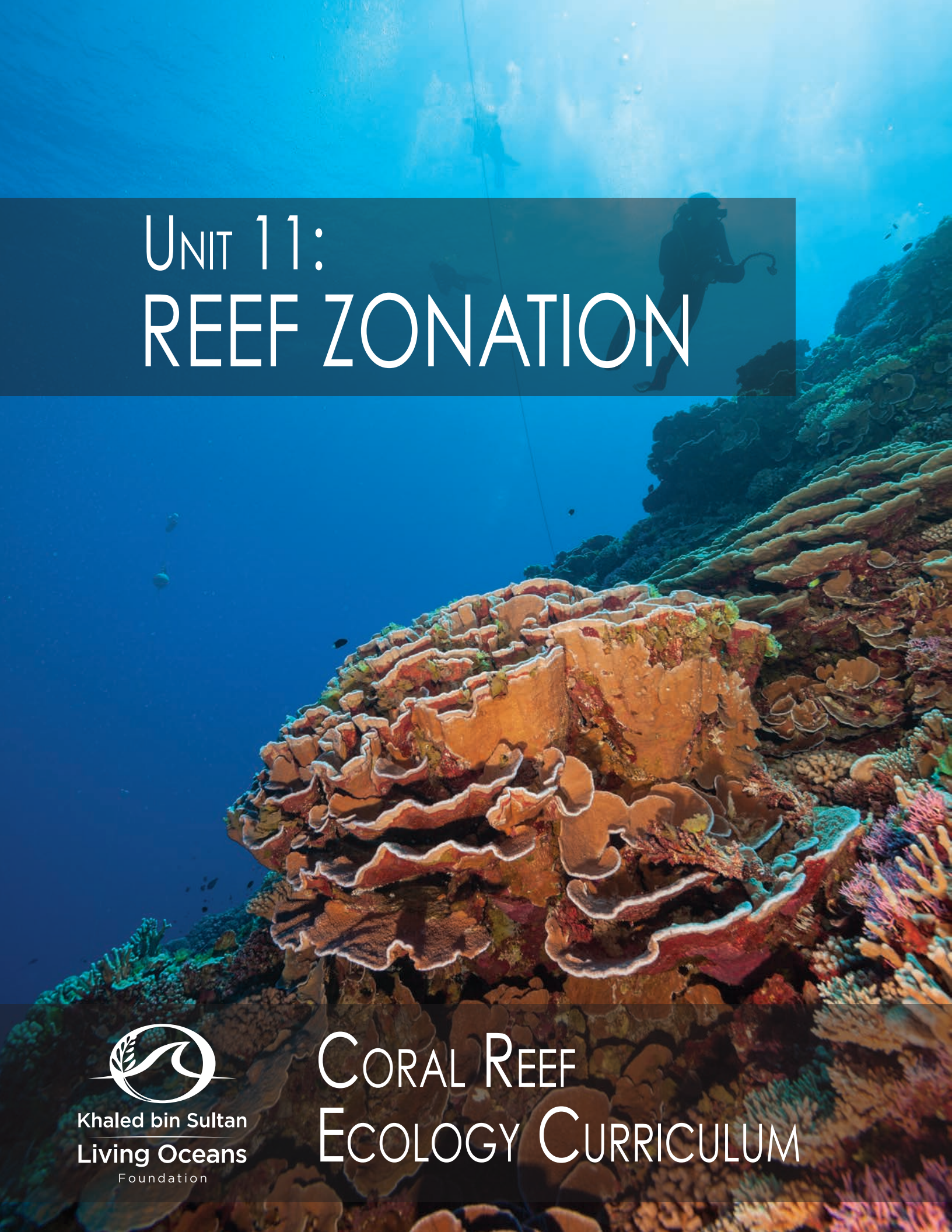

Unit 11:
REEF ZONATION

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Living Oceans
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Coral Reef Ecology Curriculum

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Living Oceans
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This unit is part of the *Coral Reef Ecology Curriculum* that was developed by the Education Department of the Khaled bin Sultan Living Oceans Foundation. It has been designed for secondary school students, but can be adapted for other uses. The entire curriculum can be found online at *lof.org/CoralReefCurriculum.*

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KEYWORDS

- Abiotic Factor
- Algal Ridge
- Atoll
- Back Reef
- Barrier Reef
- Calcium Carbonate ($CaCO_3$)
- Drop-off
- Fore Reef
- Fringing Reef
- Lagoon
- Patch Reef
- Reef Crest
- Reef Flat
- Reef Front
- Spur and Groove Reef

REEF ZONATION

This unit explains the characteristics and location of the reef zones.

STANDARDS

- **CCSS**: RST.9-10.1, 2, 3, 4, 5, 7, 8, 10; RST.11-12.1, 2, 3, 4, 8, 10; SL.9-10.1, 2, 3, 6; SL.11-12.1, 2, 3, 6
- **NGSS**: HS-ESS2-1, HS-LS2-6
- **OLP**: 5.B.7, 5.B.8, 5.C.33, 7.A.5, 7.C.2, 7.C.3

MULTIMEDIA RESOURCE

- *Coral Reef Zones* YouTube video (*https://youtu.be/1wMrB37_GvI*)

LEARNING OBJECTIVES

- Identify the three main types of coral reefs.
- List the abiotic factors that influence the distribution of organisms in each zone.
- Define reef flat and explain the conditions that corals have adapted to in this zone.
- Define lagoon and explain the conditions that corals have adapted to in this area.
- Define reef crest and explain the conditions that corals have adapted to in this zone.
- Define algal ridge
- Define spur and groove reef.
- Define reef front/fore reef and explain the conditions that corals have adapted to in this zone.
- Define drop-off.
- Define back reef and explain the conditions that corals have adapted to in this zone.
- Label the vertical zones for each of the main types of coral reefs.

UNIT PROCEDURE

1. Show *Coral Reef Zones* YouTube video.
   a. Complete **Watch It! Coral Reef Zones** student worksheet.
2. Teach *Unit 11: Reef Zonation - Background Information.*
   a. Complete **Lesson 1: Modeling the Reef** student worksheet.
   b. Complete **Lesson 2: GIS Mapping** student worksheet
3. Teach students how to read and critique blogs.
   a. Complete **Read It! Let's Name the Zones** student worksheet.
4. Evaluate students using **Unit 11: Reef Zonation Quiz** (found online at *www.lof.org/education/portal/quiz/reef-zonation-assessment-1/*). NOTE: User must be logged in.

BACKGROUND INFORMATION

A) REEF ZONES

In *Unit 10: Reef Types,* we learned that there are three main types of reefs: **fringing**, **barrier**, and **atoll** (figure 11-1; see). Each reef type can be divided into zones. These zones are defined by location and **abiotic factors** such as depth, wave energy, light intensity, temperature, and water chemistry. It's important to understand the parameters of each zone because these factors influence the distribution of particular organisms, especially corals. In this lesson, we will learn about the characteristics and location of the following reef zones: the reef flat, reef crest, fore reef or reef front, and back reef.

FIGURE 11-1. a) Fringing reef; b) Barrier reef; c) Atoll

While the **lagoon** is not technically a zone, it can be used to help describe some of the zones. This shallow body of water is separated from the ocean either by a coral reef or by land (figure 11-2). They can contain **patch reefs**, seagrass beds, coral rubble (broken coral), and sand. Lagoons occur throughout the Pacific and Indian Oceans, while smaller ones (not as deep or wide) exist in the Atlantic Ocean.

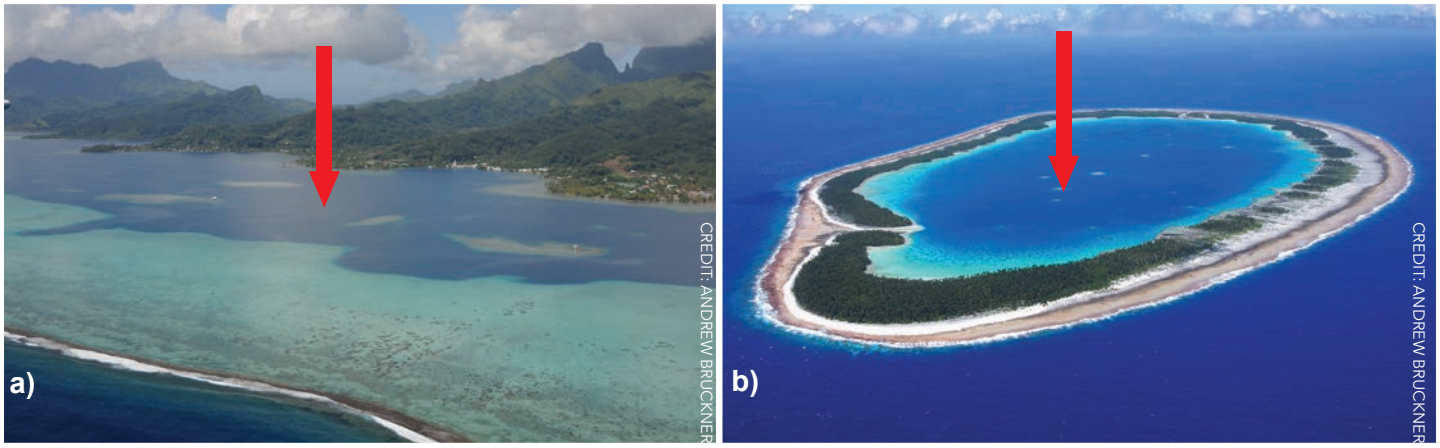

FIGURE 11-2. a) Barrier reef, Society Islands; b) Maria Est Atoll, Tuamotu Archipelago. The red arrows indicate the location of the lagoons.

Water temperature in the lagoon depends on the size and depth of the lagoon as well as the amount of wave action. For instance, a small, shallow lagoon with little wave action may get very hot.

Lagoons that are near mangroves or areas with human development may contain water with high nutrients and low visibility. It is difficult for many species of coral to thrive in this environment.

REEF FLAT

The **reef flat** is an area that is protected from wave action (figure 11-3). The reef flat can extend for feet to miles (meters to kilometers) and the depth can range from inches to several feet (centimeters to a meter). Corals in this zone have adapted to tolerate a wide range of temperatures, light intensity, and salinity. Additionally, corals have adapted to low levels of dissolved oxygen in seawater. When water temperatures are high (over 104°F/ 40°C), there is less dissolved oxygen in seawater. Sometimes during low tide, corals are exposed to air.

Due to these difficult living conditions, the diversity of life on reef flats is much lower when compared to the other zones. Species in this zone have adapted to these extreme environmental conditions and many are found exclusively in this zone.

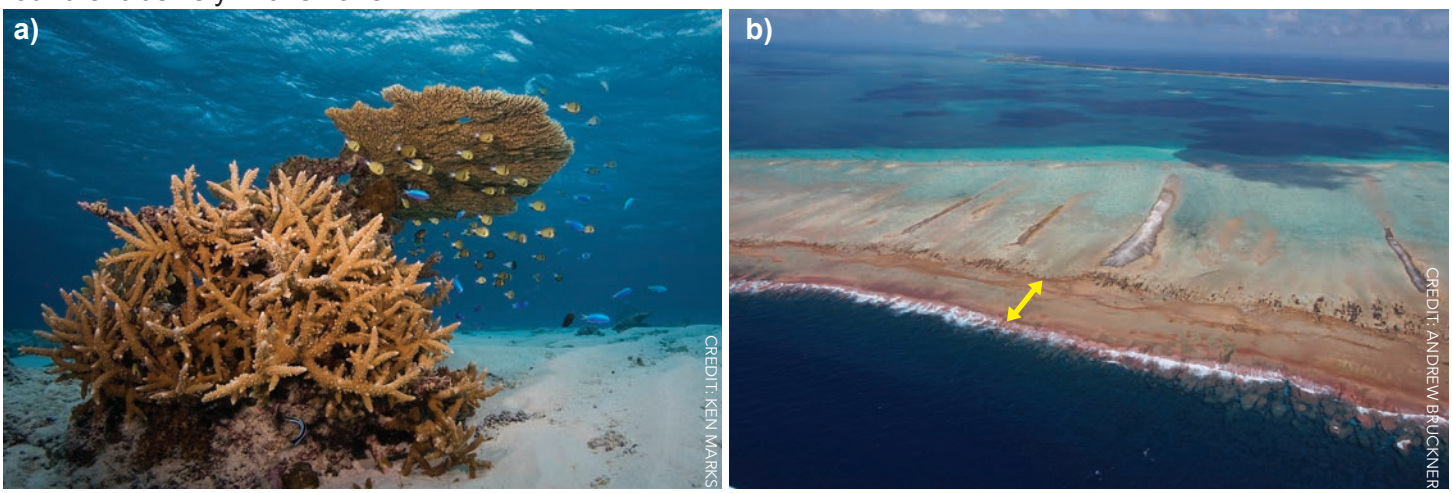

FIGURE 11-3. a) Underwater view of a reef flat; b) The yellow arrow is pointing to the width of the reef flat.

REEF CREST

The **reef crest** is the highest point of the reef (figure 11-4). The reef crest breaks waves and receives the fullest impact of wave energy. During low tide, reef crests can be exposed to air. This zone also receives the greatest amount of light intensity, as it is closest to the water's surface, or even above it. Due to these harsh conditions, not all organisms are able to live here. Corals that do live here must have strong structures that can withstand intense wave action, high light intensity, and aerial exposure in order to thrive in this zone.

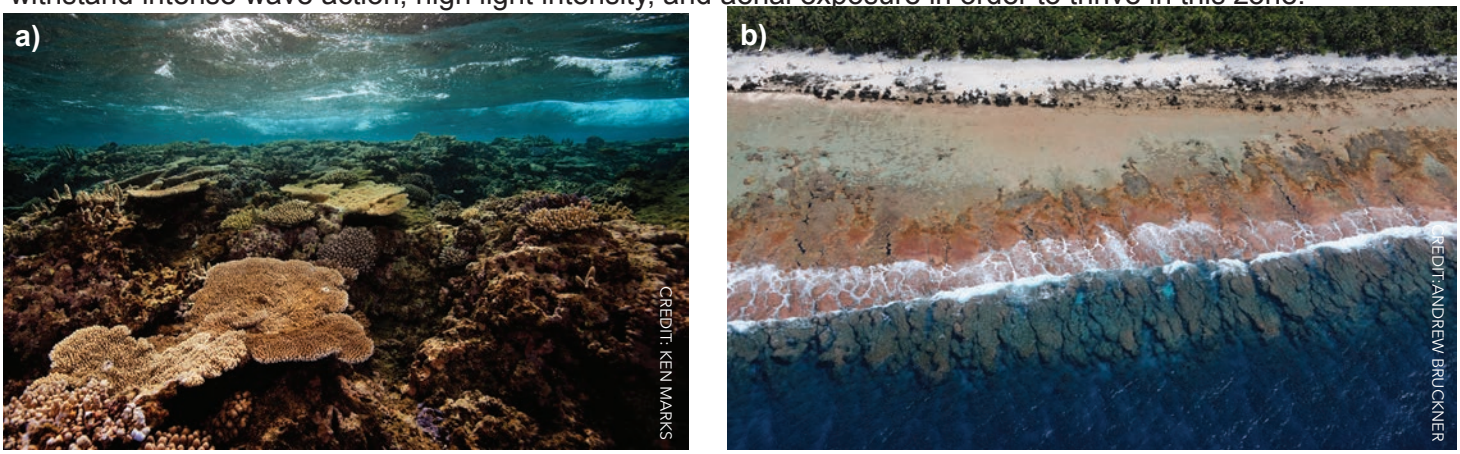

FIGURE 11-4. a) Underwater view of the reef crest; b) The area where the waves are breaking is the reef crest.

In the Pacific and Indian Oceans, this zone can be dominated by calcareous (composed of **calcium carbonate $CaCO_3$**) coralline red algae. In cases such as these, the zone is often referred to as the **algal ridge**. These hard algae are found in elevated ridges as well as **spur and groove reef** formations (figure 11-5) that extend seaward. Spurs refer to the areas that form parallel ridges of coral growth, while grooves separate these ridges and contain sediment and coral rubble that has eroded from the spurs.

FIGURE 11-5. Spur and groove reef formation

REEF FRONT OR FORE REEF

The **reef front** or **fore reef** (figure 11-6) is found at the furthest distance from shore. It slopes downward and can reach great depths. Sometimes the reef front extends almost straight down forming a vertical wall called a **drop-off**.

Most corals thrive in the intermediate zone of the reef front between 15-65 feet (5-20 meters) deep. This is where the greatest diversity of corals exist. In both shallower and deeper parts of this zone, diversity declines and some corals have adapted to living at specific depths. Corals in this intermediate zone are exposed to relatively low wave action and light. Often, corals modify their growth forms in order to survive in different zones (see *Unit 9: Coral Growth*). For instance, plate corals have more surface area allowing for these corals to receive a greater amount of light. This in turn allows zooxanthellae to create food and nutrients for the corals (see *Unit 4: Coral Feeding*).

FIGURE 11-6. Reef fronts

BACK REEF

The **back reef** is an area that slopes into a lagoon. The back reef is often shallow and more protected from wave action (figure 11-7). It can be exposed to air during low tide. Isolated patch reefs often exist here as well as coral rubble.

FIGURE 11-7. The red arrow is pointing to the back reef of the atoll in Tuamotu, French Polynesia. It is the area of turquoise water.

B) ZONATION PATTERNS

Fringing reefs, barrier reefs, and atolls may have different characteristics, yet, they have similar zonation patterns.

A fringing reef does not have a lagoon or a back reef. The reef flat extends from the shoreline, ending at the reef crest. The reef front is found on the oceanic side of the reef crest. See figure 11-8.

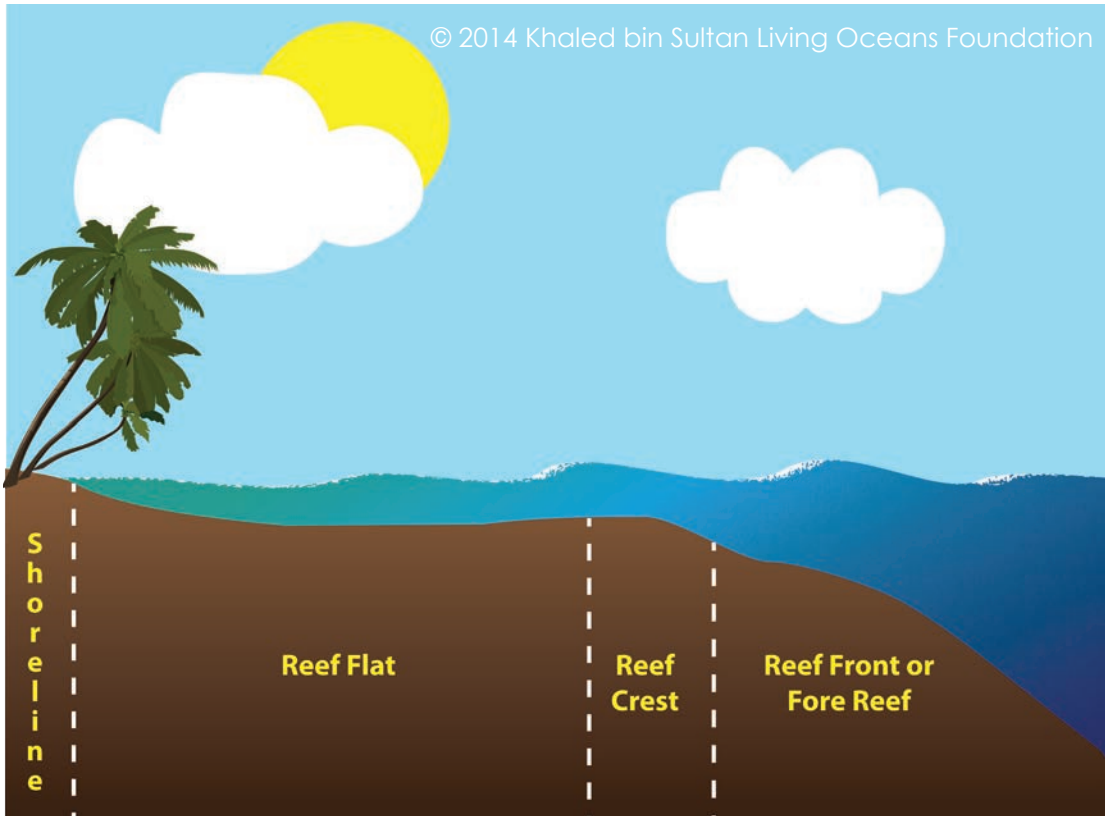

FIGURE 11-8. Cross-section of fringing reef

Barrier reefs are separated from land by a lagoon (figure 11-9). The reef crest is bordered by the back reef, on the shore side, and the reef front, on the oceanic side (when there is not reef flat). Barrier reefs can have a reef flat that is found between the back reef and reef crest (not seen in figure 11-9).

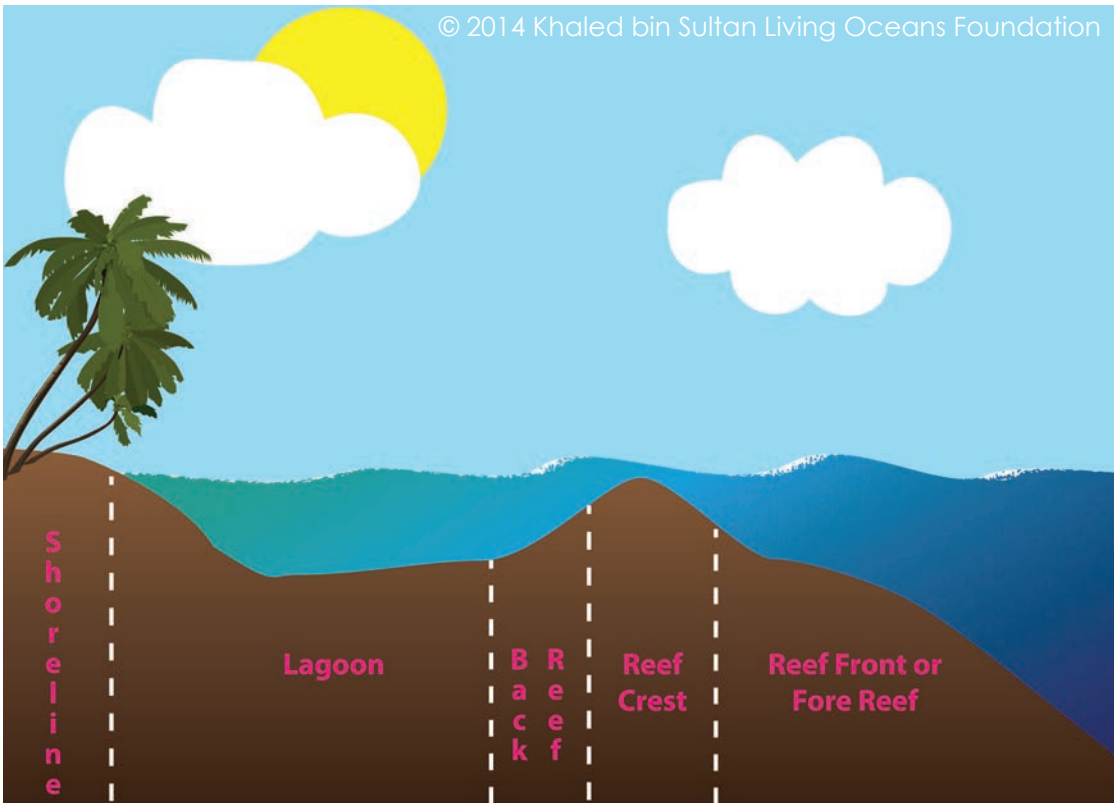

FIGURE 11-9. Cross-section of barrier reef

Remember that atolls are a somewhat circular shape. In the center of the atoll is a lagoon, which can be completely enclosed by land (figure 11-2b) or partially surrounded, allowing for water to flow in and out of the lagoon through channels. Most of the reef is on the outside of the atoll. In atolls, reef flats can be found on the ocean-facing side of land (figure 11-10) or next to the back reef (not in figure 11-10). 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.

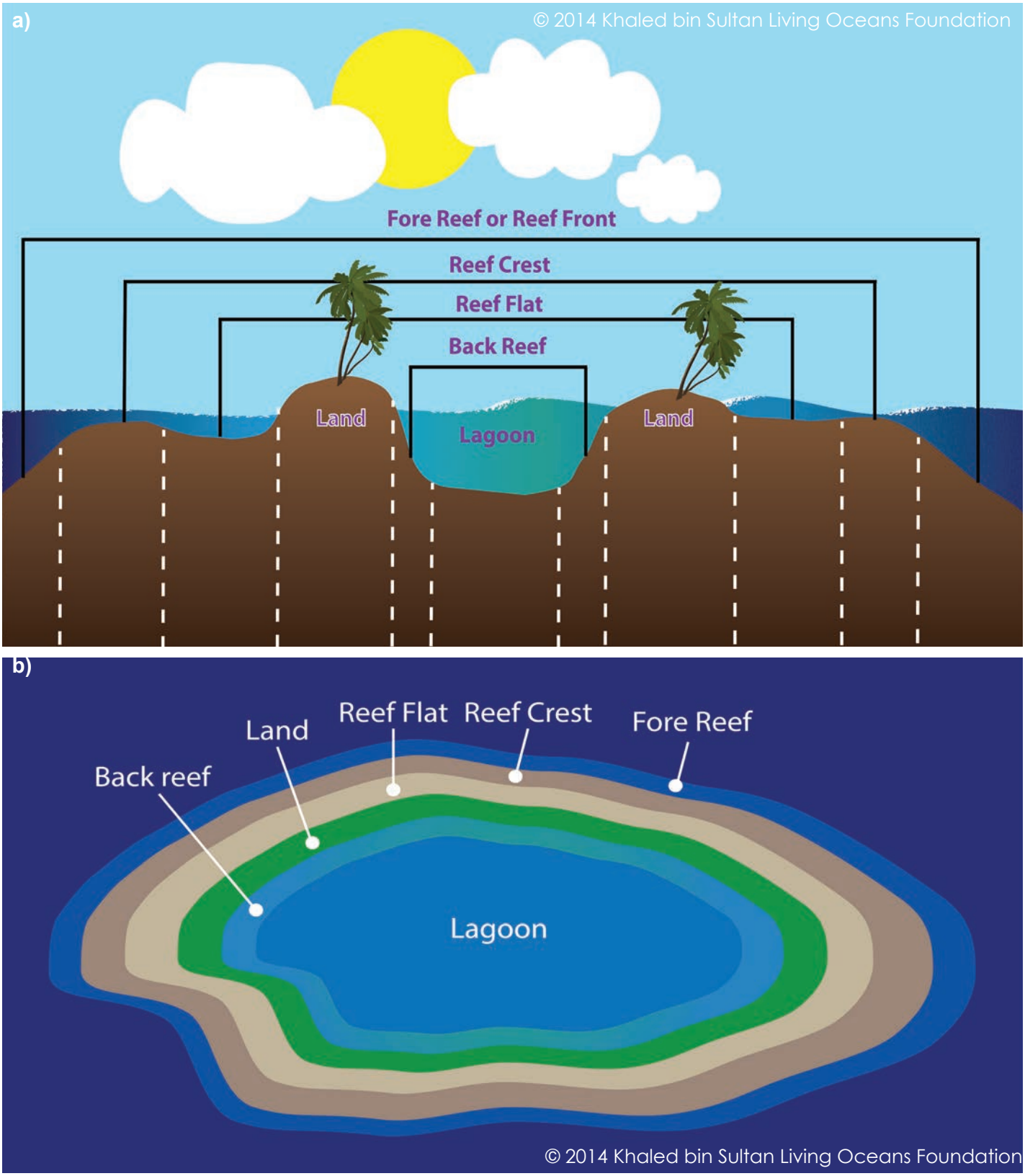

FIGURE 11-10. a) Cross-section of atoll; b) Aerial view of an atoll

ATTRIBUTION

Figure 11-8-11.10a. Palm tree vector by Sergio Fiallo [CC0 1.0 Universal (*http://creativecommons.org/publicdomain/zero/1.0/*)], 08 May 2011 via Clker.com. *http://www.clker.com/clipart-alone-palm-tree.html*.

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WATCH IT! CORAL REEF ZONES

INSTRUCTIONS: Watch *Coral Reef Zones* YouTube video (*https://youtu.be/1wMrB37_GvI*) and answer the following questions.

1. What do scientists divide coral reefs into? _____

2. List five characteristics that define coral reef zones.

_____ _____

_____ _____

_____

3. What are the main two factors influencing differing zonation?

_____

_____

4. What is the most common type of reef? _____

5. What is a fringing reef?

_____

_____

6. Describe the characteristics of a fringing reef.

_____

_____

Name: _____ Date: _____

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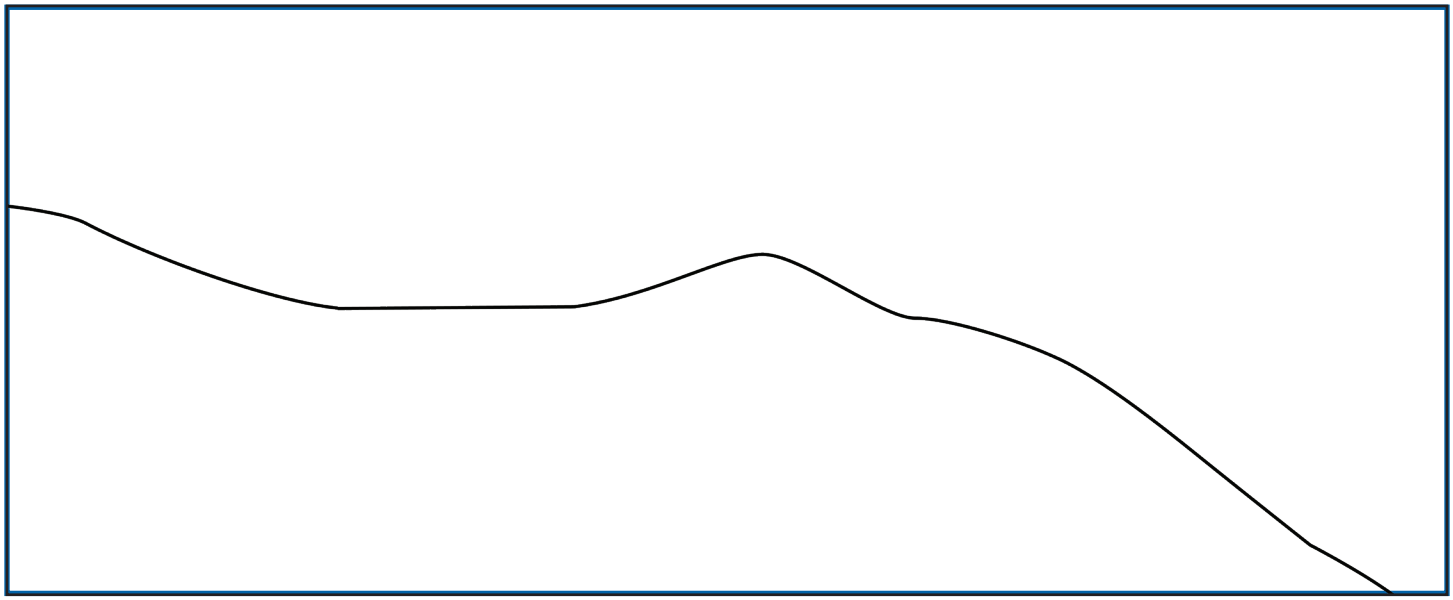
WATCH IT! CORAL REEF ZONES

7. Draw the zones of a fringing reef.



8. Why do corals look different in varying zones? _____

_____

9. What zone receives the greatest amount of sunlight? _____

10. What is the surface of the reef crest composed of? _____

11. Which zone receives the greatest amount of wave action? _____

12. Which zone has the greatest diversity of corals? _____

13. Why do corals grow wide and flat at greater depths?

_____

_____

14. What is a barrier reef?

_____

_____

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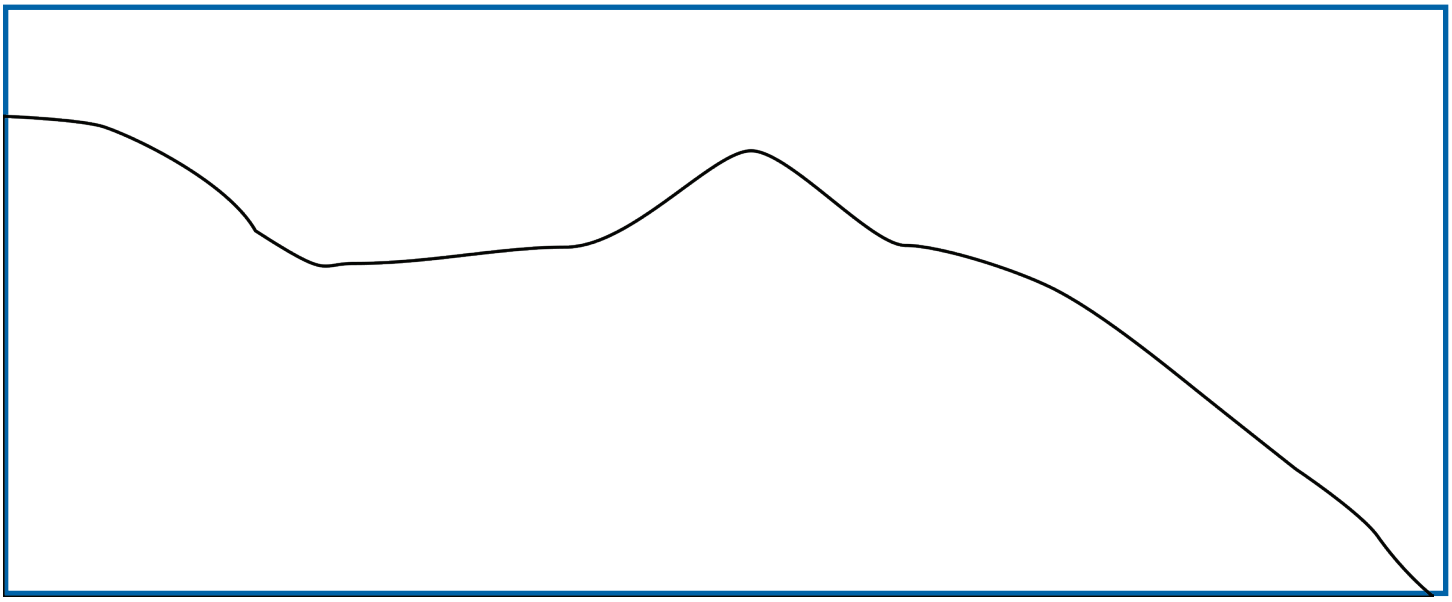
WATCH IT! CORAL REEF ZONES

15. Draw the zones of a barrier reef.

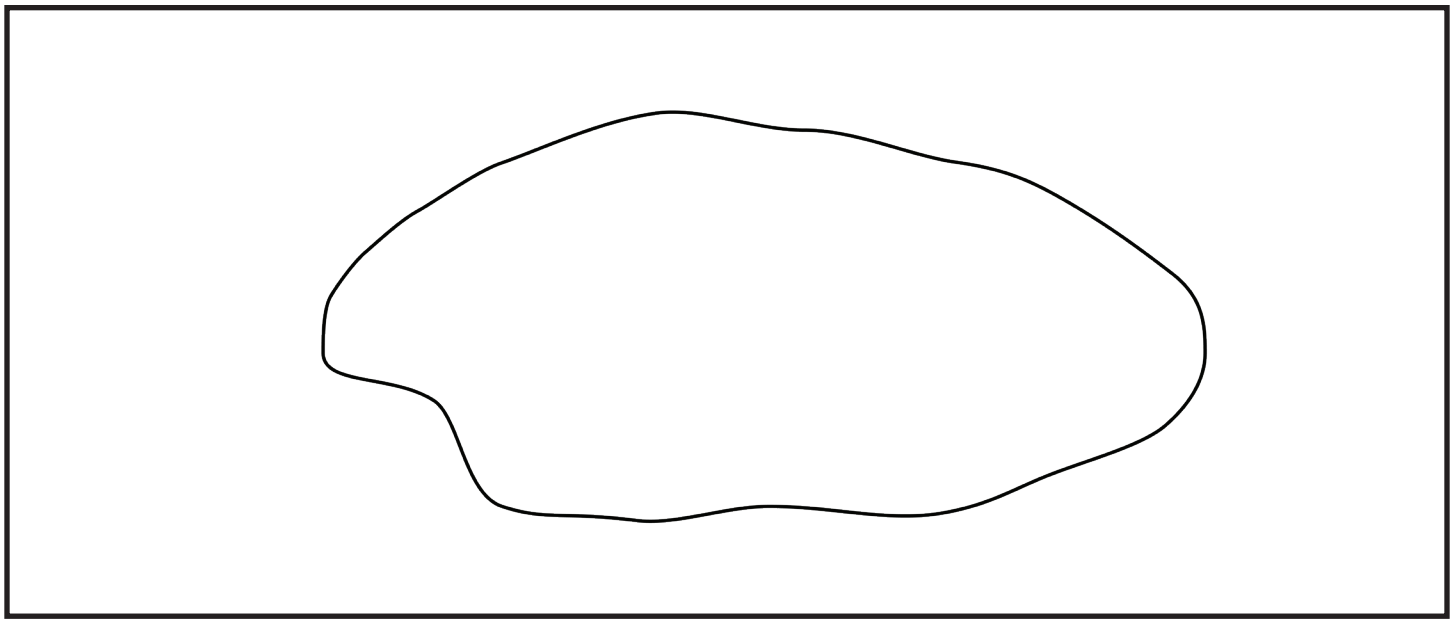


16. What is an atoll?

_____

_____

17. Draw the zones of an atoll.



Name: _____ Date: _____

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WATCH IT! CORAL REEF ZONES

VIDEO SCRIPT:

To most of us, coral reefs are simply wonderlands, thriving ecosystems that support thousands of different species.

But to scientists, this habitat is more complex and varied, and different organisms, including different types of corals, live in specific parts of the reef.

Scientists divide coral reefs into zones.

They base these divisions on location within the reef, and characteristics such as depth, wave action, light intensity, temperature, and water chemistry.

The zones can vary depending on the kind of reef and its location in the world.

The most common type of reef is the fringing reef, which grows outward from coastlines of islands and continents.

In a fringing reef, the zone found along the shoreline is called the reef flat.

For corals, it's a tough place to live.

Wide variations in temperature and salinity challenge the corals, and low tides expose them to air.

Species that survive here have adapted and often look different than they do in deeper water.

The reef flat extends out to the highest part of the reef called the reef crest. This zone receives the greatest amount of sunlight.

Its crusty surface, made of calcium carbonate, can survive the brute force of the waves, which hit hardest here.

The last zone of the fringing reef is the one farthest from shore, the reef front or fore reef.

In the shallower part of this zone, the diversity of corals is greater than in other parts of the reef.

They thrive between 5 and 20 meters deep, where sunlight filters down and wave action is gentle.

Farther out to sea, the reef front slopes downward and can reach great depths. Corals here often grow wide and flat, to take maximum advantage of the faint sunlight, a good example of organisms adjusting to a zone's characteristics.

A fringing reef may be the most common type of reef, but there are two other types whose zone pattern, or "zonation," as scientists say, is somewhat different.

One is called a barrier reef.

Here the shoreline is separated from the reef by an expanse of water called a lagoon.

Next to it, a zone named the back reef leads to the reef crest.

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WATCH IT! Coral Reef Zones

The size and depth of lagoons vary widely. The corals that live here do too.

The third type of reef is called an atoll. It's usually circular or oval in shape, with a lagoon in the center.

The same zones can be found in the atoll too.

But the back reef is located in the center along with the lagoon, while the other zones extend outwards from the shoreline.

Understanding the different zones in coral reefs contributes to our appreciation of the whole ecosystem, one of the most diverse and productive on earth.

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WATCH IT! CORAL REEF ZONES

INSTRUCTIONS: Watch *Coral Reef Zones* YouTube video (*https://youtu.be/1wMrB37_GvI*) and answer the following questions.

1. What do scientists divide coral reefs into? **Zones**

2. List five characteristics that define coral reef zones. **Answers may vary.**

Location **Depth**

Wave action **Light intensity**

Temperature **Water chemistry**

3. What are the main two factors influencing differing zonation?

Reef Type

Location in the world

4. What is the most common type of reef? **Fringing reef**

5. What is a fringing reef?

A fringing reef grows outward from islands and continents.

6. Describe the characteristics of a fringing reef.

Fringing reefs have a wide variation of temperature and salinity and they can be exposed at low tide.

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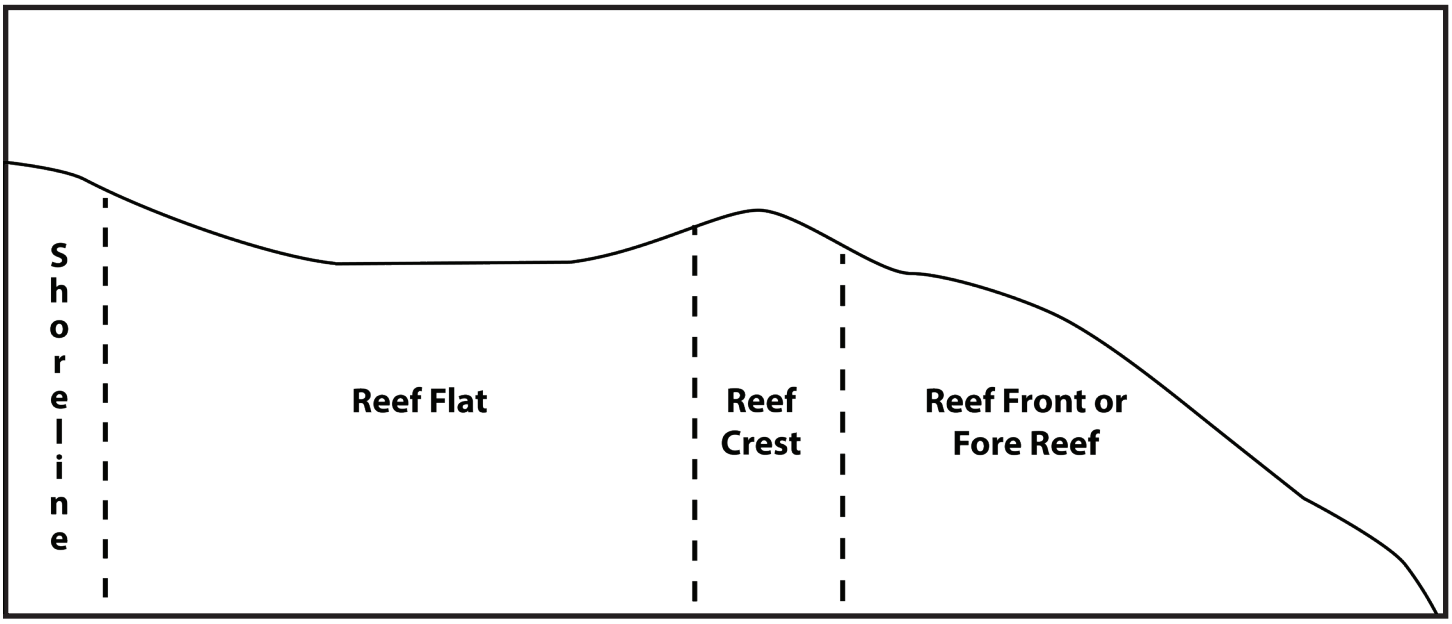
WATCH IT! CORAL REEF ZONES

7. Draw the zones of a fringing reef.



8. Why do corals look different in varying zones? **Corals have adapted to living in different environmental conditions**

9. What zone receives the greatest amount of sunlight? **Reef crest**

10. What is the surface of the reef crest composed of? **Calcium carbonate**

11. Which zone receives the greatest amount of wave action? **Reef crest**

12. Which zone has the greatest diversity of corals? **Reef front or fore reef**

13. Why do corals grow wide and flat at greater depths?

Corals grow in this formation in order to maximize the amount of sunlight they receive.

14. What is a barrier reef?

A barrier reef has a lagoon that separates the shoreline from the reef.

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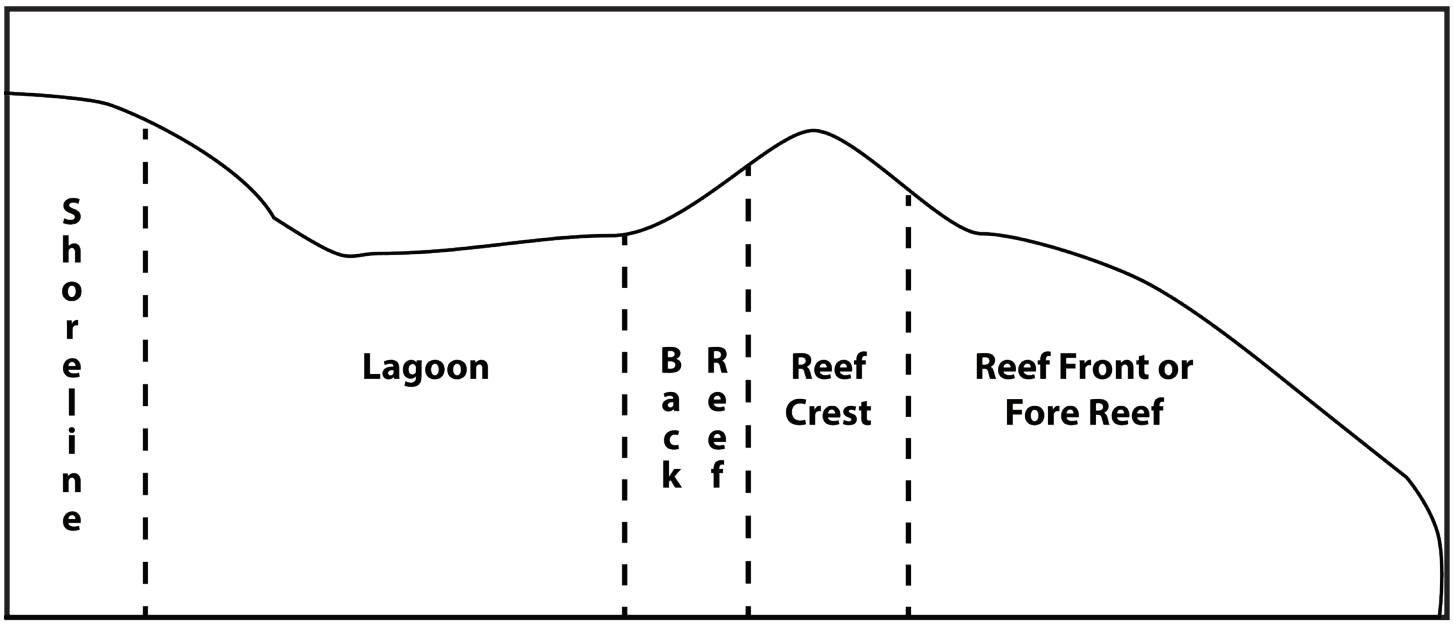
WATCH IT! CORAL REEF ZONES

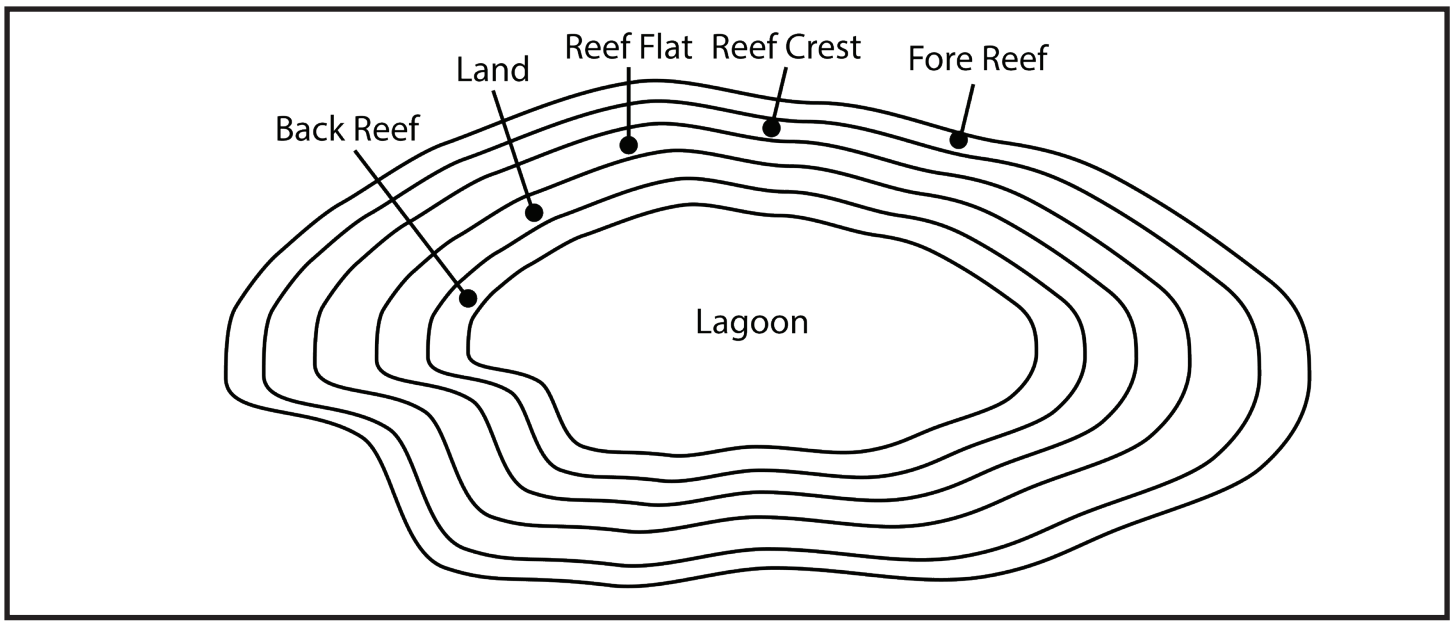
15. Draw the zones of a barrier reef.



16. What is an atoll?

An atoll is a circular or oval shaped reef with a lagoon at the center.

17. Draw the zones of an atoll.



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LESSON 1

TEACHER'S NOTES

AUTHORS

- Melinda Campbell & Ashley Miller, Khaled bin Sultan Living Oceans Foundation

LEARNING OBJECTIVES

- Identify the three main types of coral reefs.
- Observe the differences between the three main types of coral reefs.
- Describe the vertical zones (and lagoon) for the three main types of coral reefs.
- Build a model of one of the main types of coral reefs, demonstrating the vertical zonation pattern typical of that type.

KEYWORDS

- Abiotic Factor
- Algal Ridge
- Atoll
- Back Reef
- Barrier Reef
- Drop-off
- Fore Reef
- Fringing Reef
- Lagoon
- Patch Reef
- Reef Crest
- Reef Flat
- Reef Front
- Spur and Groove Reef

MATERIALS

- Internet/library
- Shoebox (have students provide) or cardboard
- Thick cardboard or another flat material to use as a base for the clay model – this needs to be water resistant if you want to do the second *Extension* activity
- Paint
- Assorted modeling tools (toothpicks, spoons, forks, wood craft sticks)
- Modeling clay
- Toothpicks
- Scissors
- Construction paper
- Markers
- **Watch It! Coral Reef Zones** student worksheet
- **Lesson 1: Modeling Coral Reefs** student worksheet
- **Appendix A: Coral Reef Photos**

INTEGRATING SUBJECTS

- Art
- Public Speaking

PRIOR KNOWLEDGE

- Students will have an understanding of the three main types of reefs. See *Unit 10: Reef Types - Background Information*.

EXTENSIONS

- Have students create a conservation poster about their assigned coral reef, displaying the negative environmental impacts that are occurring, and answering the following: What are the human induced threats that are affecting this reef? Who are the contributors to these threats? What are the negative consequences to these threats? How can we help stop these negative effects? (See *Unit 19: Threats*)
- Put one or more of the clay models into a clear, plastic container. Add water so that it covers the top of the model. Remove half of the water and discuss what happens when sea level drops. Next, add more water in order to show sea level rise and then discuss the consequences for the future. (See *Unit 12: Reef Formation*.)

EVALUATIONS

- Randomly place the **Appendix A: Coral Reef Photos** around the room. Have students match the clay models to the photos. (You may want to give the models a letter so they can easily write down their answers, matching it to the numbers on the photos.) Students should label each one as a barrier reef, fringing reef, or atoll.
- Have students use the models to create an in depth description of each of the three main types of coral reefs.

STANDARDS

- CCSS: RST.9-10.5, 7; RST.11-12.8; SL.9-10.1, 2, 3, 6; SL.11-12.1, 2, 3, 6
- NGSS: HS-ESS2-1, HS-LS2-6
- OLP: 5.B.7, 5.B.8

PROCEDURE

- See next page.

PROCEDURE

Several weeks before the lesson, have students start bringing in shoeboxes. You may want to have those who can, bring in more than one for any students who forget or do not have access to shoeboxes. You only need one per group. If shoeboxes are unavailable, use a piece of cardboard as a backdrop for their model.

1. Watch *Coral Reef Zones* YouTube video (*https://youtu.be/1wMrB37_GvI*) and answer questions on **Watch It! Coral Reef Zones** student worksheet.
2. Hand out **Lesson 1: Modeling Coral Reefs** student worksheet.
3. Teach *Unit 11: Reef Zonation - Background Information*. Have students answer questions under instruction #1 on their student worksheet.
4. Divide students into groups of 3-4 students. Hand out one of the **Appendix A: Coral Reef Photos** to each group.
5. Discuss the information in the grading rubric.
6. Give students time to research their coral reef. You may want to discuss which websites they are allowed to use.
7. Once students have answered the research questions (under instruction #2 on their student worksheet), discuss the various ways students can and cannot use the modeling tools. You may want to approve their answers to the questions under instruction #2 before they are allowed to create their models. Go over the steps in instruction #3 on the student worksheet.
8. Give students time to create the shadowbox and a clay model of their reef.
9. Label a different corner of the room with each of the three types of reefs (barrier, fringing, or atoll). Have each group present their model, paying close attention to the zonation. After each presentation, have the students vote by moving to the corner of the room that indicates which type of coral reef the model shows. Each time, ask at least one student in each corner why s/he thinks it is that type. Allow students to move after each student speaks, if they change their mind.
10. To end the discussion, have students brainstorm the differences in the zonation patterns of each type of reef. Write their answers on the board. Get a student to illustrate each one at the end.

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LESSON 1 MODELING THE REEF

INSTRUCTIONS:

1. Answer the following questions:
   a. Describe each of the three main types of coral reefs.

   b. What are the different vertical zones found in coral reefs?

   c. How do the abiotic factors differ between the zones? Add your answers to the table below.

Reef flat	Lagoon	Reef crest	Reef front	Back reef

   d. How do the biotic factors differ between the zones? Add your answers to the table below.

Reef flat	Lagoon	Reef crest	Reef front	Back reef

2. Research the coral reef assigned to you by your teacher so that you can make a model of it. Answer the following questions:

   Name of assigned reef: _____

   a. Use the picture provided to sketch an aerial view of your coral reef in the space below.

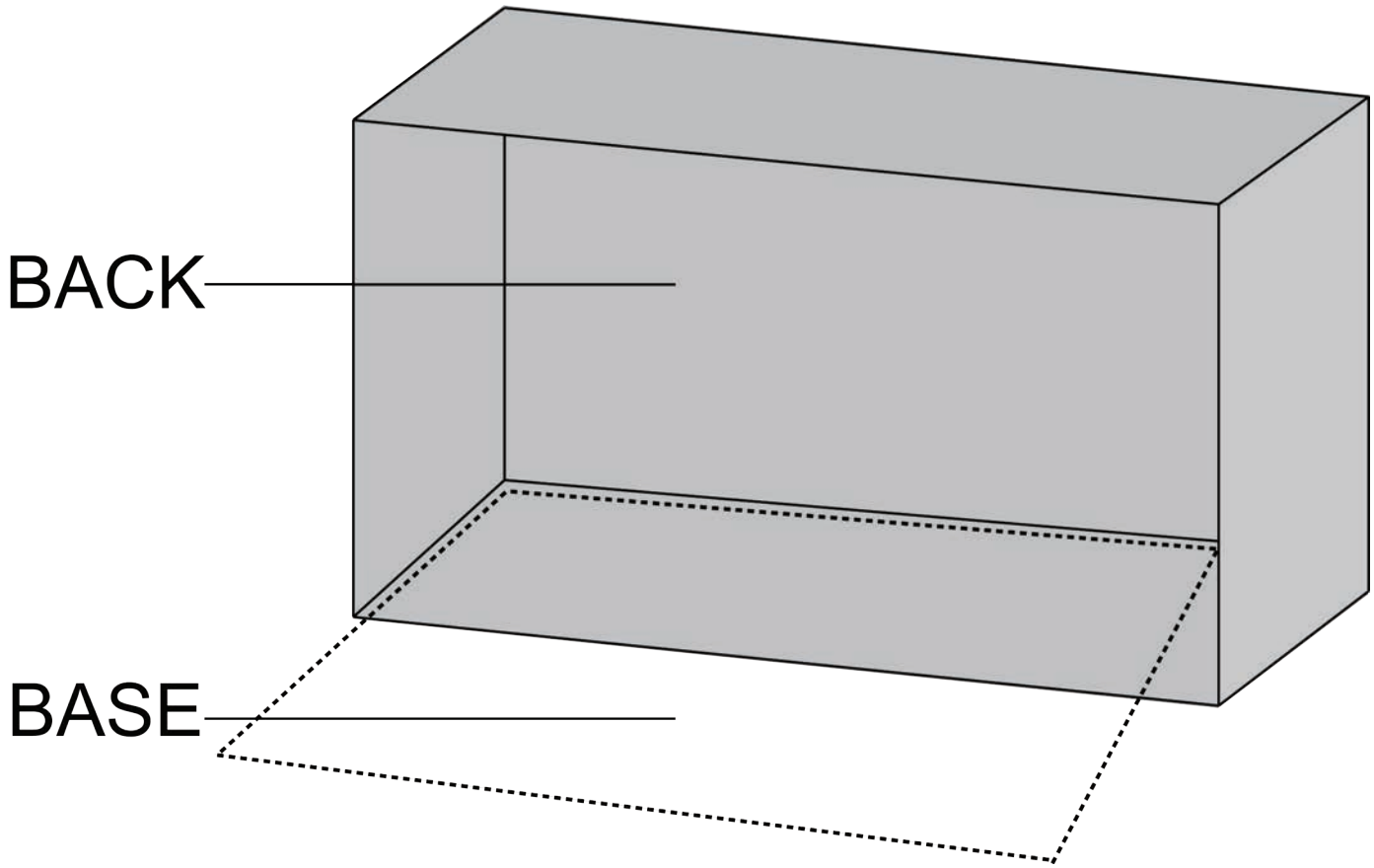
   b. Use the picture provided to sketch a cross section of your reef. You will need to estimate changes in depth. Look at the colors – the darker the blue, the deeper it is, while brown indicates shallow areas.

c. Label the reef zones in your drawings from a. and b.
d. Where in the world is your reef located? Be sure to include the name of the ocean where the reef is located, as well as a more specific area description (country, group of islands, etc.).

e. What are some coral species growing on your reef? What do they look like? Use *http://www.coralsoftheworld.org/page/home/* to explore the region you described in question d.

f. Describe some of the other animals that live on and around your reef. Be sure to include species you would want to put in your shadowbox. Put the information from your answer to question d in the "Geographical Area" box of *http://www.marinespecies.org/aphia.php?p=checklist* to identify animals found on your reef (click on Distribution in the left hand panel if you do not see this box). You may need to do a further search of the internet to find out more information about the species. You can add a term to the "Limit to taxa belonging to" box, if you would like to find certain types of animals (for instance, enter *Elasmobranchii* here if you want to see what sharks and rays are found on your reef).

3. Create your shadowbox.
   a. Make sure the base that you use for your model fits into the shoebox. It can hang out the side, but needs to be a little bit smaller than the bottom so it can slide in and out. See diagram below.



   b. Paint the back of your box with a sky and ocean water – each taking up about 50% of the backdrop. Allow to dry.
   c. Make a model of your coral reef out of the clay – you do not have to model the entire reef, but should include a good representation of all of the zones found there. Be sure you match the height of your clay model with the height of the ocean water you painted in your shoebox.
   d. Add fine details to your reef by using the modeling tools provided by your teacher.
   e. Label the different zones of your reef with a small piece of construction paper attached to a toothpick.
   f. When the box is dry, slide your clay model into it.
   g. Get creative – add waves, palm trees, clouds, fish, etc. (refer to your answers in #2).

4. When directed by your teacher, present your model to the class.

GRADING RUBRIC:

Category	4	3	2	1	Score
Research Drawings	Drawings are neat and informative. All zones are labeled.	Drawings are informative. All except 1 zone is labeled.	Drawings are messy or not informative. 2 zones are not labeled.	Drawings are not present or not useful. 3 or more zones are not labeled.	
Research Questions	All questions (d-f) are answered in complete sentences.	All questions (d-f) are answered.	3 or more of the questions (d-f) are answered.	Less than 3 questions (d-f) are answered.	
Shadowbox Model Size	Clay model is the correct size for the ocean portion of the background.	Clay model is within an inch of the correct size for the ocean portion of the background.	Clay model is within 1-3 inches of the correct size for the ocean portion of the background.	Clay model is more than 3 inches from being the correct size for the ocean portion of the background.	
Shadowbox Accuracy	Model is detailed, and accurate, including all labels.	Model is detailed and mostly accurate, including all labels.	Model is mostly accurate, including most of the labels.	Model is inaccurate with little detail and few to no labels.	
Shadowbox Creativity	There are more than 3 creative details.	There are 2-3 creative details.	There is 1 creative detail.	There are no creative details.	
Presentation Accuracy	Presentation was completely accurate.	Presentation had 1-2 minor errors.	Presentation had some inaccuracies.	Presentation had many inaccuracies.	
Presentation Delivery	Excellent and clear verbal articulation of ideas.	Explained ideas well.	Ideas were well stated, but lacked some clarity.	Ideas were difficult to understand.	
Presentation Follow-up	Student can accurately answer all questions related to the shadowbox.	Student can accurately answer about 75% of questions related to the shadowbox.	Student can accurately answer about 50% of questions related to the shadowbox.	Student appears to have insufficient knowledge about the shadowbox.	
TOTAL				**Out of 32:**	

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LESSON 1 Modeling The Reef

INSTRUCTIONS:

1. Answer the following questions:
   a. Describe each of the three main types of coral reefs.
      - **Fringing reefs: Found directly off-shore with no lagoons.**
      - **Barrier reefs: Linear reefs that run parallel to shore with an expansive lagoon between them.**
      - **Atolls: A roughly circular oceanic reef surrounding a large central lagoon that's usually located in mid-ocean.**

   b. What are the different vertical zones found in coral reefs?
      Reef flat, reef crest, reef front, and back reef. Lagoon may be included, but technically is not a zone.

   c. How do the abiotic factors differ between the zones? Add your answers to the table below.

Reef flat	Lagoon	Reef crest	Reef front	Back reef
Temperature, light, and salinity vary widely.	Temperature and light depend on the depth and nutrient levels depend on the reef's location.	Receives the highest amount of wave action and may be exposed to air at low tide.	Can have drop-offs, so varies greatly in light and temperature.	Receives low wave action, but can still be exposed to air during low tide.

   d. How do the biotic factors differ between the zones? Add your answers to the table below.

Reef flat	Lagoon	Reef crest	Reef front	Back reef
Diversity of corals is lower.	Have patch reefs, seagrass, and a lot of coral rubble and sand.	Corals are strong, but this zone is often dominated by coralline algae.	In the deeper parts, corals are often found with wider growth forms, such as foliose or plating, to catch the light.	A lot of dead coral, due to air exposure.

EXAMPLE OF SHADOW BOX

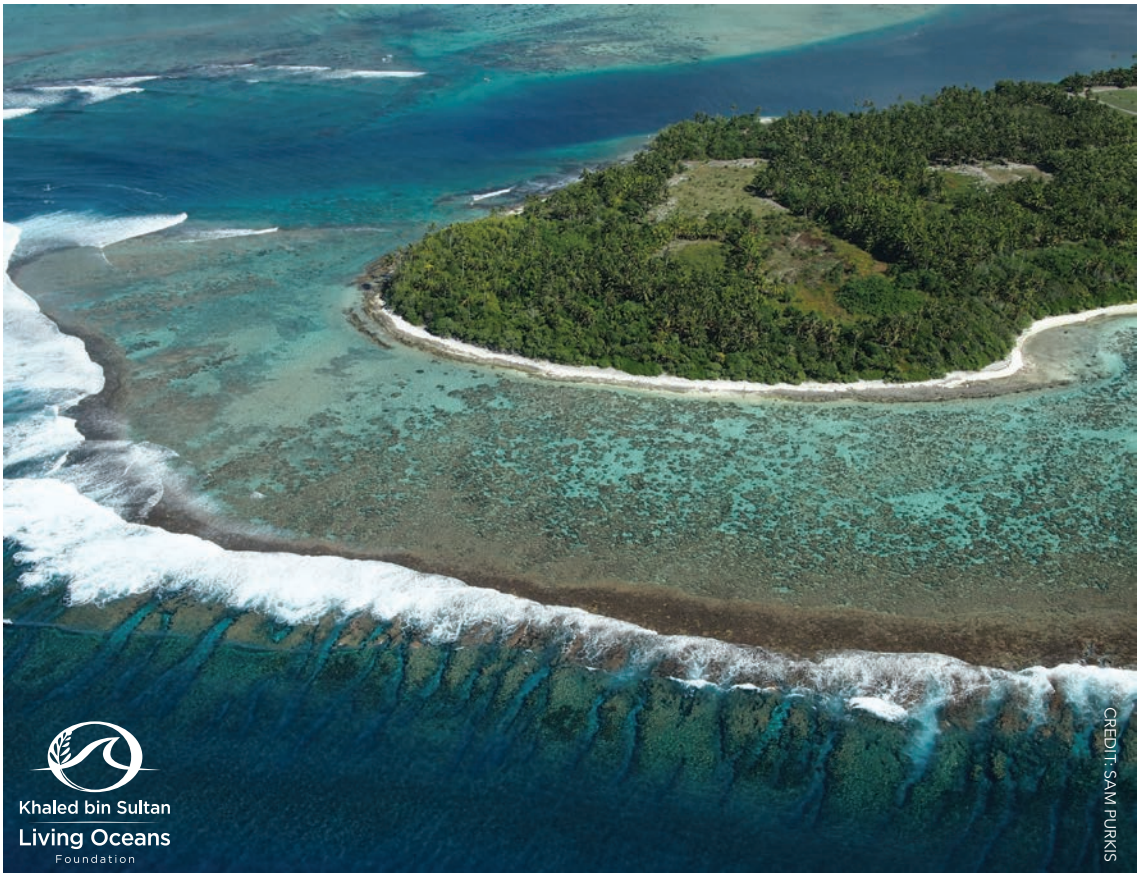
APPENDIX A ANSWER KEY

1. Fringing reef
2. Atoll
3. Fringing and barrier reef
4. Barrier reef
5. Barrier reef
6. Atoll
7. Fringing reef
8. Atoll

#1 MILMAN ISLET NATIONAL PARK, AUSTRALIA

#2 TENARARO, FRENCH POLYNESIA

#3 HUANINE, FRENCH POLYNESIA



#4 RAIATEA, FRENCH POLYNESIA

#5 BORA BORA, FRENCH POLYNESIA

#6 MOTU ONE, FRENCH POLYNESIA

#7 MOPELIA, FRENCH POLYNESIA

#8 NIAU, FRENCH POLYNESIA

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LESSON 2 TEACHER'S NOTES

AUTHORS

- Melinda Campbell, Claire Silva, & Amy Heemsoth Khaled bin Sultan Living Oceans Foundation

LEARNING OBJECTIVE

- Explore the characteristics of reef zones by using GIS maps.

KEYWORDS

- Algal Ridge
- Back Reef
- Drop-off
- Fore Reef
- GISLagoon
- Patch Reef
- Reef Crest
- Reef Flat
- Reef Front
- Spur and Groove Reef
- Topography

MATERIALS

- Computer lab
- Internet
- **Watch It! Coral Reef Zones** student worksheet
- **Lesson 2: GIS Mapping** student worksheet
- *World Web Map* (*http://maps.lof.org/lof*)

INTEGRATING SUBJECTS

- Technology

EXTENSIONS

- Discuss how natural stressors, such as hurricanes, and global climate change impact life in reef zones.
- Research how coral reef ecologists use GIS mapping to monitor the health of coral reefs over time.
- Watch *Mapping the Blue* (*https://youtu.be/1fTzilnT2zU*) and discuss how policy makers use GIS maps of reefs to create strategies for developing marine preservations for conservation.

STANDARDS

- **CCSS:** RST.9-10.2, 3, 4, 5, 7, 10; RST.11-12.2, 3, 4, 10
- **NGSS:** HS-LS2-6
- **OLP:** 7.A.5, 7.C.2, 7.C.3

PROCEDURE

1. Explore *http://maps.lof.org/lof* so you are comfortable with the tools needed for this lesson. NOTE: The *Measure Tool* (procedure #7) is not available on any mobile devices. Additionally, the *Habitat Analysis Tool* (procedure #8) is not available on phones, but is on tablets. To do this entire lesson, a computer is required.
2. Watch *Coral Reef Zones* YouTube video (*https://youtu.be/1wMrB37_GvI*) and answer questions on **Watch It! Coral Reef Zones** student worksheet.
3. Teach *Background Information Unit 11: Reef Zonation*.
4. Hand out **Lesson 2: GIS Mapping** student worksheet.
5. Allow students time to learn how to use the map tools and then have them complete the worksheet.

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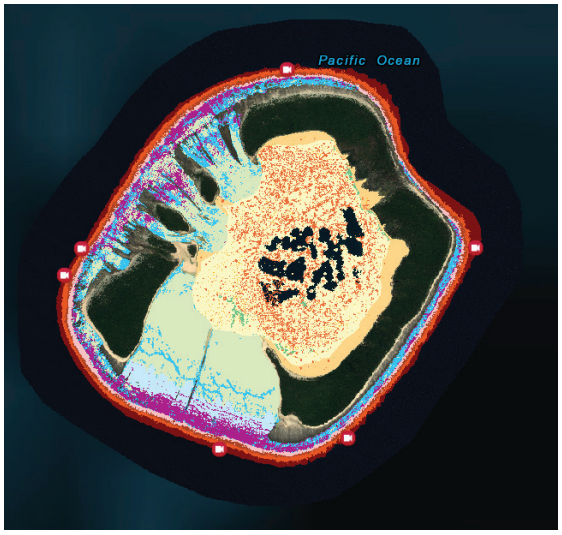
LESSON 2 GIS Mapping

ADDITIONAL BACKGROUND INFORMATION:

GIS stands for Geographic Information System. It is a tool used by scientists and other experts to display and analyze a large data set that is linked to a latitude and longitude. GIS mapping allows visualization of data so that patterns may become more easily visible. The data on a GIS map can often be manipulated and analyzed on the map itself, which allows it to be presented and displayed better than traditional graphs and tables. Often the data is stored in layers. For instance, the Khaled bin Sultan Living Oceans Foundation's World Web Map starts with a map of the world and then you can choose whether to show benthic habitat data, bathymetry, and/or depth contours on top of the map. In addition, our map has videos and photos embedded into it so you can see what the coral reef looks like in specific areas of the world.

PROCEDURES:

1. Go to *http://maps.lof.org/lof*.
2. In the upper-right hand corner is the menu. (If it is not already open, click on the icon.) Click on *Select a Location*, then *French Polynesia*, and then *Bellingshausen*, which looks like the image below. (Be patient, it may take a moment to load.)



3. In the menu, click *View Legend* to see what habitat each color on the map indicates. (You may need to click on *Select a Location* again to close that section of the toolbar.) What three habitats look like they take up the most area on Bellingshausen?

4. Use what you have learned from *Unit 11: Reef Zonation* to define the reef zone in the left-hand column of *Table 1*.

5. Use the legend to list the habitats on the Bellingshausen map that correspond with each reef zone. Fill in the second column in *Table 1*.

6. In the menu, click *Toolbar*, and then click on the  icon for the *Identify Tool*. Now if you click on the different colors on the map, a description of the individual habitats will pop up. (You may need to zoom in to accurately click on a specific habitat. The zoom bar is on the left-hand side of the map.)

7. In *Table 1*, fill in the appropriate columns to compare the topography and depth range of the different habitats in each zone. NOTE: Topography and depth range are the last topics described in the *Habitat Description*.

8. Click on one of the  video icons. (If you see an *Identify Tool* information box, and not the video, click on *Next Feature*  in the top right of the pop-up window until you get to the video.) How does this visual information compare to the written information that you get from the *Identify Tool*?

9. In the menu, click *Toolbar*, and then click on the  icon for the *Measure Tool*. Then click on the  icon and change the unit to meters. Use this tool to measure the widest part of each zone. To measure the width:
   a. Change the zoom until the zone you are measuring takes up as much space on the screen as possible while still being able to see the whole thing.
   b. Click on the edge of the widest part of the zone. A green flag will appear.
   c. Without clicking again, move the mouse until a blue line has been drawn across the widest part of the zone.
   d. Double click to plant a second green flag. (If you only click once, that is ok. Without moving your mouse, double click.)
   e. You can find your *Measurement Result* in the menu.
   f. Record the measurement in the right-hand column of *Table 1*.

10. In the menu, click *Toolbar*, and then click on the  icon for the *Habitat Analysis Tool*. To use the tool:
    a. Zoom out until you can see all of Bellingshausen reef.
    b. In the menu, change the radius to 3 km.
    c. Click on the  icon.
    d. Move your mouse to the map. A box should tell you "*Click to add a point*".
    e. Estimate where the center of Bellingshausen is and click on that spot. A red circle should appear around the entire reef.
    f. Wait a few moments for the report to appear.
    g. Excluding "*Area not mapped*" and "*Terrestrial vegetation*", what three habitats take up the most area on Bellingshausen and how many square meters do they occupy?

TABLE 1:

Reef Zone	Habitats	Topography	Depth Range	Width of Habitat
Lagoon:				
Reef Crest (Algal Ridge):				

Reef Zone	Habitats	Topography	Depth Range	Width of Habitat
Fore Reef:				
Back Reef:				

INSTRUCTIONS: Answer the following questions:

1. Why are the videos a helpful addition to the rest of the data?

2. Follow the procedures for using the tools again, but this time choose a different location. Fill out *Table 2* and use the information in *Tables 1* and *2* to answer the following questions:

   a. What is the name of this reef?

   b. What habitats did both reefs have in common?

   c. What habitats, if any, did the second reef have that Bellingshausen did not?

   d. What habitats, if any, did Bellingshausen have that the second reef did not?

   e. Which zone had the greatest change in number of habitats between the two reefs?

   f. How did the size of each zone in the new location compare to the widths you measured in Bellingshausen?

TABLE 2:

Reef Zone	Habitats	Width of Habitat
Lagoon		
Reef Crest		
Fore Reef		
Back Reef		

3. Why do scientists create GIS maps and how might they be used?

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LESSON 2 GIS Mapping

ADDITIONAL BACKGROUND INFORMATION:

GIS stands for Geographic Information System. It is a tool used by scientists and other experts to display and analyze a large data set that is linked to a latitude and longitude. GIS mapping allows visualization of data so that patterns may become more easily visible. The data on a GIS map can often be manipulated and analyzed on the map itself, which allows it to be presented and displayed better than traditional graphs and tables. Often the data is stored in layers. For instance, the Khaled bin Sultan Living Oceans Foundation's World Web Map starts with a map of the world and then you can choose whether to show benthic habitat data, bathymetry, and/or depth contours on top of the map. In addition, our map has videos and photos embedded into it so you can see what the coral reef looks like in specific areas of the world.

PROCEDURES:

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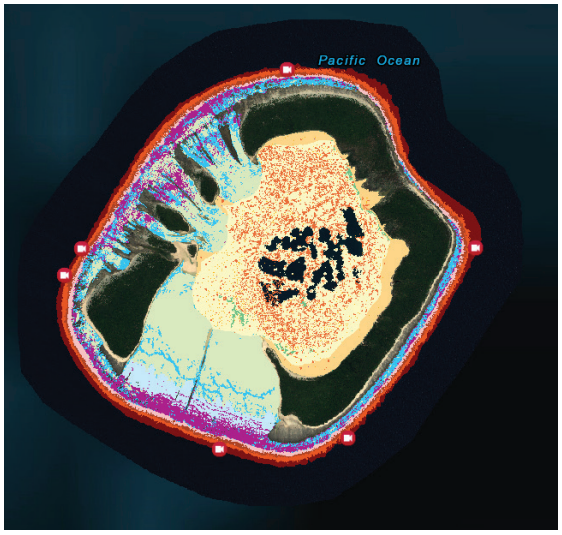
2. In the upper-right hand corner is the menu. (If it is not already open, click on the icon.) Click on *Select a Location*, then *French Polynesia*, and then *Bellingshausen*, which looks like the image below. (Be patient, it may take a moment to load.)



3. In the menu, click *View Legend* to see what habitat each color on the map indicates. (You may need to click on *Select a Location* again to close that section of the toolbar.) What three habitats look like they take up the most area on Bellingshausen?
   The top two habitats by area are clearly lagoonal floor barren and back reef sediment dominated. Third place may be difficult to determine and answers may include deep fore reef slope, back reef sediment dominated, back reef rubble dominated, back reef pavement, shallow fore reef slope, or others.

4. Use what you have learned from *Unit 11: Reef Zonation* to define the reef zone in the left-hand column of *Table 1*.

5. Use the legend to list the habitats on the Bellingshausen map that correspond with each reef zone. Fill in the second column in *Table 1*.

6. In the menu, click *Toolbar*, and then click on the  icon for the *Identify Tool*. Now if you click on the different colors on the map, a description of the individual habitats will pop up. (You may need to zoom in to accurately click on a specific habitat. The zoom bar is on the left-hand side of the map.)

7. In *Table 1*, fill in the appropriate columns to compare the topography and depth range of the different habitats in each zone. NOTE: Topography and depth range are the last topics described in the *Habitat Description*.

8. Click on one of the  video icons. (If you see an *Identify Tool* information box, and not the video, click on *Next Feature*  in the top right of the pop-up window until you get to the video.) How does this visual information compare to the written information that you get from the *Identify Tool*?
Answers may vary.

9. In the menu, click *Toolbar*, and then click on the  icon for the *Measure Tool*. Then click on the  icon and change the unit to meters. Use this tool to measure the widest part of each zone. To measure the width:
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    a. Zoom out until you can see all of Bellingshausen reef.
    b. In the menu, change the radius to 3 km.
    c. Click on the  icon.
    d. Move your mouse to the map. A box should tell you "*Click to add a point*".
    e. Estimate where the center of Bellingshausen is and click on that spot. A red circle should appear around the entire reef.
    f. Wait a few moments for the report to appear.
    g. Excluding "*Area not mapped*" and "*Terrestrial vegetation*", what three habitats actually take up the most area on Bellingshausen and how many square meters do they occupy?
    Lagoonal floor barren (2,344,313.96 m^2), back reef sediment dominated (1,975,659.10 m^2), and back reef pavement (896,767.46 m^2) are the three habitats that take up the most area on Bellingshausen reef.

TABLE 1:

Reef Zone	Habitats	Topography	Depth Range	Width of Habitat
Lagoon: **Technically not a zone, it is a shallow body of water separated from the ocean by a coral reef or by land.**	**1. Lagoonal sediment apron sediment dominated 2. Lagoonal floor barren 3. Lagoonal floor coral bommies 4. Lagoonal floor macroalgae on sediment 5. Lagoonal patch reefs 6. Lagoonal pinnacle reefs branching coral dominated**	**The barren floor, sediment apron, and macroalgae on sediment all have a generally low relief. The lagoon is broken up by isolated pinnacles rising from the lagoon floor, along with patch reefs, usually circular in shape, and coral bommies.**	**Most of the lagoonal habitats are found in shallower water, with the sediment apron only extending to -5 m, bommies to -10 m, and patch reefs -15 m. Macroalgae and pinnacles reach all the way down to -30 m, but the depths from -15 m to -35 m are mostly barren floor.**	**2,642 m**
Reef Crest (Algal Ridge): **The highest point of the reef, which breaks waves and receives the fullest impact of wave energy.**	**1. Coralline algal ridge**	**The reef crest's ocean-face is a cement-like barrier with irregularly spaced ridges and grooves. Ridges are exposed at low-tide and between waves, and grooves allow for seaward transport of water.**	**Depth ranges from +2 m to -1 m.**	**65 m Answers for this column may vary depending on location of measurement.**

Reef Zone	Habitats	Topography	Depth Range	Width of Habitat
Fore Reef: **Found at the furthest distance from shore. Slopes downward and can reach great depths.**	**1. Shallow fore reef terrace 2. Shallow fore reef slope 3. Deep fore reef slope**	**The shallow terrace has highly variable spur tops and grooves, which may continue into the shallow slope area. The shallow slope has a gentle slope, with some mounds building near the bottom and heading into the deep slope which eventually steeply drops off into the ocean depths.**	**The shallow terrace goes from emergent to a depth of -8 m, being taken over by the shallow slope down to -15 m, and finally extending into the deep slope down to -40 m.**	**210 m**
Back Reef: **The area that slopes into a lagoon. It is often shallow and more protected from wave action.**	**1. Back reef rubble dominated 2. Back reef sediment dominated 3. Back reef pavement 4. Back reef coral framework 5. Back reef coral bommies**	**Both coral framework and coral bommies lie on the shoreward side of the back reef. The sediment dominated, pavement, and rubble dominated regions of the back reef have a low-relief, although large boulders may be present.**	**The coral framework and coral bommies are found at depths of 1 m to -2 m, while pavement, sediment dominated, and rubble dominated are found from 0 m to -1 m.**	**1,607 m**

INSTRUCTIONS: Answer the following questions:

1. Why are the videos a helpful addition to the rest of the data?
   The videos give a visual representation of what has been put into writing. This allows scientists to verify that they are discussing the same thing.

2. Follow the procedures for using the tools again, but this time choose a different location. Fill out *Table 2* and use the information in *Tables 1* and *2* to answer the following questions:
   Answers may vary depending on location chosen.
   a. What is the name of this reef?

   b. What habitats did both reefs have in common?

   c. What habitats, if any, did the second reef have that Bellingshausen did not?

   d. What habitats, if any, did Bellingshausen have that the second reef did not?

   e. Which zone had the greatest change in number of habitats between the two reefs?

   f. How did the size of each zone in the new location compare to the widths you measured in Bellingshausen?

TABLE 2: Answers may vary depending on location chosen.

Reef Zone	Habitats	Width of Habitat
Lagoon		
Reef Crest		
Fore Reef		
Back Reef		

1. Why do scientists create GIS maps and how might they be used?
   Answers may vary but might include the study or management of different habitats and helping to establish policies or conservation areas.

Khaled bin Sultan Living Oceans Foundation

READ IT! Teacher's Notes

AUTHOR

- Melinda Campbell. Khaled bin Sultan Living Oceans Foundation

LEARNING OBJECTIVES

- Read, interpret, and comprehend a blog.
- Determine how to responsibly use the internet for collecting and responding to information.

MATERIALS

- Internet access
- *Let's Name the Zones* blog (http://www.lof.org/lets-name-the-zones-the-zones-the-zones-of-the-reefs-of-raivavae-and-tubuai/)
- **Read It! Let's Name the Zones** student worksheet

INTEGRATING SUBJECTS

- English Language Arts

PRIOR KNOWLEDGE

- Students will have prior knowledge about bias and how to critique the validity of websites.

STANDARDS

- **CCSS**: RST.9-10.1, 2, 4, 5, 7, 8, 10; RST.11-12.1, 2, 4, 10
- **NGSS Practices**: 6, 7, 8

PROCEDURE

1. Have students read *Let's Name the Zones* blog (http://www.lof.org/lets-name-the-zones-the-zones-the-zones-of-the-reefs-of-raivavae-and-tubuai/).
2. While reading, instruct students to take notes, connecting the information to their prior knowledge. They can note things that they agree and disagree with. A space, called *Notes*, is provided for this on the **Read It! Let's Name the Zones** student worksheet.
3. Ask students to analyze the blog to determine the elements (like tone or visual design) and content that they like and dislike. Remind students to explain why they like or dislike each element they mention. There is also a space provided for these answers on the student worksheet.
4. Have students answer the questions on their worksheet. When they are looking for definitions, they should use the context from the blog, our glossary, or other online resources. You may want to set rules distinguishing other websites or resources that they are allowed to access.
5. If you set up an online community for your class, have the students post their comment(s) from the last question and allow them to respond to each other. If you do not have an online community, have the students share their comment(s) with each other, either orally or by passing their written responses around the classroom.

Name: _____ Date: _____

Khaled bin Sultan Living Oceans Foundation

READ IT!

Let's Name The Zones

INSTRUCTIONS:

1. Read *Let's Name the Zones*, a blog from our Austral Islands, French Polynesia mission (http://www.lof.org/lets-name-the-zones-the-zones-the-zones-of-the-reefs-of-raivavae-and-tubuai/).
2. While reading the blog, take notes and connect it to your prior learning. Note things that you agree or disagree with. There is a space, below, for this.
3. Next, document what you like and dislike about this blog in the space below. Be sure to pay attention to things like style and tone, along with the content and visual design. Be sure to *explain* what it is that you do or do not like about each element.
4. Answer the questions.

NOTES

LIKES

DISLIKES

1. What is the central idea of this blog?

2. Sketch the Austral reef (ignore grooves) described here. Don't forget to label it!

3. How does the Austral fore reef change as the water gets deeper? Cite specific textual evidence to support this.

4. Did the author fully support his claim? Explain why you think this.

5. *Massive*, *digitate*, and *encrusting* are specific vocabulary for the topic of this blog. Define them below.

6. Write a sentence of your own creation that connects the three words from #5, above.

7. Is this blog a reliable source for scientific information? Why or why not?

8. Do you notice any bias in this writing? If so, what?

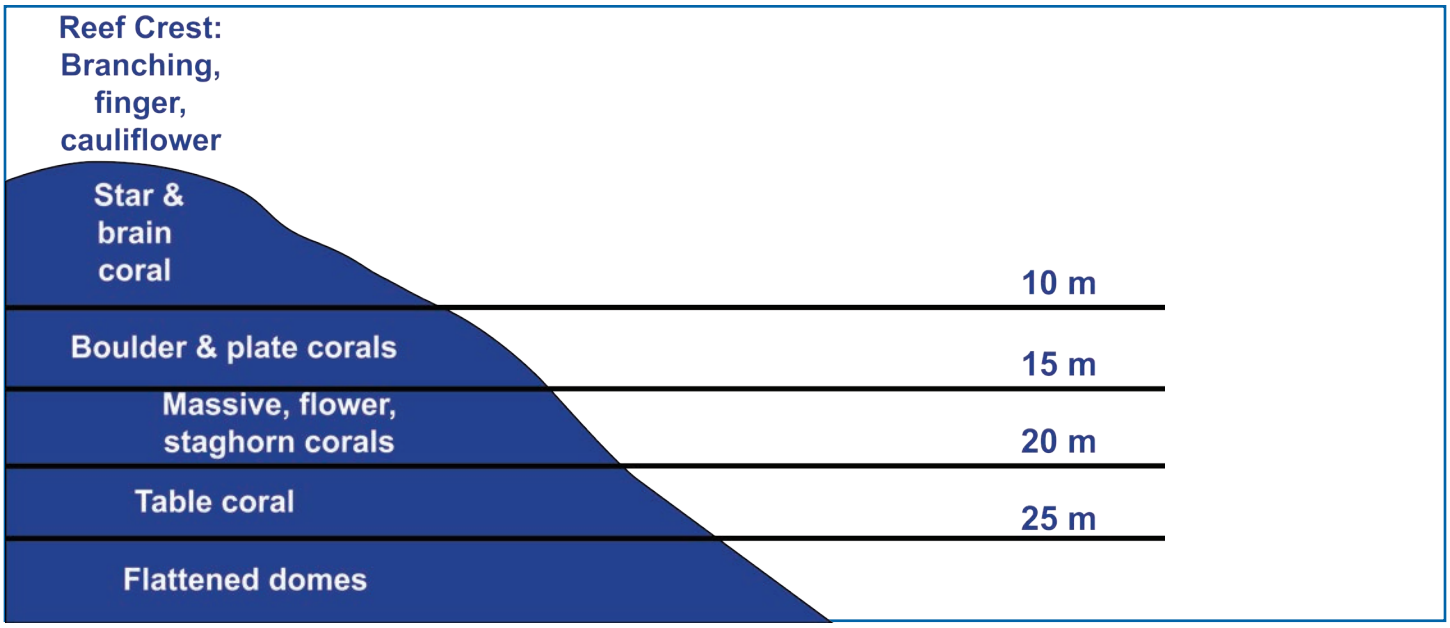
9. Describe three things that you learned while reading this blog entry (they do not have to relate to the central idea).

10. Construct a comment to post in response to this blog. Remember that a good comment makes connections, asks a question, or gives an opinion in a respectful manner. You might want to quote the part of the blog that you are specifically referring to. Don't be afraid to disagree with another writer, but be sure to explain yourself and remain polite.

1. What is the central idea of this blog?

   As you move through different zones of the reef, the coral community changes.

2. Sketch the Austral reef (ignore grooves) described here. Don't forget to label it!



3. How does the Austral fore reef change as the water gets deeper? Cite specific textual evidence to support this.

   Small corals near the surface turn into much larger corals dominating the deeper depths. Students should have specific quotes to back up this claim, which may vary but might include the following:

   - **"From 10-15 m deep, the grooves were colonized by small pore corals…"**
   - **"…the reef… transitions … to a community … of large massive and lobate corals…"**

4. Did the author fully support his claim? Explain why you think this.

   Answers may vary. Be sure they explain their reasoning.

5. *Massive*, *digitate*, and *encrusting* are specific vocabulary for the topic of this blog. Define them below.

   - **Massive: a growth form that includes corals that look like domed boulders.**
   - **Digitate: a growth form where corals are cylindrical in shape and grow upwards. They often look like fingers.**
   - **Encrusting: a growth form that adheres to rocky substrates. They do not grow upwards, they grow outward covering the rocky substrate.**

6. Write a sentence of your own creation that connects the three words from #5, above.

   Corals come in many forms, including *massive*, *digitate*, and *encrusting*.

7. Is this blog a reliable source for scientific information? Why or why not?

   Yes. This is a first-hand account of what the author has seen. It is from a reputable organization that is based on scientific research. It also links you to the author's credentials.

8. Do you notice any bias in this writing? If so, what?

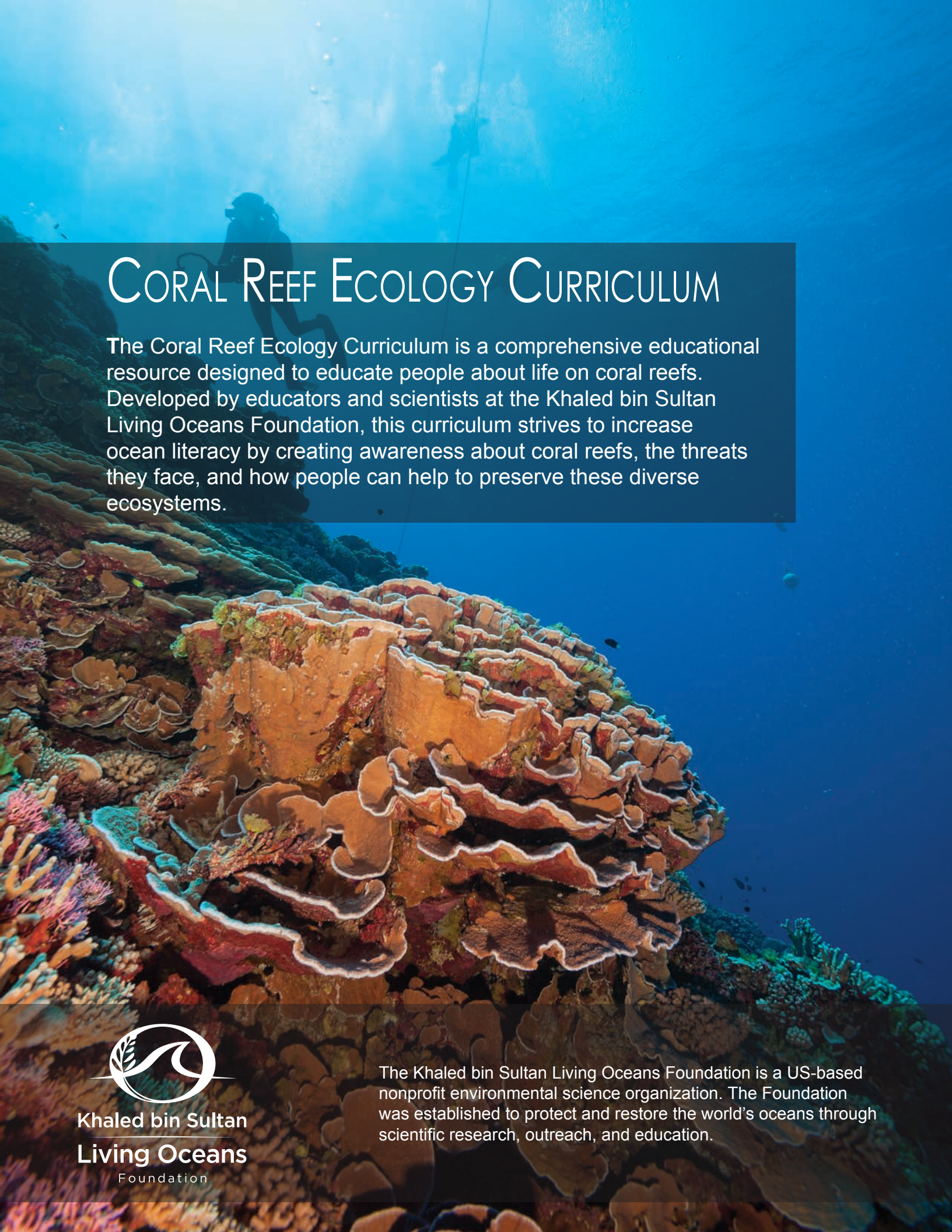
   Answers may vary, but should mention that this blog has little interpretation which would be open to bias.

9. Describe three things that you learned while reading this blog entry (they do not have to relate to the central idea).

   Answers may vary.

10. Construct a comment to post in response to this blog. Remember that a good comment makes connections, asks a question, or gives an opinion in a respectful manner. You might want to quote the part of the blog that you are specifically referring to. Don't be afraid to disagree with another writer, but be sure to explain yourself and remain polite.

    Answers may vary.



Coral Reef Ecology Curriculum

The Coral Reef Ecology Curriculum is a comprehensive educational resource designed to educate people about life on coral reefs. Developed by educators and scientists at the Khaled bin Sultan Living Oceans Foundation, this curriculum strives to increase ocean literacy by creating awareness about coral reefs, the threats they face, and how people can help to preserve these diverse ecosystems.

Khaled bin Sultan
Living Oceans
Foundation

The Khaled bin Sultan Living Oceans Foundation is a US-based nonprofit environmental science organization. The Foundation was established to protect and restore the world's oceans through scientific research, outreach, and education.