

The Marvelous Ear



How Do Our Ears Work? Quiz

1. **How do humans hear sounds?**
2. **How does human hearing work? Sketch and label the system.**
3. **Do you know any sensors that detect sound and how they might do it? Explain.**

How Do Our Ears Work? Quiz Answers

1. How do humans hear sounds?

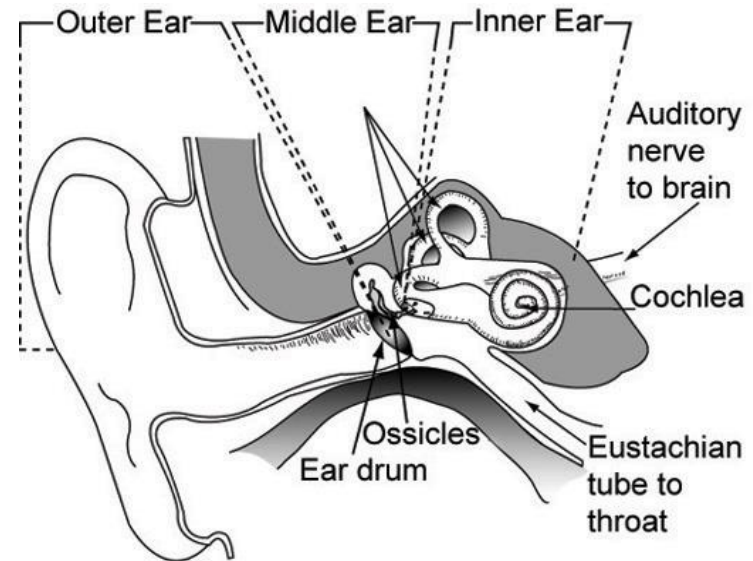
Humans hear sounds by using our ears, which have an interesting set of bones and a fluid-filled structure, to determine sound types.

2. How does hearing work?

Sketch and label the system.

Sound waves enter through the outer ear, are amplified by the middle ear, and are converted into electrical impulses within the inner ear.

sketch →



3. Do you know any sensors that detect sound and how they might do it?

A microphone is an example of a sensor that detects sound. It detects voices and instruments and converts them into electricity, which is sent to speakers that convert it back into sound.

Hearing: How Do Our Ears Work?

Activity Objective

- Investigate how hearing works.
- Learn about the differences in detecting sound intensities (loudness).
- Conduct a hands-on activity with LEGO TaskBots that uses a sound command to help understand the relationship between different noise levels created and the different sound intensities detected.

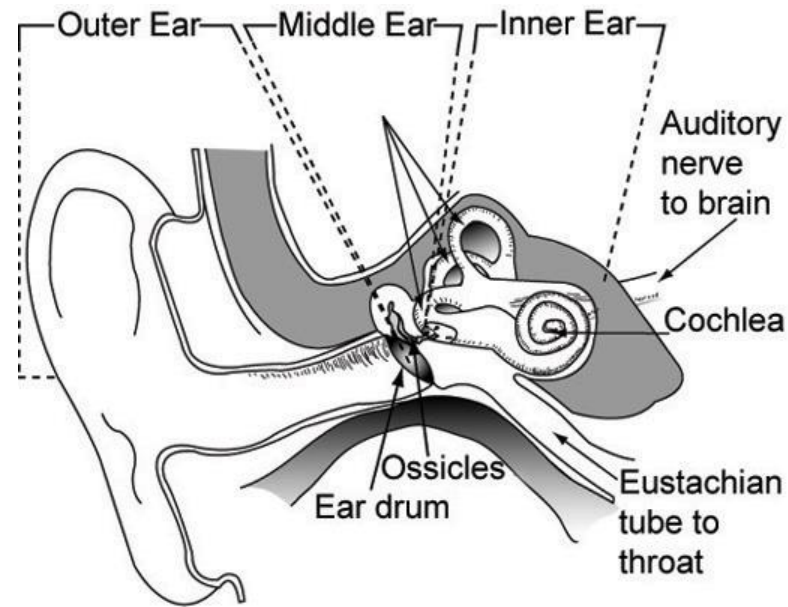
What Is It and How Does It Work?

Our ears are extraordinary organs!

- Our ears pick up all the sounds around us and translate this information into a form our brains can understand.
- One of the most remarkable things about this process is that it is completely **mechanical**, until it reaches the nerves when it becomes an **electrical** process.
- On the other hand, the senses of smell, taste and vision involve chemical reactions and electrical signals, while hearing sense is based solely on physical movement .
- Sound waves cause the tympanic membrane (eardrum) to vibrate.
- Humans can hear sounds waves with frequencies between 20 and 20,000 Hz.



How Does Hearing Work?

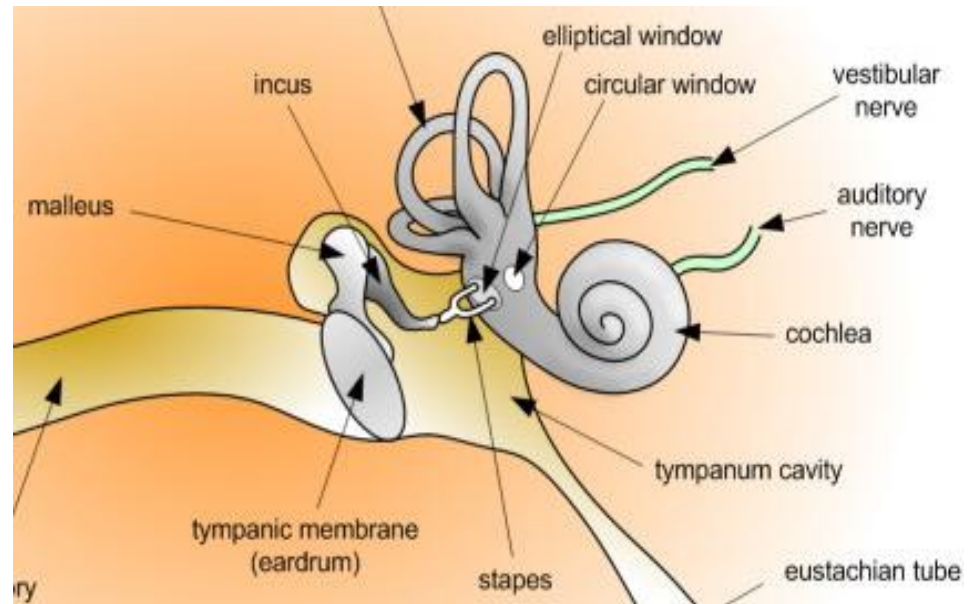


The Outer Ear

- The outer ear, also called **pinna**, catches sound waves and funnels them through the ear canal.
- The human outer ear is **angled forward** so we hear sounds in front of us better than sounds behind us.
- The **eardrum** marks the boundary to the middle ear. It is stretched tight, just like the skin of a real drum, and it is very sensitive.
- Another function of the eardrum is to stop noisy, low-pitched background sounds that come in through the ear canal. By doing this, the eardrum helps us **distinguish** more important sounds, such as conversations.

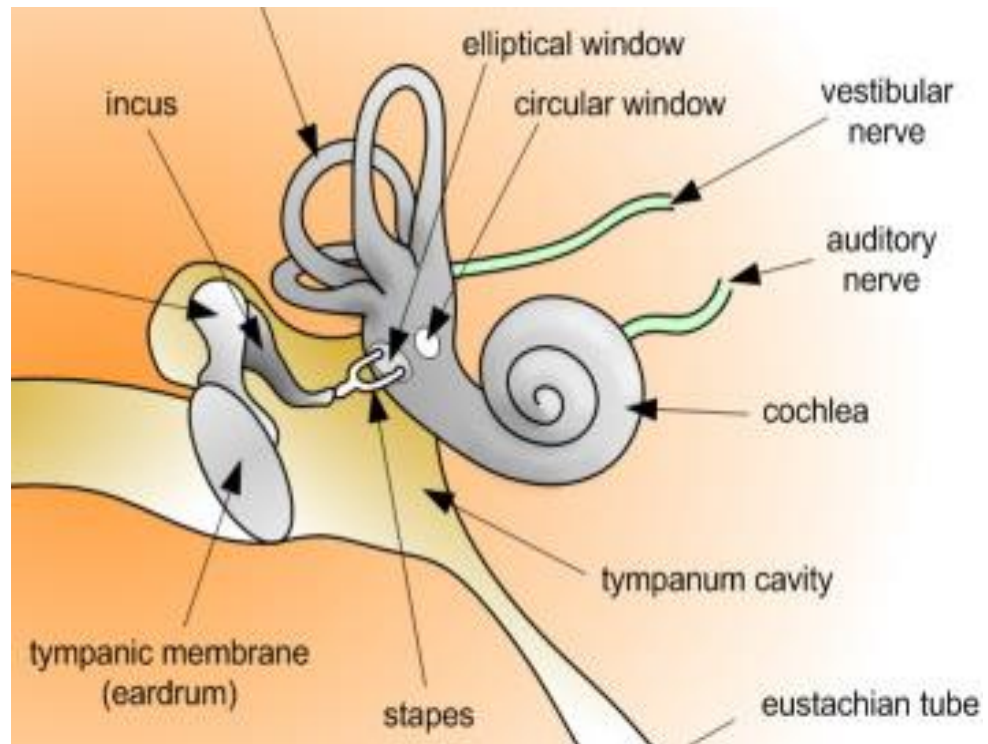
How Does Hearing Work?

The Middle Ear



- The middle ear has three tiny bones called **ossicles**.
- The first bone is the **hammer** (malleus), which is connected to the inner wall of the eardrum. On the other side, the hammer is attached to the **anvil** (incus), which in turn is attached to the **stirrup** (stapes).
- When sound makes the ear drum move, the eardrum pushes on the hammer and moves the anvil and stirrup.
- By these **mechanical steps**, the **vibrations from sounds** travel all the way to the middle and inner ears.
- The ossicles (three bones of the middle ear) are pushed harder for louder sounds and softer for softer sounds.

How Does Hearing Work?

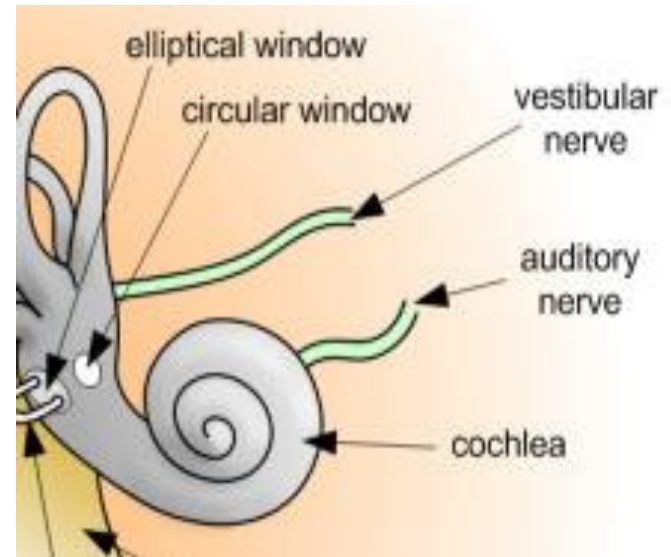


The Inner Ear

- The stirrup is a very complex part of the ear. It contains a fluid-filled system called the **cochlea**, which is responsible for hearing.
- In the cochlea, the vibrations transmitted from the eardrum through the stirrup are converted into **electrical impulses**, which are sent along the auditory nerve to the brain.
- Next to the cochlea, are three arches filled with fluid called the **vestibular system**, which is responsible for the **sense of balance**.

How Does Hearing Work?

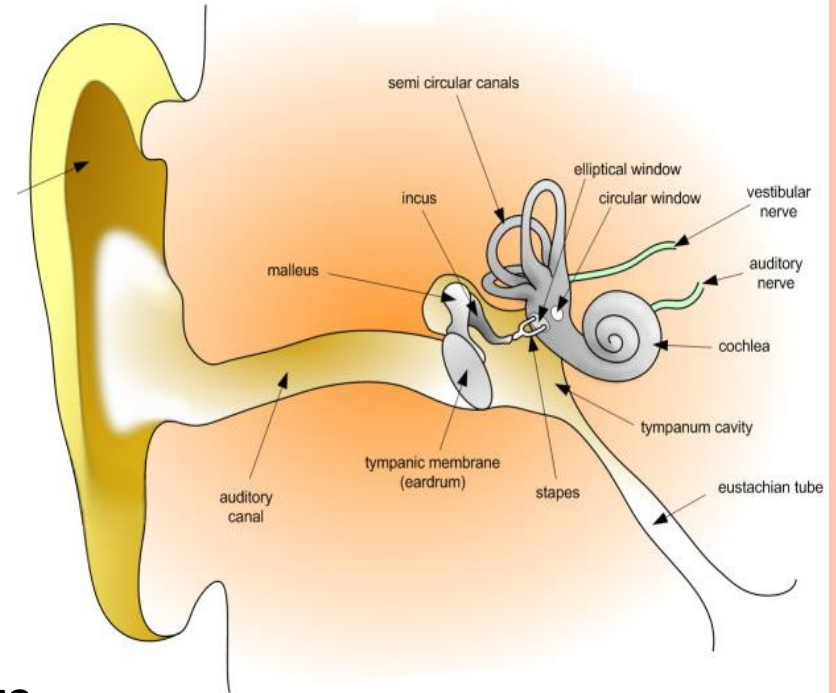
The Inner Ear - Cochlea



- The most interesting aspect of hearing takes place in the **cochlea**.
- The cochlea is **a tapered tube**, which circles around itself like the scroll on a violin.
- A basilar membrane divides the cochlear tube lengthwise into two fluid-filled canals, which are joined at the tapered end.
- The ossicles transmit the vibration to the cochlea where they attach at the oval window.
- The resultant waves travel down the basilar membrane where they are “sensed” by the 16,000-20,000 hair cells (cilia) attached to it, which poke up from a third canal called the **organ of Corti**.
- The organ of Corti transforms the stimulated hair cells into nerve (**electrical**) impulses.

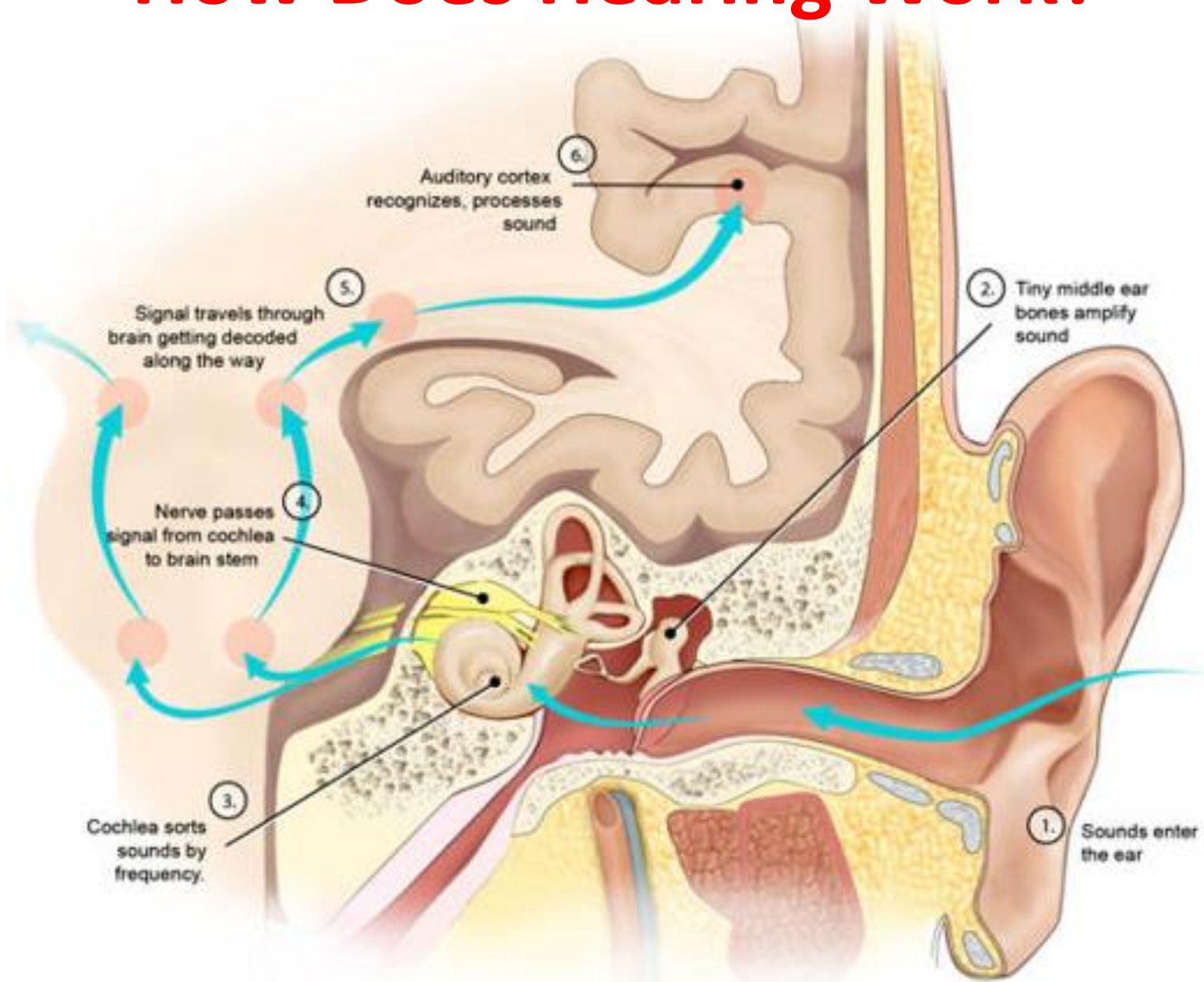
Let's Review: How Does Hearing Work?

- Sound waves enter the **outer ear** and cause the *eardrum* to vibrate.
- Vibrations of the eardrum are carried through the middle ear (**hammer, anvil,** and **stirrup**) to a fluid-filled structure called the **cochlea**.



- Different pitches cause different parts of the fluid in the cochlea to vibrate.
- When cochlear fluid vibrates, it moves the hairs (cilia) connected to nerve cells, which send signals to the brain via the **auditory nerve**.
- The brain helps you recognize the sound.

How Does Hearing Work?






LOUDNESS!

- Loudness is measured in decibels (dB):

...the louder the sound, the more **decibels**

- Decibels measure the force of sound waves.
- Approximate decibel levels for some **everyday sounds** ↓

Sound	Intensity (dB)	
watch ticking	20	
whisper	30	
normal speech	50-60	
car traffic	70	
alarm clock	80	
law mower	85	
chain saw	110	
jackhammer	120	
jet engine	130	

How Hearing Works: Animation

Watch the [short animation](http://cliftonaudiology.com/flash/howhearingworks.htm) at this website for a nice illustration of how our ears work:

<http://cliftonaudiology.com/flash/howhearingworks.htm>



Activity: Use the NXT Robot Sound Sensor to Determine Intensities of Various Sounds

Steps to prepare for the activity:

- Attach the sound sensor to any one of ports 1-4 of the NXT brick.
- Press the **orange button** to turn ON the NXT brick.
- Use the right and left move buttons to scroll over to VIEW.
- Select Sound Sensor dBA and indicate the port that the sound sensor is connected to.
- Look for a box and a % indicated within of the loudness of the sound that the NXT sound sensor is hearing —on a scale of 0 to 100.



Now you are ready begin the experiment!

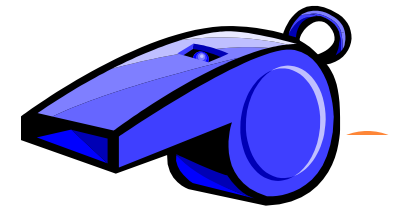
Sound Intensity Worksheet

- Measure each sound with the sound sensor approximately **6 inches** away from the source of sound, then approximately **12 inches** away.
- Use a ruler to measure each distance.
- Take note of what happens to the sensor reading when the distance to the sound changes.
- Use table on the worksheet to **record your data** on the loudness of the various tested sounds, and include some of your own choices for sound-making sources in the blank cells.

SOUND SOURCE	NXT SENSOR READING	
	6 inch distance	12 inch distance
no sound		
clap		
soft whistle		
loud whistle		
telephone ring		
vacuum cleaner		

The Marvelous Ear Quiz

1. How do humans hear sounds?
2. How does hearing work? Sketch and label the system.
3. What did you learn from the sound sensor activity?



The Marvelous Ear Quiz Answers

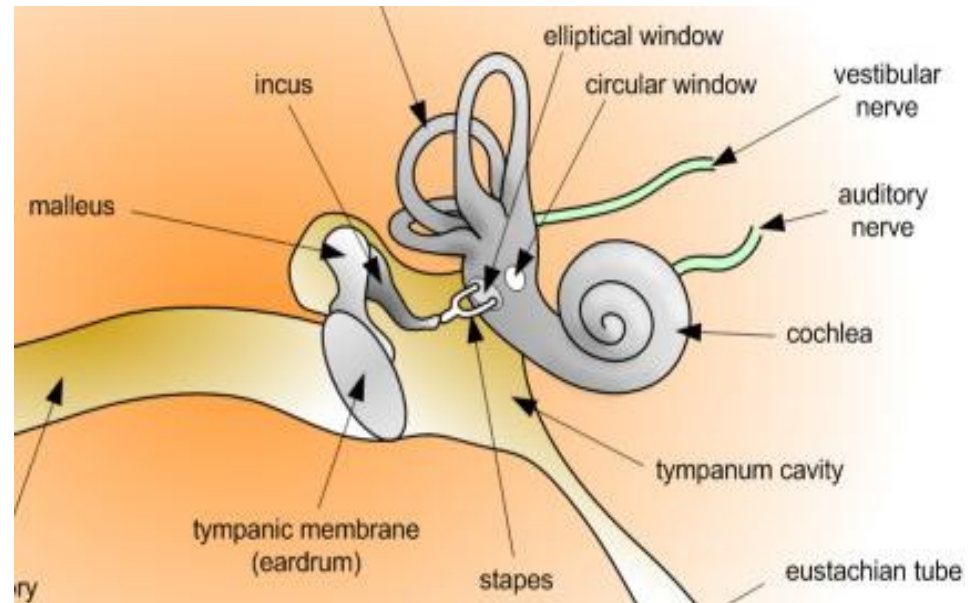
1. How do humans hear sounds?

Using our ears, which have a fascinating set of bones and a fluid-filled structure, to determine sound types.

2. How does hearing work? Sketch and label the system.

Sound enters through the outer ear, is amplified by the middle ear, and is converted into electrical impulses within the inner ear.

sketch ↗



3. What did you learn from the sound sensor activity?

Intensity of sound decreases with increasing distance.

NXT robot can determine intensity of sound, similar to our own ears.

Human hearing is a mechanical and electrical process.

Image Sources

Slide 1: photo of ear; State of Ohio <http://www.tclw.das.ohio.gov/Default.aspx?tabid=325>

Slide s 3 and 6: cutaway drawing of ear anatomy; NASA via Wikimedia Commons
http://commons.wikimedia.org/wiki/File:Outer,_middle_and_inner_ear.jpg

Slide 5: Man with megaphone at ear; Microsoft clipart <http://office.microsoft.com/en-us/images/>

Slides 7-10, and 17: Human ear anatomy; Dan Pickard, Wikimedia Commons {PD}
<http://commons.wikimedia.org/wiki/File:HumanEar.jpg>

Slide 11: Hearing mechanics medical illustration; Zina Deretsky, National Science Foundation via Wikimedia Commons {PD} http://commons.wikimedia.org/wiki/File:Hearing_mechanics.jpg

Slide 12: graphics of watch, clock, jet, Microsoft clipart <http://office.microsoft.com/en-us/images/>

Slide 13; two girls whispering & woman with bullhorn; Microsoft clipart
<http://office.microsoft.com/en-us/images/>

Slide 14: LEGO robotics sensors; www.LEGO.com

Slide 16; whistle; Microsoft clipart <http://office.microsoft.com/en-us/images/>