Lesson 2 Adaptations

Overview
The class will engage in a lab demonstrating the ways in which whales benefit from being so large. Students will create an imaginary creature with adaptations to survive in the ocean which will help students understand and apply the correlation between an animal's adaptations and the physical characteristics of its environment.

National Science Education Standards
Content Standards K-4
Science as Inquiry: Abilities necessary to do scientific inquiry, Understanding about scientific inquiry.
Life Science: The characteristics of organisms, Life cycles of organisms, Organisms and environments.
Science and Technology: Abilities to distinguish between natural objects and objects made by humans, Understanding about science and technology.
Science in Personal and Social Perspectives: Characteristics and changes in populations, Types of resources, Changes in environments.
History and Nature of Science: Science as a human endeavor.

Content Standards 5-8
Science as Inquiry: Understandings about scientific inquiry.
Life Science: Regulation and behavior, Populations and ecosystems, Diversity and adaptations of organisms.
Science in Personal and Social Perspectives: Populations, resources, and environments, Science and technology in society.
History and Nature of Science: Science as a human endeavor.

Ocean Literacy Principles
Principle 1: The earth has one big ocean with many features.
Principle 2: The ocean supports a great diversity of life and ecosystems.

Performance Objectives
Students will:

• Be able to correctly define what an adaptation is.
• Explain how adaptations develop.
• Understand how adaptations help animals survive in their environment.
• Be able to apply their understanding of adaptation to whales and correctly identify examples.
• Develop an intellectual appreciation and fascination for the unique adaptations possessed by whales.

Background
In order to survive in their particular environment, all animals must have structures and behaviors that enable them to obtain food, water, move, maintain body temperature and attract or find mates. The specific characteristics that an animal possesses which help it survive are called adaptations. Adaptations can be structural (e.g. a bird's beak) or behavioral.
(e.g. migration patterns). Due to the tremendous variety of earth's environments, there is a
great variety in animal adaptations.

All animals and plants have adaptations, including humans. It is easier to understand what an
adaptation is if it is pointed out on a familiar animal-ourselves. If a student names any
human feature, we can see what its purpose is. Here are a few examples:

- We lose about 40% of our body heat out of the tops of our heads. Hair helps us to
  retain some of that heat.
- We have ears that stick out of our heads to funnel sound waves to the ear canal.
- We have hair on our eyebrows to keep sweat and rainwater out of our eyes.
- We have eyelashes to keep dust out of our eyes.
- We have pinkie toes to help us keep our balance as we walk.
- We have opposable thumbs so that we can do a variety of tasks with our hands.

Whale Adaptations:
All mammals, including whales, have five key traits in common. These are:
- Breathe air
- Give birth to live young
- Nurse their young
- Warm blooded
- Have hair (baby whales and dolphins actually have small hairs on their rostrums
  (nose) when born and it eventually sheds away leaving behind small follicles)

These mammalian traits are a large contrast to fish. Bony fish like rockfish and cartilaginous
fish like sharks and rays obtain oxygen directly from the water through their gills. Fish are
cold blooded and have protective layers of scales.

Over the last 55 million years whales have developed many aquatic adaptations, for example;
whales' nostrils or blowholes moved to the top of their heads so they could breathe by
bringing less of their heads out of the water. When it comes to food and how they obtain it,
whale species have vastly different strategies. Whales are divided into two subgroups based
on whether they have teeth or not.

**Odontocetes** (toothed whales) are the whales and dolphins with teeth. Odontocetes use
their teeth to grasp prey and either swallow fish or squid whole. Some toothed whales, like
Orcas, dismember their prey by shaking it violently. Most toothed whales, with a few
exceptions like the sperm whale and orca, are relatively small compared to baleen whales.

**Mysticetes** (baleen whales) like the blue whale, don't have teeth at all, they are the experts at
filter feeding. They have unique structures in their mouths called baleen. Baleen is made of a
protein called keratin, which is the same substance that makes up our hair and fingernails.
Mysticetes have hundreds of long, flat plates of baleen suspended from the top of their
mouths. These plates are stacked next to each other where teeth would have been with a
small space between each plate. The inside edge of each baleen plate is hairy or fringed, like a
broom, and these baleen hairs crisscross to form a net.
There are three methods that different types of baleen whales employ for catching their food.

- **Skim feeding.** Right and bowhead whales swim along the surface and trap slow moving plankton (tiny, free-floating organisms) against the hairy linings of their baleen while water flows out of the sides.

- **Bottom or Pit Feeding.** Gray whales move along the muddy bottom on one side of their body scooping up mud. They also will position themselves vertical in the water with their head burrowing into the mud. These techniques allow them to strain their crustacean prey out with their baleen. Gray whales are the only baleen whale that feeds in this method.

- **Lunge Feeding.** Rorqual whales (baleen whales with throat pleats like the blue, fin, sei, brydes, minke, and humpback whales), lunge forward quickly, taking hundreds of gallons of water into their mouths along with a school of small fish. The pleats expand making room for the large volume of water. The whales close their mouths partway and force the water out through the baleen. The baleen hairs trap small fish and plankton inside.

One of the striking adaptations of the baleen whales is that they utilize SIZE to survive. To equate the size of a 100-foot blue whale, imagine being on the ground floor of a building with seven stories. If a blue whale was suspended head downwards, looking at you, the tip of its snout would be touching the floor and its large, grapefruit sized eyes would be staring at you from the ceiling of the second floor. Its head would end at the third floor and the rest of the body (about 60 feet) would extend all the way to the seventh floor roof or the building!

Some baleen whales have adapted an amazing way to balance their needs of feeding and reproduction. These whales migrate hundreds to thousands of miles between the cold polar waters, (which are the source of their food), to warmer waters where they may bear their young in safety and seclusion. Astonishingly, they make a full, round-trip every year. Gray whales, for example, travel up to 12,000 miles round trip between breeding and feeding grounds each year.

Swarms of krill dense enough to sustain whales' huge bodies are the most abundant near the polar regions. However, calves are born with only a minimal blubber (fat) layer and must be in warm water for their first few weeks while they rapidly gain weight from their mothers' rich milk. During their migrations and while at the calving grounds, non nursing baleen whales are known to fast almost completely. As active, warm-blooded animals, this makes their journey one of the greatest feats of fasting on earth, lasting nine months in some cases. Being large is the only way warm-blooded animals can fast for long periods. This has to do with an important concept of surface area to body mass ratio.

The bigger the animal the smaller its surface area is in relation to its volume. This can be a tough concept to grasp, so here are a few analogies to help. The surface to volume ratio is much smaller in whales than in mice. This means that a mouse has more skin in relation to its body mass than does a whale, whose skin covers a much greater bulk of internal space. Animals generate heat with their bodies (like having a built in furnace). A mouse has a little furnace and its outside skin acts as a radiator, giving off a lot of heat. Whales have a huge internal furnace yet their outer surface area amounts to what would be a very small radiator for such a big furnace. Since whales have a small surface area to body mass ratio, they
expend relatively less energy in the form of heat than a smaller animal does. Whales are equipped with blubber between their muscle layers and skin. The larger baleen whales have several inches of blubber. Since there is not enough food in the warmer regions to support the mass of a big whale, the whales fast and convert their blubber into energy instead of eating. They need to carry massive blubber reserves in order to survive these fasting periods. A mouse on the other hand, needs to eat about its own weight in food each day to survive. Another function of blubber is thermoregulation.

The process of keeping the body at the right temperature (whale body temperature is within a few degrees of humans standard temperature of 98.6°F or 37°C) is called thermoregulation. Whales have adapted special adaptations to help them thermoregulate. They cool off by sending warm blood to their external body parts (dorsal fins, flippers, and flukes). These extremities have thinner layers of blubber, or none at all, so the heat in the body can be lost to the cooler water washing over the extremity. If the whales are cold, their blubber is an excellent insulator. Whales retract their blood back inside the blubber layer. In addition to blubber, whales utilize counter current heat exchange for increasing warmth. Veins bringing back cool blood from extremities lay next to arteries carrying warm blood away from the heart, increasing the temperature of the blood in the veins. This helps to keep the blood returning to the heart from cooling the internal temperature of the body.

Another adaptation whales possess is their ability to use sound as a means of interacting with their surroundings and each other. Some baleen whales have the ability to make sounds so loud that they can be heard hundreds or thousands of miles away, even across entire ocean basins. This is possible because of the unexpected ways in which sound travels through water. Low sounds travel particularly well in the sea, losing energy by conversion to heat only after traveling very long distances. The temperature and pressure structure of deep ocean water acts to confine sounds in a duct that prevents the sound energy from dissipating as fast as it would in water of uniform pressure and temperature. Think of a fiber optic cable as an analogy. Fin and blue whales appear to take advantage of these special features of seawater as a means of making sounds that travel for very long distances. Whales vocalize to communicate information regarding food and mate selection. Male humpback whales sing long, complex songs that play an important role in courtship and mate selection. These songs are highly structured patterns of sounds similar in many ways to human music.

Toothed whales, which evolved before baleen whales, have complex social systems and live in structured social groups called pods or herds. Toothed whales can use vocalizations to maintain social bonds. Certain species of toothed whales, like bottlenose dolphins, develop a signature whistle which acts as their name. This signature whistle is developed by dolphin calves in their first year and is used for their entire lives. It is one way toothed whales communicate their location while foraging, traveling, or at play. They also use echolocation to locate and capture food without the need for eyesight. This allows them to feed in permanently murky or dark surroundings and navigate through the oceans.

**Website Videos to Watch**
Meet the sperm whale, The voice of the blue whale, Meet the gray whale, and The whistles of bottlenose dolphins.
**Key Words for Whale Wall**
Adaptation, Baleen, Migration, Mysticetes, Odontocetes, Pod, Thermoregulation

**Materials**
- Paper, pens, and crayons to create art and words for whale wall
- Five Dixie (or 2oz.) cups for each group of students
- One 12oz. cup for each group of students
- Source of hot water (140 degrees)
- One thermometer per group
- Two differently colored pencils or pens per group
- Student Journal (Datasheet A and Creatures of the Deep)
- Watch or timer

**Before Class**
1. Write on the board: “Adaptations help Animals:”
   - Get food and water?
   - Move around?
   - Maintain warm body temperature?
   - Fast for several months at a time?
   - Attract mates?
2. Cover the list with a pull down map, screen, or poster.
3. Have drawing supplies ready.
4. Set up surface area lab. Preheat water or use hot water from a tap. Count out small and large paper cups so that there are five small cups and one large cup for every four students. Set aside one thermometer per group…review safety handling glass equipment before the lab begins.

**Procedure**
1. Raise the map and define adaptation. An adaptation is a physical and/or behavioral feature that appears slowly over time and helps an organism survive in its environment. Some adaptations are structural, like a bee’s wings or a bird’s beak and some are behavioral like bird song.
2. Have the following discussion with the class: Adaptations help animals to do a lot of things.
3. “From the website videos, who can tell me an adaptation whales have to”:  
   - Get food and water?  
     (Baleen vs. teeth, feeding behaviors, water comes from prey they eat)
   - Move around?  
     (Flukes, flippers)
   - Maintain warm body temperature?  
     (Small surface area to body mass ratio and blubber also helps)
   - Fast for several months at a time?  
     (Blubber = fuel)
   - Attract mates?  
     (Male humpback whales sing songs, sperm whale codas)
4. Can you think of any other whale adaptations from the videos?  
   (Migration from feeding grounds to warmer calving waters, traveling in pods, group 'bubble net' feeding, females with calves stay silent to
avoid attracting predators, killer whales hunt in packs, baleen whales lash their tails to defend themselves.)

**Size Lab Activity: Five Mice and a Whale**

Whales and other marine mammals have a unique way of keeping warm in even the coldest water. This lab will help students understand how the adaptation of size helps keep whales warm through demonstrating the effect of surface area to volume ratio on heat loss. Remember the furnace (internal body mass) to radiator (body surface) analogy. Why is a whale so big? Great whales, like the blue whale, are the largest animals ever to live on earth. One of the least known facts about them is just why they are so large.

1. Break the class up into small groups with five students in each group. Give each group a thermometer, five small Dixie cups (represents mice), one 12 oz paper cup (represents whale) and a watch (or classroom clock) plus their Student Journal.
2. Explain to the students that this lab will demonstrate the effect of surface area on heat loss and they will be recording data of the results.
3. Have students choose a record keeper, a time keeper, and two thermometer readers.
4. Have the record keeper fill out the Size Lab Datasheet in their journal, recording the temperatures as the lab progresses. Other group members can add the data to their journal after the recording is completed.
5. Have students pour five Dixie cups of cool tap water into the large cup and mark the water level on the cup.
6. Empty the large cup.
7. Dispense hot water to each group, filling each of the five Dixie cups and the large cup to the mark. Have students record time and the temp of one small cup and the large cup as soon as they receive their water.
8. Students are to take the temperature of one Dixie cup and the large cup every minute for ten minutes.

**Discuss**

1. What were the ending temperatures of the two types of cup?
2. Did the different cups cool at the same rate, even though they started at the same temperature?
3. Which cooled faster the large or small cup?
4. Think of the size and shape of a blue whale. How does this compare to the large cup? Like the large cup, a whale has the great advantage of a large internal furnace to keep itself warm inside and a relatively small radiator through which to lose heat. This is a major factor in keeping these animals warm even when they are in water just a few degrees above freezing.
5. Collect materials and water, dry desks off.

Explain to students that the great size of whales allows them to hold enough reserve energy in the form of blubber (fat) to sustain them on one of the longest fasting periods on earth. They can survive without feeding during migration and while they spend months in warmer water bearing young, nursing and mating. Some whales fast for nine months or more without eating more than what would be for us, the equivalent of a candy bar per day of food intake.
"Creatures of the Deep" Activity

Draw a nondescript shape on the board, like an irregular oval or circle. Introduce activity by stating that there are millions of other creatures in the sea in addition to whales and dolphins. Each creature has unique adaptations to help it survive. Jellyfish have tentacles with which to capture their prey, clams build a protective house around themselves and many deep-sea creatures have built-in lights to see in the dark, attract mates, or fool predators. Tell students that they are going to help create an animal with adaptations to survive in its ocean habitat. The ocean has numerous habitats for living organisms to thrive. The ocean basins are all connected through moving and dynamic currents. The diversity of habitats is amazing and ranges from deep sea trenches, valleys, hydrothermal vents, to the open ocean, kelp forests, coral reefs, shallow water lagoons and tidepools. The adaptations among organisms are dependent upon the habitat they live in.

Ask the class for ideas on creating this new creature. As they make suggestions, invite students to come to the board and draw their suggestion on the "creature." Encourage them to be creative or to borrow adaptations from existing animals. They can even use ideas from machines or man-made objects. No one needs to be an artist. Since every student is going to be inventing a new creature the drawing doesn't have to look like anything we know or recognize! By the time your "class creature" is finished it should have adaptations to:

- Get food
- Move around
- Thermoregulate
- Attract or find a mate
- Avoid predators

Pass out the Student Journals and coloring supplies. Students will now invent their own "Creature from the Deep." Their creature can be whatever shape they want and can look however they want. Those who are artists might have a specific shape in mind, while others start with a basic blob. Each creature must, however, have adaptations to survive in their specific ocean habitat. Some example adaptations are: gills, brilliant colors to stand out, natural colors to blend in, color and texture variability, lights on body, stinging tentacles, filters to catch microscopic food, traveling in schools, fins, feet, underwater wings, or cilia to move around, mouths with adaptations to suck, chew, bite or filter.

Extension

Sizing Up

To visualize the diversity in size among whale species take the class outside or into a large space like the auditorium. With rope measure out and cut the various lengths of whales. Once the rope is placed on the floor, students can explore the various lengths of whales and how many of them make up one whale. Ask students to lay down head to foot in a row the length of the ropes.

Blue whale (largest animal on earth!): average large adult is 100 feet
Humpback whale: 52 feet
Gray whale: 46 feet
Minke whale (smallest baleen whale): 23-33 feet
Bottlenose dolphin: 8-12 feet
Orca (largest dolphin): 16-22 feet  
Vaquita (smallest toothed whale): 4-5 feet  
Sperm whale (largest toothed whale): 52 feet

**Teacher Wrap-Up**

Today we've learned about adaptation and how the challenges of living in the ocean have caused whales and other animals to develop specific characteristics to help them survive. (Review definition of adaptation.) One of the most striking aspects of great whales is their enormous size. There are at least two ways whales benefit from being so huge. Our lab demonstrated that because whales are large and voluminous, less of their internal space is near the surface where heat is lost. In order to fast for long periods of time, whales need to have great stores of energy in the form of blubber. Being large allows whales to carry many months worth of stored food.

Whales have some of the most unique and amazing adaptations on earth. Later in the week, we will learn more astonishing facts about how whales have adapted to find their way in the vast ocean and communicate with one another using sound.