

Cross-Curricular Discussion

After students have had a chance to review the article “Rebuilding reefs,” lead a classroom discussion based on the questions that follow. The discussion is subdivided roughly by topic in case you would like to focus on one particular content area. The Extension Prompts are more topic-specific or conceptually advanced. Use [Blackline Master 3](#) to accompany the discussion.

BIOLOGICAL SCIENCES

Discussion Questions:

- 1a. The article talks about different strategies for coral reproduction. Ask students to review the strategies mentioned. Ask them to brainstorm the pros and cons of each. Discuss how Dave Vaughan, at the Mote Tropical Research Laboratory, got his idea to raise coral microfragments. What do students think are the benefits of farming coral under controlled conditions? Do students think it is OK to mix farmed coral with wild coral? What if Vaughan’s technique was mixed with the selective breeding strategy of Ruth Gates, of the Hawaii Institute of Marine Biology? Are there ethical considerations to creating “super corals”?

Extension Prompts:

- 1b. What are the pros and cons for corals of reproducing sexually versus asexually (cloning)? Why would it be best to have more genetic variation in the population? [*Sexual reproduction allows for genetic variation and, when done by researchers, can be designed to select for preferred characteristics in hopes of helping coral survive. Cloning allows for quick reproduction and can replicate an organism with existing traits. However, cloning doesn’t introduce genetic diversity. If ocean conditions kill some cloned corals, it is possible that all other cloned, and thus genetically identical, corals may die.*]
- 1c. Write the general chemical equation for photosynthesis and cellular respiration. Use this information to explain the symbiotic relationship between algae and coral. [*Photosynthesis is represented by the chemical reaction: $H_2O + CO_2 \rightarrow C_6H_{12}O_6 + O_2$ (with sunlight/energy required). Cellular respiration is represented by the opposite reaction: $C_6H_{12}O_6 + O_2 \rightarrow H_2O + CO_2$ (with energy produced). Students should explain that the algae use water and carbon dioxide to create glucose and oxygen. The corals use the oxygen and glucose produced by the algae for cellular respiration.*]

EARTH SCIENCE AND PHYSICAL OCEANOGRAPHY

Discussion Questions:

- 2a. The article talks about the effect of greenhouse gases on coral reefs. What are some greenhouse gases? Asks students to list a few and give their chemical formulas [*For example: Water vapor, H_2O . Carbon dioxide, CO_2 . Methane, CH_4 . Nitrous Oxide, N_2O . Ozone, O_3 .*]

- 2b. Ask why these gases are referred to as “greenhouse gases” and what effect they are having on Earth. *[These gases absorb and emit infrared radiation, trapping heat in the atmosphere the way heat is trapped in a greenhouse. This trapped heat warms the Earth’s atmosphere.]*
- 2c. Corals live underwater, so they are dealing with the effects of increased absorption of carbon dioxide in seawater. How does carbon dioxide, a common greenhouse gas, react with water? *[In a water (aqueous) state, carbon dioxide forms carbonic acid (H_2CO_3), which loses a proton (H^+) to form bicarbonate (HCO_3^-).]* Have students examine the chemical reaction and explain how this reaction affects the pH of ocean water. *[The result of the lost proton is to increase the hydrogen ion or hydronium ion concentration in the water, decreasing the pH of the water.]* Ask students to use information in the article to develop an explanation for how the change in pH affects coral. *[As levels of carbon dioxide in the ocean increase, the pH of the ocean decreases, creating a more acidic condition – known as ocean acidification. As acidity increases, coral skeletons are weakened and skeleton growth might slow. The reef might become less healthy.]*

Extension Prompts:

- 2d. Coral exoskeletons are made from calcium carbonate. Discuss how the presence of an acid affects the solubility of calcium carbonate. Students studying chemical reactions can write the equilibrium solubility expression for calcium carbonate $[\text{CaCO}_3(s) \longleftrightarrow \text{Ca}^{2+}(aq) + \text{CO}_3^{2-}(aq)]$ and use it as evidence to support their answer. *[As hydrogen ion concentrations increase, CO_3^{2-} is consumed (producing bicarbonate, HCO_3^-). As CO_3^{2-} is consumed, more calcium carbonate will dissolve, increasing the solubility of calcium carbonate.]*

PHYSICAL SCIENCE AND EARTH AND SPACE

Discussion Questions:

- 3a. Algae that live within coral colonies need light in order to photosynthesize. The coral colonies use the products of this photosynthesis as food. Brainstorm factors that influence the concentration of light reaching the coral reefs. *[Because of the curvature of the Earth, latitude affects the angle that light hits the water and thus the light that reaches a particular location. Sea state – big waves, for example – can affect the scattering of light and thus how much light is reflected or absorbed into the water column. Water clarity (quantity of particulates, for example) affects the quantity and quality of light reaching corals. Water depth influences the wavelengths of light that can reach corals.]* Ask students which of these factors might be affected by human activity?

Extension Prompts:

- 3b. What happens to light as it enters the water? *[Light travels faster in air than in water. Therefore, when light penetrates the surface of the water, it is refracted, or bends.]*
- 3c. Explain fluorescence. *[The ability of atoms or molecules to absorb specific wavelengths of light and emit different wavelengths of light as they return to their initial state.]* From an evolutionary perspective, why might fluorescent proteins exist in corals? *[Scientists in the article suggest that fluorescent proteins might act as a sunscreen to protect photosynthetic algae from solar radiation, for example.]* Can students think of

other organisms that fluoresce? [A few examples include arthropods, deep sea fish, fireflies and glowworms.]

- 3d. Allow your students to draw relationships and make distinctions between the use of light energy in fluorescence and photosynthesis in algae. *[Light energy is absorbed to initiate both processes. In photosynthetic organisms, energy is absorbed from incident photons. This absorbed energy is either used as heat to drive the chemical reactions of photosynthesis or is re-emitted as radiation. Fluorescence is often used as an indicator of the initial events of photosynthesis.]*

ENGINEERING AND EXPERIMENTAL DESIGN

Discussion Questions (open-ended):

- 4a. The article talks about some threats to corals being global in nature and some being local. Ask students to brainstorm the nature of local threats to corals.
- 4b. Students can research what specific communities are doing to minimize their direct negative impact on the reefs.
- 4c. Are all reef-adjacent communities facing similar challenges?
- 4d. Students may want to look at what organizations foundations, such as [Reef Check](#), are doing to help educate local populations and support them in finding solutions that protect local reefs from anthropogenic impacts.
- 4e. Students may be able to find out whether these same communities are implementing specific and similar measures to protect the reefs. Students might want to research how communities can develop a [coral bleaching response plan](#).

Extension Prompts (open-ended):

- 4f. Peter Harrison of Southern Cross University created floorless mesh tents as part of his work to reseed the reefs. Have students discuss some of the variables they'd have to consider when designing such a structure. What oceanic conditions would it have to withstand? How would it be transported to the desired location and then secured? What challenges could students anticipate when designing a structure with the same goal? Students might want to draw out their plans and present them to the class.
- 4g. Identify an experiment that was described in this article. What hypothesis was tested? Can students identify the variables and whether they are dependent, independent or extraneous? Was the hypothesis validated or disproved? Students can find original research papers by following the links to "Citations" at the bottom of the [online version of "Rebuilding reefs."](#)
- 4h. How did the scientists use their results to continue their research or experimentation?
- 4i. Ask students to think of another hypothesis that could be tested to add information to support reef-rebuilding efforts. Ask them to identify the variables (dependent, independent or extraneous) of a proposed experiment and explain how these variables might be measured. If time permits, students could work alone or in teams to design an experiment to test the variables they identified.

Cross-Curricular Discussion

Directions: The following list of discussion questions is provided to help you take notes, brainstorm ideas and test your thinking in order to be more actively engaged in class discussions related to this article.

BIOLOGICAL SCIENCES

- 1a. What are some strategies for coral reproduction listed in the article? List those you find and include the pros and cons for each. Think about the potential results of combining the microfragment technique and the selective breeding strategies mentioned in the article. Would the results be beneficial? Are there ethical considerations to creating “super coral”?
- 1b. What are the pros and cons of corals reproducing sexually versus asexually (cloning)? Why would it be best to have more genetic variation in the population?
- 1c. Write the general chemical equation for photosynthesis and cellular respiration. Use this information to explain the symbiotic relationship between algae and coral.

EARTH SCIENCE AND PHYSICAL OCEANOGRAPHY

- 2a. List some greenhouse gases (including the names and any chemical formulas you know).
- 2b. Why are some gases named “greenhouse gases”? What effect are they having on the Earth?
- 2c. How does carbon dioxide, a common greenhouse gas, react with water? Try to write out the chemical reaction of carbon dioxide and water. Explain how this reaction affects the pH of ocean water.
- 2d. How does the presence of an acid affect the solubility of calcium carbonate? Write the equilibrium expression and use it as evidence to support your answer.

PHYSICAL SCIENCE AND EARTH AND SPACE

- 3a. What factors influence the concentration of light reaching the coral reefs? Which of those might be affected by human activity?
- 3b. What happens to light as it enters water?
- 3c. What is fluorescence? Why might fluorescent proteins exist in coral? What other animals can you think of that fluoresce?
- 3d. In terms of light energy, compare fluorescence and photosynthesis.

ENGINEERING AND EXPERIMENTAL DESIGN

- 4a. What are some local threats to corals?
- 4b. What are specific communities doing to minimize their negative impact on the reefs?

- 4c. Are all reef-adjacent communities facing similar challenges?
- 4d. What are foundations and organizations, such as Reef Check, doing to help educate local populations and support them in finding solutions that protect local reefs?
- 4e. How can communities develop a coral bleaching response plan?
- 4f. What oceanic conditions would the tent structure developed by Peter Harrison have to withstand? How would it be transported to the desired location and then secured in place? What challenges could you anticipate when designing a structure with the same goal?
- 4g. Find an experiment that was described in this article. What hypothesis was tested? Can you identify the variables (dependent, independent or extraneous)? Was the hypothesis validated or disproved?
- 4h. How did the scientists use their results to continue their research or experimentation?
- 4i. Can you think of another hypothesis that could be tested to add information to reef-rebuilding efforts? Identify the variables (dependent, independent or extraneous) and explain how you might measure them.