DANGEROUS DECIBELS®

EDUCATOR RESOURCE GUIDE

VERSION 2.0

A supplement to the Dangerous Decibels Educator Training Workshop, this Guide includes hands-on science activities about the anatomy and physiology of hearing, the physics of sound, and health-related behaviors for the prevention of noise-induced hearing loss and tinnitus.

Dangerous Decibels Partners:

www.dangerousdecibels.org

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Dangerous Decibels®

Educator Resource Guide

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Introduction to Dangerous Decibels®

Since 1999, Dangerous Decibels has been a public health campaign designed to reduce the incidence and prevalence of **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 children and adults about exposure to loud sound and use of hearing protection strategies.

The Dangerous Decibels activities include:

- educator resource guide
- classroom program for K-12
- educator training workshops that teach how to present the Dangerous Decibels classroom program
- museum exhibition at the Oregon Museum of Science and Industry (OMSI) in Portland
- OMSI outreach programs to schools in the Pacific Northwest
- research projects on epidemiology and prevention intervention strategies of noise-induced hearing loss
- website (www.dangerousdecibels.org) that includes information on hearing and noise-induced hearing loss, effectiveness and epidemological research projects and results, and free downloadable educator resources
- a Virtual Exhibit with eight interactive activities
- "Jolene" - a mannequin with a sound level meter in her ear for testing the volume of personal music devices.

The program was built upon an innovative collaboration between basic science researchers, museum educators, school teachers, students, civic leaders, and volunteers in a unique public/private partnership. Partners have included the Oregon Museum of Science and Industry, American Tinnitus Association, National Center for Rehabilitative Auditory Research, University of Northern Colorado, Portland State University, Marion Downs Hearing Center, OHSU's CDC-funded Oregon Prevention Research Center (Center for Healthy Communities), National Hearing Conservation Association, and American Academy of Audiology.

Partners in global dissemination are Widex Canada, New Zealand's National Foundation for the Deaf and the Pindrop Foundation, Australia's National Acoustics Laboratory, all participants of the Dangerous Decibels Educator Training Workshops, and people around the world who have developed their own "Jolene." As of November 2009, people in 17 countries and 46 US states have downloaded the "Jolene Cookbook," a how-to-make-your-own-Jolene manual.

PLEASE NOTE:

This guide is meant as a supplement to the two-day Dangerous Decibels Educator Training Workshop.

To find out more about these workshops so that you can become a certified Dangerous Decibels Educator, see Appendix G.1 and website www.dangerousdecibels.org.

Why Teach about Noise-Induced Hearing Loss?

- 36 million Americans are affected by hearing loss.[1]
- At least 10 million cases of hearing loss can be directly attributed to exposure to dangerous sounds.[2]
- Approximately 50 million Americans have tinnitus.[3]

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. Tinnitus and noise-induced hearing loss can be caused by sounds in our jobs, homes, and recreational activities.

Key Educational Messages:

All Dangerous Decibels activities are designed to address at least one of 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 exposure to the Dangerous Decibels program – whether viewing the exhibit, receiving the classroom program by a certified presenter, interacting with the games of the Virtual Exhibit, or participating in activities from this Resource Guide – students should understand the danger of loud sound and respond by one or more following methods:

- **Turn Down the Volume,**
- **Protect Your Hearing and/or**
- **Walk Away.**

[1] NIH – NIDCD - www.nidcd.nih.gov/health/statistics
[2] Noise and Hearing Loss. NIH Consensus Statement, NIH Concensus Development Conference, Jan. 22-24, 1990;8(1) 3-4
[3] American Tinnitus Association, November 2004.

Integrating with Science Curriculum

In addition to conveying the messages aimed at changing health-related behaviors, Dangerous Decibels activities in this Guide 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;
- Provide launching points for potential **scientific inquiry** work samples.

You may learn more about the information in this Guide, gain insight and strategies for teaching these concepts, and learn additional activities by watching the Dangerous Decibels DVD (order form is on the website). In addition, educators in the Pacific Northwest may schedule the OMSI outreach program for their class. Educators in and around Portland, Oregon may schedule a classroom field trip to visit the Dangerous Decibels exhibit in OMSI's Life Science Hall. Students everywhere have access to the Dangerous Decibels website and the Virtual Exhibit.

Educators anywhere may register for a Dangerous Decibels Educator Training Workshop to become a certified presenter of the complete Dangerous Decibels classroom program. See Appendix G or visit the Dangerous Decibels website for details about these two-day workshops. This guide is intended to be a supplement to the Educator Workshop and is not, by itself, the Dangerous Decibels classroom program that has been evaluated and demonstrated to be effective in changing knowledge, attitudes, and behaviors in school-aged kids about protecting their hearing.

Primary teachers may integrate the activities in this Guide, the website, and from the Dangerous Decibels classroom program into lessons on the senses, music, health, or mathematics (graphing, weighing, sorting).

Intermediate teachers may integrate the activities in this Guide, the website, and from the Dangerous Decibels classroom program into units on anatomy, the senses, health, or introductory physical science.

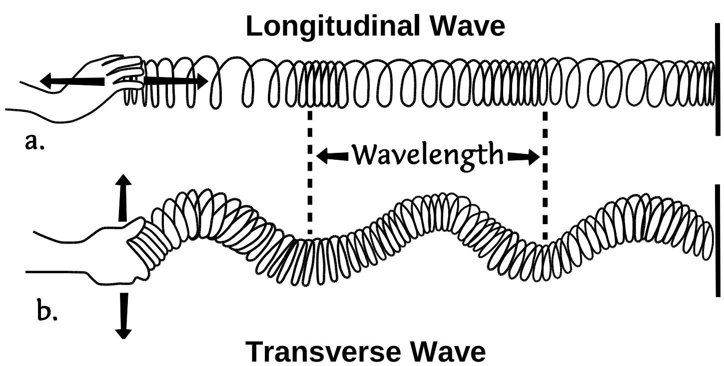
Middle and high school teachers may integrate the activities in this Guide, the website, and from the Dangerous Decibels classroom program into units on the physics of sound and waves, health, mathematics, or anatomy and physiology.

The Science of Dangerous Decibels
Background Information for the Educator

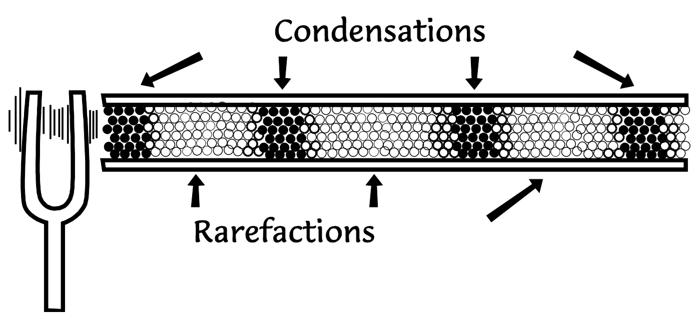
The Physics of Sound

Sound occurs when energy travels as waves of pressure through a substance such as 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 in air, depending on the temperature and humidity. Sound travels about 5 times faster 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 (condensation) and the rarefied areas (rarefaction) – 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.

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 lose 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!

See the following website for more information and illustrations about the physics of music as described by the School of Physics at the University of New South Wales, Australia - http://www.phys.unsw.edu.au/jw/strings.html.

Fun Facts about Sound:

- Sound travels at 760 miles/hr.
  Have older students calculate how long it takes for sound to travel one mile. (sound travels 1 mile in a little less than 5 seconds)
  For example, 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 mouth 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 a 1%!

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 in Appendix C.

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 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** 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** lies between the other two ossicles. When the malleus vibrates against it, the incus also begins to vibrate.

   The **stapes** 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. The stereocilia on top of each hair cell form a **hair bundle**. 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 hair bundle on the hair cells to move. The hair cells in turn stimulate the auditory nerve.

6. The **auditory nerve** 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 extremely rare, benign tumor in the ear develops around the 8^{th} cranial nerve, which is also known as the auditory nerve. It is called a vestibular schwannoma or acoustic neuroma.
- **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 can begin to be noticed after the age of 50. 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 sound, or exposure to loud sounds for a period of time. A dangerous sound is anything that is 85 dB SPL (decibels - sound pressure level) or higher lasting 8 hours or longer. Louder sounds can cause damage in much less time.

The Dangerous Decibels Program focuses on noise-induced hearing loss and tinnitus.

- **Tinnitus** – ringing, hissing, buzzing, or other sounds in the ear are caused by damage to the ear or brain and is called tinnitus. The most common cause of tinnitus is exposure to loud sound.

Noise-Induced Hearing Loss (NIHL)

- Of the roughly 36 million American adultss 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 Hertz (Hz) to 20,000 Hz.
- With loud sound exposure over time, the hair cells' delicate hair bundles 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 found in children. According to Niskar et al., 2001, 5.2 million children (6-19 years of age) suffer from hearing loss attributed to excessive amounts of hazardous sound.
- The National Institute on Deafness and Other Communication Disorders (NIDCD) estimates that approximately 15 percent (over 30 million) of Americans between the ages of 20 and 69 have high frequency hearing loss due to exposure to loud sounds or noise at work or in leisure activities.
- Over 12 million Americans experience severe tinnitus.

How Loud is Too Loud? Measuring Sound/Decibels

The pressure of a sound is measured in **decibels** (dB) sound pressure level (SPL). Like a temperature scale, the decibel scale goes below zero, which is the lowest level an average person can hear.

- The average person can hear sounds down to about 0 dB, the level of rustling leaves. Some people with extremely good hearing can hear sounds down to -15 dB.
- If a sound reaches 85 dB or stronger and lasts for 8 hours, it can cause permanent damage to your ears.
- 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. Loud sounds that reach a decibel level of 85 for 8 hours or more 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 about 65 dB, not loud enough to cause damage.
- A bulldozer that is idling (note that this is idling, *not* actively bulldozing) is loud enough at over 85 dB that it can begin to cause permanent damage after only 1 work day (8 hours).
- When listening to music on earphones at maxiumum volume level, the sound generated reaches a level of over 100 dB, loud enough to begin to cause permanent damage after just 15 minutes per day!
- A clap of thunder from a nearby storm (120 dB) or a gunshot (140-190 dB, depending on weapon) can cause immediate damage.
- Sound is one of the most common occupational hazard facing people today. It is estimated that as many as 22 million Americans are exposed to potentially harmful sounds at work.
- Even outside of work, many people participate in recreational activities that can produce harmful sound levels (musical concerts, use of power tools, etc.). Sixty million Americans own firearms, and many people do not use appropriate hearing protection devices.
- NIHL (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.

How to use this Resource Guide and its Classroom Activities

This Resource Guide is a supplement to the Dangerous Decibels classroom program and provides a series of hands-on, minds-on science activities for the K-12 classroom. These activities may be done prior to or after the classroom program. Some may be incorporated into the classroom program if time is available. 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. 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-12 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.

- **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
- **glossary in** Appendix A
- support materials in **Appendices** A through G

The Dangerous Decibels DVD:

The Dangerous Decibels DVD was developed as a practical tool for educators. It was designed as a supplement to this Guide and the educator training workshops. Dangerous Decibels educator workshops train and equip participants to present the complete classroom program. The DVD demonstrates supplementary activities visually, provides additional content, and offers 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 classroom activities, providing practical hints for the classroom, and introducing the poster.
- a scientist/audiologist walking you through a giant ear, explaining the anatomy and physiology of the ear, and describing types of hearing loss.
- a middle school student explaining how to protect your ears from loud sounds.
- a close-up look inside the ear at the basilar membrane's response to music.
- an interview with a tinnitus patient.
- a poster – an easy-to-use teaching aid displaying a thermometer-style decibel chart 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.
- activity booklet – suggested activities for inquiry-based classroom research projects and instructions on how to use a sound level meter.

Adapting to Different Grade Levels

There are a total of four central activities in this Guide. While all may be adapted to various grade levels from K through 12, the activities were designed and tested with specific age ranges and developmental stages in mind:

- **All Ages:** *Good Vibrations* and *Bend It, Break It* are fun as introductory activities for all grade levels.
- **Primary Students (K-2):** Start with *Good Vibrations* to introduce basic concepts to the students and it is also a great station-based activity.
- **Intermediate Students (grades 3-5):** Start with *Good Vibrations* to introduce basic concepts to the students. *Bend It, Break It* 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. *How Loud is too Loud* is also an excellent activity for this group.
- **Middle School Students (grades 6-8):** Start with *Good Vibrations* to introduce basic concepts to the students. *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.
- **High School Students (grades 9-12):** Start with *Good Vibrations* to introduce basic concepts to the students. *Sound Measures* is a great foundation for futher scientific inquiry and give informaiton on how to use logarithmic scales, and plot and calculate sound pressure levels. Topics of math, physical science, and biology are addressed.

Good Vibrations

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

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Hearing Sound Vibrations Energy	Listening Observing Scientific Inquiry Health Skills	K – 12

TIME REQUIRED

Advance Preparation	Set-Up	Activity	Clean-Up
30 minutes	**15 minutes**	**30 minutes**	**5 minutes**

MATERIALS

- Tuning fork
- Pan or unbreakable bowl, approx. (1–2 quart)
- Water (2–3 cups)
- Paper
- Crayons
- Ping-Pong ball
- String (about 18 inches)
- Tape

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 approximately two inches deep.
- Place crayons, paper, a tuning fork, and the pan of water at the table.

Station 2 – Sound Moves/Tuning Fork:

- Cut a piece of string approximately one foot long
- Tape one end of string to a ping-pong ball
- Place string with ping-pong ball and a tuning fork 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.** *(Note: 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 move when you talk, sing, or hum**? (*Note: 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 the two activity stations before students divide into groups and do the activities.

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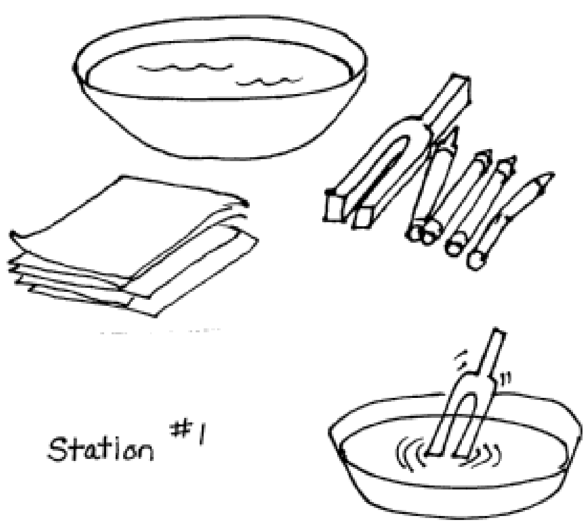
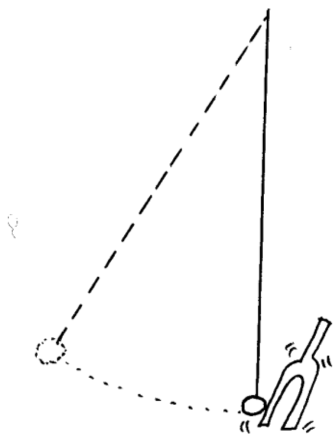
<u>Station 1– Ripples on Water/Tuning Fork:</u>

- 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 windows, eye glasses, or teeth. The tuning fork can shatter glass.

Station 2 – Sound Moves:



- Have one student in a standing position hold the string with the ping-pong ball at arm's length. Be sure the student is holding it as still as possible.
- Have another student gently move the tuning fork towards the ping-pong ball until it just barely touches it.
- Have the second student strike the tuning fork against a book or shoe and again gently move the tuning fork towards the ping-pong ball until it just barely touches it.
- One more time, have the same student gently touch the ping-pong ball with the tuning fork.

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

Questions from Stations:

Station 1– Ripples on Water/Tuning Fork:

What did you feel when you touched the tuning fork after you hit it? What did you observe happening to the water?

Station 2 – Sound Moves/Tuning Fork:

What happened when you touched the ping-pong ball with the tuning fork the first time?

What happened to the ping-pong ball when you touched it the first time after hitting the tuning fork on a book?

What happened when you touched it a second time?

Did anything surprise you when the tuning fork touched the ping-pong ball? Why do you think the ping-pong ball moved?

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?

Energy (vibration) is transferred from the tuning fork to the ping-pong ball. The amount of energy transferred will determine how far the ping-pong ball moves.

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 vibration sensors called hair bundles. 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 sounds often, or for a long time, you may begin to have trouble hearing.

Do you know anyone who seems to have trouble hearing some sounds?

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

Note: Loud sounds are not the only cause of hearing loss, but it is the most common cause in America (and in other industrialized nations). Loud sounds (above 85 dB for 8 hours or more) 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.

Doctors cannot fix ears that have been damaged by loud sound so it is very important to protect your ears.

Here is what you can do:

- Turn it down (turn the volume down)
- Walk away (get far away from the loud sound)
- Wear ear muffs or ear plugs

QUESTIONS TO TELL 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 or underwater?
- ❑ After being near loud sound, do your ears sometimes feel “full” or “stopped up”?
- ❑ When you are listening to stereo headphones does the person next to you need to raise their voice for you to understand what they are saying?

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

EXPLANATION

In-depth background information for teachers and interested students.

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.

OPTIONAL EXTENSIONS

Drum Vibrations, Kazoos, Rubber Band Guitar

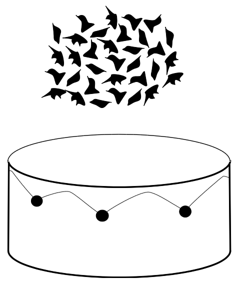
MATERIALS

- 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
- Cornflake-type 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

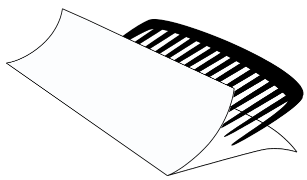
- ❑ Set up desks to create spaces for additional “sound stations” with desks arranged in 4 groups.
- ❑ Gather supplies (see materials above).
- ❑ Cut one square of waxed paper per student (have a few to spare). The wax paper squares should be approximately 10–20 cm. per side (about 4–8 inches).
- ❑ Make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

Station 1 – Drum Vibrations:



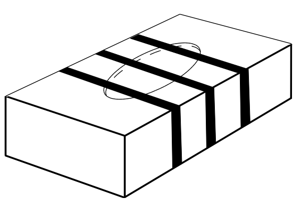
- Fill 3 – 5 small unbreakable containers (e.g., clean, empty 8 oz. yogurt containers) halfway with different dry ingredients including uncooked rice grains, cereal flakes, etc. *(Note: you may need to refill these during the class period as groups use up the ingredients).*
- Place the containers of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

Station 2 – 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.
- Question: How did your lips feel when you played your “kazoo”? What happened to the waxed paper when you hummed?

Station 3 – Rubber Band Guitar:



- Make a rubber band guitar by putting 3-4 rubber bands around an empty tissue box.
- Strum the rubber band guitar. Watch the rubber bands as they are plucked.
- Question: What did the rubber band do when you plucked it? Did you feel movements (vibrations) in your other hand (the hand holding the box)?

DISCUSSION

Ask the students the questions to facilitate an open-ended discussion.

Questions from Stations:

Station 1– Tuning Fork - Ripples on Water and Ping-Pong Ball:
What did you feel when you touched the tuning fork after you hit it?

Station 2 – Drum Vibrations:
Did the cereal flakes move or stand still? Did some materials move more than others?

Station 3 – Kazoos:
How did your lips feel when you played your “kazoo”? What happened to the waxed paper when you hummed?

Station 4 – Rubber Band Guitar:
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?

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.

OPTIONAL EXTENSIONS

Music

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

Bend It, Break It

Students use pipe cleaners to model the impact of loud sounds on the fragile hair bundles atop inner ear hair cells.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Anatomy of Hearing Sense of Hearing Hearing conservation	Observing Modeling Inferring Health Skills	3-12

TIME REQUIRED

Advance Preparation	Set-Up	Activity	Clean-Up
10 minutes	**5 minutes**	**20 minutes**	**5 minutes**

MATERIALS

- Pipe cleaners (chenille stems) – 12” (4 or 6 mm)
- Picture of the ear showing the location of the hair cells of the inner ear
- Picture of healthy and damaged hair bundles
- Music source – radio, speakers on computer, etc.
- Pencils and paper for students to draw pictures of what they see

ADVANCE PREPARATIONS

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

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.

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

Show students the diagram of the ear from Appendix C.

- 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 ear. All 18,000 would fit onto the head of a pin.
- Tell the students that on top of each hair cell is a delicate bundle of stereocilia called a hair bundle. Show the picture of the healthy hair bundle to the class (Appendix D.1). These hair bundles are pushed back and forth by sound waves.
- The mechanical energy of the movement back and forth (of the hair bundle) is converted to messages that are sent to the brain. Our brain interprets those messages as sound.

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 the first astronaut 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 sound waves on the model.

CLASSROOM ACTIVITY

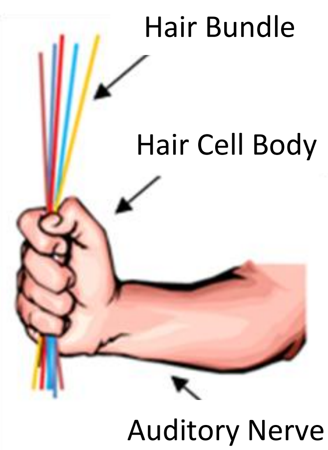
Prepare your workspace:

- Give sets of 4 or 5 pipe cleaner to each student.

Build your model:

- Have the students hold out a fist.
- Have the students hold the 4 or 5 pipe cleaners up in that same fist as though they were a bunch of flowers.
- Show them the photo of the healthy hair bundle ("A" below or Appendix D.1).

Draw a picture of your model and label the parts:



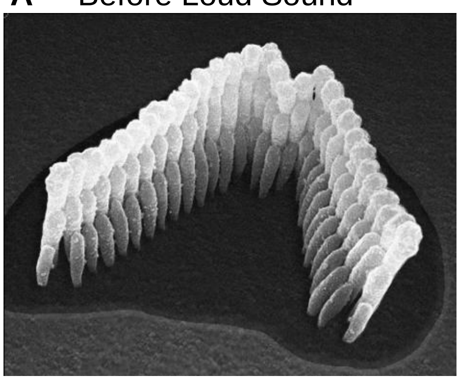
- Explain that they have just created a model of the hair cells.
- Their hand represents the cell body.
- The pipe cleaners represent the hair bundle on top of the hair cell.
- Their arm is the auditory nerve that carries signals from the hair cell (the ear) to the brain.
- Do their pipe cleaners resemble the healthy hair bundle in the photo?

Test your model:

- The teacher will turn music on softly. Students gently move their hand over the top of the pipe cleaners to the rhythm of the music.

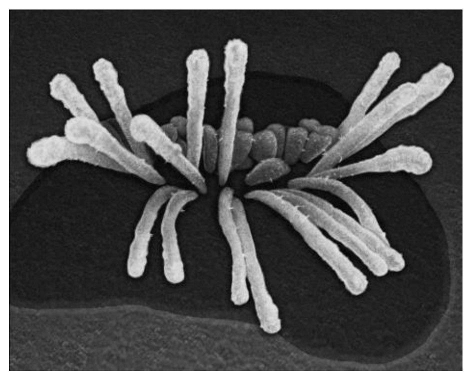
- Moving the hand over the pipe cleaners represents the sound waves. Sound waves produce vibrations strong enough to move objects much larger than microscopic hair cells represented by the pipe cleaner model.
- The teacher turns the volume of the music up a bit. Students move their hand a little more so that the pipe cleaners move from side to side, without damaging them.
- The teacher will turn the music up loud enough to be slightly annoying. Students move their hands more vigorously so the pipe cleaners are pushed forcefully and some pipe cleaners start to fall from their hands and to bend over.
- The teacher turns the music off immediately. Students stop moving their hands over the pipe cleaners.
- Ask students whether their model still looks like the photo of the healthy hair cell and hair bundle?
- Show them the photo of the damaged hair bundle ("B"). Does this photo look like your hair cell model? Compare this with the photograph of healthy hair bundle ("A").

A Before Loud Sound



Hair bundle before noise

B After Loud Sound



Hair bundle after noise

- Ask students to try to "fix" their hair bundle so that they stand straight again. Can they be fixed?
- Tell students that the hair bundle of real hair cells cannot be fixed either. When the hair bundle is damaged like this, the cell can die. Once a hair cell dies, it is permanent.

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 pipe cleaners will have fallen out of their hands and/or the pipe cleaners will be bent.

The differences in behavior of the pipe cleaner models may represent many things:

- Scientists often have to build a model several times before it works. –OR–
- Some models may have been rubbed 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 bent pipe cleaners?

- Students may have suggestions of ways to fix the bent pipe cleaners – tape, twisting, etc. These suggestions are similar to making a hypothesis.

Remember that the bent pipe cleaners represent very tiny hair bundles. Do you think that doctors can repair those hair cells after they are broken by loud sounds?

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

- There is currently no way to repair hair bundles once they are broken. Hair cells do not grow back (unless you are a bird or frog). When you have a few hair bundles 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.

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.

<u>Summarize the Three Primary Hearing Protection Steps:</u>

<u>Turn it Down!</u> Turn down the volume on your stereo, personal music player, “Boom Box”, other loud sources.

<u>Protect your ears!</u> Carry and use ear plugs when going to an amplified concert, working with power tools, or using motorcycles or other noisy vehicles like jet skis and snowmobiles.

<u>Walk Away!</u> Move away from the loud sound source.

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:

- 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 funnels to direct sound into the ear canal. 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 ear drum (*tympanic membrane*) of the **middle ear.**
- The middle ear consists of the ear drum and the three middle ear bones (the *ossicles,* consisting of the *malleus*, *incus,* and the *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 wide – they are very tiny.
- These hair cells possess tiny finger-like projections, called *stereocillia,* on their tops. The stereocilia are bundled together as *hair bundles*. The hair bundles rock 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 sound.

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 (*basilar membrane*) to move up and down. This membrane movement in turn stimulates or relays the message, to the hair cells 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.

Sound enters the cochlea at the base of the snail shaped tube. The delicate hair cells 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 not working properly). 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, muddled, 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 sound damage. Tinnitus may become permanent if sound damage is very severe or if the sound 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 – tinnitus.

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, person music player, "Boom Box", other loud sound sources.

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

3. **Walk Away!** 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 – see *Sound Measures* on page 33.

Sound Measures

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

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

TIME REQUIRED

Advance Preparation	Set-Up	Activity	Clean-Up
30 minutes	**15 minutes**	**30 minutes**	**5 minutes**

MATERIALS

- Sound level meter *
- Blender or radio
- Meter stick or tape measure

* hand-held digital sound level meters can be purchased at Radio Shack

ADVANCE PREPARATIONS

- Become familiar with the operation of the sound level meter.
- Acquire a blender or radio to produce the sound. A blender is recommended.

INTRODUCING THE ACTIVITY

Introduce the decibel chart – See page 38 and Appendix B. zero decibels represents the softest sound we can hear, the threshold of hearing. An increase of 6 decibels represents a doubling of the air pressure change created by the sound wave. A 30 decibel increase creates 32 times as much sound pressure as did the original sound. 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:

- Place blender or radio near the edge of a flat surface facing the classroom. If using a radio, turn on the radio and de-tune near a known radio station until there is a constant static sound. If using a blender, turn it onto the loudest setting.
- Set the sound level meter to 80 dB, select setting **A** for **Weighting** and set the **Response** setting to **SLOW.**
- Have a student hold the sound level meter about 4 inches away from the radio or blender.
- 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 levels change with distance.

- Without changing the speed of blender or volume on the radio, have the student move away about 4 or 5 steps from the sound source holding the sound level meter and record the sound level in dB. You may need to reduce the decibel range of the sound level meter as it is moved further away from the source of the sound.
- Have the student move back another 10 steps holding the sound level meter and record sound levels in dB.
- 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.
- Note: the results will vary depending on the acoustic characterics of the room.

DISCUSSION

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

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.

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 sounds (above 85 dB for 8 or more hours) 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

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 personal music player, can a person standing next to you hear it too? (When you are using a personal music player, you should be able to understand a person next to you speaking in a normal tone of voice.)

If you answer YES to any of these questions, you may 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** that the ear is subjected to. 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 relation 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:

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

This is a standard value defined for a 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:

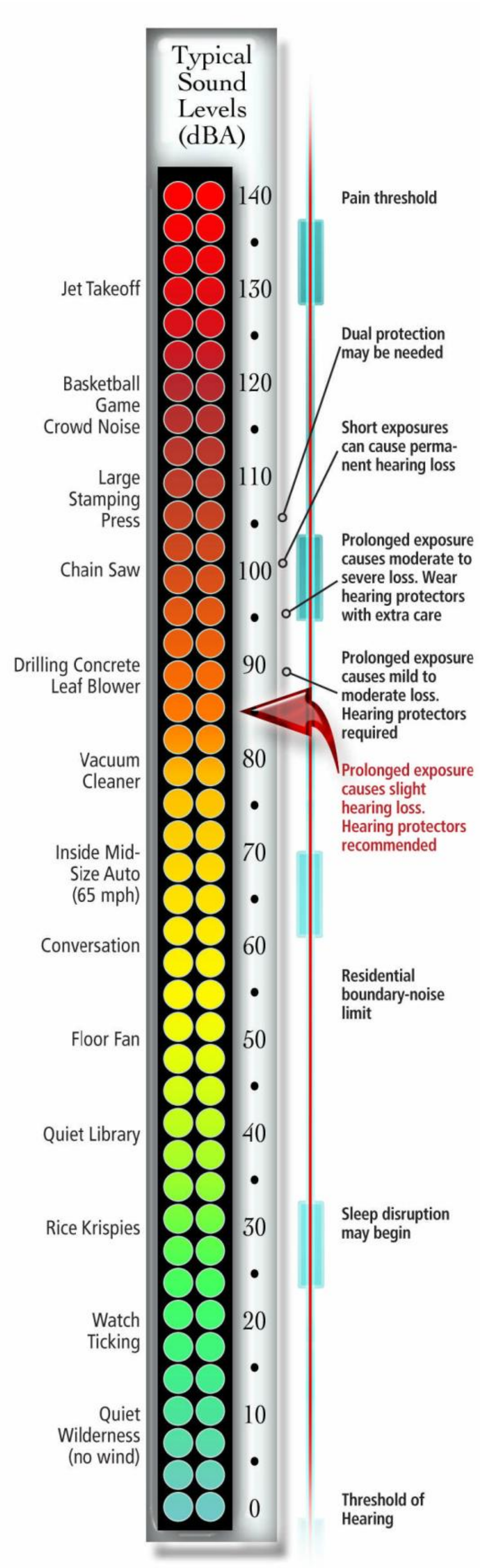
$$\mathbf{SPL = 20\ log(P/P_O)}$$

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

$\mathbf{P}_O$ 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.



How Loud Is It?

The graphic on this page was developed by Elliott Berger, MS, Senior Scientist with 3M Occupational Health and Environmental Safety Division.

It is available as a free download at http://www.e-a-r.com/hearingconservation/faq_main.cfm. This list of information sheets might be helpful to teachers and students. #1 on the list is this graphic. #2 is an excellent Excel file listing 1,700 sounds with a decibel rating on each.

OPTIONAL EXTENSIONS

- 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, 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.

How Loud is Too Loud

Students create wheel that will show them various sound sources, the decibels produced by that sound, and allowable time they can be exposed to that level of sound.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Sound Decibels Sense of Hearing	Observing Measuring Comparing Health Skills	3 - 12

TIME REQUIRED

Advance Preparation	Activity	Clean-Up
15 minutes	**30 minutes**	**5 minutes**

MATERIALS

- Scissors (1 per group)
- Glue or Scotch tape (1 per group)
- Piece “1” & “2” in Appendix F (1 set per person)
- Thumb tack or brad (1 per person)

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.

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

What is a decibel?
A decibel is a measurement of sound.

Is sound dangerous?
Yes, sounds can damage the inner ear hair cells if it is too loud for too long. If too many hairs cells are damaged and lost, hearing loss can be a result.

CLASSROOM ACTIVITY

Procedure:

Make the How Loud Wheel as follows:

- Cutting on the dashed lines only**,** use scissors to cut out the circle of Piece "1" (page 57).
- Piece "1" - Cut out the box under the word "Sound".
- Piece "1" - Cut **three** sides of the box under "How many decibels?" leaving the top as a flap to serve as a window shade for the information below.
- Cutting on the dashed lines only**,** use scissors to cut out the circle of Piece "2" (page 59).
- Put the two circles together with "1" on top of "2". Join the black dots in the middle of each circle with a thumb tack or brad. If using a thumb tack, tack the How Loud is Too Loud Wheel to a bulletin board.
- Keep the top circle in place so you can read the words on it – hold it still with your hand.
- While holding circle "1", turn circle "2" until a picture can be seen through 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 damage can occur. Anytime at or above this amount has the potential of damaging your hearing.

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

How can you protect your ears from noise-induced hearing loss?

The Answer - There are several ways a person can take to prevent noise-induced hearing loss. Following are the 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.

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, Caesar banned chariots in Rome to cut down the deafening sound of chariot wheels on stone roads. Throughout the ages people have complained that they can’t “hear themselves think” due to loud sounds. In America, some people talk of “moving to the country” to get away from the noise of the city.

Loud sound presents a real danger to people’s hearing and general health. In addition to the damage loud sound can have on our ability to hear, it can produce other physical and psychological stress. Although we may seem to become accustomed to sound, our bodies still respond and our hearing capability gradually diminishes. Exposure to loud sound has been linked to:

- permanent hearing loss 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 loud sound is damaging to our health, the sound levels in our environments continue to rise. The Acoustical Society of America indicates that since 1950, the volume of loud sound 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 sound from firearms, or sirens, or noisy engines. Also, growing accustomed to loud sound does not diminish its ability to damage our hearing or to cause other physiologic effects.

OPTIONAL EXTENSIONS

Make your own unique How Loud circles

- Use pieces “1” and “2” in Appendix F as templates.
- Find illustrations of other sound sources and have kids glue them onto the bottom circle.
- Test that sound source with a sound level meter to find out how loud these sound sources are.
- Have the kids write down the finding opposite the appropriate illustration.
- Check various web sites for lists of noise levels for various sound sources to see how long it is safe to listen to them.

Inquiry Extension

Let students design and carry out their own experiments using a sound level meter to gather data.

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

Cochlea - the spiraled (snail-shaped) part of the inner ear that contains the organ of sound reception

Decibel - the unit of measure commonly used to describe the sound pressure of sounds in our environment - based on a logarithmic scale in which an increase of 6 decibels indicates an increase in sound loudness by a factor of 2

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 Bundles - a bundle of *stereocilia* on top of each *hair cell* - sound vibrations move hair bundles which signal the hair cells to send a signal to the brain that is preceived as sound

Hair Cells - microscopic cells within the *inner ear* that have tiny, hair-like projections on top - These *hair bundles* are moved back and forth by the pressure wave in the inner ear fluid. Motion of the hair bundle 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 (Hz) - 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

Incus - the bone or ossicle of the *middle ear* that is attached to the *malleus* and the *stapes*

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.

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* and the *incus*

Middle Ear - the air-filled space between the eardrum and the *inner ear*, containing the three middle-ear bones (the *malleus*, the *incus* and the *stapes*)

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 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 2,000 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 - small finger-like or hair-like projections from the top of hair cells in the cochlea – also see *Hair Bundle*

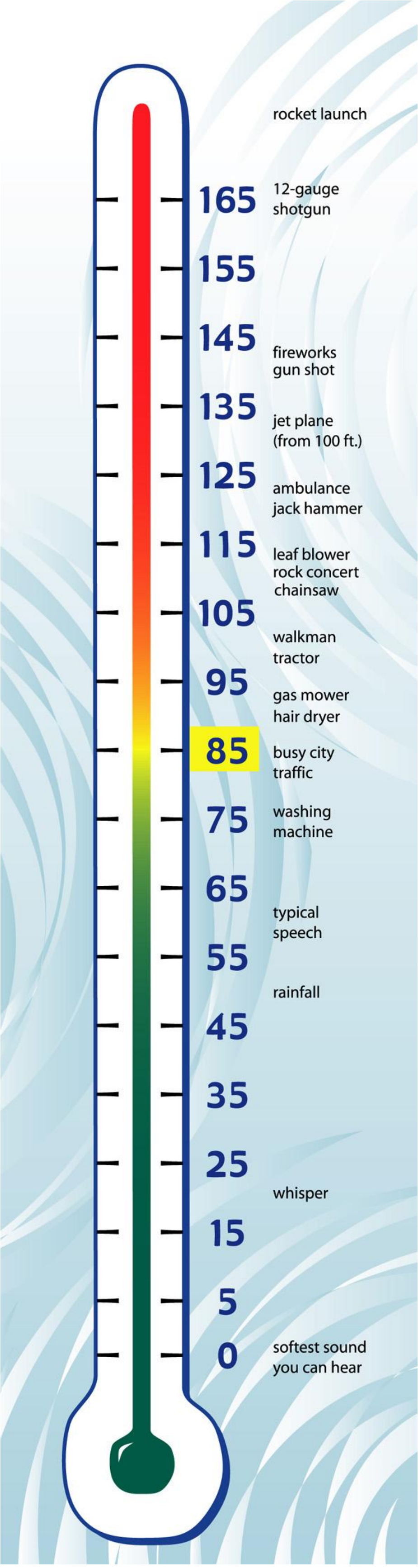
Tinnitus - ringing or other sounds in your ears or head, in the absence of an external source of sound

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

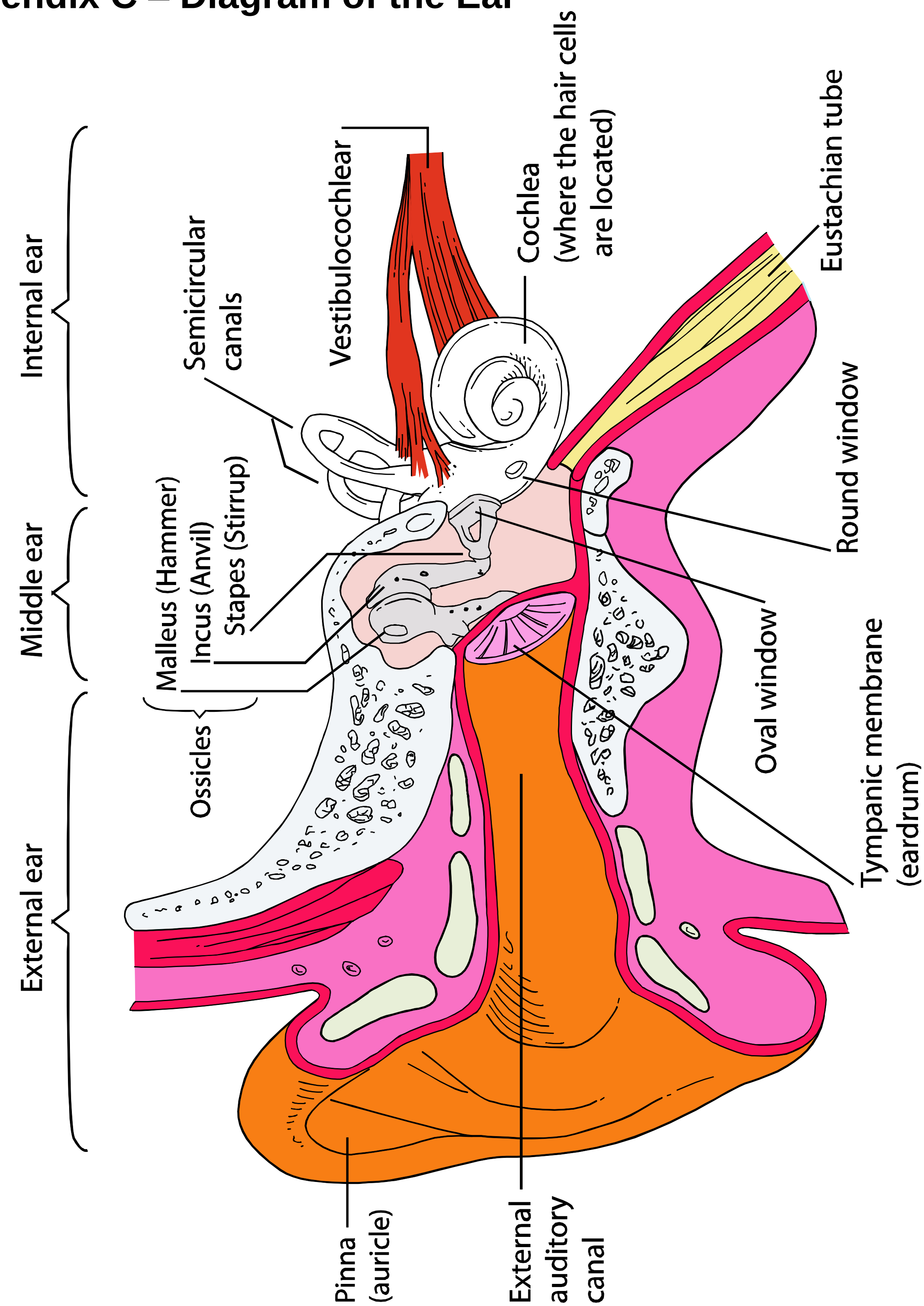
Wave - a moving disturbance (of molecules or of energy); in wave motion, energy is transferred to a new location but matter remains in its original location even though the wave motion travels through the matter



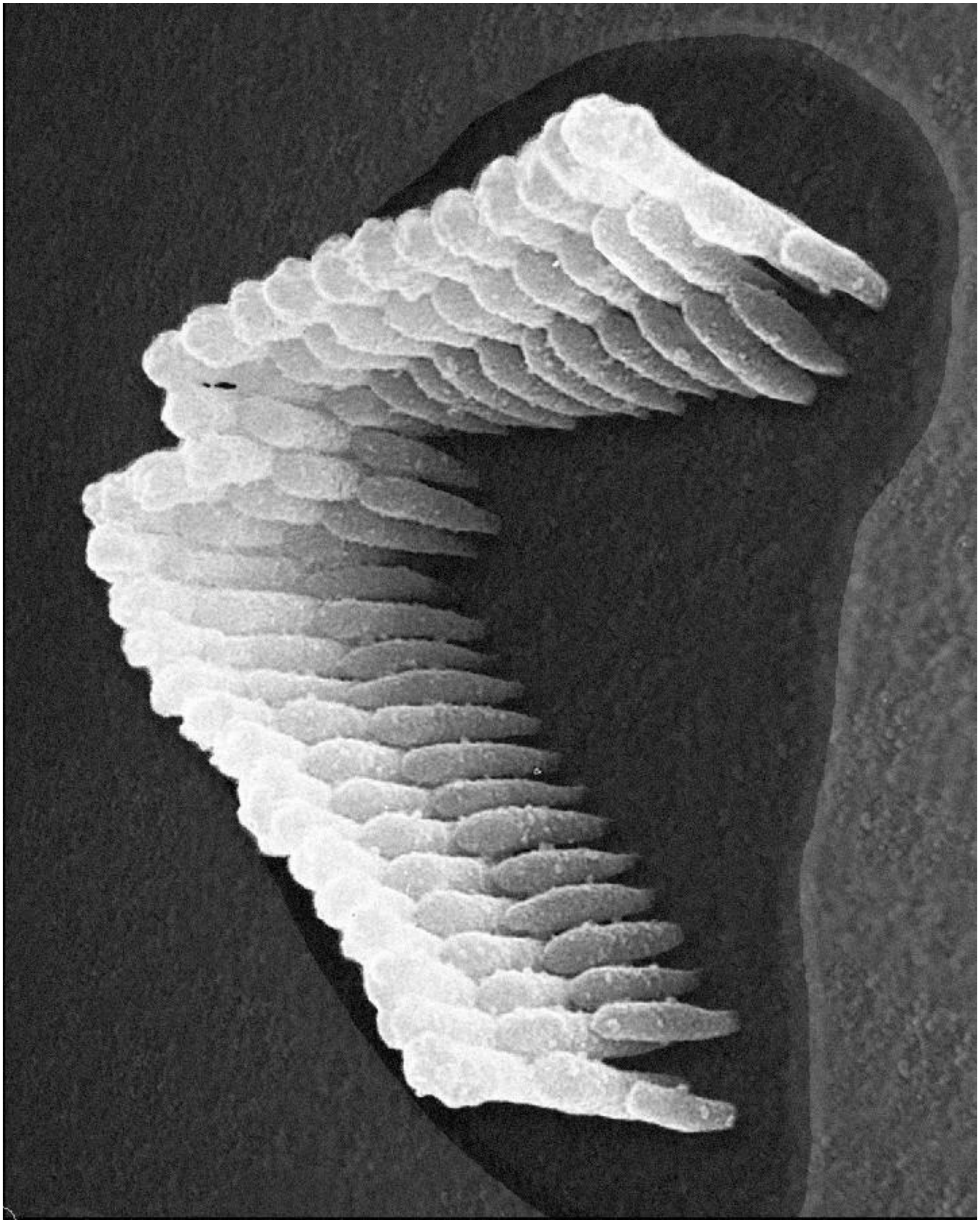
Appendix B

Sound "Thermometer" of Common Sounds

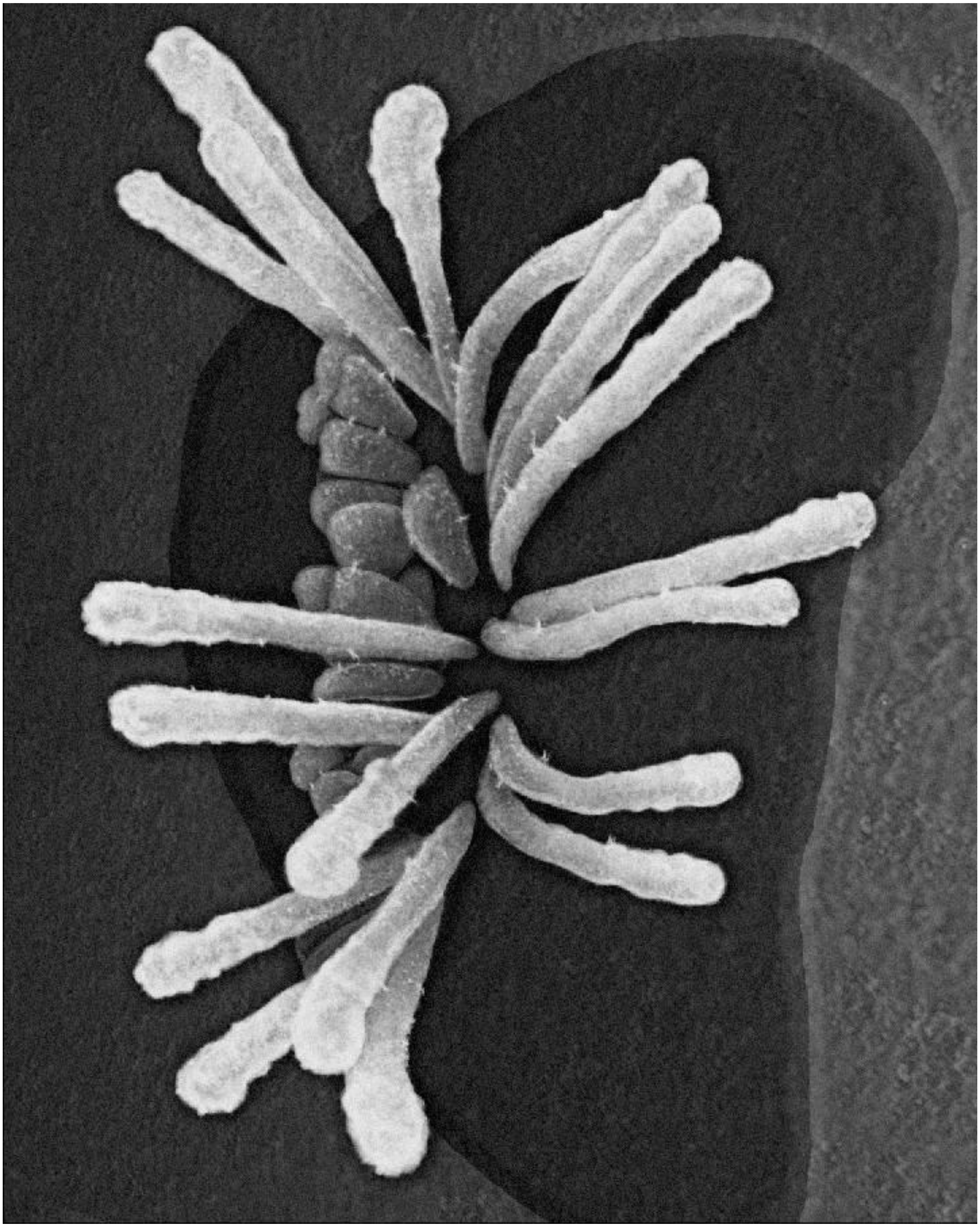
Appendix C – Diagram of the Ear



Appendix D.1 Normal Healthy Hair Cell Stereocilia (Hair Bundle)



Appendix D.2 Hair Bundle After Loud Sound Exposure



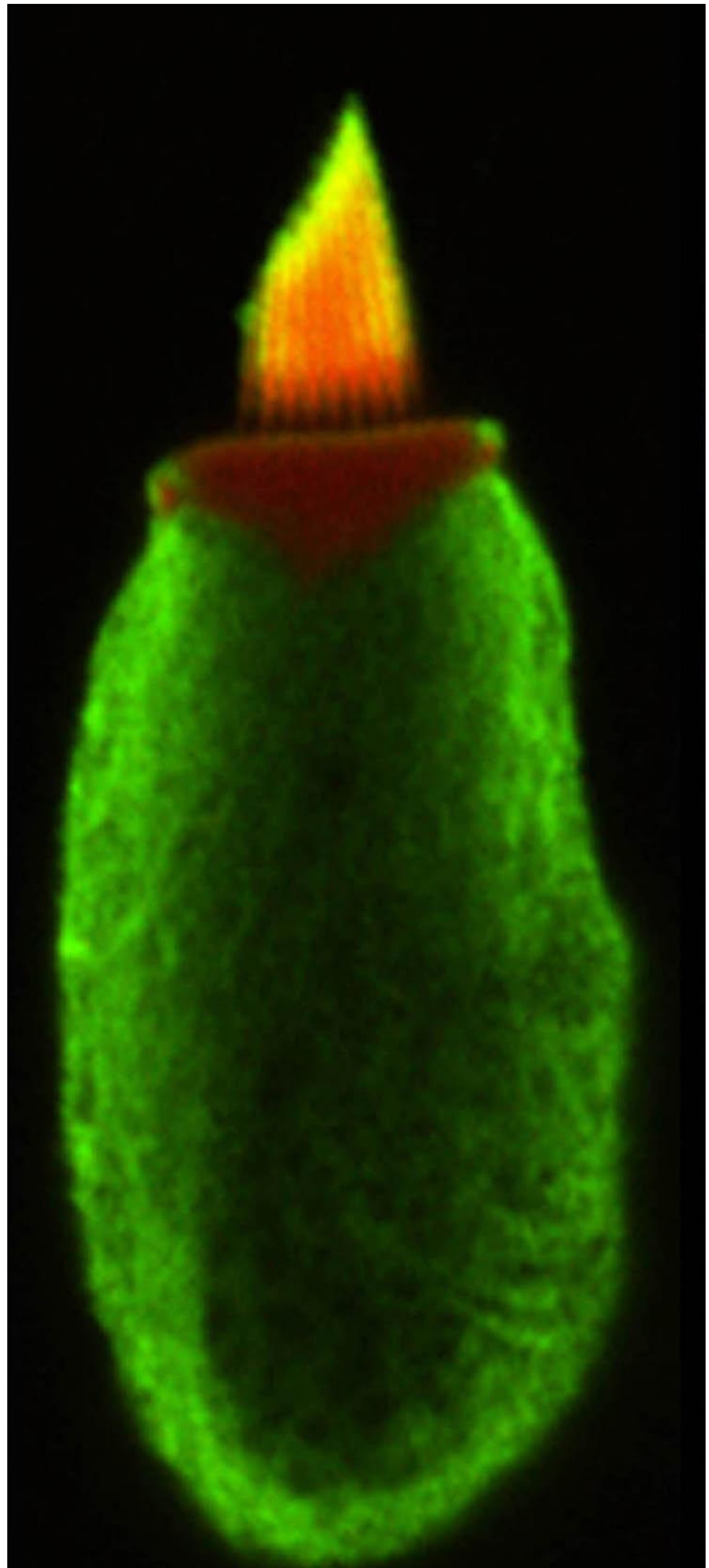
Appendix E

One Inner Ear Hair Cell

Large cell body with hair bundle on top.

Hair Bundle made of Stereocilia (Yellow)

Hair Cell Body (green)

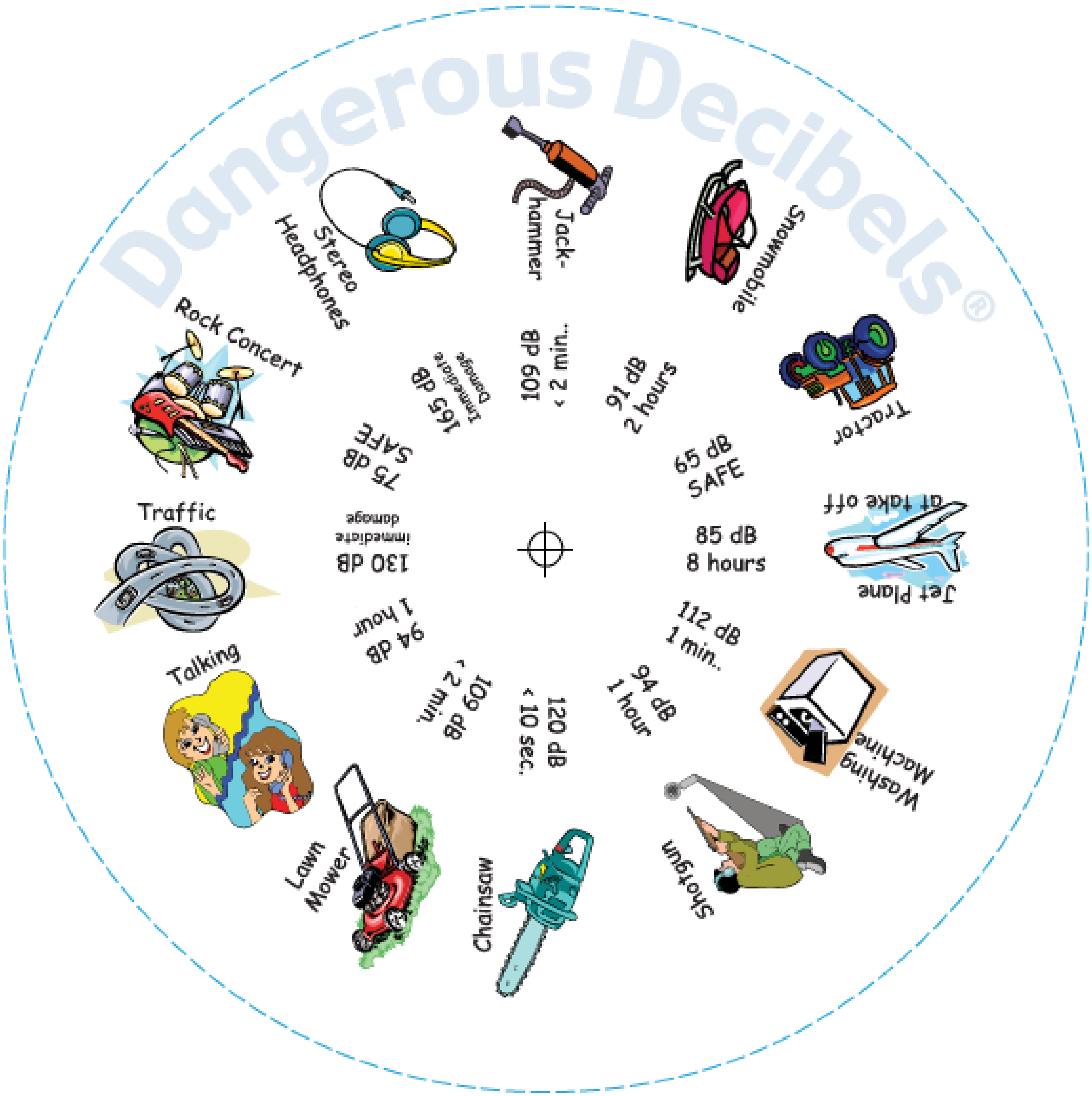


Peter Gillespie and Janet Cyr, Oregon Hearing Research Center, Oregon Health & Science University. 2005

Appendix F.1


Dangerous Decibels®
Turn It Down
Protect Your Ears
Walk Away
SOUND
How many decibels?*
How much time before damage?
Dangerous Decibels®
* Decibels are approximations according to NIOSH standards using dB(A) time weighted averages.
www.dangerousdecibels.org
Funded by grants from NIH-National Center for Research Resources, NIH-National Institute on Deafness and Other Communication Disorders, Marion Downs Hearing Center, and National Hearing Conservation Association
Dangerous Decibels® - Oregon Health & Science University, Portland, Oregon

Appendix F.2


Dangerous Decibels®
Jack-hammer
109 dB
< 2 min.
Snowmobile
91 dB
2 hours
Tractor
65 dB
SAFE
Jet Plane
at take off
85 dB
8 hours
Washing Machine
112 dB
1 min.
Shotgun
94 dB
1 hour
Chainsaw
120 dB
< 10 sec.
Lawn Mower
109 dB
< 2 min.
Talking
94 dB
1 hour
Traffic
130 dB
immediate
damage
Rock Concert
75 dB
SAFE
Stereo Headphones
165 dB
Immediate
Damage

Appendix G.1

Dangerous Decibels® **Educator Training Workshop**

YOU CAN MAKE A DIFFERENCE:

Learn a fun, interactive way to teach noise-induced hearing loss and tinnitus prevention.

Join us for the Dangerous Decibels Educator Training Workshop. We will prepare and equip you to expertly present a K-12 classroom program that is proven effective at changing knowledge, attitudes, and intended behaviors in students regarding their hearing health.

Open to all professional and educational backgrounds.

Open to anyone interested in teaching the valuable lesson of hearing loss prevention.

This two-day certification workshop (16 hours) is lead by Oregon Health & Science University, Portland State University, and University of Northern Colorado hearing conservation, health communication, educational outreach experts.

The workshop includes background information on hearing, anatomy, physics of sound, children and noise, etc. Instruction includes classroom management, hands-on activities, and an opportunity to deliver the program to instructors for critique and feedback. Workshop instructors are available after the workshop for continued support and as a resource through email or phone. We look forward to your participation.

- 16 hours of training including practice time
- Dangerous Decibels Educator Kit
- detailed script for the evaluated Dangerous Decibels' presentation
- certificate of training
- post-workshop support

OREGON HEALTH & SCIENCE UNIVERSITY

For more details about the next workshop:
www.dangerousdecibels.org/education
503-494-0670 howarthl@ohsu.edu

Appendix G.2
Dangerous Decibels Resources

Jolene

Jolene is a system for measuring the sound levels of personal stereo systems and is part of the Dangerous Decibels education and research projects.

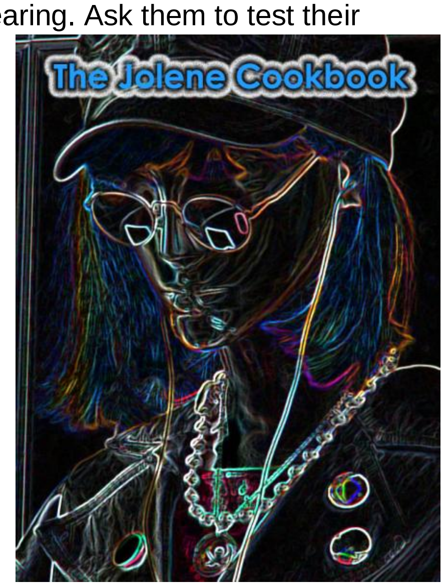
Jolene

- was constructed using a used fashion mannequin and a sound level meter wired to a silicon ear
- makes appearances at schools and universities, scientific meetings, health fairs, and many other public events
- always attracts a crowd and is helpful for promoting noise-induced hearing loss and tinnitus prevention
- has been used as a research tool to study the beliefs and listening practices regarding personal stereo systems

Jolene Cookbook

Jolene has been a success here in Oregon and many people around the world have requested instructions on how to make their own version. In response, the National Hearing Conservation Association funded the production of the *Jolene Cookbook* that is now available. To download your FREE copy of the cookbook, please go to www.dangerousdecibels.org.

We encourage all interested to download the Cookbook and create their own Jolene. Give him or her a name, take her/him to health fairs, the shopping mall, wherever people congregate. Talk to people about protecting their hearing. Ask them to test their personal stereo system (MP3s, CD players, etc.) to find out how loud they are listening to their music. Record what levels people are listening to their music. How long do they listen per day? What is their age?



Tell us where you take your “Jolene”, and about your experiences, send us a photo. We will add your comments and photos to the Jolene Family Album (dd@ohsu.edu).

Appendix G.3
Dangerous Decibels Resources

Dangerous Decibels DVD
DVD - multilayered introduction to how we hear (simple or more complex versions), what are decibels, types of hearing loss, protecting your ears, tinnitus (short or fuller version with testimonial), nine classroom activities. See page 12 in this Guide for more information about the DVD.

Dangerous Decibels Educator Kit
This kit gives you supplies to help you design and present your own classroom program on prevention of noise-induced hearing loss and tinnitus.
Included in the kit:
- Sound Level Meter
- Tuning Fork (physics of sound demo)
- Dangerous Decibels DVD
- Ear Anatomy Poster
- Caution Signs
- Ear plugs
- Pipe Cleaners (for stereocilia model)
- Ping Pong Ball (sound is vibration demo)
- Dangerous Decibels Teacher Resource Guide
- CD of Dangerous Decibels graphics
- List of Web Resources
- other fun and informative flyers and handouts

Dangerous Decibels Virtual Exhbit CD
The Virtual Exhibit is a collection of eight interactive games, simulations, and information activities to help prevent noise-induced hearing loss and tinnitus. View and play the components of the Virtual Exhibit on the Dangerous Decibels website. The activities are based on the full-sized Dangerous Decibels exhibit at the Oregon Museum of Science and Industry in Portland.

Jolene Cookbook
Download a free copy of the Jolene Cookbook (a how-to manual to build your own Jolene) from the Dangerous Decibels website or order a copy of the paper edition.

HOW TO ORDER
Please see the Dangerous Decibels website for more information on each of these and any new resources available. You will also find order forms at our online store.
WWW.DANGEROUSDECIBELS.ORG.
Or contract our office at 503-494-0670 or dd@ohsu.edu