Humpback Fun Facts

Length
Up to 55 feet, with females larger than males; newborns are about 15 feet long

Weight
At birth: 1 ton
Adult: 25 - 50 tons

Diet
Krill, small fish

Appearance
Gray or black, with white markings on their undersides

Lifespan
50 to 90 years

Threats
Entanglement in fishing gear, ship strikes, habitat impacts
The Humpback Whales Educator Guide, created by MacGillivray Freeman Films Educational Foundation in partnership with MacGillivray Freeman Films and Orange County Community Foundation, is appropriate for all intermediate grades (3 to 8) and most useful when used as a companion to the film, but also valuable as a resource on its own. Teachers are strongly encouraged to adapt activities included in this guide to meet the specific needs of the grades they teach and their students. Activities developed for this guide support Next Generation Science Standards (NGSS), Ocean Literacy Principles, National Geography Standards and Common Core Language Arts (see page 27 for a standards alignment chart).

An extraordinary journey into the mysterious world of one of nature’s most awe-inspiring marine mammals, Humpback Whales takes audiences to Alaska, Hawaii and the remote islands of Tonga for an immersive look at how these whales communicate, sing, feed, play and take care of their young. Captured for the first time with IMAX® 3D cameras, and found in every ocean on earth, humpbacks were nearly driven to extinction 50 years ago, but today are making a steady recovery. Join a team of researchers as they unlock the secrets of the humpback and find out what makes humpbacks the most acrobatic of all whales, why they sing their haunting songs, and why these 55-foot, 50-ton animals migrate up to 10,000 miles round-trip every year.

Humpback Whales is produced and distributed by MacGillivray Freeman Films and presented by Pacific Life. A One World One Ocean production, Humpback Whales is directed by two-time Academy Award®-nominated filmmaker Greg MacGillivray (The Living Sea, Dolphins). Run time 40 min. To learn more, visit www.humpbackwhalesfilm.com.

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Humpback whales are found in all of the world’s oceans. They have a vocal range that is among the broadest in the animal kingdom. Although they’re larger than a school bus, humpbacks are among the most acrobatic of all whales, launching themselves out of the water and slapping the surface with their flukes. These water wayfarers journey thousands of miles during annual migrations—but how do they know where in the world’s oceans to go?

All of these facts make humpback whales a fascinating subject, but, despite their huge size, they’re difficult creatures to study. After all, they spend most of their time underwater and out of sight. We are just beginning to understand these ocean giants, but there’s still much to discover. Thankfully, they’ve been brought back from the edge of extinction, giving us the opportunity to learn more.

Humpbacks were hunted for whalebone, meat and oil during the 1800s and 1900s. Because they frequent coastal waters and migrate to the same regions every year, humpbacks were highly vulnerable to commercial whalers. Intensive hunting between the 1920s and 1950s decimated humpback populations, killing hundreds of thousands of the whales, until their numbers were down to only 5 to 10% of their original populations.

But then something changed. Whale biologist Roger Payne and his colleagues dropped a microphone into the sea and captured the remarkable sounds of the humpback and other whales. The recordings of these whale songs were released on vinyl by Columbia Records in 1970, and sold an astonishing 100,000 copies over the next 10 years. The songs helped break down the barrier between humans and whales and laid the foundation for an environmental movement to save the whales. Meanwhile, the International

In response to these measures, most humpback populations have begun to recover. In the summer, humpbacks can be found in cold coastal waters, such as the Gulf of Maine in the Atlantic, the Gulf of Alaska in the Pacific and off Antarctica where they feed and build up their blubber reserves. Most migrate great distances in the winter to calving grounds in tropical or subtropical waters. In fact, humpback whales have one of the longest migrations of any marine mammal. In just 36 days, a humpback can travel from Alaska to Hawaii—a 3,000-mile journey.

But humpbacks’ long migrations now put them at risk. Whales are being hurt or killed by collisions with ships and by becoming entangled in heavy fishing gear. Because they spend much of their lives near shore, what we do onshore affects their well-being and survival. Ocean pollution is impacting their habitat. They still need our protection.

Newborn humpback whales, called calves, weigh up to 2,000 pounds (900 kg) and grow quickly, thanks to their mothers’ highly nutritious milk. When they reach adult size, they’ll eat up to 4,000 pounds a day—and perform a critical role in stabilizing the aquatic food chain. Mothers keep a close eye—and flipper—on their calves, swimming close to them and frequently touching them with their pectoral fins.

The calving grounds are also where humpbacks mate, and their courtship is anything but subtle. Males compete for female attention, sometimes chasing females, making vocal or bubble displays, and thrashing their tails. Sometimes they clash physically, striking each other or surfacing on top of one another. Yet, no scientist has ever observed humpback whales mating or giving birth.

In the 1970s, scientists discovered that humpbacks can be identified through the patterns on the undersides of their tail flukes. This pattern is so distinct that it’s akin to a human fingerprint. Individual whales can now be identified, tracked and studied for years.

Perhaps the most fascinating behavior humpbacks display is their singing. Head down and motionless in the warm winter waters, males sing for hours at a time, repeating the same song again and again. (Females vocalize, too, but only males sing.) A song can be 15 minutes long or more and be heard up to 20 miles away. Within a geographic area, all males sing the same song, but the complex song changes gradually from year to year. As the song changes, all of the whales in that area sing the same new song. Underwater worldwide, humpbacks are singing—but we don’t know how they learn their songs, and are uncertain why they sing at all. We still have much to learn about humpback whales.

As we see in the film, *Humpback Whales*, researchers like Drs. Fred Sharpe, Jim Darling, and Meagan Jones continue to work to understand whale songs and behaviors. People like Ali Takau are committed to conservation, and Ed Lyman and his team risk their lives to save whales from deadly entanglements. Perhaps the film and the activities presented in this guide will inspire your students to love the ocean, treasure its inhabitants, and even inspire one or more to become a conservationist or scientist who will work to protect and better understand the singers of the sea: humpback whales.
OBJECTIVE
Students will learn the role and importance sound plays in the life of humpback whales. They will see spectrograms that display sound, learn that sound travels in waves, and observe the complex structure of humpback whale song. In conclusion, students will create their own song and be introduced to the concept of noise pollution and how it impacts animals that depend on sound to navigate, feed and communicate.

LESSON LENGTH
45 minutes

IN THE FILM
In the film we observe humpback whale behavior at the breeding grounds off Hawaii, where males often compete for the attention of females, and where sound plays a role in male-to-male communication and dominance displays. We also see humpback whales in Alaska practicing a unique group-hunting strategy called bubble net feeding, where they produce sounds and bubbles to herd fish.

BACKGROUND
Marine mammals live in an aquatic environment that often has low visibility. They are often separated by distance. Marine mammals therefore cannot rely on their eyesight to locate food, mates, and for mother and calf to stay connected. Sound travels more than 4 times faster in water versus air, making it an effective tool for whales to communicate. There are a variety of sounds produced by all marine mammals but humpback whales are known for their beautiful, detailed and elaborate songs.

Scientists know that it is the male humpback whales that sing. For years, one theory has been that they sing to attract females. Further research has established another theory, that these songs are male-to-male communication, perhaps to show dominance or their fitness as a suitor for females over other males. The whales sing mainly during the breeding season. All share a similar song structure, although there are subtle changes that occur over the season. Cultural transmission of sound type has been heard among males, where they join each other for short periods and sing, then alter their future song slightly. Researchers have observed that east coast humpback males near Australia adopted the song of western Australian humpbacks, exactly matching their song in just a two-year period.

Sound in the ocean comes from a variety of sources including human use and industries such as geophysical research, oil and gas exploration, low-frequency naval sonar, large container ships, and other ships of all sizes.
including personal watercraft. The impact to whales is still under study. We are increasing our use of the ocean, from extraction of its natural resources to the continued expansion of busy shipping traffic. The underwater noise from those activities contributes to the overall sound pollution heard in the ocean and potentially changes the ability of whales to thrive.

**TO DO**

1. Display or have students enter the *Voices in the Sea* website ([www.voicesinthesea.org](http://www.voicesinthesea.org)) and locate the *Humpback Whale* page previously noted.

2. Explain that you will hear three distinct vocalizations made by humpback whales and observe these sounds in a spectrogram.

3. Play all three calls and ask students to pay attention to the bar that glides left to right as the sounds play through the spectrogram image. This allows students to “see” the sound since the lines are brighter with sound strength and the higher frequency sounds are above the lower frequency sounds.

4. From the *Voices in the Sea* website and *Humpback Whale* page noted above, play the video *Why Do Humpback Whales Sing?* narrated by Dr. Jim Darling who appears in the film.

5. Once students have heard theories about why whales sing, they will learn more about sound in the sea and what is represented in spectrograms. To better understand frequency and the movement of sound traveling in a wave pattern, students will use tuning forks.

6. Give each student group two tuning forks making sure there are two different pitches of tuning forks and two cups of water, preferably contained in clear plastic.

7. Instruct students to hold the tuning fork by the slender base and gently tap the prong portion on the side of the table and insert the prong in the cup of water.

8. Repeat for each tuning fork.

9. Ask students to make observations of the water movement. They will observe disturbance on the surface of the water through splashes, ripples and waves. This is one way to observe how sound travels. They will also see that tuning forks have different frequencies by observing the various levels of disturbance of water. These frequencies sound different, as either high or low sounds, and contribute to the complexity of humpback whale songs.

10. Instruct students that they will be creating their own original song in their small group based on the basics of humpback whale song structures and typical musical song structures.

11. Play the video *Songs of the Humpback Whale* from the *Voices in the Sea* website noted above for students.

12. Discuss as a class the typical music we hear on the radio: songs last only a couple of minutes, there is a repeating chorus, there are stories told in a song, and usually there are two to three verses.

13. In a humpback whale song we hear: songs that last 15 minutes or more sung continuously without interruption from breathing, with 2 to 9 themes in each song, and with each theme repeating 15 to 20 times! Often humpback whales will have song sessions that last for hours.

Researchers use spectrograms to analyze the sounds and songs of humpback whales. This spectrogram shows a 67-second segment of a humpback song recorded in Tonga. One can see that the repeated phrases evolve as the song progresses from one theme to another.
On the breeding grounds, as many as 30 to 40 males can often be seen chasing a single female for reasons that still remain unclear to scientists.

14 Instruct students to each have a piece of paper, to help them sketch their song they will “sing” as a group. They do not have to sing, but they can as a group repeat sentences. Each group of students will perform their song at the same time. This illustrates how all the whales are singing at the same time during the breeding season. Male humpback whales often sing the same songs while creating small, temporary groups.

15 Ask each group to create two verses (sentences) and one chorus (one sentence to repeat twice). When ready, have all the groups “sing” their songs at the same time.

16 Next, pick one student from each group and have them switch with someone in another group.

17 Have students repeat their songs again; the new student added to the group must now sing this new song version. This illustrates how male humpback whales move among each other, learning new songs to stay competitive. You could do another round and have that same group learn the new song from the new singer joining them.

Finally, ask students to sing in their separate groups and have each play another previously recorded “song” from a device. They can also try to sing their song while random noise (from car engines or loud fans or machinery) is played close to them.

18 Engage in a classroom discussion

- What is the advantage of males moving among other competitors? Disadvantage?
- Did the sound played in step 17 have an impact on your group and your ability to sing together? If so, how? What is sound pollution? What are sources of sound in the sea? Answers can be ships, sonar, oil and gas exploration air guns. Can this impact whales? How?
- To further discuss man-made sound in the ocean and impacts on marine mammals, go to Voices in the Sea website home page, select Videos; then Conservation Efforts, then Beaked Whales and watch this summary video narrated by Dr. John Hildebrand.
OBJECTIVE
Students will practice being scientists responsible for identifying individual whales by matching photos of whale flukes. They will track and map the migration patterns of whales while calculating distances covered and discuss threats whales face during migration.

LESSON LENGTH
45 minutes

IN THE FILM
In the film, we see footage of humpback whales in different geographic regions and learn there are 15 separate global populations. We witness humpback whales traveling far distances to breed in one region and feed in another, as seen in the North Pacific population of humpback whales that spend the winter in the Hawaiian Islands and summer in regions mostly off Alaska. All whales generally breed in warmer waters near the equator and feed in colder regions. We also see the large ships and numerous small private vessels that whales encounter during migration and in their seasonal habitats.

MATERIALS
□ Copies of Migration Match Fluke Cards and the Migration Map worksheet
□ Ruler for measuring during mapping activity
□ Globe or world map (optional) for students to refer to during migration measuring exercise
□ Paper for notes
□ Pen or pencils

TEACHER PREP NOTES
For each group of five students, make one copy of the Migration Match Fluke Cards. Cut out each square to make a pack of “cards” and bind together for storing. Each student needs a copy of the Migration Map to complete the lesson.

BACKGROUND
Having a complete understanding of an animal’s requirements for survival is critical to ensure the long-term survival of a species. Scientists want to know about individual whales in order to monitor their behavior and life cycle. Tracking individual animals in the ocean is difficult due to time spent underwater by the animals, their movement, ocean conditions, and not having consistent access to the areas where the animals might be. Technology has enabled researchers to attach satellite-monitored tags to whales to track their movements across oceans, and small DNA samples can be used to identify individual animals. However, the most long-standing methods for identifying (and tracking) humpback whales is through photo-identification.

Humpback whales have specific patterns of markings on their bodies and tail flukes. These distinguishing characteristics are coloration, variations of white, gray or black, nicks, notches, scars and sometimes barnacle patterns. These patterns are genetically determined, and populations in different regions can share similar body coloration. For example, humpback whales in the Southern Hemisphere have a large proportion of white on their bodies. By photographing, cataloging, and tracking individuals we can learn about life span, population numbers, mating, birthing, and migration patterns. Humpbacks are found in populations around the world and spend summer months feeding in cold, nutrient-rich water and winter months in tropical, warm water to mate and give birth. These migration routes can be up to 5,000 miles one-way in distance with whales utilizing the same feeding and breeding grounds year after year.

The migratory routes of humpback whales have distinct overlap with global shipping lanes. Collecting exact data on the number of ship strikes on whales is difficult since deceased whales often sink to the ocean floor. There is growing observation of scars on whales from boat strikes and reports of deceased whales, floating or beached, with evidence of ship strikes. Humpback whales often inhabit coastal areas, making them especially susceptible to being struck by vessels.

KEY WORDS
Population—The number of individuals in a specific species in a single area.
Fluke—The end tip of a whale tail made up of two lobe structures. While the thick tail peduncle contains bones, the fluke does not.
Migration—The movement from one geographic location to another. Animal migrations are often seasonal.
Shipping Lanes—A route used by commercial ships on a regular basis.
TO DO
1 Have a classroom discussion about humpback whales, leading with questions: Do whales stay in one region of the ocean year round? Why or why not? Why would it be important to know why animals move between locations? Why do researchers want to keep track of individual whales? How do you think they do this? Do all humpback whales look alike? Why or why not?

2 Instruct students they will be working in a small group of five students. The first activity challenges them to match whale flukes, just like scientists. The whale fluke photos are from film scientist Fred Sharpe’s archives. Two of the whales, Vulture and Melancholy, actually appear in the film.

3 Each student will receive a fluke card with the name of a whale on it. Names are: Captain Hook, Vulture, Melancholy, Arpeggio and Viking Petal. Give the group the remaining 12 cards from the set. Each student’s fluke will match two other images in the set. (There are also two cards in the set that don’t match anything.) The flukes on these cards were photographed from different angles and time periods, and some are in black and white, so identifying individual whales may not be as easy as it first seems. To aid students, explain the distinguishing characteristics of humpback whale flukes, highlighting shape, coloration and scratch pattern.

4 In each group, lay all twelve cards out, image side up. Students can take turns choosing which fluke image matches their named whale, one card per round. Students can help each other, if necessary. An answer key is found on the first card in the card deck.

5 For the second activity, ask students to locate Alaska and Hawaii on the Migration Map. A line is already drawn between these two locations, with “3,000 miles in 36 days” noted on the map. This is the time it took one whale to travel this distance—the fastest on record.

6 Ask students to calculate how many miles per day the whales in Alaska must travel to reach Hawaii in 36 days. (Answer: 83.3 miles per day)

7 Note the other whale migrations on the map (around the globe), with lines already drawn.

8 Have students take a ruler and measure the distance between the two migration points on the map (Or use a globe to measure the distance for even greater accuracy.) Students will then take the ruler and lay it against the distance chart on the map to measure the miles between the various sites and record it on the Migration Map.

9 Students will then calculate the distance whale populations travel one way and then round-trip for each migration. Mark each figure on a piece of paper. Now knowing that a humpback whale can travel 83.3 miles per day (from step 6), ask students to calculate how long it takes other populations to reach their destination one-way?

10 Discuss as a class: what are the threats whales might face during migration?

11 Refer students back to the Migration Map and have them locate the shapes found on the maps (triangles, circles, etc). Have them draw a line between the same colored shapes. (For example, draw a line between the two triangles, between the two circles, etc.) These shapes represent the major ports around the globe where large container ships transport goods to support global trade. Ask students: What do they notice about the routes both the whales and the ships take? Are there any risks ships pose to the whales? Show students photos of humpback whales with scars from ship propellers.

12 Discuss how ship strikes are a continuing threat to many species of whales. Agencies across the U.S. are looking at changing the lanes of shipping vessels to avoid areas frequented by whales and introducing speed restrictions. In 2013, the ports of Los Angeles and San Francisco made changes to their shipping lanes in an effort to reduce ship strikes on whales.

TAKING IT FURTHER
1 For older students: Have students do group or independent research on the port regions across the globe addressing the issues of whales and ship strikes. Students can choose geographic locations for their research and report their findings to the class as ongoing updates and as events happen.

2 For younger students: Have students record the distances various humpback whale populations travel during their annual migration. Ask students to keep a log for one week of their own “migration.” Using their family’s car odometer, personal pedometer, or smart device app, they can track the distances they travel by car, foot, and public transportation. How does their migration compare to a humpback whale?
Migration Match
Fluke Cards

Migration Match Key: Unmatched: F, J; Viking Petal: O, B; Vulture: K, N; Arpeggio: A, G; Captain Hook: M, P; Melancholy: I, D

Photos courtesy Fred Sharpe, Ph.D., Alaska Whale Foundation
NMFS Research Permit No. 14999
ANATOMY AND ADAPTATION

OBJECTIVE
Students will observe anatomy form and function and how it relates to an animal surviving in their habitat. They will craft their own species of plankton to observe adaptations of marine organisms. Students will practice a variety of hands-on experiments to discover feeding strategies of various marine mammals, including the unique behavior seen in humpback whales called group bubble net feeding. In addition, they will observe adaptations humpback whales possess to thrive in the ocean in a variety of temperatures.

LESSON LENGTH
60 minutes (3 activities)

IN THE FILM
In the film we see the majestic humpback whales excelling in the ocean environment. We see groups of whales cooperatively feeding, creating elaborate nets of bubbles as a team to herd their prey. We see their ability to leap out of the air in acrobatic breaches, and observe how they can make a statement to other whales through “pec” slaps (pectoral flipper slaps) and tail slaps. In the film humpback whales are shown swimming across ocean basins to feed in one area near the poles and breed in another region closer to the equator.

TEACHER PREP NOTES
This lesson has three activities that focus on exploring adaptations by marine organisms.

The Plankton Activity explores buoyancy and an ocean organism’s use of appendages. Many species of plankton are in the upper water column since they either photosynthesize or feed upon photosynthetic organisms. Without large muscular bodies plankton rely on structures such as cilia and flagella to stay afloat.

The Marine Mammal Warmth and Buoyancy Activity looks at the function of blubber and fur in providing warmth for marine mammals.

The Lunch With a Whale activity looks at the function of blubber and fur in providing warmth for marine mammals.

BACKGROUND
Humpback whales are mammals, like humans. They possess the five characteristics shared by all mammals: warm-blooded, vertebrates, air breathing, hair or fur at

MATERIALS
☐ Visit the Humpback Whales film website to watch the Humpback Whales Bubble Net Feeding video (www.humpbackwhalesfilm.com/education/bubblenetting). Project on screen or students can watch the video on individual devices.
Each student group will need:
Plankton Activity:
☐ Two graduated cylinders filled to top measurement with water
☐ Sculpey Clay (each student is given a nickel-size ball to act as plankton body)
☐ Toothpicks, pipe cleaners, and feathers to act as plankton appendages and cut into very small pieces in order to fit plankton into the graduated cylinder
☐ Stopwatch or timing device
☐ Video of plankton (see links below in activity “To Do”)

Marine Mammal Warmth and Buoyancy Activity:
☐ One large bowl
☐ Two Ziploc bags
☐ 1 - 2 cups of Crisco or other cooking shortening
☐ One thick sock and one thin sock

Lunch With a Whale Activity:
☐ Dried parsley flakes (6 tablespoons)
☐ One large bowl
☐ Tablespoon measuring spoon
☐ Measuring cup
☐ Two paper towels
☐ One large hair comb
☐ Four straws
The Secret Life of Plankton. (www.ted.com/talks/the_secret_life_of_plankton/) The video is six minutes long and can also be found on the Ted-Ed YouTube page (www.youtube.com/watch?v=xFO_fO2D7f0).

2 Have students construct plankton using a small ball of Sculpey Clay as the plankton’s body. Pipe cleaners, feathers, and toothpicks will act as the appendages that help plankton move and stay buoyant.

3 When ready to test their plankton, have students drop their plankton in the graduated cylinder at the same time and observe. Which plankton floats closest to the surface and stays there for the longest time?

4 Have students discuss their observations and how they can modify their plankton to increase buoyancy.

5 Modify and repeat.

6 Discuss how marine mammals move and stay buoyant. (They have fins, flippers for swimming and blubber to help them stay afloat). Ask students to compare how whales move to the way plankton move. If whales were the size of most small plankton, would they look the same? What if plankton were the size of a whale?

TO DO

Plankton Activity:

1 Ask students if they can define and describe plankton. Follow with video of plankton from the Ted-Ed lesson.

2 Have students construct plankton using a small ball of Sculpey Clay as the plankton’s body. Pipe cleaners, feathers, and toothpicks will act as the appendages that help plankton move and stay buoyant.

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The Secret Life of Plankton. (www.ted.com/talks/the_secret_life_of_plankton/) The video is six minutes long and can also be found on the Ted-Ed YouTube page (www.youtube.com/watch?v=xFO_fO2D7f0).

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1. To observe blubber, students will be making their own insulation glove. Have students place shortening in one Ziploc bag and spread it along the sides and bottom. To minimize mess in assembly students can use the second plastic bag as a glove. (Option: make several gloves ahead of time. Use duct tape to secure two Ziploc bags with Crisco in between. Students can share these gloves.)

2. Fill one of the large bowls with ice and water to mimic the ocean temperature in polar regions.

3. Students will take turns putting their hand in the clean and empty Ziploc bag, then in the blubbery glove, and into the ice water.

4. Have them take turns placing their hand, now wearing the glove, in the cold water making sure they leave the top of the bag out of the water so no water leaks in.

5. When they have their gloved hand in the water, ask students to place the other hand in the water as well. Lead a discussion: What do you notice? Which hand is warmer? Not all marine mammals have skin and blubber like whales do. What other types of marine mammals are there? (Seals, sea lions, sea otters, the polar bear). What do they have to help stay warm? (fur)

6. To feel the difference between blubber and fur for warmth, have students take turns putting the sock on one hand and blubbery glove on the other as well as alternating with a bare hand. Try different thicknesses of socks so they can see how fur thickness plays a role in marine mammals’ ability to stay warm.

Lunch With a Whale Activity:

1. Take one large bowl and fill it with water. Sprinkle two tablespoons of parsley flakes on top. This represents krill in the ocean.

2. Ask students to scoop up parsley with the measuring cup and pour through the comb, so parsley gets stuck in the prongs of the comb. This is an example of gulping and filtering small prey such as krill and herring in the baleen bristles of humpback whales.

3. Wipe off parsley on to paper towel.

4. Students will now add more parsley to the bowl and use the straws.

5. Instruct students to work as a group, using straws, to gently blow into water to push parsley toward the center of the bowl.

6. Once most of the parsley is in the center of the bowl they can use the measuring cup to scoop up the parsley and filter it over the comb. Wipe the parsley on the other paper towel.

7. Ask students which method collected more parsley? Was there a difference? What did the two different strategies represent? Visit the Humpback Whales film website to watch the Humpback Whales Bubble Net Feeding video (www.humpbackwhalesfilm.com/education/bubblenetting) and discuss the behavior of the whales.
LESSON 4

Bioaccumulation: It All Adds Up

OBJECTIVE
In this lesson students will create a representation of how energy flows and cycles through a food web containing a humpback whale. Using magnets of various sizes they will swim and feed through an ocean food chain and after each feeding session count the quantity of toxins attached to their predator (large magnet). By recording these numbers they will see the numeric accumulation of toxins, representing bioaccumulation.

LESSON LENGTH
60 minutes

IN THE FILM
In the film we hear how the future of humpback whales in the Southern Ocean depends on the health of the Antarctic ecosystem. We learn that having a healthy calf population now is what makes possible a healthy and abundant whale population in the future. One concern is how the abundance of toxins in the food chain can negatively impact the health of whales as well as humans who consume seafood.

MATERIALS
Each student group will need:
☐ One large bowl or baking pan with sides to hold a box of BBs
☐ One small bowl to hold large magnets
☐ Each student (or each pair of students) needs one large magnet
☐ Steel BBs that are coated with copper or brass to prevent rust. These will act as the lower trophic level organisms (such as bait fish) in the activity.
☐ Internet availability and projector to view websites, or individual student devices
☐ A copy of the Food Pyramid and Bioaccumulation worksheet and the Ocean Food Web worksheet (optional).

TEACHER PREP NOTES
Students will learn the concept of food chains and the linear relationship and order of who eats whom in the ocean. They will also learn the concept of bioaccumulation in that it takes thousands of plankton to create a small fish and then hundreds of thousands of small fish to create an adult humpback whale. Each student group needs one medium-to-large (2 to 3-inch) magnet to represent a consumer. The BBs represent the toxins in the ocean that are absorbed by producers or ingested by consumers. (Online retailers sell small cartons of BBs and various sizes of magnets.) It is recommended to complete Lesson 3: Anatomy and Adaptation before this lesson as there is an in-depth introduction to plankton as the base of the food web.

BACKGROUND
Bioaccumulation of toxic chemicals in ocean life comes from humans introducing chemicals through runoff pollution directly from land into the ocean or rivers. Once in the food chain, toxicity increases as energy moves up the food chain. If a medium size fish eats 10 small fish, then toxins in the medium fish can accumulate 10 times. Some of the most harmful toxins to humans and ocean animals such as whales include mercury, pesticides, and persistent organic pollutants (POPs). POPs stay in the environment for decades and in humans have been linked to impaired immune systems and developmental problems in young children. In the activity below students will write their data in an upside down triangle, which is the opposite of how we usually see food pyramids. Instead, this version shows the accumulation of toxins in the top predator. This activity also begins with a discussion of food chains and the roles organisms play in the food web. Consumers are organisms that eat primary producers and can be arranged in levels based on their prey choice. Primary consumers feed on producers, secondary consumers feed on the primary consumers, and tertiary consumers feed on secondary consumers. Examples include:
- **primary producer**—organisms, like plants, that produce food. Examples: phytoplankton, algae
- **primary consumer**—an animal that eats primary producers. Examples: krill, small fish, mussels

KEY WORDS

| Food Chain | A group of organisms linked in order by the food they eat, from producers to consumers and decomposers. |
| Food Web   | A food web consists of all the food chains in a single ecosystem. |
| Producer   | Organisms that make their own food and do not depend on any other organism for nutrition. In the ocean these are single-celled plant-like plankton (phytoplankton) and algae. |
| Consumer   | An organism that eats another organism, with the food choice being plant or animal. |
| Decomposer | An organism that breaks down dead plant and animal material, releasing the minerals and nutrients from organic material and recycling them back into the food web. |
| Bioaccumulation | A process by which chemicals are taken up by an organism either directly from exposure to a contaminated medium or by consumption of food containing the chemical. |
Instruct students to take the numbers in the pyramid and multiple by 100 as an estimate of daily minimum feeding requirements.

Discuss: What are examples of toxins? Where do they come from? How do they get in the ocean? Which animals have the highest number? The pyramid shows the quantity of plankton it takes to feed the top predator and others on the food pyramid. It also shows the amount of toxins that are now in the body of each animal, showing the concept of bioaccumulation.

Why did we draw an upside down pyramid? (to show the amount of toxins that accumulate in the top predator). What impact might this have on humpback whales’ health? To the health of calves born to mother whales feeding on fish with higher toxins? Who else eats fish? Is there the potential for this to impact humans that eat seafood?

Go to the One World One Ocean.com website and locate the Sustainable Seafood: Why It’s Good for Your Health infographic. (Go to Media, then Infographics) (www.oneworldoneocean.com/blog/entry/seafood_and_your_health_infographic)

Project the image on the board and discuss as a conclusion to the activity:
■ What toxins are harmful to humans?
■ In what seafood choices are those toxins found?
■ What are the better choices of seafood to make for your own health?

To view and discuss impacts of toxins and diseases on marine mammals, visit the website home page for Voices in the Sea and select the videos section Issues in Focus and watch the short video titled Unusual Mortality Events (cetus.ucsd.edu/voicesinthesea_org/index.html).

**TO DO**

1. Lead discussion on food chains and write student examples on the board (it can be terrestrial if that is most familiar to students). Ask students to give examples of “who eats whom” starting with plants and moving up to the final consumer.

2. Ask students to give the same examples of food chains found in the ocean. Review the Food Pyramid and Bioaccumulation worksheet for examples of primary producers, primary consumers, etc.

3. (Optional) Hand out the Ocean Food Web worksheet and ask students to complete it.

4. Instruct students to take one large magnet (a krill) and swim through the water with the BBs (the ocean where they feed on plankton).
   - Count the number of BBs attached to the large magnet. These represent the number of plankton and the number of toxins ingested. Write the number on the bottom (point) section of the pyramid on the Food Pyramid and Bioaccumulation worksheet. (1 swim through ocean = 1 krill eating phytoplankton).

5. Repeat using the steps below:
   - Swim the magnet through the BBs 3 times and record the number of attached BBs in the middle section of the pyramid. (3 swims through the ocean = 1 small fish eating lots of krill)
   - Swim the magnet through the BBs 5 times and record the number of attached BBs in the top of the pyramid. (5 swims through the ocean = humpback whale eating thousands of small fish or krill)

6. Lead the discussion asking: How many fish do you think humpback whales eat a day during the feeding season? Several hundred? Several thousand? (Whales can eat up to 2,000 pounds of food a day). How about the fish eating plankton? How many a day?

**ANSWER KEY:**

- **secondary consumer**—an animal that eats primary consumers. Examples: humpback whale, sardines
- **tertiary consumer**—an animal that eats secondary consumers. Examples: shark, dolphin, tuna
- **decomposer**—organisms that break down dead plant and animal material and wastes and release it again as energy and nutrients in the ecosystem. Examples: bacteria, sea cucumbers, worms, crabs

TO DO

1. Lead discussion on food chains and write student examples on the board (it can be terrestrial if that is most familiar to students). Ask students to give examples of “who eats whom” starting with plants and moving up to the final consumer.

2. Ask students to give the same examples of food chains found in the ocean. Review the Food Pyramid and Bioaccumulation worksheet for examples of primary producers, primary consumers, etc.

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**Bioaccumulation**

- **Humpback Whale:**
  - **Small Fish:**
    - **Krill:**
      - **Tertiary Consumer:**
        - **Secondary Consumer:**
          - **Primary Consumer:**
            - **Primary Producer:**
              - **Decomposer:**
                - **Sea Worm**
                - **Sea Cucumber**
                - **Crab**
                - **Photoplankton**
                - **Algae (Kelp)**
                - **Krill**
                - **Sardine**
                - **Tuna**
                - **Sea Cucumber**
                - **Sea Worm**
                - **Crab**

**Tertiary Consumer:**
- **Dolphin**
- **Tuna**

**Secondary Consumer:**
- **Humpback Whale**
- **Sardine**

**Primary Consumer:**
- **Krill**

**Primary Producer:**
- **Photoplankton**
- **Algae (Kelp)**
THE OCEAN FOOD WEBS

Next to each animal, list if they are a primary producer or primary consumer or secondary consumer or tertiary consumer or decomposer. Then draw a line between an organism they eat and any organism that eats them.
LESSON 5

“WHALE SAFE” ENGINEERING CHALLENGE

OBJECTIVE
This lesson will present a design challenge to students to solve in teams in order to create ideas, strategies and equipment that can lessen the impact of fishing gear and the entanglement of whales.

LESSON LENGTH
45 minutes

IN THE FILM
The National Oceanic and Atmospheric Association (NOAA) along with their partners have created a program to respond to entangled and distressed whales. This network of highly trained individuals can be found in several U.S. states. In the film we join the response team in the Hawaiian Islands as they work to free an entangled humpback whale.

MATERIALS
☐ On the Voices in the Sea website (www.voicesinthesea.org), select Videos in the top menu bar, then Issues in Focus, then Whale Entanglement. View the Entanglement video, either projected for the entire group, or individual students can use internet capable devices.
☐ Another option to view is on the NOAA fisheries website, How to Disentangle a Tangled Up Whale, a 9-minute podcast showing a real whale rescue in Hawaii. (www.fisheries.noaa.gov/podcasts/2014/03/disentanglement_whale.html#.U_O0Kyj_SI4)
☐ The International Smart Gear Competition page on the World Wildlife Fund website. (www.worldwildlife.org/initiatives/international-smart-gear-competition)
☐ Each student group needs a copy of the Whale Entanglement Threats handout.
☐ Photos of whales entangled in rope and nets and different kinds of commercial fishing gear and crab pots.
  ▪ A resource for photos and videos is the International Whaling Commission website and the Entanglement of Large Whales gallery page. (www.iwc.int/entanglement-gallery) (Note: There are several images on this page that take time to load, however most of the images you will need are at the top of the page and load first.)
  ▪ A resource for discussing marine debris and “ghost nets” is a website called The Ghost Below, an outreach partnership between artists and The Marine Mammal Center (www.theghostbelow.org and www.marinemammalcenter.org/)
  ▪ Paper
  ▪ Pens and pencils

TEACHER PREP NOTES
This lesson has multiple websites for students to access or view as a group, so preloading the websites and videos onto computers and/or devices would save time. Make a copy of the Whale Entanglement Threats handout for each student to refer to during the group design challenge.

BACKGROUND
Humpback whales are a global population. They swim throughout ocean basins as they migrate between feeding and breeding grounds. They also spend time near coastlines, giving birth in shallower waters or feeding in productive waters offshore. Due to the vast travel and time spent near shore, they have a high interaction with commercial fishing activities. For the humpbacks that live in the North Pacific, it’s estimated that 50% of whales have been entangled at some point in their lives based on the observations of scar patterns on their bodies.

When humpback whales become entangled in large fishing nets or long ropes from crab fishing gear, it can lead to death. The weight of the gear can cause whales to struggle to stay at the surface to breathe and can prevent them from diving to feed. If a calf becomes entangled, it may be unable to swim alongside or nurse from its mother. Entanglement is one of the main human-caused deaths to humpbacks. Every year hundreds of thousands of whales, dolphins, seals and sea lions die from entanglement. What entangles marine mammals is diverse, ranging from various plastics, discarded fishing gear such as monofilament line used by recreational and commercial fishermen and the large nets and ropes used in commercial fishing. Another cause of mortality is the infection from injuries caused by lines or nets cutting into the whale’s flesh.

KEY WORDS
Bycatch—Animals and other organisms unintentionally caught in commercial fisheries and not kept for consumption or use. To include marine mammals in the definition, NOAA added “Discarded catch of any living marine resource, plus the unobserved mortality due to a direct encounter with fishing gear.”

Derelict Fishing Gear (Ghost Nets)—Derelict fishing gear, sometimes referred to as “ghost gear” or “ghost nets,” is any discarded, lost or abandoned fishing gear in the environment.
Pass out the Whale Entanglement Threats handout to each student group and instruct that they will be creating a paper and pen design of fishing gear that can lessen humpback whale entanglements and other bycatch.

**Things for them to consider in regards to gear:**
- Rope and nets that have drifted off and are unable to be found by fishermen are known as “ghost nets.” These nets and ropes float the world’s oceans and get tangled in one another, creating even larger and heavier masses that ensnare wildlife.
- Floating lines from gear such as crab pots come up from the seabed and can entangle whales at the surface.
- Nets and ropes are strong and durable making it impossible for whales to break themselves free.
- They are made of materials that are long-lived and do not decompose or break down, making them a threat for years.

**TO DO**
1. Visit the website Voices in the Sea (www.voicesinthesea.org), and in the top menu bar select Videos, then Issues in Focus and select the Whale Entanglement video. Or you can view a 9-minute video on the NOAA Fisheries site, *How to Disentangle a Tangled Up Whale*, featuring Ed Lyman, a whale rescuer seen in the giant-screen film.
2. Lead a classroom discussion: What is entangling the whales? Where does it come from? Do you think the whales can free themselves? Why or why not? Why do you think it harms whales to be entangled? What can we do to help?
3. Visit the World Wildlife Fund website and the page *International Smart Gear Competition*, a worldwide incentive-based competition with the aim of reducing species bycatch by improving fishing gear. Project the website onto the board and read the Overview, watch and read the slideshow under *Why it Matters*. View several examples of past winners.
4. Discuss the modifications that have already been made to gear in order to reduce bycatch. Circle hooks are designed to cause less harm to the animal that swallows them (they can be pulled out versus a typical hook that is deep-hooked). Turtle Excluder Devices (TEDs) are part of trawl nets that drag along the bottom of the ocean floor to catch shrimp. When a sea turtle or other large animal hits the bars, they are sent out an opening in the net.
5. Show students photos of commercial fishing gear and of entangled humpback whales. A resource for photos and videos is the *International Whaling Commission* website under the *Entanglement of Large Whales* gallery (www.iwc.int/entanglement-gallery).
6. Pass out the Whale Entanglement Threats handout to each student group and instruct that they will be creating a paper and pen design of fishing gear that can lessen humpback whale entanglements and other bycatch.
7. Things for them to consider in regards to gear:
   - Rope and nets that have drifted off and are unable to be found by fishermen are known as “ghost nets.” These nets and ropes float the world’s oceans and get tangled in one another, creating even larger and heavier masses that ensnare wildlife.
   - Floating lines from gear such as crab pots come up from the seabed and can entangle whales at the surface.
   - Nets and ropes are strong and durable making it impossible for whales to break themselves free.
   - They are made of materials that are long-lived and do not decompose or break down, making them a threat for years.
8. Students will share their design and suggestions as a group to the rest of the class.

**TAKING IT FURTHER:**
1. Consider having students build a prototype of the device that they designed. Prototypes could be created using recycled materials.
2. Bycatch and fishing methods threaten the sustainability of numerous species of ocean wildlife. Students can do online research on sustainable seafood choices and print or download materials to share with their families on the following websites:
   - One World One Ocean campaign’s *Go! Fish* initiative (www.oneworldoneocean.com/initiatives/gofish)
   - Monterey Bay Aquarium Seafood Watch (www.seafoodwatch.org/cr/seafoodwatch.aspx)
OBJECTIVE
Students will watch videos on whaling, both commercial whaling and subsistence whaling. They will note the similarities and differences of these whaling practices. Students will research what has led to the extinction and current endangerment of different whale species and what steps have been taken to protect them. Students will examine and discuss their own role in species protection and how their daily lives impact the greater global conservation picture.

LESSON LENGTH
60 minutes

KEY WORDS
Commercial Whaling—The hunting of whales for consumer products (oil, meat, fat, and bone for monetary profit).
Subsistence Whaling—The hunting and collection of whales to support the nutritional and cultural life of native peoples and not-for-profit purposes.
Endangered Species—The classification provided to an animal or plant in danger of extinction within the foreseeable future throughout all or a significant portion of its range.
Extinct—A species no longer in existence.

IN THE FILM
Humans once hunted whales extensively for products. In the film we learn that due to these practices we brought humpback whales to the brink of extinction. Our evolving interactions with whales have moved toward appreciation, observation and awe. Ecotourism-based whale-watching programs and cultural traditions that respect animals, as we see in Tonga, have led to an increased understanding of whales.

BACKGROUND
In 1946, the International Whaling Commission (IWC) was created to manage whaling. Forty years later, the IWC enacted a moratorium that limited the number of whales being killed. Most countries have ceased whaling completely, while a few others have continued. Some subsistence whaling by native peoples continues as well. Because of these protections humpbacks are making a slow recovery. As of 2014, some humpback populations are being reviewed for possible removal from the endangered species list.

TO DO
1. Go to the Voices in the Sea website. (cetus.ucsd.edu/voicesinthesea_org/species/baleenWhales/humpback.html). (Home Page, then Species, then Baleen Whales, then choose Humpbacks).
2. Watch the short Humpback Whale Conservation video and have a class discussion: For what products were humpback whales being hunted? (primarily oil, and sometimes meat and bonemeal) Did whaling impact the total global numbers of humpback whales? What does it mean when a species is endangered?
3. On the Voices in the Sea website home page, project and watch the Modern Whaling and Subsistence Hunting videos. (Home Page, then Videos, then Issues in Focus, then two brief videos.)
4. Have students discuss: Does whaling still exist? Where? Why? What is the difference between scientific permit whaling (which Japan practices), commercial whaling, which Iceland and Norway still practice under the IWC’s “objection” procedure, and
subsistence whaling, such as the Inupiaq practice in the United States Arctic? How are they similar? How are the whales caught in both examples of whaling (scientific permit whaling and subsistence whaling)? What needs are met by subsistence whaling? What is an endangered species?

5 Instruct students they will research a now-extinct species or a current endangered species to find out more about the factors that led to the population decline, what actions were taken to protect the species, and the status of closely related species.

6 Students will share their results with the class.

7 In conclusion, lead a discussion with students asking them to explain their role in conservation. What can we do to protect all species? Protect ecosystems?

Although now protected by the International Whaling Commission’s ban on commercial whaling, humpbacks, like the sperm whale above, were once hunted for their meat, blubber and bone.

Today, whale watching is a popular tourist activity in countries all over the world, with regulations varying from fairly strict to none, depending on the country. People remain fascinated by these enormous creatures whose lives are so hidden from our own.
RESOURCES TO LEARN MORE

ALASKA WHALE FOUNDATION
alaskawhalefoundation.org
The Alaska Whale Foundation (AWF) was founded in 1996 by a team of passionate individuals who wanted to shed light on the amazing behaviors of the endangered humpback whales in Southeast Alaska. AWF continues to study humpbacks and their habitat, but with greater resources, established scientists, and ambitious graduate and undergraduate student participants.

AMERICAN CETACEAN SOCIETY
acsonline.org
The American Cetacean Society believes that the solution to threats facing cetaceans begins with education. Whales, dolphins, and porpoises (collectively known as ‘cetaceans’) have an exceptional ability to inspire people and serve as ambassadors for marine conservation. And yet they face more threats today than ever before—from entanglement in marine debris and fishing gear, ship strikes, noise pollution, climate change, ocean acidification, contaminants, loss of habitat and whaling.

DISCOVERY OF SOUND IN THE SEA (DOSITS)
dosits.org
The Discovery of Sound in the Sea website will introduce the science and uses of sound in the sea. There are several major sections on the site such as The Science of Sound in the Sea, People and Sound in the Sea, and Animals and Sound in the Sea. The Discovery of Sound in the Sea website has been developed by the University of Rhode Island’s Graduate School of Oceanography in partnership with Marine Acoustics, Inc. of Middletown, RI.

HAWAIIAN ISLANDS HUMBACK WHALE NATIONAL MARINE SANCTUARY
hawaiihumpbackwhale.noaa.gov/explore/humpback_whale.html
The Hawaiian Islands Humpback Whale National Marine Sanctuary was created by Congress in 1992 to protect humpback whales and their habitat in Hawaii. The sanctuary, which lies within the shallow (less than 600 feet), warm waters surrounding the main Hawaiian Islands, constitutes one of the world’s most important humpback whale habitats. Through education, outreach, research and resource protection activities, the sanctuary strives to protect humpback whales and their habitat in Hawaii.

INTERNATIONAL WHALING COMMISSION
iwc.int/home
The International Whaling Commission (IWC) is the global intergovernmental body charged with the conservation of whales and the management of whaling. It was set up under the International Convention for the Regulation of Whaling signed in 1946. The Commission has a current membership of 88 governments from countries around the world. The pages on this website provide detailed information about the Commission, its meetings, decisions and its current work to conserve and manage whale populations throughout the world.

NATIONAL MARINE MAMMAL LABORATORY
afsc.noaa.gov/nmml/species/species_humpback.php
The National Marine Mammal Laboratory (NMML) conducts research on marine mammals important to the mission of the National Marine Fisheries Service (NMFS) and the National Oceanic & Atmospheric Administration (NOAA), with particular attention to issues related to marine mammals off the coasts of Alaska and the North Pacific. Research projects focus on ecology and behavior, population dynamics, life history, and status and trends.

NOAA FISHERIES
nmfs.noaa.gov/stories/2012/10/noaa_fisheries_education.html
NOAA Fisheries is responsible for the stewardship of the nation’s ocean resources and their habitat. The resilience of our marine ecosystems and coastal communities depend on healthy marine species, including protected species such as whales, sea turtles, corals, and salmon. Under the Marine Mammal Protection Act and the Endangered Species Act, NOAA Fisheries works to recover protected marine species while allowing economic and recreational opportunities.

ONE WORLD ONE OCEAN CAMPAIGN
oneworldoneocean.com
MacGillivray Freeman Films, producer of the giant-screen film Humpback Whales, has created a multi-platform campaign that uses the power of film, television and new media to inspire, educate and connect millions of people worldwide in a common purpose: to protect and restore the health of the ocean. The goals of the campaign include: educate and inspire people to buy sustainable seafood; reduce plastic pollution in the ocean; and expand protected areas to 10% of the planet’s ocean.

THE HAWAIIAN ISLANDS DISENTANGLEMENT NETWORK
hawaiihumpbackwhale.noaa.gov/res/rescue_network.html
The network was formed in 2002 in an attempt to free endangered humpback whales and other marine animals from life-threatening entanglements and at the same time gather valuable information that will help mitigate the issue of marine debris and future entanglement. The network is part of the larger Pacific Islands Marine Mammal Response Network headed by NOAA’s Pacific Islands Regional Office.

VOICES IN THE SEA
voicesinthesea.org
Voices in the Sea is an interactive multimedia exhibit and companion website created by the Pacific Life Foundation and the Whale Acoustics Lab at Scripps Institution of Oceanography that seeks to bring educational content about the natural history, acoustics, and conservation of whales to aquarium visitors, students, and the general public. The educational content is available online and includes 37 short videos featuring on-camera interviews with more than 20 leading whale scientists, resource managers and community leaders.

WHALE TRUST
whaletrust.org
Whale Trust Maui is a nonprofit organization dedicated to scientific research and public awareness of whales and their environment. Based on the Hawaiian Island of Maui, they conduct and support marine research and education programs around Maui and elsewhere throughout the Pacific Ocean.
National Academic Standards

Next Generation Science Standards

LS: Life Science
ESS: Earth and Space Science
PS: Physical Science
ETS: Engineering, Technology, and Applications of Science

Lesson 1: Seeing Songs in the Sea
Third Grade
3-LS1 From Molecules to Organisms: Structures and Processes (LS1.B)
3-LS3 Heredity: Inheritance and Variation of Traits (LS3.A and LS3.B)
Fourth Grade
4-LS1 From Molecules to Organisms: Structure and Processes (LS1.D)
Fifth Grade
5-ESS3 Earth and Human Activity (ESS3.C)

Middle School
MS–PS4 Waves and Their Application in Technologies for Information Transfer (PS4.A)
MS–LS1 From Molecules to Organisms: Structures and Processes (MS–LS1.B)

Lesson 2: Migration Match
Third Grade
3-LS1 From Molecules to Organisms: Structures and Processes (LS1.B)
3-LS2 Ecosystems: Interactions, Energy, and Dynamics (LS2.D)
3-LS3 Heredity: Inheritance and Variation of Traits (LS3.A and LS3.B)
Fourth Grade
4-LS1 From Molecules to Organisms: Structures and Processes (LS1.D)
Fifth Grade
5-PS3 Energy (LS1.C)
5-ESS3 Earth and Human Activity (ESS3.C)

Middle School
MS–LS1 From Molecules to Organisms: Structures and Processes (MS–LS1.B)

Lesson 3: Anatomy and Adaptations
Third Grade
3-LS1 From Molecules to Organisms: Structures and Processes (LS1.B)
3-LS2 Ecosystems: Interactions, Energy, and Dynamics (LS2.D)
3-LS3 Heredity: Inheritance and Variation of Traits (LS3.A and LS3.B)
Fourth Grade
4-LS1 From Molecules to Organisms: Structures and Processes (LS1.A and LS1.D)
Fifth Grade
5-PS3 Energy (LS1.C)

Middle School
MS–LS1 From Molecules to Organisms: Structures and Processes (MS–LS1.B)
MS – LS1 Science and Engineering Practices (MS–LS1.B)

Lesson 4: Bioaccumulation: It All Adds Up
Third Grade
3-LS1 From Molecules to Organisms: Structures and Processes (LS1.B)
3-LS2 Ecosystems: Interactions, Energy, and Dynamics (LS2.D)
Fourth Grade
4-LS1 From Molecules to Organisms: Structures and Processes (LS1.A)

Fifth Grade
5-PS3 Energy (LS1.C)
5-LS1 From Molecules to Organisms: Structures and Processes (LS1.C)
5-ESS3 Earth and Human Activity (ESS3.C)

Middle School
MS–LS1 From Molecules to Organisms: Structures and Processes (MS–LS1.C)

Lesson 5: “Whale Safe” Engineering Challenge
Third Grade
Fifth Grade
5-ESS3 Earth and Human Activity (ESS3.C)

Middle School
MS–ESS3 Earth and Human Activity (ESS3.C)
Middle School Engineering Design (ETS1.A and ETS1.B and ETS1.C)

Lesson 6: Whaling to Whale Watching
Third Grade
Fourth Grade
4-ESS2 Earth and Human Activity (ESS3.A)
Fifth Grade
5-ESS3 Earth and Human Activity (ESS3.C)

Ocean Literacy Principles
Lesson 1: Principles 5 and 6
Lesson 2: Principles 1, 5 and 6
Lesson 3: Principles 1, 4 and 5 and 6
Lesson 4: Principles 1, 5 and 6
Lesson 5: Principles 5, 6 and 7
Lesson 6: Principles 5, 6 and 7

Ocean Literacy Principles
1. The Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of Earth.
3. The ocean is a major influence on weather and climate.
4. The ocean made Earth habitable.
5. The ocean supports a great diversity of life and ecosystems
6. The ocean and humans are inextricably interconnected.
7. The ocean is largely unexplored.

National Geography Standards
Lesson 1: Standards 4 and 5
Lesson 2: Standards 1, 3, 4, 5 and 6
Lesson 3: Standards 4
Lesson 4: Standards 4 and 5
Lesson 5: Standards 2, 4 and 5
Lesson 6: Standards 2, 4 and 5

National Geography Standards
1. The world in spatial terms
2. Places and regions
3. Physical systems
4. Human systems
5. Environment and society
6. The uses of geography

Common Core Language Arts
Reading Informational Text—Lesson 2, 4 and 6
Writing—Lesson 5 and 6
Speaking and Listening—All lessons
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WRITERS AND CONTRIBUTORS

WRITERS
Sarah Wilson, Writer, Education Specialist, and Curriculum Designer
Wendy Grant, Reuben H. Fleet Science Center

CONTENT ADVISORS
Kris Mooney, Reuben H. Fleet Science Center
Caitlin Scully, Reuben H. Fleet Science Center

DESIGN DIRECTOR
Jeff Girard, Victoria Street Graphic Design

PROJECT MANAGEMENT
Lori Rick, MacGillivray Freeman Films
Janna Emmel, MacGillivray Freeman Films Educational Foundation

SCIENCE ADVISOR
Phil Clapham, Ph.D., National Marine Mammal Laboratory

GRAPHICS
Kristina Gonzales
Pieter Folkens

Humpback Whales is a MacGillivray Freeman Film presented by Pacific Life.
A One World One Ocean production.
THE HUMPBACK WHALE

Humpback whales live in the open ocean with the help of some key features. Named for the hump of its dorsal fin, this graceful whale often jumps out of the water with powerful force. Huge mammals of the ocean, these giants are incredibly built.

TUBERCLES
The knobby structures on the snout and chin. Each tubercle contains a sensory hair. These help the whale sense vibration and temperature.

TWO BLOWHOLE
Humpbacks exhale from their twin blowholes, with a wide blow up to 13 feet high. The warm, moist lung air is mainly expelled as a cloud of condensation.

VENTRAL PLEATS
12 to 30 throat grooves span two-thirds of the length of the whale’s underside. They contain the extra skin that allows the whale’s huge mouth to expand while feeding.

PECTORAL FINS
Forward fins that are a third of the length of the whale’s body. These fins can grow up to 15 feet long.

DORSAL FIN
A relatively small fin right on the back along the humpback’s body. Humpback dorsal fins come in many different sizes and shapes.

CAUDAL PEDUNCLE
Immensely strong rear section of the humpback that is connected to the tail. The powerful muscles here lift the whole back region of the body out of the water and then slap it down onto the surface.

TAIL FLUKES
The two sides of the tail are called flukes. Often they carry scars from attacks and natural color patterns. These marks can be used by scientists to identify whales.

BALEEN
Humpback whales have baleen, not teeth. Baleen plates are made up of a protein called keratin, which also makes up human hair and fingernails. Baleen acts like a strain when humpbacks gulp and swallow food.

HUMPBACK VS HUMAN
Humpback whales grow to be about 55 feet long. They can weigh up to 50 tons. Their four-chambered heart weighs 430 pounds, about as much as three average adult human beings. Humpbacks are able to hold their breath underwater up to 45 minutes. The average human can only hold his or her breath for a few minutes.
Humpback whales are among the most awe-inspiring of all marine mammals. Nearly driven to extinction 50 years ago, humpbacks today are making a slow but remarkable recovery, thanks to international bans on whaling. Scientists estimate there are approximately 100,000 humpbacks in our oceans today. We have just begun to discover how incredible these animals are.

**The Curious World of the Humpback Whale**

- Humpbacks are known to migrate up to 10,000 miles round-trip every year.
- One rogue female humpback set a migration record of 6,089 miles traveling from Brazil to Madagascar.
- The patterns found on whale flukes are used to identify individual whales, like a human fingerprint.
- Humpbacks sing head down with their bodies motionless.
- Humpback song recordings were put on board the Voyager spacecraft in 1977, which entered interstellar space in 2012.
- Songs can last 20 minutes and are heard miles away.

**Modern Day Humpback Threats**

- Ship strikes can injure or kill humpbacks.
- Entanglement in fishing gear is a major threat to whales in the open ocean.
- Pollution by plastic, toxins, and noise inhibit whale recovery.

**Bubble netting is a unique hunting method that some humpbacks use to catch fish.**

**Some whale groups use sound and bubble nets to trap schools of herring.**

- They dive below the trapped fish and lunge up out of the water with a mouthful of food.

**Humpbacks don’t have teeth. Instead they have a comb-like baleen made of bristles.**

- They use the baleen to filter krill and small fish from the sea.

WWW.HUMPBACKWHALESFILM.COM
Humpback whales are found in all the world's oceans and in both the Northern and Southern hemispheres. Each population has its own traditional feeding and breeding grounds and customary migration routes. Their songs and social sounds can be heard around the world.

Humpbacks have been known to migrate 3,000 miles from Alaska to Hawaii in 39 days.

Pods of humpbacks in the North Pacific and North Atlantic often feed on herring using their complex bubble netting techniques.

The Arabian Sea population is the only humpback group that does not migrate.

Most humpback populations do not cross the equator.

There are over a dozen distinct populations of humpback whales.

The longest consistent migration recorded is 5,160 miles one way, between Costa Rica and Antarctica.

One rogue female humpback set a migration record of 6,089 miles traveling from Brazil to Madagascar.

Humpback whales in the South Pacific have distinct grey and white markings.

Southern populations migrate to Antarctic feeding grounds where the colder waters are nutrient rich.

Humpback songs, and the males who produce them, travel widely through the oceans. The similarity of song dialects reveal that some widely-spaced wintering populations are in acoustic contact.
HUMPBACK FUN FACTS

- A humpback’s pectoral fins can grow up to 15 feet long—that’s like having the wingspan of a Learjet!
- Humpback whales can consume up to 4,000 pounds of food in a single day.
- Female humpbacks are larger than adult males and reach an average length of 55 feet—as long as a school bus!
- As baleen whales, humpbacks filter feed on tiny crustaceans (mostly krill), plankton and small fish.
- Humpbacks migrate thousands of miles from their summer feeding grounds in cold, polar waters (like Alaska and Antarctica) to winter breeding grounds in warm, tropical waters near the equator (like Hawaii and Tonga).
- Among the 78 species of baleen and toothed whales, only a small handful are known to produce whale songs, including humpbacks.

WORD SEARCH

See if you can find each of the following words:

ANTARCTICA   DIVE
BALEEN        FLUKE
BLOW-HOLE     HAWAII
BLUBBER       HUMPBACK
BREACH        KRILL
BUBBLE        MIGRATE
CALF          SING

AVOMBMDIVERPFPVCAAB
BLUBBEROAPKRILLDRU
EDSFHILNPLEJUIOBB
MBALEENYAJUFZKCGUH
OHORDSEMSCNTWEEFBY
SUGUFIISHIKHBFJGIBG
HAEKHNJKISPEDUCALF
ASCCEAGDZWPMIGRATEJ
WPZLINDAGOIMZMRKSA
ANTARCTICADOBIIONL
IFEPHUMPBACKASTHFN
IOVSBASCYVBLOWHOLE
NGAIPLKDBGAOVTSLBE
EALOHAMORANTUEWATN
Today, humpback whales are found in all the oceans of the world. Often called the ocean’s acrobats, they like to leap high out of the water, a behavior called breaching. Though all humpbacks make sounds to communicate, only males sing. The whales in each social group all sing the same song, which can last up to 20 minutes. Their complex melodies change over time and over different regions of the world.

It’s hard to imagine that in the last century, commercial whaling almost drove humpbacks to extinction. In 1966, with less than 10% of original humpback populations remaining, the international community passed a ban on hunting humpbacks. Since then, their populations have been steadily increasing.

Over the last 50 years, we’ve studied and discovered many fascinating behaviors and facts about humpbacks, but researchers are the first to admit that we’re just beginning to understand these ocean giants. There is so much more to learn about humpback whales and their importance to the ocean and our planet.

While their populations are recovering, humpbacks still face threats from ship strikes, entanglement in fishing gear and ocean pollution. Here’s how you can help protect them:

- Be curious! Learn more about humpback whales at your library, on the internet, or at your local museum or aquarium. The more we understand humpback whales, the more we will know how to protect them.
- Support conservation organizations, scientific research and legislation aimed at preserving the health of the ocean—with your wallet, your vote, your volunteer time.
- Eat sustainable seafood to help preserve the humpback’s ocean home. Get Monterey Bay Aquarium’s Seafood Watch app to guide your shopping and dining (www.seafoodwatch.org).
- Take science classes in school and explore a career in oceanography and marine biology.
MIGRATION MAZE

Help the mother humpback on her migration from Alaska to her breeding grounds in Hawaii by making your way through this maze.
IDENTIFY WHALES

Scientists can identify individual humpback whales by studying their tail flukes. The color patterns and scars are unique marks, like your own fingerprints, that distinguish one whale from the next. Can you find the matching whale tails?
How much do you know about humpbacks?

ACROSS

4 Humpbacks use this to strain food into their mouths instead of teeth.
7 The long journey from feeding to breeding grounds.
8 These fish hang around humpback whales, often hitching a ride.
11 The only sea population of humpbacks that do not migrate.
13 The estimated number of distinct humpback whale populations.
14 The fatty tissue that stores energy and keeps humpbacks warm in deep water during long migrations.
15 The main source of humpback food.
17 When humpbacks jump out of the water, they _____ the surface.
18 The humpback is named for the arch-back _____ it does into water.
20 Humpbacks hang _____ when singing in the open ocean.
21 The name of the humpbacks tail.
21 Some Southern Hemisphere humpbacks travel to this island nation to mate and give birth.
23 Humpbacks are often caught as _____ in commercial fishing nets.

DOWN

1 The group hunting method of Alaskan humpbacks.
2 Baby humpback whale.
3 These fish are often caught by humpback bubble nets.
5 Humpbacks breathe out of this.
6 Spacecraft that took recordings of humpback songs into space in 1977.
9 This island chain has the largest humpback population.
10 Humpbacks often get _____ in fishing nets.
12 These fins can grow up to 15 feet long.
14 Hawaiian name for humpback whales.
16 Only humpback males do this.
19 Humpbacks almost became _____ in 1966.
An extraordinary journey into the mysterious world of one of nature’s most awe-inspiring marine mammals, *Humpback Whales* takes audiences to Alaska, Hawaii and the Kingdom of Tonga for an immersive look at how these whales communicate, sing, feed, play and take care of their young. Captured for the first time with IMAX® 3D cameras, and found in every ocean on earth, humpbacks were nearly driven to extinction 50 years ago, but today are making a steady recovery. Join a team of researchers as they unlock the secrets of the humpback and find out what makes humpbacks the most acrobatic of all whales, why only the males sing, and why these intelligent 50-foot, 48-ton animals migrate more than 6,000 miles round-trip every year.
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  - Educator’s Guide
  - Experiment Procedures
  - Lab Sheet
  - Discovery Sheet
Humpback Whales Learning Lab Overview

Introduction

In this guide, you will find six learning lab station activities that are designed to provide educational experiences to pair with the film, Humpback Whales. Accompanied by an introduction PowerPoint presentation, these hands-on activities align with Next Generation Science Standards, are appropriate for students in third through eighth grades, and last 10-15 minutes each.

Stations

The station activities could be used as a set or individually as components in your summer camps, overnight programs, scout programs, and school workshops. As a learning lab for schools or the public, one example for using these materials would be to begin with the PowerPoint introduction, followed by students rotating through three stations set up in your classroom. This scenario would be approximately 45 minutes, but you could choose to make it shorter or longer by changing the number of stations.

The stations are designed for groups of 8-10 students, however, several stations would benefit from having multiple sets of materials at the station so that all students may participate in the allotted time. Refer to the Helpful Tips section of the Museum Educator Guides for these suggestions.

Many of the stations utilize materials you may already have at your museum! Depending on which ones you choose, setting up individual stations could cost as little as $35, or up to $200. Ward’s Science and Carolina Biological are noted as possible places to obtain science supplies, but please note that a simple internet search may yield comparable prices!

Room Set Up & Staffing Recommendation

Each activity that you choose to implement should be set up at a different table, or “station,” with adequate space to accommodate up to ten students at a time. One adult should be present at each station.

Most activities are student directed, however two of them are specifically adult-led demonstrations which involve handling materials such as dry ice and hot water. Each lab activity also concludes with a group discussion, which would be best facilitated in the presence of an adult leader.
A Guide to the Learning Lab Documents

A Breakdown of the Documents

**Humpback Whales PowerPoint**
The Humpback Whales PowerPoint presentation is provided for use as an introduction to humpback whales. The content coincides with the topics available in the various learning lab activities. The PowerPoint is accompanied by scripted notes for the museum educator.

**Museum Educator Guides**
Museum Educator Guides provide basic set-up notes for the museum educator. Refer to the Helpful Tips section to guide you to making informed decisions about the quantity of materials you will need to accommodate large student groups.

**Task Cards**
Task Cards list step-by-step activity procedures for students. Print and laminate the Task Cards and place them at the station so that students may refer to them for directions.

**Lab Sheets**
Lab sheets are tools students can use to collect and synthesize their data. Lab sheets may be given to students as individual loose pages, or they may be combined with each other to form a booklet. For your convenience a cover for the student booklet is included on page 9.

**Discovery Sheets**
Discovery Sheets provide background information and definitions pertaining to the station. You could send them to teachers as a reference tool in advance, or laminate them and have them available at the stations for students and chaperones to use as a helpful reference guide.

**Printables**
Printables are supplemental information sheets that should be printed, laminated, and made available to students at the station. They mostly contain supplemental visuals that pertain to the individual activity being presented. They pair beautifully with the Discovery Sheets, but may also be provided to students in isolation.

**Experiment Procedures**
Experiment Procedures specifically accompany only two of the learning lab stations: Convection Currents and Ocean Acidification. These two stations are demonstrations that must be led by an adult! Experiment Procedures provide specific step-by-step directions for the adult leader. Be sure to thoroughly brief the adult leading each of these two stations prior to dispersing students into rotations.
1. Humpback Whales
Welcome students, teacher, and chaperones to your museum. Introduce yourself and any accompanying staff. Make any other announcements pertinent to your museum.

2. Creature Features
“The scientific name for the humpback whale comes from Latin words meaning giant wings. Can you guess why they are called giant wings? [Allow students to make a guess.]

Giant wings refers to the humpback’s large pectoral fins, which are about as long as one third of the whale’s body. These long pectoral fins are one of the most recognizable features that people notice when they spot humpback whales.”

“The common name humpback comes from the small dorsal fin on its back, and the appearance of a hump it creates when the whale arches its back.”

“Although they may look like a giant fish, a shark, or maybe even a bird that flies underwater, humpback whales are actually mammals, just like us.”

“Think about it: What do you already know about mammals?” [Call on students to share what they know about mammals, and then summarize by mentioning characteristics that they did not know.] “Characteristics include: are vertebrates, are endothermic, have a 4 chambered heart, have hair, give birth to and nurse live young, breathe air.”

Point out the features that have been labeled on the slide.

“Baleen whales have 2 blowholes, while toothed whales have just one!”

Students may wonder where the hair is. Tell students:

“The bumpy tubercles on a whale’s head each contain a hair follicle and some have bristles [like a hair] coming out of them!”

3. Voluntary Breathers
Play the clip of a humpback breathing/spouting.

“On average, an adult humpback whale can hold its breath between 7 and 15 minutes.”

“Calves need to breathe every 3-5 minutes.”

“Some humpback whales can amazingly hold their breath for up to 45 minutes at a time!”

4. Now Try This
Distribute the lab sheet titled, “Hold Your Breath Like a Humpback Whale” or direct them to turn to that page in their booklet (if a booklet has been created).

Guide students through the activity. Start the stopwatch once you direct students to begin holding their breath.

5. Songs in the Sea
“Humpback whales are best known for their songs. The vocalizations, or sounds that they make, travel great distances in the ocean. Sound waves travel faster in water than they do in air.”

“It may surprise you to learn that only the male humpback whales sing! They do it with their head facing down too!”

“One way scientists are able to study humpback whales is by recording their songs and vocalizations with special underwater microphones called hydrophones!”

Click the link to listen to a whale song. Direct students to look at the spectrogram, so they can ‘see’ the song as it is being sung.

6. Diet
“You may wonder what kinds of foods are needed to give such a large active whale the energy it needs to sing, swim, migrate, dive, and display surface behaviors.”

“A humpback whale’s diet consists mainly of small crustaceans called krill that are about the size of a paper clip!”
“Krill are a mere 2 inches in length, but when consumed in large quantities (up to 4,000 pounds at a time), they provide the essential nutrients that these great whales need to survive.”

7. Baleen

“Humpback whales are baleen whales. Instead of teeth, they have a series of flexible plates called baleen attached to their jaws. It may look a little like hair, but it is not. It is actually made up a material called keratin. Keratin is the same material our fingernails are made of!”

“Baleen whales feed by first swallowing a mouthful of water containing their prey. They then use the baleen in their mouths like a sieve to filter out the food from the ocean water.”

Note: If you have a real whale baleen sample for the Catching Krill activity, you may choose to show the baleen to the whole class at this time!

8. Bubble Netting

“Humpback whales are usually solitary creatures, but they have been known to come together with other humpbacks to accomplish a unique feeding strategy called bubble netting.”

“One humpback will swim below a school of krill and blow bubbles in a circle to enclose its prey. The krill get captured within the bubbles, and the whales waiting below swim upwards, engulfing the krill!”

Play the animation of the bubble netting behavior.

9. Food Chains vs. Food Webs:

“Food chains and food webs are diagrams that represent feeding relationships. Essentially, they show who eats whom. In this way, they model how energy and matter move through ecosystems. A food chain is a series of living things in which each one uses the next lower living thing as a source of food, while a food web represents multiple pathways through which energy and matter flow through an ecosystem. It includes many intersecting food chains.”

Ask students to think about whether this diagram is a food chain or a food web, and how they know. (It is a food chain, because it shows only one species consuming another one species.) Explain the components of the food chain represented using the prompts below.

10. Whales Are Important!

“When it comes to the environment and the health of the ocean ecosystem, whales are important! They help regulate the flow of food by helping maintain a stable food web. Imagine what would happen to the food web if there were no whales.”

“At first, you may think that krill and small fish would benefit from not having to face a predator, but over time these animals would overpopulate and possibly destroy the populations of other species they feed on.”

“When humpback whales feed, they drive their prey to the surface making it easier for seabirds to catch fish!”

“Even whale poop plays a large role in the environment! Phytoplankton can feed on some of the nutrients found in whale poop, and more phytoplankton means more carbon can be pulled from the atmosphere to provide a cleaner and healthier breathing environment for all animals! Phytoplankton feed fish, which in turn feed other species that require fish to survive, therefore keeping the food chain stable!”

“Now can you see just a few ways whales are important to the health of the ocean ecosystem!”

11. What We Do Today Impacts the Future!

“An ecosystem is everything that exists in a particular environment. Humpback whales are part of a marine (ocean) ecosystem.”

“Humans affect the marine ecosystem in many ways. Human impacts have the potential to not only upset the balance of food chains and the health of ocean animals, but to also alter the physical components of ocean water.”

“What happens to the future of the oceans, the Earth, and all the living things within it depends on what we do today!”
“Each person in this room can make a difference in important ways. Simple things we can do to make a positive impact include: conserving energy, putting trash in its place, and conserving water. Larger things we can do include sharing awareness about the importance of whales, buying sustainable seafood, creating whale-safe fishing gear, supporting the ban on whaling, altering shipping lanes to avoid migratory paths and promoting marine reserves. The effects can be large if we each do just a small part and learn how to better care for the environment and natural resources!”

12. Oceanography and Marine Biology

“People who are curious and have a love of the outdoors (especially the ocean) may choose to become a scientist who focuses specifically on studying the ocean.”

“Oceanography, also known as marine science, is the scientific study of the physical and biological components of Earth’s oceans. Oceanographers are scientists who help us gain a better understanding of how our oceans and the living creatures in them function as an ecosystem.”

“Marine biologists study the plants and animals that live in oceans. Marine biology includes the study of everything from small organisms such as plankton right up to very large creatures such as humpback whales!”

13. Learning Labs

“Today each of YOU will have a unique opportunity to explore and make discoveries as marine biologists and oceanographers in these various learning lab stations! Enjoy this opportunity to investigate and discover new things about amazing humpback whales, their ocean habitat, and impacts that threaten their survival.”

Indicate which labs have been set out and give a brief overview to introduce them. [Use the objective statements below.]

Tell students that each station has a Task Card with the step-by-step directions for the activity. Their Lab Sheet is where they will make a hypothesis, record their data, and draw conclusions. Most stations have Printables with helpful visuals. Finally, note whether or not a Discovery Sheet (background information) has been provided.

Station Overviews (objective statements)

A Blubbery Discovery: You will conduct a hands-on experiment to explore the insulating properties of blubber!

Catching Krill: You will observe real whale baleen and simulate catching krill as a baleen whale and as a toothed whale.

Food Web Game: You will play a game and see that even small changes in the ecology of the ocean environment can have a large impact!

Focus on Phytoplankton: You will use microscopes to observe phytoplankton, and make connections about the important roles they play in the marine environment.

Ocean Acidification: You will discover the effects of climate change on the ocean and discuss its impacts on marine life and people.

Convection Currents: You will observe a demonstration of convection currents.
This Learning Lab Booklet Belongs to:
Lab Sheet:
Hold your breath like a humpback whale!

1. Make a Hypothesis
   Predict how long you will be able to hold your breath.

2. Collect data
   a. I held my breath for this long: ________________

3. Analyze Data and Draw Conclusions
   a. Were you close to your prediction? Calculate the difference.

   b. How did you measure up to a humpback whale?

   c. Group Discussion
      Imagine repeating the experiment while burning more energy, i.e.: walking around the room, doing jumping jacks, etc.) How do you think this would affect your ability to hold your breath?

Station Overview
Students will conduct a hands-on experiment, exploring the insulating properties of blubber.

Next Generation Science Standards
4 LS 1-1: Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior and reproduction.

Disciplinary Core Idea
LS 1.A: Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior and reproduction.

Materials
— 4 sturdy quart-sized zipper lock bags
— 4 generous scoops of shortening or lard
— Spatula or spoon to scoop shortening
— Duct tape
— 16 quart plastic tub
— Cold water
— Ice
— Hand towel(s)
— Large display timer (www.carolina.com)
— Infra-red thermometers (www.carolina.com or www.grainger.com)

Create the Blubber Gloves (1 per pair of students)
1. Turn one zipper lock bag inside out and set aside.
2. Scoop about 4 heaping spoonfuls of shortening into the other zipper lock bag.
3. Put your hand inside the first zipper lock bag (currently inside out), and push it into the shortening-filled zipper lock bag.
4. Spread the shortening all around the inside of the zipper lock bags until the inner bag is covered on all sides.
5. Lock the two bags together by pressing the two zippers together, keeping the shortening between the two. Secure them with duct tape.
6. Fold the edge of the locked bags over and duct tape the fold in place.

Create the Control Gloves (1 per pair of students)
1. Turn one zipper lock bag inside out and set aside.
2. Place the inside out zipper bag inside the other bag, and lock the two bags together by pressing the two zippers together.
3. Press out as much air as you can. You do not want air between the bags.
4. Fold the edge of the locked bags over and duct tape the fold in place.

Create the Ice Baths (1 per 2 pairs of students in a group)
1. Fill the plastic tub halfway with cold water. Add enough ice to the tub to make the water feel “ice cold”. Add enough ice so that ice remains in the tub when students do the activity.
2. Affix the “Arctic Ocean Water” signs (half sheets) to the sides of the plastic tub.

Set the Remaining Materials at the Station
1. Set the blubber gloves, control gloves, ice baths, hand towel(s), infra-red thermometers, and large display timer at the station.
2. Place all printed materials at the station.

For each rotation it is optimal to have 1 control glove and 1 blubber glove per each pair of students in a group. An ice tub may be shared between 2 student pairs. The materials list states the number of supplies needed to create 1 control and 1 blubber glove.

Worksheets & Printables List

<table>
<thead>
<tr>
<th>Sheet</th>
<th>Number to Print</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Card: A Blubbery Discovery</td>
<td>1 Per Station</td>
</tr>
<tr>
<td>Lab Sheet: A Blubbery Discovery</td>
<td>1 Per Student</td>
</tr>
<tr>
<td>Discovery Sheet: A Blubbery Discovery</td>
<td>1 Per Station</td>
</tr>
<tr>
<td>Printable: Arctic Ocean Signs</td>
<td>1 Per Tub</td>
</tr>
</tbody>
</table>
Task Card: 
“A Blubbery Discovery”

Today you will conduct a hands-on experiment to explore the insulating properties of blubber!

1. Make a Hypothesis
   Which gloved hand do you predict will last the longest in the Arctic ice water?

2. Experiment Procedures
   1. Find a partner. One person will start as the recorder and the other person will start as the tester. Then you will switch roles!
   2. Recorder: Use the infra-red thermometer to measure the temperature of the water. Then measure the temperature of each of the tester’s hands before they put them into the gloves, and record this data on their lab sheet.
   3. Tester: Insert your left hand in the control glove, and your right hand in the blubber glove. When the timer starts, place both gloved hands into the ice water. Keep them in the water until it is no longer comfortable.
   4. Recorder: Watch the timer with your partner. Note the times he/she pulls each hand out, and record this data on their lab sheet.
   5. Recorder: Use the infra-red thermometer to measure the temperature of each of the tester’s hands after they pulled their hands out of the gloves, and record this data on their lab sheet.
   6. Switch roles!

3. Clean up Your Station!
   1. Dry off the control glove and the blubber glove, and wipe up any water that has spilled.
   2. Carefully straighten all materials.

4. Analyze Your Data and Draw Conclusions
   Group Discussion: What did you discover about insulation, thermoregulation, and a whale’s adaptation of blubber?
**Lab Sheet: “A Blubbery Discovery”**

**Objective**

Today you will conduct an experiment to discover the insulating properties of blubber.

**1. Make a Hypothesis**

Which gloved hand do you predict will last the longest in the Arctic ice water and explain why?

**2. Collect Data**

“Arctic Ocean Water” ice bath temperature: __________

<table>
<thead>
<tr>
<th>Type of Glove</th>
<th>Temperature of Hand Before</th>
<th>Time Held in Ice Water</th>
<th>Temperature of Hand After</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong> (no shortening)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Blubber</strong> (shortening)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**3. Analyze Data and Draw Conclusions**

Group discussion: What did you discover about insulation, thermoregulation, and a whale’s adaption of blubber?

**Draw your conclusion!**
Discovery Sheet: “A Blubbery Discovery”

Humpback whales are warm-bodied mammals that spend much of their lives in cold seas. Being a warm-bodied mammal living in the cold ocean can be difficult. Like humans, they need to stay warm.

This insulation aids in the process of thermoregulation, or the maintenance of internal body temperature within a tolerable range. Humpback whales typically have a core body temperature of 96-99 degrees Fahrenheit. Humans have a similar body temperature of 98.6 degrees Fahrenheit.

Other marine mammals such as dolphins, seals, and manatees also benefit from having a thick layer of blubber.

Definitions
Mammal: any member of the Class Mammalia; they are warm-bodied, have hair, give birth to live young, nurse their young, and breathe with lungs

Adaptation: special traits that help living organisms survive in a particular environment

Blubber: layer of fatty tissue used by marine mammals for insulation and energy storage

Insulation: a material that prevents or reduces the passage, transfer, or leakage of heat

Thermoregulation: the maintenance of internal body temperature within a tolerable range
Arctic Ocean

Attach to water tub

Arctic Ocean
Station Overview

Students will observe real whale baleen and whale teeth specimens, make predictions about which adaptation is most effective in catching krill, and then simulate each adaptation. They will use the data they collect to draw conclusions about which adaptation is most beneficial in catching krill.

Next Generation Science Standards

4 LS 1-1: Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

Disciplinary Core Idea

LS 1.A: Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.

Materials

- Dried rosemary
- 16 oz. clear plastic tub
- Water
- Fine tooth pocket comb (plastic)
- Tweezers
- Hand towel
- Paper towels
- Toothpicks
- *whale & krill specimens:
  - Baleen (borrow from your local natural history museum)
  - Whale teeth (borrow from your local natural history museum)
  - Krill specimen (borrow from your local natural history museum) or purchase freeze-dried krill (www.wardsci.com, Item #212830)

Set Up the Station

1. Place the krill tub at the station.
2. Set out the combs and tweezers.
3. Set out toothpicks, paper towels, as well as a hand towel for any spills.
4. Set out the baleen, whale teeth, and krill specimens.
5. Place all printed materials at the station.

Worksheets & Printables

<table>
<thead>
<tr>
<th>Sheet</th>
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<tbody>
<tr>
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<tr>
<td>Discovery Sheet: Catching Krill</td>
<td>1 Per Station</td>
</tr>
</tbody>
</table>
Task Card: “Catching Krill”

1. Introduction
   1. Look at the real baleen and whale teeth. Compare each to the size of the krill, and think about which adaptation would be the most effective in catching krill.
   2. Today you will simulate feeding as these two types of whales!

2. Make a Hypothesis
   Which tool do you predict will be the most effective in catching krill?

3. Experiment Procedures
   **Baleen Simulation**
   1. In one sweeping motion, skim the plastic comb across the surface of the water to collect as many krill as possible. Do not scoop or pin them against the side of the tub!
   2. Carefully move the krill from the comb to the paper towel and count them. Use a toothpick to gently separate the krill to help you count.
   3. Dry the comb and pass it to another student.
   4. Record the number of krill you captured.
   5. Repeat these steps two more times, and record your data.

   **Teeth Simulation**
   1. Pinch the tweezers together once to try to catch some krill. Do not pin the prey against the sides or bottom of the tub. It’s ok if you are not able to catch any.
   2. Carefully move any krill you caught to the paper towel and count them.
   3. Dry the tweezers and pass them to another student.
   4. Record the number of krill you captured.
   5. Repeat these steps two more times, and record your data.

4. Clean Up Your Station!
   1. Dry off the tweezers and the comb, and wipe up any spilled water.
   2. Place used paper towels and soggy krill in the trash, and carefully straighten up all materials.

5. Analyze Your Data and Draw Conclusions
   Group Discussion: What did you discover about the effectiveness of baleen vs. teeth when trying to catch krill?
Lab Sheet: “Catching Krill”

Objective
Today you will conduct an experiment to simulate the differences between a whale’s ability to catch krill with baleen vs. teeth.

1. Make a Hypothesis
Predict which tool will be the most effective in catching krill.

2. Collect Data

<table>
<thead>
<tr>
<th>Adaptation</th>
<th>Baleen (comb)</th>
<th>Tooth (tweezers)</th>
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<tbody>
<tr>
<td>Trial 1</td>
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<td>Trial 3</td>
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</table>

3. Analyze Data and Draw Conclusions
Group Discussion: What did you discover about the effectiveness of baleen vs. teeth when trying to catch krill?

BONUS!
Draw and label pictures of the real whale baleen and teeth you observed!
Discovery Sheet:
“Catching Krill”

There Are Two Main Types of Whales

Baleen whales and toothed whales. Humpback whales are an example of baleen whales. Instead of teeth, they have an adaptation called baleen. Baleen are flexible plates attached to the upper jaw. Humpback whales have between 270 and 400 pairs of overlapping baleen plates, with bristled lower edges. Each plate is approximately 2-3 feet long. It looks like a broom and is made of keratin. This is the same material our fingernails and hair are made of!

To feed, humpback whales swim forward and open their mouths. As the water flows in, it expands their accordion-like ventral pleats in their throats. This is another adaptation that allows them to gulp prey and water in very large amounts. They then use their tongues to push the water out between the baleen plates and scrape the small fish and krill trapped in the baleen into their mouths.

Humpback whales feed in cooler waters during the spring and summer months when small fish, krill, and plankton are plentiful. Humpback whales can eat as much as 2,000 pounds of food in a day! They store the excess calories in the form of blubber which provides energy and insulate them during their migration to warmer waters in the fall.

Definitions:

Adaptation: a special trait that helps living organisms survive in a particular environment

Baleen: keratin plates that hang down in fringed, parallel columns from the upper jaw or palate of baleen whales; serve as a strainer that catches plankton and small fish while a whale is feeding

Ventral pleats: long folds in the skin that expand when a whale takes in large amounts of water and food

• A humpback whale’s esophagus is about the same diameter as a baseball! They are unable to swallow large prey because large pieces of food would not be able to fit down their throats!

• 2,000 pounds is about the same weight as an African elephant, or 8,000 hamburgers!
Discovery Sheet:
“Catching Krill: Baleen vs. Toothed Whales”

**BALEEN WHALES**

- Blue Whale
- Finback Whale
- Right Whale

**TOOTHED WHALES**

- Bottle-Nosed Dolphin
- White (Beluga) Whale
- Pilot Whale
- Orca
- Sperm Whale

**Depth Markers**

0 10 20 30 40 50 60 70 80 90 100 FEET
Station Overview

Students will see that even small changes in the ecology of the ocean environment can have a large impact!

Next Generation Science Standards

3 LS 4-4: Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

Disciplinary Core Idea

LS 4.D: Populations live in a variety of habitats, and change in those habitats affects the organisms living there.

4 ESS 3-1: Obtain and combine information to describe that energy and fuels are derived from natural resources and that their uses affect the environment.

Disciplinary Core Idea

ESS 3.A: Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not.

5 LS 2-1: Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

Disciplinary Core Idea

LS 2.A: The food of almost any kind of animal can be tracked back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance or an ecosystem.

MS LS 2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Disciplinary Core Idea

LS 2.C: Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

Materials

— 1 set of Jenga (www.jenga.com)
— Permanent markers: green, blue, red, and black
— Clear tape
— Cardstock

Preparing the Station

Prepare the Jenga blocks.

1. Use the permanent markers to color the ends of the Jenga blocks as specified below.
   — 21 green (phytoplankton)
   — 12 blue (zooplankton)
   — 12 red (krill and small fish)
   — 9 black (humpback whales)

2. Tape the images from Humpback Whale Food Web Jenga Block Pictures on each of the sides of the blocks, matching them to their corresponding colors.

Worksheets & Printables

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<td>Discovery Sheet: Food Web Game</td>
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<tr>
<td>Printable: Food Web Game Jenga Block Pictures</td>
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<tr>
<td>Printable: Food Web Game Playing Cards</td>
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</tr>
</tbody>
</table>
Task Card: “Food Web Game”

Today you will discover that even small changes in the ecology of the ocean environment can have a large impact!

1. Set up the Game
   1. Build a Jenga food web tower by layering blocks in the following order:
      a. Bottom layer: phytoplankton (green)
      b. Second layer: zooplankton (blue)
      c. Third layer: krill and small fish (red)
      d. Top layer: humpback whales (black)
   2. Shuffle the playing cards and stack them face down.

2. Make a Hypothesis
   What do you think will happen as you introduce human and environmental impacts into the ecology of the ocean?

3. Play the Game!
   1. Pick a card, read it aloud, and follow the instructions on the card. (Note: You are not allowed to hold the rest of the stack together while removing the blocks. Only the block being removed or returned may be touched!)
   2. Place the used cards face-up in a discard pile.
   3. Create a discard pile for the blocks.
   4. Continue to take turns until the food web collapses, or until all cards are used up.

4. Clean up Your Station
   Sort the Jenga blocks into four piles, arranging them by color.

5. Analyze the Results and Draw Conclusions
   Group Discussion: What did you discover about human influences on the environment? How could something as large as a humpback whale be impacted by small changes in the ocean? What did this game inspire you to want to investigate further? Brainstorm ways humans can help sustain life in the ocean.

BONUS!
Create two new playing cards that include solutions to two of the human impacts you observed!
Lab Sheet:
“Food Web Game”

Objective
You will see how human and environmental factors affect both the food chain and the food web of humpback whales.

1. Make a Hypothesis
What do you think will happen as you introduce human and environmental impacts into the Ecology of the ocean?

2. Analyze the Results and Draw Conclusions
Group discussion: What did you discover about human influences on the environment? How could something as large as a humpback whale be impacted by small changes in the ocean? What did this game inspire you to want to investigate further? Brainstorm ways humans can help sustain life in the ocean.

BONUS!
• Think about two solutions to local impacts that YOU could help facilitate.
• Create 2 solution “playing cards” that could be added into the game! The top lines should state the solution, and the bottom line should state the action for the level it impacts.
Discovery Sheet: “Food Web Game”

A food chain is a series of living things in which each one uses the next lower member as a source of food. A food web shows all the interacting food chains.

**Humpback Whale**
Humpback whales use baleen, not teeth, to catch their prey. They mostly eat krill, but sometimes also consume small fish.

**Krill**
Krill are an important connection near the bottom of the food chain. They mainly feed on phytoplankton.

**Phytoplankton**
Phytoplankton are microscopic plant-like organisms. They contain chlorophyll, just like plants do, and use carbon dioxide, sunlight, and water to make their own food through the process of photosynthesis.

A food chain is a series of living things in which each one uses the next lower member as a source of food. Humpback whales feed on krill, and krill feed on plant-like organisms called phytoplankton.

A food web shows all the interacting food chains in an ecological community, such as the ocean. The humpback whale’s food chain is part of a larger food web that includes various zooplankton and phytoplankton. The Jenga tower today will represent a food web.

Food webs are part of a greater whole called an ecosystem. An ecosystem is a community of living and nonliving things that work together. Everything is connected. Humans can affect the marine ecosystem in many ways, and this has potential of upsetting the ecology of the food chain and food web of humpback whales. If the balance of one level is disturbed too much, the other levels will be affected and the food web could potentially collapse.

**Definitions**
- **Ecosystem**: everything that exists in a particular environment
- **Ecology**: the study of the relationships between a group of living things and their environment

Antarctic Food Web

Krill average about two inches in length, which is about the size of a paperclip!
Discovery Sheet:
“Food Web Game Jenga Block Pictures”

Jenga Game

Block Size: 3 x 0.5 inches

You Will Need:
• 9 Humpback illustration
• 6 Krill illustration
• 6 Fish illustration
• 12 Zooplankton

• 21 Phytoplankton
There are more phytoplankton than zooplankton illustrations

Please Note: there are a few extras of each image.
Discovery Sheet:
“Food Web Game Jenga Block Pictures”
Discovery Sheet:
“Food Web Game Jenga Block Pictures”

[Image of Jenga blocks with sun symbols]
Discovery Sheet: “Food Web Game Playing Cards”

- Sunlight reaching the ocean increases.
  - PUT BACK ONE GREEN BLOCK

- A storm hits. Pollution from storm drains flow into the ocean.
  - REMOVE ONE GREEN BLOCK AND ONE BLUE BLOCK

- Ocean currents change and disperse phytoplankton.
  - REMOVE ONE GREEN BLOCK

- Ocean acidification results from an increase in carbon dioxide.
  - REMOVE ONE RED BLOCK

- Successful beach clean-up reduces pollutants entering the ocean.
  - PUT BACK ONE GREEN BLOCK

- An oil spill occurs in a nearby harbor.
  - REMOVE ONE GREEN, ONE BLUE AND ONE RED BLOCK
Discovery Sheet:
“Food Web Game: Additional Prompts”

—Too many zooplankton are consumed by invasive filter feeding invertebrates. **Remove 1 blue block**

—Algae pulls oxygen from ocean water. **Remove 1 blue and 1 red block**

—A bloom of harmful algae creates toxins. **Remove 1 blue and 1 red block**

—Oh no! A chemical spill at a factory leaks toxins into the watershed. **Remove 1 green, 1 blue, and 1 red block**

—Whales leave the area to migrate. **Put back 1 red block**

—Changes in ocean currents decrease upwelling of nutrients for zooplankton. **Remove 1 blue block**

—A layer of smog reduces the amount of sunlight able to reach the ocean. **Remove 1 green block**

—An increase in ocean temperature leads to smaller phytoplankton. They are unsuitable as food for zooplankton. **Remove 1 blue and 1 red block**

—Humpback whales remain in an area longer than usual. **Remove 1 red block**

—Ocean temperatures continue to rise. **Remove 1 green, 1 blue, and 1 red block**

—A storm is brewing! The influx of rainwater into the ocean reduces the concentration of phytoplankton. **Remove 1 green block**

—Invasive zooplankton reduce the number of phytoplankton. **Remove 1 green block and put back 1 blue block**

—Loud noises from ship engines harm marine mammals. **Remove 1 black block**

—Sonar testing interferes with whale communication. **Remove 1 black block**

—Oil drilling in the ocean disturbs the ocean environment. **Remove 1 green and 1 blue block**

—A local power plant releases warm water into the ocean, raising water temperatures. **Remove 1 green, 1 blue, and 1 red block**

—A new marine species from a traveling fishing boat is introduced into the local environment. **Remove 1 green block**

—Fishermen dredging the ocean floor disturb the natural habitat. **Remove 1 green block**

—Fishermen overfished an area. **Remove 1 red block and replace 1 green block**
Station Overview
Students will use microscopes to observe phytoplankton, and make connections about the important roles phytoplankton play in the marine environment.

Next Generation Science Standards

**5 LS 2-1:** Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

**Disciplinary Core Idea**

**LS 2.A:** The food of almost any kind of animal can be tracked back to plants.
Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants...Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.

**LS 2.C:** Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

**5 ESS 2-1:** Develop a model using an example to describe ways in which the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

**Disciplinary Core Idea**

**ESS 2.A:** Earth’s major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth’s surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.

**MS LS 1-6:** Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow into and out of organisms.

**Disciplinary Core Idea**

**LS 1.C:** Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.

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**Materials**

*Note: There are two options for obtaining phytoplankton. Pick one that best suits your program*

- Compound microscopes (www.wardsci.com / www.carolina.com)
- Basic Microscope Slide Poster
  Plankton (www.enasco.com; Product #: SB47107M)

**Option 1:**
- Wet Mount Slides: [order phytoplankton online]
- Marine Plankton (www.wardsci.com; Item #: 680028)
- Flat microscope slides (www.wardsci.com / www.carolina.com)
- Cover slips (www.wardsci.com / www.carolina.com)
- Eye dropper

**Option 2:**
Prepared Slides:
- Elementary Microscope Slide Set – Plankton (www.enasco.com; Product #: SL10000M)

*(Note: This set includes phytoplankton & zooplankton samples. Only provide the phytoplankton slides to students for this activity! These slides will perfectly match the Plankton poster noted above.)*
Museum Educator Guide: “Focus on Phytoplankton”

Preparation of the Station
Create wet mount slides (Materials Option 1)
1. Use an eye dropper to place one drop of the marine water sample onto the microscope slide.
2. Place the coverslip at a 45 degree angle (approximately) with one edge touching the water drop and then gently let go. Performed correctly the coverslip will perfectly fall over the specimen.

Purchase the prepared slides (Materials Option 2)
1. Factor in order and delivery time!
2. Sort out the phytoplankton slides from the zooplankton slides. Only provide the phytoplankton slides to students.

Set up the Station
1. Set up the microscopes at the station (1 per student in each rotation).
2. Set the lens on the lowest objective setting.
3. Place a slide on the stage, and secure it with the stage clips.
4. Bring a phytoplankton into focus.
5. Place all printed materials at the station.

Worksheets & Printables

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<td>Discovery Sheet: Focus on Phytoplankton</td>
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</table>
Phytoplankton are microscopic plant-like organisms that live in the ocean. Phytoplankton act as the primary food source for marine species, and through the process of photosynthesis, also supply about half of the world’s oxygen supply.

Today You Will Use a Microscope to Observe Phytoplankton!

1. Make a Hypothesis
   What do you predict the phytoplankton will look like?

2. Experiment Procedures
   1. Observe your phytoplankton sample for the following:
      - color, shape, structure
   2. Record the following information on your lab sheet:
      - a detailed drawing of the specimen and identification label (use the Plankton Identification Poster as a reference)
   3. Bonus: If given permission, you may observe your sample under the different power objectives. If you are able to do this step, be sure to return the microscope lens to the original setting when you are done!

3. Analyze Your Data and Draw
   Conclusions
   1. Draw and label the food chain of the humpback whale.
   2. Group discussion: Phytoplankton act as the primary food source for marine species, and also supply about half of the world’s oxygen supply. What problems could you predict if phytoplankton populations were to decrease?
Lab Sheet: “Focus on Phytoplankton”

Marine Biologist:

Objective
You will use a microscope to observe phytoplankton.

1. Make a Hypothesis
What do you predict the phytoplankton will look like?

2. Collect Data
Group Discussion: What did you discover about human influences on the environment? How could something as large as a humpback whale be impacted by small changes in the ocean? What did this game inspire you to want to investigate further? Brainstorm ways humans can help sustain life in the ocean.

3. Analyze Data and Draw Conclusions
1. Draw and label the food chain of the humpback whale. Include the specimen you observed today as your image for phytoplankton!

2. Group discussion: Phytoplankton act as the primary food source for marine species, and also supply about half of the world’s oxygen supply. What problems could you predict if phytoplankton populations were to decrease?
Discovery Sheet:
“Focus on Phytoplankton”

The word plankton is derived from a Greek word meaning “drifter.” Plankton are the organisms that drift around in ocean currents. Phytoplankton are plant-like organisms, while zooplankton belong to the animal kingdom. Most forms of life in the ocean depend either directly or indirectly upon plankton for food.

Phytoplankton produce their own food through the process of photosynthesis. Since they need sunlight to photosynthesize, phytoplankton are generally found near the surface of the ocean. Phytoplankton use carbon dioxide and water to produce food. As part of this process, they release oxygen into the water and into the atmosphere. Half of the world’s oxygen is produced via phytoplankton photosynthesis.

Phytoplankton form the base of the food chain in the ocean. A food chain is a series of living things in which each one uses the next lower member as a source of food. Nearly all phytoplankton species are used by zooplankton as food. Krill feed on phytoplankton, and even some forms of zooplankton, and they become the food for humpback whales.

Definitions
Plankton: “drifters,” the organisms drifting or floating in the sea or fresh water
Phytoplankton: microscopic plant-like plankton; examples include diatoms and dinoflagellates
Zooplankton: plankton consisting of small animals and the immature stages of larger animals; examples include copepods and jellyfish
Photosynthesis: the process by which plants and some organisms use sunlight to synthesize foods from carbon dioxide and water; it involves the green pigment chlorophyll and generates oxygen as a byproduct
Food chain: a series of types of living things in which each one uses the next lower member of the series as a source of food
Museum Educator Guide: “Ocean Acidification”

Station Overview
Students will discover the effects of climate change on the ocean and discuss its impacts on marine life and people.

Next Generation Science Standards
3 LS 4-4: Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

Disciplinary Core Idea
LS 4.D: Populations live in a variety of habitats, and change in those habitats affects the organisms living there.

5 ESS 3-1: Obtain and combine information about ways individual communities use science ideas to protect the Earth’s resources and environment.

Disciplinary Core Idea
5 ESS 3.C: Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments.

MS LS 2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Disciplinary Core Idea
LS 2.C: Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

Materials
- Beaker, 1000mL (www.wardsci.com / www.carolina.com)
- Water
- Bromothymol blue, 0.04% Aqueous (www.wardsci.com / www.carolina.com)
- A stirring implement
- Dry ice (www.dryiceideas.com)
- Protective gloves (www.wardsci.com / www.carolina.com)
- Tongs (www.wardsci.com / www.carolina.com)
- Goggles for each student & adult (www.wardsci.com / www.carolina.com)
- Colored pencils
- 2 similar shells (e.g. slipper, scallop, ark, or small clam shells) (www.amazon.com)
- Small bowl
- White vinegar
- 2 petri dishes with covers (www.carolina.com or www.wardsci.com)
- Magnifying glasses

Carbon Emissions and Changing Reef Environments

HIGH CARBON EMISSIONS, NEGATIVE IMPACT ON REEF
REDUCED CARBON EMISSIONS, INCREASED DIVERSITY AND PRODUCTIVITY IN REEF
**Preparation of the Station:**

Prepare the shells (up to 1 day in advance).

1. Start by soaking one of the two shells in vinegar. Initially, you will notice bubbles forming. Check back every several hours for noticeable changes. Depending on the size and thickness of your shell, let it soak for several hours, but note it may take up to a day to see noticeable changes.

2. A degraded shell will be dull, pitted, translucent, thin, or even cracked. When the shell is visibly degraded, drain and rinse off the vinegar.

3. Place each shell in its own petri dish and label them respectively: non-acidified shell and acidified shell.

**Create “the Ocean” (1 “ocean” per rotation).**

1. Fill the beaker with 500 mL of water.
2. Add about 30 drops of Bromothymol blue and stir well.
3. Set the beaker at the station.

**Prepare the Dry Ice (1 chunk of dry ice per rotation).**

*Safety Note: Whenever handling dry ice, wear gloves and goggles for protection!*

1. Put on protective gloves and goggles.
2. Break off a chunk of dry ice (approx. 1-2 inches on all sides).
3. Place the tongs, gloves, goggles, and dry ice at the station.

**Set Remaining Materials at the Station**

1. Set out the colored pencils, magnifying glasses, and shells (in petri dishes) at the station.
2. Place all printed materials at the station.

**Materials Disposal**

1. At the end of all rotations, dilute the bromothymol blue solutions in the beakers with water, and pour down the drain.
2. Wash all beakers thoroughly.

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**Worksheets & Printables**

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<td>Lab Sheet: Ocean Acidification</td>
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<td>Discovery Sheet: Ocean Acidification</td>
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<tr>
<td>Printable: Bromothymol Blue</td>
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<tr>
<td>Printable: Ocean Acidification: Before &amp; After</td>
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</tbody>
</table>
Experiment Procedures:
“Ocean Acidification (Demonstration)”

*Safety Note: Dry ice should be handled by an adult only! Wear protective gloves and goggles! All students should put on goggles before the experiment begins.

**Introduction**
1. Tell students that the blue water in the beaker represents “ocean” water. A solution called Bromothymol blue has been added to it. That is what gives it the blue color!
2. Show students a chunk of dry ice and explain that it is cooled and compressed carbon dioxide.
3. Before you add it to the beaker, encourage students to share their predictions about what will happen when the dry ice is added to the ocean.

**Add the Dry Ice**
4. Using the tongs, carefully lower the chunk of dry ice into the beaker.
5. Encourage students to share their observations.

6. Direct students’ attention to the Bromothymol Blue printable. Point out the indicator and pH scale, and direct them to record their data on their lab sheet.
7. Explain: As the dry ice went from a solid to a gas, carbon dioxide bubbles entered the “ocean,” making it more acidic.

**Observe Acidification Effects on Shells**
8. Direct students’ attention to the two shell samples. One has been exposed to acidification, while the other has not. Direct students to use the magnifying glass to get a closer look at each of the shells. Discuss observations, and encourage students to record their data.

**Clean Up Procedures**
9. The museum educator will dispose of beaker contents.
10. A new beaker should be used for each rotation.
Task Card: “Ocean Acidification”

Today you will discover the effects of climate change on the ocean and marine life!

1. Make a Hypothesis
   What do you think will happen to the ocean when an excess of carbon dioxide is introduced to it?

2. Experiment Procedures
   1. Put on your goggles!
   2. Observe ocean acidification in action!
   3. Look at the Bromothymol blue pH indicator chart. Note the pH levels of each of the colors you observed in today’s experiment, and record your data.
   4. Look at the two shell samples. Use a magnifying glass to get a closer look! What do you notice?

3. Clean Up Your Station!
   Replace all goggles at the station.

6. Analyze Your Data and Draw Conclusions
   Group discussion: How do you think the effects of ocean acidification can cause problems for marine life and humpback whales in particular? How do you think it could impact people? Brainstorm solutions that could help reduce the amount of carbon dioxide being released into the environment.
Lab Sheet:
“Ocean Acidification (Demonstration)”

Oceanographer:

Objective
Today you will discover the effects of climate change on the ocean and discuss the impacts on marine life and people.

1. Make a Hypothesis
What do you think will happen to the ocean when an excess of carbon dioxide is introduced to it?

2. Collect Data
Draw and label your observations in the two blue boxes!

3. Analyze Data and Draw Conclusions
Group discussion: How do you think the effects of ocean acidification can cause problems for marine life and humpback whales in particular? How do you think it could impact people? Brainstorm solutions that could help reduce the amount of carbon dioxide being released into the environment.

IMPACTS ON THE OCEAN
Draw what you see

1. The ocean before carbon dioxide is introduced.

2. The ocean after carbon dioxide has been introduced.

3. Circle the ocean that is more acidic!

IMPACTS ON SHELL
Draw the effects of the ocean acidification on the shells

BEFORE

AFTER

What did you notice when you observed the two shell samples?

pH: ______

pH: ______
Discovery Sheet: “Ocean Acidification”

Carbon is an element that’s found all over the world and in every living thing. Oxygen is another element that’s in the air we breathe. When carbon and oxygen bond together, they can form a colorless, odorless gas called carbon dioxide, which is a heat-trapping greenhouse gas. This process is known as the Greenhouse Effect. Whenever we drive our cars, use electricity, or make new products in factories, we are burning fossil fuels and producing carbon dioxide.

Greenhouse gases trap heat in the atmosphere, which makes the Earth warmer. Most of the carbon dioxide that is released into the atmosphere ultimately ends up in the oceans. Heat trapped in the atmosphere is needed to sustain life on Earth. However, when we produce too much carbon dioxide, problems can start to arise. This is happening faster than natural processes can remove it. The increase of the Earth’s average surface temperature, due to a build-up of greenhouse gas, is a component of climate change.

Carbon dioxide not only increases temperature, but it also has the ability to change the pH of the ocean. The pH of a substance refers to how acidic or basic it is. When the carbon dioxide we add to the air mixes with the water at the surface of the ocean, they blend together and form an acid that changes the ocean’s pH. One of the major concerns scientists have is that the most vulnerable species to ocean acidification are also some of the most important for healthy marine ecosystems.

Studies have shown that a more acidic environment has a dramatic effect on some calcifying species, including oysters, clams, sea urchins, and corals. These organisms have a shell or skeleton made of calcium carbonate, which often breaks down in acid. When organisms are at risk, the entire food web may also be at risk. Ocean acidification may also adversely impact some plankton species, and their loss would ripple through food webs to impact larger animals like fish and whales.

Definitions:
- **Greenhouse gas**: a gas that contributes to the greenhouse effect by absorbing infrared radiation, i.e., carbon dioxide and chlorofluorocarbons
- **Climate change**: any significant change in the measures of climate lasting for an extended period of time. Climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer
- **pH**: a scale that refers to how acidic or basic a liquid is
- **Ocean acidification**: an effect caused by carbon dioxide entering the ocean, combining with seawater, and producing carbonic acid, which increases the acidity of the water, lowering its pH
The pH scale measures how acidic or basic a substance is. The pH scale ranges from 0 to 14. A pH of 7 is neutral. A pH less than 7 is acidic. A pH greater than 7 is basic. Note the pH levels of each of the colors you observed in today’s experiment.
Discovery Sheet:
“Ocean Acidification: Before & After”

BEFORE

AFTER
**Museum Educator Guide:**

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“Convection Currents”
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**Station Overview:**

Students will observe a convection current, seeing how warm water rises and cooler water sinks.

**Next Generation Science Standards**

- **MS ESS 2-6:** Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

**Disciplinary Core Idea**

- **ESS 2.C:** Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

**Materials**

- 5 gallon tank or clear plastic 16 qt. tub (you may want to have 3 of these)
- Short baby food jar
- Tongs
- Electric tea kettle (hot pot, or alternate way to heat water to a very hot temperature)
- Water
- Red food coloring
- Blue food coloring
- Ice cube tray and freezer
- A small cooler or ice chest
- Colored pencils
- A latex glove
- Hand towel
- White paper
- Aluminum foil
- Rubber band
- Long bamboo skewer (available at most grocery stores)

**Preparing the Station**

Prepare the ice (1-2 cubes per rotation).

1. Dye water blue and freeze in an ice cube tray.
2. Place prepared ice cubes in a small cooler to prevent melting.

**Prepare the Water Tank** (1 tank per rotation)

1. Fill up the water tank in advance, so the water comes to room temperature and is “calm.” Place it at the station.
2. Tape white paper along the back side of the tank. This provides better viewing for students later on.

**Prepare the Jar** (1 jar per rotation)

1. Add water to the hot pot. Heat it up just prior to students arriving. The adult at this station can reheat it to the desired “very hot” temperature, as needed.
2. Punch a small hole in the lid of a baby food jar.
3. Add 6 drops of red dye into the jar.

**Set Materials at the Station**

1. Place the cooler, electric tea kettle, jar and lid, tongs, hand towel, and water tank at the station.
2. Place all printed materials at the station.

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**Worksheets & Printables**

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Experiment Procedures: “Convection Currents”

Prepare the Hot Water
1. Heat the water in the hot pot.
2. When the water becomes very hot, carefully pour the water into the baby food jar (which already has red dye in the bottom).
3. Fill the jar to the very top (nearly overflowing) with hot water. Carefully cover the jar with a piece of aluminum foil and secure with a rubber band.

Place the Red Jar in the Tank
1. Use the tongs to carefully place the filled jar at the bottom of the tank, near one side. Try not to disturb the calmness of the water.
2. Use a long wooden skewer to poke a few holes in the top of the aluminum foil. The more holes, the more dyed red water will be visible.
3. Direct students to make observations, and connect what they see to the relationship between temperature and density. They may record their observations on their lab sheet.

Place the Blue Ice Cube in the Tank
1. Put on the glove (to keep the dye off your fingers) and carefully place a blue ice cube on top of the water on the opposite side of the tank (away from the baby food jar). Keep the cube on one side of the tank.
2. Direct students to make observations, and connect what they see to the relationship between temperature and density. They may record their observations on their lab sheet.
3. A second ice cube may be added if the first one melts too quickly, or all students are unable to see the stream of blue from the first one.

Clean Up!
1. Each new rotation will receive a fresh tank for the demonstration.
2. Ask the museum educator to refresh the supplies for you.
Task Card: “Convection Currents”

Today You Will Observe a Demonstration of Convection Currents!

1. Make a Hypothesis
   What will happen when an ice cube is placed in the water tank? What will happen when a jar of hot water is placed in the water tank?

2. Experiment Procedures
   1. Make observations when the red and blue water samples are placed in the water tank.
   2. Record your observations.

3. Analyze Your Data and Draw Conclusions
   Group discussion: What changes did you observe in the blue water and the red water? Did they behave the same way? How does this experiment show the relationship between water temperature and density?
**Lab Sheet:**
“Convection Currents”

Oceanographer:

**Objective**
Today you will observe a demonstration of convection currents.

1. **Make a Hypothesis**
   What will happen when ice cubes are placed in the water tank? What will happen when the warm red water is released into the tank?

2. **Collect Data**
   Draw and label your observations in the tank below!

3. **Analyze Data and Draw Conclusions**
   Group Discussion: Why did the blue water sink while the red water flowed upwards? Draw conclusions about the relationship between water temperature and density.

How do convection currents relate to the ocean and humpback whales?

Draw and label your observations in the tank below!
Discovery Sheet:
“What Convection Currents”

Ocean water moves from place to place in ocean currents, which are like rivers in the ocean. Ocean currents transport water, heat, nutrients, sediments, animals and plants, and even ships from place to place in the oceans! In general, ocean currents carry heat from the tropics to the poles. This helps distribute and equalize the amount of heat throughout the planet.

As wind blows over the ocean, it tugs on the surface of the ocean, moving the ocean surface water. These are called surface currents. Not all currents in the ocean are driven by wind across the surface, though.

Some currents are found deep in the ocean where the wind does not affect them. These deep ocean currents are one component of global ocean convection currents. Water density drives these currents. Different parts of the ocean have different densities, and the differences in density form convection currents.

Water density depends on its temperature and its salinity. Temperature is how hot or cold something is, while salinity is the amount of salt dissolved in a solution. As the temperature of water increases, its density decreases. As the salinity of water increases, its density increases.

Definitions
Current: a continuous, directed flow
Convection currents: in the ocean, dense cold salty water sinks at the poles, while warm, less salty, and less dense water rises near the equator.
Density: a measure of how much mass is contained in a given unit volume (density = mass/volume)
Salinity: the total amount of dissolved salt and minerals in grams in one kilogram of sea water
The End