**Objectives**

After this lesson, students will be able to:

- **O.2.3.1** Identify what determines the sound quality of a musical instrument.
- **O.2.3.2** Name the basic groups of musical instruments.
- **O.2.3.3** Describe how acoustics is used in concert hall design.

**Target Reading Skill**

**Previewing Visuals** Explain that looking at the visuals before they read helps students activate prior knowledge and predict what they are about to read.

**Answers**

Sample questions and answers:

**Musical Instruments**

1. **How is pitch changed in each type of instrument?** (By changing the frequency of the vibrations)
2. **How is loudness changed in each type of instrument?** (By changing the energy of the vibrations)

**Teaching Resources**

- Transparency O22

**Preteach**

**Build Background Knowledge**

**Comparing Instrumental Sounds**

Ask students who play different musical instruments to bring their instruments to class. Have each student play the same note at the same volume. Call on students in the class to describe how the different instruments sound. Ask: What do you think causes the instruments to sound different from one another? (Students might say construction materials, size, and shape.)

**Discover Activity**

**How Can You Change Pitch?**

1. Wrap two rubber bands of different thickness lengthwise around a 30-cm plastic ruler. The bands should not touch each other.
2. Place a pencil under the bands at the 10-cm mark.
3. Pluck each band. How are the sounds different?
4. Move the pencil to the 15-cm mark and repeat Step 3.

**Think It Over**

Why are the sounds you made in Step 4 different from the sounds in Step 3?

**Expected Outcome**

Because they have different thicknesses, the rubber bands will have different natural frequencies and produce sounds of different pitches. When the pencil is moved from the 5-cm mark to the 15-cm mark, the pitch becomes higher.

**Think It Over**

In Step 4, the pitch is higher because the part of the rubber band that is vibrating is shorter.

**Skills Focus**

Developing hypotheses

**Materials**

- 2 rubber bands of different thicknesses, 30-cm ruler, pencil

**Time**

- 15 minutes

**Tips**

Rubber bands that are too thick will not stretch enough. Caution students to avoid launching the rubber bands with the rulers.
Sound Quality

Most people agree on what is or is not music. Music is a set of notes that combine in patterns that are pleasing. Noise, on the other hand, has no pleasing patterns. When you describe a sound as pleasant or unpleasant, you are describing sound quality. The sound quality of music depends on the instruments making the music. The sound quality of musical instruments results from blending a fundamental tone with its overtones. Resonance also plays a role in the sound quality.

**Fundamental Tones and Overtones**

In Chapter 1, you learned that standing waves occur when waves with just the right frequency interfere as they reflect back and forth. Standing waves occur in musical instruments when they are played. In a guitar, for example, standing waves occur in a vibrating string. In a trumpet, standing waves occur in a column of vibrating air.

A standing wave can occur only at specific frequencies that are called natural frequencies. Every object has its own natural frequencies. The lowest natural frequency of an object is called the fundamental tone. The object’s higher natural frequencies are called overtones. Overtones have frequencies that are two, three, or more times the frequency of the fundamental tone. Look at Figure 14 to see how the natural frequencies of a guitar string add together to produce a unique sound.

The fundamental tone determines what note you hear. For example, when a guitar and a trumpet play middle C, they both produce waves with a frequency of 262 Hz. But each instrument produces different overtones, so the blending of the fundamental tones and overtones produces different sound qualities.

**Resonance**

Resonance affects the sound quality of a musical instrument by increasing the loudness of certain overtones. Recall that resonance occurs when one object causes a nearby object to vibrate at a natural frequency. A musical instrument is designed so that a part of it will resonate with the overtones it produces. In a guitar, for example, the vibrating strings cause the guitar’s hollow body to resonate. The shape and material of the guitar determine which overtones are loudest.

![Image]( vigv -p.jpg)

**Figure 14** Sound Quality

A guitar string can resonate at several frequencies that combine to produce a unique sound quality. **Interpreting Data** What determines the resulting wave?

- Fundamental tone
- First overtone
- Second overtone
- Resulting sound wave

The resulting sound wave is the sum of the fundamental tone and the overtones.

**Differentiated Instruction**

**Special Needs**

Observing Tones of Different Frequencies Help students understand how overtones are related to the fundamental tone. Have students use a pitch pipe or two tuning forks to play middle C (262 Hz) followed by the C above middle C (524 Hz). Explain how the two notes are related to Figure 14. learning modality: kinesthetic

**Gifted and Talented**

Demonstrating Resonance Ask students who play wind instruments to bring their instruments to class. Have them play a sound using only the mouthpiece, followed by a sound using the whole instrument. Challenge them to explain to the class how this demonstrates resonance. learning modality: kinesthetic

**Instruct**

**Sound Quality**

**Teach Key Concepts**

**Sound Quality and Natural Frequencies**

**Focus** Introduce sound quality as the characteristic that allows you to distinguish one musical instrument from another by sound alone.

**Teach** Tell students that different instruments vibrate at different natural frequencies. Explain that this is one reason why each type of instrument has a unique sound.

**Apply** Ask: What factors might account for the natural frequency of a particular instrument? (Size, shape, material) learning modality: verbal

**Independent Practice**

**Teaching Resources**

- Guided Reading and Study Worksheet: Music

**Student Edition on Audio CD**

**Monitor Progress**

**Writing** Have students explain why the same song sounds different when played on a piano and a flute.

**Answers**

**Figure 14** The sum of the fundamental tone and overtones

Overtones are an object’s higher natural frequencies that are two, three, or more times the frequency of the fundamental tone.
Groups of Musical Instruments

Teach Key Concepts

Musical Instrument Groups

Focus Introduce the three groups of musical instruments.

Teach Have students read the caption and labels of Figure 15. Write the terms Strings, Winds, and Percussion on the board. Challenge students to brainstorm the names of different instruments, including both band and orchestra instruments. Tell them to try to think of other instruments besides the examples shown in the figure. As students name the instruments, write them under the appropriate headings. (Sample answer: Strings include banjo, guitar, violin, cello, piano, harpsichord, harp; winds include harmonica, flute, oboe, bassoon, clarinet, saxophone, trumpet, trombone, and tuba; percussion include snare drum, cymbal, base drum, tympani, castanet, xylophone, and bell.)

Extend The active art will show students how musical instruments in the three groups produce sounds and change pitch and loudness. learning modality: visual

Applying Concepts

Materials whistle

Time 10 minutes

Focus Have students apply their knowledge about musical instruments as they examine a whistle.

Teach Blow into a whistle, and have students evaluate its pitch. Ask: Does a whistle make sound waves with a high or low frequency? How can you tell? (It has a high pitch, so it makes sound waves with a high frequency.) In which group of musical instruments would you classify a whistle? Why? (A whistle is a wind instrument, because movement of air through or across the mouthpiece causes the air inside the whistle to vibrate.)

Apply Challenge students to explain how the size of a whistle is related to the frequency of the sound waves it produces. (Because a whistle is small, the column of vibrating air is short, and a short air column produces high frequency sound waves.) learning modality: kinesthetic

FIGURE 15

Musical Instruments

A musician controls the vibrations of a musical instrument to change pitch and loudness. Classifying how would you classify a tuba, a tambourine, and a banjo?

Groups of Musical Instruments

How does a musician control the sounds produced by a musical instrument? To control pitch, the musician changes the fundamental tones produced by the instrument. To control loudness, the musician changes the energy of the vibrations. The way that pitch and loudness are controlled varies among the groups of instruments, as shown in Figure 15. There are three basic groups of musical instruments: stringed instruments, wind instruments, and percussion instruments.

Stringed Instruments The guitar and the violin are stringed instruments. The strings of these instruments produce sound by vibrating when they are strummed or rubbed with a bow. Their loudness is increased by resonance when the instrument’s hollow body vibrates as the strings vibrate. The pitch of each string depends on four factors: its length and thickness, the material it is made from, and how tightly it is stretched. An instrument with long strings, such as a cello, produces lower notes than an instrument with short strings, such as a violin.

Wind Instrument: Clarinet

Loudness is controlled by how hard the musician blows.

Pitch depends on the length and thickness of the strings, the material they are made of, and how tightly the strings are stretched. A short string produces a high pitch, and a longer string produces a lower pitch.
Wind Instruments  Wind instruments include brass instruments, such as trumpets, and woodwind instruments, such as clarinets. Brass instruments produce sound when a musician’s lips vibrate against the mouthpiece, causing the air column in the instrument to vibrate. Woodwinds usually contain a thin, flexible strip of material called a reed. A woodwind produces sound when the reed vibrates, causing the instrument’s air column to vibrate. In wind instruments, the length of the vibrating air column determines the note that you hear. A tuba, which has a long air column, produces lower notes than a flute, which has a short air column.

Percussion Instruments  Percussion instruments include drums, bells, cymbals, and xylophones. These instruments vibrate when struck. The pitch of a drum depends on its size, the material it is made of, and the tension in the drumhead. A large drum produces lower pitches than a small drum.

Pitch depends on the length of the air column, which can be changed by covering different holes. A short air column produces a high pitch, and a longer column produces a lower pitch.

Pitch depends on the size of the drum head, the material, and the tension in the drum head. A smaller drum produces a higher pitch.

Differentiated Instruction

- **English Learners/Beginning Comprehension: Link to Visual** Guide students in using Figure 15 to learn about the three groups of musical instruments. Explain the labels in the figure, and point out the relevant parts of the pictured instruments. Also, explain how pitch is generally controlled in instruments belonging to each group. learning modality: visual

- **English Learners/Intermediate Comprehension: Ask Questions** After students have read the information on groups of musical instruments, ask them to explain in their own words how loudness is controlled in instruments belonging to each group. If students make any errors, direct them to reread the relevant labels in Figure 15. learning modality: verbal

Monitor Progress

**Skills Check** Name several different musical instruments. Challenge students to classify each instrument by group.

**Answers**

- Drums, bells, cymbals, and xylophones

Help Students Read

**Comparing and Contrasting** Have students make a table summarizing the most important points about the three different groups of musical instruments, using as column heads Instrument Group, Examples, How Sound Is Produced, How Pitch Is Changed, How Loudness Is Changed. Tell them to use information from the text and from Figure 5. Then, have students use their tables to identify similarities and differences among the three types. (Sample answer: All three types produce sounds by making something vibrate, but they differ in what vibrates and how it is made to vibrate.)
Acoustics

Teach Key Concepts

Wave Interference Affects Sound

Focus State that wave interference in sound waves affects sounds.

Teach Ask: How do you think destructive and constructive interference affect sound? (Destructive interference diminishes or dampens sound. Constructive interference increases loudness and may distort sound.)

Apply Have students explain how their inferences might be applied in the design of a concert hall.

Monitor Progress

Answers Figure 16 Reflect sound downward

Assess

Reviewing Key Concepts

1. a. Sound quality results from the blending of a fundamental tone with its overtones. b. By increasing the loudness of certain overtones. c. In a guitar: by plucking the strings harder; In a drum: by striking the drumhead harder.

2. a. Stringed, wind, and percussion instruments. b. For strings, change the length or tension of a string; for winds, change the length of the air column; for percussion, strike a surface that has a different tension or size. c. In a guitar: by plucking the strings harder; In a drum: by striking the drumhead harder.

3. a. The study of how sounds interact with each other and the environment. b. Curved hard surfaces reflect sound waves and direct them to different parts of the hall. Soft surfaces absorb sound waves and reduce reverberation. c. With too little reverberation, instruments would sound thin and distant.

Reteach

Call on students to explain how instruments in each of the three groups produce sound.

Performance Assessment

Writing Have students describe how acoustics is used in concert hall design.

Teaching Resources

• Section Summary: Music
• Review and Reinforcement: Music
• Enrich: Music

Keep Students on Track

Have students experiment with different materials and ways to vary pitch and loudness. Ask them to organize their observations in data tables so they can generalize about the sounds produced by different designs and materials.

Acoustics

Your surroundings affect the musical sounds that you hear at a concert. To understand this, compare the sound of your voice in different places—in class, outdoors, or in a gym. The differences you hear are due to the different ways that sounds interact. Acoustics is the study of how sounds interact with each other and the environment.

Sound waves can interfere with each other. Constructive interference may distort sound, while destructive interference can produce “dead spots,” where loudness is reduced. Sound waves interact with the environment, also. For example, if you clap your hands in a gym, you hear echoes after you clap because sound waves reflect back and forth off the hard surfaces. This is reverberation, in which the echoes of a sound are heard after the sound source stops producing sound waves. The sound from a handclap can take more than a second to die out in a gym.

Acoustics is used in the design of concert halls to control reverberation and interference. Curved hard surfaces are used to direct sound waves to different parts of the concert hall. Soft surfaces absorb sound waves, reducing reverberation. But some reverberation is desirable. With too little reverberation, instruments would sound thin and distant. With too much reverberation, reflected waves interfere and individual notes become hard to pick out.

Target Reading Skill

Previewing Visuals Refer to your questions and answers about Figure 15 to help you answer Question 2 below.

Reviewing Key Concepts

1. a. Describing How do overtones affect the sound quality of a musical instrument? b. Explaining How does resonance affect the sound quality of a musical instrument?

2. a. Listing What are the three groups of musical instruments? b. Summarizing How is pitch controlled in each group of musical instruments?

3. a. Defining What is acoustics? b. Relating Cause and Effect How is acoustics used in the design of concert halls? c. Making Judgments Why is some reverberation desirable in a concert hall?

Writing in Science

Explanation A friend e-mails you and asks how your new guitar produces music. Write an e-mail that answers your friend’s question. Be sure to explain how you can change pitch, and why the guitar has a hollow body.
Changing Pitch

Problem
When you blow across the mouth of a bottle, you can play a "note." What determines the pitch you hear?

Skills Focus
developing hypotheses, controlling variables, designing experiments

Suggested Materials
- 1-L soda bottle
- 2-L soda bottle
- 250-mL graduated cylinder
- metric ruler
- straw
- water

Design a Plan
1. Practice making a sound by using a straw to blow across the mouth of a 1-L bottle. Then blow across the mouth of a 2-L bottle in the same way. Compare the pitches. Record your observations in your notebook.

2. Add 250 mL of water to both the 1-L bottle and the 2-L bottle. Blow across the mouth of each bottle and compare the pitches. Record your observations in your notebook.

3. Analyze your observations from Steps 1 and 2 to predict what may have affected the pitches. For example, measure the height of the air column, and calculate the volume of air in each bottle. (Hint: Subtract the volume of water in the bottle from the total volume of the bottle.)

4. Develop a hypothesis about what determines the pitch of the sound produced by blowing across the mouth of a bottle. Record your hypothesis in your notebook.

5. Design an experiment to test your hypothesis. Create a data table to record information about the variables. Write your plan. (Hint: You can change the height of the air column in a bottle by changing the amount of water in the bottle.)

Analyze and Conclude
1. The 2-L bottle has a lower pitch than the 1-L bottle. Both bottles have a higher pitch after water is added.

2. Answers will vary but if students hypothesized that the height of the air column determines pitch, their answer will be yes, because pitch changed as the height of the air column changed.

3. The manipulated variable was height of air column; the responding variable was pitch.

4. Sample answer: Add more water.

5. As height of the air column increases, pitch decreases.

6. Sample answer: Add different amounts of water to several identical bottles to produce all the notes needed to play a song.

More to Explore
1. Use a set of tuning forks or a pitch pipe to "tune" five bottles to match the notes C, D, E, F, and G. What can you conclude about the pitches of the five notes from the height of the air column in each bottle? Use the bottles to play the following notes: E D C D E E E D D E D C.

2. Sample answer: Add more water.

Analyze your observations from Steps 1 and 2 to predict what may have affected the pitches. For example, measure the height of the air column, and calculate the volume of air in each bottle. (Hint: Subtract the volume of water in the bottle from the total volume of the bottle.)

4.开发一个关于声音的实验假设，解释为什么音高会发生变化。

5. 依据你的实验计划，进行实验并记录结果。

Analyze and Conclude
1. 2-L瓶子的音调比1-L瓶子低。在加入水后，两个瓶子的音调都会上升。

2. 答案会根据学生们的假设而变化。如果假设是空气柱的高度决定了音调，那么它们的答案会是肯定的，因为音调确实随着空气柱的高度变化而变化。

3. 被操纵的变量是空气柱的高度；响应变量是音调。

4. 样本答案：添加更多的水。

5. 当空气柱的高度增加时，音调会降低。

6. 样本答案：向几个相同的瓶子中添加不同量的水，以产生所有需要的音符来演奏一首歌。

More to Explore
1. 使用一套音叉或音管，以“调”五个瓶子来匹配音符C、D、E、F和G。你对五个音符的高度能得出什么结论？使用这些瓶子来演奏以下音符：E D C D E E E D D E D C。

2. 样本答案：添加更多的水。

Analyze your observations from Steps 1 and 2 to predict what may have affected the pitches. For example, measure the height of the air column, and calculate the volume of air in each bottle. (Hint: Subtract the volume of water in the bottle from the total volume of the bottle.)

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6. 样本答案：向几个相同的瓶子中添加不同量的水，以产生所有需要的音符来演奏一首歌。