LESSON 1

Coral, Carbon Dioxide and Calcification

INTRODUCTION & BACKGROUND

What are corals?

Corals are marine animals found in all oceans, and are common in the tropics. Scientists classify them as **cnidarians** ("ni-DARE-ri-ans"). Types of coral vary but they all have a basic body form known as a **polyp,** which is a tubular body capped by a ring of stinging tentacles surrounding a mouth. This is the living part of a coral and resembles an anemone. Coral polyps are usually tiny, but many species have developed the ability to live in colonies. In the tropics, many coral colonies build spectacular, beautiful, and protective skeletons that form reefs. These skeletons are made of calcium carbonate, which is secreted by the polyps.

Even though the calcium carbonate skeletons of living corals is white, the brilliant colors of coral reefs result from varieties of single-celled microalgae, called **zooxanthellae** ("zo-uh-zan-THEL-ee") which live in **symbiosis** within the coral polyps. A symbiotic relationship implies that each organism provides something to another organism such that living together is beneficial to the survival of the organisms. Here, corals provide zooxanthellae a safe, protected home. In return, zooxanthellae provide corals with energy by processing light and nutrients via photosynthesis.

Where do corals live?

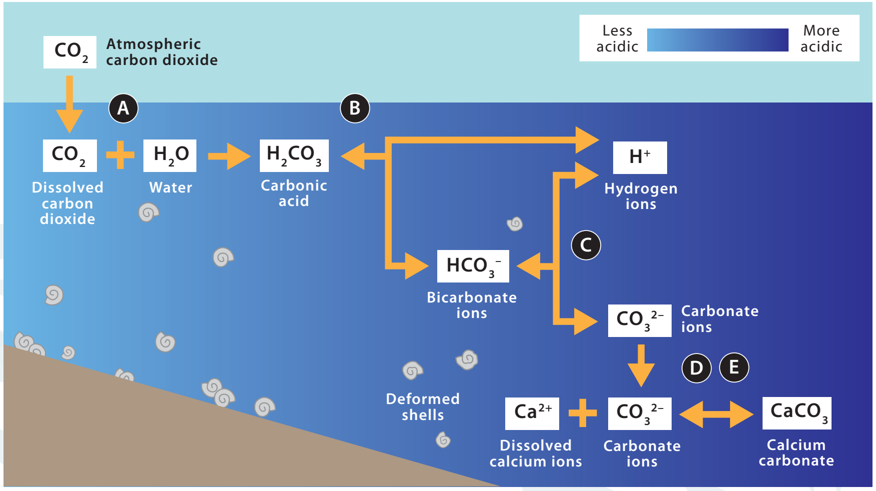
Corals have very specific requirements for temperature, salinity, water depth and clarity. These conditions are met for tropical corals between the **latitudes** of 30º North and 30º South. The optimum temperature range for coral growth is between 73-84º F (23-29º C). While most corals can tolerate some variation from this optimal range, corals do not survive at temperatures below 64º F (18º C) or for extended periods at temperatures above 104º F (40º C). Corals require water with high salinity (32-34 ppt (parts per thousand). Corals are found within 210' (70 m) of the ocean surface in clear waters, where they thrive in high amount of sunlight (NOAA: Corals, 2008).

How does the ocean process carbon dioxide?

The ocean has a complex way of processing carbon dioxide. This process is often referred to as the "ocean carbon cycle" or the "carbonate buffer system." The major points are summarized below and a more detailed description adapted from The Royal Society is included online. These basic points are part of the activity procedure.

Starting from the atmosphere and working down:

A. Carbon dioxide in the atmosphere mixes with seawater to produce carbonic acid.
B. Carbonic acid easily splits apart into hydrogen ions (H^+) and bicarbonate (HCO_3^-) ions. (An increase in the concentration of hydrogen ions increases the acidity of the water, i.e. lowers the pH).
C. Carbonate ions (CO_3^{2-}) combine with hydrogen ions to produce bicarbonate ions.
D. Carbonate ions and calcium ions are used by marine animals (such as corals, crustaceans, and zooplankton) to create hard shells and skeletons of calcium carbonate. This is called "**calcification**," or more generically, "biomineralization."



Carbonate Buffer System. Source: University of Maryland

E. Calcium carbonate dissolves into calcium ions and carbonate ions. The rate of dissolution depends on pH, pressure and the amount of carbonate ions in seawater.

To summarize, the addition of carbon dioxide to seawater increases the amounts of hydrogen ions, carbonic acid and bicarbonate ions and lowers amounts of carbonate ions. (*See Online Supplementary Background Information for Lesson 1 for more information on changes in pH in seawater.*)

ACTIVITY MISSION

Time: 45 min.

Through a series of chemical reactions and physical changes, carbon dioxide (CO_2) from the air dissolves into seawater and is used by marine organisms, such as corals and invertebrates. Students will act out key stages in this process through motions, rearranging blocks and team tasks. Students will hypothesize the potential effects when variables are changed (e.g., the addition of massive amounts of CO_2 and increased water temperature).

CONCEPTS

- Carbon dioxide from the atmosphere is used by marine organisms through chemical reactions and physical changes.
- The ocean processes global carbon through complex systems involving **biotic** and **abiotic** factors.
- The health of coral is affected by changes in temperature, pH and the concentration of important chemical compounds.

LEARNING OBJECTIVES

- Students will be able to demonstrate their comprehension of carbon utilization by acting out each stage in the process.
- Students will be able to demonstrate their application of coral ecology processes by hypothesizing results to changes in the system.

STANDARDS & PRINCIPLES

U.S.: 6.2, 6.5; 11.3, 11.3

Canada: 306-3, 311-8, 111-6

Ocean Literacy Principles: 5f

PRE-DELIVERY PREP

Supplies Needing a Day or More to Prepare: Purchase blocks

Hard-to-Obtain Materials: None

Safety Procedures: Monitor student use of small blocks.

SAFETY GUIDELINES

Hazardous Materials: Small block pieces

Safety Concerns for Students: Small block parts may pose choking hazards.

SUMMARY OF SUPPLIES

Durable Supplies

ITEM	DESCRIPTION	QUANTITY
Interlocking blocks (e.g. LEGO® bricks)	Pieces that can represent different chemical ions and compounds involved in reactions, and can be assembled/disassembled in various arrangements and stacked to form a wall	1 set/class
Large opaque container	Container that gives the impression that it contains a VERY LARGE quantity of pieces representing CO_2	1/class
Large quantity of "CO_2" pieces (optional)		As many as possible
Plastic storage boxes or tennis ball containers	One label per box: "Bicarbonate" "Carbonate" "Carbonic Acid" "Hydrogen Ions" "Calcium Ions" For *Ocean* only: "Water"	12 (one in reserve) One set each for *Ocean* and *Coral*
Table or Desks	One for *Ocean* and one for *Coral*	2
Heavy coat(s)	Clothing that will make the "*Coral*" warm and simulate rising water temperatures	1 or as many as needed
Tags/lanyards	Role Title and Job Summary	1/acting student

CONSUMABLE SUPPLIES

None

PROCESS & PROCEDURE

1. Select volunteers and have them line up side-to-side at the front of the class like an assembly line.
2. Assign roles:
   - *Coral:* 3 students — their "job" is to eat, grow, and build exoskeleton by producing calcium carbonate. Students recreate a coral: standing shoulder-to-shoulder, students on ends make "polyp" motions with one hand over their heads, the other hand can pass blocks to the middle person or build the exoskeleton. The student in the middle has use of both hands and can assemble/disassemble blocks; Add any other motions (jumping, twirling, etc.) to simulate an active, growing coral. However, *Coral* is fixed in one spot in the room — they cannot travel. *Coral*'s exoskeleton can be built on a table or desks so the rest of the class can monitor the progress of the skeleton.
   - *Ocean:* 3-5 students — their "job" is to transport components from place to place and facilitate chemical reactions. They can move about the room but can only hold one block component (carbon dioxide, carbonic acid, etc.) at a time. *Ocean* moves in fluid, wavy movements.
   - *Atmosphere:* 1 student or instructor — his/her "job" is to hold and distribute CO_2 blocks to *Ocean*.
   - *Dissolver:* 1-2 students — their job is to take apart the coral skeleton, simulating the effect of more acidic waters.

Note: each actor can handle only one block (compound) at a time.

The rest of the class observes. Encourage them to join in "talking them through" the process and doing the motions of each step.

3. Any time there is a rearrangement of atoms (chemical reaction), everyone says "Reaction, Reaction" while shaking their hands.
4. *Ocean* begins with a supply of assembled water blocks and an amount of the other components as well. *Coral* may start with a partial wall of calcium carbonate or may build from scratch, depending on time.

The actions are listed below in the order of steps A-E shown on the Carbon Buffer System Diagram.

(A) Carbon dioxide in the atmosphere mixes with ocean water to produce carbonic acid.

1. *Atmosphere:* Gets carbon dioxide (CO_2) block and passes to *Ocean*.
2. *Ocean:* takes the (carbon dioxide) block and combines it with another block combination representing water (H_2O) to make a complex combination (carbonic acid). Puts in *Ocean*'s carbonic acid box.
3. Class: Says "Reaction, reaction."

(B) Carbonic acid easily splits apart into hydrogen ions and bicarbonate ions. (An increase in the concentration of hydrogen ions increases the acidity of the water, i.e. lowers the pH).

4. *Ocean:* takes carbonic acid blocks and separates into hydrogen ion blocks and bicarbonate blocks. *Ocean* puts the hydrogen ion blocks into its hydrogen ion box and gives the bicarbonate block to *Coral*.
5. *Coral:* separates it into hydrogen and carbonate blocks, puts carbonate blocks into "Carbonate" box and passes the hydrogen ion block to *Ocean*.

(C) Carbonate ions combine with hydrogen ions to produce bicarbonate ions.

6. *Ocean:* combines hydrogen and carbonate blocks into bicarbonate blocks.
7. *Ocean:* places bicarbonate in "Bicarbonate" box.

(D) Carbonate ions and calcium ions are used by marine animals (such as corals, crustaceans, and zooplankton) to create hard shells and skeletons of calcium carbonate. This is called "calcification," or more generically, "biomineralization."

8. *Coral:* picks up a carbonate ion piece and combines it with a calcium ion piece and sets the calcium carbonate blocks in front of itself.
9. Building of pieces continues until there is a small "wall" or skeleton of calcium carbonate pieces.

Note: Arrange pieces and boxes so that Coral does as much physical activity as practical (jumping up, squatting down, turning around, clapping, etc.) during these biological processes.

(E) Calcium carbonate dissolves into calcium ions and carbonate ions.

10. *Dissolver:* takes one of the calcium carbonate blocks from the coral "wall."
11. *Dissolver:* separates it into calcium and carbonate then puts the pieces into the"Calcium" and "Carbonate" containers

Note: designate the rate at which the dissolver does this, e.g. once out of every 5 blocks that Coral builds. Optimally, the rate that Coral assembles the wall will be a little faster than the rate at which the Dissolver removes pieces. Increased temperature and low concentration of CO_2 will increase the rate of the Dissolver.

K–5 ADAPTATION

Young children may enjoy the motions. Have students help brainstorm appropriate motions. Simplify reactions.