UNIVERSITY OF ALBERTA

AN ANALYSIS OF TUNINGS AND TEMPERAMENTS IN SIXTEENTH- AND SEVENTEENTH-CENTURY ENGLISH MUSIC

BY ©

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The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "An Analysis of Tunings and Temperaments in Sixteenth and Seventeenth Century English Music," submitted by Lorne D. Pankratz in partial fulfillment of the requirements for the degree of Master of Music in Music Theory.

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Abstract

This study examines the discrepancies that occur when two diversely-tuned instruments are combined in the same piece. Keyboards, usually tuned to some shade of meantone temperament, and viols, normally equal-tempered, exhibit noticeable dissimilarities when played together. The combination of these instruments is explored with emphasis on sixteenth-century Italian and seventeenth-century English music. Chapter One provides an overview of the comments and suggestions pertaining to this problem by theorists like Giovanni de' Bardi and Hercole Bottrigari.

A rivalry between John Hothby and Bartolomeo Ramis de Pareia in fifteenth-century Italy may have influenced Dionisio Memo, who was appointed to the court of Henry VIII in 1516. Memo's presence may have persuaded the English musician to use the new temperament; however, to gain a clearer understanding, selected works by John Redford (ca. 1530) and William Byrd (ca. 1570) have been analyzed. Byrd's "Pavane No. 4" has been recorded in Pythagorean intonation and various shades of meantone temperament.

Chapter Four begins with an examination of mid-sixteenth-century Italian music; it is here where the first pieces employing viol and keyboard were composed by Diego Ortiz. Performance suggestions by this composer indicate that he may have been aware of the problem of tuning discrepancies. The focus shifts to seventeenth-century English ensemble pieces by John Jenkins and

William Lawes. Jenkins's keyboard lines are viol reductions that contain numerous tuning discrepancies, whereas Lawes creates independence between the two instrument groups, overcoming many of the problems. "O felici occhi miei," by Ortiz, *Fantasia-Suite 5* by Jenkins, and a "Pavan" by Lawes have been recorded combining equal temperament and various meantone shades.

The analysis shows how the choice of a specific shade of meantone temperament, the duplication of certain voice parts, the register, and the choice of continuo instrument can determine the degree of tuning dissimilarity. These conclusions may also guide the performer in recreating a performance bearing at least some resemblance to those that took place in the time of Jenkins and Lawes.

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Chapter One - Introduction

The primary purpose of this thesis is to focus on the pitch discrepancies that may occur when two instrumental groups with distinctly different temperaments are combined in the same piece of music. Specifically, keyboards, normally tuned to one shade of meantone, and fretted instruments, predominantly equal-tempered, by virtue of their dissimilar temperaments, exhibit some striking dissonances when played together. These discrepancies were noted by a number of Italian music theorists in the latter half of the sixteenth century. In 1550, Vicentino observed that lutes and viols were never completely in tune with instruments that divided the whole tone unequally.[1] Giovanni de' Bardi (1534-1612), of the Florentine Camerata, made a similar observation ca. 1580 when he wrote to Guilo Caccini that

> it is necessary to take great care in combining these instruments for not all of them are tuned to the same tuning, the viol and lute being tuned according to the tuning of Aristoxenus [equal temperament], the harp and gravicembalo making their modulations with other intervals. And more than once have I felt like laughing when I saw musicians struggling to put a lute or viol in proper tune with a keyboard instrument, for aside from the octave these instruments have few strings in common that are in unison . . . since until now this highly important matter has gone unnoticed or, if noticed, unremedied.[2]

Hercole Bottrigari, in his *Il desiderio* (1599), makes similar observations. His narrative takes the form of a dialogue between Gratioso Desiderio and the knowledgeable Alemanno Benelli:

> Al: Have I not told you that the Clavicembalo and such instruments sound one species, and the Lute and its like sound another?
> Gr: You have.
> Al: If then these instruments are of two different species, how can you expect them to unite perfectly together?
> Gr: You tell me, and make me see and hear, things that I never have believed. But now that I both see and hear I can only confess that you speak truly.
> Al: It should not seem so important not to know these things, since people who work at them all day and put their energies into arranging such groups of instruments (concerti) do not understand it either. That much is clear, because if they knew it and understood it they would not make such "concerts," or rather such "confusions." Therefore, having the tone divided into two equal semitones, as do the Lutes and Viols, while the Clavicembalo and its kind have it divided into two unequal semitones . . ., you do not find yourself in unison . . ., as you both heard and admitted.[3]

Bottrigari discusses this problem at some length. However, he is only one of two theorists who makes any suggestions of how to overcome these problems. He states that

> the stable but alterable instruments are all those which, after they have been tuned by the diligent player, can be changed, augmented or diminished to some degree,

> according to the good judgment of the player as he touches the frets a little higher or a little lower. This occurs with the lute and viol, even though they may have the stability of their frets.[4]

Michael Praetorius (ca.1569-1621), a German theorist, recommends the same solution in the early seventeenth century, but goes one step further. He includes small arrows above the music indicating specifically which pitches are to be lowered.[5]

This study will consider these answers as well as focus on certain shades of meantone in an attempt to determine the variety that is better suited for use in conjunction with equal temperament. Musical factors such as style of writing, choice of continuo instrument, and tempo will also be taken into account. Sixteenth- and seventeenth-century compositions by Diego Ortiz (ca. 1510-ca. 1570), John Jenkins (1592-1678), and William Lawes (baptized 1602, died 1645) will be surveyed and the results will be presented in two ways. First, tables will provide a visual analysis of the discrepancies that occur when meantone and equal temperament are combined. Some of these results are applied directly to selected musical passages. Second, recordings of three works that exhibit tuning discrepancies have been included to allow the reader to perceive the problems aurally.

The musical examples have been recorded electronically using a Proteus 2 multi-timbral sound module, manufactured by E-mu Systems, Inc. The module is designed to allow each note of the scale to be de-tuned in increments of 1.56 cents, corresponding to 1/64 of a semitone.[6] The pieces were not performed "live," but were programmed on an IBM 286 computer using the "Cakewalk" sequencer program. This program allows the user to enter notes manually according to pitch and duration and to vary certain parameters such as tempo, velocity and the number of tracks used for any given performance. Once the work is entered on the computer, it can be called up and its signal can be fed directly into the Proteus. The module then performs the piece in the designated tuning or temperament, in a specified timbre.[7] The compositions were recorded directly on a Denon DTR-2000 digital audio tape recorder (DAT) at a 48 kHz sampling rate; they were then transferred onto a standard analogue cassette tape using Dolby B noise reduction.

Chapter Two offers an overview of the tunings and temperaments of the period (ca. 1500-ca. 1650), with emphasis on just and Pythagorean intonations, and meantone and equal temperaments. Chapter Three focusses on the use of these systems in sixteenth-century England. It examines English theoretical writings and the influence of Italian musicians, and surveys English music with emphasis on keyboard works by John Redford (ca. 1485-1547) and William Byrd (1543-1623). A composition by the latter composer has been recorded in Pythagorean tuning as well as several meantone shades to aid in this endeavor.

Endnotes Chapter One

[1]Lindley, *Lutes, Viols, and Temperaments,* (Cambridge: Cambridge University Press, 1984), 44.

[2]Giovanni de' Bardi, "Discourse on Ancient Music and Good Singing," [Original edition ca. 1580] in *Source Readings in Music History: The Renaissance*, selected and annotated by Oliver Strunk (London: W. W. Norton & Company, 1965), 107.

[3]Hercole Bottrigari, *Il desiderio,* trans. Carol MacClintok, in Musicological Studies and Documents, no. 9. (1599; reprint, n.p.: American Institute of Musicology, 1962), 18-19.

[4]Bottrigari, 15.

[5]Taken from an article by Frederick K. Gable, "Possibilities for Mean-Tone Temperament Playing on Viols," *Journal of the Viola da Gamba Society* 16 (1979): 28-29.

[6]Even with an accuracy of 1.56 cents, the represented tuning and temperaments are not exact, although efforts were made to be as precise as possible.

[7]The taped performances are not intended to replicate actual performance in terms of instrumental timbre. The module's limitations had to be observed. Some settings on the Proteus cannot be modified timbrally; while the sound is a close simulation, it is not exact.

Chapter Two - An Overview of Early Tunings and Temperaments

Just Intonation

Just intonation is a system based on the natural harmonic series, featuring intervals composed of simple ratios that are "unaltered, untempered, and completely in tune without beating or wavering. Two simultaneously sounding tones create a just interval if and only if a harmonic of the first tone coincides with a harmonic of the second tone."[1] These are known as "pure," "just," or "natural" intervals, and some of the more common types, with their ratios, are summarized below:

Table 2-1:

An overview of some common just intervals expressed in ratio and cents[2]

Ratio	Interval	Cents[3]
2:1	P 8	1200
3:2	P 5	702
4:3	P 4	498
5:4	maj. 3	386
6:5	min. 3	316
9:8	maj. whole tone	204
10:9	min. whole tone	182
16:15	diatonic semitone	112

On a standard keyboard or any instrument with fixed intonation, it is impossible for all intervals and triads to be pure.[4] Two-thirds of the available perfect fifths and major thirds can be made pure, resulting in six usable major triads.[5] Some sixteenth-century theorists constructed keyboards on which some notes had multiple keys in order to produce a greater number of pure intervals and triads. One such keyboard, built by Joan Albert Ban, was based on a formula by Marin Mersenne (1558-1648).[6] Because of its limitations, just intonation did not attain a high degree of practical use during the sixteenth century. There were, however, various monochord schemes for this tuning that retained the pure major third and perfect fifth.[7] These were primarily of theoretical interest.

Pythagorean Tuning

Despite its name, Pythagorean tuning is a system which was probably in existence long before Pythagoras (fl. 6th century B.C.). The early Chinese maintained a system of twelve pitches called "*lü*," which were tuned by fifths. The names of the twelve *lü* appeared in the fourth century B.C.; however, some accurately tuned stone chimes of a substantially earlier period suggest that the Pythagorean system may have been in use as early as the second millenium B.C.[8]

Pythagorean tuning, like any other tuning, can have all of its intervals expressed as the ratio of two integers.[9] This system's foundations are the pure perfect fourth (4:3) and the pure perfect fifth (3:2). Intervals in this system are derived by the addition and subtraction of ratios.[10] For example, subtracting the perfect fourth from the perfect fifth will result in a just major whole tone[11]:

$$3/2 \ / \ 4/3 =$$
$$3/2 \ X \ 3/4 =$$
$$9/8 \text{ or}$$
$$9{:}8$$

The Pythagorean major third or "ditone" is derived by the addition of two major whole tones:

$$9/8 \ X \ 9/8 =$$
$$81/64 \text{ or}$$
$$81{:}64$$

This ditone is not pure (a pure major third has a ratio of 5:4), but is sharper than pure by about 22 cents.[12] A major third as sharp as this exhibits a noticeable beating[13] when played on an instrument tuned in this system.

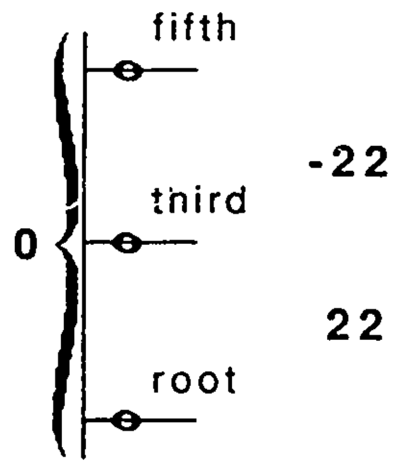
The Pythagorean system employs two sizes of semitone. A smaller diatonic semitone, or "limma," is obtained by subtracting the ditone from the perfect fourth (4:3 / 81:64) resulting in a ratio of 256:243. If the limma is subtracted from the whole tone, the larger "apotome," or chromatic semitone is the result (9:8 / 256:243 = 2187:2048).[14] The difference between these two semitones is the Pythagorean or "ditonic" comma[15] (ratio 531441:524288). An easier way to visualize this comma is to imagine tuning twelve consecutive pure perfect fifth intervals upward beginning on, for example, note C. Instead of arriving at note C seven octaves higher, the final pitch is B-sharp, which differs from high note C by 24 cents. Enharmonically related notes, such as C-sharp and D-flat, will also differ in sound by the amount of the comma.[16] It is because of this discrepancy that a "wolf fifth"[17] must be placed between two pitches, usually between G-sharp and E-flat, or B and F-sharp.

Although major thirds in Pythagorean tuning are all larger than pure, some diminished fourths form virtually pure major thirds (two cents smaller than pure). Such intervals will occur on notes D, A, E , and B.[18] With their respective fifths above and below, pure triads can be formed around all of these notes except B, above which the wolf fifth is placed. These chords are less dissonant than triads formed with major thirds.

The examination of a root position major triad demonstrates how the purity of the fifth is achieved at the expense of the third. The distance from the root to the third is about 22 cents sharp, while the distance from the third to the fifth is about 22 cents flat. The average of these differences results in a pure fifth.[19] Figure 2-1 illustrates:

Figure 2-1:

Intervallic characteristics of a major triad tuned to Pythagorean intonation, and the resultant pure interval



$$22 + -22 = 0$$

Meantone Temperament

A temperament may be defined as a modification of a tuning in which "the sizes of one or more of its natural intervals have been altered"[20] either for the purpose of adapting a tuning to a keyboard,[21] or for the benefit of putting certain intervals in better tune. The first mention of temperament or "participata" is found in the *Practica musica* (1496) of Franchinus Gafurius. Gafurius states that "this fifth, as organists maintain, permits the diminution of a small, concealed and somewhat vague quantity which these organists call temperament."[22] The kind of temperament referred to here is known as meantone.

There are several shades of meantone, all of which reduce the size of the pure fifth in order to produce a better-sounding major third. The particular shade will depend on the distribution of the "syntonic" comma, sometimes referred to as the "comma of Didymus" (ratio 81:80). This comma is the difference between the interval obtained by tuning four pure consecutive perfect fifths upwards and the interval of two octaves plus a pure major third. On an equal-tempered keyboard, there is no discrepancy, but the interval resulting from the four pure fifths exceeds that of the octaves and pure third by approximately 22 cents.[23] In order to eliminate this additional sharpness, some or all of the comma is divided among the perfect fifths in equal fractions of a comma. For example, 1/4-comma meantone reduces each fifth by 5.5 cents (22 / 4), resulting in pure major thirds. Since all of the fifths are reduced by the same amount, this is a "regular" meantone temperament. The excess of this comma has been divided among the first four perfect fifths, but tempering the remaining seven fifths (in order to continue achieving pure major thirds) will result in a deficit of one and three quarter commas. Compensation must be made by adding this amount to the eighth fifth, or "wolf."[24] This interval normally lies between G-sharp and E-flat, C-sharp and A-flat, or D-sharp and B-flat and is 36 cents sharp in 1/4-comma meantone.[25]

Conversely, the quality of the thirds can be determined by multiplying the fraction by four. (Multiplying the fraction indicates the degree to which the syntonic comma has been absorbed by the initial four flatted perfect fifths.) If the total is less than a whole, the third will be sharp by that fraction of the comma. If the total exceeds the whole comma, this indicates that the thirds will be lower than pure. For example, multiplying 2/7 by four equals 8/7, which is 1/7 of a comma greater than a whole (which would be 7/7); here the thirds will be less than pure by 1/7-comma (approximately 3 cents) because the entire fraction may not exceed the size of the whole comma. In 1/5-comma meantone, multiplying by four accounts for only 4/5 of the comma. The remaining 1/5 of a comma must be absorbed by the major third (which will be about 4.5 cents sharper than pure).

While these operations are performed primarily on the third and fifth, it also has important implications on the tones and semitones that constitute the scale. In any regular meantone system, the size of the whole tone remains constant.[26] The specific size of this interval depends on the shade; those varieties with a major third larger than pure will have the biggest whole tones. In contrast, the size of the semitone varies and can be classified into two types, a larger diatonic and a smaller chromatic. For this reason, enharmonicity is not normally feasible; only five black notes can be accommodated on any standard keyboard. In meantone set from C, the black notes are commonly C-sharp, E-flat, F-sharp, G-sharp, and B-flat,[27] which allows the keys of C, G, D, A, F, and B-flat major and G, D, and A minor to be usable. If alternate or additional accidentals are necessary, the notes must be re-tuned, unless a keyboard with split keys is available.

During the sixteenth century, a number of meantone shades were proposed, any of which may have been used; no one variety was standard throughout the Renaissance.[28] Pietro Aron (ca. 1480-ca. 1550) was the first to describe a regular meantone temperament, but it was not necessarily 1/4-comma, as is often assumed. According to Lindley, Aron "is prescribing a *more or less* regular temperament at liberty to resemble, at least in part, 2/7-comma or perhaps 2/9-comma meantone. I certainly do not argue that he would have faulted regular 1/4-comma meantone; merely that he does not specify it."[29] In 1571, Gioseffo Zarlino (1517-1590) described 1/4-comma meantone temperament in mathematical terms and said it was new, although Francisco de Salinas (1513-1590) implied in 1577 that it had been used in the 1530s.[30]

Before Aron, Arnolt Schlick (ca. 1460-post 1521) proposed a tuning formula in his *Spiegel der Orgelmacher und Organisten* (1511). This is an irregular system, in which he may have suggested that the thirds among the naturals be tempered less than those among the black notes, when he writes that "while the major thirds are not good, but all are too high, still it is necessary, and heed is to be taken, to make three thirds: C-E, F-A, and G-B better . . . than the others, because they are used often and more than the others."[31] Lindley comments that "the organ temperament proposed by Schlick is a clearly conceived scheme with white-key thirds tempered no more than in 1/6-comma meantone."[32] It is not known how widely his system was adopted.[33]

The earliest known mathematical formula for meantone temperament was presented by Zarlino in his *Institutioni armoniche* (1558) for the 2/7-comma shade. The only pure interval in this system is the chromatic semitone.[34] In *De musica libri VII* (1577), Salinas described the 1/3-comma temperament in which the minor third, its inversion, and the tritone are pure intervals. This purity is achieved at the expense of the major thirds which, as in Zarlino's 2/7-comma, are flatter than pure. It is possible that neither of these two shades was used as much as 1/4-comma with its just thirds, or those varieties with thirds larger than pure.[35] A 1/5-comma shade may have been the variety Lanfranco described in 1533 when he stated that the major thirds in his system are larger than pure.[36] If so, the only just interval would be the diatonic semitone. Meantone was the typical temperament of keyboard instruments during the sixteenth century, although it may have been used earlier.[37] The first keyboard music well suited to this system was by Conrad Paumann (1410-1473). There is some evidence to suggest that fretted instruments may occasionally have been tuned to meantone temperament (particularly in the lute music of Luis Milan[38]) even though they were usually equal-tempered.[39]

Equal Temperament

Equal temperament was first approximated numerically by Hô Tchhêng-thyén of China in about 400 A.D. when he suggested "three monochords for the chromatic octave with identical ratios, but with the fundamentals taken as 9.00, 81.00, and 100.0 respectively."[40] According to J. Murray Barbour, the first European rules for tuning equal temperament on instruments did not appear until Giovanni Maria Lanfranco (ca. 1490-1545) described the process in his *Scintille de musica* (1533).[41] Lindley disputes this claim, asserting instead that the directions set forth by Lanfranco can be best interpreted as 1/5 or 1/6-comma meantone.[42] If this assertion is correct, then no Renaissance musician is known specifically to have advocated the adoption of equal temperament for keyboard instruments.[43]

One common and practical method for adjusting fretted instruments to equal temperament was suggested by Vincenzo Galilei in 1582. He recommended using the ratio of the minor semitone (18:17) and applying it twelve times.[44] Other theorists such as Zarlino (1558) offered geometrical instructions for fretting, but it was Simon Stevin (1596) who was the first European to base his tuning on the twelfth root of two,[45] which is the mathematical foundation for theoretically correct equal temperament.

The structure of this temperament can be illustrated by modifying Pythagorean tuning. Reducing each ascending pure perfect fifth interval by two cents will eliminate the Pythagorean comma, and the resulting wolf. The fifths will be flat by this amount and the fourths will be sharp by the same. The major thirds are fourteen cents sharp while the minor thirds are sixteen cents flat. Despite the large deviations from purity, no interval is unacceptable. There is complete enharmonicity and there are no restrictions to modulation.

In summary, Pythagorean tuning began to be replaced by other tuning systems around the turn of the sixteenth century, although still advocated by Gafurius, Ornithoparchus and others for a long time thereafter.[46] Just intonation remained primarily a theoretical ideal even though various attempts were made to adapt this system to practical use through various monochord schemes and by modifications to keyboard design. Meantone, the most prominent keyboard tuning during this period, existed in various shades and remained in practical use until the mid-nineteenth century. Equal temperament, while not initially favoured as a keyboard temperament, was nevertheless used as a tuning for fretted instruments.

Endnotes Chapter Two

[1]Owen Jorgensen, *Tuning the Historical Temperaments by Ear* (Marquette: The Northern Michigan University Press, 1977), 421.

[2]The ratios and the cents values from the minor third interval onward are from Jorgensen, 421.

[3]One cent is 1/1200 of an octave. In equal temperament, a semitone can be divided into 100 equal parts. Each part is one cent.

[4]For a mathematical discussion of this tuning, see J. Murray Barbour, *Tuning and Temperament, A Historical Survey* (East Lansing: Michigan State College Press, 1951), 102-5.

[5]Owen Jorgensen, "Forgotten Sounds of Music," *Piano Technician's Journal* 14 (December 1971): 17.

[6]Lindley, *Lutes, Viols and Temperaments,* 70-72.

[7]Fogliano, in his *Musica theoretica* (Venice, 1529), devised several monochord schemes with pure major thirds and perfect fifths. Even Mersenne, who, like Zarlino and Rameau, recognized just intonation as the theoretical basis of a scale, nevertheless presented numerous tables based on just intonation, some for the spinet and lute. See Barbour, 11, 89-102.

[8]Bell N. Yung, "China," in *The New Grove Dictionary of Music and Musicians*, ed. Stanley Sadie, 20 vols. (London: MacMillan Publishers Ltd.), 260-61.

[9]Barbour, 5.

[10]In order to "add" or "subtract" ratios, the numbers are converted to fractions and then multiplied or divided.

[11]Jan Herlinger discusses intervals and their proportions in "Fractional Divisions of the Whole Tone," *Music Theory Spectrum* 3 (1981): 74-83. See Table 1, Herlinger, 77.

[12]This quantity is an approximation for the "syntonic comma," discussed under the heading "Meantone Temperament."

[13]Jorgensen states that beating occurs when "the coinciding harmonies of a just interval no longer quite coincide after the interval has been tempered. When sounding a tempered interval, opposite frequency phases of the non-coinciding (conflicting) harmonies cause periodic cancellations of the tones of the harmonics." See Jorgensen, *Tuning the Historical Temperaments by Ear*, 417.

[14]Lindley, 9.

[15]According to Jorgensen, "a comma is the difference between two sets of just intervals or combinations of just intervals. A comma always exists and creates wolf intervals in various locations on an instrument with a conventional keyboard that is tuned in just tuning or in many other systems which are very close to just tuning. A comma also prevents the intervals used on a conventional keyboard to being all justly in tune at the same time." For further explanation see Jorgensen, *Tuning the Historical Temperaments by Ear*, 417-18.

[16]According to Jorgensen, a discrepancy between two enharmonically related notes on a keyboard is called a "diesis." See Jorgensen, *Tuning the Historical Temperaments by Ear*, 418-19.

[17]A wolf is an interval that deviates from pure to the point where the harmonics of the pitches beat so rapidly that the interval is normally not usable.

[18]Mark Lindley, "Pythagorean tuning," in *New Grove Dictionary*, 486.

[19]The same process can be used to visualize a meantone-tuned major third. The distance from the root to the third is pure, but a minor third from the third to the fifth is 5.5 cents flat. Adding zero to -5.5 equals -5.5 which is the amount a perfect fifth is tempered in 1/4-comma meantone. This method was used to calculate the variations in Chapter Three, "Tuning and Temperament Considerations in the Music of William Byrd," Table 3-1.

[20]Jorgensen, *Tuning the Historical Temperaments by Ear*, 428.

[21]The development of this system may have been an attempt to transfer just intonation to an instrument of fixed pitch. See M. S. Waitzman, "Meantone Temperament in Theory and Practice," *In Theory Only* 5 (May 1981): 3.

[22]Franchinus Gafurius, *Practica Musicae,* trans. and ed. Irwin Young (Madison: The University of Wisconsin Press, 1969), 133. This is found in Chapter Three, "The Eight Mandates or Rules of Counterpoint," as Rule Two.

[23]Recall that the Pythagorean major third is sharper than pure by 22 cents.

[24]Waitzman, 4. For further clarification, see her example 3, 5.

[25]Lindley, "Mean-tone," in *New Grove Dictionary*, 875.

[26]Because the whole tone is exactly the same size, it can be defined as a *meantone*, "a tone which is exactly mid-way or equidistant between two other tones." Jorgensen, *Tuning the Historical Temperaments by Ear,* 422.

[27]The combination of these black notes with the existing white notes results in two wholetone scales. In C major these are B-flat, C, D, E, F-sharp, G-sharp and E-flat, F, G, A, B, C-sharp. Taken from Jorgensen, "Forgotten Sounds of Music," 17.

[28]Lindley, "Temperaments," in *New Grove Dictionary*, 662.

[29]Lindley, "Early 16th-century Keyboard Temperaments," *Musica Disciplina* 28 (1974): 141.

[30]Lindley, "Temperaments," 662.

[31]Lindley, "Early 16th-century Keyboard Temperaments," 131.

[32]Ibid., 150.

[33]Lindley, "Temperaments," 664.

[34]Barbour, 33.

[35]Lindley states that "all the forms of mean-tone described by Abraham Verheyen in his letter to Simon Steven of about 1600 - namely 1/3-, 2/7-, 1/4-, and 1/5-comma mean-tone - had been in use, though 1/3-comma probably least and 2/7-comma, which is difficult to tune precisely, perhaps less than 1/4-comma or some shade of mean-tone slightly larger than pure." See Lindley, "Temperaments," 662.

[36]Lindley, "Early 16th-century Keyboard Temperaments," 150.

[37]See Chapter Three, "Tuning and Temperament in Fifteenth Century Italy."

[38]Mark Lindley, "Luis Milan and Meantone Temperament," *Journal of the Lute Society of America* 11 (1978): 45-48.

[39]It is possible to deviate from strict equal temperament in fretting. See Lindley, *Lutes, Viols, and Temperaments*, 51-66.

[40]Barbour, 55.

[41]Barbour, 45.

[42]Lindley, "Early Sixteenth-Century Keyboard Temperaments, 144-51.

[43]Lindley, "Temperaments," 664-65. Girolamo Roselli may have been an early advocate of equal temperament on keyboard instruments but only for the sake of a standard concert pitch. See Lindley, "Early Sixteenth-Century Keyboard Temperaments," 151.

[44]Lindley, *Lutes, Viols and Temperaments*, 20-21.

[45]Barbour, 76.

[46]Barbour, 3.

Chapter Three - The Appropriateness of Meantone Temperament to Sixteenth-Century English Keyboard Music

Sixteenth-Century English Music Treatises

Only a few music treatises were written by English theorists during the course of the sixteenth century. According to Johannes Wolf, the English Reformation may have limited the English musician's exploration of purely theoretical matters. Instead, he was more inclined to deal with church music and liturgy.[1] Whatever the reason, it was only after the Reformation that the first English treatise was written. These treatises of the sixteenth century were in fact irrelevant to the musician who might have wanted to learn about tunings and temperaments.

A 1584 treatise entitled *A Briefe Introduction to the True Art of Musicke,* by Oxford student William Bathe (1564-1614), was the first musical textbook to appear in the English language.[2] This treatise, no longer in existence, was extensively rewritten and re-named *A Briefe Introduction to the Skill of Song* (ca. 1587), a work that survives to the present day. The purpose of both books was to enhance the music reading ability of the beginner and to teach the elements of music.

A more mystical approach to music was taken in the treatise *The Praise of Musicke* (1586); it was published anonymously and had been incorrectly attributed to John Case because of some verses by Thomas Watson.[3] "This work contains legends and anecdotes dealing with the power of music,"[4] dealing with "its powers and medicinal effects on man, and its many uses in civil, military, and ecclesiastical matters."[5] However, two years later, Case did publish a Latin work with a similar theme entitled, *Apologia musices tam vocalis quam instrumentalis et mixtae*.[6] It was written for an academic audience[7] and deals with the power of music as "an aid to virtue."[8]

In 1596, William Barley (d. 1614) published two instruction books, *The Pathway to Musicke* and *A New Booke of Tabliture*. Another work, *The Pathway of Musicke*, by an anonymous writer, reflected a growing interest in practical music. It deals with mensural music and discantus and was apparently compiled from various German treatises.[9]

Thomas Morley (1557 or 1558-1602), wrote *A Plaine and Easie Introduction to Practicall Musicke* (1597), the first English-language treatise to deal comprehensively with musical theory. Although he addresses a variety of subjects, Morley includes no direct references to any tunings or temperaments or their application to the keyboard.[10] This is somewhat surprising, since he refers to a host of theorists (including Aron, Gafurius, Zarlino) and had studied the principal theoretical works of Germany and Italy.[11] In the sixteenth century, only these few treatises and some instrumental tutors (translated from the French for lute, cittern, and gittern[12]) were written in England. It is not until the seventeenth century, when the number of English music treatises increased, that any practical reference was made to tunings and temperaments.

Tuning and Temperament in Fifteenth-Century Italy

Tunings and temperaments were among the many concerns to occupy Italian theorists of the fifteenth century. This is an important consideration when attempting to ascertain the extent of foreign influence in sixteenth-century England, because it supplies the necessary historical context.

One person who contributed to the moulding of ideas in Italy was the English composer and theorist, John Hothby (ca. 1410-1487). A Carmelite monk and Oxford graduate, Hothby travelled the Continent before settling in Italy in the 1450s. He represented a school of musical thought devoted to maintaining Boethian and Guidonian thinking in music. Three of his treatises, entitled *Excitatio*, the *Epistola*, and the *Dialogus Johannis Ottobi Anglici in arte musica*, exemplify this with their discussions of Guidonian solmization and hexachord systems, Pythagorean ratios for tuning, and medieval terminology.[13]

Hothby attempted to refute arguments offered by Bartolomeo Ramis de Pareia (ca. 1440-post 1490), who rejected the authority of Boethius and Guido and favoured practicality and clarity, particularly in regard to tuning.[14] Rather than derive intervals by adding or subtracting the ratios of Pythagorean tuning[15], Ramis suggested simplifying ratios. For example, the Pythagorean third, which has a ratio of 81:64 is better expressed as a 5:4 ratio, the minor third with a 6:5, instead of a 32:27 ratio. These recommendations are specifically intended for the performance of plainchant, according to a monochord scheme in a section of *Musica practica* (1482).[16] Ramis did not advocate an application of the monochord system to keyboard instruments. However, Lindley maintains that there are other sections of the work where "the information given by Ramos de Pareia in his *Musica Practica* of 1482 will show that the kind of tuning in question was almost certainly some form of regular meantone temperament. That is, with fifths tempered more than in equal temperament for the sake of more resonant thirds and sixths."[17] He cites Gafurius's discussion as additional evidence for this assertion[18] and remarks that certain keyboard music of the later fifteenth century is well-suited to meantone temperament.[19]

Assuming Lindley's assertions to be correct, this would suggest that meantone may have been used in Italy at least as early as the late fifteenth century. Barbour makes a similar statement when he says that Gafurius is commenting in his *Practica musica* on a procedure already in existence.[20]

A greater number of tuning treatises became available in the early sixteenth century. Pythagorean intonation was no longer the predominant tuning system for keyboard instruments; the new favourite was meantone temperament. It is ironic that those theorists-- Pietro Aron and Giovanni Lanfranco-- credited with being the first proponents of meantone temperament were actually staunch advocates of Pythagorean thought.

Foreign Influence in Early Sixteenth-Century England

An examination of the reign of Henry VIII, which began in 1509, may be of significant value in the study of temperaments in England. The monarch was a performer on several instruments[22] and a composer who advanced the stature of music in the Royal Court, the primary centre of musical activity in England. But perhaps because of the reportedly poor abilities of most English instrumental performers,[23] the King recruited foreign talent, usually of Flemish or Italian origin. The Italians in particular had a large impact on Henry, whose own compositions were "entirely similar to the great secular collections in Italy and elsewhere, by which with his taste for Italian art and music he was certainly influenced."[24]

In 1516, Henry was able to persuade Dionisio Memo (fl.1507-1539), first organist at St. Mark's Cathedral in Venice, to come to the English Court. Memo, a virtuoso performer and composer, brought with him an organ described as "a most excellent instrument"[25] and played to the "incredible admiration" of the King, Cardinal Wolsey, and the assembled royal musicians.[26] He was required to perform often in the Court. On one occasion, he entertained a group of visiting French ambassadors for four hours.[27] He was so well regarded that he was made chief of instrumentalists.

Throughout Henry's reign, the number of Italian musicians in the Court increased, but they were not always well received. Zuan de Leze arrived at the monarch's Court but failed to impress anyone and because of his shame he hanged himself.[28] However, it seems hard to imagine that a virtuoso like Memo, who commanded great respect, would not have been influential in introducing the most recent musical innovations. He would have been aware of any tuning proposals that existed in his native country, including those for meantone temperament. If he did in fact embrace the arguments for the adoption of meantone temperament for the keyboard, he could have been directly responsible for the introduction, or at least the propagation, of this system in England. Memo's music could perhaps have indicated his preferences, but, unfortunately, none of it has survived.

A Survey of Selected Early Sixteenth-Century Italian and English Music

A collection of Italian frottolas was published in Italy in 1517, a year after Memo left for England. A study of one of these compositions might serve as an indication of the overall style that Memo himself may have used. By subjecting a representative example to an analysis, it should be possible to suggest a possible tuning or temperament for the work.

Attempting to establish an argument for assigning a tuning or temperament to a specific piece is a somewhat subjective exercise, since there are no definitive or conclusive criteria by which to make a decision. The features that may provide clues are: the predominance of certain intervals (particularly thirds and fifths), the choice of key areas appropriate to a specific tuning or temperament, the use of triads,[29] and to a much lesser degree, the composer's utilization of the leading note to resolve to the tonic.[30] Simply listening to a piece in various tunings can provide useful, although necessarily inconclusive, insights.

The piece selected for discussion, "Animoso mio Desire," is the fifth frottola in a collection published by Andrea Antico, entitled *Le Frottole per "Organi" di Andrea Antico*.[31] The work was written by Bartolomeo Tromboncino (ca. 1470-1535) and, in spite of the reference to the organ in the title of the collection, could be performed on any keyboard instrument. The two possible tuning choices for this period are Pythagorean intonation and meantone temperament.[32] Intervals in these tunings, in this discussion and those following, will be compared to their pure equivalents, to each other, and to equal temperament as a point of reference for the modern reader.

"Animoso" appears to exhibit clearly identifiable transient modulations to G major and to D and G minor, all acceptable key areas in either tuning system. In Pythagorean tuning, any major third (or related compound interval) will be noticeably sharper than the pure third of meantone. (The increased sharpness is about 22 cents, the equivalent of the syntonic comma; this is 8 cents sharper than an equal-tempered major third.)

When the piece is heard in Pythagorean tuning, the sharpness just referred to is immediately encountered in measures 1, 11-12, 17, and 32 (marked *), all of which are tonic chords,[33] in root position, with the third in the upper voice. In contrast, the thirds in the same vertical structures are beatless when performed in meantone temperament, even though the fifths, 5.5 cents flatter than pure, exhibit a noticeable but not unbearable, beating. Other measures (8, 10, 16, and others) contain chords with the third omitted (fourths and fifths only). Here, the Pythagorean system would be preferable; when these measures are performed in meantone, the beating of the flat fifth (3.5 cents flatter than in equal temperament) becomes more noticeable than in those chords which include the third.

Two sharps, F-sharp and C-sharp, are used as leading notes in the transient modulations. These notes differ markedly between the two tuning systems, the F-sharps varying by 33 cents (Pythagorean: 612, meantone: 579 above a given note "C"), and C-sharps by 38 cents (P: 114, M: 76). In both cases, the accidentals are higher in Pythagorean tuning than in meantone temperament. Although the Pythagorean versions serve better as leading notes to the tonics, they are substantially higher than pure when combined with their underlying harmony. These chords, in combination with sharp-sounding major chords of resolution, lead to beat-filled progressions (see measures 3-4, 19-20, and 27). In measures 14, 15, and 16, these secondary leading notes resolve to minor triads,

Figure 3-1:

Bartolomeo Tromboncino, "Animoso mio Desire" which in Pythagorean tuning are flatter than pure by the syntonic comma (6 cents flatter than an equal-tempered minor third). The same minor chords in meantone also contain thirds which are flatter than pure, but only by 5.5 cents.

The other accidental in this piece is a B-flat found in measures 28 and 29. The difference between the representations of this note in the two tuning systems is 11 cents with meantone higher than Pythagorean (1007 cents above note C compared to 996 cents). In this section, there is not a significant difference between performances in the two tuning systems.

"Animoso" appears to sound better in meantone temperament than in Pythagorean intonation. Due to the large number of major and minor thirds throughout the work, meantone creates less harshness, even when taking into account those chords lacking a third. While it is true that those diads sound better in Pythagorean intonation, they are relatively isolated and are not easily recognized as pure open fifths. The triads with pure major thirds overshadow the beating caused by the flat fifths. Minor chords also appear to work well within this system since they contain a pure major third between the third and the fifth. (A minor chord with a third flatter than pure by 5.5 cents is still substantially closer to pure than an equal-tempered minor third, which is 16 cents less than pure.)

Hugh Aston (ca. 1485-?1558) is an early composer of English keyboard music. The composer's significance to this study lies in his only known keyboard work, entitled "A Hornepype."[34] This piece "shows a grasp of idiomatic keyboard writing in advance of continental practice of the time."[35]

The piece will not be formally analyzed because J. Murray Barbour and Fritz A. Kuttner have commented on it in their work entitled "The Theory and Practice of Just Intonation."[36] The authors contend that, overall, this composition is suitable for performance using just intonation. The piece[37] contains a high proportion of perfect fifths and major thirds. For example, measure 8, with its abundance of fifths, is well-suited to Pythagorean intonation. In contrast, there are a number of measures that begin and end with a major third (measures 2 through 7).

If the early sixteenth-century Renaissance musician did not have the ability to tune just intonation,[38] either Pythagorean tuning or meantone temperament could prove to be valid alternatives. By combining the virtues of both in one piece, Aston's work may illustrate the transition from Pythagorean tuning to meantone temperament.

John Bergsagel states that "there can be little doubt that this keyboard music was associated with Henry VIII's court, and this leads to the supposition that Aston was in London during the period 1510-25."[39] Although there is no direct evidence, this statement leads one to wonder whether or not Aston, as a keyboard composer affiliated with the Court, could have been in contact with Memo, who arrived in 1516.

In order to establish the direction this music took more accurately, two works of John Redford (ca. 1485-1547) are surveyed. He has been described as the "best-known and most representative of the organ composers of the early sixteenth century,"[40] and, unlike Aston, numerous examples of his work still exist. Nothing is known of his life prior to 1534;[41] therefore, it is not known what may have influenced his style, which Willi Apel describes as "wholly medieval" with "aims of transparency not fullness, linear tracing not chordal sound, and melodic intensity not sustaining power."[42] Thirds and sixths predominate in his music, seen most clearly when this composer writes in the English "faburden" style.[43]

A piece entitled, "O Lux on the Faburden" is found in the *Mulliner Book*.[44] As might be expected, there are a number of thirds and sixths between the highest and lowest voices. Of 56 measures, 27 begin with a major or minor third. These are indicated on the score (beginning on page 35, Figure 3-2) by an asterisk.[45] Fifteen measures begin with a major or minor sixth which, as inversions of thirds, are marked with "plus" signs.[46] While there is no evidence in the theoretical writings discussing the question of appropriate tunings, the presence of some very prominent thirds and sixths suggests that this piece is most appropriately played using meantone temperament. In the 1/4-comma shade, these intervals will be pure, or deviate by only 5.5 cents. If the piece were to be performed in Pythagorean intonation, the thirds and sixths would deviate farther from pure than any shade of meantone, or even equal temperament.

Figure 3-2:

John Redford, "O Lux on the Faburden"

The material on pages 35 to 38 has been removed because of copyright restrictions. The material contained a copy of "O Lux on the Faburden." This piece can be found in:
Stevens, Denis. *The Mulliner Book*. Vol. I of *Musica Britannica*. London: Stainer & Bell Ltd., 1951.

Redford's "Tibi omnes," also from the *Mulliner Book*,[47] offers a contrast to the faburden style (Figures 3-3 and 3-4). In analyzing this work, a more direct note-to-note approach can be used, measuring the intervals and chords according to their departures from pure in both meantone temperament and Pythagorean tuning. The numbers on the score indicate the distance from pure, with no designation meaning "sharp," and a "negative" sign indicating "flat."[48] Measurements are shown on essential notes in all three voice parts, allowing thirds, fifths and their inversions, the intervals most affected by the different tuning systems, to be highlighted. Appoggiaturas and most passing notes have been ignored, with the exception of measures 7 and 8.

In Figure 3-3, the only numerical designations that appear for meantone temperament are zero and -5.5, including those pitches aligned with the three accidentals in the piece, F-sharp (m. 6), C-sharp (m. 5), and B-flat (m. 4). The absence of any significant beating throughout most of the work contrasts sharply with the level of beating experienced in Pythagorean tuning.

Since "Tibi" contains many thirds, the pure fifths characteristic of Pythagorean tuning become virtually unnoticeable except in measures 1 and 5, which contain no third. They are overshadowed by the great number of sharp major thirds or flat minor thirds. The thirds become particularly evident when they are played in sequence (measure 7). Even in the equal-tempered system, the differences between alternating major and minor thirds is not as great. The difference in equal temperament is 30

Figure 3-3:

John Redford, "Tibi omnes" in Meantone Temperament

Figure 3-4:

John Redford, "Tibi omnes" in Pythagorean Tuning

The material on page 41 has been removed because of copyright restrictions. The material contained a copy of "Tibi omnes." This piece can be found in:

Stevens, Denis. *The Mulliner Book*. Vol. I of *Musica Britannica*. London: Stainer & Bell Ltd., 1951.

cents while in Pythagorean intonation it is 43 cents. In meantone, the difference is only 5.5 cents.

Tuning and Temperament Considerations in the Music of William Byrd

William Byrd (1543-1623), was one of the most prolific keyboard composers of the sixteenth century. A representative work, the "Pavane No. 4," (taken from *My Ladye Nevells Booke* [49]) is one in a series of pieces written by this composer in the 1570s and 1580s and preserved as a collection, dated 1591.

On the accompanying recording, "Pavane No. 4" is performed five times, the first time in Pythagorean tuning, and the subsequent renditions in the meantone shades of 1/3-, 2/7-, 1/4-, and 1/5-comma respectively. The recordings, found at the beginning of Side A on the thesis tape, supply aural examples of the various meantone shades, allowing the reader to decide which tuning or temperament is the most appropriate.

To some modern listeners, a piece performed in Pythagorean intonation sounds noticeably sharp because the major thirds are 22 cents sharper than pure. To others, an addition of 8 cents above an already sharp equal-tempered major third can be absorbed by the ear without much difficulty. In contrast to Pythagorean tuning, the meantone temperaments of all shades offer noticeable differences. These differences can best be illustrated by isolating the first measure of "Pavane No. 4" and comparing Pythagorean intonation directly with these various shades of meantone. The results of this analysis will be a model that can then be applied to the rest of the piece. These results are summarized in a chart on page 45.

Figure 3-5:

William Byrd, "Pavane No. 4," measure 1

At letter A in Figure 3-5, the pure perfect fifth in Pythagorean tuning acts as the foundation for the major third added at letter B (22 cents sharp). The major sixths, which are also 22 cents wider than pure, are found at C and D. The same passage performed in 1/3-comma meantone contains a perfect fifth and a major third that are 7 cents below pure.[50] A comparison of the major thirds resulting from these two systems is of interest because Pythagorean tuning has the largest major third and 1/3-comma contains the smallest. (The major thirds of the two systems differ by 29 cents.) In 1/3-comma, the major sixths and minor thirds at letters C and D are pure. The modern listener, accustomed to an equal-tempered major sixth (16 cents sharper than pure), may notice a distinct difference in the sound of the pure interval.

The same passage performed in 2/7-comma meantone does not differ appreciably from 1/3-comma at letter A, where the perfect fifth varies by only 1 cent (6 cents below pure). The major third at letter B is closer to pure, however, being only 3 cents flat. The intervals at letters C and D exhibit the same deviation.

The "Pavane" contains an abundance of major thirds (letter B) that are pure in 1/4-comma meantone. The interval of the perfect fifth in this shade differs from 2/7-comma by only 0.5 cent (5.5 cents less than pure).

Among the variants of meantone considered in this survey, 1/5-comma meantone has the distinction of being the only meantone shade with major thirds larger than pure (4.5 cents). The perfect fifth at letter A will also be less than pure by this amount while the major sixths at C and D will be larger than pure by 9 cents. If this temperament is compared to either 1/3- or 2/7-comma, a difference in sound is quite noticeable.

Those shades whose major thirds do not vary much from pure (2/7 and 1/5) work well in the context of this piece. The 1/3-comma temperament is perhaps the least successful. The narrow major thirds and perfect fifths deviate the farthest from pure resulting in a variety of meantone that sounds distinctly out-of-tune. The beatless major third of 1/4-comma meantone would be a strong contender as the most appropriate choice for this work.

While Pythagorean intonation may not sound unbearable to some modern listeners, it does not seem very plausible that any keyboard in the sixteenth century would have been tuned to this system for a piece like the "Pavane." The thirds deviate too much from pure and such a choice would not be logical, since there are meantone shades that offer better alternatives.

Pythagorean tuning and the meantone shades discussed above are correlated in Table 3-1, which includes the intervals of the perfect fifth, major third, and minor third (and their inversions). Their discrepancies from pure are listed and stated in cents, with a negative number indicating a quantity less than pure. The letters correspond to the areas discussed in measure one of Byrd's "Pavane" (Figure 3-5).

Table 3-1:

Quantities of selected intervals in Pythagorean tuning and selected shades of meantone temperament in relation to Byrd's "Pavane No. 4"

Tuning or Temperament	P5th(A) P4th*	Major 3rd(B) Minor 6th*	Minor 3rd Major 6th*(C,D)
Pythagorean	0	22	-22
1/3-c.	-7	-7	0
2/7-c.	-6	-3	-3
1/4-c.	-5.5	0	-5.5
1/5-c.	-4.5	4.5	-9

*These intervals have quantities opposite to the amount indicated for their inversions.

Endnotes Chapter Three

[1]Johannes Wolf, "Early English Musical Theorists," *Musical Quarterly* 25 (1939): 424.

[2]William Bathe, *A Briefe Introduction to the Skill of Song,* Introduction by Bernarr Rainbow (ca. 1584; reprint, Kilkenny: Boethius Press, 1982), 1.

[3]Binns, J. W. "Case, John," in *New Grove Dictionary,* 852.

[4]Nan C. Carpenter, "The Study of Music at the University of Oxford in the Renaissance (1450-1600)," *Musical Quarterly* 41 (April 1955): 209.

[5]Ibid.

[6]This work has been cited as a translation of *The Praise of Musicke,* although Binns claims it is not. See Binns, 852.

[7]Nan C. Carpenter, *Music in the Medieval and Renaissance Universities* (Norman: University of Oklahoma Press, 1958), 181.

[8]Binns, 852.

[9]Carpenter, *Music in the Medieval,* 182.

[10]There is a passing reference to meantone temperament and Pythagorean tuning by the editor of the work, but nothing that is helpful to this study. See Thomas Morley, *A Plaine and Easie Introduction to Practicall Musicke,* Introduction by R. Alec Harman (1597; reprint, New York: W.W. Norton & Company Inc., 1953), 103.

[11]Wolf, 424.

[12]Morley, xiii.

[13]Albert Seay, "Hothby, John," in *New Grove Dictionary,* 729.

[14]Albert Seay, "Ramis, de Pareia, Bartholomeo," in *New Grove Dictionary*, 576.

[15]See Chapter Two, "Pythagorean Tuning."

[16]Lindley, "Just intonation," in *New Grove Dictionary*, 756.

[17]Mark Lindley, "Fifteenth-Century Evidence for Meantone Temperament," *Proceedings of the Royal Musical Association* 102 (1975-1976): 37. Some of Ramis's evidence discussed in Lindley's article includes the reference to split keys on the keyboard and to "good" and "bad" intervals.

[18]Lindley states that "Gafurio's descriptive testimony of 1496 leaves no doubt that some form of temperament was in fact more or less commonly used by late 15th-century north Italian organists." Lindley, "Fifteenth-Century Evidence", 43.

[19]Lindley, "Fifteenth-Century Evidence", 50. Lindley remarks that "certainly general musical style by 1450, as defined by the harmonic usage of Ockeghem, Busnois, and the mature Dufay, was irrevocably triadic and, in fact, ideal for meantone temperament. See Lindley, "Fifteenth-Century Evidence", 51.

[20]Barbour, 25.

[21]See Chapter Two, "Meantone Temperament."

[22]Henry VIII played the lute, organ, and virginal. See David Greer, "Henry VIII," in *New Grove Dictionary*, 486.

[23]John Izon, "Italian Musicians at the Tudor Court," *Musical Quarterly* 44 (July 1958): 330. Izon states "it was the feebleness of English instrumentalists, compared with the excellence of English singers, that struck this visitor [Sagudino, an Italian ambassador's secretary] most forcibly, as he went from the music in the royal chapel at Richmond . . . 'They kept bad time, their touch was feeble, and execution poor.' England, he concluded, had much to learn, and the King tacitly acknowledged the fact."

[24]Robert Donington, "English Contribution to the Growth of Chamber Music," *Music-Survey* 4 (October 1951): 337.

[25]John M. Ward, "Memo, Dionisio," in *New Grove Dictionary,* 131.

[26]Izon, 330.

[27]Gerald Stares Bedbrook, *Keyboard Music from the Middle Ages to the Beginnings of the Baroque* (New York: Da Capo Press, 1973), 57.

[28]Izon, 330.

[29]Lindley uses this criterion in a number of his writings when discussing the appropriate use of meantone temperament. For example, see Mark Lindley, "Temperaments," in *New Grove Dictionary,* 662. He has also described the Italian *falso bordone* style (which is triadic, four-part, and homophonic) as being generally receptive to meantone temperament. See, "Fifteenth-Century Evidence for Mean-Tone Temperament, 50-51.

[30]For example, the leading tone is lower in meantone temperament than it is in Pythagorean tuning, which sometimes creates less drive to the tonic. This is a small consideration to be taken in conjunction with the others listed.

[31]Francesco Luisi, ed., *Le Frottole per "Organi" di Andrea Antico* (Rome: Societa Del Flauto Dolce, n.d.), 8-9.

[32]The primary meantone shade that will be used is 1/4-comma unless stated otherwise. Its intervals, notably the pure major third, provide a notable contrast to the intervals found in Pythagorean intonation.

[33]The term "tonic chords" refers to triadic structures consisting of a root, third, and fifth based on the "final" of the piece.

[34]There are other keyboard pieces in a style similar to Aston's, but a definitive link with this composer has not been confirmed. All of the pieces are found in the British Library, Royal Appendix 58.

[35]John Bergsagel, "Aston, Hugh," in *New Grove Dictionary*, 662.

[36]J. Murray Barbour and Fritz A. Kuttner, Introduction to *The Theory and Practice of Just Intonation*, Theory Series A, no. 3, Musurgia Records, 1958.

[37]Johannes Wolf, *Music of Earlier Times,* (New York: Broude Bros., 1900), 57-64.

[38]To date, nothing has been found to suggest that a form of just tuning was found on keyboard instruments this early in the sixteenth century. There is a reference by Zarlino later in this century in his *Sopplimenti musicali* (1558). See Lindley, "Just intonation," 756.

[39]Bersagel, 662. There appears to be ambiguity regarding the life of this composer. Some writers agree with the date of death given in this presentation (1521). P.C. Buck, E.H. Fellowes, and others attribute the confusion to the identity of Hugh Aston, as either the Archdeacon of York, or as the Canon of St. Stephen's, Westminster. See P.C. Buck, E.H. Fellowes, et al., *Tudor Church Music*, vol. x (London: Oxford University Press, 1929): xiii-xvii. Bedbrook remarks, "the date of the manuscript . . . is vague - for Hughe Aston, the composer of the "Hornpype" variations . . . may not be the priest who died in 1521, and it [the manuscript] may well belong to about 1540, to judge by the type of music contained in it." See Bedbrook, 113.

[40]Francis Routh, *Early English Organ Music from the Middle Ages to 1837* (London: Barrie & Jenkins, 1973), 25.

[41]Anthony Baines, "Redford, John," in *Grove's Dictionary of Music and Musicians,* 5th ed., ed. Eric Blom (London: The MacMillan Press Ltd., 1954), 79.

[42]Willi Apel, *The History of Keyboard Music to 1700*, trans. and rev. Hans Tischler (Bloomington: Indiana University Press, 1972), 147.

[43]In faburden, chant notes are replaced by those a sixth below (or a third above) although not always literally; sometimes the chant notes are transposed to the octave, especially at the beginning and the end. The derived melody may also be subjected to variation by figurations or inserted notes while always maintaining the basic features of the original melody. See Apel, 142.

[44]Denis Stevens, ed., *The Mulliner Book,* vol. I of *Musica Britannica* (London: Stainer & Bell Ltd., 1951), 23-24.

[45]There are a number of thirds and sixths between the inner and outer voices on many beats. However, in order to illustrate the point, it was felt that highlighting only the beginning of each measure is necessary, with one exception. The beginning of each short progression in measures 44 to 48 has been included. These are indicated by an asterisk below the staff.

[46]Minor sixths are pure and major sixths will be 5.5 cents sharper than pure in 1/4-comma meantone. In Pythagorean tuning, major and minor sixths are 22 cents sharper and flatter than pure, respectively. See Table 3-1.

[47]Stevens, 46-47.

[48]The music has been expanded from regular two-stave keyboard writing into three-stave format to assist in clarity. The numbers above the staff represent the values between the treble and lower bass clef, while the remaining numbers indicate the values between the treble and middle bass, and middle and lower bass clef.

[49]William Byrd, *My Ladye Nevells Booke,* ed., with an introduction and notes by Hilda Andrews (London: J. Curwen & Sons Ltd., 1926; reprint, Dover Publications, Inc., 1969), 96-101.

50Jorgensen states that a wolf third deviates from just by 23 cents or more and a wolf fifth by 9 cents or more. It is therefore interesting to note the near wolf intervals in both Pythagorean tuning and 1/3-comma meantone: Pythagorean - sharp major third (22 cents); 1/3-comma meantone - flat fifth (-7 cents). See Jorgensen, "Forgotten Sounds of Music," 18.

Chapter Four - Tuning and Temperament Considerations in Sixteenth- and Seventeenth-Century Ensemble Music

Music for Viol and Keyboard in Italy

With keyboard instruments tuned to some shade of meantone temperament, and viols tuned to equal temperament, it was inevitable that certain discrepancies would occur when these instruments are played together. Because of the inherent tuning problems, certain instrumental combinations were not highly recommended. De' Bardi (ca. 1580) wrote: "In your consort, then, you will as far as possible avoid combining lutes with keyboard instruments or harps or other instruments not tuned in unison."[1] There is only one published source in the sixteenth century that combined the fretted and keyboard instruments, the *Tratado de glosas*[2] (1553) by the Spanish theorist and composer Diego Ortiz (ca. 1510-ca. 1570). Ortiz spent a considerable time in Italy as a *maestro de capilla* for a number of Spanish viceroys, and it is here that he published his work, in both Spanish and Italian. The *Tratado* is divided into two parts. The first deals primarily with ornamentation and embellishment on the viol; in the second, Ortiz provides three recommendations for combining the viol and keyboard: improvisation, cantus firmus, and the use of a polyphonic composition.[3]

Although the *Tratado* contains the only known published examples, there were undoubtedly other pieces for this instrumental combination. Ian Woodfield states that "any piece of four- or five-part polyphony, sacred or secular, can be arranged for viol and keyboard following his [Ortiz's] guidelines."[4] If this combination was common, then some way of reducing the tuning discrepancies must have been possible. Since equal temperament does not appear to have been in use on keyboard instruments, there are three methods by which the performers could attempt to overcome the problem. First, the violist could alter the equally-tempered instrument sufficiently to approximate some form of meantone and thus be in better accord with the keyboard instrument. This could be done either by varying the position of the finger on the frets, by adjusting the frets themselves, or by slightly re-tuning some strings. Second, there might be a shade of meantone more compatible with an equal-tempered viol. Third, the players might use a combination of the two methods listed above.

Frederick Gable suggests various finger and fret adjustments that could facilitate a change from strict equal temperament in favour of meantone temperament. His suggestions aid in overcoming tuning problems that could occur between a viola da gamba and a keyboard instrument. At the conclusion of his article he lists four steps:

> 1) Adjust the pitches of notes by playing higher or lower on the frets (sharps should be lowered, flats raised, thirds of chords lowered).
>
> 2) Move frets 4 and 6 toward nut, and adjust

the notes of frets 1 and 3.

3) Tune open strings with a pure third and sharper fourths, move frets 3, 4, and 6 to mean-tone position and adjust pitches on fret 1.

4) Move all frets to mean-tone position, tune open strings to fretted unisons, tune tenor viol with an e string, and adjust for problem notes on fret 1.[5]

These recommendations (especially the first, which was mentioned by Bottrigari and Praetorius[6]) suggest that, despite the fretted nature of the instrument, a knowledgeable performer could adjust the instrument to be in better tune with the keyboard instrument.

While some players may have been able to compensate sufficiently to allow for some semblance of uniformity in tuning between the two instruments, there were undoubtedly others who could not. With this in mind, the composer might suggest a method that would effectively reduce the discrepancies that occur between two diversely tuned instruments. Max Schneider notes in his edition of the *Tratado de glosas* that "Ortiz prescribed that the harpsichordist should not play the soprano in this second ricercare. This line is printed with small notes."[7] This procedure contrasts with the other versions for bass viol, in which the entire soprano line is included.

A ricercare based on Arcadelt's madrigal "O felici occhi miei" appears on Side A of the thesis recording. This piece, adapted by Ortiz, consists of a treble line ornamented by the viol. Zarlino's

2/7-comma meantone has been selected for the harpsichord, since this temperament was, at the very least, a theoretical possibility at the time in question.[8] The recording has been made observing what might be termed "strict laboratory conditions":[9] the viol and the keyboard are tuned to their respective temperaments, making no allowances for slight alterations of pitch by the viol. This will allow the reader to hear the piece in unaltered form, or as a starting point; from here the performer might have made slight adjustments. Contrary to Ortiz's recommendation, the soprano line is included in order to establish the maximum level of tuning dissimilarity that might occur.

The discrepancy factors listed in Table 4-1 indicate the differences between an equal-tempered note and its counterpart in 2/7-comma meantone temperament.[10]

Table 4-1:

Discrepancy factors for 2/7-comma meantone temperament and equal temperament expressed in cents. Numbers for all tables: top row - equal temperament; middle row - 2/7-comma meantone shade; bottom row- discrepancy factor. Plus sign indicates sharp, negative sign flat. All meantone ratios taken from Barbour.[11]

C	C#	D	Eb	E	F
0	100	200	300	400	500
0	70	191	313	383	504
0	+30	+9	-13	+17	-4

F#	G	G#	A	Bb	B
600	700	800	900	1000	1100
574	696	765	887	1008	1078
+26	+4	+35	+13	-8	+22

Overall Discrepancy Factor[12]: 15.1 cents

Adjusted Discrepancy Factor[13]: 17.3 cents

Despite the large overall discrepancy factor, the tuning dissimilarities in the recording are surprisingly limited. However, they are noticeable in measures 9, 21, 30, and to a lesser degree measure 36. But even here the composer has reduced the conflict between the two systems by avoiding simultaneous use of notes with high discrepancy factors. An example is shown in Figure 4-1. Other significant areas are measures 26-27 and 49, which are short scale passages containing the notes D, C, B-flat, and A.

Figure 4-1:

Diego Ortiz, "O felici occhi miei," *Tratado de glosas*, measure 9

The material in this section has been removed because of copyright restrictions. The material contained a copy of "O felici occhi miei," *Tratado de glosas*, measure 9. This piece can be found in: Ortiz, Diego. *Tratado de glosas sobre clausulas y otros generos de puntos en la musica de violones*. Edited by Max Schneider. Kassel: Bärenreiter, 1936.

Measures 23, 42, 46, 55, 60, and 64 contain dissonances that result from cross relations. These cross relations, which are noticeable on the recording, involves the simultaneous sounding of the altered and natural form of a given note. They are mentioned so the reader will not identify them as tuning discrepancies.[14]

The lack of beating in this piece can be attributed to three factors related to tuning considerations. First, the soprano part shared by the harpsichord and viol, consisting mostly of half and whole notes, is less ornate in the keyboard line. This reduces the potential for direct unisons. Second, the unisons that do exist between the two parts generally have low discrepancy factors.[15] Third, the rapid decay of the harpsichord tone obscures many of the discrepancies. The note can be prolonged by renewal or embellishment, but the use of a sustaining instrument, such as an organ, would highlight the differences to a much greater degree.

These three factors seem to suggest that Diego Ortiz may have been aware of the tuning discrepancies that can occur. His recommendation that the soprano line be eliminated from the harpsichord part would appear to be the strongest evidence in support of this point.[16] It is necessary to point out, however, that no mention of tunings or temperaments, or the inherent problems involved when combining these two dissimilarly-tuned instruments together, is made in the *Tratado de glosas*.

Status of Tunings and Temperaments in the Early Seventeenth Century

A solution for overcoming the discrepancies between fretted and keyboard instruments was offered by Marin Mersenne (1558-1648), a French mathematician, philosopher, and music theorist who stated in 1637 that "if the organ and harpsichord were tempered according to the fretting of lutes and viols, performances in which they are combined would seem more in tune, because their tuning would agree."[17] It is uncertain if there were others who advocated applying equal temperament to keyboard instruments. Lindley suggests that in 1638 Girolamo Frescobaldi may have proposed equal temperament as the tuning for a new organ at St. Lorenzo in Damaso.[18] However, Frederick Hammond disputes this and claims that "there is no evidence that Frescobaldi was a proponent of equal temperament - even Doni's scurrilous anecdote concedes that Girolamo approved it 'against the judgment of his ears.'"[19]

Meantone temperament remained the primary tuning system of keyboard instruments; fretted instruments continued to employ equal temperament. The shade of meantone advocated most widely by theorists such as Marin Mersenne (1558-1648) and Michael Praetorius (in his *Organographia* of 1618) was 1/4-comma.[20] Shades with the major third smaller than pure, such as Salinas' 1/3-comma and Zarlino's 2/7-comma, although still in existence, were not as popular as 1/4-comma.[21] A description offered by Cyriacus Schneegass (1546-1597) in 1590 resembles 2/9-comma meantone[22] temperament with major thirds that are slightly larger than pure.[23]

English Ensemble Music

Ensemble music similar to that found in the *Tratado de glosas* would not be found in England for almost a half century after it first appeared in Italy. The period from about 1599 to 1625, known as the Jacobean period, corresponds approximately to the reign of King James I of England (1603-1625). It is during this time that the first significant strides in combining fretted and keyboard instruments in consort music were made.[24] This type of writing continued beyond the Jacobean period and with this combination came the inevitable problem of tuning. The English scholar, Sir Francis Bacon, wrote in his *Sylvum Sylvarum* (London, 1627),

> In that Musicke, which we call Broken musicke, or Consort Musicke; Some Consorts of Instruments are sweeter than others; (a Thing not sufficiently yet observed:) As the Irish Harpe and Base Viall agree well; the Recorder and Stringed Musick agree well: Organs and the voice agree well; &c. But the Virginalls and the Lute; Or the Welch-Harpe, and Irish Harpe; Or the Voice and Pipes Alone, agree not so well.[25]

In this passage, Bacon notes that the combination of diversely-tuned instruments had not been studied sufficiently, but he gives no instructions on how to deal with the problem. He also lists the virginal and the lute as a disagreeable combination, implying that the English musician had not arrived at a practical solution for the combination of a fretted and a keyboard instrument.

Instrumental choices for music between 1600-1650 are ambiguous, particularly in the case of the higher stringed (or "treble") instruments. Some manuscripts are perhaps deliberately vague[26] in order to allow the performer some latitude in choosing an instrument; a treble line might be performed by a viol or violin. The use of a keyboard instrument also varies. According to Thurston Dart and William Coates, a chamber organ is often used in combination with a consort of viols and a harpsichord with a consort of violins.[27]

John Jenkins and William Lawes are two major contributors to English chamber music in this era. An analysis of tuning discrepancies will be made by focusing on selected works by these composers.

Tuning and Temperament Considerations in the Music of John Jenkins

John Jenkins (1592-1678) was a distinguished performer on the lute and bass viol and a composer who wrote only chamber music. His music has been described as being "built on the foundation laid by Byrd and his contemporaries."[28] A work entitled *Fantasia-Suite 5*,[29] one of seventeen suites probably written during the early reign of King Charles I, is scored for treble, bass viol, and organ. The editor of this work, Christopher D.S. Field, has noted an ambiguity concerning the choice of a treble instrument. He recommends the violin, but in the introduction notes that "while close affinity with the fantasia-suites of Coprario and Lawes makes the violin . . . the natural choice, it is possible that it gave way to the viol in the East Anglian households where Jenkins worked."[30] The choice of either the viol or the violin as the treble instrument could prove significant in the context of this study (see below).

Other criteria for choosing either a viol or violin might have depended on the ability of the performer. According to Warwick Edwards, amateur string players would have been more inclined to use the viol, whereas the professional would have favoured the violin.[31] One would assume that the professional musician, unrestricted to any particular tuning or temperament (because of the fretless instrument[32]), might make an effort to sound in better tune with either the bass viol or the organ. The amateur violist, might, depending on his or her ability, find such tuning adjustments more difficult on a fretted instrument.

The differences that occur with two dissimilarly tuned instruments can again be shown in a series of tables. For this period, three shades of meantone are relevant: Salinas 1/3-comma,[33] Zarlino's 1/4-comma, and Verheyen's 1/5-comma.

Table 4-2:

Discrepancy factors for 1/3-comma meantone temperament and equal temperament expressed in cents. Numbers for all tables: top row - equal temperament; middle row - 1/3-comma meantone shade; bottom row - discrepancy factor. Plus sign indicates sharp, negative sign flat. All meantone ratios taken from Barbour.[34]

C	C#	D	D#[35]	E	F
0	100	200	300	400	500
0	64	190	254	379	505
0	+36	+10	+46	+21	-5

F#	G	G#	A	Bb	B
600	700	800	900	1000	1100
569	695	758	884	1010	1074
+31	+5	+42	+16	-10	+26

Overall Discrepancy Factor: 20.7 cents

Table 4-3:

Discrepancy factors for 1/4-comma meantone temperament and equal temperament:

C	C#	D	D#	E	F
0	100	200	300	400	500
0	76	193	269	386	503
0	+24	+7	+31	+14	- 3

F#	G	G#	A	Bb	B
600	700	800	900	1000	1100
579	697	773	890	1007	1083
+21	+3	+27	+10	- 7	+17

Overall Discrepancy Factor: 13.7 cents

Table 4-4:

Discrepancy factors for 1/5-comma meantone temperament and equal temperament:

C	C#	D	D#	E	F
0	100	200	300	400	500
0	83	195	278	390	502
0	+17	+5	+22	+10	- 2

F#	G	G#	A	Bb	B
600	700	800	900	1000	1100
586	698	781	893	1005	1088
+14	+2	+19	+7	- 5	+12

Overall Discrepancy Factor: 9.6 cents

The listing of numbers in a series of tables can be of questionable relevance unless they are applied directly to the music. Accordingly, the score to Jenkin's *Fantasia-Suite 5* is analyzed three times (beginning on page 67), each time according to one of the meantone shades listed above. In each case, the upper row indicates the differences between the treble viol and organ and the lower row shows the differences between the bass viol and organ. Recordings are included, which can be cross-referenced to the music; this allows the reader to identify a discrepancy visually once it has been heard, and to anticipate a discrepancy aurally once it has been identified in the music for the purposes of the recording. When the violin is the designated treble instrument, the upper rows of numbers in the music may be omitted. It has been assumed that the tunings between the violin and the organ would have been in agreement.[36] This instrument has been included in the first recording of each particular meantone shade. The second example of each shade substitutes an equal-tempered treble viol for the soprano line. This arrangement has been maintained throughout the six recordings (found near the middle of Side A of the tape), thus:[37]

1/3-comma: 1. violin (meantone)
2. treble viol (equal temperament)

1/4-comma: 3. violin
4. treble viol

1/5-comma: 5. violin
6. treble viol

Figure 4-2:

John Jenkins, *Fantasia Suite 5*, 1/3-comma meantone and equal temperament

The material pages 67 to 71 has been removed because of copyright restrictions. The material contained a copy of *Fantasia-Suite 5.* This piece can be found in:
Jenkins, John. *Fantasia-Suite 5.* Ed. by Christopher D.S. Field. London: Oxford University Press, 1965. Part of Musica da Camera 37.

Figure 4-3:

John Jenkins, *Fantasia-Suite 5,* 1/4-comma meantone and equal temperament

Figure 4-4:

John Jenkins, *Fantasia-Suite 5,* 1/5-comma meantone and equal temperament

The material pages 77 to 81 has been removed because of copyright restrictions. The material contained a copy of *Fantasia-Suite 5.* This piece can be found in:
Jenkins, John. *Fantasia-Suite 5.* Ed. by Christopher D.S. Field. London: Oxford University Press, 1965. Part of Musica da Camera 37.

In some sections of the work the tunings clearly do not correspond. In measures 16 to 18, for example, a number of sharps exhibit high discrepancy factors (note D-sharp in particular) if a treble viol in this experiment is used in the soprano line. The problems encountered at these points are compounded further by the inclusion of diatonic notes (B and E) which also have high discrepancy factors.

Figure 4-5:

John Jenkins, *Fantasia-Suite 5*, measures 16-18.

The bass viol exhibits the same kind of discrepancies at measures 56 to 59. However, with the resumption of the treble viol at measure 59, there are again two instruments that do not match pitch with the organ. Many of the discrepancies that occur are more noticeable in the upper tessitura of the treble viol because of its role as the primary melody instrument; there are, nevertheless, clearly audible tuning dissimilarities in the bass viol line as well.

The number of discrepancies experienced in this piece are directly proportional to the quantity of direct unisons. These intervals result when the organ line duplicates the string parts. The unison appears to be least successful when performed simultaneously in two different temperaments or tunings and a series of them, particularly in the same register, serves only to enhance the problem.[38]

In performances of music of this type, there would have been varying degrees of discrepancies depending on the skill of the string players. Although pitches on the treble viol can be adjusted, it is likely that amateur viol players, for whom much of this music was written, would have been the least successful in dealing with this problem. On the other hand, a professional violist or violinist could conceivably have reduced or eliminated the discrepancies. The recordings and data in Figures 4-2 to 4-4 also show that using 1/4- or 1/5-comma meantone temperament will help reduce the level of dissonance to a minimum.

Tuning and Temperament Considerations in the Music of William Lawes

William Lawes (ca. 1602-1645) has been described as the most important composer of the Caroline period.[39] During his short life, he was a noted writer of consort music, and from 1633 onward, worked as Music-in-ordinary for King Charles I. He entitled one of his works, "Paven and Alman of Alfonso - sett to the organ and 2 Division Base Viols by W.L.,"[40] based on a theme by Alfonso Ferrabosco II found in the organ line. The "Pavan" is the first movement of *Suite No. 2 in C Major.*

The organ part of the "Pavan" is an independent and necessary part of the composition, vital to the successful performance of the piece. This contrasts with Jenkins' *Fantasia-Suite 5* where the keyboard line is essentially a reduction of the viols. The two stringed instruments are "division" viols; this viol is the middle-sized bass instrument, described by John Playford.[41]

The piece is found at the beginning of Side B of the tape; it was recorded using the same equipment and procedures that were discussed in the earlier sections. Careful effort was made to balance both viols with the organ as accurately as possible. The organ part is tuned to the same shades of meantone 1/3, 1/4, and 1/5-comma (the order followed on the tape), with both division viols remaining in equal temperament. However, the object here is to ascertain by analysis whether instruments in a lower tessitura, with more independence from the keyboard, sound in better tune despite the potential for a large number of discrepancies. Also, the work is performed faster than might normally be possible to see if tempo has any effect in diminishing the audibility of the discrepancies.

The independence of the organ line does in fact reduce the number of direct successive unisons and the resulting mistunings. However, some clearly audible discrepancies remain. This can be attributed to a duplication of notes that still occurs between the viol and organ lines, even though they may not be direct successive unisons. Figure 4-6 illustrates:

Figure 4-6:

William Lawes, "Pavan," *Suite No. 2 in C Major*, measure 8

The material in this section has been removed because of copyright restrictions. The material contained a copy of the "Pavan" from *Suite No. 2 in C Major*, measure 8. This piece can be found in: Lefkowitz, Murray. *William Lawes: Select Consort Music*. Vol. XXI of *Musica Britannica*. London: Stainer and Bell Ltd., 1963.

In this example, notes D, E, and F are present in the viol and organ lines. The tuning dissimilarities are still apparent because of their discrepancy factors. In a comparison with 1/4-comma meantone and equal temperaments, note D has a discrepancy factor of 7 cents, note E, 14 cents, and note F, -5 cents.

Nevertheless, the "Pavan" is still the more successful of the two English pieces. Having two instruments in a lower tessitura in the same temperament does make a difference against a more sustained organ line, whose primary function in this piece is to act as a foundation for the viols. The lower register of the viols appears to exhibit a less noticeable beating when accompanied by an organ tuned in meantone temperament, partly because there are fewer prolonged notes with high discrepancy factors. (Measure 49 is an obvious exception.) The florid nature of the viol parts also does not give the listener much opportunity to focus directly on those areas where discrepancies do occur, particularly if the music is performed at a moderately quick pace. This is especially true from letter C onward. These factors contribute to making the performance of the composition in 1/5-comma meantone the least beat-filled and the most in tune. If the violists could manage to alter pitch slightly, even the greater discrepancies (such as those found in measure 49) could be adjusted to become satisfactory.

One final factor that might be taken into account is the human capacity to hear these phenomena. When dealing with two pitches, there is a roughness or beating that occurs when these pitches are brought together. The area where this roughness occurs is called the critical bandwidth (CBW). If the pitches are more than a critical bandwidth apart, the ear hears them as two separate pitches. The maximum roughness occurs approximately one-quarter of the way through the CBW. For notes in the lower register, the CBW is one octave, so the area of maximum roughness is about a minor third. For notes above middle C, the CBW is a minor third, so the maximum area of roughness is a semitone. This is why pitches that vary by any quantity will be more noticeable in the upper register.[42]

Endnotes Chapter Four

[1] De' Bardi, 107.

[2] Diego Ortiz, *Tratado de glosas*, ed. by Max Schneider (Kassel: Bärenreiter, 1936).

[3] There are six ricercars that appear in the cantus firmus style based on the "La Spagna" melody. The keyboard player is expected not only to improvise a harmonization, but to add counterpoint. The cantus firmus provides "a framework for the improvisation and also acts as a foil to the 'syncopation' of the solo instrument." A discussion describing the specific details of the *Tratado de glosas* can be obtained by referring to Ian Woodfield, *The Early History of the Viol* (Cambridge: Cambridge University Press, 1984), 172-78.

[4] Woodfield, 175.

[5] Gable, 37.

[6] See Chapter One, 2-3.

[7] Ortiz, xv. Translated from the German text supplied by the editor: "Da Ortiz seite 68 vorschreibt, das der Cembalist den Sopran in dieser zweiten Recercada lieber nicht spielen soll, ist diese Stimme hier mit kleinen Noten gedruckt."

[8] See Chapter Two, "Meantone Temperament."

[9] In producing this recording, some modification in technique was necessary. Since the Proteus does not have the ability to reproduce more than one of the two required timbres at a time, pulse tones were added to the tape to synchronize the tracks. This was done when the harpsichord part was recorded on a Fostex eight-track reel-to-reel tape recorder. When the harpsichord track was re-played, the encoded pulse tones signalled the Cakewalk program to re-start, thus enabling the viol to be recorded on a separate track.

[10]For example, in 1/3-comma meantone, the note C-sharp has a discrepancy factor of +36 cents. This means that C-sharp is 36 cents sharper in equal temperament than in meantone temperament.

[11]Barbour, 33. Barbour's number for G-sharp in 2/7-comma meantone is 817 cents, but this does not correspond to my own computations; therefore, my adjusted ratio of 765 cents is given.

[12]An overall discrepancy factor adds all the numbers from the row ignoring any negative signs and then divides the number by twelve. This number is useful when ascertaining by how much one shade of meantone differs from equal temperament.

[13]In order to be consistent with the other tables found in the section entitled "Tuning and Temperament Considerations in the Music of John Jenkins," where the tables list a D-sharp rather than an E-flat, the Adjusted Discrepancy Factor is calculated assuming a D-sharp was also present here.

[14]For a full discussion of this type of cross-relation, see James Haar, "False Relations and Chromaticism in Sixteenth-Century Music," *Journal of the American Musicological Society* 30 (1977): 391-92.

[15]For example, note D is sounded quite frequently throughout the piece with a discrepancy of 9 cents. The style of writing obscures other notes, such as F-sharp, that have high discrepancy factors; this is done by avoiding a simultaneous sounding of the note, or by embellishing it. Any dissimilarity would be reduced even further by using 1/4- or 1/5-comma meantone, since they employ an even lower overall discrepancy factor.

[16]The *Tratado de glosas* contains one other piece written for treble viol; entitled "Doulce memoire," it is based on a chanson. In this piece the soprano would have to be eliminated in the harpsichord line, since measure 3 contains a sustained C-sharp which is not embellished or syncopated, and would therefore be blatantly out of tune.

[17]Mersenne made this comment in his *Nouvelles Observations Physique et Mathematiques* (which was appended to his *Harmonie universelle).* See Lindley, *Lutes, Viols, and Temperaments,* 45 and Mark Lindley, "Mersenne on Keyboard Tuning," *Journal of Music Theory* 24 (1980): 189.

[18]Lindley, "Temperaments," 665. The organ was eventually tuned to meantone, not equal temperament.

[19]Frederick Hammond, *Girolamo Frecobaldi* (Cambridge, Massachusetts: Harvard University Press, 1983), 107.

[20]Lindley, "Temperaments," 666.

[21]Ibid.

[22]Ibid., 662.

[23]For a full explanation of Schneegass's temperament including the mathematical theory involved, see Barbour, 37-40.

[24]Some of the earliest English consort music has been compiled by Thurston Dart and William Coates and published as part of the *Musica Brittanica* series. See Thurston Dart and William Coates, "Jacobean Consort Music," vol. IX of *Musica Brittanica* (London: Stainer & Bell Ltd., 1962). The music found in this volume is only a small portion of that which survives from this era. Under the heading "Music for Strings and Keyboard," the editors have included thirteen pieces including combinations for treble viol and harpsichord (1), harpsichord and bass viol (2), violin, bass viol, and organ (2 suites, 6 movements), 2 violins, bass viol, and organ (2 suites, 6 movements), and string quartet and continuo (4).

[25]This quotation from Sir Francis Bacon is taken from Warwick Edwards' article, "The Performance of Ensemble Music in Elizabethan England," *Proceedings of the Royal Musical Association* 97 (1970-71): 113.

[26]John Jenkins, *Fantasia-Suite 5*, ed. Christopher D.S. Field (London: Oxford University Press, 1965), Introduction.

[27]Dart and Coates, viii-xix. Francis Routh also notes that "the use of the organ in conjuction with the viols was perhaps, in retrospect, inevitable. Instruments other than the organ were also used as continuo - the harp and the theorbo for instance. But the fact that the viol was not given to maintaining a sostenuto tone over any length of phrase, and that its characteristic speech consisted of short figures, made the sustained quality of organ-tone the perfect foil for it." See Routh, 52.

[28]Andrew Ashbee, "Jenkins, John," in *New Grove Dictionary*, 597.

[29]Jenkins, *Fantasia-Suite 5*.

[30]Jenkins, introduction.

[31]Warwick A. Edwards, "Consort," in *New Grove Dictionary*, 674. See also "The Performance of Ensemble Music in Elizabethan England," *Proceedings of the Royal Musical Association* 97 (1970-71): 122. Amateur players would have included aristocrats and noblemen, while professionals would have been those of a lower social status employed to supply dance music.

[32]In 1674, John Playford, in his treatise entitled *An Introduction to the Skill of Musick*, suggested that the begining violinist apply frets to the fingerboard of the instrument. This "is the best and easiest way for a Beginner who has a bad Ear; for by those Frets he has a certain Rule to direct and guide him to stop all his bad notes in exact Tune . . ." See John Playford, *An Introduction to the Skill of Musick* (1674; reprint, Ridgewood New Jersey: The Gregg Press Incorporated, 1966), 110.

[33]1/3-comma rather than 2/7-comma was used because it seemed necessary to include only one shade of meantone temperament with thirds smaller than pure. Also, this shade contains the largest overall discrepancy factor, exhibiting the maximum amount of distortion that can be heard between these two temperaments.

[34]For 1/3-comma ratios, see Barbour, 35. For 1/4-comma ratios, see Barbour, 26. For 1/5-comma ratios, see Barbour, 35.

[35]The note in this position is usually E-flat in meantone temperament; however, "Fantasia-Suite 5" contains no E-flat, but does contain a number of D-sharps. The notes are not enharmonically equivalent and so a ratio for D-sharp had to be calculated. For 1/4-comma, the process was simple: the lesser diesis of about 41 cents was subtracted from Barbour's given ratio for E-flat. For the other shades, the difference of the shade's major third from a pure major third had to be included, and added or subtracted to the diesis before the new ratio could be derived.

[36]This is for the purpose of the recordings only; a violinist may also not be completely successful in matching pitch.

[37]This piece was recorded using the same equipment and techniques which were found in the preceding section with some exceptions in the choice of instrumental timbre. The keyboard was recorded using the "chapel organ" setting, while the soprano strings alternate between "violin" (numbers 1, 3, and 5) and the "gamba musik" (2,4, and 6) settings. The latter setting was used consistently for the bass viol line. The "violin" setting on the Proteus does not have the same response as the same line performed with the "gamba musik" setting. Therefore, those passages in this work with note values greater than a sixteenth (the trills) exhibit a noticeable decrease in volume.

[38]The keyboard accompaniments of some consort pieces are mere reductions of the viol lines that might serve only as a rehearsal guide. In a personal communication, Richard Troeger has questioned whether the accompanist rendered such keyboard reductions literally. Indeed, the realization might vary, less literal for the viol because of potential tuning discrepancies and more literal for the violin. This is difficult to ascertain, but is nonetheless relevant.

[39]Murray Lefkowitz, *William Lawes: Select Consort Music,* vol. XXI of *Musica Brittanica* (London: Stainer & Bell Ltd., 1962), xiii.

[40]Murray Lefkowitz, *William Lawes* (London: Routledge and Kegan Paul, 1960), 141.

[41]Lefkowitz notes the descriptions offered by Playford: "First, Bass-Viol for Consort must be one of the largest size . . . Secondly, a Bass-Viol for Division must be of a less size . . . Thirdly, a Bass-Viol to play the Lyra-Way, that is by Tableture [sic], must be somewhat less than the two former." See Lefkowitz, *William Lawes*, 126.

[42]There are other factors that will affect the way we perceive musical pitch including timbre, amplitude, and ear sensitivity. See Chapter Five, John R. Pierce, *The Science of Musical Sound* (New York: Scientific American Books, 1983), 74-81; and Murray Campbell and Clive Greated, *The Musician's Guide to Acoustics* (New York: Schirmer Books, 1987), 165-69.

Chapter Five - Conclusions

In England, the transition from Pythagorean intonation to meantone temperament appears to have occurred around the turn of the sixteenth century. Without English treatises to provide relevant information about musical practice at this time, one can only assume that this country was influenced by external sources, notably those from Italy. The transition was epitomized in fifteenth-century Italy by Ramis and Hothby and their allies; they in turn may have influenced Dionisio Memo, who was appointed to the Court of King Henry VIII in 1516.

If Memo's presence and possible influence cannot be established beyond a reasonable doubt, John Redford's music of the 1530s is nevertheless well-suited to meantone temperament. It does not seem likely that this music and that of his contemporaries, such as Whyte, Blitheman, and Tallis, whose works are also found in *The Mulliner Book*, would have been written in a manner so appropriate to meantone temperament without some precedent because, "one should not presume that the transition to meantone was sudden."[1] The overall styles used by Redford were evidently embraced by Byrd, whose music continued to exhibit characteristics appropriate to this temperament.

At the turn of the seventeenth century, the English began writing for instrumental combinations that contained incompatible tunings. Music of this kind had been written about fifty years earlier in Italy by Diego Ortiz, whose style of writing and performance recommendations suggest an awareness of tuning problems. Apparently, this was not the case in early seventeenth-century England, where only limited reference was made to the problem and no practical solutions were offered.

Four conclusions can be elicited from the recordings and the surveys:

1) Combining 1/3-comma meantone and equal temperament results in the highest Overall Discrepancy Factor and is therefore the least successful combination. 1/4-comma works better and 1/5-comma is the least out-of-tune.

2) A composition that is not a direct reduction of the string lines will result in fewer direct unisons and tuning discrepancies.

3) Tuning dissimilarities are more evident in the higher register. The laws governing the critical bandwidth will inhibit the ear's ability to perceive some of the less obvious tuning problems in the lower range.[2]

4) The use of a sustaining instrument, such as an organ, accentuates the tuning difficulties. A harpsichord, or any other non-sustaining instrument, reduces the perceptibilty of the problem.

It is difficult to ascertain how early practical musicians reacted when confronted with tuning discrepancies. It seems likely that they tolerated the dissonances or modified appropriate pitches as well as their ability permitted. The conclusions listed cannot serve as guidelines for an "authentic" performance, but they can help the modern musician achieve an awareness of what might have been in use and practical in the Renaissance and early Baroque.

Endnotes Chapter Five

[1]Lindley, "Fifteenth Century Evidence," 51.

[2]This, of course, would depend on the number of performers. The discrepancies generated by one or two players might not be readily perceptable in the lower register, but given many performers, the tuning problems would become apparent, no matter what the range.

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Appendices

Glossary

Apotome - The larger semitone found in Pythagorean tuning. It has a ratio of 2187:2048.

Beating - Jorgensen states that beating occurs when, ". . . the coinciding harmonies of a just interval no longer quite coincide after the interval has been tempered. When sounding a tempered interval, opposite frequency phases of the non-coinciding (conflicting) harmonies cause periodic cancellations of the tones of the harmonics." See Jorgensen, *Tuning the Historical Temperaments by Ear*, 417.

Cent - 1/1200 of an octave. In equal temperament each semitone is divided into 100 equal parts. Each part is one cent.

Comma - According to Jorgensen, "a comma is the difference between two sets of just intervals or combinations of just intervals. A comma always exists and creates wolf intervals in various locations on an instrument with a conventional keyboard that is tuned in just tuning or in many other systems which are very close to just tuning. A comma also prevents the intervals used on a conventional keyboard to being all justly in tune at the same time." For further explanation see Jorgensen, *Tuning the Historical Temperaments by Ear*, 417-418.

Diesis - A discrepancy between two enharmonically related notes on a keyboard.

Discrepancy factor - The difference between identical notes tuned to different systems performed simultaneously. Measured in cents.

Equal Temperament - A system where in theory the distance from one semitone to the next is exact (100 cents). There is no wolf, and no interval is pure although the perfect fifth is only 2 cents flatter than pure.

Just Intonation - A system based on the natural harmonic series. Intervals are expressed in simple ratio. It contains numerous pure intervals including pure major and minor thirds and pure perfect fourths and fifths.

Limma - The smaller semitone found in Pythagorean tuning. It has a ratio of 256:243.

Meantone Temperament - A system where the syntonic comma is divided among the perfect fifth intervals. One shade, 1/4-comma, has pure major thirds although the perfect fifths are about 5.5 cents flatter than pure. Tempering the fifths leads to a wolf interval that is 36 cents sharp in 1/4-comma. Other common shades are 1/3, 2/7-, 1/5-, and 1/6-comma.

Overall Discrepancy Factor - A derived number in cents where all the discrepancy factors from a table have been added together ignoring any negative signs and dividing the total by twelve. Useful in determining an average discrepancy factor.

Pythagorean comma - Also known as the "ditonic" comma. It is the difference between the limma and the apotome and is about 24 cents flat with a ratio of 531441:524288.

Pythagorean tuning - A system with the pure perfect fifth interval as its basis. Other intervals are obtained by the addition and subtraction of ratios.

Syntonic comma - Is the difference between the interval obtained by tuning four pure consecutive fifths upwards and two octaves and a pure major third. The four perfect fifths will exceed the the octaves and pure third by about 22 cents. Also known as the comma of Didymus.

Wolf - A wolf is an interval that deviates from pure to the point where the harmonics of the pitches beat so rapidly that the interval is normally not usable.

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"O felici occhi miei," by Diego Ortiz found in:
Ortiz, Diego. *Tratado de glosas sobre clausulas y otros generos de puntos en la musica de violones.* Edited by Max Schneider. Kassel: Bärenreiter, 1936.

"Pavan," from *Suite No. 2 in C Major,* by William Lawes found in:
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