🫨 Tuning Basics

Tuning Basics

Vibration

- **Overtone/partial**: a resonant frequency that vibrates in addition to the fundamental
- **Harmonicity:** whether or not an overtone is a harmonic, i.e. a whole integer ratio from the fundamental
    - *Note: certain instruments like bells do not have strong harmonics, but have strong non-harmonic overtones, due to their non-1D shape.*
    - Perceived pitch does not always equal the pitch of the fundamental.
- **Timbre:** the quality of an instrument's sound, as defined by its unique combination of overtones.
- **Chroma:** the shared perceptual quality of frequencies separated by an octave; i.e. C3 and C4 sound of the same chroma

Perception of Consonance

There are three theories about what determines whether a pitch is "in" or "out" of tune.

- Roughness
    - When two frequencies are very close but not equal, they may create a *beat* which is perceived as "rough." (Also see: theory of overlapping signals within the cochlea.)
- Harmonicity
    - Two notes that have lots of overlapping overtones are perceived as consonant with one another.
    - This can be reduced to the statement: "the simpler the ratio of the fundamentals, the greater the harmonicity."
- Familiarity
    - Cultural and individual preference also affect what is perceived as consonant. For example, "rough" beating interference pattern are desired in gamelan.

Mathematics of Tuning

- Pitch perception is logarithmic, i.e. need to double frequency to go up each octave
- To convert from log space to linear space, we can use *cents*; one cent is 1/100th of a cent
- $c = 1200 \times \log_2(\frac{f_2}{f_1})$

Tuning vs. Temperament

- A **tuning** is a system in which you fix one interval (i.e. fix the M5 to 3:2 or M3 to 5:4). This can result in wolf intervals or commas, in which one single interval may be very off from its simple harmonic ratio.
- A **temperament** is a system, based on a tuning, but with affordances for corrections to notes to eliminate/minimize wolf intervals or commas.

Types of Temperaments

- Meantone temperaments: borrow from fifths to optimize thirds
- Well temperaments: borrow from fifths and thirds to optimize for transposition/modulation/circulation
- Equal temperaments: equal divisions of the octave

🕍 Historical Tunings

Historical Tunings

Pythagorean Tuning

- Pythagorean Tuning fixes the size of the M5 to 3:2, stacking eleven M5s on top of each other.
- This results in a **syntonic comma**. When you wrap around, you should reach your starting frequency (albeit a few octaves up); however, it will be off by around 23¢.

Just Intonation

- **Just Intonation** is a system where you pick a key you want to use, and tune the I, IV, and V triads to pure ratios.
- This will inevitably lead to conflicting tones; for example, if you tune to the I, IV, and V, the secondary dominant (II) triad sounds really bad.

Formula for tuning JI (in the key of C)

1. Tune G and E to their whole number ratios.
2. Tune the notes of the G chord—B and D—to their whole number ratios.
3. Tune F a whole-number M5 down from C.
4. Tune A a whole-number M3 up from F.

- Note that we only tuned white keys (the diatonic scale). You need a temperament to tune the chromatic notes. (So referring to a JI fifth makes sense, but referring to a JI tritone does not)

Meantone Temperaments

- **Meantone temperaments** borrow a few cents from fifths to optimize for thirds; however this results in a wolf fifth
- **Well temperaments** borrow from fifths *and* thirds to optimize for circulation and transposition
- **Equal temperaments** divide the octave equally

🐘 Ancient Indian Tuning

Ancient Indian Tuning

History and Sources

- Note that these sources were from disparate regions, and India should not be treated as a homogeneous unit.

Important texts

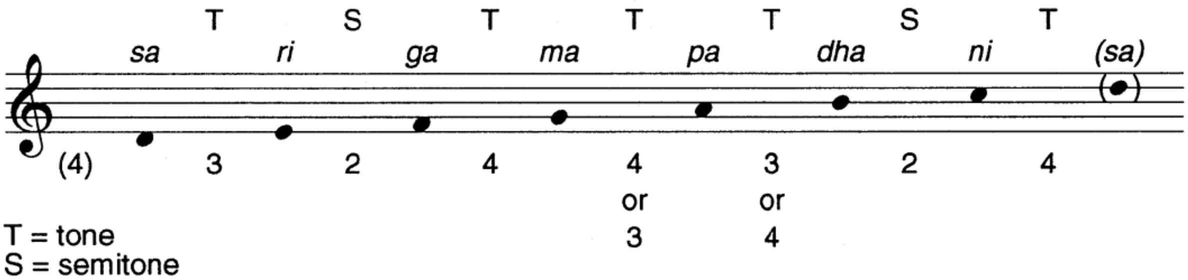
- ~200 BCE, Bharata Muni, **Nāṭya Śāstra**: written by a scholar regarded as a sage in India; first wrote about the *shruti* and their philosophical implications
- ~600 CE, Matanga, **Brihaddeshi**: touches on the *svara*
- ~1230, Sarngadeva, **Sangitaratnakara**: written in the time when Persian influence creates a divide between North and South Indian music. Introduces the *raga*
- 1550, Ramamatya, **Svaramelakalanidhi**: one of the first instances of a mathematical, systematic tuning proscription (rather than philosophical thinking)
- 17th century, Ahobala, Sangitaparijata

Definitions

- **sruti**: the smallest distinguishable unit of pitch; widely held that there are 22 *sruti* in an octave
- **svara**: a "scale degree"; 7 *svara* in an octave, but not evenly spaced
    - *svara* are "bands" of pitch; there is no fixed point where a *svara* lives. A *svara* could span multiple *sruti* and you pick the best one depending on context
    - There *is* a set number of *sruti* between each of the 7 *svara*, i.e. a pattern of 3, 2, 4, 4, etc
    - The *svara* formed a scale that's suspiciously close to our Western Dorian scale.
- **raga**: a mode/vibe/feeling of playing; there were nighttime *raga*, daytime *raga*, etc. *raga* defined what tuning would be used

	sa	ri	ga	ma	pa	dha	ni	(sa)
sa-grāma	3	2	4	4	3	2	4	
ma-grāma	3	2	4	3	4	2	4	

The equivalent in modern staff notation is:



22 śrutis	22 ETS (cents)	Nearest JI (cents)	JI ratio	JI interval name
R1	55			
R2	110	111.73	16:15	just minor second
R3	165	182	10:9	minor tone
R4	220	204	9:8	major tone
G1	275	266.87	7:6	septimal minor third
G2	330			
G3	385	386.31	5:4	Major third
G4	440	435.08	9:7	septimal major third
M1	495	498.04	4:3	perfect fourth
M2	550			
M3	605			
M4	660			
P	715	701.96	3:2	perfect fifth
D1	770	25:16	25:16	just augmented fifth
D2	825	813.69	8:5	just minor sixth
D3	880	884.36	5:3	just major sixth
D4	935	933.13	12:7	septimal major sixth
N1	990	966.109	16:9	Pythagorean minor seventh
N2	1045	1044.86	64:35	septimal neutral seventh
N3	1100	1088	15:8	just major seventh
N4	1155			
S	1200	1200	2:1	Octave

Intervals in blue denote intervals that were suspiciously close to JI.

Tuning

- There was debate among later scholars whether *sruti* were divided in 22 equal parts, or were manually tuned based on how good they sound

- If *sruti* were, in fact, divided into 22TET, they were suspiciously close to just intonation perfect ratios

🔱 Ancient Greek Tuning

Ancient Greek Tuning

Thought Camps

Pythagorean Thinkers

- Philolaus / Archytas
- Plato
- Euclid?
- Nicomachus
- Ptolemy

Aristoxenian Thinkers

- Aristoxenes
- Quintilianus

Organization of Notes

- **Tetrachords**: equal division into four notes, where the bottom and top note form a perfect fourth
- Three types of tetrachords
  - **Diatonic**: half step, whole step, whole step. i.e. E, F, G, A
  - **Chromatic**: half step, half step, 1.5 step. i.e. E, F, F#, A
  - **Enharmonic**: ¼ step, ¼ step, 2 step. i.e. E, (!), F, A.
- The scale was built using two tetrachords, one from C to F and one from G to C
  - This meant that the scale was built using only consonances, making the entire system "good"

Music and Philosophy

- Plato argued that improper music would cause moral delinquency in listeners.
- Plato proscribed different modes to different moods; i.e. Dorian for fighting, Lydian for effeminate-ness, etc.
  - *Note that these modes are not the same as our modern conception of dorian, lydian, etc.

Tuning

Pythagorean Opinion

- Pythagorean thinkers liked **epimoric** ratios, where the ratios are one number apart (8:7, 28:27, 9:8, etc.)
- His followers devised a tuning such that all ratios were epimoric

Aristoxenian Opinion

- Aristoxenus rejected Pythagoras' super mathematical/arithmetical approach towards tuning, and focused instead on perception
- He said that intervals should be tuned to whatever sounds good based on perception, rather than focusing on absolute string lengths

Possible Reconciliation of Opinions

- One theory is that Pythagorean thinkers mostly dealt with string instruments, i.e. fixed pitches, while Aristoxenian thinkers dealt with wind instruments, where you could partially cover a hole to make a note slightly sharper/flatter.
- This could have led to different priorities for both camps.

Early Chinese Tuning

Early Chinese Tuning

Sources

- **Guan Zhong**: politician around 600 BC, who also wrote about music and the Five Proper Sheng
- **Huainanzi**: around 122 BC, presented earliest tunings of twelve chromatic steps
- **Hou Hanshu**: around 5th century, first calculation of 53TET
- **Yueshu Yaolu**: Treatise of Music
- **Lulu Xinshu**: pivotal study on the 12 lu (pitch pipes)
- **Zhu Zaiyu**: maybe the first calculation of equal temperament?

Earliest Tunings

Hunan Bells

- Bells were used in the royal residence
- These bells were shaped so that they had a strong fundamental (unlike church bells)
- They seemed to be tuned to a somewhat chromatic scale, with some overlap with JI

Wuyi Bells

- Wuyi bells had multiple strike points; together, a set of 7 bells created a 12-tone chromatic scale

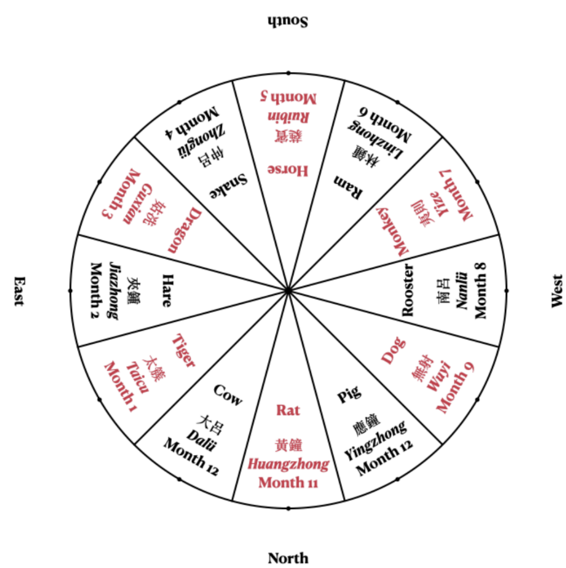
- These bells acted as “tuning forks”, setting the pitch standard for other instruments to be tuned to (like A=440Hz in the modern world)
- There were also bells that were tuned to the pitch standards of neighboring states for diplomacy purposes

Later Scholars

Mathematical Tunings vs. By Ear

- Some Chinese scholars noted that in ancient times, bells were tuned by ear, but later they were tuned by mathematical means.
- They claimed that mathematical means were inherently less precise than by tuning by ear.
- There was tempering to address the syntonic comma, but it was never explicitly mentioned

Pythagorean Tuning



- There was a system described of splitting a string into thirds, and either removing or adding a third (up a fifth or down a fourth).
- This is basically describing Pythagorean tuning

Pythagorean or Equal Temperament?

- The difference in pitch between an ET fifth and a Pythagorean fifth was so small, that it would be almost impossible to tune to either system exactly

- The conflicting writings pointing Chinese tuning to either Pythagorean tuning or ET tuning could be reconciled by experimental error

🪨 Ancient Mesopotamian Tuning

Ancient Mesopotamian Tuning

Sources

- Various tablets from 1700-600 BCE
- “Re-tuning tablet” described how to tune a 9-string lyre into 7 different modes; for each mode, only one string isn’t adjusted
- “Chart of intervals” described the names of the intervals each pair of strings produces

Background

- Music was notated based on **dichords**, i.e. a pair of strings sounded together; an early representation of harmony
- Most music in Ancient Mesopotamia had one vocal soloist and multiple lyres; so notating harmony was much more important than notating melody

Tuning of the Strings

- First, the interval of the octave was tuned.
- Then, every other string was tuned based on ear/vibes.
- This was able to work because there were only 7 distinct pitches in the scale; there was no need for modulation/chromaticism within a performance/without a retuning. So we wouldn’t run into wolf tones or commas.

Generation of the Seven Modes

Tablet CBS 1766, First Millennium BC, Penn Museum

- Lyres were tuned by starting from a scale
    - This scale was comprised of tones and semitones and roughly sounded like the Aeolian scale
- Iteratively, the tuner would identify any tritones present, and tighten/loosen strings to get rid of it. This would form the 7 different modes
    - Some of these modes were suspiciously similar to Western modes of the Major scale, like Dorian, Lydian, Ionian

🎹 The Rise of Equal Temperament

The Rise of Equal Temperament

Timeline

- Equal Temperament gradually became adopted around Europe in the 18th century.
- Pianos and wind instruments were first to convert; organs came later.

Riemann

- Riemann, a foundational music theorist, states that cognition is able to quantize frequencies to their nearest pitch chroma; notes can be “off” by up to a syntonic comma and they will still be perceived correctly.
- Additionally, the ability to freely modulate between keys without running into syntonic commas or wolf intervals is more important than having pure intervals.
- Note that he is still saying that JI is the “standard” of music, which ET simply quantizes to; he still holds up JI as the ideal form of music.

Ballanta and Africa

Ballanta and Africa

Ballanta

- Ballanta lived in Sierra Leone, which at the time was a society where freed slaves were sent by Britain (as a sort of “philanthropic” endeavor)
- He grew up in the context of Western harmony, studying at a Sierra Leone offshoot of Durham College in Britain, where he studied mainly counterpoint and the sorts

Hearing Indigenous African Music

- Ballanta claimed that indigenous African music saw the 7th as consonant, while Western music only saw overtones up to the major 3rd as consonant, and that the 7th always needs to resolve.
- Theoretically, the 7th should also be consonant since it is an overtone. In this sense, he claimed African music was more developed than Western music since it saw more overtones as consonant
- This doesn’t seem crazy to us, because we can see 7ths going unresolved in blues and jazz traditions; but for someone who grew up in the context of counterpoint at his university this was pretty groundbreaking.