A **wave** is a disturbance that travels through a medium, transporting energy from one place to another.
A **medium** is a material that the wave moves through.
A **mechanical wave** is a wave that needs a medium and uses particle-to-particle interaction
A **longitudinal wave** is a wave in which the particles of the medium move parallel to the direction of energy transport.
A **pressure wave** is a wave that has high pressure and low pressure regions moving through the medium.
Pitch is the sensation of a frequency. High pitch is higher frequency.
Frequency is how often particles in a medium vibrate when a wave passes through it. (f=speed/wavelength - speed=distance/time)
Hertz (Hz) is a way to mesure frequency (1 Hertz = 1 vibration per second)
Period is the time it takes to complete one vibrational cycle
Intensity is the amount of energy transported past a given area of the medium per unit of time. (Watts/meter squared)
Boundary is where one medium ends and another begins
Boundary behavior is how the wave acts when it reaches the boundary (reflect/ diffract/ transmission/ refraction)
Node is where there is a no movement area
Anti-node is where there is the most movement
Environmental noise: unwanted or harmful outdoor sound created by human activity, such as noise emitted by means of transport, road traffic, rail traffic, air traffic and industrial activity.
Reverberation; when you sing (in the shower) the area is smaller, so the sound doesn't take that long to reflect back, it takes less than 0.1 sec, so it sounds like the sound is prolonged.
Harmonic: Something times the fundamental frequency; ex. 440Hz's second harmonic is 880 (*2)
Consonance: A combination of two (or more) tones of different frequencies that results in a musically pleasing sound.
Dissonance: A combination of two (or more) tones of different frequencies that results in a musically displeasing sound.
Psychoacoustics: scientific study of sound perception and audiology. This includes speech, music, and other sound frequencies that travel through our ears.
Power: Moving air particles have kinetic energy, so as a sound waves moves, it transports energy along with it. Power is how fast teh sound wave carries this energy. Amound of energy transported divided by time it took.
Electromagnetic Waves: wave from the electromagnetic spectrum, can travel through any medium
Intensity: Power transmitted per area receiving energy $I = \frac{P}{A}$

Elements of Musical Sound:

Elements of music include, timbre, texture, rhythm, melody, beat, harmony, structure, tempo, pitch and dynamics.

1. Rhythm

Combinations of long and short sounds which convey movement. When learning to understand rhythm, you should try to understand it in terms of regularity. Later on, you can learn about the ways that this regularity is played with and contradicted in music.Music is measured in beats, and rhythms are made up of different types of beat. This is the steady pulse that runs throughout a piece of music.

Rhythm is the time aspect of music or the way sound in arranged through patterns of time. In many ways we feel rhythm in our heartbeat and when we breath and walk. There is also a sense of rhythm in the recurring pattern of day and night, the four seasons of the year and the rise and fall of the tides. In music it occurs in patterns of tension and release and in through musical expectation and fulfillment.

2. Beat

The underlying steady beat of music. This is what we may tap our foot to or clap along with! If you can do this then, without necessarily being able to describe the rhythm in terms of beats, you are showing awareness of something regular *pulsing* through the music. You could say that the pulse is rhythm in its simplest form.

The basic recurring unit of time in music is beat. A beat is the physical part of the music that makes us tap our toe, clap our hands or move our body. Beats form the background against which a composer or musician place notes of varying length. Expression is felt right away by rhythm. How we hear the beat can tell us if a piece of music is a march, a dance, a forceful powerful gesture or a gentle flowing elegance.

3. Duration

The length of the beats making up the music. In the main melody - the tune in a pop song which you would sing along to - this would be the different lengths of the notes which you are singing. In contrast to the pulse of the rhythm, which is regular, each note of the melody would last for different portions of the pulse.

Try clapping a pulse as you sing a melody - try *Frère Jacques* - and notice how the words aren't necessarily as long as the beats of the pulse. They can be longer (lasting for one or more claps) or shorter (multiple notes or words between claps).

4. Pitch

Pitch is how high or low a sound is - every sound has a pitch, even if it isn't musical. In written music, the notes on the staffare showing what pitch to play, when and for how long.

5. Tempo

Tempo is an element of music which dictates and describes the speed that music is performed at. This effects the mood of a piece of music. Often, sad music is slower than happy music, but this isn't a strict rule. Complex moods are created in music by using tempo in both expected and unexpected ways, as well as by changing the tempo during a piece.

Tempo can be described precisely using metronome indications and BPM (beats per minute). But it can also be described in a more general way using performance directions. Performance directions usually appear at the beginning of a piece of written music and describe the speed, or tempo, which the piece should be played at. These sorts of tempo markings won’t be as precise as a metronome indication - instead, they will state that the piece should be played ‘quickly’, ‘slowly’, ‘with fire’ or in any way the composer thought was suitable!

6. Timbre

Timbre is the particular tone which distinguishes a sound or combinations of sounds. Every sound - whether musical or not - has a timbre. When we talk about timbre we can describe it in terms of colour and shape. A sound could be warm, silvery, round or sharp - how would you describe different sounds?

7. Texture

The texture of music indicates the layers of sound in the work and the relationship between them. A full orchestra might sound swollen and heavy, whilst a solo ukulele could sound light.

8. Melody

A sequence of notes and rhythms - these complement but are not identical to the notes and beats of the accompanying sounds. They work together to make a layered sound.

The melody is what we usually sing along to (and the pulse is what we tap our feet to). In your favourite song, the voice doesn't necessarily sing the same rhythm and notes as the backing music, but it does sound as though it belongs with them. They work together to create texture.

9. Structure

Just how a novel is structured into paragraphs and chapters, and a poem is formed of lines and stanzas, this refers to the different sections of a piece and what order they are in.

In most music there is a formal structure - think of how pop songs have different verses and a repeated chorus which they return to in between. The different verses explore the theme of the song and develop it.

The chorus usually returns for one final rendition, in which it is altered or extended in some way. It is the same in other musical forms - all have a structured way in which they explored their themes, whether melodic or lyrical.

10. Harmony

This is the sounding of two or more notes at the same time. The sounds in a piece of music harmonise with one another to produce a (typically) pleasant sound. How can you tell when you have played or sung the wrong note? It was probably because it did not harmonise in the way you were expecting!

11. Dynamics

Dynamics are one of the core elements of musical expression. Learning about them will help children to listen critically and get a more nuanced sense of meaning from the music they study.

Perception:

Sound Localization

Our ability to locate the source of a sound is called sound localization. Our brain computes the discrepancies in tone, pitch and timing of sound waves reception between both ears to deduce the source location. Localization is expressed in terms of a three-dimensional position as:

- Horizontal angle
- Vertical angle
- Distance for static sounds
- Velocity for moving sounds

Human beings can detect sound in the horizontal direction compared to vertical orientations. This is due to symmetrically placed ears.

Our brain doesn't process the perceived sound frequencies uniformly between 20 Hz to 20,000 Hz. This is because the sound waves are received through an organ called the cochlea in the ear. Hair cells populate the cochlea and are distributed unevenly. They also appear in clusters facilitating us to interpret the most common sound from our environment. These hair cells play a vital role in sending electrical signals to our brain for sound interpretation. The concentration of these signals at the hair cells creates sound pressure.

Depending on the sound pressure and sound waves' frequency, there occurs a variation in the loudness of the perceived sound. Researchers created a graph to explain how sound pressure and frequency of sound waves influence our perception to understand this variation. These are called the equal loudness contours or Fletcher-Munson curves. Understanding this curve helps you balance the frequencies and render the most pleasing piece to your listeners.

A single sound source can have a tremendous impact on your perception system. However, when you try to hear multiple sounds simultaneously, you will be unable to differentiate clearly between each of them. This is because they reach the cochlea simultaneously, exciting similar regions of your hair cells. In addition, there must be a minimum frequency difference between the sounds for the auditory nerves to process them individually. This phenomenon is termed masking. To combat masking, you need to equalize your track well. For this purpose, you have to eliminate frequencies that do not count as sounds to your mix and emphasize those that matter.

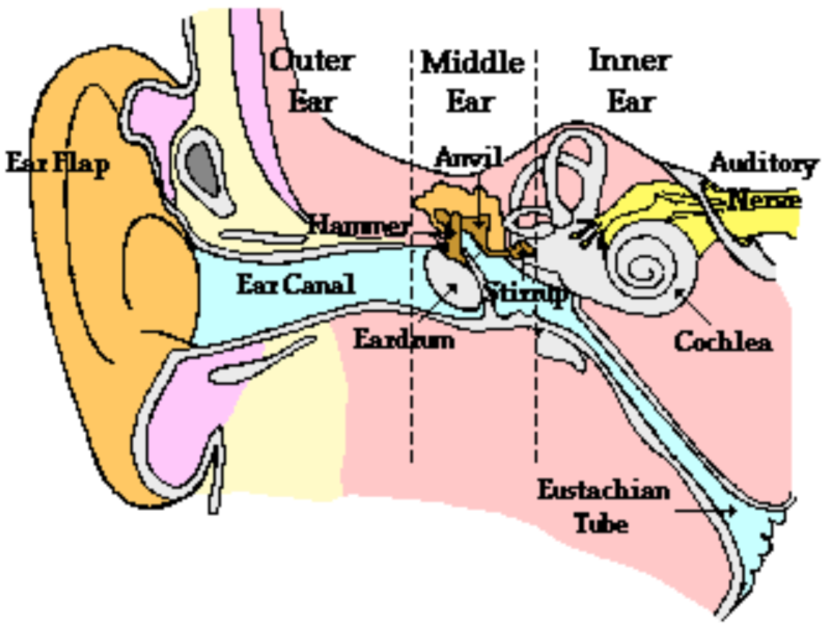
- While there are variations in individual perception of the strength of a sound, studies have shown that to a good approximation, the sound is perceived twice as loud if the sound level increases by 10 dB.
- Similarly, a 20 dB increase in the sound level is perceived as four times as loud by the normal human ear.

How to Calculate the Intensity Level of a Sound Wave

Step 1: Identify the intensity, I of the sound, in W/m^2.

Step 2: Substitute the value found in step 1 into the intensity level formula $\beta = 10\log\left(\frac{I}{I_0}\right)$ dB, where $I_0 = 10^{-12}\ W/m^2$ represents the threshold for human hearing.

The Human Ear:



Outer Ear:

- Earflap & 2cm long ear canal
- Earflap provides protection for the middle ear (to prevent damage to eardrum)
- Channels sound waves that reach the ear through the ear canal
- Can amplify sounds with frequencies > 3000Hz
- Sound is still in the form of a pressure wave

The Middle Ear:

- Air filled cavity w/ eardrum, 3 tiny interconnected bones
    - Hammer
    - Anvil
    - Stirrup
- Eardrum = durable, tightly stretched membrane that vibrates when pressure waves reach it
- The eardrum vibrates at the same frequency as the sound wave
- b/c it is connected to the hammer, that starts vibrating too
    - So do all the other bones
- The stirrup is connected to the inner ear; and thus the vibrations of the stirrup are transmitted to the fluid of the inner ear and create a compression wave within the fluid.
- The three tiny bones of the middle ear act as levers to amplify the vibrations of the sound wave.
- Due to a mechanical advantage, the displacements of the stirrup are greater than that of the hammer.
- since the pressure wave striking the large area of the eardrum is concentrated into the smaller area of the stirrup, the force of the vibrating stirrup is nearly 15 times larger than that of the eardrum.
- This feature enhances our ability to hear the faintest of sounds.
- The middle ear is an air-filled cavity that is connected by the Eustachian tube to the mouth.
- This connection allows for the equalization of pressure within the air-filled cavities of the ear.
- When this tube becomes clogged during a cold, the ear cavity is unable to equalize its pressure; this will often lead to earaches and other pains.

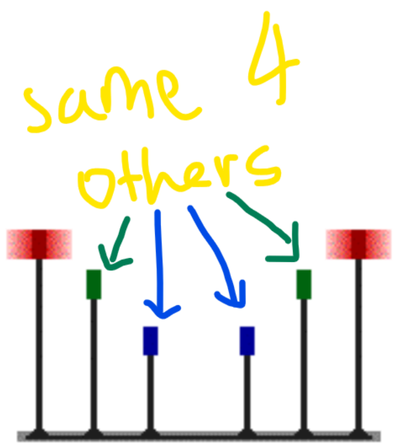
The Inner Ear:

- The inner ear consists of a cochlea, the semicircular canals, and the auditory nerve.
- The cochlea and the semicircular canals are filled with a water-like fluid.
- The fluid and nerve cells of the semicircular canals provide no role in the task of hearing; they merely serve as *accelerometers* for detecting accelerated movements and assisting in the task of maintaining balance.
- The cochlea is a snail-shaped organ that would stretch to approximately 3 cm. In addition to being filled with fluid, the inner surface of the cochlea is lined with over 20 000 hair-like nerve cells that perform one of the most critical roles in our ability to hear.
- These nerve cells differ in length by minuscule amounts; they also have different degrees of resiliency to the fluid that passes over them. As a compressional wave moves from the interface between the hammer of the middle ear and the *oval window* of the inner ear through the cochlea, the small hair-like nerve cells will be set in motion.
- Each hair cell has a natural sensitivity to a particular frequency of vibration.
- When the frequency of the compressional wave matches the natural frequency of the nerve cell, that nerve cell will resonate with a larger amplitude of vibration.
- This increased vibrational amplitude induces the cell to release an electrical impulse that passes along the auditory nerve towards the brain.
- In a process that is not clearly understood, the brain is capable of interpreting the qualities of the sound upon reception of these electric nerve impulses.

First, vibrations enter through the auditory canal, which causes the tympaniumto vibrate. These vibrations are picked up by the 3 tiny bones. The malleus transmits the vibrations to the oval window, which connects the middle ear with the inner ear. This creates pressure waves in the cochlea and inside, hair cells produce nerve impulses that are sent to the brain.

Resonance:

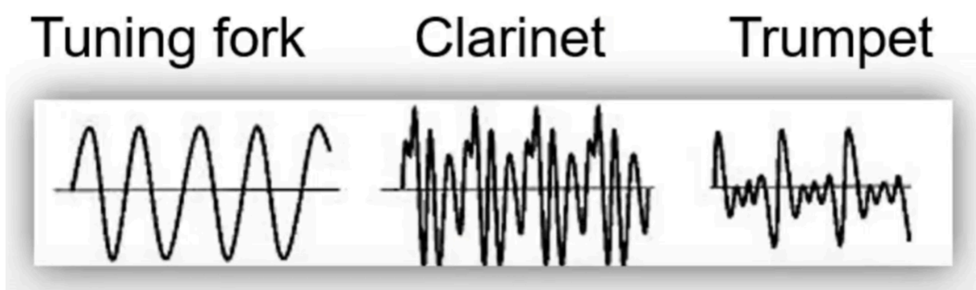
- occurs when two interconnected objects share the same vibrational frequency
- one of the objects is vibrating it forces the second object into vibrational motion
- the result is a large vibration
- if a sound wave within the audible range of human hearing is produced, a loud sound is heard.



The vibrations of the red bob forces the other red bob into resonance - large vibrations at the same frequency.

Timbre:

- timbre in music refers to the sound qualities produced by the balance of these overtones in the harmonic series.
- Every instrument, even instruments in the same family, will have a different timbre based on their construction and relationship to the harmonic series.
- why no two pianos sound exactly the same.



Overall shape of a wave of different instruments

Sound consists of a bunch of different quieter harmonics
Ex. violin plays the natural frequency, but also other harmonics with different pitches

- Add together to make the messy thing you see (up)

-

Dissonance & Consonance:

Consonance: A combination of two (or more) tones of different frequencies that results in a musically pleasing sound.
Dissonance: A combination of two (or more) tones of different frequencies that results in a musically displeasing sound.

Consonant sounds

- When notes and chords sound pleasing to the ear when played together, this effect is known as consonance.
- Establishing a balance between consonance and dissonance in music is important.
- By using consonance and dissonance together, a songwriter can produce truly memorable and catchy music.
-

* minor and major thirds
* perfect fourths and fifths
* minor and major sixths
* the octave

Dissonant sounds

- Dissonance can be used in music to create tension and a sense of anticipation.
- For the listener, it can seem as if the sounds do not fit together.
- However, songwriters will want to use dissonant sounds to create tension in their music, as long as this tension is resolved.
- This can be done by following up the dissonant sound with a consonant one. The listener may feel unease if the built-up tension is not released.
- However, sometimes this can be an intentional choice by the songwriter, although too much dissonance without a proper resolution will only annoy the listener.

* major and minor seconds
* major and minor sevenths
* major and minor ninths

(tritone)

Environmental Noise:

Environmental noise: unwanted or harmful outdoor sound created by human activity, such as noise emitted by means of transport, road traffic, rail traffic, air traffic and industrial activity.

- Noise Pollution
- Dangerous for health in school/homes/workplaces
- From road/rail/train/air traffic
    - Makes stress/tiredness/affects learning and memory

Common environmental noise levels

How loud is too loud?

Continued exposure to noise above 85 dBA (adjusted decibels) over time will cause hearing loss. The volume (dBA) and the length of exposure to the sound will tell you how harmful the noise is. In general, the louder the noise, the less time required before hearing loss will occur.

According to the National Institute for Occupational Safety and Health, the maximum exposure time at 85 dBA is eight hours. At 110 dBA, the maximum exposure time is one minute and 29 seconds. If you must be exposed to noise, it is recommended that you limit the exposure time and/or wear hearing protection. A three dBA increase doubles the amount of noise, and halves the recommended amount of exposure time.

The following decibel levels of common noise sources are typical, but will vary. Noise levels above 140dBA can cause damage to hearing after just one exposure.

    - Leads to stroke/heart disease

- 0 The softest sound a person can hear with normal hearing
- 10 normal breathing
- 20 whispering at 5 feet
- 30 soft whisper
- 50 rainfall
- 60 normal conversation
- 110 shouting in ear
- 120 thunder

Home	Work	Recreation
• 50 refrigerator • 50 – 60 electric toothbrush • 50 – 75 washing machine • 50 – 75 air conditioner • 50 – 80 electric shaver • 55 coffee percolator • 55 – 70 dishwasher • 60 sewing machine • 60 – 85 vacuum cleaner	• 40 quiet office, library • 50 large office • 65 – 95 power lawn mower • 80 manual machine, tools • 85 handsaw • 90 tractor • 90 – 115 subway • 95 electric drill • 100 factory machinery • 100 woodworking class	• 40 quiet residential area • 70 freeway traffic • 85 heavy traffic, noisy restaurant • 90 truck, shouted conversation • 95 – 110 motorcycle • 100 snowmobile • 100 school dance, boom box • 110 disco • 110 busy video arcade
• 70 TV audio • 70 – 80 coffee grinder • 70 – 95 garbage disposal • 75 – 85 flush toilet • 80 pop-up toaster • 80 doorbell • 80 ringing telephone • 80 whistling kettle • 80 – 90 food mixer or processor • 80 – 90 blender • 80 – 95 garbage disposal • 110 baby crying • 110 squeaky toy held close to the ear • 135 noisy squeeze toys	• 110 leafblower • 120 chain saw, hammer on nail • 120 pneumatic drills, heavy machine • 120 jet plane (at ramp) • 120 ambulance siren • 125 chain saw • 130 jackhammer, power drill • 130 air raid • 130 percussion section at symphony • 140 airplane taking off • 150 jet engine taking off • 150 artillery fire at 500 feet • 180 rocket launching from pad	• 110 -120 rock concert • 112 personal cassette player on high • 117 football game (stadium) • 120 band concert • 125 auto stereo (factory installed) • 130 stock car races • 143 bicycle horn • 150 firecracker • 156 capgun • 157 balloon pop • 162 fireworks (at 3 feet) • 163 rifle • 166 handgun • 170 shotgun

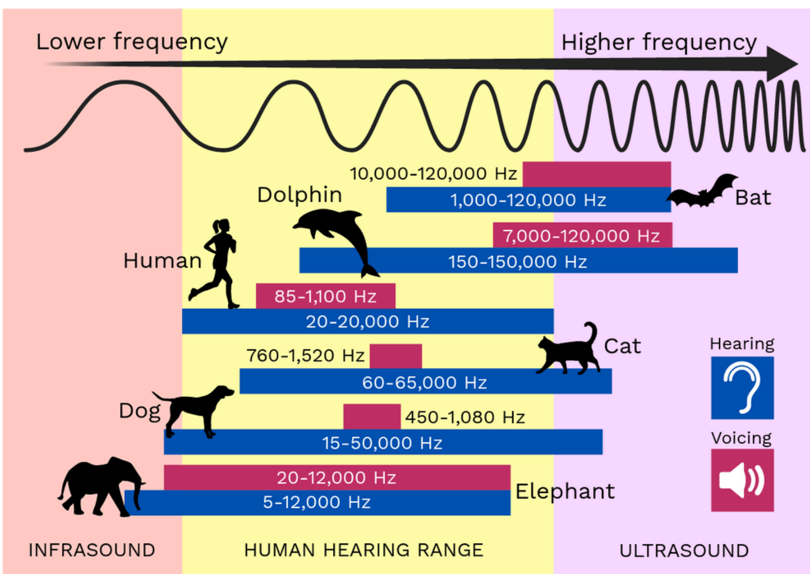
- Sounds that reach 85 decibels or higher can harm a person's ears.
- Noise pollution hurts the health and well-being of wildlife.
- Studies have shown that loud noises can cause caterpillars' dorsal vessels (the insect equivalent of a heart) to beat faster, and cause bluebirds to have fewer chicks.
- Animals use sound for a variety of reasons
  - including to navigate
  - find food
  - attract mates,
  - avoid predators.
  - Noise pollution makes it difficult for them to accomplish these tasks, which affects their ability survive.

Increasing noise is not only affecting animals on land, it is also a growing problem for those that live in the ocean. Ships, oil drills, sonar devices, and seismic tests have made the once tranquil marine environment loud and chaotic. Whales and dolphins are particularly impacted by noise pollution. These marine mammals rely on echolocation to communicate, navigate, feed, and find mates, and excess noise interferes with their ability to effectively echolocate.

Sonar is very loud

Psychoacoustics:

Psychoacoustics: scientific study of sound perception and audiology. This includes speech, music, and other sound frequencies that travel through our ears.



Bioacoustics:

Bioacoustics is a cross-disciplinary science that combines biology and acoustics. Usually it refers to the investigation of sound production, dispersion and reception in animals (including humans)

- As humans are considered as visual animals, hence, vision holds a primary distance sense since light propagates very well in the terrestrial environment.
- Meanwhile, in the underwater environment light can only propagate to some tens of meters which is why, light doesn't play a better role to explore marine environment.
- On the other hand the propagation of sound under the sea is commendable which motivates oceanographers choose sound for underwater communication.
- Therefore, it is clear that marine animals can see well but emphasize hearing just as opposite to humans who can hear well but emphasize vision.
- Gauging relative importance of audition versus vision in animals can be performed just by the comparison of number of auditory and optic nerves.
-
- Marine animals have been termed to be very vocal animals.
- In the period of 1950s to 1960s, study on dolphin's echolocating behavior using high frequency click sounds have been investigated vigorously along with studies associating with different other sounds produced by different other marine mammal species and henceforth identifying the sounds associated with different species under water.
- Most of the researches in bioacoustic field have been funded by naval research organizations as biological noise sources can interfere with military use of sound in the sea.[8]
- An experienced observer can use animal sounds to recognize a "singing" animal species, its location and condition in nature.
- Investigation of animal sounds also includes signal recording with electronic recording equipment.
- Due to the wide range of signal properties and media they propagate through, specialized equipment may be required instead of the usual microphone, such as a hydrophone (for underwater sounds), detectors of ultrasound (very high-frequency sounds) or infrasound (very low-frequency sounds), or a laser vibrometer (substrate-borne vibrational signals).
- Computers are used for storing and analysis of recorded sounds.
- Specialized sound-editing software is used for describing and sorting signals according to their intensity, frequency, duration and other parameters.
- Animal sound collections, managed by museums of natural history and other institutions, are an important tool for systematic investigation of signals.
- Many effective automated methods involving signal processing, data mining and machine learning techniques have been developed to detect and classify the bioacoustic signals.[9]
- Sounds used by animals that fall within the scope of bioacoustics include a wide range of frequencies and media, and are often not "*sound*" in the narrow sense of the word (i.e. compression waves that propagate through air and are detectable by the human ear). Katydid crickets, for example, communicate by sounds with frequencies higher than 100 kHz, far into the ultrasound range.

- Lower, but still in ultrasound, are sounds used by bats for echolocation.
- A segmented marine worm *Leocratides kimuraorum* produces one of the loudest popping sounds in the ocean at 157 dB, frequencies 1–100 kHz, similar to the snapping shrimps.
- On the other side of the frequency spectrum are low frequency-vibrations, often not detected by hearing organs, but with other, less specialized sense organs.
- The examples include ground vibrations produced by elephants whose principal frequency component is around 15 Hz, and low- to medium-frequency substrate-borne vibrations used by most insect orders.
- Many animal sounds, however, do fall within the frequency range detectable by a human ear, between 20 and 20,000 Hz.
- Mechanisms for sound production and detection are just as diverse as the signals themselves.

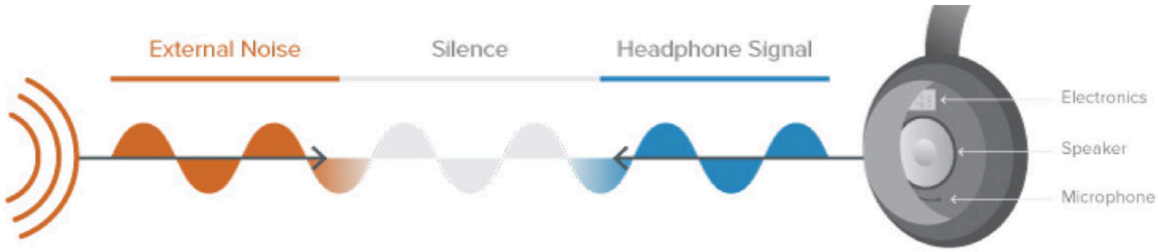
Noise and vibration caused by various forms of transportation and recreational activities: relationship between sound and cognition:

Noise cancellation:

Active noise-cancelling

Noise cancelling headphones monitor the sound around you, preventing the unwanted noise from ever reaching your ears. Miniature microphones in the earcups or earbuds listen to the outside noise frequencies and emit the exact opposite signal to effectively “cancel out” both sets of sounds when the soundwaves collide.

This is destructive interference!!



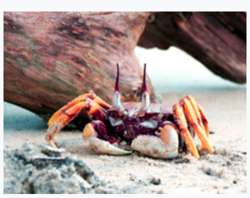
Passive noise-cancelling

1. Closed-back, over-ear headphones that separate you from ambient noise, or
2. In-ear headphones that form a tight seal to prevent sound from "getting in" and interrupting your music.

Animal calls:

	Alligator	bellow, hiss
	Alpaca	alarm call, cluck/click, hum, orgle, scream[1]
	Antelope	snort[2]
	Badger	growl[3]
	Bat	screech,[4] squeak
	Bear	roar, growl

	Bee	buzz
	Big cat (Tiger, Lion, Jaguar, Leopard)	roar,[5] growl,[6] snarl[7]
	Capybara	squeak,[8] chatter, bark
	Cat	mew, meow, purr, hiss, trill, caterwaul, growl
	Cattle	moo, low

	Chicken	cluck, buck, crow[9] cha-caw, bah-gawk (female)[10] cock-a-doodle-doo (male)
	Chinchilla	squeak[11]
	Cicada	chirp[12]
	Crab	chirp, click, creak[13]
	Crane	clang

	Cricket	chirp
	Crow	caw, cah[14]
	Curlew	pipe[15]
	Deer	bellow (buck), bleat (doe, fawn)
	Dog	bark, howl, growl, bay
	Dolphin	click[16]

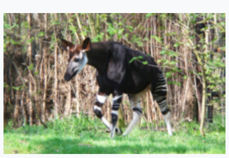
	Donkey	hee-haw,[17] bray
	Duck	quack
	Eagle	screech[18]
	Elephant	trumpet
	Elk	bugle (*male*),[19] bleat (*calves*)[20]

	Ferret	dook[21]
	Fly	buzz
	Fox	bark, scream, howl, snore, gecker[22]
	Frog	croak, ribbit
	Gaur	low, moo
	Giraffe	bleat,[23] hum[24]

	Goat	bleat, maa
	Goose	honk, hiss
	Grasshopper	chirp[25]
	Guinea pig	wheek[26]
	Hamster	squeak[27]
	Hermit crab	chirp[28]

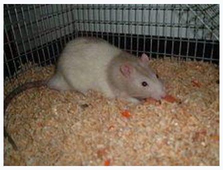
	Hippopotamus	growl[29]
	Hornet	buzz
	Horse	neigh, whinny, nicker
	Hyena	laugh
	Jackal	gecker[6]
	Koala	bellow, shriek

	Lemur	chatter, whoop
	Leopard	roar, growl, snarl
	Linnet	chuckle[30]
	Lion	roar, growl, snarl
	Locust	chirp[25]

	Magpie	chatter[31]
	Monkey	scream, chatter, gecker,[6] howl
	Moose	bellow[32]
	Mosquito	buzz, whine
	Mouse	squeak
	Okapi	cough, bellow[33]

	Owl	hoot, hiss, caterwaul for barred owls
	Ox	low, moo
	Parrot	squawk, talk
	Peacock	scream,[34] squawk, honk
	Pig	oink,[29][35] snort,[36] squeal, grunt

	Pigeon	coo
	Prairie dog	bark[37]
	Quail	call
	Rabbit	squeak
	Raccoon	trill[38]

	Rat	squeak
	Raven	caw
	River otter	blow, chatter, chirp, creek, grunt, hiccup, hiss, scream, squeak, swish, whine, whistle,[39] chatterchirp,[40] purr[41]
	Rook	caw
	Seal	bark[42]

	Sheep	bleat
	Snake	hiss, rattle
	Songbird	chirrup, chirp, tweet, sing, warble (*larks* / *warblers* / *wrens*),[43][44] twitter (*sparrows*)[45]
	Squirrel	squeak
	Swan	cry, trumpet, bugle
	Tapir	squeak[46]

	Tokay gecko	croak[47]
	Turkey	gobble
	Whale	sing
	Wild boar	grumble
	Wildebeest	low, moo
	Wolf	howl, growl, bay

	Zebra	bray, bark, whistle, yip, nicker

How sound affects animals:

How Marine Animals React to Sound

Noise pollution studies on animals have concentrated on marine animals, such as whales and dolphins. What researchers have found is that human-induced noises are impacting how these social creatures communicate with one another and their group behavior.

Non-natural noises that affect animals residing in the deep blue sea include:

- Oil drilling
- Seismic surveys
- Ship traffic
- Military sonar

North Atlantic right whales, which are endangered, are significantly impacted by ship traffic because they favor coastal waters along Georgia and Florida, which have high levels of shipping traffic. Studies show these whales' foraging and vocal behavior, as well as that of dolphins and porpoises, are affected by boat noise.

Military sonar also affects beaked whales, causing mass strandings. In fact, every multi-species beaked-whale mass stranding has happened in coordination with naval sonar exercises. Scientists believe the sonar affects the dive patterns of these whales, resulting in them coming ashore and dying.

Hearing loss is another symptom that researchers believe results from human-induced noises. In half of all stranded dolphin cases in the U.S., hearing loss was a factor.

As demonstrated in the above research, sound can harm animals. It's affected their communication with one another and their behavior, which, in many instances, has led to their deaths or becoming separated from their pods.

How Flying and Land Animals React to Sound

Studies on birds, show their behavior changes in response to noise pollution from cities and traffic. Birds like European robins change their singing periods, choosing to chirp during quieter times at night rather than the daytime.

Instead of adjusting their singing times, certain species of birds change their behavior by singing at a higher pitch. Using a higher pitch, or chirping at a greater frequency, prevent mating calls from being masked by noise pollution.

Outside of the avian realm, other studies on sound and animals include the following critters:

- Prairie dogs
- Bats
- Frogs

Research on prairie dogs found that noise can harm them by reducing their foraging efforts and increasing their vigilant behavior in response to traffic noise. Limited efforts for finding food can have a significant impact the population health of prairie dogs, especially when combined with habitat loss as more land becomes developed.

Sound also affects the foraging efforts of bats. Researchers found that Daubenton's bats decreased in foraging efficiency when near human-induced noise because it created an avoidance response. So, instead of going out to hunt, bats were discouraged.

Two decades worth of research on frogs and invertebrates also concluded that animals react to sound through behavior changes. In the cases of the frogs and insects, they mimicked great tits by changing their approach to communication.

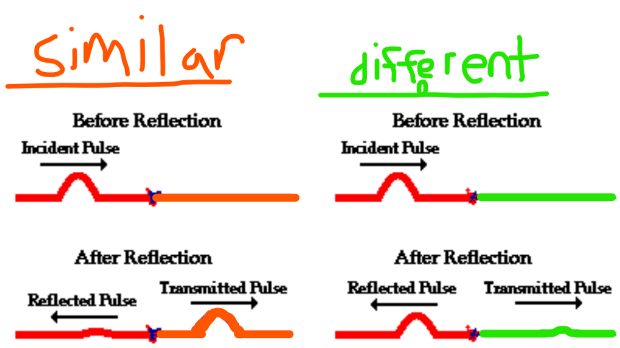
Bats and prairie dogs also experienced a shift in foraging and vigilant behavior. These behavior changes even impacted the structure of their ecological communities, indicating a single behavior change has far-reaching consequences for numerous land animals.

Boundary effects:

Bass notes tend to reflect off reflective surfaces almost in phase with the direct sound you hear
This doubles the amound of bass you perceive
People notice this at the back of studios the most

BOUNDARY BEHAVIOR:

- When one medium ends and another begins it is called a boundary
- 4 options: reflect, diffraction, refraction, transmission
    1. Reflection: bouncing off the boundary
    2. Diffraction: bending around the obstacle without crossing over the boundary
    3. Transmission: crossing of the boundary of the new space/material
    4. Refraction: (along with transmission) and change in speed/direction



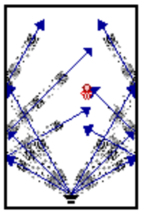
The amount of energy that is reflected depends on the similarity of the medium. More similar = less reflection and more transmission. Less similar = more reflection and less transmission.

This is why in concert halls softer material is used because it transmits more of the energy not reflects it

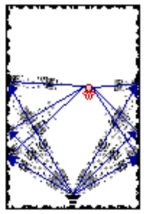
REFLECTION, REFRACTION, AND DIFFRACTION:

Reflection:
Reflection can lead to echo or reverberation.

Reverberation – If the distance ≥ 17 m, then the original sound mixes with the reflected sound. Due to repeated reflections at the reflecting surface, the sound gets *prolonged*. This effect is known as **reverberation**.



Smooth walls fail to give the room a feel of full sound.



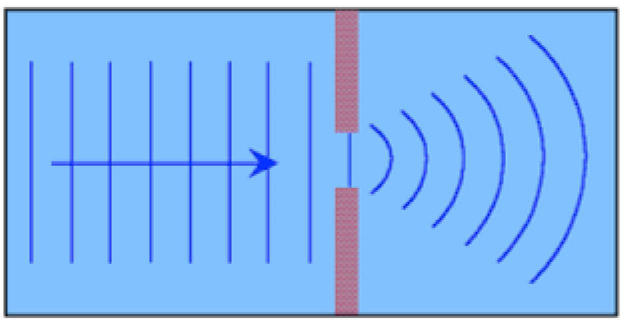
Rough walls give a room a feel of full and lively sound.

Echos happen when the room is < 17m (because the sound will have died out) and the first sound stops, and then it comes back.

BATS use ultrosonic waves to hunt

Parabolic (circular) disks make all the sound go into one place, that's why in science museums and stuff you can hear someone all the way across the room.

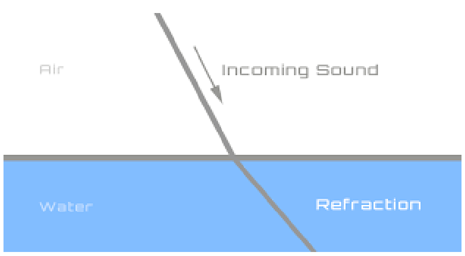
Diffraction:



Change in direction as waves pass through an opening or barrier in their path
Diffraction of sound waves is commonly observed; we notice sound diffracting around corners or through door openings, allowing us to hear others who are speaking to us from adjacent rooms.
EX: when sound waves go around doors so you can hear people in other rooms, owls hoots go around trees

Refraction:

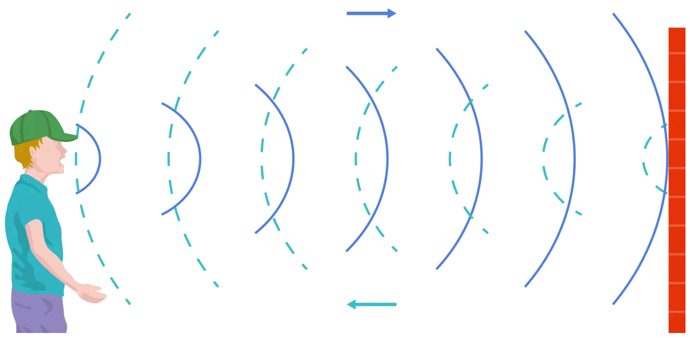
Change in the direction of waves as they pass through one medium to another
Bending of the wave changes speed and wavelength



Echoes:

If you are in a large canyon, and you yell, the sound waves would bounce off the walls. This only will happen if the canyon wall is approx.

- If the canyon wall is more than approximately 17 meters away from where you are standing, then the sound wave will take more than 0.1 seconds to reflect and return to you.
- Since the perception of a sound usually endures in memory for only 0.1 seconds, there will be a small time delay between the perception of the original sound and the perception of the reflected sound.
- Sound HAS TO REFLECT OFF THE SURFACE - IF IT IS SOFT THERE WILL BE NO ECHOES



Sonar:

Short for *Sound Navigation and Ranging*

Active Sonar

- emit an acoustic signal or pulse of sound into the water.
- If an object is in the path of the sound pulse, the sound bounces off the object and returns an “echo” to the sonar transducer. I
- if the transducer is equipped with the ability to receive signals, it measures the strength of the signal.
- By determining the time between the emission of the sound pulse and its reception, the transducer can determine the range and orientation of the object.

Passive Sonar

- used primarily to detect noise from marine objects (such as submarines or ships) and marine animals like whales.
- Unlike active sonar, passive sonar does not emit its own signal, which is an advantage for military vessels that do not want to be found or for scientific missions that concentrate on quietly “listening” to the ocean.
- Rather, it only detects sound waves coming towards it.
- Passive sonar cannot measure the range of an object unless it is used in conjunction with other passive listening devices.
- Multiple passive sonar devices may allow for triangulation of a sound source.
- First used for detecting icebergs

Sound pressure:

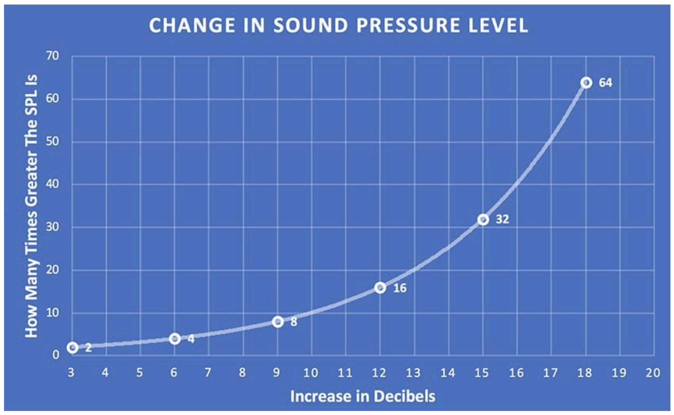
reading/interpreting sound pressure graphs

Sound Pressure: the difference between the instantaneous pressure at a point in the presence of a sound wave and the static pressure of the medium.

- The sound level (on a basic level – how loud something is) can be perceived differently by different people so we need to have a means to get an objective measurement of sound level expressed in numerical terms.
- This is defined as Sound Pressure Level (SPL) and is quite a complex thing to get to grips with.
- To understand what SPL is we must first understand what 'Sound Pressure' is.
- Sound pressure (p) is the average variation in atmospheric pressure caused by the sound.
- The unit of pressure measurement is pascal (Pa)
- We convert that into the more popular decibel scale or dB scale.

Compared to a 60 dB sound...

- 63 dB has 2 times the SPL
- 66 dB has 4 times the SPL
- 69 dB has 8 times the SPL
- 70 dB has 10 times the SPL
- 72 dB has 12 times the SPL and so on...



This one is a little more straightforward: as you move up 10 decibels, the noise *sounds* twice as loud.

Compared to a 60 dB sound...

- 70 dB sounds 2x as loud
- 80 dB sounds 4x as loud

If you're working in an environment that's a pretty constant 105 decibels and you use earmuffs with an NRR (noise reduction rating) of 25, your ears are only exposed to 80 decibels.

A 10-dB rise is a 10-time leap in loudness. That means an 80-dB sound (a vacuum cleaner) is 10 times louder than a 70-dB sound (a telephone ringing) and **100 times** louder than a 60-dB sound (normal conversation).

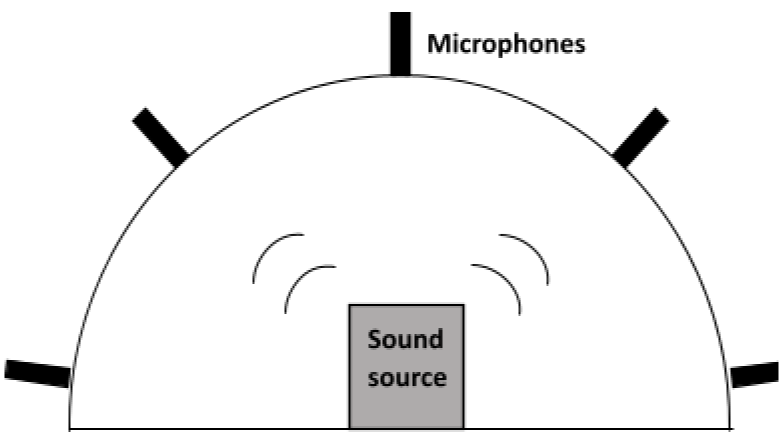
.

- minimum sound pressure possible for a human to hear is ~20 μPa (micro pascal) .
- Typically, ear discomfort is experienced at ~20 Pa and ear pain is experienced at a sound pressure of ~60 Pa.
- To put this into perspective, 20 Pa is the typically the sound pressure at a rock concert and 60 Pa is the equivalent of someone blowing a trumpet into your ear from 0.5 m away.
- Sound pressure is also commonly given in decibels (dBs) for a couple of reasons; a lot of common day-to-day sounds have very small sound pressure values, such as a normal conversion at 0.01 Pa; and the range typically runs from μPa to kPa which is a large range.
- When expressed using decibels it is referred to as sound pressure level.
- Decibels are not a unit of measure but a logarithmic function which indicates the ratio between two values. When measuring sound pressure level, we use the equation:

$$\textit{Sound Pressure Level} = 20\log_{10}(p/p_{ref})\ dB$$

Sound Power

- Sound power is the rate at which sound energy is emitted from a source per unit time.
- This produces sound pressure at some distance from the source.
- Sound power has SI units watts (W).
- This measurement is often used in the noise regulations for construction equipment so that employers can ensure that their employees are well equipped and safe to work in the environment.
- Sound power is a useful measurement as it is independent of distance from source and location of microphone.
- Quantifying sound power is therefore a more complex task but is commonly done using multiple microphones placed around the object in a semi hemisphere set up to capture the sound emitted from all around the object in all directions.



As with sound pressure, sound power level is often quantified in decibels and is given by the equation:

$$\textit{Sound Power Level} = 10\log_{10}(p/p_{ref})\ dB$$

Where P is the sound power and Pref is the universally agreed upon reference sound power, 1 pW. However, often nowadays sound power level is given in bels (1 bel = 10 decibels) so as not to confuse with sound pressure level.

Sound Intensity=Sound Pressure x Particle Velocity

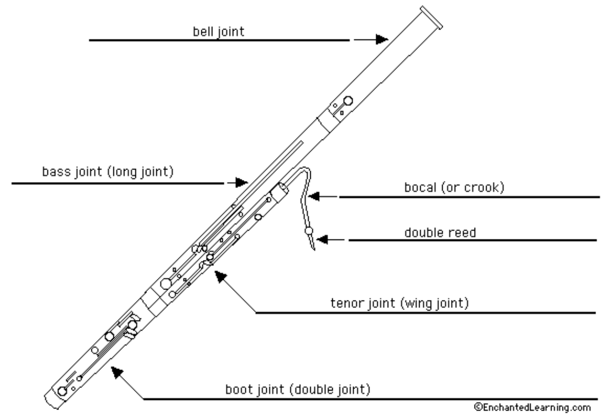
$$\text{Sound Intensity Level} = 10\log_{10}(I/I_{ref})\ \text{dB}$$

Sound Intensity Level=Sound Power Level / Area

WHEN THE SPEED OF SOUND DOUBLES…
times four the original temperature

Knowledge of common parts of various instruments:

Bassoon: tenor/bass clefs -



sometimes treble

Made of wood

- Maple
-

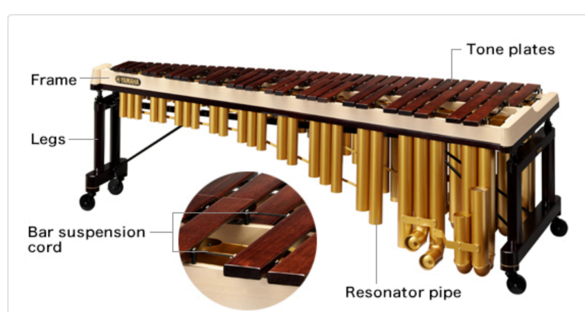
Bb1-E6

Open pipe

Marimba:

Made of rosewood

Harvested in Central/South America



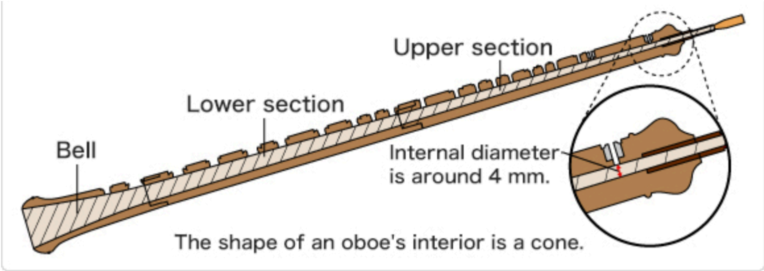
The lower the sound, the larger the tone plate

Sometimes African Padauk bass/treble clef

Oboe:

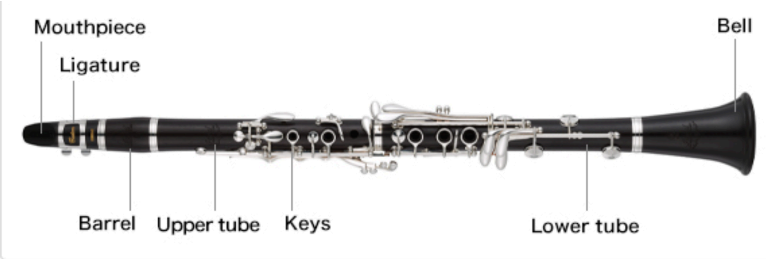
This oboe is usually made from grenadilla wood, though some are made of other woods from the rainforest, and student model oboes are usually made of plastic or resin to avoid cracking.

Treble clef



Clarinet:

Clarinets enjoy a greater variety in construction materials than most musical instruments. Plastic and wood are by far the most common, but hard rubber, metal, resin and even ivory are variations that have appeared over the years.



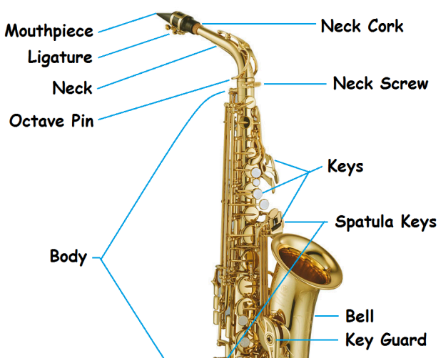
Treble CLef

At low frequencies: CLARINET IS CLOSED PIPE

The mouthpiece acts as a node,

Clarinet is a Bb instrument

Saxophone:



Brass is used to make the metal parts of a saxophone. Brass is an alloy composed of copper and zinc, and compared to iron, it has good rust resistance properties and

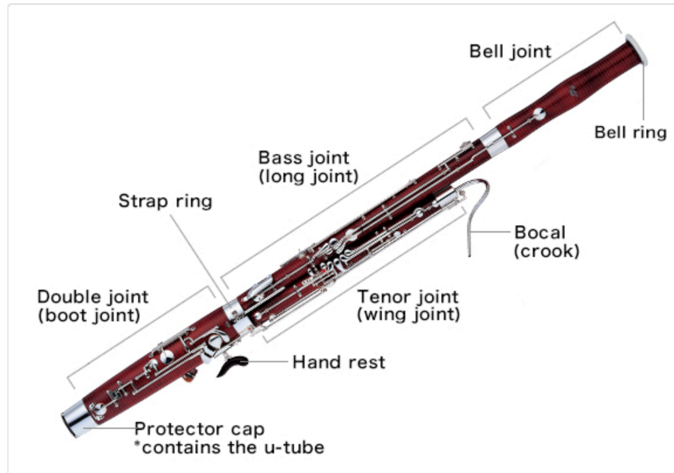
is easy to work with. Some saxophones are gold plated or silver plated, but underneath the plating is brass. Treble Clef
Is a Bb instrument

Though there are 25 tone holes, a person has far fewer fingers, so keys and levers are provided to enable the player to close distant holes simultaneously with others.

The round tone-hole covers are called pads. The largest pad on an alto saxophone is five centimeters in diameter. Of course, this large pad covers an equally large tone hole.

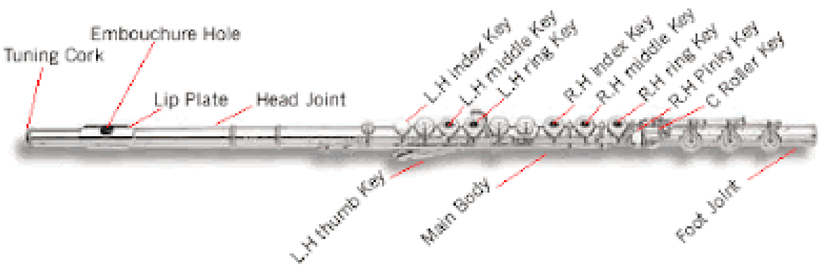
The pads are made from circles of felt covered with sheep leather.

Bassoon:



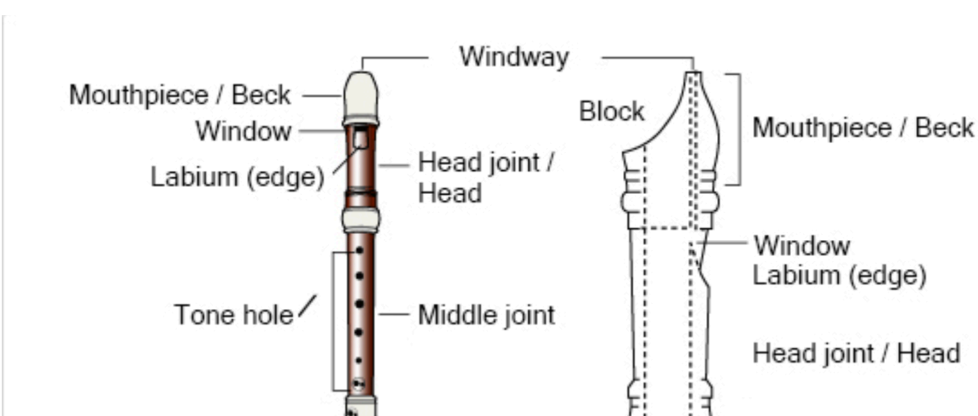
Treble clef Usually hard maple
Softer then grenadilla wood for clarinets

Flute:



Treble Clef
Made of copper-nickel, silver, gold, and grenadilla

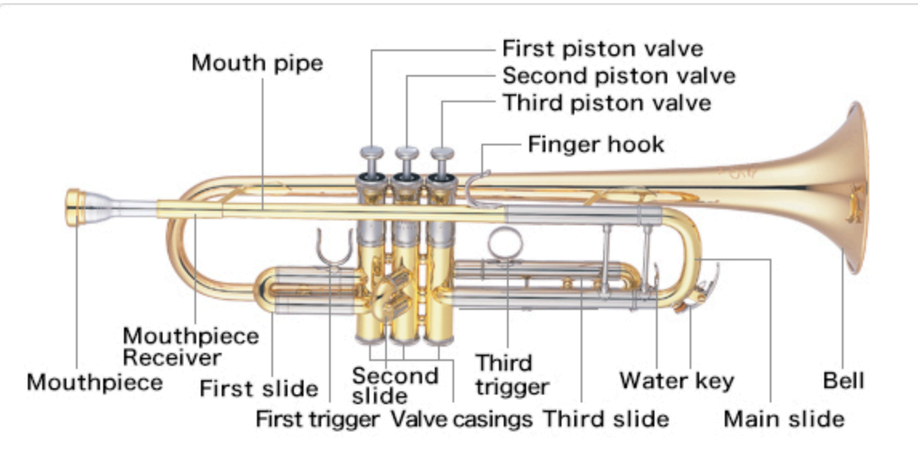
Recorder:



All treble bud bass recorder
Originally made from

wood, now from resin

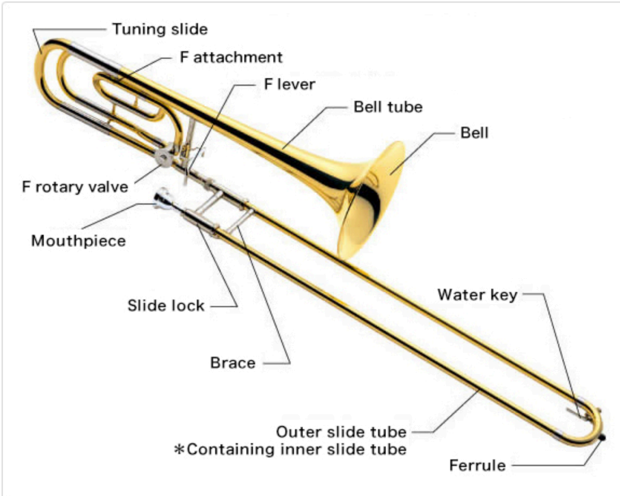
Trumpet:



Treble Clef
Brass
Pressing the valves makes the trumpet longer, and lowers the pitch
Trumpet is a Bb instrument

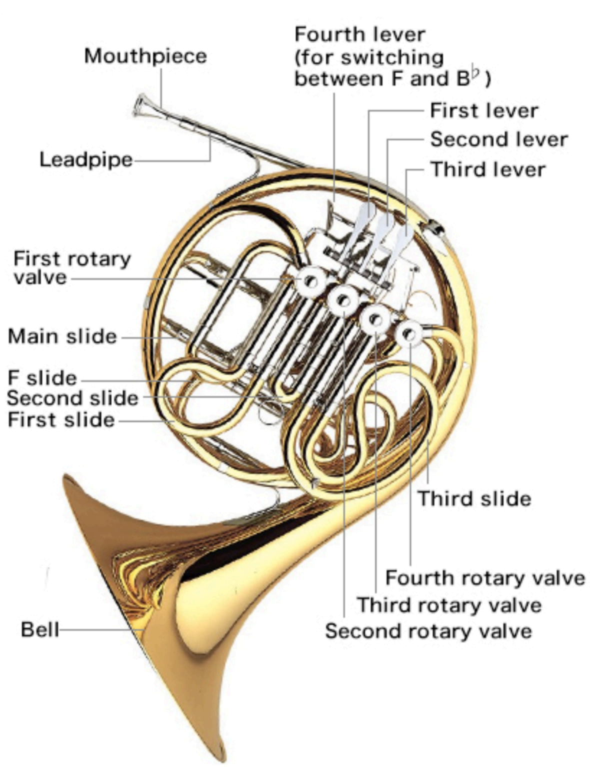
Trombone: Brass

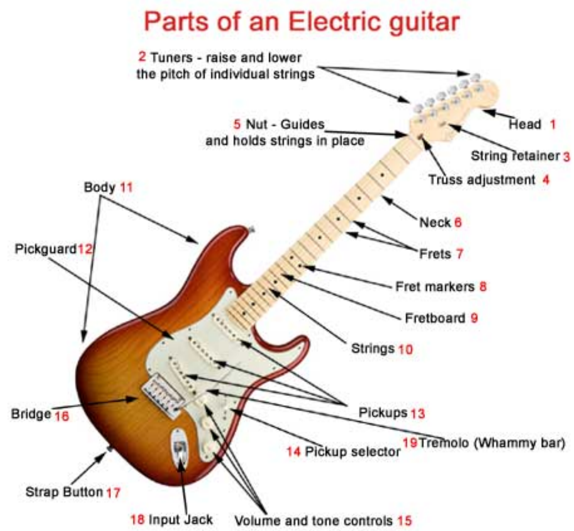
Electric Guitar: - Treble Clef - wood

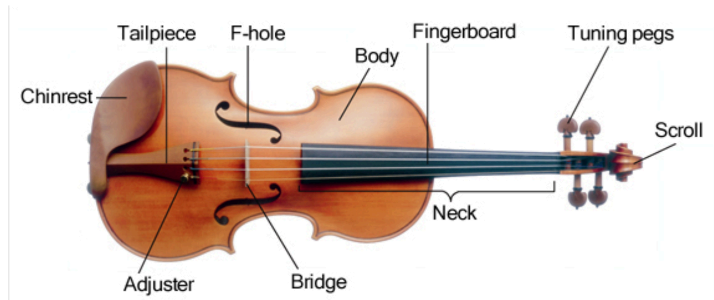


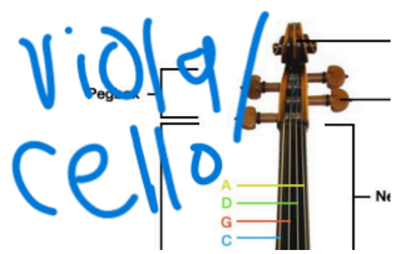
Bass Clef

French Horn:- treble clef - brass





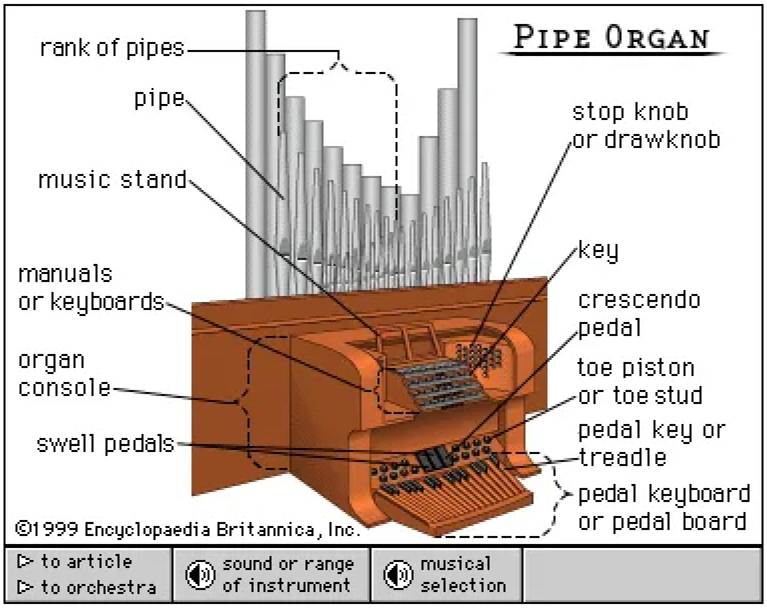




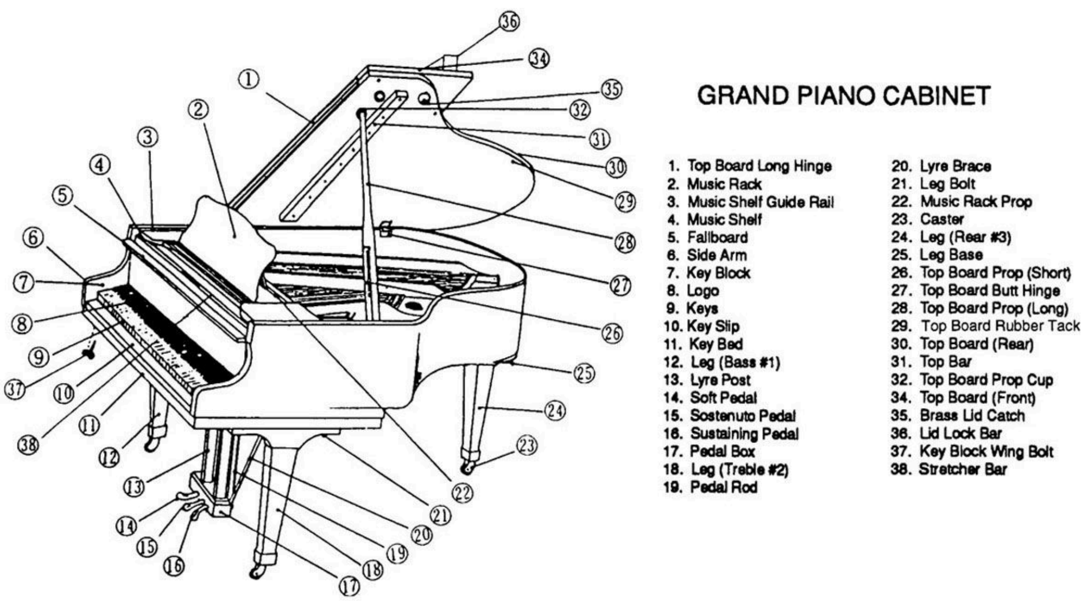
BASS: E,A,D,G
5th interval

Pipe Organ: - grand staff - anything - mostly wood/metal

Timpani: - bass clef - copper/



Piano: - grand staff - wood/ivory-ebony, but now plastic and wood /soundboard = spruce wood

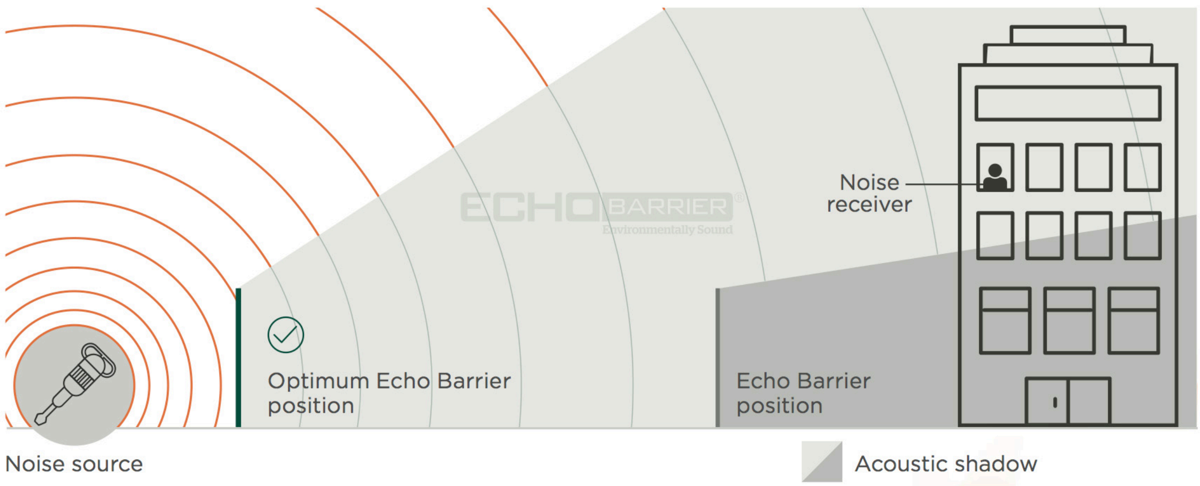


Piano has 88 keys

Drums:- natural/precussion clef - birch/beech/maple/oak/synthetic material

Acoustic Shadows:

An acoustic shadow results when sound waves fail to spread outward due to **disruptions or physical barriers** such as buildings, geographical obstructions, or wind currents and can alter our perceptions of events, and can also be controlled to diminishing the impact of high decibel noises.



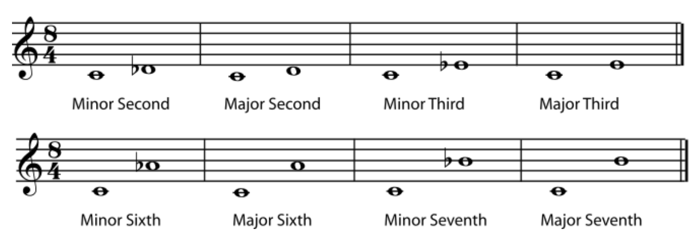
Increase tension on a string 4x for one octave higher, 16x for two octaves higher

Double the length of the string, increase the mass 4x to make it play at ½ the frequency

Word	**Common Abbreviations**	**English Definition and Description**	**Recommended beats per minute (bpm)**
Accelerando	Accel.	Gradually getting faster	
Adagio		At ease.Slowly	66 – 76
Allargando		Broaden. A slower version of rallentando	
Allegretto		Moderately fast	100
Allegro		Lively and fast	120 – 140
Andante		At an easy walking pace	56 – 88
Andantino		Between adagio and andante	
A tempo		Return to the former speed	
Largo		Broadly; Slowly	40 – 60
Larghetto		Less slowly than largo	60 – 66
Larghissimo		Very, very slow	<20
Lento	Lent	Slowly	40 – 60
Moderato		Moderately	100 – 120
Mosso		Movement. Slightly more lively	
Prestissimo		As fast as possible	>200
Presto		Very fast	150 – 200
Rallentando	Rall.	Gradually slower	
Ritardando	Rit/ Ritard	Gradually slower (but not as slow as rallentando)	
Ritenuto	Riten	Holding back	
Stretto		Quickening	
Stringendo		Tightening. Gradually faster	
Vivace		Lively. Faster than allegro	140
Vivo		Lively	

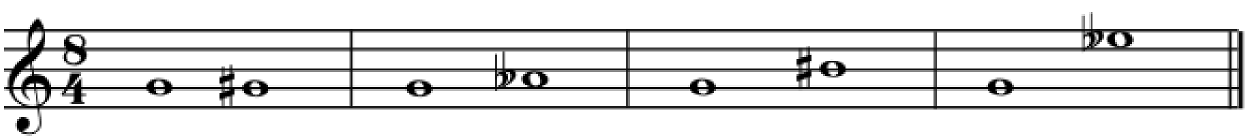
Semitones	Interval	Frequency ratio
0	Unison	1:1
1	Minor 2nd	16:15
2	Major 2nd	9:8
3	Minor 3rd	6:5
4	Major 3rd	5:4
5	Perfect 4th	4:3
6	Tritone	45:32
7	Perfect 5th	3:2
8	Minor 6th	8:5
9	Major 6th	5:3
10	Minor 7th	16:9
11	Major 7th	15:8
12	Octave	2:1
13	Minor 9th	32:15
14	Major 9th	9:4
15	Minor 10th	12:5
16	Major 10th	5:2

- 1 half-step = minor second (m2)
- 2 half-steps = major second (M2)
- 3 half-steps = minor third (m3)
- 4 half-steps = major third (M3)
- 8 half-steps = minor sixth (m6)
- 9 half-steps = major sixth (M6)
- 10 half-steps = minor seventh (m7)
- 11 half-steps = major seventh (M7)

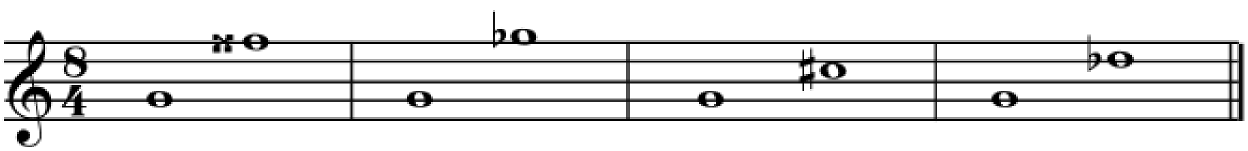


Augmented and Diminished Intervals

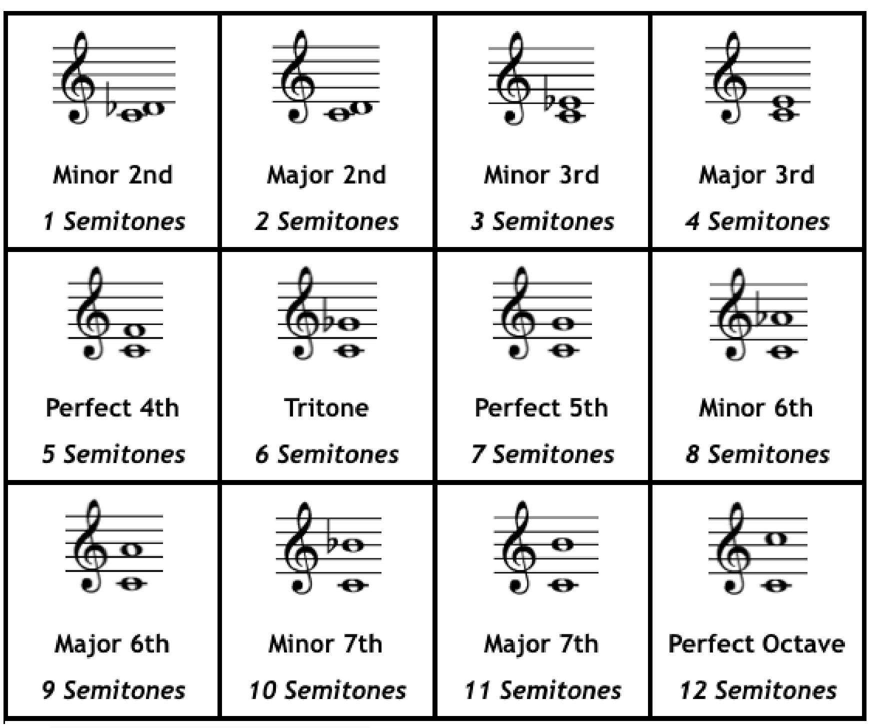
- If an interval is a half-step larger than a perfect or a major interval, it is called *augmented*.
- An interval that is a half-step smaller than a perfect or a minor interval is called *diminished*.
- A double sharp or double flat is sometimes needed to write an augmented or diminished interval correctly.
- Always remember, though, that it is the actual distance in half steps between the notes that determines the type of interval, not whether the notes are written as natural, sharp, or double-sharp.

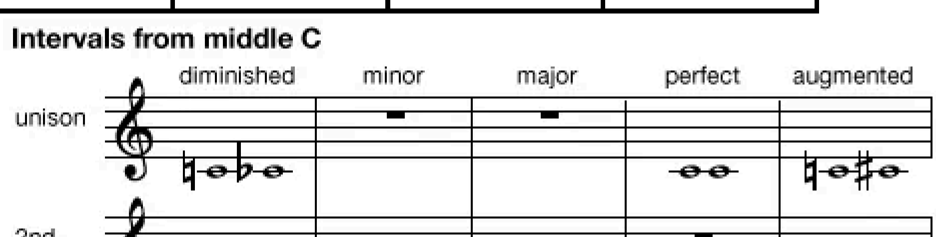


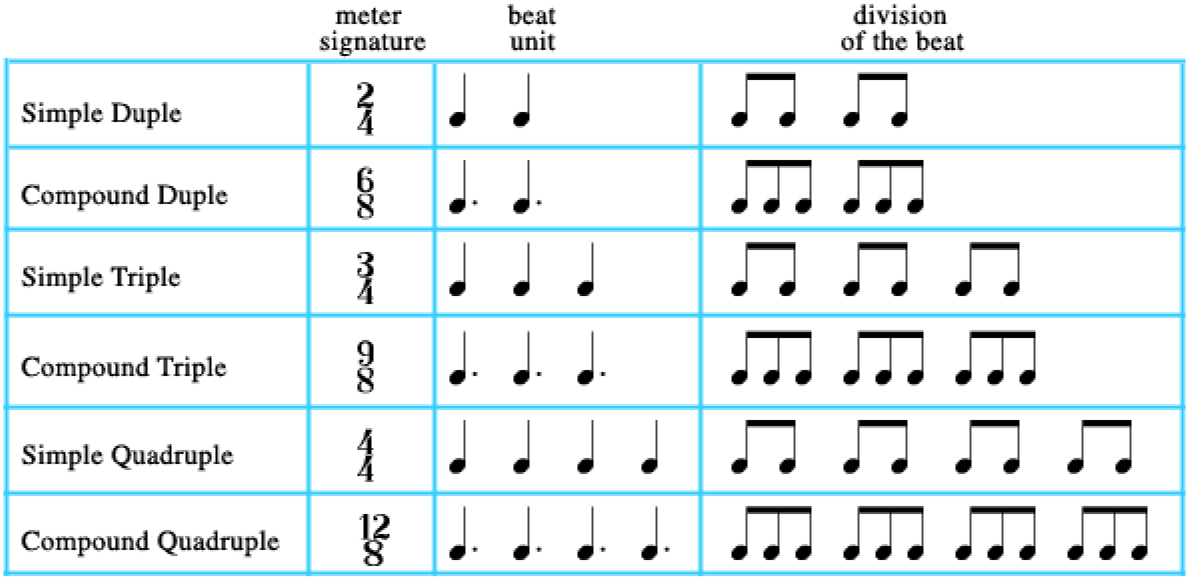
Augmented Prime   Diminished Second   Augmented Third   Diminished Sixth

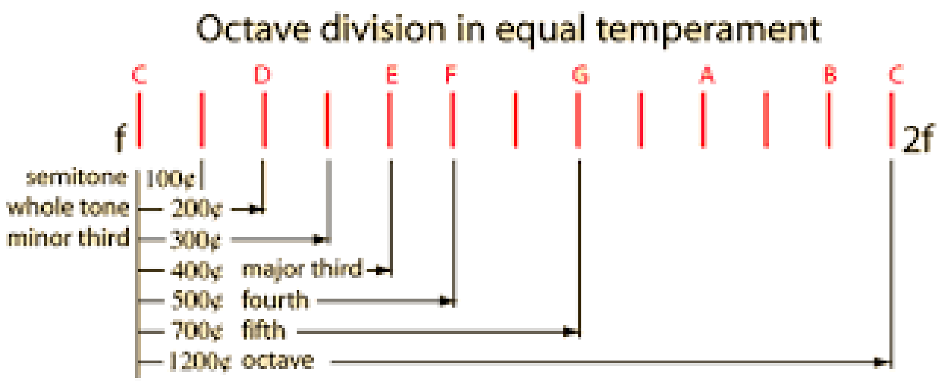


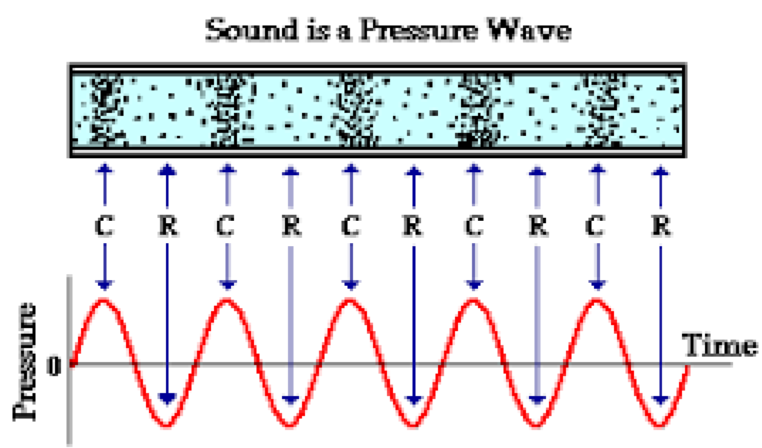
Augmented Seventh   Diminished Octave   Augmented Fourth   Diminished Fifth











NOTE: "C" stands for compression and "R" stands for rarefaction

CENTS:

It's not hard to go from semitones to cents! Simply **multiply the number of semitones by 100 cent/st** et voilà! For example, to convert 51 st to cents you calculate as follows:
cents = 51 st × (100 cent/st) = 5100 cent .
1 Hz is equal to roughly 4 cents.

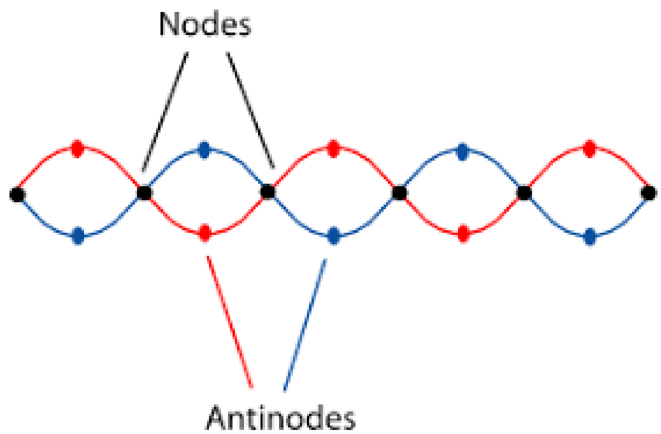
Speed of Sound:

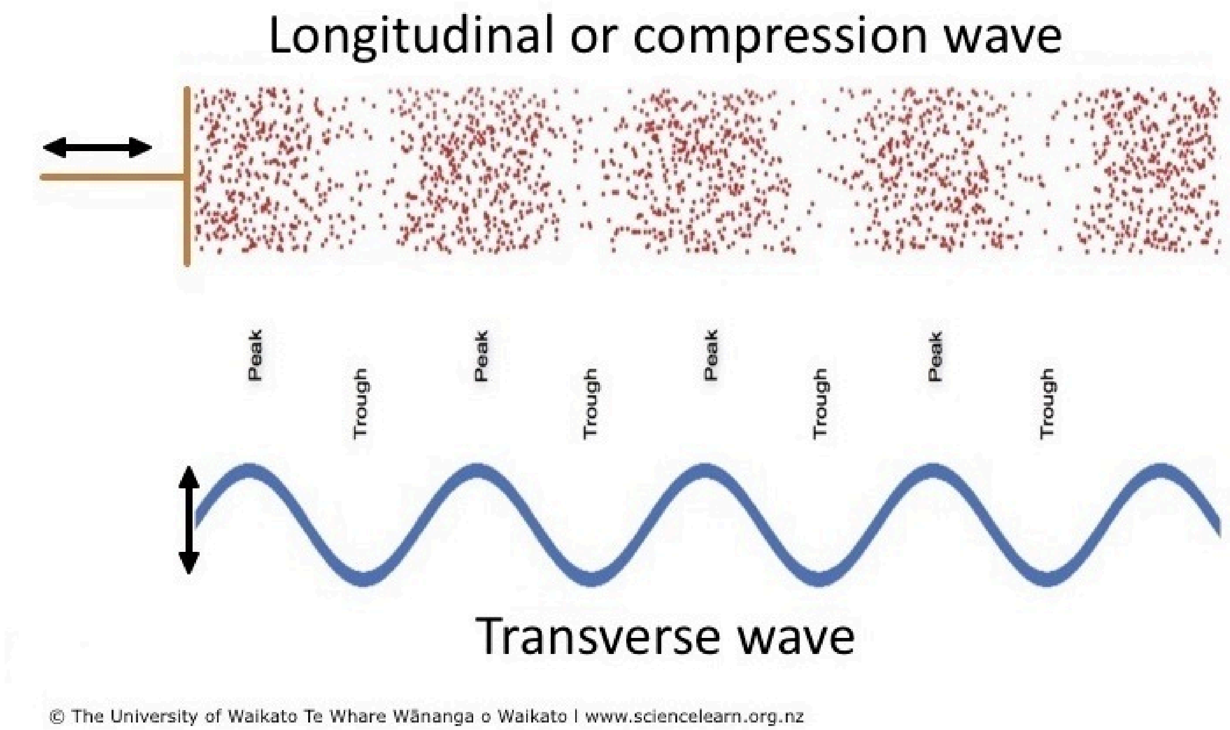
Things that Change Speed of Sound: Humidity, Temperature, Density
Things the Don't Change Speed of Sound: Air pressure

Laws and Principles:

Huygens Principle and Diffraction

When light passes through an aperture, every point on the light wave within the aperture can be viewed as a source creating a circular wave that propagates outward from the aperture. The aperture thus creates a new wave source that propagates in the form of a circular wavefront. The centre of the wavefront has greater intensity while the edges have a lesser intensity. This explains the observed diffraction pattern and why a perfect image of the aperture on a screen is not created. A daily life example of this phenomenon is common. If someone in another room calls toward you, the sound seems to be coming from the doorway.





Idiophones:

- Sound is produced by the body of the instrument vibrating, rather than a string, membrane, or column of air.
- Struck – clapping, cymbals, xylophones, bells, rattle
- Plucked – thumb piano, jaw harp
- Friction – friction sticks
- Blown – blown sticks
- Unclassified

Membranophones

- Sound is produced by the vibration of a tightly stretched membrane.
- Struck – drums (many varieties)

- Plucked – plucked drums (a string is attached to the membrane and causes the vibration)
- Friction – friction drums (rubbed rather than struck or instruments in which a cord is attached to the membrane and rubbed)
- Singing – kazoos

  Chordophones
- Bowed Instrument
- Sound is produced by the vibration of a string or strings that are stretched between fixed points.
- Simple/Zither – musical bows, zithers
- Composite – lutes, harps, tube fiddle, violins, viola, cello, bass, guitars
- Unclassified
- **Aerophones**
- Sound is produced by vibrating air.
- Free – early organs, accordion, harmonica
- Non-free – flutes, recorder, oboes, clarinet, saxophone, trumpet, trombone, euphonium, tuba
- Unclassified
- Electrophones

NOTE	OCTAVE 0	OCTAVE 1	OCTAVE 2	OCTAVE 3	OCTAVE 4	OCTAVE 5	OCTAVE 6	OCTAVE 7	OCTAVE 8
C	16.35	32.7	65.41	130.81	261.63	523.25	1046.5	2093	4186.01
C#/Db	17.32	34.65	69.3	138.59	277.18	554.37	1108.73	2217.46	4434.92
D	18.35	36.71	73.42	146.83	293.66	587.33	1174.66	2349.32	4698.63
D#/Eb	19.45	38.89	77.78	155.56	311.13	622.25	1244.51	2489.02	4978.03
E	20.6	41.2	82.41	164.81	329.63	659.25	1318.51	2637.02	5274.04
F	21.83	43.65	87.31	174.61	349.23	698.46	1396.91	2793.83	5587.65
F#/Gb	23.12	46.25	92.5	185	369.99	739.99	1479.98	2959.96	5919.91
G	24.5	49	98	196	392	783.99	1567.98	3135.96	6271.93
G#/Ab	25.96	51.91	103.83	207.65	415.3	830.61	1661.22	3322.44	6644.88
A	27.5	55	110	220	440	880	1760	3520	7040
A#/Bb	29.14	58.27	116.54	233.08	466.16	932.33	1864.66	3729.31	7458.62
B	30.87	61.74	123.47	246.94	493.88	987.77	1975.53	3951.07	7902.13