Ξεναρμονία ι΄

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BACK ISSUES STILL AVAILABLE ON ORDER

While there has been a long gap between Xenharmonic Bulletin No. 9 and this issue. we now have hope of catching up.

Since most of the material in previous issues is not time-limited, it was decided from the very outset to keep everything "in print" and a current price-list of what is available will be sent on request.

Future plans call for issuing tables and data bound in one volume if certain negotiations prove out sometime late next year.

A list of compositions in ordinary notation is available, and also a list of tape compositions in various tuning-systems available as copies, either reel or cassette.

Regular publication on any schedule, and therefore advance subscriptions to this Bulletin are not yet possible, because of the burdens of correspondence and the building and modification of new instruments and many circumstances beyond our control at this time.

A long list of leaflets and short pamphlets has been distributed as was possible, and from time to time the list of publications will be issued.

Development of new music and instruments

In February of 1978, *Guitar Player* magazine published Ivor Darreg's article on Non-Twelve-Tone guitars, with some of the fretting tables which have appeared in previous Xenharmonic Bulletins. Response was tremendous, including too much correspondence, some visitors and phone calls from very distant places, and some refretting to do.

Then Jonathan Glasier of San Diego CA started a magazine *Interval* and an Interval Foundation, devoted to non-12 music, and Ivor Darreg's instruments and compositions have been presented many times in San Diego.

March 1981 OMNI had an article by Doug Garr on musical innovators, with a full color picture of Darreg's MEGALYRA family of instruments.

POLYPHONY, the synthesizer magazine, published two short essays by Darreg on xenharmonics.

The result of this publicity has been the establishment of an informal Network of People in Non-Twelve, who are beginning to communicate with one another, and get music to progress once more, after a century or more of stagnation.

Publication of an article on *Detwelvulating* in "Musical Six-Six News-Letter" is expected shortly.

To aid readers in selecting new tuning-systems to compose and perform both existing and new music, and to compare new temperaments with just intonation and with ordinary standard twelve-tone equal temperament, our remaining pages give "Pro & Con".

TUNING SYSTEMS WITH LESS THAN TWELVE TONES PER OCTAVE

In this series of information sheets we are concerned mainly with equal temperaments, but will treat of the principal unequal systems and of Just Intonation.

The 1, 2, 3, and 4-tone equal temperaments are of course trivial and these numbers go evenly into 12, so the resulting intervals and chords, the tritone, the augmented triad, and the diminished-seventh chord of 12-tone-equal are familiar to most everyone.

The 5-tone equal temperament is found in many cultures around the world, and also other tunings which closely approximate it. Since 5 does not go into 12 evenly, this system has added importance as being the first xenharmonic system--the simplest collection of tones which does not SOUND LIKE 12-tone equal temperament. In a way, the use of 12-tone during the last two centuries by so many millions of people has created a lack, a gap, which is filled by 5 and its multiples.

If one attempts to have a 5-tone circle of fifths, it would go C G D A E B and B=C, which means, if the fifths are just, 702 cents, a 90-cent deficit (the small semitone of the Pythagorean system), so each fifth would have to be enlarged by 18 cents to 720 cents in order to close the circle. This of course is too big an alteration to be tolerated on a violin or the organ with sustained tones, but you can get away with it on percussion instruments such as marimbas and metallophones. With only 5 pitch-classes, it is moot whether we have a scale, a chord, or both.

The result will be that in order to have more melodic resources we will be inclined to use multiples of 5.

The 6-tone equal temperament is merely the whole-tone scale which was so thoroughly exploited by Debussy and other 12-tone-system composers that there is practically nothing more to do with it—they exhausted its possibilities. It should be noted that 6-tone lacks the mood of 12 which is a brilliant restlessness—the 6-tone mood is vaguer and blurred, so that such a multiple of 6 as 18 shares it. (18 proposed by Busoni, and used by Carrillo and Hába.)

The 7-tone equal temperament is closely approximated by some of the exotic ethnic scales, and so will occasionally be heard by the public now that ethnomusicology is maturing and records from far-away places are proliferating. Indonesia and Thailand are often cited as examples of use of this scale, but it must be remembered that they also use many variants of it which are far from equal.

The 8-tone equal temperament is seldom used for itself alone, but one composition does exist, a computer-performed canon by John R. Pierce. Even the synthetic partial tones of the computer synthesis were members of this scale, creating a Hammond-Organ-like timbre. A good demonstration of the dependence of rules of harmony upon timbre. 8 will be of importance mainly as a subset of 24 (quartertones).

The 9-tone equal temperament has had limited use. George Secor has composed in it very briefly. Again, 9 will be used as a subset of 18 and 36 and possibly other multiples of 9. It has a special mood.

(Systems with Less than Twelve Tones, continued)

The 10-tone equal temperament has been proposed a number of times. Allegedly, a 10-tone harpsichord was constructed around the time of the French Revolution when the introduction of the metric system caused attempts to decimalize everything else. Other references we have encountered but tantalizingly cannot re-locate, described 10-tone keyboards with an unbroken row of black and white keys produced by eliminating one of the pairs of customary white keys in 12-tone, e&f and b&c. Whether this was implemented with a 10-tone equal temperament or some other kind of tuning was not stated.

Gary Morrison a few years ago built some 10-tone instruments such as guitars, basses, and flutes. This was in connection with a decimal system project. So a few compositions for 10-tone are in existence. The mood of 10-tone is more aggressive than that of 5-tone and some of the other multiples of 5. This could never have been anticipated without actually building and hearing instruments. Let that serve as a most important warning to all those investigating tuning-systems whether just or tempered, whether equal or unequal--it is not possible to predict all the practical consequences using only silent paper and ink and mathematical calculations!

The 11-tone equal temperament is seldom heard of. George Secor did an atonal improvisation in this system as part of a demonstration of the Scalatron organ which has the capability of retuning to many different systems. Among the multiples of 11 which have been examined or used are: 22, 55, 77, and 99. (Refer to the 22-tone information sheet.)

Equal Temperaments Just Beyond 12 Tones per Octave

The 13-tone equal temperament is about the most different from 12 that one can get. 14 being an even number shares the equal tritone of half an octave, whereas 13 is prime. 11 has a minor third and major sixth not quite as bad as those of 12, but 13 is without what can really be called fourths and fifths with a straight face. Thus 13 is a melodic scale rather than one dedicated to harmony.

Very little composition has been done in 13, although the one composition of Ernst Křenek using 13 has gained some notoriety by being cited in articles and reference books. Nevertheless, 13 holds great promise for atonality and perhaps serialism, its asymmetric structure breaking up the cliché patterns of 12 which have really been a drag on the progress of 12-tone atonality.

The 14-tone equal temperament likewise has had little use and so far as we have been able to discover, no compositions as yet. The 14-tone system was among those investigated by Augusto Novaro and he provided a keyboard and notation for it. Its semitone or unit-interval is about 85 cents and thus closely approximates a semitone-size used by many string players for sharpened leading-tones. That factor alone should give it a future.

Some years ago the present writer read the repeated arguments against 14-tone in Joseph Yasser's book, *Theory of Evolving Tonality*. These arguments were based mainly on the idea that the number of principal degrees of the scale should not be the same as the number of auxiliary (chromatic) degrees, so 7 + 7 = 14 was enough to condemn 14 without any hearing.

(Equal Temperaments Just Beyond Twelve Tones Per Octave, continued)

(14-tone, concluded): So vehement were Yasser's repeated objections to the 14-tone temperament, which apparently he had never heard nor composed in nor built instruments for, that we became convinced over the years that "if Yasser got so emotionally against a system that many times in his book, there must be something in it!", and in 1979 we built an instrument of 4 octaves of metal bars in 14-tone, which has actually aroused the enthusiasm of some visitors. Definitely, there *is* something in it, although it has two circles of 7 fifths each which never can meet. That is, take C G D A E B F# C# and to force the circle to close at the 7th fifth, deduct 1/7 of 114 cents (the Pythagorean C-sharp) from each fifth and then they will each be 16.28 cents flat and the sharp and flat signs will no longer mean anything, if C# = C. The ordinary major and minor diatonic scales thus become identical in 7-tone. Now, when we go to 14, we need some kind of accidental sign, but as we just said, sharp and flat now imply members of a circle of fifths and there are only 7 tones in each of the two circles, so how about * for the 7 new pitches? The 14-tone metallophone is marked C D E and C* D* E* etc. on the bars.

The major and minor scales can now be mapped onto the 14 tones and give exciting subminor and supermajor effects, while the plain 7-tone series has a "neutral" flavor in comparison to these others.

The 15-tone equal temperament was tried out by Augusto Novaro for guitars, and given a notation and a keyboard layout. He used it principally for a partial set of the 60-tone system, by using 12- and 15-tone guitars together. As a multiple of 5-tone, 15-tone retains the mood of 5 better than 10 does.

The 16-tone system has not had much use. As the fourth power of 2, 16 is very symmetrical. Indeed one has to go up the powers of 2 all the way to 256 to get a good system of equal temperament. A special additive-synthesis electronic organ and a keyboard layout and a naming system adding Greek letters was proposed for 16-tone by J. Goldsmith in a J.A.S.A. article some years ago.

The 20-tone system has not had much press.

The 21-tone system is a usable multiple of 7, and we have refretted a guitar to it for another innovator. Given a 22-tone guitar, 21 can be obtained by moving the bridge or fitting an extra bridge, to a practical degree of approximation. With 12 it shares the factor 3.

The 23-tone system was investigated by Hornbostel and discussed in theoretical writings. It is not very harmonic, so for practical purposes ought to be doubled to 46.

A recording now exists of the theorist Easley Blackwood's 12 compositions in the 12 systems, 13-tone through 24-tone, which make a beginning of comparing all these systems.

17, 18, 19, 22, and 24 receive discussion and evaluation in greater depth on our other sheets in this set devoted to them in turn. Naturally 12-tone equal temperament and Just Intonation have their own sheets.

There are many unequal temperaments and incomplete systems, such as 12-out-of-something else. Only a few of these will prove out, since having a larger number of tones is now feasible in many cases.

TEMPERAMENTS BEYOND QUARTERTONES (24)

25-tone equal temperament does not seem to have much of a reputation. It deserves mention as being 5 x 5, thus a possible melodic way of using a multiple of 5, and as having a major third about 2 cents flat, which forms the basis of 50-tone, one of the meantone imitators, and is also a member of Yasser's Fibonacci Series, since 19 + 31 = 50. Its fifth is too far off to be useful.

The 26- and 27-tone temperaments have been mentioned by some writers, but do not afford good enough fifths to use them for harmony.

28-tone has an excellent major third, but its fifth leaves much to be desired. 84, a multiple of 12, also has this third.

29-tone has a good fifth, but the major third is about as flat as the major third of 12 is sharp. 3 x 29 = 87 and then one gets a good third. 1/29 octave is about the right size for the just and meantone diësis, ratio 125:128. The 29-tone scale was used by the Galin-Paris-Chevé singing system for a while at least, and has been discussed in the theoretical literature. The fifth is about 1½ cents sharp.

30-tone is available on one of the special pianos of Julián Carrillo, and had a string quartet composed by Hába. It is of course the fifth--tone system, and thus those subdividing the whole-tone of the 12 system will try it, but it has no harmonic merits, standing as it does between 29 and 31 it cannot.

31-tone is very important--see its special sheet. *Page 22. Xenharmonic Bulletin No. 9 carried a long article on 31, and also tables for it.*
32- and 33-tone have had very little mention.

34-tone supplies the good thirds and sixths which 17 lacks. See the special sheet. *Page 23, upper half.*

35-tone, as 7 x 5, might be a useful fretting on special instruments to be able to go back and forth freely between the 5 and 7 scales. Being between 34 and 36, it cannot have many harmonic resources.

36-tone is on the special sheet for 18 and 36. *Page 18, lower half.*

37, 38, 39, and 40 have not been much written about, and have no outstanding merits. By the time we have passed 36, the possibilities for useful new moods are much less, so other factors, such as the rendering of the harmonic series or some special points, are needed to make it worthwhile to have more tones per octave.

41 and 43 are on a special sheet, which see. *Page 24. Tables for these will appear in later issues of Xenharmonic Bulletin.*
42 is one of the systems on a Carrillo special piano.

44 and 45 have no special points of interest so far as we know.

46-tone has been cited as having some good points. It has good renderings of the harmonic series up as high as the 23rd harmonic. See the special sheet for 34 and 46. *Page 23, Lower Half.*

47-tone does not have a good enough fifth. Fokker investigated 2 x 47 which is 94 tones per octave.

EIGHTH-TONES: 48 equal and beyond

48-tone is one of the systems used by Carrillo and on one of his pianos; it was tried on a pipe-organ at least once at some university. It has been alluded to in a number of theoretical publications, and recommended for experimentation by N. Kulbin in pre-revolutionary Russia. Its chief defect is the poor major third, flat by 11 cents. 60 and 72 are better multiples of 12.

49-tone has at least tolerable representation of harmonic intervals.

50-tone temperament is attributed by Ellis, to Henfling. It represents a compromise between 19 and 31, as 19 + 31 = 50. As such it belongs in Yasser's series, and is one of the meantone family. See sheet on 50 and 55. *Page 25, Upper Half.*

51 and 52 do not seem to have had much notice.

53 is very important; see special sheet. *Page 26.*

54 is one of the Carrillo piano systems.

The 55-tone system has been discussed by theorists. See special sheet on 50 and 55. *Page 25, Lower Half.*

60 is the first multiple of both 12 and 5.

65 has a good fifth - 0.4 cent and a major third + 1.4 cents, and is the highest number of tones considered by Augusto Novaro.

72 is one of the Carrillo systems, also discussed by Russian inventors of a composer's instrument named in honor of Scriabin, and alluded to but not used by Hába, and was at least discussed by the quartertonist Vyshnegradski. Perhaps the best multiple of 12 that has any chance of being put on an instrument, since it embraces the quarter-, third-, and sixth-tone systems, and has good representation of the harmonic series.

77 also has good representation of the harmonic series.

84 is that multiple of 12 wherein the error of the major third almost cancels out, but otherwise is not as "versatile"as 72.

87 has a remarkably small major-third error, about one-tenth of a cent. Errors for harmonics are low, as one would expect for so many tones.

94 has a fifth error of 0.17 cent, but does not seem to be an improvement on 53 with fewer tones, where 53 has only .06 of a cent. However it was investigated by Adriaan Fokker of 31-tone fame.

96 has historical importance as the sixteenth-tone, the discovery in 1895 by Carrillo which set him off on a lifetime career of exploring multiples-of-6 temperaments. He composed in 96 and had a 96-tone piano with only one octave compass constructed as the last in the series of specially-made pianos. So far as harmonic representation is concerned, there are systems with fewer tones which do better.

99 has a fairly good harmonic-series representation as well as an excellent minor third.

100 Tones and Beyond

The 100-tone temperament has been actualized by a few psalteries made in Mexico and called "Harmony Harps" which have 101 strings on each side of the soundbox and an ingenious arrangement of multiple bridges to get more than one octave out of each string. Calibrated monochords are provided on each side for tuning. The 100th of an octave has been used by some theorists as a convenient decimal division. Since the fifth is nearly 6 cents flat, more than meantone or 31-tone, 99 would be a better system harmonically.

Beyond 100 tones per octave we get into the realm of paper theory, and away from actual instruments, except for computer music of course, where it will be practical enough to investigate temperaments with more tones than any keyboard could handle, right up to and beyond the ear's ability to distinguish pitch under favorable conditions.

We might mention a few numbers for the sake of completeness: 118-tone has been proposed and probably experimented with; it has a fifth with a quarter-cent error and a third with about an eighth-cent error; the theorist Joseph Schillinger proposed 144-tone and had Theremin build him a special electrical instrument capable of at least some of its pitches--this was probably an infatuation with 12 and hence with 12^2 or 144. Paul Beaver was interested in the duodecimal counting system and proposed this system, again as 12 x 12, going further to a proposed 1728th of an octave to replace the cent for measuring purposes. 12^3 is the great-gross or 1728.

The excellent minor third and major sixth of 19-tone, only a fraction of a cent off because of the errors of fifth and major third almost cancelling, suggest that there might be a multiple of 19 with good fifths and thirds, and there is: 171 = 9 x 19. Again, while unreasonable to expect from a keyboard instrument, it should be practical on a computer or automatically played apparatus.

Other really micro systems include 270, investigated by Ervin Wilson and John Chalmers, and 559 and 612, found by theorists. 612 is near the size of the skhisma and the closely similar error of the 12-tone fifth, being 3 x 17 x 12. The French theorist Sauveur proposed 7 x 43 = 301, and 301 is the mantissa of the common log of 2 to three places, so others proposed the four-place number 3010 and the five-place 30103 as "paper temperaments" because they fitted in with log tables. In France the 301st of an octave was taken as a unit and called the savart, then to make things more convenient, rounded to 1/300 octave which was called a "new savart". Hauptmann and others have used the milli-octave, .001 octave. So much for minutiae.

If intervals be plotted as angles, so that they can be used on charts, then we can have a 360-tone cycle where intervals are expressed in degrees of arc, and full circle or 360 degrees is unison or octave as one wishes. This is easy to visualize. Ellis proposed one-one-hundredth of the ordinary 12-tone tempered semitone, calling it a cent, and this has been widely used since. 1200 tones per octave, with decimals if necessary for extended calculations. Thus logarithms to the 1200th root of 2. With a modulus, common or natural logarithms of a ratio can be converted to cents on a small electronic calculator. Much easier and faster than in Ellis's or Helmholtz's day! Logarithms to base 2, again via a modulus, can be used to find decimals of an octave from ratios.

THE MEANTONE FAMILY OF TEMPERAMENTS

For the last century and a half, the piano has locked in the 12-tone equal temperament as an ideal, however well or badly it has been tuned on real pianos and organs and other fixed-pitched instruments during all that time. With the revival and finally full resumption of life and growth by the harpsichord, and the concomitant revival of the earlier types of pipe-organs, primarily for the performance of Renaissance and Baroque and other music before the 19th century, and the revival of other older instruments and playing techniques, interest has grown in the way such instruments were tuned, which meant principally the mean-tone temperament.

* Preferably, stop at this point to read the special sheet on 31-tone. *P.22.*

The 1/4-comma meantone temperament, ascribed to Aron, is the principal member of the meantone family of tunings. It is almost perfectly represented by Huygens' 31-tone equal temperament, and as tuned on real instruments and played and heard in real environments, there is no practical difference. There is a mathematical and theoretical difference, of course, which will now be explained: Meantone temperaments are *linear* rather than *cyclic*. This means that linear temperaments have an infinite number of tones in both directions from the starting point--in most cases an infinite series of fifths up and fifths down. Obviously, there is no point carrying such a series very far, since minute differences of pitch soon occur which are not audible in the real world.

Equal temperaments are cyclic, which means that even if an infinite number of names were provided, the pitches will recur after the circle closes. Usually this means a circle of fifths, although circles of other intervals occur in most equal temperaments. For instance, in the 12-tone equal temperament, the same pitch will be called D*bb* then C when the circle of 12 fifths is traversed, then B# when another round is made, then A###, and so on for infinitely many aliases. (For more on this, 12-tone can be considered as an imitation of Pythagorean intonation, whose fifths never recur because they do not close a circle no matter how far flatwards or sharpwards one carries them.)

The 31-tone circle of fifths closes in such manner that the thirty-first fifth, A-quadruple-sharp, coincides with C, whereas the A-quadruple-sharp of 1/4-comma meantone fails to reach C by 6 cents or 1/200 of an octave. This will hardly matter in the real world on real instruments, but if we try to conceal the facts in the case, someone will squawk. The point here is more a matter of philosophical principles and motivations, and to help explain what a MEAN TONE is.

In just intonation, there are two intervals with equal right to be called "whole-tones" or "major seconds" : one has ratio 8 : 9 and the other 9 : 10, and the difference between them is usually quite audible. This creates a problem in practical musical performance since it multiplies the number of tones required to perform slow sustained music in tune.

While just intonation is highly desirable in many cases, it is impractical or at least inconvenient in other cases. The 12-tone equal temperament is too crude and brute-force a solution for many occasions—something more calm and restful and less annoying and disturbing is necessary.

Many theorists and textbook writers present this black-and-white take-it--or-leave-it alternative, as though composer, performer, and listener had no rights at all, and must not be permitted ever to THINK.

Thanks to the 18th-century-and-earlier Revival abovementioned, we finally are being allowed to escape this double-bind in which so many musical "authorities" have tried to confine us. It is ironic that we couldn't just have progressed straight forward with time, as so many other fields outside music have been able to do. As the French put it, *Il faut reculer pour mieux sauter*, perhaps. Atonalists and serialists had tried to freeze us in 12-equal, but this wholesale revival of meantone tunings has re-opened the question, luckily for us.

The 1/4-comma meantone gets rid of the difference between the two just whole-tones by striking a geometric mean between them. This involves the ratio 1 : $\frac{1}{2}\sqrt{5}$. This by the way is a cousin of the famous Golden Section ratio.

What it means to the tuner is that each fifth must be flattened by $\frac{1}{4}$ of the difference between the two just whole-tones, to get a mean tone from two such fifths in succession, e.g.: C - G and G - D.

Since the just-intonation difference is called a comma, then each fifth is flattened by $\frac{1}{4}$ comma, hence the name of the system. The whole-tone or major second or major ninth is flattened by $\frac{1}{2}$ comma, cutting the comma in half being the "geometric mean". If this system be tuned on an instrument which has only 12 keys per octave, then we will get a disagreeable dissonance when we try to close the circle of 12 fifths which does not exist in meantone, and this is called the "wolf". Usually the wolf would be G# and E*b* or C# and A*b*. The wolf need not exist anymore at all!

We do not have to put up with pianos which can only have 12 keys per octave for mechanical and financial reasons; we have synthesizers and electronic organs and still other possibilities of affording and conveniently putting more than 12 notes per octave on a keyboard. Were that not so, I would not waste time and ink on meantone at all!

The mechanical (after all, 18th-century workshops didn't have precision measuring capabilities such as we have now; even 19th century factories didn't have electronic amplifiers and test equipment and integrated circuits and transistor miniaturization) and financial problems of prohibitive cost of building instruments with many keys per octave and then affording maintenance and tuning (which would have been fantastically expensive before electronic tuning-devices were put on the market) put a damper on attempts to use more than 12 meantone pitches and this spawned a whole family of meantone systems and also unequal and what are now called "well" temperaments.

To subdue the wolf, one could reduce the flattening of the fifths so that the failure to close the 12-tone circle was minimized. This is what eventually brought 12-tone-equal to its position of too much power. The greatest flattening of fifths that can be endured under normal conditions is 1/3 comma, which has a bigger wolf in 12, of course. But 1/3-comma meantone is so close to 19-tone equal that there is no practical difference between them. And it is easier to build a 19-tone keyboard than a 31-tone keyboard, so that was a possible way out in a few cases. *(Page 19)*

Compromising between 1/3 and 1/4 comma leads to the 50-tone equal temperament, probably never actually put in its entirety on an instrument. The theoretical meantone linear temperament corresponding to it thus would be named for some fraction of a comma. *(Page 25)*

That is to say: the 1/3-comma meantone system has just minor thirds and their inversions (major sixths) as well as perfect octaves, which latter are always assumed unless otherwise specifically stated. The 1/4-comma meantone, which is what is meant when "meantone" is said without qualifications, has just major thirds of exact 4:5 ratio and minor sixths of exact 5:8 ratio as well as perfect octaves.

The infinitude of theoretical pitches in the system is the consequence of insisting on two classes of intervals, i.e. octaves and thirds, both being just--this obtains for the remainder of the meantone family. However, as we stated, 1/3-comma is imitated almost to perfection by 19--tone-equal and 1/4-comma by 31-tone-equal, so there is no practical reason for making any distinction. This publication is not being written for the delectation or edification of Seekers of the Holy Grail or of Utopia or of Never-Never-Land or the Emerald City of Oz.

The 1/5-comma meantone has the octave and the major seventh (and its inversion, the diatonic semitone) just. Its wolf isn't quite as bad as that of 1/4-comma when only 12 of its tones are used. The third is allowed to get slightly sharp for the sake of less flattening of the fifth, and a leading-tone which is the same as that of just intonation. Since it is close to the 43-tone equal temperament, we don't have to make too much fuss over it. It is unlikely that it was ever used in entirety, so is primarily of historical interest. It does not seem to be very fruitful for composing new music, unless some composer finds something exciting in it in the future. 1/5-comma generates pairs of pitches which fail to close the 43-member circle by one cent, so this must be A Distinction Without A Difference! *We could have dismissed these close temperaments with a shrug, but it is necessary here to correct the rumor which has been so widely spread, about Partch's famous 43 tones being equal, when in fact they are UNEQUAL, being a subset of just intonation and sounding very unlike 43-equal.*

There is a 1/6-comma meantone with the augmented fourth just, and the fifth less flat than in the preceding systems, and the major third slightly sharper, so this is one more step along an engineer's trade--off---you give up This to get That. And so it proceeds, with meantone family members having 1/7 comma, 1/8, 1/9, till we get to 1/11-comma meantone, which coincides almost perfectly with 12-tone-equal and thus the meantone family theoretically includes ordinary 12, if you want to split hairs, or rather gnats' eyelashes. (I have a terrible uneasy feeling way back in my subnoxious mind that somebody is going to seize on this and misquote me out of context and accuse me of all kinds of things. Or use it as argument *for* 12-equal when I mean nothing of the sort.)

In earlier centuries when these various kinds of meantone were calculated, the instruments on which they were put (only a small part of them, remember, since nobody had the infinite number of keys necessary to implement a linear temperament completely) were hardly engines of micrometric precision, and didn't stay in tune long, so most of the meantone family is uninteresting to today's innovators and composers. Just intonation is now practical, carried out to various numbers of tones, and also a wide variety of equal and unequal temperaments, to suit every taste.

Theoretically we could go on to the zero-comma system, otherwise called Pythagorean, and keep on going with *negative* comma-fractions, such as

-1/7-comma where the fifths would be about 3 cents sharp and the major thirds uselessly harsh, but this is mathematical sophistry and too far from what any composer needs or wants to bother about. Just that in a world where government officials talk about negative income tax and certain banks charge negative interest in some cases, you might wonder, what would happen if? What might happen here is that equal temperaments like 17 and 22 could be approximated by negative-comma-fraction linear temperaments. As if anybody cared!

The meantone family, like the Pythagorean system which could be considered its theoretical zero, fits the existing seven-letter-name nomenclature with sharps and flats, and the corresponding staff-notation with accidentals, perfectly. Since there is an infinite number of pitches in theory, and an infinite number of possible names since one could follow any of the seven letters A B C D E F G with hundreds or millions of sharps or flats, the fit is hand-in-glove. By thus theoretically unifying Pythagorean (the system with perfect octaves and perfect 2 : 3 ratio fifths) with all the infinite number of meantone systems imaginable, we establish a thoroughgoing theoretical basis for existing nomenclature and notation, and reconcile the seeming paradox of such different-sounding systems as Pythagorean (brilliant, rousing mood) and ¼-comma meantone (soothing, calm, restful) sharing the same existing notation and nomenclature so perfectly. This is why the hair-splitting theory had to be discussed here.

It is regrettable indeed that all this network of facts had to be messed up so horribly by the zealous reformers and revivalists who did us the excellent service of reviving meantone tunings and using them for the music composed in them, but had this notion that there could be only 12 pitches per octave and they went on beyond their legitimate rights in trying to tell composers like me that we couldn't compose with more than twelve pitch-classes per octave. I resent that, and have tried to clear the air here, and hope no one else will be intimidated by their unjust dogmatism and power-tripping. They are trying to shove us back into the sixteenth century in technology as well as art, which they have no right to do. Since we can now build all kinds of instruments with more than 12 notes per octave, and have done so, their restrictions are now nothing but history.

Pythagorean Tuning (Perfect Fifths and Octaves)

This system has been kept alive by the fact that 12-tone-equal fifths are only 1/600 of an octave flat. Therefore the exact fifths of violin family bowed-instrument tuning do not beat very much with the tempered fifths of 12-tone, and when violinists play unaccompanied melodies they do not have to bother about the just 5:4 major thirds being a comma flatter than their 81:64 Pythagorean major thirds, so a modus vivendi and gentlemen's agreement situation has existed. 12 is the first and cheapest good imitation of Pythagorean. 17 is a more brilliant exaggeration. 29 is slightly more faithful to Pythagorean than 12. 41 and 53 are still better. So many music-book writers ignore the real major third and its derivative intervals, the minor third, the just diatonic semitone, etc. This creates the misinformation that the major scale is constructed out of a chain of fifths. The Pythagorean major scale is so constructed and sounds brilliant. But the just major scale is not so constructed!

But there is a trick, evidently discovered in the Near East: If you

take the E of the C-major chord by fifths upward from C, G, D, A, to E, you get a disagreeable sharp major third. But if you take fifths downward a longer distance, C, F, B*b*, E*b*, A*b*, D*b*, G*b*, C*b*, F*b* you get a usable major third only 1/614 octave too flat. This means you can imitate just intonation by using fifths only, and also suggests that the 53-tone system can be used in this manner (see the 53-tone sheet) with its F-flat deputizing for the E-one-comma-down of just intonation. The tiny interval of 1/614 octave is called the *skhisma* by Ellis because he didn't want it confused with the religious term *schism, schismatic,* which has an irregular pronunciation and such a different meaning that it would derail the music-theorist's train of thought. So for practical purposes this means that the 53-tone temperament can substitute for true Pythagorean and for just intonation in most cases.

UNEQUAL AND "WELL" TEMPERAMENTS

So long as instruments were not precision, before modern manufacturing, modern tools and measuring devices, and now electronics and computers, most musicians were limited on keyboards to 12 tones per octave, as we already said. The meantone wolf suggested innumerable dodges to get rid of it without going equal--without having to settle for 12-tone's litter of 12 Wolf Cubs. The meantone family exhibits unequal spacings of the 12 notes. But there are other ways to be unequal. Suppose that we try to get one just chord in C major and then expand or contract the 12 fifths in an attempt to close the circle, but with fifths of different sizes rather than the same size. This will cause a different amount of error in each major and each minor triad.

It is alleged by some authors that this was what J. S. Bach meant by "well" in the title for the 48, *Das wohltemperierte Klavier*; hence the newfangled term "well temperament" which is being increasingly used despite the sneers and invective of purists. It doesn't really matter what Bach did--his instruments could never have been as precise as our modern electronic wonders, so what probably happened was that he tried every practical kind of tuning he could think of and settled on what he liked to use which might or might not be the best one to use today, and might or might not have been what keyboard-instrument historians like to call "well temperaments".

This idea of fifths of varied size resulting in consonant and dissonant major and minor triads happens to coincide with various Romantic notions especially among people who take music for granted and do not want to ask "why" nor invent possibilities for the future, that "there is character in keys"--now if the tuning is varied instead of being absolute 12-tone-equal, then F# major will sound different from C major on the opposite side of the circle and intermediate keys will have intermediate characters. This is usually done to make old music sound better or different. It does not increase the number of tones in the octave and while it makes some mood-difference around the circle, it does not afford any real contrast of moods as the use of a number of non-12 equal temperaments in contrast to 12, and in contrast to just intonation, does.

Twelve tones per octave, no matter how they are tuned, are not enough to permit today's composers to get out of the rut they are in. Why put up with 1600's or 1700's problems? Why forbid composers to do something because it was impractical or impossible in 1780 or 1861?

Surely it isn't a question of saving money. These instruments built to old specifications cost as much or more than new instruments invented lately which can have more than 12 notes per octave. Surely musical studies should be for general public pleasure, not for religious cultist masochism. Nobody is going to get medals for merit because they are spending just as much money and time and effort and restricting and denying themselves what they could just as well enjoy right now!

The only obstacle to more than 12 tones per octave on violin, viola, cello, or voice is the psychological programming of the person using them.

It is, fortunately, another matter when this "well" or unequal idea is applied to more than 12 notes per octave. It is possible for instance to take 19-tone and vary its fifths, so that the near side of the circle could have the properties of 31-tone for instance. Then there could be a character-in-keys change around the 19 tones. George Secor has actually done this. He has also experimented with unequal 17-tone systems, one of which has several long harmonic series in it.

Furthermore it is possible to use just intonation in the nearby keys and to alter the intervals further away from C major so as to make say 24 or 30 just pitches do the work of twice that number for all practical purposes. Of course the purists will scream and carry on, but supposedly the one who uses an instrument , and much more the one who builds or designs it, should have final say. Let other people do it their way. It is so hard to understand the psychology of the Human Roadblock and Professional Spoil-Sport. Even after 50 long years of suffering at their hands.

Sticking to historical temperaments is pointless, since we now can tune instruments and temperaments which are impossible to do with the unaided ear. Furthermore, everyone doesn't have time to study many tuning-by-ear routines. Most professional tuners, until the recent demand for meantone, knew only one routine, that for 12-tone-equal, of which there are several. With modern affordable tuning-devices, the average instrument-owner and composer can experiment with dozens of variations.

Temperaments Which Alter the Octave

Standard theory has presumed the inviolability of the Octave, as though it were somehow more sacred or valuable than the other intervals. This does not conform entirely with the Real World Out There. Since pianos have been popular, which is about 200 years, octaves have been stretched and the stretch itself is stretched. This is supposedly due to the inharmonicity of piano strings, which are thick and behave somewhat like rods; but the stretching of octaves occurs on other instruments, such as marimbas and metallophones. In the higher register of such instruments and in the piano, perfect octaves sound too flat. They lack life and brilliance. This effect is almost nonexistent in the Middle C zone, but increases at both ends of the keyboard to an astounding degree, especially in smaller pianos and some other instruments.

Augusto Novaro in his writings tried to systematize the octave stretching, as for instance using the 7th root of 3/2 or the 19th root of 3 for 12 tones per octave instead of the theoretical 12th root of 2. This idea can be extended to non-12-tone temperaments of course.

(Temperaments which Alter the Octave, continued)

For instance, the flat fifths of 19-tone can be stretched by lesser or greater amounts—the 30th root of 3 in place of the 19th root of 2 is a considerable stretch of the octave. The 44th root of 5 in place of the 19th root of 2 gives a 1/4-comma-meantone fifth, since it too is now exactly the 4th root of 5. Arbitrary other values of the stretch are of course possible, as well as a gradually stretched stretch, but tables already exist for the ones given, which are due to E. M. Wilson. For organs and some solo instruments a stretched 31 might be desirable — one such would be the 49th root of 3, which gives a perfect twelfth (octave and a fifth, 3:1 ratio, for which stops exist on many organs). A shrunk octave might be used to mitigate the sharpness of fifths in a system like 22.

By the nature of human hands and sense of hearing, octaves will often be out-of-tune on the violin or other bowed instruments, and the tendency is to stretch them rather than to shrink them.

For purely melodic purposes, it might be desirable to have scales which deliberately avoid the octave. Stockhausen once experimented with the 25th root of 5. On wind instruments, more force is required to overblow them to sound the octave or higher harmonics, and this usually results in an automatically stretched octave. The entire harmonic series of trumpets, horns, etc. may be stretched in a similar manner.

As a sort of appendage to this idea, one might want to experiment with the psychologists' Mel Scale, which applies to simple tones presented one at a time (i.e. melodically rather than in any harmonic context).

For practical purposes, the stretched- and shrunken-octave tunings may be considered variants of the normal-octave systems. After trying out a temperament, it will be obvious whether to try stretching or shrinking.

Elastic Tuning and Self-Justifying Instruments

An ensemble of musicians using flexible instruments, such as a string quartet or an a capella choir, will by a sort of mutual biofeedback process, alter the pitches of a chord while it is sounding, usually in the direction of just intonation.

In 1962 I constructed an electronic organ out of unstable blocking oscillators which easily influence one another's frequency, and the result was that no matter what temperament this organ is tuned to, it will try in greater or lesser degree to make chords just, while they are sounding. This is in direct opposition to the usual engineering design of electronic organs, where the tone-generators are usually designed to be isolated from one another as completely as possible. However, in commercial organs it is common to have master-and-slave chains of oscillators locked in octave relation and continuously-running. Even though such locked-in synchronization has been used for decades, no-one seems to have thought of applying it to all the tones of an organ in such manner that the locking occurs gradually, the oscillators are not running continuously, and every chord on the instrument is an individual because of different amounts of pulling-in tendency--this makes all the difference:it sounds live instead of dead. The standard condemnation of electronic instruments that they "all sound alike" simply doesn't have to be true. The difference is whether the instrument be designed by a manufacturer's underling or by a composer or performer. Elastic tuning can solve many of the problems that have plagued the field of temperament and just intonation for centuries!

ADVANTAGES AND DISADVANTAGES OF JUST INTONATION

This chart assumes that at least 18 pitches per octave will be available and that at least one pair of comma-distant notes will also be available.

DISADVANTAGES

Many musical instruments are not capable of precise tuning, nor of retaining a fine tuning given them.

Even when one is harmonizing a passage in a major scale which does not modulate to any other keys, two notes a comma (81:80, ca. 1/55 octave) apart will be required to get all the major and minor triads of that scale in tune.

In rapid musical performances, say at Allegro or faster, the comma becomes a nuisance. Performers who otherwise would keep to just intervals, will fudge and bend to get rid of commas in lively pieces.

Few people will agree upon what Just Intonation IS. Some will not admit higher members of the Harmonic Series to membership in it. It becomes necessary to specify: 3-limit (Pythagorean), 5-limit (tertian, Web of Fifths & Thirds), 7-limit (septimal), 11--limit (Partchian, undecimal), etc.

Theoretically, just intonation requires a many-ordered infinitude of pitches. In practice, it can be carried to a large number, too many for some commonly-used instruments, entailing ruinous expense and complicated tuning procedures.

For mechanical, financial, and other reasons, just intonation is impossible on the piano. The strings of the piano are out of tune with themselves! Notes a comma apart cannot be accommodated.

Carried out far enough to do any good, just intonation entails tiny intervals which are too difficult to tune, such as the skhisma (ca. 1/614 octave). As a result, many experimenters tinker with these intervals and in effect, subtly temper them.

ADVANTAGES

Just intonation is restful, but also clean and brilliant. No compromise between these desirable factors need be made nor tolerated.

Justly-intoned chords do not beat. They are solid and smooth. Combinational tones form a bass to them which is in tune. This means that amplifiers which distort and generate difference-tones (called intermodulation by electronic engineers) are much kinder to just chords than to any tempered chords.

Just intonation is ideal for singers. Singers instinctively fight 12-equal. This is especially true of choruses.

Just intonation permits more and subtler modes and variations of scales and harmonies.

Just intonation uses the discriminative powers of our ears EFFICIENTLY; 12-equal WASTES them.

With modern electronic tuning-devices and electronic musical instruments, the historical problems which have plagued just intonation until now, largely disappear!

Some computers can be programmed to perform in just intonation.

Flexible instruments: trombone, voice, violin, cello, &c., instinctively tend to just intonation.

Just theory involves arithmetic and integer ratios; temperaments involve irrational numbers, roots, logarithms, fractional exponents, and all that jazz.

Electronic circuits have to be TRICKED into doing anything BUT just intonation: this is the subject of numerous patents. Getting just intervals out of electronic apparatus is EASY.

ADVANTAGES AND DISADVANTAGES OF THE STANDARD TWELVE-TONE EQUAL TEMPERAMENT

DISADVANTAGES

With so many myriads of composers continuing to exploit the melodic and harmonic resources of twelve for so long, the well was bound to run dry, and indeed is beginning to show signs of approaching exhaustion.

Serialism and Atonality concentrate on the EYE and ignore the EAR— their orderly structures are apt to be "seen and not heard". (But they could do very well in NON-12 !)

The MOOD of 12-tone is RESTLESSNESS —never any true repose.

During the 1800's, 12-tone instruments made progress possible; at the present time they have stopped musical progress and block it. Many composers have turned to the field of Noise, or even have left music entirely.

12-tone is HARSH—its thirds and sixths are out-of-tune and create a continual cloud of beats, which in turn produces fuzziness and a hash of sounds. With modern amplifiers and reproduction everywhere, distortion produces even harsher false difference-tones, which are out-of-tune even with the 12-tone system.

Until the advent of modern precision electronic tuning-devices, most of the 12-tone music played and heard by most listeners was SOFTENED down by deviations from ideal precise equality of tuning. Thus it is only lately that everyone gets to hear the full harshness of 12-tone.

Performers on flexible instruments such as violin and trombone, as well as singers, instinctively deviate from 12: they "bend" pitches.

12 does not use customary names or standard notation efficiently: 35 names are represented by only 12 pitch-classes: B# = C = D𝄫 .

Even ordinary ears can distinguish many shades of pitch and many intervals--Why not use our ears more efficiently?--and that is what 17 19 22 24 31 34 41 etc. do! Why WASTE our natural powers?

ADVANTAGES

Tens of thousands of composers have written for 12-tone-equal over a period of possibly two centuries for keyboard instruments and much longer than that for fretted instruments such as the lute family.

12-tone literature is enormous.

Economy of Means: 12 is the cheapest system that will produce any amount of worthwhile music in various styles.

Symmetry: 12 is a divisible number: 12 = 2 x 2 x 3 , creating many balanced patterns, commonly known as the whole--tone scale (6), the diminished-seventh chord (4), the augmented triad (3), and the tritone (augmented fourth = diminished fifth) (2).

Brilliance: 12 is a good imitation of Pythagorean (perfect fifths) intonation, so that violinists can pretend they are playing in it.

Standard tuning-routines are available for tuning 12 by ear, and are taught to piano and organ tuners everywhere.

Twelve-equal is compatible with the present tone-quality of pianos, and in return, pianos have kept 12 locked-in.

The idea of twelve-equal can be traced back to the Chinese and beyond. It is possibly associated with the 12 months of the year, the 12 signs of the Zodiac, 12 hours on a clock-dial, 12 pence in a shilling till recently, assorted religious notions, the Ancient Roman fraction system based on twelfths, the point/line/ /inch/foot measuring system, counting by dozens and gross and great-gross, 12 ounces in a Troy Pound, &c.

12-tone is a compromise fitting many cultures: the familiar 7 + 5 keyboard with 5 black keys in the pentatonic scale, interlaced between the 7 white keys of the diatonic scale.

12-tone-equal can express the chromatic and diatonic genera of the Ancient Greeks passably well.

Some music-textbook authors praise the numerous ambiguities of 12-tone.

ADVANTAGES AND DISADVANTAGES OF THE 17-TONE EQUAL TEMPERAMENT

DISADVANTAGES

Because both major and minor sixths and thirds are DISSONANCES in 17, almost as dissonant and far from just as they can possibly be, traditional textbook harmony with its rules is next to impossible in 17.

The unrelieved dissonances of the thirds and sixths in 17-tone make it RESTLESS in mood, about as much as twelve-tone is.

The harshness of 17 counts against its admitted brilliance.

Having G-sharp SHARPER than A-flat is more confusing to some people that having it flatter than A-flat as is the case in 19 and 31.

The strange "enharmonic equivalents" (much better called "synonyms") of 17 are also confusing: E-sharp is G-flat and A-sharp is C-flat.

The dissonances in 17-tone compel the use of bland timbres and instruments to mitigate them. Usually not suitable for organs, for instance.

Seventeen-tone equal temperament possesses the ULTIMATE DISSONANCE: the cluster of ALL 17 TONES is more dissonant than all 12 or all 19 or all 22 or 31--dissonance DECREASES beyond 17.

17 is a prime number, not divisible into halves, thirds, quarters, or sixths as twelve is, hence asymmetrical and destroying the patterns of 12. Thus 17 is incompatible with 12 and cannot be used with it unless one wishes extremely dissonant counterpoint.

ADVANTAGES

17-tone is a convenient form of exaggerated Pythagorean. This means that 17-tone harmony has to be based upon fourths, fifths, major seconds, and minor sevenths, resulting in novel kinds of melodic and harmonic progressions.

17 is very BRILLIANT. Its mood is rousing, invigorating, stimulating.

It somewhat resembles the Arabic and other Near Eastern scales.

17 is quite congenial to the bowed instruments of the violin family, because string-players are used to tuning and playing fifths, and to the sharpening of leading-tones going upward, which is what happens in seventeen-tone tuning. The flattening of leading-tones going downward also is reflected in 17.

17 fits present staff-notation very well, since it makes use of the written distinction between pairs of notes such as G-sharp and A-flat. It does so, however, in the opposite sense from such systems as 19 and 31; in 17, G-sharp is SHARPER than A-flat or a sharp is "worth" 2 unit-intervals.

17-tone sounds very "clean" and clear. No fuzziness, no veiled effects, no mushiness. Hard-edged!

17 can be distorted to give different effects, so that unequal 17 systems have been invented.

Unaccompanied violin solos and other brilliant melodies do very well in 17.

Exotic "neutral" intervals exist in 17.

17 is a prime number, so the augmented fourth is not the diminished fifth and neither is half of an octave. This gives a distinctive flavor.

THIRD- AND SIXTH-TONES: BUSONI'S PROPOSALS AND THE REALIZATIONS OF THESE INTERVALS BY HÁBA, CARRILLO, AND OTHERS.

DISADVANTAGES of 18

There are no fourths and no fifths, and this destroys ordinary harmony and scale-structures.

The normal tension and relaxation phenomenon of ordinary music is blurred and reduced.

Notation problems arise...Also what to name the 18 tones.

On each side of 18 tones per octave are the far superior systems, 17- and 19-tone with each having far more resources than 18, both melodically and harmonically.

18 is very difficult for instruments of the violin family because there are no fifths to tune by. Similarly for 18-tone guitars.

DISADVANTAGES of 36

The unit-interval of 1/36 octave is too small to be important melodically.

36-tone lies beyond the possibility of fluent guitar playing.

36 still contains 12, with all its faults, and provides no real escape, since 12 keeps being heard all the time.

Thus there are three circles of 12 fifths in 36, which never meet. One cannot use thirds, either, to escape the first group of 12 tones, to get to the other two such groups. As with quarter-tones, we have the problem of needing to use UNFAMILIAR intervals to enjoy the freedoms of this system.

To solve the problems of 36, one is tempted to press on to 72.

ADVANTAGES of 18

According to Busoni, Debussy's and others' use of the whole-tone scale points the way toward the tripartite tone (third-tone) as a viable affair.

Third-tones have a mood of vagueness which differs from the more aggressive mood of twelve. 18 might be good for serialism and atonality.

The exact third-tone, 18, has melodic value just as the units of 17 and 19 have; this is what got Busoni interested in the first place.

Carrillo had two pianos made for 18.

A 6+6+6 keyboard arrangement is possible.

9+9 is also possible, since the 9--tone system has some values.

Busoni experimented with playing the third-tones to observers in another room; they accepted them as semitones!

ADVANTAGES of 36

Septimal intervals (those whose ratios contain a factor of 7) are well-represented in 36-tone.

As Busoni points out, 36 contains 12. Conventional 12-tone harmonic techniques can be used along with the melodic potential of 18, and 36 contains both 12 and 18.

Some 36-tone compositions already exist. Hába wrote a book with information about 36, as well as composing.

36 restores the fourths and fifths and eliminates the problem of tuning violin-family instruments or guitars.

36 possesses multiple symmetry: halves, thirds, quarters, sixths, ninths, twelfths, and eighteenths of an octave.

Containing 9, it might provide atonalists with a means of using 9-tone patterns without giving up their 12.

ADVANTAGES AND DISADVANTAGES OF USING 19 TONES PER OCTAVE

DISADVANTAGES

Major seventh is flatter than the major seventh in just intonation; therefore much flatter than in 12 tone--accordingly, leading-tones are too flat if played as written.

To get sharp leading-tones, melodies must be "misspelt": e.g., A A♭ A♮ instead of A G# A .

Detuning of fifths and fourths is nearly 3½ times what it is in 12; therefore beating fourths and fifths are more noticeable.

Major third is noticeably flat instead of sharp as it is in 12--tone; therefore the difference between 19 and just major thirds is added to the error of 12-tone major thirds, not subtracted from it. Thus, more noticeable.

Because 19 is a prime number, the symmetry of the 12-tone tuning is destroyed, as also the symmetry of Busoni's proposed "third-tones" or 1/18 octave. This irritates 12-tone serialists, as well as fanciers of the whole-tone scale of Debussy et al.

There was no purely-by-ear routine for tuning instruments to the 19-tone equal temperament, as there is for 12-tone. Not until Ivor Darreg invented it in 1975.

The enharmonic tetrachord and other Enharmonic Genus patterns of the Ancient Greeks are not rendered as well in 19 as they are in 22 or 24.

The 7th harmonic and the subminor seventh and subminor third are not as well represented in 19 as in 31--indeed the 19-tone representation is slightly worse than in quartertone tuning.

Nineteen is incompatible with twelve and so cannot be played along with it unless you want super-dissonant counterpoint! 24 is totally compatible with 12, and 18 is compatible to some extent.

ADVANTAGES

19-tone has incredible zonk and pizzazz and impact. Pungent harmonies and greater contrast between its consonances and dissonances than 12 has.

Its third-tone unit-interval is quite useful melodically.

19 is a prime number, not evenly divisible into halves, thirds, and quarters. This fact greatly improves those mainstays of harmony, the augmented triad and the diminished-seventh chord. 19-tone variety in these eliminates their 12-tone monotony.

Piano timbre is quite suitable for 19-tone (2 pianos required of course!)

19-tone is quite practical and convenient on guitars and other fretted instruments; moreover, 90% or more of guitar repertoire is playable in 19 without alteration from existing sheet music!

Music intended for meantone tuning is congenial to 19; indeed, the variety of meantone called "one-third-comma" is almost identical to 19-equal.

19-tone can be made unequal or its octave can be stretched to afford more moods and varieties, such as so-called "well" temperaments.

19-tone has a valuable and startling new MOOD which tremendously increases the musical vocabulary and resources open to composers today.

Busoni's proposal back in 1907 that the third-tone or "tripartite tone" as he called it, be admitted to the musical resources available, is realized much better by the slightly smaller 1/19-of-an-octave. 18 has NO fourths or fifths, but 19 DOES have them. Busoni admitted that he would have had to halve the third-tones into sixth-tones to get the harmonies he wanted; but 19 already has plenty of harmonic resources.

All 19 tones of the system are easily reachable by FAMILIAR intervals; they are fully INTEGRATED.

19 conserves tonality.

ADVANTAGES AND DISADVANTAGES OF THE TWENTY-TWO-TONE EQUAL TEMPERAMENT

DISADVANTAGES

22-tone equal temperament is NOT the system of 22 unequal śrutis used in India. But see other column »

22-tone is incompatible with 12 and cannot be played along with it; whereas 24 (quartertones) will be compatible with 12, which it contains.

The errors of the major third and of the fifth in 22-tone being in opposite directions, do not cancel, so the minor third is much too sharp.

Absurd and ridiculous consequences follow from attempting to name the 22 tones with standard nomenclature practice: for instance, D# of the 22-tone circle of fifths makes an excellent E in C major, but the name and notation system breaks down.

The problem of the COMMA in just intonation exists in 22-tone, in an exaggerated form--e.g., there are two major seconds of different sizes. This makes the notation problem above, even worse.

While some existing music can be played well enough in 22-tone, it is difficult to read it off from existing sheet music--marking-up, tablature, numbering the tones, or other expedients may be required.

24 and 31 have neutral thirds, but 22 lacks this interval. Major and minor thirds are very close together in 22.

The fifths of 22 are so sharp that their beats are very conspicuous on most sustained-tone instruments. The 8-cent error is just about the limit of tolerance for fifths.

The standard guitar tuning runs into the abovementioned "comma" problem: either the two E-strings (1st and 6th) must be out, or a supermajor third which is very sharp must go between 2nd and 3rd (B and G) strings.

ADVANTAGES

22-tone has a very distinctive MOOD shared by no other system.

22 is more harmonious than quartertones (24-tone).

→Some theorists in India use 22-equal despite the usual theory of the inequality of the śrutis.

Unlike 24-tone, 22-tone has only one Circle of Fifths and therefore all its tones are fully INTEGRATED and accessible by FAMILIAR intervals. Modulations are easier than in 24.

22-tone gives excellent renditions of the Ancient Greek Enharmonic Genus and the Enharmonic Tetrachord pattern.

Without the sometimes soporific effect of 31, 22 is harmonious, and also more brilliant than 31-tone.

The unit-interval of 22 approximates a quartertone. Thus most melodic patterns are transferrable between the 22 and 24 systems.

The unit interval of one-twenty--second of an octave is still large enough to function melodically, but 31sts of an octave may be too small.

While not getting too far away from a good representation of the eleventh harmonic, 22-tone has a better representation of the 7th than 24-tone has.

22 contains 11-equal, which is suitable for atonality.

Certain compositions, played in 22, come to a satisfying rest-point; and this is not so apt to happen in 24.

While 22-equal does not admit of stretched octaves as 19 and 31 do, it admits of shrunken octaves, as well as a tremendous variety of unequal variations, and also of compromises with the accepted 22-tone unequal norm of India.

22-tone conserves tonality, whereas 24-tone inserts 12 oddball strangers, requiring rethinking of key-systems.

ADVANTAGES AND DISADVANTAGES OF THE QUARTERTONE SYSTEM (24 TONES PER OCTAVE)

DISADVANTAGES

The tone-quality of the piano is not congenial to quartertones because it lacks 7th and 11th harmonics.

There is no agreement on symbols for writing quartertone music; dozens of rival systems in use.

Quartertone system has two circles of 12 fifths each, so the new 12 tones cannot be reached from the familiar 12 by familiar intervals.

Difficulty in modulating to new keys because of the above.

The quartertone imitation of the 7th harmonic and intervals derived from it is inaccurate: 19 ¢ flat.

The MOOD of quartertones, especially in harmony, is weird. This has been recognized for some time.

Because of the closeness of finger-spacing required, quartertones are very difficult on the violin. (Hence, on the mandolin)

Since quartertones still contain the usual 12-tone equal temperament, they retain the restless MOOD of 12-tone, and indeed exaggerate it.

For many people, the first impression is that quartertone music is merely out-of-tune.

When quartertones are set up as two pianos (or other keyboard instruments) tuned a quartertone apart, which is the commonest realization of 24-tone up until very recently, the problem arises of keeping two performers equally BUSY, which tempts one to write too many notes in order that one of the pianists doesn't feel left out, underutilized, or insulted.

This in turn tends to set up "bi-atonality" with two 12-tone entities continually duelling and refusing to integrate.

Almost impossible to convert existing music to use quartertones efficiently.

ADVANTAGES

It is often possible and even convenient to find two pianos that are, or can be, tuned a quartertone apart.

Fretted instruments, such as the guitar and banjo, can have quartertone frets intercalated between the existing semitone (12-tone) frets without any disturbance to existing frets, and without jeopardizing one's investment in a valuable instrument.

There is a considerable body of quartertone compositions already in existence.

Once you have refretted a guitar to quartertones, you can also use it for the 22-tone system by simply moving the bridge.

The new electronic keyboard instruments can be stacked one on top of another and used for quartertones in most cases.

The eleventh harmonic and new intervals arising from its use are accurately imitated by quartertones; the difference is inaudible.

Approximations to the 7th and 13th harmonics are at least usable.

QUARTERTONES REPRODUCE THE ENHARMONIC TETRACHORD PATTERN AND THE ENHARMONIC GENUS OF THE ANCIENT GREEKS VERY WELL.

Quartertones have great melodic possibilities, thus enlarging the composer's creative vocabulary.

The frequency of AC power lines is almost exactly a quartertone off the A = 440 Hz standard for 12-tone. This makes it easier to tune instruments a quartertone apart; it also subconsciously re-conditions the Public Ear.

The 8-tone scale of three quartertones is useful and novel.
The neutral third and neutral triad are useful new resources.

Piano and organ tuners do not have to learn any new routine to tune quartertones--just one standard a quartertone higher or lower is required for them. Most new electronic tuning-devices make this easy to implement.

MANY EXOTIC CULTURES HAVE INTERVALS CLOSE TO QUARTERTONES.

ADVANTAGES AND DISADVANTAGES OF THE THIRTY-ONE-TONE EQUAL TEMPERAMENT

(MOST STATEMENTS BELOW APPLY AS WELL TO STANDARD ¼-COMMA MEANTONE)

DISADVANTAGES

31 tones per octave is a large number to deal with.

For newcomers, the "jump" from 12 to 31 is too much to expect.

In many average cases, the 31st of an octave is too small to be a telling melodic interval in its own right.

It is extremely difficult and tedious to tune 31-tone by ear; any use of the system requires electronic tuning-devices, or fretting-tables.

A 31-tone piano is impossible under present conditions because of prohibitive expenses, and if it could be made would not be worth the trouble.

31 tones per octave represents just about the practical limit for guitars of average size, and is impractical on mandolins and other small fretted instruments. There is a noticeable increase in difficulty of playing fast enough in 31 as compared with 19, 22, or 24.

The flat fifths of meantone or 31 are uncongenial to the violin, viola, and cello, as they go against the string-players' bias toward Pythagorean intonation and its perfect fifths.

By using only 12 tones of meantone, many traditionalists are creating painful roadblocks to any progress with 31—they want the horrible dissonance of the WOLF which is an avoidable mistake; just use more than 12.

Played as written, all leading-tones are too flat and insipid in meantone and therefore in 31. Notes have to be "misspelt" to get a sharp-enough leading-tone for melody.

See "MEANTONE FAMILY" Pages 8 et sqq.

ADVANTAGES

No other temperament practical on so many different instruments is as calm and restful as 31-tone.

There is a vast meantone keyboard literature and other instrumental and vocal music more or less tied to meantone. 31 can do it best.

The meantone series of fifths fails to close by 6 cents at the 31st fifth, which means that the difference between ¼-comma meantone and 31-equal is inaudible and can be neglected.

Septimal intervals are well rendered.

31-tone can easily reach remote keys with otherwise unheard and astounding effects adding to one's vocabulary.

31-tone has subminor, minor, neutral, major, and supermajor thirds, 31 of each in chords, scales, and keys. So has straight meantone of course, despite all you have heard to the contrary.

31-tone is refined and subtle.

No need for undue expense in procuring special 31-tone keyboard instruments at the start. 31-tone fretted instruments can render the vast meantone keyboard literature already mentioned.

It so happens that certain keyboards designed for 31-tone are also suitable for other systems. I.e., 31 is a good starting-point for designing a GENERALIZED keyboard.

31-tone ORNAMENTS are effective!

Thirty-one-tone makes highly EFFICIENT use of the staff-notation and name--system. The circle of fifths closes at the optimum G-double-flat-to-A--double-sharp point. It is almost as though conventional nomenclature were designed expressly for 31-equal. However, there are auxiliary synonym equivalents of semi- and sesqui-sharps and -flats for denoting septimal and other new intervals in the system.

The 31 tones are fully INTEGRATED and easily ACCESSIBLE by various modulatory and melodic routes; this contributes to the favorable mood and impression created by this system.

31-tone compositions are already available from several countries.

ADVANTAGES AND DISADVANTAGES OF THE 34- AND 46-TONE EQUAL TEMPERAMENTS

DISADVANTAGES OF 34

34-tone seems to be neglected; there is little mention of it in the music theory literature and no compositions in it so far as we know.

34 is twice 17 and contains two circles of 17 fifths each, which never intersect, creating a situation like that in 24-tone and 50-tone. Notation and nomenclature present problems, since there must be a rational notation for 17-tone and no renaming of the 17-tone subset when moving up to 34.

There might be special problems in designing a keyboard for 34.

It is just beyond the limits of fluent guitar playing on an instrument so fretted.

The septimal intervals based on the harmonic seventh are not well represented in 34-tone as against 31.

ADVANTAGES OF 34

34-tone has very good thirds and sixths, both minor and major.

34-tone retains the brilliant, rousing mood of 17, which it contains, while permitting smooth harmony which 17 does not have.

34-tone can be notated by using erect and inverted daggers (obelisks as some printers call them) before the affected notes. † ‡

34-tone gives added use to the otherwise not very useful neutral intervals in 17, harmonically.

The special mood of 34 might turn out to be important later on. Experiment shows that it contrasts with 31-tone's mood.

It should be possible to perform a wide range of existing music in 34-tone, with its brilliance for melody and good thirds and sixths for harmony.

DISADVANTAGES OF 46

We are now beyond the point where the unit-interval of a system has much melodic value.

It is probable, though not certain, that the mood-differences beyond the 31-34-36 group of systems, will be considerably attenuated. It will require more careful use of and listening to the trio of systems 41-43-46, to appreciate their mood-differences.

There does not seem to be much reference to 46 in the literature and apparently nothing has ever been composed in it. This may not really be against future use of 46, of course.

ADVANTAGES OF 46

There have been some allusions to the 23-tone scale in the theoretical literature, despite its inharmonicity. A very real gain in harmonic capability by doubling the number of tones still permits retaining and using the strangeness of 23.

The sharpness of fifth (2 cents) and major third (5 cents) with a minor third of 2½ cents flat, are inconsequential, and when this is supplemented by good approximations for 7th, 11th, 13th, and even 17th harmonics, it compares very well with other equal temperaments.

ADVANTAGES AND DISADVANTAGES OF THE 41-TONE EQUAL TEMPERAMENT

DISADVANTAGES

The flatness of the major thirds in 41 will be quite noticeable in comparison with 31 or 53.

The physicist Adriaan Fokker, who promoted the 31-tone temperament during the latter part of his life, entertained the idea of the 41-tone system for a while, but eventually decided the advantages were not worth the 10 extra tones.

Since the 41-tone system possesses a small interval approximating and functioning like a comma, this creates notation and naming problems like those of 53 or 22.

Practically no mention of anyone composing for 41-tone.

ADVANTAGES

The 41-tone system provides reasonable representations of the higher members of the harmonic series.

Fifths in 41-tone are 0.484 cent sharp, or 1/2479 octave. This is negligible for all practical musical purposes.

41 contains an interval of 2 degrees of the system which can function melodically like a quartertone.

The special 11-limit just system of Harry Partch with 43 unequally-spaced tones, can be better approximated by 41-equal than by 43-equal.

41-tone has a certain brilliance as well as the presentation of higher members of the harmonic series.

Paul Jankó, inventor of an important 12-tone keyboard, explored 41 and approved of it.

ADVANTAGES AND DISADVANTAGES OF THE 43-TONE EQUAL TEMPERAMENT

DISADVANTAGES

There would not seem to be any gain in going from 31 tones to 43 so far as increasing the musical vocabulary is concerned.

The main argument for 1/5-comma meantone as against the more usual ¼-comma meantone, has come from its use on early keyboard instruments as a variant of the regular meantone, as an example of less extreme flattening of fifths for the sake of the major thirds. These reasons are hardly as relevant now, since with new instruments it becomes more practical to use just intonation.

There does not seem to be a body of compositions for 43 tone equal.

There does not seem to be much evidence of ALL 43 pitches being made available on actual instruments.

ADVANTAGES

The 43-tone system closely approximates a member of the meantone family known as 1/5-comma meantone, since its fifths are too flat by that amount.

The theorist Sauveur recommended the 43-tone system.

The 1/5-comma system is mentioned in books on historical tunings, for performance of the meantone keyboard literature.

The major seventh and diatonic semitone are just in this system.

ADVANTAGES AND DISADVANTAGES OF THE 50- AND 55-TONE SYSTEMS

DISADVANTAGES OF 50-TONE

The flatness of the fifth, common to all the Meantone Family, is greater than in standard ¼-comma meantone temperament. The third is also flat, but of course both fifth and major third being flat compensates by cancellation of some of the minor-third error.

While the error of the subminor or harmonic seventh in 31 is microscopic and even in standard ¼-comma meantone it is small, in 50 it is large enough to count against the system, despite the improvement in 11th and 13th harmonic representations.

50 is a "second-order" system. In this case, the major third is a member of the 25 system, but the fifth is not. So there will be two circles of major thirds which do not intersect.

ADVANTAGES OF 50-TONE

50-tone temperament is a member of the Meantone Family and it represents a logical intermediate in properties and character between the 19- and 31-tone temperaments or if you will, the 1/3- and 1/4-comma meantone temperaments closely approximated by 19 and 31.

Since 50 is a multiple of 5 and 10, the moods and properties of the 5- and 10-tone temperaments may be taken advantage of on any of the 50 degrees of the system as starting-point.

At least one investigator, T. Schafer, discovered some time ago that 50-tone possessed remarkable chords and harmonic combinations.

50 is a member of the Yasser series of systems, being 19 + 31.

The 25th of an octave, 2 degrees, is a satisfactory quartertone melodically.

DISADVANTAGES OF 55-tone

With nearly 4 cents flat on its fifth and 6½ cents sharp on its major third, there are systems with fewer tones affording better approaches to justness.

There does not seem to be any composition written for 55-tone. Who the Musicians were, such that that it should be called "The Musicians' Cycle of 55" is also quite a puzzle.

55 *is one of numerous systems which get cited in the theoretical literature, or are proposed in some book on music, but have not been tried out on instruments and so there is no way of knowing if they have any special merits until they are HEARD. It may serve in this publication as stand-in for those others.*

ADVANTAGES OF 55-TONE

The 55-tone equal temperament is cited in A. J. Ellis's Appendix to Helmholtz's Sensations of Tone, as having been quoted in 1755 by Sauveur and Estève. It has been mentioned in the literature.

Ellis went on to comment: "decent approximation, convenient on paper. It would not have been worthwhile to produce ...on instruments."

ADVANTAGES AND DISADVANTAGES OF THE FIFTY-THREE-TONE MERCATOR SYSTEM

DISADVANTAGES

The interval of 1/53 octave is much too small to be used in ordinary melodies.

Since the frets would be so very close together, 53-tone is beyond the actual performance capabilities of guitarists and other players of fretted instruments. It would slow things down too much.

Shifts of a comma (i.e. moving a chord by 1/53 octave up or down) in the course of playing a piece, would often be disturbing to listeners.

The usual system of naming tones breaks down when extended to 53 fifths or major thirds—loses meaning. Notation problems also arise, of course.

53 is practically impossible to tune by ear. Accurate electronic equipment is necessary.

The harmonic seventh is about 5 cents too sharp, which would be noticed in some cases.

Such tiny intervals and fine distinctions are lost in rapid performances.

Width of normal vibrato exceeds this unit considerably.

53 is more for paper theorists than for practicing musicians, many authorities contend.

Only very few conventional instruments are capable of using 53-tone.

A system with so many tones is necessarily expensive.

ADVANTAGES

A series of 53 perfect fifths fails to close into a circle by an overshoot of 3.6 cents or 1/332 octave, which means that if each fifth were flattened by only 0.068 of a cent or 1/17647 octave, everything would come out even. Mercator found this out back in the 16th century without benefit of electronic calculators.

Such a close match far exceeds any normal achievements in musical instrument-making--no-one could hear a discrepancy of 57 parts per million.

The error of the major third is only 1.4 cents or 1/852 octave. The error in 12-tone is 9.7 times as great.

Augusto Novaro invented a 53-tone notation requiring no extra signs and uncluttering the page by eliminating all sharps and flats.

Many music theorists have written in favor of 53-tone, and a number of instruments were built in it. Now, with computers and electronics, most difficulties vanish.

The unit interval is a reasonable compromise between the comma of just intonation and the Pythagorean comma, taking care of both.

The larger errors of the 53 system are thrown onto the less-used harmonics so that the error increases with the order of the harmonic, rather than jumping around as it does in 22 or 31.

Practical 53-tone keyboards were invented a century ago or more.

53 can be warped so that many of the pitches would be just. One could have a number of just chords at the starting point in exchange for slight errors in the remote keys.