GRADE 4 UNIT 3 OVERVIEW
Aquatic Food Chains

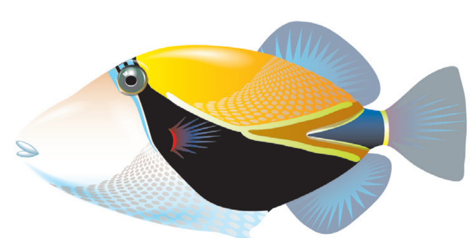
Introduction

The accidental or deliberate introduction by humans of non-native and invasive animals and plants can disrupt the fragile balance of food chains in aquatic ecosystems. Plants and animals are interdependent and when any link in the food chain is broken or disrupted, local extinction of a species that depends on that link for their survival can result. Because the Hawaiian Islands archipelago is isolated in the middle of the Pacific Ocean, it is particularly vulnerable to invasive species.

Using textbooks, online sources, PowerPoint images, compound microscopes, and other resources, students examine plant and animal cell structures for clues that might explain why plants can produce their own food, and animals cannot, although both cell structures display similar components. They discover that the chloroplast, which only plant cells have, allows plants to acquire their energy from the sun through photosynthesis. Students then demonstrate their understanding of photosynthesis by constructing an Input/Output diagram. The creation of food chains starts with plants, the basic producers in food chains, from which students can easily trace and identify animal species (the consumers) that depend on these producers for their survival. The students also review and discuss the distinct roles consumers and decomposers play in food chains, and identify animals that are herbivores, omnivores, or carnivores and apply the terms to the class bottle aquarium.

After learning about food chains, students are asked to apply their knowledge by creating bottle aquariums in which to conduct a mini food chain experiment involving common invasive freshwater organisms found in Hawaiian streams and tiny and common marine plants and animals in Hawaiʻi (e.g., elodea plants, fresh water snails, guppies, duckweed, and others). Their primary goal is to develop and combine food chains resulting from their bottle aquarium experiments into a food web on chart paper. Their mission is to plan, propose, and conduct an experiment in their mini ecosystems, and to compile relevant evidence substantiating how plants and animals interact in these mini ecosystems. Note: Please review the guidelines provided at the beginning of the lesson carefully before doing this activity. Throughout the unit, the students carefully continue to observe and record ongoing plant/animal interactions for use in subsequent lessons.

In Lesson 5, students apply what they have learned about food chains to the marine environment. They then learn about the importance of studying food chains for Hawaiian companies involved in aquaculture–the cultivation of fish and shellfish for human consumption– and mariculture–the cultivation of marine organisms in their natural habitat.



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	HCPS III BENCHMARKS	LESSON, Brief Summary, Duration
How are plant and animal cells different?	Science Standard 4: Life and Environmental Sciences: SC.4.4.1 Identify the basic differences between plant cells and animal cells. Science Standard 3: Life and Environmental Sciences: SC 4.3.1. Explain how simple food chains and food webs can be traced back to plants. Lang. Arts Standard 6: Oral Communication: LA.4.6.1: Participate in grade-appropriate oral group activities	**Lesson 1: Searching for Clues in Cells** Students examine plant and animal cells to find clues that might explain why plants can produce their own food, but animals cannot. They construct an input/output diagram to show what they understand about photosynthesis. Using PowerPoint images, students identify major cell structures. They discover that plants have cell walls and chloroplasts, which are not found in animal cells. For classes with access to a compound microscope, students prepare and examine elodea cells and human cheek cells. Classes without microscopes use images from the PowerPoint presentation, or obtain the images from suggested online sources. Two 45-minute periods
What role do plants and animals have in an ecosystem? How are plants important to food chains and webs?	Science Standard 5: Life and Environmental Sciences: SC.4.5.2 Describe the roles of various organisms in the same environment. Science Standard 4: Life and Environmental Sciences: SC.4.3.1 Explain how simple food chains and food webs can be traced back to plants. Language Arts Standard 2: Reading Comprehension: LA.4.2.5 Summarize main points found in informational texts. Language Arts LA.4.6.2 Give a short, informal presentation to inform or persuade.	**Lesson 2: Food Chains and Food Webs in an Ecosystem** Scientists study interactions among plants and animals by observing organisms in the field and in aquariums set up as mini-ecosystems that simulate the natural environment. In this lesson, students will be introduced to the bottle aquarium and they will observe it daily as a class. Students learn new vocabulary terms about feeding relationships and marine environments that they can apply to their bottle aquarium. Each student creates a food chain for an ecosystem in the ocean, and then combines his/her food chain with the food chains of fellow students to create a food web for an ecosystem. Students draw a food web. Four 45-minute periods

ESSENTIAL QUESTIONS	HCPS III BENCHMARKS	LESSON, Brief Summary, Duration
What is the role of testable hypotheses in an experimental procedure? What is the role of scientific observation in an experimental procedure? How are observations different from inferences?	Science Standard 5: Life and Environmental Sciences: SC.4.5.2 Describe the roles of various organisms in the same environment. Science Standard 1: The Scientific Process: SC 4.1.2 Differentiate between an observation and an inference. SC. 4.1.1 Describe a testable hypothesis and an experimental procedure.	**Lesson 3: Ecosystem in a Bottle** In Lesson 3, students continue to study interactions among aquatic plants and animals in the class' mini-ecosystem bottle aquarium. The class will design and carry out an experiment to find out how plants and animals in a bottle aquarium interact with each other. The class' bottle aquarium is referred to throughout the unit and evidence from the experiment is used in the unit's final lesson. Two 45-minute periods plus three 15-minute periods
What are seaweeds? What are the roles of seaweeds in coastal waters? How do seaweeds support organisms in a food web or food chain? How do invasive seaweeds impact Hawai'i 's environment?	Science Standard 3: Life and Environmental Sciences: SC.4.3.1: Explain how simple food chains and food webs can be traced back to plants. Lang. Arts Standard 5: Writing LA.4.5.1: Use appropriate facts and interesting details that develop the intended meaning and anticipate the needs of the audience.	**Lesson 4: Taking a Closer Look at Seaweeds** Students are introduced to seaweeds, the marine algae, by thinking about ways in which humans use them for foods and other products. They then engage in a scavenger hunt in which they learn to recognize and describe common native seaweeds. Looking at the term seaweed, students ponder the meaning of the term weed, and discuss whether, and under what circumstances, seaweeds should be considered weeds. Students learn the role of seaweed in a food chain. The lesson closes with connections to the on-going bottle aquarium project, pointing out that the elodea and duckweeds are aquatic plants, not seaweeds. Two 45-minute periods

ESSENTIAL QUESTIONS	HCPS III BENCHMARKS	LESSON, Brief Summary, Duration
How has technology influenced our understanding of food chains and food webs? How can knowledge about ecosystems affect our economy and environment in Hawai‘i ?	Science Standard 2: The Scientific Process: SC.4.2.1 Describe how the use of technology has influenced the economy, demography, and environment of Hawai‘i . Lang. Arts Standard 2: Reading: LA.4.2.5 Summarize main points found in informational texts. Lang. Arts Standard 6: Oral Communication: LA.4.6.1 Participate in grade-appropriate oral group activities.	**Culminating Lesson: Mariculture and Aquaculture** Students will review previous lessons about ecosystems, food chains, plants, and invasive species. They will use the information learned to discover how this knowledge has affected Hawai‘i and can affect and sustain Hawai‘i in the future, through modern day aquaculture and mariculture techniques. Students will read about current news on aquaculture in Hawai‘i , and work to incorporate the different lessons into their bottle aquarium project conclusion. One 60 minute period

**HCPS III Benchmarks from the Hawai‘i Department of Education, from Website: http://doe.k12.hi.us/standards/index.htm*

Benchmark Rubric

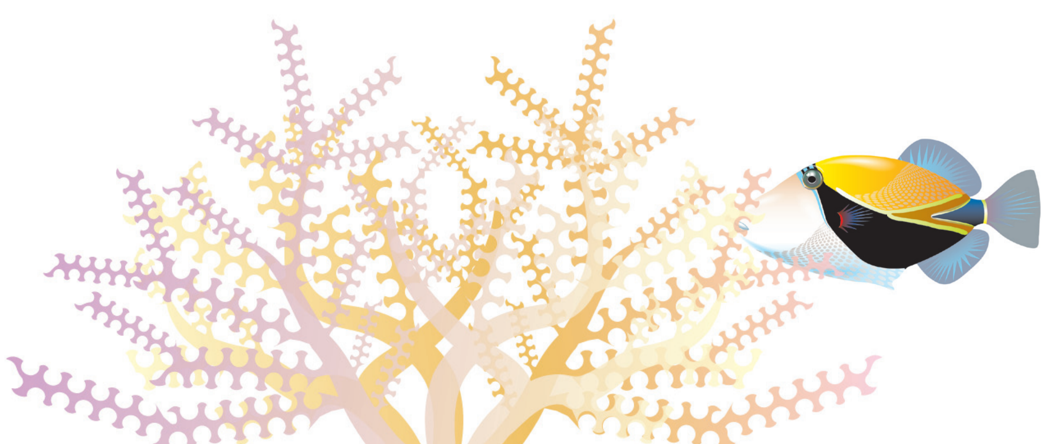
I. HCPS III Benchmarks*

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

Topic		Scientific Inquiry	
Benchmark SC.4.1.1		Describe a testable hypothesis and an experimental procedure	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Create a testable hypothesis and an experimental procedure to test it	Describe a testable hypothesis and an experimental procedure	Identify, with assistance, a testable hypothesis and an experimental procedure	Recognize, with assistance, a testable hypothesis or an experimental procedure

Topic		Scientific Knowledge	
Benchmark SC.4.1.2		Differentiate between an observation and an inference	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Explain the difference between an observation and an inference and give examples	Differentiate between an observation and an inference	Provide examples of observations and inferences	Define an observation and an inference
Topic		Science, Technology, and Society	
Benchmark SC.4.2.1		Describe how the use of technology has influenced the economy, demography, and environment of Hawai‘i	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Explain how the use of technology has influenced the economy, demography, and environment of Hawai‘i and suggest ways to conserve the environment	Describe how the use of technology has influenced the economy, demography, and environment of Hawai‘i	Give examples of how the use of technology has influenced the economy, demography, and environment of Hawai‘i	Recognize that the use of technology has influenced the economy, demography, and environment of Hawai‘i
Topic		Cycles of Matter and Energy	
Benchmark SC.4.3.1		Explain how simple food chains and food webs can be traced back to plants	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Compare the characteristics of simple food chains with those of food webs	Explain how both simple food chains and food webs can be traced back to plants	Describe how simple food chains or food webs can be traced back to plants	Recognize that simple food chains or food webs can be traced back to plants

Topic		Cells, Tissues, Organs, and Organ Systems	
Benchmark [SC.4.4.1]()		Identify the basic differences between plant cells and animal cells	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Explain and give examples of the differences between plant and animal cells	Identify the basic differences between plant cells and animal cells	Recognize very few differences between plant and animal cells	Recall, with assistance, very few differences between plant and animal cells
Topic		Unity and Diversity	
Benchmark [SC.4.5.2]()		Describe the roles of various organisms in the same environment	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Analyze how the roles of different organisms affect their interaction in the same environment	Describe the roles of various organisms in the same environment	Identify a few organisms and their role in the same environment	Recall, with assistance, very few organisms and their role in the same environment
Topic		Constructing Meaning	
Benchmark [LA.4.2.5]()		Summarize main points found in informational texts	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Summarize the main points and describe their connection to the main idea or focus in informational texts	Summarize the main points found in informational texts	Produce a summary that mixes insignificant points with main points	Summarize information not necessary to understanding the main points of informational texts, or repeat original text rather than summarize
Topic		Meaning	
Benchmark [LA.4.5.1]()		Use appropriate facts and interesting details that develop the intended meaning and anticipate the needs of the audience	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Use appropriate facts and interesting details that creatively develop the intended meaning and clearly anticipate the needs of the audience	Use appropriate facts and interesting details that develop the intended meaning and anticipate the needs of the audience	Use some trivial facts and obvious details that relate to but do not develop the intended meaning or anticipate the needs of the audience	Use inappropriate facts and irrelevant details that do not develop the intended meaning or anticipate the needs of the audience



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

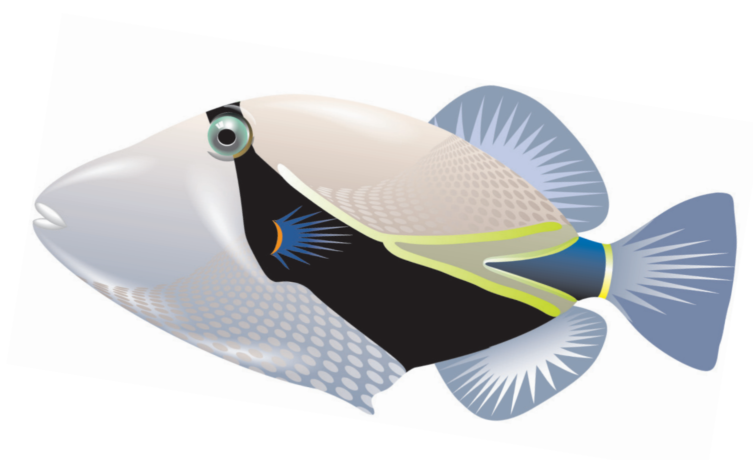
Topic		Discussion and Presentation	
Benchmark LA.4.6.2		Give short, informal presentations to inform or persuade	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Give creative, short, highly effective informal presentations to inform or persuade	Give short, informal presentations to inform or persuade	Give short, informal presentations that are somewhat informative or persuasive	Give short, informal presentations that do not inform or persuade

II. General Learner Outcomes*

Below is a list of the HIDOE General Learner Outcomes (GLOs). Each Unit of the Lessons from the Sea Curriculum addresses the GLOs. Within some lessons, there is more specific mention of individual GLOs with specific pertinence.

- **I.** Self-directed Learner. (The ability to be responsible for one's own learning.)
- **II.** Community Contributor. (The understanding that it is essential for human beings to work together.)
- **III.** Complex Thinker. (The ability to demonstrate critical thinking and problem solving.)
- **IV.** Quality Producer. (The ability to recognize and produce quality performance and quality products.)
- **V.** Effective Communicator. (The ability to communicate effectively.)
- **VI.** Effective and Ethical User of Technology. (The ability to use a variety of technologies effectively and ethically.)

* *"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 Teacher Bibliography* at the end of this section.

How are plant and animal cells different? [1] (Lesson 1)

Cells come in many different shapes and sizes and perform a variety of functions. For example, the human body is made up of approximately 200 different kinds of cells ranging from long nerve cells to tiny blood cells. Some organisms are **unicellular,** such as the amoeba, while others are **multicellular,** such as humans. Although cells appear to be very different, they have a lot in common. Even plant and animal cells have many more similarities than differences.

Plant and animal cells contain nearly all the same structural components. For example, they both contain a **cell membrane,** the protective **skin,** separating the cell contents from the outside world. The cell membrane regulates the movement of water, nutrients, and wastes into and out of the cell. Within the cell membrane is the **nucleus,** which contains the cell's genetic material or DNA. In addition to the nucleus, plant and animal cells also share a variety of **organelles,** small structures that help carry out the day-to-day functions of the cell. These include ribosomes, which participate in protein synthesis, mitochondria, which create energy through aerobic respiration, endoplasmic reticulum, which stores and transports proteins within and outside the cell, Golgi bodies, which transform proteins into more complex molecules, and lysosomes, which contain enzymes used to break down large molecules.

Despite these similarities, plant and animal cells differ in two important ways. The first difference is a structure known as **chloroplasts,** which plant cells have, and animal cells do not. Chloroplasts are what give plants their green color. More importantly, chloroplasts allow plants to acquire their energy from the sun, rather than from food, in a process known as **photosynthesis.** Photosynthesis is the primary source of energy for plants. Similar to mitochondria, chloroplasts convert energy from one form to another. However, unlike mitochondria, which use aerobic respiration to convert food molecules and oxygen into energy and carbon dioxide, photosynthesis allows chloroplasts to use energy from the sun to convert carbon dioxide and water into food molecules or carbohydrates. The second difference between plant and animal cells is a structure known as the **cell wall.** While both plant and animal cells have a cell membrane, which gives the cell shape and allows molecules to pass into and out of the cell, only plant cells have a cell wall that surrounds the entire cell, including the cell membrane. The cell wall provides plant cells with a protective covering, and gives the plant the rigidity it needs to remain erect. It also allows each cell to withstand the increased internal pressure from **osmosis,** when the plant absorbs water. The cell wall is composed mainly of **cellulose.** For additional information concerning the structure of plant and animal cells, go to http://www.emc.maricopa.edu/faculty/farabee/biobk/BioBookCELL2.html

If a living organism in an ecosystem becomes extinct, what happens to the other plants and animals that are living there, and why? [2] (Lessons 4 and 5)

Extinction is a natural process of **evolution.** Species adapt to changes in the environment through the process of **natural selection.** If they cannot adapt, they go extinct. However, human impacts such as pollution, habitat destruction, and overexploitation are now driving species extinction at an unprecedented rate in the world's history. This realization has brought the concept of **biodiversity** to the forefront of scientific research, news media, government, and international policy decision making. Biodiversity is important because no organism lives in isolation from its environment and the other living things around it. Organisms are connected through complex food webs, nutrient cycles, symbiosis, and other ecological interactions. The loss of any one species in an ecosystem can have substantial effects on many other species. Unfortunately, biologists do not understand ecosystems well enough to predict what these effects might be. This is because effects of the extinction of a species in an **ecosystem** depend on the characteristics of that ecosystem, and on the species role in the structure of the ecosystem. However, the well-studied role of **keystone species** in an ecosystem may shed some light on the ecosystem consequences of species extinction.

Cascade effects occur when the local extinction of one species significantly changes the population sizes of other species. These effects are particularly likely when the lost species is a keystone species. In a predator-controlled system, the size of the prey population is determined by **predation.** In these systems, the effects of the loss of a predator can be substantial.

Keystone predators affect not only their prey's population size, but also the community's species diversity. For example, sea otters (Enhydra lutris) are a keystone species in the kelp forests of the North Pacific. The sea otter mainly preys upon sea urchins, the most important grazers in kelp communities. Sea urchins normally feed on drift kelp, pieces that break loose and sink to the bottom or are washed ashore. But when sea otter populations are reduced or nonexistent, like those off the Southern California coast, sea urchin populations explode, transforming healthy, diverse kelp communities into **kelp barrens.** During these urchin population explosions there is not enough drift kelp, and the urchins feed on the holdfasts of live kelps. Holdfasts are structures at the base of the kelp that anchor it to the substrate. As a result, the kelps break loose, float away, and die. This removes important habitat for the numerous fish and invertebrate species that take shelter in the kelp, ultimately reducing biodiversity.

A study in the Aleutian Islands, Alaska, found that kelp forests were healthy where sea otters were common. In areas where sea otters were not present, there were many sea urchins and few kelps. Evidence suggests that otter populations declined due to predation by Orcas, which normally prefer seals and sea lions. However, the numbers of seals and sea lions have declined dramatically since the late 1980s, possibly because of a decrease in food supply resulting from over-fishing by humans. The Orcas appear to have switched to preying on sea otters when their primary food source became scarce. As the predation pressure on sea otters from Orcas increased, there was less predation pressure on the sea urchins, causing their populations to explode, followed by a subsequent decline of kelp forest communities. However, kelps were not the only species affected by the change in the ecosystem. Fish are very common in kelp communities, utilizing the food resources and shelter provided by the kelp community in many ways. For example, kelp communities provide juvenile habitat for many fishes, where increased cover protects the juvenile fishes from predators. Although the role of keystone predators in ecosystems is well studied, not all ecosystems contain a single species that exerts such a strong influence on ecosystem structure. Future research aimed at the connectivity of species and habitat in ecosystems will better enable conservation strategies to be developed. For additional information concerning the effects of decreased biodiversity in an ecosystem, go to http://pubs.wri.org/pubs_content_text.cfm?ContentID=575 or http://www.wri.org/publication/content/8214 if the other link does not work.

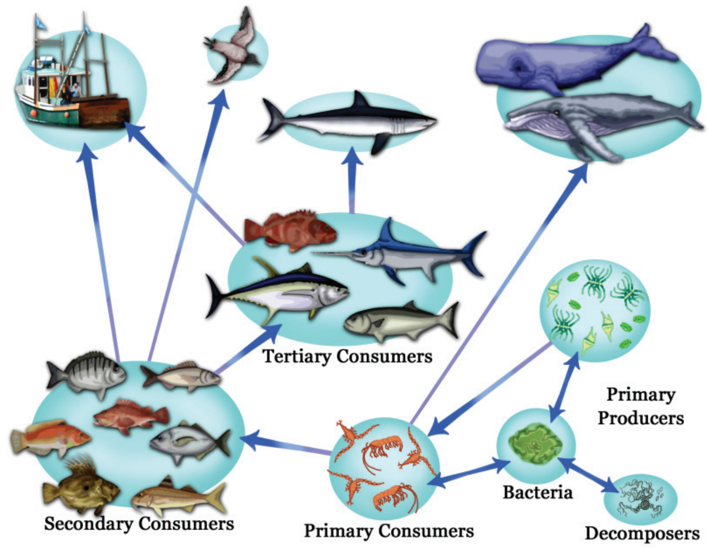
What are food chains and food webs?[5] (Lesson 2)

Food chains are simplistic linear models that describe the feeding relationships among various species of organisms in an ecological community. They are useful for understanding the different trophic levels to which organisms belong in the ecological community. Arrows are used to represent the transfer of energy from each level. An example of a food chain in a coral reef community would look like this:

algae → sea urchin → octopus → eel → ulua

In this example, the algae represent the **primary producers, autotrophic** organisms that make their own food by converting the energy from sunlight into food energy. The sea urchin is a herbivore and is considered to be a primary consumer in this example**. Consumers** are **heterotrophic** organisms that cannot produce their own food and must obtain food by eating other things; herbivores eat plants or algae in this case, and carnivores eat herbivores or other types of carnivores. The octopus is a carnivore, and because it is the first carnivore in the food chain, is a primary carnivore. The eel is a secondary carnivore. And finally, the ulua is the **top predator** in this food chain example because no other consumer eats it.

In a given ecosystem or community, many different food chains can be combined into **food webs** that give a more realistic picture of the feeding relationships. Considering the food chain described above, in reality, not only is algae eaten by sea urchins, but also by a variety of different species of fish and other invertebrates. In a food web diagram, many arrows would arise from the algae and point to all the different organisms that feed on it. Likewise, other types of consumers eat sea urchins and octopus and eels, many arrows would be present to account for the feeding relationships of all the organisms in the coral reef community. To view an image of a food web see below or visit http://www.arctic.noaa.gov/images/arctic_marine_food_web.jpg



How does energy flow through the food chain? [6] (Lessons 2, 3, and 4)

As previously mentioned, trophic levels group species into broad categories based on their energetic contribution (as a food resource) to the community. This can be represented by a simple food chain. Each community has different energy requirements and, as a result, the flow of energy through the trophic levels (i.e. food chains) of one community will look different from another community. The following example is a general model. **Primary producers** are the basis of all food chains, and their net primary productivity equals the energy available to all consumers in the community. **Primary consumers** are those that eat the primary producers. They can take the form of herbivores or decomposers, and the energy available within primary producers is first transferred to these two trophic levels. Following energy through the path of the herbivore, of the energy that is ingested (i.e. eaten), only a small fraction is actually assimilated (absorbed in the gut), and most of the energy is unused and wasted. Of the small fraction of the energy that is assimilated by the herbivore, a large part of it is used for maintaining life processes (respiratory heat). As a result, only a small fraction of energy is actually transferred from an herbivore to a secondary consumer in the form of new **biomass.**

The small amount of energy that actually gets transferred from herbivore to carnivore ends up representing only a small fraction of the energy that was available within the base trophic level of the primary producers. Each successively higher trophic level will have less and less energy available. In a majority of communities, this can be reflected in the relative abundance (number of organisms) and total biomass (amount of living matter per unit area) of organisms representing the different trophic levels. For example, in a terrestrial grassland community, plants will be very abundant with high biomass, followed by lower amounts of herbivores like mice, grasshoppers, and deer, and even less of carnivores like owls, foxes, and wolves. In the Northwestern Hawaiian Islands, however, a more unusual situation exists in the coral reef community. This ecosystem is predator dominated (higher level consumers) in terms of abundance, with more ulua, sharks, and groupers than lower-level carnivores and herbivores. This is the opposite of the general trend, and reflects how variable the trophic relationships among species in different communities can be. The main Hawaiian Islands are more populated and more fished than the NWHI. Since some of the most popular fish to catch are the apex predators, such as ulua or giant trevally (Caranx ignobilis), more of these are caught in the main Hawaiian islands causing them to be less predator dominated than the NWHI where less fishing occurs and therefore more apex predators exist.

What is plankton and what role does it play in the ocean? [3] (Lessons 2 and 4)

Plankton are diverse groups of organisms at the base of the food chain. Plankton are primarily found in the **pelagic zone,** the area of the open ocean, and more specifically in the epipelagic zone, the sunlit open ocean layer from the surface down to 200 meters (656 feet). The epipelagic zone lacks the typical primary producers found in coastal shallow water ecosystems, such as large seaweeds, seagrasses, and coral reefs, because they have no place to attach. Although floating seaweeds are important in a few places, such as the Sargasso Sea, in most of the epipelagic zone, the only primary producers are the **phytoplankton,** the photosynthetic type of plankton consisting primarily of single-celled algae and bacteria. Phytoplankton performs more than 95% of the photosynthesis in the ocean, producing nearly half the oxygen in our atmosphere. The most abundant phytoplankton are the photosynthetic picoplankton and nanoplankton. (The prefixes pico and nano are used to categorize plankton by size, with pico being the smallest, followed by nano, micro, meso, macro, and megaplankton.) The pico and nanoplankton contribute 90% or more of the epipelagic zone's photosynthesis in many places. **Cyanobacteria** are the most abundant members of the picoplankton, and contribute at least half of the ocean's total **primary production.** Larger phytoplankton, such as **diatoms** and **dinoflagellates,** are also important types of phytoplankton. Diatoms are especially common in temperate and polar regions and other nutrient-rich waters. Dinoflagellates tend to prefer warm areas and, in the tropics, may replace diatoms as the most abundant members of the larger phytoplankton. When occurring in nutrient-rich waters, dinoflagellates are known to bloom or grow explosively into huge numbers, and are sometimes called **red tides** because the sea appears red, due to red pigmentation in the algae's tissues.

Phytoplankton form the base of the food web in the ocean. The organic matter they produce and store through photosynthesis is then passed on to other creatures. The next step in the food chain occurs when **heterotrophic, herbivorous zooplankton** eat the phytoplankton. Because phytoplankton are too small for large animals to feed on, herbivorous zooplankton provide the link between the primary producers and the rest of the epipelagic zone community. The herbivores are consumed by carnivores, which are then fed upon by successively larger animals. Thus, the energy captured by the primary producers is passed up the food web. The **protozoan** zooplankton are particularly important because they can catch the tiny pico and nanoplankton, which are too small for most larger multicellular organisms to catch and eat. Without protozoans, much of the primary production in the epipelagic zone would go unutilized. Copepods, which are small crustaceans, are the most abundant zooplankton members, typically accounting for at least 70% of the zooplankton. Most copepods are omnivorous, consuming both phytoplankton and zooplankton. Other crustaceans, such as krill, are also important members of the plankton. Krill are commonly found in colder water, especially in the polar seas. Because of their large size, up to 6 cm (2.36 inches), krill are an important prey resource for many fishes, seabirds, and large filter-feeding whales. Many zooplankton spend their entire lives in the plankton and are called **holoplankton.** In contrast, **meroplankton** spend only the early stages of their life history in the plankton, and comprise the larval stages of many fish and invertebrate species. For additional information concerning the different kinds of plankton, go to www.amonline.net.au/exhibitions/beyond/what/index.htm or http://beyond.australianmuseum.net.au/what/index.htm if the prior link does not work.

Describe some of the algal species that occur in Hawai‘i [7, 8](Lessons 2 and 4)

There are a variety of algal species that occur in *Hawai‘i* . Algae are generally classified into red, green or brown algae depending on the type of chlorophyll they contain. A common problem in Hawai‘i , due to its isolation, are introduced species. Introduced species are those that were not originally found in Hawai‘i , but have been transported to the islands (by means such as ship ballast water or attachment to ship's hulls). Because introduced species often have few or no natural predators in their new environments, they have the potential to become invasive. When these species are invasive, they out-compete naturally occurring algal and animal species for habitat which can be very detrimental to the ecosystem. Some native and introduced species of algae found in Hawai‘i are:

Red Algae

Gracilaria coronopifolia – native species, endemic to *Hawai‘i* . Has solid, cylindrical branches, 1-2 mm in diameter, with short pointed tips. Extensive branching creates a small bush-like structure up to 15 cm tall. Commonly found on reef flats and eroded limestone up to 4 m deep. One of the most sought after seaweeds for food in Hawai‘i .

Gracilaria salicornia – invasive species. Has solid, cylindrical branches, 2 – 5 mm in diameter. Tends to occur in mats up to 30 cm or broader. Like its native relative, often found on reef flats up to 4 m deep. This species was first introduced in Hilo Bay, Hawai‘i in 1971 and secondarily introduced in *Kāne‘ohe Bay* and *Waikiki, O‘ahu* in the late 1970's. High growth rates make it a successful competitor with other macroalgae such as *G. coronopifolia.*

Green Algae

Codium edule – native species. Is fleshy and erect. Composed of fairly flattened fronds, 1 – 2 cm wide. Soft and spongy to the touch. Occurs intertidally to subtidally on reef flats, attached with a single holdfast. **Codium** species are part of the Hawaiian green turtle's diet. Commonly collected for food in Hawai'i .

Dictyosphaeria cavernosa – native species. Has invasive tendencies. Firm, tough texture, consisting of large bubble shaped cells. Hollow and spherical when young, becoming ruptured and irregularly lobed when old. Found attached to rocks and coral rubble on shallow, calm reef flats and in tide pools. Although native, shows invasive tendencies in reef systems experiencing nutrient enrichment and overfishing. Due to its efficiency in capturing available nutrients in its chambers, they have high growth rates that allow them to overgrow corals in areas where this species is found, such as *Kāne'ohe Bay*.

Brown Algae

Sargassum polyphyllum – native species, endemic to Hawai'i . Tough, bushy and erect, up to 70 cm tall. Blade margins often spiny with spines or wings developing on the upper and lower surface of the blade midrib. Found on wave-swept benches, tidepools and reef flats. Can account for a large part of the biomass in mature algal communities. Because it can withstand a wide range of environmental conditions such as high wave action, high salinity, and changing temperatures, it has the potential to be invasive in other areas in Hawai'i where it is not normally found. This is due to the species potential ability to heavily colonize and adversely affect other habitats.

Turbinaria ornata – native species. Stiff and erect, up to 20 cm tall. Blades conical, hard and thick with a double row of stiff spines around the margin. Usually isolated or in small groups but occasionally forms large, low mats. Found from the mid intertidal to at least 30 m deep in a variety of habitats. The morphological characteristics allow it to survive extreme environmental conditions, which could potentially enable the species to heavily colonize and adversely affect habitats in which it is not normally found, making it a potential invasive here in Hawai'i as well as elsewhere in the world.

For more information on algae found in Hawai'i , go to http://www.Hawaii .edu/reefalgae/invasive_algae/index.htm

How do invasive species affect indigenous species, and why is it important to keep invasive species out of Hawai'i ?[4] (Lessons 4 and 5)

The introduction of a non-**indigenous species**, whether deliberate or accidental into areas where they do not naturally occur, can have severe consequences on the marine environment. For example, invasive species can potentially lead to the loss or severe reduction in the numbers of individual indigenous species. **Invasive species** that become established tend to be strong competitors for food and space, and can potentially carry parasites that are also foreign to the local area, infecting the indigenous species. Over the last few decades, the number of invasive species has increased world-wide as a result of growth in the shipping industry, the introduction of fish and shellfish farming, and demand for exotic fish in the aquarium trade.

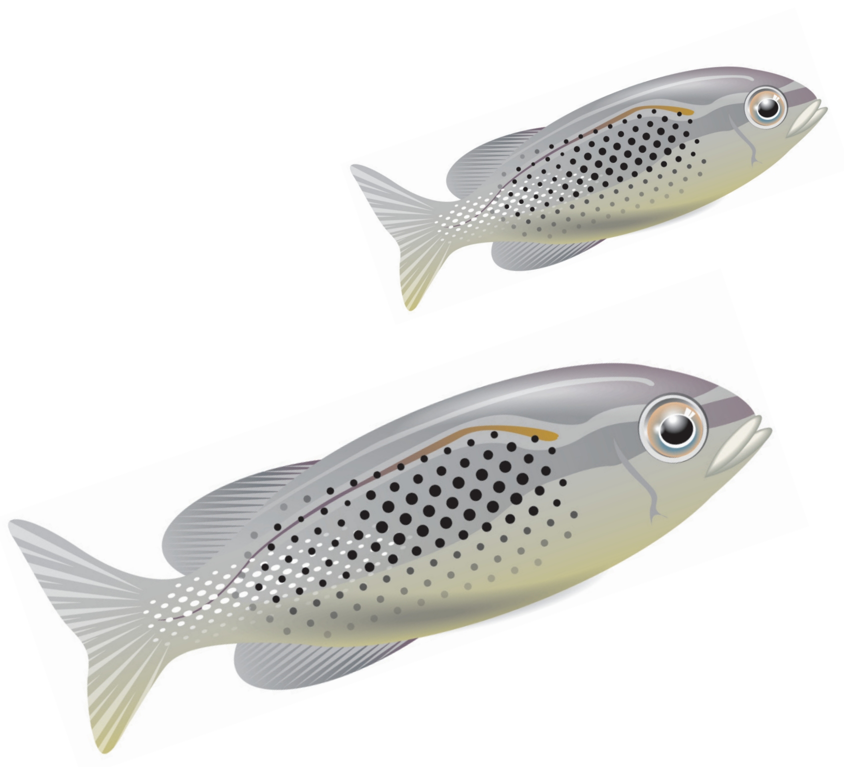
Coastal areas such as bays and estuaries that are utilized for shipping ports are particularly vulnerable to invasive species. Organisms such as seaweeds, sponges, and barnacles grow on the bottom of ships as **fouling organisms**. Once in port, these organisms can detach from the ship and establish themselves in the new environment. Ships stabilize their buoyancy by filling their hulls with ballast water. Planktonic larvae are introduced through the transport of ballast water from one port to another. For example, San Francisco Bay has approximately 250 invasive species, and it is difficult to find an indigenous species in some parts of the bay. One potential problem is that San Francisco Bay is heavily disturbed due to pollution and other human impacts. It is hypothesized that it is easier for an invasive species to become established in an unstable ecosystem because invasive species are more tolerant than indigenous species to wide fluctuations in environmental parameters such as temperature and salinity. One invasive species in the San Francisco Bay, the European green crab (Carcinus maenas) was first detected in 1989. Its range has since expanded along large stretches of the Pacific coast. The green crab is a voracious predator feeding on commercially valuable shellfish. Invasions of the green crab have also occurred in the northeastern coast of the United States, Australia, and South Africa.

Invasive species are a problem world-wide. However, geographically isolated areas, such as the Hawaiian Islands, are particularly susceptible to the harmful effects of invasive species. Prior to human impacts, invasive species were rare due to the isolation of the Hawaiian archipelago. Since the arrival of humans, however, the introduction of invasive species has become a growing problem threatening indigenous species. A recent survey of Hawaiian environments found 343 invasive species, including 287 invertebrates, 24 algae, 20 fish, and 12 flowering plants. Invasive algae species, such as *Kappaphycus striatum,* can be potentially harmful to coral reefs. Introduced in 1974 in *Kāneʻohe Bay, Oʻahu*, *Kappaphycus striatum* spread more than six kilometers (3.73 miles) inside the bay, and has begun to spread outside the bay. Invasive algae species can out-compete coral species for space and light, especially when the invasive species lacks a natural predator in its new habitat. The introduced orange sponge ***(**Mycale armata**)*** is believed to compete for space with native sponges and coral species. In *Kāneʻohe Bay*, this sponge appears to be overgrowing some coral species on patch reefs, especially finger coral ***(**Porites compressa**)***. The Philippine mantis shrimp ***(**Gonodactylaceus falcatus**)*** has been shown to drive out the native ciliated mantis shrimp ***(**Pseudosquilla ciliata**)*** from dead coral heads. Since its introduction, the *Gonodactylaceus falcatus* has almost completely replaced the once common *Pseudosquilla ciliata* in the coral heads on the shallow reefs of *Oʻahu*. For additional information concerning invasive species in *Hawaiʻi* , go to http://www2.bishopmuseum.org/HBS/invertguide/index.htm.

Science Background for the Teacher Glossary

biodiversity: the diversity or variety of plants, animals, and other living things in a particular area or region.
cell: the basic structural and functional unit of all living organisms.
cell membrane: the outer boundary of the cell, helps control what substances enter or exit the cell.
cell wall: a rigid, external coat that surrounds plant cells. It is formed outside the cell membrane and consists primarily of cellulose.
cellulose: a complex carbohydrate present in the cell walls of plant cells.
chloroplasts: organelles found in plant cells and eukaryotic algae that conduct photosynthesis.
cyanobacteria: a group of generally photosynthetic bacteria, also referred to as blue-green algae.
diatoms: unicellular algae with hard silica present in their cell walls.
dinoflagellates: unicellular protists characterized by two flagella of unequal sizes.
DNA: the material inside the nucleus of cells that carries genetic information. DNA is an acronym for *DeoxyriboNucleic Acid.*
ecosystem: all the organisms in a given area as well as the abiotic factors with which they interact; a community and its physical environment.
epipelagic zone: the lighted, open-ocean layer from the surface to approximately 200 meters (656 feet) deep.
eukaryotic: a single-celled or multicellular organism whose cells contain a distinct membrane-bound nucleus.
evolution: all the changes that have transformed life on Earth from its earliest beginnings to the diversity that characterizes it today.
fouling organisms: an assortment of benthic organisms (such as barnacles, sponges, and algae) that settle on boats, clog underwater pipes, and generally cause problems to marine vessels.
herbivores: animals that eat only plants.
heterotrophic: organisms that obtain nourishment from the ingestion and breakdown of organic matter, such as plants and animals.
holoplankton: organisms that are planktonic for their entire life cycle.
indigenous species: species that are native to a region (i.e., occur naturally).
invasive species: species that enter into new ecosystems and spread, causing damage to native species and their habitats.

keystone species: a species whose impact on its community or ecosystem are much larger and more influential than would be expected from mere abundance.
meroplankton: temporary zooplankton, such as the larval stages of some organisms (fishes and crabs, for example).
multicellular: composed of more than one cell.
natural selection: the differential survival, and/or reproduction, of individuals within a population based on hereditary characteristics.
nucleus: the cellular organelle in eukaryotes that contains most of the genetic material, or DNA.
omnivorous: heterotrophs that feed on both plants and animals.
organelles: all the different cell components surrounded by the cell membrane that make up a cell.
pelagic zone: consists of the water above the sea floor and its organisms.
photosynthesis: the process by which plants convert water and carbon dioxide into carbohydrates, using sunlight as the source of energy.
phytoplankton: the component of plankton consisting of microscopic plants.
plankton: a diverse group of animals (zooplankton) and plants (phytoplankton) that freely drift in the water.
predation: the killing and consumption of living organisms by other living organisms.
primary production: the biomass produced through photosynthesis and chemosynthesis in a community or group of communities.
protozoans: single-celled organisms that are animal-like in that they ingest food and usually move around.
red tides: phenomenon associated with population explosions (blooms) of certain types of dinoflagellates; red structures inside the dinoflagellates cause the water to have a reddish color.
unicellular: composed of a single cell.
zooplankton: the heterotrophic form of plankton.



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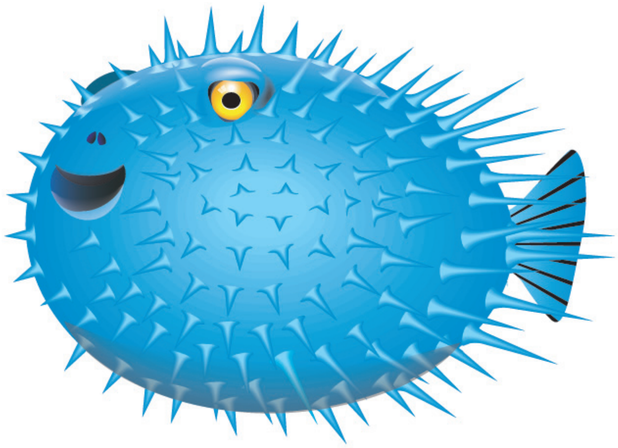


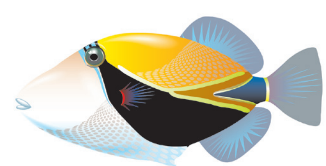
NOAA Resources

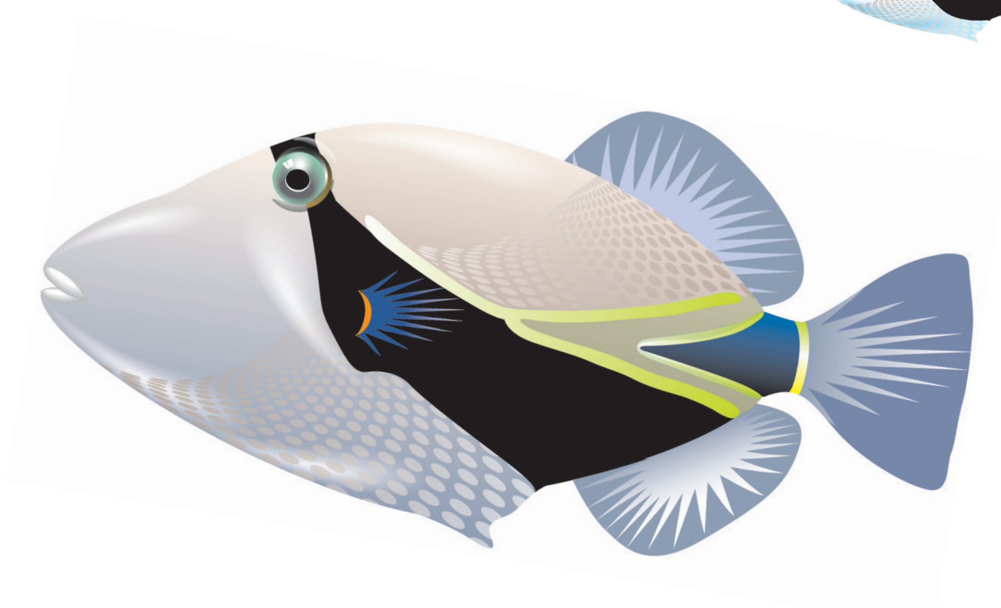
Below is a list of resources compiled by the Outreach Education Office of the National Oceanic and Atmospheric Administration. The science standards and the ocean literacy principles addressed in this unit were used as a guideline in selecting the following resources. To access the print resources listed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

- **Sea Turtles: A Coloring Book in English and Hawaiian developed by NWHI in 1995.**
- **"Catching the Current: Who Goes with the Flow?" poster by NOAA & SE-COSEE**
- **NOAA Fisheries "The Kid's Times" found at http://www.nmfs.noaa.gov/pr/education/turtles.htm and http://www.nmfs.noaa.gov/pr/education/whales.htm**





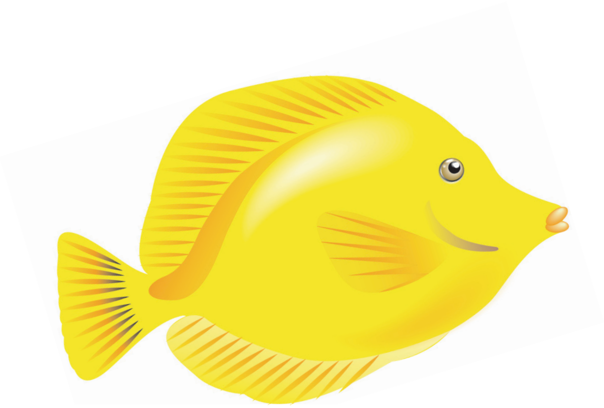
OCEAN LITERACY ESSENTIAL PRINCIPLES

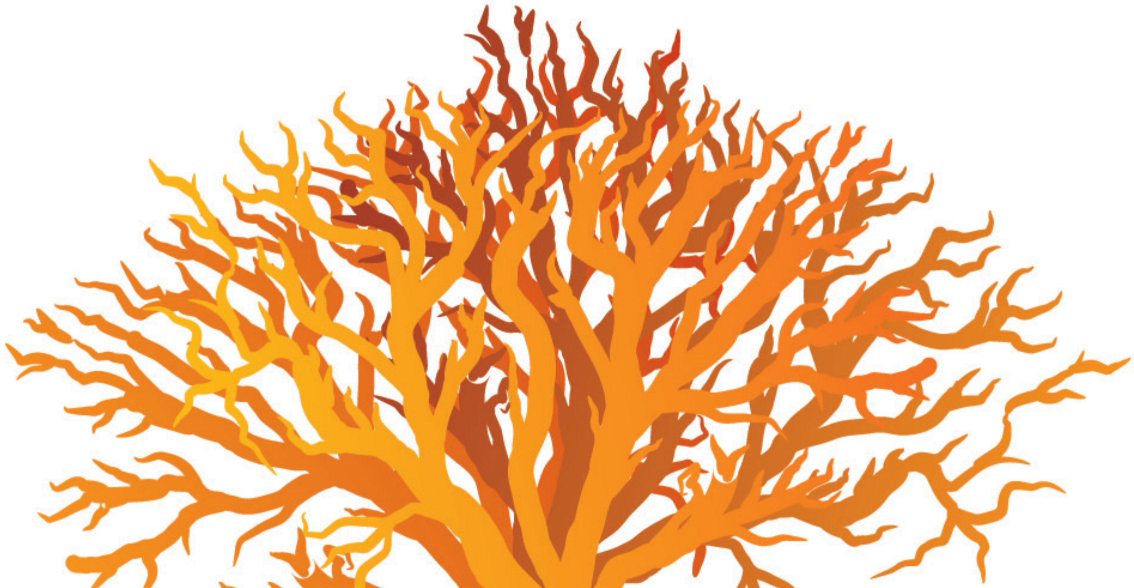
5. The ocean supports a great diversity of life and ecosystems
   - 5a. Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.
   - 5d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
   - 5i. Estuaries provide important and productive nursery areas for many marine and aquatic species.

Lesson 1: 5a. 5d.
Lesson 2: 5a. 5d.
Lesson 3: 5a. 5d.
Lesson 4: 5d.
Lesson 5: 5a. 5d. 5i.

CLIMATE LITERACY ESSENTIAL PRINCIPLES

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





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.