Sound Energy

Chapter 17B

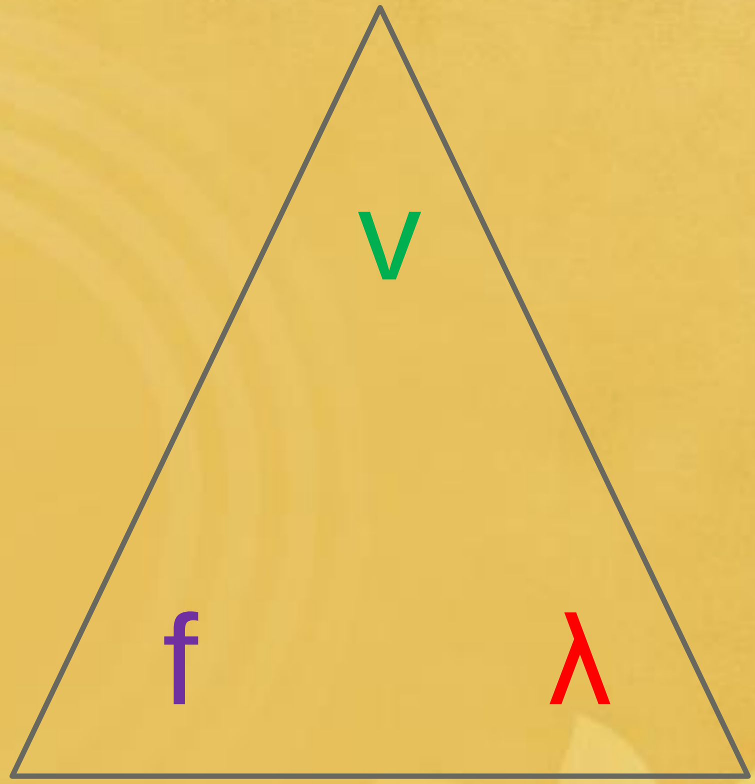
Wavelength & Frequency

v = ?

Speed of sound = ? X ?

f = ?

λ = ?



What is the relationship between frequency and wavelength at constant speed?

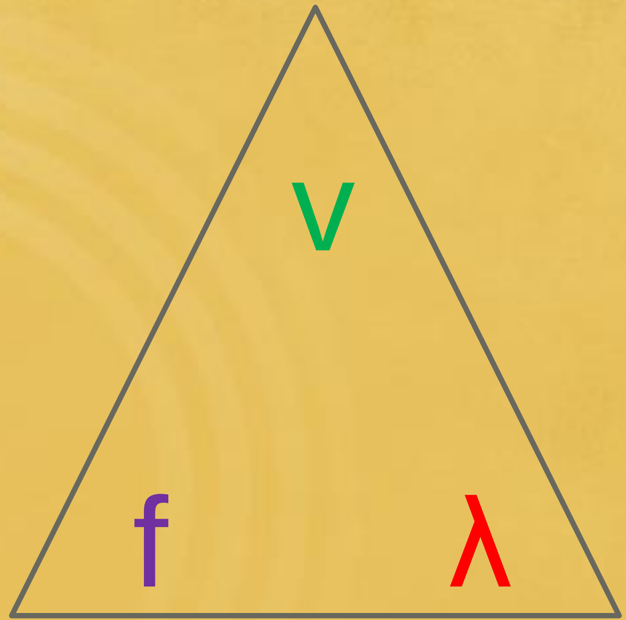
Wavelength & Frequency

$$v = f\,\lambda$$

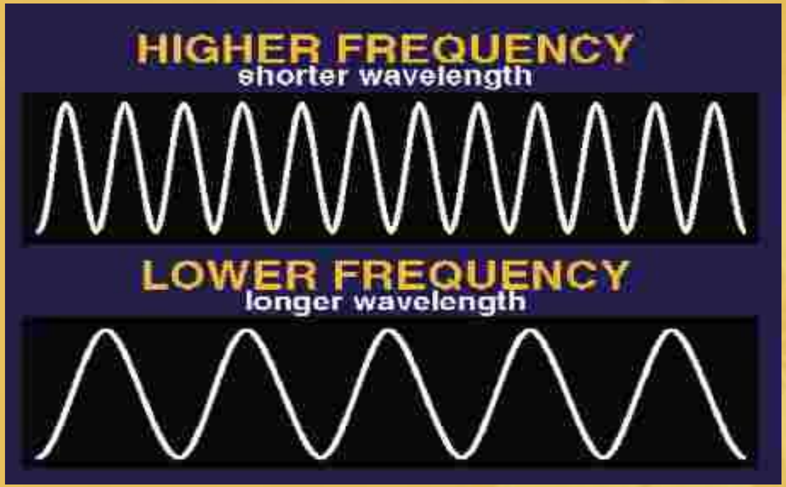
Speed of sound = frequency x wavelength

$$f = v\,/\,\lambda$$

$$\lambda = v\,/\,f$$



There is a **INVERSE** relationship between **frequency** and **wavelength** at constant speed.



Sound

Wavelength & Frequency

WARM-UP

$v = f\,\lambda$ $f = v / \lambda$ $\lambda = v / f$

Fill in the data table using the appropriate equation & 330 m/s for the speed of sound:

	Low C	D	E	F	G	A	B	High C
f (Hz)	256		320		384		480	
λ (m)		1.15		0.97		0.77		0.64

Wavelength & Frequency

$v = f\lambda$ $f = v / \lambda$ $\lambda = v / f$

Fill in the data table using the appropriate equation & 330 m/s for the speed of sound:

	Low C	D	E	F	G	A	B	High C
f (Hz)	256	**288**	320	**341**	384	**427**	480	**516**
λ (m)	**1.29**	1.15	**1.03**	0.97	**0.86**	0.77	**0.69**	0.64

λ = 330 m/s / 256 Hz

f = 330 m/s / 1.15 m

λ = 330 m/s / 320 Hz

f = 330 m/s / 0.97 m

λ = 330 m/s / 480 Hz

f = 330 m/s / 0.64 m

λ = 330 m/s / 384 Hz

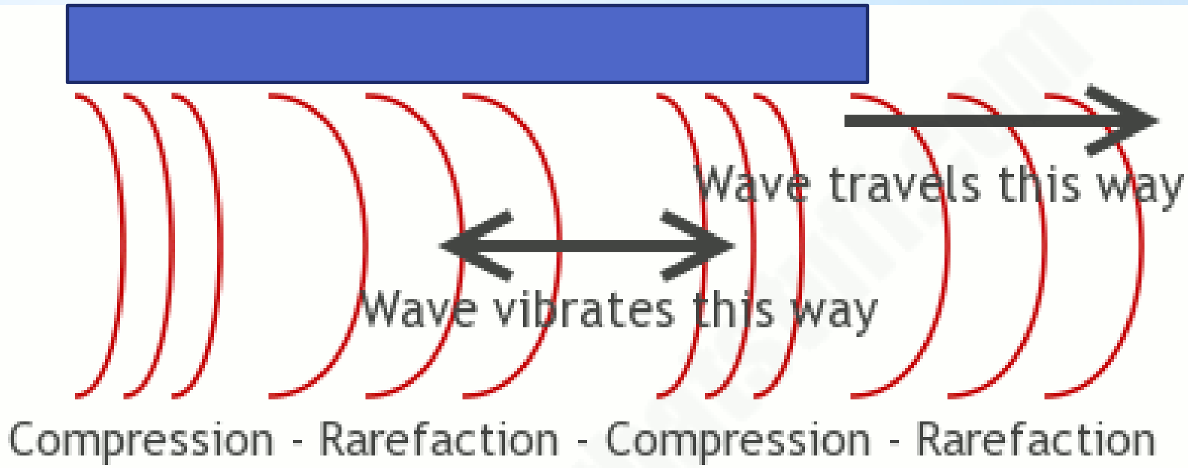
f = 330 m/s / 0.77 m

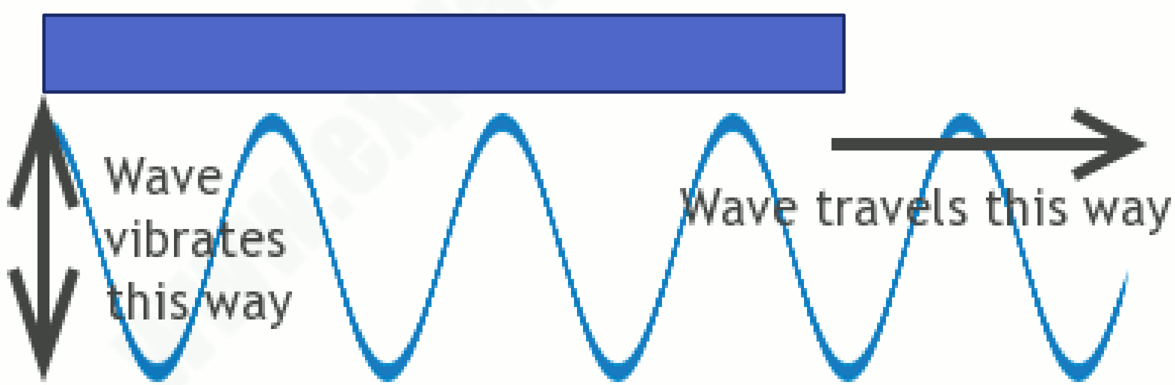
Which wave property increases as the energy of a wave increases?

Period … frequency … wavelength … amplitude

The direction of propagation of a sound wave is ___ to its direction of oscillation (___ & ___).

The direction of propagation of a ___ wave is ___ to its direction of oscillation (___ & ___).





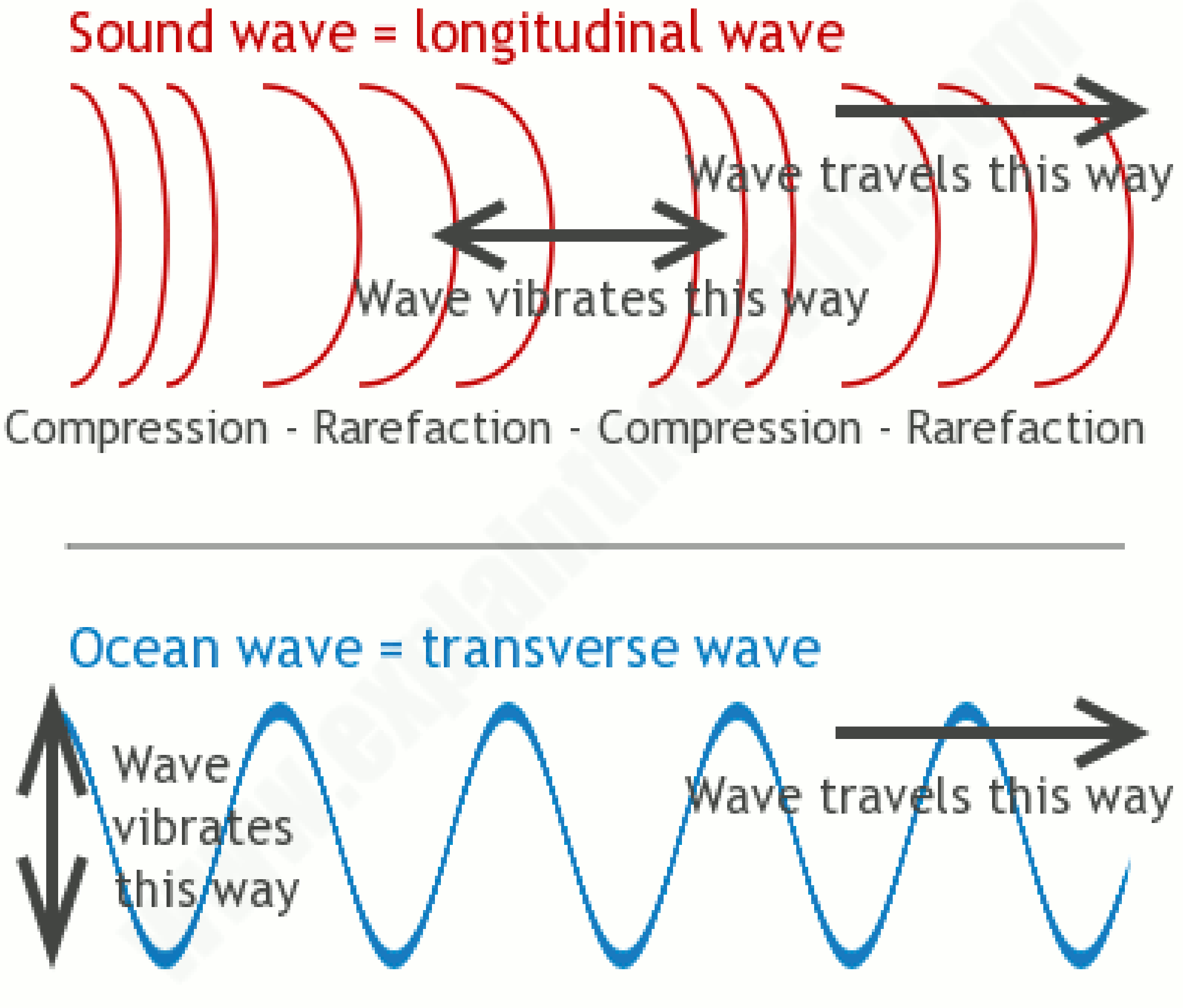
Which wave property increases as the energy of a wave increases?

Period … frequency … wavelength … **amplitude**

WARM-UP

The direction of propagation of a sound wave is **parallel** to its direction of oscillation (**back & forth**).

The direction of propagation of a **transverse wave** is **perpendicular** to its direction of oscillation (**up & down**).



Focus Questions

LESSON QUESTION

1. How is sound produced, transmitted, and heard?
2. Identify the properties of waves related to sound (longitudinal, wavelength, amplitude, frequency, speed, interference, standing waves, reflection, refraction) and calculate variables.
3. Explain and recognize behaviors of sound waves (Doppler Effect, refraction, reflection, resonance, diffraction].
4. Distinguish between pure sound, noise, and music. How do musical instruments work?

Simulation Part 2

LESSON QUESTION

How can Sound travel or be transmitted? (1:12)

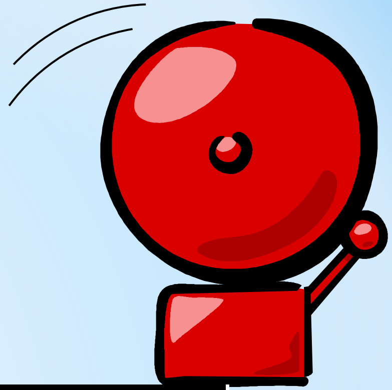
http://somup.com/cbeD3hRA7

1) Air will be removed from the Box”. What happens to sound when air is gone?

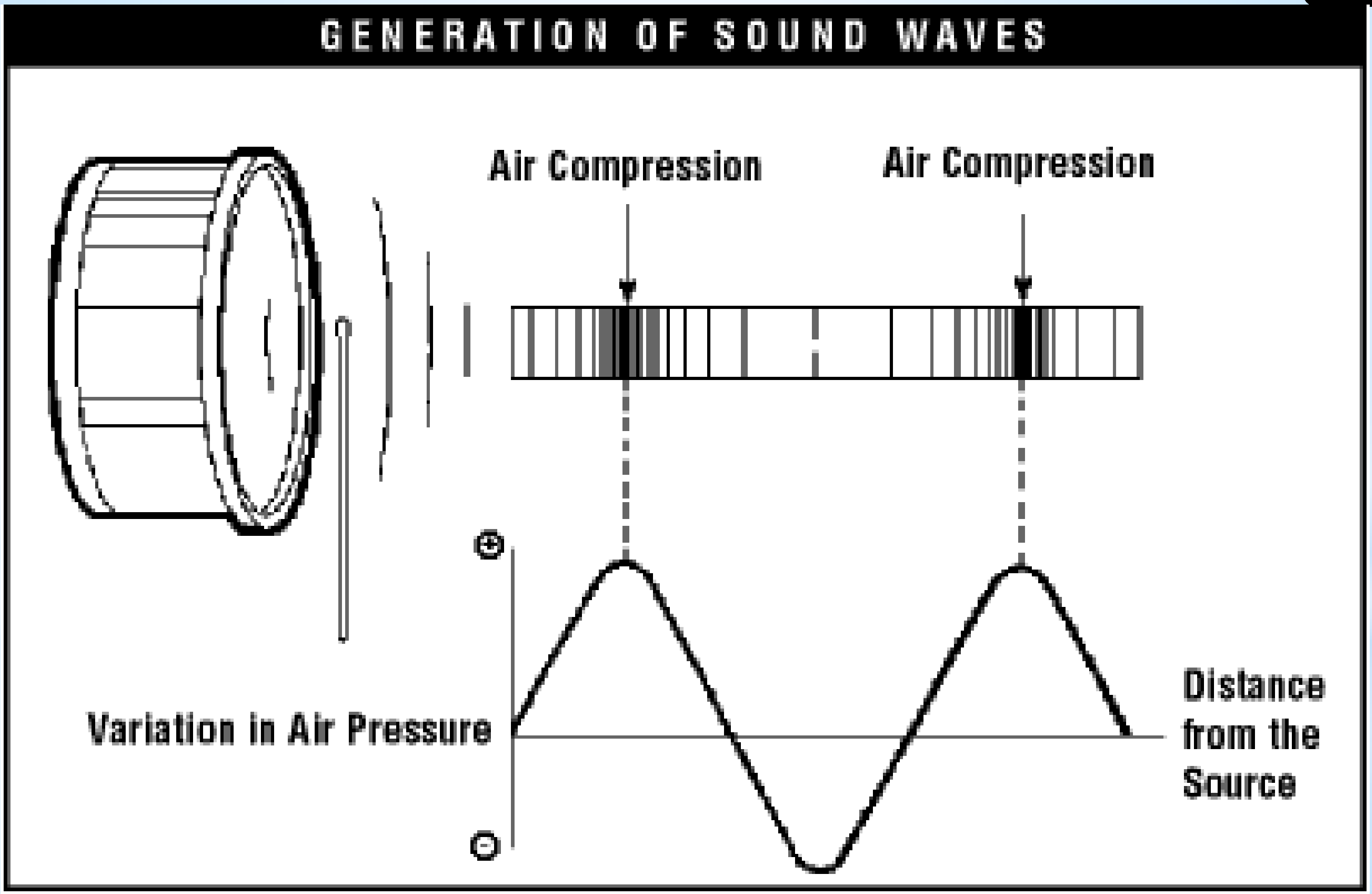
2) Air is added back into the Box”. What happens as air reenters the box?

3) What is a necessary ingredient to transmit sound?

Generation of Sound?



Vibration of Particles



If a tree falls in a forest, and there is no one there to hear it, does it make a sound?

If a tree falls in a forest, and there is no one there to hear it, does it make a sound?

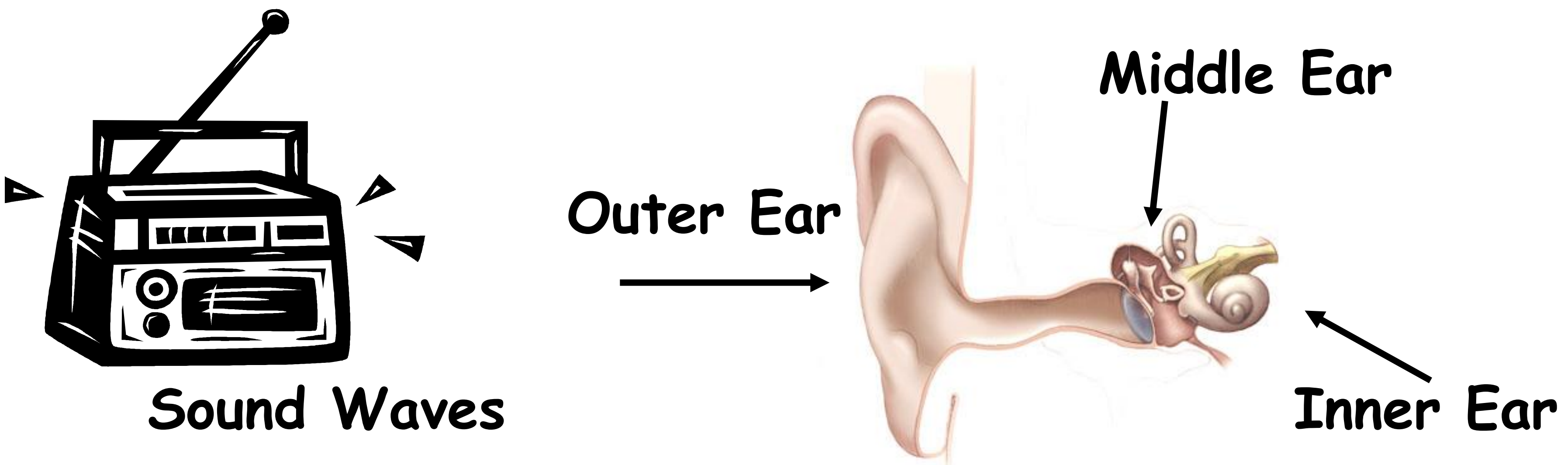
Sound is a physical disturbance in a medium.

Therefore, there IS sound in the forest, whether a human is there to hear it or not!

A person to hear it is not required. The medium (air) is required!

How do we hear?

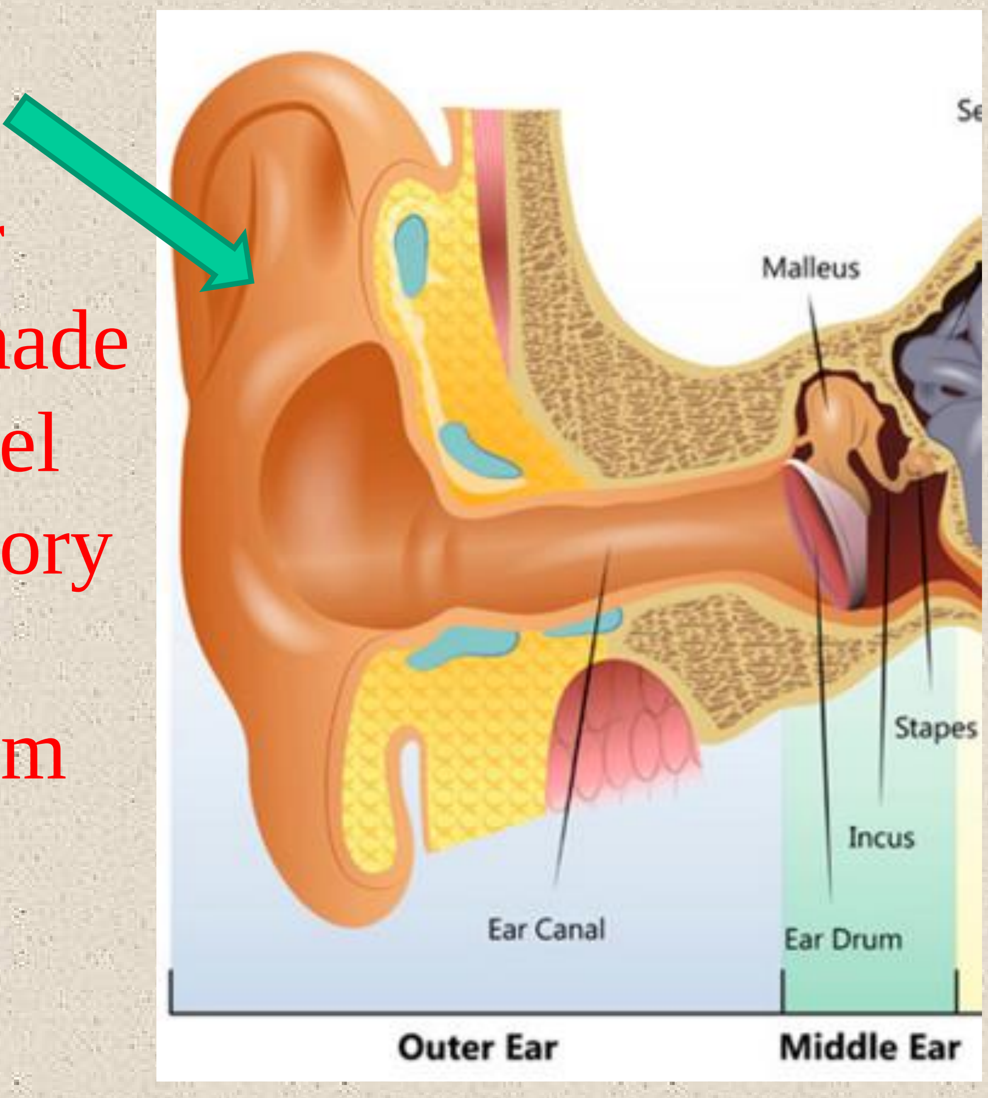
- Sound waves are sent out from vibrating objects.
- The outer ear "catches the sound waves".
- The middle ear takes the sound waves and "vibrates" the eardrum.
- The inner ear sends the messages to the brain.



- The brain puts it together and hooray! You hear your favorite song on the radio.

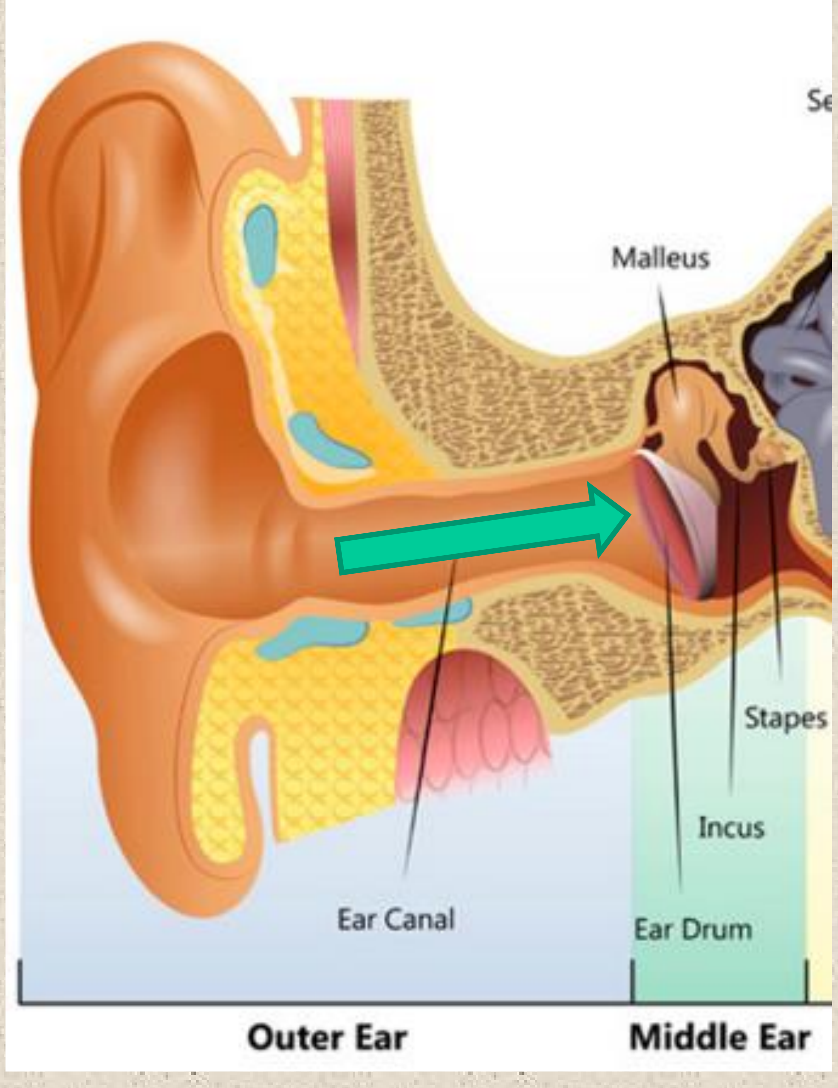
The Human Ear

The exterior part of the ear (the **auricle**, or pinna) is made of cartilage and helps funnel sound waves into the auditory (ear) canal, which has wax fibers to protect the ear from dirt.



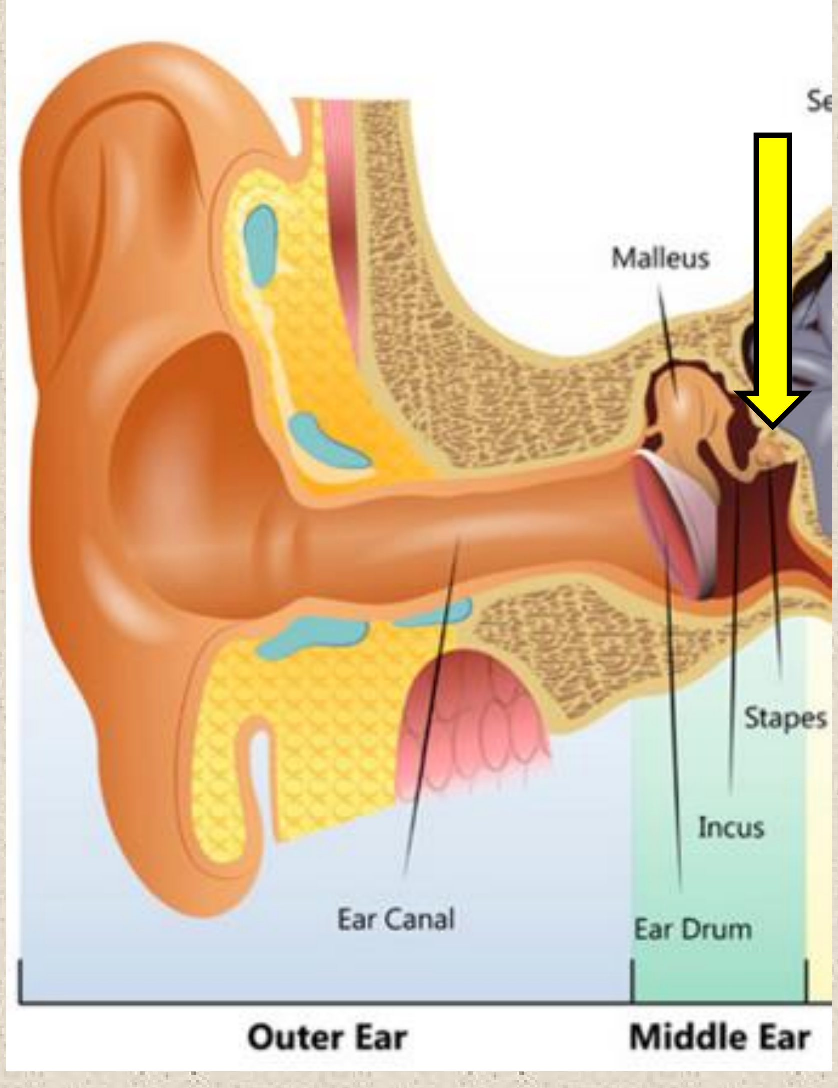
The Human Ear

At the end of the ear canal lies the **eardrum** (tympanic membrane), which vibrates with the incoming sound waves and transmits these **vibrations** along three tiny bones (ossicles) called the **hammer, anvil, and stirrup** (**malleus, incus, and stapes**).



The Human Ear

The little **stapes (stirrup)** bone is attached to the oval window, a membrane of the **cochlea**.



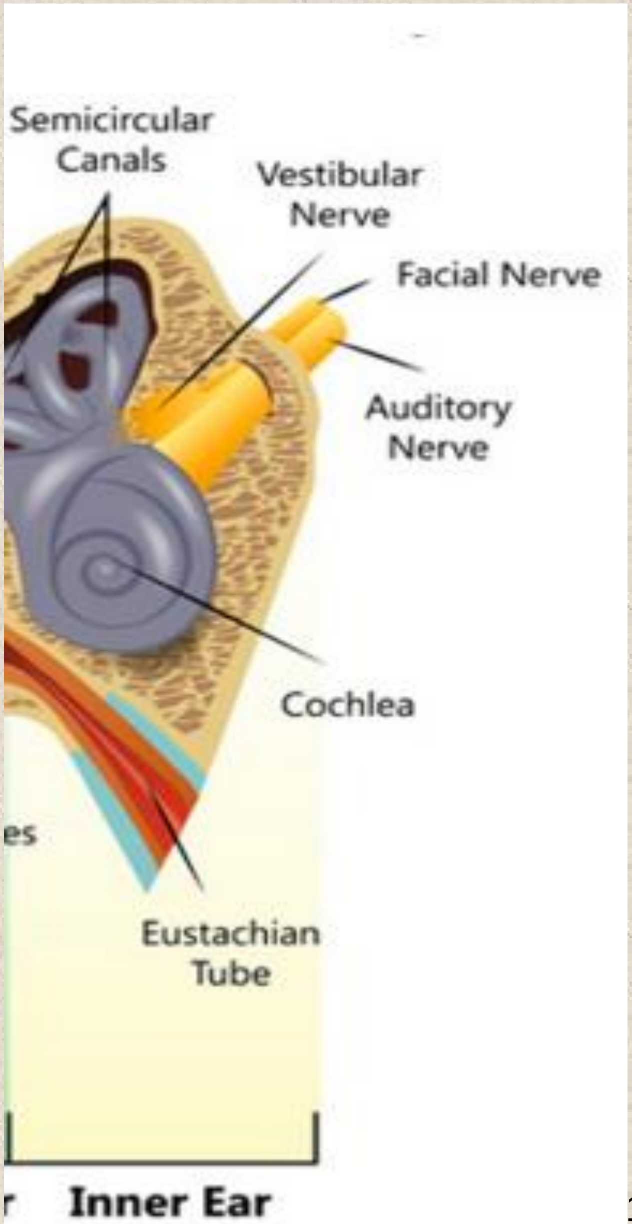
The Human Ear

The **cochlea** is a coil that converts the vibrations it receives into electrical impulses and sends them to the brain via the **auditory** nerve.

Delicate hairs (stereocilia) in the cochlea are responsible for this signal conversion.

These hairs are easily damaged by loud noises, a major cause of hearing loss!

The semicircular canals help maintain balance, but do not aid hearing.



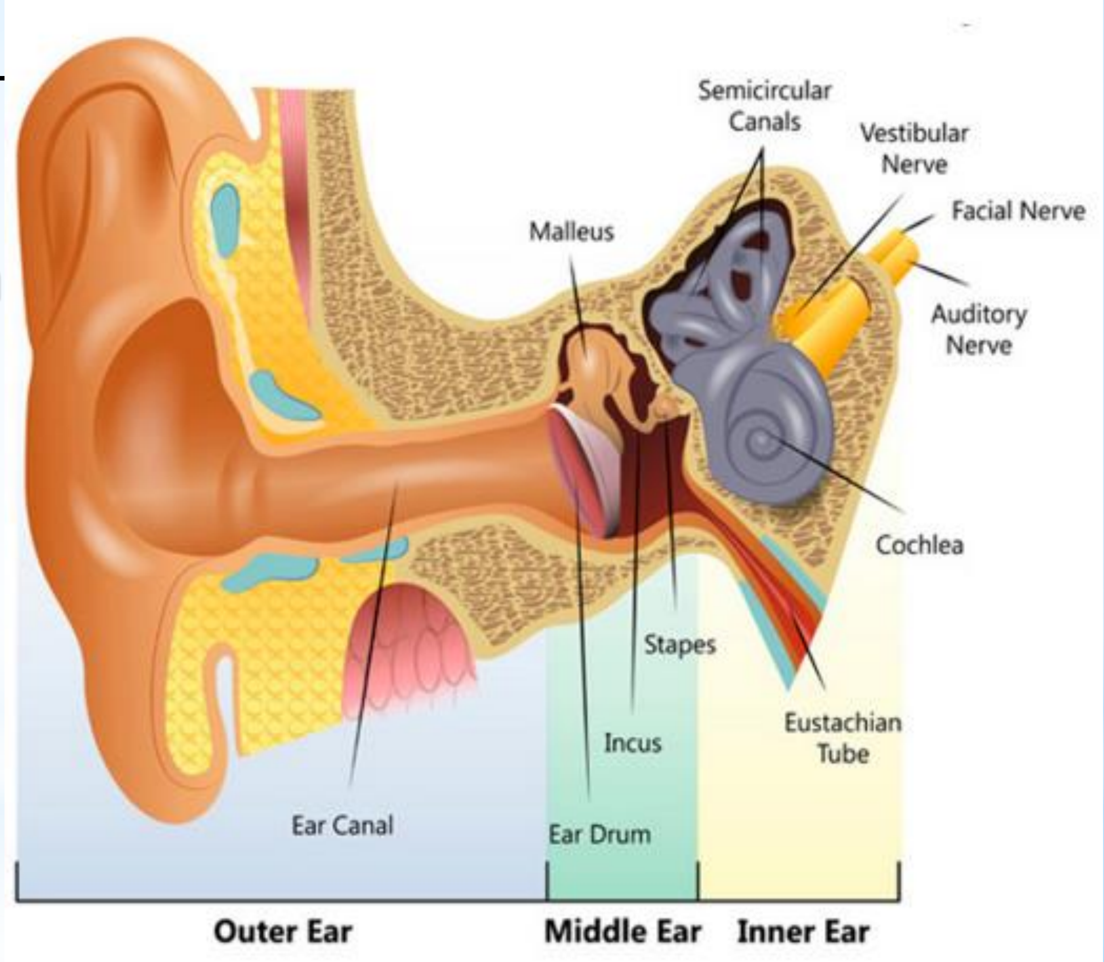
Hearing Summary

QUICK CHECK

Sound waves enter the ear canal and make the _______ vibrate. This action moves the tiny chain of bones (ossicles - ___, ___, ___) in the middle ear.

The last bone in this chain ‘knocks’ on the membrane window of the ___ and makes the ___ in the cochlea move.

The fluid movement then triggers a response in the ___ nerve.

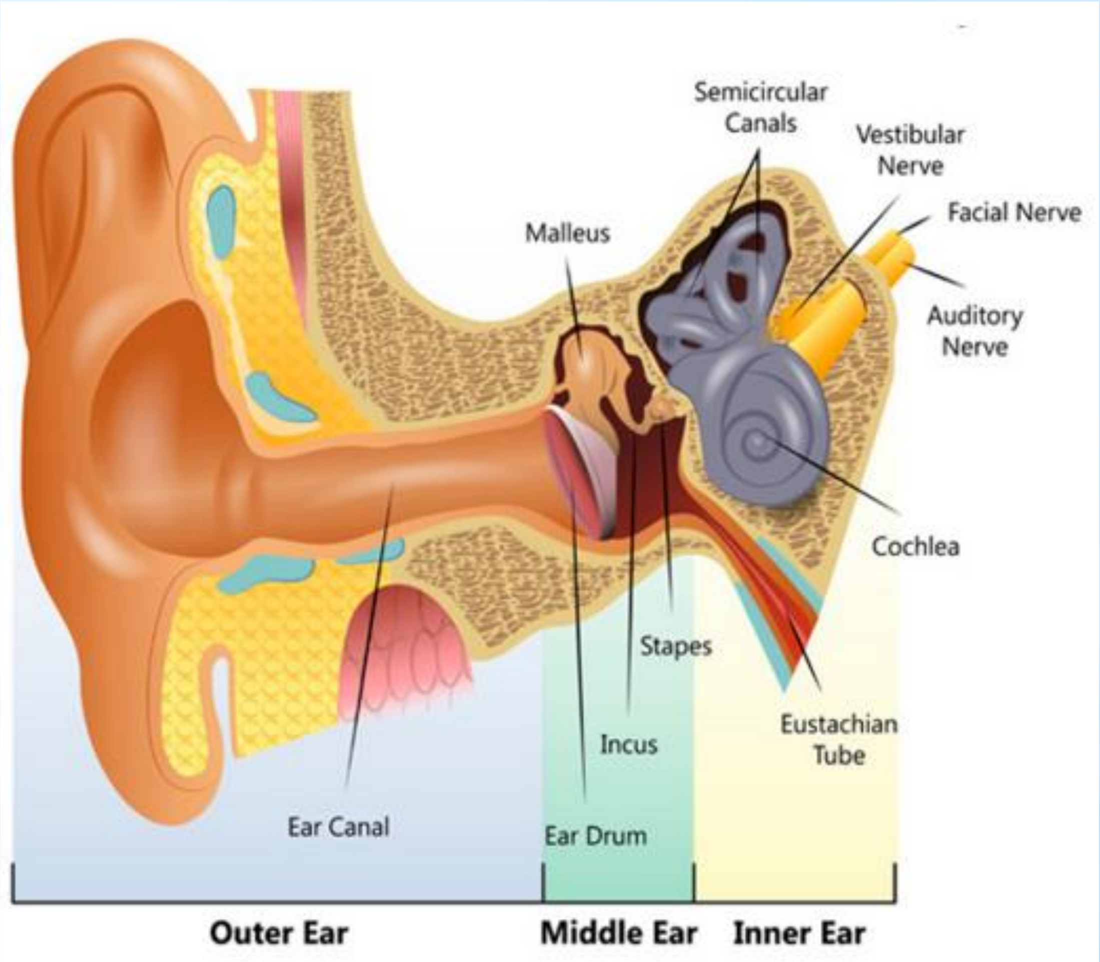


Hearing Summary

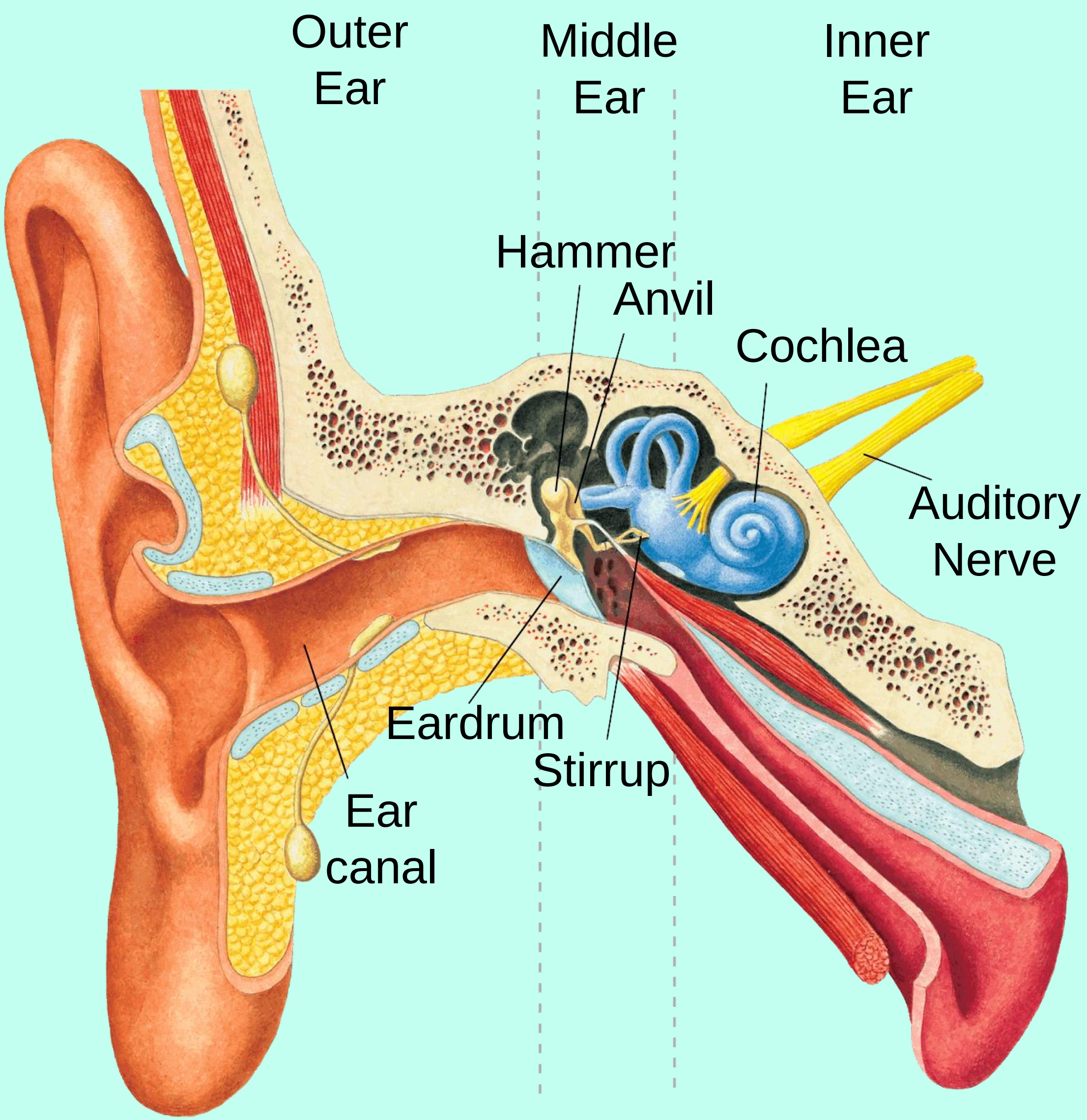
Sound waves enter the ear canal and make the ear drum (tympanic membrane) vibrate. This action moves the tiny chain of bones (ossicles - malleus, incus, stapes) in the middle ear.

The last bone in this chain ‘knocks’ on the membrane window of the cochlea and makes the fluid in the cochlea move.

The fluid movement then triggers a response in the auditory (hearing) nerve.



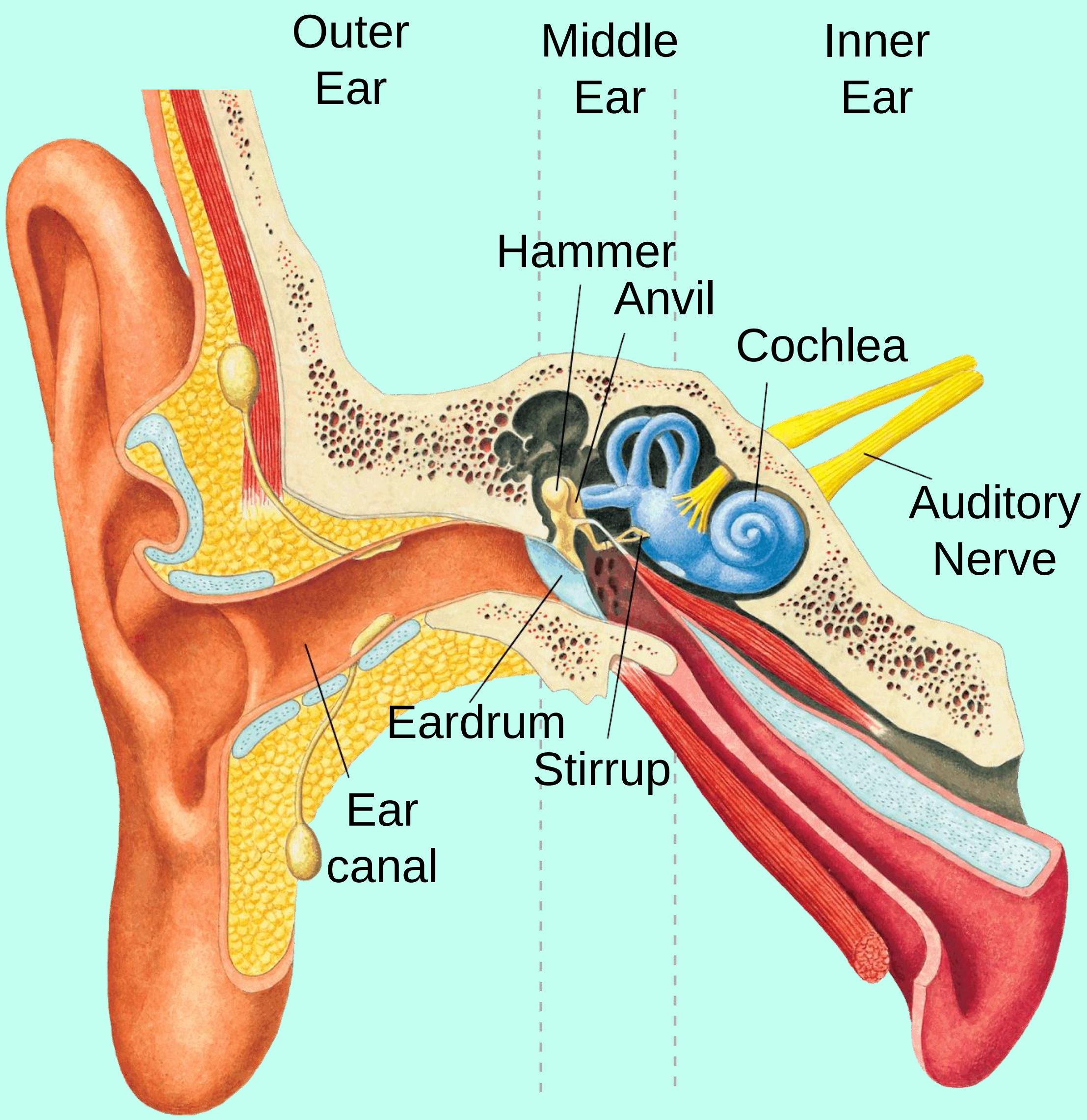
The Human Ear



What part of the human ear acts as an amplifier to increase the motion of the eardrum?

a. ear canal
b. middle ear
c. inner ear
d. auditory nerve

The Human Ear

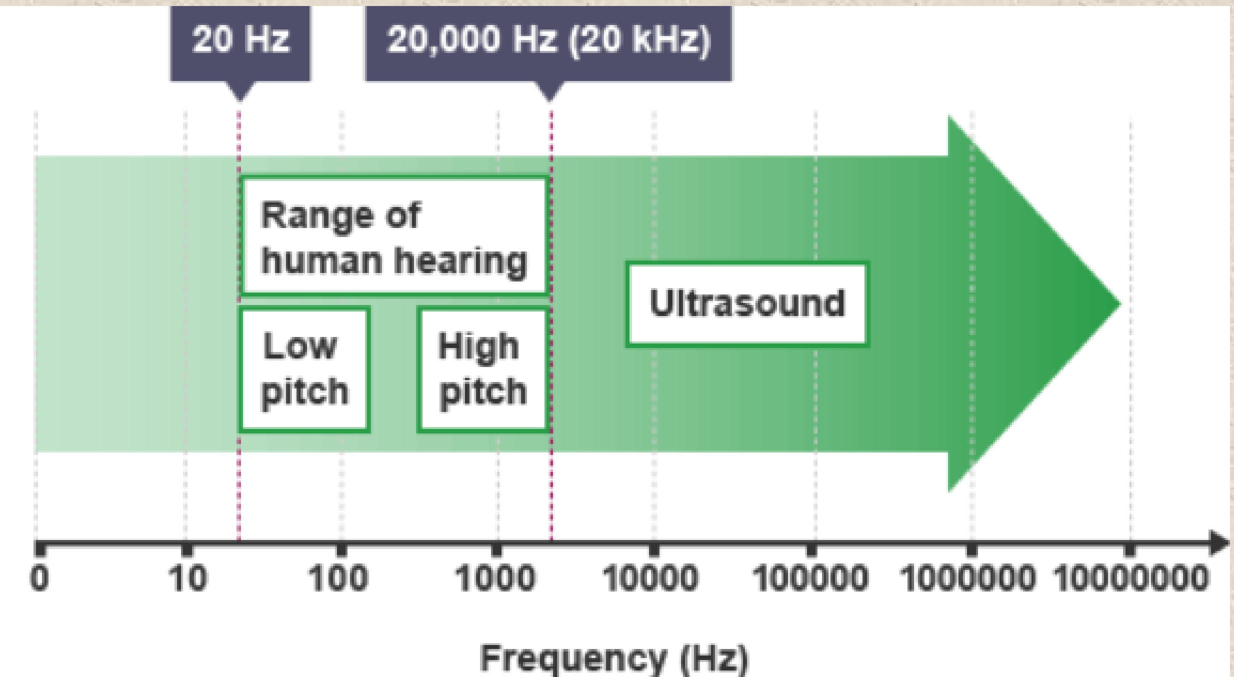


What part of the human ear acts as an amplifier to increase the motion of the eardrum?

a. ear canal
b. middle ear
c. inner ear
d. auditory nerve

Range of Human Hearing

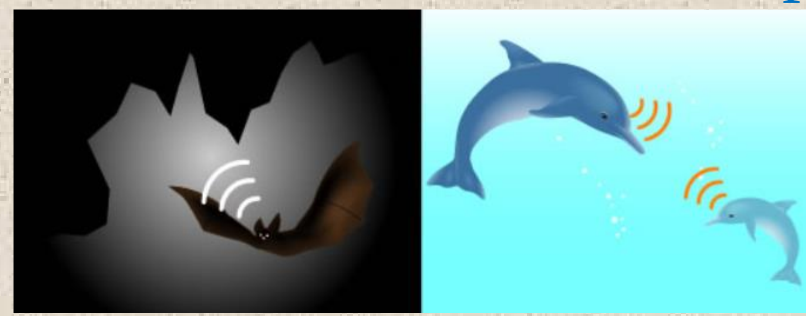
The maximum range of frequencies for most people is from about 20 hertz to 20 thousand hertz. This means if the number of high pressure fronts (wavefronts) hitting our eardrums each second is from 20 to 20 000, then the sound may be detectable. If you listen to loud music often, you'll probably find that your range (bandwidth) will be diminished.



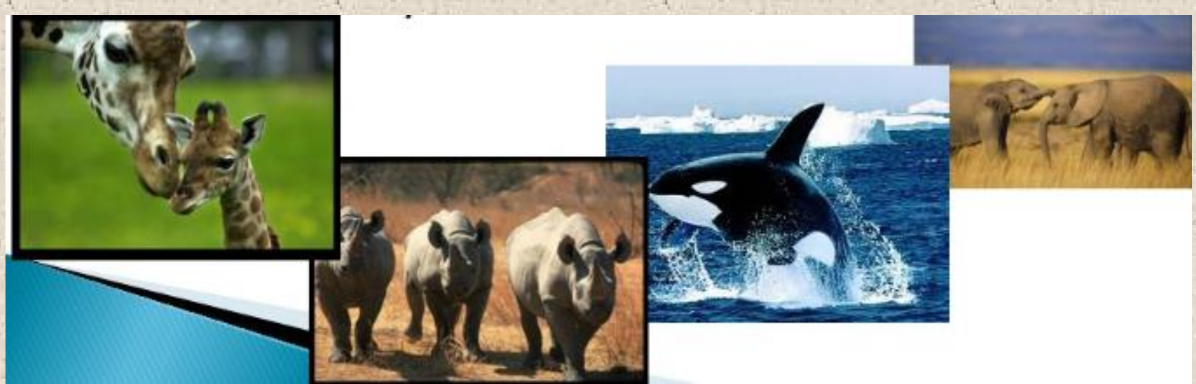
Some animals, like dogs and some fish, can hear frequencies that are higher than what humans can hear (ultrasound).

Doctors make use of ultrasound for imaging fetuses and breaking up kidney stones.

Bats and dolphins use ultrasound to locate prey by reflection (echolocation).



Elephants and some whales can communicate over vast distances with sound waves too low in pitch for us to hear (infrasound).



How does sound travel?

LESSON QUESTION

- Sound travels through all states of matter—**gases, liquids, and solids**.
- These are called the **medium**.
- Sound **cannot** travel through a **vacuum** because it needs **particles** to propagate it.
- The **medium** (air, water, metal, etc.) has **very little net movement** while the wave (disturbance) moves through the medium.

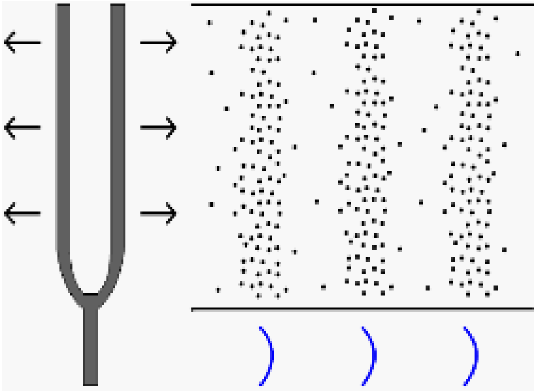
Sound Travels Through Matter

Gases

Most of the sounds we hear travel through gases, such as air.

Sound waves travel slowest through the air.

Sound from a bell, a horn, or an alarm clock travels through the air.



Liquids

Sound waves travel faster through water than through the air.

Sonar is used to locate objects under water.

What animals use sonar?

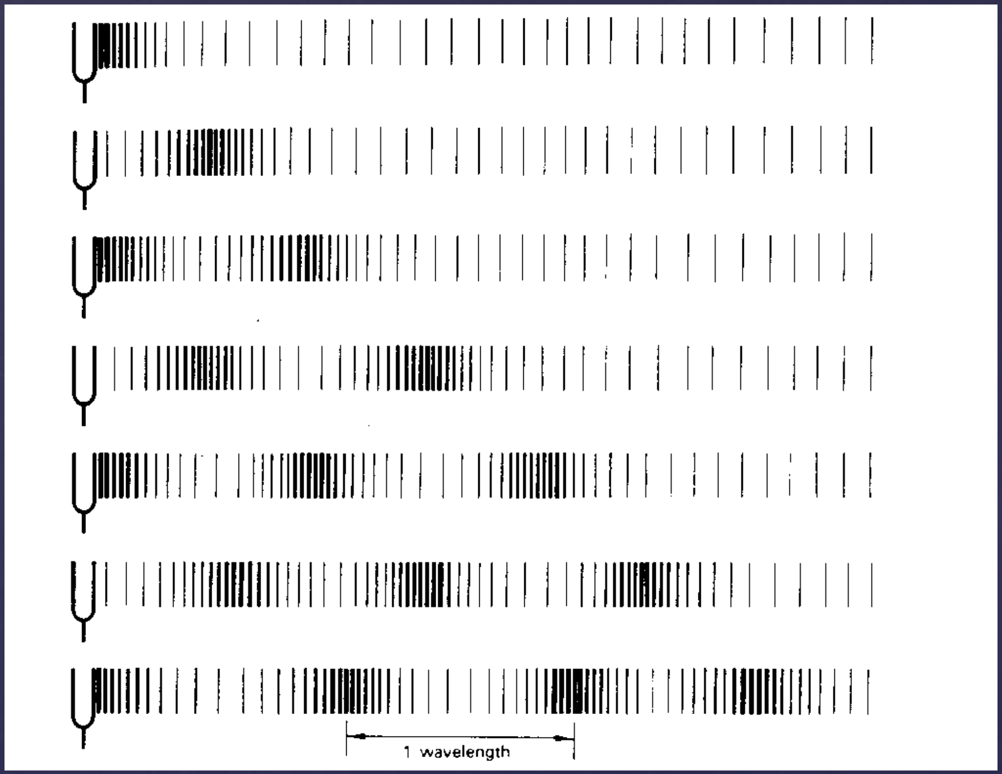
Solids

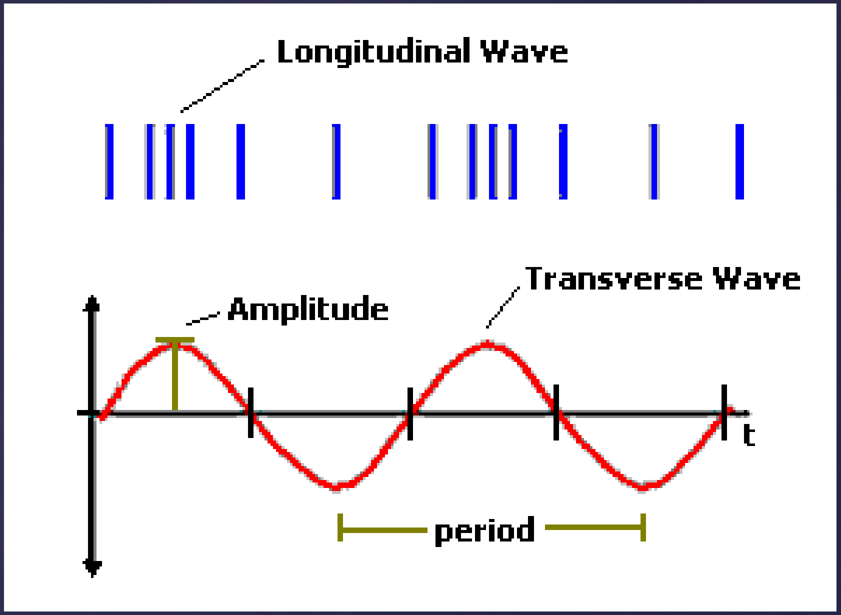
Sound waves travel fastest through solids because molecules are packed very tightly together.

You can put your ear to a railroad track and hear the trains up to hundreds of miles away.

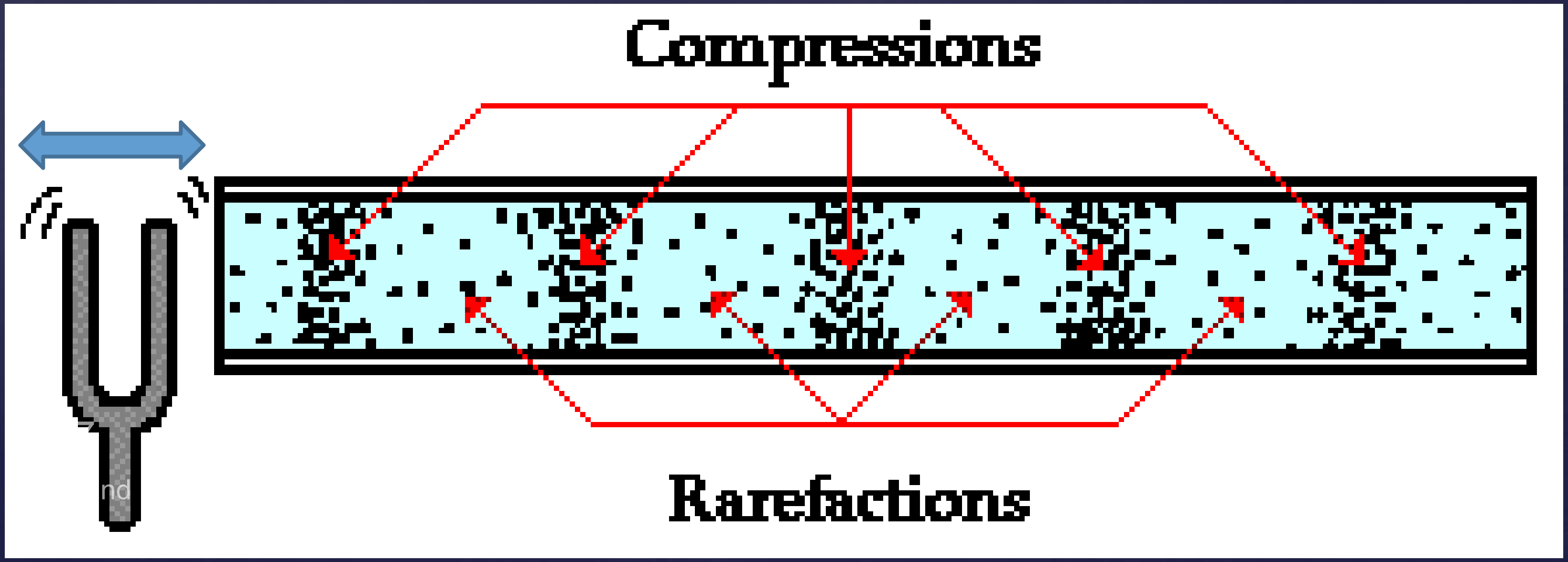
Trackers put their ears to the ground to listen.

What type of waves are sound waves?





When a tuning fork vibrates, it creates areas of high pressure (compressions) and low pressure (rarefactions). As the tines of the fork vibrate back and forth, they push on neighboring air particles. The forward motion of a tine pushes air molecules horizontally to the right and the backward retraction of the tine creates a low-pressure area allowing the air particles to move back to the left.



Explosion of a Star

Can you hear it? Explain.

How do astronauts communicate with earth?

Explosion of a Star

Outer space has no air. Therefore, no particles can transmit sound in space.

So how do astronauts communicate with earth? Radio Waves (electromagnetic) which are converted to sound.

Sound Waves

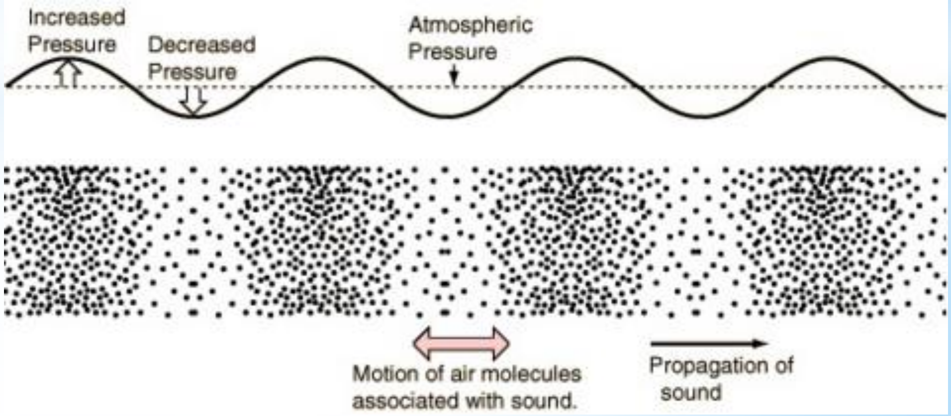
QUICK CHECK

Sound waves travel through a substance called a ____ and is fastest in (solids, liquids, gases).

Sound waves are (longitudinal, transverse).

Sound waves include high frequency waves (____), low frequency waves (____), and reflection of waves (____).

The direction of propagation of a sound wave is ____ to its direction of oscillation.



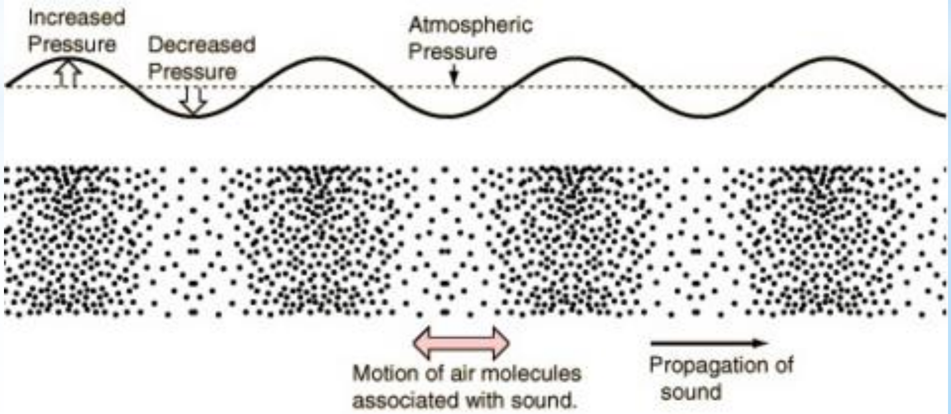
Sound Waves

Sound waves travel through a substance called a medium and is fastest in solids.

Sound waves are longitudinal.

Sound waves include high frequency waves (ultrasound), low frequency waves (infrasound), and reflection of waves (echolocation).

The direction of propagation of a sound wave is **parallel** to its direction of oscillation.



Behavior of Waves

Speed & Temperature

Frequency (Pitch)

Amplitude (Volume / Loudness)

"Resonance"

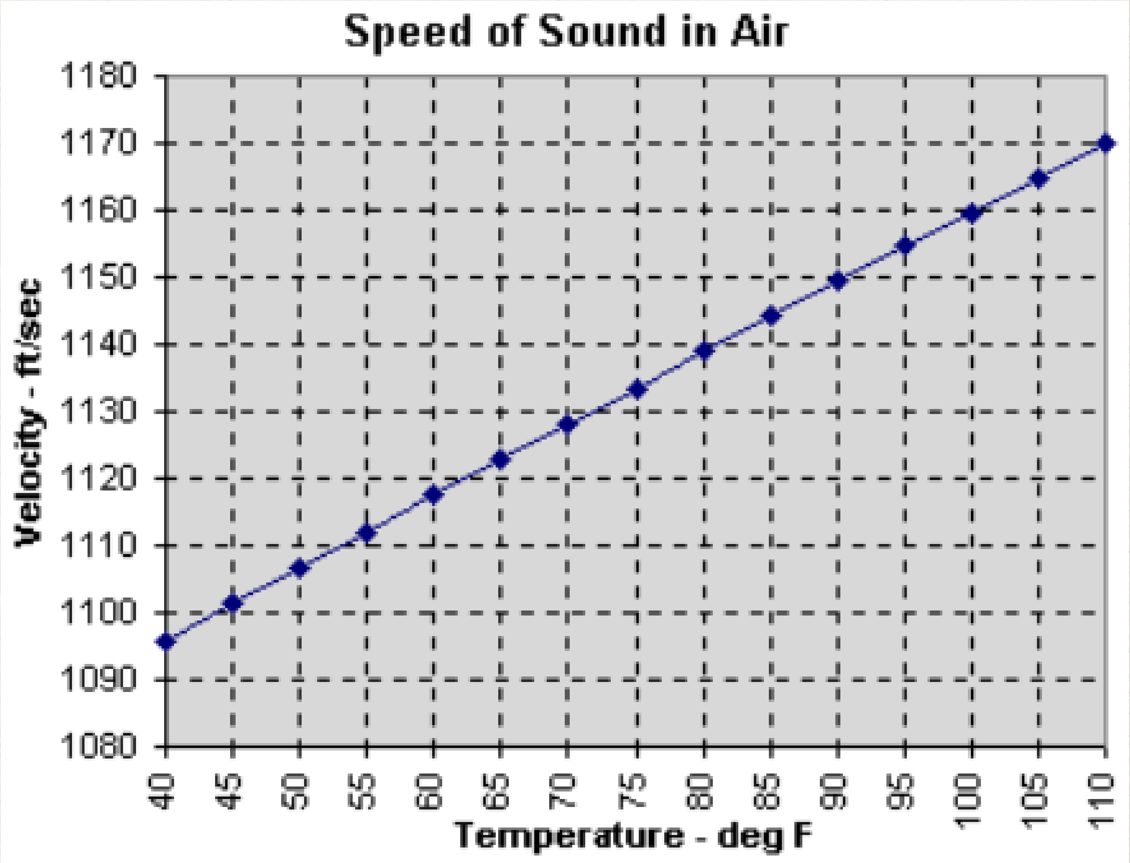
"Diffraction of Sound"

- **Standing waves**
- "**Beats**" produced by **interference**

Temperature & Speed of Sound

The speed of sound in the SAME medium is DIRECTLY proportional to that medium's temperature. (The greater the temperature in the medium, the FASTER sound travels.)

The hotter a substance is, the faster its molecules/atoms vibrate.

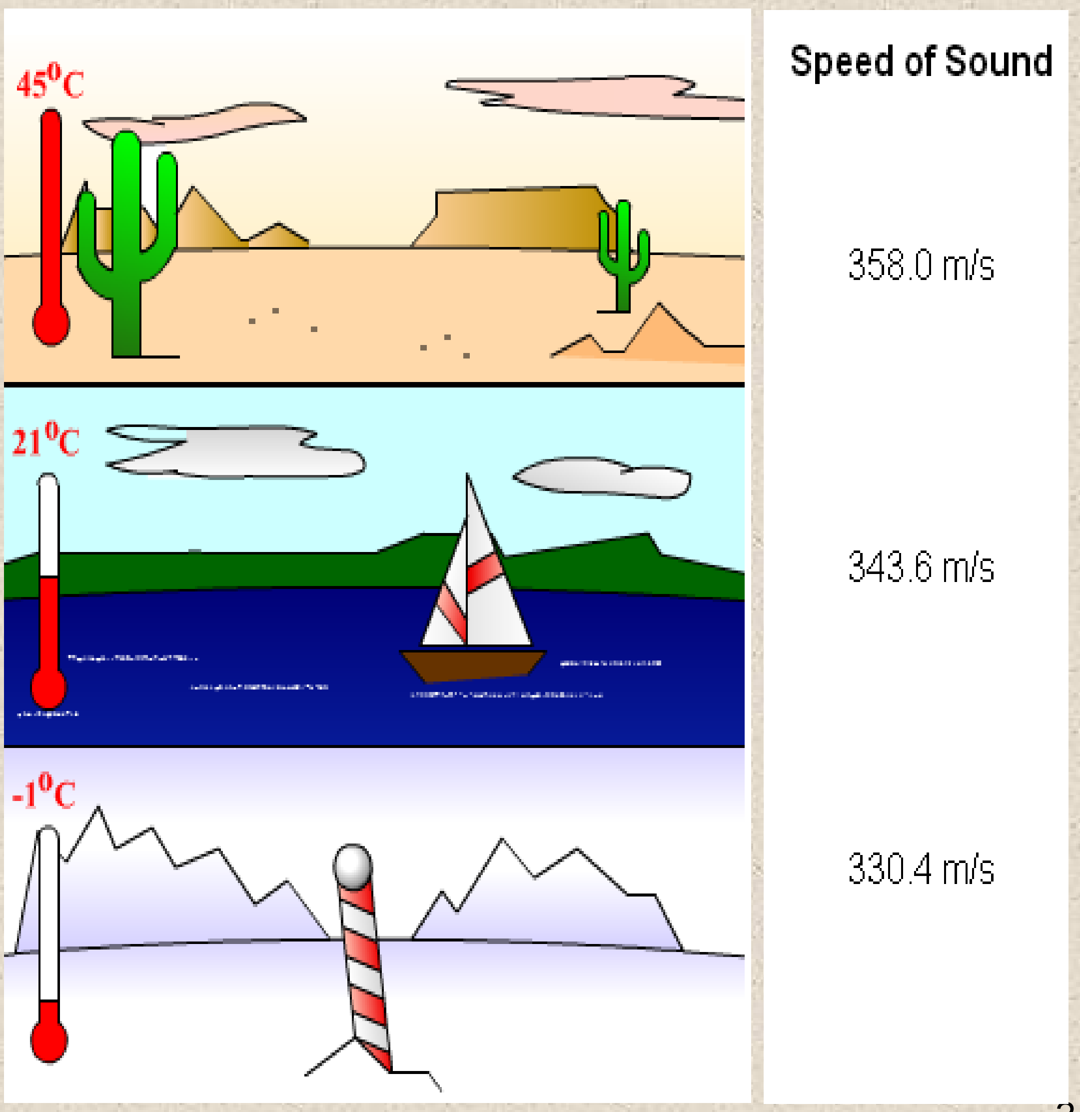


Temperature & *Speed of Sound*

In the summer, sound travels slightly faster in air than it does in the winter.

Air molecules must bump into each other in order to transmit a longitudinal wave.

When molecules move quickly, they need less time to bump into each other.



Temperature & *Speed of Sound*

The speed of sound in dry air is given by:

$$v \approx 331.4 \text{ m/s} + 0.60\,T$$

where T is air temp in °C.

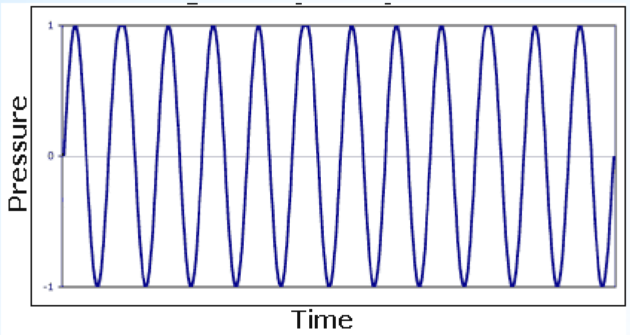
Examples of the speed of sound based on temperature:

Air, 0 °C: 331 m/s   Air, 20 °C: 343 m/s

	Temperature	Speed (m/s)
Water	0 C	1402
Water	20 C	1482
Water	25 C	1493

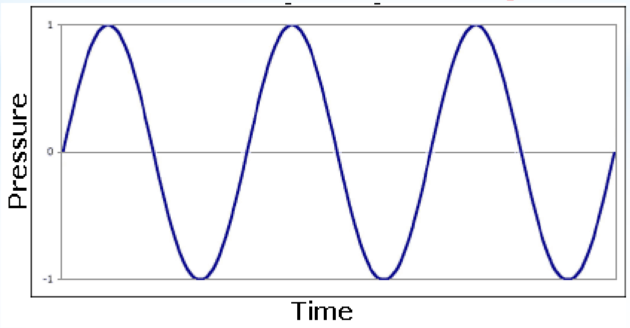
Measuring the Number of Waves

- Pitch is how high or how low a sound is.
- A **high pitched** sound has higher frequency, meaning more waves pass by in a given time.



Higher Pitch

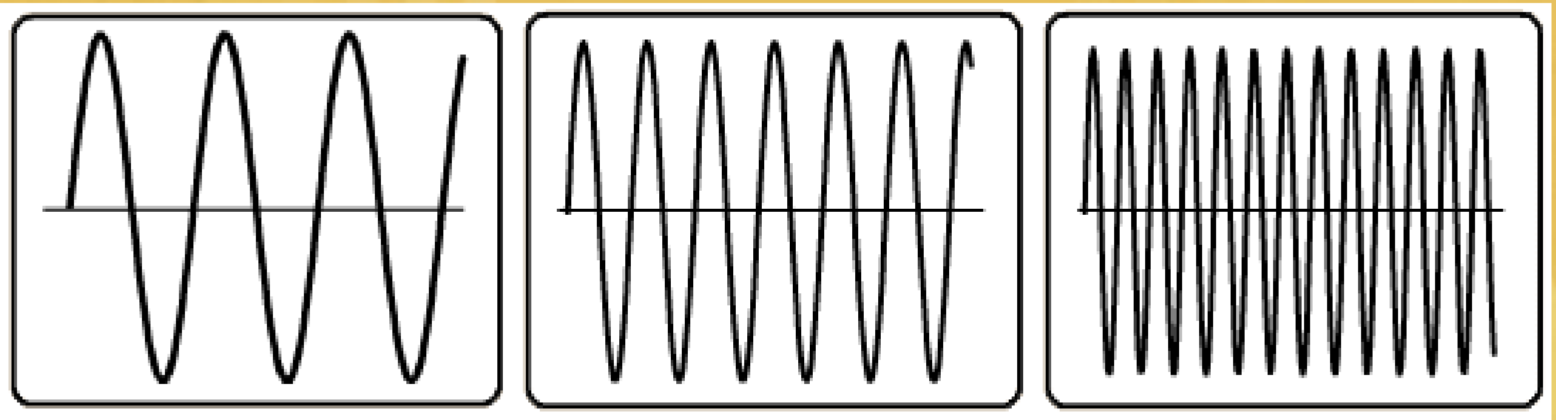
- A **low pitched** sound has lower frequency, meaning that fewer waves pass by in a given time.



Lower Pitch

Pitch & Frequency

- A measure of how high or low a sound is.
- Pitch depends on the frequency of a sound wave, measured in "Hertz" or waves per second.
- For example,



- Low pitch
- Low frequency
- Longer wavelength

- High pitch
- High frequency
- Shorter wavelength

Frequency People Cannot Hear

Supersonic

- sounds travelling faster than the speed of sound

Ultrasound

- sounds with frequencies ABOVE the normal human range of hearing.

  Sounds in the range from 20-100 kHz

Infrasound

- sounds with frequencies BELOW the normal human range of hearing.

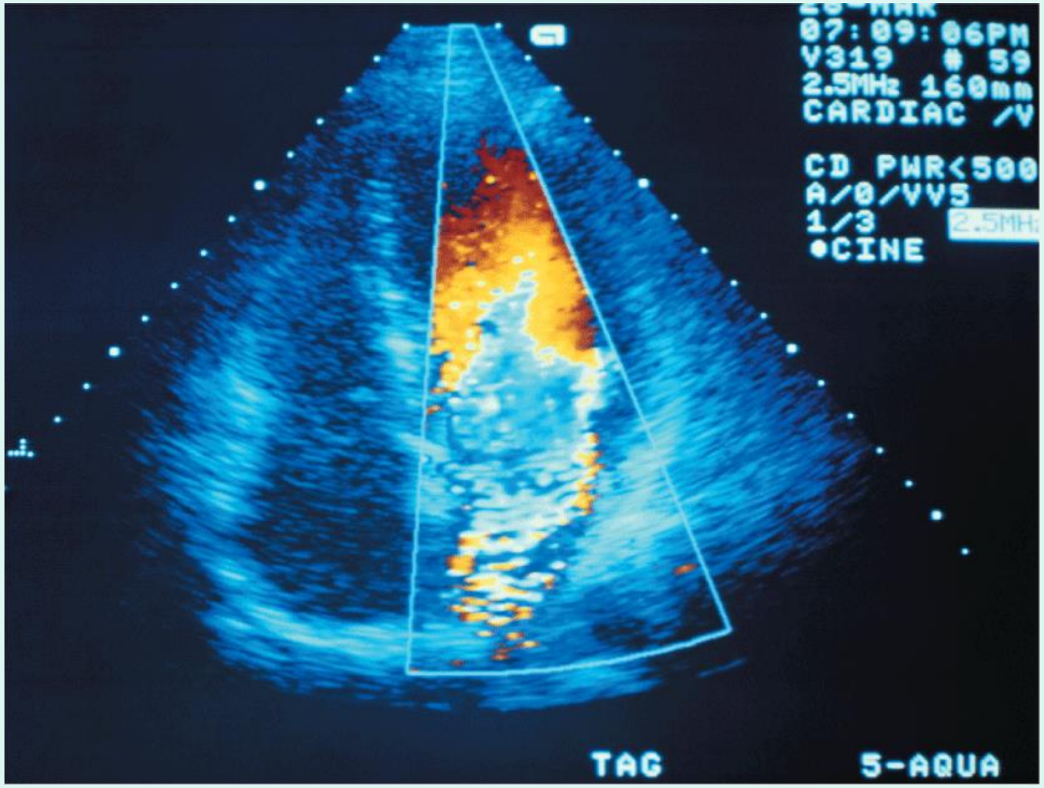
  Sounds in the 20-200 Hz range

Frequency People Cannot Hear

Ultrasound

- sounds with frequencies ABOVE the normal human range of hearing.

Sounds in the range from 20-100 kHz

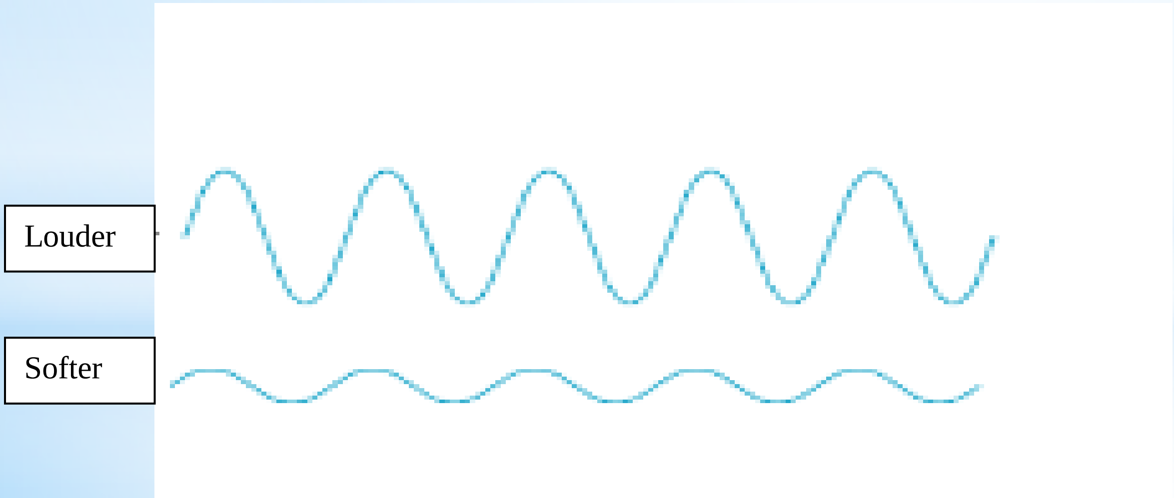


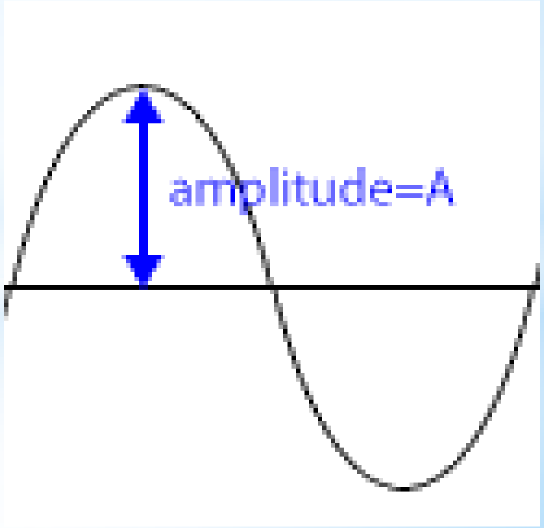
Measuring the Height of Waves

*We can make it louder or softer by changing the **amplitude** of the height of the wave.

*The higher the **amplitude**, the louder the sound.

*The lower the **amplitude** the softer the sound.





The Decibel Scale

The chart below lists the approximate sound levels of various sounds. The loudness of a given sound depends, of course, on the power of the source of the sound as well as the distance from the source. Note: Listening to loud music will gradually damage your hearing!

Source	Decibels
Anything on the verge of being audible	0
Whisper	30
Normal Conversation	60
Busy Traffic	70
Niagara Falls	90
Train	100
Construction Noise	110
Rock Concert	120
Machine Gun	130
Jet Takeoff	150
Rocket Takeoff	180

Constant exposure leads to permanent hearing loss.

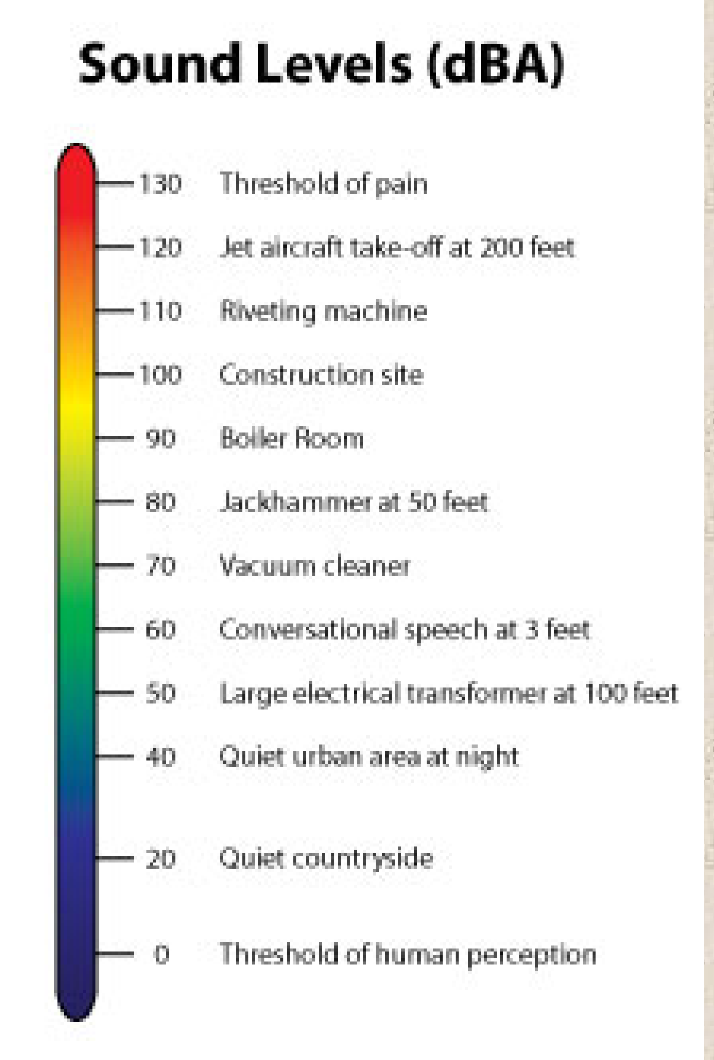
← *Pain*

← *Damage*

The Decibel Scale

Intensity & Decibels

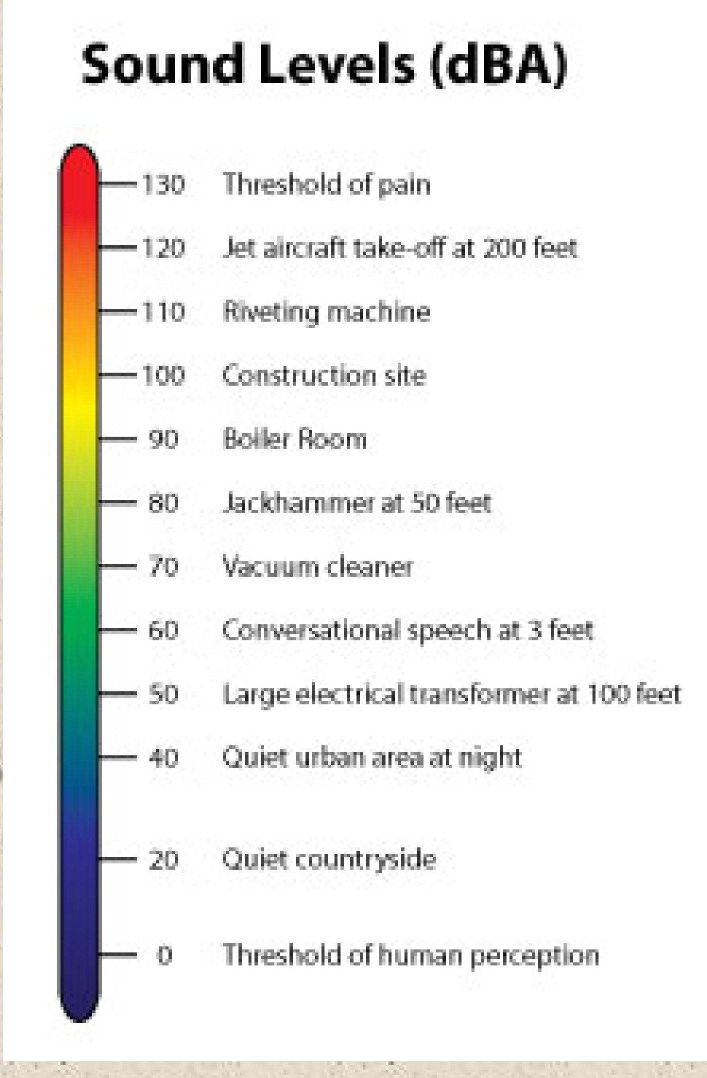
- An intensity scale based on human perception of "loudness" is often used.
- The base unit of the intensity scale is called the "*bel*". Actually the "*decibel*" (dB) is more commonly used, which is 0.1 bel.



The Decibel Scale

Intensity & Decibels

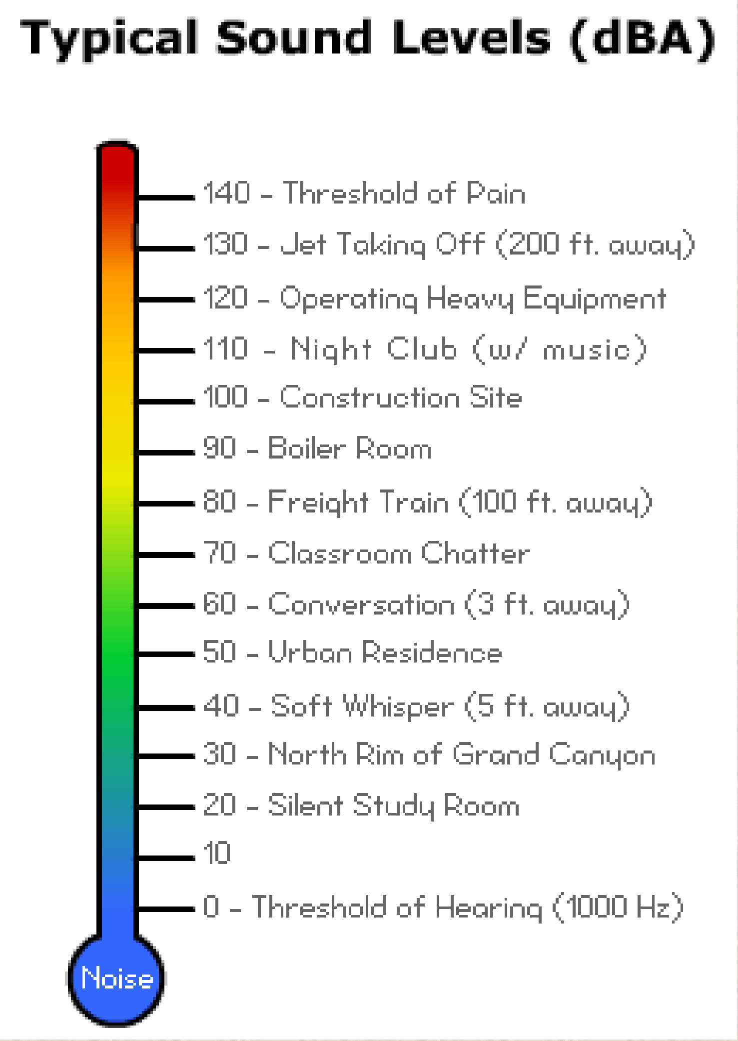
- The lowest intensity humans hear is assigned a value of 0 dB.
- The scale is logarithmic, so each increase of 1 bel = 10 times louder.
- An increase in intensity of 3 bels is $10^3 = (10 \times 10 \times 10) = 1{,}000$ times louder.



The Decibel Scale

TRY IT

Use the chart to the right. How much more intense (loud) is the sound of a jet taking off than a typical conversation with a person? What property of a sound waves governs this?



TRY IT

The Decibel Scale

Use the chart to the right. How much more intense (loud) is the sound of a jet taking off than a typical conversation with a person? What property of a sound waves governs this?

1 bel = 10 dB

Jet taking off = 130 dB x 1 bel/10 dB = 13 bels

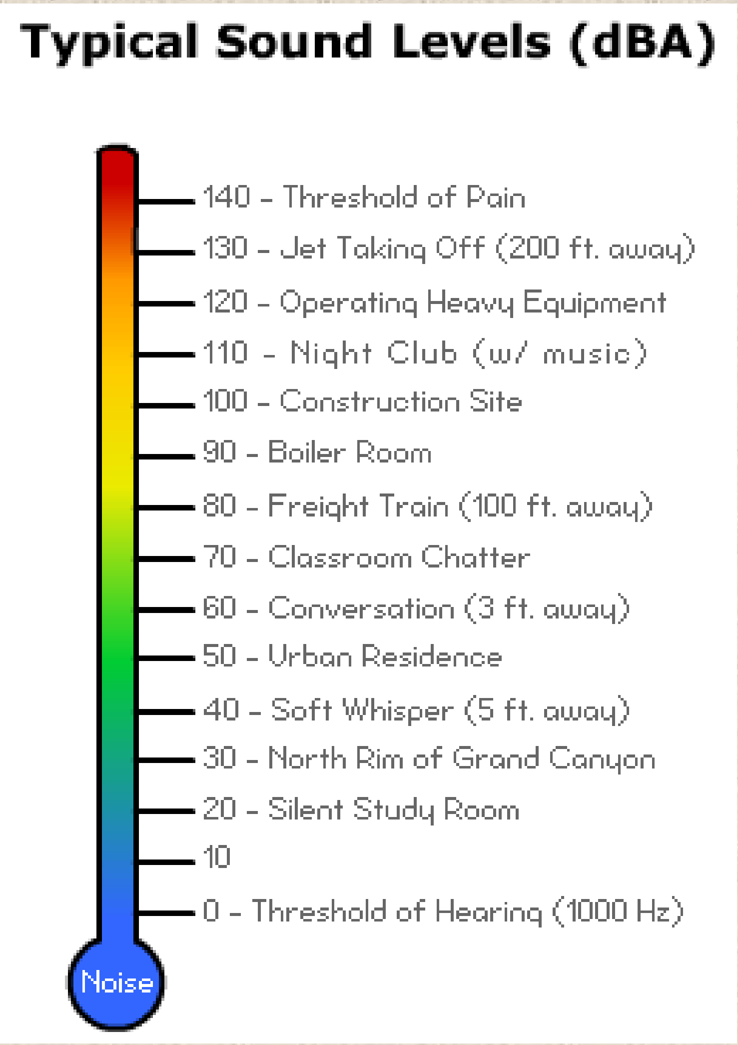
Conversation = 60 dB x 1 bel/10 dB = 6 bels

13 bels – 6 bels = 7 bels more intense

10^7 or 10 x 10 x 10 x 10 x 10 x 10 x 10

10,000,000 times more intense.

<u>Amplitude</u> governs intensity of sound.



Resonance

Sound Waves are a common type of **standing wave** caused by **RESONANCE**. This often occurs when sound is **reflected**.

Resonance – when a FORCED vibration matches an object's natural frequency thus producing vibration, sound, or even damage.

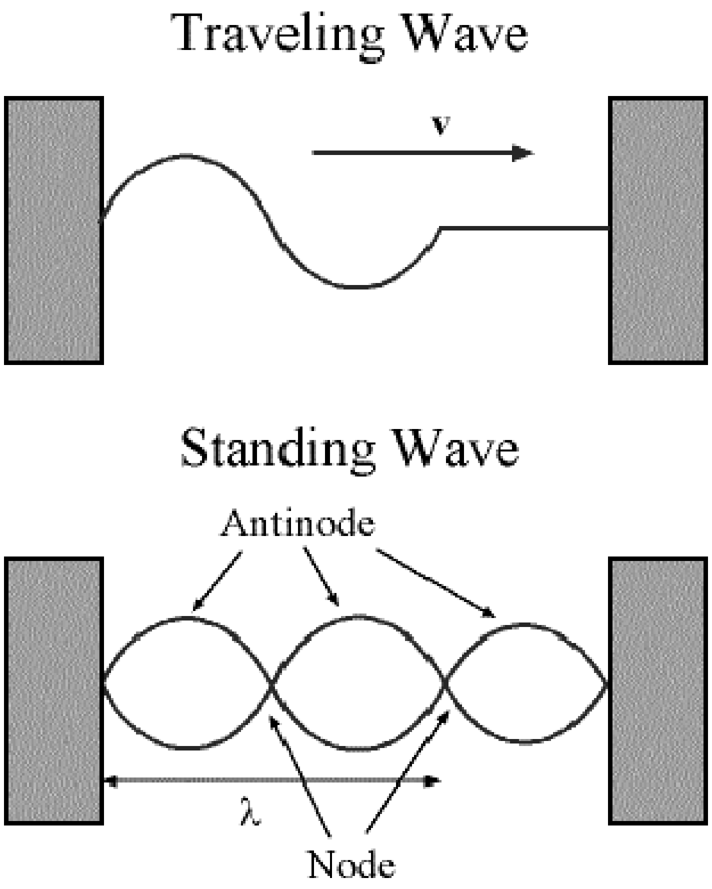
Singers can shatter a wine glass by hitting a musical note that is on the same frequency as the natural frequency of the glass. Because the frequencies resonate, or are in sync with one another, maximum energy transfer is possible.

Standing Waves *Reflection*

A standing wave is produced when a wave that is traveling is **reflected** back upon itself.

There are two main parts to a standing wave (enrichment):

> ***Antinodes*** – *Areas of MAXIMUM AMPLITUDE*
>
> ***Nodes*** – *Areas of ZERO AMPLITUDE.*



Resonance

Resonance is the cause of sound in musical instruments.

When the frequency of vibration of the source matches the frequency of vibration of the air column in the instrument, resonance occurs and sound is heard.

In the guitar, the sound hole allows resonance.

Resonance

Resonance is an important consideration when building a musical instrument. Factors affecting resonance include the **strings** and **body** (violin, piano, harp), the length of **tube** (flute, oboe, brass), **shape** (drum, horns).

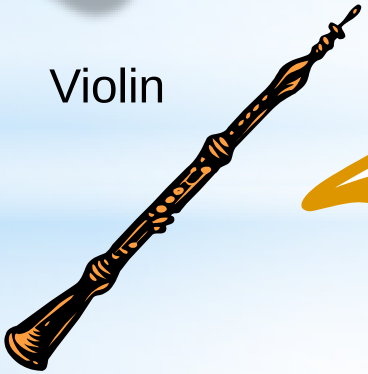

Flute


Violin


Drum


Harp


Piano


Oboe

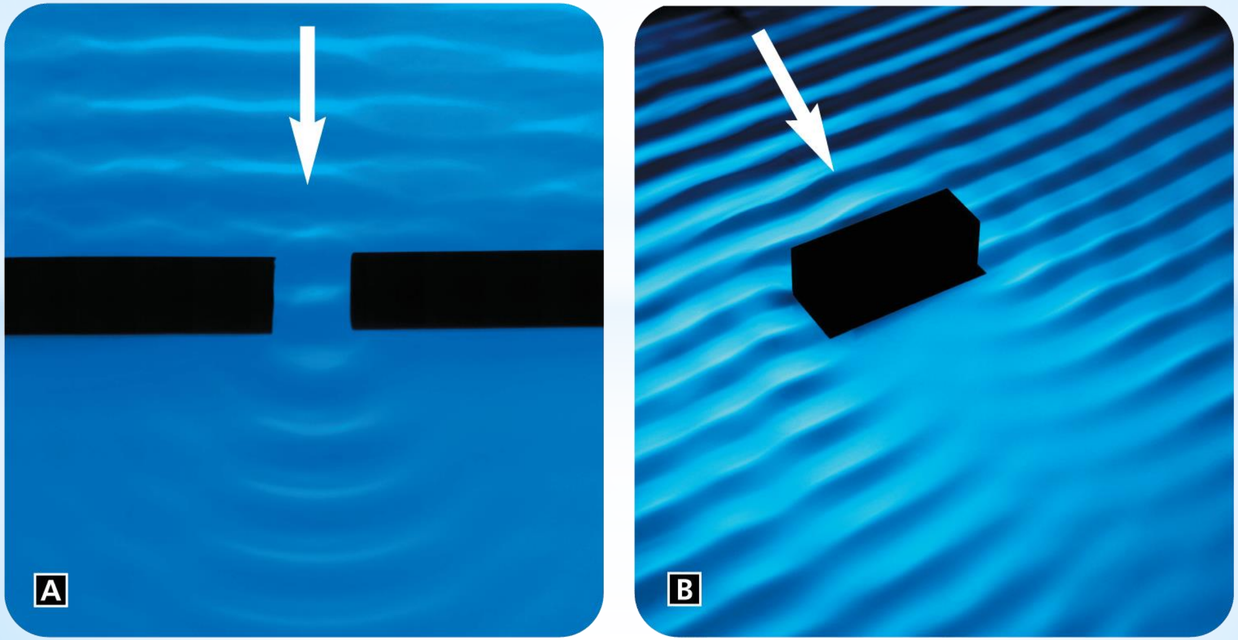

French Horn


Trumpet

Diffraction

Water waves spread out as they pass through a narrow opening.

- Diffraction also occurs when waves bend around an obstacle.
- The larger the wavelength is compared to the size of the opening or obstacle, the more the wave diffracts.



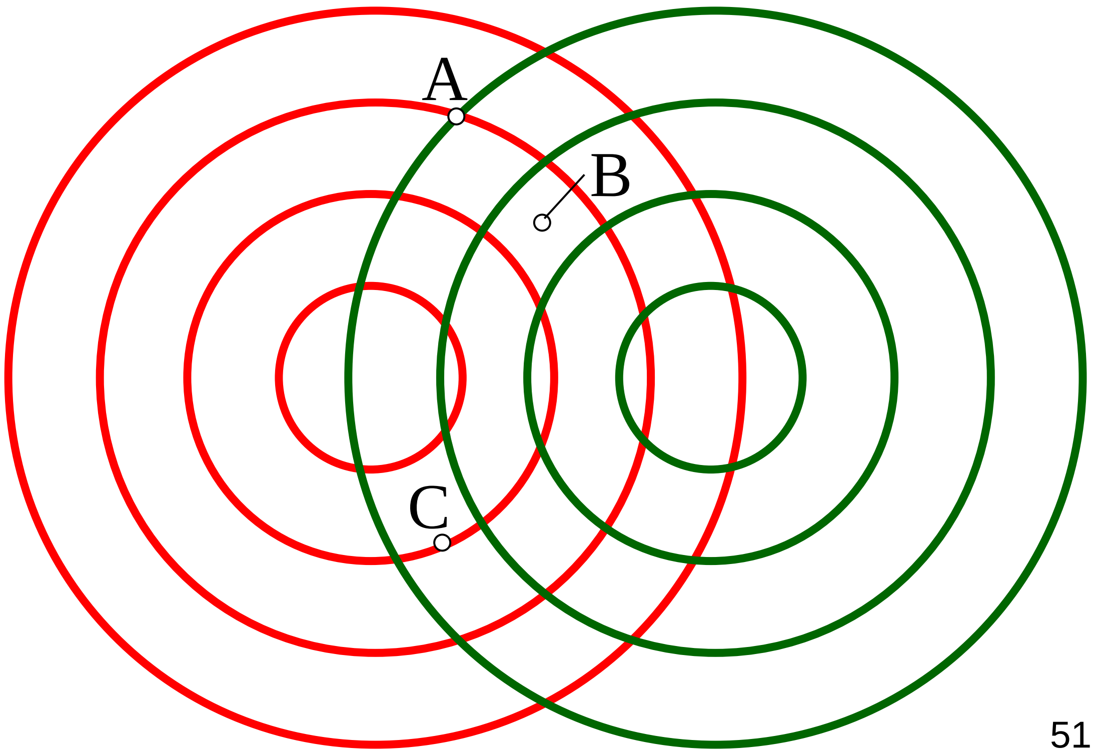
Diffraction → Interference

Sound waves can passes through each other and combine via superposition. The diagram shows two sets of wavefronts, each from a point source of sound. (*The frequencies are the same here, but this is not required for interference*.) Wherever constructive interference happens, a listener will hear a louder sound. Wherever destructive interference occurs, a listener will hear a diminished sound.

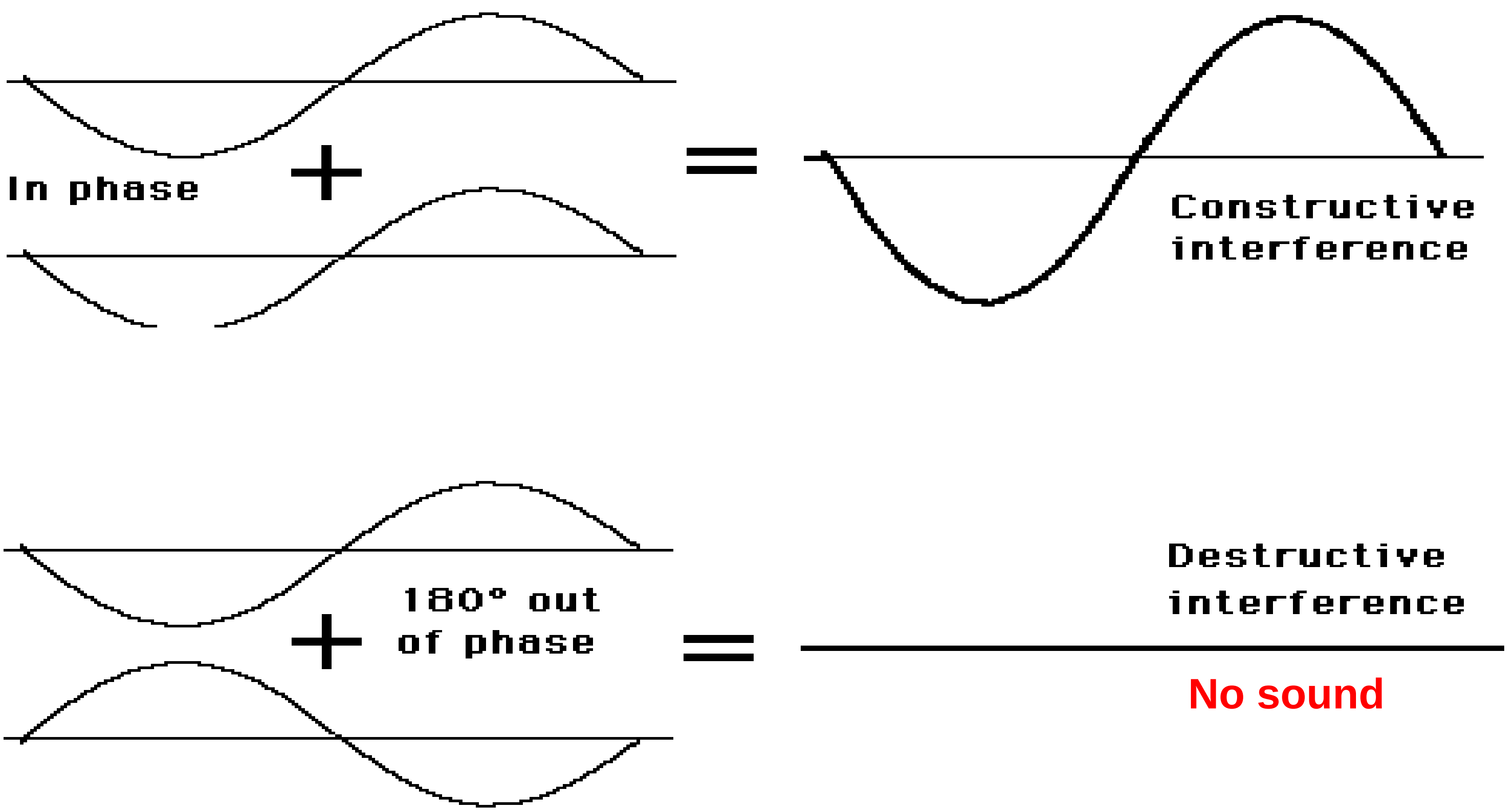
A: 2 crests meet;
constructive interference

B: 2 troughs meet;
constructive interference

C: Crest meets trough;
destructive interference

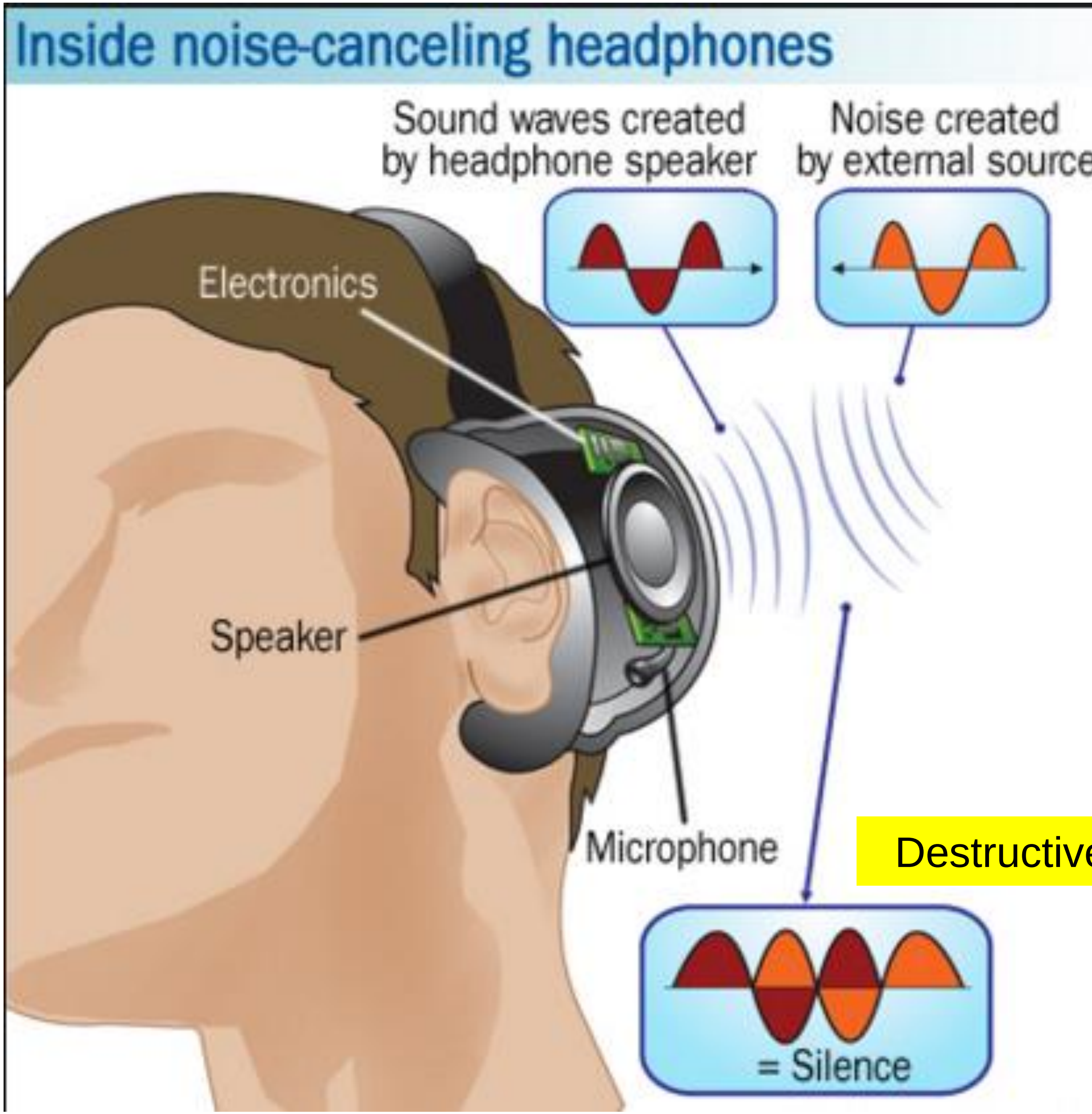


Interference



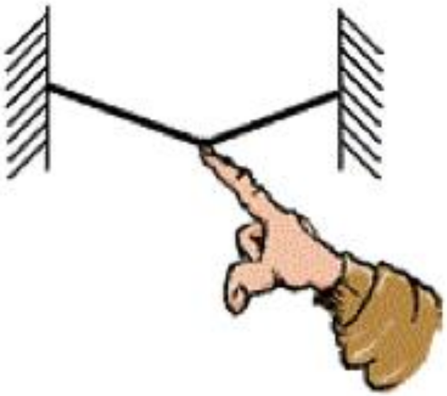
Interference

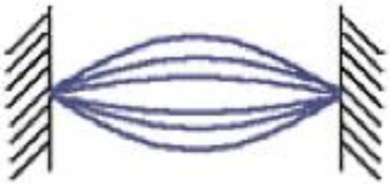
Diffraction



Destructive interference

Standing Waves *Diffraction*



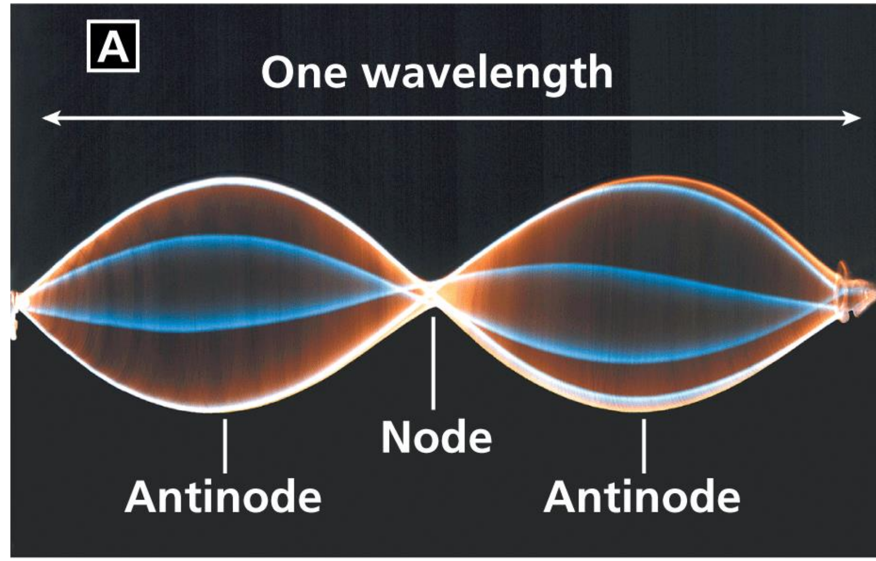


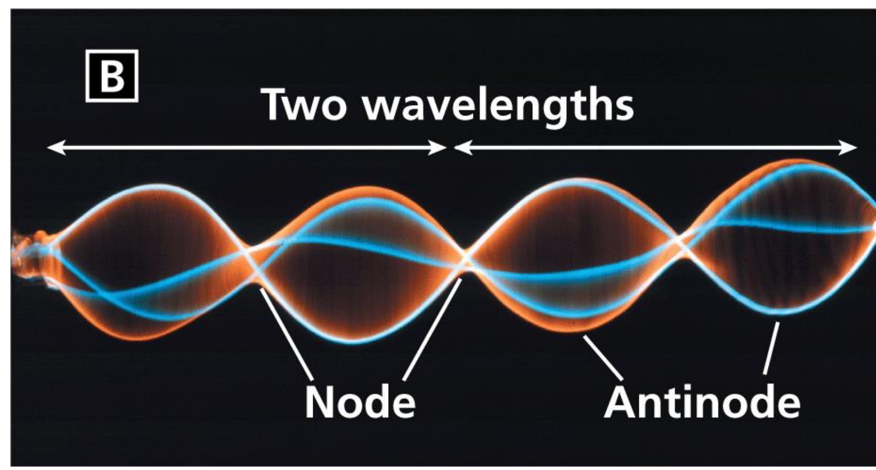
When a guitar string is plucked, it forms a standing wave representing a particular musical note (e.g. "A").

Standing Waves

Interference occurs as the incoming waves pass through the reflected waves.

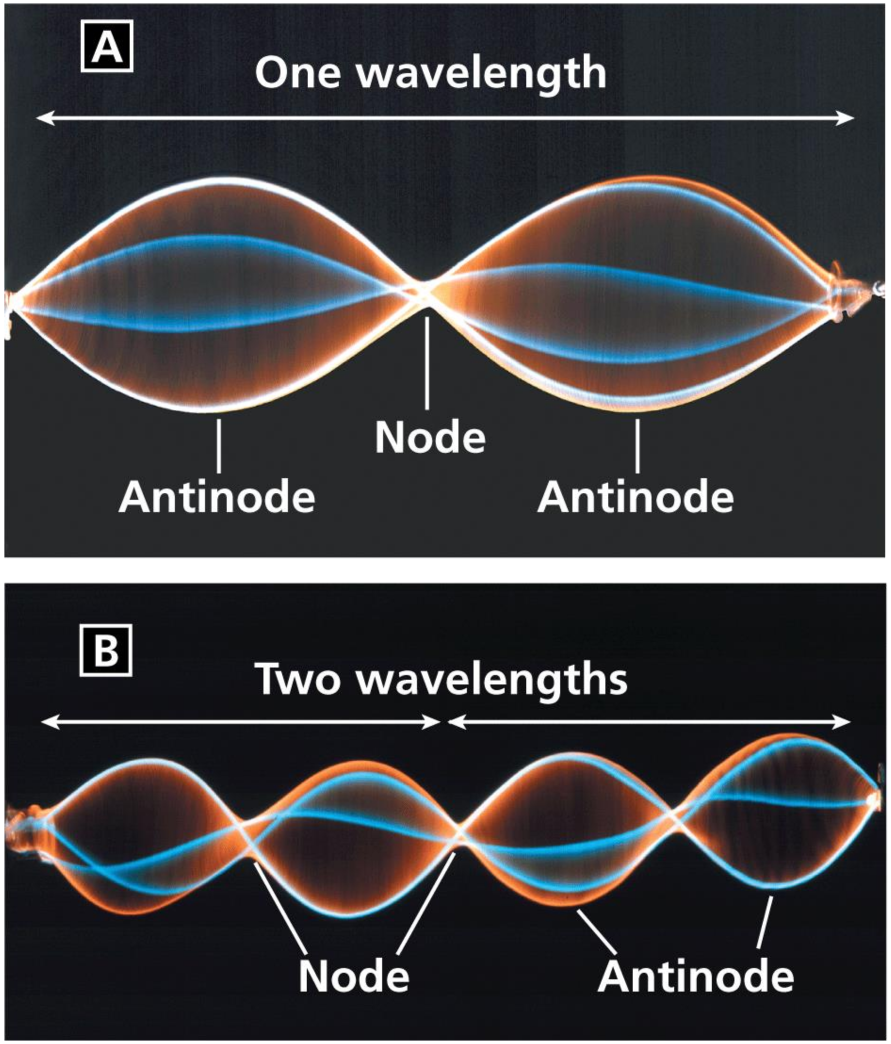
At certain frequencies, interference between a wave and its reflection can produce a standing wave.





Standing Waves

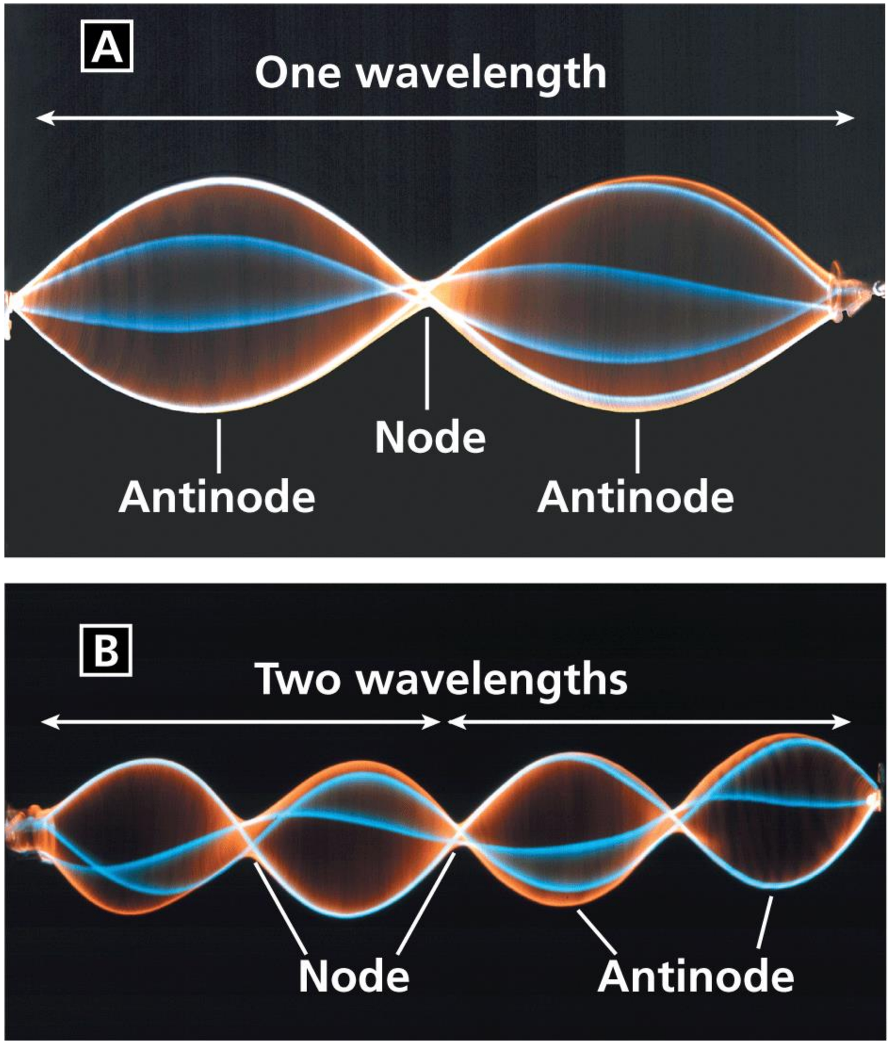
A standing wave forms only if **half** a wavelength or a **multiple** of half a wavelength fits exactly into the length of a vibrating cord.



Standing Waves

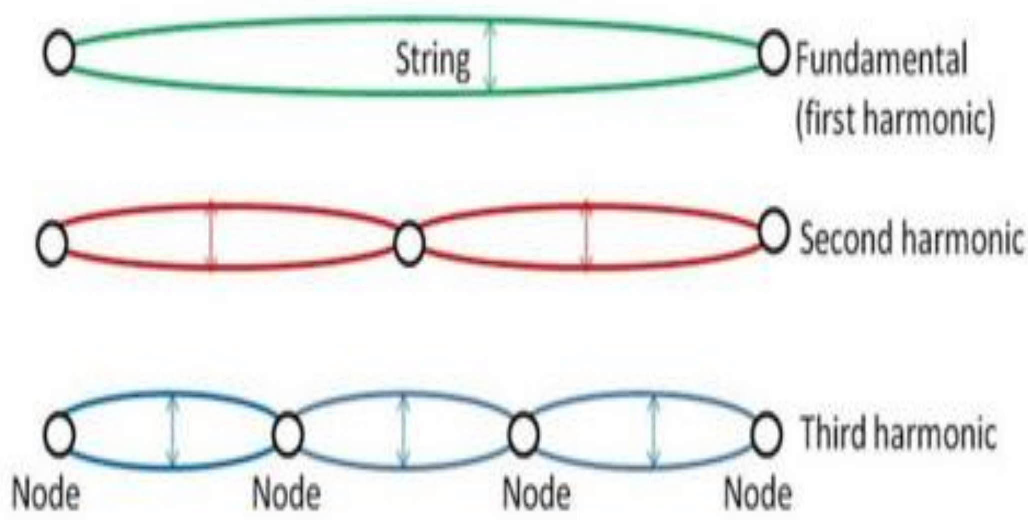
A **node** is a point on a standing wave that has no displacement from the rest position. At the nodes, there is complete destructive interference between the incoming and reflected waves.

An **antinode** is a point where a crest or trough occurs midway between two nodes.



Standing Waves *Diffraction*

Harmonics are based on constructive and destructive interference.



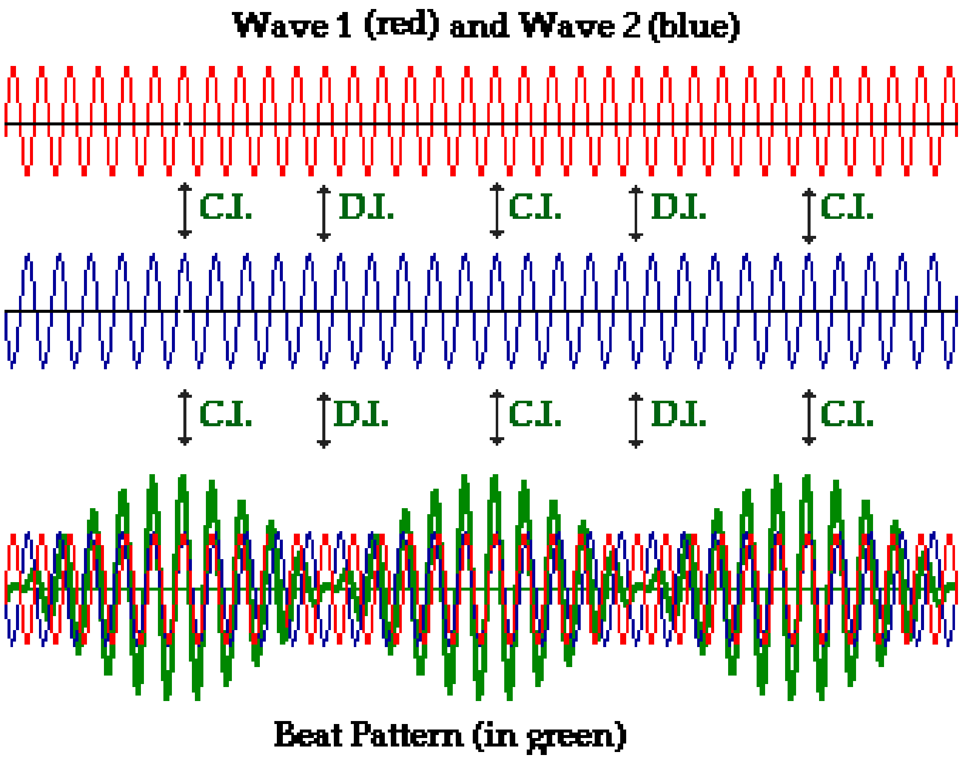
Most instruments play harmonics (the same note in different "octaves").

The human ear often cannot hear the separate frequencies. So, a musical note sounds like ONE note, but in reality it is often 2 or more frequencies combined.

Interference – "Beats"

Most music is a combination of frequencies. For instance, a guitar will play "overtones" or "harmonics" and a piano usually has 3 strings for each "note."

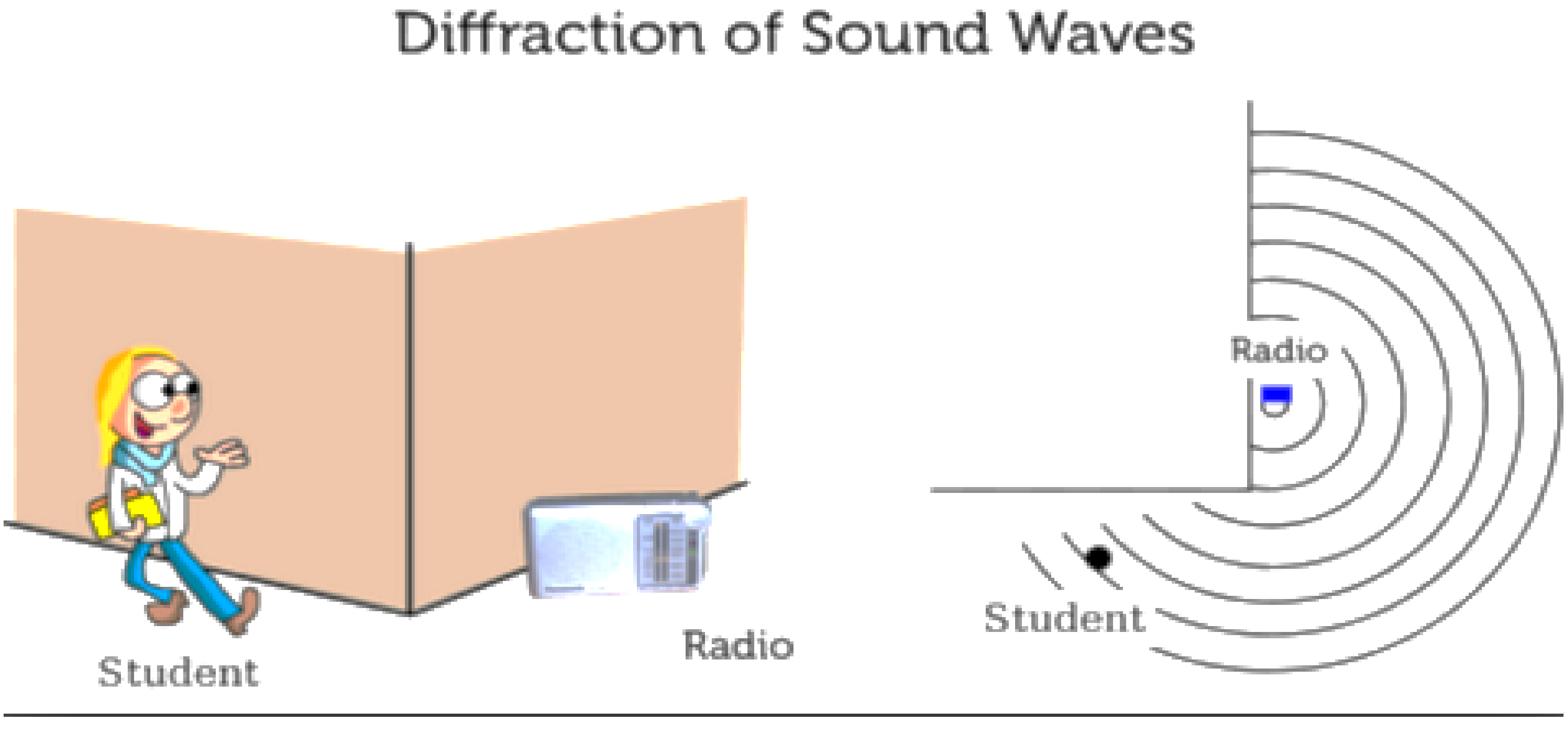
When two frequencies are close (but not equal), "beats" form which can be heard.



Tuning a piano often utilizes "beats" by comparing the sound of a string to that of a tuning fork (at the same time). If the two sound sources - the piano string and the tuning fork - produce detectable beats then their frequencies are not identical and the string must be "tuned".

Diffraction of Sound

Even though waves travel in straight lines, they also bend around obstacles so you can hear around a corner.



QUICK CHECK

The property of waves bending as they pass through a narrow opening is called

a. reflection.
b. refraction.
c. diffraction.
d. destructive interference.

A 6-meter rope is tied to a hook in the wall. Which of the following wavelengths can produce a standing wave?

1.5 m … 2.5 m … 3.5 m … 4.5 m

The amount of diffraction of a wave ____ as the size of the obstacle or opening increases.

QUICK CHECK

The property of waves bending as they pass through a narrow opening is called

a. reflection.
b. refraction.
c. **diffraction.**
d. destructive interference.

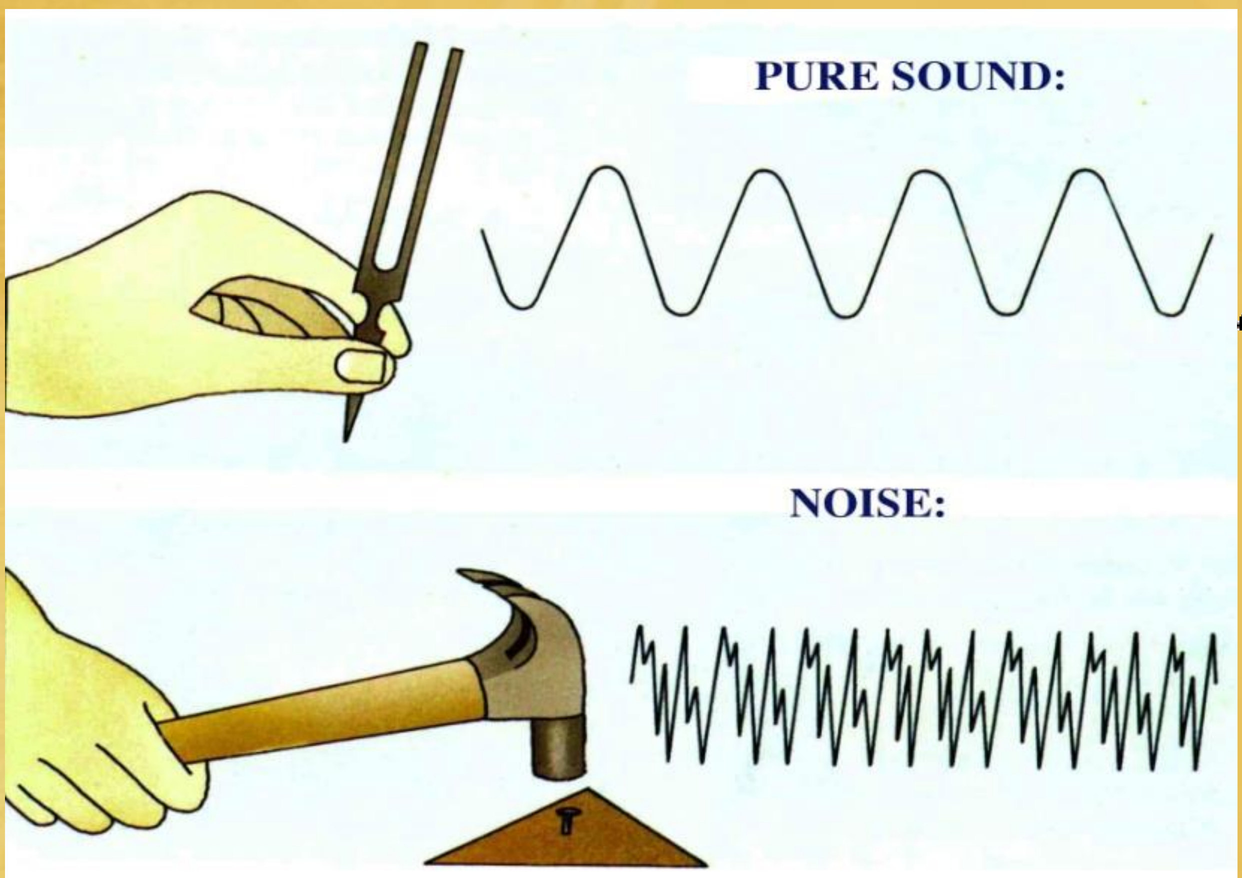
A 6-meter rope is tied to a hook in the wall. Which of the following wavelengths can produce a standing wave?

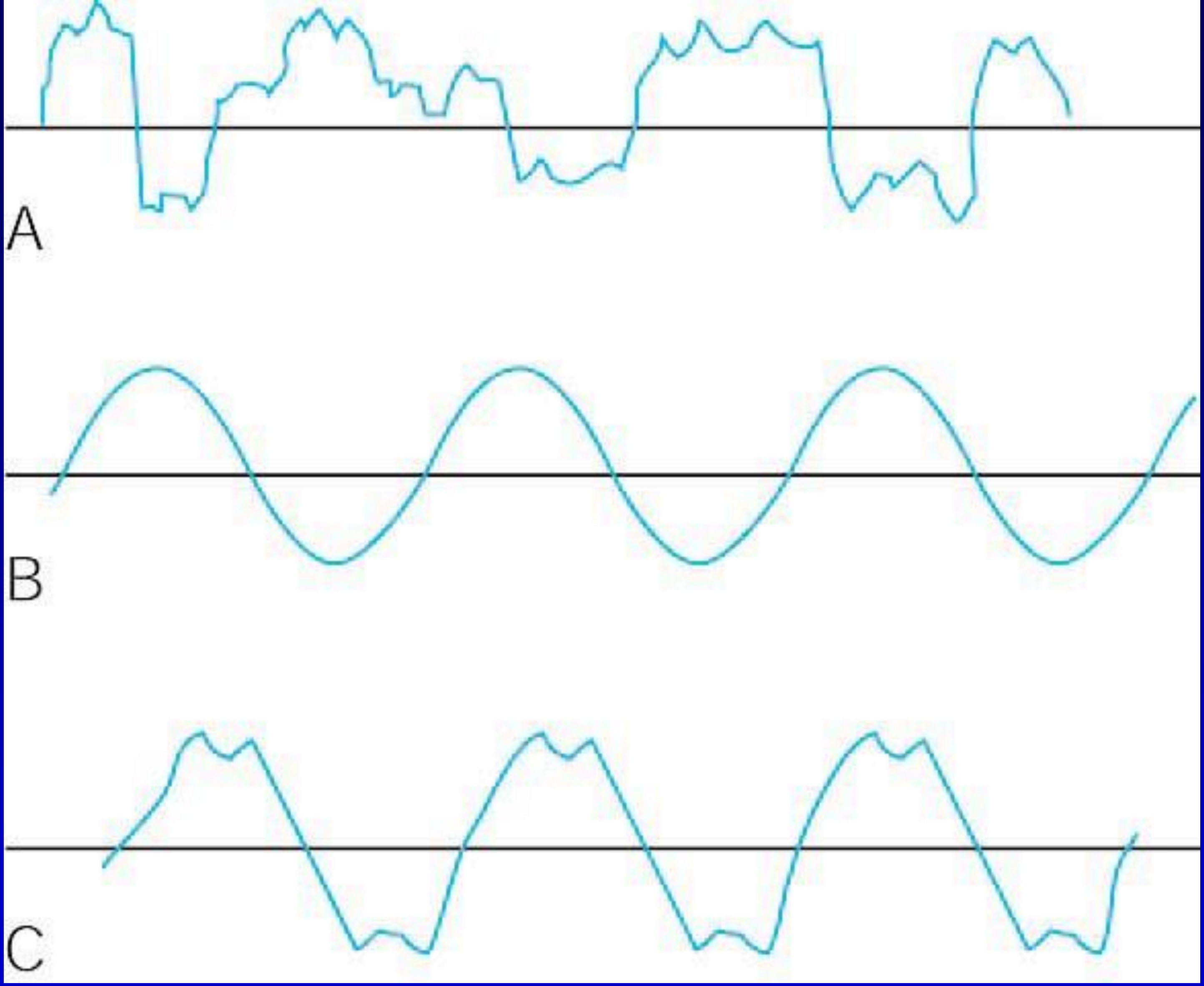
1.5 m … 2.5 m … 3.5 m … 4.5 m **(multiple of 6 m)**

The amount of diffraction of a wave **increases** as the size of the obstacle or opening increases.

Noise or Sound?

- Pure sound is based on a specific frequency or wavelength.
- Noise → ***no recognizable wave pattern; waves have different f and λ***





Different "sounds" that you hear include (A) noise, (B) pure tones, and (C) musical notes.

Frequency of Sound

- Pitch of the sound
- There are 12 musical notes on a staff from A to G# (one octave)
- Bass: Low frequency 0 to 300 Hz
- Mid range: "voice" → 300 to 6,000 Hz
- Treble: High frequency, above "middle" C note, 6,000 to 20,000 Hz
- Music has recognizable wave patterns; the sound waves have similar f and λ.

How do musical instruments create sound?

It depends on the type of instrument. There are four types.

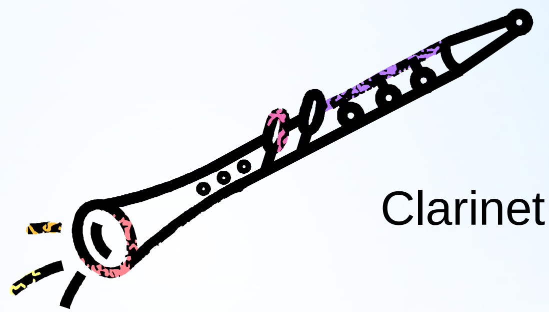
- Woodwind
- String
- Percussion
- Brass

Woodwinds Instruments

Woodwinds make music by blowing on the top of the instrument or on a reed which causes **vibration**. When the frequency of vibration of the reed matches the frequency of vibration of the air column in the instrument, **resonance** occurs and sound is heard.

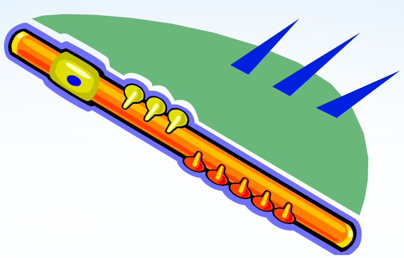
Flute

Oboe



Clarinet

Bassoon



Piccolo

String Instruments

Strings make music by plucking or strumming the strings. **Resonance** occurs as the strings **VIBRATE** back and forth and within the body of the instrument so sound can be heard.

Violin

Cello

Guitar

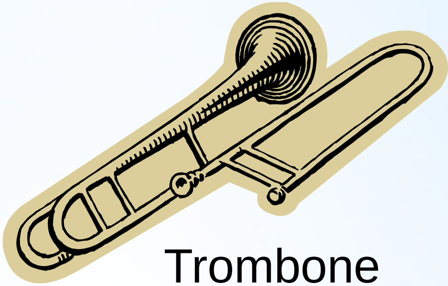
Electric Guitar

Harp

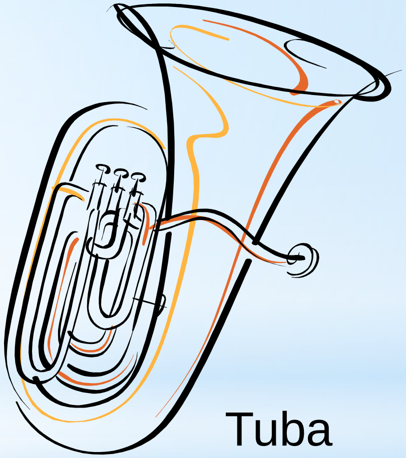
Brass Instruments

Brass instruments make music by buzzing lips while blowing, which causes **vibration**. The air in the instruments body **resonates** to form sound.

French Horn



Trombone



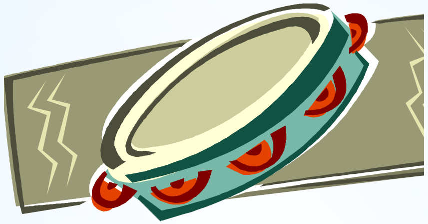
Tuba

Trumpet

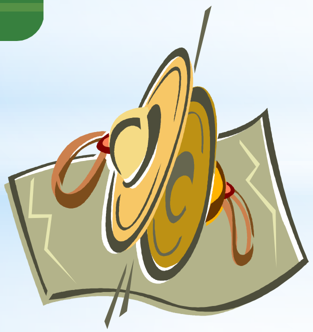
Percussion Instruments

Percussion instruments make music by striking, shaking, or scraping them, causing **vibration**. The instrument's body or membrane (material) allows **resonance**.


Drum


Tambourine


Piano


Cymbals


Xylophone


Maracas

Match the items with the Behavior of Sound:

QUICK CHECK

Diffraction   Reflection   Refraction   Resonance   Doppler Effect

Echo   Beats

Hearing around a corner   Ultrasound

musical notes (standing waves)   Sonar

Sound dies in cold weather   Reverb

Sound speeds up in warm weather

Amplifying sound due to frequency

Pitch changes when you are moving or an object moves towards or away from you.

Match the items with the Behavior of Sound:

Diffraction

Beats, hearing around a corner, musical notes (standing waves)

Reflection

Echo, reverb, ultrasound, sonar

Refraction

Sound dies in cold weather, sound speeds up in warm weather

Resonance

Amplifying sound due to frequency

Doppler Effect

Pitch changes when you are moving or an object moves towards or away from you.

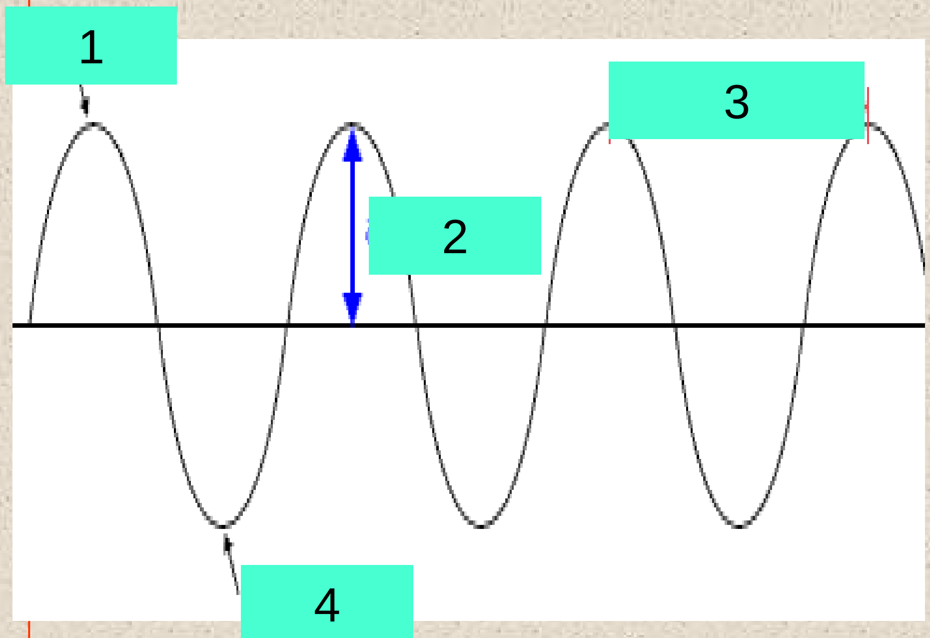
TRY IT

What goes with what?

Match the items that go together

Amplitude	low point
Crest	> Mach 1
Decibel	Pitch
Frequency	Peak/top
~331 m/s	Intensity
Sonic Boom	Loudness
Trough	Speed

Label the parts of the wave:



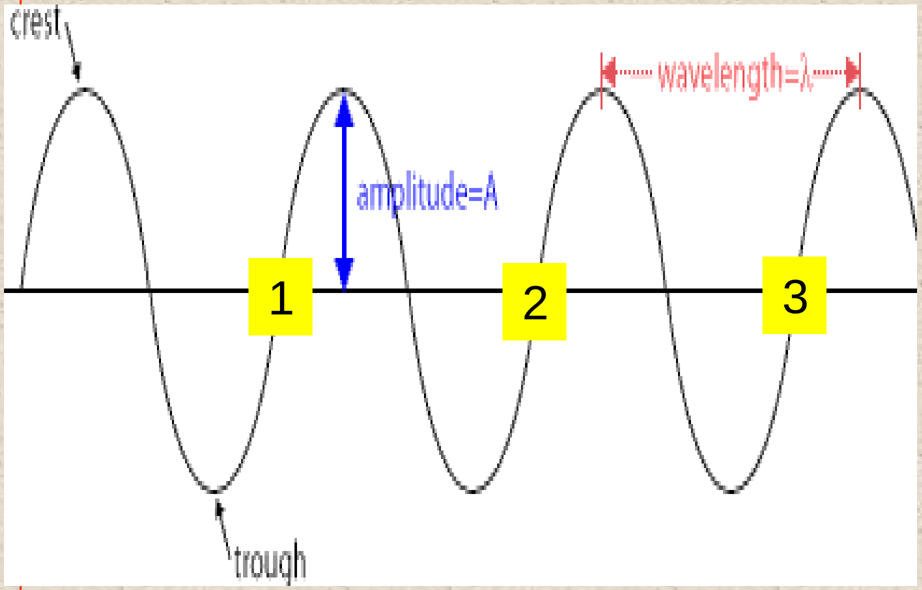
What is the frequency of the wave above if it takes 1 second to pass by?

What goes with what?

Match the items that go together

Amplitude	↔	Loudness
Crest	↔	Peak/top
Decibel	↔	Intensity
Frequency	↔	Pitch
~331 m/s	↔	Speed
Sonic Boom	↔	> Mach 1
Trough	↔	low point

Label the parts of the wave:

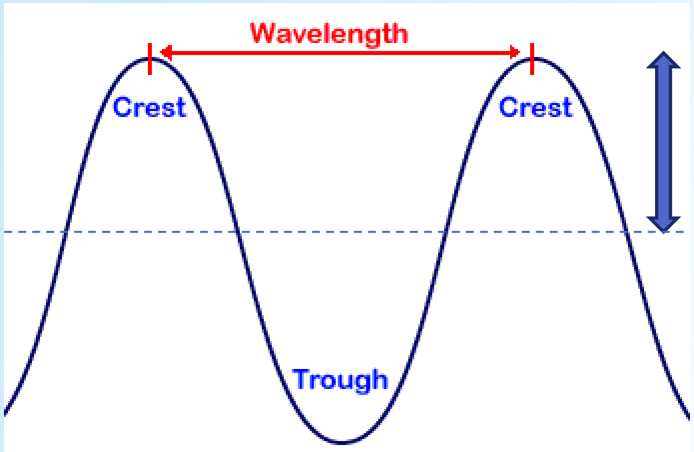


What is the frequency of the wave above if it takes 1 second to pass by? ~3.5 Hz

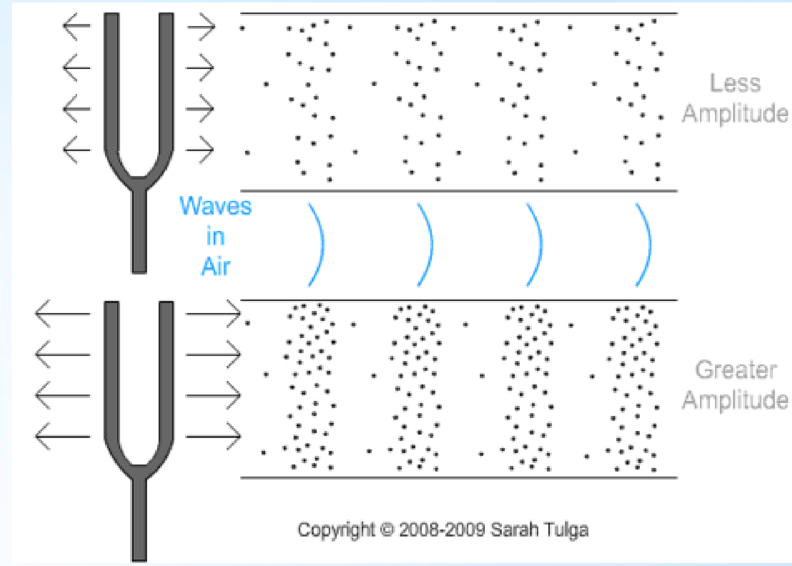
Draw a longitudinal wave and a transverse wave and label wavelength, amplitude, crest, trough, rarefaction, and compression.

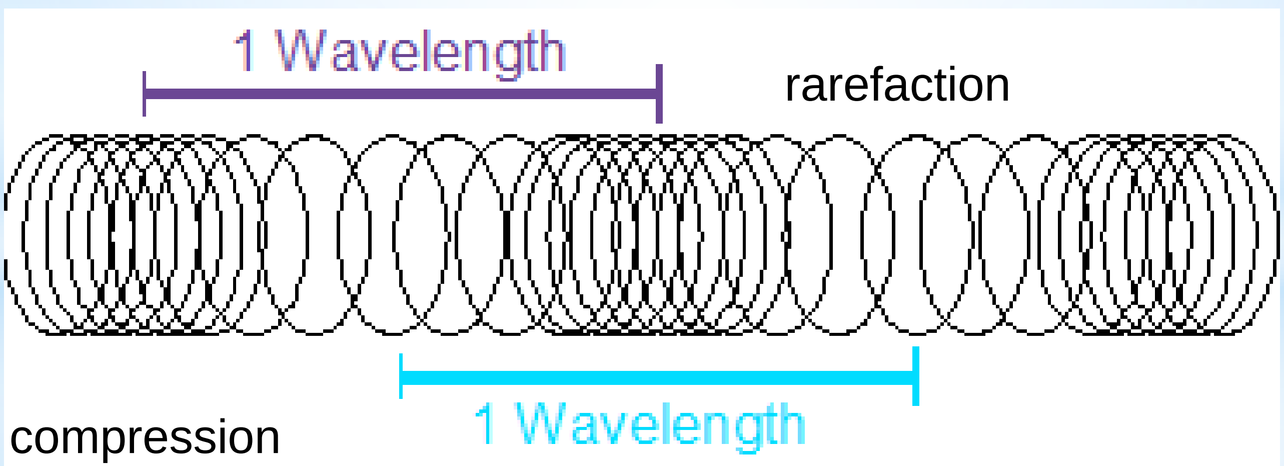
QUICK CHECK

Draw a longitudinal wave and a transverse wave and label wavelength, amplitude, crest, trough, rarefaction, and compression.



Amplitude





QUICK CHECK

What aspect of sound applies to each phrase?

What produces sound?

Determines the strength of the sound produced …

What factors affect sound?

How fast the sound travels …

How many wavelength pass by in a certain time …

How strong/loud the sound is …

Sounds can be repeated …

Sounds can be relative based on where you hear it …

Sound slows down or speeds up …

What aspect of sound applies to each phrase?

What produces sound? (*vibrations passed by particles*)

Determines the strength of the sound produced …

(*force & energy*)

What factors affect sound? (*e.g. friction, temperature, pressure*)

How fast the sound travels (*velocity*)

How many wavelength pass by in a certain time (*frequency*)

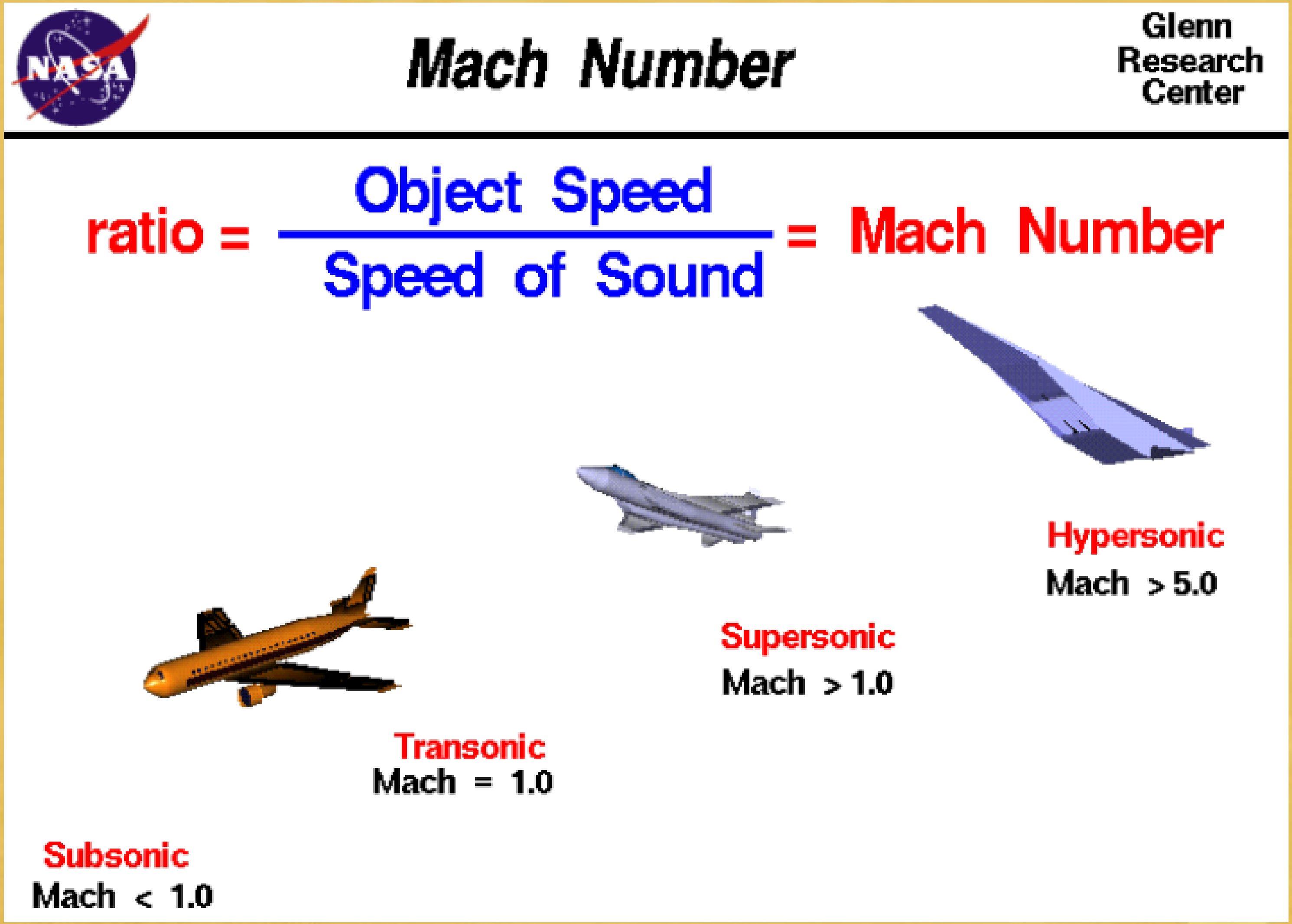
How strong/loud the sound is (*amplitude*)

Sounds can be repeated (*echo, reverberation*)

Sounds can be relative (*Doppler effect – in a car the sound of the train passing changes*)

Sound slows down or speeds up (*refraction*)

Variations Based on the Speed of Sound

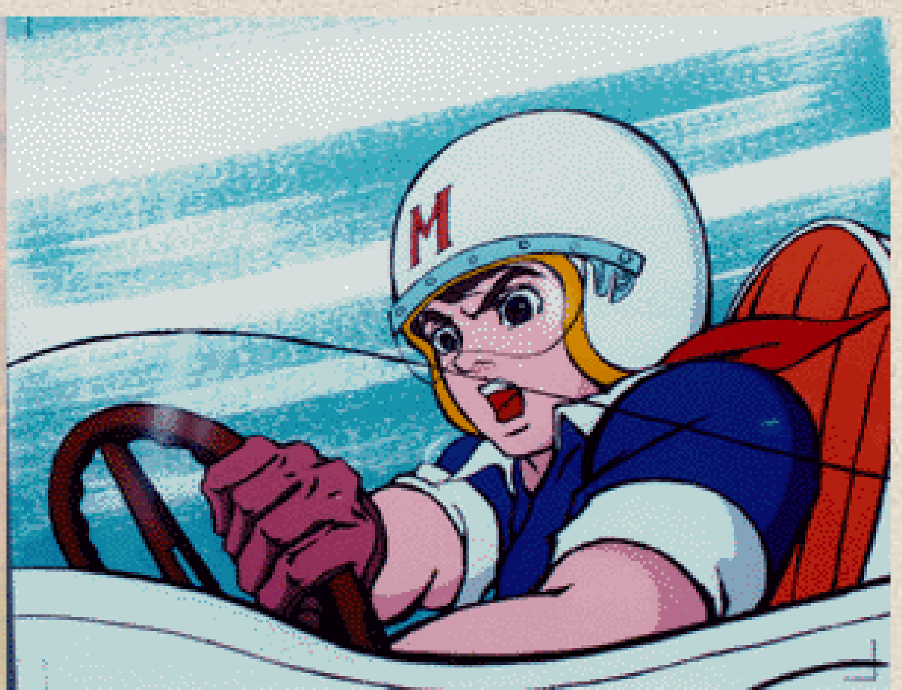


Mach Numbers

Enrichment

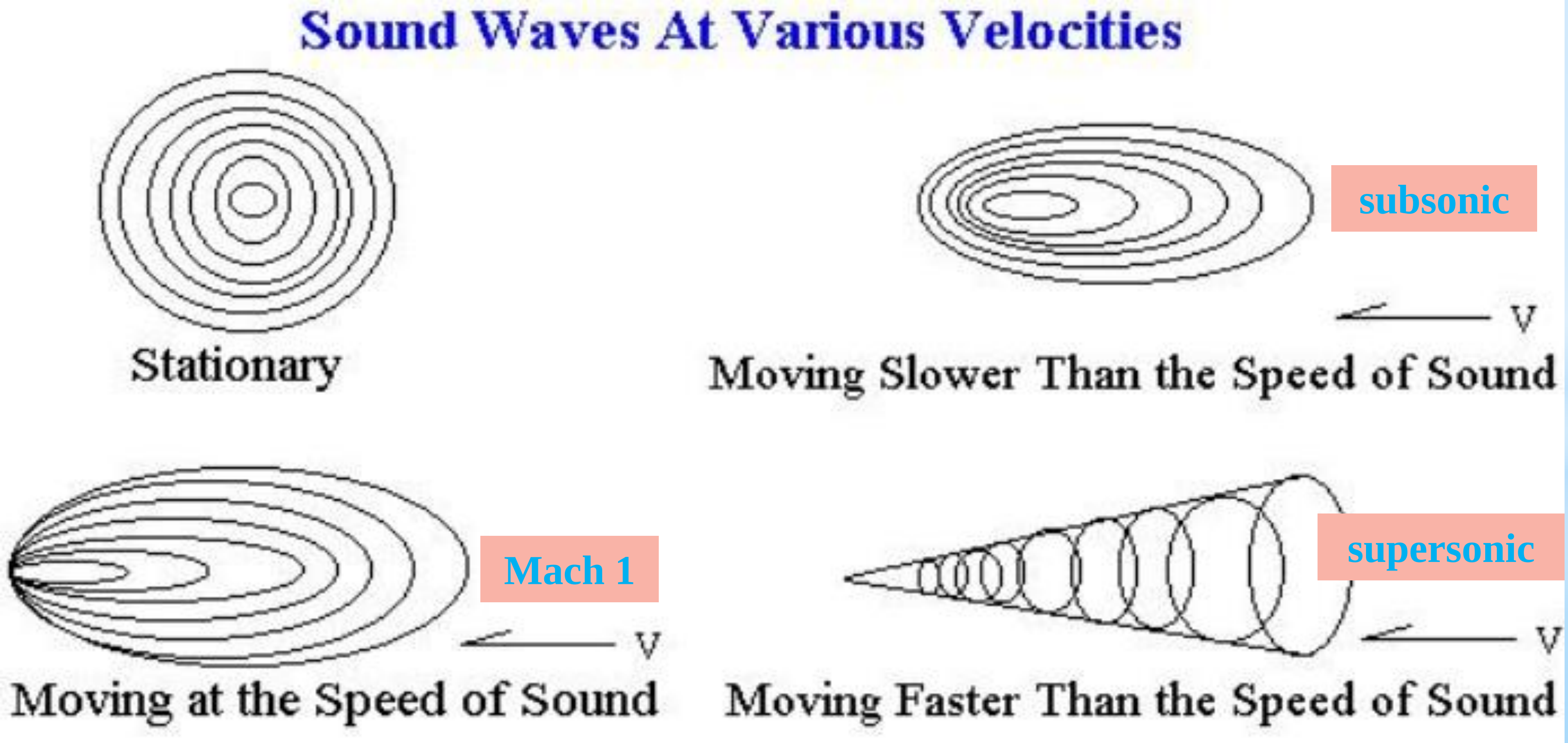
Depending on temperature, sound travels around 750 mph (330 m/s), which would be Mach 1. Twice this speed would be Mach 2, which is about the max speed for the F-22 Raptor. [*e.g. 2 x 330 m/s = 660 m/s or ~1500 mph*]

Speed Racer drives a car called "The Mach 5," which would imply it can go 5 times the speed of sound.



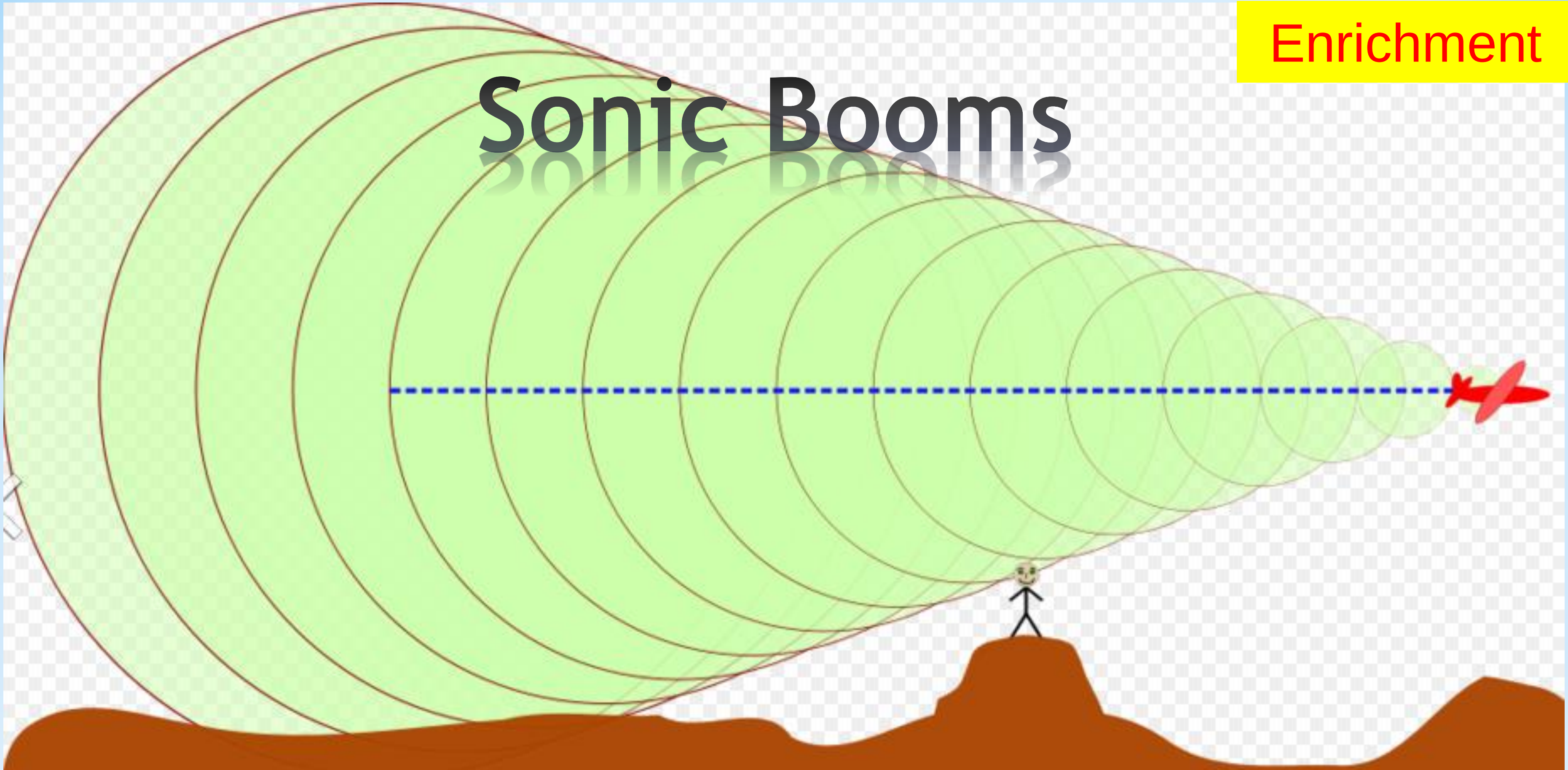
Mach One is the speed of sound.

When objects move slower than Mach one, the sound waves go out in “circles” as when you throw a pebble into a calm pond.



Enrichment

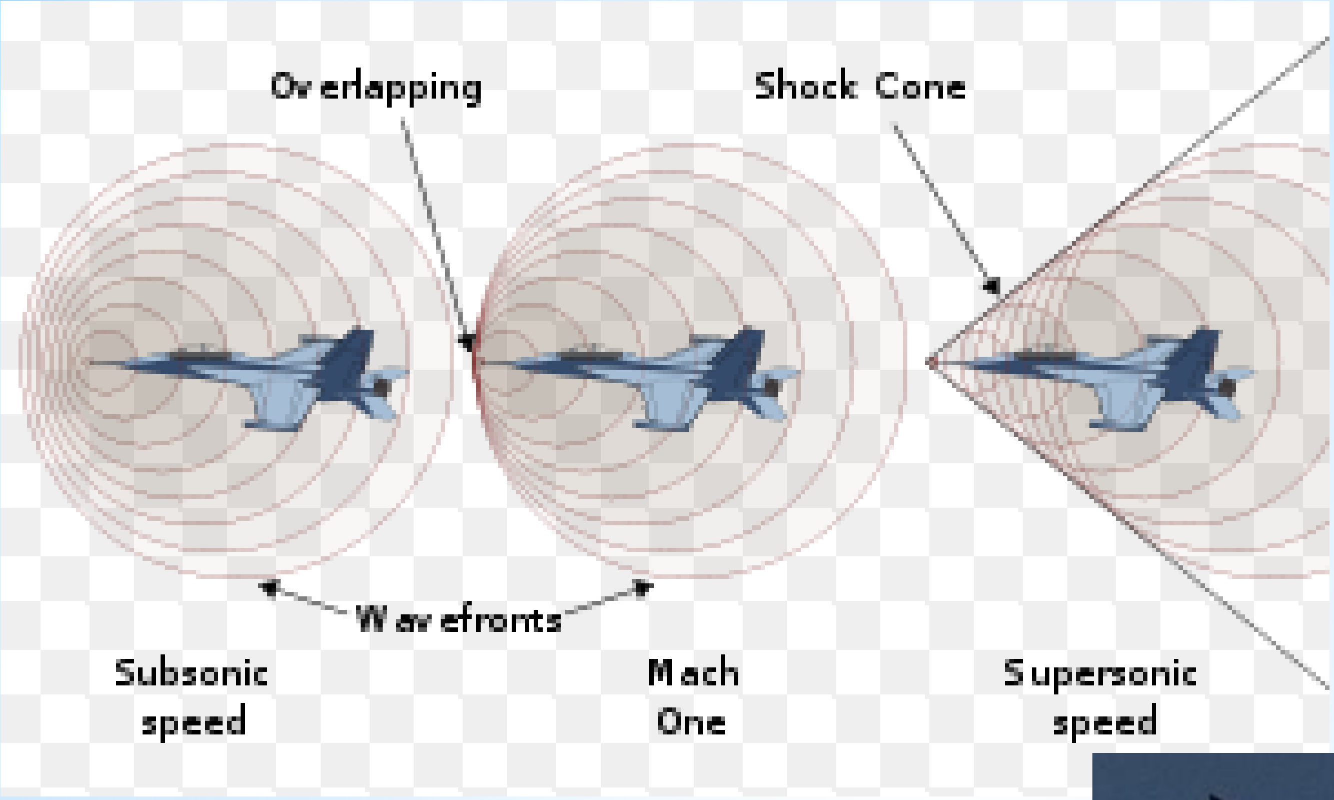
Sonic Booms



Sonic booms are created by an object **traveling** through the air **faster than the speed of sound** (Mach 1). Sonic booms generate enormous amounts of **sound energy**, sounding much like an explosion. The crack of a supersonic bullet passing overhead or the crack of a bullwhip are examples of a sonic boom in miniature.

Enrichment

Sonic Booms



There is a rise in pressure at the nose of the jet, decreasing steadily to a negative pressure at the tail, followed by a sudden return to normal pressure after the object passes.

Enrichment

Sonic Booms

http://somup.com/cFXoIEnji1 (2:07)

http://somup.com/cFXoIHnji6 (1:36)

Assessment Questions

3. Which wave property increases as the energy of a wave increases?
   a. period
   b. frequency
   c. wavelength
   d. amplitude

Assessment Questions

3. Which wave property increases as the energy of a wave increases?
   a. period
   b. frequency
   c. wavelength
   d. amplitude

   ANS: D

Assessment Questions

2. Most musical instruments vary pitch by
   a. changing the amplitude of sound waves.
   b. reflecting sound from surfaces in a room.
   c. changing the frequency of a standing wave.
   d. using the Doppler effect.

Assessment Questions

2. Most musical instruments vary pitch by
   a. changing the amplitude of sound waves.
   b. reflecting sound from surfaces in a room.
   c. changing the frequency of a standing wave.
   d. using the Doppler effect.

   ANS: C

Assessment Questions

3. The Doppler effect is
   a. a change in sound frequency caused by motion of the sound source relative to the listener.
   b. used in a variety of applications including sonar and ultrasound imaging.
   c. a technique for determining the distance to an object under water.
   d. the rate at which a wave’s energy flows through a given area.

Assessment Questions

3. The Doppler effect is
   a. **a change in sound frequency caused by motion of the sound source relative to the listener.**
   b. used in a variety of applications including sonar and ultrasound imaging.
   c. a technique for determining the distance to an object under water.
   d. the rate at which a wave’s energy flows through a given area.

   ANS: A

Assessment Questions

4. What part of the human ear acts as an amplifier to increase the motion of the eardrum?
    a. ear canal
    b. middle ear
    c. inner ear
    d. auditory nerve

Assessment Questions

4. What part of the human ear acts as an amplifier to increase the motion of the eardrum?
   a. ear canal
   b. middle ear
   c. inner ear
   d. auditory nerve

   ANS: B