National Aeronautics and Space Administration

GRADES **K-8**

Good Vibrations

airspace

Aeronautics
Research
Mission
Directorate

Museum in a BOX Series

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Good Vibrations

Lesson Overview

Noise from aircraft is an increasing problem in our environment. Contributing factors include an increase in air traffic, demand for land in cities which has pushed developments closer to airports and larger aircraft which require more powerful engines. Science, Technology, Engineering, and Mathematics (STEM) will help solve this problem. Many groups are working to create solutions. The following three hands-on activities will help students better understand several basic principles of sound:

Tuning Forks: Students will engage in a series of demonstrations that illustrate the concept of vibrations, pitch, frequency, and beats.

Thunder Drum: Students will add a simple spring to the design of a thunder drum and hear very unusual sounds.

Resonator: Students will directly observe resonance in a pair of demonstrations using a series of wooden dowels to illustrate the concepts of natural frequency and resonance.

Student worksheets are provided.

Objectives

Students will learn about transfer of energy, motions and forces, and interactions of energy and matter as they learn about the following concepts:

1. Several principles of sound.
2. Noise from aircraft is a growing problem that NASA along with many others are working to reduce the amount of
3. All sounds are caused by vibrations.
4. Vibrations can be sensed in several ways (hearing, seeing and touching).
5. Pitch is related to the speed or rate of vibration.
6. Resonance
7. Natural frequency of an object.

Materials:

In the Box

Tuning forks, set of 4

Tuning fork, C-256

Tuning fork activator

Tuning fork block (for holding the tuning forks)

Ping pong ball with attached string (1 ft.)

Large Thunder Drum

Safety glasses

Provided by User

Table

Container of water (plastic food storage container works well)

Several sheets of paper

GRADES K-8 **Time Requirements:** 1 hour 5 minutes

Background

As scientists and engineers work to reduce noise pollution from aircraft, a thorough understanding of the physics of sound is necessary. Sound is one of the most important ways we have of sensing our surroundings and communicating with others. Sound itself is a sensation created in the human brain in response to sensory inputs from the inner ear. However, not all sounds are desirable or beneficial.

All sounds are produced by vibrating objects. One of the reasons that there are so many different sounds is that there is an endless variety of materials that can vibrate and produce them. When you talk or sing, two ligaments that are hidden in your larynx vibrate. They are called your vocal cords or vocal folds. Each person has a unique set of vocal cords and a uniquely designed larynx which gives rise to the individual character of a person's voice.

Following are some properties of sound waves:

- Frequency and pitch depend on the length of an object that is vibrating; a short string will vibrate faster producing a higher frequency (or pitch) than a long string.
- Multiple sound waves can reinforce or interfere with each other.
- Sound insulation is designed to absorb sound waves. Many of the same materials used in temperature insulation can be used to reduce sound.
- Sound can be reflected (bounced off) or refracted (bent).
- Sound levels decrease rapidly as the distance from the point of origin to the receiver increases; if the distance from the source is doubled, then the intensity decreases approximately one-fourth.

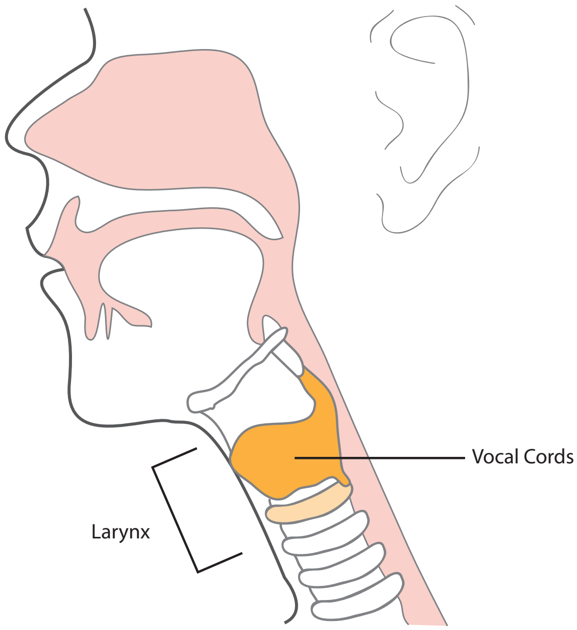


Fig. 1 Vocal cords and larynx

- Some examples of sound intensities as measured by decibels:

Jet plane at takeoff 110-140dB
Loud rock music 110-130dB
Chain saw 110-120dB
Thunderstorm 40-110dB
Vacuum cleaner 60-80dB
Normal voices 50-70dB
Whisper 20-50dB
Purring cat 20-30dB
Falling leaves 10dB
Silence 0dB

Objects have a frequency at which they prefer to vibrate. This frequency depends on its size and of the material of which it is made. This preferred frequency is called the **natural frequency.** The natural frequency is also called the **resonant frequency.** A guitar string is a good example: When plucked it will vibrate at its natural frequency.

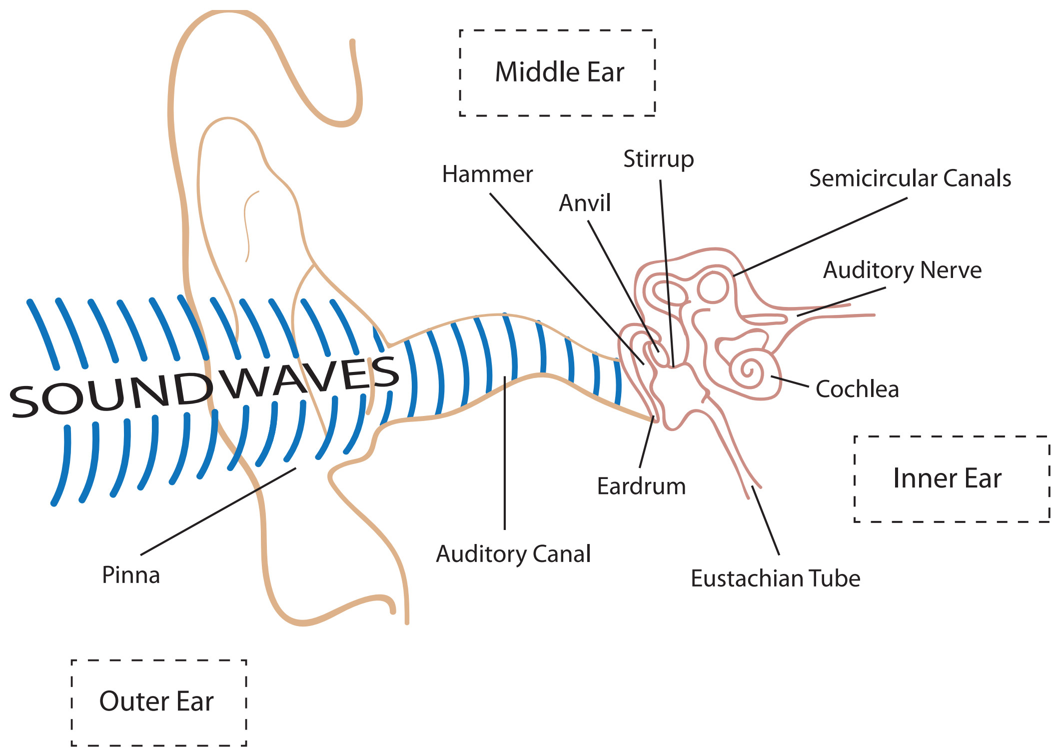


Fig. 2 The human ear

The Human Ear

- The outer ear collects sound waves.
- Sound waves travel down the ear canal and vibrate the eardrum.
- The three small bones (hammer, anvil, stirrup) vibrate behind the eardrum.
- The vibrations enter the cochlea which changes the mechanical energy of the vibrations into electrical nerve impulses that travel to the brain.
- The normal range of sound that a human can hear is about 40 – 18,000 Hertz (Hz).
- As we age, the frequency range tends to narrow; the higher range is most affected.
- Many animals can detect a wider range of sound frequencies than humans can. Dogs can hear higher frequencies than humans; elephants can hear lower frequencies.

For additional information on sound, please review the following Museum in a Box lessons:
Quieting the Popper
Speed of Sound
Seeing Sound

Activity 1 Tuning Forks

GRADES K-8

Time Requirements: 45 minutes

Materials:

In the Box

Tuning forks, set of 4

Tuning fork, C-256

Tuning fork activator

Tuning fork block (for holding the tuning fork)

Ping pong ball with attached string (1 ft.)

Provided by User

Table

Container of water (plastic food storage container works well)

Several sheets of paper

Worksheets

Tuning fork worksheet (Worksheet 1)

Reference Materials

None

Key Terms:

Frequency

Pitch

Vibrations

Interference

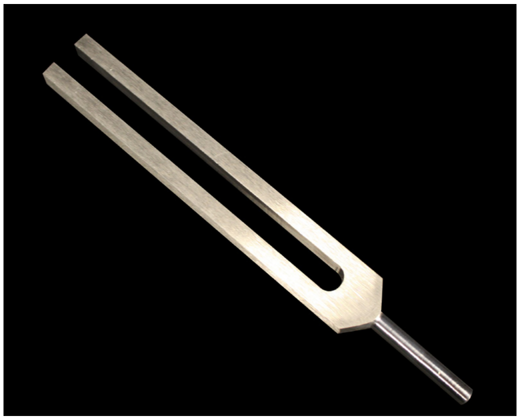
Objective:

Students will learn about motions and forces, transfer of energy, and interactions of energy and matter as they study the following:

- Several principles of sound
- Sounds are caused by vibrations
- Vibrations can be sensed in several ways (hearing, seeing, touching)
- Pitch is related to the speed or rate of vibration

Activity Overview:

Students will engage in a series of demonstrations using tuning forks that illustrate the concept of vibrations, pitch, frequency, interference and beats.



Activity:

Note: Always use the "Tuning Fork Activator" (the rubber block) to initiate the tuning fork vibrations. Activating a tuning fork on the soft edge will make it ring at its fundamental resonant frequency – no distortion from higher harmonics. The tuning fork activator also eliminates dings and scratches typically caused when tuning forks are chimed against each other or on a tabletop.

1. **Activate each of the four tuning forks and listen to the sound by placing the tuning fork close to one ear.** Compare the pitch of each of the tuning forks: 256-C, 320-E, 385-G and 512-C. The number, e.g., 256, indicates the frequency in Hertz of the tuning fork. With a 256-C tuning fork the tines, or metal forks, will be moving back-and-forth 256 times in one second. Describe what you hear on Worksheet 1.

2. **Reactivate the tuning fork using the tuning fork activator.**

3. **Place the tips of your fingers lightly on the vibrating tines of a tuning fork and feel the vibrations.** Describe what happens on Worksheet 1.

4. **Hold a sheet of paper in one hand and use the other hand to activate the tuning fork with the activator.** Touch the paper to the vibrating tines of a tuning fork. What occurs? Describe what happens on Worksheet 1.

5. **Place the tines of a vibrating tuning fork into the water.** Describe what happens on Worksheet 1.

6. **Try placing the end of the handle of a vibrating tuning fork on the top of your head.** Press the handle against your skull bone fairly hard. You may be able to hear the vibrations from the tuning fork transmitted through your skull to the tiny bones in your inner ear. Describe what you hear on Worksheet 1.

7. **Instead of using the top of your skull, try placing the handle against the skull bone immediately behind one of your ears.** Describe what happens on Worksheet 1.

8. **Try placing the handle onto the top of a table or other objects.** Describe what happens on Worksheet 1.

9. **Suspend the Ping Pong Ball with the Attached String like a pendulum by holding the free end of the attached string.** Slowly, bring a vibrating tuning fork in contact with the motionless ping pong ball. Describe what happens on Worksheet 1.

10. **Activate the two "C" note tuning forks.** Hold both vibrating tuning forks next to your ear. You should hear a pulsing sound. The sound will not be constant or consistent. The intensity should vary. You are hearing the beat frequency, caused by alternating constructive/destructive interference. In order for beats to occur, the frequencies of the two tuning forks must be close, but do not have to be exactly the same. Even though the tuning forks indicate a frequency of 256 Hz, due to the manufacturing process normally you will not find two tuning forks with exactly the same frequency. Describe what you hear on Worksheet 1.

11. **As an experiment, using the two "C" note tuning forks, place a small piece of masking tape near the top of one of the tuning fork tines.** This should be enough to slightly change the frequency of vibrations. By adding weight, and sometimes this is intentionally done, what effect do you think it will have on the frequency? (Hint: Compare the size of a 256-C and a 320-E fork.) What is the effect on the sound due to different sizes? Describe it on Worksheet 1.

Worksheet 1 Questions/Answers

1. **Circle the tuning fork that had the lowest pitch:**

   256-C   *320-E*   *385-G*   *512-C*

2. **Circle the tuning fork that had the highest pitch:**

   256-C   *320-E*   *385-G*   *512-C*

3. **Describe what happened when you placed the vibrating tines:**

   next to your fingers:

   the tines tickle your fingers

   next to a sheet of paper:

   you hear a buzzing sound made as the tines hit the paper

   in the water:

   the water splashes

   in contact with the ping pong ball

   the ping pong ball quickly bounces away

4. **Describe what happened when you placed the handle:**

   on top of your skull:

   you may begin to hear the vibrating tuning fork as the vibrations are transmitted through your skull to the tiny bones behind your ear drum

   on the skull bone behind your ear:

   same result as above

   on top of a table:

   the table may resonate and amplify the sound of the vibrating tuning fork

   on other objects:

   results vary depending on the object; some objects will resonate while others will not

Discussion Points:

1. **All sounds are produced by vibrations.** When something vibrates it moves back and forth and usually does so very quickly. If the vibrations are within the range of human hearing, we detect a sound. For example, when set in motion, the two forks (tines) of a tuning fork move back and forth, or vibrate.

2. **Ask students to correlate the frequency of a tuning fork to the pitch of the sound.** As the frequency of the sound increases, the pitch increases. *Note: it is important to activate the tuning fork properly by using the tuning fork activator. Otherwise, something called harmonics result which could cause confusion in trying to answer this question. When properly activated, very little sound from the tuning fork will be heard unless the tuning fork is placed close to the ear. Any sounds heard at a distance from the tuning fork are probably harmonics. Harmonics have a higher frequency than the fundamental natural frequency.*

The lowest frequency that an object can vibrate at is called the fundamental frequency. The fundamental frequency is the simplest way at which an object can vibrate. An object can also resonate at other frequencies and these are called harmonics. In most cases when an object vibrates, there are many harmonics produced which give musical sounds a quality known as timbre. For example, when a piano and a violin play the same note, there is a big difference in the way we perceive the sound quality. This is due to the different harmonics produced in the respective instruments. The number of harmonics produced depend on the object vibrating and the way the vibration is achieved. So, with the tuning fork, to achieve primarily the fundamental mode, it should be struck with the rubber activator.

3. **All music instruments produce sounds by something that vibrates.** Ask students to identify what vibrates in the following music instruments:

Instrument	Primary source of vibration
Guitar	Strings
Piano	Strings
Saxophone	Reed
Trumpet	Player's lips
Drum	Drumhead
Flute	Air inside the flute

4. **Since there is no engine in a glider to make noise, does a glider pilot experience any noise?**
Yes, the sound of air rushing over the wings and fuselage.

5. **When does an airplane make the most noise? Why?**
When taking off and climbing. There are many possible causes for this. Larger aircraft engines generate more noise than smaller aircraft. The sound intensity during take off and climbing are produced nearer the ground and do not have as far to travel to a person than when an aircraft is 4,000 meters in altitude. The intensity from a point source of sound obeys the inverse square law. A sound source 2 times farther away will produce only 1/4 the sound intensity.

6. **Ask students to describe their own experiences with noise from aircraft.** They might compare the noise produced by commercial jets, military jets, helicopters and propeller driven airplanes.

7. **What causes all sounds?**
Vibrations

8. **What are vibrations?**
For example, a guitar string that rapidly moves back and forth is a vibration.

9. **What is pitch?**
Highness or lowness of a sound

10. **Compare the pitch of the predominate sound made by a helicopter and a jet engine. Which do you think produces the higher pitch?**
Jet engine

11. **What is frequency?**
    The periodic change in sound pressure

12. **What units are used to measure frequency?**
    Cycles per second or in Hertz, Hz.

13. **What is pitch?**
    The degree of height or depth of a tone or of sound, depending upon the relative rapidity of the vibrations by which it is produced.

14. **How is pitch related to frequency?**
    When frequency increases, the pitch goes up.

15. **Explain noise.**
    Noise is a random mixture of frequencies.

16. **Do you think that aircraft can produce sounds that humans cannot hear but other animals can?**
    Yes; both above and below the normal range of human hearing.

NATIONAL SCIENCE STANDARDS K-4

SCIENCE AS INQUIRY

• Abilities necessary to do scientific inquiry

• Understanding about scientific inquiry

PHYSICAL SCIENCE

• Property of objects and materials

SCIENCE AND TECHNOLOGY

• Abilities of technological design

• Understanding about science and technology

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

• Abilities necessary to do scientific inquiry

• Understandings about scientific inquiry

PHYSICAL SCIENCE

• Properties and changes of properties in matter

• Transfer of energy

• Motions and forces

SCIENCE AND TECHNOLOGY

• Abilities of technological design

• Understanding about science and technology

Activity 2

Thunder Drum

GRADES **K-8**

Time Requirements: 20 minutes

Materials:

In the Box

Large Thunder Drum

Provided by User

None

Worksheets

None

Reference Materials

None

Key Terms:

Vibrations

Resonance

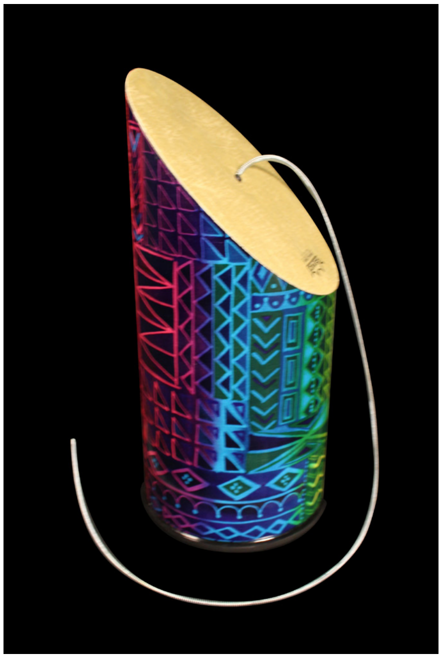
Objective:

Students will learn about motions and forces and transfer of energy as they:

- Understand that vibrations cause sound
- Are introduced to resonance

Activity Overview:

Students explore vibrations as the source of sound through the use of the Thunder Drum, which provides an introduction to the principle of resonance. A simple spring that has been added to the design produces some unusual sounds.



Activity:

The Thunder Drum is a musical instrument used in theaters to create thunderous rumbling with a twitch of the attached string. In order to play it:

1. **Place your fingers through the handle slots and shake it with a twisting motion, thus allowing the spring to vibrate.**

2. **You can create a variety of sounds by placing the opposite hand over the top and scrape the spring or strike it while it is in motion to create a variety of sounds.**

3. **Lift the spring and let it go to demonstrate a greater resonance .**

4. **Gently place your fingertips on the drumhead that does not have the spring connected while the Thunder Drum vibrates and produces a sound.** What do you feel?

Discussion Points:

1. **The Thunder Drum provides an excellent demonstration of resonance, which occurs when a vibrating object causes another similar object to vibrate.** Specifically, resonance occurs in the Thunder Drum when the drumhead with the spring begins to vibrate. The air inside the drum vibrates and transfers energy to the other end which also begins to move back and forth (vibrate).

2. **Can energy from the vibrating drumhead with the spring be transferred to the other drumhead through the drum cylinder?**
   Yes. To answer this question, place your fingertips lightly on the drum cylinder to determine if it is also vibrating.

3. **Aeronautical engineers are very concerned about resonance in the design of engines and the airframe.** In most cases it is not ideal for vibrating parts of the engine or airframe to cause other parts to begin to vibrate. Unwanted vibrations can cause critical parts to break or fail to function.

4. **Compare resonance in musical instruments with resonance in aircraft.** (Musical instruments are designed to produce resonance in the instrument. For example, a guitar string without the guitar body and sound hole would not sound very loud. Aeronautical engineers work to reduce or eliminate resonance from the engines.)

NATIONAL SCIENCE STANDARDS K-4

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

PHYSICAL SCIENCE

- Property of objects and materials

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

PHYSICAL SCIENCE

- Properties and changes of properties in matter
- Transfer of energy
- Motions and forces

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

Reference Materials

Glossary

Decibel:
Unit of sound intensity

Frequency:
The periodic change in sound pressure; frequency is measured in cycles per second or in Hertz (Hz)

Hertz (Hz):
The unit used when designating frequency; cycles per second

Intensity:
The average rate at which sound energy is transmitted through an area between a source and a receiver; sound energy is measured in watts/cm2 or in decibels (dB)

Interference:
Regarding sound waves, when two waves of the same, or nearly the same, frequency pass through the same region of space, they interact with each other and cause interference; interference can be either constructive or destructive, depending on how the waves interact

Noise:
Sound with no set patterns in rhythm or frequency; a random mixture of frequencies

Pollution:
The contamination of soil, water, or air with substances, or sounds, that do not belong

Pitch:
The highness or lowness of a sound

Resonance:
The vibration of an object when exposed to sound at its own natural frequency, as in a window pane vibrating when a helicopter flies overhead

Vibrations:
The back-and-forth motion of an object, usually rapid; when referring to sound, many different "objects" can vibrate, such as a guitar string, a column of air, the reed in a clarinet, or your vocal chords

Fig. 1 Vocal cords and larynx

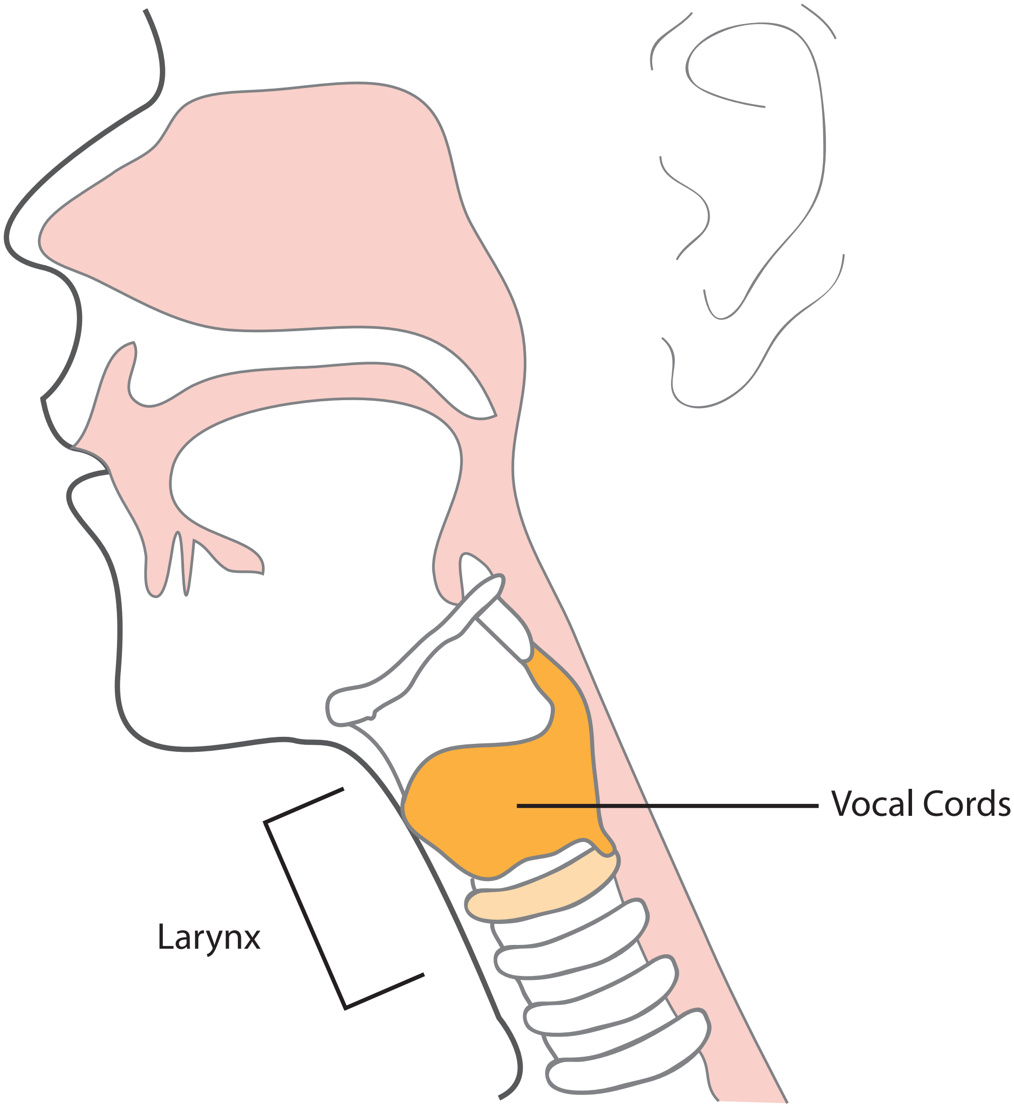
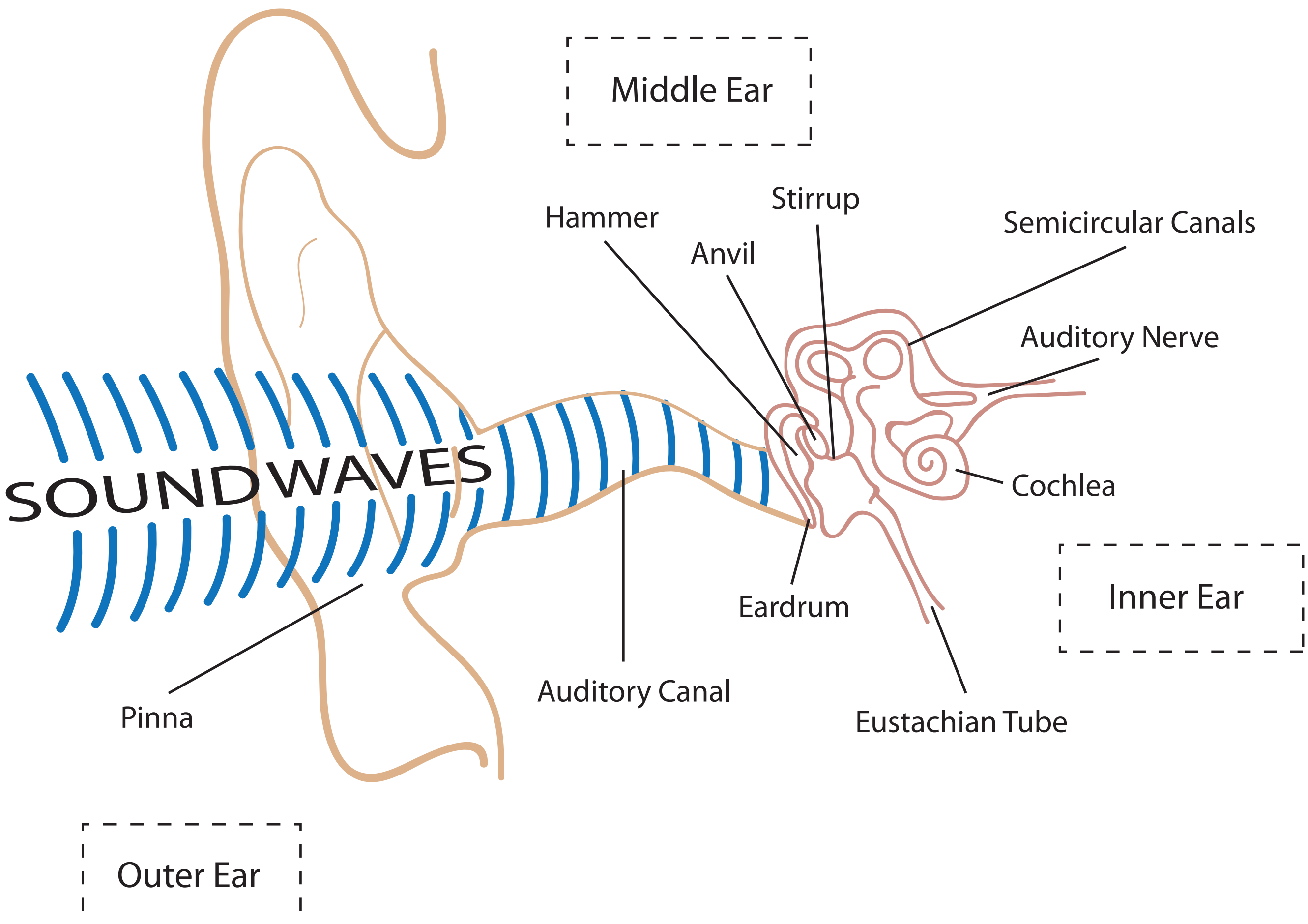


Fig. 2 The human ear



Worksheets

Worksheet 1 Tuning Forks

1. **Circle the tuning fork that had the lowest pitch:**

   256-C *320-E* *385-G* *512-C*

2. **Circle the tuning fork that had the highest pitch:**

   256-C *320-E* *385-G* *512-C*

3. **Describe what happened when you placed the vibrating tines:**
   next to your fingers:

   next to a sheet of paper:

   in the water:

   in contact with the ping pong ball

4. **Describe what happened when you placed the handle:**
   on top of your skull:

   on the skull bone behind your ear:

   on top of a table:

   on other objects:

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