NOAA's **aquarius**
America's Innerspace Station

Are You Concentrating?

Focus
Concentration gradients

Grade Level
9-12 (Life Science/Chemistry)

Focus Question
How do concentration gradients and flow velocity affect rates of dissolution?

Learning Objectives
Students will be able to explain the concept of concentration gradient.

Students will be able to explain the effect of flow velocity on concentration gradients.

Students will be able to explain the importance of concentration gradients and flow velocity to the nutrition of reef-building corals.

Materials
- Concentrated sugar solution (see Learning Procedure), approximately 120 ml per student group
- Water, approximately 250 ml per student group
- Graduated cylinders, 100 ml capacity
- 6 oz paper cups, 3 per student or student group
- Lifesaver candy (fruity variety), 4 pieces per student group (plus extras for student consumption, if allowed)
- Clock or stopwatch
- Lab notebooks
- Pencils
- Paper Towels
- Optional: Triple beam balance

Audio/Visual Materials
None

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Groups of 2-3 students

Maximum Number of Students
30

Key Words
Concentration gradient
Flow velocity
Solution
Solvent
Solute
Zooxanthellae
Coral

Background
Aquarius is an undersea laboratory owned by the National Oceanic and Atmospheric Administration (NOAA). Its purpose is to support research on oceans and coastal resources by allowing scientists to live and work on the seafloor for extended periods of time. Aquarius is presently deployed three and a half miles off-shore in the Florida Keys National Marine Sanctuary. It operates 62 feet beneath the surface at Conch Reef. Missions typically last ten days and aquanaut candidates undergo five days of specialized training before each mission starts. Visit http://www.uncw.edu/aquarius/ for more information, including a virtual tour of the Aquarius laboratory.

Aquarius missions are focussed on understanding our changing ocean and the condition of coral reefs. Coral reefs are threatened locally, regionally, and globally by increasing amounts of pollution, over-harvesting of fisheries, disease, and climate change. Marine protected areas (MPAs) are recognized as an important management tool for marine conservation, and can help stop dwindling fish populations, conserve critical habitats and biodiversity, and manage sites to avoid conflicts among fishers, boaters, and divers. Effective design and management of MPA s to protect coral reefs requires specific information on the complex ecosystems typically associated with these reefs, particularly fish populations. In recent years, visual censuses by scuba divers have become increasingly important to marine conservation programs. In addition to research conducted by professional scientists, many fish population surveys are also done by volunteers. The Reef Environmental Education Foundation's Fish Survey Project, for example, allows volunteer SCUBA divers and snorkelers to collect and report information on marine fish populations. The data are collected using a standardized method, and are archived in a publicly-accessible database on REEF's Website (http://www.reef.org).

Corals are invertebrate animals that belong to the phylum Cnidaria, which also includes jellyfish, sea fans, and hydroids. Like other members of this phylum, corals are equipped with stinging cells called nematocysts that are used for defense and food capture. In addition to capturing animals with nematocysts, corals often have two other means of obtaining food. Most reef-building corals have symbiotic algae called zooxanthellae (pronounce zoh-zan-THEL-ee) that live inside the corals' tissues and provide nutritional materials through photosynthesis. The third nutritional strategy is direct absorption of nutritional chemicals from the surrounding environment. This third strategy depends upon fundamental chemical properties of concentration and solubility. In the following activities, students will investigate some of the factors that affect these properties.

Learning Procedure

1. Advance Preparation: Prepare concentrated sugar solution by adding sugar to boiling water in a ratio of about 100 grams of sugar per 100 ml water. Remove from heat and stir until dissolved. Allow the sugar solution to cool to room temperature. Allow approximately 120 ml sugar solution per student group.

2. Tell students that they will compare the rate of dissolution of a lifesaver candy in plain water with the rate of dissolution of a similar candy in a concentrated sugar solution, and also will investigate the effects of water movement on the rate of dissolution. Review the terms solubility, solvent, and solute. Ask students to make hypotheses on what they believe will happen, and record these on the board. Give each student group three 6 oz cups. In two of the cups add about 100 ml of room temperature tap water. In the other add 100 ml of concentrated sugar solution. Place a lifesaver candy (the fruity variety, not the minty) into each of the cups. Have students take turns gently swirling one of the cups containing tap water so that the water is in constant motion. The other two cups should remain motionless for the remainder of the observation period.

   Have the students make observations every 5 minutes or so, and record data in their lab notebooks. This may be a good time to briefly review background information on the Aquarius habitat, corals, and coral reefs (http://www.uncw.edu/aquarius provides "one-stop shopping" for this review). You may also want to have students review the New England Aquarium's book on coral reefs (http://www.uncw.edu/aquarius/education/coral_reefs/coral1.htm) and complete the "Coral Crossword Challenge" (http://www.uncw.edu/aquarius/education/lessons.html).

3. Re-examine the students' hypotheses and discuss their results. Students should have observed that the lifesavers in the cups containing tap water began to dissolve, and understand that this is the result of a concentration gradient between the lifesavers and the water. Dissolution begins as the sugar molecules in the lifesaver begin to move out of the candy and into the water. This happens because molecules tend to move along a concentration gradient until equilibrium is established. In other words, the lifesaver has more sugar molecules than the tap water, so they move into the tap water to balance everything out. This is similar to when two people are on a seesaw. To make it balance, you need to have two people with similar weights. Otherwise it is uneven, and one person is always stuck up in the air.

   Things are a little different with the lifesaver in the sugar solution. The concentration of the sugar in the solution is much closer to that of the lifesaver, so the concentration gradient is much smaller and the sugar molecules in the solution and the lifesaver are nearer to equilibrium. The only change you may see is the food dye in the lifesaver moving into the sugar water and coloring it... another concentration gradient!

   When students swirled the water in one of the cups, they increased the flow velocity (the speed of the water) over the lifesaver. This maintained a greater concentration gradient between the water and the surface of the lifesaver. Be sure students recognize that the surface of the lifesaver is where dissolution is actually taking place. So the dissolution rate depends upon difference in sugar concentration between the lifesaver's surface and the water immediately adjacent to this surface, rather than the overall concentration of sugar molecules in the entire 100 ml of water. Swirling the cup constantly brings water having a lower concentration of sugar into contact with the lifesaver's surface, so a larger concentration gradient is maintained than in the motionless cup in which water movement is generated by diffusion alone. If there were no water movement at all (an impossibility except at a temperature of absolute zero), the water in contact with the lifesaver's surface would quickly become saturated with sugar and dissolution would stop.

4. Discuss the relationship of these observations to reef-building corals. Students should realize that corals obtain much of their food from plankton they catch, but in addition often have symbiotic algae (zooxanthellae) living inside their tissues. The zooxanthellae photosynthesize and provide an additional food source for the corals. To carry out this process, zooxanthellae need sunlight, as well as a sufficient exchange of gases from the surrounding water. Without this exchange both the coral and the zooxanthellae would die. So, the process of corals exchanging gases with the surrounding ocean is similar to the process of lifesavers exchanging sugar molecules with the surrounding tap water. However, if there were not a sufficient concentra-

tion gradient between the coral and the surrounding water then, like the lifesaver in the sugar solution, there would be no exchange of molecules. So for corals to exchange molecules with the surrounding water, the concentration of these molecules inside the coral must be different from the concentration of the molecules in the surrounding water. If the external concentration is too similar to the coral's internal conditions, then there will not be an exchange.

Flow velocity of surrounding water is very important to maintaining adequate concentration gradients, as well as to keep sediment off of the corals' surface. In the cup where the water was still, it took longer for the lifesaver to dissolve. If a coral were to live in a habitat with very low flow velocity it would have a difficult time exchanging oxygen and carbon dioxide with the surrounding water.

The Bridge Connection

www.vims.edu/bridge/ – Click on "ocean science" in the navigation menu to the left, then "Ecology," then "Coral."

The "Me" Connection

Have students write a short essay describing three examples of concentration gradients in their own bodies, and how these gradients are maintained.

Connections to Other Subjects

Mathematics, English/Language Arts

Evaluation

Observations and hypotheses recorded in lab notebooks, participation in group discussions, graphic analyses (if done), and Coral Crossword Challenges (if done) provide opportunities for assessment.

Extensions

You may want to have students quantify their observations by removing the lifesavers from the cups every 5 minutes or so, blotting with a paper towel, weighing on a triple beam balance and then returning them to the cups for another five minute interval. Students may then create and interpret graphs (plotting lifesaver mass vs time) and tables to present and analyze their data. Discuss with students how the graph demonstrates the rates of change in the size of the lifesavers (for example, the slope is the rate of mass flux).

Resources

http://www.uncw.edu/aquarius– The Aquarius project website

http://www.marinebiology.org/science.htm – Odyssey Expeditions website, with lots of information about coral reefs and reef ecology

http://www.reef.org – Reef Environmental Education Foundation website

http://www.nos.noaa.gov/education/corals/supp_coral_roadmap.html – National Ocean Service website's Roadmap to Resources about corals, with links to many other sources of coral reef data, background information, and reports

National Science Education Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Structure and properties of matter
- Chemical reactions

Content Standard C: Life Science

- The cell
- Interdependence of organisms

- Matter, energy, and organization in living systems

Content Standard F: Science in Personal and Social Perspectives

- Natural resources
- Environmental quality

[Note: This activity was designed by Kristi Gardner, University of South Carolina]