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## **Harmonic Space & Hegemonic Process**

Skriftlig reflektion inom självständigt arbete

Till dokumentationen hör även följande inspelning:

*Cast of Mind*



# Table of Contents

<b>Introduction</b>	<b>4</b>
<b>The Dominant Consensus</b>	<b>5</b>
<b>Empty The Belief</b>	<b>6</b>
<b>Estrangement</b>	<b>8</b>
<b>Bondage To Formula</b>	<b>9</b>
<b>Cast Of Mind</b>	<b>11</b>
<i>Intervalic Sequence</i>	<b>14</b>
<i>Dedication</i>	<b>15</b>
<b>Terminology</b>	<b>16</b>
<i>Periodicity</i>	<b>16</b>
<i>Rational</i>	<b>16</b>
<i>Tuning</i>	<b>16</b>
<i>Harmonic Space</i>	<b>16</b>
<i>Pythagorean Tuning</i>	<b>17</b>
<i>Just Intonation</i>	<b>17</b>
<i>Temperament</i>	<b>18</b>
<i>Meantone Temperament &amp; Well Temperament</i>	<b>18</b>
<i>Equal Temperament</i>	<b>18</b>
<i>Cultural Hegemony</i>	<b>19</b>
<b>Bibliography</b>	<b>20</b>

## Introduction

This text investigates the harmonic dimension of music and the various social, cultural and political consequences that arise through the act of tuning and tempering harmonic space. While no singular musical domain can exist divorced from the rest (i.e., duration, rhythm, dynamics, spatiality, etc.), in order to examine its afflictions and possible remedies, this text focuses only on the harmonic domain and the severity of its influence over listeners. This text questions the standardisation of twelve tone equal temperament, the implications it has inflicted culturally, the capital agents it may serve, and the possible insights just tuning systems and alternate temperaments may provide.

This text was written, foremost, for the isolated islands of musicians and composers scratching at the realm of just intonation: may we collectively formulate a coherent vision to support our pursuit of harmonic destandardization so that future generations may be aware of (and inspired by) their choice of tuning and temperament. Depending on the anachronistic and cultural context, choosing to tune untempered can be a subversive and radical act. However, one must remember that only exercising this choice does not inherently make a tuned piece of music an instance of artistic activism. That would require the music to resonate within listening sonorous bodies who may then serve as a linkage point to other forms of intervention.

As this text is presented in an academic context, it is also a call for the academy to inform their students about the scientific properties of harmonic space and how to uniquely mold it beyond microtonal equal temperament. This text also welcomes readers who may not be familiar with such tuning systems and concepts but are interested in musical connections to cultural hegemony. If the reader is not at least vaguely familiar with the terminology listed in the table of contents, then it is advised that they review the terminology section prior to the point of departure.

Thank you Ellen Arkbro, Marcus Pal, Caterina Barbieri, Aaron Miller Rehm, Jan Börjeson, Gerhard Eckel, Mattias Sköld and Mattias Petersson for your participation, guidance, insights and support in my work.

## The Dominant Consensus <sup>1</sup>

The act of tuning is inherently a process of exclusion and glorification of infinite harmonic relations. When tuning systems are socially manifested as fossilised temperaments, a democratic consensus of priority, compromise and exclusion becomes culturally inflicted and normalised upon the harmonic series, and in turn reflects and affects emotional, social and political values of hegemony.

Every order is predicated on the exclusion of other possibilities. It is in that sense that it can be called 'political' since it is the expression of a particular structure of power relations. Power is constitutive of the social because the social could not exist without the power relations through which it is given shape. What is at a given moment considered as the 'natural' order - jointly with the 'common sense' which accompanies it is the result of sedimented hegemonic practices: it is never the manifestation of a deeper objectivity exterior to the practices that bring it into play.<sup>2</sup>

Similar to cultural signifiers such as architecture, which reflect the market, means of labour, confines of leisure, values of privacy, class systems and constructs of public space, the structuring of harmonic space also conditions the boundaries of emotional content and social archetypes, from which people relate via sound. Systems of labour, architecture, cartography, language, curriculum, temperament ... and so on, are the combinations of power relations around which a given society is structured to influence the confines of interaction, expression, and sensation.<sup>3</sup> It is rarely doubted that an architect's structure will shape and determine the parameters of a person's cognitive pathways depending on how they engage with a specific division of space, matter and social behaviour. But how do we acknowledge the implication temperament systems (*harmonic architecture*) have on a society's ability to perceive, identify and influence the complex structures of emotional understanding and social behaviour?

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<sup>1</sup> "Unveil All That Is Repressed By The Dominant Consensus" Chantal Mouffe, *Artistic Activism and Agonistic Spaces*. 2007, p. 4

<sup>2</sup> Chantal Mouffe, *Artistic Activism and Agonistic Spaces*. 2007, p. 2

<sup>3</sup> "Architecture should be understood not so much as a single building, or act of design, but as a symbolic system that profoundly contributes to the formation of individual experience. As discussed, like language, we can view architecture as forming the basis for an understanding of the development of personal identity; against architecture subjectivity is brought forward, for architecture fixes one into a certain ordering that goes beyond physical spatiality - or rather, it complicates such spatiality by rendering it symbolic and culturally coded. In other words, *architecture functions within the larger sphere of social values by partially representing a given bias*. Such representation occurs through the physical contours of spatial design; it literally dictates one's moments as a cultural and social body. In turn, architecture liberates the individual by allowing a conscious exertion of will (speech, articulation, reflection in language, and free movement, access and mobility through architecture, and by confining it to a set of values conventions of speech, limits of articulation, and the harnessing of free movement and access). Architecture frees the individual and traps him at the same time" Brandon LaBelle. *Background Noise: Perspectives on Sound Art*. 2006, p. 161

## Empty The Belief<sup>4</sup>

Temperament systems have played a crucial role in providing unique cultural information, not only concerning music, but also various structures and values in a given society. Until the standardisation of equal temperament, many meantone temperaments were implemented and differed depending on the place of a music. Instruments were tempered to suit castles or churches, mountains or seashores, a big city or a small village. Temperaments were utilised to reflect and condition the immediate reality of the listener and aid the purpose of their context. A pipe organ tuned Für ein grosse Stadt<sup>5</sup> (for a big city) barred more harmonic compromises similar to equal temperament in order to fulfil the high demands placed by the educated musicians and elite city listeners for key modulations and liberal instrument combinations. Whereas an organ tuned for Für ein Dorf (for a village) had a much narrower possibility for modulation and hindered certain instrument groups from playing with each other, yet it maintained pure 3rds and 5ths intended for the common uneducated musician to play during church services and to intuitively tune by ear.<sup>6</sup> Contextual instances such as these diverging meantone temperaments draw parallels between the complexity and simplicity of a society in regards to its implemented tuning system.

Since the distancing from Pythagorean tuning until the standardisation of twelve tone equal temperament in the mid 18th century, temperament discussions have tormented philosophical debates. European philosophers have long toiled over whether to subscribe to systems rooted in mathematical purities (modelled by natural truths whose objectivity is only culturally claimed) versus adapting to modern systems arbitrarily compromised by various social agendas. From Plato's declarations that perfect harmonious music shapes ideal citizens and harnesses divine insight, to Boethius' (and then later Kepler's) esoteric belief in the power of celestial harmony sourced from cosmic ratios, to Descartes insistence that understanding and pleasure may only derive from systems built on the mathematic purities of 5-limit just intonation, and then to Rousseau's resistance to equal temperament as a destructive sceptre of modernity which finally resulted in his own

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<sup>4</sup> "Verily, things are of necessity through their conception and belief. Then let us destroy or change conception, and empty the belief." Austin Osman Spare, *The Book of Pleasure (Self - Love)*. 1913, p 6

<sup>5</sup> Johann Georg Neidhardt, *Gänzlich erschöpfte, Mathematische Abtheilungen des Diatonisch-Chromatischen, temperirten Canonis Monochordi*, 1732

<sup>6</sup> Jan Börjeson, *Organ Tuner Interviewed by Kali Malone*. 2017, Stockholm: Enskilde Kyrka, 2017.

*Theoretical Well Temperament.*<sup>7</sup> The eventual standardisation of equal temperament emptied the belief upheld since ancient times, that the aesthetic products of humans were meaningless if they did not adhere to the laws of nature.<sup>8</sup> This transition of cultural belief displays how “every hegemonic order is susceptible of being challenged by counter-hegemonic practices, i.e. practices which will attempt to disarticulate the existing order so as to install another form of hegemony<sup>9</sup>”.

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<sup>7</sup> Noel David Hudson, *Abandoning nature : European philosophy and the triumph of equal temperament*. 2007  
Anicius Manlius Severinus Boethius, *Musica Universalis*. c540 CE.  
René Descartes, *Musicae Compendium*. 1618.  
Johannes Kepler, *Harmonices Mundi*. 1619.  
Plato, *Republic*. c380 BC.  
Plato, *Timaeus*. c360 BC.  
Jean Jacque Rousseau, “Tempérament”, *Dictionnaire de Musique*. Paris, 1765.  
Jean Jacque Rousseau, *Discourse on the Arts and Sciences*. London, 1751.

<sup>8</sup> Noel David Hudson, *Abandoning nature : European philosophy and the triumph of equal temperament*. 2007, p. 24

<sup>9</sup> Chantal Mouffe, *Artistic Activism and Agonistic Spaces*. 2007, p. 3

## Estrangement

The senses modify and evolve to absorb and reflect the social, political and cultural climate of a given time and place. In attempt to observe the senses in consequence with the division of labour, the reification of nature and the surmounting immersion of commodity production, reduction and exchange; one may see that the senses have been spliced apart and conditioned by market-aligned motives, resulting in a question of sensory alienation.<sup>10</sup>

Not only does man create societies and institutions in his own mind's image, but these in the end create him. This 'mental language' manifests itself as man's universal capacity not only to formulate structures, but also to submit his own nature to the demands of their structuring.<sup>11</sup>

It is of no doubt that the average 21st century composer, musician and listener is estranged from the sciences of the harmonic series and the basic concept of tempering harmonic space. This estrangement is concerning on a multitude of levels. Modern ears are foreign to the foundational structures of harmony, yet are made to believe that current western compositional methods and listening capabilities are more advanced and intricately organised than ever (a general trend of rationalisation that capitalist societies adapt as a means to accept and pursue massive standardisations that over time result in the extermination of ancient and specialised knowledge, labour and culture). Music workers and consumers consent to the governance of the equal tempered system, passively disregarding untempered harmonic relations that could prove to be liberating as they bare access to other psychological territories. However, the periodic pitfalls of equal temperament and the righteous limitations of just intonation shouldn't only be simplified to the aesthetic properties of their particular intervals, for these systems serve and represent a systemic power construct of sensory alienation that is much broader than itself.

An equally serious problem with twelve-tone equal temperament is that it supplies composers with an artificially simplified, one-dimensional model of musical relationships. By substituting twelve equally spaced fixed tones for a potentially unlimited number of tones, interconnected by a web of subtle and complex musical relationships, equal temperament not only impoverished the sonic palette of Western music, but also deprived composers and theorists of the means for thinking clearly about goal relationships, causing them to confuse close relationships with remote ones and consonances with dissonances.<sup>12</sup>

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<sup>10</sup> Sam Halliday, *Sonic Modernity*. 2013, p. 24

<sup>11</sup> Terence Hawkes, *Structuralism & Semiotics*. 1977, p. 14.

<sup>12</sup> David B. Doty, *The Just Intonation Primer*. 2002, p. 1

## Bondage To Formula <sup>13</sup>

Within the framework of capitalism and cultural hegemony, equal temperament has been a sincere success. From the illusion of intonation conflict resolution amongst instrument groups, to the production prosperity of the romantic era and the convenient standardisation of instruments brought by the industrial revolution — a musical infrastructure rooted in equal temperament rapidly conquered temperament debates and projected the musical framework for generations to come. Therefore it is no mystery as to why the discussion of temperament has been nearly absent from music education and popular culture during the last century, as irrational methods become invisible and excused when a profitable industry depends on them. It must also be acknowledged that the standardisation of the musical process via equal temperament has created an expansion of industry for music workers.

The adoption of twelve-tone equal temperament was strictly a matter of expediency. Equal temperament allowed composers to explore increasingly complex chromatic harmonies and remote modulations without increasing the complexity of instrument design or the difficulty of playing techniques.<sup>14</sup>

In the guise of intonation conflict resolution, the factory of the orchestra has grown to accept all instrument groups playing with each other and now composers have every orchestral instrument to utilise and put to work. Composers must delegate labour in order to justify employing all music workers in the orchestra, and at times their musical product is a reflection of this labour delegation rather than a vision of the music the composer may have intended. Equal tempered orchestral music is of course not the only music subject to this alienation, but serves as a prime example of the means of production depriving the composer of their right to envision beyond the parameters and goals that the encasing system has predetermined.

In the attempt to increase the production output and efficiency of composition, the standardisation of equal temperament disregarded and nearly erased the enormous variety of harmonic combinations that just intonation and older temperament systems provide. In doing so, 18th and 19th century composers using the equal tempered system quickly exhausted what few tonal resources were available in the twelve tone system, evoking an early 20th century exploration of extended techniques seeking liberation from and rejuvenation of the common-practice system.

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<sup>13</sup> “We are what we believe and what it implies by a process of time in the conception; creation is caused by this bondage to formula.” Austin Osman Spare, *The Book of Pleasure (Self-Love)*, 1913, p. 2

<sup>14</sup> David B Doty, *The Just Intonation Primer*, 2002, p. 4

[Twentieth century composers] have created a variety of essentially arbitrary systems, which, although they may seem reasonable in the minds of their creators, fail to take into account the capabilities and limitations of the human auditory system [...] Some theorists and composers did, in fact, advocate the adoption of new, microtonal tuning systems, but most of these proposals were for microtonal equal temperaments, such as quarter tones, third tones, sixth tones, or the like, which merely divided the existing twelve-tone scale into smaller, arbitrary intervals, and which made no improvement in the tuning of Western music's most fundamental intervals.<sup>15</sup>

While the sincere efforts of 20th century composers to disrupt the dominant hegemony of the common-practice system and install new postwar musical methods is recognised, Doty suggests that their replacement of extended equal temperament is unfortunately still rooted in the foundational structures that prompted their initial desire for emancipation. This is ultimately what hindered the longevity of their movement. If the cure for music's ailments lay in the foundational restructuring of a now inadequate tuning system, how is systemic change possible when the past 200 years have nourished a massive establishment that relies on equal temperament as a foundation of its structural rooting? This is not only a question for composers, but for the every facet contributing to the operation of music. How is it possible to invigorate change in a tonal monopoly if all resources are designed to fulfil an all encompassing agenda of equal temperament?

Since the standardisation of equal temperament, the vast majority of people may never experience music made from rational divisions of the harmonic series or hear periodic pitch. Attaining intellectual and experiential access with just intonation can appear difficult, especially since it is nearly absent from education and isn't valued in most instrument standards. However, there are actually many resources available to harness radical harmonic combinations beyond the confines of twelve tone equal temperament.<sup>16</sup> Alongside the tunable acoustic instruments (the voice, string instruments, wind and brass instruments), there are several options of open source software that recognise rational calculations as exact pitch, digital archives collecting essential texts and online forums sharing technique and troubleshooting assistance. There is also an increasing popularity of CV within hardware synthesisers offering an alternative control from the standard of equal tempered MIDI. Considering the availability of practical and technological resources, the implementation of justly tuned music is arguably the easiest it has ever been.

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<sup>15</sup> David B Doty. *The Just Intonation Primer*. 2002, pg. 5

<sup>16</sup> A suggested introduction to multiple harmonic spaces in just intonation: download a trial of the [Hayward Tuning Vine](#) (a software designed by Robin Hayward that presents a visual and aural representation of just harmonic space). Save ratio combinations and then implement them on whatever tunable instrument of choice. [SuperCollider](#) and [PureData](#) are recommended open source synthesis softwares to use for making music in just intonation.

## Cast Of Mind

*Cast of Mind* is my exam piece for the bachelors degree in electroacoustic composition. It was spatially presented over 29 channels at The Royal College of Music in Stockholm on April 28, 2017. The piece is comprised of chords in 7 limit just intonation played on woodwind and brass instruments by musicians Yoann Durrant, Isak Hedstjärn and Mats Äleklint. Initially this music was conceived with stable sawtooth waveforms in December 2016 and was later adapted for these acoustic instruments when presented with the opportunity of collaborating with saxophonist Yoann Durrant. For the progression of my studies in just intonation, it was a sound decision to explore the tuneable woodwind and brass instrument family after having previously written justly tuned music for string instruments, buchla modular synthesiser, and in the coding environments PureData and SuperCollider. I have also been eager to write for wind and brass instruments ever since hearing Arthur Russell's *Tower of Meaning* (Part 2, 1983), a piece that has been aesthetically influential for *Cast of Mind*.

The sheer difficulty of tuning in real time is heard in *Cast of Mind*. As the wind and brass instruments weave in and out of harmonic stability, the human struggle to reach and maintain precise intonation is exposed, addressing the ever-present contrast between “the idea of tuning and the reality of tuning”<sup>17</sup>. During the recording process, the instruments were recorded separately while individually intonating to a fixed, non-fluctuating sawtooth waveform. As there was zero leniency for pitch deviation, the slightest diversion from the fixed sawtooth waveform would produce extreme beatings in the musician's ear - making this a challenging task both physically and mentally for them. However, this struggle was not an initial theme when conceiving of the piece. After becoming so accustomed to the perfection and stability of machine generated oscillators, the fragility of breath generated harmony came as an initial surprise, yet over time this human aspect grew to become a precious element of the piece. During the recording and editing process I began my studies tuning pipe organs under the mentorship of Jan Börjeson. From our tuning conversations and practices I arrived to a humbled understanding and appreciation of the lively fluctuating nature of acoustic instruments, greatly influencing my approach towards working with and embracing this imperfectly human material.

When first working with the periodic sawtooth waveforms, the intention of unleashing a stable current of emotionally rich septimal intervals<sup>18</sup> was to see if

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<sup>17</sup> Jan Börjeson, *Organ Tuner Interviewed by Kali Malone*. Stockholm: Enskilde Kyrka, 2017.

<sup>18</sup> For more in depth reflections upon the emotive characteristics of septimal harmonic space consult Ellen Arkbro's bachelor thesis *Tuning to Tuning*, Stockholm, 2015.

consistent exposure to septimal harmonic space could trigger altered states of perception, excavating depths of empathy and furthering insights into emotional complexity. My specific interest in tonal experiences is due to their effectiveness in provoking emotional understandings; emotion is absolutely central to understanding what happens in us - our perceptions, belief systems, decision making, actions and desires. It is of course impossible to know if the music can achieve this lofty aim, as these experiences are completely subjective (even projected) and burrow into the areas of consciousness where language cannot reach. However, due to both the inconsistent harmonic stability of the acoustic instruments and the arbitrary rhythmical interplay arranged, this specific iteration of *Cast of Mind* did not achieve the same expectations that I set in the early compositional stages when using stable waveforms, but rather made way for its own.

I collected the harmonic ratios using the Hayward Tuning Vine, a graphic software that presents a visual and aural representation of harmonic space and separates the dimensions via colour, allowing the user to explore between the primes and experiment with harmonic combinations. After deciding upon the chords, I later developed the sequence through manual and generative operations in PureData. The intervallic sequence attached expresses the linear harmonic progression heard in the recording of *Cast of Mind*, however it does not contain temporal, rhythmic or dynamic information. Those parameters heard in the recording were intuitively arranged inspired by the fluctuating nature of material I recorded.

There are many possible temporal, timbral and sequential iterations of *Cast of Mind*. A person or ensemble playing this piece shall simply begin with the first chord and move on to the next chord on their own temporal will (other iterations I've made include sawtooth waveforms and bassoon which only play the first chord, such iteration is still within the confines of being *Cast of Mind*). In the recording process the musicians were instructed to hold a stable tone for the duration of their internal perception of 4, 6, 8, and 10 seconds. With the exception of a few cases, the musician's internal sense of time rarely aligned with the clock time and fluctuated depending on their current expenditure of breath. For instance, a mid to high range pitch instructed to be held for 8 perceived seconds was stretched to 12 clock seconds (being in a comfortable range of breath control), and a very low pitch (requiring lots of breath) instructed to be held for 8 perceived seconds was deflated to last only 4 clock seconds.

Throughout the piece time stretches and shrinks. Time is understood as the shifting rate of breath, which effects the way partials flow and transform through operations, producing a variety of harmonic combinations and sensational impressions. The listener or performer may become caught in the gravitational pull of this musical time; despite their own wishes and temporal conditioning, their internal sense of time

increasingly becomes structured around the dilation<sup>19</sup> and deflation<sup>20</sup> of musical time-frames. *Cast of Mind* exercises the use of dilated time as a core compositional element, the use of permutation interplay to condition and challenge aural memory, and the use of slowness, continuity and septimal harmonic space as a force of psychological impact.

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<sup>19</sup> Flood the harmonic spectrum with layers of complex waveforms that have varying rates of oscillation and intervallic densities.

<sup>20</sup> Constrict the harmonic spectrum and simplify the rate of oscillations and intervallic combinations.

*Cast of Mind - Intervallic Sequence**Kali Malone*

A. Saxophone I	A. Saxophone II	B. Clarinet I	B. Clarinet II	Trombone I	Trombone II
1/1	4/7	4/7	3/7	3/7	2/7
4/3	8/7	8/7	4/7	4/7	8/21
8/7	8/9	8/9	16/21	16/21	16/63
21/16	7/8	7/8	7/12	7/12	7/16
8/7	8/9	8/9	16/21	16/21	16/63
4/3	4/3	8/7	4/7	4/7	8/21
1/1	4/7	4/7	3/7	3/7	2/7
4/3	8/7	8/7	4/7	4/7	8/21
21/16	7/8	7/8	7/12	7/12	7/16
8/7	8/9	8/9	16/21	16/21	16/63
4/3	8/7	8/7	4/7	4/7	8/21
18/7	3/2	3/2	9/14	9/14	3/7
12/7	9/7	9/7	8/7	8/7	8/21
63/8	18/7	18/7	4/7	4/7	3/7
21/4	63/16	63/16	6/7	6/7	4/7
63/8	18/7	18/7	4/7	4/7	3/7
63/16	8/7	8/7	16/21	16/21	16/63
21/4	63/16	63/16	6/7	6/7	4/7
63/16	8/7	8/7	16/21	16/21	16/63
18/7	3/2	3/2	9/14	9/14	3/7
12/7	9/7	9/7	8/7	8/7	8/21
63/16	8/7	8/7	16/21	16/21	16/63
21/4	63/16	63/16	6/7	6/7	4/7
63/16	8/7	8/7	16/21	16/21	16/63
63/8	18/7	18/7	4/7	4/7	3/7
63/16	8/7	8/7	16/21	16/21	16/63
12/7	9/7	9/7	8/7	8/7	8/21
18/7	3/2	3/2	9/14	9/14	3/7
4/3	8/7	8/7	4/7	4/7	8/21
1/1	4/7	4/7	3/7	3/7	2/7
4/3	8/7	8/7	4/7	4/7	8/21
21/16	7/8	7/8	7/12	7/12	7/16
8/7	8/9	8/9	16/21	16/21	16/63
4/3	4/3	8/7	4/7	4/7	8/21

*Cast of Mind* is dedicated to the victims and survivors of the 2016 Ghost Ship tragedy. This piece was created for and first performed at The Benefit Show For Oakland Fire Victims presented by Rhinocerospolis, Glob and the MCA Denver at the Aztlan Theatre in Denver, Colorado on December 17, 2016.

# Terminology <sup>21</sup>

## Periodicity

Tones of definite pitch are the products of periodic vibrations - motions that repeat in a consistent pattern at a consistent time interval [...] When struck with sufficient force by such vibrations, our eardrums move in and out in a manner corresponding to the variations of pressure, setting up a chain of events in the middle and inner ear which ultimately results in the conversion of these mechanical vibrations into nerve impulses which the brain interprets as sound.<sup>22</sup>

## Rational

A value expressed as a ratio of whole numbers (ex: 2/1, 3/2, 4/3, 5/4, 5/3....)

To calculate frequency in Hz multiply the fundamental frequency by the ratio.

## Tuning

Intervals which may be determined exactly by ear, given an appropriate timbre and register, are for the most part representable by small number ratios of the first 28 natural numbers [...] Tuning an interval precisely means establishing a stable periodic pattern, or signature, which characterises its sound.<sup>23</sup>

## Harmonic Space

The *space* of pitch perception is multidimensional and called harmonic space.<sup>24</sup> The dimensionality of an implied harmonic space corresponds to the selected prime numbers required to realise frequency ratios. Each prime number has a defining periodic, aesthetic and dimensional characteristic.

The harmonic space implied by a “Pythagorean” scale, based exclusively on fifths (3/2), fourths (4/3), and octaves (2/1), is two-dimensional, since the frequency ratios defining its constituent intervals involve only powers of 2 and 3 (see Figure 1). The harmonic space implied by a “just” scale, which includes natural thirds (5/4, 6/5) and sixths (5/3, 8/5), is three-dimensional, since its frequency ratios include powers of 5, as well as 2 and 3. A scale incorporating the natural minor seventh (7/4) and other “septimal” intervals would imply a harmonic space of four dimensions, and Partch’s “11-limit” scale would imply a harmonic space of five dimensions (corresponding to the prime factors 2, 3, 5, 7, and 11) — if (and only if) we assume that all of its constituent intervals are distinguishable.<sup>25</sup>

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<sup>21</sup> This terminology does not provide an extensive overview of music theory, history, or acoustics. For further investigation consult the work of Herman Helmholtz, Harry Partch, Ben Johnston, James Tenney, Maryanne Amacher, Marc Sabbat, David Doty, La Monte Young and Tony Conrad.

<sup>22</sup> David B. Doty, *The Just Intonation Primer*, 2002, p. 9

<sup>23</sup> Marc Sabbat, *Microtonally Extended Just Intonation: Notation, Tuneable Intervals and Aggregates*, 2016, p. 2

<sup>24</sup> James Tenney, *John Cage and the Theory of Harmony*, 1983, p. 21

<sup>25</sup> James Tenney, *John Cage and the Theory of Harmony*, 1983, p. 22

## Pythagorean Tuning (c. 560 - 480 B.C.E.)

Pythagorean tuning is constructed by tuning all intervals by purely intonated perfect fifths ( $3/2$ ). To make a scale, one begins with a note then produces perfect fifths above it for 7 octaves, generating a 12-tone chromatic scale that finishes at a note about 21.5 cents ( $81/80$ ) away from the starting note. This  $81/80$  intervalic difference between the starting and ending note is called a *syntonic comma*. Pythagorean tuning was developed in the sixth century BC through a series of experiments with monochords by Pythagoras. The studies were conducted by dividing a single string to  $3/2$  to generate a pitch a fifth above the fundamental note, however through this method the major thirds were very sharp and the minor thirds were very flat. Therefore, thirds and sixths were thought to be dissonances until the additions of just intonation altered the primary tuning system in the fifteenth century. In the middle ages, Pythagoras' tuning system was the primary ancient greek tuning system known in detail. Coined as *universal harmony*, the Pythagorean theory of harmony based on relationships of small number integers was then included in the teachings of natural sciences.<sup>26</sup>

## Just Intonation

History aside and most simply defined, just intonation is any system of tuning in which the frequency of all intervals can be represented using (preferably small) whole number frequency ratios.<sup>27</sup> Unlike Pythagorean tuning which strictly uses harmonics derivative of the 3rd prime, extended just intonation can conceivably construct harmonic space using all prime numbers. 3 limit, 5 limit, and 7 limit just intonation are the most perceptibly distinguishable harmonic spaces, after surpassing these lower prime numbers the harmonicity may appear indistinguishable as their tolerance range decreases.

Whether all such intervals among a given set of pitches are in fact distinguishable depends, of course, on the tolerance range, and it is this which prevents an unlimited proliferation of "dimensions" in harmonic space. That is, at some level of scale- complexity, intervals whose frequency ratios involve a higher-order prime factor will be indistinguishable from similar intervals characterised by simpler frequency ratios, and the prime factors in these simpler ratios will define the dimensionality of harmonic space in the most general sense.<sup>28</sup>

Just intonation can be thought of as an extension of Pythagorean tuning, with its main difference being the inclusion of the 5th prime, contributing the just major third ratio ( $5/4$ ) which greatly conveniences the process of obtaining pitch. For instance, the E note could now be located directly from C instead of ascending by fifth for over two octaves. Similar to Pythagorean tuning, Just intonation is an untempered scale constructed from pure tones derived from the unequally divided octave by use of small number, rational intervals.

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<sup>26</sup> Claudio Di Veroli, *Unequal Temperaments: Theory, History, and Practice*, 2013, p. 18

<sup>27</sup> <sup>27</sup>David B Doty, *The Just Intonation Primer*, 2002, pg. 1

<sup>28</sup> James Tenney, *John Cage and the Theory of Harmony*, 1983, p. 22

## Temperament

The stylistic distribution of the syntonic comma in various proportions throughout the octave, rendering certain keys playable and capable of modulation while compromising the tuning of other tones that absorb the comma.

## Meantone Temperament & Well Temperament

Throughout the late fifteenth century and nineteenth century, many different tempered tuning systems were developed. Temperament was a common craft that musicians and composers utilised to their individual style, although the majority of tuning systems fell under the general principles of meantone temperament or well temperament. The defining aspects of meantone temperament and well temperament are the principles of regularity and restriction in regards to how the temperaments disperse the syntonic comma over the octave. Meantone temperament is regular (only one odd sized 5th, being the tempered syntonic comma) and restricted (modulation is limited to three sharps and two flats due to the existence of wolf tones - the tones that absorb the syntonic comma in the act of tempering. Due to their compromised tuning the wolf tones were considered to be unmusical howls). Well temperament is irregular (with more than one odd sized fifth) and unrestricted (has complete freedom of modulation, most similar to today's equal temperament but without an equally divided octave).<sup>29</sup>

## Equal Temperament

The predominant tuning system for the past 200 years has been equal temperament, which sounds radically different from older systems of temperament as it attempts to satisfy three incompatible elements- true intonation, complete freedom of modulation, and convenience for keyed and fretted instruments to play alongside other instrument group. Equal temperament only achieves perfect intonation on the octave interval, and aside from this interval, all other interval ratios have compromised tuning. This due to the division of the octave into twelve equal parts in order to achieve freedom of key modulation. In equal temperament the syntonic comma must be compensated for in order to achieve freedom of key modulation, therefore every interval except the octave is mistuned.<sup>30</sup> The advantage of equal temperament over meantone or well temperament is that every key is functional - "*equally good or equally bad*".<sup>31</sup>

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<sup>29</sup> Kyle Gann, *An Introduction to Historical Tunings*, 1997

<sup>30</sup> "The equally tempered 5th is approximately two cents narrower than the just perfect fifth, whereas the equally tempered major third is approximately fourteen cents wider than the just third, and the equally tempered minor third is approximately sixteen cents narrower than the just minor third" David Doty, *The Just Intonation Primer*, 2002, p. 4

<sup>31</sup> David B Doty, *The Just Intonation Primer*, 2002, p. 4

Technological innovations of the 1800's greatly influenced the tuning of keyboard instruments. Improvements in metallurgy initiated the creation of more powerful instruments. Cast iron was employed to withstand the strain of much tighter wires, inspiring the development of the modern piano consequent of the industrial age. With a societal and cultural infatuation with science and mathematics, equal temperament was embraced as a mathematically reasonable, convenient and convertible tuning.

In comparison to the history of temperament, twelve - tone equal temperament is a relatively recent development in tuning history that has rapidly defined the sound of our present day music. Although it has been theorised about in Europe and China for centuries, it was never utilised because the general consensus was that it sounded colourless and dissolved the character of individual keys.<sup>32</sup>

### **Cultural Hegemony<sup>33</sup>**

The cultural and social identities to which an individual subscribes are constructed out of symbols and archetypes which the individuals themselves didn't create. Identity is given by society rather than created by the individual. The State and ruling class infiltrate forms of social and cultural practice to reinforce their strength and normalise their political and economic agendas. Power is wielded to create cultural ideas that condition civilians who then, through their culturally assembled belief systems, reinforce the initial power structures.<sup>34</sup>

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<sup>32</sup> Kyle Gann, *Tuning in Pre-20th Century Europe*, 1977

<sup>33</sup> The concept Cultural Hegemony was developed by Italian Marxist Antonio Gramsci in the early 20th century while in fascist Italian prison

<sup>34</sup> Chantal Mouffe, *Artistic Activism and Agonistic Spaces*. 2007. p. 2

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