Educator's Guide

THE ULTIMATE WAVE TAHITI

FEATURING KELLY SLATER

About the Film

Featuring nine-time world surfing champion Kelly Slater, *The Ultimate Wave Tahiti* follows a quest to find the perfect wave-riding experience. The film's action focuses on Tahiti and the volcanic islands of French Polynesia, home to some of the world's most challenging surfing and to astounding coral reef ecosystems at the turbulent interface between island and ocean.

With their host, Tahitian surfer Raimana Van Bastolaer, Kelly Slater and a group of friends seek out the best waves breaking on the reef at Tahiti's famed surf site Teahupo'o. Kelly and Raimana share a passion for the waves, but have different ideas about what surfing means to them: is it a modern competitive sport or an ancient Polynesian wave-riding art? As the surf quest unfolds, the film explores the hidden forces at work shaping the waves and the islands that lie in their path. The great waves arrive, and surfing play becomes surfing survival as the riders tackle some of the biggest, heaviest surf on the planet.

The Ultimate Wave Tahiti is presented by Suzuki, with supporting sponsorships from Tahiti Tourisme and Quiksilver.

Dear Educator

WITH *THE ULTIMATE WAVE TAHITI*, we are pleased to offer a unique opportunity to engage your students in the science of waves through the thrilling context of surfing. The story told by nine-time world champion surfer Kelly Slater also links to topics that include geography, weather, biology, and social studies. This *Guide* is designed to help you explore these opportunities and bring the excitement and beauty of giant waves into your classroom.

The activities have been developed to provide connections to National Science Education Standards for grades 4 – 8. With minor modifications, these activities may also be used with older or younger students. A matrix correlating each lesson with specific standards is provided on page 24. Understanding that curriculum requirements vary widely across the U.S., we offer this *Teacher's Guide* as a collection of ideas that will be adapted by individual educators to meet the specific needs of their students. In addition, there are many cross-curricular opportunities with English/Language Arts, Social Studies, Mathematics and even Fine Arts. Through these activities, students are encouraged to understand that science is connected to every aspect of their lives, and can offer exciting ways to experience and understand their world.

Contents

[Note: Glossary words are **highlighted** when they are first used in the text.]

Introduction to Waves

Note: With the exception of Student Inquiry Guides, *explanations and procedures in this* Guide *are written at a level appropriate to professional educators. Because state Science Education Standards vary widely in the treatment of wave phenomena, some educators may wish to focus on the connections between waves and energy. In this context, we might begin with chemical energy in the atoms and molecules of the Sun. This chemical energy is transformed into radiant energy, some of which reaches the molecules of Earth's atmosphere and ocean. As radiant energy causes increased vibration among these molecules, it is transformed into thermal (heat) energy. As the added thermal energy causes air molecules to move, it is transformed into the mechanical energy of wind. Wind blowing across the ocean's surface transfers some of its energy to the water, producing the mechanical energy of waves. Lessons 1, 2, 3, and 6 explore what happens to this wave energy.*

How many different kinds of **waves** can you think of? Sound waves, light waves, microwaves, ocean waves, earthquake waves, slinky waves…waves are everywhere! All waves have three features in common:

1. They are energy transport phenomena. This means that they are involved in transporting energy, but do not transfer matter (matter may be moved by a wave, but there is no net transfer from one place to another).
2. The energy of waves moves in specific patterns.
3. Waves have characteristics that include wavelength, amplitude, velocity, and sometimes frequency.

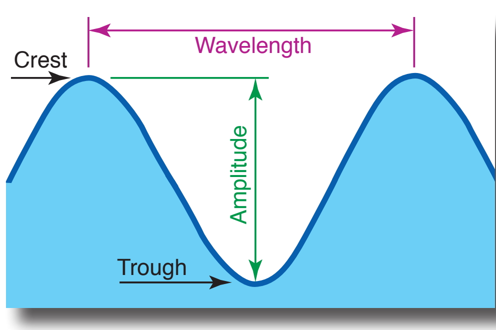
Waves as Energy Transport Phenomena–

When we see a wave, it often appears that something is moving from one place to another. In reality, we are seeing a disturbance moving through a solid, liquid, or gaseous medium. The particles of the medium may move, but return to their original position after the wave passes. In a stadium wave, the fans raise their hands, then put their hands down. After the wave passes, everyone is still where they were before the wave arrived. The only thing that actually moved from one place to another was the energy of the wave.

Wave Characteristics–

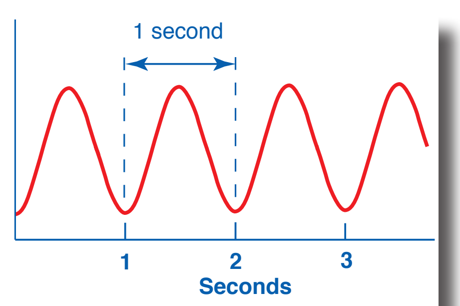
Wavelength is the distance over which a wave's shape repeats. The wavelength of a water wave is the distance between two crests or two troughs.

Amplitude is the height of a wave, measured from a particle's resting position to the wave **crest** ("rest -to-crest" or peak amplitude), or between the particle's highest and lowest positions ("**trough**-to-crest" or peak-to-peak amplitude).



Wavelength and **amplitude**

Period is the amount of time it takes for one particle to complete its full range of motion and return to its original position.



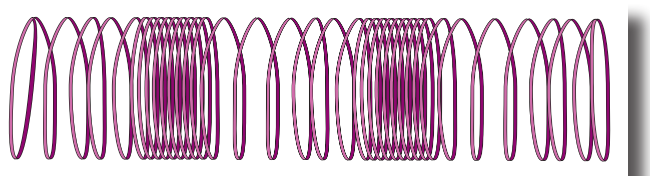
Period. This wave has a period of one second.

Waves that require a medium through which they transfer energy are called **mechanical waves**. There are also other types of waves, such as radio waves and light waves, that do not involve a medium. These waves are composed of an electric field and a magnetic field that are oscillating together, and are called electromagnetic waves. These waves can also be thought of as particles called photons: massless packets of energy that travel at the speed of light.

Wave Patterns–

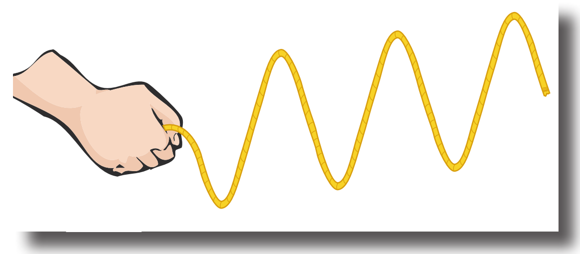
Waves can be classified by comparing the motion of individual particles in a medium to the direction in which the wave energy moves:

- In a **longitudinal or compression wave**, the particles of the medium move in a direction that is parallel to the direction in which the wave energy moves.



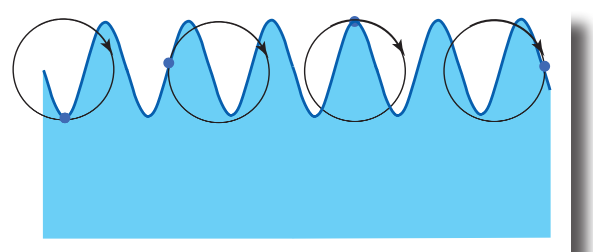
Longitudinal or **compression** wave

- In a **transverse wave**, the particles of the medium move in a direction that is perpendicular to the direction in which the wave energy moves.



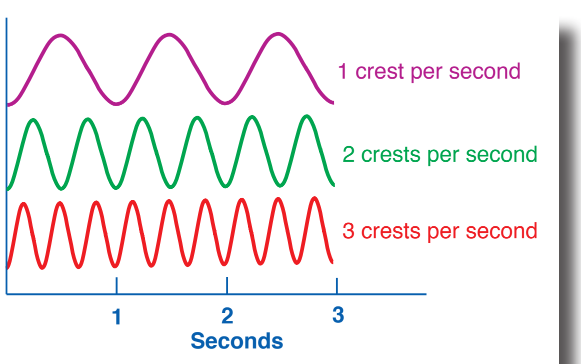
Transverse wave

- In a **surface or circular wave**, the particles of the medium move in a circular or elliptical pattern. Wave patterns are discussed further in Lesson 3, Ocean Motion.



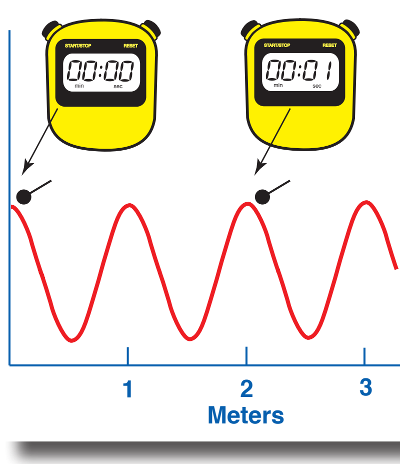
Surface or **circular** wave

Frequency is the number of crests that pass a given point in a certain amount of time.



Frequency. These waves have different frequencies.

Velocity is a measure of the distance traveled by the crest of a wave in a certain amount of time.



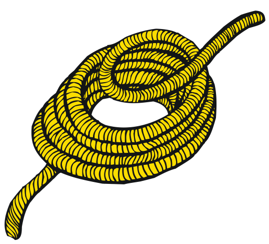
Velocity. The crest marked with a circle traveled two meters in one second, so it has a velocity of two meters per second.

Lesson 1: Making Waves

Focus
Waves as energy transport phenomena

Key Concept
A wave transports energy without transporting matter.

Objective
Students will be able to describe waves in terms of moving energy from one place to another, and contrast this process with transfer of matter from one place to another.



Materials
- 2.5 m (minimum) length of rope (a flexible material such as braided nylon is best; if possible choose a bright color and at least 9 mm diameter for good visibility)

Preparation
Practice forming a wave in the rope to determine how much slack is needed to produce a clearly visible wave.

Procedure
Step 1.
Have two students hold opposite ends of a piece of rope with enough slack so that a wave will form when one end of the rope is repeatedly raised and lowered. Instruct the two students to form a wave in the rope, and have other students record their observations on the *Inquiry Guide*.

Step 2.
Arrange half of your students so that they are seated side-by-side in a straight line. Have the students form a stadium wave (most students will know what this means, but you may have to provide specific instructions for those who haven't seen it done at a sports event). Have other students record their observations on the *Inquiry Guide*. Repeat with the two groups of students exchanging roles.

Step 3.
Have students write answers to questions on the *Inquiry Guide*.

Step 4.
Discuss: Students should realize that portions of the rope moved in the rope wave, and students moved in the stadium wave, but that neither rope nor students ended up in a different location. Students may be puzzled by this point, because in both cases they saw "something" moving from one place to another. Encourage students to think again about exactly what they saw, and provide sufficient hints to lead them to identify a disturbance as the "thing" that moved, and that the disturbance was caused by an input of energy that moved through the system with the wave. The energy caused portions of the rope (or individual students) to temporarily move from their original position, but they returned to these positions when the energy moved to adjacent portions (or students).

Students should realize that stadium waves are not "natural" waves, since their behavior depends upon the intentions of individual people involved rather than processes that happen without conscious thought. You may want to discuss some ways in which stadium waves resemble rope waves, and some ways in which they are different. Similarities include the appearance of crests and troughs, as well as characteristics of frequency, period, amplitude, and wavelength. Differences include the fact that energy isn't transferred from one person to the next in a stadium wave, and that the appearance of a stadium wave depends entirely upon cooperation between the individuals participating. If a few individuals choose not to move in the right way at the right time, the wave falls apart; but individual particles in a rope wave don't have that option!

Making Waves Student Inquiry Guide

Rope Waves

Draw a sketch and write a description of a rope wave:

Stadium Waves

Draw a sketch and write a description of a stadium wave:

Wave Questions

1. What moved in the rope wave and stadium wave?

2. As the wave moved along the rope, was anything moved from one location to another location?

3. After the stadium wave, was anyone in a different location than before the wave?

4. Sound also travels in waves. What particles move when sound waves travel?

Lesson 2: The Wave Factory

Focus

How and where are waves born?

Key Concept

Ocean waves are born from winds that transfer energy to the sea surface.

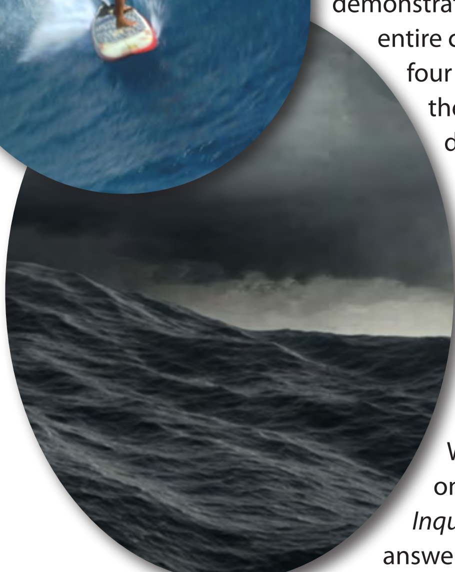
Objectives

- Students will identify winds as the primary source of energy for ocean waves.

- Students will identify heat energy from the Sun as the source of energy for winds.

Materials

- Rectangular clear plastic storage container, approximately 30 cm x 46 cm x 15 cm (about 9 L capacity)
- (Optional) Food coloring
- Plastic tubing, 12 mm inside diameter, about 60 cm long
- Wooden block, approximately 5 cm x 10 cm x 15 cm
- Piece of plain paper, about 10 cm x 10 cm



Preparation

This activity may be done as a demonstration/discussion involving the entire class, or by groups of two to four students. If you plan to do the activity as a demonstration/discussion, pour water into the plastic container until it is about half full. You may add a few drops of food coloring to make the water more visible.

Procedure

Demonstration/Class Discussion Option

Work through the nine questions on the *Wave Factory Student Inquiry Guide*, discussing students' answers to questions for each step:

Step 1.

Students should recognize waves on the water surface.

Steps 2. and 3.

Suggestions may include raising and lowering an object such as the wooden block, and blowing through one end of the plastic tubing while holding the other end close to the water surface. Demonstrate several ideas as they are suggested, or have students demonstrate them.

Step 4.

Wind is the answer we are looking for, but other ideas may include earthquakes, volcanoes, and influence of the Moon and/or the Sun. There may be some confusion about tsunamis that are caused by earthquakes and volcanoes, but these are not the waves that are normally ridden by surfers. Be sure students understand that the Sun and Moon influence movements of the ocean that we see as tides, but tidal motion is much slower than the motion of waves that are suitable for surfing.

Step 5.

Students should predict that the initial effect of the wind will be to cause ripples to appear on the ocean's surface.

Step 6.

Depending upon prior experience, most students will predict that the ripples will become larger and form waves.

Step 7.

Students should infer that the ripples increase the surface area that the wind can push against. When students push the flat piece of paper, they can only push against the very small area that is actually in contact with their fingertips, but folds in the paper increase the contact area. Tell students that increasing surface area makes it possible for more and more energy to be transferred from the wind to the waves. In fact, as wind speed increases, the height of waves increases exponentially (wave height is proportional to the third power of wind speed). This is why storm waves can be so unexpectedly destructive.

Step 8.

Students should realize that kinetic energy is being transferred from moving air particles (wind) to water particles.

Step 9.

If students do not say that winds are the result of the Sun heating the Earth, discuss one or more of the hints. You can model this process by adding a few drops of food coloring to a glass container of water that is being heated on a hotplate or gas burner. When solar heating has been identified as the cause of winds, ask additional questions to ensure students understand that winds result from uneven heating across Earth's surface and atmosphere. The most obvious example of this is that at any time, half the Earth is in daylight and the other half is in darkness. Uneven heating also results from the angle at which sunlight strikes a point on Earth's surface (polar regions are colder than equatorial regions), as well as the tilt of the Earth's axis, which causes the amount of solar radiation received by the northern and southern hemispheres to change seasonally. Students should know that heated air rises. When it does, cooler air flows in to replace the air that has risen. This flow of air is wind.

For more about winds and the effects of solar heat and Earth's shape and rotation, see the NOVA Online interactive activity, "Giving Rise to the Jet Stream" (linked from http://www.pbs.org/wgbh/nova/vanished/jetstream.html).

Student Group Option

Step 1.

Provide each group with a copy of the *Wave Factory Student Inquiry Guide* and access to the materials listed above. Tell students to follow instructions in the Guide to find answers to the nine inquiry questions.

Step 2.

When student groups have finished answering the questions, lead a class discussion of their results and inferences. See the Demonstration/Class Discussion Option for key points that should be included.

Wave Factory Student Inquiry Guide

Observe

1. Pour water into the plastic container until it is about half full. Your teacher may have you add a few drops of food coloring to make the water more visible. Watch the water through the side of the container, raise one end of the container about two inches, then lower it quickly. What do you observe?

Predict

2. How could you use the wood block or plastic tubing to create waves in the container?

Experiment

3. Try your ideas for using the wood block and plastic tubing to create waves. What do you observe?

Infer

4. What causes waves that surfers ride?

Predict

5. Imagine the surface of the ocean on a calm day. What happens if a wind begins to blow?

6. What will happen if the wind continues to blow?

7. Use your fingertips to push the piece of plain paper across a smooth desk or tabletop (be sure your fingers are completely dry!). Now make several folds in the paper as if you were making a fan, then push the paper again. How do ripples influence the effect of wind on the lake's surface?

8. What is happening when wind causes waves to form on the lake surface.?

9. What causes winds? Hints: (a) How does the Sun affect temperatures on Earth? (b) Is the effect of the Sun the same at every location on Earth? (c) Does air move when it is heated?

Lesson 3: Ocean Motion

Focus

What factors influence the size and shape of ocean waves?

Key Concept

The size and shape of ocean waves are determined by wind velocity, fetch, duration, and sea bottom topography.

Objectives

- Students will be able to identify the crest, trough, wavelength, and height of a wave.
- Students will be able to identify and explain the three factors that determine the height of an ocean wave.
- Students will be able to identify and discuss conditions that cause a wave to **break**.

Materials

Option A (See Preparation Procedure, Step 2)

- Two-speed electric fan
- Wave tank or stream table
- Flat piece of thin plywood, cookie sheet, etc; approximately 30 cm x 20 cm (only needed if your wave tank or stream table is square; see Procedure Step 2c)

Preparation

Make a copy of the *Ocean Waves Student Inquiry Guide* for each student. If you have a wave tank or stream table and an electric fan, follow instructions for Option A in Step 2. Set up the wave tank or stream table prior to beginning the class, be sure the fan is operating on both speeds, and that you have a ground fault-protected electric circuit available. If you do not have this equipment, make copies of Figures 1, 2, and 3 for each student and follow instructions for Option B in Step 2.

Procedure

Step 1.

Briefly review the key concepts of Lessons 1 & 2:

- A wave transports energy without transporting matter; and
- Ocean waves are born from winds that transfer energy to the sea surface.

Tell students that they will be investigating things that affect the size and shape of ocean waves.

Step 2.

Option A

a. If your stream table or wave tank is rectangular, turn the fan on at the lower speed, and place the fan so that it blows onto the water surface across one of the short sides. Have students draw several waves and record their observations in words.

b. Turn the fan to the higher speed, and have students record their observations.

c. If your stream table or wave tank is rectangular, place the fan so that it blows onto the water surface across one of the long sides. If your stream table or wave tank is square, place a flat piece of wood or a cookie sheet perpendicular to the direction of the air stream from the fan, about halfway between the fan and the opposite side of the wave tank or stream table. Have students record their observations.

Option B

Provide students with copies of Figures 1-3.

Step 3.

Have students complete Steps 1–8 on the *Ocean Waves Student Inquiry Guide*, then lead a discussion of their results.

- Students should have labeled their drawings as illustrated on Page 2.
- The wave period should increase as distance from the fan increases.
- Wave size (height) should increase as the fan speed increases.
- When the fan blew across a shorter distance, the size of the waves should have decreased.
- Three factors that influence wave size are how long the wind blows (duration), distance over which the wind blows (called the wind's "**fetch**"), and strength of the wind.
- The storm in the Pacific would produce the largest waves, since the fetch of the wind would be greater in the Pacific.
- Be sure students understand the distinction between **spilling breakers** and **plunging breakers**. Coral reefs can build up the sea bottom and thus decrease water depth. Where reefs grow on a steeply sloping surface (such as at Teahupo'o) the result can be formation of plunging breakers. Where coral reefs form a barrier away from the shore, they can help protect shorelines from the direct impact of ocean waves.

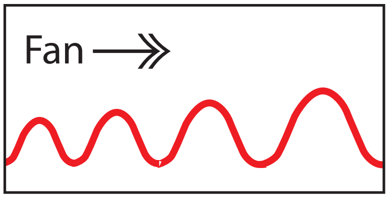


Figure 1. Fan speed = low

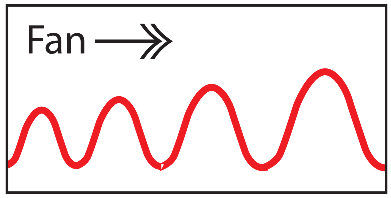


Figure 2. Fan speed = high

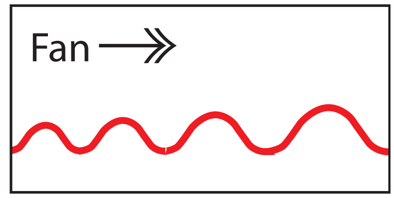


Figure 3. Fan blows over shorter distance

Ocean Waves Student Inquiry Guide

Your teacher will tell you whether to use your own observations or Figures 1, 2, and 3 to complete the following.

1. The high point of a wave is called the crest. Label the crest of one wave on Figure 1 or your own drawing.

2. The low point of a wave is called the trough. Label the trough of one wave on Figure 1 or your own drawing.

3. The distance from one wave crest to the next crest is called the wavelength. Label the wavelength on Figure 1 or your own drawing.

4. The time needed for two wave crests in a row to pass a given point is called the period of the wave. Is the wave period longer near the fan or farther away from the fan?

5. What happened after the fan was turned to a higher speed?

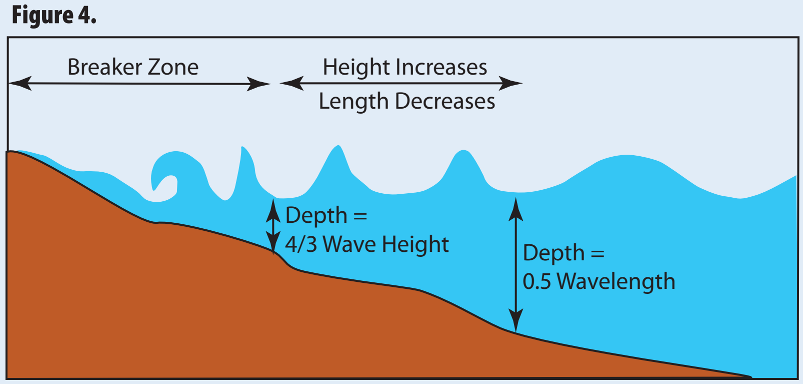
6. When the fan blew across a shorter distance, what happened to the size of the waves?

7. When winds blow over water for a long time they produce bigger waves than if they only blow for a short time. From your observations, what are two other factors that affect wave height?

8. Suppose a strong storm forms in the western Atlantic Ocean with winds that blow steadily toward the east at 60 miles per hour, and an identical storm forms in the western Pacific Ocean with winds that blow at the same speed in the same direction. Which storm will generate the largest waves? Why?

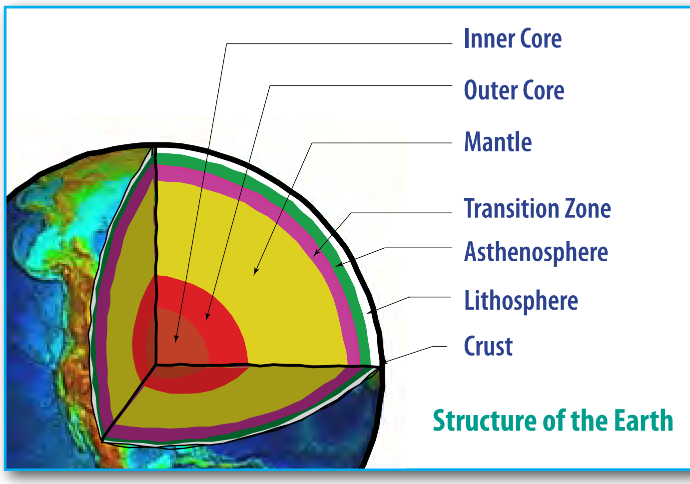
9. When waves move into shallow water, they begin to interact with the sea bottom. When the water depth is one-half the wavelength, the waves' shape changes as their crests become shorter and their troughs become longer. Their wavelength decreases, and the waves are higher and closer together. The waves break when the depth is about 4/3 of the wave height. If the slope of the sea bottom is steep, waves will break close to shore and crash violently along the shoreline. These are called "plunging breakers." If the slope of the sea bottom is more gentle, waves will break farther from shore, producing "spilling breakers." How do you think coral reefs might affect waves as they approach the shore?

Figure 4.



Introduction to Volcanic Islands

Many islands are formed by volcanoes that happen because of the movement of **tectonic plates** that make up the Earth's crust. The outer shell of the Earth (called the **lithosphere**) consists of about a dozen large plates of rock (called tectonic plates) that float on a hot flowing mantle layer called the **asthenosphere**.



Structure of the Earth

Heat within the asthenosphere creates **convection currents**. (The demonstration described in Step 9 on Page 7 may be used here as well). These convection currents cause the tectonic plates to move. Moving tectonic plates may move away from each other, bump together, or slide horizontally so that they rub together.

Where tectonic plates move apart (for example, along the mid-ocean ridge in the middle of the Atlantic Ocean) a **rift** is formed, which allows **magma** (molten rock) to escape from deep within the Earth and harden into solid rock known as **basalt**.

Where tectonic plates bump together, one plate may descend beneath the other in a process called **subduction**, which generates high temperatures and pressures that can lead to explosive volcanic eruptions (such as the Mount St. Helens eruption which resulted from subduction of the Juan de Fuca tectonic plate beneath the North American tectonic plate).

Tectonic plates slide horizontally past each other at **transform plate boundaries**. The motion of the plates rubbing against each other sets up huge stresses that can cause portions of the rock to break, resulting in earthquakes. Places where these breaks occur are called faults. A well-known example of a transform plate boundary is the San Andreas fault in California.

Volcanoes can also be formed by **hotspots**, which are thought to be natural pipelines to reservoirs of magma in the upper portion of the Earth's mantle. If a tectonic plate moves over a hotspot, a series of volcanoes may be formed that can produce a chain of islands called an **archipelago**. Tahiti and other Society Islands are one example of this process.

Coral reefs are an important part of the development and evolution of these islands. Over time, limestone rock produced by reef-building corals may completely cover all the volcanic rock that is underwater. If the island becomes completely submerged, it is then called a **seamount**. Movement of tectonic plates may eventually transport islands and seamounts out of tropical waters, so that coral growth slows or stops. Scientists believe that the Emperor Seamount Chain to the northwest of Hawaii was formed in this way.

Dramatic night view of activity at Pu'u O'o on Kilauea's east rift on June 29, 1983. Individual lava fragments are visible in the spray and molten flows are visible on the flanks of the cone. Photo credit: G.E. Ulrich, Hawaiian Volcano Observatory, U.S. Geological Survey. http://www.ngdc.noaa.gov/hazard/img/200_res/33/33_661.tif

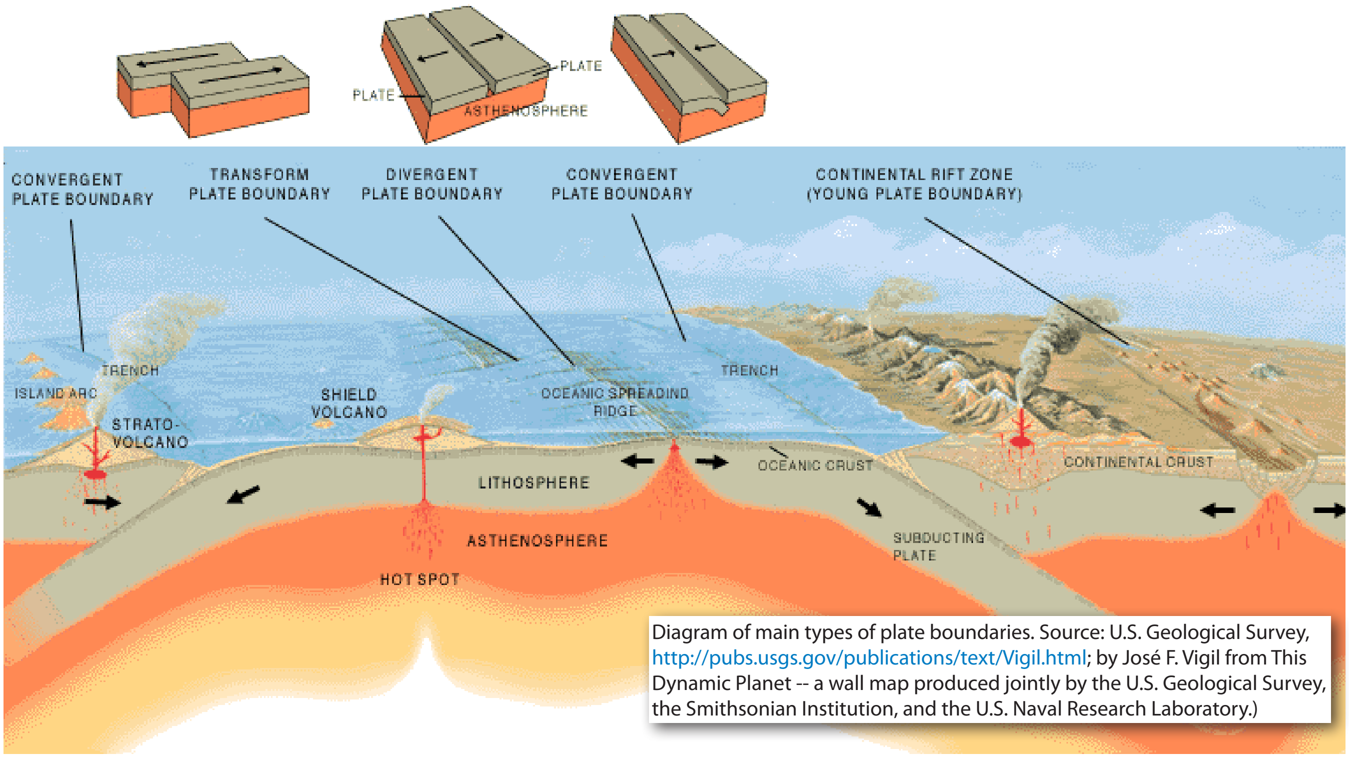
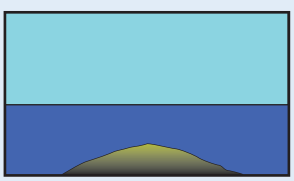


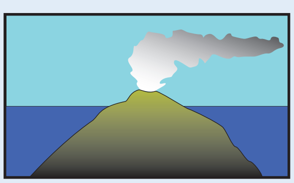
Diagram of main types of plate boundaries. Source: U.S. Geological Survey, http://pubs.usgs.gov/publications/text/Vigil.html; by José F. Vigil from This Dynamic Planet -- a wall map produced jointly by the U.S. Geological Survey, the Smithsonian Institution, and the U.S. Naval Research Laboratory.)

For more information and links, see "This Dynamic Earth," http://pubs.usgs.gov/gip/dynamic/dynamic.pdf.

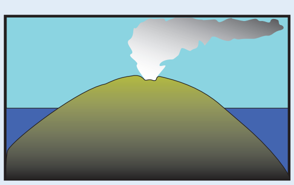
Stages in the growth of volcanic islands include:



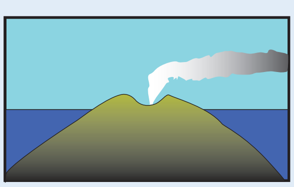
1. **Deep submarine stage:** Underwater volcanic eruptions that eventually reach the ocean surface



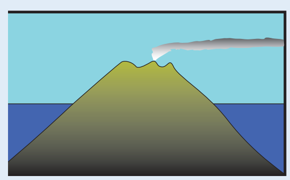
2. **Shallow submarine stage:** Crater forms above water, and lava flows from the side of the cone



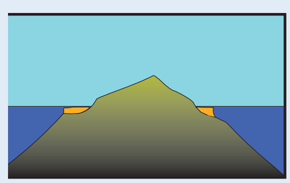
3. **Subaerial shield-building stage:** Highest point of the volcanic cone collapses to form a caldera; lava continues to flow from the summit and side of the cone



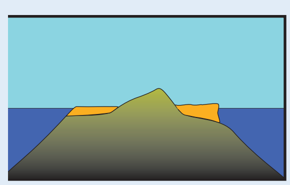
4. **Post-caldera stage:** Lava fills and overflows the caldera to form a rounded summit



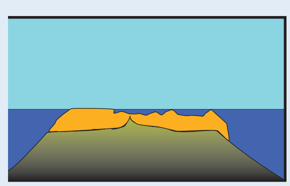
5. **Erosional stage:** Lava flow stops, and the volcanic cone is attacked by erosion from waves and rainfall forming cliffs, deep valleys and sharp ridges; coral grows on shallow underwater portions of the cone



6. **Reef growth stage:** Erosion continues and the volcanic island is slowly sinking, but coral growth may keep pace with sinking so that reefs can form



7. **Post-erosional eruptions stage:** Minor volcanic activity that may form a few small cones or lava flows



8. **Atoll stage:** Lava rock has been eroded below sea level, and only the coral reef remains at the surface

Lesson 4: The Tahitian Hotspot

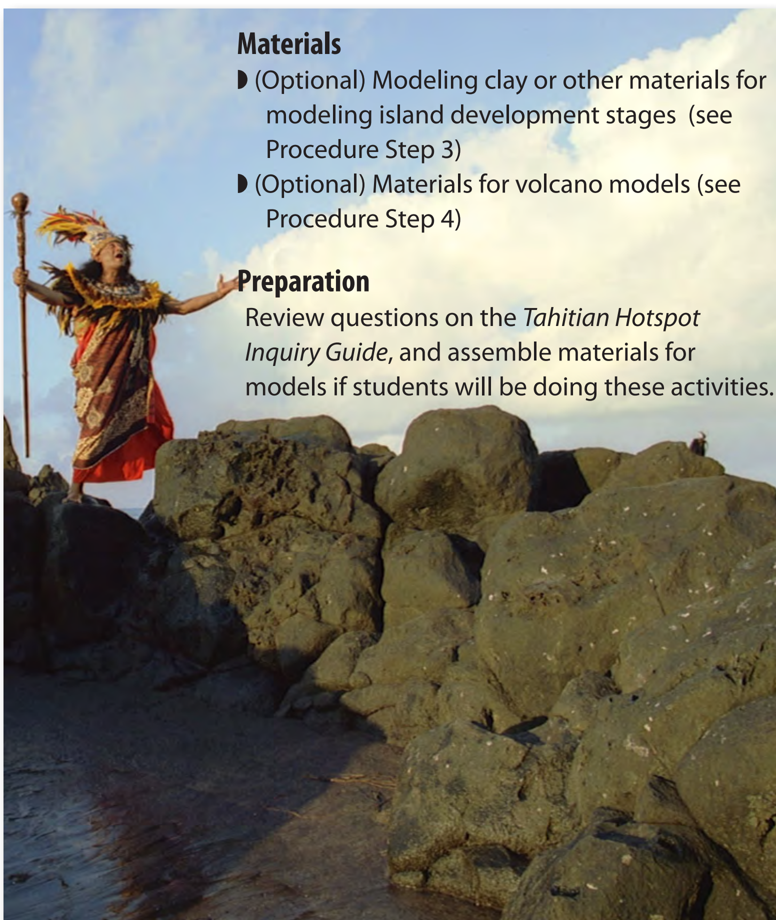
Focus
Geologic processes that produced the island of Tahiti

Key Concept
Volcanic islands result from the movements of tectonic plates, sometimes in combination with hotspots.

Objectives
- Students will be able to explain the stages of development of volcanic islands.
- Students will be able to describe a hotspot.
- Students will be able to explain the relationship between movement of tectonic plates and hotspot activity in the formation of island archipelagos such as the Society Islands.

Materials
- (Optional) Modeling clay or other materials for modeling island development stages (see Procedure Step 3)
- (Optional) Materials for volcano models (see Procedure Step 4)

Preparation
Review questions on the *Tahitian Hotspot Inquiry Guide*, and assemble materials for models if students will be doing these activities.



Procedure

Step 1.
Briefly review the major layers of Earth's structure, and if students are not familiar with the concept of plate tectonics, briefly introduce this idea. Explain the eight stages in the development of volcanic islands. Provide each student or student group with a copy of the *Tahitian Hotspot Student Inquiry Guide* and have them answer the questions.

Step 2.
Lead a discussion of students' results. Students should recognize that the Society Islands are part of the Pacific tectonic plate. Since the islands are not on the edge of the plate, they should infer that a hotspot probably caused the volcanoes that formed the islands. Students should also infer that the oldest Society Islands are at the northwestern end of the archipelago, since islands that are farthest from the hotspot would be expected to be older than islands nearer the hotspot.

Step 3.
Optional: Assign each group one of the stages in the development of volcanic islands, and make a model of that stage.

Step 4.
Optional: Have each group make a model of a volcano. See http://volcano.oregonstate.edu/education/models/index.html for ideas.

For more information and activities, see Volcano World at http://volcano.oregonstate.edu, and http://volcano.oregonstate.edu/education/vwlessons/lessons/Hot_Spot/Hot_Spot1.html for an interactive lesson on hotspot volcanoes.

Tahitian Hotspot Student Inquiry Guide

Background

Volcanic eruptions occur only in certain places on Earth. This is because Earth's surface is broken into a series of slabs known as tectonic plates. Tectonic plates are rigid, but they float on a hotter, softer layer in the Earth's mantle. Heating in this layer causes the plates to move, and when the plates move they spread apart, collide, or slide past each other. Volcanoes occur most frequently at plate boundaries. Some volcanoes, though, happen at places called hot spots where there seem to be natural channels into molten rock in Earth's mantle. Most of the active volcanoes we see on land are in locations where plates collide, but the greatest number of Earth's volcanoes are out of sight because they happen along spreading ridges on the ocean floor.

Interpret

Tahiti is one of a group of islands called the Society Islands. All of the Society Islands were formed by volcanoes. Look at the diagram of main tectonic plates and find the location of the Society Islands. What tectonic plate includes the Society Islands?

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Infer

1. What do you think caused the volcanoes that formed the Society Islands? Why?

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2. The Pacific tectonic plate is presently moving toward the northwest at about 11 cm per year. Look at the map of the Society Islands. Which islands do you think are the oldest? Why?

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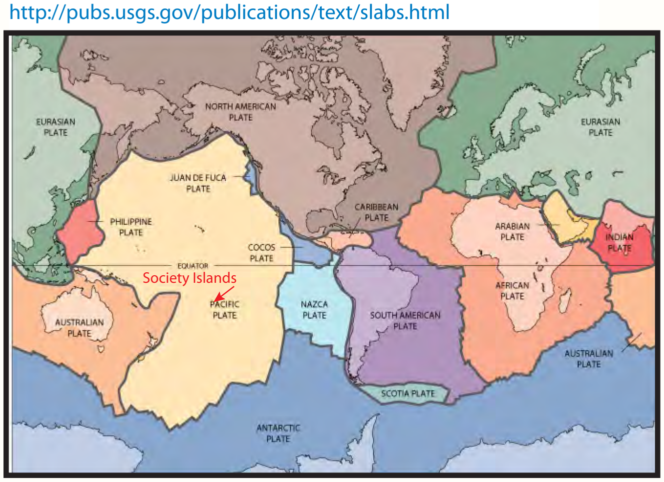
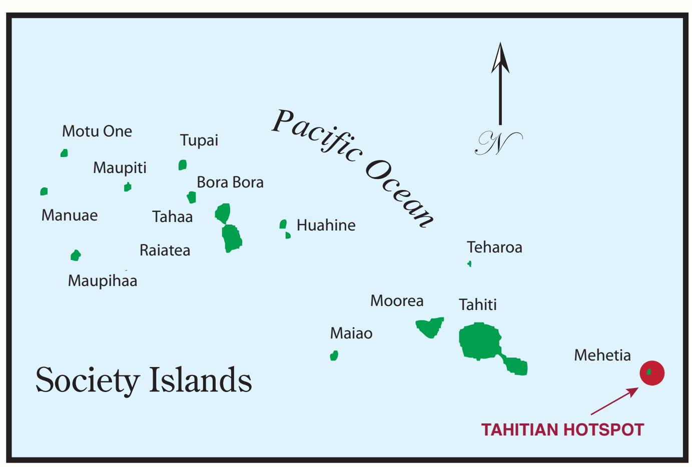
Diagram of major tectonic plates. Source: U.S. Geological Survey, http://pubs.usgs.gov/publications/text/slabs.html





Lesson 5: Living Rocks

A living reef of reddish hard corals and feathery soft corals. Credit: NOAA

Focus

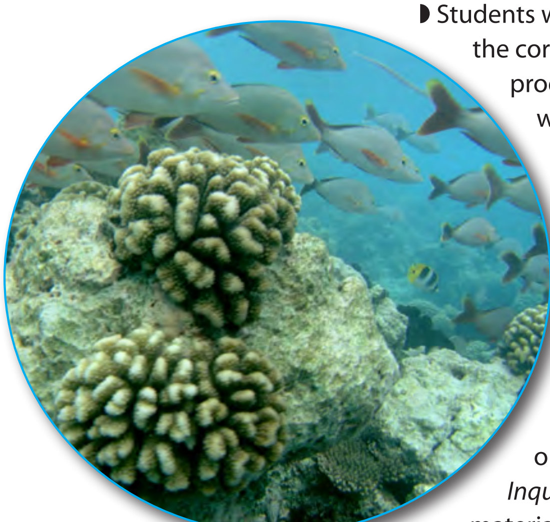
Coral **reefs**

Key Concept

Coral reefs are important to humans in a variety of ways, and play a key role in creating the legendary surf at Teahupo'o; but some human activities threaten the health of coral reefs.

Objectives

- Students will be able to describe reef-building corals, discuss how they obtain food, and explain how they form reefs.
- Students will be able to explain at least three ways that coral reefs are important to humans.
- Students will be able to explain at least three ways that human activities threaten the health of coral reefs.
- Students will be able to explain how the coral reef at Teahupo'o helps produce Tahiti's legendary waves.



Materials

(Optional) Materials for edible coral reef models (see Procedure Step 3)

Preparation

Review background information and questions on the *Coral Reefs Student Inquiry Guide*, and assemble materials for edible reef models if students will be doing this activity.

Procedure

Step 1.

Briefly discuss the relevance of coral reefs to tropical volcanic islands. Students should realize that the limestone rock produced by reef-building corals can build up on the surface of volcanic rock, and eventually cover all the rock that is underwater. The shape of corals in shallow water is directly related to the influence of waves, and corals in these areas are specially adapted to high wave energy conditions (compare the shallow water corals in the lower photo on Page 15 with the deeper water corals in the photo on the left). Students should also realize that coral reefs can significantly affect the shape of the sea bottom, and thus influence the waves that form near shore as discussed in Lesson 3, Ocean Motion. Ask students about other ways that coral reefs may be important to humans. Tell students that their assignment is to find out more about coral reefs, including how reefs help to produce the "perfect waves" at Teahupo'o, Tahiti. Give each student a copy of the *Coral Reefs Inquiry Guide*, and have them complete the questions.

Step 2.

Lead a discussion of students' results. Ways that coral reefs are important to humans include:

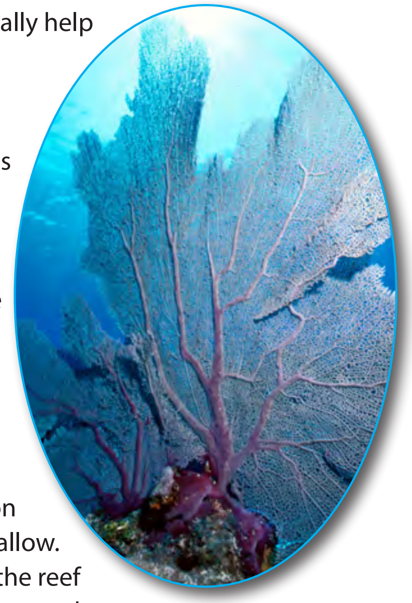
- Coral reefs are beautiful to look at.
- Coral reefs protect shorelines against waves, storms, and floods; and help prevent loss of life, property damage, and erosion.
- Coral reefs are a breeding ground for commercially important fish and other species. Millions of people and thousands of communities all over the world depend on coral reefs for food.
- Coral reef ecosystems support recreational fisheries.
- Local economies around the world receive billions of dollars from visitors to reefs through diving tours, recreational fishing trips, hotels, restaurants, and other businesses based near reef ecosystems.
- Coral reefs are home to thousands of other species. Scientists estimate that there may be another one to eight million undiscovered species living in and around reefs! Coral reefs support more species per square foot than

any other marine environment. This diversity of living organisms is key to finding new medicines for the 21st century. Many drugs are now being developed from coral reef animals and plants as possible cures for cancer, arthritis, human bacterial infections, viruses, and other diseases.

Worldwide, coral reefs appear to be in serious trouble. Most scientists believe this damage is caused by a combination of natural stresses and human activities. Some of the biggest problems are:

- **Excessive Fishing –** Many coral reefs have very few fishes because they have been captured for food or aquariums. In healthy reef ecosystems, fishes graze on algae. Without the fishes, algae can grow rapidly and smother coral polyps. Some algae produce poisons that make the problem even worse.
- **Destruction of Habitats –** Fishing with large nets that are dragged across the bottom can completely destroy living reefs. In some countries, fishermen use dynamite to stun fish, which kills coral animals and damages the reef structure. Reefs that are popular with tourists may be destroyed by people standing on living corals, holding onto them for support, or collecting them for souvenirs.
- **Pollution –** Chemical poisons from sewers, farm runoff, and other sources kill corals and many other ocean species. Fishermen in some areas use cyanide which kills corals as well as fishes.
- **Invasive Species –** Plants and animals that do not naturally live on reefs can damage the reef ecosystem. Some invasive seaweeds can grow rapidly enough to smother reef-building corals.
- **Ocean Warming –** Reef-building corals in shallow water need warm temperatures, but corals can overheat if temperatures rise a few degrees above normal. When corals are stressed, polyps may lose their **zooxanthellae** and the coral colony becomes completely white. This is called "coral bleaching," and is happening more often as many areas on Earth become warmer. Coral polyps can live for a short period of time without zooxanthellae, but if bleaching lasts too long the coral may die.
- **"The Rise of Slime" –** Many reefs are becoming overgrown with marine algae and films of bacteria. Part of the problem is pollution. In the Gulf of Mexico, for example, fertilizer pollution causes excessive growth of algae that is responsible for a **"dead zone"** the size of New Jersey. Removal of fish that normally feed on algae and bacterial films is another cause. Habitat destruction, over-fishing, and pollution also kill natural filters like oysters and sponges that normally help clean the water.

The big problem is that many people do not understand what is happening to Earth's ocean, and what the ocean will be like in the future. Students have a real opportunity to make a difference by informing others.



Seafans are soft corals that tolerate strong currents and wave forces. Credit: NOAA

The coral reef at Teahupo'o helps create Tahiti's legendary waves because as large ocean waves approach Tahiti, corals growing on lava rock make the water very shallow. **Friction** between the wave and the reef slows down the lower part of the wave, but the upper part continues to travel (similar to your own motion when you trip over an object on the ground). Water piles up on the upper part of the wave until it breaks, forming the famous barrels of Teahupo'o.

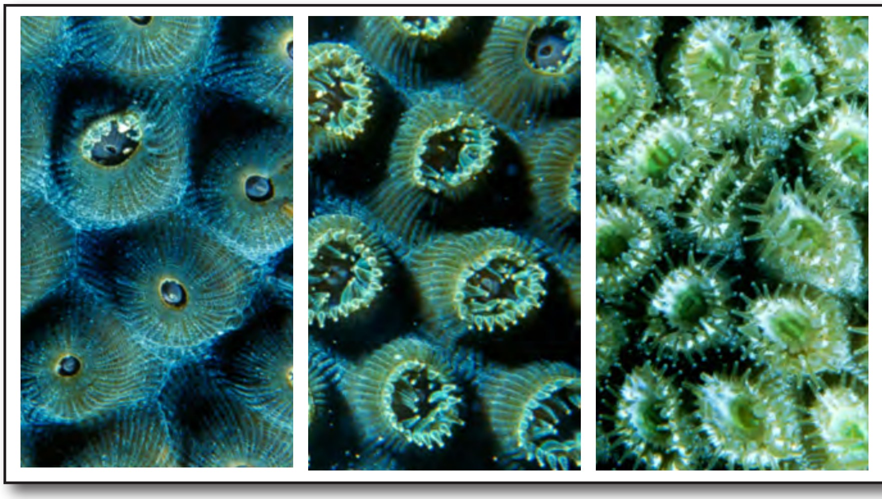
Step 3.

Optional: Have student groups create edible models of a coral reef using a pan of cornbread and various decorating materials such as broccoli, shapes sculpted from carrots, vegetable pureés (to represent algae and bacterial films), etc.

For more information and activities, see http://coralreef.noaa.gov/getinvolved/whatyoucando/welcome.html – "Things You Can Do to Protect Coral Reefs," from NOAA's Coral Reef Conservation Program.

Shallow-water reef corals create friction on the sea bottom that slows the progress of waves and helps cause them to break. Credit: NOAA

Coral Reefs Student Inquiry Guide



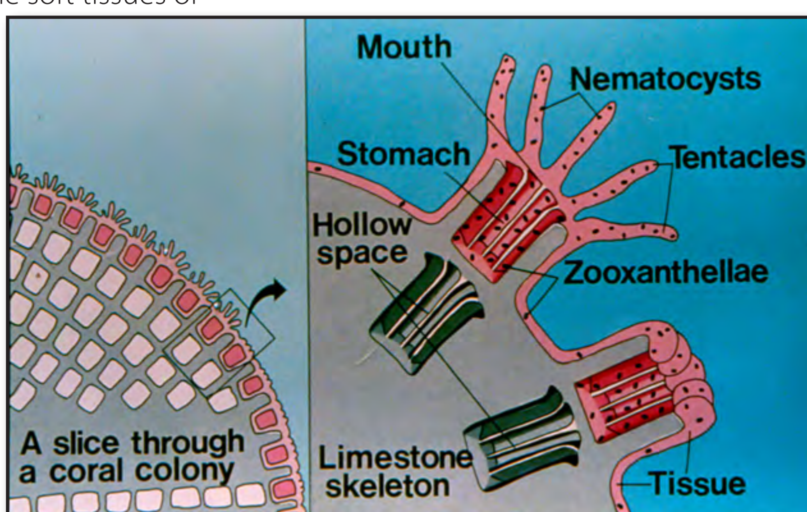
Montastrea cavernosa polyps closed at left and fully open for feeding at right.
Credit: Sandy Goodwin

Background

Corals are animals that do not have backbones, and are related to jellyfish. The large boulders that we see in pictures of coral reefs are colonies of many individual coral animals called polyps ("PAHL-ips"). Each polyp makes its own cup-shaped skeleton from limestone (calcium carbonate). The outer surface of the skeleton is covered by the soft tissues of the coral.

Polyps have a mouth surrounded by a ring of arms called tentacles. The tentacles have stinging cells called nematocysts ("nee-MAT-oh-sists") that polyps use to capture food. Most corals are carnivorous, and feed on small floating animals or even fish. Many corals also feed by collecting very small bits of floating material on strings of mucous, which they pull into their mouths. Food is digested by digestive filaments in the stomach. Waste is expelled through the mouth. Most reef-building corals have very small polyps, about one to three millimeters in diameter; but all of the polyps in a whole colony can make a limestone rock that weighs several tons!

As polyps grow and multiply, the coral colony may become shaped like boulders, branches or flattened plates. Some corals form tall columns, others resemble mushrooms, and some simply grow as a thin layer on top of rocks or the skeletons of dead corals. When corals reproduce, they release free-swimming larvae that can be carried many miles away by ocean currents. A new reef begins when these larvae attach to underwater rocks or other hard surfaces along the edges of islands or continents. As the corals grow



Major parts of a coral polyp.

and expand, other animals and plants join the reef system. Sponges and soft corals (sea fans and sea rods) are particularly visible on many reefs. Various types of seaweed and algae are also important. Some algae produce limestone structures that add to the overall reef structure. Fishes and many other types of animals take advantage of shelter provided by the reef, and feed on algae and bacteria that grow on surfaces within the reef.

Most reef-building corals also contain algae that live inside the soft tissue of the polyp. These algae are called zooxanthellae ("zoh-zan-THELL-ee"), and like other algae are able to use energy from the sun to make food. So the corals and algae have a relationship that is called "mutualistic." This means that the coral and algae both benefit from the relationship: The coral gives the algae a protected environment and chemicals the algae need to make food. In return, the algae provide the coral with food, oxygen and help remove wastes from the coral. This relationship allows corals to grow in waters that do not have much food available. Zooxanthellae are also responsible for the bright colors of many corals.

Research, Analyze, and Infer

Use the Internet or library resources to find answers to these questions:

1. What are at least three ways that coral reefs are important to humans?

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2. How does the coral reef at Teahupo'o help produce Tahiti's legendary waves?

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3. What are at least three ways that human activities threaten the health of coral reefs?

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Lesson 6: Catch a Wave

Focus

Physical principles of surfing

Key Concept

Surfing involves the interaction of many physical properties and principles, including mass, volume, density, buoyancy, gravity, speed, and friction.

Objectives

- Students will be able to define mass, volume, density, buoyancy, gravity, speed, and friction.
- Students will be able to explain how mass, volume, density, buoyancy, gravity, speed, and friction are involved in the basic processes of surfing.

Materials

None

Preparation

Review questions on the *Surfing Physics Inquiry Guide*, and make one copy of the *Guide* for each student. Surfing involves many principles and properties that affect objects in motion, fluids, oceans, and weather systems. The physical properties included in the *Inquiry Guide* are those most often encountered in middle school curricula. If this lesson is adapted to higher grade levels, educators may include properties such as acceleration, momentum, surface tension, viscosity, thrust, drag, and lift.

Procedure

Step 1.

Briefly review information about breaking waves found in Lesson 3. Point out that most amateur surfers ride spilling breakers, but experts are able to surf some barrels formed by plunging breakers (part of being an expert is knowing which waves NOT to surf; even experts have been killed trying to surf monster waves). Ocean waves have been recorded with speeds of 160 km per hour, wavelengths of more than 1,600 m, and heights greater than 30 m. These waves take a long time to die out, and can travel far beyond the vicinity of the storms that produced them. When these swells enter shallower waters within the reach of most surfers, their wavelength shortens, their height increases, and giant waves appear.

Step 2.

If students are not familiar with all of the properties listed in Step 1 of the *Surfing Physics Student Inquiry Guide*, you may want to introduce these concepts. Tell students that their assignment is to use physical principles to explain some of the basic processes involved in surfing, and provide each student with a copy of the *Inquiry Guide*.

Step 3.

Lead a discussion of students' answers to *Inquiry Guide* questions. The following points should be included:

- **Mass** is the amount of matter in a substance.
- **Volume** is the amount of space occupied by a substance or vacuum.
- **Density** is mass per unit of volume, or mass divided by volume.
- **Buoyancy** is a force that acts on an object in a fluid, and is equal to the weight of fluid displaced by an object.
- **Gravity** is a force between two objects with mass that causes these objects to attract each other; the term is commonly used to refer to the attractive force between Earth and other objects.
- **Speed** is the distance travelled in a given amount of time.
- Friction is a force that opposes movement between two objects in contact with each other.
- The surfer sitting on her board doesn't sink because the surfer and her board both are buoyed by a force that is equal to the mass of the volume of water they displace, and this force is greater than the combined mass of the surfer and her board.
- The surfer has to paddle to catch the wave, because the wave will move past her if she is not moving. To start her ride, she needs to be able to move with the wave until her board begins to fall down the face of the wave.
- As the surfer catches the wave she is lifted up, creating gravitational potential energy. Now the surfer can match the speed of the breaking wave by allowing her board to fall down the face of the wave. As her board falls, gravitational potential energy is converted to kinetic energy which accelerates her to the wave's speed. At that point she must steer her board to control the acceleration so that she doesn't outrun the wave.
- Gravity and friction keep the surfer's feet from slipping off of the surfboard. Surfers often use wax to increase friction.

Surfing Physics Student Inquiry Guide

Breaking waves contain huge amounts of energy. A surfer who rides a breaking wave taps into this energy and uses it to get a fast ride to shore. This involves many physical principles, as well as a great deal of skill. In this inquiry, you will use your knowledge of physical science to explain what takes place when a surfer rides a wave.

1. Define the following physical properties:
   Mass
   Volume
   Density
   Buoyancy
   Gravity
   Speed
   Friction

2. Imagine a surfer getting ready to ride a fun wave (not an extreme wave!). She starts out from shore and paddles out while lying on her board. When

she reaches the line-up where waves start to break, she sits up on her board and floats while she watches the wave sets (ocean waves usually arrive along a shoreline in groups of several waves followed by short intervals in which there are no waves; these groups of waves are called sets). When she sees the wave she wants to ride, she lies down on her board again and paddles hard. Just before the wave starts to break, she pushes down on the board as though she were doing a push-up, and at the same time pulls her legs under her body and stands up. She steers the board by shifting her weight so that she stays just ahead of the breaking wave, all the way to shore. Nice ride!

Use the properties you defined in Step 1 to answer these questions:

a. When the surfer is sitting on her board, why doesn't she sink?

b. Why does the surfer have to paddle hard to catch a wave?

c. Fun waves often have a speed around 33 km per hour, and there is no way a surfer can paddle that fast! But to keep in front of the breaking wave, a surfer's speed must match the wave's speed. How does she reach this speed, and what keeps her in front of the wave during her ride to shore?

d. Surfboards have smooth surfaces, and a surfer's feet are wet (obviously!). What physical properties stop a surfer's feet from slipping off of the surfboard?

Lesson 7: Where Did They Come From?

Focus

Ancient mariners and navigation

Key Concept

Ancient sea voyagers who colonized Polynesia were able to navigate long distances over open ocean using winds, waves, astronomical observations, and other natural phenomena instead of instruments such as the compass, sextant, and astrolabe used by navigators in Asian and European cultures.

Objective

Students will be able to describe at least three techniques for **wayfinding** that may have been used by ancient Polynesians.

Materials

- Pencil and piece of string approximately 12 inches long

Preparation

Review questions on the *Wayfinding Student Inquiry Guide*, and make one copy of the *Guide* for each student. Depending upon available time, there are many other activities that students can do to explore sea voyaging by ancient Polynesians. If you have star charts available for your area, you may want to have students construct their own **star compass**es using Step 2 of the *Inquiry Guide* as a starting point. Groups of students may research sea voyaging canoes and construct models of the boats that may have been used by ancient Polynesian explorers. For additional ideas, see:

- http://pvs.kcc.hawaii.edu/edresources.html – Education Materials from the Polynesian Voyaging Society; and
- http://www.ethnomath.org/resources/prel1996.pdf – Reading the Wind, Navigation and the Environment in the Pacific / A Teacher's Guide from the Pacific Region Educational Laboratory, 1996.
- You may also want to visit http://www.pbs.org/wayfinders/index.html, a Web site for "Wayfinders: A Pacific Odyssey," a film about ancient Polynesian sea voyaging.

Procedure

Step 1.

Lead a brief brainstorming discussion of techniques that ancient mariners might have used to navigate over long distances between the islands of Polynesia. You may also want to discuss the first two paragraphs of the *Wayfinding Student Inquiry Guide* with the entire class , and describe some of the instruments used by European and Asian navigators, such as the compass, astrolabe, and sextant. Provide each student with a copy of the *Inquiry Guide*, as well as a pencil and piece of string for Question 2.

Step 2.

Lead a discussion of students' answers to *Inquiry Guide* questions. Include the following points:

- Polynesian navigators probably didn't choose 11.25 degrees as the width of the Star Compass segments, but rather chose to divide the circular horizon into 32 segments because this is easily done with tools that were available. Figure 1 shows how this can be done with a pencil and string (or with a thin rope and charcoal stick).
- The navigator uses the rising and setting positions of the Sun to find direction, but these positions can't be determined when the Sun is high above the horizon. So, when the Sun is too high, other methods must be used.
- Winds are more likely to quickly change direction than swells, so swells would be a more stable indicator of direction.
- Two straight lines are needed to find a specific location on the water. Since each line requires two **landmark**s, a total of four landmarks are needed to locate a specific spot.

Wayfinding Student Inquiry Guide

"If you can read the ocean, you will never be lost."

When Europeans first visited the islands of Polynesia in the 16th century, they were surprised to find that many of the islands were inhabited by thriving societies, even though the people did not have ocean-going ships, navigational instruments, or even metal. Equally surprising was the fact that the languages spoken on different Polynesian islands were nearly identical, and that these languages were related to a large family of languages centered in the islands of Southeast Asia. Cultural traditions among the islands include many stories of ocean voyages over long distances. But no one could explain how the Polynesians could have sailed and navigated across an area of 25 million square kilometers of the Pacific Ocean. In the 1940's a Norwegian adventurer and a New Zealand historian attempted to prove that this kind of intentional migration never happened. The Norwegian's theory was that the first people to inhabit Polynesia came from South America on rafts made of balsa logs, while the New Zealander suggested that settlers arrived in Polynesia by accident when they drifted off their intended course or were carried away by storms.

In 1973, the Polynesian Voyaging Society was founded to discover how Polynesian seafarers could have deliberately discovered and settled nearly every inhabitable island in the Pacific Ocean before European explorers arrived in the 16th century. As part of this effort, the Society built two replicas of ancient canoes and completed several voyages in the South Pacific that demonstrated the capabilities of these vessels, as well as the effectiveness of ancient methods of navigation not requiring instruments used by European and Asian navigators. This inquiry will help you explore some of these navigation methods known as wayfinding.

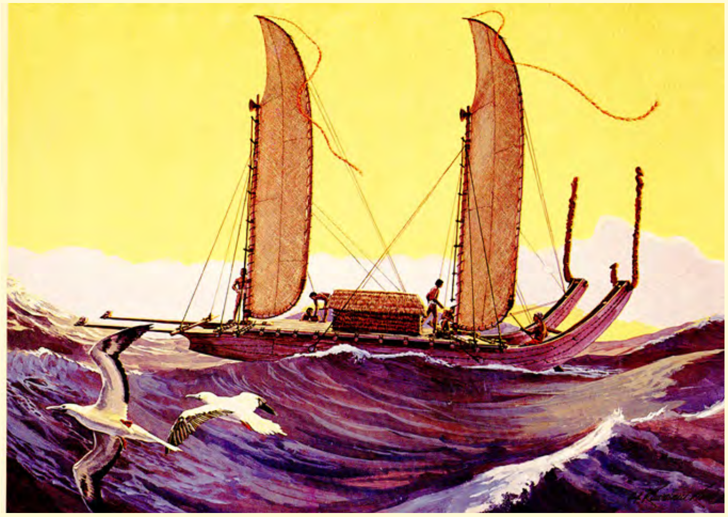


Image courtesy: The Polynesian Voyaging Society Archives at the Kamehameha Schools Archives (http://pvs.kcc.hawaii.edu/L2migrations.html)

Wayfinding uses many different sources of information. One of the fundamental ideas for traditional Polynesian navigation is the Star Compass, which divides the horizon into 32 equal segments. For each segment, ancient Polynesian navigators identified a recognizable star (usually a star in a familiar constellation) that appeared to come out of the ocean within the segment or go back into the ocean within the segment. These places on the horizon are called houses of the stars. Each house is 11.25 degrees wide, so all 32 houses add up to 360 degrees.

1. An angle of 11.25 degrees may seem to be an awkward number. Why to you think the Polynesians chose this as the width of each house?

2. Remember that ancient Polynesians did not have rulers or metal tools. Suppose you had a thin piece of homemade rope and a stick of charcoal. Could you draw a circle and divide it into 32 segments?

   The Sun is the main guide for navigation by wayfinding. Twice a day, at sunrise and sunset, it gives a directional point to the traveler as it rises in the east and sets in the west. According to one navigator, *"Sunrise is the most important part of the day. At sunrise you memorize where the wind is coming from. The wind generates the swells. You determine the direction of the swells, and when the Sun gets too high, you steer by them."*

3. Why does the navigator use swells to find direction "when the Sun gets too high?"

   "When it gets cloudy and you can't use the Sun or the stars, all you can do is rely on the ocean waves." The direction of the wind can also be used to hold a course.

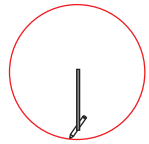
4. Do you think swells or winds are more likely to change direction quickly? Which of these two would be the most reliable indicator of direction?

   On coastal voyages, a navigator can steer by landmarks. Lining up two landmarks (such as a large tree and a mountain) allows him to steer along a straight line.

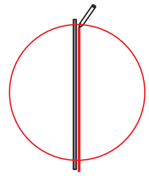
5. How many landmarks would be needed to find a specific location on the water?

NOTE: Quotations above are from "Wayfinding, or Non-Instrument Navigation" by Dennis Kawaharada; http://pvs.kcc.hawaii.edu/navigate/navigate.html.

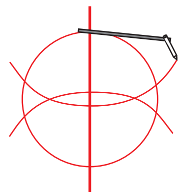
How to Draw a Star Compass



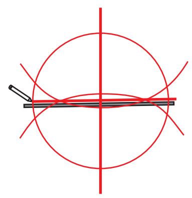
1. Use the pencil and string as a drafting compass and draw a circle.



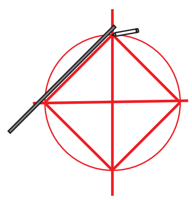
2. Hold the string tight and use it as a guide to draw a straight line through the center of the circle.



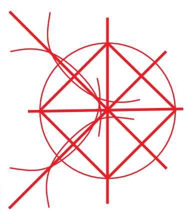
3. Use the pencil and string as a drafting compass to draw two arcs from each end of the line where it intersect the circle.



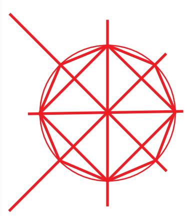
4. Hold the string tight and use it as a guide to draw a straight line connecting the two points where the arcs overlap. This line bisects the first line. You have now divided the circle into four segments.



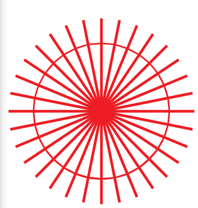
5. Hold the string tight and use it as a guide to draw four straight lines connecting the points where each line intersects the circle.



6. Use the same technique as in Steps 3 and 4 to bisect each of the lines drawn in Step 5. Now you have divided the circle into eight segments.



7. Hold the string tight and use it as a guide to draw eight straight lines connecting the points where each line drawn in Step 6 intersects the circle. Bisect each of these lines as in Steps 3 and 4. Now you have 16 segments.



8. Repeat Step 7 once more to obtain 32 segments.

Glossary

amplitude – the height of a wave

archipelago – a string of islands

asthenosphere – a hot flowing layer of Earth's mantle

barrel – a hollow tube formed by a plunging breaker

basalt – a hard, dense volcanic rock

break – the collapse of a water wave caused by interaction with a surface beneath the water

buoyancy – a force that acts on an object in a fluid, and is equal to the weight of fluid displaced by an object

circular wave – a mechanical wave in which the particles of a medium move in a circular or elliptical pattern

compression wave – a mechanical wave in which the particles of a medium move in a direction that is parallel to the direction in which the wave energy moves

convection current – movement in a fluid caused by heating

crest – the highest point of a wave

dead zone – an area of ocean that has little or no dissolved oxygen, often as a result of pollution that causes excessive growth of algae

density – mass per unit of volume, or mass divided by volume

fetch – the distance over which wind blows

frequency – the number of times the pattern of a wave repeats in a specified time

friction – a force that opposes movement between two objects in contact with each other

gravity – a force between two objects with mass that causes these objects to attract each other; commonly used to refer to the attractive force between Earth and other objects

hotspot – natural pipelines to reservoirs of magma in the upper portion of Earth's mantle

house – in traditional Polynesian navigation, the place on the horizon where a star rises or sets

landmark – a recognizable feature on land, such as a mountain or structure

line-up – an area of ocean near a shoreline where waves start to break

lithosphere – Earth's outer shell

longitudinal wave – see *compression wave*

magma – molten rock

mantle – part of Earth between the central core and the crust

mass – the amount of matter in a substance

mechanical wave – a wave that requires a medium through which energy is transferred

nematocysts – stinging cells found in corals, jellyfish, and other members of the phylum Cnidaria

period – the amount of time it takes to complete one cycle of a wave

plunging breaker – a wave that collapses violently, usually close to shore in shallow water

polyps – individual coral animals

reef – a spreading rock-like formation; often refers to geologic structures made by corals

rift – the junction between two tectonic plates that are moving away from each other

seamount – a sunken volcanic island that is completely beneath the ocean's surface

speed – distance traveled in a specified time

spilling breaker – a wave that collapses without a sudden, violent release of energy, usually farther from shore than plunging breakers

star compass – a concept in traditional Polynesian wayfinding that divides the horizon into 32 segments, each having a width of 11.25 degrees

subduction – a process in which two tectonic plates collide, with one plate forced beneath the other

surface wave – see *circular wave*

swell – a wave that has moved away from the place that it was formed

tectonic plate – large plates of rock that make up Earth's crust

transform plate boundary – a junction of two tectonic plates that slide horizontally against each other

transverse wave – a mechanical wave in which the particles of a medium move in a direction that is perpendicular to the direction in which the wave energy moves

trough – the lowest point of a wave

velocity – distance traveled in a specified time and the direction of travel

volume – the amount of space occupied by a substance or vacuum

wave – movement of energy through a medium or through space without moving matter from one place to another

wave set – a series of waves that are close together

wavelength – the distance over which a wave's shape repeats; for example, the distance between two crests or troughs in a water wave

wayfinding – navigation without instruments such as a sextant or compass

zooxanthellae – single-celled algae that live inside the tissues of many reef-building corals

National Education Standards

	A. Science As Inquiry	B. Physical Science	C. Life Science	D. Earth and Space Science	E. Science and Technology	F. Science in Personal and Social Perspectives	G. History and Nature of Science
1. Making Waves	●	●		●		●	
2. The Wave Factory	●	●		●		●	
3. Ocean Motion	●	●		●		●	
4. The Tahitian Hotspot	●	●		●		●	
5. Living Rocks	●		●	●		●	
6. Catch A Wave	●	●		●	●	●	
7. Where Did They Come From?	●			●	●	●	●

For More Information

http://www.ultimatewavetahiti.com/ – Web site for *The Ultimate Wave Tahiti* with lots of information and links to other sites

http://celebrating200years.noaa.gov/edufun/book/welcome.html – "Discover Your World with NOAA: An Activity Book," with 43 different activities for family explorations

http://oceanexplorer.noaa.gov/ – Web site for the Ocean Explorer program from NOAA's Office of Ocean Exploration and Research

http://oceanservice.noaa.gov/education/kits/corals/welcome.html – Online tutorial on coral reefs from NOAA's National Ocean Service

http://oceanservice.noaa.gov/education/kits/currents/welcome.html – Online tutorial on ocean currents, including a section on waves, from NOAA's National Ocean Service

http://pvs.kcc.hawaii.edu/index.html – Web site for the Polynesian Voyaging Society, including an Education Resources section with links to many other sources of information about Polynesian history and culture

http://volcano.oregonstate.edu/ – Volcano World Web site from Oregon State University

http://www.pbs.org/wayfinders/about.html – Web site to accompany the PBS film, "Wayfinders: A Pacific Odyssey"

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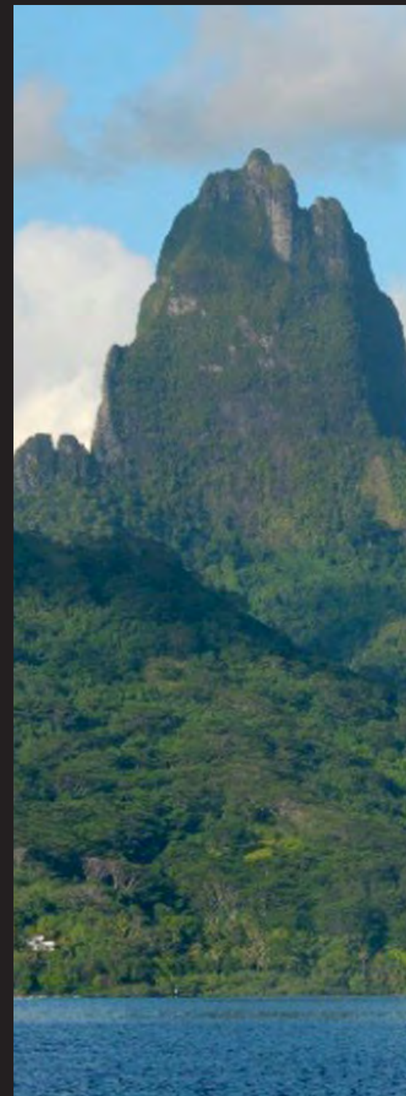

THE ULTIMATE WAVE TAHITI

FEATURING KELLY SLATER

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