

An Introduction to Historical Tunings

By Kyle Gann

- [1. Tuning in Pre-20th Century Europe](#)
- [2. Meantone Tuning](#)
- [3. Werckmeister III and Bach's W.T.C.](#)
- [4. Well Temperament and 18th-Century Music](#)
- [5. A Word about Pythagorean Tuning](#)
- [6. Conclusion](#)

[Return to the Alternate Tunings page](#)

1. Tuning in Pre-20th Century Europe

Those who attack equal temperament, the tuning of our modern pianos - as I do on my [Just Intonation Explained](#) page - seem to be attacking the great European musical tradition itself. After all, the music of Bach, Mozart, Beethoven, et al, was written for 12 equally-spaced pitches to the octave, right? And if we change our tuning, that music would no longer be playable as it was intended to be heard, right?

Dead wrong.

Equal temperament - the bland, equal spacing of the 12 pitches of the octave - is pretty much a 20th-century phenomenon. It was known about in Europe as early as the early 17th century, and in China much earlier. But it wasn't used, because the consensus was that it sounded awful: out of tune and characterless. During the 19th century (for reasons we'll discuss later), keyboard tuning drifted closer and closer to equal temperament over the protest of many of the more sensitive musicians. Not until 1917 was a method devised for tuning exact equal temperament on the piano.

So how was earlier European music tuned? What are we missing when we hear older music played in 20th-century equal temperament?

[\(Return to top menu\)](#)

2. Meantone Tuning

Let's start with Europe's most successful tuning, if endurance can be equated with success. Meantone tuning appeared sometime

around the late 15th century, and was used widely through the early 18th century. In fact, it survived in pockets of resistance, especially in the tuning of English organs, all the way through the 19th century. No other tuning has survived in the west for 400 years. Let's see what meantone offered.

Every elegant tuning has a generating principle. The generating principle behind meantone was that it was more important to preserve the consonance of the major thirds (C to E, F to A, G to B) than it was to preserve the purity of the perfect fifths (C to G, F to C, G to D). There are acoustical reasons for this, namely - though I wouldn't want to go into the math involved - that the notes in a slightly out-of-tune third, being closer together than those in a fifth, create faster and more disturbing beats than those in a slightly out-of-tune fifth. (I can confirm this from experience with my own Steinway grand, which I keep tuned to an 18th-century tuning.) The aesthetic motivation for meantone was that composers had fallen in love with the sweetness of the major third, and were trying to get away from the medieval austerity of open perfect fifths.

In a purely consonant major third, the two strings vibrate at a frequency ratio of 5 to 4. For example, if

A
vibrates at
440 cycles per second,

then

C#
vibrates at
550 cycles per second.

Or if G vibrates at 100 cycles per second, then B vibrates at 125, and so on. (If you'd like this explained in more detail, visit my [Just Intonation Explained](#) page.) The size of a pure 5:4 major third is 386.3 cents, a cent being one 1200th of an octave, or one 100th of a half-step. Since an octave is 1200 cents, by definition, it is easy to see that three pure major thirds ($3 \times 386.3 \text{ cents} = 1158.9$) do not equal an octave. That's the whole problem of keyboard tuning, where you're limited to 12 steps per octave. Where do you put the gaps in your chains of perfect major thirds?

A pure perfect fifth is a 3 to 2 frequency ratio; if

A
vibrates at
440 cycles per second,

then

E
vibrates at
660 cycles per second.

A pure perfect fifth should be 702 cents wide, which is just about 7/12 of an octave; our current equal-tempered tuning accomodates perfect fifths (at 700 cents) within 2 cents, which is closer than most people can distinguish, but the thirds (at 400 cents) are way off, and form audible beats that are ugly once you're sensitized to hear them.

Let's look at the meantone solution. There was no one invariable meantone tuning; before the 20th century, tuning was an art, not a science, and each tuner had his own method of tuning according to his own taste. The following is a chart of what was initially the most common form of meantone, called *1/4-comma meantone*, first documented by Pietro Aaron in 1523, though he didn't draw it out to all twelve pitches:

Pitch:	C	C#	D	Eb	E	F	F#	G	G#	A	A#	B	C
Cents:	0	76.0	193.2	310.3	386.3	503.4	579.5	696.8	772.6	889.7	1006.8	1082.9	1200

(I adapt this chart, and ones following below, from an invaluable book, the bible of historical keyboard tuning: Owen Jorgensen's [Tuning: Containing the Perfection of Eighteenth-Century Temperament, the Lost Art of Nineteenth-Century Temperament, and the Science of Equal Temperament](#), Michigan State University Press, 1991.) Now let's look at the sizes of the major thirds and perfect fifths on each pitch:

Major third	Cents	Perfect Fifth	Cents
C - E	386.3	C - G	696.8
Db - F	427.4	Db - Ab	696.6
D - F#	386.3	D - A	696.5
Eb - G	386.5	Eb - Bb	696.5
E - G#	386.3	E - B	696.6
F - A	386.3	F - C	696.6
F# - A#	427.3	F# - C#	696.5
G - B	386.1	G - D	696.4
Ab - C	427.4	Ab - Eb	737.7
A - C#	386.3	A - E	696.6
Bb - D	386.4	Bb - F	696.6
B - D#	427.4	B - F#	696.6

A major third and perfect fifth on the same pitch, of course, make up a major triad, the most common chord in European music from 1500 to 1900 - the meantone era. Let's look at what kind of major triads we have in meantone tuning.

The major thirds that are about 386 cents wide will be sweet, consonant, attractive. Eight pitches have virtually perfect major thirds on them - all except Db, F#, Ab, and B, whose major thirds are all about 427 cents. A third of 427 cents sounds like this: WAWAWAWAWAWAWAWA...!!! and is unusable for normal musical purposes. (Trust me on this.) All of the fifths are about 696 cents except for one, that on Ab, which is 737 cents and sounds terrible. The fifths would sound better at 702 cents, but at

696 or 697 you don't really notice the difference, especially if the chord is filled in with that perfect major third to smooth over the discrepancy. This is where the practice originated in European music of never having an open fifth sounding by itself without a third filling it in: the spare perfect fifth isn't quite consonant, and that fact becomes obvious if the third isn't there.

So meantone tuning gives us, if we're limited to a 12-pitch keyboard, eight usable major triads: on C, D, Eb, E, F, G, A, and Bb. If you're writing a piece in meantone, those are the major triads you have available. Look through some 16th-century keyboard music: how many F#-major and Ab-major triads do you see? Probably none, and if you do see some, it means the composer was counting on a meantone tuning centered around some pitch other than C. If you want to use I, IV, and V chords in your piece, you can write in the keys of C, D, F, G, A, or Bb major. If you're writing in A major, you can't go to the V/V chord (B major), because it sounds awful. Renaissance and early Baroque music tends to be in a few keys grouped (in the circle of fifths) around C, usually C, F, G, D, Bb, or A. Ever wonder why Palestrina and Orlando Gibbons and Heinrich Schutz didn't get around to composing in F# major or Ab major? They couldn't, it sounded terrible in their tuning. (There were a few purely vocal early works that went through triads in diverse keys, such as Di Lasso's [Prophetiae sybyllarum](#) and the [Absalon fili mi](#) motet once attributed to Josquin, the tuning and even notation of which have been subjects of much 20th-century controversy.)

Before we leave the subject of meantone, let's look at the available minor triads:

Minor third	Cents	Perfect Fifth	Cents
C - Eb	310.3	C - G	696.8
C# - E	310.3	C# - G#	696.6
D - F	310.2	D - A	696.5
Eb - Gb	269.2	Eb - Bb	696.5
E - G	310.5	E - B	696.6
F - Ab	269.2	F - C	696.6
F# - A	310.2	F# - C#	696.5
G - Bb	310.0	G - D	696.4
G# - B	310.3	G# - D#	737.7
A - C	310.3	A - E	696.6
Bb - Db	269.2	Bb - F	696.6
B - D	310.3	B - F#	696.6

A pure minor third is supposed to have a frequency ratio of 6:5. For example, if C# vibrates at 550 cycles per second, E should vibrate at 660. A 6:5 ratio interval is 315.64 cents wide. None of the minor thirds in this meantone are quite that wide, but most of them are 310 cents, which is, pardon the expression, close enough for jazz. (Actually, a narrow 7/6 minor third, often used by La Monte Young, is 266.8 cents, invitingly close to that 269; but 7/6 is an interval that was never recognized by European theory, though

used in jazz and Arabic music among others.) Therefore the minor triads on C, C#, D, E, F#, G, A, and B are acceptable. (Not the one on G#, despite its OK minor third, because it has that wildly beating fifth.) If you think about it, these triads define the relative minor of the major keys implied by the major triads above:

Major:	C	D	E ^b	E	F	G	A	B ^b
Minor:	A	B	C	C [#]	D	E	F [#]	G

These 16 triads, 8 major and 8 minor, constitute the harmonic vocabulary of Renaissance and early Baroque keyboard music, at least. Don't believe me? Look through a 16th- or 17th-century keyboard collection, such as the [Fitzwilliam Virginal Book](#). You won't find a piece in a key signature of more than two sharps or flats.

One important keyboard work from the early 17th century (a real masterpiece, in fact) is Orlando Gibbons's [Lord Salisbury Pavane](#). It's in A minor. If you look at it (it's in the [Historical Anthology of Music](#)), Gibbons several times goes to the major triads on F, G, and C (which are in A natural minor), E (in the harmonic major), and D (not in A minor). He never, however, uses an F# major (V/ii) triad, because it doesn't really exist in the tuning of his harpsichord. He does use, quickly, a B major triad even though D# doesn't exist in his scale; but because he never uses Eb it's entirely possible that he retuned the Eb strings to D#, which would have only taken a moment on his clavichord or virginal. Had Gibbons begun in the key of C minor, he would have had to write a different piece, because instead of moving from A minor to F major, he would have had to move from C minor to Ab major, and Ab major, strictly speaking, didn't exist on his harpsichord.

Here is the beginning of Orlando Gibbons's Lord Salisbury Pavane played in 1/4-comma meantone temperament:

0:00 / 0:00

Here is the same passage played in 12-tone equal temperament:

0:00 / 0:00

Because it determines what sounds good, tuning has a pervasive influence on compositional tendencies. Every piece of pitched music is the expression of a tuning. Meantone encouraged composers to use major and minor triads, to avoid open perfect fifths without thirds, and to not stray more than three or four steps in the circle of fifths away from a central key. Renaissance and early Baroque music played in meantone sounds seductively sweet and attractive. By playing it in modern equal temperament, we do violence to its essential nature. Perhaps that's why this repertoire is no longer often heard. It's been painted over with the ugly gray of equal temperament.

Why is it called meantone? Because it splits the difference on where to place certain pitches. If C and E are tuned as a perfect

major third of 386 cents, D should be tuned at 204 cents (9/8) for the key of C, but at 182 cents (10/9) for the key of D. Tuned at 193, D is right in the middle, halfway between C and E, and halfway between the two points it needs to be in for the various common keys; 193 is the mean between 182 and 204. Meantone temperament sacrificed the seconds, which were mainly melodic intervals rather than harmonic ones anyway, to achieve beautiful thirds.

A last point of interest: 1/4-comma meantone is very closely approximated (as was known in the 16th century) by a scale of 31 equal steps to the octave. Ten steps of such a scale equal 387.1 cents, which is a very good major third indeed. C to C# (the chromatic half-step) will be two such steps, and C to Db (the diatonic half-step) will be three; in meantone, C# and Db are not the same pitch, nor are F# and Gb, etc. Mozart favored 1/6-comma meantone, which is closely approximated by a 55-step division of the octave. His C to C# was 4/55 of an octave, and C to Db was 5/55. (See "Mozart's Teaching of Intonation" by John Hind Chesnut, *Journal of the American Musicological Society* Vol. 30, No. 2 (Summer, 1977), pp. 254-271.)

[\(Return to top menu\)](#)

3. Werckmeister III and Bach's W.T.C.

While the Italians generally hewed to meantone throughout the 18th century, the more intellectual Germans veered in a different direction. If you are or were ever a college music student, you probably read, or were told, that Johann Sebastian Bach wrote his collection of preludes and fugues The Well-Tempered Clavier in all 24 major and minor keys in order to demonstrate equal tempered tuning.

If so, you were misinformed.

Bach did not use equal temperament. In fact, in his day there was no way to tune strings to equal temperament, because there were no devices to measure frequency. They had no scientific method to achieve real equal-ness; they could only approximate.

Bach was, however, interested in a tuning that would allow him the possibility of working in all 12 keys, that did not make certain triads off-limits. A master of counterpoint, he chafed and fumed when the music in his head demanded a triad on A-flat and the harpsichord in front of him couldn't play it in tune. (In fact, he once tormented the famous organ tuner Silbermann by playing sour Ab-major triads while trying out one of his meantone organs.) So he was glad to see tuners develop a tuning that, today, is known as well temperament. Back then, they did call it equal temperament (or sometimes *circulating* temperament) - not because the 12 pitches were equally spaced, but because you could play equally well in all keys. Each key, however, was a little different, and Bach wrote *The Well-Tempered Clavier* in all 24 major and minor keys in order to *capitalize* on those differences, not because the differences didn't exist.

In any case (according to Jorgensen), the error that Bach wrote the *W.T.C.* in order to take advantage of what we call equal temperament crept into the 1893 *Grove Dictionary*, and has since been uncritically taught as fact to millions of budding musicians. Lord knows how long it will take to get that error out of the reference books.

The theorist who came up with the easiest way to tune the kind of well temperament Bach needed was the German organist Andreas Werckmeister (1645-1706), whose most famous tuning, dating from 1691, is known as Werckmeister III. A table for Werckmeister III is as follows:

Pitch:	C	C#	D	E $\flat$	E	F	F#	G	G#	A	A#	B	C
Cents:	0	90.225	192.18	294.135	390.225	498.045	588.27	696.09	792.18	888.27	996.09	1092.18	1200

Notice that we've moved considerably closer to equal temperament; no pitch is more than 12 cents off. The following perfect fifths are 3/2 ratios of 701.955 cents each: G $\flat$ - D $\flat$ - A $\flat$ - E $\flat$ - B $\flat$ - F - C, as well as A - E - B. The Pythagorean comma - 23.46 cents, the difference between seven octaves and twelve perfect fifths - is distributed among the remaining fifths, C - G - D - A and B - F#, each of which is flattened to 696.09 cents. Let's look at the triads we now have on each pitch, organized for clarity's sake following the circle of fifths:

Major third	Cents	Perfect Fifth	Cents	Minor third	Cents
C - E	390.225	C - G	696.09	C - E $\flat$	294.135
G - B	396.09	G - D	696.09	G - B $\flat$	300.0
D - F#	396.09	D - A	696.09	D - F	305.865
A - C#	401.955	A - E	701.955	A - C	311.73
E - G#	401.955	E - B	701.955	E - G	305.865
B - D#	401.955	B - F#	696.09	B - D	300.0
F# - A#	407.82	F# - C#	701.955	F# - A	300.0
D $\flat$ - F	407.82	D $\flat$ - A $\flat$	701.955	C# - E	300.0
A $\flat$ - C	407.82	A $\flat$ - E $\flat$	701.955	G# - B	300.0
E $\flat$ - G	401.955	E $\flat$ - B $\flat$	701.955	E $\flat$ - G $\flat$	294.135
B $\flat$ - D	396.09	B $\flat$ - F	701.955	B $\flat$ - D $\flat$	294.135
F - A	390.225	F - C	701.955	F - A $\flat$	294.135

As you look down the columns, you can get an idea of the quality of each triad. Note that no perfect fifth is narrower than 696 cents, nor wider than 702; this is what renders all 12 (or 24 keys) usable. The closest major thirds to perfect are C-E and F-A. G-B, D-F#, and B $\flat$ -D are each 396.09 cents, still sweeter than equal temperament. A-C#, E-G#, and E $\flat$ -G are around 401 cents, close to equal temperament; they therefore have a rather bland, neutral quality. The major thirds on F#, D $\flat$, and A $\flat$ are 408 cents wide, the same size as in Pythagorean tuning (for which, see below), and not very attractive. Again, the best minor triads are grouped around A minor, with the minor third A-C, at 312 cents, coming closest to the optimum of 316 cents.

So what is the effect of Werckmeister III? Can the ear really hear a difference from equal temperament?

I've done [experiments with students at Bard and Bucknell, playing preludes from the W.T.C. in different keys on a sampled piano tuned to Werckmeister III](#); say, playing the C major prelude in B, C, and D (computer-sequenced, so that the quality of the transposed performances wasn't a factor). **The students could often pick which was the appropriate key for each prelude**, and even when they were mistaken they formed strong opinions about their preferences. In keys with poor consonances, like F# major, Bach will pass quickly by the major third, and the slight touches of dissonance give the prelude a bright, sparkly air. In more consonant keys, as in the C major prelude, the tonality is much more mellow, and Bach can afford to dwell on the tonic triad. Each key has a different color (as opposed to the uniform color of all keys in equal temperament), and even (or especially!) the unpracticed ear can hear appropriate and inappropriate correspondences between the character of each prelude and the color of each key. Of course, there are preludes that sound fine in more than one key; but it's disconcerting to move a prelude to a distant key, such as from Bb to B, or C# minor to Eb minor.

Playing Bach's [Well-Tempered Clavier](#) in today's equal temperament is rather like exhibiting Rembrandt paintings with wax paper taped over them.

[\(Return to top menu\)](#).

4. Young's Well Temperament and Classical-Era Music

I keep my own grand piano tuned to Thomas Young's first well temperament of 1799. Some synthesizers offer an alternate temperament called Vallotti-Young, which is Young's second temperament; the Young referred to is Thomas Young (not, of course, La Monte). Jorgensen considers Young's Well Temperament to be the most elegant well temperament, with a fluid variety of tonal colors and a symmetry that matches the piano keyboard: all intervals are symmetrical around D and G# - that is, D-F# and D-Bb are the same size, G#-F# and Ab-Bb the same size, and so on. The chart is as follows:

Pitch:	C	C#	D	Eb	E	F	F#	G	G#	A	A#	B	C
Cents:	0	93.9	195.8	297.8	391.7	499.9	591.9	697.9	795.8	893.8	999.8	1091.8	1200

This is even closer to equal temperament; even so, when I switched to it, my piano tuner had to return twice within two months before it began to stabilize. (You'd be surprised how exactly your piano's soundboard can remember a 6-cent difference.) Let's look at the quality of the triads:

Major third	Cents	Perfect Fifth	Cents	Minor third	Cents
C - E	391.7	C - G	697.9	C - Eb	297.8
G - B	393.9	G - D	697.9	G - Bb	301.9

D - F#	396.1	D - A	698	D - F	304.1
A - C#	400.1	A - E	697.9	A - C	306.2
E - G#	404.1	E - B	700.1	E - G	310.3
B - D#	406	B - F#	700.1	B - D	304
F# - A#	407.9	F# - C#	702	F# - A	301.9
Db - F	406	Db - Ab	701.9	C# - E	297.8
Ab - C	404.2	Ab - Eb	702	G# - B	296
Eb - G	400.1	Eb - Bb	702	Eb - Gb	294.1
Bb - D	396	Bb - F	700.1	Bb - Db	294.1
F - A	393.9	F - C	700.1	F - Ab	295.9

This is a subtle tuning, quite usable in all keys, and the differences from equal temperament are more evident to the pianist playing in it than to the listener. The best major thirds are grouped in the circle of fifths around C-E, whereas the perfect fifths become more perfect in the black keys, which all have fifths of 702 cents. This gives the keys related to C a sweet, gentle quality, the black-note keys an austere, noble quality (especially in minor), and middle keys like Eb and A a neutral, ambiguous quality.

Certain keys are warmer than others; F# minor, for instance, imparts a lush quality to the slow movement of the *Hammerklavier* Sonata. Db major is surprising, almost too harsh, and if I happen to play Db and F alone on the keyboard the buzzy beats make me jump as though I had played a wrong note. It's interesting that Beethoven chose this bright key for the mellow slow movement of his *Appassionata* Sonata, but I find that it loses energy when I play it in C; in fact, in C I have a visceral urge to play it faster because the harmonies aren't interesting enough, but in Db I can take my time.

Nineteenth-century musicians used to argue about what colors the various keys represented; whether Eb major was gold, for example, and D major red. Twentieth-century musicians have dismissed such arguments as sentimental nonsense, but when you play 19th-century music in well temperament, you begin to hear the differences of color. Is it far-fetched to suggest that Mozart and Beethoven wrote keyboard music with certain key-colors in mind, and that we miss subtle but pervasive qualities in the music when we homogenize it into equal temperament?

[\(Return to top menu\)](#)

5. A Word about Pythagorean Tuning

Before the advent of meantone tuning, French theorists associated with Notre Dame (13th and 14th centuries) followed a medieval tradition since Boethius (4th century) and Guido d'Arezzo (11th century) in decreeing that only a series of perfect fifths could make up a scale; their ratio was $3/2$, and 3, after all, was the perfect number, connoting the Trinity among other things. Thus the Pythagorean scale is a just-intonation scale on a series of perfect fifths, all the ratio numbers powers of either 3 or 2:

Pitch:	C	C#	D	Eb	E	F	F#	G	G#	A	A#	B	C
Ratios:	1/1	2187/2048	9/8	32/27	81/64	4/3	729/512	3/2	128/81	27/16	16/9	243/128	2/1
Cents:	0	113.7	203.9	294.1	407.8	498	611.7	702	792.2	905.9	996.1	1109.8	1200

This was an appropriate scale for a music in which perfect fifths and fourths were the overwhelmingly dominant sonority. Though used, the thirds were theoretical dissonances, and therefore avoided at final cadences: the major third, 81/64, was 408 cents wide, and the minor third, 32/27, 294 cents. As Margo Schuller has convincingly written me, however, those wide thirds do provide a compelling pull to the perfect fifths they usually resolve outward to; that is, in a cadence typical of Guillaume de Machaut (c. 1300-1377), a D and F# 408 cents apart will move outwardly to C and G. Gradually, especially under the English influence of John Dunstable and others, the thirds began to be redefined as 5-related intervals, 5/4 and 6/5, precipitating the necessity of meantone tuning and a revolution in musical style that led to the Renaissance. Since equal temperament has close-to-perfect fifths (700 cents compared to a perfect 702), much music written in Pythagorean tuning doesn't fare too badly in equal temperament. The Hilliard Ensemble observes Pythagorean tuning in its recordings of the Machaut Notre Dame Mass (Hyperion) and the organum of Perotin (ECM).

[\(Return to top menu\)](#)

6. Conclusion

I wish I could offer a wider discography of recordings in historical tunings. Luckily, a few recordings in documented historical temperaments have appeared in the last few years:

Enid Katahn, piano; Edward Foote, piano tuner: Beethoven in the Temperaments - Gasparo GSCD-332 (Moonlight Sonata, the Waldstein, and the Pathétique in late-18th-century temperaments)

Enid Katahn, piano; Edward Foote, piano tuner: Six Degrees of Tonality - Gasparo GSCD-344 (Scarlatti, Mozart, Haydn, Beethoven, Chopin, Grieg, in a variety of meantone and well temperaments)

J.S. Bach: Well Tempered Clavier, Robert Levin, keyboards - Hanssler 116 (in Werckmeister temperament)

Lou Harrison: Piano Concerto - Keith Jarrett, piano; Naoto Otomo conducting the New Japan Philharmonic; New World NW 366-2. (Harrison tunes the solo piano to Kimberger temperament.)

Guillaume de Machaut: Messe de Notre Dame, Hilliard Ensemble - Hyperion

It may be that some of the many original-practice harpsichord recordings and European organ recordings use meantone without documenting their tuning. For those further interested, I highly recommend Owen Jorgensen's four-inch thick Tuning

compendium (Michigan State University Press, 1991). And I hope this will spark some interest that will lead to further experiments in reclaiming the original beauty of Europe's musical past.

[\(Return to top menu\)](#).

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Return to the [Just intonation Explained](#) page.



If you find any of this not clearly enough expressed, [e-mail me](#).



return to the home page

