Chapter 3

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Sound

Have you ever heard nothing at all? Probably not. Even in a space suit while orbiting Earth, you can still hear the sound of your blood flowing and your heart beating!

FAST FACT

Bats don't use their eyes to catch prey. They use their ears! Bats send out high-pitched squeaks and clicks that bounce off objects. The returning echoes direct them to their prey. Using echoes, some bats can find an insect as thin as a human hair in total darkness!

Vocabulary Preview

sound
compression
sound wave
loudness
pitch
speed of sound
echo
sonic boom

FAST FACT

Every type of animal has a different hearing and voice range. When the Canadian Pacific Railroad switched to air-driven horns, large numbers of female moose were killed by trains. Biologists determined that the low-pitched horns sounded like the calls of male moose! Changing the pitch of the horns has greatly reduced the number of moose on the tracks.

Sound and Hearing

	Hearing Range (Vibrations per Second)	Voice Range (Vibrations per Second)
Bats	1,000–120,000	10,000–120,000
Cats	60–65,000	750–1500
Dogs	15–50,000	452–1080
Dolphins	150–150,000	7000–120,000
Humans	20–20,000	80–1500
Robins	250–20,000	2000–15,000

FAST FACT

When a volcano on the island of Krakatau, Indonesia, erupted in 1883, it made the loudest natural sound ever observed. Heard 4500 km (2796 mi) away, the eruption was so strong that it blew the island apart!

LESSON 1

What Is Sound?

In this lesson, you can . . .

INVESTIGATE making and hearing sounds.

LEARN ABOUT the way sound travels.

LINK to math, writing, social studies, and technology.

◀ Hitting cymbals together produces a loud sound that can be heard over that of an entire band or orchestra.

INVESTIGATE

Sound from a Ruler

Activity Purpose Sit still a moment and listen. What do you hear? People talking, car horns honking, dogs barking, the refrigerator humming? We hear different kinds of sounds all day long. In this investigation you will **observe** how a sound is made. You will also observe some ways to change sound.

Materials

- plastic ruler

Activity Procedure

1. Place the ruler on a tabletop. Let 15 to 20 cm stick out over the edge of the table.
2. Hold the ruler tightly against the tabletop with one hand. Use the thumb of your other hand to flick, or strum, the free end of the ruler. (Picture A)
3. **Observe** the ruler with your eyes. **Record** your observations.
4. Repeat Step 2. **Observe** the ruler with your ears. **Record** your observations.

Picture A

Picture B

5 Flick the ruler harder. **Observe** the results. **Record** your observations.

6 Change the length of the ruler sticking over the edge of the table, and repeat Steps 2 through 5. **Observe** the results. **Record** your observations. (Picture B)

Draw Conclusions

1. What did you **observe** in Step 3?
2. What did you **observe** in Step 4?
3. **Make a hypothesis** to explain what you **observed** in Steps 3 and 4. How could you test your explanation?
4. **Scientists at Work** When scientists want to learn more about an experiment, they change one part of it and **observe** the effect. What did you change in Step 6? What effect did you observe?

Investigate Further Place one ear on the tabletop. Cover the other ear with your hand. Have a partner repeat Steps 1 and 2. What do you **observe?**

Process Skill Tip

When people use the word *observe*, they usually think of seeing. But you can use all your senses to **observe.** In this investigation you also used your sense of hearing to observe the effects of the movements of the ruler.

LEARN ABOUT

Characteristics of Sound

FIND OUT

- causes of sounds
- how sound travels
- how your ears help you hear

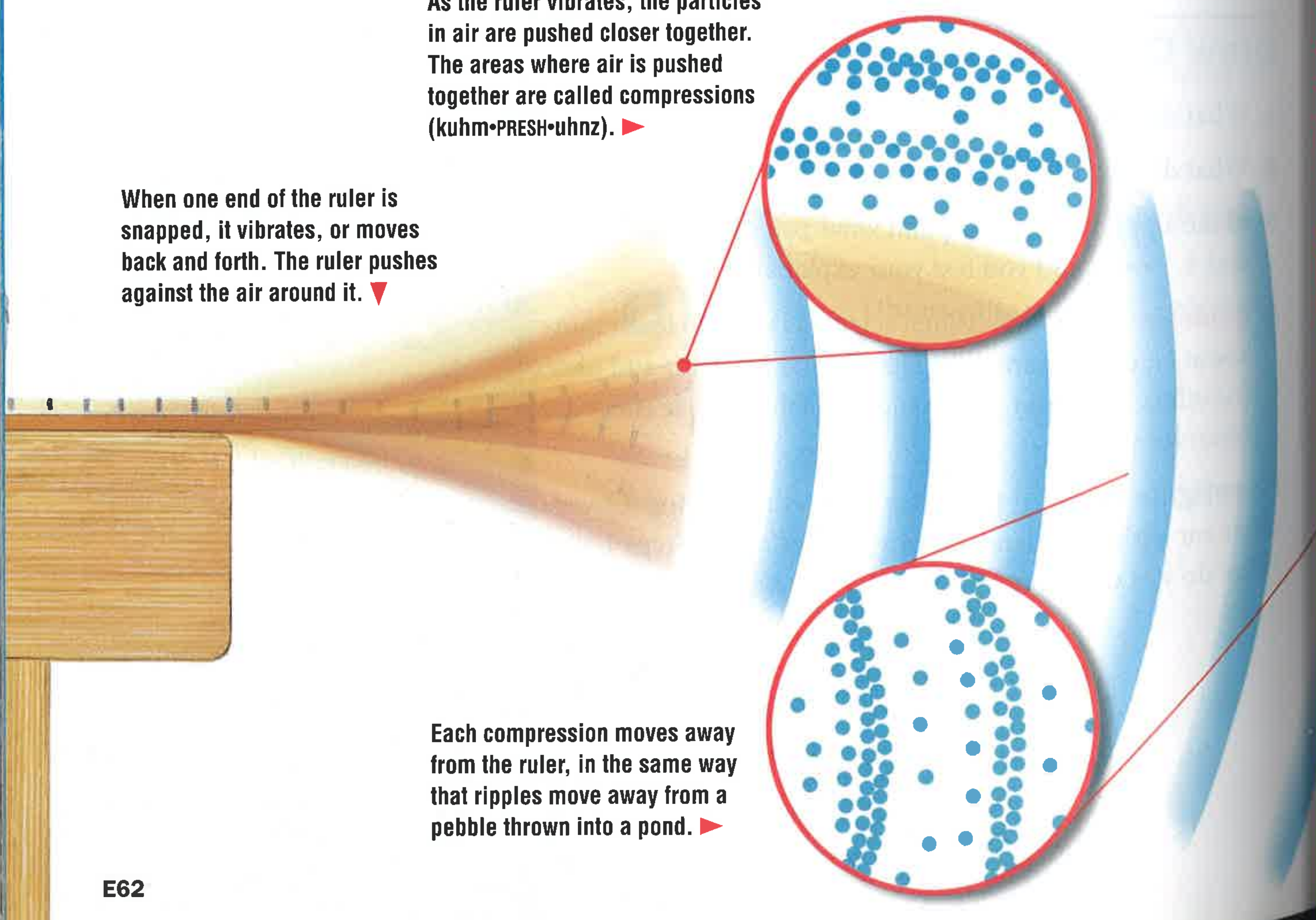
VOCABULARY

sound
compression
sound wave

Vibrations

Strumming a guitar string, snapping a ruler, or humming a note—all of these actions make sounds. Each of them also starts a back-and-forth movement called a *vibration* (vy•BRAY•shuhn). **Sound** is a series of vibrations that you can hear. You can't see vibrations of particles in air. But you can watch or feel the vibrations of objects that make sounds. In the investigation you saw the ruler vibrate after you snapped it. After you strum a guitar string, it vibrates for a while and slowly stops. You hear the guitar note start and then slowly fade away. When you hum a note, you can feel the vibrations of your larynx (LAIR•inks), or voice box, by putting your fingers on the outside of your throat.

✔ **What is sound?**



As the ruler vibrates, the particles in air are pushed closer together. The areas where air is pushed together are called compressions (kuhm•PRESH•uhnz). ►

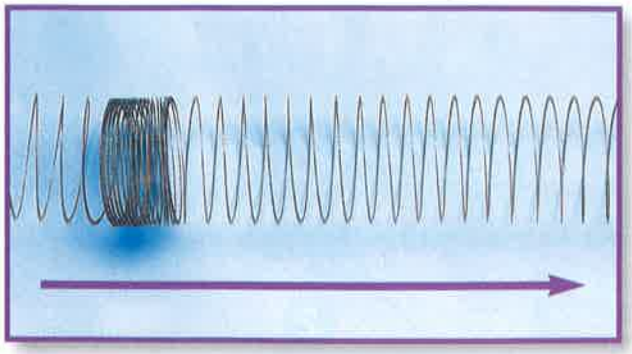
When one end of the ruler is snapped, it vibrates, or moves back and forth. The ruler pushes against the air around it. ▼

Each compression moves away from the ruler, in the same way that ripples move away from a pebble thrown into a pond. ►

Traveling Waves

The vibrations of the guitar string, the ruler, and your voice box push and then pull on the particles of air around them. As they push, they increase the pressure in the air. The area where air is pushed together is called a **compression**. As the vibrations pull, they decrease the pressure in the air. This results in alternating areas of high and low pressure in the air. **Sound waves** are quickly moving areas of high and low pressure. All sound is carried through matter as sound waves.

Sound waves move out in all directions from a vibrating object. You can hear something making sound all around you, above you, and below you. As the sound waves move away from their source, their energy is spread over a larger area. So the farther you are from the source of a sound, the softer the sound is.



▲ **A wave travels through this spring toy just as a sound wave travels through the air. The places where the springs are close together are like compressions, or areas of high pressure, in the air. The places where the springs are far apart are like areas of low pressure in the air.**

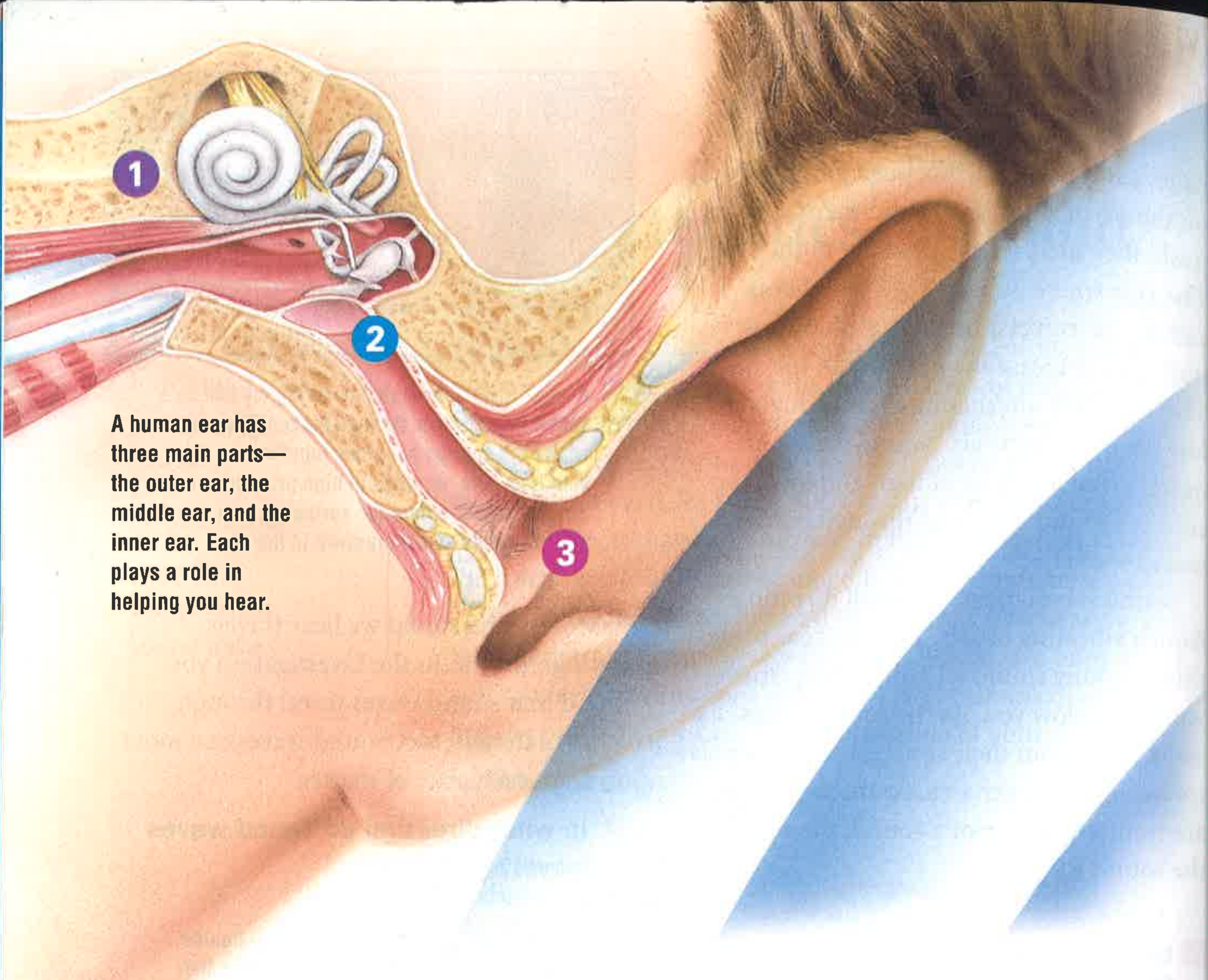
Most of the sound we hear travels through the air. In the investigation you found that sound waves travel through other materials, too. Sound waves can move through each state of matter.

✔ **In what direction do sound waves travel?**

1 **Each instrument in a marching band makes a sound by vibrating something. For example, the head of a bass drum vibrates when it is hit. The vibrations cause sound waves in the air. The audience watching and listening to the parade hears the drumbeat.**

2 **Sound waves can also travel through liquids. These underwater swimmers could hear the band play if it marched by the pool.**

3 **Someone behind a closed door could hear the band, too, because sound waves can also travel through solids.**



A human ear has three main parts—the outer ear, the middle ear, and the inner ear. Each plays a role in helping you hear.

1 The inner ear is a snail-shaped tube filled with liquid. Tiny hairs on the inside are connected to nerves. Sounds move the hairs, which then send signals along nerves to the brain. Your brain figures out the signal, and you hear a sound.

2 The middle ear is made up of three tiny bones that connect the outer ear to the inner ear. The three bones are called the hammer, the anvil, and the stirrup because of their shapes.

3 The outer ear is like a funnel. It collects sounds and guides them to the eardrum.

Hearing Sounds

We hear sound when sound waves reach our ears. Our ears take in the sound waves and turn them into signals that go to our brains. Our brains figure out these signals and tell us what the sound is.

The first part of the ear that a sound wave hits is the outer ear. The outer ear is like a funnel that collects sound waves and guides them to the eardrum.

The eardrum is made of thin material that bends easily. It is about 1 centimeter ($\frac{1}{2}$ in.) across. It works like the top of a drum. The eardrum vibrates when sound waves hit it. As the eardrum moves back and forth, it moves a tiny bone at the outside end of the middle ear.

The middle ear is about the size of the tip of your little finger. In it, vibrations pass through three tiny bones. The bones connect the eardrum to the inner ear.

The inner ear is shaped like a snail. It is filled with liquid. The walls of the inner ear are lined with tiny hairs. These hairs are connected to nerves.

The third bone of the middle ear vibrates one end of the inner ear. These vibrations cause waves in the liquid. The waves move the tiny hairs. This causes nerve cells to send signals to your brain. Your brain interprets the signals as sounds.

✓ **Which part of the ear connects it to the outside world?**

Summary

Sound is made by vibrating objects. The vibrations travel through matter as areas of high and low pressure called sound waves. Sound waves move through the three parts of the ear. You sense the vibrations as sound.

Review

1. What is sound?
2. What are sound waves?
3. Which part of the ear is connected to nerves that send signals to the brain?
4. **Critical Thinking** Sometimes you can hear and feel the rumble of a passing truck. What are you feeling?
5. **Test Prep** The middle ear contains —
   A liquid
   B the eardrum
   C three bones
   D hairs

LINKS

MATH LINK

Music Scales Some music scale notes can be found by shortening the length of a string to a fraction. For example, if the base pitch is played on a length of 1, an *octave* (AHK•tiv) higher would be played on a length of $\frac{1}{2}$. What would be the length of the second octave higher? The third octave?

WRITING LINK

Informative Writing—Description Suppose that you are a sound wave traveling through someone's ear. Write a description for your classmates of what happens to you as you move from the outer ear to the inner ear.

SOCIAL STUDIES LINK

Flutes and Drums In many countries traditional music is played on flutelike and drumlike instruments. Choose a country. Find pictures of these types of musical instruments from that country. Make a map showing the location of the country. Add labeled pictures of the instruments.

TECHNOLOGY LINK

Learn more about early recorders by visiting the Jerome and Dorothy Lemelson Center for Invention and Innovation Internet site.
www.si.edu/harcourt/science

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LESSON 2

Why Do Sounds Differ?

In this lesson, you can . . .

INVESTIGATE making different sounds.

LEARN ABOUT differences in sounds.

LINK to math, writing, music, and technology.

◀ The word *piano* is short for *pianoforte* (pee•ah•noh•FOR•tay). *Piano* is the Italian word for "soft." *Forte* is the Italian word for "loud." Why do you think this instrument is called a pianoforte?

INVESTIGATE

Making Different Sounds

Activity Purpose If you pluck a guitar string, you hear a sound. If you pluck another guitar string, you hear a different sound. How are the sounds different? What causes the difference? In this activity you will **observe** sounds made by a vibrating rubber band. You will **compare** observations and **infer** what causes differences in sounds.

Materials

- safety goggles
- foam cup
- long rubber band
- paper clip
- ruler
- masking tape

CAUTION

Activity Procedure

1. CAUTION **Put on the safety goggles.** With a pencil, punch a small hole in the bottom of the cup. Thread the rubber band through the paper clip. Put the paper clip inside the cup, and pull the rubber band through the hole. (Picture A)
2. Turn the cup upside down on a table. Stand the ruler on the table next to it, with the 1-cm mark at the top. Tape one side of the cup to the ruler. Pull the rubber band over the top of the ruler, and tape it to the back. (Picture B)

Picture A

Picture B

3. Pull the rubber band to one side and let it go. **Observe** the sound. **Record** your observations.
4. Repeat Step 3, but this time pull the rubber band farther. **Observe** the sound. **Record** your observations.
5. With one finger, hold the rubber band down to the ruler at the 4-cm mark. Pluck the rubber band. **Observe** the sound. **Record** your observations.
6. Repeat Step 5, but this time hold the rubber band down at the 6-cm mark. Then do this at the 8-cm mark. **Observe** the sounds. **Record** your observations.

Draw Conclusions

1. **Compare** the sounds you observed in Steps 3 and 4.
2. **Compare** the sounds you observed in Steps 5 and 6.
3. When was the vibrating part of the rubber band the shortest?
4. **Scientists at Work** Scientists use their observations to help them **infer** the causes of different things. Use your observations from Steps 5 and 6 to infer what caused the differences in the sounds.

Investigate Further Try moving your finger up and down the ruler as you pull on the rubber band. Can you play a scale? Can you play a tune? What other ways can you investigate sounds made by the rubber band?

Process Skill Tip

Scientists use their observations to **infer** the causes of their results. In this investigation your observations helped you infer the causes of different sounds.

LEARN ABOUT

Differences in Sounds

FIND OUT

- the difference between loud and soft sounds
- the difference between high and low sounds

VOCABULARY

loudness
pitch

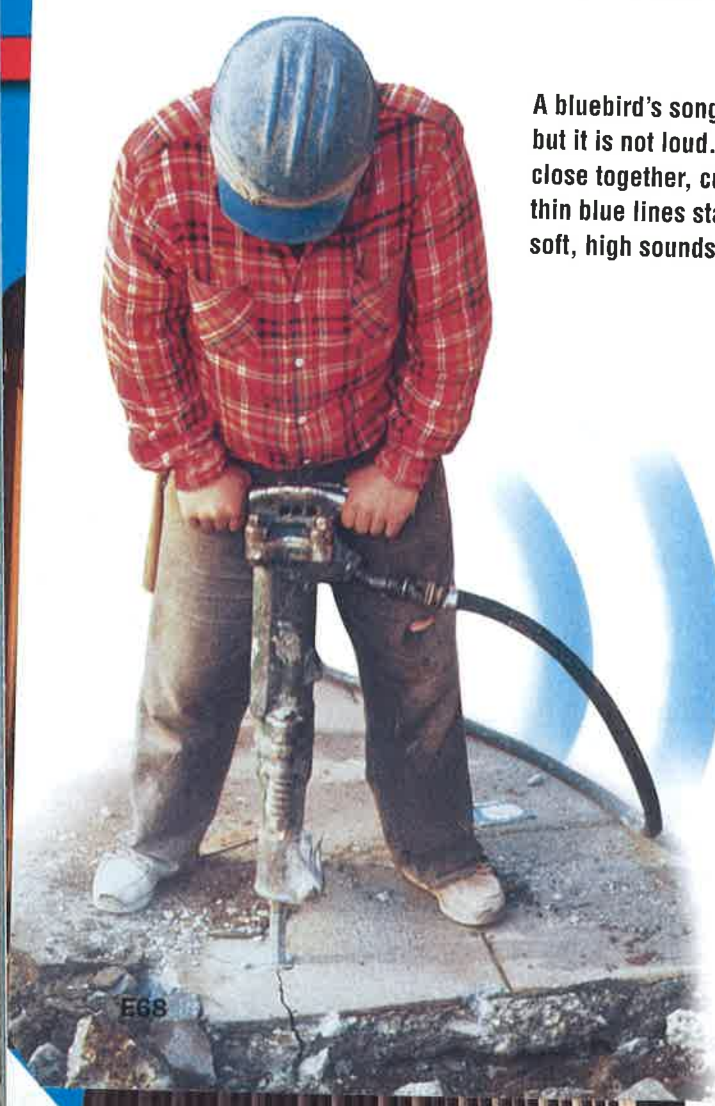
Loudness

You can whisper and you can shout. One sound is soft, and the other is loud. You can close a door softly, or you can bang shut so hard that everyone inside the building can hear. You ca hear how loud or soft a sound is. This property is called loud- ness. **Loudness** is a measure of the amount of sound energy reaching your ears.

The loudness of a sound depends on how far the vibrating object is moving as it goes back and forth. In the investigation the sound was louder when you pulled the rubber band farthe You added more energy to the rubber band by stretching it more. In the same way, if you hit a drum harder or slam a door harder, you make a louder sound.

✔ **What does loudness measure?**

A bluebird's song is pretty, but it is not loud. The close together, curved, thin blue lines stand for soft, high sounds. ►



◄ Noise from a jackhammer is much louder than a bluebird's song. It's so loud that it will injure your ears if you don't protect them. The far apart, curved, thick blue lines stand for loud, low sounds.

A tuba makes low sounds. The compressions of a tuba's sound wave are far apart.

Piccolo music reminds some people of the high sounds of singing birds. A piccolo makes fast vibrations. The compressions of a piccolo's sound wave are close together.

Pitch

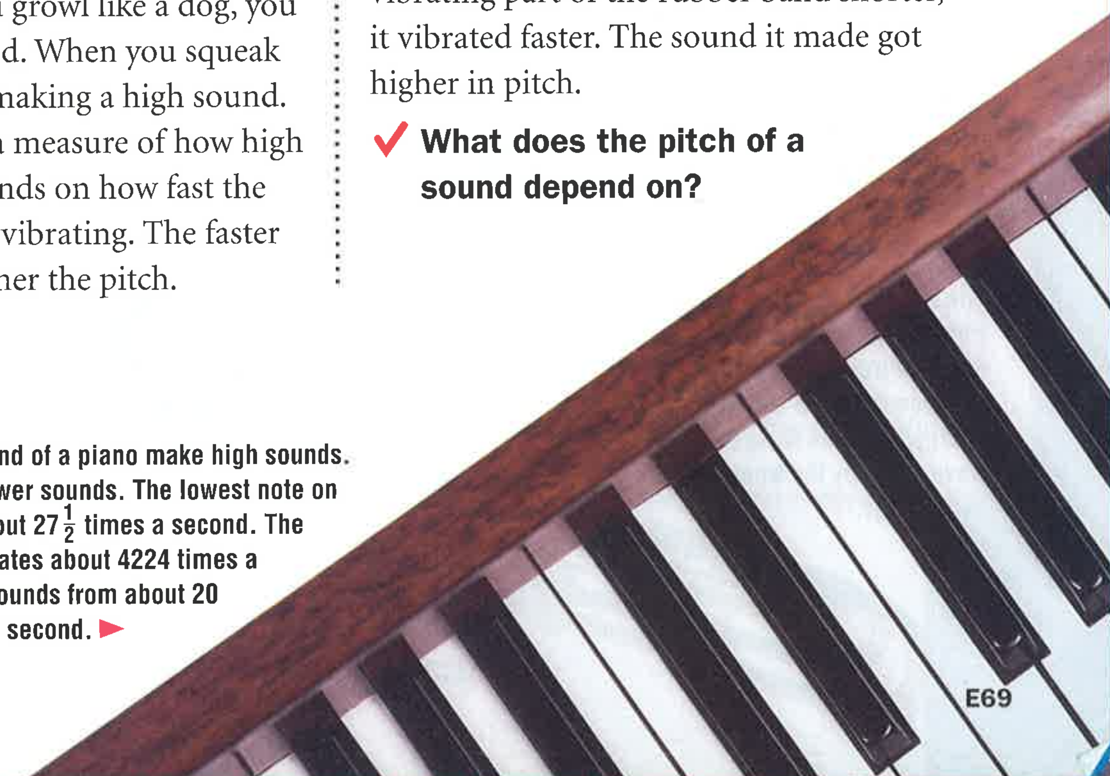
You can make loud sounds and soft sounds. You can also make high sounds and low sounds. When you growl like a dog, you are making a low sound. When you squeak like a mouse, you are making a high sound.

A sound's **pitch** is a measure of how high or low it is. Pitch depends on how fast the source of the sound is vibrating. The faster the vibrations, the higher the pitch.

You can change how fast a string or rubber band vibrates by changing its length. In the investigation, when you made the vibrating part of the rubber band shorter, it vibrated faster. The sound it made got higher in pitch.

✓ **What does the pitch of a sound depend on?**

The keys at the right-hand end of a piano make high sounds. The keys to the left make lower sounds. The lowest note on a modern piano vibrates about $27\frac{1}{2}$ times a second. The highest note on a piano vibrates about 4224 times a second. Humans can hear sounds from about 20 to about 20,000 vibrations a second.



Changing Pitch

Many musical instruments can be played at different pitches by changing the length of certain parts. A guitar or violin player puts his or her fingers down on the strings in different places. This changes the lengths of the vibrating strings. As a result, the violin or guitar plays different pitches.

Another way to make a different pitch is to change the thickness of the material that vibrates. A thin string vibrates faster than a thick string. Low-pitched guitar and piano strings have wire wrapped around them to make them thicker.

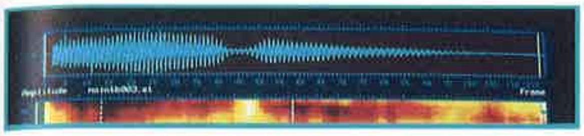
✓ **Name two ways you can change the pitch of a vibrating object.**

A trombone is a long tube. To play a note, a trombone player's lips vibrate. This makes the air inside the tube vibrate. ▼

When a trombone player pushes the slide out, the tube gets longer. This makes the pitch of the sound lower than before. ▼

The cone-shaped object in the trombone is a mute (MYOOT). It makes a trombone note softer because the mute absorbs sound energy. With the mute the sound wave made by the trombone has less energy. ▼

A voiceprint is an electronic "picture" of a voice. It shows the changing pitch and loudness of the voice as a person speaks. ▼



Summary

Loudness is a measure of the sound energy reaching your ears. It depends on the size of the vibrations. Pitch is a measure of how high or low a sound is. Pitch depends on how fast an object vibrates. You can change pitch by changing the length or the thickness of a vibrating object.

Review

1. What is the loudness of a sound?
2. What is the pitch of a sound?
3. What happens to sound as it gets farther away from the object making the sound?
4. **Critical Thinking** How do you think the finger holes on the side of a piccolo control the pitch of its sound?
5. **Test Prep** If you put your finger down on a guitar string to make the string shorter, the sound the string makes will get —

   A lower C louder
   B higher D softer

LINKS

MATH LINK

Calculate the Difference in Pitch The highest note on a piano vibrates 4224 times a second. The lowest note on a piano vibrates $27\frac{1}{2}$ times a second. What is the difference between these two pitches?

WRITING LINK

Informative Writing—Description Sit still and listen for one minute. Time yourself. As you're listening, make a list of every sound you hear. Then write a paragraph for your teacher describing all the sounds. Be sure to include loudness and pitch in your descriptions.

MUSIC LINK

High and Low Two of the families of instruments in an orchestra are the brass instruments and the woodwind instruments. Find out the names of the instruments in each of these families. Then find out the highest and lowest pitches each instrument family can play.

TECHNOLOGY LINK

Learn more about how scientists and engineers are using sound energy by viewing *Sound Wave Energy* on the **Harcourt Science Newsroom Video.**

CNN Turner Le@rning

LESSON 3

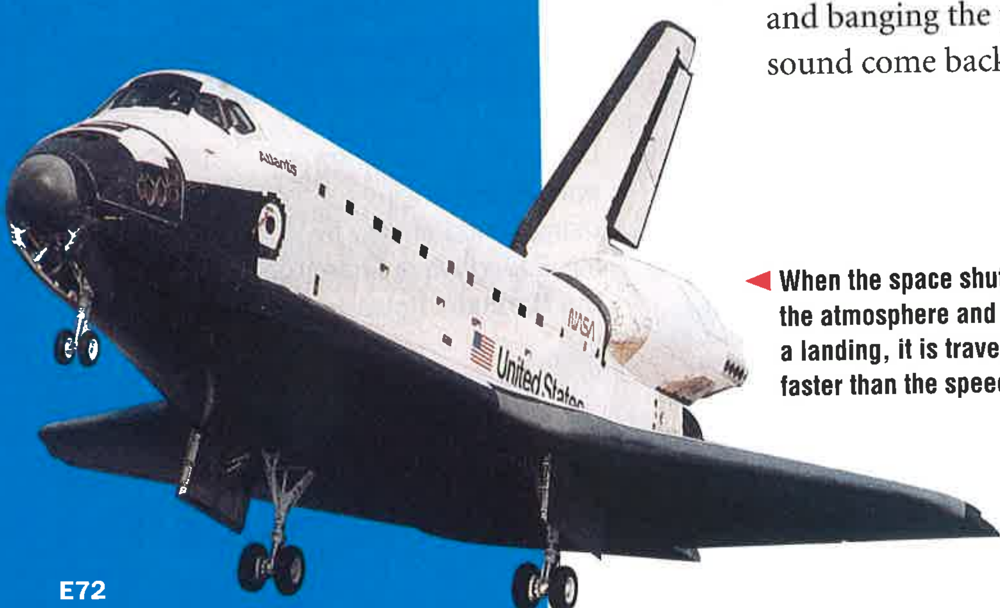
How Do Sound Waves Travel?

In this lesson, you can . . .

INVESTIGATE ways sound is reflected.

LEARN ABOUT how sound waves travel.

LINK to math, writing, health, and technology.



INVESTIGATE

Hearing Sounds

Activity Purpose Have you ever made a sound and heard it come back to you? In this investigation you will **gather and record data** while making a sound and listening to find out if it comes back to you.

Materials

- large metal spoon
- metal pot
- red crayon

Activity Procedure

1. Find a playing field with a scoreboard or building at one end. Use a pencil to make a drawing of the playing field.
2. Walk out onto the playing field. Bang the spoon against the pot once. Wait and **observe** whether or not the sound comes back to you. (Picture A)
3. Use a pencil to **record** on your drawing where you are on the playing field and which way you are facing. (Picture B)
4. Keep moving to new locations on the field and banging the pot until you hear the sound come back to you.

When the space shuttle reenters the atmosphere and coasts toward a landing, it is traveling much faster than the speed of sound.

5. **Record** on your drawing where you are on the playing field and which way you are facing each time you bang the pot. Use the red crayon to mark the places where the sound came back to you.

6. Move forward and back. Move from side to side. Each time you move, bang the pot once and wait to see whether or not the sound comes back to you.

7. **Record** on your drawing where you are on the playing field and which way you are facing each time you bang the pot. Use the red crayon to mark the places where the sound came back to you. Make sure your drawing shows at least 20 different positions.


Picture A


Picture B

Draw Conclusions

1. Look at your drawing. How many different positions did you show? At how many different places did the sound come back to you?
2. Look at all the places marked in red on your drawing. Do they have anything in common?
3. **Scientists at Work** Each mark that you made on your drawing was a piece of data. When scientists do investigations, they **gather and record** as much **data** as they can. All the data helps them draw conclusions. How could you gather more data in an organized way?

Investigate Further Move to each of the places on the field where you heard the sound come back to you. Blow a whistle loudly in each place. Does the sound come back to you? Why do you think it did or didn't?

Process Skill Tip

Scientists often use drawings when they **gather and record data.** Their drawings help them see patterns in the information they gather. They use the patterns to help them draw conclusions.

LEARN ABOUT

How Sound Travels

FIND OUT

- how quickly sound travels
- the cause of echoes
- what happens when you go faster than sound

VOCABULARY

speed of sound
echo
sonic boom

Speed

Have you ever been to a baseball game and watched a bat hit a home run? If you were sitting all the way across the ba park, you saw the batter hit the ball a split second before yo heard the crack of the bat. This is because sound waves take more time to move through the air than light does. Even so, took less than a second for the sound wave to travel from th to your ears.

The speed at which a sound wave travels is called the **speed of sound**. Sound waves move at different speeds thro different materials. In dry, cool air, sound waves travel 340 meters (about 1115 ft) per second. The speed of sound trave through steel is 5200 meters (about 17,070 ft) per second.

In hard, solid materials, sound waves move very fast. This because the particles in solids are close together and bump i each other often. The particles in liquids don't bump into ea other as often as particles in solids do. So vibrations take lon to move through liquids. Sound moves more slowly through uids than through most solids.

On the Concorde jet, you can fly faster than sound. One flight goes from Paris, France, to New York. This trip of 6,000 kilometers (about 3,700 mi) across the Atlantic Ocean takes only three and one half hours. A regular 747 jet takes almost eight hours.