Unit 2. Lesson 2. Sound Production and Reception

Lesson Objectives: After completing this lesson and the activities, students will be able to grasp the basic ideas of how sound is generated and how it is interpreted in the human and marine mammal ear.

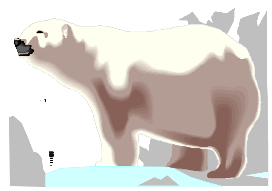
Vocabulary Words: vocal cords, phonating, rostrum, pharynx, and nasal system

Note: Remember the words cetaceans, sirenians, dolphins, whales and manatees will be used continuously through the unit, referring to marine mammals

Sound Production

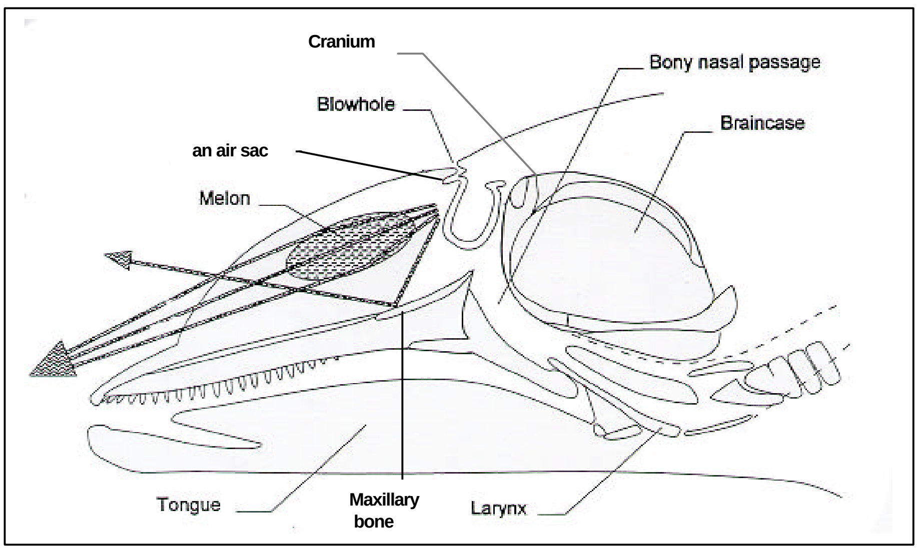
Before beginning the study of how a marine mammal makes sound, let's briefly discuss how humans talk. Humans have elastic ligaments called **vocal cords** attached to the bones in the throat. When air is passed over these cords, they vibrate and make sound. The sound can be modified in intensity, and by using the tongue, teeth and lips in **vocalization**.

Marine mammals also make many sounds by vibrating elastic ligaments (vocal cords) in the **larynx**. Passing air across these ligaments makes vibrations (much like in the human body). Actions of the tongue, teeth and mouth shape can alter the sound produced. The **nasal system**, the sinuses, and air sacs found in the **pharynx** (pharyngeal air sacs) also have an effect on the sound produced. These structures are set up to provide a marine mammal with optimum ability to communicate.



Seals, sea otters, and polar bears create sounds like barking, crying, growling and roaring. Manatees make squeaky and ragged sounds using vocal cords. **Phonating** (of, or pertaining to making sound) dolphins do not move the larynx during high frequency vocalization. They actually use a combination of structures in the nasal system. These structures include the nasal plug and the elaborate nasal air sac system.

The processes marine mammals use to make and receive sound signals is complex. Cetaceans in particular have a very complicated system of sound production and propagation. After the sound is generated, it must be sent through the environment, so that other animals can receive it or so it can return to the dolphin or whale to collect information. Nasal air sacs, sloping **maxillary bones**, and the **cranium** (it is cup-shaped and acts like a satellite receiver) reflect sound within the animal's head, and help focus the sound beam forward through a structure call the melon. (Humans do not have this special structure.) The melon is composed of fat, and transmits sounds produced in the head to the environment. Sounds pass easily from animal to head because the densities in the melon and saltwater are about equal.



Sound Reception

Many marine mammals rely on the reception of sound to communicate, navigate, and explore their environment for things like food and predators. We have learned that the making of sounds can be complex. The reception or 'hearing' of sound is also complex, and it is specialized for hearing sounds underwater.

See the diagram of the human ear on the following page.

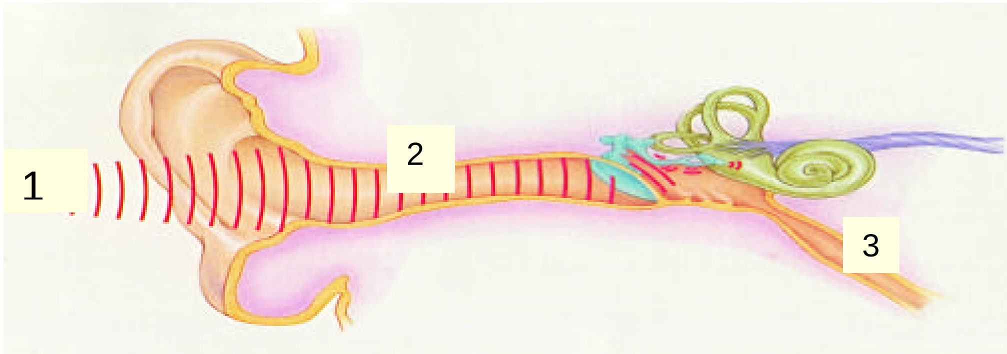


Figure 2. All mammalian ears, including those of marine mammals, have three basic divisions: (1) an outer ear, (2) an *air*-filled middle ear with membranes and bony structures, (3) a *fluid*-filled inner ear with resonators and sensory cells.

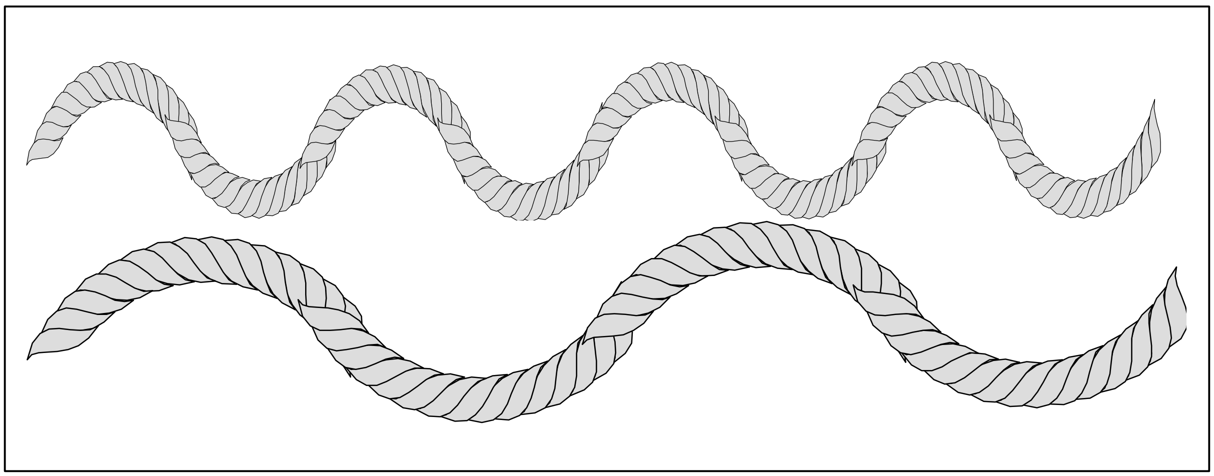
In the cetaceans, the outer ear has been modified or no longer exists. In other orders, the outer ear collects sound. The middle ear detects the sounds, and transforms the energy into mechanical signals with the bony structures so that they may be detected by the inner ear. The inner ear interprets the mechanical message and transfers the sound into **neural impulses.** Humans detect sounds in the same manner.

How do Marine Mammals (and other Organisms) use Sound in the Water?

In understanding how marine mammals use sound in their environment, it is important to remember the basic measures of sound. These are frequency, speed, wavelength, and wave height, which equals the intensity of the sound. The speed of sound is directly related to the density of the medium. Sound travels faster in water than in air, because water is denser than air. The speed of sound in water is approximately 1530 m/sec. The speed of sound in air is 340 m/sec. Sound can travel approximately five times faster and greater distance in seawater than air!

Remember, frequency is the measure of the number of waves passing a given point in a given unit of time. If a marine mammal emits a sound that has a low frequency, then the wavelength will be long. Sounds having long wavelengths can travel great distances. The opposite is true for a high frequency sound. It has a short wavelength, and will travel only short distances because it does not have a lot of energy. Low frequency sounds have a wavelength with much more energy. These can travel a long distance.

Figure 2- 1. The top rope represents a sound of high frequency. The wavelength is short and is used to identify small objects. The bottom rope is a sound of low frequency, and has a wavelength twice the one on the top. It is used to identify large objects and is necessary for navigation.

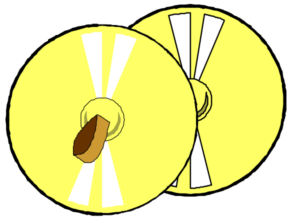


There are reasons that animals emit sounds of different frequency. Some of these include navigation, exploration, finding food, and hiding from predators. A sound wave of low frequency (long wavelength) is used for identifying or detecting large objects or targets. These objects might be larger animals, research vessels, underwater structures, and even land masses the size of islands. High frequency sound waves (short wavelength) are necessary to determine the size of small objects or the fine detail in a large object. For more examples of the types of sound waves that animals emit, see the Student Information Sheet for this lesson.

Activity 2-1. Listening skills.

If you were asked which of your five senses you use most often, the obvious answer would be sight. A person without vision, or an animal that survives by interpreting sound signals alone, must rely on sound for many things that our eyes do for us every day.

Materials:



- a friend
- a blindfold
- a noise maker (keys, a party toy, cymbals, etc.)
- a radio or CD player and CD's

Procedure:

Find that sound. In a quiet room or area, sit down and cover your eyes with the blindfold. Make sure the ears are uncovered. Have a friend stand in different locations in the room and make noise with the keys, the toys, etc. Only make one sound at at time in a single location.

- Can you determine where your friend is using the sound signals alone?

What to tune out. Play the CD, or tune the radio to a local talk show. While you are blindfolded, have a friend tell you a story, or describe what they are seeing. Turn off the CD player, and then repeat the same story back to your friend. Remember to include all details.

- Did you find this difficult? That is because you must listen for the correct sounds. A blind person must discriminate which sounds to listen to, and which ones to tune out. For example, when a blind person needs to cross the street, they must be able to determine if there are any cars coming in their direction.

Seeing like a bat, can you echolocate? While blindfolded, have friends lead you to a different room or location. A small closet or bathroom will even work. Have your friend position you in the center of the room and clap your hands twice.

- Is it possible to tell if you are in a small, medium, or large room?

While blindfolded, stand in front of a large wall. The side of a building will do, a gymnasium will work. Clap your hands as you walk toward the wall.

- Hopefully, the differences in sound will stop you from bumping into the wall. The sound from the claps bouncing off the walls will change due to the distance from the wall. The closer you get, the faster the sound will return to you.

Activity 2-2. Mathematic Magnitudes

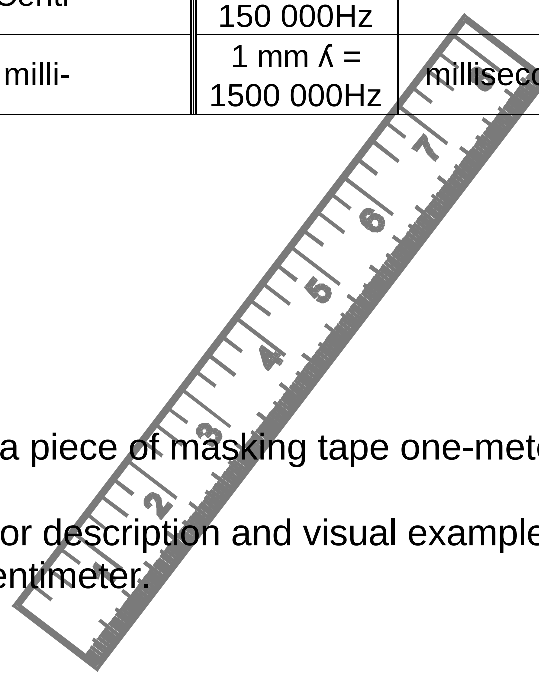
Measurements come in many sizes and forms. Oceanographers use the metric system to be consistent with other oceanographers around the world. The Metric System is a unit of measure that is based on a scale of ten. The following table describes the values used by scientists, as well as some of the terms that acoustic oceanographers use to describe sound waves emitted from marine mammals.

Standard Units			Acoustic units	
Value	magnitude	Length representative prefix	frequency in water (Hertz)	duration (seconds)
10^6	1,000,000	Mega-	MegaHertz	Megaseconds
10^5	100,000			
10^4	10,000			
10^3	1,000	Kilo-	1000 m ʎ = 1.5Hz	kilosecond
10^2	100	Meters		
10^1	10	Meters		seconds
10^0	1	Meter	1 m ʎ = 1500 Hertz	seconds
10^{-1}	0.1	Deca-		
10^{-2}	0.01	Centi-	1 cm ʎ = 150 000Hz	
10^{-3}	0.001	milli-	1 mm ʎ = 1500 000Hz	milliseconds[a]

[a] most important in acoustic measurements

Materials:

- meter stick
- masking tape
- classroom floor



Procedure:

1. Using the meter stick, place a piece of masking tape one-meter in length on the floor.
2. Explain to the students that for description and visual example, one meter will represent 1 centimeter.

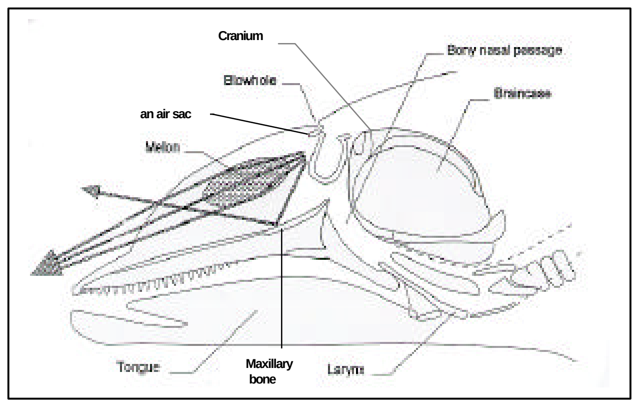
3. Break the centimeter down into millimeters by placing 10 pieces of tape in equal distances from each other on the "1 centimeter measure"
4. Explain to the students that each centimeter can not only be broken down into 10 segments, but each millimeter can be broken down into ten segments as well.
5. Add 10 more pieces of tape between the millimeter marks. These will represent micrometers.
6. Discuss with the students the magnitude differences of centimeters, meters and kilometers. Every 10 centimeters makes a meter, every 1000 meters makes a kilometer, and so on.

Student Information Sheet 2. Sound Production and Reception

Marine mammals make a variety of sounds. Some marine mammals produce sound using a mechanism similar to the one humans use. Humans have vocal cords attached to the bones in the throat. When air passes over these cords, they vibrate back and forth producing sound. All sounds can be using the tongue, teeth and lips.

Many marine mammals make sound by vibrating elastic ligaments in the larynx. Passing air across these ligaments makes vibrations. The nasal system, the sinuses, and air sacs found in the **pharynx,** as well as movements of the mouth, tongue and lips alter the sounds produced.

Nasal air sacs, sloping **maxillary** bones, and the cranium reflect sound within the animal's head, and help focus the sound beam forward through a structure called the melon. The melon, composed of fat, transmits sound to the environment. The oily melon, which is located above the forehead, acts as an acoustic lens to focus sound in a forward direction. Fat tissues located around the lower jaw to the middle ear transmit echoes received to the rear of the lower jaw.



All mammalian ears have three basic divisions: (1) outer ear, (2) an air-filled middle ear, and (3) a fluid-filled inner ear that interprets the sound message and transfers the message to the body.

Marine mammals (as well as other marine animals) use sound waves in the water for navigation, exploration, communication, and hiding from predators.

Teachers Information Sheet

Table 2-1. This table shows the frequency and types of sounds that different animals emit. The sounds are very different in frequency and type of sound used by each animal.

Group	Examples of animal in the order	Details	Example of frequency (kHz)	Sounds emitted	Other notes
Odontocetes	Bottlenose dolphin	high frequency sounds	0.8-150	whistles, clicks, bark, yelps	Some animals emit low or high frequency sounds. Others use a combination of the two in the wild.
	Commerson's dolphin	low frequency sounds	<10	pulsed sounds, clicks	
Mysticetes	Northern Right Whale	low frequency sounds	<0.4 others emit	call, songs, moans, pulses	Others in group emit between 0.02 and 3.5
	Humpback Whale	Infrasonic they also produce audible sounds	0.012-0.4 and 1-4	songs, shrieks, moans, grunts	this order emits low frequency sounds
Seals (Phocidae)	Harbor seal	high and low frequency sounds	0.7-150	clicks, roar, growl, grunt, creak	The Harbor seal has the widest range of sound frequency, most of the other seals in this group are low frequency animals.
Trichechidae	manatee	low frequency	0.6-16	squeaks, pulses	much is still to be learned about manatee sound emission and reception