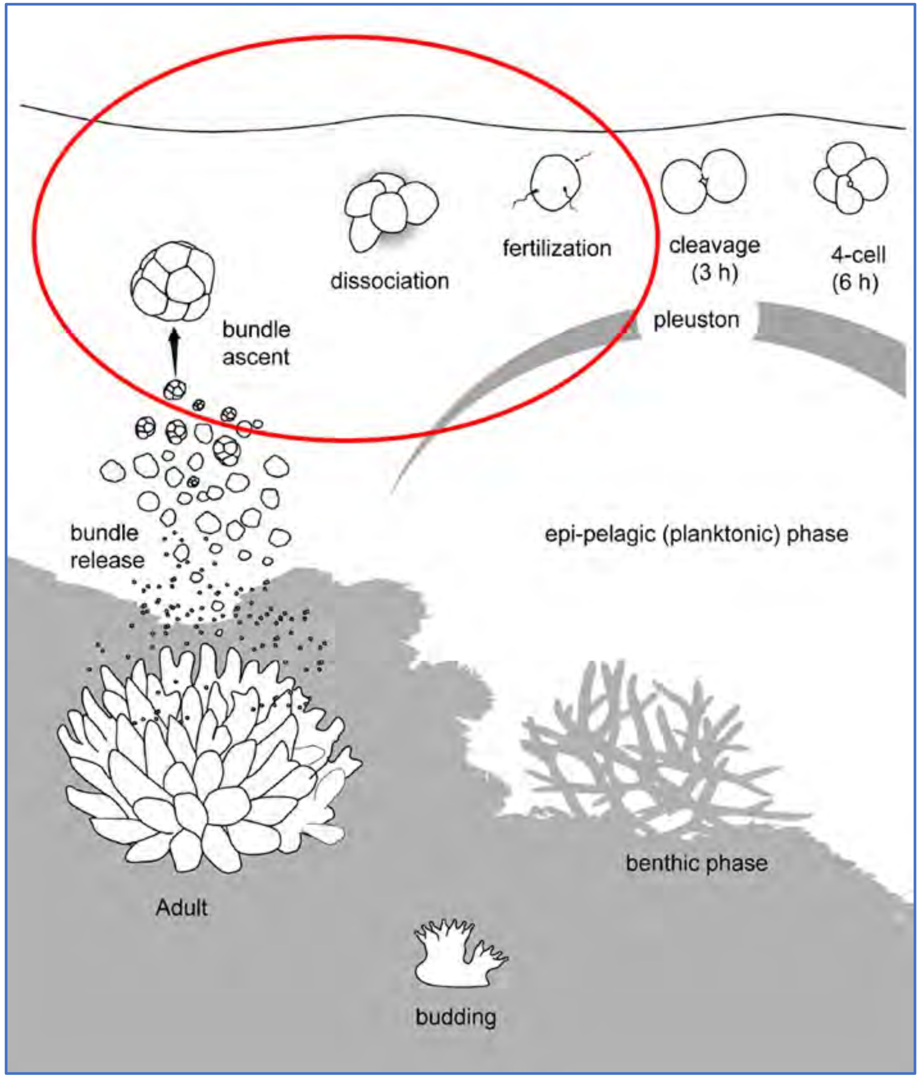
Image: Jones, R., Ricardo, G., & Negri, A. (2015). Effects of sediments on the reproductive cycle of corals. *Marine Pollution Bulletin*, *100*(1), 13-33. doi: 10.1016/j.marpolbul.2015.08.021 CC BY 4.0

The mucous binding the bundles of gametes together dissolves, releasing individual sperm and eggs.
Some species of corals release sperm and eggs separately.

The eggs continue to float and the sperm sink to prevent self-fertilization.

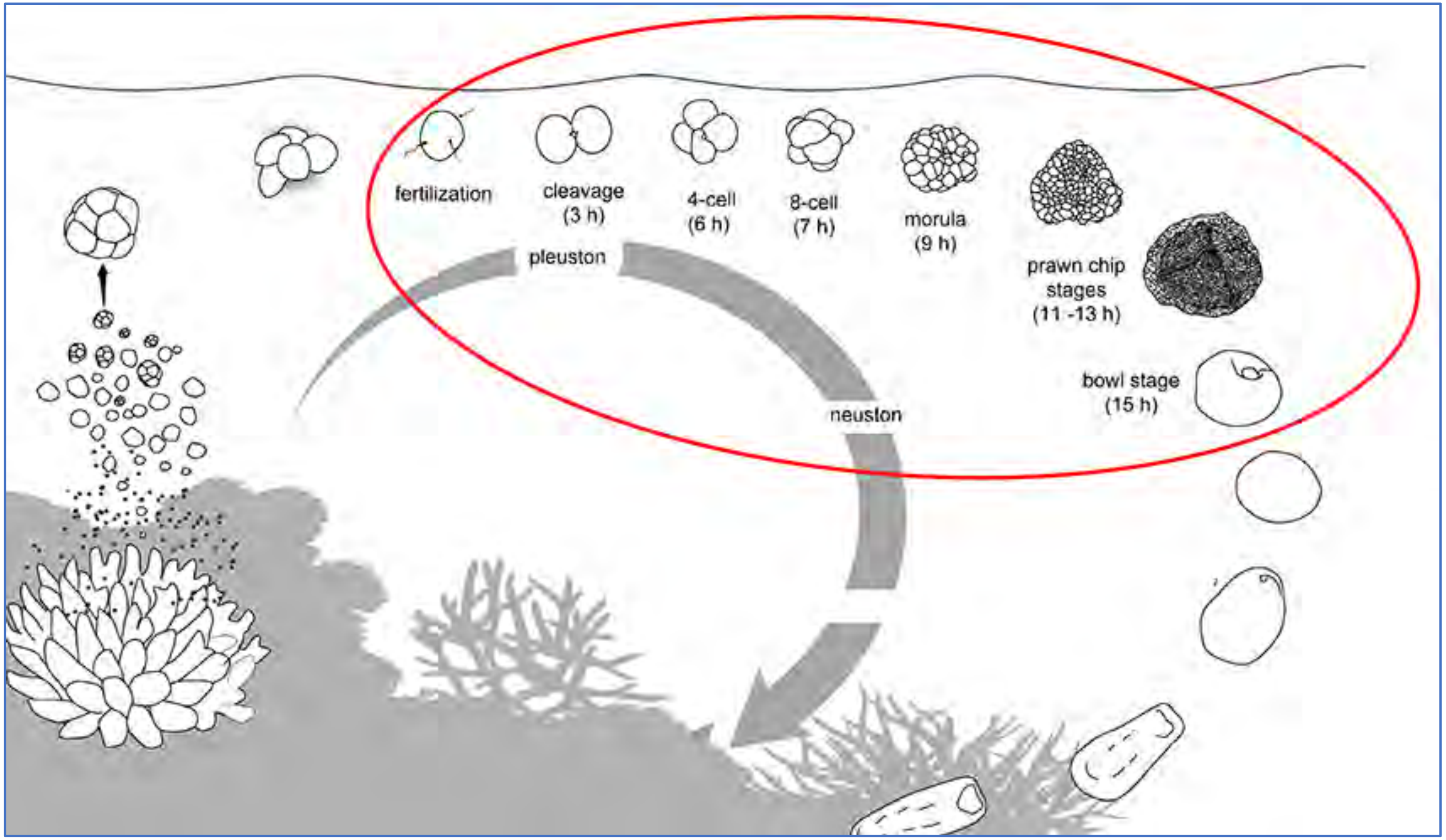
Fertilisation is dependent on the sperm finding coral eggs from a different colony of the same species.

The fertilised egg (now known as a zygote) continues to float on or near the surface.



Gametes separate and fertilise

Embryogenesis (the dividing of the embryo) continues near the surface and in the upper levels of the water column.

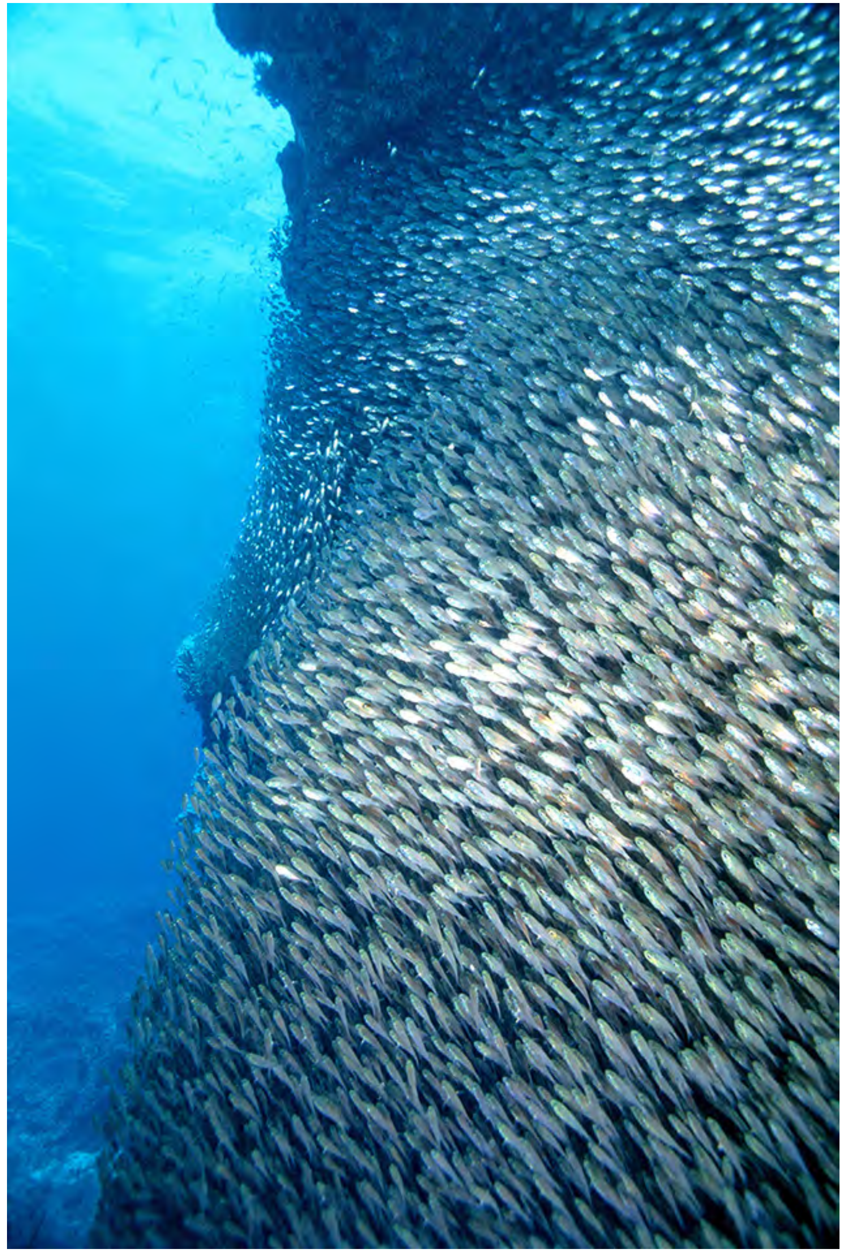


Embryological development of coral

Image: Jones, R., Ricardo, G., & Negri, A. (2015). Effects of sediments on the reproductive cycle of corals. *Marine Pollution Bulletin*, *100*(1), 13-33. doi: 10.1016/j.marpolbul.2015.08.021 CC BY 4.0

Most coral eggs and early stage larvae are eaten by “the wall of mouths” (corals, plankton, fish etc) on the reef or drift away from the reef.

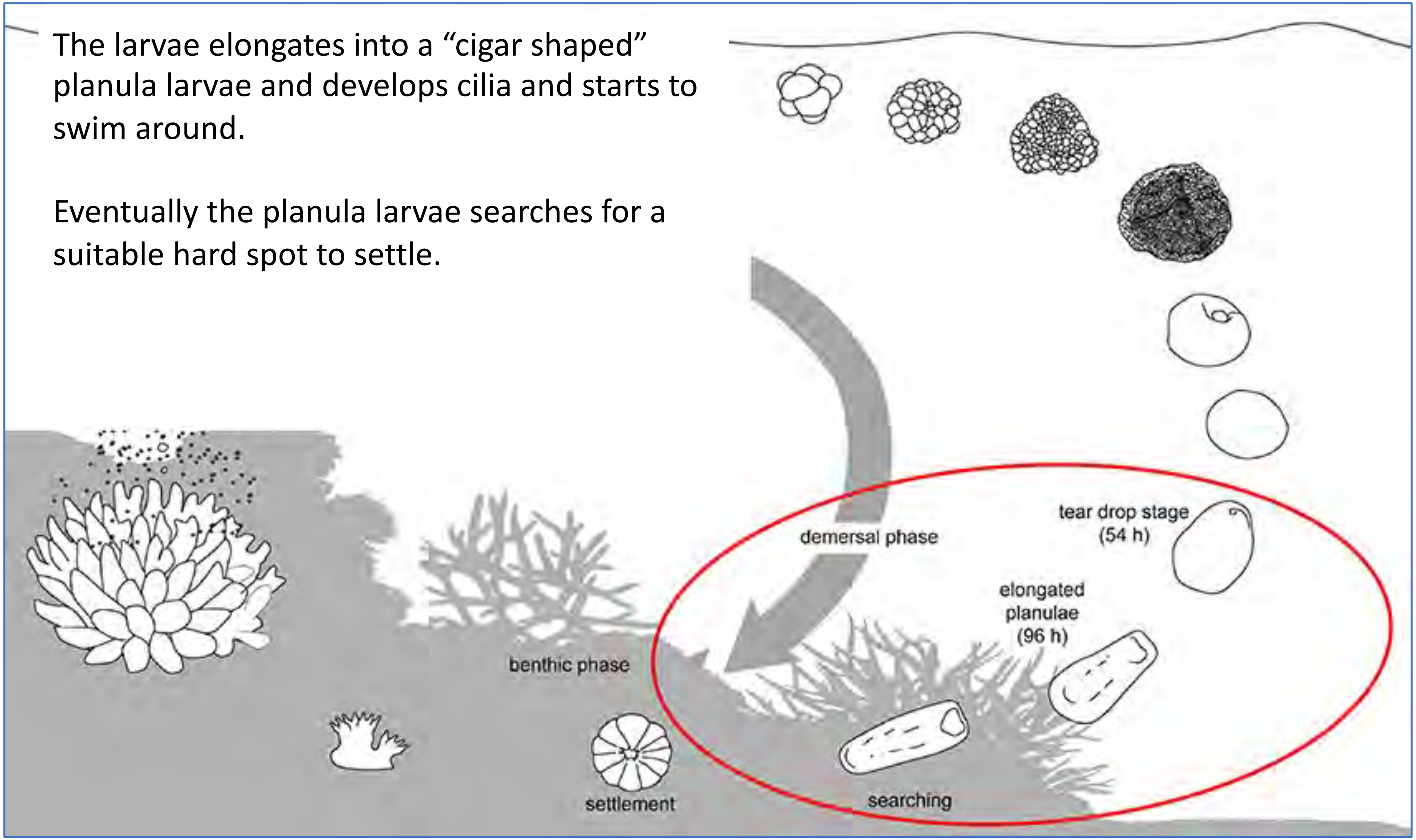
Only a tiny percentage of the trillions of eggs released will ever mature into an adult coral.



A wall of mouths

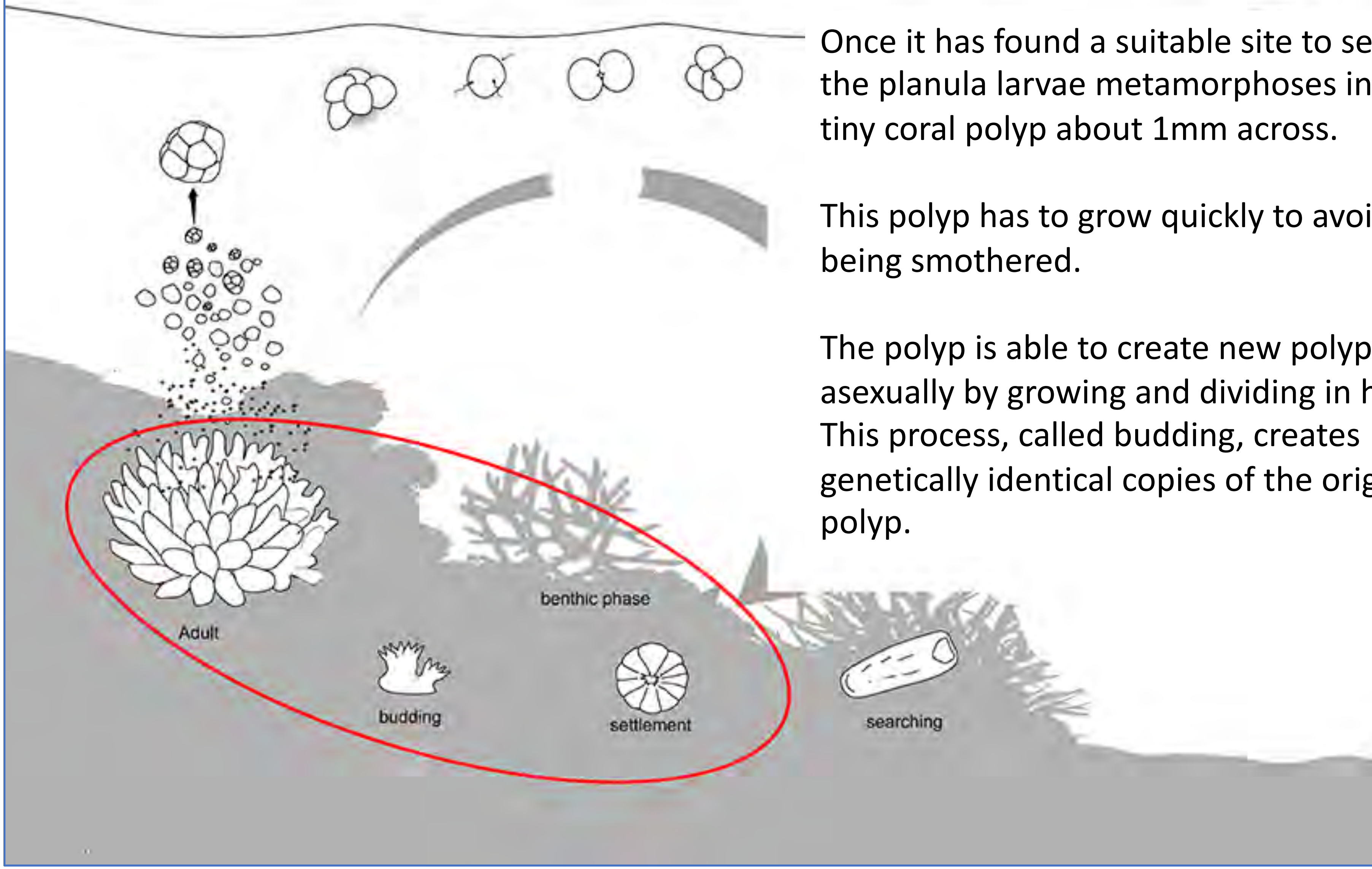
The larvae elongates into a “cigar shaped” planula larvae and develops cilia and starts to swim around.

Eventually the planula larvae searches for a suitable hard spot to settle.



Development of planula larva

Image: Jones, R., Ricardo, G., & Negri, A. (2015). Effects of sediments on the reproductive cycle of corals. *Marine Pollution Bulletin*, *100*(1), 13-33. doi: 10.1016/j.marpolbul.2015.08.021 CC BY 4.0



Once it has found a suitable site to settle, the planula larvae metamorphoses into a tiny coral polyp about 1mm across.

This polyp has to grow quickly to avoid being smothered.

The polyp is able to create new polyps asexually by growing and dividing in half. This process, called budding, creates genetically identical copies of the original polyp.

Settlement and growth by budding

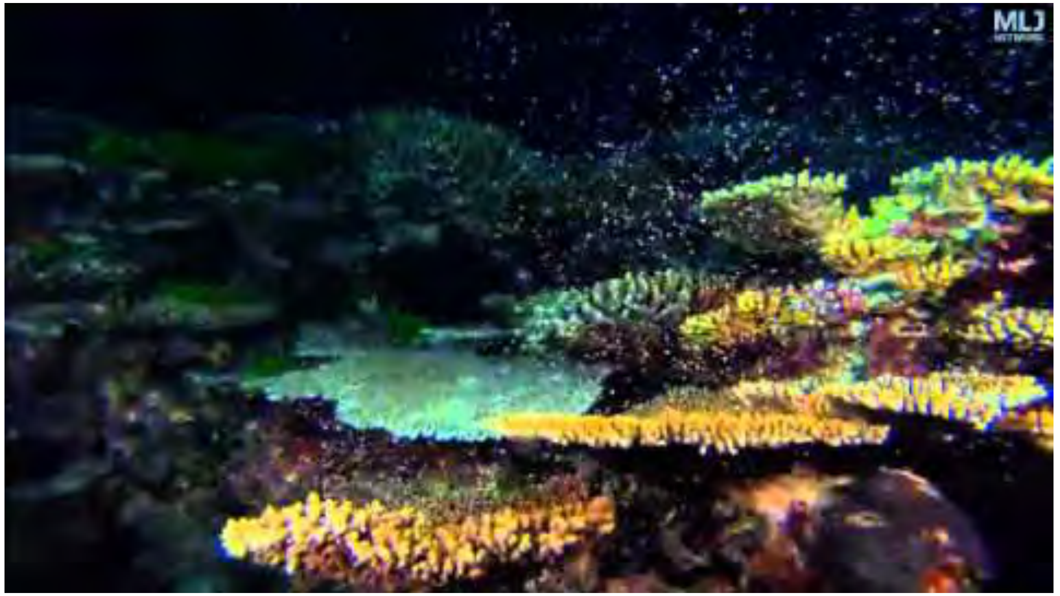
Image: Jones, R., Ricardo, G., & Negri, A. (2015). Effects of sediments on the reproductive cycle of corals. *Marine Pollution Bulletin*, *100*(1), 13-33. doi: 10.1016/j.marpolbul.2015.08.021 CC BY 4.0

Mass spawning

The annual spawning event is one of the most spectacular events in nature.
By releasing gametes at the same time, individual corals maximise the chance of fertilisation, and the sheer number of organisms spawning overwhelms predators: they can't eat them all.

https://youtu.be/U7iS6gKhUEk

This short YouTube video shows some incredible footage of coral spawning on the Great Barrier reef.



Coral sea dreaming: coral spawning
YouTube video available: https://youtu.be/U7iS6gKhUEk

Spawning occurs after full moon in October-December.

The exact timing is determined by water temperature, day length, tide height and salinity; and varies between species and location.

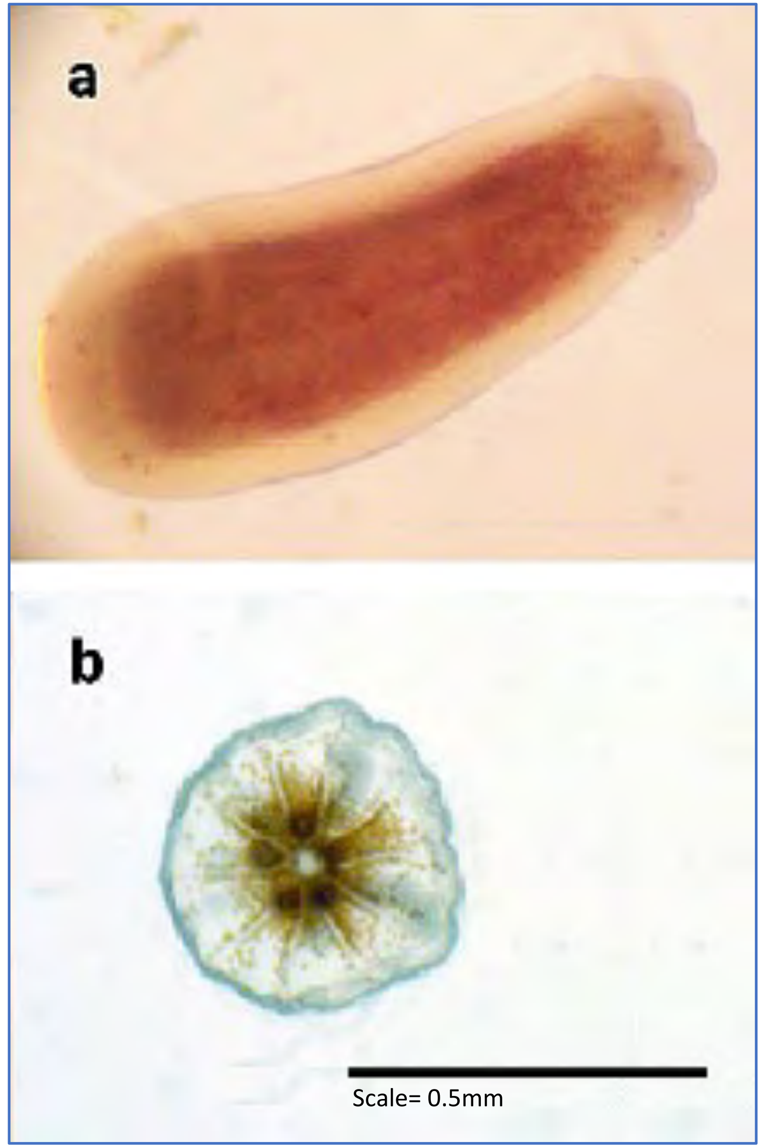
Coral spawn slick, Capricorn Bunker Group.

Brooders

Some coral species are brooders. Instead of broadcast spawning, these corals spawn sperm, but retain the eggs.

Fertilisation and embryogenesis occur inside the adult polyp.

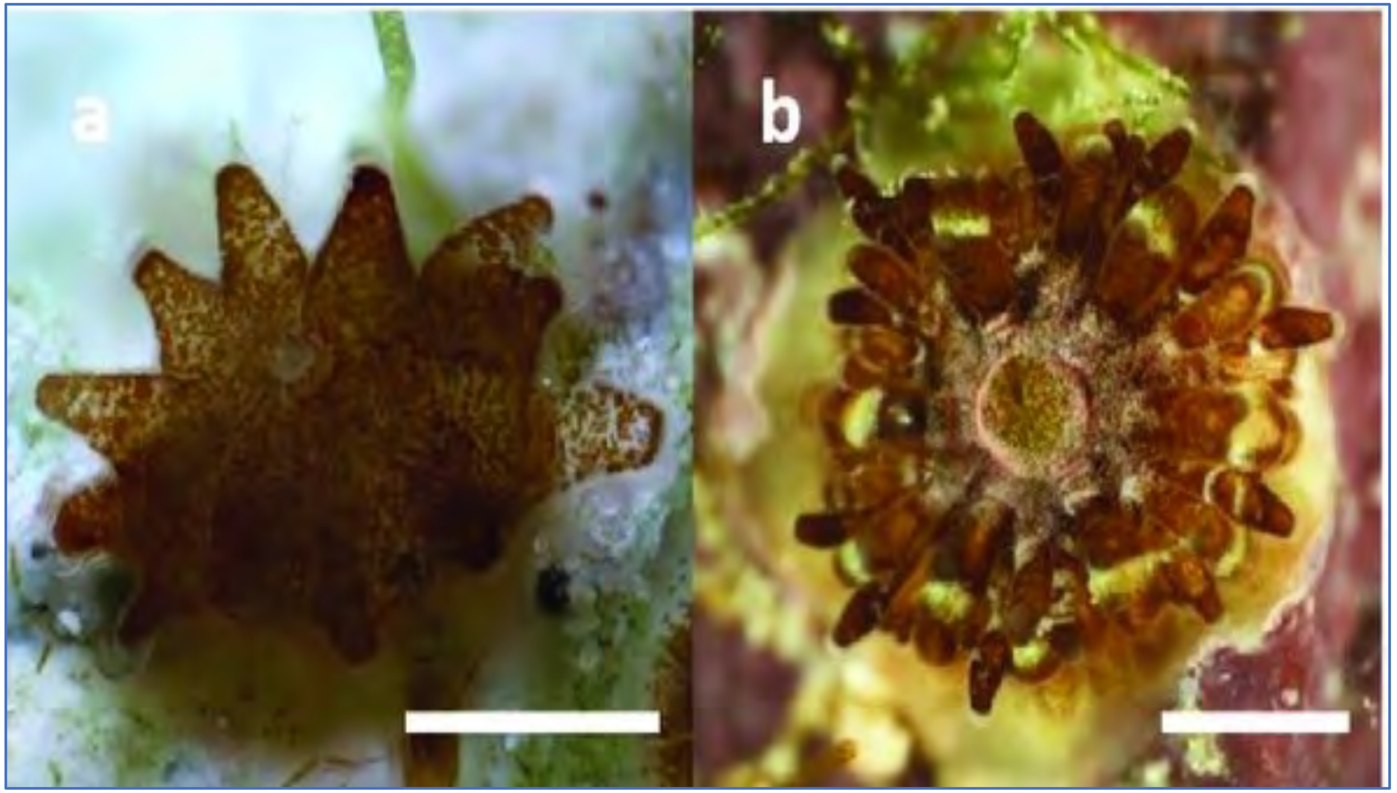
Relatively few, relatively large larvae are released when they are ready for settlement.



Planula and primary polyp

Images from Jones, R., Ricardo, G., & Negri, A. (2015). Effects of sediments on the reproductive cycle of corals. *Marine Pollution Bulletin*, *100*(1), 13-33. doi: 10.1016/j.marpolbul.2015.08.021. Lower photo credited to Moeller et al. (2017) in text. Full text article available CCBY Open access: https://www.researchgate.net/publication/329449638_Coral_Larvae_Every_Day_Leptastrea_purpurea_a_Brooding_Species_That_Could_Accelerate_Coral_Research CC BY 4.0

Brooding species, such as this *Leptastrea purpurea* are popular in research as the larvae easier to obtain and available for a longer period of time.



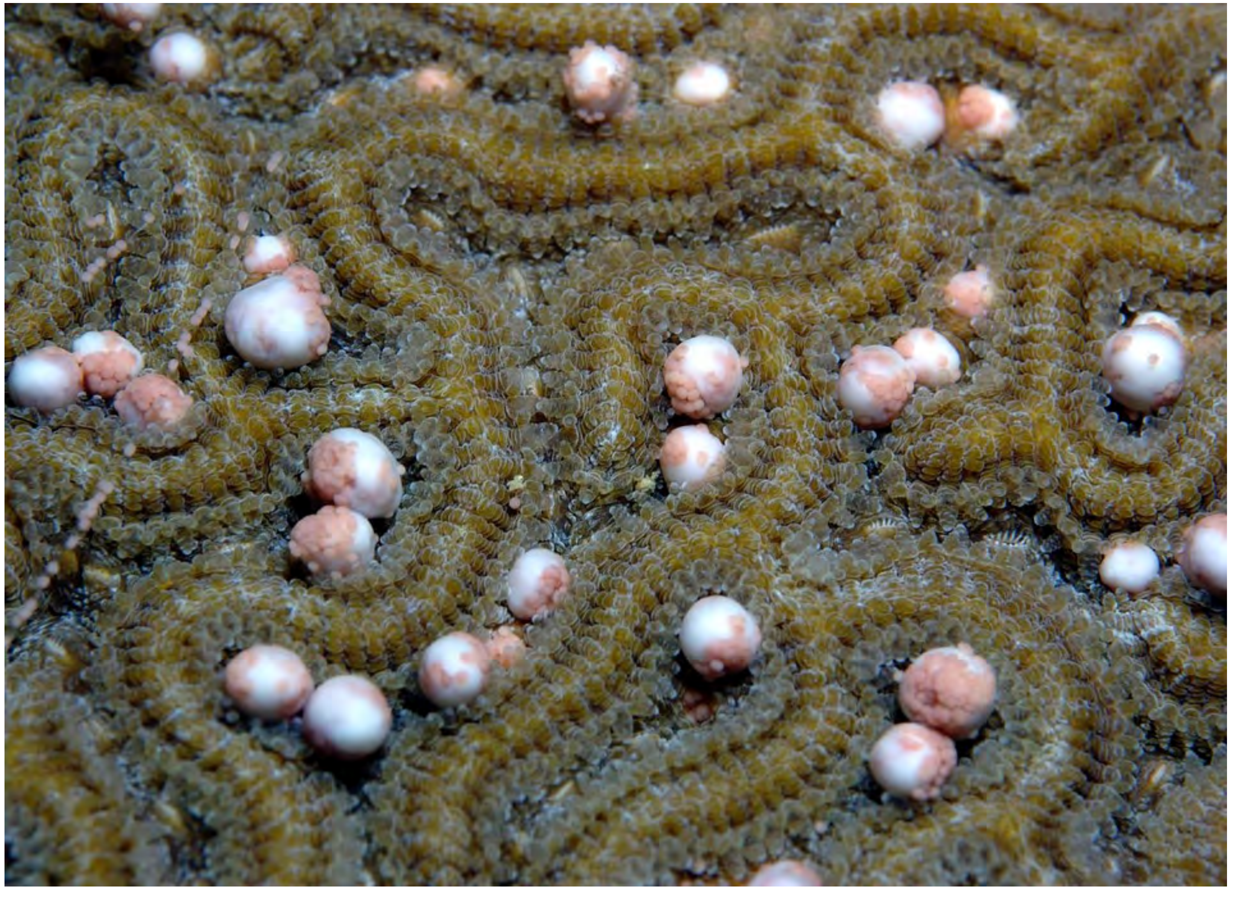
Polyps 4 and 8 weeks post settlement. Scale = 1mm

Images from Jones, R., Ricardo, G., & Negri, A. (2015). Effects of sediments on the reproductive cycle of corals. *Marine Pollution Bulletin*, *100*(1), 13-33. doi: 10.1016/j.marpolbul.2015.08.021. Lower photo credited to Moeller et al. (2017) in text. Full text article available CCBY Open access: https://www.researchgate.net/publication/329449638_Coral_Larvae_Every_Day_Leptastrea_purpurea_a_Brooding_Species_That_Could_Accelerate_Coral_Research CC BY 4.0

Sexual reproduction

Broadcast spawning and brooding are two ways that corals reproduce using sexual reproduction.

Sexual reproduction involves the combination of gametes and results in genetically unique offspring.



Gamete bundles of *Colpophyllia natans* about to be released.

Image: NOAA [Public domain], via Wikimedia Commons

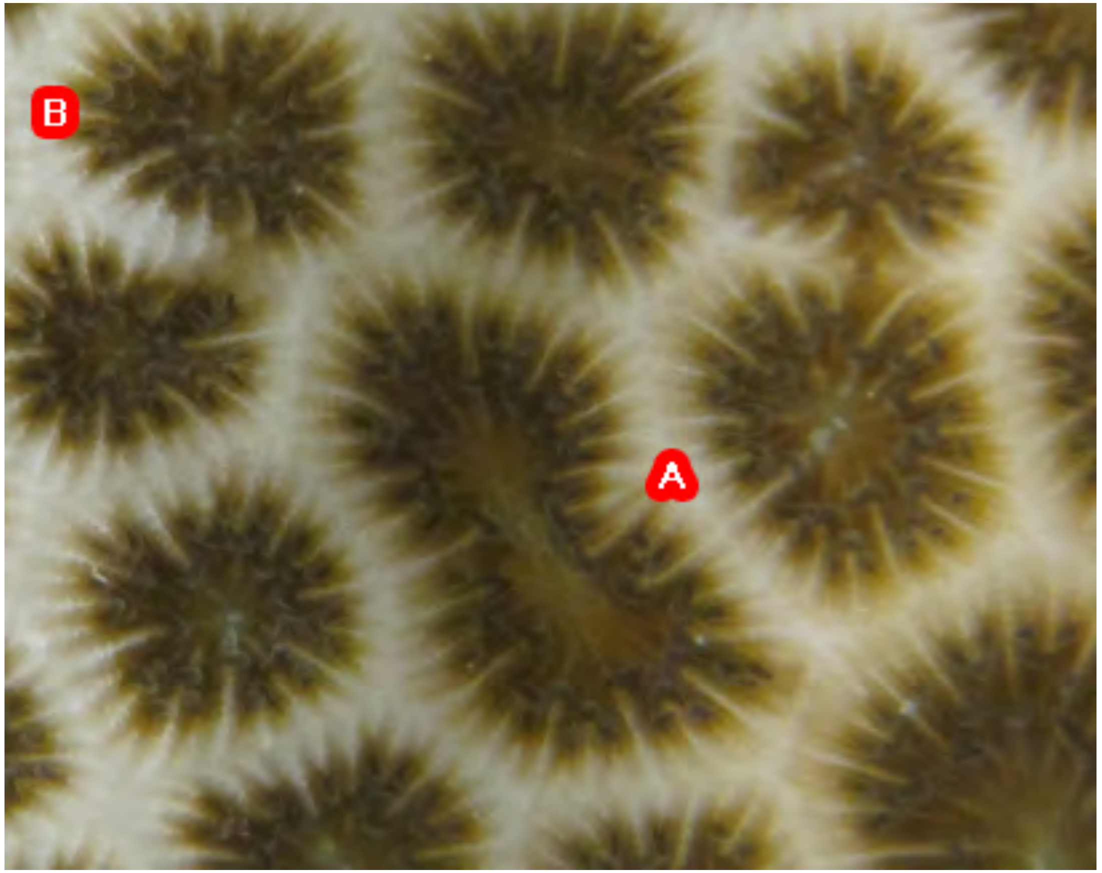
Asexual reproduction

Asexual reproduction results in offspring that are genetically identical clones of the parent.

Budding is a form of asexual reproduction.

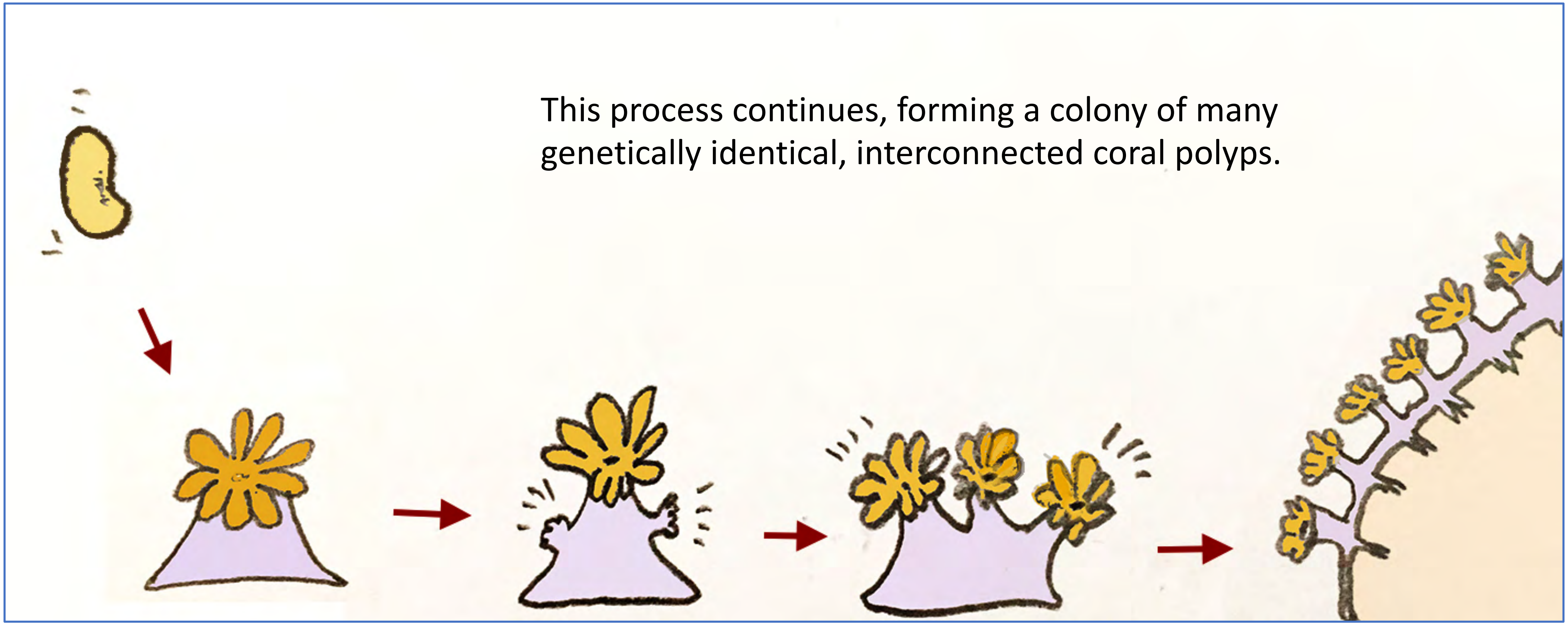
Budding is when new polyps "bud" off or divide to form new polyps or grow colonies

Entire colonies are made out of genetically identical polyps.



Polyp A is in the process of budding.
Recently separated polyps can be seen at B

The planula larva settles and grows into a polyp. The polyp grows and then "buds" off new genetically identical polyps.



Fragmentation is another form of asexual reproduction, that occurs when an entire section colony (not just one polyp) separates to form a new colony.

Fragmentation happens when a section of coral is broken off by wave action or storms.

Sometimes the fragment may attach and grow in to a new colony.

Fragmentation is being used regrow coral reefs, as this YouTube video shows:

https://youtu.be/0UlnRnHWFqU

Coral gardening | South Pacific | BBC Earth
YouTube video available: https://youtu.be/0UlnRnHWFqU

Two more forms of asexual reproduction:

Parthenogenesis occurs when coral larvae develop without being fertilised.

Larvae produced by parthenogenesis are genetically identical to the parent. Pathernogenesis has only been confirmed in a few species.

Bail out occurs when a single coral polyp withdraws from the coenosarc and separates itself from the colony.

This polyp can move a short distance and resettle. Bail out only has a low success rate (5%) and usually only occurs to escape stress events.

Polyp bail out in *Pocillopora damicornis*

Image from: Fordyce AJ, Camp EF and Ainsworth TD. Polyp bailout in *Pocillopora damicornis* following thermal stress [version 2]. *F1000Research* 2017, **6**:687 (doi: 10.12688/f1000research.11522.2) CC BY 4.0

Watch this YouTube video, which summarises this topic:

https://www.youtube.com/watch?v=yKcHF58L34M&feature=youtu.be

UQx TROPIC101x 4.4.3 Reproduction of reef building corals

YouTube video available: https://www.youtube.com/watch?v=yKcHF58L34M&feature=youtu.be

Questions

1. Complete the diagram of the life-cycle of a typical reef-forming hard coral.

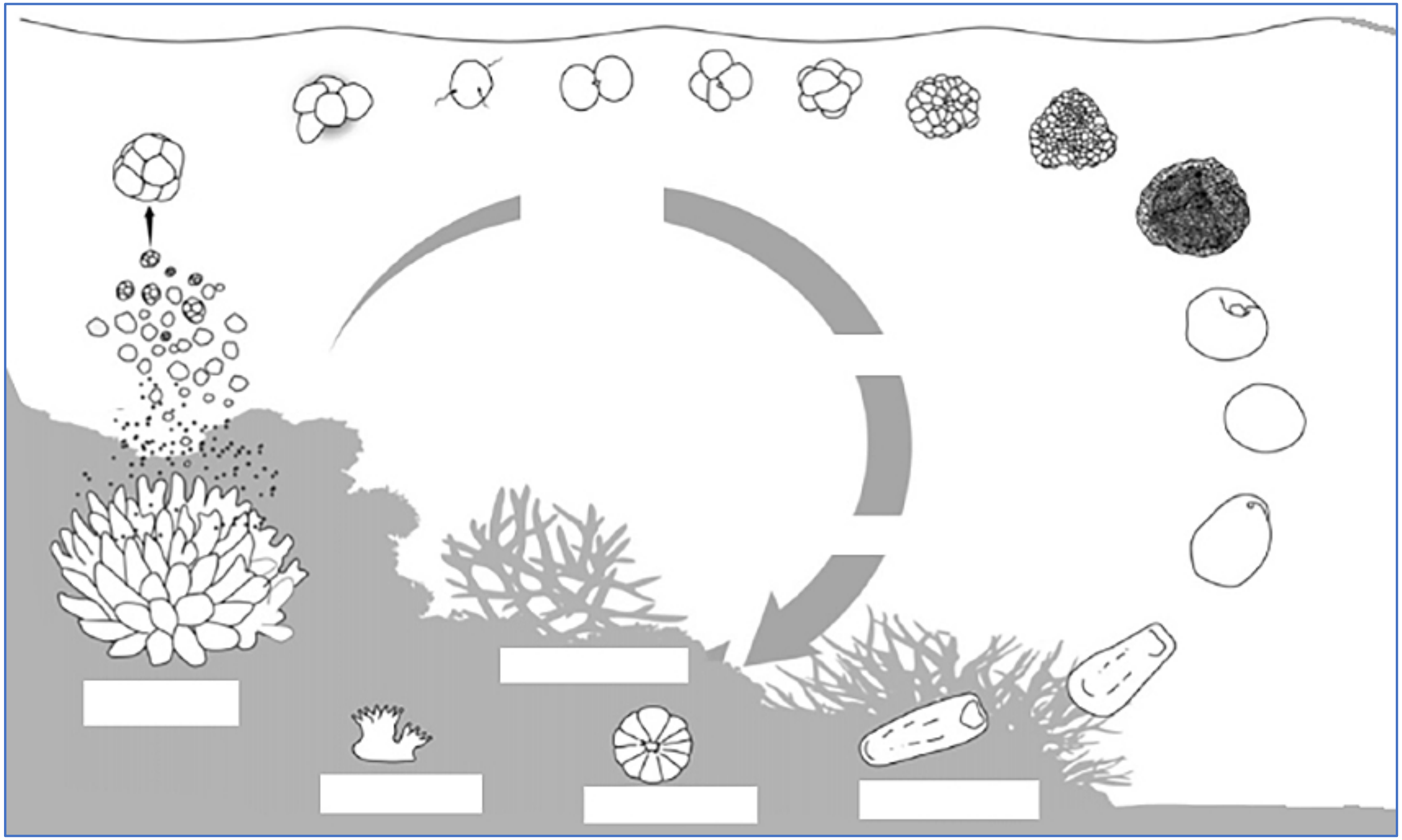


Image: Jones, R., Ricardo, G., & Negri, A. (2015). Effects of sediments on the reproductive cycle of corals. *Marine Pollution Bulletin*, *100*(1), 13-33. doi: 10.1016/j.marpolbul.2015.08.021 CC 4.0 By

Answers

1. Sketch the life-cycle of a typical reef-forming hard coral.

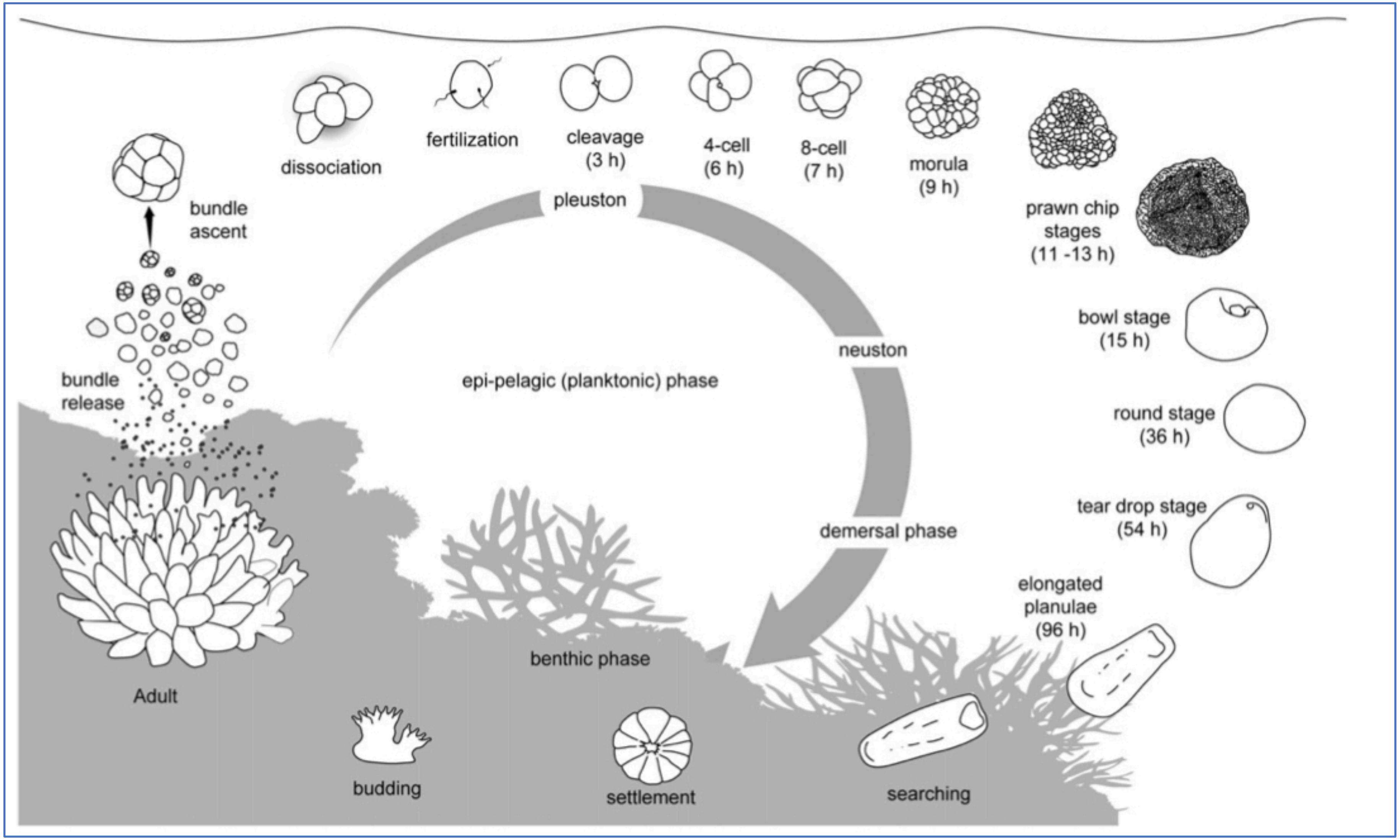


Image: Jones, R., Ricardo, G., & Negri, A. (2015). Effects of sediments on the reproductive cycle of corals. *Marine Pollution Bulletin*, *100*(1), 13-33. doi: 10.1016/j.marpolbul.2015.08.021 CC 4.0 By

2. Describe the stages of sexual reproduction

3. List three ways corals can reproduce asexually.

4. Describe how one of these enables a coral colony to grow.

5. How are the offspring of sexual reproduction and asexual reproduction different?

Answers

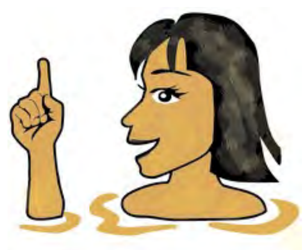
2. Describe the stages of sexual reproduction

- Gametes (sperm and eggs) form in the adult polyps.
- Spawning occurs during a full moon in October- December
- Fertilisation occurs, forming a zygote, near the surface.
- Some zygotes develop into a planula larvae. Most are eaten in the food chain.
- Planulae larvae settle then metamorphose into a polyp.

Answers

3. List any three ways corals can reproduce asexually.

- Budding
- Fragmentation
- Parthenogenesis or
- Polyp bail-out



Answers

4. Describe how budding enables a coral colony to grow.

Budding is when new polyps “bud” off or divide to form new polyps or grow colonies

Answers

5. How are the offspring of sexual reproduction and asexual reproduction different?

Sexual reproduction creates offspring that are genetically distinct from the parents, caused by the combination of gametes.

Asexual reproduction creates genetically identical clones of the parent.

Further activities

See

https://coralwatch.org/index.php/education-2/curriculum-materials/marine-science/

by

CORALWATCH

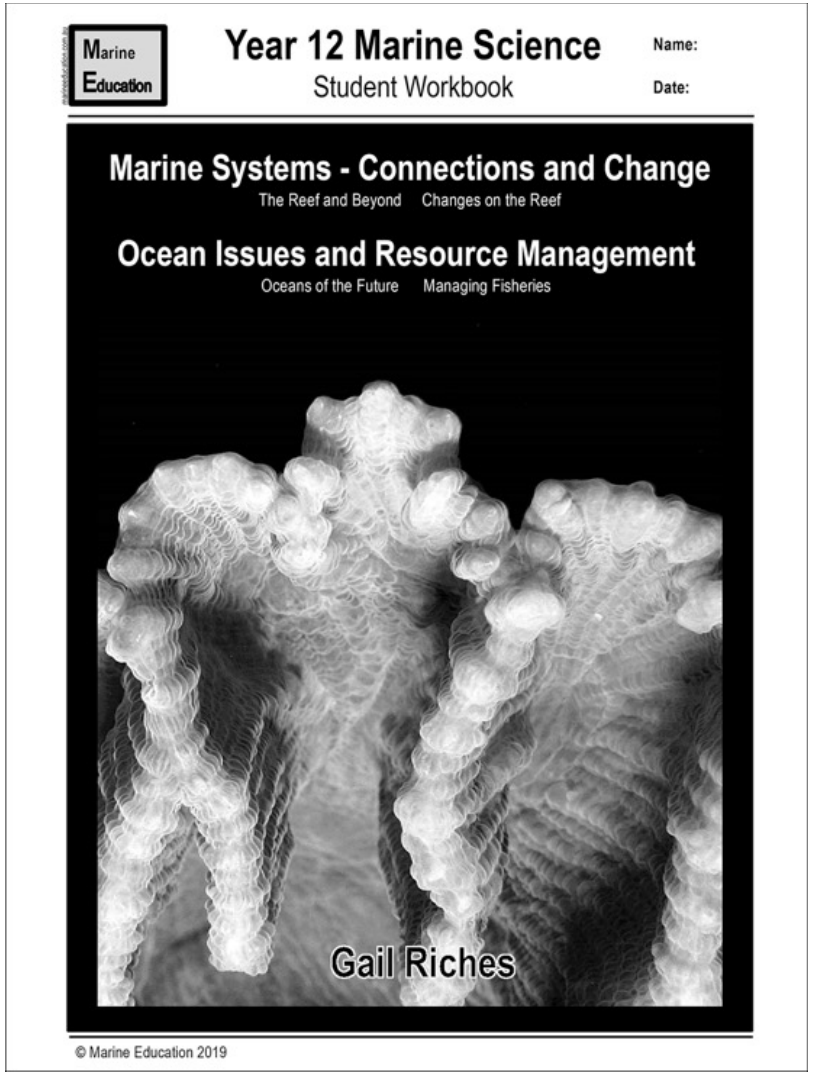
Further activity

Worksheet –

Coral Babies
by

Gail Riches

www.marineeducation.com.au



T083 Larval dispersal

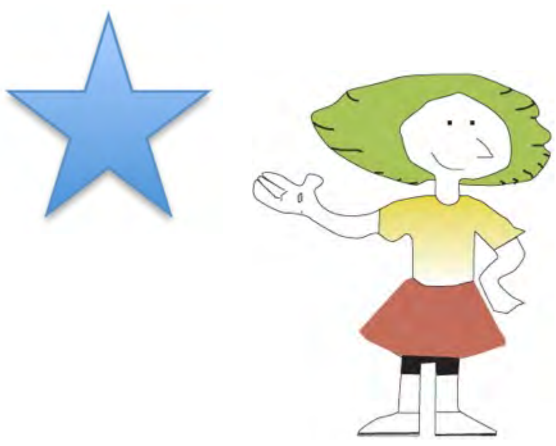
Adam Richmond

Syllabus statement

At the end of this topic you should be able to ...

Explain

the process of larval dispersal, site selection, settlement and recruitment



Explain

- make an idea or situation plain or clear by describing it in more detail or revealing relevant facts;
- give an account;
- provide additional information

Objectives

1. Recall the meaning of the terms: larval dispersal, site selection, settlement and recruitment

2. Describe the process of larval dispersal, site selection, settlement and recruitment of a coral species.

3. Identify factors that affect larval dispersal, site selection, settlement and recruitment of coral species,
   i.e. Currents, bathymetry, substrate, sediment, predation, competition.

4. Describe in detail how one of these identified factors affects larval dispersal, site selection, settlement and recruitment of coral species

This topic will explain how a new coral can arrive on a reef through the complex sequence of larval dispersal, site selection, settlement and recruitment.

Definitions

Larval dispersal - occurs when the planktonic larval stages of coral are distributed throughout the reef, and spread between reefs.

Site selection - is when a coral planula investigates and selects a suitable site for settlement

Settlement - is when the planula attaches itself to its chosen substrate and develops into a polyp.

Recruitment - occurs when the coral polyp has successfully established as a member of the reef community.

Larval dispersal

Coral larvae, and the larvae of many reef-dwelling species, spend a part of their lifecycle drifting in the plankton.

Since adult corals are sessile, the dispersal (transport away from the parent corals) of coral larvae is a key determinant in the distribution of coral reefs.

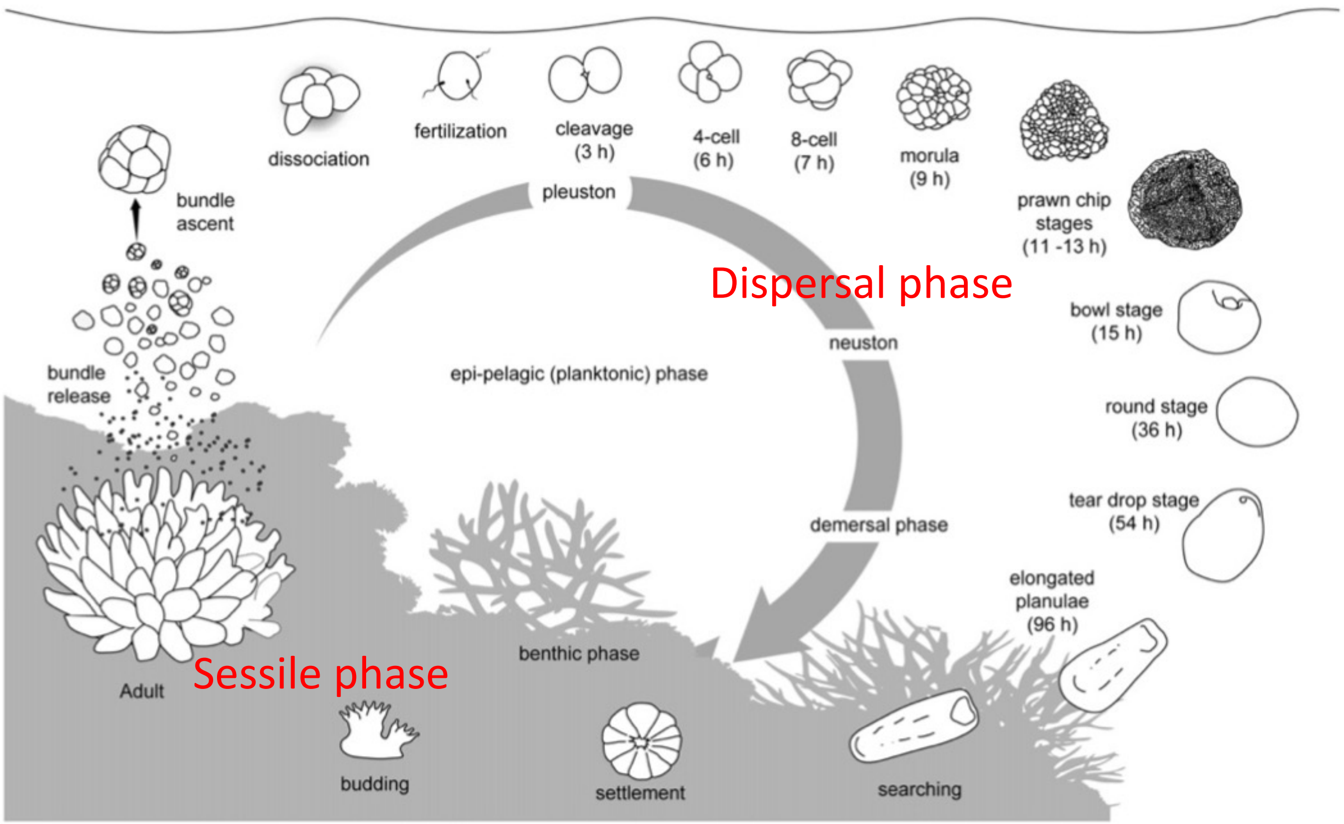
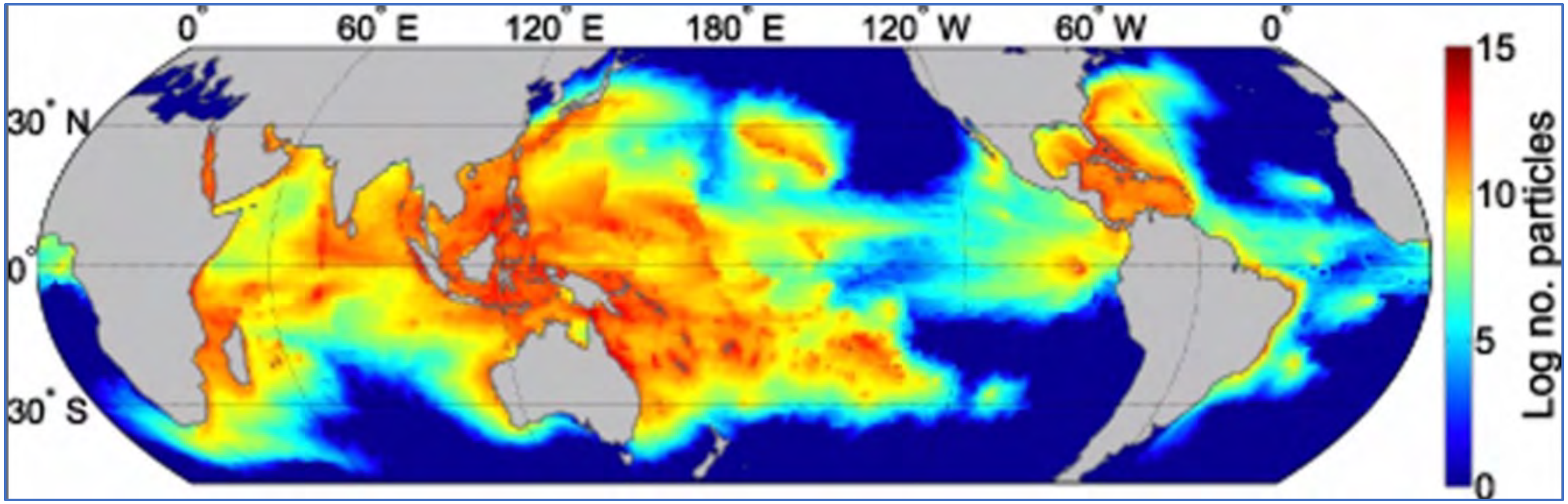


Image: Jones, R., Ricardo, G., & Negri, A. (2015). Effects of sediments on the reproductive cycle of corals. *Marine Pollution Bulletin*, *100*(1), 13-33. doi: 10.1016/j.marpolbul.2015.08.021 CC 4.0 BY

Coral larvae are weak swimmers and predominantly rely on currents for dispersal.
Larvae that spend more time in the plankton can be transported further, and often have a larger geographical range.

Directly tracking larvae is difficult, so researchers use a range of models to determine larval connectivity between reefs, based on ocean currents and larval duration.



Map showing the global dispersal of model coral larvae.

Figure from Wood, S., Paris, C., Ridgwell, A., & Hendy, E. (2013). Modelling dispersal and connectivity of broadcast spawning corals at the global scale. *Global Ecology And Biogeography*, *23*(1), 1-11. doi: 10.1111/geb.12101. CC BY 4.0

Some corals stay close to home

Many corals that broadcast spawn have coral larvae that are settlement competent (developed enough to settle) within 4-10 days.

Some of these larvae will "self-seed" or return to the reef they were spawned from. A study at Helix Reef found that 70% of corals settle within 300m of the source.[1]

Brooding corals incubate their larvae until they are settlement competent. Brooding corals do not commonly disperse beyond the parent reef.

Brooded planula larvae visible inside tentacle

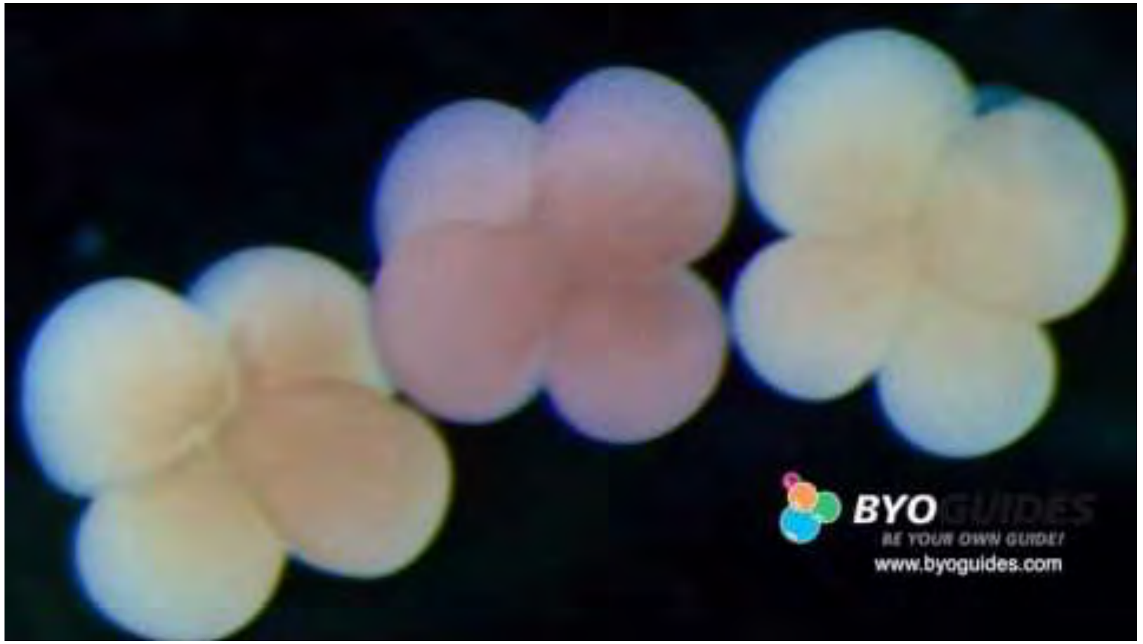
1. Sammarco, P. W., and J. C. Andrews. 1988. Localized Dispersal and Recruitment in Great Barrier Reef Corals: The Helix Experiment. *Science*, 239:1422–1424.

Some coral larvae are transported a long way from home

Coral larvae that take longer to develop may be carried into the open ocean. These larvae may be able to reach reefs hundreds of kilometers away, but are exposed to very high levels of predation.

Acropora coral larvae are typically up to 20 days old before becoming settlement competent.

A study showed that *Pocillopora* planula larvae contain enough energy reserves to survive for over 100 days- long enough to migrate across the Pacific Ocean. [1]



Early larval stages of *Acropora tenuis*
YouTube video by BYOGuides available: https://youtu.be/cc9NcuUmQ5A

1. Richmond, R. (1987). Energetics, competency, and long-distance dispersal of planula larvae of the coral Pocillopora damicornis. *Marine Biology*, *93*(4), 527-533. doi: 10.1007/bf00392790

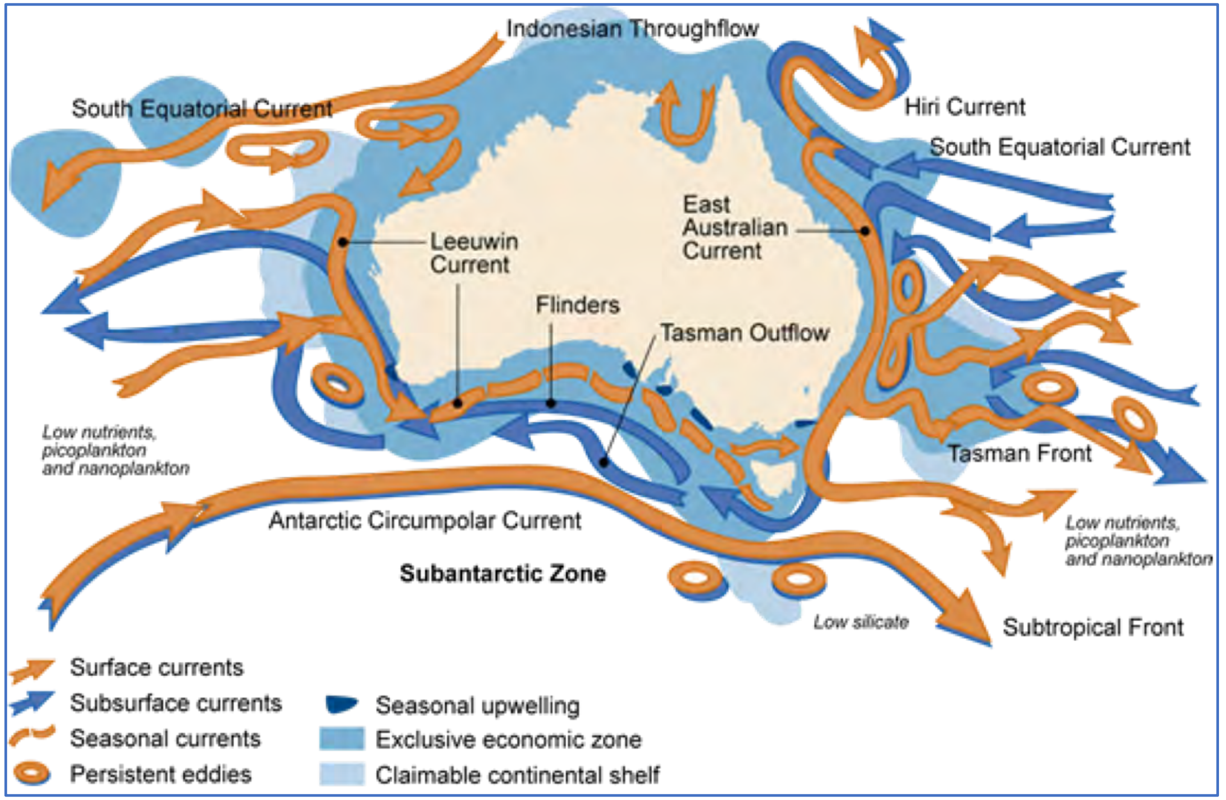
Video
https://youtu.be/cc9NcuUmQ5A

The role of currents

Ocean currents are a key factor affecting larval dispersal.

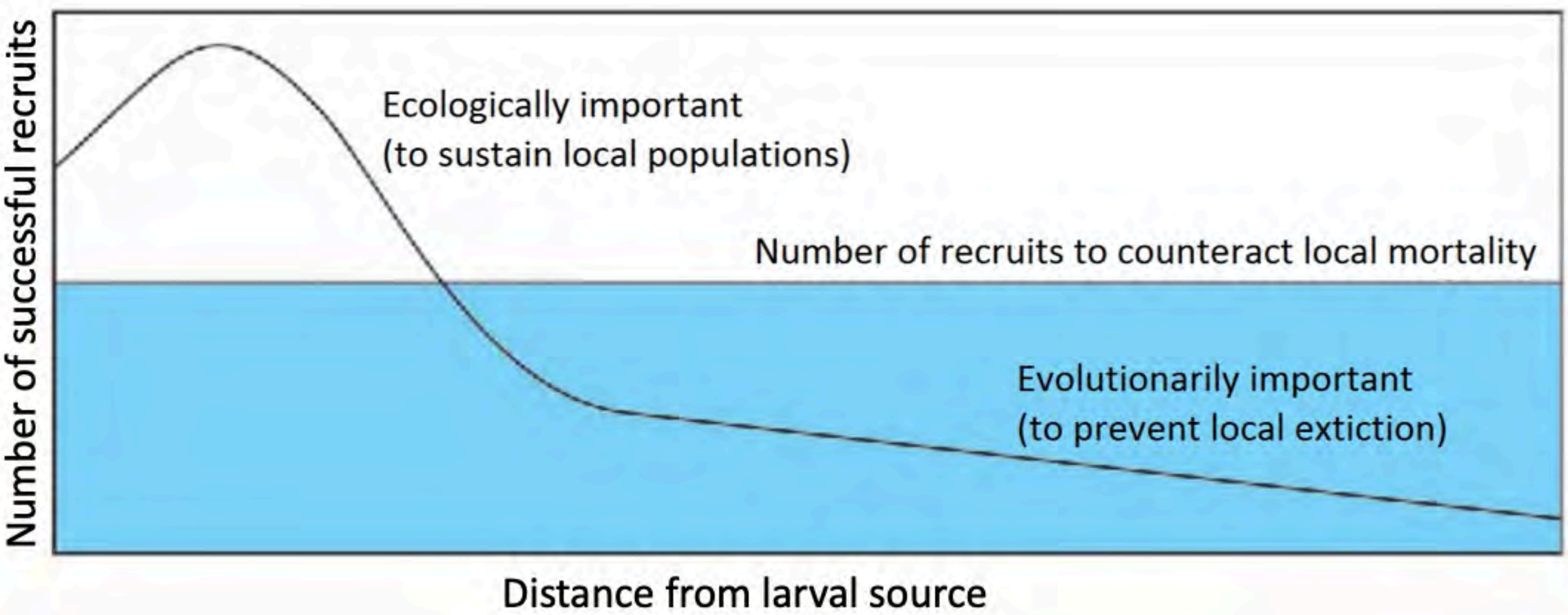
The widespread distribution of corals throughout the Indo-Pacific region is caused by larval dispersal on ocean currents and using islands and reefs as “stepping stones”

The East Australian Current extends the distribution of tropical coral species into subtropical regions, such as Moreton Bay.



Australian currents

Larvae that travel short and long distances are both important. Larvae that remain locally are ecologically important for replenishing corals that die; those that drift far away increase genetic diversity. The long “tail” on this figure extends the geographic distribution of corals..



Dispersal kernel for ecological and evolutionary connectivity

After Steneck, R. S. 2006. Staying Connected in a Turbulent World. *Science*, 311:480–481.

Site selection

When a coral planula is developed enough, it begins searching for a favourable settlement location.

The planula has many sensory cells and exhibits a complex searching behaviour, actively and repeatedly testing the substrate for particular characteristics.

This YouTube video shows some planula larvae testing a settlement site.

https://youtu.be/KzpnIUbtxEI

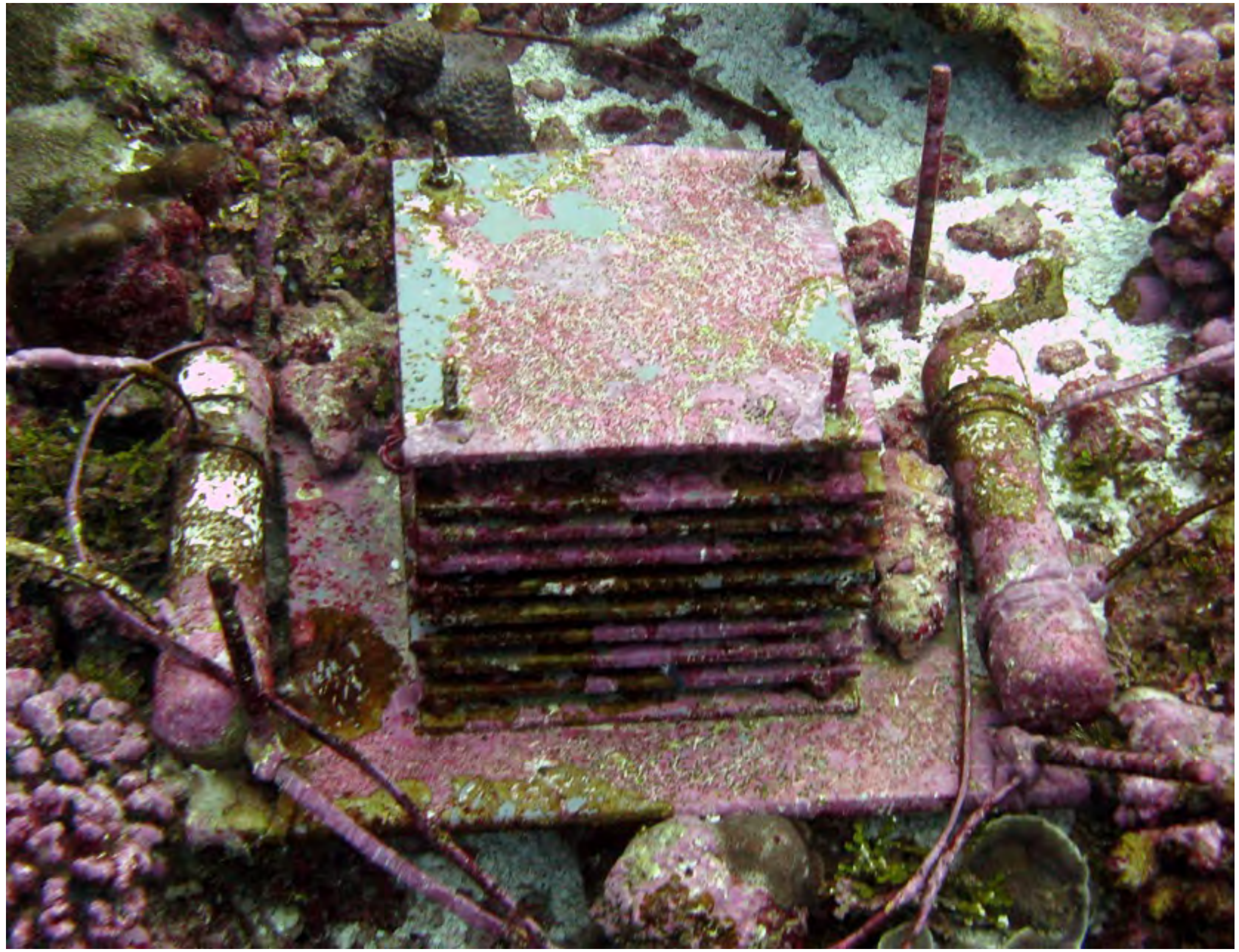
Coral larvae on the move

YouTube video by SECOREcoral, available: https://youtu.be/KzpnIUbtxEI

Planula larvae are sensitive to light, and will swim away from light when at the surface, and towards the light when they are at depth.

Larvae often settle on the edges or shaded underside of settlement plates used by researchers.

This may be due to reduced waterflow or eddies produced, reduced light intensity, or protection from predation.



An ARMS (Autonomous Reef Monitoring Structure) is colonized by a diverse community of reef invertebrates.

Image: NOAA, https://www.pifsc.noaa.gov/cred/survey_methods/arms/img/arms_recruitment_after_two_years_med.jpg

Many coral larvae detect and distinguish between chemosensory cues produced by different species of algae.

Some coral larvae show a preference for substrates covered in crustose coralline algae. Others prefer biofilm- a bacterial community- that lives on the substrate.

Chemical extracts taken from red algae have been shown to cause settlement of *Acropora* larvae.

Crustose coralline algae
Image: Maggie D. Johnson, Scripps Institution of Oceanography,
Retrieved: https://ocean.si.edu/ocean-life/plants-algae/coralline-algae-unsung-architects-coral-reefs

Coral settlement is reduced by elevated temperature, salinity variations, sedimentation, and UV radiation.

The presence of turf algae, macroalgae and cyanobacteria can also reduce settlement.

Some planula larvae don't find a suitable settlement site and can remain in the plankton for a longer period of time.

Larvae that have zooxanthellae have more energy reserves and survive longer.

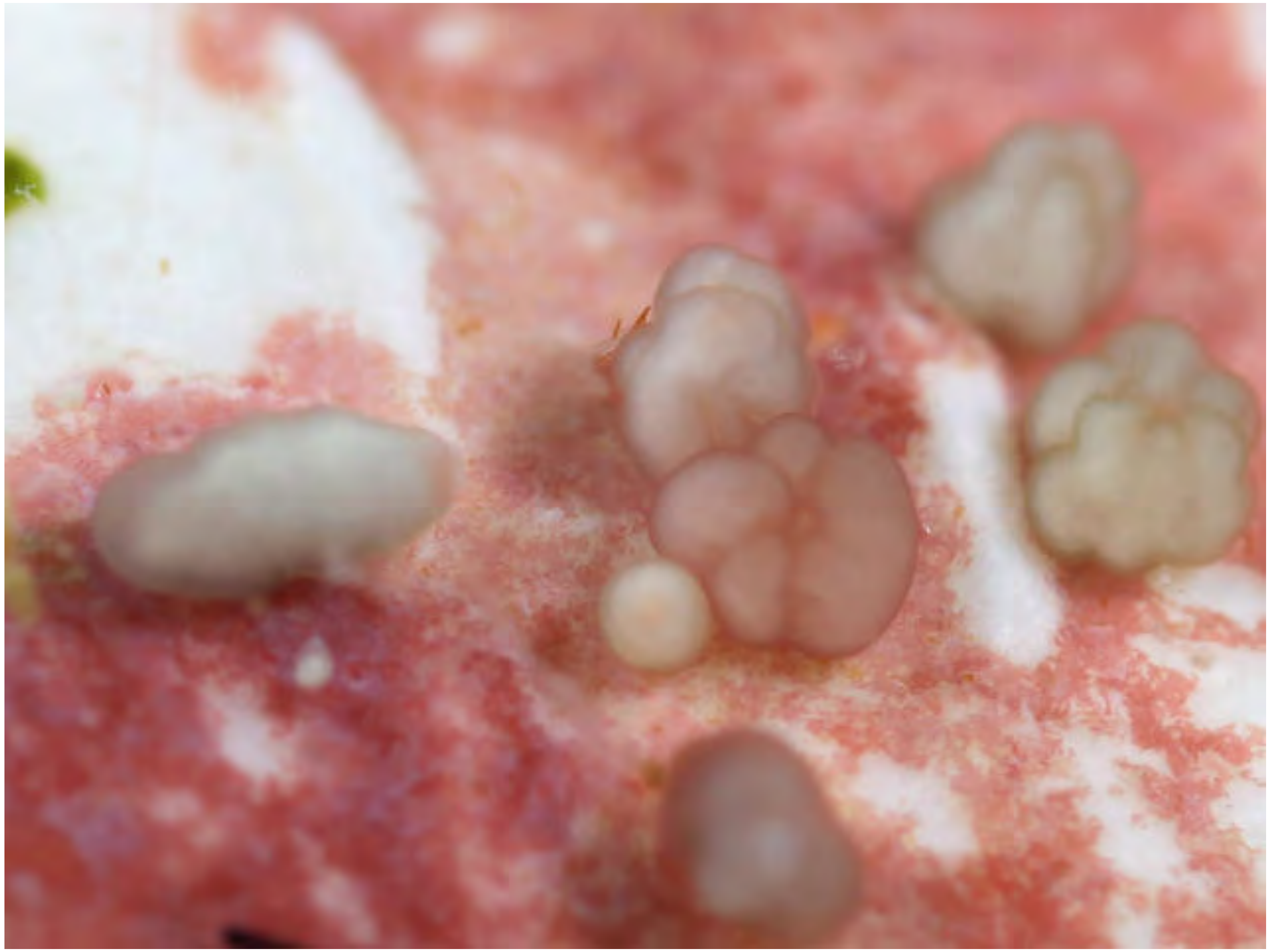
Acropora larvae searching for a suitable settlement site

Image: Jamie Craggs. Copyright reproduced with permission. SECORE, Available:

Settlement has occurred when the larvae has attached and metamorphosed into a primary polyp.

If a newly metamorphosed polyp doesn't like its new spot it can leave its secreted skeleton and try again.

This "reverse metamorphosis"can only occur a limited number of times because it uses a lot of energy.



Acropora planula undergoing metamorphosis

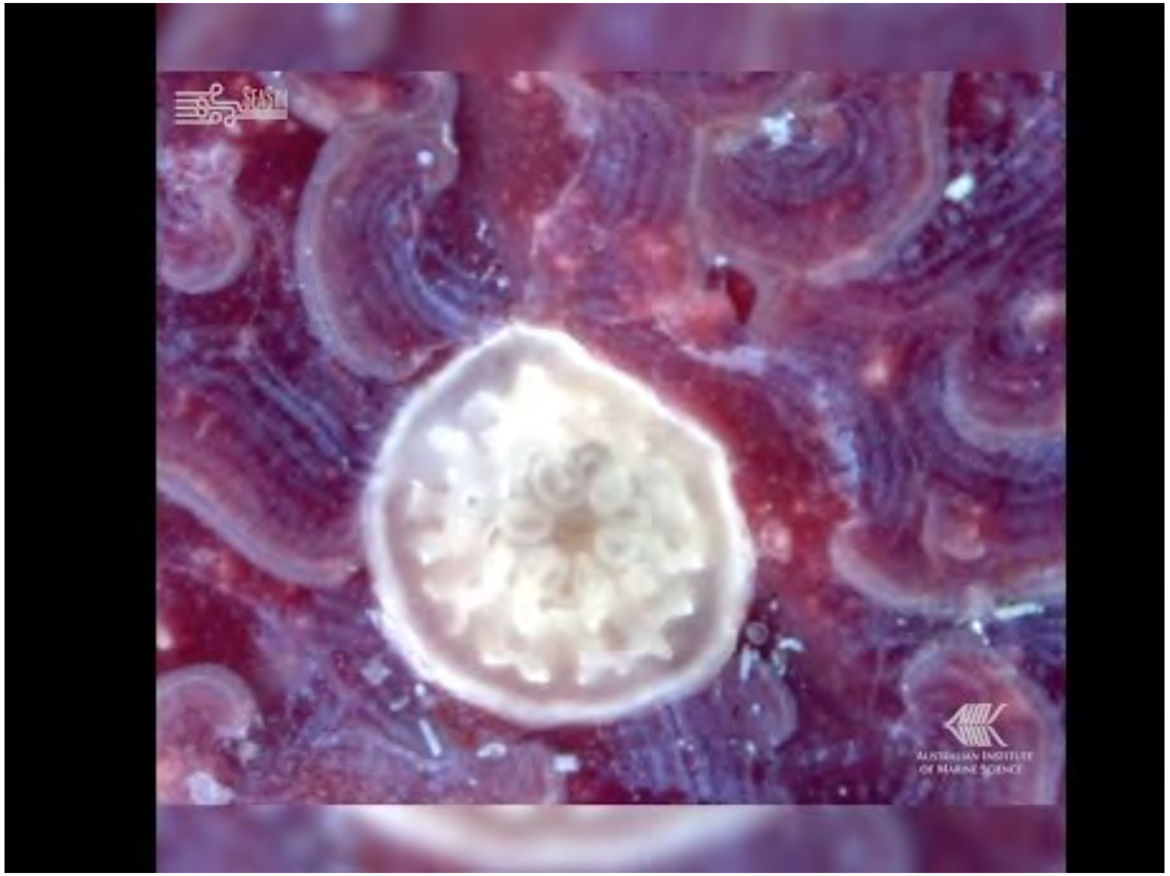
Image: Jamie Craggs, SECORE, Available: http://www.secore.org/export/35/359232nVC6f6QI3V0.jpeg
Reproduced with permission. http://www.secore.org

In this time lapse, coral larvae can be seen testing the substrate and metamorphosing into a polyp.

Most studies of larval corals are conducted in aquaria, as juvenile wild coral are really difficult to find!

Video:

https://youtu.be/e7H5FZykTVU



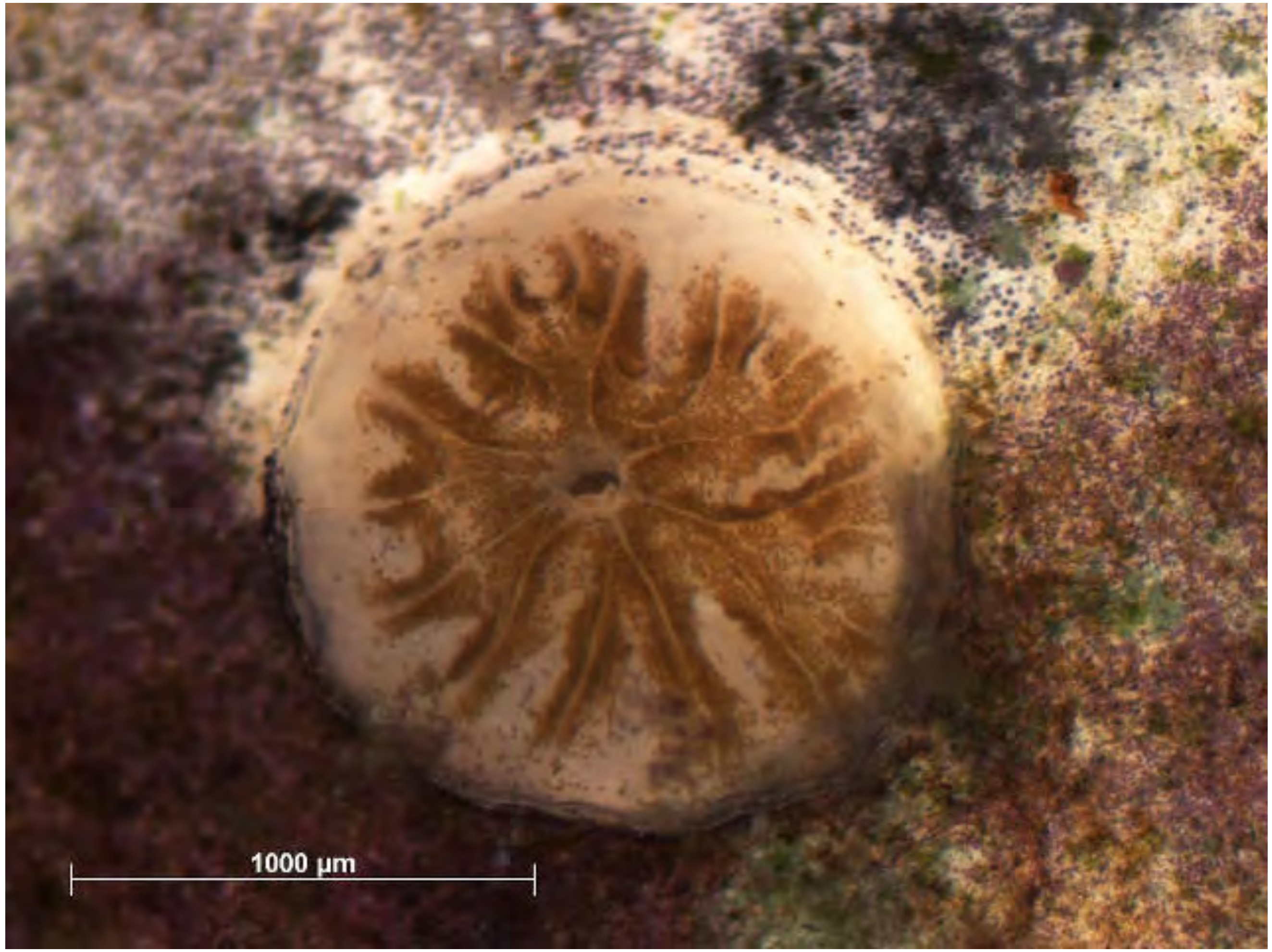
Coral larvae settling and developing in the national sea simulator

YouTube video by Australian Institute of Marine Science, Available: https://youtu.be/e7H5FZykTVU

Newly settled larvae are small and vulnerable.

Competition and predation cause most post-settlement mortality.

Survival is also affected by pulse disturbances such as bleaching and disease.



This primary polyp of *Agaricia humilis* is barely 1mm across

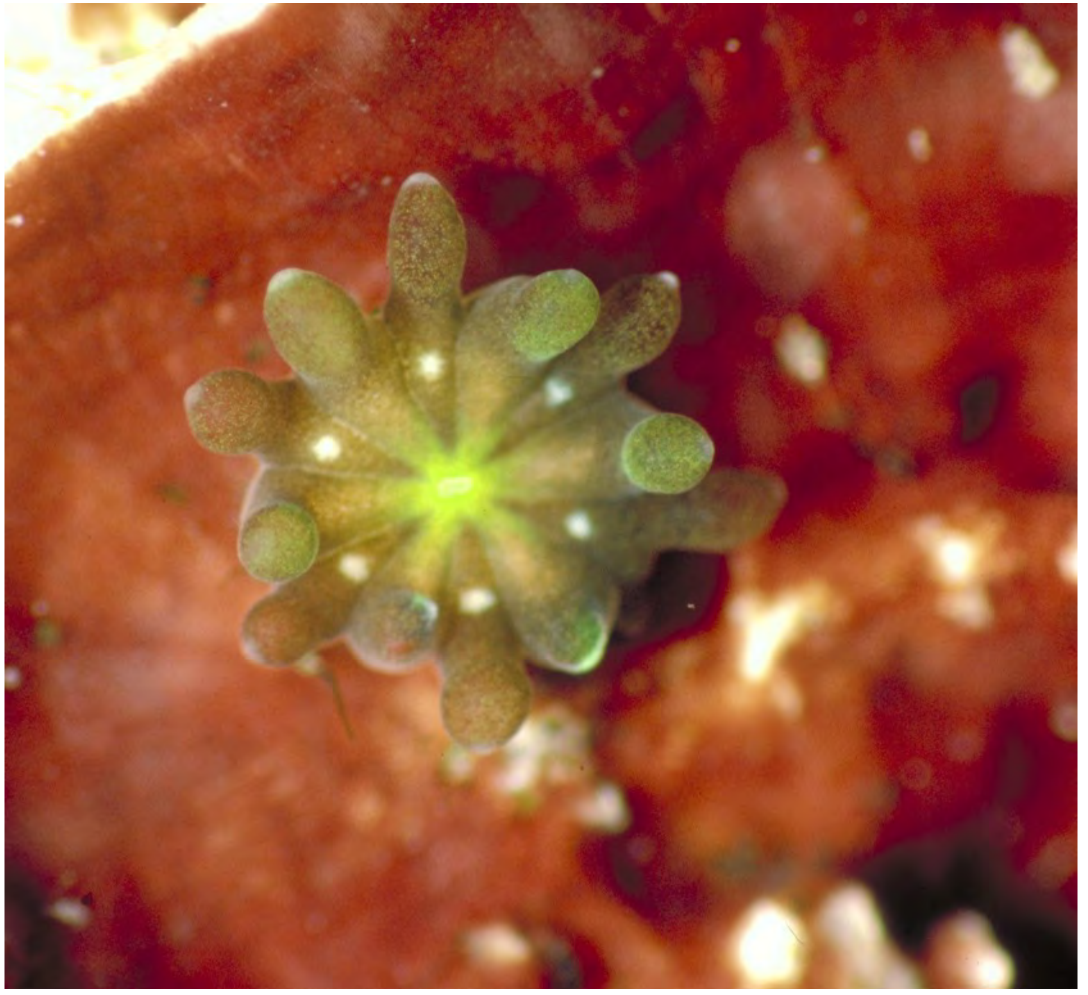
Image: Dirk Petersen, SECORE, Available: http://www.secore.org/export/71/719232uthhxAxqCTm.jpeg

Reproduced with permission. http://www.secore.org

Overgrowth by algae and encrusting invertebrates (such as sponges, bryozoans and bivalves) and smothering by sediment can all inhibit growth and survival of newly settled corals.

Algae occupy available space, shade and abrade developing corals.

Studies show that sponges and algae contain allelopathic chemicals that inhibit the growth of corals.



A single coral polyp soon after settlement.
Image:R. Babcock, Copyright Commonwealth of Australia (GBRMPA)
108584

Recruitment

The highest levels of mortality in newly settled corals occur on outer surfaces exposed to algae growth and subsequent grazing by reef herbivores, such as parrotfish and sea urchins.

Sub-cryptic habitats (protected, internal surfaces) offer coral recruits much higher survivorship rates, but lower growth rates.

A coral recruit of *Acropora tenuis*

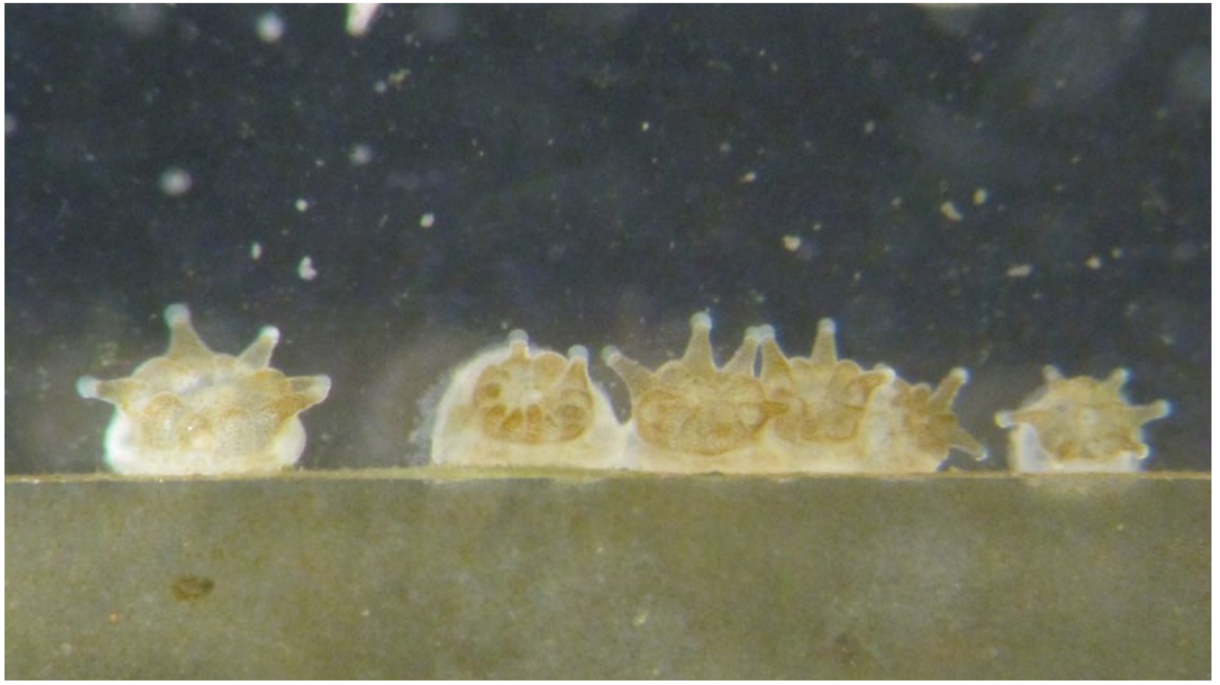
Image: Dirk Petersen. Copyright.
Reproduced with permission. http://www.secore.org

Studies estimate the percentage of new recruits that survive to become juvenile (10 - 50mm diameter) ranges between 0 (none) and 77%.

This huge variation occurs across different scales of time (hours, days, seasons, years) and space (microhabitat, reef zone, reef, sector).

Abiotic factors affecting survival include: sedimentation, light, nutrients, depth, substrate orientation, water motion and temperature.

Biotic factors include: competition from corals and other invertebrates; predation and incidental grazing by fish, smothering by macroalgae.



Coral recruits

Competition from other corals

Corals compete with each other for space.

Many corals have sweeper tentacles- specialised long tentacles- that are used to sting their neighbours.

The sweeper tentacles of *Galaxea sp.* can extend up to 10 cm and damage any other corals within reach.

Sweeper tentacles on a *Galaxea* coral

Some corals can extend their mesenterial (stomach) filaments to attack and digest their neighbours.

Other corals, including many soft corals, use allelopathic chemicals to retard growth and cause localized mortality in nearby hard corals

Mesenterial filaments digesting nearby coral.

Researchers are investigating the best types and shapes of substrate for coral settlement in an attempt to restore coral reefs.

https://youtu.be/fPT-7gDCF7k

Results suggest that coral larvae prefer substrate that is hard, and rough textured.

Ceramic and concrete seem to be as successful as natural aragonite, so long as a biofilm and crustose coralline algae are present.

Artificial substrates for shaping the reef

YouTube video by Australian Institute of Marine Science, Available: https://youtu.be/fPT-7gDCF7k

Questions

1. Recall the meaning of the terms: larval dispersal, site selection, settlement and recruitment

2. Describe the process of larval dispersal, site selection, settlement and recruitment of a coral species.

3. Identify factors that affect larval dispersal, site selection, settlement and recruitment of coral species.

4. Describe in detail how one of these identified factors affects larval dispersal, site selection, settlement and recruitment of coral species.

Answers

Recall the meaning of the terms: larval dispersal, site selection, settlement and recruitment

1. Larval dispersal- occurs when the planktonic larval stages of coral are distributed throughout the reef, and spread between reefs.
2. Site selection- is when a coral planula investigates and selects a suitable site for settlement
3. Settlement- is when the planula attaches itself to its chosen substrate and develops into a polyp.
4. Recruitment- occurs when the coral polyp has successfully established as a member of the reef community.

Answer

Identify factors that affect larval dispersal, site selection, settlement and recruitment of coral species,

Currents, bathymetry, substrate, sediment, predation, competition.

Further activities

See

https://coralwatch.org/index.php/education-2/curriculum-materials/marine-science/

by

CORALWATCH

Further activity

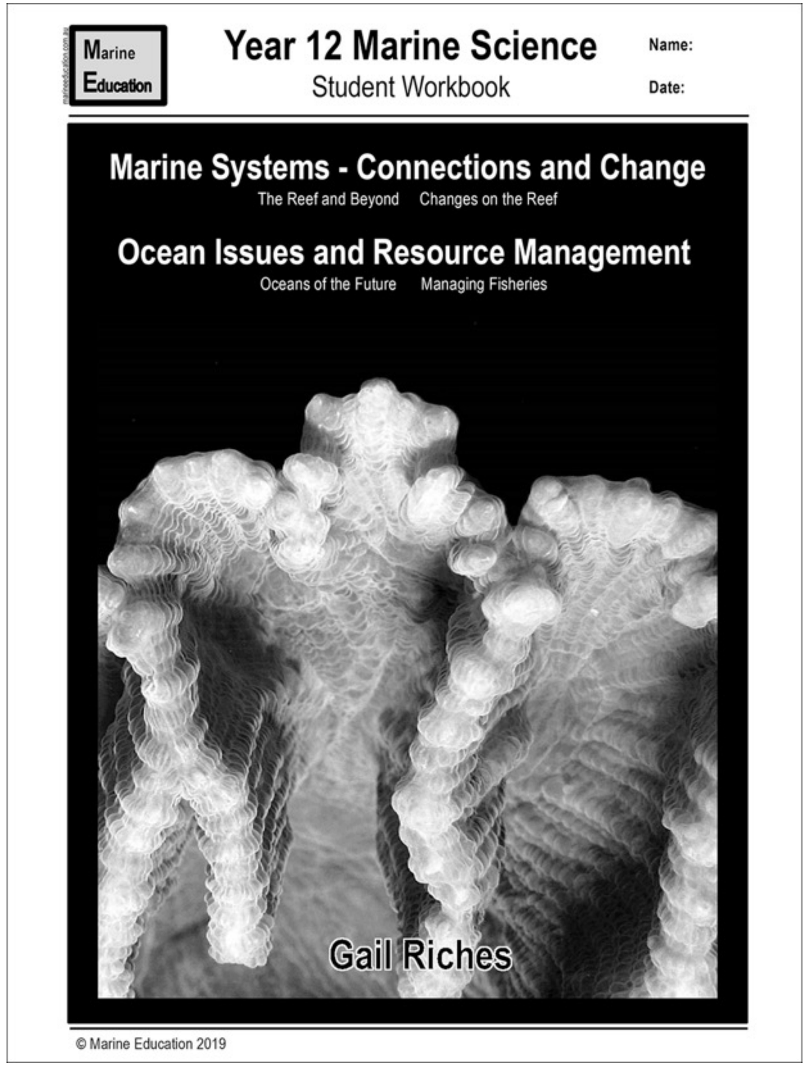
Worksheet –

Just keep swimming

by

Gail Riches

www.marineeducation.com.au



T084 How reefs grow

Adam Richmond

Syllabus statement

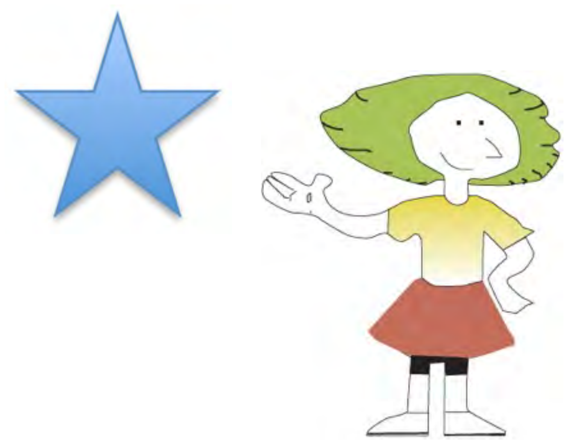
At the end of this topic you should be able to ...

Explain

that growth of reefs is dependent on accretion processes being greater than destructive processes.

Explain

- make an idea or situation plain or clear by describing it in more detail or revealing relevant facts;
- give an account;
- provide additional information



Objectives

1. Recall definitions for accretion and erosion.

2. Explain mechanical and bio-erosive forces.

3. Determine whether a reef is growing or being destroyed.

This YouTube video introduces calcification:

https://youtu.be/9aQRD3DB688

UQx TROPIC101x 4.2.1 How to measure calcification
YouTube video available: https://youtu.be/9aQRD3DB688

Accretion

Accretion refers to the growth of coral substrate due to calcification rate (syllabus definition).

This accretion process, or calcification, occurs when there is an increase in the amount of $CaCO_3$ on a reef over time.

Brain coral Image: Deep voyage

Corals grow at different rates

Massive corals grow slowly, adding 5-25 mm per year.

Branching corals grow much faster, up to 20cm per year.

The growth of corals is affected by many factors. These were covered in T071, and will be looked at again next topic

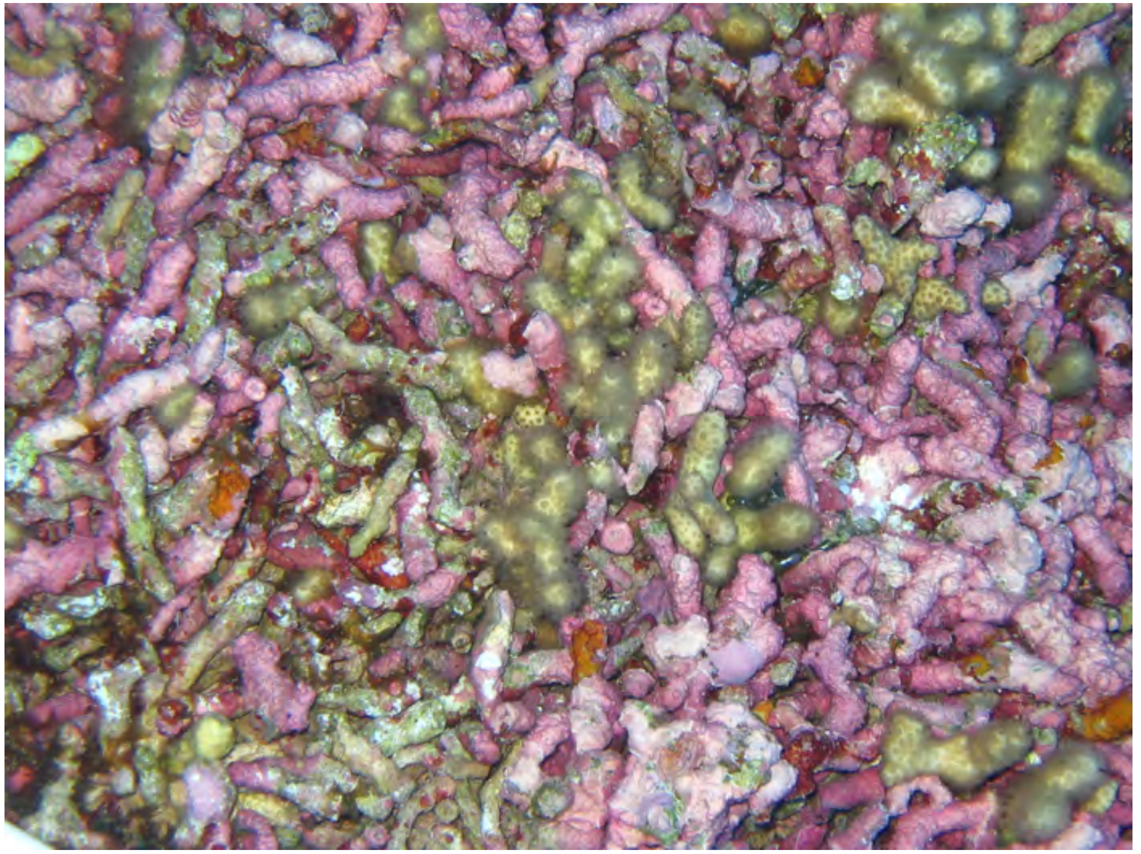
This *Porites* coral is estimated to be 1000 years old

Image: Phillip Colla
Reproduced with permission
www.oceanlight.com

Non-coral organisms also contribute to accretion.

Crustose coralline algae (CCA), bivalves, barnacles and other organisms create $CaCO_3$ on the reef.

Of these, CCA produce the most $CaCO_3$, but also maintain stability by cementing reef together and producing the chemical cues for settling coral larvae.



Crustose coralline algae

Image: NOAA CCMA Biogeography Team, https://www.photolib.noaa.gov/bigs/reef2697.jpg

This YouTube video introduces Decalcification:

https://youtu.be/tSVqg6IwFBM

UQx TROPIC101x 4.2.2Decalcification and its causes

YouTube video available: https://youtu.be/tSVqg6IwFBM

Erosion

Destructive processes that counter reef growth are referred to as erosion.

This decalcification process, or erosion, of the reef occurs when there is a decrease in the amount of $CaCO_3$ on a reef over time.

Staghorn coral
Image: Copyright Commonwealth of Australia (GBRMPA)
Photographer: L. Zell, 114350

Mechanical erosion is physical destruction cause by waves, storms, currents etc.

These images show a section of reef before and after Category 5 Tropical Cyclone Ita.

Images: Catlin Seaview survey, http://static.catlinseaviewsurvey.com/sites/default/files/styles/catlin-732-x/public/field/image/B%26A.jpg?itok=NOkkpKig

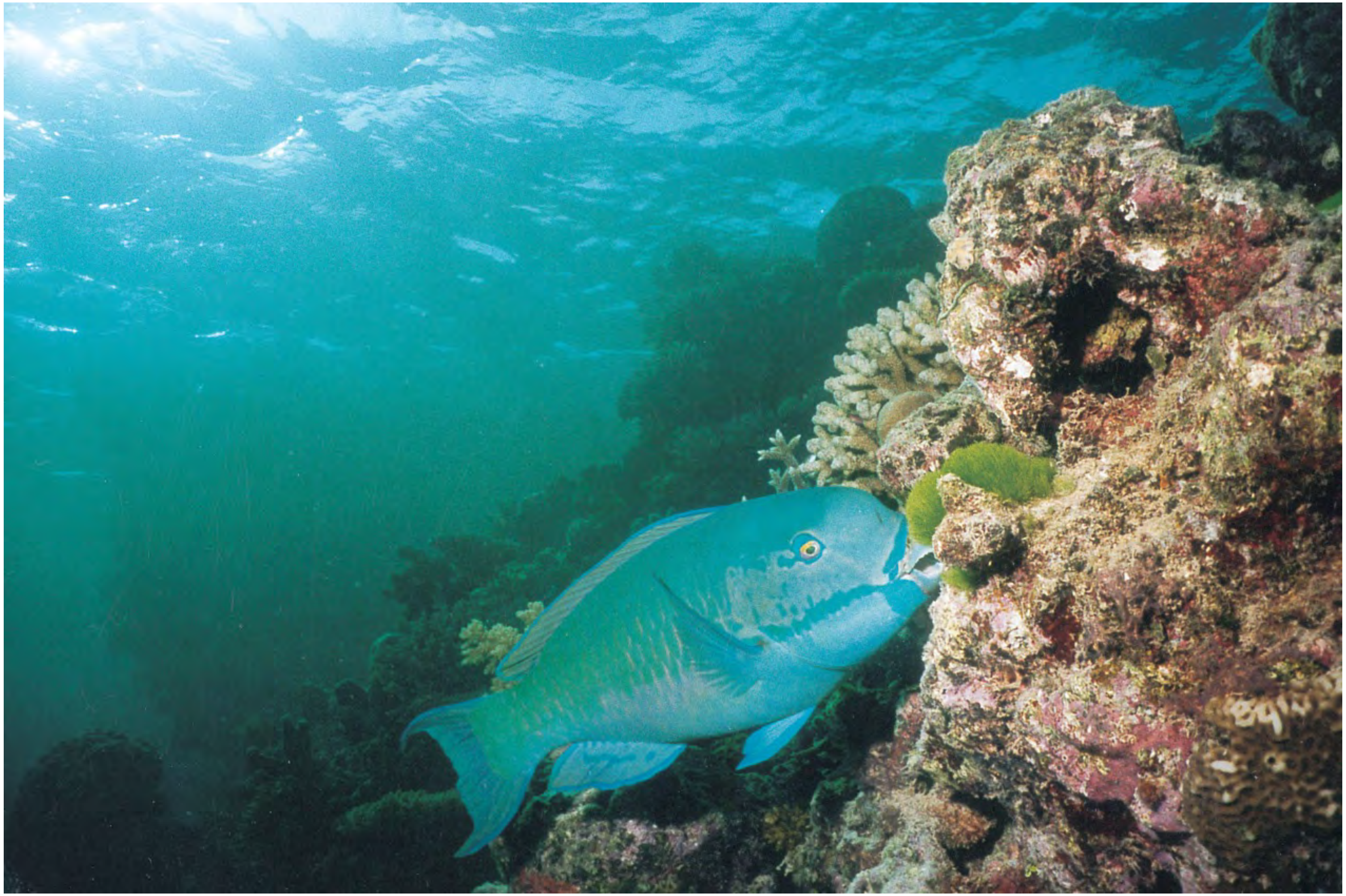
Biological erosion, or bioerosion is erosion caused by living organisms on the reef.

Herbivorous fish such as parrotfish erode the reef by scraping $CaCO_3$ while grazing on the overlying algal or coral tissue.

Sea urchins are significant $CaCO_3$ grazers on temperate reefs.

This type of erosion is sometimes called mechanical erosion.

Grazing scars from parrotfish



Parrotfish grazing on overlying algal and coral tissue.

Polychaete worms, sponges and bivalves also bore into coral structures. Borers are most common in areas where there is not live coral cover.

Christmas tree worms bore into coral

Image: vjacob, via Pixabay, https://pixabay.com/photos/christmastree-worms-close-up-coral-202320/

Algae, fungi and bacteria are called microborers due to their tiny size. However, they are one of the bioeroders* on coral reefs.

The rates of erosion caused by grazing and boring organisms varies in different regions.

Bioeroder	Inshore reef	Offshore reef
Grazer	0.004	0.68
Macroborer	0.13	0.03
Microborer*	0.15	1.4

Bioerosion rates on the Great Barrier Reef (kg $CaCO_3/m^2/yr$)

Table- Adam Richmond, with data from Tribollet and Golubi, 2005, cited in Silbiger, N. (2015). Environmental Drivers of the Coral Reef Accretion-Erosion Balance in Present and Future Ocean Conditions.
Retrieved from http://hdl.handle.net/10125/51127

Bioeroders* are the biological agents that break down coral reefs.
Microborers* are organisms that bore microscopic holes into the surface of the coral substrate. These include tiny endolithic algae, cyanobacteria and fungi.

Chemical erosion

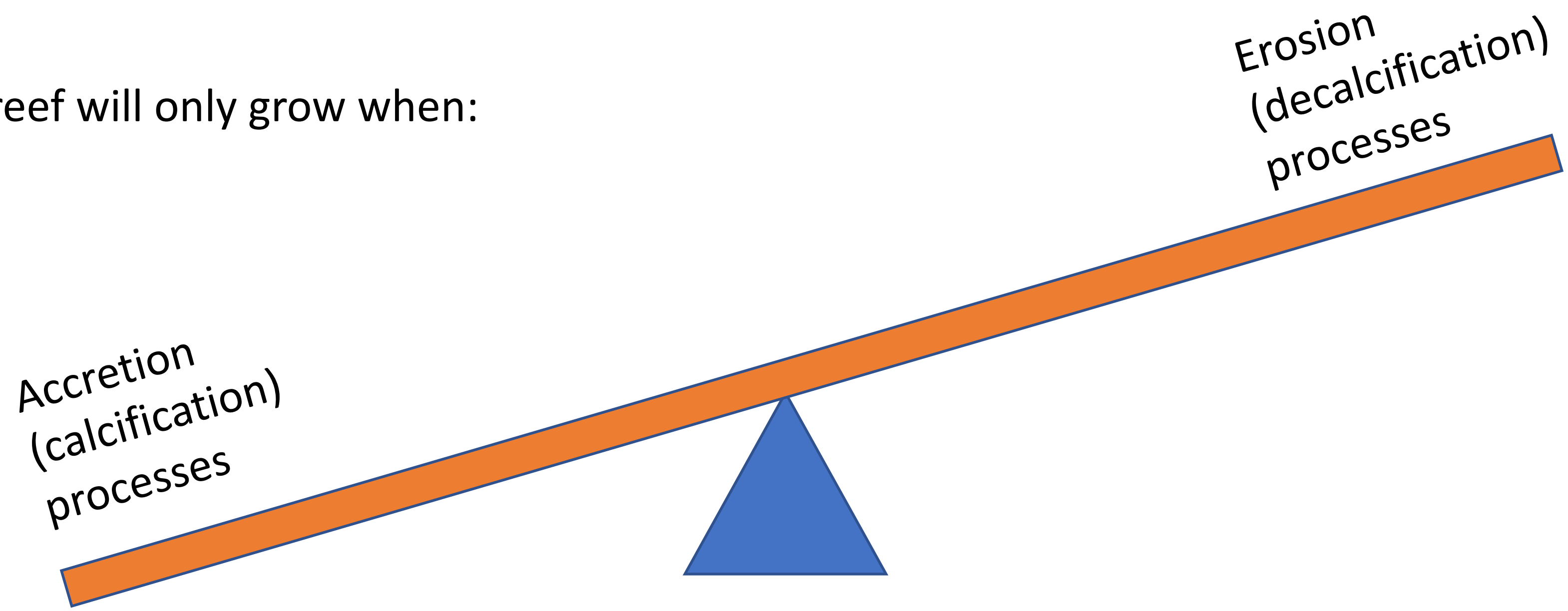
Sponges are bioeroders, but instead of biting or rasping coral, they use chemical bio-erosion.
Chemical bioerosion is where the $CaCO_3$ is dissolved with acidic chemicals.

Bioerosion by sponges can remove up to 20kg of CaCO3 per m2/year, reducing the coral skeletons to fine sediment.

Typical coral accretion rates are usually less than 20kg per square meter per year. What affect would sponge erosion have on a reef that is stressed?

Coral reef growth

A coral reef will only grow when:

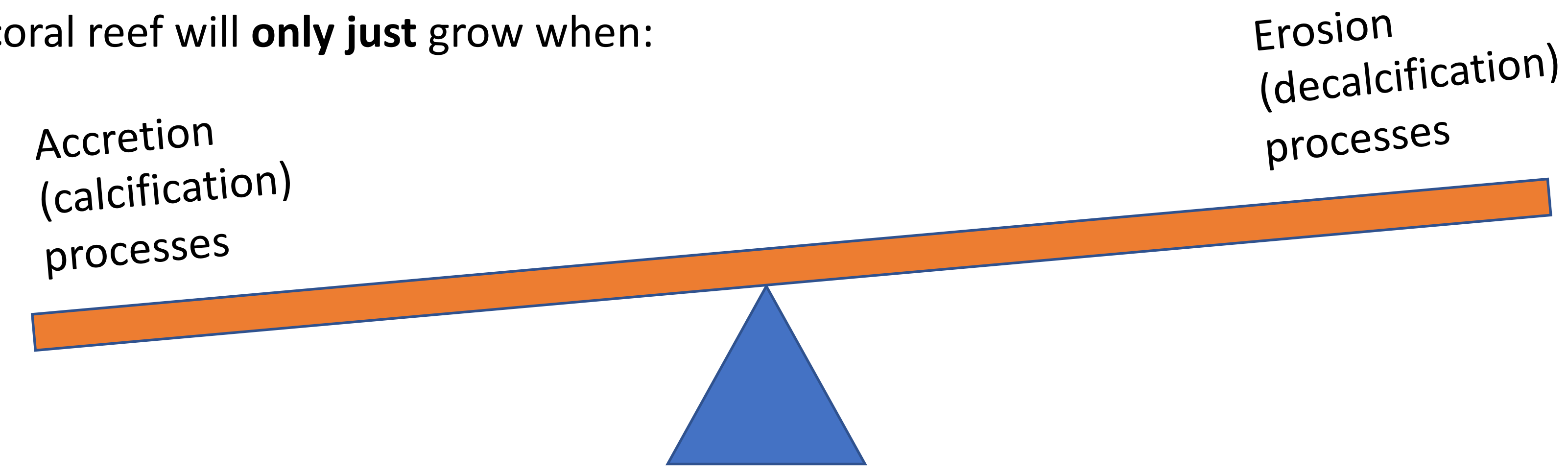


The rate of accretion processes **is greater than** the rate of erosion processes. This is common on reef slopes along the inner Great Barrier Reef, which average growth rates of 11.5 +/- 1.1 mm/year. [1]

1. van Woesik, R., & Cacciapaglia, C. (2018). Keeping up with sea-level rise: Carbonate production rates in Palau and Yap, western Pacific Ocean. *PLOS ONE*, *13*(5), e0197077. doi: 10.1371/journal.pone.0197077 Creative Commons 4.0 (CC BY)

Coral reef growth

A coral reef will **only just** grow when:



The rate of accretion is **only just** greater than the rate of erosion processes.
This is common on most reef flats, since sea levels stabilised 5000 years ago.
A healthy reef might accumulate 4 kg CaCO3/m2/yr, which is approximately 3mm.[1]

1. van Woesik, R., & Cacciapaglia, C. (2018). Keeping up with sea-level rise: Carbonate production rates in Palau and Yap, western Pacific Ocean. *PLOS ONE*, *13*(5), e0197077. doi: 10.1371/journal.pone.0197077 Creative Commons 4.0 (CC BY)

Rising atmospheric CO_2

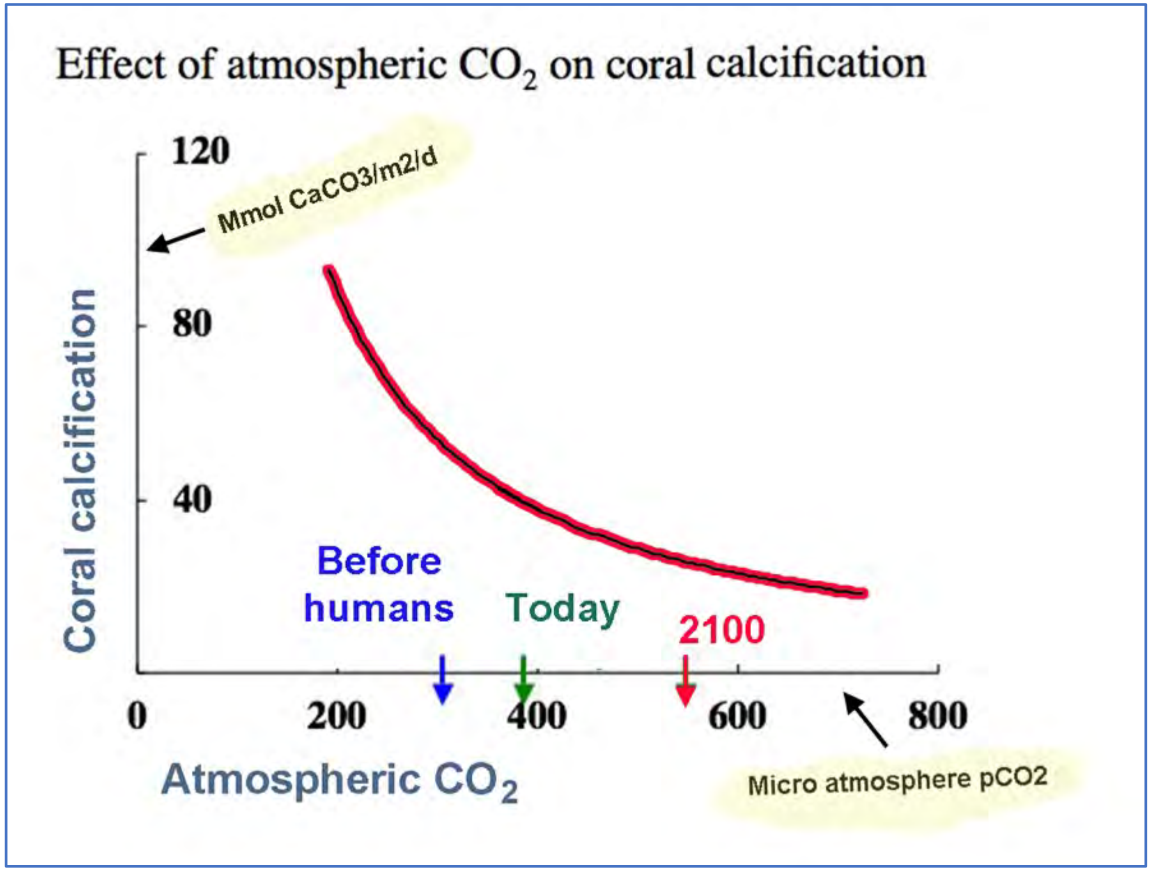
The impact of rising atmospheric CO_2 levels in open oceans is well understood, but this is not the case for shallow nearshore environments such as the Great Barrier Reef.

Carbonate chemistry has great variability over a range of special and temporal scales.

This is an important and current area of research at the Australian Institute of Marine Science (AIMS).

Further discussion

More on this in Topic 113.



Calcification rate as a function of CO_2 concentration

After: Langdon, C. (2002). Review of Experimental Evidence for Effects of CO2 on Calcification of Reef builders. *Proceedings 9Th International Coral Reef Symposium*, 1091-1098. Modified.

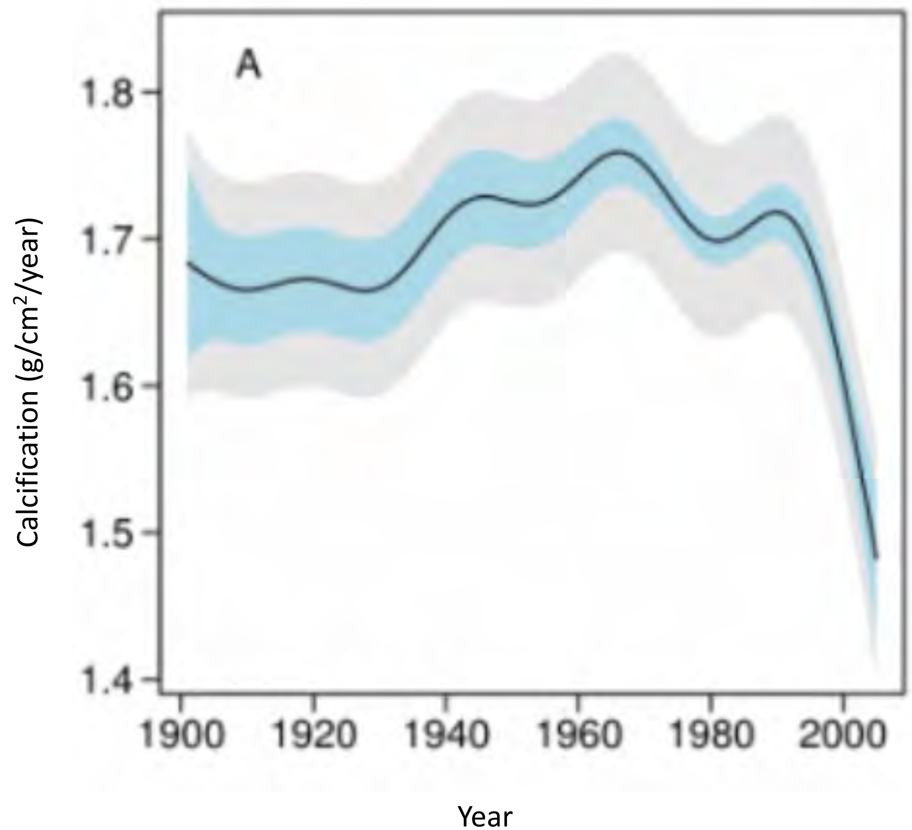
Declining coral growth

"This graph shows an overall decrease in the rate of calcification in *Porites* corals on the Great Barrier Reef since 1900.

Since 1980, there has been a dramatic decrease in the calcification rate, which has been attributed to increasing acidification and increasing sea temperature stress.

The light blue bands indicate 95 per cent confidence intervals for comparison between years, and the green bands indicate 95 per cent confidence intervals for the predicted value for any given year."

From Great Barrier Reef Outlook Report 2009



From: Langdon, C. (2002). Review of Experimental Evidence for Effects of CO_2 on Calcification of Reef builders. *Proceedings 9Th International Coral Reef Symposium*, 1091-1098. Copyright, reproduced with permission may not be altered.

Review

Put this quote from a scientific paper into your own words:

"Coral reefs persist in a balance between reef growth (accretion) and reef breakdown (erosion). Corals and other calcifying organisms secrete calcium carbonate ($CaCO_3$) skeletons, while a diverse community of bioeroders erode reefs through grazing on and boring into the skeletal structure of the reef."

"Enhanced rates of bioerosion can compromise the function of the reef framework, undermining the mechanical stability, structural complexity, and net accretion of coral reefs… if bioerosion exceeds accretion, coral reefs will drown as a result of sea-level rise."

Silbiger, N. (2015). Environmental Drivers of the Coral Reef Accretion-Erosion Balance in Present and Future Ocean Conditions. Retrieved from http://hdl.handle.net/10125/51127

Questions

1. Write definitions for the following terms as they apply to coral growth.
    - accretion
    - erosion

2. Explain how mechanical and bio-erosive forces affect coral growth.

3. How do scientists determine if a reef is growing or being destroyed.

Further activity

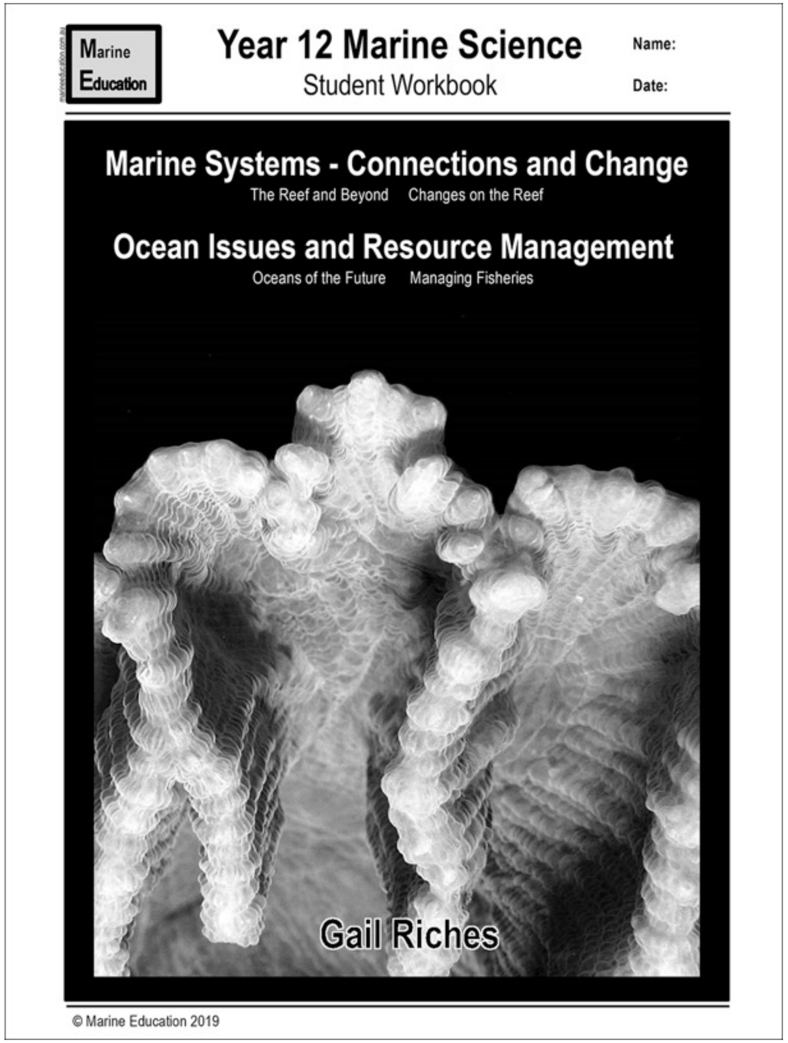
Worksheet –

Construction and destruction

by

Gail Riches

www.marineeducation.com.au




T085 Abiotic factors affecting reef distribution
Adam Richmond

Syllabus statement

At the end of this topic you should be able to ...

Assess

data of abiotic factors (e.g. dissolved oxygen, salinity, substrate) that affect the distribution of coral reefs.

Assess

- measure, determine, evaluate, estimate or make a judgment about the value, quality, outcomes, results, size, significance, nature or extent of something .

Objectives

To locate and interpret existing (secondary) data of the following eight abiotic factors that affect coral reef distribution.

1. Dissolved oxygen (DO)
2. Light availability
3. Salinity
4. Temperature
5. Substrate and sediment
6. Seawater carbonate chemistry (Aragonite)
7. Nutrients (nitrates and phosphates)
8. Exposure, waves, tides and storms

Make informed judgements with reference to each of these 8 abiotic factors.

Prior knowledge

Discussion in this topic assumes knowledge of following statistical terms:

- Range, average and standard deviations of environmental parameters
- Pearson's correlation coefficient

- You should also review Topic 071 Coral Geographic distribution with respect to your answers to the abiotic factors in the table below:

Factor	Explanation of how these factors affect coral distribution	How factor may have changed over time
Dissolved oxygen		
Light availability		
Salinity		
Temperature		
Substrate		
Aragonite		
Low levels of nitrates and phosphates		

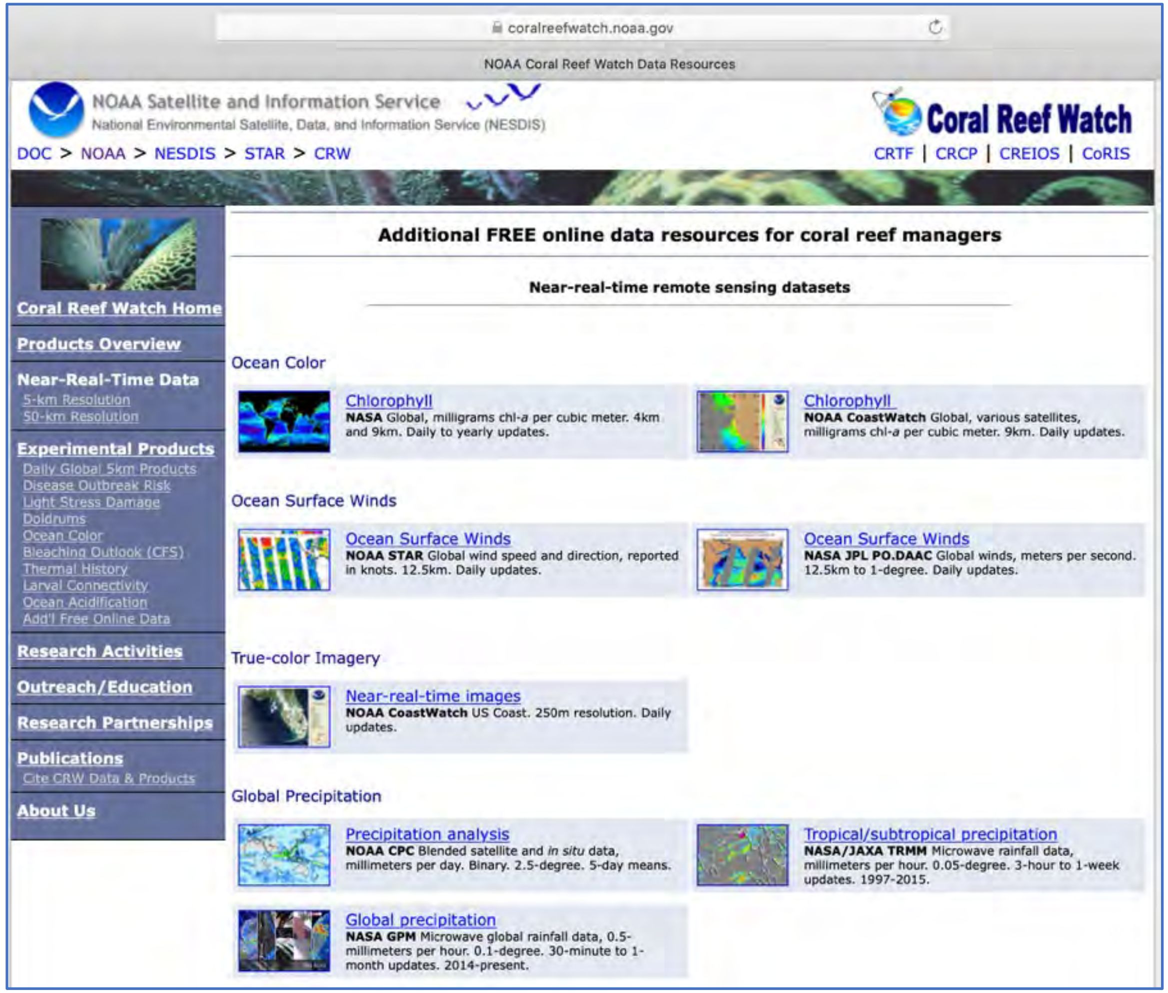
Finding data

The syllabus is asking you to assess data that can be used to study reefs.

The US based government agency NOAA has free data for reef scientists.

So spend some time looking at the types of data sets available.

https://coralreefwatch.noaa.gov/crtr/data_resources.php



https://coralreefwatch.noaa.gov/crtr/data_resources.php

Interpreting data

Data can be compared with the range, average and standard deviations of environmental parameters summarised by Kleypas *et al.* 1999.

This paper can be downloaded here:
https://academic.oup.com/icb/article/39/1/146/124572

You have seen this table before in Topic 71.

Variable	Minimum	Maximum	Mean	Std dev.
Temperature				
Average	21	29.5	27.6	1.1
Minimum	16	28.2	24.8	1.8
Maximum	24.7	34.4	30.2	0.6
Salinity (ppt)				
Maximum	23.3	40	34.3	1.2
Minimum	31.2	41.8	35.3	0.9
Nutrients(µmol/L)				
NO_3	0	3.34	0.25	0.28
PO_4	0	0.54	0.13	0.08
Aragonite saturation (Ω_{arag})				
Average	3.28	4.06	3.83	0.09
Maximum depth of light penetration (m)				
Average	-9	-81	-53	13.5
Minimum	-7	-72	-40	13.5
Maximum	-10	-91	-65	13.4

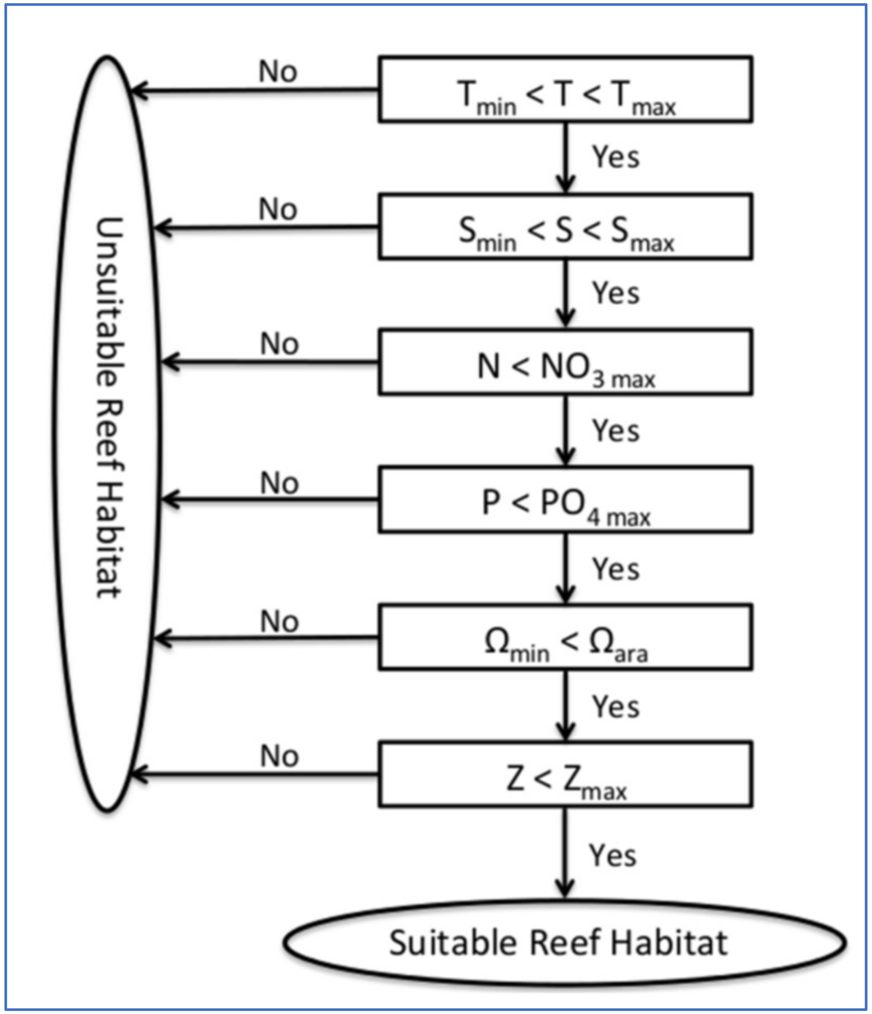
 Table, after:
Kleypas, J., Mcmanus, J., &, Menez L. (1999). Environmental Limits to Coral Reef Development: Where Do We Draw the Line?. *American Zoologist*, *39*(1), 146-159. doi: 10.1093/icb/39.1.146

Data decision flow chart

The flow chart presented by Guan Y, Hohn S, & Merico A (2015) can be used to determine whether the data is suitable for coral.

Just follow the steps* to get the answer.

- T = temperature
- S = salinity
- N = nitrate
- P = phosphate
- Ω = aragonite
- Z= depth (based on light intensity)



Guan Y, Hohn S, Merico A (2015) Suitable Environmental Ranges for Potential Coral Reef Habitats in the Tropical Ocean. PLoS ONE 10(6): e0128831. doi:10.1371/journal.pone.0128831

This flow chart works from the top:

Is temp in the acceptable range?

Yes- go to salinity

No- unsuitable habitat.

1. Dissolved oxygen (DO)

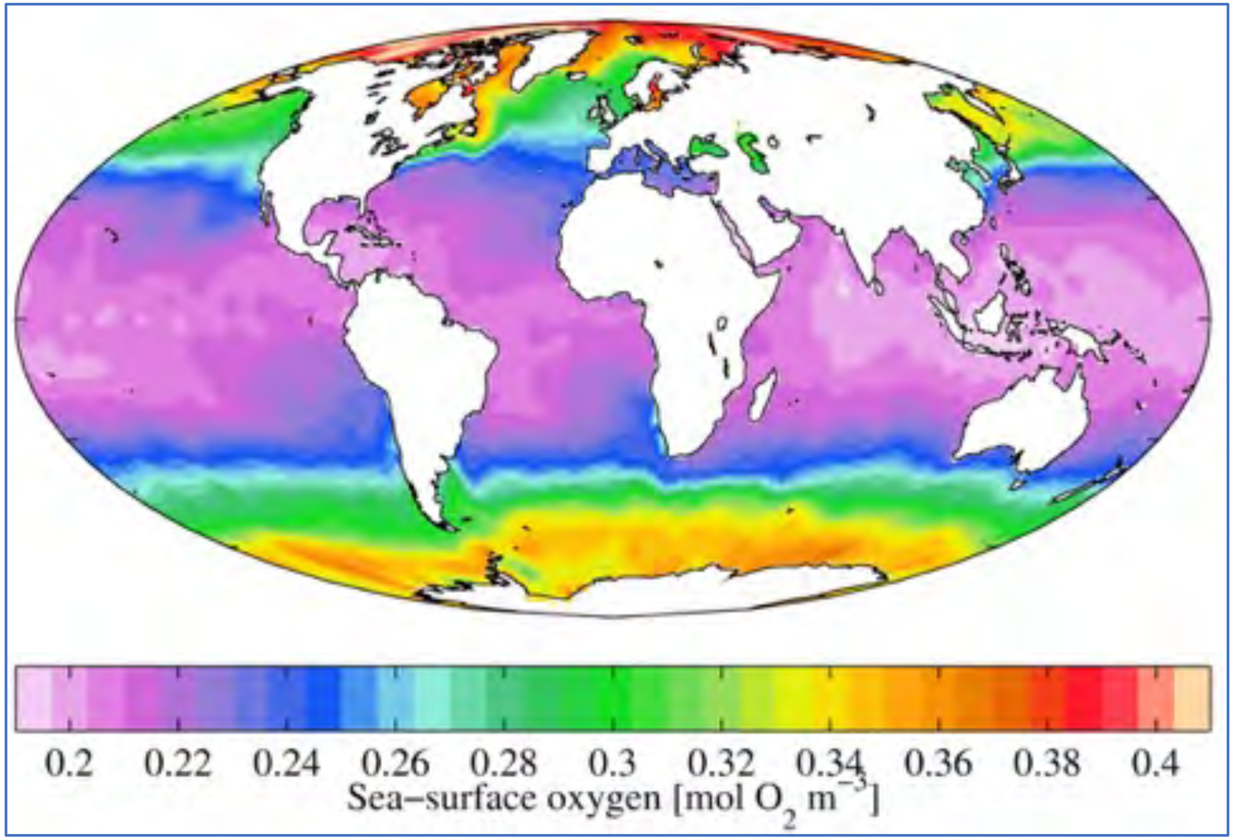
Study the data from the image opposite and discuss these questions.

a) Determine the DO level on the Great Barrier Reef.

b) Where is DO the highest?

c) Describe the trend in DO concentration, as you move away from the Equator.

d) Suggest the relationship between DO and sea surface temperature.



Dissolved oxygen levels at the ocean’s surface

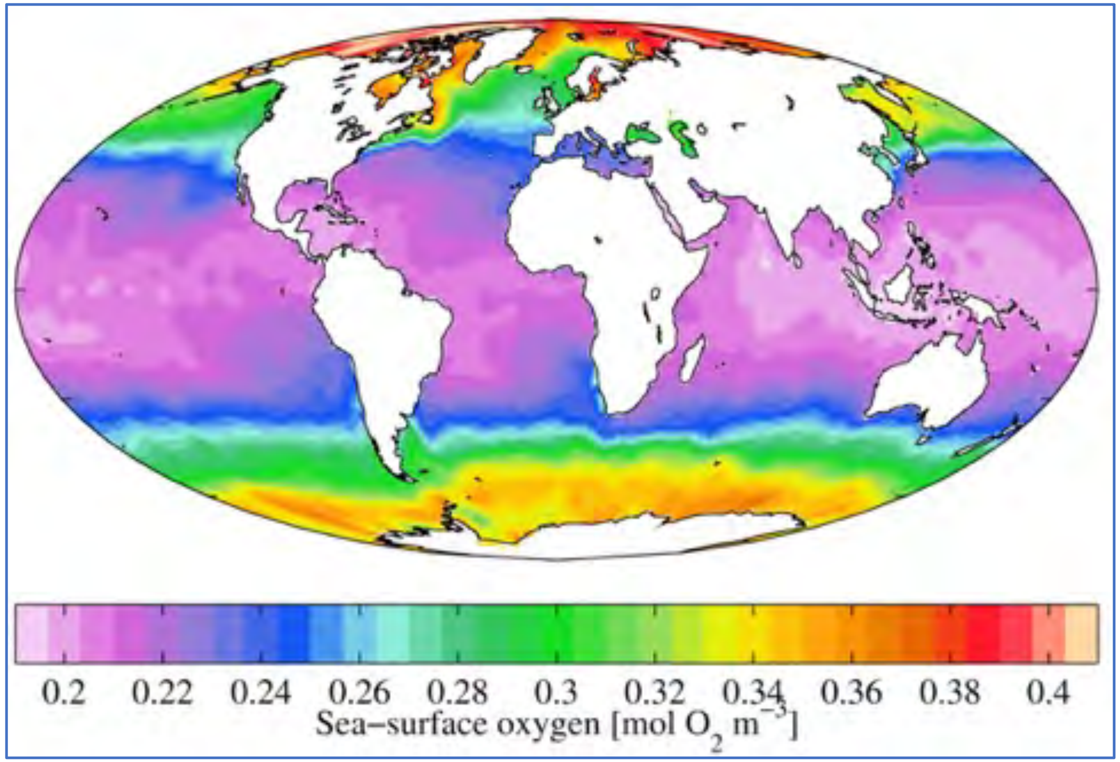
How did you go?

a. Determine the DO level on the Great Barrier Reef.
Ans: 0.20-0.22

b. Where is DO the highest?
Ans: : North pole, at 0.38

c. Describe the trend in DO concentration, as you move away from the Equator.
Ans: DO increases with increasing distance from the poles

d. Suggest the relationship between DO and sea surface temperature.
Ans: Warmer waters have less DO

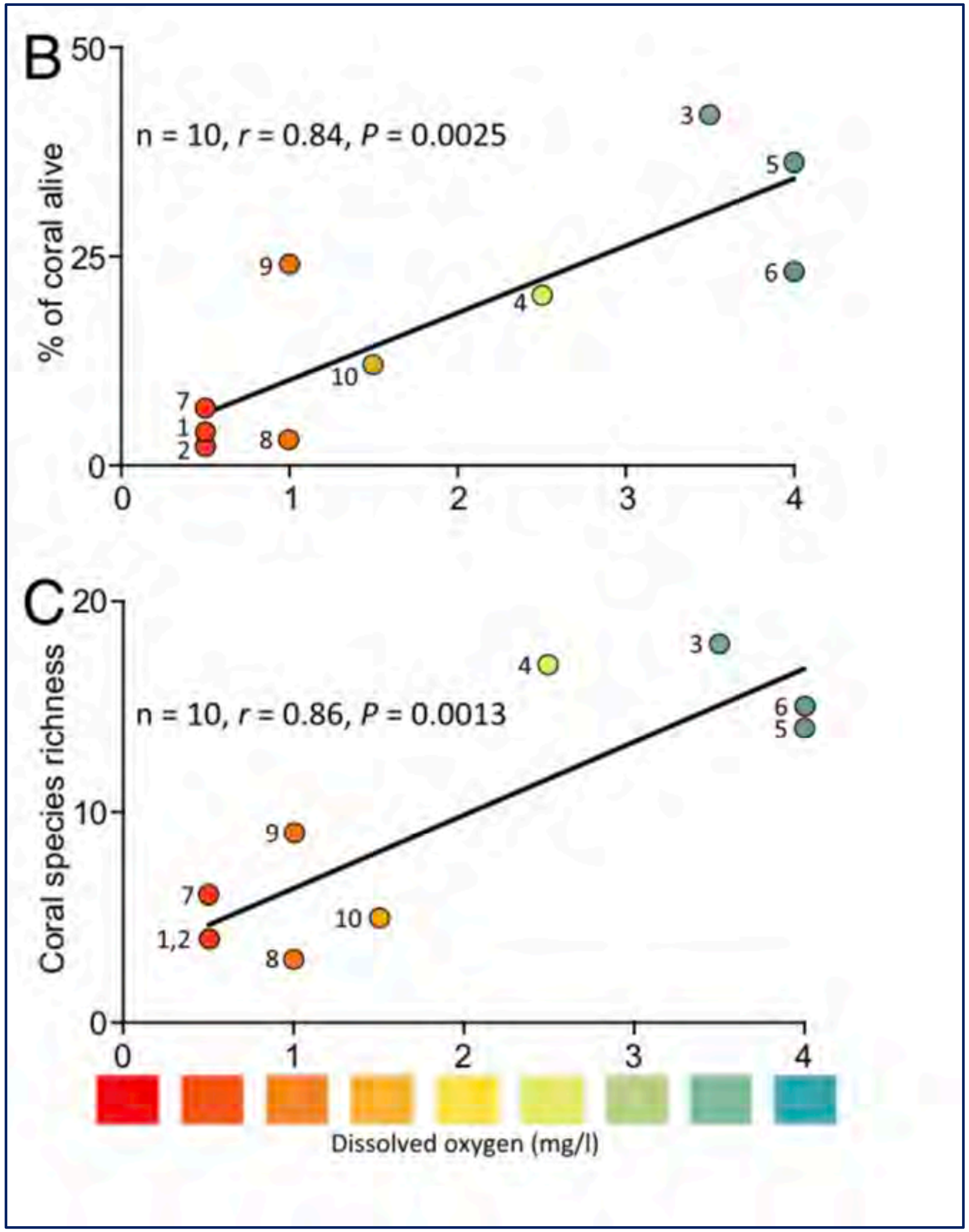


Dissolved oxygen levels at the Ocean's surface

Discussion

Following a hypoxic (low oxygen) event, Altieri *et al* (2017) observed these changes in % coral alive (B) and species richness (C).

Sites that are red and orange in the figures were exposed to low oxygen conditions; blue experienced normal oxygen levels.



Note: The graphs show correlation between DO level and corals alive, and species richness.

Altieri, A., Harrison, S., Seemann, J., Collin, R., Diaz, R. and Knowlton, N. (2017). Tropical dead zones and mass mortalities on coral reefs. *Proceedings of the National Academy of Sciences*, 114(14), pp.3660-3665. Available PNAS open access- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5389270/

Questions

Study the data from the graphs opposite and answer these questions.

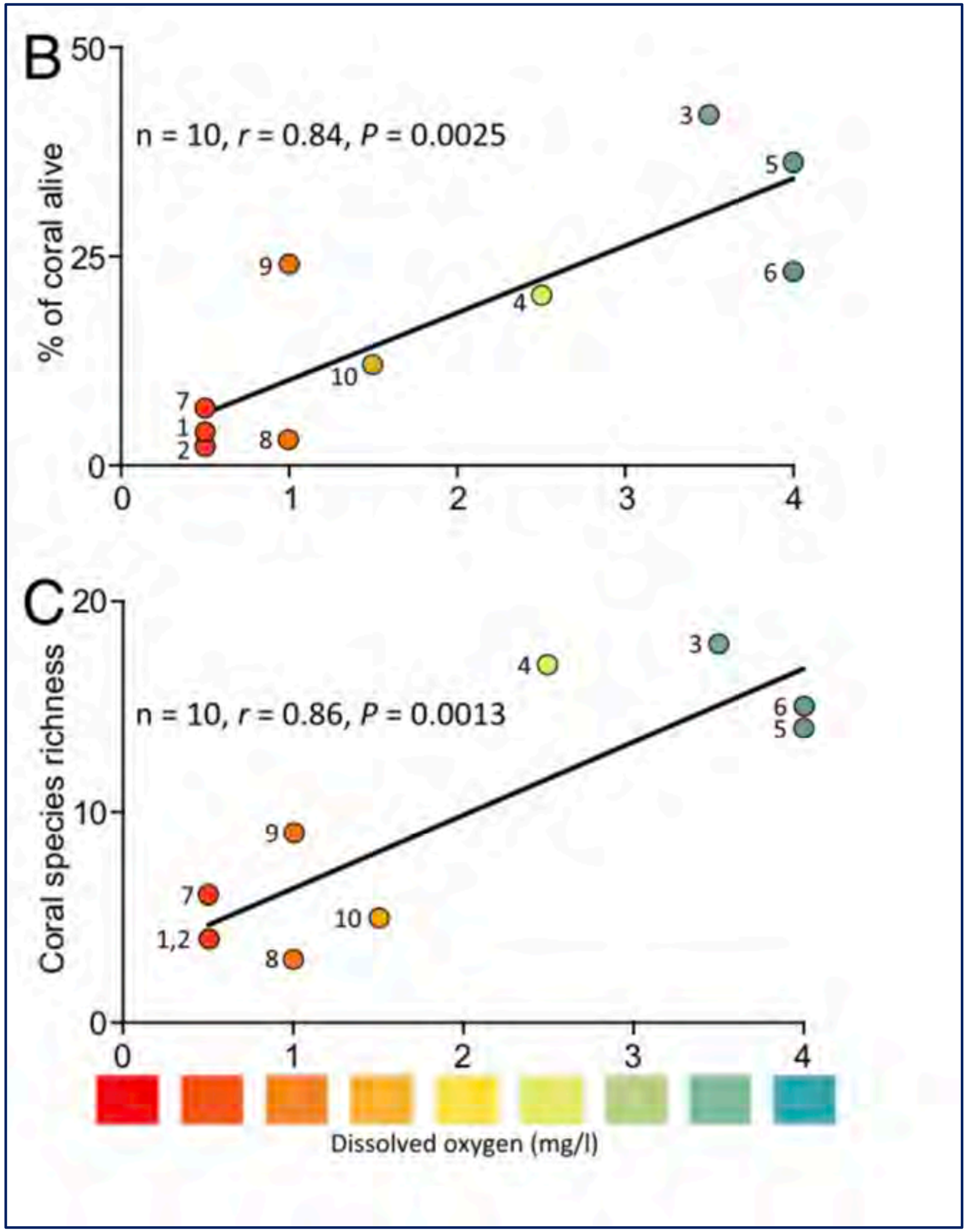
a. Which 2 sites experienced normal O_2 levels?

b. Which 3 sites experienced hypoxic conditions?

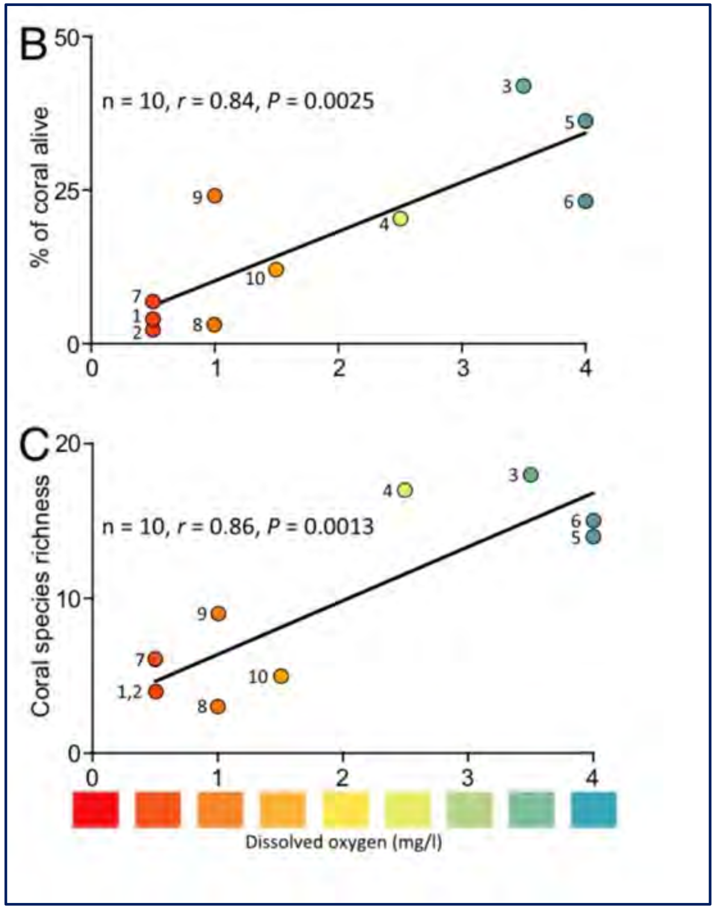
c. Explain the trend in both graphs.

d. Pearson's correlation coefficient is r= 0.84.
What does this tell you?

e. The P value is less than 0.05 (5%).
What does this indicate?



Altieri, A., Harrison, S., Seemann, J., Collin, R., Diaz, R. and Knowlton, N. (2017). Tropical dead zones and mass mortalities on coral reefs. *Proceedings of the National Academy of Sciences*, 114(14), pp.3660-3665. Available PNAS open access- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5389270/



Altieri, A., Harrison, S., Seemann, J., Collin, R., Diaz, R. and Knowlton, N. (2017). Tropical dead zones and mass mortalities on coral reefs. *Proceedings of the National Academy of Sciences*, 114(14), pp.3660-3665. Available PNAS open access- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5389270/

How did you go?

a. Which 2 sites experienced normal O_2 levels?

Ans: 5 and 6

b. Which 3 sites experienced hypoxic conditions?

Ans: 1, 2, & 7

c. Explain the trend in both graphs.

Ans: Less corals are alive at lower O_2 levels, more alive at higher levels. Species richness is reduced following hypoxic conditions.

d. What does r= 0.84 tell you?

Ans: There is a high correlation between % corals alive and O_2 levels.

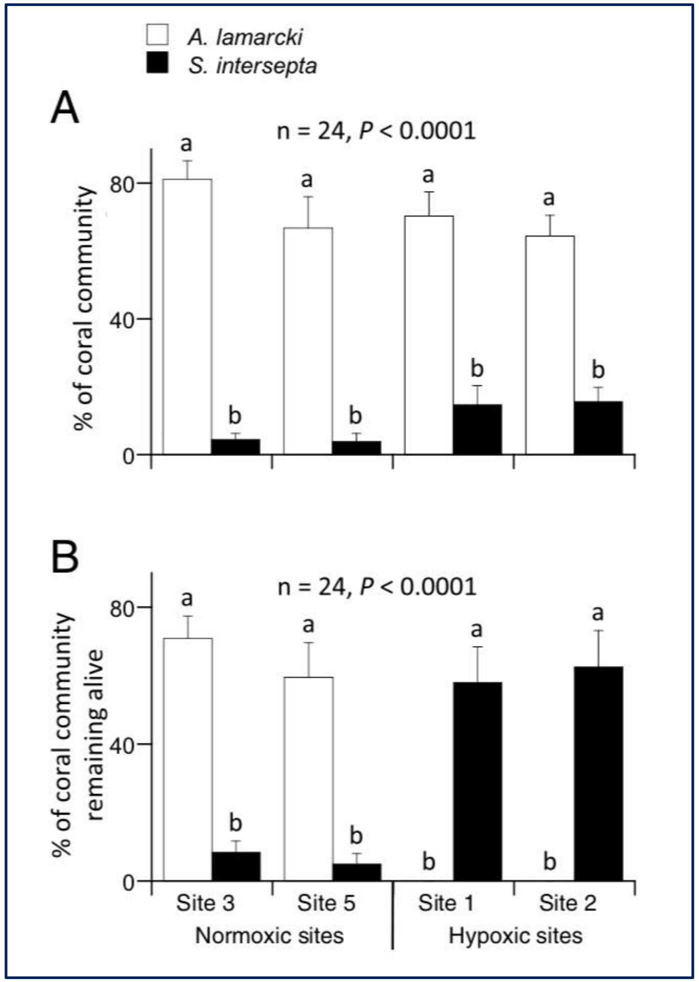
e. The P value is less than 0.05 (5%). What does this indicate?

Ans: These results are statistically significant: there is a less than 5% chance that these corals could have had the same species richness % alive.

Discussion

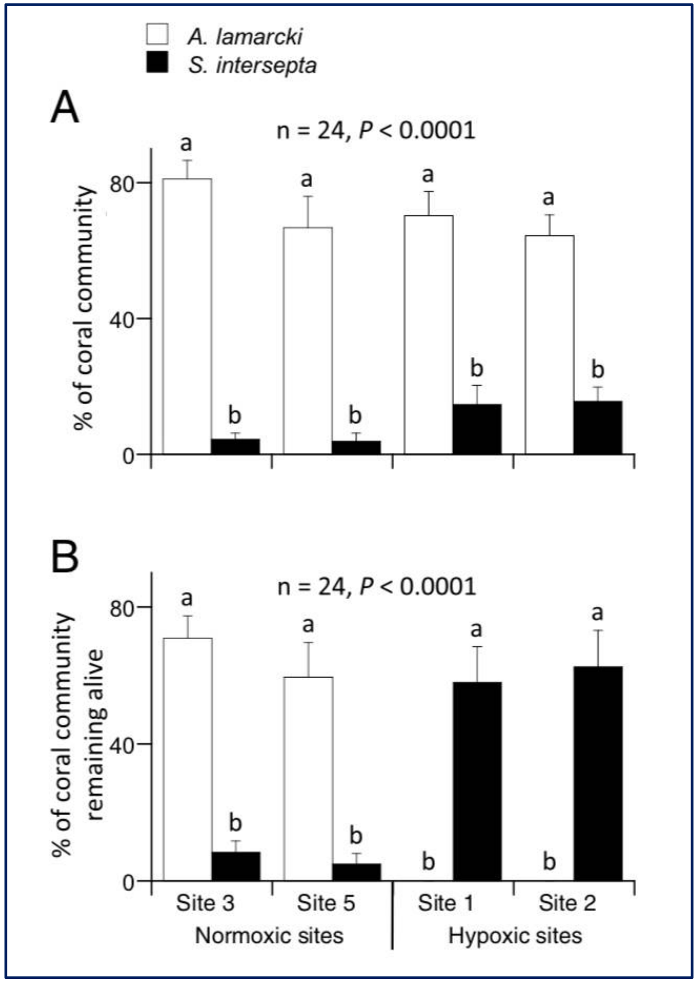
In the same study, 2 different coral species showed different tolerance to hypoxia.

Graph A shows the relative abundance of the 2 species before the hypoxic event. Graph B shows the relative abundance of live corals after the event.



Altieri, A., Harrison, S., Seemann, J., Collin, R., Diaz, R. and Knowlton, N. (2017). Tropical dead zones and mass mortalities on coral reefs. *Proceedings of the National Academy of Sciences*, 114(14), pp.3660-3665. Available PNAS open access (CC BY-NC-ND 4.0) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5389270/

Bar graphs show change in coral community structure before a n anoxic event.



Altieri, A., Harrison, S., Seemann, J., Collin, R., Diaz, R. and Knowlton, N. (2017). Tropical dead zones and mass mortalities on coral reefs. *Proceedings of the National Academy of Sciences*, 114(14), pp.3660-3665. Available PNAS open access- (CC BY-NC-ND 4.0)https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5389270/

Questions

Study the data from the graphs opposite and answer these questions.

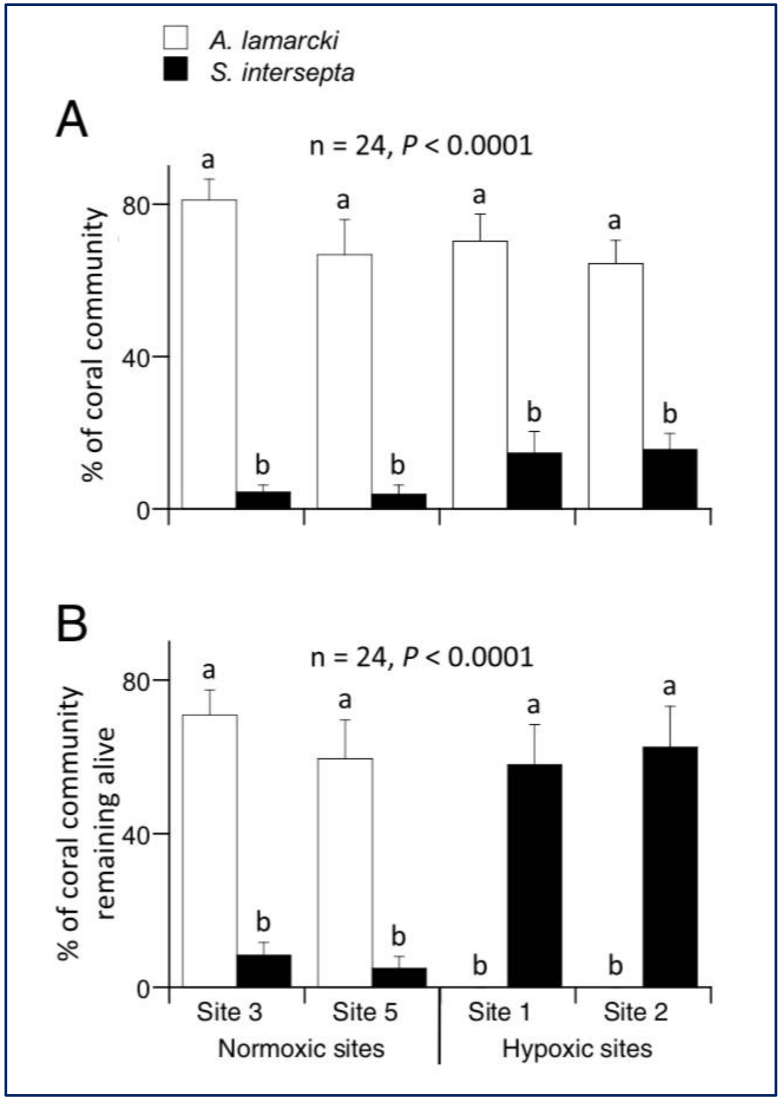
a. Which coral species was initially most abundant?

b. Which coral species was most abundant at sites 1 and 2 after the hypoxic event?

c. Sites 3 and 5 had normal conditions. What happened to the coral community at these sites?

d. Which species is more tolerant of hypoxic events?

e. What affect could repeated frequent hypoxic events have on this reef?



Altieri, A., Harrison, S., Seemann, J., Collin, R., Diaz, R. and Knowlton, N. (2017). Tropical dead zones and mass mortalities on coral reefs. *Proceedings of the National Academy of Sciences*, 114(14), pp.3660-3665. Available PNAS open access- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5389270/ (CC BY-NC-ND 4.0)

How did you go?

a. Which coral species was initially most abundant?
Ans: *A lamarki* was most abundant at all sites

b. Which coral species was most abundant at sites 1 and 2 after the hypoxic event?
Ans: *S intersepta*

c. Sites 3 and 5 had normal conditions. What happened to the coral community at these sites?
Ans: Did not change

d. Which species is more tolerant of hypoxic events?
Ans: *S intersepta*

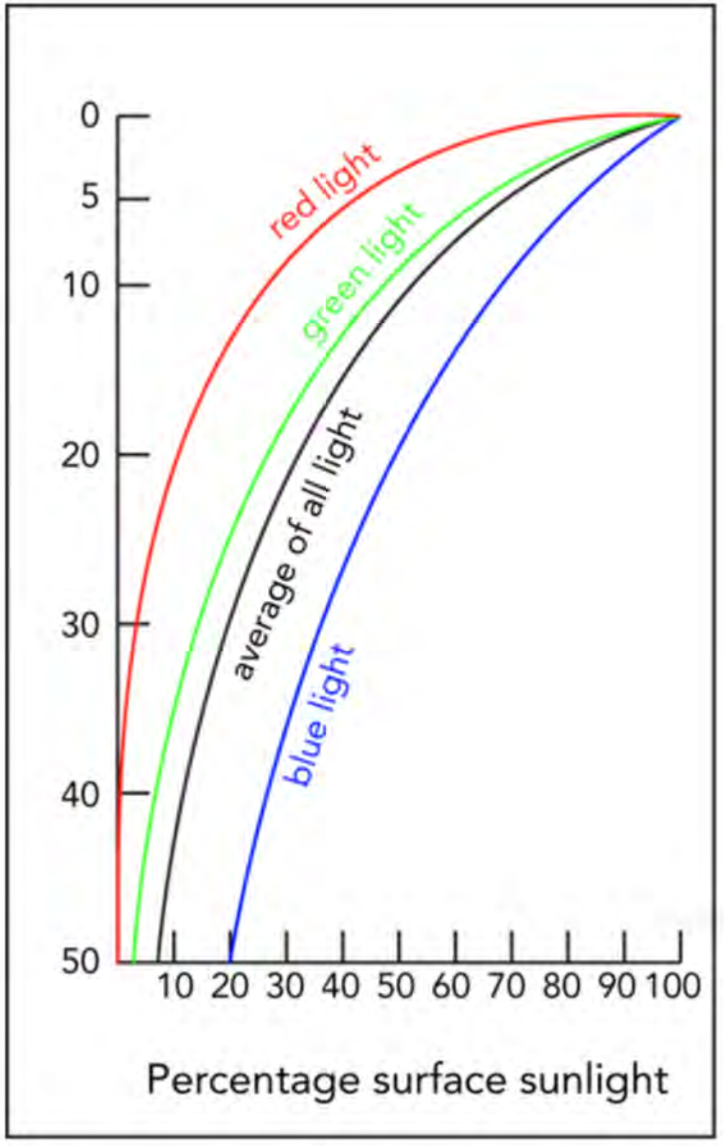
e. What affect could repeated frequent hypoxic events have on this reef?
Ans: *A lamarki* would not survive. Loss of species richness.

2. Light availability

There is some interesting research on the effects of lighting arising from the aquaculture and aquarium industries.

In nature, light intensity is confounded by depth and turbidity.

However in aquaria, light intensity and the light spectrum can be manipulated.



The intensity of sunlight decreases with depth

Image by Byron Inouye Reproduced with permission https://manoa.hawaii.edu/exploringourfluidearth/physical/ocean-depths/light-ocean

These graphs show the calcification rate and photosynthesis rate of *Acropora variabilis* and *Porites lutea* with full visible spectrum (control) and 4 experimental colour spectra.

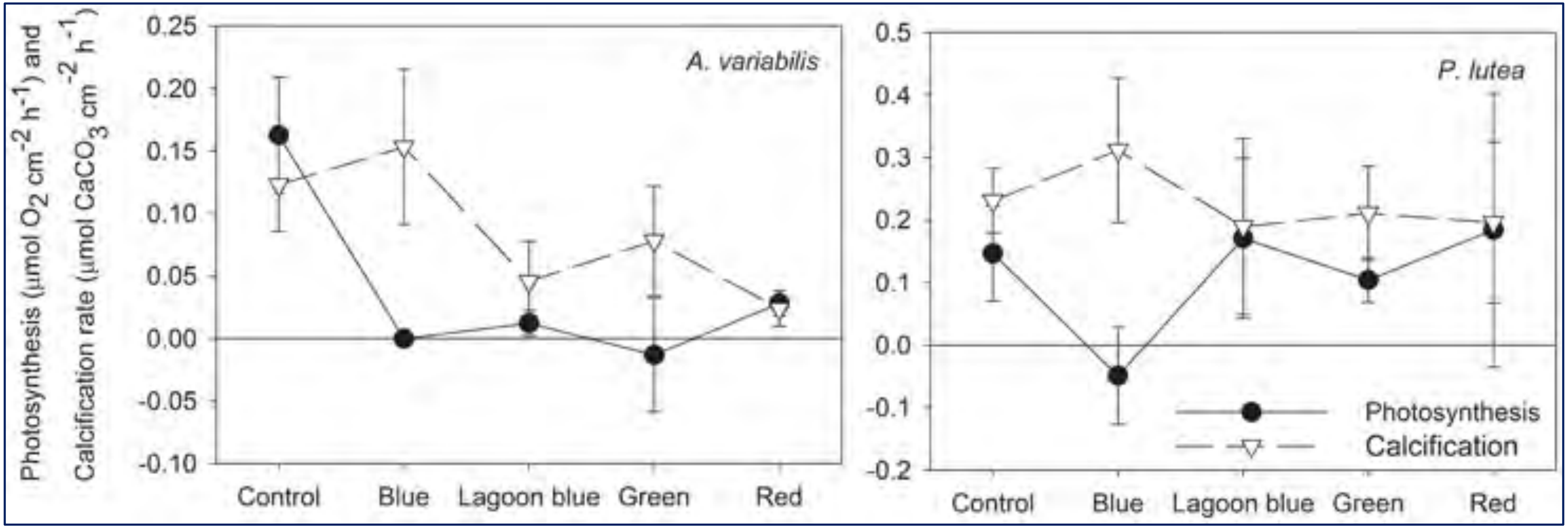


Figure from: Cohen, I., Dubinsky, Z., & Erez, J. (2016). Light Enhanced Calcification in Hermatypic Corals: New Insights from Light Spectral Responses. *Frontiers In Marine Science*, *2*. doi: 10.3389/fmars.2015.00122. (CCBY). Available: https://www.frontiersin.org/articles/10.3389/fmars.2015.00122/full#h8

Questions

a. Contrast the rate of photosynthesis of *A. variabilis* at different light spectra.

b. Which light colour did not support photosynthesis in either coral?

c. Which light colour supported the highest calcification rate?

How did you go?

a. Contrast the rate of photosynthesis of *A. variabilis* at different light spectra.

Ans: Photosynthesis is highest in the control. Much less in red and lagoon blue, zero in blue and negative in red.

b. Which light colour did not support photosynthesis in either coral? Ans: Blue

c. Which light colour supported the highest calcification rate? Ans: Blue. (Interestingly, blue light is a cue for calcification. It is not involved in photosynthesis)

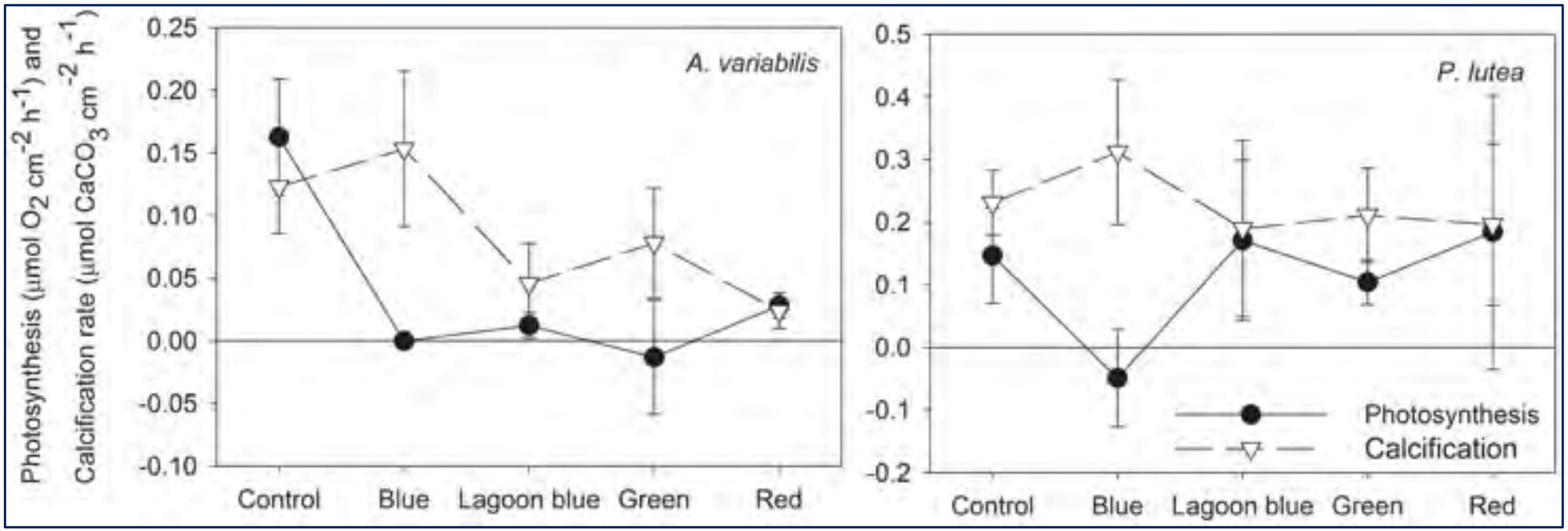
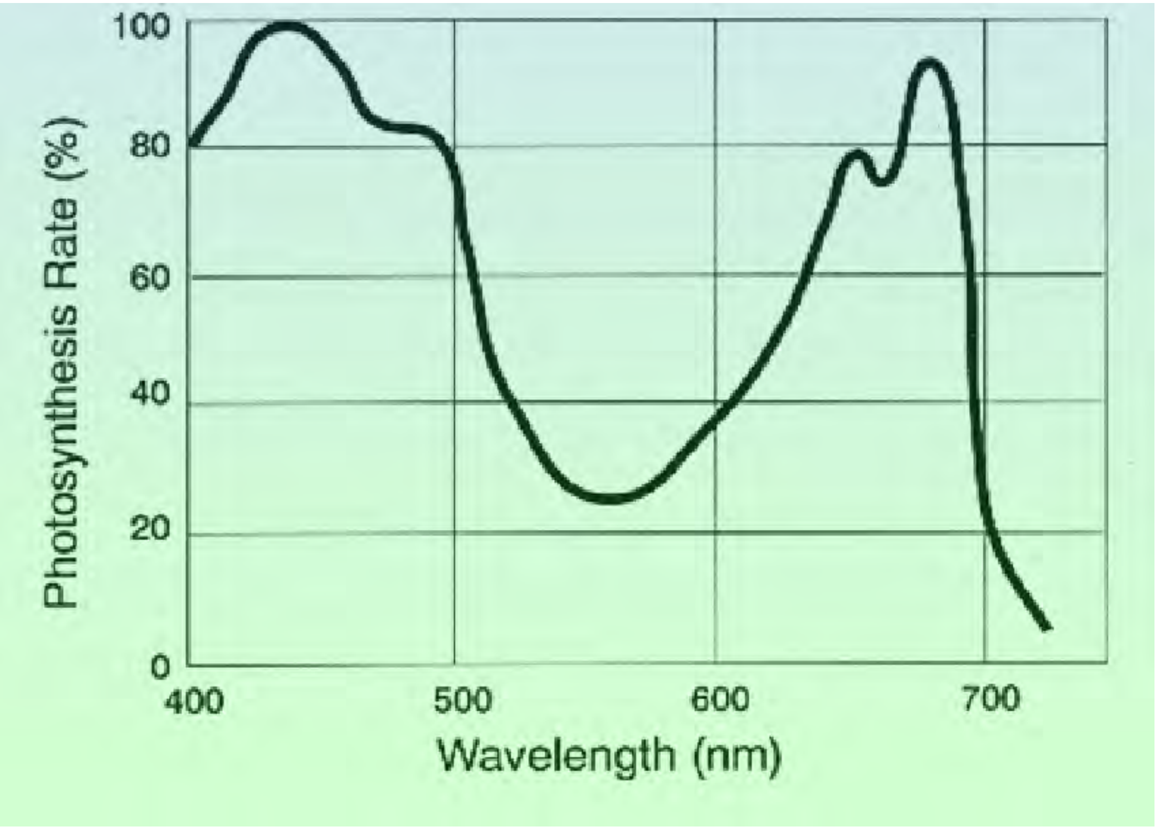


Figure from: Cohen, I., Dubinsky, Z., & Erez, J. (2016). Light Enhanced Calcification in Hermatypic Corals: New Insights from Light Spectral Responses. *Frontiers In Marine Science*, *2*. doi: 10.3389/fmars.2015.00122. (CCBY) Available: https://www.frontiersin.org/articles/10.3389/fmars.2015.00122/full#h8

The next graph looks at photosynthetically active radiation, often abbreviated PAR.

PAR designates the spectral range (wave band) of solar radiation from 400 to 700 nanometers that photosynthetic organisms are able to use in the process of photosynthesis.



PAR action spectrum for chloroplasts (oxygen evolution per incident photon) of an isolated chloroplast.

By John Whitmarsh and Govindjee. - http://www.life.uiuc.edu/govindjee/paper/gov.html, from "Concepts in Photobiology: Photosynthesis and Photomorphogenesis", Edited by GS Singhal, G Renger, SK Sopory, K-D Irrgang and Govindjee, Narosa Publishers/New Delhi; and Kluwer Academic/Dordrecht, pp. 11-51. From unpublished data., CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=6958887

This table shows the light ranges required for coral growth, as suggested by an aquarium lighting manufacturer.

Note: *The units of Photosynthetically Active Radiation (PAR) in this table are in Microeinsteins per second per square metre (µE m^2sec)- which is not a standard SI measure

Table: PAR light ranges* required for coral growth in

Genus	Minimum	Ideal	Maximum
Acropora	131	246	503
Cyphastrea	100	150	200
Montipora	122	224	300
Pocillopora	225	299	417
Pavona	110	230	350
Porites	267	358	450
Sinularia	200	300	400
Stylophora	40	250	600

Table: Adam Richmond, using a selection of data from Seneye, in association with Arcadia. Reproduced with permission Seneye. CC BY-NC-ND 3.0 Retrieved from: http://answers.seneye.com/index.php?title=en/Aquarium_help/What_is_PAR_%26_PUR_%3F/marine_coral_reef_PAR_levels

Questions

a. Identify the coral genus with the lowest "ideal" light requirement.

b. Predict which corals would struggle in an aquarium with 250 µE m^2sec lighting.

c. Deduce which coral might be the best filter feeder of this selection.

How did you go?

1. Identify the coral genus with the lowest “ideal” light requirement.
Ans: *Cyphastrea*

2. Predict which corals would struggle in an aquarium with 250 μE m^2sec lighting.
Ans: All with ideal > 250: *Pocillopora, Porites, Sinularia*

3. Deduce which coral might be the best filter feeder of this selection.
Ans: *Stylophora*- since it can survive with very low light

Genus	Minimum	Ideal	Maximum
Acropora	131	246	503
Cyphastrea	100	150	200
Montipora	122	224	300
Pocillopora	225	299	417
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Retrieved from:
http://answers.seneye.com/index.php?title=en/Aquarium_help/What_is_PAR_%26_PUR_%3F/marine_coral_reef_PAR_levels

3. Salinity

Corals in the Persian Arabian Gulf (PAG) are known to have greater thermal tolerance than corals in the Indo Pacific (IP).

These graphs show the mean wet weight of colonies of *Montipora foliosa*, from IP, and *Porites lobata* from PAG, cultured at salinities of 36.5 and 42 ppt.

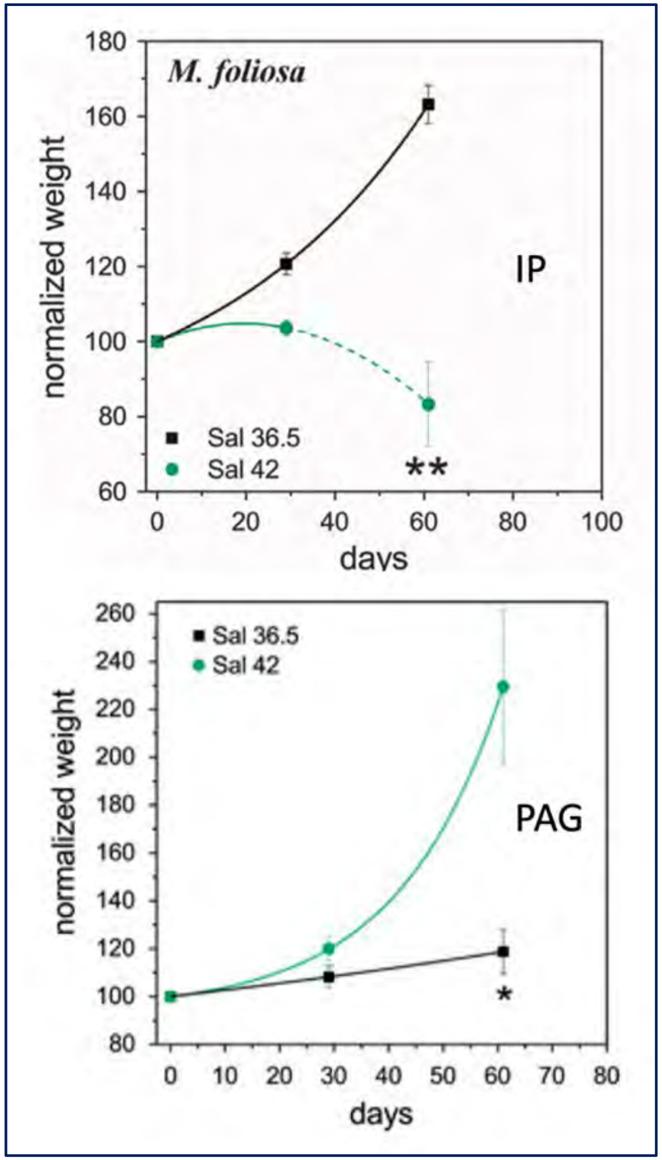
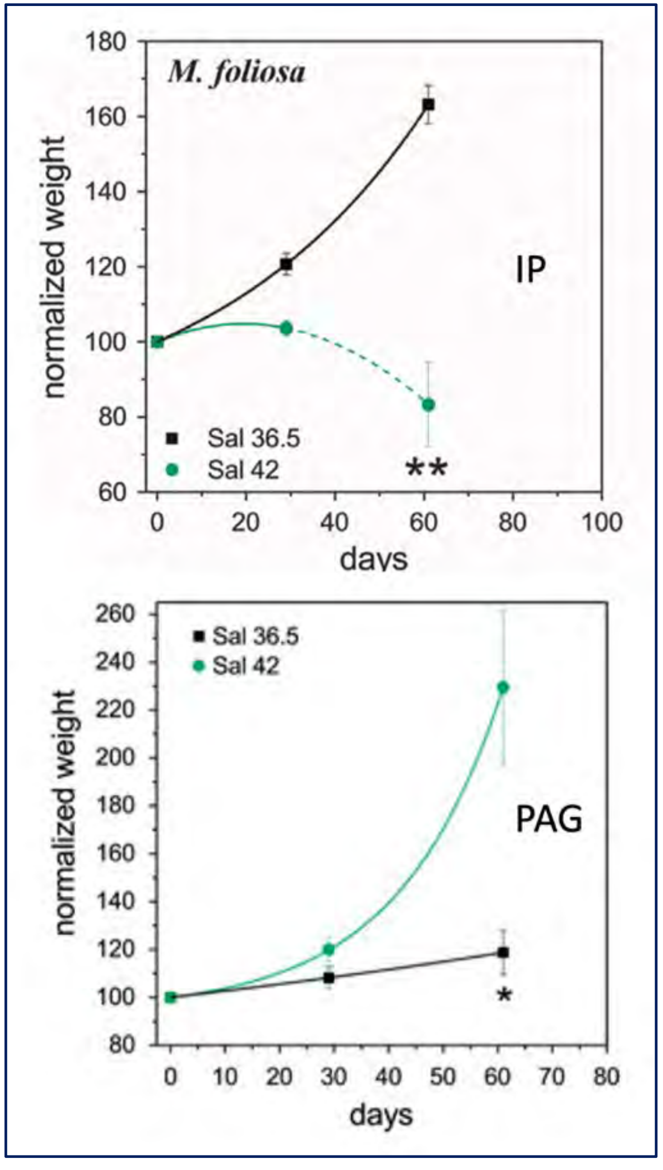


Figure from: D'Angelo, C., Hume, B., Burt, J., Smith, E., Achterberg, E., & Wiedenmann, J. (2015). Local adaptation constrains the distribution potential of heat-tolerant Symbiodinium from the Persian/Arabian Gulf. *The ISME Journal*, *9*(12), 2551-2560. doi: 10.1038/ismej.2015.80 CCBY4.0
Available:
https://www.researchgate.net/publication/277014470_Local_adaptation_constrains_the_distribution_potential_of_heattolerant_Symbiodinium_from_the_PersianArabian_Gulf



Questions

a. Compare the salinity tolerance of PAG corals and IP corals.

b. Infer the salinity of waters in the Persian Arabian Gulf.

c. Predict what may happen to the Great Barrier Reef if salinities significantly rise.

d. What is a limitation of this dataset and why may it have been unavoidable?

Figure from: D'Angelo, C., Hume, B., Burt, J., Smith, E., Achterberg, E., & Wiedenmann, J. (2015). Local adaptation constrains the distribution potential of heat-tolerant Symbiodinium from the Persian/Arabian Gulf. *The ISME Journal*, *9*(12), 2551-2560. doi: 10.1038/ismej.2015.80 CCBY4.0
Available:
https://www.researchgate.net/publication/277014470_Local_adaptation_constrains_the_distribution_potential_of_heattolerant_Symbiodinium_from_the_PersianArabian_Gulf

How did you go?

a. Compare the salinity tolerance of PAG corals and IP corals.
Ans: PAG corals grow better in 42 ppt, IP corals better in 36.5.

b. Infer the salinity of waters in the Persian Arabian Gulf.
Ans: 42ppt (not everywhere, but near the coast)

c. Predict what may happen to the Great Barrier Reef if salinities significantly rise.
Ans: *M foliosa* data suggests GBR corals won't grow. (the dotted green line denotes death of all replicates)

d. What is a limitation of this dataset? Why may it have been unavoidable?
Ans: The species were different- but the same species may not occur in both regions

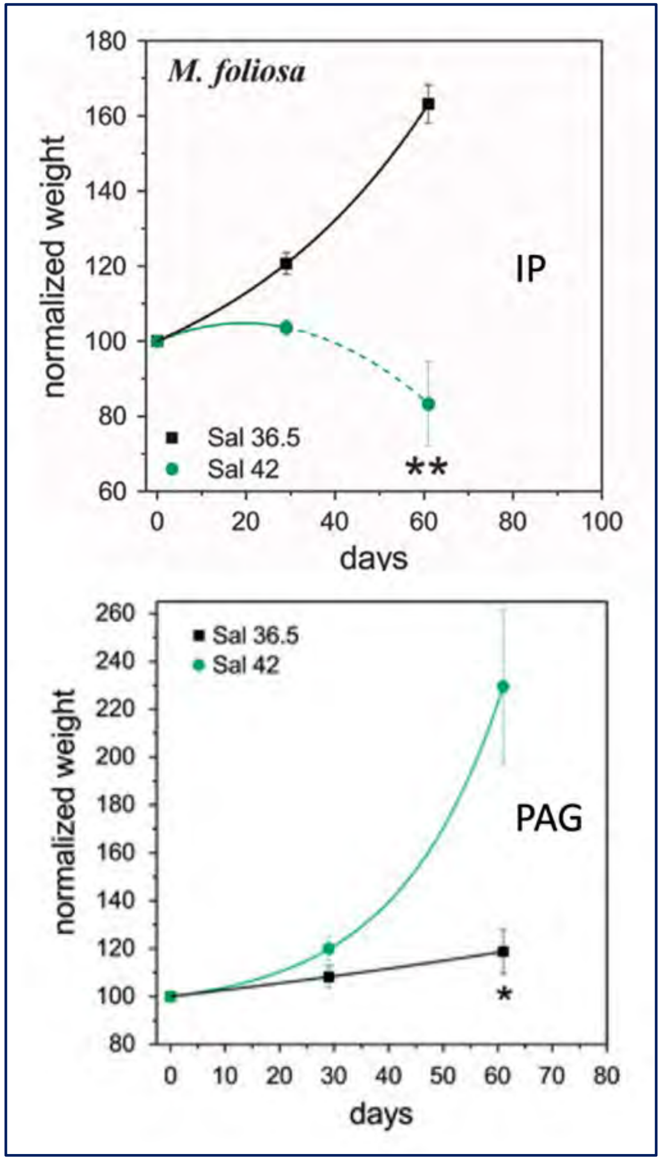


Figure from: D'Angelo, C., Hume, B., Burt, J., Smith, E., Achterberg, E., & Wiedenmann, J. (2015). Local adaptation constrains the distribution potential of heat-tolerant Symbiodinium from the Persian/Arabian Gulf. *The ISME Journal*, *9*(12), 2551-2560. doi: 10.1038/ismej.2015.80 CCBY4.0
Available:
https://www.researchgate.net/publication/277014470_Local_adaptation_constrains_the_distribution_potential_of_heattolerant_Symbiodinium_from_the_PersianArabian_Gulf

4. Temperature

Corals are affected by increased temperature and by how long they are exposed to those elevated temperatures.
This graph shows "Degree heating weeks" (DHW) for Lizard Island, during the bleaching events of 2016/2017.

Download your own data here:

https://coralreefwatch.noaa.gov/satellite/vs/index.php

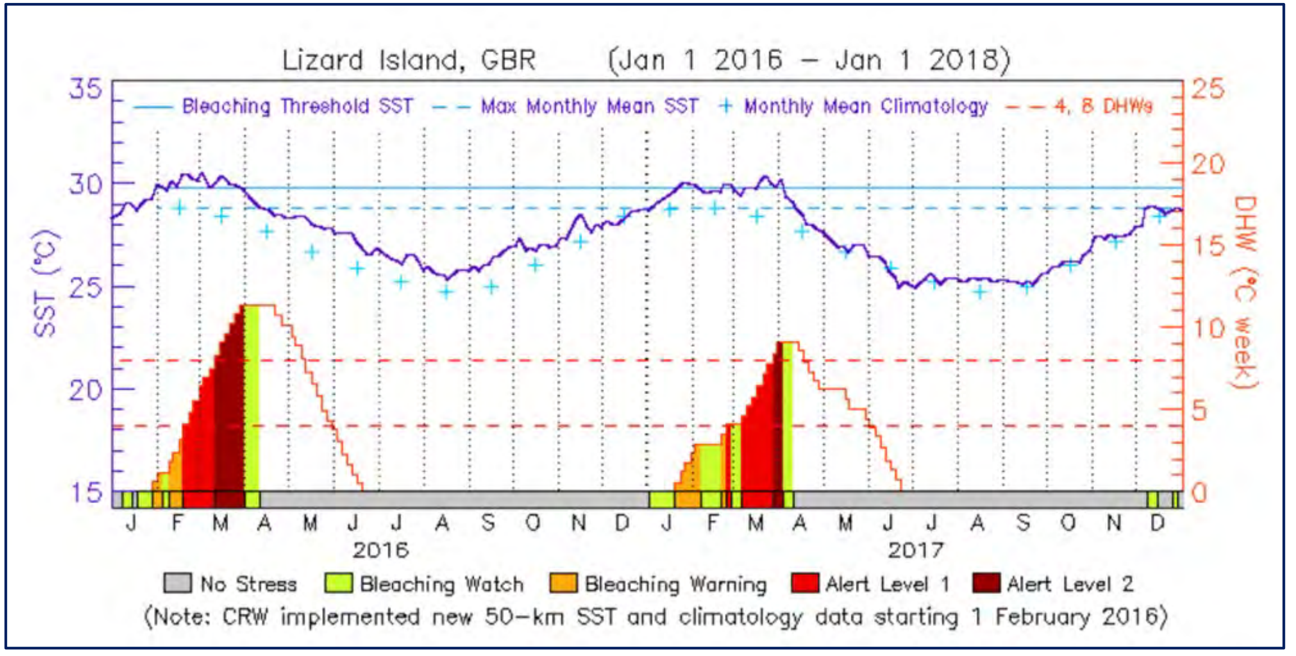


Image: NOAA Coral Reef Watch. 2000, updated twice-weekly. *NOAA Coral Reef Watch Operational 50-km Satellite Coral Bleaching Degree Heating Weeks Product*, Jan. 1, 2001-Dec. 31, 2010. Silver Spring, Maryland, USA: NOAA Coral Reef Watch. Data set accessed 03/03/2019 at https://coralreefwatch.noaa.gov/satellite/hdf/index.php.

Questions

a. What temperature is the bleaching threshold at Lizard island?

b. What is the pattern of Sea surface temperature over a calendar year?

c. Do the “bleaching watch” periods always coincide with high SST?

d. When do alert level 1 and 2 tend to occur?

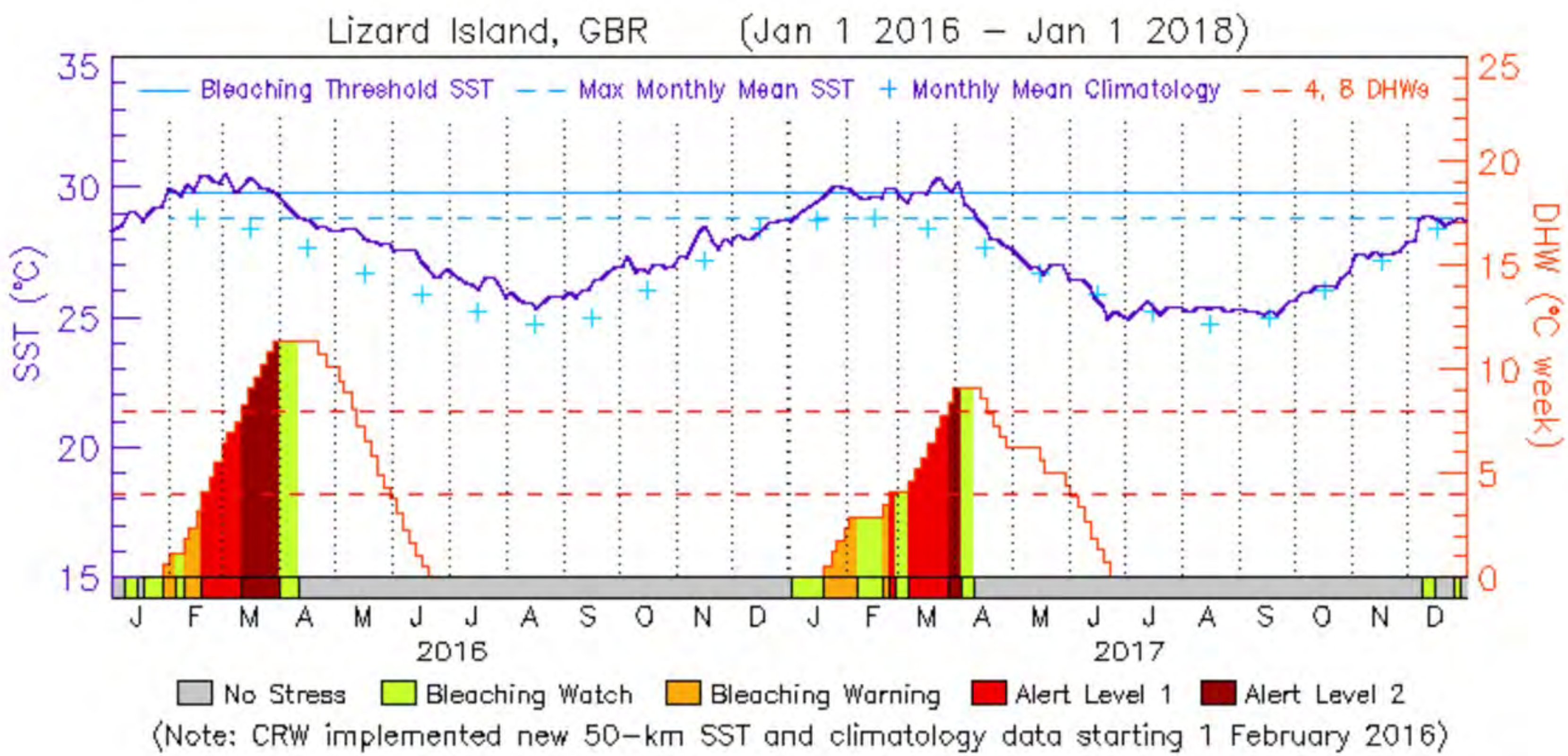


Image: NOAA Coral Reef Watch. 2000, updated twice-weekly. *NOAA Coral Reef Watch Operational 50-km Satellite Coral Bleaching Degree Heating Weeks Product*, Jan. 1, 2001-Dec. 31, 2010. Silver Spring, Maryland, USA: NOAA Coral Reef Watch. Data set accessed 03/03/2019 at https://coralreefwatch.noaa.gov/satellite/hdf/index.php.

How did you go?

a. What temperature is the bleaching threshold at Lizard island?

Ans: 30°C

b. What is the pattern of Sea surface temperature over a calendar year?

Ans: Higher in summer, less in winter, cyclical

c. Do the “bleaching watch” periods always coincide with high SST?

Ans: No - Eg April bleach watch- SST is below threshold

d. When do Alert level 1 And 2 tend to occur?

Ans: Alert 1- when SST reaches threshold, alert 2- when temp > threshold for some time

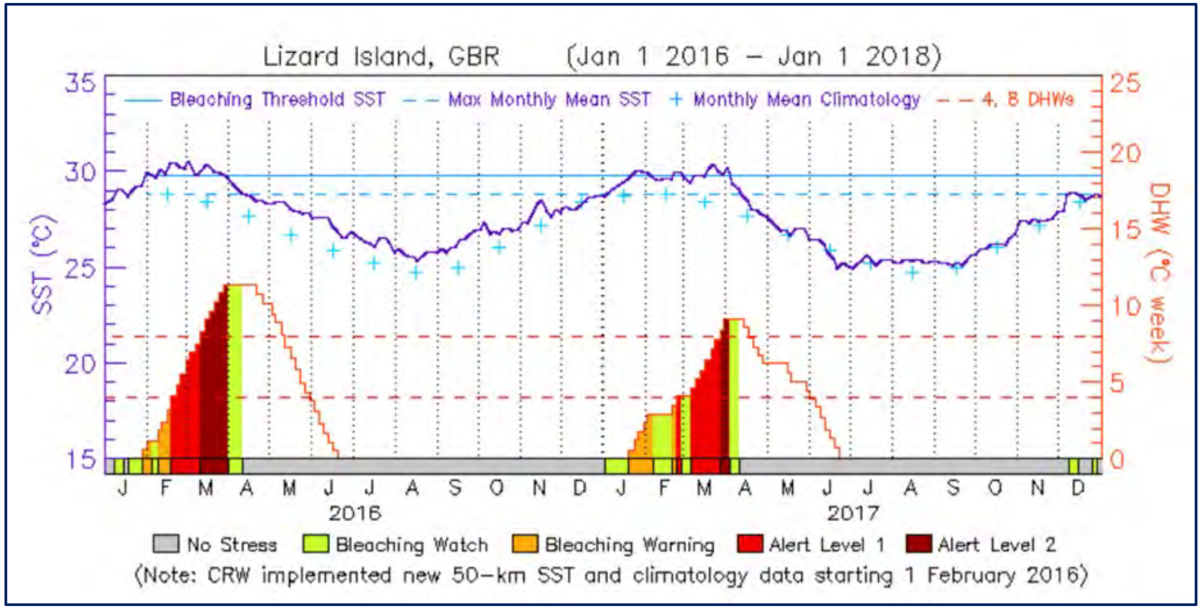


Image: NOAA Coral Reef Watch. 2000, updated twice-weekly. *NOAA Coral Reef Watch Operational 50-km Satellite Coral Bleaching Degree Heating Weeks Product*, Jan. 1, 2001-Dec. 31, 2010. Silver Spring, Maryland, USA: NOAA Coral Reef Watch. Data set accessed 03/03/2019 at https://coralreefwatch.noaa.gov/satellite/hdf/index.php.

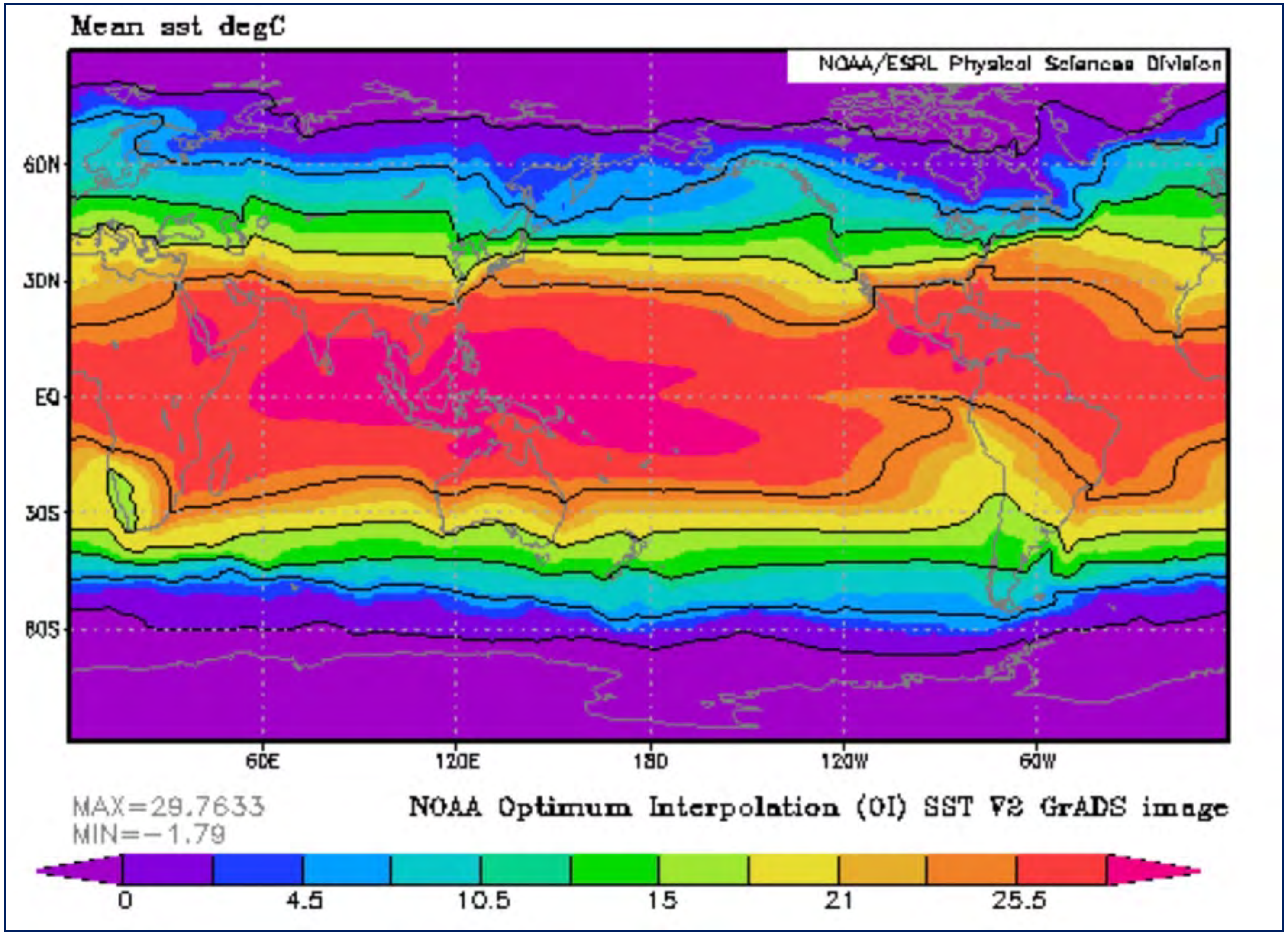
Activity

This is the monthly mean sea surface temperature *(SST)* from 1981- 2019.

A. Generate your own map here:

https://www.esrl.noaa.gov/psd/cgi-bin/db_search/DBSearch.pl?Dataset=NOAA+Optimum+Interpolation+(OI)+SST+V2&Variable=Sea+Surface+Temperature

B. Compare SST with the distribution of coral reefs on the next slide



COBE-SST2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at https://www.esrl.noaa.gov/psd/

Now study the distribution of reef building corals in the illustration below.

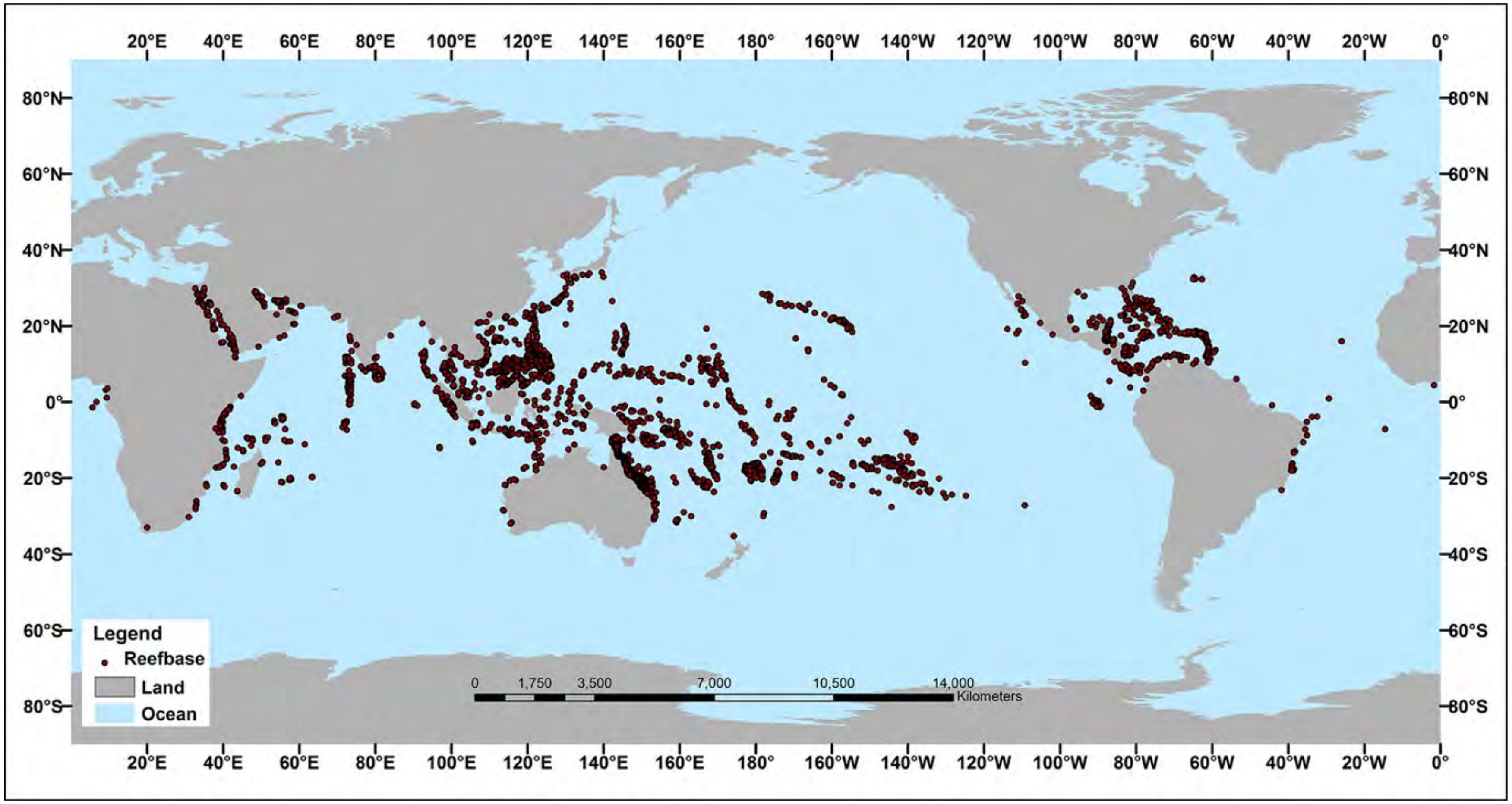


Image: NOAA National Ocean Service. https://oceanservice.noaa.gov/education/tutorial_corals/media/coral05a_480.jpg

Now compare SST with the distribution of coral reefs.

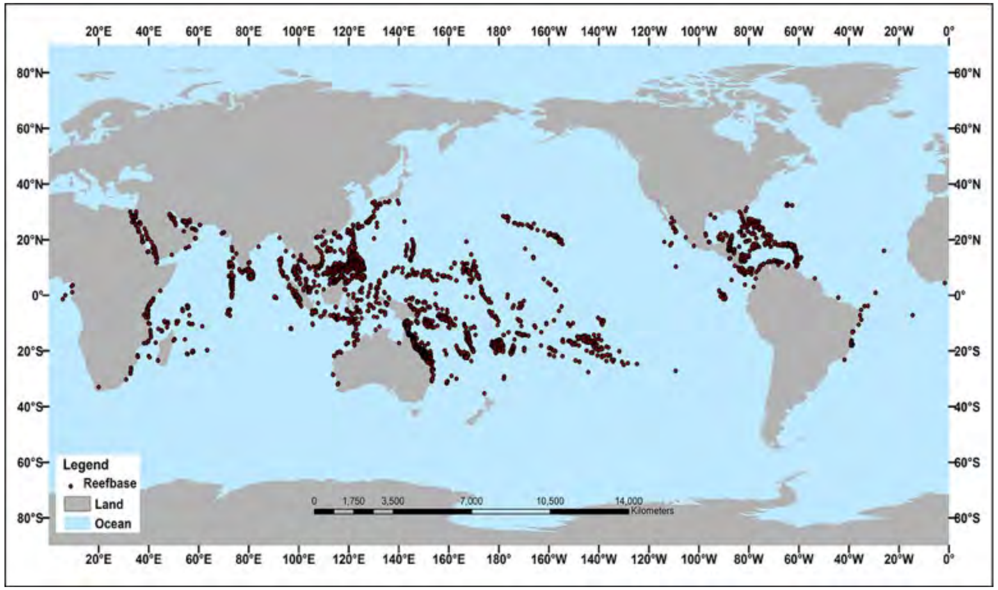
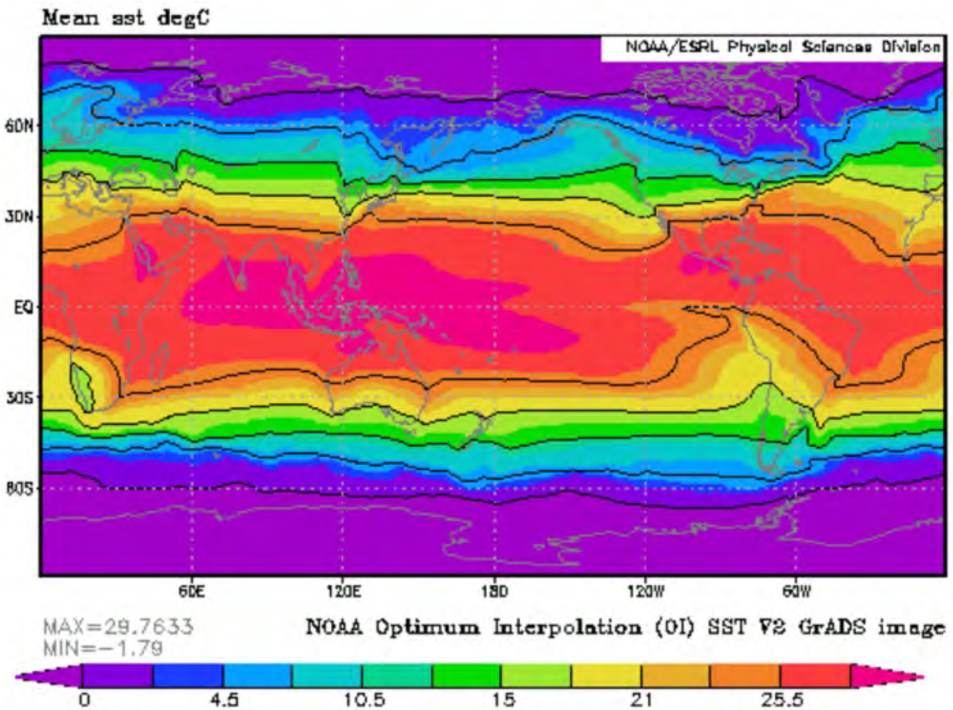


Image: NOAA National Ocean Service.
https://oceanservice.noaa.gov/education/tutorial_corals/media/coral05a_480.jpg



COBE-SST2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at https://www.esrl.noaa.gov/psd/

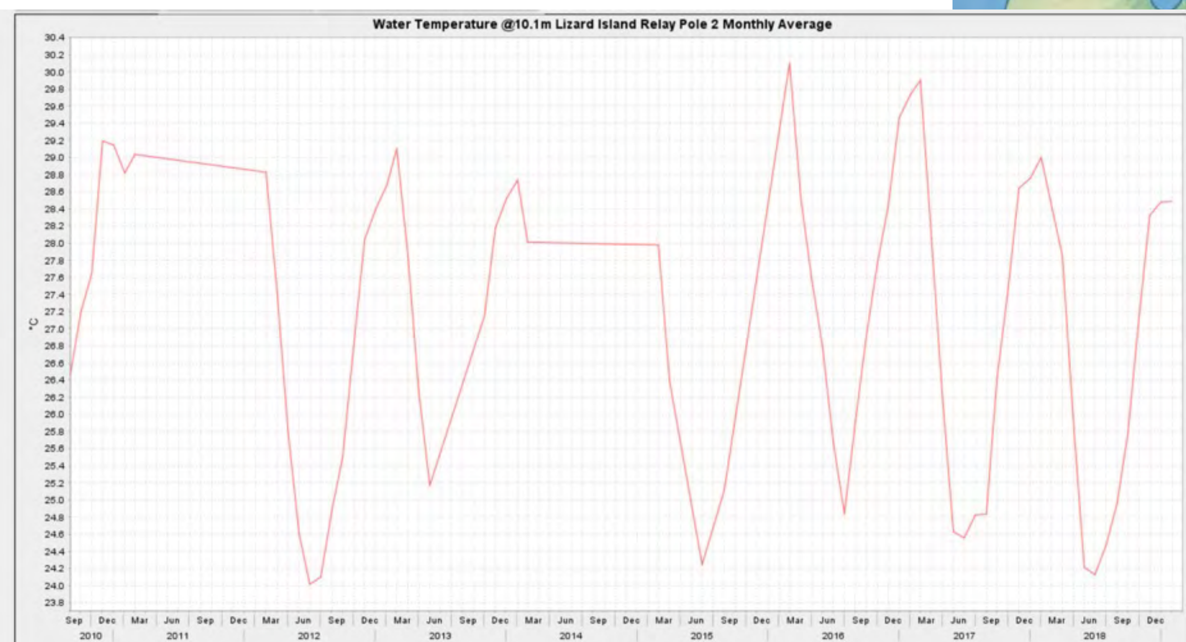
Can you see that

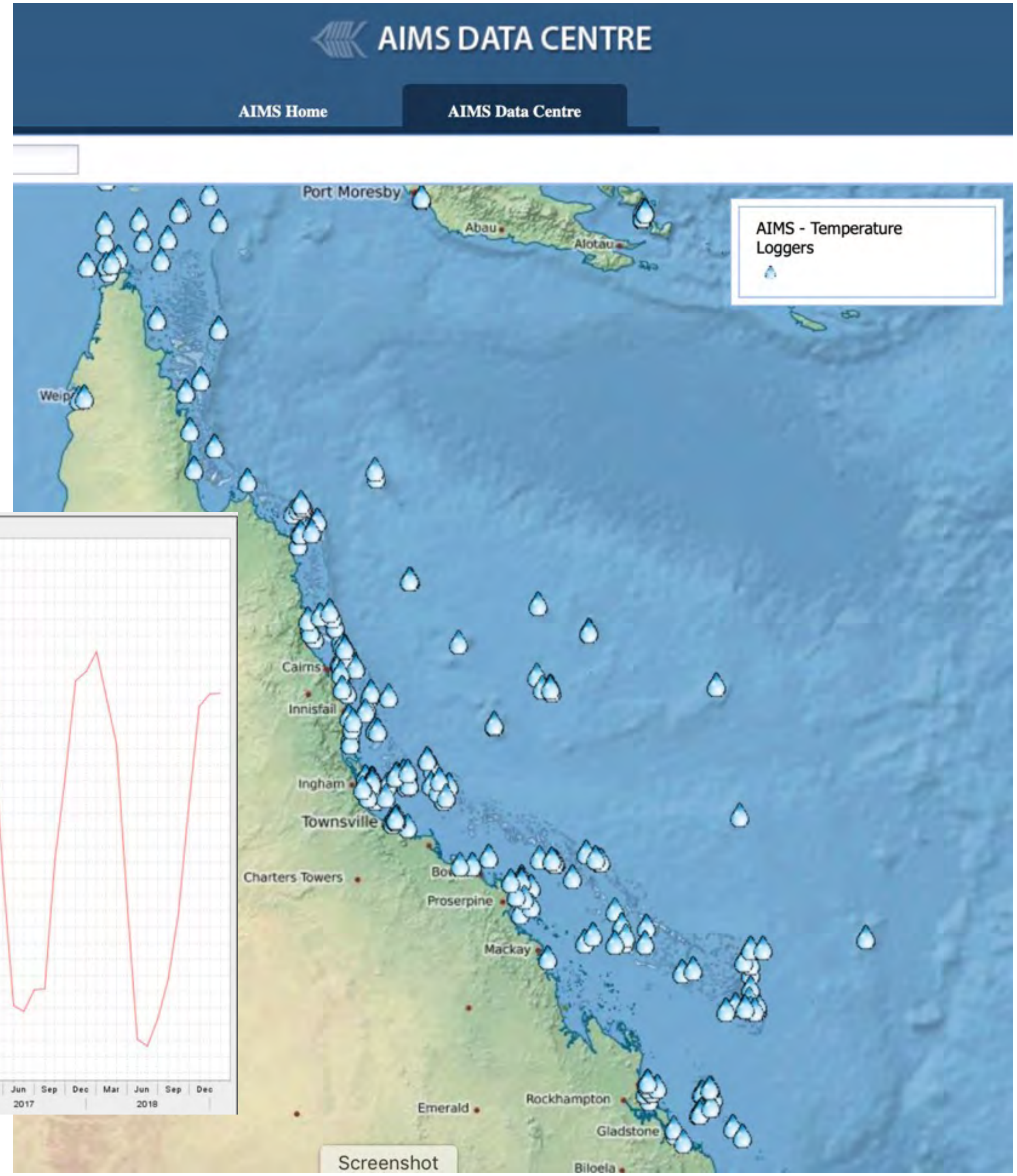
Reef building corals occur between 30°N and 30°S, which is the same as the distribution of pink and red on the graph, depicting water with temperature 25.5°C or more.

Significance- most corals occur in warm tropical waters

You can download temperature data from over 100 sites at the AIMS Data Centre: https://www.aims.gov.au/docs/data/data.html

Below is the data from the temperature logger at Lizard Island





Source: Australian Institute of Marine Science

5. Substrate and sediment

This image is from a NASA satellite shows a 12 km wide plume of sediment-laden water reaching out to the outer Great Barrier reef.

Image: NASA Earth Observatory. Wiki commons CC 4.0 BY

These flood plumes carry sediment and nutrients into the usually clear offshore waters.

The Australian Institute of Marine Science and CRC Reef synthesized research into the impacts of terrestrial runoff.

This article can be downloaded using the link below.

Flood plume

Image: C. Honchin. Copyright Commonwealth of Australia (GBRMPA) 134464

Link to online paper:
https://www.researchgate.net/publication/7997270_Effects_of_terrestrial_runoff_on_the_ecology_of_corals_and_coral_reefs_Review_and_synthesis

The direct effects of runoff on coral growth and survival are shown in this table:

	Dissolved Inorganic Nitrogen	Dissolved Inorganic Phosphate	Particulate organic matter	Light reduction	Sedimentation
Calcification	↓	↓	↑	⬇	⬇
Tissue thickness	-	-	🡑	🡓	⬇
Zooxanthellae density	⬆	-	↑	↑	🡓
Photosynthesis	🡑	🡑	🡑	⬇	⬇
Adult colony survival	-	-	🡑	🡓	⬇

Heavy arrow = strong effect

Medium arrow = moderate effect

Light arrows = weak effect

Data from : Fabricius, K. (2005). Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. *Marine Pollution Bulletin*, *50*(2), 125-146. doi: 10.1016/j.marpolbul.2004.11.028

Questions

a. What is the impact of sedimentation of coral growth and survival?

b. Why do the dissolved nutrients cause an increase in photosynthesis?

c. Why does zooxanthellae density increase with reduced light?

How did you go?

a. What is the impact of sedimentation of coral growth and survival?

Ans: Negative: less calcification, tissue thickness, zooxanthellae density, photosynthesis and survival

b. Why do the dissolved nutrients cause an increase in photosynthesis?

Ans: N & P are plant nutrients, so promote plant growth and photosynthesis

c. Why does zooxanthellae density increase with reduced light?

Ans: Coral may recruit more zooxanthellae to maintain energy production

	Dissolved Inorganic Nitrogen	Dissolved Inorganic Phosphate	Particulate organic matter	Light reduction	Sedimentation
Calcification	↓	↓	↑	↓	↓
Tissue thickness	-	-	↑	↓	↓
Zooxanthellae density	↑	-	↑	↑	↓
Photosynthesis	↑	↑	↑	↓	↓
Adult colony survival	-	-	↑	↓	↓

Data from : Fabricius, K. (2005). Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. *Marine Pollution Bulletin*, *50*(2), 125-146. doi: 10.1016/j.marpolbul.2004.11.028

The effects of runoff on coral reproduction are shown below:

	Dissolved inorganic nutrients	Particulate organic matter	Light reduction	Sedimentation
Fecundity	↓		↓	↓
Fertilisation	**↓**	↓	-	-
Embryo dev't/ Larval survival	**↓**	↓	-	-
Settlement/ metamorphosis	↓	↓	**↓**	**↓**
Recruit survival			↓	**↓**
Juvenile growth/ survival			↓	↓

Data from : Fabricius, K. (2005). Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. *Marine Pollution Bulletin*, *50*(2), 125-146. doi: 10.1016/j.marpolbul.2004.11.028

Questions

a. Explain the trends shown in this table.

b. Are there any positive effects of runoff on coral reproduction?

How did you go?

a. Explain the trends shown in this table.

Ans: All the effects of runoff (DIN, POM, LR and S) have a negative impact on coral reproduction.

b. Are there any positive effects of runoff on coral reproduction?

Ans: None

	Dissolved inorganic nutrients	Particulate organic matter	Light reduction	Sedimentation
Fecundity	↓		↓	↓
Fertilisation	**↓**	↓	-	-
Embryo dev't/ Larval survival	**↓**	↓	-	-
Settlement/ metamorphosis	↓	↓	**↓**	**↓**
Recruit survival			↓	**↓**
Juvenile growth/ survival			↓	↓

Data from : Fabricius, K. (2005). Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. *Marine Pollution Bulletin*, *50*(2), 125-146. doi: 10.1016/j.marpolbul.2004.11.028

This table shows the effect of runoff on factors that affect coral cover

	Dissolved Inorganic nutrients	Particulate organic matter	Light reduction	Sedimentation
Coralline algae	↓			⬇
Bioeroders	↑	⬆		↓
Macroalgae	⬆	↑	⬇	↓
Filter feeders		⬆	⬆	↓
Coral diseases	↑			↑
Coral predators		⬆		

Data from : Fabricius, K. (2005). Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. *Marine Pollution Bulletin*, *50*(2), 125-146. doi: 10.1016/j.marpolbul.2004.11.028

Questions

a. Identify the impact sedimentation would have on coralline algae.

b. Infer what the impact on coralline algae (from part a) would have on the reef.

How did you go?

a. Identify the impact sedimentation would have on coralline algae.
Ans: Sedimentation reduces the amount of coralline algae

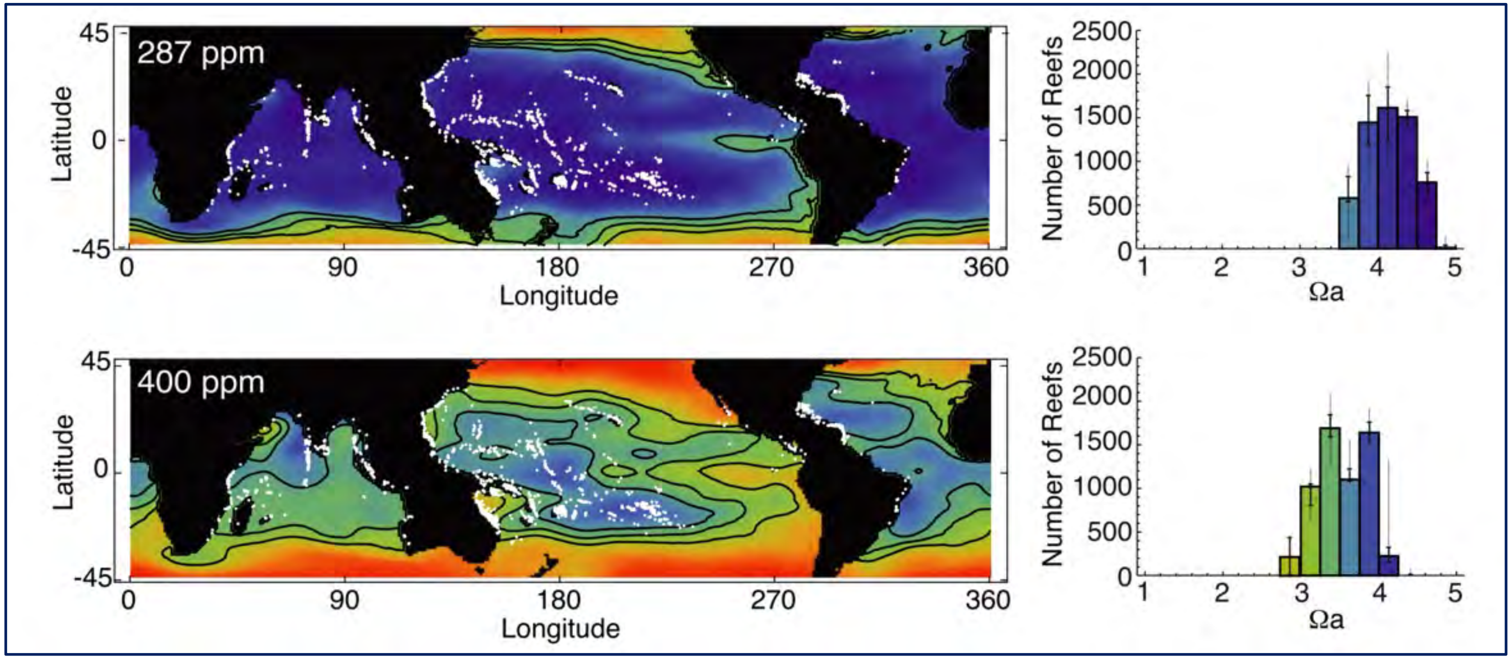
b. Infer what the impact on coralline algae (from part a) would have on the reef.
Ans: Coralline algae bind the reef together, and is a cue for settlement, so the reduction in coralline algae will reduce reef strength and larval recruitment.

	Dissolved Inorganic nutrients	Particulate organic matter	Light reduction	Sedimentation
Coralline algae	↓			⬇
Bioeroders	↑	⬆		↓
Macroalgae	⬆	↑	⬇	↓
Filter feeders		⬆	⬆	↓
Coral diseases	↑			↑
Coral predators		⬆		

Data from : Fabricius, K. (2005). Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. *Marine Pollution Bulletin*, *50*(2), 125-146. doi: 10.1016/j.marpolbul.2004.11.028

6. Seawater carbonate chemistry (aragonite)

These maps show simulations of the Aragonite saturation (Ω_{arag}) in 1860 and current day. Atmospheric CO_2 concentrations are shown in the top left corner. The histograms show Ω_{arag} of the seawater surrounding coral reefs.



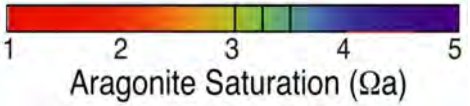


Figure from Open Access article : Ricke, K., Orr, J., Schneider, K., & Caldeira, K. (2013). Risks to coral reefs from ocean carbonate chemistry changes in recent earth system model projections. *Environmental Research Letters*, *8*(3), 034003. doi: 10.1088/1748-9326/8/3/034003

Questions

a. Describe the trend in Ω_{arag} in 1860, moving away from the equator.

b. Contrast the Ω_{arag} in 1860 and current day

How did you go?

a. Describe the trend in Ω_{arag} in 1860, moving away from the equator.

Ans: Ω_{arag} remains above 4 past latitude 30, falling to 3 near the poles.

b. Contrast the Ω_{arag} in 1860 and current day

Ans: Ω_{arag} is lower over most of the Oceans, 3-4 near the Equator, less than 2 near the poles.

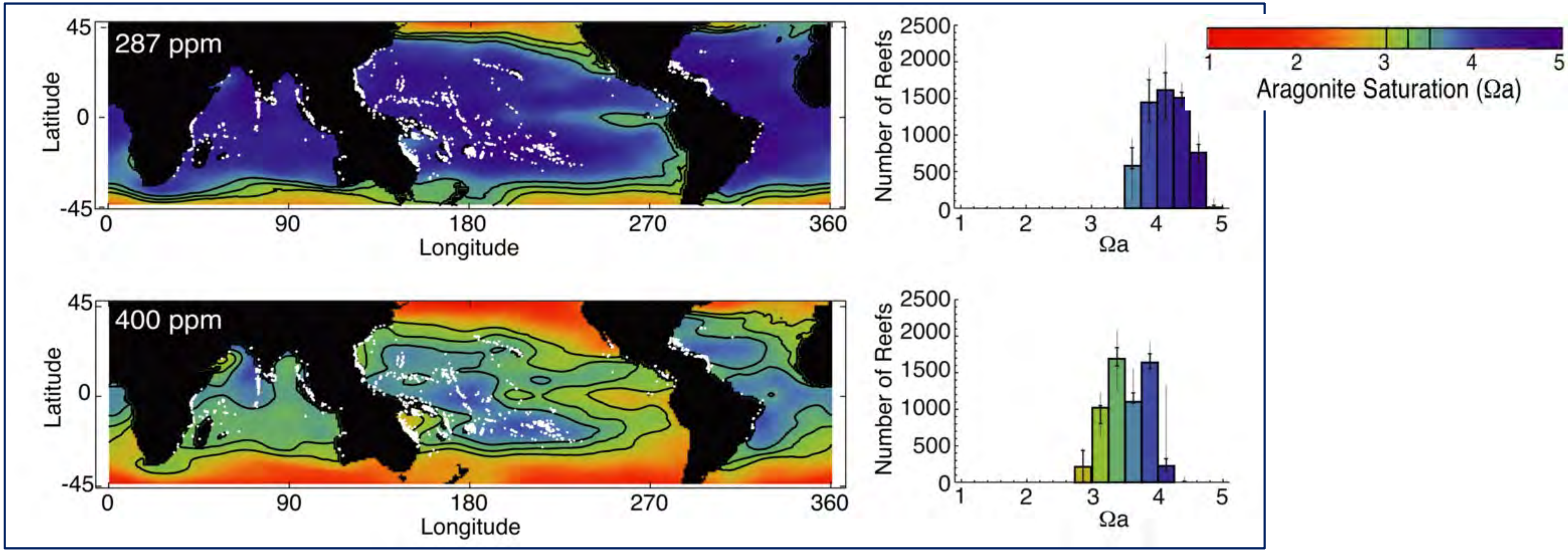


Figure from Open Access article : Ricke, K., Orr, J., Schneider, K., & Caldeira, K. (2013). Risks to coral reefs from ocean carbonate chemistry changes in recent earth system model projections. *Environmental Research Letters*, *8*(3), 034003. doi: 10.1088/1748-9326/8/3/034003

These maps show Ω_{arag} projections into the future with [CO2] 550 and 900ppm.

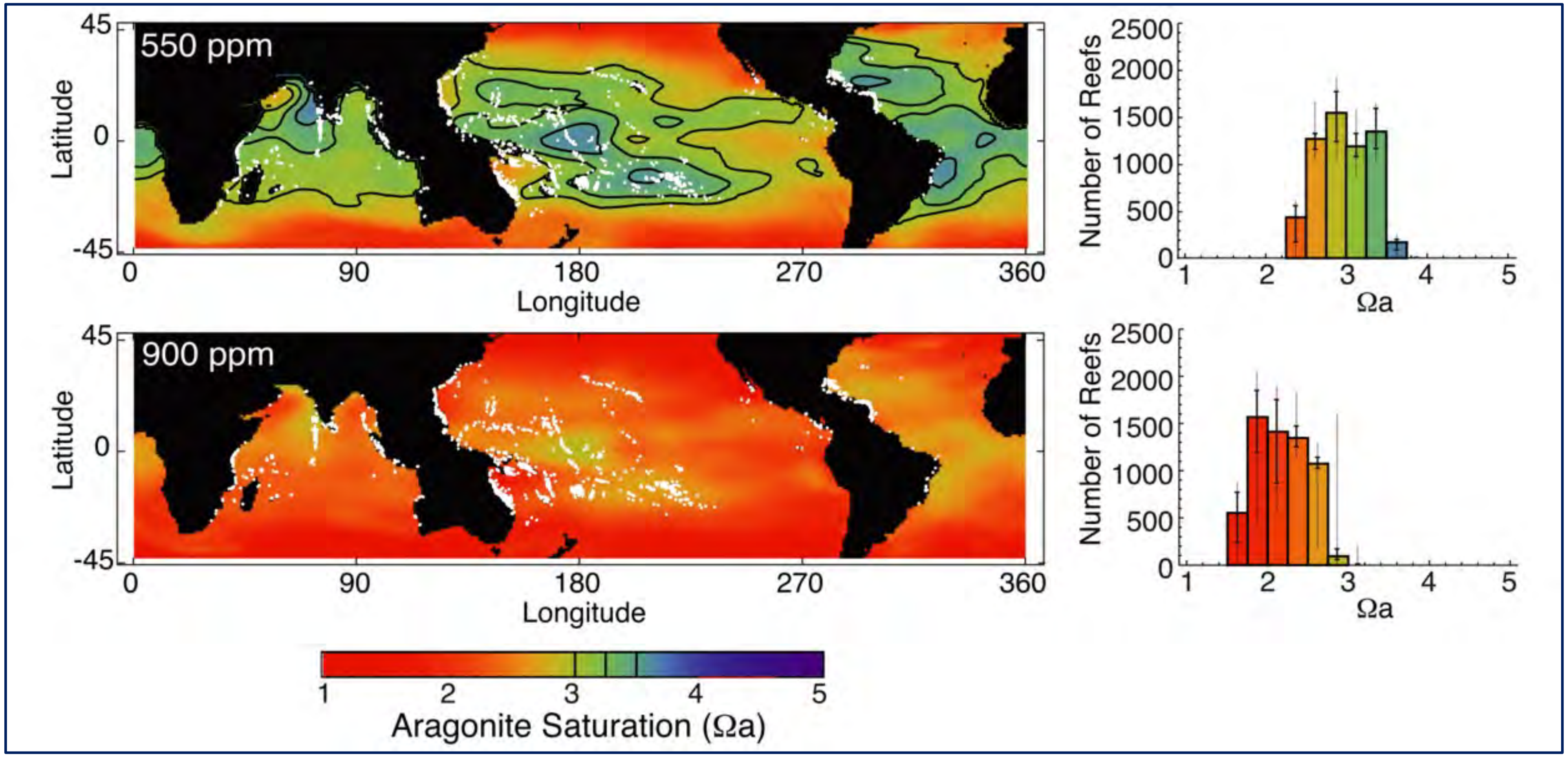


Figure from Open Access article : Ricke, K., Orr, J., Schneider, K., & Caldeira, K. (2013). Risks to coral reefs from ocean carbonate chemistry changes in recent earth system model projections. *Environmental Research Letters*, *8*(3), 034003. doi: 10.1088/1748-9326/8/3/034003

Questions

a. Describe the trend in average Ω_{arag} over time.

b. Compare Ω_{arag} over all 4 graphs.

c. Infer the effect of 900ppm [CO_2] on calcification rates of corals.

How did you go?

a. Describe the trend in average Ω_{arag} over time.

Ans: The Ω_{arag} is reducing across all the Oceans.

b. Compare Ω_{arag} over all 4 graphs.

Ans: The Ω_{arag} near the equator is dropping, and the low Ω_{arag} regions are spreading.

c. Infer the effect of 900ppm [CO2] on calcification rates of corals.

Ans: Calcification will be reduced due to lower Ω_{arag}

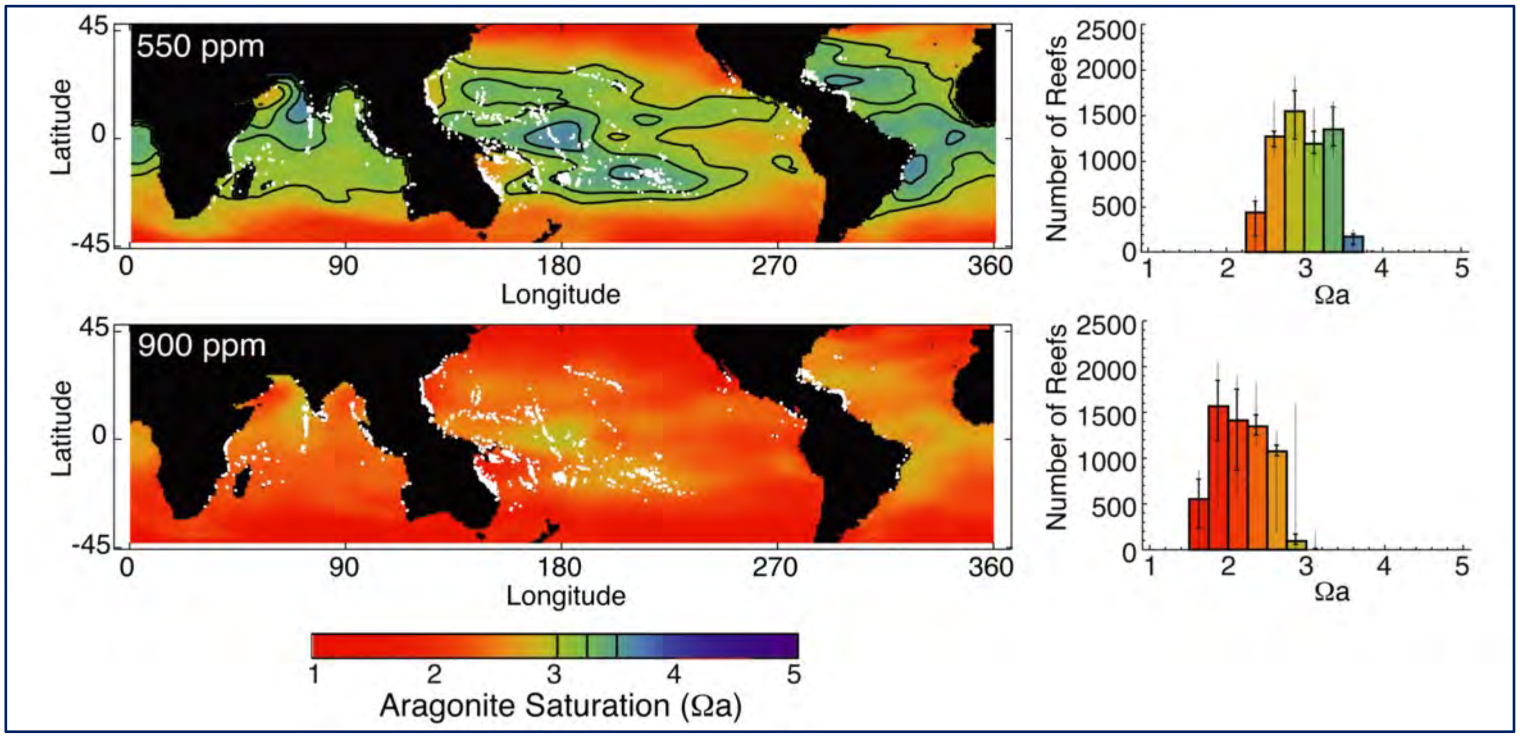
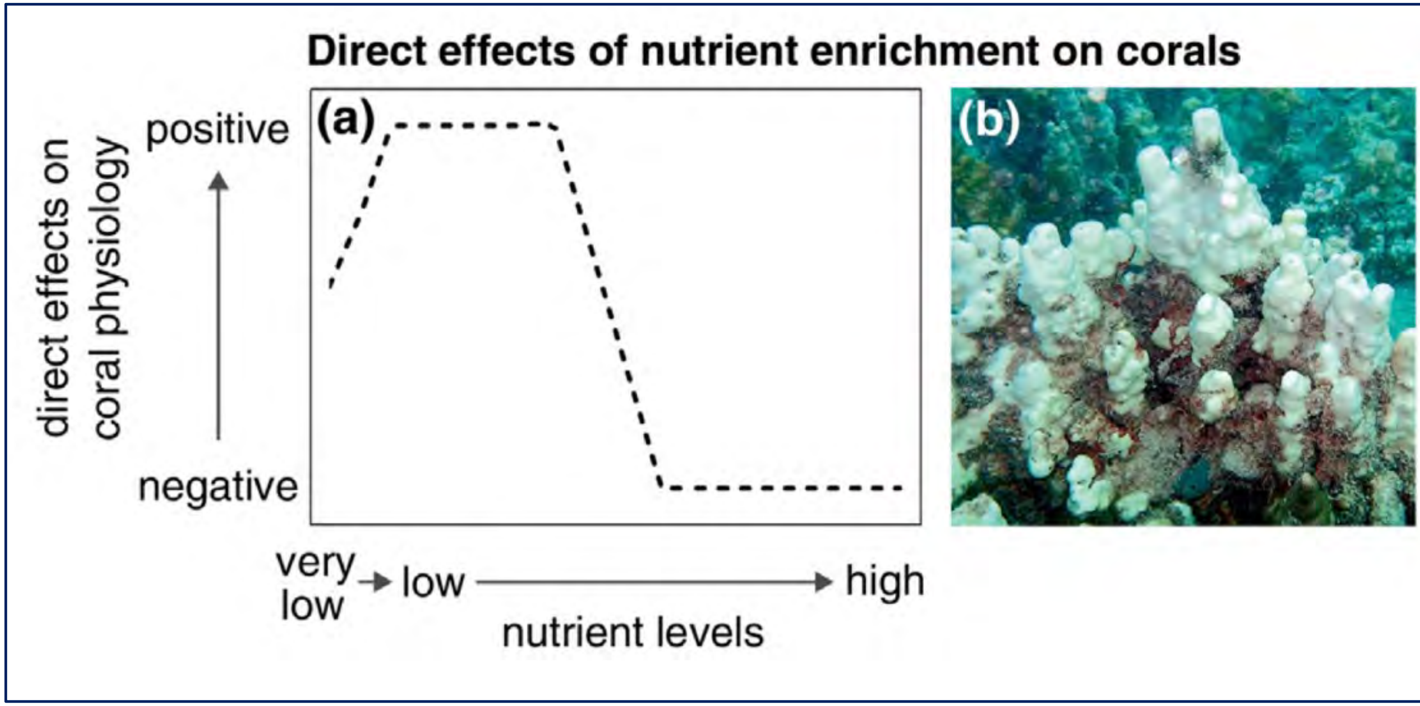


Figure from Open Access article : Ricke, K., Orr, J., Schneider, K., & Caldeira, K. (2013). Risks to coral reefs from ocean carbonate chemistry changes in recent earth system model projections. *Environmental Research Letters*, *8*(3), 034003. doi: 10.1088/1748-9326/8/3/034003

7. Nutrients (nitrates and phosphates)

Small increases in nutrient levels can be beneficial for corals, however large increases cause reduced reproductive success, calcification rates, and increased susceptibility to heat stress.



(b) Shows a coral bleaching in response to heat stress

Figure from: D'Angelo, C., & Wiedenmann, J. (2014). Impacts of nutrient enrichment on coral reefs: new perspectives and implications for coastal management and reef survival. *Current Opinion In Environmental Sustainability*, *7*, 82-93. doi: 10.1016/j.cosust.2013.11.029 Open access CCBY

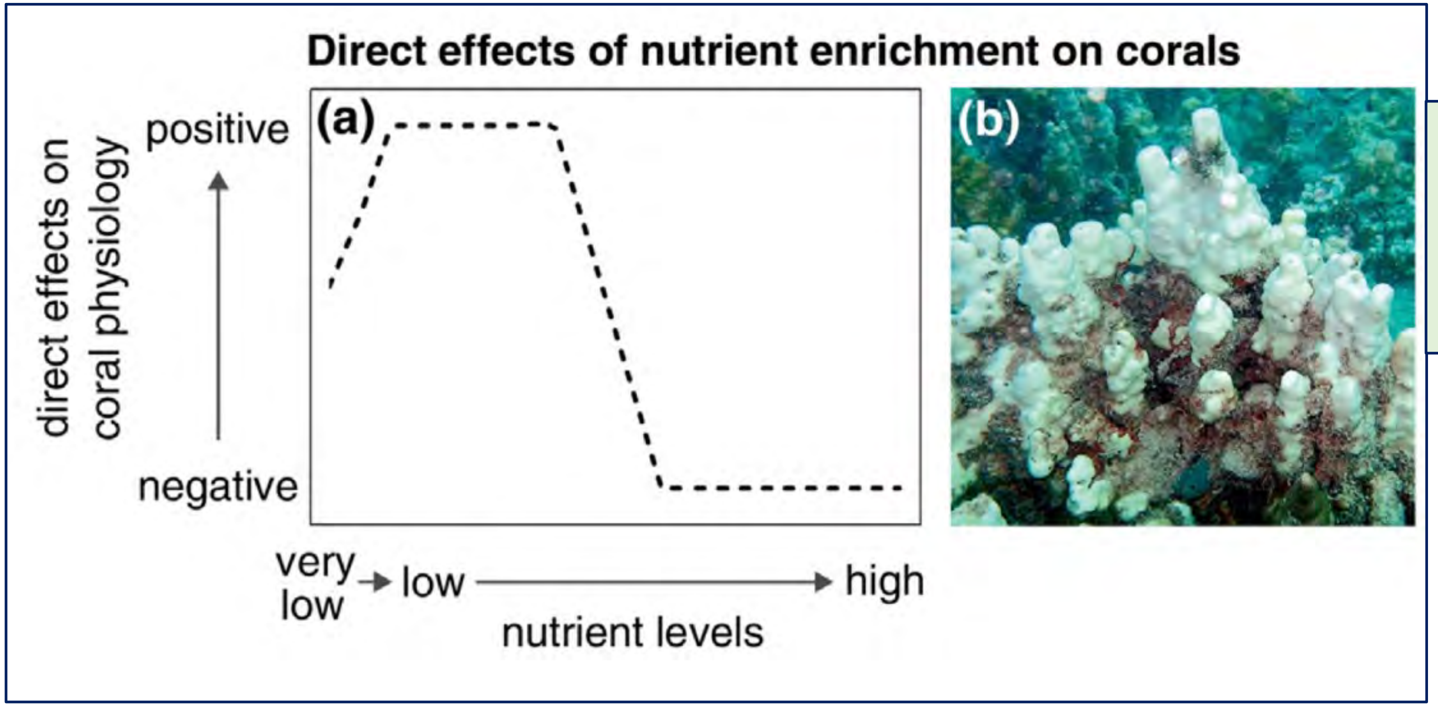
Question

Identify the relationship between nutrient levels and coral health shown in the graph.

How did you go?

Identify the relationship between nutrient levels and coral health shown in the graph.

Ans: A low level of nutrients has a slight positive direct effect on coral physiology, but nutrient levels that are too high have a rapid, strong negative direct effect

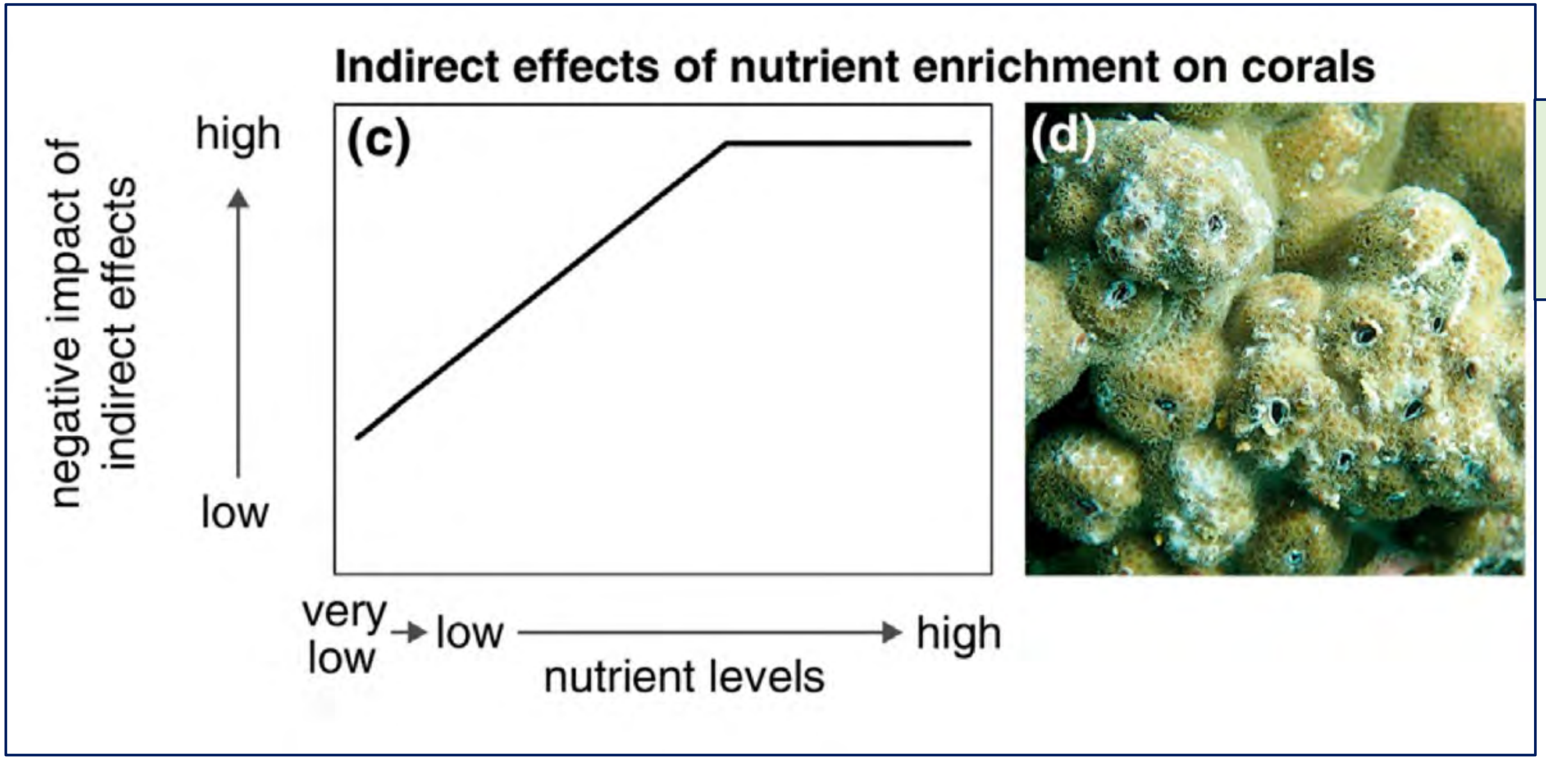


(b) Shows a coral bleaching in response to heat stress

Figure from: D'Angelo, C., & Wiedenmann, J. (2014). Impacts of nutrient enrichment on coral reefs: new perspectives and implications for coastal management and reef survival. *Current Opinion In Environmental Sustainability*, *7*, 82-93. doi: 10.1016/j.cosust.2013.11.029 Open access CCBY

Nutrients also have indirect effects on coral reefs.

Increased levels of ammonium and phosphate trigger phytoplankton blooms, which in turn , improve the survival of Crown of Thorns starfish (COTS), which are a major threat to coral reefs. Nutrients stimulate growth of macroalgae and filter feeders and bioeroders.



(d) Shows increased bioeroders in response to increased nutrient levels.

Figure from: D'Angelo, C., & Wiedenmann, J. (2014). Impacts of nutrient enrichment on coral reefs: new perspectives and implications for coastal management and reef survival. *Current Opinion In Environmental Sustainability*, *7*, 82-93. doi: 10.1016/j.cosust.2013.11.029 Open access CCBY

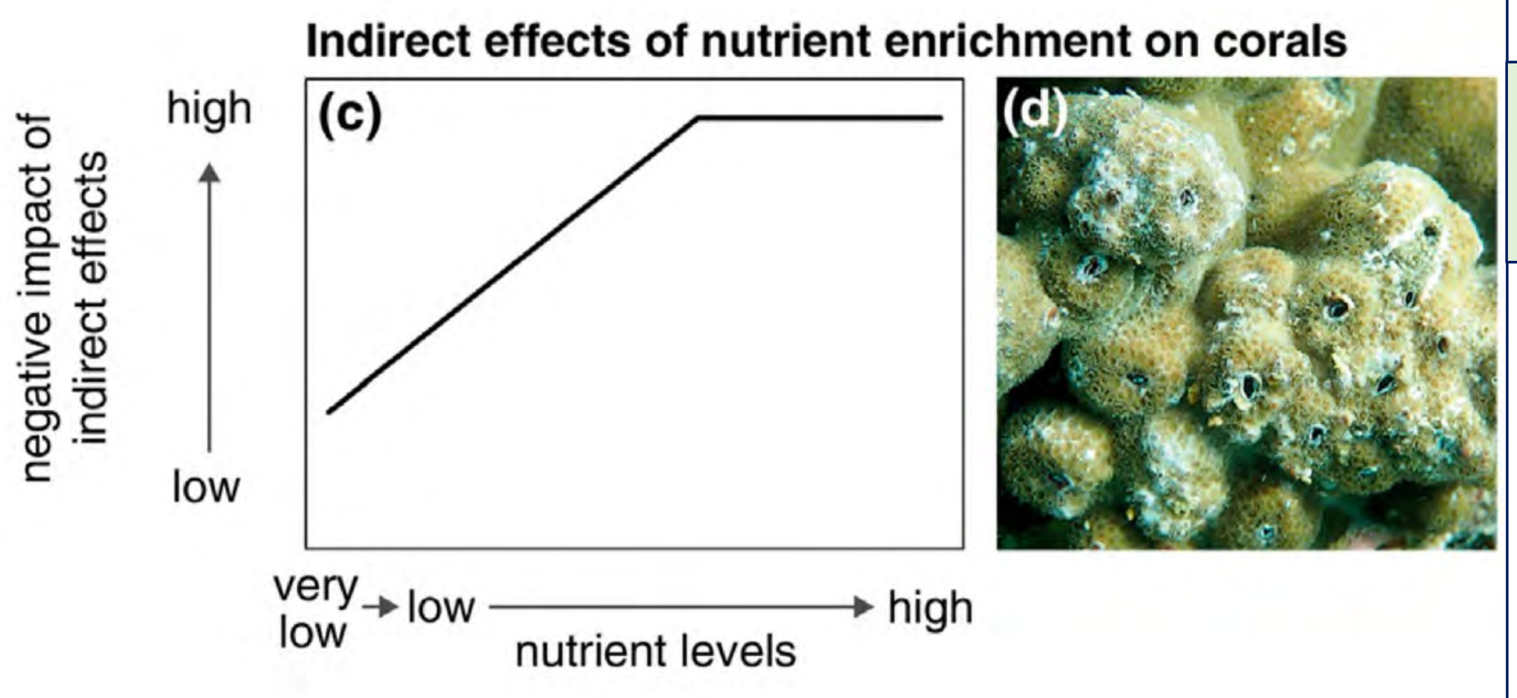
Question

Identify the relationship between nutrient levels and coral health shown in the graph.

How did you go?

Identify the relationship between nutrient levels and coral health shown in the graph.

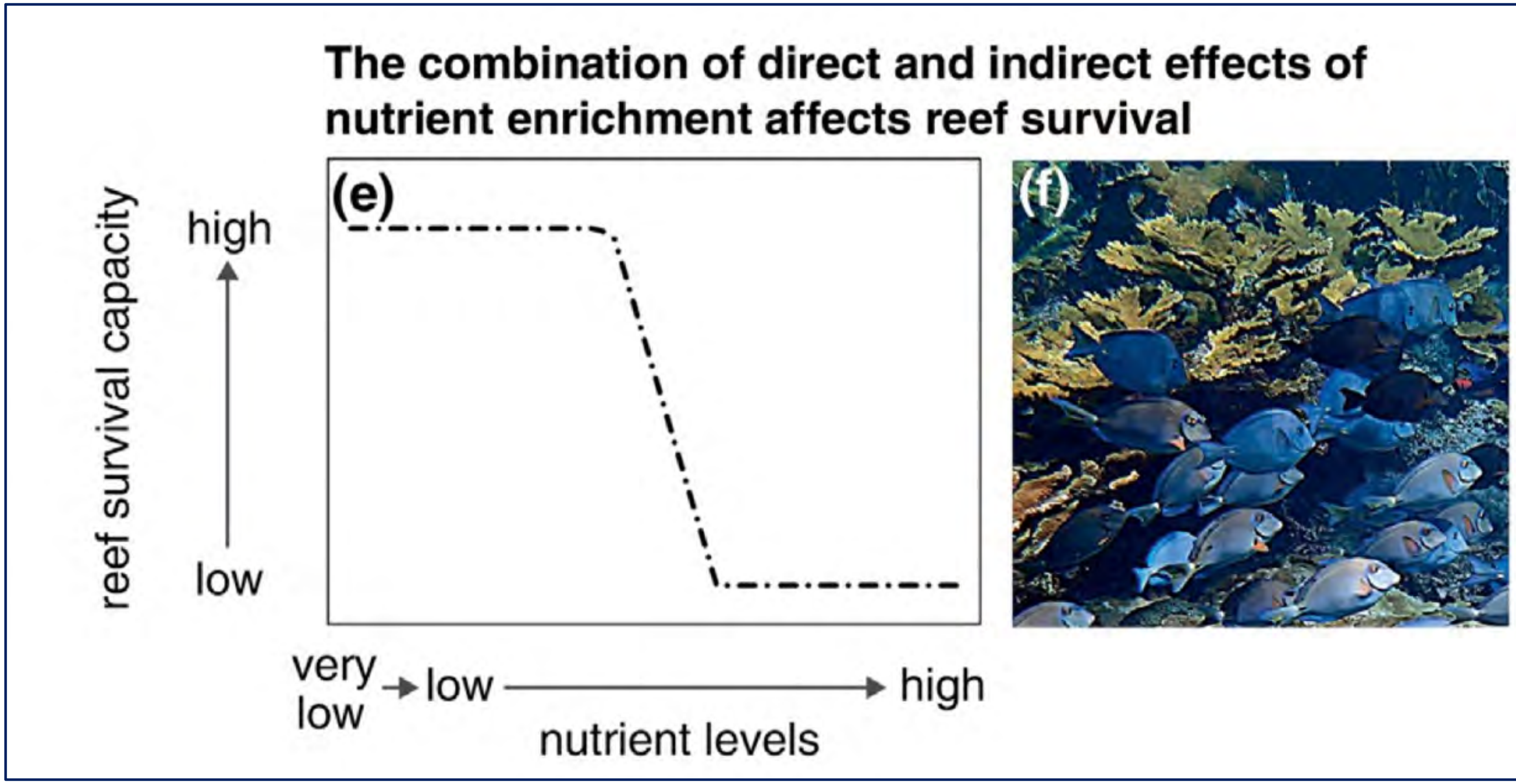
Ans: Very low nutrient have little negative impact on corals.
The indirect negative impact increases steadily as nutrient levels increase to a medium level, where they have a high impact.



(d) Shows increased bioeroders in response to increased nutrient levels.

Figure from: D'Angelo, C., & Wiedenmann, J. (2014). Impacts of nutrient enrichment on coral reefs: new perspectives and implications for coastal management and reef survival. *Current Opinion In Environmental Sustainability*, *7*, 82-93. doi: 10.1016/j.cosust.2013.11.029

Excess nutrients are negative for coral physiological performance and ecosystem functioning. The balance of direct and indirect effects determine reef resilience and survival.



(f) Herbivorous fish on a healthy reef could reduce algal competition caused by elevated nutrients

Figure from: D'Angelo, C., & Wiedenmann, J. (2014). Impacts of nutrient enrichment on coral reefs: new perspectives and implications for coastal management and reef survival. *Current Opinion In Environmental Sustainability*, *7*, 82-93. doi: 10.1016/j.cosust.2013.11.029 Open access CCBY

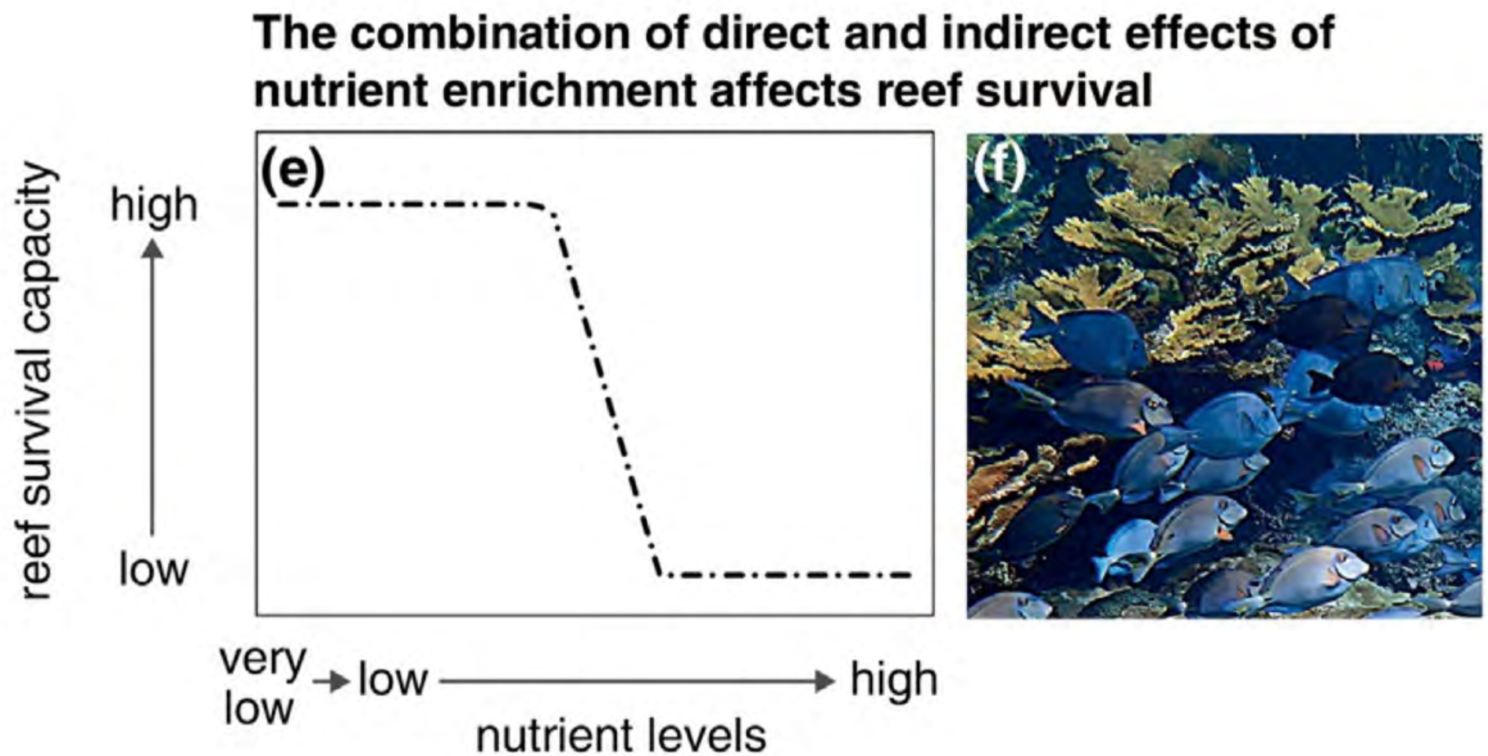
Question

Identify the relationship between nutrient levels and reef survival capacity (e)

How did you go?

Identify the relationship between nutrient levels and reef survival capacity (c ??e).

Ans: Reef survival capacity remains high (on a healthy reef) when nutrient levels increase to medium levels, but when nutrient levels become high reef survival capacity decreases rapidly.



(f) Herbivorous fish on a healthy reef could reduce algal competition caused by elevated nutrients

Figure from: D'Angelo, C., & Wiedenmann, J. (2014). Impacts of nutrient enrichment on coral reefs: new perspectives and implications for coastal management and reef survival. *Current Opinion In Environmental Sustainability*, *7*, 82-93. doi: 10.1016/j.cosust.2013.11.029 Open access CCBY

8. Exposure, waves, tides and storms

Cyclone Yasi crossed the Great Barrier reef in 2011, damaging 15% of the total reef area of the GBR.

https://earthobservatory.nasa.gov/images/49074/tropical-cyclone-yasi

This graph shows the proportion and damage levels of reefs in the path of Cyclone Yasi.

Question

At point A in the illustration opposite, determine the % and number of undamaged (green) and damaged (black) level 5 corals at point A.

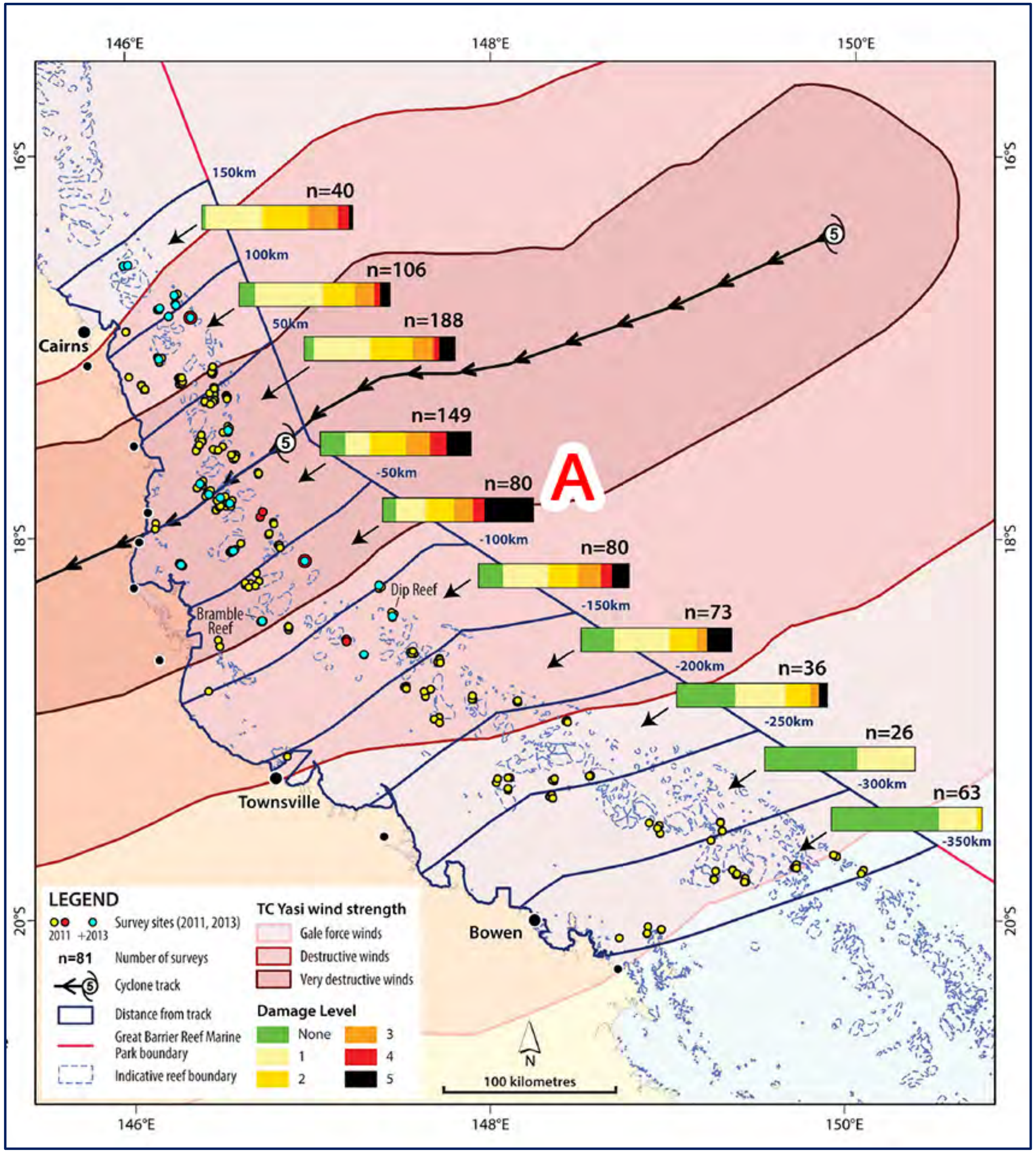


Image from: Beeden, R., Maynard, J., Puotinen, M., Marshall, P., Dryden, J., Goldberg, J., & Williams, G. (2015). Impacts and Recovery from Severe Tropical Cyclone Yasi on the Great Barrier Reef. *PLOS ONE*, *10*(4), e0121272. doi: 10.1371/journal.pone.0121272 Open Access at plos.org

How did you go?

At point A in the illustration opposite, determine the % and number of undamaged (green)

Ans: 5-10%, so 4-8 corals

and

damaged level 5 (black)

Ans: 30%, so 24 corals

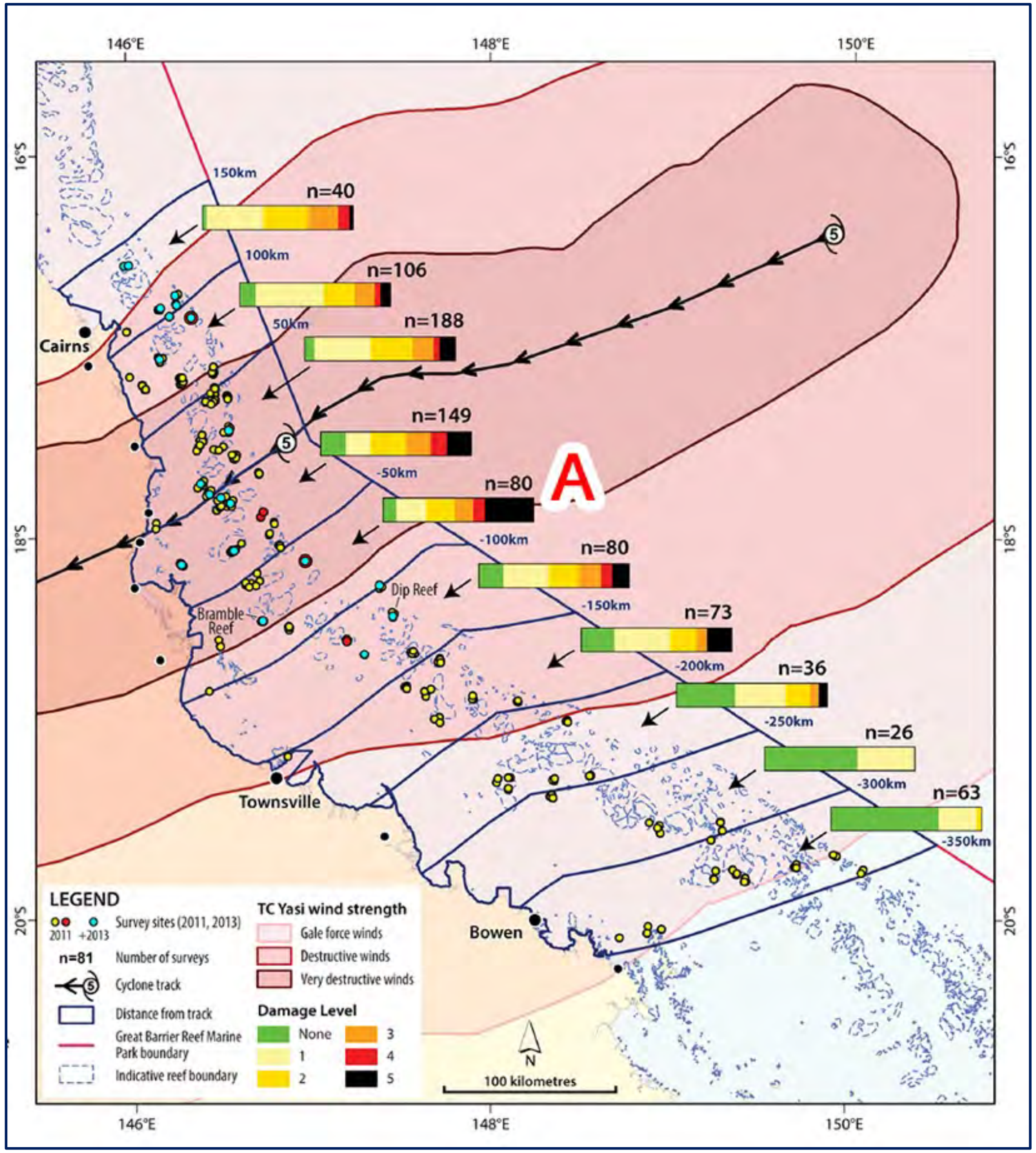


Image from: Beeden, R., Maynard, J., Puotinen, M., Marshall, P., Dryden, J., Goldberg, J., & Williams, G. (2015). Impacts and Recovery from Severe Tropical Cyclone Yasi on the Great Barrier Reef. *PLOS ONE*, *10*(4), e0121272. doi: 10.1371/journal.pone.0121272 Open Access at plos.org

Assessing coral damage by TC Yasi.

Damage levels 1, 2 and 3 relate to coral damage, while 4 and 5 relate to reef structural damage.

Damage Levels	
0	No damage
1	Minor coral damage
2	Moderate coral damage
3	High coral damage / Minor reef damage
4	Severe coral damage / Moderate reef damage
5	Extreme coral damage / High reef damage

Damage Level 1 (Minor damage):
Some (1-30%) corals partially damaged; primarily broken tips and some branches or plate edges.

Damage Level 2 (Moderate damage):
Many (31-75%) corals partially damaged; most fragile colonies have tips or edges broken, some branches missing or as large rubble fragments.

Damage Level 3 (High damage):
Up to 30% of colonies removed, some scarring by debris, soft corals torn, coral rubble fragments from fragile and robust coral lifeforms.

Damage Level 4 (Severe damage):
Many (31-50%) colonies dead or removed, extensive scarring by debris, rubble fields littered with small live coral fragments, soft corals severely damaged or removed and some large coral colonies dislodged.

Damage Level 5 (Extreme damage):
Most (51-100%) corals broken or removed, soft corals removed and many large coral colonies dislodged.

Figures and image from: Beeden, R., Maynard, J., Puotinen, M., Marshall, P., Dryden, J., Goldberg, J., & Williams, G. (2015). Impacts and Recovery from Severe Tropical Cyclone Yasi on the Great Barrier Reef. *PLOS ONE*, *10*(4), e0121272. doi: 10.1371/journal.pone.0121272 Open Access at plos.org

The table below describes reef damage from the cyclone.

Damage Level	Damage Level Descriptions	Total Reef Area Affected (km^2)	Proportion of Affected Reef Area Within the Marine Park (%)
Level 0	No Damage	21,005	84.5
Level 1	Minor Coral Damage	1,388	5.6
Level 2	Moderate Coral Damage	933	3.8
Level 3	Severe Coral Damage	564	2.3
Level 4	Severe Coral Damage and Moderate Structural Damage	447	1.8
Level 5	Extreme Coral Damage and High structural Damage	502	2.0

doi:10.1371/journal.pone.0121272.t001

Questions

a. Identify the % of reef area within the national park that suffered extreme coral damage.

b. Calculate the % of reef area that suffered some damage.

c. Categorise the level of damage in the two photos at Bramble reef (right)

Figures and image from: Beeden, R., Maynard, J., Puotinen, M., Marshall, P., Dryden, J., Goldberg, J., & Williams, G. (2015). Impacts and Recovery from Severe Tropical Cyclone Yasi on the Great Barrier Reef. *PLOS ONE*, *10*(4), e0121272. doi: 10.1371/journal.pone.0121272 Open Access at plos.org

Damage Level	Damage Level Descriptions	Total Reef Area Affected (km^2)	Proportion of Affected Reef Area Within the Marine Park (%)
Level 0	No Damage	21,005	84.5
Level 1	Minor Coral Damage	1,388	5.6
Level 2	Moderate Coral Damage	933	3.8
Level 3	Severe Coral Damage	564	2.3
Level 4	Severe Coral Damage and Moderate Structural Damage	447	1.8
Level 5	Extreme Coral Damage and High structural Damage	502	2.0

doi:10.1371/journal.pone.0121272.t001

How did you go?

a. Identify the % of reef area within the national park that suffered extreme coral damage.

Ans: 2.0%

b. Calculate the % of reef area that suffered some damage.

Ans: (100- 84.5)= 15.5%

c. Categorise the level of damage in the two photos at Bramble reef (right)

Ans: Left= no damage; Right= level 4

Figures and image from: Beeden, R., Maynard, J., Puotinen, M., Marshall, P., Dryden, J., Goldberg, J., & Williams, G. (2015). Impacts and Recovery from Severe Tropical Cyclone Yasi on the Great Barrier Reef. *PLOS ONE*, *10*(4), e0121272. doi: 10.1371/journal.pone.0121272 Open Access at plos.org

Review

Review the graphs of nitrates, phosphates (Factor 6)
and aragonite concentration (Factor 7).

1. Where can you locate data of abiotic factors that affect coral reef distribution?

2. Can you …
   - Interpret existing (secondary) data?
   - Explain trends and patterns in data?
   - Extrapolate this beyond the data set?

3. Can you draw a conclusion based on your analysis data, an back it up with reference to the data?

Further activities

See

https://coralwatch.org/index.php/education-2/curriculum-materials/marine-science/

by

CORALWATCH

Further activity

Worksheet –

Abiotic borders

by

Gail Riches

www.marineeducation.com.au