Acoustical Society of America

Sound and Music

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ASA Activity Kit Committee

Students explore the physics of sound, how the ear hears and how musical instruments work through interactive demonstrations and student activities.

Science Topics	Process Skills	Subject Integration	Grade Level
Sound Vibrations Resonance Frequency Anatomy of the ear Conservation of Energy	Observing Predicting Making models Scientific Inquiry Comparing Communicating	Physical Science Musical acoustics Speech Psychological & Physiological Acoustics	3-12

Time Required

Advanced Preparation	Set-Up	Activity*	Clean-Up
10 minutes (with kit) gather materials	5 minutes	40-50 minutes	5 minutes

*If you are using the optional worksheet, then we believe it may add an extra 10 minutes to the activity.

Learning Goals

Students will be able to

- describe and identify the source of a sound – vibrations.
- identify the difference between the direction a wave travels and the direction the medium moves.
- explain that Sound carries energy and identify how sound energy transfers
- explain resonant or natural frequency.
- relate the terms pitch, frequency and high/low sounds.
- demonstrate the path that sound vibrations follow through the ear.
- Describe how ears can be permanently damaged by loud sounds

Materials

Kit: (free from ASA to K-12 teachers)

- 1 cup instrument
- Tuning forks (10)
- Ping pong balls with string attached (10)
- Posters (four)
- Straws that slide together (30 of each kind = 60)
- Pipe cleaners (150)

Please forward any questions or comments to:
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Materials not in kit:

- Scissors (1 per group)
- Pasta Noodles – 3 long and dry
- 3 Raisins or small marshmallows

Optional Materials (not in kit):

- Rubber mallets (other objects such as text books, rubber soles on shoes or a knee work just as well)
- Instructor Computer*
    - http://www.burninwave.com/#freqsweep
        - (10 sec wave)
    - http://www.noiseaddicts.com/2009/03/can-you-hear-this-hearing-test/
    - http://www.kettering.edu/physics/drussell/Demos/waves-intro/waves-intro.html
- Assistant**
- Student worksheet to fill out during the lesson (page 13-15)***

*If no computers are available, then skip the sections requiring computers
**With more than 15 students it's helpful to have an assistant to distribute and collect materials
***The worksheet is an option if a written log of the activity is desired. All of our testing has been successful without it so far.

Advanced Preparations

- Watch pasta demonstration and practice
    - Kit demo or original source
- Acquire materials
    - Many materials can be obtained through the kit and the rest can be easily found.

Set Up

- Gather supplies (see materials list)
- Set up materials so they can be easily passed out to students during the lesson
    - Tuning forks
    - Ping Pong Balls w/ string attached
    - Fuzzy sticks
    - Straws

Introducing the Activity

Students will assemble into groups of two or three. Students will sit quietly and listen to the sounds around them, then share one or two of the sounds they heard with their groups.

Tell the class that even though all these sounds seem very different, all sounds are caused by the same thing. Explain that they will be sound detectives for the day to try to find out what causes sound.

Doing the Activity

All of this information can be found in the accompanying power point file. The power point can be used for the teacher's view only or can be shown to the class. It is animated so that the answers do not appear on the screen until the teacher presses the arrow, or return keys.

What is Sound?

Tell the students they will make a sound using the tuning fork and that the tuning forks always make the same clear sound. Show students that you are holding the rounded handle and that the two "tines" make a narrow "U". Show them how to strike the fork properly. If struck on a hard surface the fork could be damaged changing the frequency.

> **Note:**
> Tuning forks should NOT be struck against hard surfaces like desks. A mallet is ideal but the heal of your tennis shoe, your kneecaps, your palm, or a textbook are good substitutes.

Have the students strike the tuning fork and:

- Listen to the fork
- Look very closely at the fork while it's making a sound.

Ask the class what they observed.

Have the students touch the fork when it is making a sound.

> **Note:**
> Don't touch tuning forks to your glasses or teeth- they can chip.
>
> Try eyelashes, lips (not teeth), bridge of your nose, tip of your nose, ear lobes, fingers, etc instead.

Ask the class:

- **What do you feel when it's making a sound?**
- **What do you feel if it's silent?**
- **When the fork is making a sound, how can you make the sound stop?**

Students guess what is vibrating. To check their hunches they try to stop the sound by stopping the vibration.

Sympathetic Vibration

Set the handle end of your tuning fork (not the tines!) on the tabletop and ask the class:

- **What happens?**
- **Why?**

Tell the class that this is called sympathetic vibration, and explain what is happening. Note: this is different than resonance.

Ping Pong Balls – see video

Each group should take their tuning fork and ping-pong balls. One student will hang a ball from the string, and another will *gently* touch the *quiet* (not vibrating) tuning fork to the ping-pong ball.

- **What did you observe?**

Now touch a vibrating tuning fork to the ping-pong ball.

- **What happens?**
- **Why is this?**

Your Ear

Show the large anatomy of the ear poster. Ask students if any of them have learned anything about the ear before. Let students offer ideas for a minute or so the get them thinking about the ear.

How We Hear – see video

Ask the class what the outside of the ear is called. (*The pinna or auricle.*)

Explain how sound vibrations are funneled into the ear by the pinna and then travel along the ear canal into the ear.

Point to the eardrum and ask what the pink part at the end of the ear canal is called.

Repeat again that vibrations are funneled into the ear canal by the pinna, travel along the cannal to the ear drum and make the ear drum vibrate.

Ask the class what the three tiny bones are called. (The ossicles: the malleus, the incus, and the stapes).

Repeat the route through the ear again, explaining now how the ear drum vibrations then make the ossicles each vibrate one at a time. The eardrum vibrations make the malleus vibrate because it's attached to the eardrum. The malleus is attached to the incus so it makes it vibrate and then the incus is attached to the stapes. Finally the stapes sends the vibrations into this snail shaped thing (point to the cochlea).

Ask the class what the snail shaped thing is called.

The vibrations continue through the tree tiny bones in your middle ear (the ossicles) to the cochlea**.** The cochlea is filled with thousands of tiny sensors like this:

- Hold up the hair cell picture next to the ear anatomy poster.

Ask the class what it looks like to them. (It's fun the ask students to tell you what they think the hair cell looks like. You might get a candle or other choices, but our favorite is a flaming pickle!)

Ask if anyone knows what it is called.

Tell the class it is a tiny sensor called a hair cell and that the cochlea is filled with them. The green part is the cell body and the yellow part is the hair bundle.

Explain that the hair cells are what turn those vibrations into electrical signals that are sent to the brain so your brain can interpret what the sound is, whether it's a piano playing, someone playing a guitar, or the teacher talking. Maybe even a fire alarm.

Hold up the healthy hair bundle poster. Tell them this is what a healthy hair bundle looks like (the yellow part of the pickle). See how the hairs are standing straight up? But when you listen to loud sounds you can actually damage them. It's the hair bundle at the top that can be damaged when you listen to your music too loud or you are around some loud sounds for too long.

Show the unhealthy hair bundle poster and explain that they are damaged hair cells. See how some of them are laying down and others are broken off?

What could have caused this?

The loud sounds have bent and broken them.

Build a Model – see video

Ask the class if anyone has ever built a model before. You should get all sorts of offers, model car, model of the solar system etc.. Tell them "good, you know what a model is."

Explain that the class is going to make a model.

Pass out pipe cleaners to each student, and instruct them not to bend or mess with them yet!

Students will make a fist and hold it out. The fist is the green (pickle) part- the body of the hair cell.
Students will place their pipe cleaners in their fist. The pipe cleaners are the hair bundle.

Any ideas what your arm will be?
It's the nerve taking the signal from the hair cells to the brain.

Tell the following story to the class:

You're sitting at the table talking to your parents.

Demonstrate how to gently brush their hands back and forth over the fuzzy sticks as your dad talks to you in a normal conversational voice.

Dad says we're going to the fireworks show today. We get to sit in the (insert your stadium name here) stadium—the best seats there are! But if you want to go, you have to mow the lawn first.

Do you think a lawn mower is kind of loud?

After students guess, tell them a typical push lawn mower is actually a safe sound for up to two hours. Is your yard safe? It depends on how big your yard is!

So, we're going to go out to the yard and start the lawn mower. It's going to get a little louder

brush the hair cells a little harder (not too hard).

Now we get to go to the (insert local name here) stadium.

How loud are fireworks if you get really, really close?

We're pretty excited and then they start! Boom!, bang, boom.

Have students hit their hair bundles hard now as their hands go past.

What do your hair bundles look like now? Can you fix them?

That's what happens in our ears. These are nerve cells and we can't regrow them (unless you're a bird or a frog.)

☺ **<u>Your Ear</u>**

Listen to a range of sounds from 20 Hz to 20,000 Hz using the ten second wave from http://www.burninwave.com/#freqsweep (links also in power point file accompanying this lesson plan)

Then play each frequency from the following website:

http://www.noiseaddicts.com/2009/03/can-you-hear-this-hearing-test

Have students raise their hands when they hear the sound.

Students enjoy hearing the high sound and seeing what they are able to hear, and love to see that they can hear high sounds better than their teacher! (or any other adults in the room)

Explain that not everyone's ears are the same; some are more sensitive, so if you can't hear the 18000 Hz, even when you're young, it doesn't have to be because of damage. Most adults can't hear higher than 12-15,000 Hz.

Use the words "low pitch" and "high pitch"

<u>Your Voices –</u> <u>see video</u>
Instruct the students to hold their fingers on the front of their throats and say Aaaah.
Notice the vibration?

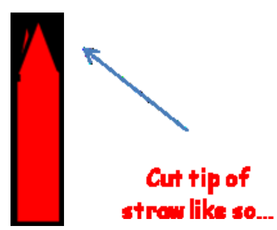
Now have the class make a high-pitched Aaaah and a low-pitched Aaaah.

Do low and high voices feel different?

<u>Straw Instrument –</u> <u>see video</u>

To build a straw instrument students:

- Take the smaller straw and the scissors, and cut off the tip of the straw to a point, like so. (Try to get both sides to be the same.)



- Gently chew on the straw to soften the tip, and to get the edges to be smooshed together. The two tips should be *almost* touching each other.
- Blow really hard into the pointy end. If it is done correctly (it might take some practice), a *<u>very</u>* loud sound will emit from the straw instrument!

Some students will nibble with their front teeth and not get the straw very warm. We've seen a few who do this have trouble making sound. Instruct the students to chew with their side teeth and their lips closed. This helps it soften up and work better.

What is vibrating?

The tips of the straw are vibrating

Have students try gently touching their tongue to the tips of the straw while they make a sound. They will feel it tickling their tongue**.** It's quite annoying!!

Does the person across the room hear your straw instrument?

Does the air you blow into the straw go in his/her ear for them to hear?

If you have bad breath (eat tuna) can the person across the room smell it when they hear you talk?

Why is that?

Sound Travels

Use http://www.kettering.edu/physics/drussell/Demos/waves-intro/waves-intro.html (also in powerpoint file accompanying this lesson plan) to illustrate the following ideas.

Do the wave! (Students stand up and sit down across the room)

Did the wave make it across the room?

How did you move? Did the people who started it move across the room?

Name a student or two who were at the beginning of the wave. Ask them if they actually went with the wave across the room. Students will describe that they did not.

Ask what their arms did?
Now show the sound wave sim at the above link. Show how the wave travels through the air but the air molecules just move back and forth and then stop.

Straw Instrument – trombone – see video

Put the bigger straw over the end of your straw instrument. This makes a straw trombone!
Have the class:

Make the lowest pitch (bass notes) that you can.
Make the highest pitch (treble notes) that you can.

Is the buzzing on your lips different with low and high sounds?
High sounds make a high pitch
High sounds are caused by higher frequencies – more wiggles per second.

Tell the students that they get to keep their straw instruments. Instruct them to put their instruments away (not just on a desk- out of sight!)

Resonance
Explain following two terms: frequency (rate) and resonant or natural frequency

- Frequency (rate) – wiggles per second (moves back and forth)
- Natural frequency – the frequency at which an object likes to vibrate.
- Resonance – When one object is vibrating and it is put in contact with another object, if the frequency of the first object is at the natural frequency for the second object, the second object will start vibrating vigorously at its natural frequency. (see the pasta demo below)

Pasta Demo - see video

This is a demonstration done by the teacher.

Hold three sticks of pasta in one hand, each held at a different length. First shake your hand slowly, and the long pasta will swing vigorously back and forth. Shake at a medium frequency for the middle to swing vigorously. A high frequency will cause the short one to vigorously wave back and forth. Doing any of the three fast enough will cause the past to snap off.

Why does the longer pasta shake more when the hand is moved slowly?

Straw resonance

- Straws are similar. Different lengths of straws like different frequencies or pitches.
- Air moves a lot at the resonant frequency (like the pasta) so the sound is loud.

For a low (bass) frequency, was your straw longer or shorter?

Cup Instrument – see video

This is a teacher demonstration.

Have one student come up to the front of the room and help you play the cup instrument. Tie the string to a table leg (don't try to just hold it) and pull the cup very tight. Then have a student pluck the string.

What happens?

Now try plucking the string when it's shorter. Try several lengths (always using the up to amplify)

How does the sound change?

Try plucking the string without using the cup (hold the string right before the cup so the vibrations cannot travel into the cup). There is an entire activity "Musical Instruments Part II" that allows students to build and investigate their own cup instrument.

Review

Review what the class has learned and put ideas together while using the anatomy of the ear poster and hair cell posters.

Explanation

In-depth background information for teachers and interested students

We used Science of Sound, 3rd Ed. by Rossing, Moore and Wheeler as a reference.

Sound is used to describe two different things:

1. An auditory sensation in the ear;
2. The disturbance in a medium that can cause this sensation.

By making this distinction, the age-old question “If a tree falls in a forest and no one is there to hear it, does it make a sound?” can be answered.

Key Points

- Sound waves consist of very small but rapid variations in air pressure. (If traveling in air).
  Here we focus on “Vibrations make sound”. It is also true that changing airflow (sirens, speech & singing) and changing heat sources (lightning/thunder) make sound and are technically not vibrations. This is a more advanced idea however and might be best to present after a solid more thorough understanding of sound and energy are acquired by students. Presenting it in the beginning could confuse students and these details are not included in most elementary standards.
- Sound carries energy. It can make things move.

Build a Model

Loud sounds carry more energy than soft sounds.
Listening to loud sounds for too long can damage the hair cells, and these can’t be fixed.
High pitch is a high sound and low pitches are low (bass) sounds.
Pitch is how we hear frequency

Sound Travels

Sound carries energy- it travels through air. Air is not the sound.
Air moves back and forth as sound energy goes past.

Straw Instrument

When the combination of the two straws is as long as possible, you can get the lowest sounds. Low pitch has a lower rate of vibration – lower frequency or less wiggles per second. However frequency and pitch are different things. Pitch is what your ear senses and frequency is the vibrations per second and is something that can be measured with an instrument.

Note: A straw instrument is a reed instrument with the ends of the straw forming a double reed. Trombones are brass instruments where sound is created by blowing into a mouthpiece. The slide on the straw instrument adjusts pitch similar to the slide on a trombone by creating a longer cavity for the air to flow.

Key Terms:

- Pinna – The visible part of the outer ear also called the auricle- if you can wiggle your ears, the pinna is what you wiggle
- Ossicles – Three bones found in the ears of all mammals. These bones are the smallest bones in a person’s body and they act like a system of levers.
  - Malleus – Also called the hammer. The bone of the middle ear that is attached to the eardrum and the incus (anvil).
  - Incus – Also called the anvil. The bone of the middle ear that is attached to the malleus (hammer) and the stapes (stirrup).
  - Stapes – The tiny stirrup-shaped bone of the middle ear that is connected to a window (oval window) in the cochlea.
- Cochlea – The snail-shaped part of the inner ear which contains the organ of Corti also known as the organ of hearing.
- Hair cell – signal the auditory nerve
- Vibrations – a shaking back and forth movement

- Pitch – How low or high a tone sounds to a person – it is how a person perceives the *frequency* of a sound. High *frequency* sound has a high pitch or tone (treble notes), but low *frequency* has a low/deep pitch or tone (bass notes). High sounds are usually above 2000 Hertz and low below 200 Hertz.
- Sympathetic vibration – When a *vibrating* object causes another object to vibrate at the same *frequency*, which may or may not be a *resonance* frequency. For example, if you place the handle of a vibrating *tuning fork* onto a table it becomes a *soundboard* and will vibrate at the same frequency. The table top moves more air than the tuning fork so the sound is louder. A piano string causes the *soundboard* of a piano to vibrate at the same *frequency* as the string.
- Frequency (rate) – wiggles per second (moves back and forth)
- Natural frequency – the frequency at which an object likes to vibrate.
- Resonance – When one object is vibrating and it is put in contact with another object, if the *frequency* of the first object is at the *natural frequency* for the second object, the second object will start vibrating vigorously at its *natural frequency*. (pasta demo is an nice clean example of resonance)

Sympathetic Vibration

Some of the energy from the tuning fork is transferred to the table and makes the tabletop vibrate. The tabletop moves a lot more air than the tuning fork does. Air moving is sound so this makes a louder sound. Notice that the tabletop vibrates for a shorter time than the fork alone. *Energy is conserved:* the tuning fork dissipates less energy (quieter sound) for a longer time. The table dissipates more energy (louder sound) for a shorter time.

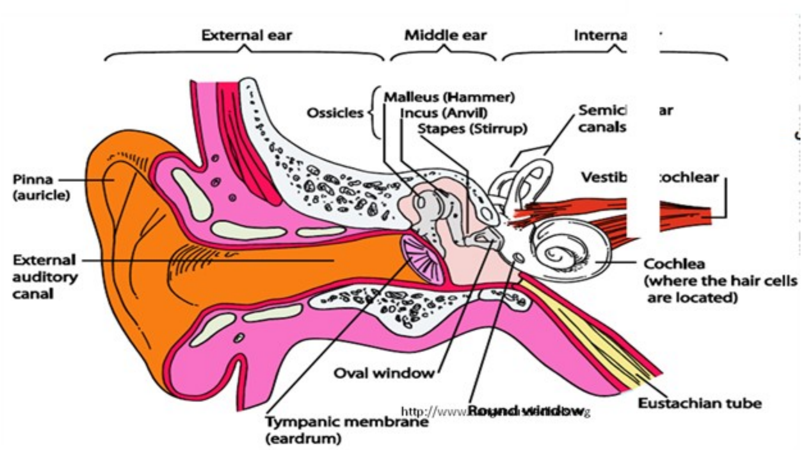
Sound travels in waves that spread onward from the source to our ears. All things are made up of molecules. The molecules in solids like metal or wood are tightly packed together and they can carry sound waves more efficiently than the spread-out molecules in air. Solids are good transmitters of sound. Sound travels through steel 15 times faster than through air. Water's good too, carrying sound four times faster than air.

Ping Pong Balls

Students should note that nothing happens when a quiet fork is touched to a ball. The ball should bounce vigorously away from the vibrating tuning fork. The ball is very light and the fork is vibrating with a fair amount of energy, so it makes the ball move a lot by transferring some of its vibrational energy to the ball when touched.

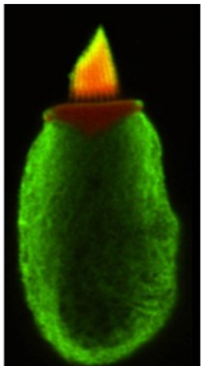
How We Hear

The outside of the ear is called the pinna. It collects the sound and funnels that sound into the ear. Sound waves travel through the air, reach the pinna, and are funneled down to the eardrum.



Sound waves hit the eardrum and cause it to vibrate.

The three tiny bones are the ossicles: the Malleu**s**, the Incus, and the Stapes (stape-ees). That's Latin for hammer, anvil, and stirrup. The bones are named for their shapes. The vibrations continue through the tree tiny bones in your middle ear (the ossicles)



Peter Gillespie and Janet Cyr, Oregon Hearing Research Center, Oregon Health & Science University. 2005

The green part is the cell body. The yellow part is made up of hair bundles.

How We Hear

Low pitch has a lower rate of vibration- less wiggles per second.

Resonance With the Pasta Demo:

- Longer pasta shakes at lower frequencies
    - ***Lower frequencies have longer wavelengths***
- Remember: **Low pitch is a low sound and low pitch has less wiggles per second**
- Frequency is wiggles per second that air shakes. ***Pitch is how we hear frequency.***

Review

Review what the class has learned and put ideas together. Different parts of the cochlea have different resonant frequencies so are sensitive to different pitches. The hairs in the front of the cochlea sense higher sounds and the hairs towards the back are sensitive to lower sounds. This is partly due to the tension of the basilar membrane in different parts of the cochlea. The hair cells in the front typically get damaged first since they are closer to the sound. This means when you have hearing damage the sound is messed up, not just quieter.

- Sound is caused by vibrations
- Sound carries energy
- The vibrations travel through the ear canal, eardrum, ossicles (the three tiny bones) and then into the cochlea.
- Different parts of the cochlea resonate with certain frequencies…
    - Some like high pitches
    - Some like low pitches
- The hair cells sense the sound and send electrical signals to your brain.

Optional Extensions /Modifications

Modifications:

- It's important to tell students with modifications what they should be looking for ahead of time so they are more willing to stay engaged with the activity and understand what they're getting out of the experience.
- Hard of hearing students can feel vibrations through speakers by touching them, or by touching the instrument itself. With the straw instrument, they can feel the vibrations ont their lips and their tongue.

<u>Extensions:</u>

- There is an activity called "How musical Instruments Work" that helps students sort out the difference between resonance and sympathetic vibration and their respective roles in musical instruments. This activity is recommended as a follow on the Musical Instruments I and II.
- There is a game on the Dangerous Decibels virtual lab that lets you hear what different sounds will sound like if you have hearing damage.

What is Sound Extension: Look at other objects that make sounds with highly visible vibrations.

- Musical instruments: triangles, tambourine, guitar, drum, cymbal
- Household items: wind-up clock with an alarm, kitchen timer, hand bell, wind chimes

Sympathetic Vibration Extension: Students can place a vibrating fork on other surfaces

- A chair, the floor, the teacher's desk, a recess ball, a lunch box, etc.
- Ask if they detected any patterns in what made the fork's sound louder? Softer?

If necessary, guide their theorizing by pointing out that some things- like a rubber recess ball- have spaces filled largely with air, while others- the table- are packed quite solid.

- **Can the vibrations move more easily through air or a solid?**

Sound Travels Extension:

- If you have a computer in the room, show the PhET "Sound" simulation.
- Choose the last tab- "Listen with Varying Pressure".
- **What happens to the sound when the air is removed from the box?**

Cup Instrument Extension:

- The activity called Musical Instruments Part II is an entire lesson that utilizes the cup instrument and investigates other stringed instruments.

Sound and Music

Name: ___________________________

1. After striking the fork, what do you observe?

2. What do you feel when the fork is making a sound?

3. How can you make the sound stop?

4. What is making the sound?

5. What happens when you set the handle on a table top?

6. What happens if you touch a vibrating tuning fork to a ping pong ball? Why?

7. Do you know what the outside of the ear is called?

8. When looking at the diagram of the ear, what is the pink part at the end of the ear canal?

9. What are the three tiny little bones?

10. What is the snail shaped part of the ear called?

11. Look at the picture of the green and yellow object. What does it look like to you? (be creative) What is it really?

12. Write down any models you've made at school or at home.

13. What would your arm represent in our model of the ear?

14. Do you think when you mow the lawn that your lawnmower is loud enough to damage y our ears? Does it matter how long you mow your lawn?

15. How about fireworks when you sit in the best seats – are they loud enough to damage your ears?

16. Can you fix your hair bundles after modeling the sound of close fireworks?

17. What is the highest frequency you can hear?

18. When your fingers are on your throat, how do high and low "aaaaahs" feel different?

19. What is vibrating when you play your straw instrument?

20. How does the sound get from your straw instrument to the person across the room?

21. When the whole class does the “wave”, how did you move? Did you go with the wave?

22. How does sound travel across the room?

23. How do you make the lowest possible pitch with your straw instrument when you have two straws?

24. Is the vibration of the straw tip different with low and high sounds? If so, how is it different?

25. Why do you think the long pasta wiggled the most when the hand is shaken slowly but the other sticks only wiggled a little bit?

26. What do you think will happen if the string on the cup instrument is shorter?

27. What do you remember about how the ear works from today? Write a description of how sound travels from the Pinna to your brain.