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Tuning and Temperament

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Sensitivity to tuning and awareness of historical tuning systems is a vitally important part of Renaissance performance style. Perhaps the single most important facet of the Renaissance approach to tuning over that of more recent eras is the primacy of the pure major third: the preference for a major third that is narrower than an equal-tempered major third by about 1/7 of a semitone. Such a major third is called "pure" because it produces no "beats" (audible pulsations produced when two slightly out-of-tune notes are sounded together). Unfortunately, modern musicians are generally so used to equal-tempered major thirds that they initially hear a pure major third as dolefully narrow or flat. This is something most listeners will quickly overcome once they have the purity of the interval pointed out to them and get used to hearing it. The really insurmountable problem related to tuning in the Renaissance, as should be evident from the discussion below, has to do with the basic incompatibility of the nature of sound with our instruments and our system of notes. But this is a problem that applies equally to music of any era, so don't be discouraged. There is still much that can be done with tuning to enhance the performance of Renaissance music, and it is not as difficult as it might seem at first.

Keyboard

We speak of the "circle of fifths," that procedure whereby, starting on any note and going up or down in series by the interval of a fifth, eventually we arrive at a note with the same name as the one we started on. The problem is that if we tune fifths that are acoustically pure, the note we arrive at after a circle of twelve fifths will be about one-quarter of a semitone sharp to the starting note. Similarly, we think of an octave as made up of a series of three major thirds, like C to E, E to G♯, and G♯ (or A♭) to C. But again, if we tune

acoustically pure major thirds, we arrive at a note that is almost half a semitone flat to the starting note.

So, while acoustically pure fifths and acoustically pure major thirds would seem to be desirable sonorities to have in performance, there is no way that either one of them can be completely reconciled to the 12 available pitches of the keyboard octave. Either we tune 11 perfect fifths and leave the last one dissonant and unusable, or we compromise the perfection of the fifths and create what is known as a temperament.

Pythagorean Tuning

Until about the middle of the fifteenth century, practically the only system described or recommended by theorists was one involving the use of pure fifths. It had historical preeminence, since the mathematical ratio for pure fifths, 3:2, had first been expounded by the Greek philosopher Pythagoras and continued to be cited by theorists throughout the medieval period. It also made sense musically, since in so much of the music of the time, the interval of the open fifth was the predominant sonority. And few enough accidentals were used that it was usually possible to avoid the dissonant "fifth"—the "wolf fifth" as it was called—without too much difficulty. We know this system now as Pythagorean Tuning or Pythagorean Intonation.

Equal temperament is actually not a bad approximation of Pythagorean Intonation. The dissonance of the Pythagorean "wolf" is averaged out over the circle of twelve fifths, so that each interval is only slightly narrower than pure, a difference of only about 1/50 of a semitone.

The real shortcoming of Pythagorean Tuning (and of equal temperament, for that matter) is the imperfection of the major thirds. Pythagorean thirds are very wide—not at all pleasant, so as composers began to use more thirds in their harmonic writing in the fifteenth century, performers must have found the system to be increasingly unsatisfactory. As we shall see, one solution was to "transpose" the system so that it had more usable major thirds.

The standard Pythagorean Tuning is represented in Table 22.1 using a system of "cents" in which 100 cents is equal to an equal tempered semitone. The tuning is created by tuning pure fifths (702c) down to E♭ and up to G♯, leaving the "wolf" between those two notes.

You will notice that there are two sizes of semitone, termed major (M) and minor (m). The major third which appears commonly in the system

TABLE 22.1 Pythagorean Tuning expressed in cents

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B	C
0	114	204	294	408	498	612	702	816	906	996	1110	1200
	M	m	m	M	m	M	m	M	m	m	M	m

(C–E, D–F♯, etc.) is more properly known as the Pythagorean ditone and consists of two major and two minor semitones (2M + 2m). This is the interval that is extremely sharp, at 408c (the *pure* major third is only 386c). But it can also be seen that a *good* major third (384c) occurs in four places in this system as a diminished fourth (M + 3m): B–E♭ (D♯), F♯–B♭, C♯–F, G♯–C. Henri Arnaut (ca. 1440) introduced or, at least, transmitted a transposed Pythagorean system in which three of those good major thirds occurred in more useful places: B–D♯ (as in Pythagorean), D–F♯, E–G♯, A–C♯ (see Table 22.2). While these may not seem at first glance to be so useful, they occur often at approaches to cadences, whereas cadential resolutions are still, in the early to mid-fifteenth century, likely to be open fifths and therefore less in need of good major thirds. Arnaut's system is created by tuning perfect fifths down to G♭ (which Arnaut still calls F♯) and up to B. This leaves the wolf fifth at the interval B–F♯, which, of course, may need to be adjusted for a particular piece if it occurs prominently.

TABLE 22.2 Arnaut's transposed Pythagorean Tuning expressed in cents

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B	C
0	90	204	294	408	498	588	702	792	906	996	1110	1200
m	M	m	M	m	m	M	m	M	m	M	m	

Meantone Temperaments

Pythagorean Tuning works fairly well into the second half of the fifteenth century, giving good realizations of many of the works in the *Buxheim Organ Book,* for example, particularly those based on early fifteenth-century chansons. But by the late fifteenth century, according to indications in *Musica practica* of Ramos de Pareja (1482), keyboard players seem to have arrived at a new solution—one that made extensive use of the ratio for the pure major third, 5:4, first formally revived from classical theory by Gafurius in 1518. In the classic temperament of this type, 1/4 comma meantone (among the many varieties of meantone temperaments—I once heard Bob Marvin refer to this one as "God's Meantone"), there are eight pure major thirds (2M + 2m), and four excruciating ones (3M + m). The real cost of the pure major thirds is not these four unusable ones, however, but rather that in order to achieve the pure major thirds, it is necessary to temper (narrow) the fifths more than 2–1/2 times the amount necessary for equal temperament, rendering them noticeably narrow and dissonant compared to those of the Pythagorean or even the equal tempered system. Most Renaissance music has lots of thirds, however, and the bitterness of the fifths tends to get lost in the overwhelming sweetness of the thirds. *It is impossible to overemphasize the positive and colorful effect of 1/4 comma meantone on keyboard music of the Renaissance.*

The name 1/4 comma meantone (Table 22.3) comes from two different characteristics of the temperament: If you were to tune four pure fifths up

TABLE 22.3 1/4 comma meantone: usual notes expressed in cents

C	C♯	D	E♭	E	F	F♯	G	G♯/A♭	A	B♭	B	C
0	75.5	193	310.5	386	503.5	579	696.5	772/814	889.5	1007	1082.5	1200
m	M	M	m	M	m	M	m/M	M/m	M	m	M	

from C (C up to G, to D, to A, then to E), the note E that you arrive at would be sharper than a pure major third above C by 22c (about 1/5 of a semitone), an amount known as a *syntonic comma.* But if, in order to tune that E as a pure major third, you divide up the discrepancy among the four fifths, each interval of a fifth would be tempered (narrowed) by 1/4 of that amount, hence "quarter-comma." The term "meantone" comes from the fact that, in this system, the whole tone is exactly half of the pure major third. (Note that, as in Pythagorean Tuning, there are two different sizes of semitone; in meantone, however, the chromatic semitone is minor and the diatonic semitone is major.)

To set 1/4 comma meantone on the keyboard, tune C–E in the tenor octave as a pure major third then, using a flashing metronome, narrow the C–G fifth to beat at about 74 beats/minute at a′ = 440 (70/min. at a′ = 415); widen the D–G fourth to beat at 110 (104)/min.; narrow the D–A fifth to beat at 82 (77)/min.; check that the E–A fourth is beating about 123 (116)/min.; if it is not, check the above intervals again. (If you are using an A fork, tune A–D–G–C, then C–E pure, checking it with the A.) The rest of the temperament can be set entirely by tuning pure major thirds above and below those notes. The usual question is G♯/A♭, which can be set as a pure major third either to E or to C depending on which note is needed for the music.

In practice, 1/4 comma meantone works beautifully as long as a note is not used in more than one of its enharmonic forms throughout a piece of music. This can include some fairly chromatic works, such as Giles Farnaby's "His Humour" from the *Fitzwilliam Virginal Book* and Sweelinck's *Fantasia chromatica.* However, once a note is used in more than one enharmonic form, as happens more frequently in music after 1600 (e.g., Frescobaldi's *Cento Partite*), it is necessary either to have split keys on the keyboard, to tolerate one or more pungent surprises, to set the pitch of the note halfway between the two pure major third positions, or to choose a different temperament.

Other meantone systems advocated in the Renaissance include 2/7 comma (Zarlino, 1558) and 1/3 comma (Salinas, 1577)—temperaments in which the fifths and the major thirds are even smaller than in 1/4 comma meantone. (1/3 comma meantone was actually intended for an instrument with many split keys and, as such, results in a useful system of 19 equal notes to the octave, pure minor thirds, and no wolf fifth.) It is also possible that less extreme forms of meantone, such as 2/9, 1/5, and 1/6 comma as well as some irregular temperaments (having many different sizes of fifth and major third) might have evolved in practice in a search for better fifths than 1/4 comma's, even though the improving fifths result in worsening major thirds. These temperaments, especially the less extreme forms of regular meantone systems, may be useful as a compromise, if the keyboard instrument must play with fretted instruments.

Fretted Instruments

> And more than once I have felt like laughing when I saw musicians struggling to put a lute or viol into proper tune with a keyboard instrument . . .
>
> —Giovanni de' Bardi to Giulio Caccini (ca. 1580)
> (quoted in Strunk, *Source Readings*, p. 297)

The nature of fretted instruments, with strings tuned in fourths and a major third, yet needing the frets to serve for all the strings and produce pure octaves and unisons across the compass, does not easily allow the use of unequal fretting. To cite some examples, if the one major third between open strings is tuned pure, it becomes more difficult to tune octaves from one side to the other of that interval. If the fourth fret of an A lute is tuned as a pure major third to the open string to accommodate all the sharp notes there, it ruins the tuning if the fourth fret E♭ is used extensively in a piece. So while adjustments in the fretting can be made (and were made during the Renaissance), and while good players can vary the pitch of a note against the frets by pulling and pushing the stopped string (*intensione* and *remissione* according to Aaron, 1545) to raise and lower, respectively, the pitch, fretted instruments like to play in equal temperament. After 1550, this was clearly a prevalent system, which is why the conflict with keyboard instruments arose. However, some writers were advocating Pythagorean Tuning into the middle of the sixteenth century(!), and there is some musical and theoretical evidence for the use of meantone temperaments right through the century. Thus, shadings one way or the other from equal temperament are possible and, indeed, when fretted instruments are played with keyboards, we assume that some sort of compromise was made which enabled them to sound in tune with each other.

Pythagorean Tuning

Pythagorean Tuning would not seem to be very appropriate for music as late as it was still recommended (Bermudo, 1555). Probably, the sixteenth-century theorists advocating it were not in close touch with the practical aspects of lute and viol playing. Still, instructions such as those provided for Pythagorean Tuning by Oronce Fine in 1530 result in a workable system for the fifteenth century at least, corresponding to Arnaut's transposed system

for keyboard (see Table 22.5). Along a single string, the arrangement of major and minor semitones is the same as in Arnaut's scale with the exception of the last two intervals, which are reversed, since Fine tunes the eleventh fret as a pure fourth to the sixth fret rather than as a pure fifth to the fourth fret. (In cents, the value would be 1086 rather than 1110.)

Equal Temperament

A Pythagorean whole tone has the ratio 9:8. In attempting to divide that into semitones and still use simple ratios, some Renaissance writers advocated that 9:8 (18:16) be divided into 18:17 (minor semitone) and 17:16 (major semitone). Interestingly, in practice, musicians found only 18:17 to be useful in fretting. According to Martin Agricola in 1545, many lutenists and gambists made all their frets equal and used only the minor semitone. In fact, 18:17 as a ratio from one fret to the next results in a very satisfying equal temperament comparable to one using the more correct scientific method (see Table 22.5). It is possible that the discrepancies are made negligible by such variables as the increased tension of the string when it is depressed to the fingerboard. It is also likely that any temperament such as this was shaded by ear by a good player, with frets 1, 4 (especially), and 6 being the obvious candidates for slight adjustment toward a meantone scheme.

Meantone Temperaments

It seems clear that some music for fretted instruments, particularly before 1550, is better served by a meantone system than an equal-tempered one. Certain tablature choices of string and fret in situations where there is more than one possibility lead to that conclusion. Also, although no one has yet done a thorough study of them, surviving sixteenth-century instruments with fixed frets (including citterns, bandoras, and orpharions) show a tendency toward meantone schemes. In addition, some fretting instructions from the period speak of major and minor semitones in places that would correspond to meantone rather than to Pythagorean Tuning. Obviously, players could not have tuned their open fourths so wide and the major third so narrow, or adjusted their frets to the extent that they were unable to push or pull the unisons and octaves into tune. But they may have preferred the coloristic effect of a meantone approximation, and they must have done something to make it possible to play with keyboard instruments. In fact, it *is* possible to approximate meantone tuning on a fretted instrument, but it requires two things: the setting of the frets according to the interval ratios in meantone, and the tuning of the open strings to the intervals created by the fretting (this may be checked against a meantone-tuned keyboard). Table 22.4 is a reference chart showing the notes for open strings and frets of three common tunings for Renaissance lutes and viols. Table 22.5 gives

TABLE 22.4 Chart of notes for fretted instruments in G, A, and D

Fret						
	G	C	F	A	D	G
1.	G♯	C♯	F♯	B♭	E♭	G♯
2.	A	D	G	B	E	A
3.	B♭	E♭	G♯	C	F	B♭
4.	B	E	A	C♯	F♯	B
5.	C	F	B♭	D	G	C
6.	C♯	F♯	B	E♭	G♯	C♯
7.	D	G	C	E	A	D
8.	E♭	G♯	C♯	F	B♭	E♭
9.	E	A	D	F♯	B	E
10.	F	B♭	E♭	G	C	F
11.	F♯	B	E	G♯	C♯	F♯
12.	G	C	F	A	D	G

Fret						
	A	D	G	B	E	A
1.	B♭	E♭	G♯	C	F	B♭
2.	B	E	A	C♯	F♯	B
3.	C	F	B♭	D	G	C
4.	C♯	F♯	B	E♭	G♯	C♯
5.	D	G	C	E	A	D
6.	E♭	G♯	C♯	F	B♭	E♭
7.	E	A	D	F♯	B	E
8.	F	B♭	E♭	G	C	F
9.	F♯	B	E	G♯	C♯	F♯
10.	G	C	F	A	D	G
11.	G♯	C♯	F♯	B♭	E♭	G♯
12.	A	D	G	B	E	A

Fret						
	D	G	C	E	A	D
1.	E♭	G♯	C♯	F	B♭	E♭
2.	E	A	D	F♯	B	E
3.	F	B♭	E♭	G	C	F
4.	F♯	B	E	G♯	C♯	F♯
5.	G	C	F	A	D	G
6.	G♯	C♯	F♯	B♭	E♭	G♯
7.	A	D	G	B	E	A
8.	B♭	E♭	G♯	C	F	B♭
9.	B	E	A	C♯	F♯	B
10.	C	F	B♭	D	G	C
11.	C♯	F♯	B	E♭	G♯	C♯
12.	D	G	C	E	A	D

fretting ratios for Pythagorean Tuning, equal temperament, and 1/6, 1/5, and 1/4 comma meantone temperaments. In order to use the information in Table 22.5, measure the distance from the nut to the bridge on the instrument in question and multiply that amount by the ratios to give the correct theoretical placement of the frets in each system. It should be noted that while professional players may start with formulas for placing the frets, they always make minute adjustments based on checking octaves and unisons across the strings.

Finally, in attempting to achieve a flexible meantone system, some modern players have had success with "split frets" or taped-on partial frets to accommodate both *mi* and *fa* possibilities. For a bass viol of average string length, this would require separation of the strands of the fret by just over

TABLE 22.5 Fretting ratios for Pythagorean Tuning, equal temperament, 1/6 comma meantone, 1/5 comma meantone, and 1/4 comma meantone

Fret	*Pythagorean*	*Equal*	*1/6 Comma*	*1/5 Comma*	*1/4 Comma*
1.	.0508	.0561	.0499(.0605 Fa)	.0471(.0625 Fa)	.0429(.0654 Fa)
2.	.1112	.1091	.1074	.1067	.1056
3.	.1563	.1591	.1615	.1625	.1641
4.	.2100	.2063	.2033(.2133 Fa)	.2020(.2148 Fa)	.2000(.2183 Fa)
5.	.2500	.2508	.2515	.2518	.2523
6.	.2881	.2929	.2889(.2969 Fa)	.2871(.2986 Fa)	.2845(.3012 Fa)
7.	.3333	.3326	.3320	.3317	.3309
8.	.3672	.3700	.3724	.3735	.3750
9.	.4075	.4054	.4037	.4030	.4018
10.	.4375	.4388	.4398	.4403	.4410
11.	.4661	.4703	.4678	.4667	.4650

half an inch for the first fret, proportionately less for the fourth and sixth frets. In practice, the first fret is the one most in need of "splitting" and the one where the separation is large enough to allow even lutenists to make the necessary distinction in difficult situations such as bar chords. This is a good compromise, but if you are using single frets, try working with *fa* on the first fret and *mi* on the fourth and sixth frets. There is also the possibility that the tied frets on lutes and viols were sometimes slanted. The first fret of a G lute, for example, might be slanted to give a longer string length in the bass in view of the sharped notes there, and a shorter string length in the treble in view of the flatted notes there, although the top string's first fret note would be unusable as a G♯ in such an arrangement.

Voices, Violins, and Other Musical Wind Instruments

Performance media such as these with greater "real-time" tuning flexibility than keyboard and fretted instruments may aspire to the perfection of Just Intonation, a system in which all fifths and major thirds are tuned pure. This is not to say that they cannot use other systems as well. Many woodwind makers, for example, use a 1/4 comma meantone basis for their instruments even though there may still be a tendency for players to want to play the fifths as pure as possible. On the other hand, I have found that singers will quite easily accommodate themselves to singing with an organ tuned in 1/4 comma meantone in spite of the discomfort of singing the narrow meantone fifths *a cappella*. Thus, it is clear that performers with tuning flexibility can and should adjust to instruments with fixed systems.

But what of Just Intonation? Is it a chimera? Performances by vocal groups like the Hilliard Ensemble, the Tallis Scholars, and Gothic Voices have made it apparent that approaching perfection in tuning is not an impossible dream. While a good part of their tuning precision is due to good ears, outstanding musicianship, and intuition, there are a few conscious adjustments that can be made that will begin to "justify" the tuning of any ensemble.

The Just scale contains some characteristics of both the Pythagorean and 1/4 comma meantone systems. However, many of the notes in the system must maintain the flexibility to adjust depending on the context. Some notes are fairly stable and others need only a couple of different positions. Of the notes in the C diatonic scale, A is the most likely to need adjustment; its sharper form makes a pure fifth with the regular D, and its flatter form makes a pure fifth with E and a pure major third with F. D itself may occasionally need adjustment if the A is already prevailing in its flatter form. Similarly, F or B♭ will need to be adjusted when those two notes sound together. The other accidentals are tuned as pure major thirds and fifths to the diatonic notes, the most common flip-flop being at the G♯/A♭ level.

TABLE 22.6 Just Intonation: most common cents values and frequent alternates

C	C♯	D	E♭	E	F	F♯	G	G♯/A♭	A/A	B♭	B	C
0	70	204	316	386	498	590	702	772/814	884/906	1018	1088	1200
	(92)	(182)			(520)					(996)		

Bibliography

Original Sources

Agricola–*Musica*; Arnaut de Zwolle–Manuscript; Aaron–*Toscanello*; Aaron–*Lucidario*; Bermudo–*Declaración*; Fine–*Epithoma*; Gafurius–*Practica*; Gafurius–*De harmonia*; Ramos de Pareja–*Musica*; Salinas–*De musica*; Zarlino–*Istitutione.*

Secondary Sources

Perhaps the best introduction to the subject is Mark Lindley's "Temperaments" in *The New Grove.*

For keyboard tunings, the following may be useful: Barbour–*Tuning*; Jorgenson–*Tuning*; Leedy–Personal; Lindley–Early; Lindley–Instructions; Pepe–Pythagorean; Reply Marvin–*Courant.*

For fretted instrument tunings, the most thorough source is Lindley–*Lutes.*

For Just Intonation, a useful discussion with scrutiny of many tuning systems is found in Blackwood–*Structure.*

See also Knighton/Fallows(Covey-Crump)–*Companion.*

Suggested Listening

Keyboard

Pythagorean

Miri it is. Organ played by Alan Wilson. Plant Life PLR 043.

Meantone

Buxheimer Orgelbuch. Ton Koopman. Astrée AS 78.

William Byrd: Harpsichord Music. Colin Tilney. EMI-Reflexe 1C063–30 120.

Fretted

Seventeenth-Century English Music for Viols and Organ, Les Filles de Sainte-Colombe with Frances Fitch, Organ. Titanic Ti-95. (1/4 comma with split keys and split frets).

John Dowland: Musicke for the Lute, Paul O'Dette. Astrée AS 90 or CD E7715 (1/6 comma approximation with split first fret).

Luys Milan: El Maestro, Hopkinson Smith. Astrée AS 95 (1/4 comma approximation with split frets).

Voices

Pythagorean and Just Intonation

The Service of Venus and Mars, Gothic Voices. Hyperion CDA 66238.

Just Intonation

Thomas Tallis: Lamentations of Jeremiah, The Hilliard Ensemble. ECM 1341 833308–2.

Victoria: Requiem, Tallis Scholars. Gimell CDGIM-012.

(*N.B.* There are many other recordings by these three ensembles that would serve as admirable

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