Interactive Exploration of Coral Bleaching

hhmi | BioInteractive

Interactive Video
Educator Materials

OVERVIEW

Interactive Exploration of Coral Bleaching is an animation with automatic pause points, during which students access additional information in the form of text, illustrations, videos, questions, and interactive widgets. This information allows for a richer exploration of coral reefs, symbiosis, and other topics in biology.

The animation zooms in to explore the tiny animals that build reefs, the photosynthetic algae inside their cells, and the damaging process of coral bleaching. The examples in this animation can be used to explore the concepts of biodiversity and ecosystem services, sexual and asexual reproduction, the differences between plant and animal cells, symbiotic relationships, photosynthesis, and more.

This document contains multiple resources for using the interactive exploration with students, including the following (select links to go directly to each section):

- general teaching tips for this resource, including common misconceptions and scientific language support
- suggested procedures for providing context, using the interactive exploration, and using the "Student Worksheet"; includes a table of the main topics covered and where to find them
- assessment guidance for the "Student Worksheet"

Additional information related to pedagogy and implementation can be found on this resource's webpage, including suggested audience, estimated time, and curriculum connections.

KEY CONCEPTS

- Coral reefs support high biodiversity and provide a variety of ecosystem services.
- Coral reefs are colonies of animals called polyps, which rely on symbiotic algae for survival.
- Coral bleaching reduces coral survival by driving polyps to destroy or expel their symbionts.
- Most coral bleaching worldwide is caused by unusually warm temperatures due to climate change.

STUDENT LEARNING TARGETS

For the "Student Worksheet":

- Part 1: Coral Reefs
  - Identify living and nonliving components of an ecosystem and their potential interactions.
  - Describe how ecosystems, such as coral reefs, benefit humans and other organisms.
- Part 2: The Corals
  - Differentiate between sexual and asexual reproduction.
  - Compare plant and animal cells, including their major structures and how they use energy.
- Part 3: The Symbiont
  - Identify different types of symbiotic relationships, based on descriptions of how organisms interact.
  - Describe the process of endocytosis.
- Part 4: The Chloroplasts
  - Diagram the process of photosynthesis.
  - Distinguish between photosynthesis, cellular respiration, and their corresponding organelles.
  - Interpret and explain the value of simple models.
- Part 5: Coral Bleaching
  - Explain the process of coral bleaching and how it can be caused by climate change.

- Describe the impacts of coral bleaching on corals and other organisms.
- Describe the process of exocytosis and how it compares with that of endocytosis.

PRIOR KNOWLEDGE

Students should have a basic understanding of:

- characteristics of living vs. nonliving things
- biological organization (cells to ecosystems)
- cell structure and organelles
- climate change

TEACHING TIPS

General

- This resource covers a broad range of topics, so you should tailor which parts you use to your course learning objectives and students' needs. The "Using the Interactive Exploration" section below provides more information on the different modules and their contents.
- Students are encouraged to watch the entire animation without pause points first. You can access a version of the animation without pause points from the *Coral Bleaching* webpage.

Common Misconceptions

Student misconceptions and points of confusion may include the following:

- Students may have the **misconception that corals are *not* animals**. They may think that corals are rocks due to the hard structures of reefs, or that coral polyps are plants due to their flower-like bodies.
  - The interactive exploration addresses this in "The Corals" module.
  - The "Student Worksheet" addresses this in Question 9.
- Students may have the **misconception that coral cells contain chloroplasts** and can perform photosynthesis on their own. However, chloroplasts are not part of the coral cells but rather are part of the zooxanthellae (symbiotic algae) that live inside coral cells.
  - The interactive exploration addresses this in the modules "The Corals" and "The Chloroplast."
  - The "Student Worksheet" addresses this in Question 14.
- Students may have the **misconception that plants and zooxanthellae only perform photosynthesis and *not* also cellular respiration**. Plants and zooxanthellae have both chloroplasts for photosynthesis and mitochondria for cellular respiration. So, they can produce food (sugars) through photosynthesis *and* break down that food for energy through cellular respiration.
  - The interactive exploration shows that plants have both mitochondria and chloroplasts in the "Corals Are Animals" section of the module "The Corals."
  - The "Student Worksheet" addresses this in Question 14.

Scientific Language Support

The scientific language in the resource may be new and overwhelming to students. Provide support as needed, which could include the following strategies:

- **Clarify what students should focus on early.**
  - At the start of a lesson or activity, share the learning objectives with students. Ask students to focus on addressing these objectives, rather than on memorizing scientific terms.
  - Provide students with a short list of specific terms they *will* be expected to know and use in class (if any).
- **Help students access information about the terms.**
  - Make students know that they can select bold underlined terms throughout the interactive exploration to view their definitions.

- The "Glossary" in the "Materials" section of this resource's webpage contains a list of the scientific terms in the resource. You may wish to adapt and share it with your students.

- **Implement strategies for helping students learn key terms.**
  - Guide students through learning and using key scientific terms using the activity "Learning Scientific Language with a Graphic Organizer." The "Educator Materials" document for that activity provides additional suggestions for supporting language learning.
  - Encourage students to continually practice explaining their ideas about science and scientific terms. Repeated practice can help students build stronger language skills.

PROCEDURE

Usage of the interactive exploration and its materials is flexible and can be adapted based on your classroom context. As a starting point, some suggestions are provided for the following (select links to go directly to each section):

Providing Context

Before starting the activity, it is recommended to provide students with a clear transparency statement about the purpose of the activity and what they will get out of doing it.

- The "Introduction" section of the "Student Worksheet" provides an example; modify this text as needed to add context and relevancy for your students.
- Not all students may be familiar with or particularly interested in coral reefs. You may need other ways to relate the content to students' contexts. For example, you could:
  - Highlight how the concepts apply more broadly to other organisms or ecosystems.
  - Discuss the impacts of climate change on more local contexts.
  - Make connections to environmental justice and human inequities (e.g., Donner and Potere 2007).
  - Have students come up with their own applications, as in Questions 4 and 11 of the "Student Worksheet."

You may also want to provide **context for the locations** mentioned in the interactive exploration by showing students where they are on a map.

- The first module, "Coral Reefs," has a map of coral reef locations worldwide that you can reference.
- You could point out the location of Ofu in American Samoa, which is referenced at the beginning of the animation, and of the Great Barrier Reef in Australia, which is referenced in the fifth module, "Coral Bleaching."

Using the Interactive Exploration

The interactive exploration uses coral reefs to illustrate how multiple key biology concepts are connected. It contains five automatic pause points, during which students access modules with additional information in the form of text, illustrations, videos, and questions. Descriptions of each module are as follows:

1. **Coral Reefs** introduces the coral reef ecosystem and how it benefits humans and other organisms. It explores the concepts of ecosystems, biodiversity, and ecosystem services.
2. **The Corals** examines the characteristics of coral polyps, the tiny organisms that make up coral reefs. It introduces the differences between sexual and asexual reproduction, and plant and animal cells.
3. **The Symbiont** focuses on zooxanthellae, the symbiotic algae that live inside coral tissue. It includes the concepts of symbiosis (mutualism, parasitism, and commensalism), autotrophy, and endocytosis.
4. **The Chloroplasts** shows how zooxanthellae use chloroplasts to produce food. It introduces photosynthesis and some of the cellular structures involved in this process.

5. **Coral Bleaching** explains why corals may lose their zooxanthellae and how this affects both corals and the ecosystems they support. It describes the mechanisms for coral bleaching, including the role of rising temperatures, and its consequences for coral reefs worldwide.

Depending on your class, you could use all the modules or choose to assign only certain parts.

- For a **general biology course**, the resource as a whole could be used for an end-of-the-year review. Determine which sections students should focus on based on the content of your course.
- For **more specific lessons**, use Table 1 to determine which modules and module sections would be the most relevant. Related questions from the "Student Worksheet" are also provided.

Table 1. A summary of the main topics covered in this resource, including the relevant modules in the interactive exploration and related questions from the "Student Worksheet."

Area	Topics	Module	Sections in the Module	Worksheet Questions
Ecology	Ecosystems	Coral Reefs	Coral Reef Ecosystems	1, 2, 4
	Biodiversity	Coral Reefs	Biodiversity of Coral Reefs	1
	Autotrophs and heterotrophs	The Corals	Corals Are Animals	7, 9, 14
		The Symbiont	Symbiosis with Corals	
	Symbiotic relationships	The Symbiont	What Is a Symbiont	10, 11, 12
Environmental science	Ecosystem services	Coral Reefs	Ecosystem Services of Coral Reefs	1, 3, 4, 20
	Human impacts on ecosystems	Coral Bleaching	What Is Coral Bleaching, Global Consequences of Bleaching	17, 18, 20
	Climate change	Coral Bleaching	How Temperature Triggers Bleaching	18
Cell biology	Plant vs. animal cell structure and organelles	The Corals	Corals Are Animals	6, 9
	Asexual vs. sexual reproduction	The Corals	Why Are Polyps in a Colony Identical	5
	Endocytosis	The Symbiont	How Corals Get Symbionts	13, 19
	Exocytosis	Coral Bleaching	How Corals Get Rid of Symbionts	19
	Cellular respiration	The Corals	Corals Are Animals	14
	Photosynthesis	The Chloroplast	What Are Chloroplasts	14, 15
	Chloroplast function and structure	The Chloroplast	What Are Chloroplasts, Structure of a Chloroplast	14, 16
Science practices	Using geographical maps	Coral Reefs	Coral Reef Ecosystems	
	Using heat maps	Coral Bleaching	How Temperature Triggers Bleaching	
	Using cell and anatomical diagrams	The Corals	Corals Are Animals, The Parts of a Polyp	6, 8
	Using 3D models	The Chloroplast	What Are Chloroplasts, Structure of a Chloroplast	16

Using the Worksheet

The "Student Worksheet" is designed to guide students through the entire interactive exploration. It is divided into parts that correspond to different modules of the interactive exploration. The "Worksheet Questions" column of Table 1 above lists which questions correspond to which topics.

General recommendations for using this worksheet are as follows:

- **Customize the worksheet** as needed to better fit your learning objectives and students' needs. For example, you may want to assign only certain parts, modify or remove questions, or add more explanations.
- **Have students work in pairs or small groups.** Students may benefit from discussing their ideas with each other.
- **Address student questions.** The "Before and After the Exploration" section at the beginning of the worksheet has students pose their own questions. If possible, acknowledge and answer these questions during a small-group or whole-class discussion.

The worksheet includes several intentionally **open-ended questions** to increase student choice and relevancy. For example:

- Questions 4 and 11 ask students to apply the concepts to new examples of their choice.
- Questions 12, 15, and 19 ask students to create their own diagrams or explanations to connect multiple terms.

Consider having students share their responses to these open-ended questions in small groups or as a class. This can help center students' voices and show a greater diversity of perspectives. You could also provide options for students to respond in different formats (e.g., presentation, poster, audio recording, etc.).

ASSESSMENT GUIDANCE

Before and After the Exploration

The purpose of this section is to engage students and have them reflect on their own learning. Student answers will vary; be open to a range of reasonable responses.

PART 1: Coral Reefs

1. Define each of these terms in your own words.
   Student answers will vary. Definitions from the resource are shown below.
   a. Ecosystem
      A community of organisms interacting with the environment in a particular area.
   b. Biodiversity
      The variety of species in an ecosystem.
   c. Ecosystem services
      The various ways in which humans benefit from ecosystems.
2. All ecosystems, including coral reefs, have both living and nonliving components that interact.
   a. Describe **three** specific *living* components of a coral reef. (*Hint:* These could be examples of organisms found in coral reefs.)
      Student answers will vary. Examples include corals and any of the other animals discussed in the "Biodiversity of Coral Reefs" section, such as crustaceans, fish, sea urchins, turtles, etc.
   b. Describe **three** specific *nonliving* components of a coral reef. (*Hint:* These could be characteristics of the environments where coral reefs are typically found.)
      Student answers will vary. Examples include lots of sunlight, warm temperatures, shallow depth (by the coast), salt water (in the ocean), etc.

c. Pick one living component and one nonliving component. Give an example of how they could interact.
Student answers will vary depending on the parts they chose; be open to a range of reasonable responses.

3. Imagine that you are writing for an environmental group's social media account. Write 3–4 sentences to persuade the general public that coral reefs are valuable. Include at least **two** specific ecosystem services.
Student answers will vary depending on the ecosystem services they chose. Examples include benefits to fisheries, tourism, shoreline protection, medicine, nutrient cycling, and culture.

4. Think of an ecosystem that is *not* a coral reef. This ecosystem could be one that you've learned about, or one that you are personally interested in or familiar with. You could pick an ecosystem that covers a smaller area, such as a pond or a garden, or one that covers a larger area, such as an entire city or region.
   a. Describe **three** specific *living* components of this ecosystem.
   b. Describe **three** specific *nonliving* components of this ecosystem.
   c. Describe **two** specific ecosystem services that this ecosystem could provide.

   These questions parallel the previous questions and have students transfer these concepts to a new ecosystem of their choice. Student answers will vary depending on the ecosystem they chose. Consider having students share their responses in small groups or as a class.

PART 2: The Corals

5. One characteristic of living things is that they can reproduce.
   a. Explain the difference between asexual reproduction and sexual reproduction.
   Asexual reproduction has only one parent and produces offspring that are genetically identical to that parent. Sexual reproduction has two parents and produces offspring that have combinations of the parents' DNA.
   b. Does asexual reproduction or sexual reproduction lead to greater genetic diversity? Why?
   Sexual reproduction leads to greater genetic diversity, because it produces organisms with new combinations of genetic material.

6. Another characteristic of living things is that they are made of cells. The table below describes some common cell parts and whether they are found in coral cells. Use the diagram in the interactive exploration to complete this table.

Part	Function	In coral cells? (Yes/No)
Nucleus	Contains the cell's DNA and controls cell growth.	Yes
Cell wall	***Provides protection and support for the cell.***	***No***
Mitochondria	***Performs cellular respiration to produce energy that can be used by the cell.***	***Yes***
Chloroplast	***Performs photosynthesis to convert energy from the sun into chemical energy stored in organic molecules. (Students will learn more about photosynthesis in the fourth module, "The Chloroplast.")***	***No***

7. Autotrophs and heterotrophs are two main groups of living things.
   a. Explain the difference between an autotroph and a heterotroph.
   An autotroph produces its own food. A heterotroph relies on other organisms for food.
   b. Are corals autotrophs or heterotrophs? Provide evidence for your decision.
   Corals are heterotrophs because they rely on other organisms for food. For example, corals catch and eat zooplankton. (Students will learn that corals also get food from zooxanthellae in the third module, "The Symbiont.")

8. The table below describes the parts of a coral polyp. Use the diagram in the interactive exploration to complete this table.

Part	**Function**
Epidermis	***Contains stinging cells in the tentacles to help catch prey.***
Exoskeleton	***Provides protection and support for the polyp.***
Gonads	Produces egg and sperm for sexual reproduction.
Gastrodermis	***Contains organisms called zooxanthellae. (Students will learn more about the role of zooxanthellae in the third module, "The Symbiont.")***
Stomach	Digests food.
Mouth	Takes in food and releases waste.

9. Imagine that a classmate tells you corals are either a type of rock or a plant. How could you explain to them, with at least **two** pieces of supporting evidence, why that claim is incorrect?
   Student answers will vary. An example response:
   Corals are living things because they can reproduce and are made of cells. This means that corals can't be rocks, though they do create hard, rock-like structures. Corals are also heterotrophs, meaning that they get food from other organisms. For example, they catch prey using their tentacles. Plants are typically autotrophs, not heterotrophs, and don't have tentacles, so corals are not plants either. Corals are actually a type of animal called a cnidarian.

PART 3: The Symbiont

10. Assign each symbiosis in the table below to a specific type (mutualism, parasitism, or commensalism) based on its description.

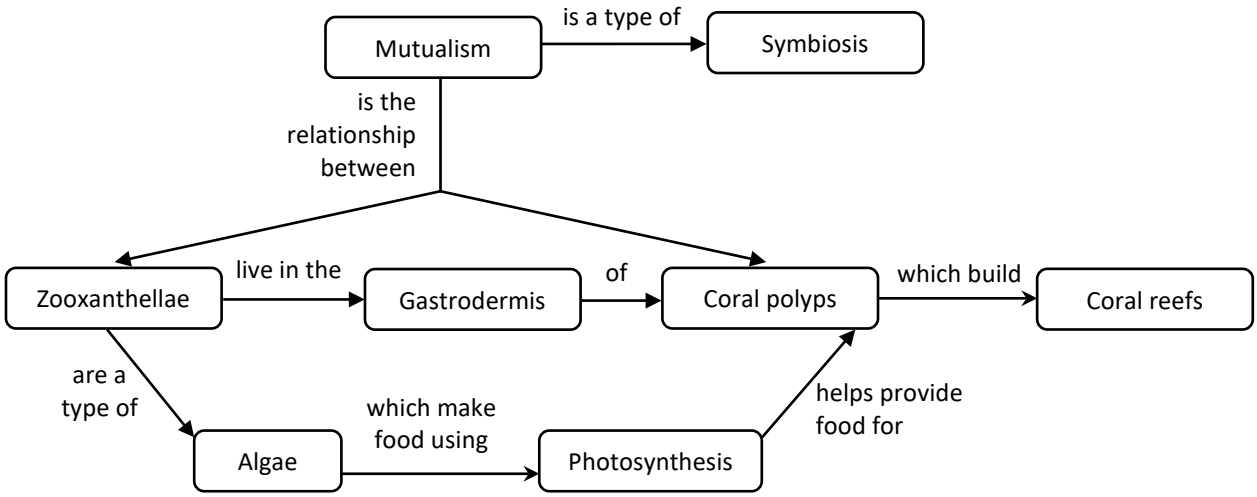
Description of the symbiosis	**Type of symbiosis**
Bacteria in a human's intestines feed on large sugar molecules. The bacteria break these sugars down into smaller molecules that human cells can use.	***Mutualism***
A tapeworm in a pig's intestines feeds on partially digested food, taking nutrients away from the pig.	***Parasitism***
An ant colony lives inside a tree. The ants kill other plants nearby that could compete with the tree for resources.	***Mutualism***
A bird builds a nest on a tree, without affecting the tree's growth or survival.	***Commensalism***

11. Think of another relationship that could be a symbiosis, which is *not* from the table above or the interactive exploration. The example can be from something else you learned or your own interests/experiences.
    a. Briefly describe the relationship you chose.
    b. Explain why you think this relationship is a symbiosis.
    c. What type of symbiosis do you think this relationship is, and why?
    These questions have students transfer their knowledge of symbiosis to a new example. Student answers will vary depending on the example they chose. Consider having students share their responses in small groups or as a class.

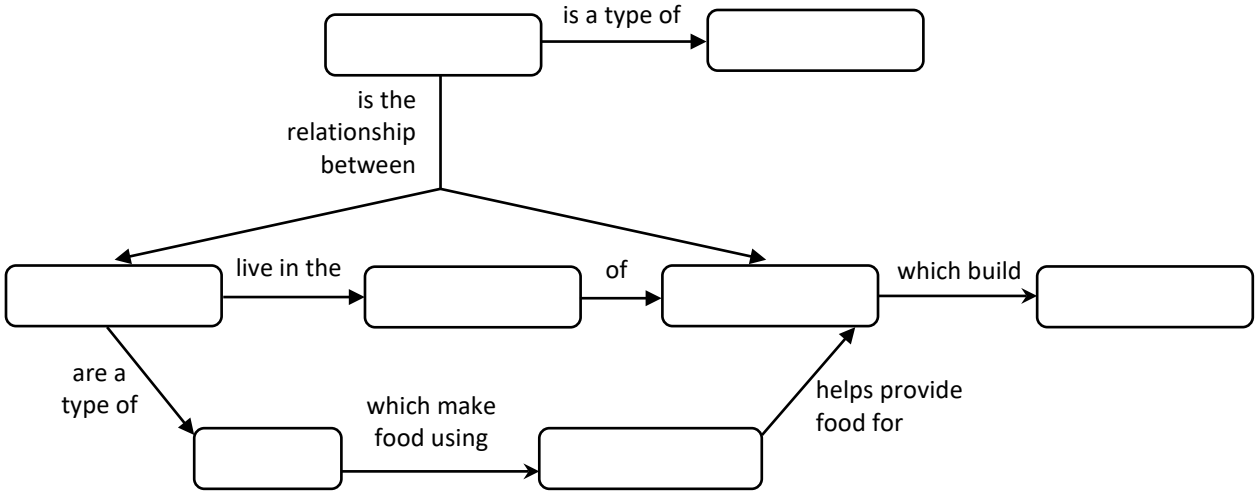
12. Create a diagram, such as a concept map, that shows how the following terms are connected.
    - Algae
    - Coral polyps
    - Coral reefs
    - Gastrodermis
    - Mutualism
    - Photosynthesis

- Symbiosis
- Zooxanthellae

Student diagrams will vary. An example is shown below.



To scaffold this question, you could give students a version of the concept map with blank boxes, as shown below. Students could then fill in the missing boxes instead of creating their own concept map from scratch. If desired, you could fill in some of the boxes as examples or have students use an online whiteboard, such as Google Jamboard.



13. Think about the cellular process that brings zooxanthellae from the water into coral cells.
    a. What is this process called?
    Endocytosis (or, more specifically, phagocytosis)
    b. In one or two sentences, summarize how this process works.
    The cell membrane pinches inward to surround the zooxanthellae. The membrane forms a sac-like structure called a vesicle, which carries the zooxanthellae into the cell.

PART 4: The Chloroplast

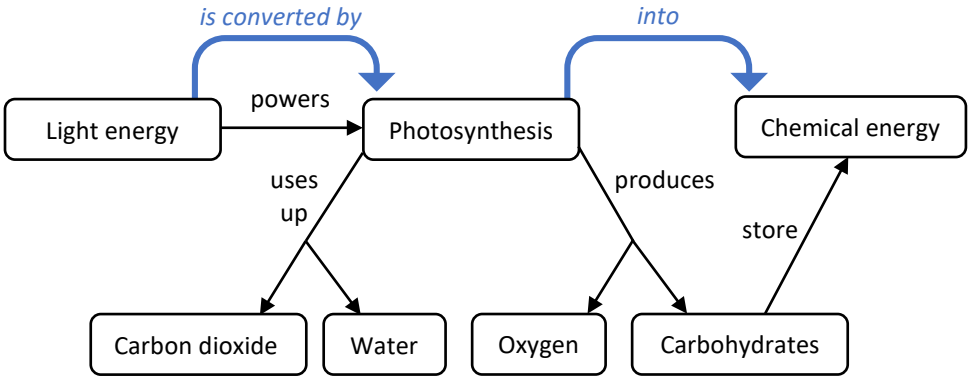
14. Determine whether corals and zooxanthellae have each characteristic in the table below. Complete the table by writing either "Yes" or "No" in the corresponding columns. (For some of this information, you may want to review the "Corals Are Animals" section at the second pause point, "The Corals.")

Characteristic	Corals	Zooxanthellae
Has chloroplasts.	***No***	***Yes***
Can perform photosynthesis.	***No***	***Yes***
Uses food (sugars) that was produced by photosynthesis.	***Yes***	***Yes***
Has mitochondria.	***Yes***	***Yes***
Can perform cellular respiration.	***Yes***	***Yes***

If students struggle with this question, you may need to remind them that heterotrophs like corals have mitochondria but not chloroplasts. Autotrophs like zooxanthellae have both mitochondria and chloroplasts. Chloroplasts perform photosynthesis, which produces food (sugars). Mitochondria perform cellular respiration, which breaks down food (sugars).

15. Create a diagram, such as a concept map, that shows how the following terms are connected. The style of this diagram can be similar to the one in Question 12.
    - Carbohydrates
    - Carbon dioxide
    - Chemical energy
    - Light energy
    - Oxygen
    - Photosynthesis
    - Water

    Student diagrams will vary. An example is shown below.



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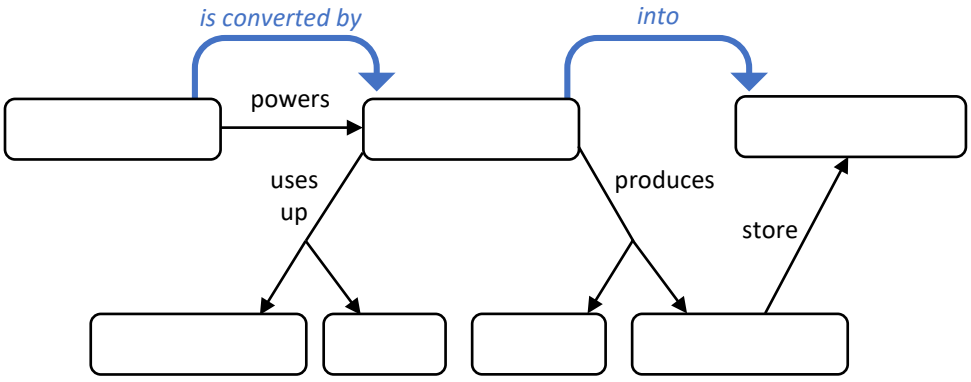
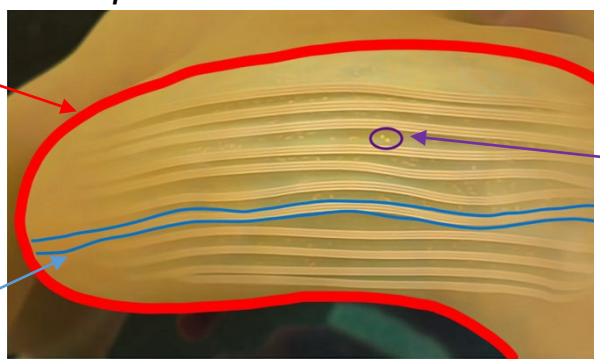


16. The image below shows part of a 3D model that appears in the video.
    a. Label and/or describe how **chloroplasts**, **thylakoids**, **pigments**, and **photosystems** are represented in this model.
    Student answers will vary. An example with labels is shown below.

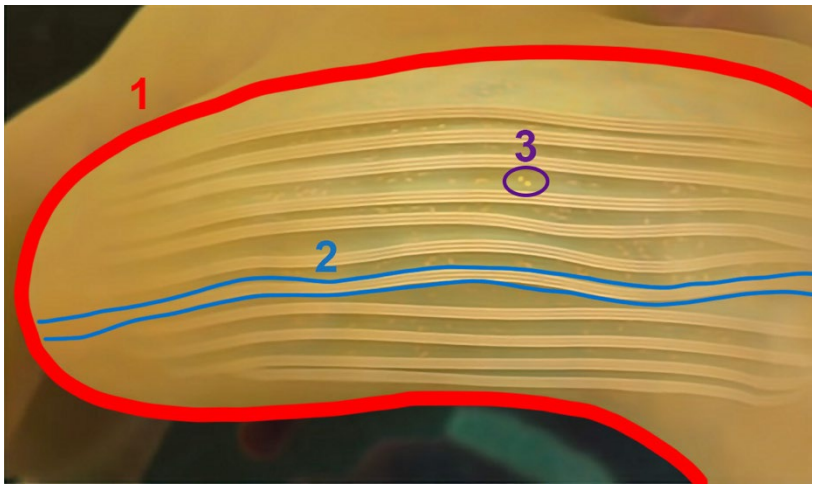
The entire rounded structure is part of a chloroplast.



The dots on the thylakoids are photosystems. The pigments are part of the photosystems.

The thin layers inside the chloroplast are the thylakoids.

To scaffold this question, you could give students a version of this image that has the parts labeled with numbers, as shown below. Students could then match the terms to the numbers.



    b. What might be an advantage of using a model in the video rather than showing real images of the organism?
    Student answers will vary. They could say that the model helps us visualize features that are too small to see directly and simplifies things so that we can focus on the specific parts involved in photosynthesis.

PART 5: Coral Bleaching

17. Coral bleaching is a major threat to coral reefs worldwide.
    a. Why is coral bleaching dangerous for corals?
    Coral bleaching is a process where corals force zooxanthellae out of their cells. This is dangerous for corals because they rely on zooxanthellae for most of their food. If the corals are without zooxanthellae for too long, they can die.
    b. Why does coral bleaching cause corals to lose their color?
    Most of a coral's color comes from zooxanthellae. During bleaching, the coral loses its zooxanthellae, so it also loses its color.

18. Write a paragraph or create a diagram that explains how climate change can cause coral bleaching. Include the following terms:
    - climate change

- coral bleaching
- coral polyps
- heat stress
- photosystems
- reactive oxygen molecules
- zooxanthellae

Student answers will vary. An example response:
Climate change is causing ocean temperatures to warm, which increases stressful heat conditions called heat stress. The heat stress can damage the photosystems in zooxanthellae, causing them to produce harmful reactive oxygen molecules. To protect themselves from these harmful molecules, coral polyps force the zooxanthellae out of their cells, which results in coral bleaching.

19. Compare the processes of exocytosis and endocytosis (discussed at the third pause point, "The Symbiont"). How are these processes similar, and how are they different?
Both exocytosis and endocytosis are cellular processes that transport materials across the cell membranes using vesicles. These processes differ in terms of direction: endocytosis transports materials* into *the cell, whereas exocytosis transports materials* out *of the cell.

20. Coral bleaching negatively impacts not only corals but also many other organisms.
    a. Propose **two** specific negative impacts that coral bleaching may have on humans.
    Student answers will vary and may include reduced availability of seafood, economic losses for fisheries and tourism, increased storm damage in coastal areas, loss of important cultural sites, etc. If students struggle with this question, you may want them to review the ecosystem services in the first module, "Coral Reefs."
    b. Propose **two** specific ways that humans could help reduce coral bleaching.
    Student answers will vary. One strategy mentioned in the resource is transplanting heat-resistant corals to damaged reefs. Students may suggest other ways to restore or cool down coral reefs. They may also suggest ways to mitigate climate change, as it is the main cause of coral bleaching.

CREDITS

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