TEACHER BACKGROUND INFORMATION

CLIMATE CHANGE AND CORAL REEFS

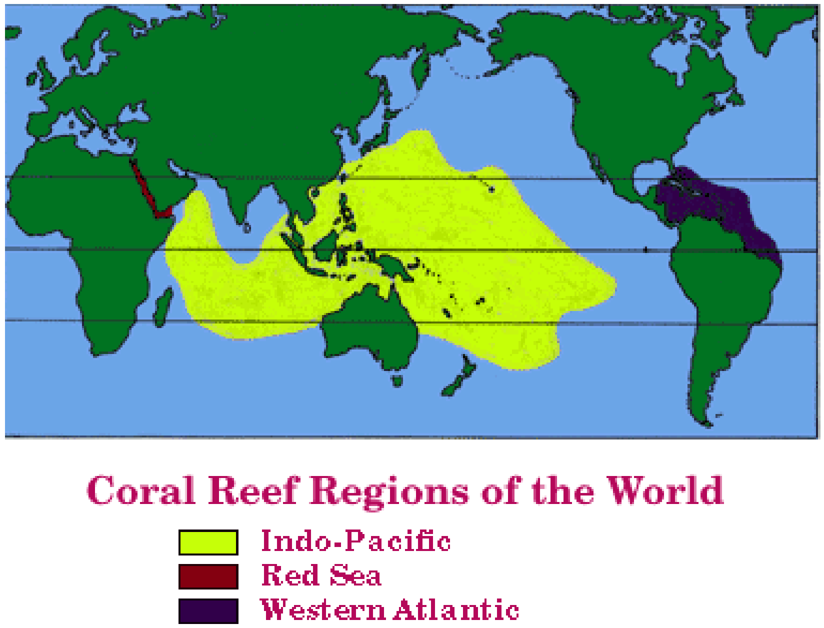
Climate change is becoming an ever more important issue in our lives. We have come to realize that the modern ways of man place a enormous amount of stress on the Earth that nature simply can not handle. Some of the climatic problems that are developing today, such as global warming, ozone depletion and El Nino, will have severe effects on reef ecosystems all around the world. Reefs might give us an early indication of the effects of global climate changes, as slight variations in sea temperature caused by climatic variations have already been shown to produce extreme responses from reef ecosystems.

Coral polyps

Corals have in their tissues millions of microscopic symbiotic algae called z**ooxanthellae**. These photosynthetic algae pass on certain products of photosynthesis (such as sugars and amino acids) to the coral host. The coral host provides the zooxanthellae with nutrients and shelter.

Examples of several types of coral diseases

Bleaching is the term for when the corals expell the zooxanthellae from their tissues, resulting in the loss of the characteristic brown colour of symbiotic corals. A large proportion of the corals food comes from zooxanthellae, and the coral host often dies soon after bleaching, but they may recover. Bleaching of corals generally occurs when the coral animal is under stress The main cause of bleaching is currently thought to be small rises (as small as 1 or 2°C) in sea temperature. Only a few days of elevated temperatures are needed to cause bleaching. Other factors such as increased UV radiation, sedimentation and reduced light levels and salinity changes are also thought to play a role in bleaching, if only by adding to the stress that the coral is under.



Coral bleaching events were first observed in the 1940's, but in the period since 1980 to the present there have been over 60 cases of coral bleaching from all over the world, including French Polynesia, the Caribbean, Palau, Australia, and the eastern Pacific. The El Ninõ events of recent years have caused major bleaching events in the eastern Pacific, from increases in sea temperatures. On a larger scale, global warming is a major concern as widespread sea temperatures may result. Bleaching events have started to become more frequent and widespread, in the last decade, and this is of great concern to scientists and environmentalists. Coral bleaching may be the first sign from a sensitive ecosystem of the global changes that are occurring to the marine environment.

The formation of coral reefs is influenced by the ocean's role in the **global carbon cycle**. In the ocean, carbon moves from the aquatic environment as carbon dioxide (CO_2), enters living organisms such as fish and algae, or binds with other elements to form solid particles, and eventually returns to the aquatic environment.

There are 2 different processes involved in carbon cycling: 1) carbon entering and leaving living organisms through **photosynthesis** and **respiration** (known as **organic carbon metabolism)**, and 2) the opposite, calcium carbonate dissolving (known as **inorganic carbon metabolism).**

The simplified chemical equations that illustrate these exchanges of CO_2 are as follows:

ORGANIC CARBON METABOLISM

- **PHOTOSYNTHESIS** (Equation 1)

$$CO_2 + H_2O \rightarrow CH_2O + O_2$$

Plants and algae in the water **take in carbon dioxide** from the environment, and, using chlorophyll, convert this gas to sugar (CH_2O). Only photosynthetic organisms do this, such as plants and zooxanthellae (algae) that are found in the tissues of corals.

- **RESPIRATION** (Equation 2)

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

Animals and plants **produce carbon dioxide** during cellular respiration, which happens in the mitochondria, the energy producing organelles found inside cells (cells other than bacteria).

Inorganic carbon metabolism

- **CALCIFICATION (**Equation 3)

$2HCO_3^- + Ca^{2+} \rightarrow CaCO_3 + CO_2 + H_2O$ Bicarbonate (HCO^3-) combines with calcium ions in the water to make calcium carbonate ($CaCO_3$, limestone).

This process can occur both within organisms such as corals or as a simple chemical reaction in the water itself. In corals, calcium carbonate or limestone is the building block of coral reefs. As corals produce calcium carbonate they slowly add on to their existing reef structure allowing the reef to grow in size.

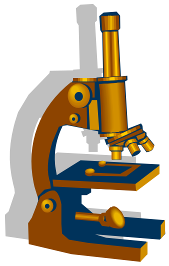
- **DISSOLUTION OF CARBONATE** (Equation 4)

$CaCO_3 + CO2 + H_2O \rightarrow 2HCO_3^- + Ca^{2+}$ Calcium carbonate can combine with carbon dioxide and water to make bicarbonate, a process that releases calcium ions (Ca^{2+}).

EFFECTS OF A GREENHOUSE GAS – CO_2 – ON OCEAN CHEMISTRY

Carbon dioxide (CO_2) concentrations, a greenhouse gas found in the Earth's atmosphere, have increased since pre-industrial times primarily due to the burning of fossil fuels. Based on realistic scenarios of future emissions this trend will continue and atmospheric CO_2 concentrations are expected to reach double pre-industrial levels by 2065 (Houghton et al. 1996). If the amount of CO_2 in the air increases, the amount of CO_2 in the ocean will also increase, because atmospheric CO_2 and seawater CO_2 are in equilibrium.

Based on equation 4 we now know that increases in CO_2 will cause a reaction where CO_2, H_2O, and $CaCO_3$ will all be consumed and HCO_3 - and Ca^2+ will be produced. This is a concern to scientists because coral reef structures are made from $CaCO_3$. Increasing CO_2 has the net effect of causing the dissolution of $CaCO_3$. Coral reefs produce new $CaCO_3$ at a very slow rate, which is why it takes many years for large reefs to become established. Slight increases in the rate of $CaCO_3$ dissolution can cause the loss of total coral reef structure. When the reef structure fails, so to will the reef community including many species of fish that rely on the reef for life.



LABORATORY ACTIVITY

CO2 and Coral Calcification

GOALS:

In this activity students will:

- demonstrate the role of carbon dioxide (CO_2) in photosynthesis and cellular respiration.
- demonstrate carbonic acid's impact on calcification and dissolution of coral skeletons, and its ability to influence pH.

[Note: Humans and other animals take in an air mixture and, in the lungs, oxygen is diffused to capillaries. Carbon dioxide waste, carried from cells as a by-product of cellular respiration, is removed by lung alveoli and diffuses into the lungs, where it is exhaled (or diffused depending on the animal). Plants also respire, producing CO_2, and some of this CO_2 is reused in photosynthesis.]

PART 1: (This may be done as a teacher demonstration)

MATERIALS:

- 300 ml of bromthymol blue
- 500 ml beaker
- drinking straw
- sprig of *Elodea* (may be purchased at aquarium stores) or other aquatic plant

PROCEDURE:

1. Note the color of the bromthymol blue. Be sure to record your observation in Table 1. (When CO_2 is added to bromthymol blue, its color will change from blue to greenish yellow.)

2. Carefully place 300 ml of bromthymol blue into the beaker.
   - Inhale deeply with your nose, then, using a straw, carefully blow bubbles into the blue liquid.
     CAUTION: DO NOT SLURP OR INGEST BROMTHYMOL BLUE!!
   - Repeat blowing bubbles 2 more times.
   - Note the color of the liquid and record your observations in Table 1.

3. Now add a sprig of *Elodea* to your bromthymol blue solution into which you exhaled.
   - Leave undisturbed for 24 hours. The next day, observe and record your observations.

Note: This activity can also be done without using the Elodea. It may have the same basic result since the high CO_2 will tend to diffuse out of the water into the room very slowly.

PART 2: (Teacher demonstration OR in small groups by more advanced students.)

MATERIALS

- 4 beakers, 50-100 ml each (all same size)
- 240ml distilled water
- 240 ml clear soft drink (soda pop) or vinegar
- pH paper or pH probes if available
- 2 calcite chip samples OR 2 small pieces of coral rock (if available)
- triple- beam or electronic balance
- labeling tape or wax pencil (glass marking pencil)

PROCEDURE:

1. Place 30 ml of water in each of 2 beakers and 30 ml of clear soft drink in each of 2 beakers.

2. Label your beakers: H_2O, H_2O + Calcite, Soda, Soda + Calcite.

3. Using probes or pH paper, obtain the pH of each solution and record in Table 3a.

4. Check for the initial presence of calcium ions by adding 5 drops of ammonium oxalate ($NH_4C_2O_4$) to each of the beakers. **(The presence of Ca+2 is indicated by a white precipitate forming in the solution.)**
    - Record your results in **Table 2.**
    - Discard the solutions with the indicator and rinse the beakers.
    - Place 30 ml of water and 30 ml of soda in the corresponding beakers.

5. Mass each calcite chip and record it's mass.
    - Be sure to note which chip will be placed in which beaker.

6. Place each calcite chip in its corresponding beaker. (It is important that you keep track of which chip goes where as you continue your data collecting each day.

7. Check the pH of your solutions with the calcite chip and record in Table 3. Leave undisturbed until the next day.

8. **Days 2-5.** Test the pH of each solution.
    - Record pH value in **Table 3a (and/or 3b**) and indicate whether this value is acid, base or neutral (example: *7, Neutral*).

9. **Days 2-5**. Take out the calcite. Dry the piece using paper towels and measure mass.
    - Record your data in **Table 4.**

10. **Day 5**: To test for presence of calcium ions (Ca^2+), after removing the calcite or coral chips, add 5 drops of ammonium oxalate ($NH_4C_2O_4$) to each beaker. (If Ca^2+ (calcium ions) are present, a white precipitate will form.)
    - Record your observations in **Table 5.**

DATA TABLES 1-5

TABLE 1: Color change of bromthymol blue with exhaled air and aquatic plant over 24 hours.

Bromthymol Blue (Original Color)	Color after Exhale	Color Day 2 (w/plant)	Observations

TABLE 2: Ammonium oxalate test for presence of calcium ions by white precipitate (Baseline)

Beaker Conditions → $NH_4C_2O_4$ Test ↓	H_2O	H_2O + Calcite	Soft Drink	Soft Drink + Calcite
White precipitate (+ or -)				
Ca^{2+} present? (Yes or No)				

TABLE 3: pH quantitative and qualitative values of solutions and change in pH over 5 days.

Beaker Conditions → Days ↓	H_2O	H_2O + Calcite	Soft Drink Soft	Soft Drink + Calcite
1 (Initial)				
2				
3				
4				
5				
CHANGE				

TABLE 4: Mass in grams of calcite in H_2O and soft drink and change in mass over 5 days.

Beaker Conditions → Days ↓	H_2O + Calcite	Soft Drink + Calcite
1		
2		
3		
4		
5		
CHANGE		

TABLE 5: Ammonium oxalate test for presence of calcium ions by white precipitate.

Beaker Conditions → $NH_4C_2O_4$ Test ↓	H_2O	H_2O + Calcite	Soft Drink	Soft Drink + Calcite
White precipitate (+ or -)				
Ca^2+ present? (Yes or No)				

DATA ANALYSIS:

PART 1:

1. What was color change in the bromthymol blue after bubbles were blown into it? What caused the color change? What is the source of this cause?

2. What did you observe after placing an aquatic plant in the bromthymol blue solution?

3. Explain what caused this new (2nd) color change by referring to the **NOTE**.

PART 2:

1. State your hypothesis (use *if…then*) about what you and your group expect to occur in this experiment.

2. a. Why is water alone used in one beaker?
   b. Why is soft drink alone used?
   c. In the scientific method, what are these conditions called?

3. Explain the results of Table 2. Why do you think this was done on Day 1 when it will be repeated on Day 5?

4. a. What was the initial pH of the soft drink?
   b. From the background information provided, and knowing that this soft drink is carbonated, which acid may be found in this solution?

5. Explain the results of **Table 3 (a and/or b)**. If there was a change, why did this occur, and why were there no changes in some conditions?

6. Using **Table 4 (a and/or b**), in which solutions did you observe changes in the masses of the calcite (or coral rock)? Explain.

7. At the end of the experiment, in which conditions were calcium ions detected?Why?

8. Review the introductory information. Where did calcium ions come from?

9. What does the presence of calcium ions mean for corals on a coral reef (calcite chips)?

*10. Relate the findings of this experiment to the plight of coral calcification. How does this experiment show that coral skeletons are in danger of slowing their rates of calcification?

11. Where does the CO_2 in the oceans come from?

12. How has human activity contributed to increase atmospheric CO_2?

13. Suggest ways that changes in human behavior can improve the conditions for coral calcification and health.

INSTRUCTIONAL ACTIVITY

REEF RELIEF?

BACKGROUND:

Coral are tiny animals that live in the ocean. They are related to hydras, jellyfish, and sea anemones. A coral reef is a large rock-like calcium carbonate skeleton secreted by colonies of coral.

Close-up view of a coral reef.

Coral reefs are very important to the ocean ecosystem. Many plants and animals rely on coral reefs for shelter. They also find their food there. Algae, sponges, clams, and many species of fish are among the organisms that live on coral reefs.

A tropical fish takes shelter in a coral reef.

Coral reefs are home to so many types of organisms that they are often called the "tropical rainforest of the ocean." A loss in coral reef habitat can lead to a dramatic loss of biodiversity. Many scientists are concerned that such a loss of biodiversity is already happening.

Photos: Australia's Great Barrier Reef provides a home for many species of fish.

According to the U.S. Environmental Protection Agency's Coral Reef Initiatives, an estimated 10 percent of Earth's coral reefs have already been seriously harmed, and a much higher percentage is threatened.

One possible relief for dwindling reefs and their inhabitants may lie with ***artificial reefs***- basically, garbage left or placed on the sea floor by humans. The trash immediately becomes the foundation of new habitat for marine organisms and a new area to explore for divers.

OBJECTIVES:

Students will:

- hypothesize whether human-made objects in the water can provide good habitats for marine animals;
- view pictures of human-made marine habitats, and discuss what they see;
- make charts hypothesizing the pros and cons of artificial reefs;
- read and answer questions about two articles concerning artificial reefs; and
- write paragraphs on the pros and cons of sinking a ship off the Florida coast to create an artificial reef.

PROCEDURE:

SCENARIO

The Committee on Reef Area Loss (CORAL) is concerned about the loss of biodiversity that could accompany a greatly reduced coral reef area. It has been looking into ways to prevent such a loss of biodiversity. CORAL is considering building artificial reefs where natural reefs are being destroyed. They have asked you to consider the pros and cons of artificial reefs and evaluate how well they would preserve biodiversity. You are to do research and prepare a report to deliver to the group in 2 weeks.

OPENING:

1. Pose this question to the class: "Can human-made objects, such as sunken ships or oil rigs, provide good habitats for marine animals?"

2. Ask students to think about the question for a minute, and spend about five minutes discussing their initial ideas.

DEVELOPMENT:

1.Make sure the students know that coral reefs are barriers and ridges created by the limestone remains of tiny coral polyps, and that they attract a wide variety of marine animals.

2. Define the term "artificial reef" as a human-made structure in the ocean or sea. Explain that, like coral reefs, artificial reefs frequently attract marine animals from the surrounding ocean areas.

3. Show students some pictures of examples of artificial reefs. Discuss the different types of structures they see and the types of animals and plants they see living on or around the structures:

4. Ask students to make "pros and cons" charts that hypothesize the positive and negative impacts of artificial reefs on the marine ecosystem. They can make their charts individually, in small groups, or as a class, but be sure to discuss the charts as a class.

5. Have students read the National Geographic News article, Artificial Reefs: Trash to Treasure, either individually or as a class. Ask them to answer the following questions as they read:

- Why are marine organisms attracted to a sunken ship?
- When a ship sinks and turns into an artificial reef, does it matter how it is shaped or what it is made of? Why?
- Over time, do artificial reefs become very similar to or very different from natural reefs?
- How might a sunken ship help a nearby natural coral reef?

6. Have students do further research and answer these questions:

- How might artificial reefs "fool" fishermen into thinking there are more fish than before the artificial reef existed?
- What are the ecological arguments against artificial reefs?

7.Have students make new "pros and cons" lists based on the information they have gathered.

CLOSING:
Discuss students' new lists as a class. Overall, do they think artificial reefs are a good idea? Under what circumstances might they be more damaging than beneficial?

SUGGESTED STUDENT ASSESSMENT:
Have students consider the pros and cons of creating a new artificial reef by deliberately sinking a ship off the west coast of Florida. There are already a number of artificial reefs in this area, as shown on this map of Pinellas County. Ask them to write paragraphs explaining the pros and cons of sinking the ship and to provide their own opinions about what should be done.

Extending the Lesson:

- Present students with this scenario:

  The country of Denmark has signed the Kyoto Agreement, agreeing to reduce its carbon dioxide emissions. This is good news for air quality, global warming, and many animal and plant species. In the process of reducing emissions, Denmark has built sea-based windmill parks to harness energy from the wind. The question remains as to how these windmill structures, which rise out of the sea, will affect the marine ecosystem. Will seals and porpoises be disturbed by these structures? How might other parts of the marine ecosystem be affected by these windmills, and how might impacts on invertebrates and fish affect marine mammals?

  Ask students to write paragraphs predicting the effects of the Danish windmills on the marine ecosystem. They should base their predictions on what they have already learned about artificial reefs and on additional research into artificial reefs and the behaviors and habitats of seals and porpoises.

Artificial Reefs: Trash to Treasure

R. J. Kern,National Geographic News,(February 5, 2001)

Shipwrecks may have redeeming ecological value. The ships often become artificial reefs and habitats, providing shelter for the very creatures threatened by humanity's original intrusion. Red Sea researchers have found several shipwrecks have become thriving coral communities. These artificial reefs attract divers, easing human pressure on natural reefs.

A shipwreck- an artificial reef- provides new habitat for marine organisms and divers.

"Coral reefs around the world are experiencing substantial decline, partly due to human activity," says marine biology professor Yehuda Benayahu, who is studying how artificial reefs become part of the natural environment of the Red Sea.

" The University of Tel Aviv project is supported by the National Geographic Society's Committee for Research and Exploration. The project is looking at how coral reef communities around ten Red Sea wrecks serve as models of artificial reefs. Benayahu is comparing the artificial reefs with adjacent natural reefs in the area. "With time, the shipwreck becomes part of the natural environment," he says. He hopes the study will provide information for future artificial reef projects aimed at the restoration and conservation of their natural counterparts.

New Habitats Utilized Quickly

When a ship sinks, it immediately becomes shelter for marine organisms. Such habitats provide new food sources, greater protection for juveniles, and more space for settlement, says Benayahu. Space is at a premium in a coral reef environment. "The new habitat is utilized by fish very quickly," says Benayahu.

Coral, which is composed of small and delicate polyps, develops more slowly,covering a shipwreck's surface over a period of many years.

The ships in Benayahu's study range in age from 16 to 130 years, Representing various stages of reef development in the same locality. The ships close proximity to natural reefs allows scientists to make comparisons between the two environments. "It's a wonderful opportunity to study the rate of development and the potential of use of artificial reefs," says Benayahu.

What are the differences between a coral community that develops on a shipwreck and a natural reef?

"Orientation of space may play a role in determining what kind of corals and how fast they grow on horizontal or vertical features," says Benayahu. "We are able to predict, with quite a lot of success, what kind of corals will appear on various surfaces."

Most shipwrecks, especially those with intact masts, represent vertical structures that attract soft corals, such as the colorful *dendronphya* and *scleronephthya,* which add attractive framework to many reefs in the Red Sea and elsewhere in the Indian and Pacific oceans.

Ships made of wood provide a different hosting environment than those built of steel," says Benayahu. "Steel is a very successful choice of reef as wood decays. Steel structures are also covered fast by calcareous algae, which provide an adequate surface for coral larvae to grow quickly."

The Red Sea is a paradise for discovering new species," says Benayahu. "It is one of the richest reef habitats in the world, in terms of density and diversity of species."

Perhaps the most unexpected advantage of shipwrecks that act as hosts for corals, is that they can ease human pressure on natural reefs. The presence of artificial reefs as an alternative dive site can reduce the stress placed on the natural reefs," says U.S. National Oceanic and Atmospheric Administration scientist Mark Eakin. "In many cases, artificial reefs will decrease the total dives on natural reefs."