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

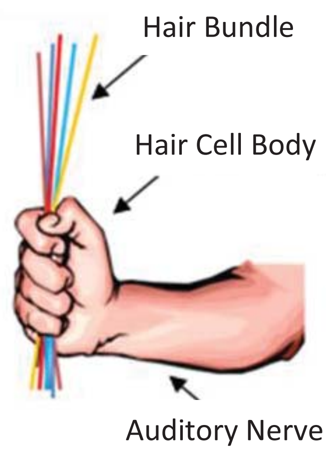
Prepare your workspace:

- 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:



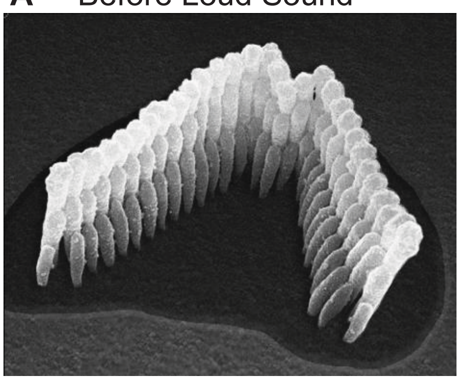
- Explain that they have just created a model of the hair cells.
- Their hand represents the cell body.
- The pipe cleaners represent the hair bundle on top of the hair cell.
- Their arm is the auditory nerve that carries signals from the hair cell (the ear) to the brain.
- Do their pipe cleaners resemble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

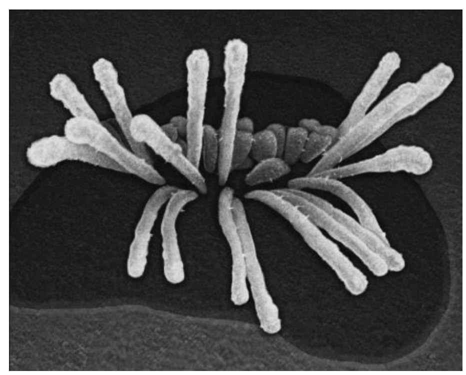
- Moving the hand over the pipe cleaners represents the sound waves. Sound waves produce vibrations strong enough to move objects much larger than microscopic hair cells represented by the pipe cleaner model.
- The teacher turns the volume of the music up a bit. Students move their hand a little more 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.