# Section 17.4

## 1 FOCUS

### Objectives

**17.4.1** **Describe** the properties of sound waves and **explain** how sound is produced and reproduced.

**17.4.2** **Describe** how sound waves behave in applications such as ultrasound and music.

**17.4.3** **Explain** how relative motion determines the frequency of sound an observer hears.

**17.4.4** **Analyze** the functions of the main regions of the human ear.

**Reading Focus**

### Build Vocabulary L2

**Paraphrase** Some terms in this section, such as *intensity, decibel,* and *resonance,* may be unfamiliar to students. Have students create a definition in their own words for these or other difficult words.

### Reading Strategy L2

**a.** Intensity and loudness **b.** Frequency and pitch

## 2 INSTRUCT

### Properties of Sound Waves

#### Use Community Resources L2

Invite members of the school band or orchestra or a community band or orchestra to demonstrate musical instruments for the class. Allow students to pose questions to the musicians, such as "How is the pitch of your instrument changed?" or "How do you increase the volume of sound coming from your instrument?"
**Musical, Visual**

# 17.4 Sound and Hearing

**Reading Focus**

### Key Concepts

- What properties explain the behavior of sound?
- How is ultrasound used?
- How does frequency of sound change for a moving source?
- What are the functions of the three main regions of the ear?
- How is sound recorded?
- How do musical instruments vary pitch?

### Vocabulary

- sound waves
- intensity
- decibel
- loudness
- pitch
- sonar
- Doppler effect
- resonance

### Reading Strategy

**Using Prior Knowledge** Copy the web diagram below. Before you read, add properties you already know about. Then add details about each property as you read.

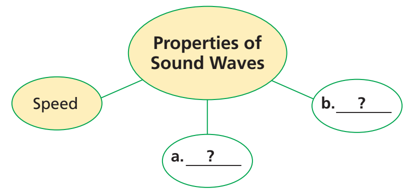



**Figure 14** The speed of sound is shown here for a variety of materials.
**Making Generalizations** ***How does temperature affect the speed of sound?***

**Speed of Sound**

| Medium (at 1 atm) | Speed (m/s) |
|---|---|
| Dry air, 0°C | 331 |
| Dry air, 20°C | 342 |
| Fresh water, 0°C | 1401 |
| Fresh water, 30°C | 1509 |
| Salt water, 0°C | 1449 |
| Salt water, 30°C | 1546 |
| Lead, 25°C | 1210 |
| Cast iron, 25°C | 4480 |
| Aluminum, 25°C | 5000 |
| Borosilicate glass, 25°C | 5170 |

Take a moment to listen. Even in a quiet room you can usually hear many different sounds. You might hear someone opening a book, people talking in the hall, cars and trucks driving outside, and maybe even an airplane flying overhead. You can identify sounds without seeing them because sound waves carry information to your ears.

## Properties of Sound Waves

**Sound waves** are longitudinal waves—compressions and rarefactions that travel through a medium. Have you ever stopped to question why sounds can hurt your ears? Why there is a delay before you hear an echo down a long, empty hallway at school? **Many behaviors of sound can be explained using a few properties—speed, intensity and loudness, and frequency and pitch.**

**Speed** Why is there a delay when you hear an echo? It takes time for sound to travel from place to place. In dry air at 20°C, the speed of sound is 342 meters per second. That's more than ten times faster than your speed in a car on a highway!

Figure 14 shows how the speed of sound varies in different media. In general, sound waves travel fastest in solids, slower in liquids, and slowest in gases. This is partly due to the fact that particles in a solid tend to be closer together than particles in a liquid or a gas. The speed of sound depends on many factors, including the density of the medium and how elastic the medium is.



### Section Resources

**Print**

- ***Laboratory Manual,*** Investigations 17A and 17B
- ***Reading and Study Workbook With Math Support,*** Section 17.4
- ***Transparencies,*** Section 17.4

**Technology**

- ***Interactive Textbook,*** Section 17.4
- ***Presentation Pro CD-ROM,*** Section 17.4
- ***Go Online,*** *Science News*, Sound

**Intensity and Loudness** Intensity is the rate at which a wave's energy flows through a given area. Sound intensity depends on both the wave's amplitude and the distance from the sound source. If someone whispers in your ear, the sound intensity may be greater than when someone shouts at you from the other end of a field.

Sound intensity levels are measured in units called decibels. The **decibel** (dB) is a unit that compares the intensity of different sounds. The decibel scale is based on powers of ten. For every 10-decibel increase, the sound intensity increases tenfold. Figure 15 shows the intensity levels of some common sounds. A 0-decibel sound can just barely be heard. A 20-decibel sound has 100 times more energy per second than a 0-decibel sound. A 30-decibel sound delivers 1000 times more energy per second than a 0-decibel sound.

Unlike intensity, loudness is subjective—it is subject to a person's interpretation. **Loudness** is a physical response to the intensity of sound, modified by physical factors. The loudness you hear depends, of course, on sound intensity. As intensity increases, loudness increases. But loudness also depends on factors such as the health of your ears and how your brain interprets the information in sound waves.

**Sound Intensity Level**

| Sound | Intensity Level (decibels) |
|---|---|
| Threshold of human hearing | 0 |
| Whisper | 15–20 |
| Normal conversation | 40–50 |
| Street noise | 60–70 |
| Inside a bus | 90–100 |
| Operating heavy machinery | 80–120 |
| Rock concert (in audience) | 110–120 |
| Threshold of pain | 120 |
| Jet plane (taking off) | 120–160 |

**Figure 15** Lengthy exposure to sounds more intense than 90 decibels can cause hearing damage. **Analyzing Data** ***Which sounds are potentially dangerous?***

**Frequency and Pitch** Try plucking a stretched rubber band. Then, stretch the rubber band farther and pluck again. You should be able to see the vibration become faster as you hear the sound frequency become higher. The frequency of a sound wave depends on how fast the source of the sound is vibrating.

The size of a musical instrument tells you something about the frequencies it can produce. The trumpet in Figure 16 can produce higher frequencies than the French horn. Both instruments produce different frequencies by changing the length of tubing through which air moves. The air in the tubing forms a standing wave. The longer the tubing, the longer is the wavelength of the standing wave, and the lower is the frequency of the note produced.

**Pitch** is the frequency of a sound as you perceive it. Pitch does depend upon a wave's frequency. High-frequency sounds have a high pitch, and low-frequency sounds have a low pitch. But pitch, like loudness, also depends on other factors such as your age and the health of your ears.

Reading Checkpoint *What is loudness?*

**Figure 16** The French horn can produce lower notes than the trumpet because it can make a longer tube for a standing wave.





## Build Science Skills

L2

**Observing** ACTIVITY

**Purpose** Students use tuning forks to model vibrations and sound waves.

**Materials** set of tuning forks of similar construction

**Class Time** 10 minutes

**Procedure** Instruct students in the proper way to strike the tuning forks. Emphasize that hitting the forks on a desk or other hard surface can damage them and also make it harder to hear the tone. Have students strike several different tuning forks and compare their pitches. Ask, **What is the relationship between the length of the tuning fork and its pitch?** *(The longer tuning forks produce lower pitches.)* Have students place the base of a vibrating tuning fork against a surface that can act as a soundboard, such as a window pane, desk, or thin board. Ask, **What happened when the vibrating tuning fork was placed against the soundboard?** *(The sound got louder.)*

**Expected Outcome** Students will observe that tuning forks of different lengths produce different pitches and that soundboards amplify sound.
**Visual, Kinesthetic**

## Customize for Inclusion Students

**Hearing Impaired**
Depending on their degree of hearing loss, hearing-impaired students may have some difficulty with many of the concepts in this section. Since sound originates from vibrating objects, touch can substitute for hearing in some cases. Allow students to feel the vibrations of musical instruments as they are being played. Encourage them to describe differences in what they feel as high and low pitches are played. Students can also "see" vibrations if you strike a tuning fork, then quickly place the end of it in a pan of water. The ripples in the water show the vibrations.

## *Answer to . . .*

**Figure 14** *From the data given, the speed of sound increases with increasing temperature.*

**Figure 15** *Riding in a bus, operating heavy machinery, attending a rock concert, and listening to a jet taking off are sounds that may damage hearing.*

Reading Checkpoint *Loudness is a physical response to the intensity of sound, modified by physical factors.*

## Ultrasound

### Build Reading Literacy L1

**SQ3R** Refer to page **530D** in **Chapter 18**, which provides the guidelines for SQ3R (Study, Question, Read, Recite, Review).

Teach this independent study skill as a whole-class exercise. Direct students to survey Section 17.4 and list the headings: Speed, Intensity and Loudness, Frequency, Pitch, and so on. As they survey, have students write one question for each heading, such as "What is one common application for ultrasound?" Then, have students write answers to the questions as they read the section. After reading, have students recite the questions and answers, explaining that vocalizing in your own words helps you retain what you learned.
**Auditory, Group**

## The Doppler Effect

### Use Visuals L1

**Figure 18** Point out that the ambulance was in a different place when each circular wave was emitted. Reproduce this diagram on the board and number the waves 1 through 6, starting with the largest wave. Ask, **In the figure, where was the ambulance when wave 1 was emitted?** *(At the center of that wave)* **Where was the ambulance when the other waves were emitted?** *(At the center of each wave, moving to the right)*
**Visual, Logical**

**Go Online PLANETDIARY**

Find links to additional activities and have students monitor phenomena that affect Earth and its residents.

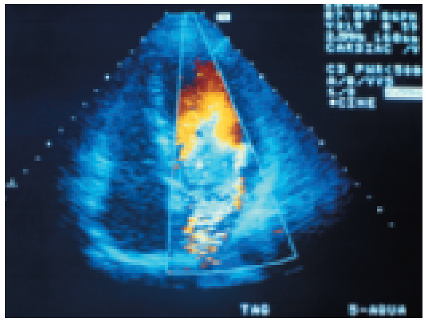


**Figure 17** Ultrasound can be used to make images of the heart, which help doctors diagnose disease.

**Go Online PLANETDIARY**

**For:** Activity on sonar and marine mammals
**Visit:** PHSchool.com
**Web Code:** ccc-2174

## Ultrasound

Most people hear sounds between 20 hertz and 20,000 hertz. Infrasound is sound at frequencies lower than most people can hear, and ultrasound is sound at frequencies higher than most people hear. **Ultrasound is used in a variety of applications, including sonar and ultrasound imaging.**

**Sonar** is a technique for determining the distance to an object under water. Sonar stands for *so*und *n*avigation *a*nd *r*anging. The distance to the object is calculated using the speed of sound in water and the time that the sound wave takes to reach an object and the echo takes to return.

Ultrasound imaging is an important medical technique. Figure 17 shows an image of the heart made by sending ultrasound pulses into a patient. A pulse is a very short burst of a wave. Each ultrasound pulse is short—about $\frac{1}{8000}$ of a second—so that it doesn't interfere with the reflected pulse. Computer software uses the reflected pulses to make a detailed map of structures and organs inside the body.

## The Doppler Effect

Perhaps you have heard the pitch of a siren change as it passed you. This is the **Doppler effect**—a change in sound frequency caused by motion of the sound source, motion of the listener, or both. The Doppler effect was discovered by the Austrian scientist Christian Doppler (1803–1853).

**As a source of sound approaches, an observer hears a higher frequency. When the sound source moves away, the observer hears a lower frequency.** Figure 18 shows a single frequency emitted by the ambulance siren. As the ambulance moves toward observer B, the wave fronts bunch together. Observer B hears a higher frequency than the frequency of the source. For observer A, however, the wave fronts are spread out, and the frequency is lower than the source frequency.

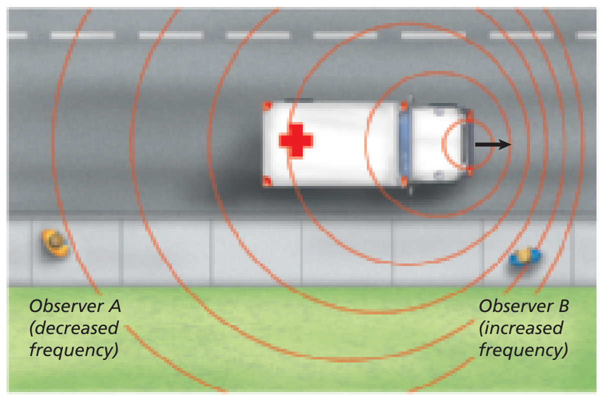



**Figure 18** Observer A hears a lower-pitch sound than observer B because the wave fronts are farther apart for observer A. **Inferring** ***What can you infer about the pitch the ambulance driver hears?***



## Facts and Figures

**Diffraction of Sound** All sound waves are diffracted when they pass by an obstacle or through an opening. The human voice has a range of approximately 70 to 400 Hz. This corresponds to wavelengths between 4.9 m and 0.86 m. Recall that the amount of diffraction depends on the wavelength of the wave compared to the size of the opening or obstacle. Because sound waves have wavelengths approximately the same size as the width of a doorway or a window opening, the sound of a person's voice easily diffracts from room to room.

516 Chapter 17

## Hearing and the Ear

Can you feel sound waves with your hand at this very moment? Probably you can't. But suppose you hold a balloon. Then your hand can feel sounds because the balloon membrane vibrates. Just like the balloon, your ear has a membrane that vibrates when sound waves strike it.

Your ear is a complex system that consists of three main regions—the outer ear, the middle ear, and the inner ear—as shown in Figure 19. **The outer ear gathers and focuses sound into the middle ear, which receives and amplifies the vibrations. The inner ear uses nerve endings to sense vibrations and send signals to the brain.**

Go Online SCIENCE NEWS®

**For:** Articles on sound
**Visit:** PHSchool.com
**Web Code:** cce-2174

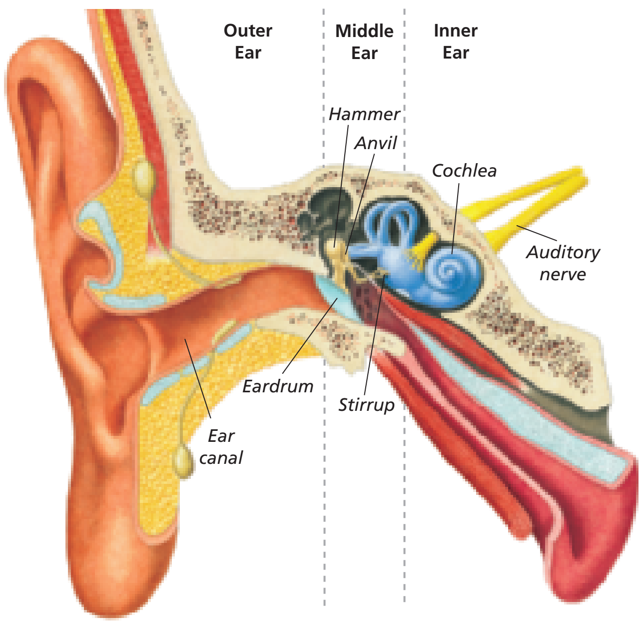
**Figure 19**

### The Anatomy of the Ear

**Outer Ear** The part of the ear you can see funnels sound waves down the ear canal, a tunnel about 2.5 cm long. There, sound waves strike the eardrum, a tightly stretched membrane between the outer and middle ear. The eardrum vibrates at the same frequency as the sound waves striking it.

**Middle Ear** The middle ear contains three tiny bones—the hammer, the anvil, and the stirrup. When the eardrum vibrates, the hammer vibrates at the same frequency. The hammer strikes the anvil, which in turn moves the stirrup back and forth. The three bones act as a lever system to amplify the motion of the eardrum.

**Inner Ear** Vibrations from the stirrup travel into the cochlea, a spiral-shaped canal filled with fluid. The inside of the cochlea is lined with thousands of nerve cells with tiny hair-like projections. As the fluid in the cochlea vibrates, the projections sway back and forth and send electrical impulses to the brain.






## Hearing and the Ear

### Use Visuals

L1

**Figure 19** This figure contains a lot of information and is worth some extra time. Point out important features of the diagram for students. The outer ear is made up of the visible, sound-collecting part (the pinna) and the ear canal. The pinna gathers and reflects sound waves down the canal. Ask, **How do sounds get to the eardrum?** *(Through the air in the ear canal)* **What is the stirrup?** *(One of the small bones in the middle ear)* **What does the stirrup do?** *(It transfers vibrations into the cochlea.)* **What is the function of the auditory nerves?** *(To transmit nerve impulses to the brain)*
**Visual, Logical**

Go Online SCIENCE NEWS®

*Science News* provides students with current information on sound.

**Answer to . . .**

**Figure 18** *The frequency for the driver is unchanged because the driver has no motion relative to the siren.*

## How Sound Is Reproduced

**Address Misconceptions** L2

Students sometimes think that sound waves can push a dust particle away from a speaker or blow out a candle flame placed in front of a speaker. However, sound waves would actually make the dust particle or candle flame vibrate back and forth in a direction parallel to the direction in which the wave is moving.
**Verbal**

SCIENCE and History

### Sound Recording L2

Edison, who was slightly deaf, discovered he could feel the vibrations in a telephone speaker with his finger. If a loudspeaker is available, have students gently touch the surface of the speaker grille as music is being played. They should easily be able to detect the vibrations. Ask, **What is causing the vibrations?** *(Sound waves striking the grille)* Students can also hold a book in front of their face, sing a note or speak loudly, and feel the vibrations in the book. Ask, **What is causing the vibrations of the book?** *(Sound waves in air striking the book)* Edison also noticed that a paper telegraph tape, when pulled through a telegraph machine at high speed, made sounds that resembled a human voice. He put these two ideas together and designed the first phonograph.

Over the years since, inventors have constructed many other types of recording devices. Today, there are several different digital audio compression technologies available in addition to MP3. Only time will tell if one becomes the preferred standard.
**Logical, Kinesthetic**

**Writing in Science**

Students should compare and contrast the new technology with a previous technology. To be persuasive, their writing must use facts to support benefits claimed for the new technology.
**Logical**

## How Sound Is Reproduced

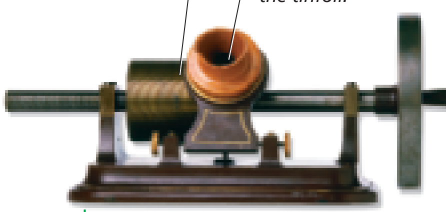
Sound has been reproduced in many ways, from old-fashioned records to modern digital technologies. But no matter how sound is recorded or stored, in the end it must be converted back into sound waves by loudspeakers. **Sound is recorded by converting sound waves into electronic signals that can be processed and stored. Sound is reproduced by converting electronic signals back into sound waves.**

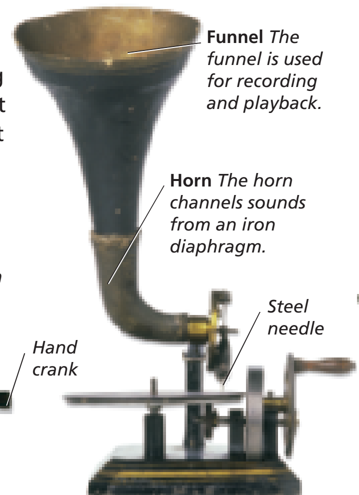
A modern speaker produces sound waves in much the same way that a drum does. A drum skin vibrates up and down like a trampoline. As the drum vibrates, it sends a series of compressions and rarefactions through the air across the room. They carry energy to your ears in the form of sound waves.

DK SCIENCE and History

### Sound Recording

Recording technology has come a long way since Thomas Edison made the first sound recording of the human voice at his New Jersey laboratory in 1877.





**1877** American inventor Thomas Edison records his voice on a tinfoil cylinder phonograph.

**1885** The wax-coated cylinder is introduced as an improvement on Edison's first design.

**1887** German-born American Emile Berliner invents the Gramophone, which stores sounds as grooves in the wax surface of a flat disc.

**1900** Danish inventor Valdemar Poulsen unveils a magnetic recording device, called the Telegraphone.

**1928** Tape with a magnetic coating is developed in Germany. Further refinements and a 1930s tape recorder called the Magnetophone make reel-to-reel recording popular.

1875 | 1900 | 1925



### Facts and Figures

**Sound Reproduction** The first audio recordings were made by purely mechanical action. The singer or instrumentalist sang or played into a funnel-shaped tube that led directly to a cork diaphragm. The diaphragm was attached through a series of levers to a needle that would carve a groove into a wax cylinder or disk. Since there was no way to duplicate a recording, the orchestra or performer would be required to play the composition over and over for hours as up to 10 individual recordings were made at a time. Ensembles of musicians made recordings in a small room. One wall of the room was the opening of the huge recording tube. In an interesting historical twist, several contemporary musicians have started to use this old technology to record their compositions.

In a speaker, an electronic signal causes a magnet to vibrate. The magnet is attached to a membrane. The vibrating membrane sends sound waves through the air. Larger-diameter speakers, like a large bass drum, are better at reproducing lower frequencies of sound. Smaller-diameter speakers, like a small bongo drum, are better for reproducing higher frequencies of sound.

When a singer sings into a microphone, the reverse process happens. Sound waves from the singer's voice vibrate a membrane inside the microphone. The membrane causes a magnet to vibrate, which produces an electronic signal in the microphone wires. The energy of sound waves has been converted into an electronic signal that can be processed and stored.

**Writing in Science**

**Writing to Persuade**
Research one type of recording technology. Write a product review as if you lived at the time it was invented. Persuade people that this technology is much better than previously available technologies.

VINYL LONG PLAYING

*Audio cassettes, a compact version of reel-to-reel magnetic tapes, are soon in demand.*

CASSETTE TAPE RECORDER

MP3 PLAYER

**1948** Columbia introduces the first 12-inch vinyl records. Relatively cheap to make, these allow for a longer playing time.

**1962** Philips, based in the Netherlands, demonstrates its first compact audio cassette. It is sold the following year with dictation machines. A stereo version is introduced in 1967.

**1982** The first digital audio compact discs (CDs) are sold in Japan.

**1998** MP3 technology becomes popular. This format allows music to be compressed, stored, and transferred digitally over computer networks.

1950 | 1975 | 2000



## Integrate Social Studies L2

Thomas Edison is generally credited as the inventor of the phonograph, which he publicly demonstrated in 1877. He did not pursue the invention at first. Alexander Graham Bell, his cousin Chester Bell, and C. S. Tainter made improvements to Edison's design to improve the sound quality. They called their device the graphophone. The Bells and Tainter offered to combine their patents and designs with Edison's work, but Edison rejected the offer. Instead, he developed an improved machine similar to the graphophone. Edison's new system used thicker, reusable wax cylinders and a jewel-tipped recording stylus that did not need to be replaced after every recording. Emile Berliner further improved the phonograph by using a flat disk and a system for duplicating records from a steel master. These various phonographs were very popular, and after 1895, hundreds of companies appeared, yet quickly failed. Only a few companies survived into the twentieth century. Have students research later technological developments that affected phonographs and record players. **Logical**

Mechanical Waves and Sound 519

HOW It Works

## The Piano L2

Several keyboard instruments predated the piano. The most popular was the harpsichord. When a key is pressed on a harpsichord, a corresponding string is plucked. Consequently, it is difficult to control the loudness of the instrument. In a piano, however, the string is struck by a felt-covered hammer. Pressing the key with more force causes the string to be struck harder, producing a louder sound. Because of this, these instruments were called fortepianos (literally “loud-soft”) for their ability to change dynamics. As the instrument evolved, the name was shortened to piano.

When a piano key is pressed, two things happen. The hammer strikes the string and rebounds, while the damper pad moves away. Therefore, the string will continue to vibrate as long as the key is held down.

The use of cast-iron frames allows heavier strings to be strung with greater tension. Greater tension in the string produces a better, cleaner sound and allows the string to vibrate much longer.

**Interpreting Photos** When a piano key is struck, a series of levers causes the hammer to strike a string. The vibration of the string is amplified by the soundboard.
**Visual, Musical**

## For Enrichment L3

The piano and its family of instruments probably originated with the hammered dulcimer, which is played by striking the strings with small “hammers.” Interested students can research the origin of plucked and struck stringed instruments such as dulcimers and harps.
**Verbal, Portfolio**

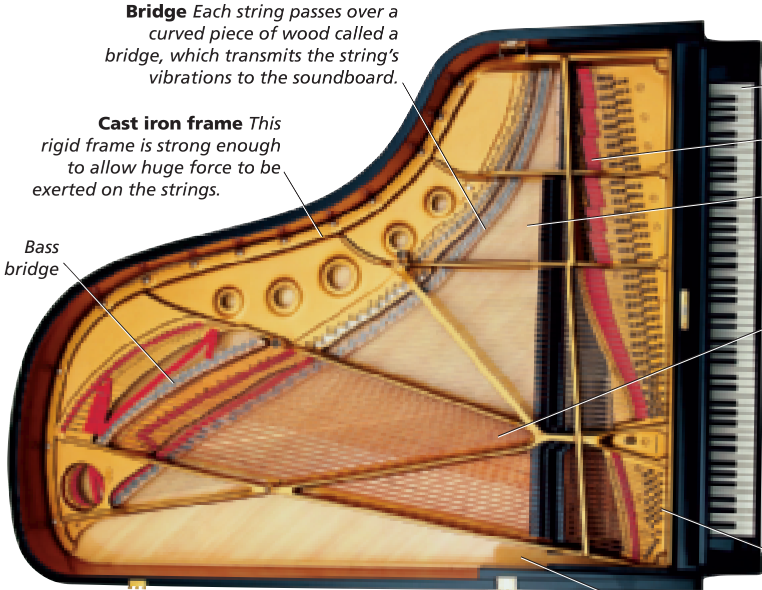
HOW It Works

# The Piano

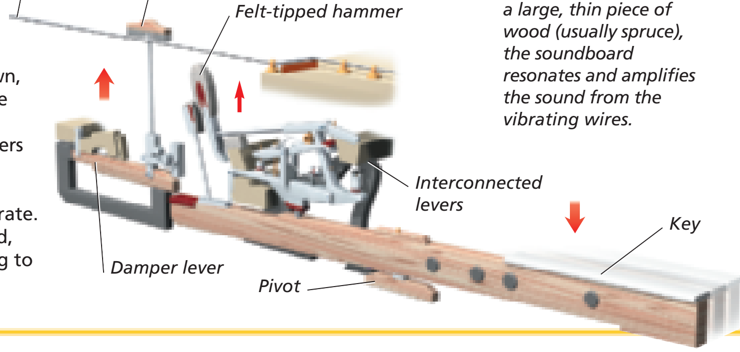
The piano is a highly versatile musical instrument. Usually there are 88 separate keys, which produce a range of notes and volume. The sounds are made by wire strings that vibrate against a soundboard inside the piano.

**Interpreting Photos** ***What causes the strings in a piano to vibrate?***

**Grand piano**
Pianos can be upright or, like this grand, horizontal. A grand piano makes a rich and powerful sound.




**Keyboard action**
As a key is pressed down, the section beyond the pivot moves up. This activates a series of levers that flick a hammer upward to strike the string and make it vibrate. The damper is released, which allows the string to continue vibrating.



## Music

Musical instruments can produce a wide variety of sounds. In a wind instrument, such as a flute or trumpet, holes are closed using fingers or valves. This changes the length of the column of air in which a standing sound wave is produced. For some stringed instruments, such as a violin, musicians change the length of the strings by pressing down with their fingers. For other instruments, such as a piano, they use a fixed set of strings of different lengths. **Most musical instruments vary pitch by changing the frequency of standing waves.**

Musical instruments often use resonance to amplify sound. **Resonance** (REZ uh nuhns) is the response of a standing wave to another wave of the same frequency. Think of a child being pushed on a swing. If the pushes are timed at the right frequency, the child can swing higher and higher. In the same way, one wave can "push" another wave to a higher amplitude. Resonance can produce a dramatic increase in amplitude. A piano, for example, amplifies sound with a soundboard. The soundboard resonates in response to the vibrating strings.

Once sound waves leave an instrument, they can take several routes to a listener. In a large concert hall, interference with reflected sound waves can be a problem. Theaters such as the one in Figure 20 are designed with reflecting panels and sound-absorbing tiles. These are located with great care to prevent "dead spots" where the volume is reduced by destructive interference of reflected sound waves.

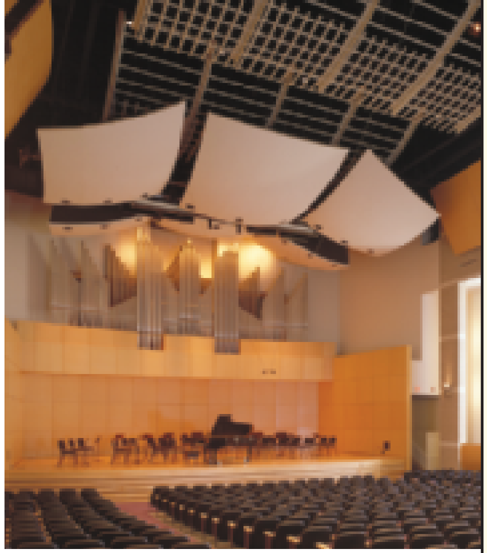


**Figure 20** The Central Michigan University Music Building, like many concert halls, was designed by acoustic engineers. Sound-absorbing tiles (on the sides and rear) reduce unwanted reflections. The curved reflecting panels above the stage help gather and direct sound waves toward the audience.

## Section 17.4 Assessment

### Reviewing Concepts

1. List five properties used to explain the behavior of sound waves.
2. Name two uses for ultrasound.
3. What is the Doppler effect?
4. What are the ear's three main regions? Describe the function of each region.
5. How is sound recorded?
6. How does a musical instrument produce notes at different pitches?

### Critical Thinking

7. **Applying Concepts** If workers in a distant stone quarry are blasting, why can you feel the explosion in your feet before you hear it?
8. **Comparing and Contrasting** How does the intensity of a 40-decibel sound compare to the intensity of a 20-decibel sound?
9. **Applying Concepts** How could a bat use reflections of sound waves to determine distance to an insect?

**Connecting Concepts**

**Frames of Reference** Review what you learned about combining velocities in Section 11.2. Then explain why the Doppler effect depends on the velocity of the sound source in the observer's frame of reference.



## Music

### Integrate Language Arts L2

The folk musician Greg Brown has set several of William Blake's poems to music. Many other performers have found musical inspiration in poetry. Choose a recording, such as Greg Brown's setting of Blake's poem "The Chimney Sweeper," and allow students to listen. Ask, **How did the performer use rhythm or pitch to enhance the meaning of the poem?** *(Possible answers: A simple melody can heighten the drama of powerful images, such as those in "The Chimney Sweeper." The rhythm of the music can enhance the sense of rhythm in the poem.)*
**Verbal, Musical**

## 3 ASSESS

### Evaluate Understanding L2

Have students outline and summarize the section. Then, divide the class into groups and have students exchange papers and edit each other's outlines. Exchange the papers again, and have students edit the edits. Then, return the papers to the original owners to rewrite.

### Reteach L1

Write the vocabulary words for this section. Have students review the section and create definitions for the vocabulary words in their own words.

**Connecting Concepts**

Choosing a particular frame of reference does not change the sound heard by the observer. In physics, one often chooses a frame of reference that makes it easier to understand or solve a problem. With the Doppler effect, one simple choice is to use the observer's frame of reference. The shift in frequency can then be determined from the speed of the sound source in this frame of reference.

Interactive Textbook If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 17.4.

### Section 17.4 Assessment

**1.** Speed, intensity, loudness, frequency, pitch
**2.** Medical imaging, sonar
**3.** The Doppler effect occurs when an observer hears a higher frequency as a sound source approaches. When a sound source moves away, the observer hears a lower frequency.
**4.** The outer ear gathers and focuses sound into the middle ear, which amplifies the vibrations. The inner ear has nerve endings that sense vibrations and transmit signals to the brain.
**5.** Sound is recorded by converting sound waves into other forms of energy.
**6.** By changing the frequency of standing waves
**7.** The speed of sound in solids is generally faster than the speed of sound in air, so the sound wave reaches your feet first through the ground.
**8.** The intensity of a 40-dB sound is 100 times greater than the intensity of a 20-dB sound.
**9.** A bat can determine distance based on the amount of time it takes for ultrasound waves the bat emits to reach the insect and bounce back to the bat's ears.