

Ch 13 Coral reef distribution

- T070 Identify reefs globally**
- T071 Coral geographic distribution**
- T072 Coral geological record**
- T073 GBR and sea level change**
- T074 Reef structures**
- T075 Reef cross-section zonation**



T070 Identify reefs globally

Adam Richmond

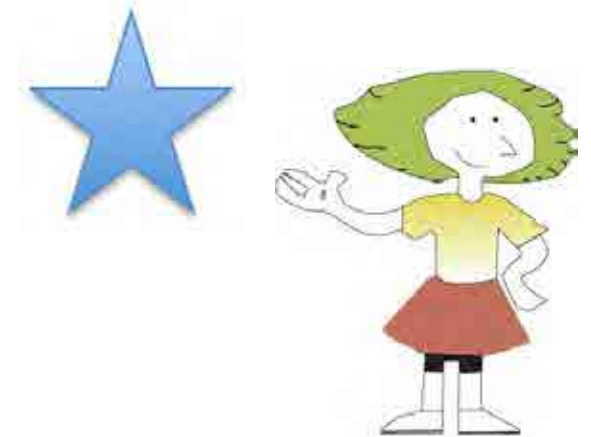
T070 DRAFT SLIDE 1

Syllabus statement

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

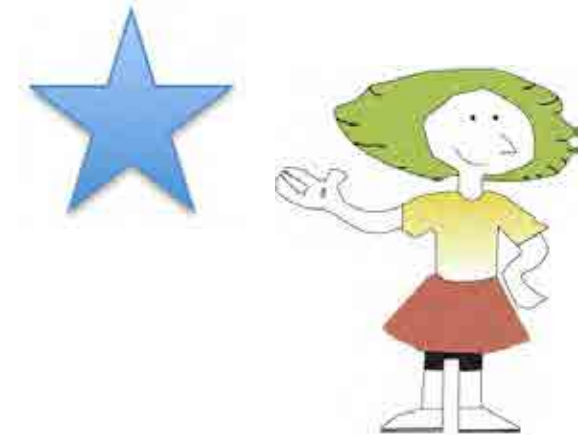
Identify

the distribution of coral reefs globally and in Australia.



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



Objectives

1. On a map of the world, indicate where coral reefs are distributed.
2. On a map of the east Australian coast, mark where coral reefs occur.



Watch this introductory YouTube video:

<https://www.youtube.com/watch?v=GAyRBqKk3hk&feature=youtu.be>



Queensland Australia: Great Barrier Reef.

YouTube video available: <https://www.youtube.com/watch?v=GAyRBqKk3hk&feature=youtu.be>

T070 DRAFT SLIDE 5

Definition

A reef is a a ridge of jagged rock, coral, or sand just above or below the surface of the sea.



Tuvarua island, Fiji

Image : Tavyland [CC BY-SA 3.0 (<https://creativecommons.org/licenses/by-sa/3.0/>)], from Wikimedia Commons https://upload.wikimedia.org/wikipedia/commons/1/10/Tavarua_Island%2C_Fiji.JPG

Coral reef distribution

Coral reefs are found in tropical and temperate waters.

Shallow water reefs are found between 30°N to 30°S of the equator to depths of 50 m.

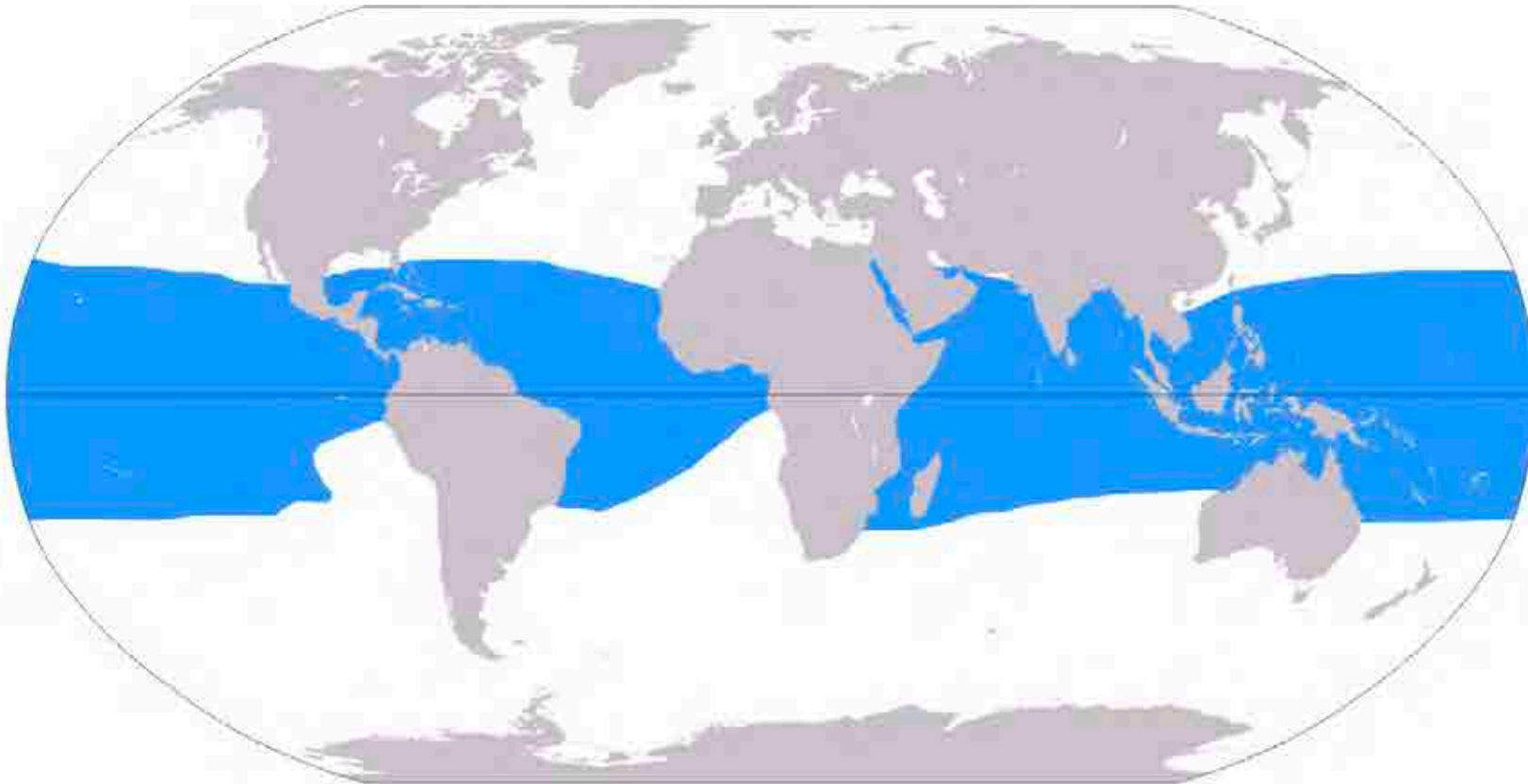


Image: Public Domain, <https://commons.wikimedia.org/w/index.php?curid=540031>

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Coral reef locations

Coral reefs are distributed worldwide as shown in the illustration below.

Note that deep water corals occur at greater depths and colder temperatures at much higher latitudes, as far north as Norway, but are not the focus of this unit.



Image: Public Domain, <https://commons.wikimedia.org/w/index.php?curid=84687>

T070 DRAFT SLIDE 8

The Great Barrier Reef
comprises

- over 2,900 individual reefs
and 900 islands stretching
for over 2,600 kilometres
from the northern most
tip to to just North of
Bundaberg.

Satellite image showing
the extent of the Great
Barrier Reef



Image: Envisat satellite [CC BY-SA 3.0-igo (<https://creativecommons.org/licenses/by-sa/3.0-igo>)], via Wikimedia Commons

In Queensland, reefs are found as far North as the Torres Strait.



Torres Strait islands and reefs

Photograph Tourism and Events Queensland Government

T070 DRAFT SLIDE 10



[Destination Information](#) > [Torres Strait Islands](#)



Torres Strait Islands

At the very tip of Cape York where the South Pacific Ocean and the Arafura Sea mix their currents are the 274 islands of the Torres Strait, including Thursday and Horn Islands. This unique tropical region is home to the indigenous Torres Strait Islanders whose culture is rich in the arts and whose lifestyle has evolved from the sea and its abundance of wildlife.

This unique tropical location is a melting pot of Melanesian and Indigenous Australian cultures boasting about 20 different communities and offering visitors a rich cultural experience. Step back in time to discover a diverse history spanning World War Two and the pearling industry, vibrant headdresses and colourful dance, ancient carving and modern printmaking, plus a welcoming people who live in paradise.

Thursday Island is the administrative centre of the Torres Strait with modern accommodation, tours and the award-winning Gab Titui Cultural Centre which takes visitors on a journey from the past to the present and into the future showing Torres Strait Islander culture through artefacts, artwork, song, dance and stories.

Connect with us



In Cairns they can be found around islands.



Islands off Cooktown have fringing reefs.

Photograph Bob Moffatt

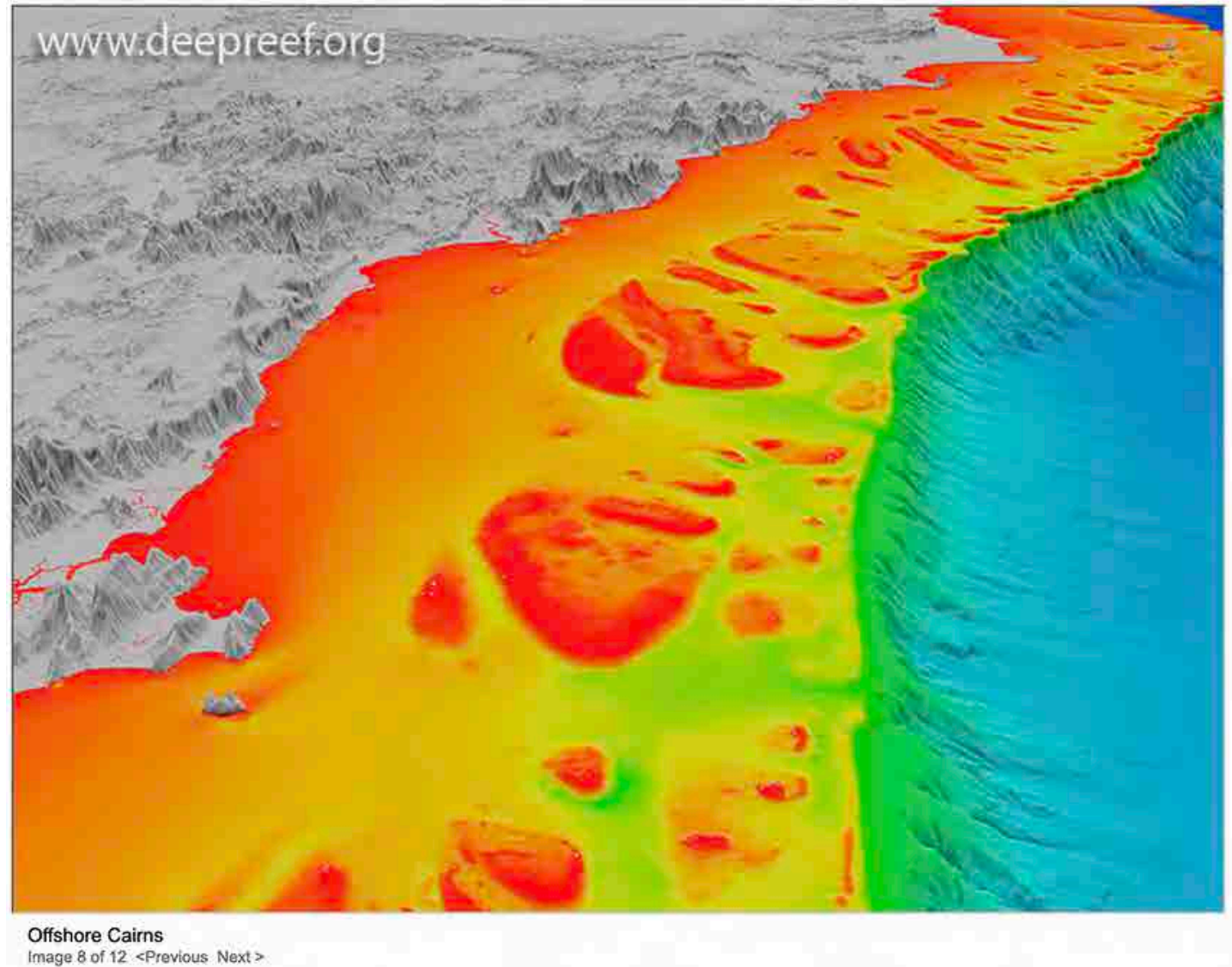
T070 DRAFT SLIDE 12

They can also be found offshore.

Note

Amazing images of Queensland coastline reef bathymetry can be found at:-

www.deepreef.org



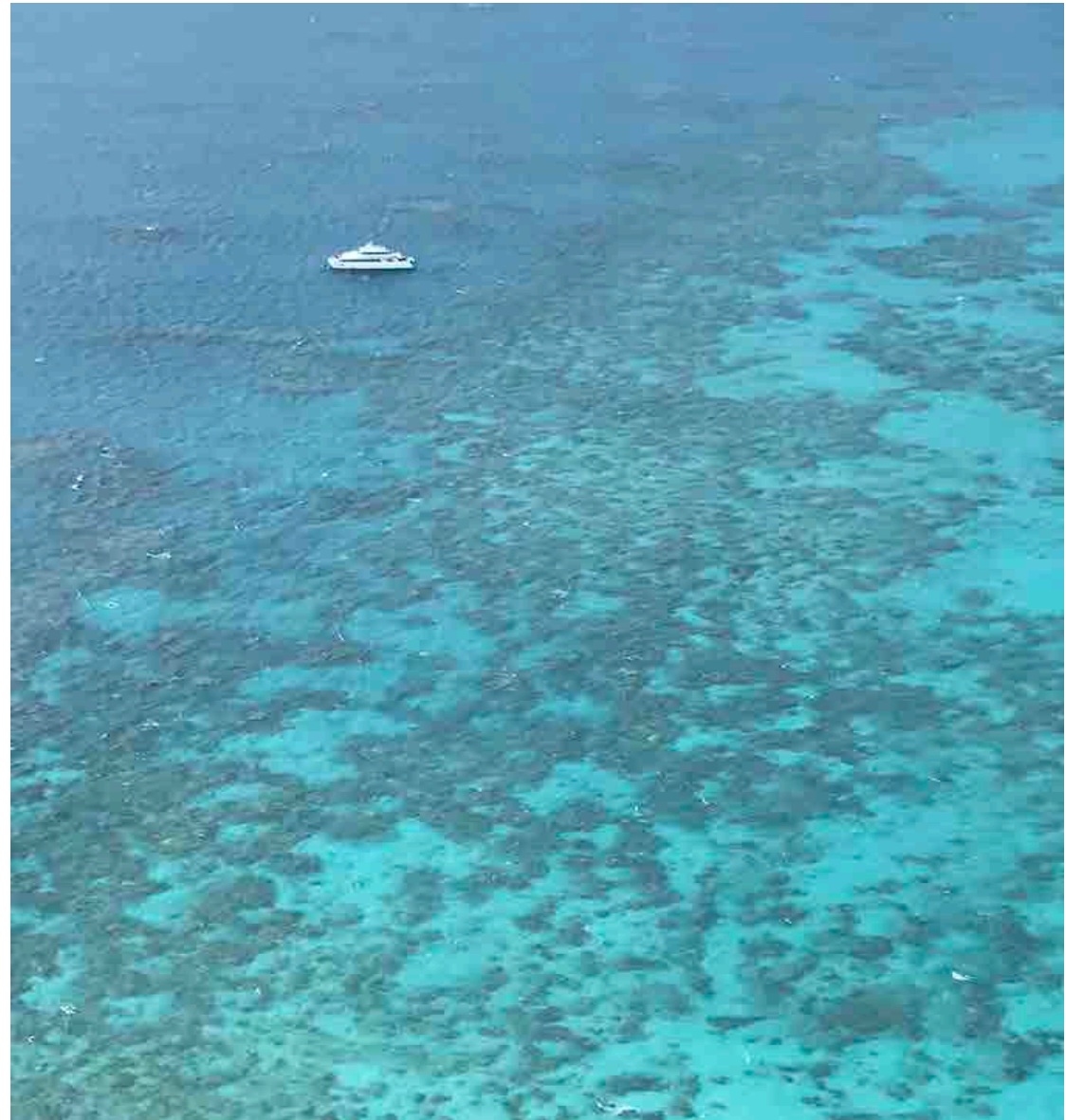
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T070 DRAFT SLIDE 13

For example, Hastings Reef is set on the outer edge reef, about 30 nautical miles from Cairns.

“The reef itself spans a 10 square kilometre patch of ocean, encompassing a spectacular collection of corals and wildly exotic fish”

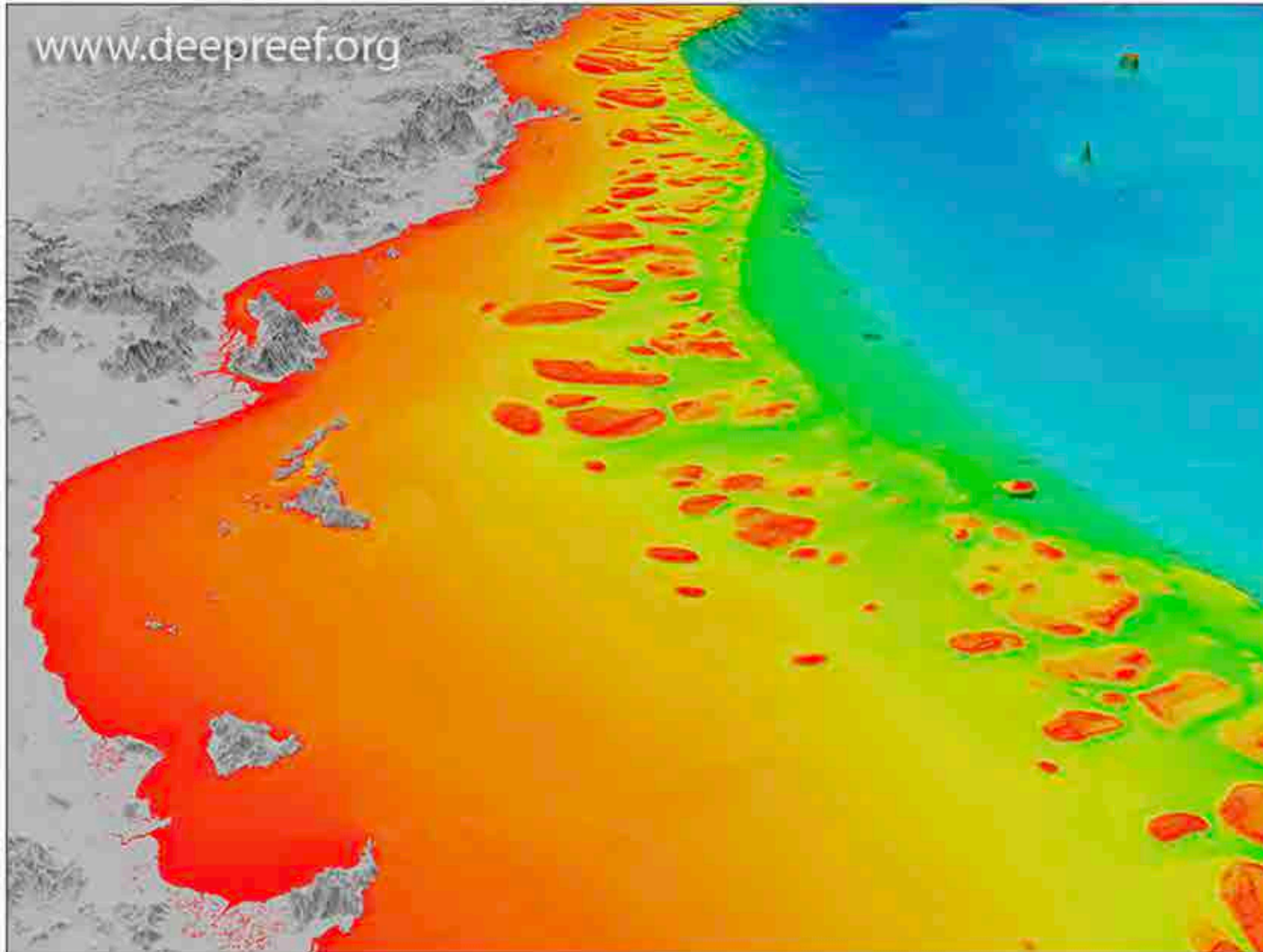
Cairns tourism.



Hastings Reef - Cairns

CedricLau [CC BY-SA 4.0 (<https://creativecommons.org/licenses/by-sa/4.0/>)]

Reefs are also found offshore from Townsville. Here the continental shelf widens so they are further out.



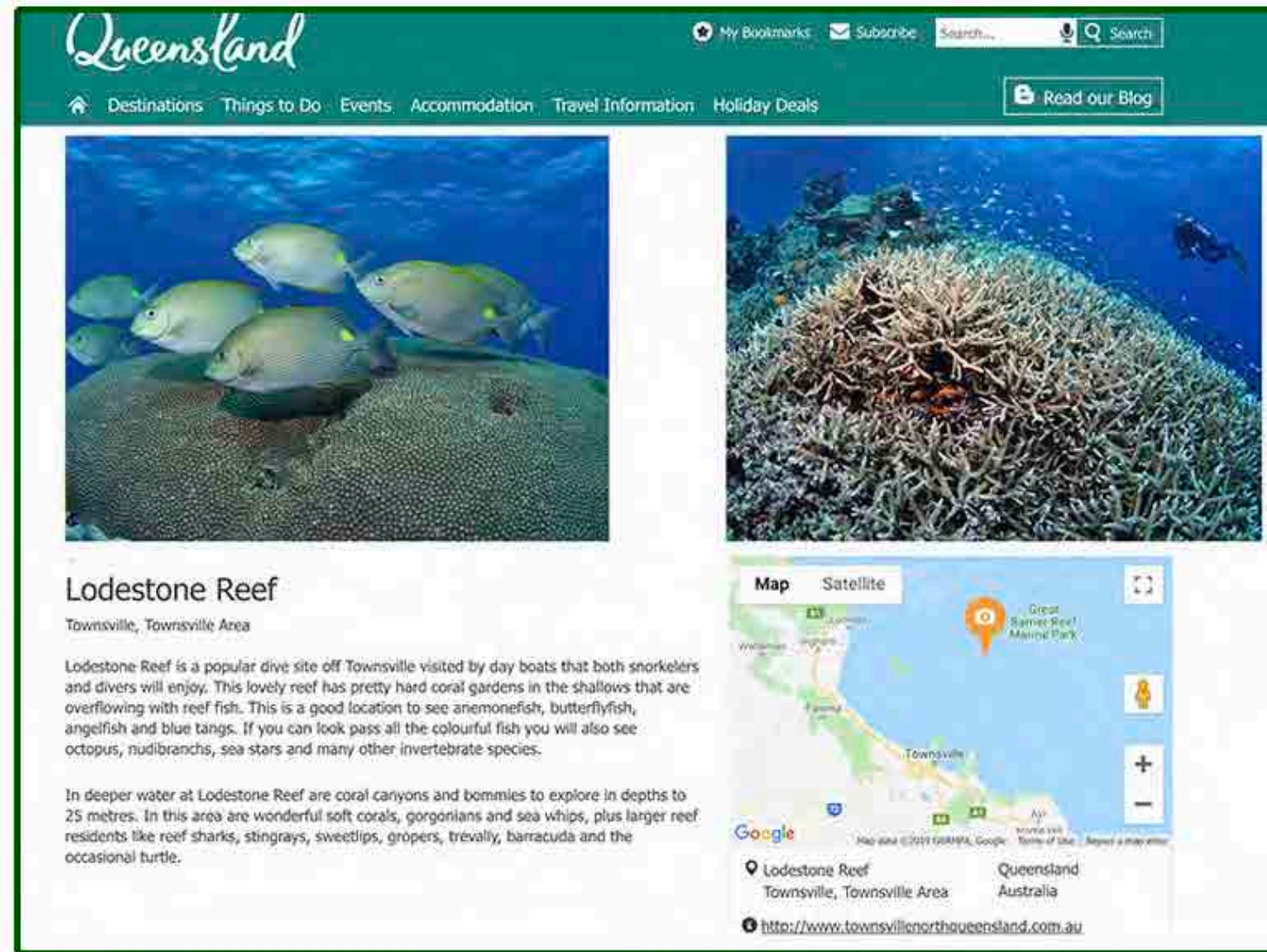
Offshore Townsville
Image 4 of 12 <Previous Next >

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Townsville

Queensland Tourism describes Lodestone Reef as “The most dived reef in the Townsville region ... and ...is the closest of all the outer reefs to Townsville and Magnetic Island.

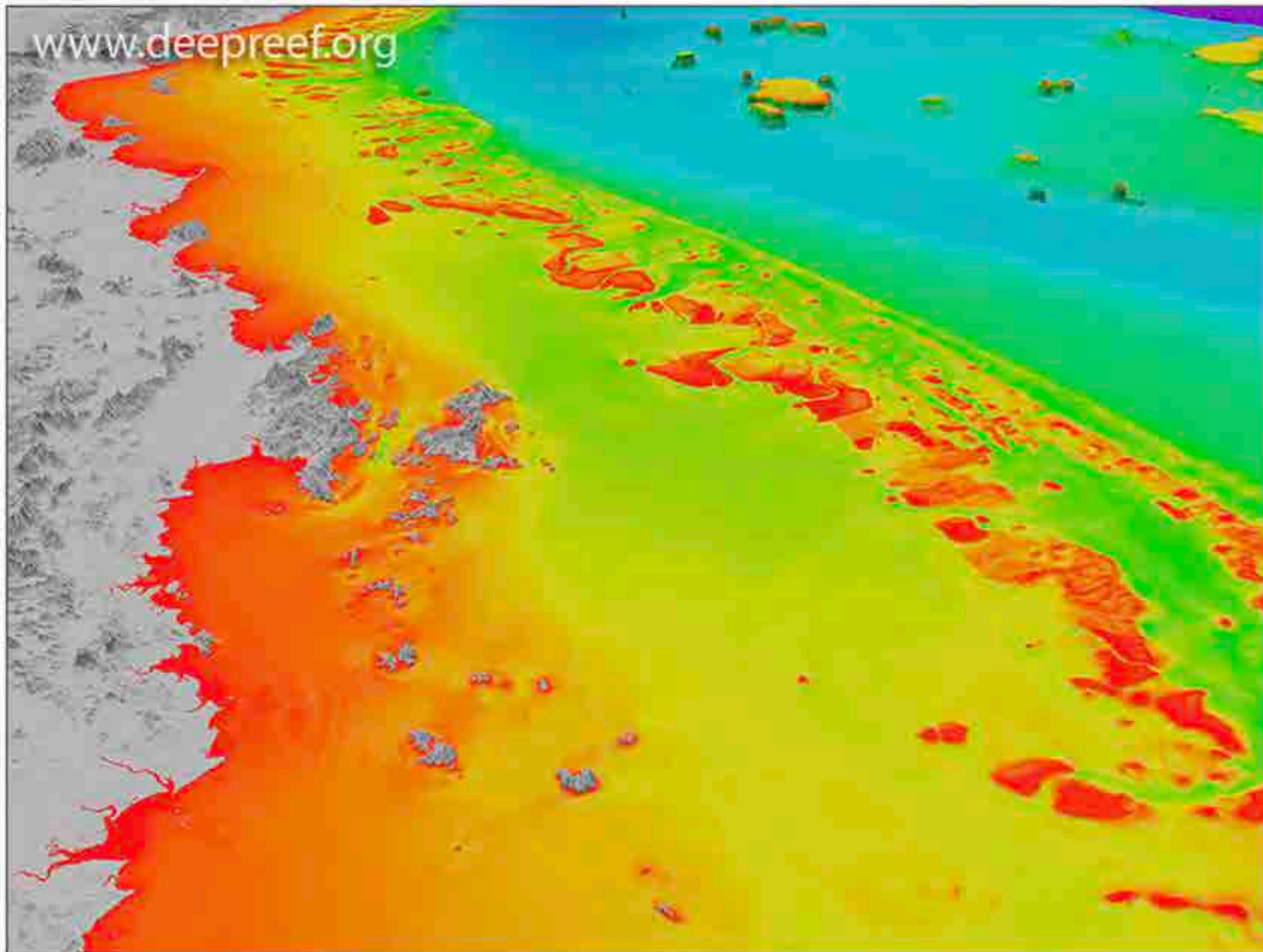
A dive and snorkelling boat runs day trips to Lodestone, picking up from Townsville and Magnetic Island on the way.”



The screenshot shows the Queensland Tourism website. At the top, the 'Queensland' logo is on the left, and navigation links for 'My Bookmarks', 'Subscribe', 'Search...', and 'Read our Blog' are on the right. Below the logo, a menu includes 'Destinations', 'Things to Do', 'Events', 'Accommodation', 'Travel Information', and 'Holiday Deals'. The main content area features two underwater photographs of the reef. The left photo shows a school of yellow-striped snappers swimming over a large brain coral. The right photo shows a diver swimming over a dense field of branching coral. Below the photos, the heading 'Lodestone Reef' is followed by the location 'Townsville, Townsville Area'. The text describes the reef as a popular dive site with hard coral gardens and a variety of reef fish. It also mentions deeper water features like coral canyons and bommies. At the bottom right, there is a Google Map showing the location of Lodestone Reef on the coast of Queensland, Australia, with a link to the website <http://www.townsvillenorthqueensland.com.au>.

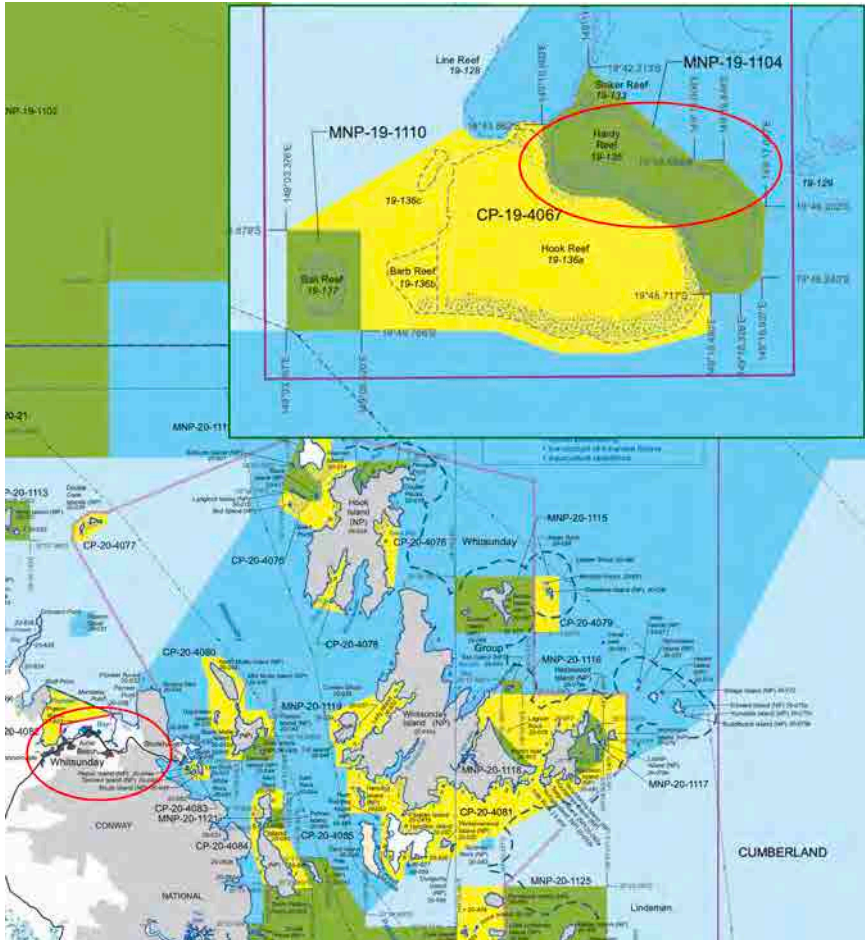
Copyright Queensland Tourism Reproduced with permission

As the continental shelf continues to widen, reefs are found further out from the central Queensland coast.



Mackay and the Whitsunday Islands

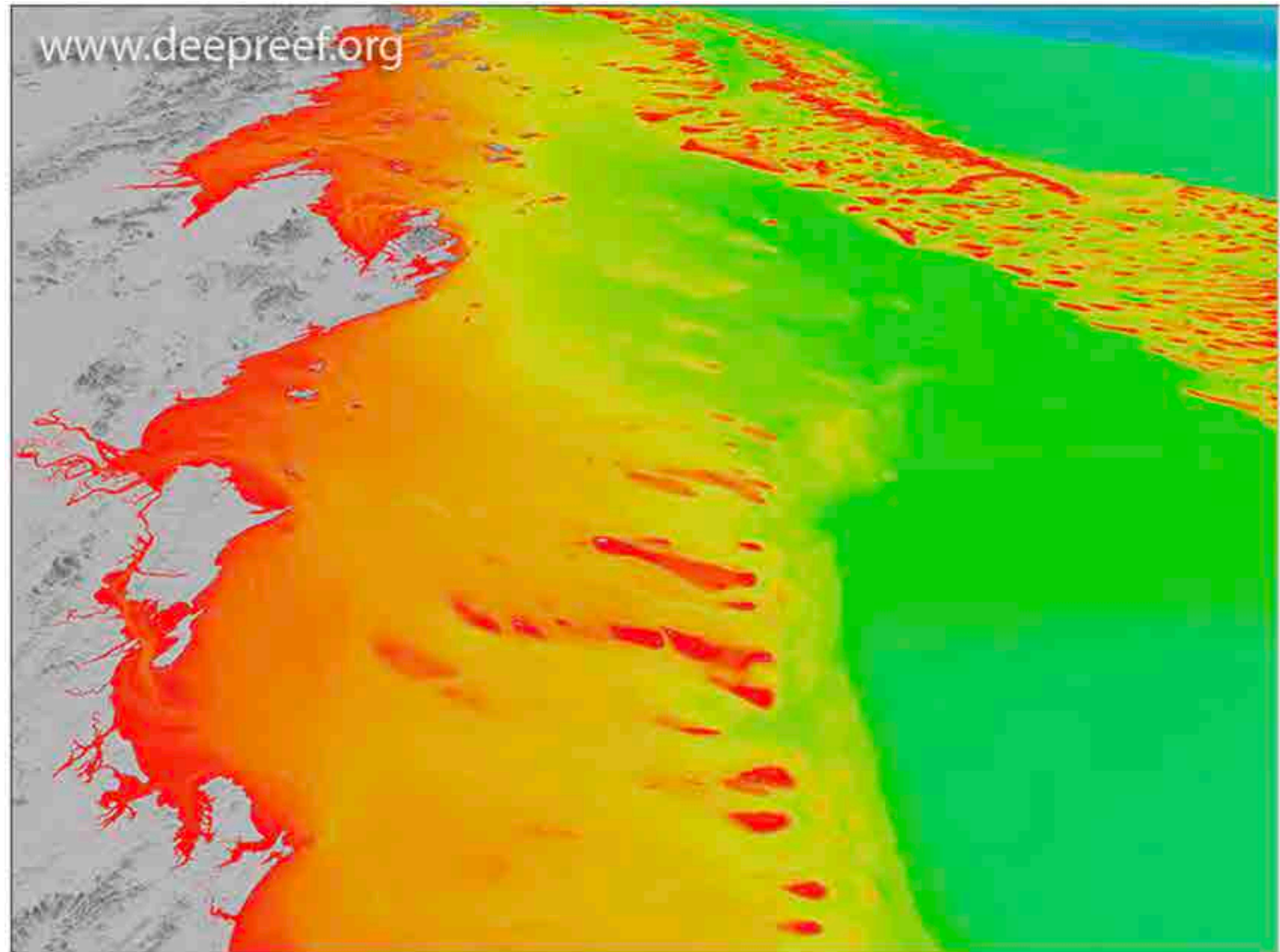
Hardy Reef, on the Great Barrier Reef off Airlie Beach, is home to the Reefworld Pontoon.



Hardy Reef pontoon
Bob Moffatt

Central Queensland

The continental shelf is at its widest off the coast in central Queensland making the outer reefs lying between 120km and 250km offshore from St Lawrence the most eastern and southern development of the Great Barrier Reef.



Offshore Gladstone
Image 11 of 12 <Previous Next >

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Rockhampton and Gladstone

Heron Island is a coral cay located near the Tropic of Capricorn in the southern Great Barrier Reef.

It is 80 kilometres North-East of Gladstone.

The island is situated on the leeward (Western) side of Heron Reef, a fringing platform reef of significant biodiversity, supporting around 900 of the 1,500 fish species and 72% of the coral species found on the Great Barrier Reef.



CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=49421>

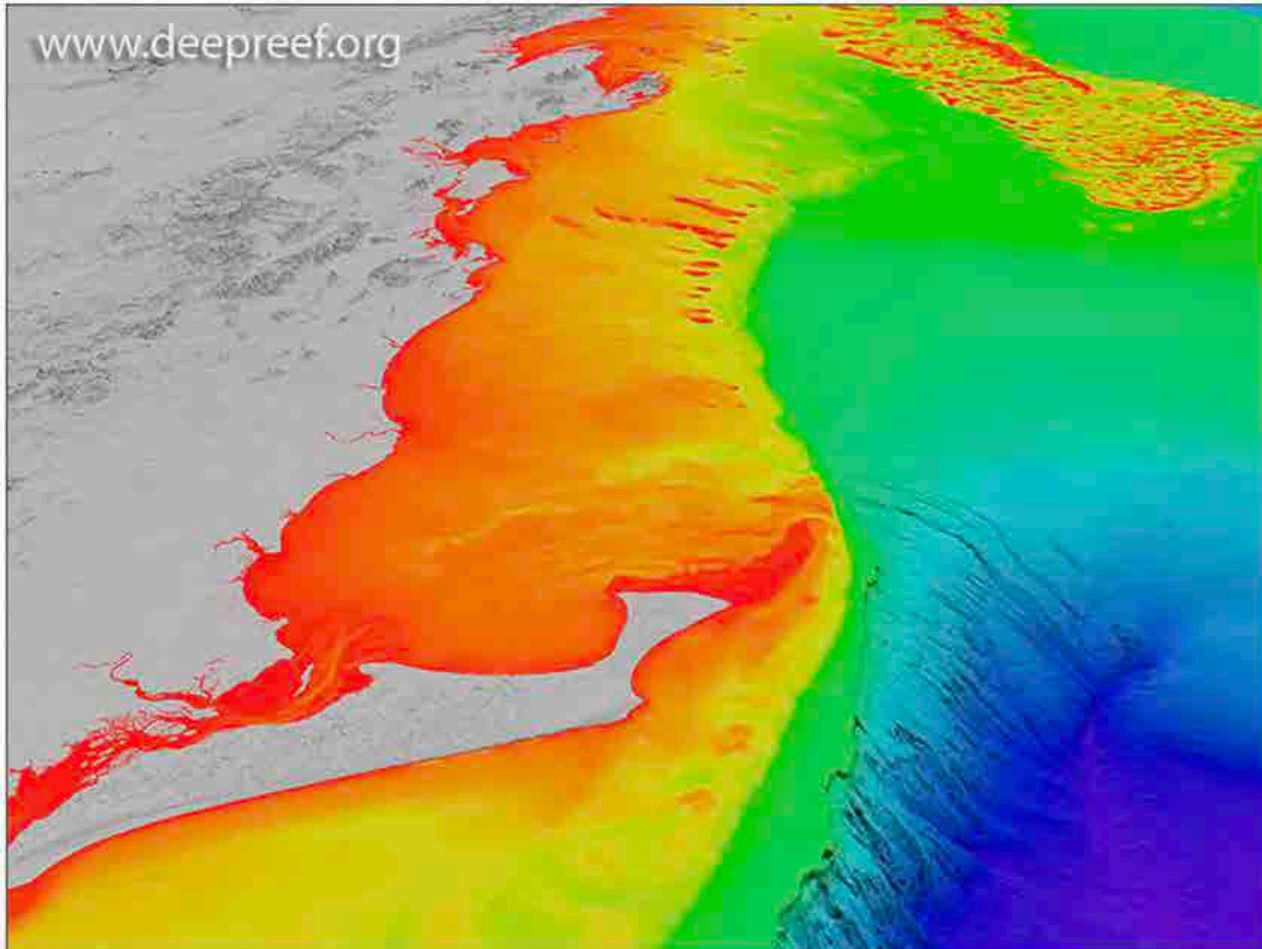
However reefs are also found around islands just offshore. These are called fringing reefs which were discussed in Unit 1.



Great Kepple Island
Bob Moffatt circa 1985

Wide Bay and Bundaberg

This is where the Great Barrier Reef ends, however corals can exist much further south.



Off Fraser Island the continental shelf retreats towards the mainland.

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Lady Elliot Island is the southernmost coral cay of the Great Barrier Reef, Australia.

The island lies 46 nautical miles north-east of Bundaberg and covers an area of approximately 45 hectares.

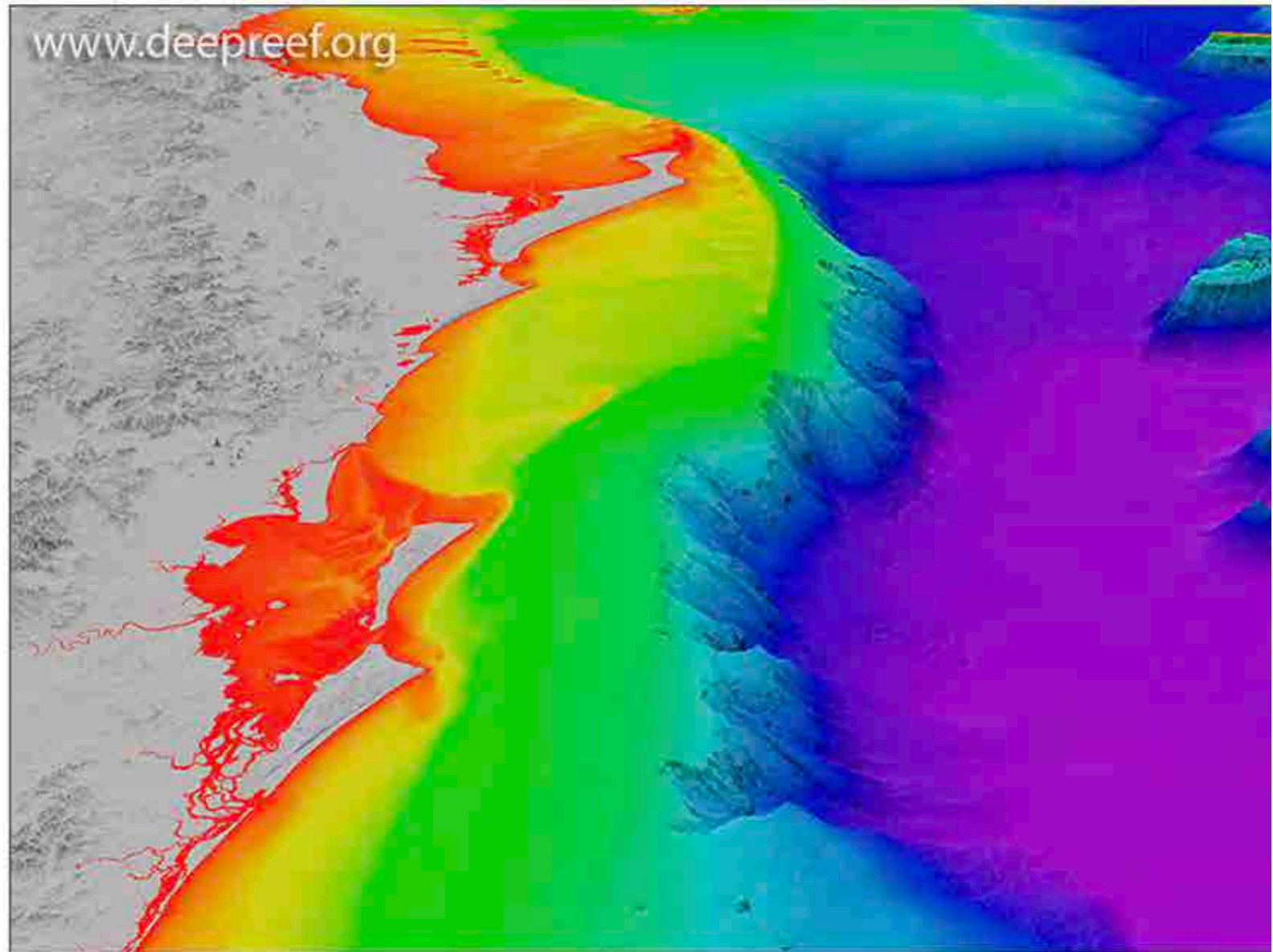
It is part of the Capricorn and Bunker Group of islands and is owned by the Commonwealth of Australia.



LordDimwit at English Wikipedia [Public domain]https://upload.wikimedia.org/wikipedia/commons/3/3f/Lady_Elliot_Island.jpg

South east
Queensland

Corals continue to
be found off
shore in South
East Queensland.



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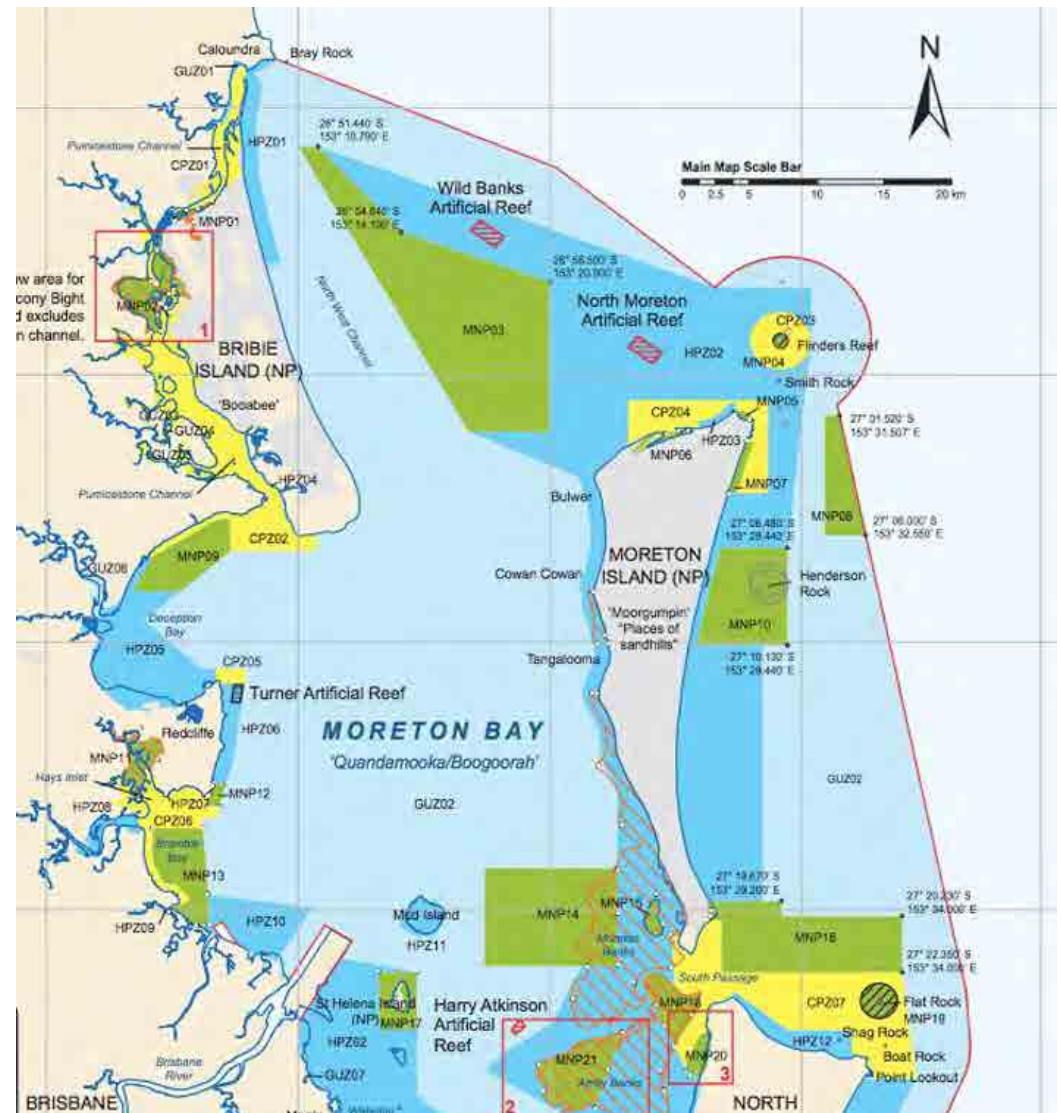
Offshore Brisbane
Image 6 of 12 <Previous Next >

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Flinders Reef is a small isolated reef near Moreton Island, 5 kilometres north-east of Cape Moreton South East Queensland

“It has a high number of coral species for any subtropical reef system along Australia's east coast and is the nearest true coral reef to Brisbane. Flinders Reef is one of Queensland's most popular dive sites.”

Tourism Queensland.



Corals are also found in Moreton Bay.

There are however no reefs, like those found on the Great Barrier Reef, in Moreton Bay.

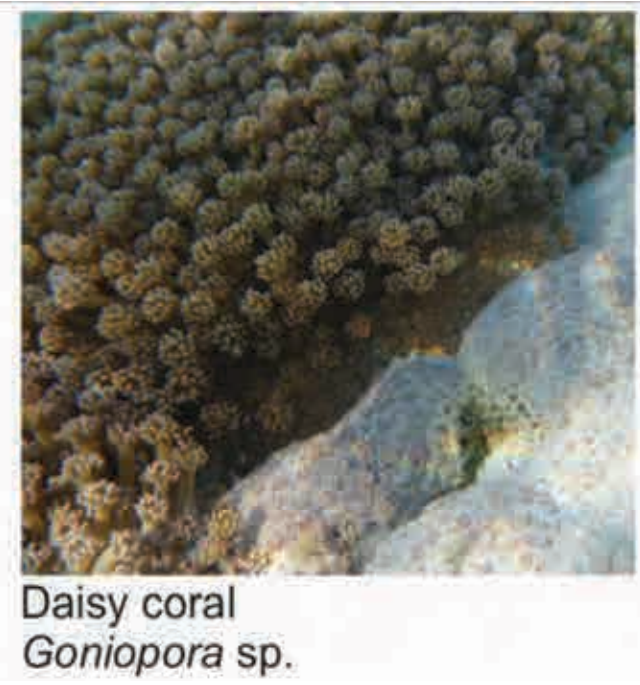


Coral underwater near the wrecks at Moreton Island

Bob Moffatt

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However there are 120 species of corals found in Moreton Bay



Check out the CoralWatch website for more information about Moreton Bay corals:
<https://coralwatch.org/index.php/ambassadors/corals-at-your-doorstep/>

Images: © CoralWatch, June 2017. Photos: Cedric van den Berg, Monique Grol, Kyra Hay, Diana Kleine, Chris Roelfsema & CoralWatch reproduced from: http://vm-203-101-224-174.qld.nectar.org.au/wordpress/wp-content/uploads/2018/12/MB-coral-ID-guide_2017.pdf

Coal reefs are also found much further south.



Geoscience Australia



Lord Howe
Island corals and
algae

Bob Moffatt

The world's Southernmost coral reef is at Lord Howe Island.



Reefs off Lord Howe Island

Images: Bob Moffatt, Wiki Commons

T070 DRAFT SLIDE 29

The coral triangle

The coral triangle is a geographical term so named as it refers to a roughly triangular area of the tropical marine waters.

Note

The world's Northernmost coral reef is located in the Korea Strait.



Image: Benutzer:Devil_m25 - Transferred from de.wikipedia to Commons.(Original text : selbst erstelltTopographische Karte: <http://www.shadedrelief.com>Ausdehnung: <http://www.coraltrianglecenter.org>Riffe: <http://www.coralreefinfo.com>Nationalerbesymbol:

The coral triangle is recognised as the global centre of marine biodiversity and a global priority for conservation.

Organisations from around the world seek to learn more and network each other to conserve what is left of the world's coral reefs.

Why not do a google search and see how many you can find?



CoralWatch

CoralWatch is a not-for-profit citizen science program based at The University of Queensland.

Coral Watch works with volunteers worldwide to increase understanding of coral reefs, coral bleaching and climate change.

See

<https://www.coralwatch.org>

g



Organisations such as CoralWatch monitor coral reefs around the world

Image: NASA 2018 from <https://www.coralwatch.org/web/guest/map>

The Great Barrier Reef Marine Park Authority

GBRMPA webpage:

<http://www.gbrmpa.gov.au/access-and-use/zoning/zoning-maps>

The Queensland wide distribution of corals is shown on this web page.

You can download a pdf to show you which coral reef is nearest to you.

Zoning maps for the Great Barrier Reef

Image from: <http://www.gbrmpa.gov.au/access-and-use/zoning/zoning-maps>



Reef guardians

The Great Barrier Reef Marine Park Authority's (GBRMPA) Reef Guardian program recognises the good environmental work undertaken by communities and industries to protect the Great Barrier Reef.

The program involves working closely with those who use and rely on the Reef, or its catchment, for recreation or business, to help build a healthier and more resilient Reef.



Sarah Strutt (GBRMPA) with Rockhampton grazier and Reef Guardian Jeff Mills

Questions

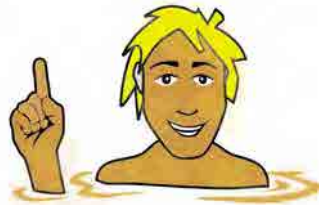
Q1. On a map of the world below, draw where corals are distributed.



Dmthoth [CC BY-SA 3.0 (<https://creativecommons.org/licenses/by-sa/3.0>) or GFDL (<http://www.gnu.org/copyleft/fdl.html>)], from Wikimedia Commons

Q2. On a map of east Australian coast such as this one, mark where coral reefs can be found.

You need to do a quick sketch so you can show the distribution of corals.



<https://commons.wikimedia.org/wiki/File:GA20891.pdf#file>
From Wikimedia Commons, Geoscience Australia copyright.

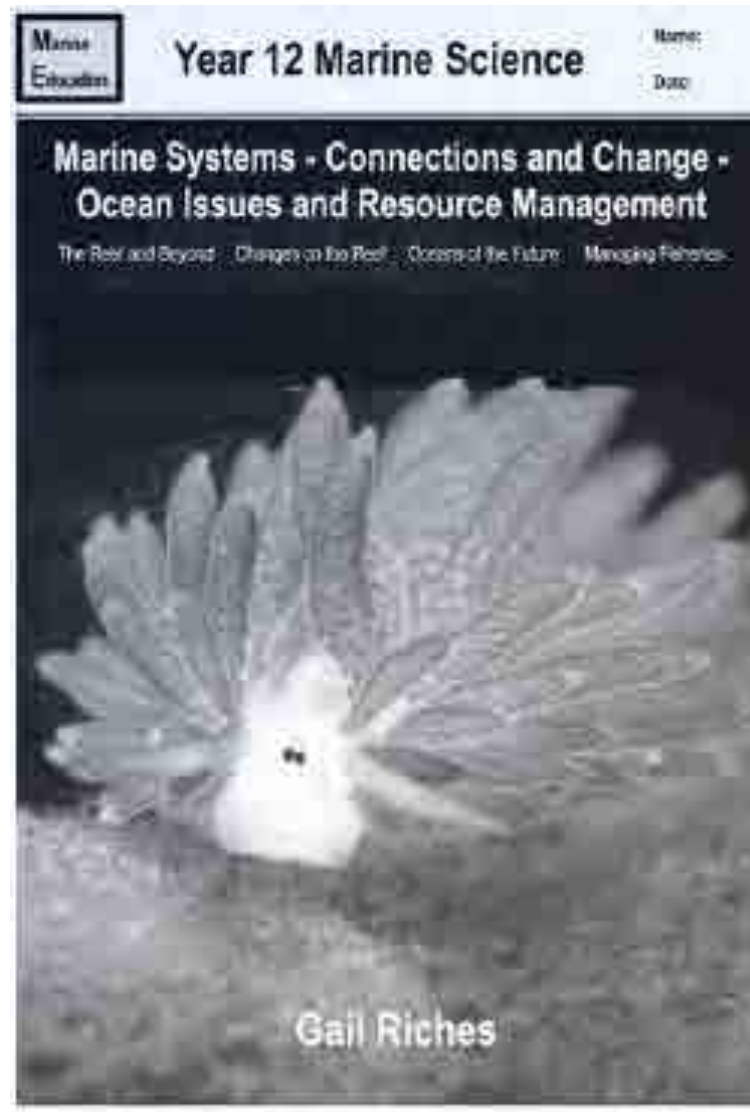
Worksheet

The formula for life

by

Gail Richie

www.marineeducation.com.au



Further activity

The worksheet

Coral reef distributions

Marine systems connections and change

By

CoralWatch



T071 Coral geographic distribution

A tropical beach scene at sunset. The foreground shows a sandy beach with shallow, rippling water. In the middle ground, two boats are visible in the water. The background features a sunset sky with soft colors and a few birds flying.

Adam Richmond

T071 DRAFT SLIDE 1

Syllabus statement

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

Identify

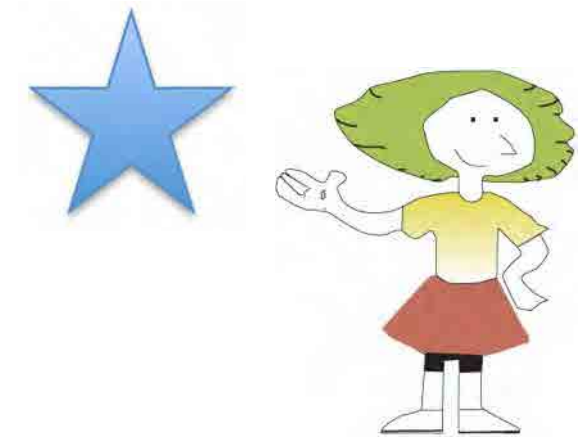
abiotic factors that have affected the geographic distribution of corals over geological time including ...

- dissolved oxygen,
- light availability,
- salinity,
- temperature,
- substrate,
- aragonite and
- low levels of nitrates and phosphates.



Identify

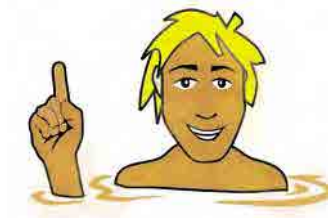
- distinguish;
- locate, recognise and name;
- establish or indicate who or what someone or something is;
- provide an answer from a number of possibilities;
- recognise and state a distinguishing factor or feature



Objective

Complete the following table to show you can

- Identify factors that affect coral distribution and
- How these factors may have changed over time



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		

Coral distribution

In 2004 a Worldwide Coral Reef Library was created in a partnership with NASA, international agencies, universities and other organisations to provide natural resource managers a comprehensive world data resource on coral reefs and adjacent land areas. This is what they produced.



Geographical distribution of corals in 2005

Image :NASA, retrieved from: http://www.nasa.gov/vision/earth/lookingatearth/coralreef_image.html

Other sources of information on coral reef distribution include web sites such as

Nature Education Knowledge

<https://www.nature.com/scitable/knowledge/library/coral-reefs-15786954>

This article answers the question:-

What are the abiotic and biotic interactions that structure this diverse ecosystem?



A screenshot of the Nature Education Knowledge Project website. The page title is "Coral Reefs" under the "Library" section. The article is by Timothy P. Henkel, a lead editor in the "BASIC" category. The main text asks, "Coral reefs are one of the most diverse ecosystems on the planet. What are the abiotic and biotic interactions that structure this diverse ecosystem?". Below the text is a photograph of a clownfish swimming near a large, yellow, tentacled sea anemone. The website header includes navigation links like HOME, LIBRARY, PEOPLE, GROUPS, BLOGS, and NATURE JOBS, along with a search bar and social media icons. A sidebar on the left lists "Updates" and "Topic Rooms" related to the subject.

<https://www.nature.com/scitable/knowledge/library/coral-reefs-15786954>

Coral reef history

Corals appeared 500 million years ago (MYA) in the Cambrian period and have experienced several extinction events.

These were most likely caused by 5 abiotic factors:

- Changes in ocean circulation caused by the break up of Pangaea;
- Changes in sea level, due to ice ages and interglacial periods;
- Changes in O₂ and CO₂ levels in the atmosphere, due to volcanic activity or meteor impacts;
- Reduced sunlight caused by meteor impact;
- Global warming events.



Extinct rugose coral from 300 MYA

Image credit: By Wilson44691 - Own work, CC0,
<https://commons.wikimedia.org/w/index.php?curid=28878525>

Geographical distribution of corals in the past

The illustration opposite shows approximate periods of coral presence in our geological history.

The web link below has accurate information about coral reef history, including extinction events.

<http://globalreefproject.com/coral-reef-history.php>

GEOLOGICAL TIME SCALE


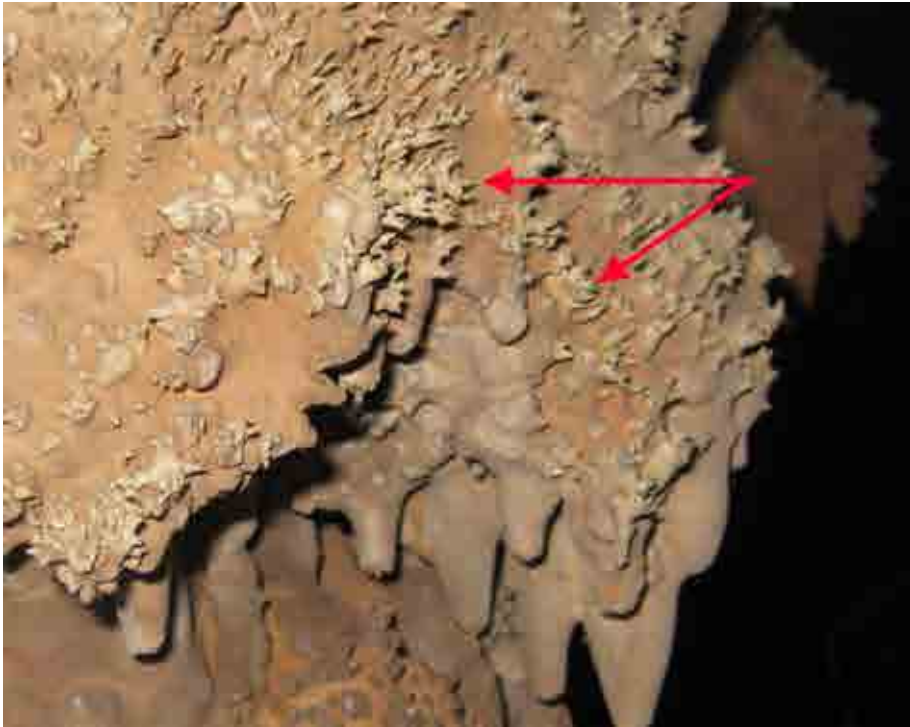
Era	Geological period	Approx time	Period of coral reef presence
Cenozoic	Holocene	0.5 mya	 First coral reefs in Australia Coral growth continental shelf
	Oligocene	18 mya	
	Eocene	35 mya	
Mesozoic	Paleocene	55 mya	Specialisation of mammals, sediments flowed from rivers onto continental shelves
	Cretaceous	70 mya	Australian plate still moving north and fracturing
	Jurassic	100 mya	Expansion of mammals, coral sea forms
Paleozoic	Triassic	200 mya	Mass extinction Dinosaurs became extinct, Australia still joined to Antarctica
	Permian	230 mya	First mammals and birds
	Carboniferous	285 mya	Mass extinction First Dinosaurs
	Devonian	350 mya	Expansion of primitive reptiles
	Silurian	400 mya	Mass extinction Expansion of sharks and fish
Precambrian	Ordovician	430 mya	Mass extinction First Insects
	Cambrian	440 mya	Mass extinction First land plants
	Precambrian	4600 mya	First corals First fish First marine invertebrates The beginning of life in the Sea

Illustration Bob Moffatt

In Unit 1 you learnt that Devonian reefs were similar to reefs of today.



Photograph Bob Moffatt



Photograph Viewfinder

What you did not learn was that there were at least four mass extinction events in the past 500 million years of evolution.

Reference

https://en.wikipedia.org/wiki/Extinction_event

Geikie Gorge is a 350 million year old fossil reef.

The limestone has been exposed by erosion by the Fitzroy River, Western Australia and contains evidence of coral mass extinction events.



Geikie Gorge

Photograph Bob Moffatt

TO71 DRAFT SLIDE 10

Recent studies of fossilised coral reefs off the coast of Texas indicate that sea-level rise has occurred in sharp bursts when glaciers melted, and not gradually. This has implications for future sea-level changes.

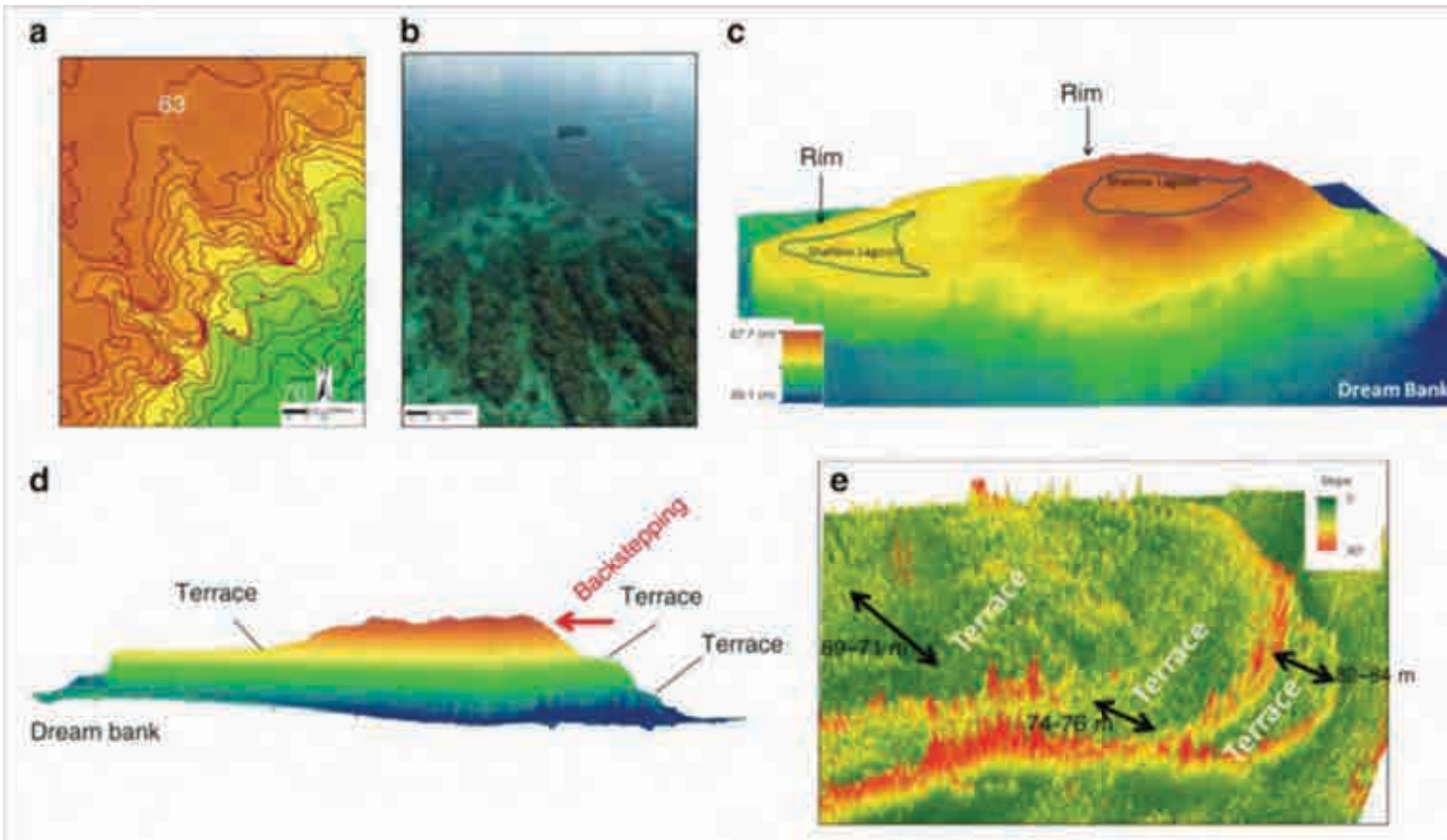


Image from: Khanna, P., Droxler, A. W., Nittrouer, J. A., Jr, J. W. T., & Shirley, T. C. (2017). *Coralgal reef morphology records punctuated sea-level rise during the last deglaciation*. *Nature Communications*, 8(1), 1046. doi:10.1038/s41467-017-00966-x

Reference: <https://www.nature.com/articles/s41467-017-00966-x>

T071 DRAFT SLIDE 11

Abiotic factors

The survival, and thus distribution, of corals is controlled by:

- Dissolved oxygen²
- Light availability¹
- Salinity¹
- Temperature¹
- Substrate² and sediment¹
- Seawater carbonate chemistry¹ (Aragonite²)
- Nutrients¹ (nitrates and phosphates²)
- Exposure, waves, tides and storms¹



1. Sheppard, C., Davy, S., & Pilling, G. (2009). *The biology of coral reefs*. Oxford: Oxford University Press.
2. 2. Marine Science 2019 v1.2 syllabus

Reference

<https://scripps.ucsd.edu/projects/coralreefsystems/about-coral-reefs/biology-of-corals/>

Dissolved oxygen

All organisms require oxygen for respiration. Dissolved oxygen (DO) is the amount of O₂ molecules in the water- not bonded to any other molecules (H₂O doesn't count!)

The amount of DO required varies between species:

- active fish need higher levels (4-15mg/L) whilst benthic organisms need less (1-6mg/L).

DO levels are affected by temperature, pressure, salinity, photosynthesis and respiration, depth, amount of mixing, decomposition and eutrophication.



A fish kill caused by oxygen depletion

Image: United States Fish and Wildlife Service. [Public domain], via Wikimedia Commons
https://commons.wikimedia.org/wiki/File:Fish_kill_pollution.jpg#/media/File:Fish_kill_pollution.jpg

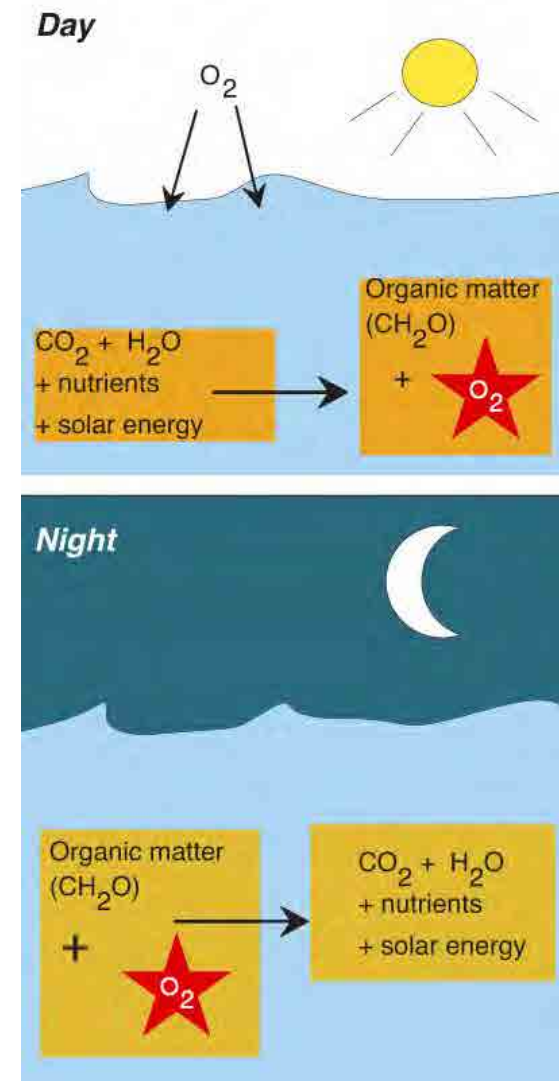
DO levels also fluctuate on a **daily** and **seasonal** basis.

You can read more at

<http://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/>

<https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/>

There are some particularly useful graphs and figures.

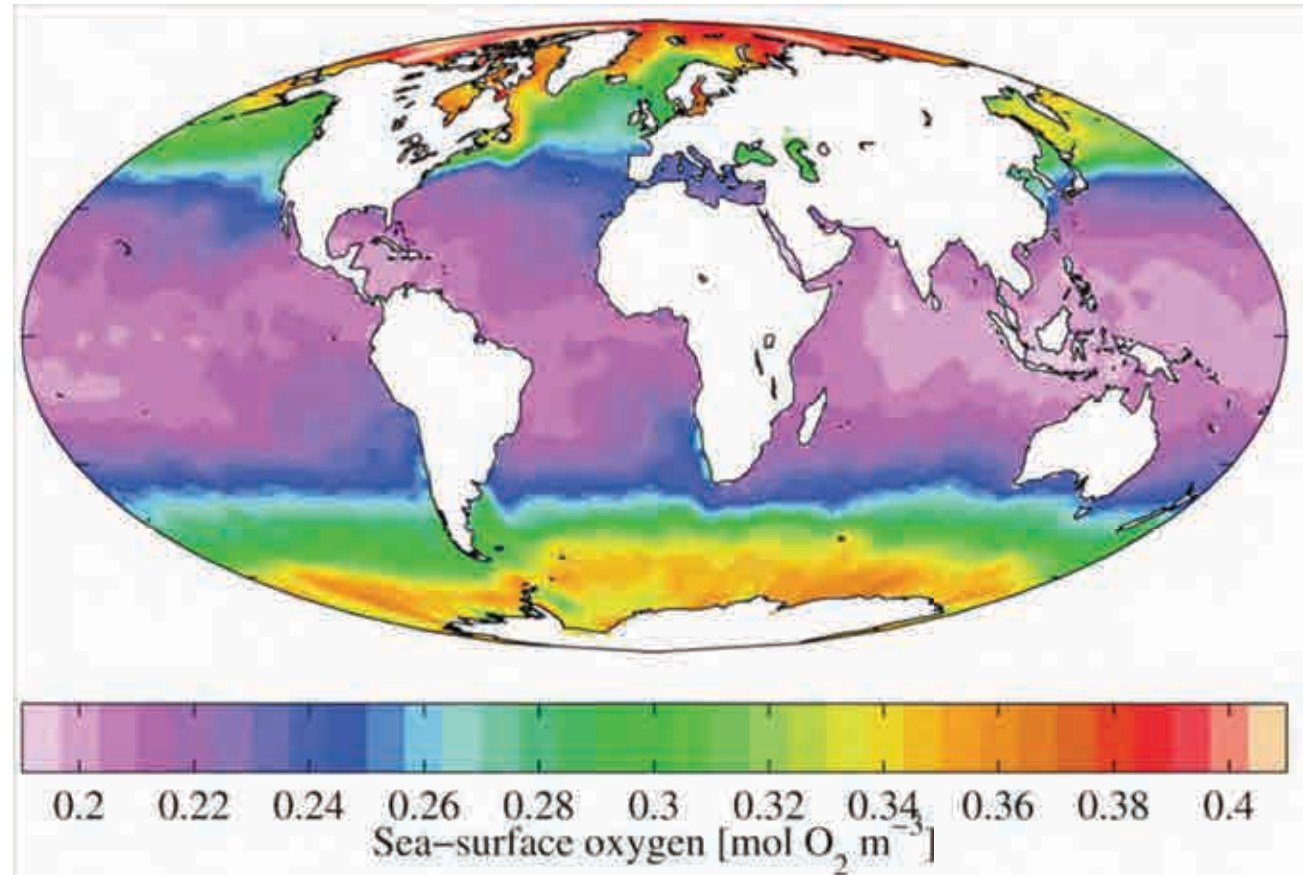


Bob Moffatt

Most coral reefs occur in areas with very low sea-surface oxygen concentrations.

However, the DO levels tend to stay high near coral reefs, due to photosynthesis, eddies and breaking waves.

Hypoxic (low O₂) conditions cause “dead zones”, which can cause coral bleaching and death.



Dissolved oxygen levels at the Ocean's surface

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

Light availability

Corals have a symbiotic relationship with zooxanthellae, that provide up to 98%¹ of a coral polyp's energy requirements.

As the zooxanthellae require light for photosynthesis, corals are restricted to regions where there is enough light.

The zone where there is enough light for photosynthesis is the **euphotic zone**.



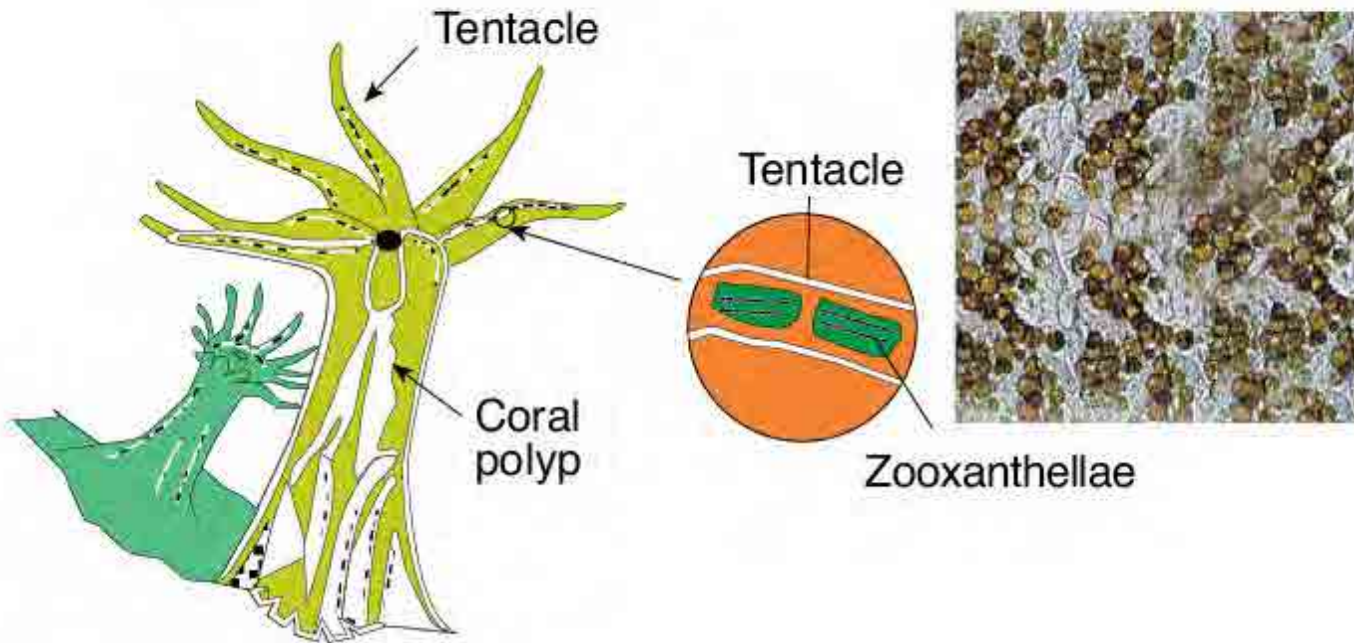
Zooxanthellae through a microscope

Image: Adam Richmond

1. Reid, C., Marshall, J., Logan, D. & Kleine, D.(2012). *Coral reefs and climate change* (2nd ed.). St Lucia, Qld.: CoralWatch, University of Queensland.

Most of their nutrients come from the zooxanthellae.

Like plants, zooxanthellae use the sun to make food for themselves and the coral. This is why it is important for corals to live in clear, shallow waters where they can get lots of sunlight. (GBRMPA)



Zooxanthellae are dinoflagellates
Illustration Mark Moffatt, Photo CSIRO

In the tropics, sunlight reaches the ocean surface at almost 90° , so more energy penetrates the surface than at higher latitudes where more energy is reflected due to sunlight striking the surface at an angle.

Scientists use the term PAR (photosynthetically available radiation) to describe the amount of sunlight energy reaching the water surface.



Clear water allows light to penetrate further.

Image: Murray Waite

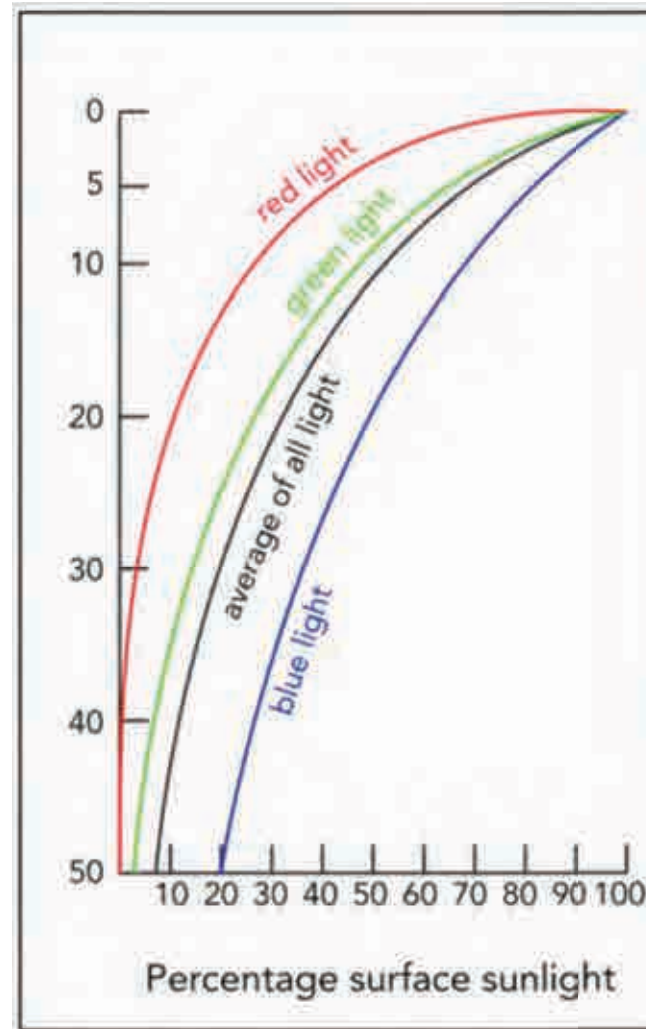
Light availability (and depth)

The depth of coral reef formation is generally 30-50 m, but can be up to 75 m in very clear water.

Corals may live at greater depths, but reef development is unlikely as growth rates are less than erosion

It is important for corals to live in clear, shallow waters where zooxanthellae can get lots of sunlight.

- This tends to limit corals to shallow depths as most reef building corals occur in less than 25 m of seawater.



The intensity of sunlight decreases with depth

Image by Byron Inouye

<https://manoa.hawaii.edu/exploringourfluidearth/physical/ocean-depths/light-ocean>

Remember from Units 1 and 2

Turbidity reduces light penetration, which restricts coral growth.

High sedimentation rates can also bury or smother these sessile animals.



Turbidity (NTU)



Turbidity NTU samples

From WaterWatch Queensland

Further reference

<https://www.nature.com/scitable/knowledge/library/coral-reefs-15786954>)

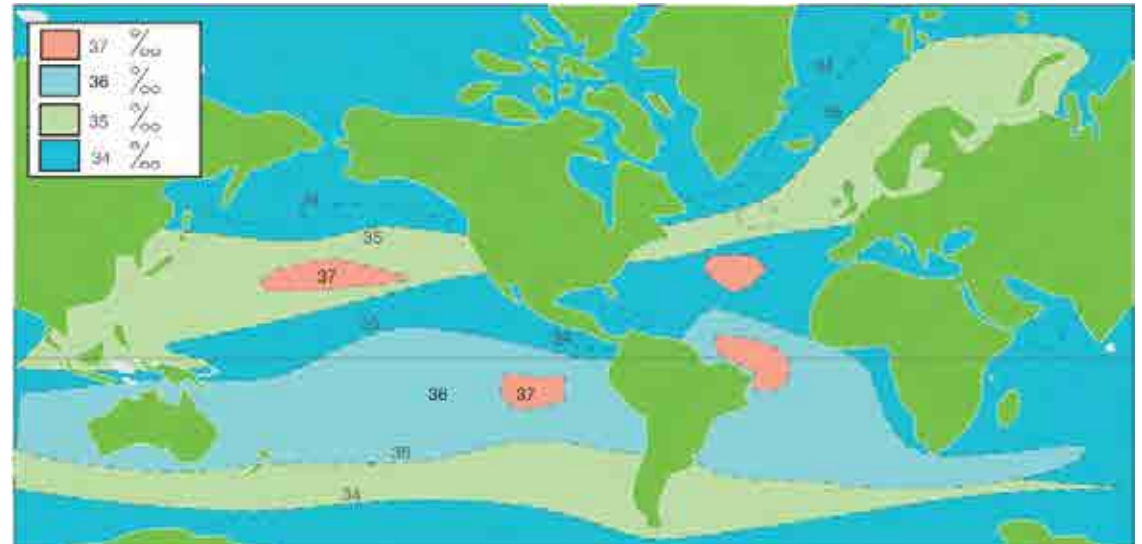
Salinity

Most coral reefs occur in regions where salinity is stable and in the range of 34-36 ppt (Parts per thousand).

Salinity fluctuations are commonly caused by heavy rainfall, cyclones and flood runoff. Low salinity causes hypo-osmotic stress and causes tissue swelling, stops photosynthesis and can cause coral bleaching.

Few species are tolerant of salinity fluctuations, but more are tolerant of gradual change.

Some coral species can survive in salinities as low as 23 ppt or as high as 42 ppt.



World salinities

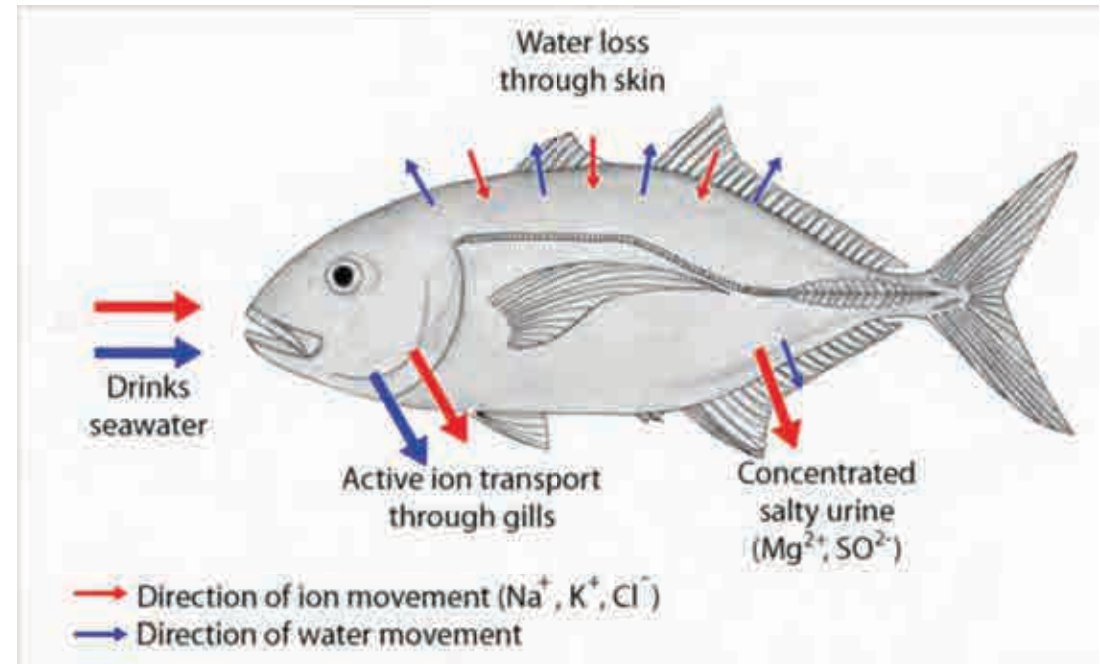
Illustration Bob Moffatt

Corals, like most marine invertebrates, are osmo-conformers -

- their tissues generally have the same salt content as the surrounding seawater, but
- they can adjust their water content during salinity fluctuations.

Note:

Fish actively control the salt concentration of their tissues.



Osmoregulation in a fish

Image: Kare Kare Creative commonsCC3.0

https://en.wikipedia.org/wiki/File:Osmoregulation_Carangoides_bartholomaei_bw_en2.png#/media/File:Osmoregulation_Carangoides_bartholomaei_bw_en2.png

Temperature

The distribution of corals reefs is restricted to warm waters in the tropical zone near the Equator.

This distribution is extended by warm currents and reduced by cold currents, upwellings and river runoff (eg. West coast of South America and Africa)

The diversity of coral species is higher in warmer waters, and the number of species present decreases toward the poles.

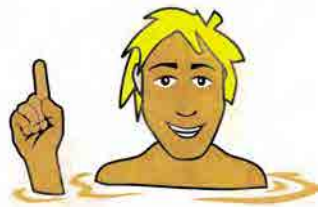


Most corals occur within the 20°C isotherm (blue)

Image: Creative Commons https://commons.wikimedia.org/wiki/File:20_Grad_Isotherme.png#filelinks

Low temperatures reduce coral feeding and growth.

- Many corals cannot tolerate water temperatures as low as 18°C or cold air temperatures.
- In cooler areas some corals survive, but cannot form a reef.



Some corals can withstand extremes as low as 16°C and as high as 34°C, but most are found in water 18°C- 30°C.



Viewfinder

Coral reefs occur in water that is already close to their upper limits of heat tolerance.

- Increased water temperature that is excessive or sustained for too long can cause coral bleaching.
- Corals can recover if conditions return to normal soon enough.

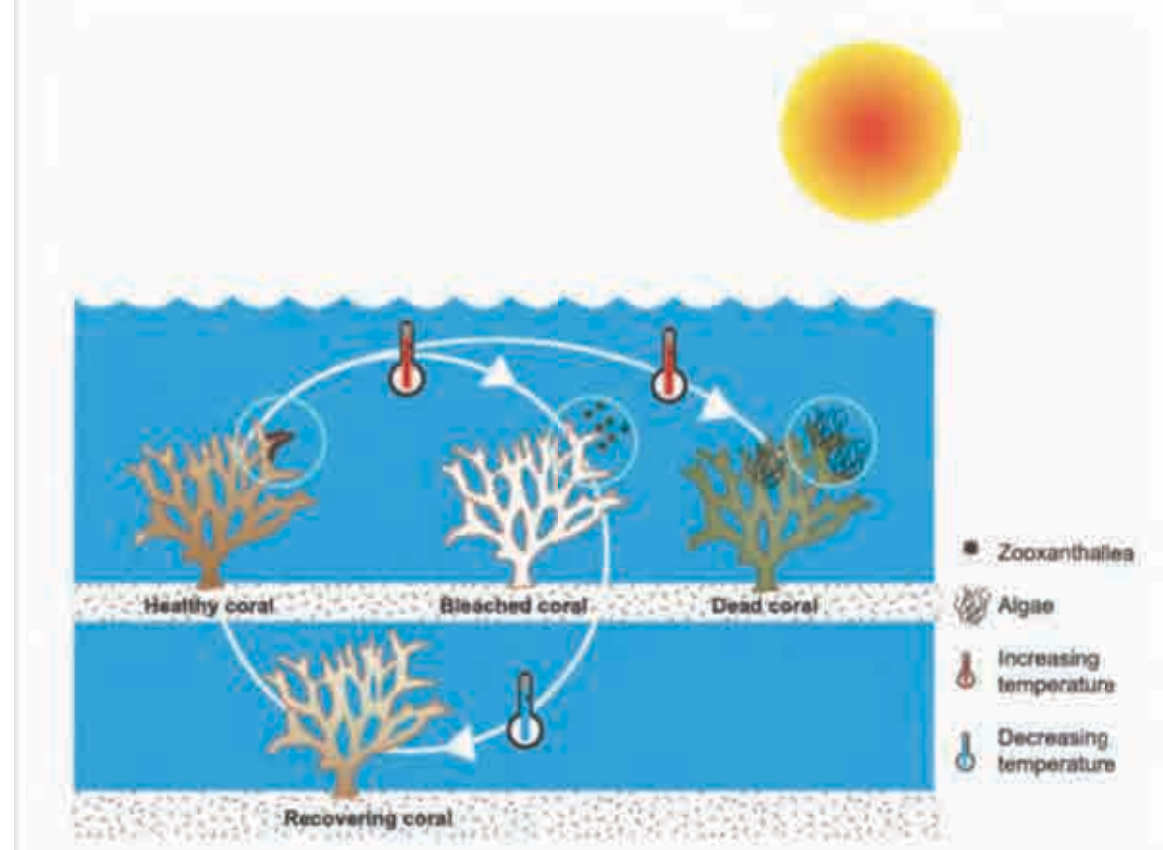


Image: CoralWatch, <http://vm-203-101-224-174.qld.nectar.org.au/wordpress/wp-content/uploads/2018/06/bleaching-processes.jpg>

Read more about coral bleaching on the CoralWatch website here:

<https://coralwatch.org/index.php/about/coral-bleaching/>

Substrate and sediment

Coral larvae (planulae) need a hard substrate on which to attach and grow.

- They will not settle on sand or on substrates covered in bacterial slime.
- Adult corals can remove sediment but it uses energy, and blocks light for photosynthesis.



YouTube video by Reef Patrol,
available at:

www.youtube.com/reefpatrol

How and why do some corals “sneeze”?

Muddy areas, such as those found in the inshore coastal zone, are unsuitable as the water is too turbid, and the sediment too soft.

- Coarse grained sandy areas are also unsuitable as the sediment is washed about by waves and currents and can bury corals.

Research into artificial substrates used for coral reef restoration is investigating

- Physical factors such as:-
 - Composition, texture, colour,
- AND
- Chemical and design factors such as
 - profile, shelter, shading, size, and stability.¹



Coral nubbins planted in non-toxic cement

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

1. Spieler, R., Gilliam, D., & Sherman, R. (2001). ARTIFICIAL SUBSTRATE AND CORAL REEF RESTORATION:WHAT DO WE NEED TO KNOW TO KNOW WHAT WE NEED. *BULLETIN OF MARINE SCIENCE*, 69(2:), 1013–1030,.

Retrieved from:

https://www.researchgate.net/publication/233650162_Artificial_substrate_and_coral_reef_restoration_What_do_we_need_to_know_to_know_what_we_need

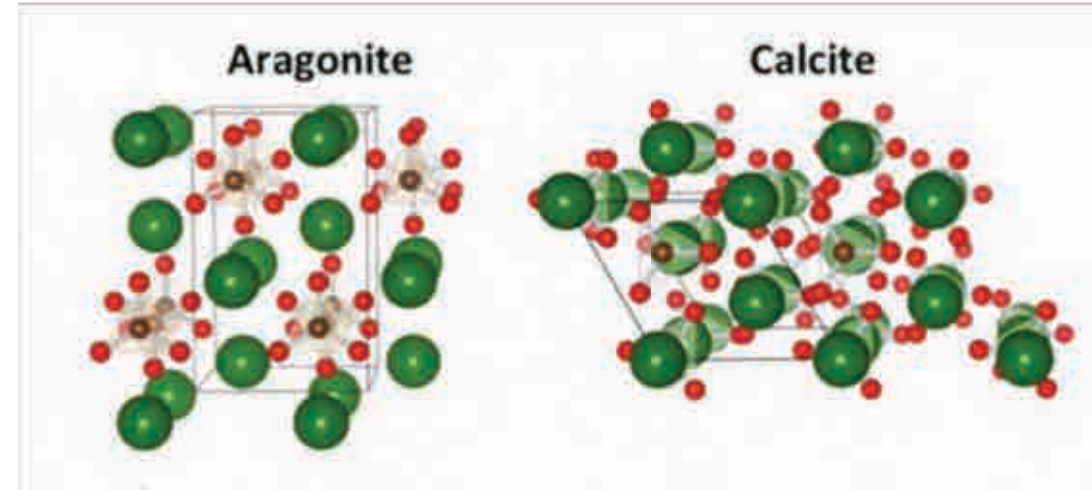
Aragonite

Calcium carbonate (CaCO_3) crystals can have several different forms.

Reef building corals deposit CaCO_3 in the form of **aragonite**.

Other marine organisms such as pteropods, macroalgae and molluscs also deposit aragonite.

Others, such as calcareous algae, echinoderms, crustaceans and forams deposit CaCO_3 as calcite. Aragonite structure is stronger and more resistant to stress.



Crystal structure of aragonite and calcite

Image from: Soldati, A. L. *et al.* Element substitution by living organisms: the case of manganese in mollusc shell aragonite. *Sci. Rep.* **6**, 22514; doi: 10.1038/srep22514 (2016).

If the carbonate saturation state is too low (there is not enough CaCO_3 dissolved in the seawater), carbonate remains in solution and cannot be deposited.

Aragonite saturation (Ω_{arag}) depends on the concentrations of Calcium Ca^{2+} and Carbonate CO_3^{2-} ions.

Aragonite saturation has at least the same impact on coral reef distribution as temperature.¹



1. 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

Nitrate and phosphate levels

Nitrogen (N) and phosphorus (P) are essential nutrients for primary productivity by corals, macroalgae and seagrass.

- Coral reefs exist in very nutrient-poor water, yet support very high levels of primary productivity. This is possible due to highly efficient recycling of nutrients.
- Corals can tolerate higher nutrient levels, but increased nutrients increase macroalgae and phytoplankton growth, which in turn compete for space and light with coral.



A coral reef overgrown with algae

Image: J Davidson. Copyright Commonwealth of Australia (GBRMPA) 125903

Suitable reef habitat flow chart

A flow chart presented by Guan Y, Hohn S, & Merico A (2015)

T = temperature

S = salinity

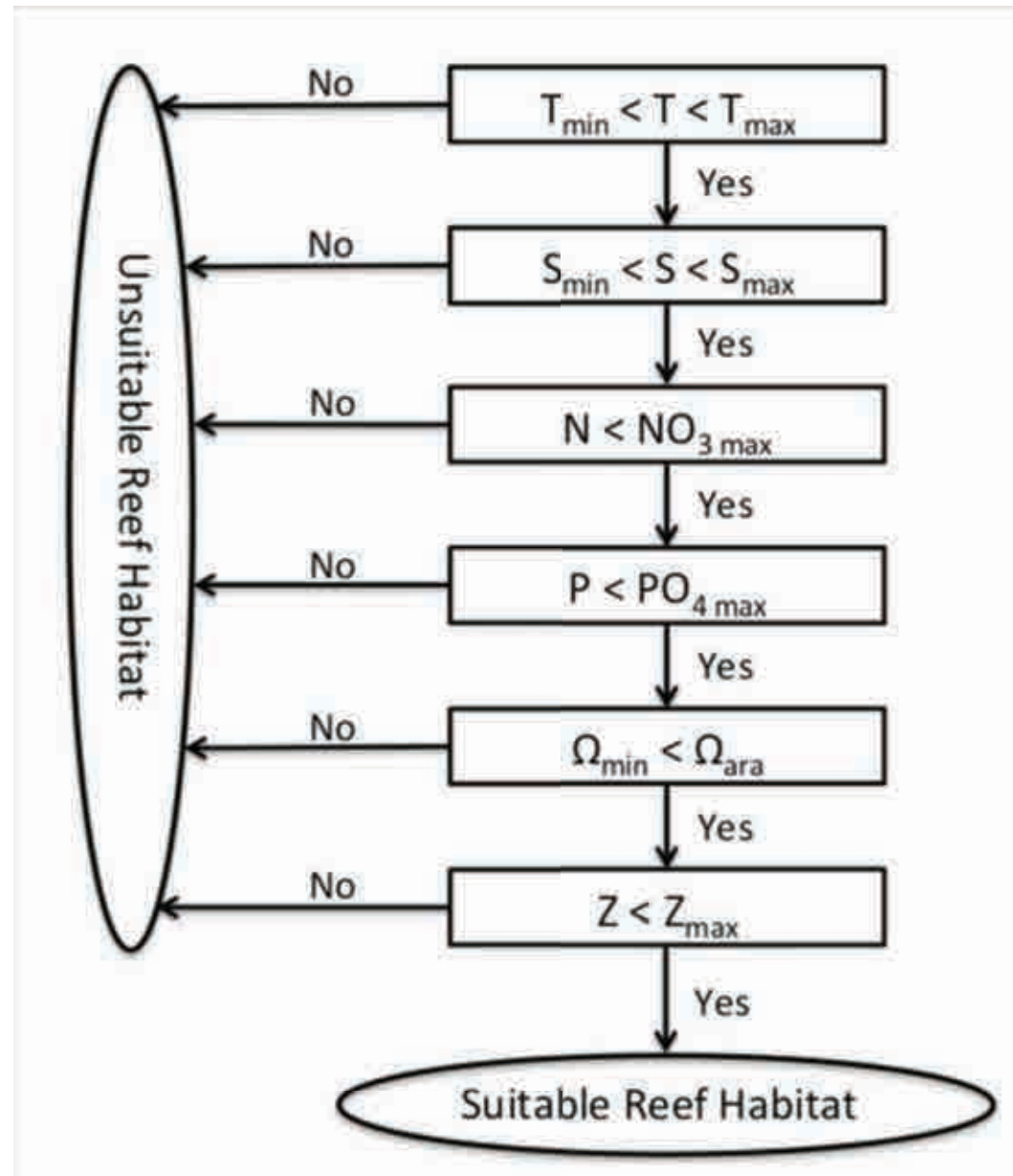
N = nitrate

P = phosphate

Ω = aragonite

Z = depth (based on light intensity)

Can you use the chart to predict whether an area near you is a suitable reef habitat?

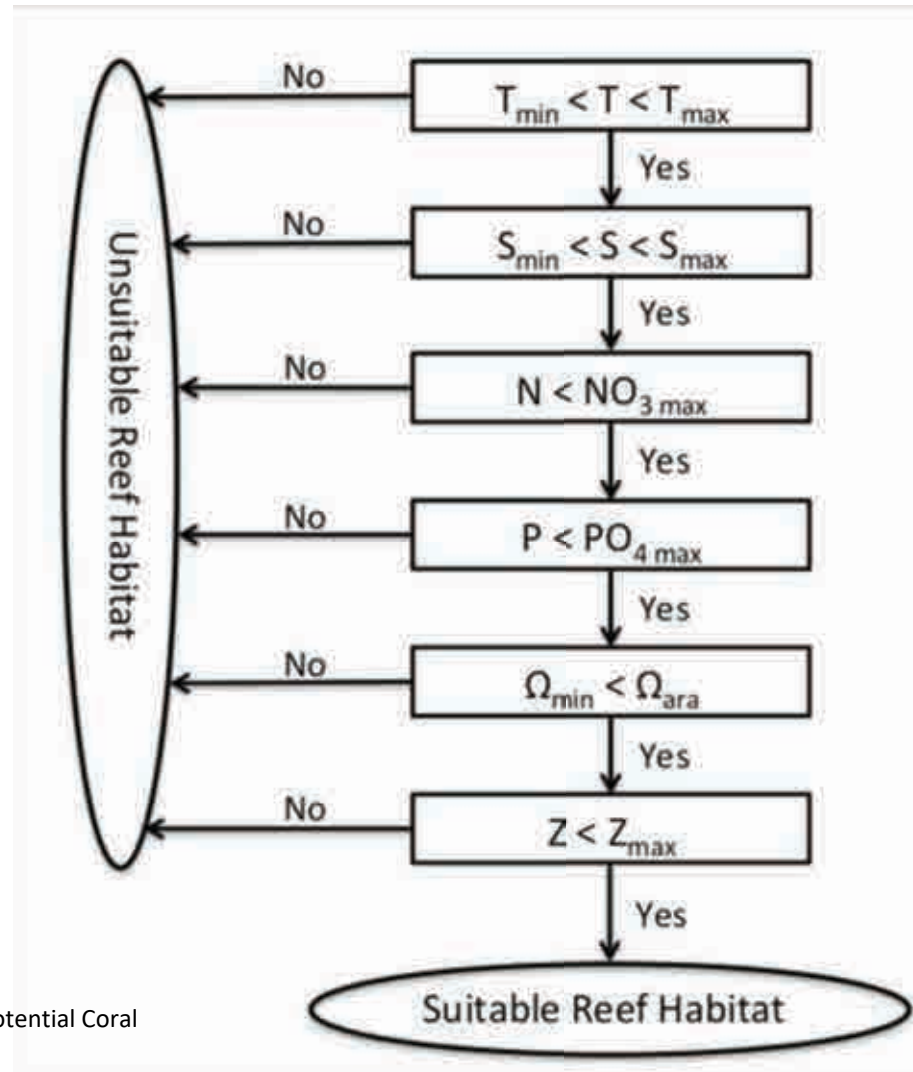


This flow chart works from the top:

Is temperature in the acceptable range?

Yes- go to salinity,

No- unsuitable habitat



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

Abiotic statistics from coral reef communities

A summary

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($\mu\text{mol/L}$)				
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

Kleypas *et al* defined the environmental tolerance limits of coral reef distribution.

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

Video review

Environmental requirements for carbonate coral reefs

<https://www.youtube.com/watch?v=de8RASG5WQU>



UQ x TROPIC101x 2.2.4 Environmental requirements for carbonate coral reefs

YouTube video available: <https://www.youtube.com/watch?v=de8RASG5WQU>

TO71 DRAFT SLIDE 34

Question

Q 1. Which of these factors affect coral distribution?

- aragonite
- dissolved oxygen
- light availability
- nitrates and phosphate levels
- salinity
- substrate,
- temperature

Q2. How have these factors changed over long time scales?



Q3. Complete the following summary table for this topic.

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		

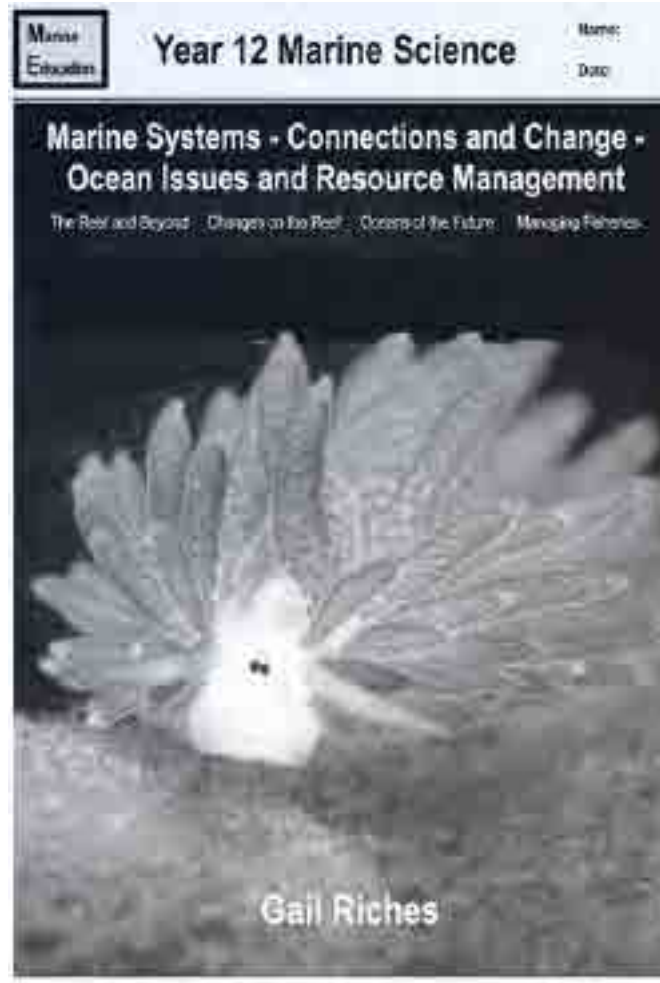
Worksheet

Paleo- perspectives

by

Gail Richie

www.marineeducation.com.au



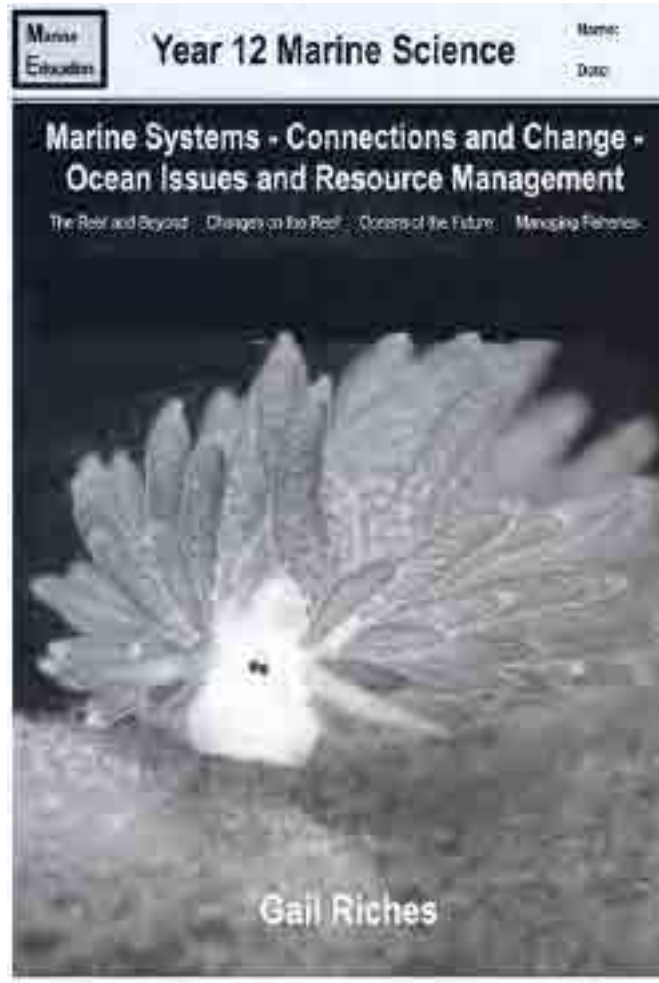
Worksheet

What is aragonite?

by

Gail Richie

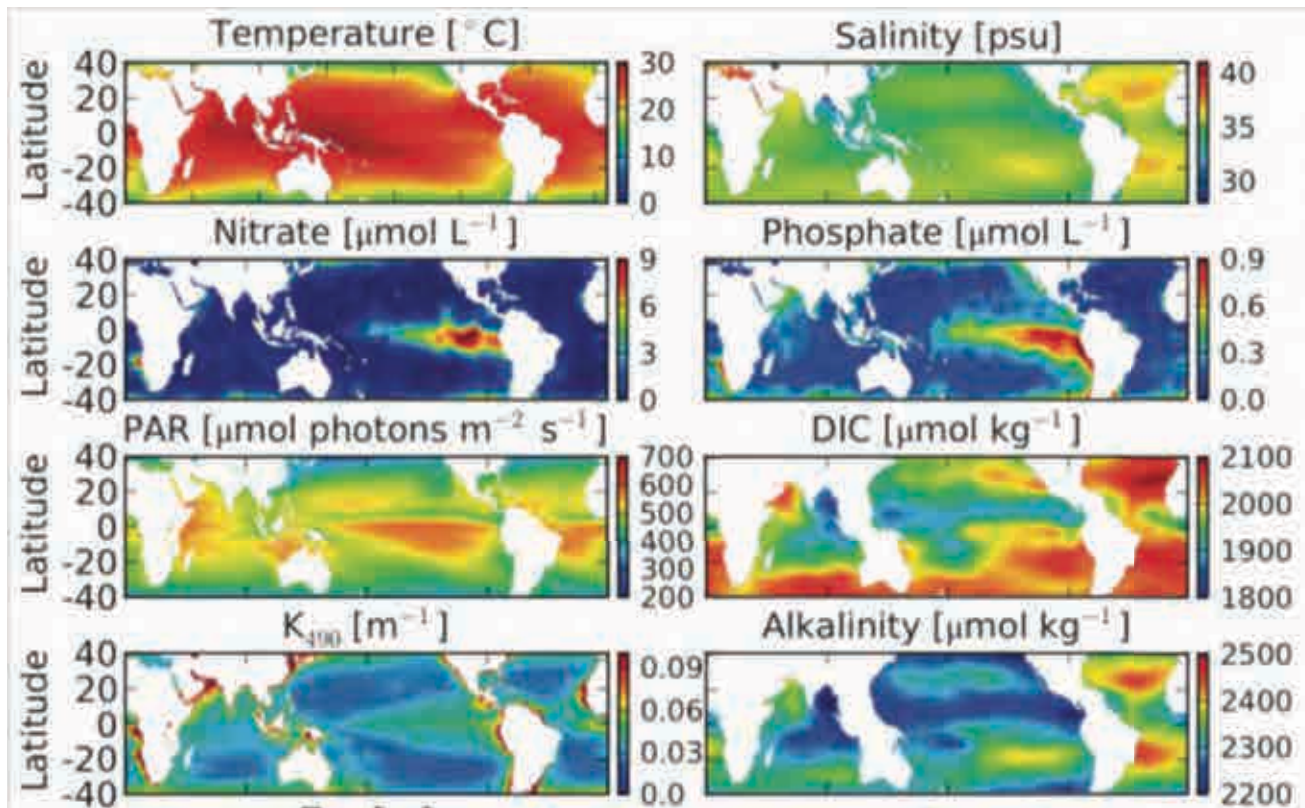
www.marineeducation.com.au



Extension

Study the graphs below.

How can you tell that oxygen depends on salinity and temperature?



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

T072 Coral geological record

A tropical beach scene at low tide. The foreground is dominated by intricate, wavy patterns of coral reefs, showing various shades of brown, tan, and green. The water is shallow and clear, reflecting the sky. In the middle ground, two traditional wooden boats with thatched roofs are anchored. The background shows a calm sea meeting a sky with soft, wispy clouds, suggesting a sunset or sunrise. The overall atmosphere is serene and natural.

Adam Richmond

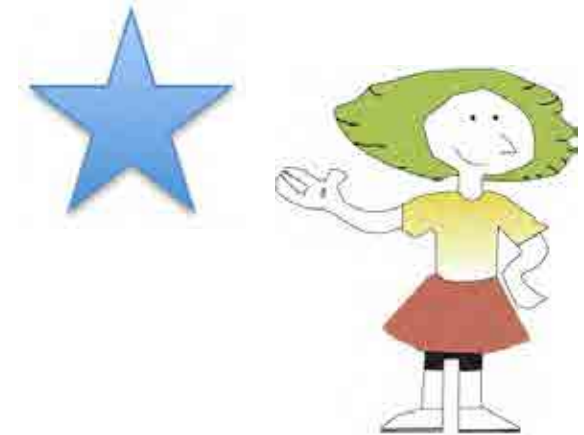
T072 DRAFT SLIDE 1

Syllabus statement

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

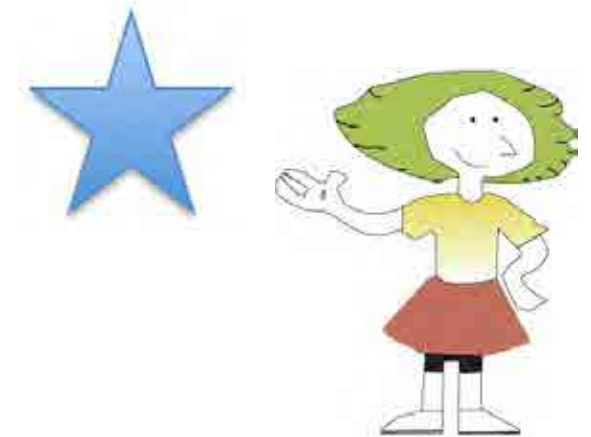
Recall

that corals first appeared within the geological record over 250 million years ago but not in Australian waters until approximately 500 000 years ago.



Recall

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



Objectives

Either

In a conversation, recall

- when Scleractinian corals first appeared in the geological record and
- when corals reefs appeared in Australian waters.

OR

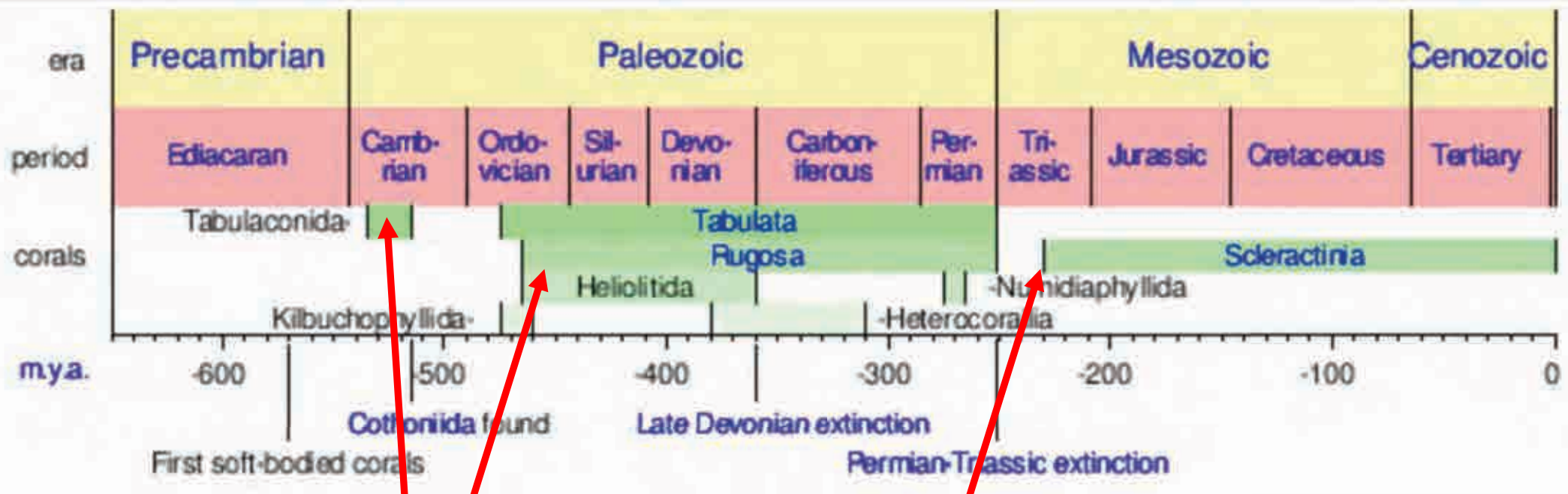
On a multiple choice test question, recall when corals first appeared

- on Earth and
- in Australia



Coral timeline

Geological records show when corals first appeared on Earth



Several classes of coral emerged over 500 million years ago in the fossil record but are now extinct.

Modern reef-building, stony (Scleractinian) corals first appeared ~ 250 million years ago

Two excellent figures showing the divergence of animal life and corals can be found at

<https://www.researchgate.net/publication/51830168>

[The Cambrian Conundrum Divergence and Later Ecological Success in the Early History of Animals/figures?lo=1](#)

A high res version is available here:

<http://science.sciencemag.org/content/sci/suppl/2011/11/22/334.6059.1091.DC1/Erwin.SOM.pdf>



Geological record

Stratigraphy is a branch of geology that examines layers of rock (or strata).

Fossils in a devonian reef in Northern Territory

Bob Moffatt



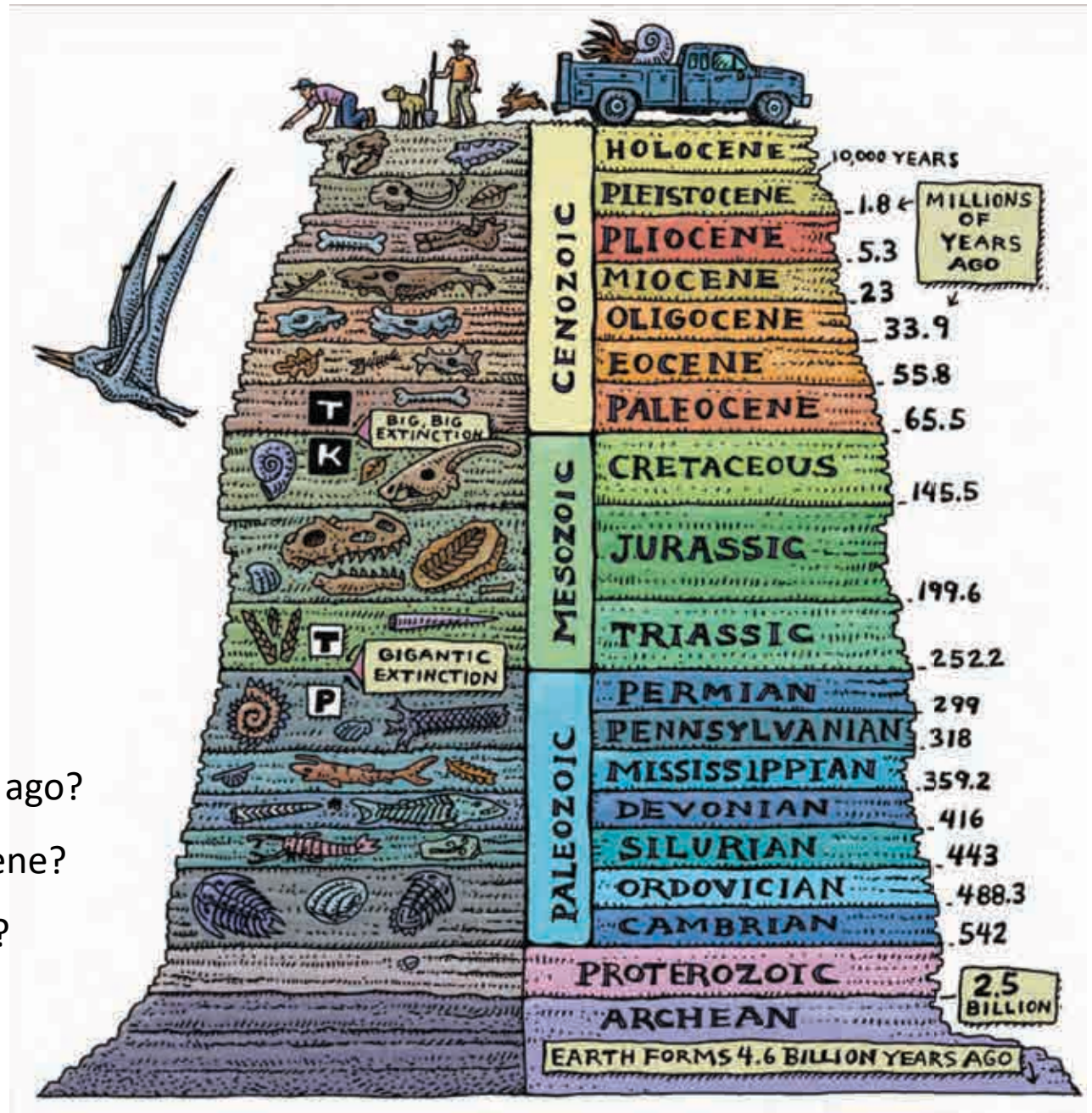
The relative age of rocks and fossils can be determined by their placement in these strata.

Radiometric dating can determine the absolute age of strata by measuring the amount of radioactive isotopes (such as carbon dating).

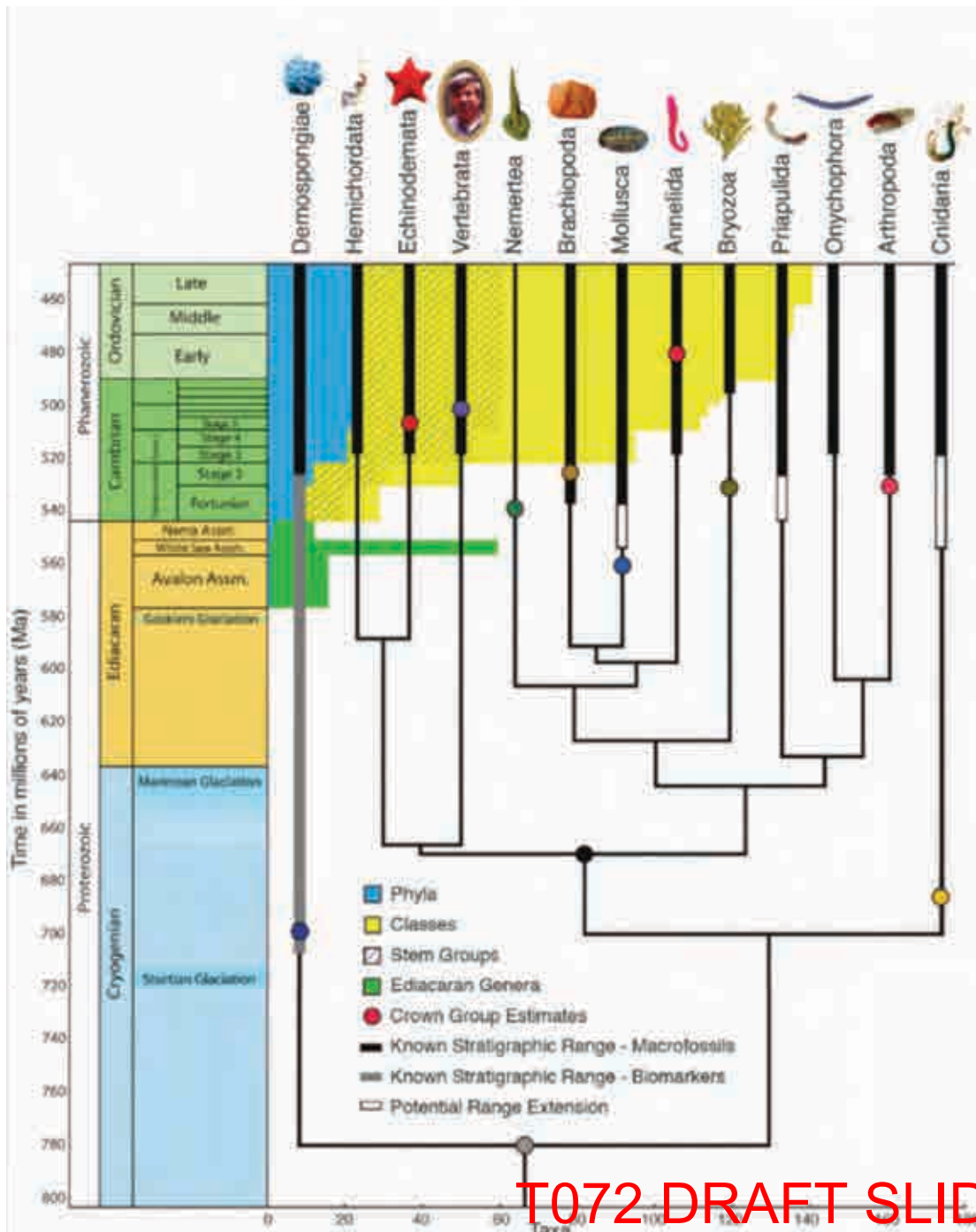
What period was it 200 million years ago?

What period came before the Holocene?

When was the PT gigantic extinction?



Artwork: reproduced with permission © Ray Troll 2019



An evolutionary tree of Marine life

Download the full text article featuring this image here:

<http://faculty.jsd.claremont.edu/dmcfarlane/bio145mcfarlane/PDFs/cambrian%20conundrum.full.pdf>

From [Erwin, D., Laflamme, M., Tweedt, S., Sperling, E., Pisani, D., & Peterson, K. (2011). The Cambrian Conundrum: Early Divergence and Later Ecological Success in the Early History of Animals. *Science*, 334(6059), 1091-1097. doi: 10.1126/science.1206375]. Reprinted with permission from AAAS

Use the downloaded image to study this graphic carefully.
Can you locate when the coral - *Acropora* appeared on Earth?



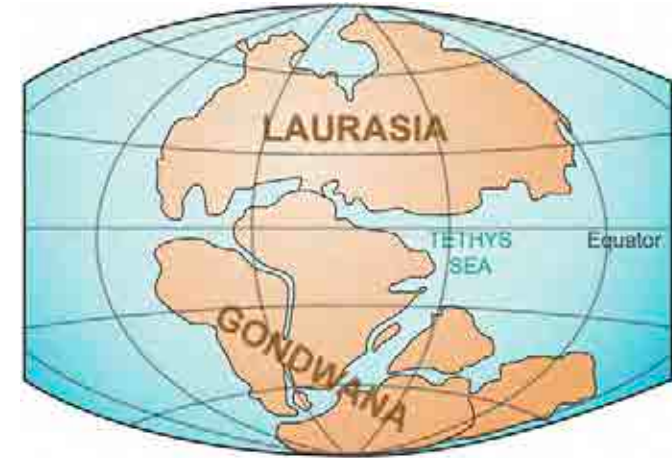
From [Erwin, D., Laflamme, M., Tweedt, S., Sperling, E., Pisani, D., & Peterson, K. (2011). The Cambrian Conundrum: Early Divergence and Later Ecological Success in the Early History of Animals. *Science*, 334(6059), 1091-1097. doi: 10.1126/science.1206375]. Reprinted with permission from AAAS

The Great Barrier Reef is relatively young at 500,000 years. When reef-building corals evolved, Australia was part of Gondwanaland, in waters too cold for coral reefs.

While corals have existed on the Great Barrier Reef for as long as 25 million years, they didn't form large structured reefs like those we see today.

The earliest record we have of complete reef structures (like those we see today) is from 600 000 years ago. ²

Based on deep drilling samples, the best estimate for the timing of the onset of full reef conditions at the Northern section of the Great Barrier Reef (Ribbon Reef 5) is 600 +/- 280 thousand years ³.



Gondwanaland 200 mya

Image: User:LennyWikidata [CC BY 3.0 (https://creativecommons.org/licenses/by/3.0)], via Wikimedia Commons

2 Great Barrier Reef Marine Park Authority (2006). "A "big picture" view of the Great Barrier Reef" (PDF). *Reef Facts for Tour Guides*. Accessed: https://web.archive.org/web/20070620013057/http://www.gbrmpa.gov.au/_data/assets/pdf_file/0017/12437/Reef-Facts-01.pdf


3. International Consortium for Great Barrier Reef Drilling. (2001). New constraints on the origin of the Australian Great Barrier Reef: Results from an international project of deep coring. *Geology*, 29(6), 483-486. doi: 10.1130/0091-7613(2001)029<0483:ncotoo>2.0.co;2

Corals also suffered a series of mass extinctions as shown in the diagram opposite.

You can read more in the Global reef project article at

<http://globalreefproject.com/coral-reef-history.php>

GEOLOGICAL TIME SCALE

Era	Geological period	Approx time	Period of coral reef presence
Cenozoic	Holocene	05 mya	 First corals in Australia Coral growth continental shelf
	Oligocene	18 mya	
	Eocene	35 mya	
Mesozoic	Paleocene	55 mya	Specialisation of mammals, sediments flowed from rivers onto continental shelves Australian plate still moving north and fracturing Mass extinction Expansion of mammals, coral sea forms
	Cretaceous	70 mya	
	Jurassic	100 mya	
Paleozoic	Triassic	200 mya	Dinosaurus became extinct, Australia still joined to Antarctica First mammals and birds Mass extinction First Dinosaurus Expansion of primitive reptiles Mass extinction Expansion of sharks and fish First Insects Mass extinction First land plants
	Permian	230 mya	
	Carboniferous	285 mya	
	Devonian	350 mya	
Precambrian	Silurian	400 mya	First fish First corals on Earth First marine invertebrates The beginning of life in the Sea
	Ordovician	430 mya	
	Cambrian	500 mya	
	Precambrian	4600 mya	

Bob Moffatt

Questions

Q1. When did Scleractinian corals appear in the fossil record?

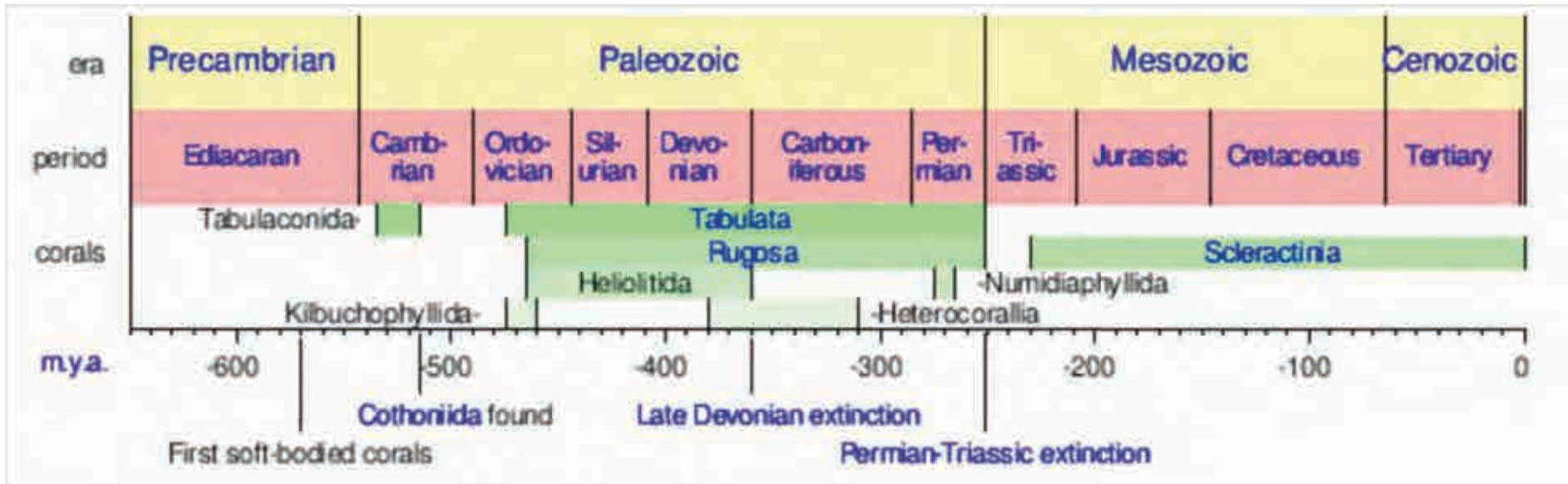


Image credit: <https://i2.wp.com/upload.wikimedia.org/wikipedia/en/timeline/2660254dde951a41506bd0471480c622.png?zoom=2>



Q2. Which of the following is *correct*?

Corals first appeared on Earth

- a) 1000 mya
- b) 500 mya
- c) 200 mya
- d) 100 mya

Q3. Which of the following is *correct*?

Corals first appeared in Australia

- a) 10,000 years ago
- b) 100,000 years ago
- c) 500,000 years ago
- d) 1,000,000 years ago



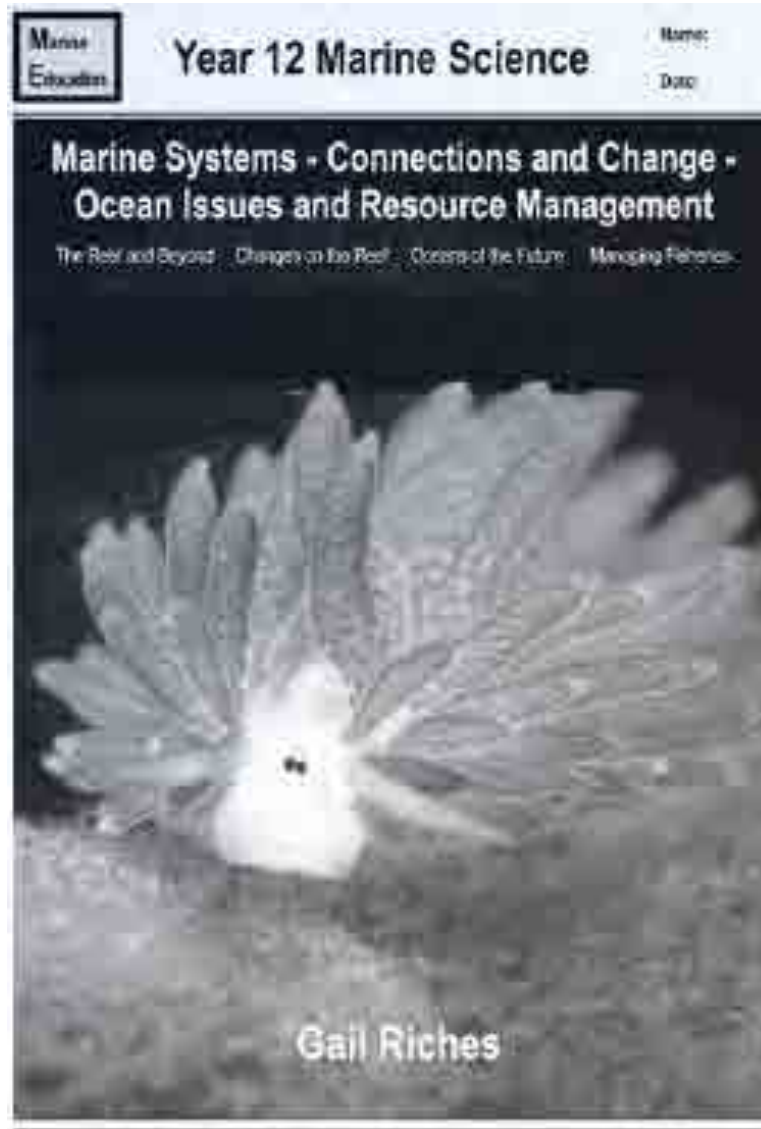
Worksheet

Written in Stone

by

Gail Richie

www.marineeducation.com.au



Further activity

Worksheet –

Tracking Change

by CoralWatch

Marine Systems Connection and
Change



T073 GBR and sea level change

A photograph of a tropical beach at low tide. The foreground is dominated by a vast expanse of wet sand, intricately patterned with shallow, winding channels of water that catch the light. In the middle ground, two boats are visible on the water. The larger boat on the left has a canopy and appears to be a fishing vessel. The smaller boat on the right is a traditional outrigger canoe. The background shows a clear blue sky with a few birds flying. The overall scene is serene and captures the natural beauty of a coastal environment.

Adam Richmond

T073 DRAFT SLIDE 1

Syllabus statement

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

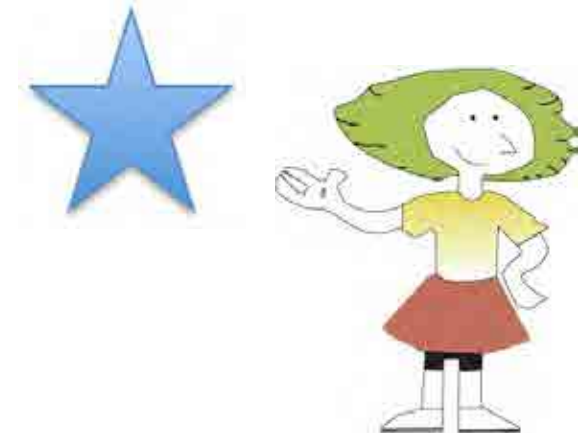
Recognise

that the Great Barrier Reef of today has been shaped by changes in sea levels that began over 20 000 years before present (BP) and only stabilised 6500 years BP.



Recognise (e.g. features)

- identify or recall particular features of information from knowledge;
- identify that an item, characteristic or quality exists;
- perceive as existing or true; be aware of or acknowledge



Objectives

In a sentence,

- Recall key dates when sea level change occurred on the Great Barrier Reef.
- Use a set set of diagrams to show how sea level changes shaped the Great Barrier Reef.



65 million years of climate change

The Earth has been gradually cooling by about 20°C in polar regions for the past 65 million years with lots of fluctuations.

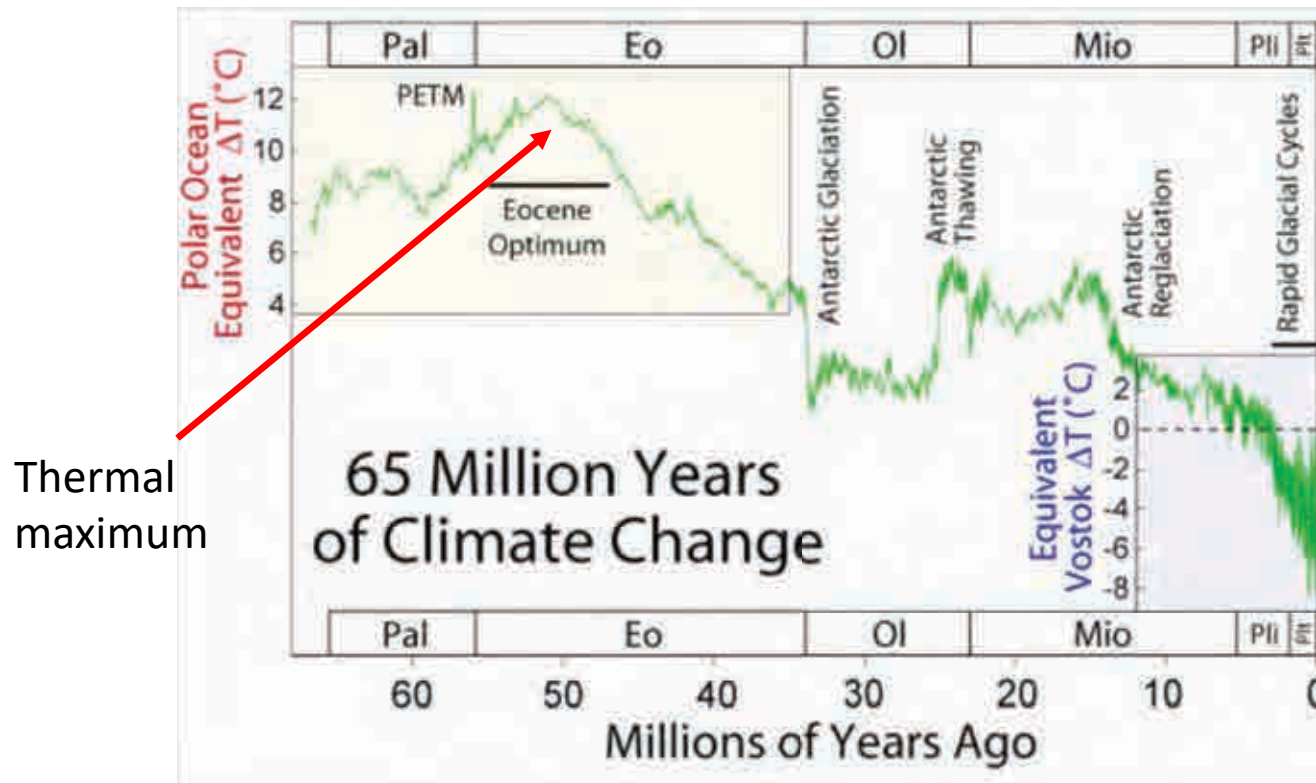


Image: Robert A. Rhode, Global warming Art project. CC 3.0 ,
https://upload.wikimedia.org/wikipedia/commons/1/1b/65_Myr_Climate_Change.png

450 thousand years of ice ages

The Earth has also been subject to a series of ice ages over the past 450,000 years.

Ice Age Temperature Changes

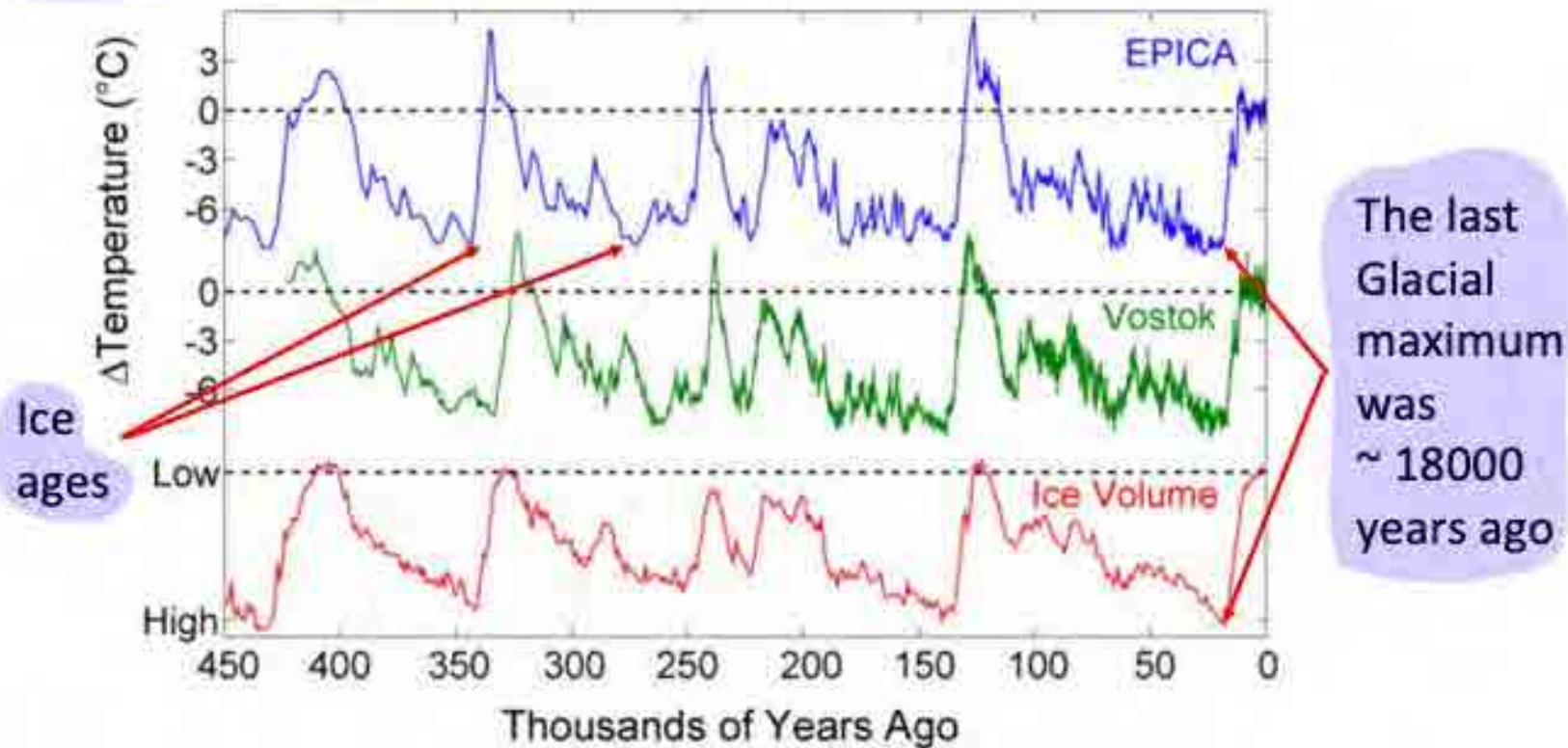
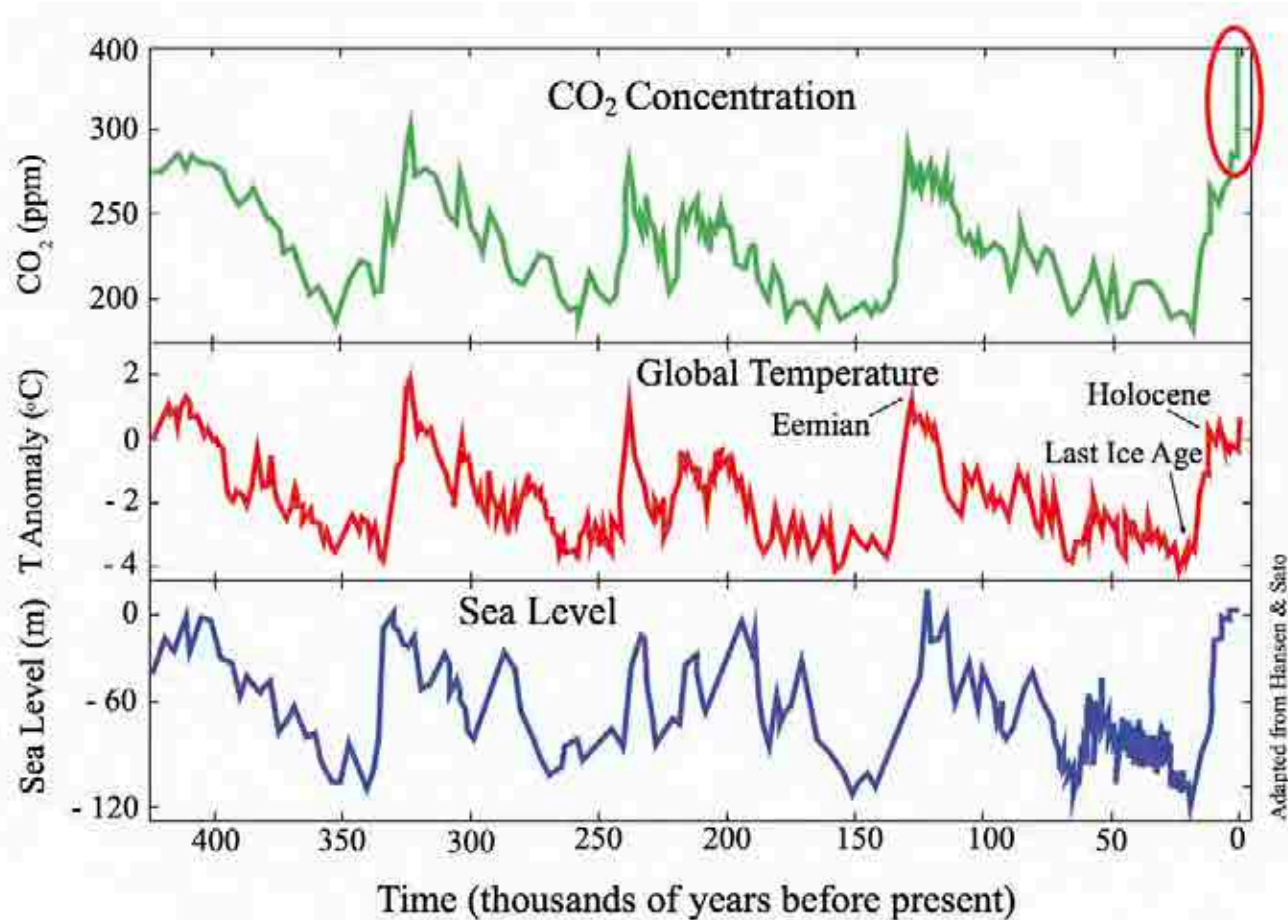


Image: Robert A. Rhode, Global warming Art project. CC 3.0
https://upload.wikimedia.org/wikipedia/commons/f/f8/Ice_Age_Temperature.png

T073 DRAFT SLIDE 6

Global temperatures and sea level

This graph of temperature, CO₂ concentration and sea level, clearly shows the correlation between sea level and global temperature.



When temperatures increase, polar ice stores melt, and sea levels rise.

Sea levels have oscillated several times by approximately 100 metres.



The Sydney harbour bridge is about 100 meters high

By Adam.J.W.C. - Own work, CC BY 3.0,

<https://commons.wikimedia.org/w/index.php?curid=5846929>

T073 DRAFT SLIDE 8

There are some sea level experiments that you can try that demonstrate the effect melting land and sea ice and thermal expansion causing sea level rise.

Experiments:

<https://www.jpl.nasa.gov/edu/teach/activity/whats-causing-sea-level-rise-land-ice-vs-sea-ice/>

<https://www.jpl.nasa.gov/edu/teach/activity/thermal-expansion-model/>



Modelling melting sea-ice

Measuring thermal expansion

Image: Adam Richmond

T073 DRAFT SLIDE 9

140 thousand years of sea level change

Sea levels dropped by 120 metres as ice accumulated up until the last glacial maximum 20 000 years ago (A)

During the last 20 000 years melting ice has increased sea levels by 10-45mm per year (B)

Sea levels have been relatively stable for the last 7-8000 years (C)

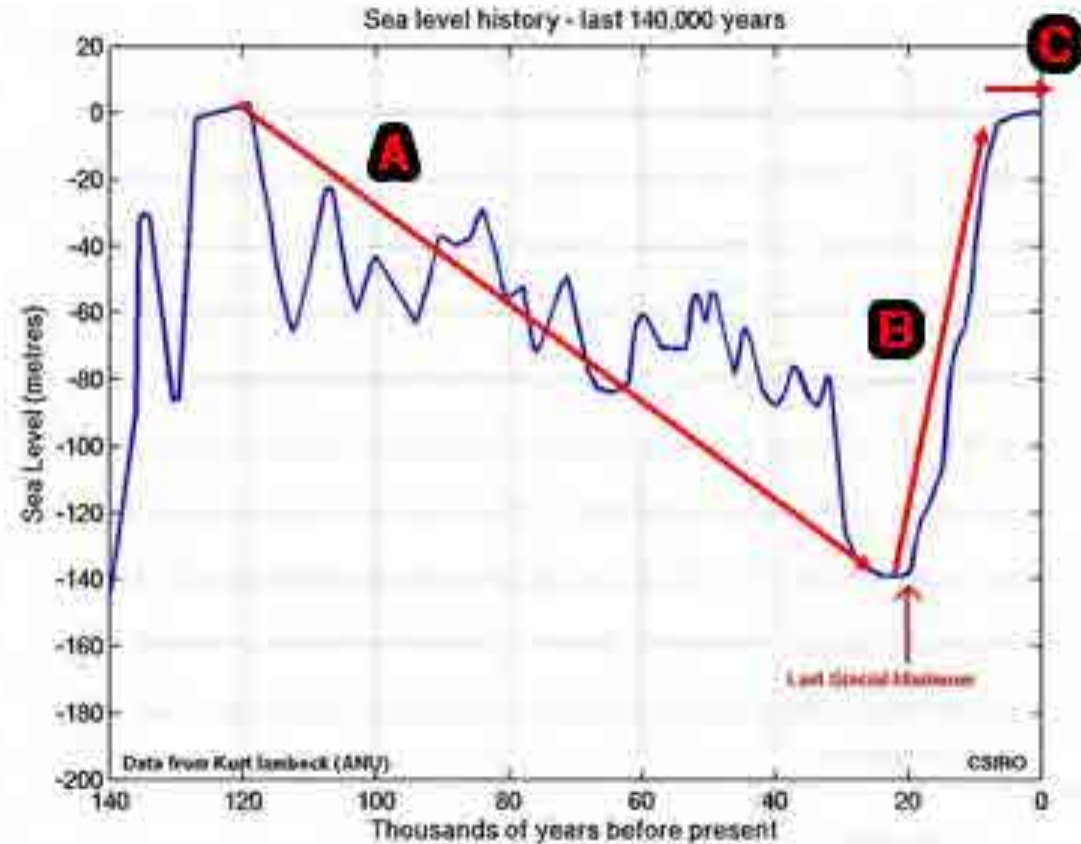


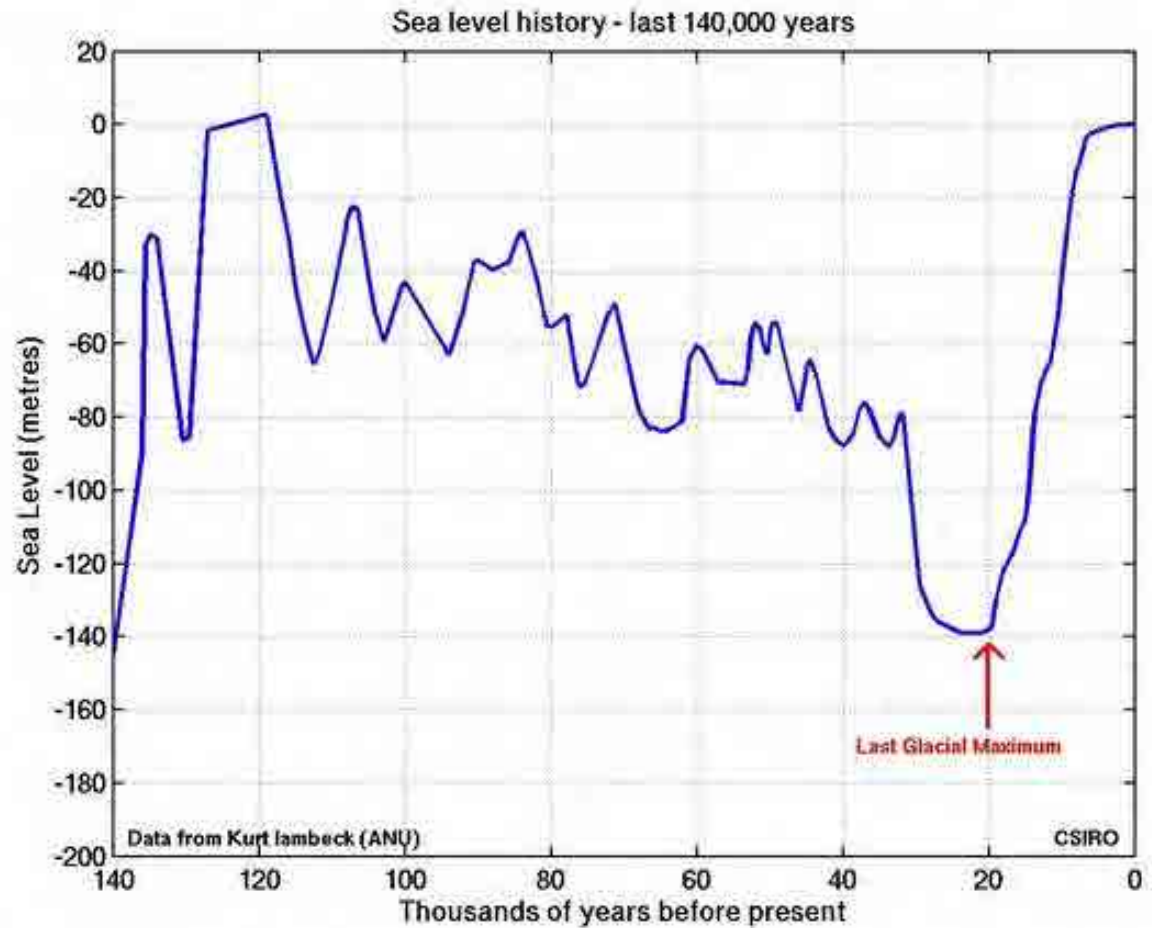
Image: Rise and fall of sea level in Nauru area over a nodal cycle
Figure on ResearchGate.
Available from:
https://www.researchgate.net/figure/Sea-level-changes-over-the-last-140-thousand-years-CSIRO-2010_fig2_262962940

Australian sea levels rose an extra 1-3 m 7000-2000 years ago due to the extra weight of water on the continental shelf.

Questions:

What were sea levels 20 000 years ago?

60 000 years ago?



Reference:

<https://coastadapt.com.au/how-climate-and-sea-level-have-changed-over-long-term-past>

Watch this

The end of second Ice age almost fatal to Great Barrier Reef.

Video link:

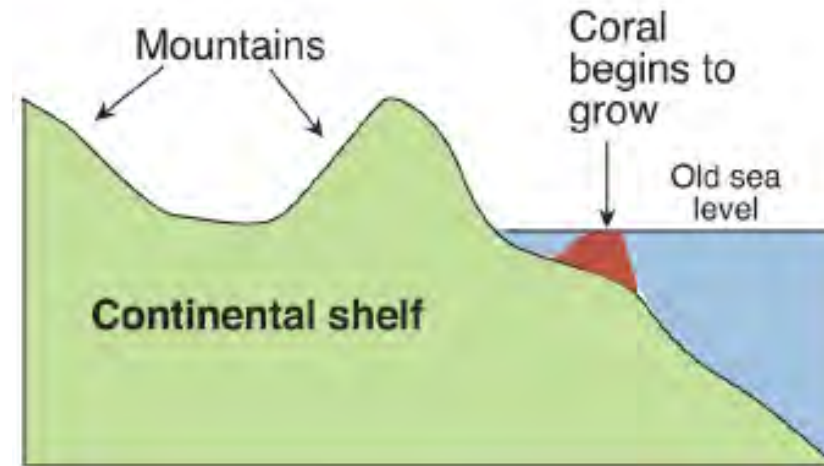
<https://www.youtube.com/watch?v=5s3bqYvNxlo&feature=youtu.be>



Sea level changes and the Great Barrier Reef

Coral started to grow on the continental shelf off the Australian coast 18 million years ago, as Northern Australia was warm enough for corals to grow.

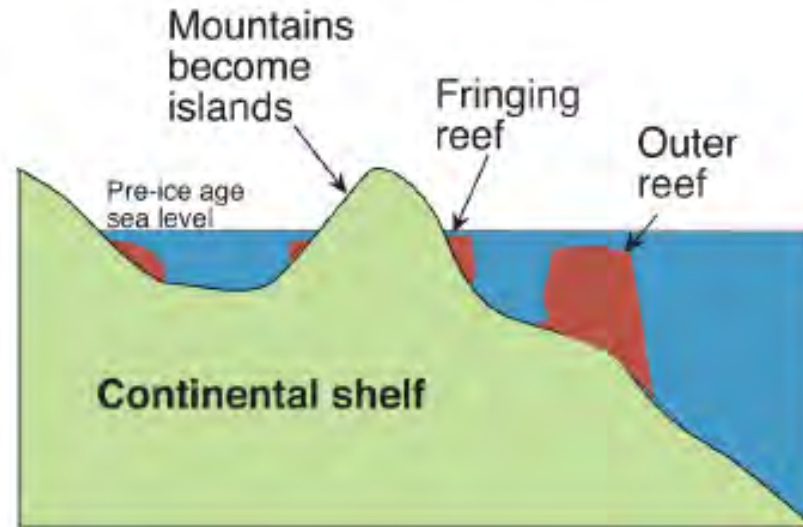
Southern reefs may be as young as 2 million years old.



Illustrations by Bob Moffatt, based on original drawings by GBRMPA

As sea levels gradually rose, corals were able to keep up with rising sea level.

Inland mountains and hills became continental islands, where fringing reefs grew.



Illustrations by Bob Moffatt, based on original drawings by GBRMPA



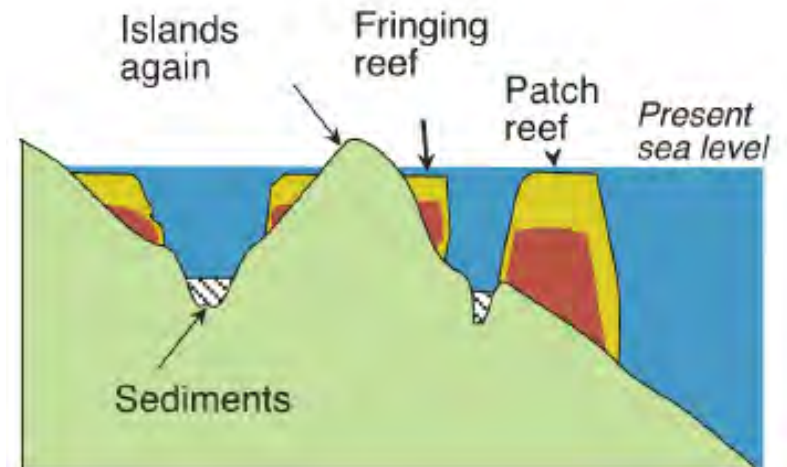
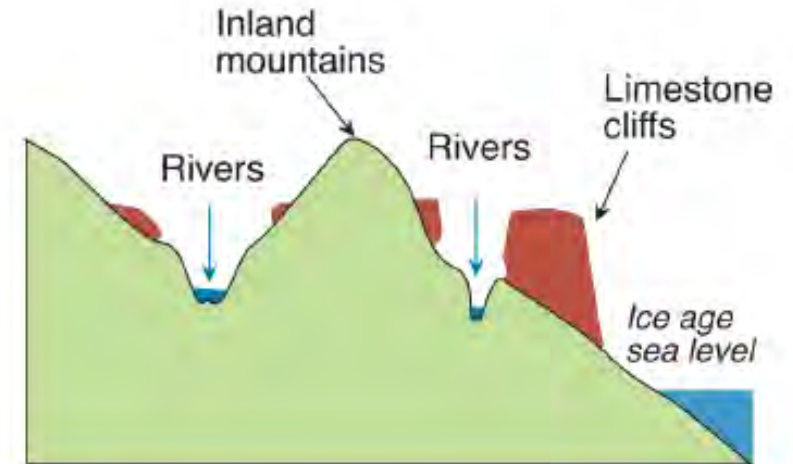
Image: eyeintim [CC BY 2.0 (<https://creativecommons.org/licenses/by/2.0>)], via Wikimedia Commons

Ice ages caused sea levels to drop, exposing the limestone reef skeleton to erosion by wind and weather.

Rivers moved sediment and carved depressions, sinkholes and caves.

As sea levels rose again, new corals settled on the skeletons of old ones and grew.

Mountains became islands and smaller hills became patch reefs.



Illustrations by Bob Moffatt, based on original drawings by GBRMPA

The last 20 000 years

The most recent ice age was ending 20 000 years ago.

Sea levels were at their lowest (Glacial maximum) approximately 18 000 years ago, at 120 metres lower than they are today.

Beaches would have looked much the same as they do today, but would have been further offshore- eg Townsville would have been 70 km from the beach.

Gunggandji people could have walked to Green Island and Fitzroy island from where Cairns is today.



Image: Patrick Nunn. Professor Geography, University of the Sunshine Coast

Since the last ice age sea levels have risen quite rapidly (in geological time). Coral were mostly able to keep up by growing upwards and landwards.

Several melt water pulses (MWP) occurred, when glaciers melted and sea levels rose faster than corals could grow, contributing to 5 reef-death events.

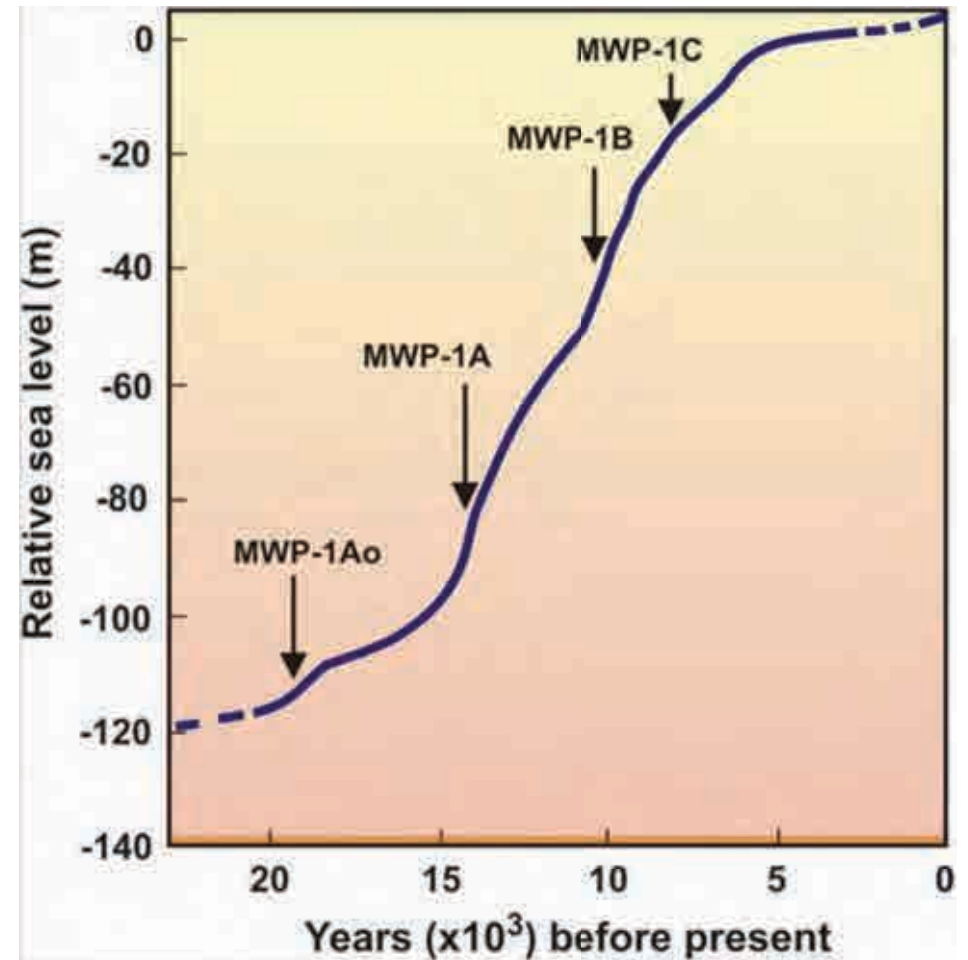
Sea levels have been relatively stable for the last 6500 years.

Erosion and sediment deposition has led to the development of extensive reef flats and lagoons as seen on the current day Great Barrier Reef.

Reference

<https://www.abc.net.au/news/science/2018-05-29/great-barrier-reef-coral-death-event-climate-change-sea-levels/9801634>

For a supporting article.



Sea levels over the past 20 000 years

Image: Courtesy NASA

Retrieved: https://www.giss.nasa.gov/research/briefs/gornitz_09/slr.jpg

Watch the summary video



<https://www.youtube.com/watch?v=PmRk4sMIFBE>

Creative Commons
Attribution license

UQ x TROPIC101x 2.3.0 A look back in time.

YouTube video available : <https://www.youtube.com/watch?v=PmRk4sMIFBE>
Creative Commons Attribution license

Questions

1. When did the Great Barrier reef start to look like it does today?
2. When did sea levels last stabilise?
3. What were sea levels like 20000 years ago?
4. How have sea level changes affected the development of the Great Barrier reef?



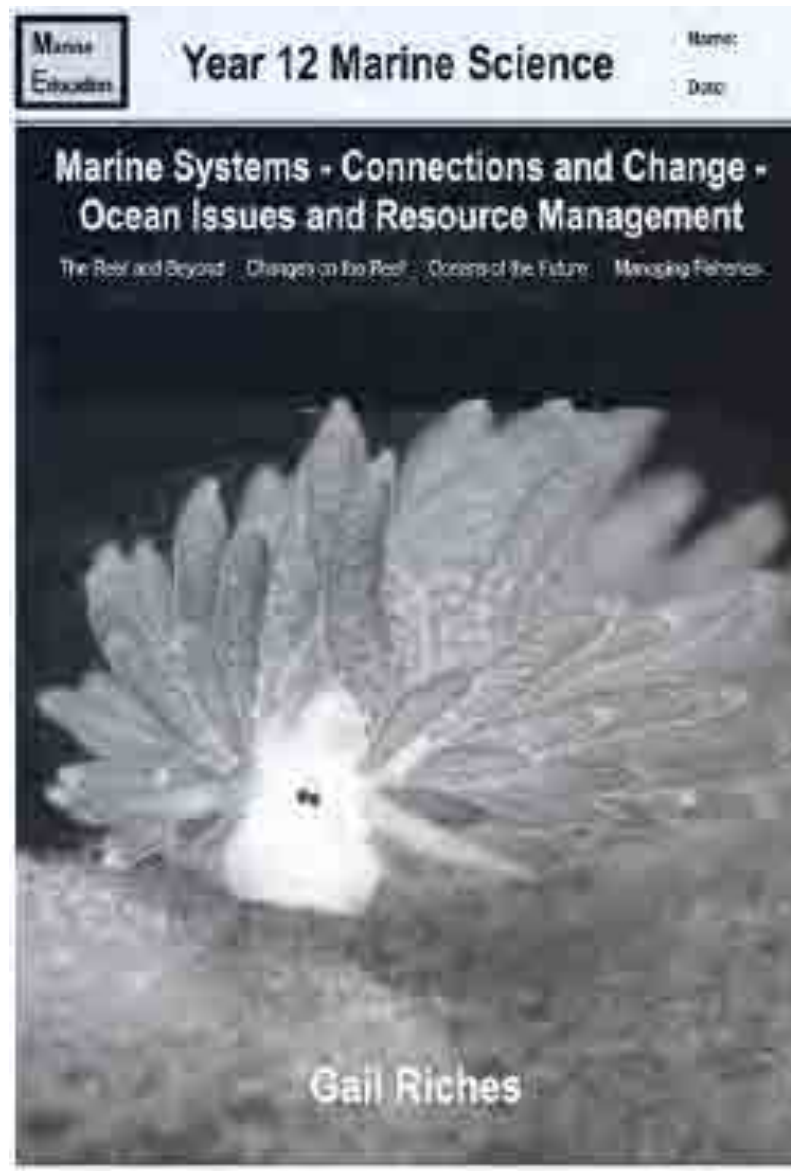
Worksheet

20,000 years ago

by


Gail Richie

www.marineeducation.com.au



T073 DRAFT SLIDE 20

Read further



In the beginning, as far back as we remember, our home islands were not islands at all as they are today. They were part of a peninsula that jutted out from the mainland and we roamed freely throughout the land without having to get in a boat like we do today. Then Garnguur, the seagull woman, took her raft and dragged it back and forth across the neck of the peninsula letting the sea pour in and making our homes into islands.

Ancient Aboriginal stories preserve history of a rise in sea level

January 13, 2015 6:29am AEST

Image and text from: <https://theconversation.com/ancient-aboriginal-stories-preserve-history-of-a-rise-in-sea-level-36010>

Check out this fully reproducible article from The Conversation:

<https://theconversation.com/ancient-aboriginal-stories-preserve-history-of-a-rise-in-sea-level-36010>

<http://tinyurl.com/k63anzm>

T073 DRAFT SLIDE 21

T074 Reef structures

A wide-angle photograph of a reef flat at low tide. The foreground is dominated by the rhythmic, wavy patterns of sand and shallow water. In the middle ground, two boats are visible: a larger one with a canopy on the left and a smaller one on the right. The sky is a mix of blue, white, and soft orange/pink, indicating a sunset or sunrise. The overall scene is serene and captures the natural beauty of a coastal reef environment.

Adam Richmond

T074 DRAFT SLIDE 1

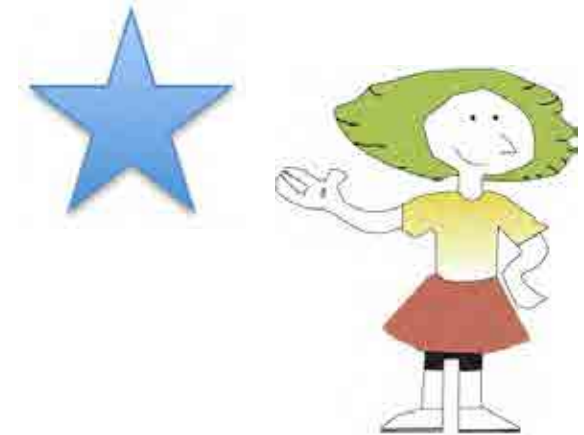
Syllabus statement

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

Recall

the different types of reef structure

(e.g. fringing, platform, ribbon, atolls, coral cays).



Recall

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



Objectives

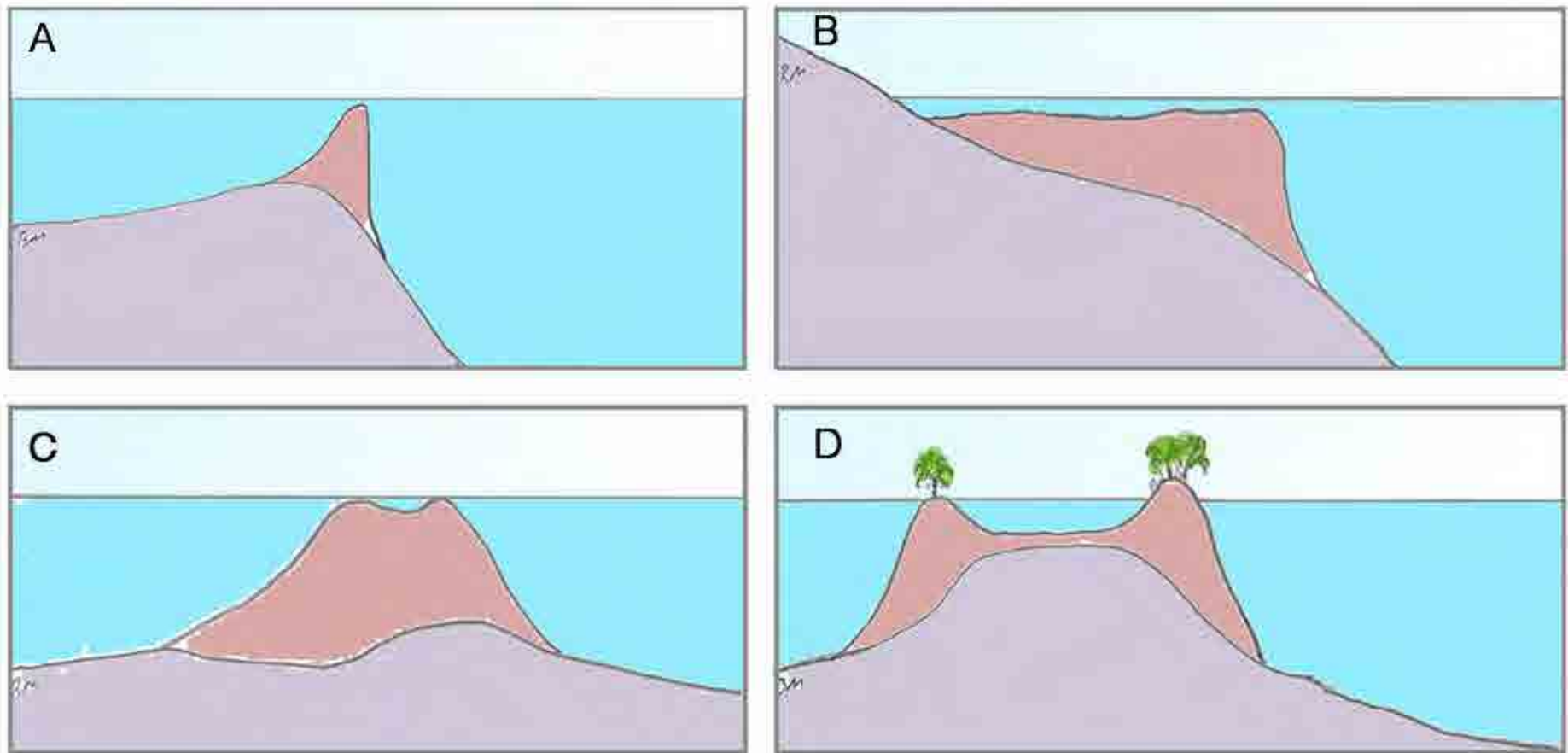
1. Complete a table, recalling key characteristics, drawing a diagram and giving an example of the following reef structures.
 - Fringing
 - Platform
 - Ribbon
 - Atolls
 - Coral cays

2. Identify each of the above from a series of photographs.



Types of coral reefs

Coral scientists recognise four main types of coral reefs: fringing reefs, barrier reefs, atolls, and platform reefs.



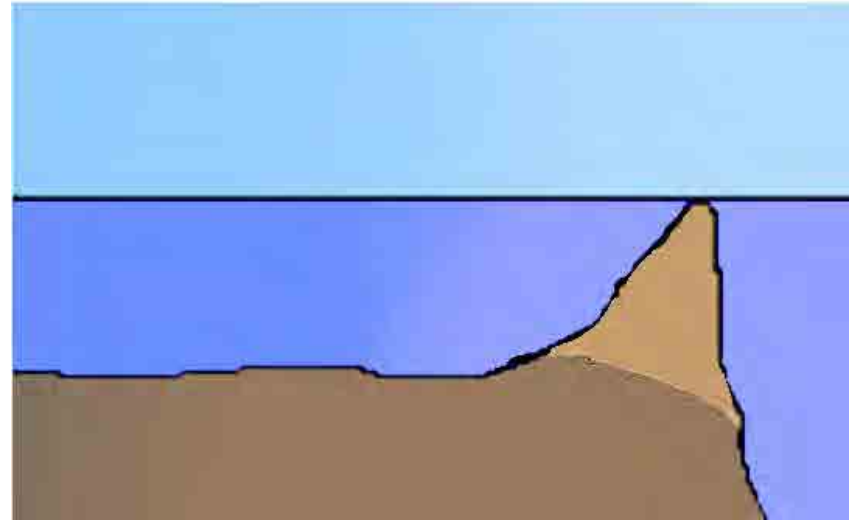
Bob Moffatt

T074 DRAFT SLIDE 5

Barrier reefs

Barrier reefs are formed away from the land, and are separated by a lagoon that is deep enough for navigation.

Barrier reefs are usually roughly parallel to the shore.



Bob Moffatt (After Normann Z [Public domain], via Wikimedia Commons)



Images: Jumbo Aerial Photography, Copyright Commonwealth of Australia (GBRMPA)

Barrier reefs can form as a fringing reef extends away from the shore, and the mainland subsides.

The barrier reef in New Caledonia is the longest continuous barrier reef in the world and is the second largest after Australia's Great Barrier Reef.

Northern tip of Grande Terre,
New Caledonia



Image: the Enhanced Thematic Mapper Plus on NASA's Landsat 7 satellite, Jesse Allen, Michon Scott. [Public domain], via Wikimedia Commons



Aerial view of Hook Reef

Images: Jumbo Aerial Photography, Copyright Commonwealth of Australia (GBRMPA)

T074 DRAFT SLIDE 8

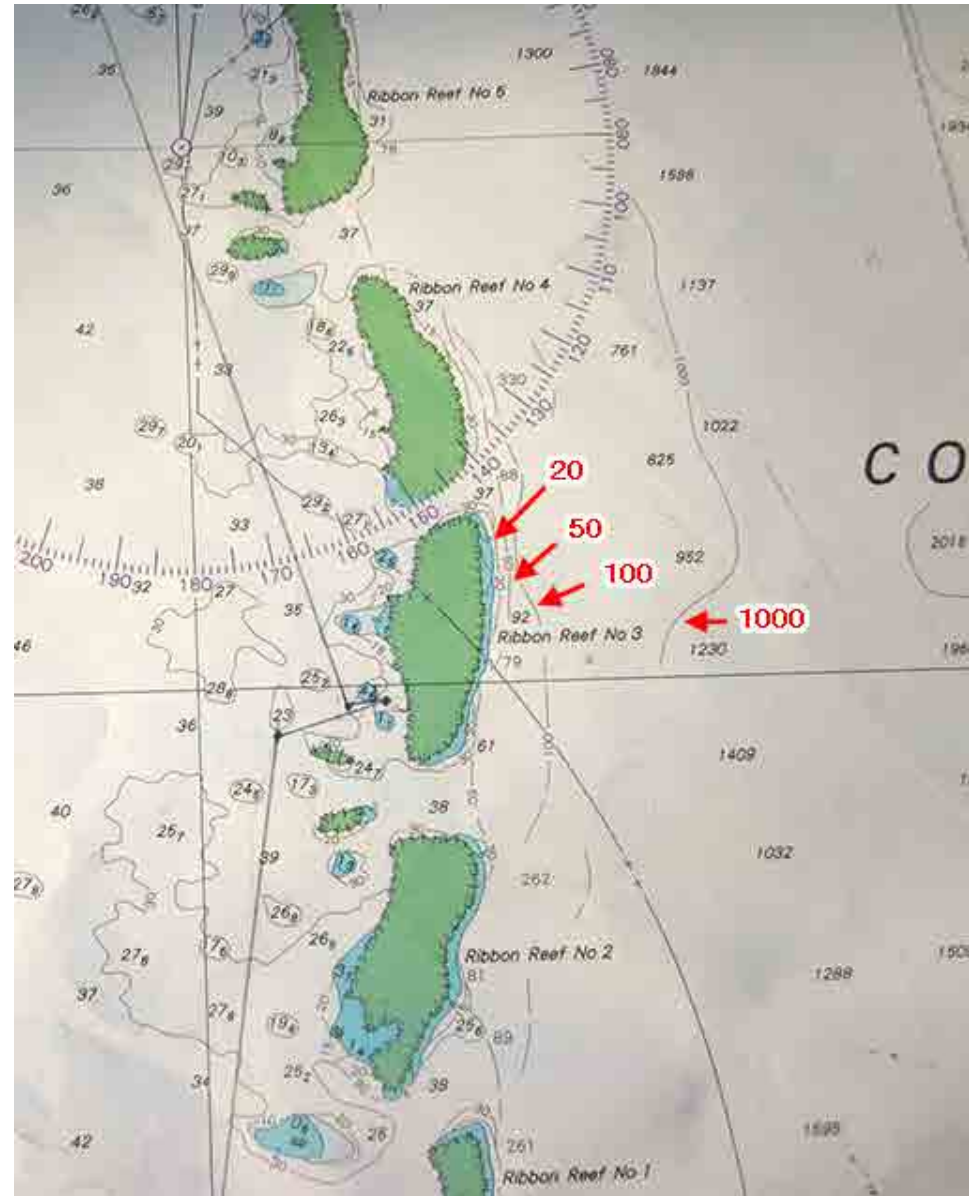
Ribbon reefs

Sometimes barrier reefs contain Ribbon reefs.

These are long winding reefs that grow along the edge of the continental shelf, are usually 300-500 m wide from seaward side to lagoonward edge.



Bob Moffatt



Coral Expeditions

Strong currents cause the ends of ribbon reefs to curve back, giving the ribbon reef a crescent shape.



Ribbon Reef No 7 Copyright Commonwealth of Australia (GBRMPA) Photographer: L. Zell Image 136393

T074 DRAFT SLIDE 10

Fringing reefs

There are six different major ways in which fringing reefs grow and develop.[1].

They can;

1. develop vertically as far as the space below the surface allows.
2. expand seaward from the shore.
3. grow atop muddy sediments
4. form in a gradual, sporadic manner, with alternate vertical and horizontal growth episodes.
5. develop when an offshore reef grows to sea level forming a barrier.
6. form their barrier using storms to move coral and other debris inwards.

Reference

https://en.wikipedia.org/wiki/Fringing_reef

[1]. Kennedy, D.M. and Woodroffe, C.D. 2002.Fringing reef growth and morphology: a review. Earth-Science Reviews. 57:255-277.

Structure

There are two main components that make up a fringing reef, the reef flat and the reef slope.

Reef flat (back reef)

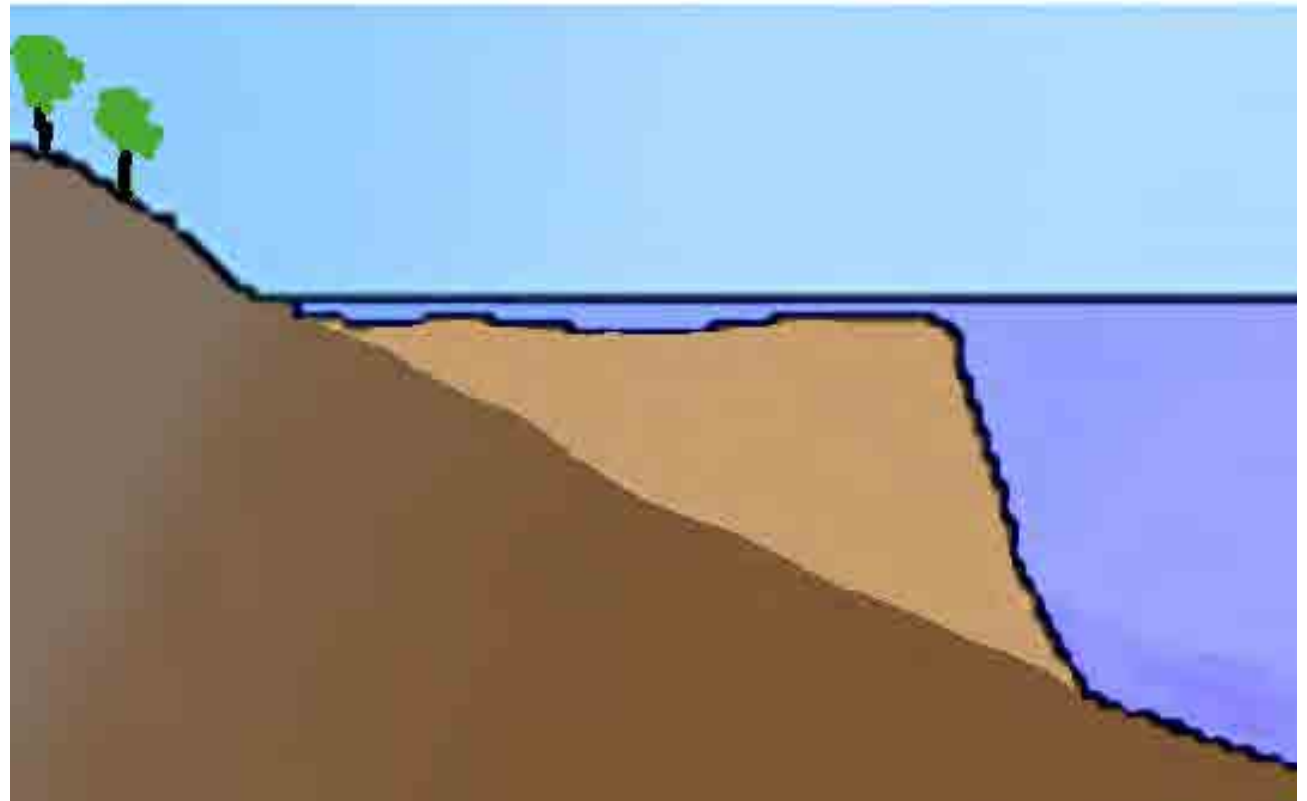
Reef slope (fore reef)

These are discussed in the next topic.



Public Domain,
<https://commons.wikimedia.org/w/index.php?curid=425699>

Fringing reefs can grow around continental islands, with a reef flat that extends to the beach.



Bob Moffatt (After Normann Z [Public domain], via Wikimedia Commons)

Lizard Island is a good example of a fringing reef.



Lizard Island

By Emily Cox [CC BY-SA 4.0 (<https://creativecommons.org/licenses/by-sa/4.0>)], from Wikimedia Commons
https://commons.wikimedia.org/wiki/File:Lizard_Island_Reef.jpg

760 of the 3400 individual reefs on the Great Barrier reef are fringing reefs.

The reef flats seen today started growing 6000 years ago when sea levels stabilised.

The fringing reef at 'Eua Island, Tonga (right) is largely exposed at low tide.



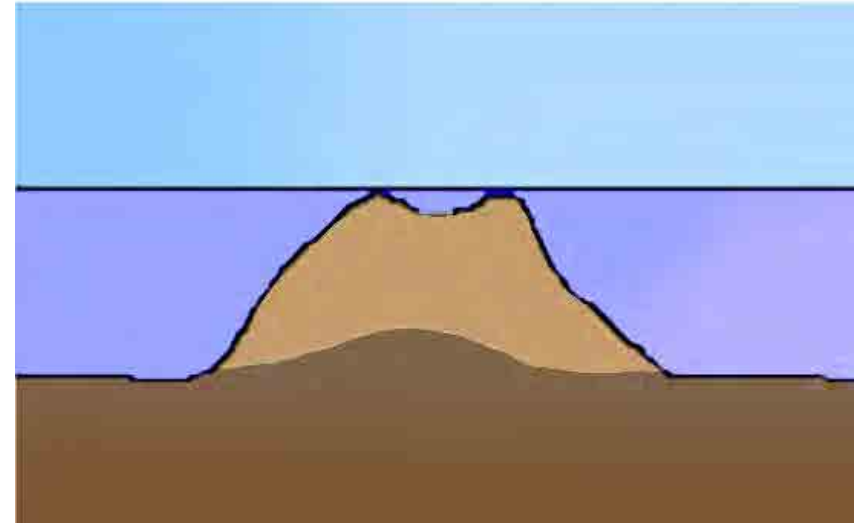
Image: Adam Richmond

Platform reefs

Platform reefs grow on the continental shelf where the seabed rises close enough to the surface. They are flat topped and have very shallow lagoons

They can vary greatly in size and shape, but are commonly oval or elongated.

They may be completely submerged, or may support coral cays.



Bob Moffatt (After Normann Z [Public domain], via Wikimedia Commons)

Heart reef is a 14 m wide patch reef located within Hardy Reef, Whitsundays.



Heart reef

Image: J. Johnson, Copyright Commonwealth of Australia (GBRMPA) 132283

T074 DRAFT SLIDE 17

Coral cays

Sometimes sand accumulates on a platform reef to form a coral cay.

A coral cay is an island formed on top of a coral reef that contains no continental rocks.

Waves and wind move sediment to a particular part of the reef.

Larger coral boulders and rubble remain on the windward side, whilst smaller debris is moved to the leeward side.



An unvegetated coral cay

Image: J. Jones, Copyright Commonwealth of Australia (GBRMPA) 131017

The shape and position of coral cays changes with wind and weather.

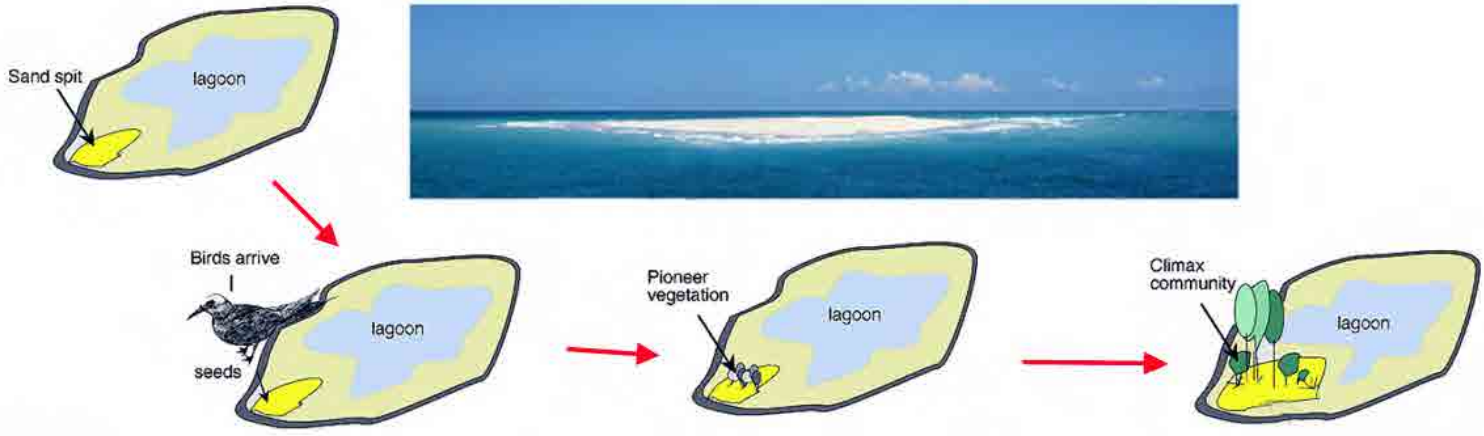
Sediment eventually forms beach rock, birds introduce guano and pioneering plants that help stabilise the cay.

Lady Elliot Island is the Southernmost coral cay on the Great Barrier Reef.



Image: LordDimwit at English Wikipedia [Public domain], from Wikimedia Commons

You would have studied this last year.



Atolls

Atolls or atoll reefs are barrier reefs that form a partial or complete barrier around a lagoon without an island.



Bora Bora has been described as an “almost atoll” because it still has an island in the centre.

Bora Bora image: NASA Johnson Space Center [Public domain], via Wikimedia Commons



Nukuoro atoll in Polynesia, viewed from space.

Image: NASA/Johnson Space Center, Image Science & Analysis Laboratory [Public domain], via Wikimedia Commons



By Borabora.jpg: User:Taka-0905derivative work: Marsilio (talk) - Borabora.jpg, Public Domain,
<https://commons.wikimedia.org/w/index.php?curid=7012221>

T074 DRAFT SLIDE 22

Atoll formation

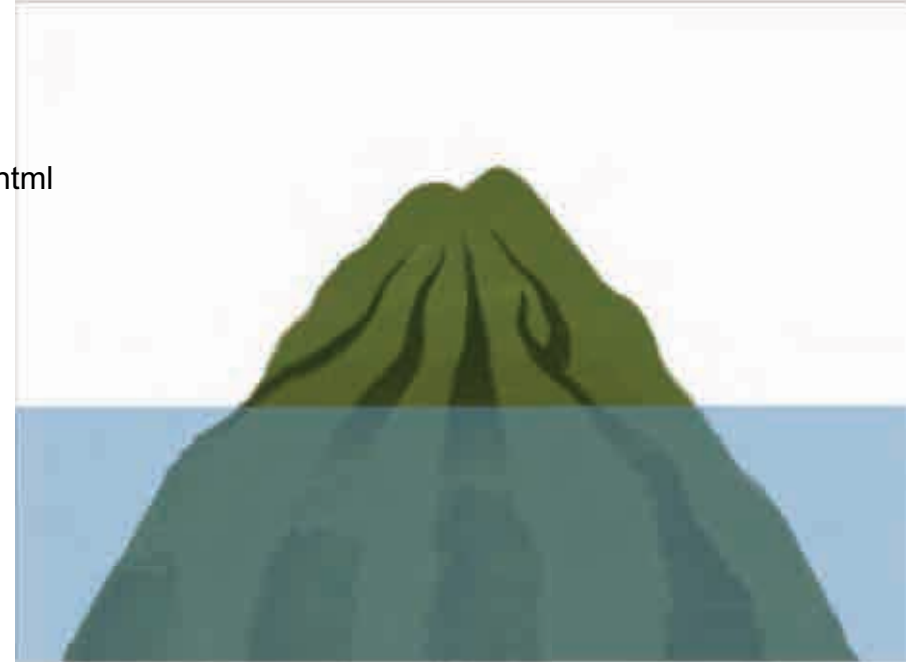
You can see this at

http://www.oceanservice.noaa.gov/education/kits/corals/media/supp_coral04a.html

As this animated gif shows, atolls are usually formed from a fringing reef around a volcanic island.

This process would normally take up to 30 million years!

Some atolls may have formed by sea levels rising rather than island sinking.



Animation from: http://www.oceanservice.noaa.gov/education/kits/corals/media/supp_coral04a.html in the public domain on Wikipedia at https://en.wikipedia.org/wiki/Coral_reef#/media/File:Coral_atoll_formation_animation.gif

Charles Darwin described fringing reefs, barrier reefs and atolls.

Darwin's theory begins with a volcanic island that becomes extinct.



A fringing reef begins to grow in the shallow waters surrounding the island. The island begins to erode and subside.



Images: Susan Mayfield and Sara Boore, modified by Eurico Zimbres
http://commons.wikimedia.org/wiki/Image:Atoll_forming.jpg

Over time, the island subsides and erodes further, whilst the fringing reef grows.

A lagoon develops between the island and the outer edge of the fringing reef, which becomes a barrier reef.

The island eventually sinks below sea level.

The barrier reef becomes an atoll enclosing a central lagoon.



Images: Susan Mayfield and Sara Boore, modified by Eurico Zimbres
http://commons.wikimedia.org/wiki/Image:Atoll_forming.jpg

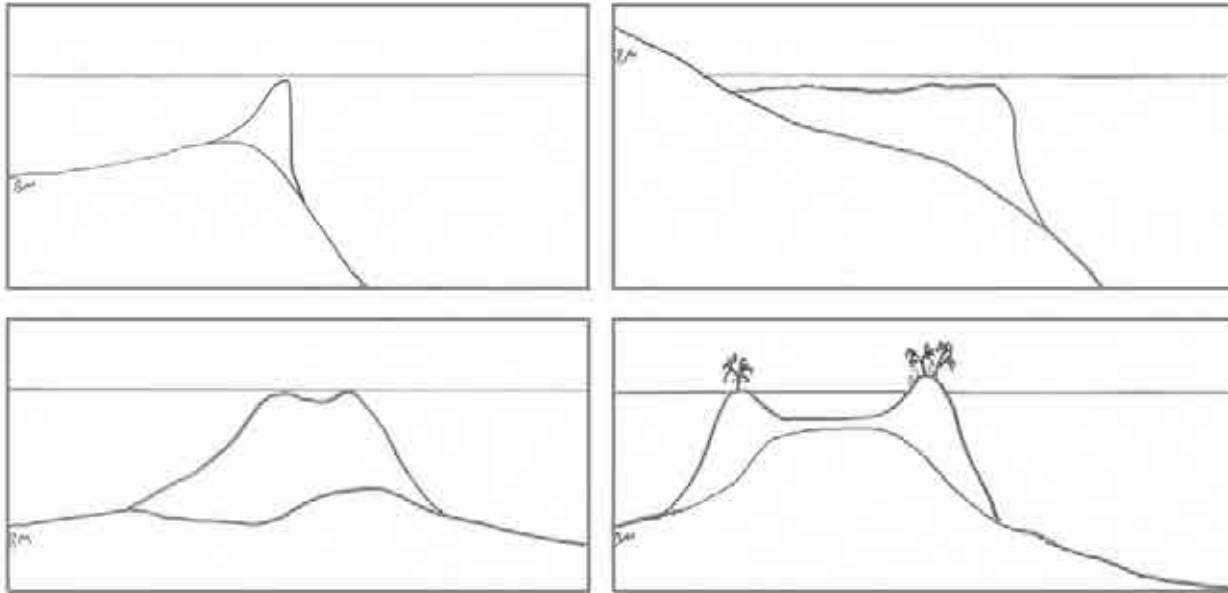
Questions

1. Complete this table by recalling information from this slideshow.

Reef structure	Key characteristics	Example	Diagram
Fringing reef			
Barrier reef			
Platform reef			
Coral cay			
Atoll			



2. Complete the following diagrams to show you can distinguish between barrier, fringing, platform reefs and atolls. On which would a coral cay form?



3. Answer the following questions.

- Which reef structure is usually attached to land?
- How would you define a coral cay?
- How is an atoll formed?
- Where are ribbon reefs found?

Q4. What type of reefs are shown in the following slides?





Image: P. Koloj, Copyright Commonwealth of Australia (GBRMPA) 133668

T074 DRAFT SLIDE 29

Platform reef with coral cay
and fringing reef.



Image: P. Koloï, Copyright Commonwealth of Australia (GBRMPA) 133668

T074 DRAFT SLIDE 30



Image: Jumbo Aerial Photography, Copyright Commonwealth of Australia (GBRMPA)

T074 DRAFT SLIDE 31

Barrier reef, with platform reefs
and lagoon visible behind

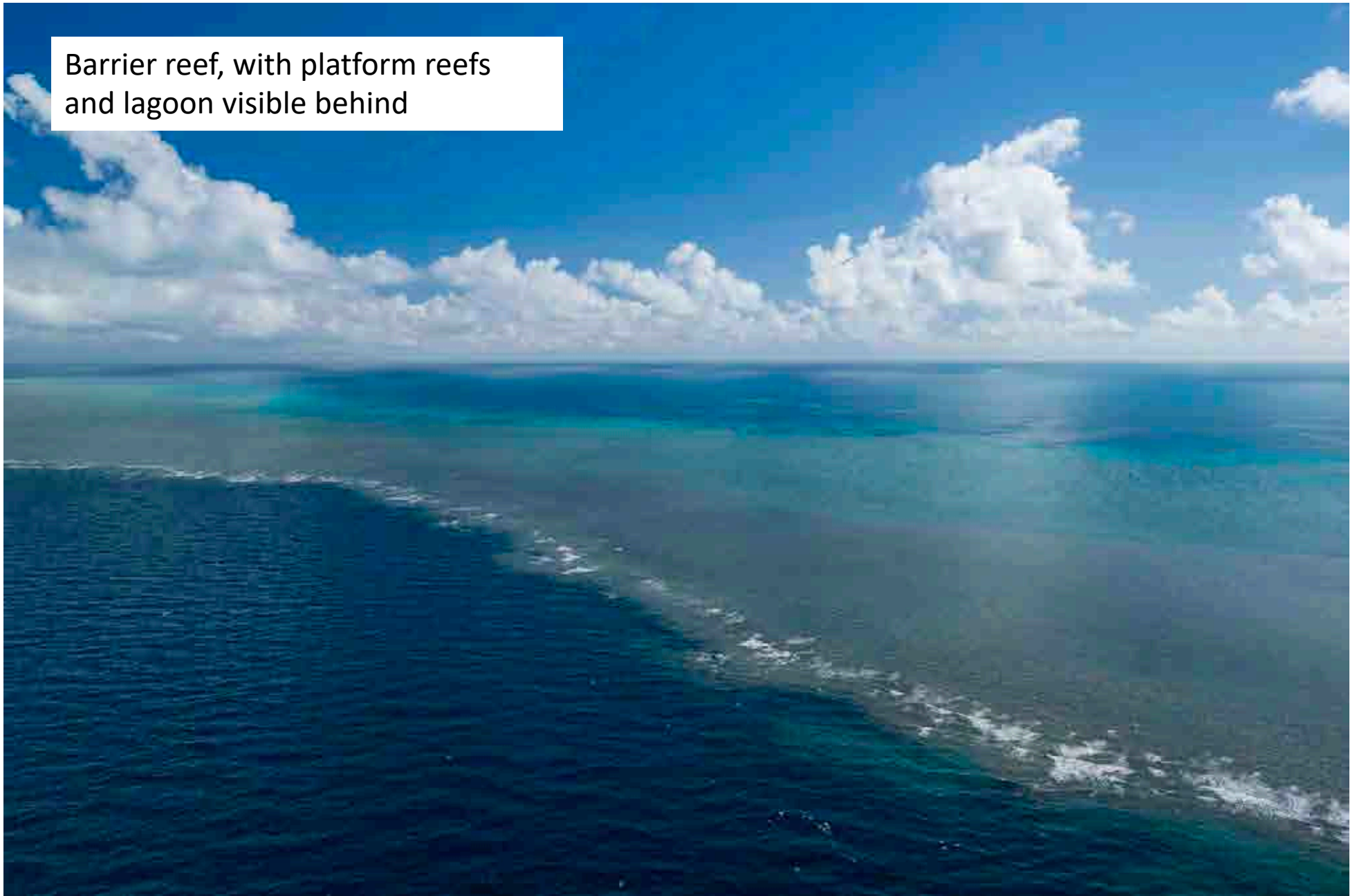




Image: Jumbo Aerial Photography, Copyright Commonwealth of Australia (GBRMPA)

T074 DRAFT SLIDE 33

Platform reef, with barrier reef and open ocean visible behind.



Image: Jumbo Aerial Photography, Copyright Commonwealth of Australia (GBRMPA)

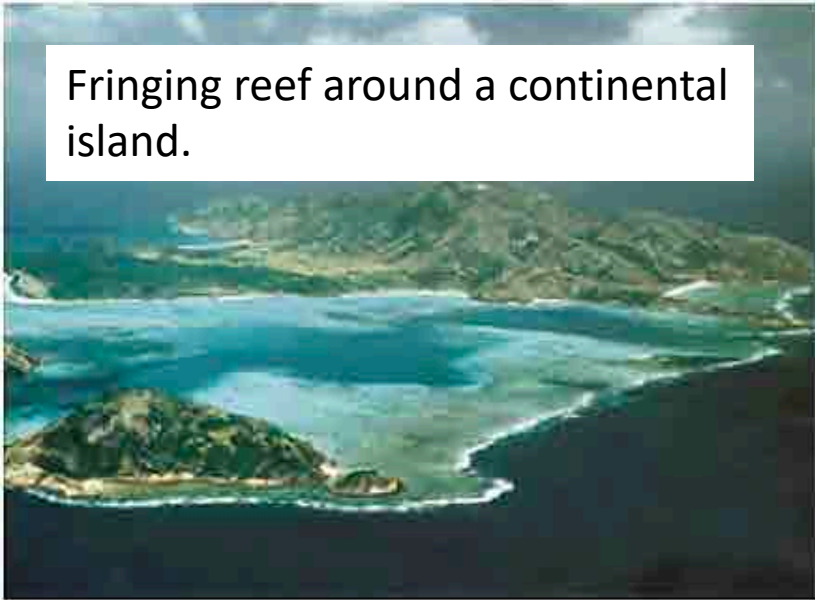
T074 DRAFT SLIDE 34



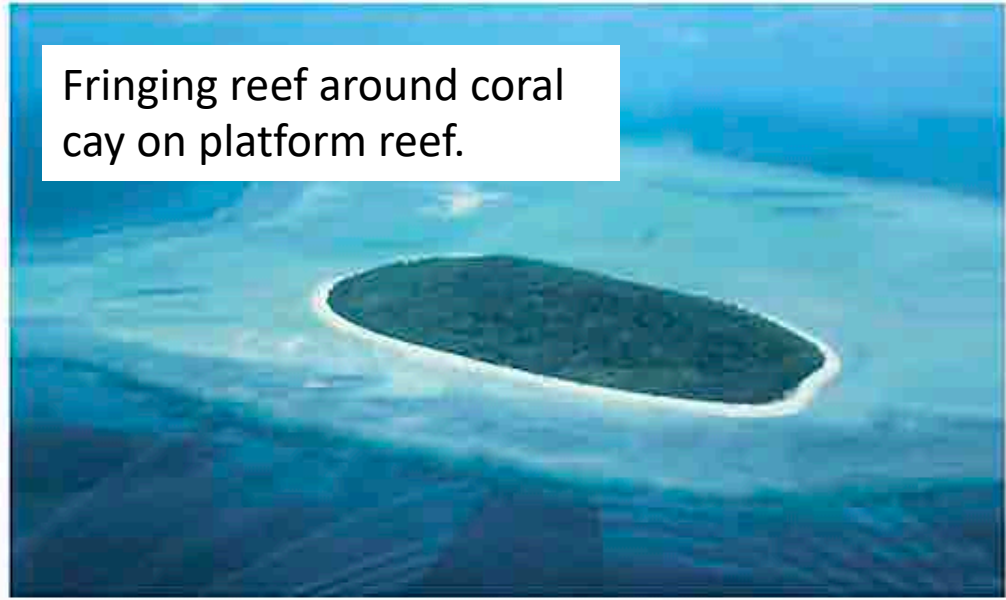
Top left GBRMPA, Top right Bob Moffatt , Bottom left Sam Watson, Bottom right <https://commons.wikimedia.org/w/index.php?curid=7012221>

T074 DRAFT SLIDE 35

Fringing reef around a continental island.



Fringing reef around coral cay on platform reef.



Barrier reef.



Atoll.



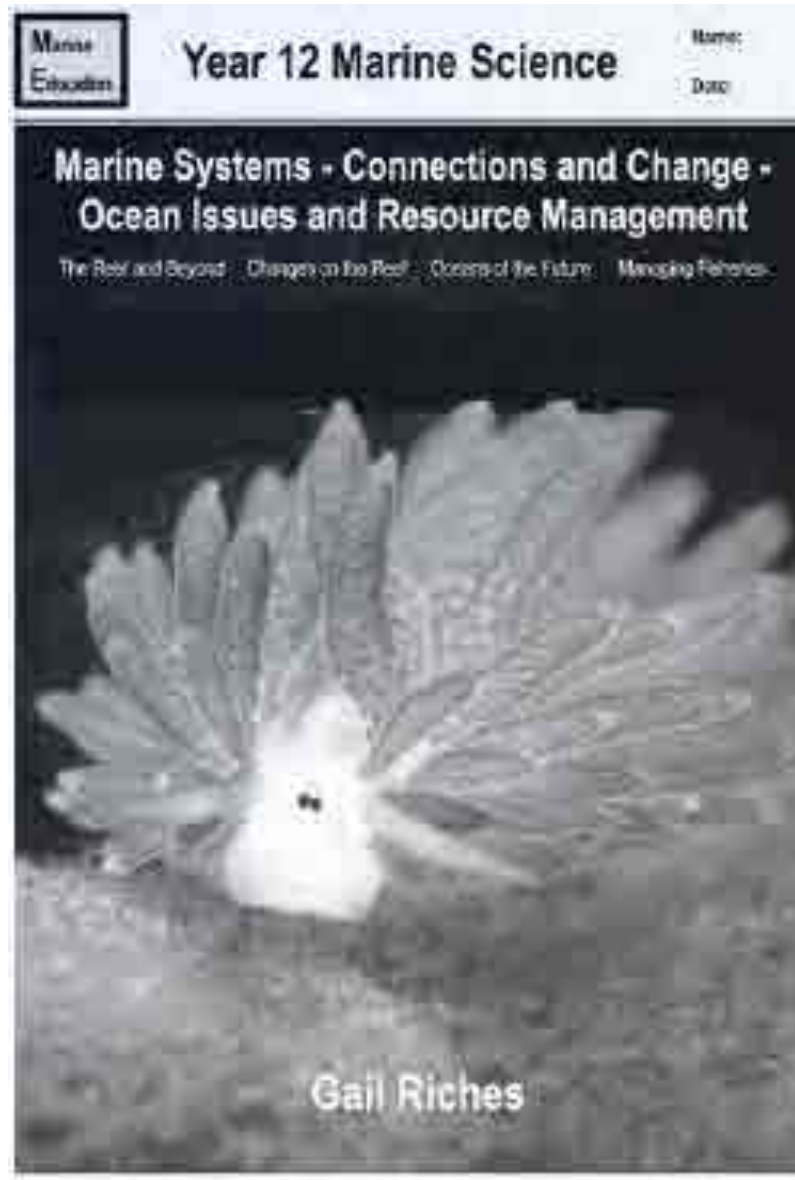
Worksheet

Coral Necklaces and Ribbons

by

Gail Richie

www.marineeducation.com.au



T074 DRAFT SLIDE 37

Further activity

The worksheet

Reef structures

Marine systems connections and change

By CoralWatch

And pages 92-94 of Coral reefs and Climate Change



T075 Reef cross-section zonation

Adam Richmond

T075 DRAFT SLIDE 1

Syllabus statement

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

Recognise

the zonation within a reef cross-section
(e.g. reef slope, reef crest/rim, lagoon/back reef).



Recognise (e.g. features)

- identify or recall particular features of information from knowledge;
- identify that an item, characteristic or quality exists;
- perceive as existing or true; be aware of or acknowledge



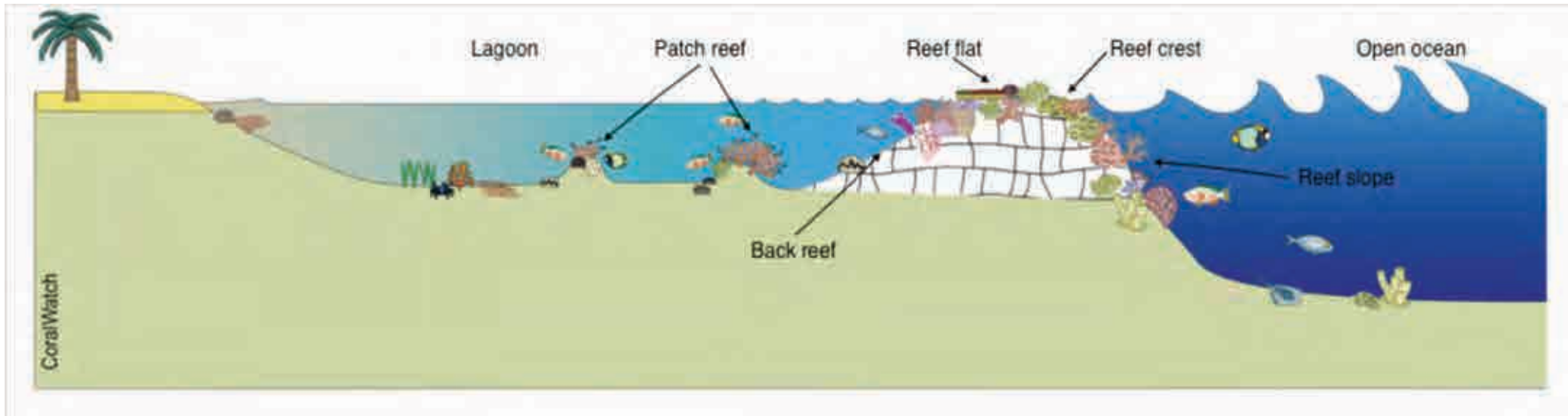
Objectives

TO

Label a diagram of a reef cross-section, identifying the reef slope, reef crest (rim) , reef flat, lagoon (back reef)

AND

Recall key characteristics of each zone.



Reef habitats from beach to ocean

Image: CoralWatch, Healthy Reefs - from Polyp to Policy p23

T075 DRAFT SLIDE 4

Introductory video:

https://www.youtube.com/watch?v=1wMrB37_GvI



See

<https://www.livingoceansfoundation.org/education/portal/course/reef-zonation/#reef-zones-1>

for a whole unit on coral reef zonation

by Khaled bin Sultan Living Oceans Foundation

Coral Reef zones

Khaled bin Sultan Living Oceans Foundation, YouTube video available: https://youtu.be/1wMrB37_GvI

T075 DRAFT SLIDE 5

Coral reef zones

Look at the image below. How many different zones can you see?



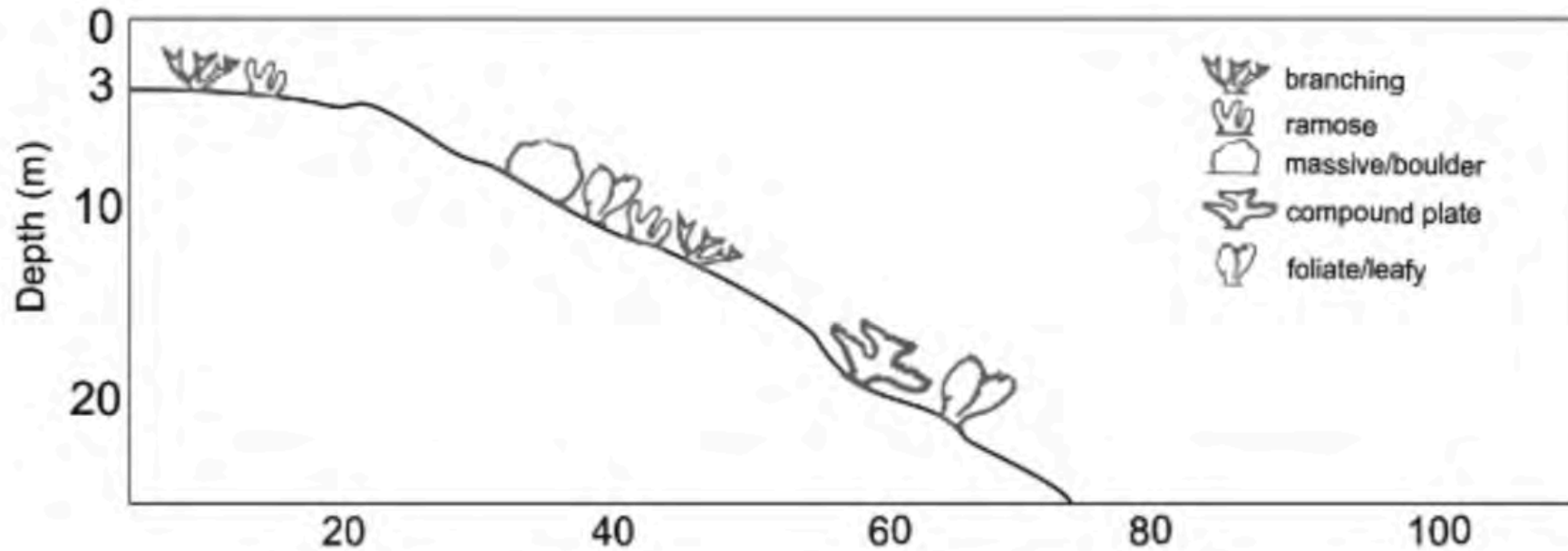
Agincourt reef

Image: L. Zell Copyright Commonwealth of Australia (GBRMPA) 135111

T075 DRAFT SLIDE 6

As you learnt previously*, abiotic factors, such as depth, temperature, light intensity, wave action and tidal range change in different sections of the reef.

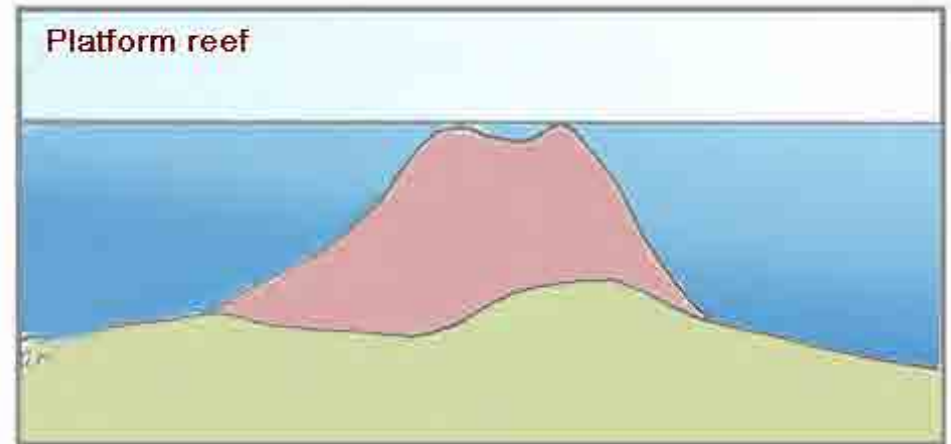
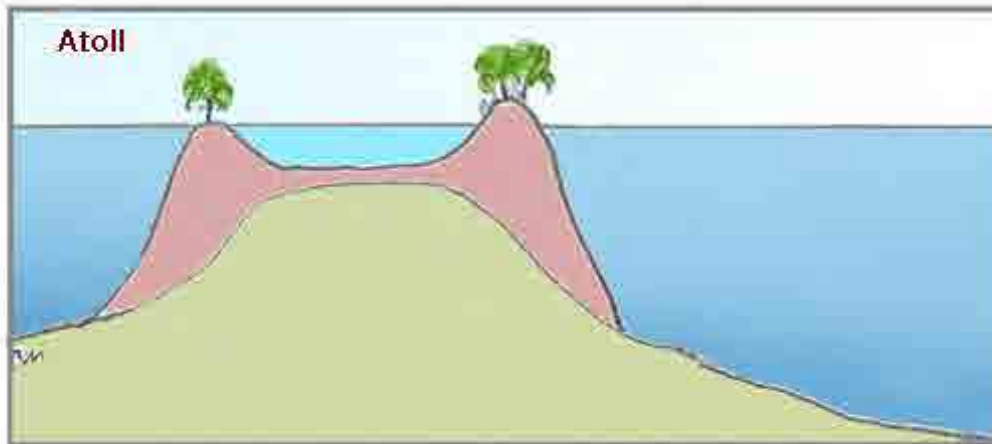
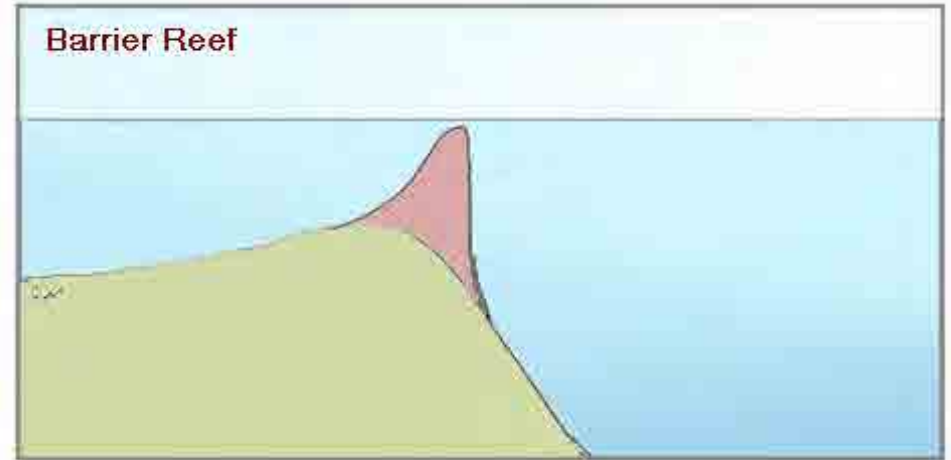
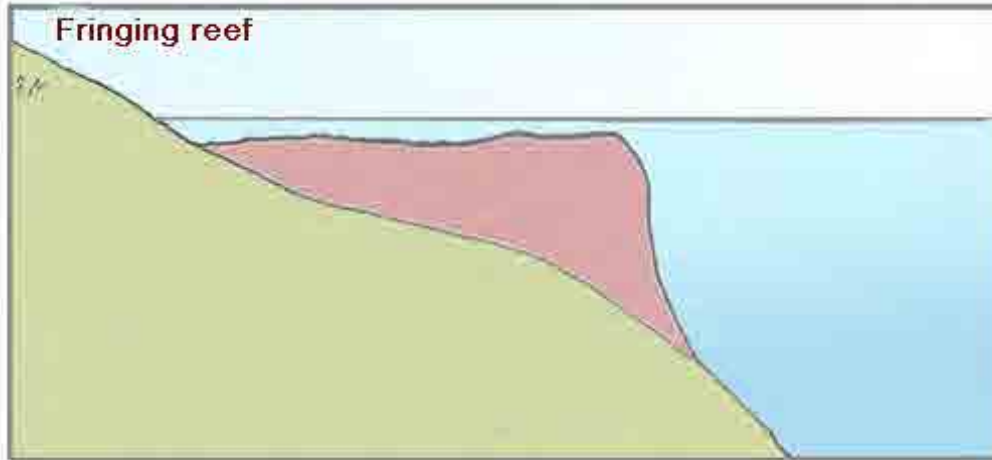
These parameters cause distinct zones, each containing organisms that are particularly adapted to those conditions.



Cross section showing coral forms in each zone

Image: Reza, Akbar & Sancayaningsih, Retno. (2017). Diversity, Distribution and Abundance of Scleractinian Coral in District-based Marine Protected Area Olele, Bone Bolango, Gorontalo - Indonesia. KnE Life Sciences. 3. 14. 10.18502/kls.v1i1.683.

Each type of reef has different patterns of zonation due to these abiotic factors.



Bob Moffatt

Fringing reef zones

A fringing reef has three main zones:

1. Inner reef or reef flat, inside the reef crest
2. Reef crest
3. Outer reef (or reef front or fore reef) is on the oceanic side of the reef crest

A fringing reef does not usually have a lagoon or a back reef.

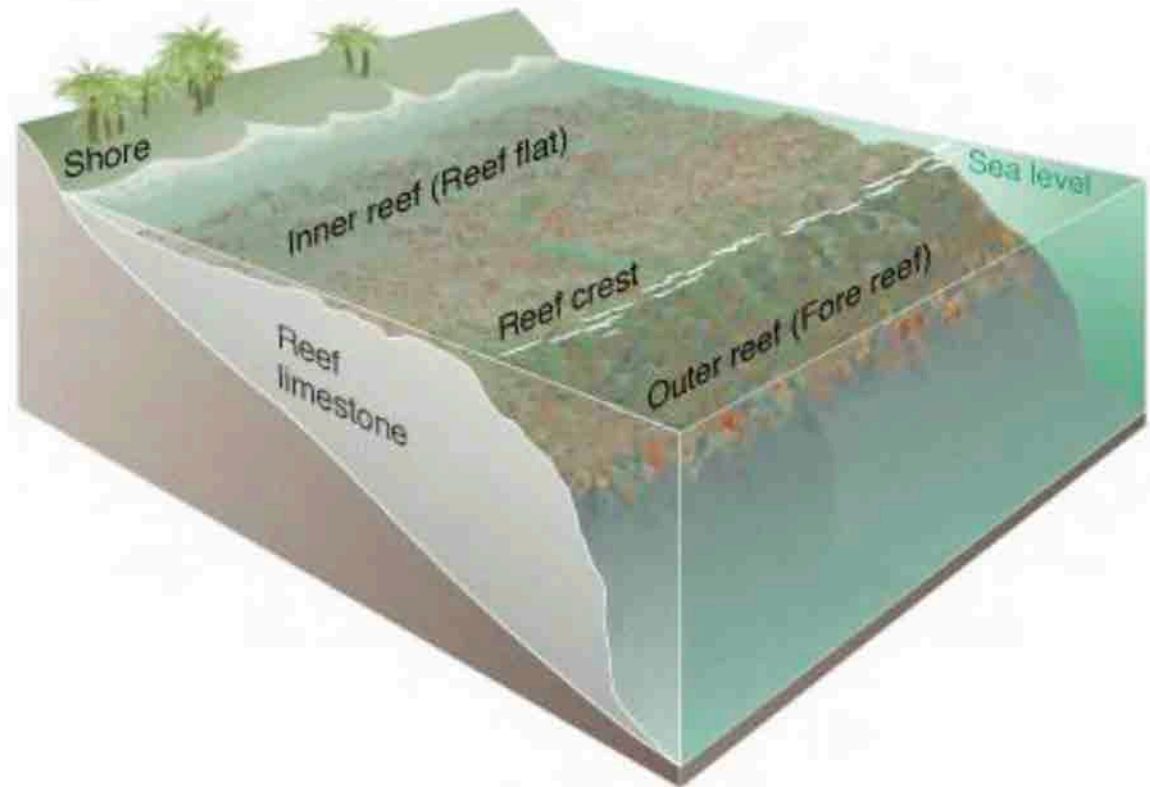
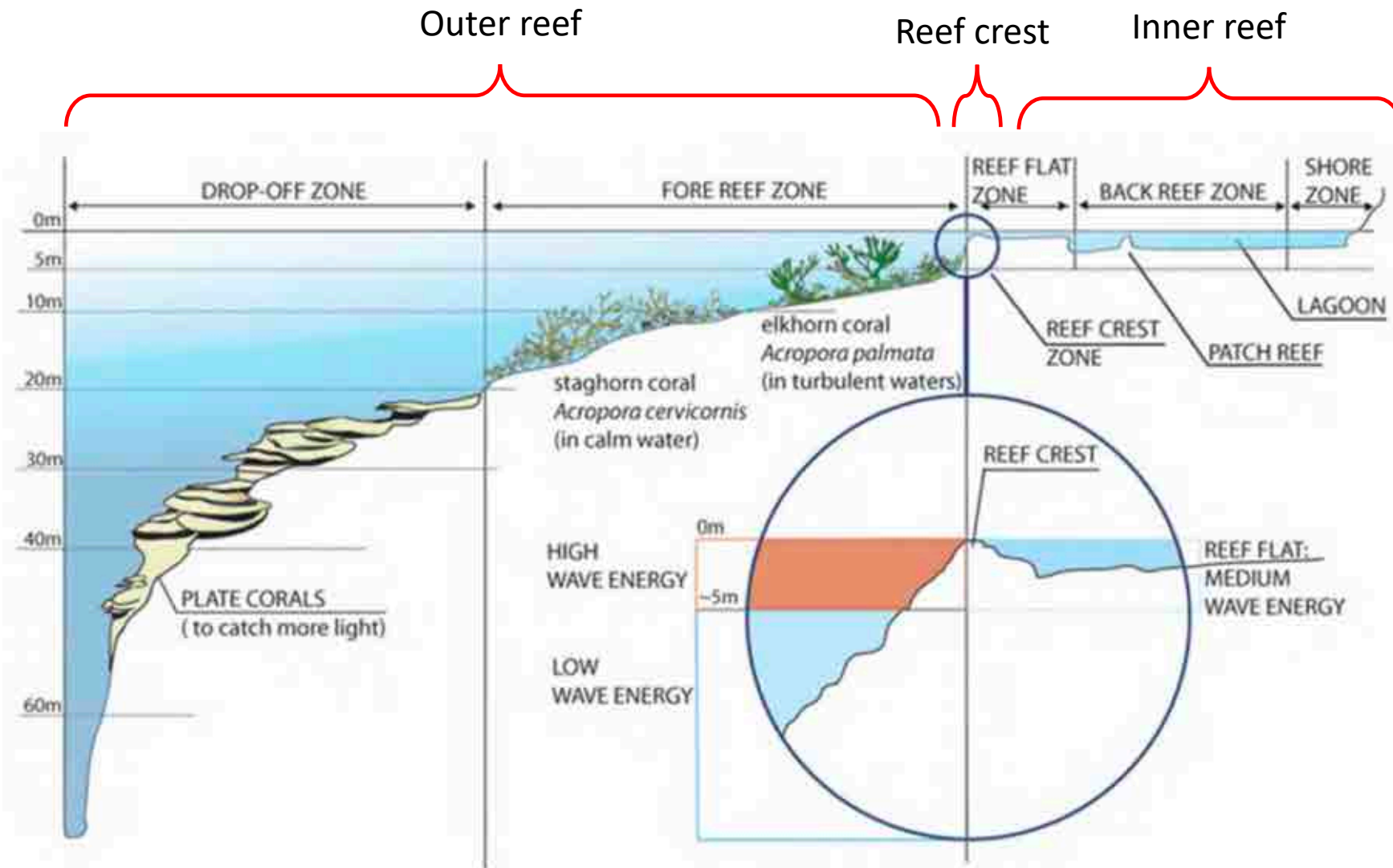


Image: https://upload.wikimedia.org/wikipedia/commons/1/11/Coral_reef_diagram.jpg

The shape and size of corals varies in these zones.



Reef flat

The reef flat is the zone closest to land on a fringing reef, and on the inshore side of a reef crest on a barrier reef, or atoll.

Low growing branching corals
on Green Island reef flat.

Image: A. Elliott, Copyright Commonwealth of Australia (GBRMPA) 123308



Barrier reef zones

Barrier reefs are separated from land by a lagoon.

- On the landward side of the reef crest is the back reef.
- The reef front is on the oceanic side of the reef crest.

Barrier reefs can have a reef flat between the back reef and reef crest

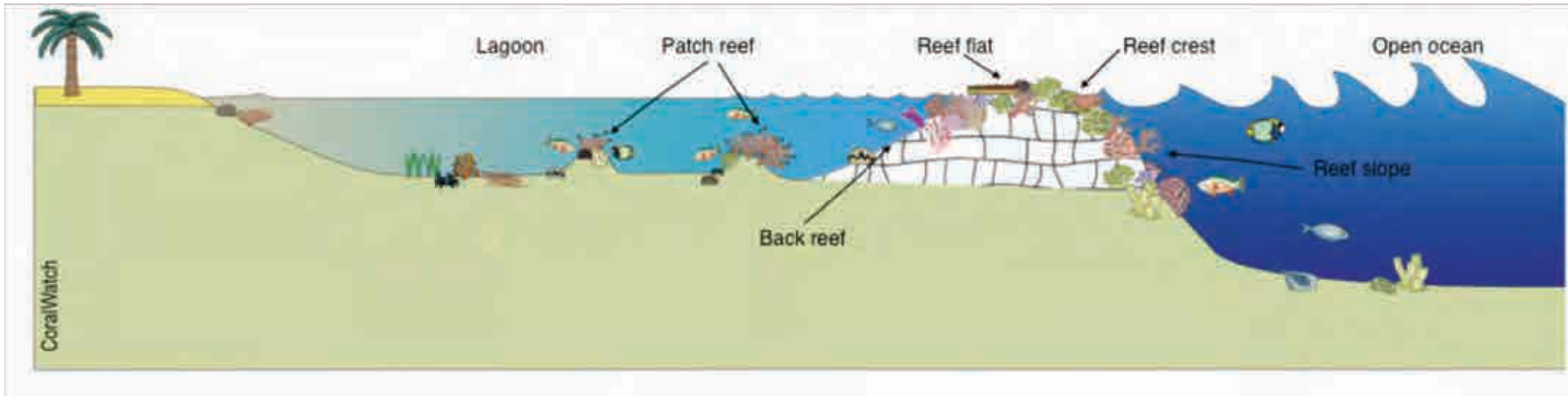


Image: CoralWatch, Healthy Reefs - from Polyp to Policy p23

Atoll reef zones

Reef flats are found on the oceanic side of land. The reef front is found on the outer, oceanic side of the atoll. There can be a back reef on the inner part of the atoll that slopes into a lagoon.



Bikini Atoll nuclear test site, showing zones on an atoll

Image: Ron Van Oers [CC BY-SA 3.0-igo (<https://creativecommons.org/licenses/by-sa/3.0-igo/>)], via Wikimedia Commons

Reef flats are shallow and are often exposed to air at low tide.

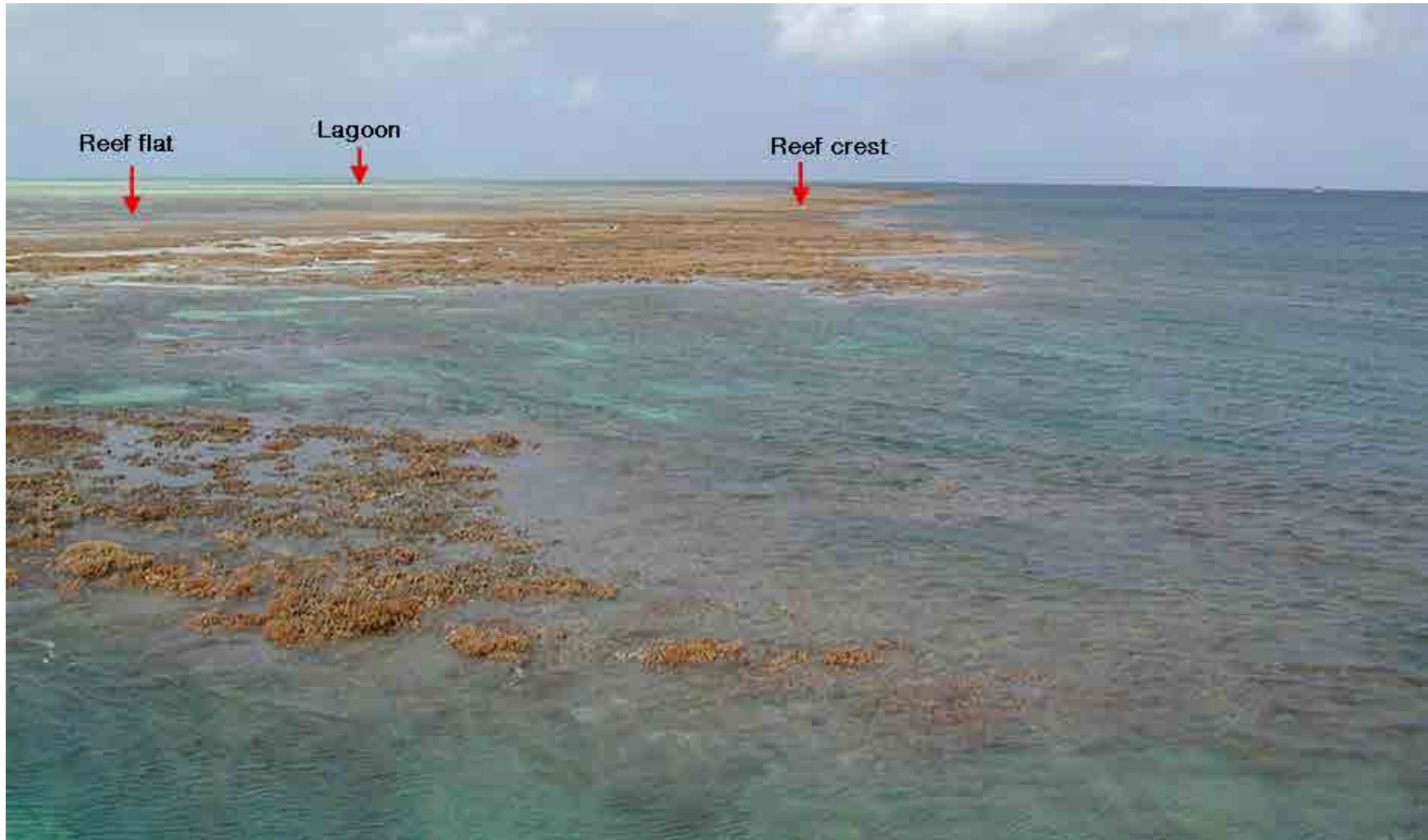
- Coral growing above this height die.
- This leads to the flat surface.



Bob Moffatt Lady Elliott Island

Reef flats are protected from strong waves and currents by the reef crest.

- By being close to shore, reef flats are affected by sediments and fresh water runoff.



Reef flats often contain patches of sand, rubble and living and dead corals, of relatively few species.



Reef flats however are home to the highest diversity of species, including crabs, oysters, clams and worms.



Bob Moffatt Lady Elliott Is.

T075 DRAFT SLIDE 17

Lagoon

The lagoon is a relatively deep (deep enough for boats to safely travel) body of water between a barrier reef and the shore, or within an atoll.

The lagoon is protected from strong waves and currents by the reef crest, and usually have a soft sediment.

Seagrass beds and platform reefs grow in shallow sunlit areas.



Yachts anchored in the lagoon of Lady Musgrave Island

Back reef

The back reef slope can be shallow or steep, where the lagoon floor slopes upwards on the shoreward (leeward) side of the reef crest of a barrier reef or atoll.

The back reef is protected from strong waves and currents by the reef crest, but waves move lots of sediment down the slope.

Higher turbidity means less species diversity.

The back reef at Bowl Reef can be seen behind the waves breaking as they wash into the bommie-filled lagoon.

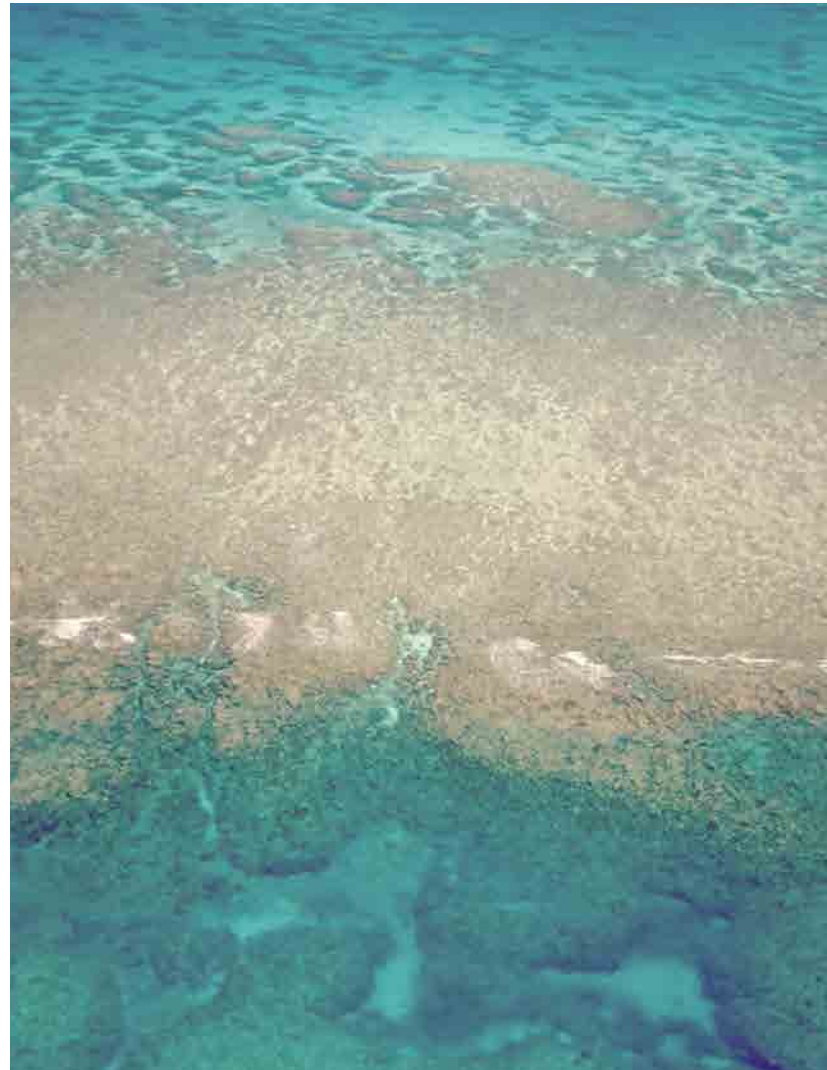


Image: R. Kenchington, Copyright Commonwealth of Australia (GBRMPA) 136528

Reef crest

The reef crest is the shallowest part of the reef and are often exposed to air at low tide.

Reef crests are fully exposed to from strong ocean waves and currents.

Areas with strong wave action may have an algal ridge; where coralline algae cement rubble and fragments together.

Strong, encrusting or short, stubby corals are common here.



Reef crest on Lady Elliot Island reef

Image: M. Simmons, Copyright Commonwealth of Australia (GBRMPA) 119758

Coral growth and other marine life is most luxuriant near or just below the reef crest.



Viewfinder

T075 DRAFT SLIDE 21

Reef slope

The reef slope or reef front is on the seaward side of the reef crest. The reef slope has the largest coral colonies and is home to many fish. The highest coral diversity is found between 5-20 metres.

Strong currents and wave action provide water circulation and supply nutrients and zooplankton. This high energy water flow creates spur and groove ridge formations.



Spur and groove formations at Wistari Reef

Image: L. Zell, Copyright Commonwealth of Australia (GBRMPA) 135358



Image: Unknown, Copyright Commonwealth of Australia (GBRMPA) 124575

Profile of a reef slope movie

YouTube

UQ ED X video reference:

https://www.youtube.com/watch?v=PWSnmxwBvs8&index=16&list=PLc5Eea_1b-wDmRNmcy_rTSI9bw_7AHIWE&t=0s



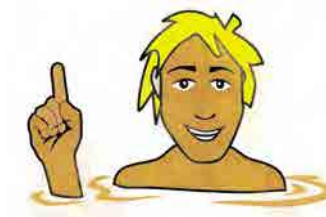
https://www.youtube.com/watch?v=PWSnmxwBvs8&index=16&list=PLc5Eea_1b-wDmRNmcy_rTSI9bw_7AHIWE&t=0s

Questions

1. Redraw this table to summarise the characteristics of reef zones.

Zone	Location	Depth, light, temp, salinity, wave exposure	What lives here?
Reef flat			
Lagoon			
Back reef			
Reef crest			
Reef slope (aka buttress zone)			
Fore reef (aka reef front drop off)			

2. Which zone is the furthest from shore?
3. Which is the closest?
4. Which zone experiences the greatest wave action?
5. Which zone has the greatest diversity of corals?
6. Which zone contains the greatest diversity of organisms?



8. Redraw this image and then label the zones on this reef cross section.

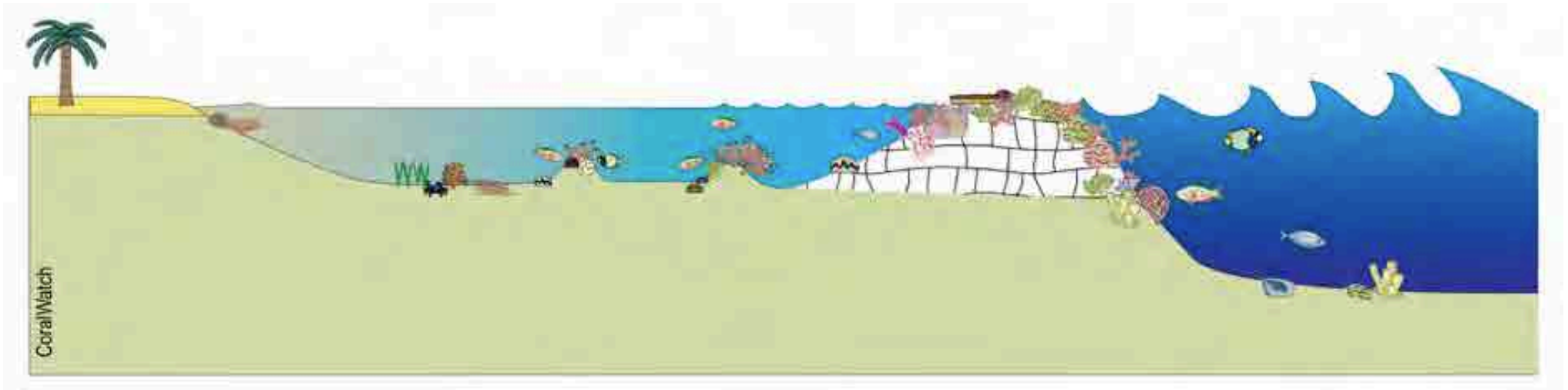


Image: CoralWatch, Healthy Reefs - from Polyp to Policy p23



Answer Q 1.

	Zone	Location	Depth, light, Temp, Salinity, Wave exposure	What lives here?
Back reef	Reef flat	Closest to land, connects shore line to reef c	Shallow (<1m), Protected from waves, high light, high temp and salinity variation, frequent air exposure, sandy sediment	
	Lagoon	Part of reef flat	Shallow, Protected from waves, high light, high temp and salinity variation, frequent air exposure, sandy sediment	Corals tolerant of air exposure, high temp, low O2 Patches of live and dead coral, Coral growth limited by tide depth- grow outwards forming microatolls Not much coral, but Highest diversity of species- crabs oysters, clams, worms
	Back reef	Outer edge of reef flat/lagoon. sloping upwards, shoreward (leeward) edge of the reef crest	Shallow, protected. Isolated patch reefs and coral rubble	
Fore reef	Reef crest	Beyond lagoon, visible ridge. Highest point of reef	Exposed at low tide, fully exposed to breaking waves and currents. Frequent sun/air exposure High light intensity.	Strong corals: Short and stubby corals, branching corals, Encrusting corals (algal ridge) Mucous (sunscreen)making corals rubble and fragments cemented together by coralline algae
	Reef slope (buttress zone,	Beyond reef crest. Outer part of the fore reef.	Spur and groove ridge formations created by high energy water ebb and flow off reef flat, jut out from the wall. Grooves contain sediment and rubble from spurs 5-20 m	Highest diversity. Large coral colonies, many fish Sharks, barracuda
	fore reef, reef front/ Drop off	Slopes downwards beyond reef slopes Reef wall	Deeper, 5-20 m+. Less light. Less wave activity. Steep reef front is a drop off	Highest coral diversity 5-20 m, Less diversity either side of this depth Plate corals

Answer Q8.

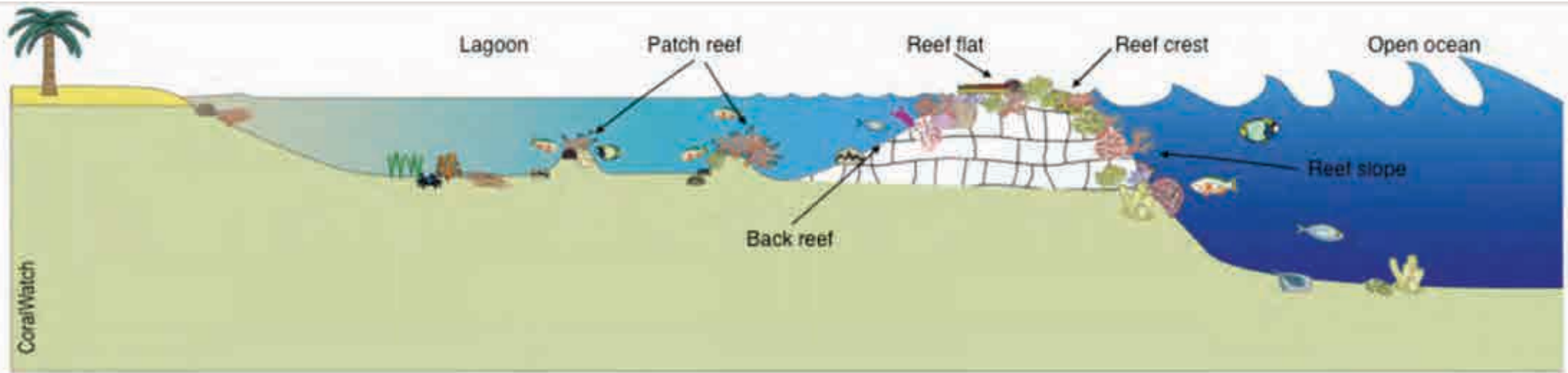


Image: CoralWatch, Healthy Reefs - from Polyp to Policy p23

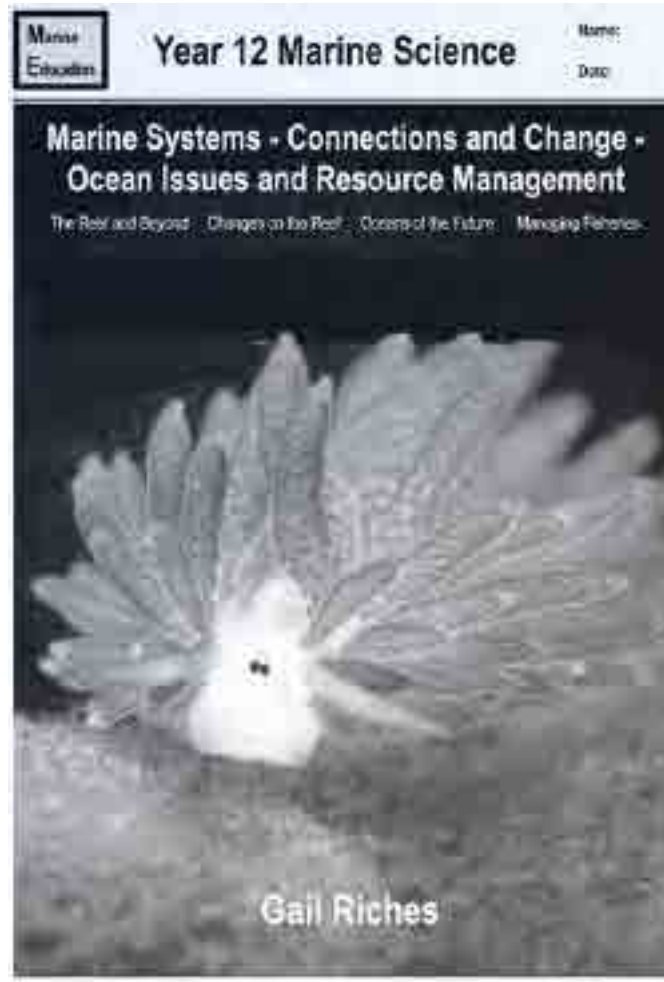
Worksheet

Zone it

by

Gail Richie

www.marineeducation.com.au



Further activity

The worksheet

Single reef zonation

Marine systems connections and change

By CoralWatch

