THE LIVING SEA

An Educational Resource for Teachers
Introduction

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.

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

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.

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.

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 1/4 pieces, draw a human; on the other, a human with an “X” drawn through it.

5. Now the land partner will cut the 1/4 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 1/4 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 pieces 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.
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.

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
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.

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.
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 blowing over a warm current pick up moisture and heat.

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.

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.
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.

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 pull of the two bodies is added together. These extreme tides are called spring tides, which come 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 one 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 underwater. 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. 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.

**LIVING SEA**

**TEACHER'S GUIDE**

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**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 moons, 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 between 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.
WORKSHEET: CHAPTER 4

Tidal Variations for Central California, December 1994

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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.
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.

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.

**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.

**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:**

1. Prepare by covering your work surface with protective paper.
2. Give each student a sheet of white construction paper and a drinking straw.
3. Put tempera paint in shallow bowls. Water down the paint to the consistency of water.
4. 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.
5. 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.

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.
Food Webs

If you think about it, the “goal” of every organism is to stay alive. Almost all organisms are more-or-less generalists—they eat a wide variety of prey. So while this complex set of organisms-eating-other-organisms has been called a food chain, it is more accurate to think of it as a food web.

As an example, let’s look at what eats what in the open ocean (away from the shore) off almost any coast. A typical food web in the open ocean looks something like the diagram on the facing page.

Phytoplankton form the base of the food web. These are microscopic, often one-celled plants, which absorb dissolved nutrients (nitrites, nitrates, phosphates, etc.) from the water and use sunlight for energy to grow and reproduce. These bottom-rung organisms are called primary producers, because they use light energy to create organic material. Above the primary producers are tiny animals, zooplankton, which are the first-order consumers. These are organisms that must eat primary producers in order to obtain energy. Many kinds of animals form the zooplankton. Some, such as copepods or krill, live their entire lives as tiny organisms. Others, such as the larvae of fish, crabs or worms, are just passing through; they eventually leave as they grow. Even at this level in the web there are already complications. For example, some forms of zooplankton, such as copepods, eat both phytoplankton and young fish larvae. Fish larvae return the favor; as they grow larger they eat copepods.

The next rung above zooplankton in the ocean food web are the second-order consumers, and these are an amazing assortment of animals. While you might expect to see small fishes (such as herrings) and squids at this level, there are also jellyfish and the world’s largest marine fish and mammal. Seventy-foot-long whale sharks eat zooplankton, as do 80-foot blue whales. Blue whales concentrate on various species of krill. It is estimated that an average blue whale, weighing 75 to 80 tons, must eat four tons of krill every day. Since krill aren’t that big, we’re talking about 40,000,000 krill here. Of course, there are other levels above this. Third-order consumers include tunas, seals, sea gulls and molas (ocean sunfish); fourth-order consumers are the orcas and white sharks of the world.

The Food Web Game

Purpose: This activity helps show how life in the ocean is interconnected, with each student acting as part of a food web, using the illustration on next page.

Materials: One ball of yarn, one index card and safety pin per student and a copy of the food web.

Procedure:

1. Referring to the food web figure, each student decides what organism to be, writes its name on a card and pins it to his or her shirt.

2. Stand in a circle with your students holding a ball of yarn. Start the game by saying “I’m a squid and I need fish larvae for food.” Holding one end of the string, pass the ball to a fish larva person. The fish larva person might say, “I’m a fish larva and I eat diatoms” or “I’m a fish larva and jellyfish eat me” and, holding some yarn, passes the ball along.

3. Eventually, everyone will be all tied together in a tangle of yarn, which emphasizes the whole point: All living things are connected in some way.

4. Now, cut the string at some point. The food web is broken. What might happen to the various organisms in the food web?

Activity Age Modification: For younger children, two or three organisms from each group; primary, first order, second order etc., could be drawn or actual pictures used to identify which order eats the other. Another option is to give each child a picture of one of the animals in the pyramid and toss the yarn to each in the order they would be eaten.
The complex system of organisms eating other organisms has been called a food chain, but it is more accurate to think of it as a food web.
Another way of looking at food relationships in the ocean is by depicting how many organisms (or what weight of organisms) are in each food web layer. Because of the shape this relationship invariably takes, it is often called a food pyramid. There are always more organisms at the bottom-rung than in the layer above, and always more in that layer than in the next one above that. This is no coincidence; this pattern exists because energy decreases as it flows through the system. Sometimes only as little as 10% of the energy from the “eatee” is stored in the “eatee” as flesh; the rest is lost as waste heat or is used by the eater to pursue prey, reproduce or otherwise maintain itself. Because of this energy loss, each successive level contains fewer organisms and their total weight is smaller.

Why would the largest mammal and the largest fish in the world eat some of the smallest creatures in the sea? Why don’t blue whales and whale sharks eat 300-pound yellowfin tuna or 1,000-pound black marlin? Basically, it’s for the same reason that the largest land animals, elephants, eat trees instead of lions. First, there are many more trees than there are lions, so it’s really much easier to eat a tree than a lion. Lions have an inconvenient habit of running away if you try to eat them. In addition, while you may eventually catch one, if you are the size of an elephant, you will probably expend more energy running it down than you will gain by eating it. Of less importance, but also to be kept in mind, is that lions tend to bite you if you insist on chewing on them. Trees, on the other hand, are pretty stoic about the whole process. You can saunter up to one, rip it to shreds with your trunk, and just sort of inhale it.

Similarly, a blue whale certainly could catch and swallow a big yellowfin tuna or a bottlenose dolphin, but it might take four days to catch one and there’s just no profit margin in that. By comparison, krill are just perfect. They swarm by the millions and can’t swim very quickly; the whale can catch them by just opening its mouth and leisurely swimming through.

**WORDS TO KNOW**

**Food Pyramid:** organisms arranged in layers according to what they eat. This food web invariably takes the shape of a pyramid.

**KEY IDEAS**

1. There are always more organisms at the bottom of the food chain than in the layer above it. This pattern exists because energy decreases as it flows through the system.
2. The largest mammals, like whales, eat some of the smallest sea creatures, like krill. For this reason, large mammals use a small percentage of their food energy in obtaining prey and therefore can be more efficient in using their food energy for reproducing, maintaining their body temperature and other body functions.

**ACTIVITY: CHAPTER 7**

**PEANUT PYRAMID GAME**

**Purpose:** Students learn how energy is lost as it travels through a food web.

**Materials:** 20 plastic sandwich bags with 20 peanuts each
7 empty plastic sandwich bags
Large pyramid diagram
20 signs on large index cards saying:
- **Producers:** Green Plants
- **First-Order Consumer:** Herbivores
- **Second-Order Consumer:** Meat Eater
- **Third-Order Consumer:** Top Predator

**Procedure:**
1. Have 20 students act as “producers” or green plants. Pin or hang the signs on them. Give each one a plastic bag with 20 peanuts in it, representing 20 energy units. This energy comes to the plant from sunlight and from nutrients and gases in the water. Total energy units available at the beginning = 400
2. Each “plant” may eat 5 peanuts. This represents the amount of energy the plant consumes for respiration and normal growth activity. The remaining 15 energy units are stored in the plant tissue.
   **Note:** There are now 300 unused energy units (stored in the plant tissue) remaining.
3. Next, four students acting as first-order consumers (herbivores) feed on the phytoplankton to get their energy. Each one takes an empty plastic bag and collects 75 energy units (peanuts) from the green plants. Each one may collect from any or all the plants until each one has 75. Since herbivores require a lot of energy to get their food, each one may eat 45 energy units (peanuts). The 30 remaining energy units are stored in the herbivores as fat, flesh, bones and internal organs.
   **Note:** There are now 120 energy units (stored in the animal tissue) left.
4. Two students acting as second-order consumers (carnivores) each collect 60 energy units from any of the herbivores. In nature, this could even mean a flight over a catch or the sharing of one. The hunt and the generally high respiration of the predator would use up 30 energy units. Therefore, each carnivore...
may now eat 30 peanuts, storing the remaining energy units as body tissue.

Note: There are now 60 energy units (stored in the animal tissue) left.

One student acting as the top predator (shark, orca, etc.) collects all the remaining 60 energy units. If the hunt was very strenuous, the predator may have required all 60 units, leaving nothing left for growth. This could result in a stunted animal or one that could not reproduce or would become ill from lack of resistance to disease. Perhaps the animal would hunt in a wider area, which would include more sources of food to supply a larger supply of energy units. Our predator is pretty healthy, so only 30 units of energy are consumed (the student eats 30 peanuts) and the remaining are stored in the predator's body.

### Food Pyramid Assignments

<table>
<thead>
<tr>
<th>Order</th>
<th>Students</th>
<th>Units Taken</th>
<th>Units Eaten</th>
<th>Units Surrendered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producers</td>
<td>20</td>
<td>20</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td><strong>FIRST ORDER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbivores</td>
<td>4</td>
<td>75</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td><strong>SECOND ORDER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meat Eaters</td>
<td>2</td>
<td>60</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><strong>THIRD ORDER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top Predators</td>
<td>1</td>
<td>60</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

Activity Age Modification: This activity would be appropriate for 3rd grade and up. For preschool through 2nd grade, a game based on *Upset the Fruit Basket* could be substituted. For this game, have all the children form a circle and choose four children to be "it." They are the top predators. The remaining children would be numbered off as green plants, herbivores or meat eaters (i.e.: 1st child is green plant, 2nd child herbivore, 3rd child meat eater, etc.). The top predators call out one of the orders and everyone in that order switches places with someone else in their order. The object is to avoid being caught by the top predators. If they are caught, they become a top predator, and the top predator becomes whatever the captive was, and the game proceeds. Each top predator only captures one person on each turn. Each order could wear a piece of yarn around their wrist to signify which order they represent.

For smaller groups of children, the energy units given to each child could be increased (i.e.: instead of using 20 children as producers, use only 10, but increase their energy units from 20 per child to 40 per child). They now each represent two plants instead of one; they would eat 10 energy units instead of five. This scale may be used throughout the entire exercise. Larger groups may do the same, except the energy units are decreased instead of increased.
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 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.

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!

### 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.

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

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

3. 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 thrusts 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 disappear 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.
First of all, what are jellyfish? I'm sure you are not surprised to learn that, like starfish or cuttlefish, jellyfish are not fish. These are coelenterates or cnidarians, a group of semi-goopy invertebrates that, along with the jellies, include such organisms as sea anemones and corals. A jellyfish is more properly called a medusa. (Medusa was the woman in Greek mythology who had snakes for hair.) A jellyfish, or medusa, has two parts: the bell and the tentacles. The bell—which ranges in shape from a Frisbee to a helmet to an umbrella—contains a mouth and stomach, usually the reproductive organs, and some nerves. Medusae have no brains, no hearing systems and some have nothing resembling an eye.

Tentacles, containing stinging cells called nematocysts, are the business end of these animals. Many medusae slowly raise and lower their tentacles, basically fishing at various depths. When a ctenacle encounters something, nematocysts in the vicinity fire, explosively discharging a spiny tube through which venom flows.

It has been estimated that a single tentacle of a Portuguese man-of-war (Physalia physalis) may contain 750,000 nematocysts. While a small ctenacle might cause 50 of them to discharge, something big, like a fish, might receive several hundred thousand stings.

There are hundreds of medusa species, they feed on a wide variety of prey, primarily zooplankton and small fish. There is evidence that some species of medusa follow chemical trails emitted by their plankton prey.

The nematocysts of some species are extremely powerful and the tubes are propelled with such force that researchers report they (the nematocysts, not the researchers) can slow down a surgical glove. However, the vast majority of medusae are harmless to humans; their nematocysts are too weak to penetrate human skin.

There are hundreds of medusa species found all over the world, from the Arctic to the tropics, and while most occur in shallow marine waters, some have been found down to more than 12,000 feet. While most jellies are small (with bells ranging from one to 20 inches across and short tentacles), a few may reach six feet in diameter and have tentacles stretching out for 100 feet or more.

Virtually all medusae can swim, by rhythmically pulsating their bells. Many are not particularly strong swimmers and these are more or less at the mercy of current and wind.

Perhaps the most bizarre medusa population lives in Jellyfish Lake, a marine lake on the island of Eil Malk, Palau. Jellyfish Lake is a 1,300-foot-long, 90-foot-deep lake that connects to the sea via various fissures and cracks in the coral island. The lake has two deep basins, one in the eastern section and one in the western. While there are very few species of animals in the lake, the population of medusae is large. They take two types of migrations every day. At night, most go out in the center of the western basin and repeatedly dive from the surface to about 50 feet. They stay in the center to avoid the shoreline's sharp mangrove roots and medusa-eating sea anemones. They probably dive to the mid-water to absorb some of the nutrients that concentrate in deeper water. These medusae "farm" algae in their bodies and they probably absorb the nutrients to fertilize these plants.

These animals make one other kind of migration. Every day at sunrise you can find all of them at the eastern end of the lake. As the sun travels the sky, the jellies slowly make their way westward, avoiding shadows along the shore, thus maximizing their exposure to the sun. In addition, as the animals swim westward, they slowly pirouette counterclockwise. Both of these behaviors provide their algae with equal and long-term doses of sunlight.

Jellies feed on a wide variety of prey, primarily zooplankton and small fishes. But how do organisms without eyes, ears and brains find food? Until recently, the conventional wisdom was that most jellies were random predators, either drifting or swimming about until their tentacles by chance brushed up against brunch. While this may be true for many species, new evidence shows that two species (Aequorea victoria and Aurelia aurita) follow chemical trails emitted by their plankton prey. On the other hand, many animals, such as sea turtles and molas (ocean sunfish) eat jellies.

Humans have eaten jellyfish for hundreds of years and today there is a major jellyfish fishery throughout the South Pacific and Indian oceans. After capture, jellyfish are salted, then dried.
how does salted, dried jellyfish taste? Well, right out of the package (available at most Asian markets), jellyfish taste...well...just about like nothing. As far as I can tell, dried jellyfish have virtually no taste. They do have a rather pleasing consistency though; when you bite down on each limp little strip, there is a very definite crunch.

ACTIVITY: CHAPTER 8

EATING JELLYFISH

Here's something fun to do with your class—make a jellyfish dish. Most Chinese cookbooks have at least one recipe. Here is a good one from Madame Chu's Chinese Cooking School Cookbook (Grace Zia Chu, Simon and Schuster).

Jellyfish and Icicle Radish Salad

Ingredients:
- 1 1/2 tbl. light soy sauce
- 2 tsp. sesame seed oil
- 2 oz. soaked, drained and shredded jellyfish
- 1/2 cup chopped scallions, green part only
- 1/2 tsp. sugar
- 1 tsp. salt
- 1/2 tsp. Chinese hot pepper oil (optional)
- 1 medium-sized radish

Preparation: Wash jellyfish a number of times in cold water. Combine the soy sauce, sesame seed oil, sugar and hot pepper oil (if used) and refrigerate until serving time. Peel icicle radish and cut into fine shreds. Measure 1 1/2 cups of shreds, using more radishes if needed. Sprinkle salt over the radish and let stand for 25-30 minutes. Rinse and drain. Mix jellyfish, radish and chopped scallions in a salad bowl. Just before serving, pour sauce over salad. Serve cold.

ALTERNATE ACTIVITY: CHAPTER 9

PARACHUTE JELLYFISH

Materials: One large parachute

Procedure:
1. Have children form a circle around the parachute and hold on with two hands.
2. Have them raise their hands above their heads and take several steps toward the center. The parachute will fill with air.
3. Then have the children step back to their original position and the parachute will flatten out. The parachute represents the bell and the children are the tentacles. As the parachute goes up and down, this rhythmic action symbolizes the travel of the medusa. The children can also rotate counterclockwise to show medusa pirouetting, as they do in Jellyfish Lake.
**Resources**

- Marine Biology, An Ecological Approach  
  Nybakken, James W. Harper & Row, NY, 1993
- Oceanography, An Invitation to Marine Science  
  Garrison, T. Wadsworth Press, Belmont, CA, 1993
- Fishes: A field laboratory manual on their structure, identification, and natural history  
- Readings in Ichthyology  
- Marine Activities, Resources and Education (MARE)  
  University of California, Berkley, Lawrence Hall of Science

**Additional Resources for Children**

- When the Tide is Low  
  Cole, Sheila. Lothrop, 1985
- Life on a Coral Reef  
  Bender, Lionel. First Sight series, Watts, 1989
- Coasts  
  Lye, Keith. Our World series, Silver Burdett, 1988

**Acknowledgements**

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Author of Everyman's Guide to Ecological Living: Readings in Ichthyology; Fishes: A Field and Laboratory Manual on Their Structure, Identification and Natural History; and Probably More Than You Want to Know About the Fishes of the Pacific Coast  
Editorial Assistance by Alice Casbara, Catherine Girard and Dorine Imbach  
Designed by Jeff Girard, Victoria Street Graphic Design, San Clemente, CA  
Illustrated by Phil Roberts  
All illustrations © 1995 Phil Roberts. All rights reserved.

We wish to recognize these contributors to this study guide:

Exercises 1 and 3 are adapted from material created by MARE: Marine Activities, Resources and Education, Lawrence Hall of Science, University of California, Berkeley.

Special thanks to the Ocean Film Network Theaters.

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Printed in USA
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