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The Grail of Harmony: Just Intonation Vs. Equal Temperament

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An Annotated Bibliography

Abstract. Western art music is founded upon the system of tuning known as *equal temperament.* The European continental based harmonic science which defines classical music was effectively established upon the science of this system. The opposite system is that of *just intonation,* of which the method of tuning yields scales with partials, tones smaller than those in existent in common practice, commonly referred to as microtones. Eastern music is founded upon this system. There has been debate on both systems sparsely throughout history since earliest recorded antiquity. Numerous performers, scholars, theorists, and scientists have observed problems with common practice *equal temperament.* Advocates for *just intonation* address limitations *equal temperament* causes on the ear in addition to composition. The following annotated bibliography brings to light the benefits of music founded upon *just intonation* in comparison to the limitations of *equal temperament* through the work of musicians, composers, scholars, philosophers, and scientists.

1.Barbieri, Patrizio. *Enharmonic: Instruments and Music 1470-1900.* Rome: Il Levante Liberia Editrice, 2008.

On the subject of *just intonation,* its instruments and pioneers, Patrizio Barbieri's monograph is an indispensable resource. As a musicologist and graduate of the University of Rome in electronic engineering Barbieri has left an indelible mark on the field of study of temperament and tonality. The author has also received the honorary Frances Densmore Prize by the American Musical Instrument Society for his work in 2008.

In *Enharmonic: Instruments and Music 1470-1900* Barbieri illuminates the place of *just intonation* and microtonality termed, the enharmonic genus, one of 3 defining genera of western music, from the given centuries. He does not make the point of superiority of *just intonation* over *equal temperament,* but rather its special place in western art music through its theorists, instrument makers, and composers. In addition to illustrating the vast array of systems of tuning such as the Pythagorean mean tone, among others, to achieve *just intonation* and pure intervals he makes a key point of the use of partials in music history: ornamental, as in non-harmonic tones, and actual harmony. Barbieri successfully brings to light a goldmine of potentiality in western harmony that has been widely overlooked. While he does answer questions around the obscurity of the practice he rather focuses on the many contributions in Italy and abroad. He uses medieval theorists as well as Renaissance contrapuntists such as Gioseffo Zarlino and Nicola Vicentino, facsimiles of ancient tuning charts, photographs of restored enharmonic

constructed harpsichords and organs and stringed instruments, and excerpts of compositions demonstrating partials and commas of the diesis as evidence. The book comes with an accompanying CD of midi recordings of each of the musical excerpts.

2. Bartel, Dietrich. "Andreas Werckmeister's Final Tuning: The Path to Equal Temperament." *Early Music,* 43, no.3 (2015): 503-512.

Bartel has done extensive into the life work of Andreas Werckmeister, having studied the baroque tuner's treatises and done numerous translations with commentaries. Bartel is an organist and professor at Canadian Mennonite University in Winnipeg and holds a Ph.D from the Albert Ludwigs Universitat in Freiburg, Germany. Bartel champions *equal temperament* as the superior tuning and argues that Werckmeister himself also did so later in his career. The author makes a convincing case that Werckmeister favored *equal temperament* in the end through examination of his latter treatises such as *Paradoxal-Discourse.* Bartel cites Werckmeister stating he wishes "to institute a temperament in which all 5ths are tempered by 1/12, major 3rds by 2/3, and minor 3rds by ¾ of a comma, resulting in all consonances possessing equal temperament…."[1] The author constructs his argument by extracting statements of Werckmeister advocating *equal temperament.* He cites Werckmeister's recognition of conveniences offered by equal octave division, but is unable locate any specific statement regarding *equal temperament's* superiority. Bartel indirectly implies Werckmeister's considerations for the demands of the keyboard perfomers, but fails to mention Bach, Buxtehude, and others of his day. He also cites Werckmeister's theological thoughts on God, nature, and tuning, attempting to make another case for Werckmeister using religion as validation for the superiority of *equal temperament.* While Bartel makes a convincing case for Werckmeister's role in the hegemony of *equal temperament,* he fails to factually state its superiority verbatim.

3. Blackwood, Easley, composer. *Twelve Microtonal Etudes for Electronic Music Media.* Released 1980, Not on label. Lp.

Easley Blackwood is an accomplished composer of music utilizing microtonality and associated tunings. He was educated at Yale University and later studied in Paris with noted composer/teachers Olivier Messiaen, Paul Hindemith, and Nadia Boulanger. Later he became professor of music at the University of Chicago. He has authored a number of theory books.

With synthesizers Blackwood evokes an orchestra performing thematic variations containing striking chromaticism. He uses percussive accompaniment including bells and others. The composer utilizes polyrhythms such as 5/8 against 3/8 to heighten some of the harmonies

[1] Bartel, 503

containing partials. He makes use of timbres offered by the electronic instruments, nearly infinite, appropriate to the moods of the themes throughout. Through the employment of chromatic extremities within conventionally derived harmonies, triple sharps, double flats, commas, etc., Blackwood demonstrates a new frontier in western harmony through subtractive synthesis. He shows a way in which *just intonation* can be achieved in a functional way electronically. He also manages to bridge *equal temperament* at times by means of such tuned synthesizers in close proximity to those tuned in *just.*

4. Cho, Gene Jinsiong. *The Discovery of Musical Equal Temperament in China and Europe in the Sixteenth Century.* Studies in the History and Interpretation of Music, vol. 93. Lewiston, New York: The Edwin Mellen Press, 2003.

Gene Jinsiong Cho presents a unitarian case on *equal temperament* in world music. Taiwan born with a Ph.D. in Music Theory from Northwester University, with additional degrees in musicology and composition, Cho is a renaissance man with studies in philosophy, theology, science and economics. *The Discovery of Musical Equal Temperament* verifies these credentials as he examines evidence of music in the ancient B.C.E to the common era through lesser know political, religious, and economical historical events. An advocate of *equal temperament*, with one of his many arguments in its favor being "for the purpose of facilitating transposition of music."[2] Cho makes the case that *equal temperament* was discovered in China and Europe at approximately the same time, within the 16th century. He delineates the life and work of Zhu Zaiyu, a mathematician of the Ming Dynasty along with Christian missionary Matteo Ricci and Dutch mathematician and engineer Simon Stevin. Zhu and Stevin were both believed to have found a mathematical formula for the equal tempered scale.[3] Cho manages to unearth evidence of flaws in Stevin's work with more legitimacy in Zhu's. While there is evidence in primary documents of Stevin this question remains unanswered as none of the evidence is concrete enough. Ricci and the Jesuit missionaries would being Chinese temperament back to Europe but the evidence defining *equal temperament* in common practice today is vague. Nevertheless, Cho's monograph succeeds greatly in presenting the interplay of east and west establishing the system known today as *equal temperament.*

5. Duffin, Ross W. *How Equal Temperament Ruined Harmony (and Why You Should Care).* New York: W.W. Norton and Company, Inc. 2007.

Duffin's bold statement on a problem with western music is balanced by humorous, sarcastic, and rhetorical writing. A musicologist and professor of historical performance practice,

[2] Cho, 4-6
[3] Ibid, 4

Duffin received his master's and doctoral degrees from Stanford University. Duffin doesn't make *just intonation* as the one and only, the truth, but rather than *equal temperament* in its dominance of western harmony has harmed the ear by causing limitations in composition, performance, and understanding music, that it should not be the only system in use. Early on in illustrating this argument he uses former Cleveland Orchestra conductor Christoph von Dohnanyi with the adage "what most musicians don't know *has* hurt them, along with injuring the music they make."[4] In the anecdote Duffin recalls Dohnanyi's preparation for a farewell performance of Beethoven's 9th Symphony. In the rehearsal, despite several run throughs, he couldn't be satisfied with the transition of a D minor to a Bb major, a simple major 3rd. Duffin then boldly asserts that "It's all wrapped up in recent evolutions in musical performance and teaching, the result of decades of delusion, convenience, ignorance, conditioning, and oblivion."[5] He references Pablo Casals to support his claim in the late maestro's advocation for "expressive intonation," being the practice leading tones tuned higher or lower in position to their resolutions than in common practice *equal temperament.*[6] The author delineates the principles of math and music to prove his point through the ratios that define intervals. He identifies the major third as the primary problem due to the vibrational width of the triad in comparison to the "acoustically pure 5:4 major thirds."[7] With his humorous style he likens the width of it to an elephant and states "some people claim to prefer the elephant; they have grown to like elephantine thirds."[8] He further provides accompanying comic illustrations on this other points throughout the book. Pragmatically speaking Duffin doesn't offer solutions to the problem, but rather offers his argument for musicians today to consider, to be open to other tunings as different modes of expression for composition and performance.

6. Mathieu, W.A. *Harmonic Experience: Tonal Harmony from Its Natural Origins to its Modern Expression.* Rochester, Vt: Inner Traditions International, 1997.

Mathieu's monograph is both a study on *just intonation* and *equal temperament* as well as theory and practice book. While recognizing problems with *equal temperament* as the sole system, observing that "the accumulated result of centuries of impure, approximate tunings has given our ears a kind of jet lag, a condition of aesthetic depletion," he nonetheless sees its value as evidence by the "splendid body of music" it has created.[9] He is of the opinion that the two should co-exist harmoniously and be used as colors on the artist's palette. He also feels that, in esoteric terms, the rejection of "pure intervals" of *just intonation* in favor of "impure intervals" of *equal temperament* is a reflection of man's disconnection to the natural world today. Like Partch he emphasizes the importance of human experience behind the act of music

[4] Duffin, 16
[5] Ibid, 16
[6] Ibid, 19
[7] Ibid, 27
[8] Ibid, 29
[9] Mathieu, 1

making….feeling harmonies. The book is academic with its research in conflicts in hierarchical tuning systems, philosophical with the author's esoteric doctrine on bodily and spiritual experiencing of music, theoretical with numerous exercises in conventional harmony(cadences formulae, modulations, etc.), analysis, and the employment of commas and partials in composition. Mathieu's book is both complete and pragmatic. While not offering extensive research on the history as other scholars have, he delivers potent information with detailed exercises for practice. He answers the question on the superiority of *equal temperament* with the question of why is just intonation not taught? He observes that music teachers have been conditioned solely with *equal temperament* and thus "feel threatened" by *just intonation.* He also offers a subjective statement that "the west is not a humble culture."[10] In addition to the numerous detailed exercises for experiencing and composing music he offers a list of advice such as investing in "weird modes" and focusing on self-trust while absorbing the rules of conventional music theory. Mathieu's vast range of knowledge and holistic approach to harmony makes sense with his varied background as a teacher, performer, and composer…having studies composition with William Russo, Easley Blackwood, Hamza El Din, arranged and composed for the Stan Kenton and Duke Ellington orchestras, and taught at the San Francisco Conservatory of Music and Mills College.

7. Partch, Harry. *Genesis of a Music.* 2nd ed. New York: Da Capo Press, 1979.

Harry Partch's seminal work on his theory of music is essential for all scholars of *just intonation.* In *Genesis* Partch reveals a deeply personal motive for a theory of music alternative to the standard 20th century classical and previous. He identifies with ancient Greek culture and religion, claiming to be in direct contact with the deities and placing importance of the "realization of the *daimon."*[11] The book is a combination of Partch's take on music theory in his own translated/devised system of *just intonation,* his philosophical reasons revealing a discontent with common practice *equal temperament*, evidence of historical practice through diagrams of tunings and interval ratios as well as referencing ancient Greek philosophers and mathematicians. In one section of interval ratios he displays a diagram of the 3 ancient Greek genera of Ptolemy…..the enharmonic, chromatic, and diatonic, with ratios identifying locations of the tetrachords. Partch's authority lies solely in his word and his accomplishments. He was largely self-educated, a voracious reader, and was exposed to music and instruments from a very young age. His book also contains sections on his invented instruments with lengthy descriptions on use and temperament. He explains the problems of modern day western music from both a philosophical and music theory point of view. Despite Partch's presentation of a well, self-educated man his writing is at times incoherent. Like some other 20th century music theorists and composers, Partch places importance on experiencing music through the natural world around.

[10] Mathieu, 516
[11] Partch, xvi

8. ———*Revelation in the Courthouse Park.* Conducted by Danlee Mitchell. Recorded at the Great Hall, University of the Arts, Philadelphia, Penn., October 12, 1987. The American Music Theater Festival Production. Tomato. R2 70390, 1989. 2 CDs.

Revelation is arguably the magnum opus of the composer Harry Partch, requiring his full body of originally invented instruments, capable of exuding the power of the mythical e*thos* of ancient Greece in the eyes of the composer. It is an adaptation of the ancient play the *Bacchae of Euripides.* Partch demonstrates his acoustically derived tuning theory in *Genesis of a Music* to full extent accompanied by his full body of imaginatively conceived instruments in a full opera. Less a merging of the modern day western art tradition, it serves as a work of musical art in the nearly lost annals of music history intended to elicit an individual experience on the listener. In between arias and operatic themes chant to Greek deities accompanied by microtonal harmonies create exotic atmospheres, while timbres of wind sections at times evoke the modern day symphony. The opera shows the full scope of the composer's vision of harmony, timbre, and theology and philosophy.

9. Randel, Don Michael. *The Harvard Dictionary of Music,* s.v. "Just Intonation," 4th ed. Cambridge, Massachusetts: The Belknap Press of Harvard University Press, 2003.

Randel's entry in *The Harvard Dictionary of Music* provides a replete overview of *just intonation.* He begins by defining the method of the tuning of a primary interval in the harmonic series yielding acoustically pure intervals, particularly 3rds and 5ths.[12] He further explains how such naturally derived tuning results in unstable, or unequal octaves. Like many scholars he cites Zarlino's work solution of "two different tunings for one or more pitches."[13] He notes the complexity required for an instrument create such sonorities and the problem posed of common practice modulation as well as transposition in tonal harmony."[14] He observes the most ancient and obscure western theorists whom championed *just intonation* such as Theinred of Dover and Walter Odington. He also cites the Bartolomeo Ramos de Pareja as "the earliest theorist to publish a complete just tuning,"[15] but does not state the known title nor any citation or reference on it. He concludes the entry on 20th century composer pioneers of *just intonation* mentioning luminaries such as Partch and La Monte Young. The definitions and methodical and historical overviews the author provides are informative, but he does not explain the mechanics, or nuts and bolts, of the methods for tuning in *just intonation*. He provides a helpful bibliography at the end for further research on his findings.

[12] Randel, 440
[13] Ibid, 440
[14] Ibid, 440
[15] Ibid 440

10. Reinhard, Johnny. *Bach and Tuning.* New York: Da Capo Press, 1979.

Microtonal composer, bassoonist, founder of The American Festival of Microtonal Music, Inc., and professor of music at New York University, Reinhard has collaborated with numerous musicians in the world-wide *just intonation* community. He has also reconstructed the *Universe Symphony* by Charles Ives. In *Bach and Tuning* Reinhard makes a case that Bach favored *just intonation* composed in it. Reinhard begins by examining the baroque maestro's family and associations. Johann Gottfried Walther, a cousin and close friend, and Andreas Werckmeister, are at the core of the composer's involvement with microtonality. Werckmeister famously authored a tuning treatise entitled *Musicalische Temperatur*(1691). Reinhard recognizes the birth of well temperament the harmonic geography of the keyboard allowing for virtuosity and ease of execution through all 24 major and minor keys as opposed to the previous systems of meantone temperaments.[16] He further notes that in the period of transition from the unequal scale construction of early Renaissance keyboards the meantone commas still favored by composers could only be performed by instruments such as the violin or flute.[17] With the onset of the Baroque period Walther based a system of microtonal notation based on the tuning of Fabio Colonna.[18] While there remains no concrete evidence through surviving manuscript or publishings of Bach's having composed in *just intonation*, Reinhard provides the evidence of Bach's having used Werckmeister's tuning III containing partials in the scale division. He states that Bach's statement in the *Well-Tempered Claivier* "Through all Tones and Semitones would have a "special meaning."[19] Reinhard succeeds in making compelling points through copious references of other scholars' research through historical records, letters, and other surviving primary sources.

11. Muzzulini, Daniel. "Isaac Newton's Microtonal Approach to Just Intonation." *Empirical Musicology Review.* 15, no.3-4 (2021):223-248.

It has been long been understood in the academic community that Isaac Newton had some involvement with music in his work. Musicologist, mathematician, information technologist, and expert in Schenkerian analysis, Daniel Muzzulini of Zurich University of the Arts offers illuminating findings on Newton's theory centered on temperament. At the time of his death Newton had in his possession an unpublished notebook of a treatise on tuning. Newton's proposition was to divide the *just intonation* system into equal divisions of the octave(EDO),

[16] Reinhard, 9
[17] Ibid, 12
[18] Ibid, 12
[19] Ibid, 117

specifically, octave divisions into 53 and 120 equal parts.[20] Muzzulini uses software such as least square deviations to calculate precisely Newton's formulae. He notes that Newton "had accurate tables of (base 10) logarithms at his disposal and he used them to measure just intonation intervals with 12-EDO semitones, but he had no powerful computers and software."[21] Muzzulini references Descartes extensively citing his *Compendium Musicae* which Newton partly based his upon. The author connects the principles of this work, tracing the dots Euclid and Boethius. He also notes Guido of Arrezo's use of Pythagorean mean tone in overlapping hexachords.[22] The article reveals astute findings on temperament, through the author's application of electronics with theory. He offers functional systems of tuning in *just intonation* for musicians and scholars, as well as history. The systems are, however, of his interpretation, thus the reader would be advised to consult with the manuscript of Newton's work as well as other primary sources.

12. Walker, D.P. "Kepler's Celestial Music." *Journal of the Warburg and Courtauld Institutes,* 30 (1967): 228-250.

In his article on Johannes Kepler and his system advocating *just intonation,* D.P. Walker explores esotericism as a primary motive, in the medieval view of music as well as Pythagorean principles. Walker makes a case for "celestial harmonies" in ancient Greek philosophy being more audible in the pure thirds and sixths of *just intonation.*[23] Walker also observes that Kepler's tuning system for consonances is based on the ratios of geometrical patterns as opposed to numerically derived ratios.[24] Through identifying Kepler's medieval philosophy and practice of music theory he seeks to use metaphysical principles and natural laws to justify *just intonation.* He also observes the use of polyphony in Kepler's system. Although bringing subjective ideologies into the justification of an alternate system of musical temperament, he states an "objective validity of Kepler's celestial harmonies,"[25] in that Kepler would derive ratios from the sun and planetary orbits to construct consonant harmonies and, effectively, the *music of the spheres.* Although Walker expresses a preference for *just intonation* regarding the performance of "celestial harmonies" he nevertheless recognizes the "triumph of equal temperament as the ideal intonation" for modulation and ease of navigation through multiple tonal centers."[26] Walker references Kepler's cosmic musical treatise *Harmonice Mundi extensively* and makes for a thought provoking statement on Kepler's geometrically derived musical ratios for *just intonation* superior to that of the universal triadic sequence in Plato's *Timaeus* in that geometry is physical and that numerically derived ratios are merely

[20] Muzzulini, 223
[21] Ibid, 224
[22] Ibid, 225
[23] Walker, 228
[24] Ibid, 228
[25] Ibid, 229
[26] Ibid, 232

continuous."[27] The author succeeds in demonstrating Kepler's mastery of both geometry and mathematics by citing numerous tables of ratios and mathematical formulae and their role behind music. He weaves a holistic tapestry of *just intonation* temperament with an esoteric, Pythagorean-like doctrine as its foundation. Although clearly in favor of Kepler's work the use of *just intonation* for capturing the harmonies of the heavens, Walker identifies some problems with it in terms of polyphony. Walker fails to find a concrete way of putting Kepler's *just intonation* into functional polyphonic practice. Nevertheless, the possibilities elicited by the system corresponding to an ancient world-view offers a fascinating alternative way of understanding music. Walker writes in the voice a of modern-day humanist. Although not a musicologist, Walker wrote extensively on music in his work as author of western occultism. He was educated at the University of London and later chair of the History of the Classical Tradition at the Warburg Institute. His books on western esotericism, many of which highlight music, are regarded as among the most important in the field of the 20th century.

[27] Ibid, 236