10.7 Nature and Sound Waves

Figure 1 Bats can hardly see, yet they catch insects at night in mid-flight.

Bats can hardly see, yet they catch flying insects at night (**Figure 1**). Dolphins can catch fast-moving fish in murky waters, where visibility is extremely low. Elephants can find each other over distances of several kilometres, yet their eyesight is relatively poor. Household cats cannot see very well up close, yet they easily catch small houseflies that fly right in front of them. How do these animals perform these seemingly impossible tasks? The answer is that they use sound waves. In this section, you will learn some of the ways sound waves are used in nature.

Echolocation

Dolphins, sperm whales, and orca whales produce sound and detect the echoes to locate prey, navigate through the water, and communicate with others of their species in dark, murky waters. This process is called **echolocation**, which means using echoes, or reflected sound, to locate an object. These animals use a variety of frequencies (40 kHz to 130 kHz) produced by clicks that last from 50 ms to 128 ms.

echolocation the location of objects through the analysis of echoes, or reflected sound

Dolphins

Dolphins use nasal sacs to make high-frequency sounds. The sounds pass through the melon, which is an oval-shaped sac filled with special fats called acoustical lipids (**Figure 2**). The fats help the melon act like a lens for sound. From the melon, the sound is focused into a beam in front of the dolphin. When the sound waves reflect off an object in the water, such as a fish, the echo returns to the dolphin and provides the object's location. The dolphin receives the echo through its lower jaw. High-frequency waves do not travel far in water, so the range of echolocation is limited to between 5 m and 200 m for an object 5 cm to 15 cm in length.

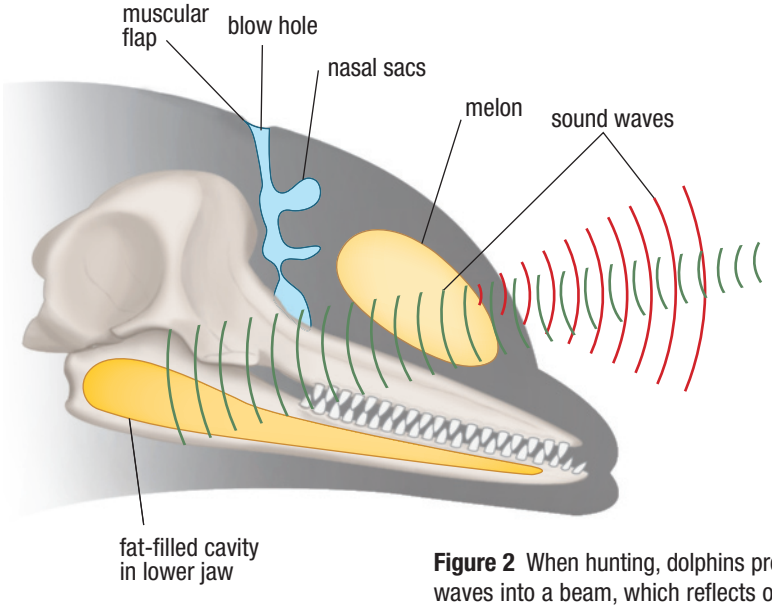

Figure 2 When hunting, dolphins produce high-frequency sound clicks. The melon directs the sound waves into a beam, which reflects off fish.

The fat-filled cavities in the lower jaw conduct the vibrations to the middle ear, which leads to the inner ear and then through the auditory nerve and to the brain. The dolphin brain receives these vibrations as nerve impulses, which it then interprets. Dolphins can detect the size, shape, speed, distance, and direction of objects. They can even detect information about the internal structure of objects. With experience, they can learn to recognize echoes from a preferred prey. Despite the many advantages of echolocation, research has shown that dolphins are much more effective hunters when they use sight with echolocation. Orca whales and sperm whales use a similar method to detect prey. The main difference is in the method of sound production and the frequencies of sound produced.

WEB LINK

To learn more about echolocation,

GO TO NELSON SCIENCE

Research This

Dolphin Echolocation and Detecting Underwater Mines

Skills: Researching, Analyzing, Evaluating, Communicating, Defending a Decision

SKILLS HANDBOOK A5.1

The U.S. Navy Marine Mammal Program trains dolphins and other marine animals to use their echolocation capabilities to detect underwater mines (**Figure 3**). In this activity, you will research this topic and form an opinion on whether or not dolphins should be used for this dangerous activity.

Figure 3 Dolphins are being trained to detect underwater mines.

1. How do dolphins detect the underwater mines?
2. How does using dolphins or other marine mammals for this activity help humans?
3. What advantages do dolphins have over humans to perform this activity?

A. Should we use any animals to perform dangerous tasks for us? T/I A

B. Form an opinion on the use of dolphins for this activity. T/I A

C. Organize your findings and your opinion in a format that is easily shared with your classmates. C A

GO TO NELSON SCIENCE

Bats

Bats use echolocation to navigate in complete darkness and detect the size, shape, and texture of objects such as insects when they are hunting. Bats produce sound in the larynx, and the sound passes out through the mouth. The frequencies of the sounds produced (up to 110 kHz) are often well above frequencies that humans can detect. A flap of skin in the bat's inner ear detects the sound.

While a bat is searching for prey, it produces sound at a rate of 10 to 20 pulses per second. To conserve energy, the bat breathes and beats its wings at the same frequency. When a bat detects prey, the bat heads toward the prey while producing high-frequency pulses, which can be as high as 200 pulses per second (**Figure 4**). As it approaches the target, the duration and loudness of the pulses decrease until the bat reaches the target. The bat then scoops the prey into its wing membranes and then into its mouth.

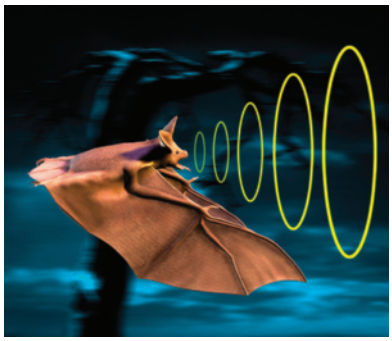

Figure 4 The yellow circles represent the high-frequency pulses that many bats emit. The pulses reflect off surrounding objects back to the bat's ears.

Elephants

Elephants have the largest brain of any land animal, and their behaviours demonstrate a high degree of intelligence. A large portion of their brain is devoted to hearing. Many people look at those large ears and think they understand how elephants can detect sound over large distances and find other elephants. Actually, the large pinnae have just as much to do with cooling the animals and other behaviours, such as displays of aggression as they defend their young from predators.

Unlike with humans, the ear is not the only detector of sound in elephants. Elephants also have hearing receptors in their trunks and feet. Elephants have been seen pressing their trunks against the ground when trying to detect sounds. They also lift up one foot to press the other three more firmly against the ground (**Figure 5**). Elephants do this because they send sounds through the ground as well as through the air. This low-frequency (infrasound) sound is produced at 15 Hz to 35 Hz and can be as loud as 117 dB. Typically, the sound travels much farther than higher frequencies, up to 10 km. The sound can be detected by the sensitive receptors in their feet and trunk. Some researchers think that the bottom of an elephant's foot actually resonates with these low frequencies like a drum.

Figure 5 Elephants often lift one foot off the ground when listening to distant low-frequency sounds from other elephants.

Figure 6 Cats have large movable pinnae to amplify sound and detect the direction from which a sound is coming.

House Cats

House cats have excellent hearing, among the best of any mammal. They can detect a wide range of frequencies, from 55 Hz to 79 kHz (higher than frequencies that both humans and dogs can detect). They also have large movable pinnae, which help amplify the sound and sense the direction from which the sound is coming (**Figure 6**). This is extremely helpful in hunting.

Cats can see in dim lighting conditions but, in doing so, sacrifice some detail and the perception of some colours. As a result, cat vision is poor up close. They often compensate for this by using their large pinnae to detect the high-pitched noises produced by their prey at the end of the hunt. These noises help locate the exact position of the prey up close when cat vision is poor.

10.7 Summary

- Natural phenomena can be explained with reference to the characteristics and properties of sound waves.
- Dolphins, sperm whales, and orca whales use echolocation to navigate and detect prey in dark, murky waters.
- Bats also use echolocation to detect prey.
- Elephants produce infrasound waves, which travel partially through the ground. They can detect these sounds with their feet and trunks pressed against the ground.
- Cats use their large movable pinnae to amplify sound and to detect the direction from which sounds are coming.

10.7 Questions

1. Research the term "sonar." Echolocation is also called biosonar. Explain why this term is used for echolocation by comparing it to "sonar." Use diagrams in your answer. T/I C
2. The speed of sound in sea water is 1470 m/s. Using echolocation, a dolphin can detect small objects 5 m to 200 m away. Calculate the maximum and minimum times for the echo to return to the dolphin when detecting small objects. T/I
3. Echolocation only works well when the object is as long as or longer than one wavelength of the sound produced. K/U T/I
   (a) Why do you think bats need to use such high frequencies for echolocation?
   (b) Estimate the size of the smallest object a bat can detect using echolocation when the air temperature is 22 °C.
   (c) Explain why dolphins use high frequencies when hunting using echolocation.
4. Research an animal that uses echolocation. Create a table, like **Table 1**, and compare the echolocation of the animal you chose to dolphin and bat echolocation. T/I C

Table 1 Echolocation in Animals

Animal	Method of producing sound	Frequencies of sound used	Method of receiving sound	Information gained using echolocation
your animal				
dolphin				
bat				

5. Draw a neatly labelled diagram of an elephant showing why it can detect sound over large distances. K/U C
6. The Elephant Listening Project has done some innovative research on elephant communication and hearing. Research this organization, and summarize, in a format of your choice, what they have learned about elephant language and hearing. T/I C
7. Explain why you think elephants hold their ears out wide when listening to sounds. T/I
8. List three hearing advantages that (a) elephants and (b) house cats have over humans in terms of hearing ability. K/U

GO TO NELSON SCIENCE