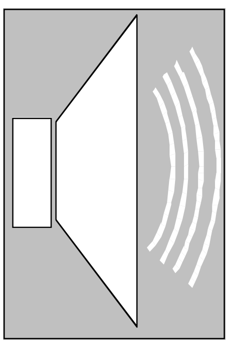
Unit 2. Lesson 1. Introduction to Marine Mammals and Acoustics

Lesson Objectives:

- Introduce basic acoustic principles and the movement of sound through air and water.
- Students will gain an understanding of the importance of the study of acoustic oceanography.
- Students will gain an understanding of why and how marine mammals use sound.

Vocabulary: sound, acoustics, medium, amplitude, pitch, frequency

What is Sound?



Sound has many definitions. The most familiar one is a noise, vocal utterance, or musical tone. Although most ideas of sound center on something that is heard by the human ear, it can have many other definitions. For example, it can mean secure and reliable. It can also mean a relatively narrow passage of water between larger bodies of water and also a body of water between the mainland and an island.

Much can be learned from studying sound. The military uses sound to locate ships and submarines in the water, researchers use sound to study the ocean floor, biologists use it to track marine mammals and study the ocean floor **(topography).** Sound is used to help make medical diagnoses. Ships used sound to avoid obstacles under the surface of the water. The study of sound is called **acoustics**.

Introduction to Basic Acoustics

Acoustics is the science that deals with the creation, spreading and delivery of energy in the form of vibrational waves in air, water or other **medium**. Sounds begin as a vibration that is transferred through a medium in a series of waves.

Sound waves travel with certain intensity called **amplitude.** When the amplitude of a sound increases, the intensity of the sound increases, as does the amount of energy that is transferred.

Another property of sound is **pitch,** which is highness or lowness of a sound. The pitch depends on the frequency of the sound waves, or how many waves pass a given point per second. The higher the frequency, the higher the pitch, and the lower the frequency, the lower the pitch. An example of pitch is the roar of a lion and the chirp of a bird. A lion's roar is a low pitch, while the bird is a high pitch.

An understanding of acoustics is necessary to understand the sounds produced by fish and marine mammals in the ocean, how fast *and* far sound can travel, noise pollution, how energy moves as sound, and the things that interfere with sound signals.

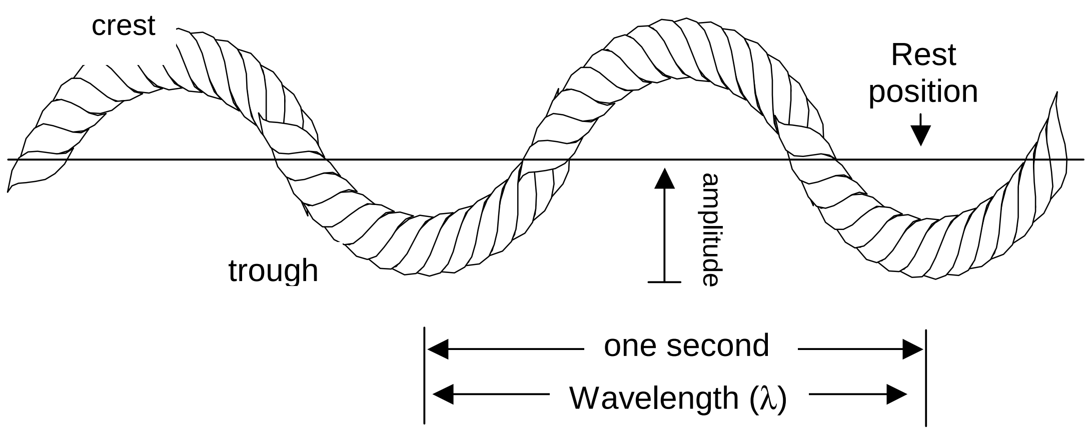
How Does Sound Move?

The movement of sound is in waves. Amplitude, frequency (f), and wavelength are properties used to characterize waves**.** Every sound has a unique set of wavelengths and frequencies, which are related to velocity, or the speed at which sound travels. Sound or acoustic energy travels best through solids and liquids. Sound travels in **sinusoidal** and **compressional waves**. Sinusoidal waves look like a like jump rope moving up and down or the surface of the ocean as it is moving. Compressional waves look like a slinky moving down a flight of stairs.

Before continuing, let's discuss the components of a sinusoidal wave, which are less complicated than those of the compressional wave.

The following figure shows a sinusoidal wave and its components. The definitions and their components are listed.

trough: the lowest point of a wave
crest: the highest point of a wave
wavelength: the distance between a point on one wave, and the identical point on the next wave. Expressed as λ.
amplitude: distance from the crest (or trough) of a wave to the rest position of a wave
rest position: the level of the medium the wave is moving through when it's not in motion
frequency: number of wave crests (or troughs) that pass a fixed point each second. Expressed in hertz (Hz). One hertz is the same as one wave per second.



Sound also travels in compressional waves. To see how this works, hold one end of a slinky and squeeze all of the coils together. Release one end of the slinky, and allow it to fall. This will produce a compressional wave. As the wave moves, some of the coils are squeezed together. This is called compression. Other areas spread apart and these areas are called rarefaction. As the wave moves, the rings of the slinky alternate between compression and rarefaction. The wave carries energy forward, the medium the wave travels through does not move.

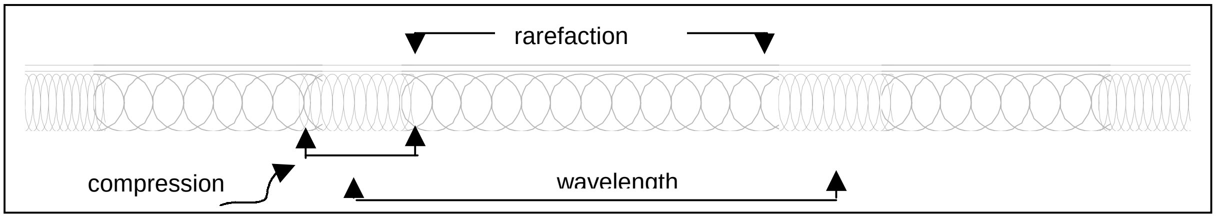


Figure 1. A compressional wave and its components.

compression: the dense area in a compressional wave
rarefaction: the less dense area of a compressional wave
wavelength: distance between a point on one wave and the identical point on the next wave

The relationships between the sinusoidal wave and the compressional wave are that sinusoidal waves are pure sound. For example, it is a continuous sound with no fluctuation in pitch. A compressional wave represents the sound, or sounds that humans and animals use to communicate.

Why Study Acoustical Oceanography?

The dramatic sight of the ocean surface fascinates almost everyone. What lies beneath the churning surface? How can we study the depths of the ocean? What can be seen under the dark and mysterious waters? Without searchlights and high tech research vessels, humans are literally "blind as a bat" under the ocean at depths greater than 100m.

Bats *can* navigate, communicate and find food in the darkness. Bats use acoustics to do so. They send out high-pitched sounds to a target (this may be prey), and their brains act like sophisticated signal processors. Scientists and inventors have taken a lesson from the morphology of animals to advance the study of sound in the oceans.

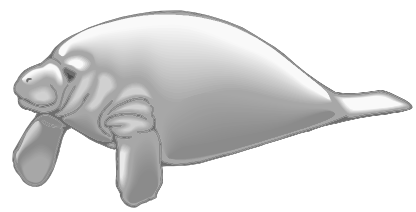
The study of acoustical oceanography is very important to the military for detection of submarines and icebergs, to oceanographers for ocean mapping and depth determination, commercial fishermen for locating fish and engineers for telecommunications through the ocean. Acoustics has also helped biologists learn about the sounds animals make and how they use them.

Introduction to Marine Mammals

Mammals of various types are found all over the world. Marine mammals are special because they depend on the aquatic environment for survival. They are found near continental coastlines all over the world (including the north and south poles), and living in the **pelagic** realm of the ocean. Marine mammals represent three different **orders** of animals. They include the **Carnivora** (polar bears, otters, seals, sea lions, and walruses), the **Cetacea** (whales, dolphins, and porpoises) and the **Sirenia** (manatees and dugongs). Each group is very different, but they do have many things in common.

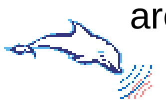
<u>Common characteristics of marine mammals</u>

- occupy and depend on aquatic habitats for survival
- most have a large body size
- streamlined shape compared to terrestrial relatives
- dense fur and blubber for insulation
- reduction of appendage size
- similar adaptations for diving, orientation and communication



For the purposes of this unit, cetaceans will be the main focus. However, carnivores and sirenians have also developed many sounds to communicate with each other. These sounds include squeaks, chirps, whistles, buzzes and grunts.

The cetaceans (including dolphins, whales and porpoises) emit either clicking sounds or whistles. The clicks are short pulses of about 300 sounds per second, emitted from a mechanism located just below the blowhole. These clicks are used for the **echolocation** of objects. Cetaceans can explore and identify their environment by emitting sounds and interpreting them when they bounce back. 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.

This echolocation system, similar to that of a bat, enables the dolphin to navigate, to detect fish, squid, and even small shrimp, and it may be used for communication by some species of toothed whales. The whistles are toned squeals that may be produced in the **larynx**, although they may come from the same area as echolocation clicks. The dolphins use some whistles to communicate and maintain contact with other dolphins.

How Echolocation Works for Marine Mammals

Sounds produced by animals for echolocation function as a kind of **biological sonar**, whereas vocalization sounds—the most famous of which are the “songs” of the humpback whale—seem to function as a means of communication between members of the same species.

By directing sounds produced in the head region toward an object and then receiving the sound waves after they have bounced off an object, the animals can make fine discriminations as to size, density, distance, and so on.

Because the sound waves are waterborne and travel very efficiently through water, cetaceans have been able to discard the external ear that land mammals developed to gather airborne sounds. More details about how a marine mammal produces and receives sound will be discussed in Lesson 2. This system of sensing the environment is obviously of enormous advantage in orienting, navigating, and capturing prey in dark or turbid waters. It is a means of scanning by sound for the same information humans and most other land mammals perceive by vision. On the other hand, cetaceans do not necessarily have poor eyesight.

Echolocation research has mainly concentrated on the bottlenose dolphin. Similar sounds emitted by other species of cetaceans have been hypothesized to be echolocation sounds.

Activity 1-1. How Fast Does a Wave Travel?

Before the speed of a wave can be calculated, the components of a wave must be understood. See the following table for definitions.

trough: the lowest point of a wave
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wavelength: the distance between a point on one wave, and the identical point on the next wave. Expressed as λ.
amplitude: distance from the crest (or trough) of a wave to the rest position of a wave
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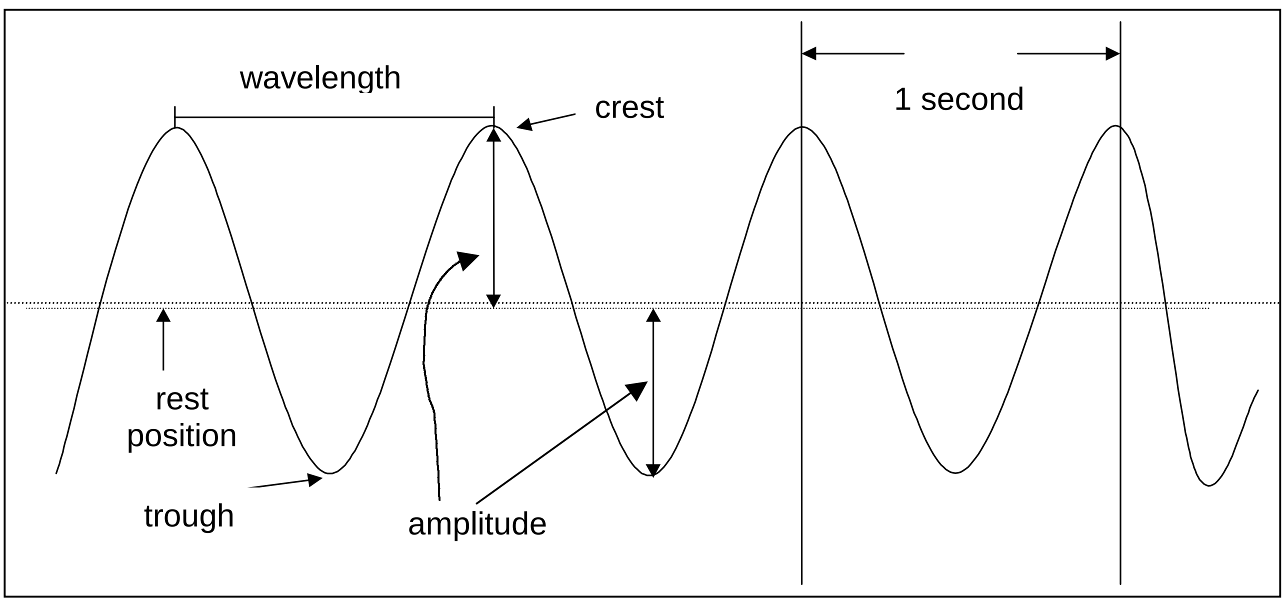
frequency: number of wave crests (or troughs) that pass one place each second. Expressed in hertz (Hz). One hertz is the same as one wave per second.

Wave velocity, v, describes how fast the wave moves forward. It can be calculated by multiplying the wavelength and frequency as shown below.

velocity = wavelength x frequency

$v = \lambda \times f$



Activity 1-1. How fast does a Wave Travel (mathematics)?

A. What happens to the wavelength (λ) as the frequency (f) increases?

B. Calculate the velocity of the following wave.

A wave is generated in the bathtub. The wavelength is 1.5m. The frequency of the wave is 0.5Hz. What is the velocity of the wave? Follow this method.

Known information:

wavelength, $\lambda = 1.5$m

frequency, $f = 0.5$ hertz

Another way to express Hertz is 1/second, so,

0.5 hertz = 0.5/second

Unknown information: velocity (v)

Equation to use: $v = \lambda \times f$

C. Calculate the frequency of the following wave.

An underwater earthquake produces a wave that travels at 250m/s. It has a wavelength about 10 m. What is the frequency of the wave?

Known information.

velocity, $v = 250$m/s

wavelength, $\lambda = 10$m

Remember, Hz = 1/s, so m/s ÷ m = 1/s = 1 Hz

Unknown information

frequency (f)

Equation to use: $f = v \div \lambda$

Activity 1-2. How Do We hear?

A look inside your ear would reveal a thin membrane stretched across the end of a short tube that is about the width of a pea. When sound reaches the ear, the eardrum sets into motion an arrangement of tiny bones, tubes, hairs and nerves that work together with the brain to let sound be heard.

Materials:

- an empty frozen juice can
- a can opener
- a balloon
- a rubber band
- glue
- a piece of mirror that is ½ cm square (ask a glass or hardware store for the scraps)
- a dark room
- a flashlight

Procedure:

1. Remove both ends of the can.
2. Cut the balloon in half across its width.
3. Stretch the balloon over one end of the can so that the balloon is very taut. A rubberband might be necessary to hold it in place.
4. Glue the mirror to the outside of the stretched balloon about 1 cm from the edge of the can.
5. Turn out the lights, and shine the flashlight onto the mirror at an angle, so that a bright spot is reflected from the mirror onto the wall or ceiling.
6. Shout into the can from the open end. Sing high and low notes, and speak softly. What happens to the spot on the wall?

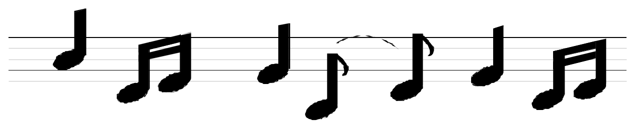
HOW IT WORKS

Any sound that is made into the can travels through the air into the stretched balloon. The sound makes the balloon vibrate, which in turn makes the mirror vibrate. The vibrations can be seen in the reflecting light on the wall. Sound travels in the human ear in a similar way. The sound is collected by the outer ear, and travels down a small tube, called the ear canal, to the eardrum. When sound reaches the eardrum, it vibrates just like the balloon did.

Activity 1-3 Sing Ladies and Gentlemen.

Why do males and females have different sounding voices? Well, don't investigate throats and vocal cords. Try this simple experiment.

Materials:



- medium sized book
- medium sized rubber band
- 2-4 pencils

Procedure:

1. Slide the rubberband lengthwise around the book. Make sure there are no twists.
2. Slide two pencils under the rubberband, with the sharpened ends off the end of the book.
3. Pluck the band with a finger. Listen, and watch the rubberband vibrate.
4. Move the pencil to the middle of the book. Observe the difference in vibrations, and how the sound differs.

HOW IT WORKS.

When the whole band is plucked, the vibrations are slow. Slower vibrations give off a lower sound or pitch. Faster vibrations come from a shorter area, and are of higher pitch. A female has shorter vocal cords than men do. The vocal cords act like two rubberbands in a box when a person speaks or sings. Touch the bony part of the neck and hum. The fronts of each person's vocal cords are attached here, and the vibration can be felt.

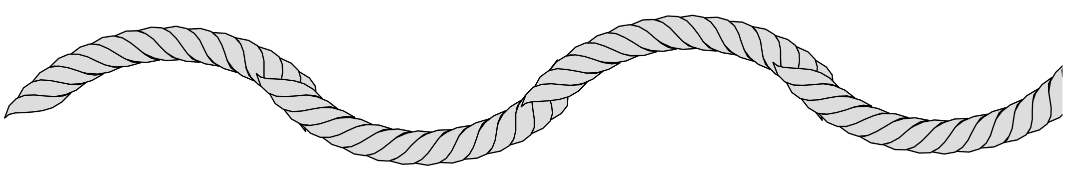
Student Information Sheet 1: Introduction to Marine Mammals and Acoustics

What can you make, but not see? What travels through solids but makes no holes in them? Give up? It's sound. The following lessons will contain information and fun activities to teach you how sound moves, as well as how the study of sound (acoustics) is used in marine mammal studies and oceanography.

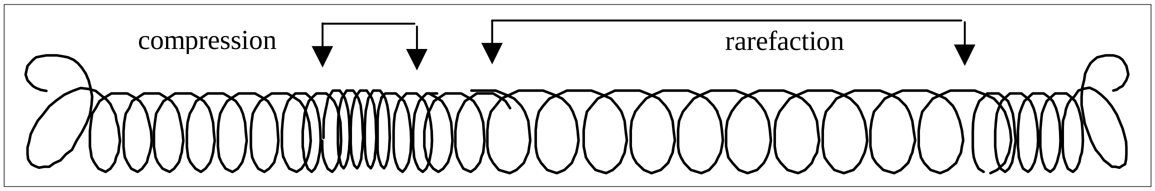
Sound surrounds us all. Think about waking up every morning. The following sounds were probably around, but *were* they really heard?

- the water running in the sink
- the alarm going off
- the rattle of dishes
- juice being poured into a glass
- the slam of a door

Some sounds travel in a transverse wave. The highest points of this wave are called the crest, the lowest are called the troughs. The distance between a point on one wave and the identical point on the next wave, such as from crest to crest or trough to trough is called a wavelength.



Other sounds move in a more complex wave pattern. That wave pattern is called a **compressional wave**. A spring or a slinky can show how compressional waves can be formed. Imagine a slinky moving down a flight of stairs going end over end. Think about how the springs move close together and then further apart. As the wave moves, some of the coils are squeezed together. This crowded area is called **compression** (in the slinky, when it lands on each step). The compressed area then expands, spreading the coils apart, creating a less dense area. This area is called a **rarefaction**. In the slinky demonstration, this is when the slinky is turning over and falling to the next step. This wave carries energy forward.



Marine mammals are special because they depend on the aquatic environment for food, water, transportation, and much more. They are found all over the world (including the north and south poles). Others live in the **pelagic** realm of the ocean. Marine mammals represent three different **orders** of animals. They include the **Carnivora** (polar bears, otters, seals, sea lions, and walruses), **Cetacea** (whales, dolphins, and porpoises) and the **Sirenia** (manatees and dugongs). Each group is very different, but they do have many things in common.

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Marine mammals are unique, but have many similarities. Cetaceans and how they use sound will be the focus for this unit, even though other groups have also developed many sounds to communicate with each other. These sounds include squeaks, chirps, whistles, buzzes and grunts.