Activity 1B:
Sound—From Production to Perception

Students experiment with and "dissect" a speaker to see firsthand how these devices convert electrical impulses into physical vibrations. This provides a concrete example of the fact that vibrating objects produce sound, and also demonstrates the relationship between wave amplitude and sound volume.

Understandings

- Sounds are produced by vibrating objects.
- The ear converts the vibration of air molecules into a signal to the brain.

Materials Needed

- Optional: Functioning speaker
- Speakers to take apart (1 per team—see Advance Preparation for the unit)
- **Handout 3: Anatomy of a Speaker**
- Materials for dissecting speakers:
  - Safety goggles (1 pair per student)
  - Small screwdrivers in a variety of sizes (several per team)
  - Scissors (1 pair per team)
  - Craft knife or utility knife (1 per team)
  - Wire cutters/strippers (1 per team)
  - Alligator clip cables (2 per team)
  - 9-volt battery (1 per team)
  - Voltmeter, ammeter, or multimeter (1 per team)
- **Handout 4: From There to Ear**
- **Handout 5: Playing the Eardrum**
- Optional: Audio clip, *Sound as Touch*, 4:39–6:53 (see Advance Preparation)
- Optional: Computer with Internet access and speakers
- Students' completed copies of Handout 1
- Chart paper from Activity 1A with questions and observations about sound

1. Introduce the activity.

Explain that learning about how speakers work will help students understand sound and, since the soundtrack for any media project reaches the audience through speakers, can help them create better soundtracks. Ask students:

- What do you already know about how speakers work?

If you have a functioning speaker available, you can ask a few students to put their hands on it while you play a loud, low-frequency sound and have them describe what they feel to their classmates. Otherwise, ask students:

- Have you touched a speaker while it was in use or stood next to a large speaker at a concert? If so, what did you feel? What do you think caused this sensation?

2. Have students perform the "dissection."

Distribute **Handout 3: Anatomy of a Speaker** and divide the class into teams of two to four students. (Base team sizes on the number of speakers for dissection you were able to obtain.) Have students work in teams to complete the steps described in the handout and answer the questions.

3. Share results.

Discuss the questions from Handout 3 and ask students to share their observations. See how much students were able to figure out about how the speaker works and then fill in any details.

Teacher's Notes: How Speakers Work

When an electric current is applied to the voice coil, the coil becomes an electromagnet. Depending on the direction of the current, the coil is either attracted to or repelled by the permanent magnet. Since the cone is connected to the voice coil, it moves in when the coil moves in and moves out when the coil moves out. The moving cone pushes against adjacent air molecules. Handouts 4 and 5 explain more about what happens once these molecules are in motion.

A simple speaker can be used in reverse as a microphone. If you have ever used a simple intercom or walkie-talkie that doesn't let you talk and listen at the same time, it's because it was constructed with one device to serve as both the microphone and the speaker.

For further detail about how speakers and microphones work, see *Additional Resources for Teachers.*

4. Explain how sound travels to the ear.

Distribute **Handout 4: From There to Ear** and **Handout 5: Playing the Eardrum**. Explain that any source of sound, such as a tuning fork, a loudspeaker, or a musical instrument, vibrates. This causes vibrations in whatever separates the vibrating object from our ears—usually air, but vibrations can pass through solids and liquids as well. If the vibrations are strong enough to travel to our ears, and if the rate of vibration is within the range our ears are sensitive to, our ears turn that vibration into a signal that our brains perceive as sound.

Note: If you have time and wish to cover the topic of sound perception in more detail, play the audio clip from *Sound as Touch*.

Teacher's Notes: Radio Waves and Sound Waves

This session may be a good opportunity to correct a common misconception among students, which is that radio waves and sound waves are the same thing.

- *Sound waves* are mechanical waves—molecules vibrating back and forth, causing the adjacent molecules to move back and forth, and so on. Sound waves make our eardrums vibrate, which is why we can hear sound.
- *Radio waves* are a type of electromagnetic wave, like light. Unlike mechanical waves, radio waves and other electromagnetic waves do not need a medium to travel through—they can travel through a vacuum. Since our ears are sensitive to molecules moving back and forth and radio waves do not make molecules move back and forth, we cannot hear radio waves.

You may want to show again, or just refer back to, the video clip of the bell in the vacuum jar. When there was no air in the jar, no sound waves could travel from the bell to observers' ears. But the fact that the bell could still be seen demonstrates that electromagnetic waves such as light waves could travel to and from the bell, even through the vacuum.

5. Discuss connections to the *Sounds All Around* video clips.

Ask students to apply what they've learned to the *Sounds All Around* video clips and the questions they noted on Handout 1 and the chart paper from Activity 1A. What parts of the video could the activities you did in this session help explain? You may want to prompt them to think about these clips in particular:

1. Bell in a vacuum jar, spaceship

   Possible answer: *If sound travels by air molecules bumping into each other, then sound can't travel where there are no molecules.*

2. Wine glass shattering

   Possible answer: *The vibrating air molecules make the glass vibrate so forcefully that it breaks.*

3. Orchestra tuning up

   Possible answer: *Musical instruments produce sound by making the air vibrate.*

Handout 3:
Anatomy of a Speaker

A microphone takes sound and converts it into an electrical signal that can be stored for later playback. A speaker takes this electrical signal and converts it back into sound. Learn more about how this works and exactly what sound is by "dissecting" a speaker.

Background Information

Speaker is short for *loudspeaker*. A loudspeaker consists of some kind of cabinet or enclosure with one or more drivers inside, along with any electronics needed to process the incoming electrical signal. A *driver* is the part of the speaker that converts the electrical signal into physical vibrations.

Loudspeaker with cover removed to show three drivers inside.
Image from http://commons.wikimedia.org/wiki/File:Spkrs.jpg, licensed under Creative Commons Attribution ShareAlike 3.0

Speakers work because they receive electrical signals from a computer, television, or other sound system component. In this activity, since the speakers being dissected are no longer connected to one of these systems, you will use a battery to provide the electrical signal. While a sound system sends a signal consisting of a varying electrical voltage, the battery can only send a very simple signal—it's either on or off!—so there won't be much variety in the sounds produced during this investigation.

Materials

- Safety goggles
- Small screwdrivers in a variety of sizes
- Scissors
- Craft knife or utility knife
- Wire cutters/strippers
- 2 alligator clip cables
- 9-volt battery
- Voltmeter, ammeter, or multimeter

Procedure

Note: Try to do as little damage as possible to the speaker at each stage, so that it continues to function throughout as much of the procedure as possible.

1. Put on your safety goggles.

You may need to pry the speaker apart using a screwdriver, and pieces of the speaker may go flying through the air. Even if your team is not prying apart the speaker, other teams may be, and the flying pieces can travel several feet.

2. Remove the driver.

What needs to be done to expose the driver varies widely from speaker to speaker. Here are some general guidelines:

- Most speakers have some kind of mesh or grill cover on the front. Try to remove this.
  - If this cover is screwed on, remove the screws and lift the cover off.
  - If there are no visible screws, you may be able to pry the cover off with a screwdriver.
  - A mesh cover can be cut away with scissors or a knife.
- Once the cover has been removed, you will see the front of the driver.
  - If the driver is held in place with screws, unscrew them and carefully remove the driver.
  - If there are no visible screws, see if you can simply lift the driver out.
  - If you are not able to remove the driver from the front of the speaker, you will need to take apart the speaker cabinet. Look for small screws on the front and back. If there are no screws, or if removing the screws does not enable you to open the cabinet, you may need to pry the cabinet apart with a screwdriver. Once the cabinet is open, remove the driver.

If you are unable to remove the driver, you should still try to complete as much as possible of the remaining steps.

A loudspeaker driver that has been removed from its cabinet.
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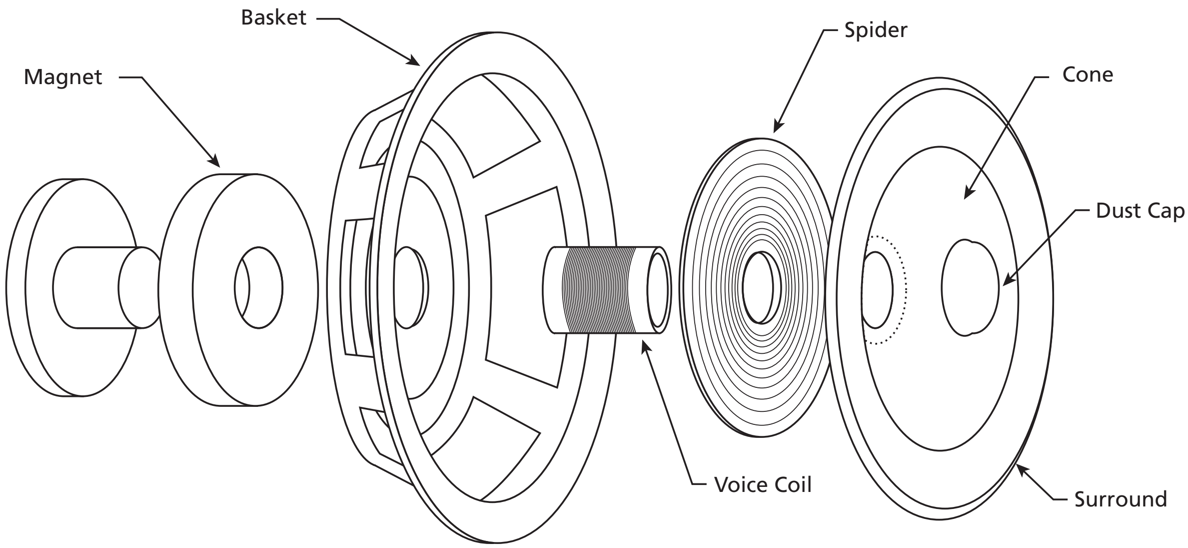
3. Disconnect the driver wiring from the rest of the speaker and connect it to the battery.

Two wires connect the underside of the speaker cone to the inside of the speaker cabinet. (Any other wires can be cut and then ignored.)

- The wires leading from the cone may be connected to the rest of the speaker by small plugs. If this is the case, unplug the wires, and attach an alligator clip cable to each plug remaining on the driver.
- If the wires leading from the cone cannot be unplugged, use wire cutters/strippers to cut the wires. Then strip some insulation off the ends of the wires and attach an alligator clip cable to the end of each wire. Attach the free end of one alligator clip to one battery terminal.



Parts of a driver

Touch the free end of the other alligator clip to the other battery terminal to complete the circuit. Try this repeatedly and answer the following questions:

- What do you hear?
- What does the cone do?
- What do you see and hear if you connect the wires to the opposite terminals of the battery?

Leave the alligator cables attached to the driver, and leave one alligator clip attached to the battery.

4. Expose the spider and voice coil.
Use a craft knife or utility knife to remove part of the cone by cutting halfway around the surround and then across the cone and dust cap. (Remove the half of the cone that does not have wires attached to it.) Again, use the free end of the alligator clip cable to complete the circuit with the battery.

- What do you hear?
- What parts of the driver move?
- What changes if you connect the alligator clip cables to the opposite terminals of the battery?

Use the knife to remove half the spider. Again, connect the free end of the alligator clip cable to the battery. Look for the voice coil (a coil of very fine copper wire).

- When you complete the circuit with the battery, what does the voice coil do?

5. See what you can determine about how a speaker works.

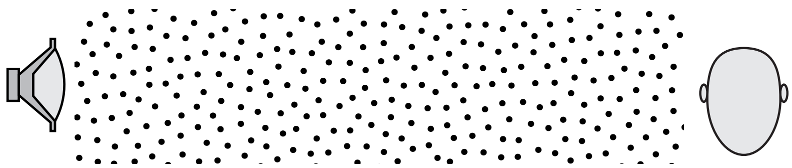
- Based on your observations, what have you figured out about how a speaker works?
- What questions about how a speaker works do you still have?

6. Connect the speaker wires to a voltmeter or ammeter.
Movement of the needle on a voltmeter or ammeter indicates that electricity is flowing.

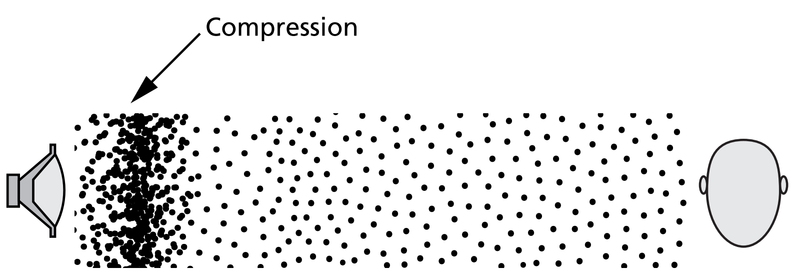
- Move the cone in and out with your fingers. How does the meter respond?
- Can you make the cone move by blowing on it or shouting near it?
- Given your observations, what ideas do you have about how microphones work?

Handout 4:
From There to Ear

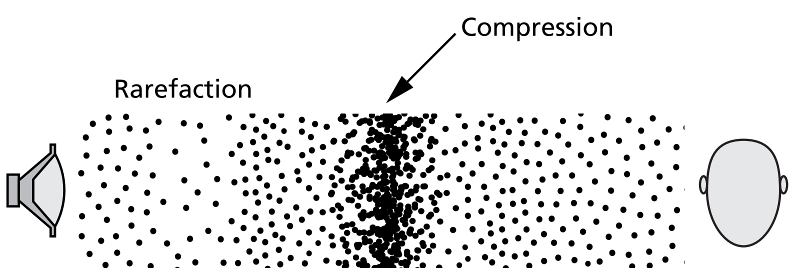
Any source of sound, such as a tuning fork, a loudspeaker, or a musical instrument, vibrates. This causes vibrations in whatever separates the vibrating object from our ears—usually air, but vibrations can pass through solids and liquids as well. If the vibrations are strong enough to travel to our ears, and if the rate of vibration is within the range our ears are sensitive to, our ears turn that vibration into a signal that our brains perceive as sound.



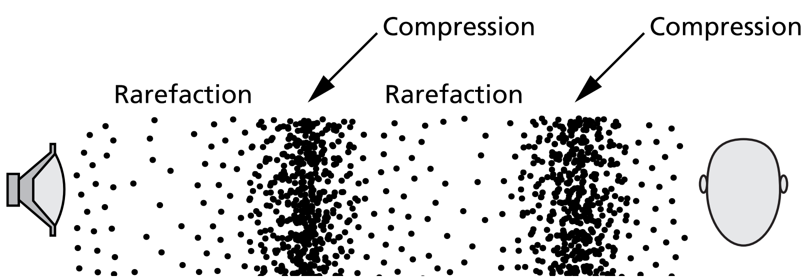
In the absence of sound, the air molecules between the speaker and the ear are spread out evenly.



In response to an electrical signal, the speaker cone moves to the right, hitting the nearby air molecules and resulting in a region of compressed air.



The air molecules bump into other molecules, and so on, resulting in a region of compression that moves away from the speaker. Meanwhile, as the speaker cone moves to the left, a region of lower air pressure, called a *rarefaction*, forms.



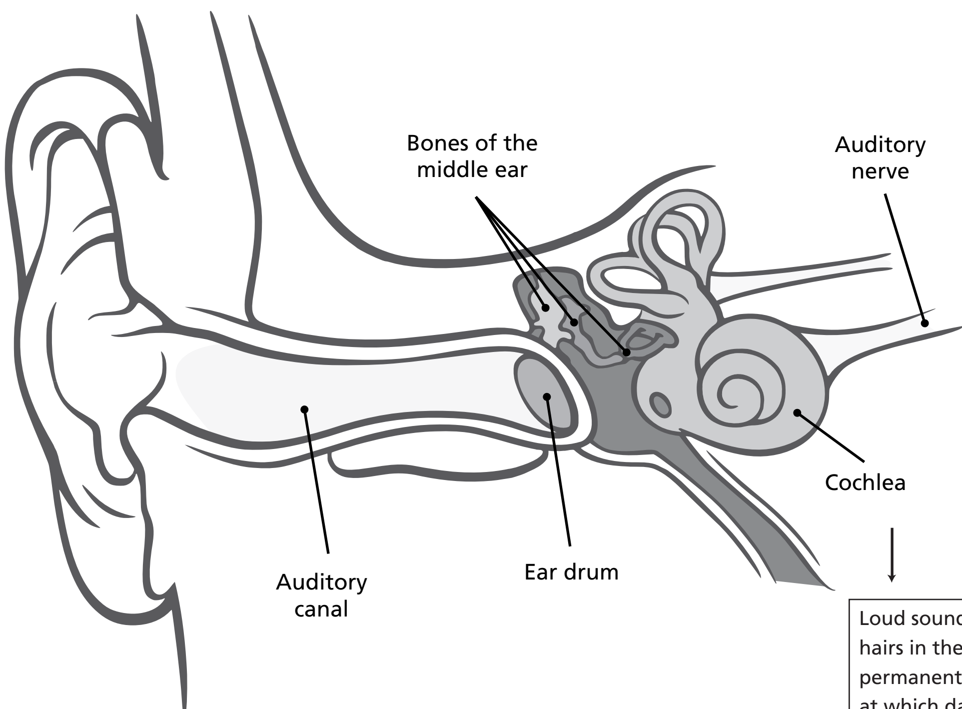
The speaker cone continues to move in and out, creating alternating regions of compression and rarefaction that travel to a listener's ear.

Handout 5:
Playing the Eardrum

When you listen to sound from a speaker, vibrations travel this path to your ear:

diaphragm of the speaker
↓
air molecules between you and the speaker
↓
air molecules in your auditory canal
↓
eardrum (tympanic membrane)
↓
tiny bones in the middle ear
↓
fluid in the cochlea
↓
tiny hairs in the fluid

The motion of these hairs results in an electrical signal being sent along the auditory nerve to your brain.



Loud sounds can damage the tiny hairs in the cochlea, resulting in permanent hearing loss. The volume at which damage occurs is much lower than the volume at which a listener feels pain.

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