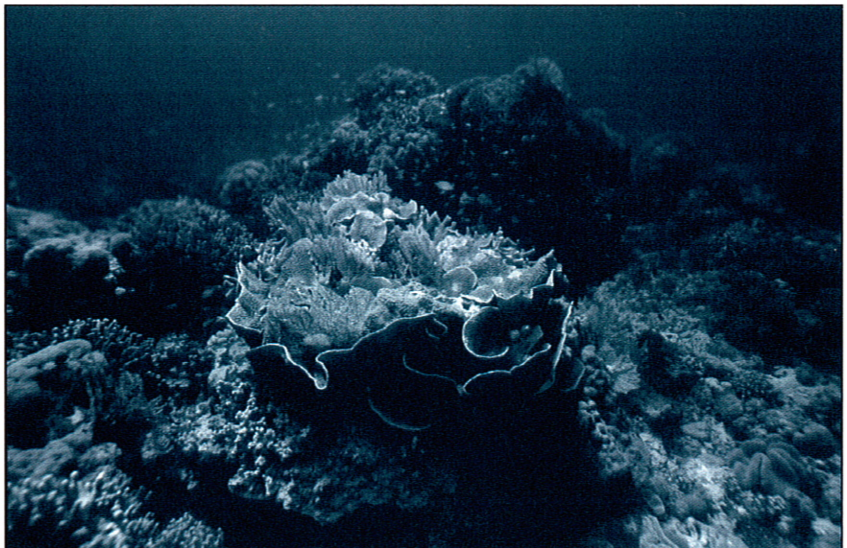
THE LIVING SEA

The Living Sea invites you on a voyage of discovery through a colorful and vibrant underwater world. Filled with exotic creatures and seafaring adventure, the film focuses on the fragile relationships between the ocean, its inhabitants and people. *The Living Sea* offers a powerful message of hope for future generations, emphasizing our capability to reverse the damage humans have wrought on the ocean ecosystem with the help of scientific advances. The world ocean is a vital part of our existence on the planet, but it will only remain healthy if we can inspire a new generation of scientists to learn more about the ocean and how to maintain the delicate balance required to sustain life.



CREATION OF *THE LIVING SEA*

The Living Sea is the realization of a long-time dream for filmmaker Greg MacGillivray, who has surfed and scuba-dived for most of his life. Though the making of the film was certainly a labor of love, it also presented a formidable challenge.

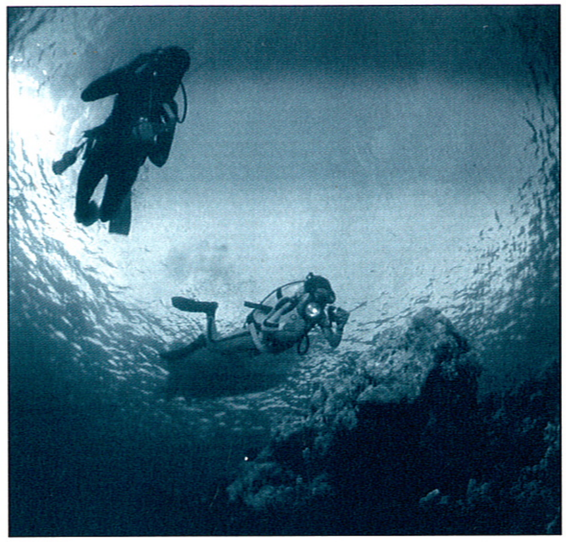
Ordinary underwater photography is difficult enough: first imagine a film crew shooting footage on land, with all their equipment and lighting and personnel, then imagine the entire effort underwater! The crew must be able to not only scuba-dive, but also must perform complex tasks underwater at the same time. Further, lighting is more complicated underwater and the currents can buffet a camera about. *The Living Sea* also used the large-format IMAX® camera, so managing its bulky size and weight only increased the challenge.

In order to obtain the spectacular footage used in the film, the crew had to invent new ways to work underwater. For example, in the Central Pacific islands of Palau, ocean currents are stronger because of the island's proximity to the equator, so it was hard to keep the camera steady for long shots. Director of underwater photography Howard Hall, one of the most experienced and creative underwater photographers in the business, invented a new tripod for underwater photography, the first of its kind for an IMAX camera. Hall also developed a scooter for the camera made of two diver propulsion vehicles which allows the camera to glide rapidly through the water. This gives the audience the feeling of "flying" over a coral reef.

Why does everything look blue underwater? Water absorbs sunlight, so as you dive deeper, all the colors turn into blue because sunlight can't penetrate to reflect their true colors. But if you add powerful lighting (about 4,000-6,000 watts is required) the brilliant colors return!

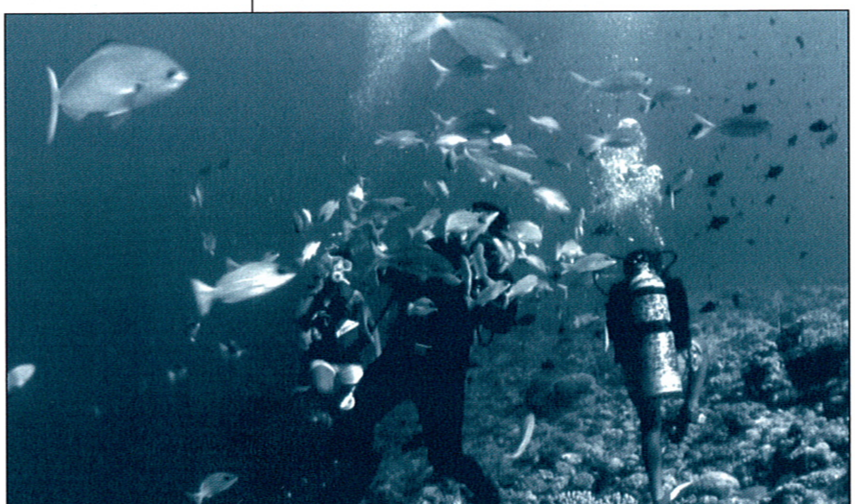
S.C.U.B.A. stands for Self Contained Underwater Breathing Apparatus. Scuba equipment includes a tank of compressed air worn on the back with a regulator, hose and mouthpiece. It is worn by divers so they can breathe underwater. In THE LIVING SEA, we see a Palauan named Francis Toribiong and his two children scuba-diving near a coral reef. As Francis says, "Mostly we do scuba for fun, but also, it's a kind of courtship. I hope my children will fall in love with the sea."

The crew built a super-strong camera mount on a Coast Guard rescue boat to film the boat as it lunged through the ferocious surf at Cape Disappointment. Worried that the mount might not survive the tremendous pounding of the crashing waves, the camera mount was reinforced to withstand the expected beating it would take from the powerful waves. After an hour of filming in surf rougher than any the boat had previously encountered, the mount held firm, but the boat itself popped a seam!



FRAGILITY OF THE OCEAN ECOSYSTEM

Humans depend on the ocean. Not only is it a major source of food, but we rely on it to help produce the air we breathe and the water we drink. Some cultures, such as the



islanders of Palau, have learned to live in harmony with the sea. Other cultures have exploited or endangered the natural resources of the sea without regard for the consequences to human, animal and plant life.

"We are all islanders."

—Francis Toribiong

THE LIVING SEA explores the fragile ecosystem of ocean life, from the variety of species in the relatively untouched waters of Palau, to the workings of oceanic food webs, to the life cycle and migration of whales. *THE LIVING SEA* presents a wonderful metaphor for the symbiotic relationship shared by inhabitants of the ocean: the siphonophore. This bizarre creature, about the size of a ten-story building, inhabits depths to which a human cannot dive. The siphonophore is actually composed of several separate organisms, each of which performs a different function. There is a bell-shaped swimming organism, a separate creature is the stomach, another is the reproductive organism, and so on. Each different creature is dependent on the next for its very life, just as each species in the ocean is dependent on the next.

But what happens if humans upset the delicate balance of ocean life? Can anything be done to ward off the disastrous consequences of a sick ocean? *THE LIVING SEA* offers hope for the future, as it shows the rejuvenation of a species through aquaculture. The film looks at the depletion of the giant clam population in Palau through overfishing by outsiders, and how Palauans and Western scientists are working together to refurbish the population by speeding up the clams' spawning cycle on a "clam farm" and then planting baby clams back on the reef in the ocean. The film also visits a pod of humpback whales on their migration in the Northeast, where the species seems to be enjoying a comeback after years of near-extinction.

In Jellyfish Lake, the film visits a species of jellyfish "farmers" which have evolved to grow their own internal crop of algae. The camera dives among thousands of these graceful creatures as they make their daily rotation between sunlight and fertilizer, a microcosm for the larger ecosystem of the ocean.

Discussion Questions

1. *What happens in a food web if one species becomes extinct?*
2. *How does energy travel through a food web?*
3. *How can we protect the ecosystem of the ocean?*

CIRCULATION OF THE WORLD OCEAN

Though we talk about the Pacific or Atlantic ocean, the Mediterranean or the Baltic sea, there is really only one ocean—the world ocean. The waters of the world ocean flow over 70% of the Earth's surface, united by global currents into a single dynamic system. Currents are created by varying temperatures of water. Warm water, such as that found on the Equator, expands. Cold water, such as that found at the Poles, contracts. This global variance creates a slight slope between warmer (expanded) and colder (contracted) water. Then gravity takes over and pulls the water "downhill," creating a current.

About 97.5% of seawater is just that: water. But the other 2.5% contains particles of just about every element on our planet. The most abundant elements in seawater are chloride and sodium, which is why it tastes salty. But any sample from around the world will also contain all the other elements. Ocean currents carry essential nutrients all over the world. In essence, they are the arteries for our planet's lifeblood.

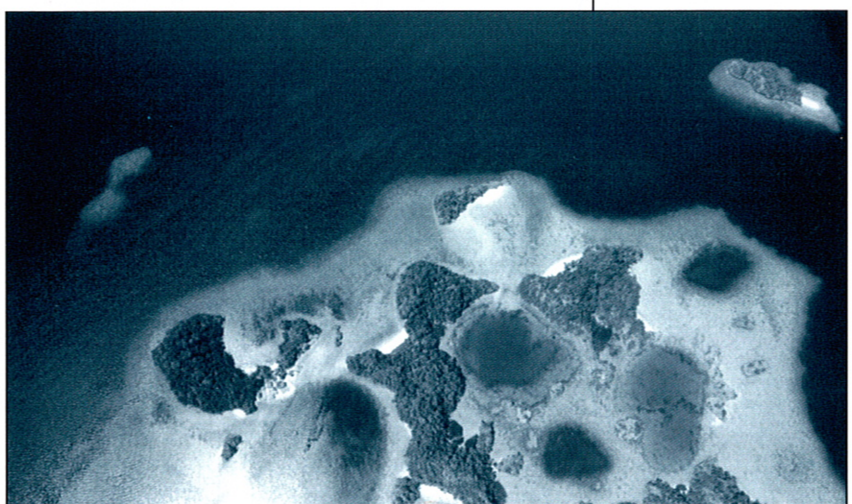
Recent discoveries made with the help of the Remotely Operated Vehicle (ROV), however, have added to our understanding of our planet's circulatory system. As water makes the cycle from sea to vapor to rain, and the rainwater flows through rivers, it picks up minerals from the river bed which it carries to the sea. But river water does not have the same concentration of salt as in seawater. So where does the seawater pick up the extra salt? The ROV has allowed scientists to discover deep-sea hydrovents. These occur when ocean water seeps into volcanic fissures of the earth's crust. The water encounters subterranean lava, which has a high chloride content. The water is then spewed back into the ocean through the hydrovent, carrying chloride with it. *The Living Sea* explores the circulation of water around the world and through the Earth's crust in the caverns of Death Valley, and clam beds located more than 3,000 feet below the surface where no life could survive without the presence of the mineral rich influx of water from the hydrovent.

Discussion Questions

1. *Why is the sea salty?*
2. *What makes water move in currents?*
3. *Is seawater the same all over the world? Why?*

ec-o-sys-tem: The plants and animals of an ecological community, together with their environment, forming an interacting system of activities and functions regarded as a unit.

[The American Heritage Student's Dictionary, Houghton-Mifflin Company, c. 1986]



POWER OF THE TIDES

The Living Sea journeys around the globe to illustrate the power and rhythms of global tides. Tides are created by the combined gravitational pull of the sun, the moon and the Earth's rotation. Although the sun is vastly bigger than the moon, the moon exerts more than twice as much gravitational pull on tides, due to its proximity to Earth. Tides vary throughout the month, with the highest highs and lowest lows occurring when the sun and moon are pulling in the same direction.

Tidal patterns reflect how often the highs and lows occur within a single 24-hour period, while tidal range measures the difference between high tide and low tide water levels. Tidal patterns and ranges vary all over the world. For example, the tidal ranges of the

Did you know:

- *Almost ¾ of the world's surface (139,000,000 square miles!) is covered with water?*
- *There may be more species in the ocean than on land and air combined?*
- *Seaplants provide most of our planet's oxygen?*
- *The greatest depth of the ocean is more than 36,000 feet?*

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MACGILLIVRAY FREEMAN FILMS
in association with
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Norfolk, Virginia
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Omniversum, *Den Haag, The Netherlands*
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National Museum of Natural Science, *Taichung, Taiwan, R.O.C.*
Science World British Columbia, *Vancouver, Canada*
Executive Producer: **WHITE OAK ASSOCIATES, INC.**
Academic Advisor: **DR. ROBERT BALLARD**

west and east coasts of North America tend to be about 6-8 feet. The Bay of Fundy, however, in Canada, has a tidal range of about 50 feet. *THE LIVING SEA* shows this dramatic tidal range in time-lapse photography, where a boat floating in the bay at high tide is beached when the tide goes out, and then floats again when the tide returns.

Tidal rhythms also create surf. *THE LIVING SEA* rides the waves with surfers in Hawaii and California, showing the sheer magnitude of this natural force and the people who love it. The film also journeys to Cape Disappointment to face the some of the roughest waters on the planet with Coast Guard cadets who risk their lives to save others.

Discussion Questions

1. *What are spring tides? What are neap tides?*
2. *How are waves measured?*
3. *How do tides affect ocean life?*

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A MESSAGE OF HOPE

The film is highlighted by segments in Palau, one of the most spectacular underwater habitats in the world, to show the beauty and potential of a healthy ocean. The Palauans are raised to respect the sea and to nurture it, because it nurtures their population in return. As islanders surrounded by ocean, they are dependent on the sea, just as the sea is dependent on them. And as Francis, the native Palauan featured in the film observes about humankind, "We are all islanders."

It was the filmmakers' goal to show not only the fragility of ocean life, and how we depend upon it, but also that with care we can reverse the damaging effects of civilization on the ocean. *THE LIVING SEA* does not emphasize the destruction of the ocean currently underway around the world, rather it shows that people can learn new ways to protect the ocean and that by nurturing our ocean, the world environment will be healthier. This is a message that is especially important for the next generation, a generation which will inherit the ocean's problems if they are not mended today.

Resources

Bender, Lionel. ***Life On a Coral Reef****, First Sight series, Watts, c. 1989. For ages 8-12.*

Cole, Sheila. ***When the Tide is Low****, Lothrop, c. 1985. Picture book for ages 4-7.*

Lye, Keith. ***Coasts****, Our World series, Silver Burdett, c. 1988. For junior high and high school students.*

Sharp, Peter J. ***The Atlantic Ocean****, World Nature Encyclopedia series, Raintree Publishers, c. 1989.*

Bottini, Luciana, Lucini, Massa. ***The Pacific Ocean****, World Nature Encyclopedia series, Raintree Publishers, c. 1989.*

THE LIVING SEA™

TEACHER'S GUIDE

THE LIVING SEA is an IMAX/OMNIMAX® motion picture produced by MacGillivray Freeman Films in association with Nauticus—The National Maritime Center, the Ocean Film Network, White Oak Associates, Inc., and Dr. Robert Ballard, Director of Marine Exploration at Woods Hole Oceanographic Institution.

Introduction

Sea water is a sort of "Earth tea," containing the dissolved atoms of probably every element on our planet.

In the film THE LIVING SEA, we understand the widest perspective of the oceans; that of a single, global system and its importance to all life on earth.

In a way, we are the ocean and the ocean is us. Life probably began in the ocean and thrived there for more than three billion years before some proto-amphibian gathered up its courage and slopped onto the dirt! All of us—humans, wombats and redwoods—still carry an ocean inside. Our blood, eggs, the fluid behind the corneas of our eyes and the insides of our cells are salt water. Just as about three-fourths of the earth's surface is salt water, about three-fourths of each of us is salt water.

Above and beyond the personal, the ocean has a profound effect on our planet and on ourselves. It moderates and affects weather. The majority of the earth's oxygen is generated by ocean plants, and most of the earth's reservoir of carbon dioxide (a gas critical to plant survival and the control of climate) is dissolved in the ocean. The ocean provides us with an immense amount of food and other natural resources, and ninety percent of the world's trade is transported on its waves. If it weren't for the ocean, there probably would be no life on earth.

Written By MILTON LOVE, PhD, Associate Research Biologist, Marine Science Institute, University of California, Santa Barbara

HOW BIG IS THE OCEAN AND WHAT'S IT REALLY LIKE?

CHAPTER 1

The earth is a water planet. The ocean covers 71% of its surface (61% of the Northern Hemisphere and 81% of the Southern Hemisphere). We use the term ocean because it is a single entity. Traditionally, we have divided the waters into "oceans" (e.g., Pacific, Atlantic, Indian) and "seas" (e.g., Mediterranean, Caribbean, Baltic), using various land masses as boundaries. But in reality, these terms are just for our convenience; all of these water masses are interconnected and water flows freely throughout. As far as its chemical makeup is concerned, cups of sea water taken from off California, Texas, Italy, Mozambique and Macao are almost identical; it's all from the world ocean.

WORDS TO KNOW

World Ocean: *all oceans and seas are interconnected.*

Photic Zone: *the layer of ocean where light penetrates.*

Upwelling Areas: *areas where cold water rises to the surface and plant nutrients are concentrated.*

KEY IDEAS

1. *The ocean covers 71% of the earth's surface.*
2. *The ocean waters are all interconnected.*
3. *The deepest spot in the ocean is the Challenger Deep, located east of Guam.*
4. *Most of the living things in the ocean are in a very small portion near the surface. Plants live there because they need light. Most animals live there because they depend on plants.*
5. *Upwelling is the process where cold, nutrient-rich water comes up to replace surface waters that are pushed offshore by winds.*

There's no doubt, when we talk about the ocean, we are talking substantial. The ocean covers 139 million square miles and its average depth is about 12,450 feet (by comparison, the average height of the land is 2,772 feet). And it's cold, too. Despite all those pictures of warm seas lapping against tropical isles, the average ocean temperature is 39°F. This is because most of the ocean is deep and, even in the tropics, deep water is cold water.

How deep is it and where is the deepest spot in the ocean? It's the Challenger Deep, an additional divot in the already cavernous Mariana Trench, located just east of Guam. The floor at this spot is 36,163 feet from the surface. If you put Mount Everest into the Challenger Deep, there still would be 7,191 feet left before you broke the surface.

Yet for all its size, most of the ocean's life is concentrated in a very small portion, near the surface and in the shallow waters near coastlines. First, remember that most life in the water ultimately depends on sunlight. This is because the bottom of the food web is made up of plants, and these need light in order to survive. Even in very clear water, sunlight only penetrates a short distance, maybe 100 feet or so.

The layer of ocean where light penetrates is called the photic zone; this is where most of the action takes place. Since plants require sunlight for survival, all plants live in the photic zone.

The other reason most life lives in shallow water is that it is where plant nutrients are concentrated. Many of these nutrients (such as nitrates) are carried from the land by water (in rivers, for instance) and tend to stay near the coast. However, in a few select locations, plant nutrients are extremely concentrated, and here is where life really gets going. These are called upwelling areas.

Upwelling is an extremely important process, one that has a profound effect on the productivity of the ocean. Upwelling is the process where deep, cold, nutrient-rich water comes up to replace surface waters as they are moved offshore by winds. Most upwelling occurs along coastlines, and only a few coastlines at that. Major upwelling only occurs along the coasts of California, Peru, Chile, West Africa and a few other scattered spots.

What effect does upwelling have? Well, first remember that microscopic plants (phytoplankton) absorb dissolved nutrients (such as nitrogen) from the water. As we have just discussed, plants live near the ocean's surface, so surface waters tend to be low in nutrients. On the other hand, deeper water has little phytoplankton and, therefore, lots of nutrients. When this nutrient-rich water hits the surface, phytoplankton start reproducing. Phytoplankton forms the basis for most ocean food webs, and the more phytoplankton there is, the more phytoplankton eaters can live in the system. For this reason, upwelling areas usually contain more organisms (by numbers or weight) than any other open ocean habitat.

ACTIVITY: CHAPTER 1

PLANET OF THE APPLES

Purpose: It's important for students to be aware that the productive parts of the planet comprise only a small proportion of the whole. Students will model this with apples and paper plates.

Life on earth is not spread evenly around the globe. In fact, on land and in the ocean, the really productive parts (where oxygen is made and where humans get their food) form a very small chunk.

Materials: Pair off the students. Each pair should have an apple, a plastic serrated knife, a paper plate, a number of colored markers and several paper towels.

Procedure: The students are divided into pairs, one of the pair will be the land (and will cut the apple first) the other one will be the ocean (and will draw and label the plate first). Partners will switch jobs in the second part of the activity.

The Land

1 Have the land partner cut the apple into four equal pieces from top to bottom; three of the pieces represent the three quarters of the world that is covered by ocean, the fourth piece is the area not under water. Set the three ocean pieces aside.

2 After the land partner cuts the apple, the ocean partner divides the plate (using a colored marker) with $3/4$ of the plate representing the ocean and $1/4$ of the plate representing the land, labeling each accordingly: "ocean" or "land."

3 The land partner will now cut the one quarter of the apple representing the land into two equal pieces. One piece represents the land that is too dry, too wet, too cold or too hot (mountains, river basins, deserts) for human habitation. Set this piece aside.

4 The partner drawing and labeling will now draw a line dividing in half the $1/4$ piece representing the land. On one of the resulting $1/8$ pieces, draw a human; on the other, a human with an "X" drawn through it.

5 Now the land partner will cut the $1/8$ piece representing the habitable land into four equal pieces. Set aside three of these. Hold up the remaining piece, it represents the portion of habitable land on which food can grow.

6 Have the drawing partner, on the plate, divide the $1/8$ piece representing the habitable portion into four slices. Color one of the resulting $1/32$ pieces to represent the food-growing portion and label it "all our food."

7 Have the land partner take the $1/32$ piece of apple and cut off the thinnest slice possible; this represents $3/100$ of 1% of the earth's surface. This area supplies all of our drinkable water.

8 Now have the drawing partner show the drinkable water as a dot in the section colored in to represent the area on which we can grow food.

The Ocean

1 The ocean partner now cuts the apple and the land partner draws on the paper plate. Have the ocean partner take one of the three pieces representing the ocean and cut it in half. This piece represents the productive zones of the oceans. Though we might think the ocean is a vast, infinite resource, most regions are not very productive. Most life is concentrated near shore.

2 Have the drawing partner divide one of the quarters on the plate marked "ocean" in half. Draw a fish on one of the halves.

3 Now have the ocean partner cut the "productive" piece of apple into four equal pieces. There are only about four truly rich regions of the ocean—the major upwelling areas. One is located along the Pacific Coast of North America, from Alaska to Baja California.

4 Have the drawing partner divide the piece on the plate representing the productive ocean into four slices. Color one of the resulting pieces to represent the productive upwelling off North America.

5 Now the ocean partner will take one of the small apple pieces and cut off a thin slice. This tiny slice represents $1/100$ of 1% of the world's surface—the photic zone, the top 300 feet through which light penetrates and plants grow. All plant life, the basis of the ocean food web, grows in this zone. Most of the life in the ocean is concentrated in this narrow region below the surface of the sea.

6 Have the drawing student show the photic zone on the plate as a dot in the section colored to represent the West Coast of North America. Label this "$1/100$ of 1% Photic Zone."

7 Now have the students look at the two tiny slices in relation to the rest of the apple or the plate. One represents the resource necessary for much of the life on land; the other, that necessary for most life in the ocean. They also represent the parts of the land and ocean which humans impact the most. These are the places on our planet that are the most susceptible to human damage and must be the first to be protected.

Activity Age Modifications: For preschoolers, do Land steps 1-4 and Water steps 1-2 as a class. A cantaloupe could be used instead of an apple. For grades K-2nd, Land steps 1-4 and Water steps 1-2 can be done with the teacher; then each student colors in their own paper plate. Grades 3rd-4th, do Land steps 1-4 and Water steps 1-3 with a partner; the rest of the activity can be done as an entire class. Grades 5th and above can do all steps with a partner or small group with the teacher or an adult leading them through each step.

CHAPTER 2 WHAT'S THE OCEAN MADE OF?

Most sea water (97.5%) is just that, water; but the rest is dissolved salts. While the most common salt in the ocean is "table salt," made of sodium and chloride, salts also include compounds formed from various other constituents, such as sulfate, magnesium, calcium and potassium. In fact, sea water is a sort of "Earth tea," containing the dissolved atoms of probably every element on our planet. And while the most abundant elements in sea water are chloride and sodium, every cupful contains all the other elements, including such exotics as gold, silver and uranium.

So why is the sea salty? First, it's salty because rivers dissolve and bring down bits of the earth's crust and have been busily doing so for billions of years. Even though rivers are "fresh," they contain minute amounts of dissolved elements. But if you take river water and concentrate its salts, they are not in the same proportion as are the salts in the ocean. River water has too little chloride. In other words, there is too little table salt in river water to explain its concentration in the ocean.

Fortunately, scientists have recently discovered another major source of elements for the ocean —the earth's mantle. The molten part of the mantle comes to the surface as lava and hot gas. Since the ocean covers 71% of the earth's surface, most volcanoes and gas vents are under water, and the material that escapes into the ocean is similar to the chemical composition of the sea. In particular, hot-water vents are a source of mineral-rich water. This occurs when ocean water seeps into volcanic fissures, encounters subterranean magma and returns to the ocean loaded with chloride.

So, the best explanation for the large amounts of table salt in the sea is that much of the sodium in the ocean comes from rivers dissolving away the Earth's crust, and much of the chloride comes from volcanic vents under the sea.

All of the salt we put on our food originates, one way or another, in the ocean. Worldwide, about one-third is produced in huge evaporation ponds situated near salt water. The remainder comes from salt mines that recover salt laid down by the evaporation of ancient seas. Since all salt originally came from the ocean, what is the difference between "table salt" and "sea salt"? Table salt is almost pure sodium chloride. When salt manufacturers evaporate sea water, the first salt that comes out is calcite (calcium chloride). When this occurs, the brine is shifted to another pond, more evaporation occurs and gypsum (calcium sulphate) precipitates out. What is left in the brine is primarily sodium chloride, or table salt. Sea salt retains all of the other salts.

WORDS TO KNOW

Earth Tea: *sea water. It is called this because it contains the dissolved atoms of every element on our planet.*

Table Salt: *almost pure sodium chloride.*

Sea Salt: *sodium chloride plus calcium chloride and calcium sulphate.*

Hot Water Vents: *occur when ocean water seeps into volcanic fissures, encounters subterranean magma and returns to the ocean. A source of mineral-rich water.*

KEY IDEAS

1 *Most sea water is 97.5% water. The other 2.5% is salt, composed of sodium, chloride, magnesium, calcium, potassium and other trace elements.*

2 *River water contains too little sodium and chloride to account for all that is found in the ocean. Another source of chloride for the ocean's waters comes from volcanic vents under the sea.*

3 *The difference between table salt and sea salt is that table salt is almost pure sodium chloride, while sea salt also contains calcite (calcium chloride) and gypsum (calcium sulphate).*

ACTIVITY: CHAPTER 2

BE YOUR OWN OCEAN

Purpose: In this exercise, students imitate rivers, creating an ocean filled with dissolved salts. Afterward, they learn how the ocean evaporates sea water, producing fresh-water rain.

Materials: In this project, students make salt water, then distill off the water and recover the salt. You will need three tablespoons rock (kosher) salt (the granular form can make the water cloudy), 4" by 4" cheesecloth, funnel, one cup sand, measuring spoons, baster or eye droppers, a pot with a lid and a heat source (this will be used either by the teacher or under close adult supervision).

A River Runs Through It

Procedure: Have the students do this in small groups, each with an adult, or do this as a class.

1 Ask students to help mix together a cup of sand and three tablespoons of rock salt.

2 Now have the students line the funnel with the cheesecloth and place the sand and salt mixture inside it. (The cheesecloth prevents the sand/salt from running down the funnel.)

3 Now have them suspend the funnel over a pot and, with a baster or eye dropper, slowly drip warm or hot

Ocean water moves vertically as well as horizontally. Winds drive surface water away from the coast and deep water moves upward to replace it (upwelling). Water also moves downward—ocean water sinks when it is saltier or colder than surrounding water.

water over the sand/salt mixture. This will dissolve the salt and carry it into the pot. Have the students continue this process until the salt is dissolved. In the pot you now have your own little ocean.

4 Now that you have a miniature ocean, cover the pot, put it on a burner or hot plate and bring the water to a boil.

5 Periodically, lift off the lid and let the drops of water that have condensed on its underside drain into a cup.

6 Eventually, all of the water (minus the vapor that escapes when you lift the lid) will be in the cup, and salt will line the pot. Because salt does not rise with the vapor, the water in the cup will be fresh.

What do we make of this? This is how salt is extracted from sea water. The only difference is that salt extraction companies use the heat of the sun and the process takes weeks. Further, this demonstrates how the sun can evaporate sea water and produce fresh-water rain. In nature, as water vapor rises, it eventually hits cooler air, condenses and falls to earth.

Activity Age Modifications: For preschool-4th grade, this activity could be done as a group with the children helping the teacher with each step. 5th grade and above may want to have several "ocean" groups, with supervision during water heating.

CHAPTER 3

HOW DOES THE OCEAN MOVE?

Water is in constant motion in the ocean and much of that motion occurs within currents. The term current usually refers to water flowing horizontally (parallel to the ocean's surface), but masses of water also can move vertically. Currents can be rapid and almost river-like (such as the Gulf Stream) or they can be slow and diffuse.

What causes water to move? Ultimately, the sun does the job. Warm water expands and cold water contracts. Ocean water is warmer at the equator (the sun shines on it more) than at the poles. Equatorial water is actually about three inches thicker than polar water, because it is warmer and has expanded slightly. This global difference creates a very slight slope and warm equatorial water flows "downhill" (poleward) in response to gravity. However, this movement is only the beginning. Surface water also is propelled by winds. Winds move water through friction between moving air molecules and water molecules. As the surface water molecules begin to move, they pull with them some of the molecules below, which triggers the current.

Water also moves vertically. As mentioned previously, winds can drive surface water away from the coast and deep water can move upward (upwelling). However, water also moves downward. Ocean water sinks when it is saltier or colder than surrounding water. A prime example of this takes place in Antarctica, where Antarctic Bottom Water is formed. This is the densest water in the ocean and it is created in the winter when sea ice forms. This ice only takes up about 15% of the ocean's salt and the rest forms an extremely cold brine. This sinks to the bottom and spreads northward from Antarctica. In the Pacific Ocean, this water actually may reach the Aleutian Islands off Alaska, a trip that takes about 1,600 years.

Ocean currents have a profound effect on the weather. An example is the perhaps apocryphal remark of Mark Twain: "The coldest winter I ever spent was a summer in San Francisco." Summer months there are cool, windy and foggy. On the other hand, Washington, D.C.—at about the same latitude but on the Atlantic Ocean—has hot and muggy summers. The reason for this difference is that the City by the Bay sits on the edge of the cold California Current. Winds approaching the California coast lose heat to this cold water and chill San Francisco. Washington, D.C., is hit by winds that have flowed over the warm Gulf Stream, picking up heat and moisture as they pass over that current.

WORDS TO KNOW

Current: *usually refers to water flowing horizontally, but masses of water also can move vertically.*

KEY IDEAS

1. *The ocean water is moved by currents. Currents are created by the sun warming the waters in certain areas, like at the equator. The warmer water has expanded slightly, creating a slope. The warm water runs downhill toward the poles. The winds also help trigger currents by propelling surface waters.*
2. *Ocean currents can affect the weather. If the current off a coast is cold, the wind blowing across it will lose heat, creating cold weather. Winds blowing over a warm current pick up moisture and heat.*

ACTIVITY: CHAPTER 3

A CURRENT AFFAIR

Deep currents are generated by differences in salinity and temperature between two bodies of water.

Salinity Currents: Salt water is more dense than fresh water and sinks below it. In the first experiment, the blue salt water on top will soon replace the clear fresh water below. Similarly, in the second half of the exercise, the clear tap water above will remain on top of the blue salt water.

Temperature Currents: Like salt water, cold water is more dense than hot water. When placed on top, it will sink down and displace the hotter water. Hot water will sit on top of cold water. However, as the temperatures equalize, they will begin to mix.

Purpose: Students will create their own water currents, using differences in water salinity and water temperature.

Materials: You will need two 1-liter clear plastic soda bottles, index cards, food coloring, table salt and measuring spoons.

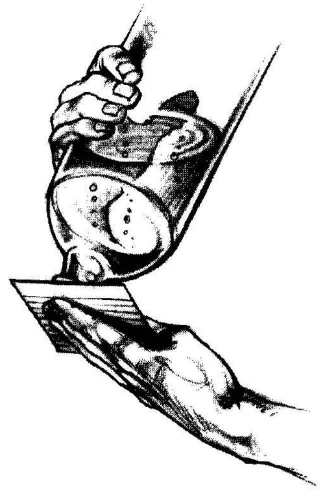
Salinity Currents

Procedure: In this experiment, students will fill one bottle with just tap water and the other with tap water, salt and food coloring. They will predict what will happen to the colored water before doing the experiment, then will observe and record the direction of the actual water flow. Have them write down their predictions on their worksheets.

1. Divide students into small groups, each with an adult, or do this as a class.
2. Have students fill both bottles with room-temperature tap water. Add approximately 1 Tbl. of salt and 8 drops

of blue food coloring to one bottle and shake well. Don't add anything to the water in the other bottle. Make sure both bottles are completely filled to the top.

3 Have a student place a index card over the mouth of the colored-water bottle and turn it upside down. Do this over a dish to prevent spillage. The students should hold the card in place as they turn the bottle over, then gently remove their hand from the card. The upward air pressure will hold the card in place. Center the upside down bottle directly over the mouth of the upright bottle containing the clear water. Place the bottles in a dish to catch spills and slowly slide the card from between the bottles.



Observe the results for a few minutes. Color the illustrations on the worksheet to show how the colored water moved and where it ended up.

4 Now the students can empty and rinse the bottles and do the experiment again, but this time turn the clear bottle upside down. Again, record your predictions and what actually happens.

Temperature Currents

Procedure: This experiment is similar to the preceding one, except that in this experiment you will fill two bottles with water of different temperature. Again, after preparing the bottles, make sure to predict what will happen to the colored water after the card is removed.

1 Fill one bottle with ice-cold tap water, add 8 drops of blue food coloring and shake well. Fill the second bottle with hot tap water. Make sure both bottles are completely filled to the top.

2 Align the bottles over each other with the index card separating the contents as directed in step **2** of the activity above. Slowly slide the card from between the bottles. Observe the results for a few minutes. Color the illustrations on the worksheet to show how the colored water moved and where it ended up.

3 Empty the bottles and do the experiment again, but this time turn the clear hot water bottle upside down.

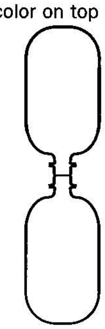
Activity Age Modifications: Preschool-3rd grade can do this project as a class with the teacher leading and asking for volunteers. 4th-6th grade would do the project in small groups with an adult. Within each small group, students would be chosen for each of the following positions; recorders, experiment performers, and observers. 7th grade and above would do the same as the group above, but more independently.

Salinity Currents

Part 1: Colored salty water on top.

Predictions

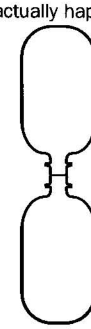
1 Predict the final color on top and bottom when the colored salty water starts on top. Shade the area where the color will be after the card is removed.



Results

2 Now show what actually happened.

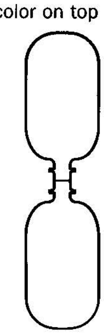
3 Are the results different then your predictions? Why do you think they are different?



Part 2. Clear, fresh water on top.

Predictions

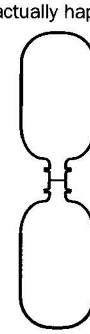
1 Predict the final color on top and bottom when the clear fresh water starts on top. Shade the area where the color will be after the card is removed.



Results

2 Now show what actually happened.

3 Are the results different then your predictions? Why do you think they are different?

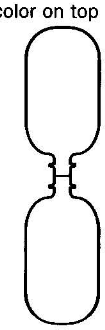


Temperature Currents

Part 1. Colored cold water on top.

Predictions

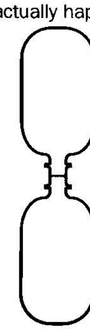
1 Predict the final color on top and bottom when the cold water starts on top. Shade the area where the color will be after the card is removed.



Results

2 Now show what actually happened.

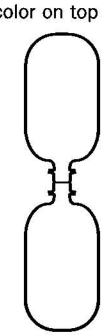
3 Are the results different then your predictions? Why do you think they are different?



Part 2. Hot water on top.

Predictions

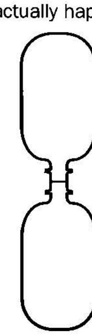
1 Predict the final color on top and bottom when the hot water starts on top. Shade the area where the color will be after the card is removed.



Results

2 Now show what actually happened.

3 Are the results different then your predictions? Why do you think they are different?



OF TIDES AND TIME

Tides have long intrigued us. Perhaps it's the fact that they represent a predictable and wholly unstoppable force. Tides are rhythmic, predictable and periodic changes in the height of a body of water caused by a combination of the gravitational pulls of the moon and sun, and the motion of the earth. The contribution to tidal height of the moon (lunar tide) is about twice that of the sun (solar tide). Even though the sun is 27 million times more massive than the moon, the moon is about 400 times closer to the earth and exerts a much stronger gravitational pull.

WORDS TO KNOW

Lunar Tides: *occur when the gravitational pull of the moon causes the height of the water in the ocean to change.*

Solar Tides: *occur when the gravitational pull of the sun affects the tides of the ocean.*

Spring Tides: *occur during the full or new moon, when the combined gravitational pull of the sun and moon cause extreme tides.*

Neap Tides: *least-varying tides occurring when the sun, earth and moon form a right angle.*

Semi-diurnal Tides: *occur when some areas have two low tides and two high tides in a 24-hour period.*

Diurnal Tides: *occur in places having one high tide and one low tide per 24 hours.*

Intertidal Zone: *the area between the extremes of high and low tide.*

KEY IDEAS

1. *Tides are rhythmic, predictable and are affected by the gravitational pull of the sun and moon.*
2. *Tides vary in their height. The lowest and highest tides occur during the full moon and the new moon, when the moon, earth and sun are aligned.*
3. *Tidal range can vary dramatically, depending on the shape of the water basin that the tides flow through. Tides also play a major role in the marine life that lives in the intertidal habitats.*

Throughout the month, tides vary in their heights. The highest highs and lowest lows occur together during the new and full moons, when both moon and sun are pulling in the same direction. In this case, the pulls of the two bodies are added together. These extreme tides are called spring tides, which comes from the Old English word *springen,* meaning "to jump or move quickly." Spring tides occur every two weeks and alternate with least-varying neap tides, which occur when the earth, moon and sun form a right angle.

Tidal patterns (how often highs and lows occur within 24 hours) and ranges (the difference between high tide and low tide water levels) differ throughout the world. Some areas, such as much of the east and west coasts of North America, usually have two high and two low tides per 24 hours. These are semi-diurnal tides. On the other hand, the Gulf of Mexico tends to have one high and one low tide (diurnal tides) during the same period.

Tidal ranges vary dramatically, depending on the shape of the water basin the tides flow through. The narrow Bay of Fundy in New Brunswick, Canada, has tides of about 50 feet. Remember, this does not mean that the water goes inshore 50 feet. It means that it rises in height that amount. If the land is pretty flat, the sea might flow inshore for miles before reaching the necessary elevation. Tidal ranges for most of the ocean are smaller. On the west and east coasts of North America, they tend to be around six to eight feet; in the Gulf of Mexico, the tides are even narrower, often only a foot or two.

Tides are a major (perhaps *the* major) controlling force in many marine intertidal habitats, because they help dictate how long organisms are under water. In areas with wide tidal ranges, organisms must have adaptations that allow them to survive in the air. These include facing such hazards as drying out, wide temperature fluctuations, influxes of fresh water (from rain) and attacks by various terrestrial predators.

ACTIVITY: CHAPTER 4

CAN IT BE DONE?

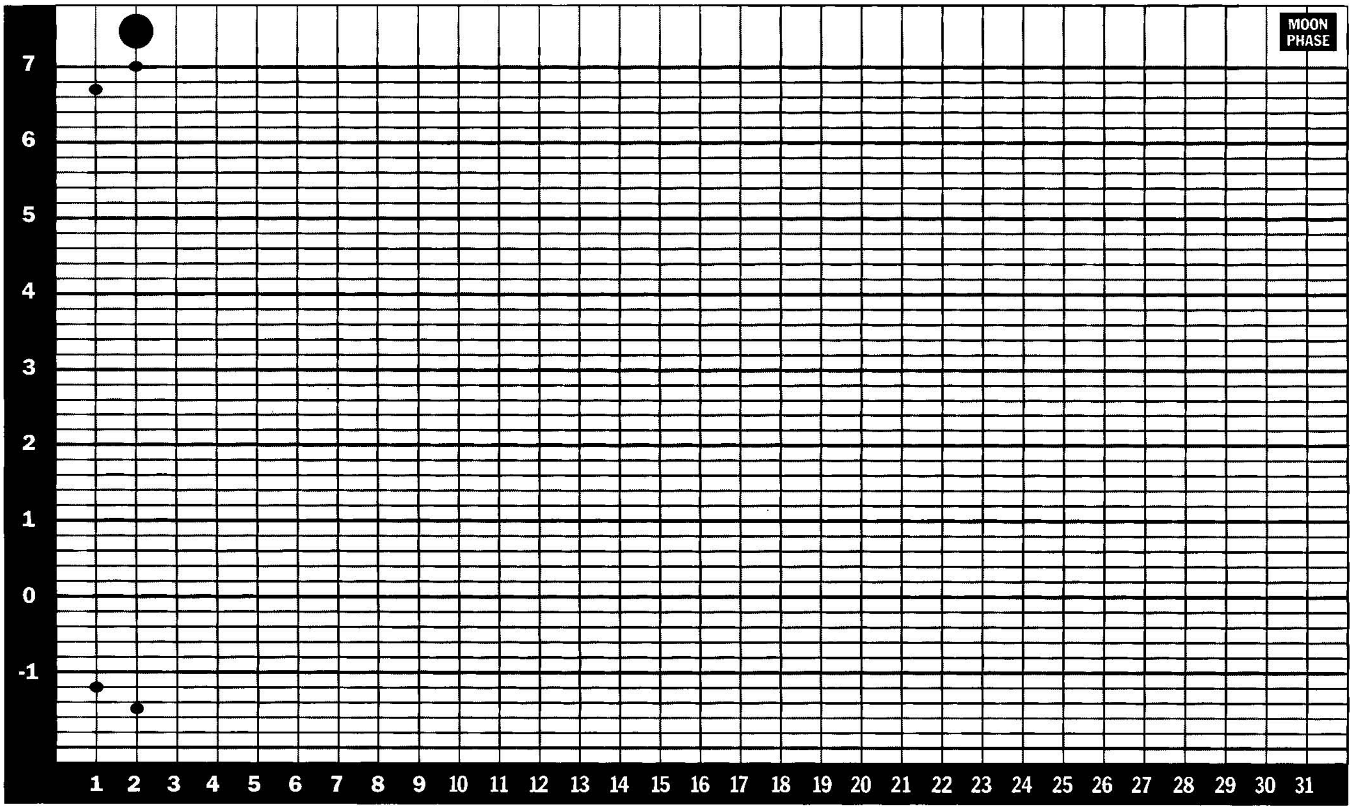
No one can turn back the tides, but you can easily see their patterns and how the moon plays a major role. In the table below, we give you the major high and low tides for Central California for December 1994 and the moon phases for the same period. We also have provided a mostly-empty graph of the tidal ranges from that month. Your job is to fill in the high and low tide heights for the whole month (we've done the first one for you) and list the moon phases on the correct days (we've done the new moon). By plotting the high and low tides for every day, you can see how the moon affects the tides.

Purpose: This exercise demonstrates two phenomena. First, tides are rhythmic. Second, their heights are related to moon phase.

Materials: Copies of the worksheet (you may give one to each student, each group, or do it as a class), colored pencils and a tide chart from the newspaper.

To The Teacher: We've included a completed worksheet for this activity on page 20. The important lessons are that tides are cyclical and that they closely follow moon phase, with greatest tides around the new and full moons. The students should notice that during the new and full moons, the distance between the high and low tides increases, which means that high tides get higher and low tides get lower, simultaneously.

Tidal Variations for Central California, December 1994



High and Low Tides for Central California
December 1994

DATE	LOW	HIGH	DATE	LOW	HIGH
1	−1.2	6.7	**16**	-0.4	5.8
2	-1.5	7.0	**17**	-0.5	5.9
3	-1.6	7.0	**18**	-0.5	5.9
4	-1.4	6.8	**19**	-0.5	5.7
5	-1.1	6.4	**20**	-0.3	5.5
6	-0.6	4.2	**21**	-0.1	5.2
7	-0.1	4.2	**22**	0.2	3.8
8	0.5	4.3	**23**	0.5	4.0
9	0.9	4.5	**24**	0.9	4.2
10	1.3	4.7	**25**	1.3	4.5
11	1.6	4.9	**26**	1.6	4.9
12	1.8	5.2	**27**	1.7	5.3
13	0.3	5.4	**28**	1.8	5.8
14	0.0	5.5	**29**	-0.9	6.3
15	-0.2	5.7	**30**	-1.4	6.7
			31	-1.6	6.9

New Moon Dec. 2 **First Quarter** Dec. 9
Full Moon Dec. 17 **Last Quarter** Dec. 25

ALTERNATE ACTIVITY: CHAPTER 4

CHANGING TIDES

Purpose: This activity demonstrates how the gravity from the moon and sun can displace water toward these sources of gravity.

Materials: One 9" round balloon, water and one circle 2" in diameter, cut from construction paper.

Procedure: Fill the balloon with water, let out all excess air and tie the top with a knot. Tape the paper circle onto the center of the balloon. Notice as you hold one hand at the bottom of the balloon and the other at the knot that the water is evenly distributed around the paper circle.
Now let go of the hand supporting the bottom and notice how elongated the balloon becomes. The gravity of earth pulls the balloon and water down. Likewise, the moon's and sun's gravitational pulls cause the ocean tides to rise and fall.

CHAPTER 5

WIND AND WAVES

For thousands of years, poets have turned to waves for inspiration. The images created have certainly run the gamut, from the sensitivity of Rimbaud ("Lighter than a cork I danced on the waves") to the antic of Carroll ("And thick and fast they came at last, and more, and more, and more—all hopping through the frothy waves, and scrambling to the shore") to the Byronic of Byron ("Once more upon the waters, yet once more! And the waves bound beneath me as a steed, that knows his rider!").

But, besides universal metaphors for just about every human condition, just what are waves? While waves are caused by various forces, most of the waves we see are caused by wind. In the ocean, wind waves are generated by air molecules from the wind blowing along the sea surface and transferring energy to adjacent water molecules. As the water molecules begin to move, they start to travel in vertical circles, producing tiny wavelets. These tiny waves expose more water surface to the wind and more wind energy is transferred to the water, creating larger and larger waves. When winds slow or cease, waves continue on, though they become more rounded; these are swells.

WORDS TO KNOW

Wind Waves: *generated by wind blowing across the surface of water, transferring energy from the wind to adjacent water molecules, resulting in waves.*

Trough: *the lowest part of the wave.*

Crest: *the highest part of the wave above the still-water line.*

Wave Period: *the time it takes for two successive waves to pass a particular point.*

Wave Frequency: *the number of waves that pass a particular point in a given time period.*

KEY IDEAS

1 *Most of the waves we see are caused by wind. The wind transfers its air molecules to adjacent water molecules which begin to move in vertical circles causing small wavelets. These tiny waves expose more water surface to the wind which result in larger waves.*

2 *The parts of a wave are the crest (highest point) and the trough (lowest point).*

3 *A wave's height is the distance between crest and trough; its length is the distance between crests.*

Waves come in various parts. The crest is the highest part of the wave (above the still-water level) and the trough is the lowest part. A wave's height is the distance between the crest and trough, and its length is the horizontal distance between each crest. In the open ocean, wave length averages 200 to 500 feet, but may reach 2,000 feet in extreme cases. A wave's period is the time it takes for two successive waves to pass by a particular point; wave frequency measures how many waves pass that point in a given time period. Wind period varies from a few seconds to as much as 20 seconds.

How high do waves get? Really high. The highest waves ever officially recorded were measured by the executive officer of the U. S. Navy tanker *Ramapo* on February 7, 1933, in the North Pacific Ocean. The tanker was heading from the Philippines to San Diego and for days a steady 65-mile-per-hour wind had blown, with gusts to 80 mph. At about 3 a.m., with a bright moon illuminating the seas, the personnel on watch noted a particularly large set of waves bearing down on them. When the ship settled into the trough of one, the executive officer noted that the crow's nest of the mainmast was level with the crest of the next wave. He calculated that the wave had to be 112 feet high.

ACTIVITY: CHAPTER 5

MAKE SOME WAVES!

Blow Painting

Purpose: To simulate the effect of wind across the surface of water and how the water moves in the direction of the wind. This is done by blowing air through a straw across watered-down paint.

Materials: White construction paper, two or three colors of tempera paint, small bowls, small spoons and drinking straws.

Procedure: Prepare by covering your work surface with protective paper.

1 Give each student a sheet of white construction paper and a drinking straw.

2 Put tempera paint in shallow bowls. Water down the paint to the consistency of water.

3 With a spoon, apply a puddle of paint into the center of the paper and blow through the straw, across the paint. Apply one color of paint at a time.

4 Notice how the air moves the paint in the direction you blow it.

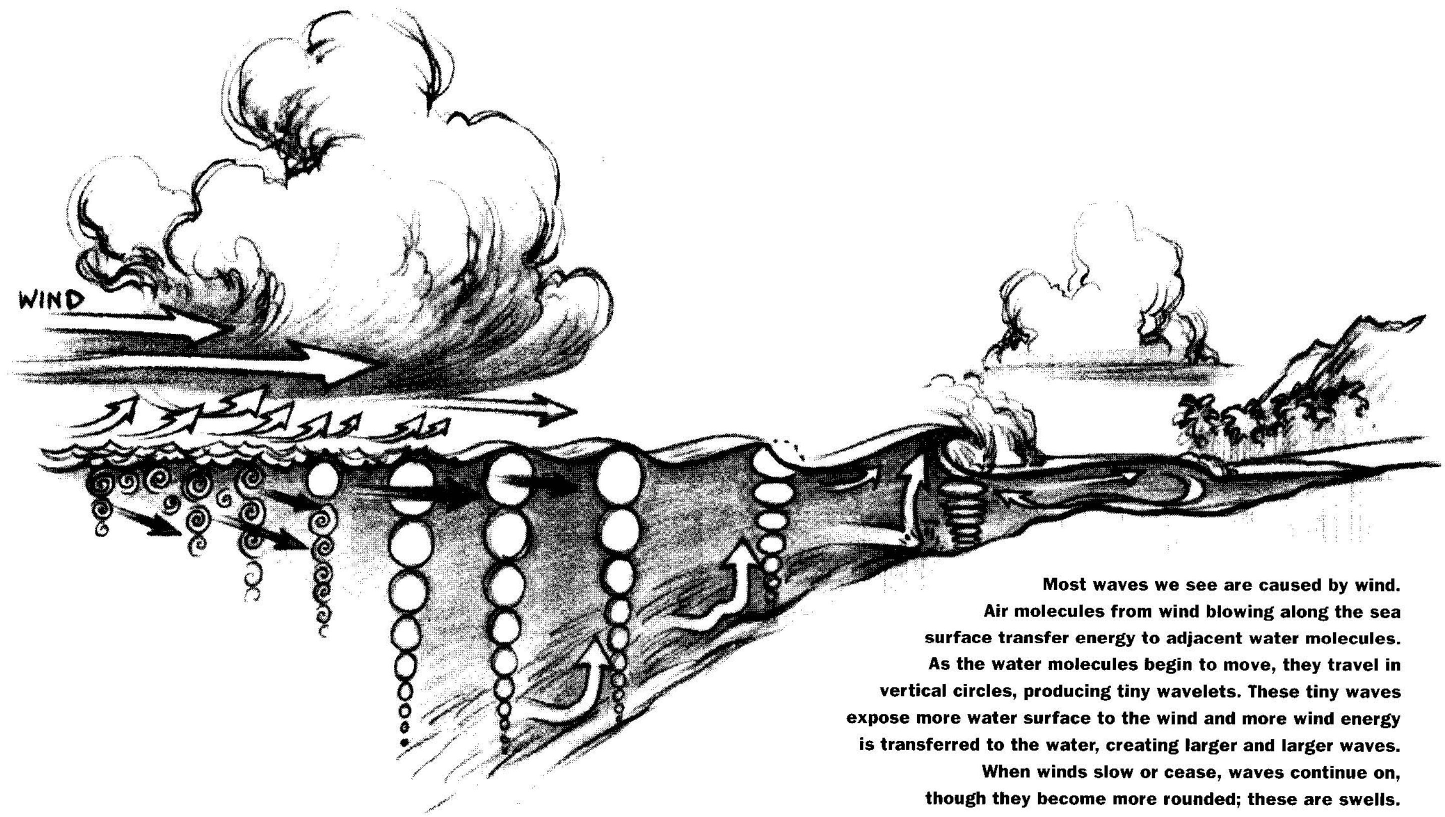
Parachute Waves

Purpose: To show how energy can move through the water to form a wave.

Materials: Parachute and a small, soft, rubber ball. The parachute should be large enough for your students to stand side by side and hold on with both hands. If it's smaller, do this activity in groups.

Procedure:

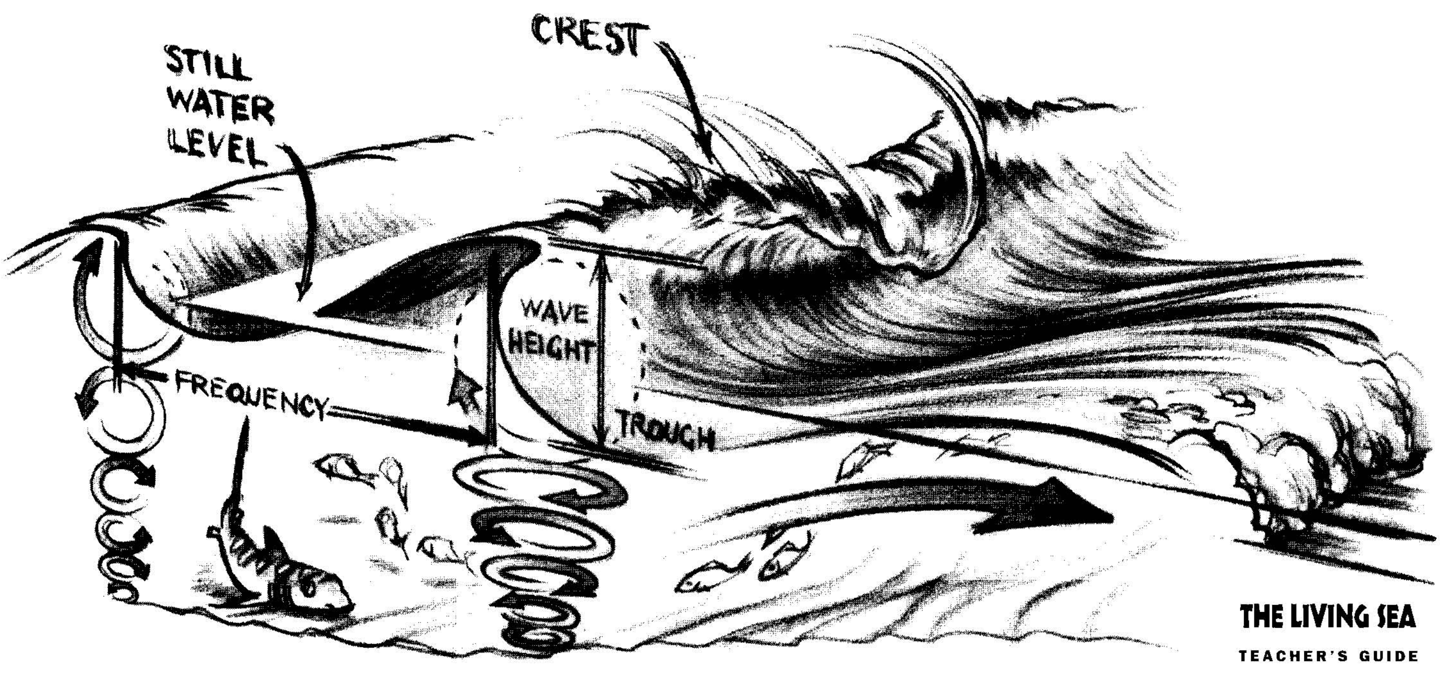
1 Have students stand around the parachute and hold on with both hands. Have one side of the circle lift their arms up and down, which will start a rippling



Most waves we see are caused by wind. Air molecules from wind blowing along the sea surface transfer energy to adjacent water molecules. As the water molecules begin to move, they travel in vertical circles, producing tiny wavelets. These tiny waves expose more water surface to the wind and more wind energy is transferred to the water, creating larger and larger waves. When winds slow or cease, waves continue on, though they become more rounded; these are swells.

effect across the parachute. The other side holds the parachute still. Watch to see how far the ripples go, then have the other side try it.

2 The small, soft, rubber ball could be started on one side. Students on one side lift the parachute and watch the ball travel to the other side. This simulation shows how the energy started far out at sea can be transferred through the water without actually moving the water forward, but up and down instead. Because the bottom of the ocean changes and becomes shallower toward the shore, the up and down movement becomes steeper and finally spills over into a breaking wave.



6

REEF BUILDERS

Coral reefs look like something Picasso would have painted if he had eaten one too many chocolate bars. These places are definitely wilder, grander and sometimes more bizarre than almost any other ocean habitat.

Coral reefs, particularly the ones in the region around Palau in the western Pacific, probably contain more animal species than any other marine habitat in the world. Worldwide, coral reefs cover millions of square miles of shallow, inshore waters. In fact, around many of the smaller islands, there is no other habitat, because the island itself is made of coral.

Coral reefs (and islands) are unique because they are made entirely by living creatures; there are no granite boulders or sandstone walls here. Basically, you can think of corals as tiny jellyfish that secrete and live in calcium carbonate (limestone) split-levels. Tropical corals form huge colonies, and over millions of years, these colonies become truly massive.

Perhaps the most interesting structures corals form are atolls, —ring-shaped islands that dot the Pacific. Why are so many of these islands round and how did they form in the first place?

Charles Darwin was the first to suggest what has turned out to be the correct explanation. Darwin reasoned that a coral atoll started life as a coral reef surrounding a volcano that had thrust its way, sometimes many thousands of feet, from the ocean floor to the surface. Over time, the volcano became dormant and slowly began to sink back into the sea. If it sank quickly, it dragged the coral with it and both disappeared from view. Because corals live only in shallow water, the sinking corals died. However, if the volcano sank slowly, the coral reef grew fast enough to compensate and stayed at the surface. Eventually, the volcano receded hundreds or thousands of feet down, leaving no trace of its presence, except for a mysterious, thin, ring-shaped coral island.

Proof that Darwin was right came in 1952, when scientists drilled deep into Eniwetok Atoll in the Pacific, preparing for thermonuclear bomb testing. The drills had to push through 4,156 feet of coral before they hit the ancient volcano. Those corals had been busy for millions of years. Another nice example of the industriousness of these animals is Florida. The entire state is an ancient coral reef!

WORDS TO KNOW

Coral Reefs: *calcium carbonate structures composed of the skeletons of colonies of tiny jelly-fish-like organisms.*

Atolls: *ring-shaped islands formed by coral which at one time surrounded a volcano.*

KEY IDEAS

1 *Coral reefs are created by tiny jellyfish-like animals which secrete calcium carbonate. Coral reefs grow in shallow water and are made entirely by living creatures.*

2 *Charles Darwin was the first to suggest that an atoll is the result of a coral reef forming around a volcano that long ago sank. The volcano sank slowly, allowing the coral reef enough time to grow and stay at the surface.*

ACTIVITY: CHAPTER 8

SEA HUNT

Purpose: Why are so many coral reef animals, particularly fishes, covered in a fantastic array of garish colors? There are a number of theories, but a leading contender is that these colors (called "poster colors") actually help them blend in with the already riotous colors and patterns of their environment. Animals that developed these colors were less likely to be seen and eaten by predators; natural selection worked in their favor. This activity will illustrate natural selection in action.

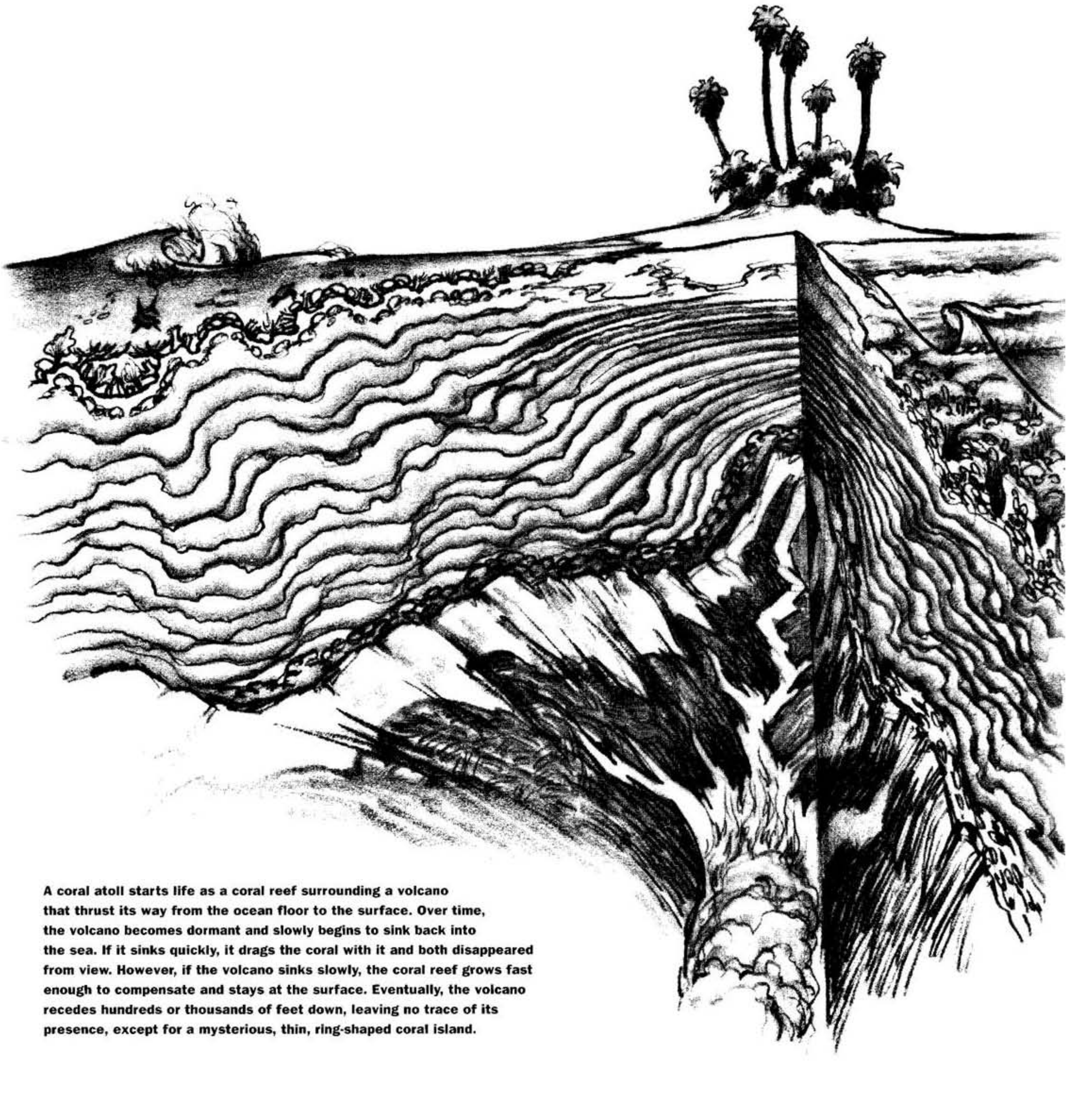
Materials: You will need 25 pipe cleaners in five different colors, giving you a total of 125 pipe cleaners Make sure one of your colors is green, and have an equal amount of each color. You will also need one set of chopsticks for each member on one team. These will be shared with all the teams in turn. A 25" by 32" piece of tagboard, double-stick tape and a large, grassy area (it will work best on grass; however, the activity can be done indoors on a large piece of paisley or similarly patterned cloth. In this case, use a hole punch to produce large numbers of round, paper prey of various colors).

Procedure: Each pipe cleaner can be cut into thirds giving you 75 pipe cleaner sections for each of the five colors. In this activity, the pipe cleaner sections will be the "prey" and the students will be the "predators." To make this a little more sporting, the predators have to catch the prey with chopsticks. Since this is a coral reef, we will assume the prey are variously colored pipefishes and the predators will be jacks, groupers, barracudas, stonefishes, etc.

On the tagboard, lay out long strips of double-sided tape, one row for each pipe cleaner color.

1 Mix up the pipe cleaner sections and scatter them over a large expanse of lawn.

2 Divide the students into predatory groups and give each one a name ("groupers," "barracudas," etc.). Keep the groups small, so there will not be havoc on the lawn. Give each predator a pair of chopsticks.



A coral atoll starts life as a coral reef surrounding a volcano that thrust its way from the ocean floor to the surface. Over time, the volcano becomes dormant and slowly begins to sink back into the sea. If it sinks quickly, it drags the coral with it and both disappeared from view. However, if the volcano sinks slowly, the coral reef grows fast enough to compensate and stays at the surface. Eventually, the volcano recedes hundreds or thousands of feet down, leaving no trace of its presence, except for a mysterious, thin, ring-shaped coral island.

3 Send the groups out one at a time for a short period, perhaps a few minutes. As the predators find the prey, they must "swim" back to the tag board and stick their prey on the tape, one color per row, then return to the coral reef. When their time is up, one group of predators returns and hands over the chopsticks to the next group.

4 At the end of the exercise, count how many of each color the predators managed to capture. Most often, the colors that tend to blend in with the lawn are caught the least often. The pipe cleaners are counted, recorded and removed from the board so the next group can mount their pipe cleaners (be sure to record how many of each color is found).

Activity Age Modification: This activity would be appropriate for ages 2nd grade and up. Preschool through 1st grade would enjoy this activity on a smaller scale and without chopsticks. Younger children would also enjoy it done as an "egg hunt" with various colored paper fish to find.