Cybersenses

Activity 2: Grades 9-12

In Tune

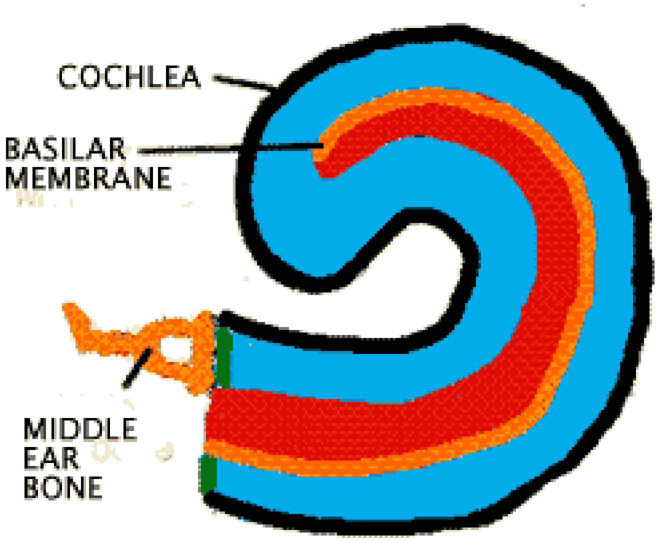
As you saw in "Every Sound is a Present," a cochlear implant is an electronic device that can bring sounds to people who are deaf. The implant consists of two parts: an external electronics package and an electrode that is implanted into the cochlea, a liquid-filled, coiled chamber within the inner ear. Sounds detected by an external microphone are converted into electrical signals. These signals are transmitted along the implanted electrode to the underlying nerve cells of the cochlea. The stimulated nerve cells transfer these electrical signals along the auditory nerve to the brain for processing.

A Closer Look at the Cochlea

Sounds enter and travel through the cochlea as vibrations in the fluid within it. The center of the cochlea's coiled chamber is not hollow, but instead contains a long filament that extends much of the chamber's length.

Covering one side of the filament is the basilar membrane. This membrane contains a series of fibers of varying lengths. These lengths are tuned to different sound frequencies. The longest of these fibers responds to low pitches and is located near the tip of the filament. The shorter fibers respond to high pitches and are located near the point where the filament meets the ear structure.

When the tuned filaments vibrate, they stimulate nearby nerve cells. These cells produce impulses that are transmitted along the auditory nerve to the brain.



Sound Science

Remind students that sound is a vibration that is transferred by matter. In order to make a sound, you need to coax matter into vibrating. When you blow into a soda container, you create vibrations in the enclosed air space. This semi-trapped air begins to vibrate. As it vibrates, it produces waves that spread into the surrounding air. We detect these waves as the distinct tone of the soda-container whistle.

If you add liquid to the container, the vibrating space gets smaller. Smaller spaces produce short waves. Short waves have high frequencies. That's why the pitch, or tone, goes up as you add water to your whistle-blowing container.

There's a different sound-making process at work when we strike a glass container with a spoon. This time, the vibration originates in the solid matter of the container itself. The glass vibrates and transfers this movement to the surrounding air. Again, we detect the vibrations as sound.

When water is added to the container, it reacts as if it were part of the glass. When the glass is struck, both the solid container and the liquid water vibrate. The pitch of the sound reflects this additional matter.

As you add more water to the container, it takes on a greater vibrating mass. Like the thicker strings of a bass, the larger mass produces sounds of lower frequency. That's why the pitch goes down when you add water to a glass that you are striking with a spoon.

In this activity, you'll observe how structures can be "tuned" to respond to different frequencies.

OBJECTIVE

This activity page will offer:

- an overview of cochlear implants
- an activity in sound making and sound transfer
- an opportunity to "tune" a vibrating receiver

MATERIALS

- Six 1-liter plastic bottles
- Water

PROCEDURE

Part 1-Sounding Off

1. Work with a partner. Clean and dry all plastic bottles.
2. Blow into the neck of a 1-liter bottle to produce a sustained note.
3. What will happen to this note if water is added to the bottle? Make a prediction and then find out by filling the bottle one-third full with tap water. When you blow into the bottle, is the note higher or lower than when the bottle was empty?
4. Add more water and observe the differences in the sound quality.

QUESTIONS

1. What happens to the sound quality as more water is added to the bottle?
2. What happens to the amount of air within the bottle space as water is added to the container?
3. How does the mass of a vibrating object affect its pitch?
4. Why does adding water to the bottle affect the pitch?

PROCEDURE

Part 2 - Tuned Whistles

1. Obtain three 1-liter bottles. Fill a 1-liter bottle 1/3 full with water. Fill a second bottle 2/3 full of water. Position these two water-filled bottles along with an empty bottle side-by-side on a desk.
2. Select a fourth 1-liter bottle as the "master" tone maker.
3. Have a partner put his/her ear close to the mouths of the three stationary bottles. From a distance of a few feet, blow into the master bottle to produce a steady tone. Then stop.
4. Have your partner note in which stationary bottle the sound continues

to ring loudest. 5. Fill the "master" 1/3 full of water. Repeat step 3. Note in which bottle the sound continues to ring loudest. 6. Repeat step 3 using a master bottle that is 2/3 full of water. Note in which bottle the sound continues to ring loudest.

QUESTIONS

1. In what form was energy transferred from the master tone maker to the other containers?
2. Which container continues to ring after the empty master is sounded?
3. Which container continues to ring after the 1/3-full container is sounded?
4. What relationship can you infer from these observations?

Bringing It All Together

Review how the cochlea separates sounds according to frequency. Then, have students discuss the concept of a tuned "reed." Apply this understanding to the transferring of whistle tones between bottles. You might wish to present the following sequence of scripted questions:

1. What causes the central filament within the cochlea to vibrate?
2. How is the basilar membrane adapted to distinguish pitches?
3. What caused the target container to produce the sound of the master tone maker?
4. Why didn't all of the containers respond to the master sound tone?
5. How is the tuning of the basilar membrane and the water-filled containers similar?

EXTENSIONS

Noteworthy Connection

Use a piano or portable keyboard as a guide for creating a set of plastic bottles that will correspond to the notes of the musical scale. Work in a group, using the set of plastic bottles to produce a musical composition that includes all of the notes.

Critical Thought

When you gently tap on a glass with a metal utensil, you also produce a musical note. Think about it. As you add water to this glass, the sounded note drops in pitch. Can you explain this result?

Exploring the Ear's Energy Transfer

Sound energy moves through the surrounding air as compression waves. When these waves strike the eardrum, the wave energy is changed into vibratory motion in the drum. This vibration is passed mechanically through the middle ear bones. This mechanical energy is then transferred to the liquid within the inner ear. Nerve cells that line the cochlea detect these movements and generate an electric impulse. This impulse moves through the neuron, eventually reaching the tip of the cell's axon. Here, the electric impulse is turned into a chemical signal. The chemical signal is released into the gap between neighboring cells. A chemical change stimulates the next neuron. Once again the impulse becomes electrical. It continues to flip-flop between an electrical and chemical signal as it races to the brain.

Review this transfer sequence with students. Then, challenge teams to construct a large mural that depicts these transfers. If applicable, supply them with materials and have students assemble an alternate pathway (from sound to brain) using Rube Goldberg-type mechanics.

Model Building

Build a model of the ear. Use print and electronic resources to uncover information about ear anatomy. If practical, include working parts such as a vibrating eardrum and moving middle ear structure.

Web Connection

A Virtual Tour of the Ear

http://www.augie.edu/perry/ear/hearmech.htm

An Introduction to Cochlear Implants

http://www.hope4hearing.org/implant.htm

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In Tune

Part 1-Sounding Off

QUESTIONS

1. What happens to the sound quality as more water is added to the bottle?
   (The pitch goes up.)
2. What happens to the amount of air within the bottle space as water is added to the container?
   (It decreases because the air is forced out of the bottle.)
3. How does the mass of a vibrating object affect its pitch?
   (The greater the mass, the lower the pitch.)
4. Why does adding water to the bottle affect the pitch?
   (As water is added, the pitch goes up because the size of the vibrating air mass has decreased.)

Part 2 - Tuned Whistles

QUESTIONS

1. In what form was energy transferred from the master tone maker to the other containers?
   (The energy was transferred as sound waves that traveled through the surrounding air.)
2. Which container continues to ring after the empty master is sounded?
   (The empty test container.)
3. Which container continues to ring after the 1/3-full container is sounded?

(The 1/3-full container.)

4. What relationship can you infer from these observations?
   (Containers will vibrate "in-sync" if they contain the same amount of water as the master tone maker.)

Bringing It All Together

Review how the cochlea separates sounds according to frequency. Then, have students discuss the concept of a tuned "reed." Apply this understanding to the transferring of whistle tones between bottles. You might wish to present the following sequence of scripted questions:

1. What causes the central filament within the cochlea to vibrate?
   (Vibrations within the surrounding fluid.)
2. How is the basilar membrane adapted to distinguish pitches?
   (It has a series of fibers with varying lengths. Each length responses to a specific frequency.)
3. What caused the target container to produce the sound of the master tone maker?
   (Vibrations traveled through the air and struck the container causing it to vibrate.)
4. Why didn't all of the containers respond to the master sound tone?
   (Only the containers that were "tuned" to that frequency responded.)
5. How is the tuning of the basilar membrane and the water-filled containers similar?
   (Objects or regions will vibrate if they are "in tune" to the surrounding waves. If they are not in tune, they won't respond.)

EXTENSIONS

Critical Thought

When you gently tap on a glass with a metal utensil, you also produce a musical note. Think about it. As you add water to this glass, the sounded note drops in pitch. Can you explain this result?

(In this case it is the container, not the volume of trapped air that is vibrating. As water is added to the glass, it becomes part of the "container." When a greater mass vibrates, it produces a tone of lower pitch.)