

369G –MUSIC

ORCHESTRAL INSTRUMENTS

ACOUSTICS & HARMONIC SERIES

TUNING & TEMPERAMENTS

ELECTRONIC MUSIC

ETHICS IN PUBLICATION

FINALE & MAX – VISUAL REPRESENTATION

AUDACITY– MULTITRACK PROJECT

<http://www.ele.uri.edu/courses/ele369g/>

Introduction of Topics – Questions?

- ▶ Why do we need to know about orchestral instruments?
- ▶ What do we mean by Music Technology?
- ▶ Electronic Music? Audio samples
- ▶ What is Musical temperament?
- ▶ Math?
- ▶ What is Synthesis?
- ▶ The software? MAX, Finale, Protools
- ▶ The hardware?
- ▶ Ethics? Oh, No!
- ▶ Project? Create Music or Musical Instrument
- ▶ Concert – Extra credit (March 31 at 3pm, URI, Music Dpt)

- ▶ Electronic and digital music technology is the use of electronic or digital instruments, computers, electronic effects units, software or digital audio equipment by a musician, composer, sound engineer, DJ or record producer to make, perform or record music.
- ▶ **Mathematics & Music.** Counting, rhythm, scales, intervals, patterns, symbols, harmonies, time signatures, overtones, tone, pitch. The notations of composers and sounds made by **musicians** are connected to **mathematics**. Plato, the Greek Philosopher, claimed that mathematics is key to understanding the real world. Sound is part of the real world, therefore there is math in sound/music.
- ▶ In musical tuning, a temperament is a tuning system that slightly compromises the pure intervals of just intonation to meet other requirements. Most modern Western musical instruments are tuned in the equal temperament system.
- ▶ **Sound synthesis** is the technique of generating **sound**, using electronic hardware or software, from scratch. The most common use of **synthesis** is musical, where electronic instruments called synthesizers are used in the performance and recording of music. Terminology: Additive, subtractive, FM, granular
- ▶ Examples of software and hardware in .doc file.

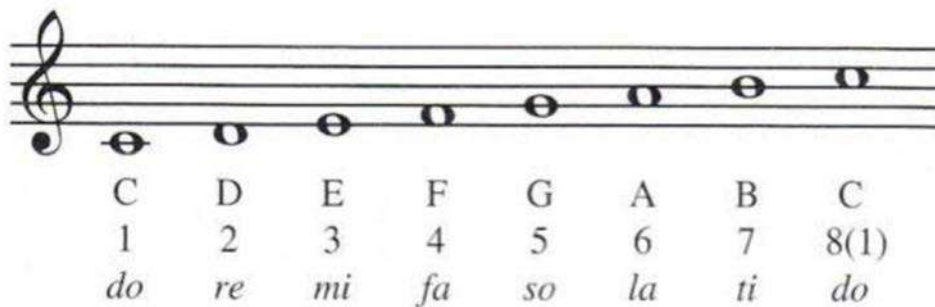
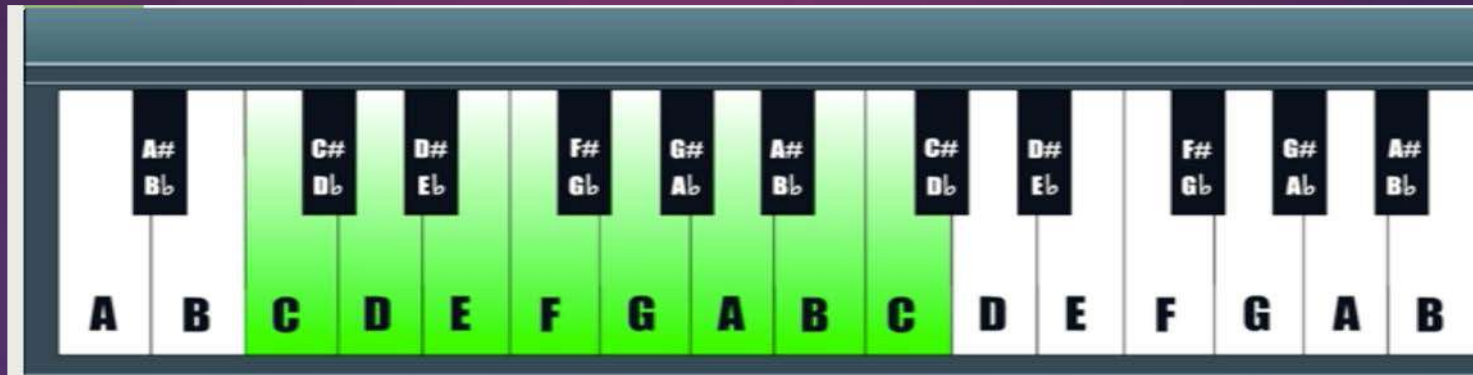
Cards:

- 1: Do you know the the notes of the scale?
- 2: Do you know where the notes are on a piano?
- 3: Do you read music? What clef?
- 4: Do you play an instrument or sing in a choir?
- 5: Have you ever produced a musical project?

Useful Links:

<https://www.pianoscales.org/the-keyboard.html>

<https://www.wikihow.com/Learn-Keyboard-Notes>



Octave: In **music**, an **octave** (Latin: octavus: eighth) is the interval between one **musical** pitch and another with double its frequency. In **music** notation, notes separated by an **octave** (or multiple **octaves**) have the same letter name or solfege name and are of the same pitch class.

Orchestral Instruments

Four Categories

1. **Percussion**
2. **Strings: Plucked or Bowed**
3. **Brass**
4. **Woodwind**

<https://www.mydso.com/dso-kids/learn-and-listen/instruments/clarinet>

Listen to Peter and the Wolf and Young Person's Guide to the Orchestra

<https://www.youtube.com/watch?v=4vbmhU22uAM>

https://en.wikipedia.org/wiki/The_Young_Person%27s_Guide_to_the_Orchestra

Keyboard



Can be considered a 5th category – but not always part of orchestra

Hydraulis (pipe organ) Earliest Keyboard Instrument
3d Century BCE, Ancient Greece. [PIC + audio?]

Organ only keyboard instrument till 14th Century. [PIC + audio]

Clavichord & Harpsichord: 14th Century: [PIC+ audio]

Piano (18th Century) was revolutionary
Can vary the volume (dynamics) [PIC + audio]
Becomes part of Orchestra in late 18th Century (Piano Concertos)

Synthesizers will be addressed later in this course

—Four Categories—

1. **Percussion**: Drums - since 6000 BCE

Percussion sounds used in rituals since dawn of humanity [PIC +Audio]

Too many and too varied to be described here.

Pitched

Non pitched

Membranophone

Idiophone

Wooden

Metallophone

Mallets

Keyboards

Timpani

Bass drum

Cymbal

Triangle

Vibraphone

Xylophone

Orchestra Bells – glockenspiel

Gong

Snare drum

Tambourine

Cow bells

Maracas

Wood-block

ACTIVITY: Match instruments with categories

Hint: instruments can belong to several categories

2. **Strings: Plucked or Bowed** – resonance table [PIC]

Earliest string instruments: in Ancient Mesopotamia in 2500 to 3000 BC –lyres (bowed and plucked)

Bowed: Violin (16th century, perfected in 17th century), Viola, Cello, Double-bass

Plucked: Harp, and pizzicato (no guitar in orchestra)

Strings = Foundation of the orchestra.

Early: perfected to its current shape in 17th century

Number of instruments: violins, violas, cellos, double basses

Richness of timbre and agility

In any one orchestra, the bowed instruments make up about 2/3 of an orchestra

Harps: used in orchestra since 18th century

Add color and delicacy pianos: leading role when combined with orchestra



3. **Brass:** Used outdoor (hunting), military, and ceremonies (King) –
Blazing sound

[PIC] Trumpet • French Horn • Trombone • Tuba

French Horn used consistently in orchestra since 1700 because it blends well
Trumpets, then trombones, then Tuba

The oldest brass instruments are the horn and the trumpet which were initially constructed out of animal horns. Before joining the orchestra, most brass instruments were used for military or ceremonial purposes. In 1815, when valves were invented, the brass instruments were adjusted to produce different tones by diverting the airflow through the tubing.

French horn: first brass instrument to be used consistently by composers in orchestras (1700s).

Timbre of horn blends easily with the strings and the woodwinds.

Trumpet: can supersede the entire orchestra. Highest pitched of the brass instruments. Normally two or three are used in a symphonic orchestra for that reason. The tone of the tuba is much deeper than the trumpet due to the large size of the instrument and its tubing system.

4. **Woodwind:**

Flutes: wind instrument made from a tube with holes along it that are stopped by the fingers or keys, held vertically or horizontally so that the player's breath strikes a narrow edge. The modern flute is made of metal and is held horizontally and has an elaborate set of keys.



Single-reed: Clarinets and Saxophones

Use only one reed to produce sound. Earliest single-reed: from Egypt (2700 BCE)



Double-reed: Oboes, English Horn, & Bassoons

No mouthpiece; the two parts of the reed vibrate against one another. Reeds are traditionally made of cane and produce sound when air is blown across or through them.

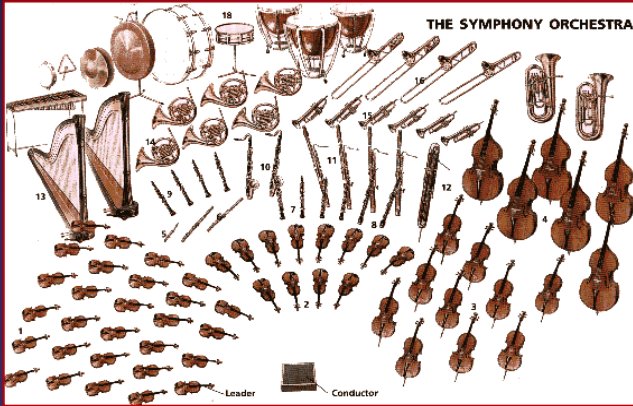
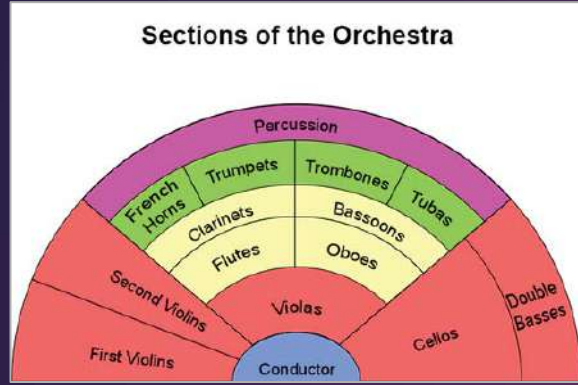


<https://newt.phys.unsw.edu.au/jw/Bows.html>

Orchestra History: Small to Large

- ▶ Semicircular space in front of the stage used by the chorus and instruments in Ancient Greek theatres.
- ▶ First **orchestra** (as we know it) came in the early 17th century. Claudio Monteverdi formally assigned specific instruments to perform his music
- ▶ As music developed and became more complex, so more instruments joined in, and eventually some sort of order was created – Conventional Scoring
- ▶ 18th century: the conductor was born
- ▶ Why the first violins sit to the left of the conductor ? Why is the seating of the instruments so 'set in stone?'
- ▶ **In the 1800s**, the orchestra changed a lot - Haydn's and Beethoven's time.
 - Strings are prominent, keyboard instruments less so.
 - Orchestration and scoring evolve and become an art in itself.
 - Composers also began to be more adventurous about combining instruments to get different sounds and colors
- ▶ Combination of timbres
- ▶ Later in the 1800s, the orchestra reached the size and proportions we know today
- ▶ **Expanded in 19th century**
- ▶ Improvement in Instrument design and construction : piccolo and tuba now available for orchestras
- ▶ Arnold Schoenberg wrote *Gurrelieder* for a 150-piece orchestra!
- ▶ **20th century:**
 - Freedom and experimentation with the orchestra.
 - Superstar conductors
 - Add or subtract instruments from basic symphonic orchestra structure (huge percussion section, lots of woodwinds & brasses).

ORCHESTRA



Audio 1

Audio 2

Audio 3

MUSICAL SCORE

Allegro con brio

2 Flauti
2 Oboi
2 Clarinetti in B
2 Fagotti
2 Corni in Es
2 Trombe in C
Timpani in C-G

Allegro con brio (d. 108)

2 Flauti
2 Oboi
2 Clarinetti in B
2 Fagotti
2 Corni in Es
2 Trombe in C
Timpani in C-G

Violino I
Violino II
Viola
Violoncello
Contrabasso

Violino I
Violino II
Violoncello
Contrabasso

Play four excerpts

Explain parts of score: tempo, rhythms, staves, height (pitch), notes, flags, beams, symbols.

Dynamics, language, role of conductor, score order

Terrain vs map

<https://www.youtube.com/watch?v=1IHOYvIhLxo>

<https://www.youtube.com/watch?v=gH3y6568ANc>

ORGANIZATION

- ▶ **Pitch – tuning to play together—> Frequency (expressed in Hz)**
1 hertz is one cycle per second
- ▶ **Volume – balance of orchestral forces —> Amplitude (Decibels, dB)**
- ▶ **Timbre – sound of various instruments**

Determined by:

1. harmonic content
2. dynamic characteristics such as vibrato
3. envelope [A D S R] attack-decay-sustain-release

EX: Pitch vs Timbre

▶ **Tempo – Metronome Mark (MM) —> Number of beats/minute = bpm**

▶ **Rhythm –**

1. The aspect of music comprising all the elements (accent, meter, & tempo) that relate to forward movement.
2. Systematic arrangement of sounds, according to duration and periodic stress (accents).

Difference between tempo and rhythm

Tempo is how fast or slow a piece of music is performed, while rhythm is the placement of sounds in time, in a regular and repeated pattern. Tempo generally is measured as the number of beats per minute, where the beat is the basic measure of time in music. Rhythm can be thought of as the pattern of music in time.

Ex of melody at same tempo with different rhythms, and with different tempos but same rhythm

Beat, in music, the basic rhythmic unit of a measure, or bar, not to be confused with rhythm as such; nor is the beat necessarily identical with the underlying pulse of a given piece of music, which may extend over more than a single beat. The number and relative positions of accented and unaccented beats furnish the basis of proper metric articulation, with the strongest accent usually falling on the first beat after the bar line. In Western musical notation the number of beats to the measure is indicated by the upper figure of the time signature at the beginning of a musical composition, while the time value of each separate beat (e.g., a quarter or eighth note) is indicated by the lower figure.

Why do we need to know these concepts, why are they relevant?

To understand technological developments in music, one must know the basics

Acoustic & Harmonic Series

ACOUSTIC

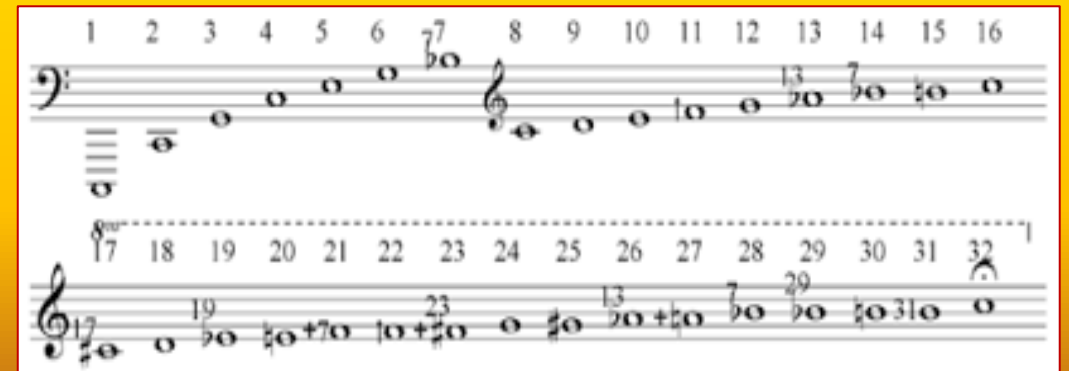
1. Relating to sound or the sense of hearing
2. (Of instruments) not having electrical amplification.
 1. The properties or qualities of a room or building that determine how sound is transmitted in it.
 2. The branch of physics concerned with the properties of sound.

WHAT IS SOUND? vibrations that travel through the air or another medium and can be heard when they reach a person's or animal's ear.

A **harmonic series** is the **sequence** of sounds—pure tones, represented by sinusoidal waves—in which the frequency of each sound is an integer multiple of the fundamental, the lowest frequency.

The **musical** timbre of a steady tone from such an instrument is strongly affected by the relative strength of each **harmonic**.

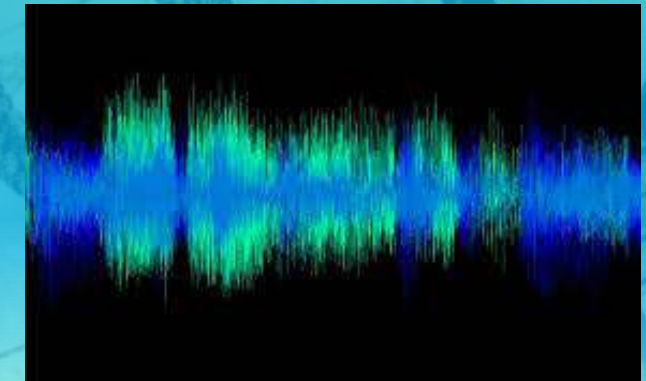
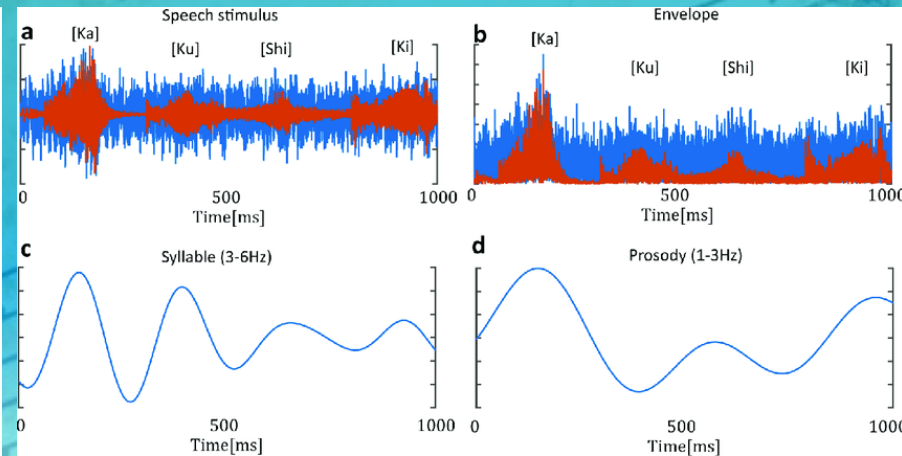
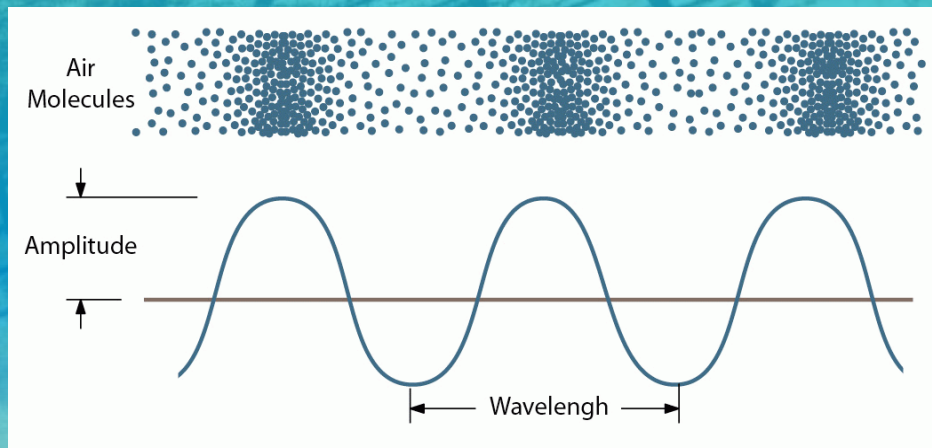
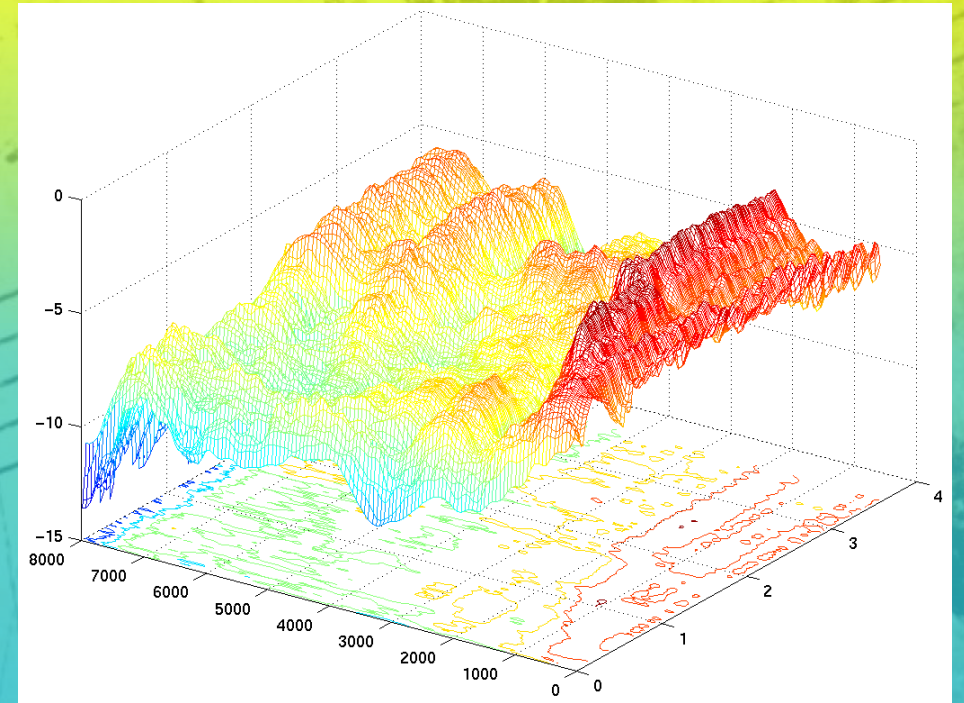
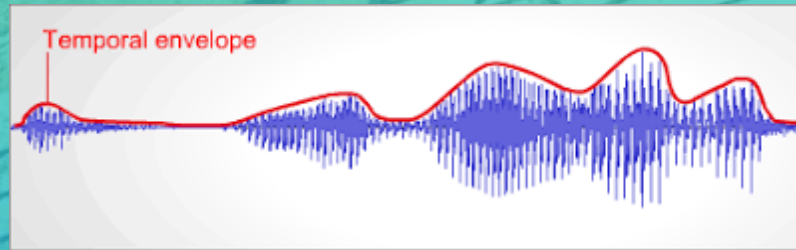
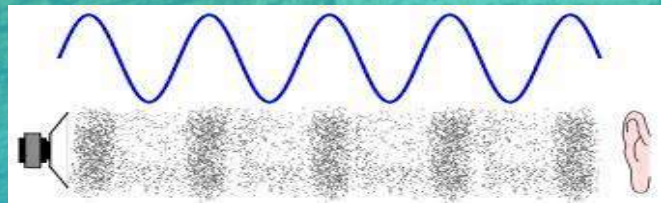
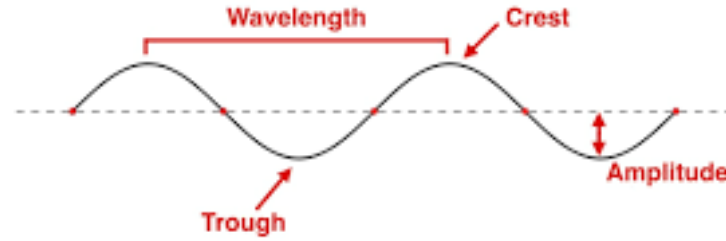
<https://www.youtube.com/watch?v=OATjHiOuc70>



Making Waves:



What is Sound?



Making Waves

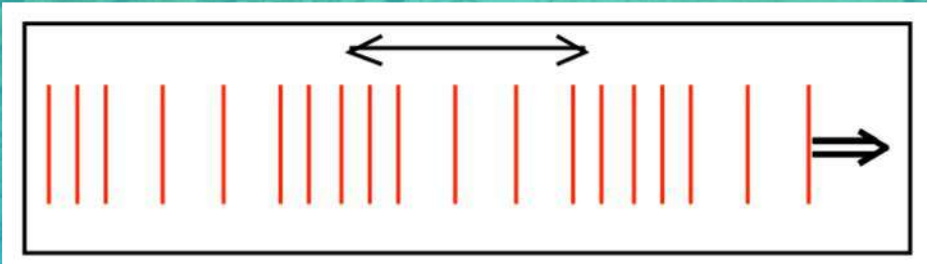
A wave is a transfer of energy without a transfer of matter. If you and a friend hold onto both ends of a rope you can get energy down to her simply by moving the rope back and forth. Although the rope has some motion, it isn't actually transferred to her, only the energy is transferred.

Streaming through the place you're in right now is a multitude of waves known as electromagnetic waves. Their wavelengths vary from so small that millions would fit into a millimeter, to miles long. They're all here, but you miss most of them. The only ones you're sensitive to are a small group that stimulates the retinas of your eyes (visible light) and a small group that you detect as heat (infrared). Another type of wave is a sound wave. The others are totally undetectable. But they're there.

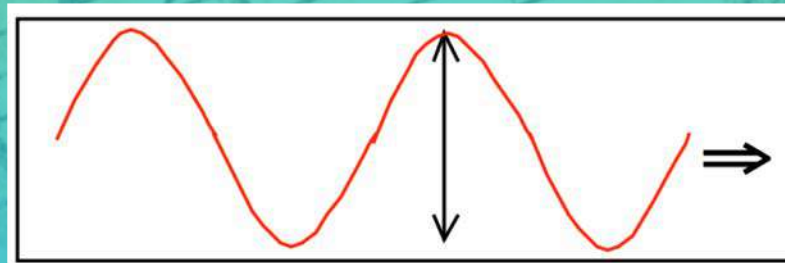
The energy in a wave is proportional to the square of the amplitude (height) of the wave. That means that if you compare the energy of a 4-foot wave that you might surf on to the tsunami, even though the tsunami is only about 6 times the height, it would have 62 or 36 times more energy. A 100-foot tsunami (like the one that hit the coast of the East Indies in August 1883) would have 252 or 625 times more energy than the four-foot wave.

Making Waves

Compressional waves are also known as longitudinal waves. A compressional wave is one in which the medium vibrates in the same direction as the movement of energy in the wave



A transverse wave is one in which the medium vibrates at right angles to the direction the energy moves. (slinky)



Standing Waves - see video https://www.youtube.com/watch?v=3BN5-JSsu_4

<https://newt.phys.unsw.edu.au/jw/flutes.v.clarinets.html>

Longitudinal waves - see video <https://www.youtube.com/watch?v=7cDAYFTXq3E>

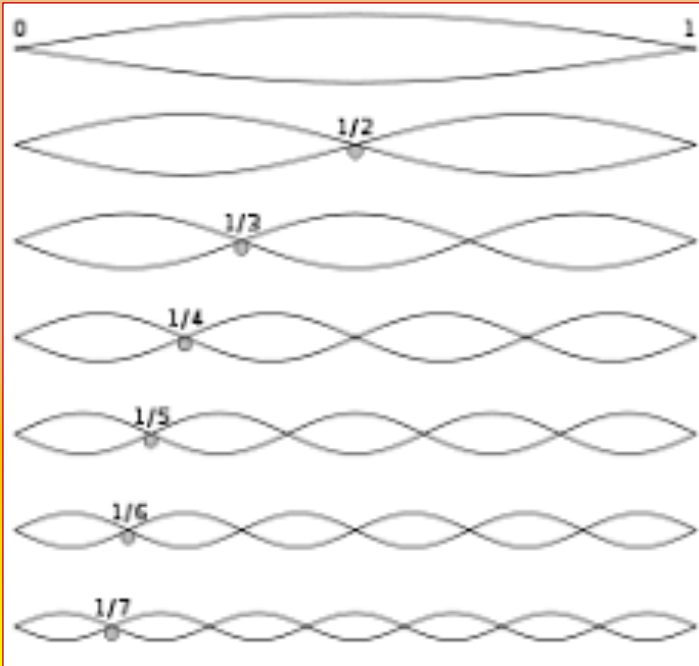
Fundamental
Harmonic series
Partials
Overblowing

Construction & Acoustic Properties see word doc. for definitions

STRINGS – 2/3 of orchestra

String properties

The vibration of the strings on stringed instruments have the form of standing waves which produce a fundamental frequency and all harmonics of that fundamental frequency simultaneously. These frequencies depend upon the tension, mass and length of the string. The harmonics make the sound timbre fuller and richer than the fundamental alone. The particular mix of harmonics present depends upon the method of excitation of the string.



Harmonic Series
Partials (multiply
fundamental/root
by integers)

String Excitation

The frequencies produced by stretched strings are determined by the tension, mass and length of the strings, and consist of a fundamental frequency and all harmonics of that fundamental. Even though these frequencies are determined, the timbre of the sound produced by the string can vary considerably depending upon the method of excitation of the string. In the violin family the string may be bowed or plucked (pizzicato). In the piano the string is struck by a felt hammer, and in the harpsichord the strings are plucked by a "quill". Even when the form of excitation is established, there are differences in harmonic content depending upon the location of excitation on the string. If a violin is bowed close to the bridge (sul ponticello) then the sound is brighter with more harmonic content. If bowed further from the bridge (sul tasto) then the sound is darker, more mellow with less harmonic content

<http://hyperphysics.phy-astr.gsu.edu/hbase/Music/stringa.html>

Why 56 strings = 2/3 of orchestra, 3 trumpets, and two oboes?

<http://newt.phys.unsw.edu.au/jw/musFAQ.html>

<https://newt.phys.unsw.edu.au/jw/musical-sounds-musical-instruments.html>

String Instruments: Making Waves

▶ String Instrument Resonances

▶ In addition to the string properties and the method of excitation of strings, the sound timbre is significantly affected by resonances in the body of the instrument itself.

▶ Bows and strings

▶ Many of the most useful features of the orchestral string instruments result from their use of bows. Compared with *pizzicato* (plucking the string), the bow allows the player to continuously input energy and so to maintain a note. This is important to the timbre, too: after a pluck, the high harmonics fade away quickly, leaving only the fundamental and some weak lower harmonics. Bowing maintains the rich harmonic spectrum.

▶ The part of the bow that touches the strings is made of horsehair (or a synthetic substitute). In the contemporary bow, the wooden support for the hair is bent towards the hair - not away from it like an archery bow, or like the violin bows of the eighteenth century.

▶ This difference in bow shape makes a big difference to playing and sound.

BOWS – Mode of excitation

- Bowed strings, wind instruments and the voice can produce steady sustained tones, because they can convert a steady ('DC') supply of energy from the arms or breath into that of oscillatory ('AC') motion.

This observation is of fundamental importance in music acoustics because it gives rise to harmonic spectra and thus, to harmony.

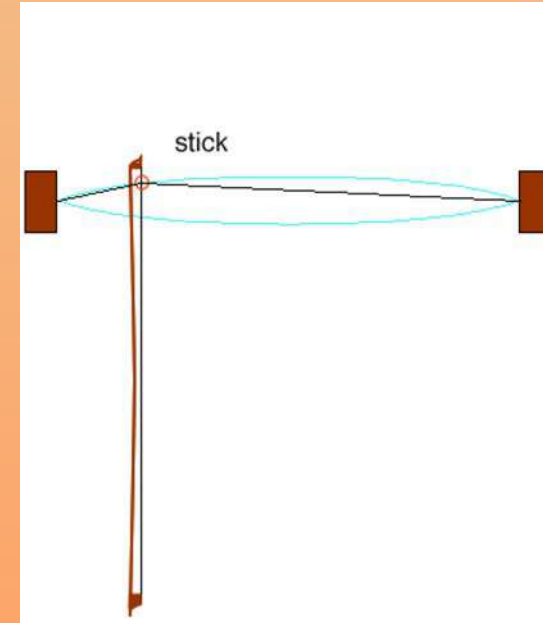
String: has 4 modes of vibration

Longitudinal

Torsional

Lateral

Transient



The animation at right shows how a bow, travelling with a steady speed (Direct Current), excites a vibration (Alternating Current) in a string. (The lateral force between bow and string is related to their relative speed & other variables by equations that are nonlinear: the force is not proportional to the speed (or position)).

<https://newt.phys.unsw.edu.au/jw/Bows.html>

Wind Instruments

In woodwind and brass, the reed, air jet or player's lips provide the non-linear element (somewhat analogous to the bow in the string family). Instead of a vibrating string, the resonator is a tube of air, which has a number of different configurations and geometries.

The relations between the vibration of a brass player's lips, a woodwind reed, a flute's air jet or a singer's vocal folds and the air flow past or through them are nonlinear (meaning that the change in air flow is not proportional to the change in the other variable).

This nonlinearity has the effect of producing periodic vibration with high harmonics, and the presence of harmonics means musical pitch and timbre.

BRASS Brilliant and blazing sounds.

Made of metal tubes with cylindrically shaped **mouthpieces**.

Bell shaped end = **Pavilion**

Sounds: produced when the air column within vibrates. Lips buzz (vibrate) as air is blown through the mouthpiece.

To tune brass instruments, the length of the tube must be shortened or lengthened.

Trumpet (6 foot tube)

Horn (12 foot tube)

Trombone (9 feet)-slide to change length of tube- 350 years ago

Tuba (12-14 feet)

WOODWINDS

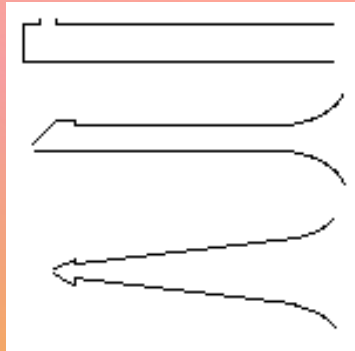
FLUTES

OBOES

CLARINETS/SAXOPHONES

Questions related to wind instruments

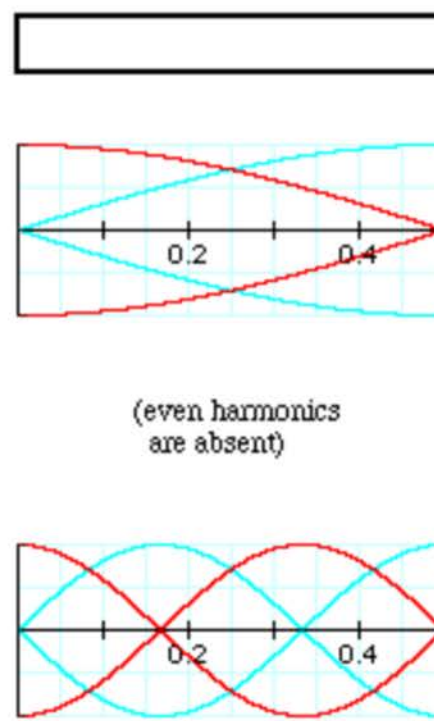
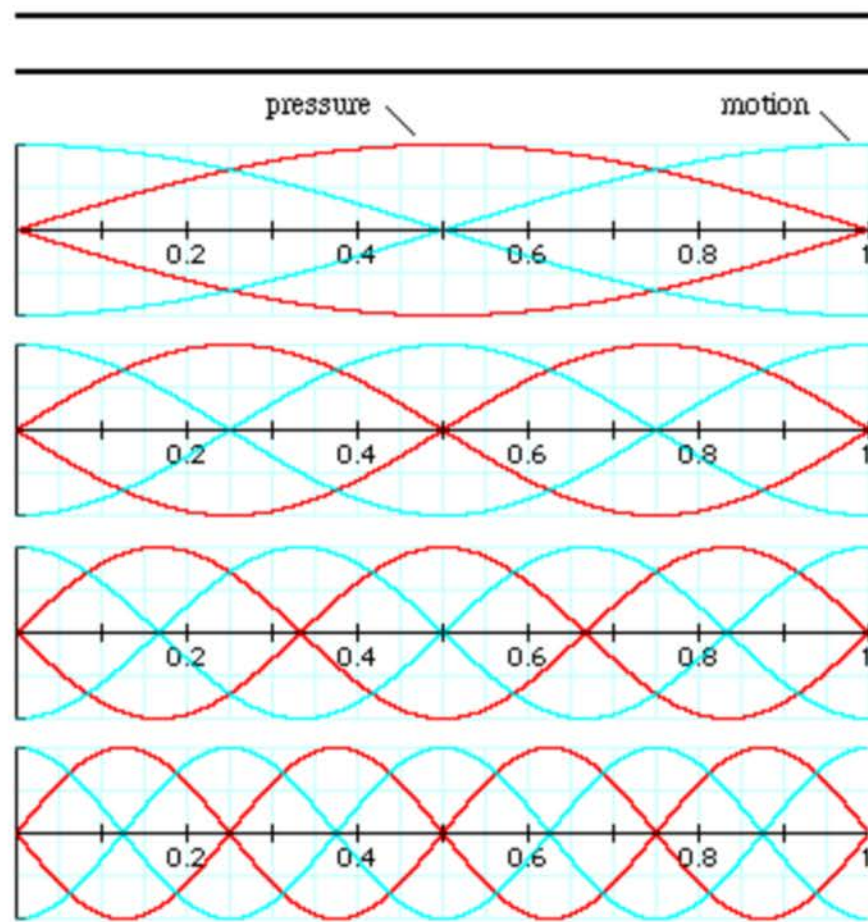
• *How do you explain the waves and harmonics in flutes, clarinets and oboes? A flute is open at both ends and a flute ~60 cm long plays a lowest note of C4, which has a wavelength about twice as long as the instrument. A clarinet is open at one end and closed at the other, so it should play a note about four times as long as the instrument, and it does: a clarinet is ~60 cm long and plays a lowest note of D3 or Db3, nearly an octave below the flute. So far so good. But an oboe is also ~60 cm and closed at one end, and its lowest note is much closer to the lowest note on a flute than to the lowest note on a clarinet. Why? This question requires diagrams and a bit of concentration. [Pipes and harmonics](#).*



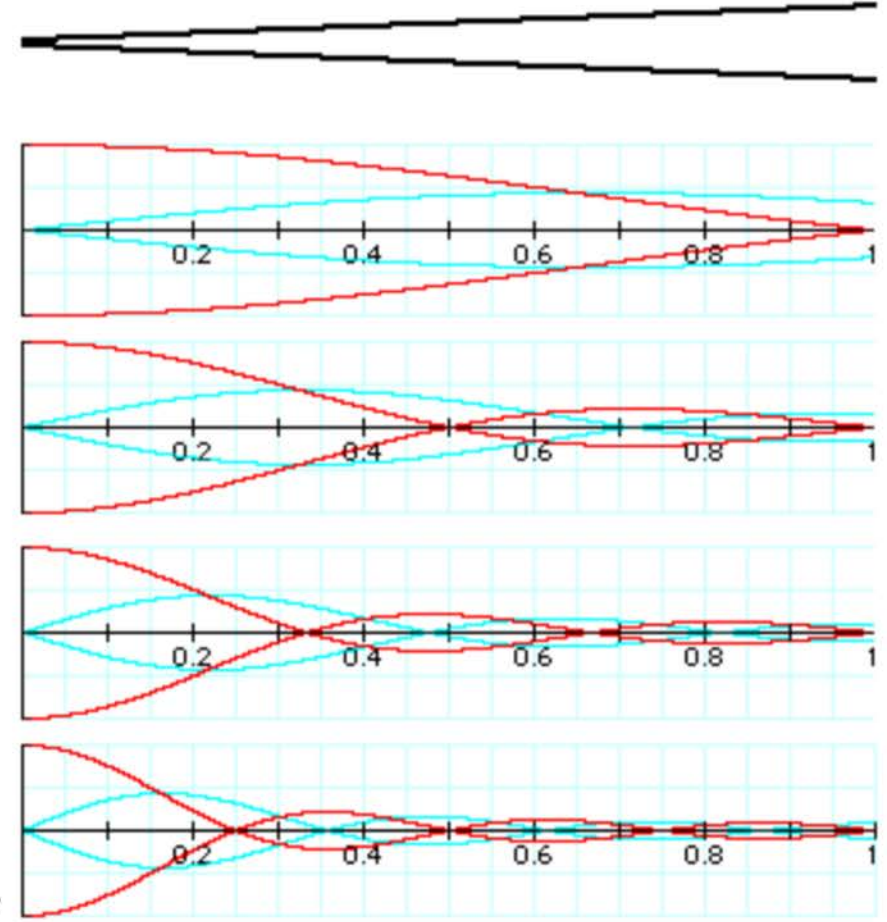
Here we give an answer to this frequently asked question, but it involves discussing a few concepts: there is no three-sentence answer. For a background to this discussion, it is worth looking at the difference between closed and open pipes, which is explained in [Open vs closed pipes \(Flutes vs clarinets\)](#), which compares them using wave diagrams, air motion animations and frequency analysis.

To compare cylindrical, conical, closed and open pipes, let's look first at diagrams of the standing waves in the tube.

VOICE?



J. Wolfe, UNSW



Three simple but idealised air columns: open cylinder, closed cylinder and cone. The red line represents sound pressure and the blue line represents the amplitude of the motion of the air. The pressure has a node at an open end, and an antinode at a closed end. The amplitude has a node at a closed end and an antinode at an open end. These three pipes all play the same lowest note: the longest wavelength is twice the length of the open cylinder (eg flute), twice the length of the cone (eg oboe), but four times the open length of the closed cylinder (eg clarinet). Thus a flutist (diagram at left) or oboist (diagram at right) plays C4 using (almost) the whole length of the instrument, whereas a clarinetist (middle) can play approximately C4 (written D4) using only half the instrument. If you have a flute or oboe and a clarinet, this experiment is easy to do. Play the lowest note on the flute or oboe, and then compare this with the lowest note on half a clarinet (ie removing the lower joint and bell). **Important:** in all three diagrams, the frequency and wavelength are the same for the figures in each row. When you look at the diagrams for the cone, this may seem surprising, because the shapes look rather different. This distortion of the simple sinusoidal shape is due to the $1/r$ term, which is discussed below. (A good technical treatment is given by Ayers *et al.* (1985) [Am. J. Phys., 53, 528](#) and also by Ruiz in *Physics Education*.)