GRADE 4 UNIT 1 OVERVIEW

Island Formations

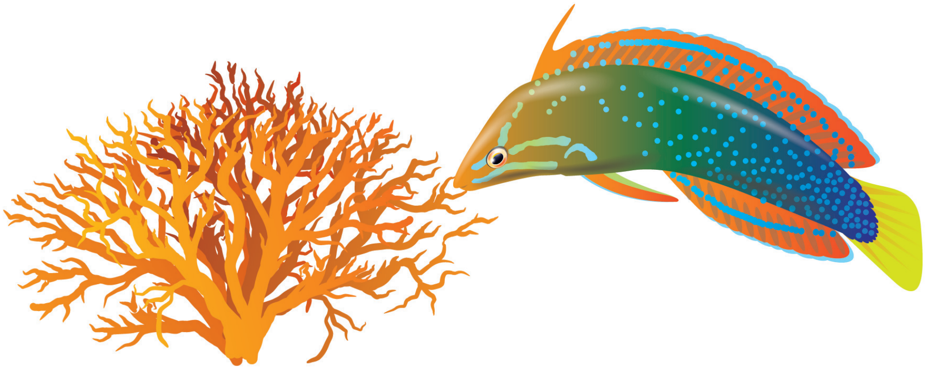
Introduction

Islands form as a result of the movement of the Earth's crustal plates, called tectonic plates. Near the junctures between moving plates, Earthquakes, volcanic activity, mountain building and oceanic trenches, island formation occurs. Islands may form along a convergent boundary where a heavier oceanic plate sinks below, or subducts, beneath a lighter plate. As the under-riding, water rich, oceanic plate travels deeper beneath the lighter plate, the water trapped in the plate's rock boils off. The heat from the boiling water melts the rocks of the overlying plate; this melt rises buoyantly through the crust and results in "subduction zone volcanism" and one type of island formation. Islands also form over hot spots, localized areas of the upper mantle where magma from the lower mantle upwells as the result of convection, circulation of heat currents, within the Earth. The magma typically erupts within the interior of a tectonic plate and prolonged activity forms volcanic islands. Some island chains, like Hawai‘i, trace the movement of a tectonic plate over a hot spot.

Islands in the Hawaiian archipelago were created by a stationary *hot spot* that has, over millions of years, acted as a channel for magma from the Earth's lower mantle to the surface of the Pacific plate. This hot spot is currently located below the Big Island of Hawai‘i. As the Pacific plate moves slowly over the hot spot in a northwesterly direction, older Hawaiian Islands that lie on top of and move with the plate erode and subside, becoming smaller islands, atolls, and seamounts (underwater mountains). The average rate of movement of the Pacific Plate is approximately 10 cm/yr and it is currently moving in a northwesterly direction. It *subducts* in Alaska along the trace of the Aleutian Islands, which are *subduction* zone volcanoes.

In this unit, students locate the Hawaiian Islands on world and regional maps, using latitude and longitude coordinates. They create a class wall map and bar graphs showing a connection between islands' sizes and ages. Students also study plate tectonic theory and hot spots, discuss tectonic activities, and learn to differentiate between volcanoes resulting from tectonic plate shifts and those resulting from hot spots. They also ponder the different forces of nature that shape islands through slow or fast changes, and reinforce that knowledge through games.

The unit's five lessons culminate with a *formal* play presented in Hawaiian storytelling style, in which students assume roles that demonstrate knowledge of island formations. The island-forming beliefs of ancient Hawaiian Elders, and *mo‘olelo* (legends), although not based on scientific facts, are woven into the play's plot as a reminder to students and other *keiki* (children) that legends continue to play an essential and vital part in Hawaiian culture.

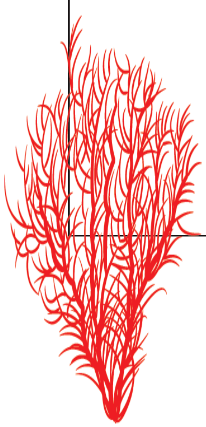


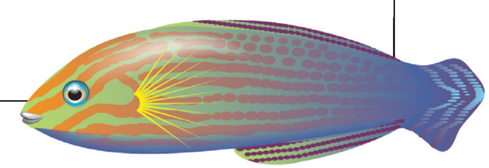
At a Glance

Each Lesson addresses HCPS III Benchmarks.
The Lessons provide an opportunity for students to move toward mastery of the indicated benchmarks.

ESSENTIAL QUESTIONS	HCPSIII BENCHMARKS*	LESSON, Brief Summary, Duration
How can latitude and longitude help locate the Hawaiian Island chain? Where is the Hawaiian Island chain located relative to other landmasses? What are the major geographic characteristics of the Hawaiian archipelago?	Social Studies Standard 7: Geography: SS.4.7.1 Identify the major geographic characteristics and demographics of the pre-contact Hawaiian archipelago, including its relative location to other major land masses.	**Lesson 1: Where in the World Do I Live?** Students begin this lesson by creating a graphic organizer to assess their prior knowledge regarding maps. Through a hands-on activity using an orange or a tennis ball that represents the Earth, students gain an understanding of latitude and longitude. With that knowledge, students locate the Hawaiian Island chain on a map of the world, and are able to describe its location relative to other landmarks. Finally using a regional map, students locate and identify the eight main Hawaiian Islands and the three types of islands in the Northwestern Hawaiian Islands (NWHI). Two 45-minute periods
What patterns do we see when we look at the age of each island in the Hawaiian island chain? How can bar graph data help me see the pattern in age and size of the islands in the Hawaiian archipelago?	Math Standard 11: Data Analysis, Statistics, and Probability: MA.4.11.2 Label the parts of a graph (e.g., axes, scale, legend, title). Social Studies Standard 7: Geography: SS.4.7.2 World Spatial Terms. Collect, organize, and analyze data to interpret and construct geographic representations.	**Lesson 2: Patterns in the Hawaiian Islands** The lesson begins with information about the age, size and location of each of the islands found in the Hawaiian archipelago. Using data provided, the students construct a bar graph showing the relationship of each island's size and age relative to its location in the chain. This information will assist the class in preparing a wall map of the Hawaiian island chain. The students will work individually, or with a partner, to design, cutout, and label the island assigned to them. As a class, using latitude and longitude, each of the islands will be placed in its correct geographic location on the wall map. Two 45 minute periods

ESSENTIAL QUESTIONS	HCPSIII BENCHMARKS*	LESSON, Brief Summary, Duration
What is plate tectonics? How does the Earth's crust move along plate boundaries? What is a hot spot and where are they found? How does plate tectonics help explain the characteristics of an island chain formed by a hot spot?	Science Standard 8: Physical Earth and Space Sciences: SC.4.8.1 Describe how slow processes sometimes shape and reshape the surface of the Earth.	**Lesson 3: How Did the Island Chain Form?** Students view two video segments presented by the NOAA's Learning Center. In these short videos, students learn about the theory of plate tectonics and hot spots. Students then participate in a class discussion, and complete a diagram showing the different types of tectonic movements. One 60-minute period
How do forces of nature act to change islands over time? How do coral reefs form? How do coral reefs play a role in shaping the features of the Hawaiian Islands?	Science Standard 8: Physical Earth and Space Sciences: SC.4.8.1 Describe how slow processes sometimes shape and reshape the surface of the Earth. SC.4.8.2 Describe how fast processes sometimes shape and reshape the surface of the Earth. Math Standard 1: Numbers and Operations: MA.4.1.3 Identify equivalent forms of commonly used fractions and decimals. Math Standard 11: Data Analysis, Statistics, and Probability: MA.4.11.1 Pose questions, collect data using observations and experiments, and organize the data into tables or graphs. Math Standard 13: Data Analysis, Statistics, and Probability: MA.4.13.1 Propose and justify conclusions/predictions based on data.	**Lesson 4: Changing Islands** Students examine and discuss forces of nature that lead to the slow or fast changes to an island. Students then focus on how coral reefs play a part in island formation. They view a PowerPoint presentation describing environmental factors necessary to promote the healthy growth and development of a coral reef, and how, eventually, an atoll, barrier reef, and fringing reef are formed. Students play a game to help them understand how fragile coral reef development is. Two 45-minute periods

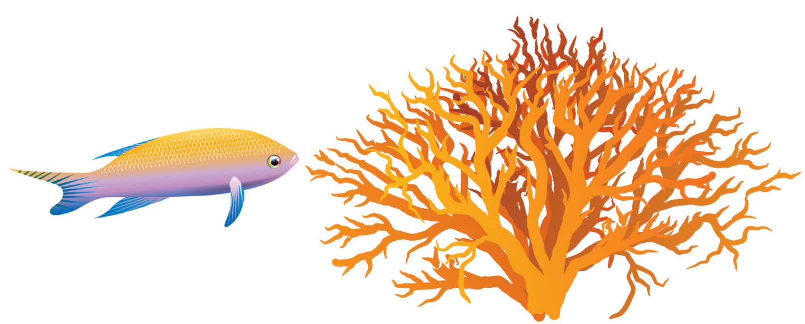




ESSENTIAL QUESTIONS	HCPSIII BENCHMARKS*	LESSON, Brief Summary, Duration
How do hot spot volcanoes form, and how can they be recognized? How do plate tectonics help explain the characteristics of an island chain formed by a hot spot?	Science Standard 8: Physical Earth and Space Sciences: SC.4.8.1 Describe how slow processes sometimes shape and reshape the surface of the Earth. SC.4.8.2 Describe how fast processes sometimes shape and reshape the surface of the Earth. Fine Arts Standard 3: Drama and Theatre: FA.4.3.1 Interpret a character's external motivations. Language Arts Standard 6: Oral Communication: LA.4.6.1 Participate in grade-appropriate oral group activities.	**Culminating Lesson: The Formation of the Hawaiian Archipelago – A Play** Students demonstrate their knowledge by participating in a short play that illustrates the idea of plate tectonics and hot spots during the formation of the Hawaiian archipelago. They perform this play for other classes and parents. After their play, they will complete an assessment drawing. Three or Four 45-minute periods

Note: The context in which the terms weathering and erosion are used could determine whether they are "fast" or "slow" processes. These processes can be fast when compared with plate tectonics and glacial movements, but it is slow when compared to volcanoes and Earthquakes. However, for this unit, weathering and erosion will be considered fast processes.

*"Hawai'i Content & Performance Standards III Database." Hawai'i Department of Education. June 2007. Department of Education. 17 Dec. 2007.



Benchmark Rubric

I. HCPS III Benchmarks*

Below is a general Benchmark Rubric. Within each lesson, there are other assessment tools and additional rubrics specific to the performance tasks within each lesson.

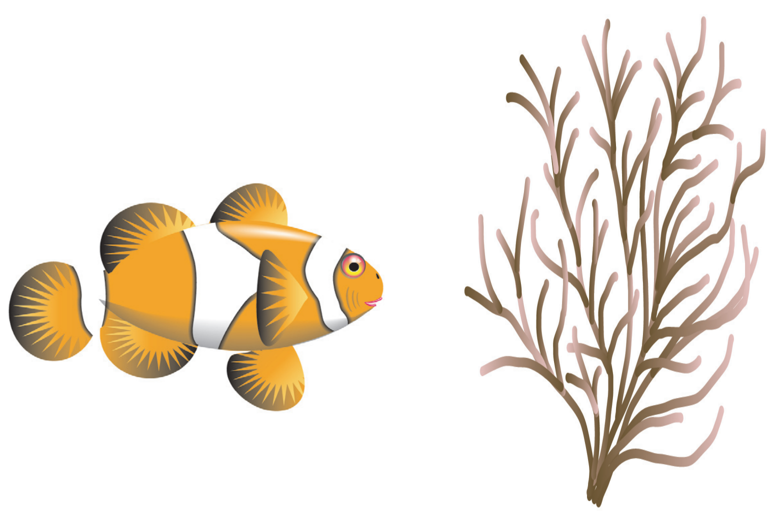
Topic		Forces that Shape the Earth	
Benchmark SC.4.8.1		Describe how slow processes sometimes shape and reshape the surface of the Earth	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Use evidence to explain how slow processes have shaped and reshaped the surface of the Earth	Describe how the shaping and reshaping of the Earth's land surface is sometimes due to slow processes	Provide examples of the shaping and reshaping of the Earth's land surface due to slow processes	Recognize that the shaping and reshaping of the Earth's land surface is sometimes due to slow processes

Topic		Forces that Shape the Earth	
Benchmark SC.4.8.2		Describe how fast processes (e.g., volcanoes, Earthquakes) sometimes shape and reshape the surface of the Earth	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Use evidence to explain how fast processes have shaped and reshaped the surface of the Earth	Describe how the shaping and reshaping of the Earth's land surface is sometimes due to fast processes	Provide examples of the shaping and reshaping of the Earth's land surface due to fast processes	Recognize that the shaping and reshaping of the Earth's land surface is sometimes due to fast processes

Topic		Places and Regions	
Benchmark SS.4.7.1		Identify the major geographic characteristics and demographics of the pre-contact Hawaiian archipelago, including its relative location to other major land masses	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Identify, with accuracy, the major geographic characteristics and demographics of the pre-contact Hawaiian archipelago, including its relative location to other major land masses	Identify, with no significant errors, the major geographic characteristics and demographics of the pre-contact Hawaiian archipelago, including its relative location to other major land masses	Identify, with a few significant errors, the major geographic characteristics and demographics of the pre-contact Hawaiian archipelago, including its relative location to other major land masses	Identify, with many significant errors, the major geographic characteristics and demographics of the pre-contact Hawaiian archipelago, including its relative location to other major land masses

Topic		World In Spatial Terms	
Benchmark [SS.4.7.2]		Collect, organize, and analyze data to interpret and construct geographic representations	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Collect, organize, and analyze data to interpret and construct geographic representations, with accuracy	Collect, organize, and analyze data to interpret and construct geographic representations, with no significant errors	Collect, organize, and analyze data to interpret and construct geographic representations, with a few significant errors	Collect, organize, and analyze data to interpret and construct geographic representations, with many significant errors
Topic		Numbers and Number Systems	
Benchmark [MA.4.1.3]		Identify equivalent forms of commonly used fractions and decimals	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Consistently identify equivalent forms of commonly used fractions and decimals	Usually identify equivalent forms of commonly used fractions and decimals	Sometimes identify equivalent forms of commonly used fractions and decimals	Rarely identify equivalent forms of commonly used fractions and decimals
Topic		Data Collection and Representation	
Benchmark [MA.4.11.1]		Pose questions, collect data using observations and experiments, and organize the data into tables or graphs	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Pose questions, collect data using observations and experiments, and organize the data into tables or graphs, with accuracy	Pose questions, collect data using observations and experiments, and organize the data into tables or graphs, with no significant errors	Pose questions, collect data using observations and experiments, and organize the data into tables or graphs, with a few significant errors	Pose questions, collect data using observations and experiments, and organize the data into tables or graphs, with many significant errors

Topic		Data Collection and Representation	
Benchmark [MA.4.11.2]		Label the parts of a graph (e.g., axes, scale, legend, title)	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Effectively label the parts of a graph	Sufficiently label the parts of a graph	Label the parts of a graph, with a few omissions or errors	Label the parts of a graph, with significant omissions or errors

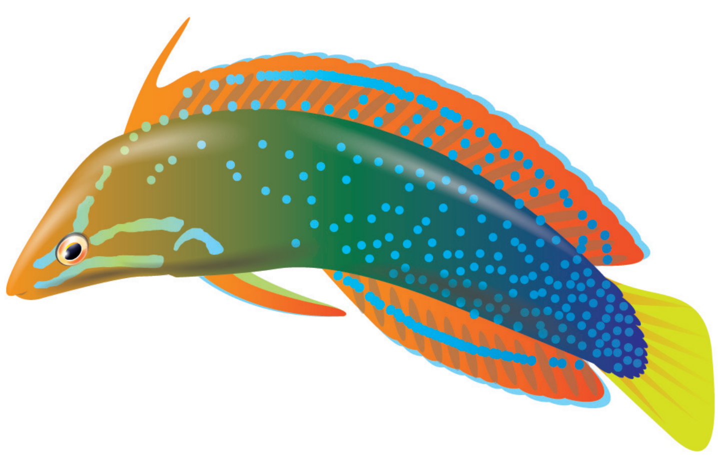


Topic		Predictions and Inferences	
Benchmark MA.4.13.1		Propose and justify conclusions/predictions based on data	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Propose and effectively justify conclusions or predictions based on data	Propose and sufficiently justify conclusions or predictions based on data	Propose and justify, in minimal detail, conclusions or predictions based on data	Propose implausible conclusions or predictions based on data

Topic		Discussion and Presentation	
Benchmark LA.4.6.1		Participate in grade-appropriate oral group activities	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Participate in grade-appropriate oral group activities, in a highly effective way	Participate in grade-appropriate oral group activities	Participate in grade-appropriate oral group activities, in a limited way or in a way that only partially facilitates the group's work	Participate very little in grade-appropriate oral group activities or participate in a way that does not facilitate the group's work

Topic		How the Arts are Organized	
Benchmark FA.4.3.1		Interpret a character's external motivations	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Interpret a character's external motivations using a wide variety of movement and vocal expression; assume roles that exhibit concentration, focus, and commitment, and contribute to the action of the dramatization	Interpret a character's external motivations, using variations of movement and vocal expression; assume roles that exhibit concentration, and contribute to the action of the dramatization	Interpret a character's external motivations, using a few variations of movement and vocal expression; assume roles that exhibit some concentration, and contribute to the action of the dramatization	Interpret a character's external motivations, using one or two variations of movement and vocal expression; assume roles that do not exhibit concentration, and do little to contribute to the action of the dramatization

**"Hawai'i Content & Performance Standards III Database." Hawai'i Department of Education. June 2007. Department of Education. 17 Dec. 2007.*



Science Background for the Teacher

Note: Bolded words found within this section are defined in the *Science Background for the Teacher Glossary.* The footnotes refer to the references found in the *Science Background for the Teacher Bibliography* at the end of this section.

What is Plate Tectonics?[1] (Lesson 3)

The theory of **plate tectonics** combines the principles of **continental drift** and **seafloor spreading** to explain the large-scale movements of the Earth's crust. Sea-floor spreading describes the geologic process that creates the ocean floor, contributing to the movement of the continents. Alfred Wegener, who based his theory on the geographic puzzle-like fit of the continents, first proposed the idea of continental drift and the similarity of fossils collected on different continents.

The Earth is made up of a series of layers from the surface to the inner core of the planet. The thin outer shell of the Earth is called the *crust* and is composed of two parts, the solid masses of the continents that lie on the thicker **continental crust,** and the sea floor which lies on the thinner **oceanic crust.** Below the crust is the **mantle.** The upper mantle is fused to the continental and oceanic crusts to form the rigid **lithosphere.** The lower mantle is the solid but more deformable **asthenosphere.** It is considered 'plastic' because of the high temperature and pressures within it, and in this context the asthenosphere is also called the 'soft zone' of the mantle. Below the mantle towards the center of the Earth are the dense, liquid outer core and the dense, solid inner core. The solid inner core is extremely dense, made primarily of iron and has tremendous capacity for heat. The liquid outer core is made of iron and nickel, and spins with the rotation of the Earth, causing the Earth's magnetic field.

The lithosphere is broken up into what are called tectonic plates: seven major plates and numerous minor plates. The Hawaiian Islands reside on the Pacific plate, which is currently moving in a northwesterly direction. It is the movement of these rigid lithospheric plates above the fluid-like layer of asthenosphere that explains much of Earth's geologic activity. More specifically, it is the boundaries between these moving plates that are the sites of Earthquakes, volcanic activity, mountain building and **oceanic trench** formation. For an image of the Earth's tectonic plates see: http://pubs.usgs.gov/gip/Earthq1/fig1.gif

There are three types of plate boundaries depending on how the plates are interacting with one another. **Divergent plate boundaries** are defined as two plates that are moving away from each other due to new material being pushed upwards from the mantle asthenosphere between them; these are the sites of **spreading centers** and **mid-ocean ridges** and are also termed *constructive boundaries* because of the formation of new material. **Convergent plate boundaries** are also termed *active margins* because two plates are being pushed toward each other. These processes typically result in three types of formations. At **subduction** sites where one oceanic plate sinks beneath the other, deep oceanic trenches form along the trace of the subduction boundary. Also at these **subduction** sites, volcanic islands (like the Northern Mariana Islands) can form adjacent to subduction sites, arising on the plate that is above the one that is sinking into the asthenosphere. At **hot spots,** volcanic islands (like the Hawaiian Islands) can form in the interior of a tectonic plate where mantle material upwells and erupts on the surface of the plate for prolonged periods of time, Where two continental plates are converging, mountains form on the continents (like the Himalayas), and if an oceanic plate is converging with a continental plate, coastal mountains, often containing volcanoes (like the Andes mountains in South America), and volcanoes form (like Mount St. Helens and Mount Rainier in Washington state). **Transform plate boundaries** occur where two plates are sliding next to each other. Due to the friction between the two plates the sliding is more similar to grinding. As a result, large faults are formed along these boundaries which is where Earthquakes occur (like the San Andreas Fault along the coast of California).

Plate tectonic movements traced over the last 225 million years explain the breakup of **Pangaea** to form the present position of the continents. Late in the Triassic Period (248 – 206 million years ago), Pangaea began to break apart. Its segments, Laurasia (composed of all the present-day northern continents) and Gondwana (the present-day southern continents) gradually moved apart, resulting in the formation of the Atlantic Ocean. For animated examples of plate tectonics see: http://www.ucmp.berkeley.edu/geology/tectonics.html. For in depth information on plate tectonics see http://pubs.usgs.gov/gip/dynamic/dynamic.html (For this last link, the most relevant portion is from the Mesozoic to present time period.)

What is a hot spot and how do the Hawaiian Islands form?[2] (Lesson 3)

Scattered around the Earth are approximately forty usually fixed areas of isolated volcanic activity known as hot spots. They are found under continents and oceans, in the center of plates, and at the mid-ocean ridges. These hot spots channel magma to the surface from the inner mantle. At hot spots below oceanic crust, mantle material may rise through the lithosphere, melting and fracturing rocks along the way, to form a seamount, or submarine volcano.

As a crustal plate moves over a hot spot during the process of plate tectonics, successive and usually non-explosive eruptions can produce a linear series of peaks or seamounts. The youngest peak is closest to the hot spot source, and the age of seamounts increases with increasing distance from the hot spot. The **islands** and seamounts of the Hawaiian Archipelago were created by a hot spot that has been periodically channeling molten material through a plume over the last 41 million years. The Big island of Hawaiʻi with its active volcanoes is presently over the hot spot and is the youngest island in the chain. The newest volcanic seamount in this series is *Lōʻihi,* lying 45km (28mi) east of the Big Island of Hawaiʻi's southernmost tip, rising more than 2,450m (8,000ft) above the sea floor and 969m (3,178 ft) below the surface of the ocean. Currently, *Lōʻihi* is taller than Mount St. Helens when measured from the sea floor.

The entire Hawaiian Archipelago begins at *Lōʻihi* and continues for another 2,400 km to the northwest, ending at Kure Atoll. The 'main eight' islands of Hawaiʻi are considered the 'high islands' and include *the Big Island of Hawaiʻi, Maui, Kahoʻolawe, Lānaʻi, Molokaʻi, Oʻahu, Kauaʻi and Niʻihau.* After *Niʻihau* lie the Northwestern Hawaiian Islands, where the volcanic peaks that were once above sea level as high islands have since eroded and subsided over millions of years to become small pinnacles, atolls and seamounts. At Kure Atoll, the chain bends in a more northerly direction, indicating that the Pacific plate began moving more westward some 40-50 million years ago. In this more northwardly directed region, completely submerged seamounts make up the Emperor Seamount Chain. For more information on hot spots and the formation of the Hawaiian Islands see http://pubs.usgs.gov/gip/dynamic/hotspots.html

To listen to an interview with John Wiltshire of NOAA's Hawaiʻi Undersea Research Laboratory (HURL) regarding technology used to monitor island formation, please visit http://www.Earthsky.org/interviewpost/water/john-wiltshires-undersea-laboratory-explores-expanding-Hawaii or listen to the podcast included with this unit.

Corals and Coral Reef Formation[3] (Lesson 4)

Corals are in fact animals, even though they may exhibit some of the characteristics of plants and are often mistaken for rocks. Stony or reef building corals are simple invertebrate animals. Reef coral is made of many small individual animals called *polyps.* Each polyp has a mouth surrounded by tentacles. Most reef-building corals have a mutually beneficial relationship with microscopic unicellular algae called zooxanthellae that live within the cells of the coral's gut. As much as 90 percent of the organic material the algae manufacture is transferred to the host coral tissue through photosynthesis. Due to the need for sunlight to conduct photosynthesis, this type of energy production happens during daylight hours. Thus, reef-building corals prefer clear and shallow water, where lots of sunlight filters through to their symbiotic algae. Shallow coral reefs grow best in warm water (70–85° F or 21–29° C). Based on current estimates, shallow water coral reefs occupy approximately 284,300 square kilometers (110,000 square miles) of the sea floor. [a] If all of the world's shallow water coral reefs were placed side-by-side, they would occupy an area a bit larger than the state of Texas. This area represents less than 0.015 percent of the ocean, yet coral reefs harbor more than one quarter of the ocean's biodiversity. Corals also need salt water to survive (between 32 to 42 parts per thousand), so they also grow poorly near river openings with fresh water runoff. [c] Other factors influencing coral distribution are availability of hard-bottom substrate, the availability of food such as plankton, and the presence of species that help control macroalgae, like urchins and herbivorous fish.

In this lesson, only reef forming corals (Hard corals) also known as scleractinian and stony coral will be discussed, not soft corals or deep sea corals. Hard corals produce a rigid skeleton made of calcium carbonate ($CaCO_3$) in crystal form called aragonite. Hard corals are the primary reef-building corals. Colonial hard corals consisting of hundreds to hundreds of thousands of individual polyps are cemented together by the calcium carbonate 'skeletons' they secrete. Living coral grow on top of the skeletons of their dead predecessors. A layer of tissue covers the skeleton and connects coral polyps, allowing for distribution of nutrients as well as communication amongst individuals of the colony. [b] Over time, this growth forms the primary structure of a coral reef. The rate at which a stony coral colony lays down calcium carbonate depends on the species, but some of the branching species can increase in height or length by as much as 10 cm a year (about the same rate at which human hair grows). Other corals, like the dome and plate species are more bulky and may only grow 0.3 to 2 cm per year. [c]

Coral Reef Formation: Coral reefs begin to form when free-swimming coral larvae attach to submerged rocks or other hard surfaces along the edges of islands or continents. Corals and other reef-building organisms quickly colonize the available shallow waters that surround the island. Once all the available horizontal space is colonized, corals begin to grow upward toward the sun until they reach just below the sea surface, maximizing as much space as possible for growth. As the corals grow and expand, reefs take on one of three major characteristic structures —fringing, barrier or atoll.

How big are coral polyps? Polyps range in size depending on the type or species of coral. For example, brain corals are some of the most recognizable coral species. The individual polyps average 1-3 mm in diameter; however, some corals, such as *Fungia* plate corals, are solitary and have single polyps that can grow as large as 25 cm in diameter. In comparison, the head of a typical straight pin is 1.5 mm in diameter and the diameter of a US penny is 1.9 cm.

How old are today's reefs? The geological record indicates that ancestors of modern coral reef ecosystems were formed at least 240 million years ago. The coral reefs existing today began growing as early as 50 million years ago. Most established coral reefs are between 5,000 and 10,000 years old.

What is a fringing reef?[4] (Lesson 4)

Fringing reefs develop along the shoreline margins of islands. Fringing reefs form a skirt around the base of the island; corals and other reef building organisms colonize the available shallow waters that surround the island as they grow. Where islands form within and near the boundaries of the tropics, as in the Hawaiian Islands, fringing reefs are common.

What is a barrier reef?[5] (Lesson 4)

A **barrier reef** is a fringing reef that has been separated from land due to erosion and subsidence, or sinking, of the tectonic plate on which the island is located. A barrier reef encloses the lagoon formed between the reef and the island. Conditions for coral growth are better on the seaward edge. Corals in the lagoon tend to have slower growth due to the influence of sediment inputs and freshwater runoff from land. Barrier reefs are more common among islands that lie well within the margins of the tropics. Because the Hawaiian Islands reside near the northern boundary of the tropics, few barrier reefs can be found. An excellent example of a barrier reef is found on *Oʻahu* in *Kāneʻohe Bay.* The barrier reef sheltering *Kāneʻohe Bay* is the northern most barrier reef in the Pacific. It is not considered a 'true' barrier reef, because it is not composed solely of reef material. A landslide that occurred over one million years ago on the eastern side of the *Koʻolau volcano* initially formed the bay. Coral reef organisms started to colonize the volcanic rock that was pushed into the sea from the landslide and as *Oʻahu* subsided, coral growth kept up with the subsidence, forming the barrier reef we see today.

How are atolls formed?[6] (Lesson 4)

Atolls are a ring-shaped coral reef or string of closely spaced small coral islands that enclose or nearly enclose a shallow lagoon. They form around volcanic islands that usually lie within the latitudes of the **Tropic of Cancer** (~23˚ North) and the **Tropic of Capricorn** (~23˚ South). However, Kure Atoll is the most northerly atoll in the world at 28 degrees N. As the volcanic island grows, the first type of reef structure to form is a fringing reef along the margin of the shoreline. As the islands continue to erode and the tectonic plate underneath the island subsides, the fringing reef becomes a barrier reef that protects a lagoon located between the reef and the island. If the rate of coral growth surpasses the rate at which the island is eroding and subsiding, an atoll will eventually form as the island becomes completely submerged under the surface of the ocean. The most visible structure of the atoll is the ring of coral reef enclosing the shallow lagoon. Most of the Northwestern Hawaiian Islands are low islands that are characterized by atolls, for example the Midway Atoll, Pearl and Hermes Atolls and Kure Atoll. For aerial images of the Northwestern Hawaiian Islands visit http://www.oceandots.com/pacific/nwhi/ and http://Hawaiiatolls.org/maps/index.php

One can compare the ages of islands based on the type of reef structure surrounding the island. Younger islands tend to have fringing reef structures or barrier reef structures and are considered **high islands** because of the amount of volcanic landmass still present above the surface. Older islands that have little to no volcanic landmass left above the sea surface are considered **low islands.** They are composed primarily of sand or coral material and have lagoons enclosed by a barrier reef. Low islands are considered atolls when the land mass is no longer above the sea surface.

For more information about the different types of coral reef formations see:
http://www.oceanservice.noaa.gov/education/kits/corals/coral04_reefs.html
http://www.starfish.ch/reef/reef.html
http://www.coris.noaa.gov/about/what_are/

How do islands change over time?[7] (Lesson 4)

As one follows the volcanic tropical islands of the Hawaiian Archipelago from the newest seamount, *Lōʻihi,* to the oldest atoll in the island chain, Kure, the different stages of island change become apparent. Over time, the greatest cause of island change results from the subsidence of the underlying tectonic plate, wind erosion, water erosion and changing sea levels. Over millions of years, as the Pacific plate moves above the hot spot that created the islands, the effects of erosion and subsidence slowly breakdown the volcanic landmass of the island. If the subsidence of the island occurs at a rate less than or equal to coral growth, coral reef structures become the prominent feature. The skirt of coral, or the fringing reef, that originally began growing along the margin of the land, becomes a barrier reef, creating and protecting a lagoon between the island and the reef. Eventually, the landmass of the island becomes submerged completely and all that is left is an atoll. If the plate that the submerged island is located on moves in a northerly or southerly direction away from the latitudinal tropics, the water temperature becomes too cold to support coral growth.

Kure Atoll represents the northern-most atoll in the Northwestern Hawaiian Island chain; its latitudinal position is farther from the equator than any other reef ecosystem. As the Pacific plate continues to move north, the corals of Kure will eventually slow their growth due to cooler sea surface temperatures. Eventually the structure of the coral reef will also start to sink with the island itself as coral growth slows. As this happens, the island becomes a **guyot,** a flat-topped seamount that at one time was tall enough to penetrate or approach the sea surface. These types of structures comprise the Emperor Seamount chain that lies northwest of the Hawaiian Archipelago, and represent the final stage of transformation of islands through time.

Science Background for the Teacher Glossary

absolute location: the exact location on the planet where something resides, or the latitude and longitude of a place.

asthenosphere: upper, deformable portion of the Earth's mantle located below the lithosphere; extending some 700 m below the surface; partially molten; convection currents present in this layer drive plate tectonics.

archipelago: a group of islands in an expanse of water, with many scattered islands.

atolls: a ring-shaped coral reef or string of closely spaced small coral islands that enclose or nearly enclose a shallow lagoon.

barrier reefs: a reef that runs parallel to shore, with the shoreline and reef separated by a lagoon.

continental crust: the solid masses of the Earth's crust that lies directly underneath the continents; composed primarily of granite.

continental drift: motion of the continents due to plate tectonics.

convergent plate boundary: a region of the lithosphere where two or more tectonic plates are moving towards one another.

core: the very center of the Earth.

divergent plate boundary: a region of the lithosphere where tectonic plates are moving away from one another.

equator: imaginary line of 0° latitude that traces the circumference of the Earth at its widest point perpendicular to the Earth's axis of rotation; passes through central Africa, northern South America, and Indonesia.

fringing reefs: a reef that runs parallel to and is in close proximity or is directly adjacent to the shoreline.

guyot: a submerged seamount that at one time was above or in close proximity to the sea surface.

hemisphere: half the Earth, divided at the equator (northern and southern hemispheres) or at the Prime Meridian and International Date Line (western and eastern hemispheres).

high islands: islands that are composed of volcanic rock whose landmass is above the sea surface.

hot spots: generally localized plumes of magma that originate in the Earth's mantle and move outward through the crust; magma movement may result in volcanic eruptions.

inner core: made of iron and nickel, the inner core is 7000 to 13000 degrees, is under extreme pressure and acts as a solid.

islands: a land mass, especially one smaller than a continent, entirely surrounded by water.

lagoon: a body of relatively shallow water that is parallel to land and is protected and separated from the open ocean by a barrier reef.

leeward: the downwind side of an island.

lines of latitude: numerical system of imaginary circles on Earth's surface that lie parallel to the Equator and are used to describe position north and south of the Equator; measured in increasing degrees north and south away from the Equator.

lines of longitude: numerical system of imaginary half circles on Earth's surface that lie perpendicular to the Equator and end at the poles, used to describe position east and west, measured in degrees with 0° at the Prime Meridian.

lithosphere: outer, rigid portion of the Earth; includes the continental and oceanic crust and the upper part of the mantle.

low islands: islands that are composed dominantly of coral or sand whose landmass is above the sea surface

mantle: main volume of the Earth between the crust and the core; increases in pressure and temperature with depth.

mid-ocean ridges: oceanic mountain ranges formed where Earth's tectonic plates are gradually moving apart.
oceanic crust: the mass of the Earth's crust which lies under the ocean floor; composed primarily of basalt rock.
oceanic trench: long, narrow depressions of the ocean floor marking a subduction zone where one of Earth's tectonic plates sinks beneath another; the sinking plate remelts in the mantle.
outer core: above the inner core and below the mantle, this layer is liquid iron and nickel and is between 4000 and 9000 degrees.
Pangaea: hypothetical supercontinent proposed by Alfred Wegener in 1912 as part of his theory of continental drift. In theory, Pangaea (from Greek: *pangaia*, "all Earth") covered about half the Earth and was completely surrounded by a world ocean called Panthalassa.
plate tectonics: geologic theory that combines the concepts of seafloor spreading and continental drift to explain the large-scale movement of the Earth's crustal plates.
Prime Meridian: Longitude line of 0° from which all other longitudes are measured; passes through western Europe and Africa.
seafloor spreading: the process that describes how new oceanic crust is created by volcanic activity along mid-ocean ridges; old crust eventually moves away from the ridge as new crust is formed.
spreading center: axes of oceanic rises and ridges where new geologic material is formed; mid-ocean ridges
subduct: sinking beneath, as in subduction of the Earth's tectonic plates.
subduction: the process by which the edge of a crustal plate is forced beneath another. The more dense plate sinks beneath the plate of lesser density, into the Earth's interior.
subsidence: lowering or sinking of a portion of the Earth's crust.
transform plate boundary: a region of the lithosphere where two tectonic plates slide and grind against each other in a primarily side-to-side motion.
Tropic of Cancer: northern-most latitude at which the sun is directly overhead at noon, marking the first day of the northern hemisphere summer and the first day of the southern hemispheres winter (June solstice).
Tropic of Capricorn: southern-most latitude at which the sun is directly overhead at noon, marking the first day of the southern hemisphere summer and the first day of the northern hemispheres winter (December solstice).

Science Background for the Teacher – Bibliography

[1-6] ***Science background information condensed and/or compiled from the following sources:***

1: Kious, J. W., & Tilling, R. I. (February 1996). *This dynamic Earth.* Retrieved April 11, 2007, from http://pubs.usgs.gov/gip/dynamic/dynamic.html.

UC Berkeley. (1997). Geology: Plate tectonics. Retrieved April 5, 2007 from http://www.ucmp.berkeley.edu/geology/tectonics.html

2: Watson, J. M. (1999) Hotspots: Mantle thermal plumes. Retrieved April 5, 2007 from http://pubs.usgs.gov/gip/dynamic/hotspots.html

3: NOAA, Coral reef conservation Program (November 4, 2009) *Coral 101.* Retrieved January 29, 2010 From http://coralreef.noaa.gov/aboutcorals/coral101/

4, 5, 6: Anderson, G. (June 30, 2003). *Coral reef formation*. Retrieved April 14, 2007, from http://www.marinebio.net/marinescience/04benthon/crform.htm

NOAA, Coral Reef Information System. (January 23, 2007). *What are corals and coral reefs?* Retrieved April 13, 2007, from http://www.coris.noaa.gov/about/what_are/.

NOAA, National Ocean Service Discovery Kits. (December 2, 2004). *How do coral reefs form?* Retrieved April 13, 2007, from http://www.oceanservice.noaa.gov/education/kits/corals/coral04_reefs.html.

Zubi, T. (2007). Ecology: coral reefs. Retrieved April 13, 2007 from http://www.starfish.ch/reef/reef.html

7: Anderson, G. (June 30, 2003). *Coral reef formation*. Retrieved April 14, 2007, from http://www.marinebio.net/marinescience/04benthon/crform.htm

Gardiner, L. (February 26, 2007). *Plate tectonics.* Retrieved April 11, 2007, from http://www.windows.ucar.edu/tour/link=/Earth/interior/plate_tectonics.html.

National Wildlife Refuge, Midway Atoll. (September 5, 2002). *Landscape of Midaway Atoll*. Retrieved April 16, 2007, from http://www.fws.gov/midway/intro/land.html.

NOAA Resources

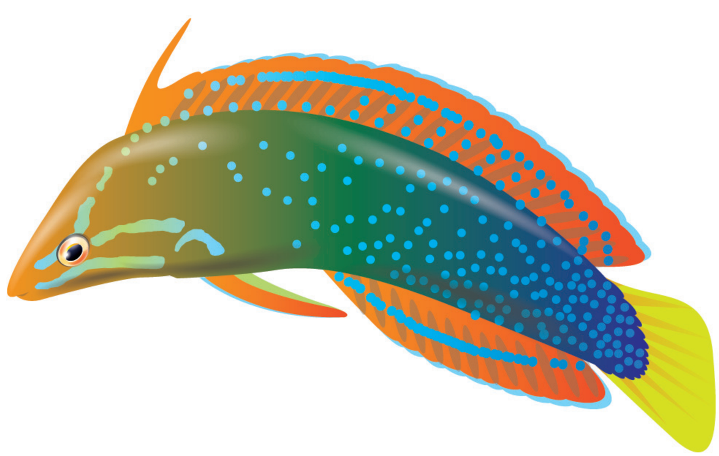
Below is a list of resources compiled by the Outreach Education Office of the National Oceanic and Atmospheric Administration. The science standards and the ocean literacy principles addressed in this unit were used as a guideline in selecting the following resources. To access the print resources listed below, contact NOAA's Outreach Education Office directly:

Outreach Unit
NOAA Office of Public and Constituent Affairs
1305 East West Highway #1W514
Silver Spring, MD 20910
Phone: (301) 713-1208
Email: NOAA-OUTREACH@noaa.gov
http://www.education.noaa.gov/

Resources:

- **NOAA OAR Tsunami poster with Could It Happen Here activity.**
- **Oceans for Life lesson Hawaiian Hot Spots about undersea volcanic studies (grades 6–8, but can be adapted).**
- **Oceans for Life lesson Natural Disasters about undersea plate tectonics (grades 6–8, but can be adapted).**
- **Ocean Explorer lesson Mystery of Alaskan Seamounts – good for compare and contrast (grades 9–12), from:** http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/mystery9_12.pdf
- **Ocean Explorer lesson What's the Difference? – volcanic processes at convergent and divergent tectonic plate boundaries, from:** http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_difference.pdf
- **NWHI lesson Life of an Island for grades 4–6, which teaches about the evolution of a volcanic island from origin to erosion, from:** http://www.Hawaiiatolls.org/teachers/lesson_life_of_an_island.php
- **Ocean Explorer lesson Islands, Reefs, and a Hot Spot for grades 5–6 about the eight stages in the formation of the island in the Hawaiian archipelago, from:** http://www.oceanexplorer.noaa.gov/explorations/02Hawaii/background/education/media/nwhi_hot.pdf
- **Ocean Explorer lesson Hawaiian Bowl! for grades 7–8 about plate tectonics in the Hawaiian archipelago from:** http://www.oceanexplorer.noaa.gov/explorations/02Hawaii/background/education/media/nwhi_hot.pdf
- **Ocean Explorer lesson Roots of the Hawaiian Hot Spot for grades 9–12 on plate tectonics and volcanism, from:** http://www.oceanexplorer.noaa.gov/explorations/02Hawaii/background/education/media/nwhi_roots.pdf

Northwestern Hawaiian Islands (NWHI) http://www.coris.noaa.gov/about/eco_essays/nwhi/archipelago.html



OCEAN LITERACY ESSENTIAL PRINCIPLES

1. The Earth has one big ocean with many features.
    1a. The ocean is the dominant physical feature on our planet Earth- covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian and Arctic.
    1b. An Ocean Basin's size, shape and features (islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

2. The ocean and life in the ocean shape the features of the Earth.
    2a. Many Earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.
    2c. Erosion- the wearing away of rock, soil and other biotic and abiotic Earth materials- occurs in coastal areas as wind, waves, and currents in rivers and the ocean move sediments.
    2e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

5. The ocean supports a great diversity of life and ecosystems.
    5e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.
    5f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e. it is "patchy." Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

6. The ocean and humans are inextricably interconnected.
    6c. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.

7. The ocean is largely unexplored.
    7b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
    7f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Lesson 1: 1a.
Lesson 2: 2a. 2c. 2e.
Lesson 3: 1a. 1b. 2a. 2c. 2e. 7b.
Lesson 4: 2a. 5e. 5f.
Lesson 5: 5f. 6c. 7b. 7f.
Culminating : 1a. 1b. 2a. 2c. 6c.

CLIMATE LITERACY ESSENTIAL PRINCIPLES

There is no appropriate alignment of Climate Literacy Essential Principles to the unit lessons.

NOAA Marine Science Career - Case Studies

Wendy K. Stovall - Ph.D Volcanology

Hi! I'm Wendy. I study volcanoes.
I am called a Volcanologist (vol·can·ol·o·gist).

It is important to study volcanoes because they can be very dangerous. All volcanoes are different and people who live near volcanoes need to know how they may erupt. I am interested in learning how volcanoes work, and I would like to help people understand the threats of volcanic activity.

I am able to learn how volcanoes might erupt by observing the bubbles within the volcanic rock. Volcanic rocks contain bubbles because when they cool, small gas pockets are trapped within the rocks. The gases control how explosive a volcano can be. Imagine shaking up a bottle of soda and then taking off the top, it will explode. Volcanoes are very similar... the gas is dissolved (you can't see it) until the pressure is released and it explodes.

I travel to volcanoes to conduct fieldwork and collect rocks. When I study the rocks, I take many measurements and write down what I see. Then I look at slices of the rock (less than the thickness of a blade of grass) using a very powerful microscope. With the microscope, I am able to see the small bubbles in the rock. I then write papers and give presentations about what I have observed. I am able share what I learn with people all over the world.

Watching a volcanic eruption is always cool and is different each time. I have studied volcanoes in Ecuador, Russia, New Zealand, Iceland and here in Hawai‘i. The coolest thing I have done was to travel to the Kamchatka Peninsula in Russia where I got a ride in a helicopter to a remote volcano. While I was collecting rocks, the volcanic dome was smoking and releasing small ash pieces. Our field team had to be very careful because there was a constant threat of eruption.

In high school, I did not take Earth science and I did not realize that the study of the solid material that makes up the Earth (geology) was a possible career path. After watching many documentaries on volcanoes, I realized I wanted to be one of the scientists who are interviewed. It was something I had never really considered, but I knew I could do it because I was so interested in learning about them. I was also confident because a mentor believed in my abilities as a scientist, which helped me to have confidence to complete graduate school.

When choosing a career for your future, realize that you can do anything you want. Think about what you really enjoy and try to find a career in that area. You will always be successful if your job is doing what you love. Also, it will make your job easier!

Glossary of Cooperative Learning Techniques

In an effort to maximize student engagement and learning, the NOAA Sea Earth and Atmosphere curricular resources were designed using cooperative learning techniques. This guide defines the expectations for implementation of each technique.

What is Cooperative Learning?

Cooperative learning may be broadly defined as any classroom learning situation in which students of all levels of performance work together in structured groups toward a shared or common goal. According to Johnson, Johnson and Holubc, (1994): "Cooperative learning is the instructional use of small groups through which students work together to maximize their own and each other's learning." In classrooms where collaboration is practiced, students pursue learning in groups of varying size: negotiating, initiating, planning and evaluating together. Rather than working as individuals in competition with every other individual in the classroom, students are given the responsibility of creating a learning community where all students participate in significant and meaningful ways. Cooperative learning requires that students work together to achieve goals which they could not achieve individually.

Jigsaw

To Jigsaw materials refers to the use of a strategy in which each student on a team receives only a piece of the material that is to be learned in which that student becomes the "expert." Once the material is learned each member of the team takes a turn teaching the other members their assigned content. This type of dynamic makes the students rely on the other members of their team to learn all of the material.

Think-Pair-Share

This four-step discussion strategy incorporates wait time and aspects of cooperative learning. Students (and teachers) learn to LISTEN while a question is posed, THINK (without raising hands) of a response, PAIR with a neighbor to discuss responses, and SHARE their responses with the whole class. Time limits and transition cues help the discussion move smoothly. Students are able to rehearse responses mentally and verbally, and all students have an opportunity to talk.

Numbered Heads

This structure is useful for quickly reviewing objective material in a fun way. The students in each team are numbered (each team might have 4 students numbered 1, 2, 3, 4). Students coach each other on material to be mastered. Teachers pose a question and call a number. Only the students with that number are eligible to answer and earn points for their team, building both individual accountability and positive interdependence.

KWL Chart

A pre-assessment tool consisting of three vertical columns. Students list what they "**K**now" about a topic. What they "**W**ant" to know about a topic. The last column students share what they have "**L**earned" about a topic.

KWL CHART

Be sure to bullet your list.

Use content words only (nouns, verbs, names of people and places, dates, numbers, etc.).

WHAT DO I KNOW?	WHAT DO I WANT TO KNOW? *or* WHAT DO I WANT TO SOLVE?	WHAT HAVE I LEARNED?
•		•

Role Cards

Assign students to cooperative learning groups. Once students are in their groups the teacher will hand out premade role cards that will help each member of the group contribute to the completion of the given task. Before roles are assigned, the teacher should explain and model the task as well as the individual roles for students so that they know and understand how his/her individual role will contribute to the success of the group completing the task. When this technique is used, taking on a different role will aid in student proficiency.

Example of role cards:

Role Card #1

Facilitator:

Makes certain that everyone contributes and keeps the group on task.

Role Card #2

Recorder:

Keeps notes on important thoughts expressed in the group. Writes final summary.

Role Card #3

Reporter:

Shares summary of group with large group. Speaks for the group, not just a personal view.

Role Card #4

Materials Manager:

Picks up, distributes, collects, turns in, or puts away materials. Manages materials in the group during work.

Role Card #5

Time Keeper:

Keeps track of time and reminds groups how much time is left.

Role Card #6

Checker:

Checks for accuracy and clarity of thinking during discussions. May also check written work and keeps track of group point scores.

Round Table

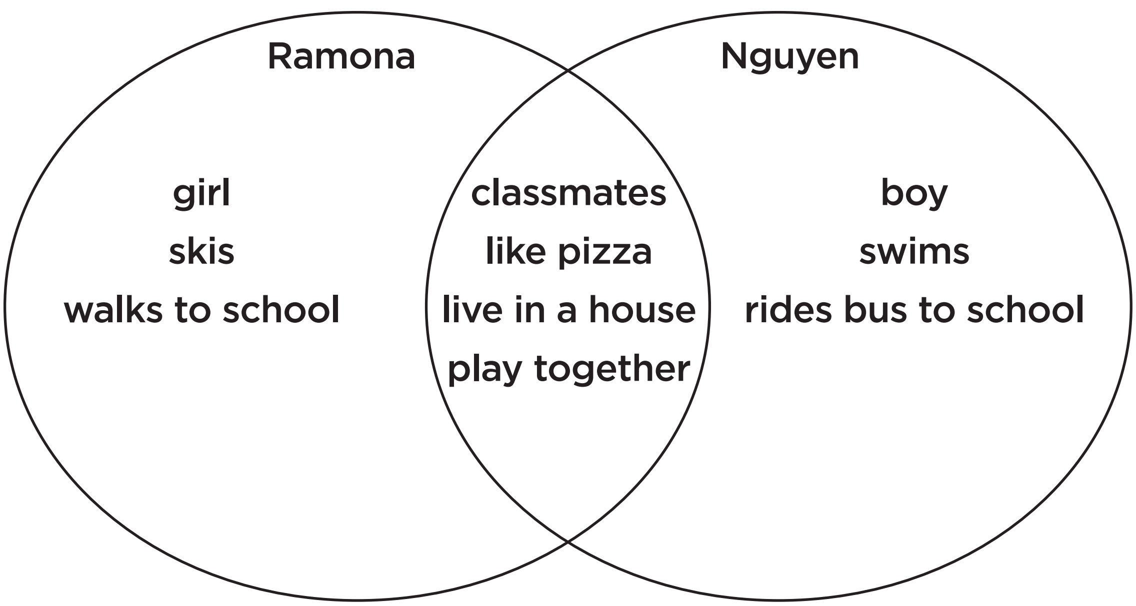
Round table can be used for brainstorming, reviewing, or practicing while also serving as a team builder. Students sit in teams of 3 or more, with one piece of paper and one pencil. The teacher asks a question which has multiple answers. Students take turns writing one answer on the paper, then passing the paper and pencil clockwise to the next person. When time is called, teams with the most correct answers are recognized. Teams reflect on their strategies and consider ways they could improve.

Three-Step Interview

This involves structured group activity with students. Using interviews/listening techniques that have been modeled; one student interviews another about an announced topic. Once time is up, students switch roles as interviewer and interviewee. Pairs then join to form groups of four. Students take turns introducing their pair partners and sharing what the pair partners had to say. This structure can be used as a team builder, and also for opinion questions, predicting, evaluation, sharing book reports, etc.

Venn Diagram

A diagram using circles to represent sets, with the position and overlap of the circles comparing and contrasting the relationships between two given pieces of information.



References and Credits

From Lesson 1:

Suggested References for Teachers:

http://www.Hawaiireef.noaa.gov/imagery/graphicmaps.html
http://www.navigatingchange.org/ This website no longer exists, but some info from the site can be found at http://www.Hawaiianatolls.org/maps/nav_change/Final%20map%20back.pdf
http://www.Hawaiianatolls.org/partners/index.php

References and Resources Used by Writers:

http://www.navigatingchange.org/ This website no longer exists, but some info from the site can be found at http://www.Hawaiianatolls.org/maps/nav_change/Final%20map%20back.pdf
http://www.Hawaiireef.noaa.gov/imagery/graphicmaps.html

Credits from Maps:

NOAA's Pacific Service Center, Honolulu, HI.

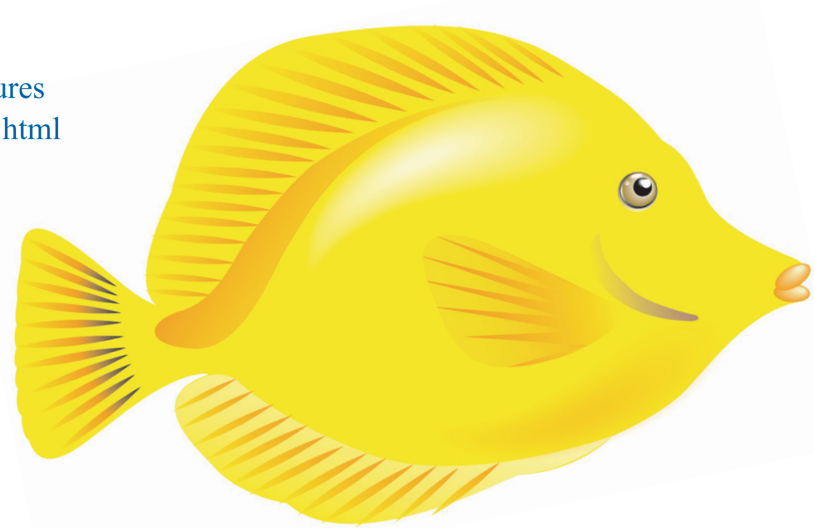
From Lesson 2:

Suggested References for Teachers: (*All information retrieved May 2007*.)

http://www.soest.Hawaii.edu/GG/HCV/haw_formation.html
www.oceanexplorer.noaa.gov
http://en.wikipedia.org
www.Hawaiianatolls.org
http://www.radiojerry.com/frigate/
http://www.pbs.org/kqed/oceanadventures
http://Hawaiireef.noaa.gov/about/kure.html
http://books.nap.edu

References and Resources Used by Writers:

http://www.soest.Hawaii.edu/GG/HCV/haw_formation.html
www.oceanexplorer.noaa.gov
http://en.wikipedia.org
www.Hawaiianatolls.org
http://www.radiojerry.com/frigate/
http://www.pbs.org/kqed/oceanadventures
http://Hawaiireef.noaa.gov/about/kure.html
http://books.nap.edu



From Lesson 3:

National Geographic Oceans for Life Education Network.
http://www.ngsednet.org/community/index.cfm?community_id=128
PBS Savage Earth website. *Hell's Crust: Our Everchanging Planet.*
http://www.pbs.org/wnet/savageEarth/animations/hellscrust/main.html

References and Resources Used by Writers:
http://www.ngsednet.org/community/index.cfm?community_id=128
PBS Savage Earth website, *Hell's Crust: Our Everchanging Planet*;
http://www.pbs.org/wnet/savageEarth/animations/hellscrust/main.html

From Lesson 4:

Essentials of Geology, An Introduction to Planet Earth. (2003-2007). W.W. Norton and Company. Retrieved June 15, 2007, from:
http://www2.wwnorton.com/college/geo/egeo/index/animations.htm
Anderson, G. *Welcome to Marine Science.* Retrieved June 15, 2007, from:
http://www.biosbcc.net/ocean/marinesci
NOAA, National Ocean Service Discovery Kits. (2004). *How do coral reefs form?* Retrieved April 13, 2007, from: http://www.oceanservice.noaa.gov/education/kits/corals/coral04_reefs.html
http://www.vims.edu/bridge
NOAA, Coral Reef Information System. (2007). *What are corals and coral reefs?* Retrieved April 13, 2007, from: http://www.coris.noaa.gov/about/what_are/

References and Resources Used by Writers:
Essentials of Geology, An Introduction to Planet Earth. (2003-2007). W.W. Norton and Company. Retrieved June 15, 2007, from:
http://www2.wwnorton.com/college/geo/egeo/index/animations.htm
Anderson, G.. *Welcome to Marine Science.* Retrieved June 15, 2007, from:
http://www.biosbcc.net/ocean/marineci
http://www.vims.edu/bridge
NOAA, National Ocean Service Discovery Kits. (2004) *How do coral reefs form?* Retrieved April 13, 2007, from: http://www.oceanservice.noaa.gov/education/kits/corals/coral04_reefs.html

Student Readings

Anderson G. *Welcome to Marine Science.* Retrieved June 15, 2007, from:
http://www.biosbcc.net/ocean/marinesci

Culminating Lesson
http://oceanexplorer.noaa.gov/explorations/02Hawaii/background/education/media/nwhi_hot.pdf
http://www.mgf-Hawaii.org/PDF/ETI/geology/onstage.pdf

References and Resources Used by Writers:
http://oceanexplorer.noaa.gov/explorations/02Hawaii/background/education/media/nwhi_hot.pdf