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ABSTRACT

This activity book on coral reefs for middle school students is divided into 10 sections. Section 1 contains the introduction. Section 2 describes what coral reefs are while section 3 describes how coral reefs reproduce and grow. Section 4 discusses where coral reefs are found and section 5 describes life on a coral reef. Section 6 discusses the conservation of coral reefs. Section 7 includes a review with section 8 being the answer section. Section 9 features the reference section and section 10 contains a resource section. (SAH)

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Coral Reefs

An English Compilation of Activities for Middle School Students

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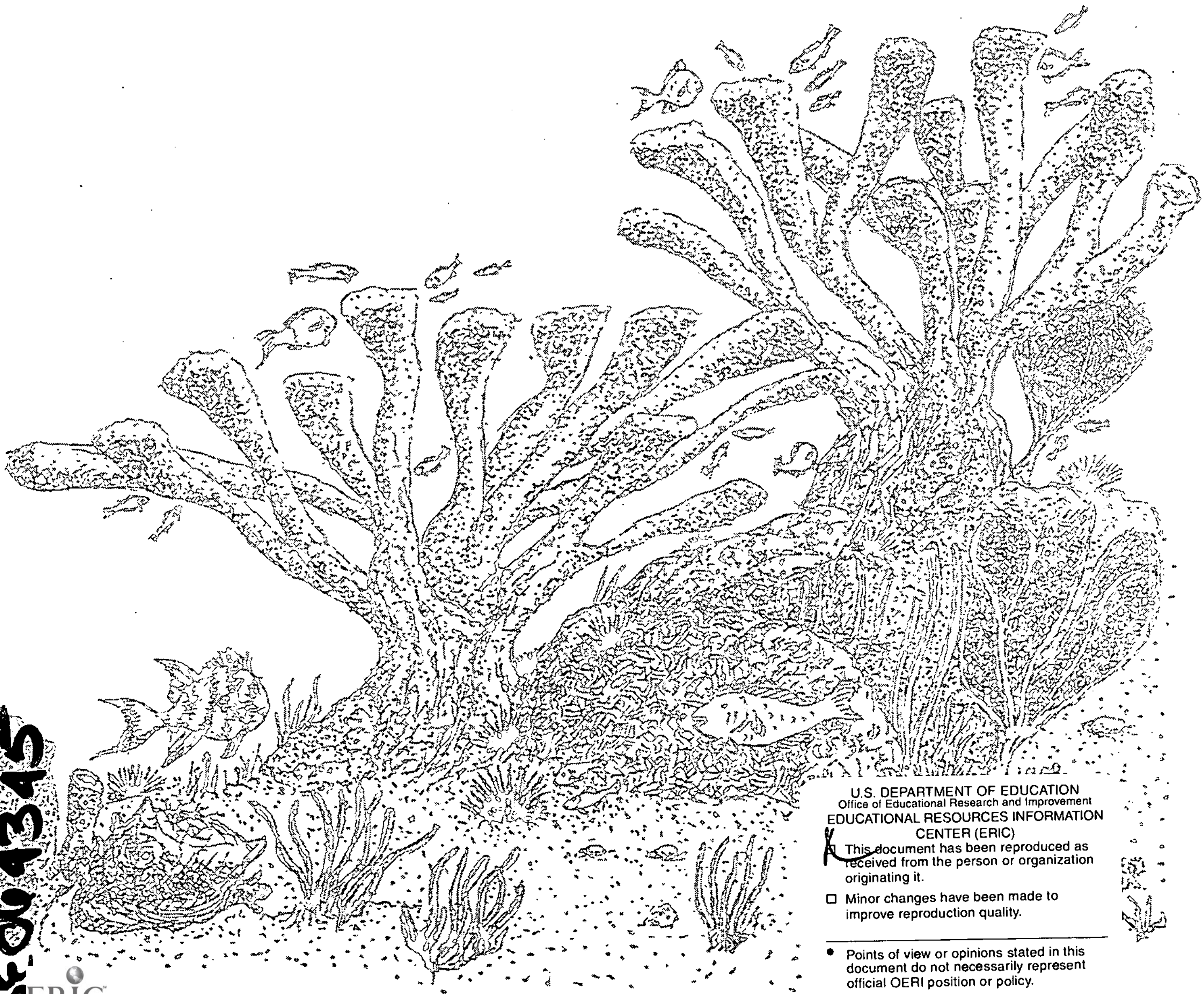
November 1997



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Cover illustration by Raymond Rohrer Roberts, 1933 - 1985.

Coral Reefs:

An English
Compilation of Activities
for Middle School Students

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"The wonder is not that coral reefs are in danger—and they are—but rather, that they have tolerated so much for so long."

—Dr. Sylvia Earle, 1995

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PREFACE

> More than fifty millions of years ago, long, long, long before man built his first crude hut, a bizarre, intricate form of life began construction of the world's greatest edifices. Time passed and Earth was transformed. Battling against wind and wave, thwarted and harassed by the icy breath of a planet in the throes of the ice ages, this pulsing mass worked on and on and on. While mountains lifted and seas drained and continents floated over the face of the Earth, the diaphanous creatures perfected their craft . . . the blind, unthinking workers toiled to the rhythms of the oceans, steadily building up and out. From ions dissolved in the sea, they shaped delicate microscopic crystals that were wedded to older tissues—day after day, millennium after millennium. The accretions grew into massive boulders, and slowly, very slowly, into giant walls and buttresses that could withstand the poundings of the oceans.
>
> Douglas Faulkner, Living Corals (New York: Clarkson N. Potter, Inc., Distributed by Crown Publishers, Inc., 1979) p.17.

The breathtakingly beautiful coral reefs of the world cover less than a half of one percent of our planet's sea floor. And yet, these magnificent underwater empires are home to an estimated 25 percent of all oceanic species, a dazzling diversity of sea creatures. Like the teeming metropolis of Rome, a coral reef "was not built in a day." Rather, the coral heads in a reef grow at a painstakingly slow average rate of half an inch per year and require epochs of geological time to amass into reefs and coral cays.

Coral reefs, in addition to providing food and shelter for countless varieties of marine life, provide benefits beyond estimation for humankind. Healthy reefs are essential for an adequate supply of seafood to nourish the world's populations and sustain regional fishing industries. Reefs enhance tourist businesses by attracting millions of divers and by continuously supplying coastal beaches with shimmering white sand, the fine-grained rubble of dead corals and calcareous reef algae. By breaking waves, reefs protect nearby shorelines from soil and sand erosion and from the brunt of ravaging hurricanes. A wealth of commercial and medical applications has been discovered for corals and other components of the reef community. From coral reefs come additives for cement and mortar, compounds used in violin varnishes, substances for surgically replacing broken human bones, and promising treatments for infections, viruses, arthritis, asthma, and cancer. Scientists agree that this is only the tip of the iceberg as far as important findings and innovations which will result from continued research of coral reefs.

In recent years, as appreciation for the remarkable and irreplaceable coral reefs has increased, so also has grown the alarming realization that the reefs are in trouble. It has been said that we are literally "loving our reefs to death." Souvenir shops have taken their toll as reefs are chipped away to make coral curios for tourists to buy. The most accessible reefs are rapidly deteriorating due to the sheer numbers of visitors. Even the slightest touch of a hand or a swim fin can crush the fragile polyps that constitute a coral head, exposing the entire head to algal overgrowth or bacterial infection.

Over and above the damage done by careless snorkelers and divers, anchor impacts, accidental boat groundings, and propeller damage, reefs around the globe are dying as the result of pollution of their native waters. Fishing boats, cruise ships, and cargo vessels jettison tons of garbage and debris into the oceans each year. Coastal deforestation and development are responsible for clouding near shore waters with sediments that smother corals and deprive them of needed sunlight. In some cases, land development has led to increased freshwater runoff which has killed or stunted nearby reefs. Well-established agricultural practices have the unfortunate consequence of tainting seawater with toxic pesticide runoff. Fertilizer, sewage, and phosphate-laden detergents leaching into the sea have promoted algal blooms which rob the water of oxygen and lead to coral disease. Oil drilling and manufacturing enterprises have also contributed to the demise of coral reefs by diminishing water quality.

Efforts are underway around the world to reduce destructive reef fishing and pet shop/aquarium collecting practices—especially those that use dynamite, cyanide, and bleach—and to raise awareness of the problem of overcollecting which has been documented to drastically upset the delicate natural balance of the reef ecosystem.

Yet another dire threat to corals is the often irreversible "bleaching" which results when corals are subjected to such stresses as excessive increase in water temperature. It is reported that more than 80 percent of the Atlantic's reefs have suffered from bleaching since 1988, and serious incidences of bleaching have been noted on the Great Barrier Reef as well as on Indo-Pacific reefs. Many investigators attribute the bleaching to global warming which has resulted as modern civilization has filled Earth's atmosphere with a variety of pollutants that trap heat which otherwise would have dissipated into outer space (i.e., the "greenhouse effect").

In the face of these ominous worldwide threats to coral reefs, *now* is the time to take action to preserve the sea's finest treasures. The year 1997 has been officially designated by the United Nations as **THE INTERNATIONAL YEAR OF THE REEF**, a year to launch what must be an ongoing campaign to educate people of all ages about the marvels of coral reefs and the need for their conservation.

This manual is a compilation of some of the finest teaching activities available on coral reefs, gathered from around the globe. Teachers will find exercises and projects for students in grades four through eight which can be integrated into all disciplines of learning—reading, writing, math, science, social studies, arts, drama, recreation—and even classroom refreshments. Some of the activities are simple and can be quickly conducted while others will require more extensive preparation and time to perform.

The text of many activities in this teacher's guide is written for classroom instructors, however, some activities address students directly. When utilizing this manual, a photocopier may prove useful for preparing handouts or overhead transparencies. Material in this manual may be copied solely for educational purposes and may not be sold for a profit or presented without proper credit to the original sources.

Gratitude is extended to the many publishers, institutions, agencies, and individual authors who have contributed the material reprinted in this resource guide. The views expressed by the contributors do not necessarily reflect positions of the U.S. Government, the University of Southern Mississippi, the Institute of Marine Sciences, or the University of Puerto Rico. Users of this manual are invited to submit outstanding coral reef teaching activities to: CORAL REEF ACTIVITIES, c/o J.L. Scott Marine Education Center and Aquarium, Institute of Marine Sciences, P.O. Box 7000, Ocean Springs, Mississippi, U.S.A. 39566-7000.

Source: Center for Marine Conservation, Washington, DC. Used with permission.

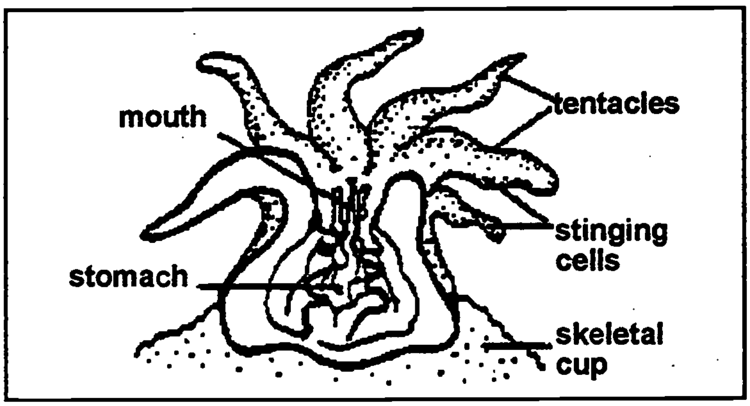
1. CORAL REEFS: A FACT SHEET

Why are they important?

Coral reefs have often been described as "underwater gardens." Their beautiful colors, intricate shapes and exotic creatures remind us of the diversity and splendor of tropical rainforests. Like rain forests, reefs are valuable resources and important parts of the global ecosystem. Coral polyps, because of their unique ability to grow in nutrient-poor water, are responsible for incredible communities of fish and other marine life in waters that might otherwise have been barren. People all over the world depend on reefs for food and protection from waves; many tropical islands and beaches are constructed completely of coral fragments. Despite the ecological significance and beauty of reefs, they are being threatened around the globe by human activities such as boat groundings, overfishing, and pollution. As in the case of rain forests, it will be up to humans to stop the damage and learn how to protect coral reefs for future generations.

What is coral?

Coral reefs can be made up of hundreds of different species of coral. There are two main types: "hard" coral with an outer skeleton of calcium carbonate ($CaCO_3$) and "soft" corals that embed bits of $CaCO_3$ inside their bodies. Although it comes in many shapes and sizes, all coral is composed of tiny individual ***polyps***. A polyp is a tiny animal that looks like an upside-down jellyfish. In soft corals, each polyp contains little spikes of $CaCO_3$ that help hold many polyps together in structures that look like fans or whips. In hard corals, polyps sit inside little cups which they build out of calcium carbonate. Many of these cups are cemented together to make up a coral colony. Reefs are formed when hundreds of hard coral colonies grow next to and on top of each other. Since most species of coral polyps stay deep within their calcium carbonate cups during the day, the casual observer may think of coral as inanimate rocks. At night, however, the polyps emerge, and wave their tiny stinging tentacles in the water to catch microscopic organisms called ***plankton***.



What makes coral polyps so unique is that plankton is only part of their diet. Each polyp harbors within its body special algae called ***zooxanthellae***. These one-celled plants use sunlight and carbon dioxide to conduct ***photosynthesis***, a process that produces oxygen ... and other nutrients needed by the polyps. In return, the algae get protection and a constant supply of carbon dioxide and other raw materials they need for photosynthesis. Such a mutually beneficial relationship is called ***symbiosis***. Without this special relationship, it is likely that there would be far fewer animals in clear, tropical waters since they typically cannot support life. It is important to realize that the fish, crabs, snails, worms and other reef creatures depend on the health and growth of the coral reef for their existence.

How do coral reefs form?

To start a new reef, coral polyps can reproduce sexually, using sperm and eggs. Male polyps send sperm into the water where it enters female polyps and fertilizes the eggs within. [Fertilization is internal in corals known as "brooders." "Broadcasters" shed their eggs and sperm into the water, and fertilization is external.] Baby corals [called planulae] develop and leave the polyps, floating on the current until they reach a suitable surface where they can attach and begin to grow into new coral polyps. Sexual reproduction allows corals to distribute themselves. To simply add onto an existing colony, polyps undergo asexual reproduction in which new polyps "bud" off the parents and form their own $CaCO_3$ cup right beside the older polyp. Polyps formed this way are exact copies of each other, creating entire colonies of coral with exactly the same genes.

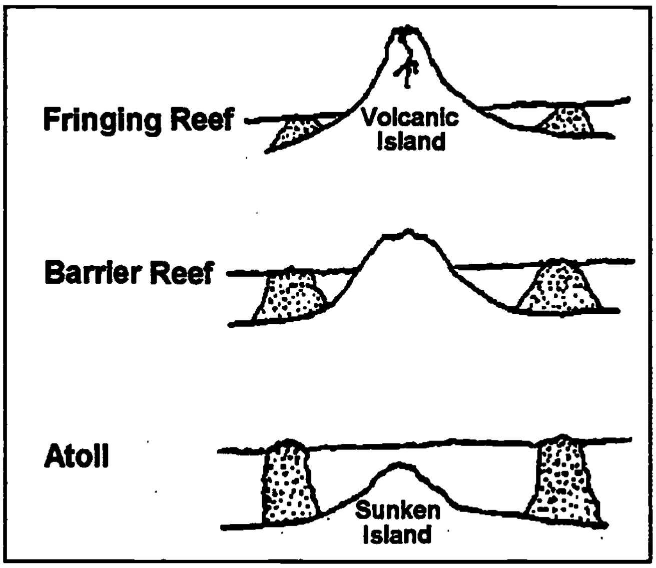
How fast do reefs grow?

Some reef corals are capable of growing 15 centimeters (6 inches) in a year. [Massive corals such as star coral and brain coral grow considerably slower, typically only 1/8 inch to 3/4 inch per year.] As old corals die, new ones usually settle and grow over the dead skeletons. Many generations of settlement, competition, growth and death result in structures like the Great Barrier Reef in Australia, which is hundreds of feet thick and millions of years old.

Where do coral reefs form?

True reef-building corals can only grow where the water is clear, warm and shallow. Average water temperatures typically do not fall below 20 degrees Centigrade (68 degrees Fahrenheit) and it is generally no deeper than 100 meters (325 feet). [Most corals grow in depths of less than 40 meters.] These conditions are met in tropical waters near the equator, on the eastern sides of continents and around oceanic islands.

When a reef forms close to shore it is a ***fringing reef***. As the reef matures, the oldest corals near the shore may die and the reef will become an offshore ***barrier reef*** with a lagoon in between it and the shore. When corals grow around a volcanic island an ***atoll*** results as the island gradually subsides, leaving only a ring of coral visible near the sea surface.



Changes in sea level can also expose pieces of a fringing or barrier reef, turning them into small coral islands like the Florida Keys.

What threatens reefs?

Natural threats

Both hard and soft corals are vulnerable to unusually strong waves (e.g., those formed by a hurricane) as well as dramatic changes in the temperature and saltiness of the water. Predation by fish, snails, worms, crabs, shrimp and starfish, and overgrowth by fleshy algae can also kill corals. Parrotfish, for example, have strong teeth with which they break through the $CaCO_3$ cup to the polyp inside. Corals also compete against each other for light and space. The faster growing corals usually dominate. However, slow growers like brain coral are better at surviving physical disturbances such as storms.

Over thousands of years, corals have evolved ways to defend against the natural threats they face. Extending polyps only at night, using toxic chemicals (fire coral is an example) and producing huge numbers of larvae all help corals survive and prosper. Unfortunately, these adaptations may be of little use when it comes to threats from humans.

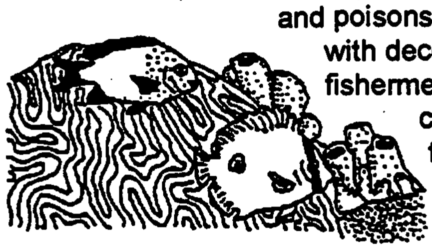
Human activities
We are capable of damaging and destroying reefs in a variety of ways, including pollution, deforestation, fishing and collecting.

Pollution
There are basically two kinds of pollution that damage a reef. One is the introduction of any substance into the water that increases its cloudiness. Zooxanthellae must have absolutely clear water in order to get enough sunlight and still remain embedded in the tissues of the polyp. Sediments stirred up by boaters and swimmers, washed off land by rain or expelled by oil drilling rigs can kill a reef by depriving it of light. (Polyps can also be smothered by blankets of sediment.) The other type of pollution is chemical. Fertilizer runoff and sewage discharge fill the water with nutrients that allow algae to grow faster than the corals, overgrowing and smothering the polyps. In addition, reef organisms are poisoned by heavy metals, pesticides and oil. Even low levels of oil can slow down reproduction by making it difficult for microscopic larvae to swim and settle. Slower reproduction means that reefs cannot repair damage as quickly as usual.

Power plants
Many power and desalination plants draw huge quantities of seawater into their machinery. The filters through which this water passes often become clogged with the bodies of fish that were attracted to the intake pipes. Microscopic plankton that travel through the filter screens are killed by excessive heat inside the pipes. Hot water discharged from plants can be as lethal as any poison to organisms accustomed to the stable temperatures of tropical seas. The location of such plants near coral reefs upsets the normal balance of the reef ecosystem by serving as a huge, indiscriminate predator and a source of constant disturbance.

Deforestation
Extensive logging results in erosion of soil into rivers that carry it out to sea, increasing the cloudiness and nutrient content of water. Another effect of deforestation is the possible rise of global temperatures due to the increase in carbon dioxide from the burning of trees (and fossil fuels). Changes in sea level and water temperature brought on by global warming could affect reefs by making shallow water too warm for polyps. There is evidence that suggests higher than normal temperatures have already affected corals around the world by causing polyps to eject their zooxanthellae. This phenomenon, known as "bleaching" [since the algae within corals gives them color], significantly weakens the ability of reefs to grow, repair themselves and combat disease.

Fishing and Collecting
In many parts of the world reef fishes are a significant source of food. Fishing with a simple hook and line is usually not harmful to coral reefs, but blasting with dynamite, setting traps and using poisons such as cyanide can cause irreparable damage. Besides the obvious physical destruction of the coral, underwater explosions stir up sediment that prevents sunlight from penetrating to the polyps. Traps and poisons often kill far more animals than the fishers can use and fill the area with decomposing bodies which use up dissolved oxygen. Recreational fishermen can also cause damage by running aground on coral, breaking coral with anchors, dumping trash into the water, and taking too many fish to allow populations to maintain their numbers. Some reefs are overwhelmed with divers and snorkelers who stand on and break off coral, collect indiscriminately and stir up sediment with their fins.



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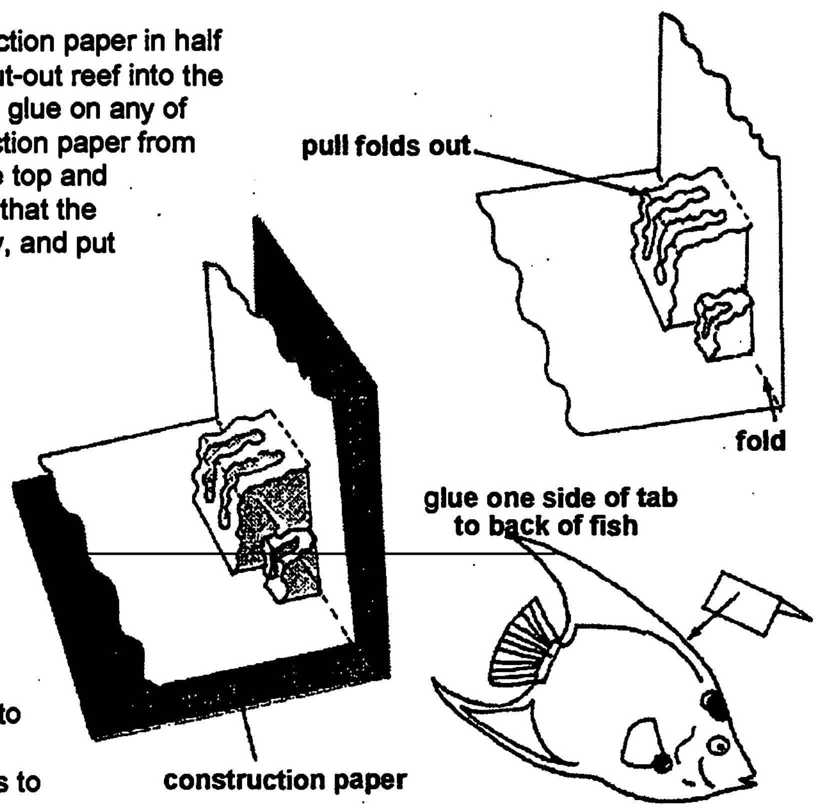
2. A POP-UP CORAL REEF

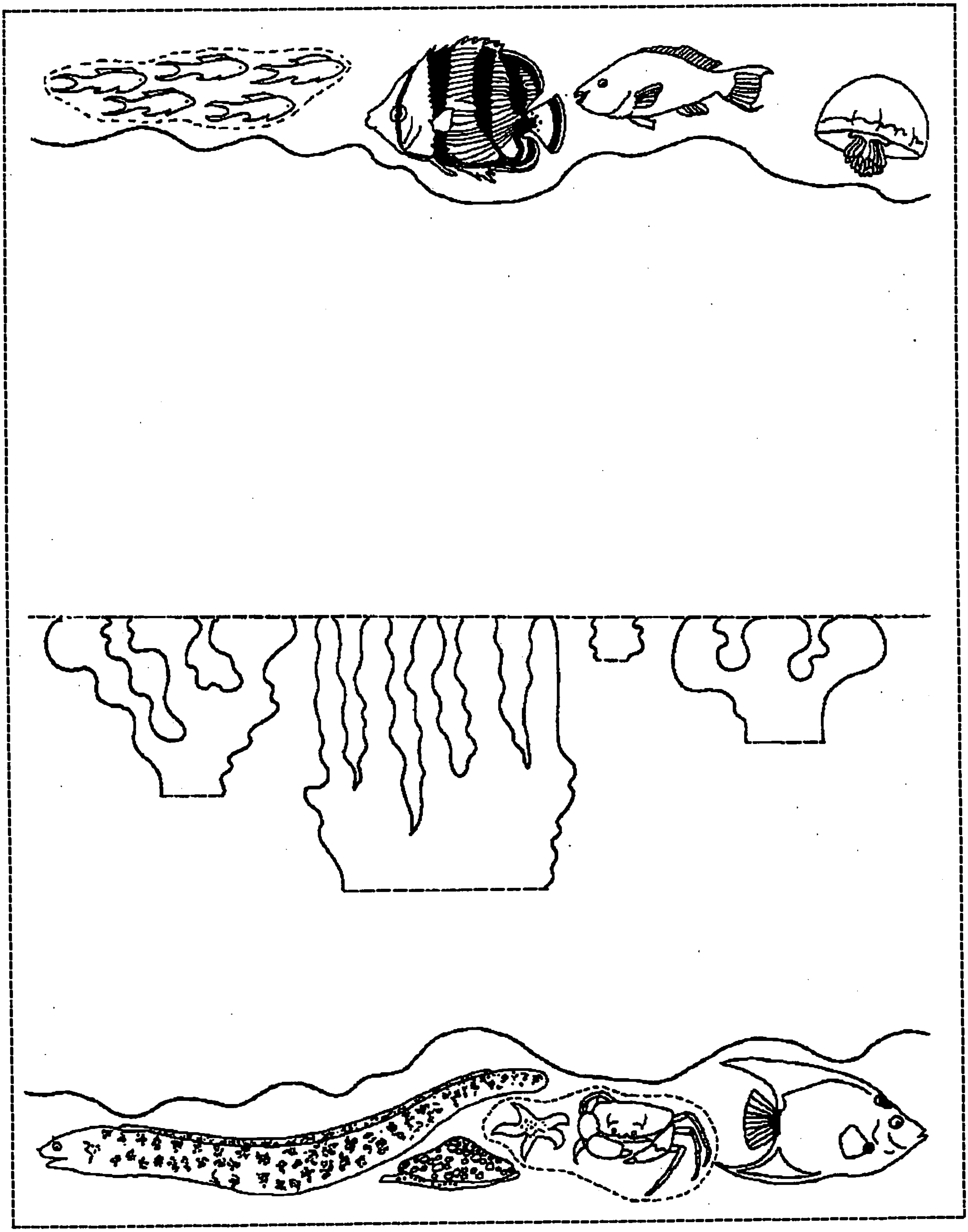
Make a 3-D coral reef. **Ages:** Intermediate and Advanced

Materials: copies of the following page (reef scene), construction paper, scissors, blunt pens or ball-point pens, glue, crayons, markers, or colored pencils, rulers.

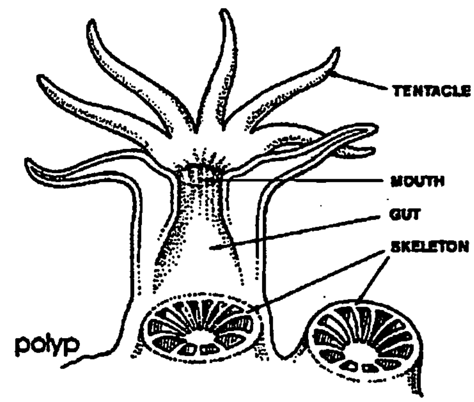
This pop-up reef is easy and fun to make. Here's how to do it:

1. Spread a thin film of glue over the back of the page with the reef scene, and glue it to a sheet of construction paper. (Be sure to cover the *entire sheet* with glue.) Trim away the excess construction paper.
2. Remove the drawings of the reef animals at both ends of the sheet by cutting along the wavy lines. Set these drawings aside to use later.
3. Score all the dashed lines with a blunt pencil or ball-point pen. Press firmly, but be careful not to tear the paper. (You might want to use a ruler to help you keep your lines straight.)
4. With the printed side facing out, fold the page in half along the dashed line. Crease well with the edge of a pencil or ruler.
5. Cut through both layers of the paper along all the *solid* lines. (You will cut some pieces out completely. But be sure that you don't cut along any dashed lines.)
6. Open the page carefully. Gently pull the cut-out features outward, in the opposite direction that they were originally folded in. Crease each construction paper feature along its folded edges. Then carefully close the pop-up again.
7. Fold a different-colored piece of construction paper in half width-wise. Then glue the fold of the cut-out reef into the fold of the construction paper. Don't put glue on any of the cut-out parts. Trim excess construction paper from the sides only, leaving extra paper at the top and bottom. Close the pop-up, making sure that the cut-out parts are folded out the right way, and put under a heavy book to dry.
8. Color the reef animals you set aside earlier and cut them out.
9. Glue the animals onto your pop-up reef. You can glue some of them to the pop-up part and some to the flat background. To make the reef animals stand out from the background, make a tab by folding a small piece of construction paper in half. The folded tab should be smaller than the animal you are gluing it to so it won't show. Glue one side of the tab to the animal and the other side to the reef. You can add pop-up rocks, different types of coral, or other features to your reef.





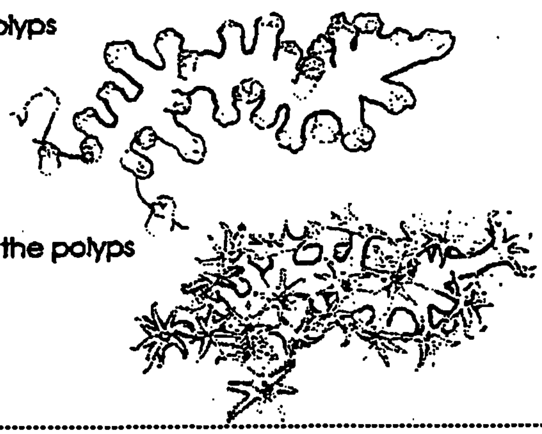
3. WHAT IS A CORAL POLYP?



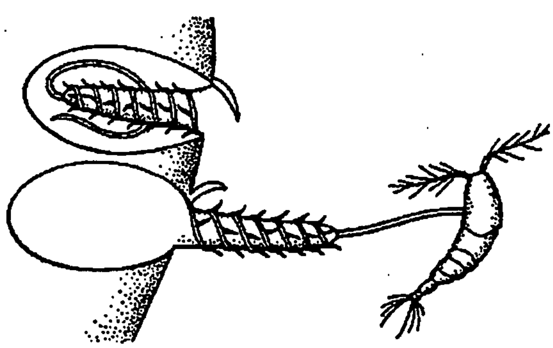
Most corals consist of many small polyps living together in a large group or a colony. A single polyp has a tube-shaped body with a mouth which is surrounded by tentacles.

The polyp of hard corals produces a stony skeleton of calcium carbonate (limestone or chalk) beneath and around its base. Often the skeleton forms a cup-like structure in which the polyp lives.

The **CORAL POLYP** shown at the right is cut away to show the gut and the skeleton beneath the polyp. A skeleton without its polyp is shown at the right.



When feeding, particularly at night, the polyps stretch out their tentacles to gather food. During the day, or when threatened, the polyps withdraw into their protective cups. Part of a coral branch is shown here....



The tentacles have small stinging cells called nematocysts, which can shoot poison spears into small animals drifting by. These animals (called zooplankton) are used as food and are passed to the mouth by the tentacles.

The drawing at the left shows an enlargement of part of a tentacle. Two **stinging cells** are shown. The top cell has not fired its poison spear. The bottom cell has fired its poison spear into a small floating animal.

Only a few corals, such as the fire corals (actually hydroids), have stinging cells which are powerful enough to affect humans.

Besides capturing food drifting in the water currents, coral polyps get food from small plant cells (called zooxanthellae) which live inside their tissue. The plant cells use sunlight and nutrients in the sea water to produce food which is shared with the coral.

The plants gain shelter and the corals gain food from this relationship which is call **symbiosis.** Corals therefore, like plants, require sunlight for photosynthesis and can only live in clear, brightly lit waters.

VOCABULARY WORDS

Symbiosis (pronounced "sim-by-o-sis"): A relationship between two different creatures which live together for the benefit of both. Plant cells (called Zooxanthellae) have a symbiotic relationship with coral polyps.
Zooplankton: Small animals, or the larvae of larger animals, which drift in the sea.

Source: The following activity is contributed by the J.L. Scott Marine Education Center, Biloxi, Mississippi. Used with permission.

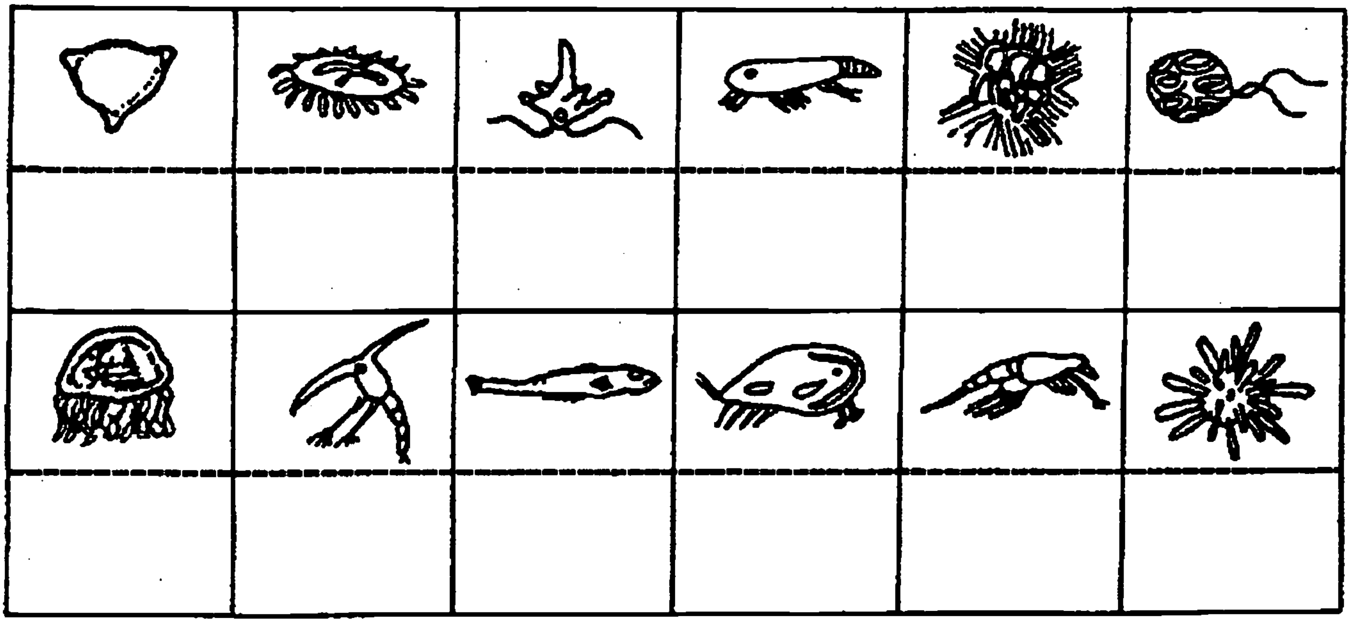
Follow-up Activity: Plankton Roundup

Students will be intrigued to learn that the tentacles of corals bear an arsenal of pistol-like stinging cells. The following game mimics this unusual hunting equipment and provides a magnified glimpse at the zooplankton that are an important part of the diet of many corals.

1) Cut out the squares on the following page and write a point value (between 1 and 5) on the back of each. Fold the squares in half, with planktonic pictures on the outside, and seal each with a small piece of tape. Use short lengths of string or yarn to hang the folded squares from the rim of a paper plate. Tie another piece of string or yarn to the middle of the plate and suspend it in a doorway, with plankton dangling below.

2) Tell students that they will pretend to be coral polyps. Point out that a coral polyp has *many very tiny* stinging cells. Also remind the class that zooplankton are so *small* as to be all but invisible to the naked eye. The students will use blow-up party favors (pictured below) to mimic individual stinging cells being fired at zooplankton. Have the students ("coral polyps") take turns "shooting" zooplankton. If a student succeeds in hitting a zooplankton when he or she inflates a party favor, cut the folded square from the string and hand it to the student. If a student hits more than one square, the turn is forfeited and no zooplankton are collected.

3) After four rounds of "shooting" (or when all plankton are gone), have students unfold the squares they have collected. The student with the most points is the winner.



Cut on solid lines. Fold on dashed lines.

Source: Coral Forest Teacher's Guide. Coral Forest, 400 Montgomery Street, Suite 1040, San Francisco, California 94104 Tel: (415)788-REEF Fax: (415)398-0385 e-mail: coral@igc.apc.org Used with permission.

4. THE EDIBLE CORAL POLYP

Objective: Students will review the parts of a coral polyp by building an edible coral polyp model.

Interdisciplinary Index: Science, Math, Language Arts

Vocabulary: coral, polyp, limestone, coral colony, coral reef, tentacles, endosymbionts

Materials:

white baking chocolate, candiquik mix, or other hard candy coating (½ ounce for each child)
one marshmallow for each student (substitute: section of banana or strawberry)
toothpicks
red licorice (regular or whip): six two-inch strips for each child. If regular licorice is used, cut the pieces into small, thin strips.
blue, red or green sprinkles
heat source (microwave or hot plate) for melting candy coating only
pan for candy coating
paper plates

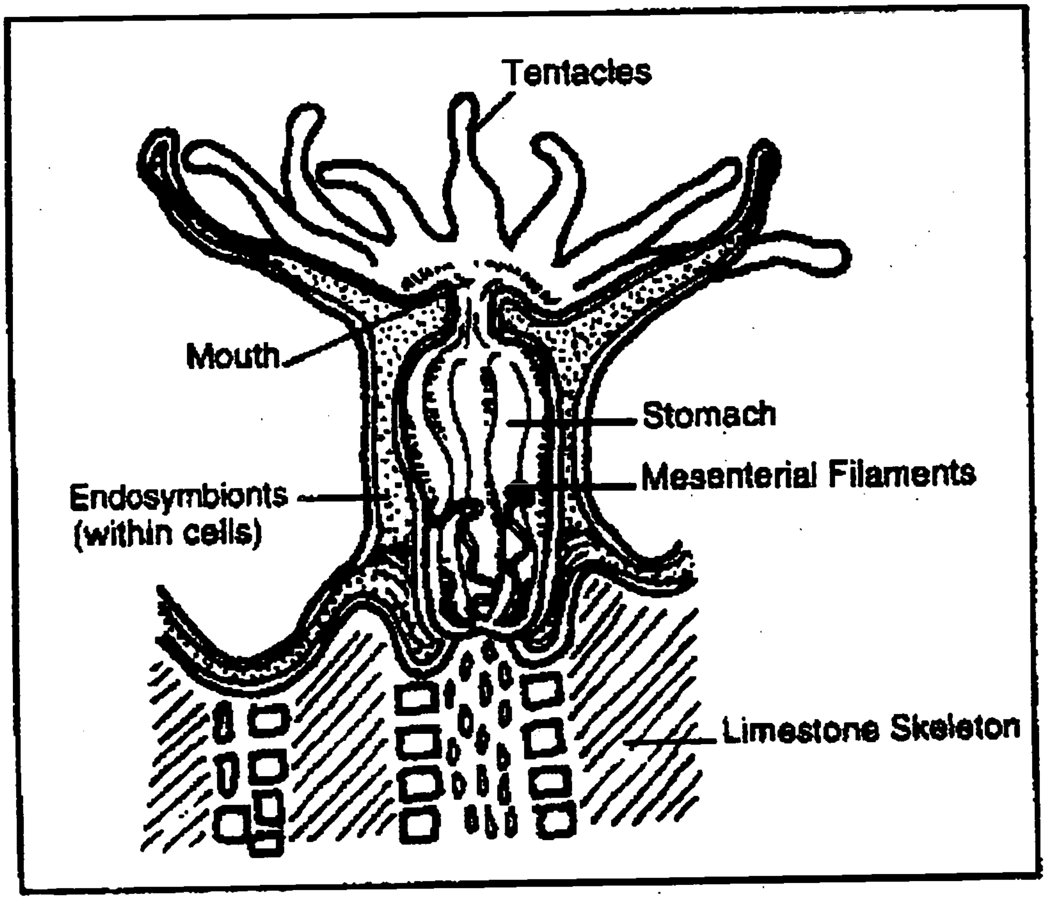
Presentation:

You may want to prepare a model colony to show your students before they make their own.

1. Group the students into pairs.

2. Give each pair of students a paper plate. The plate represents the limestone base to which the coral is attached.

3. Give each student a marshmallow on a toothpick and six strips of licorice. The marshmallow represents the polyp body and The licorice represents the tentacles.



4. Give each pair one ounce of melted candy coating from the heat source in a shallow container (the candy represents the limestone skeleton).

5. Have the students work together. Roll the sides of the marshmallow in the melted candy coating and stand the marshmallows on a paper plate. If the marshmallows are placed close enough together, they will attach to each other and resemble a coral colony.

6. Have the students insert six licorice strips around the top of the marshmallow. Children may want to use their toothpicks to help them poke the holes. [Be careful to remove *all* toothpicks!]

7. Slightly dampen the marshmallow with water and sprinkle it with the sprinkles. The sprinkles represent the endosymbionts. Use only one color per polyp.

8. Discuss the edible polyp model. Explain what the marshmallow, the candy, the licorice, the sprinkles, and the plate represent.

9. Now have the students pretend that they are parrotfish or crown-of-thorns sea stars and eat their polyps. YUM!

Follow-up/Extension:
Students may want to write a story about their polyp or draw a diagram. For a math project, students can count the number of tentacles on their polyp and multiply by the number of students in the class to find the total number of tentacles in the classroom coral colony.

5. EGG CARTON CORAL

Egg cartons can be used to construct models of coral colonies showing many aspects of the coral's natural history - including the structure of coral polyps and the coral colony's colonial life style.

Materials: Egg cartons, paper, tape, scissors, markers (especially green)

To make the model:

Begin by cutting a sheet of paper into three strips horizontally. Each strip will become a coral polyp. Roll each strip into a tube about the diameter of your finger. Tape the bottom to keep the tube from unrolling. Tape the bottom of the tube shut.

To make the tentacles of the polyp, make several cuts from the top of the tube, 3/4 of the way to the bottom of the tube.

Get the tentacles to curl by running each fringe over the blade of a scissor or a metal ruler.

To make the shell of the coral, cut the top and closing flap off an egg carton, leaving just the section with the twelve egg cups. Place this upside down on a table and punch a hole in the bottom of each egg cup with scissors.

Insert one polyp tube in each egg cup, pulling it partway through the hole. Tentacles should be on the top of the egg carton.

Using markers you can add small dots on the polyp to symbolize the zooxanthellae. Although they all have chlorophyll, like other plants, zooxanthellae can have a variety of other pigments giving them different overall colors. It is the zooxanthellae that give reef building corals their color; the lime skeleton is white, and the coral polyp itself is largely colorless.

Using the models:

You can talk about many aspects of coral as you construct the models with students. Some important concepts you can illustrate with the models follow.

The large reef is built by the shells of thousands of individual polyps. Although each polyp is a separate animal, the polyps are linked in a colony. The shape of the egg carton suggests the channels that link neighboring polyps. Polyps in the colony share food.

Corals get food in two ways. Small zooplankton are captured by stinging cells on the tentacles. They are then brought into the polyp where they are digested. You can simulate this with the model. The simple digestive cavity of the polyp is basically a hollow cavity, with one open end (surrounded by the tentacles). Coral also get food from their symbiotic algae, the zooxanthellae, which live in their tissue.

During daylight hours, coral polyps pull back as far as possible into their shells, though, of course, they have no way of closing these shells, and living tissue always covers the coral colony. You can show this by pulling the tube back. During the night the tentacles extend to feed.

Extensions:

The egg carton corals can be arched and taped, and added to a coral reef model activity.

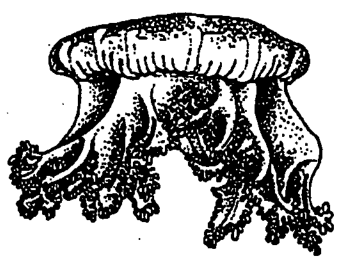
Source: Adapted from Survival Publication: The Great Barrier Reef by Harry Breidahl. © 1987, 1989 Gould League of Victoria, Inc., P.O. Box 446 (67 High Street), Prahran, Victoria 3181, Australia. Used with permission.

6. CORALS AND THEIR COUSINS

Corals belong to a large group of colorful and fascinating animals called the Coelenterata, or Cnidaria. As well as such well-known creatures as sea jellies (jelly fish), sea anemones and corals, the group includes the lesser-known sea fans, sea pens and the fragile fern-like hydroids. Although coelenterates show a wide range of shapes and sizes, they share the same basic body plan—a simple sack-like stomach with a single mouth opening that is surrounded by a ring of stinging tentacles. Apart from the basic structural similarities, one feature common to all coelenterates is the presence of special stinging capsules.

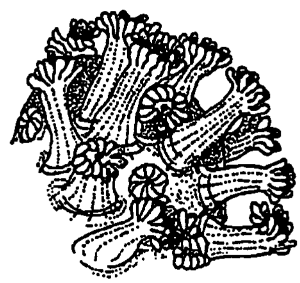
Some Coelenterate Types

Sea anemones live on the sea floor with tentacles pointing up.



Sea jellies float or swim in the sea with tentacles trailing below.

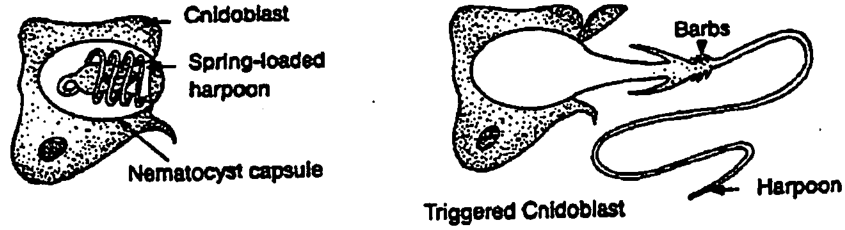
Hydroids are fern-like colonies of tiny polyps.



Corals are similar in appearance to anemones but generally have a hard outer skeleton and live in colonies.

Coelenterate Stings

Despite their colorful flower-like appearance, coral polyps are in fact ravenous feeders. Their simple bodies have a sack-like stomach with a mouth that is surrounded by a ring of tentacles that capture food.



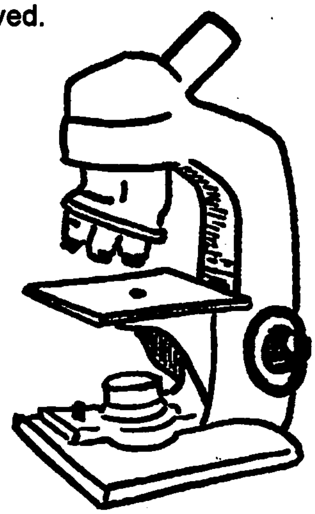
The surface of each tentacle has thousands of special cells called cnidoblasts. Each cnidoblast contains spring-loaded stinging capsules called nematocysts. When a fish, or other small animal, touches a tentacle, thousands of nematocysts are fired like poisonous harpoons to kill and hold the victim. The unfortunate animal is then passed to the mouth and into the stomach where it is digested.

Corals and all their relatives have cnidoblasts in their tentacles—thus the name Cnidaria for the group. Human skin is too thick to feel the stings of most corals. However you should always be careful when exploring a reef. Fire Corals can give a powerful sting. Stinging hydroids, close relative of the fire corals, are also capable of producing a powerful sting. Other cnidarians that are capable of stinging humans are the sea jellies, including the deadly Sea Wasp, some sea anemones and the common Bluebottle.

Source: The following activity is contributed by the J.L. Scott Marine Education Center, Biloxi, Mississippi. Used with permission.

Follow-up Activity: High-Powered Look at Hydra

To enhance students' understanding of the preceding article, the teacher may wish to conduct the following laboratory exercise in which a fresh-water relative of coral is observed.



Materials:

living hydra (*Hydra*, available from a biological supply company)
brine shrimp larvae (*Artemia*, available from a biological supply company) that have been hatched in salt water and resuspended in fresh water

small glass dish
magnifying glass
microscope slides and coverslips
forceps
pond water
lamp
microscope
dissecting probe
medicine dropper
0.5% methylene blue

Procedure:

1. Place healthy specimens of hydra, attached to substrate, in a glass dish with a small volume of pond water. Observe a single hydra with a magnifying glass for several minutes. Note the body bending and the tentacles moving.
2. Many high-school and college biology textbooks will have an illustration of a hydra. If such a diagram is available, look at a living hydra and try to locate all the anatomical structures that are labeled in the diagram.
3. Use a dissecting probe to dislodge a hydra. How long does it take for the hydra to reattach completely?
4. Gently place a drop of brine shrimp larvae suspension near the expanded tentacles of a hydra, taking care not to cause the animal to contract. What happens to the larvae when they come in contact with the tentacles? Describe the hydra's behavioral sequence for feeding .
5. Use the forceps to remove several brine shrimp that appear to have made contact with the hydra's tentacles but have not been ingested. Place these on a microscope slide and flatten under a coverslip. Under the high power lens of a microscope, look for discharged nematocysts. These will appear as small seed-like structures at the ends of threads and are responsible for the paralysis and death of the hydra's prey. If you have trouble seeing the nematocysts, add a drop of 0.5% methylene blue and replace the coverslip.
6. Place some of the tentacles of a lively feeding hydra on a clean microscope slide. Add a drop of 0.5% methylene blue and flatten under a coverslip. Can you see the see the nematocysts firing and taking up the stain? A drop or two of tap water may accelerate the nematocyst discharge. Describe the firing action of the stinging cells that are characteristic of corals and their relatives.

Source: Activity developed by Laura Causey. Reprinted in part from The Monroe County Environmental Story: Teacher Activity Guide.

7. CORAL: WHAT PORTION IS ALIVE?

Outcome/Objective: Students will comprehend the living portion of stony corals are all on the exterior non-attached surface.

Materials: Assorted pieces of stony coral. Dome-shaped pieces (such as brain coral) are best.

Key words: Surface area, displacement, volume.

Instructor notes: Do not collect samples of "live" coral for this activity. The kind of coral sample you choose will determine the difficulty of the task. It is easier with dome corals; difficult with irregular shaped pieces. Select your samples with the math skills of the students in mind.

Procedure: Divide the class into groups. Give samples of coral to each group. Provide them with plastic wrap.

Instruct them to wrap the outer surface of the coral with the plastic wrap so that it fits into all of the convolutions. Use a single thickness of wrap. While they are doing this, you may teach them that the living coral on the surface is no thicker than the plastic wrap they are using.

Have the students unwrap their coral. They then need to measure the total surface area of the plastic that represents the layer of living coral. They can divide the plastic into squares or use other techniques to determine the total surface area of the living colony.

Conclusions: Students should have a better understanding of the fragility and importance of coral, and understand that it lives only on the surface.

Extensions: The students may also investigate the volume of the coral sample by using a displacement method. Submerge the sample in water and measure how far the water rises in a graduated cylinder. They can do this for different shapes of coral. Then have them make a graph of the relationship of surface area to volume for various shapes.

This activity provides a good opportunity to discuss impacts of humans, vessel groundings, anchors and other impacts to coral.

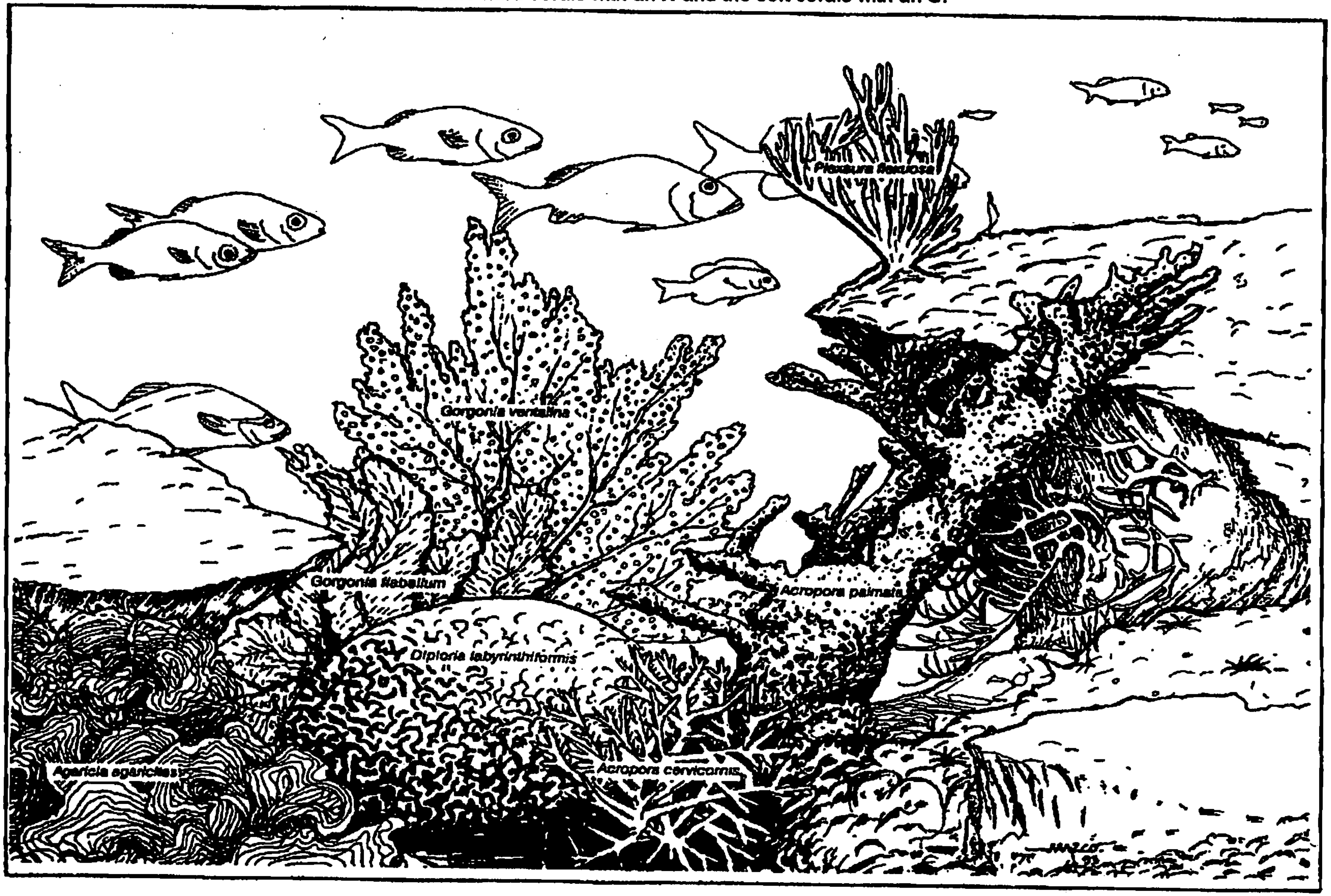
Source: Serie Educacion Ambiental "Sian Ka'an, Introduccion a los Ecosistemas de la Peninsula de Yucatan," Modulo "El Mar y sus Recursos."

8. TWO TYPES OF CORAL

Besides hard corals, there are others called soft corals or gorgonians. These are also commonly known as sea fans, sea feathers or sea whips. They also form polyps, but of a different kind. The skeleton of soft corals is not massive but flexible and it does not have the little holes. Furthermore, it is flattened and branched lke a small tree. In the drawing included in this exercise, you will see examples of hard and soft corals. It is very easy to tell them apart. The hard ones look like stones and the soft ones resemble plants. But they are not; rememeber, they are colonies (in other words, assemblages) of animals.

IDENTIFY THE TYPES OF CORAL

This activity involves identifying coral types. Study the drawing below and mark the hard corals with an H and the soft corals with an S.



Source: Excerpted from Science and Children's Literature by Mary Cerullo, published by Heinemann, Portsmouth, New Hampshire. Used with permission.

9. MEALTIME FOR CORALS

Concept: This activity illustrates the feeding activity of a coral colony. Individual polyps, though connected, feed independently.

Procedure:
Cut X's in several places in an old bedsheet to create holes large enough for children's hands to fit through. Give each child a surgical glove to represent one coral polyp. Discuss how much bigger their polyps are than a real coral polyp (usually about the size of an eraser on the end of a pencil). Explain that coral polyps live symbiotically with plants, single-celled algae called zooxanthellae. Students may choose to put dots of gold or green marker on their gloves to represent the zooxanthellae.

Have students crouch beneath the sheet that is suspended between chairs or desks. You can't fit the whole class under one bedsheet, so you may take turns or use several sheets to do the feeding activity. When they reach up through the holes in the sheet, feed them goldfish crackers or bits of sandwiches, which they will have to pull back through the sheet to eat.

EXTENSION: CORAL WARS

Concept: Corals recognize their own kind. They don't attack their own species even if it's a different colony.

Procedure:
If you use several sheets, each one may represent a different kind of coral. Explain to students that sometimes coral colonies of different species attack each other when they grow too close together, stinging each other with their nematocysts and leaving behind white, scarred dead coral on the other colony.

If neighboring "colonies" abut each other, they may attack each other. However, you need to set strict rules of engagement, such as, only a light tap on your neighbor is permitted, so these coral colonies aren't damaged!

Tell students that different colonies of the *same* species, although they may look different depending on factors such as the amount of sunlight each receives, don't attack each other. Therefore, they need to determine if the neighboring colony is the same species they are.

Since all humans are the same species, why can't they get along??

Source: Developed by Dr. Carol Landis. Math, Science, and Technology Education Section, Ohio State University, Columbus, Ohio. Used with permission.

10. "YOU SCRATCH MY BACK AND I'LL SCRATCH YOURS"

That old saying was used to refer to an informal agreement. It usually meant, "I'll do this for you, if you'll do that for me." Actually, that kind of a relationship exists between many different kinds of living things. Such a "mutualistic" relationship exists where two different organisms benefit from living closely with each other. **Can you think of some examples?**

For example, bees get nectar from flowers. While the bee gets the food it needs, some of the pollen from the flower gets caught on the bristles on the bee's body. The pollen is carried to the next flower the bee visits and may be transferred. This can pollinate the flower. Another example, from the ocean, can be seen by watching a fish called a goby (go'-bee). Gobies are small fish that set up "cleaning stations" where they pick particles and small parasitic living things out of the mouths and gills of larger fish (like groupers). The goby stays by a certain place—its "station." The grouper swims to the cleaning station and stops there, holding its mouth open. The grouper does not close its mouth or try to eat the goby. Both organisms benefit; the goby gets a "free meal" without having to find food, and the grouper gets rid of some pesky *parasites.*

Background Information

Some corals and a certain group of algae have a mutualistic relationship as well. Scientists don't understand all of the factors that are important in this relationship. However, it is well established that certain kinds of brownish algae called "zooxanthellae" (zo'-uh-zan-thell'-ee) can live inside the body of some kinds of corals. The algae live in the lining of the "gut" of each of the *coral polyps* (paul'ips).

During the daytime, the algae carry on *photosynthesis* , just like plants, to produce their food and provide energy and materials for their other cell processes. The algae use carbon dioxide and give off oxygen during photosynthesis. While in the polyp, the algae get a protected place to live, a constant source of carbon dioxide, ammonia, and other substances for photosynthesis. Meanwhile, the polyp uses the oxygen given off by the algae and the sugars produced through photosynthesis. This process is called cell *respiration*. **What is one exchange that occurs in this mutualistic relationship?**

The algae provide oxygen to the coral polyps, which give off carbon dioxide used by the algae. Likewise, polyps use the sugars produced by the algae as food and give off nitrogen compounds that are used by the algae.

Materials

20 waxed paper sandwich bags, or translucent plastic cups
wrapped carmel candies, or butterscotch lifesavers
a yellow circle made of posterboard labeled " Sun"
student chairs
a blanket
a ball of yarn, or a roll of string

Role Play – Round 1: PHOTOSYNTHESIS

Set several chairs (10-20) close to each other and all facing the same direction. One student should sit in each chair. Ask the students to move their chairs close together. Each student will hold a bag/cup with about a half dozen yellowish-brown candies in it. Each bag/cup now represents a coral polyp with algae in it, and the whole group of students represents a colony of coral. The set of chairs represents the stony structure which we often call "coral" which is the basis of the larger structure known as a "reef."

Select a student to be the "Sun" and give him/her the yellow circle of posterboard to carry. Have this student walk around the set of chairs, making a complete circle. Because the Earth spins, we see the Sun in the daytime, but not at night. As the person representing the Sun moves in front of the chairs and becomes visible to the students seated in them, the seated students should shake their "polyp" bags/cups with the "algae" in them to represent the chemical activity of photosynthesis. Since photosynthesis requires sunlight, the shaking should cease when the Sun goes behind the chairs. At this time (i.e., night), the students should wave their arms ("tentacles") above their heads, as if they are gathering food particles from the "water" and placing them into their mouths.

Note: The teacher should point out that the notion that the Sun moves across the sky is an historic misrepresentation of the astronomical phenomenon of day and night. To better represent what really happens, the student representing the Sun should stand in one place while the set of chairs revolves and spins around him/her. This is obviously impractical! A teacher-demonstration using a "lazy Susan" and a flashlight may be useful before the Role Play.

Role Play -- Round 2: EFFECTS OF EXTREME TEMPERATURES
Have the students remain in the chairs, as in Round 1, but this time ask a student to stand by the chalkboard and write a different number (water temperature) on the board at 15 second intervals. Have another student assist by timing and keeping track of which temperature is next. Begin with 26° C and increase the temperature by one degree every 15 seconds until the temperature is 32° C. When the temperature reaches 30°, have half of the students empty out most of their "algae" candies and just move their bags/cups once as the Sun passes in front of them. ***How do the "corals" look now?***

They are less colorful and the algae within them are less active.

Explain that the loss of algae is often referred to as "coral bleaching" since the corals look lighter than normal in color. The polyps are still alive, but they do not benefit from the interactions with the algae at this time. If the polyps were to lose all of the algae, their tissue would be completely transparent and would look white because of the background color of their stony cup. (If photographs of bleached coral are available, show these to the class.) Bleaching also occurs at times when the water temperature is unusually low, when the oxygen level is too high, when the water becomes too salty, when too many particles are floating in the water making it less clear, when the amount of different wavelengths of light changes, or when corals become diseased. Scientists are still learning about the combinations of factors that contribute to coral bleaching. ***What might cause the water to be less clear?***

This can occur when sand is stirred up from the bottom, or because of silt and mud washing off the land into the ocean.

Now have the student at the chalkboard successively decrease the temperature by one degree every 15 seconds until it reaches 26° again. As the temperature goes under 30° C, the "bleached" corals can add "algae" to their "polyps" and, when the Sun shines on them, shake their bags/cups as before.

Explain that the algae remaining in the polyps can reproduce and restore themselves to their normal numbers inside the coral polyps once conditions become favorable again. This can occur within days of the bleaching event. Scientists have learned that corals often recover from bleaching events that last several weeks, or longer. However, the longer the corals remain bleached, the less likely they are to recover. Prolonged periods of bleaching, without recovery, will ultimately lead to the death of polyps.

Have the group do another round where the temperature stays high and the polyps do not recover all their algae, and therefore die. Use string or yarn to rope off and cover the surface of the chairs where the coral died, representing filamentous algae that cover the surface of the coral skeletons in the absence of living polyps.

Role Play -- Round 3: EFFECTS OF LACK OF SUNLIGHT
This time, block the light from one section of the reef. Place a movable chalkboard or a blanket between the path of the Sun and the "reef" to prevent sunlight from reaching the algae. ***Can you predict what might happen to the reef?***

The algae do not receive any sunlight, so they cannot carry out photosynthesis. (Algae, like plants, need adequate sunlight to thrive.) The coral polyps do not receive food and oxygen from the algae and also lose their ability to gather food.

What are some things that might block the light from the algae?

A coating of sand and silt covering the corals blocks the sunlight. Also, garbage bags, clothing and other things that are lost or tossed overboard from ships can get tangled and caught on the reef.

Remove the object shading the coral. ***How might the corals respond to increased sunlight?***

The corals may recover if the algae are able to sufficiently reproduce.

Decide as a group whether or not the affected coral polyps will recover. Consider how long the sunlight was blocked, and how long the polyps showed the effects of bleaching. Enact re-exposure to sunlight.

Explain to students that the effect of severe shading on coral varies, depending on whether sunlight is blocked due to suspended sediments in the water, or whether an object (marine debris) rests on the surface of the coral. In the latter case, the algae cannot photosynthesize productively, moreover the polyps cannot feed by gathering particles from the water. ***What will undoubtedly happen to polyps that are shaded and also unable to feed from the water?***

They will die.

Summary
The close association of algae and coral polyps is not completely understood. Scientists have known for a long time that algae live inside the coral polyps, and that they carry on photosynthesis and respiration in a mutualistic relationship. More studies will help us to better understand the processes and the interactions between these different organisms. Coral reefs provide nutrition and a place to live for many kinds of organisms. Some factors that cause stress for the organisms of the reef include: increased water temperature which can make the water more salty by evaporation, increased silt and other things that cover the reef's surface, and changes in the amount and kinds of energy that are received from the Sun. Because coral reefs are important parts of the marine ecosystem, and recent changes that can be seen are hard to explain, scientists will continue to study the organisms and conditions that are associated with coral reef systems. We are conscious about the impact of a variety of human activities on the complex system of living things, in the oceans and elsewhere.

Review
1. What kind of relationship exists between algae and coral polyps in reefs?
2. What does each of the organisms gain from this relationship?
3. List some factors that affect the ability of the algae to survive.
4. Explain how corals feed.
5. What are some examples of human actions that interfere with the normal processes of coral reef communities?
6. What are some ways that we can reduce the stresses on the reefs?
7. What are some factors that we cannot control?

Glossary

Calcification: The hardening of tissue from the addition of calcium carbonate and other calcium-based compounds (examples: formation of coral reefs and bones of humans and other mammals).
Coral polyp: A single coral animal with a cylindrical body and tentacles. Many polyps form a colony. Over many years, a large colony can produce a structure called a reef.
Organism: Any living thing (examples: fish, butterfly, horse, or human).
Parasite: An organism that lives on or in another one and damages or weakens the host (examples: tapeworms, fleas, tooth decay bacteria, etc.).
Photosynthesis: A chemical reaction by which plants and algae use energy from sunlight to produce sugar. This reaction uses carbon dioxide and gives off oxygen.
Respiration: The process of using oxygen and giving off carbon dioxide, as part of the chemical reactions in cells.

Source: Klemm, E.B., S.A. Reed, F.M. Pottenger, C.Porter, T.W. Speitel. 1995. **HMSS The Living Ocean.** Honolulu, HI: Curriculum Research & Development Group, University of Hawaii. pp.179-83. Adapted and reformatted from the original. Used with permission.

11*. A CLOSER LOOK: IDENTIFYING CORAL SPECIES

To a person unfamiliar with corals, most corals look alike. But the details of their skeletal structure distinguish one type from another. In this activity you will learn how to identify different corals.

A distinguishing feature of coral is its calyx (the plural is *calyces*), or cup. The diameter of each calyx is one of the first features to note when examining a coral skeleton. Fig. 1 shows living coral polyps and empty calyces with the coral tissue removed. The partitions radiating inward are called septa (Latin *septum* = fence). In some solitary corals the calyx has side walls; in others it does not. See Fig. 1.

In colonial corals the calyces may be separated, leaving gaps, or not separated and touching. In some, parts of their side walls are missing. See Fig. 2. The edges of the calyx may be even with the coral surface or raised above it. In some species the septa may extend outside the calyx and join with the septa of nearby calyces. See Fig. 3. The septa may be solid, porous, or reduced in size. See Fig. 4.

ACTIVITY
Examine five coral specimens and record their features.

Materials:
5 different reef-building coral skeletons
dissecting microscope or hand lens
copy of Table 1 (worksheet).
centimeter ruler
coral key references (optional)

Procedure:
1. Place each sample on the dissecting microscope stage. Adjust the lighting to show contrasts. Because coral skeletons are white, they may reflect light and be difficult to see. Try to produce shadows.
2. Describe the features of the coral cups in Table 1. Refer to Figs. 2 through 4 as needed.
3. If a coral key is available, identify the corals by their scientific names.

Questions:
1. How do the cup features of the colonial coral specimens differ? Which differed most?
   a. Do different specimens have distinctive cup features? Describe or draw them.
   b. If your samples came from beach gravel, how might you positively identify the coral type? Explain.
2. Which coral cup parts are lacking in a solitary coral like *Fungia?* See Fig. 1.
3. How does a colonial coral seem to grow? Explain by making sketches.
4. Which of the species you observed would probably break during a storm? What skeletal features make one coral more fragile than another?
5. Define the following terms :(a) polyp, (b) colonial, (c) elevated cup, (d) septa
6. Some coral polyps are as small as the little "o" in words in this text. How can these small animals create coral heads? Massive coral reefs?

* *Answers in Section VIII.*

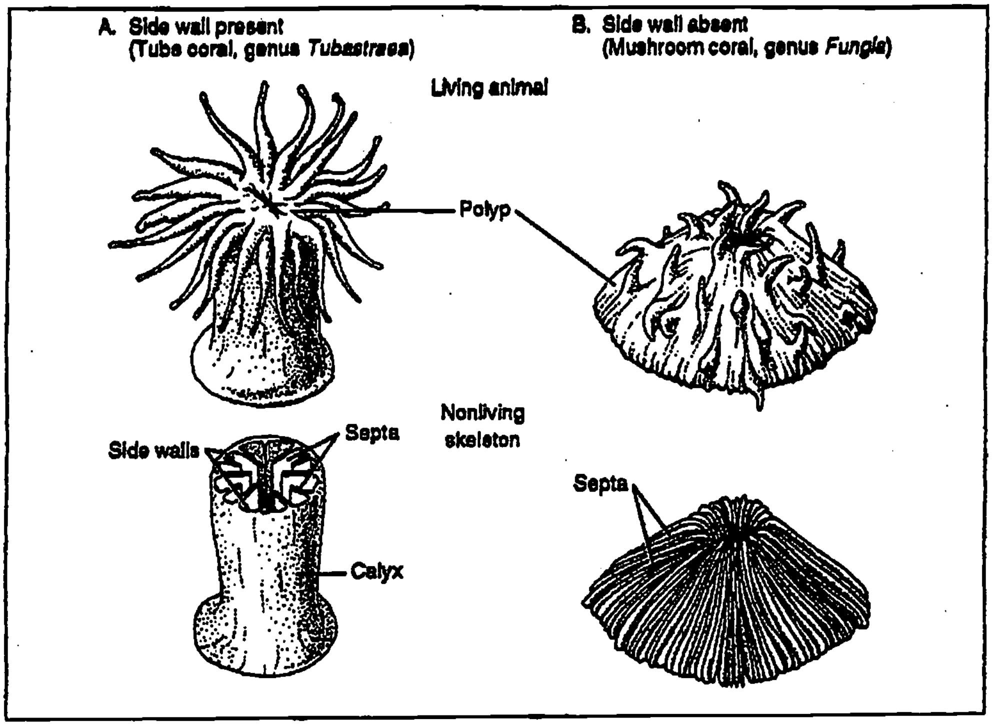
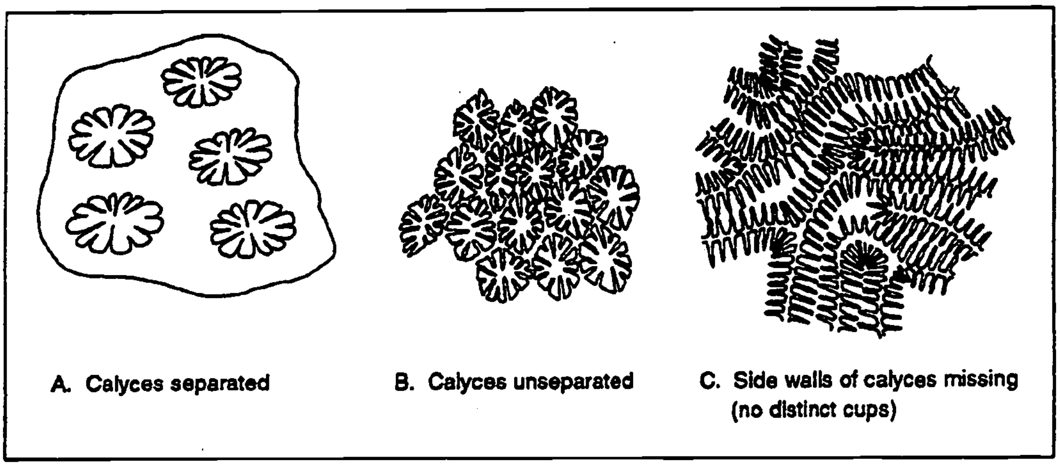


Figure 1: Solitary coral calyx

Figure 2: Arrangement of calyces (cups) in some colonial corals.



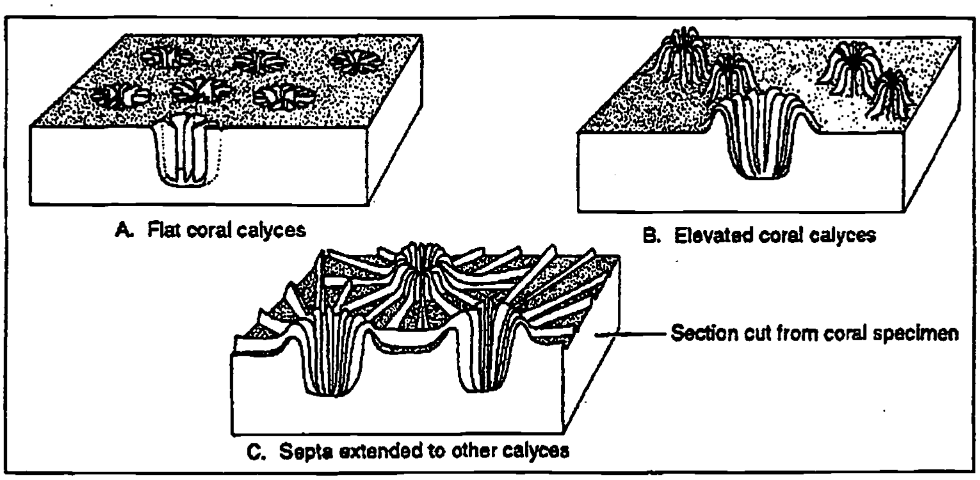


Figure 3: Arrangement of septa in some colonial corals.

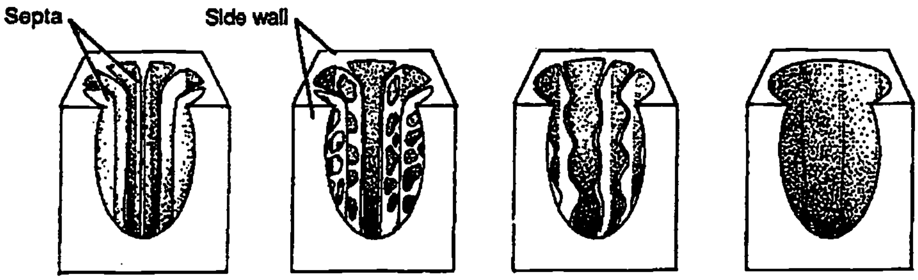


Figure 4: Septa variations in colonial corals (shown with part of side walls removed)

Table 1: Skeletal features of five corals.

Description and measurements	Drawing of coral
Calyx description Calyx diameter___mm Gaps between calyces? yes___no___ Calyx elevated? yes___no___ Septa description Number of septa per calyx___ Entire___Porous___Reduced___ Join other calyces? yes___no___	
Calyx description Calyx diameter___mm Gaps between calyces? yes___no___ Calyx elevated? yes___no___ Septa description Number of septa per calyx___ Entire___Porous___Reduced___ Join other calyces? yes___no___	
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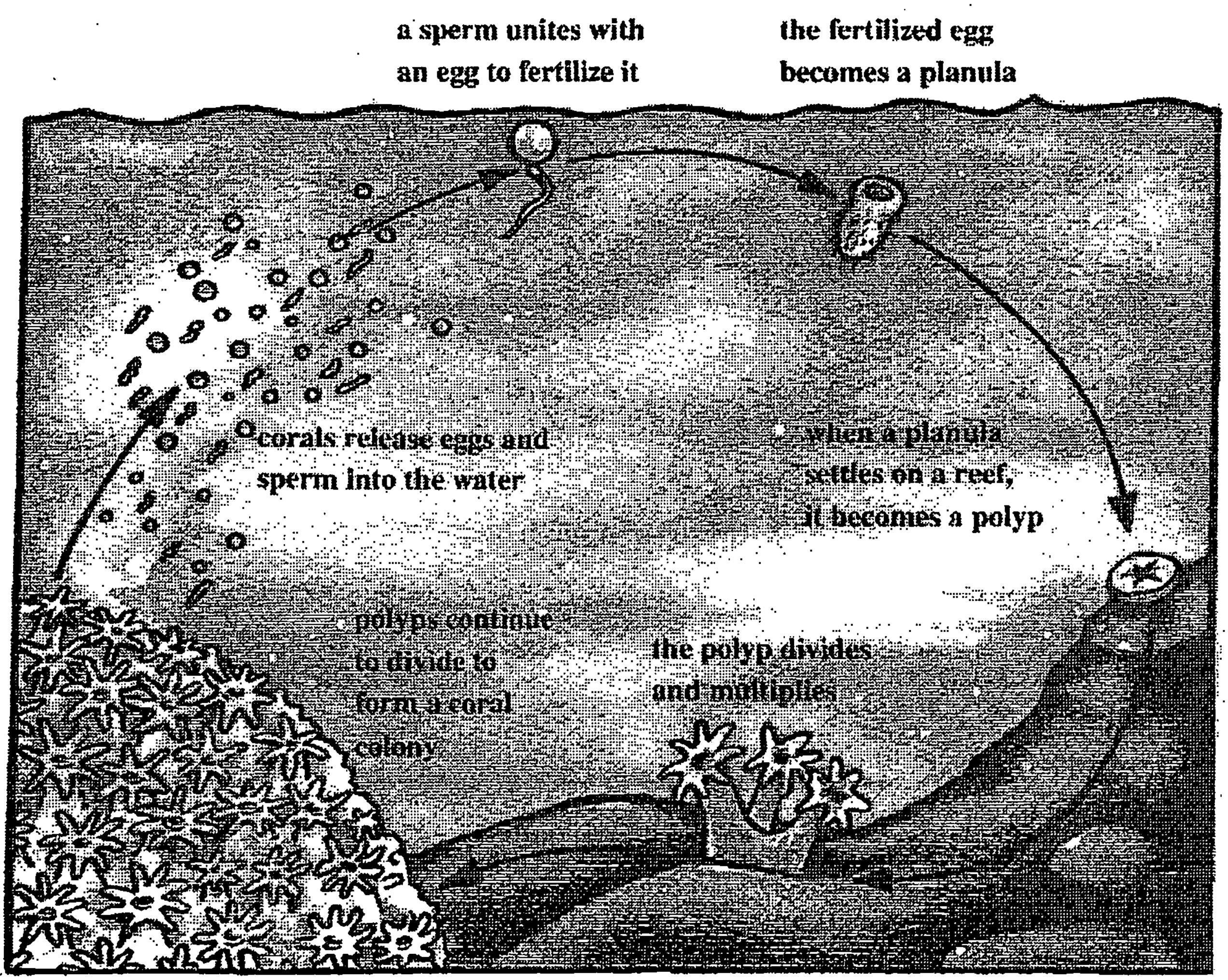
Calyx description Calyx diameter___mm Gaps between calyces? yes___no___ Calyx elevated? yes___no___ Septa description Number of septa per calyx___ Entire___Porous___Reduced___ Join other calyces? yes___no___	BEST COPY AVAILABLE

12. CORAL REPRODUCTION

Corals reproduce by releasing their eggs and sperm into the water. This is called spawning. Most corals spawn at exactly the same time. During a mass spawning, the water is filled with brightly colored bundles of eggs and sperm. The sperm and egg cells join to form larvae called **planulae**. The planulae drift in the ocean as plankton for up to thirty days. When a planula finally settles, it turns into a single coral polyp. This polyp divides to make two polyps, and each new polyp continues to divide, eventually forming a coral colony.

Corals spawn only once a year. It is not known why corals spawn at the same time, but some ecologists think that the answer might be related to the fact that spawning always occurs a night or two after the full moon.

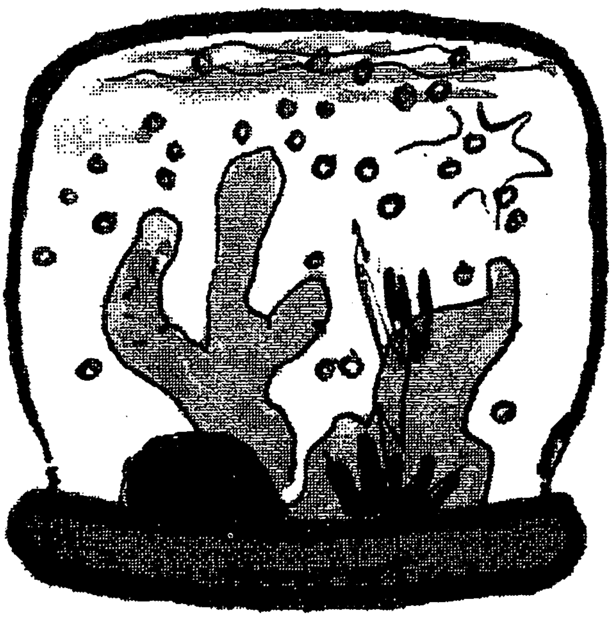
On different reefs, coral spawning happens at different times of the year. On the Great Barrier Reef, corals spawn in late spring or early summer, often in November. On Ningaloo Reef in Western Australia, the mass spawning happens in autumn, in March or April.



Source: The following activities are contributed by the J.L. Scott Marine Education Center and Aquarium, Biloxi, Mississippi. Used with permission.

Follow-up Activities: Clay, Comics, and Other Crafts

1. Present an overview of coral reproduction to the class. You may wish to use the figure on the preceding page to prepare a blackboard diagram or to make an overhead transparency.
2. Give students lumps of modeling clay and instruct them to mold (i) a single coral polyp, (ii) a polyp as it begins to divide, with a "bud" appearing, and (iii) two polyps that have resulted from division.
3. Ask students to draw comic strips that illustrate, in sequence, the process of coral reproduction.
4. The massed coral spawning event that occurs annually on the Great Barrier Reef has been described as an "upside down snowstorm," with flurries of egg and sperm packets released into the sea simultaneously. The following craft depicts the magical beauty of coral spawning.



"Upside down snowstorm" jar

Provide each student with a clean empty baby-food jar. Ask students to create miniature coral reefs using styrofoam, waxed paper, foil, colorful plastic tape, toothpicks, pipe cleaners, beads, and other supplies. The corals may be colored with waterproof paint and permanent markers. Have students anchor their corals onto their jar lids using modeling clay (or a glue gun, used with close teacher supervision). Fill the babyfood jars with water tinted with blue food coloring. Add a small amount of silver glitter to each jar and then twist the lid tightly on the jar, sealing the outside rim with rubber cement. Have students turn their jars over (so the reef will be at the bottom) and gently shake them to simulate coral spawning.

Explain to students that coral spawning is a *rare* event. Furthermore, unlike snow flakes (and glitter) which settle to the ground, coral egg and sperm packets *rise* toward the surface of the ocean.

Source: Corals and Coral Reefs: 4–8 Teacher's Guide. A Sea World Education Department Publication. Used with permission.

13. A CHANCE OF SUCCESS

Objective: Students will learn about the physical factors that limit where coral reefs develop.

Materials: 1 die, copy of score card

Action:

1. Lead students in a discussion about what things might limit where coral reefs develop. Ask them to name some of the conditions they know reef-building corals need to survive. *(Right water temperature; clear, shallow water; strong wave action to bring in nutrients)* Write these on the board. Explain to students that a site must meet all these criteria for a reef to successfully establish and thrive.
2. Show students the die and explain that they'll be playing a game in which they'll all be coral planulae in search of a settling site. Each student will roll the die three times, once for each survival factor.
3. Explain that to survive, they must roll one of these numbers when casting the die for that condition:

   Temperature = 2,3,4,5 (1 too cold, 6 too hot)
   Substrate/depth = 1,2,3,4 (5,6 too deep)
   Wave action = 4,5,6 (1,2,3 too weak to bring in nutrients)

4. Place the score sheet on an overhead projector, or have a student keep score on the board.
5. Invite students up one at a time to roll the die. Be sure to state what factor they're rolling for each time. If they get a good number for all three rolls, they qualify for the next round.
6. Gather the qualifying "planulas" [planulae] in front of the class for the final round. Ask each student the following questions:

   - What are coral temperature requirements?
   - What are depth requirements?
   - Why do reef-building corals need strong wave action?

   Those students that can answer the questions are the winning polyps.
7. Remind your students that corals release thousands of eggs and sperm, some of which join and develop into planulae. Do they think all the planulae survive? Why not? Explain that the reproductive process leans towards high numbers to allow for high mortality. Many planulae are eaten by marine animals before they settle and attach to the bottom. By producing hundreds of thousands of eggs at a time, a coral polyp increases the chance that one of its offspring will mature and reproduce, the measure of a species' survival success.

Deeper Depth: Calculate the percentage of planulae that survive each round.

NAME	WATER TEMPERATURE	WATER DEPTH	WAVE ACTION

Source: Corals and Coral Reefs 4 - 8 Teacher's Guide. A Sea World Education Department Publication. Used with permission.

14. GROWING CORAL

Objective:
Students will observe the growth of crystals that develop in a way similar to how coral polyps create their calcium carbonate cups.

Materials:
plastic bowls (have students bring from home)
pieces of charcoal, porous brick, tile, cement, or sponge
water
table salt (iodized or plain)
liquid bluing (found with bleaches at grocery stores)
food coloring
measuring tablespoons
masking tape
pens
ammonia (to be handled by an adult)
sugar
clear glass

Action:
1. Ask students to label their bowl with pieces of masking tape with their names on them. Have them put some pieces of charcoal, brick tile, sponge, or cement into their bowls.
2. Students should pour two tablespoons of water, two tablespoons of salt, and two tablespoons of liquid bluing over the base material (charcoal, etc.). Set bowls on a table or counter top. Formations need free air circulation to develop.
3. The next day have them add two more tablespoons of salt.
4. On the third day, pour in the bottom of the bowl (not directly on the base material) two tablespoons each of salt, water, and bluing; then add a few drops of food coloring to each piece of base material.
5. A crystal formation should appear by the third day. If not, it may be necessary to add two tablespoons of household ammonia to aid the growth. **(Only teachers or other adults should handle and add the ammonia).** To keep your formation growing, just add more bluing, salt, and water from time to time.
6. Ask students to describe what they think happened between the bluing, water, and dissolved salt to create the formation. Explain to students that when the three materials combined, a chemical reaction took place and formed a new substance. Tell them that coral polyps, with the help of zooxanthellae, remove dissolved calcium carbonate from seawater and use it to create the stony cup that protects their soft bodies.
7. Demonstrate the concept of a dissolved substance by pouring some sugar into a glass of water. Ask the students if they can see the sugar. Stir the water vigorously for about five seconds. Ask the students if they can see any of the sugar in the water. Stir the solution again, this time for about one minute, or until all the sugar has dissolved. Ask the students if there is still any sugar in the water. Stress that although they can't see the sugar, it's still there, in dissolved form.

Source: Reprinted from Life on a Coral Reef: Marine Science Curriculum, Grades 7 - 9. The Seattle Aquarium . Used with permission.

15. MAKING CORAL SKELETONS

Objectives:
1. The student will understand that the raw materials of coral skeletons are contained within sea water.
2. The student will realize that the coral polyp has the ability to extract these raw materials from sea water, and to produce a solid substance.

Materials:

One cup white vinegar in glass container.
One stick white blackboard chalk, broken into several pieces.
One cup tap water in glass container.
Six teaspoons baking soda.
A two-cup capacity glass container.

Teacher Preparation:
1. In nature, lime (composed of calcium and oxygen) is dissolved in sea water. A coral polyp extracts this lime from the surrounding water, combines it with carbon and oxygen within its cells, and produces aragonite, a form of calcium carbonate ($CaC0_3$). Thus, the clear sea water provides substance for the construction of solid white material by the coral.
2. In this demonstration, we suggest how corals are able to produce calcium carbonate from clear sea water. Although we cannot duplicate, in the classroom, the exact process by which corals extract lime from sea water, we can show that the materials for making coral skeletons exist in the clear sea water.

Procedure:
1. Mix one cup white vinegar with one stick of white blackboard chalk, broken into small pieces. Let stand for two hours. Pour off and save the clear liquid. The remaining chalk can be discarded.
2. In another container, mix one cup tap water with six teaspoons baking soda. Stir occasionally for 15 minutes. Let settle. Pour off and save the clear liquid. Any remaining baking soda can be discarded.
3. Combine the two clear liquids in a glass container. A white precipitate will form and settle. This mixing process represents a coral polyp extracting calcium from the sea water, combining it with carbon dioxide, and producing aragonite, the hard white material of coral skeletons.
4. If the mixture does not become cloudy, add more baking soda solution until a precipitate forms.
5. Let the mixture stand until the white precipitate settles. This white material represents the white coral skeleton produced by the coral polyp.
6. If desired, the liquid can be poured off, and the white precipitate dried to show its solid nature. This dried material can be further tested. Calcium carbonate, the substance of coral skeletons, reacts with week acid (such as vinegar). After explaining this to the students, add a small amount of white vinegar to the precipitate, and observe the fizzing reaction. This reaction demonstrates that the material is indeed calcium carbonate.
7. Discuss the chemistry of these reactions.

16. HOW ARE CORAL REEFS FORMED?

The following activity explores how the barrier reef was formed through lithification involving coral polyps and encrusting calcareous algae (coralline algae).

Objective:
Students will demonstrate how a limestone exoskeleton is produced from carbon dioxide and dissolved calcium.

Materials:

Lime water (Dissolve calcium hydroxide in water and filter until clear.)
Small cup (empty)
Small cup, filled to a depth of 3 cm (about 1 in) with lime water
Two drinking straws
Small (No.2) coffee filter
Small cup filled with water

To demonstrate the formation of calcium carbonate, introduce to the students the idea of solids (such as sugar or salt) that dissolve readily in water, and solids (shell, bone, or coral) that do not readily dissolve in water. Ask students to discuss where sugar, salt, shell, bone and coral come from? Are they made up of other solids? Ask students what the coral polyp cups are made of. (Calcium carbonate.) Suggest to them that the coral polyp makes calcium carbonate with the help of zooxanthellae. They combine different chemicals together. Ask for a student volunteer to tell the class the color of the liquid in the cup. Have the student blow into the cup filled with lime water. Remind the student not to swallow or blow too hard. Tell the student to stop blowing as soon as a white precipitate is seen. Filter this precipitate out, using the small coffee filter placed over the empty cup. Repeat the same exercise, using a cup of water instead of the lime water. No precipitate should form. Ask students why the second cup did not produce a precipitate. (The chemicals in the first and second cups are different.) Explain that both cups were supplied with carbon dioxide when the student exhaled. In the first cup, the carbon dioxide combined with a chemical to produce calcium carbonate. What do you think the chemical was? (Calcium, hence calcium carbonate.) In corals, calcium from the water and carbon dioxide from cell respiration are brought into the polyp's gut, where the zooxanthellae assist in combining and moving the chemicals to the area where calcification occurs and the protective cup is formed.

For older students

The chemical reaction in forming calcium carbonate is:

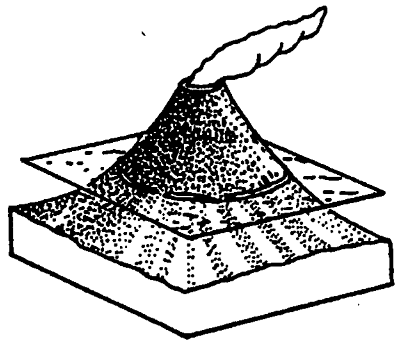
$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$

Source: King, Dr. Michael and illustrated by S. Belew and M.King. __Coral Reefs in the South Pacific Handbook__.

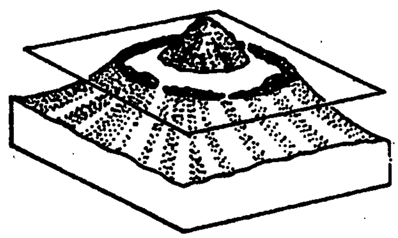
17. TYPES OF REEFS

There are three basic types of coral reefs - fringing reefs, barrier reefs, and atolls.

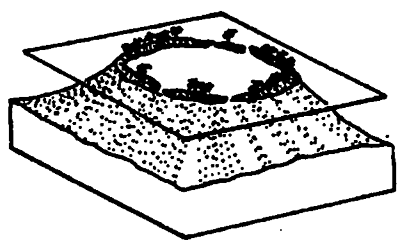
FRINGING REEFS
grow at the edges of continents and islands. The reef front contains actively growing corals, and pieces of broken coral are washed up as rubble on the reef flat.



BARRIER REEFS
are separated from the shore line by a lagoon which is often deep. Corals grow in the calm waters of the lagoon as well as on the reef front.



ATOLLS
are coral reefs growing in the shape of a circle. The reef, which often has small islets on it, surrounds a lagoon.



One explanation of how an atoll forms involves the gradual sinking of an oceanic island over thousands of years. The reef front of the fringing reef around the original island actively grows as the island slowly sinks. Eventually a lagoon forms between the sinking island and the growing coral which becomes a barrier reef. When the island sinks beneath the sea, the barrier reef becomes a circular atoll.

Source: Activity contributed by Jeannie Flint. J.L. Scott Marine Education Center and Aquarium, Biloxi, Mississippi. Used with permission.

Follow-up Activity: Cooking Up Coral Reefs

These edible models of the different kinds of reefs are a fun way to reinforce teaching and involve children in an explanation they will remember.

1) Fringing Reef

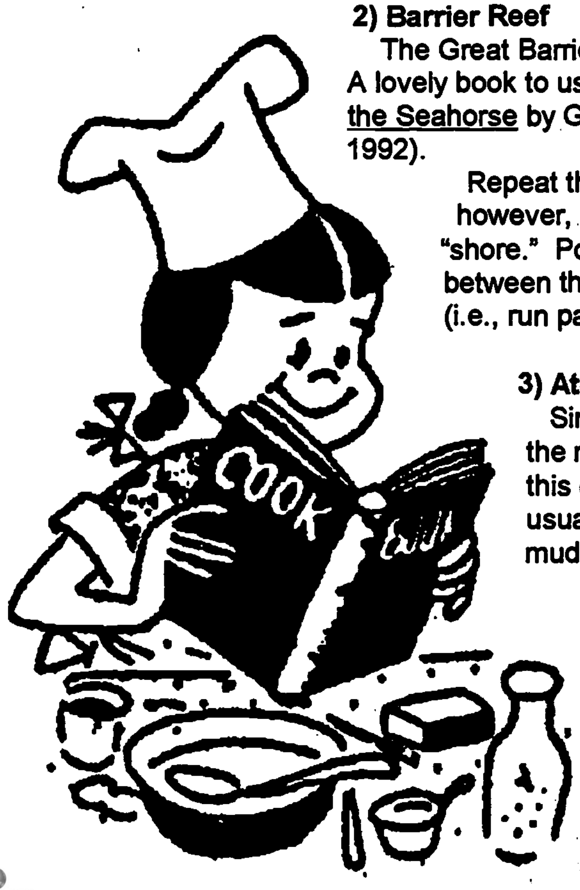
A fringing reef is a submerged platform of living coral animals that extends from the shore to the sea. Use a shallow (one inch thick or less) sheet cake to illustrate this type of reef. Cut the cake in half lengthwise. Lay the two halves end to end in the middle of a large piece of cardboard.

To create a shore, spread a thick layer of pink or white icing on the cardboard along one of the long sides of the cake. The icing "shore" should be a little deeper than the cake "reef." Sprinkle the shore with sugar to simulate sand. Mention to the students that the sand is actually fragments of coral skeletons that have been crushed by the action of waves and tides.

Place assorted decorative candies on top of the cake as you describe various kinds of coral. Explain how corals of a fringing reefs extend the reef platform toward the sea.

Tint a container of vanilla icing with blue-green food coloring. Melt the icing to a watery consistency by heating it for 40 seconds in a microwave oven. State that fringing reefs grow in shallow tropical waters as you submerge the "reef" by pouring the watery icing over the cake, candy, and a portion of the shore. The "water" will harden while you handle questions and discussion.

Eat the reef.



2) Barrier Reef

The Great Barrier Reef of Australia is a grand example of this type of reef. A lovely book to use while doing a presentation on barrier reefs is The Sign of the Seahorse by Graeme Base (New York: Harry N. Abrams, Inc., Publishers, 1992).

Repeat the above procedure to create a barrier reef. This time, however, leave a wide separation between the cake "reef" and icing "shore." Pour blue icing "water" over the reef, filling the space between the reef and shore. Point out to the students that reefs follow (i.e., run parallel to) shore lines.

3) Atoll

Since an atoll reef is basically a ring-shaped coral island in the middle of the open sea, use a tube or bundt pan to prepare this cake. Again, use candies to show how the corals build up, usually around a crater of a sunken volcano or on a submerged mud bank.

After you have built the reef, use watery (warmed) blue icing to create a lagoon in the center of the atoll. Cut out a slice of the cake to show how channels may connect the atoll to the open sea. Pour more icing "water" into the lagoon, allowing it to run into the channel.

This is fun marine science with a purpose. Enjoy!

Source: Klemm, E.B., S.A. Reed, F.M. Pottenger, C.Porter, T.W. Speitel. 1995. HMSS The Living Ocean. Honolulu, HI: Curriculum Research & Development Group, University of Hawaii. pp. 187 - 89. Adapted and reformatted from the original. Used with permission.

18*. BIOLOGICAL AND PHYSICAL AGENTS OF CHANGE ON A CORAL REEF

Background:
A reef is made of coral and coralline algae that form a structure used by other organisms as a dwelling place. A coral reef, like a forest, is a complex community of many associated plants and animals. Organisms act as agents of change to cause the reef to grow or be destroyed. Physical conditions also determine the growth or destruction of the reef.

Biological agents of change include all the plants and animals that build up and destroy reefs. See Table 1. Reef-building agents are organisms that secrete the calcium carbonate skeletons that form the reef. *Crack-filling agents* are organisms that produce sediment or live in the cracks and crevices of the reef. *Passive agents* use the structure of the reed to live and hide in. They do not affect the reef structure but may eat other reef organisms or be eaten by them. *Destructive agents* erode the reef by grinding, chewing, or boring into it.

Physical agents of change—waves, currents, pollution, moving sand, silt deposits, fresh water, and severe shifts in temperature—kill corals and wear away the reef. See Table 1.

Activity:
Compare the agents of change on a coral reef and in a forest.

Materials:
copy of Table 2

Procedure:
1. Fill in Table 2 with examples of specific agents that affect the structure of a forest.
2. Compare Table 2 with Table 1 and discuss the similarities and differences between the agents of change on a coral reef and in a forest.

Questions:
1. What do we mean by the "structure" of a forest? Of a reef? Describe the structure of the reef.
2. In what ways are corals in a reef like trees in a forest? How are they different?
3. What happens to the trees when they die? To the corals?
4. What are the differences between the growth of a tree and the growth of a forest? What are the differences between the growth of a single coral colony and the growth of a coral reef?
5. Compare the biological and physical agents that damage a forest and a coral reef. How are they similar? How are they different?
6. How does the amount of sunlight affect the growth of a coral reef? A forest?

Table 1: Agents of change affecting the growth of a coral reef.

Agents of change	Examples
Constructive agents—reef builders	Calcareous corals Encrusting coralline algae
Crack fillers	Encrusting coralline algae Fragments of corals *Foraminifera* (one-celled animals that make shells—for example, paper shells) Mollusks Echinoderms
Passive agents	Anemones Crustaceans Many fish Worms Red, green, and brown algae Octopuses Many mollusks
Destructive biological agents (organisms that destroy by chewing, eroding, blanketing, or producing acid)	Boring sponges Coral-eating fish (parrotfish) Worms Sea urchins and sea stars Boring mollusks Rapid-growing algae
Constructive physical agents (builders)	Calm water Adequate sunlight Optimum salinity Clear water Solid substrate Adequate nutrients
Destructive physical agents	Pounding waves Moving sand Smothering sediments (silt) Freshwater rain Very low tides Rising seafloor Sinking seafloor Rising or falling water temperature Runoff from land Excessive nutrients in water Pollution

Table 2: Agents affecting the growth of a forest.

Agents and conditions of change	Examples
Forest builders	
Forest floor organisms	
Passive residents	
Destructive organisms	
Constructive physical agents	
Destructive physical agents	

Source: The JASON Project is internationally recognized as an outstanding interdisciplinary and technology rich approach to teaching and learning. These materials are selected components from a comprehensive curricular approach. For more background, check out the JASON Project homepage:http://www.jasonproject .org For more information on the JASON Project, contact: JASON Foundation for Education, 395 Totten Pond Road, Waltham, MA 02154 Tel:(617)487-9995 or send e-mail to: info@jason.org

19. CORALS NEED CRYSTAL CLEAR WATER TO LIVE

Turbidity

Turbid water might be described as "murky" in appearance; the clearer the appearance of the water, the lower its turbidity. When turbidity is high, water loses its ability to support a diversity of aquatic organisms. Solid particles—such as sediment—suspended in the water can block out light that aquatic plants and organisms need. Suspended solids can also absorb heat from sunlight, raising the temperature of the water. As the water becomes warmer, it loses its ability to hold oxygen. This causes dissolved oxygen levels to drop, further reducing the number of plants and animals that can live in the water.

You will use a Secchi disk to measure turbidity. A Secchi disk is a scientific tool for measuring the relative clarity of deep water. The clearer the water, the lower the turbidity. The murkier the water, the higher the turbidity.

Materials

Plastic lid, white or light-colored, 20 cm (about 8 in) in diameter
One black waterproof marker
Several meters of fishing line
Flagging tape or strips of colored ribbon
Meter stick
Eyebolt with 2 nuts and washers
Several sharpened pencils

Methods

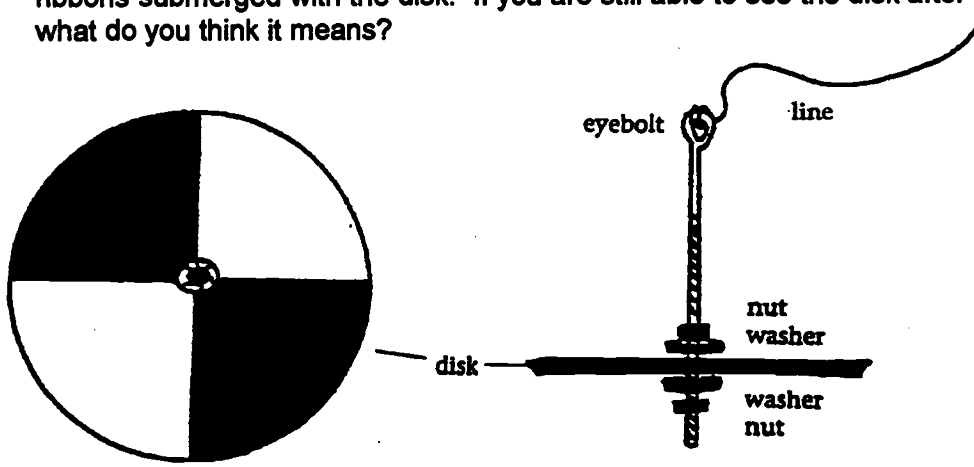
1. Use a sharpened pencil to punch a hole in the center of the plastic lid.
2. Use your waterproof marker to divide the top (outside) of the lid into four pie-shaped pieces of equal size (see illustration). Color the upper left and lower right sections black.
3. Thread a nut and washer (in that order) onto the eyebolt.
4. With the nut and washer on the eyebolt, insert the eyebolt through the hole in the center of the lid. Then add the other washer and nut (in that order) to the eyebolt on the underside of the lid (see illustration).
5. Tie one end of the fishing line to the eye of the eyebolt.
6. Using the meter stick, measure out from the eyebolt 250 centimeters (about 10 in) along the line, and tightly tie ribbon around the line. Continue tying ribbons to the line every 250 centimeters. In the field, you will lower the Secchi disk into the water. As soon as you can no longer see it, you will stop and count the number of ribbons to determine the turbidity level.

Field Experiment

1. If possible, stand on a bridge over the water at your aquatic site. If there is no bridge, simply conduct this experiment from the bank. Lower the Secchi disk into the water just to the point where you can no longer see it.
2. When you can no longer see the Secchi disk, count the number of ribbons remaining above the surface of the water. Subtract this number from the total number of ribbons on the line to calculate the number of ribbons submerged with the disk. This is your turbidity reading.

   Example: Suppose you count 10 ribbons above the water at the time you can no longer see your Secchi disk. If your fishing line has a total of 15 ribbons, you would subtract 10 from 15, and your turbidity reading would be 5.

   If your Secchi disk reaches the bottom and you can still see it, you should still record the number of ribbons submerged with the disk. If you are still able to see the disk after it has reached the bottom, what do you think it means?



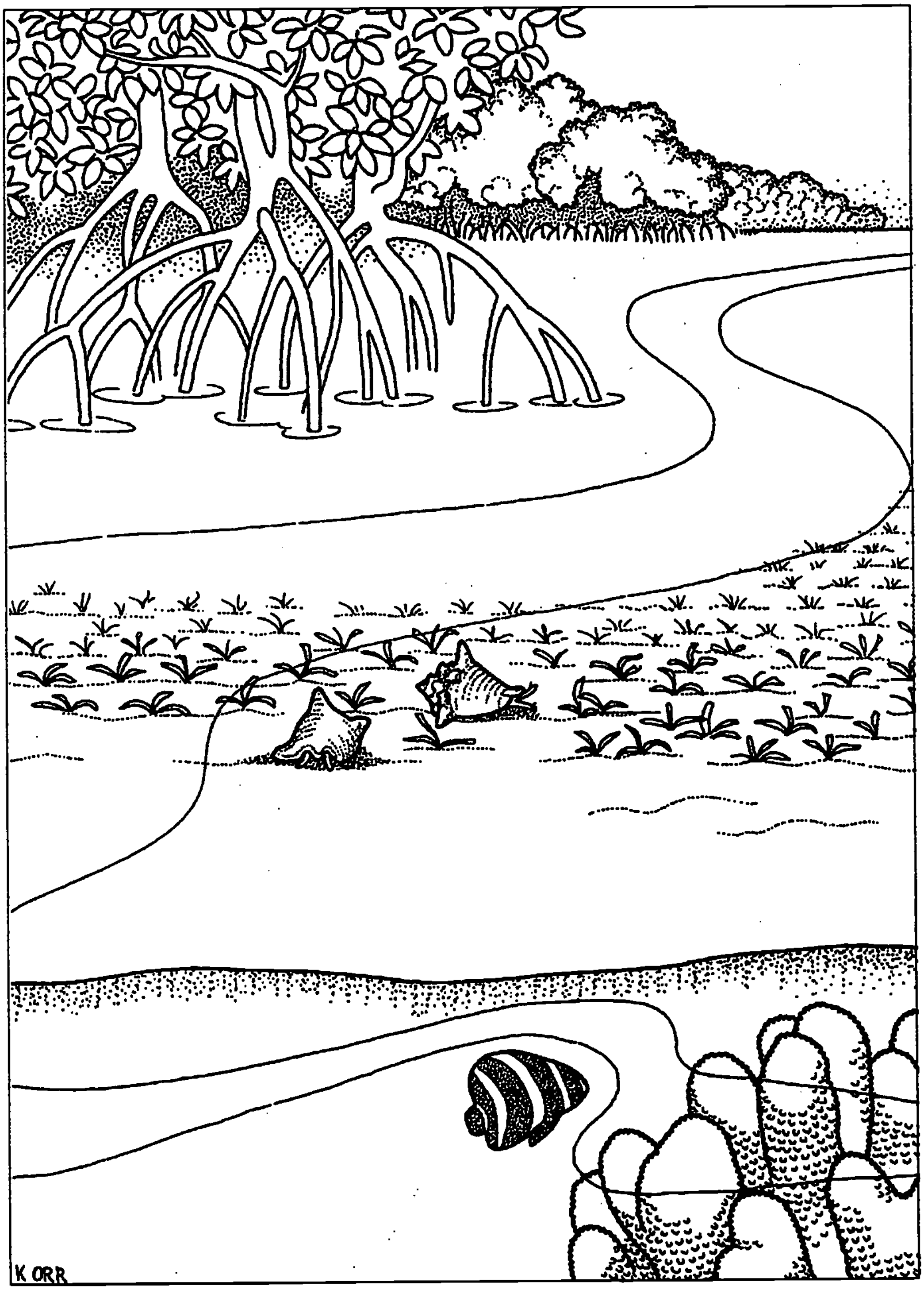
3. Repeat the experiment one or two times. Record the turbidity each time. To get an average of your Readings, add the turbidity readings and then divide by the number of times you did the experiment.

Source: **The Coral Reef Coloring Book** by Katherine Orr. © 1988 Katheirine Orr. Stemmer House Publishers, Inc., Owings Mill, Maryland. Used with permission.

20. REEFS DEPEND ON THEIR SURROUNDINGS

Coral reef systems cannot exist by themselves. They depend upon warmth and light from the sun. They need a constant supply of fresh, clear sea-water from the surrounding ocean. Some reefs need the help of nearby mangrove forests. The mangrove roots keep seawater clear by trapping soil found in muddy rain and river waters. Many reef animals depend on the mangroves and seagrass beds for food and as nurseries for their young.

Because the coral reef depends on its surroundings, changes in the nearby environment will also affect the reef. Because the reef is a living system, damage to one part will hurt the rest. This means coral reefs can be damaged easily. And since corals grow so slowly, the damage is not easily repaired.



Source: This activity is adapted from **Coral Reefs: A Gallery Program** produced at the National Aquarium in Baltimore, Maryland. Used with permission.

21*. WHERE DO CORAL REEFS GROW?

Introduction

The term "reef" refers to a hard structure that rises above the ocean floor. Sometimes reefs are large rocks; the Exxon Valdez hit a rock reef. Coral reefs consist of calcium carbonate ($CaCO_3$) deposited as skeletons by animals related to anemones and jellyfish called stony or reef-building corals. In addition to corals, coraline algae also produce calcium carbonate. These rock-like red algae live on dead coral. They cement the branches and mounds of coral skeletons into a solid structure. Anytime there is a hard surface for plants and animals to attach to, ocean creatures are abundant. Think of pier pilings or the bottoms of boats that become covered with seaweed and marine animals. In addition, swimming animals like fish come to reefs for both food and shelter. Humans take advantage of this when they make artificial reefs from ships, old cars or cement-filled tires. Coral reefs are exciting places to visit. They have some of the greatest numbers of different kinds of organisms living in the world's oceans; they are very diverse.

Where Do Coral Reefs Grow?

The coral animals that build the reef by depositing layer upon layer of calcium carbonate skeleton have very specific requirements. Reef-building corals need warm water. They tolerate 18° to 29° C, but 24° C is optimum. The sun shines most directly year round on areas near the equator. It warms tropical oceans all year. This means coral reefs usually occur in tropical waters.

1. Use the map on the following page (or your own world map) to locate the area between the Tropic of Cancer and Capricorn. Do coral reefs grow everywhere in the tropics? List two tropical countries lacking coral reefs.

Winds along the equator blow from east to west, pushing water across the ocean. Coriolis forces caused by the spinning of the Earth and the continents' location across the path of wind driven water, create circular currents in the oceans. They move clockwise in the northern hemisphere and counter-clockwise in the southern.

2. Draw arrows showing these currents on the map.

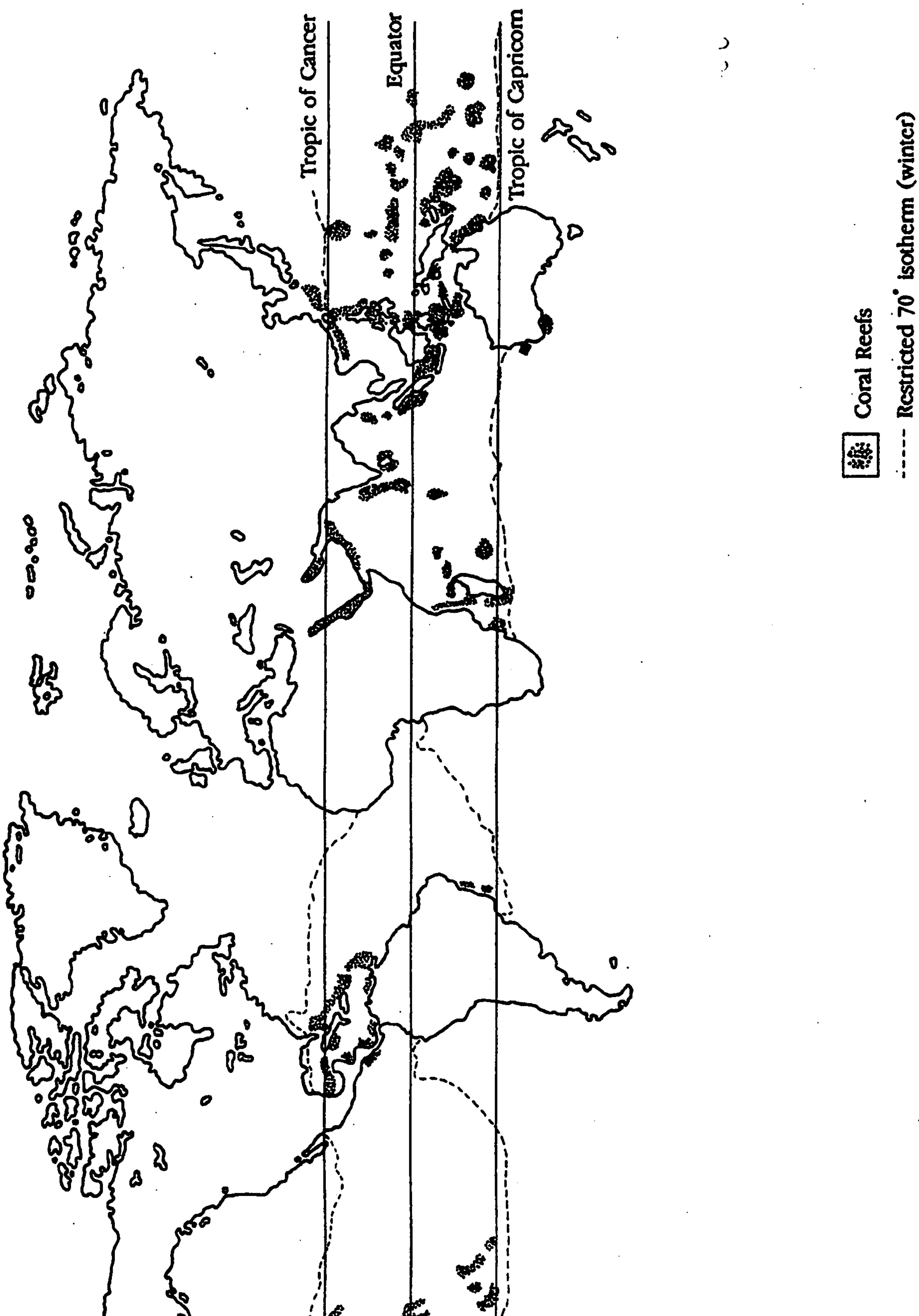
Water warms as it moves westward along the equator. It cools as it passes across the northern and southern parts of the oceans.

3. Which coasts have the warm water? Cold? Write a general hypothesis that explains coral reef distribution based on water temperature.

Reef-building corals require ocean-strength salt water (35 ppt with a range of tolerance from 25-40 ppt). Fresh water kills them. In addition to temperature and salinity, reef-building corals have a strange need for animals: they require light! Anything that blocks light kills corals. They do not grow in water with sediment or dirt (turbid water) nor do they grow in deep water where the water itself absorbs the light.

4. Look at a world map. Name a place that should have coral reefs if temperature were the only criterion. Account for this lack of reefs based on light and salinity. Hint: think geography of the adjacent land.

* *Answers in Section VIII.*

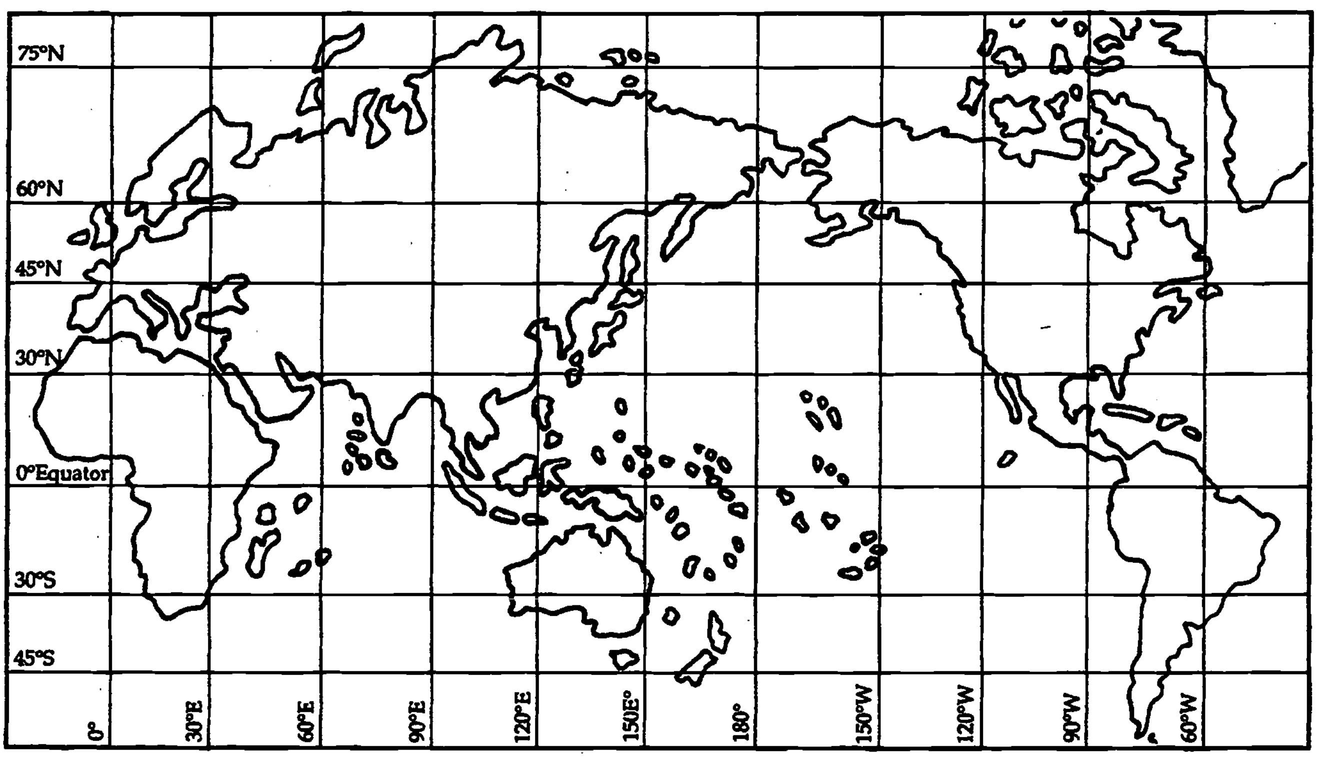

Tropic of Cancer
Equator
Tropic of Capricorn
Coral Reefs
Restricted 70° isotherm (winter)

Source: **Corals and Coral Reefs 4-8 Teacher's Guide**. A Sea World Education Department Publication. Used with permission.

22*. THE REEF REGION

Use the latitudes and longitudes in the table below to mark the location of these coral reefs. Study the finished map and identify the area of the world where most reef-building corals grow. Use colored pencils or crayons to color in the "reef belt." Between what latitudes is the reef belt?

Location	Latitude	Longitude
Great Barrier Reef	19° 10' S	149° E
Maui, Hawaii	20° 45' N	156° 20' W
Key West, Florida	24° 33' N	81° 48' W
French Polynesia	16° S	145° W
Red Sea	25° N	38° W
Jamaica	18° 15' N	77° 30' W
Belize	17° 15' N	88° 45' W
Cabo San Lucas	23° N	110° W
Seychelles Islands	8° S	55° E
Philippines Islands	13° N	122° E
Java	7° 20' S	110° E
Celebes Islands	2° S	121° 10' E
Bahama Islands	24° 15' N	76° W



Coral distribution map

Deeper Depths: Ask students to research what other habitats besides coral reefs are found in the reef belt.

** Answers in Section VIII.*

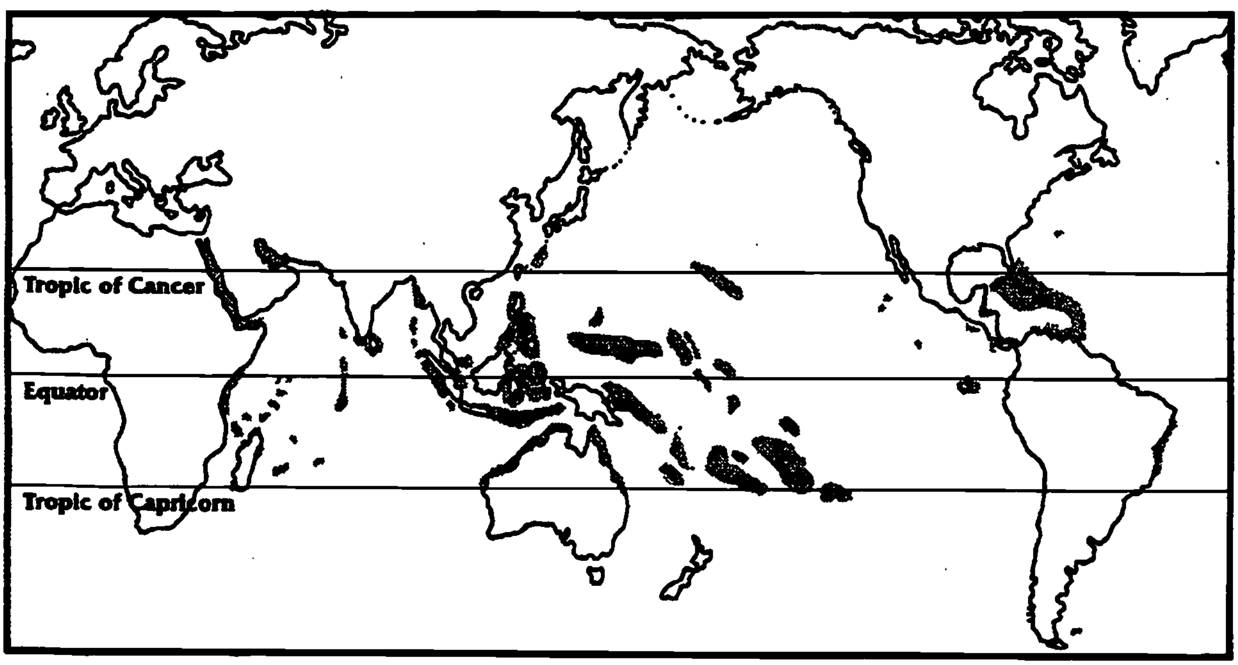
Source: Coral Forest Teacher's Guide. Coral Forest, 400 Montgomery Street, Suite 1040, San Francisco, California 94104 Tel: (415)788-REEF FAX: (415)398-0385 e-mail: coral@igc.apc.org Used with permission.

23*. MAPPING THE REEFS

Objective: Students locate coral reefs on a world map.
Interdisciplinary Index: Geography, Science
Vocabulary: longitude, latitude, equator, tropic of Cancer, tropic of Capricorn

Materials: a map of the world; copies of the **Coral Reefs of the World** map (below), the **Coral Reef Map** and the **Geography Map Key** (one of each for every group of two students); two copies of the list of **Geography Clues**; thin colored markers (ink pens may be substituted)

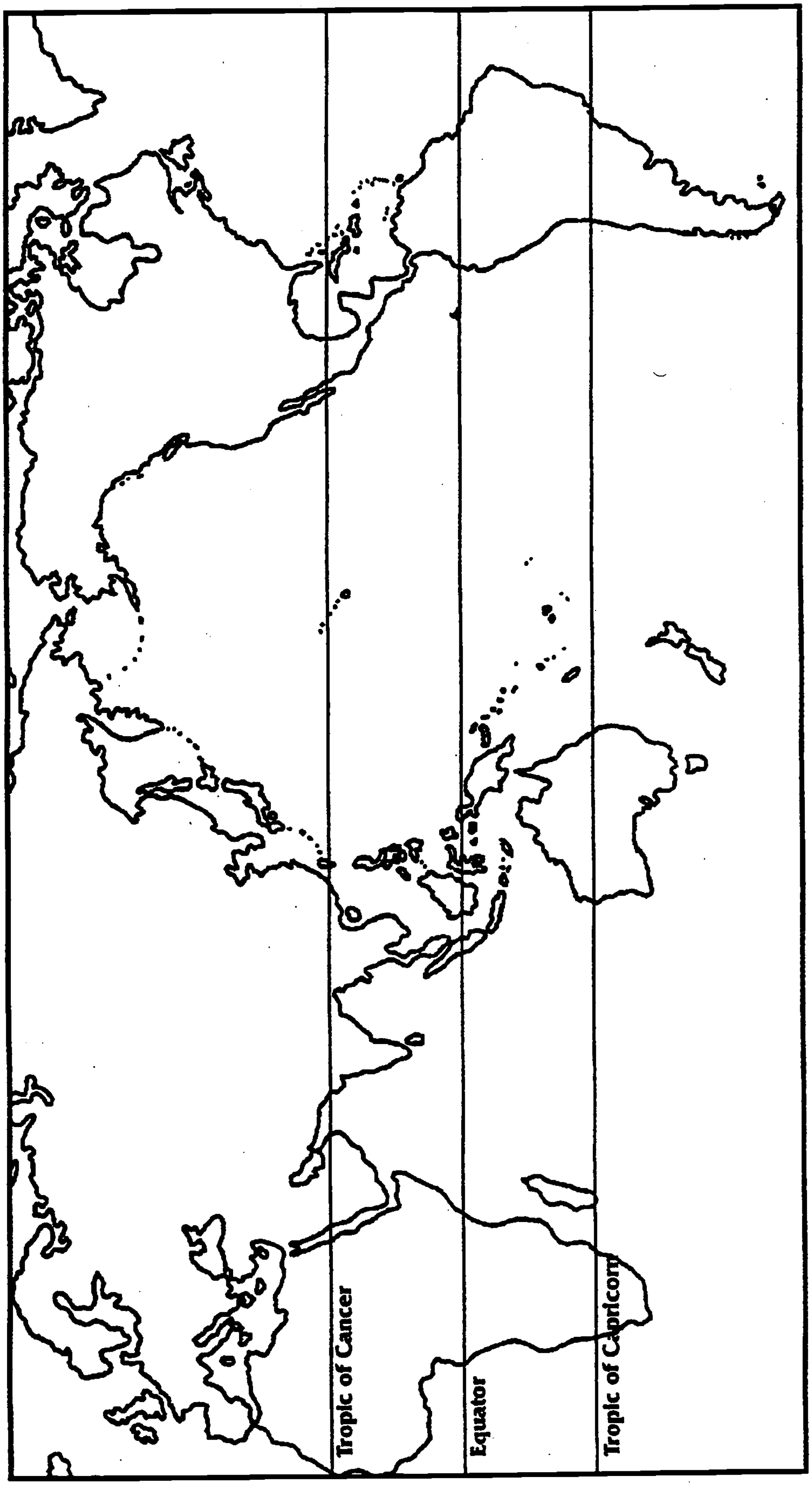
Presentation:
1. Before class, cut the two copies of the **Geography clues** sheet into strips with one clue per strip.
2. Divide the class into groups of two.
3. Hand out a copy of the **Coral Reefs of the World** map, a **Coral Reef Map**, and a **Geography Map Key**, one for every two students. Hand out one clue strip per group.
4. Referring to the **Coral Reefs of the World** map, students should mark the location of coral reefs around the world using a colored marker. Referring to the world map, students then need to answer the geography clues and mark their location on the **Coral Reef Map** with the clue number.
5. Then they should record the name of the location on the **Geography Map Key**. The number of letters in the location will also serve as a clue.
6. After completing both of these steps for a clue, one member of the team should exchange the original clue for another clue. This process should be repeated until all thirteen clues have been used.
7. As each group completes the locating and recording section, have them work together (or separately) to complete the follow-up question.



Coral reefs of the world *(illustration: Wendy Weir)*

* *Answers in Section VIII.*

CORAL REEF MAP



GEOGRAPHY MAP KEY

1. _ _ _ _ _ _ IS _ _ _ _ _
2. _ _ _ _ _ _
3. _ _ _ _ _ _ _ _ _
4. _ _ _ _ _ _ _ _ _ _
5. _ _ _ _ _ _ _
6. _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
7. _ _ _ _ _ _ _
8. _ _ _ _ _ _
9. _ _ _ _ _ _ _
10. _ _ _ _ _ _
11. _ _ _ _ _ _ _ _ _ _ _
12. _ _ _ _ _ _
13. _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Follow up: Describe in general terms where these coral reefs are located.

GEOGRAPHY CLUES
Each of these locations has coral reefs.

1. Group of islands northeast of Cuba

2. Central American country bordering the Caribbean and Guatemala

3. Fifteen percent of the world's coral reefs are located in this sea

4. Large island off the eastern coast of Africa

5. Largest ocean in the world

6. Largest barrier reef in the world, located off the eastern coast of Australia

7. Island country south of Cuba

8. Central American country adjacent to South America

9. United States peninsula state

10. United States island state

11. Collection of many islands located in the South China Sea

12. Body of water between Africa and Asia

13. A group of islands in the Pacific where Kwajalein, the world's largest atoll, is located

Source: J.L.Scott Marine Education Center and Aquarium, Biloxi, Mississippi. Used with permission.

24. RECIPE FOR A HAPPY REEF

Write the following list of ingredients on the chalkboard:

<u>**Recipe for a Happy Reef**</u>
sunshine *corals flourish in lower latitudes where sunlight is intense*
shallow water *corals ordinarily do not grow below 40 meter depths*
clarity *corals cannot thrive in water that is clouded with suspended particles*
salt *corals require high salinity, ideally between 34 and 37 parts per thousand salt*
warmth *reef-building corals grow best between 25 and 31 degrees Centigrade*
hard bottom *corals prefer a firm footing to a shifting sand seafloor*

Here is another recipe for a happy reef that will make your students happy too.

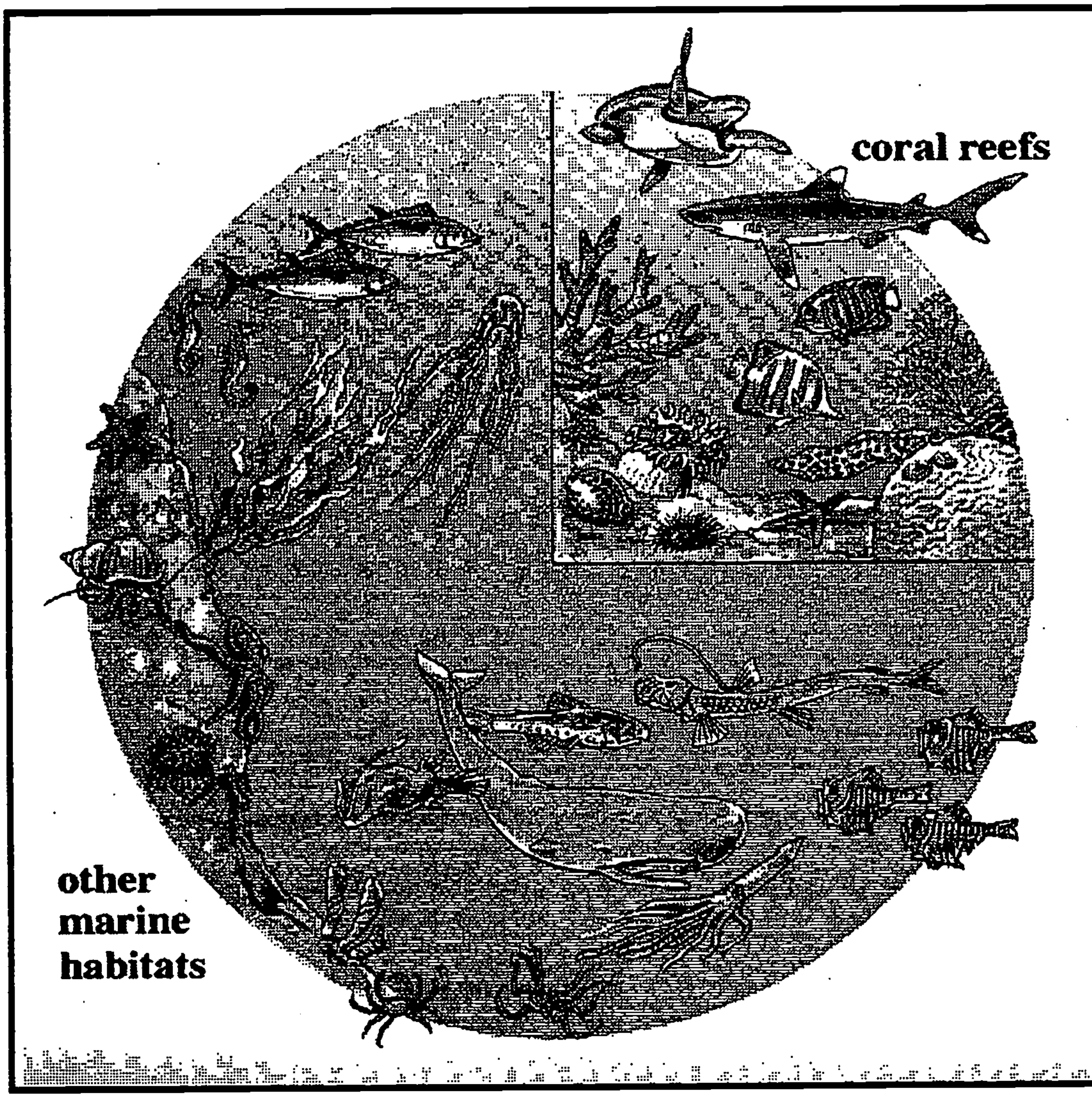
2 envelopes Knox plain gelatin
2 boxes blue Jello
½ cup sugar
1 ½ cup boiling hot water
½ cup cool water
2 cups cold water with ice cubes

2 or 3 sugar cookies
assorted candies
frosting or peanut butter
gummy fish
whipped cream

Place cookies in the bottom of a large (1 ½ quart) glass bowl or jar. Cover the tops of the cookies with candies, creating a "coral reef." Use frosting or peanut butter to cement the candies in place. In a separate dish, sprinkle plain gelatin over ½ cup cool water and let stand for one minute before adding 1 ½ cups hot water, blue Jell-O and sugar. Stir until dissolved. To this mixture, add 2 cups cold water with ice cubes. Continue stirring until the gelatin is just beginning to thicken. Immediately remove any remaining ice and pour the "seawater" around the "coral reef." Add gummy fish. Refrigerate for one hour. Before serving, add whip cream "waves." Serves 8 - 10.

Source: Text from The Living Reef by Harry Breidahl. © 1994 Harry Breidahl. Macmillan Education Australia Pty Ltd. Illustration from Coral reefs by Harry Breidahl. © 1994 Harry Breidahl. Macmillan Education Australia, Pty Ltd. Used with permission.

25. ENDLESS VARIETY



Coral reefs are often regarded as the rain-forests of the sea. Just as in a rainforest, a coral reef scene is a riot of colors and forms. A coral reef not only supports an infinite variety of living things, it also supports an abundance of each living thing. The shoals of colorful fish that dart in and out of the labyrinths of coral provide a constant reminder of this abundance.

Nobody can say exactly how many species (different kinds) of marine organisms live on coral reefs of the world. This is because scientists are only just beginning to explore the oceans in a systematic way. Modern equipment such as SCUBA enables scientists to explore reefs more closely. It has been estimated that coral reefs may be the home for a quarter of all the marine organisms on Earth.

Source: The following activity is contributed by the J.L Scott Marine Education Center and Aquarium, Biloxi, Mississippi. Used with permission.

Follow-up Activity: Coral Reef Scavenger Hunt

"Biodiversity" has been referred to as our "planetary insurance policy." In other words, the more varied the genetic blueprints on our planet, the more likely that life on Earth will find a way to survive by adapting to changes that will come over the course of time. It is prudent for humans to seek to preserve rainforests on account of their "biodiversity," and likewise to protect the rich and largely unexplored variety found on coral reefs.

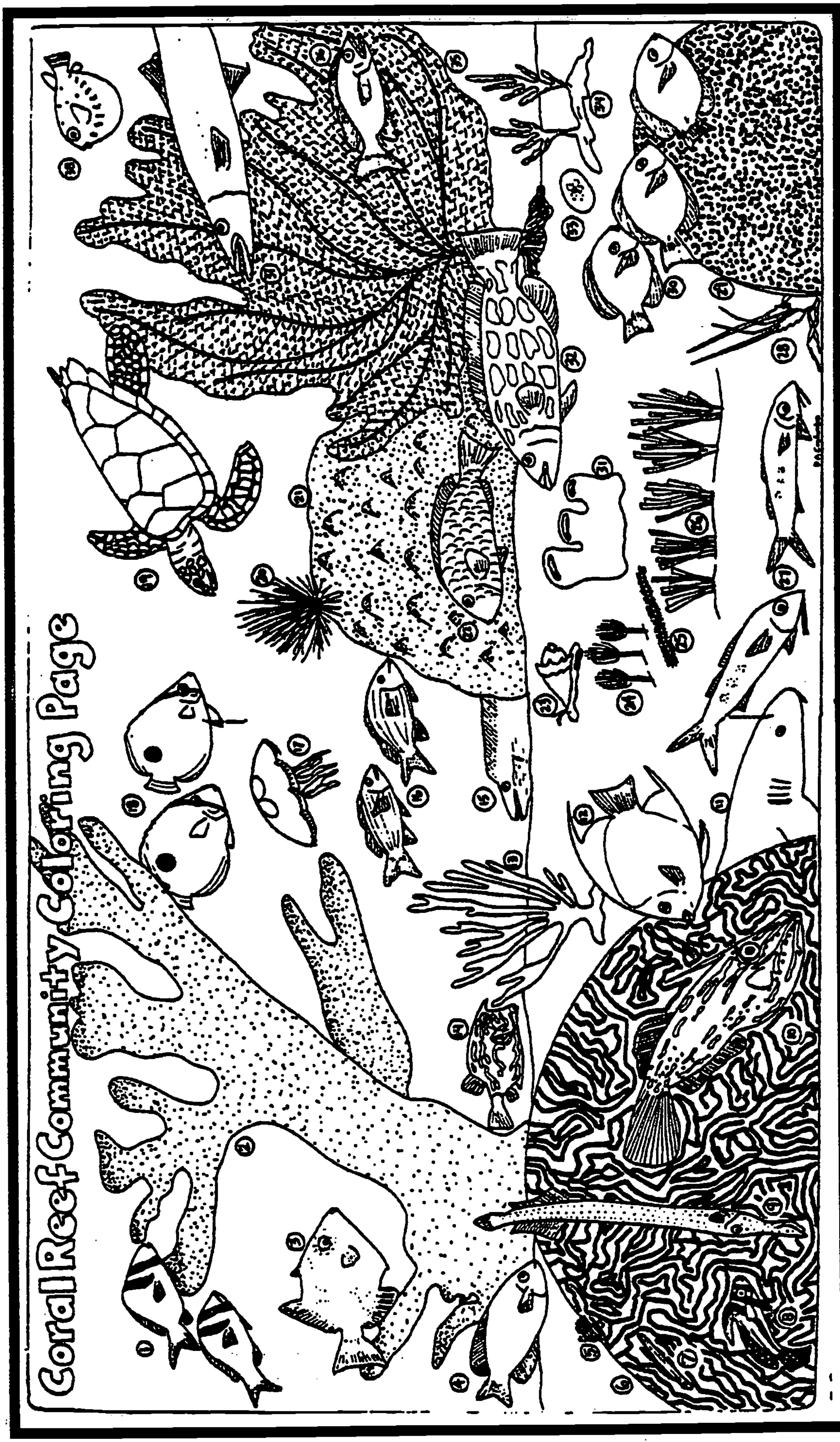
To help students appreciate this incredible variety, hold a "Coral Reef Scavenger Hunt." Students may work individually or as teams to find a different item appropriate for each description on the list. The hunt may be done on a snorkeling fieldtrip, at an aquarium reef exhibit, in the classroom with magazine photographs and/or posters depicting coral reefs, or with students searching their imaginations. The first student or team to find all twenty items is "the winner." For more advanced students, the teacher may wish to write new descriptions, such as "Something which can change color," "Something that hunts at night," "Something that lives in a mutualistic relationship," etc.

1. Something beautiful
2. Something yellow
3. Something sharp
4. Something blind
5. Something with legs
6. Something slippery
7. Something at least fifty years old
8. Something you could not take home
9. Something clear or translucent
10. Something long and slender
11. Something swift
12. Something with a shell
13. Something valuable
14. Something that lives in large communities
15. Something ugly
16. Something round
17. Something edible to humans
18. Something alive that would fit in a teacup
19. Something shiny
20. Something with stripes

Source: Our Living Coral Reef. Illustrated by Deborah A. Coulombe. Produced by the "Living with Nature Committee" of the Junior League of Miami, Inc. Used with permission.

26. CORAL REEF COMMUNITY COLORING PAGE

1. Porkfish
2. Elkhorn coral
3. Triggerfish
4. Damselfish
5. Christmas Tree worm
6. Brain coral
7. Neon goby
8. Spotted drum
9. Trumpet fish
10. Filefish
11. Nurse shark
12. Angelfish
13. Sea rod coral
14. Cowfish
15. Moray eel
16. Grunts
17. Moon jelly
18. Four eye butterflyfish
19. Hawksbill turtle
20. Long spiny urchin
21. Mountainous coral
22. Parrotfish
23. Queen conch
24. Neptune's shaving brush (alga)
25. Bristle worm
26. Turtle grass
27. Goatfish
28. Spiny lobster
29. Star coral
30. Blue tangs
31. Sponge
32. Grouper
33. Sea bisquit
34. Fire coral
35. Sea fan
36. Snapper
37. Barracuda
38. Bandtail puffer


Coral Reef Community Coloring Page

Source: Corals and Coral Reefs 4 - 8 Teacher's Guide. A Sea World Education Department Publication. Used with permission.

27*. WHAT'S MY NAME?

Objective: Students will learn to use a dichotomous key to identify a variety of reef organisms.

Materials:
copies of the last two pages of this activity (one set of pages for each group of four students)
pencils
scissors

Action:

1. Lead students in a discussion about organizing objects into groups based on things they have in common. For example, ask students to describe how books are organized in a library (*alphabetically for fiction, by topic for nonfiction*). Why is it important to have a system to organize books? (*so it's easy for people to find what they're looking for*) What other examples of grouping by similarities can students think of? (*items in a grocery store, businesses in a phone directory, record collections, etc.*) Explain that biologists also have a system to organize living things. It places organisms into groups that have clear-cut similarities. Ask students to name some of the characteristics of birds and to explain why a fish isn't a mammal.

   Tell students that there is a scientific method for determining to what group an organism belongs. It's a key that leads you through a series of choices based on your observation of the organism. Eventually, you make a final choice that identifies the organism. Because there are two choices at every step, this system is called a dichotomous key (*di means two, chotomous means branched*).
2. Use an overhead projector to show the picture of the fireworm (card number C) or just hold the card up for the class to see. Demonstrate how the key works by leading the class through two or three steps, but don't identify the creature for them. Read the statements from the key out loud, and let students make the decisions based on their observations.
3. Divide class into groups of four students each. Have students cut out picture cards of organisms and divide them among the members of their group. Each group should select one person to read from the key.
4. One student selects an organism from her/his pile, and the person with the key reads the criteria. All members of the group should agree on whether or not the organism fits the criteria before moving on to the next step of the key.
5. When the organism has been identified, the person whose pile it came from writes its name on the picture and sets it aside. The next person selects a card from his/her pile and the group repeats the steps in keying it out.
6. When all the groups have identified each organism, review their findings as a class. Explain that since they were using only pictures of the animals, their criterion was limited to overall appearance only. If they had the actural organism in front of them, what other criteria could they have used? (*size, color, weight, features that may have been hidden in the drawing*)

Deeper Depths:
The animals in this activity are invertebrates from the phyla Cnidaria, Mollusca, Arthropoda, Echinodermata, Annelida, and Platyhelminthes. Have the students hypothesize which animals are related. Then have the students do research and determine the characteristics of animals in each of these phyla and identify the phylum for each animal.

* *Answers in Section VIII.*

CORAL REEF ANIMAL KEY

1. a. Long spines: go to 2
   b. Very short spines or no spines: go to 4

2. a. Spines all over body: go to 3
   b. Spines projecting only from the edge of the shell: *Atlantic thorny oyster*

3. a. Spines are long, thin, and finely pointed: *long-spined urchin*
   b. Spines shorter and very thick: *club urchin*

4. a. Stonelike appearance with branches: go to 5
   b. Not stonelike: go to 7

5. a. Branches extend horizontally and vertically: go to 6
   b. Branches only extend vertically: *pillar coral*

6. a. Blunt, fingerlike branches: *finger coral*
   b. Broad, flat branches: *elkhorn coral*

7. a. Transparent: go to 8
   b. Not transparent: go to 9

8. a. Numerous, fine tentacles line edge of round body: *moon jelly*
   b. Two hairlike tentacles trail behind oval body: *comb jelly*

9. a. Five to six distinct arms: go to 10
   b. No distinct arms or more that six arms: go to 11

10. a. Slender, whiplike arms, spines project from sides of arms: *brittle star*
    b. Thick, fingerlike arms with blunt tips: *comet star*

11. a. Numerous tentacles: go to 12
    b. Few or no tentacles: go to 13

12. a. Tentacles long, slender, and fine-tipped: *corkscrew anemone*
    b. Tentacles short and blunt-tipped: *sun anemone*

13. a. Wormlike: go to 14
    b. Not wormlike: go to 16

14. a. Tufts of bristles along both sides of body: *fire worm*
    b. No brisltes: go to 15

15. a. Thick, tubelike body resembling a cucumber: *soft sea cucumber*
    b. Flat, ribbonlike body with smooth edges: *polyclad flatworm*

16. a. Hinged shell with zigzag shell opening: *Frons oyster*
    b. No hinged shell: go to 17

17. a. Round body shape: go to 18
    b. Body shape not round: go to 19

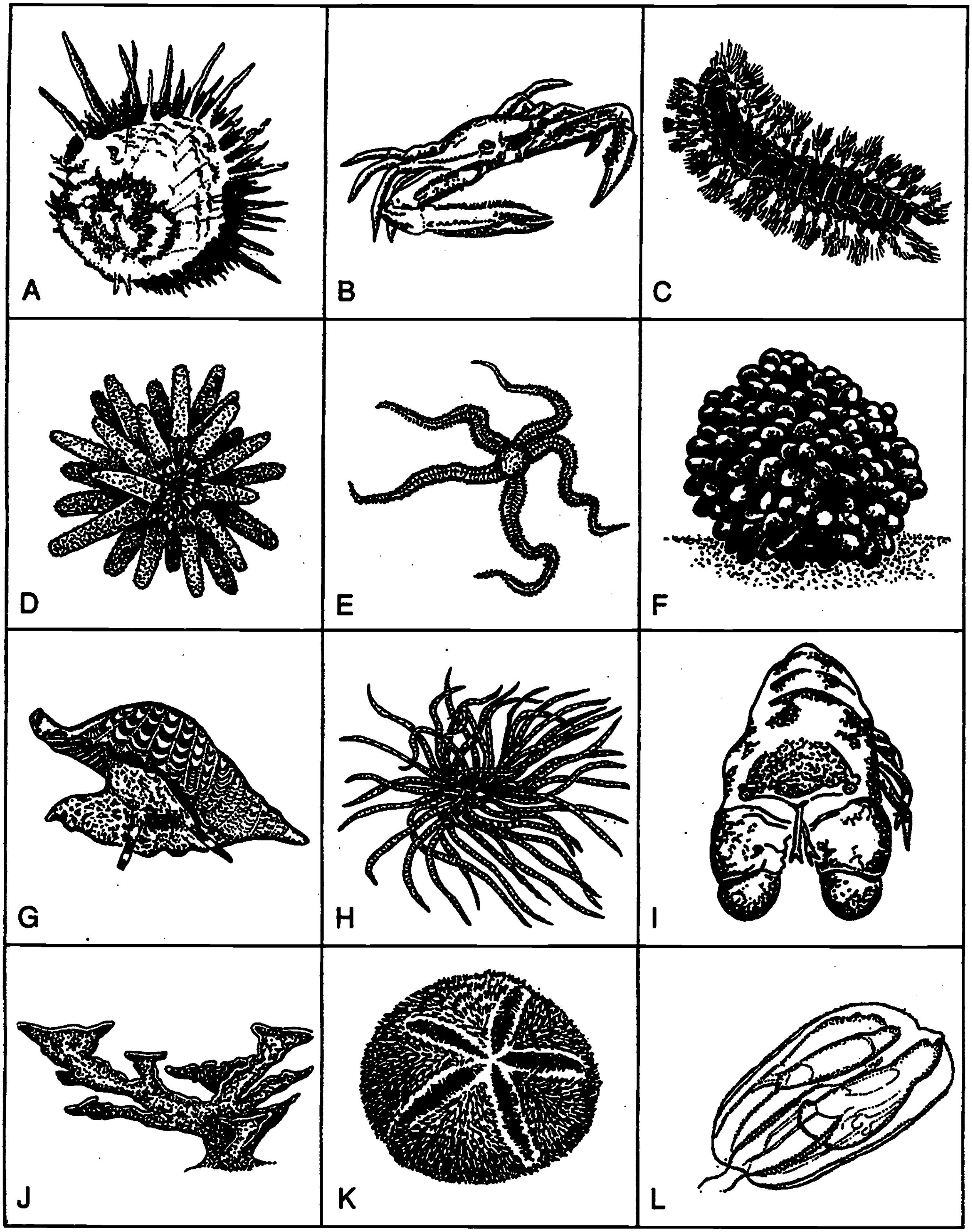
18. a. Five pointed star on surface: *heart urchin*
    b. Grooves form wavy pattern on surface: *brain coral*

19. a. Crablike with prominent front claws: *swimming crab*
    b. Not crablike: go to 20

20. a. Legs: go to 21
    b. No legs: *trumpet triton*

21. a. Long antennae: go to 22
    b. Short, flat antennae: *Spanish lobster*

22. a. No spines on body: *rock lobster*
    b. Spines on body: *spiny lobster*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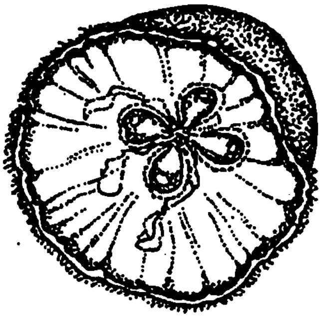
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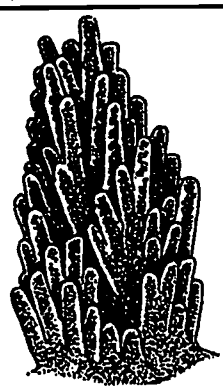
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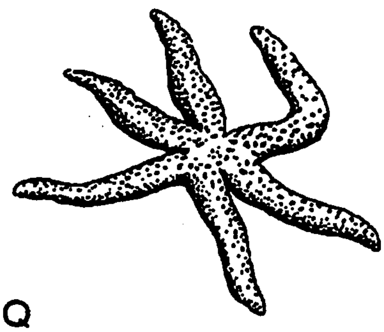
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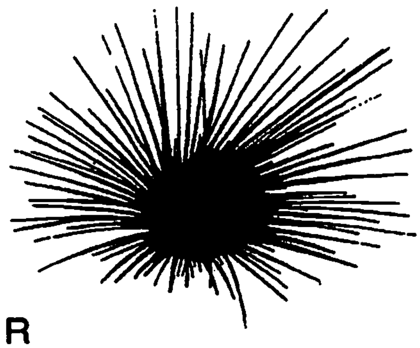
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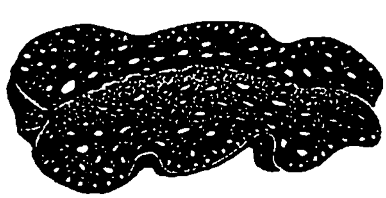
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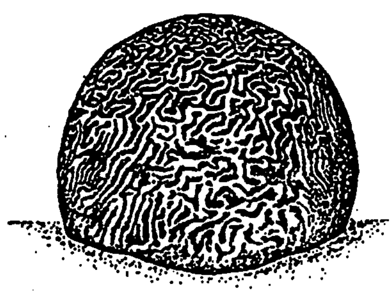
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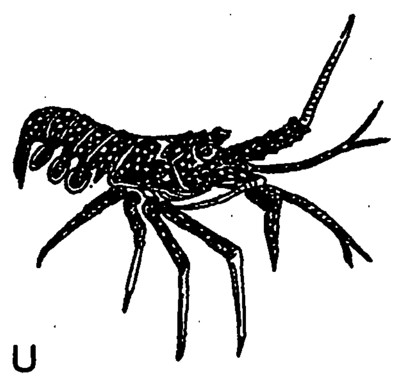
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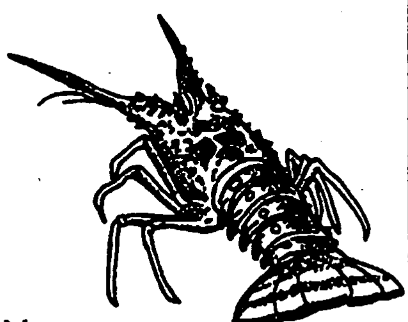
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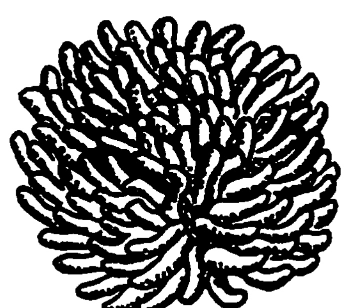
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Source: Klemm, E.B., S.A. Reed, F.M. Pottenger, C. Porter, T.W. Speitel. 1995. HMSS The Living Ocean. Honolulu, HI: Curriculum Research & Development Group, University of Hawaii. Pp. 14 - 21. Adapted and reformatted from the original. Used with permission.

28*. CLASSIFICATION OF REEF FISH: NOMENCLATURE AND KEYS

Background:
Butterflyfish are popular tropical reef fish. But there are more than a dozen species of butterflyfish. Common names are not adequate for identifying fish species for several reasons:

1. Different common names are often used for a single species. In English, for example, the fish pictured below is called a raccoon butterflyfish in Hawaii, a cross butterflyfish in other parts of Polynesia, and a red-striped butterflyfish in Melanesia.

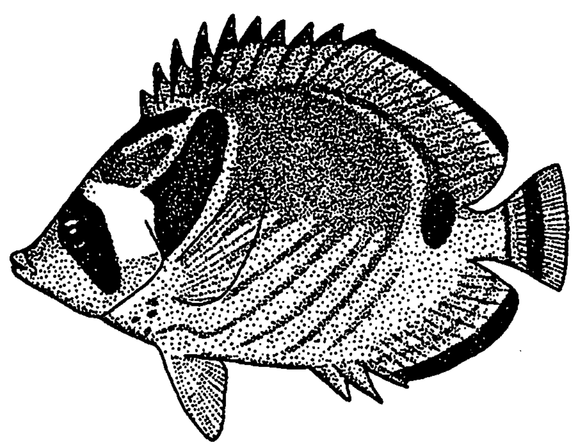
2. A common name may refer to several similar but different species. In Hawaiian, for example, only two common names, *kikakapu and lauhau*, are used for the 15 species of butterflyfish listed in Table 2 and shown in Figure 1.

3. Common names sometimes contain misleading descriptive words. For example, starfish, jellyfish, and crayfish are not fish.

Binomial Nomenclature
Scientists around the world, no matter what their language, use a two-name or **binomial** system for naming organisms. **Scientific names** usually combine word parts from Latin (L) or Greek (G). Table 1 shows Latin and Greek word parts used in naming the butterflyfish. A scientific name includes the names of both the genus and the species. For example, the scientific name of the raccoon butterflyfish is *Chaetodon lunula*. The genus name comes before the species name. In writing, both names are either underlined or printed in italics (slanting type). The first letter of the genus name is always capitalized. If the genus has already been mentioned, its scientific name may be abbreviated: *C. Lunula*.

Identification Keys
Over 2 million species of organisms have been named by

A. Common names
In Hawaii: raccoon butterflyfish
In Polynesia: cross butterflyfish
In Melanesia: red-striped butterflyfish



B. Using biological classification

Category	Key characteristic	Meaning
Kingdom	Animalia	▪ animal
Phylum	Chordata	▪ has a notochord (a supporting bony rod)
Subphylum	Vertebrata	▪ has a vertebral column (a "backbone")
Class	Osteichthyes	▪ fish with a bony skeleton
Order	Perciformes	▪ shaped like a perch
Family	Chaetodontidae	▪ teeth shaped like bristles
Genus	*Chaetodon*	▪ bristle teeth
Species	*lunula*	▪ shaped like a moon

C. Scientific name: *Chaetodon lunula*
Abbreviated scientific name: *C. lunula*

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* *Answers in Section VIII.*

scientists; probably millions more are still unnamed. To distinguish species, biologists make keys using easily identifiable features. A biological key is a series of decisions for identifying a species by its features.

In a word key, each number on the left identifies a decision point related to a pair of descriptive statements. The user selects a decision point, then looks at the number on the right (at the end of the sentence) that tells where to find the next level of descriptions. A number in parentheses shows the previous decision point, the one that led to this point in the key.

Activity: Use a word classification key to identify several species of butterflyfish.

Materials:
copy of Table 2 and Fig. 1
scissors
optional (glue and sheet of construction paper)

Procedure:
1. (Optional) Cut out the fish cards from Fig 1.

Table 1. Some Latin (L) and Greek (G) word parts

Word part and its meaning	
auri- (L). Gold, golden	***lineo*** (L). A line
bi- (L). Two	***lun-*** (L). The moon
chaet (G). Bristle	***macula*** (L). Spot, spotted
cinct (L). Girdled	***miliar*** (L). Millet (a grass) seed
citrin (G). A lemon	***multi-*** (L). Many
-ellus (L). Small	***-odon*** (G). Tooth
ephippi (G). A saddle	***ornat*** (L). Adorned
fasciat (L). Banded	***quadri-*** (L). Four
frem (L). Roar, murmur	***reticul*** (L). A network
-latus (L). Side, broad, wide	***tri-*** (L). Three

2. Select the butterflyfish M. Using the word key in Table 2, key out butterflyfish M by following these steps:
   a. Starting at decision point 1, read the two statements describing a feature of butterflyfish.
   b. Decide which statement fits the picture of fish M. (The description "Pelvic fin dark" is the correct description for fish M.)
   c. Note the number to the right side of this statement. It is 2.
   d. Go to decision point 2. Read the two descriptions. Decide which statement better describes fish M. (The second statement "Lacks two large white spots below dorsal fin," is the correct choice.)
   e. Find the number in the right-hand column for the statement you chose. Go to the decision point with that number at the left.
   f. Again select the proper description. (Of the two choices there, "Tail with one dark bar at tip" is the correct choice.) This description identifies the organism, and its name appears: *Chaetodon kleini.*
   g. Record the name of your fish below its picture in Figure 1 (Because all fish in Fig. 1 are in the genus *Chaetodon*, the name of the genus may be abbreviated as *C* and *Chaetodon kleini* may be identified as *C. kleini.*)

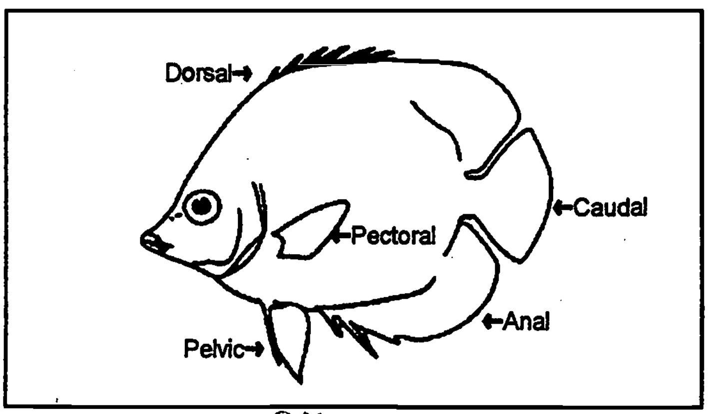
3. Identify all the butterflyfish in Figure 1.
   a. Read the two descriptions at each decision point, then select the description that matches the fish.
   b. When you identify a fish, write its scientific name under its picture. Continue until you identify all the fish.
   c. If you are using cards, remove each card from the deck when you identify the fish on it.

Questions:
4. What kind of feature should be used to construct a key for a group of animals or plants?
5. How might biological keys handle the problem of a species of fish that has different color patterns in juvenile and adult stages?
6. Color and markings are usually poor characteristics to use in identification keys. Why?

Decision Point		Choices	Decision
1		Pelvic fin dark	2
		Pelvic fin light	4
2	(1)	Two large white spots below dorsal fin	*C. quadrimaculatus*
		Lacks two large white spots below dorsal fin	3
3	(2)	Tail with two dark bars at tip	*C. reticulatus*
		Tail with one dark bar at tip	*C. kleini*
4	(1)	Posterior or dorsal fin has long filament extension	5
		Filament extension lacking from dorsal fin	6
5	(4)	Large dark spot on body near filament	*C. ephippium*
		Small dark spot on body near filament	*C. auriga*
6	(4)	No vertical band through eye	*C. fremblii*
		Vertical band through eye	7
7	(6)	Incomplete eyeband on face (does not go to top of head)	*C. multicinctus*
		Complete eyeband on face (extends to top of head)	8
8	(7)	Nose area with band	9
		Nose area lacks band	10
9	(8)	Fewer than eight diagonal bands on body	*C. ornatissimus*
		More than eight diagonal bands on body	*C. trifasciatus*
10	(8)	Distinct white spot splits eyeband above eye	*C. lineolatus*
		No white spot above eye; eyeband not split	11
11	(10)	Upper third of body under dorsal fin dark	*C. tinkeri*
		Upper third of body under dorsal fin not dark	12
12	(11)	Distinct small spots arranged in rows	13
		No distinct small spots; body has large spot or band	14
13	(12)	No black band on caudal fin	*C. citrinellus*
		Obvious black band on caudal peduncle	*C. miliaris*
14	(12)	Side with a large black teardrop; no dark bars on tail	*C. unimaculatus*
		Large black shoulder patch; tail with dark bars	*C. lunula*

Table 2. Word key to the butterfly fish of the genus Chaetodon.

Table 3. Fish fins.



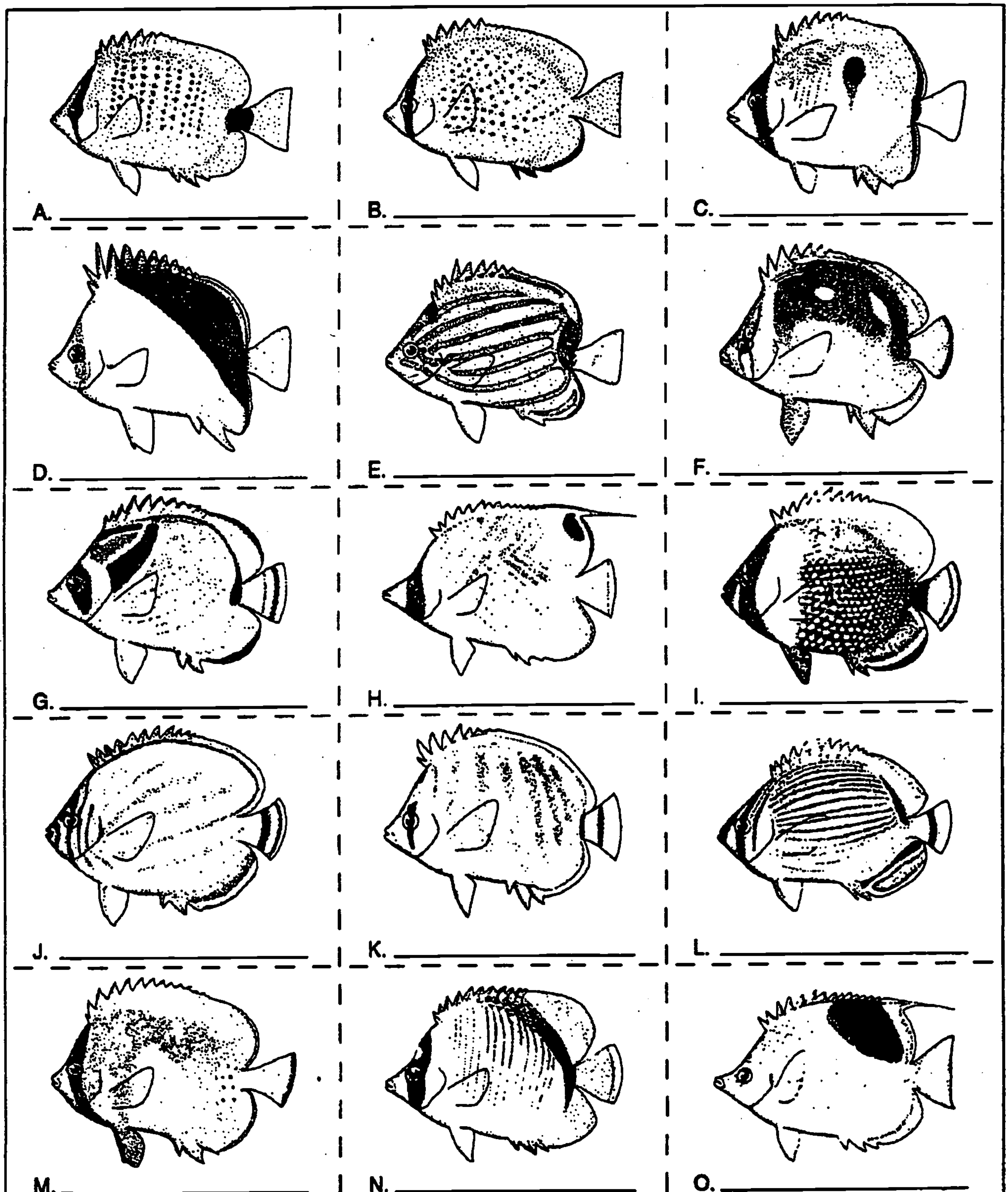


Figure 1. Butterfly fish

29*. PARTNER WANTED

Partners for Life

Clownfish and Sea Anemone:

Several species of fish and invertebrates spend part or all of their lives in association with sea anemones. A clownfish, in fact, will never stray far from its anemone host. The fish avoids its enemies by staying nestled among the anemone's stinging tentacles. Scientists believe clownfish have a special mucous coating that prevents anemone stinging capsules from firing.

Many scientists think that the most important thing clownfish do for their anemone hosts is to protect them by chasing away animals such as butterfly fish, which often eat anemones.

Pistol Shrimp and Goby:

In sandy areas of a coral reef, the pistol shrimp sometimes shares its burrow with a fish called a goby. The pistol shrimp spends most of its time digging and cleaning out its burrow. This shrimp finds food near the entrance of its home but can't sense when predators are near as well as the goby can. The goby hovers near the shrimp's burrow, and when a predator approaches, it flicks its tail and dives for cover inside the burrow. This signals danger and sends the shrimp down into the burrow too. Without the goby's alarm signal, the shrimp might not be able to escape danger in time.

Hermit Crab and Sea Anemone:

A few species of hermit crabs—crabs that live in the empty shells of sea snails—usually have sea anemones attached to their shells. The anemones protect the crab from enemies—especially the octopus, which eats hermit crabs but is very sensitive to anemone stings. The anemones may also help camouflage the hermit crab.

Scientists aren't sure whether hermit crabs feed their anemone partners. But the anemones do get a free ride around the reef from the hermit crabs. By riding from place to place on top of a crab, an anemone probably gets scraps of food it might not have been able to get on its own.

Cleaner Fish and Grouper:

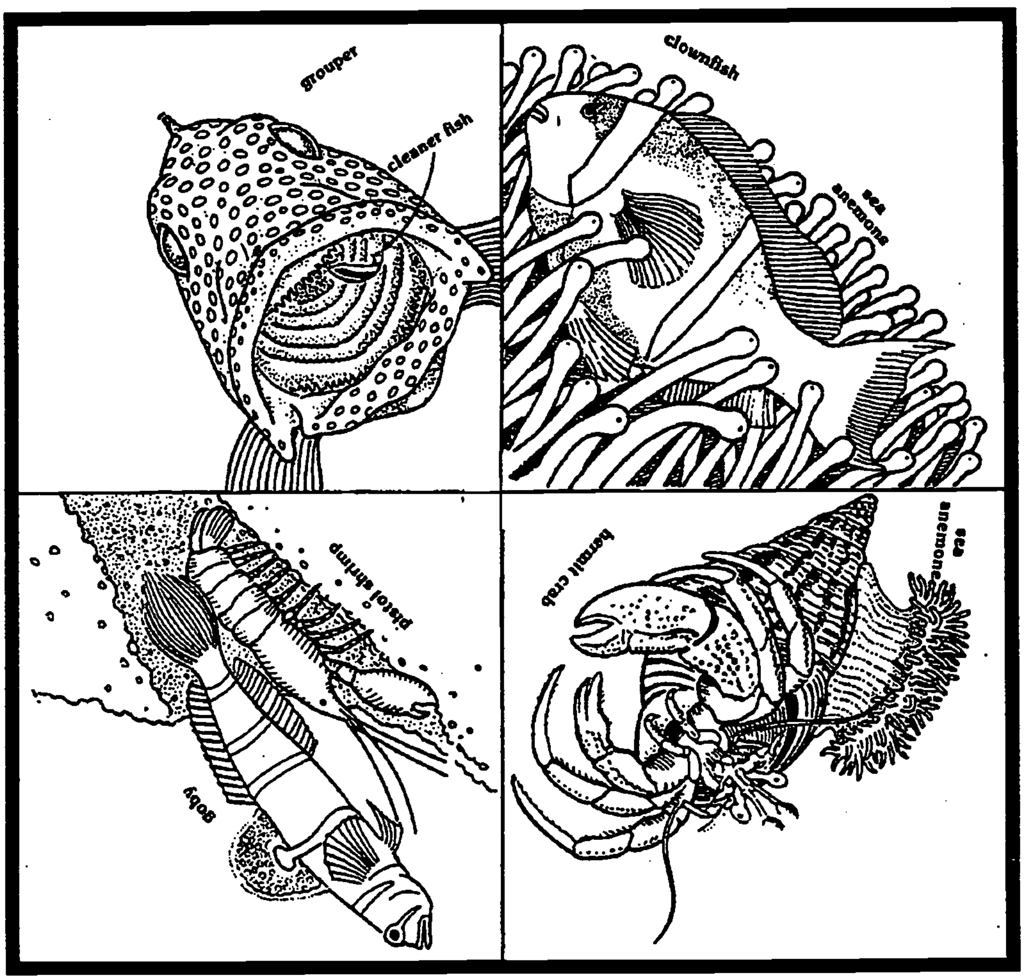
Several species of small fish and shrimp perform a cleaning service for other fish. A cleaner fish usually stays in a small territory known as a cleaning station. When a potential "customer" enters the cleaning station, the tiny fish does a little "dance" identifying itself as a cleaner. The customer may be a large predator such as a grouper. But it recognizes the colors and movements of the cleaner fish and allows itself to be cleaned without harming the smaller fish. The cleaner fish even cleans up the wounds of reef fish, which helps them heal. In turn, the cleaner fish gets its food as it picks off pests and food particles from the larger animal's scales, mouth, and gills.

Activity

Here's a fun way to reinforce what the kids have learned about coral reef partnerships. Make copies of the "want ads" below and pass them out to the kids. Have the kids try to identify which of the reef buddies (described above) might have placed each ad and which might have responded to each ad. To do this they should match up the "box numbers" for each ad. For example, the first ad (box 1) represents an ad that an anemone might place. It goes with the ad in box 4, which represents a clownfish's ad. The kids could write "box 1 box 4" for their answer.

THE REEF WEEKLY — WANT ADS

Safe and secure place for rent. I'll take in anyone that can keep unwanted company away. Write only if you can stand my "stinging" personality. Write: Coral Reef/Box 1	**Strong digger in need of a "watchdog." Bonus: Plenty of extra space in my burrow. Write: Coral Reef/Box 5**
Seeking extra protection and a disguise. Willing to take on hitchhikers. Write: Coral Reef/Box 2	**Worried about safety? I can provide the added protection you need in exchange for a free ride around the reef. Write: Coral Reef/Box 6**
Need a cleaning? Count on me! I'll keep you spotless and healthy in exchange for meals. Write: Coral Reef/Box 3	**In search of a personal groomer. I have a "tough guy" image, but with the right partner, I'm gentle as a lamb. Write if you want to eat in peace. Write: Coral Reef/Box 7**
Fish needs bodyguard and good home. (Not easily "stung.") Willing to help protect home from danger. Write: Coral Reef/Box 4	**"Lookout" fish in search of a ready-made underground hideout. Lots of guard-duty experience. Write: Coral Reef/Box 8**



** Answers in Section VIII.*

Source: Australian UNESCO Project, Marine Science Curriculum Materials for South Pacific Schools, Volume 3, **Corals and Coral Reefs**. Used with permission.

30*. ANIMALS THAT BITE AND STING

The reef environment can be dangerous for those with no knowledge or understanding of the animals that live there. It is natural for a reef animal to defend itself when it is threatened. Learn to recognize and avoid animals that cause harm. Depending on what activities you are engaged in on the reef you will be exposed to different animals.

A. fire worm

B. lion fish

C. rabbit fish

D. box jellyfish

E. Stomatopod

F. moray eel

G. stingray

H. surgeon fish

I. fire coral

J. bluebottle

K. blue-ring octopus

L. *Diadema* sp.

M. stone fish

N. Conus shell

O. Crown-of-Thorns

P. stinging hydroid

Some of the animals on the Great Barrier Reef that can be dangerous to humans. Can you match the names with the pictures? Choose one animal to read about in an encyclopedia or reference book.

Source: William & Edwards. ***Coral and Coral Reefs of the Caribbean.*** © Caribbean Conservation Association, 1993. Reprinted by permission.

31. CORAL REEF PLANTS

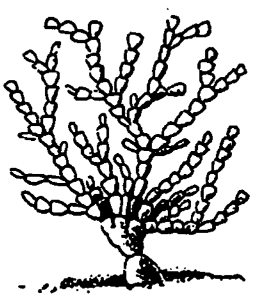
Algae and seagrasses are the main types of plants found in a coral reef environment. They are primary producers and provide the basic food supply for the entire reef ecosystem.

Algae range in size from simple unicellular plants such as zooxanthellae, found in the coral polyp to multicellular branching forms which are commonly called sea weeds. Pigments in the algae give each type its characteristic color, for example red algae, brown algae and green algae.

Two main types of multicellular algae found on reefs are **coralline algae and calcareous algae.** Not only are these algae food for some coral reef animals, but they also contribute to the making of the limestone framework of the reef.

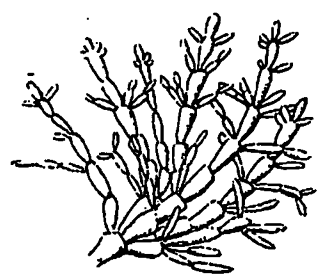
Coralline algae are made up of masses of very fine thread-like filaments, that spread out in thin layers over the reef rock surface. These filaments produce calcium carbonate thus giving the algae an appearance more like a rock than a plant. The encrusting filaments trap sediments of sand, as well as cement the particles of sand together. Thus coralline algae help to stabilize the coral reef structure.

Calcareous algae do not encrust like coralline algae, but grow erect. They too produce calcium carbonate (limestone). When these algae die, the limestone remains produce sand. One type of calcareous algae known as *Halimeda* produces about fifty percent of the sand found on some of our beaches in the Caribbean.
Below are diagrams of some reef algae.



HALIMEDA

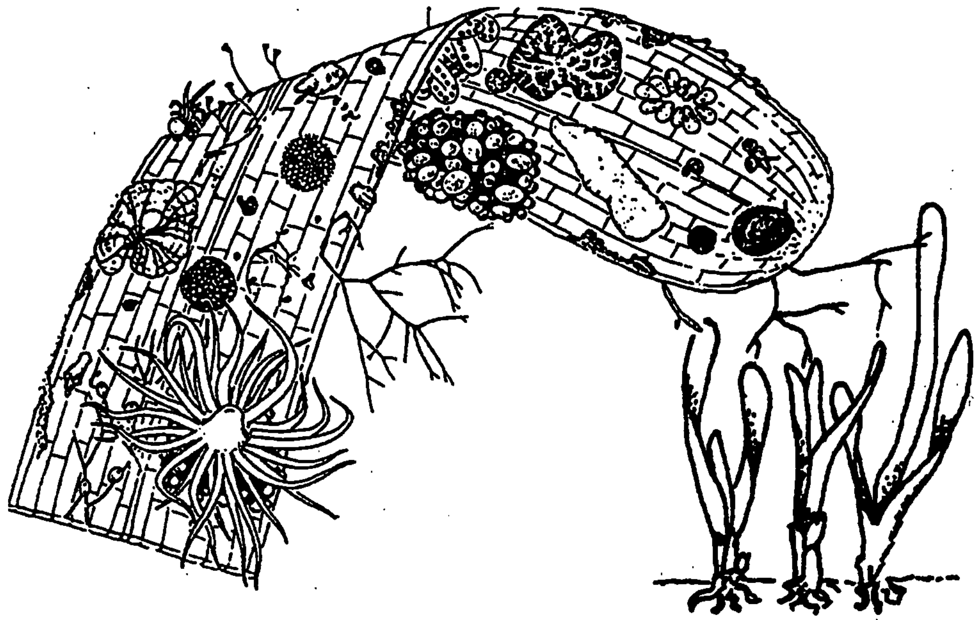
PENCILLUS



CORALLINA

Seagrass beds are often found in areas where coral reefs grow. Turtle grass, manatee grass and shoal grass are three types of seagrasses commonly found in the Caribbean Sea. Unlike algae, seagrasses are true flowering plants.

Seagrasses serve as a habitat and shelter for reef animals such as the young or juveniles of conch and lobsters. These plants also provide food for many herbivorous reef fish. The leaves of seagrass are also a habitat for very tiny organisms.



ENLARGED DIAGRAM OF A SEAGRASS LEAF

Seagrasses have extensive interwoven underground creeping stems with roots attached. These stems are called **rhizomes**. They anchor the plant in the sandy sea bed and help to keep the sea water clean by filtering and trapping large amounts of fine sediments. These rhizomes also bind the sand on the sea bed and prevent the sand from being carried away by water currents. They are important in preventing beach erosion.

Teachers' Notes and Follow-up Activity

The coral reef is a community. Each organism depends on others and each has a role to play if the community is to survive. The interrelationships must therefore be stressed. Take students on a visit to a nearby marine aquarium, or in a glass bottom boat (if available) to observe coral reef plants.

Source: Great Barrier Reef Marine Park Authority. Project Reef-Ed: Educational Activities. Used with permission.

32. FOLLOWING A FRIENDLY FISH

Concepts: Fish structure, Fish behavior, Interrelationships, Adaptations

Skills: Observing, Recording underwater

Aim: To investigate the lifestyle of a single fish. This activity consists of two parts—an introductory exercise and an in-depth exercise for those who wish to investigate their fish further.

You will need:

Snorkeling gear and appropriate protection from the sun
Underwater slate and pencil

What to do:

Introductory activity

1. In a reef pool or harbor follow a particular fish quietly.
2. Observe its feeding behavior. How much searching and "working" for food is performed?
3. What structural adaptations possessed by the fish help it to find and take its food?

In-depth activity—a single fish

4. Select one fish which you can observe carefully. (A parrotfish, butterfly fish or puffer fish is suggested.)
   (a) Observe and record its general structure. Note its size; sketch it, noting scale; record exact color patterns, relative size and position of fins, size, shape and position of mouth.
   (b) Observe and record its
   - method of locomotion (note use of all fins, tail, etc.)
   - method of catching/obtaining food and ingesting—snorkel around with the fish to observe
   - method of perceiving and reacting to the environment
   - sense organs
   - response to changes (waves/depths/other fish/other groups/you)
   - special behavior, e.g., territoriality, special relationships (symbiotic, commensal, parasitic).

Note: To get definitive data you will need to devise a record sheet which
- is easy to use and record on in the field,
- allows you to record factual data such as measurements, numbers.
- allows you to obtain statistically valid data, i.e., number of observations, to enable you to put forward an hypothesis on behavior.

5. After your snorkel, identify your fish by reading.

Ideas for further things to do

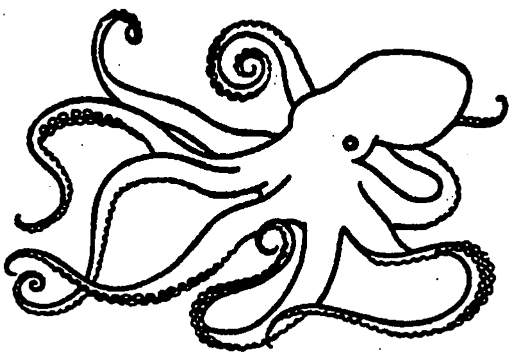
6. Refer to library books and other resources and compare the authors' notes with your own observations.

7. Check previous research findings on the species you've observed.

Source: The Ocean Book: Consider the Connections ..., Center for Marine Conservation, Washington, D.C. and New England Aquarium. Reprinted with permission.

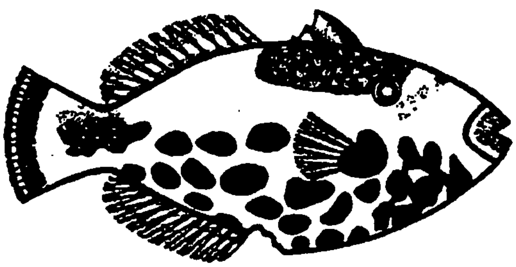
33. IMPORTANCE OF COLOR

Coloration may help hide an animal or draw attention to its role in a coral reef community.



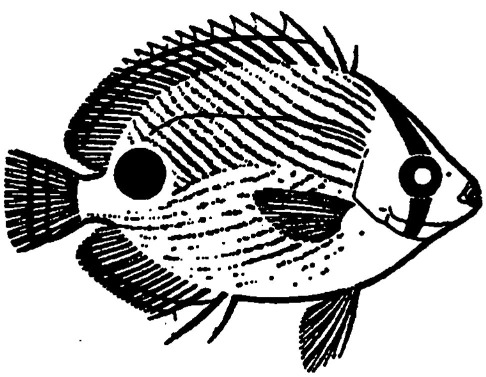
Camouflage
Camouflage coloration helps animals blend in with their surroundings. The octopus changes color instantly from black to gray to red to match its background. It can also change the texture of its skin, becoming bumpy or smooth to blend in with rocks and seaweeds.

⇦*octopus*



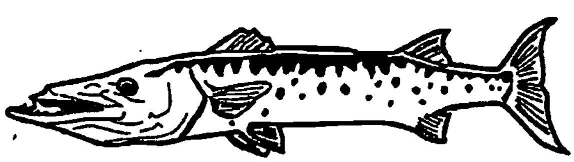
Disruptive Coloration
Spots and stripes break up the body shape of some fishes and conceal them against their backgrounds. This kind of camouflage, called disruptive coloration, is common in coral reef fishes.

⇦*clown triggerfish*



False Eye Spots
Unusual color patterns may hide vulnerable parts of an animal's body. The true eyes of a four-eye butterflyfish are hidden in a band of black, but near the tail are two prominent "false eyes." A confused predator may attack these instead of the real eyes, allowing the butterflyfish to escape in the opposite direction.

⇦*four-eye butterfly*



Countershading
Many open ocean animals have dark backs and light bellies. This protective coloration is called countershading. Viewed from above, dark backs blend with the darkness of the deep ocean. From below, it is difficult for predators to see light bellies against bright sunlit surface waters.

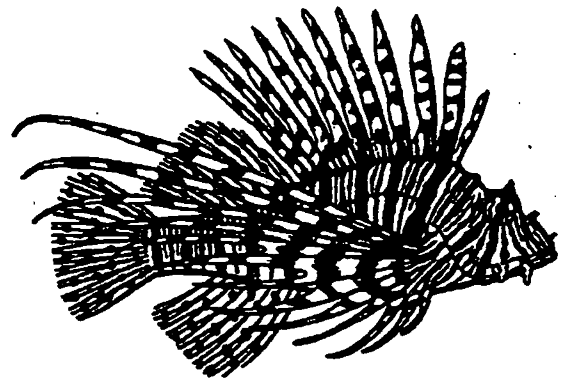
⇦*barracuda*

Advertising Coloration
Some animals have coloration that attracts attention and advertises a special service. Cleaner fishes help other fishes by removing harmful parasites from their skin. Predators recognize the bright color patterns of cleaners and do not harm them because of the useful service they perform.

cleaner wrasse⇨

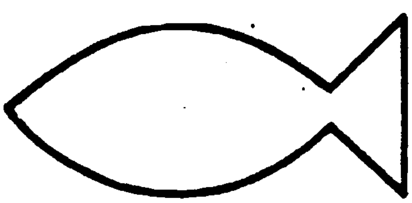
Warning
Some animals are so well protected with spines, poisons, and armor that their coloration is a warning for other species to stay away. The lionfish has brightly striped fins with poisonous spines that it displays to would-be attackers.

lion fish⇨

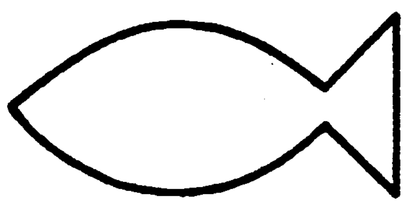


WORKSHEET: COLORATION

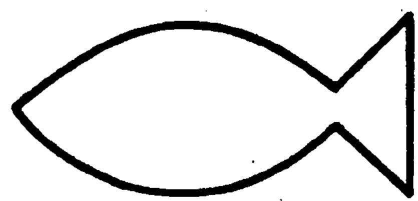
1. **Protective Coloration** helps animals survive in their natural habitats. Protect the fish below by giving them the proper coloration:



Countershading



Disruptive Coloration



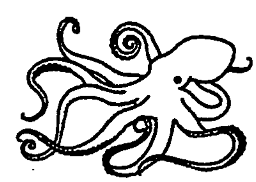
False Eye Spots

2. What is **Advertising Coloration** and how does it help an animal survive?

____

____

3. What is **Camouflage** and how does it help an animal survive?



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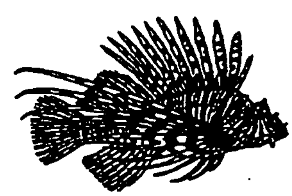
4. What is **Warning Coloration** and how does it help an animal survive?



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Source: This activity is adapted from **Living In Water: an aquatic science curriculum for grades 4 - 6** produced at the National Aquarium in Baltimore, Maryland. Used with permission.

34. HIDE AND SEEK

WHAT DOES IT LOOK LIKE UNDER WATER? WHAT DO ANIMALS SEE? IS CAMOUFLAGE THE SAME BELOW WATER AS ABOVE?

Objectives:

- Students will be able to explain why color patterns that are easy to see in air may be hard to see under water.
- Students will experience the problems predators face when searching for camouflaged prey and develop foraging strategies for these prey.

Introduction:

Some colors of light (wavelengths) are absorbed faster than others when passing through water, particularly red and yellow. Blues are transmitted best. At night, red light is the least available. These facts have interesting consequences for color and color patterns and their distribution among animals that live in water. Fish that live in shallow, well-lighted water may have color vision. But what do most fish see? Fish that live in deep water or are active at night seldom have color vision. Fish that live in murky or muddy water may be almost blind and depend on touch or electrical fields to sense their surroundings.

In this exercise your students will experience what the world looks like to fish that live far enough below the surface that the world looks blue, the only color to effectively penetrate very deep. This activity also models shallow water species that are active at night. On coral reefs, red fish are nocturnal.

Materials:

For Class:

- blue cellophane from school art supply store
- stapler
- clear tape
- string
- underwater photographs cut from magazines that show bright colors and others that are of wide views that are predominantly blue; SCUBA magazines or *National Geographic* are good sources

For Each Student:

- red construction paper 4" x 8"
- other construction paper or poster stock 4" x 11"
- scissors
- pencil

Lesson Plan:

Before Class:

Have the students review their knowledge of fish anatomy in drawing and cutting out a fish made of red construction paper. Did they remember paired pectoral and pelvic fins, the tail (caudal), dorsal and anal fins? [Refer to diagram on page 52.] Explain that the red color is typical of many saltwater fish that hang out around rocks in 10 m (33 ft) or more of water. Many shallow water nocturnal fish are also red, and red is a very common color for deep sea animals generally.

Have each student construct a pair of goggles. Inexpensive blue cellophane available in rolls from school art supply stores is folded to make three or four layers over the eye holes. Tape the cellophane in place. Staple, tape or tie strings to hold the goggles in place. Explain they will use the goggles to see as fish see. Do not allow students to wear the blue goggles for more that five minutes. To do so longer will bleach (temporarily) some of their visual pigments.

During Class:
When the students are not in the classroom, distribute all the red fish around the room against *dark* backgrounds. Turn the classroom lights off and create dim light. It is darker in 10 m of water, or in shallow water at night, than at the surface. Pin or tape the fish to bulletin boards, prop on shelves, put them in corners on the floor. Hold a pair of goggles up to check that you are placing the fish against backgrounds with the same value.

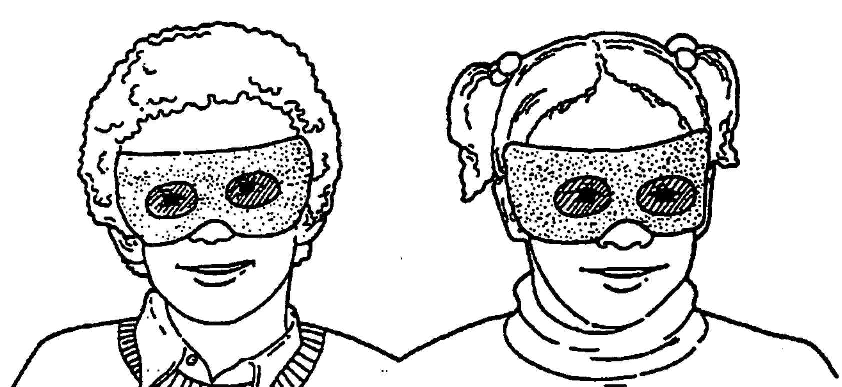
Meet the class outside the room with the goggles. When the goggles are in place, have the students enter the room and sit down. Tell them they are predators searching for red fish in 10 m of water. They are wearing the goggles because blue is the primary color of light that penetrates very far into water. Have them start searching for the fish at the same time. Time them if you want to repeat the exercise without the goggles.

Stop them before all the fish are found and have them sit back down. Remove their goggles. Now can they see the fish they missed? Why were the fish hard to see? The filter allowed only blue light through. The fish reflect only red. Under water there would be no red to see. If you wish, repeat the exercise without the goggles to compare the time it takes to find the fish when red is visible.

Results:
A fish that appears very colorful to us (red) may, in fact, be very well CAMOUFLAGED from predators. The fish is hard to see because red light is missing as it is being absorbed by the water and, therefore, cannot be reflected to the fish's predator's eyes.

Use the color photographs to illustrate. Any colorful underwater photograph was shot with a flash which provided all the wavelengths of light. Any photo in which the predominant color is blue shows what it really looks like under water.

Conclusions:
You cannot make judgments about animals based on human perceptions. Fish in shallow, clear water may see things in a way that is similar to us, but fish that live in dark, murky water or deep water probably do not have color vision and may use vision very little, depending on other senses.



Source: Excerpted from Science and Children's Literature by Mary Cerullo, published by Heinemann, Portsmouth, New Hampshire. Used with permission..

35. CHANGING OF THE GUARD

Overview:

Each of us has a biological clock that tells us when to wake up and when to go to sleep. Songbirds (and most humans) wake with the day and return to roost at night. Bats erupt from caves and barns at nightfall to hunt for insects. Mosquitoes buzz around in search of blood at dawn and dusk.

Coral reefs are larger and more densely populated than any city on Earth. To make room for all its residents, the coral reef community is divided into creatures of the day, the night, and twilight. As one animal crawls out of its den, another prepares to take it over. The daytime crew depends mostly on sight and color to find or to avoid other residents of the reef. Nocturnal animals prowl a world without light, relying on their keen senses of smell, taste, and touch. In between day and night, large predators roam the reef, alert for weary commuters going home after a day of foraging or groggily waking up for a night on the town. Scientists estimate that one-half to two-thirds of all reef fishes are diurnal, that is, active by day. Another one-quarter to one third sleep by day and hunt by night. Only ten percent of all reef species are most active at dawn and dusk.

Activities:

1) Now that you know more about the coral creatures of the day shift, night shift and twilight, which would you rather be? Choose one coral reef animal and write a story about 24 hours in its life. Think about these questions as you prepare your biography: When are you most active? Where do you go to rest? What would you eat? Who eats you? How might you attract a mate or avoid predators? What problems or opportunities do you have in daylight/twilight/nighttime?

2) Create a mural of twenty-four hours on the reef, with three different backgrounds: black for night, grey for dawn and dusk, bright blue for daytime. Have students research which animals are active during each period. Draw them and mount the animals they researched on the most suitable part of the diurnal cycle.

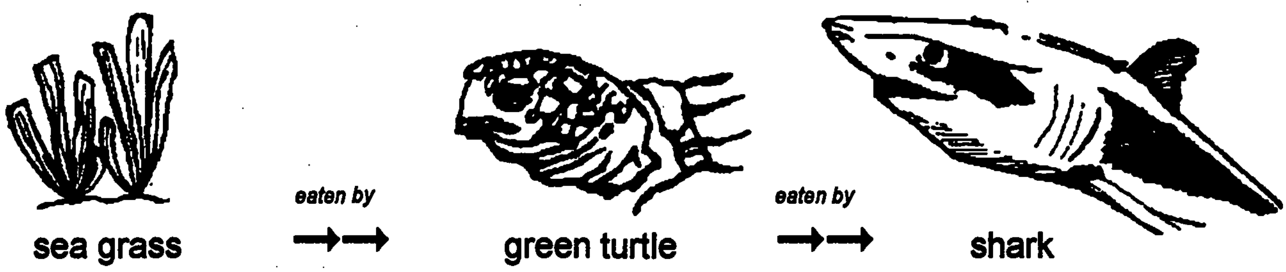
NIGHT	TWILIGHT	DAY
EEL	SHARK	BUTTERFLYFISH
OCTOPUS	GROUPER	CLOWNFISH
SQUIRRELFISH	JACKS	ANGELFISH
SPINY URCHINS	SEVERAL OTHER PREDATORS	CLEANER FISH
HARD CORAL POLYPS		

Source: From "**Life on the Coral Reef**," an educational pack comprising interactive wall-chart, fact/activity cards and teachers notes. Available from Coral Cay Conservation, 154 Clapham Park Road, London SW4 7DE, UK. Tel: +44(0)171 498 6248 Fax: +44 (0)171 498 8447 WWW:http://www.demon.co.uk/coralcay/home.tml

36*. WHO EATS WHO?

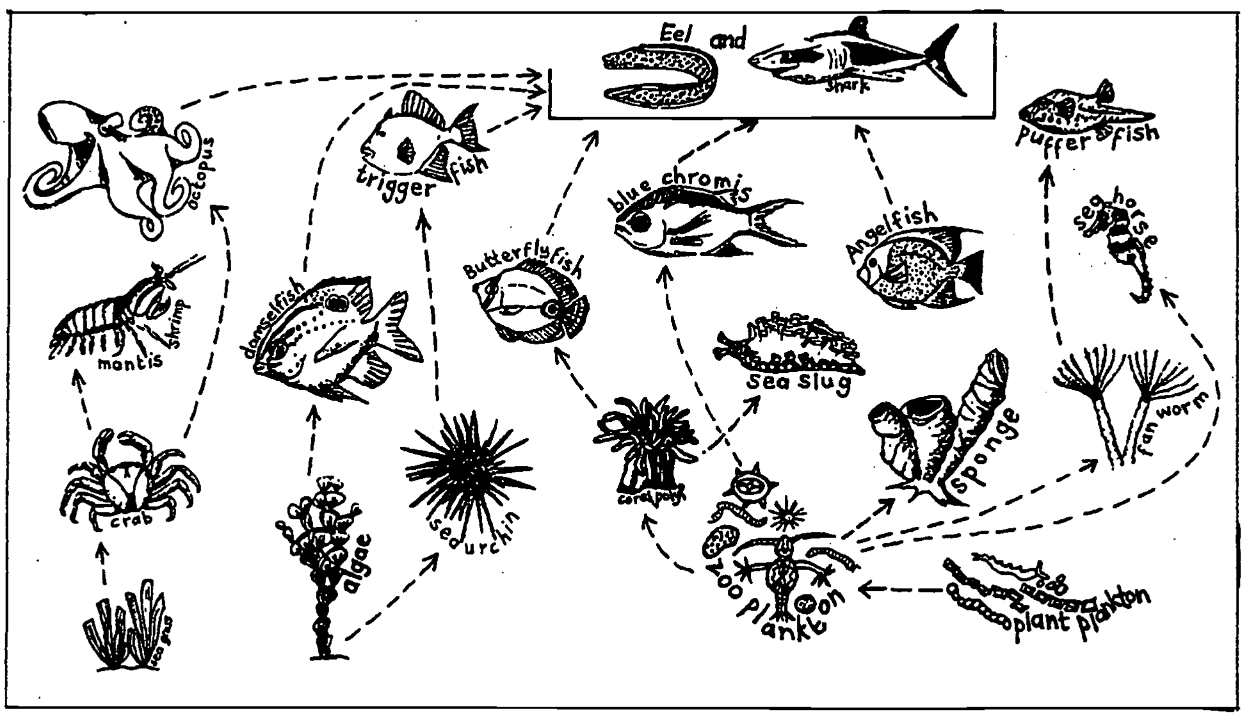
Food Chains

On the reef as elsewhere, all the living things feed on each other. Lets look at an example. In a lagoon green turtles eat seagrass, and sharks eat the green turtles. This is called a **food chain.**



Energy

Energy in a food chain moves from the plant to the first animal, and on the second animal. At each stage **energy** is used for many things. Seagrass uses some of its **energy** to flower and make seeds. The turtle uses its **energy** to breed and move about.



Food chains tell us about **one** feeding relationship. In a place like a lagoon or the reef, there are **many** different feeding relationships which are connected together to form a **food web.** Food webs are not fixed because feeding relationships can change. In the food web below all the plants and animals depend on each other.

Solve a Puzzle

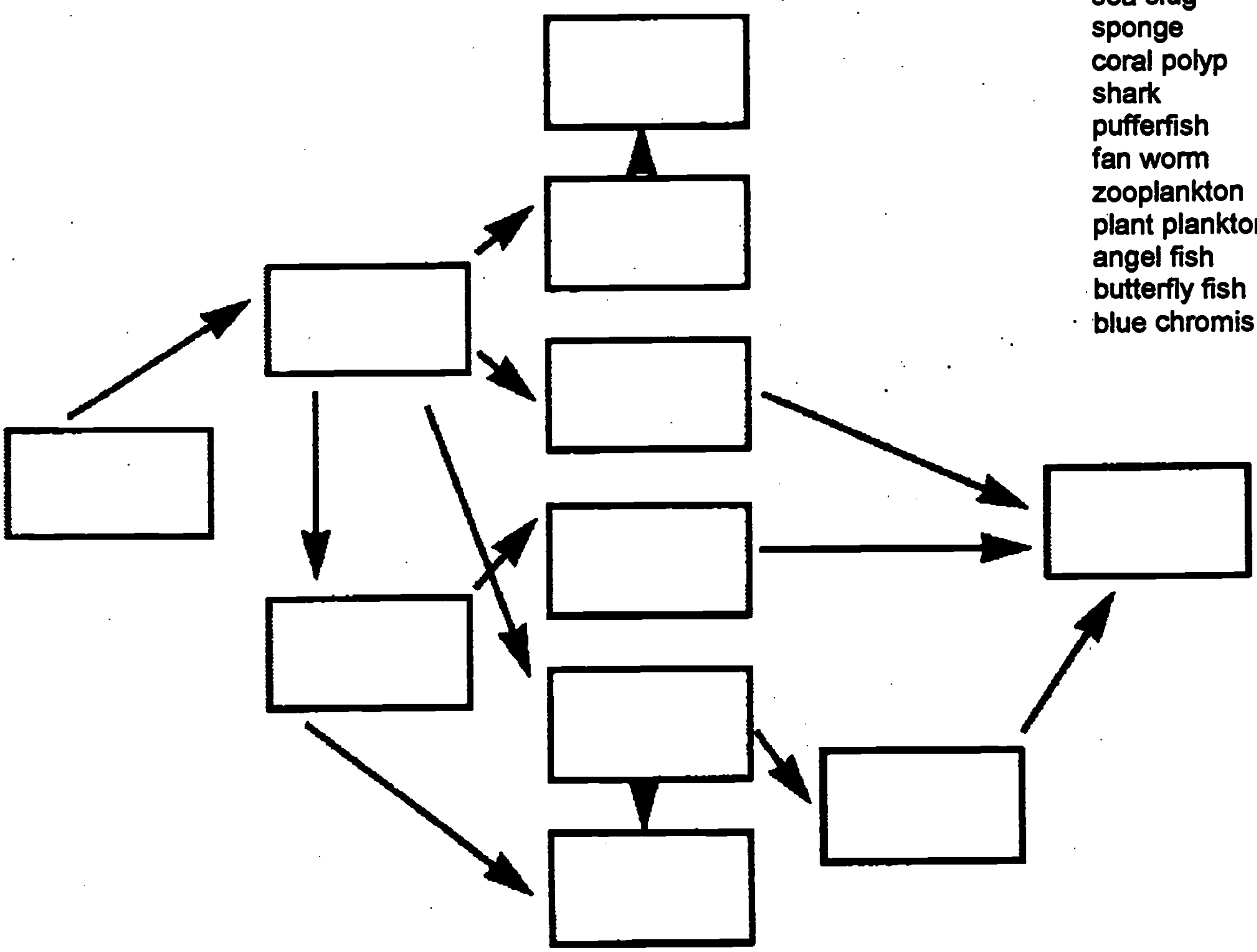
Copy out the boxes arrows and species list onto a whole page and fill in the answers.

Facts to help you:

- Plankton are very small, there are two types: plants and animals.
- Food chains start with a plant.
- Arrows show the movement of energy.
- Sea slugs eat sponges and coral polyps.
- Puffer fish eat fan worms.
- Animal plankton eat plant plankton.
- Coral polyps eat animal plankton.
- Sharks eat angel fish, butterfly fish and blue chromis.
- Fanworms eat plankton.
- Butterfly fish eat coral polyps.
- Blue chromis eat animal plankton.
- Angelfish eat sponges.
- Sponges eat animal plankton.

Tick off the species when you have used them.

sea slug
sponge
coral polyp
shark
pufferfish
fan worm
zooplankton
plant plankton
angel fish
butterfly fish
blue chromis



Source: Corals and Coral Reefs: 4 - 8 Teacher's Guide. A Sea World Education Department Publication. Used with permission.

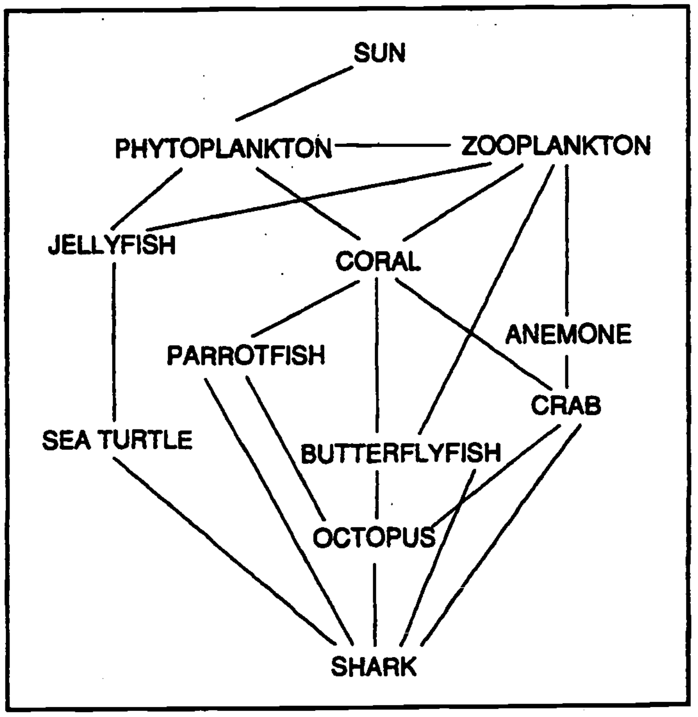
37. WEAVE A FOOD WEB

Objective: Students will discover the food/energy relationships within a food web in a coral reef habitat.

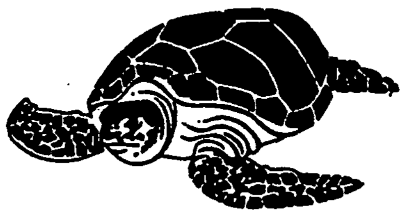
Materials: Copies of the following page enlarged 200% (so that you have one animal for each student), yarn or string, large playing area

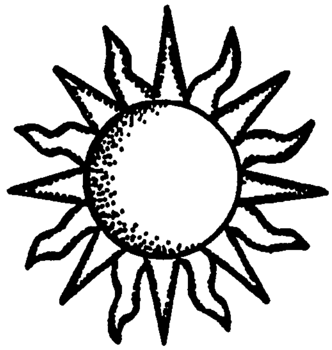
Action:

1. Cut out pictures of members of the reef ecosystem and use yarn to create signs students can wear around their necks. (Be sure you only have one sun.) Roll the rest of the yarn into a ball.
2. Define a food web for your students: write the words sun, phytoplankton, jellyfish, and sea turtle on the board and draw pictures to symbolize each one. Share with students the idea that phytoplankton gets its energy from the sun, the jellyfish gets energy by eating the phytoplankton, and then the sea turtle gets its energy by eating the jellyfish. Explain that most animals eat more than one thing. Tell them that the transfer of energy through food between life-forms in an ecosystem is called a *food web.*
3. Take students out to playing area, and have them form a large circle. Give everyone an animal card to wear.
4. Have the person who is wearing the sun card hold one end of the string. Ask students which member of the food web gets its energy from the sun (phytoplankton, a type of plant). As they volunteer answers, unroll the yarn and have students wearing those signs hold onto the yarn. Next, ask students which members of the food web get their energy directly from phytoplankton (coral polyps and zooplankton—refer to diagram below). Have those students hold onto the yarn, too. Continue until the food web is complete.
5. Direct students to gently and carefully lay the yarn on the ground so that the web stays intact. Have them step back and notice the pattern created by the interaction of organisms.
6. Explain that many factors can disrupt a food web: pollution, overfishing, and habitat destruction. As you name each factor, use your foot to discreetly disturb part of the yarn web.
7. Have the students pick up the yarn again and ask them if the web looks the same. Explain that many factors including pollution, habitat destruction, and overharvesting resources destroy ecosystems.
8. Instruct students to set the web down again. Ask all corals to take a step back. Have students pick up the web again. Ask students what happens to the food web when an animal becomes extinct.

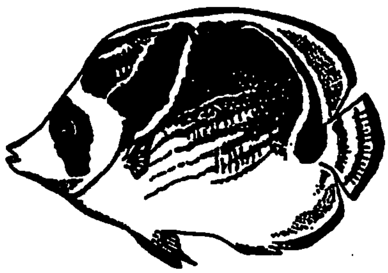


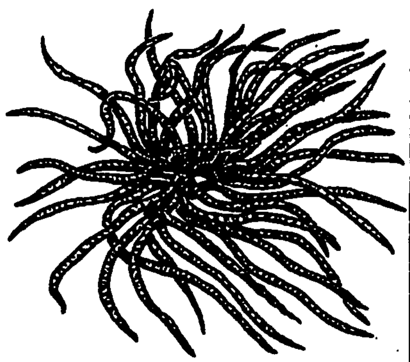
FOOD WEB CARDS


sea turtle

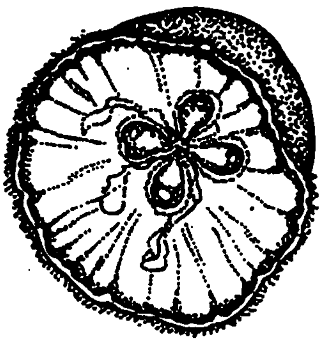

sun

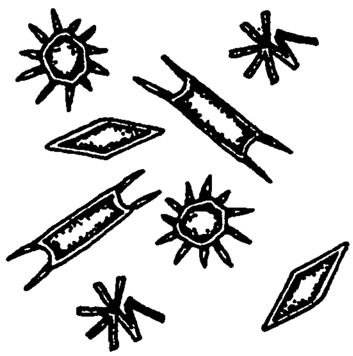

zooplankton


butterflyfish


anemone


octopus


jellyfish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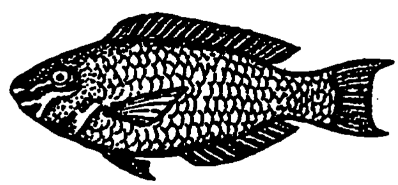
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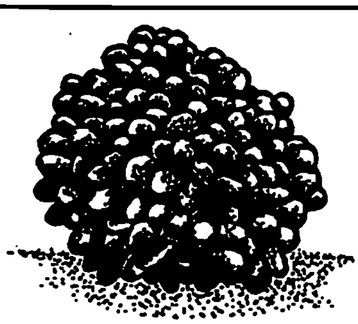
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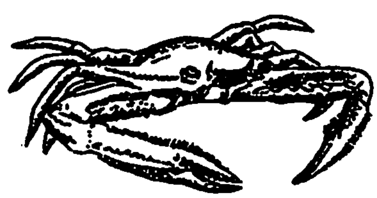

crab


shark

Source: Coral Reef Teacher's Guide, produced by the World Wildlife Fund, 1250 Twenty-Fourth St. NW, Washington, DC 20037-1175. Used with permission.

38. THE CORAL REEF COMMUNITY

Goal: to familiarize students with important members of a Caribbean coral reef ecosystem, and the role they play there.

Objectives:
1. Students will be able to name at least six animals common to Caribbean coral reef ecosystems.
2. Students will be able to explain why some of these animals are restricted to certain parts of reef systems.
3. Students will be able to describe energy transfer from the sun, to plants, to plant-eaters, and finally to animal-eaters.
4. Students will be able to define the term "food web," and ecosystem.

Materials Required:

Coral Reef Clue Cards (following procedure)
Coral Reef Cards (illustrated cards following Coral Reef Clue Cards)
(Cut out and paste both sets of cards to light cardboard.)
Thumb Tacks (about 30)
Bulletin Board
Large piece of newsprint with Reef Outline drawn upon it
Blackboard and chalk

Student Background:

Hundreds of different types of plants and animals live in coral reefs—certainly more than we could learn about here. In the following activities, we will learn about members of important groups of reef-dwellers and reef-neighbors.

First, we will just get to know them, finding out about where they live on the reef, and interesting details of the way they live.

Next, we will investigate their eating habits. You know that you must eat food in order to grow and to have enough energy to go to school, play, and just to be healthy. Think for a moment about that phrase "to have enough energy." What do people mean when they talk about that kind of "energy"? (Discuss.)

All living things, plants and animals alike, need energy. Energy is the ability to do any kind of work—to move, to grow, even to think takes energy.

If energy is so important, where does it come from? (Discuss.)

We get it from the plants and animals we eat. But where do animals and plants get energy from?

Animals get energy from eating plants and animals, just as do we. But what about plants? They don't eat. Does anyone know where plant energy comes from? (Discuss.) They too need energy for growing and reproducing. When you eat a mango, you are eating energy that the mango plant has transformed into food.

Plants harvest energy from the sun. That's where the whole business of energy begins—for us, and for the creatures of the reef. Plants change the sun's energy into plant tissues—leaves, stems, or seaweeds. Large numbers of animals eat those plants, and other animals eat them, in turn.

Some scientists organize communities of living things according to "who-eats-who." This type of organizing tells them how energy from the sun is transferred among members of natural communities such as coral reefs.

There are three main groups in this system:

- Animal-eaters or Carnivores. These animals prey only upon other animals.
- Plant-eaters or Herbivores. These animals eat plants only.
- Plant-and-animal-eaters or Omnivores. These animals have a mixed diet of both plants and animals.

Can you think of examples of these groups? (Discuss.)

Today's activity looks at the complex web of food and eating relationships that exist in a coral reef. In fact, scientists call these relationships a food web. You are going to make a coral reef food web in the classroom, after you learn some of the creatures that live there.

The food web you make here will not be totally realistic. This is because you will not learn the amounts of various animals and plants that live in a coral reef. In the ocean, there are relatively larger numbers of small bottom dwellers that eat plants, small fishes of all kinds, and the plants themselves. Very large animals, such as sharks, have no other creatures that eat them—unless we are talking about baby sharks. Extremely small sharks probably get eaten by many large fish. It is hard to show such a complex food web in your classroom. But, you will get the idea of how food webs work. That's the most important idea.

During this activity, remember this little poem written in the 1800s. The poet sums up the idea of a food web in a funny way*. (Ad infinitum is the Latin phrase meaning "and so on, forever.")

> Great Fleas have little fleas upon their back to bite'em,
> And little fleas have lesser fleas, and so, ad infinitum.
> And the great fleas themselves in turn, have greater fleas to go on,
> While these again have greater still, and greater still, and so on.
>
> **from A Budget of Paradox, Augustus Morgan, 1806-1871*

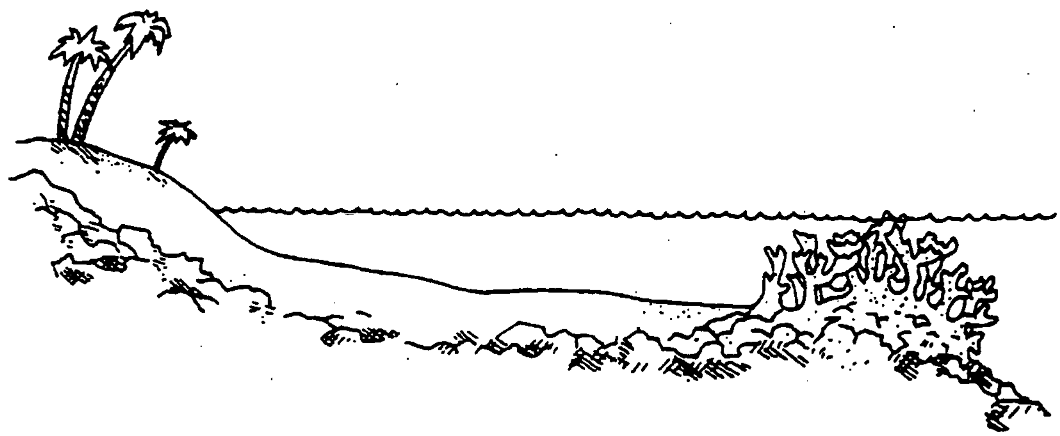
Procedure:

1. Prior to activity assign background reading to students. [E.g., **Coral Reef Coloring Book** written and illustrated by Katherine Orr, © 1988, Stemmer House Publishers, Inc. This coloring book is derived from a project funded by World Wildlife—U.S. Encourage students to color the illustrations.]

   Cut out the Coral Reef Clue Cards (following procedure). Paste them to light cardboard.

   Cut out the illustrated Coral Reef Cards (following Clue Cards). Paste them to light cardboard. Put them in a basket or box.

   On a large sheet of newsprint, draw the outline of a coral reef system as shown below. Make a large drawing, so that there will be enough room to pin the Reef Cards in place. Color and add other details (no plants or animals on the cards) according to your artistic talents.



   Post this drawing on the classroom bulletin board. Keep extra tacks nearby.

   On the blackboard, write three headings: Plants, Animal-eaters, Plant-eaters, Plant-and-Animal-eaters.

2. In class read Student Background (above) aloud.

3. Pass out Reef Cards, one per student. If there are cards left over, give some students two or more. If there are too few cards, have students team up.

4. Explain the outline of the reef you have drawn. Tell students that they must do three things with their cards:
   (a) First, they must listen to you read clues, raising their hands as soon as the Coral Reef Clues describe the animal or plant on their Reef Card. You can call on students for the name of their animal or plant, or, for a livelier atmosphere, have students call out the name.
   (b) Secondly, the first student to name the correct animal or plant must pin their card to the part of the reef community where their creature belongs. They should explain their reasoning to the class.
   (c) Thirdly, they must write their animal or plant's name on the blackboard, underneath one of the headings you have written there.
   Pause to make sure that everyone understands these instructions.

5. Begin reading Coral Reef Clues at random, one card at a time.
   DO NOT READ THE LAST STATEMENT ON EACH CARD. Allow time for students to think about the clues. Repeat if necessary.
   (Sometimes, several students will raise their hands at once. Tell them keep their hands up until they hear a clue which does not apply to their creature. This will probably happen several times. Students will soon realize that *your* clues proceed from general to specific information.)

6. When a student correctly identifies an animal or plant, have student show the class what it looks like, and then pin the card on the reef outline. The student should explain the position—why they place the card where they do—seaward beyond the reef, or between reef and shore, or on the reef itself. Also, tell the students to consider if the animal or plant is to be placed on the bottom, floating, or swimming in the water?

7. Give the student the corresponding Coral Reef Clues Card. Ask student to re-read the clues and decide which column on the blackboard applies to the creature on the card. Student should write the animal or plant's card under one column, explaining why to class.
   Student should sit down again, keeping the Clue Card.

8. Then read another Reef Card Clue. Continue until all cards have been pinned on the reef outline.
   If the game begins to lag, have students place cards on reef drawing, but write the plant or animal's name in the correct blackboard column while you go ahead and call new clue cards.

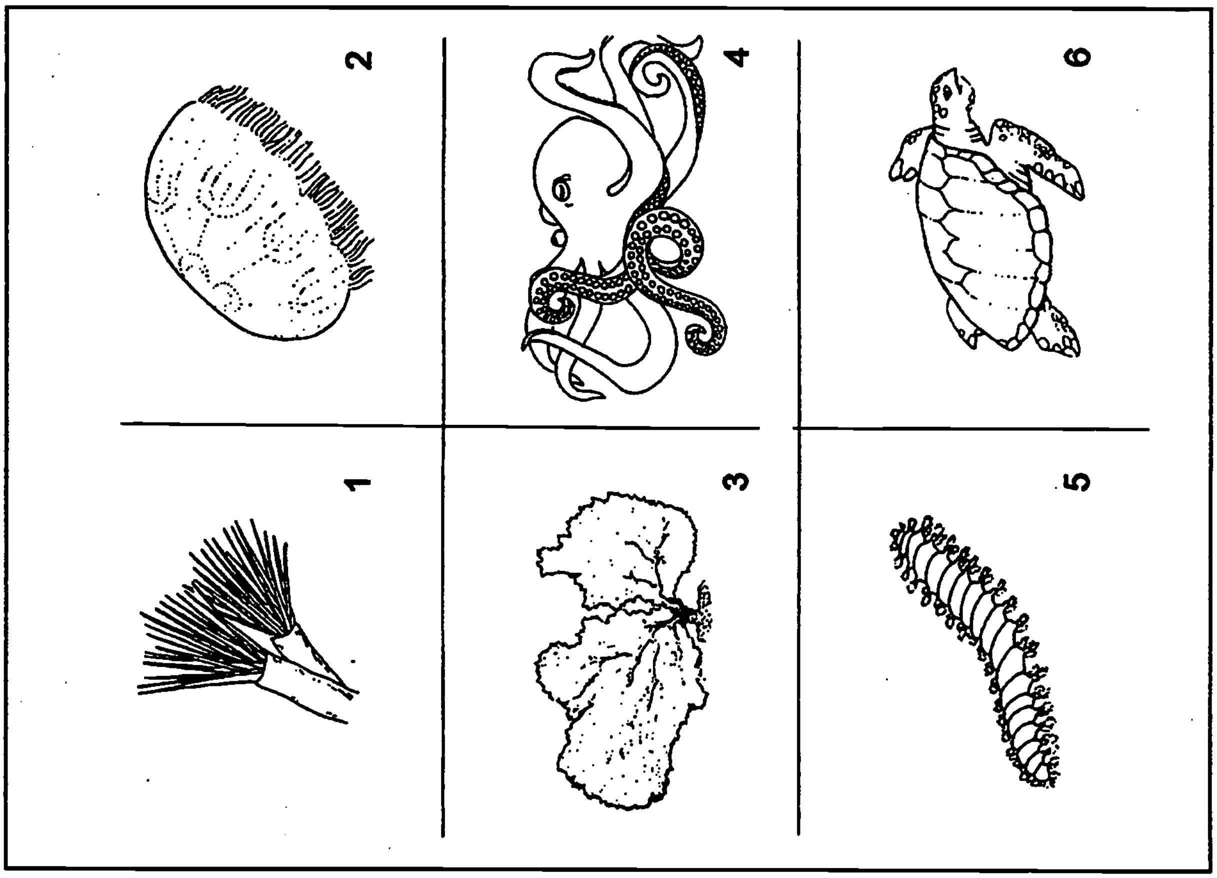
9. After all the plants and animals have been written in one of the three columns, discuss the following questions with the class:

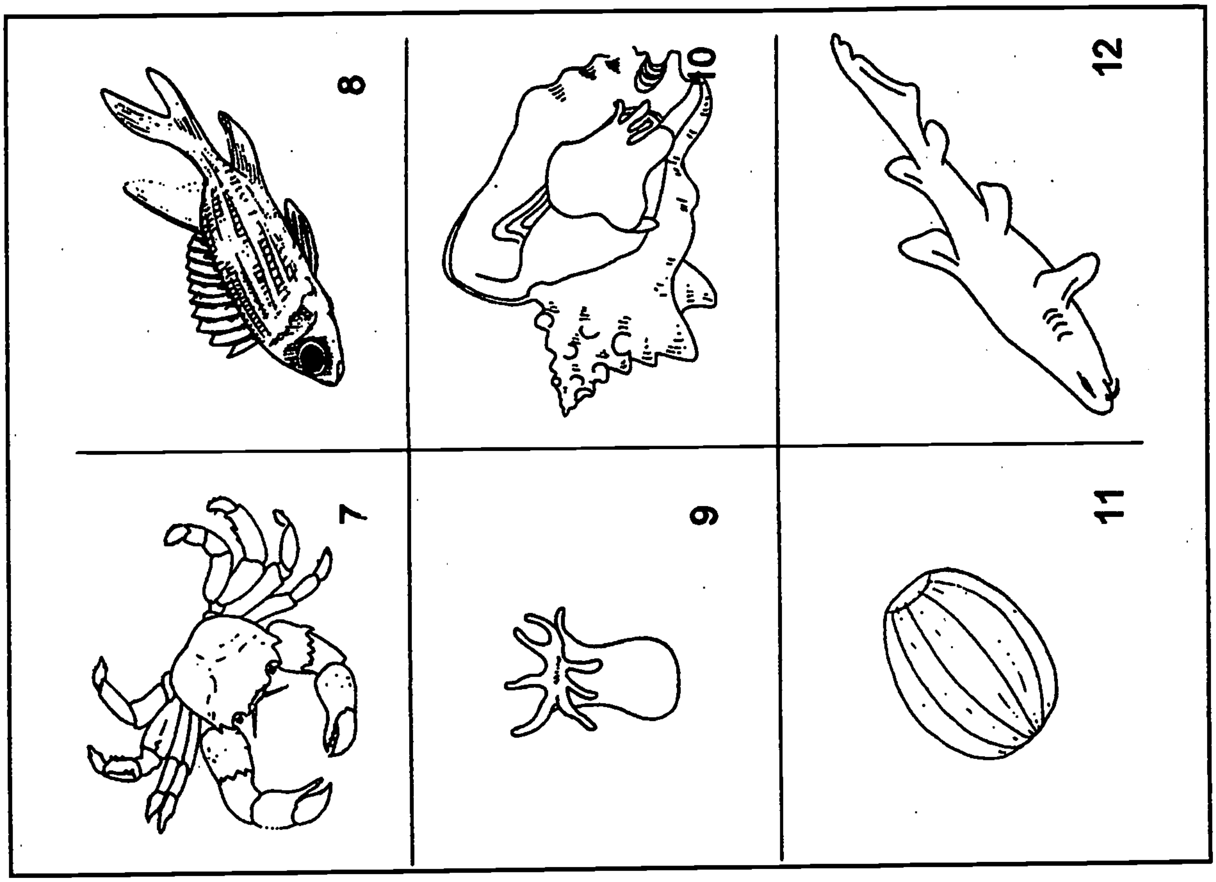
   - What common characteristics are shared within each group?
   - Can we tell which group is the most important?
   - What would happen if all the animal-eaters disappeared from the reef?
   - What would happen if all the plant-eaters disappeared?
   - What would happen if all the plants died?
   - Can a coral reef be healthy if any of the groups disappeared?

1. I live in a hard tube that I build for myself. I draw myself quickly into my tube if I need to hide from some animal trying to eat me. With my gills, I catch tiny, drifting animals called "zooplankton." I have fine, thin gills on my head. They filter my food. I am a type of <u>worm</u> with bristles. I am a FEATHER DUSTER WORM.	**2.** I have a radial, or circular type body outline. I swim freely on the surface of the ocean. My stinging tentacles catch fish, which I eat. I am almost clear and transparent. Loggerhead turtles eat me. I am a MOON JELLYFISH.
3. I am a whole colony of animals, all alike. I grow into a fan-shaped creature that waves back and forth in the water. With my tentacles I catch small drifting animals called "zooplankton." Fireworms eat me. I am a type of "soft" coral. I am a SEA FAN.	**4.** I possess neither shell nor backbone. I crawl along the bottom and hide in cracks and holes of the reef. I can change color quickly, and hide in a cloud of inky water. I catch clams and snails. Eels and groupers eat me. I have eight arms. I am an OCTOPUS or SCUTTLE.
5. My body is divided into many segments. Each segment has legs below and bristles above. My bristles sting! I crawl around the reef and eat coral polyps. I am a type of <u>worm</u> with many bristles. I am a FIREWORM.	**6.** I have a backbone, four flipper-like legs, and a hard shell. I breathe air Lizards and snakes are closer relatives to me than fishes. I visit the coral reefs and seagrass beds. There I eat sponges and sea grasses, especially turtle grass. People kill many animals like me for our meat and shells. People and dogs eat our eggs, which are laid on beaches. We are in danger of disappearing from the face of the Earth. I am a GREEN SEA TURTLE.
7. I am a "jointed-leg" animal, with a hard outer shell for a skeleton. I have ten limbs. Two of my limbs are much larger than the others. They have claws which I use to catch and crush my food. I eat small fish, pieces of sea animals, and other things I find on the sea bottom. I especially like eating sea urchins and snails. I am a CORAL CRAB.	**8.** I have a backbone, scales, and fins. I am bright red, with big, round eyes. I have very sharp spines on my top fin. I hide under corals. I swim through the water and eat shrimp and small fish. I have to be careful though, because Groupers and Eels eat me. I am a SQUIRREL FISH or POPEYE ANTI.
9. I am one individual in a colony of animals just like me. I have tentacles with stingers. I deposit a stony skeleton below me. I catch small drifting animals called "zooplankton." Colonies of animals like me make up a coral reef. Parrotfish and Foureye Butterfly Fish eat me. I am a CORAL POLYP.	**10.** I live in a beautiful, spiraling shell. I move along the sea bottom and eat algae. I lay my eggs in the sand. Spiny lobsters eat me when I am small. When I am bigger, people catch me for food. I am a type of snail. In the past, there were many like me in the Caribbean. Now we have become harder to find. I am a "LAMBI" or QUEEN CONCH.
11. I have a radial, circular-type body form. I drift freely through the water, though you may find me washed up on the beach. I feed on small animals called zooplankton. I am almost clear and colorless. Jellyfish eat me. I am called a SEA WALNUT	**12.** My soft backbone and skeleton are made of cartilage. I look like a fish, but I am not a true fish. I have a good sense of smell, and two whisker-like "barbels" near my mouth. The barbels help me find food. I eat clams, crabs, and lobsters. I sleep in coral reef caves. Many people are afraid of me, but I am seldom dangerous to them. I am a NURSE SHARK.

13. I am a spiny-skinned animal, with a star-shaped body. I have five long, thin arms. I move on many tiny feet on the bottom of my arms. If I lose an arm, I can grow one in its place! I eat algae and bits of dead plants and animals on the reef. I hide from daylight in dark cracks and crevices of the reef. I am a BRITTLE STARFISH	**14.** I don't eat food because I make my own food using energy from the sun. I grow on the sandy bottom between the reef and land. I am a plant. I have long, thin leaves. Many young fish, shellfish, and other animals find shelter among my leaves. Turtles eat me. I am TURTLE GRASS.
15. I have a backbone, fins, and scales. I have a long, smooth body, and very sharp teeth. I swim very fast. I eat many small fish such as four-eyed butterflyfish, and parrotfish. Few other animals bother me, but humans sometimes catch me. I am a BARRACUDA.	**16.** I have a tube-shaped body with tentacles. I usually grow attached to a solid surface, such as rocks or seashells. My tentacles catch small fish. Sometimes I grow on seashells in which crabs are living. I steal bits of food from the crab, and protect it from octopuses and other crabs. I am eaten by starfish and sea slugs. I am a SEA ANENOME.
17. I have a soft body, with ten long arms. These arms help me swim freely and quickly—to people it looks as if I am swimming backwards. Two of my arms are long tentacles which catch my food—small fish. I can change color quickly. Sharks and people eat me. I am very fast. I am a SQUID or a CUTTLEFISH.	**18.** I belong to a group of unrelated animals that come in many shapes. The only thing we have in common is that we are very tiny. You could see me only through a magnifying glass or a microscope. Some of my group grow up to be larger animals. Some stay tiny. Probably trillions of animals like me drift through a reef's waters. Some of my group eat tiny algae plants. Others eat members of our own group! I am a ZOOPLANKTON.
19. I have a backbone, fins, and scales. I am round-shaped almost like a coin. I eat zooplankton (during parts of my life), the soft polyps of corals, and various worms. I have two big spots near my tail. It fools bigger fish—such as barracudas—that try to eat me. I am a FOUREYE BUTTERFLYFISH.	**20.** I am a jointed-leg animal, with a hard, outside skeleton. I have ten legs. After I lay my eggs, I carry them under my curled-under tail. I have two large antennae which I use to defend myself. I eat snails, worms, and crabs. Groupers eat me. People catch and eat so many like me that not many of us are left. I am a SPINY LOBSTER.
21. I am a spiny-skinned animal, with a circular body shape. I eat algae growing along the reef and ocean floor. I have long spines to protect myself. Turbot, or queen triggerfish eat me. I am a LONG-SPINED SEA URCHIN or SEA EGG.	**22.** I have a backbone, fins, and scales. My funny mouth looks like the beak of a bird. I am brightly colored. I am one of the largest reef fish, but I also eat algae growing on dead coral and inside coral polyps. Barracudas eat me. I am a PARROTFISH.
23. I have a backbone and fins. I am quite big. I am not a shark or a fish, however. My body is warm, like yours. I breathe air. I come in from the open sea to visit the edge of the reef. I often travel in schools, or groups. I eat tuna, sardines, and other fish that swim in schools. I am a DOLPHIN or PORPOISE.	**24.** I have a backbone, fins, and scales. I have a soft skeleton, like my relative, the shark. I have a barb on my tail. It has a nasty sting. My body is very flat, and I spend most of my time lying partly buried on the sandy bottom. I eat snails, crabs, and clams. I am a RAY.

25. **I have a backbone, fins, and scales.** **I have a big mouth, and am marked with spots and stripes.** **I can swim, but usually I keep still and try not to be seen.** **I am eaten by sharks, and caught by fishermen.** **I eat small fish like Squirrel fish.** **I am a GROUPER.**	**26,** **I have a backbone, am an air-breather, and live on land.** **I eat groupers, turtles, squid, parrotfish, conch, and many other animals.** **I often catch so many animals on the reef that they have a hard time surviving.** **Sometimes, things that I do on land hurt animals and plants of the reef.** **I use coral to decorate my body.** **I am a HUMAN BEING.**
27. **I have a backbone, gills, fins, and tiny scales.** **I am well-known for my large, fierce jaws.** **I am long and snake-like.** **I eat octopuses, squirrel fishes, and sometimes eat chunks off careless SCUBA divers.** **I am a MORAY EEL.**	**28.** **I am a plant.** **Some plants in my group are so small that they drift in the water without being seen.** **Others grow large, leafy or grass-like.** **Some plants in my group grow on stones or dead coral.** **I need only sunlight, water, and substances dissolved in the water to live.** **I am eaten by snails like the queen conch, parrotfish, and many baby fish and sea creatures.** **I am ALGAE.** **When I drift in the water, I am called PHYTOPLANKTON.**





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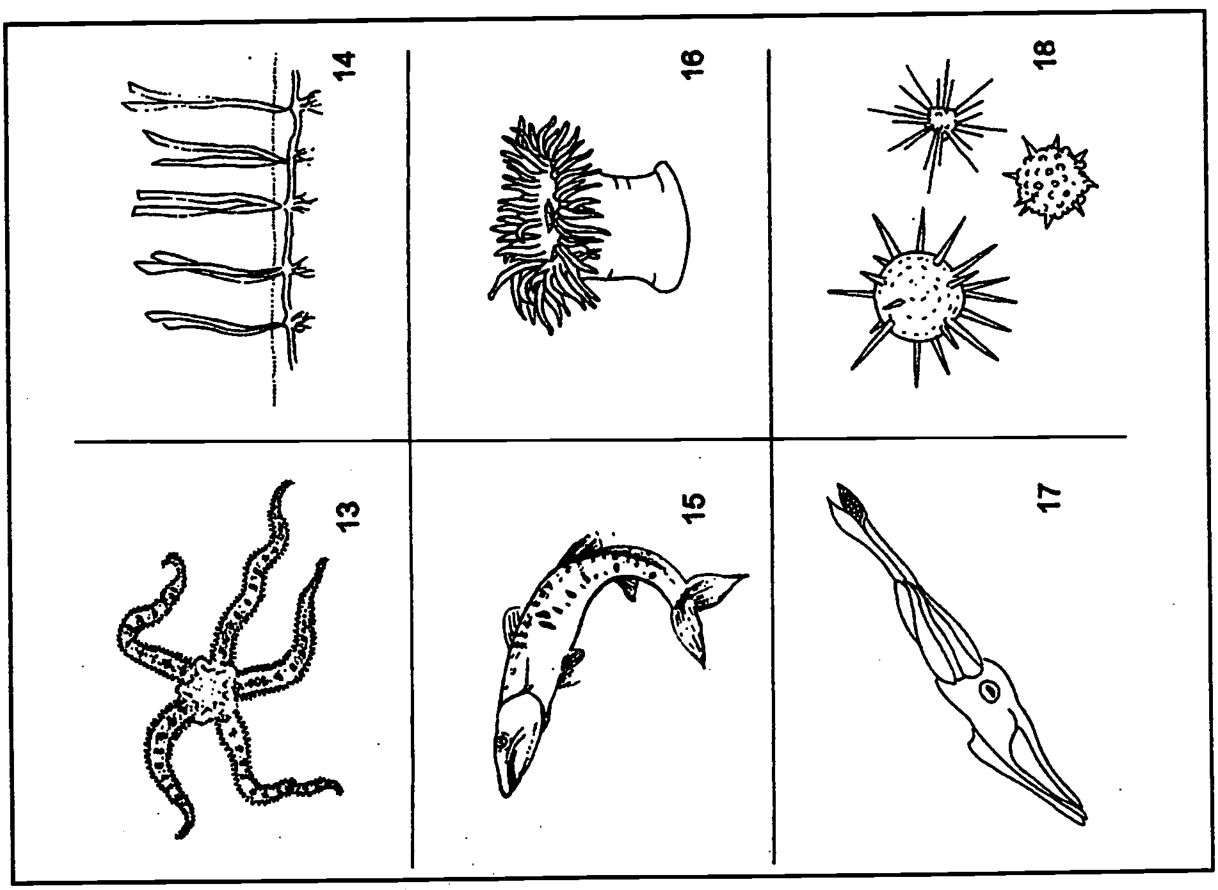

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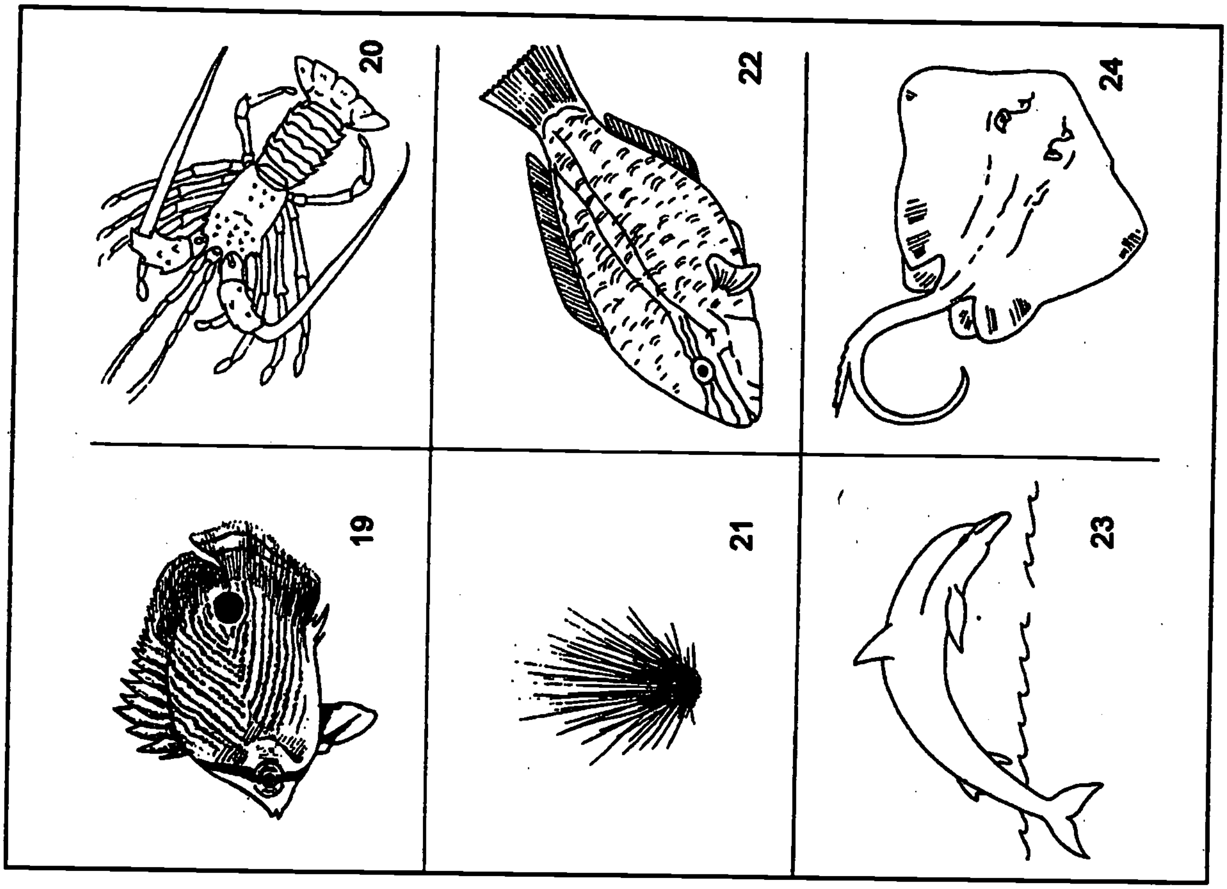
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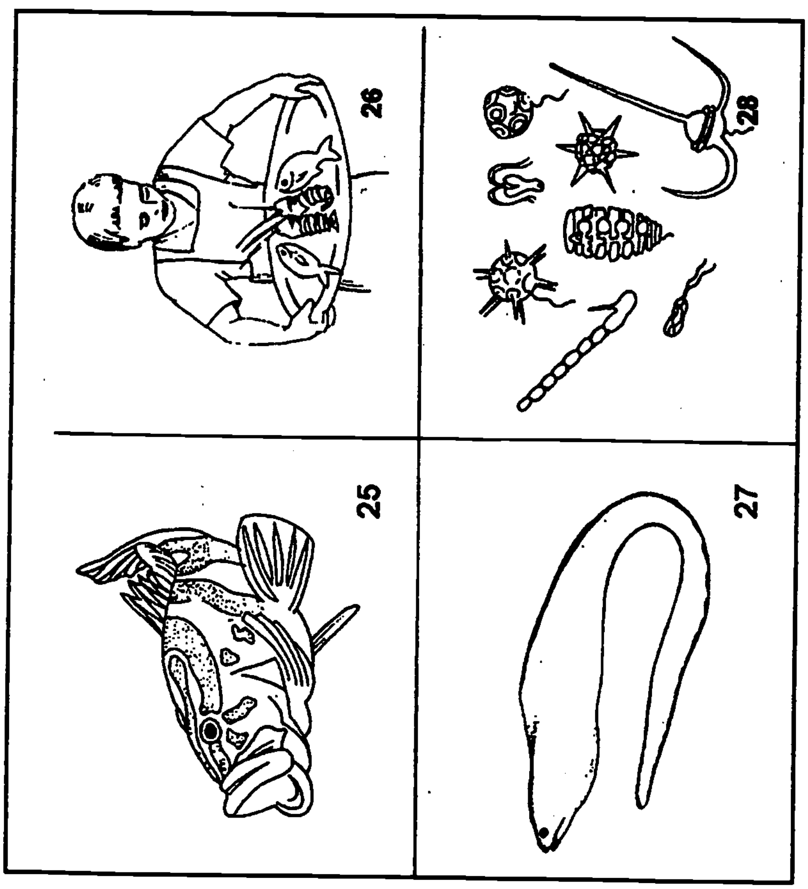
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Source: This acitivity is adapted from **Coral Reefs: A Gallery Program** produced at the National Aquarium in Baltimore, Maryland. Used with permission.

39*. FEEDING FRENZY

The graph below shows the results of samples taken from the stomachs of patch reef fish and from the floor of the reef itself. Use the graph to answer the following questions:

1. Which prey items are most abundant?
2. Which prey items are eaten the most?
3. According to these results, do you think that the reef fish studied rely on worms as a primary food source?
4. What other factors might have affected these results?

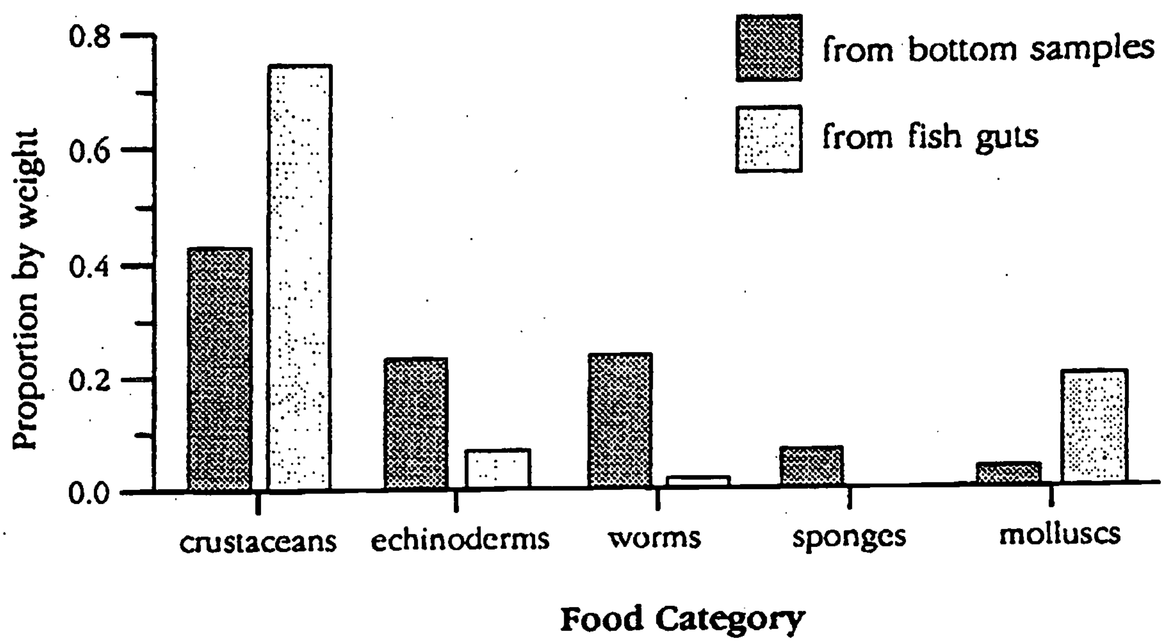


Figure 1 Comparison between weight of prey consumed (from all fish guts) and the composition by weight of prey (from patch reef habitats), for a fish assemblage from the northwestern Hawaiian Islands. Data are from Parrish et al. (1985).

[§]Peter F. Sale, The Ecology of Fishes on Coral Reefs. San Diego, CA: Academic Press, 1991, p. 161.

* Answers in Section VIII.

Source: Coral Forest Teacher's Guide. Coral Forest, 400 Montgomery Street, Suite 1040, San Francisco, California 94104 Tel: (415)788-REEF FAX: (415)398-0385 e-mail: coral@igc.apc.org Used with permission.

40. CORAL REEF COMPARISONS

Objective: Students use compiled data to create a variety of graphs and use these graphs to draw conclusions about coral reef populations.

Interdisciplinary Index: Math, Science

Vocabulary: data, species, population, herbivore, carnivore, omnivore

Materials: graph paper, colored pencils or markers, overhead projector and transparencies (optional)

Presentation:
1. Tell students that they are going to compare the number of various coral reef species found on an Australian reef and a Caribbean reef.
2. Put the following data on an overhead or the chalkboard for everyone to see.

% of Total Community

Species	Australia	Caribbean
Damselfish (herbivore)	18%	20%
Parrotfish (herbivore)	8%	5%
Giant clam (herbivore)	7%	0%
Barracuda (carnivore)	3%	3%
Grouper (carnivore)	10%	15%
Shark (carnivore)	2%	3%
Angelfish (omnivore)	12%	9%
Hard coral (omnivore)	31%	35%
Sea star (omnivore)	9%	10%

(Note: The percentages given here are fictional, end are presented for the sake of comparison only.)

3. Discuss and describe the species listed.
4. Have students construct a bar graph comparing the percentage of herbivores, carnivores, and omnivores which dwell on the Australian reef.
5. Once the graphs are completed, discuss the following questions.
   - Which group accounts for the largest population in the Australian reef? Smallest?
   - What percentage of coral reef life eats plants? (Include both herbivores and omnivores)
   - Predict what would happen to the number of carnivores if the number of herbivores decreased.
   - Predict what would happen to the number of herbivores if the number of carnivores decreased.
6. Repeat steps 4 and 5 using data from the Caribbean reef.
7. Have students construct a bar graph comparing the percentage of each species of herbivore in the Australian reef to the percentage of that species in the Caribbean reef.

8. Repeat this process for the carnivores and omnivores, and discuss any similarities or differences that may occur.

Follow-up/Extension:
Have students average the two percentage figures for each species. Once students have calculated the average, have them graph it on a large piece of paper. Students can then draw pictures of each species represented and arrange pictures and graphs on a bulletin board.

Source: This activity is adapted from Coral Reefs: A Gallery Program produced at the National Aquarium in Baltimore, Maryland. Used with permission.

41*. REEF HOMES: ZONATION OF A CORAL REEF

One interesting feature of reef-building corals is that their growth form varies with their location. Green plants show the same response. A plant that grows in the shade is usually taller than the same kind of plant growing in the sun. Generally, corals grow in more flat or plate-like forms in deeper water—a shape that efficiently captures the reduced available light needed to keep their zooxanthellae alive.

1. *Place the platelike leaf coral on the reef cross section diagram.*

Coral species, as well as other reef animals, differ in their need for light and wave action. They also vary in tolerance for salinity, temperature, and ability to shed sediment. Hence coral reefs have distinct zones of coral distribution.

A coral reef typically has the kind of zonation shown in the reef diagram. In the lagoon or near shore there may be a turtle grass bed. The lagoon may also have sandy areas and coral patches surrounded by grass beds. Sometimes a "halo" of bare sand occurs between a grass bed and a patch reef. Sea urchins and other grazers hide from their fish predators on the patch reef during the day. At night they eat the turtle grass.

2. *Place turtle grass and staghorn corals in the lagoon. Use the above information to write a hypothesis about the formation of the "halo" around the patch reef and design a test for it.*

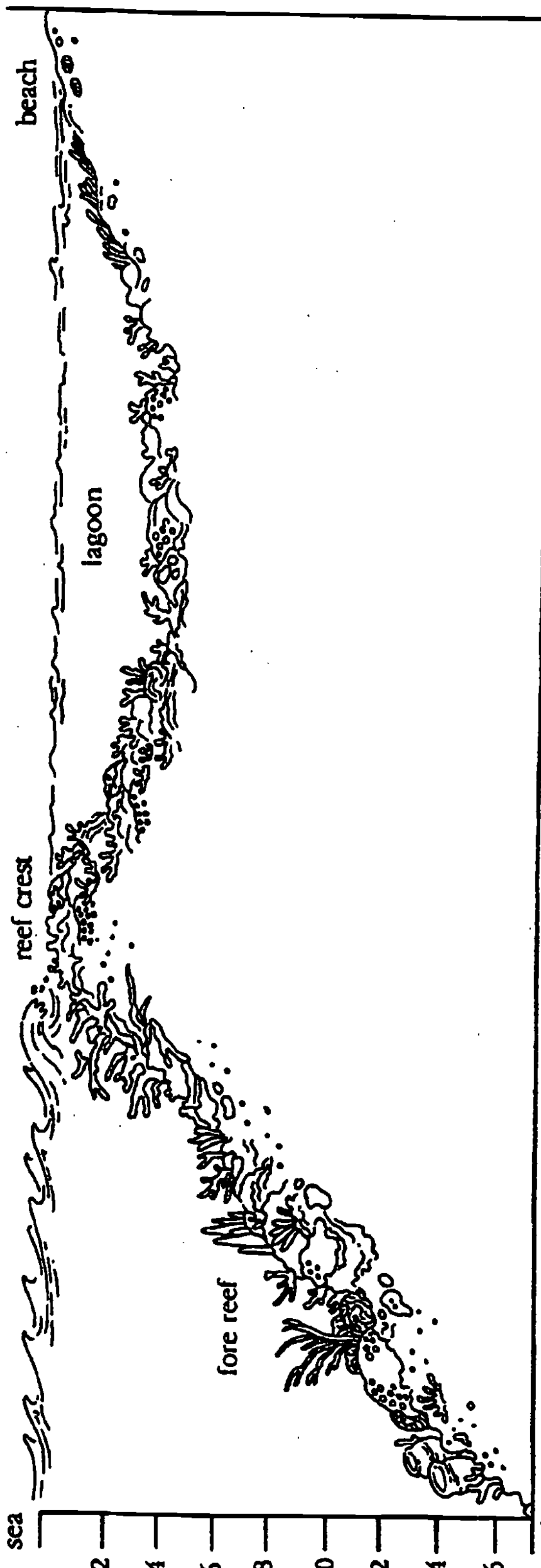
Some corals grow best in heavy waves. Thus at the reef crest (the front edge of the reef), a band or corals forms that grows up to the surface.

Flat sheets of fire coral and colonial anemones called sea mat are typical of this high wave energy zone. This reef crest provides protection from strong storms and waves for the lagoon and the shoreline. Purple sea fans are also more common near the reef crest. They grow across the incoming waves which carry the tiny animals from the open sea that feed sea fans and many other reef inhabitants.

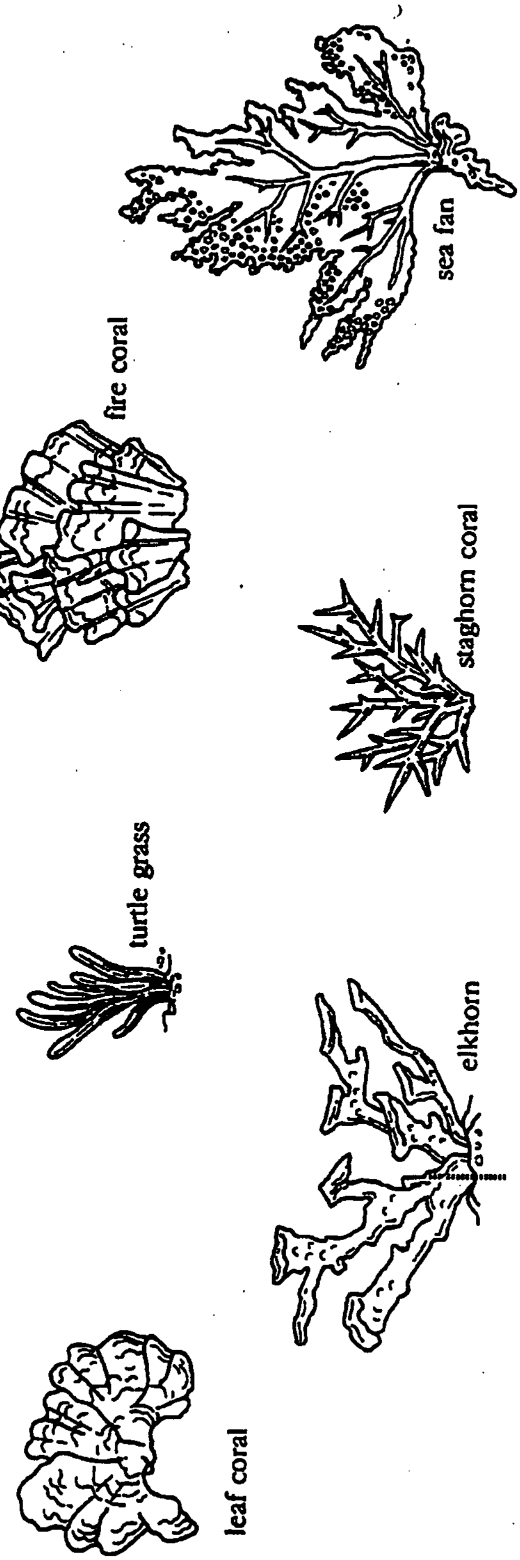
3. *Place sea fans and fire coral on the reef crest in the diagram.*

As you move down the fore reef (seaward side of the reef), elkhorn corals (which really look more like moose antlers) dominate. In deeper water, flat leaf corals replace them.

4. *Place elkhorn coral on the diagram.*



Zonation of a Coral Reef



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42. CORAL REEF ZONES COLOR PAGE AND 3-D MURAL

Objective: The students will be able to identify the following coral reef zones:

a) Lagoon:
- Beach
- Mangroves
- Patch Reef
- Seagrass

b) Reef Crest

c) Reef Face:
- Upper Zone
- Lower Zone

They will also be able to name at least one life form found in each zone.

Interdisciplinary Index: Science, Language Arts

Vocabulary: coral reef zones, lagoon, reef crest, reef face, mangroves, beach, seagrass, patch reef, coral reef plants and animals

Materials:

For the Color Page:

- **Coral Reef Zones** handout for each student
- crayons, colored pencils, and/or markers

For the 3-D Mural:

- overhead projector
- transparency of **Coral Reef Zones** handout
- scissors
- glue
- tempera and watercolor paints
- paint brushes
- butcher paper (all colors)
- construction paper, tissue paper (optional)

Presentation:

For the Coral Reef Zones Color Page:

1. Pass out a copy of the **Coral Reef Zones** to each student.
2. Provide each student with markers, crayons, or colored pencils.
3. Explain to the students that there are many parts to the coral reef, and that all of these parts are interconnected. We call the different parts "reef zones" (areas where different plants and animals live). Direct the student's attention to each reef zone and have him/her add animals and plants and color in each zone as you discuss it.
   a) The seaward facing slope of the reef is called the reef face. This is where life on the reef is most abundant. It is home to corals, fishes, sharks, turtles, and many other creatures.
   b) The reef crest is the highest and shallowest part of the reef. At low tide, shallow pools of water form among the coral and are home to nudibranchs, marine snails, crabs, sea stars, worms and small fishes.

c) The lagoon is the protected body of shallow water between the beach and the reef. Many coral reef plants and animals live here on patch reefs and among the seagrass, like fish, lobsters, sea turtles, and small sharks. The seagrass serves as a nursery for young fish.
d) Mangroves grow in the area where the land meets the sea. Mangrove roots grow in the saltwater and serve as an important habitat for many marine animals.
e) Beaches are often formed from the breakdown of coral skeletons. Animals, such as sea turtles and certain birds, use the beaches to lay their eggs and build nests.
f) Tropical rainforests often border the beaches. These rainforests are the home of thousands of plants and animals, such as parrots, monkeys, fruit bats, and snakes. Protecting the tropical rainforests also helps to protect the coral reefs. When rainforests are cut down, the sediment that was once held down by the plants and tree roots washes into the water and out to the reefs where it smothers and kills the coral.
g) Have students draw a picture of their favorite coral reef creature in the box.

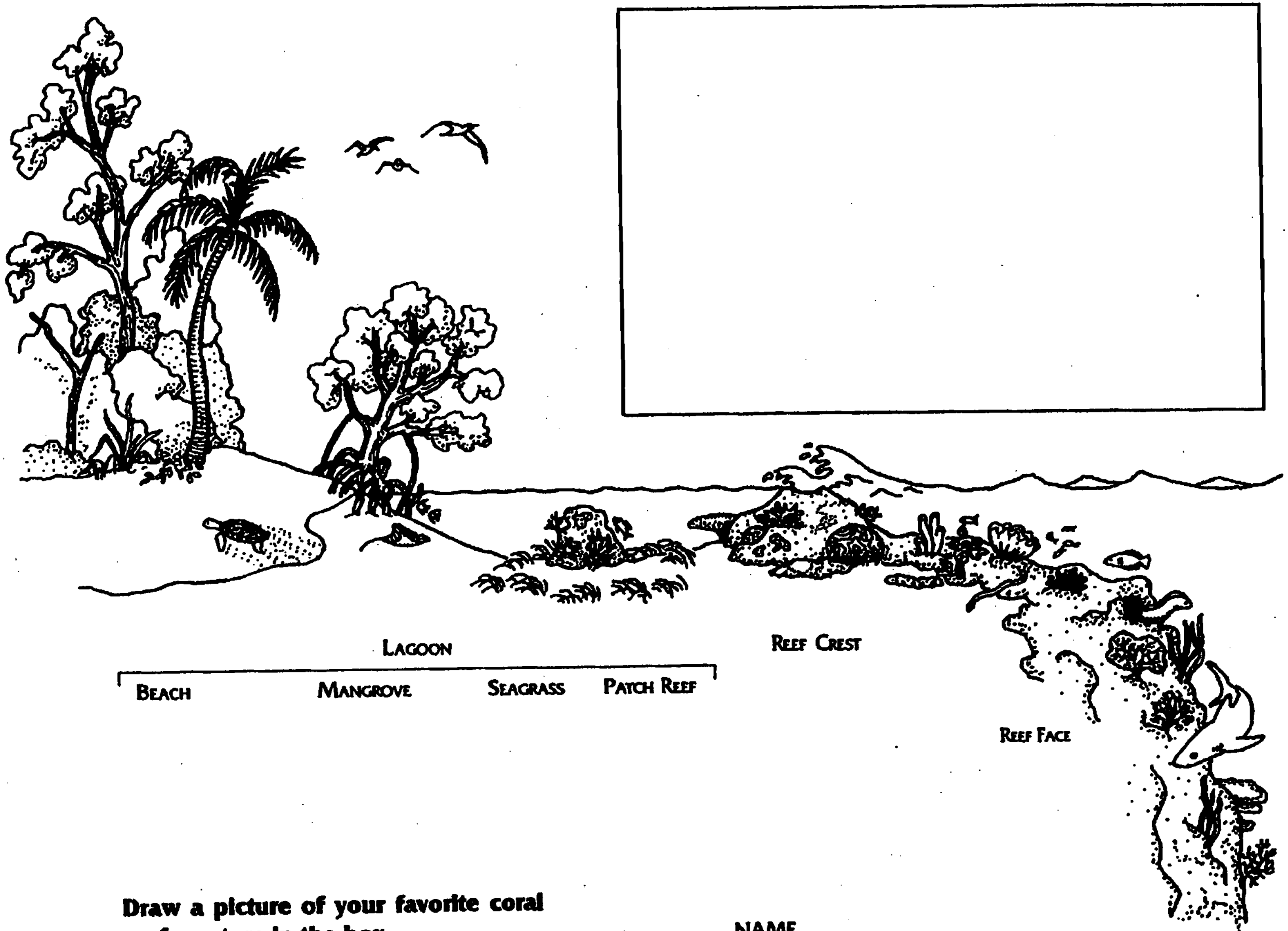
For the 3-D Coral Reef Zones Mural:

1. Make a transparency of the **Coral Reef Zones** handout.
2. Use an overhead projector to project the transparency onto white butcher paper (3 feet by 6 feet). Trace the **Coral Reef Zones** handout onto the paper, deleting the box and words. (If you do not have an overhead projector, lightly trace the **Coral Reef Zones** handout onto the paper.)
3. Let the students work in groups of 6-8. This works well as a learning center activity. You will be creating three or four murals, depending upon the number of students in your class.
4. Have students use watercolors to paint in the water and sky.
5. Let other students use tempera to paint in the corals and other creatures on the sea floor.
6. Using brown butcher paper (or white paper painted brown), twist the paper into long strips that the students can form into mangrove roots and branches. Glue these onto the mural.
7. Have students design a coral reef creature of their choice on construction paper. Color the creature. Place the colored sheet on top of a plain sheet of construction paper and cut both sheets out together into the shape of the creature. Have students glue the outlines of the creatures together, leaving an opening to stuff in newspaper. Stuff in the newspaper and completely glue the two sheets together. The finished creature should look 3-D, sort of like a pillow.
8. Let students put their finished creatures in the appropriate reef zones. (**Suggestion:** You might want to assign different creatures to each student corresponding to different parts of the reef zone. For example, some students might make only young reef fishes that live among the mangrove roots. Other students might make fish that feed on corals. Other students may create worms and sea stars that live on the reef crest, etc.)
9. Discuss the different reef zones and the interdependence of life in these zones.

Follow-Up/Extension:

1. Have students do reports on their creatures.
2. Have students look up more information on each of the coral reef zones and report to the class.

CORAL REEF ZONES



Draw a picture of your favorite coral reef creature in the box.

NAME ____________________

Source: The Incredible Coral Reef by Toni Albert. Trickle Creek Books, 500 Andersontown Road, Mechanicsburg, Pennsylvania 17055 Tel: 1-800-353-2791. Used with permission.

43. THE IMPORTANCE OF THE CORAL REEF

Directions: Read the sentences below. Which do you think states the most important reason for protecting coral reefs? Put an X next to the one you choose. Then find out what your choice says about you.

WHAT IS THE MOST IMPORTANT REASON FOR PROTECTING CORAL REEFS?

_____ 1. The coral reef is a special place with an incredible diversity of animal life. It is home to many endangered and threatened species of marine wildlife.

_____ 2. The coral reef attracts visitors from all over the world who like diving, boating, fishing, and exploring nature. Tourist dollars support many local businesses and are often crucial to local economies.

_____ 3. As our world population continues to grow, we look to the oceans as an important source of food. Many edible marine species depend on healthy coral reefs for breeding and nursery grounds in order to survive.

_____ 4. Scientists are discovering how to make new agricultural, industrial, and medical products from marine organisms. The coral reef has yielded new medicines, foods, fertilizers, and emulsifiers used in industry.

_____ 5. When thriving coral reefs become distressed, it is a warning sign that something is critically wrong—something that will ultimately affect our own survival too. It alerts us to examine what we are doing to our air, water, and earth.

_____ 6. Reefs help protect tropical shores from erosion. Waves caused by tropical storms are weakened as they break on the reefs before reaching the shore.

WHAT DOES YOUR CHOICE SAY ABOUT YOU?

1. If you chose the first reason, you are a nature lover. You know more about animals and plants than most of your friends do. You could help protect coral reefs by sharing what you know.
2. If you chose the second reason, you have a good mind for business. You could help protect coral reefs by raising funds for an environmental organization.
3. If you chose the third reason, you care about the basic needs of people. You could help protect coral reefs by writing letters to politicians and businessmen who make decisions that affect people's lives.
4. If you chose the fourth reason, you are a person who values science and technology. You could help protect reefs by coming up with a new idea for letting people know reefs are threatened.
5. If you chose the fifth reason, you "think big" and accept responsibility for actively caring for the earth. You could help protect coral reefs by taking practical steps in your own life, such as conserving resources and recycling.
6. If you chose the sixth reason, you are a practical person who respects the order and balance of nature. You could help others understand why coral reefs are important in the world.

Source: **<u>The Incredible Coral Reef</u> by Toni Albert. Trickle Creek Books, 500 Andersontown Road, Mechanicsburg, Pennsylvania 17055 Tel: 1-800-353-2791. Used with permission.**

44*. THREATS TO THE CORAL REEF

Coral reefs have existed for millions of years. They have survived countless large and small changes in the environment. But today, coral reefs around the world are threatened as never before. Reefs in at least twenty countries, including the United States, Mexico, Indonesia, Japan, and Australia, are showing signs of stress and distress. Coral reefs in Florida are disappearing at an alarming rate. Coral diseases and **coral bleaching** occur when the water off Florida is no longer clear and clean, or when the water temperatures rise. In Hawaii, beautiful coral reefs have been damaged or killed by sewage pollution, dumped waste, or dredged mud. Many scientists agree that if the trend continues for another twenty or thirty years, there may not be any healthy coral reefs left on earth.

Directions: Read below about threats to coral reefs. Put an N next to the natural threats (caused by nature) and an H next to the human threats (caused by people). Which do you think are more dangerous to coral reefs—natural events or the activities of people?

_____ 1. Hurricanes and tropical storms break and topple coral and batter fish.

_____ 2. Construction on or near the reef destroys coral or muddies the water, so that corals smother.

_____ 3. Overfishing and destructive fishing methods (such as using dynamite, cyanide, bleach, fish traps, gill nets, or huge forty-mile-long drift nets) spoil the reef ecosystem.

_____ 4. Too much rain dilutes the water, so that it isn't salty enough for corals.

_____ 5. Marine debris is dangerous to corals, birds, sea turtles, fish, and other marine animals.

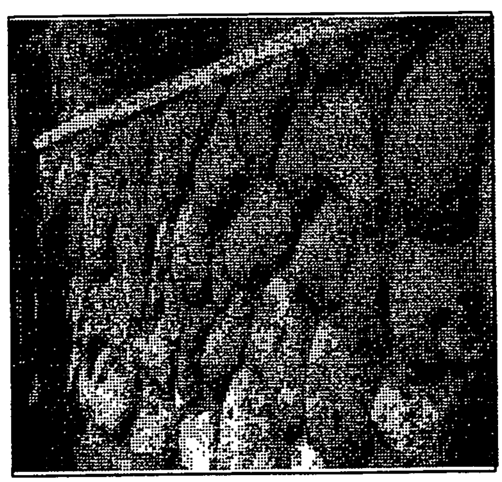
_____ 6. Divers, snorkelers, and fishermen damage the reef with boats, anchors, and heavy gear. Even touching coral or standing on it can kill it.

_____ 7. Changes in currents can smother corals in mud.

_____ 8. Collecting tropical fish, corals, and shells strips the reef of life.

_____ 9. Pollution from oil spills, chemical wastes, run-off from farms and factories, and sewage ruins the water quality that corals need.

_____ 10. Natural predators, such as parrotfish, sponges, and sea urchins, eat corals or weaken it by boring into it.



Coral is often used in construction.

_____ 11. Warmer water caused by the greenhouse effect may cause coral bleaching, a dangerous condition that occurs when corals lose their algae partners.

* *Answers in Section VIII.*

Source: From República de Panamá Ministerio de Educación Guía Didáctica de Educación Marina by William Irons. Produced in conjunction with Peace Corps/Panama, the Panamanian Ministry of Education, the Smithsonian Tropical Research Institute and UNICEF. Used with permission.

45. A MARINE SHORT STORY

Learning Objective: To identify through a short story some of the damages inflicted on coral reefs by human beings.

Technique: A short-story

Ecological message: The coral reef is an important and fragile ecosystem. We must take care of it and not cause imbalance in the marine life.

Materials: Color illustrations.

Procedure:

1. Ask a student to read the following story aloud.

CORAL REEF

Near a very beautiful island, surrounded by an immense sea, is a precious place. It is a place where multicolor fishes, lobsters of different sizes and many little animals live. Everyone likes to go there to visit. Do you know what the name of the place is? Coral reef.

One day, a boy went fishing with his father in a small boat. To get hold of a lobster, they stepped all over the corals, breaking and destroying the delicate structures. The little corals began to cry, "Why do you all hurt us so much? Don't kill us! We help all the inhabitants of this island."

The little boy and his father were scared when they heard hear those words. With amazement, they asked, "Who hurt you?"

The little corals answered back, "People—grasping us, when they throw boat anchors overboard they hurt us, the divers step on us. Also, when it rains very hard, all the sediments that people drain run into the sea and make it hard for us to breathe. Every day many of our brothers die."

The boy and his father were very saddened. From that day on they promised to take good care of the corals in the reef and to tell other people what had happened to them so that others also would not destroy the reef.

2. Discuss the content of the story, reviewing the different ways in which corals are harmed.
3. Ask each student to write his/her own short story, or they can write collectively in a small group, about a coral reef and how we can protect it.
4. Comment on the students' stories.
5. Ask them to illustrate the above story.

Source: Corals and Coral Reefs 4 - 8 Teacher's Guide. A Sea World Education Department Publication. Used with permission.

46. SURVIVAL FACTORS

Objective: Students will be able to analyze the impact of humans on the coral reef ecosystem as a result of human social, political, and economic activities.

Materials: copies of Survival Factor cards, copies of Identity cards enlarged 200%, small construction paper squares (five per student), yarn

Action:

1. Copy and cut Survival Factor cards and Identity cards. Attach yarn to Identity cards so students can wear them around their necks.

2. Have students stand in a circle. Pass out Identity cards. Each student now represents a life-form found in a coral reef ecosystem.

3. Give each student five paper squares. Explain that each square represents a population of organisms. [A population is made up of all the organisms found in a specific area.]

4. Tell students that you're going to read some statements that describe events that take place everyday that might or might not affect the reef and its inhabitants. Explain that if they think the statement you read would make it difficult or impossible for their organism to survive, they must put one of their paper squares on the floor in front of them. When students have one square left, they must stand on one foot. When they lose their balance and fall, they must sit down—this species is no longer found on the reef. They also must sit down when they run out of squares.

5. Continue to play until everyone is sitting.

6. Discuss the game with students. Tell them that their species became endangered when they became few in number, as represented by the one paper square. Explain that endangered refers to a population that is in danger of extinction, or disappearing completely. Was it easy for the students to stay in the game when they reached the point of standing on one foot? When a species becomes endangered, they're on shaky survival ground.

Deeper Depths:

Have students compare and contrast other habitats (old growth forest, wetlands, desert) and their survival factors. What survival factors are the same for each habitat? Different? How can each one of us make a difference in protecting the balance in each type of habitat?

SURVIVAL FACTORS

Recreational boaters drop anchors on you.	A tourist takes you from the reef to carry home as a souvenir.
An oil tanker spills thousands of gallons of oil into the water over you.	You swallow some abandoned fishing line.
Agricultural fertilizers have washed into the sea, so now there is a lot more algae in the water around you.	To make money from the tropical fish trade, collectors use dynamite and cyanide, a poison, to stun and capture you and your relatives.
You become tangled in a drift net.	Large pieces of your skeleton are broken off and sold for use in home aquariums.
Ocean pollution from pesticides, heavy metals, and garbage is surrounding you.	The water temperature surrounding the reef mysteriously rises, causing you to expel your zooxanthellae.
A snorkler sits on you and pokes around to get a better look at marine life.	A tropical forest is cleared, washing topsoil down river and into the ocean in the vicinity of your home, a large reef ecosystem.
A scuba diver takes more than the legal limit of your species.	Coastal development destroys the beach you breed on.
Human population growth increases.	Humans think you're delicious, and actively hunt you.

IDENTITY CARDS

pillar coral	zebra moray eel	monk seal
hawksbill sea turtle	queen conch (snail)	painted triggerfish
green sea turtle	four-eyed butterflyfish	trumpet triton (snail)
lined sea horse	king crab	brain coral
barracuda	striped shrimp	elkhorn coral
star-eyed hermit crab	sharpnose pufferfish	emperor angelfish
cowfish	sea urchin	sea anemone
anemone fish	blue-barred parrotfish	stony coral
little star coral	slipper lobster	sea star
branching coral	reef octopus	moorish idol (fish)

Source: Coral Forest Teacher's Guide. Coral Forest, 400 Montgomery Street, Suite 1040, San Francisco, California 94104 Tel: (415)788-REEF Fax: (415)398-0385 e-mail: coral@igc.apc.org Used with permission.

47*. FISHY PROBLEMS

Objective:
Students gain a greater understanding of the problems facing coral reefs and native coastal people by calculating the answers to the questions on the following page.

Interdisciplinary Index: Math

Materials:

TABLE OF EQUIVALENTS
1 kilogram = 2.205 pounds
1 metric ton = 2,204.623 pounds
1 kilometer - .621 miles
1 mile = 5,280 feet

one **Fishy Problems** handout per student

Presentation:
1. Discuss the various anthropogenic threats affecting coral reefs and the native coastal people dependent upon them for survival.
2. Distribute a copy of the **Fishy Problems** handout to each student and have them answer the questions.
3. Discuss the answers with the students and their feelings about the impact these situations are having on the environment., people, local and global economies, etc. What solutions might they recommend? Emphasize that all of the questions are based upon actual scientific information.

FISHY PROBLEMS

Questions:

1. The world's oceans are fished by over one million large fishing ships and two million smaller ones. Around the world, 12.5 million people make their living catching fish, and another 150 million people are employed in on-shore operations or the processing of fish.

   a) How many ships fish the world's oceans?

   b) For every single fishing boat, how many people are needed, on the average, to catch fish?

   c) For every single fishing boat, how many people are needed, on the average, to handle on-shore fishing operations and processing?

2. "Almost all tuna stocks worldwide are in peril from overfishing, with the Atlantic bluefin tuna declining 90 percent in the last two decades, from 225,000 in 1970 to only ________ in 1990."

3. Shrimpers off the southern coast of the United States catch approximately 48,000 endangered sea turtles a year. It is estimated that one quarter of these are killed in the shrimp nets. How many turtles are killed each year?
4. In a coral reef area near Santiago Island in the Philippines, observers recorded 6 dynamite fishing explosions per hour, with an estimated catch of 1800 kg of fish per day.

   a) Assuming there are eight hours in the fishing day, how many dynamite explosions occurred in one day?

   b) How many kg of fish on the average would have been caught after each explosion?

   c) How many pounds of fish would have been caught in a day?

   d) How many pounds caught in one hour?

   Surveys indicated that more than half of the corals in that area had been killed by the dynamite blasting.

5. In the Maldives, a coral reef was destroyed which caused increased erosion of the beach and loss of sand. This could have the disastrous effect of increasing the loss of life and property during storms, decreasing income from tourism, and harming habitat. As a result, the government spent $12 million for 1 km of seawall to replace the destroyed reef.

   a) How many feet long was the seawall?

   b) What was the cost per foot to build?

6. It is important to consider the economic value, both short term and long term, of environmental conservation. However, often this is not done. For example, in the Philippines a logging concession was expected to yield $13 million from cutting down the rainforest over a 10-year period. The resulting environmental problems, such as erosion and siltation, would have severely damaged the adjacent coral reefs where fishing was done. If this had happened, it was estimated that up to $75 million in fishing revenue would have been lost. If this logging concession had been granted, what would have been the net loss of revenue?

7. In the Philippines, it is estimated that 1 square kilometer of coral reef in poor condition produces only 5 metric tons of fish per year, just enough to feed 100 people. A healthy reef, however, can feed between 400 to 700 people per year.

   a) How many metric tons of fish would be produced by a healthy reef?

   b) How many pounds of fish would this equal?

8. At a conservative estimate, coral reef destruction in the Philippines has meant a loss of 37% in fish production each year, or 159,000 metric tons.

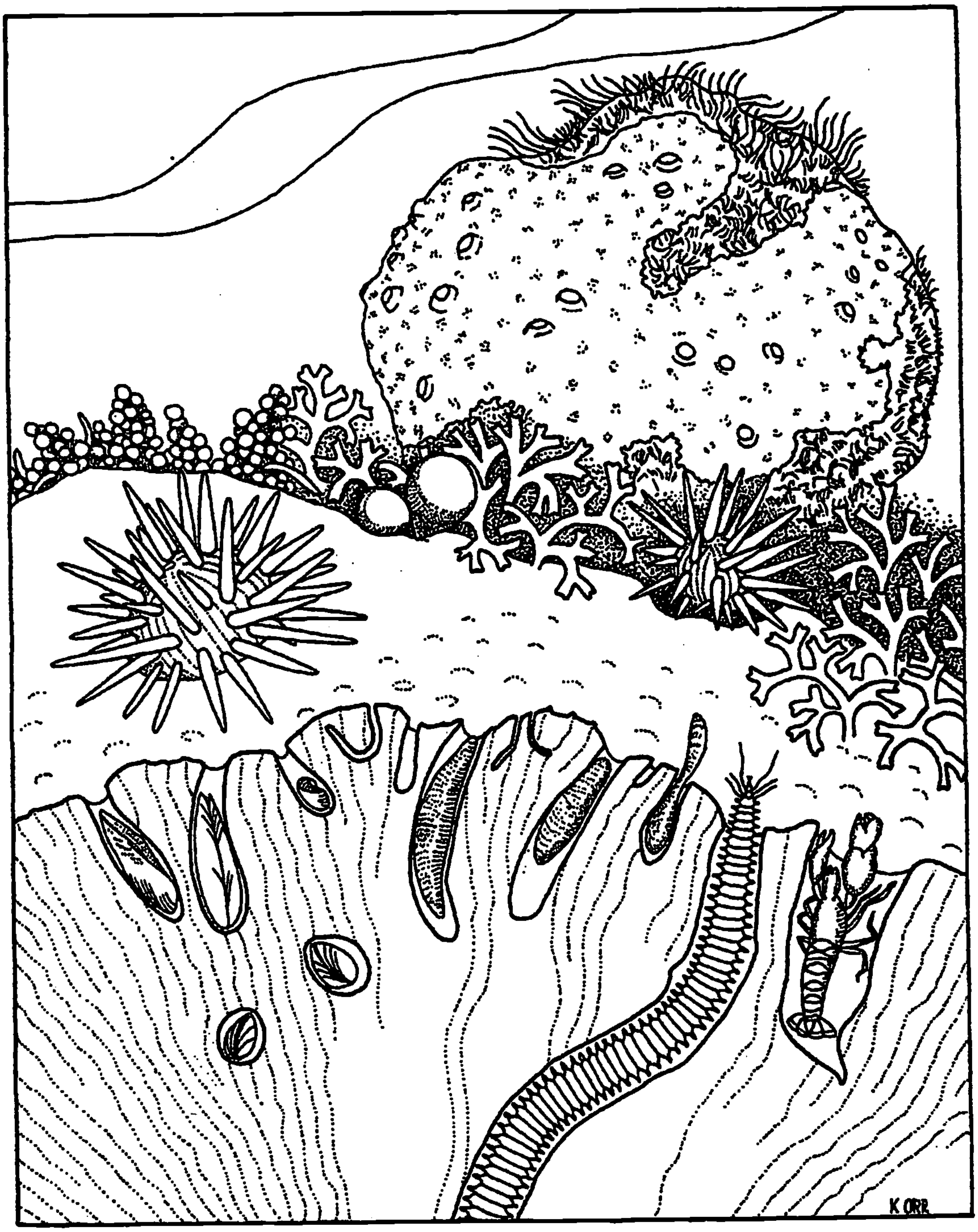
   a) If the coral reefs were healthy and fish production was at 100%, how many metric tons of fish would be produced?

   This 37% loss means that 3 million people now get no seafood protein, or 6 million people get only half the protein they need.

   b) How many pounds of fish does each of these people now eat in a year?

* *Answers in Section VIII.*

48. CAN A DAMAGED REEF RECOVER?



Certain snails, worms, and fish eat coral polyps. They create small dead spots on the living coral surface. On a healthy reef this is not a problem. The surrounding polyps can spread over these small spots and repair the damage. But large spots of dead coral cannot be repaired because the polyps grow more slowly than other creatures.

Algae and sponges settle on bare, hard surfaces and grow rapidly. They quickly cover the area and prevent new polyps from settling. Many boring animals also settle on these dead spots. Boring sponges, sea urchins, boring clams, snails and worms scrape holes for their homes in coral rock. These animals weaken the coral. Eventually it will crumble. If corals are weakened by silt or pollution, they may never grow back. A damaged reef may take 20 or 50 years to recover.

Source: Waikiki Aquarium Education Department, Waikiki Aquarium, Honolulu, Hawaii. Used with permission.

49. THE "CORAL REEF RACE FOR SURVIVAL" GAME

Objectives:

1. To foster an understanding of the survival needs of corals in their natural habitat and some of the destructive influences of human behaviors.
2. To prompt discussion of coral conservation efforts.

Materials:

1. Four "planula" badges (or headbands).
2. Enough "coral" badges (or headbands) to provide one for each student in the class.
3. Three copies of each of the two **planula survival cards** listing requirements for a planula (larva or young stage coral) to successfully settle on the bottom.
4. Three copies of each of the two **planula disaster cards** listing conditions in which planula can not settle.
5. Two copies of each of the four **reef survival cards** detailing coral survival needs.
6. One copy of each of the eight **reef disaster cards** listing damage to coral reefs caused by human activity.
7. Two containers to hold the cards—one container (basket, bag, box) for **planula survival and disaster cards** and one for **reef survival and disaster cards**.
8. Floor space for students to sit and form coral reefs by linking arms.

Procedures and Game Directions:

1. Divide the class into two teams. The object of the game is to see which team will be the fastest to build a healthy reef.

2. Clear an area on the floor for children to sit and "form coral reefs."

3. Ask each team to choose one boy and one girl to represent planulae, (the coral larvae or young stage) that will start their reef formation. Each student wears a planula badge on a headband or pinned to clothes.

4. Each planula student takes a turn pulling a **planula card** from the **planula card** container. If they chose a **planula survival card** listing appropriate places for corals to settle, ask them to read the card aloud to their classmates. Then they go to the front of the room and settle on the floor. If both planulae from the same team are successful, they sit (settle) together, linking arms. Once they sit, they are no longer planulae, but have transformed into a young coral colony, and trade in their planulae badges for coral badges. The teacher might remind students that, "On a real reef, coral planulae are settling all the time, but for our game, we will just have them settle once to get us started."

5. If the planulae students pull a **planula disaster card,** they cannot settle. They return to their seats.

Their team has to choose another pair of planulae. But they will be a turn behind the other team.

6. The new corals take turns pulling numbers from the **reef card** container. If they choose a **reef survival card** listing appropriate conditions for coral growth, the coral students can then select two other students to join them. The chosen students link arms with their coral teammates and are given coral badges. A coral reef is beginning to form. If the corals choose **reef disaster cards,** the reef cannot grow so the reef loses a coral (the student who drew a **reef disaster** number returns to the team.)

7. If a team has only one coral on the reef and that coral receives a **disaster card**, he or she returns to the team and two other students are selected as planulae.

8. The teams keep taking turns drawing cards and adding or losing corals to the reef. (When choosing new "corals" try to give turns to students who haven't been chosen previously). After each drawing, the students read their cards aloud to insure that students understand why their reef grew or not. The object is to see which team is fastest to build a reef of ten corals. (Or you may decide on the number that means a team has won.) You may not consider it a healthy reef until all the students on one team become corals. But that may take considerable time, just like building real coral reefs.

PLANULA SURVIVAL CARD **Congratulations!** **You have just settled on a clean, hard lava rock!** **You grow and become a coral colony!**	**PLANULA DISASTER CARD** **Too Bad!** **You have just settled in shifting sands and cannot attach and grow into a coral colony!** **Return to your team**	**REEF DISASTER CARD** **Too Bad!** **People decide to save money by dumping sewage close to shore. This causes algae to grow over the reef so that the corals cannot receive the sunlight they need to grow!** **LOSE ONE CORAL FROM YOUR REEF!**
PLANULA SURVIVAL CARD **Congratulations!** **You have just settled on a clean, hard section of old coral reef!** **You grow and become a coral colony!**	**PLANULA DISASTER CARD** **Too Bad!** **A Hawaiian sergeant fish or mamo eats you! No chance to settle now!** **Return to your team.**	**REEF DISASTER CARD** **Too Bad!** **A golf course uses fertilizes incorrectly. Rain washes the fertilizer onto the reef helping the algae to grow. The coral is shaded from needed sunlight.** **LOSE ONE CORAL FROM YOUR REEF!**

REEF DISASTER CARD Too Bad! A huge oil tanker hits your reef, tearing a huge hole in the ship's side. The reef is bathed in thick, black oil. LOSE ONE CORAL FROM YOUR REEF!	REEF DISASTER CARD Too Bad! Someone decides to break off a coral head to take home. They spray paint it neon pink and sell it illegally! LOSE ONE CORAL FROM YOUR REEF!	REEF DISASTER CARD Too Bad! Hundreds of people come to admire you. But they walk all over you, break your branches and tear your delicate living tissues. LOSE ONE CORAL FROM YOUR REEF!
REEF DISASTER CARD Too Bad! To prevent floods, humans line the stream beds with concrete. They clear ground for new houses and roads. Now whenever it rains, mud and freshwater pour over the reef, smothering the corals. LOSE ONE CORAL FROM YOUR REEF!	REEF DISASTER CARD Too Bad! A fisherman pours bleach over you to force fish out of your branches! LOSE ONE CORAL FROM YOUR REEF!	REEF DISASTER CARD Too Bad! A sailboat pauses overhead so snorkelers can admire your coral community. Unfortunately, they drop an anchor right on your "head." LOSE ONE CORAL FROM YOUR REEF!
REEF SURVIVAL CARD Congratulations! You spend the day bathed in sunlight. Your zooxanthellae make plenty of food for themselves and for you! ADD TWO NEW CORALS TO YOUR REEF!	REEF SURVIVAL CARD Congratulations! You spend the year in clear, clean saltwater free of silt and sediment. This allows you to receive all the sunlight you need for growth. ADD TWO NEW CORALS TO YOUR REEF!	
REEF SURVIVAL CARD Congratulations! You spend the year in saltwater just the right temperature for your growth! (64 to 86 Degrees F.) ADD TWO NEW CORALS TO YOUR REEF!	REEF SURVIVAL CARD Congratulations! You capture several small plankton animals for food. ADD TWO NEW CORALS TO YOUR REEF!	

Source: Coral Reef Teacher's Guide, produced by the World Wildlife Fund, 1250 Twenty-Fourth St. NW, Washington, DC 20037-1175. Used with permission.

50. THE CORAL CONSERVATION GAME

Adapted from a game by Roseanne W. Fortner, Ohio State University

Goal: to show students the many factors that must be balanced to conserve a natural resource with commercial and other values.

Objectives:

Students will be able to name four ways that coral reefs benefit people.
Students will be able to name four ways that people damage coral reefs and corals.
Students will be able to discuss important factors in "managing" a coral reef.
Students will be able to debate: give pro and cons of exploiting commercial uses of coral reefs.

Time: 45 minutes to one hour

Materials:

Game boards (You may duplicate the enclosed game board by copying its folded quarters and taping it together. Make enough game boards for four players per game.)
One piece of notepaper per student, and pen or pencil.
Make copies in the following quantities:

*Game Board: one board per game (four students)
*Chance Cards: one set per game
*Option, Spinner, Token page: one per game
*Game Summary sheet: one per game
*Currency: twenty pages per game

Student Background:

Today you will play a game called The Coral Reef Game. On the game board you will use, the game is drawn on the outline of a coral that looks something like elkhorn coral—a rapidly-growing coral... [illustrations of elkhorn coral appear on the cover of this manual and on page 80].

In this game, you are a fisherman who makes at least part of your living from coral. You have a problem shared by nearly all fishermen—if you take lots of coral, you make good money at first. But if you and others do this for too long, the coral will not be able to grow back fast enough. Then, there will be none, or very little, and you will have lost the source of your business.

The secret, of course, is wise use and protection of the natural resource you make a living from. And that is no easy task, as you will see from the game you are about to play.

The object of this game is to arrive at the FINISH space with the most coral. Coral grows on offshore reefs around the island and amounts of coral are measured in centimeters. Players may also gain centimeters of other types of coral, such as the valuable but delicate black coral.

Players should keep a record of all the centimeters of coral they gain or lose throughout the game. Use the tally sheet you have been given. You should also carefully control the amount of money you have. As the game starts, assume that one inch of coral is worth about $500.

Procedure:

1. Prior to class assign background reading. [E.g., **Coral Reef Coloring Book** written and illustrated by Katherine Orr, © 1988, Stemmer House Publishers, Inc. This coloring book is derived from a project funded by World Wildlife—U.S. Encourage students to color the illlustrations.]
2. This game requires copying, if the entire class is to play the game at once. If you cannot make

copies, have students play the game in groups of four, during several class periods. Use your judgement as to whether to have students help you assemble Game Boards, cut Chance and Option cards, assemble spinners and tokens (glued on cardboard, for best use), and cut up currency.

3. Divide the class into groups of four. Have them move desks together to play.
4. Distribute game boards, spinners, tokens, and currency (20 sheets of money per game, $2,000 per player). Give each student an Option Card also. Keep spare currency on the side, "in the bank" for payments to players.
5. Read **Background** and remaining instructions (5-11) to students.
6. Begin at the **START** space with $2,000 and 25 centimeters of coral. Shuffle the **CHANCE** cards and place them face down near the board. Now, write down your beginning assets on a sheet of notepaper.

   Organize your notepaper like this: **(Show on blackboard. . .)**

Coral		Money
Start:	+25 cm	+2,000
Turn 1	....	......
Turn 2	....	......
Etc.	....	......

7. Two to four players may play at one time. Spin the spinner to see who moves first. The player with the highest number will move first. Play then goes around the board to the left.
8. Move around the games board by moving your token the number of spaces shown on the spinner. Change your amount of money and coral as the board and **CHANCE** cards direct.
9. Early in the game you will have to choose which path you wish to take around the board. The regular path may be followed, or you may choose the "High Finance Bypass" and take extra risks in order to finish earlier. You may not back-track after choosing one path or the other.
10. If you spin **CHANCE** or land on a **CHANCE** space, pick up the top CHANCE card and do as it instructs. Then put the card back on the bottom of the deck.
11. Each player receives on **OPTION** card as the game starts. This card gives you an opportunity to make a deal with other players, buying or selling any amount of coral for which a price can be agreed. Once you have used your option card, you must give it up.
12. You cannot go "in the red" and spend more than you have, and if you run out of money, you are no longer a competitor for coral. The same rule applies to running out of coral. You may continue to play in hopes of gaining more money or coral, but if you should be required to spend money or lose centimeters that you do not have, you are out of the game.
13. You must land exactly on the **FINISH** space to complete the game. The first player to reach **FINISH** earns an additional $1,000, but the game is not over until all players have finished or been eliminated. The winner is the person having the most coral. It is possible that there will be no winner!
14. After each group has finished their game, fill out the Game Summary Sheet together.
15. Discuss the Game Summary with the class. If you live in a coral reef area, be sure to discuss important negative and positive influences going on nearby.

Summary Sheet

1. In the chart on the following page, list human and natural factors your group encountered in the game.
2. For each factor, note below its positive or negative effect on the amount of coral (+ or - cm) and its positive or negative economic impact (+ or - dollars).
3. Discuss how the results of human factors change. Can people alter natural events as well? How, and with what impacts?

Natural Factors

Type of Factor	Effects on Coral	Effects on Economics
e.g. Hurricane	-5 cm	-$800

Human Factors

Type of Effect	Effects on Coral	Effects on Economics
e.g. Island Festival	-4 cm	+$350

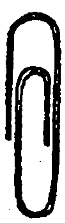
CHANCE CARDS

(Paste on light card and cut out)

Island officials decide not to dredge the harbors this year. Silting of reefs is prevented, but trade drops off. Lose $2,000 and gain 5 cm of coral.	Fertilizers from fields wash into water. Excessive algae growth threatens coral. Spend $1,000 for runoff control, or lose 8 cm.
Hurricane Adam bypasses the island, and expected rains do not come. Fresh water can kill coral, but this time disaster was prevented. Take another turn.	Loss of species diversity (fewer types of animals) makes the reef more susceptible to ecological disturbances. All players lose 5 cm.

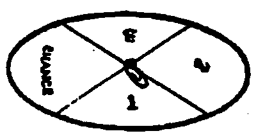
People all over the Caribbean watch a television program about the importance of coral reefs. Surveys show increased knowledge and improved attitudes. All players gain 5cm.	Stop to visit the underwater park. Skip one turn.
Coral reefs break the force of waves and prevent destruction of beach property when violent storms come. Collect $3,000 for protecting the coastline.	A harbor festival brings in new customers for coral. You may exchange up to 10cm and receive $500 per 3cm.
Warm waters and gentle waves in the coral lagoons encourage more tourists to visit these areas. All players earn an extra $1,000.	Classrooms teach children about the value of the reef. Protection allows 5cm more to grow for all players.
The price tourists will pay for good coral specimens goes up 25%. You may sell up to 25cm to other players if a price can be agreed upon.	Brain corals resist damage better than branching forms. Take another turn.
The island hosts a water festival, drawing many tourists. Great damage to reefs from anchors, hull-dragging, and unlicensed collectors. All players lose 12cm.	Parrotfish eat algae that competes with coral. You gain 3cm.
Barracudas eat most of the queen triggerfish. Urchin population explodes and coral loses 5cm. If you choose to skip one turn, 3 cm of coral can grow back.	Dead coral skeletons are inhabited by sea anemones that compete with live corals. Lose one turn.
Island-hopping. Exchange places with any player you choose.	Corals provide shelter for cleaning shrimp. Take another turn.
Scuba divers with spearguns take many groupers from the reef. Spend $500 for protection against this.	Toxic chemical spill is caused by the player on your left. Collect $2,000 in damages from that player.

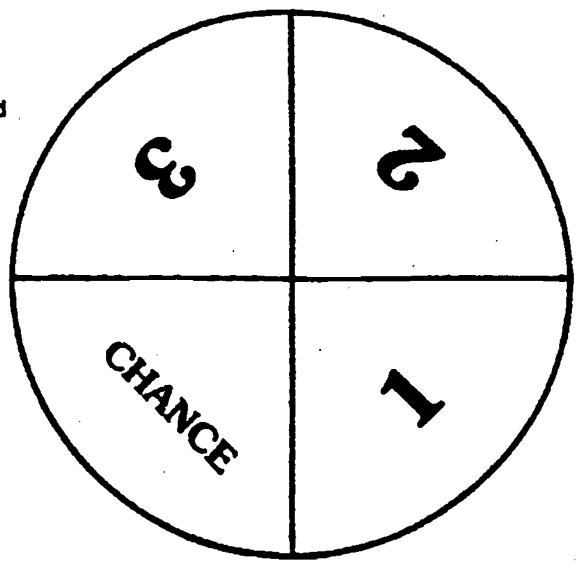
OPTION	**OPTION**
OPTION	**OPTION**



Paper clip

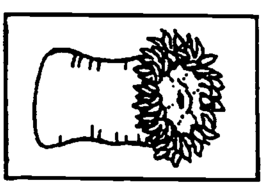
Spinner
Cut out the spinner and paste it on a piece of cardboard. Punch a hole in the center and put a paper fastener through the hole so it will hold the paper clip and allow it to spin.

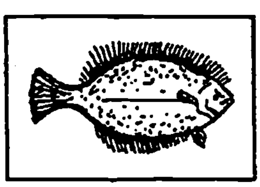


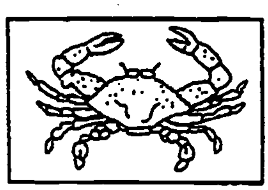


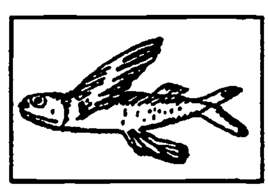
Paper fastener

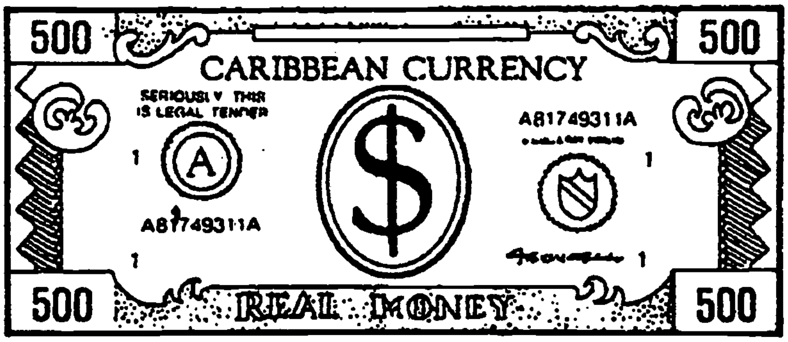
TOKENS
(Cut out and color)







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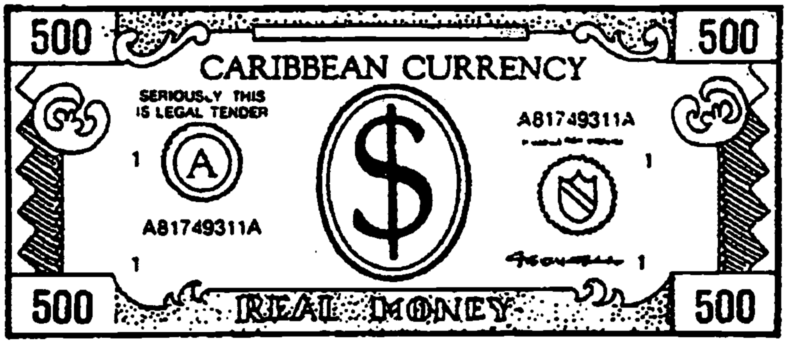
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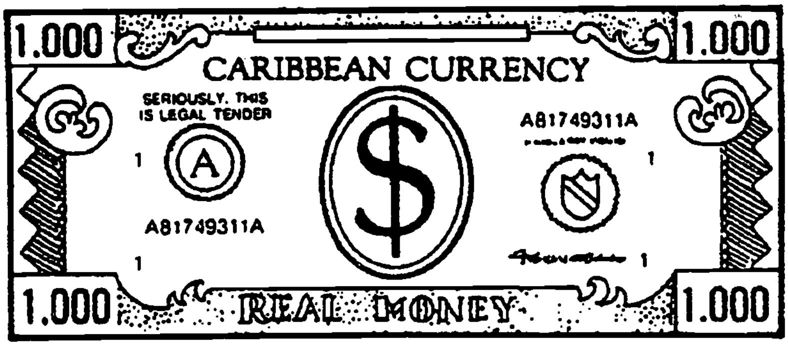
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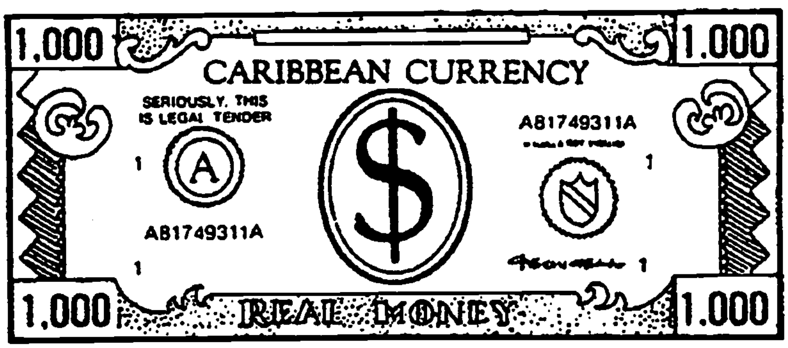
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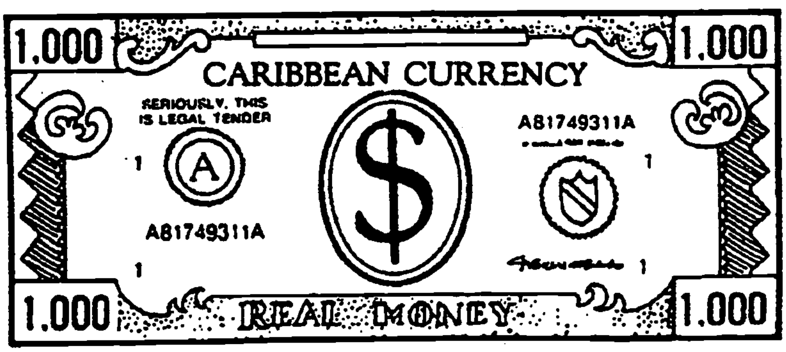
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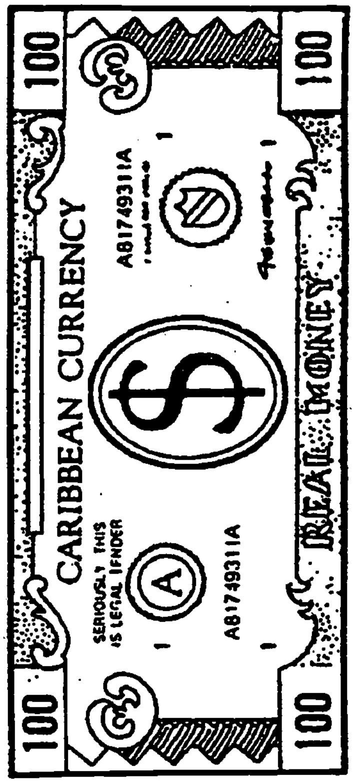
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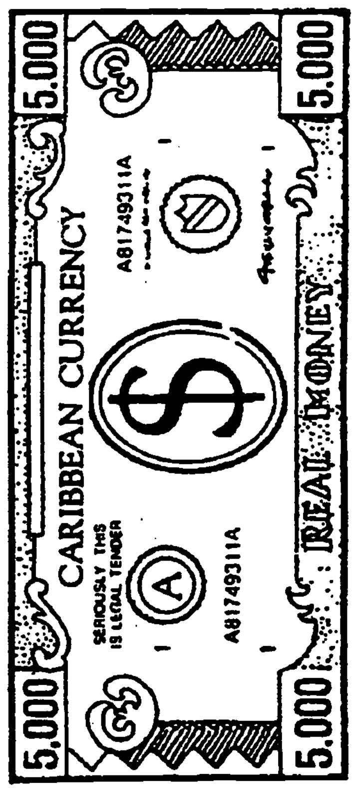
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Source: Adapted from <u>**Marine Reserves: an education resource kit**</u> produced by Jock Whitley and Bill Ballantine. Leigh Marine Laboratory of the University of Auckland, Warkworth, New Zealand. Used with permission.

51. DESIGN TASKS FOR A CORAL REEF MARINE RESERVE

Explain to the class that a coral reef can be legally protected by setting up a coral reef marine reserve. Specific rules and regulations will then govern the use of the reef and the waters surrounding it. Some countries such as New Zealand have enacted strict limitations to safeguard their marine reserves (e.g., **no** killing or removal of marine life, **no** construction or dumping nearby). Such tight controls have not yet been imposed in reserves in the U.S.A. or many other parts of the world where reefs are endangered.

Tell the students to ...

Imagine that the Department of Conservation decides to establish a coral reef marine reserve in your area. You accept the contract from the Department of Conservation or from regional authorities for the following design tasks:

(Each class member chooses **one** *of the following:)*
- a brochure or pamphlet advertising the coral reef marine reserve for local use
- a notice-board display that describes reef etiquette for visitors (e.g., snorkelers, divers)
- a brochure, describing the marine reserve, for oversea tourists
- a poster about the marine reserve for distribution in grade schools or high schools

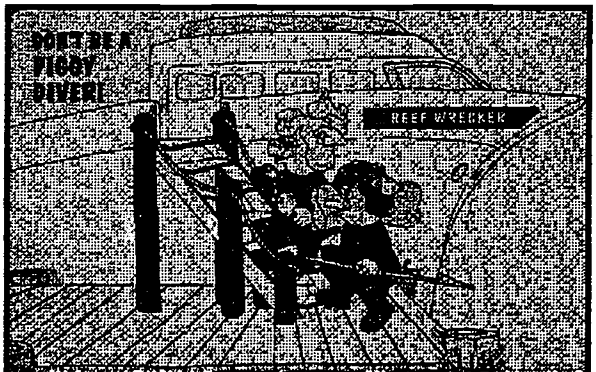
The class as a whole may share ideas on what rules and practices will be enforced in the new reserve. Post the accompanying examples in the classroom to assist students in coming up with ideas for their projects. Suggest that students use their *imagination* if they do not have facts.

Provide large sheets of newsprint, typing and ruled notebook paper, poster board, pens, markers and poster paint for the design tasks. Encourge the students to make their designs "user friendly," presenting important information, perhaps reducing the emphasis on what is not allowed and suggesting *positive* things to do in the marine reserve. Tell them to do their best to create designs with ***impact***.

Display the best efforts around the school, in local shops, or send them to the local newspaper for publication.

Source: Adapted from <u>Palaces Under the Sea, a guide to understanding the coral reef environment</u> written by Dr. Joe Strykowski. The Star Thrower Foundation, P.O. Box 2200, Crystal River, Florida 34423 Tel: (352)563-0022, Fax: (352) 563-2064. Used with permission.

REMOVE NOTHING FROM THE REEF
EXCEPT
NOURISHMENT FOR THE SOUL,
CONSOLATION FOR THE HEART,
INSPIRATION FOR THE MIND.



Because you are a diver, you're already more aware of and more alarmed by changes in our environment than most.

Living coral reefs attract millions of snorklers and scuba divers each year. By the year 2000 there will be 10 million new divers in North America alone.

The dive operators who gave you [this bulletin] share an increasing awareness and growing concern for the protection and wise management of the coral reef ecosystem.

There is no question about divers causing damage. More than one million U.S. divers impact coral reefs 36 million times each year. Our coral reefs are being used up faster than they can replenish themselves.

Many divers still believe corals are an inexhaustible resource composed of an inanimate, indestructible rock.

A study by the University of South Florida has confirmed that divers can pose a serious threat to our coral reefs. The average scuba diver knocks, bumps into, pushes over, or kicks living corals an average of seven times for every 30 minutes under water. Snorklers have at least one negative contact with the corals for every 30 minutes in the water.

Every diver, novice and expert alike, is a vital link in nature's complex eco-system.

Each of us can help protect the world's coral reefs. The problems are critical ... but not hopeless. YOU CAN MAKE A DIFFERENCE!

Source: Adapted from **"Piggy Divers Wreck Our Reefs"** produced by Dr. Joe Strykowski. The Star Thrower Foundation, P.O. Box 2200, Crystal Crystal River, Florida 34423 Tel: (352) 563-0022, Fax: (352)563-2064. Used with permission.

National Marine Sanctuary Program

Florida Keys

REEF ETIQUETTE

Your visit to the Florida Keys National Marine Sanctuary will delight you with beautiful coral formations and a variety of reef organisms in a tropical reef setting.

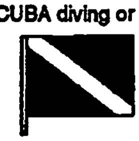
Please follow the guidelines and regulations below while in the Sanctuary:

Just touching coral may cause damage to this fragile animal, therefore, do not allow your hands, knees, fins, gauges or tank to contact the coral.

When anchoring, the anchor, anchor chain or line should not be in contact with coral. Use mooring buoys that are provided. If one is not available, ask to tie off to another stem. If neither option is available carefully anchor in sand.

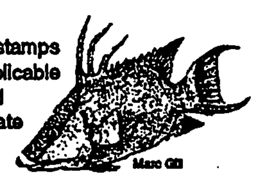
Corals, shells, sea biscuits and other animals, living or dead, cannot be removed from the Key Largo or Looe Key National Marine Sanctuaries.

The red and white divers down flag must be flown while SCUBA diving or snorkeling. Boats must slow to no-wake speed within 100 yards of a dive flag. Divers should stay within 100 yards of their dive flag.



Spearfishing, possession of spearfishing equipment or of speared fish is not allowed within the boundaries of the Key Largo National Marine Sanctuary. Within the Looe Key National Marine Sanctuary, spearfishing is not allowed, however, equipment may be stowed and not readily available onboard. Call the Florida Marine Patrol concerning other closed areas.

Florida law requires a fishing license. Special stamps are required for lobster, snook and tarpon. Applicable size, bag limits and seasons must be observed when harvesting seafood products. Consult State and Federal authorities for current regulations.



Source: **"Reef Etiquette/Safe Boating Tips."** Florida Keys National Marine Sanctuary, Upper Keys Region, P.O. Box 1083, Key Largo, Florida 33037. Used with permission.

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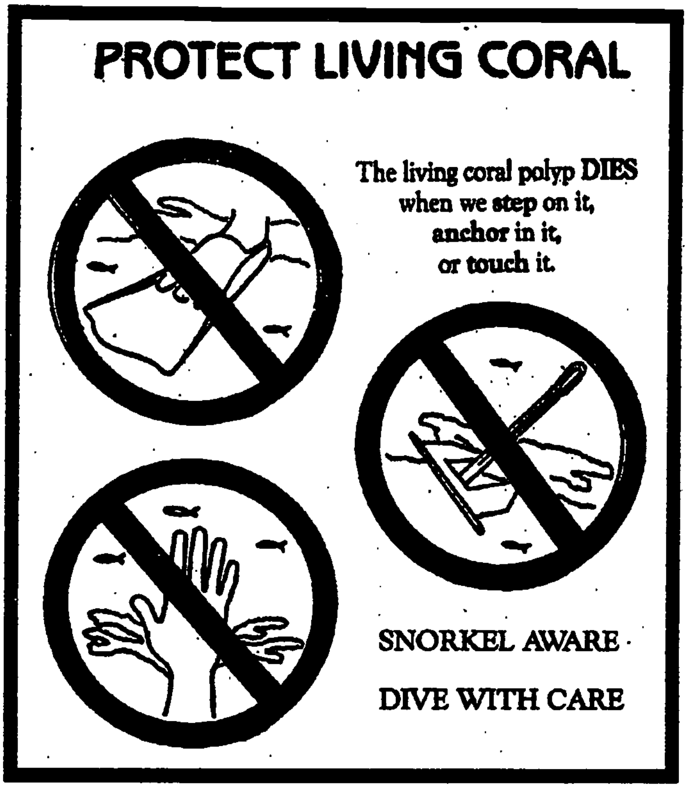


Source: (Figure at left) © Reef Relief, P.O. Box 430, Key West, Florida 33041 Tel: (305)294-3100 Fax: (305)293-9515

Source: (Figure below) Lynne Hinkey-Mac-Donald, "*You can help protect our coral,*" **Coast Notes**: Fact sheet #28, A Virgin Islands Marine Advisory Services Publication, University of the Virgin Islands. University of Puerto Rico Sea Grant College Program. Used with permission.

You can help protect our corals

1. Never stand on or touch the coral reef.
Coral is not a rock. Each coral colony is made up of tiny living animals called **polyps**, which are closely related to sea anemones. Touching, holding, standing on or kicking coral can crush and kill these animals. The coral polyps are connected and completely interdependent. **When you harm one, you hurt the entire colony.** It may take years for a coral to fully recover from an injury, and corals grow very slowly. Even small breakages can cause long-term or even irreparable damage. If you must stand while swimming, snorkeling or diving, please stand only on sandy-bottomed areas.

2. Don't feed the fish.
Bread, cooked vegetables, cheese and other human foods are indigestible for fish. They may fill up on these foods, but they can't assimilate the nutrients so may easily become weakened or sick. In addition, these foods disturb the natural balance of ocean life and may contribute to harmful algae growth and the decline of other species.

3. Swim without stirring up the sand.
Stirred up sand can cover corals, sponges and other animals and plants. This is called **siltation, and it can injure or even kill these organisms.** Besides, sand suspended in the water column interferes with our view of fish and other marine life. Keep track of where you kick your feet and flippers. Make sure they don't touch the coral or stir up the sand.

4. Pick up any trash you find in the water and place it in a garbage can.
If no garbage cans are available, take trash home and dispose of it properly. Plastic bags and other litter in the water may be mistaken for food by turtles, sea birds and other organisms. If eaten, marine debris can suffocate and starve animals. Or it may entangle or otherwise fatally injure them.

5. Use only waterproof sunscreen.
Some sunscreens wash off in the water and become a pollutant. At high-use beaches, washed off sunscreen can pose a real problem for marine plants and animals. Use only waterproof sunscreen or wear a t-shirt when you swim.

6. Use the restrooms.
Urine adds unwanted nutrients to the water. These nutrients encourage algae growth, which can limit the amount of sunlight that reaches the reef. Corals depend on sunlight for energy. With insufficient light, reefs will die.

7. Take only photos. Leave only footprints.
The health of our marine ecosystems depends upon a delicate balance of many natural processes. Removing organisms from the waters or beaches, or adding any new substances (trash, food, pollutants) can seriously disturb the balance Nature has created. To ensure the beauty and health of the Virgin Islands' environment for future visits and for future generations, please take only photos and leave only footprints.

8. Share this information with a friend.
Teach others to care for the Virgin Islands' reefs and beaches for the enjoyment of all.

Source: Adapted from an activity by Ann-Marie McCoy in **Trees to Seas: educational activities contrasting forest and coastal ecology in New England and tropical climates** to be published by New Hampshire Sea Grant Extension. Used with permission.

52. "GRIEF ON THE REEF": A SOAP OPERA

People trying to reach decisions about coral reef management and conservation can be much like a daytime soap. There are friends and there are enemies, there are triumphs and there are tragedies, there is confidence and there is uncertainty. In order to better understand the complexity of the issues and stakes, students become representatives of various public and private interest groups in a fictitious episode of "Grief on the Reef."

DAY ONE: Write the following roles on slips of paper. You may wish to omit some of the roles.

government authority
commercial fisherman
coastal native
recreational scuba diver
tourist resort developer
conservationist
underwater photographer
manager of a souvenir shop
scientist
artist who draws inspiration from nature
owner of a coastal industry that pollutes
collector of tropical fish for pet shops
recreational angler

Explain to students that they will be writing and presenting a soap opera drama about a public hearing on how nearby coral reefs will be managed. The production will be called "Grief on the Reef." Have students draw from a hat to discover their part in the soap opera drama. Then help the students understand the concerns and perspectives of the various characters. Raise questions about policies to protect reefs that might be proposed at the hearing. What would be the consequences to all the parties involved? For example, should coastal industry and development be restricted if these pollute or muddy the seawater? If so, how would restrictions affect the local economy? How much fishing and collecting should be allowed? Will the tourist trade suffer if coral trinkets and shell souvenirs cannot be sold? Would it be wise to make the reef a marine sanctuary that can be visited by divers, or to completely restrict access except to scientists? You may wish to furnish some background information for student research. Discuss what reef management proposals might be offered at the public hearing by the different members of the cast.

DAY TWO: Lead the class in deciding on a story line for "Grief on the Reef." Once a coherent plot has been agreed upon, appoint a group of students to collaborate on writing a script that includes parts for all characters. Place another group of students in charge of scenery and props.

DAY THREE: The writing of the script should be completed. After the teacher has edited the script, copies should be made and sent home with students so they can learn their parts.

DAY FOUR: Rehearse the play several times. Scenery and props should be ready for the final performance.

DAY FIVE: Perform "Grief on the Reef" before another class of students or an audience of parents. If possible, videotape the production, occasionally zooming in on the faces of the characters to create a sense of melodrama. Allow students to replay and critique their soap opera. How do they expect a real public meeting would differ from their theatrical version?

Source: From Save Our Coral Reefs, an educational manual published by Ocean Voice International, Ottawa, Canada. Used with permission.

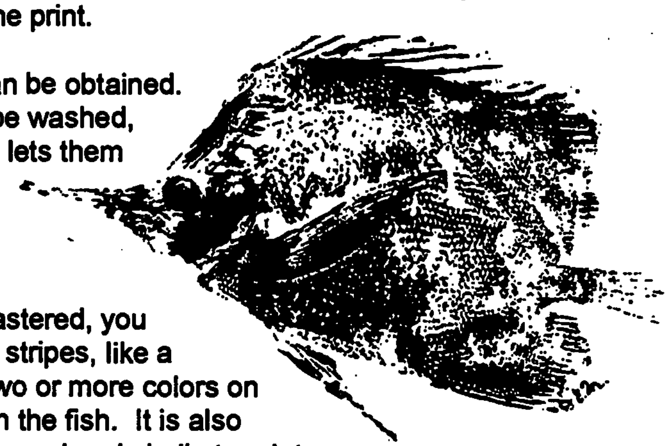
53. MAKING FISH AND SHELL PRINTS: GYO-TAKU

Methods that enable a natural resource to be re-used several times to make saleable objects are much gentler to the environment than methods where thousands of animals are sold directly, as in shellcraft. Fish and shell-printing is one such gentle craft. Fish and shell-prints, printed in color on fine paper, are craft-items enjoying a growing interest amongst American and Japanese tourists.

Gyo-taku is a method of making a print or illustration of an object using the object itself. Fish, molluscs, leaves and other natural objects may be used for gyo-taku. In the **direct method**, the object is lightly and evenly linked or painted. The painted object is then pressed against paper, leaving behind an image. If the object is rounded, then the object may need to be rolled up and down or back and forth to print the whole surface. If the object is rolled, take care that it is not shifted during rolling or a double image may be printed. In the **indirect method**, the object is wrapped smoothly in paper and a piece of cloth lightly dipped in ink or paint, is rubbed over the outside of the paper; paper over ridges and bumps on the object are inked more heavily, "valleys" remain white.

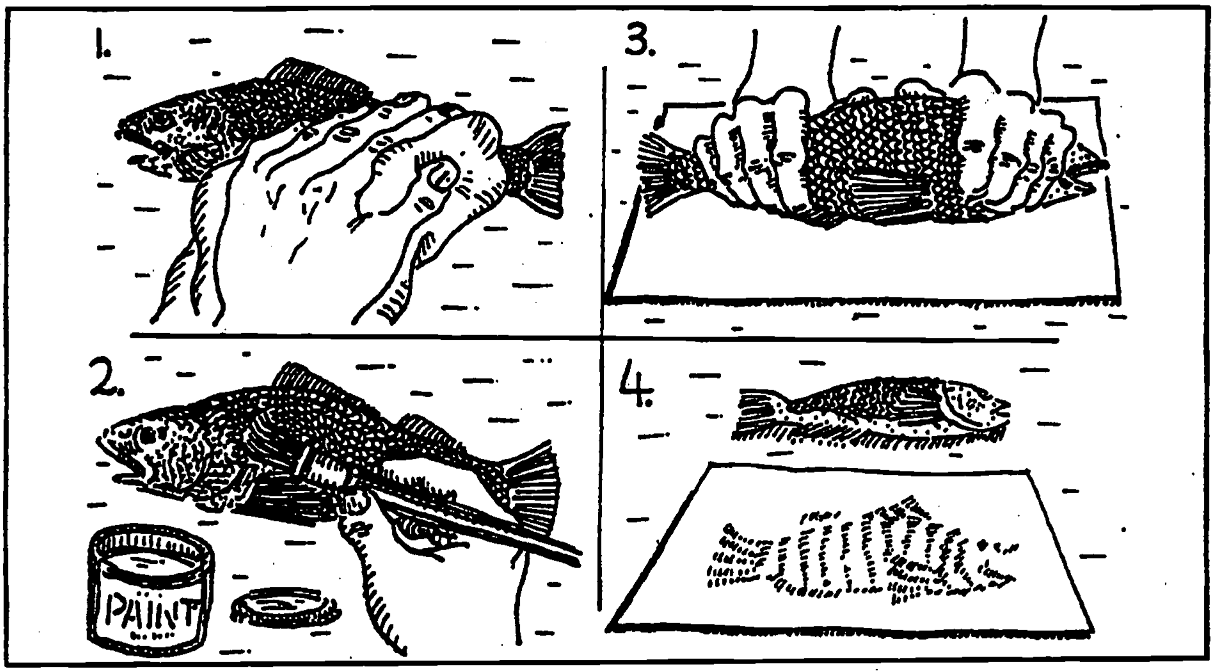
What do you need to make gyo-taku? Obtain a quality paper that will last well, has a nice color and texture. Choose a paint or ink that is **non-toxic** (not poisonous)—then afterwards, if desired, a fish used for printing can be eaten, and it will be safe to leave the ink or paint around the house where there are young children. Find inks or paints that will not bleach when exposed over time to sunlight. With good paper and permanent-style ink, the purchaser of the gyo-taku will then be able to enjoy the print. for many years. Chinese or Japanese **sumi** ink or India Ink can be used for black; non-toxic artist's water colors, poster colors or gouache can be used for colors.

A clean dry shell requires no previous preparation. But a fish should first be wiped clean with a cloth so there is no mucus or moisture on the skin. The object to be printed, is covered with ink using a brush or a wad of cloth lightly dipped in ink or paint. Only the raised higher points are inked, the grooves and crannies are left free of ink. The object is then pressed firmly on the paper and lifted off, or carefully rolled once if it is rounded. With a fish, the fins can be spread out carefully and pressed separately against the paper. The print can then be left to dry. The name of the mollusc or fish, your town and province, and the artist can be neatly written on the print.



By treating the fish carefully a number of prints can be obtained. If non-toxic ink has been used, then the fish can be washed, skinned and cooked. The hard structure of shells lets them be used any number of times as a printing stamp. You could sell one shell a hundred times this way!

Once the simple method of gyo-taku has been mastered, you can try fancier ones. If the fish you are using has stripes, like a Moorish idol, then just paint the stripes, or paint two or more colors on the fish for printing, matching the natural colors on the fish. It is also possible to make simple scenes using fishes, seaweed and shells to print the picture. Or you may wish to add value to your print by mounting it on paper, making a matte, framing it with wood or bamboo, and covering the print with glass or plastic.



A damp cloth to wipe the fish clean, sumi ink, a brush or wad of cloth to spread the ink on the fish, and suitable paper are needed to make a gyo-taku or fish print.

Source: Adapted from **Coral Forest Teacher's Guide**. Coral Forest, 400 Montgomery Street, Suite 1040, San Francisco, California 94104 Tel: (415)788-REEF Fax: (415)398-0385 e-mail: coral@igc.apc.org Used with permission.

54. CORAL REEF WORD FIND

Objective: Students will review and become familiar with words related to coral reefs.

Interdisciplinary Index: Language Arts, Science

Materials: A blank **Coral Reef Word Find**, one for each student; pencils

Presentation:
1. Review the vocabulary. (See lists above each **Word Find** grid.)
2. Tell students they are going to make their own **Word Find.**
3. Have students place the review words (one letter in each square) randomly across, down, or diagonally on the grid.
4. When all of the words have been placed on the grid, students will fill in the empty squares with letters.
5. Have students exchange **Word Finds** and solve.

Follow-up/Extension:
Give each student another **Word Find** sheet as homework. The student can make a word find for a friend or relative to solve.

CORAL REEF WORD FIND 1

Use the words related to coral reef benefits, threats, and solutions to make a word search. See if someone else can solve your puzzle.

food	hurricane	pollution	cleanup
shelter	sediment	boats	sustainable
beach	disease	divers	sanctuary
tourism	cyanide	extinct	conserve
medicine	dynamite	endangered	education

CORAL REEF WORD FIND II

Use the words related to life on the coral reef to make a word search. See if someone else can solve your puzzle. Do they know what these words mean?

phytoplankton	polyp	lobster	crab	sponge
damselfish	shark	triton	crepuscular	mangrove
trunkfish	juvenile	nudibranch	lagoon	omnivore
barracuda	zooplankton	endosymbiont	coral	herbivore
clam	parrotfish	octopus	seagrass	carnivore
clownfish	anemone	mollusk	triggerfish	

Source: From Save Our Coral Reefs, an educational manual published by Ocean Voice International, Ottawa, Canada. Used with permission.

55. Questions to Stimulate Discussions and Test Understanding

The answers given here do not include all possible replies. And sometimes they may be wrong for a particular area! Sometimes only partial answers are given. Answers are often bigger than questions!

1. **Are corals alive, or are they just rock?**
Reef-building corals are live animals with tiny co-op algae in their soft parts.
2. **Why are the tiny coral-plants in the soft parts of the coral so important?**
The tiny coral-plants in the soft parts of coral are important because they provide four-fifths of the coral's food and energy.
3. **Why do corals need sunlight?**
The small co-op algae in the coral's soft parts need sunlight and share the sun's energy with the corals.
4. **What do corals feed on at night?**
At night the corals feed on plankton, using their tentacles.
5. **How do water currents help corals?**
Water currents carry plankton to the corals, and clean salty sea water.
6. **Does fresh water kill corals?**
Fresh water kills corals if they are exposed to it for very long. Freshwater flooding or even a heavy rain at low tide can kill corals.
7. **Why is shore vegetation important to coral reefs?**
Shore vegetation is important to coral reefs because it helps smooth the flow of harmful freshwater onto the reefs and it filters out cloudy water and mud.
8. **How long do corals live?**
Some corals reach 50, others hundreds or even over a thousand years in age.
9. **Where are the richest coral reefs in the world?**
The richest coral reefs in the world are in the "Coral Triangle" between the Philippines, Borneo, and New Guinea.
10. **Do healthy reefs have more species of fishes and invertebrates than sand or mud bottomed areas? Why?**
Healthy coral reefs have more species of fishes and invertebrates than sand or mud bottomed areas because coral reefs provide them with more food and with shelter from predators and waves.
11. **Name 10 different kinds of sea life that can be harvested from coral reefs.**
Kinds of sea life that can be harvested from coral reefs include: products for the food, pharmaceutical, aquarium and tourist industries through harvest of fishes, molluscs, seaweeds, betang [sea cucumbers], sea urchins, crabs, lobsters, and shrimps. Tourists can also be caught!
12. **How do coral reefs protect coastal communities?**
Coral reefs protect coastal communities by acting as a breakwater. This weakens storm and typhoon waves, and reduces wave damage.
13. **Where does the coral sand on our beautiful beaches come from?**
The beautiful coral sand comes from coral reefs. Coral is ground up into sand by parrot fishes, certain molluscs, and storm waves.
14. **Why do tourists come to coasts with healthy reefs?**
Tourists come to coasts with healthy reefs because healthy reefs have many rich colorful corals of different shapes, active colorful fishes, and many astonishing invertebrates. Healthy coral reefs produce fine coral sand beaches and calm water in which to swim and travel by [boat] behind the protection of the reef. And delicious seafood can be found there too.

15. Name five businesses that benefit from coral reefs.
Businesses that benefit from coral reefs include food fishing, boat making, restaurants, hotels, tourist guides, diving tours, aquarium fish industry.

16. How many metric tons of fishes does a square kilometer of healthy reef produce each year? How many tons of fishes does a square kilometer of degraded reef produce each year?
A healthy coral reef produces up to 35 metric tons of fishes per square kilometer each year. A degraded reef produces only 5 metric tons.

17. Why are catches of fishes and invertebrates poor on degraded coral reefs?
Catches of fishes and invertebrates on degraded coral reefs are small because such reefs provide less food and little shelter from predators and waves; as the dead coral breaks up there are fewer holes to hide in.

18. Why should one leave some "seed" fishes and shells on reefs?
One should leave "seed" fishes and shells on the reef to produce babies for later catches.

19. Name four sources of cloudy water and mud.
Cloudy water and mud that can harm coral reefs can come from clear-cut logging, farming on steep slopes, lack of stream-side vegetation, removal of trees from the coast, construction right on the coast, removal of mangrove swamps and seagrass beds.

20. What kinds of farm chemicals can harm coral fishes and reefs?
Herbicides and insecticides can harm fishes and corals. Excess fertilizer washed into the sea can encourage growth of harmful seaweed or crown-of thorns starfishes.

21. Name three sources of wastes which are harmful to coral reefs.
Untreated sewage wastes from cities, mine tailings, and factory pollution can harm coral reefs.

22. How far can pollution travel in the oceans?
Pollution of long-lasting substances can travel world-wide in the oceans.

23. Do marine reserves have any advantages for coastal communities?
Marine reserves provide seed fishes, shellfishes and corals for neighboring areas and slowly contribute to better catches. They are also attractive spots for tourists.

24. Is research important in conservation?
Research is needed in conservation. We need to complete the scientific description and mapping of nature and awareness of diversity. We need to know the needs—the ecology and biology of animals and plants, and to understand what ecological services are provided by nature.

ANSWERS

#11 A Closer Look: Identifying Coral Species (pp. 19-21)
Answers to Questions: **1.** Answers will vary. Calyces whose side walls are missing leave long grooves, giving the coral skeleton a distinctly different appearance from species whose cups are distinct. **a.** Cup features are determined genetically and therefore have different structures.
b. Answers will vary. If you have specimens from a shoreline, use them as an example to help answer this question. If some of the features used for identification are still visible, the species can usually be determined. The shape and density of the skeleton can sometimes be used as clues to the species. **2.** The side walls are absent. **3.** After the larva settles down on a suitable substrate, it begins to secrete a skeleton. In colonial corals new polyps gradually grow around the original polyp. These new polyps continue to secrete new material, making the skeleton grow in diameter. The colony grows over the substrate in an ever-increasing encrusting mass. If the species is a branching type, a stalk starts to grow upward from somewhere in the center of the colony. New polyps and more skeleton are added to the tips of the branches, forming a bushlike shape. If the coral is an encrusting type, the colony continues to grow in diameter over the substrate. **4.** Most branching coral species are subject to breakage during a storm. Encrusting corals, because of their low profile, are less likely to break. During violent storms large chunks of coral break off the reef, and heavy wave action batters them back and forth, scouring other corals. A coral reef may take several decades to grow back to its original cover and beauty.
5a. A principal form of the body plan of cnidarians, consisting of a bag-within-a-bag construction and a central mouth opening ringed by tentacles. Polyps attach to hard surfaces with their mouths pointing upward. **b.** Many individuals fused together in a cooperating biological unit. **c.** The edges (side walls) of a calyx extending above the surface of a coral skeleton. **d.** Radiating partitions inside the side wall of the calyx. The septa sometimes extend outside the side wall to other calyces. **6.** Most reef-building corals are colonial. That is, individual animals fuse together at their bases in vast colonies. Skeleton is produced simultaneously by all individuals in the colony, forming large coral heads. On a coral reef thousands of colonies live side by side, each contributing to the formation of the reef structure.

#18 Biological and Physical Agents of Change on a Coral Reef (pp. 30-32)
Suggested Answers for Table 2: **Forest builders:** Trees, shrubs, bushes, vines, plants; **Forest floor organisms:** Herbs, flowering annual plants, worms, snails, fungus, rabbits, deer, squirrels, birds, insects; **Passive residents:** herbs, plants, snails, rabbits; **Destructive organisms:** Deer, fungi, woodpeckers, beavers, bears, humans; **Constructive physical agent:** Rain, warm temperatures, sunlight, nutrients in soil; **Destructive physical agents:** Wind, floods, severely cold winter, heavy snow, drought, landslides. *Answers to Questions:* **1.** The structure is the arrangement of physical features in a habitat. In a forest, it includes the number of trees and their shape, density, and sizes, along with the kinds and sizes of shrubs. In a reef, it includes the number of corals and their shapes, sizes, density, height, and depth of growth. **2.** Both supply the structure of the habitat. Corals are animals; trees are plants. The skeleton of corals is calcium carbonate; the tree's skeleton is wood. **3.** Trees fall to the forest floor and decay from the action of fungus. The chemicals of the tree return to the soil to be recycled. Coral skeletons move back and forth by the action of wave energy, gradually grinding the skeletons into sand. Some of the sand washes toward shore, forming sandy beaches; some moves down the reef face, forming deep water sand deposits. **4.** A tree begins its growth as a seed and grows bigger with time. If a branch breaks off, it dies, but the tree usually heals and continues to grow. Eventually something (fire, disease, uprooting) kills the tree.

A forest is a complicated assembly of species of trees, shrubs, bushes, herbs, and the animals that live there. The growth of the forest depends on the relative rates of growth of the organisms, primarily the trees, which grow at different rates. Often one species of tree grows faster than another species, changing the makeup of the dominant trees in a process called succession. Parts of the forest may be killed by fire, wind, or other physical forces. A single species of tree may be killed by disease. Gradually the forest changes in composition. If a major fire, landslide, or wholesale logging occurs, the forest as a unit may die, along with the individuals in all of the species, both plant and animal. Seeds of some plants may survive to grow and start the process of forest formation again.

A coral begins its growth when a larva settles on the bottom of the shallow ocean and starts to grow. If a branch is broken, it dies, but the coral usually heals and continues to grow. Eventually something (waves from a storm, pollution, fresh water) kills the coral.

A coral reef is a complicated assembly of species of corals, algae, crabs, octopus, and the fish that live there. The growth of the coral reef depends on the relative rates of growth of the organisms, primarily the corals. Different corals grow at different rates. Often one species of coral grows faster than another species, changing the makeup of the dominant corals on the reef in a process called succession. Parts of the reef may be killed by wave action, sediments, or other physical forces. Gradually the coral reef changes in composition. If a major storm, pollution, or dragging of anchors by ships occurs, the coral reef as a unit may die, along with all individuals in all of the species, both plant and animal. Larvae of some corals may move into the region with water currents and settle on the bottom to grow and start the process of reef formation again. **5.** Wind directly damages a forest. Wind causes ocean waves that damage the coral. Fresh water in the form of a flood could damage a forest. Fresh water damages a coral reef because corals cannot live in fresh water. Air pollution (such as acid rain) might kill many trees in a forest. Water pollution and sediments might kill many corals on a reef.
6. Most reef-building corals have symbiotic algae growing in their tissues. The rate of coral growth depends on the amount of sunlight the algae receive. Therefore corals do

not grow in deep water or under ledges or in caves.

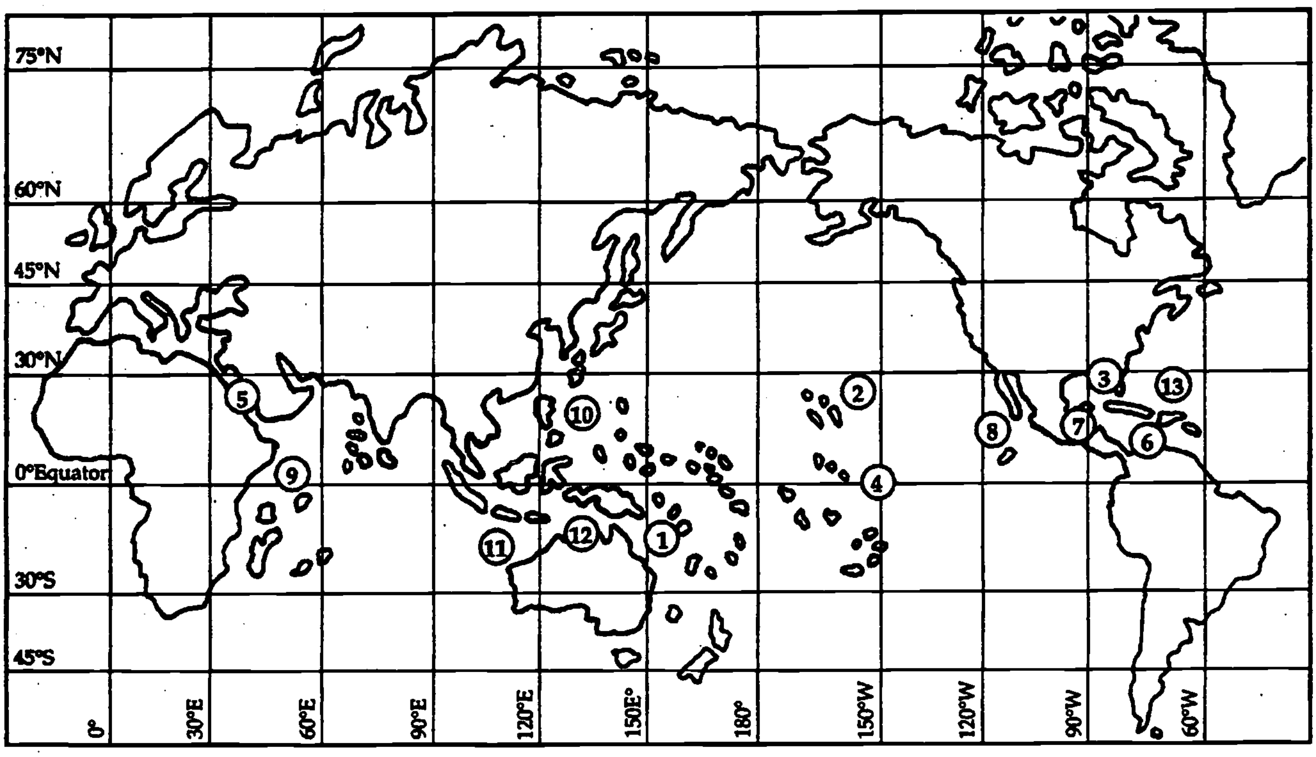
The upper surfaces of the tallest trees receive most of the sunlight, shading the smaller plants lower down. Plants on the forest floor must be shade-tolerant to survive.

#21 Where Do Coral Reefs Grow? (pp. 35-36)
1. no; Brazil, all of Central Africa on west coast, all of tropical South America on the west coast; 2. arrows are counter clockwise in northern hemisphere and clockwise in southern hemisphere; 3. eastern coastlines; western coastlines; coral reefs grow only in warm water; 4. Brazil; Sediment loaded fresh water flows from Amazon River into the Atlantic Ocean.

#22 The Reef Region (p. 37)
See map below. 1. Great Barrier Reef; 2. Maui, Hawaii; 3. Key West, Florida; 4. French Polynesia; 5. Red Sea; 6. Jamaica; 7. Belize; 8. Cabo San Lucas; 9. Seychelles Islands; 10. Philippines Islands; 11. Java; 12. Celebes Islands; 13. Bahama Islands

anemone; I. Spanish crab; J. elkhorn coral; K. club urchin; L. comb jelly; M. moon jelly; N. soft sea cucumber; O. Frons oyster; P. pillar coral; Q. comet star; R. long-spined urchin; S. polyclad flatworm; T. brain coral; U. rock lobster; V. spiny lobster; W. sun anemone

#28 Classification of Reef Fish (pp. 50-53)
Classification of Butterflyfish (decision points in sequence): A. *C. miliaris* (1-4-6-7-8-10-11-12-13); B. *C. citrinellus* (1-4-6-7-8-10-11-12-13); C. *C. unimaculatus* (1-4-6-7-8-10-11-12-14); D. *C. tinkeri* (1-4-6-7-8-10-11); E. *C. fremblii* (1-4-6); F. *C. quadrimaculatus* (1-2) ; G. *C. lunula* (1-4-6-7-8-10-11-12-14); H. *C. auriga* (1-4-5); I. *C. reticulatus* (1-2-3); J. *C. ornatissimus* (1-4-6-7-8-9); K. *C. multicintus* (1-4-6-7); L. *C. trifasciatus* (1-4-6-7-8-9); M. *C. kleini* (1-2-3); N. *C. lineolatus* (1-4-6-7-8-10); O. *C. ephippium* (1-4-5);
Answers to Questions: 4. Features that do not vary within a group (species) but differ from other groups (species). Whenever possible, the features should be easy to see.
5. Use characteristics other than color to construct the key.
6. Some color patterns change as the animal grows or



#23 Mapping the Reefs (pp. 38-41)
Answers to Geography Clues: 1. Bahama Islands; 2. Belize; 3. Caribbean; 4. Madagascar; 5. Pacific; 6. Great Barrier Reef; 7. Jamaica; 8. Panama; 9. Florida; 10. Hawaii; 11. Philippines; 12. Red Sea; 13. Marshall Islands

#27 What's My Name? (pp. 46-49)
Coral Reef Animal Key: A. Atlantic thorny oyster; B. swimming crab; C. fire worm; D. club urchin; E. brittle star; F. finger coral; G. trumpet triton; H. corkscrew

ages. Patterns and colors often differ with the sex of the animal. Patterns or colors sometimes change suddenly when the animal becomes aggressive or fearful. Some color patterns fade rapidly when the animal dies; other colors persist long after it dies.

#29 Partner Wanted (pp. 54-55)
Box 1 (sea anemone) and **Box 4** (clownfish); **Box 2** (hermit crab) and **Box 6** (sea anemone); **Box 3** (cleaner fish) and **Box 7** (grouper); **Box 5** (pistol shrimp) and **Box 8** (goby)

#30 Animals that Bite and Sting (p. 56)
1. D/box jellyfish; **2.** L/*Diadema* sp.; **3.** G/stingray; **4.** P/stinging hydroid; **5.** B/lion fish; **6.** N/Conus shell; **7.** I/fire coral; **8.** O/Crown-of-thorns; **9,** C/rabbit fish; **10.** K/blue-ring octopus; **11.** H/surgeon fish; **12.** M/stone fish; **13.** A/fire worm; **14.** J/bluebottle; **15.** F/moray eel; **16.** E/Stomatopod

#36 Who Eats Who? (pp. 65-66)
See figure below.

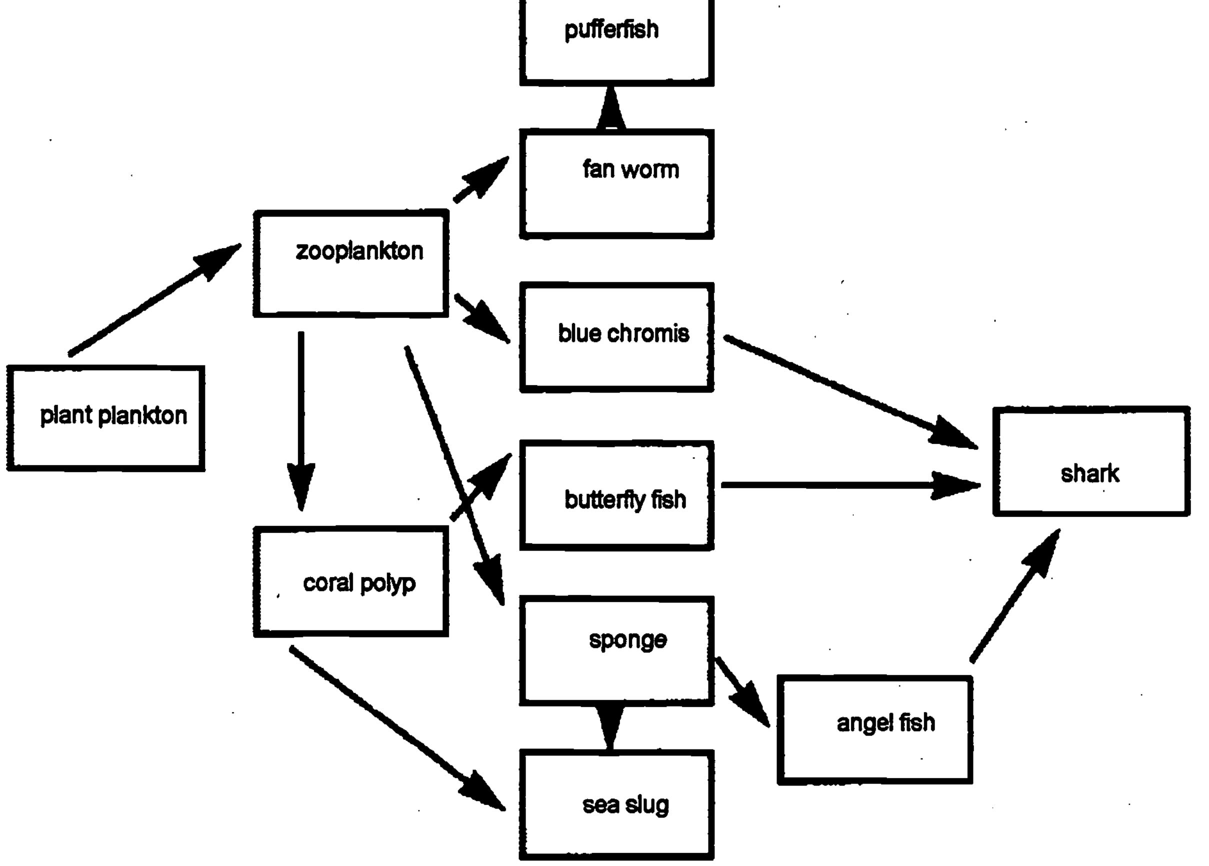
#39 Feeding Frenzy (p. 77)
1. crustaceans; **2.** crustaceans and molluscs; **3.** availability of prey, size of predator population

#41 Reef Homes: Zonation of a Coral Reef (pp. 79-80)
2. *Hypothesis:* Halo is caused by grazers moving between patch reef where they hide and the grass bed where they feed.

#44 Threats to the Coral Reef (p. 85)
1. N; **2.** H; **3.** H; **4.** N; **5.** H; **6.** H; **7.** N; **8.** H; **9.** H; **10.** N; **11.** H. The activities of people are the major cause of destruction to coral reefs.

#47 Fishy Problems (p. 90)
1a. 3 million; **b.** 4; **c.** 50; **2.** 22,500; **3.** 12,000; **4 a.** 48; **b.** 37.5 kg.; **c.** 3969 lbs.; **d.** 496 lbs.; **5a.** 3279 ft.; **b.**$3,660 /ft.; **6.** $62 million; **7a.** between 20 to 35 metric tons; **b.** 44,092.5 to 77,161.8 lbs.; **8a.** 429,730 metric tons; **b.** 3 million people eat 0 lbs. of fish, 6 million people eat 58.42 lbs./person

#36 Who Eats Who? (pp.65-66)



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RESOURCES

CORAL REEF PUBLIC AQUARIUM EXHIBITS AND PARKS

UNITED STATES: Arizona Sonoran Sea Aquarium, Tucson; **California** Marine World/Africa, U.S.A., Vallejo; Monterey Bay Aquarium, Monterey; Birch Aquarium at Scripps Institution of Oceanography, La Jolla; Sea World of California, San Diego; Steinhart Aquarium, San Francisco; **Colorado** Denver Zoological Gardens; **Connecticut** Mystic Marinelife Aquarium, Mystic; **District of Columbia** The National Aquarium, Washington; The National Museum of Natural History, Washington; **Florida** Bahia Honda State Park, Big Pine Key; Biscayne National Park, Homestead; Clearwater Science Center Aquarium, Clearwater; Dry Tortugas National Park, Key West; The Florida Aquarium, Tampa; Key West Aquarium, Key West; Florida Keys National Marine Sanctuaries (305)451-1621; John Pennekamp Coral Reef State Park, Key Largo; "Living Seas" at the Epcott Center, Lake Buena Vista; Lowry Park Zoological Gardens, Tampa; Marineland of Florida, St. Augustine; Miami Seaquarium, Miami; Mote Marine Aquarium, Sarasota; Sea World of Florida, Orlando; Theater of the Sea, Islamorada; **Hawaii** Sea Life Park Hawaii, Waimanalo; Waikiki Aquarium, Honolulu; **Illinois** Shedd Aquarium, Chicago; **Indiana** Fort Wayne Children's Zoo, Fort Wayne; Indianapolis Zoo, Indiana; **Kentucky** Louisville Zoological Gardens, Louisville; **Louisiana** Aquarium of the Americas (Audubon), New Orleans; **Maryland** National Aquarium in Baltimore, Baltimore; **Massachusetts** The Berkshire Museum, Pittsfield; New England Aquarium, Boston; **Michigan** Belle Isle Aquarium, Detroit; **Minnesota** Lake Superior Zoological Gardens, Duluth; Minnesota Zoological Garden, Apple Valley; **Missouri** Mid-America Aquacenter, St. Louis; St. Louis Zoological Park, St. Louis; **Nebraska** Henry Doorly Zoo, Omaha; Scott Aquarium, Omaha; **New Jersey** New Jersey State Aquarium, Camden; **New Mexico** Albuquerque Aquarium, Albuquerque; **New York** Aquarium at Niagara Falls, Niagara Falls; New York's Aquarium for Wildlife Conservation, Brooklyn; **North Carolina** North Carolina Aquarium, Fort Fisher; **Ohio** Cleveland Metroparks Zoo, Cleveland; Sea World of Ohio, Aurora; Toledo Zoological Garden, Toledo; **Oklahoma** Oklahoma City Zoological Park, Oklahoma City; Tulsa Zoo and Living Museum, Tulsa; **Pennsylvania** Carnegie Science Center, Pittsburgh; Pittsburgh Zoo, Pittsburgh; **South Carolina** South Carolina Aquarium, Charleston; **Tennessee** Memphis Zoo & Aquarium, Memphis; **Texas** Dallas Zoo & Aquarium, Dallas; Flower Gardens National Marine Sanctuary, Bryan; Houston Zoological Gardens, Houston; San Antonio Zoological Gardens & Aquarium, San Antonio; Sea World of Texas, San Antonio; Texas State Aquarium, Corpus Christi; **Washington** Seattle Aquarium, Seattle; The Point Defiance Zoo & Aquarium, Tacoma; **Wisconsin** Racine Zoological Gardens, Racine

BAHAMAS Coral World Marine Park, Nassau; **BERMUDA** Bermuda Aquarium, Museum & Zoo, Flatt's FL BX; **CANADA** Vancouver Aquarium, Vancouver; Ontario Science Center, Toronto; Montreal Aquarium, Montreal; Quebec Aquarium, Quebec; **DOMINICAN REPUBLIC** El Acuario Nacional, Santo Domingo; **DUTCH WEST ANTILLES** Aquarium in Curacao; Antilles Underwater Park; **ENGLAND** Aquarium at The Liverpool Museum, Liverpool; **MEXICO** Acuario Veracruz, Veracruz; Cabo Frailes near Cabo San Luca, Baja, California; Aquarium XCARET, Cancun; **BRITISH VIRGIN ISLANDS** Marine Park, Saba; **U. S. VIRGIN ISLANDS** Coral World Observatory, St.Thomas; Marine Biosphere Reserve, St. John; **PANAMA** Aquarium of the Smithsonian Tropical Research Institute, Panama City; **SPAIN** The Barcelona Zoo Aquarium, Barcelona

TO LEARN OF EXHIBIT AND PARK SITES IN YOUR AREA, CONTACT YOUR LOCAL CHAMBER OF COMMERCE OR CHECK WITH THE DEPARTMENTS OF NATURAL RESOURCES AND TOURISM FOR YOUR STATE/PROVINCE.

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THE FOLLOWING ORGANIZATIONS AND AGENCIES MAY BE CONTACTED TO INQUIRE ABOUT AVAILABLE CORAL REEF-RELATED EDUCATION/CONSERVATION RESOURCES AND PROGRAMS. MANY MATERIALS ARE OFFERED WITHOUT CHARGE OR FOR A NOMINAL PRICE. (Sp) INDICATES THAT SOME RESOURCES ARE AVAILABLE IN SPANISH. ADDITIONAL RESOURCES ARE LISTED IN THE REFERENCE SECTION OF THIS MANUAL.

Amigos de Sian Ka´an, A.C., Av. Cobá Numero 5, Plaza América, Local 50, 77500 Cancún, Q. Roo, Mexico *El Mar y Sus Recursos student book and workbook. (Sp)*

Asociacion Oceanica de Panama, Apdo. Postal 6-2305, El Dorado, Republica de Panama Fax: (507)226-2020 *quarterly bulletin, slides, brochure, videos, exhibits, conferences, field programs, and educational programs for students. (Sp)*

Caribbean Conservation Association, Savannah Lodge, The Garrison, St. Michael, Barbados (809)426-5373 *Corals & Coral Reefs in the Caribbean guidebook.*

Center for Ecosystem Survival (CES), Department of Biology, San Francisco State University, 1600 Holloway Avenue, San Francisco, California 94132 *Adopt A Reef© program.*

Center for Marine Conservation, 1725 DeSales St., N.W., Washington, DC 20036 (202)429-5609 *fact sheet.*

Coral Cay Conservation (USA) Ltd., Suite 124, 230 12th Street, Miami Beach, Florida 33139 (305)757-2955 WWW: http://www.demon.co.uk/coralcay/home.html *"Life on the Coral Reef" educational pack for students ages 9 - 11 comprising interactive wall-chart, fact/activity cards and teachers notes; also pack for ages 11 - 16 and CD ROM.*

Coral Forest, 400 Montgomery Street, San Francisco, California 94104 (415)788-REEF e-mail: coral@igc.apc.org *curriculum for K-12, poster, scripted slide presentation, children's book, in-school and teacher in-service workshops. (Sp)*

Coral Health and Monitoring Program, Ocean Chemistry Division, NOAA/AOML, 4301 Rickenbacker Causeway, Miami, Florida 33149-1026 *homepage on World Wide Web—which includes underwater photographs, satellite images, news bulletins, marine environmental data, coral-related literature abstracts, directory of researchers, etc.—at http://coral.aoml.noaa.gov*

Coral Reef Alliance, 809 Delaware Street, Berkeley, California 94710 (510)528-2492 *fact sheets; video; "Coral Reefs, the Vanishing Rainbow" slide presentation; coral reef calendar; speakers bureau; "International Year of the Reef" brochure; "International Year of the Reef" homepage, featuring calendar of IYOR activities and list of educational resources available around the world, can be visited on World Wide Web at http: //www.coral.org/*

Curriculum Research & Development Group, University of Hawaii, 1776 University Avenue, Honolulu, Hawaii 96822 (800)799-8111 e-mail: crdg@hawaii.edu *The Hawaii Marine Science Studies (HMSS) program is a one-year multidisciplinarycourse set in a marine context for students in grades 9-12. There are two companion student books (The Fluid Earth and The Living Ocean) which explore the physics, chemistry, biology, and geology of the oceans and their applications in ocean engineering and related technologies.*

HMSS is a product of the Curriculum Research & Development Group (CRDG) of the University of Hawaii. CRDG conducts systematic research, design, development, publication, staff development, and related services for elementary and secondary schools. The CRDG has curriculum development projects in science, mathematics, English, Pacific and Asian studies, marine studies, environmental studies, Hawaiian and Polynesian studies, Japanese language and culture, music, nutrition, art, drama, technology, health, and computer education. Research and school service projects focus on educational evaluation, teacher development, reduction of in-school segregation of students, and programs for students educationally at risk.

Departmento de Recursos Naturales y Ambientales, Area de Investigaciones Cientificas, Programa de Educación en Recursos Acuáticos, Apdo. 5887, Puerta de Tierra, Puerto Rico (809)725-8619 *posters, other resources. (Sp)*

Education/Information Section, Great Barrier Reef Marine Park Authority (GBRMPA), P.O. Box 1379, Townsville, QLD 4810, Australia *Project Reef Ed curriculum manual, teaching kits, books, pamphlets, videos, slides.*

ENCORE (Environment and Coastal Resources)/ World Wildlife Fund, P.O. Box 1383, Castries, St. Lucia, West Indies (758)453-6780 *studies /inventories on coastal resources including reefs, slides, videos.*

Environmental Media & Marine Grafics, P.O. Box 1016; Chapel Hill, North Carolina 27514 (800)368-3382 *videos. (Sp)*

FishEye View-Cam, Coral Gables, Florida *CD ROMs; World Wide Web site—from which remote underwater camera movies of a living coral reef may be downloaded—at http://www.qltech.com/livingreef.html*

Florida Keys National Marine Sanctuary Program, Education Department, P.O. Box 1083; Key Largo, Florida 33037 (305)451-1644 *videos, posters, brochures. (Sp)*

FOR SEA/Marine Science Center, 17771 Fjord Drive NE, Poulsbo, Washington 98370 (360)779-5540 *curriculum, CD ROMs.*

Gray's Reef National Marine Sanctuary, 10 Ocean Science Circle, Savannah, Georgia 31411 (912)598-2345 *posters, other resources.*

James Cook University of North Queensland, Sir George Fisher Centre for Tropical Marine Studies, Townsville, QLD. 4811, Australia *Australian UNESCO Project Marine Science Curriculum Materials for South Pacific Schools.*

JASON Foundation for Education, 395 Totten Pond Road, Waltham, Massachusetts 02154 (617)487-9995 e-mail: info@jason.org *JASON Project with teacher's curriculum manual, satellite broadcasts, and computer components.*

The Jean-Michel Cousteau Institute, 1933 Cliff Drive, Suite #4, Santa Barbara, California 93109 (805)899-8899 *"Jean Michel Cousteau's World, Vol. 1: Cities Under the Sea—Coral Reefs" PC or CD ROM curriculum.*

Leave Only Bubbles, Inc., P.O. 2397, Key Largo, Florida 33037 (800)890-0134 *videos, CD ROMs, jigsaw puzzles, stickers, etc.*

Macmillan Education Australia Pty. Ltd., 107 Moray Street, South Melbourne 3205, Australia *Coral Reefs and The Living Reef books for children/ youth.*

MARE: Marine Activities, Resources & Education; Lawrence Hall of Science, University of California, Berkeley, California 94702 (510)642-5008 *Teacher's Guide to Coral Reefs grade 7 curriculum.*

Monterey Bay Aquarium, 886 Cannery Row, Monterey, California 93940-1085 (408)648-4835 *poster, brochures, bibliography, articles, "Underwater World" site on World Wide Web—dive into a shark's mouth, go on an underwater tour, other activities—at http://pathfinder.com/path/finder/kidstuff/underwater/*

Mystic Marinelife Aquarium, Education Department, 55 Coogan Boulevard, Mystic, Connecticut 06355-1977 (203)572-5955 *articles, activities, bibliography.*

National Aquarium in Baltimore, Education Department, Pier 3/501 East Pratt Street, Baltimore, Maryland 21202 *"Project ReefAction," reef adoption program, "Rescue the Reef" sticker, "Coral Reefs Are Rain Forests of the Sea" brochure, articles. (Sp)*

National Audubon Society, 325 Route 4, Sharon, Connecticut 06069 (860)364-0520 *"Coral Reef, Sunken Treasure" poster with leader's guide and student book available from Audubon Adventures division.*

National Wildlife Federation, 1412 16th St., N.W., Washington, D.C. 20036-2266 (800)822-9919 *"NatureScope: Diving Into Oceans" magazine for grades K-7.*

The Nature Conservancy, 1815 N. Lyn Street, Arlington, Virginia 22209 (800)84-ADOPT *"Rescue the Reef" adoption packets, newsletter, annotated list of "Organizations Involved in the Protection of Coral Reefs."*

New England Aquarium, Teacher Resource Center, Central Wharf, Boston, Massachusetts 62110 (617)973-6590 *books, videos, reprints. (Sp)*

New World Publications, 1861 Cornell Road, Jacksonville, Florida 32207 (800)737-6558 *field guides, other resources.*

Newfound Harbor Marine Institute/SEACAMP Association, 1300 Big Pine Avenue, Big Pine Key, Florida 33043-3336 (305)872-2331 *marine science programs and camps for students, SCUBA..*

Ocean Voice International, Box 37026, 3332 McCarthy Road, Ottawa, ON K1V 0W0, Canada (613)264-8986 *Save Our Coral Reefs manual, quarterly bulletin, other resources.*

Ocean Watch, P.O. Box 1618, Vienna, Virginia 22183-1618 (703)827-2591 e-mail:oceanwatch @aol.com *"The Fragile Ring of Life" video and teacher's guide.*

Planetary Coral Reef Foundation, 32038 Caminito Quieto, Bonsall, California 92003 (619)723-7433 *educational materials.*

Reef Relief, P.O. Box 430, Key West, Florida 33041 (305)294-3100 *on-the-water interpretive program, multi-media educational campaign, newsletter, fact sheets. (Sp)*

Sanctuaries and Reserves Division, Attn: Mr. Justin Kenney, National Ocean Service, NOAA-Building 4, 1305 East-West Highway, Silver Spring, Maryland 20910 *posters .*

Save Our Seas, P.O. Box 598, Hanalei, Hawaii 96714 (808)826-2525 *"Project Ocean Pulse" enlists the aid of middle school students in creating coral reef databases.*

Sea Grant Education Program, Humacao University College, Humacao, Puerto Rico 00791 *curriculum for grades K-9, videos , slides. (Sp)*

Sea Grant Extension Service, 1000 Pope Road, Honolulu, Hawaii 96822 (808)956-8191 *curriculum for grades K-12, Pacific Island Network Marine Science Summer Program at Fagatele Bay National Marine Sanctuary in Samoa.*

Sea World of California Education Department, 1720 South Shores Road, San Diego, California 92109-7995 (619)226-3834 *All About Corals and Coral Reefs curriculum with teacher's guide and student books for grades K-3 and 4-8.*

The Seattle Aquarium, 1483 Alaskan Way, Seattle, Washington 98101 (206)386-4320 *curriculum guides for grades K-3, 4-6, and 7-9.*

Secret Sea Visions; P.O. Box 162931; Austin, Texas 78716 (512)328-1201 *videos.*

Siwa-ban Foundation, 47 Caye Caulker, Belize, Central America *teacher training workshops on marine ecosystems (mangroves, sea grass beds, reefs). (Sp)*

Small World Music and Videos, 117 30th Avenue S., Nashville, Tennessee 37212 (800)757-2277 *award-winning videos —"Coral Sea Dreaming" (spectacular reef footage, orchestral sound track without narrative is ideal for bilingual classrooms) and "Life on the Coral Reef" educational documentary.*

Smithsonian Institution, Environmental Awareness Program, 3123 Ripley Center, MRC 705, Washington, D.C. 20560 *"Ocean Planet" homepage on World Wide Web at http://seawifs.gsfc.nasa.gov/ocean_planet.html*

Smithsonian Tropical Research Institute, Office of Education, Apartado 2072, Balboa, Ancon, Republica de Panama (507)227-6022 *Guia Didactica de Educacion Marina school book with activities, marine posters with educational kits, teachers workshop manual, teacher's guide and courses for middle school teachers. "Our Reefs: Caribbean Connections" traveling coral reef exhibit in Spanish/English will visit sites throughout the Caribbean—call for exhibit itinerary. (Sp)*

South Coast Conservation Foundation, 91A Old Hope Road, Kingston 6, Jamaica, West Indies (809)978-4047 *community marine education program.*

South Pacific Regional Environment Programme, P.O. Box 240, Apia, Western Samoa *books, brochures, other resources.*

The Star Thrower Foundation, P.O. Box 2200, Crystal River, Florida 34423 (352)563-0022 *Palaces Under the Sea book, Piggy Divers Wreck our Reefs comic book, "10 Things to Save the Reefs" brochure.*

Trickle Creek Books, 500 Andersontown Roads, Mechanicsburg, Pennsylvania 17055 (800)353-2791 *The Incredible Coral Reef activity book.*

United States Environmental Protection Agency, Public Information Center, 401 M Street S.W., Washington, D.C. 20460 *student and teacher kits.*

University of Miami/RSMAS-MGG, Attn: Dr. Robert Ginsburg - IYOR, 4600 Rickenbacker Causeway, Miami, Florida 33149 Fax:(305)361-4094 *"Coral Cities" slide presentation with teacher's manual. (Sp)*

University of Alberta, Earth and Atmospheric Sciences Department, Attn: Dr. Paul Blanchon, 1-26 Earth Science Building, Edmonton, Alberta, Canada T6G 2E3 *"Reef Resource Page" on World Wide Web —for students of coral reefs, includes critique of organizations and other web sites—at http://www.ualberta.ca/~pblancho/index.html*

Resource Video Fish Book, 1825 NE 149 St., Miami, Florida 33181 (800)741-1112 *videos.*

The Video Project, Media Consulting, 43124 Manila Avenue, Oakland, California 94609 *"Crisis In Our Oceans" brochure features list of videos, CD ROMs, books and supplemental materials on coral reefs, and suggested activities for young people to help protect reefs.*

Virgin Islands Marine Advisory Services, University of the Virgin Islands, Eastern Caribbean Center, St. Thomas, U.S. Virgin Islands 00802 *fact sheets, other resources.*

Waikiki Aquarium, Education Department, 2777 Kalakaua Avenue, Honolulu, Hawaii 96815 (808)923-9741 *curriculum, student programs.*

The Wan Smolbag Theatre, P.O. Box 1024, Port Vila, Vanuatu *"On the Reef" theatrical video, "Environmental Songs" audio cassette, other resources.*

Wet Paper Publications, 14 Milbong Terrace, Ashmore, QLD 4214, Australia *books, curricular materials.*

World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge, CB3 ODL, United Kingdom *poster map. (Sp)*

World Wildlife Fund, 1250 Twenty-fourth Street, N.W., Washington, D.C. 20037-11751 (202)293-4800 *conservation projects, newsletter, reports, books, videos.*

XCARET, Depto de Educacion y Promocion Ambiental, KM 282 Carr. Chetumal-PTO. Juarez, Playa del Carmen, Q.Roo, Mexico *in-school reef education program coordinated with student aquarium visits. (Sp)*

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