Dangerous Decibels®

Teacher Resource Guide

A K-8 curriculum supplement with hands-on science activities about the anatomy and physiology of hearing, the physics of sound, and health-related behaviors for prevention of noise-induced hearing loss.

Partners:

OMSI
OREGON MUSEUM OF SCIENCE AND INDUSTRY

OHSU

Affiliates:

Veterans Affairs National Center for Rehabilitative Auditory Research
American Tinnitus Association

Funded by:

National Institute of Health
Science Education Partnerships Awards of
The National Center for Research Resources
(NCRR Award # R25 RR15634)
The Northwest Health Foundation
The OHSU Tinnitus Clinic
The Collins Medical Trust
The Harold and Arlene Schnitzer CARE Foundation

Department of Health and Human Services • National Institutes of Health
NCRR
Supported by a Science Education Partnership Award (SEPA) from the National Center for Research Resources

Dangerous Decibels®

Teacher Resource Guide

The Oregon Museum of Science and Industry
Portland, Oregon

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Acknowledgements:

We would like to thank the following people for their contributions to the success of this project:

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Introduction to Dangerous Decibels

Dangerous Decibels is designed to help prevent **Noise-Induced Hearing Loss (NIHL)** and **tinnitus** (ringing in the ears, which is an early indicator of hearing loss) by changing knowledge, attitudes, and behaviors of school-aged children.

Aspects of the Dangerous Decibels project include this teacher resource guide with K-8 classroom activities, a teacher training program available with this curriculum on DVD, a museum exhibit at the Oregon Museum of Science and Industry (OMSI) in Portland, Oregon, OMSI Outreach programs to schools and fairs in the Pacific Northwest, a website (www.dangerousdecibels.org), and a research project.

The project is built upon an innovative collaboration between basic science researchers, museum educators, civic leaders, Oregon and Southwest Washington schools and volunteers in a unique public/private partnership.

Partners are the Oregon Museum of Science and Industry (OMSI), the Oregon Hearing Research Center at the Oregon Health & Science University (OHSU) in affiliation with the Portland VA National Center for Rehabilitative Auditory Research and the American Tinnitus Association.

Funding for the project comes from a National Science Partnership Award (SEPA) from the National Center for Research Resources (NCRR) division of the National Institute of Health, the Northwest Health Foundation, the OHSU Tinnitus Clinic, the Collins Medical Trust, and the Harold and Arlene Schnitzer CARE Foundation.

Why Teach About Noise-Induced Hearing Loss?

- Twenty-eight million Americans are affected by hearing loss.
- Over fifty million Americans have tinnitus.[1]
- Approximately one third of all hearing loss can be attributed to noise-induced hearing loss.[2]

Although many people are familiar with hearing loss among the elderly (called **presbycusis)**, fewer are aware of the extent of hearing problems among younger generations. Rates of noise-induced hearing loss are on the rise in all age groups. Tinnitus and noise-induced hearing loss can be caused by sounds in our jobs, homes, and recreational activities.

The Dangerous Decibels classroom activities are designed to help students understand and answer the following questions:

- What are the common sources of sounds that can damage ears?
- What are the effects of these "dangerous decibels"?
- How can I protect myself from them?

Behavior-Related Objectives

After participating in the Dangerous Decibels project – whether viewing the exhibit, receiving the outreach program, or participating in classroom activities from the teacher resource guide – students should understand the danger of loud sound and respond by one or more of the three following methods:

- **Turn Down the Volume,**
- **Use Hearing Protection, and/or**
- **Walk Away.**

1 American Tinnitus Association, November 2004.

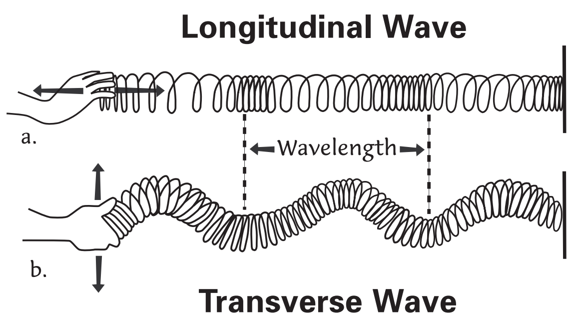
2 Noise and Hearing Loss. NIH Consensus Statement, NIH Consensus Development Conference, Jan. 22-24, 1990;8(1) 3-4

The Science of Dangerous Decibels
Background Information for the Teacher

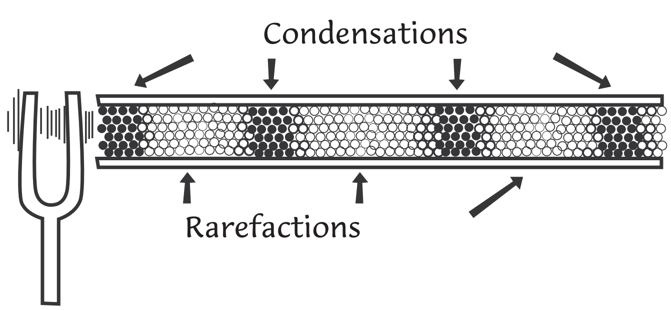
The Physics of Sound

Sound occurs when energy travels as waves of pressure through a substance like air, water, or even solid materials. Almost anything that vibrates can produce sound. When something vibrates it pushes the particles around it, and those particles in turn push the air particles around them, carrying the pulse of the vibration in all directions from the source. The particles themselves don't move very far, but the transfer of energy can be very fast, about 760 miles/hour (1 kilometer/3 seconds) in air, depending on the temperature and humidity. Sound travels about 5 times as fast in water and about 14 times faster in steel than in air because the molecules are closer together and the motion can be transferred more rapidly.

Sound waves are called **"longitudinal"** pressure waves, which are different from the **"transverse"** waves we're familiar with in water because the molecules move back & forth rather than up and down (see diagram below).



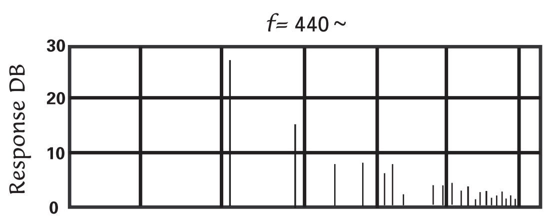
Sound has three characteristics basic to how we experience it: **loudness, pitch,** and **timbre.** The **loudness** of a sound results from the difference in pressure between the compressed areas and the rarefied areas – a greater difference being louder. (See diagram below showing a graphical representation of the sound produced by a tuning fork.)



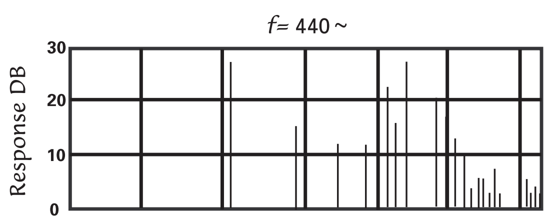
Pitch results from the rate or "frequency" of the vibrations, which we experience as higher and lower tones like the "do – re – mi" of a musical scale. The frequency of vibrations is not the same as the speed of sound. Different frequencies all travel at the same speed in the same medium – imagine listening to music if they didn't!

The **timbre** is what makes a sound distinct and recognizable as a particular instrument, voice, vowel sound, or just noise. Almost all vibrating objects create several vibrations of various frequencies and intensities in addition to the main or "fundamental" frequency. These are called "overtones" and if they are simple whole number multiples or "harmonics" of the fundamental frequency (2x, 3x, 4x...) we hear the overall sound as a pleasing or musical tone. If they are a more random combination of frequencies we usually just call it noise. Different sources may create the same fundamental note with all the same harmonics, but individual harmonics are louder or softer depending on the source. That's what makes violins, saxophones, and voices all sound unique.

violin



piano



A piano and a violin playing the same note (A-440hz). The unique set of harmonics that each one produces is what makes them sound different.

This is also how we create vowel sounds: by altering the shape of our mouth we change which harmonics resonate loudly and which are suppressed. So, if you loose the ability to hear the higher tones it can become difficult to hear the difference between an "a" "e" "i" "o" and "u." The result is not just an inability to hear high-pitched sounds, but to distinguish one type of sound from another!

Fun Facts About Sound:

- Sound travels at 760 miles/hr.
  Have older students calculate how long it takes for sound to travel one mile. (1 mile in a little less than 5 seconds) So during a storm you can calculate the distance to a lightning strike by counting the seconds between a lightning strike and the resulting thunder and then dividing it by 5 to get the approximate distance in miles!
- Frequency and wavelength are inversely related (freq. = speed of sound/ wavelength), so given the range of voices from bass to soprano we can figure that the sound waves coming from our mouths are between 1 and 12 feet long!
- The actual difference in the density of the compressed and rarefied air in a sound wave, from a piano string for example, is only about 1/100th of 1%!
- For more about the Physics of Sound and of Music look for Physics of Music demonstrations in the physics lab at the Oregon Museum of Science and Industry.

Add more fun facts that you or your students find below:

More Fun Facts About Sound

Anatomy and Physiology of the Ear:
The Mechanics of Hearing

Note: Refer to the color diagram of the ear on page 92 (Appendix B) of this resource guide.

1. The **pinna** is the only part of your ear located on the outside of your head. It is what we commonly refer to as the ear. It is made of skin and cartilage. The pinna helps direct sounds into the ear. It also helps your brain to figure out where the sound is coming from.

2. The **auditory canal** (commonly called the ear canal) is a short tube. An adult's ear canal is only about one inch long and directs sound to the eardrum. This is also the part of our ear where **earwax** is found. Earwax is actually a good thing to have; the wax traps dirt before it reaches the eardrum, keeps skin moist and protected, and also repels bugs with its scent!

3. The **eardrum**, or **tympanic membrane**, is a thin membrane that vibrates in response to sound. The tympanic membrane vibrates at the same frequency (rate of vibration) as the incoming sound, and in turn, causes a small bone in the ear to vibrate at that same frequency.

4. The **ossicles** are three bones found in the ears of all mammals. (The root word 'os' refers to bones.) These bones are the smallest bones in a person's body, and they act like a system of levers.
   The **malleus**, or hammer, is the bone attached to the eardrum. When the eardrum begins to vibrate as a result of sound, it pushes on the malleus, which then begins to vibrate.
   The **incus**, or anvil, lies between the other two ossicles. When the malleus vibrates against it, the incus also begins to vibrate.
   The **stapes**, or stirrup, is the third ear bone. When the incus vibrates against it, the plate at the end of the stapes vibrates. The stapes is connected to a window in the cochlea.

5. The **cochlea** is the snail-shaped structure in the inner ear. The cochlea is filled with fluid, and lined with about 18,000 microscopic **hair cells**. They are called hair cells because they are topped by hair-like structures called stereocilia. All 18,000 hair cells could stand on the head of a pin. As vibrations from the stapes enter the cochlea, the fluid is set into motion, causing the stereocilia on the hair cells to move. The hair cells in turn stimulate the auditory nerve.

6. The **auditory nerve** (not shown in the diagram) acts like a telephone line to the brain. The electrical signals generated by the hair cells are sent to the brain via the auditory nerve. The hearing centers in the brain interpret the signals as sounds we can recognize.

Causes of Hearing Loss

There are many different causes of hearing loss. The following are a few examples of some specific causes of hearing loss:

- **Otosclerosis** – a disease that causes bony growth on the ossicles. As a result the stapes becomes immobile and prevents the transfer of sound vibrations to the cochlea.
- **Meniere's disease** – a problem involving fluid pressure within the cochlea resulting in intermittent episodes of hearing loss, dizziness, and tinnitus. These episodes can occur any time and for varying lengths of time. Episodes are often associated with stress.
- **Drug-induced** – prolonged use of some medications (called ototoxic) results in an unwanted side effect of damage to the auditory system. Examples of drugs known to cause hearing loss include: aminoglycoside antibiotics (such as streptomycin, neomycin, kanamycin); salicylates in large quantities (aspirin), loop diuretics (lasix, ethacrynic acid); and drugs used in chemotherapy regimens (cisplatin, carboplatin, nitrogen mustard).
- **Tumors** – one common tumor in the ear develops around the 8^{th} cranial nerve, which is also known as the auditory nerve.
- **Trauma** – trauma to the ear can include fractures of the temporal bone, puncture of the eardrum by foreign objects, sudden changes in air pressure, and very loud noises.
- **Presbycusis** – this hearing loss is caused by natural aging of the human body and begins after age 20 but often, it is not noticed until the ages of 55 to 65. Presbycusis affects the high frequencies in the speech range, making understanding and hearing speech difficult.
- **Noise-Induced Hearing Loss (NIHL)** - this is hearing loss due to exposure to either a sudden, loud noise or exposure to loud noises for a period of time. A dangerous sound is anything that is 85 dB SPL (sound pressure level) or higher.

Dangerous Decibels focuses on noise-induced hearing loss.

Noise-Induced Hearing Loss (NIHL)

- Of the roughly 28 million Americans suffering from hearing loss, 10 million can be attributed to Noise-Induced Hearing Loss (NIHL).
  NIHL can be caused by a one-time exposure to loud sound as well as by repeated exposure to sounds at various loudness levels over an extended period of time.

- Damage happens to the microscopic hair cells found inside the cochlea. These cells respond to the mechanical sound vibrations by sending an electrical signal to the auditory nerve.
  Different groups of hair cells are responsible for different frequencies (rate of vibrations). The healthy human ear can hear frequencies ranging from 20 Hz to 20,000 Hz.

- With noise exposure over time, the hair cells' hair-like stereocilia may get damaged or broken. If enough of them are damaged, hearing loss results. The high frequency area of the cochlea is often damaged by loud sound. Many people with noise-induced hearing loss have trouble distinguishing high-frequency sounds, because the hair cells responsible for high-frequency sounds are located at the base of the cochlea. Vibrations here tend to be more forceful, resulting in more damage to cells.

- Cases of noise-induced hearing loss and/or tinnitus are on the rise. Niskar says that 6.2 million US children (6-19 years of age) have hearing loss, **5.2 million due to noise-induced hearing loss (1998 & 2001).**

How Loud Is Too Loud?

Measuring Sound/Decibels

The pressure of a sound is measured in **decibels** (dB), or more specifically, dB sound pressure level (SPL). The decibel measure was developed to compare sound intensities. Like many temperature scales, the decibel scale goes below zero, the lowest level an average person can hear.

- Decibels (dBs) actually express a ratio. There has to be a reference value in order to calculate a ratio. The reference value for 0 dB SPL is 2 X 10^5 Newtons/meter^2. A filter can be used when measuring sound to give a correction equivalent to that of human hearing. When this is done, the units are measured in dB A (meaning the A-weighted measurement of sound pressure level).

- The average person can hear sounds down to about 0 dB[3], the level of rustling leaves. Some people with very good hearing can hear sounds down to -15 dB.

- If a sound reaches 85 dB or stronger, it can cause permanent damage to your hearing.

- The amount of time you listen to a sound affects how much damage it will cause. The quieter the sound, the longer you can listen to it safely. If the sound is very quiet, it will not cause damage even if you listen to it for a very long time; however, exposure to some common sounds can cause permanent damage. With extended exposure, noises that reach a decibel level of 85 can cause permanent damage to the hair cells in the inner ear, leading to hearing loss.

- Many common sounds may be louder than you think.

- A typical conversation occurs at 60 dB, not loud enough to cause damage.

- A bulldozer that is idling (note that this is idling, *not* actively bulldozing) is loud enough at 85 dB that it can cause permanent damage after only 1 work day (8 hours).

- **When listening to music on many earphones at a mid-level volume, the sound generated reaches a level of 100 dB, loud enough to cause permanent damage after just 15 minutes per day!**

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[3] This is true only at 3 KHz frequency. Hearing specialists prefer to use a term dBA, a calibration of sound pressure level (SPL) using frequency range and sensitivity similar to human hearing. However, in this curriculum we will refer to the more commonly used dB.

- A clap of thunder from a nearby storm (120 dB) or a gunshot (140-190 dB, depending on weapon) can cause immediate damage.

- Noise is probably the most common occupational hazard facing people today. It is estimated that as many as 30 million Americans are exposed to potentially harmful sounds at work.

- Even outside of work, many people participate in recreational activities that can produce harmful noise (musical concerts, use of power tools, etc.). Sixty million Americans own firearms, and many people do not use appropriate hearing protection devices.

- Noise-induced hearing loss is of particular concern to veterans. Because NIHL is not immediately apparent (having a gradual onset), many veterans leaving the service are unaware of the full extent of hearing damage.

Tips for Communicating with Individuals with a Hearing Loss

presented by:

The Audiology Awareness Campaign

The following tips are provided to enhance communication with individuals that have a hearing loss. Often, very minor adjustments by the person speaking will greatly increase the ability of the listener to understand what is being said. These tips can even help communication among individuals with normal hearing.

1. Always speak clearly and naturally

   Shouting can cause distortion of hearing aids and often makes the words even more unintelligible. Speak slowly enough that the words can be distinguished from one another, but not so slow that the natural rhythm of the sentence is disrupted.

2. Use different words if you are misunderstood.

   Certain sounds may cause the listener difficulty, so if you need to repeat your sentence, try to use different words that may be easier to understand.

3. Face the listener and encourage speech/lip reading

   Many people can speech/lip read to some degree even if they have not been formally trained. Do not hide your mouth or chew while talking. Also try to have the room lighting in front of you to prevent shadows.

4. Attract their attention BEFORE you begin

   Be sure the listener knows that you are trying to communicate with them before you even begin your sentence. You can say their name or lightly touch them to let them know your intentions.

5. Stay close to the listener

   If the listener can hear better on one side, try to stay on that side if possible. Also do not attempt to talk to someone if you are in a different room or if there is distracting noises. Always try to remain within 3 to 5 feet of the listener.

6. Turn off or decrease room noises

   Other noises can mask out or block speech. Televisions, radios and even other people talking can greatly affect the ability to discriminate speech. For example, you can request a quiet corner of a restaurant instead of sitting in the main seating area. Reduce the background noise as much as possible before beginning a conversation.

7. Use facial expressions and hand gestures to emphasis your feelings

   This will help the listener understand your emotions and thereby help them understand what you are trying to communicate.

How to Use this Resource Guide and the Classroom Activities

This teachers' resource guide provides a series of hands-on, minds-on science activities for the K-8 classroom. The activity format has been teacher-tested. Care has been taken to provide content explanations for the teacher or interested gifted student who wants to explore further. In addition to rich science content, each lesson emphasizes the behaviors needed to reduce the risk of noise-induced hearing loss, as well as grade-level appropriate science process skills. Because teachers may choose to do only one activity, you will find some redundancy in the content and behavioral messages from one activity to the next. In Appendix E you will find a useful at-home activity, "How Loud is Too Loud," that provides a fun activity to send home with your students. You will find that all activities in this resource guide:

- are safe
- are affordable
- are practical and easy to use
- have been classroom tested
- are supported by rich content
- have been reviewed by K-8 teachers
- have been reviewed by science content specialists
- have been reviewed by hearing specialists
- were tested in primary, intermediate, and middle school classrooms
- have been aligned with national science standards
- are linked to the behavioral objectives of Dangerous Decibels

For your convenience the curriculum is organized into detailed, easy-to-follow sections described below with individual sections designated by **bold** text.

- **science topics** that are covered
- **science process skills** that are used
- **time required** for each stage of the activity:
    - **advance preparation** for teacher *(does not include gathering supplies),*
    - **set-up** before class,
    - doing the **activity** with students, and
    - **clean-up** after the activity

  materials supplies list
- detailed step-by-step **activity** procedure instructions
- hints for **introducing the activity** in a manner that facilitates inquiry process, speculation, independent thinking and discovery
- hints to guide **class discussion** and encourage student analysis and conclusion building
- **explanations** of in-depth scientific content for teachers and interested students
- **optional extensions** and **cross curricular connections** to disciplines, such as math or music, for teachers who enjoy extending lessons and for those who integrate disciplines throughout their lessons
- **alignment with science content standards** is given on the website at www.dangerousdecibels.org
- **glossary** in Appendix A
- support materials in **Appendices** A through F

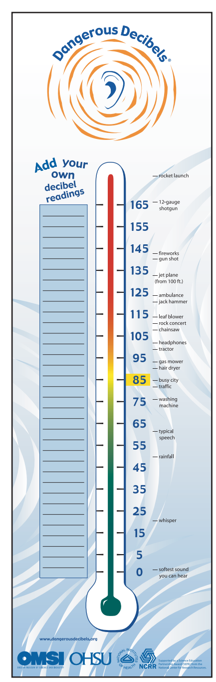
The Dangerous Decibels DVD:

The Dangerous Decibels DVD was developed as a practical tool for teachers. It was designed as an alternative to the teacher training workshops that were developed, piloted, and evaluated during the development phase of the Dangerous Decibels project. While the Dangerous Decibels teacher workshops were well received, we understand the huge demands on teacher time. To protect valuable teacher time while providing expert support, convenience, and additional comfort using the activities presented in this guide, we produced an introductory DVD to answer questions, demonstrate activities visually, provide additional content, and offer optional segments for use in the classroom, with a youth club, at a parents meeting, or during an after school program. You may choose to view any or all of the segments on the DVD program.

The DVD program includes:

- a teacher/professional development manager and a curriculum developer introducing the project, walking you through the class room activities, providing practical hints for the classroom, and introducing the poster.
- an audiologist walking you through a giant ear, explaining the anatomy and physiology of the ear, describing types of hearing loss, and presenting an interactive "How Loud Is Too Loud" activity you can do with your students.
- a middle school student explaining how to protect your hearing.
- a researcher providing a close-up look inside the ear at the basilar membrane's response to music.
- an interview with a tinnitus patient.

The Dangerous Decibels Poster: The Dangerous Decibels poster packaged with the DVD is an easy-to-use teaching aid displaying a thermometer-style decibel meter to acquaint students with the decibel levels of common sounds. The back of the poster displays ways to protect your ears from dangerous decibels, fun facts, and a graphic to help students determine how long they can safely listen to sounds at various decibel levels. This poster makes a useful teaching visual or can serve as a launching point for students to do their own investigation of sounds in their environment.



Integrating with Science Curriculum

In addition to conveying the messages aimed at changing health-related behaviors, the Dangerous Decibels activities are designed to meet the following objectives:

- Introduce science content related to the **physiology of hearing**;

- Introduce science content related to the **physics of sound**;

- Address specific **science standards**, benchmarks, and optional grade level mapping as set forth by AAAS (American Association for the Advancement of Science) *Atlas of Science Literacy* and the Oregon Science Standards set by the Oregon Department of Education. Because the standards change over time, the links to standards are maintained only on the website: www.dangerousdecibels.org/teachersguide/standards .

- Provide launching points for potential ***scientific inquiry*** work samples.

Teachers may learn more about the curriculum and gain insight and strategies for teaching the curriculum by watching the training program available on DVD. Teachers in the Pacific Northwest may also schedule the OMSI outreach program for their class. Teachers in and around Portland, Oregon may schedule a classroom field trip to visit the Dangerous Decibels exhibit in OMSI's Life Science Hall. Teachers may alternatively utilize this guide to prepare for implementation of any of the hands-on Dangerous Decibels classroom activities by reading the teacher instructions included with each activity. It would be beneficial to first read the following section of this manual: "The Science of Sound, Hearing, and Noise-Induced Hearing Loss – Background Information for the Teacher."

Primary teachers may integrate these activities into lessons on the senses, music, health, or mathematics (graphing, weighing, sorting).

Intermediate teachers may integrate the activities into units on anatomy, the senses, health, or introductory physical science.

Middle school teachers may integrate the activities into units on the physics of sound and waves, health, mathematics, or anatomy and physiology.

Adapting to Different Grade Levels

There are a total of four central activities in this curriculum. While all may be adapted to various grade levels from K through 8, the activities were designed and tested with specific age ranges and developmental stages in mind:

- **All Ages**: *Balloon Drum*, the first activity, is fun as an introductory activity for all grade levels.
- **Primary Students (K-2):** Start with Activity 1, *Balloon Drum*, to introduce basic concepts to the students. *Good Vibrations*, the second activity, is a great station-based activity.
  A Sound Balancing Act is an optional activity for primary teachers looking for more depth or a math activity extension.
- **Intermediate Students (grades 3-5):** Start with Activity 1, *Balloon Drum*, to introduce basic concepts to the students. *Shake It, Break It*, the fourth activity, was designed to give intermediate students a model to understand the fragile nature of their ear. Models are often used by scientists to understand scientific phenomena. Intermediate students are able to understand the idea of models and to practice drawing conclusions from them. Intermediate students also need this tangible, three-dimensional representation to better understand what is happening inside the ear. Teachers looking for more depth or a mathematics extension may try *Sound Measures* as a guided classroom activity.
- **Middle School Students (grades 6-8):** Start with Activity 1, *Balloon Drum*, to introduce basic concepts to the students. The final two activities are designed for more depth with middle school students. *The Shapes of Sound* gives students an understanding of the physics of sound waves and vibrations, as well as practice observing and carrying out investigations. *Sound Measures* is a great foundation for further scientific inquiry. Students will gain enough experience and expertise to form new questions, design experiments, collect and analyze data, and draw conclusions and analysis. Both activities have applicable math components.

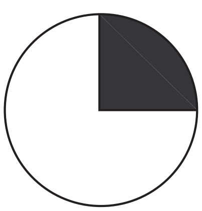
Balloon Drum

Students create an apparatus that allows them to observe the movement of objects in response to sound waves.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Waves	Observing	K-2 (except step 1)
Vibrations	Controlling Variables	3-8
Sound	Inferring	
Sense of Hearing	Questioning	
Noise Pollution		

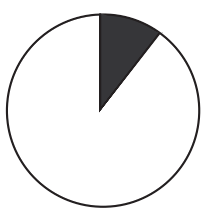
TIME REQUIRED

Advance Preparations



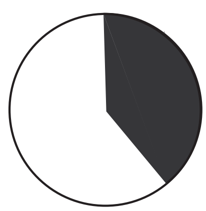
15 minutes

Set-Up



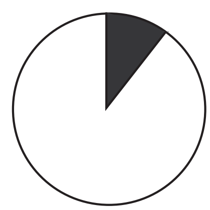
5 minutes

Activity



20 minutes

Clean-Up



5 minutes

MATERIALS

- jar, can, or yogurt-type container (round container with opening 8 to 12 centimeters (3 to 5 inches) in diameter)
  1 for each group of 4 students
  Note: *If the container is plastic, it should not be too flexible. It needs to retain its shape when a balloon is stretched across the opening.*
- balloons (at least 12”) (1 for each group of students)
- salt or sand (at least 1 teaspoon per group)
- scissors
- rubber bands (1 per group)
- metal bowl or pan
- wooden spoon
- source of music (radio set to music station) or tape/CD player with a music tape. (Preferably use music the students would listen to in their spare time.)
- pillow or bubble wrap
- scissors
- ear plugs recommended

ADVANCE PREPARATIONS

❏ Gather the following **for each group of students**:
- 1 twelve inch or larger balloon
- 1 can, plastic jar, or non-breakable container with a mouth approx. 8 to12 cm (3 to 5 inches) wide
- 1 rubber band
- scissors

- [ ] Gather **for each table group**:

    - a small container with 1/2 to 1 cup of salt or sand or a salt shaker

- [ ] If your class is primary students (K-2), make the balloon drum for them, or have older students prepare the balloon drums by following step 1 in the activity procedure below.

- [ ] Before doing the activity with the class, practice the activity procedure below.

SAFETY PRECAUTION:	STUDENTS WITH LATEX ALLERGIES SHOULD NOT HANDLE BALLOONS

INTRODUCING THE ACTIVITY

Ask the students the following questions in **bold.**
Possible student answers are shown in *italics.*

What is sound?
Some students will give examples. Some students will talk about waves or vibrations. Some will talk in terms of the ear and our ability to hear.

Can you see sound?
We may see the vibration of a drum, the waves of a recording device or on an oscilloscope, etc.

Is sound dangerous?
Research indicates between 15% and 20% of American teens have already suffered hearing damage due to noise exposure by the time they leave high school. Although they may not be aware of their hearing loss (because early effects of hearing damage are often subtle), Noise-Induced Hearing Loss causes significant changes in both the quantity and quality of the sound one is able to hear.

In the experiment students will look at the power of sound and test whether or not sound can actually move objects.

SAFETY REMINDER:	STUDENTS WITH LATEX ALLERGIES SHOULD NOT HANDLE BALLOONS.

CLASSROOM ACTIVITY

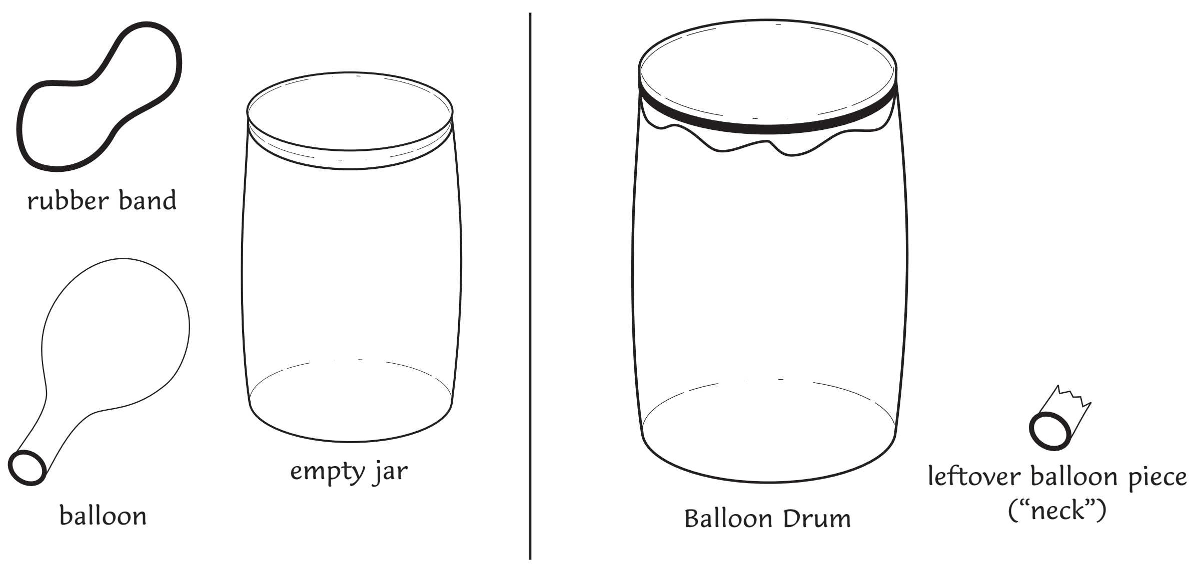
Caution: Students may choose to test loud sounds. Have students wear earplugs around loud noise or music.

Students may work individually or in pairs. Each group follows the procedure below. Grades 3-8 may make their own balloon drum following the instructions in step 1. The teacher or older student helpers should make the drum for younger K-2 students. Begin then with step 2 for K-2.

Procedure:

STEP 1: **Make a "Balloon Drum" as follows:**

- Inflate one 12" balloon and then deflate it.
- With scissors, cut the neck off of the balloon.
  Note: *Dispose of the rubber neck of the balloon carefully. If left in the environment, balloon pieces can be dangerous for animals that swallow them.*
- Stretch the remainder of the rubber balloon tightly over the open end of the plastic container and secure with a rubber band. This apparatus can now be called a "balloon drum."



STEP 2: **Conduct tests with the Balloon Drum in small groups as follows:**

- Set the "balloon drum" on a desk or table.
- Sprinkle some salt or sand crystals onto the stretched rubber surface.
- Speak very close to the edge of the container just below the rubber membrane (balloon). Be careful not to blow on the crystals; bend or kneel down if necessary. *(Students may place their hand in front of their mouth to be sure that they do not blow the salt on the drum.)*
- Observe what happens. Record observations.

STEP 3: **Conduct tests with other sounds as follows:**

- Hold a deep metal bowl or sauce pan near the balloon drum's edge and strike it sharply with a wooden spoon.
- Observe what happens. Record observations.
- Repeat steps 2 and 3, making the sounds louder or softer, with the spoon or with your voice.
- Take note of changes you made to the procedures, make observations about the results, and record your observations in written and/or picture form.

STEP 4: **Test the Balloon Drum with music as follows:**

- Gather students in a semicircle around a radio, tape player, etc. Position them so they are at least 5 feet away from the speaker as you will be turning the volume up quite loud for a brief moment.
- Place the "balloon drums" in front of a music speaker. Gently place about a teaspoon of salt on the stretched balloon.
- Tell students you are going to use the speaker to produce sound waves and you want them to observe what happens as you turn the volume up.
- Turn the volume up slowly until you can see the salt begin to vibrate slightly. Pause and let students observe.
- Move the drums farther from the sound source and observe.

- Place a pillow or bubble wrap between the balloon drum and the sound source and note any differences.
- Warn the students that you are going to turn the volume up higher and ask them to put their hands over their ears to muffle the sound slightly while continuing to watch the salt. (If students are wearing their earplugs, this step is not necessary.)
- Turn up the volume until the salt begins to jump up. Some should actually bounce off the drumhead. Turn the music off.

CLASS DISCUSSION

Can we actually see sound waves?
Can we see things move as a result of sound waves?

Ask for student observations. There is no correct answer. Let students guide the discussion and present their hypotheses before discussing explanations.

Explain that the salt jumping off the balloon drum actually occurred due to the pressure of sound waves!

Show students the picture of the ear from page 92 (Appendix B) at the back of this resource guide. Discuss the fact that in our inner ear, sound waves actually move small hair-like structures called "stereocilia." These hair-like parts are attached to the tops of the specialized sensory cells (called hair cells). This action is similar to the way in which sound vibration caused the salt to move on the balloon drum. The inner-ear stereocilia or "hairs" are much smaller than grains of sand. If incoming sound is intense enough, the sound waves cause some of the stereocilia to move slightly back and forth. With repeated exposure over time, or if sound is sufficiently intense, the stereocilia will bend or break. When more and more hair cells suffer damage over time, the result will be a permanent hearing loss. This is known as "Noise-Induced Hearing Loss (NIHL)."

Ask the students if they noticed any times that the salt on the balloon drum was less active.

Salt should have been less active when there was insulation (pillow or bubble wrap, or even hands) covering the speaker, when the drum was moved away from the sound, and when the volume was turned down.

Actions that caused the crystals to move less on the drum:

- Moving the drum farther away from the source of noise. **(WALKING AWAY!)**

- Putting a pillow, or some other protective barrier in between the balloon drum and the source of the sound. **(WEARING PROTECTION LIKE EAR PLUGS!)**

- Turning the sound (e.g., the music) down. **(TURN DOWN THE VOLUME!)**

Ask students to give examples of some loud sounds they are exposed to in their environment.

Noise is not the only cause of hearing loss, but it is the most common cause in America (and in other industrialized nations). Loud noises (above 85 dB) can hurt your ears by damaging the sensitive hair cells of the inner ear. It makes no difference whether you like the loud sounds or not – if they are over 85 dB, they can begin to damage hair cells in your inner ear. The rule of thumb is:

> **If the sound is loud enough that you have to raise your voice to be understood, it is probably loud enough to damage your hair cells.**

Show students the decibel scale with sample sounds from the end of this guide (Appendix C, page 93.)

Because there is currently no treatment to repair hair cells that have been damaged by loud sound, it is important for people to protect themselves from such damage. Fortunately, there are several actions a person can take to prevent Noise-Induced Hearing Loss. Following are three major ways to obtain hearing protection.

- **Turn down the volume**
- **Walk away (put as much distance as possible between your ears and the sound source)**
- **Wear hearing protection**

EXPLANATION

In-depth background information for teachers and interested students.

For details about the anatomy of hearing, see the section **Anatomy and Physiology of the Ear: Mechanics of Hearing** on page 9.

For details about the **Physics of Sound,** see page 6.

More about Common Sounds:
Sound is produced when an object vibrates. Near the vibrating surface adjacent air molecules also begin to vibrate, or **oscillate.** The oscillations spread from one molecule to the next, and a sound wave moves outward from the vibrating surface. The intensity of the waves (**amplitude**) and how rapidly they repeat (**frequency**) produce the differences in sound. More intense oscillation produces a louder sound. Faster oscillations produce a higher pitch. When the sound waves travel through the air, the oscillation of the air molecules next to the surface of the balloon will cause the balloon to vibrate. You can feel the sound energy with a light fingertip touch on the balloon. Hold an inflated balloon next to your music speaker to feel it for yourself.

Speech and other vocalized sounds are produced in your **larynx** (voice box, which is a triangular cavity between your windpipe [trachea] and your tongue). The larynx is made of muscle tissue and cartilage, which protrudes at the front of your neck. Your vocal cords, which are made of elastic tissue, are stretched across the opening of the larynx. When you exhale and air passes over the vocal cords, they vibrate, setting up resonant waves that are changed into sound by the action of throat muscles and the shape of your mouth.

QUESTIONS TO DETERMINE WHETHER YOU ARE BEING EXPOSED TO EXCESSIVE SOUND THAT MAY DAMAGE YOUR HEARING:

- ❑ Are you often in an environment where the sound is so loud that you have to shout to make yourself understood?
- ❑ After exposure to loud sound, have you ever noticed tinnitus (ringing or other noises in your ears or head)?
- ❑ Does music sound slightly strange or distorted after you have been listening for a while?
- ❑ Do voices sound muffled after you've been around loud music or other loud sounds for an extended time?
- ❑ After exposure to loud sound, do your ears sometimes feel "full" or "stopped up"?
- ❑ When you are listening to stereo headphones or a Walkman, can a person standing next to you hear it too? (When you are using stereo headphones, you should be able to hear a person next to you speaking in a normal tone of voice, and they should NOT be able to hear your headphones.)

If you answer YES to any of these questions, you have been exposed to damaging sound levels.

Noise Pollution

Learn More about Noise pollution in the "How Loud Is Too Loud" Activity, Appendix E, page 101.

OPTIONAL EXTENSIONS

Experiencing Sound Energy

- Carefully cut the neck off a balloon. Stretch the remaining part of the balloon over the end of a cardboard tube (e.g., an empty toilet paper or paper towel tube). Secure the balloon with a small wide rubber band. Take turns talking softly and loudly into the tubes while you lightly touch the balloon end with your fingertips.
- Can you feel the vibrations?
  Do they change as your voice changes?
- Use your balloon tube to feel sound vibrations from a speaker. Hold the open end of the balloon tube right in front of, but not touching, the speaker. Now, if available, change the bass and treble settings on your stereo.
- Can you feel a difference?
- Can you also feel the vibrations within your body?
- What do you feel the most, the vibrations from a high bass setting or a high treble setting?

Inquiry Extension

Let students design and carry out their own experiments using their balloon drum to gather data. (For example, how far does my balloon drum need to be from various sources of noise in my home to decrease the bouncing of the sand?) Students can collect numerical data, transform the data into graphical presentations, analyze their data, and present it to the class.

CROSS-CURRICULAR CONNECTIONS

MUSIC

Musical Comb

- Fold a piece of wax paper in half and place a comb inside the fold.
- Hold the comb at each end, pressing the paper against the teeth of the comb.
- Gently press your lips against the paper and hum, keeping your lips slightly parted.

Kazoo

- Use an empty cardboard tube; with a paper punch, punch a hole at one end of the tube about 1/2” from the end.
- Cut a square of wax paper large enough to cover the end of a toilet paper tube (not smaller than 4”).
- Fold the wax paper down over one end of the toilet paper tube and rubber band it firmly in place.

Explanation:
Humming causes the paper to vibrate and produce a buzzing sound. You can play a tune this way.

STUDY HABITS

Students develop an experiment to investigate whether noise affects concentration. For example, assign a poem to memorize or some math problems to do and have one group of students try to complete the assignment in a noisy environment (such as a cafeteria) while the other group works in a very quiet environment. Document results and report to the class. Perhaps publish results in a school newspaper.

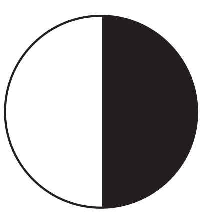
Good Vibrations

Students experiment with various noise sources, including their own voices, to gain an understanding of the connection between sound and vibration.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Hearing Sounds Vibration	Listening Observing	K, 1-2

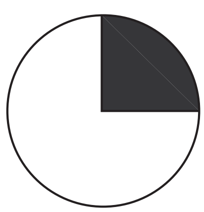
TIME REQUIRED

Advance Preparations



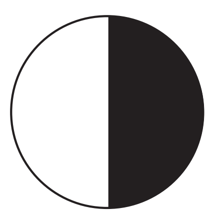
30 minutes

Set-Up



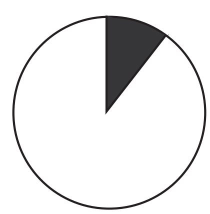
15 minutes

Activity



30 minutes

Clean-Up



5 minutes

MATERIALS

- tuning fork
- pan or unbreakable bowl, approx. 1–2 liter (1–2 quart)
- water (approx. 0.5–0.8 liters, or 2–3 cups)
- paper
- crayons
- drum(s) (any drum or tambourine will work)
- 2–5 small unbreakable containers (e.g., a plastic cup or 8 oz. clean, empty, yogurt container)
- spoon (plastic or metal, coffee spoon size is fine)
- rice grains
- cereal flakes
- optional: other small dry ingredients similar to rice and cornflakes
- wastebasket
- empty tissue box (flat rectangular variety)
- rubber bands of various sizes
- waxed paper
- new, small, plastic combs (1 per pupil) (small combs work well)

ADVANCE PREPARATIONS

- [ ] Set up desks to create spaces for four "sound stations" with desks arranged in 4 groups.
- [ ] Gather supplies (see materials above).
- [ ] Cut one square of wax paper per student (have a few to spare). The wax paper squares should be approximately 10–20 cm. per side (about 4–8 inches).

❑ Make a Rubber Band Guitar:
Stretch a rubber band around tissue box so that the elastic crosses over the box opening. Place other rubber bands of different widths across the box in the same way. *Depending on the size of class, teachers may want to make several Rubber Band Guitars.*

SET-UP

Set the supplies at each station as follows:

Station 1– Ripples on Water/Tuning Fork:

- Add water to the pan or bowl to five centimeters depth (approximately two inches).
- Place crayons, paper, a tuning fork, and the pan of water at the table.

Station 2 – Drum Vibrations:

- Half fill 3 – 5 small unbreakable containers (e.g., clean, empty 8 oz. yogurt containers) with different dry ingredients including uncooked rice grains, cereal flakes, etc. *(Note: you may need to refill these during the class period as groups use up the ingredients).*
- Place the containers of ingredients, a spoon, and a drum at the station.
- Place a wastebasket near the station.

Station 3 – Kazoos:

- Place one plastic comb and one square of wax paper per student at the table.

Station 4 – Rubber Band Guitar:

- Place one or more tissue box guitars at the table.

INTRODUCING THE ACTIVITY

Let the students speculate. Do not encourage a single correct answer. Do not offer answers to any questions. The answers at the right are provided primarily for the teacher's benefit.

Begin with an introductory, interactive demonstration in which students feel the vibrations created by their own voices. Talk to or ask the students the questions in **bold.** Possible student responses are shown in *italics.*

- **We are going to feel the movement made by our voices when we talk, sing, hum, or shout.** *(Tiny repeating movements are called* vibrations.*)*

- **Can you feel the sound of your voice by putting your hand on your body while you talk?**

- **Where do you think is the best place to feel your body vibrate when you talk, sing, or hum?** *(Encourage a variety of answers. Each answer represents what they know about sound. Students may think the vibrations will be strongest coming from their mouths, but they are actually stronger at the throat.)*

- **Test your hypotheses with a partner.** Have students test various hypotheses suggested by the class and possibly the teacher. Test by having students place their hand on a part of their body while they talk.

- **Include testing of the face and throat:** Have each student hold her hand against her own face as she talks and feel the movement (vibrations). Next, have students put a finger on the front of their throat, close to their "voice box" *(middle of the throat),* being careful not to press too hard.

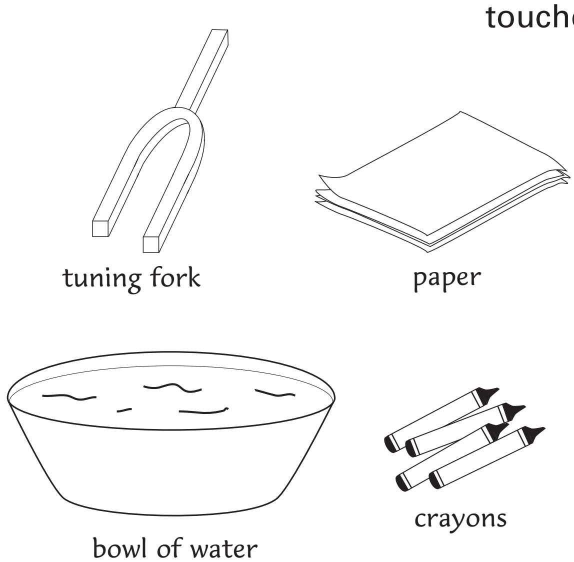
- **Do you feel tiny movements from speaking? Where do you feel them best?**

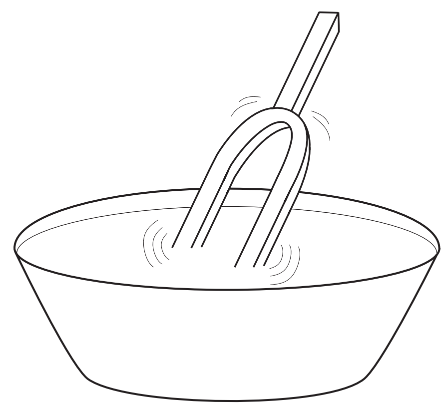
- **Ask students to share their observations.**

Demonstrate each of the four activity stations before students divide into groups and do the activities.

Station 1– Ripples on Water/Tuning Fork:

- Strike a tuning fork against a book and dip the fork in the pan or bowl of water.
- Tell students that when they do this activity, they will also have paper and crayons to draw what they see.
- To think about: What did you feel when you touched the tuning fork after you hit it?

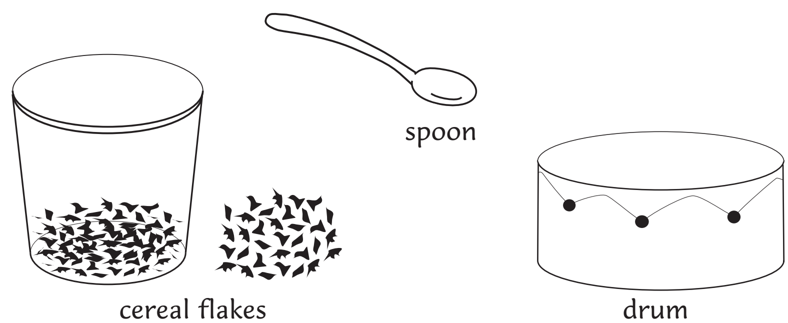




Caution: the resonating (fork) end of the tuning fork should *only* be placed in the water. Do not put the resonating end of the fork against the furniture, windows, or any part of the body.

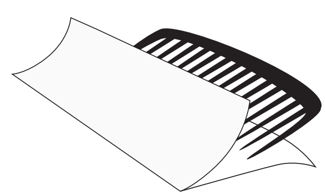
Station 2 – Drum Vibrations:

- Tap on the drum and notice if you can see movement.
- Place a spoonful of cereal flakes on top of the drum.
- Tap on the drum again.
- Notice if the cereal flakes move.
- The students will have a variety of materials (cereal flakes, rice, etc.) that they can test.
- Remind students to clean up the first material before testing a new one.
- To think about: Did the cereal flakes move or stand still? Did some materials move more than others?



Station 3 – Kazoos:

- Make a kazoo by folding a piece of waxed paper in half.
- Slip a comb into the waxed paper so that the teeth are against the fold.
- Put the comb into your mouth so that your lips rest on the folded edge of the waxed paper. *(It is best if students avoid getting the paper wet.)*
- Blow or hum.
- To think about: How did your lips feel when you played your "kazoo"? What happened to the waxed paper when you hummed?



kazoo

Station 4 – Rubber Band Guitar:

- Strum the Rubber Band Guitar. Watch the rubber bands as they are plucked.
- To think about: What did the rubber band do when you plucked it? Did you feel movements (vibrations) in your other hand (the hand holding the box)?

rubber band guitar

CLASSROOM ACTIVITY

Divide the students into 4 groups. Have the students rotate through the stations, and do the activities as demonstrated (see above).

Caution: Remind students that the resonating (fork) end of the tuning fork should *only* be placed in the water, and nowhere else.

DISCUSSION

Ask the students the questions in **bold** and facilitate an open-ended discussion. Possible answers are shown in *italics.*

Questions from Stations:

<u>Station 1– Ripples on Water/Tuning Fork:</u>

What did you feel when you touched the tuning fork after you hit it?

<u>Station 2 – Drum Vibrations:</u>

Did the cereal flakes move or stand still? Did some materials move more than others?

<u>Station 3 – Kazoos:</u>

How did your lips feel when you played your "kazoo"? What happened to the waxed paper when you hummed?

<u>Station 4 – Rubber Band Guitar:</u>

For the rubber band guitar, what did the rubber band do when you plucked it? Did you feel movements (vibrations) in your other hand (the hand holding the box)?

What was each one of these objects doing as it was making a sound (including your throat)?

What else did you notice (observe) with your eyes or ears?

Can we see sound move?
The sound made by the tuning fork made a pattern of waves that showed in the water. If we could see the air around us, we would be able to see the same kind of waves as sound moves through the air from a radio to your ears.

Can sound move things?
The rice and cereal was moved on the drum by the sound of the drum. The sound from your humming voice moved the wax paper on the comb and tickled your lips.

This sound movement is felt by special parts of your ear (tiny hair cells of the inner ear). Deep inside your ear, sound waves actually move small structures that look like very tiny hairs (stereocilia). These parts of your ear are much smaller than grains of sand. If sound is strong (loud) enough, the sound waves cause some of them to bend or break. When you are around loud noises often, or for a long time, you may begin to have trouble hearing. *(See Appendix D, Stereocilia pictures, page 94).*

Do you know any older people who seem to have trouble hearing some sounds?

Give examples of some loud sounds you are exposed to in your environment.

Check to see if your sounds are on the Decibel Meter on the "thermometer" poster that comes packaged with the teacher training DVD for this curriculum. Review the sources of sound on the chart.

Note: Noise is not the only cause of hearing loss, but it is the most common cause in America (and in other industrialized nations). Loud noises (above 85 dB) can hurt your ears by damaging the sensitive hair cells of the inner ear. It makes no difference whether you like the loud sounds or not – if they are 85 dB and over, they can begin to damage hair cells in your inner ear. ***Remember, if you have to raise your voice to be understood, its probably loud enough to be dangerous!***

<u>Doctors cannot fix ears that have been damaged by loud sound. So it is very important to protect your ears.</u>

Here is what you can do:

- <u>Turn down the volume</u> (make the TV quieter)
- <u>Walk away</u> (get far away from the loud sound)
- <u>Wear ear muffs or ear plugs</u>

QUESTIONS TO SEE IF YOU ARE AROUND SOUND THAT MAY HARM YOUR HEARING:

- ❑ **Do you often have to shout for people to hear you?**
- ❑ **After being around loud sound, did you ever have a ringing or other noises in your ears or head (tinnitus)?**
- ❑ **Does music sound a little strange after you listen for a while?**
- ❑ **After being near loud sound, does it sound like people are talking to you through a pillow?**
- ❑ **After being near loud sound, do your ears sometimes feel "full" or "stopped up"?**
- ❑ **When you are listening to stereo head-phones or a Walkman, can a person standing next to you hear it too?**

If you answered YES to any of these questions, you have been exposed to damaging sound levels.

EXPLANATION

In-depth background information for teachers and interested students.

Read about the **Physics of Sound** on page 4.

Sound is produced when an object vibrates. Near the vibrating surface, air follows that surface and the air molecules begin to vibrate, or **oscillate.** These oscillations spread from one molecule to the next, and a sound wave moves outward from the vibrating surface. The intensity of the waves (**amplitude**) and how rapidly they repeat (**frequency**) produce the differences in sound. More intense oscillation produces a louder sound. Faster oscillations produce higher pitched sounds. When sound waves travel through the air, the oscillation of the air molecules next to the surface of an object (such as the surface of the drum) will cause that object to vibrate. You can even feel the sound energy with a light fingertip touch on many of the objects used in this activity.

Speech and other vocalized sounds are produced in your **larynx** (voice box). The larynx is made of muscle tissue and cartilage, which can be seen as the bump protruding from the front of your neck. The larynx moves when you swallow. The vocal cords, which are made of tough, elastic tissue, are stretched across the opening of the larynx. When you exhale, the air passing through your larynx causes your vocal cords to vibrate. This produces sound waves that are converted into vocal sounds by the muscles of your throat and the shape of your mouth. The faster the air moves through the vocal cords, the higher the volume, or the louder the sound; the more tightly the vocal cords are stretched, the higher the pitch.

OPTIONAL EXTENSIONS

Music

Have a class concert, using the drum(s), kazoos, guitar(s), and voices!

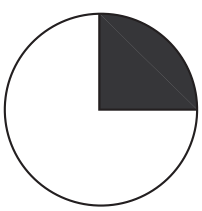
A Sound Balancing Act

Students measure "noisemaker" sounds on a "hearing scale" to help them distinguish between sound that is harmful and sound that is not.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Hearing Sound Balancing Dangerous Decibels	Observing	K, 1-2 3-5 (have students make balance)

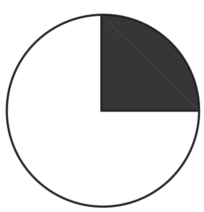
TIME REQUIRED

Advance Preparations



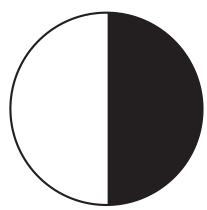
15 minutes

Set-Up



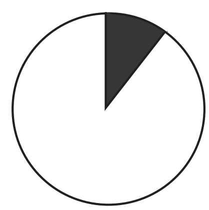
15 minutes

Activity



30 minutes

Clean-Up



5 minutes

MATERIALS

- **Optional:** Letter to parents (Master A or your own letter)
- **Optional:** Container for collecting coins (jar, cottage cheese container, tissue box)
- Photocopies of noisemaker pictures (Master B.1 and B.2)
- Crayons
- Tape (lightweight clear tape)
- Scissors
- Coins – nickels and dimes
- Balance scale or material for building balance (see Advance Preparation step 6, below)
- Poster board, cardboard, or similarly thick paper
- Small amount of clay or play dough (approximately 2.5 square centimeters or 1 square inch)

ADVANCE PREPARATIONS

- [ ] **Optional:** If appropriate for your student population, have students collect coins for the activity as a fundraiser for a hearing-related charity. Photocopy Master A, a letter to the parents, and send home to the parents approximately one month before the activity is scheduled. Have students decorate a container for collecting coins. Collect coins throughout month.

- [ ] Make photocopies of noisemakers (Masters B.1 and B.2) (Have one noisemaker picture per student.) Cut out one noisemaker for each student.

- [ ] Make a photocopy of each of the labels (Masters C and D).
- [ ] Obtain or create a simple equal arm balance.

Note: The DVD that accompanies the teacher resource guide demonstrates another way to make an equal arm balance that was obtained using instructions obtained at: http://www.topscience.org/balancing2.htm
We present a slightly simpler version of the activity in this guide. The version presented in this guide retains the use of paper cups to hold the items to be measured and eliminates the use of envelopes to hold the coins and noisemaker pictures as demonstrated in the DVD. Feel free to use the method that suits you best.

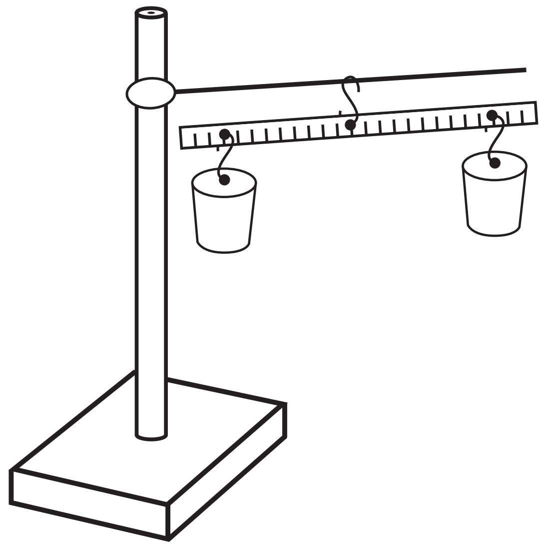
If you do not have an equal arm balance you can make one as follows:

Materials:

- Ruler with holes
- Tape
- Paper cups (2)
- 3 paper clips
- A stand or place to hang the balance without interference
- A one-hole punch

Steps:

1. Use a paper clip to suspend the ruler from a hole in the middle of the ruler.
2. Punch a hole approximately 0.5 cm (or about 0.25 inch) from the top of a paper cup. Repeat with a second paper cup.
3. Use a paper clip to hang the first paper cup from a hole at one end of the suspended ruler. Use another paper clip to suspend the second paper cup from a hole at the opposite end of the suspended ruler.
4. Use pieces of tape to hold the paper cups in place if necessary and to adjust the balancing cups until the ruler with the cups rests horizontally when both cups are empty.



- [ ] Attach Master C to poster board or other heavy weight paper or cardboard*. (This labeled "poster" will set behind your equal arm balance and will allow your students to "measure" the objects they will be weighing.)*
- [ ] Cut out the ear and clock picture from Master D.
- [ ] Tape a nickel to the back of the clock picture from Master D.
- [ ] Tape three nickels to the ear picture from Master D.
- [ ] Photocopy Master B1 and B2 to make one noisemaker picture for each student. Cut out the noisemakers on the dotted lines.
- [ ] Have on hand the following coins at the start of the activity:

  - for each student in Noisemaker Group A, 4 nickels
  - for each student in Noisemaker Group B, 3 nickels
  - for each student in Noisemaker Group C, 3 dimes
  - for the Ear, 3 nickels
  - for the Clock, 1 nickel

SET-UP

Position the copy of Master C behind the equal arm balance. You can use the modeling clay to attach Master C to the table so that it is standing upright behind the scale. (Watch the teacher training DVD for visual instructions.)

The class can now use the scale to test their noisemakers.

INTRODUCING THE ACTIVITY

- Have students close their eyes and listen to the sounds in the room. What do they hear?
- Ask students if they have heard sounds that hurt their ears. Explain that some sounds can cause hearing loss. Explain that some, very loud sounds can cause hearing loss right away, while others will not cause permanent damage unless you listen to them for a long time.
- Tell the students that we are going to learn which sounds can hurt your hearing.
- Pass out a picture of a noisemaker to each student.
- Give each student the coins that match the picture they receive as follows:

    - for each student in Noisemaker Group A (fireworks, gun, rock musician, or jet), 4 nickels
    - for each student in Noisemaker Group B (washing machine, rain), 3 dimes
    - for each student in Noisemaker Group C (motor cycle, race car, car), 3 nickels

CLASSROOM ACTIVITY

Student Procedure:

STEP 1: Color in the picture of your noisemaker.

STEP 2: Tape your coins to the back of your picture.

STEP 3: Follow your teacher's instructions for "weighing" your noisemaker.

Teacher-Facilitated Procedure:

STEP 4: Explain that the weight of the coins represents or "stands for" how loud the sound is for the noise-maker in their picture.

STEP 5: Teacher places the ear on the right hand side of the balance to represent the healthy ear.

STEP 6: Each student, in turn, places their noisemaker on the balance arm opposite the ear picture.

STEP 7: IF a student's noisemaker causes the balance to point to the "Stop" sign, the student will take their noisemaker and move to the "STOP SIGN GROUP." Tell students that this represents noises that are too loud and can damage the ear.

STEP 8: After all noisemakers have been weighed the class will be divided into two groups. One group will be the "RED STOP SIGN GROUP." This group represents noisemakers that are responsible for noise-induced hearing loss. Students holding pictures of noisemakers that register as "RED STOP SIGNS" have noisemakers that can cause immediate damage to hearing. Explain that all the people exposed to the sounds represented by the pictures held by the "RED STOP SIGN GROUP" can experience immediate hearing damage **unless they protect their ears, turn down the sound, or walk away from the sound.**

Review the ways to **protect your ears** (earplugs used properly or protective earmuffs, the sort that look like old earphones. These can be purchased at many home improvement stores, safety stores, or hardware stores.)

Ask students: When can you **turn down the sound**? When watching TV?, listening to a car radio?, using a walkman?, listening to music?

Ask students: When should you **walk away from the sound**? When you can't turn it down. For example, if live music is too loud, move back. If the sound of street equipment is hurting your ears, walk away.

STEP 9: Now the teacher adds the clock to the side of the balance opposite the side that holds the ear envelope. Explain that this clock means that you listen to a sound for a longer time.

STEP 10: Students that are NOT in the "RED STOP SIGN GROUP" will now reweigh their noisemakers by placing their noisemaker with the picture of the clock. Students are "measuring" what would happen to their ears if they listen to their sound for a longer period of time.

STEP 11: Have the remaining students "weigh" their noisemakers. If the balance now points to the YELLOW CAUTION SIGN, have the student take their noise maker and stand with the "YELLOW CAUTION SIGN GROUP." Students holding pictures of noisemakers that register as "YELLOW CAUTION SIGNS" have noisemakers that cause damage to hearing if you listen to them for a longer time.

STEP 12: The pictures that weighed as Happy Ears should still show as Happy Ears. There is no limit for listening to that noise. No matter how long you hear the sound, it won't cause damage to hearing.

DISCUSSION

Ask the students:

Which noisemakers are the most dangerous to your ears right away?
Were you surprised by any of the noisemakers that showed a RED STOP SIGN?
What can you do to protect your ears around these noises?

Which noisemakers are dangerous to your ears if you listen to them often or for a long time?
Were you surprised by any of the noisemakers that showed a YELLOW CAUTION SIGN?
What can you do to protect your ears around these noises?

Did you know that video arcades, motorboats, and other sounds, can cause hearing loss that will last your whole life? What can you do to protect your hearing? Show the students the "how loud is too loud" wheel (Masters A & B on pages 103-104) and review more noisemakers.

Ask the students how they can protect their ears.
Some suggestions include:

- ***walking away from the noise, turning the noise down if possible, or using hearing protection.***

Remind Students: It is not difficult to avoid most exposure to damaging sounds. There are three main methods for making sure your hair cells don't undergo noise-induced damage:

- **Turn it Down!** (Stereo, Walkman, "Boom Box", etc.)

- **Walk Away!** (This is what you do if you can't do either #1 or #2 above). It's easy to demonstrate how increasing the distance between you and the sound source can reduce the amount of sound you are exposed to.

- **Protect your ears!** (Carry and use ear plugs when going to an amplified concert, when using power tools, when around motorcycles or other noisy vehicles like jet skis and snowmobiles).

NOTE: Using Kleenex or similar soft materials doesn't provide much protection against intense noise—although some people believe it helps. Scientific evidence shows that you only get adequate protection from earplugs (or protective headphones such as those worn by airport workers or construction workers). If you do not have earplugs or headphones with you when you find yourself exposed to really intense sound, you can use your fingers to close off your ear canals and thus get good sound protection. This method may not be practical if the sound exposure goes on for a long time, but it works well if it is just a short-lasting sound.

Show your students the "Protecting Your Ears" segment on the Dangerous Decibels DVD.

EXPLANATION

In-depth background information for teachers and interested students.

An overview of the mechanism of hearing (see picture of ear on page 92, Appendix B

- Sound waves enter the **outer ear** (*pinna* and *ear canal*). The outer ear collects more of a sound wave than a simple hole in the side of one's head would. Some animals have larger ears that function like ear cones. Some animals can also turn their ears, to listen more effectively to sounds from particular directions.
- The outer ear directs the sound via the ear canal to the eardrum *(tympanic membrane)* of the **middle ear**.
- The middle ear consists of the eardrum and the three middle ear bones (the *ossicles*, consisting of the hammer or *malleus*, the anvil or *incus*, and the stirrup or *stapes*. (These are the smallest bones in the body.)
- The middle ear transforms sound waves into mechanical energy (movements of the middle ear bones), conducting sound to the inner ear.
- The inner ear (*cochlea*) contains microscopic cells ("hair cells") that are specialized to convert mechanical energy into electrochemical energy.
- These are approximately 10 –15 microns, considerably less than 1/1000th of an inch.
- There are about 18,000 hair cells in each cochlea.
- All 18,000 hair cells can fit on the head of a pin.
- These hair cells possess tiny finger-like projections, called *stereocilia,* at their tops. The stereocilia are bent back and forth when sound waves reach the inner ear.
- The electrochemical activity of the hair cells activates nerves in the inner ear that, in turn, transmit the sound-induced activity to the brain.
- The brain interprets the incoming neural activity as "I hear something."

Just as exposure to bright sun for too long can cause sunburn and damage your skin, exposure to intense noise can damage the hair cells in your inner ear, especially if the noise goes on for very long. Unfortunately, the stereocilia of the hair cells of the inner ear do not regenerate, as the skin will.

The delicate hairs at the base of the cochlea are exposed to all sounds and are very susceptible to damage. Because these first hair cells are most sensitive to high frequency sounds, higher frequency hearing is usually the first to be lost when someone acquires Noise-Induced Hearing Loss (NIHL). So NIHL does not just make everything seem quieter—it actually changes the complex pattern of sound frequencies that the person is able to hear (high frequencies become more difficult or impossible to hear). Speech, for example, is composed of a complex mixture of many different sound frequencies. The result of changing the sound frequencies that we can hear is to make speech sound "mushy" and much harder to understand particularly when there is background noise. Often, people with NIHL think everyone else is mumbling, when it is really their own hearing that is down.

OPTIONAL EXTENSIONS

- Visit the charity to which the money has been donated, or ask if the charity has a speaker that can visit.
- Ask an ear doctor to speak to the class.
- Gather ear protection devices, such as protective headphones, and let students explore the world without sound, in order to understand what the world would be like if they were to lose hearing. If protective devices are not available, the students can also press their palms against their ears for a similar effect.

Dear Parents:

Next month we will be starting a new unit about sound, hearing, and hearing loss. We have some fun activities planned, and are really excited to make some noise!

As part of our hearing unit, we will be collecting money to be donated to a hearing related charity. Please give your child any spare change that you would like to donate. We will collect the money in a jar in the front of the room, and at the end of the month, will donate it. If possible, please try to send a variety of coins (nickels, dimes, quarters) with your child, as we will be using the coins in one of our hearing activities before donating them.

I'm happy to give our students a chance to help the community and learn about hearing at the same time!

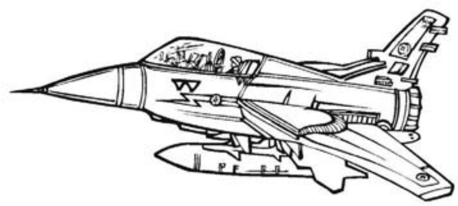
Thank you so much for your help,

MASTER A

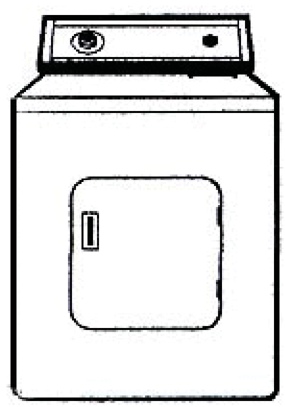
(Handout Masters are for teachers to photocopy)

Letter for The "A Sound Balancing Act" Primary Grade Activity

Group A

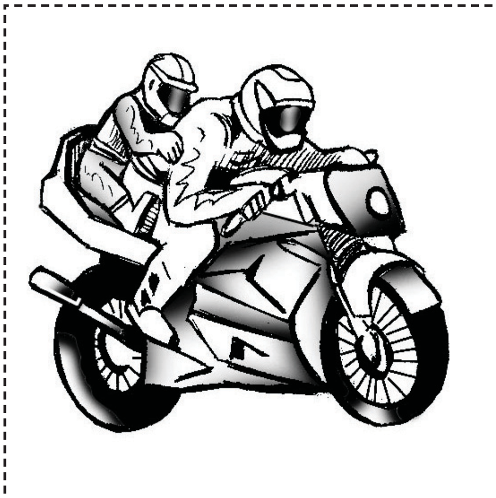


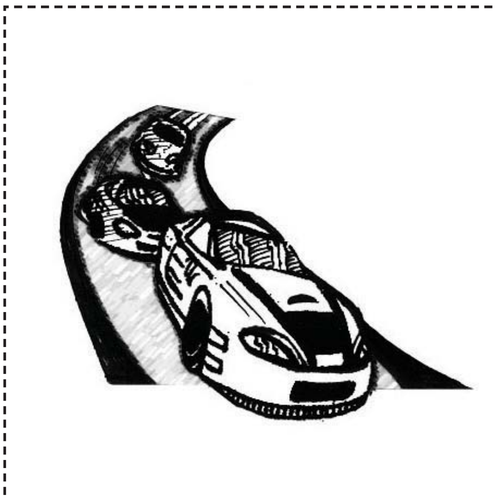
Group B

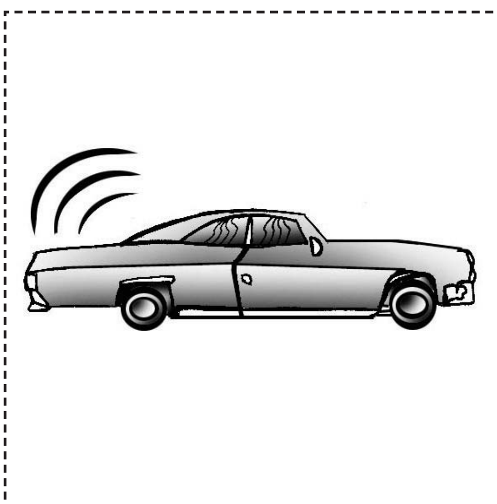


MASTER B.1
(Handout Masters are for teachers to photocopy)
Images for “A Sound Balancing Act” Primary Grade Activity

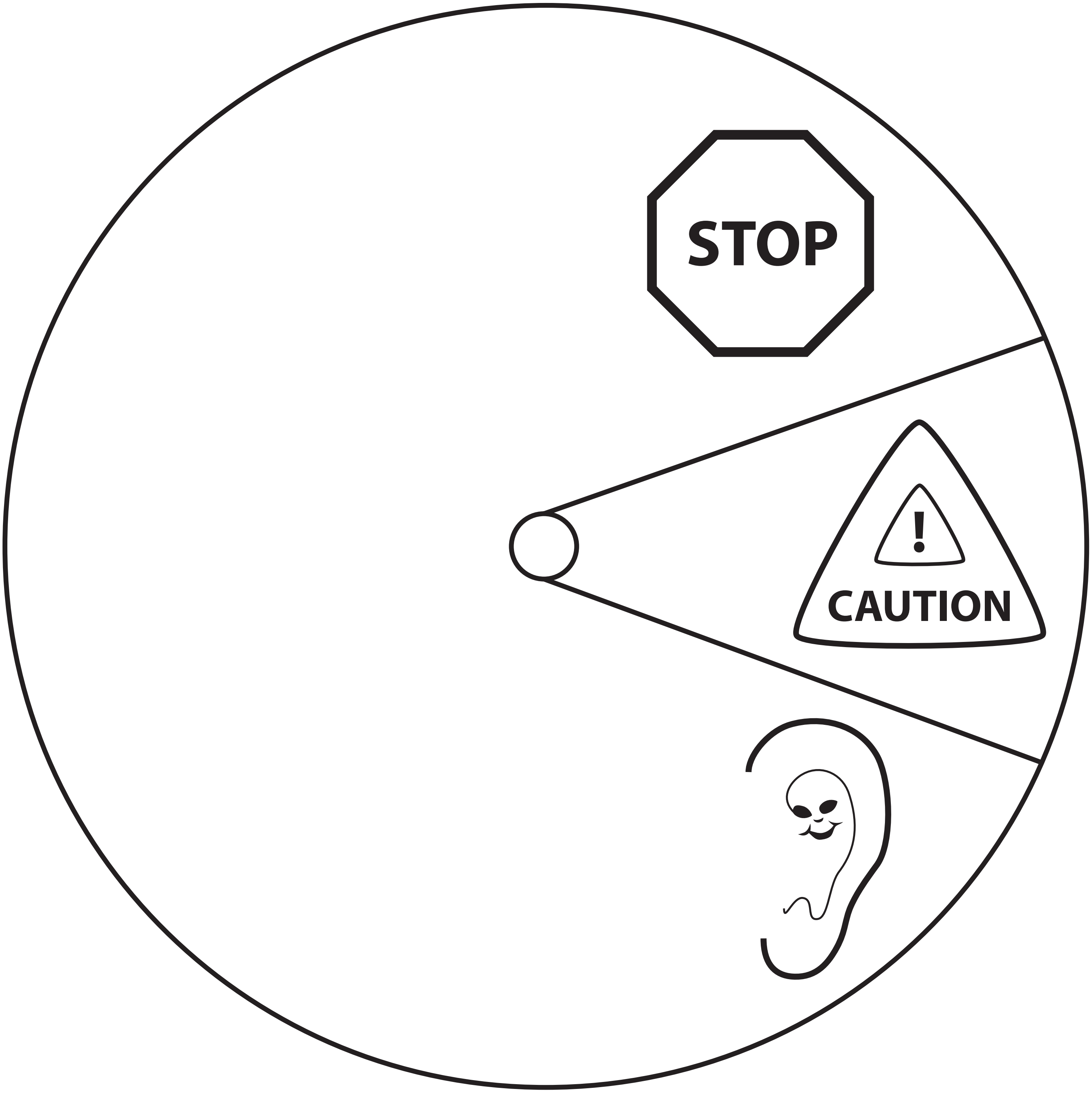
Group C



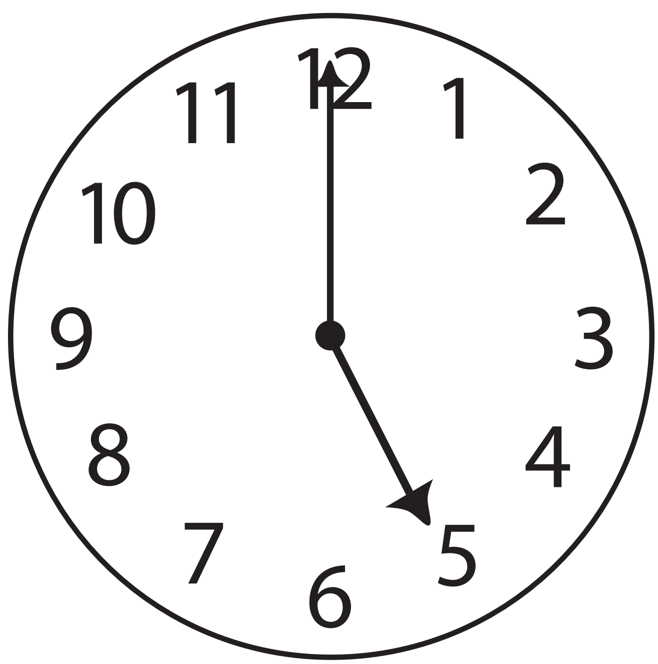




MASTER B.2
(Handout Masters are for teachers to photocopy)
More Images for "A Sound Balancing Act" Primary Grade Activity



MASTER C
(Handout Masters are for teachers to photocopy)
Scale Backdrop for “A Sound Balancing Act” Primary Grade Activity



MASTER D

(Handout Masters are for teachers to photocopy)

Labels for Envelopes for "A Sound Balancing Act" Primary Grade Activity

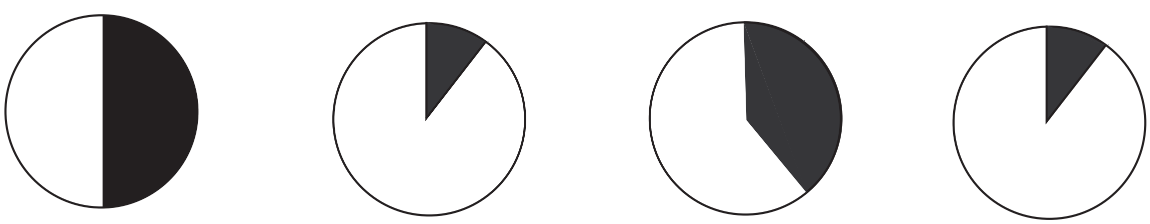
Shake It, Break It

Students use pasta to model the impact of noise on the fragile stereocilia that line the hair cells of the inner ear.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Anatomy of Hearing	Observation	3-8
Sense of Hearing	Modeling	
Hearing Conversation	Inferring	

TIME REQUIRED

Advance Preparations	Set-Up	Activity	Clean-Up



30 minutes	5 minutes	20 minutes	5 minutes

MATERIALS

- uncooked angel hair pasta (a very thin spaghetti available in the supermarket)
- large marshmallows
- newspaper or scrap paper to protect the work area
- picture of the ear showing the location of the hair cells of the inner ear, see Appendix B, page 92
- picture of healthy and damaged stereocilia, see Appendix D, page 94
- source of music (radio set to music station) or tape/CD player with a music tape, preferably with music that students will like

ADVANCE PREPARATIONS

❑ For each student gather the following supplies:

- a piece of scrap paper or newspaper
- 10-20 pieces of angel hair pasta
- 2 large marshmallows
- a ruler
- a soft-tipped marker

Teachers' note: *If you do not have angel hair pasta and you use thicker spaghetti, you may choose to omit step 2 in the procedure and have the students use 10 to 20 strands of full length spaghetti in order to get the desirable breakage effect during the activity. Unfortunately this eliminates the measuring practice for the students.*

❑ Before doing the activity with the class, practice the activity procedure below and create a sample to show the class.

NOTE: You may want to do the Balloon Drum activity first so that students understand that sound can move objects. This fact will have relevance to their models.

INTRODUCING THE ACTIVITY

Some science lessons introduce content to students before they explore and form their own hypotheses and make observations. This introduction is designed to introduce content so that students can build models.

If students have done the Balloon Drum activity prior to this activity, they will have more useful background information.

Review the workings of the inner ear and the fact that the delicate hair cells transmit the sound message to our brains.

Show the students the picture of the ear from Appendix B, page 92.

- Point out the outer ear, middle ear, and inner ear. Point out the eardrum.
- Tell the students that today they will be building a model of the tiny hair cells of the inner ear (Cochlea) or snail shaped spiral in the picture of the ear.
- Tell the students that the inner ear is lined with hair cells that are too tiny to see without a microscope. There are 18,000 hair cells per cochlea. All 18,000 would fit on the head of a pin.
- Tell the students that the hair cells are lined with small thin finger-like projections called stereocilia. Show the picture of the stereocilia to the class (Appendix D). These stereocilia are bent back and forth by sound waves.
- The mechanical energy of the movement back and forth (of the stereocilia) is converted to messages that are sent to the brain. Our brain interprets those messages as "I hear something."

Explain the purpose of creating scientific models.

This activity will demonstrate what happens to the hair cells when they are exposed to sound. To do that, students will create models.

Scientists cannot always experiment on an actual system or living organism. For example, before scientists sent John Glenn into space, they built and tested many models. A model is something that represents, but is not exactly the same as something being studied. The tiny hair cells in the ear are too small to be seen by the unaided human eye. It is important that we do not experiment with a real person's ear and risk hearing loss. So we will be building a "model" of the hair cells of the inner ear and test the impact of noise waves on the model.

CLASSROOM ACTIVITY

Students may work individually or in pairs.

STEP 1: **Prepare your workspace:**

- Place a piece of scrap paper or newspaper on the desk. Do the activity on top of this paper.

STEP 2: **Prepare your pasta:**

- Line up 10 pieces of pasta.
- Use a ruler to determine the middle of your pasta. (Measure the length of the pasta and divide by two.)
- With a marker, gently mark the middle of the pasta.
- Break each piece of pasta into two pieces of approximately the same size by breaking the pasta where the middle was marked. You should now have 20 half-lengths of pasta.
  (Note: If a few have broken, don't worry. There are extra pieces because pasta is fragile and some may break.)

STEP 3: **Build your model:**

- Stand a large marshmallow on its flat side like an upright drum.
- Holding the marshmallow with one hand, gently insert 10-15 pieces of pasta into your

marshmallow. It works best to place them in a circle around the outer edge of the marshmallow. *(Note: The pasta should be placed upright like a fence,* ***not*** *outward like the spokes of a wheel.) (Note: Angel hair pasta is very fragile. Be gentle. Don't worry if a few pieces break. You have extra. Throw away the pieces you break by mistake.)*

- While carefully holding the pasta pieces, gently place a second marshmallow on the top of the standing pasta. One at a time, gently push the top of each piece of pasta into the top marshmallow. It is okay if a few pieces are not inserted. *(Note: Be gentle and try not to break the pasta. Don't worry if a few pieces break. You have extra. Throw away the pieces you break by mistake.)*

STEP 4: **Draw a picture of your model and label the parts:**

- The noodles represent stereocilia of the hair cells of the inner ear.
- The bottom marshmallow represents the hair cells of the cochlea.

STEP 5: **Test your model:**

- The teacher will turn music on softly. Students gently move the bottom marshmallow so that the pasta sways to the rhythm.
- **Moving the pasta by hand represents of sound waves.**
  Sound waves produce vibrations strong enough to move objects much larger than microscopic hair cells represented by the pasta model.
- The teacher turns the volume of the music up a bit. Students move their pasta models a little more so that the pasta sways from side to side, without breaking.
- The teacher will turn the music up loud enough to be slightly annoying. Students move the models more vigorously so the pasta sways forcefully and several pieces may break off.
- The teacher turns the music off immediately. Students stop moving their models.

CLASS DISCUSSION

Ask for student observations. There is no correct answer. Let students guide the discussion and present their hypotheses before discussing explanations.

Ask students the questions in **bold.** Possible responses are in *italics.*

Can you describe what happened to your model?
Some of the pasta may have broken. The pasta may not have broken for some of the models. The differences in behavior of the pasta models may represent many things:

- *Scientists often have to build a model several times before it works. –OR–*

- *Some models may have been shaken harder than others. These models might represent ears that were closer to the source of noise, or less protected from the noise. –OR–*

- *There are natural differences between people. Some people have ears that are more susceptible to Noise-Induced Hearing Loss.*

Can you fix the broken pasta?

- *Students may have suggestions of ways to fix the broken pasta – glue, tape, wetting the pasta, etc. (You might ask if pasta could still be cooked and used for its original purpose if it were taped or glued.) These suggestions are similar to making a hypothesis. Doctors also try to think of possible ways to repair broken hair cells.*

Remember that the broken pasta represents very tiny hair cells (less than 1/1000 of an inch). Do you think that doctors can repair those hair cells after they are broken by loud noise?

Let students speculate. Do not immediately reinforce a single "correct answer."

There is currently no way to repair hair cells once they are broken. Hair cells do not grow back (unless you are a bird or a frog!). When you have a few hair cells that are broken, you may not notice that the ability to hear is diminished. **(Show the picture of the inner ear with the hair cells.)** Explain that each time you are exposed to very loud sounds, you are likely to have a few more hair cells destroyed so that the damage accumulates over time).

What do you think would be examples of sounds that would be loud enough to cause damage to hair cells?

Let students speculate.

****Show the "Decibel Scale of Common Sounds" from Appendix C, page 93 or look at the How Loud is Too Loud wheel from Appendix E, page 96.**

Spend time discussing the sounds at the various levels that cause noise-induced hearing loss.

How Can You Protect Your Ears?

Let the students talk about what they learned from the activity.

Summarize the Three Primary Hearing Protection Steps:

Turn It Down! (Turn down the volume on your stereo, Walkman, "Boom Box", other heavy sources)

Protect Your ears! (Carry and use ear plugs when going to an amplified concert, when using power tools, when around motorcycles or other noisy vehicles like jet skis and snow-mobiles)

Walk Away! (This is what you do if you can't do either #1 or #2 above).

Discuss times when the students have protected their ears, and times when they can protect them in the future.

EXPLANATION

In-depth background information for teachers and interested students.

An overview of the mechanism of hearing:

1. Sound waves enter the **outer ear** *(pinna and ear canal)*. The outer ear *(auricle* or *pinna)*, collects more of a sound wave than a simple hole in the side of one's head would. Some animals have larger ears that function like ear cones. Some animals can also turn their ears, to listen more effectively to sounds from particular directions.
2. The outer ear directs the sound via the ear canal to the eardrum *(tympanic membrane)* of the **middle ear**.
3. The middle ear consists of the eardrum and the three middle-ear bones (the *ossicles,* consisting of the hammer or *malleus*, anvil or *incus,* and the stirrup or *stapes*. (These are the smallest bones in the body.)
4. The middle ear transforms sound waves into mechanical energy (movements of the middle ear bones), conducting sound to the inner ear.
5. The inner ear *(cochlea)* contains microscopic cells ("hair cells") that are specialized to convert mechanical energy into electrochemical energy. These are approximately 10–15 microns wide, very tiny (considerably less than 1/1000th of an inch).
6. These hair cells possess tiny finger-like projections, called *stereocilia,* at their tops. The stereocilia rock back and forth when sound waves reach the inner ear.
7. The electrochemical activity of the hair cells activates nerves in the inner ear that, in turn, transmit the sound-induced activity to the brain.
8. The brain interprets the incoming neural activity as "I hear something."

Summary:

Sound energy travels through air as sound waves. The visible, external part of the outer ear called the pinna, or auricle captures these sound waves. Once in the ear, sound waves enter the ear canal and strike the eardrum, making it vibrate. This mechanical energy is amplified and transmitted via the middle ear bones to the inner ear or cochlea. Inside the cochlea, the sound travels as a moving wave in the fluid and structures of the inner ear, where the wave causes the tiny hairs (stereocilia) on the tops of the hair cells to move. The hair cells are highly specialized cells that convert the sound into electrochemical energy. In turn, that causes the auditory nerves to become activated and they transmit nerve impulses to the part of the brain where "hearing" occurs. Overall, this is a very complex system from the outer ear through the cochlea, which acts to make us very sensitive to sound, even low-level sound. It is the great

sensitivity of the hair cells that makes them so easily damaged by noise. Another way to visualize this process is as a sort of relay race. The vibrations of an object, such as a drum or piano, create sound waves. These sound waves are passed from one air molecule to another until they pass through the outer ear and are 'handed off' to the mechanical system of the middle ear. A portion of the middle ear relays the sound to the fluid of the middle ear where the pressure wave causes a membrane (the basilar membrane) to move up and down. This membrane movement in turn stimulates or relays the message, to the hair cells (stereocilia) of the inner ear. The hair cells convert the wave to electro-chemical energy and it is passed to the hearing (auditory) nerve, which relays it to the brain.

Noise-Induced Hearing Loss (NIHL):

We live in an increasingly noisy world. Just as the eye's sensitivity to light makes it vulnerable to damage from too much light, the ear's special sensitivity to sound makes it vulnerable to damage from loud sounds, referred to as Noise-Induced Hearing Loss (NIHL). The structures of the ear are tiny and delicate, and can simply be overwhelmed by the effect of loud sound. The louder a sound is, the less time is required to produce damage to hearing. Just as exposure to bright sun for too long can cause sunburn and damage your skin, exposure to intense noise can damage the hair cells in your inner ear, especially if the noise goes on for very long. Unfortunately, the stereocilia of the hair cells of the inner ear do not regenerate, as the skin will.

The delicate hairs at the base of the cochlea are exposed to all sounds and are very susceptible to damage. Because these first hair cells are sensitive to high frequency sounds, higher frequencies hearing is usually the first lost when someone acquires Noise-Induced Hearing Loss. So NIHL does not just make everything seem quieter – it actually changes the complex mixture of sound frequencies that the person is able to hear (high frequencies become more difficult or impossible to hear). Speech, for example, is composed of a complex mixture of sound frequencies. The result of changing the sound frequencies that we can hear is to make speech sound "mushy" and much harder to understand particularly when there is background noise. Often, people with Noise-Induced Hearing Loss think everyone else is mumbling (when it is really their own hearing that is down). When the mix is altered due to such selective hearing loss, one's ability to understand speech is impaired, and simply "turning up the volume" with a hearing aid does not fully restore hearing capability. Another unwanted result of the loss of certain sound frequencies is distortion of music. Music may sound distorted, tinny, or "harsh". Noise-Induced Hearing Loss can cause people to lose their ability to enjoy music. Although they can still hear the music, it no longer sounds good to them.

NIHL often results in **tinnitus** (ringing or other noises in your ears or head) – no one else can hear these sounds, they are heard only by the person who has undergone noise damage. Tinnitus may become permanent if noise damage is very severe or if the noise exposures are repeated frequently. About 12 million Americans experience permanent, severe tinnitus that often interferes with sleeping and causes other problems in daily life.

The fact that Noise-Induced Hearing Loss is often accompanied by tinnitus means that the person has two problems, not just one. Not only do they have trouble hearing what they want to hear, but they hear something they don't want to hear.

Protecting the Ears

It is not difficult to avoid most exposure to damaging sounds. There are three main methods for making sure your hair cells don't undergo noise-induced damage.

1. **Turn it Down!** (Stereo, Walkman, "Boom Box", other heavy sources)

2. **Protect your ears!** (Carry and use ear plugs when going to an amplified concert, when using power tools, when around motorcycles or other noisy vehicles like jet skis and snowmobiles)

> **NOTE:** Using Kleenex or similar soft materials doesn't provide much protection against intense noise – although some people believe it helps, scientific evidence shows that you only get adequate protection from earplugs (or protective earmuffs such as those worn by airport workers or construction workers). If you do not have earplugs or earmuffs with you when you find yourself exposed to really intense sound, you can use your fingers to close off your ear canals and thus get good sound protection. This method may not be practical if the sound exposure goes on for a long time but it works well if it is just a short-lasting sound.

3. **Walk Away!** (This is what you do if you can't do either #1 or #2 above). It's easy to demonstrate how increasing the distance between you and the sound source can reduce the amount of sound you are exposed to.

OPTIONAL EXTENSIONS

Students choose a TV show and watch it keeping a chart of situations or environmental sounds that could be dangerous to hearing. Lists should include any examples of people practicing hearing conservation. Students may also wish to explain what people **could** have done to protect their hearing in those situations.

CROSS-CURRICULAR CONNECTIONS

LANGUAGE ARTS

1. **Have students write or prepare a speech on the topic:**
   "How would losing some or all of my hearing change my life?"

   There is no right or wrong answer. Have students discuss, or write down their ideas.
   Students could write a short drama to act out a scenario in which one or more players has experienced subtle high frequency hearing loss. Ask students to keep the drama as respectful as possible. See if they could do the drama without exaggerating. Examples of impact include the inability to hear speech in a group conversation or when background noise is present, the inability to hear music as clearly as before, thus reducing the enjoyment from music; and difficulties understanding TV and movies (because of distortion of sound caused by NIHL).

2. **Have students research lifestyles in a "quiet" versus "noisy" culture.** Examine the types of noise people in each culture may experience. Are there any that may contribute to Noise-Induced Hearing Loss?

3. **Students create a series of one-minute Public Service Announcements (PSAs)** about causes of hearing loss and alternative practices to prevent hearing loss. Students practice reading their PSAs to classmates. If possible, arrange to have the PSAs used on a local radio station or used in an all-school assembly. Students can create Posters (about causes of hearing loss and ways to avoid hearing loss). The posters could be displayed throughout the school or featured in an all-school assembly.

4. **Write letters to manufacturers of noisy appliances, stereo systems, etc.** If possible, provide the decibel level you measured for their product using a sound meter. Explain the hazards of exposure to loud sounds to the manufacturer and suggest ways to lower the noise level. (Teachers need to instruct students where to place the sound level meter to obtain appropriate reading: For an individual activity (like using a hair dryer, a leaf blower, or a power saw) the meter should be placed in approximately the same position as the listener's ear, and facing toward the sound source, but not into the blast of wind generated by the hair dryer or the leaf blower. This may require a helper to hold the sound level meter and read the value on it (difficult for one person to do alone). For a group activity, like watching TV or attending an amplified concert or a sport event, the meter should be held or placed at several different locations corresponding to actual places where people sit or stand during the event. There will be quite a lot or variation from place to place and it is important to measure the range of different values. For example, sound levels for a person standing right near the amplifier at a rock concert might be 20 dB higher than for a person near the back, but even in the back the sound level is guaranteed to be well into the dangerous range.

PHYSICS & MATH

Use a sound meter to check the sound levels in various locations throughout the school and also during various different events such as sporting events, concerts, or school dances. Write a letter to the principal (or even the superintendent or school board) suggesting ways to reduce noise levels (turn down sources of sound, provide sound-absorbing coverings for walls and ceilings, etc.) Present the data in a graph.

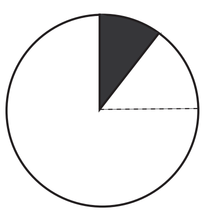
Shapes of Sound

Students observe the sound-producing modes of vibration of an object.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Waves Vibrations Sound Sense of Hearing	Observing Controlling Variables Inferring Questioning Hypothesizing	5-9

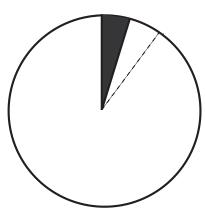
TIME REQUIRED

Advance Preparations



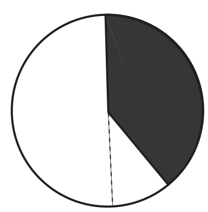
5-15 minutes

Set-Up



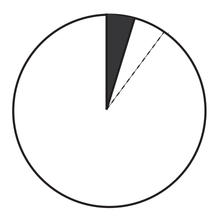
2-5 minutes

Activity



20-30 minutes

Clean-Up



2-5 minutes

MATERIALS

- Earplugs, one pair for each student, teacher, and other person in the room
- Glass or metal cooking pot lids at least 20 cm (8 in.) in diameter and with a central handle (one per group)
- A cup of fine sand or salt
- Rosin (as used for violin bows, available from any musical instrument shop or through the music teacher at your school)
- A violin bow
  —OR— large hack-saw and ball of cotton string, nylon cord, or dental floss (one per group is optional)

ADVANCE PREPARATIONS

❑ **STEP 1: PREPARING THE BOW:**

- Utilize an available violin bow (not from a fine instrument, but a spare bow) – one per group is optional. - OR - If you have no violin bow, remove the blade from a large hacksaw. Leave the adjustment screw loose. Unwind some cotton string, nylon string, or floss and tie it where you removed the hacksaw blade. You should be able to tighten the string or use the adjustment screw on the hacksaw.
- Rub rosin along the length of the bow or the tightened string on the hacksaw.

❑ **STEP 2: GATHER FOR EACH TABLE GROUP –**
if you do not have enough supplies for multiple groups, have student groups rotate through one "station."

- pot lid
- violin bow or hacksaw bow
- sand or salt (about 1/8 cup per group)

INTRODUCING THE ACTIVITY

Ask the students the questions in **bold.** Possible answers are shown unbold in *italics.*

What is sound?
Some students will give examples. Some students will talk about waves or vibrations. Some will talk in terms of the ear and our ability to hear. If students know a great deal about sound vibrations and waves, ask them how sound waves might be the same or different than radio, microwaves, or ocean waves. If no one is sure, assign homework research, asking students to research sound waves for future discussion.

Can you sense sound other than through your ears?
We may see the vibration of a drum, the waves of a recording device or on an oscilloscope, etc. Beethoven was deaf and sawed off the legs of his piano so that he could feel vibrations through the floor.

Is sound dangerous?
Research indicates between 15% and 20% of American teens have already suffered hearing damage due to noise exposure by the time they leave high school. Although they may not be aware of their hearing loss (because early effects of hearing damage are often subtle), Noise-Induced Hearing Loss causes significant changes in both the quantity and quality of the sound one is able to hear.

In the experiment today, we will look at the ability of sound to actually move matter and how objects vibrate. The "power" of sound vibrations will become obvious.

Students should work in groups of at least three.

Caution: This experiment may produce loud, high-pitched sounds. Always have students wear earplugs when working with loud noise or music.

Student Procedure:

1. Assign roles for the experiment. In each group there should be a "Holder," a "Bower" and an "Observer/Recorder."

2. Sprinkle a sparse dusting of fine sand or salt evenly over the entire surface into the upside-down pot lid or Chladni Plate (Optional Extension A).

3. Hold the base of the Chladni Plate assembly or handle of the pot lid firmly on a desktop without touching the Chladni Plate or pot lid.

4. Make sure the bow has rosin on it and draw it slowly down along the edge of the plate or lid. (If you have made a Chladni Plate in optional extension A, draw the bow along the middle of one edge of a rectangular plate.)

5. After several passes with the bow, record the pattern made by the sand or salt. The pattern may be sketched or photographed.

6. Spread out the sand or salt again and repeat by bowing in the same spot. Record the resulting pattern.

7. Spread out the sand or salt again and try bowing in a different spot or touching the surface edge of the plate or lid with a knitting needle (or tip of a scissors) and bowing.

DISCUSSION

Ask for student observations.
Observed patterns will vary depending on the shape and material of the plate or pot lid. It may take some practice to generate a pattern using a knitting needle or scissors to force a node. Check for understanding as to why the sand or salt formed a pattern. Remember that the sand or salt is moved by the energy of motion of the sound vibrations and collects or piles up where there is no vibration.

Can we actually see sound waves? No, but we can see what they do.
The sound produced by the vibrating Chladni Plates (or pan lids) resulted from the vibration patterns revealed by the sand or salt. We can also see sound waves with the aid of an oscilloscope, which turns sound waves into electrical energy.

Can we see things move as a result of sound waves?
The sand or salt was moved into the Chladni patterns by the energy of the vibrating object that also produced a sound. This sound energy is what is collected by the outer ear and transferred by the middle ear to the cochlea in the inner ear. The energy moves through the fluid-filled cochlea causing the tiny stereocilia on the hair cells to move. Those movements are responsible for hearing.

Discuss the fact that in our inner ear, sound waves actually move small hair-like structures (called stereocilia) that are attached to the tops of the specialized sensory cells (called hair cells). This action is similar to the way in which sound vibration caused the salt or sand to move on the Chladni Plate. These hairs are "tuned" to different frequencies of vibrations making different parts of the cochlea more or less sensitive to different frequencies of sound. The inner-ear stereocilia are much smaller than grains of sand. If incoming sound is intense enough, the sound waves cause some of the stereocilia to bend over or even break. The stereocilia may be able to straighten out and return to their normal position if the sound exposure was not too intense. However, with repeated exposure to loud sounds over time, or if sound is made sufficiently intense, more and more hair cells will suffer damage. Some stereocilia will break, for which there is no repair (unless you're a bird or a frog!). The result will be a permanent decrease in the ability to hear. This often occurs as a gradual loss of hearing which may not be noticeable at first. Most musicians, especially rock musicians suffer hearing loss even in early adulthood. This is known as "Noise-Induced Hearing Loss" (NIHL).

Ask students to give examples of some loud sounds they are exposed to in their environment.
Noise is not the only cause of hearing loss, but it is the most common cause in America (and in other industrialized nations). Loud noises (at or above 85 dB) can hurt your ears by damaging the sensitive hair cells of the inner ear. It makes no difference whether you like the loud sounds or not – if they are at or over 85 dB, they can begin to damage hair cells in your inner ear.

Because there is currently no treatment to repair hair cells that have been damaged by loud sound, it is important for people to protect themselves from such damage. Fortunately, there are several actions a person can take to prevent Noise-Induced Hearing Loss.

Following are three major ways to protect hearing:

- **Turn down the volume**
- **Walk away (put as much distance as possible between your ears and the sound source)**
- **Wear hearing protection such as ear plugs or "ear muffs"**

Revisit the "QUESTIONS TO DETERMINE WHETHER YOU ARE BEING EXPOSED TO EXCESSIVE SOUND THAT MAY DAMAGE YOUR HEARING" in the Balloon Drum Activity, page 26.

If you answer YES to any of the questions, you have been exposed to damaging sound levels.

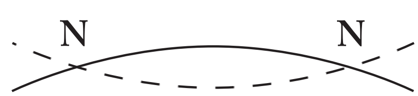
Remember: A concert can be just as damaging as noise from firearms or sirens or noisy engines. Also, growing accustomed to loud noise does not diminish its ability to damage our hearing or to cause other physiologic effects.

EXPLANATION

In-depth background information for teachers and interested students.

The rectangular or circular plate assemblies are usually called "Chladni Plates" in honor of 18th century scientist Ernest Chladni. Chladni conducted extensive work on fixed circular plates and developed Chladni's Law which states that modal frequencies of fixed circular plates varies according to f~(m+2n)^2, where n is the number of circular nodes and m is the number of diametric nodes.

It has been found theoretically and experimentally that thin plates or membranes resonate at certain "modes." A **mode** is just a term for one of the many ways an object can vibrate. This concept can be demonstrated with a vibrating string: tie one end of a string to a fixed object and smoothly vibrate the other end of the string. If vibrated fast enough, there will be a point or points in the middle that seem to be still while the rest of the string vibrates wildly. These points are the nodes. Imagine what happens when you strike a xylophone bar in the middle or a cymbal on the edge and set it vibrating. The bar is supported at two points towards the ends. The simplest mode of vibration is this: when the middle of the bar goes up (as shown by the solid lines in the figure) the ends of the bar go down. When the middle goes down (dashed lines), the ends go up. For the circular cymbal, the clamp in the middle forces a place where there is no motion. The points that do not move are called **nodes** and are marked N in the diagram of the xylophone bar below. (A good way to keep the terms "mode" and "node" from getting mixed up is to remember that the **no**de has **no** motion.)



Due to initial conditions imposed upon the plate (i.e. fixed edges, shape, distribution of mass) the plate and other objects can vibrate only at certain allowable frequencies and will demonstrate predictable "node" patterns. The patterns of vibration can be very complex and may also depend on where the energy causing the vibration is applied. Nodes are points on the plate that vibrate with zero amplitude (are motionless), while other surrounding points have non-zero amplitude (vibrate some distance). On a two-dimensional vibrating plate, the nodes are not points, but curves. With the circular plate, the most commonly observed pattern is concentric circular nodes and diametric modes, while with the rectangular plate commonly produces nodes parallel with the boundaries. In an object that is not firmly clamped, a vibration cannot easily move the center of mass of the object. It follows that, if some part is going up, another part is going down. In the simple motion at resonance, the point(s) that divide(s) these regions are nodes. When a violin or an isolated part is vibrating, the center of mass doesn't move much, so once again it can be divided into parts that are going up and others that are going down.

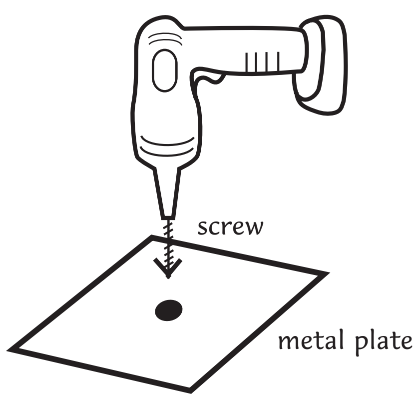
OPTIONAL EXTENSIONS

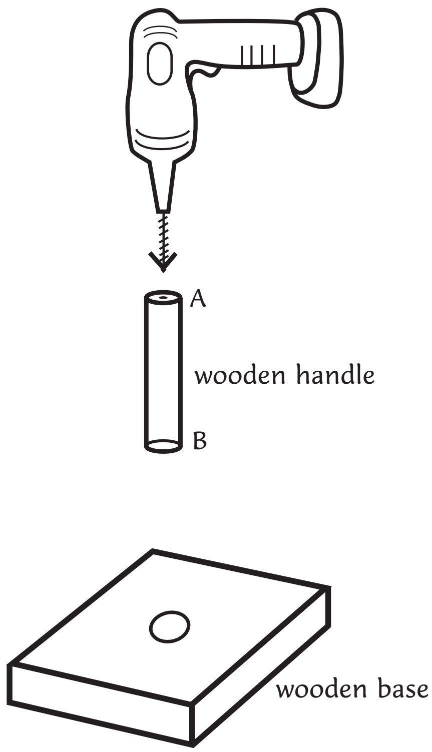
A. Make Your Own Chladni Plate Standing Display
See labeled picture on page 78 for supplies.

1. Your plate can be any size and any thickness—however, remember that the plate will be fixed in the middle at one point. If your metal is thin, make the plate small. A 1 mm-thick metal plate should be 10 to 15 cm (4 to 6 inches) square. If the plate is not perfectly shaped—no matter. Try to file the edges as flat as possible. Don't dent or scratch the surface if you can avoid it.

2. Drill a hole in the middle of the metal plate (the diameter of the hole is dependent on the size of the screw you use to secure the plate).

3. Cut off a length of rod (broom handle or wooden dowel) approximately 15cm (6 in.) long. Mark one end of the dowel or broomstick "A" and the opposite end "B."





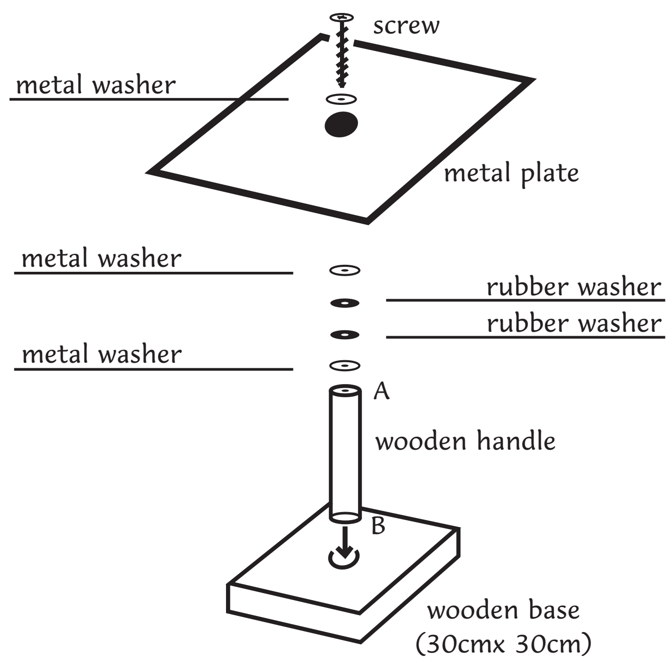
4. Carefully drill a small hole into end “A” of rod (broom handle or dowel). This hole should be smaller than the actual screw that will go into the dowel in step 7, below. (Drilling the smaller hole first will prevent the (dowel or broom handle) from splitting when you screw the plate on in step 7.

5. In this step you will be preparing the square piece of wood board, approximately 30 cm. by 30 cm. (1 ft. by 1 ft.) to serve as a base for a vertical rod (the broomstick or dowel) in much the way a Christmas tree stand might hold up a Christmas tree: Drill a hole the diameter of the broom handle or the dowel in the center of the board. To find the center you can draw a diagonal lines from opposite corners of the board. Where the two diagonal lines meet, at the center of an “X”, is the center of the board. This is where you will drill the hole.

The broom handle or dowel will need to wedge tightly into this hole. If you don't have a large enough drill bit, try filing a smaller hole to the appropriate size.

6. Insert the "B" end of the rod (dowel or broomstick) into the hole of the wooden base. This results in a horizontal wooden base with a vertical rod standing securely upright.

7. Finally place a metal washer on top of the "A" end of the upright rod (broom handle or dowel), followed by the two rubber washers, another metal washer, then the plate, the final metal washer on that and screw the assembly in place.



B. Experiencing Sound Energy

1. Carefully cut the neck off a balloon.
2. Stretch the remaining part of the balloon over the end of a cardboard tube (e.g., an empty toilet paper or paper towel tube.)
3. Secure the balloon with a small wide rubber band. Take turns talking softly and loudly into the tubes while you lightly touch the balloon end with your fingertips.
4. Can you feel the vibrations?
5. Do they change as your voice changes?

C. Bass and Treble

1. Use your balloon tube from optional extension B to feel sound vibrations from a speaker.
2. Hold the open end of the balloon tube right in front of, but not touching, the speaker.
3. If available, change the bass and treble settings on your stereo.
4. Can you feel a difference?
5. Can you also feel the vibrations within your body?
6. What do you feel the most, the vibrations from a high bass setting or a high treble setting?

D. Balloon Drum

Try the Dangerous Decibels Balloon Drum Activity from the Intermediate curriculum, page 19. Have students bring in their own music tapes to test.

E. Inquiry

Students develop an experiment to investigate whether noise affects concentration. For example, assign a poem to memorize or some math problems to do and have one group of students try to complete the assignment in a noisy environment (such as cafeteria) while the other group works in a very quiet environment. Document results and report to the class. Perhaps publish results in a school newspaper. Repeat the experiment changing roles of the two groups. (See further information about Noise Pollution in the "How Loud Is Too Loud" activity explanation on page 101, Appendix E.)

CROSS-CURRICULAR CONNECTIONS

MUSIC

A. Musical Comb

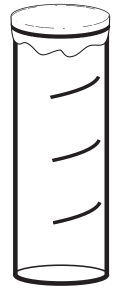
Fold a piece of wax paper in half and place a comb inside the fold.
Hold the comb at each end, pressing the paper against the teeth of the comb.
Gently press your lips against the paper and hum, keeping your lips slightly parted.

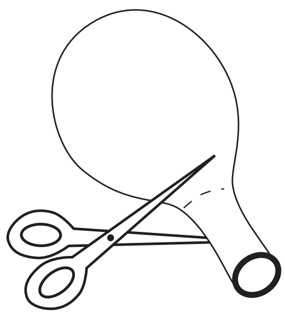
B. Kazoo

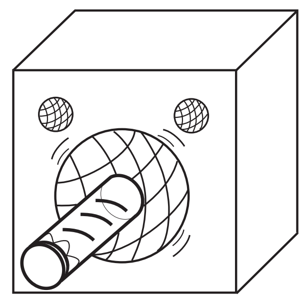
Take an empty cardboard tube and, using a paper punch, make a hole at one end of the tube about 1/2" from the end.

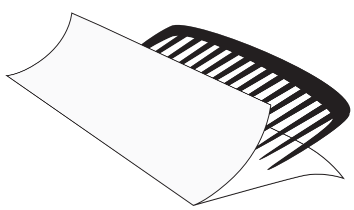
Cut a square of wax paper large enough to cover the end of a toilet paper tube (not smaller than 4”). Fold the wax paper down over one end of the toilet paper tube and rubber band it in firmly in place.

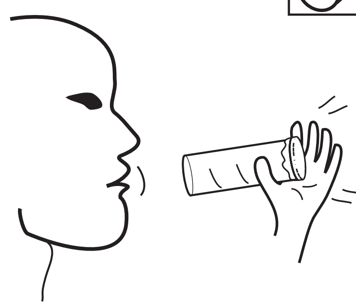
Explanation:
Humming causes the paper to vibrate and produce a buzzing sound. You can play a tune this way.











RESOURCES

Acoustic and Vibration Animations

http://www.kettering.edu/~drussell/Demos/MembraneCircle/Circle.html

This site by Dan Russel, Ph.D. Associate Professor of Applied Physics at Kettering University in Flint MI contains animations which visualize certain concepts concerning acoustics and vibration. In particular, this page shows various modes of vibration of a circular membrane. Go to the home page to select other examples.

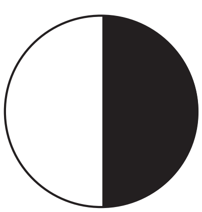
Sound Measures

Students use a sound level meter to measure, compare and graph sound levels in different environments.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Waves	Observing	5-9
Vibrations	Controlling Variables	
Sound	Inferring	
Sense of Hearing	Questioning	
	Hypothesizing	
	Collecting Data	
	Analyzing Data	
	Graphing	

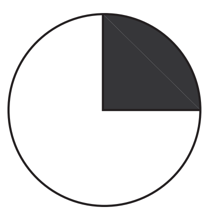
TIME REQUIRED

Advance Preparations



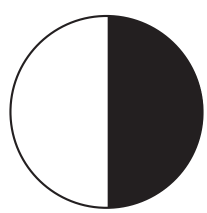
30 minutes

Set-Up



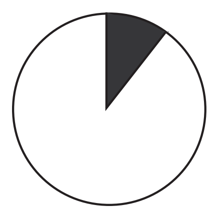
15 minutes

Activity



30 minutes

Clean-Up



5 minutes

MATERIALS

For **Sound Level Meter** Activity**:**

- Radio Shack® Digital Sound Level Meter (model 33-2055)
- Blender or radio
- Meter stick or tape measure

ADVANCE PREPARATIONS

For **Sound Level Meter** Activity**:**

- ❑ Become familiar with the operation of the Radio Shack Sound Level Meter.
- ❑ Acquire a blender or radio to produce the sound. A blender is recommended because it produces a fuller range of sound frequencies.

INTRODUCING THE ACTIVITY

Introduce the decibel chart.
0 decibels represents the softest sound we can hear, the threshold of hearing. An increase of 10 decibels represents a little more than a 3-fold increase (about 3.16) in the air pressure change created by the sound wave. A 20 decibel increase is more than a 3 times 3 increase in sound pressure (about 10 times greater). And a 30 decibel increase is an increase in sound pressure of more than 3 times 3 times 3 (3.16 raised to the third power or 3.16 cubed). In other words, a 40 decibel sound creates sound pressure levels that are more than 30 times as great as a 10 decibel sound. The threshold of pain for the average human ear is 120 decibels. **This represents a pressure change over 991,000 times greater than that experienced by the ear when exposed to a 0 decibel sound!**

Ask students to make hypotheses about what happens to a sound as you get further and further away from the source or closer to the source. Does the sound get louder or softer? How fast does the sound change?

CLASSROOM ACTIVITY

Procedure:

1. Place blender or radio near the edge of a flat surface facing the classroom. If using a radio, turn on the radio and tune between known radio stations until there is a constant static sound.

2. Set the Sound Level Meter to 80 dB, select setting **A** for **Weighting** and set the **Response** setting to **SLOW.**

3. Locate the Sound Level Meter 10cm (4 in.) away from the radio.

4. Adjust the speed of the blender or volume of the radio to get as close to a steady 80 dB reading as possible. This will be the initial sound level and the zero distance for comparing sound level changes with distance.

5. Without changing the speed of blender or volume on the radio, move the Sound Level Meter 25 cm (10 in.) further away from the speaker and record the sound level in dB. You may need to reduce the decibel range of the Sound Meter as it is moved further away from the source of the sound.

6. Continue moving the Sound Level Meter away from the blender or radio in 25 cm (10 in.) increments and record sound levels in dB until the level falls below the 50 dB limit of the meter.

7. Collected data can be graphed with distance as the independent variable (x-axis) and sound level as the dependent variable (y-axis).

   Procedure may be repeated with the weighting adjustment selected for C-weighting.

DISCUSSION

Sound Level Meter

Ask students if the sound level changed with distance as they had predicted. Was the change faster or slower than they thought it might be?
Answers will vary with predictions.

Sometimes scientists collect sound level data using measurements that take other factors into account. There are special scales that include weighting factors. Weighting refers to the range of frequencies that the sound level meter is measuring. "A"weighting primarily measures frequencies in the range which corresponds to the range of greatest sensitivity for the human ear. "C" weighting means that the meter will measure sound levels uniformly over the frequency range from 32-10,000 Hz, giving an indication of the overall sound level.

Ask students to give examples of some loud sounds they are exposed to in their environment.
Noise is not the only cause of hearing loss, but it is the most common cause in America (and in other industrialized nations). Loud noises (above 85 dB) can hurt your ears by damaging the sensitive hair cells of the inner ear. It makes no difference whether you like the loud sounds or not – if they are over 85 dB, they can begin to damage hair cells in your inner ear.

Because there is currently no treatment to repair hair cells that have been damaged by loud sound, it is important for people to protect themselves from such damage. Fortunately, there are several actions a person can take to prevent Noise-Induced Hearing Loss.

Following are three major ways to obtain hearing protection.

- **Turn down the volume**
- **Walk away (put as much distance as possible between your ears and the sound source)**
- **Wear hearing protection**

Revisit the "QUESTIONS TO DETERMINE WHETHER YOU ARE BEING EXPOSED TO EXCESSIVE SOUND THAT MAY DAMAGE YOUR HEARING" in the Balloon Drum Activity, page 27.

If you answer YES to any of these questions, you have been exposed to damaging sound levels.

EXPLANATION

In-depth background information for teachers and interested students.

The ability of a normal, healthy human ear to hear spans an enormous range. Because of this, the scale for measuring sound must also span an enormous range yet still be easy and compact to write. This is why the **decibel** scale is related logarithmically to the huge range of **pressure amplitudes** to which the ear is subjected to. This makes sense because research indicates that humans have evolved to have a logarithmic response to sound. This helps us to compress the huge range of hearing so that our response to variations in loud sounds is similar to the response to variations in weak sounds. The pressure change experienced by the ear when subjected to a 120 decibel sound **(Caution! This is the pain threshold for the average human ear!)** is about one million times greater than the pressure change created by the softest sound we can hear, defined as 0 decibels. It is easier and takes less room to write 0 dB or 120 dB than a number followed by six zeroes!

To understand the relationship between pressure amplitude and decibels it helps to understand that as a sound wave moves through the air, slight increases and decreases of the background air pressure occur. The size of these increases and decreases are called **pressure amplitude**. The size of these increases and decreases is also related to the loudness of the sound.

Decibel scales can be used for many measurements other than sound where there are large ranges of values. There are decibel scales defined for use in electronics and optics. The scales vary depending on what quantity is being used as a reference. One of the decibel scales for sound provides a way of creating a logarithmic scale **relative** to a pressure amplitude reference. This reference value is referred to as the **threshold of hearing** (for obvious reasons). The pressure amplitude for the threshold of hearing is

$$2 \times 10^{-5}\ N/m^2$$

This is a standard value defined for a 0 dB pure sine wave at a frequency of 1000 Hz.
The decibel scale for pressure amplitude is called **Sound Pressure Level,** typically abbreviated **SPL.** The formula relating SPL to pressure amplitudes is:

$$\mathbf{SPL = 20\ log(P/P_0)}$$

Where: **SPL** is the sound pressure level in decibels

P_0 is the reference threshold of hearing, 2×10^{-5} N/m^2

P is the measured pressure amplitude in N/m^2

Using this formula, it can be shown that an increase of 6 decibels results in a doubling of the pressure amplitude (and a decrease of 6 dB cuts the pressure amplitude in half). Or that increasing the SPL from 70 dB to 80 dB increases the pressure amplitude experienced by the ear by 3.16 times and increasing from 70 dB to 90 dB increases pressure amplitude by $(3.16)^2$ or about 10 times.

See **Decibels Scale of Common Sounds,** Appendix C, page 93.

OPTIONAL EXTENSIONS

Sound Meter

- Allow students to use Sound Level Meter to monitor sound levels during activities around the school such as Lunch Room, Pep Rally, Classroom, Test Time, and Playground etc.
- Allow students to check out Sound Level Meters and monitor at-home activities such as Street, Interior Auto, and Music Listening sound levels.

RESOURCES

http://webphysics.ph.msstate.edu/jc/library/15-5/
This page includes an applet for comparing sounds to a reference. Requires computer with sound.

http://www.temple.edu/cetp/temp/dcblevel.html
A simple chart of some typical sound levels of various activities.

http://www.audiophilia.com/hardware/spl.htm
A primer on the use of the RadioShack Sound Level Meter in optimizing music listening spaces.

http://www.howstuffworks.com/framed.htm?parent=question124.htm&url=http://arts.ucsc.edu/ems/music/tech_background/TE-06/teces_06.html
An explanation of the general definition and use of the term *decibel.*

Appendix A

Dangerous Decibels Glossary

Auditory Nerve
The nerve that carries electrical signals generated by sound from the inner ear to the brain.

Auricle
The visible part of the outer ear. Also called the pinna.

Basilar Membrane
The membrane that forms the lower boundary of the cochlear canal, and on which rests the organ of Corti, of which the hair cells of the cochlea are part.

Cerumen
Ear wax.

Cilia
Small finger-like or hair-like projections from cells in the body

Cochlea
The spiraled part of the inner ear that contains the organ of sound reception.

Decibel
The unit of measure commonly used to describe the loudness of sounds in our environment. Based on a logarithmic scale in which an increase of 20 decibels (20 dB) indicates an increase in sound loudness by a factor of 10, 40 dB indicates increasing by a factor of 100, and 60 dB indicates increasing by a factor of 1000.

dB
A measure of sound intensity (abbreviation for Decibel)

Eardrum
The tympanic membrane, the inner end of the auditory canal.

External Auditory Canal
The conduit from the auricle, or pinna, to the tympanic membrane.

Frequency
The speed with which a repetitive wave repeats itself

Hair Cells
Microscopic cells within the inner ear that have tiny, finger-like projections on top. These "hairs" are moved back and forth by the pressure wave in the inner ear fluid. Motion of the hairs leads to the activation of nerves, and it is the electrochemical impulses in these auditory nerves that are transmitted to the brain causing hearing sensations.

Hertz
A unit of frequency (of change in state or cycle in a sound wave, alternating current, or other cyclical waveform) of one cycle per second. It replaces the earlier term of "cycle per second (cps)." The unit of measure is named after Heinrich Hertz, German physicist.

Inner Ear
A complex structure of interconnected fluid-filled chambers and canals within the bone of the skull. One portion of the inner ear is not involved in hearing, but instead provides a sense of balance. The other portion of the inner ear, called the *cochlea*, is the organ of hearing.

Kazoo
A musical instrument made by blowing against paper folded around a comb.

Labyrinth
The interconnected fluid-filled chambers of the inner ear.

Malleus
The bone or ossicle of the middle ear that is attached to the eardrum.

Middle Ear
The air-filled space between the eardrum and the inner ear, containing the three middle-ear bones (the hammer or *malleus*, the anvil or *incus* and the stirrup or *stapes*).

Mode
The way an object vibrates. Mode depends on shape, thickness, material and many other factors.

Node
Points on an object that vibrates with zero amplitude (remain motionless), while other surrounding points have non-zero amplitude (move). Nodes are points for a one-dimensional object like a string, or lines for a two-dimensional object like a plate.

Oscillation
Back and forth movement that repeats regularly between two fixed positions.

Oval Window
An opening into the inner ear that is filled by the “footplate” of the stirrup (stapes).

Perception
Physical sensation (e.g. touch, taste, hearing, vision) as interpreted by the brain

Pinna
The visible part of the outer ear, also called the auricle. If you can wiggle your ears, this is what you wiggle.

Pitch
The aspect of sound that depends on our ability to perceive different sound frequencies; high-pitched sounds are those with relatively high sound frequencies (e.g. above 1000 cycles per second) while low-pitched sounds are generally those with relatively low sound frequencies (e.g. 200 cycles per second or lower).

Pollution
The concentration of a substance (or sound) to levels harmful to the natural environment (including humans).

Reflection
Bouncing back of wave energy. When a wave strikes the boundary between two media in which the wave’s velocity is different, part of the wave is reflected.

Sensitivity
The degree to which one responds to a stimulus.

Sound Wave
A longitudinal wave of motion, spread through oscillating molecules, initiated by a vibrating surface or by a sudden, rapid force (as in an explosion). In the case of sound waves, the molecules do not actually move to a new location, instead each set of molecules “bumps” the molecules next to it, progressively transferring motion to new sets of molecules further and further away from the sound source until the wave motion dies out.

Stapes
The tiny stirrup-shaped ossicle of the middle ear that contacts the oval window of the cochlea.

Stereocilia
Tiny hairs. See “hair cells” of the inner ear.

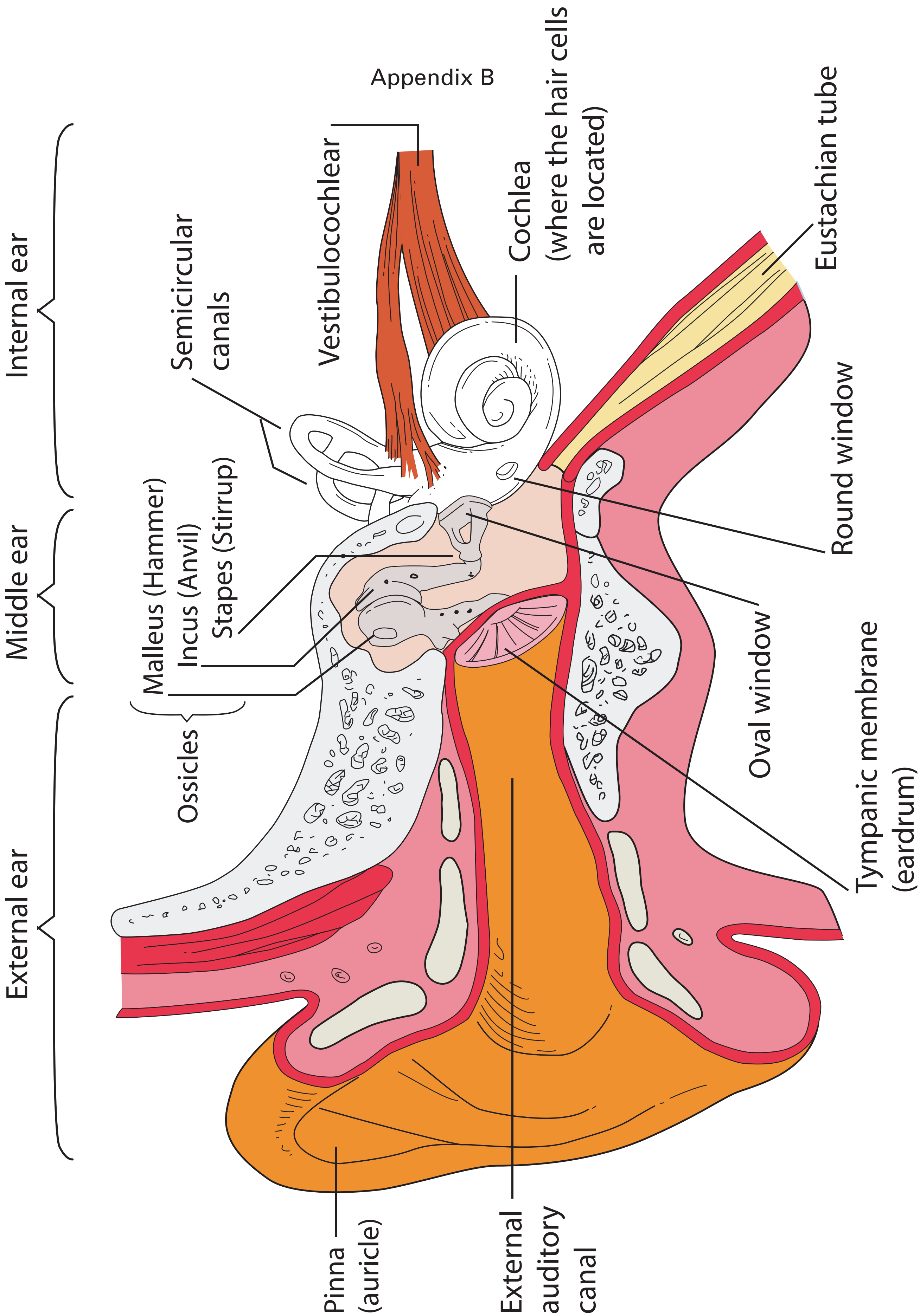
Tinnitus
Ringing or other sounds in your ears or head, not caused by any outside source of sound.

Tuning Fork
A special instrument used for producing a specific tone when the fork is struck.

Tympanic Membrane
The ear drum; this is a very thin membrane that forms the inner ear of the ear canal. The ear drum is the first component in the system of mechanical transmission of sound energy through the middle ear.

Vibration
A regular movement or shaking back and forth of some object

Wave
A moving disturbance (of molecules or of energy); in wave motion, energy is transferred to a new location but matter remains in its original location even though the wave motion travels through the matter.

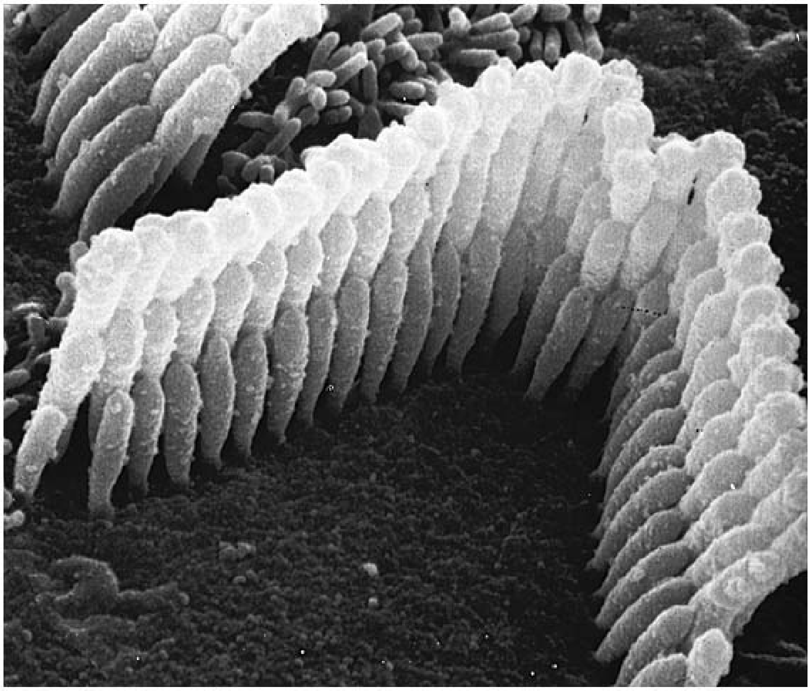

Internal ear
Middle ear
External ear
Semicircular canals
Vestibulocochlear
Cochlea (where the hair cells are located)
Eustachian tube
Round window
Oval window
Tympanic membrane (eardrum)
Malleus (Hammer)
Incus (Anvil)
Stapes (Stirrup)
Ossicles
Pinna (auricle)
External auditory canal

Appendix C

Decibel Scale of Common Sounds

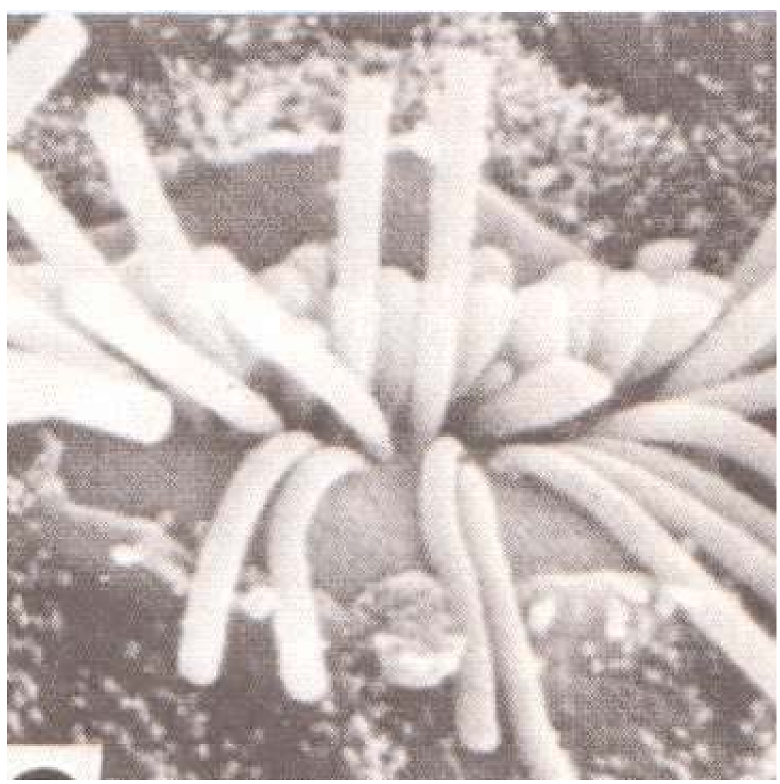
EXAMPLE NOISE LEVELS IN DECIBELS

Noise Source	Decibel Level	Noise Effect
Jet takeoff (25 M)	150	Eardrum rupture
Aircraft carrier deck	140	Earphones at high level
Jet takeoff (100 M)	130	
Thunderclap, live rock music,	120	Human pain threshold
Chain Saw Steel Mill, Riveting, auto horn at 1 M	110	
Jet takeoff (305 M), outboard motor, power lawn mower, motorcycle, farm tractor, jackhammer, garbage truck	100	Serious hearing damage (8 hrs)
Busy urban street, diesel truck, food blender	90	Hearing damage (8 hrs)
Garbage disposal, dishwasher, average factory, freight train (15 M)	80	Possible hearing damage
Freeway traffic at 15 M, vacuum cleaner	70	Annoying
Conversation in restaurant, office, background music	60	
Quiet suburb, conversation at home	50	Quiet
Library	40	
Quiet rural area	30	
Whisper, rustling leaves	20	Very Quiet
Breathing	10	
	0	Threshold of hearing



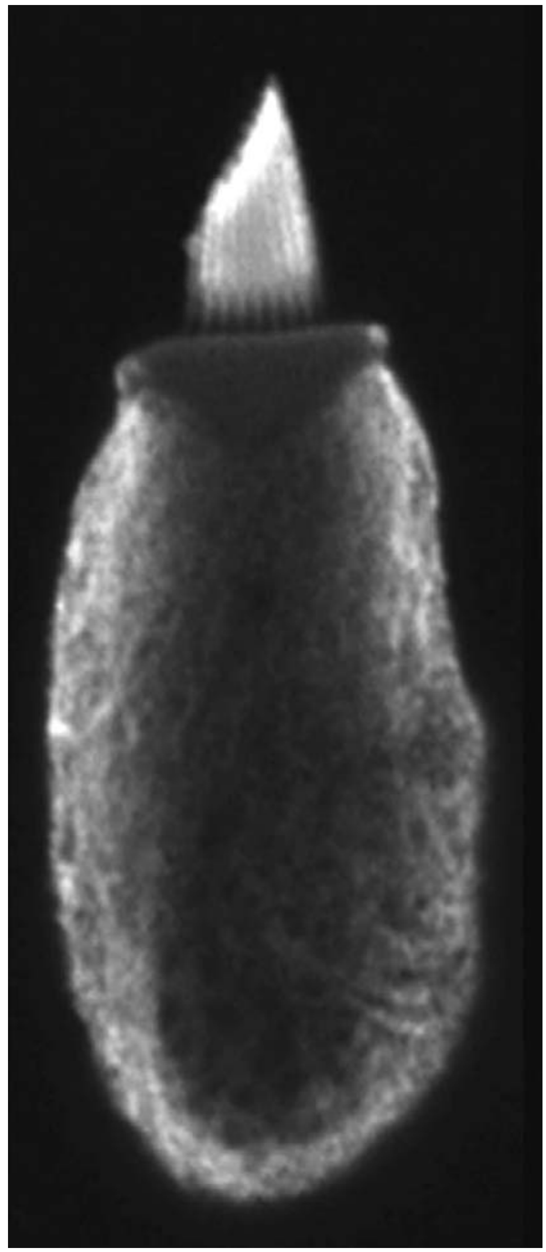
Normal stereocilia photo -
David J. Lim. Functional Structure of the Organ of Corti: A Review. Hearing Research, 22 (1986) 117-146 Elsevier 2b –

Damaged stereocilia photo -
Hunter-Duvar, I.M. (1977): Morphology of the normal and the acoustically damaged cochlea. SEM 1977, II, 421-428.



Flaming Pickle - whole stereocilia cell

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



Appendix E

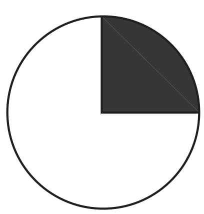
How Loud Is Too Loud?

An activity to do at home or with a youth group. Construct a fun learning tool to help recognize safe levels of exposure to various sounds.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Sound Decibels Sense of Hearing	Observing Measuring Comparing	7-12 (requires reading)

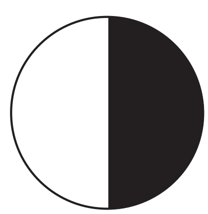
TIME REQUIRED

Getting Ready



15 minutes

Activity



30 minutes

SUPPLIES YOU'LL NEED

1 per person of the following

- Paper fastener (brad)
- Masters A and B

1 per group of the following

- Scissors
- Glue or Scotch tape

GET READY

For the adult supervisor.

- Have supplies on hand.
- Print or photocopy Master A and Master B for each person. (These are the large circles with the dotted lines for cutting.)
- For older children, print or copy the sections in boxes so they can follow instructions to do the activity independently. If you will be working with a group, follow the instructions below to make a sample "How Loud Is Too Loud" wheel to show the children.

TALK WITH THE CHILDREN FIRST

Questions for the parent or adult supervisor to ask children before the activity to get children thinking about sound.

Ask the children the following questions in bold.
Possible answers are shown in italics.

What are some quiet sounds?
Whispering, music (sometimes!), a baby breathing, the wind, tiptoe steps, sleeping, mice, the TV turned down very low, a feather falling, etc.

What are some loud sounds?
Motorcycles, music (sometimes!), drums, guns, lawn-mowers, hammers, crying babies, cats fighting, screaming, concerts, car races, motor boats, etc.

Are sounds ever too loud?
Some children will say yes, others may say no. Let them voice their opinions.

What do you usually do when you are around loud sounds?
Again answers will vary.

If you are working with a group, show children your sample "How Loud is Too Loud " wheel so they can visualize what they will make.
Hand out a copy of Masters A and B to each child. Masters A and B are the inner and outer wheel for them to cut.

MAKING THE "How Loud Is Too Loud" WHEEL

You may give the older children the instructions and let them work on their own. Younger children may need supervision or help.

STEPS TO FOLLOW

How to Make a "How Loud Is Too Loud" Wheel

Step 1. Find the paper with a picture of an ear in the middle.

Step 2. Cut along the black dotted line.

Step 3. Find the paper with a circle that looks like a bicycle wheel with spokes.

Step 4. Cut out the circle by cutting along the black dotted.

Step 5. Place both circles with the pictures facing up on the desk.

Step 6. Put your circles with the picture of the ear on top of the circle with the spokes.

Step 7. Join the two circles by pressing and fastening a brad through the center of both circles at the black dot.

You have completed your "How Loud is Too Loud" wheel. To use your wheel, hold the top circle and turn the bottom circle until you can see a picture in the "SOUND" window. Directly across from it, you can see how many decibels are produced, on average, by the sound source. It also tells you how long you can listen to it before hearing damage can occur.

FURTHER DISCUSSIONS

What are some quiet sounds? Some loud sounds?
Talking is a quiet sound. The rock concert and the chain saw are very loud sounds.

Which sounds could damage your hearing quickly? Can you think of other sounds that might be too loud?
Stereo headphones, a rock concert, and a chainsaw.

Does it matter how long you listen to a sound?
Children may have noticed that every sound on their wheel had a time attached to it (except the safe sound level from conversational talking).
The times on the "How Loud Is Too Loud Wheel" refer to the amount of time you can listen to a sound before your hearing is damaged.

Note: **Even when hearing damage occurs, the impact on your total hearing is gradual.**
Rock musicians often don't notice they have damaged their hearing until it is too late. Most rock musicians have hearing loss.

To prevent noise-induced hearing loss: Study the Caution Message signs on your wheel and follow the 3 basic rules:

3 basic rules to…….. PROTECT YOUR EARS!

1. **Turn It Down** (Turn down the volume!)
2. **Walk Away**
3. **Protect Your Ears**
   (Earplugs, ear muffs and fingers in the ears work. Tissue in the ears doesn't work.)

LEARN MORE

In-depth background information for adults and interested children.

Visit the Dangerous Decibels Exhibit at the Oregon Museum of Science and Industry (OMSI) in Portland, Oregon. Book an OMSI Dangerous Decibels program in your community (if you live in the Pacific Northwest of the U.S., or visit www.dangerousdecibels.org.

More about ‘How Loud is Too Loud’: Noise Pollution

Noise is defined as “unwanted sound” and it is America’s most widespread nuisance. It is not a new problem. In the first century BC, Julius Caesar banned chariots in Rome to cut down the deafening noise of chariot wheels on stone roads. Throughout the ages people have complained that they can’t “hear themselves think” due to noise. Some people talk of “moving to the country” to get away from the noise of the city. Noise presents a real danger to people’s hearing and general health. In addition to the damage noise can cause to our ability to hear, noise can produce other physical and psychological stresses. Although we may seem to become accustomed to noise, our bodies still respond and our hearing capability gradually diminishes. Noise exposure has been linked to:

- permanent hearing damage resulting in reduced ability to communicate
- increased adrenaline, high blood pressure and faster heart rate
- heart and circulatory disease
- overall stress on the body
- problems with fetal development and low birth weight
- interference with the development of language skills
- interference with conversation and social interaction
- diminished work efficiency
- diminished quantity and quality of sleep
- increase in antisocial behavior, extreme emotions and behavior
- accidents, due to overall stress and due to obscuring audible alarms

Despite our knowledge that noise is damaging to our health, the noise levels in our environments continue to rise. The Acoustical Society of America indicates that since 1950 the volume of noise in daily life has doubled every ten years.

Unfortunately, the damage that sound can inflict on our ears does not depend on whether we like it or not. A concert can be just as damaging as noise from firearms or sirens or noisy engines. Also, growing accustomed to loud noise does not diminish its ability to damage our hearing or to cause other physiological effects.

TAKE IT FARTHER…
TEST THE SOUNDS AROUND YOU

Make your own "How Loud Is Too Loud" wheel

SUPPLIES

- a sound level meter (purchase, e.g. from Radio Shack™, or borrow one)
- paper
- paper clips or glue stick
- scissors
- ruler
- something to draw with (crayons, colored pencils, markers, etc.)

Measure and draw 12 rectangular boxes 1.5 inch by 1 inch (3.5 by 2.5 cm).
Choose 6 sources of sound in your environment.
Draw small pictures of 6 sound sources in 6 of your small boxes.
Use a sound level meter to measure the decibel level for the sound sources from each of your 6 pictures.
Write down the decibel sound pressure level reading for each sound on the back of the picture of the sound. Write the same decibel reading in one of the 6 empty rectangular boxes along with the "safe listening times" from the following table:

Decibel Level	Length of Time
85	8 hrs.
88	4 hrs.
91	2 hrs.
94	1 hr.
97	30 min.
100	15 min.
115	30 sec.

- Cut out your twelve boxes.
- Place one of your sound pictures over each of the six print pictures on the bottom circle of your "How Loud Is Too Loud" Wheel. (Master B)
- Place the rectangular box with the matching sound level reading on the opposite side of the circle.
- Attach the pictures and the sound level measurements with paper clips or glue stick.
- Assemble your personalized "How Loud is Too Loud" Wheel.
- Use the wheel to teach or quiz you family and friends.

Piece "A"

Cut along dotted lines only.

SOUND

How many decibels?*

How much time before damage?

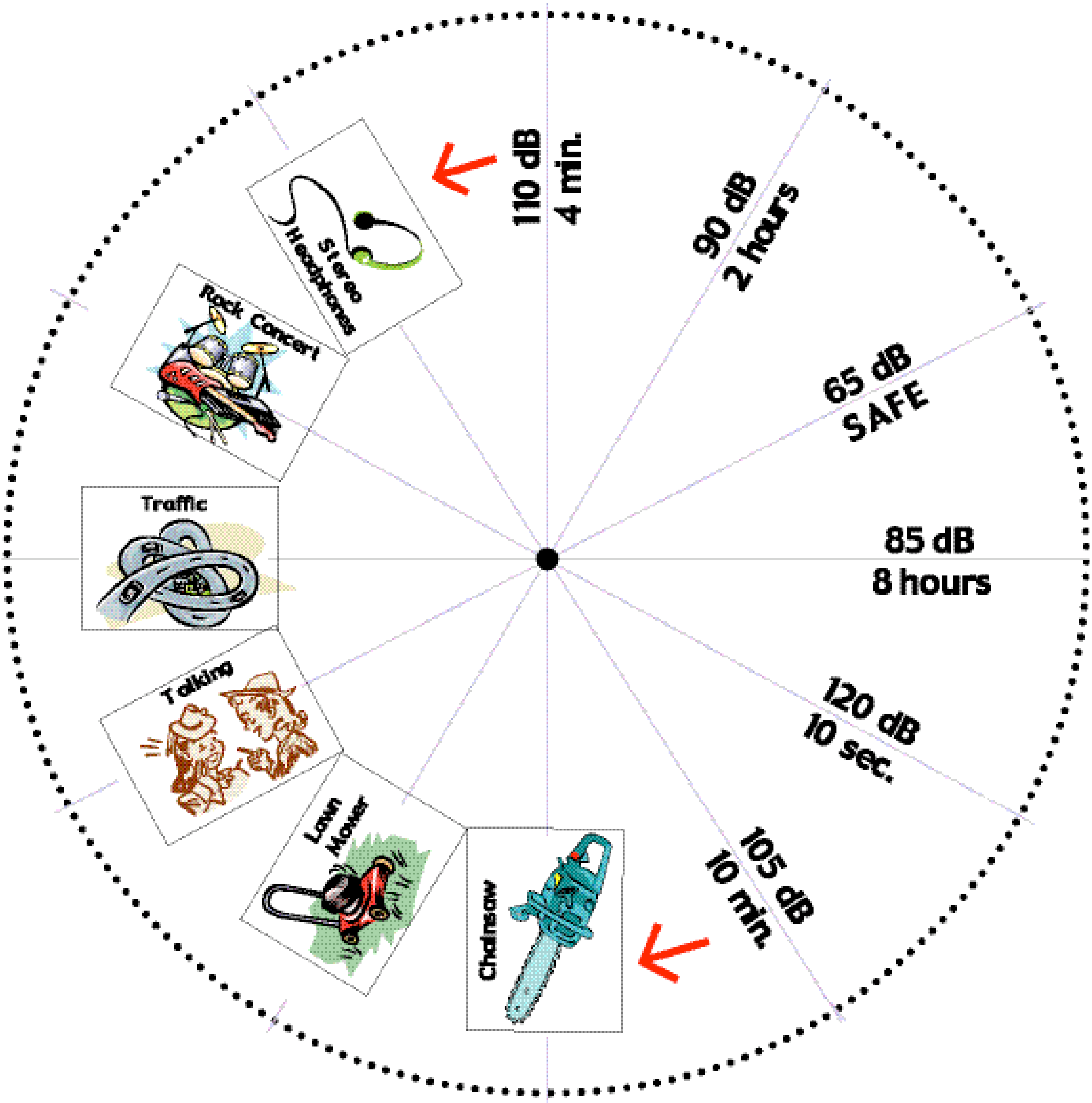
* Decibels are approximations according to NIOSH Standards using dB(A) time weighted averages.

www.dangerousdecibels.org

Funded by grants from NIH-NRC, NIH-NIDCD, Northwest Health Foundation, Collins Medical Trust, Harold & Arlene Schnitzer CARE Foundation, Ford Family Foundation, Crane Creek Family Foundation, and Dal L. Baker Charitable Lead Annuity Trust

Piece "B"

Cut along dotted lines only.



Appendix F

Alignment of Dangerous Decibels Curriculum with Science Standards and Benchmarks

Science Standards taken from National Science Education Standards:
http://www.nap.edu/readingroom/books/nses/html/

PHYSICAL SCIENCE STANDARDS

Properties of Objects and Materials	Grade Level	DD Activity
Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances. Those properties can be measured using tools, such as rulers, balances, and thermometers.	K - 4	Balloon Drum, Good Vibrations,
Position and Motion of Objects		
Sound is produced by vibrating objects. The pitch of the sound can be varied by changing the rate of vibration	K - 4	Balloon Drum, Good Vibrations, Shake It Break It,
Transfer of Energy		
Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.	5-8	Balloon Drums, A Sound Balancing Act, Shake it Break It, Shapes of Sounds, Sound Measures

LIFE SCIENCE STANDARDS

The Characteristics of Organisms		
Each plant or animal has different structures that serve different functions in growth, survival, and reproduction. For example, humans have distinct body structures for walking, holding, seeing, and talking.	K - 4	Balloon Drums, Good Vibrations, A Sound Balancing Act, Shake it Break it
Organisms and Their Environments		
Humans depend on their natural and constructed environments. Humans change environments in ways that can be either beneficial or detrimental for themselves and other organisms.	K - 4	Balloon Drums, Goof Vibrations, Shake it Break it,

LIFE SCIENCE STANDARDS CONTINUED

Structure and Function in Living Systems	Grade Level	DD Activity
Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue, such as a muscle. Different tissues are in turn grouped together to form larger functional units, called organs. Each type of cell, tissue, and organ has a distinct structure and set of functions that serve the organism as a whole.	5-8	Balloon Drums, A Sound Balancing Act, Shake it Break It, Shapes of Sound

Regulation and Behavior		
Behavior is one kind of response an organism can make to an internal or environmental stimulus. A behavioral response requires coordination and communication at many levels, including cells, organ systems, and whole organisms. Behavioral response is a set of actions determined in part by heredity and in part from experience.	5-8	A Sound Balancing Act, Shake it Break it, Sound Measures, How Loud is Too Loud

SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES STANDARDS

Personal Health		
Individuals have some responsibility for their own health. Students should engage in personal care--dental hygiene, cleanliness, and exercise--that will maintain and improve health. Understandings include how communicable diseases, such as colds, are transmitted and some of the body's defense mechanisms that prevent or overcome illness.	K - 4	Goof Vibrations, A Sound Balancing Act, Shake it Break it,
The potential for accidents and the existence of hazards imposes the need for injury prevention. Safe living involves the development and use of safety precautions and the recognition of risk in personal decisions. Injury prevention has personal and social dimensions.	5-8	Balloon Drums, A Sound Balancing Act, Shake it Break it, Shapes of Sound, Sound Measures, How Loud is too Loud

Changes in Environments		
Changes in environments can be natural or influenced by humans. Some changes are good, some are bad, and some are neither good nor bad. Pollution is a change in the environment that can influence the health, survival, or activities of organisms, including humans.	K - 4	Shake it Break it,

Science and Technology in Local Challenges		
People continue inventing new ways of doing things, solving problems, and getting work done. New ideas and inventions often affect other people; sometimes the effects are good and sometimes they are bad. It is helpful to try to determine in advance how ideas and inventions will affect other people.	K - 4	Shake it Break it,

SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES STANDARDS CONTINUED

Risks and Benefits	Grade Level	DD Activity
Students should understand the risks associated with natural hazards (fires, floods, tornadoes, hurricanes, earthquakes, and volcanic eruptions), with chemical hazards (pollutants in air, water, soil, and food), with biological hazards (pollen, viruses, bacterial, and parasites), social hazards (occupational safety and transportation), and with personal hazards (smoking, dieting, and drinking).	5-8	A Sound Balancing Act, Shake it Break it, Shapes of Sound, Sound Measures, How Loud is too Loud
Important personal and social decisions are made based on perceptions of benefits and risks	5-8	A Sound Balancing Act, Shake it Break it, Shapes of Sound, Sound Measures, How Loud is too Loud