Name: _________________________________   Period: _____________

L3 Student Reading: How Do Insects Make Sounds?

We live in a noisy world. One of the noisiest inhabitants on Earth are insects. No matter where you go, you can't escape them. It is estimated that 75% of the over 8 million different species of life on Earth are insects. No wonder it's impossible to escape their constant, noisy chatter.

But how do insects make sounds? As you read, think about what is similar in how sound is produced in all these insects, and how that compares to what you have figured out in your investigations in class about how instruments produce sound.

Crickets Among the noisiest of insects are crickets. Only male species of crickets make sounds and surprisingly, not all species of crickets produce sound. Crickets make sounds for many reasons, but one of the main reasons is for male crickets to attract female mates.

When a male cricket wants to attract a mate, he lifts up his wings and rubs them together. Each wing has "teeth," much like a comb does. The chirping sound is created by running the top of one wing along the teeth at the bottom of the other wing. When the cricket does this, the teeth strike each other, and thin portions of the wing deform, change shape, and vibrate and make the sound.

Grasshoppers Grasshoppers are another group of insects that use sound in their everyday life. One way they make sounds is by rubbing their hind leg, which has rows of pegs on the inside and scraping against the stiff outer edge of their wing. These sounds are produced in order to mate and protect their territory. Grasshoppers can also make loud snapping or cracking sounds with their wings as they fly. They do this by popping their wings by causing the membranes between the veins to stiffen, leading them to change shape and vibrate. This is another way to get attention when they are trying to court another grasshopper for mating.

Cicadas Another noisy insect is the cicada. Cicadas make the loudest mating song of any insect or animal. Some species can produce songs as loud as the sound from a car's speakers at maximum volume.

The male cicada makes sounds by changing the shape of two membranes in his ribs called tymbals. By contracting a muscle, the cicada bends the membrane inward, producing a loud click. As the membrane snaps back, it clicks again. This produces vibrations that move through his abdomen to make the sound louder. They also make sounds to attract mates and protect territories.

Cricket image from https://en.wikipedia.org/wiki/Cricket_(insect)#/media/File:African.field.cricket.arp.jpg
Grasshopper image from https://en.wikipedia.org/wiki/Grasshopper#/media/File:American_Bird_Grasshopper.jpg
Cicada image from https://en.wikipedia.org/wiki/Cicada#/media/File:Gratopsaltria_Nigrofuscata_Young.jpg

These materials were developed with support from the Gordon and Betty Moore Foundation to Northwestern University and support from the NGSX Project at Clark University, Tidemark Institute, and Northwestern University.

Questions:

Q1: What are some similarities in the way these insects produce sounds and the way instruments produce sounds?

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Q2: Think about the sound that a bee, mosquito, or fly makes as it flies near your ear. Each produces a buzzing sound as they fly. Then, go online and analyze one of the slow motion videos below of one insect flying to figure out what might be producing these sounds as they are doing this. Both videos are posted on youtube. The web addresses listed here are shortcuts to the original videos:

- Mosquitos: http://goo.gl/6qivCu
- Bees: http://goo.gl/XtjAXX (minutes 1:30 to 2:00)

Then draw and annotate a "comic strip" view that shows the way that the wings are moving and changing shape over time. If you don't have access to the video, then create a comic strip, that is a prediction of what you think you would see.

Q3: How does the way the wings of these insects make sound compare to the way that instruments make sound?

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Name: _______________________________ Period: ____________

L4 Student Reading: Where Else Are Lasers Used to Detect Vibrations?

Refer to printouts of both of these articles to answer the questions below:

- http://www2.le.ac.uk/news/blog/2017-archive/march/engineers-measure-big-ben2019s-bong
- http://indianapublicmedia.org/amomentofscience/the-vibrating-moon/

University of Leicester researchers measure Big Ben's bong

Q1: How is this setup similar to the investigation you conducted in class to determine if the table was vibrating? How is it different?

The Vibrating Moon

Q2: What pattern would you expect to see in the motion of the laser dot over three years that was reflected back to Earth from the mirrors that astronauts left on the moon?

Q3: What pattern would you expect to see in the motion of the laser dot over six years?

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Student Graph Analysis 6 - How Can Graphs of Vibrations Help Me Understand the Sounds Produced by a Sound Source?

The graphs to the right represent the position of sound source that is vibrating. The sound source in each case is a xylophone which was struck with a mallet at different times.

Q1: What can you claim about the sound that was made by hitting a xylophone in each case based on the three graphs to the right? Why do you think that?

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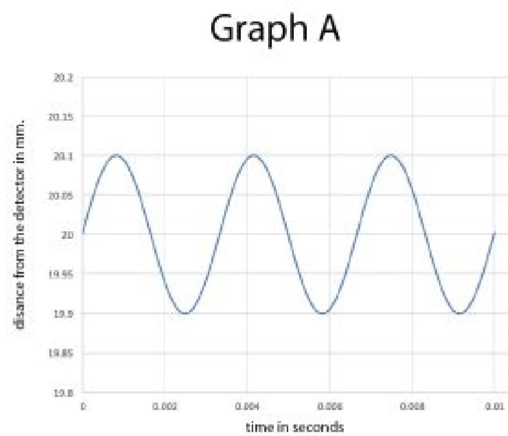
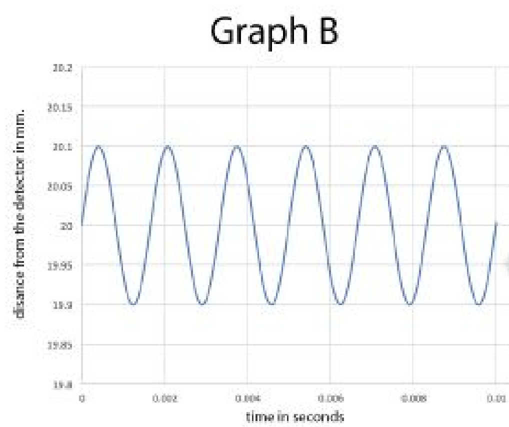
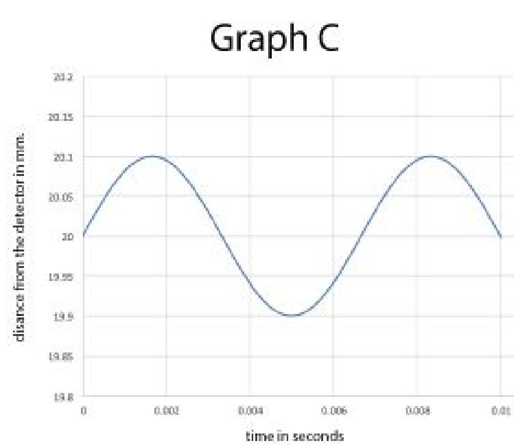
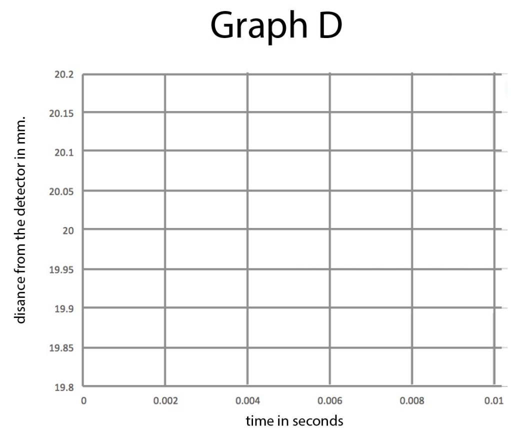




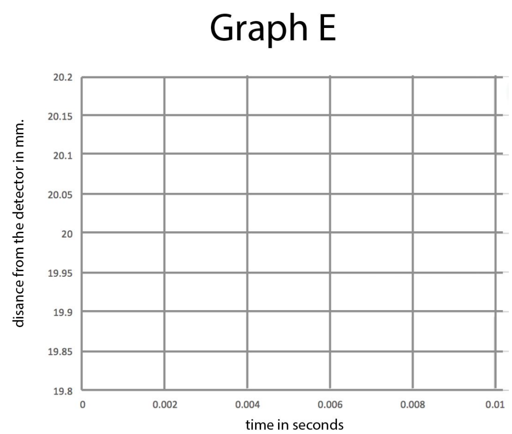


These materials were developed with support from the Gordon and Betty Moore Foundation to Northwestern University and support from the NGSX Project at Clark University, Tidemark Institute, and Northwestern University.

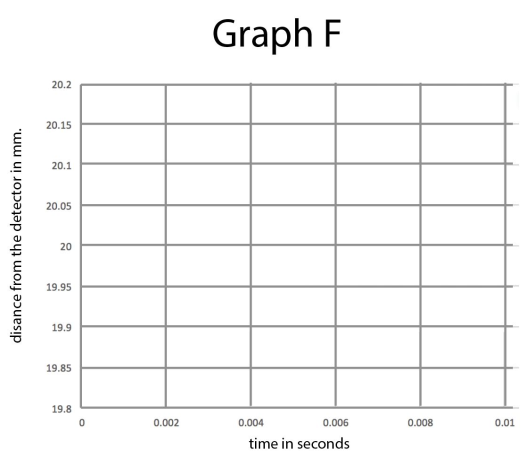
Q2: Draw a **Graph D** that represents the vibrations of a sound source from an instrument that was deformed with just as much amplitude as the ones shown on the previous page but vibrating with a frequency that produced four back and forth motions (four waves) in 0.01 seconds.



Q3: Draw a **Graph E** that represents the vibration of the sound source of the same instrument that is producing a sound at a frequency of four waves in 0.01 seconds but with a smaller amplitude.



Q4: Draw a **Graph F** that represents the vibration of the sound of an instrument that is just as loud as the one in Q3, but has a lower pitch.



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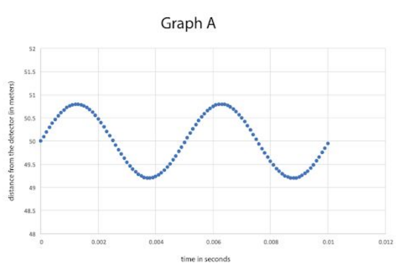
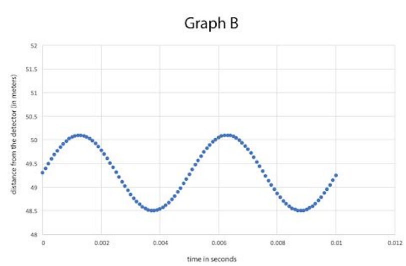
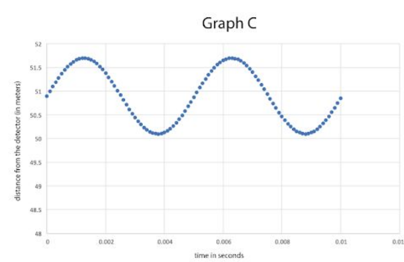
Q5: If a sound source is producing the same pitch sound, and it is vibrating with a frequency of two waves per 2 seconds, then how many times would it move back and forth in 10 seconds?

Q6: How many times would that same sound source producing the same pitch sound move back and forth in 20 seconds?

Q7: An object is struck and a motion graph is recorded (Graph A). The motion detector is moved just a bit closer to the object, and the object is struck again with the same amount of force and a second graph is produced (Graph B). The motion detector is moved slight further from the object, and it is struck again with the same amount of force and a third graph is produced (Graph C).







How does the amplitude of Graph A compare to Graph B? (check one of the boxes below)

- ☐ Graph A has a **larger** amplitude than Graph B.
- ☐ Graph A has a **smaller** amplitude than Graph B.
- ☐ Graph A has a the **same** amplitude as Graph B.

How does the amplitude of Graph B compare to Graph C? (check one of the boxes below)

- ☐ Graph B has a **larger** amplitude than Graph C.
- ☐ Graph B has a **smaller** amplitude than Graph C.
- ☐ Graph B has a the **same** amplitude as Graph C.

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Supplemental Investigation 7A: What Else Besides It's Length Affects the Frequency it Vibrates at When Struck or Plucked?

In class you saw examples of instruments that had different length bars, boards, or times that produced different pitch sounds. And you saw how this led to this chain of cause and effect represented by this system model.

A. The shorter the length of an object → B. The more frequently it vibrated back and forth when it was struck/plucked → C.The higher the pitch sound it produces

But changing the length of an object isn't the only to affect the things listed in B and C above.
Pick one of these two possible investigations to conduct. You may need a helper to capture the data you will need:

A. Explore how changing how tightly stretched a material in A is and its effect on B and C
    a. Materials needed: 1 rubber band
    b. Optional material: Slow motion camera on a smartphone

B. Explore how think an object is and its effect on B and C
    a. Materials needed: 6 coffee stirrers
    b. Optional material: Slow motion camera on a smartphone

If you conduct investigation A, try stretching the rubber band a greater amount and comparing what happens when you pluck it each time .

If you conduct investigation B, tape a stack of three coffee stirrers tightly together, and tape a stack of two coffee stirrers tightly together. Save one coffee stirrer to test on its own. Hold down the end of each bundle so that most of the bundle is overhanging a counter. Pluck the end of each.

If you have a slow motion camera on your smartphone, record video and compare how frequently the object vibrates to the pitch of sound it produces If you don't have a slow motion camera to use, simply record what you hear on C, and summarize what you know much be happening to the frequency of vibrations for B in each case. Record what you discovered in the boxes below that correspond to the same elements in the system outlined above:

A. → B. → C.

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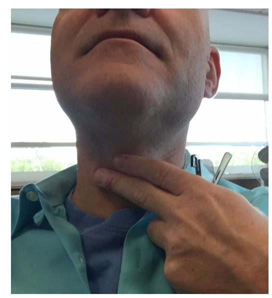
Supplemental Investigation 7B: How Do People Force Their Voice to Make Different Kinds of Sounds?

Text adapted from from: http://www.entnet.org/content/how-voice-works **American Academy of Otolaryngology- Head and Neck Surgery**
Optional audio storyline to listen to at: http://www.npr.org/2012/01/20/145459323/using-a-new-voice-to-enjoy-life-after-cancer

We rely on our voices every day to interact with others, and a healthy voice is critical for clear communication. But just as we walk without thinking about it, we usually speak without thinking how our body makes it happen. However, figuring out how we make sound is useful to maintaining the health and effectiveness of our voices.

To explore these ideas further, you will conduct a few investigations. The third investigation will require that you have a balloon that is deflated that you can experiment with.

Investigation 1 - What do you feel when you sing a note?



Q1: If you held your fingers lightly against your throat (as shown in the photo) and sang a note and held that note for a couple seconds, what do you think you would feel?

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Q2: Take a deep breathe and try and do this. Then try it again, singing much quieter. Then try it again, singing much louder. How did what you felt compare?

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Q3: How does what you felt relate to what you figured out about vibrations and amplitude?

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Investigation 2 - How Can You Use a Balloon to Simulate the Function of the Vocal Cords?

The part of your throat that you feel vibrating when you sing is sometimes referred to as your vocal cords or **vocal folds**. Talking, singing, laughing, crying, screaming are all sounds that originate from this primary sound source. Other sound production mechanisms produced from the same general area of the body involve the production of unvoiced consonants like a click or a whistle. Generally speaking, the mechanism for generating the human voice can be subdivided into **three parts: 1) the lungs, 2) the vocal folds within the larynx, and 3) the articulators.**

1. The Power Source: The lungs. The power for your voice comes from air that you exhale. This airstream you exhale pushes against the vocal folds. The stronger the push of air, the more force that is applied to your vocal cords and the further they deform, and the louder the sound they will produce.

2. The Primary Sound Source: The larynx (or voice box) contains two **vocal folds** (or vocal cords) that open during breathing and close during swallowing and voice production. When we produce voice, the airstream passes between these folds that have come together. These folds vibrate very fast (from 100 to 1000 times per second), depending on their length and the amount of them as the air pushes past. This can be adjusted by muscles in the larynx, which pull and stretch the folds, resulting in different pitch sounds being produced.

3. The Secondary Sound Sources (the articulators): Other structures in the vocal tract above the larynx such as the tongue, palate, cheek, and lips help form additional sounds and also filter the sound emanating from the larynx and to some degree can interact with it to strengthen it or weaken it.

Q4: If you filled up a balloon with air, and pinched the neck of the balloon, how might you use it to simulate this cause and effect relationship? - *"The stronger the airstream, the more force that is applied you vocal cords and the further they deform, and the louder the sound they will produce."*

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Q5: Use the photograph to plan how you will adjust the neck of the balloon, to simulate this cause and effect relationship? - *"These folds vibrate very fast (from 100 to 1000 times per second), depending on the length and tension of the vocal folds as the air pushes past them. This can adjusted by muscles in the larynx, which pull and stretch the folds, resulting in different pitch sounds being produced."*

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Procedure

1. **Try some of the ideas you came up with using the balloon your teacher gave you.**
2. **Record your observations below.**

Observations

For Producing Sounds of Different Volume:	For Producing Sounds of Different Pitch:

Investigation 3 - How do the Articulators Help Us Say So Many Words?

Procedure

1. **Say the first six letters of the alphabet out loud.**
2. **Pay attention to which of the structures in your mouth were pushing against each other to help form each letter. Repeat if necessary.**
3. **Record your observations with a check mark in the table below.**

Letter spoken	**Which structures were pushing against each other?**				
	tongue	palate	cheek	lip	**teeth**
A					
B					
C					
D					
E					
F					

Q6: Which spoken letter(s), provided the strongest evidence that something you did forced your tongue, palate, cheek, and/or lips to vibrate as you said that letter?

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Q7: Construct a scientific explanation, using evidence from these three investigations, to answer the question, How Do People Force Their Voice To Make Different Kinds Of Sounds?

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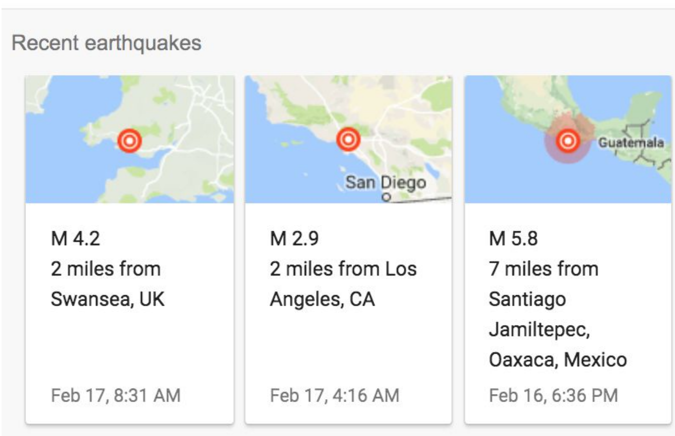
Reading 13: How Are Earthquakes Related to What We Figured Out So Far?

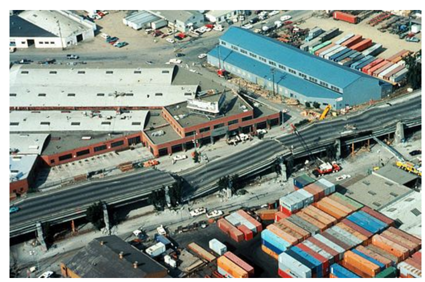
The building and the bridge shown to the right, collapsed after experiencing an earthquake.

Earthquakes are the shaking, rolling, or sudden movement of the earth's surface. Earthquakes can be felt over large areas, even though they usually last less than one minute.
Some earthquakes are so weak they cannot be felt. Some are so strong they can toss people around and destroy whole cities.

If you google "earthquake," the first set of results you will get are all the places in the world where earthquakes have occured in the past few days. In the results below, the earthquake in Mexico was the strongest. This can be determined by comparing the numbers after the "M," which shows the magnitude of the earthquake, a measure of the amount of energy released by the earthquake.



Collapsed Gran Hotel building in the San Salvador metropolis, after the shallow 1986 San Salvador earthquake. Image from:https://en.wikipedia.org/wiki/Earthquake#/media/File:HotelSanSalvador.jpg



A collapsed highway in the Oakland area of San Francisco: large, unsupported sections are more vulnerable to collapse. (Loma Prieta earthquake, 1989.) By H.G. Wilshire, U.S. Geological Survey [Public domain], via Wikimedia Commons

Many earthquakes are caused when rock underground suddenly breaks. This typically occurs far below the earth's surface. Some earthquakes originate more than 40 miles below the surface.

Q1: Why do you think some earthquakes are stronger than others?

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Once an earthquake starts, the rock around the source of the earthquake is compressed and stretched back and forth. A wave passes through it as this happens. The larger the magnitude of the earthquake, the farther this wave can travel and be detected. Some earthquakes have been felt hundreds of miles away from where they originated.

Q2: What investigations has your class conducted so far, that provided evidence that all solids are elastic and can be compressed or stretched up to a point?

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Earthquake shaking and damage is the result of three types of elastic waves. Two of the three travel within the rock that makes up the ground. Each of these types of waves travels at different speeds.

The faster of these body waves is called the **primary wave** or **P wave**. It alternately pushes (compresses) on and pulls on (dilates) the rock. These P waves are able to travel through both solid rock, such as mountains, and liquid material, such as volcanic magma or the water in oceans.

Another slower wave that travels through the body of rock is called the **secondary wave** or **S wave**. As an S wave travels through rock, it shears the rock sideways at right angles to the direction of travel. If a liquid is sheared sideways or twisted, it will not spring back like a solid does. Because of this, S waves cannot travel through liquid parts of the earth, such as oceans and lakes.

The third general type of earthquake wave is called a surface wave. It is called a surface wave because its motion only occurs near the ground surface. This type of wave is similar to those you see when ripples of water travel across a lake.

Use a web browser to compare the type of motion in the P wave to the S wave by viewing the animations at these two web addresses:
- **Animation of a P wave:** http://goo.gl/LT66Fs
- **Animation of a S wave:** http://goo.gl/VChnFZ

Q3: Which of these waves is more like a sound wave? Why?

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If you don't have a web browser available, then re-read the text above and use it to help you answer the last two questions.

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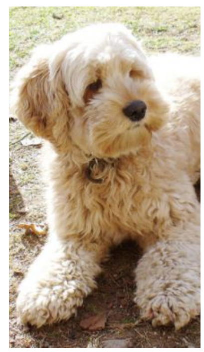
Reading 14: What is going on inside the ears of other animals that can explain the sounds they can hear?

Connecting to class: In class you explored some of the structures found in our ears that help them detect and decode sounds. We know, for example, that we are able to hear sounds with different pitches, because our cochlea and the basilar membrane inside it have different areas that detect different pitches.

Both elephants and dogs also have a cochlea, but as you can see in the diagram below, they are able to hear a different range of pitches of sound. The diagram below shows the range of hearing for elephants, humans, and dogs in Hz, kHz, and MHz. Hz stands for hertz (the number of waves per second).



https://en.wikipedia.org/wiki/Dog_breed#/media/File:Dog_morphological_variation.png

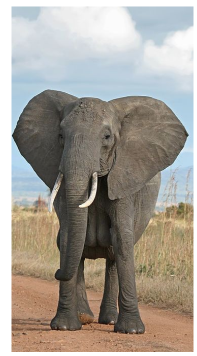


Image from: https://en.wikipedia.org/wiki/Elephant#/media/File:African_Bush_Elephant.jpg

Animal	Lowest frequency sound they can hear	Highest frequency sound they can hear
Elephant	**17 Hz**	**10,500 Hz**
Human	**31 Hz**	**19,000 Hz**
Dog	**64 Hz**	**44,000 Hz**
Little brown bat	**10,300 Hz**	**115,000 Hz**
Beluga whale	**1,000 Hz**	**123,000 Hz**

Q1: Based on the information in the table above, which of these three animals—an elephant, a human, or a dog—can hear the lowest pitch sounds? __________________

A dog whistle, also known as silent whistle or Galton's whistle, is a type of whistle that emits sound in a higher range of frequencies than people can hear. Some other animals, including dogs and domestic cats, can hear these higher frequency sounds, so it is used in their training. It was invented in 1876 by Francis Galton and is mentioned in his book *Inquiries into Human Faculty and its Development*, in which he describes experiments to test the range of frequencies that could be heard by various animals such as a house cat.

Dog whistle Image from: https://en.wikipedia.org/wiki/Dog_whistle#/media/File:Dog_whistle.jpg

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

The maximum upper range of human hearing is about 19,000 Hz for children, declining to around 16,000 Hz for middle-age adults. The top end of a dog's hearing range is about 45,00o Haz kHz, while a cat's is 64,000 Hz This suggests that there are some high pitch sounds that many children can hear but can't be heard by many adults. Most people don't have whistles they can use at home to test whether an adult or a cat or a child can hear a certain pitch of sound that the other can't.

But there are computer apps available online that produce sounds of different frequencies. You could use these apps to test the range of sounds that you and others in your family can hear. Here are some recommended apps that are free to download to your phone. Or maybe you want to explore and find your own app to test:

- For Android phones: https://play.google.com/store/apps/details?id=mobile.eaudiologia&hl=en
- For iPhones: https://itunes.apple.com/us/app/mimi-hearing-test-check-your-ears/id932496645?mt=8
- For computers: http://onlinetonegenerator.com/

Q2: If you end up conducting a series of hearing tests at home, summarize your results here.

Constructing Explanations - How hearing range works: Our ability to hear a wide range of sounds depends on the structures in the inner ear. Some of the key structures that affect hearing range are:

- The ratio of the width of the cochlea at the base (bottom) compared to the apex (top)
- The stiffness of the basilar membrane
- The structure and organization of the hair cells.

The table below shows the hearing ranges and the characteristics of the cochlea of a different animals.

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

In a previous lesson we learned from the ear doctor that stereocilia in a person's inner ear can get damaged by being knocked over. Doctors advise people to avoid exposure to sounds that are very loud and sounds that are at a very high frequency, particularly for extended amounts of time.

They claim that louder sounds are more damaging than quieter sounds, and that higher frequency sounds are more damaging that lower frequency sounds.

Q3: Why might louder sounds be more damaging to these structures than quieter sounds?

Q4: Why might higher pitch sounds be more damaging than lower pitch sounds?

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Lesson 17 Reading: How can I use ideas about the reflection of sounds to explain and design solutions to engineering problems?

Where else do we see structures that were designed to reflect sound waves?

An advertisement for a toy for young children is listed as "Flexible plastic talking tubes." This is what they advertise:

- ***Stay connected to your siblings or friends!***
- ***Tubes provide incredible sound!***
- ***Inspires imaginative play!***
- ***Includes 3.3 yards of flexible tubing, as well as 2 handsets in red and blue.***
- ***Recommended for children 3 years of age and older.***

Q1: Develop a model to support or refute the claim made that a flexible plastic tube could be used to provide incredible sound. Could they? If so, how? If not, why not?

Q2: Do the cones on the device shown to the right serve the same function as the cone on the device you saw at the start of the unit (the record, needle and cone)? Explain.

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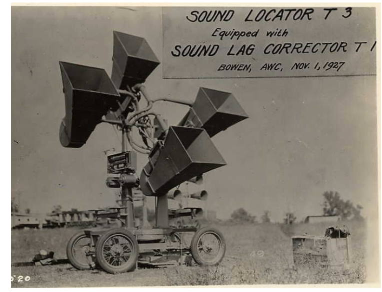
https://en.wikipedia.org/wiki/Megaphone#/media/File:Riverside_Stompers_-_Wolfgang_Straka_2007_e.jpg

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

What other shaped structures are used to reflect and redirect sound waves?

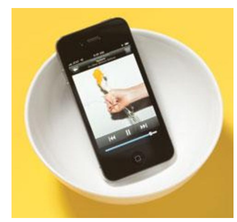
Cone-shaped structures can redirect sound waves through reflection by redirecting and amplifying the energy that reaches a certain point. But cones aren't the only shapes that are effective at doing this. The structures shown to the right are that were used to try to solve a related problem in the 1930s—trying to detect the sound of enemy airplanes in flight from far away before electronic radar was invented.

https://en.wikipedia.org/wiki/Acoustic_mirror#/media/File:WW1AcousticMirrorKilnsea(PaulGlazzard)Jan2007.jpg



https://en.wikipedia.org/wiki/Acoustic_location#/media/File:T3_sound_locator.jpg

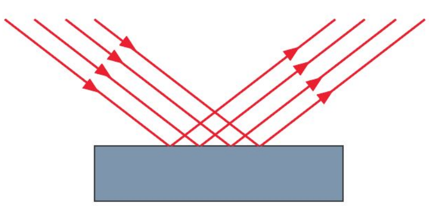
Here is an investigation you can try at home to see how effective a bowl-shaped structure is at reflecting some of the sound waves, which would otherwise radiate away from your phone, back toward your ear.



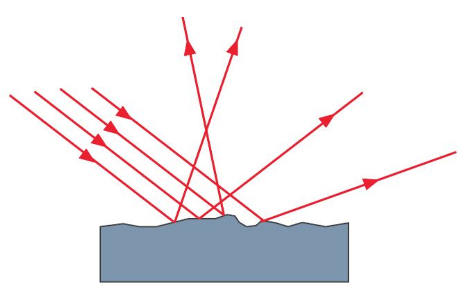
1. Set your phone to play a song at the maximum volume setting.
2. Then take the phone and place it an empty bowl right side up, so that its speaker is facing downward.
3. You might want to try different shaped bowls and bowls made of different materials.
    a. Does the shape of the bowl affect the volume of the sound you hear?
    b. Does the type of material the bowl is made of affect the volume?
    c. Does plastic, metal, or glass work better?

How does the roughness of the material affect how sound waves reflect off of it?

The model below shows how sound waves approaching a surface from the left would reflect off a smooth vs. a rough surface when they reach it.



Smooth surface



Rough surface

Do this: Trace each line in these diagrams with your finger, and you will see that each part of the sound waves that reaches the barrier bounces off in a symmetrical V.

Because the surface on the right (the rough one) isn't flat, the bends in the surface affect the direction that the reflected wave travels after it bounces off. Because of this effect, rough surfaces tend to scatter waves that reach them in lots of different directions, while smooth surfaces tend to reflect waves that reach them in uniform directions.

The type of reflection caused by a flat surface generates an effect called an **echo**. Echos are very noticeable when the distance between your ear and the surface that the sound bounces off of is far enough away to cause a delay in what you hear.

Q3: What are some places you have been outside where you have shouted something or made a loud sound and then heard an echo of that same sound a moment later?

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Some places where people notice this effect include things like shouting into a canyon or shouting toward the outside wall of a large building. Both of these examples are places **<u>outside</u>** where the time it takes the sound to reach a surface and bounce off of it and come back to you is relatively long, because the distance the sound has to travel is far.

But even when you don't recognize a delay between the sound that you make and the reflected sound that you hear, echos still can change the quality of the sound you hear. Some people describe the quality of sound **<u>inside</u>** a large room with flat surfaces, like a gymnasium as sounding "echoey." In such settings, it often hard to make out words that people are speaking. This is because in these rooms, sound bounces off the walls and comes back to the ears of the person speaking, singing, or shouting from multiple directions at slightly different times. This amplifies the sounds you hear (increases the amount of sound energy that reaches your ears). And because of the short delay in the time it takes for the sound to come back to you from one wall vs. another, this makes it hard to distinguish one sound from another.

Q4: Think about these places: a new school library, basketball gym, concert hall, or cafeteria.

In which of these places would it be better if the sound in them was reflected by the walls and ceiling instead of being scattered?

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In which of these places would it be better if the sound in them was scattered by the walls and ceiling instead of being reflected?

Q5: For any one of the places you identified, suggest a type of material to use for remodeling the walls and ceiling of that space. Why would that material contribute to affecting what you want to achieve?

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Name: ____ Period: _________ Date: ____________

Lesson 18 Home-Learning: How can we design solutions to sound-related problems?

How does the roughness of the material affect how sound waves reflect off of it?

The drummer in the image complains that when he plays his drum in this room, he is hearing too much echo.

Q1: He wants to use this room to practice his drums in. What changes or additions could you make to the walls or ceiling of this room to decrease the amount of echo? Add these to the pictures (and label them).

Q2: Summarize in words, why you think this would decrease the amount of echo in the room. What is happening to the sound waves in your revised room design?

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Lesson 19 Home-Learning: What areas of my school are using the right (or wrong) materials for absorbing or reflecting sound?

Foam isn't the only material that absorbs sound. Other materials like that have lots of small air pockets throughout them that are flexible and change shape. They are good sound absorbers. These include things like carpet, heavy draperies and open-cell foams.

Q1: Where are some places where it is desirable to use materials on the walls, ceiling, floors, or furniture to help **decrease the volume** of sounds heard in that space?	**Q2:** Where are some places where it is desirable to use material on the walls, ceiling, floors, or furniture to help **increase the volume** of sounds heard in that space?

Q3: Circle all the places in your table above that seem to be using the right materials for the desired outcome. Put a star near any places that it seems are not using the right materials for the desired outcome.

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Q4: In the space below, draw two models that explain choice A **or** B:

A. **Two solutions that are currently working in your school**: Model 1 is one room where the materials in it help absorb sounds and Model 2 is another room where the materials in it help reflect sounds**.** Draw a model for each that includes sound sources, rays of sound energy radiating from those sources, and what happens to them when they reach various objects in the room.

B. **A solution that you are proposing for a problem area in your school:** Model 1 is a room in its current state. Model 2 is the room after the materials were changed in it. For each model include sound sources, rays of sound energy radiating from those sources, and what happens to them when they reach various objects in the room.

Model 1:
Model 2:

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Reading 21: How does an electronic device produce different sounds through a a speaker?

You attached a 1.5V battery to power the speaker you used in class today to make its cone deform.

And you figured out that:

- If you changed how quickly you supplied and removed electrical energy to the speaker over time, you could cause it to deform back and forth at different rates.
- If you supplied the speaker more electrical energy you would cause it to deform a further distance, and if you supplied it less electrical energy, it would not deform as far.

Q1: Which of these can explain how a speaker can be forced to make louder and softer sounds?

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Q2: Which of these can explain how a speaker can be forced to make different pitch sounds?

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This is how an electronic device forces the speaker to produce different sounds. The pattern in how much electrical energy is sent to the speaker over time can affect the volume and pitch of sounds produced.

Q3 Predict: How do you think an electronic device stores information about how much electrical energy to send the speaker over time in order to playback different songs and sounds?

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	Time (s)	Position (m)
1	0.04	0.543
2	0.08	0.524
3	0.12	0.508
4	0.16	0.494
5	0.20	0.483
6	0.24	0.475
7	0.28	0.470
8	0.32	0.468
9	0.36	0.470
10	0.40	0.476
11	0.44	0.484
12	0.48	0.494
13	0.52	0.507
14	0.56	0.522
15	0.60	0.537
16	0.64	0.551
17	0.68	0.562
18	0.72	0.569
19	0.76	0.569
20	0.80	0.563
21	0.84	0.553
22	0.88	0.540
23	0.92	0.526
24	0.96	0.514
25	1.00	0.500

Electronic devices store the information about how much electrical energy to send through the speaker wires in a **digital file** within the device. That file stores that information as a series of numbers.

You saw this type of data in an earlier lesson (Lesson 5 Home-learning assignment), when the motion detector **recorded** the position of the stick over time as a table of time vs. position values.

Let's look back at the numbers in that table again. These numbers are shown in the table to the right.

Though this was a record of the position of the end of the stick vs. time for something that happened in the past, imagine that those same numbers were used as information about how much to move something (like the stick or a speaker) in the future.

That is the type of information that a digital electronic device uses to produce different sounds. It uses the numbers in a file as information that tells it how much electrical energy to send the speaker at different times.

While the table shown here has only 25 samples recorded in it per second, most digital sound files have 44,100 samples of information in it for every second of sound recorded in the file. That's a lot of data!

For that reason, digital music files didn't become a popular way to record, copy, and play back music until people started using computers more to store and exchange music files. This didn't become common until around 1998 to 2001. By 2001, the cost of hard drive storage space had dropped to a level that allowed pocket-sized computers (like ipods, smartphones, and tablets) to store larger and larger sets of data (libraries of music) for relatively little cost. At that point, because digital files can easily be copied and shared over the internet, they became the way that more and more people began to record, store, and share their music.

Q4: Before hard drives on computers and the internet were used to store, share, and play back songs and audio recordings, what are some other technologies that you think people might have used to store and play back songs?

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Name: ________________________________ Period: _____________

Reading 22: How do speakers, microphones, and hearing aids work?

What parts make up an electric speaker?

You built an electric speaker in class. The diagram to the right shows a cutaway of another electric speaker. Compare the structures you noticed in class to those shown in the diagram below.

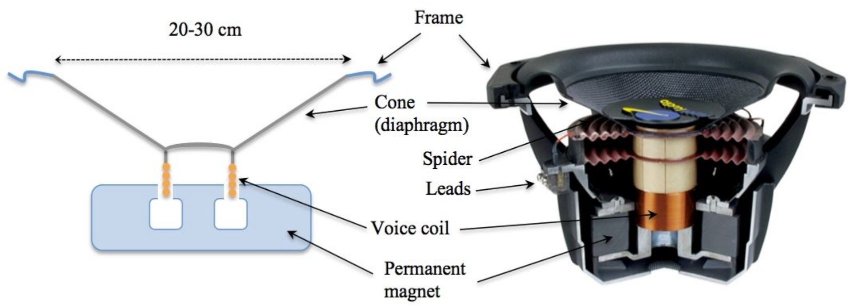

Image is from soundphysics.ius.edu/wp-content/uploads/2014/01/speaker1.jpg

Q1: What are three structures that you see in the diagram above that are similar to the ones you used in the speaker you built in class?

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You may have noticed some structures in this diagram that are different than the ones that were in the speaker you built. For example, the **leads** shown in the diagram are the locations where you would attach the wires from the electronic music player to the speaker. The **spider** is a structure made of material-like paper that is often folded to make a flexible lightweight spring for the top of the speaker so it can move up and down more easily.

But the the wire coil and its attachment to a cone, plate, or other surface and the permanent magnet are key components in electronic speaker that are considered an **electromagnet**. The way they interact helps explain how a speaker can produce all the different sounds it can produce. Electromagnets are found in other devices, like electric motors in fans, drills, and electric cars. They all convert electrical energy to movement.

Q2: How do you think using a different strength magnet or a different number of coils of wire in building your own speaker might affect what you hear?

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What technologies can help people who can't hear get a better sense of sound?

Before the first electric hearing aid was created in 1898, some people who were had trouble hearing used ear trumpets to increase the amplitude of the sounds that reached their ears (or **amplify** the sound).

image from https://en.wikipedia.org/wiki/History_of_hearing_aids#/media/File:Madame_de_Meuron.jpg

These days there are two types of technologies that can help provide a sense of sound to people who suffer from hearing loss or who are profoundly deaf.

One is a **hearing aid**, which a removable electronic medical device that makes sounds louder. The other is a **cochlear implant**, which is an electronic medical device that replaces the function of the damaged inner ear. A hearing aid is removable and a cochlear implant is not.

Q3: Do you know anyone who wears a hearing aid or a cochlear implant?

How do both of these devices help people hear?

Hearing aid and cochlear implants use a small microphone to turn sound into electrical signals.

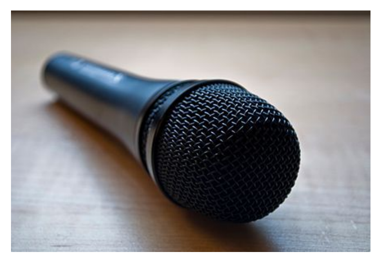

Image from https://en.wikipedia.org/wiki/Microphone#/media/File:SennMicrophone.jpg

Most people have seen larger microphones used for public address systems for concert halls and public events and would recognize a picture of a microphone like the one shown to the right.

But smaller microphones are harder to identify. To see the one found inside a hearing aid, you would have to take it apart.

There is also a small microphone inside of many electronic devices you use. Usually there is a grill in front of the microphone (just like there was on the outside of speaker) that protects the parts inside of it, but still lets the vibrations traveling through the air get past the grill.

Q4: What are some types of devices that you think might have small microphones in them?

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What parts make up a microphone?

A microphone has three basic parts: a cone (or plate), a permanent magnet, and a coil of wire.

Sound familiar? These are the same parts that make up a speaker. Why would that be? How can the same parts that are used to produce sounds from an electronic device be used to detect sounds as well?

Let’s review how the parts of a speaker work together to produce sound and then use the same chain of reasoning to figure out how a microphone detects sound.

How does a speaker work?

You may recall that the electronic speaker works by the following:

A. The electronic device sends different amounts of electrical energy through the wires around the coil.
B. This causes the magnet and the cone to which it is attached to be pushed and deformed different amounts over time, forcing it to vibrate at different frequencies and at different amplitudes.
C. These vibrations produce sound waves in the surrounding **medium** (the matter surrounding the cone).

How does a microphone work?

The microphone works in exactly the reverse order as the speaker.

C. Different sound waves from the medium hit the diaphragm (a plate or cone) under the outer grill of the microphone.
B. The plate or cone (and the magnet attached to it) is forced to vibrate at different frequencies and amplitudes.
A. This causes different amounts of electrical energy to move through the coil of wire.

In this way, the microphone converts the energy in sound waves into vibrations and then converts those vibrations into electrical energy, while a speaker converts electrical energy into vibrations, and then those vibrations into sound waves.

The electronic speaker you built in class could also work as an electronic microphone, because a microphone does exactly what an electronic speaker does but in reverse, using the same basic parts!

To see this in action, take a pair of headphones and plug it into the microphone jack on your phone or computer and try to use them to talk into and record your voice using a computer program that records audio.

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How does an electronic device record the sounds it detects?

An electronic device doesn't actually record the pattern of the entire sound wave that reaches the microphone. Instead, it records the pattern of electrical energy going through the wires over time.

And it doesn't actually record the entire pattern. It only records some samples of that pattern, just like the motion detector you used in class and read about earlier, only recorded some samples of the pattern of motion of the vibrating stick.

Each sample that the electronic device records is saved into a **digital file** within the device. That file stores that information as a series of numbers. Most digital sound files have 44,100 samples of information recorded in it for every second of sound they detected.

How can a digital device amplify the sound it detects?

The numbers stored in the digital file represent how much electrical energy was detected. These same numbers can be used to determine how much electrical energy should be sent through a circuit to an electronic speaker. This is how a electronic recording can be used to play back a sound.

Hearing aids have the ability to scale up (amplify) the electrical energy coming from its microphone and going to its speaker, depending on the the volume level the person sets their hearing aid to.

Q5: Where do you think the hearing aid shown above gets the additional energy from to amplify sounds that are detected by the microphone? Refer to the parts shown in the diagram above to support your claim.

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