

Marine Mammal Adaptations and Climate Change

Background:

(excerpted and adapted from <http://cetus.ucsd.edu/VoicesintheSea/test/lessons/Lesson202.pdf>)

In order to survive in their particular environment, all animals must have structures and behaviors that enable them to obtain food and 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 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.

All mammals, including marine mammals, have five key traits in common. These are:

- Breathe air
- Give birth to live young
- Nurse their young
- Warm-blooded (maintain a consistent internal body temperature)
- Have hair (baby whales and dolphins actually have small hairs on their rostrums (nose) when born that eventually shed 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. Marine mammals have lungs and must come to the surface to breath.

Over the last 55 million years, whales have developed many aquatic adaptations, for example:

- 1) Whales' nostrils, or blowholes, moved to the top of their heads so they can breathe by bringing less of their heads out of the water.
- 2) Whales have fins that work like paddles to help them move through water.

- 3) Whales have a streamlined body shape so that they move through water more efficiently.
- 4) 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 or not they have teeth:

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

Mysticetes (baleen whales), like the right whale, don't have teeth at all. 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. This makes them experts at filter feeding. All the local species of whales mentioned above are baleen whales. 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 using this method.
 - *Lunge Feeding:* Humpback whales (baleen whales with throat pleats like the blue, fin, sei, Bryde's, minke, and rorqual 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.
- 5) 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 roof of the building (top of the seventh floor)!

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 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. The whales convert their blubber into energy instead of eating. 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 such long periods.

6) Another use 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 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 countercurrent heat exchange for increasing warmth. Veins, bringing back cool blood from extremities, lay next to arteries carrying warm blood away from the heart, which increases the temperature of the blood in the veins. This helps keep the blood returning to the heart from cooling the internal temperature of the body.

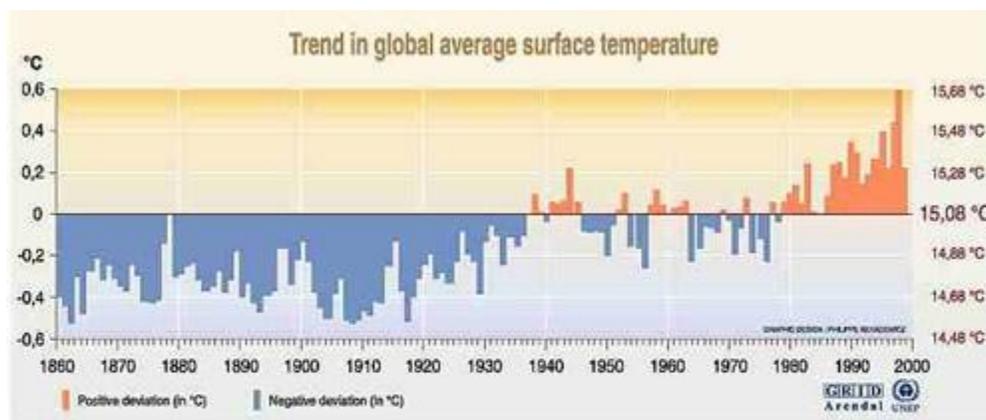
7) Another adaptation whales possess is their ability to use sound as a means of interacting with their surroundings and each other. Some baleen whales have the ability to make sounds so loud that they can be heard hundreds of thousands of miles away, even across entire ocean basins. This is possible due to the way 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.

Climate Change background

(excerpted from: http://www.eo.ucar.edu/basics/cc_1.html):

Our weather is always changing and scientists are now discovering that our climate changes as well. Climate, the average weather over a period of many years, differs in regions of the world that receive different amounts of sunlight and have different geographic factors, such as proximity to oceans and altitude.



This graph shows the amount of difference between each year's global average temperature and the overall average (15.08°C) since 1860. The upward trend since the early 1990s indicates global warming.

Courtesy GRID/UNEP

Climates will change if the factors that influence them fluctuate. To change climate on a global scale, either the amount of heat that is let into the system changes, or the amount of heat that is let out of the system changes. For instance, warming climates are either due to increased heat let into Earth's atmosphere or a decrease in the amount of heat leaving Earth's atmosphere.

The heat that enters Earth's system comes from the sun. Sunlight travels through space and our atmosphere, heating up the land's surface and oceans. The warmed Earth then releases heat back into the atmosphere. However, the amount of sunlight let into the system is not always the same. Changes in Earth's orbit over thousands of years, and changes in the Sun's intensity, affect the amount of solar energy that reaches the Earth.

Heat exits Earth's system as the Earth's surface, warmed by solar energy, radiates heat away. However, certain gases in our atmosphere allow the lower atmosphere to absorb the heat radiated from Earth's surface, acting like a blanket trapping heat within the Earth system. These gases such as water vapor, carbon dioxide, methane, and nitrous oxide, are an important part of our atmosphere because they



keep Earth from becoming an icy sphere with surface temperatures of about 0°F. However, over the past century or so, the amounts of these heat trapping gases within our atmosphere have been increasing rapidly. This is mainly due to the burning of fossil fuels such as gas, oil, and coal, which release carbon dioxide into the atmosphere. The heat-trapping gases create a blanket effect which has steadily been warming the earth's atmosphere as well as the world's oceans. Consequently, in the past one hundred years, global temperatures have been increasing more rapidly than they have prior to the last hundred years.

As the oceans gradually warm there are effects on marine ecosystems and marine life. When the oceans warm, the temperature rise affects the surface water where much of the marine life lives. Slight temperature shifts can destabilize the balance there.

For example, krill have been shown to reproduce less in warm water and they are a major food source for humpback whales. During the spring, the humpbacks migrate to their feeding grounds, the Gulf of Maine in the Atlantic and the Gulf of Alaska in the Pacific. They go to the cold, nutrient rich water in the north to feed so that they can build up their blubber (fat) reserves for calving in the winter. If krill populations were to shrink or relocate as the location of cold, nutrient rich water changes then that would impact whale distributions. Similarly, North Atlantic right whales feed on the copepods growing in the cold, nutrient rich water. Their distributions would be impacted by warming waters and shifting copepod distributions.

Also, as water heats up it expands causing rising sea levels. This can lead to shoreline erosion and inundation of coastal habitats. Warming oceans leads to more frequent and stronger tropical storms and hurricanes. It can also lead to melting ice in Polar Regions as well as changes in the amount of seasonal ice.

Excess carbon dioxide in the atmosphere also leads to acidification in surface ocean waters. As carbon dioxide dissolves in sea water it leads to ocean acidity. An acidic environment is detrimental for organisms such as tiny zooplankton called pteropods that need to make and grow shells. This has far reaching impacts as you travel up the food web. Additionally, acidification can affect animal's metabolism and behavior.

Over long periods of time animals do adapt. Adaptations do not happen overnight. The animals in our ocean are adapted for a specific habitat, temperature, salinity, pH, feeding strategy, etc. As the climate changes at a rapid rate the animals are forced to change their behavior in response to their changing environment. This can impact their numbers, distribution, and population health.

What can be done? We can reduce other stresses on the marine ecosystem by supporting good fisheries practices. We can model good energy usage. We can support people making policy changes



that recognize the danger of excess carbon dioxide. We can share this information and encourage others to modify their behavior as well.

Lessons:

Introduce yourself as a representative of NOAA and PSB. Show students (**slide 1**) where we are located in Woods Hole.

Introduction (5-10 minutes):

Questions to ask while showing the slideshow intro:

- (a) What is an adaptation? As an example, make a list of adaptations humans have and how that relates to our habitat. After generating the list show **slide 2**.
- (b) Today we are talking about marine mammals. What is a marine mammal? What is the marine habitat like? Show **slide 3** to generate ideas.
- (c) What adaptations do marine mammals have for living in the ocean? Make a list of adaptations marine mammals have and how that relates to their habitat and then show **slide 4**. Show them the real artifacts to illustrate: sperm whale teeth, minke and fin whale baleen, sperm whale vertebrae, harbor seal pelt, harbor seal skull, and sperm whale rib. For perspective, have one student hold the human rib and have 5 hold the sperm whale rib (this is a great photo-op for the classroom).

Activity 1:

ADAPTATION IDENTIFICATION

Goals:

- Introduce students to the (mostly) local marine mammal.
- Reaffirm the idea of adaptations and have them apply the concept independently.

Materials:

- Laminated pictures of polar bear, local seals, and whales
1. Give each student a laminated picture.
 2. Ask the students to spend the next 2 minutes looking at their pictures and identifying structural adaptations they see on their animal. They should think about what the animal uses that adaptation for.



3. As they finish, they should discuss the adaptations they have found with their neighbor until the whole class has finished. When everyone is done ask students to raise their hands and share one adaptation they found on their animal with the class. They need to state the adaptation and explain how it makes the animal well suited for its environment. For example, if they have the humpback whale they can say talk about the tail and how it helps the animal move in the water.
4. After taking examples from the class, put up the review **slides 5** and **6**. Remind them of how that relates to the ocean habitat and add a comment or two on the adaptations humans have that allow them to do the same thing on land. For example, the seal has flippers to help it move through water. Humans have legs to help them walk on land.

Activity 2:

DEM BONES

(adapted from OIMB GK12 Curriculum: <http://pages.uoregon.edu/oimb/Academics/GK12/fifthgrade.html>)

***If you are doing this lesson in your classroom on your own, you can print out images of bones and have them assemble paper skeletons. Images can be found at:

Human skeleton: <http://www.exploringnature.org/db/detail.php?dbID=24&detID=687>

Orca whale skeleton: <http://www.ptmsc.org/boneatlas>

Goals:

- Introduce students to the common dolphin or harbor porpoise.
- Compare the skeletal anatomy of whales and humans (whales are mammals and therefore their skeletons share similarities with those of other mammals).
- Explain the interdependence of animals and the environment, and how adaptation influences survival.

Materials:

- Dolphin or porpoise skeleton (Plastic totes with flipper/upper vertebrae/Skull/half ribs, flipper/lower vertebrae/ tail bones/half ribs)
 - Human skeleton (Cloth fish bags labeled skull, ribs, L1-L5, L6-L10, R1-R5, R6-R10, vertebrae, foot & hand, plastic bag of misc bones we will not use)
 - Dolphin/Human skeleton comparison worksheet
1. Introduce the short-beaked common dolphin (**slide 7**). Ask the students to identify specific adaptations they see and hypothesize their function. Pause on the second slide, comparing a dolphin skeleton to a human skeleton (**slide 8**). Ask if they are both mammals.
 2. Let the students know that they are going to put together a real common dolphin or harbor porpoise skeleton and a fake human skeleton. We will be looking for similarities and differences. Please tell the students that this skeleton belongs to PSB and they should treat it VERY carefully. Also let the students know that the dolphin was found dead. The skeleton was



cleaned up to use for education. No dolphin was purposefully killed to get the skeleton. They will not have all the bones as there are many small ones (we grouped some together and excluded some).

3. Tell the students that if they are having trouble figuring out where a bone goes, to think about their own body. Feel your arm and leg. Which one has longer bones? Where do you feel multiple bones?
4. Clear a large area of the room. Set out the dolphin/porpoise skull at one end of the room and the human skull in another area.
5. Divide students into 4 groups and hand out the human left side (both bags with L1-L10), human right side (both bags with R1-R10), and dolphin bones with one dot and dolphin bones with 2 dots.
 - a. **Human Group:** Place the human spinal column, ribs, and tail bone on the floor and tell the human group that they need to place these bones first as a group before starting on their own bones. Also dump out the hand and foot and explain that our skeleton only came with one foot and hand but humans usually have 2 of each. Hand the teacher the cheat sheet and instruct them to help if needed.
6. Instruct the students to build their part of the skeleton in a way that it will contribute to the whole skeleton (e.g. vertebrae group should start below the skull, rib group to each side, flipper or arm group to one side of the ribs).
7. Notes:
 - a. Flipper: If they get stuck remind them that a whale's flipper is similar in placement and structure to our hand and arm. Have the students feel the bones in their own arms and fingers as a guide.
 - b. Allow time for the students to experiment with placement of the bones. Limit guidance— with time, the students often work it out on their own and gain a sense of accomplishment. If necessary, move a bone and explain its placement (3rd grade will obviously need more guidance than 4th and 5th).
 - c. Patella (kneecap) — let them experiment with this bone placement as it tends to stump most groups.
8. Once the skeletons are put together, have the students trade places and look at the skeleton they did not put together. They are looking for similarities and differences. After a few minutes have them form a circle around one of the skeletons. Congratulate them! Discuss how they are similar and different. Discuss how the internal structure (anatomy) is similar but the function and external structure is different and adapted to living in their specific habitat (**slide 8**).



- (a) Congratulate the class again on a job well done and get the students to help put the bones GENTLY back into their bags.
- (b) Tell the students you are giving the teacher the whale/human skeleton comparison worksheet to either send home or do later after you are gone.

Activity 3:

CLIMATE CHANGE

Goals:

- Introduce students to climate change.
 - Have students understand how climate change impacts marine mammals.
1. Explain that global temperatures have been increasing faster over the last century than we would naturally expect and this had led to extreme weather patterns (**slide 9**)—a phenomenon called climate change. Wet places are getting wetter and dry places are getting dryer.
 2. Sample explanation: **Slide 10.** Our earth has an atmosphere of gases such as water vapor and carbon dioxide that blanket the planet trapping heat from the sun and keeping our planet from being an icy sphere. However, as we burn fossil fuels like gas in our cars and heating oil in our houses we are producing **extra** carbon dioxide. This excess, or extra, carbon dioxide goes into our atmosphere and acts like a heat trapping, or really warm, blanket. This warms the atmosphere up and our oceans too!
 3. Where do these heat trapping gases come from (**slide 11**)?
 4. What does climate change and warming oceans mean to marine mammals? How might it affect them? (**slide 12**) Sample explanation: For example, in the ocean our primary producers (plant-like organisms) are phytoplankton. In the North Atlantic Ocean, some of the phytoplankton species like cold water. They grow really well in cold water but do not grow so well in warm water. As the heat trapping blanket warms the ocean it affects where the phytoplankton can live and grow well. Zooplankton, such as copepods, eat phytoplankton and North Atlantic right whales in turn eat the copepods. Less phytoplankton means less zooplankton. So if there is no food the right whales will have to travel to a different area where they can find some food. This would be like going to Friendly's and hearing they are closed for the season and having to find somewhere else to eat!

Scientist Spotlight

Gordon Waring is a PSB scientist (**slide 13**). Gordon looks at harbor and gray seals: assessing their numbers and where they are located. One way of doing this is putting tags on seals and watching their



movements. He analyzes how they are using their habitat, and how that habitat usage changes depending on the season (winter, spring, summer, and fall). A big part of what he does is figuring out how humans impact the seals.

Conclusion/Follow up

1. What is an adaptation?
2. What adaptation would you like to have if you could choose one?
3. How are the animals we discussed today adapted to their specific environment?
4. What is climate change?
5. How can students in Falmouth (us) affect climate change (**slide 14**)? Encourage the students to think of how they can get their school or community to use these solutions. Challenge them to get their whole classroom, grade, school, or neighborhood cleaning up the beaches, reducing their energy usage, etc. Show the video clip <http://www.montereybayaquarium.org/climate/default.aspx?c=dd> If there is extra time, you can click on any yellow word on **slide 14** to show a quick conservation video clip.

***If you are running low on time, feel free to cut some of the lesson. The students really seem to enjoy the short video from Monterey Bay Aquarium, so it works to end with it even if you have to cut other activities short.

Lesson Link to Next Generation Science Standards

*All of the lessons reinforce the scientific method by asking students to observe, predict, hypothesize, participate in an experiment or activity, sort/classify, and make conclusions.

3rd through 5th grade

- a. 3-LS4-3 - Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all. In this lesson students analyze various marine mammals and discover the adaptations that make them best suited for the marine environment.
- b. 4-LS1-1 - Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. In this lesson students compare the external and internal anatomy of a human and harbor porpoise and relate it to the animal's habitat.



- c. 4-ESS3-1 - Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment. In this lesson students learn about fossil fuel consumption and climate change.