Standardization of A 440
The official 440 Hz standard, recognized by orchestras all over the world, was first declared the norm by the International Organization for Standardization in 1955, and they doubled down on that frequency 20 years later. ISO decision based on British Standards Institution meeting of 1939. And that frequency was a reaffirmation of yet another conference, this one in Austria in 1885.

Percussion Activity

Orchestra: three to four main musical layers: Melody, Harmony, Rhythm & Effects, Bass

EXAMPIES
Vivaldi bassoon
https://www.youtube.com/watch?v=YWlsLJ1pyPU

Beethoven 5th
https://www.youtube.com/watch?v=lHOYvLhLx0&t=9s

Star Wars: John Williams
https://www.youtube.com/watch?v=EjMNpIlksal

HP by JW
https://www.youtube.com/watch?v=GTXBLyp7_Dw

Concerto vs Symphony
The main difference between a concerto and a symphony is that a concerto is a musical piece where there is a solo instrument accompanied by an entire orchestra whereas a symphony is a musical piece having several segments (movements) that involve the orchestra without extensive solo part.

Some Common Italian Terminology: Solo, tutti, divisi etc… Slide 12
In music, a **solo** (from the Italian: solo, meaning alone) is a piece or a section of a piece played or sung featuring a single performer, who may be performing completely alone or supported by an accompanying instrument such as a piano or organ, a continuo group (in Baroque music), or the rest of a choir, orchestra…

**Tutti** is an Italian word literally meaning all or together and is used as a musical term, for the whole orchestra as opposed to the soloist. It is applied similarly to choral music, where the whole section or choir is called to sing.

**Divisi** a musical direction indicating that a section of players should be divided into two or more groups each playing a different part. Used for strings "violas divisi"

**Movements = different parts of a symphonic work**
With rare exceptions, the four movements of a symphony conform to a standardized pattern. The first movement is brisk and lively; the second is slower and more lyrical; the third is an energetic minuet (dance) or a boisterous scherzo (“joke”); and the fourth is a rollicking finale. A movement is a self-contained part of a musical composition or musical form. While individual or selected movements from a composition are sometimes performed separately, a performance of the complete work requires all the movements to be performed in succession.

**Speeds:**

![Crescendo and Decrescendo symbols]

**Abbreviation Italian word English meaning**

| ! | pp | pianissimo | very soft |
| ! | p | piano | Soft |
| ! | mp | mezzo piano | medium soft |
| ! | mf | mezzo forte | medium loud |
| ! | f | forte | Loud |
| ! | ff | fortissimo | very loud |
| ! | < | crescendo | getting louder |
| ! | (cresc) | diminuendo | getting softer |
| ! | > | (dim.) |  |
**Interval**: difference in pitch between two sounds. An interval may be described as horizontal, linear, or melodic if it refers to successively sounding tones, such as two adjacent pitches in a melody, and vertical or harmonic if it pertains to simultaneously sounding tones, such as in a chord.

**Octave** is the interval between one musical pitch and another with double its frequency.

*Sing in class (G – Sol – *Row Your Boat*)*

**Arpeggio**: the notes of a chord played in succession, either ascending or descending. From the word arpa (Harp)

https://www.youtube.com/watch?v=UQwIdGoxREg

**Scales**: Any set of musical notes ordered by fundamental frequency or pitch. A scale ordered by increasing pitch is an ascending scale, and a scale ordered by decreasing pitch is a descending scale.

**Major Minor**

**Vibrato** (Italian, from past participle of "vibrare", to vibrate) is a musical effect consisting of a regular, pulsating change of pitch. It is used to add expression to vocal and instrumental music. Vibrato can add depth and beauty to a piece of music – and it’s pretty much an irreplaceable tool when it comes to expression.

https://en.wikipedia.org/wiki/Vibrato

Berlioz Requiem: Instrumentation (1837)

The Requiem is scored for a very large orchestra, including four brass choirs at the corners of the stage, and chorus:

<table>
<thead>
<tr>
<th>Woodwinds</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 flutes</td>
</tr>
<tr>
<td>2 oboes</td>
</tr>
<tr>
<td>2 cors anglais</td>
</tr>
<tr>
<td>4 clarinets in B-flat</td>
</tr>
<tr>
<td>8 bassoons</td>
</tr>
<tr>
<td><strong>Brass</strong></td>
</tr>
<tr>
<td>12 horns (4 parts + 2 extra in Mvt 2, in D, E, A, and C)</td>
</tr>
<tr>
<td>4 cornets in B-flat</td>
</tr>
<tr>
<td>4 tubas</td>
</tr>
<tr>
<td><strong>Percussion</strong></td>
</tr>
<tr>
<td>16 timpani (6 pairs,4 single)</td>
</tr>
<tr>
<td>2 bass drums</td>
</tr>
<tr>
<td>10 pairs of cymbals</td>
</tr>
<tr>
<td>4 tam-tams</td>
</tr>
<tr>
<td><strong>Orchestras</strong></td>
</tr>
<tr>
<td>Orchestra 1 to the North</td>
</tr>
<tr>
<td>4 cornets</td>
</tr>
<tr>
<td>4 trombones</td>
</tr>
<tr>
<td>Orchestra 2 to the East</td>
</tr>
<tr>
<td>4 trumpets (in E)</td>
</tr>
<tr>
<td>4 trombones</td>
</tr>
<tr>
<td>Orchestra 3 to the West</td>
</tr>
<tr>
<td>4 trumpets (in D)</td>
</tr>
<tr>
<td>4 trombones</td>
</tr>
<tr>
<td>Orchestra 4 to the South</td>
</tr>
<tr>
<td>4 trumpets (in C)</td>
</tr>
<tr>
<td>4 trombones</td>
</tr>
<tr>
<td>4 ophicleides (usually substituted by tubas)</td>
</tr>
<tr>
<td><strong>Voices</strong></td>
</tr>
<tr>
<td>Chorus:</td>
</tr>
<tr>
<td>80 sopranos and altos (exact ratio not specified)</td>
</tr>
<tr>
<td>60 tenors</td>
</tr>
<tr>
<td>70 basses</td>
</tr>
<tr>
<td>Tenor solo</td>
</tr>
<tr>
<td><strong>Strings</strong></td>
</tr>
<tr>
<td>25 violin I</td>
</tr>
<tr>
<td>25 violin II</td>
</tr>
<tr>
<td>20 violas</td>
</tr>
<tr>
<td>20 violoncellos</td>
</tr>
<tr>
<td>18 double basses</td>
</tr>
</tbody>
</table>

In relation to the number of singers and strings, Berlioz indicates in the score that, "The number [of performers] indicated is only relative. If space permits, the chorus may be doubled or tripled, and the orchestra be proportionally increased. But in the event of an exceptionally large chorus, say 700 to 800 voices, the entire chorus should only be used for the "Dies irae", the "Tuba mirum", and the "Lacrimosa", the rest of the movements being restricted to 400 voices."
The work premiered with over four hundred performers.

2. Musical/sound perception: Rhythm, Melody, Harmony, Timbre, Texture
   What do we hear?

1) Rhythm: Physical motion (Pulse Exercise in class)
   Arrangement of various durations (length of each note in time) within a fixed metric pattern
   Meter: recurring pattern of a fixed number of beats.
   For example, a pattern of three beats where beat one is accented (1 2 3, 1 2 3, 1 2 3, etc.)
   Tempo: Defines the speed of music. Can be slow, medium, fast. Is expressed in beat per minute.
   There can be multiple rhythmic combinations at the same tempo, and the same rhythms can be
   played at different tempó (slow or fast)

2) Melody: Mental emotion (Mozart Concerto piano 23, 2nd mvt, Brahms Symphony 3, 3d mvt,
   Villa Lobos Bachianas Brasileiras 5, and HP themes)

3. Harmony: recent (mentioned in 9th century, developed from 12th to 15 century) and sophisticated
   element – play same song in major, then minor or whole tone. Organum, independent voices, faux-
   bourdon.
   Chords: Triad (three notes) CEG, ACE: exercise in class – build more triads

   A B C D E F G A ....

Thursday 1/31/2019

4) Timbre: Tone Color Quality of sound produced by a particular medium of musical tone
   production.
   Individual instruments and instruments in combinations

5. Texture: Monophony, Homophony, Polyphony
   Perception – auditory system
   Blending of timbres/sounds = Grouping vs streaming -hearing distinct (instrumental) timbres
   Bregman: Gestalt theory
   Sequential grouping - Simultaneous grouping
   Behav-Sci.pdf
   Gestalt is a psychology term which means "unified whole"
   Horns: glue of the orchestra – Help different timbres stick together

Concert Halls?
Public Venues from mid 17th century (for nobility and upper class) – Louis the XIVth
   A concert hall is a cultural building with a stage that serves as a performance venue and
   an auditorium filled with seats. While early halls built in the 18th and 19th century were
   designed for classical orchestra, concerto and opera concerts and ballet performances,
   halls built in the 20th and 21st century were often built to accommodate a wider range of
   performance types, including musicals. In the 2010’s, popular music such as rock
   music and traditional music such as folk music are also performed in these venues. Many
   concert halls exist as one of several halls or performance spaces within a
   larger performing arts center. In many towns, the concert hall is combined with
   a convention center. Concert halls typically also contain orchestral rehearsal rooms.
Many larger cities have both public and private concert halls. Particularly in smaller cities with fewer alternative venues, concert halls may also be used to accommodate other activities, from theatrical performances to academic presentations and university graduation ceremonies.

**Orchestra** – slide 11 (History)

3. Why Study Orchestra? Orchestral Instruments serve as reference (to emulate or to reject) to electronic music & synthesized sounds. In the 60’s synthetic sounds were supposed to be new, to add to the collection of acoustic existing sounds. Since the 80’s, synthesized sounds also want to electronically recreate the original acoustic sounds. Since then, both types co-exist.

   Ligeti [https://www.youtube.com/watch?v=71hNI_skTZQ](https://www.youtube.com/watch?v=71hNI_skTZQ)
   Blake Robinson: [http://www.syntheticorchestra.com/mine/?id=474](http://www.syntheticorchestra.com/mine/?id=474)
   COMPARE: start at 22”, then at 1’54 [https://www.youtube.com/watch?v=qstOC_D1HU0](https://www.youtube.com/watch?v=qstOC_D1HU0)

Digital Sound Processing (DSP) = Manipulation of samples (acoustic or not)

4. **Visualizing Orchestra/score** – Slides 12,13 and **Visualizing Sound** – slides 16, 17
   [https://www.nde-ed.org/EducationResources/HighSchool/Sound/frequencypitch.htm](https://www.nde-ed.org/EducationResources/HighSchool/Sound/frequencypitch.htm)

5. **Define Sound** – Card Activity slide 15
   - Physical - wave and propagation
   - Physiological/psychological - perception

6. **ACOUSTIC: Slides 16-18 (waves)**
   See the vibration [https://www.guitarplayer.com/miscellaneous/-no-this-is-how-plucked-guitar-strings-look-in-slow-motion-video](https://www.guitarplayer.com/miscellaneous/-no-this-is-how-plucked-guitar-strings-look-in-slow-motion-video)

   **Course page: 02c - David Lapp**
   [http://www.ele.uri.edu/courses/ele369g/01b_PhysicsMusicInstruments.pdf](http://www.ele.uri.edu/courses/ele369g/01b_PhysicsMusicInstruments.pdf)
   [http://www.ele.uri.edu/courses/ele369g/02c_MusicalAcoustics.pdf](http://www.ele.uri.edu/courses/ele369g/02c_MusicalAcoustics.pdf)

7. **Definitions:**
   **Standing Waves:** Up and Down motion or oscillation (of string)
   [https://www.youtube.com/watch?v=3BN5-JSsu_4](https://www.youtube.com/watch?v=3BN5-JSsu_4)
   In physics, a standing wave – also known as a stationary wave – is a wave which oscillates in time but whose peak amplitude profile does not move in space. The peak amplitude of the wave oscillations at any point in space is constant with time, and the oscillations at different points throughout the wave are in phase. Makes the air move which produces a pressure wave that travels (to the eardrum)


**Longitudinal waves** = compression waves
Fundamental frequency \((f_0)\) is a property of sound and is perceived by the ear as pitch. It is the lowest frequency of a periodic waveform.

8. Harmonic series

Pitched musical instruments are often based on an acoustic resonator such as a string or a column of air, which oscillates at numerous modes (partials) simultaneously (gives timbre). At the frequencies of each vibrating mode, waves travel in both directions along the string or air column, reinforcing and canceling each other to form standing waves. Interaction with the surrounding air causes audible sound waves, which travel away from the instrument. Because of the typical spacing of the resonances, these frequencies are mostly limited to integer multiples, or harmonics, of the lowest frequency, and such multiples form the harmonic series.

The musical pitch of a note is usually perceived as the lowest partial present (the fundamental frequency), which may be the one created by vibration over the full length of the string or air column, or a higher harmonic chosen by the player. The musical timbre of a steady tone from such an instrument is strongly affected by the relative strength of each harmonic.

Partials/overtones: An overtone is any frequency greater than the fundamental frequency of a sound. Using the model of Fourier analysis, the fundamental and the overtones together are called partials. Harmonics, or more precisely, harmonic partials, are partials whose frequencies are numerical integer multiples of the fundamental (including the fundamental, which is 1 times itself). These overlapping terms are variously used when discussing the acoustic behavior of musical instruments.

Sine Wave: A sine wave or sinusoid is a mathematical curve that describes a smooth periodic oscillation. A sine wave is a continuous wave. It is named after the function sine, of which it is the graph. It occurs often in pure and applied mathematics, as well as physics, engineering, signal processing and many other fields.

TUESDAY 2/5/2019

Virtual Piano here:

https://www.apronus.com/music/flashpiano.htm

Sound: made of waves
Waves in oscillators: Basic Waveforms http://beausievers.com/synth/synthbasics/
1. Sine
2. Sawtooth
3. Square
4. **Triangle**

**Sound Waves in Air**

A sound wave in air is an example of a longitudinal (compressional) wave – the direction of the air particles’ vibrational motion is in the same direction that the wave is propagating. The wave is characterised by a series of alternate compressions (condensations) and rarefactions (expansions) as shown in figure 1 for a pure tone (single frequency) sound. The compressions correspond to the crests and the rarefactions are the troughs of a wave. The propagation speed of sound in air depends on the air temperature. At 20 °C, the speed is \( v = 343 \text{ m.s}^{-1} \).

The superposition of sine waves of the harmonic series produces timbre (complex and rich)


**Tone Quality !  Timbre**

A pure tone (aka simple tone) consists of a single frequency, e.g., \( f = 100 \text{ Hz} \).

Pure tones are rare in nature – natural sounds are often complex tones, consisting of having more than one frequency – often many!

A complex tone = a superposition (aka linear combination) of several many frequencies, each with its own amplitude and phase.

Musical instruments with a steady tone (i.e., a tone that doesn’t change with time) create a periodic complex acoustical waveform (periodic means that it repeats every so often in time, e.g., with repeat period, !):

A complex tone - e.g., plucking a single string on a guitar - is perceived as a single note, but consists of the fundamental frequency \( f_1 \), plus integer harmonics of the fundamental frequency \( f_2 = 2f_1, f_3 = 3f_1, f_4 = 4f_1, f_5 = 5f_1 \), etc.

**Additive Synthesis**: Adding harmonics/partials together to produce a complex waveform. https://www.youtube.com/watch?v=SDw0Ht1SZbo
https://www.youtube.com/watch?v=YsZKvLf7wU

**Harmonics and non-linearities**

When a periodic wave is composed of a fundamental and only odd harmonics (f, 3f, 5f, 7f, ...), the summed wave is half-wave symmetric; it can be inverted and phase shifted and be exactly the same. If the wave has any even harmonics (0f, 2f, 4f, 6f, ...), it will be asymmetrical; the top half will not be a mirror image of the bottom.

Conversely, a system which changes the shape of the wave (beyond simple scaling or shifting) creates additional harmonics (harmonic distortion). This is called a non-linear system. If it affects the wave symmetrically, the harmonics produced will only be odd, if asymmetrically, at least one even harmonic will be produced (and probably also odd).
Adding two waves with a slightly different wavelength results in a beating pattern.

Acoustics of wind instruments

https://www.britannica.com/art/wind-instrument/The-production-of-sound#ref131153  
http://www.phikwadraat.nl/duck_wakes/

**Overblowing:** Because the tubes of flutes and reed instruments (in contrast to those of trumpet-type aerophones) are short in relation to their diameter, they are generally capable of sounding the fundamental and respond best to pitches low in the *overtone* series. To play in the upper register, the player must *overblow*, breaking the air column into parts, each of which vibrates at a frequency that is in direct proportion to the fundamental. Oboes, bassoons, and *saxophones*—all open tubes with conical bores—overblow at the octave; clarinets, whose cylindrical bore acts as a closed pipe, overblow at the 12th. In overblowing, the player tightens his lips on the reed. Increasing lip pressure is not always sufficient by itself, however, and a variety of techniques and mechanisms have been developed to assist the player in making the notes of the upper register emerge clearly and instantaneously. For example, on flutes and bassoons, the first finger hole is positioned so that, when it is opened on certain high pitches, low partials are prevented from forming; opening a special key on the clarinet, the *saxophone*, and the modern oboe serves the same purpose.

**Power spectra:** p. 27, 30 shows strength of respective partials in harmonic series.  
http://www.ele.uri.edu/courses/ele369g/01b_PhysicsMusicInstruments.pdf

6. More useful and common musical concepts:

**Staff:** like a ladder on which the pitches (notes) are organized by height.
Clefs: Treble                 Bass:

Useful to show where middle C is.

Middle C

a. Consonant 8,6,5,4,3 vs Dissonant: 2, 7, tritone
Main Qualities: Perfect, Major, minor, augmented and diminished
https://www.britannica.com/art/consonance-music

Consonance and dissonance. Intervals are traditionally considered either consonant or dissonant. Consonant intervals are usually described as pleasant and agreeable. Dissonant intervals are those that cause tension and desire to be resolved to consonant intervals.

b. Inversion of chords:
Root position: CEG (fundamental/root in bass), 1st inversion EGC (3d in bass), 2d inversion GCE (5th in bass)
Inversion ACTIVITY

c. Keys: https://en.wikipedia.org/wiki/Key_(music)
In music theory, the key of a piece is the group of pitches, (scale), that forms the basis of a music composition in classical, Western art, and Western pop music.
The group features a tonic note (=name of key = name of scale) and its corresponding chords, also called a tonic or tonic chord, which provides a subjective sense of arrival and rest, and also has a unique relationship to the other pitches of the same groupSCALE, their corresponding chords, and pitches and chords outside the group. Notes
and chords other than the tonic in a piece create varying degrees of tension, resolved when the tonic note or chord returns.

The key may be in the major or minor mode, though musicians assume major in a statement like, "This piece is in C." Longer pieces in the classical repertoire may have sections and/or movements in contrasting keys.

d. Transposition: https://en.wikipedia.org/wiki/Transposition_(music)

![Transposition example from Koch](https://en.wikipedia.org/wiki/Transposition_(music))

Transposition example from Koch - The melody on the first line is in the key of D, while the melody on the second line is identical except that it is major third lower, in the key of B♭.

In music transposition refers to the process, or operation, of moving a collection of notes (pitches or pitch classes) up or down in pitch by a constant interval.

The shifting of a melody, a harmonic progression or an entire musical piece to another key, while maintaining the same tone structure, i.e. the same succession of whole tones and semitones and remaining melodic intervals.

— Musikalisches Lexicon, 879 (1865), Heinrich Christoph Koch (trans. Schuijer)

### Tuning and Temperament

**Best lecture:** [https://www.yuvalnov.org/temperament/](https://www.yuvalnov.org/temperament/)

http://www.math.uwaterloo.ca/~mrubinst/tuning/tuning.html
http://www.kevinboone.net/equal_tempered_scale.html

**Pythagorean tuning (by perfect 5th) / meantone:** Best for Pentatonic Music (CGDAE in order = CDEGA) and 7 notes scales. Not great for scales with 12 notes and modulations (change of keys in the middle of the piece)

Problems with tuning and transposing keys on keyboard instruments.

C is not B# (quarter of semitone off)

**Pythagorean tuning** is a system of musical tuning in which the frequency ratios of all intervals are based on the ratio 3:2. This ratio, also known as the "pure" perfect fifth, is chosen because it is one of the most consonant and easiest to tune by ear and because of importance attributed to the integer 3.

**Compared to equal temperament which has 5ths tuned to 700 cents Pythagorean temperament has 5ths tuned to 702 cents 1200 cents per perfect octave.**

F -- C -- G -- D -- A -- E -- B -- F# -- C# -- G# -- D# -- A#-- E#. On Keyboard E# = F but not in Pythagorean temperament.

Look at keyboard: A fifth has seven semi-tones - between B and F there are 6 semitones. We need F# and C# and D# etc.
**Meantone:** tried to improve the sound of 3ds with the same principle of tuning 5ths. Wolf is growing bigger and more unpleasant.

Wolf fifth examples:
https://www.youtube.com/watch?v=Dl7iIzvUMGg
https://www.youtube.com/watch?v=K7QuSf9nSgY
https://en.wikipedia.org/wiki/Meantone_temperament

**Just Intonation / temperament** – Using ‘natural’ system of overtones and ratios from the fundamental.

When a musical instrument is tuned using a just intonation tuning system, the size of the main intervals can be expressed by small-integer ratios, such as 1:1 (unison), 2:1 (octave), 3:2 (perfect fifth), 4:3 (perfect fourth), 5:4 (major third), 6:5 (minor third).

https://pages.mtu.edu/~suits/scales.html

<table>
<thead>
<tr>
<th>Interval</th>
<th>Ratio to Fundamental</th>
<th>Ratio to Fundamental</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Just Scale</td>
<td>Equal Temperament</td>
</tr>
<tr>
<td>Unison</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>Minor Second</td>
<td>25/24 = 1.0417</td>
<td>1.05946</td>
</tr>
<tr>
<td>Major Second</td>
<td>9/8 = 1.1250</td>
<td>1.12246</td>
</tr>
<tr>
<td>Minor Third</td>
<td>6/5 = 1.2000</td>
<td>1.18921</td>
</tr>
<tr>
<td>Major Third</td>
<td>5/4 = 1.2500</td>
<td>1.25992</td>
</tr>
<tr>
<td>Fourth</td>
<td>4/3 = 1.3333</td>
<td>1.33483</td>
</tr>
<tr>
<td>Diminished Fifth</td>
<td>45/32 = 1.4063</td>
<td>1.41421</td>
</tr>
<tr>
<td>Fifth</td>
<td>3/2 = 1.5000</td>
<td>1.49831</td>
</tr>
<tr>
<td>Minor Sixth</td>
<td>8/5 = 1.6000</td>
<td>1.58740</td>
</tr>
<tr>
<td>Major Sixth</td>
<td>5/3 = 1.6667</td>
<td>1.68179</td>
</tr>
<tr>
<td>Minor Seventh</td>
<td>9/5 = 1.8000</td>
<td>1.78180</td>
</tr>
<tr>
<td>Major Seventh</td>
<td>15/8 = 1.8750</td>
<td>1.88775</td>
</tr>
<tr>
<td>Octave</td>
<td>2.0000</td>
<td>2.0000</td>
</tr>
</tbody>
</table>

Wolf fifth
https://www.youtube.com/watch?v=Dl7iIzvUMGg
https://www.youtube.com/watch?v=K7QuSf9nSgY
https://en.wikipedia.org/wiki/Meantone_temperament

In classical music and Western music in general, the most common tuning system since the 18th century has been twelve-tone equal temperament (also known as 12 equal temperament, 12-TET or 12-ET), which divides the octave into 12 parts, all of which are equal on a logarithmic scale, with a ratio equal to the 12th root of 2 ($\approx 1.05946$). That resulting smallest interval, $\frac{1}{12}$ the width of an octave, is called a semitone or half step. In modern times, 12TET is usually tuned relative to a standard pitch of 440 Hz, called A440, meaning one note, A, is tuned to 440 hertz and all other notes are defined as some multiple of semitones apart from it, either higher or lower in frequency. The standard pitch has not always been 440 Hz. It has varied and generally risen over the past few hundred years.

![Comparison between Pythagorean tuning (blue), equal-tempered (black), quarter-comma meantone (red) and third-comma meantone (green). For each, the common origin is arbitrarily chosen as C. The degrees are arranged in the order of the cycle of fifths; as in each of these tunings all fifths are of the same size, the tunings appear as straight lines, the slope indicating the relative tempering with respect to Pythagorean, which has pure fifths (3:2, 702 cents). The Pythagorean A♭ (at the left) is at 792 cents, G♯ (at the right) at 816 cents; the difference is the Pythagorean comma. Equal temperament by definition is such that A♭ and G♯ are at the same level. Quarter-comma meantone produces the "just" major third (5:4, 386 cents, a syntonic comma lower than the Pythagorean one of 408 cents). Third-comma meantone produces the "just" minor third (6:5, 316 cents, a syntonic comma higher than the Pythagorean one of 294 cents). In both these meantone temperaments, the enharmony, here the difference between A♭ and G♯, is much larger than in Pythagorean, and with the flat degree higher than the sharp one.](image-url)
Concert opportunities
Orchestra and Band Concerts at URI: [https://web.uri.edu/music/music-department-events/](https://web.uri.edu/music/music-department-events/)
March 2 Symphony Orchestra
March 22 Remy
March 31 Aberdam
April 28 Symphony Orchestra

RI Philharmonic Concerts at the VET, Providence (Spring 2019)
[https://tickets.riphil.org/home/classical/?spektrix_bounce=true](https://tickets.riphil.org/home/classical/?spektrix_bounce=true)
[https://tickets.riphil.org/home/rush-hour/](https://tickets.riphil.org/home/rush-hour/)
[https://tickets.riphil.org/home/openrehearsal/](https://tickets.riphil.org/home/openrehearsal/)
DC-AC conversion


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. Nearly harmonic spectra can be produced by plucked and struck strings, but this comparatively, a very recent invention.

The animation at right shows how a bow, travelling with a steady speed (DC), excites a vibration (AC) in a string. (From Bows and strings.)

Similarly, 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).

Without going into mathematical details, we note that this nonlinearity has the effect of producing periodic vibration with high harmonics, and the presence of harmonics has the important musical consequences noted above.

The graph below is a schematic of air flow vs time past a vibrating reed for successively higher dynamic levels. Vibration up and down the bold line converts DC flow into AC flow in reed instruments. More details at Introduction to clarinet acoustics.